



**ESCUELA UNIVERSITARIA POLITÉCNICA
DE LA ALMUNIA DE DOÑA GODINA (ZARAGOZA)**

Appendixes

**Design of a modular BMS for EV
focused on MotoStudent**

**Diseño de un BMS modular para EV
enfocado a MotoStudent**

424.16.96

Author: Xavier Anzuela Recasens

Supervisor: David Asiain Ansorena

Date: 29/11/2016



**ESCUELA UNIVERSITARIA POLITÉCNICA
DE LA ALMUNIA DE DOÑA GODINA (ZARAGOZA)**

Blueprints & Schematics

**Design of a modular BMS for EV
focused on MotoStudent**

**Diseño de un BMS modular para EV
enfocado a MotoStudent**

424.16.96

Author: Xavier Anzuela Recasens

Supervisor: David Asiain Ansorena

Date: 29/11/2016

Autor: Xavier Anzuela Recasens

424.16.96

Blueprints & Schematics Content:

Blueprints

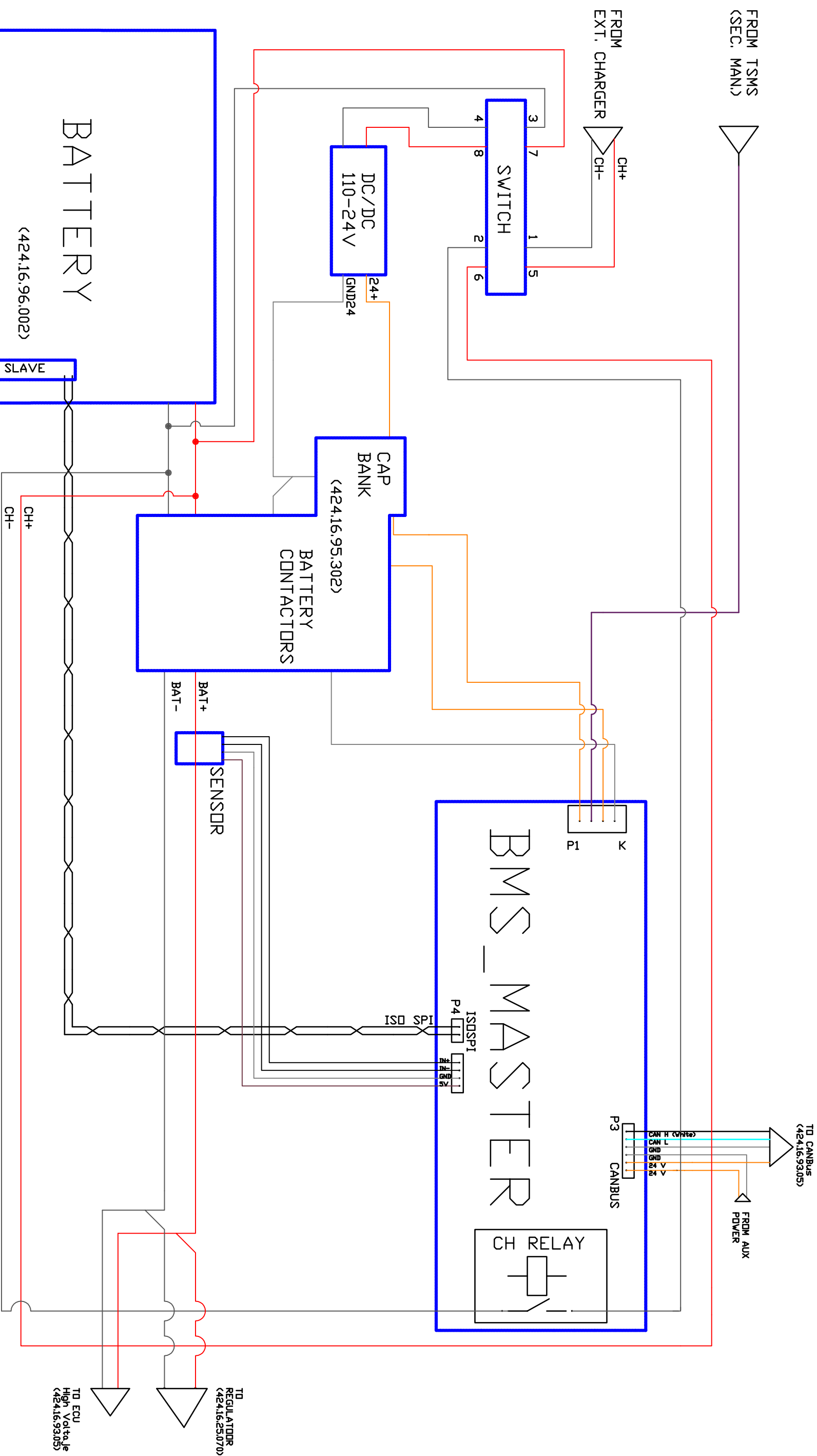
Battery	424.16.95.300
Master-Slave relationship	424.16.96.001
Master connection	424.16.96.301
BMS monitoring Slave 1	424.16.96.101
BMS monitoring Slave 2	424.16.96.102
BMS monitoring Slave 3	424.16.96.103
BMS monitoring Slave 4	424.16.96.104
BMS monitoring Slave 5	424.16.96.105
BMS temperature sensing Slave 1	424.16.96.201
BMS temperature sensing Slave 2	424.16.96.202
BMS temperature sensing Slave 3	424.16.96.203
BMS temperature sensing Slave 4	424.16.96.204
BMS temperature sensing Slave 5	424.16.96.205

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Manufacturing PCB Top	424.16.96.302
Manufacturing PCB Bottom	424.16.96.303
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Bottom Components	424.16.96.305



Note:
General BMS connection Blueprint 424.16.96.001
Master Board Connection Blueprint 424.16.95.301
BMS cell connection Blueprint 424.16.95.101-105
BMS temp. sensing Blueprint 424.16.95.201-205

Fecha	Nombre	
Dibujado	Il-2016	Xavier Anzueta
Comprobado	Il-2016	TRIBUNAL 1
Id. s. normas		UNE-EN-DIN
ESCALA:		
-		

Design of a Modular BMS

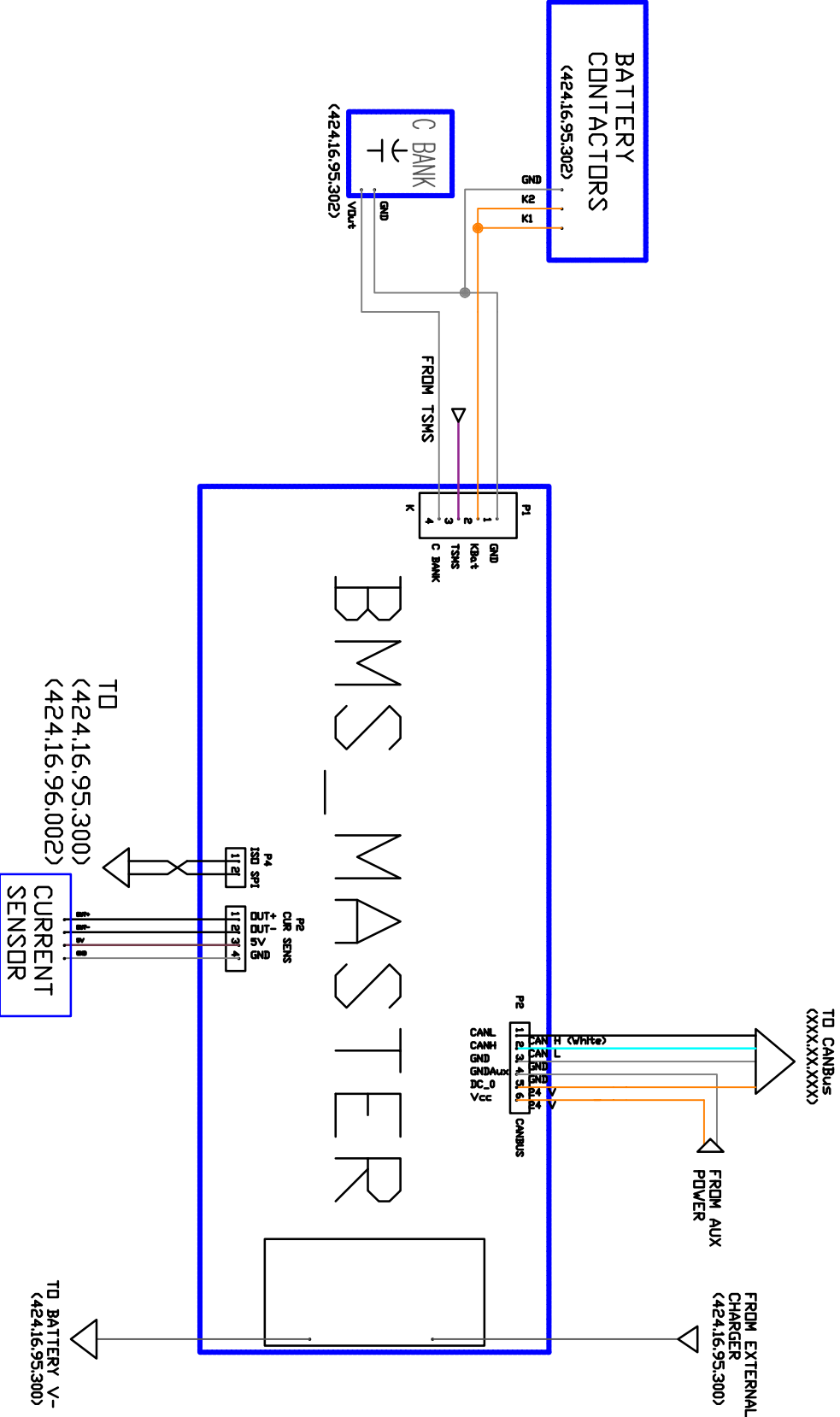
Battery Management System

General Battery Blueprint

Nº P. :

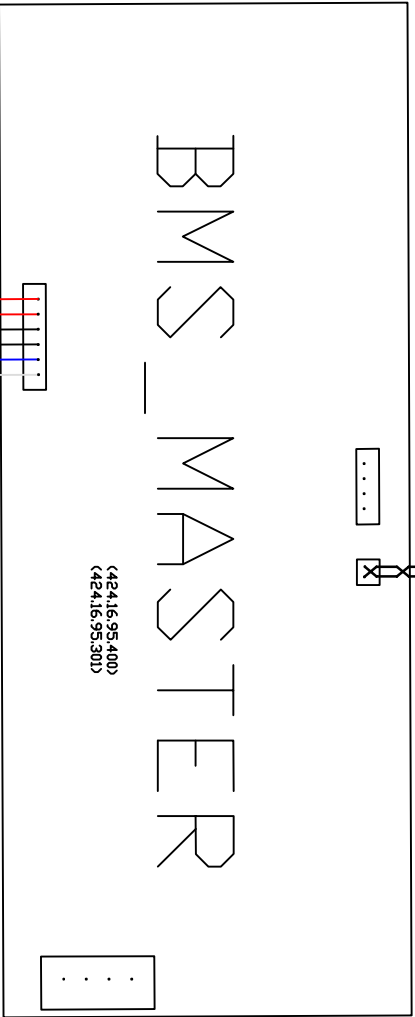
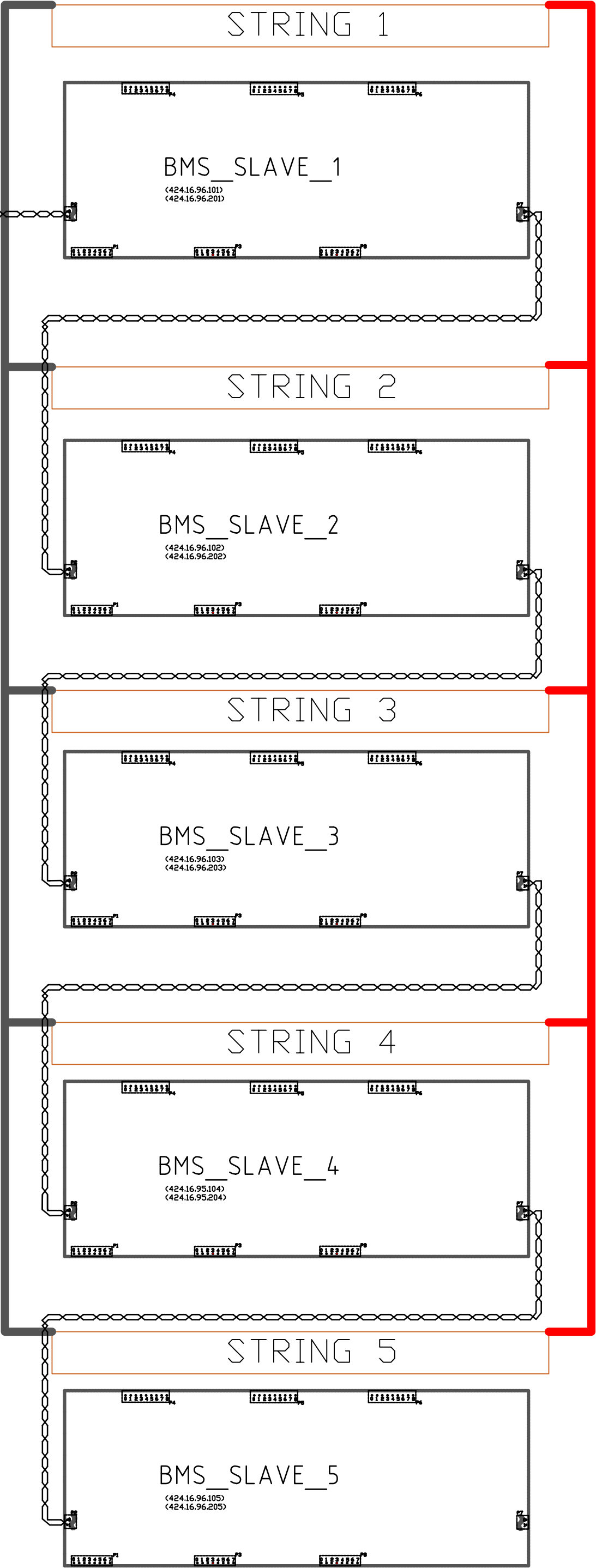
Nº O. :424.16.95.300

Nom.Arch:Bateria.dwg



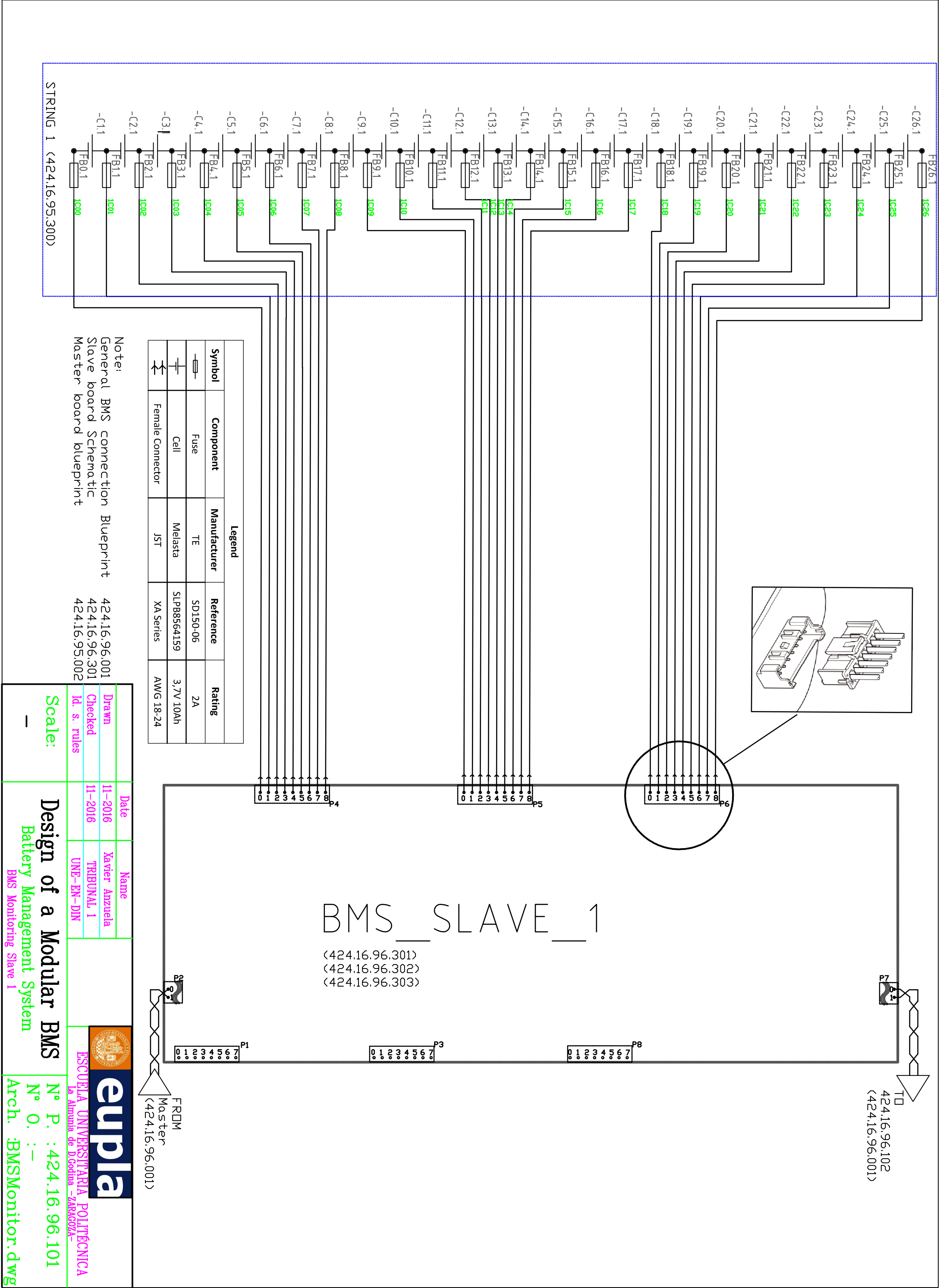
Note:
General BMS connection Blueprint 424.16.96.001
BMS cell connection Blueprint 424.16.96.101
BMS temp. sensing Blueprint 424.16.96.201

	Fecha	Nombre		eupla
Dibujado	11-2016	Xavier Anzueta		
Comprobado	11-2016	TRIBUNAL 1		
Id. s. normas		UNE-EN-DIN		
ESCALA:	Design of a Modular BMS			
—	Battery Management System			
	Master connection			
			Escuela Universitaria Politécnica	
			La Alfranca de D.Godina - ZARAGOZA-	
			Nº P. : 424.16.95.301	
			Nº O. : 424.16.95.301	
			Norm. Arch: Master.dwg	



Note:
BMS cell connection blueprint: 424.16.96.101-105
BMS temp. sensing blueprint: 424.16.96.201-205
Slave board Schematic: 424.16.96.301
Master board Schematic: 424.16.95.400
Master connection blueprint: 424.16.95.301
General Battery blueprint: 424.16.95.300

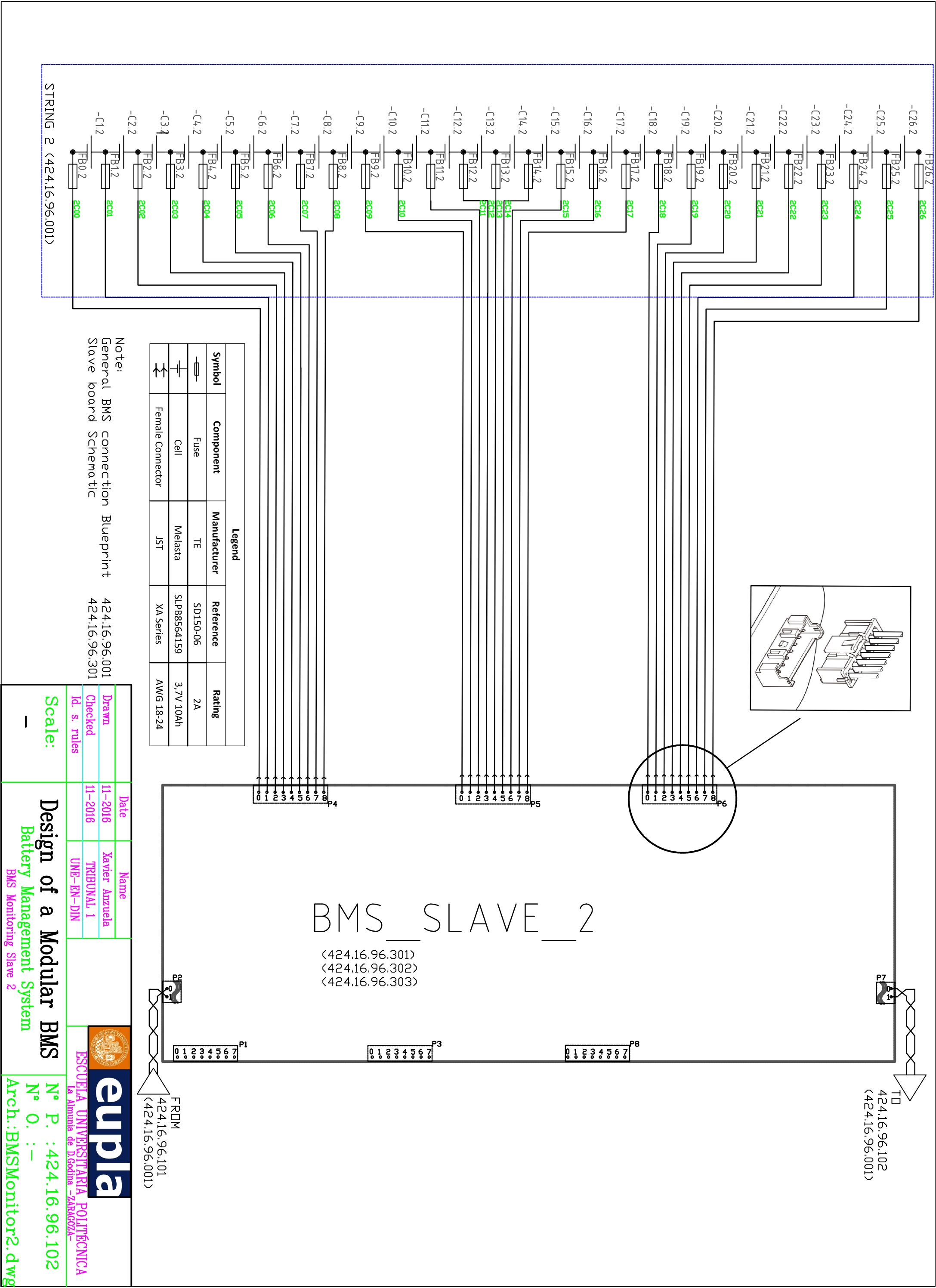
	Date	Name		
Drawn	11-2016	Xavier Anzueta		
Checked	11-2016	TRIBUNAL, I		
Id. s. rules		UNE-EN-DIN		
Scale:	Design of a Modular BMS			
—	Battery Management System			
	Connection Between Master and Slaves			
	Nº P. : 424.16.96.001			
	Nº O. : —			
	Arch.: MasterSlaves.dwg			

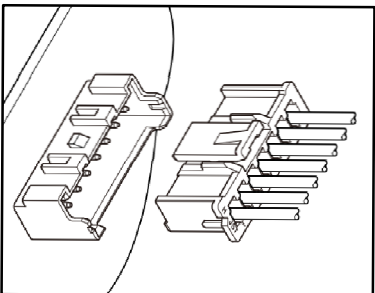


Legend				
Symbol	Component	Manufacturer	Reference	Rating
	Fuse	TE	SD150-06	2A
	Cell	Melasta	SLPB8564159	3,7V 10Ah
	Female Connector	JST	XA Series	AWG 18-24

Note:
General BMS connection Blueprint 424.16.96.001
Slave board Schematic 424.16.96.301
Master board blueprint 424.16.95.002

Scale:		Design of a Modular BMS	
—		Battery Management System	
BMS Monitoring Slave 1		Arch. :BMSMonitor.dwg	
Drawn	11-2016	Name	Xavier Anzueta
Checked	11-2016	TRIBUNAL 1	
Id. s. rules		UNE-EN-DIN	
ESCUELA UNIVERSITARIA POLITÉCNICA		eupla	
La Alfranca de D.Godina -ZARAGOZA-		Nº P. :424.16.96.101	
		Nº O. :—	
		FROM Master (424.16.96.001)	





FROM
424.16.96.103
<424.16.96.101>

0	1	2	3	4	5	6	7
---	---	---	---	---	---	---	---

^{P1}

A diagram of a 2-to-1 multiplexer. It has two inputs labeled '0' and '1', and an output labeled 'P2'. The output 'P2' is shown with a shaded area, indicating it is the selected output.

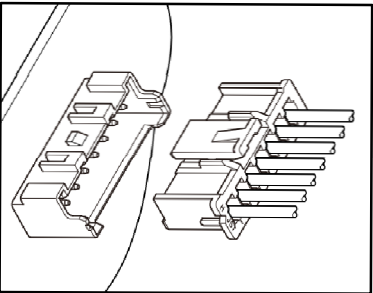
424.16.96.001
424.16.96.301



Scale:

Battery Management System

Arch.:BMSMonitor4.dwg



(424.16.96.301)
(424.16.96.302)
(424.16.96.303)



424.16.96.001
424.16.96.301

Name	Date
Xavier Anzueta	11-2016
TRIBUNAL 1	11-2016
UNE-EN-DIN	

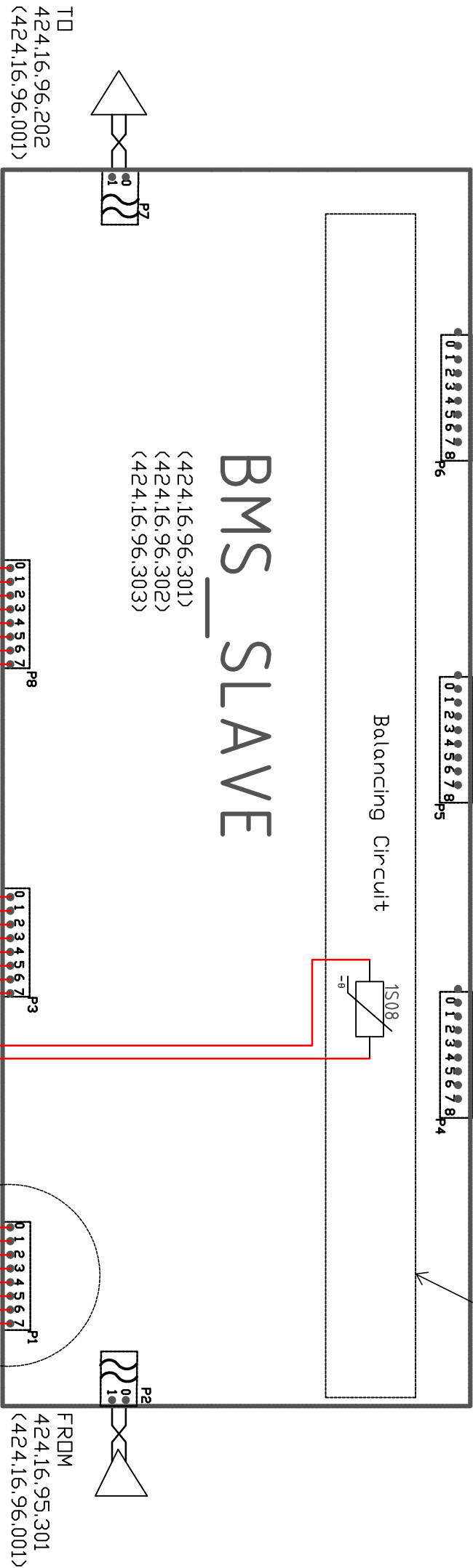
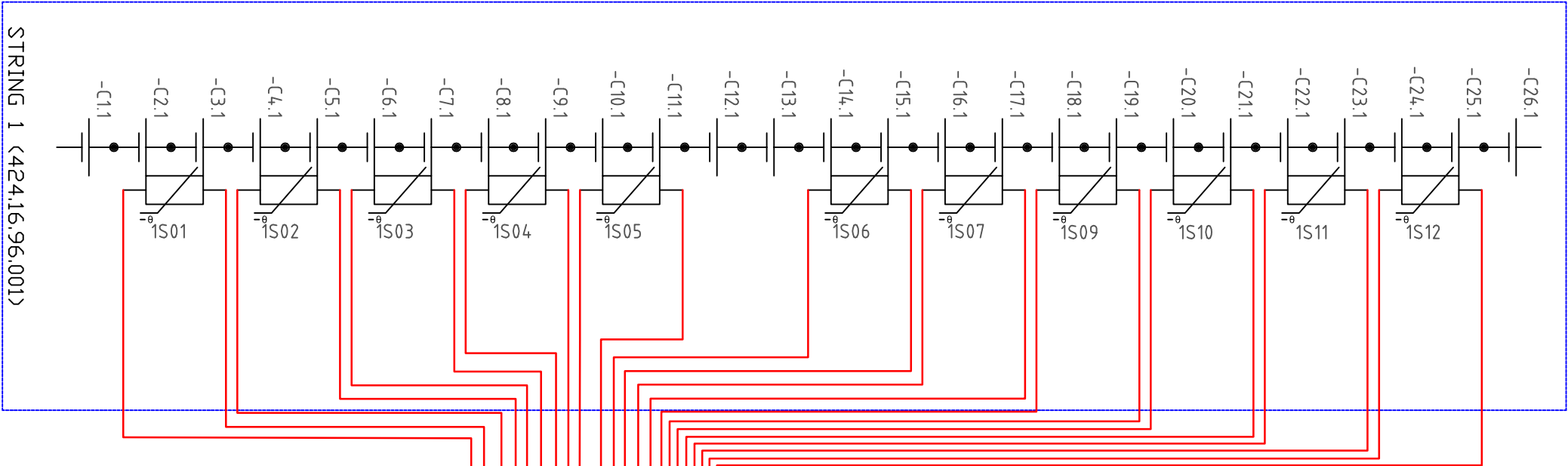


eupla

ESCUELA UNIVERSITARIA POLITÉCNICA

Alumna de D.Godina -ZARAQOZA-

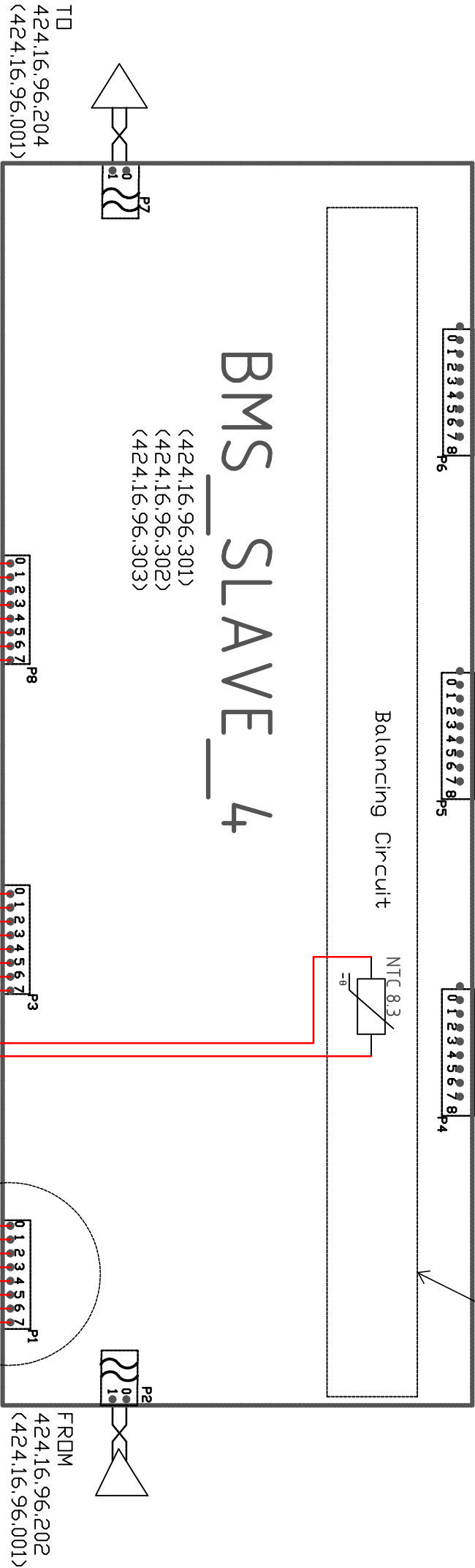
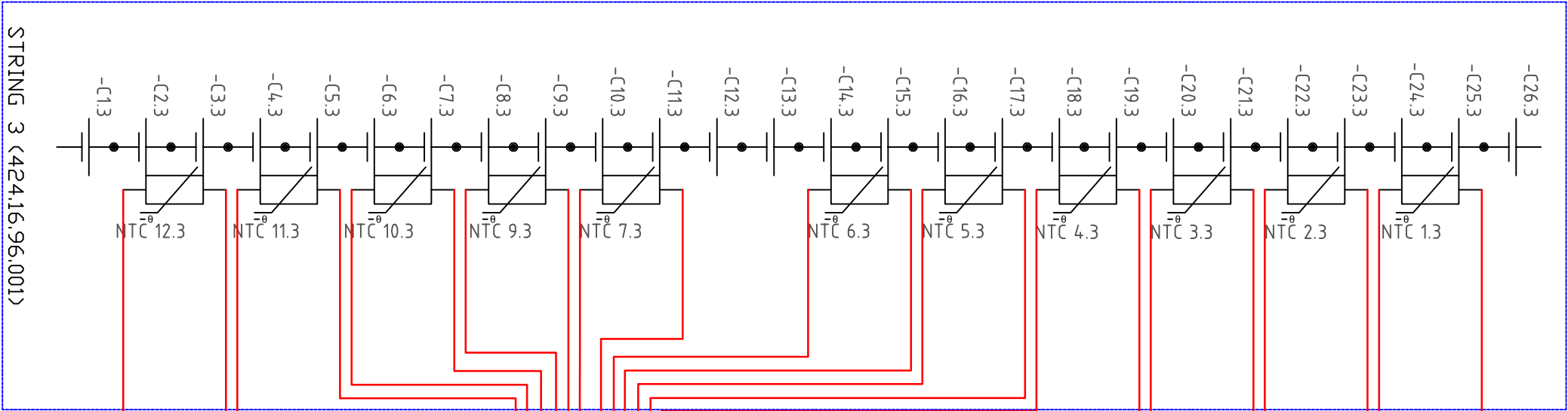
STRING 5 (424.16,96,001)



Legend				
Symbol	Component	Manufacturer	Reference	Rating
	NTC	AVX	NJ28RA0104H	100K 25°C
	Female Connector	JST	XA Series	AWG 18-24

Note:
General BMS connection Blueprint: 424.16.96.001
Slave board Schematic: 424.16.96.301
Master connection: 424.16.95.301

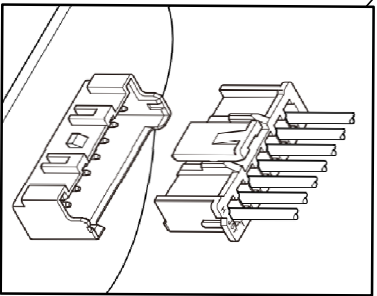
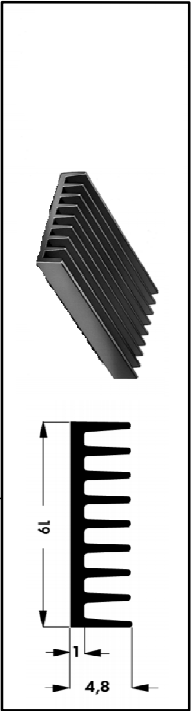
	Date	Name			 eupla
Drawn	11-2016	Xavier Anzueta			
Checked	11-2016	TRIBUNAL 1			
Id. s. rules		UNE-EN-DIN			
Scale:	Design of a Modular BMS Battery Management System BMS Temperature Sensing Slave 1				Nº P. : 424.16.96.201 Nº O. : — Arch. : BMSTempl.dwg
—					



Legend			
Symbol	Component	Manufacturer	Reference
	NTC	AVX	NJ28RA0104H
	Female Connector	JST	XA Series

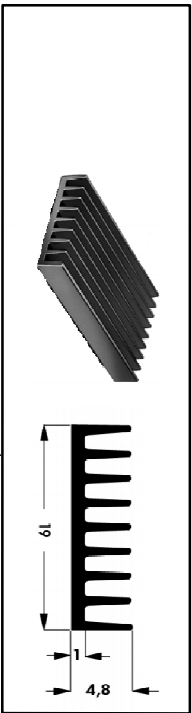
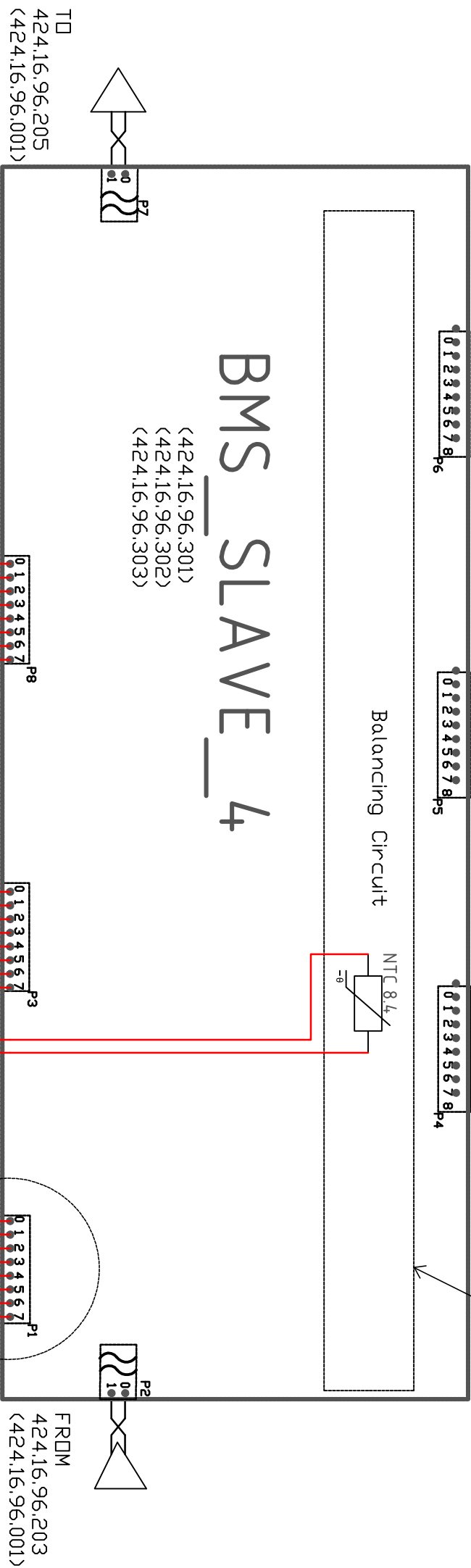
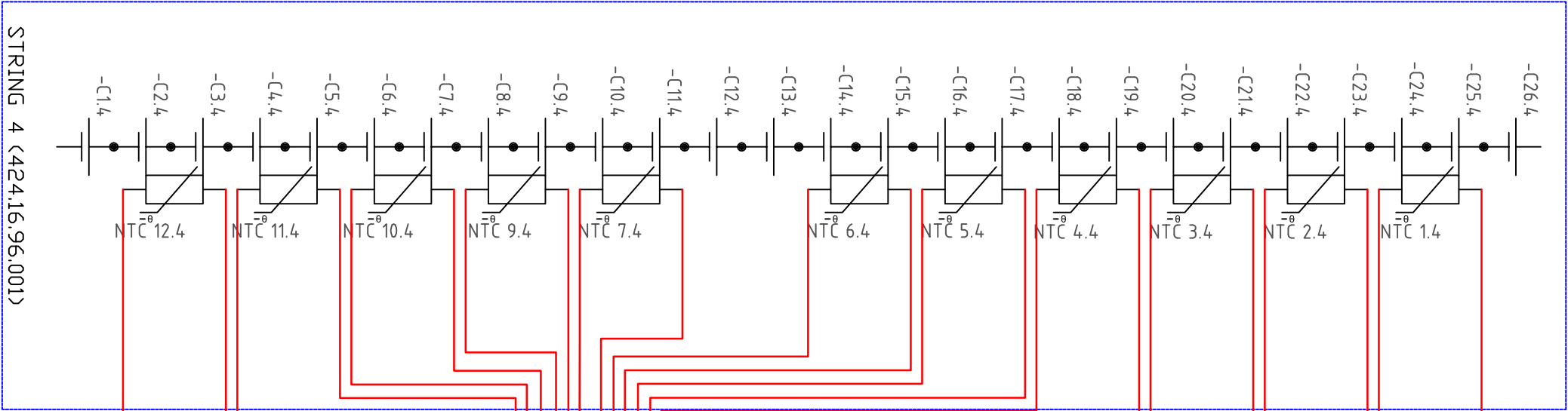
Note:

General BMS connection Blueprint: 424.16.96.001
Slave board Schematic: 424.16.96.301
Master connection: 424.16.95.301



ESCUELA UNIVERSITARIA POLITÉCNICA
La Alhambra de Granada - ZARAGOZA

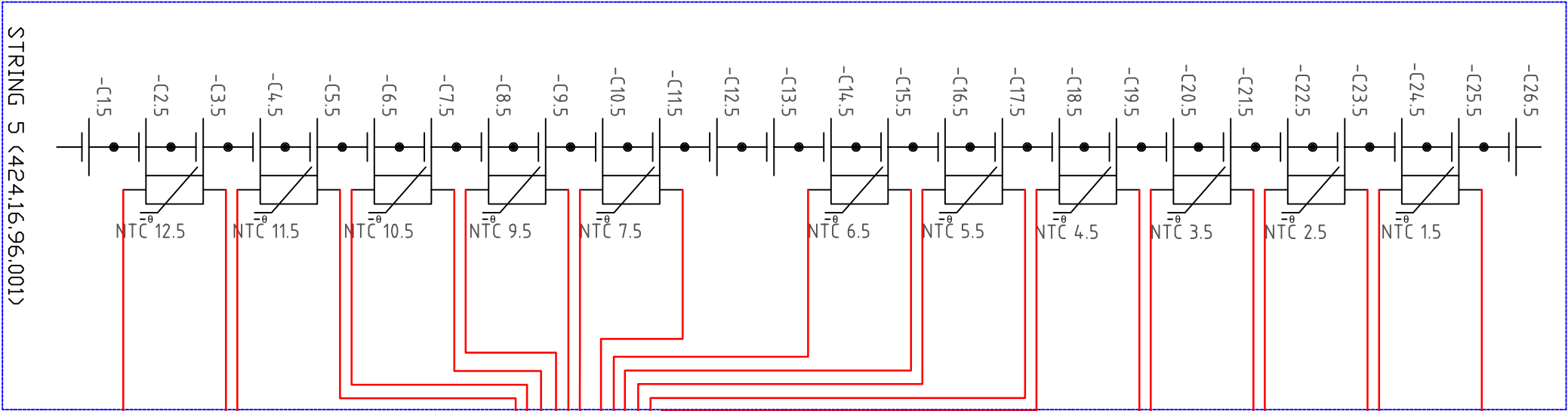
Date	Name		
Drawn	II-2016	Xavier Anzueta	
Checked	II-2016	TRIBUNAL 1	
Id. s. rules		UNE-EN-DIN	
Scale:	—	Design of a Modular BMS	Nº P. : 424.16.96.203
		Battery Management System	Nº O. : —
		BMS Temperature Sensing Slave 3	Arch. : BMSTemp3.dwg



Legend				
Symbol	Component	Manufacturer	Reference	Rating
	NTC	AVX	NU28RA0104H	100K 25°C
	Female Connector	JST	XA Series	AWG 18-24

Note:
General BMS connection Blueprint: 424.16.96.001
Slave board Schematic: 424.16.96.301
Master connection: 42416.95.301

Drawn	Il-2016	Xavier Anzueta		eupla
Checked	Il-2016	TRIBUNAL 1		
Id. s. rules		UNE-EN-DIN		
Scale:	—	Design of a Modular BMS Battery Management System BMS Temperature Sensing Slave 4		
Nº P. : 424.16.96.204 Nº O. : — Arch. : BMSTemp4.dwg				

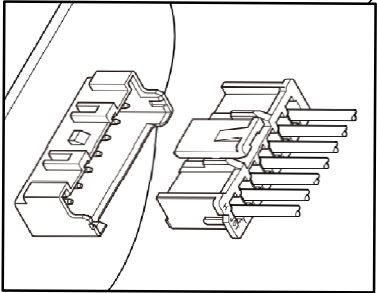
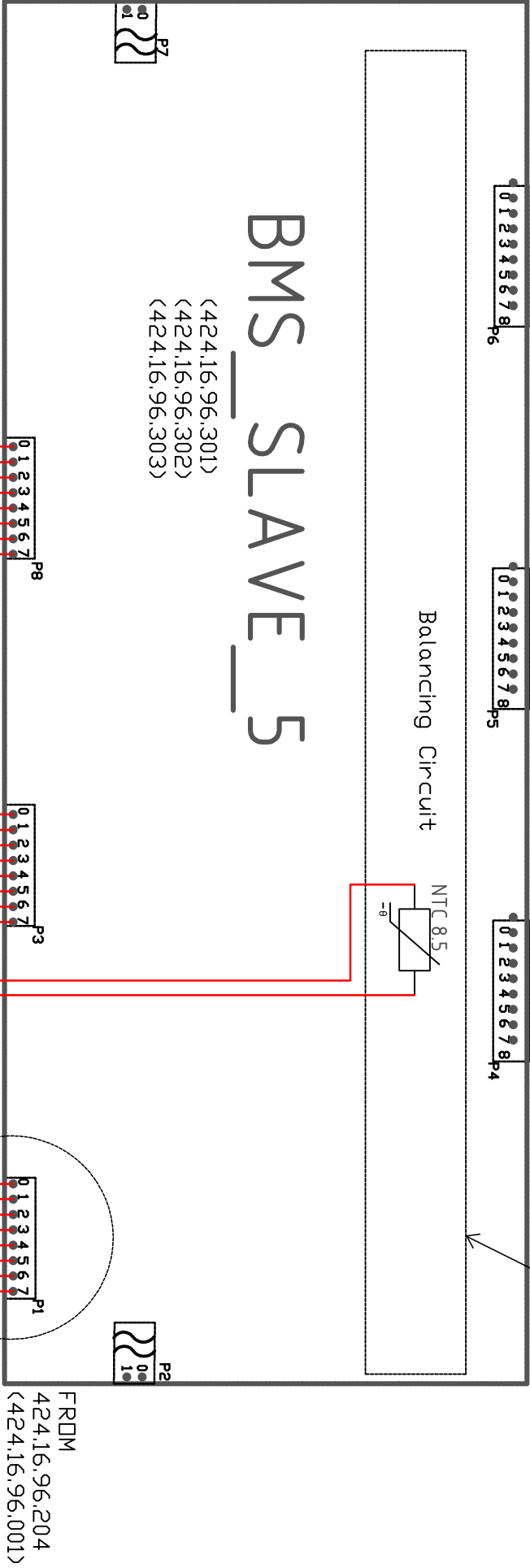
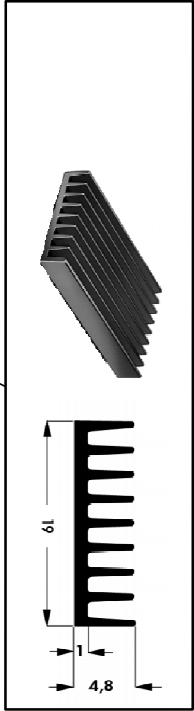


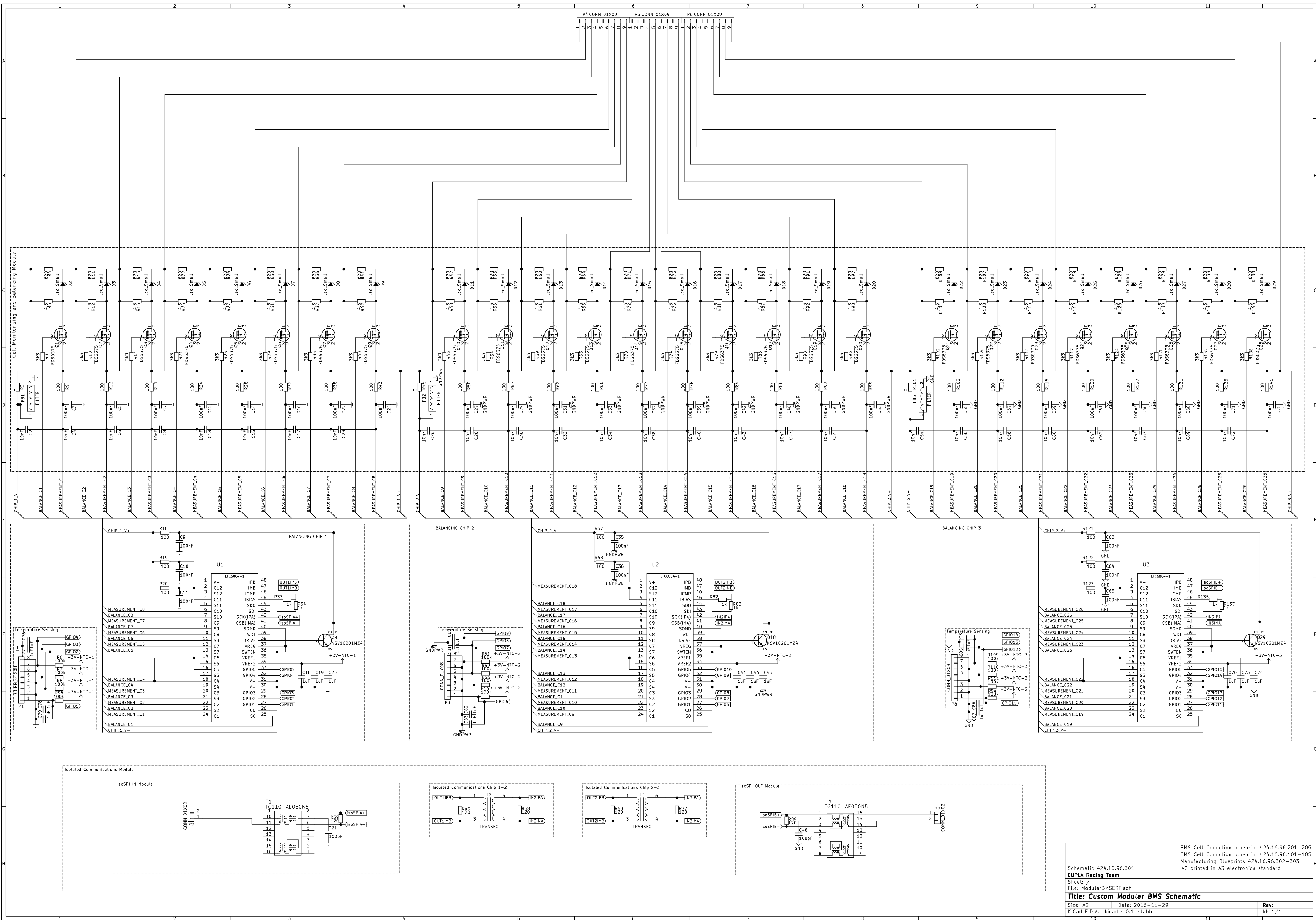
STRING 5 (424.16.96.001)

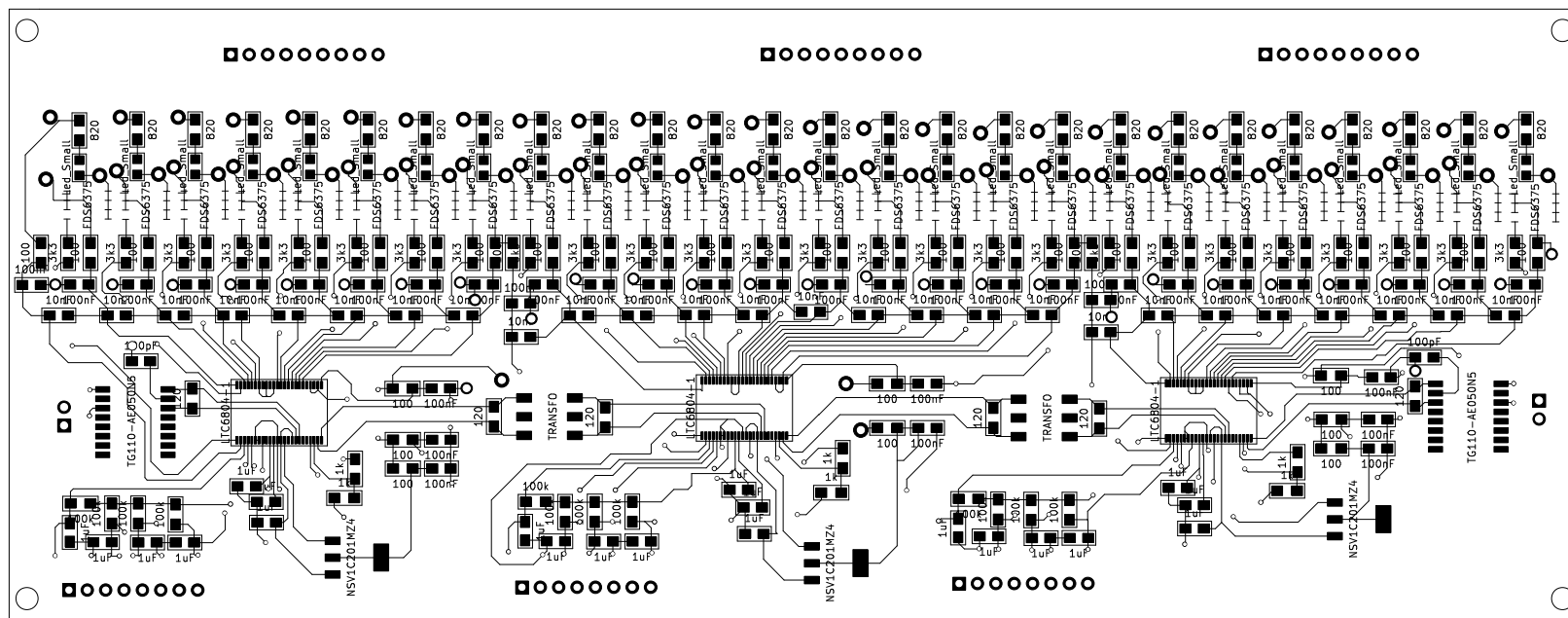
Legend				
Symbol	Component	Manufacturer	Reference	Rating
	NTC	AVX	NJ28RA0104H	100K 25°C
	Female Connector	JST	XA Series	AWG 18-24

Note:
General BMS connection Blueprint: 424.16.96.001
Slave board Schematic: 424.16.96.301
Master connection: 424.16.95.301

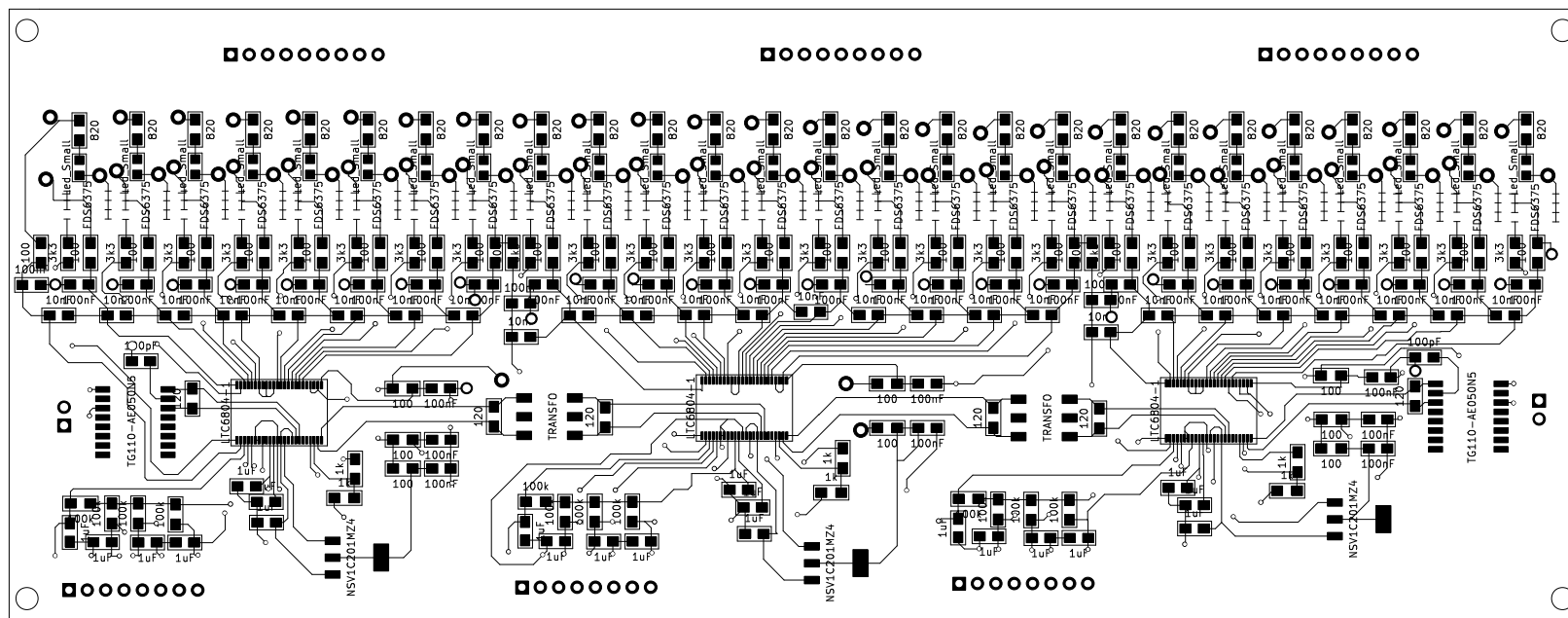
Scale:		Design of a Modular BMS	
—		Battery Management System	
BMS Temperature Sensing Slave 5		BMS Temp5.dwg	
Id. s. rules	Date	Name	
Checked	11-2016	Xavier Anzueta	
Id. s. rules	11-2016	TRIBUNAL 1	
Id. s. rules	11-2016	UNE-EN-DIN	
Scale:		Design of a Modular BMS	
—		Battery Management System	
BMS Temperature Sensing Slave 5		BMS Temp5.dwg	



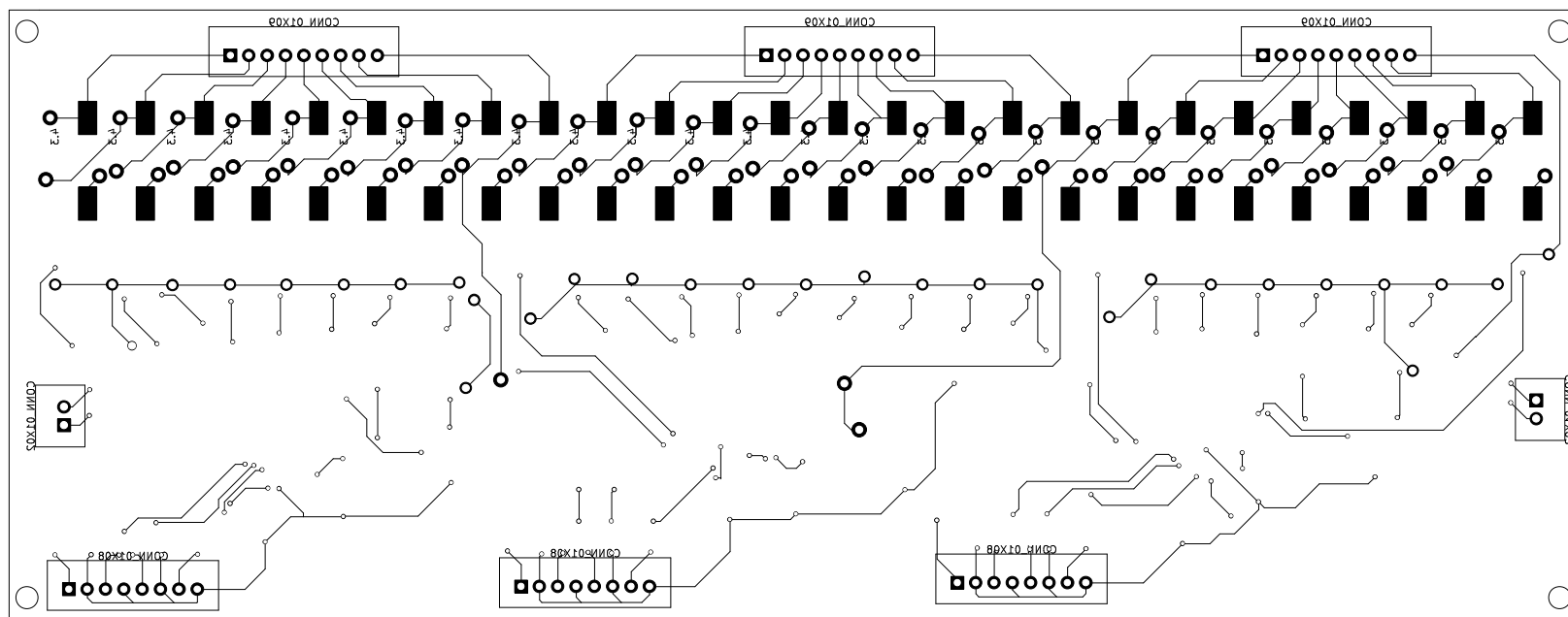




Slave Schematic: 424.16.96.301	
Manufacturing PCB Bottom : 424.16.96.303	
Components PCB Top: 424.16.96.304	
Blueprint: 424.16.96.302	
Eupla Racing Team	
Sheet:	
File: ModularBMSERT.kicad_pcb	
Title: Manufacturing PCB Top	
Size: A4	Date: 2016-11-29
KiCad E.D.A. kicad 4.0.1-stable	Rev: 29/11/2016
	Id: 1/1



Slave Schematic: 424.16.96.301	
Manufacturing PCB Top : 424.16.96.302	
Blueprint: 424.16.96.304	
Eupla Racing Team	
Sheet:	
File: ModularBMSERT.kicad_pcb	
Title: Components Top	
Size: A4	Date: 2016-11-29
KiCad E.D.A. kicad 4.0.1-stable	Rev: 29/11/2016
	Id: 1/1



Slave Schematic: 424.16.96.301	
Manufacturing PCB Bottom : 424.16.96.303	
Blueprint: 424.16.96.305	
Eupla Racing Team	
Sheet:	
File: ModularBMSERT.kicad_pcb	
Title: Components Bottom	
Size: A4	Date: 2016-11-29
KiCad E.D.A. kicad 4.0.1-stable	Rev: 29/11/2016
	Id: 1/1



**ESCUELA UNIVERSITARIA POLITÉCNICA
DE LA ALMUNIA DE DOÑA GODINA (ZARAGOZA)**

Tables Appendix

Design of a modular BMS for EV
focused on MotoStudent

Diseño de un BMS modular para EV
enfocado a MotoStudent

424.16.96

Author: Xavier Anzuela Recasens

Supervisor: David Asiain Ansorena

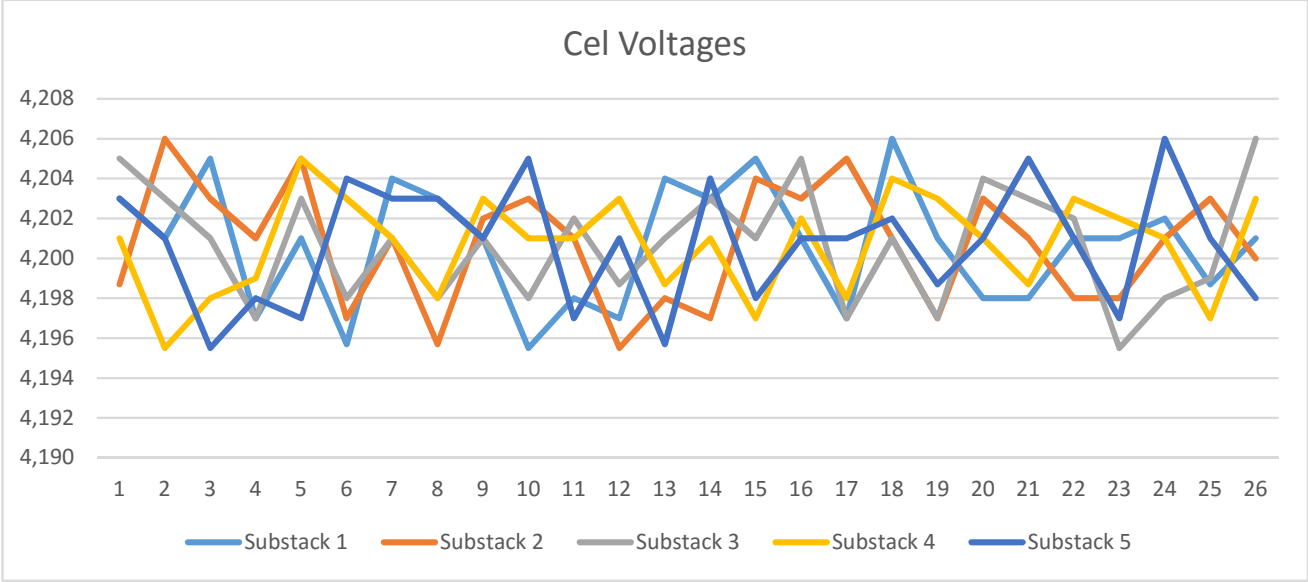
Date: 29/11/2016

Autor: Xavier Anzuela Recasens

424.16.96

Balanced Cells Data

	Substack 1	Substack 2	Substack 3	Substack 4	Substack 5		
1	4,203	4,199	4,205	4,201	4,203	v	
2	4,201	4,206	4,203	4,196	4,201		
3	4,205	4,203	4,201	4,198	4,196		
4	4,197	4,201	4,197	4,199	4,198		
5	4,201	4,205	4,203	4,205	4,197		
6	4,196	4,197	4,198	4,203	4,204		
7	4,204	4,201	4,201	4,201	4,203		
8	4,203	4,196	4,198	4,198	4,203		
9	4,201	4,202	4,201	4,203	4,201		
10	4,196	4,203	4,198	4,201	4,205		
11	4,198	4,201	4,202	4,201	4,197		
12	4,197	4,196	4,199	4,203	4,201		
13	4,204	4,198	4,201	4,199	4,196		
14	4,203	4,197	4,203	4,201	4,204		
15	4,205	4,204	4,201	4,197	4,198		
16	4,201	4,203	4,205	4,202	4,201		
17	4,197	4,205	4,197	4,198	4,201		
18	4,206	4,201	4,201	4,204	4,202		
19	4,201	4,197	4,197	4,203	4,199		
20	4,198	4,203	4,204	4,201	4,201	Max. Voltage	4,196
21	4,198	4,201	4,203	4,199	4,205	Min. Voltage	4,206
22	4,201	4,198	4,202	4,203	4,201	Median	4,201
23	4,201	4,198	4,196	4,202	4,197	Avg. Voltage	4,201
24	4,202	4,201	4,198	4,201	4,206	Typical Deviation	0,0010
25	4,199	4,203	4,199	4,197	4,201	Standar Deviation	0,0028
26	4,201	4,200	4,206	4,203	4,198		



COMPANY	MODEL	FUNCTION	MIN.CELL	MAX.CELL	BATTERY OVER-VOLTAGE PROTECCIÓN.	COMMUNICATION	DEMO BOARDS
LINEAR	LTC6801	MONITORING	1	12	5V	CLOCK (ANALOG)	DC1469B
	LTC6802-1	MONITORING	1	12	5V	DAISYCHAINABLE 1MB/s SPI	DC1331D
	LTC6802-2	MONITORING	1	12	5V	ADDRESABLE SPI	DC1393B
	LTC6803-1	MONITORING	1	12	5V	DAISYCHAINABLE 1MB/s SPI	DC1651A/DC1653A
	LTC6803-2	MONITORING	1	12	5V	ADDRESABLE SPI	DC1652A/DC1835A/DC2064A
	LTC6803-3(UPGRADE 03-1)	MONITORING	1	12	5V	DAISYCHAINABLE 1MB/s SPI	DC1651A/DC1653A
	LTC6803-4(UPGRADE 03-2)	MONITORING	1	12	5V	ADDRESABLE SPI	DC1652A/DC1835A/DC2064A
	LTC6804-1	MONITORING	1	12	5V	IsoSPI(Mirar LTC6820 "chip comm.)	DC1894B
	LTC6804-2	MONITORING	1	12	5V	IsoSPI(Mirar LTC6820 "chip comm.)	DC1942C
	BQ76940	MONITORING	9	15	4,6V	I2C	
TEXAS INSTRUMENTS	BQ76930	MONITORING	6	10	4,6V	I2C	
	BQ76920	MONITORING	3	5	4,6V	I2C	
	BQ76PL536A	MONITORING	3	6	5V	SPI	
	BQ76PL56A-Q1	MONITORING	3	6	5V	SPI	

OV--> OVER VOLTAGE PROTECTION

OC-->OVER CURRENT PROTECTION

SCD--> SHORT CIRCUIT DISCHARGA

UV--> UNDERVOLTAGE

Chip	Communication	Ev.Boards
LTC6804-1	IsoSPI	DC1894B
LTC6804-2	IsoSPI	DC1942C
BQ76PL56A-Q1	SPI	BQ76PL56A-EVM

COMPANY	CHIP	NUMBER OF CELLS
LINEAR	LTC6801	02-dic
	LTC6802-1	02-dic
	LTC6802-2	02-dic
	LTC6803-1	02-dic
	LTC6803-2	02-dic
	LTC6803-3(UPGRADE 03-1)	02-dic
	LTC6803-4(UPGRADE 03-2)	02-dic
	LTC6804-1	02-dic
	LTC6804-2	02-dic
TEXAS INSTRUMENTS	BQ76940	sep-15
	BQ76930	06-oct
	BQ76920	03-may
	BQ76PL536A	03-jun
	BQ76PL56A-Q1	03-jun

PROTECTION FEACTURES	MAX MESURE ERROR	SPECIAL FEACTURES	OPERATING CURRENT	VIN	BALANCING TYPE	DRAINING CURRENT(D)	APLICATIONS	PRICE	SOFTWARE
OV/OC/UV	1%	NO BALANCING	-	60V	NO	-	MONITORING	6,99 €	-
OV/OC/UV	0,25%	BALANCING/2TEMP/2GPIO	1,1mA	60V	PASSIVE	60-70mA	EV/HEV	13,99 €	-
OV/OC/UV	0,25%	BALANCING/2TEMP/2GPIO	1,1mA	60V	PASSIVE	60-70mA	EV/HEV	13,99 €	-
OV/OC/UV	0,25%	BALANCING/2TEMP/2GPIO		75V	PASSIVE	60-70mA	EV/HEV	15,53 €	LINDUINO LIBRARY INCLUDED
OV/OC/UV	0,25%	BALANCING/2TEMP/2GPIO		75V	PASSIVE	60-70mA	EV/HEV	15,53 €	LINDUINO LIBRARY INCLUDED
OV/OC/UV	0,25%	BALANCING/2TEMP/2GPIO		75V	PASSIVE	60-70mA	EV/HEV	15,53 €	LINDUINO LIBRARY INCLUDED
OV/OC/UV	0,25%	BALANCING/2TEMP/2GPIO		75V	PASSIVE	60-70mA	EV/HEV	15,53 €	LINDUINO LIBRARY INCLUDED
OV/OC/UV	0,25%	BALANCING/5GPIO		75V	PASSIVE	70-80mA	EV/HEV	17,08 €	LINDUINO LIBRARY INCLUDED
OV/OC/UV	0,25%	BALANCING/5GPIO		75V	PASSIVE	70-80mA	EV/HEV	17,08 €	LINDUINO LIBRARY INCLUDED
OV/OC/UV/SCD							GENERAL PURPOSE		
OV/OC/UV/SCD							GENERAL PURPOSE		
OV/OC/UV/SCD							GENERAL PURPOSE		
OV/OC/UV							GENERAL PURPOSE		
OV/OC/UV							EV/HEV		

Protection	Precision	Software
OV/OC/UV	0,25%	Libraries Included
OV/OC/UV	0,25%	Libraries Included
OV/OC/UV	0,25%	No libraries

BALANCING	EXTRAS
NO	NO BALANCING
PASSIVE	2TEMP/2GPIO
PASSIVE	2TEMP/2GPIO
PASSIVE	2TEMP/2GPIO
PASSIVE	2TEMP/2GPIO
PASSIVE	2TEMP/2GPIO
PASSIVE	2TEMP/2GPIO
PASSIVE	2TEMP/2GPIO
PASSIVE	BALANCING/5GPIO
PASSIVE	BALANCING/5GPIO
PASSIVE	BALANCING
PASSIVE	BALANCING
PASSIVE	BALANCING
PASSIVE	BALANCING/3GPIO
PASSIVE	BALANCING/3GPIO



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Components & DemoBoards Appendix

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Author: Xavier Anzuela Recasens

Supervisor: David Asiaín Ansorena

Date: 29/11/2016

FEATURES

- Measures Up to 12 Battery Cells in Series
- Stackable Architecture Supports 100s of Cells
- Built-In isoSPI™ Interface:
 - 1Mbps Isolated Serial Communications
 - Uses a Single Twisted Pair, Up to 100 Meters
 - Low EMI Susceptibility and Emissions
- 1.2mV Maximum Total Measurement Error
- 290μs to Measure All Cells in a System
- Synchronized Voltage and Current Measurement
- 16-Bit Delta-Sigma ADC with Frequency Programmable 3rd Order Noise Filter
- Engineered for ISO26262 Compliant Systems
- Passive Cell Balancing with Programmable Timer
- 5 General Purpose Digital I/O or Analog Inputs:
 - Temperature or other Sensor Inputs
 - Configurable as an I²C or SPI Master
- 4μA Sleep Mode Supply Current
- 48-Lead SSOP Package

APPLICATIONS

- Electric and Hybrid Electric Vehicles
- Backup Battery Systems
- Grid Energy Storage
- High Power Portable Equipment

DESCRIPTION

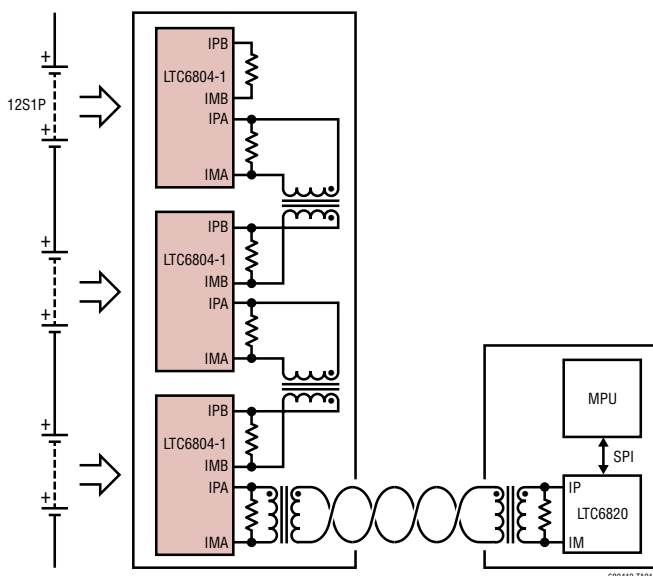
The LTC[®]6804 is a 3rd generation multicell battery stack monitor that measures up to 12 series connected battery cells with a total measurement error of less than 1.2mV. The cell measurement range of 0V to 5V makes the LTC6804 suitable for most battery chemistries. All 12 cell voltages can be captured in 290μs, and lower data acquisition rates can be selected for high noise reduction.

Multiple LTC6804 devices can be connected in series, permitting simultaneous cell monitoring of long, high voltage battery strings. Each LTC6804 has an isoSPI interface for high speed, RF-immune, local area communications. Using the LTC6804-1, multiple devices are connected in a daisy-chain with one host processor connection for all devices. Using the LTC6804-2, multiple devices are connected in parallel to the host processor, with each device individually addressed.

Additional features include passive balancing for each cell, an onboard 5V regulator, and 5 general purpose I/O lines. In sleep mode, current consumption is reduced to 4μA. The LTC6804 can be powered directly from the battery, or from an isolated supply.

LT, LT, LTC, LTM, Linear Technology and the Linear logo are registered and isoSPI is a trademark of Linear Technology Corporation. All other trademarks are the property of their respective owners.

TYPICAL APPLICATION



**Total Measurement Error
vs Temperature of 5 Typical Units**

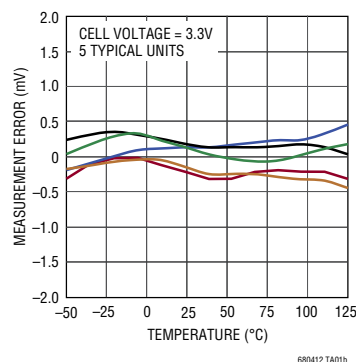


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ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage V^+ to V^- 75V
 Input Voltage (Relative to V^-)

C0 -0.3V to 0.3V
 C12 -0.3V to 75V
 C(n) -0.3V to MIN (8 • n, 75V)
 S(n) -0.3V to MIN (8 • n, 75V)
 IPA, IMA, IPB, IMB -0.3V to $V_{REG} + 0.3V$
 DRIVE Pin -0.3V to 7V
 All Other Pins -0.3V to 6V

Voltage Between Inputs

C(n) to C(n - 1) -0.3V to 8V
 S(n) to C(n - 1) -0.3V to 8V
 C12 to C8 -0.3V to 25V
 C8 to C4 -0.3V to 25V
 C4 to C0 -0.3V to 25V

Current In/Out of Pins

All Pins Except V_{REG} , IPA, IMA, IPB, IMB, S(n) .. 10mA
 IPA, IMA, IPB, IMB 30mA

Operating Temperature Range

LTC6804I -40°C to 85°C
 LTC6804H -40°C to 125°C

Specified Temperature Range

LTC6804I -40°C to 85°C
 LTC6804H -40°C to 125°C

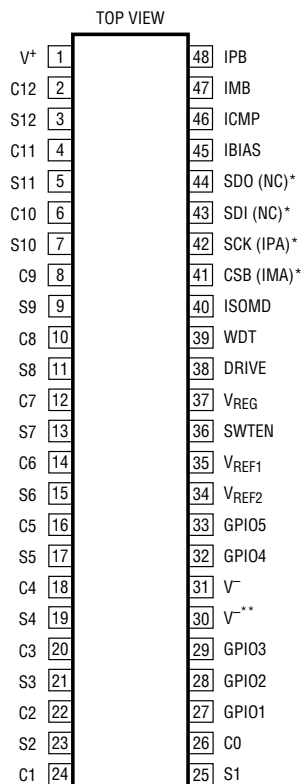
Junction Temperature 150°C

Storage Temperature -65°C to 150°C

Lead Temperature (Soldering, 10sec) 300°C

PIN CONFIGURATION

LTC6804-1



G PACKAGE
48-LEAD PLASTIC SSOP

$T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 55^{\circ}\text{C/W}$

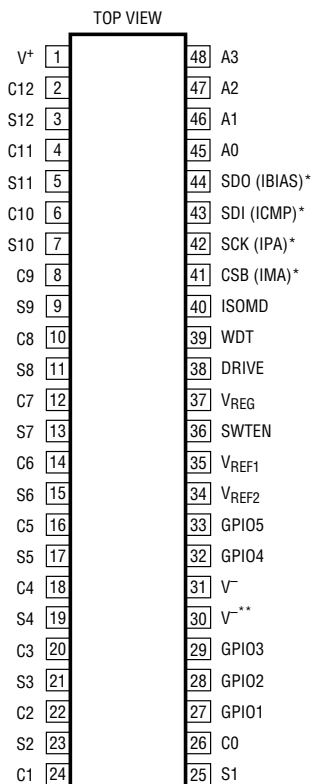
*THE FUNCTION OF THESE PINS DEPENDS ON THE CONNECTION OF ISOMD

ISOMD TIED TO V^- : CSB, SCK, SDI, SDO

ISOMD TIED TO V_{REG} : IMA, IPA, NC, NC

**THIS PIN MUST BE CONNECTED TO V^-

LTC6804-2



G PACKAGE
48-LEAD PLASTIC SSOP

$T_{JMAX} = 150^{\circ}\text{C}$, $\theta_{JA} = 55^{\circ}\text{C/W}$

*THE FUNCTION OF THESE PINS DEPENDS ON THE CONNECTION OF ISOMD

ISOMD TIED TO V^- : CSB, SCK, SDI, SDO

ISOMD TIED TO V_{REG} : IMA, IPA, ICMP, IBIAS

**THIS PIN MUST BE CONNECTED TO V^-

ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING*	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE
LTC6804IG-1#PBF	LTC6804IG-1#TRPBF	LTC6804G-1	48-Lead Plastic SSOP	-40°C to 85°C
LTC6804HG-1#PBF	LTC6804HG-1#TRPBF	LTC6804G-1	48-Lead Plastic SSOP	-40°C to 125°C
LTC6804IG-2#PBF	LTC6804IG-2#TRPBF	LTC6804G-2	48-Lead Plastic SSOP	-40°C to 85°C
LTC6804HG-2#PBF	LTC6804HG-2#TRPBF	LTC6804G-2	48-Lead Plastic SSOP	-40°C to 125°C

Consult LTC Marketing for parts specified with wider operating temperature ranges. *The temperature grade is identified by a label on the shipping container. Consult LTC Marketing for information on nonstandard lead based finish parts.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandreel/>

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. The test conditions are $V^+ = 39.6\text{V}$, $V_{\text{REG}} = 5.0\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
ADC DC Specifications						
	Measurement Resolution		●	0.1		mV/bit
	ADC Offset Voltage	(Note 2)	●	0.1		mV
	ADC Gain Error	(Note 2)	●	0.01 0.02		% %
	Total Measurement Error (TME) in Normal Mode	C(n) to C(n-1), GPIO(n) to $V^- = 0$		±0.2		mV
		C(n) to C(n-1) = 2.0		±0.1	±0.8	mV
		C(n) to C(n-1), GPIO(n) to $V^- = 2.0$	●		±1.4	mV
		C(n) to C(n-1) = 3.3		±0.2	±1.2	mV
		C(n) to C(n-1), GPIO(n) to $V^- = 3.3$	●		±2.2	mV
		C(n) to C(n-1) = 4.2		±0.3	±1.6	mV
		C(n) to C(n-1), GPIO(n) to $V^- = 4.2$	●		±2.8	mV
		C(n) to C(n-1), GPIO(n) to $V^- = 5.0$		±1		mV
		Sum of Cells, $V(\text{CO}) = V^-$	●	±0.2	±0.75	%
		Internal Temperature, T = Maximum Specified Temperature		±5		°C
		V_{REG} Pin	●	±0.1	±0.25	%
		V_{REF2} Pin	●	±0.02	±0.1	%
		Digital Supply Voltage V_{REGD}	●	±0.1	±1	%

ELECTRICAL CHARACTERISTICS The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. The test conditions are $V^+ = 39.6\text{V}$, $V_{\text{REG}} = 5.0\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS	
	Total Measurement Error (TME) in Filtered Mode	C(n) to C(n – 1), GPIO(n) to V ⁻ = 0		±0.1			mV	
		C(n) to C(n – 1) = 2.0		±0.1	±0.8		mV	
		C(n) to C(n – 1), GPIO(n) to V ⁻ = 2.0	●			±1.4		mV
		C(n) to C(n – 1) = 3.3		±0.2	±1.2		mV	
		C(n) to C(n – 1), GPIO(n) to V ⁻ = 3.3	●			±2.2		mV
		C(n) to C(n – 1) = 4.2		±0.3	±1.6		mV	
		C(n) to C(n – 1), GPIO(n) to V ⁻ = 4.2	●			±2.8		mV
		C(n) to C(n – 1), GPIO(n) to V ⁻ = 5.0		±1			mV	
		Sum of Cells, V(CO) = V ⁻	●	±0.2	±0.75		%	
		Internal Temperature, T = Maximum Specified Temperature		±5			°C	
		V _{REG} Pin	●	±0.1	±0.25		%	
		V _{REF2} Pin	●	±0.02	±0.1		%	
		Digital Supply Voltage V _{REGD}	●	±0.1	±1		%	
			Total Measurement Error (TME) in Fast Mode	C(n) to C(n – 1), GPIO(n) to V ⁻ = 0		±2		
C(n) to C(n – 1), GPIO(n) to V ⁻ = 2.0	●					±4		mV
C(n) to C(n – 1), GPIO(n) to V ⁻ = 3.3	●					±4.7		mV
C(n) to C(n – 1), GPIO(n) to V ⁻ = 4.2	●					±8.3		mV
C(n) to C(n – 1), GPIO(n) to V ⁻ = 5.0				±10			mV	
Sum of Cells, V(CO) = V ⁻	●			±0.3	±1		%	
Internal Temperature, T = Maximum Specified Temperature				±5			°C	
V _{REG} Pin	●			±0.3	±1		%	
V _{REF2} Pin	●			±0.1	±0.25		%	
Digital Supply Voltage V _{REGD}	●			±0.2	±2		%	
	Input Range			C(n), n = 1 to 12	●	C(n – 1)	C(n – 1) + 5	
		C0	●	0				
		GPIO(n), n = 1 to 5	●	0	5		V	
I _L	Input Leakage Current When Inputs Are Not Being Measured	C(n), n = 0 to 12	●	10	±250		nA	
		GPIO(n), n = 1 to 5	●	10	±250		nA	
	Input Current When Inputs Are Being Measured	C(n), n = 0 to 12		±2			μA	
		GPIO(n), n = 1 to 5		±2			μA	
	Input Current During Open Wire Detection		●	70	100	130	μA	

LTC6804-1/LTC6804-2

ELECTRICAL CHARACTERISTICS The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. The test conditions are $V^+ = 39.6\text{V}$, $V_{\text{REG}} = 5.0\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
Voltage Reference Specifications								
V _{REF1}	1st Reference Voltage	V _{REF1} Pin, No Load	●	3.1	3.2	3.3	V	
	1st Reference Voltage TC	V _{REF1} Pin, No Load		3			ppm/°C	
	1st Reference Voltage Hysteresis	V _{REF1} Pin, No Load		20			ppm	
	1st Reference Long Term Drift	V _{REF1} Pin, No Load		20			ppm/√kHr	
V _{REF2}	2nd Reference Voltage	V _{REF2} Pin, No Load	●	2.990	3	3.010	V	
		V _{REF2} Pin, 5k Load to V ⁻	●	2.988	3	3.012	V	
	2nd Reference Voltage TC	V _{REF2} Pin, No Load		10			ppm/°C	
	2nd Reference Voltage Hysteresis	V _{REF2} Pin, No Load		100			ppm	
	2nd Reference Long Term Drift	V _{REF2} Pin, No Load		60			ppm/√kHr	
	General DC Specifications							
I _{VP}	V ⁺ Supply Current (See Figure 1: LTC6804 Operation State Diagram)	State: Core = SLEEP, isoSPI = IDLE	V _{REG} = 0V		3.8		6	μA
			V _{REG} = 0V	●	3.8		10	μA
			V _{REG} = 5V		1.6		3	μA
			V _{REG} = 5V	●	1.6		5	μA
		State: Core = STANDBY		18	32	50	μA	
			●	10	32	60	μA	
		State: Core = REFUP or MEASURE		0.4	0.55	0.7	mA	
			●	0.375	0.55	0.725	mA	
I _{REG(CORE)}	V _{REG} Supply Current (See Figure 1: LTC6804 Operation State diagram)	State: Core = SLEEP, isoSPI = IDLE	V _{REG} = 5V		2.2		4	μA
			V _{REG} = 5V	●	2.2		6	μA
		State: Core = STANDBY		10	35	60	μA	
			●	6	35	65	μA	
		State: Core = REFUP		0.2	0.45	0.7	mA	
			●	0.15	0.45	0.75	mA	
		State: Core = MEASURE		10.8	11.5	12.2	mA	
			●	10.7	11.5	12.3	mA	
I _{REG(isoSPI)}	Additional V _{REG} Supply Current if isoSPI in READY/ACTIVE States Note: ACTIVE State Current Assumes t _{CLK} = 1μs, (Note 3)	LTC6804-2: ISOMD = 1, R _{B1} + R _{B2} = 2k	READY	●	3.9	4.8	5.8	mA
			ACTIVE	●	5.1	6.1	7.3	mA
		LTC6804-1: ISOMD = 0, R _{B1} + R _{B2} = 2k	READY	●	3.7	4.6	5.6	mA
			ACTIVE	●	5.7	6.8	8.1	mA
		LTC6804-1: ISOMD = 1, R _{B1} + R _{B2} = 2k	READY	●	6.5	7.8	9.5	mA
			ACTIVE	●	10.2	11.3	13.3	mA
		LTC6804-2: ISOMD = 1, R _{B1} + R _{B2} = 20k	READY	●	1.3	2.1	3	mA
			ACTIVE	●	1.6	2.5	3.5	mA
		LTC6804-1: ISOMD = 0, R _{B1} + R _{B2} = 20k	READY	●	1.1	1.9	2.8	mA
			ACTIVE	●	1.5	2.3	3.3	mA
		LTC6804-1: ISOMD = 1, R _{B1} + R _{B2} = 20k	READY	●	2.1	3.3	4.9	mA
			ACTIVE	●	2.7	4.1	5.8	mA

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SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
	V^+ Supply Voltage	TME Specifications Met (Note 6)	● 11	40	55	V
V_{REG}	V_{REG} Supply Voltage	TME Supply Rejection $< 1\text{mV/V}$	● 4.5	5	5.5	V
	DRIVE output voltage	Sourcing $1\mu\text{A}$	● 5.4	5.6	5.8	V
			● 5.2	5.6	6.0	V
		Sourcing $500\mu\text{A}$	● 5.1	5.6	6.1	V
V_{REGD}	Digital Supply Voltage		● 2.7	3.0	3.6	V
	Discharge Switch ON Resistance	$V_{\text{CELL}} = 3.6\text{V}$	●	10	25	Ω
	Thermal Shutdown Temperature			150		$^\circ\text{C}$
$V_{\text{OL(WDT)}}$	Watchdog Timer Pin Low	WDT Pin Sinking 4mA	●		0.4	V
$V_{\text{OL(GPIO)}}$	General Purpose I/O Pin Low	GPIO Pin Sinking 4mA (Used as Digital Output)	●		0.4	V

ADC Timing Specifications

t_{CYCLE} (Figure 3)	Measurement + Calibration Cycle Time When Starting from the REFUP State in Normal Mode	Measure 12 Cells	● 2120	2335	2480	μs
		Measure 2 Cells	● 365	405	430	μs
		Measure 12 Cells and 2 GPIO Inputs	● 2845	3133	3325	μs
	Measurement + Calibration Cycle Time When Starting from the REFUP State in Filtered Mode	Measure 12 Cells	● 183	201.3	213.5	ms
		Measure 2 Cells	● 30.54	33.6	35.64	ms
		Measure 12 Cells and 2 GPIO Inputs	● 244	268.4	284.7	ms
	Measurement + Calibration Cycle Time When Starting from the REFUP State in Fast Mode	Measure 12 Cells	● 1010	1113	1185	μs
		Measure 2 Cells	● 180	201	215	μs
		Measure 12 Cells and 2 GPIO Inputs	● 1420	1564	1660	μs
t_{SKEW1} (Figure 6)	Skew Time. The Time Difference between C12 and GPIO2 Measurements, Command = ADCVAX	Fast Mode	● 189	208	221	μs
		Normal Mode	● 493	543	576	μs
t_{SKEW2} (Figure 3)	Skew Time. The Time Difference between C12 and C0 Measurements, Command = ADCV	Fast Mode	● 211	233	248	μs
		Normal Mode	● 609	670	711	μs
t_{WAKE}	Regulator Start-Up Time	V_{REG} Generated from Drive Pin (Figure 28)	●	100	300	μs
t_{SLEEP}	Watchdog or Software Discharge Timer	SWTEN Pin = 0 or DCTO[3:0] = 0000	● 1.8	2	2.2	sec
		SWTEN Pin = 1 and DCTO[3:0] $\neq$ 0000		0.5	120	min
t_{REFUP} (Figure 1, Figures 3 to 7)	Reference Wake-Up Time	State: Core = STANDBY	● 2.7	3.5	4.4	ms
		State: Core = REFUP	●		0	ms
f_s	ADC Clock Frequency		● 3.0	3.3	3.5	MHz

SPI Interface DC Specifications

$V_{\text{IH(SPI)}}$	SPI Pin Digital Input Voltage High	Pins CSB, SCK, SDI	● 2.3			V
$V_{\text{IL(SPI)}}$	SPI Pin Digital Input Voltage Low	Pins CSB, SCK, SDI	●		0.8	V
$V_{\text{IH(CFG)}}$	Configuration Pin Digital Input Voltage High	Pins ISOMD, SWTEN, GPIO1 to GPIO5, A0 to A3	● 2.7			V
$V_{\text{IL(CFG)}}$	Configuration Pin Digital Input Voltage Low	Pins ISOMD, SWTEN, GPIO1 to GPIO5, A0 to A3	●		1.2	V

LTC6804-1/LTC6804-2

ELECTRICAL CHARACTERISTICS The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. The test conditions are $V^+ = 39.6\text{V}$, $V_{\text{REG}} = 5.0\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$I_{\text{LEAK(DIG)}}$	Digital Input Current	Pins CSB, SCK, SDI, ISOMD, SWTEN, A0 to A3	●		± 1	μA
$V_{\text{OL(SDO)}}$	Digital Output Low	Pin SDO Sinking 1mA	●		0.3	V

isoSPI DC Specifications (See Figure 16)

V_{BIAS}	Voltage on IBIAS Pin	READY/ACTIVE State IDLE State	●	1.9	2.0 0	2.1	V V
I_{B}	Isolated Interface Bias Current	$R_{\text{BIAS}} = 2\text{k}$ to 20k	●	0.1		1.0	mA
A_{IB}	Isolated Interface Current Gain	$V_A \leq 1.6\text{V}$ $I_{\text{B}} = 1\text{mA}$ $I_{\text{B}} = 0.1\text{mA}$	● ●	18 18	20 20	22 24.5	mA/mA mA/mA
V_A	Transmitter Pulse Amplitude	$V_A = V_{\text{IP}} - V_{\text{IM}} $	●			1.6	V
V_{ICMP}	Threshold-Setting Voltage on ICMP Pin	$V_{\text{TCMP}} = A_{\text{TCMP}} \cdot V_{\text{ICMP}}$	●	0.2		1.5	V
$I_{\text{LEAK(ICMP)}}$	Input Leakage Current on ICMP Pin	$V_{\text{ICMP}} = 0\text{V}$ to V_{REG}	●			± 1	μA
$I_{\text{LEAK(IP/IM)}}$	Leakage Current on IP and IM Pins	IDLE State, V_{IP} or $V_{\text{IM}} = 0\text{V}$ to V_{REG}	●			± 1	μA
A_{TCMP}	Receiver Comparator Threshold Voltage Gain	$V_{\text{CM}} = V_{\text{REG}}/2$ to $V_{\text{REG}} - 0.2\text{V}$, $V_{\text{ICMP}} = 0.2\text{V}$ to 1.5V	●	0.4	0.5	0.6	V/V
V_{CM}	Receiver Common Mode Bias	IP/IM Not Driving		$(V_{\text{REG}} - V_{\text{ICMP}}/3 - 167\text{mV})$			V
R_{IN}	Receiver Input Resistance	Single-Ended to IPA, IMA, IPB, IMB	●	27	35	43	$\text{k}\Omega$

isoSPI Idle/Wakeup Specifications (See Figure 21)

V_{WAKE}	Differential Wake-Up Voltage	$t_{\text{DWELL}} = 240\text{ns}$	●	200			mV
t_{DWELL}	Dwell Time at V_{WAKE} Before Wake Detection	$V_{\text{WAKE}} = 200\text{mV}$	●	240			ns
t_{READY}	Startup Time After Wake Detection		●			10	μs
t_{IDLE}	Idle Timeout Duration		●	4.3	5.5	6.7	ms

isoSPI Pulse Timing Specifications (See Figure 19)

$t_{1/2\text{PW(CS)}}$	Chip-Select Half-Pulse Width		●	120	150	180	ns
$t_{\text{INV(CS)}}$	Chip-Select Pulse Inversion Delay		●			200	ns
$t_{1/2\text{PW(D)}}$	Data Half-Pulse Width		●	40	50	60	ns
$t_{\text{INV(D)}}$	Data Pulse Inversion Delay		●			70	ns

SPI Timing Requirements (See Figure 15 and Figure 20)

t_{CLK}	SCK Period	(Note 4)	●	1			μs
t_1	SDI Setup Time before SCK Rising Edge		●	25			ns
t_2	SDI Hold Time after SCK Rising Edge		●	25			ns
t_3	SCK Low	$t_{\text{CLK}} = t_3 + t_4 \geq 1\mu\text{s}$	●	200			ns
t_4	SCK High	$t_{\text{CLK}} = t_3 + t_4 \geq 1\mu\text{s}$	●	200			ns
t_5	CSB Rising Edge to CSB Falling Edge		●	0.65			μs
t_6	SCK Rising Edge to CSB Rising Edge	(Note 4)	●	0.8			μs
t_7	CSB Falling Edge to SCK Rising Edge	(Note 4)	●	1			μs

ELECTRICAL CHARACTERISTICS The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. The test conditions are $V^+ = 39.6\text{V}$, $V_{\text{REG}} = 5.0\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
isoSPI Timing Specifications (See Figure 19)							
t_8	SCK Falling Edge to SDO Valid	(Note 5)	●			60	ns
t_9	SCK Rising Edge to Short ± 1 Transmit		●			50	ns
t_{10}	CSB Transition to Long ± 1 Transmit		●			60	ns
t_{11}	CSB Rising Edge to SDO Rising	(Note 5)	●			200	ns
t_{RTN}	Data Return Delay		●		430	525	ns
$t_{\text{DSY(CS)}}$	Chip-Select Daisy-Chain Delay		●		150	200	ns
$t_{\text{DSY(D)}}$	Data Daisy-Chain Delay		●		300	360	ns
t_{LAG}	Data Daisy-Chain Lag (vs Chip-Select)		●	0	35	70	ns
$t_{6(\text{GOV})}$	Data to Chip-Select Pulse Governor		●	0.8		1.05	μs

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: The ADC specifications are guaranteed by the Total Measurement Error specification.

Note 3: The ACTIVE state current is calculated from DC measurements. The ACTIVE state current is the additional average supply current into V_{REG} when there is continuous 1MHz communications on the isoSPI ports with 50% data 1's and 50% data 0's. Slower clock rates reduce the supply current. See Applications Information section for additional details.

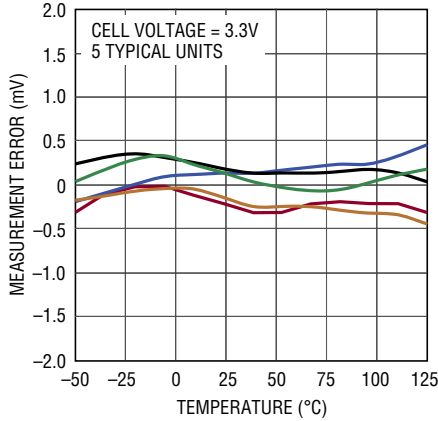
Note 4: These timing specifications are dependent on the delay through the cable, and include allowances for 50ns of delay each direction. 50ns corresponds to 10m of CAT-5 cable (which has a velocity of propagation of 66% the speed of light). Use of longer cables would require derating these specs by the amount of additional delay.

Note 5: These specifications do not include rise or fall time of SDO. While fall time (typically 5ns due to the internal pull-down transistor) is not a concern, rising-edge transition time t_{RISE} is dependent on the pull-up resistance and load capacitance on the SDO pin. The time constant must be chosen such that SDO meets the setup time requirements of the MCU.

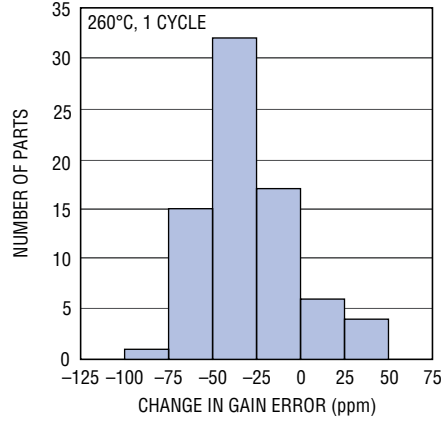
Note 6: V^+ needs to be greater than or equal to the highest $C(n)$ voltage for accurate measurements. See the graph Top Cell Measurement Error vs V^+ .

TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$, unless otherwise noted.

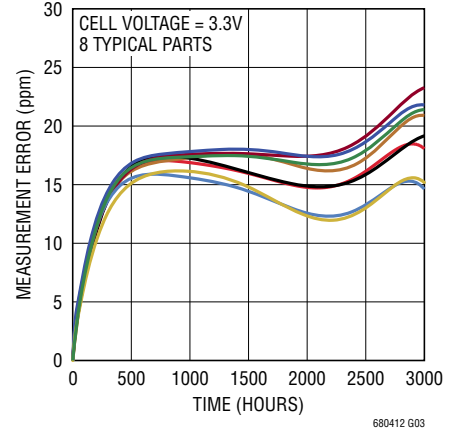
Measurement Error vs Temperature



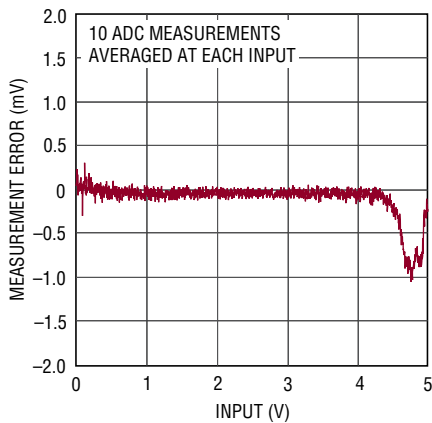
Measurement Error Due to IR Reflow



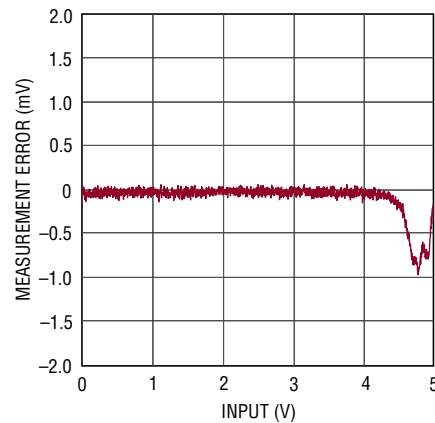
Measurement Error Long-Term Drift



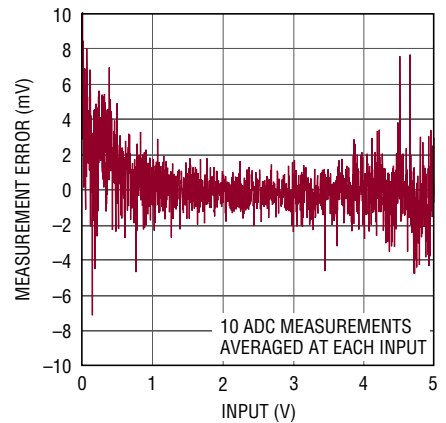
Measurement Error vs Input, Normal Mode



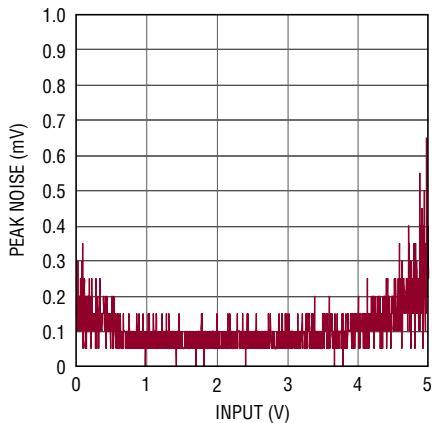
Measurement Error vs Input, Filtered Mode



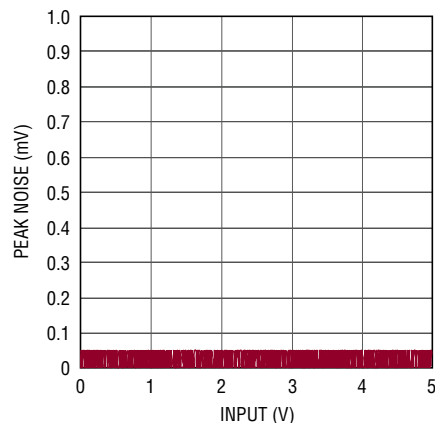
Measurement Error vs Input, Fast Mode



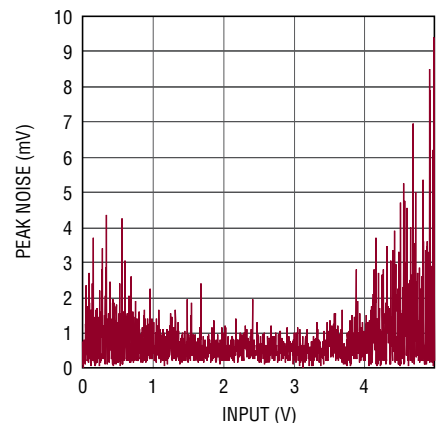
Measurement Noise vs Input, Normal Mode



Measurement Noise vs Input, Filtered Mode

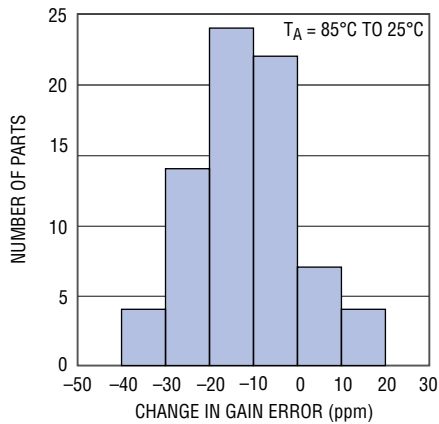


Measurement Noise vs Input, Fast Mode

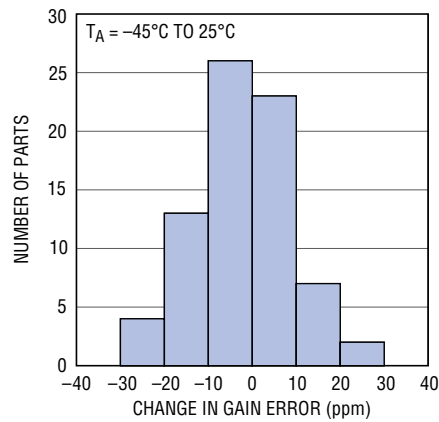


TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$, unless otherwise noted.

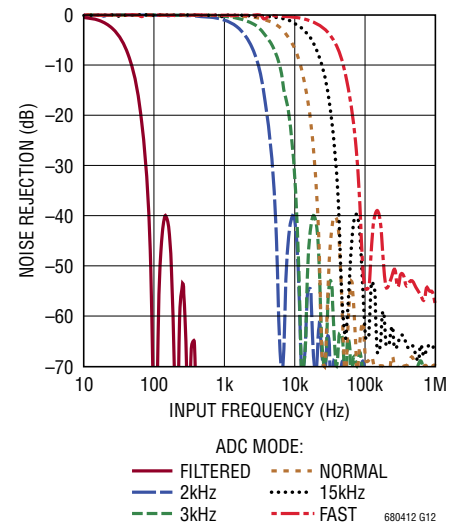
Measurement Gain Error Hysteresis, Hot



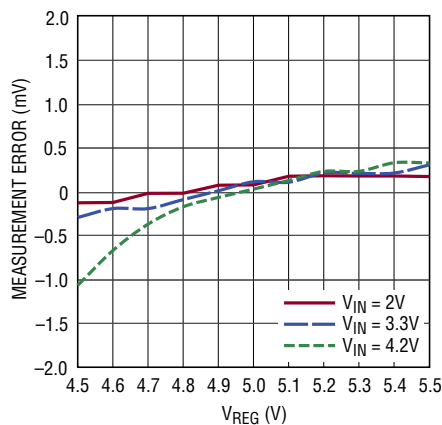
Measurement Gain Error Hysteresis, Cold



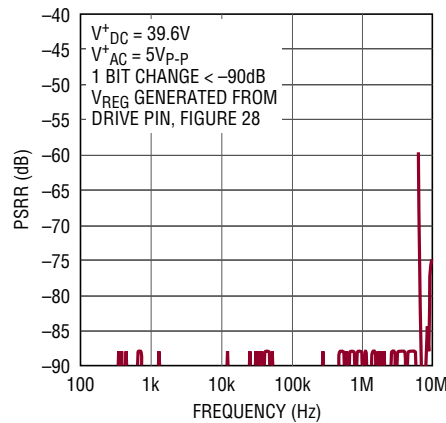
Noise Filter Response



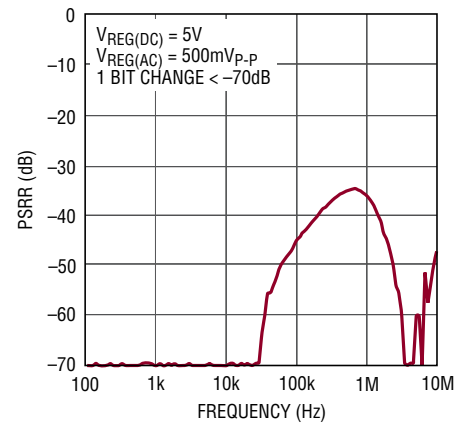
Measurement Error vs V_{REG}



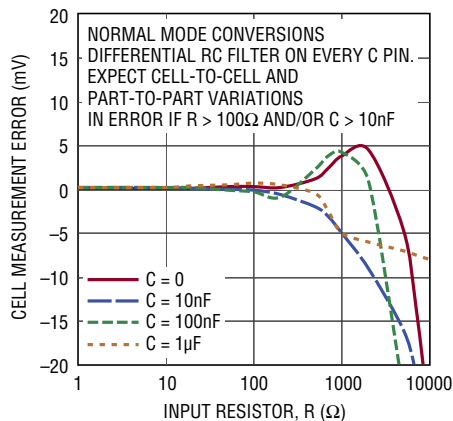
Measurement Error V^+ PSRR vs Frequency



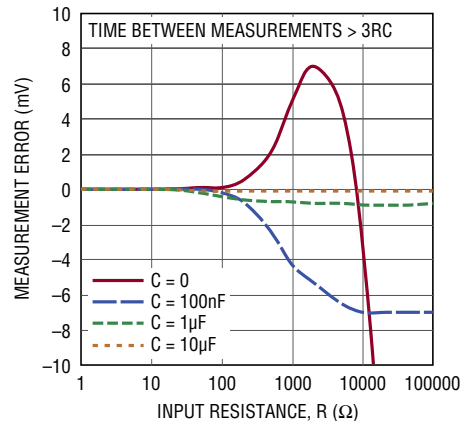
Measurement Error V_{REG} PSRR vs Frequency



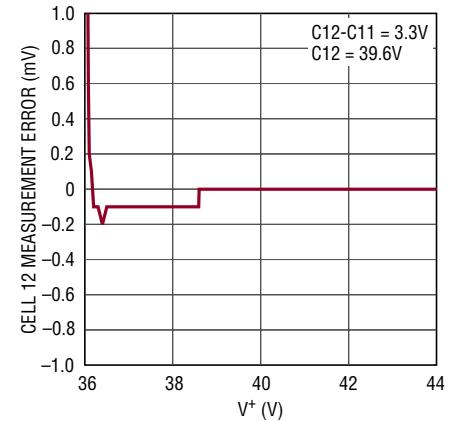
Cell Measurement Error vs Input RC Values



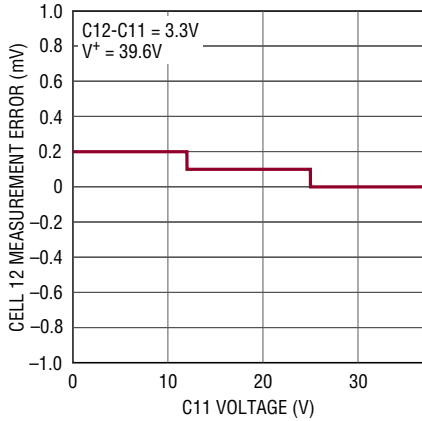
GPIO Measurement Error vs Input RC Values



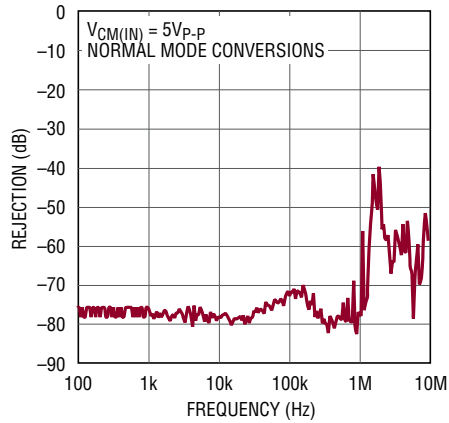
Top Cell Measurement Error vs V^+



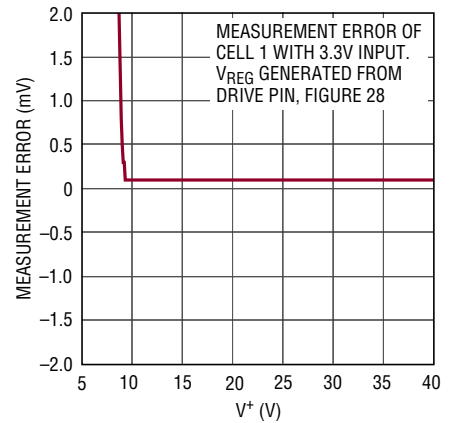
TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$, unless otherwise noted.

Cell Measurement Error vs Common Mode Voltage


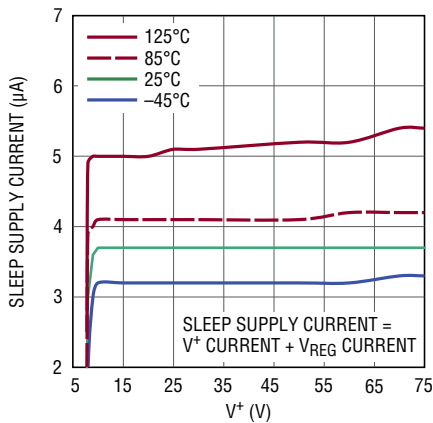
680412 G19

Cell Measurement CMRR vs Frequency


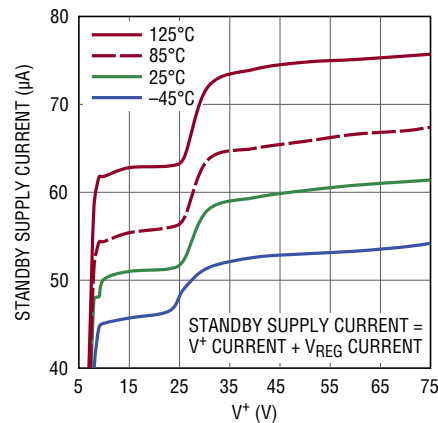
680412 G20

Measurement Error vs V^+


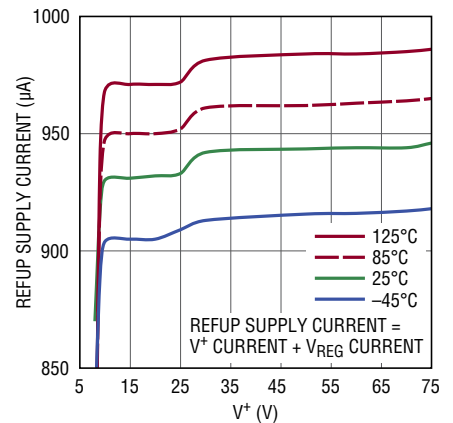
680412 G21

Sleep Supply Current vs V^+


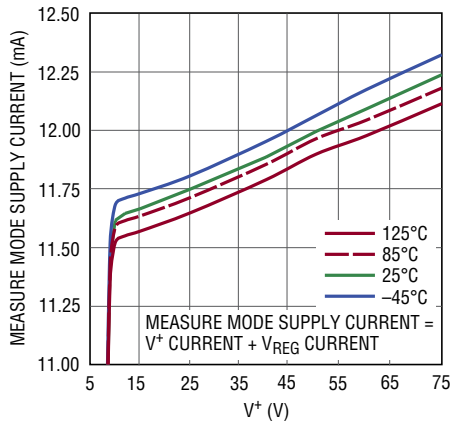
680412 G22

Standby Supply Current vs V^+


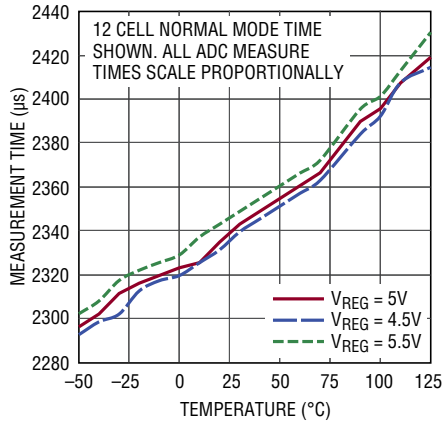
680412 G23

REFUP Supply Current vs V^+


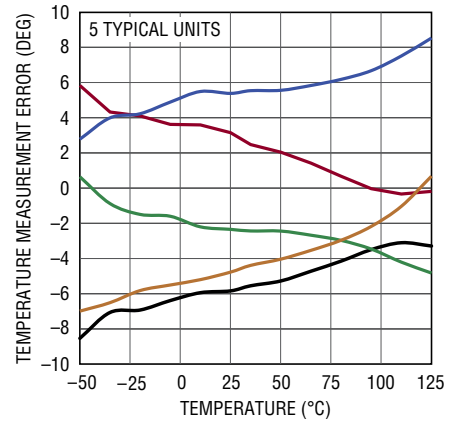
680412 G24

Measure Mode Supply Current vs V^+


680412 G25

Measurement Time vs Temperature


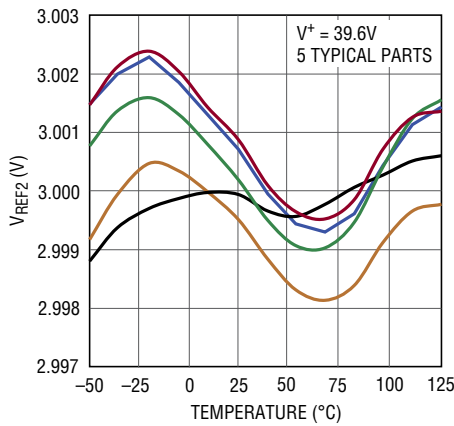
680412 G26

Internal Die Temperature Measurement Error vs Temperature


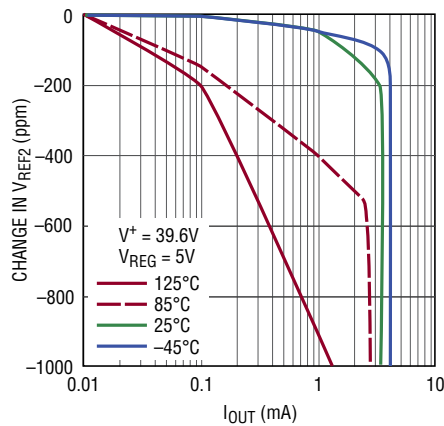
680412 G27

680412fb

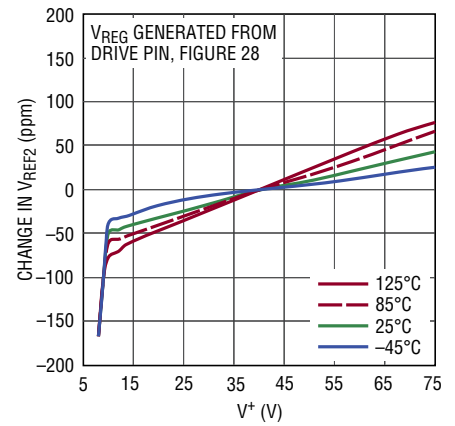
TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$, unless otherwise noted.

V_{REF2} vs Temperature

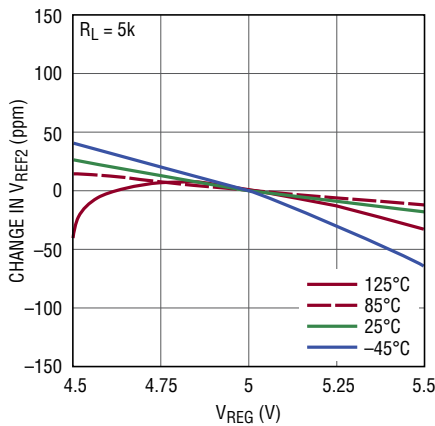
680412 G28

V_{REF2} Load Regulation

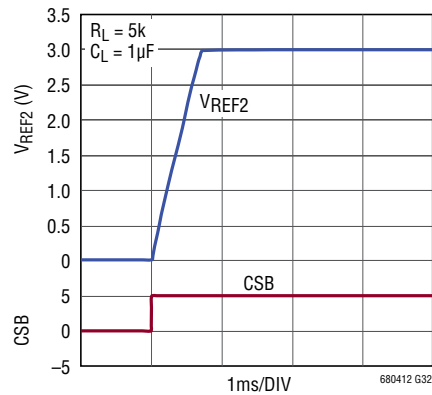
680412 G29

V_{REF2} V⁺ Line Regulation

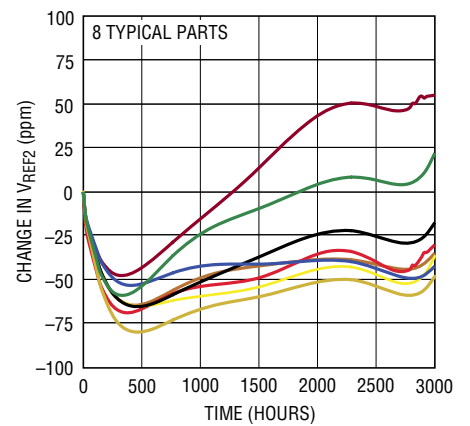
580412 G30

V_{REF2} V_{REG} Line Regulation

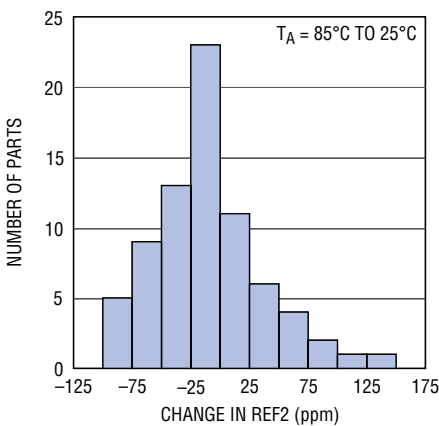
680412 G31

V_{REF2} Power-Up

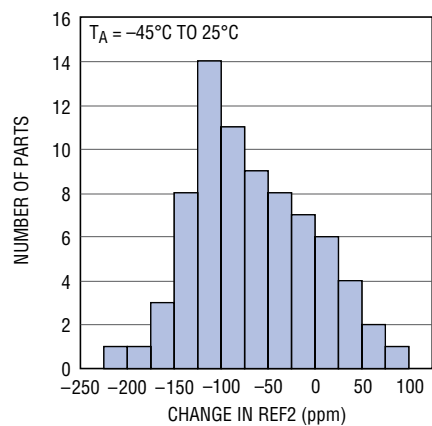
680412 G32

V_{REF2} Long-Term Drift

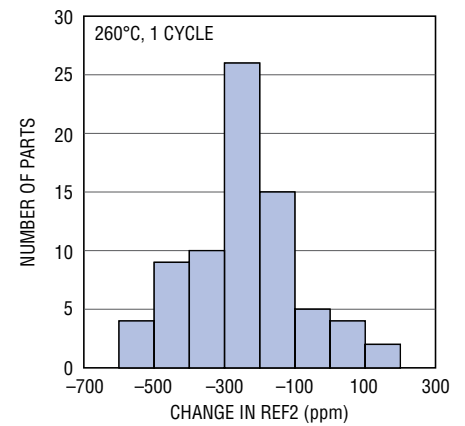
680412 G33

V_{REF2} Hysteresis, Hot

680412 G34

V_{REF2} Hysteresis, Cold

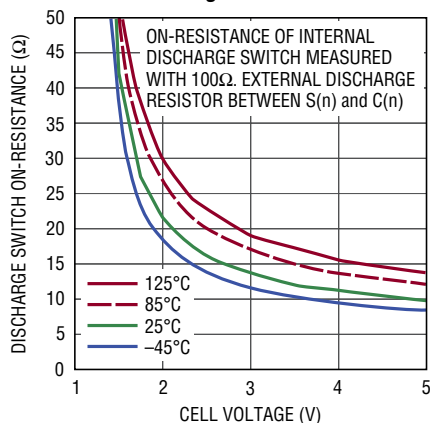
680412 G35

V_{REF2} Change Due to IR Reflow

680412 G36

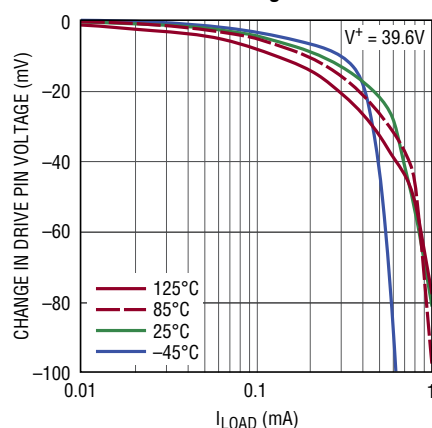
TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$, unless otherwise noted.

Discharge Switch On-Resistance vs Cell Voltage



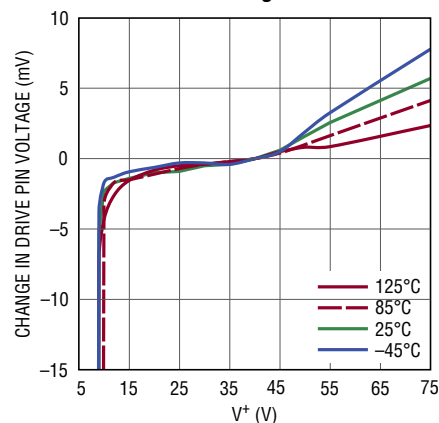
680412 G37

Drive Pin Load Regulation



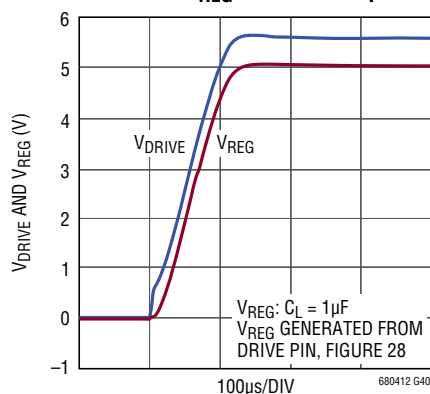
680412 G38

Drive Pin Line Regulation



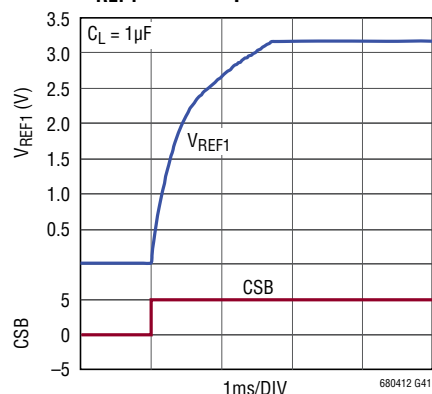
680412 G39

Drive and VREG Pin Power-Up



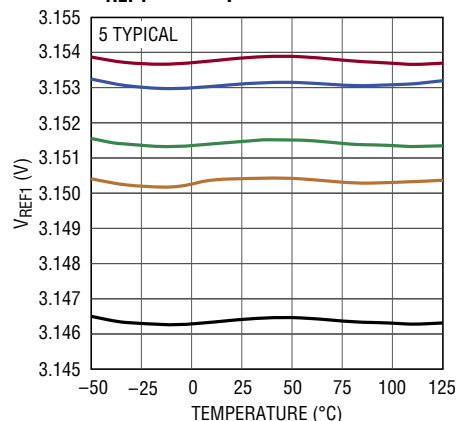
680412 G40

VREF1 Power-Up



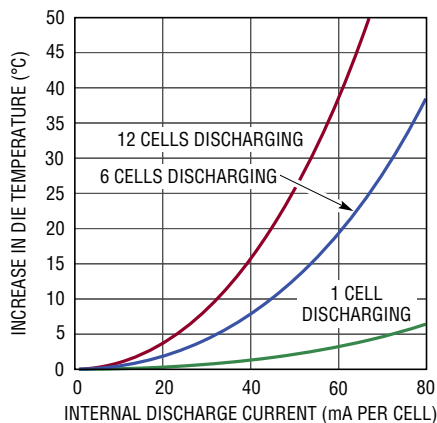
680412 G41

VREF1 vs Temperature



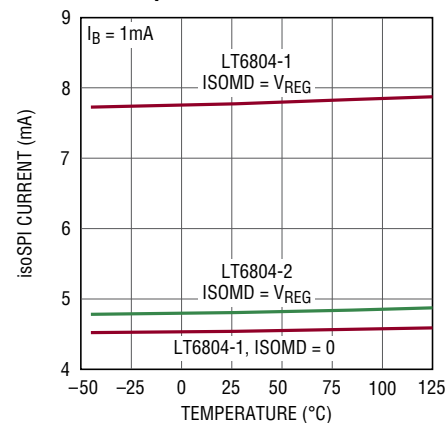
680412 G42

Internal Die Temperature Increase vs Discharge Current



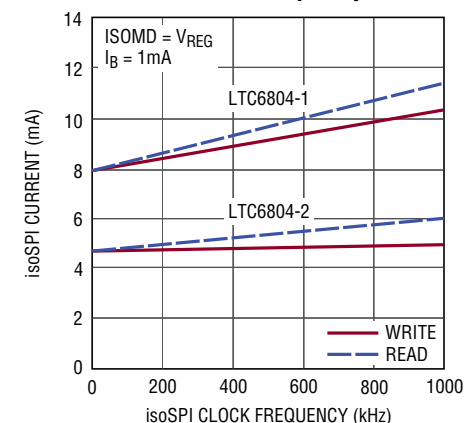
680412 G43

isoSPI Current (READY) vs Temperature



680412 G44

isoSPI Current (READY/ACTIVE) vs isoSPI Clock Frequency

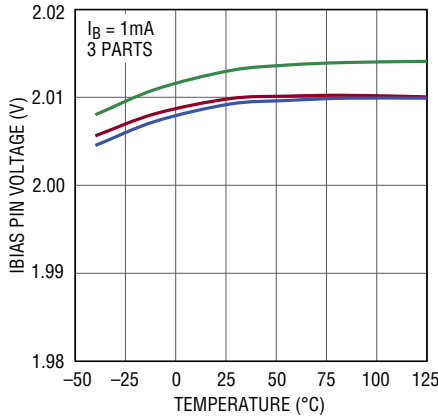


680412 G45

680412fb

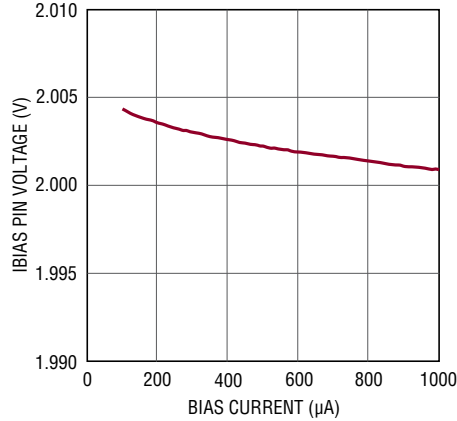
TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$, unless otherwise noted.

IBIAS Voltage vs Temperature



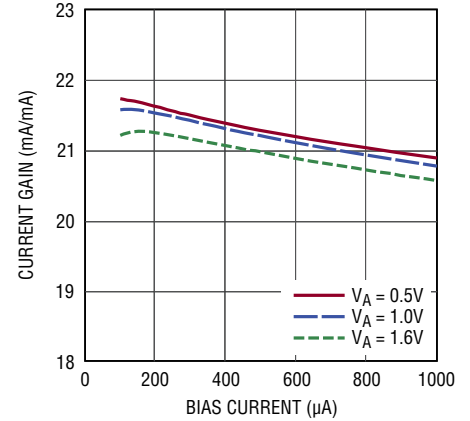
680412 G46

IBIAS Voltage Load Regulation



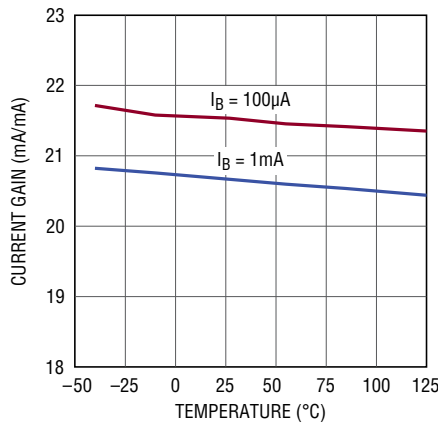
408912 G47

isoSPI Driver Current Gain (Port A/PortB) vs Bias Current



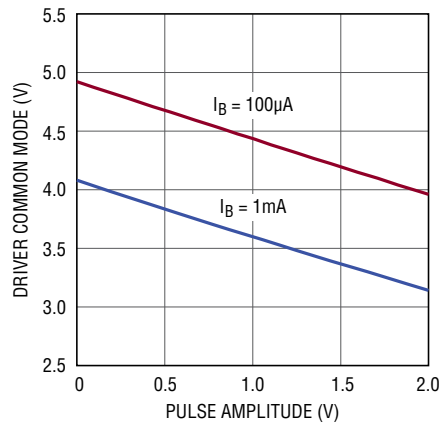
680412 G48

isoSPI Driver Current Gain (Port A/PortB) vs Temperature



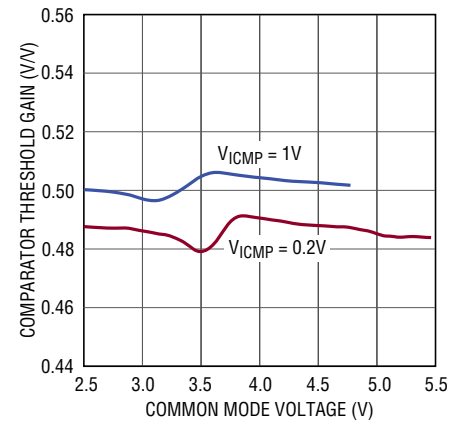
680412 G49

isoSPI Driver Common Mode Voltage (Port A/Port B) vs Pulse Amplitude



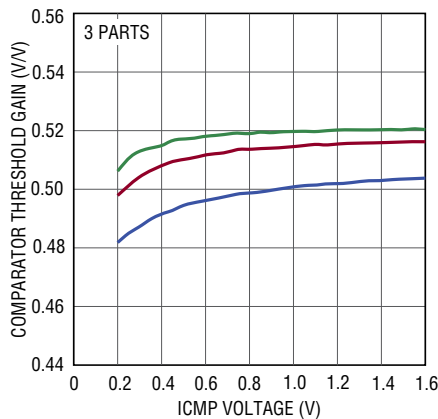
680412 G50

isoSPI Comparator Threshold Gain (Port A/Port B) vs Common Mode



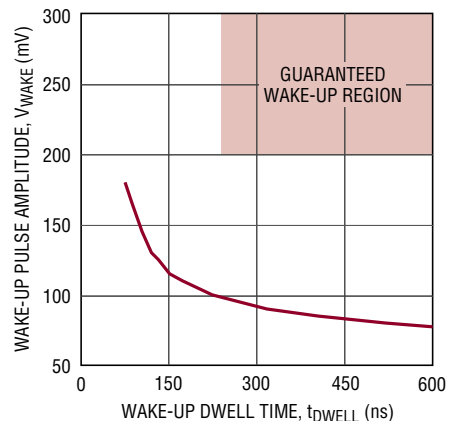
680412 G51

isoSPI Comparator Threshold Gain (Port A/Port B) vs ICMP Voltage



680412 G52

Typical Wake-Up Pulse Amplitude (Port A) vs Dwell Time

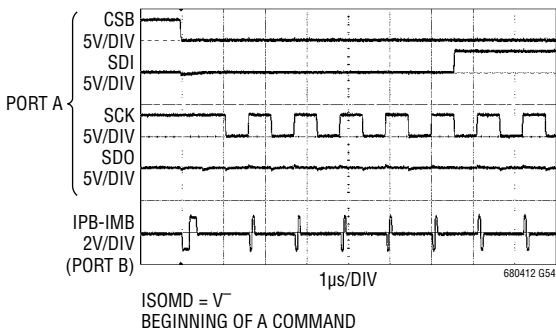


680412 G53

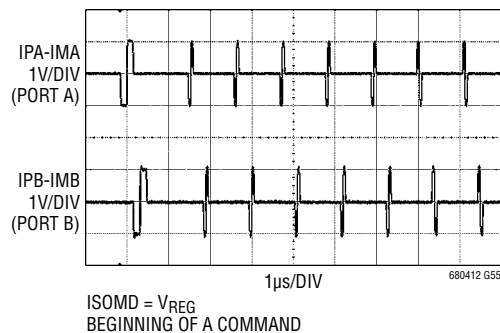
680412fb

TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$, unless otherwise noted.

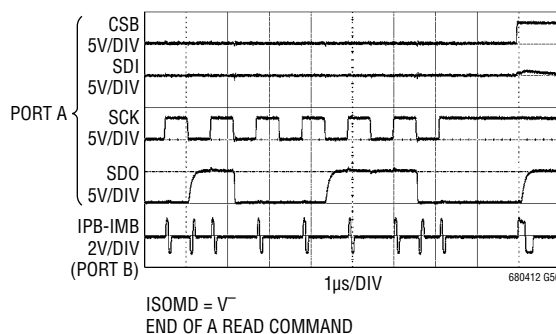
Write Command to a Daisy-Chained Device (ISOMD = 0)



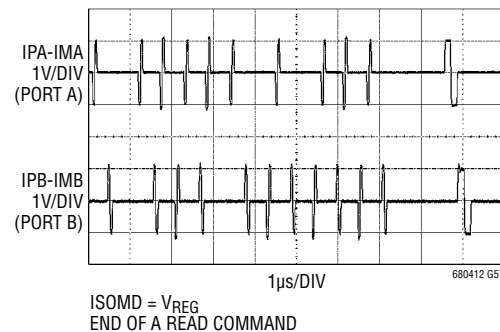
Write Command to a Daisy-Chained Device (ISOMD = 1)



Data Read-Back from a Daisy-Chained Device (ISOMD = 0)



Data Read-Back from a Daisy-Chained Device (ISOMD = 1)



PIN FUNCTIONS

C0 to C12: Cell Inputs.

S1 to S12: Balance Inputs/Outputs. 12 N-MOSFETs are connected between S(n) and C(n – 1) for discharging cells.

V⁺: Positive Supply Pin.

V⁻: Negative Supply Pins. The V⁻ pins must be shorted together, external to the IC.

V_{REF2}: Buffered 2nd reference voltage for driving multiple 10k thermistors. Bypass with an external 1μF capacitor.

V_{REF1}: ADC Reference Voltage. Bypass with an external 1μF capacitor. No DC loads allowed.

GPIO[1:5]: General Purpose I/O. Can be used as digital inputs or digital outputs, or as analog inputs with a measurement range from V⁻ to 5V. GPIO [3:5] can be used as an I²C or SPI port.

SWTEN: Software Timer Enable. Connect this pin to V_{REG} to enable the software timer.

DRIVE: Connect the base of an NPN to this pin. Connect the collector to V⁺ and the emitter to V_{REG}.

V_{REG}: 5V Regulator Input. Bypass with an external 1μF capacitor.

ISOMD: Serial Interface Mode. Connecting ISOMD to V_{REG} configures Pins 41 to 44 of the LTC6804 for 2-wire isolated interface (isoSPI) mode. Connecting ISOMD to V⁻ configures the LTC6804 for 4-wire SPI mode.

WDT: Watchdog Timer Output Pin. This is an open drain NMOS digital output. It can be left unconnected or connected with a 1M resistor to V_{REG}. If the LTC6804 does not receive a wake-up signal (see Figure 21) within 2 seconds, the watchdog timer circuit will reset the LTC6804 and the WDT pin will go high impedance.

Serial Port Pins

	LTC6804-1 (DAISY-CHAINABLE)		LTC6804-2 (ADDRESSABLE)	
	ISOMD = V _{REG}	ISOMD = V ⁻	ISOMD = V _{REG}	ISOMD = V ⁻
PORT B (Pins 45 to 48)	IPB	IPB	A3	A3
	IMB	IMB	A2	A2
	ICMP	ICMP	A1	A1
	IBIAS	IBIAS	A0	A0
PORT A (Pins 41 to 44)	(NC)	SDO	IBIAS	SDO
	(NC)	SDI	ICMP	SDI
	IPA	SCK	IPA	SCK
	IMA	CSB	IMA	CSB

CSB, SCK, SDI, SDO: 4-Wire Serial Peripheral Interface (SPI). Active low chip select (CSB), serial clock (SCK), and serial data in (SDI) are digital inputs. Serial data out (SDO) is an open drain NMOS output pin. SDO requires a 5k pull-up resistor.

A0 to A3: Address Pins. These digital inputs are connected to V_{REG} or V⁻ to set the chip address for addressable serial commands.

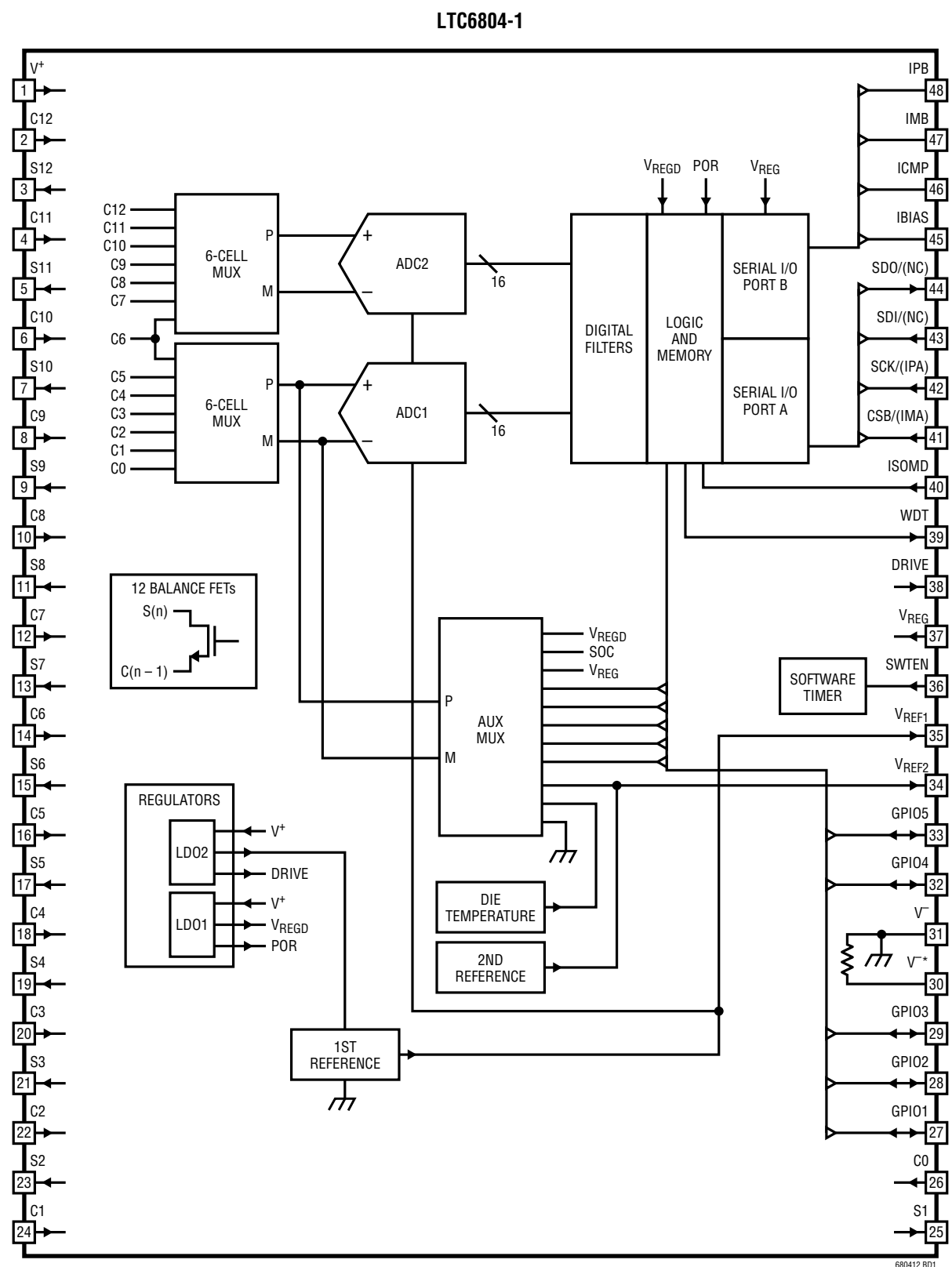
IPA, IMA: Isolated 2-Wire Serial Interface Port A. IPA (plus) and IMA (minus) are a differential input/output pair.

IPB, IMB: Isolated 2-Wire Serial Interface Port B. IPB (plus) and IMB (minus) are a differential input/output pair.

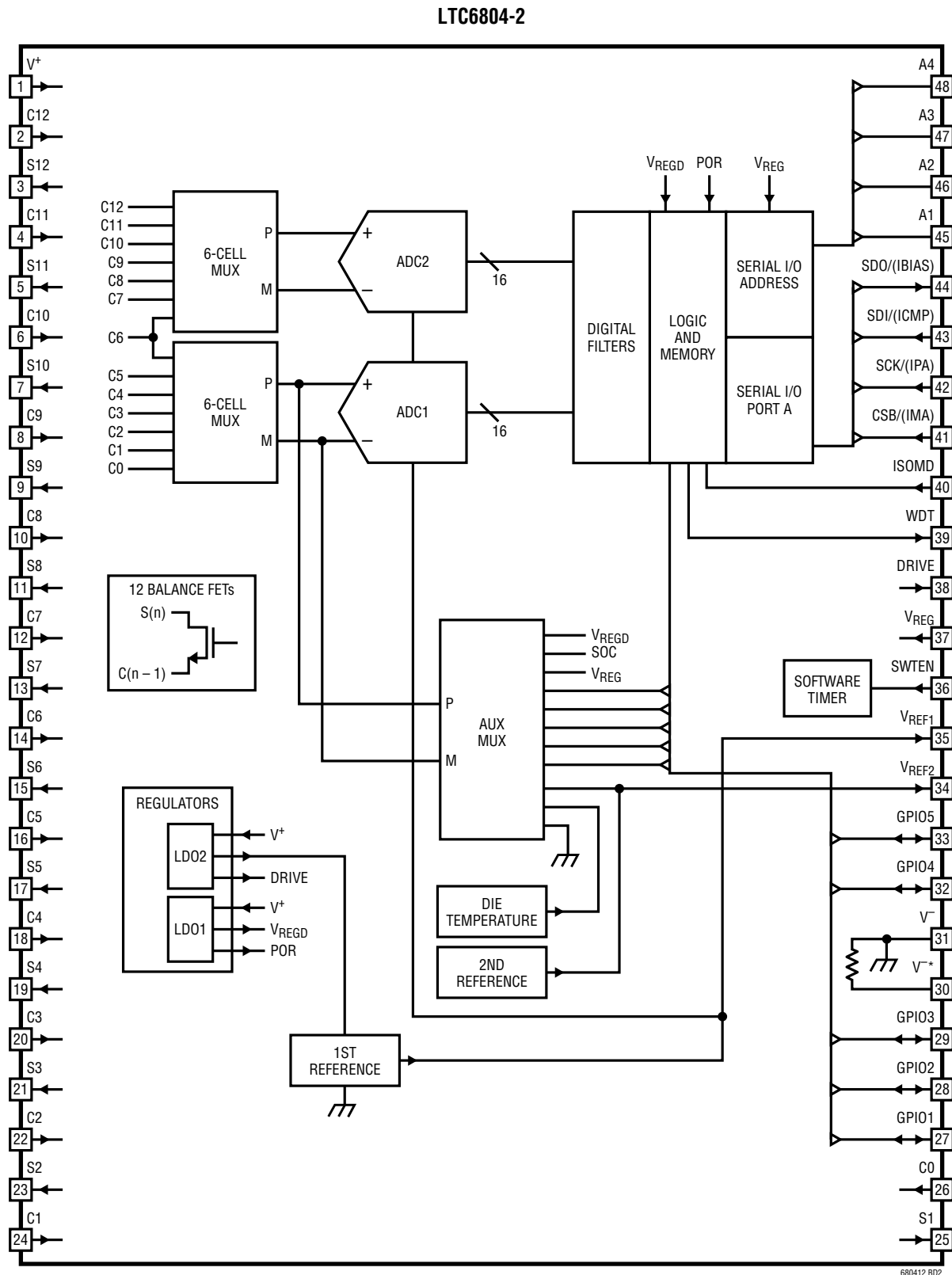
IBIAS: Isolated Interface Current Bias. Tie IBIAS to V⁻ through a resistor divider to set the interface output current level. When the isoSPI interface is enabled, the IBIAS pin voltage is 2V. The IPA/IMA or IPB/IMB output current drive is set to 20 times the current, I_B, sourced from the IBIAS pin.

ICMP: Isolated Interface Comparator Voltage Threshold Set. Tie this pin to the resistor divider between IBIAS and V⁻ to set the voltage threshold of the isoSPI receiver comparators. The comparator thresholds are set to 1/2 the voltage on the ICMP pin.

BLOCK DIAGRAM



BLOCK DIAGRAM



OPERATION

STATE DIAGRAM

The operation of the LTC6804 is divided into two separate sections: the core circuit and the isoSPI circuit. Both sections have an independent set of operating states, as well as a shutdown timeout.

LTC6804 CORE STATE DESCRIPTIONS

SLEEP State

The reference and ADCs are powered down. The watchdog timer (see Watchdog and Software Discharge Timer) has timed out. The software discharge timer is either disabled or timed out. The supply currents are reduced to minimum levels. The isoSPI ports will be in the IDLE state.

If a WAKEUP signal is received (see Waking Up the Serial Interface), the LTC6804 will enter the STANDBY state.

STANDBY State

The reference and the ADCs are off. The watchdog timer and/or the software discharge timer is running. The DRIVE pin powers the V_{REG} pin to 5V through an external transistor. (Alternatively, V_{REG} can be powered by an external supply).

When a valid ADC command is received or the REFON bit is set to 1 in the Configuration Register Group, the IC pauses for t_{REFUP} to allow for the reference to power up and then enters either the REFUP or MEASURE state. If there is no WAKEUP signal for a duration t_{SLEEP} (when both the watchdog and software discharge timer have expired) the LTC6804

returns to the SLEEP state. If the software discharge timer is disabled, only the watchdog timer is relevant.

REFUP State

To reach this state the REFON bit in the Configuration Register Group must be set to 1 (using the WRCFG command, see Table 36). The ADCs are off. The reference is powered up so that the LTC6804 can initiate ADC conversions more quickly than from the STANDBY state.

When a valid ADC command is received, the IC goes to the MEASURE state to begin the conversion. Otherwise, the LTC6804 will return to the STANDBY state when the REFON bit is set to 0, either manually (using WRCFG command) or automatically when the watchdog timer expires. (The LTC6804 will then move straight into the SLEEP state if both timers are expired).

MEASURE State

The LTC6804 performs ADC conversions in this state. The reference and ADCs are powered up.

After ADC conversions are complete the LTC6804 will transition to either the REFUP or STANDBY states, depending on the REFON bit. Additional ADC conversions can be initiated more quickly by setting REFON = 1 to take advantage of the REFUP state.

Note: Non-ADC commands do not cause a Core state transition. Only an ADC conversion or diagnostic commands will place the Core in the MEASURE state.

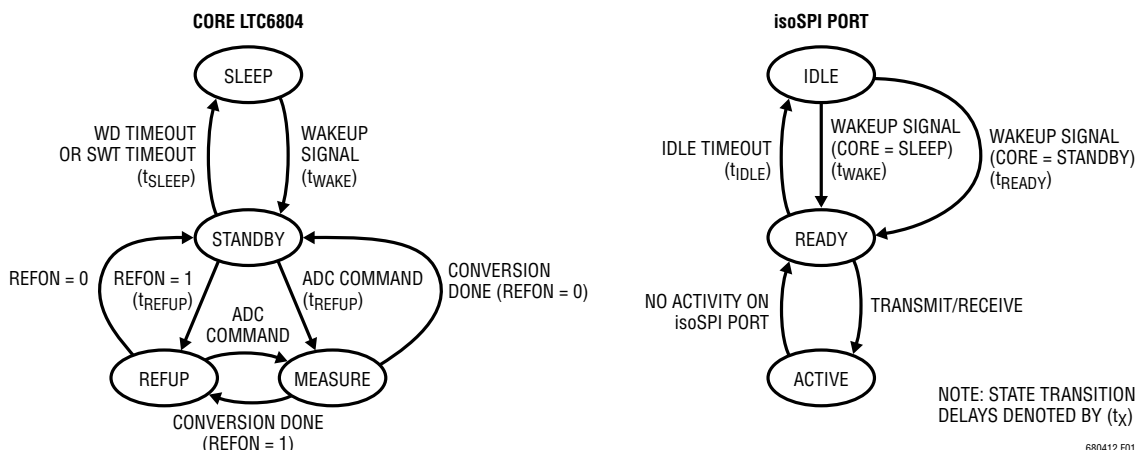


Figure 1. LTC6804 Operation State Diagram

OPERATION

isoSPI STATE DESCRIPTIONS

Note: The LTC6804-1 has two isoSPI ports (A and B), for daisy-chain communication. The LTC6804-2 has only one isoSPI port (A), for parallel-addressable communication.

IDLE State

The isoSPI ports are powered down.

When isoSPI port A receives a WAKEUP signal (see Waking Up the Serial Interface), the isoSPI enters the READY state. This transition happens quickly (within t_{READY}) if the Core is in the STANDBY state because the DRIVE and V_{REG} pins are already biased up. If the Core is in the SLEEP state when the isoSPI receives a WAKEUP signal, then it transitions to the READY state within t_{WAKE} .

READY State

The isoSPI port(s) are ready for communication. Port B is enabled only for LTC6804-1, and is not present on the LTC6804-2. The serial interface current in this state depends on if the part is LTC6804-1 or LTC6804-2, the status of the ISOMD pin, and $R_{\text{BIAS}} = R_{\text{B1}} + R_{\text{B2}}$ (the external resistors tied to the IBIAS pin).

If there is no activity (i.e., no WAKEUP signal) on port A for greater than $t_{\text{IDLE}} = 5.5\text{ms}$, the LTC6804 goes to the IDLE state. When the serial interface is transmitting or receiving data the LTC6804 goes to the ACTIVE state.

ACTIVE State

The LTC6804 is transmitting/receiving data using one or both of the isoSPI ports. The serial interface consumes maximum power in this state. The supply current increases with clock frequency as the density of isoSPI pulses increases.

POWER CONSUMPTION

The LTC6804 is powered via two pins: V^+ and V_{REG} . The V^+ input requires voltage greater than or equal to the top cell voltage, and it provides power to the high voltage elements of the core circuitry. V^+ can be directly connected to the top cell of the battery stack, or to an external supply. The V_{REG} input requires 5V and provides power to the remaining core circuitry and the isoSPI circuitry. The V_{REG} input can be powered through an external transistor, driven by

the regulated DRIVE output pin. Alternatively, V_{REG} can be powered by an external supply.

The power consumption varies according to the operational states. Table 1 and Table 2 provide equations to approximate the supply pin currents in each state. The V^+ pin current depends only on the Core state and not on the isoSPI state. However, the V_{REG} pin current depends on both the Core state and isoSPI state, and can therefore be divided into two components. The isoSPI interface draws current only from the V_{REG} pin.

$$I_{\text{REG}} = I_{\text{REG(CORE)}} + I_{\text{REG(isoSPI)}}$$

Table 1. Core Supply Current

STATE		I_{V^+}	$I_{\text{REG(CORE)}}$
SLEEP	$V_{\text{REG}} = 0\text{V}$	$3.8\mu\text{A}$	$0\mu\text{A}$
	$V_{\text{REG}} = 5\text{V}$	$1.6\mu\text{A}$	$2.2\mu\text{A}$
STANDBY		$32\mu\text{A}$	$35\mu\text{A}$
REFUP		$550\mu\text{A}$	$450\mu\text{A}$
MEASURE		$550\mu\text{A}$	11.5mA

In the SLEEP state the V_{REG} pin will draw approximately $2.2\mu\text{A}$ if powered by a external supply. Otherwise, the V^+ pin will supply the necessary current.

ADC OPERATION

There are two ADCs inside the LTC6804. The two ADCs operate simultaneously when measuring twelve cells. Only one ADC is used to measure the general purpose inputs. The following discussion uses the term ADC to refer to one or both ADCs, depending on the operation being performed. The following discussion will refer to ADC1 and ADC2 when it is necessary to distinguish between the two circuits, in timing diagrams, for example.

ADC Modes

The ADCOPT bit (CFGRO[0]) in the configuration register group and the mode selection bits MD[1:0] in the conversion command together provide 6 modes of operation for the ADC which correspond to different over sampling ratios (OSR). The accuracy of these modes are summarized in Table 3. In each mode, the ADC first measures the inputs, and then performs a calibration of each channel. The names of the modes are based on the -3dB bandwidth of the ADC measurement.

OPERATION

Table 2. isoSPI Supply Current Equations

isoSPI STATE	DEVICE	ISOMD CONNECTION	$I_{REG(isoSPI)}$
IDLE	LTC6804-1/LTC6804-2	N/A	0mA
READY	LTC6804-1	V_{REG}	$2.8mA + 5 \cdot I_B$
		V^-	$1.6mA + 3 \cdot I_B$
	LTC6804-2	V_{REG}	$1.8mA + 3 \cdot I_B$
		V^-	0mA
ACTIVE	LTC6804-1	V_{REG}	Write: $2.8mA + 5 \cdot I_B + (2 \cdot I_B + 0.4mA) \cdot \frac{1\mu s}{t_{CLK}}$ Read: $2.8mA + 5 \cdot I_B + (3 \cdot I_B + 0.5mA) \cdot \frac{1\mu s}{t_{CLK}}$
		V^-	$1.6mA + 3 \cdot I_B + (2 \cdot I_B + 0.2mA) \cdot \frac{1\mu s}{t_{CLK}}$
	LTC6804-2	V_{REG}	Write: $1.8mA + 3 \cdot I_B + (0.3mA) \cdot \frac{1\mu s}{t_{CLK}}$ Read: $1.8mA + 3 \cdot I_B + (I_B + 0.3mA) \cdot \frac{1\mu s}{t_{CLK}}$
		V^-	0mA

Table 3. ADC Filter Bandwidth and Accuracy

MODE	–3dB FILTER BW	–40dB FILTER BW	TME SPEC AT 3.3V, 25°C	TME SPEC AT 3.3V, –40°C, 125°C
27kHz (Fast Mode)	27kHz	84kHz	±4.7mV	±4.7mV
14kHz	13.5kHz	42kHz	±4.7mV	±4.7mV
7kHz (Normal Mode)	6.8kHz	21kHz	±1.2mV	±2.2mV
3kHz	3.4kHz	10.5kHz	±1.2mV	±2.2mV
2kHz	1.7kHz	5.3kHz	±1.2mV	±2.2mV
26Hz (Filtered Mode)	26Hz	82Hz	±1.2mV	±2.2mV

Note: TME is the total measurement error.

Mode 7kHz (Normal):

In this mode, the ADC has high resolution and low TME (total measurement error). This is considered the normal operating mode because of the optimum combination of speed and accuracy.

Mode 27kHz (Fast):

In this mode, the ADC has maximum throughput but has some increase in TME (total measurement error). So this mode is also referred to as the fast mode. The increase in speed comes from a reduction in the oversampling ratio. This results in an increase in noise and average measurement error.

Mode 26Hz (Filtered):

In this mode, the ADC digital filter –3dB frequency is lowered to 26Hz by increasing the OSR. This mode is also referred to as the filtered mode due to its low –3dB frequency. The accuracy is similar to the 7kHz (Normal) mode with lower noise.

Modes 14kHz, 3kHz and 2kHz:

Modes 14kHz, 3kHz and 2kHz provide additional options to set the ADC digital filter –3dB frequency at 13.5kHz, 3.4kHz and 1.7kHz respectively. The accuracy of the 14kHz mode is similar to the 27kHz (fast) mode. The accuracy of 3kHz and 2kHz modes is similar to the 7kHz (normal) mode.

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OPERATION

The conversion times for these modes are provided in Table 5. If the core is in STANDBY state, an additional t_{REFUP} time is required to power up the reference before beginning the ADC conversions. The reference can remain powered up between ADC conversions if the REFON bit in Configuration Register Group is set to 1 so the core is in REFUP state after a delay t_{REFUP} . Then, the subsequent ADC commands will not have the t_{REFUP} delay before beginning ADC conversions.

ADC Range and Resolution

The C inputs and GPIO inputs have the same range and resolution. The ADC inside the LTC6804 has an approximate range from $-0.82V$ to $5.73V$. Negative readings are rounded to $0V$. The format of the data is a 16-bit unsigned integer where the LSB represents $100\mu V$. Therefore, a reading of $0x80E8$ (33,000 decimal) indicates a measurement of $3.3V$.

Delta-Sigma ADCs have quantization noise which depends on the input voltage, especially at low over sampling ratios (OSR), such as in FAST mode. In some of the ADC modes, the quantization noise increases as the input voltage approaches the upper and lower limits of the ADC range. For example, the total measurement noise versus input voltage in normal and filtered modes is shown in Figure 2.

The specified range of the ADC is $0V$ to $5V$. In Table 4, the precision range of the ADC is arbitrarily defined as $0.5V$ to $4.5V$. This is the range where the quantization noise is relatively constant even in the lower OSR modes (see Figure 2). Table 4 summarizes the total noise in this range for all six ADC operating modes. Also shown is the noise

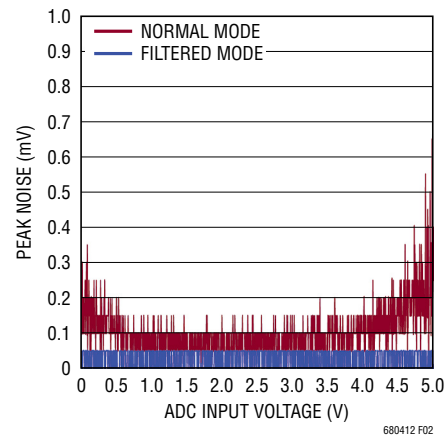


Figure 2. Measurement Noise vs Input Voltage

free resolution. For example, 14-bit noise free resolution in normal mode implies that the top 14 bits will be noise free with a DC input, but that the 15th and 16th least significant bits (LSB) will flicker.

ADC Range vs Voltage Reference Value:

Typical Delta-Sigma ADC's have a range which is exactly twice the value of the voltage reference, and the ADC measurement error is directly proportional to the error in the voltage reference. The LTC6804 ADC is not typical. The absolute value of V_{REF1} is trimmed up or down to compensate for gain errors in the ADC. Therefore, the ADC total measurement error (TME) specifications are superior to the V_{REF1} specifications. For example, the $25^{\circ}C$ specification of the total measurement error when measuring $3.300V$ in $7kHz$ (normal) mode is $\pm 1.2mV$ and the $25^{\circ}C$ specification for V_{REF1} is $3.200V \pm 100mV$.

Table 4. ADC Range and Resolution

MODE	FULL RANGE ¹	SPECIFIED RANGE	PRECISION RANGE ²	LSB	FORMAT	MAX NOISE	NOISE FREE RESOLUTION ³
27kHz (Fast)	$-0.8192V$ to $5.7344V$	$0V$ to $5V$	$0.5V$ to $4.5V$	$100\mu V$	Unsigned 16 Bits	$\pm 4mV_{p-p}$	10 Bits
14kHz						$\pm 1mV_{p-p}$	12 Bits
7kHz (Normal)						$\pm 250\mu V_{p-p}$	14 Bits
3kHz						$\pm 150\mu V_{p-p}$	14 Bits
2kHz						$\pm 100\mu V_{p-p}$	15 Bits
26Hz (Filtered)						$\pm 50\mu V_{p-p}$	16 Bits

1. Negative readings are rounded to $0V$.

2. PRECISION RANGE is the range over which the noise is less than MAX NOISE.

3. NOISE FREE RESOLUTION is a measure of the noise level within the PRECISION RANGE.

OPERATION

Measuring Cell Voltages (ADCV Command)

The ADCV command initiates the measurement of the battery cell inputs, pins C0 through C12. This command has options to select the number of channels to measure and the ADC mode. See the section on Commands for the ADCV command format.

Figure 3 illustrates the timing of ADCV command which measures all twelve cells. After the receipt of the ADCV command to measure all 12 cells, ADC1 sequentially measures the bottom 6 cells. ADC2 sequentially measures the top 6 cells. After the cell measurements are complete, each channel is calibrated to remove any offset errors.

Table 5 shows the conversion times for the ADCV command measuring all 12 cells. The total conversion time is given by t_{6C} which indicates the end of the calibration step.

Figure 4 illustrates the timing of the ADCV command that measures only two cells.

Table 6 shows the conversion time for ADCV command measuring only 2 cells. t_{1C} indicates the total conversion time for this command.

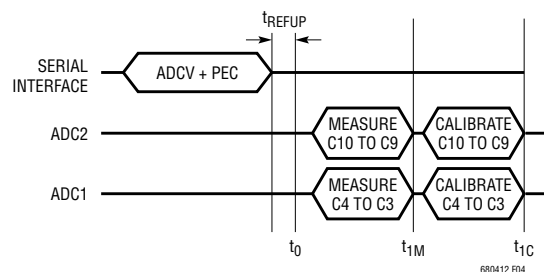


Figure 4. Timing for ADCV Command Measuring 2 Cells

Table 6. Conversion Times for ADCV Command Measuring Only 2 Cells in Different Modes

MODE	CONVERSION TIMES (in μs)		
	t_0	t_{1M}	t_{1C}
27kHz	0	57	201
14kHz	0	86	230
7kHz	0	144	405
3kHz	0	260	521
2kHz	0	493	754
26Hz	0	29,817	33,568

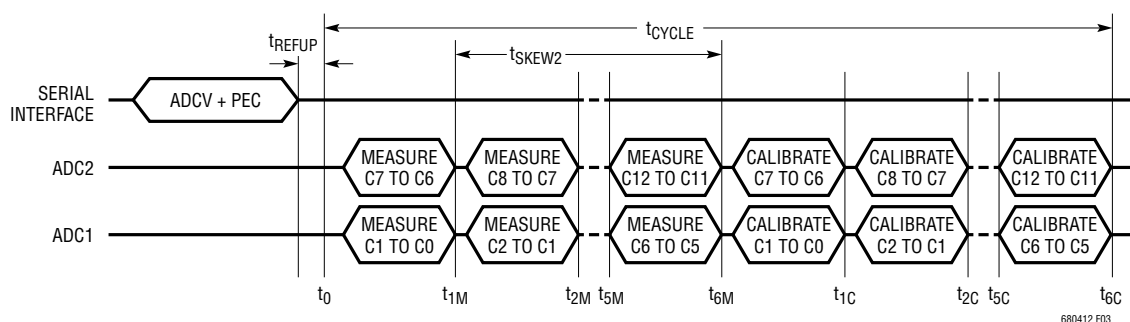


Figure 3. Timing for ADCV Command Measuring All 12 Cells

Table 5. Conversion Times for ADCV Command Measuring All 12 Cells in Different Modes

MODE	CONVERSION TIMES (in μs)								
	t_0	t_{1M}	t_{2M}	t_{5M}	t_{6M}	t_{1C}	t_{2C}	t_{5C}	t_{6C}
27kHz	0	57	103	243	290	432	568	975	1,113
14kHz	0	86	162	389	465	606	742	1,149	1,288
7kHz	0	144	278	680	814	1,072	1,324	2,080	2,335
3kHz	0	260	511	1,262	1,512	1,770	2,022	2,778	3,033
2kHz	0	493	976	2,425	2,908	3,166	3,418	4,175	4,430
26Hz	0	29,817	59,623	149,043	178,850	182,599	186,342	197,571	201,317

OPERATION

Under/Overvoltage Monitoring

Whenever the C inputs are measured, the results are compared to undervoltage and overvoltage thresholds stored in memory. If the reading of a cell is above the overvoltage limit, a bit in memory is set as a flag. Similarly, measurement results below the undervoltage limit cause a flag to be set. The overvoltage and undervoltage thresholds are stored in the configuration register group. The flags are stored in the status register group B.

Auxiliary (GPIO) Measurements (ADAX Command)

The ADAX command initiates the measurement of the GPIO inputs. This command has options to select which GPIO input to measure (GPIO1-5) and which ADC mode. The ADAX command also measures the 2nd reference. There are options in the ADAX command to measure each GPIO and the 2nd reference separately or to measure all 5 GPIOs and the 2nd reference in a single command. See the section on commands for the ADAX command format. All auxiliary measurements are relative to the V^- pin voltage. This command can be used to read external temperature

by connecting the temperature sensors to the GPIOs. These sensors can be powered from the 2nd reference which is also measured by the ADAX command, resulting in precise ratiometric measurements.

Figure 5 illustrates the timing of the ADAX command measuring all GPIOs and the 2nd reference. Since all the 6 measurements are carried out on ADC1 alone, the conversion time for the ADAX command is similar to the ADCV command.

Measuring Cell Voltages and GPIOs (ADCVAX Command)

The ADCVAX command combines twelve cell measurements with two GPIO measurements (GPIO1 and GPIO2). This command simplifies the synchronization of battery cell voltage and current measurements when current sensors are connected to GPIO1 or GPIO2 inputs. Figure 6 illustrates the timing of the ADCVAX command. See the section on commands for the ADCVAX command format. The synchronization of the current and voltage measurements, t_{SKEW1} , in FAST MODE is within 208 μ s.

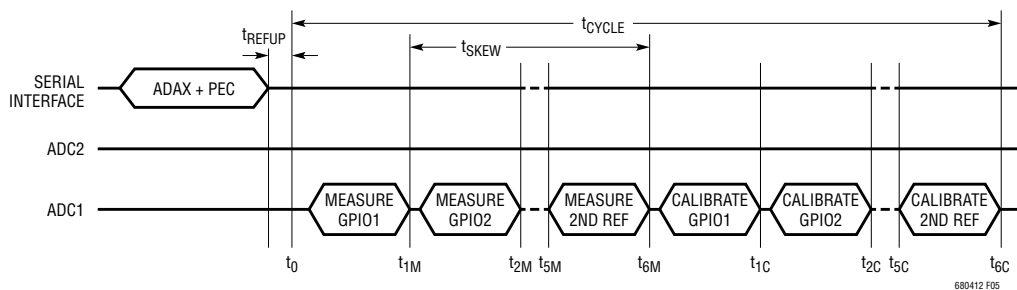


Figure 5. Timing for ADAX Command Measuring All GPIOs and 2nd Reference

Table 7. Conversion Times for ADAX Command Measuring All GPIOs and 2nd Reference in Different Modes

MODE	CONVERSION TIMES (in μ s)								
	t_0	t_{1M}	t_{2M}	t_{5M}	t_{6M}	t_{1C}	t_{2C}	t_{5C}	t_{6C}
27kHz	0	57	103	243	290	432	568	975	1,113
14kHz	0	86	162	389	465	606	742	1,149	1,288
7kHz	0	144	278	680	814	1,072	1,324	2,080	2,335
3kHz	0	260	511	1,262	1,512	1,770	2,022	2,778	3,033
2kHz	0	493	976	2,425	2,908	3,166	3,418	4,175	4,430
26Hz	0	29,817	59,623	149,043	178,850	182,599	186,342	197,571	201,317

OPERATION

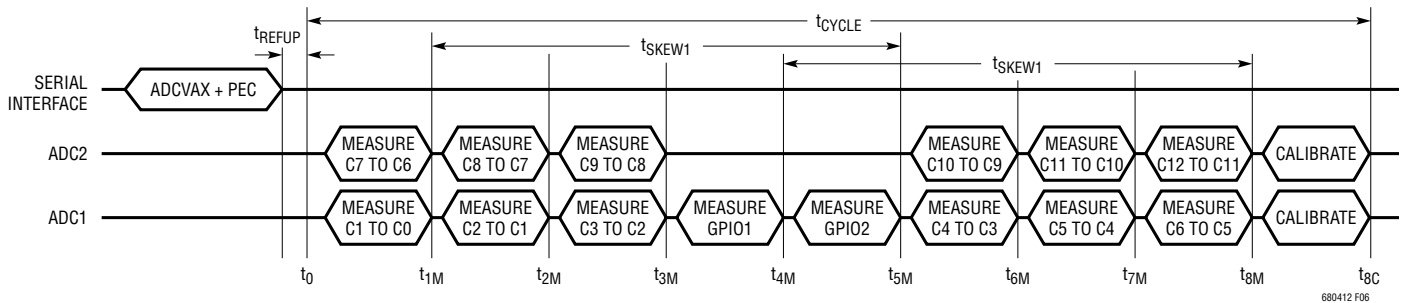


Figure 6. Timing of ADCVAX Command

Table 8. Conversion and Synchronization Times for ADCVAX Command in Different Modes

MODE	CONVERSION TIMES (in μ s)										SYNCHRONIZATION TIME (μ s)
	t ₀	t _{1M}	t _{2M}	t _{3M}	t _{4M}	t _{5M}	t _{6M}	t _{7M}	t _{8M}	t _{8C}	t _{SKEW1}
27kHz	0	57	106	155	216	265	326	375	424	1,564	208
14kHz	0	86	161	237	320	396	479	555	630	1,736	310
7kHz	0	144	278	412	553	687	828	962	1,096	3,133	543
3kHz	0	260	511	761	1,018	1,269	1,526	1,777	2,027	4,064	1009
2kHz	0	493	976	1,459	1,949	2,432	2,923	3,406	3,888	5,925	1939
26Hz	0	29,817	59,623	89,430	119,244	149,051	178,864	208,671	238,478	268,442	119234

Table 8 shows the conversion and synchronization time for the ADCVAX command in different modes. The total conversion time for the command is given by t_{8C}.

DATA ACQUISITION SYSTEM DIAGNOSTICS

The battery monitoring data acquisition system is comprised of the multiplexers, ADCs, 1st reference, digital filters, and memory. To ensure long term reliable performance there are several diagnostic commands which can be used to verify the proper operation of these circuits.

Measuring Internal Device Parameters (ADSTAT Command)

The ADSTAT command is a diagnostic command that measures the following internal device parameters: sum of all cells (SOC), internal die temperature (ITMP), analog power supply (VA) and the digital power supply (VD). These parameters are described in the section below. All 6 ADC modes are available for these conversions. See the section on commands for the ADSTAT command format. Figure 7 illustrates the timing of the ADSTAT command measuring all 4 internal device parameters.

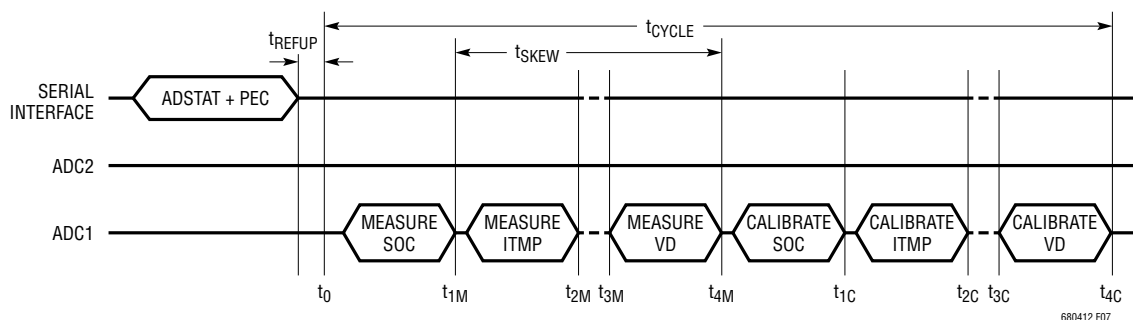


Figure 7. Timing for ADSTAT Command Measuring SOC, ITMP, VA, VD

OPERATION

Table 9 shows the conversion time of the ADSTAT command measuring all 4 internal parameters. t_{4c} indicates the total conversion time for the ADSTAT command.

Sum of Cells Measurement: The sum of all cells measurement is the voltage between C12 and C0 with a 20:1 attenuation. The 16-bit ADC value of sum of cells measurement (SOC) is stored in status register group A. Any potential difference between the C0 and V^- pins results in an error in the SOC measurement equal to this difference. From the SOC value, the sum of all cell voltage measurements is given by:

$$\text{Sum of all Cells} = \text{SOC} \cdot 20 \cdot 100\mu\text{V}$$

Internal Die Temperature: The ADSTAT command can measure the internal die temperature. The 16-bit ADC value of the die temperature measurement (ITMP) is stored in status register group A. From ITMP the actual die temperature is calculated using the expression:

$$\text{Internal Die Temperature } (^{\circ}\text{C}) = (\text{ITMP}) \cdot 100\mu\text{V} / (7.5\text{mV})^{\circ}\text{C} - 273^{\circ}\text{C}$$

Power Supply Measurements: The ADSTAT command is also used to measure the analog power supply (V_{REG}) and digital power supply (V_{REGD}).

The 16-bit ADC value of the analog power supply measurement (VA) is stored in Status Register Group A. The 16-bit ADC value of the digital power supply measurement (VD) is stored in status register group B. From VA and VD, the power supply measurements are given by:

$$\text{Analog power supply measurement } (V_{\text{REG}}) = V_A \cdot 100\mu\text{V}$$

$$\text{Digital power supply measurement } (V_{\text{REGD}}) = V_D \cdot 100\mu\text{V}$$

The nominal range of V_{REG} is 4.5V to 5.5V. The nominal range of V_{REGD} is 2.7V to 3.6V.

Accuracy Check

Measuring an independent voltage reference is the best means to verify the accuracy of a data acquisition system. The LTC6804 contains a 2nd reference for this purpose. The ADAX command will initiate the measurement of the 2nd reference. The results are placed in auxiliary register group B. The range of the result depends on the ADC measurement accuracy and the accuracy of the 2nd reference, including thermal hysteresis and long term drift. Readings outside the range 2.985 to 3.015 indicate the system is out of its specified tolerance.

MUX Decoder Check

The diagnostic command DIAGN ensures the proper operation of each multiplexer channel. The command cycles through all channels and sets the MUXFAIL bit to 1 in status register group B if any channel decoder fails. The MUXFAIL bit is set to 0 if the channel decoder passes the test. The MUXFAIL bit is also set to 1 on power-up (POR) or after a CLRSTAT command.

The DIAGN command takes about 400 μs to complete if the core is in REFUP state and about 4.5ms to complete if the core is in STANDBY state. The polling methods described in the section Polling Methods can be used to determine the completion of the DIAGN command.

Digital Filter Check

The delta-sigma ADC is composed of a 1-bit pulse density modulator followed by a digital filter. A pulse density modulated bit stream has a higher percentage of 1s for higher analog input voltages. The digital filter converts this high frequency 1-bit stream into a single 16-bit word.

Table 9. Conversion Times for ADSTAT Command Measuring SOC, ITMP, VA, VD

MODE	CONVERSION TIMES (in μs)								
	t_0	t_{1M}	t_{2M}	t_{3M}	t_{4M}	t_{1c}	t_{2c}	t_{3c}	t_{4c}
27kHz	0	57	103	150	197	338	474	610	748
14kHz	0	86	162	237	313	455	591	726	865
7kHz	0	144	278	412	546	804	1,056	1,308	1,563
3kHz	0	260	511	761	1,011	1,269	1,522	1,774	2,028
2kHz	0	493	976	1,459	1,942	2,200	2,452	2,705	2,959
26Hz	0	29,817	59,623	89,430	119,237	122,986	126,729	130,472	134,218

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OPERATION

This is why a delta-sigma ADC is often referred to as an oversampling converter.

The self test commands verify the operation of the digital filters and memory. Figure 8 illustrates the operation of the ADC during self test. The output of the 1-bit pulse density modulator is replaced by a 1-bit test signal. The test signal passes through the digital filter and is converted to a 16-bit value. The 1-bit test signal undergoes the same digital conversion as the regular 1-bit pulse from the modulator, so the conversion time for any self test command is exactly the same as the corresponding regular ADC conversion command. The 16-bit ADC value is stored in the same register groups as the regular ADC conversion command. The test signals are designed to place alternating one-zero patterns in the registers. Table 10 provides a list of the self test commands. If the digital filters and memory are working properly, then the registers will contain the values shown in Table 10. For more details see the section Commands.

ADC Clear Commands

LTC6804 has 3 clear commands – CLRCELL, CLRAUX and CLRSTAT. These commands clear the registers that store all ADC conversion results.

The CLRCELL command clears cell voltage register group A, B, C and D. All bytes in these registers are set to 0xFF by CLRCELL command.

The CLRAUX command clears auxiliary register group A and B. All bytes in these registers are set to 0xFF by CLRAUX command.

The CLRSTAT command clears status register group A and B except the REVCODE and RSVD bits in status register group B. A read back of REVCODE will return the revision code of the part. All OV flags, UV flags, MUXFAIL bit, and THSD bit in status register group B are set to 1 by CLRSTAT command. The THSD bit is set to 0 after RDSTATB command. The registers storing SOC, ITMP, VA and VD are all set to 0xFF by CLRSTAT command.

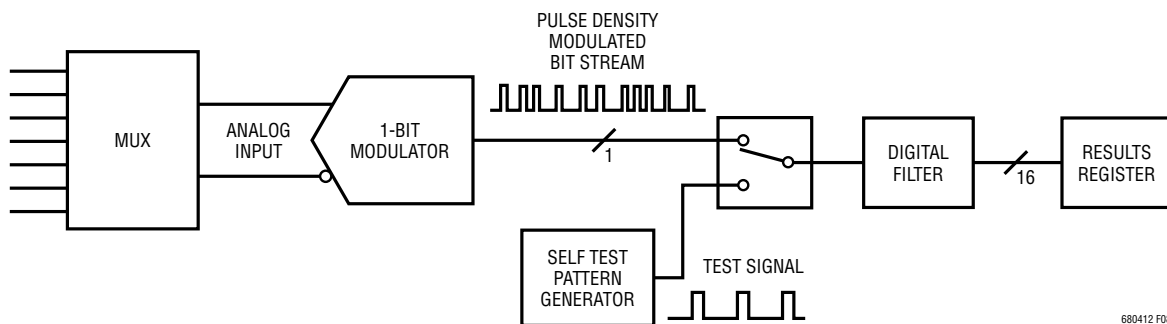


Figure 8. Operation of LTC6804 ADC Self Test

Table 10. Self Test Command Summary

COMMAND	SELF TEST OPTION	OUTPUT PATTERN IN DIFFERENT ADC MODES						RESULTS REGISTER GROUPS
		27kHz	14kHz	7kHz	3kHz	2kHz	26Hz	
CVST	ST[1:0]=01	0x9565	0x9553	0x9555	0x9555	0x9555	0x9555	C1V to C12V (CVA, CVB, CVC, CVD)
	ST[1:0]=10	0x6A9A	0x6AAC	0x6AAA	0x6AAA	0x6AAA	0x6AAA	
AXST	ST[1:0]=01	0x9565	0x9553	0x9555	0x9555	0x9555	0x9555	G1V to G5V, REF (AUXA, AUXB)
	ST[1:0]=10	0x6A9A	0x6AAC	0x6AAA	0x6AAA	0x6AAA	0x6AAA	
STATST	ST[1:0]=01	0x9565	0x9553	0x9555	0x9555	0x9555	0x9555	SOC, ITMP, VA, VD (STATA, STATB)
	ST[1:0]=10	0x6A9A	0x6AAC	0x6AAA	0x6AAA	0x6AAA	0x6AAA	

OPERATION

Open-Wire Check (ADOW Command)

The ADOW command is used to check for any open wires between the ADCs in the LTC6804 and the external cells. This command performs ADC conversions on the C pin inputs identically to the ADCV command, except two internal current sources sink or source current into the two C pins while they are being measured. The pull-up (PUP) bit of the ADOW command determines whether the current sources are sinking or sourcing 100 μ A.

The following simple algorithm can be used to check for an open wire on any of the 13 C pins (see Figure 9):

- 1) Run the 12-cell command ADOW with PUP = 1 at least twice. Read the cell voltages for cells 1 through 12 once at the end and store them in array CELL_{PUP(n)}.

- 2) Run the 12-cell command ADOW with PUP = 0 at least twice. Read the cell voltages for cells 1 through 12 once at the end and store them in array CELL_{PD(n)}.
- 3) Take the difference between the pull-up and pull-down measurements made in above steps for cells 2-12: $CELL_{\Delta(n)} = CELL_{PUP(n)} - CELL_{PD(n)}$.
- 4) For all values of n from 1 to 11: If $CELL_{\Delta(n+1)} < -400mV$, then C(n) is open. If the $CELL_{PUP(1)} = 0.0000$, then C(0) is open. If the $CELL_{PD(12)} = 0.0000$, then C(12) is open.

The above algorithm detects open wires using normal mode conversions with as much as 10nF of capacitance remaining on the LTC6804 side of the open wire. However, if more external capacitance is on the open C pin, then the length of time that the open wire conversions are ran in steps 1 and 2 must be increased to give the 100 μ A current sources time to create a large enough difference for the algorithm to detect an open connection. This can be accomplished by running more than two ADOW commands in steps 1 and 2, or by using filtered mode conversions instead of normal mode conversions. Use Table 11 to determine how many conversions are necessary:

Table 11

EXTERNAL C PIN CAPACITANCE	Number of ADOW Commands Required in Steps 1 and 2	
	NORMAL MODE	FILTERED MODE
$\leq 10nF$	2	2
100nF	10	2
1 μ F	100	2
C	$1 + \text{ROUNDUP}(C/10nF)$	2

Thermal Shutdown

To protect the LTC6804 from overheating, there is a thermal shutdown circuit included inside the IC. If the temperature detected on the die goes above approximately 150°C, the thermal shutdown circuit trips and resets the configuration register group to its default state. This turns off all discharge switches. When a thermal shutdown event has occurred, the THSD bit in status register group B will go high. This bit is cleared after a read operation has been performed on the status register group B (RDSTATB command). The CLRSTAT command sets the THSD bit

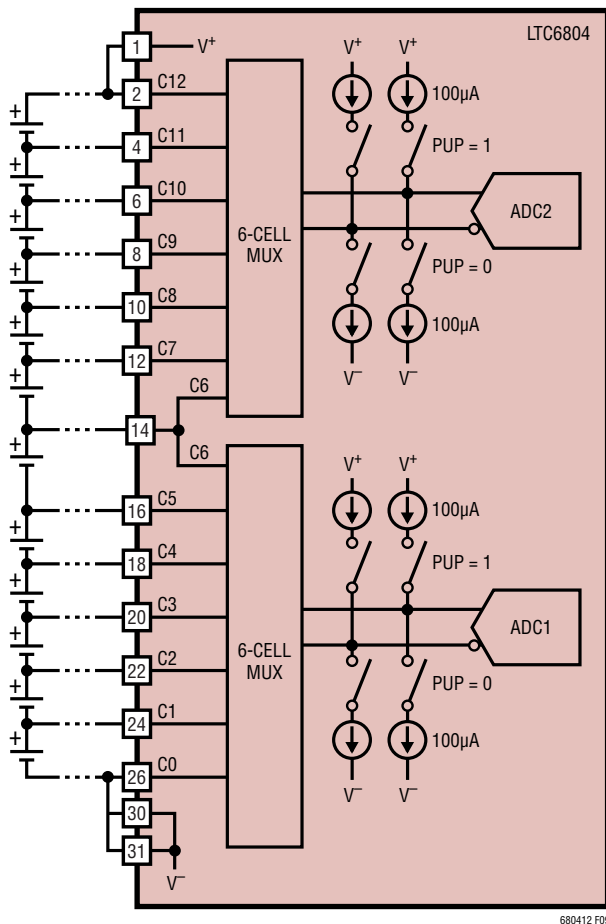


Figure 9. Open-Wire Detection Circuitry

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high for diagnostic purposes, but does not reset the configuration register group.

Revision Code and Reserved Bits

The status register group B contains a 4-bit revision code and 2 reserved bits. If software detection of device revision is necessary, then contact the factory for details. Otherwise, the code can be ignored. In all cases, however, the values of all bits must be used when calculating the packet error code (PEC) on data reads.

WATCHDOG AND SOFTWARE DISCHARGE TIMER

When there is no wake-up signal (see Figure 21) for more than 2 seconds, the watchdog timer expires. This resets configuration register bytes CFGR0-CFGR3 in all cases. CFGR4 and CFGR5 are reset by the watchdog timer when the software timer is disabled. The WDT pin is pulled high by the external pull-up when the watchdog time elapses. The watchdog timer is always enabled and is reset by a qualified wake-up signal.

The software discharge timer is used to keep the discharge switches turned ON for programmable time duration. If the software timer is being used, the discharge switches are not turned OFF when the watchdog timer is activated.

To enable the software timer, SWTEN pin needs to be tied high to V_{REG} (Figure 10). The discharge switches can now be kept ON for the programmed time duration that is determined by the DCTO value written to the configuration register. Table 12 shows the various time settings and the corresponding DCTO value. Table 13 summarizes the status of the configuration register group after a watchdog timer or software timer event.

Table 13

	WATCHDOG TIMER	SOFTWARE TIMER
SWTEN = 0, DCTO = XXXX	Resets CFGR0-5 When It Activates	Disabled
SWTEN = 1, DCTO = 0000	Resets CFGR0-5 When It Activates	Disabled
SWTEN = 1, DCTO ! = 0000	Resets CFGR0-3 When It Activates	Resets CFGR4-5 When It Fires

Unlike the watchdog timer, the software timer does not reset when there is a valid command. The software timer can only be reset after a valid WRCFG (write configuration register) command. There is a possibility that the software timer will expire in the middle of some commands.

If software timer activates in the middle of WRCFG command, the configuration register resets as per Table 14.

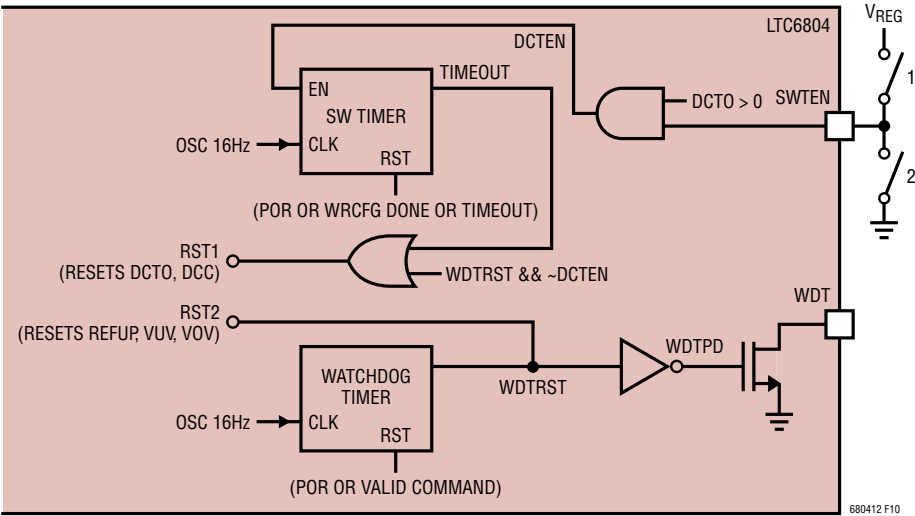


Figure 10. Watchdog and Software Discharge Timer

Table 12. DCTO Settings

DCTO	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Time Min	Disabled	0.5	1	2	3	4	5	10	15	20	30	40	60	75	90	120

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However, at the end of the valid WRCFG command, the new data is copied to the configuration register. The new data is not lost when the software timer is activated.

If software timer activates in the middle of RDCFG command, the configuration register group resets as per Table 14. As a result, the read back data from bytes CRFG4 and CRFG5 could be corrupted.

I²C/SPI MASTER ON LTC6804 USING GPIOs

The I/O ports GPIO3, GPIO4 and GPIO5 on LTC6804-1 and LTC6804-2 can be used as an I²C or SPI master port to communicate to an I²C or SPI slave. In the case of an I²C master, GPIO4 and GPIO5 form the SDA and SCL ports of the I²C interface respectively. In the case of a SPI master,

GPIO3, GPIO5 and GPIO4 become the chip select (CSBM), clock (SCKM) and data (SDIOM) ports of the SPI interface respectively. The SPI master on LTC6804 supports only SPI mode 3 (CHPA = 1, CPOL = 1).

The GPIOs are open drain outputs, so an external pull-up is required on these ports to operate as an I²C or SPI master. It is also important to write the GPIO bits to 1 in the CFG register group so these ports are not pulled low internally by the device.

COMM Register

LTC6804 has a 6-byte COMM register as shown in Table 15. This register stores all data and control bits required for I²C or SPI communication to a slave. The COMM register contains 3 bytes of data Dn[7:0] to be transmitted to or received from the slave device. ICOMn [3:0] specify control actions before transmitting/receiving the data byte. FCOMn [3:0] specify control actions after transmitting/receiving the data byte.

If the bit ICOMn[3] in the COMM register is set to 1 the part becomes an I²C master and if the bit is set to 0 the part becomes a SPI master.

Table 16 describes the valid write codes for ICOMn[3:0] and FCOMn[3:0] and their behavior when using the part as an I²C master.

Table 17 describes the valid codes for ICOMn[3:0] and FCOMn[3:0] and their behavior when using the part as a SPI master.

Note that only the codes listed in Tables 16 and 17 are valid for ICOMn[3:0] and FCOMn[3:0]. Writing any other code that is not listed in Tables 16 and 17 to ICOMn[3:0] and FCOMn[3:0] may result in unexpected behavior on the I²C and SPI ports.

Table 14

DCTO (READ VALUE)	TIME LEFT (MIN)
0	Disabled (or) Timer Has Timed Out
1	$0 < \text{Timer} \leq 0.5$
2	$0.5 < \text{Timer} \leq 1$
3	$1 < \text{Timer} \leq 2$
4	$2 < \text{Timer} \leq 3$
5	$3 < \text{Timer} \leq 4$
6	$4 < \text{Timer} \leq 5$
7	$5 < \text{Timer} \leq 10$
8	$10 < \text{Timer} \leq 15$
9	$15 < \text{Timer} \leq 20$
A	$20 < \text{Timer} \leq 30$
B	$30 < \text{Timer} \leq 40$
C	$40 < \text{Timer} \leq 60$
D	$60 < \text{Timer} \leq 75$
E	$75 < \text{Timer} \leq 90$
F	$90 < \text{Timer} \leq 120$

Table 15. COMM Register Memory Map

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
COMM0	RD/WR	ICOM0[3]	ICOM0[2]	ICOM0[1]	ICOM0[0]	D0[7]	D0[6]	D0[5]	D0[4]
COMM1	RD/WR	D0[3]	D0[2]	D0[1]	D0[0]	FCOM0[3]	FCOM0[2]	FCOM0[1]	FCOM0[0]
COMM2	RD/WR	ICOM1[3]	ICOM1[2]	ICOM1[1]	ICOM1[0]	D1[7]	D1[6]	D1[5]	D1[4]
COMM3	RD/WR	D1[3]	D1[2]	D1[1]	D1[0]	FCOM1[3]	FCOM1[2]	FCOM1[1]	FCOM1[0]
COMM4	RD/WR	ICOM2[3]	ICOM2[2]	ICOM2[1]	ICOM2[0]	D2[7]	D2[6]	D2[5]	D2[4]
COMM5	RD/WR	D2[3]	D2[2]	D2[1]	D2[0]	FCOM2[3]	FCOM2[2]	FCOM2[1]	FCOM2[0]

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Table 16. Write Codes for ICOMn[3:0] and FCOMn[3:0] on I²C Master

CONTROL BITS	CODE	ACTION	DESCRIPTION
ICOMn[3:0]	0110	START	Generate a START Signal on I ² C Port Followed By Data Transmission
	0001	STOP	Generate a STOP Signal on I ² C port
	0000	BLANK	Proceed Directly to Data Transmission on I ² C Port
	0111	No Transmit	Release SDA and SCL and Ignore the Rest of the Data
FCOMn[3:0]	0000	Master ACK	Master Generates an ACK Signal on Ninth Clock Cycle
	1000	Master NACK	Master Generates a NACK Signal on Ninth Clock Cycle
	1001	Master NACK + STOP	Master Generates a NACK Signal Followed by STOP Signal

Table 17. Write Codes for ICOMn[3:0] and FCOMn[3:0] on SPI Master

CONTROL BITS	CODE	ACTION	DESCRIPTION
ICOMn[3:0]	1000	CSBM low	Generates a CSBM Low Signal on SPI Port (GPIO3)
	1001	CSBM high	Generates a CSBM High Signal on SPI Port (GPIO3)
	1111	No Transmit	Releases the SPI Port and Ignores the Rest of the Data
FCOMn[3:0]	X000	CSBM low	Holds CSBM Low at the End of Byte Transmission
	1001	CSBM high	Transitions CSBM High at the End of Byte Transmission

COMM Commands

Three commands help accomplish I²C or SPI communication to the slave device: WRCOMM, STCOMM, RDCOMM

WRCOMM Command: This command is used to write data to the COMM register. This command writes 6 bytes of data to the COMM register. The PEC needs to be written at the end of the data. If the PEC does not match, all data in the COMM register is cleared to 1's when CSB goes high. See the section Bus Protocols for more details on a write command format.

STCOMM Command: This command initiates I²C/SPI communication on the GPIO ports. The COMM register contains 3 bytes of data to be transmitted to the slave. During this command, the data bytes stored in the COMM register are transmitted to the slave I²C or SPI device and the data received from the I²C or SPI device is stored in the COMM register. This command uses GPIO4 (SDA) and GPIO5 (SCL) for I²C communication or GPIO3 (CSBM), GPIO4 (SDIOM) and GPIO5 (SCKM) for SPI communication.

The STCOMM command is to be followed by 24 clock cycles for each byte of data to be transmitted to the slave device while holding CSB low. For example, to transmit 3 bytes of data to the slave, send STCOMM command and its PEC followed by 72 clock cycles. Pull CSB high at the end of the 72 clock cycles of STCOMM command.

During I²C or SPI communication, the data received from the slave device is updated in the COMM register.

RDCOMM Command: The data received from the slave device can be read back from the COMM register using the RDCOMM command. The command reads back 6 bytes of data followed by the PEC. See the section Bus Protocols for more details on a read command format.

Table 18 describes the possible read back codes for ICOMn[3:0] and FCOMn[3:0] when using the part as an I²C master. Dn[7:0] contains the data byte either transmitted by the I²C master or received from the I²C slave.

In case of the SPI master, the read back codes for ICOMn[3:0] and FCOMn[3:0] are always 0111 and 1111 respectively. Dn[7:0] contains the data byte either transmitted by the SPI master or received from the SPI slave.

Figure 11 illustrates the operation of LTC6804 as an I²C or SPI master using the GPIOs.

Any number of bytes can be transmitted to the slave in groups of 3 bytes using these commands. The GPIO ports will not get reset between different STCOMM commands. However, if the wait time between the commands is greater than 2 seconds, the watchdog will timeout and reset the ports to their default values.

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Table 18. Read Codes for ICOMn[3:0] and FCOMn[3:0] on I²C Master

CONTROL BITS	CODE	DESCRIPTION
ICOMn[3:0]	0110	Master Generated a START Signal
	0001	Master Generated a STOP Signal
	0000	Blank, SDA Was Held Low Between Bytes
	0111	Blank, SDA Was Held High Between Bytes
FCOMn[3:0]	0000	Master Generated an ACK Signal
	0111	Slave Generated an ACK Signal
	1111	Slave Generated a NACK Signal
	0001	Slave Generated an ACK Signal, Master Generated a STOP Signal
	1001	Slave Generated a NACK Signal, Master Generated a STOP Signal

To transmit several bytes of data using an I²C master, a START signal is only required at the beginning of the entire data stream. A STOP signal is only required at the end of the data stream. All intermediate data groups can use a BLANK code before the data byte and an ACK/NACK signal as appropriate after the data byte. SDA and SCL will not get reset between different STCOMM commands.

To transmit several bytes of data using SPI master, a CSBM low signal is sent at the beginning of the 1st data byte. CSBM can be held low or taken high for intermediate data groups using the appropriate code on FCOMn[3:0]. A CSBM high signal is sent at the end of the last byte of data. CSBM, SDIOM and SCKM will not get reset between different STCOMM commands.

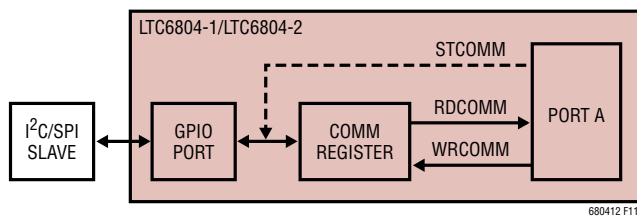


Figure 11. LTC6804 I²C/SPI Master Using GPIOs

Figure 12 shows the 24 clock cycles following STCOMM command for an I²C master in different cases. Note that if ICOMn[3:0] specified a STOP condition, after the STOP signal is sent, the SDA and SCL lines are held high and all data in the rest of the word is ignored. If ICOMn[3:0] is a NO TRANSMIT, both SDA and SCL lines are released, and rest of the data in the word is ignored. This is used when a particular device in the stack does not have to communicate to a slave.

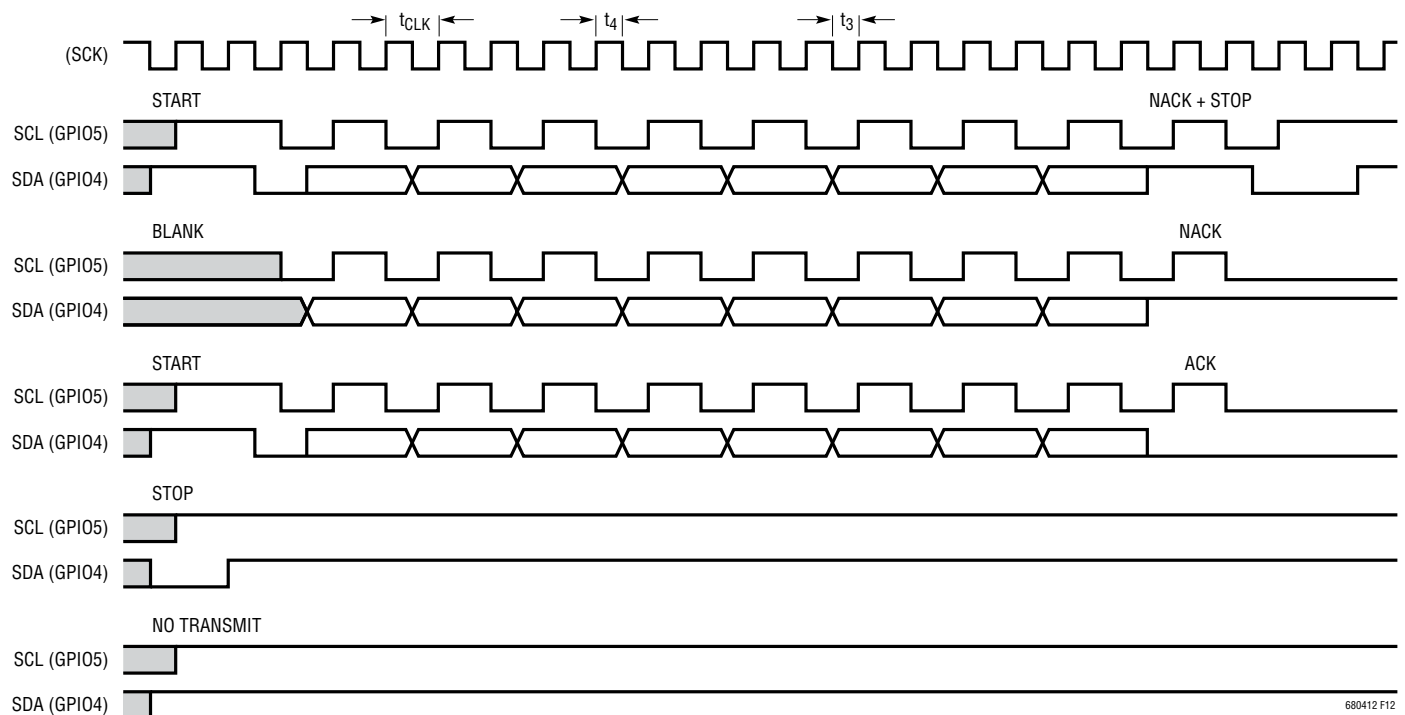


Figure 12. STCOMM Timing Diagram for an I²C Master

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Figure 13 shows the 24 clock cycles following STCOMM command for a SPI master. Similar to the I²C master, if ICOMn[3:0] specified a CSBM HIGH or a NO TRANSMIT condition, the CSBM, SCKM and SDIOM lines of the SPI master are released and the rest of the data in the word is ignored.

Timing Specifications of I²C and SPI master

The timing of the LTC6804 I²C or SPI master will be controlled by the timing of the communication at the LTC6804's primary SPI interface. Table 19 shows the I²C master timing relationship to the primary SPI clock. Table 20 shows the SPI master timing specifications.

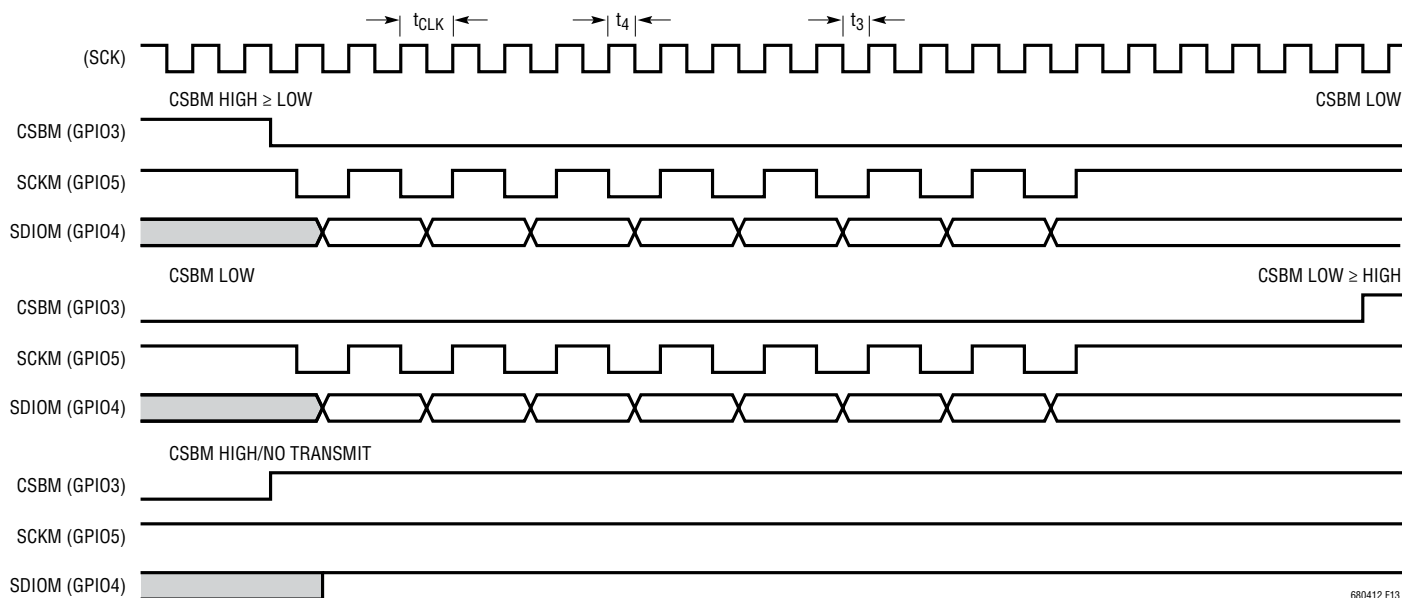


Figure 13. STCOMM Timing Diagram for a SPI Master

Table 19. I²C Master Timing

I ² C MASTER PARAMETER	TIMING RELATIONSHIP TO PRIMARY SPI INTERFACE	TIMING SPECIFICATIONS AT $t_{CLK} = 1\mu s$
SCL Clock Frequency	$1/(2 \cdot t_{CLK})$	Max 500kHz
$t_{HD}; STA$	t_3	Min 200ns
t_{LOW}	t_{CLK}	Min 1μs
t_{HIGH}	t_{CLK}	Min 1μs
$t_{SU}; STA$	$t_{CLK} + t_4^*$	Min 1.03μs
$t_{HD}; DAT$	t_4^*	Min 30ns
$t_{SU}; DAT$	t_3	Min 1μs
$t_{SU}; STO$	$t_{CLK} + t_4^*$	Min 1.03μs
t_{BUF}	$3 \cdot t_{CLK}$	Min 3μs

*Note: When using isoSPI, t_4 is generated internally and is a minimum of 30ns. Also, $t_3 = t_{CLK} - t_4$. When using SPI, t_3 and t_4 are the low and high times of the SCK input, each with a specified minimum of 200ns.

Table 20. SPI Master Timing

SPI MASTER PARAMETER	TIMING RELATIONSHIP TO PRIMARY SPI INTERFACE	TIMING SPECIFICATIONS AT $t_{CLK} = 1\mu s$
SDIOM Valid to SCKM Rising Setup	t_3	Min 200ns
SDIOM Valid from SCKM Rising Hold	$t_{CLK} + t_4^*$	Min 1.03μs
SCKM Low	t_{CLK}	Min 1μs
SCKM High	t_{CLK}	Min 1μs
SCKM Period (SCKM_Low + SCKM_High)	$2 \cdot t_{CLK}$	Min 2μs
CSBM Pulse Width	$3 \cdot t_{CLK}$	Min 3μs
SCKM Rising to CSBM Rising	$5 \cdot t_{CLK} + t_4^*$	Min 5.03μs
CSBM Falling to SCKM Falling	t_3	Min 200ns
CSBM Falling to SCKM Rising	$t_{CLK} + t_3$	Min 1.2μs
SCKM Falling to SDIOM Valid	Master requires $< t_{CLK}$	

*Note: When using isoSPI, t_4 is generated internally and is a minimum of 30ns. Also, $t_3 = t_{CLK} - t_4$. When using SPI, t_3 and t_4 are the low and high times of the SCK input, each with a specified minimum of 200ns.

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SERIAL INTERFACE OVERVIEW

There are two types of serial ports on the LTC6804, a standard 4-wire serial peripheral interface (SPI) and a 2-wire isolated interface (isoSPI). Pins 41 through 44 are configurable as 2-wire or 4-wire serial port, based on the state of the ISOMD pin.

There are two versions of the LTC6804: the LTC6804-1 and the LTC6804-2. The LTC6804-1 is used in a daisy chain configuration, and the LTC6804-2 is used in an addressable bus configuration. The LTC6804-1 provides a second isoSPI interface using pins 45 through 48. The LTC6804-2 uses pins 45 through 48 to set the address of the device, by tying these pins to V^- or V_{REG} .

4-WIRE SERIAL PERIPHERAL INTERFACE (SPI) PHYSICAL LAYER

External Connections

Connecting ISOMD to V^- configures serial Port A for 4-wire SPI. The SDO pin is an open drain output which requires a pull-up resistor tied to the appropriate supply voltage (Figure 14).

Timing

The 4-wire serial port is configured to operate in a SPI system using $CPHA = 1$ and $CPOL = 1$. Consequently, data on SDI must be stable during the rising edge of SCK. The timing is depicted in Figure 15. The maximum data rate is 1Mbps.

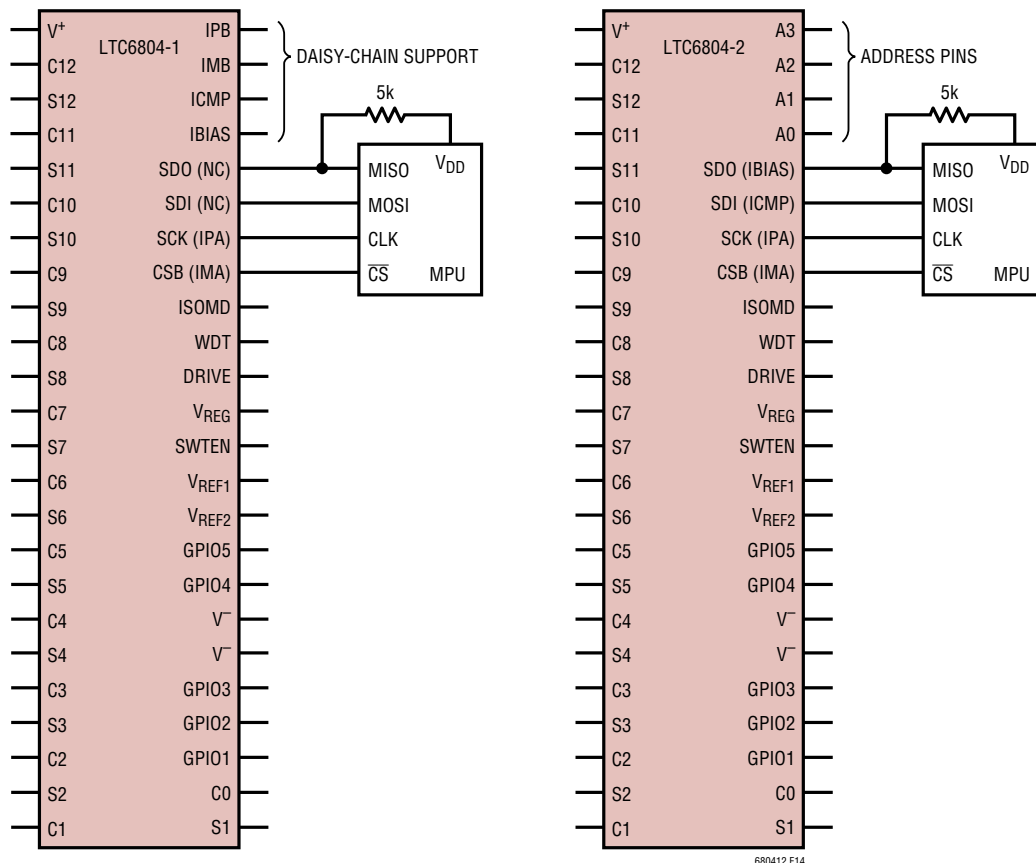


Figure 14. 4-Wire SPI Configuration

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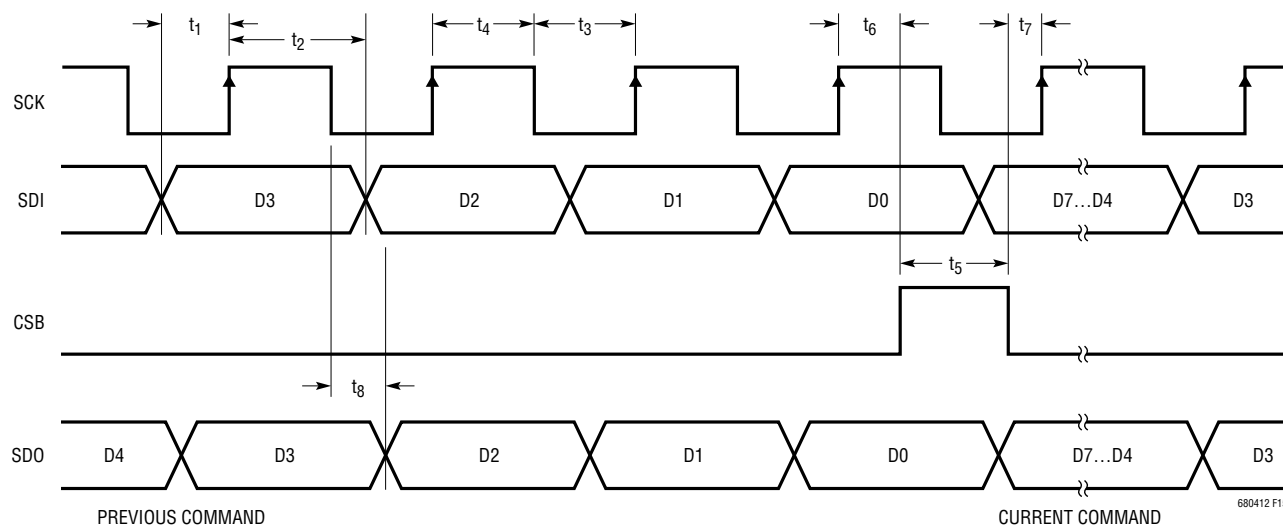


Figure 15. Timing Diagram of 4-Wire Serial Peripheral Interface

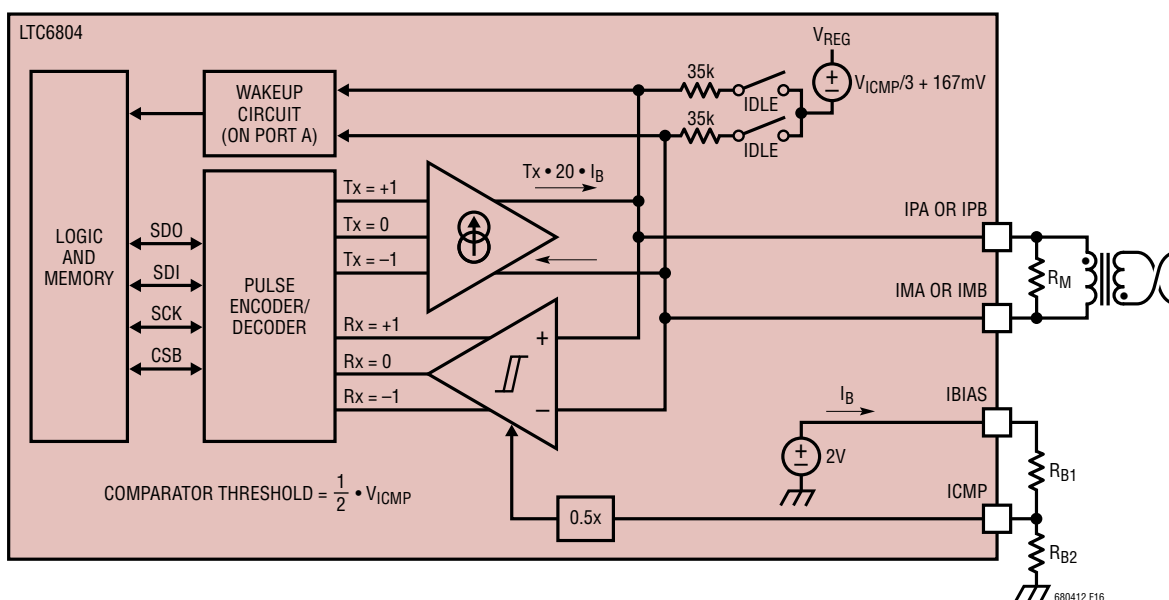


Figure 16. isoSPI Interface

2-WIRE ISOLATED INTERFACE (isoSPI) PHYSICAL LAYER

The 2-wire interface provides a means to interconnect LTC6804 devices using simple twisted pair cabling. The interface is designed for low packet error rates when the cabling is subjected to high RF fields. Isolation is achieved through an external transformer.

Standard SPI signals are encoded into differential pulses. The strength of the transmission pulse and the threshold

level of the receiver are set by two external resistors. The values of the resistors allow the user to trade off power dissipation for noise immunity.

Figure 16 illustrates how the isoSPI circuit operates. A 2V reference drives the IBIAS pin. External resistors R_{B1} and R_{B2} create the reference current I_B . This current sets the drive strength of the transmitter. R_{B1} and R_{B2} also form a voltage divider of the 2V reference at the ICMP pin. This sets the threshold voltage of the receiver circuit.

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External Connections

The LTC6804-1 has 2 serial ports which are called Port B and Port A. Port B is always configured as a 2-wire interface (master). The final device in the daisy chain does not use this port, and it should be terminated into R_M . Port A is either a 2-wire or 4-wire interface (slave), depending on the connection of the ISOMD pin.

Figure 17 is an example of a robust interconnection of multiple identical PCBs, each containing one LTC6804-1. The microprocessor is located on a separate PCB. To achieve 2-wire isolation between the microprocessor PCB and the 1st LTC6804-1 PCB, use the LTC6820 support IC. The LTC6820 is functionally equivalent to the diagram in Figure 16.

The LTC6804-2 has a single serial port (Port A) which can be 2-wire or 4-wire, depending on the state of the ISOMD pin. When configured for 2-wire communications, several devices can be connected in a multi-drop configuration, as shown in Figure 18. The LTC6820 IC is used to interface the MPU (master) to the LTC6804-2's (slaves).

Selecting Bias Resistors

The adjustable signal amplitude allows the system to trade power consumption for communication robustness, and the adjustable comparator threshold allows the system to account for signal losses.

The isoSPI transmitter drive current and comparator voltage threshold are set by a resistor divider ($R_{BIAS} = R_{B1} + R_{B2}$) between the IBIAS and V^- . The divided voltage is connected to the ICMP pin which sets the comparator threshold to 1/2 of this voltage (V_{ICMP}). When either isoSPI interface is enabled (not IDLE) IBIAS is held at 2V, causing a current I_B to flow out of the IBIAS pin. The IP and IM pin drive currents are $20 \cdot I_B$.

As an example, if divider resistor R_{B1} is 2.8k and resistor R_{B2} is 1.21k (so that $R_{BIAS} = 4k$), then:

$$I_B = \frac{2V}{R_{B1} + R_{B2}} = 0.5mA$$

$$I_{DRV} = I_P = I_M = 20 \cdot I_B = 10mA$$

$$V_{ICMP} = 2V \cdot \frac{R_{B2}}{R_{B1} + R_{B2}} = I_B \cdot R_{B2} = 603mV$$

$$V_{TCMP} = 0.5 \cdot V_{ICMP} = 302mV$$

In this example, the pulse drive current I_{DRV} will be 10mA, and the receiver comparators will detect pulses with IP-IM amplitudes greater than $\pm 302mV$.

If the isolation barrier uses 1:1 transformers connected by a twisted pair and terminated with 120Ω resistors on each end, then the transmitted differential signal amplitude ($\pm$) will be:

$$V_A = I_{DRV} \cdot \frac{R_M}{2} = 0.6V$$

(This result ignores transformer and cable losses, which may reduce the amplitude).

isoSPI Pulse Detail

Two LTC6804 devices can communicate by transmitting and receiving differential pulses back and forth through an isolation barrier. The transmitter can output three voltage levels: $+V_A$, 0V, and $-V_A$. A positive output results from IP sourcing current and IM sinking current across load resistor R_M . A negative voltage is developed by IP sinking and IM sourcing. When both outputs are off, the load resistance forces the differential output to 0V.

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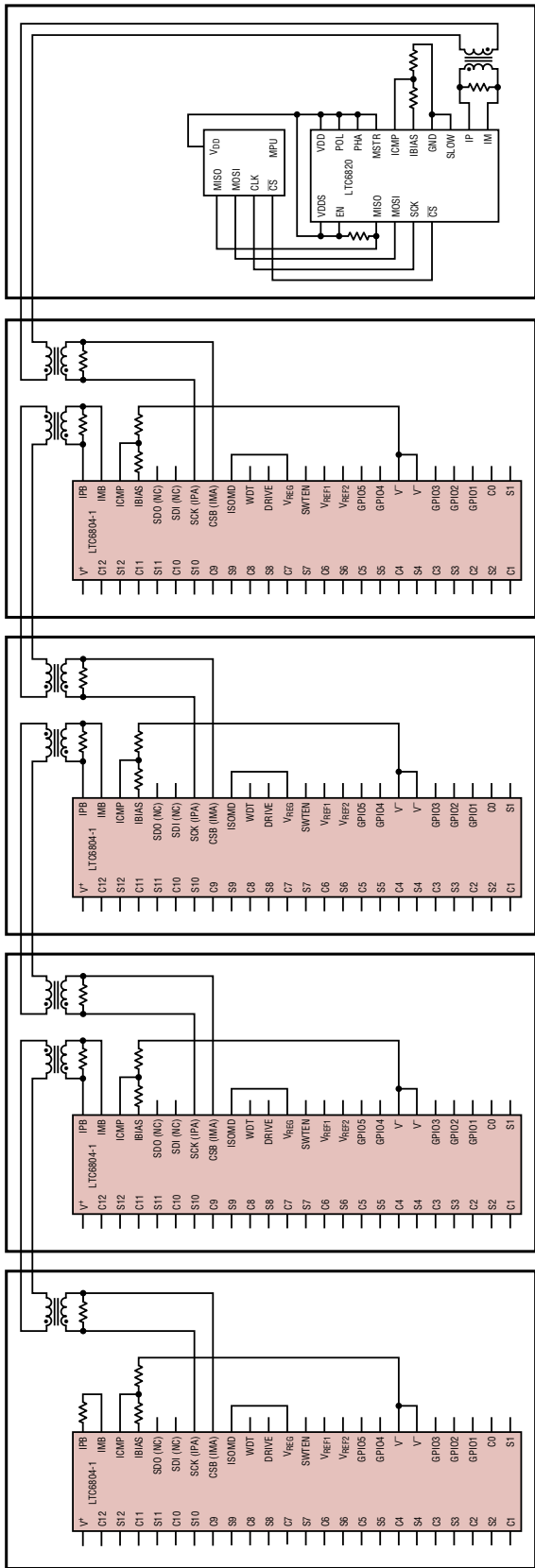


Figure 17. Transformer-Isolated Daisy-Chain Configuration Using LTC6804-1

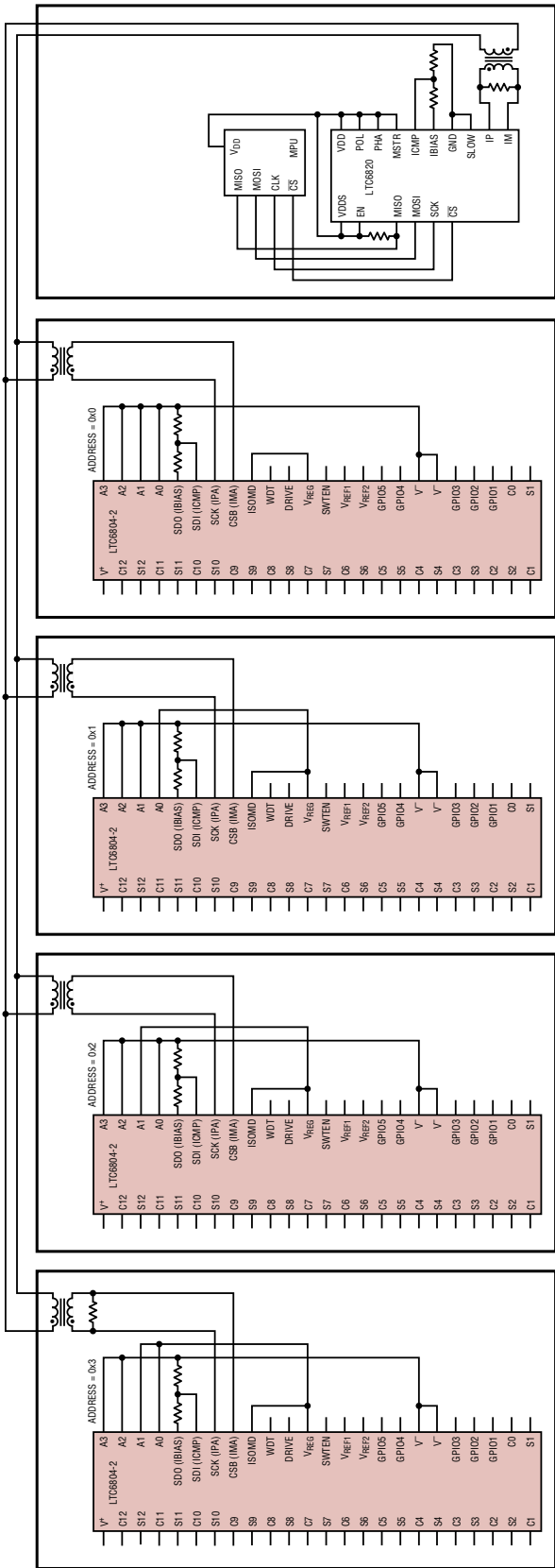


Figure 18. Multi-Drop Configuration Using LTC6804-2

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To eliminate the DC signal component and enhance reliability, the isoSPI uses two different pulse lengths. This allows for four types of pulses to be transmitted, as shown in Table 21. A +1 pulse will be transmitted as a positive pulse followed by a negative pulse. A -1 pulse will be transmitted as a negative pulse followed by a positive pulse. The duration of each pulse is defined as $t_{1/2PW}$, since each is half of the required symmetric pair. (The total isoSPI pulse duration is $2 \cdot t_{1/2PW}$).

Table 21. isoSPI Pulse Types

PULSE TYPE	FIRST LEVEL ($t_{1/2PW}$)	SECOND LEVEL ($t_{1/2PW}$)	ENDING LEVEL
Long +1	+V _A (150ns)	-V _A (150ns)	0V
Long -1	-V _A (150ns)	+V _A (150ns)	0V
Short +1	+V _A (50ns)	-V _A (50ns)	0V
Short -1	-V _A (50ns)	+V _A (50ns)	0V

A host microcontroller does not have to generate isoSPI pulses to use this 2-wire interface. The first LTC6804 in the system can communicate to the microcontroller using the 4-wire SPI interface on its Port A, then daisy-chain to other LTC6804s using the 2-wire isoSPI interface on its Port B. Alternatively, an LTC6820 can be used to translate the SPI signals into isoSPI pulses.

LTC6804-1 Operation with Port A Configured for SPI

When the LTC6804-1 is operating with port A as an SPI (ISOMD = V⁻), the SPI detects one of four communication events: CSB falling, CSB rising, SCK rising with SDI = 0, and SCK rising with SDI = 1. Each event is converted into one of the four pulse types for transmission through the LTC6804-1 daisy chain. Long pulses are used to transmit CSB changes and short pulses are used to transmit data, as explained in Table 22.

Table 22. LTC6804-1 Port B (Master) isoSPI Port Function

COMMUNICATION EVENT (PORT A SPI)	TRANSMITTED PULSE (PORT B isoSPI)
CSB Rising	Long +1
CSB Falling	Long -1
SCK Rising Edge, SDI = 1	Short +1
SCK Rising Edge, SDI = 0	Short -1

On the other side of the isolation barrier (i.e. at the other end of the cable), the 2nd LTC6804 will have ISOMD = V_{REG}. Its Port A operates as a slave isoSPI interface. It receives each transmitted pulse and reconstructs the SPI signals internally, as shown in Table 23. In addition, during a READ command this port may transmit return data pulses.

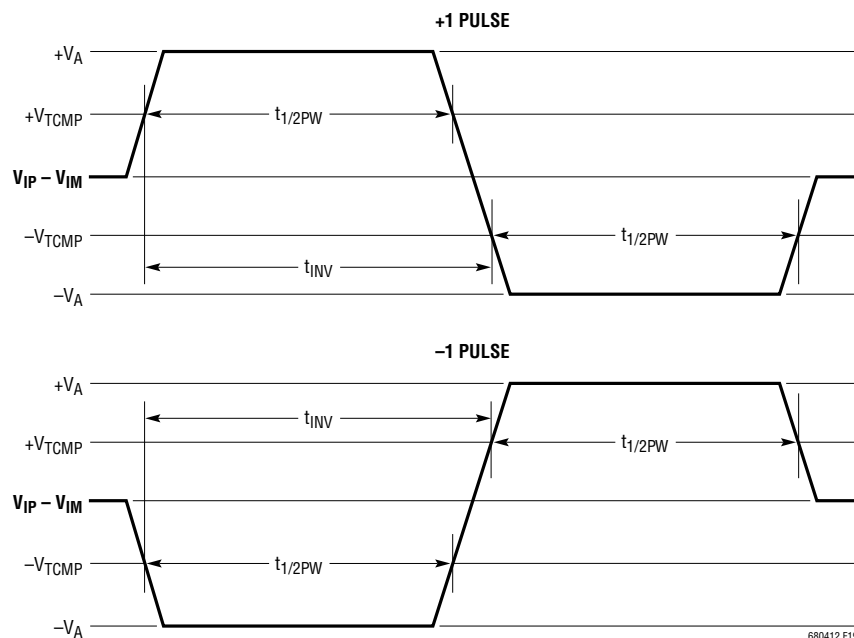


Figure 19. isoSPI Pulse Detail

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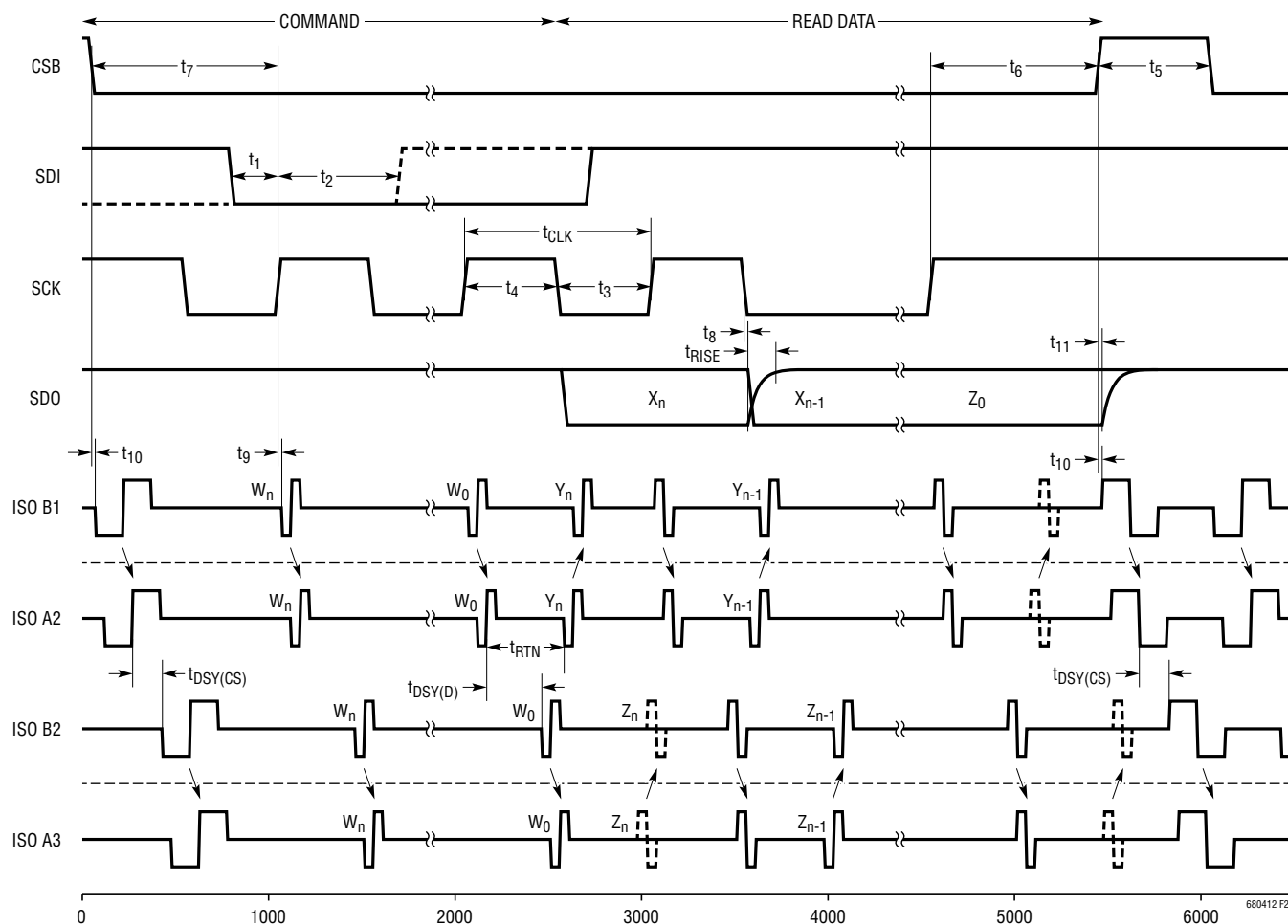
Table 23. LTC6804-1 Port A (Slave) isoSPI Port Function

RECEIVED PULSE (PORT A isoSPI)	INTERNAL SPI PORT ACTION	RETURN PULSE
Long +1	Drive CSB High	None
Long -1	Drive CSB Low	
Short +1	1. Set SDI = 1 2. Pulse SCK	Short -1 Pulse if Reading a 0 bit
Short -1	1. Set SDI = 0 2. Pulse SCK	(No Return Pulse if Not in READ Mode or if Reading a 1 bit)

The lower isoSPI port (Port A) never transmits long (CSB) pulses. Furthermore, a slave isoSPI port will only transmit short -1 pulses, never a +1 pulse. The master port recognizes a null response as a logic 1. This allows for multiple slave devices on a single cable without risk of collisions (Multidrop).

Figure 20 shows the isoSPI timing diagram for a READ command to daisy-chained LTC6804-1 parts. The ISOMD pin is tied to V^- on the bottom part so its Port A is configured as a SPI port (CSB, SCK, SDI and SDO). The isoSPI signals of three stacked devices are shown, labeled with the port (A or B) and part number. Note that ISO B1 and ISO A2 is actually the same signal, but shown on each end of the transmission cable that connects parts 1 and 2. Likewise, ISO B2 and ISO A3 is the same signal, but with the cable delay shown between parts 2 and 3.

Bits W_n - W_0 refers to the 16-bit command code and the 16-bit PEC of a READ command. At the end of bit W_0 the 3 parts decode the READ command and begin shifting out data which is valid on the next rising edge of clock SCK. Bits X_n - X_0 refer to the data shifted out by Part 1. Bits Y_n - Y_0


Figure 20. isoSPI Timing Diagram

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refer to the data shifted out by Part 2 and bits Z_n-Z_0 refer to the data shifted out by Part 3. All this data is read back from the SDO port on Part 1 in a daisy-chained fashion.

Waking Up the Serial Interface

The serial ports (SPI or isoSPI) will enter the low power IDLE state if there is no activity on Port A for a time of t_{IDLE} . The WAKEUP circuit monitors activity on pins 41 and 42.

If $ISOMD = V^-$, Port A is in SPI mode. Activity on the CSB or SCK pin will wake up the SPI interface. If $ISOMD = V_{REG}$, Port A is in isoSPI mode. Differential activity on IPA-IMB wakes up the isoSPI interface. The LTC6804 will be ready to communicate when the isoSPI state changes to READY within t_{WAKE} or t_{READY} , depending on the Core state (see Figure 1 and state descriptions for details.)

The LTC6804-1 sends a Long +1 pulse on Port B after it is ready to communicate. In a daisy-chained configuration, this pulse wakes up the next device in the stack which will, in turn, wake up the next device. If there are 'N' devices in the stack, all the devices are powered up within the time $N \cdot t_{WAKE}$ or $N \cdot t_{READY}$, depending on the Core State. For large stacks, the time $N \cdot t_{WAKE}$ may be equal to or larger than t_{IDLE} . In this case, after waiting longer than the time of $N \cdot t_{WAKE}$, the host may send another dummy byte and wait for the time $N \cdot t_{READY}$, in order to ensure that all devices are in the READY state.

Figure 21 illustrates the timing and the functionally equivalent circuit. Common mode signals will not wake up the serial interface. The interface is designed to wake up after receiving a large signal single-ended pulse, or a low-amplitude symmetric pulse. The differential signal $|SCK(IPA) - CSB(IMA)|$, must be at least $V_{WAKE} = 200mV$ for a minimum duration of $t_{DWELL} = 240ns$ to qualify as a wake up signal that powers up the serial interface.

DATA LINK LAYER

All Data transfers on LTC6804 occur in byte groups. Every byte consists of 8 bits. Bytes are transferred with the most significant bit (MSB) first. CSB must remain low for the entire duration of a command sequence, including between a command byte and subsequent data. On a write command, data is latched in on the rising edge of CSB.

NETWORK LAYER

Packet Error Code

The packet error code (PEC) is a 15-bit cyclic redundancy check (CRC) value calculated for all of the bits in a register group in the order they are passed, using the initial PEC seed value of 000000000010000 and the following characteristic polynomial: $x^{15} + x^{14} + x^{10} + x^8 + x^7 + x^4 + x^3 + 1$. To calculate the 15-bit PEC value, a simple procedure can be established:

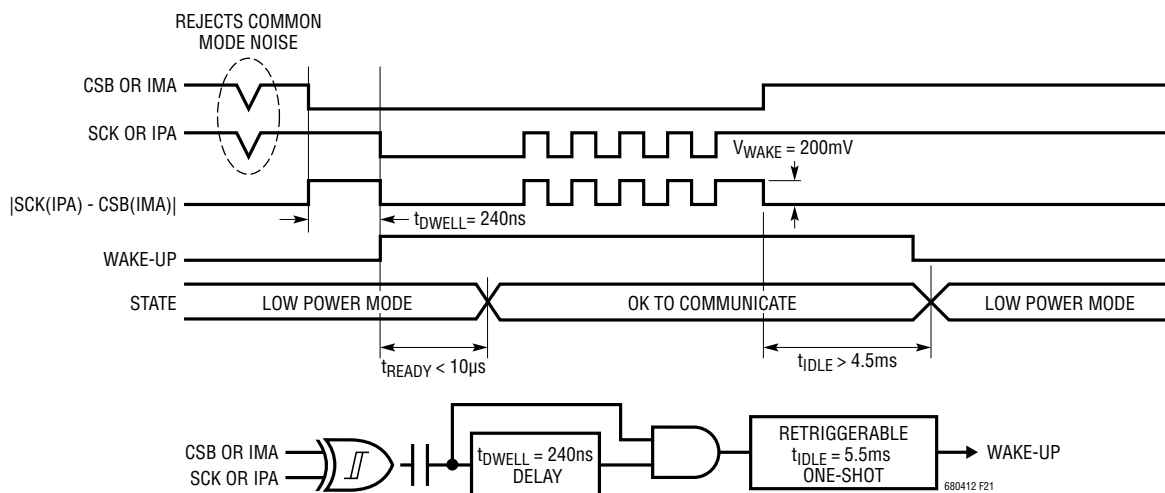


Figure 21. Wake-Up Detection and IDLE Timer

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1. Initialize the PEC to 000000000010000 (PEC is a 15-bit register group)

2. For each bit DIN coming into the PEC register group, set

$$IN0 = \text{DIN XOR PEC}[14]$$

$$IN3 = IN0 \text{ XOR PEC}[2]$$

$$IN4 = IN0 \text{ XOR PEC}[3]$$

$$IN7 = IN0 \text{ XOR PEC}[6]$$

$$IN8 = IN0 \text{ XOR PEC}[7]$$

$$IN10 = IN0 \text{ XOR PEC}[9]$$

$$IN14 = IN0 \text{ XOR PEC}[13]$$

3. Update the 15-bit PEC as follows

$$\text{PEC}[14] = IN14,$$

$$\text{PEC}[13] = \text{PEC}[12],$$

$$\text{PEC}[12] = \text{PEC}[11],$$

$$\text{PEC}[11] = \text{PEC}[10],$$

$$\text{PEC}[10] = IN10,$$

$$\text{PEC}[9] = \text{PEC}[8],$$

$$\text{PEC}[8] = IN8,$$

$$\text{PEC}[7] = IN7,$$

$$\text{PEC}[6] = \text{PEC}[5],$$

$$\text{PEC}[5] = \text{PEC}[4],$$

$$\text{PEC}[4] = IN4,$$

$$\text{PEC}[3] = IN3,$$

$$\text{PEC}[2] = \text{PEC}[1],$$

$$\text{PEC}[1] = \text{PEC}[0],$$

$$\text{PEC}[0] = IN0$$

4. Go back to step 2 until all the data is shifted. The final PEC (16 bits) is the 15-bit value in the PEC register with a 0 bit appended to its LSB

Figure 22 illustrates the algorithm described above. An example to calculate the PEC for a 16-bit word (0x0001) is listed in Table 24. The PEC for 0x0001 is computed as 0x3D6E after stuffing a 0 bit at the LSB. For longer data streams, the PEC is valid at the end of the last bit of data sent to the PEC register.

LTC6804 calculates PEC for any command or data received and compares it with the PEC following the command or data. The command or data is regarded as valid only if the PEC matches. LTC6804 also attaches the calculated PEC at the end of the data it shifts out. Table 25 shows the format of PEC while writing to or reading from LTC6804.

While writing any command to LTC6804, the command bytes CMD0 and CMD1 (See Table 32 and Table 33) and the PEC bytes PEC0 and PEC1 are sent on Port A in the following order:

CMD0, CMD1, PEC0, PEC1

After a broadcast write command to daisy-chained LTC6804-1 devices, data is sent to each device followed by the PEC. For example, when writing the configuration register group to two daisy-chained devices (primary device P, stacked device S), the data will be sent to the primary device on Port A in the following order:

CFGR0(S), ..., CFGR5(S), PEC0(S), PEC1(S), CFGR0(P), ..., CFGR5(P), PEC0(P), PEC1(P)

After a read command for daisy-chained devices, each device shifts out its data and the PEC that it computed for its data on Port A followed by the data received on Port B. For example, when reading status register group B from

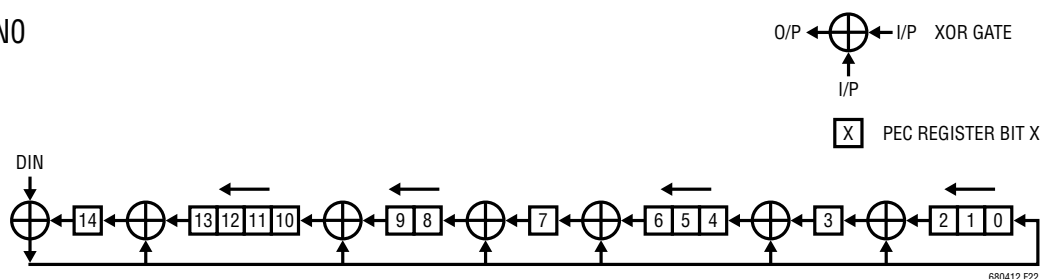


Figure 22. 15-Bit PEC Computation Circuit

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Table 24. PEC Calculation for 0x0001

PEC[14]	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
PEC[13]	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0
PEC[12]	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1
PEC[11]	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1	1
PEC[10]	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1	1	1
PEC[9]	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	1
PEC[8]	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0
PEC[7]	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	1	1	1
PEC[6]	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
PEC[5]	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
PEC[4]	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1
PEC[3]	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
PEC[2]	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
PEC[1]	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
PEC[0]	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
IN14	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0		0
IN10	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1	1		PEC Word
IN8	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0		
IN7	0	0	1	0	0	0	0	0	0	0	1	1	1	0	1	1		
IN4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1		
IN3	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0		
IN0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1		
DIN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
Clock Cycle	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	

Table 25. Write/Read PEC Format

NAME	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
PEC0	RD/WR	PEC[14]	PEC[13]	PEC[12]	PEC[11]	PEC[10]	PEC[9]	PEC[8]	PEC[7]
PEC1	RD/WR	PEC[6]	PEC[5]	PEC[4]	PEC[3]	PEC[2]	PEC[1]	PEC[0]	0

two daisy-chained devices (primary device P, stacked device S), the primary device sends out data on port A in the following order:

STBR0(P), ..., STBR5(P), PEC0(P), PEC1(P), STBR0(S),
..., STBR5(S), PEC0(S), PEC1(S)

Address Commands (LTC6804-2 Only)

An address command is one in which only the addressed device on the bus responds. Address commands are used only with LTC6804-2 parts. All commands are compatible with addressing. See Bus Protocols for Address command format.

Broadcast Commands (LTC6804-1 or LTC6804-2)

A broadcast command is one to which all devices on the bus will respond, regardless of device address. This command format can be used with LTC6804-1 and LTC6804-2 parts. See Bus Protocols for Broadcast command format. With broadcast commands all devices can be sent commands simultaneously.

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Broadcast vs Address Commands

CONFIGURATION		TYPE OF COMMAND		
DEVICE	INTERFACE	READ	WRITE	POLL
LTC6804-2 (Address/Parallel)	SPI	Address-Only	Address or Broadcast	Address or Broadcast
	isoSPI			Address-Only [†]
LTC6804-1 (Daisy-Chain)	SPI or isoSPI	Broadcast-Only		N/A

[†]The LTC6804-2 will not return data pulses when using broadcast commands in isoSPI mode. Therefore, ADC commands will execute, but polling will not work.

In parallel (LTC6804-2) configurations, broadcast commands are useful for initiating ADC conversions or for sending write commands when all parts are being written with the same data. The polling function (automatic at the end of ADC commands, or manual using the PLADC command) can also be used with broadcast commands, but only with parallel SPI interfaces. Polling is not compatible with parallel isoSPI. Likewise, broadcast read commands should not be used in a parallel configuration (either SPI or isoSPI).

Daisy-chained (LTC6804-1) configurations support broadcast commands only, because they have no addressing. All devices in the chain receive the command bytes simultaneously. For example, to initiate ADC conversions in a stack of devices, a single ADCV command is sent, and all

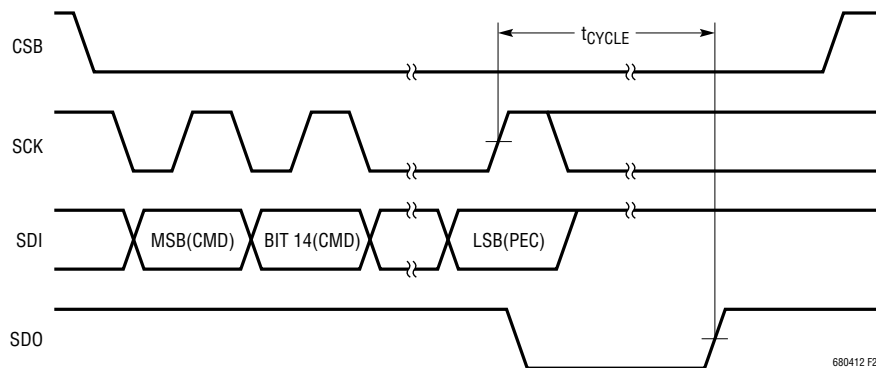


Figure 23. SDO Polling After an ADC Conversion Command

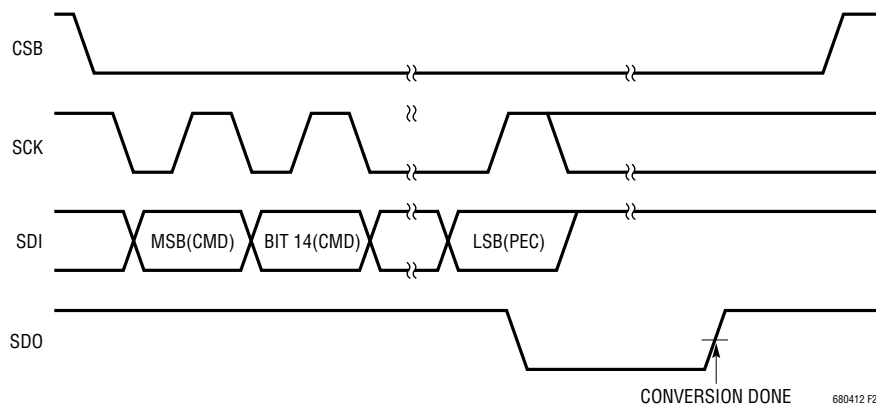


Figure 24. SDO Polling Using PLADC Command

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devices will start conversions at the same time. For read and write commands, a single command is sent, and then the stacked devices effectively turn into a cascaded shift register, in which data is shifted through each device to the next device in the stack. See the Serial Programming Examples section.

Polling Methods

The simplest method to determine ADC completion is for the controller to start an ADC conversion and wait for the specified conversion time to pass before reading the results. Polling is not supported with daisy-chain communication (LTC6804-1).

In parallel configurations that communicate in SPI mode (ISOMD pin tied low), there are two methods of polling. The first method is to hold CSB low after an ADC conversion command is sent. After entering a conversion command, the SDO line is driven low when the device is busy performing conversions (Figure 23). SDO is pulled high when the device completes conversions. However, the SDO will also go back high when CSB goes high even if the device has not completed the conversion. An addressed device drives the SDO line based on its status alone. A problem with this method is that the controller is not free to do other serial communication while waiting for ADC conversions to complete.

The next method overcomes this limitation. The controller can send an ADC start command, perform other tasks, and then send a poll ADC converter status (PLADC) command to determine the status of the ADC conversions (Figure 24). After entering the PLADC command, SDO will go low if the device is busy performing conversions. SDO is pulled high at the end of conversions. However, the SDO will also go high when CSB goes high even if the device has not completed the conversion. See Programming Examples on how to use the PLADC command with devices in parallel configuration.

In parallel configurations that communicate in isoSPI mode, the low side port transmits a data pulse only in response to a master isoSPI pulse received by it. So, after entering an address command in either method of polling described above, isoSPI data pulses are sent to

the part to update the conversion status. These pulses can be sent using LTC6820 by simply clocking its SCK pin. In response to this pulse, the LTC6804-2 returns an isoSPI pulse if it is still busy performing conversions and does not return a pulse if it has completed conversions. If a CSB high isoSPI pulse is sent to the LTC6804-2, it exits the polling command. Note that broadcast poll commands are not compatible with parallel isoSPI.

Bus Protocols

Protocol Format: The protocol formats for both broadcast and address commands are depicted in Table 27 through Table 31. Table 26 is the key for reading the protocol diagrams.

Table 26. Protocol Key

CMD0	First Command Byte (See Tables 32 and 33)
CMD1	Second Command Byte (See Tables 32 and 33)
PEC0	First PEC Byte (See Table 25)
PEC1	Second PEC Byte (See Table 25)
<i>n</i>	Number of Bytes
...	Continuation of Protocol
	Master to Slave
	Slave to Master

Command Format: The formats for the broadcast and address commands are shown in Table 32 and Table 33 respectively. The 11-bit command code CC[10:0] is the same for a broadcast or an address command. A list of all the command codes is shown in Table 34. A broadcast command has a value 0 for CMD0[7] through CMD0[3]. An address command has a value 1 for CMD0[7] followed by the 4-bit address of the device (a3, a2, a1, a0) in bits CMD0[6:3]. An addressed device will respond to an address command only if the physical address of the device on pins A3 to A0 match the address specified in the address command. The PEC for broadcast and address commands must be computed on the entire 16-bit command (CMD0 and CMD1).

Commands

Table 34 lists all the commands and its options for both LTC6804-1 and LTC6804-2

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Table 27. Broadcast/Address Poll Command

8	8	8	8	
CMD0	CMD1	PEC0	PEC1	Poll Data

Table 28. Broadcast Write Command (LTC6804-1)

8	8	8	8	8		8	8	8	8		8
CMD0	CMD1	PEC0	PEC1	Data Byte Low	...	Data Byte High	PEC0	PEC1	Shift Byte 1	...	Shift Byte <i>n</i>

Table 29. Broadcast/Address Write Command (LTC6804-2)

8	8	8	8	8		8	8	8
CMD0	CMD1	PEC0	PEC1	Data Byte Low	...	Data Byte High	PEC0	PEC1

Table 30. Broadcast Read Command (LTC6804-1)

8	8	8	8	8		8	8	8	8		8
CMD0	CMD1	PEC0	PEC1	Data Byte Low	...	Data Byte High	PEC0	PEC1	Shift Byte 1	...	Shift Byte <i>n</i>

Table 31. Address Read Command (LTC6804-2)

8	8	8	8	8		8	8	8
CMD0	CMD1	PEC0	PEC1	Data Byte Low	...	Data Byte High	PEC0	PEC1

Table 32. Broadcast Command Format

NAME	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
CMD0	WR	0	0	0	0	0	CC[10]	CC[9]	CC[8]
CMD1	WR	CC[7]	CC[6]	CC[5]	CC[4]	CC[3]	CC[2]	CC[1]	CC[0]

Table 33. Address Command Format

NAME	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
CMD0	WR	1	a3*	a2*	a1*	a0*	CC[10]	CC[9]	CC[8]
CMD1	WR	CC[7]	CC[6]	CC[5]	CC[4]	CC[3]	CC[2]	CC[1]	CC[0]

*ax is Address Bit x

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Table 34. Command Codes

COMMAND DESCRIPTION	NAME	CC[10:0] - COMMAND CODE										
		10	9	8	7	6	5	4	3	2	1	0
Write Configuration Register Group	WRCFG	0	0	0	0	0	0	0	0	0	0	1
Read Configuration Register Group	RDCFG	0	0	0	0	0	0	0	0	0	1	0
Read Cell Voltage Register Group A	RDCVA	0	0	0	0	0	0	0	0	1	0	0
Read Cell Voltage Register Group B	RDCVB	0	0	0	0	0	0	0	0	1	1	0
Read Cell Voltage Register Group C	RDCVC	0	0	0	0	0	0	0	1	0	0	0
Read Cell Voltage Register Group D	RDCVD	0	0	0	0	0	0	0	1	0	1	0
Read Auxiliary Register Group A	RDAUXA	0	0	0	0	0	0	0	1	1	0	0
Read Auxiliary Register Group B	RDAUXB	0	0	0	0	0	0	0	1	1	1	0
Read Status Register Group A	RDSTATA	0	0	0	0	0	0	1	0	0	0	0
Read Status Register Group B	RDSTATB	0	0	0	0	0	0	1	0	0	1	0
Start Cell Voltage ADC Conversion and Poll Status	ADCV	0	1	MD[1]	MD[0]	1	1	DCP	0	CH[2]	CH[1]	CH[0]
Start Open Wire ADC Conversion and Poll Status	ADOW	0	1	MD[1]	MD[0]	PUP	1	DCP	1	CH[2]	CH[1]	CH[0]
Start Self-Test Cell Voltage Conversion and Poll Status	CVST	0	1	MD[1]	MD[0]	ST[1]	ST[0]	0	0	1	1	1
Start GPIOs ADC Conversion and Poll Status	ADAX	1	0	MD[1]	MD[0]	1	1	0	0	CHG [2]	CHG [1]	CHG [0]
Start Self-Test GPIOs Conversion and Poll Status	AXST	1	0	MD[1]	MD[0]	ST[1]	ST[0]	0	0	1	1	1
Start Status group ADC Conversion and Poll Status	ADSTAT	1	0	MD[1]	MD[0]	1	1	0	1	CHST [2]	CHST [1]	CHST [0]
Start Self-Test Status group Conversion and Poll Status	STATST	1	0	MD[1]	MD[0]	ST[1]	ST[0]	0	1	1	1	1
Start Combined Cell Voltage and GPIO1, GPIO2 Conversion and Poll Status	ADCVAX	1	0	MD[1]	MD[0]	1	1	DCP	1	1	1	1
Clear Cell Voltage Register Group	CLRCCELL	1	1	1	0	0	0	1	0	0	0	1
Clear Auxiliary Register Group	CLRAUX	1	1	1	0	0	0	1	0	0	1	0
Clear Status Register Group	CLRSTAT	1	1	1	0	0	0	1	0	0	1	1
Poll ADC Conversion Status	PLADC	1	1	1	0	0	0	1	0	1	0	0
Diagnose MUX and Poll Status	DIAGN	1	1	1	0	0	0	1	0	1	0	1
Write COMM Register Group	WRCOMM	1	1	1	0	0	1	0	0	0	0	1
Read COMM Register Group	RDCOMM	1	1	1	0	0	1	0	0	0	1	0
Start I ² C/SPI Communication	STCOMM	1	1	1	0	0	1	0	0	0	1	1

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Table 35. Command Bit Descriptions

NAME	DESCRIPTION	VALUES								
MD[1:0]	ADC Mode	MD	ADCOPT(CFGR0[0]) = 0				ADCOPT (CFGR0[0]) = 1			
		01	27kHz Mode (Fast)				14kHz Mode			
		10	7kHz Mode (Normal)				3kHz Mode			
		11	26Hz Mode (Filtered)				2kHz Mode			
DCP	Discharge Permitted	DCP								
		0	Discharge Not Permitted							
		1	Discharge Permitted							
CH[2:0]	Cell Selection for ADC Conversion			Total Conversion Time in the 6 ADC Modes						
		CH		27kHz	14kHz	7kHz	3kHz	2kHz	26Hz	
		000	All Cells	1.1ms	1.3ms	2.3ms	3.0ms	4.4ms	201ms	
		001	Cell 1 and Cell 7	201μs	230μs	405μs	501μs	754μs	34ms	
		010	Cell 2 and Cell 8							
		011	Cell 3 and Cell 9							
		100	Cell 4 and Cell 10							
		101	Cell 5 and Cell 11							
		110	Cell 6 and Cell 12							
PUP	Pull-Up/Pull-Down Current for Open-Wire Conversions	PUP								
		0	Pull-Down Current							
		1	Pull-Up Current							
ST[1:0]	Self-Test Mode Selection			Self-Test Conversion Result						
		ST		27kHz	14kHz	7kHz	3kHz	2kHz	26Hz	
		01	Self Test 1	0x9565	0x9553	0x9555	0x9555	0x9555	0x9555	
		10	Self test 2	0x6A9A	0x6AAC	0x6AAA	0x6AAA	0x6AAA	0x6AAA	
CHG[2:0]	GPIO Selection for ADC Conversion			Total Conversion Time in the 6 ADC Modes						
		CHG		27kHz	14kHz	7kHz	3kHz	2kHz	26Hz	
		000	GPIO 1-5, 2nd Ref	1.1ms	1.3ms	2.3ms	3.0ms	4.4ms	201ms	
		001	GPIO 1	201μs	230μs	405μs	501μs	754μs	34ms	
		010	GPIO 2							
		011	GPIO 3							
		100	GPIO 4							
		101	GPIO 5							
		110	2nd Reference							
CHST[2:0]*	Status Group Selection			Total Conversion Time in the 6 ADC Modes						
		CHST		27kHz	14kHz	7kHz	3kHz	2kHz	26Hz	
		000	SOC, ITMP, VA, VD	748μs	865μs	1.6ms	2.0ms	3.0ms	134ms	
		001	SOC	201μs	230μs	405μs	501μs	754μs	34ms	
		010	ITMP							
		011	VA							
		100	VD							

*Note: Valid options for CHST in ADSTAT command are 0-4. If CHST is set to 5/6 in ADSTAT command, the LTC6804 treats it like ADAX command with CHG = 5/6.

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Table 36. Configuration Register Group

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
CFGR0	RD/WR	GPI05	GPI04	GPI03	GPI02	GPI01	REFON	SWTRD	ADCOPT
CFGR1	RD/WR	VUV[7]	VUV[6]	VUV[5]	VUV[4]	VUV[3]	VUV[2]	VUV[1]	VUV[0]
CFGR2	RD/WR	VOV[3]	VOV[2]	VOV[1]	VOV[0]	VUV[11]	VUV[10]	VUV[9]	VUV[8]
CFGR3	RD/WR	VOV[11]	VOV[10]	VOV[9]	VOV[8]	VOV[7]	VOV[6]	VOV[5]	VOV[4]
CFGR4	RD/WR	DCC8	DCC7	DCC6	DCC5	DCC4	DCC3	DCC2	DCC1
CFGR5	RD/WR	DCT0[3]	DCT0[2]	DCT0[1]	DCT0[0]	DCC12	DCC11	DCC10	DCC9

Table 37. Cell Voltage Register Group A

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
CVAR0	RD	C1V[7]	C1V[6]	C1V[5]	C1V[4]	C1V[3]	C1V[2]	C1V[1]	C1V[0]
CVAR1	RD	C1V[15]	C1V[14]	C1V[13]	C1V[12]	C1V[11]	C1V[10]	C1V[9]	C1V[8]
CVAR2	RD	C2V[7]	C2V[6]	C2V[5]	C2V[4]	C2V[3]	C2V[2]	C2V[1]	C2V[0]
CVAR3	RD	C2V[15]	C2V[14]	C2V[13]	C2V[12]	C2V[11]	C2V[10]	C2V[9]	C2V[8]
CVAR4	RD	C3V[7]	C3V[6]	C3V[5]	C3V[4]	C3V[3]	C3V[2]	C3V[1]	C3V[0]
CVAR5	RD	C3V[15]	C3V[14]	C3V[13]	C3V[12]	C3V[11]	C3V[10]	C3V[9]	C3V[8]

Table 38. Cell Voltage Register Group B

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
CVBR0	RD	C4V[7]	C4V[6]	C4V[5]	C4V[4]	C4V[3]	C4V[2]	C4V[1]	C4V[0]
CVBR1	RD	C4V[15]	C4V[14]	C4V[13]	C4V[12]	C4V[11]	C4V[10]	C4V[9]	C4V[8]
CVBR2	RD	C5V[7]	C5V[6]	C5V[5]	C5V[4]	C5V[3]	C5V[2]	C5V[1]	C5V[0]
CVBR3	RD	C5V[15]	C5V[14]	C5V[13]	C5V[12]	C5V[11]	C5V[10]	C5V[9]	C5V[8]
CVBR4	RD	C6V[7]	C6V[6]	C6V[5]	C6V[4]	C6V[3]	C6V[2]	C6V[1]	C6V[0]
CVBR5	RD	C6V[15]	C6V[14]	C6V[13]	C6V[12]	C6V[11]	C6V[10]	C6V[9]	C6V[8]

Table 39. Cell Voltage Register Group C

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
CVCR0	RD	C7V[7]	C7V[6]	C7V[5]	C7V[4]	C7V[3]	C7V[2]	C7V[1]	C7V[0]
CVCR1	RD	C7V[15]	C7V[14]	C7V[13]	C7V[12]	C7V[11]	C7V[10]	C7V[9]	C7V[8]
CVCR2	RD	C8V[7]	C8V[6]	C8V[5]	C8V[4]	C8V[3]	C8V[2]	C8V[1]	C8V[0]
CVCR3	RD	C8V[15]	C8V[14]	C8V[13]	C8V[12]	C8V[11]	C8V[10]	C8V[9]	C8V[8]
CVCR4	RD	C9V[7]	C9V[6]	C9V[5]	C9V[4]	C9V[3]	C9V[2]	C9V[1]	C9V[0]
CVCR5	RD	C9V[15]	C9V[14]	C9V[13]	C9V[12]	C9V[11]	C9V[10]	C9V[9]	C9V[8]

Table 40. Cell Voltage Register Group D

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
CVDR0	RD	C10V[7]	C10V[6]	C10V[5]	C10V[4]	C10V[3]	C10V[2]	C10V[1]	C10V[0]
CVDR1	RD	C10V[15]	C10V[14]	C10V[13]	C10V[12]	C10V[11]	C10V[10]	C10V[9]	C10V[8]
CVDR2	RD	C11V[7]	C11V[6]	C11V[5]	C11V[4]	C11V[3]	C11V[2]	C11V[1]	C11V[0]
CVDR3	RD	C11V[15]	C11V[14]	C11V[13]	C11V[12]	C11V[11]	C11V[10]	C11V[9]	C11V[8]
CVDR4	RD	C12V[7]	C12V[6]	C12V[5]	C12V[4]	C12V[3]	C12V[2]	C12V[1]	C12V[0]
CVDR5	RD	C12V[15]	C12V[14]	C12V[13]	C12V[12]	C12V[11]	C12V[10]	C12V[9]	C12V[8]

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Table 41. Auxiliary Register Group A

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
AVAR0	RD	G1V[7]	G1V[6]	G1V[5]	G1V[4]	G1V[3]	G1V[2]	G1V[1]	G1V[0]
AVAR1	RD	G1V[15]	G1V[14]	G1V[13]	G1V[12]	G1V[11]	G1V[10]	G1V[9]	G1V[8]
AVAR2	RD	G2V[7]	G2V[6]	G2V[5]	G2V[4]	G2V[3]	G2V[2]	G2V[1]	G2V[0]
AVAR3	RD	G2V[15]	G2V[14]	G2V[13]	G2V[12]	G2V[11]	G2V[10]	G2V[9]	G2V[8]
AVAR4	RD	G3V[7]	G3V[6]	G3V[5]	G3V[4]	G3V[3]	G3V[2]	G3V[1]	G3V[0]
AVAR5	RD	G3V[15]	G3V[14]	G3V[13]	G3V[12]	G3V[11]	G3V[10]	G3V[9]	G3V[8]

Table 42. Auxiliary Register Group B

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
AVBR0	RD	G4V[7]	G4V[6]	G4V[5]	G4V[4]	G4V[3]	G4V[2]	G4V[1]	G4V[0]
AVBR1	RD	G4V[15]	G4V[14]	G4V[13]	G4V[12]	G4V[11]	G4V[10]	G4V[9]	G4V[8]
AVBR2	RD	G5V[7]	G5V[6]	G5V[5]	G5V[4]	G5V[3]	G5V[2]	G5V[1]	G5V[0]
AVBR3	RD	G5V[15]	G5V[14]	G5V[13]	G5V[12]	G5V[11]	G5V[10]	G5V[9]	G5V[8]
AVBR4	RD	REF[7]	REF[6]	REF[5]	REF[4]	REF[3]	REF[2]	REF[1]	REF[0]
AVBR5	RD	REF[15]	REF[14]	REF[13]	REF[12]	REF[11]	REF[10]	REF[9]	REF[8]

Table 43. Status Register Group A

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
STAR0	RD	SOC[7]	SOC[6]	SOC[5]	SOC[4]	SOC[3]	SOC[2]	SOC[1]	SOC[0]
STAR1	RD	SOC[15]	SOC[14]	SOC[13]	SOC[12]	SOC[11]	SOC[10]	SOC[9]	SOC[8]
STAR2	RD	ITMP[7]	ITMP[6]	ITMP[5]	ITMP[4]	ITMP[3]	ITMP[2]	ITMP[1]	ITMP[0]
STAR3	RD	ITMP[15]	ITMP[14]	ITMP[13]	ITMP[12]	ITMP[11]	ITMP[10]	ITMP[9]	ITMP[8]
STAR4	RD	VA[7]	VA[6]	VA[5]	VA[4]	VA[3]	VA[2]	VA[1]	VA[0]
STAR5	RD	VA[15]	VA[14]	VA[13]	VA[12]	VA[11]	VA[10]	VA[9]	VA[8]

Table 44. Status Register Group B

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
STBR0	RD	VD[7]	VD[6]	VD[5]	VD[4]	VD[3]	VD[2]	VD[1]	VD[0]
STBR1	RD	VD[15]	VD[14]	VD[13]	VD[12]	VD[11]	VD[10]	VD[9]	VD[8]
STBR2	RD	C40V	C4UV	C30V	C3UV	C20V	C2UV	C10V	C1UV
STBR3	RD	C80V	C8UV	C70V	C7UV	C60V	C6UV	C50V	C5UV
STBR4	RD	C120V	C12UV	C110V	C11UV	C100V	C10UV	C90V	C9UV
STBR5	RD	REV[3]	REV[2]	REV[1]	REV[0]	RSVD	RSVD	MUXFAIL	THSD

Table 45. COMM Register Group

REGISTER	RD/WR	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
COMM0	RD/WR	ICOM0[3]	ICOM0[2]	ICOM0[1]	ICOM0[0]	D0[7]	D0[6]	D0[5]	D0[4]
COMM1	RD/WR	D0[3]	D0[2]	D0[1]	D0[0]	FCOM0[3]	FCOM0[2]	FCOM0[1]	FCOM0[0]
COMM2	RD/WR	ICOM1[3]	ICOM1[2]	ICOM1[1]	ICOM1[0]	D1[7]	D1[6]	D1[5]	D1[4]
COMM3	RD/WR	D1[3]	D1[2]	D1[1]	D1[0]	FCOM1[3]	FCOM1[2]	FCOM1[1]	FCOM1[0]
COMM4	RD/WR	ICOM2[3]	ICOM2[2]	ICOM2[1]	ICOM2[0]	D2[7]	D2[6]	D2[5]	D2[4]
COMM5	RD/WR	D2[3]	D2[2]	D2[1]	D2[0]	FCOM2[3]	FCOM2[2]	FCOM2[1]	FCOM2[0]

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Table 46. Memory Bit Descriptions

NAME	DESCRIPTION	VALUES																																																																				
GPIOx	GPIOx Pin Control	Write: 0 -> GPIOx Pin Pull-Down ON; 1-> GPIOx Pin Pull-Down OFF (Default) Read: 0 -> GPIOx Pin at Logic 0; 1 -> GPIOx Pin at Logic 1																																																																				
REFON	Reference Powered Up	1 -> Reference Remains Powered Up Until Watchdog Timeout 0 -> Reference Shuts Down after Conversions (Default)																																																																				
SWTRD	SWTEN Pin Status (Read Only)	1 -> SWTEN Pin at Logic 1 0 -> SWTEN Pin at Logic 0																																																																				
ADCOPT	ADC Mode Option Bit	ADCOPT: 0 -> Selects Modes 27kHz, 7kHz or 26Hz with MD[1:0] Bits in ADC Conversion Commands (Default). 1 -> Selects Modes 14kHz, 3kHz or 2kHz with MD[1:0] Bits in ADC Conversion Commands.																																																																				
VUV	Undervoltage Comparison Voltage*	Comparison voltage = (VUV + 1) • 16 • 100µV Default: VUV = 0x000																																																																				
VOV	Overvoltage Comparison Voltage*	Comparison voltage = VOV • 16 • 100µV Default: VOV = 0x000																																																																				
DCC[x]	Discharge Cell x	x = 1 to 12 1 -> Turn ON Shorting Switch for Cell x 0 -> Turn OFF Shorting Switch for Cell x (Default)																																																																				
DCTO	Discharge Time Out Value	<table><tr><td>DCTO (Write)</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr><tr><td>Time (Min)</td><td>Disabled</td><td>0.5</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>10</td><td>15</td><td>20</td><td>30</td><td>40</td><td>60</td><td>75</td><td>90</td><td>120</td></tr><tr><td>DCTO (Read)</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr><tr><td>Time Left (Min)</td><td>Disabled or Timeout</td><td>0 to 0.5</td><td>0.5 to 1</td><td>1 to 2</td><td>2 to 3</td><td>3 to 4</td><td>4 to 5</td><td>5 to 10</td><td>10 to 15</td><td>15 to 20</td><td>20 to 30</td><td>30 to 40</td><td>40 to 60</td><td>60 to 75</td><td>75 to 90</td><td>90 to 120</td></tr></table>	DCTO (Write)	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	Time (Min)	Disabled	0.5	1	2	3	4	5	10	15	20	30	40	60	75	90	120	DCTO (Read)	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	Time Left (Min)	Disabled or Timeout	0 to 0.5	0.5 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 15	15 to 20	20 to 30	30 to 40	40 to 60	60 to 75	75 to 90	90 to 120
DCTO (Write)	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F																																																						
Time (Min)	Disabled	0.5	1	2	3	4	5	10	15	20	30	40	60	75	90	120																																																						
DCTO (Read)	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F																																																						
Time Left (Min)	Disabled or Timeout	0 to 0.5	0.5 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 10	10 to 15	15 to 20	20 to 30	30 to 40	40 to 60	60 to 75	75 to 90	90 to 120																																																						
CxV	Cell x Voltage*	x = 1 to 12 16-Bit ADC Measurement Value for Cell x Cell Voltage for Cell x = CxV • 100µV CxV Is Reset to 0xFFFF on Power-Up and After Clear Command																																																																				
GxV	GPIO x Voltage*	x = 1 to 5 16-Bit ADC Measurement Value for GPIOx Voltage for GPIOx = GxV • 100µV GxV Is Reset to 0xFFFF on Power-Up and After Clear Command																																																																				
REF	2nd Reference Voltage*	16-Bit ADC Measurement Value for 2nd Reference Voltage for 2nd Reference = REF • 100µV Normal Range Is within 2.985V to 3.015V																																																																				
SOC	Sum of Cells Measurement*	16-Bit ADC Measurement Value of the Sum of All Cell Voltages Sum of All Cells Voltage = SOC • 100µV • 20																																																																				
ITMP	Internal Die Temperature*	16-Bit ADC Measurement Value of Internal Die Temperature Temperature Measurement (°C) = ITMP • 100µV/7.5mV/°C – 273°C																																																																				
VA	Analog Power Supply Voltage*	16-Bit ADC Measurement Value of Analog Power Supply Voltage Analog Power Supply Voltage = VA • 100µV Normal Range Is within 4.5V to 5.5V																																																																				
VD	Digital Power Supply Voltage*	16-Bit ADC Measurement Value of Digital Power Supply Voltage Digital Power Supply Voltage = VA • 100µV Normal Range Is within 2.7V to 3.6V																																																																				
CxOV	Cell x Overvoltage Flag	x = 1 to 12 Cell Voltage Compared to VOV Comparison Voltage 0 -> Cell x Not Flagged for Overvoltage Condition. 1 -> Cell x Flagged																																																																				
CxUV	Cell x Undervoltage Flag	x = 1 to 12 Cell Voltage Compared to VUV Comparison Voltage 0 -> Cell x Not Flagged for Undervoltage Condition. 1 -> Cell x Flagged																																																																				
REV	Revision Code	Device Revision Code. See Revision Code and Reserved Bits in Operation Section.																																																																				
RSVD	Reserved Bits	See Revision Code and Reserved Bits in Operation Section.																																																																				

OPERATION

Table 46. Memory Bit Descriptions

NAME	DESCRIPTION	VALUES											
MUXFAIL	Multiplexer Self-Test Result	Read: 0 -> Multiplexer Passed Self Test 1 -> Multiplexer Failed Self Test											
THSD	Thermal Shutdown Status	Read: 0 -> Thermal Shutdown Has Not Occurred 1 -> Thermal Shutdown Has Occurred THSD Bit Cleared to 0 on Read of Status Register Group B											
ICOMn	Initial Communication Control Bits	Write	I2C	0110		0001		0000		0111			
				START		STOP		BLANK		NO TRANSMIT			
			SPI	1000			1001			1111			
				CSB Low			CSB High			NO TRANSMIT			
		Read	I2C	0110		0001		0000		0111			
				START from Master		STOP from Master		SDA Low Between Bytes		SDA High Between Bytes			
			SPI	0111									
Dn	I ² C/SPI Communication Data Byte	Data Transmitted (Received) to (From) I ² C/SPI Slave Device											
FCOMn	Final Communication Control Bits	Write	I2C	0000		1000			1001				
				Master ACK		Master NACK			Master NACK + STOP				
			SPI	X000				1001					
				CSB Low				CSB High					
		Read	I2C	0000		0111		1111		0001		1001	
				ACK from Master		ACK from Slave		NACK from Slave		ACK from Slave + STOP from Master		NACK from Slave + STOP from Master	
			SPI	1111									

*Voltage equations use the decimal value of registers, 0 to 4095 for 12 bits and 0 to 65535 for 16 bits.

PROGRAMMING EXAMPLES

The following examples use a configuration of 3 stacked LTC6804-1 devices: S1, S2, S3. Port A on device S1 is configured in SPI mode (ISOMD pin low). Port A on devices S2 and S3 is configured in isoSPI mode (ISOMD pin high). Port B on S1 is connected to Port A on S2. Port B on S2 is connected to Port A on S3. The microcontroller communicates to the stack through Port A on S1.

Waking Up Serial Interface

1. Send a dummy byte. The activity on CSB and SCK will wake up the serial interface on device S1.
2. Wait for the amount of time $3 \cdot t_{WAKE}$ in order to power up all devices S1, S2 and S3.

For large stacks where some devices may go to the IDLE state after waking, apply steps 3 and 4:

3. Send a second dummy byte.

4. Wait for the amount of time $3 \cdot t_{READY}$

5. Send commands

Write Configuration Registers

1. Pull CSB low
2. Send WRCFG command (0x00 0x01) and its PEC (0x3D 0x6E)
3. Send CFGR0 byte of device S3, then CFGR1(S3), ... CFGR5(S3), PEC of CFGR0(S3) to CFGR5(S3)
4. Send CFGR0 byte of device S2, then CFGR1(S2), ... CFGR5(S2), PEC of CFGR0(S2) to CFGR5(S2)
5. Send CFGR0 byte of device S1, then CFGR1(S1), ... CFGR5(S1), PEC of CFGR0(S1) to CFGR5(S1)
6. Pull CSB high, data latched into all devices on rising edge of CSB

OPERATION

Calculation of serial interface time for sequence above:

Number of LTC6804-1s in daisy chain stack = n

Number of bytes in sequence (B):

Command: 2 (command byte) + 2 (command PEC) = 4

Data: 6 (Data bytes) + 2 (Data PEC) per LTC6804 = 8 bytes per device

$$B = 4 + 8 \cdot n$$

Serial port frequency per bit = F

$$\text{Time} = (1/F) \cdot B \cdot 8 \text{ bits/byte} = (1/F) \cdot [4 + 8 \cdot n] \cdot 8$$

Time for 3 LTC6804 example above, with 1MHz serial port = $(1/1\text{e}6) \cdot (4 + 8 \cdot 3) \cdot 8 = 224\mu\text{s}$

Note: This time will remain the same for all write and read commands.

Read Cell Voltage Register Group A

1. Pull CSB low
2. Send RDCVA command (0x00 0x04) and its PEC (0x07 0xC2)
3. Read CVAR0 byte of device S1, then CVAR1(S1), ... CVAR5(S1), PEC of CVAR0(S1) to CVAR5(S1)
4. Read CVAR0 byte of device S2, then CVAR1(S2), ... CVAR5(S2), PEC of CVAR0(S2) to CVAR0(S2)
5. Read CVAR0 byte of device S3, then CVAR1(S3), ... CVAR5(S3), PEC of CVAR0(S3) to CVAR5(S3)
6. Pull CSB high

Start Cell Voltage ADC Conversion

(All cells, normal mode with discharge permitted) and poll status

1. Pull CSB low
2. Send ADCV command with MD[1:0] = 10 and DCP = 1 i.e. 0x03 0x70 and its PEC (0xAF 0x42)
3. Pull CSB high

Clear Cell Voltage Registers

1. Pull CSB low
2. Send CLRCELL command (0x07 0x11) and its PEC (0xC9 0xC0)
3. Pull CSB high

Poll ADC Status

(Parallel configuration and ISOMD = 0)

This example uses an addressed LTC6804-2 with address A [3:0] = 0011 and ISOMD = 0

1. Pull CSB low
2. Send PLADC command (0x9F 0x14) and its PEC (0x1C 0x48)
3. SDO output is pulled low if the LTC6804-2 is busy. The host needs to send clocks on SCK in order for the polling status to be updated from the addressed device.
4. SDO output is high when the LTC6804-2 has completed conversions
5. Pull CSB high to exit polling

Talk to an I²C Slave Connected to LTC6804

The LTC6804 supports I²C slave devices by connection to GPIO4(SDA) and GPIO5(SCL). One valuable use for this capability is to store production calibration constants or other information in a small serial EEPROM using a connection like shown in Figure 25.

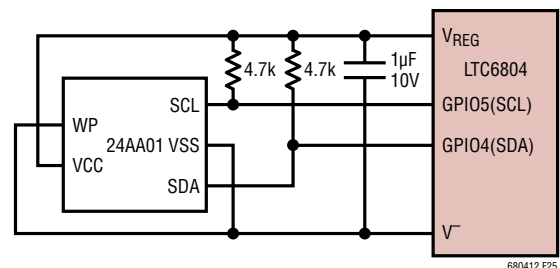


Figure 25. Connecting I²C EEPROM to LTC6804 GPIO Pins

OPERATION

This example uses a single LTC6804-1 to write a byte of data to an I²C EEPROM. The LTC6804 will send three bytes of data to the I²C slave device. The data sent will be B0 = 0xA0 (EEPROM address), B1 = 0x01 (write command), and B2 = 0xAA (data to be stored in EEPROM). The three bytes will be transmitted to the I²C slave device in the following format:

START – B0 – NACK – B1 – NACK – B2 – NACK – STOP

1. Write data to COMM register using WRCOMM command

- Pull CSB low
- Send WRCOMM command (0x07 0x21) and its PEC (0x24 0xB2)
- Send
COMM0 = 0x6A, COMM1 = 0x08 ([START] [B0] [NACK]),
COMM2 = 0x00, COMM3 = 0x18 ([BLANK] [B1] [NACK]),
COMM4 = 0x0A, COMM5 = 0xA9 ([BLANK] [B2] [NACK+STOP])
and PEC = 0x6D 0xFB for the above data
- Pull CSB high

2. Send the 3 bytes of data to I²C slave device using STCOMM command

- Pull CSB low
- Send STCOMM command (0x07 0x23) and its PEC (0xB9 0xE4)
- Send 72 clock cycles on SCK
- Pull CSB high

3. Data transmitted to slave during the STCOMM command is stored in the COMM register. Use the RDCOMM command to retrieve the data

- Pull CSB low
- Send RDCOMM command (0x07 0x22) and its PEC (0x32 0xD6)
- Read COMM0-COMM5 and the PEC for the 6 bytes of data.

Assuming the slave acknowledged all 3 bytes of data, the read back data in this example would look like:

COMM0 = 0x6A, COMM1 = 0x07, COMM2 = 0x70,
COMM3 = 0x17, COMM4 = 0x7A, COMM5 = 0xA1,
PEC = 0xD0 0xDE

- Pull CSB high

Note: If the slave returns data, this data will be placed in COMM0-COMM5.

Figure 26 shows the activity on GPIO5 (SCL) and GPIO4 (SDA) ports of the I²C master for 72 clock cycles during the STCOMM command in the above example.

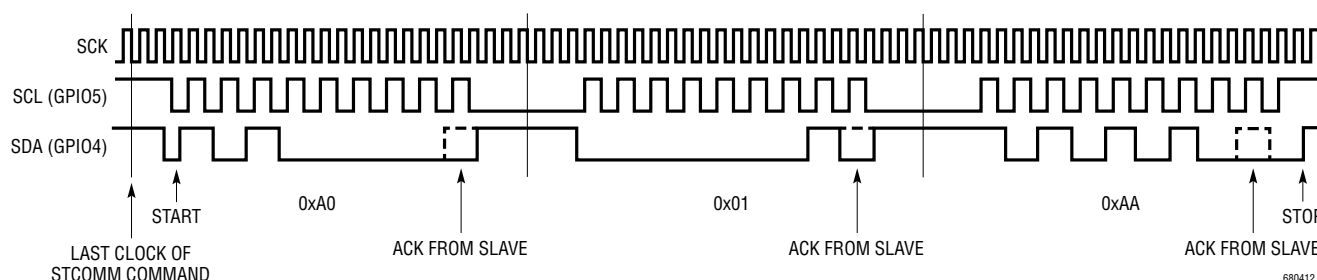


Figure 26. LTC6804 I²C Communication Example

OPERATION

Talk to a SPI Slave Connected to LTC6804

This example uses a single LTC6804-1 device which has a SPI device connected to it through GPIO3 (CSBM), GPIO4 (SDOM) and GPIO5 (SCKM). In this example, the LTC6804 device sends out 3 bytes of data B0 = 0x55, B1 = 0xAA and B2 = 0xCC to the SPI slave device in the following format: CSB low – B0 – B1 – B2 – CSB high

1. Write data to COMM register using WRCOMM command
 - a. Pull CSBM low
 - b. Send WRCOMM command (0x07 0x21) and its PEC (0x24 0xB2)
 - c. Send
 COMM0 = 0x85, COMM1 = 0x50 ([CSBM low] [B0] [CSBM low]),
 COMM2 = 0x8A, COMM3 = 0xA0 ([CSBM low] [B1] [CSBM low]),
 COMM4 = 0x8C, COMM5 = 0xC9 ([CSBM low] [B2] [CSBM high])
 and PEC = 0x89 0xA4 for the above data.
 - d. Pull CSB high
2. Send the 3 bytes of data to SPI slave device using STCOMM command
 - a. Pull CSB low
 - b. Send STCOMM command (0x07 0x23) and its PEC (0xB9 0xE4)
 - c. Send 72 clock cycles on SCK
 - d. Pull CSB high

3. Data transmitted to slave during the STCOMM command is stored in the COMM register. Use the RDCOMM command to retrieve the data.

- a. Pull CSB low
- b. Send RDCOMM command (0x07 0x22) and its PEC (0x32 0xD6)
- c. Read COMM0-COMM5 and the PEC for the 6 bytes of data. The read back data in this example would look like:

COMM0 = 0x755F, COMM1 = 0x7AAF, COMM2 = 7CCF, PEC = 0xF2BA

- d. Pull CSB high

Note: If the slave returns data, this data will be placed in COMM0-COMM5.

Figure 27 shows the activity on GPIO3 (CSBM), GPIO5 (SCKM) and GPIO4 (SDOM) ports of SPI master for 72 clock cycles during the STCOMM command in the above example.

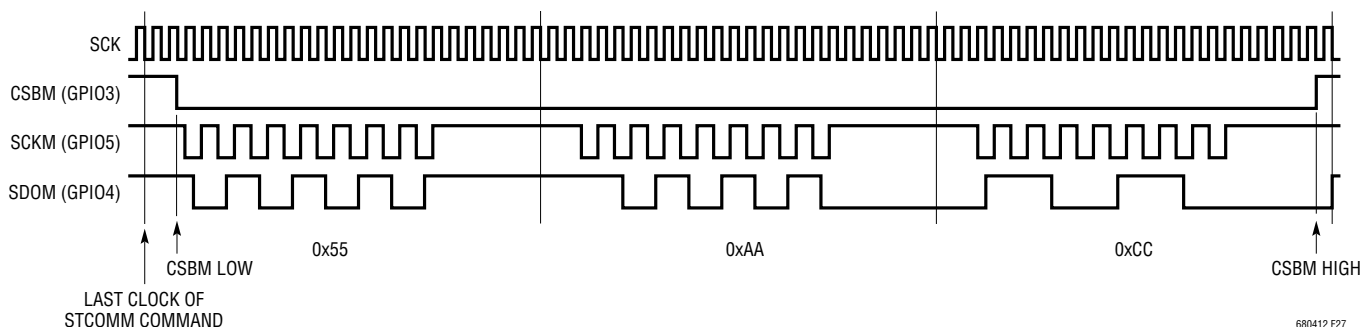


Figure 27. LTC6804 SPI Communication Example

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APPLICATIONS INFORMATION

SIMPLE LINEAR REGULATOR

The LTC6804 draws most of its power from the V_{REG} input pin. $5V \pm 0.5V$ should be applied to V_{REG} . A regulated DC/DC converter can power V_{REG} directly, or the DRIVE pin may be used to form a discrete regulator with the addition of a few external components. When active, the DRIVE output pin provides a low current 5.6V output that can be buffered using a discrete NPN transistor, as shown in Figure 28. The collector power for the NPN can come from any potential of 6V or more above V^- , including the cells being monitored or an unregulated converter supply. A $100\Omega/100nF$ RC decoupling network is recommended for the collector power connection to protect the NPN from transients. The emitter of the NPN should be bypassed with a $1\mu F$ capacitor. Larger capacitor values should be avoided because they increase the wake-up time of the LTC6804. Some attention to the thermal characteristic of the NPN is needed, as there can be significant heating with a high collector voltage.

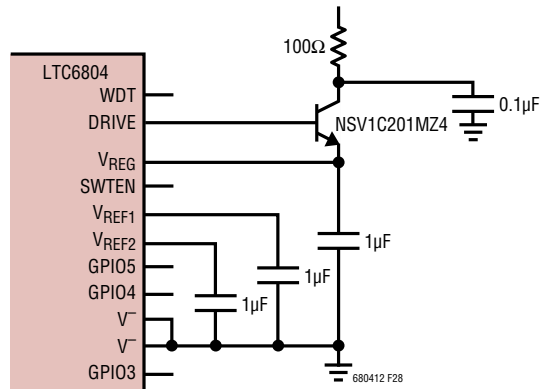


Figure 28. Simple V_{REG} Power Source Using NPN Pass Transistor

IMPROVED REGULATOR POWER EFFICIENCY

To minimize power consumption within the LTC6804, the current drawn on the V^+ pin has been designed to be very small ($500\mu A$). The voltage on the V^+ pin must be at least as high as the top cell to provide accurate measurement. The V^+ and V_{REG} pins can be unpowered to provide an exceptionally low battery drain shutdown mode. In many applications, the V^+ will be permanently connected to the top cell potential through a decoupling RC to protect against transients ($100\Omega/100nF$ is recommended).

For better running efficiency when powering from the cell stack, the V_{REG} may be powered from a buck converter rather than the NPN pass transistor. An ideal circuit for this is based on the LT3990 as shown in Figure 29. A $1k$ resistor should be used in series with the input to prevent inrush current when connecting to the stack and to reduce conducted EMI. The EN/UVLO pin should be connected to DRIVE so that the converter sleeps along with the LTC6804. The LTC6804 watchdog timer requires V_{REG} power to timeout. Therefore, if the EN/UVLO pin is not connected to DRIVE, care must be taken to allow the LTC6804 to timeout first before removing V_{REG} power; otherwise the LTC6804 will not enter sleep mode.

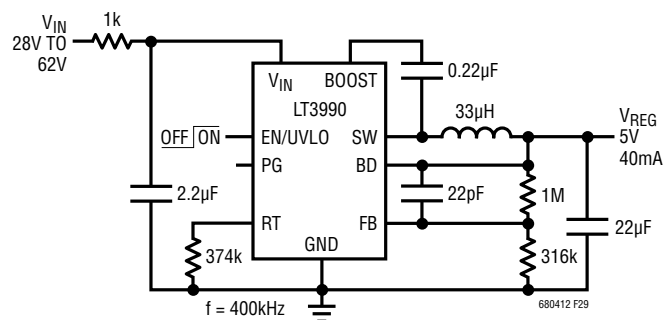


Figure 29. V_{REG} Powered from Cell Stack with High Efficiency

APPLICATIONS INFORMATION

FULLY ISOLATED POWER

A simple DC/DC flyback converter can provide isolated power for an LTC6804 from a remote 12V power source as shown in Figure 30. This circuit, along with the isoSPI transformer isolation, results in LTC6804 circuitry that is completely floating and uses almost no power from the batteries. Aside from reducing the amount of circuitry that operates at battery potential, such an arrangement prevents battery load imbalance. The LTC6804 watchdog timer requires V_{REG} power to timeout. Therefore, care must be taken to allow the LTC6804 to timeout first before removing V_{REG} power; otherwise the LTC6804 will not enter sleep mode.

READING EXTERNAL TEMPERATURE PROBES

Figure 31 shows the typical biasing circuit for a negative-temperature-coefficient (NTC) thermistor. The $10k\Omega$ at 25°C is the most popular sensor value and the V_{REF2} output stage is designed to provide the current required to directly bias several of these probes. The biasing resistor is selected to correspond to the NTC value so the circuit will provide 1.5V at 25°C (V_{REF2} is 3V nominal). The overall circuit response is approximately $-1\%/^\circ\text{C}$ in the range of typical cell temperatures, as shown in the chart of Figure 31.

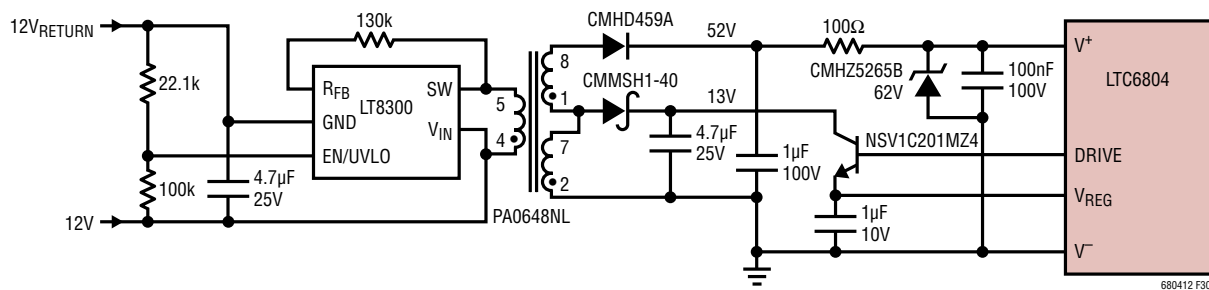


Figure 30. Powering LTC6804 from a Remote 12V Source

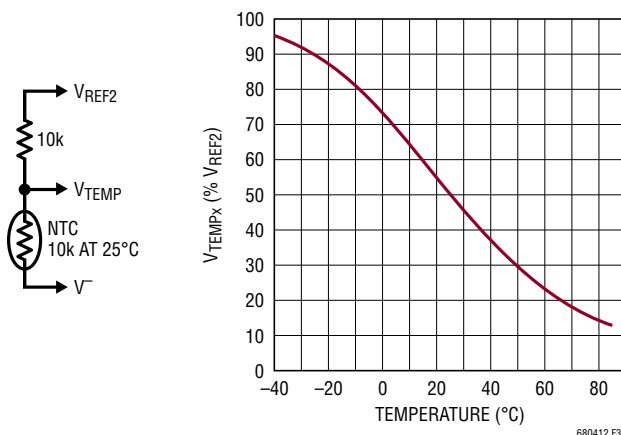


Figure 31. Typical Temperature Probe Circuit and Relative Output

APPLICATIONS INFORMATION

EXPANDING THE NUMBER OF AUXILIARY MEASUREMENTS

The LTC6804 provides five GPIO pins, each of which is capable of performing as an ADC input. In some applications there is need to measure more signals than this, so one means of supporting higher signal count is to add a MUX circuit such as shown in Figure 32. This circuit digitizes up to sixteen source signals using the GPIO1 ADC input and MUX control is provided by two other GPIO lines configured as an I²C port. The buffer amplifier provides for fast settling of the selected signal to increase the usable conversion rate.

INTERNAL PROTECTION FEATURES

The LTC6804 incorporates various ESD safeguards to ensure a robust performance. An equivalent circuit showing the specific protection structures is shown in Figure 33. While pins 43 to 48 have different functionality for the -1 and -2 variants, the protection structure is the same. Zener-like suppressors are shown with their nominal clamp voltage, other diodes exhibit standard PN junction behavior.

FILTERING OF CELL AND GPIO INPUTS

The LTC6804 uses a delta-sigma ADC, which has delta-sigma modulator followed by a SINC3 finite impulse response (FIR) digital filter. This greatly reduces input filtering requirements. Furthermore, the programmable oversampling ratio allows the user to determine the best trade-off between measurement speed and filter cutoff frequency. Even with this high order lowpass filter, fast transient noise can still induce some residual noise in measurements, especially in the faster conversion modes. This can be minimized by adding an RC lowpass decoupling to each ADC input, which also helps reject potentially damaging high energy transients. Adding more than about 100Ω to the ADC inputs begins to introduce a systematic error in the measurement, which can be improved by raising the filter capacitance or mathematically compensating in software with a calibration procedure. For situations that demand the highest level of battery voltage ripple rejection, grounded capacitor filtering is recommended. This configuration has a series resistance and capacitors that decouple HF noise to V⁻. In systems where noise is less

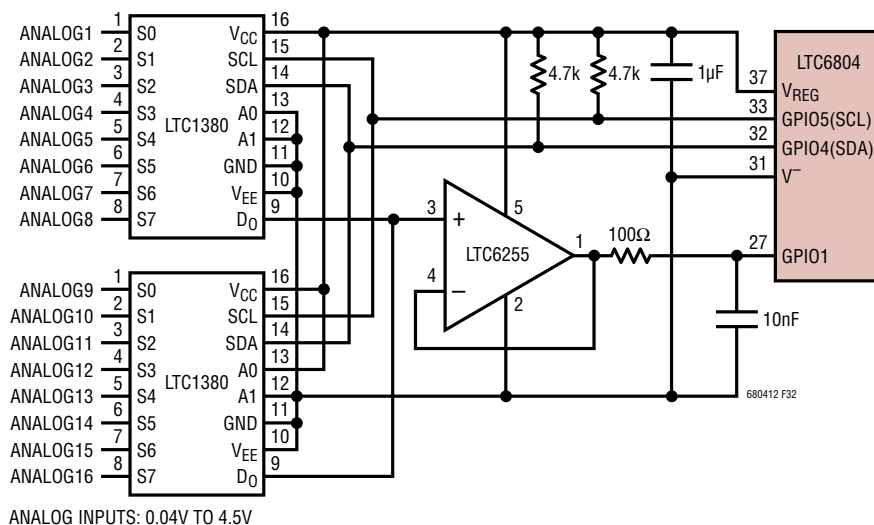


Figure 32. MUX Circuit Supports Sixteen Additional Analog Measurements

APPLICATIONS INFORMATION

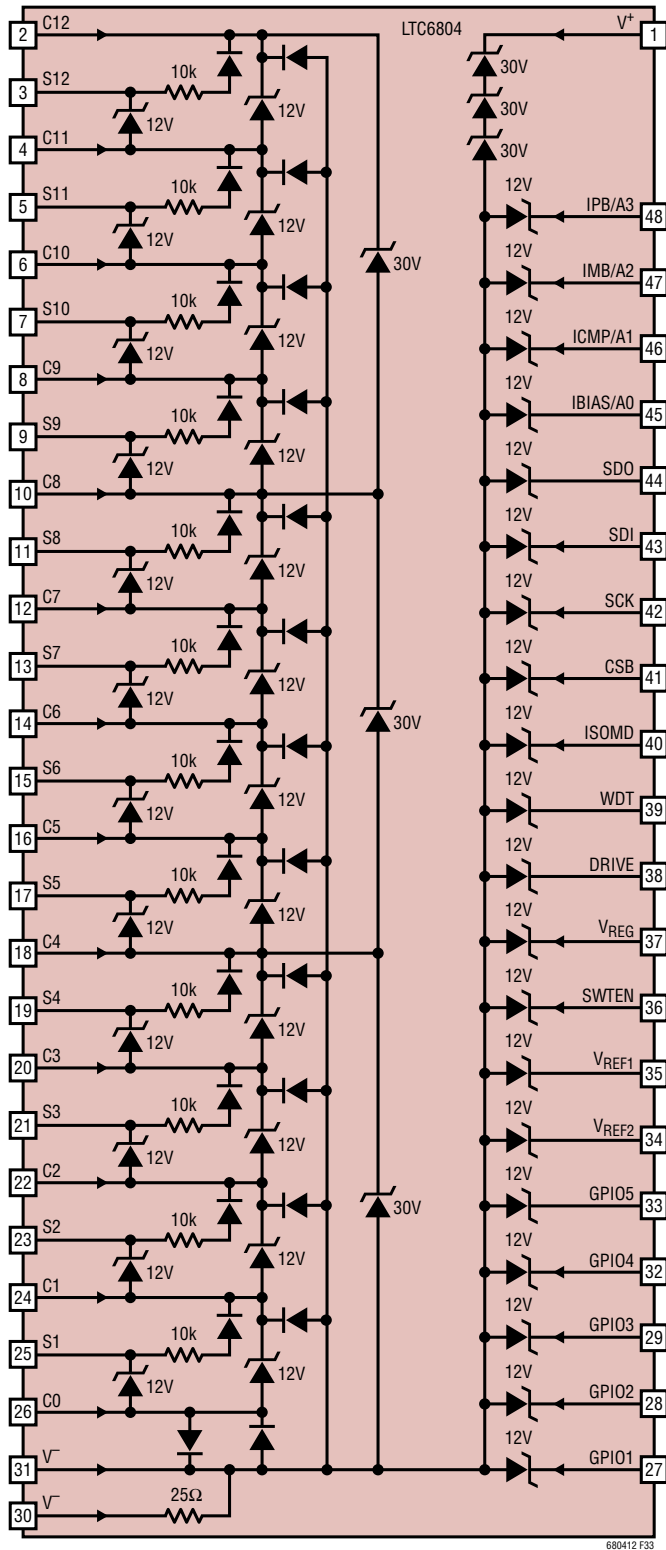


Figure 33. Internal ESD Protection Structure of LTC6804

periodic or higher oversample rates are in use, a differential capacitor filter structure is adequate. In this configuration there are series resistors to each input, but the capacitors connect between the adjacent C pins. However, the differential capacitor sections interact. As a result, the filter response is less consistent and results in less attenuation than predicted by the RC, by approximately a decade. Note that the capacitors only see one cell of applied voltage (thus smaller and lower cost) and tend to distribute transient energy uniformly across the IC (reducing stress events on the internal protection structure). Figure 34 shows the two methods schematically. Basic ADC accuracy varies with R, C as shown in the Typical Performance curves, but error is minimized if $R = 100\Omega$ and $C = 10\text{nF}$. The GPIO pins will always use a grounded capacitor configuration because the measurements are all with respect to V^- .

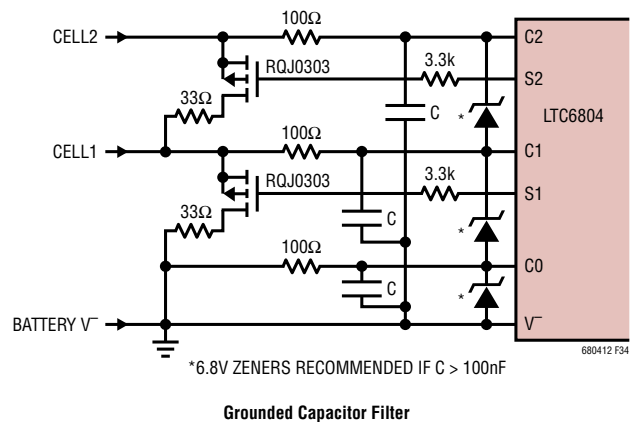
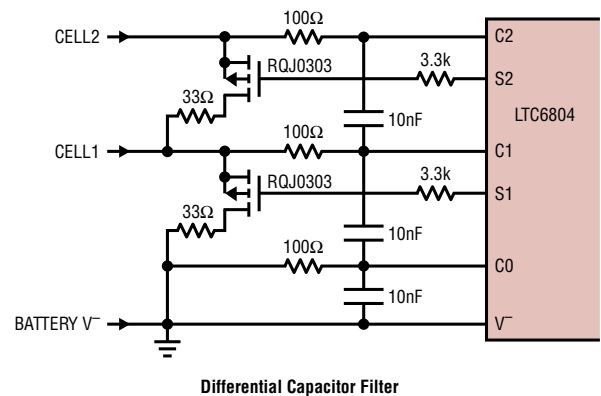


Figure 34. Input Filter Structure Configurations

APPLICATIONS INFORMATION

CELL BALANCING WITH INTERNAL MOSFETS

The S1 through S12 pins are used to balance battery cells. If one cell in a series becomes overcharged, an S output can be used to discharge the cell. Each S output has an internal N-channel MOSFET for discharging. The NMOS has a maximum on resistance of 20Ω. An external resistor should be connected in series with the NMOS to dissipate heat outside of the LTC6804 package as illustrated in Figure 35. It is still possible to use an RC to add additional filtering to cell voltage measurements but the filter R must remain small, typically around 10Ω to reduce the effect on the programmed balance current. When using the internal MOSFETs to discharge cells, the die temperature should be monitored. See Power Dissipation and Thermal Shutdown section.

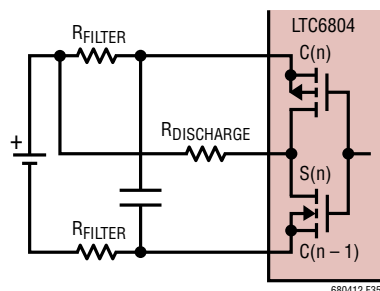


Figure 35. Internal Discharge Circuit

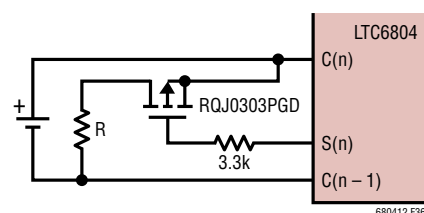


Figure 36. External Discharge Circuit

CELL BALANCING WITH EXTERNAL MOSFETS

The S outputs include an internal pull-up PMOS transistor. The S pins can act as digital outputs suitable for driving the gate of an external MOSFET. For applications requiring high battery discharge currents, connect a discrete PMOS switch device and suitable discharge resistor to the cell, and the gate terminal to the S output pin, as illustrated in Figure 36. Figure 34 shows external MOSFET circuits that include RC filtering.

DISCHARGE CONTROL DURING CELL MEASUREMENTS

If the discharge permitted (DCP) command bit is high in a cell measurement command, then the S pin discharge states are not altered during the cell measurements. However, if the DCP bit is low, any discharge that is turned on will be turned off when the corresponding cell or adjacent cells are being measured. Table 47 illustrates this during an

Table 47. Discharge Control During an ADCV Command with DCP = 0

DISCHARGE PIN	CELL MEASUREMENT PERIODS						CELL CALIBRATION PERIODS					
	CELL1/7	CELL2/8	CELL3/9	CELL4/10	CELL5/11	CELL6/12	CELL1/7	CELL2/8	CELL3/9	CELL4/10	CELL5/11	CELL6/12
	t ₀ to t _{1M}	t _{1M} to t _{2M}	t _{2M} to t _{3M}	t _{3M} to t _{4M}	t _{4M} to t _{5M}	t _{5M} to t _{6M}	t _{6M} to t _{1C}	t _{1C} to t _{2C}	t _{2C} to t _{3C}	t _{3C} to t _{4C}	t _{4C} to t _{5C}	t _{5C} to t _{6C}
S1	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF
S2	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON
S3	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON
S4	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON
S5	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF
S6	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF
S7	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF
S8	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON
S9	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON
S10	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON
S11	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF
S12	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF

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APPLICATIONS INFORMATION

ADCV command with DCP = 0. In this table, OFF implies that a discharge is forced off during that period even if the corresponding DCC[x] bit is high in the configuration register. ON implies that if the discharge is turned on, it will stay on during that period. Refer to Figure 3 for the timing of the ADCV command.

POWER DISSIPATION AND THERMAL SHUTDOWN

The internal MOSFETs connected to the pins S1 through S12 pins can be used to discharge battery cells. An external resistor should be used to limit the power dissipated by the MOSFETs. The maximum power dissipation in the MOSFETs is limited by the amount of heat that can be tolerated by the LTC6804. Excessive heat results in elevated die temperatures. Little or no degradation will be observed in the measurement accuracy for die temperatures up to 125°C. Damage may occur above 150°C, therefore the recommended maximum die temperature is 125°C. To protect the LTC6804 from damage due to overheating a thermal shutdown circuit is included. Overheating of the device can occur when dissipating significant power in the cell discharge switches. The thermal shutdown circuit is enabled whenever the device is not in sleep mode (see LTC6804 Core State Descriptions). If the temperature detected on the device goes above approximately 150°C the configuration registers will be reset to default states turning off all discharge switches. When a thermal shutdown has occurred, the THSD bit in the status register group B will go high. The bit is cleared after a read operation of the status register group B. The bit can also be set using the CLRSTAT command. Since thermal shutdown interrupts normal operation, the internal temperature monitor should be used to determine when the device temperature is approaching unacceptable levels.

METHOD TO VERIFY BALANCING CIRCUITRY

The functionality of the discharge circuitry is best verified by cell measurements. Figure 37 shows an example using the LTC6804 battery monitor IC. The resistor between the battery and the source of the discharge MOSFET causes cell voltage measurements to decrease. The amount of measurement change depends on the resistor values and the MOSFET on resistance.

The following algorithm could be used in conjunction with Figure 37:

1. Measure all cells with no discharging (all S outputs off) and read and store the results.
2. Turn on S1 and S7
3. Measure C1-C0, C7-C6
4. Turn off S1 and S7
5. Turn on S2 and S8
6. Measure C2-C1, C8-C7
7. Turn off S2 and S8
- ...
14. Turn on S6 and S12
15. Measure C6-C5, C12-C11
16. Turn off S6 and S12
17. Read the voltage register group to get the results of steps 2 thru 16.
18. Compare new readings with old readings. Each cell voltage reading should have decreased by a fixed percentage set by R_{B1} and R_{B2} (Figure 37). The exact amount of decrease depends on the resistor values and MOSFET characteristics.

Improved PEC Calculation

The PEC allows the user to have confidence that the serial data read from the LTC6804 is valid and has not been corrupted by any external noise source. This is a critical feature for reliable communication and the LTC6804 requires that a PEC be calculated for all data being read from and written to the LTC6804. For this reason it is important to have an efficient method for calculating the PEC. The code below demonstrates a simple implementation of a lookup table derived PEC calculation method. There are two functions, the first function `init_PEC15_Table()` should only be called once when the microcontroller starts and will initialize a PEC15 table array called `pec15Table[]`. This table will be used in all future PEC calculations. The `pec15` table can also be hard coded into the microcontroller rather than running the `init_PEC15_Table()` function at startup. The `pec15()` function calculates the PEC and will return the correct 15 bit PEC for byte arrays of any given length.

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APPLICATIONS INFORMATION

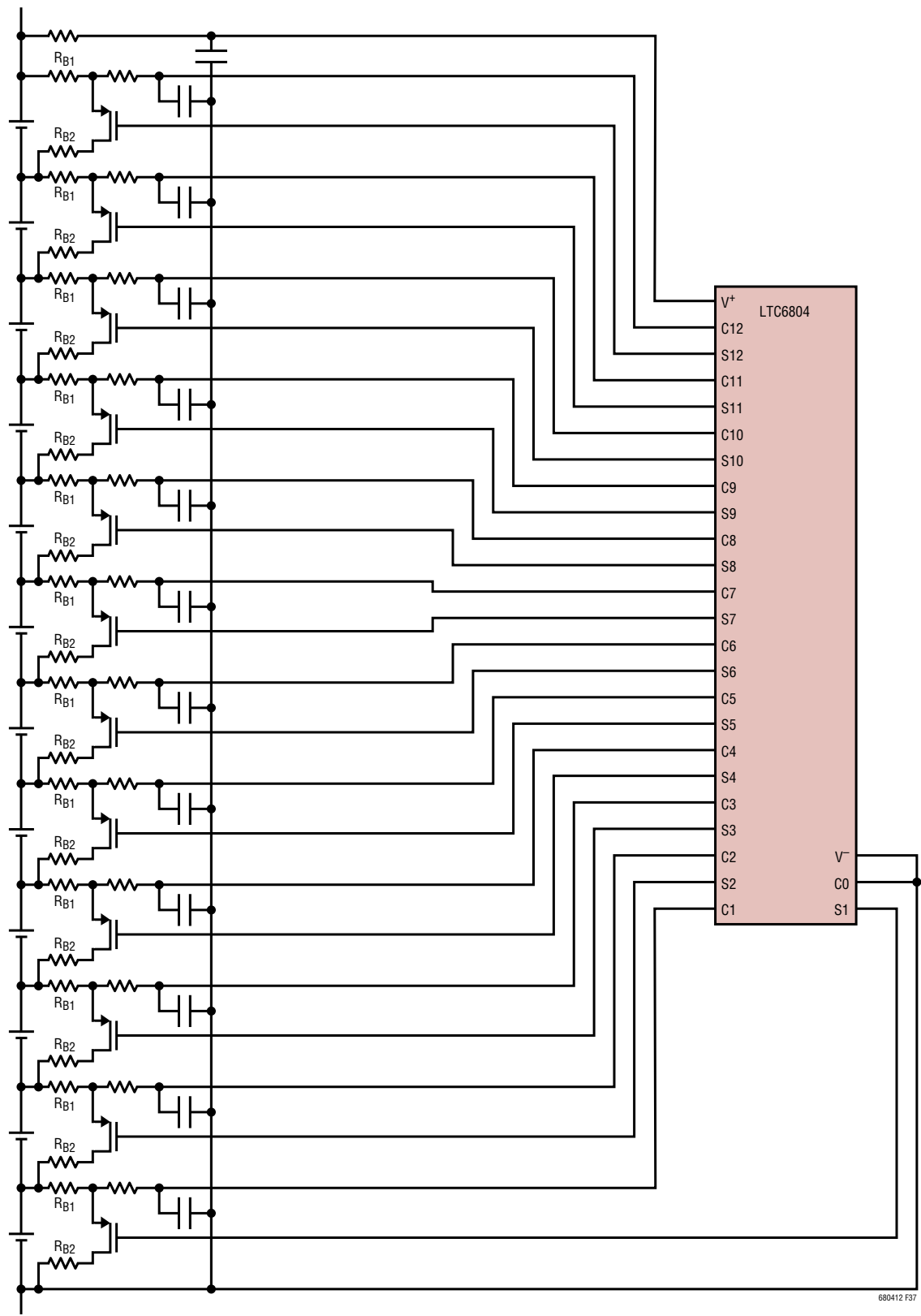


Figure 37. Balancing Self Test Circuit

APPLICATIONS INFORMATION

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*****/

```
int16 pec15Table[256];
int16 CRC15_POLY = 0x4599;
void init_PEC15_Table()
{
    for (int i = 0; i < 256; i++)
    {
        remainder = i << 7;
        for (int bit = 8; bit > 0; --bit)
        {
            if (remainder & 0x4000)
            {
                remainder = ((remainder << 1));
                remainder = (remainder ^ CRC15poly)
            }
            else
            {
                remainder = ((remainder << 1));
            }
        }
        pec15Table[i] = remainder&0xFFFF;
    }
}

unsigned int16 pec15 (char *data , int len)
{
    int16 remainder,address;

    remainder = 16;//PEC seed
    for (int i = 0; i < len; i++)
    {
        address = ((remainder >> 7) ^ data[i]) & 0xff;//calculate PEC table address
        remainder = (remainder << 8 ) ^ pec15Table[address];
    }
    return (remainder*2);//The CRC15 has a 0 in the LSB so the final value must be multiplied by 2
}
```

APPLICATIONS INFORMATION

CURRENT MEASUREMENT WITH A HALL EFFECT SENSOR

The LTC6804 auxiliary ADC inputs (GPIO pins) may be used for any analog signal, including those from various active sensors that generate a compatible voltage. One such example that may be useful in a battery management setting is the capture of battery current. Hall-effect sensors are popular for measuring large battery currents since the technology provides a non-contact, low power dissipation solution. Figure 38 shows schematically a typical Hall sensor that produces two outputs that proportion to the V_{CC} provided. The sensor is powered from a 5V source

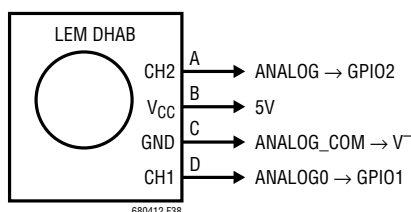


Figure 38. Interfacing a Typical Hall-Effect Battery Current Sensor to Auxiliary ADC Inputs

and produces analog outputs that are connected to GPIO pins or inputs of the MUX application shown in Figure 32. The use of GPIO1 and GPIO2 as the ADC inputs has the possibility of being digitized within the same conversion sequence as the cell inputs (using the ADCVAX command), thus synchronizing cell voltage and cell current measurements.

CURRENT MEASUREMENT WITH A SHUNT RESISTOR

It is possible to measure the battery current on the LTC6804 GPIO pins with a high performance current sense amplifier and a shunt. Figure 39 shows 2 LTC6102s being used to measure the discharge and charge currents on a 12-cell battery stack. To achieve a large dynamic range while maintaining a high level of accuracy the LTC6102 is required. The circuit shown is able to accurately measure ± 200 Amps to 0.1 Amps. The offset of the LTC6102 will only contribute a 20mA error. To maintain a very low sleep current the V_{DRIVE} is used to disable the LTC6102 circuits so that they draw no current when the LTC6804 goes to sleep.

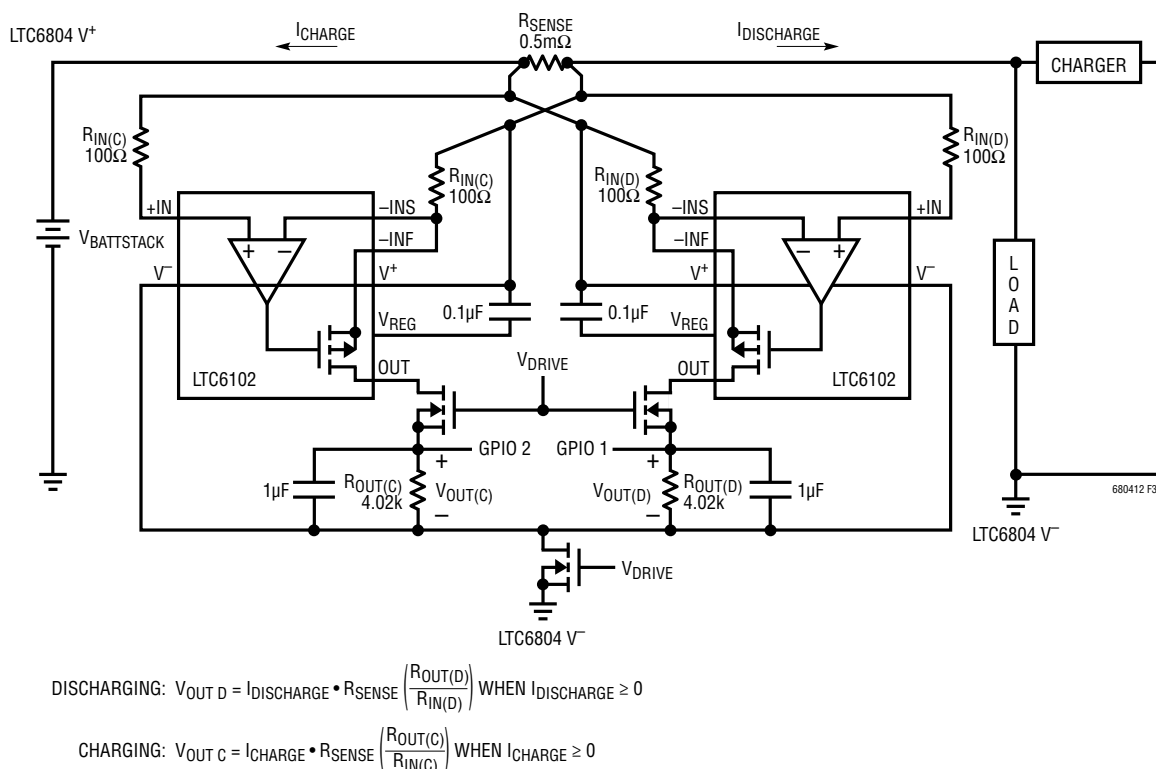


Figure 39. Monitoring Charge and Discharge Currents with a LTC6102

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APPLICATIONS INFORMATION

USING THE LTC6804 WITH LESS THAN 12 CELLS

If the LTC6804 is powered by the battery stack, the minimum number of cells that can be monitored by the LTC6804 is governed by the supply voltage requirements of the LTC6804. The sum of the cell voltages must be at least 11V to properly bias the LTC6804. Figure 40 shows an example of the LTC6804 when used to monitor eight cells with best cell measurement synchronization. The 12 cells monitored by the LTC6804 are split into two groups of 6 cells and are measured using two internal multiplexers and two ADCs. To optimize measurement synchronization in applications with less than 12 Cells the unused C pins should be equally distributed between the top of the second

mux (C12) and the top of the first mux (C6). If there are an odd number of cells being used, the top mux should have fewer cells connected. The unused cell channels should be tied to the other unused channels on the same mux and then connected to the battery stack through a 100Ω resistor. The unused inputs will result in a reading of 0V for those cells channels. It is also acceptable to connect in the conventional sequence with all unused cell inputs at the top.

CONNECTING MULTIPLE LTC6804-1 ON THE SAME PCB

When connecting multiple LTC6804-1 devices on the same PCB, only a single transformer is required between the LTC6804-1 isoSPI ports. With multiple LTC6804-1 devices on the same PCB, the noise rejection requirements are significantly lower and the isolation requirements are simplified. For this reason, a single transformer should be adequate to provide the required isolation and noise rejection between ICs on the battery stack. Figure 41 shows an example application that has multiple LTC6804-1s on the same PCB, communicating to the bottom MCU through a LTC6820.

CONNECTING A MCU TO AN LTC6804-1 WITH AN isoSPI DATA LINK

A separate device, the LTC6820, will convert standard 4-wire SPI into a 2-wire isoSPI link that can communicate directly with the LTC6804. An example is shown in Figure 42. The LTC6820 can be used in applications to easily provide isolation between the controller and the stack of LTC6804s. The LTC6820 also enables system configurations that have the BMS controller at a remote location relative to the LTC6804 ICs and the battery pack.

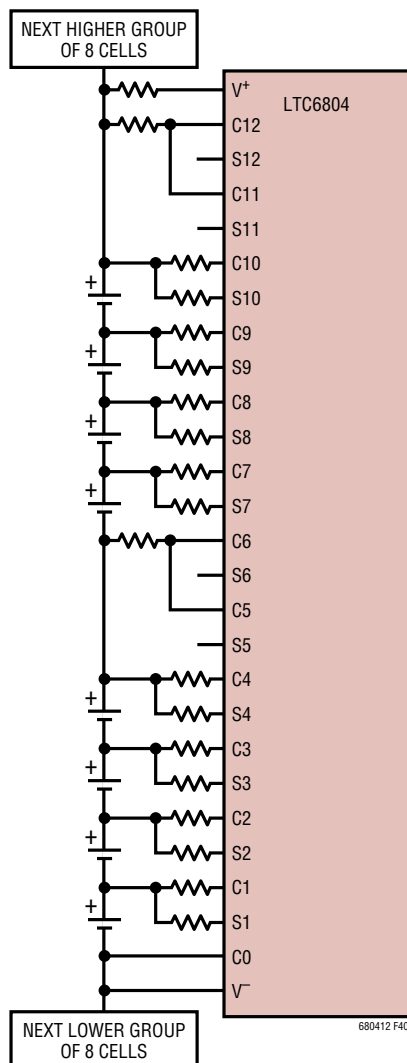


Figure 40. 8 Cell Connection Scheme

APPLICATIONS INFORMATION

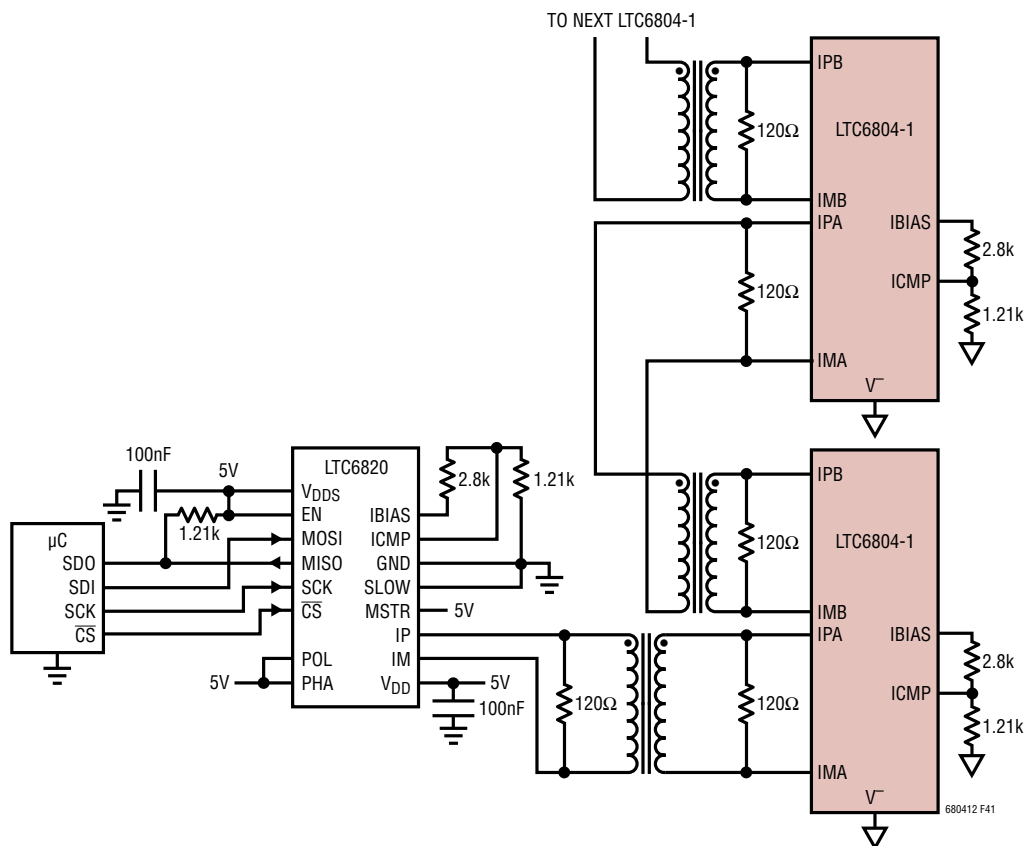


Figure 41. Connecting Multiple LTC6804-1 Devices on the Same PCB

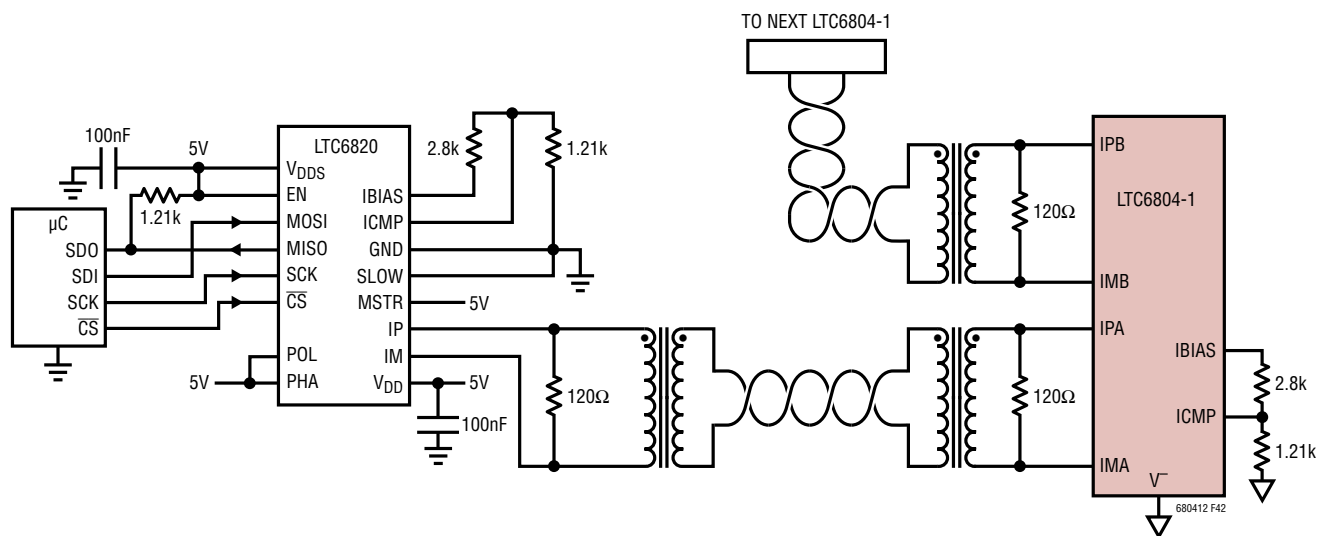


Figure 42. Interfacing an LTC6804-1 with an LTC6820 for Isolated SPI Control

APPLICATIONS INFORMATION

CONFIGURING THE LTC6804-2 IN A MULTI-DROP isoSPI LINK

The addressing feature of the LTC6804-2 allows multiple devices to be connected to a single isoSPI master by multi-dropping them along one twisted pair essentially creating a large parallel SPI network. An example multi-drop system is shown in Figure 43, the twisted pair should be terminated only at the beginning (master) and the end. In between, the additional LTC6804-2's will be con-

nected to stubs on the twisted pair. These stubs should be kept short, with as little capacitance as possible, to avoid degrading the termination along the isoSPI wiring. When a LTC6804-2 is not addressed, it will not transmit data pulses. This eliminates the possibility for collisions, as only the addressed device will ever be returning data to the master. The standard filtering circuits and layout guidelines outlined in the EMC section should be followed in multi drop networks.

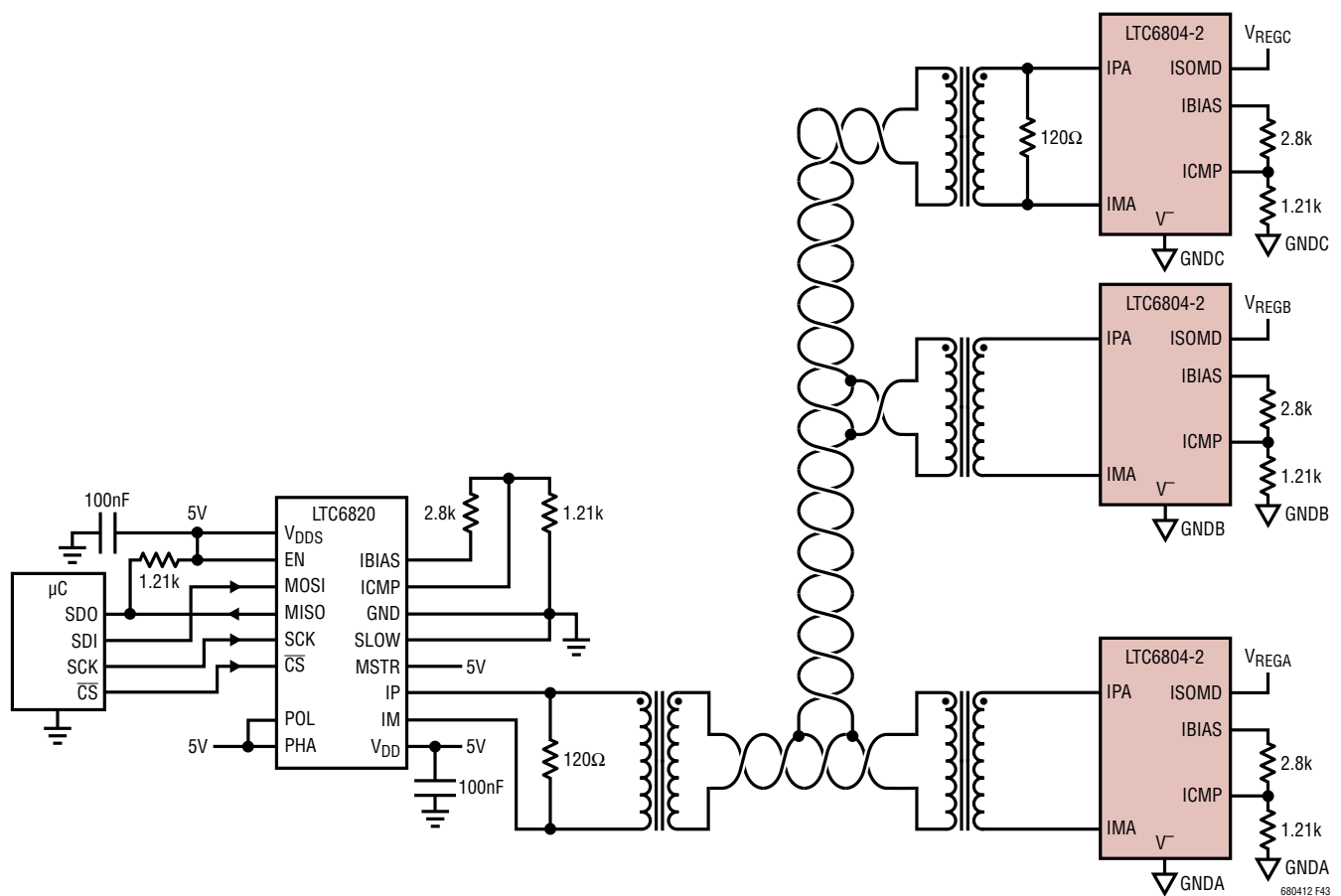


Figure 43. Connecting the LTC6804-2 in a Multi-Drop Configuration

APPLICATIONS INFORMATION

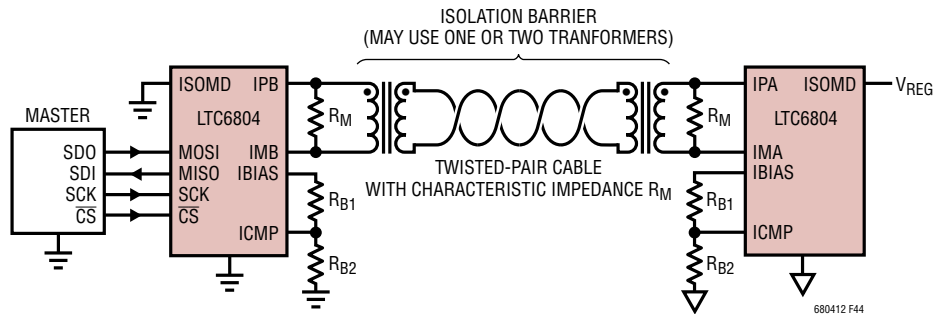


Figure 44. isoSPI Circuit

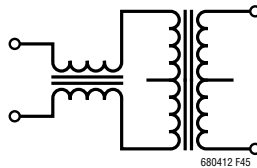


Figure 45. Transformer with Common Mode Choke

Table 48. Recommended Transformers

MANUFACTURER	PART NUMBER	ISOLATION VOLTAGE	TURNS RATIO	TEMPERATURE RANGE	CM CHOKE	CENTER TAP
Halo	TG110-AEX50N5LF (Dual)	1500V _{RMS}	1:1	–45°C to 125°C	Yes	Yes
Halo	TG110-AE050N5LF (Dual)	1500V _{RMS}	1:1	–45°C to 85°C	Yes	Yes
Halo	TGR01-6506V6NL	3000V _{RMS}	1:1	–40°C to 105°C	No	No
Pulse	PE-68386NL	1500VDC	1:1	–40°C to 130°C	No	No
Pulse	HX1188NL (Dual)	1500V _{RMS}	1:1	–40°C to 85°C	Yes	Yes
Würth	7490100111 (Dual)	1500V _{RMS}	1:1	–40°C to 105°C	Yes	Yes
Würth	750340848	3750V _{RMS}	1:1	–40°C to 105°C	No	No
Sumida	CEP99	3500VDC	1:1	–40°C to 125°C	No	Yes

TRANSFORMER SELECTION GUIDE

As shown in Figure 44, a transformer or a pair of transformers are used to isolate the isoSPI signals between two isoSPI ports. The isoSPI signals have programmable pulse amplitudes up to 1.6V and pulse widths of 50ns and 150ns. To meet these requirements, choose a transformer having a magnetizing inductance ranging from 40μH to 1000μH, and a 1:1 turns ratio. Minimizing transformer insertion loss will reduce required transmit power; generally an insertion loss of less than –1.5dB is recommended. To optimize common mode noise rejection, choose a center tapped transformer or a transformer with an integrated

common mode choke as show in Figure 45. The center tap should be tied to a 27pF or smaller capacitor (larger will restrict the driver's ability to set the common mode voltage). If the transformer has both a center tap and common mode choke on the primary side, a larger 100pF capacitor may be used. Table 48 shows a recommended list of transformers for use with the LTC6804. 10/100BaseTX Ethernet transformers are inexpensive and work very well in this application. Ethernet transformers have an added benefit in that they normally have common mode chokes built in improving their common mode rejection versus other transformers.

APPLICATIONS INFORMATION

Capacitive Isolation Barrier

In some applications two LTC6804s can be monitoring the same group of batteries for redundancy or two strings of batteries connected in parallel. In these applications both of the LTC6804s will be at the same common mode voltage so the high CMRR of the transformers may not be required. In this situation an alternative to transformers is to use capacitors as the isolation barrier. The use of capacitors is suitable for low cost, isolated signaling over short distances (1 meter or less) that do not require high noise rejection. The capacitors will provide galvanic isolation, but no common mode rejection. This option uses the drivers in a different way, by using pull up resistors to maintain the common mode voltage near V_{REG} , only the sinking drive current has any effect. Figure 46 shows an example circuit using a capacitive isolation barrier capable of driving 1 meter of cable.

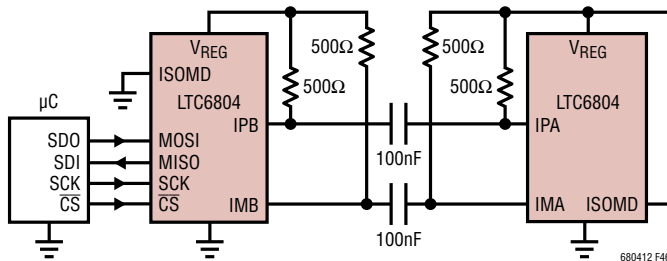


Figure 46. Capacitor Isolation Barrier

isoSPI Setup

The LTC6804 allows the isoSPI link in each application to be optimized for power consumption or for noise immunity. The power and noise immunity of an isoSPI system is determined by the programmed I_B current. The I_B current can range from 100μA to 1mA. A low I_B reduces the isoSPI power consumption in the READY and ACTIVE states, while

a high I_B increases the amplitude of the differential signal voltage V_A across the matching termination resistor, R_M . I_B is programmed by the sum of the R_{B1} and R_{B2} resistors connected between the IBIAS pin and GND as shown in Figure 44. For most applications setting I_B to 0.5mA is a good compromise between power consumption and noise immunity. Using this I_B setting with a 1:1 transformer and $R_M = 120\Omega$, R_{B1} should be set to 2.8k and R_{B2} set to 1.2k. In a typical CAT5 twisted pair these settings will allow for communication up to 50m. For applications that require cables longer than 50m it is recommended to increase the I_B to 1mA. This compensates for the increased insertion loss in the cable and maintains high noise immunity. So when using cables over 50m and, again, using a transformer with a 1:1 turns ratio and $R_M = 120\Omega$, R_{B1} would be 1.4k and R_{B2} would be 600Ω. Other I_B settings can be used to reduce power consumption or increase the noise immunity as required by the application. In these cases when setting threshold voltage V_{ICMP} and choosing R_{B1} and R_{B2} resistor values the following rules should be used:

For cables under 50m:

$$\begin{aligned} I_B &= 0.5\text{mA} \\ V_A &= (20 \cdot I_B) \cdot (R_M/2) \\ V_{TCMP} &= \frac{1}{2} \cdot V_A \\ V_{ICMP} &= 2 \cdot V_{TCMP} \\ R_{B2} &= V_{ICMP}/I_B \\ R_{B1} &= (2/I_B) - R_{B2} \end{aligned}$$

For cables over 50m:

$$\begin{aligned} I_B &= 1\text{mA} \\ V_A &= (20 \cdot I_B) \cdot (R_M/2) \\ V_{TCMP} &= \frac{1}{4} \cdot V_A \\ V_{ICMP} &= 2 \cdot V_{TCMP} \\ R_{B2} &= V_{ICMP}/I_B \\ R_{B1} &= (2/I_B) - R_{B2} \end{aligned}$$

APPLICATIONS INFORMATION

The maximum data rate of an isoSPI link is determined by the length of the cable used. For cables 10 meters or less the maximum 1MHz SPI clock frequency is possible. As the length of the cable increases the maximum possible SPI clock rate decreases. This is a result of the increased propagation delays through the cable creating possible timing violations. Figure 47 shows how the maximum data rate is reduced as the cable length increases when using a CAT 5 twisted pair.

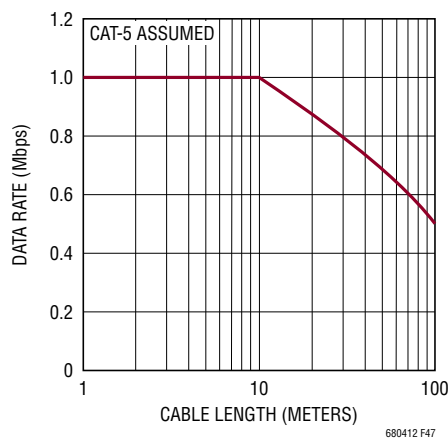


Figure 47. Data Rate vs Cable Length

Cable delay affects three timing specifications, t_{CLK} , t_6 and t_7 . In the Electrical Characteristics table, each is derated by 100ns to allow for 50ns of cable delay. For longer cables, the minimum timing parameters may be calculated as shown below:

$$t_{CLK}, t_6 \text{ and } t_7 > 0.9\mu s + 2 \cdot t_{CABLE}$$

EMC

For the best electromagnetic compatibility (EMC) performance, it is recommended to use one of the circuits in Figures 48 and 49. The center tap of the transformer should be bypassed with a 100pF capacitor. The center tap capacitor will help attenuate common mode signals. Large center tap capacitors greater than 100pF should be avoided as they will prevent the isoSPI transmitters common mode voltage from settling. If a transformer without

a center tap is used, the termination resistor should be split into two equal halves and connected in series across the IP and IM lines. The center of the two resistors should be bypassed with a capacitor as shown in Figure 49. To improve common mode current rejection a common mode choke should also be placed in series with the IP and IM lines of the LTC6804. The common mode choke will both increase EMI immunity and reduce EMI emission. When choosing a common mode choke, the differential mode impedance should be 20Ω or less for signals 50MHz and below. Common mode chokes similar to what is used in Ethernet applications are recommended.

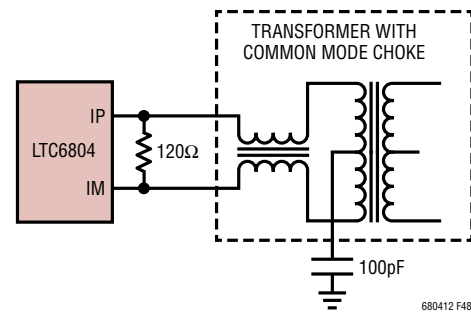


Figure 48. Recommended isoSPI Circuit for Best EMC Performance

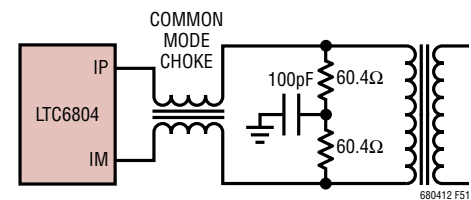


Figure 49. Recommended isoSPI Circuit for Best EMC Performance when Using a Transformer without a Center Tap

Table 49. Recommended Common Mode Chokes

MANUFACTURER	PART NUMBER
TDK	ACT45B-220-2P
Murata	DLW43SH510XK2

APPLICATIONS INFORMATION

Layout of the isoSPI signal lines also plays a significant role in maximizing the immunity of a circuit. The following layout guidelines should be followed:

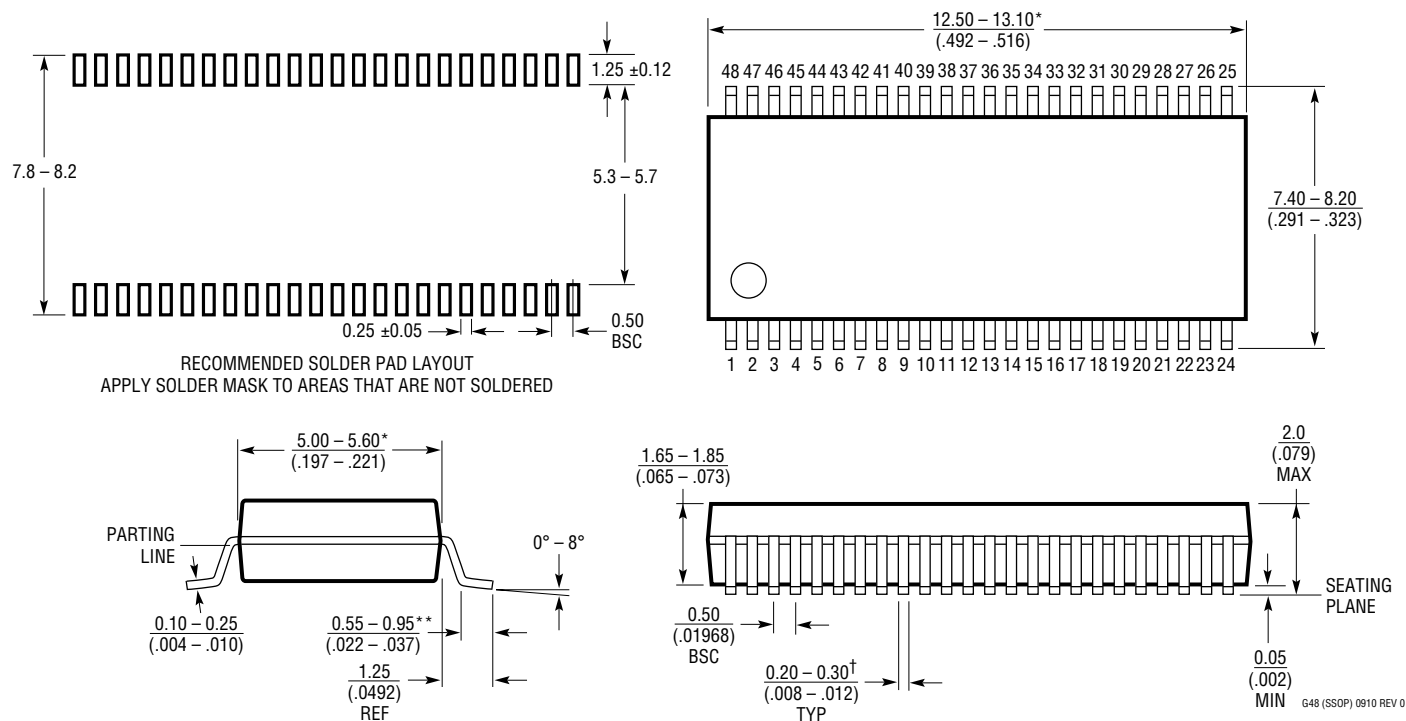
1. The transformer should be placed as close to the isoSPI cable connector as possible. The distance should be kept less than 2cm. The LTC6804 should be placed at least 1cm to 2cm away from the transformer to help isolate the IC from magnetic field coupling.
2. On the top component layer, no ground plane should be placed under the transformer, the isoSPI connector, or in between the transformer and the connector.
3. The isoSPI signal traces should be isolated from surrounding circuits and traces by ground metal or space. No traces should cross the isoSPI signal lines, unless separated by a ground plane on an inner layer.

The isoSPI drive currents are programmable and allow for a trade-off between power consumption and noise immunity. The noise immunity of the LTC6804 has been evaluated using a bulk current injection (BCI) test. The BCI test injects current into the twisted-pair lines at set levels over a frequency range of 1MHz to 400MHz. With the minimum I_B current, 100 μ A, the isoSPI serial link was capable of passing a 40mA BCI test with no bit errors. A 40mA BCI test level is sufficient for industrial applications. Automotive applications have a much higher BCI requirement so the LTC6804 I_B is set to 1mA, the maximum power level. The isoSPI system is capable of passing a 200mA BCI test with no transmitted bit errors. The 200mA test level is typical for automotive requirements.

PACKAGE DESCRIPTION

Please refer to <http://www.linear.com/designtools/packaging/> for the most recent package drawings.

G Package 48-Lead Plastic SSOP (5.3mm) (Reference LTC DWG # 05-08-1887 Rev 0)



REVISION HISTORY

REV	DATE	DESCRIPTION	PAGE NUMBER
A	10/13	T _{JMAX} corrected from 125°C to 150°C	3
		WDT pin description updated	17, 30, 56, 57
		Information added to Recommended Transformers table	68
B	6/14	Correction to TME Test Conditions, V(CO) = V ⁻	4, 5
		Description of T _{SLEEP} added to STANDBY State Discussion	20
		Correction to Temperature Range for TMS Spec, 125°C instead of 85°C	22
		Note regarding potential differences between CO and V ⁻ added	27
		Correction to Measurement Range for Accuracy Check, 2.985V to 3.015V	27, 51
		Clarification of CLRSTAT command, which also clears RSVD bits	28
		Description of Reserved Bits Added	30, 51
		Clarification: Watchdog timer is reset by Qualified Wake-up Signal	30
		Clarification: SPI master supports only SPI mode 3	31
		Correction to data register, Dn[3:0] changed to Dn[7:0]	32
		Discussion of Address, Broadcast and Polling Commands edited for Clarity	43-46

[illegible]

PART NUMBER	DESCRIPTION	COMMENTS
LTC6801	Independent Multicell Battery Stack Fault Monitor	Monitors Up to 12 Series-Connected Battery Cells for Undervoltage or Overvoltage. Companion to LTC6802 , LTC6803 and LTC6804
LTC6802	Precision Multicell Battery Stack Monitor	1st Generation: Superseded by the LTC6804 and LTC6803 for New Designs
LTC6803	Precision Multicell Battery Stack Monitor	2nd Generation: Functionally Enhanced and Pin Compatible to the LTC6802
LTC6820	Isolated Bidirectional Communications Interface for SPI	Provides an Isolated Interface for SPI Communication Up to 100 Meters, Using a Twisted Pair. Companion to the LTC6804
LTC3300	High Efficiency Bidirectional Multicell Battery Balancer	Bidirectional Synchronous Flyback Balancing of Up to 6 Li-Ion or LiFeP04 Cells in Series. Up to 10A Balancing Current (Set by External Components). Bidirectional Architecture Minimizes Balancing Time and Power Dissipation. Up to 92% Charge Transfer Efficiency. 48-Lead Exposed Pad QFN and LQFP Packages

Customer Specification

PART NO. 3051

Construction

		Diameters (In)
1) Component 1	1 X 1 HOOKUP	
a) Conductor	22 (7/30) AWG TC	0.030
b) Insulation	0.016" Wall, Nom. PVC	0.062+/- 0.002
(1) Print	ALPHA WIRE E163869-* RU AWM STYLES 1569 105C OR 1007 80C VW-1 300V 22 AWG ---- LXXXX CSA TR-64 90C FT1 ROHS {0} * = Factory Code <i>[Note: Product may have c(UL) or CSA markings depending upon plant of manufacture.]</i>	
(2) Color(s)	WHITE, BLACK, RED, GREEN, YELLOW, BLUE, BROWN ORANGE, SLATE, VIOLET, WHITE/BLACK, WHITE/RED WHITE/GREEN, WHITE/YELLOW, WHITE/BLUE WHITE/BROWN, WHITE/ORANGE, WHITE/SLATE WHITE/VIOLET, GREEN/YELLOW, YELLOW/GREEN, PINK	

Applicable Specifications

1) UL	AWM/STYLE 1007	80°C / 300 V _{RMS}
	AWM/STYLE 1569	105°C / 300 V _{RMS}
	VW-1	
2) CSA International	TR-64	90°C
	FT1	

Environmental

1) EU Directive 2011/65/EU(RoHS2):	
	All materials used in the manufacture of this part are in compliance with European Directive 2011/65/EU regarding the restriction of use of certain hazardous substances in electrical and electronic equipment. Consult Alpha Wire's web site for RoHS C of C.
2) REACH Regulation (EC 1907/2006):	
	This product does not contain Substances of Very High Concern (SVHC) listed on the European Union's REACH candidate list in excess of 0.1% mass of the item. For up-to-date information, please see Alpha's REACH SVHC Declaration.
3) California Proposition 65:	The outer surface materials used in the manufacture of this part meet the requirements of California Proposition 65.

Properties

Physical & Mechanical Properties	
1) Temperature Range	-40 to 105°C
2) Bend Radius	10X Cable Diameter
3) Pull Tension	5.5 Lbs, Maximum
Electrical Properties	
(For Engineering purposes only)	
1) Voltage Rating	300 V _{RMS}
2) Inductance	0.06 µH/ft, Nominal
3) Conductor DCR	16.2 /1000ft @20°C, Nominal

Other

Packaging	Flange x Traverse x Barrel (inches)
a) 5000 FT	12 x 4.5 x 3.5 Continuous length
b) 1000 FT	6.5 x 4 x 2.5 Continuous length
c) 100 FT	2.75 x 2 x 1.125 Continuous length
	<i>[Spool dimensions may vary slightly]</i>
Notes:	
a) Certain colors and put-up combinations may only be available by special order, minimums may apply.	

www.alphawire.com

Alpha Wire | 711 Lidgerwood Avenue, Elizabeth, NJ 07207
Tel: 1-800-52 ALPHA (25742)

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EU/China ROHS CERTIFICATE OF COMPLIANCE

To Whom It May Concern:

Alpha Wire Part Number: 3051

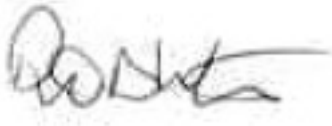
3051 , RoHS-Compliant Commencing With 1/1/2005 Production

This document certifies that the Alpha part number cited above are manufactured in accordance with Directive 2011/65/EU of the European Parliament, better known as the RoHS Directive, with regards to restrictions of the use of certain hazardous substances used in the manufacture of electrical and electronic equipment. The reader is referred to these Directives for the specific definitions and extents of these Directives. **No Exemptions are required for RoHS Compliance on this item.** Additionally, Alpha certifies that the listed part number is in compliance China RoHS "Marking for Control of Pollution by Electronic Information Products" standard SJ/T 11364-2006.

Substance	Maximum Control Value
Lead	0.1% by weight (1000 ppm)
Mercury	0.1% by weight (1000 ppm)
Cadmium	0.01% by weight (100 ppm)
Hexavalent Chromium	0.1% by weight (1000 ppm)
Polybrominated Biphenyls (PBB)	0.1% by weight (1000 ppm)
Polybrominated Diphenyl Ethers (PBDE) , Including Deca-BDE	0.1% by weight (1000 ppm)

The information provided in this document and disclosure is correct to the best of Alpha Wire's knowledge, information and belief at the date of its release. The information provided is designed only as a general guide for the safe handling, storage, and any other operation of the product itself or the one that it will become part of. The intent of this document is not to be considered a warranty or quality specification. Regulatory information is for guidance purposes only. Product users are responsible for determining the applicability of legislation and regulations based on their individual usage of the product.

Authorized Signatory for the Alpha Wire Company:



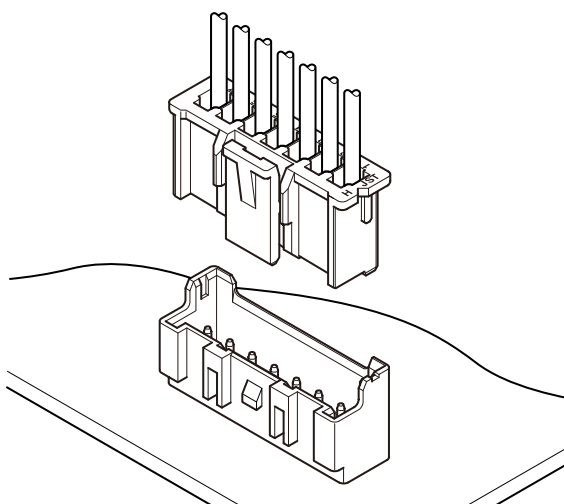
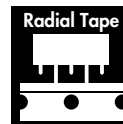
Dave Watson, Director of Engineering & QA

1/31/2013



XA CONNECTOR

2.5mm pitch/Disconnectable Crimp style connectors



- **Secure locking device**
- **Solder crack preventive material**
- **Low insertion force**
- **Insertion guide mechanism**
- **Applicable to automatic board mounting machine**
- **Polarizing boss**

Specifications

- Current rating: 3A AC DC (AWG #22, #20)
- Voltage rating: 250V AC DC
- Temperature range: -25°C to +85°C
(including temperature rise in applying electrical current)
- Contact resistance: Initial value/10m Ω max.
After environmental testing/20m Ω max.
- Insulation resistance: 1,000M Ω min.
- Withstanding voltage: 1,000V AC/minute
- Applicable wire: AWG #28 to #20
- Applicable PC board thickness: 1.6mm
- * Compliant with RoHS.
- * Refer to "General Instruction and Notice when using Terminals and Connectors" at the end of this catalog.
- * Contact JST for details.

Standards

Ⓜ Recognized E60389

Ⓢ Certified LR20812

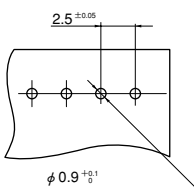
Ⓜ R9851220

PC board layout (viewed from component side) and Assembly layout

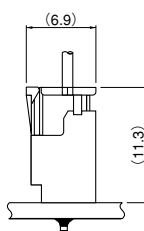
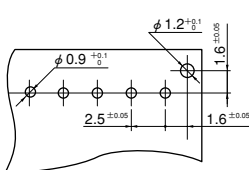
<Through-hole type>

Top entry type

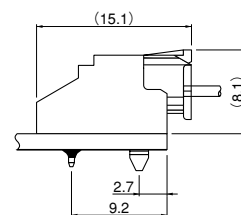
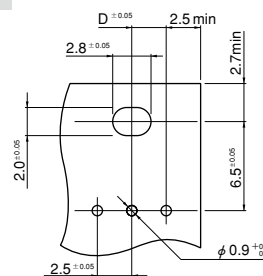
without a boss



with a boss



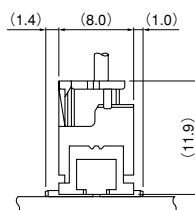
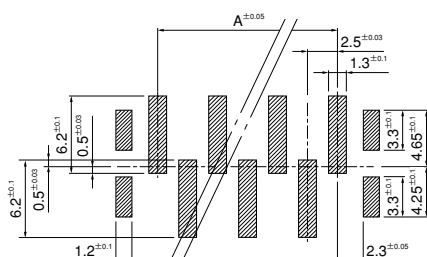
Side entry type



Dimension D: Refer to the Model No. chart of header side entry type.

<SMT type>

Top entry type

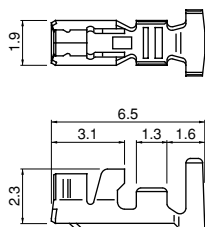


Note: 1. Tolerances are non-cumulative: ±0.05mm for all centers.

2. Hole dimensions differ according to the kind of PC board and piercing method. The dimensions above should serve as a guideline. Contact JST for details.

XA CONNECTOR

Contact



Model No.	Applicable wire			Q'ty / reel
	mm²	AWG#	Insulation O.D. (mm)	
SXA-001T-P0.6	0.08~0.33	28~22	0.8~1.9	8,000
SXA-01T-P0.6	0.22~0.5	24~20	1.5~1.9	8,000
SXA-001T-P0.6L	0.13~0.33	26~22	1.3~1.7	8,000

Material and Finish

Phosphor bronze, tin-plated (reflow treatment)

RoHS compliance

Note :1. SXA-001T-P0.6L is low-insertion force type contact, for easier insertion/withdrawal, which would be less resistant to the vibration. The crimp height is different from the standard contact.
2. Contact JST for gold-plated products.

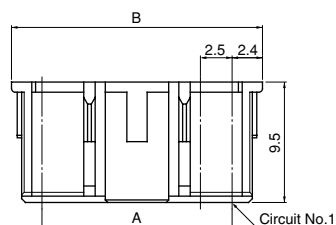
Contact	Crimping machine	Applicator			
		Crimp applicator	Dies	Crimp applicator with dies	
SXA-001T-P0.6	AP-K2N	MKS-L	MK/SXA/M-001-06	APLMK SXA/M001-06	
		*MKS-SC	SC/SXA/M-001-06	APLSC SXA/M001-06	
SXA-001T-P0.6L		MKS-L	MK/SXA-001-06L	APLMK SXA001-06L	
		*MKS-SC	SC/SXA-001-06L	APLSC SXA001-06L	

Contact	Crimping machine	Applicator		
		Crimp applicator	Dies	Crimp applicator with dies
SXA-01T-P0.6	AP-K2N	MKS-L	MK/SXA/M-01-06	APLMK SXA/M01-06
		*MKS-SC	SC/SXA/M-01-06	APLSC SXA/M01-06

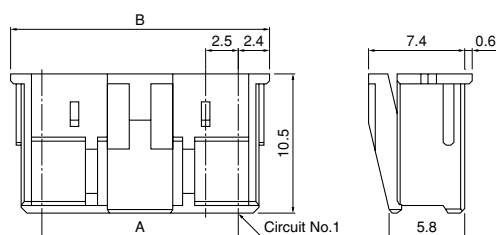
Note: *Strip-crimp applicator

Housing

Standard type



Retainer mountable type



Circuits	Model No.		Dimensions (mm)		Q'ty / bag	
	Standard type	Retainer mountable type	A	B	Standard type	Retainer mountable type
2	XAP-02V-1	XARP-02V	2.5	7.3	1,000	1,000
3	XAP-03V-1	XARP-03V	5.0	9.8	1,000	1,000
4	XAP-04V-1	XARP-04V	7.5	12.3	1,000	1,000
5	XAP-05V-1	XARP-05V	10.0	14.8	1,000	1,000
6	XAP-06V-1	XARP-06V	12.5	17.3	1,000	1,000
7	XAP-07V-1	XARP-07V	15.0	19.8	1,000	1,000
8	XAP-08V-1	XARP-08V	17.5	22.3	1,000	1,000
9	XAP-09V-1	XARP-09V	20.0	24.8	1,000	1,000
10	XAP-10V-1	XARP-10V	22.5	27.3	1,000	1,000
11	XAP-11V-1	XARP-11V	25.0	29.8	1,000	1,000
12	XAP-12V-1	XARP-12V	27.5	32.3	1,000	1,000
13	XAP-13V-1	XARP-13V	30.0	34.8	1,000	1,000
14	XAP-14V-1	XARP-14V	32.5	37.3	500	1,000
15	XAP-15V-1	XARP-15V	35.0	39.8	500	1,000
18	—	XARP-18V	42.5	47.3	—	500
20	XAP-20V-1	—	47.5	52.3	500	—

Material

PA 66, UL94V-0, natural (white)

RoHS compliance

<For reference> As the color identification, the following alphabet shall be put in the underlined part. For availability, delivery and minimum order quantity, contact JST.

<Standard type>

ex. **XAP-02V-1-oo**

(blank)...natural (white)

K...black R...red E...blue Y...yellow L...lemon yellow

M...green O...orange N...brown H...gray P...purple

LE...light blue PK...pink FY...vivid yellow Z...ivory

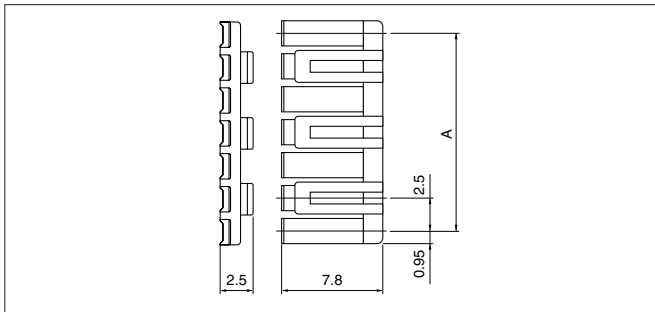
<Retainer mountable type>

ex. **XARP-02V-oo**

(blank)...natural (white)

K...black R...red E...blue L...lemon yellow

Retainer



Material

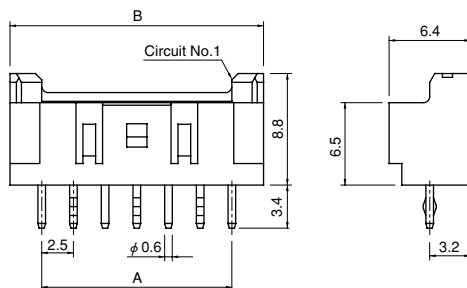
Glass-filled PA 66, UL94V-0, natural (ivory)

RoHS compliance

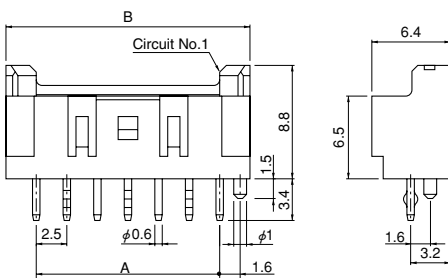
Circuits	Model No.	A	Q'ty / bag
2	XMS-02V	2.5	1,000
3	XMS-03V	5.0	1,000
4	XMS-04V	7.5	1,000
5	XMS-05V	10.0	1,000
6	XMS-06V	12.5	1,000
7	XMS-07V	15.0	1,000
8	XMS-08V	17.5	1,000
9	XMS-09V	20.0	1,000
10	XMS-10V	22.5	1,000
11	XMS-11V	25.0	1,000
12	XMS-12V	27.5	1,000
13	XMS-13V	30.0	1,000
14	XMS-14V	32.5	1,000
15	XMS-15V	35.0	1,000

Through-hole type shrouded header

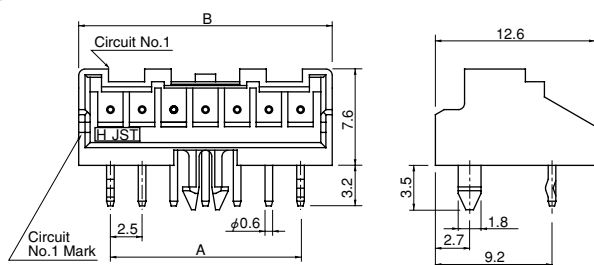
Top entry type without a boss



Top entry type with a boss



Side entry type with a hook



Circuits	Model No.		Dimensions (mm)		Q'ty / box
	Top entry type		A	B	
	Without a boss	With a boss			
2	B02B-XASK-1	B02B-XASK-1-A	2.5	7.5	1,000
3	B03B-XASK-1	B03B-XASK-1-A	5.0	10.0	400
4	B04B-XASK-1	B04B-XASK-1-A	7.5	12.5	400
5	B05B-XASK-1	B05B-XASK-1-A	10.0	15.0	400
6	B06B-XASK-1	B06B-XASK-1-A	12.5	17.5	400
7	B07B-XASK-1	B07B-XASK-1-A	15.0	20.0	250
8	B08B-XASK-1	B08B-XASK-1-A	17.5	22.5	250
9	B09B-XASK-1	B09B-XASK-1-A	20.0	25.0	250
10	B10B-XASK-1	B10B-XASK-1-A	22.5	27.5	250
11	B11B-XASK-1	B11B-XASK-1-A	25.0	30.0	200
12	B12B-XASK-1	B12B-XASK-1-A	27.5	32.5	200
13	B13B-XASK-1	B13B-XASK-1-A	30.0	35.0	100
14	B14B-XASK-1	B14B-XASK-1-A	32.5	37.5	100
15	B15B-XASK-1	B15B-XASK-1-A	35.0	40.0	100
20	B20B-XASK-1	B20B-XASK-1-A	47.5	52.5	100

Material and Finish

Pin: Copper alloy, copper-undercoated, tin-plated (reflow treatment)
Wafer: Glass-filled PA 66, UL94V-0, natural (ivory)

RoHS compliance This product displays (LF)(SN) on a label.

Note: Contact JST for gold-plated products.

Circuits	Model No.	Dimensions (mm)			Q'ty / box
	Side entry type with a hook	A	B	D	
2	S02B-XASS-1	2.5	7.5	1.25	250
3	S03B-XASK-1	5.0	10.0	2.50	250
4	S04B-XASK-1	7.5	12.5	3.75	200
5	S05B-XASK-1	10.0	15.0	5.00	200
6	S06B-XASK-1	12.5	17.5	6.25	200
7	S07B-XASK-1	15.0	20.0	7.50	200
8	S08B-XASK-1	17.5	22.5	8.75	100
9	S09B-XASK-1	20.0	25.0	10.00	100
10	S10B-XASK-1	22.5	27.5	11.25	100
11	S11B-XASK-1	25.0	30.0	12.50	100
12	S12B-XASK-1	27.5	32.5	13.75	100
13	S13B-XASK-1	30.0	35.0	15.00	100
14	S14B-XASK-1	32.5	37.5	16.25	100

Material and Finish

Pin: Copper alloy, copper-undercoated, tin-plated (reflow treatment)
Wafer: Glass-filled PA 66, UL94V-0, natural (ivory)

RoHS compliance This product displays (LF)(SN) on a label.

Note: 1. Dimension D...See PC board layout.

2. Contact JST for gold-plated products.

<For reference> As the color identification, the following alphabet shall be put in the underlined part.
For availability, delivery and minimum order quantity, contact JST.

ex. **S02B-XASK-1**

S...natural (ivory)

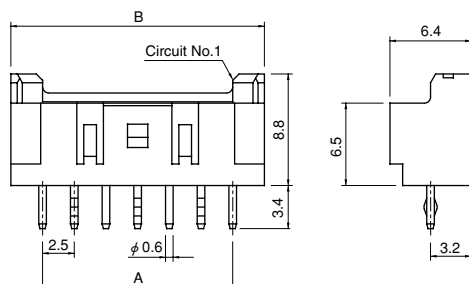
K...black R...red E...blue M...green Y...yellow

XA CONNECTOR

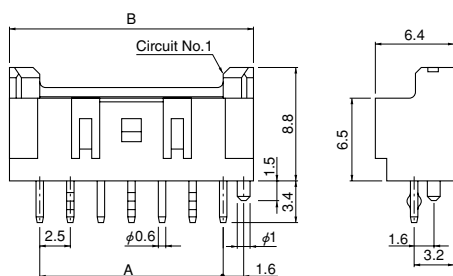
Through-hole type shrouded header

N type

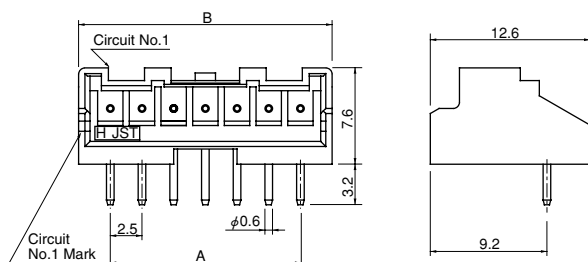
Top entry type without a boss



Top entry type with a boss



Side entry type without a hook



Circuits	Model No.		Dimensions (mm)		Q'ty / box
	Top entry type		A	B	
2	B02B-XASK-1N	B02B-XASK-1N-A	2.5	7.5	1,000
3	B03B-XASK-1N	B03B-XASK-1N-A	5.0	10.0	400
4	B04B-XASK-1N	B04B-XASK-1N-A	7.5	12.5	400
5	B05B-XASK-1N	B05B-XASK-1N-A	10.0	15.0	400
6	B06B-XASK-1N	B06B-XASK-1N-A	12.5	17.5	400
7	B07B-XASK-1N	B07B-XASK-1N-A	15.0	20.0	250
8	B08B-XASK-1N	B08B-XASK-1N-A	17.5	22.5	250
9	B09B-XASK-1N	B09B-XASK-1N-A	20.0	25.0	250
10	B10B-XASK-1N	B10B-XASK-1N-A	22.5	27.5	250
11	B11B-XASK-1N	B11B-XASK-1N-A	25.0	30.0	200
12	B12B-XASK-1N	B12B-XASK-1N-A	27.5	32.5	200
13	B13B-XASK-1N	B13B-XASK-1N-A	30.0	35.0	100
14	B14B-XASK-1N	B14B-XASK-1N-A	32.5	37.5	100
15	B15B-XASK-1N	B15B-XASK-1N-A	35.0	40.0	100
18	B18B-XASK-1N	—	42.5	47.5	100

Material and Finish

Pin: Copper alloy, copper-undercoated, tin-plated (reflow treatment)
Wafer: Glass-filled PA 66, UL94V-0, natural (white)

RoHS compliance This product displays (LF)(SN) on a label.
Note: Not TÜV approved.

<For reference> As the color identification,
the following alphabet shall be put in the underlined part.
For availability, delivery and minimum order quantity, contact JST.

ex. **B02B-XASK-1N-A**

S...natural (white)

K...black R...red E...blue Y...yellow L...lemon yellow

M...green O...orange N...brown H...gray P...purple

LE...light blue PK...pink FY...vivid yellow

Circuits	Model No.		Dimensions (mm)		Q'ty / box
	Side entry type without a hook		A	B	
2	S02B-XASS-1N-BN		2.5	7.5	250
3	S03B-XASS-1N-BN		5.0	10.0	250
4	S04B-XASS-1N-BN		7.5	12.5	200
5	S05B-XASS-1N-BN		10.0	15.0	200
6	S06B-XASS-1N-BN		12.5	17.5	200
7	S07B-XASS-1N-BN		15.0	20.0	200
8	S08B-XASS-1N-BN		17.5	22.5	100
9	S09B-XASS-1N-BN		20.0	25.0	100
10	S10B-XASS-1N-BN		22.5	27.5	100
11	S11B-XASS-1N-BN		25.0	30.0	100
12	S12B-XASS-1N-BN		27.5	32.5	100
13	S13B-XASS-1N-BN		30.0	35.0	100
14	S14B-XASS-1N-BN		32.5	37.5	100

Material and Finish

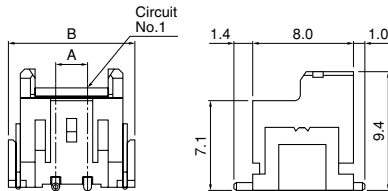
Pin: Copper alloy, copper-undercoated, tin-plated (reflow treatment)
Wafer: Glass-filled PA 66, UL94V-0, natural (white)

RoHS compliance This product displays (LF)(SN) on a label.

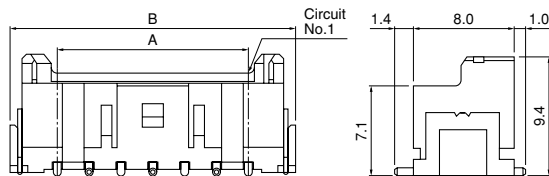
Note: 1. As for side entry type, we recommend to use a product with a boss (hook) because stress is applied directly to fillet part when handling the wire. When using the side entry type product without a boss (hook), please handle the wire with care.
2. Not TÜV approved.

SMT type shrouded header

(2 circuits)



(3 to 15 circuits)



Circuits	Model No.	Dimensions (mm)		Q'ty / reel
	Top entry type	A	B	
2	BM02B-XASS-TF	2.5	10.0	500
3	BM03B-XASS-TF	5.0	12.5	500
4	BM04B-XASS-TF	7.5	15.0	500
5	BM05B-XASS-TF	10.0	17.5	500
6	BM06B-XASS-TF	12.5	20.0	500
7	BM07B-XASS-TF	15.0	22.5	500
8	BM08B-XASS-TF	17.5	25.0	500
9	BM09B-XASS-TF	20.0	27.5	500
12	BM12B-XASS-TF	27.5	35.0	500
13	BM13B-XASS-TF	30.0	37.5	500
15	BM15B-XASS-TF	35.0	42.5	500

Material and Finish

Pin: Copper alloy, copper-undercoated, tin-plated (reflow treatment)
 Wafer: PA, UL94V-0, natural
 Solder tab: Brass, copper-undercoated, tin-plated (reflow treatment)

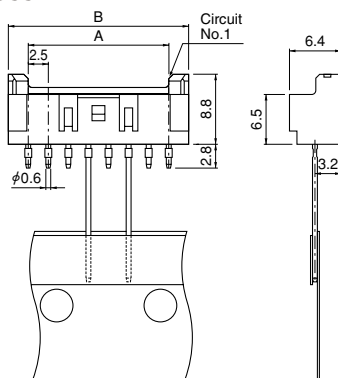
RoHS compliance This product displays (LF)(SN) on a label.

<For reference> As the color identification, the following alphabet shall be put in the underlined part.
 For availability, delivery and minimum order quantity, contact JST.

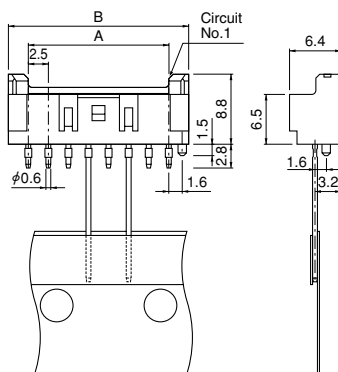
ex. **BM02B-XASS-TF**
 S...natural
 K...black R...red E...blue M...green D...orange
 L...lemon yellow

Through-hole type shrouded header on radial-tape

Top entry type without a boss



Top entry type with a boss



Circuits	Model No.		Dimensions (mm)		Q'ty / box
	Top entry type without a boss	Top entry type with a boss	A	B	
2	B02B-XASS-1-T	—	2.5	7.5	1,000
3	B03B-XASS-1-T	B03B-XASS-1-A-T	5.0	10.0	1,000
4	B04B-XASS-1-T	B04B-XASS-1-A-T	7.5	12.5	500
5	B05B-XASS-1-T	B05B-XASS-1-A-T	10.0	15.0	500
6	B06B-XASS-1-T	B06B-XASS-1-A-T	12.5	17.5	500
7	B07B-XASS-1-T	B07B-XASS-1-A-T	15.0	20.0	500
8	B08B-XASS-1-T	B08B-XASS-1-A-T	17.5	22.5	500

Material and Finish

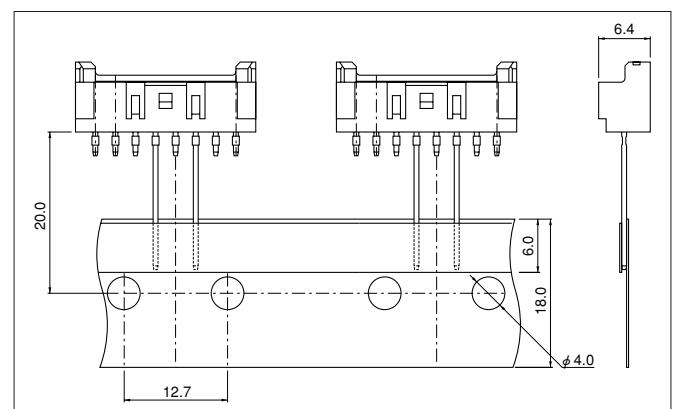
Pin: Copper alloy, copper-undercoated, tin-plated (reflow treatment)
 Wafer: Glass-filled PA 66, UL94V-0, natural (ivory)

RoHS compliance This product displays (LF)(SN) on a label.

<For reference> As the color identification, the following alphabet shall be put in the underlined part.
 For availability, delivery and minimum order quantity, contact JST.

ex. **B03B-XASS-1-A-T**
 S...natural (ivory)
 R...red E...blue M...green

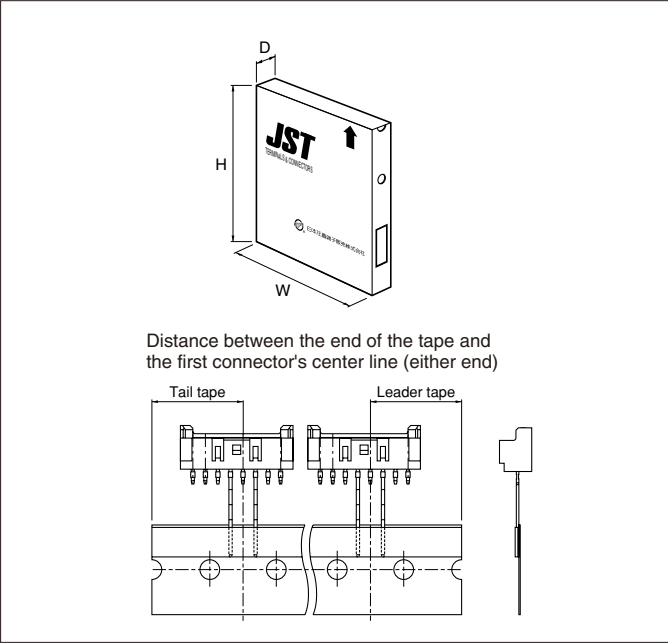
Taping specifications



Note: Conforms to JIC C 0806 of "Tape packaging of components with unidirectional leads on continuous tapes".

XA CONNECTOR

Packaging specifications



Package type		Flat pack (zigzag folded)
Distance between folds		24 indexing holes per fold (304.8mm)
Box size		316(W)×45(D)×330(H)mm
Distance between the end of the tape and the first connector's center line (either end)		19.05mm
Quantity	2, 3 circuits	1,000 pcs. / box
	4~8 circuits	500 pcs. / box

*Note: Products of different packaging specifications are also available.
Contact JST for details.*

Current Transducer HAIS 50..400-P and HAIS 50..100-TP

For the electronic measurement of currents : DC, AC, pulsed, mixed, with a galvanic isolation between the primary circuit (high power) and the secondary circuit (electronic circuit).



All Data are given with a $R_L = 10\text{ k}\Omega$

Electrical data

Primary nominal current rms I_{PN} (A)	Primary current, measuring range I_{PM} (A)	Type	RoHS since date code
50	± 150	HAIS 50-P, HAIS 50-TP ¹⁾	45231, 46272
100	± 300	HAIS 100-P, HAIS 100-TP ¹⁾	45231, 46012
150	± 450	HAIS 150-P	46172
200	± 600	HAIS 200-P	45231
400	± 600	HAIS 400-P	planned
V_{OUT}	Output voltage (Analog) @ I_P $I_P = 0$	$V_{REF} \pm (0.625 \cdot I_P / I_{PN})$ V $V_{REF} \pm 0.025$ V	
V_{REF}	Reference voltage ²⁾ - Output voltage	2.5 ± 0.025 V	
	V_{REF} Output impedance	typ. 200 Ω	
	V_{REF} Load impedance	≥ 200 k Ω	
R_L	Load resistance	≥ 2 k Ω	
R_{OUT}	Output internal resistance	< 10 Ω	
C_L	Capacitive loading	< 1 μ F	
V_C	Supply voltage ($\pm 5\%$)	5 V	
I_C	Current consumption @ $V_C = 5$ V	22 mA	

Accuracy - Dynamic performance data

X	Accuracy ³⁾ @ I_{PN} , $T_A = 25^\circ\text{C}$	$\leq \pm 1$	% of I_{PN}
e_L	Linearity error $0 \dots 3 \times I_{PN}$	$\leq \pm 0.5$	% of I_{PN}
TCV_{OE}	Temperature coefficient of V_{OE} @ $I_P = 0$	$\leq \pm 0.3$	mV/K
TCV_{REF}	Temperature coefficient of V_{REF}	$\leq \pm 0.01$	%/K
$TCV_{OUT/V_{REF}}$	Temperature coefficient of V_{OUT}/V_{REF} @ $I_P = 0$	$\leq \pm 0.2$	mV/K
TCV_{OUT}	Temperature coefficient of V_{OUT}	$\leq \pm 0.05\%$	of reading/K
V_{OM}	Magnetic offset voltage @ $I_P = 0$, after an overload of $3 \times I_{PN\text{ DC}}$	$< \pm 0.4$	% of I_{PN}
t_{ra}	Reaction time @ 10 % of I_{PN}	< 3	μ s
t_r	Response time to 90 % of I_{PN} step	< 5	μ s
di/dt	di/dt accurately followed	> 100	A/ μ s
V_{no}	Output voltage noise (DC .. 10 kHz)	< 15	mVpp
	(DC .. 1 MHz)	< 40	mVpp
BW	Frequency bandwidth (-3 dB) ⁴⁾	DC .. 50	kHz

Notes : ¹⁾ -TP version is equipped with a primary bus bar.

²⁾ It is possible to overdrive V_{REF} with an external reference voltage between 2 - 2.8 V providing its ability to sink or source approximately 2.5 mA.

³⁾ Excluding offset and hysteresis.

⁴⁾ Small signal only to avoid excessive heatings of the magnetic core.

$$I_{PN} = 50 \dots 400\text{ A}$$



Features

- Hall effect measuring principle
- Galvanic isolation between primary and secondary circuit
- Isolation test voltage 2500V
- Low power consumption
- Single power supply +5V
- Fixed offset & gain
- Bus bar version available for 50A and 100A ratings.
- Isolated plastic case recognized according to UL94-V0.

Advantages

- Small size and space saving
- Only one design for wide current ratings range
- High immunity to external interference.
- V_{REF} IN/OUT

Applications

- AC variable speed drives
- Static converters for DC motor drives
- Battery supplied applications
- Uninterruptible Power Supplies (UPS)
- Switched Mode Power Supplies (SMPS)
- Power supplies for welding applications.

Application domain

- Industrial

Current Transducer HAIS 50..400-P and HAIS 50..100-TP

General data

T_A	Ambient operating temperature	- 40 .. + 85 °C
T_S	Ambient storage temperature	- 40 .. + 85 °C
m	Mass (in brackets : TP version)	20 (30) g
	Standards	EN 50178: 1997

Isolation characteristics

V_b	Rated isolation voltage rms with IEC 61010-1 standards and following conditions - Single insulation - Over voltage category III - Pollution degree 2 - Heterogeneous field	300	V rms
V_b	Rated isolation voltage rms with EN 50178 standards and following conditions - Reinforced insulation - Over voltage category III - Pollution degree 2 - Heterogeneous field	600	V rms
V_d	Rms voltage for AC isolation test, 50 Hz, 1 min	2.5	kV
V_e	Partial discharge extinction voltage rms @ 10pC		
	HAIS 50..400-P	> 1	kV
	HAIS 50..100-TP	> 1.4	kV
$\hat{V}_w$	Impulse withstand voltage 1.2/50 μ s	8	kV
dCp	Creepage distance	> 8	mm
dCl	Clearance distance	> 8	mm
CTI	Comparative tracking index (Group I)	> 600	

If insulated cable is used for the primary circuit, the voltage category could be improved with the following table :

Cable insulation (primary)	Category
HAR 03	450V CAT III
HAR 05	550V CAT III
HAR 07	650V CAT III

Safety



This transducer must be used in electric/electronic equipment with respect to applicable standards and safety requirements in accordance with the following manufacturer's operating instructions.



Caution! Risk of electrical shock

When operating the transducer, certain parts of the module can carry hazardous voltage (eg. primary busbar, power supply).

Ignoring this warning can lead to injury and/or cause serious damage.

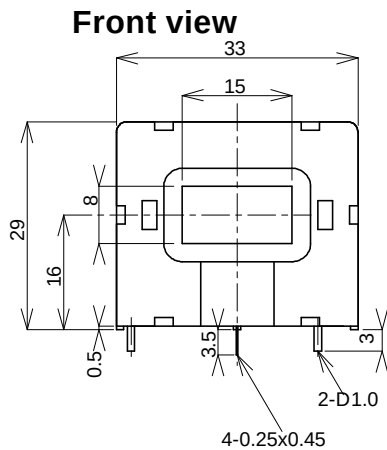
This transducer is a built-in device, whose conducting parts must be inaccessible after installation.

A protective housing or additional shield could be used.

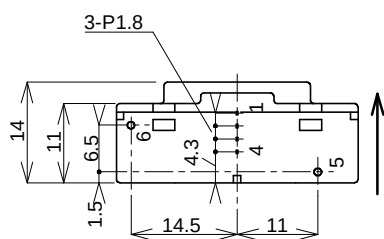
Main supply must be able to be disconnected.

Dimensions HAIS 50..400-P and HAIS 50..100-TP (in mm. 1 mm = 0.0394 inch)

HAIS 50..400-P



Bottom view



Terminal Pin Identification

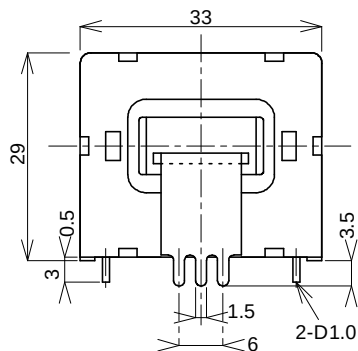
- 1...+5V
- 2...0V
- 3...OUTPUT
- 4...Vref. (IN/OUT)
- 5...Core Earth (*)
- 6...NC.

Recommended PCB hole

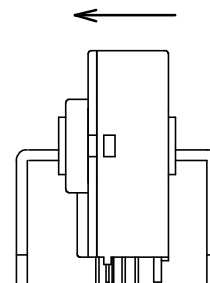
- Pin 1-4 : $0.7 \pm 0.1\text{mm}$
- Pin 5-6 : $1.5 \pm 0.1\text{mm}$
- Primary bus bar : $2.3 \pm 0.1\text{mm}$
- General tolerance : $\pm 0.2\text{mm}$
- Unit : mm

HAIS 50..100-TP

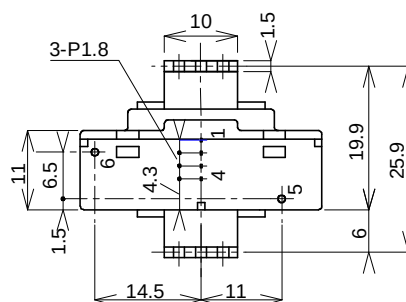
Front view



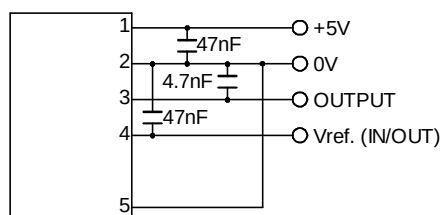
Right view



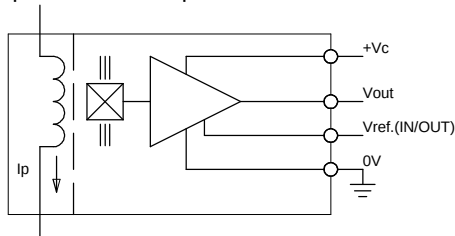
Bottom view



Required Connection Circuit



Operation Principle



(*) should be connected to 0V of Power Supply for better dv/dt immunity.
Arrow indicates positive current direction.

LTC6820

isoSPI 2-Wire Serial Interface

DESCRIPTION

Demonstration circuit 1941 is an isoSPI™ transceiver board, based on Linear Technology's LTC®6820. The LTC6820 provides a method of interconnecting standard serial peripheral interface (SPI) devices using a single twisted pair of wire up to 100 meters of distance, with full galvanic isolation. This proprietary 2-wire interface is called isoSPI and the LTC6820 encodes SPI signals, up to 1Mbps, into a differential isoSPI signal. The isoSPI signal can then be transmitted across a simple pulse transformer through a twisted pair, where an isoSPI receiver decodes the transmission and recreates SPI signals.

The SPI Bus is a synchronous serial data link that uses four single-ended signals to transmit information over short distances (typically on a single PCB). SPI devices communicate in master/slave mode, where the master device initiates the data frame and multiple slave devices are allowed. Typically, the LTC6820 will be used in one of two ways: See Figures 1 and 2.

Design files for this circuit board are available at <http://www.linear.com/demo>

LT, LT, LTC, LTM, Linear Technology and the Linear logo are registered and isoSPI and QuikEval are trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.

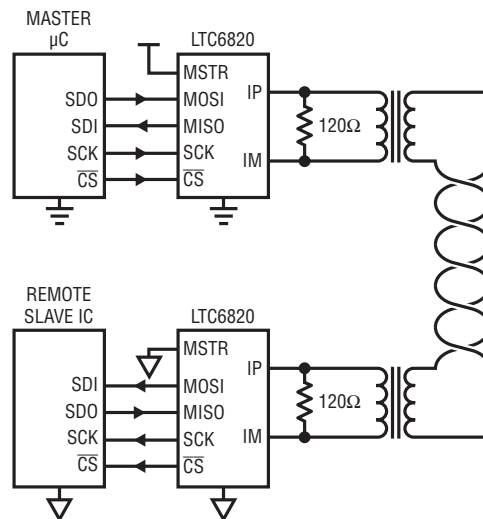


Figure 1. Connect an SPI Master Device to an SPI Slave Device

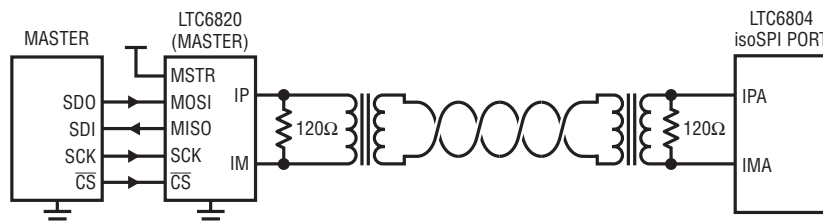


Figure 2. Connect an SPI Master (Typically a Microprocessor) to the Built-In isoSPI of an LTC6804

DEMO MANUAL DC1941B

CONNECTIONS

Each DC1941 contains an LTC6820, pulse transformer and support electronics to evaluate isoSPI. To communicate over the isoSPI bus, each SPI device requires one DC1941. Since the LTC6804 devices already have built-in isoSPI, a DC1941 is not required to connect to an LTC6804 (or LTC6804 demo board). The 2-wire interface is accessible using standard RJ45 connectors (J1 on the DC1941). This allows for isoSPI interconnection using simple CAT5 cable¹.

When the DC1941 is used to connect to an LTC6804, a special interface is available to connect to a PC, and an LTC6804 graphical user interface (GUI) is available to display this information. The connection between the DC1941 and the PC is made using Linear Technology's

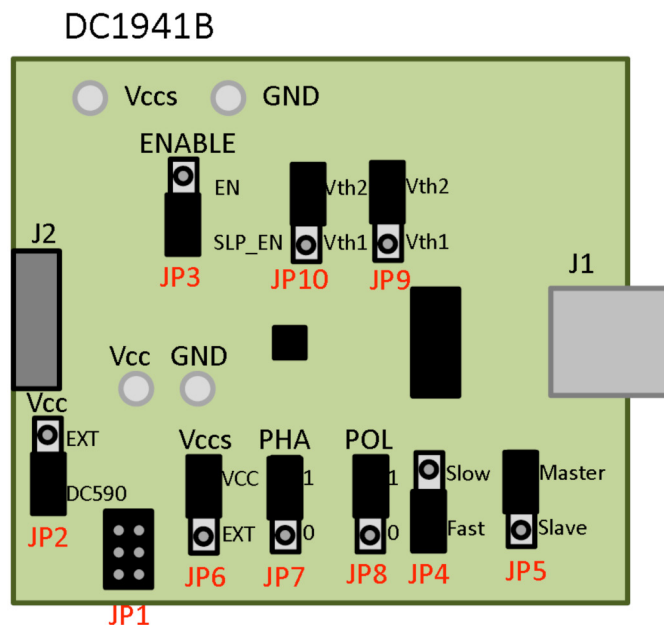
DC590B (USB serial controller). The DC590B is connected to the DC1941 through J2 (DC590B connector, a 14-pin ribbon connector). The DC590B can be used to power the DC1941, or power can be provided externally (see jumper settings).

There are several options for connecting SPI devices to the DC1941. The J2 connector and JP1 (SPI connector, a 6-pin header) both provide access to the SPI connections. Power can be supplied via J2, JP1 or the turrets on the board.

Note 1: A single twisted pair inside the CAT5 is used for the isoSPI interconnection.

JUMPERS

Jumper settings are provided on the DC1941 to configure the SPI mode, speed and master/slave operation. Jumpers are also provided to configure the isoSPI shutdown and output power level, as well as power supply options.



JUMPERS

JP2 – VCC to EXT/DC590:

EXT: Set to EXT if the DC1941 is powered from an external supply. External power can be provided through J2, JP1 or the turrets on the board.

DC590B (DEFAULT): Set to DC590 if the DC1941 is powered through the 14-pin ribbon cable (J2 on the DC1941). The DC590B connects to the DC1941 through this 14-pin ribbon cable.

JP3 – EN/SLP_EN:

EN: Set to have the LTC6820 always enabled.

SLP_EN (DEFAULT): When selected, the LTC6820 will enter shutdown after 4ms of inactivity and will require a wake up pulse.

JP4 – SLOW/FAST:

SLOW: Set for SPI clock frequencies of 100kHz or less.

FAST (DEFAULT): Set for SPI clock frequencies greater than 100kHz.

JP5 – MASTER/SLAVE:

MASTER(DEFAULT): Configures the SPI for master mode; the LTC6820 will operate as the isoSPI master. When this jumper is set to 'master', the J2 connector should be connected to a SPI master.

SLAVE: Configures the SPI for slave mode; the LTC6820 will operate as an isoSPI slave. The DC1941 should be connected to a SPI slave device.

JP6 – VCCS to VCC/EXT:

VCC (DEFAULT): Sets the LTC6820 SPI input/output supply voltage (V_{CCS}) to V_{CC} , which sets the SPI logic levels to V_{CC} .

EXT: Allows the SPI input/output supply (V_{CCS}) to be connected to a separate voltage from V_{CC} , which allows the logic levels to be set to a different voltage. An external supply can be connected on the turret labeled V_{CCS} .

JP7,8 – PHA/POL:

These jumpers set the SPI mode per the following table.

Table 1

MODE	POL	PHA
0	0	0
1	0	1
2	1	0
3 (Default)	1	1

Set to mode 3 for use with LTC6804.

JP9,10 – VTH1/VTH2:

VTH1: Sets the LTC6820 output drive to 1V, and the receiver input threshold to 500mV.

VTH2 (DEFAULT): Sets the LTC6820 output drive to 1.2V, and the receiver input threshold to 600mV. The VTH2 settings are compatible with LTC6804 demo boards.

LTC6820 TO LTC6804 SETUP

1. Connect a USB port to DC590.
2. Connect DC590 14-pin connector to DC1941 14-pin connector (J2) with 14-wire ribbon.
3. Connect LTC6820 J1 to LTC6804 PORT A or isoSPI IN using an ethernet patch cable.
4. Check jumpers on both boards and set if necessary.
5. Run LTC6804 software as normal.

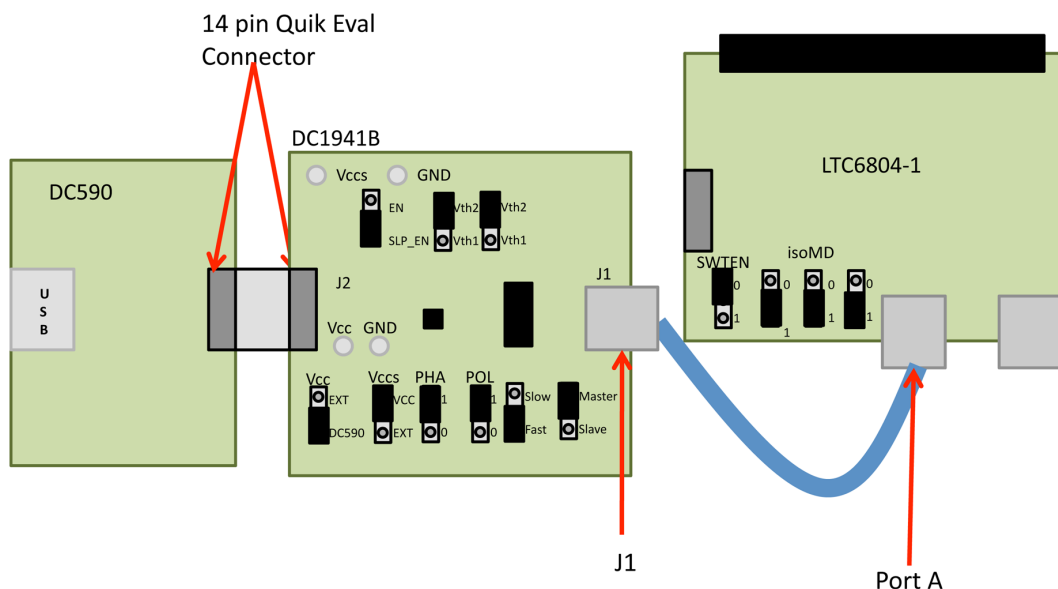


Figure 3. Hardware and Jumper Settings to Connect to LTC6804-1

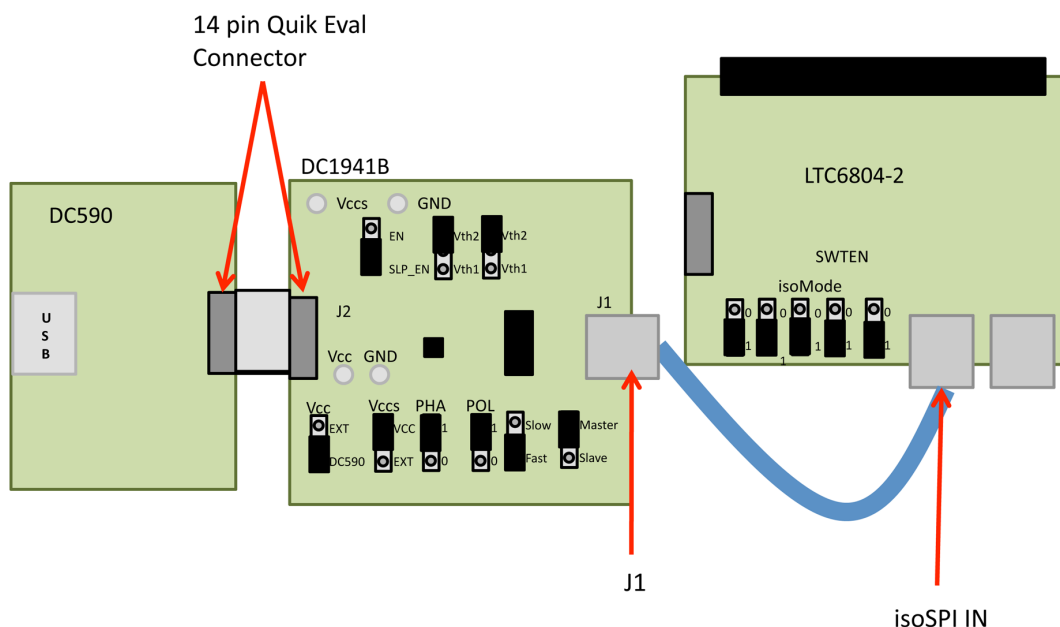


Figure 4. Hardware and Jumper Settings to Connect to LTC6804-2

LTC6820 TO LTC6804 SETUP

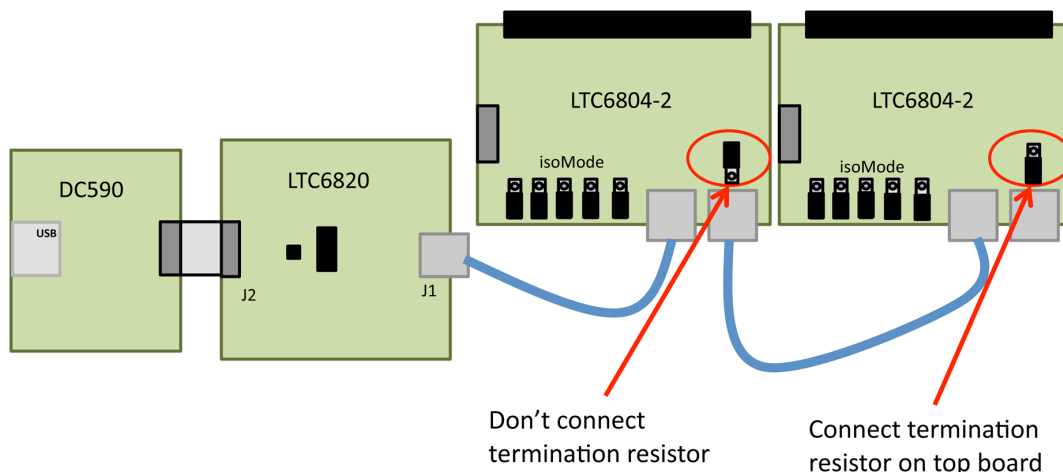


Figure 5. LTC6804-2 Multidrop Example

LTC6820 TO LTC6820 SETUP

1. Connect a USB port to DC590.
2. Connect DC590 14-pin connector to the Master DC1941 14-pin connector (J2) with 14-wire ribbon cable.
3. Connect the Master DC1941 J1 (board A) to the slave DC1941 (board B) J1 connector using an ethernet patch cable.
4. Check Jumpers on both boards and set if necessary (Figure 6).
5. Connect compatible QuikEval board to the slave DC1941 J2 connector.
6. Connect appropriate power supply for both boards.
7. Run DC1941 programmer to set target QuikEval board.
8. Run standard QuikEval software.

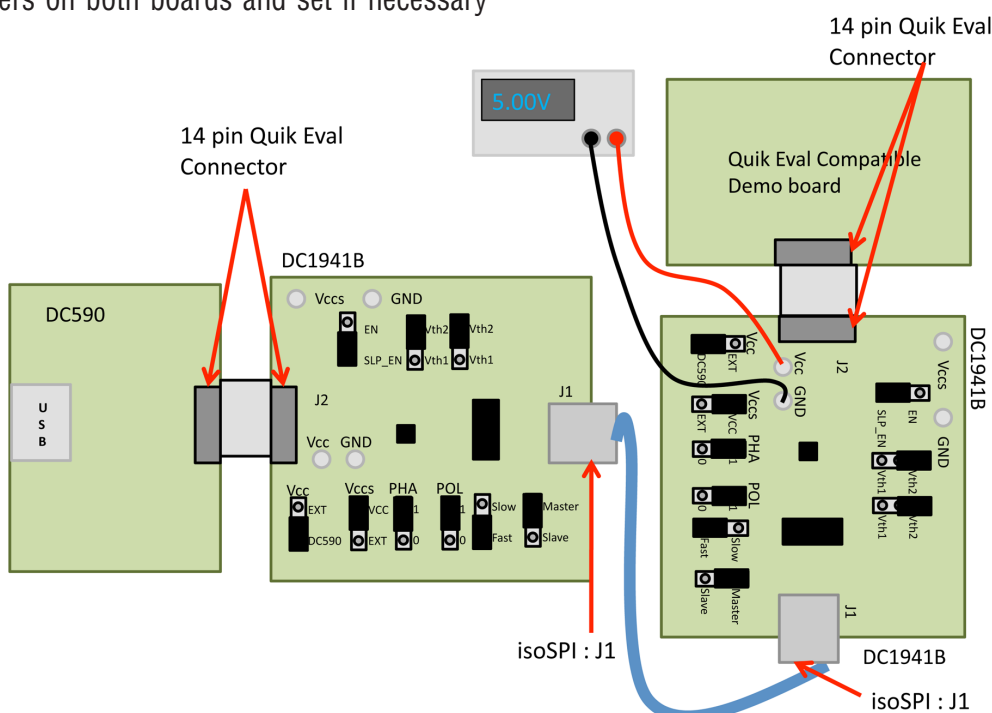


Figure 6. Hardware and Jumper Settings to Connect Two DC1941s and Add isoSPI Capability to a Standard SPI Slave

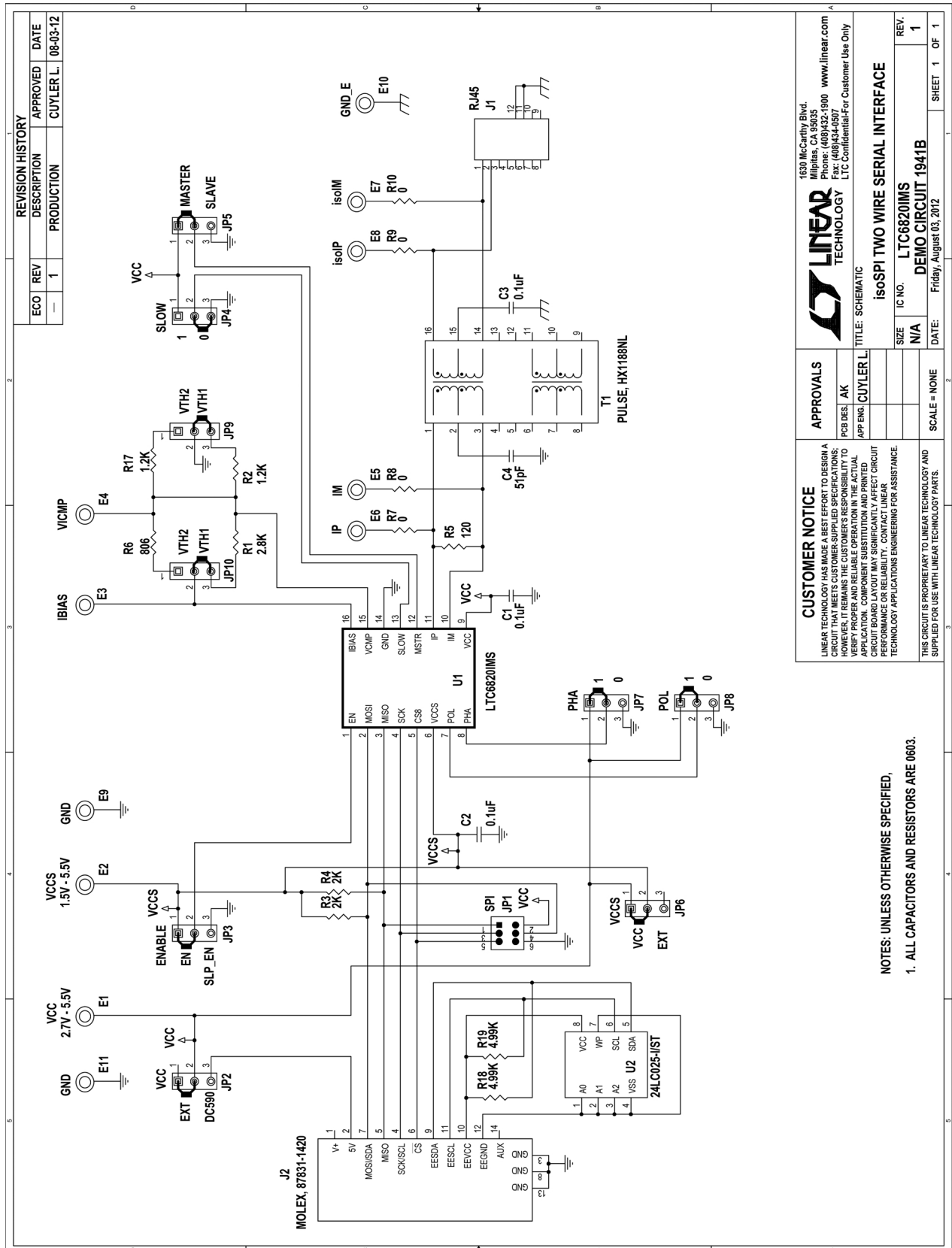
dc1941bf

DEMO MANUAL DC1941B

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
1	2	C1, C2	CAP.,X7R, 0.1μF, 16V, 10%, 0603	AVX, 0603YC104KAT2A
2	0	C3	CAP, 0603 OPT	
3	1	C4	CAP.,NPO, 51pF, 50V, 5%, 0603	AVX, 06035A510JAT
4	11	E1-E11	TESTPOINT, TURRET, 0.063"	MILL-MAX, 2308-2-00-80-00-00-07-0
5	1	JP1	HEADER, 2X3PIN, 0.100"	SAMTEC, TSW-103-07-D
6	9	JP2-JP10	HEADER, 1X3 , 0.079" SINGLE ROW	SULLINS, NRPN031PAEN-RC
7	9	XJP2-XJP10	SHUNT, 0.079" CENTER	SAMTEC, 2SN-BK-G
8	1	J1	CONNECTOR RJ45, CACE CODE 00779	TYCO, 5406298-1
9	1	J2	HEADER, 2X7PIN, 0.079CC	MOLEX, 87831-1420
10	1	R1	RESISTOR, 2.8k, 1% 0603	VISHAY, CRCW06032K80FKEA
11	2	R2, R17	RESISTOR, 1.2k, 1% 0603	VISHAY, CRCW06031K20FKEA
12	2	R3, R4	RESISTOR, 2k 1% 0603	NIC, NRC06F2001TRF
13	1	R5	RESISTOR, 120Ω 1% 0603	VISHAY,CRCW0603120RFKEA
14	1	R6	RESISTOR, 806Ω 1% 0603	VISHAY, CRCW0603806RFKEA
15	4	R7, R8, R9, R10	RESISTOR, 0Ω 1% 0603	VISHAY, CRCW06030000Z0EA
16	2	R18, R19	RESISTOR, 4.99k 1% 0603	NIC, NRC06F4991TRF
17	1	T1	XFMR 10/100BASE-T SINGLE PORT SMT	PULSE, HX1188NLT
18	1	U1	I.C. LTC6820IMS, MS16	LINEAR TECH., LTC6820IMS
19	1	U2	I.C. 24LC025-I/ST	MICROCHIP 24LC025-I/ST
20	1		CABLE, 1FT PATCH CAT5	ASSMANN ELECTRONICS INC., DK-1611-001/BL
21	4	MH1, MH2, MH3, MH4	STANDOFF, SNAP ON	KEYSTONE_8831T

SCHEMATIC DIAGRAM



dc1941bf

DEMO MANUAL DC1941B

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FDS6375

P-Channel 2.5V Specified PowerTrench[®] MOSFET

General Description

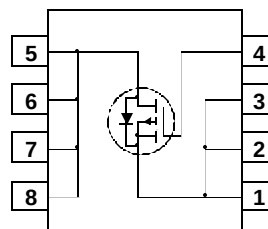
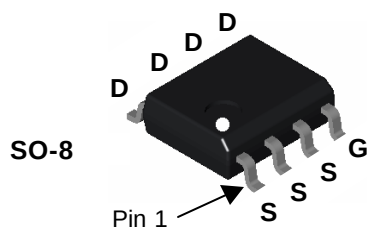
This PChannel 2.5V specified MOSFET is a rugged gate version of Fairchild Semiconductor's advanced PowerTrench process. It has been optimized for power management applications with a wide range of gate drive voltage (2.5V – 8V).

Applications

- Power management
- Load switch
- Battery protection

Features

- –8 A, –20 V. $R_{DS(ON)} = 24\text{ m}\Omega$ @ $V_{GS} = -4.5\text{ V}$
 $R_{DS(ON)} = 32\text{ m}\Omega$ @ $V_{GS} = -2.5\text{ V}$
- Low gate charge (26 nC typical)
- High performance trench technology for extremely low $R_{DS(ON)}$
- High current and power handling capability



Absolute Maximum Ratings $T_A = 25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	Ratings	Units
V_{DSS}	Drain-Source Voltage	–20	V
V_{GSS}	Gate-Source Voltage	± 8	V
I_D	Drain Current – Continuous (Note 1a) – Pulsed	–8	A
		–50	
P_D	Power Dissipation for Single Operation (Note 1a) (Note 1b) (Note 1c)	2.5	W
		1.2	
		1.0	
T_J, T_{STG}	Operating and Storage Junction Temperature Range	–55 to +175	$^\circ\text{C}$

Thermal Characteristics

$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (Note 1a)	50	$^\circ\text{C/W}$
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (Note 1c)	125	$^\circ\text{C/W}$
$R_{\theta JC}$	Thermal Resistance, Junction-to-Case (Note 1)	25	$^\circ\text{C/W}$

Package Marking and Ordering Information

Device Marking	Device	Reel Size	Tape width	Quantity
FDS6375	FDS6375	13"	12mm	2500 units

Electrical Characteristics $T_A = 25^\circ\text{C}$ unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
--------	-----------	-----------------	-----	-----	-----	-------

Off Characteristics

BV_{DSS}	Drain–Source Breakdown Voltage	$V_{GS} = 0\text{ V}, I_D = -250\text{ }\mu\text{A}$	-20			V
$\frac{\Delta BV_{DSS}}{\Delta T_J}$	Breakdown Voltage Temperature Coefficient	$I_D = -250\text{ }\mu\text{A}$, Referenced to 25°C		-13		mV/ $^\circ\text{C}$
I_{DSS}	Zero Gate Voltage Drain Current	$V_{DS} = -16\text{ V}, V_{GS} = 0\text{ V}$			-1	μA
I_{GSSF}	Gate–Body Leakage, Forward	$V_{GS} = 8\text{ V}, V_{DS} = 0\text{ V}$			100	nA
I_{GSSR}	Gate–Body Leakage, Reverse	$V_{GS} = -8\text{ V}, V_{DS} = 0\text{ V}$			-100	nA

On Characteristics (Note 2)

$V_{GS(th)}$	Gate Threshold Voltage	$V_{DS} = V_{GS}, I_D = -250\text{ }\mu\text{A}$	-0.4	-0.7	-1.5	V
$\frac{\Delta V_{GS(th)}}{\Delta T_J}$	Gate Threshold Voltage Temperature Coefficient	$I_D = -250\text{ }\mu\text{A}$, Referenced to 25°C		3		mV/ $^\circ\text{C}$
$R_{DS(on)}$	Static Drain–Source On–Resistance	$V_{GS} = -4.5\text{ V}, I_D = -8\text{ A}$ $V_{GS} = -2.5\text{ V}, I_D = -7\text{ A}$ $V_{GS} = -4.5\text{ V}, I_D = -8\text{ A}, T_J = 125^\circ\text{C}$		14 19 18	24 32 39	m Ω
$I_{D(on)}$	On–State Drain Current	$V_{GS} = -4.5\text{ V}, V_{DS} = -5\text{ V}$	-50			A
g_{FS}	Forward Transconductance	$V_{DS} = -5\text{ V}, I_D = -8\text{ A}$		35		S

Dynamic Characteristics

C_{iss}	Input Capacitance	$V_{DS} = -10\text{ V}, V_{GS} = 0\text{ V},$ $f = 1.0\text{ MHz}$		2694		pF
C_{oss}	Output Capacitance			480		pF
C_{rss}	Reverse Transfer Capacitance			229		pF

Switching Characteristics (Note 2)

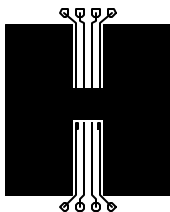
$t_{d(on)}$	Turn–On Delay Time	$V_{DD} = -10\text{ V}, I_D = -1\text{ A},$ $V_{GS} = -4.5\text{ V}, R_{GEN} = 6\text{ }\Omega$		12	22	ns
t_r	Turn–On Rise Time			9	17	ns
$t_{d(off)}$	Turn–Off Delay Time			124	197	ns
t_f	Turn–Off Fall Time			57	92	ns
Q_g	Total Gate Charge	$V_{DS} = -10\text{ V}, I_D = -8\text{ A},$ $V_{GS} = -4.5\text{ V}$		26	36	nC
Q_{gs}	Gate–Source Charge			5		nC
Q_{gd}	Gate–Drain Charge			6		nC

Drain–Source Diode Characteristics and Maximum Ratings

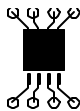
I_S	Maximum Continuous Drain–Source Diode Forward Current			-2.1		A
V_{SD}	Drain–Source Diode Forward Voltage	$V_{GS} = 0\text{ V}, I_S = -2.1\text{ A}$ (Note 2)		-0.7	-1.2	V

Notes:

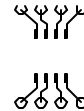
1. $R_{\theta JA}$ is the sum of the junction-to-case and case-to-ambient thermal resistance where the case thermal reference is defined as the solder mounting surface of the drain pins. $R_{\theta JC}$ is guaranteed by design while $R_{\theta CA}$ is determined by the user's board design.



a) 50 $^\circ\text{C/W}$ when mounted on a 1in² pad of 2 oz copper



b) 105 $^\circ\text{C/W}$ when mounted on a .04 in² pad of 2 oz copper



c) 125 $^\circ\text{C/W}$ when mounted on a minimum pad.

Scale 1 : 1 on letter size paper

2. Pulse Test: Pulse Width < 300 μs , Duty Cycle < 2.0%

Typical Characteristics

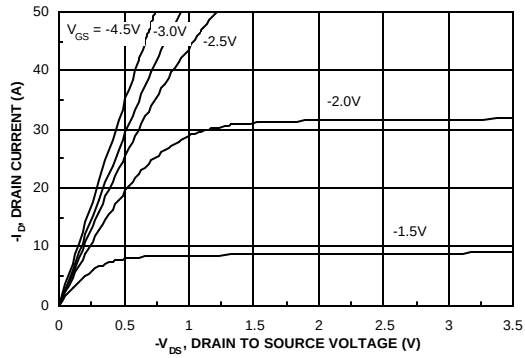


Figure 1. On-Region Characteristics.

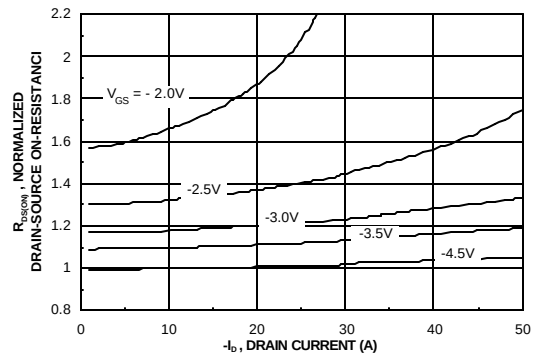


Figure 2. On-Resistance Variation with Drain Current and Gate Voltage.

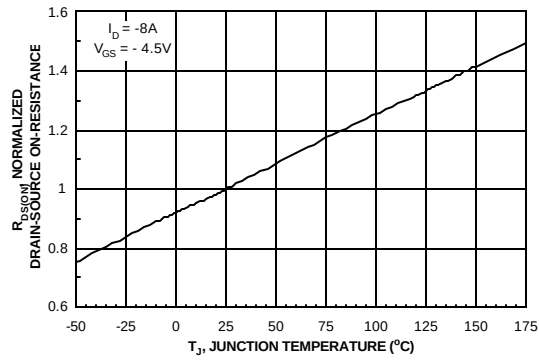


Figure 3. On-Resistance Variation with Temperature.

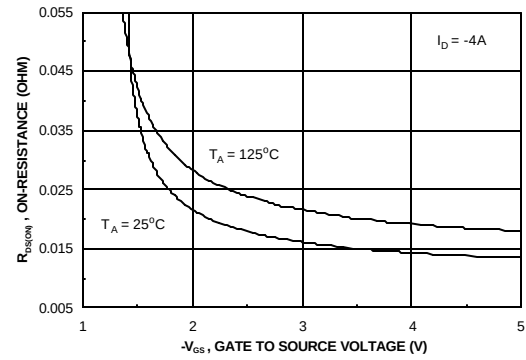


Figure 4. On-Resistance Variation with Gate-to-Source Voltage.

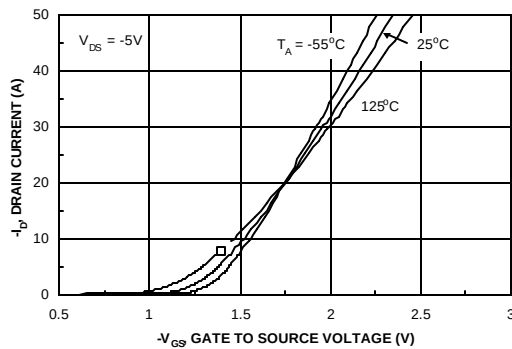


Figure 5. Transfer Characteristics.

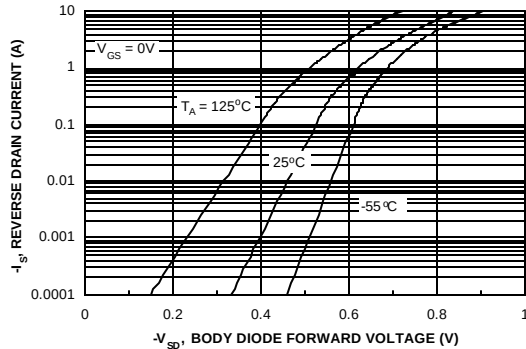


Figure 6. Body Diode Forward Voltage Variation with Source Current and Temperature.

Typical Characteristics

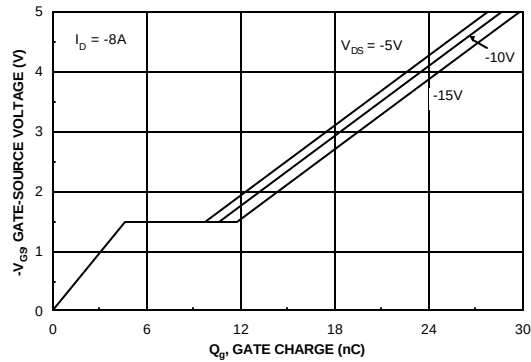


Figure 7. Gate Charge Characteristics.

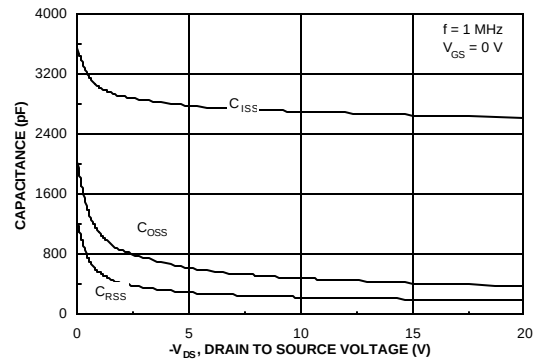


Figure 8. Capacitance Characteristics.

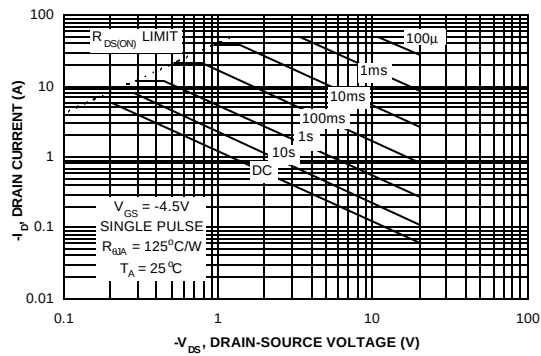


Figure 9. Maximum Safe Operating Area.

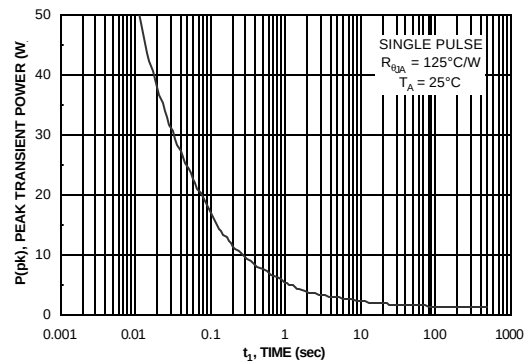


Figure 10. Single Pulse Maximum Power Dissipation.

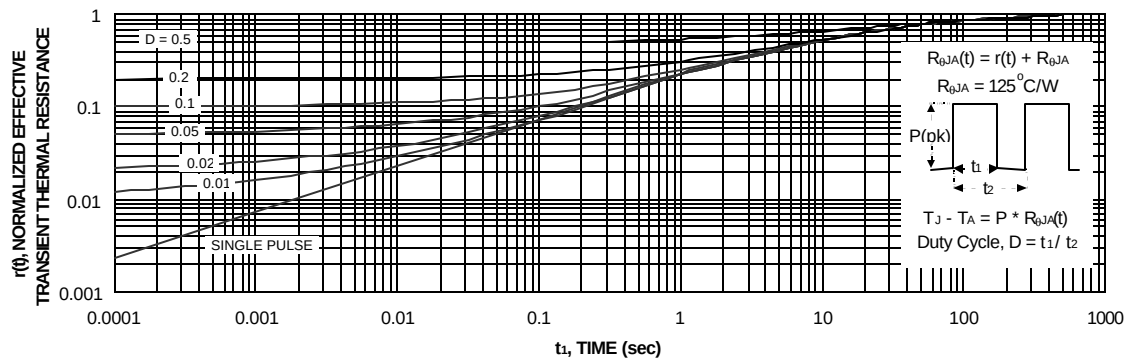


Figure 11. Transient Thermal Response Curve.

Thermal characterization performed using the conditions described in Note 1c.
Transient thermal response will change depending on the circuit board design.

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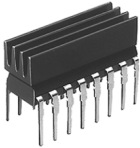
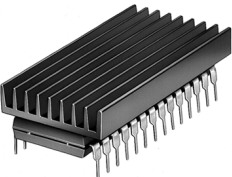
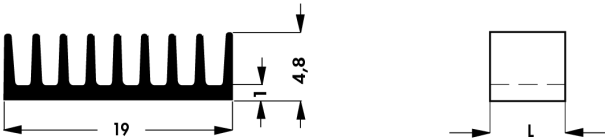
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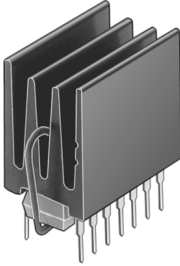
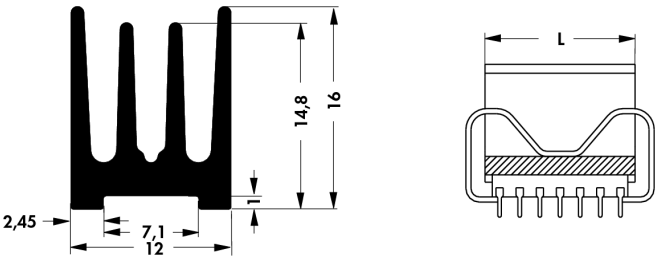
For additional information, please contact your local
Sales Representative

Heatsinks for DIL-IC

			
art. no.	R_{th} [K/W]	for housings	dim. [mm] L
ICK 14 16 L	46	14/16 contacts	19.0
ICK 20 L	34	20 contacts	25.0
ICK 6 8 L	83	6/8 contacts	8.5
			
art. no.	R_{th} [K/W]	for housings	dim. [mm] L
ICK 14 16 B	50.0	14/16 contacts	6.3
ICK 24 B	13.0	24 contacts	33.0
ICK 28 B	11.5	28 contacts	37.0
ICK 36 B	9.5	36 contacts	47.0
ICK 40 B	8.5	40 contacts	51.0
ICK 1000 B	—	—	1000.0

other length on request
surface: black anodised

with clip

			
art. no.	R_{th} [K/W]	for housings	dim. [mm] L
ICK 14 H	20	14 contacts	18.0
ICK 16 H	18	16 contacts	20.5
ICK 18 H	16	18 contacts	23.0
ICK 1000 H	—	—	1000.0

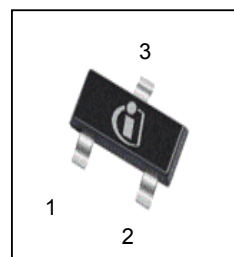
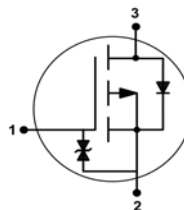
other length on request
surface: black anodised

OptiMOS™ P3 Small-Signal-Transistor
Features

- P-channel
- Enhancement mode
- Logic level (4.5V rated)
- ESD protected
- Qualified according to AEC Q101
- 100% lead-free; RoHS compliant
- Halogen-free according to IEC61249-2-21


Product Summary

V_{DS}		-30	V
$R_{DS(on),max}$	$V_{GS}=-10\text{ V}$	80	$m\Omega$
	$V_{GS}=-4.5\text{ V}$	130	
I_D		-2.0	A

PG-SOT-23


Type	Package	Tape and Reel Information	Marking	Lead Free	Packing
BSS308PE	PG-SOT23	H6327: 3000 pcs/ reel	YFs	Yes	Non dry

Maximum ratings, at $T_j=25\text{ °C}$, unless otherwise specified

Parameter	Symbol	Conditions	Value	Unit
Continuous drain current	I_D	$T_A=25\text{ °C}$	-2.0	A
		$T_A=70\text{ °C}$	-1.6	
		$T_A=25\text{ °C}$	-8.0	
Pulsed drain current	$I_{D,pulse}$	$T_A=25\text{ °C}$	-8.0	
Avalanche energy, single pulse	E_{AS}	$I_D=-2\text{ A}$, $R_{GS}=25\text{ }\Omega$	-10.7	mJ
Reverse diode dv/dt	dv/dt	$I_D=-2\text{ A}$, $V_{DS}=-16\text{ V}$, $di/dt=-200\text{ A}/\mu\text{s}$, $T_{j,max}=150\text{ °C}$	6	kV/ μs
Gate source voltage	V_{GS}		± 20	V
Power dissipation ¹⁾	P_{tot}	$T_A=25\text{ °C}$	0.5	W
Operating and storage temperature	T_j , T_{stg}		-55 ... 150	°C
ESD Class		JESD22-A114 -HBM	2 (2kV to 4kV)	
Soldering Temperature			260 °C	°C
IEC climatic category; DIN IEC 68-1			55/150/56	°C

Parameter	Symbol	Conditions	Values			Unit
			min.	typ.	max.	

Thermal characteristics

Thermal resistance, junction - ambient	R_{thJA}	minimal footprint ¹⁾	-	-	250	K/W
--	------------	---------------------------------	---	---	-----	-----

Electrical characteristics, at $T_j=25\text{ °C}$, unless otherwise specified

Static characteristics

Drain-source breakdown voltage	$V_{(BR)DSS}$	$V_{GS}=0V, I_D=-250\mu A$	-30	-	-	V
Gate threshold voltage	$V_{GS(th)}$	$V_{DS}=V_{GS}, I_D=-11\mu A$	-2.0	-1.5	-1.0	
Drain-source leakage current	I_{DSS}	$V_{DS}=-30V, V_{GS}=0V, T_j=25\text{ °C}$	-	-	-1	μA
		$V_{DS}=-30V, V_{GS}=0V, T_j=150\text{ °C}$	-	-	-100	
Gate-source leakage current	I_{GSS}	$V_{GS}=-20V, V_{DS}=0V$	-	-	-5	μA
Drain-source on-state resistance	$R_{DS(on)}$	$V_{GS}=-4.5V, I_D=-1.7A$	-	88	130	m Ω
		$V_{GS}=-10V, I_D=-2A$	-	62	80	
Transconductance	g_{fs}	$ V_{DS} >2 I_D R_{DS(on)max}, I_D=-1.6A$		4.6	-	S

¹⁾ Performed on 40mm² FR4 PCB. The traces are 1mm wide, 70 μ m thick and 20mm long; they are present on both sides of the PCB.

Parameter	Symbol	Conditions	Values			Unit
			min.	typ.	max.	

Dynamic characteristics

Input capacitance	C_{iss}	$V_{GS}=0\text{ V}, V_{DS}=-15\text{ V},$ $f=1\text{ MHz}$	-	376	500	pF
Output capacitance	C_{oss}		-	196	261	
Reverse transfer capacitance	C_{rss}		-	12	18	
Turn-on delay time	$t_{d(on)}$	$V_{DD}=-15\text{ V},$ $V_{GS}=-10\text{ V},$ $I_D=-2\text{ A}, R_G=6\ \Omega$	-	5.6	-	ns
Rise time	t_r		-	7.7	-	
Turn-off delay time	$t_{d(off)}$		-	15.3	-	
Fall time	t_f		-	2.8	-	

Gate Charge Characteristics

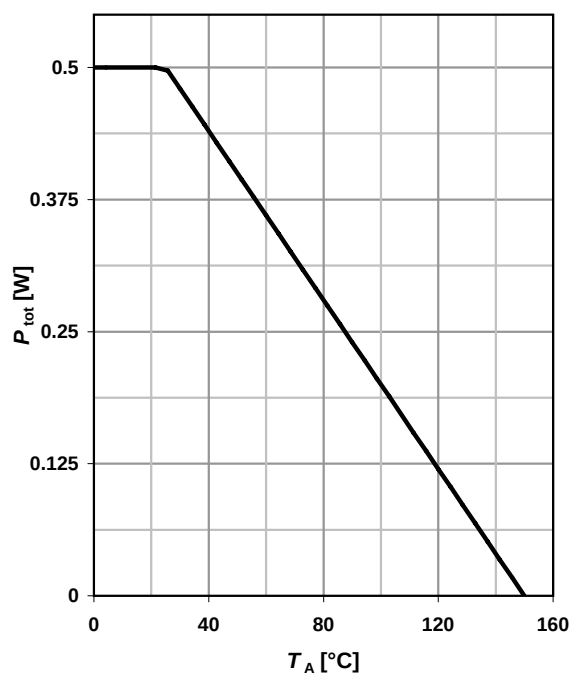
Gate to source charge	Q_{gs}	$V_{DD}=-15\text{ V}, I_D=-2\text{ A},$ $V_{GS}=0\text{ to }-10\text{ V}$	-	-1.2	-	nC
Gate to drain charge	Q_{gd}		-	-0.6	-	
Gate charge total	Q_g		-	-5.0	-	
Gate plateau voltage	$V_{plateau}$		-	-3.1	-	V

Reverse Diode

Diode continuous forward current	I_S	$T_A=25\text{ °C}$	-	-	-0.4	A
Diode pulse current	$I_{S,pulse}$		-	-	-8.4	
Diode forward voltage	V_{SD}	$V_{GS}=0\text{ V}, I_F=-2\text{ A},$ $T_j=25\text{ °C}$	-	-0.8	-1.1	V
Reverse recovery time	t_{rr}	$V_R=10\text{ V}, I_F=-2\text{ A},$ $di_F/dt=100\text{ A}/\mu\text{s}$	-	14	-	ns
Reverse recovery charge	Q_{rr}		-	-5.9	-	nC

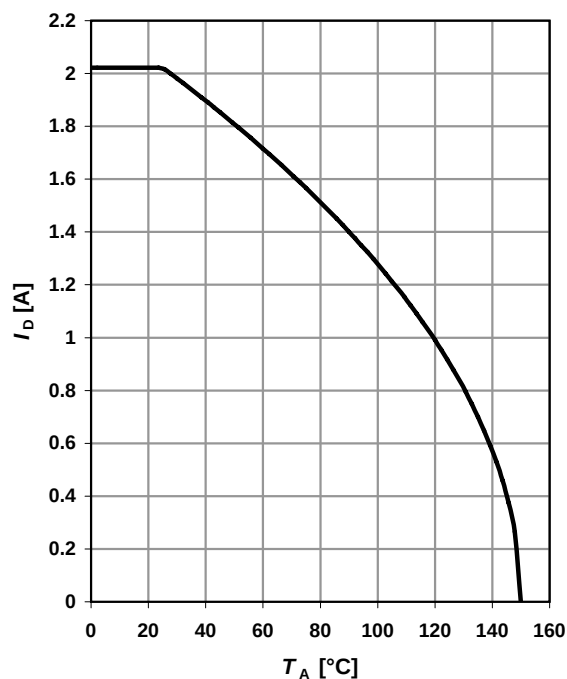
1 Power dissipation

$$P_{\text{tot}} = f(T_A)$$



2 Drain current

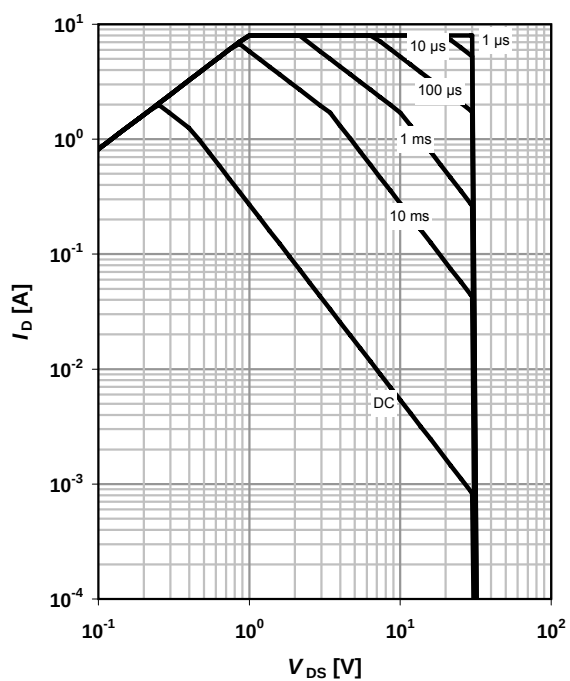
$$I_D = f(T_A); V_{\text{GS}} \geq 10 \text{ V}$$



3 Safe operating area

$$I_D = f(V_{\text{DS}}); T_A = 25^\circ\text{C}; D = 0$$

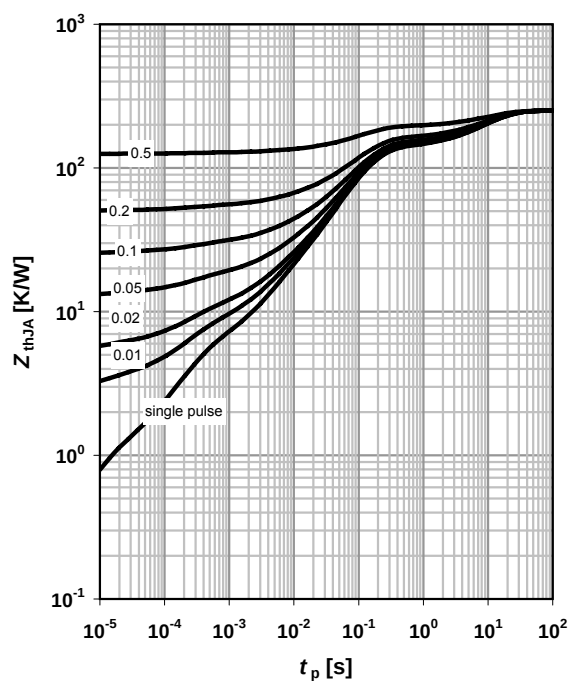
parameter: t_p



4 Max. transient thermal impedance

$$Z_{\text{thJA}} = f(t_p)$$

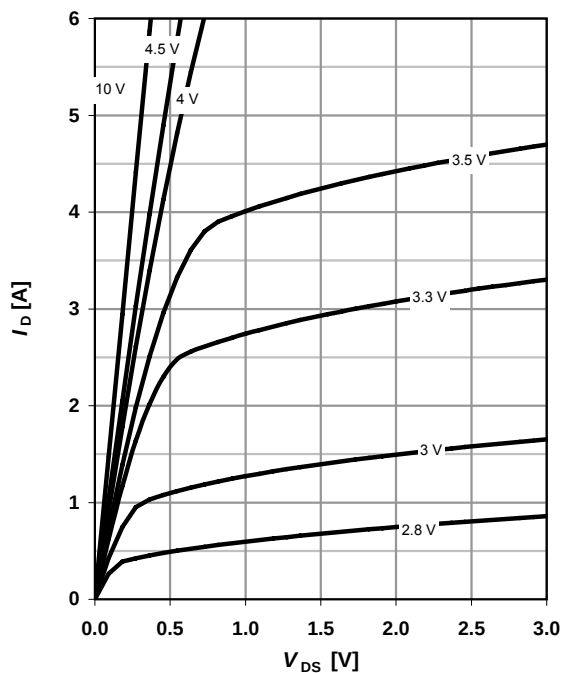
parameter: $D = t_p/T$



5 Typ. output characteristics

$$I_D = f(V_{DS}); T_J = 25^\circ\text{C}$$

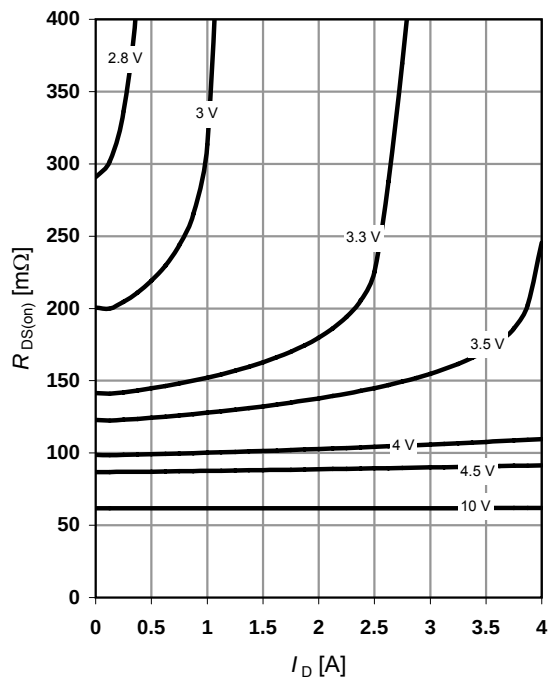
parameter: V_{GS}



6 Typ. drain-source on resistance

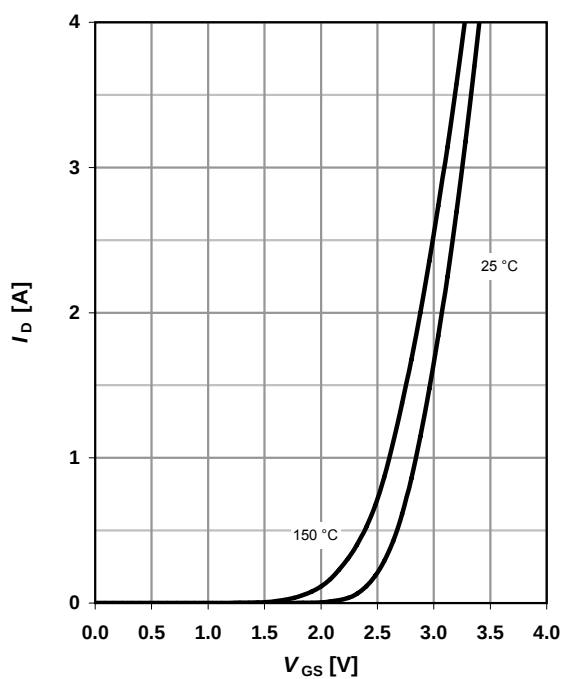
$$R_{DS(on)} = f(I_D); T_J = 25^\circ\text{C}$$

parameter: V_{GS}



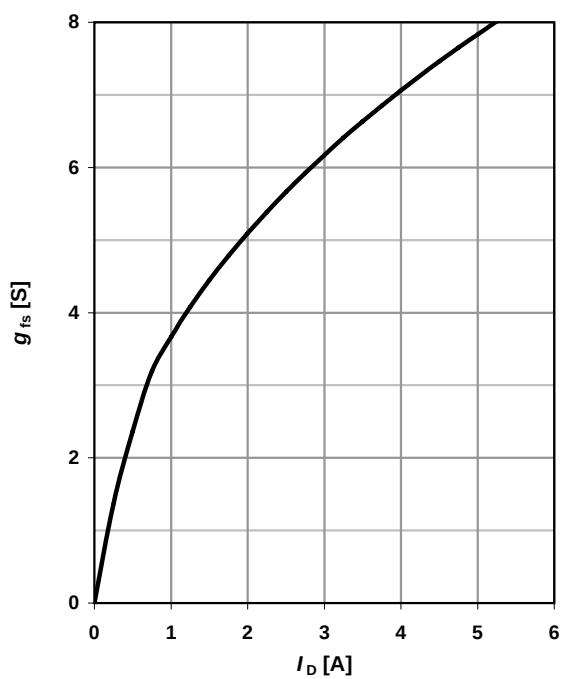
7 Typ. transfer characteristics

$$I_D = f(V_{GS}); |V_{DS}| > 2|I_D|R_{DS(on)max}$$



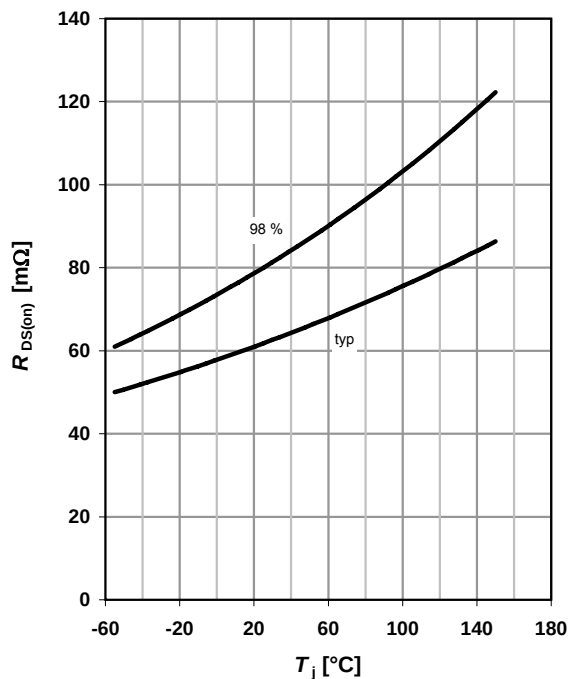
8 Typ. forward transconductance

$$g_{fs} = f(I_D); T_J = 25^\circ\text{C}$$



9 Drain-source on-state resistance

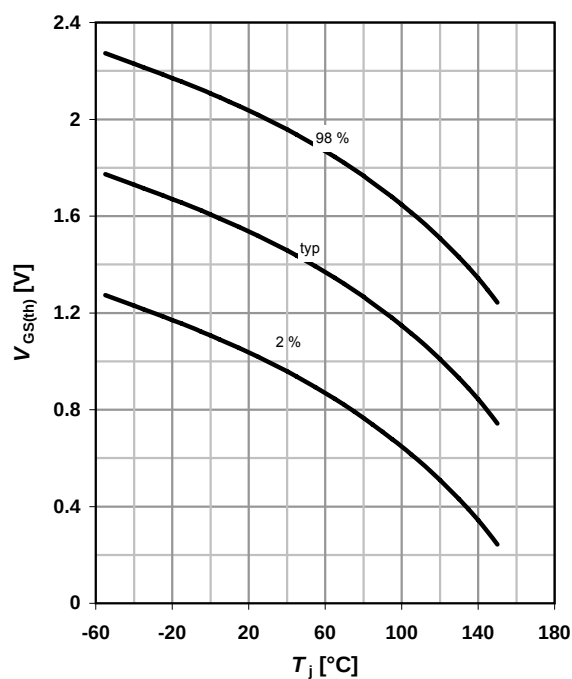
$$R_{DS(on)} = f(T_j); I_D = -2 \text{ A}; V_{GS} = -10 \text{ V}$$



10 Typ. gate threshold voltage

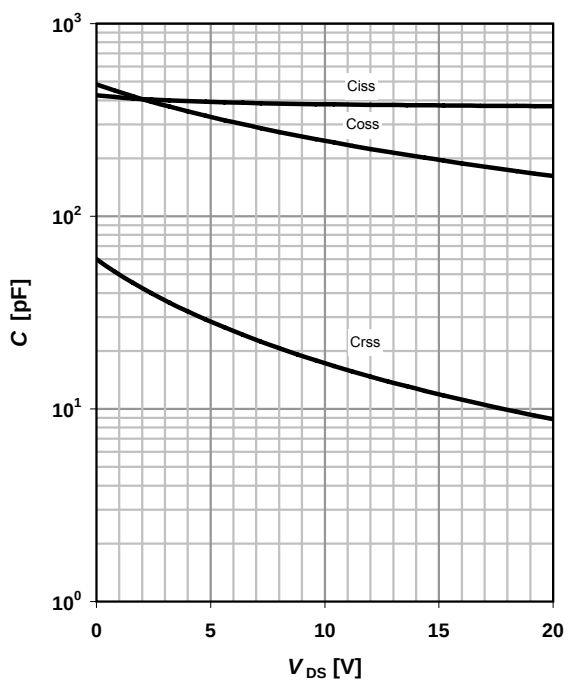
$$V_{GS(th)} = f(T_j); V_{DS} = V_{GS}; I_D = 11 \mu\text{A}$$

parameter: I_D



11 Typ. capacitances

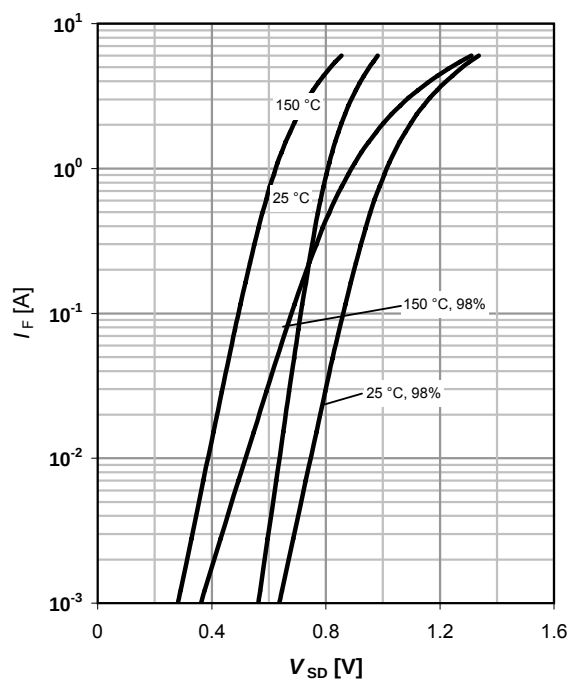
$$C = f(V_{DS}); V_{GS} = 0 \text{ V}; f = 1 \text{ MHz}; T_j = 25^\circ\text{C}$$



12 Forward characteristics of reverse diode

$$I_F = f(V_{SD})$$

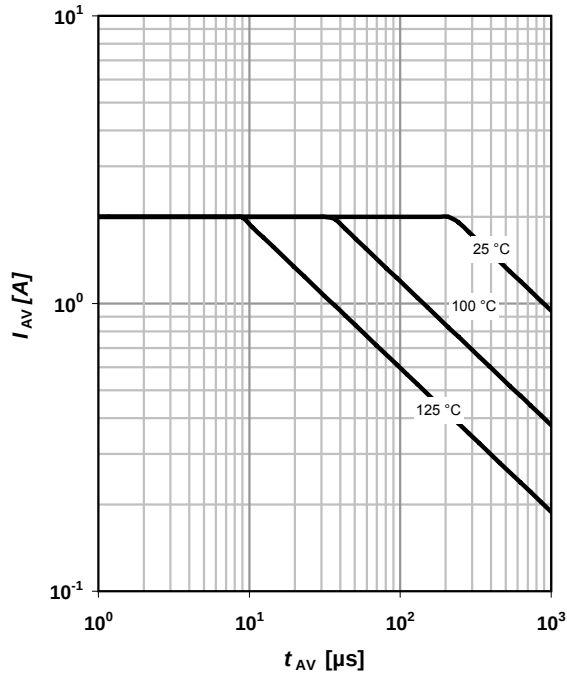
parameter: T_j



13 Avalanche characteristics

$$I_{AS}=f(t_{AV}); R_{GS}=25\ \Omega$$

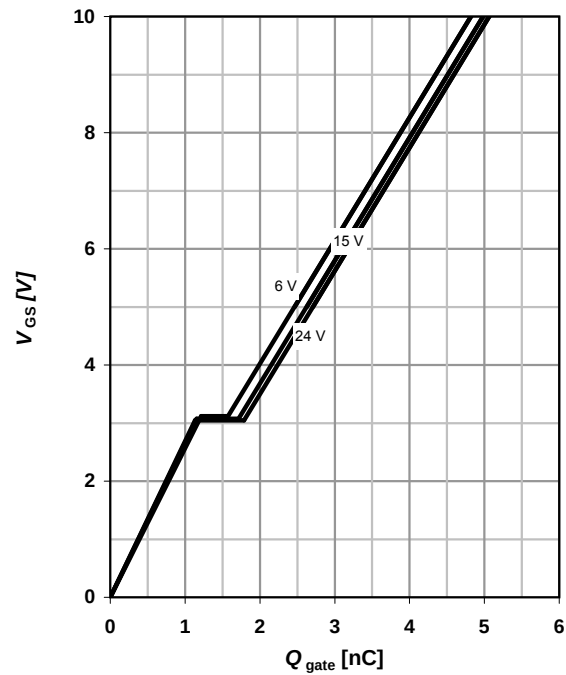
parameter: $T_{j(\text{start})}$



14 Typ. gate charge

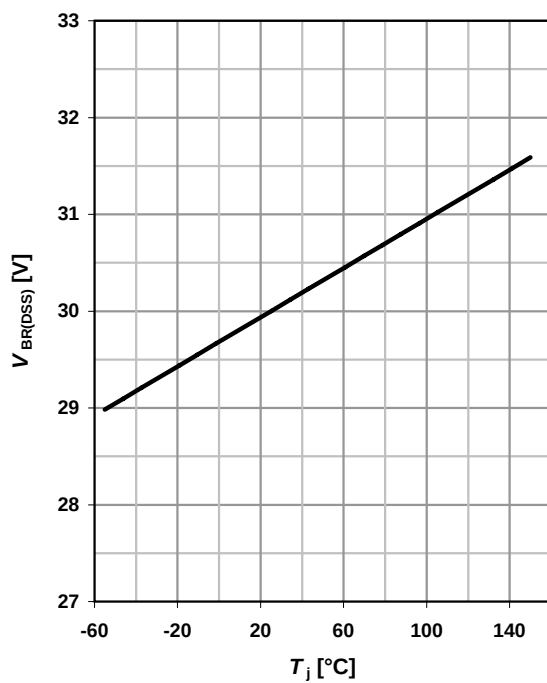
$$V_{GS}=f(Q_{\text{gate}}); I_D=-2\ \text{A pulsed}$$

parameter: V_{DD}

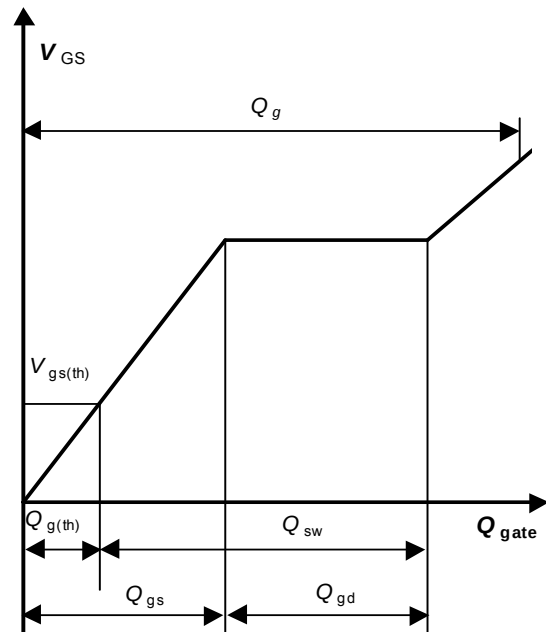


15 Drain-source breakdown voltage

$$V_{BR(DSS)}=f(T_j); I_D=250\ \mu\text{A}$$

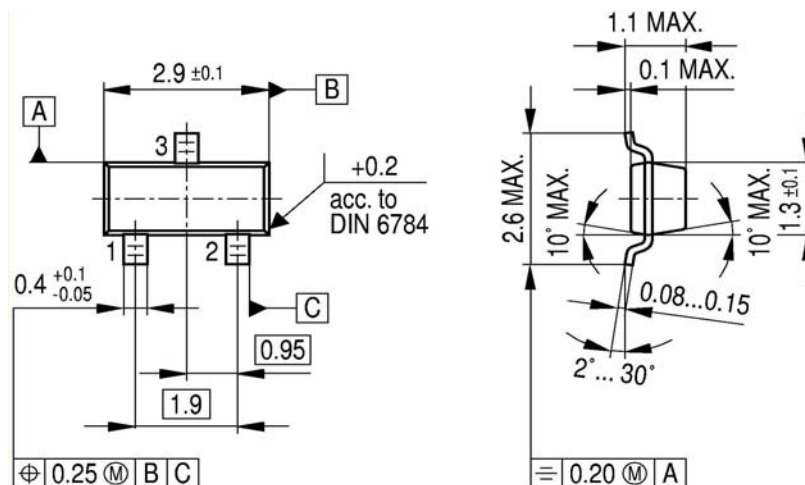


16 Gate charge waveforms

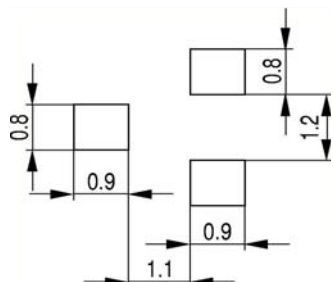


SOT-23

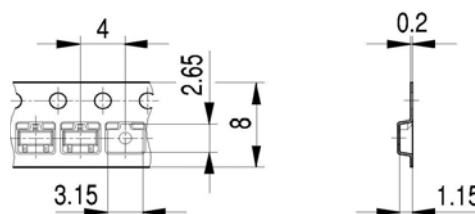
Package Outline:



Footprint:



Packaging:



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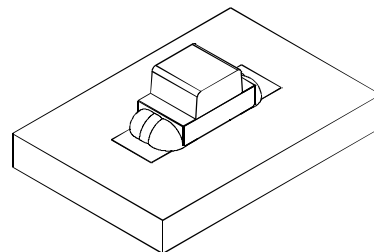
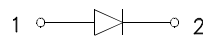
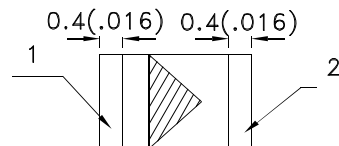
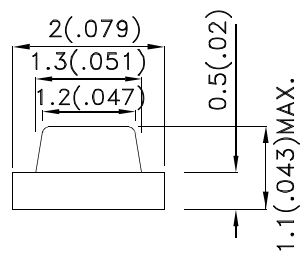
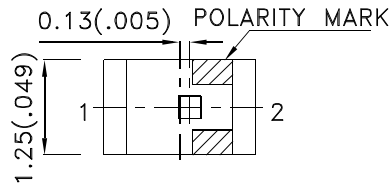
Features

- 2.0mmx1.25mm SMT LED, 1.1mm thickness.
- Low power consumption.
- Wide viewing angle.
- Ideal for backlight and indicator.
- Various colors and lens types available.
- Package : 2000pcs / reel.
- Moisture sensitivity level : level 3.
- Low current IF=2mA operating..
- RoHS compliant.

Description

The Super Bright Green source color devices are made with Gallium Phosphide Green Light Emitting Diode.

Package Dimensions



Notes:

1. All dimensions are in millimeters (inches).
2. Tolerance is ± 0.1 (0.004") unless otherwise noted.
3. The specifications, characteristics and technical data described in the datasheet are subject to change without prior notice.
4. The device has a single mounting surface. The device must be mounted according to the specifications.



Selection Guide

Part No.	Dice	Lens Type	Iv (mcd) [2] @ 2mA		Viewing Angle [1]
			Min.	Typ.	2θ1/2
KP-2012LSGC	Super Bright Green (GaP)	WATER CLEAR	0.3	0.8	120°

Notes:

1. θ1/2 is the angle from optical centerline where the luminous intensity is 1/2 of the optical peak value.
2. Luminous intensity/ luminous Flux: +/-15%.

Electrical / Optical Characteristics at TA=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λpeak	Peak Wavelength	Super Bright Green	565		nm	If=2mA
λD [1]	Dominant Wavelength	Super Bright Green	568		nm	If=2mA
Δλ1/2	Spectral Line Half-width	Super Bright Green	30		nm	If=2mA
C	Capacitance	Super Bright Green	15		pF	Vf=0V;f=1MHz
Vf [2]	Forward Voltage	Super Bright Green	1.9	2.5	V	If=2mA
Ir	Reverse Current	Super Bright Green		10	uA	VR=5V

Notes:

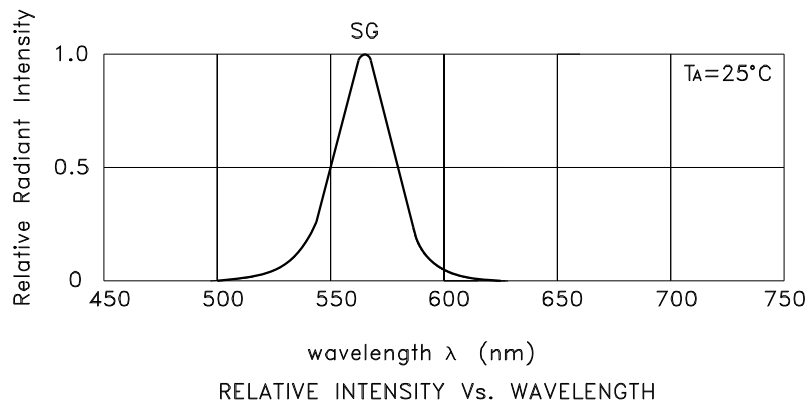
- 1.Wavelength: +/-1nm.
2. Forward Voltage: +/-0.1V.

Absolute Maximum Ratings at TA=25°C

Parameter	Super Bright Green	Units
Power dissipation	62.5	mW
DC Forward Current	25	mA
Peak Forward Current [1]	140	mA
Reverse Voltage	5	V
Operating Temperature	-40°C To +85°C	
Storage Temperature	-40°C To +85°C	

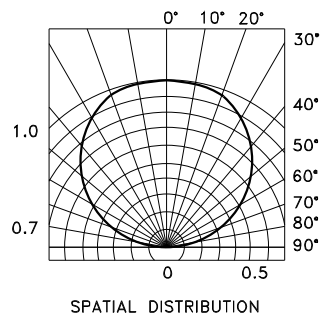
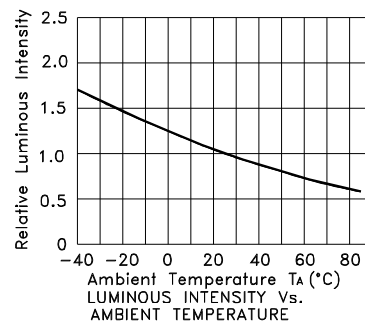
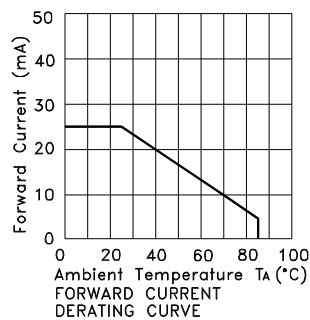
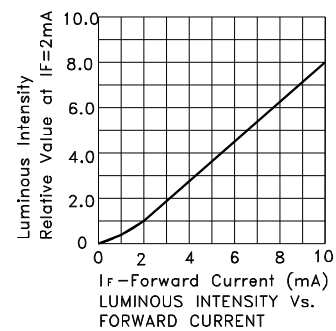
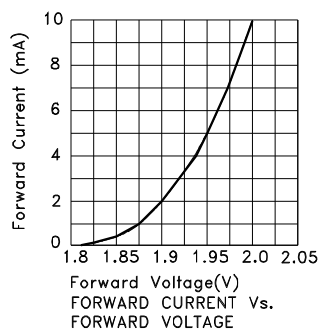
Note:

1. 1/10 Duty Cycle, 0.1ms Pulse Width.



Super Bright Green

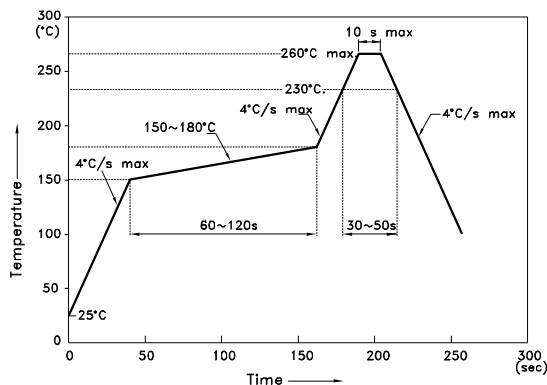
KP-2012LSGC



KP-2012LSGC

Reflow soldering is recommended and the soldering profile is shown below.
Other soldering methods are not recommended as they might cause damage to the product.

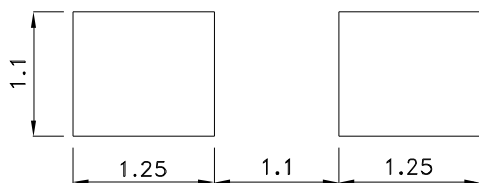
Reflow Soldering Profile For Lead-free SMT Process.



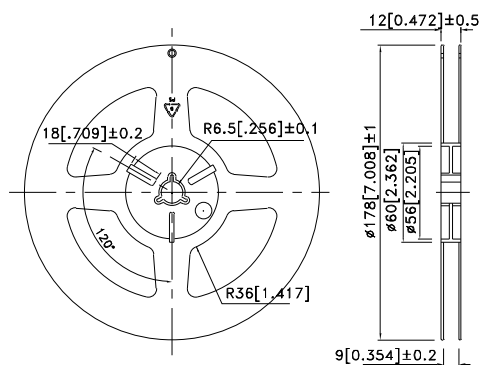
NOTES:

1. We recommend the reflow temperature 245°C(+/-5°C). The maximum soldering temperature should be limited to 260°C.
2. Don't cause stress to the epoxy resin while it is exposed to high temperature.
3. Number of reflow process shall be 2 times or less.

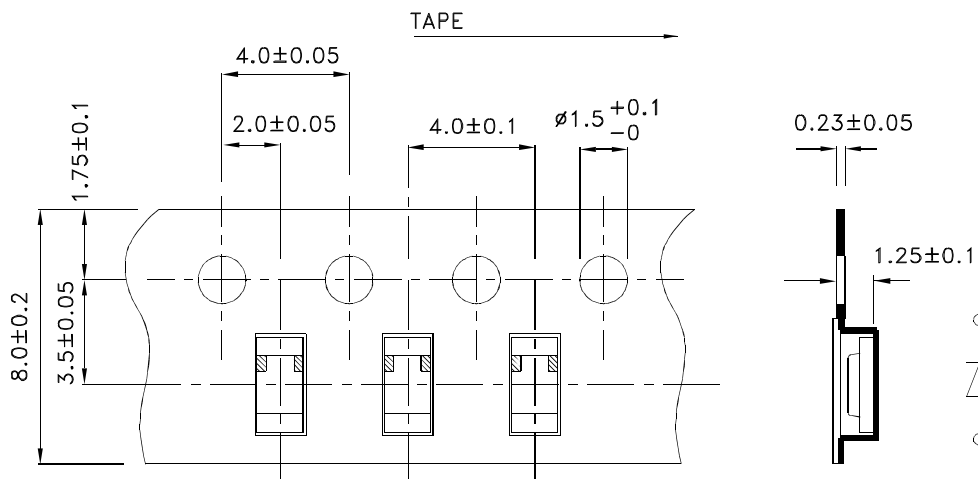
Recommended Soldering Pattern (Units : mm; Tolerance: ± 0.1)



Reel Dimension

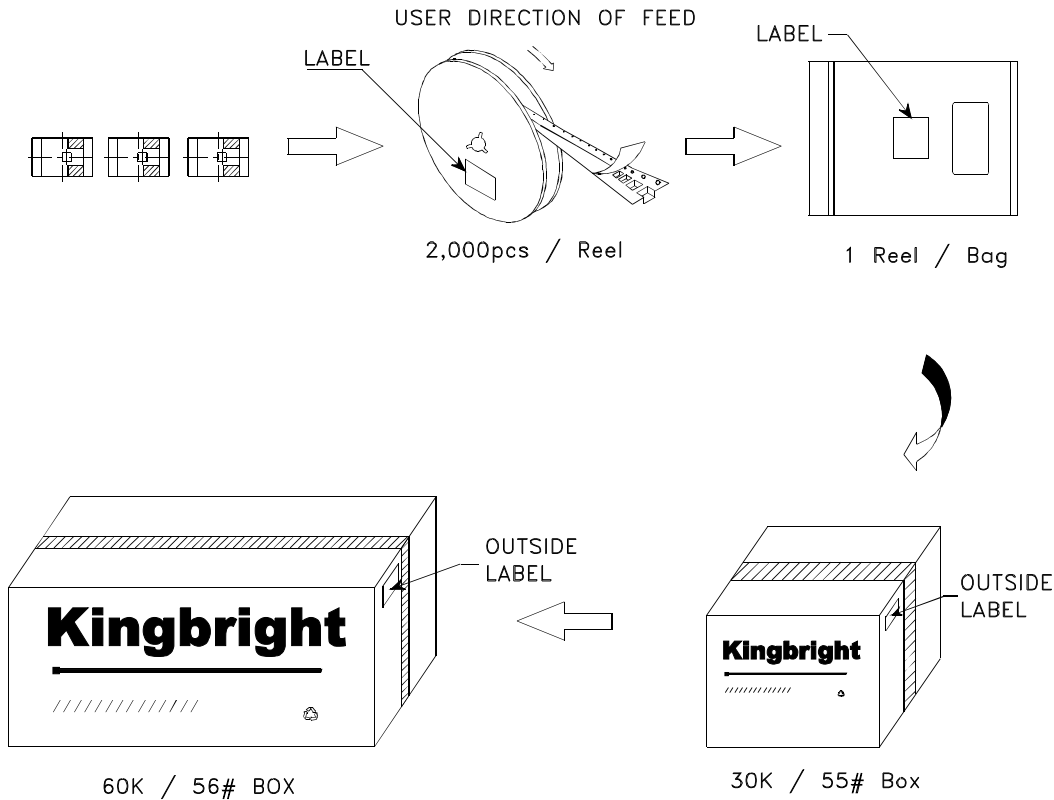


Tape Dimensions (Units : mm)



PACKING & LABEL SPECIFICATIONS

KP-2012LSGC



Kingbright	
P/NO: KP-2012xxx	
QTY: 2,000 pcs	Q.C. Q C XX XX XXXX PASSED
S/N: XXXX	
CODE: XXX	
LOT NO:  XXXXXXXXXXXXXXXXXXXX	
RoHS Compliant	

Thick Film Chip Resistor 0805



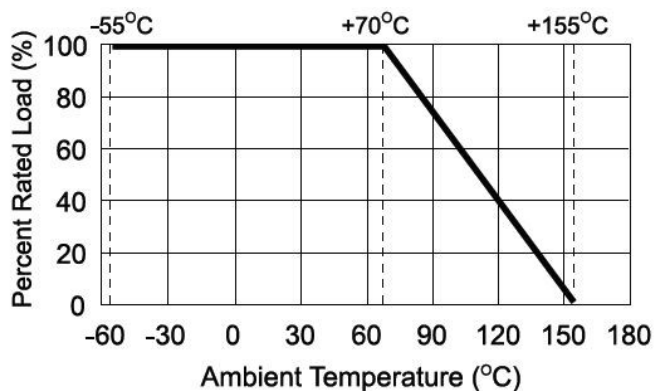
Features

- Small size and light weight
- Suitable for both wave and reflow soldering
- Reduction of assembly costs

Performance Specification

Temperature Coefficient	: 1Ω to 10Ω ±400PPM/°C 11Ω to 100Ω ±200PPM/°C >100Ω ±100PPM/°C
Short Time Overload	: ±5% : ±(2% +0.1Ω)Max. ±1% : ±(1% +0.1Ω)Max.
Insulation Resistance	: Min. 1,000MΩ
Dielectric Withstanding Voltage	: No evidence of flashover, mechanical damage, arcing or insulation breakdown.
Terminal Bending	: ±(1% +0.05Ω) Max.
Soldering Heat	: ±(1% +0.05Ω) Max.
Solderability	: Min. 95% coverage
Temperature Cycling	: ±5% : ±(1% +0.05Ω) Max. ±1% : ±(0.5% +0.05Ω) Max.
Humidity (Steady State)	: ±5% : ±(3% +0.1Ω) Max. ±1% : ±(0.5% +0.1Ω) Max.
Load Life in Humidity	: ±5% : ±(3% +0.1Ω) Max. ±1% : ±(1% +0.1Ω) Max.
Load Life	: ±5% : ±(3% +0.1Ω) Max. ±1% : ±(1% +0.1Ω) Max.

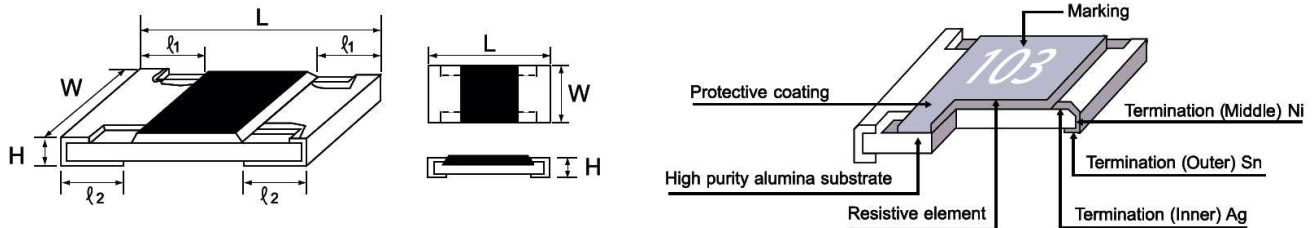
Derating Curve



Thick Film Chip Resistor 0805



Dimension



Type	Dimension (mm)				
	L	W	H	ℓ ₁	ℓ ₂
0805	2 ±0.15	1.25 ^{+0.15} _{+0.1}	0.55 ±0.1	0.4 ±0.2	0.4 ±0.2

Type	Power Rating at 70°C	Max. Working Voltage	Max. Overload Voltage	Dielectric Withstanding Voltage	Tolerance %	Resistance Range
0805	1/8W-S 1/16W	2A	4A	-	Jumper	<50mΩ
		150V	300V	500V	±1%	10Ω to 1MΩ
					±2%	1Ω to 10MΩ
					±5%	1Ω to 10MΩ

Part Number Table

Description	Part Number	Description	Part Number
Resistor, 1K, 0.1W, 1%, 0805, Reel	MC01W080511K	Resistor, 1R1, 0.1W, 1%, 0805	MC01W080511R10
Resistor, 1K, 0.1W, 1%, 0805	MC01W080511K	Resistor, 1K15, 0.1W, 1%, 0805, Reel	MC01W080511K15
Resistor, 1M, 0.1W, 1%, 0805, Reel	MC01W080511M	Resistor, 1K15, 0.1W, 1%, 0805	MC01W080511K15
Resistor, 1M, 0.1W, 1%, 0805	MC01W080511M	Resistor, 1M15, 0.1W, 1%, 0805, Reel	MC01W080511M15
Resistor, 1R, 0.1W, 1%, 0805, Reel	MC01W080511R0	Resistor, 1M15, 0.1W, 1%, 0805	MC01W080511M15
Resistor, 1R, 0.1W, 1%, 0805	MC01W080511R0	Resistor, 1R15, 0.1W, 1%, 0805, Reel	MC01W080511R15
Resistor, 1K05, 0.1W, 1%, 0805, Reel	MC01W080511K05	Resistor, 1R15, 0.1W, 1%, 0805	MC01W080511R15
Resistor, 1K05, 0.1W, 1%, 0805	MC01W080511K05	Resistor, 1K2, 0.1W, 1%, 0805, Reel	MC01W080511K2
Resistor, 1M05, 0.1W, 1%, 0805, Reel	MC01W080511M05	Resistor, 1K2, 0.1W, 1%, 0805	MC01W080511K2
Resistor, 1M05, 0.1W, 1%, 0805	MC01W080511M05	Resistor, 1M2, 0.1W, 1%, 0805, Reel	MC01W080511M20
Resistor, 1K1, 0.1W, 1%, 0805, Reel	MC01W080511K1	Resistor, 1M2, 0.1W, 1%, 0805	MC01W080511M20
Resistor, 1K1, 0.1W, 1%, 0805	MC01W080511K1	Resistor, 1R2, 0.1W, 1%, 0805, Reel	MC01W080511R20
Resistor, 1M1, 0.1W, 1%, 0805, Reel	MC01W080511M10	Resistor, 1R2, 0.1W, 1%, 0805	MC01W080511R20
Resistor, 1M1, 0.1W, 1%, 0805	MC01W080511M10	Resistor, 1K21, 0.1W, 1%, 0805, Reel	MC01W080511K21
Resistor, 1R1, 0.1W, 1%, 0805, Reel	MC01W080511R10	Resistor, 1K21, 0.1W, 1%, 0805	MC01W080511K21

Thick Film Chip Resistor

0805



Description	Part Number
Resistor, 1M21, 0.1W, 1%, 0805, Reel	MC01W080511M21
Resistor, 1M21, 0.1W, 1%, 0805	MC01W080511M21
Resistor, 1R21, 0.1W, 1%, 0805, Reel	MC01W080511R21
Resistor, 1R21, 0.1W, 1%, 0805	MC01W080511R21
Resistor, 1K27, 0.1W, 1%, 0805, Reel	MC01W080511K27
Resistor, 1K27, 0.1W, 1%, 0805	MC01W080511K27
Resistor, 1R27, 0.1W, 1%, 0805, Reel	MC01W080511R27
Resistor, 1R27, 0.1W, 1%, 0805	MC01W080511R27
Resistor, 1K3, 0.1W, 1%, 0805, Reel	MC01W080511K3
Resistor, 1K3, 0.1W, 1%, 0805	MC01W080511K3
Resistor, 1M3, 0.1W, 1%, 0805, Reel	MC01W080511M30
Resistor, 1M3, 0.1W, 1%, 0805	MC01W080511M30
Resistor, 1R3, 0.1W, 1%, 0805, Reel	MC01W080511R30
Resistor, 1R3, 0.1W, 1%, 0805	MC01W080511R30
Resistor, 1K33, 0.1W, 1%, 0805, Reel	MC01W080511K33
Resistor, 1K33, 0.1W, 1%, 0805	MC01W080511K33
Resistor, 1M33, 0.1W, 1%, 0805, Reel	MC01W080511M33
Resistor, 1M33, 0.1W, 1%, 0805	MC01W080511M33
Resistor, 1R33, 0.1W, 1%, 0805, Reel	MC01W080511R33
Resistor, 1R33, 0.1W, 1%, 0805	MC01W080511R33
Resistor, 1K4, 0.1W, 1%, 0805, Reel	MC01W080511K40
Resistor, 1K4, 0.1W, 1%, 0805	MC01W080511K40
Resistor, 1M4, 0.1W, 1%, 0805, Reel	MC01W080511M40
Resistor, 1M4, 0.1W, 1%, 0805	MC01W080511M40
Resistor, 1R4, 0.1W, 1%, 0805, Reel	MC01W080511R40
Resistor, 1R4, 0.1W, 1%, 0805	MC01W080511R40
Resistor, 1K47, 0.1W, 1%, 0805, Reel	MC01W080511K47
Resistor, 1K47, 0.1W, 1%, 0805	MC01W080511K47
Resistor, 1M47, 0.1W, 1%, 0805, Reel	MC01W080511M47
Resistor, 1M47, 0.1W, 1%, 0805	MC01W080511M47
Resistor, 1K5, 0.1W, 1%, 0805, Reel	MC01W080511K5
Resistor, 1K5, 0.1W, 1%, 0805	MC01W080511K5
Resistor, 1M5, 0.1W, 1%, 0805, Reel	MC01W080511M50
Resistor, 1M5, 0.1W, 1%, 0805	MC01W080511M50
Resistor, 1R5, 0.1W, 1%, 0805, Reel	MC01W080511R5
Resistor, 1R5, 0.1W, 1%, 0805	MC01W080511R5
Resistor, 1K54, 0.1W, 1%, 0805, Reel	MC01W080511K54
Resistor, 1K54, 0.1W, 1%, 0805	MC01W080511K54
Resistor, 1K6, 0.1W, 1%, 0805, Reel	MC01W080511K6

Description	Part Number
Resistor, 1K6, 0.1W, 1%, 0805	MC01W080511K6
Resistor, 1M6, 0.1W, 1%, 0805, Reel	MC01W080511M60
Resistor, 1M6, 0.1W, 1%, 0805	MC01W080511M60
Resistor, 1R6, 0.1W, 1%, 0805, Reel	MC01W080511R60
Resistor, 1R6, 0.1W, 1%, 0805	MC01W080511R60
Resistor, 1K62, 0.1W, 1%, 0805, Reel	MC01W080511K62
Resistor, 1K62, 0.1W, 1%, 0805	MC01W080511K62
Resistor, 1M62, 0.1W, 1%, 0805, Reel	MC01W080511M62
Resistor, 1M62, 0.1W, 1%, 0805	MC01W080511M62
Resistor, 1R62, 0.1W, 1%, 0805, Reel	MC01W080511R62
Resistor, 1R62, 0.1W, 1%, 0805	MC01W080511R62
Resistor, 1K69, 0.1W, 1%, 0805, Reel	MC01W080511K69
Resistor, 1K69, 0.1W, 1%, 0805	MC01W080511K69
Resistor, 1M69, 0.1W, 1%, 0805, Reel	MC01W080511M69
Resistor, 1M69, 0.1W, 1%, 0805	MC01W080511M69
Resistor, 1R69, 0.1W, 1%, 0805, Reel	MC01W080511R69
Resistor, 1R69, 0.1W, 1%, 0805	MC01W080511R69
Resistor, 1K78, 0.1W, 1%, 0805, Reel	MC01W080511K78
Resistor, 1K78, 0.1W, 1%, 0805	MC01W080511K78
Resistor, 1M78, 0.1W, 1%, 0805, Reel	MC01W080511M78
Resistor, 1M78, 0.1W, 1%, 0805	MC01W080511M78
Resistor, 1K8, 0.1W, 1%, 0805, Reel	MC01W080511K8
Resistor, 1K8, 0.1W, 1%, 0805	MC01W080511K8
Resistor, 1M8, 0.1W, 1%, 0805, Reel	MC01W080511M80
Resistor, 1M8, 0.1W, 1%, 0805	MC01W080511M80
Resistor, 1R8, 0.1W, 1%, 0805, Reel	MC01W080511R80
Resistor, 1R8, 0.1W, 1%, 0805	MC01W080511R80
Resistor, 1K87, 0.1W, 1%, 0805, Reel	MC01W080511K87
Resistor, 1K87, 0.1W, 1%, 0805	MC01W080511K87
Resistor, 1M87, 0.1W, 1%, 0805, Reel	MC01W080511M87
Resistor, 1M87, 0.1W, 1%, 0805	MC01W080511M87
Resistor, 1R87, 0.1W, 1%, 0805, Reel	MC01W080511R87
Resistor, 1R87, 0.1W, 1%, 0805	MC01W080511R87
Resistor, 1K96, 0.1W, 1%, 0805, Reel	MC01W080511K96
Resistor, 1K96, 0.1W, 1%, 0805	MC01W080511K96
Resistor, 1M96, 0.1W, 1%, 0805, Reel	MC01W080511M96
Resistor, 1M96, 0.1W, 1%, 0805	MC01W080511M96
Resistor, 1R96, 0.1W, 1%, 0805, Reel	MC01W080511R96
Resistor, 1R96, 0.1W, 1%, 0805	MC01W080511R96

Thick Film Chip Resistor

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Description	Part Number
Resistor, 10K, 0.1W, 1%, 0805, Reel	MC01W0805110K
Resistor, 10K, 0.1W, 1%, 0805	MC01W0805110K
Resistor, 10M, 0.1W, 1%, 0805, Reel	MC01W0805110M0
Resistor, 10M, 0.1W, 1%, 0805	MC01W0805110M0
Resistor, 10R, 0.1W, 1%, 0805, Reel	MC01W0805110R
Resistor, 10R, 0.1W, 1%, 0805	MC01W0805110R
Resistor, 10K5, 0.1W, 1%, 0805, Reel	MC01W0805110K5
Resistor, 10K5, 0.1W, 1%, 0805	MC01W0805110K5
Resistor, 10R5, 0.1W, 1%, 0805, Reel	MC01W0805110R5
Resistor, 10R5, 0.1W, 1%, 0805	MC01W0805110R5
Resistor, 100K, 0.1W, 1%, 0805, Reel	MC01W08051100K
Resistor, 100K, 0.1W, 1%, 0805	MC01W08051100K
Resistor, 100R, 0.1W, 1%, 0805, Reel	MC01W08051100R
Resistor, 100R, 0.1W, 1%, 0805	MC01W08051100R
Resistor, 100R, 0.1W, 1%, 0805	MC01W08051100R
Resistor, 105K, 0.1W, 1%, 0805, Reel	MC01W08051105K
Resistor, 105K, 0.1W, 1%, 0805	MC01W08051105K
Resistor, 105R, 0.1W, 1%, 0805, Reel	MC01W08051105R
Resistor, 105R, 0.1W, 1%, 0805	MC01W08051105R
Resistor, 11K, 0.1W, 1%, 0805, Reel	MC01W0805111K
Resistor, 11K, 0.1W, 1%, 0805	MC01W0805111K
Resistor, 11R, 0.1W, 1%, 0805, Reel	MC01W0805111R
Resistor, 11R, 0.1W, 1%, 0805	MC01W0805111R
Resistor, 11K5, 0.1W, 1%, 0805, Reel	MC01W0805111K5
Resistor, 11K5, 0.1W, 1%, 0805	MC01W0805111K5
Resistor, 11R5, 0.1W, 1%, 0805, Reel	MC01W0805111R5
Resistor, 11R5, 0.1W, 1%, 0805	MC01W0805111R5
Resistor, 110K, 0.1W, 1%, 0805, Reel	MC01W08051110K
Resistor, 110K, 0.1W, 1%, 0805	MC01W08051110K
Resistor, 110R, 0.1W, 1%, 0805, Reel	MC01W08051110R
Resistor, 110R, 0.1W, 1%, 0805	MC01W08051110R
Resistor, 115K, 0.1W, 1%, 0805, Reel	MC01W08051115K
Resistor, 115K, 0.1W, 1%, 0805	MC01W08051115K
Resistor, 115R, 0.1W, 1%, 0805, Reel	MC01W08051115R
Resistor, 115R, 0.1W, 1%, 0805	MC01W08051115R
Resistor, 12K, 0.1W, 1%, 0805, Reel	MC01W0805112K
Resistor, 12K, 0.1W, 1%, 0805	MC01W0805112K
Resistor, 12R, 0.1W, 1%, 0805, Reel	MC01W0805112R
Resistor, 12R, 0.1W, 1%, 0805	MC01W0805112R
Resistor, 12K1, 0.1W, 1%, 0805, Reel	MC01W0805112K1

Description	Part Number
Resistor, 12K1, 0.1W, 1%, 0805	MC01W0805112K1
Resistor, 12R1, 0.1W, 1%, 0805, Reel	MC01W0805112R1
Resistor, 12R1, 0.1W, 1%, 0805	MC01W0805112R1
Resistor, 12K4, 0.1W, 1%, 0805, Reel	MC01W0805112K4
Resistor, 12K4, 0.1W, 1%, 0805	MC01W0805112K4
Resistor, 12K7, 0.1W, 1%, 0805, Reel	MC01W0805112K7
Resistor, 12K7, 0.1W, 1%, 0805	MC01W0805112K7
Resistor, 12R7, 0.1W, 1%, 0805, Reel	MC01W0805112R7
Resistor, 12R7, 0.1W, 1%, 0805	MC01W0805112R7
Resistor, 120K, 0.1W, 1%, 0805, Reel	MC01W08051120K
Resistor, 120K, 0.1W, 1%, 0805	MC01W08051120K
Resistor, 120R, 0.1W, 1%, 0805, Reel	MC01W08051120R
Resistor, 120R, 0.1W, 1%, 0805	MC01W08051120R
Resistor, 121K, 0.1W, 1%, 0805, Reel	MC01W08051121K
Resistor, 121K, 0.1W, 1%, 0805	MC01W08051121K
Resistor, 121R, 0.1W, 1%, 0805, Reel	MC01W08051121R
Resistor, 121R, 0.1W, 1%, 0805	MC01W08051121R
Resistor, 127K, 0.1W, 1%, 0805, Reel	MC01W08051127K
Resistor, 127K, 0.1W, 1%, 0805	MC01W08051127K
Resistor, 127R, 0.1W, 1%, 0805, Reel	MC01W08051127R
Resistor, 127R, 0.1W, 1%, 0805	MC01W08051127R
Resistor, 13K, 0.1W, 1%, 0805, Reel	MC01W0805113K
Resistor, 13K, 0.1W, 1%, 0805	MC01W0805113K
Resistor, 13R, 0.1W, 1%, 0805, Reel	MC01W0805113R
Resistor, 13R, 0.1W, 1%, 0805	MC01W0805113R
Resistor, 13K3, 0.1W, 1%, 0805, Reel	MC01W0805113K3
Resistor, 13K3, 0.1W, 1%, 0805	MC01W0805113K3
Resistor, 13R3, 0.1W, 1%, 0805, Reel	MC01W0805113R3
Resistor, 13R3, 0.1W, 1%, 0805	MC01W0805113R3
Resistor, 130K, 0.1W, 1%, 0805, Reel	MC01W08051130K
Resistor, 130K, 0.1W, 1%, 0805	MC01W08051130K
Resistor, 130R, 0.1W, 1%, 0805, Reel	MC01W08051130R
Resistor, 130R, 0.1W, 1%, 0805	MC01W08051130R
Resistor, 133K, 0.1W, 1%, 0805, Reel	MC01W08051133K
Resistor, 133K, 0.1W, 1%, 0805	MC01W08051133K
Resistor, 133R, 0.1W, 1%, 0805, Reel	MC01W08051133R
Resistor, 133R, 0.1W, 1%, 0805	MC01W08051133R
Resistor, 14K, 0.1W, 1%, 0805, Reel	MC01W0805114K0
Resistor, 14K, 0.1W, 1%, 0805	MC01W0805114K0

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Description	Part Number
Resistor, 14R, 0.1W, 1%, 0805, Reel	MC01W0805114R0
Resistor, 14R, 0.1W, 1%, 0805	MC01W0805114R0
Resistor, 14K7, 0.1W, 1%, 0805, Reel	MC01W0805114K7
Resistor, 14K7, 0.1W, 1%, 0805	MC01W0805114K7
Resistor, 14R7, 0.1W, 1%, 0805, Reel	MC01W0805114R7
Resistor, 14R7, 0.1W, 1%, 0805	MC01W0805114R7
Resistor, 140K, 0.1W, 1%, 0805, Reel	MC01W08051140K
Resistor, 140K, 0.1W, 1%, 0805	MC01W08051140K
Resistor, 140R, 0.1W, 1%, 0805, Reel	MC01W08051140R
Resistor, 140R, 0.1W, 1%, 0805	MC01W08051140R
Resistor, 147K, 0.1W, 1%, 0805, Reel	MC01W08051147K
Resistor, 147K, 0.1W, 1%, 0805	MC01W08051147K
Resistor, 147R, 0.1W, 1%, 0805, Reel	MC01W08051147R
Resistor, 147R, 0.1W, 1%, 0805	MC01W08051147R
Resistor, 15K, 0.1W, 1%, 0805, Reel	MC01W0805115K
Resistor, 15K, 0.1W, 1%, 0805	MC01W0805115K
Resistor, 15R, 0.1W, 1%, 0805, Reel	MC01W0805115R
Resistor, 15R, 0.1W, 1%, 0805	MC01W0805115R
Resistor, 15K4, 0.1W, 1%, 0805, Reel	MC01W0805115K4
Resistor, 15K4, 0.1W, 1%, 0805	MC01W0805115K4
Resistor, 15R4, 0.1W, 1%, 0805, Reel	MC01W0805115R4
Resistor, 15R4, 0.1W, 1%, 0805	MC01W0805115R4
Resistor, 150K, 0.1W, 1%, 0805, Reel	MC01W08051150K
Resistor, 150K, 0.1W, 1%, 0805	MC01W08051150K
Resistor, 150R, 0.1W, 1%, 0805, Reel	MC01W08051150R
Resistor, 150R, 0.1W, 1%, 0805	MC01W08051150R
Resistor, 154K, 0.1W, 1%, 0805, Reel	MC01W08051154K
Resistor, 154K, 0.1W, 1%, 0805	MC01W08051154K
Resistor, 154R, 0.1W, 1%, 0805, Reel	MC01W08051154R
Resistor, 154R, 0.1W, 1%, 0805	MC01W08051154R
Resistor, 16K, 0.1W, 1%, 0805, Reel	MC01W0805116K
Resistor, 16K, 0.1W, 1%, 0805	MC01W0805116K
Resistor, 16R, 0.1W, 1%, 0805, Reel	MC01W0805116R
Resistor, 16R, 0.1W, 1%, 0805	MC01W0805116R
Resistor, 16K2, 0.1W, 1%, 0805, Reel	MC01W0805116K2
Resistor, 16K2, 0.1W, 1%, 0805	MC01W0805116K2
Resistor, 16R2, 0.1W, 1%, 0805, Reel	MC01W0805116R2
Resistor, 16R2, 0.1W, 1%, 0805	MC01W0805116R2
Resistor, 16K9, 0.1W, 1%, 0805, Reel	MC01W0805116K9

Description	Part Number
Resistor, 16K9, 0.1W, 1%, 0805	MC01W0805116K9
Resistor, 16R9, 0.1W, 1%, 0805, Reel	MC01W0805116R9
Resistor, 16R9, 0.1W, 1%, 0805	MC01W0805116R9
Resistor, 160K, 0.1W, 1%, 0805, Reel	MC01W08051160K
Resistor, 160K, 0.1W, 1%, 0805	MC01W08051160K
Resistor, 160R, 0.1W, 1%, 0805, Reel	MC01W08051160R
Resistor, 160R, 0.1W, 1%, 0805	MC01W08051160R
Resistor, 162K, 0.1W, 1%, 0805, Reel	MC01W08051162K
Resistor, 162K, 0.1W, 1%, 0805	MC01W08051162K
Resistor, 162R, 0.1W, 1%, 0805, Reel	MC01W08051162R
Resistor, 162R, 0.1W, 1%, 0805	MC01W08051162R
Resistor, 169K, 0.1W, 1%, 0805, Reel	MC01W08051169K
Resistor, 169K, 0.1W, 1%, 0805	MC01W08051169K
Resistor, 169R, 0.1W, 1%, 0805, Reel	MC01W08051169R
Resistor, 169R, 0.1W, 1%, 0805	MC01W08051169R
Resistor, 17K8, 0.1W, 1%, 0805, Reel	MC01W0805117K8
Resistor, 17K8, 0.1W, 1%, 0805	MC01W0805117K8
Resistor, 17R8, 0.1W, 1%, 0805, Reel	MC01W0805117R8
Resistor, 17R8, 0.1W, 1%, 0805	MC01W0805117R8
Resistor, 178K, 0.1W, 1%, 0805, Reel	MC01W08051178K
Resistor, 178K, 0.1W, 1%, 0805	MC01W08051178K
Resistor, 178R, 0.1W, 1%, 0805, Reel	MC01W08051178R
Resistor, 178R, 0.1W, 1%, 0805	MC01W08051178R
Resistor, 18K, 0.1W, 1%, 0805, Reel	MC01W0805118K
Resistor, 18K, 0.1W, 1%, 0805	MC01W0805118K
Resistor, 18R, 0.1W, 1%, 0805, Reel	MC01W0805118R
Resistor, 18R, 0.1W, 1%, 0805	MC01W0805118R
Resistor, 18K7, 0.1W, 1%, 0805, Reel	MC01W0805118K7
Resistor, 18K7, 0.1W, 1%, 0805	MC01W0805118K7
Resistor, 18R7, 0.1W, 1%, 0805, Reel	MC01W0805118R7
Resistor, 18R7, 0.1W, 1%, 0805	MC01W0805118R7
Resistor, 180K, 0.1W, 1%, 0805, Reel	MC01W08051180K
Resistor, 180K, 0.1W, 1%, 0805	MC01W08051180K
Resistor, 180R, 0.1W, 1%, 0805, Reel	MC01W08051180R
Resistor, 180R, 0.1W, 1%, 0805	MC01W08051180R
Resistor, 187K, 0.1W, 1%, 0805, Reel	MC01W08051187K
Resistor, 187K, 0.1W, 1%, 0805	MC01W08051187K
Resistor, 187R, 0.1W, 1%, 0805, Reel	MC01W08051187R
Resistor, 187R, 0.1W, 1%, 0805	MC01W08051187R

Thick Film Chip Resistor

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Description	Part Number
Resistor, 19K6, 0.1W, 1%, 0805, Reel	MC01W0805119K6
Resistor, 19K6, 0.1W, 1%, 0805	MC01W0805119K6
Resistor, 19R6, 0.1W, 1%, 0805, Reel	MC01W0805119R6
Resistor, 19R6, 0.1W, 1%, 0805	MC01W0805119R6
Resistor, 196K, 0.1W, 1%, 0805, Reel	MC01W08051196K
Resistor, 196K, 0.1W, 1%, 0805	MC01W08051196K
Resistor, 196R, 0.1W, 1%, 0805, Reel	MC01W08051196R
Resistor, 196R, 0.1W, 1%, 0805	MC01W08051196R
Resistor, 2K, 0.1W, 1%, 0805, Reel	MC01W080512K
Resistor, 2K, 0.1W, 1%, 0805	MC01W080512K
Resistor, 2M, 0.1W, 1%, 0805, Reel	MC01W080512M00
Resistor, 2M, 0.1W, 1%, 0805	MC01W080512M00
Resistor, 2R, 0.1W, 1%, 0805, Reel	MC01W080512R0
Resistor, 2R, 0.1W, 1%, 0805	MC01W080512R0
Resistor, 2K05, 0.1W, 1%, 0805, Reel	MC01W080512K05
Resistor, 2K05, 0.1W, 1%, 0805	MC01W080512K05
Resistor, 2M05, 0.1W, 1%, 0805, Reel	MC01W080512M05
Resistor, 2M05, 0.1W, 1%, 0805	MC01W080512M05
Resistor, 2K15, 0.1W, 1%, 0805, Reel	MC01W080512K15
Resistor, 2K15, 0.1W, 1%, 0805	MC01W080512K15
Resistor, 2R15, 0.1W, 1%, 0805, Reel	MC01W080512R15
Resistor, 2R15, 0.1W, 1%, 0805	MC01W080512R15
Resistor, 2K2, 0.1W, 1%, 0805, Reel	MC01W080512K2
Resistor, 2K2, 0.1W, 1%, 0805	MC01W080512K2
Resistor, 2M2, 0.1W, 1%, 0805, Reel	MC01W080512M20
Resistor, 2M2, 0.1W, 1%, 0805	MC01W080512M20
Resistor, 2R2, 0.1W, 1%, 0805, Reel	MC01W080512R2
Resistor, 2R2, 0.1W, 1%, 0805	MC01W080512R2
Resistor, 2K26, 0.1W, 1%, 0805, Reel	MC01W080512K26
Resistor, 2K26, 0.1W, 1%, 0805	MC01W080512K26
Resistor, 2R26, 0.1W, 1%, 0805, Reel	MC01W080512R26
Resistor, 2R26, 0.1W, 1%, 0805	MC01W080512R26
Resistor, 2K37, 0.1W, 1%, 0805, Reel	MC01W080512K37
Resistor, 2K37, 0.1W, 1%, 0805	MC01W080512K37
Resistor, 2M37, 0.1W, 1%, 0805, Reel	MC01W080512M37
Resistor, 2M37, 0.1W, 1%, 0805	MC01W080512M37
Resistor, 2R37, 0.1W, 1%, 0805, Reel	MC01W080512R37
Resistor, 2R37, 0.1W, 1%, 0805	MC01W080512R37
Resistor, 2K4, 0.1W, 1%, 0805, Reel	MC01W080512K4

Description	Part Number
Resistor, 2K4, 0.1W, 1%, 0805	MC01W080512K4
Resistor, 2M4, 0.1W, 1%, 0805, Reel	MC01W080512M40
Resistor, 2M4, 0.1W, 1%, 0805	MC01W080512M40
Resistor, 2R4, 0.1W, 1%, 0805, Reel	MC01W080512R40
Resistor, 2R4, 0.1W, 1%, 0805	MC01W080512R40
Resistor, 2K49, 0.1W, 1%, 0805, Reel	MC01W080512K49
Resistor, 2K49, 0.1W, 1%, 0805	MC01W080512K49
Resistor, 2M49, 0.1W, 1%, 0805, Reel	MC01W080512M49
Resistor, 2M49, 0.1W, 1%, 0805	MC01W080512M49
Resistor, 2R49, 0.1W, 1%, 0805, Reel	MC01W080512R49
Resistor, 2R49, 0.1W, 1%, 0805	MC01W080512R49
Resistor, 2K61, 0.1W, 1%, 0805, Reel	MC01W080512K61
Resistor, 2K61, 0.1W, 1%, 0805	MC01W080512K61
Resistor, 2M61, 0.1W, 1%, 0805, Reel	MC01W080512M61
Resistor, 2M61, 0.1W, 1%, 0805	MC01W080512M61
Resistor, 2R61, 0.1W, 1%, 0805, Reel	MC01W080512R61
Resistor, 2R61, 0.1W, 1%, 0805	MC01W080512R61
Resistor, 2K7, 0.1W, 1%, 0805, Reel	MC01W080512K7
Resistor, 2K7, 0.1W, 1%, 0805	MC01W080512K7
Resistor, 2M7, 0.1W, 1%, 0805, Reel	MC01W080512M70
Resistor, 2M7, 0.1W, 1%, 0805	MC01W080512M70
Resistor, 2R7, 0.1W, 1%, 0805, Reel	MC01W080512R70
Resistor, 2R7, 0.1W, 1%, 0805	MC01W080512R70
Resistor, 2K74, 0.1W, 1%, 0805, Reel	MC01W080512K74
Resistor, 2K74, 0.1W, 1%, 0805	MC01W080512K74
Resistor, 2M74, 0.1W, 1%, 0805, Reel	MC01W080512M74
Resistor, 2M74, 0.1W, 1%, 0805	MC01W080512M74
Resistor, 2R74, 0.1W, 1%, 0805, Reel	MC01W080512R74
Resistor, 2R74, 0.1W, 1%, 0805	MC01W080512R74
Resistor, 2K87, 0.1W, 1%, 0805, Reel	MC01W080512K87
Resistor, 2K87, 0.1W, 1%, 0805	MC01W080512K87
Resistor, 2R87, 0.1W, 1%, 0805, Reel	MC01W080512R87
Resistor, 2R87, 0.1W, 1%, 0805	MC01W080512R87
Resistor, 20K, 0.1W, 1%, 0805, Reel	MC01W0805120K
Resistor, 20K, 0.1W, 1%, 0805	MC01W0805120K
Resistor, 20R, 0.1W, 1%, 0805, Reel	MC01W0805120R
Resistor, 20R, 0.1W, 1%, 0805	MC01W0805120R
Resistor, 20K5, 0.1W, 1%, 0805, Reel	MC01W0805120K5
Resistor, 20K5, 0.1W, 1%, 0805	MC01W0805120K5

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Thick Film Chip Resistor

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Description	Part Number
Resistor, 20R5, 0.1W, 1%, 0805, Reel	MC01W0805120R5
Resistor, 20R5, 0.1W, 1%, 0805	MC01W0805120R5
Resistor, 200K, 0.1W, 1%, 0805, Reel	MC01W08051200K
Resistor, 200K, 0.1W, 1%, 0805	MC01W08051200K
Resistor, 200R, 0.1W, 1%, 0805, Reel	MC01W08051200R
Resistor, 200R, 0.1W, 1%, 0805	MC01W08051200R
Resistor, 205K, 0.1W, 1%, 0805, Reel	MC01W08051205K
Resistor, 205K, 0.1W, 1%, 0805	MC01W08051205K
Resistor, 205R, 0.1W, 1%, 0805, Reel	MC01W08051205R
Resistor, 205R, 0.1W, 1%, 0805	MC01W08051205R
Resistor, 21K5, 0.1W, 1%, 0805, Reel	MC01W0805121K5
Resistor, 21K5, 0.1W, 1%, 0805	MC01W0805121K5
Resistor, 21R5, 0.1W, 1%, 0805, Reel	MC01W0805121R5
Resistor, 21R5, 0.1W, 1%, 0805	MC01W0805121R5
Resistor, 215K, 0.1W, 1%, 0805, Reel	MC01W08051215K
Resistor, 215K, 0.1W, 1%, 0805	MC01W08051215K
Resistor, 215R, 0.1W, 1%, 0805, Reel	MC01W08051215R
Resistor, 215R, 0.1W, 1%, 0805	MC01W08051215R
Resistor, 22K, 0.1W, 1%, 0805, Reel	MC01W0805122K
Resistor, 22K, 0.1W, 1%, 0805	MC01W0805122K
Resistor, 22R, 0.1W, 1%, 0805, Reel	MC01W0805122R
Resistor, 22R, 0.1W, 1%, 0805	MC01W0805122R
Resistor, 22K6, 0.1W, 1%, 0805, Reel	MC01W0805122K6
Resistor, 22K6, 0.1W, 1%, 0805	MC01W0805122K6
Resistor, 22R6, 0.1W, 1%, 0805, Reel	MC01W0805122R6
Resistor, 22R6, 0.1W, 1%, 0805	MC01W0805122R6
Resistor, 220K, 0.1W, 1%, 0805, Reel	MC01W08051220K
Resistor, 220K, 0.1W, 1%, 0805	MC01W08051220K
Resistor, 220R, 0.1W, 1%, 0805, Reel	MC01W08051220R
Resistor, 220R, 0.1W, 1%, 0805	MC01W08051220R
Resistor, 226K, 0.1W, 1%, 0805, Reel	MC01W08051226K
Resistor, 226K, 0.1W, 1%, 0805	MC01W08051226K
Resistor, 226R, 0.1W, 1%, 0805, Reel	MC01W08051226R
Resistor, 226R, 0.1W, 1%, 0805	MC01W08051226R
Resistor, 23K7, 0.1W, 1%, 0805, Reel	MC01W0805123K7
Resistor, 23K7, 0.1W, 1%, 0805	MC01W0805123K7
Resistor, 23R7, 0.1W, 1%, 0805, Reel	MC01W0805123R7
Resistor, 23R7, 0.1W, 1%, 0805	MC01W0805123R7
Resistor, 237K, 0.1W, 1%, 0805, Reel	MC01W08051237K

Description	Part Number
Resistor, 237K, 0.1W, 1%, 0805	MC01W08051237K
Resistor, 237R, 0.1W, 1%, 0805, Reel	MC01W08051237R
Resistor, 237R, 0.1W, 1%, 0805	MC01W08051237R
Resistor, 24K, 0.1W, 1%, 0805, Reel	MC01W0805124K
Resistor, 24K, 0.1W, 1%, 0805	MC01W0805124K
Resistor, 24R, 0.1W, 1%, 0805, Reel	MC01W0805124R
Resistor, 24R, 0.1W, 1%, 0805	MC01W0805124R
Resistor, 24K9, 0.1W, 1%, 0805, Reel	MC01W0805124K9
Resistor, 24K9, 0.1W, 1%, 0805	MC01W0805124K9
Resistor, 24R9, 0.1W, 1%, 0805, Reel	MC01W0805124R9
Resistor, 24R9, 0.1W, 1%, 0805	MC01W0805124R9
Resistor, 240K, 0.1W, 1%, 0805, Reel	MC01W08051240K
Resistor, 240K, 0.1W, 1%, 0805	MC01W08051240K
Resistor, 240R, 0.1W, 1%, 0805, Reel	MC01W08051240R
Resistor, 240R, 0.1W, 1%, 0805	MC01W08051240R
Resistor, 249K, 0.1W, 1%, 0805, Reel	MC01W08051249K
Resistor, 249K, 0.1W, 1%, 0805	MC01W08051249K
Resistor, 249R, 0.1W, 1%, 0805, Reel	MC01W08051249R
Resistor, 249R, 0.1W, 1%, 0805	MC01W08051249R
Resistor, 26K1, 0.1W, 1%, 0805, Reel	MC01W0805126K1
Resistor, 26K1, 0.1W, 1%, 0805	MC01W0805126K1
Resistor, 26R1, 0.1W, 1%, 0805, Reel	MC01W0805126R1
Resistor, 26R1, 0.1W, 1%, 0805	MC01W0805126R1
Resistor, 261K, 0.1W, 1%, 0805, Reel	MC01W08051261K
Resistor, 261K, 0.1W, 1%, 0805	MC01W08051261K
Resistor, 261R, 0.1W, 1%, 0805, Reel	MC01W08051261R
Resistor, 261R, 0.1W, 1%, 0805	MC01W08051261R
Resistor, 27K, 0.1W, 1%, 0805, Reel	MC01W0805127K
Resistor, 27K, 0.1W, 1%, 0805	MC01W0805127K
Resistor, 27R, 0.1W, 1%, 0805, Reel	MC01W0805127R
Resistor, 27R, 0.1W, 1%, 0805	MC01W0805127R
Resistor, 27K4, 0.1W, 1%, 0805, Reel	MC01W0805127K4
Resistor, 27K4, 0.1W, 1%, 0805	MC01W0805127K4
Resistor, 27R4, 0.1W, 1%, 0805, Reel	MC01W0805127R4
Resistor, 27R4, 0.1W, 1%, 0805	MC01W0805127R4
Resistor, 270K, 0.1W, 1%, 0805, Reel	MC01W08051270K
Resistor, 270K, 0.1W, 1%, 0805	MC01W08051270K
Resistor, 270R, 0.1W, 1%, 0805, Reel	MC01W08051270R
Resistor, 270R, 0.1W, 1%, 0805	MC01W08051270R

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Description	Part Number
Resistor, 274K, 0.1W, 1%, 0805, Reel	MC01W08051274K
Resistor, 274K, 0.1W, 1%, 0805	MC01W08051274K
Resistor, 274R, 0.1W, 1%, 0805, Reel	MC01W08051274R
Resistor, 274R, 0.1W, 1%, 0805	MC01W08051274R
Resistor, 28K7, 0.1W, 1%, 0805, Reel	MC01W0805128K7
Resistor, 28K7, 0.1W, 1%, 0805	MC01W0805128K7
Resistor, 28R7, 0.1W, 1%, 0805, Reel	MC01W0805128R7
Resistor, 28R7, 0.1W, 1%, 0805	MC01W0805128R7
Resistor, 287K, 0.1W, 1%, 0805, Reel	MC01W08051287K
Resistor, 287K, 0.1W, 1%, 0805	MC01W08051287K
Resistor, 287R, 0.1W, 1%, 0805, Reel	MC01W08051287R
Resistor, 287R, 0.1W, 1%, 0805	MC01W08051287R
Resistor, 3K, 0.1W, 1%, 0805, Reel	MC01W080513K
Resistor, 3K, 0.1W, 1%, 0805	MC01W080513K
Resistor, 3M, 0.1W, 1%, 0805, Reel	MC01W080513M00
Resistor, 3M, 0.1W, 1%, 0805	MC01W080513M00
Resistor, 3R, 0.1W, 1%, 0805, Reel	MC01W080513R0
Resistor, 3R, 0.1W, 1%, 0805	MC01W080513R0
Resistor, 3K01, 0.1W, 1%, 0805, Reel	MC01W080513K01
Resistor, 3K01, 0.1W, 1%, 0805	MC01W080513K01
Resistor, 3M01, 0.1W, 1%, 0805, Reel	MC01W080513M01
Resistor, 3M01, 0.1W, 1%, 0805	MC01W080513M01
Resistor, 3K16, 0.1W, 1%, 0805, Reel	MC01W080513K16
Resistor, 3K16, 0.1W, 1%, 0805	MC01W080513K16
Resistor, 3M16, 0.1W, 1%, 0805, Reel	MC01W080513M16
Resistor, 3M16, 0.1W, 1%, 0805	MC01W080513M16
Resistor, 3R16, 0.1W, 1%, 0805, Reel	MC01W080513R16
Resistor, 3R16, 0.1W, 1%, 0805	MC01W080513R16
Resistor, 3K3, 0.1W, 1%, 0805, Reel	MC01W080513K3
Resistor, 3K3, 0.1W, 1%, 0805	MC01W080513K3
Resistor, 3M3, 0.1W, 1%, 0805, Reel	MC01W080513M30
Resistor, 3M3, 0.1W, 1%, 0805	MC01W080513M30
Resistor, 3R3, 0.1W, 1%, 0805, Reel	MC01W080513R3
Resistor, 3R3, 0.1W, 1%, 0805	MC01W080513R3
Resistor, 3K32, 0.1W, 1%, 0805, Reel	MC01W080513K32
Resistor, 3K32, 0.1W, 1%, 0805	MC01W080513K32
Resistor, 3M32, 0.1W, 1%, 0805, Reel	MC01W080513M32
Resistor, 3M32, 0.1W, 1%, 0805	MC01W080513M32
Resistor, 3R32, 0.1W, 1%, 0805, Reel	MC01W080513R32

Description	Part Number
Resistor, 3R32, 0.1W, 1%, 0805	MC01W080513R32
Resistor, 3K48, 0.1W, 1%, 0805, Reel	MC01W080513K48
Resistor, 3K48, 0.1W, 1%, 0805	MC01W080513K48
Resistor, 3M48, 0.1W, 1%, 0805, Reel	MC01W080513M48
Resistor, 3M48, 0.1W, 1%, 0805	MC01W080513M48
Resistor, 3R48, 0.1W, 1%, 0805, Reel	MC01W080513R48
Resistor, 3R48, 0.1W, 1%, 0805	MC01W080513R48
Resistor, 3K6, 0.1W, 1%, 0805, Reel	MC01W080513K6
Resistor, 3K6, 0.1W, 1%, 0805	MC01W080513K6
Resistor, 3M6, 0.1W, 1%, 0805, Reel	MC01W080513M60
Resistor, 3M6, 0.1W, 1%, 0805	MC01W080513M60
Resistor, 3R6, 0.1W, 1%, 0805, Reel	MC01W080513R60
Resistor, 3R6, 0.1W, 1%, 0805	MC01W080513R60
Resistor, 3K65, 0.1W, 1%, 0805, Reel	MC01W080513K65
Resistor, 3K65, 0.1W, 1%, 0805	MC01W080513K65
Resistor, 3M65, 0.1W, 1%, 0805, Reel	MC01W080513M65
Resistor, 3M65, 0.1W, 1%, 0805	MC01W080513M65
Resistor, 3R65, 0.1W, 1%, 0805, Reel	MC01W080513R65
Resistor, 3R65, 0.1W, 1%, 0805	MC01W080513R65
Resistor, 3K83, 0.1W, 1%, 0805, Reel	MC01W080513K83
Resistor, 3K83, 0.1W, 1%, 0805	MC01W080513K83
Resistor, 3M83, 0.1W, 1%, 0805, Reel	MC01W080513M83
Resistor, 3M83, 0.1W, 1%, 0805	MC01W080513M83
Resistor, 3R83, 0.1W, 1%, 0805, Reel	MC01W080513R83
Resistor, 3R83, 0.1W, 1%, 0805	MC01W080513R83
Resistor, 3K9, 0.1W, 1%, 0805, Reel	MC01W080513K9
Resistor, 3K9, 0.1W, 1%, 0805	MC01W080513K9
Resistor, 3M9, 0.1W, 1%, 0805, Reel	MC01W080513M90
Resistor, 3M9, 0.1W, 1%, 0805	MC01W080513M90
Resistor, 3R9, 0.1W, 1%, 0805, Reel	MC01W080513R90
Resistor, 3R9, 0.1W, 1%, 0805	MC01W080513R90
Resistor, 30K, 0.1W, 1%, 0805, Reel	MC01W0805130K
Resistor, 30K, 0.1W, 1%, 0805	MC01W0805130K
Resistor, 30R, 0.1W, 1%, 0805, Reel	MC01W0805130R
Resistor, 30R, 0.1W, 1%, 0805	MC01W0805130R
Resistor, 30K1, 0.1W, 1%, 0805, Reel	MC01W0805130K1
Resistor, 30K1, 0.1W, 1%, 0805	MC01W0805130K1
Resistor, 30R1, 0.1W, 1%, 0805, Reel	MC01W0805130R1
Resistor, 30R1, 0.1W, 1%, 0805	MC01W0805130R1

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Description	Part Number
Resistor, 300K, 0.1W, 1%, 0805, Reel	MC01W08051300K
Resistor, 300K, 0.1W, 1%, 0805	MC01W08051300K
Resistor, 300R, 0.1W, 1%, 0805, Reel	MC01W08051300R
Resistor, 300R, 0.1W, 1%, 0805	MC01W08051300R
Resistor, 301K, 0.1W, 1%, 0805, Reel	MC01W08051301K
Resistor, 301K, 0.1W, 1%, 0805	MC01W08051301K
Resistor, 301R, 0.1W, 1%, 0805, Reel	MC01W08051301R
Resistor, 301R, 0.1W, 1%, 0805	MC01W08051301R
Resistor, 31K6, 0.1W, 1%, 0805, Reel	MC01W0805131K6
Resistor, 31K6, 0.1W, 1%, 0805	MC01W0805131K6
Resistor, 31R6, 0.1W, 1%, 0805, Reel	MC01W0805131R6
Resistor, 31R6, 0.1W, 1%, 0805	MC01W0805131R6
Resistor, 316K, 0.1W, 1%, 0805, Reel	MC01W08051316K
Resistor, 316K, 0.1W, 1%, 0805	MC01W08051316K
Resistor, 316R, 0.1W, 1%, 0805, Reel	MC01W08051316R
Resistor, 316R, 0.1W, 1%, 0805	MC01W08051316R
Resistor, 33K, 0.1W, 1%, 0805, Reel	MC01W0805133K
Resistor, 33K, 0.1W, 1%, 0805	MC01W0805133K
Resistor, 33R, 0.1W, 1%, 0805, Reel	MC01W0805133R
Resistor, 33R, 0.1W, 1%, 0805	MC01W0805133R
Resistor, 33K2, 0.1W, 1%, 0805, Reel	MC01W0805133K2
Resistor, 33K2, 0.1W, 1%, 0805	MC01W0805133K2
Resistor, 33R2, 0.1W, 1%, 0805, Reel	MC01W0805133R2
Resistor, 33R2, 0.1W, 1%, 0805	MC01W0805133R2
Resistor, 330K, 0.1W, 1%, 0805, Reel	MC01W08051330K
Resistor, 330K, 0.1W, 1%, 0805	MC01W08051330K
Resistor, 330R, 0.1W, 1%, 0805, Reel	MC01W08051330R
Resistor, 330R, 0.1W, 1%, 0805	MC01W08051330R
Resistor, 332K, 0.1W, 1%, 0805, Reel	MC01W08051332K
Resistor, 332K, 0.1W, 1%, 0805	MC01W08051332K
Resistor, 332R, 0.1W, 1%, 0805, Reel	MC01W08051332R
Resistor, 332R, 0.1W, 1%, 0805	MC01W08051332R
Resistor, 34K8, 0.1W, 1%, 0805, Reel	MC01W0805134K8
Resistor, 34K8, 0.1W, 1%, 0805	MC01W0805134K8
Resistor, 34R8, 0.1W, 1%, 0805, Reel	MC01W0805134R8
Resistor, 34R8, 0.1W, 1%, 0805	MC01W0805134R8
Resistor, 348K, 0.1W, 1%, 0805, Reel	MC01W08051348K
Resistor, 348K, 0.1W, 1%, 0805	MC01W08051348K
Resistor, 348R, 0.1W, 1%, 0805, Reel	MC01W08051348R

Description	Part Number
Resistor, 348R, 0.1W, 1%, 0805	MC01W08051348R
Resistor, 36K, 0.1W, 1%, 0805, Reel	MC01W0805136K
Resistor, 36K, 0.1W, 1%, 0805	MC01W0805136K
Resistor, 36R, 0.1W, 1%, 0805, Reel	MC01W0805136R
Resistor, 36R, 0.1W, 1%, 0805	MC01W0805136R
Resistor, 36K5, 0.1W, 1%, 0805, Reel	MC01W0805136K5
Resistor, 36K5, 0.1W, 1%, 0805	MC01W0805136K5
Resistor, 36R5, 0.1W, 1%, 0805, Reel	MC01W0805136R5
Resistor, 36R5, 0.1W, 1%, 0805	MC01W0805136R5
Resistor, 360K, 0.1W, 1%, 0805, Reel	MC01W08051360K
Resistor, 360K, 0.1W, 1%, 0805	MC01W08051360K
Resistor, 360R, 0.1W, 1%, 0805, Reel	MC01W08051360R
Resistor, 360R, 0.1W, 1%, 0805	MC01W08051360R
Resistor, 365K, 0.1W, 1%, 0805, Reel	MC01W08051365K
Resistor, 365K, 0.1W, 1%, 0805	MC01W08051365K
Resistor, 365R, 0.1W, 1%, 0805, Reel	MC01W08051365R
Resistor, 365R, 0.1W, 1%, 0805	MC01W08051365R
Resistor, 38K3, 0.1W, 1%, 0805, Reel	MC01W0805138K3
Resistor, 38K3, 0.1W, 1%, 0805	MC01W0805138K3
Resistor, 38R3, 0.1W, 1%, 0805, Reel	MC01W0805138R3
Resistor, 38R3, 0.1W, 1%, 0805	MC01W0805138R3
Resistor, 383K, 0.1W, 1%, 0805, Reel	MC01W08051383K
Resistor, 383K, 0.1W, 1%, 0805	MC01W08051383K
Resistor, 383R, 0.1W, 1%, 0805, Reel	MC01W08051383R
Resistor, 383R, 0.1W, 1%, 0805	MC01W08051383R
Resistor, 39K, 0.1W, 1%, 0805, Reel	MC01W0805139K
Resistor, 39K, 0.1W, 1%, 0805	MC01W0805139K
Resistor, 39R, 0.1W, 1%, 0805, Reel	MC01W0805139R
Resistor, 39R, 0.1W, 1%, 0805	MC01W0805139R
Resistor, 390K, 0.1W, 1%, 0805, Reel	MC01W08051390K
Resistor, 390K, 0.1W, 1%, 0805	MC01W08051390K
Resistor, 390R, 0.1W, 1%, 0805, Reel	MC01W08051390R
Resistor, 390R, 0.1W, 1%, 0805	MC01W08051390R
Resistor, 4K02, 0.1W, 1%, 0805, Reel	MC01W080514K02
Resistor, 4K02, 0.1W, 1%, 0805	MC01W080514K02
Resistor, 4M02, 0.1W, 1%, 0805, Reel	MC01W080514M02
Resistor, 4M02, 0.1W, 1%, 0805	MC01W080514M02
Resistor, 4K22, 0.1W, 1%, 0805, Reel	MC01W080514K22
Resistor, 4K22, 0.1W, 1%, 0805	MC01W080514K22

Thick Film Chip Resistor

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Description	Part Number
Resistor, 4R22, 0.1W, 1%, 0805, Reel	MC01W080514R22
Resistor, 4R22, 0.1W, 1%, 0805	MC01W080514R22
Resistor, 4K3, 0.1W, 1%, 0805, Reel	MC01W080514K3
Resistor, 4K3, 0.1W, 1%, 0805	MC01W080514K3
Resistor, 4M3, 0.1W, 1%, 0805, Reel	MC01W080514M30
Resistor, 4M3, 0.1W, 1%, 0805	MC01W080514M30
Resistor, 4R3, 0.1W, 1%, 0805, Reel	MC01W080514R30
Resistor, 4R3, 0.1W, 1%, 0805	MC01W080514R30
Resistor, 4K42, 0.1W, 1%, 0805, Reel	MC01W080514K42
Resistor, 4K42, 0.1W, 1%, 0805	MC01W080514K42
Resistor, 4M42, 0.1W, 1%, 0805, Reel	MC01W080514M42
Resistor, 4M42, 0.1W, 1%, 0805	MC01W080514M42
Resistor, 4R42, 0.1W, 1%, 0805, Reel	MC01W080514R42
Resistor, 4R42, 0.1W, 1%, 0805	MC01W080514R42
Resistor, 4K64, 0.1W, 1%, 0805, Reel	MC01W080514K64
Resistor, 4K64, 0.1W, 1%, 0805	MC01W080514K64
Resistor, 4M64, 0.1W, 1%, 0805, Reel	MC01W080514M64
Resistor, 4M64, 0.1W, 1%, 0805	MC01W080514M64
Resistor, 4R64, 0.1W, 1%, 0805, Reel	MC01W080514R64
Resistor, 4R64, 0.1W, 1%, 0805	MC01W080514R64
Resistor, 4K7, 0.1W, 1%, 0805, Reel	MC01W080514K7
Resistor, 4K7, 0.1W, 1%, 0805	MC01W080514K7
Resistor, 4M7, 0.1W, 1%, 0805, Reel	MC01W080514M70
Resistor, 4M7, 0.1W, 1%, 0805	MC01W080514M70
Resistor, 4R7, 0.1W, 1%, 0805, Reel	MC01W080514R7
Resistor, 4R7, 0.1W, 1%, 0805	MC01W080514R7
Resistor, 4K75, 0.1W, 1%, 0805, Reel	MC01W080514K75
Resistor, 4K75, 0.1W, 1%, 0805	MC01W080514K75
Resistor, 4K87, 0.1W, 1%, 0805, Reel	MC01W080514K87
Resistor, 4K87, 0.1W, 1%, 0805	MC01W080514K87
Resistor, 4R87, 0.1W, 1%, 0805, Reel	MC01W080514R87
Resistor, 4R87, 0.1W, 1%, 0805	MC01W080514R87
Resistor, 4K99, 0.1W, 1%, 0805, Reel	MC01W080514K99
Resistor, 4K99, 0.1W, 1%, 0805	MC01W080514K99
Resistor, 40K2, 0.1W, 1%, 0805, Reel	MC01W0805140K2
Resistor, 40K2, 0.1W, 1%, 0805	MC01W0805140K2
Resistor, 40R2, 0.1W, 1%, 0805, Reel	MC01W0805140R2
Resistor, 40R2, 0.1W, 1%, 0805	MC01W0805140R2
Resistor, 402K, 0.1W, 1%, 0805, Reel	MC01W08051402K

Description	Part Number
Resistor, 402K, 0.1W, 1%, 0805	MC01W08051402K
Resistor, 402R, 0.1W, 1%, 0805, Reel	MC01W08051402R
Resistor, 402R, 0.1W, 1%, 0805	MC01W08051402R
Resistor, 42K2, 0.1W, 1%, 0805, Reel	MC01W0805142K2
Resistor, 42K2, 0.1W, 1%, 0805	MC01W0805142K2
Resistor, 42R2, 0.1W, 1%, 0805, Reel	MC01W0805142R2
Resistor, 42R2, 0.1W, 1%, 0805	MC01W0805142R2
Resistor, 422K, 0.1W, 1%, 0805, Reel	MC01W08051422K
Resistor, 422K, 0.1W, 1%, 0805	MC01W08051422K
Resistor, 422R, 0.1W, 1%, 0805, Reel	MC01W08051422R
Resistor, 422R, 0.1W, 1%, 0805	MC01W08051422R
Resistor, 43K, 0.1W, 1%, 0805, Reel	MC01W0805143K
Resistor, 43K, 0.1W, 1%, 0805	MC01W0805143K
Resistor, 43R, 0.1W, 1%, 0805, Reel	MC01W0805143R
Resistor, 43R, 0.1W, 1%, 0805	MC01W0805143R
Resistor, 430K, 0.1W, 1%, 0805, Reel	MC01W08051430K
Resistor, 430K, 0.1W, 1%, 0805	MC01W08051430K
Resistor, 430R, 0.1W, 1%, 0805, Reel	MC01W08051430R
Resistor, 430R, 0.1W, 1%, 0805	MC01W08051430R
Resistor, 44K2, 0.1W, 1%, 0805, Reel	MC01W0805144K2
Resistor, 44K2, 0.1W, 1%, 0805	MC01W0805144K2
Resistor, 44R2, 0.1W, 1%, 0805, Reel	MC01W0805144R2
Resistor, 44R2, 0.1W, 1%, 0805	MC01W0805144R2
Resistor, 442K, 0.1W, 1%, 0805, Reel	MC01W08051442K
Resistor, 442K, 0.1W, 1%, 0805	MC01W08051442K
Resistor, 442R, 0.1W, 1%, 0805, Reel	MC01W08051442R
Resistor, 442R, 0.1W, 1%, 0805	MC01W08051442R
Resistor, 46K4, 0.1W, 1%, 0805, Reel	MC01W0805146K4
Resistor, 46K4, 0.1W, 1%, 0805	MC01W0805146K4
Resistor, 46R4, 0.1W, 1%, 0805, Reel	MC01W0805146R4
Resistor, 46R4, 0.1W, 1%, 0805	MC01W0805146R4
Resistor, 464K, 0.1W, 1%, 0805, Reel	MC01W08051464K
Resistor, 464K, 0.1W, 1%, 0805	MC01W08051464K
Resistor, 464R, 0.1W, 1%, 0805, Reel	MC01W08051464R
Resistor, 464R, 0.1W, 1%, 0805	MC01W08051464R
Resistor, 47K, 0.1W, 1%, 0805, Reel	MC01W0805147K
Resistor, 47K, 0.1W, 1%, 0805	MC01W0805147K
Resistor, 47R, 0.1W, 1%, 0805, Reel	MC01W0805147R
Resistor, 47R, 0.1W, 1%, 0805	MC01W0805147R

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Description	Part Number
Resistor, 47K5, 0.1W, 1%, 0805, Reel	MC01W0805147K5
Resistor, 47K5, 0.1W, 1%, 0805	MC01W0805147K5
Resistor, 470K, 0.1W, 1%, 0805, Reel	MC01W08051470K
Resistor, 470K, 0.1W, 1%, 0805	MC01W08051470K
Resistor, 470R, 0.1W, 1%, 0805, Reel	MC01W08051470R
Resistor, 470R, 0.1W, 1%, 0805	MC01W08051470R
Resistor, 475R, 0.1W, 1%, 0805, Reel	MC01W08051475R
Resistor, 475R, 0.1W, 1%, 0805	MC01W08051475R
Resistor, 48K7, 0.1W, 1%, 0805, Reel	MC01W0805148K7
Resistor, 48K7, 0.1W, 1%, 0805	MC01W0805148K7
Resistor, 48R7, 0.1W, 1%, 0805, Reel	MC01W0805148R7
Resistor, 48R7, 0.1W, 1%, 0805	MC01W0805148R7
Resistor, 487K, 0.1W, 1%, 0805, Reel	MC01W08051487K
Resistor, 487K, 0.1W, 1%, 0805	MC01W08051487K
Resistor, 487R, 0.1W, 1%, 0805, Reel	MC01W08051487R
Resistor, 487R, 0.1W, 1%, 0805	MC01W08051487R
Resistor, 49K9, 0.1W, 1%, 0805, Reel	MC01W0805149K9
Resistor, 49K9, 0.1W, 1%, 0805	MC01W0805149K9
Resistor, 49R9, 0.1W, 1%, 0805, Reel	MC01W0805149R9
Resistor, 49R9, 0.1W, 1%, 0805	MC01W0805149R9
Resistor, 499K, 0.1W, 1%, 0805, Reel	MC01W08051499K
Resistor, 499K, 0.1W, 1%, 0805	MC01W08051499K
Resistor, 5K1, 0.1W, 1%, 0805, Reel	MC01W080515K1
Resistor, 5K1, 0.1W, 1%, 0805	MC01W080515K1
Resistor, 5M1, 0.1W, 1%, 0805, Reel	MC01W080515M10
Resistor, 5M1, 0.1W, 1%, 0805	MC01W080515M10
Resistor, 5R1, 0.1W, 1%, 0805, Reel	MC01W080515R10
Resistor, 5R1, 0.1W, 1%, 0805	MC01W080515R10
Resistor, 5K11, 0.1W, 1%, 0805, Reel	MC01W080515K11
Resistor, 5K11, 0.1W, 1%, 0805	MC01W080515K11
Resistor, 5M11, 0.1W, 1%, 0805, Reel	MC01W080515M11
Resistor, 5M11, 0.1W, 1%, 0805	MC01W080515M11
Resistor, 5R11, 0.1W, 1%, 0805, Reel	MC01W080515R11
Resistor, 5R11, 0.1W, 1%, 0805	MC01W080515R11
Resistor, 5K36, 0.1W, 1%, 0805, Reel	MC01W080515K36
Resistor, 5K36, 0.1W, 1%, 0805	MC01W080515K36
Resistor, 5R36, 0.1W, 1%, 0805, Reel	MC01W080515R36
Resistor, 5R36, 0.1W, 1%, 0805	MC01W080515R36
Resistor, 5K6, 0.1W, 1%, 0805, Reel	MC01W080515K6

Description	Part Number
Resistor, 5K6, 0.1W, 1%, 0805	MC01W080515K6
Resistor, 5M6, 0.1W, 1%, 0805, Reel	MC01W080515M60
Resistor, 5M6, 0.1W, 1%, 0805	MC01W080515M60
Resistor, 5R6, 0.1W, 1%, 0805, Reel	MC01W080515R60
Resistor, 5R6, 0.1W, 1%, 0805	MC01W080515R60
Resistor, 5K62, 0.1W, 1%, 0805, Reel	MC01W080515K62
Resistor, 5K62, 0.1W, 1%, 0805	MC01W080515K62
Resistor, 5R62, 0.1W, 1%, 0805, Reel	MC01W080515R62
Resistor, 5R62, 0.1W, 1%, 0805	MC01W080515R62
Resistor, 5K9, 0.1W, 1%, 0805, Reel	MC01W080515K90
Resistor, 5K9, 0.1W, 1%, 0805	MC01W080515K90
Resistor, 5M9, 0.1W, 1%, 0805, Reel	MC01W080515M90
Resistor, 5M9, 0.1W, 1%, 0805	MC01W080515M90
Resistor, 5R9, 0.1W, 1%, 0805, Reel	MC01W080515R90
Resistor, 5R9, 0.1W, 1%, 0805	MC01W080515R90
Resistor, 51K, 0.1W, 1%, 0805, Reel	MC01W0805151K
Resistor, 51K, 0.1W, 1%, 0805	MC01W0805151K
Resistor, 51R, 0.1W, 1%, 0805, Reel	MC01W0805151R
Resistor, 51R, 0.1W, 1%, 0805	MC01W0805151R
Resistor, 51K1, 0.1W, 1%, 0805, Reel	MC01W0805151K1
Resistor, 51K1, 0.1W, 1%, 0805	MC01W0805151K1
Resistor, 51R1, 0.1W, 1%, 0805, Reel	MC01W0805151R1
Resistor, 51R1, 0.1W, 1%, 0805	MC01W0805151R1
Resistor, 510K, 0.1W, 1%, 0805, Reel	MC01W08051510K
Resistor, 510K, 0.1W, 1%, 0805	MC01W08051510K
Resistor, 510R, 0.1W, 1%, 0805, Reel	MC01W08051510R
Resistor, 510R, 0.1W, 1%, 0805	MC01W08051510R
Resistor, 511K, 0.1W, 1%, 0805, Reel	MC01W08051511K
Resistor, 511K, 0.1W, 1%, 0805	MC01W08051511K
Resistor, 511R, 0.1W, 1%, 0805, Reel	MC01W08051511R
Resistor, 511R, 0.1W, 1%, 0805	MC01W08051511R
Resistor, 53K6, 0.1W, 1%, 0805, Reel	MC01W0805153K6
Resistor, 53K6, 0.1W, 1%, 0805	MC01W0805153K6
Resistor, 53R6, 0.1W, 1%, 0805, Reel	MC01W0805153R6
Resistor, 53R6, 0.1W, 1%, 0805	MC01W0805153R6
Resistor, 536K, 0.1W, 1%, 0805, Reel	MC01W08051536K
Resistor, 536K, 0.1W, 1%, 0805	MC01W08051536K
Resistor, 536R, 0.1W, 1%, 0805, Reel	MC01W08051536R
Resistor, 536R, 0.1W, 1%, 0805	MC01W08051536R

Thick Film Chip Resistor

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Description	Part Number
Resistor, 56K, 0.1W, 1%, 0805, Reel	MC01W0805156K
Resistor, 56K, 0.1W, 1%, 0805	MC01W0805156K
Resistor, 56R, 0.1W, 1%, 0805, Reel	MC01W0805156R
Resistor, 56R, 0.1W, 1%, 0805	MC01W0805156R
Resistor, 56K2, 0.1W, 1%, 0805, Reel	MC01W0805156K2
Resistor, 56K2, 0.1W, 1%, 0805	MC01W0805156K2
Resistor, 56R2, 0.1W, 1%, 0805, Reel	MC01W0805156R2
Resistor, 56R2, 0.1W, 1%, 0805	MC01W0805156R2
Resistor, 560K, 0.1W, 1%, 0805, Reel	MC01W08051560K
Resistor, 560K, 0.1W, 1%, 0805	MC01W08051560K
Resistor, 560R, 0.1W, 1%, 0805, Reel	MC01W08051560R
Resistor, 560R, 0.1W, 1%, 0805	MC01W08051560R
Resistor, 562K, 0.1W, 1%, 0805, Reel	MC01W08051562K
Resistor, 562K, 0.1W, 1%, 0805	MC01W08051562K
Resistor, 562R, 0.1W, 1%, 0805, Reel	MC01W08051562R
Resistor, 562R, 0.1W, 1%, 0805	MC01W08051562R
Resistor, 59K, 0.1W, 1%, 0805, Reel	MC01W0805159K0
Resistor, 59K, 0.1W, 1%, 0805	MC01W0805159K0
Resistor, 59R, 0.1W, 1%, 0805, Reel	MC01W0805159R0
Resistor, 59R, 0.1W, 1%, 0805	MC01W0805159R0
Resistor, 590K, 0.1W, 1%, 0805, Reel	MC01W08051590K
Resistor, 590K, 0.1W, 1%, 0805	MC01W08051590K
Resistor, 590R, 0.1W, 1%, 0805, Reel	MC01W08051590R
Resistor, 590R, 0.1W, 1%, 0805	MC01W08051590R
Resistor, 6K04, 0.1W, 1%, 0805, Reel	MC01W080516K04
Resistor, 6K04, 0.1W, 1%, 0805	MC01W080516K04
Resistor, 6K19, 0.1W, 1%, 0805, Reel	MC01W080516K19
Resistor, 6K19, 0.1W, 1%, 0805	MC01W080516K19
Resistor, 6R19, 0.1W, 1%, 0805, Reel	MC01W080516R19
Resistor, 6R19, 0.1W, 1%, 0805	MC01W080516R19
Resistor, 6K2, 0.1W, 1%, 0805, Reel	MC01W080516K2
Resistor, 6K2, 0.1W, 1%, 0805	MC01W080516K2
Resistor, 6M2, 0.1W, 1%, 0805, Reel	MC01W080516M20
Resistor, 6M2, 0.1W, 1%, 0805	MC01W080516M20
Resistor, 6R2, 0.1W, 1%, 0805, Reel	MC01W080516R20
Resistor, 6R2, 0.1W, 1%, 0805	MC01W080516R20
Resistor, 6K49, 0.1W, 1%, 0805, Reel	MC01W080516K49
Resistor, 6K49, 0.1W, 1%, 0805	MC01W080516K49
Resistor, 6M49, 0.1W, 1%, 0805, Reel	MC01W080516M49

Description	Part Number
Resistor, 6M49, 0.1W, 1%, 0805	MC01W080516M49
Resistor, 6R49, 0.1W, 1%, 0805, Reel	MC01W080516R49
Resistor, 6R49, 0.1W, 1%, 0805	MC01W080516R49
Resistor, 6K8, 0.1W, 1%, 0805, Reel	MC01W080516K8
Resistor, 6K8, 0.1W, 1%, 0805	MC01W080516K8
Resistor, 6M8, 0.1W, 1%, 0805, Reel	MC01W080516M80
Resistor, 6M8, 0.1W, 1%, 0805	MC01W080516M80
Resistor, 6R8, 0.1W, 1%, 0805, Reel	MC01W080516R8
Resistor, 6R8, 0.1W, 1%, 0805	MC01W080516R8
Resistor, 6K81, 0.1W, 1%, 0805, Reel	MC01W080516K81
Resistor, 6K81, 0.1W, 1%, 0805	MC01W080516K81
Resistor, 6M81, 0.1W, 1%, 0805, Reel	MC01W080516M81
Resistor, 6M81, 0.1W, 1%, 0805	MC01W080516M81
Resistor, 6R81, 0.1W, 1%, 0805, Reel	MC01W080516R81
Resistor, 6R81, 0.1W, 1%, 0805	MC01W080516R81
Resistor, 61K9, 0.1W, 1%, 0805, Reel	MC01W0805161K9
Resistor, 61K9, 0.1W, 1%, 0805	MC01W0805161K9
Resistor, 61R9, 0.1W, 1%, 0805, Reel	MC01W0805161R9
Resistor, 61R9, 0.1W, 1%, 0805	MC01W0805161R9
Resistor, 619K, 0.1W, 1%, 0805, Reel	MC01W08051619K
Resistor, 619K, 0.1W, 1%, 0805	MC01W08051619K
Resistor, 619R, 0.1W, 1%, 0805, Reel	MC01W08051619R
Resistor, 619R, 0.1W, 1%, 0805	MC01W08051619R
Resistor, 62K, 0.1W, 1%, 0805, Reel	MC01W0805162K
Resistor, 62K, 0.1W, 1%, 0805	MC01W0805162K
Resistor, 62R, 0.1W, 1%, 0805, Reel	MC01W0805162R
Resistor, 62R, 0.1W, 1%, 0805	MC01W0805162R
Resistor, 620K, 0.1W, 1%, 0805, Reel	MC01W08051620K
Resistor, 620K, 0.1W, 1%, 0805	MC01W08051620K
Resistor, 620R, 0.1W, 1%, 0805, Reel	MC01W08051620R
Resistor, 620R, 0.1W, 1%, 0805	MC01W08051620R
Resistor, 64K9, 0.1W, 1%, 0805, Reel	MC01W0805164K9
Resistor, 64K9, 0.1W, 1%, 0805	MC01W0805164K9
Resistor, 64R9, 0.1W, 1%, 0805, Reel	MC01W0805164R9
Resistor, 64R9, 0.1W, 1%, 0805	MC01W0805164R9
Resistor, 649K, 0.1W, 1%, 0805, Reel	MC01W08051649K
Resistor, 649K, 0.1W, 1%, 0805	MC01W08051649K
Resistor, 649R, 0.1W, 1%, 0805, Reel	MC01W08051649R
Resistor, 649R, 0.1W, 1%, 0805	MC01W08051649R

Thick Film Chip Resistor

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Description	Part Number
Resistor, 68K, 0.1W, 1%, 0805, Reel	MC01W0805168K
Resistor, 68K, 0.1W, 1%, 0805	MC01W0805168K
Resistor, 68R, 0.1W, 1%, 0805, Reel	MC01W0805168R
Resistor, 68R, 0.1W, 1%, 0805	MC01W0805168R
Resistor, 68K1, 0.1W, 1%, 0805, Reel	MC01W0805168K1
Resistor, 68K1, 0.1W, 1%, 0805	MC01W0805168K1
Resistor, 68R1, 0.1W, 1%, 0805, Reel	MC01W0805168R1
Resistor, 68R1, 0.1W, 1%, 0805	MC01W0805168R1
Resistor, 680K, 0.1W, 1%, 0805, Reel	MC01W08051680K
Resistor, 680K, 0.1W, 1%, 0805	MC01W08051680K
Resistor, 680R, 0.1W, 1%, 0805, Reel	MC01W08051680R
Resistor, 680R, 0.1W, 1%, 0805	MC01W08051680R
Resistor, 681K, 0.1W, 1%, 0805, Reel	MC01W08051681K
Resistor, 681K, 0.1W, 1%, 0805	MC01W08051681K
Resistor, 681R, 0.1W, 1%, 0805, Reel	MC01W08051681R
Resistor, 681R, 0.1W, 1%, 0805	MC01W08051681R
Resistor, 7K15, 0.1W, 1%, 0805, Reel	MC01W080517K15
Resistor, 7K15, 0.1W, 1%, 0805	MC01W080517K15
Resistor, 7R15, 0.1W, 1%, 0805, Reel	MC01W080517R15
Resistor, 7R15, 0.1W, 1%, 0805	MC01W080517R15
Resistor, 7K5, 0.1W, 1%, 0805, Reel	MC01W080517K5
Resistor, 7K5, 0.1W, 1%, 0805	MC01W080517K5
Resistor, 7M5, 0.1W, 1%, 0805, Reel	MC01W080517M50
Resistor, 7M5, 0.1W, 1%, 0805	MC01W080517M50
Resistor, 7R5, 0.1W, 1%, 0805, Reel	MC01W080517R50
Resistor, 7R5, 0.1W, 1%, 0805	MC01W080517R50
Resistor, 7K87, 0.1W, 1%, 0805, Reel	MC01W080517K87
Resistor, 7K87, 0.1W, 1%, 0805	MC01W080517K87
Resistor, 7R87, 0.1W, 1%, 0805, Reel	MC01W080517R87
Resistor, 7R87, 0.1W, 1%, 0805	MC01W080517R87
Resistor, 71K5, 0.1W, 1%, 0805, Reel	MC01W0805171K5
Resistor, 71K5, 0.1W, 1%, 0805	MC01W0805171K5
Resistor, 71R5, 0.1W, 1%, 0805, Reel	MC01W0805171R5
Resistor, 71R5, 0.1W, 1%, 0805	MC01W0805171R5
Resistor, 715K, 0.1W, 1%, 0805, Reel	MC01W08051715K
Resistor, 715K, 0.1W, 1%, 0805	MC01W08051715K
Resistor, 715R, 0.1W, 1%, 0805, Reel	MC01W08051715R
Resistor, 715R, 0.1W, 1%, 0805	MC01W08051715R
Resistor, 75K, 0.1W, 1%, 0805, Reel	MC01W0805175K

Description	Part Number
Resistor, 75K, 0.1W, 1%, 0805	MC01W0805175K
Resistor, 75R, 0.1W, 1%, 0805, Reel	MC01W0805175R
Resistor, 75R, 0.1W, 1%, 0805	MC01W0805175R
Resistor, 750K, 0.1W, 1%, 0805, Reel	MC01W08051750K
Resistor, 750K, 0.1W, 1%, 0805	MC01W08051750K
Resistor, 750R, 0.1W, 1%, 0805, Reel	MC01W08051750R
Resistor, 750R, 0.1W, 1%, 0805	MC01W08051750R
Resistor, 78K7, 0.1W, 1%, 0805, Reel	MC01W0805178K7
Resistor, 78K7, 0.1W, 1%, 0805	MC01W0805178K7
Resistor, 78R7, 0.1W, 1%, 0805, Reel	MC01W0805178R7
Resistor, 78R7, 0.1W, 1%, 0805	MC01W0805178R7
Resistor, 787K, 0.1W, 1%, 0805, Reel	MC01W08051787K
Resistor, 787K, 0.1W, 1%, 0805	MC01W08051787K
Resistor, 787R, 0.1W, 1%, 0805, Reel	MC01W08051787R
Resistor, 787R, 0.1W, 1%, 0805	MC01W08051787R
Resistor, 8K2, 0.1W, 1%, 0805, Reel	MC01W080518K2
Resistor, 8K2, 0.1W, 1%, 0805	MC01W080518K2
Resistor, 8M2, 0.1W, 1%, 0805, Reel	MC01W080518M20
Resistor, 8M2, 0.1W, 1%, 0805	MC01W080518M20
Resistor, 8R2, 0.1W, 1%, 0805, Reel	MC01W080518R20
Resistor, 8R2, 0.1W, 1%, 0805	MC01W080518R20
Resistor, 8K25, 0.1W, 1%, 0805, Reel	MC01W080518K25
Resistor, 8K25, 0.1W, 1%, 0805	MC01W080518K25
Resistor, 8R25, 0.1W, 1%, 0805, Reel	MC01W080518R25
Resistor, 8R25, 0.1W, 1%, 0805	MC01W080518R25
Resistor, 8K66, 0.1W, 1%, 0805, Reel	MC01W080518K66
Resistor, 8K66, 0.1W, 1%, 0805	MC01W080518K66
Resistor, 8R66, 0.1W, 1%, 0805, Reel	MC01W080518R66
Resistor, 8R66, 0.1W, 1%, 0805	MC01W080518R66
Resistor, 82K, 0.1W, 1%, 0805, Reel	MC01W0805182K
Resistor, 82K, 0.1W, 1%, 0805	MC01W0805182K
Resistor, 82R, 0.1W, 1%, 0805, Reel	MC01W0805182R
Resistor, 82R, 0.1W, 1%, 0805	MC01W0805182R
Resistor, 82K5, 0.1W, 1%, 0805, Reel	MC01W0805182K5
Resistor, 82K5, 0.1W, 1%, 0805	MC01W0805182K5
Resistor, 82R5, 0.1W, 1%, 0805, Reel	MC01W0805182R5
Resistor, 82R5, 0.1W, 1%, 0805	MC01W0805182R5
Resistor, 820K, 0.1W, 1%, 0805, Reel	MC01W08051820K
Resistor, 820K, 0.1W, 1%, 0805	MC01W08051820K

Thick Film Chip Resistor

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Description	Part Number
Resistor, 820R, 0.1W, 1%, 0805, Reel	MC01W08051820R
Resistor, 820R, 0.1W, 1%, 0805	MC01W08051820R
Resistor, 825K, 0.1W, 1%, 0805, Reel	MC01W08051825K
Resistor, 825K, 0.1W, 1%, 0805	MC01W08051825K
Resistor, 825R, 0.1W, 1%, 0805, Reel	MC01W08051825R
Resistor, 825R, 0.1W, 1%, 0805	MC01W08051825R
Resistor, 86K6, 0.1W, 1%, 0805, Reel	MC01W0805186K6
Resistor, 86K6, 0.1W, 1%, 0805	MC01W0805186K6
Resistor, 86R6, 0.1W, 1%, 0805, Reel	MC01W0805186R6
Resistor, 86R6, 0.1W, 1%, 0805	MC01W0805186R6
Resistor, 866K, 0.1W, 1%, 0805, Reel	MC01W08051866K
Resistor, 866K, 0.1W, 1%, 0805	MC01W08051866K
Resistor, 866R, 0.1W, 1%, 0805, Reel	MC01W08051866R
Resistor, 866R, 0.1W, 1%, 0805	MC01W08051866R
Resistor, 9K09, 0.1W, 1%, 0805, Reel	MC01W080519K09
Resistor, 9K09, 0.1W, 1%, 0805	MC01W080519K09
Resistor, 9M09, 0.1W, 1%, 0805, Reel	MC01W080519M09
Resistor, 9M09, 0.1W, 1%, 0805	MC01W080519M09
Resistor, 9K1, 0.1W, 1%, 0805, Reel	MC01W080519K1
Resistor, 9K1, 0.1W, 1%, 0805	MC01W080519K1
Resistor, 9M1, 0.1W, 1%, 0805, Reel	MC01W080519M10
Resistor, 9M1, 0.1W, 1%, 0805	MC01W080519M10
Resistor, 9R1, 0.1W, 1%, 0805, Reel	MC01W080519R10
Resistor, 9R1, 0.1W, 1%, 0805	MC01W080519R10
Resistor, 9K53, 0.1W, 1%, 0805, Reel	MC01W080519K53
Resistor, 9K53, 0.1W, 1%, 0805	MC01W080519K53

Description	Part Number
Resistor, 9R53, 0.1W, 1%, 0805, Reel	MC01W080519R53
Resistor, 9R53, 0.1W, 1%, 0805	MC01W080519R53
Resistor, 90K9, 0.1W, 1%, 0805, Reel	MC01W0805190K9
Resistor, 90K9, 0.1W, 1%, 0805	MC01W0805190K9
Resistor, 90R9, 0.1W, 1%, 0805, Reel	MC01W0805190R9
Resistor, 90R9, 0.1W, 1%, 0805	MC01W0805190R9
Resistor, 909K, 0.1W, 1%, 0805, Reel	MC01W08051909K
Resistor, 909K, 0.1W, 1%, 0805	MC01W08051909K
Resistor, 909R, 0.1W, 1%, 0805, Reel	MC01W08051909R
Resistor, 909R, 0.1W, 1%, 0805	MC01W08051909R
Resistor, 91K, 0.1W, 1%, 0805, Reel	MC01W0805191K
Resistor, 91K, 0.1W, 1%, 0805	MC01W0805191K
Resistor, 91R, 0.1W, 1%, 0805, Reel	MC01W0805191R
Resistor, 91R, 0.1W, 1%, 0805	MC01W0805191R
Resistor, 910K, 0.1W, 1%, 0805, Reel	MC01W08051910K
Resistor, 910K, 0.1W, 1%, 0805	MC01W08051910K
Resistor, 910R, 0.1W, 1%, 0805, Reel	MC01W08051910R
Resistor, 910R, 0.1W, 1%, 0805	MC01W08051910R
Resistor, 95K3, 0.1W, 1%, 0805, Reel	MC01W0805195K3
Resistor, 95K3, 0.1W, 1%, 0805	MC01W0805195K3
Resistor, 95R3, 0.1W, 1%, 0805, Reel	MC01W0805195R3
Resistor, 95R3, 0.1W, 1%, 0805	MC01W0805195R3
Resistor, 953K, 0.1W, 1%, 0805, Reel	MC01W08051953K
Resistor, 953K, 0.1W, 1%, 0805	MC01W08051953K
Resistor, 953R, 0.1W, 1%, 0805, Reel	MC01W08051953R
Resistor, 953R, 0.1W, 1%, 0805	MC01W08051953R

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NSS1C201MZ4, NSV1C201MZ4

100 V, 2.0 A, Low $V_{CE(sat)}$ NPN Transistor

ON Semiconductor's e²PowerEdge family of low $V_{CE(sat)}$ transistors are miniature surface mount devices featuring ultra low saturation voltage ($V_{CE(sat)}$) and high current gain capability. These are designed for use in low voltage, high speed switching applications where affordable efficient energy control is important.

Typical applications are DC-DC converters and power management in portable and battery powered products such as cellular and cordless phones, PDAs, computers, printers, digital cameras and MP3 players. Other applications are low voltage motor controls in mass storage products such as disc drives and tape drives. In the automotive industry they can be used in air bag deployment and in the instrument cluster. The high current gain allows e²PowerEdge devices to be driven directly from PMU's control outputs, and the Linear Gain (Beta) makes them ideal components in analog amplifiers.

Features

- NSV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q101 Qualified and PPAP Capable
- These Devices are Pb-Free, Halogen Free and are RoHS Compliant

MAXIMUM RATINGS ($T_A = 25^\circ\text{C}$)

Rating	Symbol	Max	Unit
Collector-Emitter Voltage	V_{CEO}	100	Vdc
Collector-Base Voltage	V_{CBO}	140	Vdc
Emitter-Base Voltage	V_{EBO}	7.0	Vdc
Collector Current – Continuous	I_C	2.0	A
Collector Current – Peak	I_{CM}	3.0	A

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Total Device Dissipation $T_A = 25^\circ\text{C}$ Derate above 25°C	P_D (Note 1)	800 6.5	mW mW/ $^\circ\text{C}$
Thermal Resistance, Junction-to-Ambient	$R_{\theta JA}$ (Note 1)	155	$^\circ\text{C}/\text{W}$
Total Device Dissipation $T_A = 25^\circ\text{C}$ Derate above 25°C	P_D (Note 2)	2.0 15.6	W mW/ $^\circ\text{C}$
Thermal Resistance, Junction-to-Ambient	$R_{\theta JA}$ (Note 2)	64	$^\circ\text{C}/\text{W}$
Total Device Dissipation (Single Pulse < 10 sec.)	$P_{D\text{single}}$ (Note 3)	710	mW
Junction and Storage Temperature Range	T_J, T_{stg}	-55 to +150	$^\circ\text{C}$

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

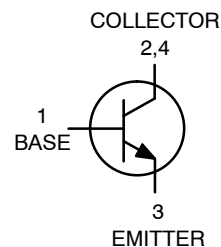
1. FR-4 @ 7.6 mm², 1 oz. copper traces.
2. FR-4 @ 645 mm², 1 oz. copper traces.
3. Thermal response.



ON Semiconductor®

<http://onsemi.com>

100 VOLTS, 2.0 AMPS NPN LOW $V_{CE(sat)}$ TRANSISTOR

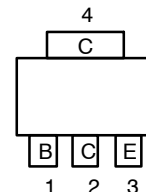


MARKING DIAGRAM



A = Assembly Location
Y = Year
W = Work Week
1C201 = Specific Device Code
▪ = Pb-Free Package

PIN ASSIGNMENT



Top View Pinout

ORDERING INFORMATION

Device	Package	Shipping†
NSS1C201MZ4T1G NSV1C201MZ4T1G	SOT-223 (Pb-Free)	1000/ Tape & Reel
NSS1C201MZ4T3G	SOT-223 (Pb-Free)	4000/ Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

NSS1C201MZ4, NSV1C201MZ4

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector–Emitter Breakdown Voltage (I _C = 10 mAdc, I _B = 0)	V _{(BR)CEO}	100			Vdc
Collector–Base Breakdown Voltage (I _C = 0.1 mAdc, I _E = 0)	V _{(BR)CBO}	140			Vdc
Emitter–Base Breakdown Voltage (I _E = 0.1 mAdc, I _C = 0)	V _{(BR)EBO}	7.0			Vdc
Collector Cutoff Current (V _{CB} = 140 Vdc, I _E = 0)	I _{CBO}			100	nA
Emitter Cutoff Current (V _{EB} = 6.0 Vdc)	I _{EBO}			50	nA

ON CHARACTERISTICS

DC Current Gain (Note 4) (I _C = 10 mA, V _{CE} = 2.0 V) (I _C = 500 mA, V _{CE} = 2.0 V) (I _C = 1.0 A, V _{CE} = 2.0 V) (I _C = 2.0 A, V _{CE} = 2.0 V)	h _{FE}	150 120 80 40		360	
Collector–Emitter Saturation Voltage (Note 4) (I _C = 0.1 A, I _B = 0.010 A) (I _C = 0.5 A, I _B = 0.050 A) (I _C = 1.0 A, I _B = 0.100 A) (I _C = 2.0 A, I _B = 0.200 A)	V _{CE(sat)}			0.030 0.060 0.100 0.180	V
Base–Emitter Saturation Voltage (Note 4) (I _C = 1.0 A, I _B = 0.100 A)	V _{BE(sat)}			1.10	V
Base–Emitter Turn–on Voltage (Note 4) (I _C = 1.0 A, V _{CE} = 2.0 V)	V _{BE(on)}			0.850	V
Cutoff Frequency (I _C = 100 mA, V _{CE} = 5.0 V, f = 100 MHz)	f _T		100		MHz
Input Capacitance (V _{EB} = 0.5 V, f = 1.0 MHz)	C _{ibo}		305		pF
Output Capacitance (V _{CB} = 3.0 V, f = 1.0 MHz)	C _{obo}		22		pF

4. Pulsed Condition: Pulse Width = 300 msec, Duty Cycle ≤ 2%.

TYPICAL CHARACTERISTICS

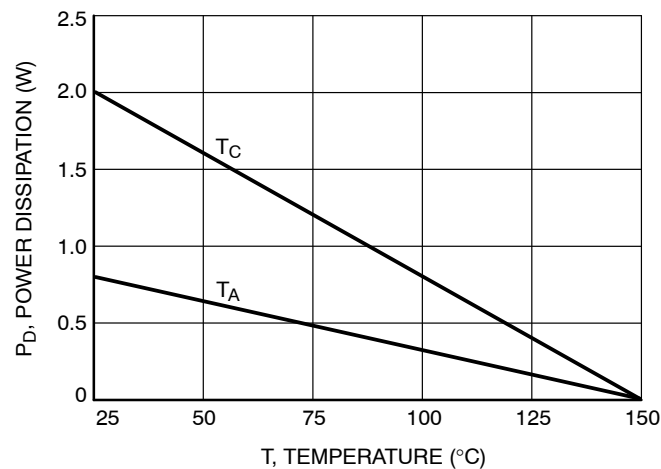


Figure 1. Power Derating

TYPICAL CHARACTERISTICS

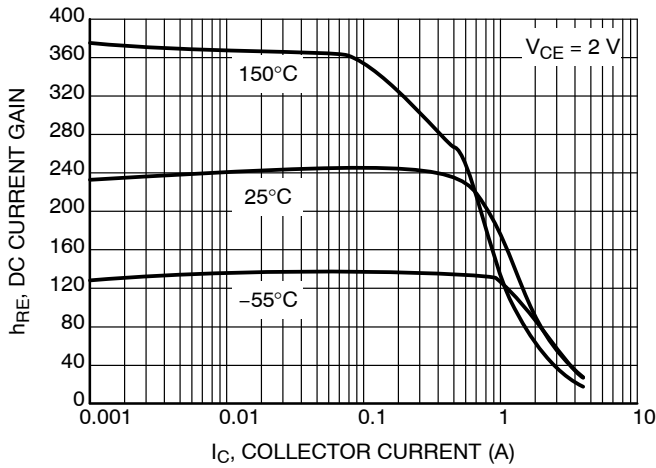


Figure 2. DC Current Gain

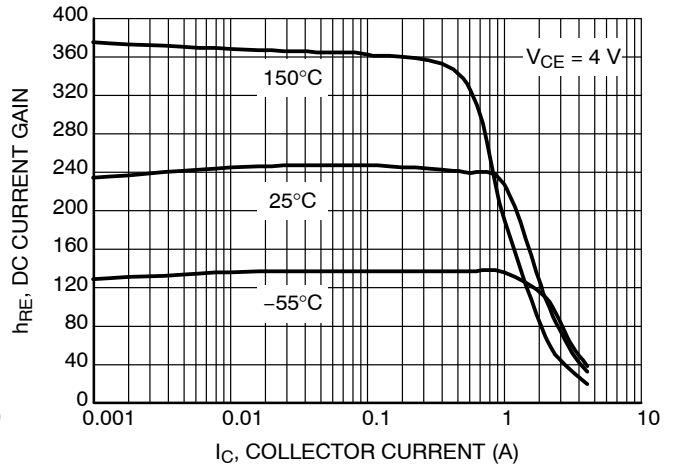


Figure 3. DC Current Gain

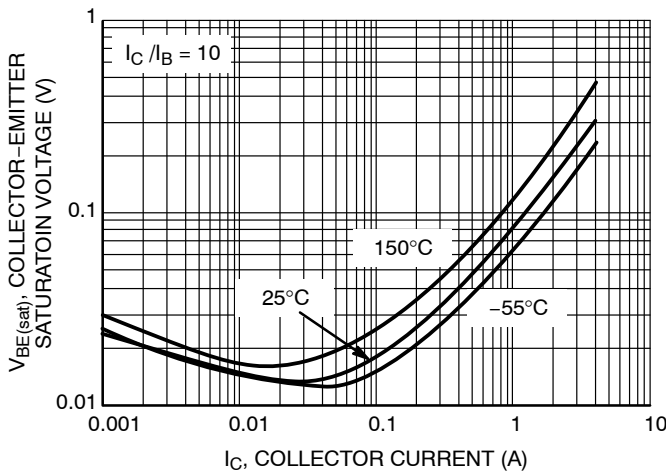


Figure 4. Collector-Emitter Saturation Voltage

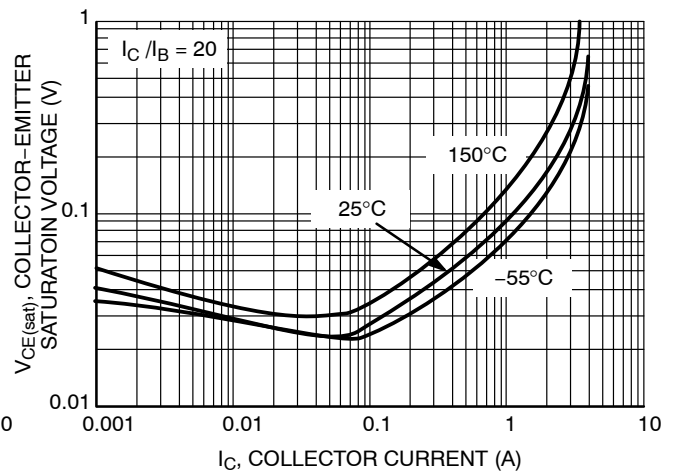


Figure 5. Collector-Emitter Saturation Voltage

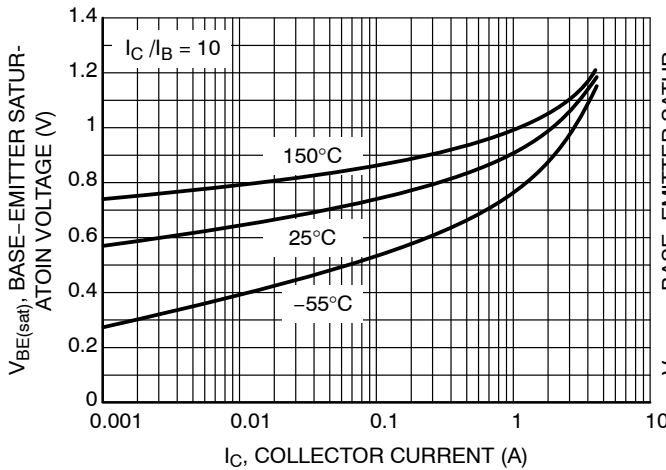


Figure 6. Base-Emitter Saturation Voltage

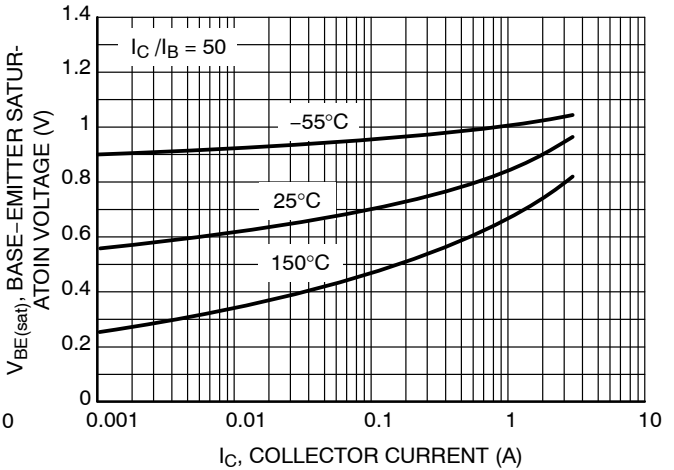


Figure 7. Base-Emitter Saturation Voltage

TYPICAL CHARACTERISTICS

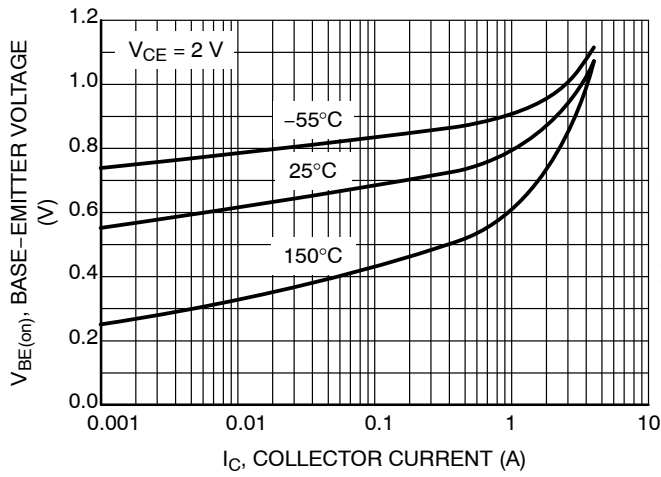


Figure 8. Base-Emitter Voltage

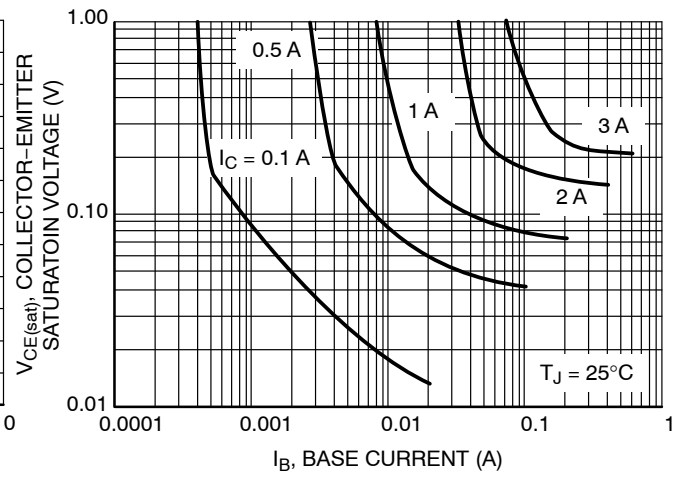


Figure 9. Collector Saturation Region

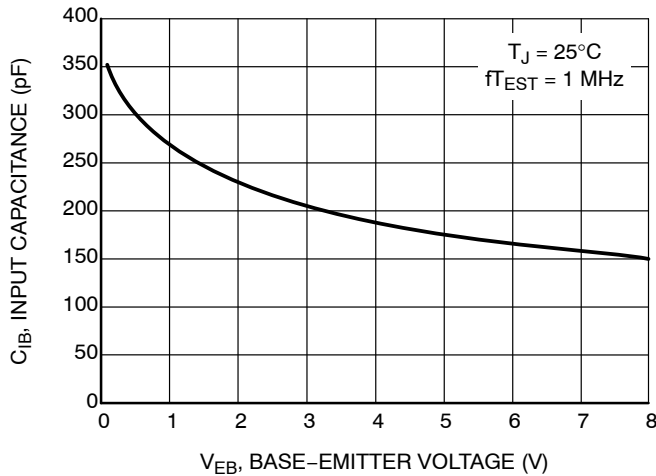


Figure 10. Input Capacitance

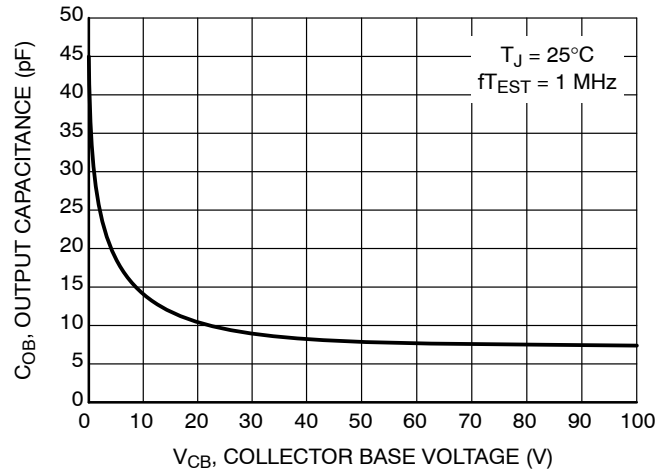


Figure 11. Output Capacitance

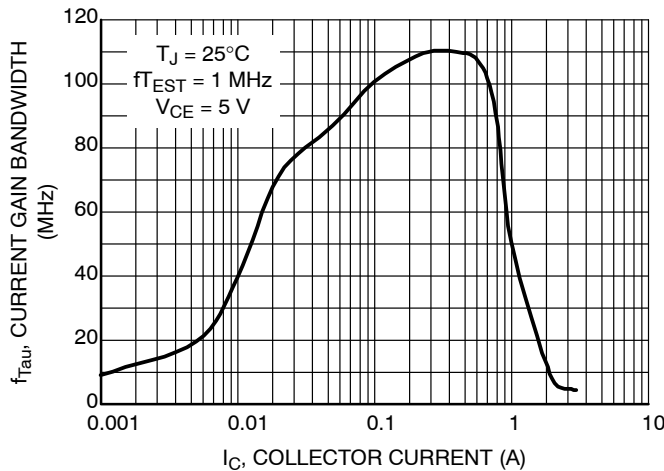


Figure 12. Current Gain Bandwidth Product

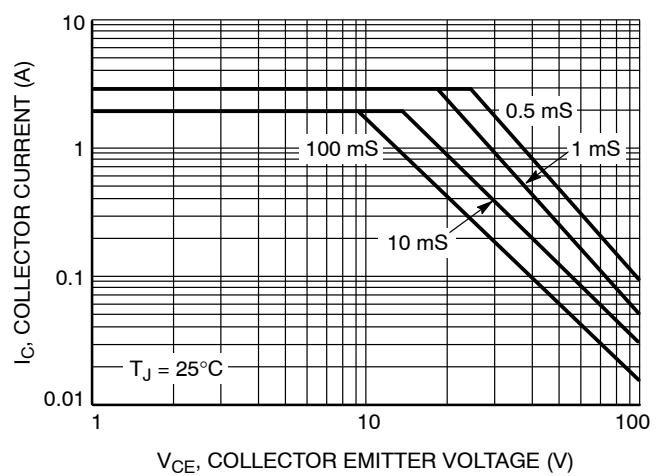
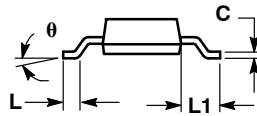
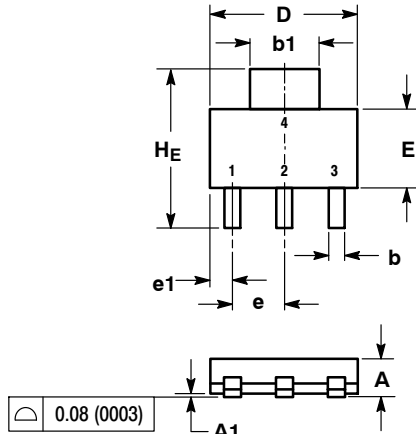


Figure 13. Safe Operating Area

NSS1C201MZ4, NSV1C201MZ4

PACKAGE DIMENSIONS

SOT-223 (TO-261)
CASE 318E-04
ISSUE N

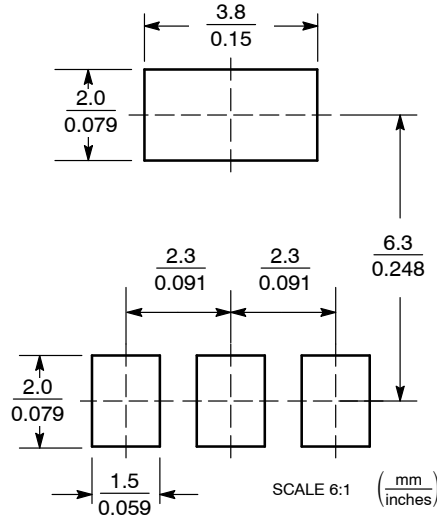


NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCH.

DIM	MILLIMETERS			INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	1.50	1.63	1.75	0.060	0.064	0.068
A1	0.02	0.06	0.10	0.001	0.002	0.004
b	0.60	0.75	0.89	0.024	0.030	0.035
b1	2.90	3.06	3.20	0.115	0.121	0.126
c	0.24	0.29	0.35	0.009	0.012	0.014
D	6.30	6.50	6.70	0.249	0.256	0.263
E	3.30	3.50	3.70	0.130	0.138	0.145
e	2.20	2.30	2.40	0.087	0.091	0.094
e1	0.85	0.94	1.05	0.033	0.037	0.041
L	0.20	---	---	0.008	---	---
L1	1.50	1.75	2.00	0.060	0.069	0.078
HE	6.70	7.00	7.30	0.264	0.276	0.287
theta	0°	---	10°	0°	---	10°

STYLE 1:
PIN 1. BASE
2. COLLECTOR
3. EMITTER
4. COLLECTOR

SOLDERING FOOTPRINT*



*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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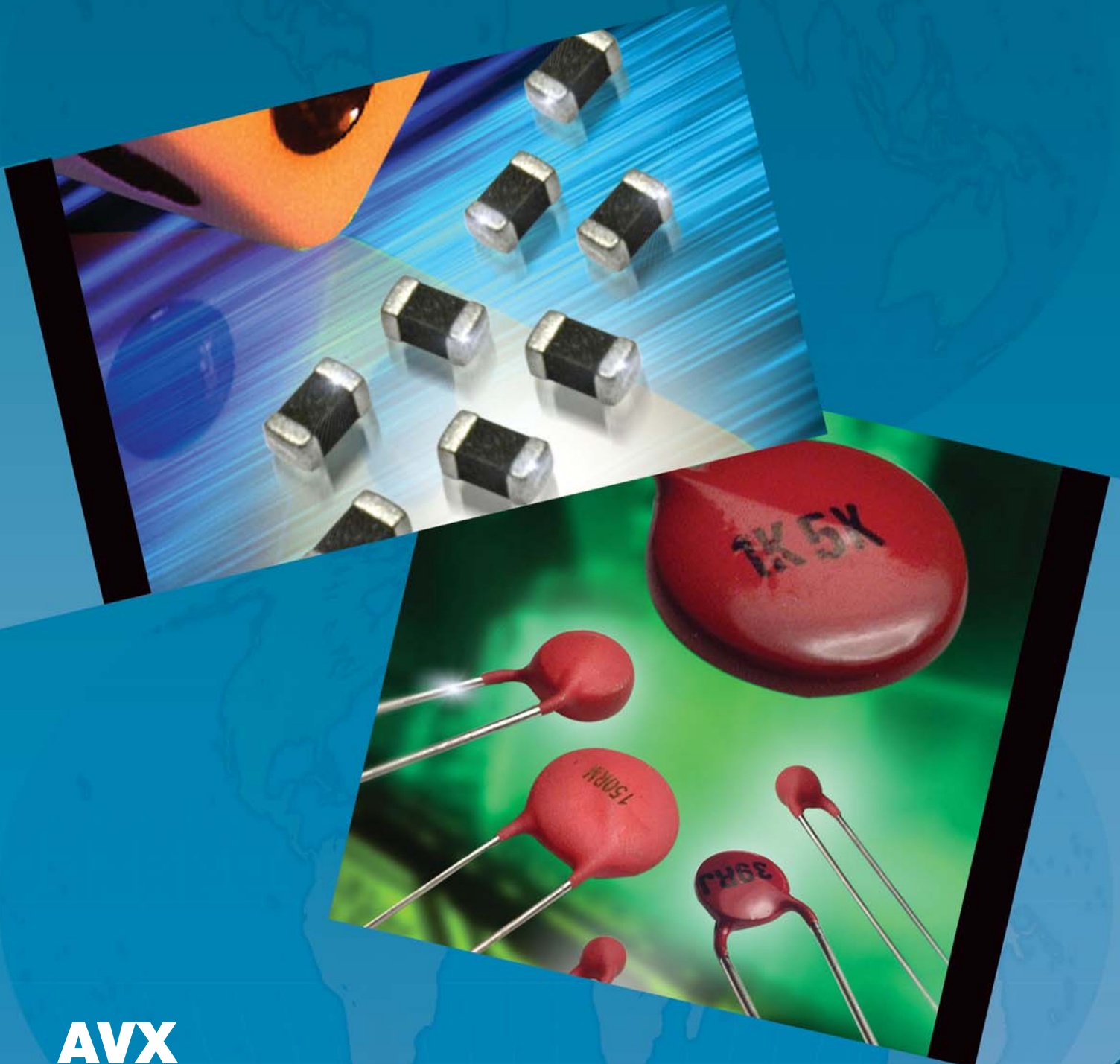
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NSS1C201MZ4/D



AVX NTC Thermistors

<Version 11.4>

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NTC Thermistors



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NTC Thermistors

General Characteristics

1 – INTRODUCTION

NTC thermistors are thermally sensitive resistors made from a mixture of Mn, Ni, Co, Cu, Fe oxides. Sintered ceramic bodies of various sizes can be obtained. Strict conditions of mixing, pressing, sintering and metallization ensure an excellent batch-to-batch product characteristics.

This semi-conducting material reacts as an NTC resistor, whose resistance decreases with increasing temperature. This Negative Temperature Coefficient effect can result from an external change of the ambient temperature or an internal heating due to the Joule effect of a current flowing through the thermistor.

By varying the composition and the size of the thermistors, a wide range of resistance values (0.1Ω to 1MΩ) and temperature coefficients (-2 to -6% per °C) can be achieved.

RoHS (Restriction of Hazardous Substances - European Union directive 2002/95/EC).

ELV (End of Life-Vehicle - European Union directive 2000/53/EC).

All Thermistor Products have been fully RoHS/ELV since before 2006.

Chip Thermistor NB RoHS/ELV Status: external Plating 100% smooth semi-bright Sn as standard SnPb Termination available on request.

2 – MAIN CHARACTERISTICS

2.1 CHARACTERISTICS WITH NO DISSIPATION

2.1.1. Nominal Resistance (R_n)

The nominal resistance of an NTC thermistor is generally given at 25°C. It has to be measured at near zero power so that the resultant heating only produces a negligible measurement error.

The following table gives the maximum advised measurement voltage as a function of resistance values and thermal dissipation factors.

This voltage is such that the heating effect generated by the measurement current only causes a resistance change of 1% ΔR_n/R_n.

Ranges of values (Ω)	Maximum measuring voltage (V)			
	δ = 2 mW/°C	δ = 5 mW/°C	δ = 10 mW/°C	δ = 20 mW/°C
R 10				0.10
10 < R 100		0.13	0.18	0.24
100 < R 1,000	0.25	0.38	0.53	0.24
1,000 < R 10,000	0.73	1.1	1.5	2.0
10,000 < R 100,000	2.1	3.2	4.6	
R < 100,000	6.4	9.7	14.5	

2.1.2. Temperature -

Resistance characteristics R (T)

This is the relation between the zero power resistance and the temperature. It can be determined by experimental measurements and may be described by the ratios R (T) / R (25°C) where:

R (T) is the resistance at any temperature T

R (25°C) is the resistance at 25°C.

These ratios are displayed on pages 29 to 33.

2.1.3. Temperature coefficient (α)

The temperature coefficient (α) which is the slope of the curve at a given point is defined by:

$$\alpha = \frac{100}{R} \cdot \frac{dR}{dT} \text{ and expressed in \% per } ^\circ\text{C}.$$

2.1.4. Sensitivity index (B)

The equation $R = A \exp (B/T)$ may be used as a rough approximation of the characteristic R (T).

B is called the sensitivity index or constant of the material used.

To calculate the B value, it is necessary to know the resistances R₁ and R₂ of the thermistor at the temperatures T₁ and T₂.

$$\text{The equation: } R_1 = R_2 \exp B \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$\text{leads to: } B (K) = \frac{1}{\left(\frac{1}{T_1} - \frac{1}{T_2} \right)} \cdot \ln \left(\frac{R_1}{R_2} \right)$$

Conventionally, B will be most often calculated for temperatures T₁ = 25°C and T₂ = 85°C (298.16 K and 358.16 K).

In fact, as the equation $R = A \exp (B/T)$ is an approximation, the value of B depends on the temperatures T₁ and T₂ by which it is calculated.

For example, from the R (T) characteristic of material M (values given on page 29), it can be calculated:

$$B (25 - 85) = 3950$$

$$B (0 - 60) = 3901$$

$$B (50 - 110) = 3983$$

When using the equation $R = A \exp (B/T)$ for this material, the error can vary by as much as 9% at 25°C, 0.6% at 55°C and 1.6% at 125°C.

Using the same equation, it is possible to relate the values of the index B and the coefficient α:

$$\alpha = \frac{1}{R} \cdot \frac{dR}{dT} = \frac{1}{A \exp (B/T)} \cdot A \exp (B/T) \cdot \frac{-B}{T^2}$$

$$\text{thus } \alpha = - \frac{B}{T^2} \text{ expressed in \% } ^\circ\text{C}$$

NTC Thermistors

General Characteristics

2.1.5. Further approximation of R (T) curve

The description of the characteristic R (T) can be improved by using a greater number of experimental points, and by using the equation:

$$\frac{1}{T} = A + B (\ln R) + C (\ln R)^3$$

The parameters A, B and C are determined by solving the set of equations obtained by using the measured resistances at three temperatures.

The solution of the above equation gives the resistance at any temperature:

$$\ln R(T) = \frac{1}{3} \left[\sqrt[3]{-\frac{27}{2} \left(\frac{A-1/T}{C} \right) + \frac{3}{2} \sqrt{3 \left(\sqrt{27 \left(\frac{A-1/T}{C} \right)^2 + 4 \left(\frac{B}{C} \right)^3} \right)}} \right. \\ \left. - \sqrt[3]{\frac{27}{2} \left(\frac{A-1/T}{C} \right) + \frac{3}{2} \sqrt{3 \left(\sqrt{27 \left(\frac{A-1/T}{C} \right)^2 + 4 \left(\frac{B}{C} \right)^3} \right)}} \right]$$

The precision of this description is typically 0.2°C for the range -50 to +150°C (A, B, C being determined with experimental values at -20, +50 and 120°C) or even better if this temperature range is reduced. The ratios R(T)/R(25°C) for each of the different materials shown on pages 29 to 33 have been calculated using the above method.

2.1.6. Resistance tolerance and temperature precision

An important characteristic of a thermistor is the tolerance on the resistance value at a given temperature.

This uncertainty on the resistance ($\Delta R/R$) may be related to the corresponding uncertainty on the temperature (ΔT), using the relationship:

$$\Delta T = 100 \cdot \frac{\Delta R}{R} \cdot \frac{1}{\alpha}$$

Example: consider the thermistor ND06M00152J —

- R (25°C) = 1500 ohms
- Made from M material
- R (T) characteristic shown on page 23 gives:
 $\alpha = -4.4\%/^{\circ}\text{C}$ at 25°C
- Tolerance $\Delta R/R = \pm 5\%$ is equivalent to:
 $\Delta T = 5\%/4.4\%/^{\circ}\text{C} = \pm 1.14^{\circ}\text{C}$

2.1.7. Resistance tolerance at any temperature

Any material used for NTC manufacturing always displays a dispersion for the R (T) characteristic.

This dispersion depends on the type of material used and has been especially reduced for our accuracy series thermistors.

Thus, the tolerance on the resistance ($\Delta R_2/R_2$) at a temperature T_2 is the sum of two contributions as illustrated on Figure 1:

- the tolerance $\Delta R_1/R_1$ at a temperature T_1 used as a reference.
- an additional contribution due to the dispersion on the characteristic R (T) which may be called “Manufacturing tolerance” (Tf).

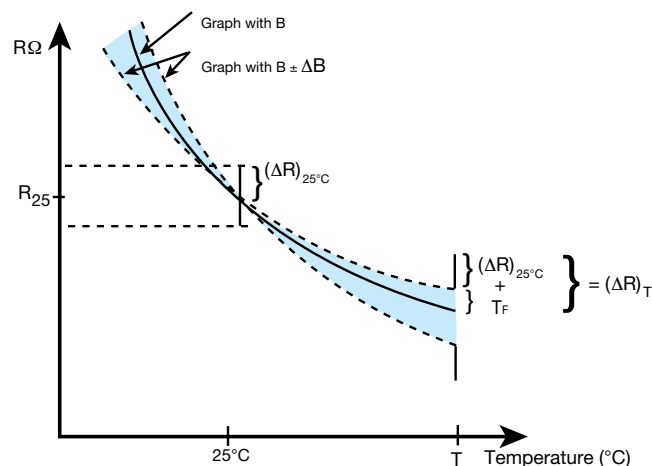


Figure 1

Differentiating the equation $R = A \exp(B/T)$, the two contributions on the tolerance at T can also be written:

$$\frac{\Delta R_2}{R_2} = \frac{\Delta R_1}{R_1} + \left| \frac{1}{T_1} - \frac{1}{T_2} \right| \cdot \Delta B$$

The T(f) values given with the resistance – temperature characteristics on pages 29 to 33 are based on a computer simulation using this equation and experimental values.

2.1.8. Designing the resistance tolerances

Using the fact that the coefficient α decreases with temperature ($\alpha = -B/T^2$), it is generally useful to define the closest tolerance of the thermistor at the maximum value of the temperature range where an accuracy in °C is required.

For example, let us compare the two designs 1 and 2 hereafter:

T (°C)	R (Ω)	α (%/°C)	Design 1		Design 2	
			$\Delta R/R(\%)$	$\Delta T(^{\circ}\text{C})$	$\Delta R/R(\%)$	$\Delta T(^{\circ}\text{C})$
0	3275	-5.2	3.5	0.7	5.0	1.0
25	1000	-4.4	3.0	0.7	4.5	1.1
55	300	-3.7	3.5	1.0	4.0	1.1
85	109	-3.1	4.1	1.3	3.4	1.1
100	69.4	-2.9	4.5	1.6	3.0	1.0

Only the Design 2 is able to meet the requirement $\Delta T \approx 1^{\circ}\text{C}$ from 25°C to 100°C.

NTC Thermistors

General Characteristics

2.1.9. Shaping of the R (T) characteristic

By the use of a resistor network, it is possible to modify the R (T) characteristic of a thermistor so that it matches the required form, for example a linear response over a restricted temperature range.

A single fixed resistor R_p placed in parallel with a thermistor gives a S-shape resistance-temperature curve (see Figure 2) which is substantially more linear at the temperature range around the inflexion point (R_o , T_o).

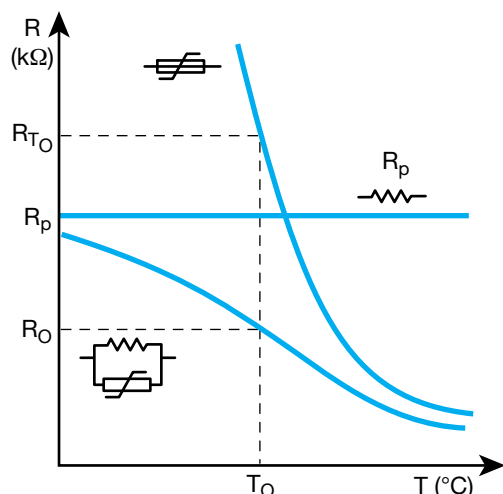


Figure 2 – Linearization of a thermistor

It can be calculated that better linearization is obtained when the fixed resistor value and the mid-range temperature are related by the formula:

$$R_p = R_{T_o} \times \frac{B - T_o}{B + 2T_o}$$

For example, with a thermistor ND03N00103J —

$$R_{25^\circ\text{C}} = 10\text{k}\Omega, B = 4080\text{ K}$$

good linearization is obtained with a resistor in parallel where the value is:

$$R_p = 10,000\ \Omega \times \frac{4080 - 298}{4080 + (2 \times 298)} = 8088\ \Omega$$

2.1.10. Demonstration of the R (T) parameters calculation

To help our customers when designing thermistors for temperature measurement or temperature compensation, software developed by our engineering department is available upon request.

2.2 CHARACTERISTICS WITH ENERGY DISSIPATION

When a current is flowing through an NTC thermistor, the power due to the Joule effect raises the temperature of the NTC above ambient.

The thermistor reaches a state of equilibrium when the power supplied becomes equal to the power dissipated in the environment.

The thermal behavior of the thermistor is mainly dependent on the size, shape and mounting conditions.

Several parameters have been defined to characterize these properties:

2.2.1. Heat capacity (H)

The heat capacity is the amount of heat required to change the temperature of the thermistor by 1°C and is expressed in J/°C.

2.2.2. Dissipation factor (δ)

This is the ratio between the variation in dissipated power and the variation of temperature of the NTC. It is expressed in mW/°C and may be measured as:

$$\delta = \frac{U.I}{85 - 25}$$

where U.I is the power necessary to raise to 85°C the temperature of a thermistor maintained in still air at 25°C.

2.2.3. Maximum permissible temperature (T max)

This is the maximum ambient temperature at which the thermistor may be operated with zero dissipation. Above this temperature, the stability of the resistance and the leads attachment can no longer be guaranteed.

2.2.4. Maximum permissible power at 25°C (Pmax)

This is the power required by a thermistor maintained in still air at 25°C to reach the maximum temperature for which it is specified.

For higher ambient temperatures, the maximum permissible power is generally derated according to the Figure 3 hereafter and $T_L = T_{\text{max}} - 10^\circ\text{C}$.

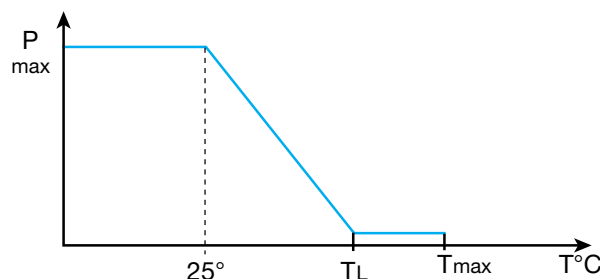


Figure 3 – Derating of maximum power

NTC Thermistors

General Characteristics

2.2.5. Voltage – Current curves V (I)

These curves describe the behavior of the voltage drop V measured across the NTC as the current I through the NTC is increased.

They describe the state of equilibrium between power resulting from Joule effect and dissipated power in the surroundings. (Figure 4)

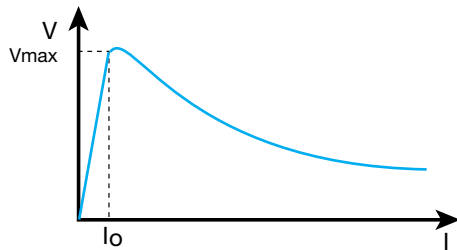


Figure 4 – Voltage – current curve V (I)

Several zones can be identified:

- low current zone
dissipated energy only produces negligible heating and the curve V (I) is almost linear.
- non-linear zone
the curve V (I) displays a maximum voltage Vmax for a current Io. This maximum voltage Vmax and the temperature Tmax reached by the NTC under these conditions can be determined by using the equations:

$$P = V^2/R = \delta (T - T_{amb}) \quad \text{and}$$

$$R = R_{amb} \cdot \exp B (1/T - 1/T_{amb})$$

therefore:

$$T_{max} = B/2 - \sqrt{B^2/4 - BT_{amb}} \simeq T_{amb} \left(\frac{1+T_{amb}}{B} \right)$$

$$V_{max} = \sqrt{\delta (T_{max} - T_{amb}) \cdot R_{amb} \exp \left[B \left(\frac{1}{T_{max}} - \frac{1}{T_{amb}} \right) \right]}$$

where δ is the dissipation factor and T_{amb} is the ambient temperature.

- high current zone
for higher currents, an increase in temperature of the NTC decreases the resistance and the voltage more rapidly than the increase of the current. Above a certain dissipated power, the temperature of the NTC exceeds the permissible value.

2.2.6. Current – Time curves I(t)

When voltage is applied to a thermistor, a certain amount of time is necessary to reach the state of equilibrium described by the V(I) curves.

This is the heating up time of the thermistor which depends on the voltage and the resistance on one side and the heat capacity and dissipation on the other.

The curves I(t) are of particular interest in timing applications.

2.2.7. Thermal time constant

When a thermistor is self-heated to a temperature T above ambient temperature T_{amb} , and allowed to cool under zero power resistance, this will show a transient situation.

At any time interval dt, dissipation of the thermistor ($\delta(T - T_{amb})dt$) generates a temperature decrease $-HdT$, resulting in the equation:

$$\frac{1}{(T - T_{amb})} dT = - \frac{\delta}{H} dt$$

The solution to this equation for any value of t, measured from $t = 0$, is:

$$\ln \frac{(T - T_{amb})}{(T_0 - T_{amb})} = - \frac{\delta}{H} t$$

We can define a thermal time constant τ as:

$$\tau = H/\delta \quad \text{expressed in seconds.}$$

Where the time $t = \tau$:

$$(T - T_{amb}) / (T_0 - T_{amb}) = \exp - 1 = 0.368$$

expressing that for $t = \tau$, the thermistor cools to 63.2% of the temperature difference between the initial T_0 and T_{amb} (see Figure 5).

According to IEC 539 our technical data indicates τ measured with $T_0 = 85^\circ\text{C}$, $T_{amb} = 25^\circ\text{C}$ and consequently $T = 47.1^\circ\text{C}$.

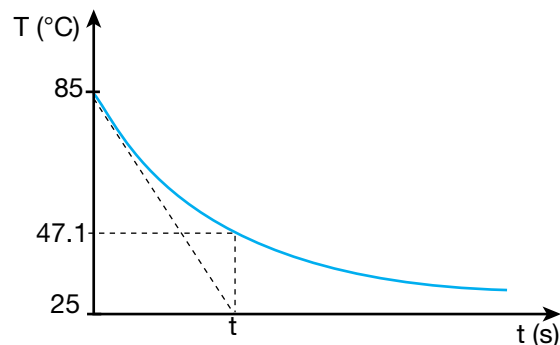


Figure 5 – Temperature – time curve T(t)

2.2.8. Response time

More generally, it is possible to define a response time as the time the thermistor needs to reach 63.2% of the total temperature difference when submitted to a change in the thermal equilibrium (for example from 60°C to 25°C in silicone oil 47V20 Rhodorsil).

NTC Thermistors

Application Notes

TEMPERATURE MEASUREMENT

High sensitivity and low cost make NTC thermistors the most common device used for temperature measurement.

Non-linearity of the R - T curve generally leads to the use of a resistor network to linearize the signal. An example is given in Figure 6.

More precise measurements and temperature display can also be achieved with simple electronic equipment as shown in Figure 7.

The choice of the model will particularly take into account the small size (better response time) and the resistance tolerance. Mounting conditions (dissipation), and input voltage (self-heating) will also be carefully defined to avoid serious errors in temperature measurement.

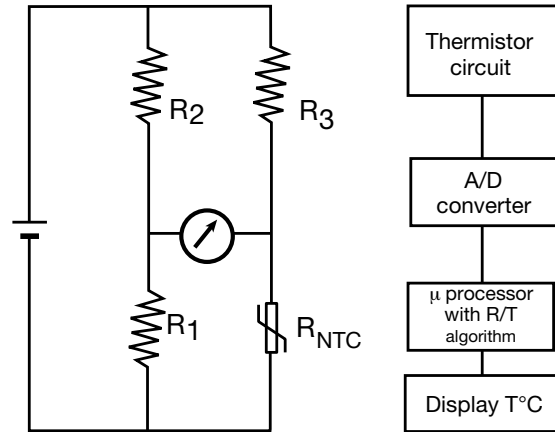


Figure 6

Figure 7

TEMPERATURE CONTROL AND ALARM

NTC thermistors can be used as a simple on-off control temperature system or temperature alarm system. Figure 8 gives an example of such a circuit.

When the temperature increases to a defined value, the resistance of the thermistor decreases and the current becomes sufficiently high to energize the relay and provide temperature alarm or heating system turn-off.

The high sensitivity of thermistors (about 4% resistance change for 1°C) allows the temperature to be controlled very precisely.

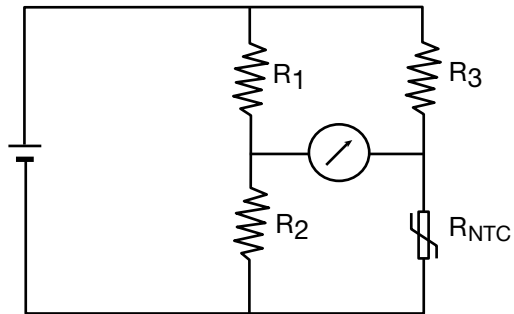


Figure 8

TEMPERATURE COMPENSATION

As many electronic components (integrated circuits, amplifiers,...) have a positive temperature coefficient of resistance, NTC thermistors represent a cheap and interesting solution to compensate for this effect and provide an improved temperature stability for electronic equipment.

It is necessary to include the thermistor in a resistor network (Figure 10) calculated in such a manner that the network coefficient compensates exactly for the positive temperature coefficient of the other component (Figure 9).

Common leaded discs or chip thermistors are well suited for this application.

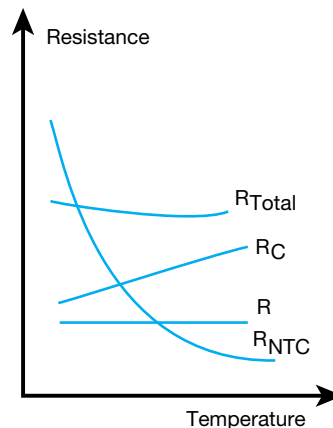


Figure 9

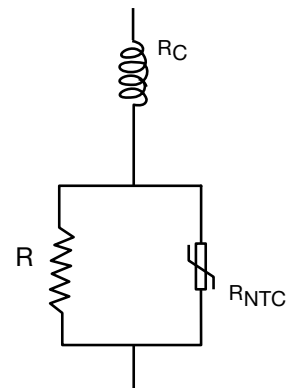


Figure 10

NTC Thermistors

Application Notes



LIQUID LEVEL OR FLOW DETECTION

The dissipation of a thermistor is significantly different in a liquid or in a gas, in a static fluid or in a stirred one. A liquid level detector or a gas-flow measurement can be designed using this property.

In Figure 11, the output voltage measured on the thermistor depends upon the dissipation factor of its environment, and can be illustrated by V-I curves (Figure 12).

This voltage can be used to detect the presence (V_2) or absence (V_1) of liquid around the thermistor or measure the flow speed.

A good design should define a precise operating temperature range, where dissipation in the high dissipating medium at highest ambient temperature remains higher than the dissipation in low dissipating medium at lowest ambient temperature.

SURGE PROTECTION

A soft start of sensitive apparatus can be achieved by using NTC thermistors as described in Figures 13 and 14.

At turn-on, the NTC absorbs the surge current, limits the current across the equipment and protects it. Then, the thermistor heats, its resistance decreases and most of the power becomes applied to the apparatus.

In its design, the thermistor will be selected with a thermal capacity higher than the surge energy to absorb.

TIME DELAY

The current-time characteristic of a thermistor is used in time delay applications such as delaying energization of a relay after application of power to an electrical circuit.

The time delay, time necessary for the thermistor to heat up to the temperature where its resistance allows the current to reach the switching value of the relay, is mainly defined with the nominal resistance of the thermistor.

The time delay is also strongly dependent upon the ambient temperature, as shown in Figure 15.

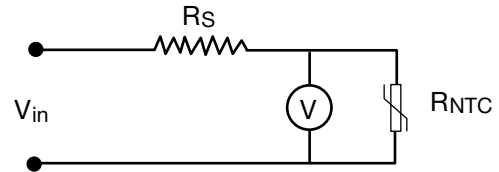


Figure 11

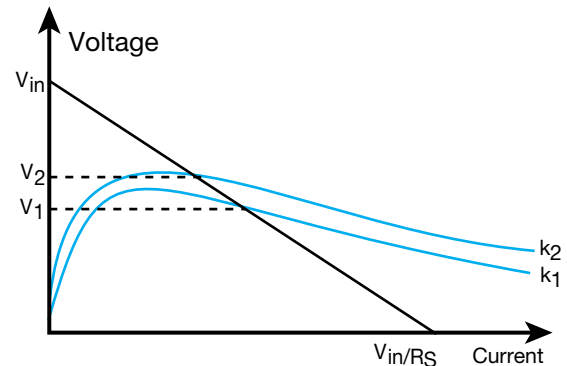


Figure 12

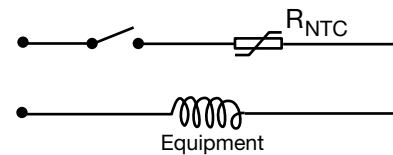


Figure 13

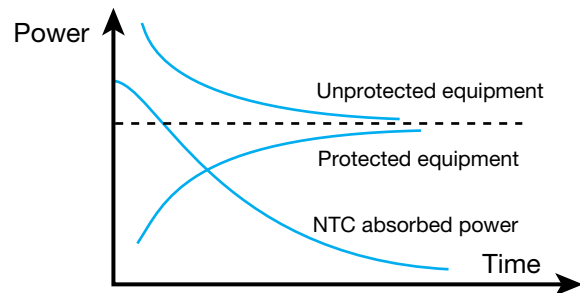


Figure 14

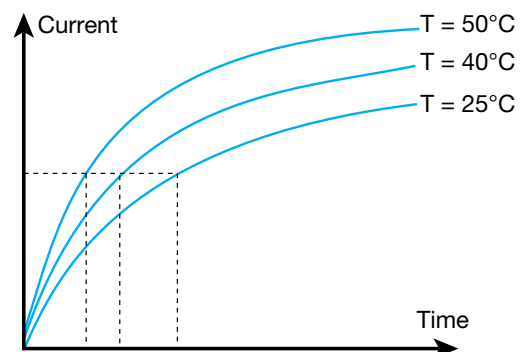
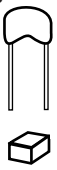
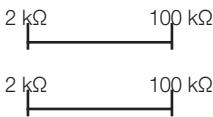
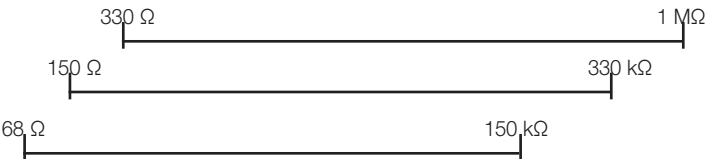


Figure 15

NTC Thermistors

Selection Guide



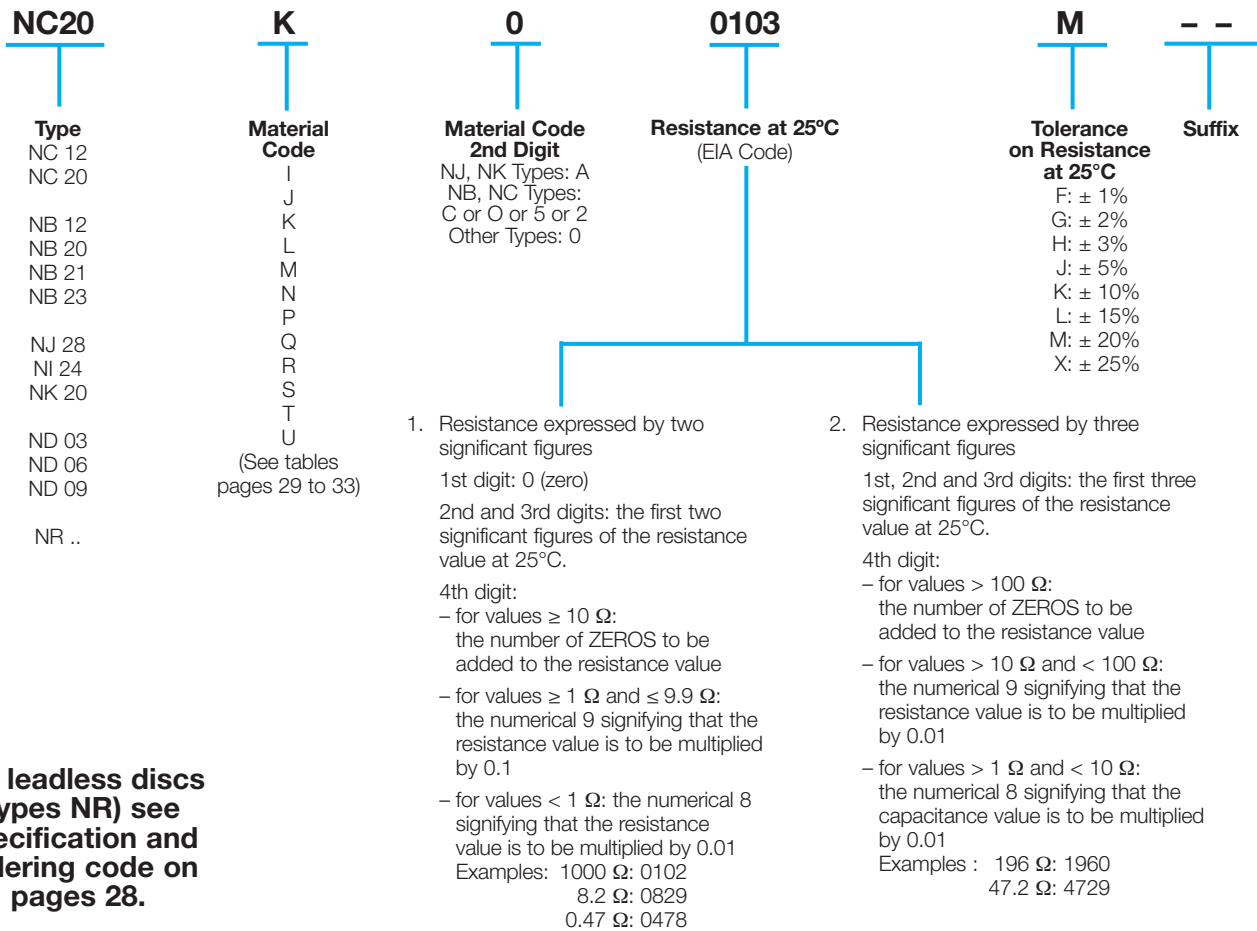
Types	Range of Values R at 25°C	Main Applications	Page
SMD NC 12/20 NB 12/20 NB 21/23 		- Hybrid circuit - Temperature Compensation	10 12 14
Accuracy Series NJ 28 NI 24 NP 30 NK 20 		- Temperature measurement	19
Leaded Discs N.03 N.06 N.09 		- Temperature measurement and regulation - Level detection - Compensation	21
Leadless Discs NR 	Custom designed products generally defined at two temperatures	- Automotive and industrial thermal control	27

NTC Thermistors

Ordering Code



HOW TO ORDER



For leadless discs (types NR) see specification and ordering code on pages 28.

ROHS/ELV COMPLIANCE BY PRODUCT FAMILY



RoHS (Restriction of Hazardous Substances - European Union directive 2002/95/EC).
 ELV (End of Life-Vehicle - European Union directive 2000/53/EC).
 All Thermistor Products have been fully RoHS/ELV since before 2006.
 Chip Thermistor NB RoHS/ELV Status: external Plating 100% smooth semi-bright Sn as standard SnPb Termination available on request.

Products that are supplied AS STANDARD in RoHS/ELV compliant form for listed

Industrial Product Family		RoHS Compliant for Material Listed					
Group	Series	Cadmium	Hexavalent Chromium	Lead	Mercury	PBBs	PBDEs
Leaded NTC Thermistors	Thermistors NF NI	✓	✓	✓	✓	✓	✓
	Thermistors ND NJ NP	✓	✓	✓	✓	✓	✓
SMD Thermistors	Thermistors NC	✓	✓	✓	✓	✓	✓
	Thermistors NB	✓	✓	✓	✓	✓	✓



NTC SMD Thermistors

NC 12 – NC 20



Chip thermistors are a high quality and low cost device especially developed for surface mounting applications. They are widely used for temperature compensation but can also achieve temperature control of printed circuits. Its silver -

palladium - platinum metallization provides a high degree of resistance to dewetting of the terminations during soldering (typically 260°C / 30 s).

Types	NC 12 IEC SIZE : 0805	NC 20 IEC SIZE : 1206
DIMENSIONS: millimeters (inches)		
Terminations	Silver – palladium – platinum metallization	
Marking	On packaging only	
Climatic category	40/125/56	
Operating temperature	-55°C to +150°C	
Tolerance on R _n (25°C)	±5%, ±10%, ±20%	
Maximum dissipation at 25°C	0.12 W	0.24 W
Thermal dissipation factor	2 mW/°C	4 mW/°C
Thermal time constant	5 s	7 s

Resistance - Temperature characteristics: pages 29 to 33.

APPLICATIONS

- LCD compensation
- Battery packs
- Mobile phones
- CD players
- Heating systems
- Air-conditioning systems
- Temperature control of Switch Mode Power Supplies
- Compensation of pressure sensors
- Protection of power transistors in various electronic circuits

HOW TO ORDER

NC 20

Type

K 0

Material Code

K
(See tables pages 11, 29-33)

0103

Resistance
10,000 Ω

M

Tolerance
M (±20%)
J (±5%)
K (±10%)

BA

Suffix: Packaging

– –: Bulk
BA: Plastic tape
(180mm diam. reel)
BE: Plastic tape (1/2 reel)
BC: Plastic tape
(330mm diam. reel)
BB: Cardboard tape
(180mm diam. reel)
BF: Cardboard tape (1/2 reel)
BD: Cardboard tape
(330mm diam. reel)



NTC SMD Thermistors

NC 12 – NC 20



TABLE OF VALUES

NC 12 IEC SIZE : 0805				
Types	Rn at 25°C (Ω)	Material Code	B (K) ($\Delta B/B$ (1) $\pm 5\%$ (2) $\pm 3\%$)	α at 25°C (%/°C)
NC 12 KC 0 180 NC 12 KC 0 220 NC 12 KC 0 270 NC 12 KC 0 330 NC 12 KC 0 390 NC 12 KC 0 470 NC 12 KC 0 560 NC 12 KC 0 680 NC 12 KC 0 820 NC 12 KC 0 101	18 22 27 33 39 47 56 68 82 100	KC	3470 $\pm$ 5%	- 3.9
NC 12 MC 0 121 NC 12 MC 0 151 NC 12 MC 0 181 NC 12 MC 0 221 NC 12 MC 0 271 NC 12 MC 0 331 NC 12 MC 0 391 NC 12 MC 0 471 NC 12 MC 0 561 NC 12 MC 0 681 NC 12 MC 0 821 NC 12 MC 0 102 NC 12 MC 0 122 NC 12 MC 0 152 NC 12 MC 0 182 NC 12 MC 0 222 NC 12 MC 0 272 NC 12 MC 0 332	120 150 180 220 270 330 390 470 560 680 820 1,000 1,200 1,500 1,800 2,200 2,700 3,300	MC	3910 $\pm$ 3%	- 4.4
NC 12 J 0 0332 NC 12 J 0 0392 NC 12 J 0 0472 NC 12 J 0 0562	3,300 3,900 4,700 5,600	J	3480 $\pm$ 3%	- 3.9
NC 12 K 0 0682 NC 12 K 0 0822 NC 12 K 0 0103 NC 12 K 0 0123	6,800 8,200 10,000 12,000	K	3630 $\pm$ 3%	- 4.0
NC 12 L 0 0153 NC 12 L 0 0183	15,000 18,000	L	3790 $\pm$ 3%	- 4.2
NC 12 M 0 0223 NC 12 M 0 0273 NC 12 M 0 0333 NC 12 M 0 0393	22,000 27,000 33,000 39,000	M	3950 $\pm$ 3%	- 4.4
NC 12 N 0 0473 NC 12 N 0 0563	47,000 56,000	N	4080 $\pm$ 3%	- 4.6
NC 12 L 2 0683 NC 12 N 0 0823	68,000 82,000	L2 N	3805 $\pm$ 3% 4080 $\pm$ 3%	- 4.1 - 4.6
NC 12 P 0 0104 NC 12 P 0 0124 NC 12 P 0 0154 NC 12 P 0 0184	100,000 120,000 150,000 180,000	P	4220 $\pm$ 3%	- 4.7
NC 12 Q 0 0224	220,000	Q	4300 $\pm$ 3%	-4.7

NC 20 IEC SIZE : 1206				
Types	Rn at 25°C (Ω)	Material Code	B (K) ($\Delta B/B$ (1) $\pm 5\%$ (2) $\pm 3\%$)	α at 25°C (%/°C)
NC 20 KC 0 100 NC 20 KC 0 120 NC 20 KC 0 150 NC 20 KC 0 180 NC 20 KC 0 220 NC 20 KC 0 270 NC 20 KC 0 330 NC 20 KC 0 390 NC 20 KC 0 470 NC 20 KC 0 560 NC 20 KC 0 680 NC 20 KC 0 820 NC 20 KC 0 101	10 12 15 18 22 27 33 39 47 56 68 82 100	KC	3470 $\pm$ 5%	- 3.9
NC 20 MC 0 121 NC 20 MC 0 151 NC 20 MC 0 181 NC 20 MC 0 221 NC 20 MC 0 271 NC 20 MC 0 331 NC 20 MC 0 391 NC 20 MC 0 471 NC 20 MC 0 561 NC 20 MC 0 681 NC 20 MC 0 821 NC 20 MC 0 102 NC 20 MC 0 122 NC 20 MC 0 152	120 150 180 220 270 330 390 470 560 680 820 1,000 1,200 1,500	MC	3910 $\pm$ 3%	- 4.4
NC 20 I 0 0182 NC 20 I 0 0222 NC 20 I 0 0272 NC 20 I 0 0332	1,800 2,200 2,700 3,300	I	3250 $\pm$ 5%	- 3.7
NC 20 J 0 0392 NC 20 J 0 0472 NC 20 J 0 0562 NC 20 J 0 0682	3,900 4,700 5,600 6,800	J	3480 $\pm$ 3%	- 3.9
NC 20 K 0 0822 NC 20 K 0 0103 NC 20 K 0 0123 NC 20 K 0 0153	8,200 10,000 12,000 15,000	K	3630 $\pm$ 3%	- 4.0
NC 20 L 0 0183 NC 20 L 0 0223	18,000 22,000	L	3790 $\pm$ 3%	- 4.2
NC 20 M 0 0273 NC 20 M 0 0333 NC 20 M 0 0393 NC 20 M 0 0473	27,000 33,000 39,000 47,000	M	3950 $\pm$ 3%	- 4.4
NC 20 N 0 0563 NC 20 N 0 0683 NC 20 N 0 0823 NC 20 N 0 0104	56,000 68,000 82,000 100,000	N	4080 $\pm$ 3%	- 4.6
NC 20 P 0 0124 NC 20 P 0 0154 NC 20 P 0 0184 NC 20 P 0 0224	120,000 150,000 180,000 220,000	P	4220 $\pm$ 3%	- 4.7
NC 20 Q 0 0274 NC 20 Q 0 0334 NC 20 Q 0 0394 NC 20 Q 0 0474	270,000 330,000 390,000 470,000	Q	4300 $\pm$ 3%	- 4.7
NC 20 R 0 0564 NC 20 R 0 0684 NC 20 R 0 0824 NC 20 R 0 0105	560,000 680,000 820,000 1,000,000	R	4400 $\pm$ 3%	- 4.8

NTC SMD Thermistors

With Nickel Barrier Termination NB 12 - NB 20

Chip thermistors are high quality and low cost devices especially developed for surface mounting applications. They are widely used for temperature compensation but can also achieve temperature control of printed circuits.

A nickel barrier metallization provides outstanding qualities of solderability and enables this chip to meet the requirements of the most severe soldering processes.

Types	NB 12 IEC SIZE : 0805	NB 20 IEC SIZE : 1206
DIMENSIONS: millimeters (inches)		
Terminations	Nickel Barrier	
Marking	On packaging only	
Climatic category	40/125/56	
Operating temperature	-55°C to +150°C	
Tolerance on R _n (25°C)	±5%, ±10%, ±20%	
Maximum dissipation at 25°C	0.12 W	0.24 W
Thermal dissipation factor	2 mW/°C	4 mW/°C
Thermal time constant	5 s	7s

Resistance - Temperature characteristics: pages 29 to 33.

APPLICATIONS

- LCD compensation
- Battery packs
- Mobile phones
- CD players
- Heating systems
- Air-conditioning systems
- Temperature control of Switch Mode Power Supplies
- Compensation of pressure sensors
- Protection of power transistors in various electronic circuits

HOW TO ORDER

NB 20

Type

K 0

Material Code
K
(See tables page 13)

0103

Resistance
10,000 Ω

M

Tolerance
M (±20%)
J (±5%)
K (±10%)

BA

Suffix: Packaging
- -: Bulk
BA: Plastic tape
(180mm diam. reel)
BE: Plastic tape (1/2 reel)
BC: Plastic tape
(330mm diam. reel)
BB: Cardboard tape
(180mm diam. reel)
BF: Cardboard tape (1/2 reel)
BD: Cardboard tape
(330mm diam. reel)

NTC SMD Thermistors



With Nickel Barrier Termination NB 12 – NB 20

TABLE OF VALUES

NB 12 IEC SIZE : 0805				
Types	Rn at 25°C (Ω)	Material Code	B (K) $\left(\frac{\Delta B/B}{\Delta T} \pm 5\%\right)$ ($\pm 3\%$)	α at 25°C (%/°C)
NB 12 KC 0 180 NB 12 KC 0 220 NB 12 KC 0 270 NB 12 KC 0 330 NB 12 KC 0 390 NB 12 KC 0 470 NB 12 KC 0 560 NB 12 KC 0 680 NB 12 KC 0 820 NB 12 KC 0 101	18 22 27 33 39 47 56 68 82 100	KC	3470 ± 5%	– 3.9
NB 12 MC 0 121 NB 12 MC 0 151 NB 12 MC 0 181 NB 12 MC 0 221 NB 12 MC 0 271 NB 12 MC 0 331 NB 12 MC 0 391 NB 12 MC 0 471 NB 12 MC 0 561 NB 12 MC 0 681 NB 12 MC 0 821 NB 12 MC 0 102 NB 12 MC 0 122 NB 12 MC 0 152 NB 12 MC 0 182 NB 12 MC 0 222 NB 12 MC 0 272 NB 12 MC 0 332	120 150 180 220 270 330 390 470 560 680 820 1,000 1,200 1,500 1,800 2,200 2,700 3,300	MC	3910 ± 3%	– 4.4
NB 12 J 0 0332 NB 12 J 0 0392 NB 12 J 0 0472 NB 12 J 0 0562	3,300 3,900 4,700 5,600	J	3480 ± 3%	– 3.9
NB 12 K 0 0682 NB 12 K 0 0822 NB 12 K 0 0103	6,800 8,200 10,000	K	3630 ± 3%	– 4.0
NB 12 L 0 0123 NB 12 L 0 0153	12,000 15,000	L	3790 ± 3%	– 4.2
NB 12 M 0 0183 NB 12 M 0 0223 NB 12 M 0 0273 NB 12 M 0 0333	18,000 22,000 27,000 33,000	M	3950 ± 3%	– 4.4
NB 12 N 0 0393 NB 12 N 0 0473 NB 12 N 0 0563	39,000 47,000 56,000	N	4080 ± 3%	– 4.6
NB 12 L 2 0683	68,000	L2	3805 ± 3%	– 4.1
NB 12 N 5 0683 NB 12 N 5 0823	68,000 82,000	N5	4160 ± 3%	– 4.7
NB 12 P 0 0104	100,000	P	4220 ± 3%	– 4.7
NB 12 SC 0104	100,000	SC	4500 ± 3%	– 4.8
NB 12 P 0 0124 NB 12 P 0 0154 NB 12 P 0 0184	120,000 150,000 180,000	P	4220 ± 3%	– 4.7
NB 12 Q 0 0224 NB 12 Q 0 0274	220,000 270,000	Q	4300 ± 3%	– 4.7
NB 12 R 0 0105	1,000,000	R	4400 ± 3%	– 4.8

NB 20 IEC SIZE : 1206				
Types	Rn at 25°C (Ω)	Material Code	B (K) $\left(\frac{\Delta B/B}{\Delta T} \pm 5\%\right)$ ($\pm 3\%$)	α at 25°C (%/°C)
NB 20 MC 0 221 NB 20 MC 0 102	220 1,000	MC	3910 ± 3%	– 4.4
NB 20 J 0 0472 NB 20 J 0 0562 NB 20 J 0 0682	4,700 5,600 6,800	J	3480 ± 3%	– 3.9
NB 20 J 5 0822	8,200	J5	3480 ± 3%	– 3.9
NB 20 K 0 0103 NB 20 K 0 0123	10,000 12,000	K	3630 ± 3%	– 4.0
NB 20 L 0 0153 NB 20 L 0 0183 NB 20 L 0 0223	15,000 18,000 22,000	L	3790 ± 3%	– 4.2
NB 20 M 0 0273 NB 20 M 0 0333 NB 20 M 0 0393 NB 20 M 0 0473	27,000 33,000 39,000 47,000	M	3950 ± 3%	– 4.4
NB 20 N 0 0563 NB 20 N 0 0683 NB 20 N 0 0823	56,000 68,000 82,000	N	4080 ± 3%	– 4.6
NB 20 N 5 0104	100,000	N5	4160 ± 3%	– 4.7
NB 20 P 0 0124 NB 20 P 0 0154 NB 20 P 0 0184 NB 20 P 0 0224	120,000 150,000 180,000 220,000	P	4220 ± 3%	– 4.7
NB 20 Q 0 0274 NB 20 Q 0 0334 NB 20 Q 0 0394 NB 20 Q 0 0474 NB 20 Q 0 0564	270,000 330,000 390,000 470,000 560,000	Q	4300 ± 3%	– 4.7
NB 20 R 0 0684 NB 20 R 0 0824 NB 20 R 0 0105	680,000 820,000 1,000,000	R	4400 ± 3%	– 4.8

NTC SMD Thermistors

With Nickel Barrier Termination NB 21

Chip thermistors are high quality and low cost devices especially developed for surface mounting applications. They are widely used for temperature compensation but can also achieve temperature control of printed circuits.

A nickel barrier metallization provides outstanding qualities of solderability and enables this chip to meet the requirements of the most severe soldering processes.

Types	NB 21 IEC SIZE : 0603
DIMENSIONS: millimeters (inches)	
Terminations	Nickel Barrier
Marking	On packaging only
Climatic category	40/125/56
Operating temperature	-55°C to +150°C
Tolerance on R _n (25°C)	±5%, ±10%, ±20%
Maximum dissipation at 25°C	0.07 W
Thermal dissipation factor	1 mW/°C
Thermal time constant	4 s

Resistance - Temperature characteristics: pages 29 to 33.

APPLICATIONS

- LCD compensation
- Battery packs
- Mobile phones
- CD players
- Heating systems
- Air-conditioning systems
- Temperature control of Switch Mode Power Supplies
- Compensation of pressure sensors
- Protection of power transistors in various electronic circuits

HOW TO ORDER

NB 21

Type

K 0

Material Code
K
(See tables page 13)

0103

Resistance
10,000 Ω

M

Tolerance
M (±20%)
J (±5%)
K (±10%)

BB

Suffix: Packaging
--: Bulk
BB: Cardboard tape
(180mm diam. reel)
BF: Cardboard tape (1/2 reel)
BD: Cardboard tape
(330mm diam. reel)

NTC SMD Thermistors

With Nickel Barrier Termination NB 21

TABLE OF VALUES

NB 21 IEC SIZE : 0603				
Types	R _n at 25°C (Ω)	Material Code	B (K) (⁽¹⁾ ± 5% ⁽²⁾ ± 3%) (ΔB/B)	α at 25°C (%/°C)
NB 21 KC 0 470 NB 21 KC 0 101 NB 21 KC 0 471	47 100 470	KC	3470 ± 5%	− 3.9
NB 21 MC 0 102	1,000	MC	3910 ± 3%	− 4.4
NB 21 J 0 0472	4,700	J	3480 ± 3%	− 3.9
NB 21 J 5 0682 NB 21 J 5 0103	6,800 10,000	J5	3480 ± 3% 3480 ± 3%	− 3.9 − 3.9
NB 21 K 0 0103 NB 21 K 0 0153	10,000 15,000	K	3630 ± 3%	− 4.0
NB 21 L 0 0223	22,000	L	3790 ± 3%	− 4.2
NB 21 M 0 0333 NB 21 M 0 0473	33,000 47,000	M	3950 ± 3%	− 4.4
NB 21 L 2 0683	68,000	L2	3805 ± 3%	− 4.1
NB 21 N 0 0683	68,000	N	4080 ± 3%	− 4.6
NB 21 N 5 0104	100,000	N5	4160 ± 3%	− 4.7
NB 21 P 0 0154	150,000	P	4220 ± 3%	− 4.7
NB 21 Q 0 0334 NB 21 Q 0 0474	330,000 470,000	Q	4300 ± 3%	− 4.7

Packaging for Automatic Insertion

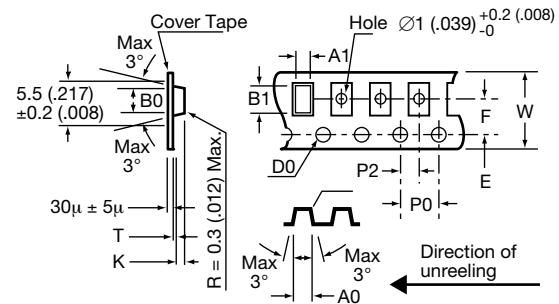
NTC Chip Thermistors / NC/NB Series



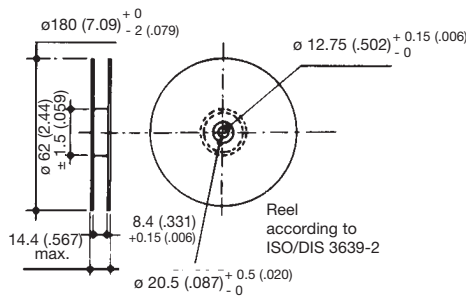
AUTOMATIC INSERTION

Super 8 Plastic Tape Packaging:

The mechanical and dimensional reel characteristics are in accordance with the IEC publication 286-3.



Designation	Symbol	Value	Tolerance
Tape width	W	8	± 0.2
Tape thickness	T	0.4 max.	
Pitch of the sprocket holes	P0	4	± 0.1
Diameter of the sprocket holes	D0	1.5 -0	± 0.1
Distance	E	1.75	± 0.1
Distance (center to center)	F	3.5	± 0.05
Distance (center to center)	P2	2	± 0.1
Sizes of the cavities NC 12 (0805) NC 20 (1206)	A0	1.5	± 0.1
	B0	2.4	± 0.1
	K	1.4 max.	K ± 0.1 (size is adjustable) (K = t1 +0.2)
	A0	1.95	± 0.1
	B0	3.55	± 0.1
	K	1.5 max.	K ± 0.1 (size is adjustable) (K = t1 +0.2)



QUANTITY PER REEL

Type	Suffix	Qty Per Reel
NC - NB 12	BA	4000
	BE	2000
NC 20 - NB 20	BA	3000
	BE	1500

Packaging for Automatic Insertion

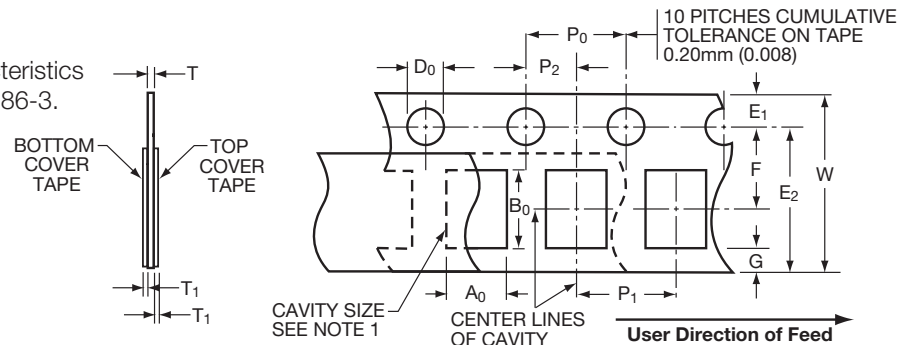
NTC Chip Thermistors / NC/NB Series



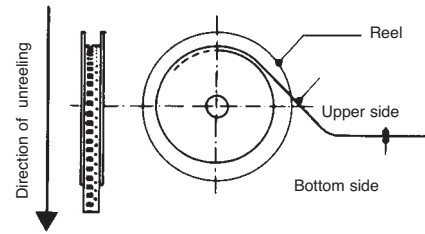
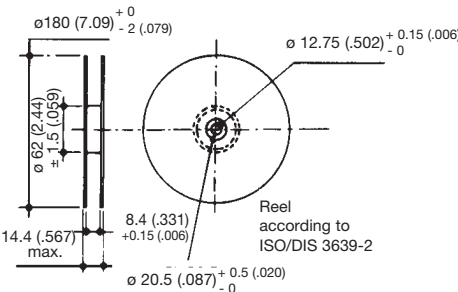
AUTOMATIC INSERTION

8mm Paper Tape Packaging:

The mechanical and dimensional reel characteristics are in accordance with the IEC publication 286-3.



Designation	Symbol	Value	Tolerance
Tape width	W	8	$-.0.1/+0.3$
Tape thickness	T	1.1 max.	
Pitch of the sprocket holes	P_0	4	± 0.1
Diameter of the sprocket holes	D_0	1.5 $-0/+0.1$	± 0.1
Distance	E_1	1.75	± 0.1
Distance (center to center)	F	3.5	± 0.05
Distance (center to center)	P_2	2	± 0.05
Cover tape thickness	T_1	0.10 max.	
Distance	E_2	6.25 min.	
Distance	G	0.75 min.	
Component pitch 0805/0603	P_1	4	± 0.1
0402		2	± 0.1



QUANTITY PER REEL

Type	Suffix	Qty Per Reel
NB - NC 12	BB	4000
NB 21	BF	2000



Surface Mounting Guide

Chip Thermistor – Application Notes

STORAGE

Good solderability is maintained for at least twelve months, provided the components are stored in their “as received” packaging at less than 40°C and 70% RH.

SOLDERABILITY / LEACHING

Terminations to be well soldered after immersion in a 60/40 tin/lead solder bath at $235 \pm 5^\circ\text{C}$ for 2 ± 1 seconds.

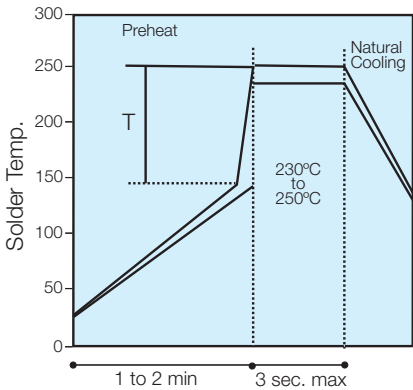
Terminations will resist leaching for at least the immersion times and conditions recommendations shown below.

P/N	Termination Type	Solder Tin/Lead	Solder Temp °C	Immersion Time Seconds
NC	AgPdPt	60/40	260 ± 5	15 max
NB	Nickel Barrier	60/40	260 ± 5	30 ± 1

NB products are compatible with a wide range of soldering conditions consistent with good manufacturing practice for surface mount components. This includes Pb free reflow processes with peak temperatures up to 270°C . Recommended profiles for reflow and wave soldering are shown below for reference.

NC products are recommended for lead soldering application or gluing techniques.

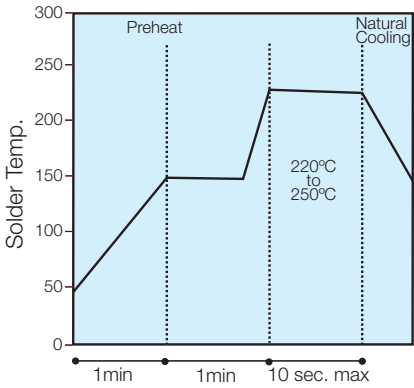
Wave



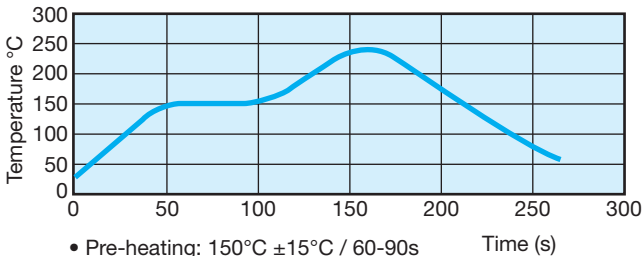
(Preheat chips before soldering)
T/maximum 150°C

- The visual standards used for evaluation of solder joints will need to be modified as lead free joints are not as bright as with tin-lead pastes and the fillet may not be as large.
- Resin color may darken slightly due to the increase in temperature required for the new pastes.
- Lead-free solder pastes do not allow the same self alignment as lead containing systems. Standard mounting pads are acceptable, but machine set up may need to be modified.

Reflow



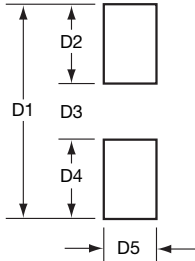
(Minimize soldering time)



- Pre-heating: $150^\circ\text{C} \pm 15^\circ\text{C}$ / 60-90s
- Max. Peak Gradient: 2.5°C/s
- Peak Temperature: $245^\circ\text{C} \pm 5^\circ\text{C}$
- Time at $>230^\circ\text{C}$: 40s Max.

RECOMMENDED SOLDERING PAD LAYOUT

Dimensions in mm (inches)



REFLOW SOLDERING

Case Size	P/N	D1	D2	D3	D4	D5
0402	NB23	1.70 (.067)	0.60 (.024)	0.50 (.020)	0.60 (.024)	0.50 (.020)
0603	NB21	2.30 (.091)	0.80 (.031)	0.70 (.028)	0.80 (.031)	0.75 (.030)
0805	NB12	3.00 (.118)	1.00 (.039)	1.00 (.039)	1.00 (.039)	1.25 (.049)
1206	NB20	4.00 (.157)	1.00 (.039)	2.00 (.079)	1.00 (.039)	2.50 (.098)

WAVE SOLDERING

Case Size	P/N	D1	D2	D3	D4	D5
0603	NB21	3.10 (.122)	1.20 (.047)	0.70 (.028)	1.20 (.047)	0.75 (.030)
0805	NB12	4.00 (.157)	1.50 (.059)	1.00 (.039)	1.50 (.059)	1.25 (.049)
1206	NB20	5.00 (.197)	1.50 (.059)	2.00 (.079)	1.50 (.059)	1.60 (.063)

NTC Accurate Thermistors

NJ 28 – NI 24 – NK 20



High precision resistance and an outstanding ability to reproduce the sensibility index B, make these ranges of products the types of thermistors ideal for temperature measurement applications.

Leaded or unleaded, these small size and rapid response time thermistors are able to meet the most accurate requirements.

Types	NJ 28	NP 30	NI 24	NK 20
Finish	Coated chip with phenolic resin + varnish + tinned copper wires	Coated chip with epoxy	Coated chip with epoxy AWG30 insulated leads + Silver plated nickel wires	Chip
DIMENSIONS: millimeters (inches)				
Marking	On packaging only			
Operating temperature	-55°C to +150°C			
Tolerance on R _n (25°C)	±1%, ±2%, ±3%			
Maximum dissipation at 25°C	0.16 W			
Thermal dissipation factor*	3 mW/°C		3 mW/°C	2 mW/°C
Thermal time constant	8 s		8 s	6 s
Response time	< 2 s			

TABLE OF VALUES

Types	R _n at 25°C (Ω)	Material Code	B (K)	α at 25°C (%/°C)
N_ _ _ KA 0202	2,000	KA	3625 ± 1%	- 4.1
N_ _ _ MA 0302	3,000	MA	3960 ± 0.5%	- 4.5
N_ _ _ MA 0502	5,000	MA	3960 ± 0.5%	- 4.5
N_ _ _ MA 0103	10,000	MA	3960 ± 0.5%	- 4.5
N_ _ _ NA 0103	10,000	NA	4100 ± 1%	- 4.6
N_ _ _ PA 0203	20,000	PA	4235 ± 1%	- 4.8
N_ _ _ QA 0503	50,000	QA	4250 ± 1%	- 4.8
N_ _ _ RA 0104	100,000	RA	4380 ± 1%	- 4.9

* – = Add type as outlined above (Example NJ 28).

Resistance - Temperature characteristics: pages 29 to 33.

HOW TO ORDER

NJ28

Type

MA

Material Code
MA
(See table above)

0502

Resistance
5 kΩ

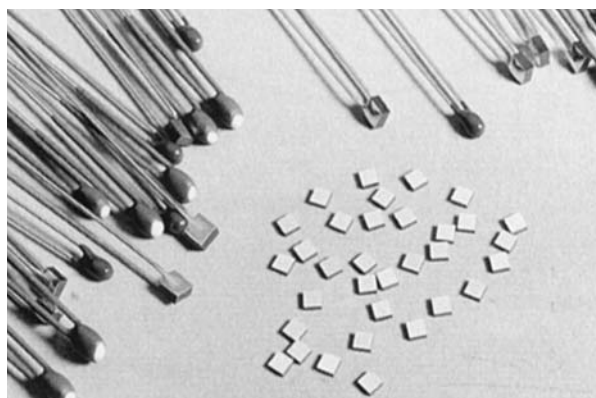
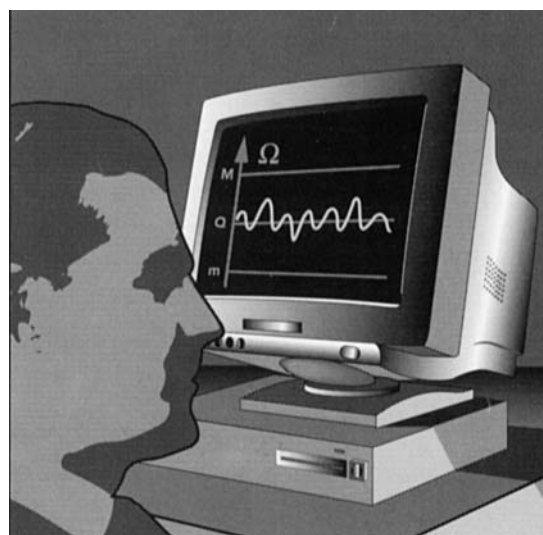
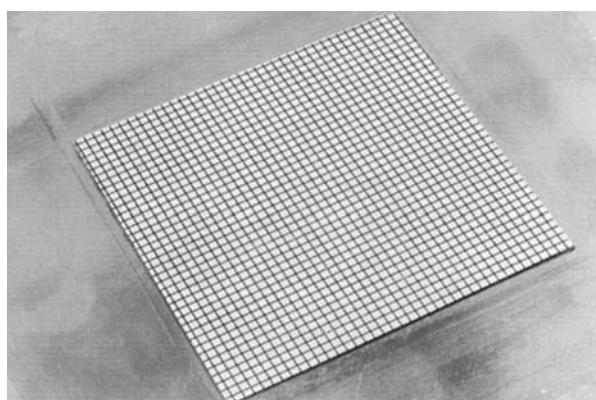
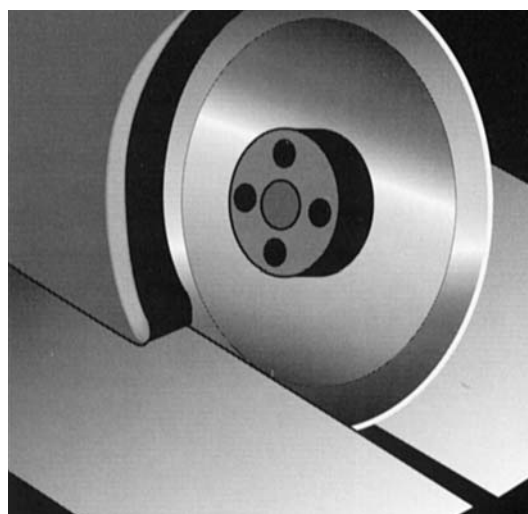
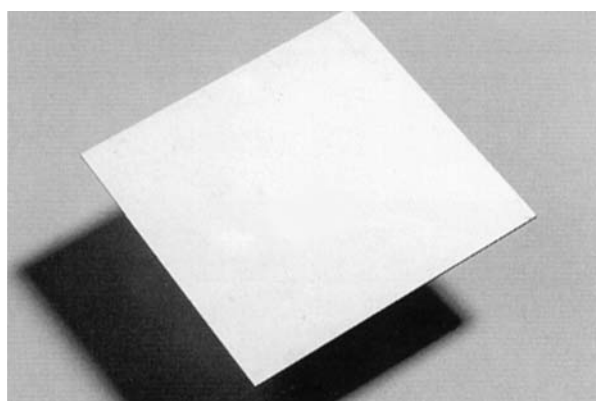
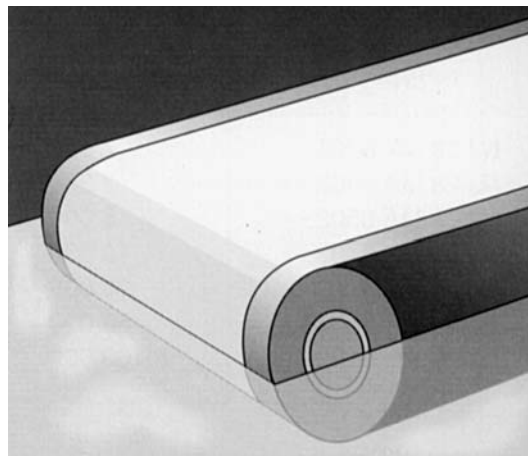
F--

Tolerance
F (±1%)



NTC Thermistors Manufacturing Process **AVX**

NJ 28 – NI 24 – NK 20



NTC Disc Thermistors

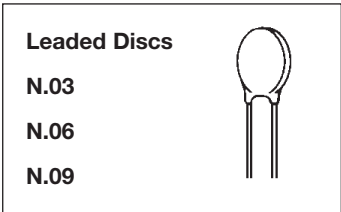
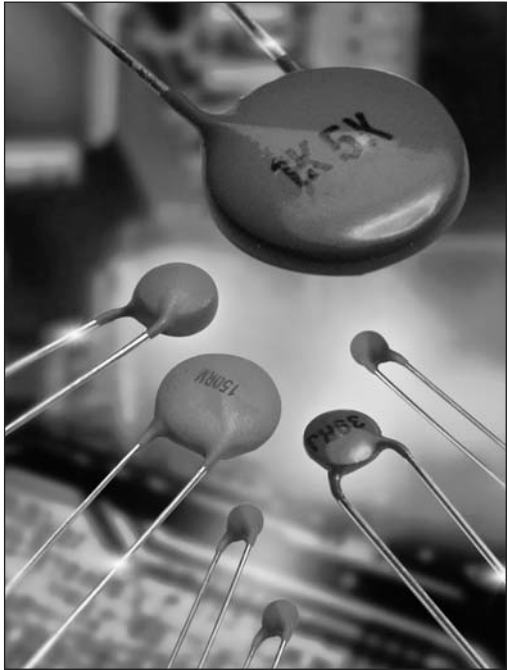
ND 03/06/09 • NE 03/06/09 • NV 06/09

APPLICATIONS

- Commodity Product: 2 families
ND or NE : general purpose
NV : professional
- Alarm and temperature measurement application
- Temperature regulation application
- Level detection application
- Compensation application

TECHNOLOGY

- ND: epoxy-phenolic resin coating
NE: epoxy resin coating (recommended for severe mounting conditions)
NV: epoxy varnish coating
- Leads: Radial copper wire tinned
- Marking: on package only for ND03 & NE03
ND/NE 06/09: Nominal resistance and tolerance for $\pm 5\%$, $\pm 10\%$
NV06/09: Nominal resistance and tolerance
- Delivery Mode: Bulk, reeled or ammopacked



PERFORMANCE CHARACTERISTICS

Types	General purpose			Professional	
	ND03 or NE03	ND06 or NE06	ND09 or NE09	NV06	NV09
Climatic category				55/125/56-434	55/125/56-434
Operating Temperature	-55 to +150°C	-55 to +150°C	-55 to +150°C	-55 to +150°C	-55 to +150°C
Tolerance on Rn (25°C)	330Ω to 1MΩ : $\pm 5, 10, 20\%$ 1500Ω to 150 kΩ : $\pm 3\%$	$\pm 5\%, \pm 10\%, \pm 20\%$	$\pm 5\%, \pm 10\%, \pm 20\%$	$\pm 2\%, \pm 5\%, \pm 10\%$	$\pm 2\%, \pm 5\%, \pm 10\%$
Maximum dissipation at 25°C	0.25 W	0.71 W	0.9 W	0.69 W	0.85 W
Thermal dissipation factor	5 mW/°C	7.1 mW/°C	9 mW/°C	6.9 mW/°C	8.5 mW/°C
Thermal time constant	10 s	22 s	30 s	18 s	30 s
Response time	< 3s				

STANDARDIZATION

NV range : approved by NFC 93271
Type: TN115 A for NV06
TN116 for NV09
List: GAM-T1
List: LN2

OPTIONS

Consult factory for availability of options:

- other nominal resistance values
- other tolerances
- alternative lead materials or lengths
- controlled dimensions

NTC Disc Thermistors

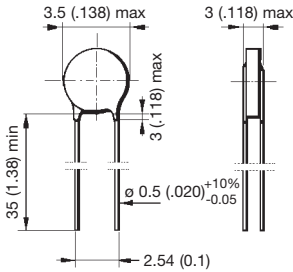
ND/NE 03



TABLE OF VALUES

ND03/NE03 TYPE

ND03/NE03



Part Number	R _n at 25°C (Ω)	Material Code	B (K) ($\Delta B/B$ (1) $\pm 5\%$ (2) $\pm 3\%$)	α at 25°C (%/°C)
N_03I00331 N_03I00471	330 470	I	3250 (1)	- 3.7
N_03J00681 N_03J00102	680 1,000	J	3480 (2)	- 3.9
N_03K00152 N_03K00222	1,500 2,200	K	3630 (2)	- 4.0
N_03L00272 N_03L00332	2,700 3,300	L	3790 (2)	- 4.2
N_03M00472 N_03M00682	4,700 6,800	M	3950 (2)	- 4.4
N_03N00103 N_03N00153	10,000 15,000	N	4080 (2)	- 4.6
N_03P00223 N_03P00333	22,000 33,000	P	4220 (2)	- 4.7
N_03Q00473 N_03Q00683	47,000 68,000	Q	4300 (2)	- 4.7
N_03R00104 N_03R00154	100,000 150,000	R	4400 (2)	- 4.8
N_03S00224	220,000	S	4520 (2)	- 5.0
N_03T00334 N_03T00474	330,000 470,000	T	4630 (2)	- 5.1
N_03U00105	1,000,000	U	4840 (2)	- 5.3

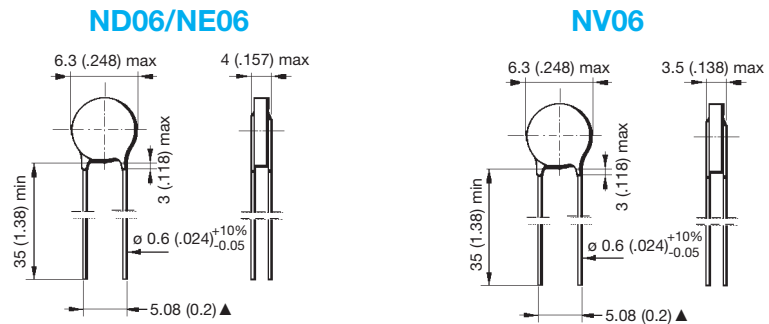
NTC Disc Thermistors

ND/NE/NV 06



TABLE OF VALUES

ND06/NE06/NV06



Part Number	R _n at 25°C (Ω)	Material Code	B (K) ($\Delta B/B$ (1) $\pm 5\%$ (2) $\pm 3\%$)	α at 25°C (%/°C)
N_06J00151 N_06J00221	150 220	J	3480 (2)	- 3.9
N_06K00331 N_06K00471	330 470	K	3630 (2)	- 4.0
N_06L00681 N_06L00102	680 1,000	L	3790 (2)	- 4.2
N_06M00152	1,500	M	3950 (2)	- 4.4
N_06N00222 N_06N00332	2,200 3,300	N	4080 (2)	- 4.6
N_06P00472 N_06P00682 N_06P00103	4,700 6,800 10,000	P	4220 (2)	- 4.7
N_06Q00153 N_06Q00223	15,000 22,000	Q	4300 (2)	- 4.7
N_06R00333	33,000	R	4400 (2)	- 4.8
N_06S00473 N_06S00683	47,000 68,000	S	4520 (2)	- 5.0
N_06T00104	100,000	T	4630 (2)	- 5.1
N_06U00154 N_06U00224 N_06U00334	150,000 220,000 330,000	U	4840 (2)	- 5.3

For other resistance values, please consult us.

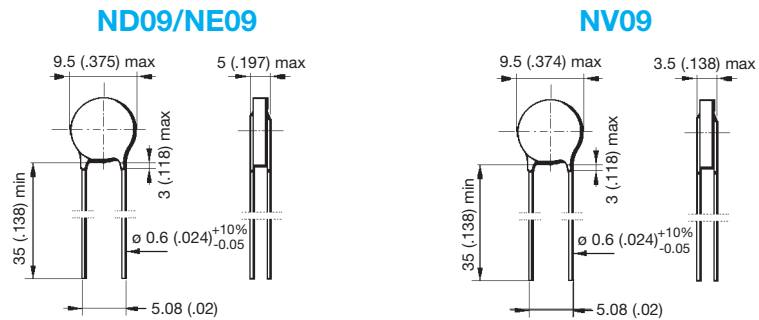
NTC Disc Thermistors

ND/NE/NV 09



TABLE OF VALUES

ND09/NE09/NV09



Part Number	R _n at 25°C (Ω)	Material Code	B (K) ($\Delta B/B$ (1) $\pm 5\%$ (2) $\pm 3\%$)	α at 25°C (%/°C)
N_09J00680 N_09J00101	68 100	J	3480 (2)	- 3.9
N_09K00151 N_09K00221	150 220	K	3630 (2)	- 4.0
N_09L00331	330	L	3790 (2)	- 4.2
N_09M00471 N_09M00681	470 680	M	3950 (2)	- 4.4
N_09N00102 N_09N00152	1,000 1,500	N	4080 (2)	- 4.6
N_09P00222 N_09P00332	2,200 3,300	P	4220 (2)	- 4.7
N_09Q00472 N_09Q00682	4,700 6,800	Q	4300 (2)	- 4.7
N_09R00103 N_09R00153	10,000 15,000	R	4400 (2)	- 4.8
N_09S00223	22,000	S	4520 (2)	- 5.0
N_09T00333 N_09T00473	33,000 47,000	T	4630 (2)	- 5.1
N_09U00683 N_09U00104 N_09U00154	68,000 100,000 150,000	U	4840 (2)	- 5.3



NTC Disc Thermistors

Packaging for Automatic Insertion

PACKAGING AND KINK SUFFIXES

Tables below indicate the suffixes to specify when ordering to get the required kink and packaging. For devices on tape, it is necessary to specify the height (H or Ho) which is the distance between the tape axis (sprocket holes axis) and the seating plane on the printed circuit board. The following types can be ordered on tape either in AMMOPACK (fan folder) or on REEL in accordance with IEC 286-2.

– Straight leads:

H represents the distance between the sprocket holes axis and the bottom plane of component body (base of resin or base of stand off).

– Kinked leads and flat leads:

Ho represents the distance between the sprocket holes axis and the base on the knee (kinked leads) or the bottom of the flat part (flat leads).

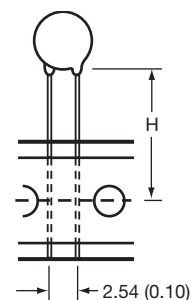
• Reel & Ammopack

millimeters (inches)

Types	Suffix	H or Ho	Leads	Quantity/Size	Packaging
ND/NE 03 & NJ28	CA	16 ± 0.5 (0.630 ± 0.020)	Straight	3000	AMMOPACK
	CB	16 ± 0.5 (0.630 ± 0.020)	Straight	3000	REEL
	CC	19.5 ± 0.5 (0.768 ± 0.020)	Straight	3000	AMMOPACK
	CD	19.5 ± 0.5 (0.768 ± 0.020)	Straight	3000	REEL
ND/NE/NV 06/09	DA	16 ± 0.5 (0.630 ± 0.020)	Straight	1500	AMMOPACK
	DB	16 ± 0.5 (0.630 ± 0.020)	Straight	1500	REEL
	DC	19.5 ± 0.5 (0.768 ± 0.020)	Straight	1500	AMMOPACK
	DD	19.5 ± 0.5 (0.768 ± 0.020)	Straight	1500	REEL
	DL	16 ± 0.5 (0.630 ± 0.020)	Kinked	1500	AMMOPACK
	DM	16 ± 0.5 (0.630 ± 0.020)	Kinked	1500	REEL
	DN	19.5 ± 0.5 (0.768 ± 0.020)	Kinked	1500	AMMOPACK
	DP	19.5 ± 0.5 (0.768 ± 0.020)	Kinked	1500	REEL

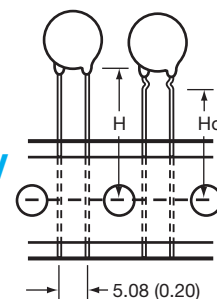
NTC

Type
ND03
NE03
NJ28



NTC

Types
ND/NE/NV
06/09



• Bulk

Type	Quantity/box
ND/NE03	3000
ND/NE06	1500
ND/NE09	1500
NV06	100
NV09	100
NJ24 NJ28 NK20	1000

HOW TO ORDER

ND06

Type

P0

Material Code
P

0103

Resistance
10 kΩ

K

Tolerance
K (±10%)

--

Packaging
Bulk

Automatic Insertion

NTC Disc Thermistors

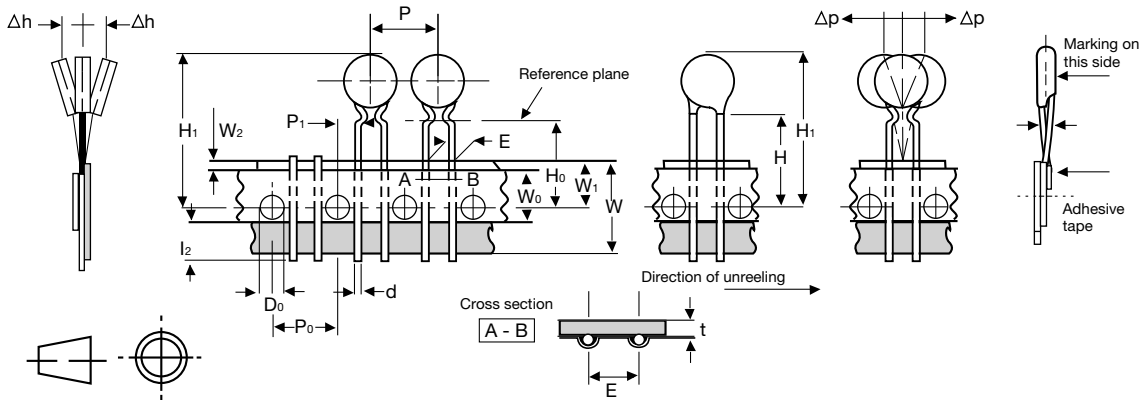
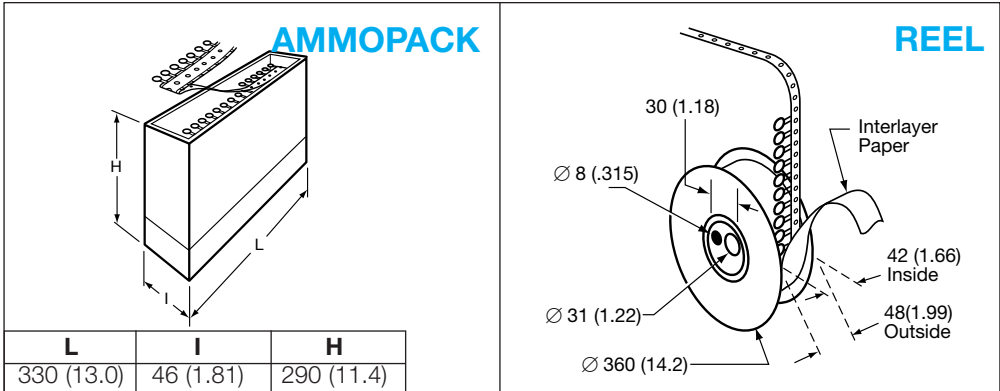
TAPING CHARACTERISTICS

Missing components

A maximum of 3 consecutive components may be missing from the bandolier, surrounded by at least 6 filled positions. The number of missing components may not exceed 0.5% of the total per packing module.

The beginning and the end of tape exhibit 8 or 9 blank positions.

DIMENSIONS: millimeters (inches)



Value	Tolerance	Dimensions Characteristics
18	+1 / -0.5	W Leading tape width
6	±0.3	W ₀ Adhesive tape width
9	+0.75 / -0.5	W ₁ Sprocket hole position
3 max.		W ₂ Distance between the top of the tape and the adhesive
4	±0.2	D ₀ Diameter of sprocket hole
16/19.5	±0.5	H ₀ Distance between the tape axis and the seating plane of the component
		H ₁ Distance between the tape axis and the top of component body

Value	Tolerance	Dimensions Characteristics
12.7	±0.2	P ₀ Sprocket holes pitch
254	±1	- Distance between 21 consecutive holes 20 pitches
0.7	±0.2	t Total thickness of tape
2.54	+0.6 / -0.1	E Lead spacing
5.08	± 0.7	P ₁ Distance between the sprocket hole axis and the lead axis
12.7	±1.0	P Spacing of components
0.5	±5%	d Lead diameter
0	±1.3	°P Verticality of components
0	±2	°h Alignment of components

This type of product is widely used in automotive and consumer applications.

They are assembled in custom-probes for sensing the temperature of liquids (water, oil, ...), gases or surface of any other component.

The metallization covers completely the surfaces of the thermistor.

The particularly flat and smooth surfaces ensure an excellent electrical and thermal contact under pressure.

Types	NR
Physical data (dim. in mm)	
Marking	On package only / On parts upon request
Operating temperature	-40°C to +200°C
Values and tolerances	Custom - designed products defined with: $D \pm \Delta D$ $R_1 \pm \Delta R_1 / R_1$ at T_1 $E \pm \Delta E$ $R_2 \pm \Delta R_2 / R_2$ at $T_2, \dots$

DESIGN OF THE THERMISTOR

Choice of the resistances

If the application is to measure the temperature around a defined point, a unique nominal resistance can be chosen (for example, among standard values of the ND range products presented on pages 20 to 24).

When it is required to measure the temperature over selected ranges $T_1 - T_2$, $T_2 - T_3$, ..., the corresponding resistance R_1 , R_2 , R_3 , ..., must be such that they can be located on the $R(T)$ characteristic of an existing NTC material (for example among standard materials whose $R(T)$ are displayed on pages 29 to 33).

The resistances must also be compatible with the resistivity of the material and the dimensions of the thermistor.

Choice of the tolerances

The precision of the temperature measurement determines the calculation of the tolerance on the resistance:

$$\Delta R/R = \alpha \text{ (}\%/\text{°C)} \cdot \Delta T \text{ (°C)}$$

For example, the NTC NR55--3002-99, using "N5" material ($R(T)$ characteristic displayed on page 31), requires a precision of 1°C over the temperature range 110°C - 120°C.

The tolerances can be calculated:

$$\Delta R_{110^\circ\text{C}} / R_{110^\circ\text{C}} = 1^\circ\text{C} \cdot 2.91\%/\text{°C} = 2.91\%$$

$$\Delta R_{120^\circ\text{C}} / R_{120^\circ\text{C}} = 1^\circ\text{C} \cdot 2.76\%/\text{°C} = 2.76\%$$

*For your specific requirements, please consult us.

HOW TO ORDER

NR55 - - **3002** - 99

Type P/N Code

We present below some examples of our custom - designed products as an illustration of the different ways to define products.

DIMENSIONS: millimeters (inches)

Types	D	E	Material Code	B (k)	$R_1 \pm \Delta R_1$ at T_1	T_1 (°C)	$R_2 \pm \Delta R_2$ at T_2	T_2 (°C)	$R_3 \pm \Delta R_3$ at T_3	T_3 (°C)
NR 55 -- 3002 - 99	5.5 (.217) $\pm$ 0.5 (.020)	1.1 (.043) $\pm$ 0.4 (.016)	N5	4160	1230 $\Omega \pm 7.5\%$	40	160 $\Omega \pm 5\%$	96.5	–	–
NR 67 -- 3068 - 99	6.7 (.264) $\pm$ 0.5 (.020)	1.7 (.067) $\pm$ 0.3 (.012)	N	4080	150 $\Omega \pm 3.3\%$	100	51 $\Omega \pm 5.3\%$	140	–	–
NR 55 -- 3049 - 99	5.5 (.217) $\pm$ 0.5 (.020)	1.0 (.040) $\pm$ 0.2 (.008)	N5	4160	107 $\Omega \pm 2.9\%$	110	80.6 $\Omega \pm 2.8\%$	120	–	–
NR 55 -- 3046 - 99	5.5 (.217) $\pm$ 0.5 (.020)	1.3 (.051) $\pm$ 0.4 (.016)	S	4520	48600 $\Omega \pm 7.5\%$	25	3210 $\Omega \pm 5\%$	90	–	–
NR 49 -- 3119 - 99	4.9 (.193) $\pm$ 0.3 (.012)	1.5 (.060) $\pm$ 0.4 (.016)	M	3950	840 $\Omega \pm 10\%$	37.8	84 $\Omega \pm 5\%$	104.4	–	–
NR 55 -- 3114 - 99	5.5 (.217) $\pm$ 0.4 (.016)	1.0 (.040) $\pm$ 0.2 (.008)	P	4220	5000 $\Omega \pm 10\%$	25	–	–	–	–
NR 70 -- 3121 - 99	7.0 (.275) $\pm$ 0.3 (.012)	1.2 (.047) $\pm$ 0.2 (.008)	L	3790	210 $\Omega \pm 10\%$	40	40 $\Omega \pm 7.5\%$	90	30 $\Omega \pm 6.7\%$	100
NR 29 -- 3107 - 99	2.9 (.014) $\pm$ 0.3 (.012)	1.7 (.067) $\pm$ 0.3 (.012)	K	3630	2050 $\Omega \pm 6\%$	25	193 $\Omega \pm 5.4\%$	96.5	–	–
NR 55 -- 3122 - 99	5.5 (.217) $\pm$ 0.5 (.020)	1.5 (.060) $\pm$ 0.4 (.016)	J	3480	210 $\Omega \pm 5\%$	25	–	–	–	–
NR 55 -- 3126 - 99	5.5 (.217) $\pm$ 0.5 (.020)	1.0 (.040) $\pm$ 0.2 (.008)	P	4220	3340 $\Omega \pm 10\%$	25	264 $\Omega \pm 7\%$	90	107 $\Omega \pm 7\%$	120
NR 47 -- 3116 - 99	4.7 (.185) $\pm$ 0.4 (.016)	1.2 (.047) $\pm$ 0.2 (.008)	R	4400	33000 $\Omega \pm 2\%$	25	–	–	–	–
NR 49 -- 3113 - 99	4.9 (.193) $\pm$ 0.3 (.012)	1.2 (.047) $\pm$ 0.2 (.008)	N	4080	1680 $\Omega \pm 10\%$	40	382 $\Omega \pm 6.7\%$	80	176 $\Omega \pm 5\%$	105
NR 47 -- 3101 - 99	4.6 (.181) $\pm$ 0.3 (.012)	1.4 (.055) $\pm$ 0.3 (.012)	J	3480	146 $\Omega \pm 13\%$	40	22 $\Omega \pm 10\%$	100	–	–
NR 55 -- 3071 - 99	5.8 (.228) $\pm$ 0.3 (.012)	1.0 (.040) $\pm$ 0.2 (.008)	L	3790	262 $\Omega \pm 8.7\%$	40	120 $\Omega \pm 10\%$	60	35.5 $\Omega \pm 7.8\%$	100
NR 61 -- 3063 - 99	6.1 (.240) $\pm$ 0.3 (.012)	1.5 (.060) $\pm$ 0.3 (.012)	N	4080	760 $\Omega \pm 9.2\%$	50	130 $\Omega \pm 8.5\%$	100	56.6 $\Omega \pm 8.5\%$	130
NR 67 -- 3053 - 99	6.7 (.264) $\pm$ 0.4 (.016)	1.7 (.067) $\pm$ 0.3 (.012)	N	4080	540 $\Omega \pm 11\%$	60	144 $\Omega \pm 7\%$	100	–	–
NR 50 -- 3048 - 99	5.0 (.197) $\pm$ 0.5 (.020)	1.5 (.060) $\pm$ 0.5 (.020)	J	3480	233 $\Omega \pm 10\%$	25	13.3 $\Omega \pm 7\%$	121	–	–
NR 60 -- 3021 - 99	6.0 (.236) $\pm$ 0.5 (.020)	3.2 (.125) $\pm$ 0.3 (.012)	P	4220	3640 $\Omega \pm 3\%$	40	457 $\Omega \pm 3\%$	96.5	–	–
NR 55 -- 3016 - 99	5.5 (.217) $\pm$ 0.5 (.020)	1.1 (.043) $\pm$ 0.4 (.016)	Q	4300	5500 $\Omega \pm 9\%$	40	650 $\Omega \pm 7.7\%$	96.5	–	–

Resistance - Temperature characteristics: pages 29 to 33.

Tables of Resistance vs Temperature

T (°C)	Material code B (K)									T (°C)
	I 3250			J-J5 3480			K 3630			
	R (T) / R25	TF (%)	α (°/°C)	R (T) / R25	TF (%)	α (°/°C)	R (T) / R25	TF (%)	α (°/°C)	
- 55	42.35	21.9	- 5.98	51.74	20.5	- 6.43	56.26	21.4	- 6.46	- 55
- 50	31.48	20.0	- 5.78	37.97	17.7	- 6.21	41.21	18.5	- 6.26	- 50
- 45	23.63	18.1	- 5.59	28.15	15.2	- 6.01	30.47	15.9	- 6.06	- 45
- 40	17.91	16.3	- 5.41	21.07	13.0	- 5.81	22.73	13.6	- 5.88	- 40
- 35	13.70	14.6	- 5.23	15.91	11.0	- 5.62	17.11	11.5	- 5.70	- 35
- 30	10.58	13.1	- 5.06	12.13	9.3	- 5.44	12.98	9.7	- 5.53	- 30
- 25	8.232	11.6	- 4.90	9.320	7.8	- 5.26	9.930	8.1	- 5.36	- 25
- 20	6.460	10.1	- 4.74	7.221	6.4	- 5.10	7.654	6.7	- 5.21	- 20
- 15	5.110	8.8	- 4.59	5.640	5.2	- 4.94	5.945	5.4	- 5.05	- 15
- 10	4.072	7.5	- 4.45	4.438	4.2	- 4.78	4.650	4.4	- 4.91	- 10
- 5	3.268	6.3	- 4.31	3.517	3.3	- 4.64	3.663	3.4	- 4.76	- 5
0	2.641	5.1	- 4.18	2.807	2.5	- 4.50	2.905	2.6	- 4.63	0
5	2.148	4.0	- 4.05	2.255	1.8	- 4.36	2.319	1.9	- 4.50	5
10	1.759	2.9	- 3.92	1.824	1.2	- 4.23	1.862	1.3	- 4.37	10
15	1.449	1.9	- 3.81	1.484	0.7	- 4.10	1.505	0.8	- 4.25	15
20	1.200	0.9	- 3.69	1.215	0.3	- 3.98	1.223	0.3	- 4.13	20
25	1.000	0.0	- 3.58	1.0000	0.0	- 3.87	1.0000	0.0	- 4.01	25
30	.8377	0.9	- 3.48	.8278	0.3	- 3.76	.8219	0.3	- 3.90	30
35	.7054	1.8	- 3.38	.6889	0.7	- 3.65	.6792	0.7	- 3.80	35
40	.5969	2.6	- 3.28	.5763	1.1	- 3.55	.5641	1.1	- 3.69	40
45	.5076	3.5	- 3.19	.4845	1.5	- 3.45	.4708	1.6	- 3.59	45
50	.4336	4.3	- 3.10	.4092	2.0	- 3.35	.3949	2.1	- 3.50	50
55	.3720	5.1	- 3.01	.3473	2.5	- 3.26	.3327	2.6	- 3.41	55
60	.3206	5.9	- 2.93	.2960	3.0	- 3.17	.2816	3.1	- 3.32	60
65	.2774	6.6	- 2.85	.2534	3.5	- 3.09	.2393	3.7	- 3.23	65
70	.2410	7.4	- 2.77	.2178	4.1	- 3.01	.2043	4.3	- 3.14	70
75	.2102	8.1	- 2.70	.1879	4.7	- 2.93	.1751	4.9	- 3.06	75
80	.1839	8.8	- 2.63	.1628	5.3	- 2.85	.1507	5.5	- 2.99	80
85	.1616	9.5	- 2.56	.1415	5.9	- 2.78	.1301	6.1	- 2.91	85
90	.1424	10.2	- 2.49	.1235	6.5	- 2.70	.1128	6.8	- 2.84	90
95	.1259	10.9	- 2.43	.1081	7.1	- 2.64	.09812	7.4	- 2.77	95
100	.1117	11.5	- 2.36	.09500	7.7	- 2.57	.08565	8.1	- 2.70	100
105	.09938	12.2	- 2.30	.08373	8.4	- 2.50	.07502	8.7	- 2.63	105
110	.08869	12.8	- 2.25	.07403	9.0	- 2.44	.06592	9.4	- 2.57	110
115	.07938	13.4	- 2.19	.06565	9.7	- 2.38	.05810	10.1	- 2.50	115
120	.07124	14.0	- 2.14	.05838	10.3	- 2.33	.05137	10.8	- 2.44	120
125	.06410	14.6	- 2.08	.05207	11.0	- 2.27	.04555	11.5	- 2.39	125
130	.05783	15.2	- 2.03	.04567	11.6	- 2.22	.04050	12.2	- 2.33	130
135	.05230	15.7	- 1.98	.04175	12.3	- 2.16	.03611	12.8	- 2.27	135
140	.04741	16.3	- 1.94	.03753	13.0	- 2.11	.03229	13.5	- 2.22	140
145	.04308	16.8	- 1.89	.03382	13.6	- 2.06	.02894	14.2	- 2.17	145
150	.03924	17.4	- 1.85	.03055	14.3	- 2.02	.02600	14.9	- 2.12	150

T (°C)	Material code B (K)									T (°C)
	KA 3625			KC 3470			L 3790			
	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	
-55	61.21	7.1	- 6.77	60.08	34.0	- 7.00	82.52	22.3	- 7.38	-55
-50	44.24	6.1	- 6.53	43.19	29.4	- 6.71	58.01	19.3	- 7.11	-50
-45	32.33	5.3	- 6.30	31.42	25.3	- 6.44	41.30	16.6	- 6.84	-45
-40	23.88	4.5	- 6.08	23.13	21.6	- 6.18	29.75	14.2	- 6.60	-40
-35	17.81	3.8	- 5.88	17.22	18.4	- 5.94	21.67	12.0	- 6.36	-35
-30	13.41	3.2	- 5.68	12.95	15.5	- 5.71	15.96	10.1	- 6.13	-30
-25	10.19	2.7	- 5.49	9.842	12.9	- 5.49	11.88	8.5	- 5.92	-25
-20	7.814	2.2	- 5.31	7.550	10.7	- 5.29	8.930	7.0	- 5.72	-20
-15	6.040	1.8	- 5.14	5.845	8.7	- 5.10	6.776	5.7	- 5.32	-15
-10	4.707	1.5	- 4.98	4.564	6.9	- 4.91	5.188	4.5	- 5.34	-10
-5	3.696	1.1	- 4.83	3.594	5.4	- 4.74	4.007	3.6	- 5.16	-5
0	2.923	.9	- 4.68	2.853	4.1	- 4.58	3.120	2.7	- 4.99	0
5	2.329	.6	- 4.53	2.281	3.0	- 4.42	2.449	2.0	- 4.83	5
10	1.867	.4	- 4.40	1.838	2.0	- 4.27	1.937	1.3	- 4.68	10
15	1.507	.3	- 4.27	1.491	1.2	- 4.13	1.543	.8	- 4.53	15
20	1.224	.1	- 4.14	1.217	0.5	- 4.00	1.238	.4	- 4.39	20
25	1.0000	0.0	- 4.02	1.0000	0.0	- 3.90	1.0000	0.0	- 4.25	25
30	.8217	.1	- 3.91	.8267	0.5	- 3.74	.8129	.3	- 4.12	30
35	.6788	.2	- 3.80	.6873	1.1	- 3.63	.6648	.7	- 4.00	35
40	.5638	.4	- 3.69	.5747	1.8	- 3.52	.5409	1.2	- 3.88	40
45	.4707	.5	- 3.59	.4830	2.5	- 3.41	.4525	1.6	- 3.77	45
50	.3948	.7	- 3.49	.4081	3.3	- 3.31	.3765	2.2	- 3.66	50
55	.3328	.9	- 3.40	.3465	4.1	- 3.21	.3148	2.7	- 3.55	55
60	.2818	1.0	- 3.31	.2955	5.0	- 3.12	.2646	3.3	- 3.45	60
65	.2396	1.2	- 3.22	.2532	5.9	- 3.03	.2235	3.8	- 3.36	65
70	.2046	1.4	- 3.14	.2179	6.8	- 2.94	.1896	4.5	- 3.26	70
75	.1754	1.6	- 3.06	.1883	7.8	- 2.86	.1616	5.1	- 3.17	75
80	.1510	1.8	- 2.98	.1634	8.7	- 2.78	.1383	5.7	- 3.09	80
85	.1305	2.0	- 2.90	.1423	9.7	- 2.71	.1189	6.4	- 3.00	85
90	.1131	2.3	- 2.83	.12441	10.8	- 2.63	.1026	7.1	- 2.92	90
95	.09846	2.5	- 2.76	.10915	11.8	- 2.56	.08889	7.7	- 2.85	95
100	.08597	2.7	- 2.69	.09608	12.9	- 2.50	.07729	8.4	- 2.77	100
105	.07531	2.9	- 2.63	.08486	13.9	- 2.43	.06745	9.1	- 2.70	105
110	.06618	3.1	- 2.56	.07519	15.0	- 2.37	.05906	9.8	- 2.63	110
115	.05834	3.4	- 2.50	.06683	16.1	- 2.31	.05189	10.5	- 2.57	115
120	.05158	3.6	- 2.44	.05957	17.2	- 2.25	.04573	11.3	- 2.50	120
125	.04573	3.8	- 2.39	.05325	18.3	- 2.20	.04043	12.0	- 2.44	125
130	.04066	4.0	- 2.33	.04774	19.4	- 2.14	.03585	12.7	- 2.38	130
135	.03625	4.3	- 2.28	.04290	20.5	- 2.09	.03188	13.4	- 2.33	135
140	.03240	4.5	- 2.23	.03866	21.6	- 2.04	.02843	14.1	- 2.27	140
145	.02903	4.7	- 2.18	.03492	22.7	- 1.99	.02543	14.8	- 2.22	145
150	.02608	5.0	- 2.13	.03162	23.8	- 1.95	.02279	15.6	- 2.17	150

Tables of Resistance vs Temperature

T (°C)	Material code B (K)									T (°C)
	L2 3805			M 3950			MA 3960			
	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	
- 55	62.45	22.4	- 6.4	99.56	23.2	- 7.71	104.2	3.9	- 7.89	- 55
- 50	45.40	19.3	- 6.2	68.95	20.1	- 7.42	71.63	3.4	- 7.57	- 50
- 45	33.33	16.6	- 6.0	48.38	17.3	- 7.15	49.94	2.9	- 7.28	- 45
- 40	24.70	14.2	- 5.9	34.37	14.8	- 6.89	35.28	2.5	- 7.00	- 40
- 35	18.47	12.1	- 5.7	24.71	12.5	- 6.64	25.25	2.1	- 6.73	- 35
- 30	13.92	10.2	- 5.5	17.96	10.6	- 6.41	18.28	1.8	- 6.48	- 30
- 25	10.58	8.5	- 5.4	13.20	8.8	- 6.18	13.39	1.5	- 6.25	- 25
- 20	8.110	7.0	- 5.2	9.803	7.3	- 5.97	9.917	1.2	- 6.02	- 20
- 15	6.260	5.7	- 5.1	7.351	5.9	- 5.77	7.419	1.0	- 5.81	- 15
- 10	4.867	4.6	- 4.9	5.585	4.7	- 5.57	5.605	.8	- 5.61	- 10
- 5	3.810	3.6	- 4.8	4.251	3.7	- 5.39	4.275	.6	- 5.42	- 5
0	3.003	2.7	- 4.7	3.275	2.8	- 5.21	3.289	.5	- 5.24	0
5	2.382	2.0	- 4.5	2.544	2.0	- 5.04	2.552	.3	- 5.06	5
10	1.901	1.3	- 4.4	1.992	1.4	- 4.88	1.997	.2	- 4.90	10
15	1.526	0.8	- 4.3	1.572	.8	- 4.73	1.574	.1	- 4.74	15
20	1.232	0.4	- 4.2	1.249	.4	- 4.58	1.250	.1	- 4.59	20
25	1.0000	0.0	- 4.1	1.0000	0.0	- 4.44	1.0000	0.0	- 4.45	25
30	.8161	0.3	- 4.0	.8057	.4	- 4.30	.8053	.1	- 4.31	30
35	.6694	0.7	- 3.9	.6534	.8	- 4.17	.6527	.1	- 4.18	35
40	.5518	1.2	- 3.8	.5331	1.2	- 4.05	.5323	.2	- 4.06	40
45	.4570	1.7	- 3.7	.4376	1.7	- 3.93	.4367	.3	- 3.94	45
50	.3802	2.2	- 3.6	.3612	2.2	- 3.81	.3604	.4	- 3.82	50
55	.3178	2.7	- 3.5	.2998	2.8	- 3.71	.2990	.5	- 3.71	55
60	.2667	3.3	- 3.5	.2501	3.4	- 3.60	.2493	.6	- 3.61	60
65	.2248	3.9	- 3.4	.2097	4.0	- 3.50	.2090	.7	- 3.51	65
70	.1902	4.5	- 3.3	.1767	4.6	- 3.40	.1760	.8	- 3.41	70
75	.1615	5.1	- 3.2	.1496	5.3	- 3.31	.1489	.9	- 3.32	75
80	.1377	5.8	- 3.1	.1272	6.0	- 3.22	.1266	1.0	- 3.23	80
85	.1179	6.4	- 3.1	.1087	6.7	- 3.13	.1081	1.1	- 3.14	85
90	.1012	7.1	- 3.0	.09321	7.4	- 3.05	.09262	1.2	- 3.06	90
95	.08721	7.8	- 2.9	.08027	8.1	- 2.97	.07970	1.3	- 2.98	95
100	.07539	8.5	- 2.9	.06939	8.8	- 2.89	.06885	1.5	- 2.91	100
105	.06538	9.2	- 2.8	.06020	9.5	- 2.82	.05969	1.6	- 2.83	105
110	.05688	9.9	- 2.8	.05243	10.2	- 2.75	.05194	1.7	- 2.76	110
115	.04963	10.6	- 2.7	.04581	11.0	- 2.68	.04535	1.8	- 2.69	115
120	.04343	11.3	- 2.6	.04017	11.7	- 2.61	.03973	2.0	- 2.63	120
125	.03812	12.0	- 2.6	.03533	12.5	- 2.55	.03491	2.1	- 2.56	125
130	.03354	12.7	- 2.5	.03117	13.2	- 2.48	.03077	2.2	- 2.50	130
135	.02960	13.5	- 2.5	.02759	14.0	- 2.42	.02721	2.3	- 2.44	135
140	.02618	14.2	- 2.4	.02449	14.7	- 2.37	.02412	2.5	- 2.39	140
145	.02322	14.9	- 2.4	.02180	15.5	- 2.31	.02145	2.6	- 2.33	145
150	.02064	15.6	- 2.3	.01945	16.2	- 2.26	.01912	2.7	- 2.28	150

T (°C)	Material code B (K)									T (°C)
	MC 3910			N 4080			NA 4100			
	R (T) / R25	TF (%)	α (°/°C)	R (T) / R25	TF (%)	α (°/°C)	R (T) / R25	TF (%)	α (°/°C)	
-55	100.6	23.0	- 7.88	110.1	24.0	- 7.81	109.5	8.0	- 7.83	-55
-50	69.29	19.9	- 7.55	75.90	20.7	- 7.53	75.42	6.9	- 7.54	-50
-45	48.41	17.1	- 7.24	52.98	17.8	- 7.26	52.63	6.0	- 7.27	-45
-40	34.27	14.6	- 6.96	37.43	15.2	- 7.01	37.18	5.1	- 7.01	-40
-35	24.57	12.4	- 6.68	26.75	12.9	- 6.77	26.58	4.3	- 6.76	-35
-30	17.83	10.5	- 6.42	19.33	10.9	- 6.54	19.22	3.7	- 6.52	-30
-25	13.09	8.7	- 6.18	14.12	9.1	- 6.32	14.04	3.1	- 6.30	-25
-20	9.714	7.2	- 5.95	10.41	7.5	- 6.10	10.37	2.5	- 6.09	-20
-15	7.283	5.9	- 5.73	7.758	6.1	- 5.90	7.730	2.1	- 5.89	-15
-10	5.515	4.7	- 5.53	5.834	4.9	- 5.71	5.817	1.6	- 5.70	-10
-5	4.215	3.7	- 5.33	4.426	3.8	- 5.53	4.416	1.3	- 5.51	-5
0	3.251	2.8	- 5.15	3.387	2.9	- 5.35	3.382	1.0	- 5.34	0
5	2.528	2.0	- 4.97	2.614	2.1	- 5.18	2.611	.7	- 5.17	5
10	1.983	1.4	- 4.80	2.033	1.4	- 5.02	2.032	.5	- 5.01	10
15	1.567	0.8	- 4.65	1.593	.9	- 4.87	1.593	.3	- 4.86	15
20	1.247	0.4	- 4.49	1.258	.4	- 4.72	1.258	.1	- 4.71	20
25	1.0000	0.0	- 4.40	1.0000	0.0	- 4.57	1.0000	0.0	- 4.57	25
30	.8072	0.4	- 4.21	.8004	.4	- 4.44	.8004	.1	- 4.44	30
35	.6558	0.8	- 4.08	.6448	.8	- 4.31	.6446	.3	- 4.31	35
40	.5361	1.2	- 3.96	.5228	1.3	- 4.18	.5224	.4	- 4.19	40
45	.4409	1.7	- 3.84	.4264	1.8	- 4.06	.4258	.6	- 4.07	45
50	.3647	2.2	- 3.72	.3497	2.3	- 3.94	.3491	.8	- 3.96	50
55	.3033	2.8	- 3.61	.2885	2.9	- 3.83	.2877	1.0	- 3.85	55
60	.2535	3.4	- 3.51	.2392	3.5	- 3.72	.2383	1.2	- 3.74	60
65	.2130	4.0	- 3.41	.1994	4.1	- 3.62	.1984	1.4	- 3.64	65
70	.1798	4.6	- 3.31	.1671	4.8	- 3.52	.1660	1.6	- 3.55	70
75	.1525	5.2	- 3.22	.1406	5.5	- 3.42	.1396	1.8	- 3.45	75
80	.1299	5.9	- 3.13	.1189	6.2	- 3.33	.1178	2.1	- 3.36	80
85	.1112	6.6	- 3.05	.1010	6.9	- 3.24	.09991	2.3	- 3.28	85
90	.09551	7.3	- 2.97	.08617	7.6	- 3.16	.08507	2.5	- 3.20	90
95	.08238	8.0	- 2.89	.07381	8.3	- 3.07	.07273	2.8	- 3.12	95
100	.07132	8.7	- 2.81	.06347	9.1	- 2.99	.06241	3.0	- 3.04	100
105	.06198	9.4	- 2.74	.05480	9.8	- 2.92	.05376	3.3	- 2.96	105
110	.05405	10.1	- 2.67	.04148	10.6	- 2.84	.04648	3.5	- 2.89	110
115	.04730	10.9	- 2.60	.04129	11.3	- 2.77	.04032	3.8	- 2.82	115
120	.04153	11.6	- 2.54	.03603	12.1	- 2.70	.03510	4.1	- 2.76	120
125	.03657	12.3	- 2.48	.03155	12.9	- 2.64	.03065	4.3	- 2.69	125
130	.03231	13.1	- 2.42	.02771	13.7	- 2.57	.02685	4.6	- 2.63	130
135	.02863	13.8	- 2.36	.02442	14.4	- 2.51	.02359	4.8	- 2.57	135
140	.02544	14.6	- 2.30	.02158	15.2	- 2.45	.02079	5.1	- 2.51	140
145	.02267	15.3	- 2.25	.01913	16.0	- 2.39	.01838	5.4	- 2.45	145
150	.02025	16.1	- 2.20	.01700	16.8	- 2.34	.01629	5.6	- 2.40	150

Tables of Resistance vs Temperature

T (°C)	Material code B (K)									T (°C)
	NC 4080			NE 4100			N5			
	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	
- 55	105.44	24.0	- 7.5	97.27	24.1	- 7.2	115.8	16.3	- 7.83	- 55
- 50	72.89	20.7	- 7.2	67.99	20.8	- 7.0	79.70	14.1	- 7.56	- 50
- 45	51.04	17.8	- 7.0	48.08	17.9	- 6.8	55.53	12.1	- 7.30	- 45
- 40	36.18	15.2	- 6.7	34.39	15.3	- 6.5	39.14	10.4	- 7.06	- 40
- 35	25.94	12.9	- 6.5	24.85	13.0	- 6.3	27.90	8.8	- 6.82	- 35
- 30	18.81	10.9	- 6.3	18.15	11.0	- 6.1	20.11	7.4	- 6.60	- 30
- 25	13.78	9.1	- 6.1	13.38	9.2	- 6.0	14.64	6.2	- 6.38	- 25
- 20	10.20	7.5	- 5.9	9.96	7.6	- 5.8	10.77	5.1	- 6.17	- 20
- 15	7.621	6.1	- 5.7	7.479	6.2	- 5.6	7.995	4.2	- 5.97	- 15
- 10	5.748	4.9	- 5.5	5.664	4.9	- 5.4	5.991	3.3	- 5.78	- 10
- 5	4.373	3.8	- 5.4	4.325	3.8	- 5.3	4.529	2.6	- 5.60	- 5
0	3.355	2.9	- 5.2	3.328	2.9	- 5.1	3.453	2.0	- 5.43	0
5	2.595	2.1	- 5.0	2.581	2.1	- 5.0	2.655	1.4	- 5.26	5
10	2.023	1.4	- 4.9	2.016	1.4	- 4.9	2.057	1.0	- 5.10	10
15	1.588	0.9	- 4.7	1.585	0.9	- 4.7	1.606	.6	- 4.95	15
20	1.256	0.4	- 4.6	1.255	0.4	- 4.6	1.263	.3	- 4.80	20
25	1.0000	0.0	- 4.5	1.0000	0.0	- 4.5	1.0000	0.0	- 4.65	25
30	.8014	0.4	- 4.4	.8017	0.4	- 4.3	.7973	.3	- 4.52	30
35	.6463	0.8	- 4.2	.6466	0.8	- 4.2	.6398	.5	- 4.39	35
40	.5243	1.3	- 4.1	.5245	1.3	- 4.1	.5167	.9	- 4.26	40
45	.4278	1.8	- 4.0	.4278	1.8	- 4.0	.4198	1.2	- 4.14	45
50	.3510	2.3	- 3.9	.3508	2.3	- 3.9	.3430	1.6	- 4.02	50
55	.2896	2.9	- 3.8	.2891	2.9	- 3.8	.2819	2.0	- 3.91	55
60	.2401	3.5	- 3.7	.2394	3.5	- 3.7	.2329	2.4	- 3.80	60
65	.2001	4.1	- 3.6	.1992	4.2	- 3.6	.1934	2.8	- 3.69	65
70	.1675	4.8	- 3.5	.1666	4.8	- 3.5	.1615	3.3	- 3.59	70
75	.1409	5.5	- 3.4	.1399	5.5	- 3.4	.1354	3.7	- 3.50	75
80	.1190	6.2	- 3.3	.11794	6.2	- 3.4	.1141	4.2	- 3.40	80
85	.1010	6.9	- 3.2	.09987	6.9	- 3.3	.09660	4.7	- 3.31	85
90	.08605	7.6	- 3.2	.08491	7.6	- 3.2	.08212	5.2	- 3.23	90
95	.07360	8.3	- 3.1	.07246	8.4	- 3.1	.07011	5.7	- 3.14	95
100	.06319	9.1	- 3.0	.06207	9.1	- 3.1	.06010	6.2	- 3.06	100
105	.05446	9.8	- 2.9	.05336	9.9	- 3.0	.05172	6.7	- 2.98	105
110	.04710	10.6	- 2.9	.04604	10.6	- 2.9	.04467	7.2	- 2.91	110
115	.04087	11.3	- 2.8	.03985	11.4	- 2.8	.03873	7.7	- 2.83	115
120	.03559	12.1	- 2.7	.03461	12.2	- 2.8	.03370	8.2	- 2.76	120
125	.03109	12.9	- 2.7	.03015	12.9	- 2.7	.02942	8.8	- 2.70	125
130	.02724	13.7	- 2.6	.02635	13.7	- 2.7	.02576	9.3	- 2.63	130
135	.02394	14.4	- 2.5	.02309	14.5	- 2.6	.02264	9.8	- 2.57	135
140	.02111	15.2	- 2.5	.02030	15.3	- 2.5	.01995	10.3	- 2.51	140
145	.01866	16.0	- 2.4	.01789	16.1	- 2.5	.01764	10.9	- 2.45	145
150	.01654	16.8	- 2.4	.01581	16.8	- 2.4	.01564	11.4	- 2.39	150

T (°C)	Material code B (K)									T (°C)
	P 4220			PA 4235			Q 4300			
	R (T) / R25	TF (%)	α (°/°C)	R (T) / R25	TF (%)	α (°/°C)	R (T) / R25	TF (%)	α (°/°C)	
- 55	121.3	24.8	- 7.88	23.3	8.3	- 8.00	98.02	25.5	- 7.14	- 55
- 50	83.32	21.4	- 7.61	84.31	7.2	- 7.71	69.51	22.0	- 6.95	- 50
- 45	57.91	18.4	- 7.36	58.37	6.2	- 7.43	49.72	18.9	- 6.77	- 45
- 40	40.71	15.8	- 7.11	40.92	5.3	- 7.17	35.86	16.2	- 6.59	- 40
- 35	28.95	13.4	- 6.88	29.03	4.5	- 6.92	26.08	13.7	- 6.42	- 35
- 30	20.80	11.3	- 6.66	20.83	3.8	- 6.69	19.12	11.6	- 6.26	- 30
- 25	15.10	9.4	- 6.44	15.10	3.2	- 6.46	14.12	9.7	- 6.10	- 25
- 20	11.07	7.8	- 6.24	11.07	2.6	- 6.25	10.51	8.0	- 5.94	- 20
- 15	8.196	6.3	- 6.04	8.189	2.1	- 6.05	7.876	6.5	- 5.79	- 15
- 10	6.123	5.1	- 5.85	6.117	1.7	- 5.85	5.946	5.2	- 5.64	- 10
- 5	4.615	4.0	- 5.67	4.610	1.3	- 5.67	4.520	4.1	- 5.50	- 5
0	3.507	3.0	- 5.49	3.504	1.0	- 5.49	3.460	3.1	- 5.36	0
5	2.688	2.2	- 5.33	2.686	.7	- 5.32	2.666	2.2	- 5.23	5
10	2.078	1.5	- 5.16	2.075	.5	- 5.16	2.067	1.5	- 5.09	10
15	1.616	.9	- 5.01	1.615	.3	- 5.01	1.613	.9	- 4.96	15
20	1.267	.4	- 4.86	1.266	.1	- 4.86	1.266	.4	- 4.84	20
25	1.0000	0.0	- 4.72	1.0000	0.0	- 4.72	1.0000	0.0	- 4.72	25
30	.7949	.4	- 4.58	.7949	.1	- 4.58	.7944	.4	- 4.60	30
35	.6360	.8	- 4.45	.6359	.3	- 4.45	.6347	.8	- 4.48	35
40	.5120	1.3	- 4.32	.5119	.4	- 4.32	.5099	1.3	- 4.37	40
45	.4148	1.8	- 4.20	.4145	.6	- 4.20	.4119	1.9	- 4.26	45
50	.3380	2.4	- 4.06	.3376	.8	- 4.09	.3345	2.5	- 4.15	50
55	.2769	3.0	- 3.96	.2765	1.0	- 3.98	.2730	3.1	- 4.05	55
60	.2282	3.6	- 3.86	.2276	1.2	- 3.87	.2239	3.7	- 3.95	60
65	.1890	4.3	- 3.75	.1883	1.4	- 3.77	.1846	4.4	- 3.85	65
70	.1573	5.0	- 3.65	.1566	1.7	- 3.67	.1529	5.1	- 3.75	70
75	.1316	5.7	- 3.55	.1308	1.9	- 3.58	.1272	5.8	- 3.66	75
80	.1106	6.4	- 3.45	.1098	2.1	- 3.48	.1063	6.5	- 3.57	80
85	.09338	7.1	- 3.36	.09258	2.4	- 3.40	.08928	7.3	- 3.48	85
90	.07919	7.9	- 3.28	.07838	2.6	- 3.31	.07527	8.1	- 3.39	90
95	.06744	8.6	- 3.19	.06662	2.9	- 3.23	.06373	8.8	- 3.31	95
100	.05767	9.4	- 3.11	.05686	3.1	- 3.15	.05417	9.6	- 3.23	100
105	.04951	10.2	- 3.03	.04871	3.4	- 3.07	.04623	10.4	- 3.15	105
110	.04267	10.9	- 2.95	.04189	3.7	- 3.00	.03961	11.2	- 3.07	110
115	.03691	11.7	- 2.88	.03614	3.9	- 2.93	.03405	12.0	- 3.00	115
120	.03204	12.5	- 2.81	.03130	4.2	- 2.86	.02939	12.9	- 2.93	120
125	.02791	13.3	- 2.74	.02719	4.5	- 2.79	.02545	13.7	- 2.86	125
130	.02440	14.1	- 2.67	.02370	4.7	- 2.73	.02211	14.5	- 2.79	130
135	.02139	14.9	- 2.61	.02072	5.0	- 2.67	.01928	15.3	- 2.72	135
140	.01882	15.7	- 2.55	.01817	5.3	- 2.61	.01686	16.1	- 2.66	140
145	.01660	16.5	- 2.49	.01598	5.5	- 2.55	.01479	17.0	- 2.60	145
150	.01469	17.3	- 2.43	.01410	5.8	- 2.49	.01302	17.8	- 2.54	150

Tables of Resistance vs Temperature

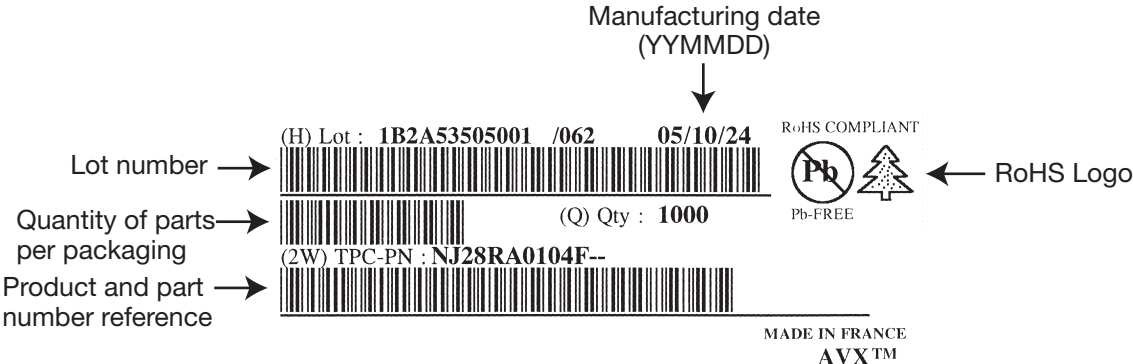
T (°C)	Material code B (K)									T (°C)
	QA 4250			R 4400			RA 4380			
	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	
- 55	1101.8	8.3	- 7.36	113.9	25.9	- 7.42	110.7	8.6	- 7.53	- 55
- 50	71.33	7.2	- 7.13	79.69	22.4	- 7.22	77.22	7.4	- 7.29	- 50
- 45	50.51	6.2	- 6.91	56.29	19.2	- 7.03	54.43	6.4	- 7.07	- 45
- 40	36.14	5.3	- 6.70	40.12	16.4	- 6.84	38.76	5.5	- 6.85	- 40
- 35	26.11	4.5	- 6.50	28.85	14.0	- 6.66	27.86	4.6	- 6.65	- 35
- 30	19.05	3.8	- 6.31	20.92	11.8	- 6.48	20.22	3.9	- 6.46	- 30
- 25	14.02	3.2	- 6.12	15.29	9.8	- 6.31	14.81	3.3	- 6.27	- 25
- 20	10.41	2.6	- 5.85	11.27	8.1	- 6.14	10.94	2.7	- 6.09	- 20
- 15	7.791	2.1	- 5.78	8.367	6.6	- 5.98	8.143	2.2	- 5.92	- 15
- 10	5.879	1.7	- 5.62	6.260	5.3	- 5.83	6.112	1.8	- 5.76	- 10
- 5	4.470	1.3	- 5.46	4.719	4.1	- 5.67	4.622	1.4	- 5.60	- 5
0	3.424	1.0	- 5.31	3.583	3.1	- 5.53	3.522	1.0	- 5.45	0
5	2.642	.7	- 5.17	2.739	2.3	- 5.38	2.702	.8	- 5.31	5
10	2.052	.5	- 5.03	2.108	1.5	- 5.24	2.087	.5	- 5.17	10
15	1.605	.3	- 4.90	1.634	.9	- 5.11	1.623	.3	- 5.03	15
20	1.263	.1	- 4.77	1.274	.4	- 4.97	1.270	.1	- 4.91	20
25	1.0000	0.0	- 4.65	1.0000	0.0	- 4.84	1.0000	0.0	- 4.78	25
30	.7965	.1	- 4.53	.7897	.4	- 4.72	.7920	.1	- 4.66	30
35	.6380	.3	- 4.42	.6273	.9	- 4.60	.6308	.3	- 4.55	35
40	.5139	.4	- 4.31	.5012	1.4	- 4.48	.5052	.5	- 4.43	40
45	.4162	.6	- 4.20	.4026	1.9	- 4.36	.4068	.6	- 4.33	45
50	.3388	.8	- 4.10	.3255	2.5	- 4.25	.3292	.8	- 4.22	50
55	.2771	1.0	- 4.00	.2644	3.1	- 4.14	.2678	1.0	- 4.12	55
60	.2278	1.2	- 3.90	.2159	3.8	- 4.04	.2189	1.3	- 4.02	60
65	.1881	1.4	- 3.81	.1772	4.5	- 3.93	.1797	1.5	- 3.93	65
70	.1560	1.7	- 3.72	.1462	5.2	- 3.83	.1483	1.7	- 3.84	70
75	.1300	1.9	- 3.63	.1212	5.9	- 3.74	.1228	2.0	- 3.75	75
80	.1088	2.1	- 3.55	.1009	6.7	- 3.64	.1022	2.2	- 3.67	80
85	.0914	2.4	- 3.47	.08441	7.4	- 3.55	.08537	2.5	- 3.58	85
90	.07708	2.6	- 3.39	.07093	8.2	- 3.46	.07160	2.7	- 3.50	90
95	.06527	2.9	- 3.31	.05985	9.0	- 3.38	.06029	3.0	- 3.42	95
100	.05547	3.2	- 3.24	.05072	9.8	- 3.29	.05095	3.2	- 3.35	100
105	.04731	3.4	- 3.17	.04315	10.6	- 3.21	.04322	3.5	- 3.28	105
110	.04049	3.7	- 3.10	.03686	11.4	- 3.13	.03679	3.8	- 3.21	110
115	.03160	12.2	- 3.06	.03478	3.9	- 3.03	.03143	4.1	- 3.14	115
120	.02996	4.2	- 2.96	.02720	13.1	- 2.98	.02693	4.3	- 3.07	120
125	.02590	4.5	- 2.90	.02349	13.9	- 2.91	.02316	4.6	- 3.01	125
130	.02246	4.7	- 2.84	.02036	14.7	- 2.84	.01997	4.9	- 2.94	130
135	.01953	5.0	- 2.78	.01771	15.6	- 2.77	.01728	5.2	- 2.88	135
140	.01704	5.3	- 2.72	.01545	16.4	- 2.71	.01499	5.4	- 2.82	140
145	.01490	5.5	- 2.67	.01353	17.2	- 2.64	.01305	5.7	- 2.77	145
150	.01307	5.8	- 2.61	.01188	18.1	- 2.58	.01138	6.0	- 2.71	150

T (°C)	Material code B (K)									T (°C)
	RC 4340			S 4520			SC 4500			
	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	R (T) / R25	TF (%)	α (%/°C)	
- 55	105.68	25.5	- 7.2	126.1	26.6	- 7.55	129.77	26.5	- 7.5	- 55
- 50	74.01	22.1	- 6.9	87.73	23.0	- 7.35	89.31	22.9	- 7.3	- 50
- 45	52.37	19.0	- 6.7	61.59	19.8	- 7.16	62.15	19.7	- 7.1	- 45
- 40	37.43	16.2	- 6.6	43.62	16.9	- 6.97	43.72	16.8	- 6.9	- 40
- 35	27.01	13.8	- 6.4	31.17	14.3	- 6.79	31.07	14.3	- 6.7	- 35
- 30	19.66	11.6	- 6.2	22.45	12.1	- 6.62	22.29	12.0	- 6.5	- 30
- 25	14.44	9.7	- 6.0	16.31	10.1	- 6.45	16.15	10.0	- 6.3	- 25
- 20	10.70	8.0	- 5.9	11.94	8.3	- 6.28	11.80	8.3	- 6.1	- 20
- 15	7.990	6.5	- 5.7	8.808	6.8	- 6.12	8.703	6.8	- 6.0	- 15
- 10	6.013	5.2	- 5.6	6.548	5.4	- 5.96	6.470	5.4	- 5.8	- 10
- 5	4.559	4.1	- 5.4	4.904	4.2	- 5.81	4.849	4.2	- 5.7	- 5
0	3.482	3.1	- 5.3	3.699	3.2	- 5.66	3.662	3.2	- 5.5	0
5	2.678	2.2	- 5.2	2.810	2.3	- 5.52	2.786	2.3	- 5.4	5
10	2.074	1.5	- 5.0	2.149	1.6	- 5.38	2.135	1.6	- 5.2	10
15	1.616	0.9	- 4.9	1.654	1.0	- 5.24	1.647	0.9	- 5.1	15
20	1.267	0.4	- 4.8	1.282	.4	- 5.10	1.279	0.4	- 5.0	20
25	1.0000	0.0	- 4.7	1.0000	0.0	- 4.97	1.0000	0.0	- 4.8	25
30	.7936	0.4	- 4.5	.7848	.4	- 4.85	.7865	0.4	- 4.7	30
35	.6334	0.8	- 4.4	.6196	.9	- 4.72	.6223	0.9	- 4.6	35
40	.5083	1.3	- 4.3	.4922	1.4	- 4.60	.4953	1.4	- 4.5	40
45	.4100	1.9	- 4.2	.3932	2.0	- 4.48	.3963	2.0	- 4.4	45
50	.3325	2.5	- 4.1	.3158	2.6	- 4.37	.3189	2.6	- 4.3	50
55	.2709	3.1	- 4.0	.2551	3.2	- 4.26	.2579	3.2	- 4.2	55
60	.2218	3.7	- 3.9	.2072	3.9	- 4.15	.2096	3.9	- 4.1	60
65	.1825	4.4	- 3.8	.1691	4.6	- 4.05	.1712	4.6	- 4.0	65
70	.1508	5.1	- 3.8	.1387	5.3	- 3.94	.1405	5.3	- 3.9	70
75	.1251	5.8	- 3.7	.1144	6.1	- 3.84	.1159	6.0	- 3.8	75
80	.1043	6.6	- 3.6	.09477	6.8	- 3.75	.09595	6.8	- 3.7	80
85	.08727	7.3	- 3.5	.07888	7.6	- 3.65	.07980	7.6	- 3.6	85
90	.07332	8.1	- 3.4	.06595	8.4	- 3.56	.06664	8.4	- 3.6	90
95	.06184	8.9	- 3.4	.05539	9.2	- 3.47	.05588	9.2	- 3.5	95
100	.05235	9.7	- 3.3	.04671	10.1	- 3.39	.04704	10.0	- 3.4	100
105	.04448	10.5	- 3.2	.03956	10.9	- 3.30	.03975	10.8	- 3.3	105
110	.03793	11.3	- 3.1	.03364	11.7	- 3.22	.03371	11.7	- 3.3	110
115	.03245	12.1	- 3.1	.02872	12.6	- 3.14	.02869	12.5	- 3.2	115
120	.02785	12.9	- 3.0	.02461	13.4	- 3.07	.02450	13.4	- 3.1	120
125	.02399	13.7	- 3.0	.02117	14.3	- 2.99	.02100	14.2	- 3.0	125
130	.02072	14.5	- 2.9	.01828	15.1	- 2.92	.01805	15.1	- 3.0	130
135	.01796	15.4	- 2.8	.01584	16.0	- 2.85	.01557	15.9	- 2.9	135
140	.01561	16.2	- 2.8	.01376	16.8	- 2.78	.01347	16.8	- 2.9	140
145	.01360	17.0	- 2.7	.01201	17.7	- 2.72	.01169	17.6	- 2.8	145
150	.01189	17.8	- 2.7	.01050	18.6	- 2.65	.01017	18.5	- 2.7	150

Tables of Resistance vs Temperature

T (°C)	Material code B (K)						T (°C)
	T 4630			U 4840			
	R (T) / R25	TF (%)	α (°/°C)	R (T) / R25	TF (%)	α (°/°C)	
- 55	137.0	27.2	- 7.64	173.7	28.5	- 8.04	- 55
- 50	94.92	23.5	- 7.45	118.2	24.6	- 7.83	- 50
- 45	66.34	20.2	- 7.26	81.16	21.2	- 7.63	- 45
- 40	46.77	17.3	- 7.09	56.25	18.1	- 7.44	- 40
- 35	33.25	14.7	- 6.90	39.33	15.4	- 7.25	- 35
- 30	23.83	12.4	- 6.72	27.74	12.9	- 7.07	- 30
- 25	17.22	10.3	- 6.56	19.73	10.8	- 6.89	- 25
- 20	12.54	8.5	- 6.39	14.15	8.9	- 6.71	- 20
- 15	9.205	6.9	- 6.23	10.23	7.3	- 6.54	- 15
- 10	6.806	5.6	- 6.08	7.456	5.8	- 6.38	- 10
- 5	5.069	4.3	- 5.92	5.475	4.5	- 6.22	- 5
0	3.803	3.3	- 5.78	4.051	3.4	- 6.06	0
5	2.873	2.4	- 5.63	3.019	2.5	- 5.91	5
10	2.185	1.6	- 5.49	2.267	1.7	- 5.76	10
15	1.673	1.0	- 5.35	1.714	1.0	- 5.61	15
20	1.289	.4	- 5.22	1.305	.5	- 5.47	20
25	1.0000	0.0	- 5.09	1.0000	0.0	- 5.33	25
30	.7805	.4	- 4.96	.7715	.4	- 5.20	30
35	.6129	.9	- 4.83	.5991	.9	- 5.06	35
40	.4842	1.4	- 4.71	.4681	1.5	- 4.94	40
45	.3847	2.0	- 4.59	.3681	2.1	- 4.81	45
50	.3074	2.6	- 4.48	.2911	2.8	- 4.69	50
55	.2470	3.3	- 4.37	.2316	3.4	- 4.57	55
60	.1996	4.0	- 4.26	.1853	4.2	- 4.45	60
65	.1621	4.7	- 4.15	.1491	4.9	- 4.34	65
70	.1323	5.4	- 4.04	.1207	5.7	- 4.23	70
75	.1086	6.2	- 3.94	.09813	6.5	- 4.12	75
80	.08953	7.0	- 3.84	.08023	7.3	- 4.02	80
85	.07417	7.8	- 3.75	.06592	8.2	- 3.91	85
90	.06173	8.6	- 3.65	.05443	9.0	- 3.82	90
95	.05161	9.5	- 3.56	.04515	9.9	- 3.72	95
100	.04334	10.3	- 3.47	.03763	10.8	- 3.63	100
105	.03655	11.2	- 3.39	.03151	11.7	- 3.54	105
110	.03095	12.0	- 3.31	.02650	12.6	- 3.45	110
115	.02632	12.9	- 3.22	.02237	13.5	- 3.38	115
120	.02247	13.7	- 3.15	.01897	14.4	- 3.28	120
125	.01925	14.6	- 3.07	.01615	15.3	- 3.20	125
130	.01656	15.5	- 2.99	.01381	16.2	- 3.12	130
135	.01429	16.4	- 2.92	.01185	17.1	- 3.04	135
140	.01238	17.3	- 2.85	.01020	18.0	- 2.97	140
145	.01076	18.1	- 2.78	.00882	19.0	- 2.90	145
150	.00938	19.0	- 2.72	.00765	19.9	- 2.83	150

On the packaging of all shipped thermistors, you will find a bar code label.
This label gives systematic information on the type of product, part number, lot number, manufacturing date and quantity.
An example is given below:



This information allows complete traceability of the entire manufacturing process, from raw materials to final inspection.
This is extremely useful for any information request, customer complaint or product return.

Circuit Protection Portfolio

Application Guide



	AVX PRODUCTS																		
	Fast Blow SMT Fuse (Surface Mount Fuse)	SMT Broadband LCT Filter (Feedthru)	SMT Broadband LCT Filter Array (Feedthru Array)	SMT Bidirectional Transient Voltage Suppressors & EMI Filters (TransGuard)	SMT Bidirectional Transient Voltage Suppressors & EMI Filters Arrays (MultiGuard)	SMT Bidirectional Transient Voltage Suppressors & EMI Filters (StaticGuard)	Low Capacitance SMT Bidirectional Transient Voltage Suppressors	Low Capacitance Bidirectional Transient Voltage Suppressors (AntennaGuard)	Bidirectional Transient Voltage Suppressors for Low, Medium & High Speed CAN Networks (CAN BUS Series)	Bidirectional Transient Voltage Suppressors for USB Applications (USB Series)	Bidirectional Transient Voltage Suppressors for Low Leakage CMOS Applications (UltraGuard)	Bidirectional Transient Voltage Suppressors for High Energy Transients (Medium Power MLV)	Bidirectional Transient Voltage Suppressors for Jump Start Auto Applications (Medium Power Automotive Series)	Leaded Negative Temperature Coefficient Thermistors	SMT Negative Temperature Coefficient Thermistors	General Purpose Radial Leaded Power MOV (Metal Oxide Varistors)			
APPLICATIONS																			
ESD							X		X	X	X								
In Rush Current Limit															X	X			
Long Wave Transient				X	X		X					X	X	X				X	
EMI Filtering		X	X	X															
EMI Filtering + Transient				X	X	X	X	X	X	X	X	X	X	X					
Load Dump				X								X							
Automotive		X		X	X	X	X	X	X			X			X	X			
Mil Std 461-E				X															
ISO 7637				X								X							
IEC 61000				X	X	X	X	X	X	X	X	X						X	
Telecom Protection				X									X						
Over Current Protection	X																		
Diode Replacement				X	X	X			X	X	X	X							
Zener Replacement				X	X	X			X	X	X	X							
Military A-A-55682				X															
Radiation Resistance				X	X														
Industrial		X		X	X	X	X		X	X		X			X			X	
UL 1449																		X	
UL 1414																		X	
Medical (EN 60601)		X		X															
High Speed Data Line Protection								X		X									
Optic Transceiver Protection								X		X									
Temperature Sensing															X	X			
Low Leakage Circuit											X								
DATA																			
Data Sheet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Application Notes		X	X	X	X	X		X	X	X		X			X	X	X		
Reliability Data		X			X														
Distributed Element Model				X	X	X	X	X	X	X	X	X							
Frequency Response		X	X	X	X	X	X	X	X	X		X							

Circuit Protection Portfolio

Terminology Guide



Fast Blow SMT Fuse (Surface Mount Fuse)

High accuracy, fast blow, surface mount fuses. Case sizes: 0402, 0603, 0805, 1206, 0612. Current ratings 250 mA to 5 Amps.

SMT Broadband LCT Filter (Feedthru)

Miniature surface mount broadband LC T configuration EMI filters. FeedThru current ratings to 300 mA.

SMT Broadband LCT Filter Array (Feedthru Array)

Miniature surface mount broadband 4 element LC T configuration EMI filter arrays. FeedThru current ratings of 300 mA.

SMT High Current Broadband LCT Filter (High Current Feedthru)

High current, surface mount, broadband LC T configuration filters. Feedthru currents up to 5 Amps.

SMT Bidirectional Transient Voltage Suppressors & EMI Filters (TransGuard)

Miniature surface mount, bidirectional transient voltage suppressor. Steady state operating voltages of 3.3 volts to 60 volts. Case sizes: 0402, 0603, 0805, 1206, 1210, 1812, 2220.

SMT Bidirectional Transient Voltage Suppressors & EMI Filter Arrays (MultiGuard)

Miniature surface mount bidirectional transient voltage suppressor 2 or 4 element arrays. Steady state operating voltages of 5.6 volts to 18 volts. Case sizes: 0405, 0508, 0612.

Low Capacitance SMT Bidirectional Transient Voltage Suppressors & EMI Filters (StaticGuard)

Bidirectional transient voltage suppressor intended for low leakage CMOS based IC protection. Can be operated at voltages up to 18V. Case sizes: 0402, 0405, 0508, 0603, 0612, 0805, 1206.

SMT Bidirectional LCT Transient Voltage Suppressor Filters (TransFeed)

Miniature bidirectional transient voltage suppressor filter LC T configuration. Relatively narrow band, high attenuation filter. Discrete filter in 0508 package, 4 element array filter in 0612 package.

Low Capacitance Bidirectional Transient Voltage Suppressors (AntennaGuard)

Low capacitance, bidirectional transient voltage suppressor intended for high speed or high frequency applications. Available in 0402 and 0603 case sizes. Capacitance values of 3 pF and 12 pF available.

Bidirectional Transient Voltage Suppressors for Low, Medium & High Speed CAN Networks (CAN BUS Series)

Bidirectional transient voltage suppressor intended for high speed and slow speed CAN circuitry. Available configurations: 0603 discrete, 0405 two element array, 0612 four element array.

Bidirectional Transient Voltage Suppressors for USB Applications (USB Series)

Bidirectional transient voltage suppressor intended for Universal Serial Bus applications. Available configurations: 0402 and 0603 discrete; 0405 two element array; 0508 three element array; 0612 four element array.

Bidirectional Transient Voltage Suppressors for Low Leakage CMOS Applications (UltraGuard)

Low leakage, bidirectional transient voltage suppressor intended for CMOS battery powered designs. Steady state operating voltages of 3, 5, 7, 10 and 15 volts (DC). Available configurations: 0402, 0603 and 0805 discrete; 0405 two element array; 0508 and 0612 four element array.

Bidirectional Transient Voltage Suppressors for High Energy Transients (Medium Power MLV)

Medium power, bidirectional transient voltage suppressor. Available in operating voltages of: 18, 26, 30, 48, 60 volts (DC). Case sizes: 1206, 1210, 1812, 2220. Energy ratings 0.9 to 1.5 joules.

Bidirectional Transient Voltage Suppressors for Load Dump & Jump Start Auto Applications (Medium Power Automotive Series)

Medium power, bidirectional transient voltage suppressor. Available in operating voltages of: 16 and 34 volts (DC). Case sizes: 1206, 1210, 1812, 2220. Energy ratings 0.6 to 12 joules. Load dump and jump start rated.

Bidirectional Transient Voltage Suppressors for Telecom Applications (Medium Power MLV for Telecom)

Medium power, bidirectional transient voltage suppressor. Available in operating voltages of: 60 and 90 Vrms in 1812 case size. Energy ratings of 5 and 6 joules. CCITT 10x700µs 2kV capable.

Leaded Negative Temperature Coefficient Thermistors

Negative temperature coefficient thermistors high accuracy NTCs from 2k ohm to 100k ohm, general purpose NTCs from 10 ohms to 1 meg ohm. Stud mounted NTCs from 10 ohms to 330 k ohms.

SMT Negative Temperature Coefficient Thermistors

Surface mount negative temperature coefficient thermistor in 0402, 0603, 0805 and 1206 case sizes.

General Purpose Radial Leaded Power MOV (Metal Oxide Varistors)

Radial Metal Oxide varistors 11 Vrms to 625 Vrms. Energy ratings to >500 J. Peak current ratings to 10,000 A.

AMERICAS

AVX Greenville, SC
Tel: 864-967-2150

AVX Northwest, WA
Tel: 360-699-8746

AVX Midwest, IN
Tel: 317-861-9184

AVX Mid/Pacific, CA
Tel: 408-988-4900

AVX Northeast, MA
Tel: 617-479-0345

AVX Southwest, CA
Tel: 949-859-9509

AVX Canada
Tel: 905-238-3151

AVX South America
Tel: +55-11-4688-1960

EUROPE

AVX Limited, England
Tel: +44-1276-697000

AVX S.A.S., France
Tel: +33-1-69-18-46-00

AVX GmbH, Germany
Tel: +49-0811-95949-0

AVX SRL, Italy
Tel: +39-02-614-571

AVX Czech Republic
Tel: +420-57-57-57-521

AVX/ELCO UK
Tel: +44-1638-675000

ELCO Europe GmbH
Tel: +49-2741-299-0

AVX S.A., Spain
Tel: +34-91-63-97-197

AVX Benelux
Tel: +31-187-489-337

ASIA-PACIFIC

**AVX/Kyocera (S) Pte Ltd.,
Singapore**
Tel: +65-6286-7555

**AVX/Kyocera, Asia, Ltd.,
Hong Kong**
Tel: +852-2363-3303

**AVX/Kyocera Yuhan Hoesa,
South Korea**
Tel: +82-2785-6504

**AVX/Kyocera HK Ltd.,
Taiwan**
Tel: +886-2-2656-0258

**AVX/Kyocera (M) Sdn Bhd,
Malaysia**
Tel: +60-4228-1190

**AVX/Kyocera International
Trading Co. Ltd.,
Shanghai**
Tel: +86-21-3255 1933

**AVX/Kyocera Asia Ltd.,
Shenzen**
Tel: +86-755-3336-0615

**AVX/Kyocera International
Trading Co. Ltd.,
Beijing**
Tel: +86-10-6588-3528

**AVX/Kyocera India
Liaison Office**
Tel: +91-80-6450-0715

ASIA-KED

(KYOCERA Electronic Devices)

KED Hong Kong Ltd.
Tel: +852-2305-1080/1223

**KED Hong Kong Ltd.
Shenzen**
Tel: +86-755-3398-9600

**KED Company Ltd.
Shanghai**
Tel: +86-21-3255-1833

**KED Hong Kong Ltd.
Beijing**
Tel: +86-10-5869-4655

KED Taiwan Ltd.
Tel: +886-2-2950-0268

**KED Korea Yuhan Hoesa,
South Korea**
Tel: +82-2-783-3604/6126

**KED (S) Pte Ltd.
Singapore**
Tel: +65-6509-0328

**Kyocera Corporation
Japan**
Tel: +81-75-604-3449

Contact:



SMT Gate Drive Transformers

>1500V_{DC} Basic and Functional Insulation



-  >1500V_{DC} isolation between Gate and Drive
-  Basic insulation (1.4mm creepage/clearance) and functional available
-  Operating frequency: 50kHz and up

Electrical Specifications @ 25°C - Operating Temperature -40°C to +130°C⁵

Part ^{3,4} Number	Turns Ratio	Pri-Sec Insulation	MAX ¹ V*μsec	Primary Inductance (μH MIN)	Leakage ² Inductance (μH MAX)	DCR Primary (Ω MAX)	DCR Secondary (Ω MAX)	Package Size (L x W x H) (mm MAX)
Functional Insulation								
PE-68386NL	1:1	1500 Vdc	9.7	785	0.46	0.60	0.60	8.6 x 6.7 x 2.5
P0926NL	1:1:1	1500 Vdc	23.8	300	0.50	2.00	2.00	8.0 x 6.6 x 5.3
P0544NL	1:1:1	1500 Vdc	45.1	3300	0.80	1.25	1.25	9.0 x 8.6 x 7.6
PA0264NL	1:1:1	1000 Vrms	12.7	1140	0.65	0.75	0.75	8.6 x 6.7 x 3.6
PA1323NL	1:1	1500 Vrms	21.7	600	2.0	1.25	1.25	9.5 x 7.1 x 5.3
Basic Insulation (1.4mm creepage and clearance between Primary and Secondary)								
PA0173NL	1:1:1	1500 Vrms	17.2	980	0.75	0.62	0.88	11.8 x 8.8 x 4.0
PA0185NL	1:1	1500 Vrms	17.2	980	0.75	0.88	0.62	11.8 x 8.8 x 4.0
PA0184NL	1:1	1500 Vrms	27.2	1200	0.50	0.91	0.91	9.0 x 8.6 x 7.6
PA0297NL	2:1:1	1500 Vrms	27.2	1200	0.60	0.91	0.46	9.0 x 8.6 x 7.6
PA2777NL	1:1	1500 Vrms	9.3	335.2	0.36	0.70	0.70	7.1 x 6.1 x 5.5
PA0510NL	2.5:1:1	1500 Vrms	27.2	1200	0.68	0.91	0.380	9.0 x 8.6 x 7.6
PA3493NL	1.25:1	1650 Vrms	23	656	1.3	1.03	0.85	10.9 x 9.7 x 2.7

Notes:

1. The Maximum volt-μsec rating limits the peak flux density to 2200 Gauss when used in a unipolar drive application. For bi-polar drive applications, a maximum volt-sec of two times this rating is acceptable (ie: 2* (volt*μsec rating) = (voltage applied to the primary) * dutycycle / Frequency = V * alpha / Freq_Hz = V * μsec
2. Leakage inductance is measured at primary terminals with all secondaries shorted.
3. Optional Tape & Reel packaging can be ordered by adding a "T" suffix to the part number (i.e. P0544NL becomes P0544NLT). Pulse complies to industry standard tape and reel specification EIA481.
4. The "NL" suffix indicates an RoHS-compliant part number. Non-NL suffixed parts are not necessarily RoHS compliant, but are electrically and mechanically equivalent to NL versions. If a part number does not have the "NL" suffix, but an RoHS compliant version is required, please contact Pulse for availability.
5. The temperature of the component (ambient plus temperature rise) must be within the stated operating temperature range.

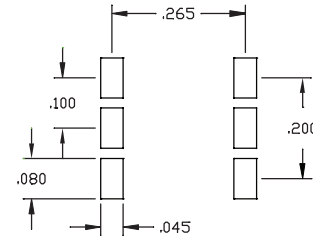
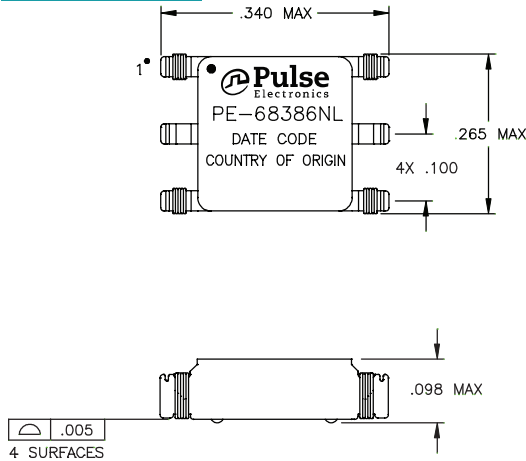
SMT Gate Drive Transformers

>1500V_{DC} Basic and Functional Insulation

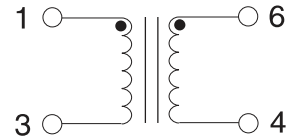
Mechanicals

Schematics

PE-68386NL



SUGGESTED PAD LAYOUT



Weight 0.28 grams

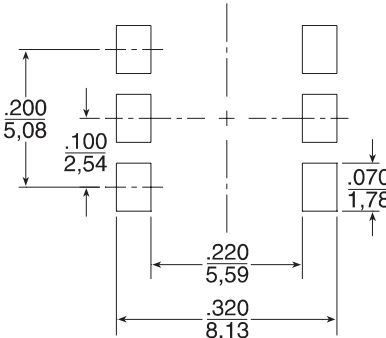
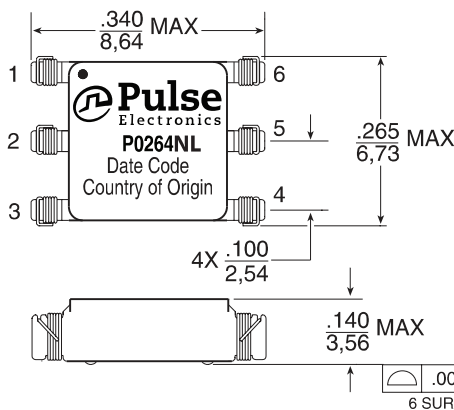
Tape & Reel 1500/reel

Tube 60/tube

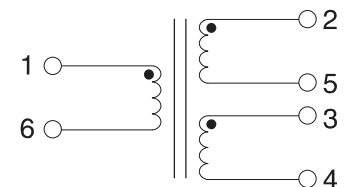
Dimension: $\frac{\text{Inches}}{\text{mm}}$

Unless otherwise specified, all tolerances are $\pm \frac{.010}{0,25}$

PA0264NL



SUGGESTED PAD LAYOUT



Weight 0.28 grams

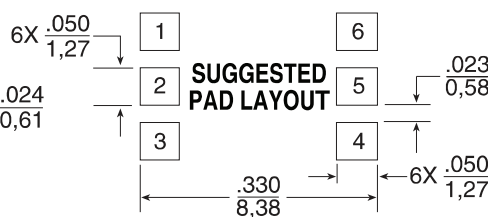
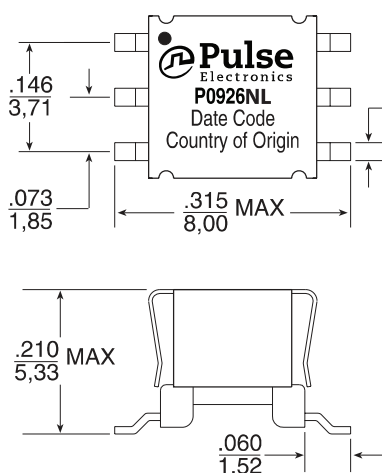
Tape & Reel 1500/reel

Tube 60/tube

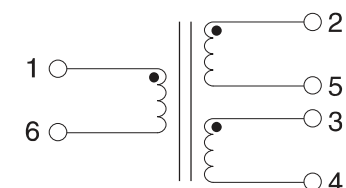
Dimension: $\frac{\text{Inches}}{\text{mm}}$

Unless otherwise specified, all tolerances are $\pm \frac{.010}{0,25}$

P0926NL



SUGGESTED PAD LAYOUT



Weight 0.48 grams

Tape & Reel 1000/reel

Tube 80/tube

Dimension: $\frac{\text{Inches}}{\text{mm}}$

Unless otherwise specified, all tolerances are $\pm \frac{.010}{0,25}$

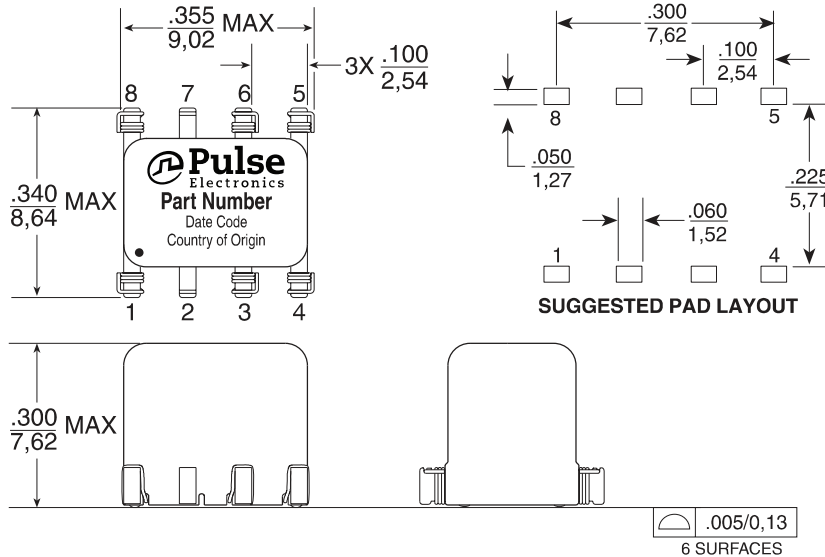
SMT Gate Drive Transformers

>1500V_{DC} Basic and Functional Insulation

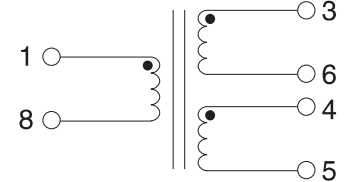
Mechanicals (continued)

Schematics

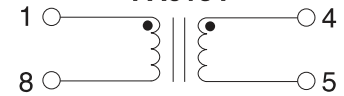
P0544NL, PA0297, PA0510, PA0184NL



P0544 / PA0297 / PA0510



PA0184



Weight 0.60 grams

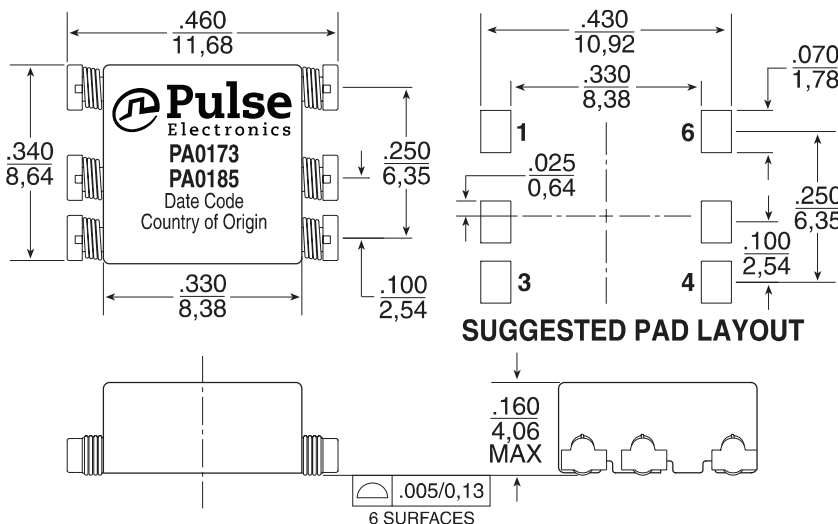
Tape & Reel 40/reel

Tube 50/tube

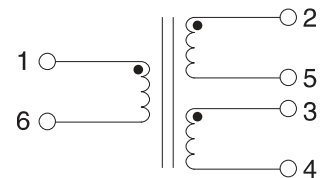
Dimension: $\frac{\text{Inches}}{\text{mm}}$

Unless otherwise specified, all tolerances are $\pm \frac{.010}{0.25}$

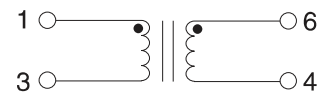
PA0173, PA0185



PA0173



PA0185



Weight 0.48 grams

Tape & Reel 900/reel

Tube 60/tube

Dimension: $\frac{\text{Inches}}{\text{mm}}$

Unless otherwise specified, all tolerances are $\pm \frac{.010}{0.25}$

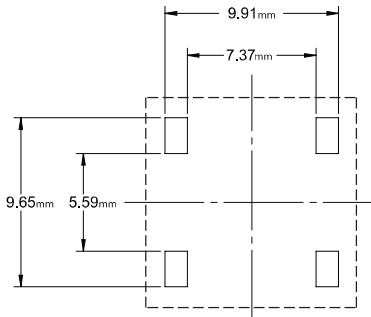
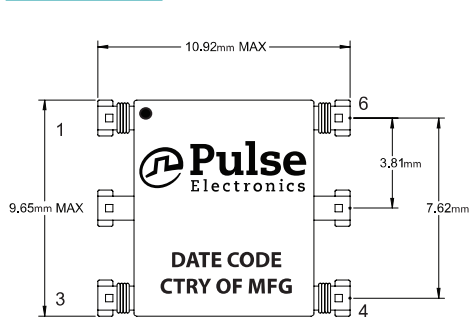
SMT Gate Drive Transformers

>1500V_{DC} Basic and Functional Insulation

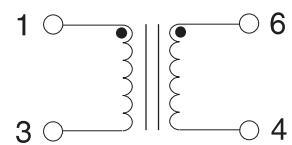
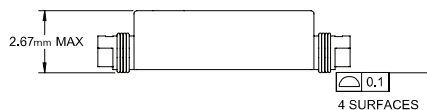
Mechanicals (continued)

Schematics

PA3493NL



SUGGESTED FOOTPRINT

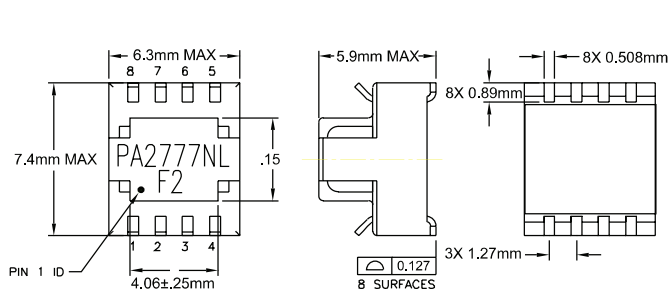


Weight 0.31 grams
Tape & Reel 1250/reel
Tube 50/tube

Dimension: mm

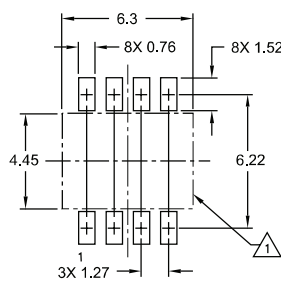
Unless otherwise specified, all tolerances are $\pm 0,25$

PA2777NL

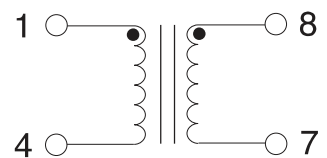


TOP VIEW

BOTTOM VIEW



SUGGESTED LAND PATTERN



Weight 0.32 grams
Tape & Reel 850/reel
Tube 120/tube

Dimension: mm

Unless otherwise specified, all tolerances are $\pm 0,25$

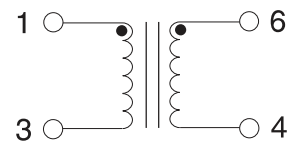
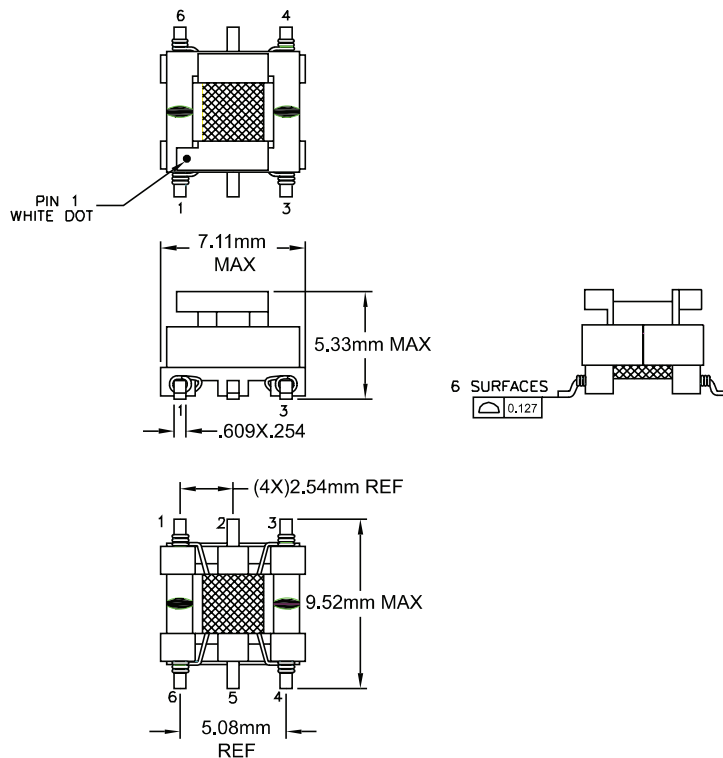
SMT Gate Drive Transformers

>1500V_{DC} Basic and Functional Insulation

Mechanicals *(continued)*

Schematics

PA1323NL



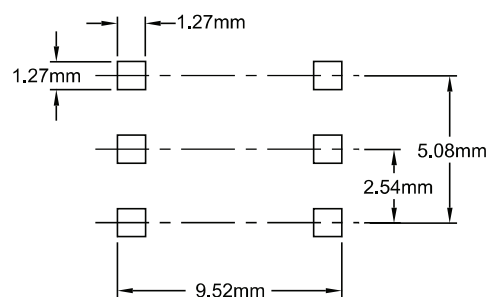
Weight 0.4 grams

Tape & Reel 700/reel

Tube 225/tube

Dimension: mm

Unless otherwise specified, all tolerances are ± 0.25



SUGGESTED PCB LAYOUT

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

Pulse:

[PE-68386](#) [PE-68386T](#) [P0544](#) [PA0264T](#) [P0926](#) [PA0297T](#) [PA0297](#) [PA0184T](#) [PA0173T](#) [P0926NLT](#) [PA0184NLT](#)
[PE-68386NLT](#) [PA0173NLT](#) [PA0264NLT](#) [P0926NL](#) [P0544NLT](#) [PE-68386NL](#) [P0544NL](#) [PA0185NLT](#) [P0926T](#)
[PA0297NL](#) [PA0264NL](#) [PA0173NL](#) [PA0297NLT](#) [PA0184NL](#) [PA3493NLT](#)

Type SM Series

Key Features

- Low Profile Design
- Available on Tape
- Very Wide Value Range
- Ideal for Power Circuitry
- Available in 2,3 or 5 Watts
- Flameproof Coating UL94V0



TE Connectivity (TE) introduces a surface mount power resistor suited to meet today's circuit design needs. Each size offers low profile case design with flexible tinned copper terminations for reliable solder joints. All styles utilize a fully welded construction technique, unlike other designs that rely solely on tinned termination connections. These features allow the SM Series to withstand the higher temperatures associated with reflow, vapour phase, or infrared (IR) manufacturing processes without degradation.

Characteristics - Electrical

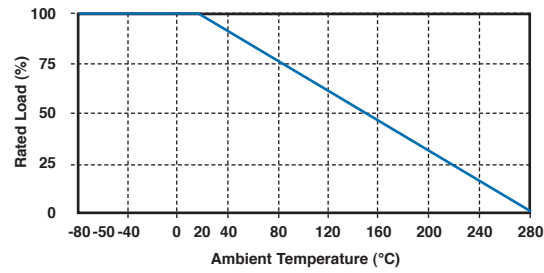
	SM (Wire)	SM (Metal Film)
Values SM_2:	R10 – 200R	201R – 2M
Values SM_3:	R10 – 300R	301R – 2M
Values SM_5:	R10 – 500R	501R – 2M
Value Grid:	E24	
Resistance Tolerance:	1% or 5%	
Power Rating @ 25°C SM_2:	2.0 Watts	
Power Rating @ 25°C SM_3:	3.0 Watts	
Power Rating @ 25°C SM_5:	5.0 Watts	
Derating:	See Curve Below	
Max Operating Voltage SM_2:	300 Volts	
Max Operating Voltage SM_3:	500 Volts	
Max Operating Voltage SM_5:	500 Volts	

Characteristics - Environmental

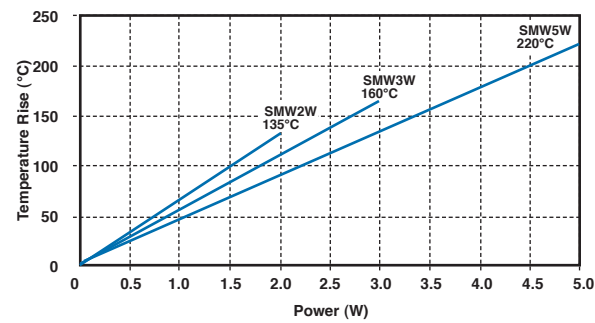
Test	Condition	SM (Wire)	SM (Metal Film)
Temperature Coefficient of Resistance:	-55°C – +200°C	± 200ppm /°C	± 100ppm /°C
Short Time Overload:	5 times of rated wattage for 5 sec.	± 1%	± 0.5%
Rated Load:	Rated voltage for 30 minutes	± 1%	± 0.5%
Insulation Resistance:	500VDC	10,000 MΩ	10,000 MΩ
Load Life:	70°C 1.5 hrs on 0.5 hrs off for 1000 hrs	± 2%	± 1%
Humidity Load Life:	40°C ±2°C @ 90-95% RH 500 hrs 1.5 hrs on 0.5 hrs off	± 2%	± 1%
Voltage Withstand:	500VAC for 60 seconds	No Physical damage	
Solderability:	235°C ±5°C for 2 seconds	95% coverage	
Resistance to Soldering Heat:	270°C ±5°C for 10 ±1seconds	Resistance value change within ± 1%	

Type SM Series

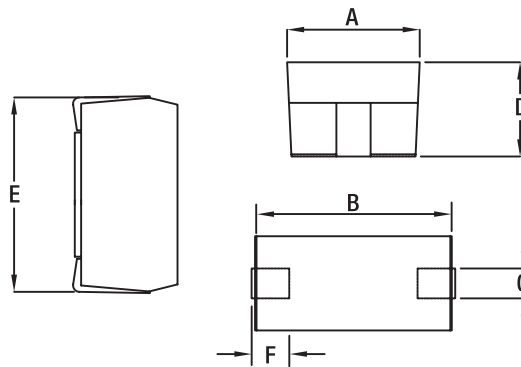
Power Derating



Maximum Allowable Body Temperature



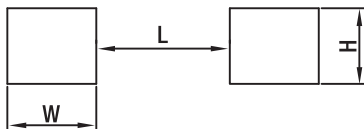
Dimensions



	A ±0.3	B ±0.3	C ±0.3	D ±0.3	E max	F±0.3	Qty Per Reel
SM_2	4.0	6.7	1.4	3.55	7.9	1.5	2000
SM_3	5.5	10.5	1.7	5.0	12.0	2.3	1000
SM_5	7.3	13.5	1.7	6.8	17.0	2.5	1000

Type SM Series

Recommended Pad Dimensions



	W Nom.	H Nom.	L Nom.
SM_2	2.6	2.9	2.8
SM_3	4.0	3.4	6.0
SM_5	4.5	3.4	11.0

How to Order

SMW	2	1R0	F	T
Common Part	Case Size	Resistance Value	Tolerance	Pack Style
SMW – Wirewound SMF – Metal Film	2 – 2 Watts 3 – 3 Watts 5 – 5 Watts	0.1 ohm (100 milli ohms) R10 1 ohm (1000 milli ohms) 1R0 100 ohm (100 ohms) 100R 1K ohm (1000 ohms) 1K0 100K ohm (100,000 ohms) 100K	J – $\pm 5\%$ F – $\pm 1\%$	T – Taped

TE Connectivity, TE connectivity (logo) and TE (logo) are trademarks.

Other logos, product and Company names mentioned herein may be trademarks of their respective owners.

While TE has made every reasonable effort to ensure the accuracy of the information in this datasheet, TE does not guarantee that it is error-free, nor does TE make any other representation, warranty or guarantee that the information is accurate, correct, reliable or current. TE reserves the right to make any adjustments to the information contained herein at any time without notice. TE expressly disclaims all implied warranties regarding the information contained herein, including, but not limited to, any implied warranties of merchantability or fitness for a particular purpose. The dimensions in this datasheet are for reference purposes only and are subject to change without notice. Specifications are subject to change without notice. Consult TE for the latest dimensions and design specifications.

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

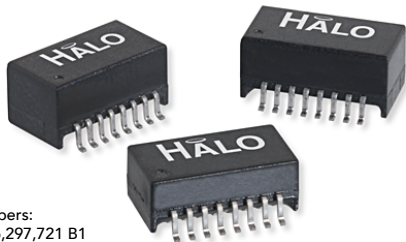
[TE Connectivity:](#)

[SMW54R3JT](#)

ULTRA™ Family of Transformers

SMD Single Port 10/100BASE-TX Transformer

HALO
ELECTRONICS, INC.



US Patent Numbers:
5,656,985 6,297,721 B1
6,297,720 B1 6,320,489 B1
6,344,785 B1 6,662,431 B1

Product Features:

- ULTRA™, E-ULTRA™, and ULTRA-II™
- IEEE802.3u Compliant
- UL/EN60950 Recognized
- 100% Electrical Testing
- 1500Vrms Hi-Pot
- Patented Open Frame Construction

ULTRA™ Part Number	Circuit Package		Temp. Range	Turns Ratio ±3% (1-3:16-14) (6-8:11-9)		Cw/w (pF)	PRI LL (μH max)	PRI DCR (Ω max)	RoHS¹
TG110-S050N2LF	A	N2	0 to 70°C	1CT:1CT	1CT:1CT	35 max	0.4	0.9	Pb-Free
TG110-S050N2RL	A	N2	0 to 70°C	1CT:1CT	1CT:1CT	35 max	0.4	0.9	RoHS (7a)
TG110-S055N2LF	B	N2	0 to 70°C	1CT:1CT	1CT:1CT	35 max	0.4	0.9	Pb-Free
TG110-S055N2RL	B	N2	0 to 70°C	1CT:1CT	1CT:1CT	35 max	0.4	0.9	RoHS (7a)
TG110-S120N2LF	B	N2	0 to 70°C	2CT:1CT	1CT:1CT	30 max	0.9	0.9	Pb-Free
TG110-S120N2RL	B	N2	0 to 70°C	2CT:1CT	1CT:1CT	30 max	0.9	0.9	RoHS (7a)
TG110-S125N2LF	B	N2	0 to 70°C	1CT:1CT	2CT:1CT	30 max	0.4	0.9	Pb-Free
TG110-S125N2RL	B	N2	0 to 70°C	1CT:1CT	2CT:1CT	35 max	0.4	0.9	RoHS (7a)
TG110-S131N2LF	B	N2	0 to 70°C	1.41CT:1CT	1CT:1CT	35 max	0.4	1.5	Pb-Free
TG110-S131N2RL	B	N2	0 to 70°C	1.41CT:1CT	1CT:1CT	35 max	0.4	1.5	RoHS (7a)
TG110-S139N2LF	B	N2	0 to 70°C	1.25CT:1CT	1CT:1CT	15 typ	0.9	0.9	Pb-Free
TG110-S139N2RL	B	N2	0 to 70°C	1.25CT:1CT	1CT:1CT	15 typ	0.9	0.9	RoHS (7a)
TG110-S141N5LF	B	N5	0 to 70°C	1CT:1.41CT	1CT:1CT	35 typ	0.4	0.9	Pb-Free
TG110-S141N5RL	B	N5	0 to 70°C	1CT:1.41CT	1CT:1CT	35 typ	0.4	0.9	RoHS (7a)
TG110-S177N2LF	B	N2	0 to 70°C	1.41CT:1CT	1.41CT:1CT	30 max	0.6	0.9	Pb-Free
TG110-S177N2RL	B	N2	0 to 70°C	1.41CT:1CT	1.41CT:1CT	30 max	0.6	0.9	RoHS (7a)

ULTRA-II™									
TG110-3506N6LF²	C	N6	0 to 70°C	1CT:1CT	1CT:1CT	20 typ	0.4	1.3	Pb-Free
TG110-3506N6RL²	C	N6	0 to 70°C	1CT:1CT	1CT:1CT	20 typ	0.4	1.3	RoHS (7a)
TG110-S101N6LF²	D	N6	0 to 70°C	1CT:1CT	1CT:1CT	20 typ	0.4	1.3	Pb-Free
TG110-S101N6RL²	D	N6	0 to 70°C	1CT:1CT	1CT:1CT	20 typ	0.4	1.3	RoHS (7a)

Notes:

1. Pb-Free parts are RoHS 6/6 compliant. RoHS (7a) parts contain lead per exemption 7a which is set to expire in July 2016.
2. Not for use in Auto-MDIX circuits/auto-transformer must be on the TX channel.
3. Parts with RL suffix are not recommended for new designs.
4. Contact the factory or your local representative for individual datasheet or additional information.

For additional information contact your [local representative](#), or HALO's support staff at (650) 903-3800 or info@haloelectronics.com

ULTRA™ Family of Transformers

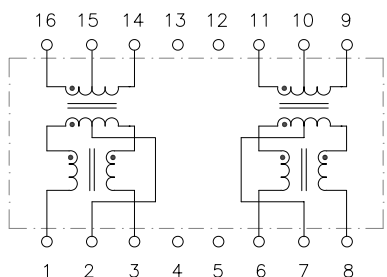


E-ULTRA™ Part Number	Circuit	Package	Temp. Range	Turns Ratio ±3%		Cw/w (pF)	PRI/SEC			RoHS¹
				(1-3:16-14)	(6-8:11-9)		LL (μH max)	PRI DCR (Ω max)		
TG110-E050N5LF	A	N5	-40 to +85°C	1CT:1CT	1CT:1CT	35 max	0.4	1.0		Pb-Free
TG110-E050N5RL	A	N5	-40 to +85°C	1CT:1CT	1CT:1CT	40 max	0.4	1.0		RoHS (7a)
TG110-E055N5LF	B	N5	-40 to +85°C	1CT:1CT	1CT:1CT	35 max	0.4	1.0		Pb-Free
TG110-E055N5RL	B	N5	-40 to +85°C	1CT:1CT	1CT:1CT	40 max	0.4	1.0		RoHS (7a)
TG110-E120N5LF	B	N5	-40 to +85°C	2CT:1CT	1CT:1CT	40 max	0.9	1.3		Pb-Free
TG110-E120N5RL	B	N5	-40 to +85°C	2CT:1CT	1CT:1CT	40 max	0.9	1.3		RoHS (7a)
TG110-E125N5LF	B	N5	-40 to +85°C	1CT:1CT	2CT:1CT	40 max	0.9	1.1		Pb-Free
TG110-E125N5RL	B	N5	-40 to +85°C	1CT:1CT	2CT:1CT	40 max	0.9	1.1		RoHS (7a)
TG110-E139N5LF	B	N5	-40 to +85°C	1.25CT:1CT	1CT:1CT	30 typ	0.4	1.3		Pb-Free
TG110-E139N5RL	B	N5	-40 to +85°C	1.25CT:1CT	1CT:1CT	30 typ	0.4	1.3		RoHS (7a)

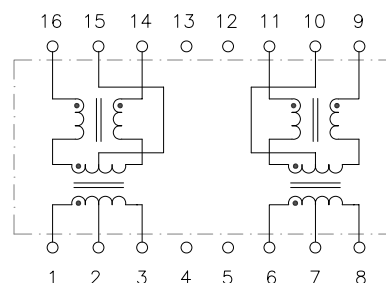
Notes:

1. Pb-Free parts are RoHS 6/6 compliant. RoHS (7a) parts contain lead per exemption 7a which is set to expire in July 2016.
2. Parts with RL suffix are not recommended for new designs.
3. Contact the factory or your local representative for individual datasheet or additional information.

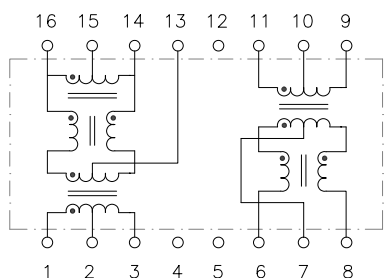
Circuit A



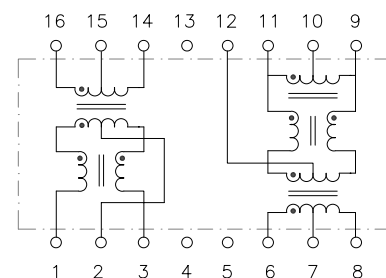
Circuit B



Circuit C

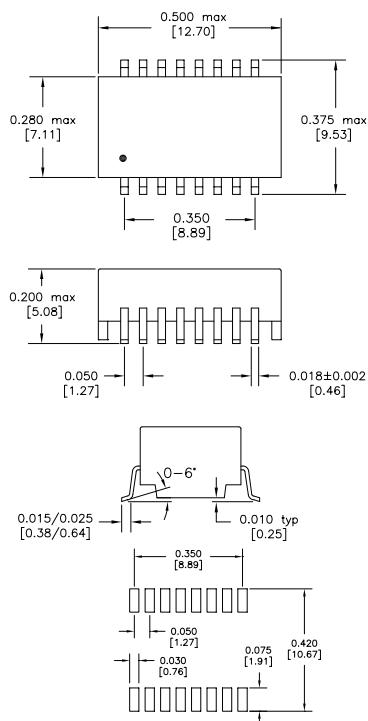


Circuit D



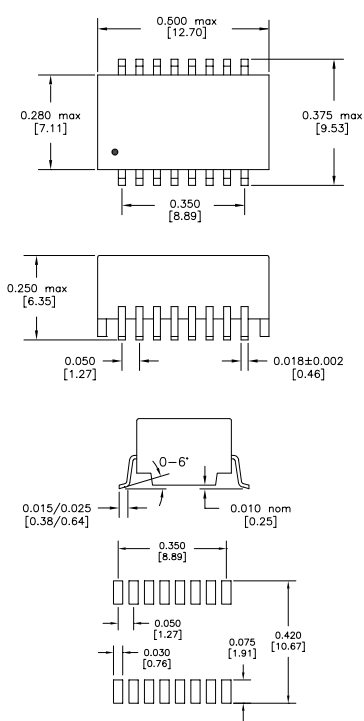
HALO ULTRA 10/100BASE-TX Ethernet Transformers

N2 Package



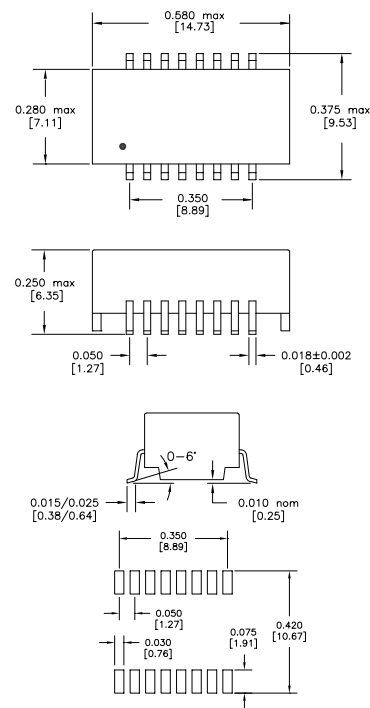
Recommended Solder Pad Dimensions

N5 Package



Recommended Solder Pad Dimensions

N6 Package



Recommended Solder Pad Dimensions

Dimensions: inch [mm]

Co-Planarity: 0.004 [0.10]

HALO
ELECTRONICS, INC.

2880 Lakeside Drive #116
Santa Clara, CA 95054
(650) 903-3800

www.halo-electronics.com

HALO® Electronics is a leading supplier of high quality communication magnetics including signal transformers, filters, CMR chokes, PoE power transformers, DC/DC converters, and integrated Ethernet connectors. HALO's leading edge technology solutions are manufactured in ISO9001 and ISO14001 factories offering high quality products at a competitive price.

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Revised 8/2015. Download the latest version at www.halo-electronics.com/pdf/discrete-ultra-100baset.pdf

APPROVAL SHEET

MULTILAYER CERAMIC CAPACITORS

High Capacitance Series

0402 to 1812 Sizes

X7R, X5R & Y5V Dielectrics

RoHS Compliance

*Contents in this sheet are subject to change without prior notice.

1. DESCRIPTION

MLCC consists of a conducting material and electrodes. To manufacture a chip-type SMT and achieve miniaturization, high density and high efficiency, ceramic condensers are used.

WTC high capacitance MLCC offers low ESR and excellent frequency characteristics to be suited for coupling and decoupling applications in circuit. The high dielectric constant material X7R, X5R and Y5V are used for this series product.

2. FEATURES

- a. Small size with high capacitance.
- b. Capacitor with lead-free termination (pure Tin).

3. APPLICATIONS

- a. Digital circuit coupling or decoupling applications.
- b. For high frequency and high-density type power suppliers.
- c. For bypassing.

4. HOW TO ORDER

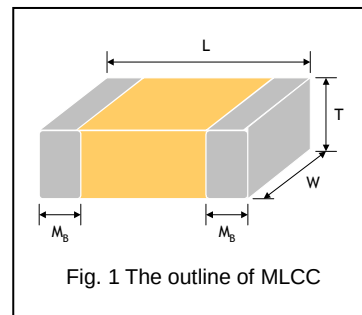
<u>1206</u>	<u>E</u>	<u>106</u>	<u>Z</u>	<u>100</u>	<u>C</u>	<u>I</u>
<u>Size</u>	<u>Dielectric</u>	<u>Capacitance</u>	<u>Tolerance</u>	<u>Rated voltage</u>	<u>Termination</u>	<u>Packaging</u>
Inch (mm) 0402 (1005) 0603 (1608) 0805 (2012) 1206 (3216) 1210 (3225) 1812 (4532)	B =X7R X =X5R F =Y5V	Two significant digits followed by no. of zeros. And R is in place of decimal point. eg.: 106=10x10 ⁶ =10μF	K =±10% M =±20% Z =-20/+80%	Two significant digits followed by no. of zeros. And R is in place of decimal point. 6R3 =6.3 VDC 100 =10 VDC 160 =16 VDC 250 =25 VDC 500 =50 VDC 101 =100 VDC	C =Cu/Ni/Sn	T =7" reeled G =13" reeled

5. EXTERNAL DIMENSIONS

Size Inch (mm)	L (mm)	W (mm)	T (mm)/Symbol	Remark	M _B (mm)
0402 (1005)	1.00±0.05	0.50±0.05	0.50±0.05	N	0.25 +0.05/-0.10
	1.00±0.20	0.50±0.20	0.50±0.20	E	
0603 (1608)	1.60±0.10	0.80±0.10	0.80±0.07	S	0.40±0.15
	1.60+0.15/-0.10	0.80+0.15/-0.10	0.80+0.15/-0.10	X	
0805 (2012)	2.00±0.15	1.25±0.10	0.80±0.10	B	0.50±0.20
			1.25±0.10	D	
	2.00±0.20	1.25±0.20	1.25±0.20	I	
1206 (3216)	3.20±0.15	1.60±0.15	0.95±0.10	C	0.60±0.20
			1.25±0.10	D	
	3.20±0.20	1.60±0.20	1.15±0.15	J	
			1.60±0.20	G	
	3.20+0.30/-0.10	1.60+0.30/-0.10	1.60+0.30/-0.10	P	
1210 (3225)	3.20±0.30	2.50±0.20	0.95±0.10	C	0.75±0.25
			1.25±0.10	D	
	3.20±0.40	2.50±0.30	1.60±0.20	G	
			2.00±0.20	K	
			2.50±0.30	M	
1812 (4532)	4.50±0.40	3.20±0.30	1.25±0.10	D	0.75±0.25
			2.00±0.20	K	
	4.50±0.40	3.20±0.40	2.50±0.30	M	
			2.80±0.30	U	

Reflow soldering only is recommended.

*1 : For 0603/X5R/6.3V/Cap ≥ 10μF products



6. GENERAL ELECTRICAL DATA

Dielectric	X7R	X5R	Y5V
Size	0402, 0603, 0805, 1206, 1210, 1812		
Capacitance range*	0.56μF to 47μF	0.027μF to 100μF	1μF to 100μF
Capacitance tolerance**	K (±10%), M (±20%)		Z (-20/+80%)
Rated voltage (WVDC)	6.3V, 10V, 16V, 25V, 50V, 100V		
DF(Tan δ)*	Note 1		
Operating temperature	-55 to +125℃	-55 to +85℃	-25 to +85℃
Capacitance characteristic	±15%		+30/-80%
Termination	Ni/Sn (lead-free termination)		

* Measured at 1.0±0.2Vrms, 1.0kHz±10% for C≤10μF; 0.5±0.2Vrms, 120Hz±20% for C>10μF, 30~70% related humidity, 25℃ ambient temperature for X7R, X5R and at 20℃ for Y5V.

** Preconditioning for Class II MLCC: Perform a heat treatment at 150±10℃ for 1 hour, then leave in a mbient condition for 24±2 hours before measurement.

Note 1:

X7R/X5R

Rated vol.	D.F. ≤	Exception of D.F. ≤
≥ 50V	≤ 2.5%	≤ 3% 0201(50V); 0603 ≥ 0.047μF; 0805 ≥ 0.18μF; 1206 ≥ 0.47μF
		≤ 5% 1210 ≥ 4.7μF
		≤ 10% 0603 ≥ 1μF; 0805 ≥ 1μF; 1206 ≥ 4.7μF; 1210 ≥ 10μF
35V	≤ 3.5%	≤ 10% 0805 ≥ 2.2μF; 1210 ≥ 10μF
25V	≤ 3.5%	≤ 5% 0201 ≥ 0.01μF; 0805 ≥ 1μF; 1210 ≥ 10μF
		≤ 7% 0603 ≥ 0.33μF; 1206 ≥ 4.7μF
		≤ 10% 0402 ≥ 0.10μF; 0603 ≥ 0.47μF; 0805 ≥ 2.2μF; 1206 ≥ 6.8μF; 1210 ≥ 22μF; TT series
16V	≤ 3.5%	≤ 5% 0201 ≥ 0.01μF; 0402 ≥ 0.033μF; 0805 ≥ 0.68μF; 1206 ≥ 2.2μF; 1210 ≥ 4.7μF
		≤ 10% 0402 ≥ 0.22μF; 0603 ≥ 0.68μF; 0805 ≥ 2.2μF; 1206 ≥ 4.7μF; 1210 ≥ 22μF; TT series
		≤ 15% 0201 ≥ 0.012μF; 0402 ≥ 0.33μF; 0603 ≥ 0.33μF; 0805 ≥ 2.2μF; 1206 ≥ 2.2μF; 1210 ≥ 22μF; TT series
10V	≤ 5%	≤ 10% 0201 ≥ 0.012μF; 0402 ≥ 0.33μF; 0603 ≥ 0.33μF; 0805 ≥ 2.2μF; 1206 ≥ 2.2μF; 1210 ≥ 22μF; TT series
6.3V	≤ 10%	≤ 15% 0201 ≥ 0.1μF; 0402 ≥ 1μF; 0603 ≥ 10μF; 0805 ≥ 4.7μF; 1206 ≥ 47μF; 1210 ≥ 100μF; TT series
		≤ 20% 0402 ≥ 2.2μF
4V	≤ 15%	-- --

Y5V

Rated vol.	D.F. ≤	Exception of D.F. ≤
≥ 50V	5%	7% 0603 ≥ 0.1μF; 0805 ≥ 0.47μF; 1206 ≥ 4.7μF
35V	7%	---
25V	5%	7% 0402 ≥ 0.047μF; 0603 ≥ 0.1μF; 0805 ≥ 0.33μF; 1206 ≥ 1μF; 1210 ≥ 4.7μF
		9% 0402 ≥ 0.068μF; 0603 ≥ 0.47μF; 1206 ≥ 4.7μF; 1210 ≥ 22μF
		12.5% 0402 ≥ 0.22μF
16V (C<1.0μF)	7%	9% 0402 ≥ 0.068μF; 0603 ≥ 0.68μF
16V (C ≥ 1.0μF)	9%	12.5% 0603 ≥ 2.2μF; 0805 ≥ 3.3μF; 1206 ≥ 10μF; 1210 ≥ 22μF; 1812 ≥ 47μF
10V	12.5%	20% 0402 ≥ 0.47μF
6.3V	20%	---

7. CAPACITANCE RANGE

7-1 X7R Dielectric

DIELECTRIC		X7R															
SIZE		0603				0805					1206						
Rated Voltage (VDC)		6.3	10	16	25	6.3	10	16	25	50	6.3	10	16	25	50	100	
Capacitance	0.56μF (564)	X	X	X													
	0.68μF (684)	X	X	X													
	0.82μF (824)	X	X	X													
	1.0μF (105)	X	X	X	X		D	D	D	I		J	J	J	P	P	
	1.5μF (155)						I	I	I		J	J	J	P			
	2.2μF (225)		X			I	I	I	I		J	J	J	P	P		
	3.3μF (335)										P	P	P	P			
	4.7μF (475)					I	I	I			P	P	P	P	P		
	6.8μF (685)																
	10μF (106)					I	I				P	P	P	P			
	22μF (226)											P					
	47μF (476)																

The letter in cell is expressed the symbol of product thickness.

DIELECTRIC		X7R										
SIZE		1210					1812					
Rated Voltage (VDC)		10	16	25	35	50	100	10	16	25	50	100
Capacitance	0.56μF (564)											
	0.68μF (684)											
	0.82μF (824)											
	1.0μF (105)	D	D	D		D	K	D	D	D	K	K
	1.5μF (155)						M					K
	2.2μF (225)		K	G			M				M	M
	3.3μF (335)			G								
	4.7μF (475)	K	K	K		M						
	6.8μF (685)											
	10μF (106)	K	K	K	M	M						
	22μF (226)		M	M								
	47μF (476)	M										

The letter in cell is expressed the symbol of product thickness.

7-2 X5R Dielectric

Dielectric		X5R																								
Size		0402				0603					0805					1206					1210					
Rated Voltage (VDC)		6.3	10	16	25	6.3	10	16	25	50	6.3	10	16	25	50	6.3	10	16	25	50	6.3	10	16	25	50	
Capacitance	0.027µF (273)			N																						
	0.033µF (333)			N																						
	0.039µF (393)			N																						
	0.047µF (473)			N																						
	0.056µF (563)		N	N																						
	0.068µF (683)		N	N																						
	0.082µF (823)	N	N	N																						
	0.10µF (104)	N	N	N	N																					
	0.15µF (154)		N																							
	0.22µF (224)	N	N	N	N				X	X																
	0.27uF (274)							X	X																	
	0.33µF (334)	N	N			X	X	X	X																	
	0.39µF (394)						X	X																		
	0.47µF (474)	N	N				X	X	X																	
	0.68µF (684)	N	N				X	X	X																	
	0.82uF (824)					X	X	X																		
	1.0µF (105)	N	N	N	N	X	X	X	X	X		D	D	D	I											
	1.5µF (155)					X						I	I	I	I			J	J				K	K		
	2.2µF (225)	N	N			X	X	X	X			I	I	I	I			J	J	P			K	K		
	3.3µF (335)											I	I	I	I			P	P	P						
	4.7µF (475)	E				X	X	X				I	I	I	I	I	P	P	P	P	P		K	K	K	
	6.8uF (685)																P	P								
	10µF (106)	E				X	X					I	I	I	I		P	P	P	P		K	K	K	K	M
	22µF (226)					X						I	I				P	P	P			M	M	M	M	
	47µF (476)											I					P	P				M	M	M		
	100µF (107)																P					M	M			

The letter in cell is expressed the symbol of product thickness.

7-3 Y5V Dielectric

DIELECTRIC		Y5V										
SIZE		0402				0603				0805		
RATED VOLTAGE (VDC)		63	10			63	10	16	25	6.3	10	50
Capacitance	1.0μF (105)	N	N				S	X	X		B	D
	1.5μF (155)						S				D	D
	2.2μF (225)					S	S	X			D	I
	3.3μF (335)										D	D
	4.7μF (475)					X	X				D	I
	6.8μF (685)										I	
	10μF (106)									I	I	I
	22μF (226)									I		

DIELECTRIC		Y5V														
SIZE		1206					1210					1812				
RATED VOLTAGE (VDC)		6.3	10	16	25	35	50	6.3	10	16	25	35	50	10	16	25
Capacitance	1.0μF (105)		C	C	C		C		C	C	C		C	D	D	D
	1.5μF (155)		C	C	C				C	C	C			D	D	D
	2.2μF (225)		C	C	C		J		C	C	C		G	D	D	D
	3.3μF (335)		J	J	J				C	C	C			D	D	D
	4.7μF (475)		J	J	J	J	P		C	C	D		G	D	D	D
	6.8μF (685)		J	J					C	C	D			D	D	D
	10μF (106)		J	J	P				D	D	G	K		D	D	K
	22μF (226)		P						K	K						
	47μF (476)	P						K	K						M	
	100μF (107)							M								

The letter in cell is expressed the symbol of product thickness.

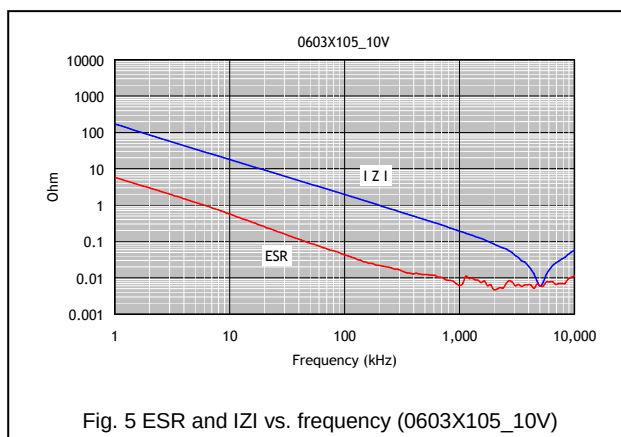
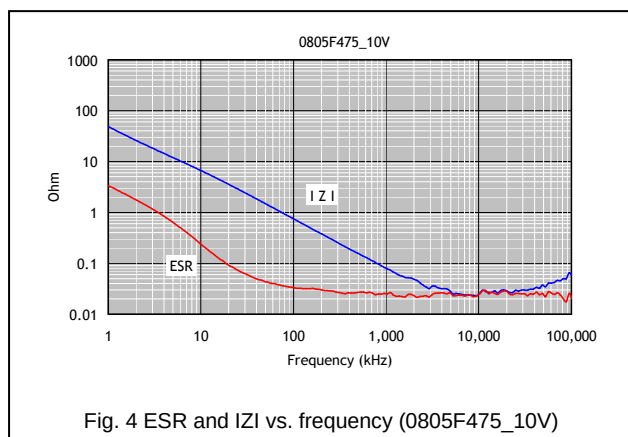
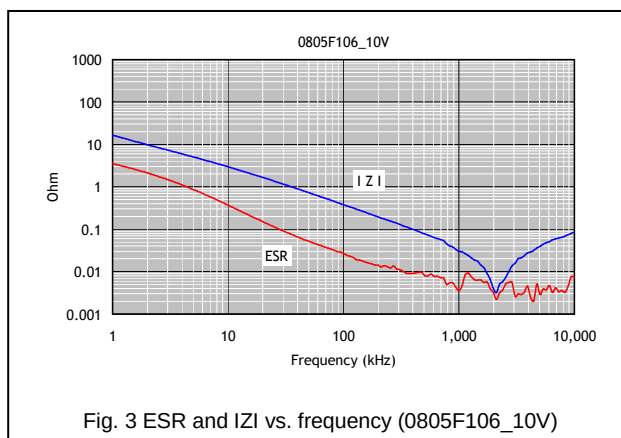
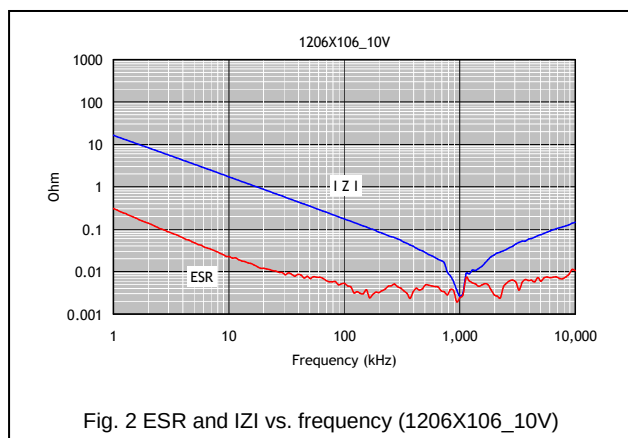
8. PACKAGING STYLE AND QUANTITY

Size	Thickness (mm)/Symbol		Paper tape		Plastic tape	
			7" reel	13" reel	7" reel	13" reel
0402 (1005)	0.50±0.05	N	10k	50k	-	-
	0.50±0.20	E	10k	-	-	-
0603 (1608)	0.80±0.07	S	4k	15k	-	-
	0.80±0.20	X	4k	15k	-	-
0805 (2012)	0.80±0.10	B	4k	15k	-	-
	1.25±0.10	D	-	-	3k	10k
	1.25±0.20	I	-	-	3k	10k
1206 (3216)	0.95±0.10	C	-	-	3k	10k
	1.15±0.15	J	-	-	3k	10K
	1.25±0.10	D	-	-	3k	10k
	1.60±0.20	G	-	-	2k	10k
	1.60+0.30/-0.10	P	-	-	2k	9k
1210 (3225)	0.95±0.10	C	-	-	3k	10k
	1.25±0.10	D	-	-	3k	10k
	1.60±0.20	G	-	-	2k	-
	2.00±0.20	K	-	-	1k	6k
	2.50±0.30	M	-	-	1k	6k
1812 (4532)	1.25±0.10	D	-	-	1k	5k
	2.00±0.20	K	-	-	1k	-
	2.50±0.30	M	-	-	0.5k	3k
	2.80±0.30	U	-	-	0.5k	-

Unit: pieces

9. ELECTRICAL CHARACTERISTICS

Typical Impedance/ESR vs. Frequency



10. RELIABILITY TEST CONDITIONS AND REQUIREMENTS

No.	Item	Test Condition	Requirements																																																
1.	Visual and Mechanical	---	* No remarkable defect. * Dimensions to conform to individual specification sheet.																																																
2.	Capacitance	Class I: NP0 Cap≤1000pF 1.0±0.2Vrms, 1MHz±10% Cap>1000pF 1.0±0.2Vrms, 1kHz±10%	* Shall not exceed the limits given in the detailed spec.																																																
3.	Q/ D.F. (Dissipation Factor)	Class II: X7R,X7E, X5R,Y5V Cap≤10μF, 1.0±0.2Vrms, 1kHz±10% ** Cap>10μF, 0.5±0.2Vrms, 120Hz±20% ** Test condition: 0.5±0.2Vrms · 1kHz±10% X7R: 0603 ≥ 225(10V),0805=106(6.3V&10V) X5R: 01R5 ≥ 103, 0201 ≥ 224 (6.3V), 0402 ≥ 475 (6.3V), 0402 ≥ 225(10V), 0603=106 (6.3V), TT18X ≥ 475(10V) , TT15X series	NP0: Cap≥30pF, Q≥1000; Cap<30pF,Q≥400+20C X7R, X5R:																																																
			<table><tr><th>Rated vol.</th><th>D.F. ≤</th><th colspan="2">Exception of D.F. ≤</th></tr><tr><td rowspan="3">≥ 50V</td><td rowspan="3">≤ 2.5%</td><td>≤ 3%</td><td>0201(50V); 0603 ≥ 0.047μF; 0805 ≥ 0.18μF;1206 ≥ 0.47μF</td></tr><tr><td>≤ 5%</td><td>1210 ≥ 4.7μF</td></tr><tr><td>≤ 10%</td><td>0603 ≥ 1μF; 0805 ≥ 1μF; 1206 ≥ 4.7μF; 1210 ≥ 10μF</td></tr><tr><td>35V</td><td>≤ 3.5%</td><td>≤ 10%</td><td>0805≥2.2μF; 1210 ≥ 10μF</td></tr><tr><td rowspan="3">25V</td><td rowspan="3">≤ 3.5%</td><td>≤ 5%</td><td>0201 ≥ 0.01μF;0805 ≥ 1μF; 1210 ≥ 10μF</td></tr><tr><td>≤ 7%</td><td>0603 ≥ 0.33μF; 1206 ≥ 4.7μF</td></tr><tr><td>≤ 10%</td><td>0402 ≥ 0.10μF;0603 ≥ 0.47μF; 0805 ≥ 2.2μF; 1206 ≥ 6.8μF ; 1210 ≥ 22μF ; TT series</td></tr><tr><td rowspan="3">16V</td><td rowspan="3">≤ 3.5%</td><td>≤ 5%</td><td>0201 ≥ 0.01μF;0402 ≥ 0.033μF; 0805 ≥ 0.68μF;1206 ≥ 2.2μF;1210 ≥ 4.7μF</td></tr><tr><td rowspan="2">≤ 10%</td><td>0402 ≥ 0.22μF; 0603 ≥ 0.68μF;0805 ≥ 2.2μF; 1206 ≥ 4.7μF; 1210 ≥ 22μF; TT series</td></tr><tr><td>≤ 10%</td><td>0201 ≥ 0.012μF;0402 ≥ 0.33μF;0603 ≥ 0.33μF; 0805 ≥ 2.2μF; 1206 ≥ 2.2μF;1210 ≥ 22μF; TT series</td></tr><tr><td rowspan="2">10V</td><td rowspan="2">≤ 5%</td><td>≤ 15%</td><td>0201 ≥ 0.1μF; 0402 ≥ 1μF</td></tr><tr><td>---</td><td>---</td></tr><tr><td>6.3V</td><td>≤ 10%</td><td>≤ 15%</td><td>0201 ≥ 0.1μF;0402 ≥ 1μF;0603 ≥ 10μF; 0805 ≥ 4.7μF; 1206 ≥ 47μF :1210 ≥ 100μF; TT series</td></tr><tr><td rowspan="2">4V</td><td rowspan="2">≤ 15%</td><td>---</td><td>---</td></tr><tr><td>---</td><td>---</td></tr></table>	Rated vol.	D.F. ≤	Exception of D.F. ≤		≥ 50V	≤ 2.5%	≤ 3%	0201(50V); 0603 ≥ 0.047μF; 0805 ≥ 0.18μF;1206 ≥ 0.47μF	≤ 5%	1210 ≥ 4.7μF	≤ 10%	0603 ≥ 1μF; 0805 ≥ 1μF; 1206 ≥ 4.7μF; 1210 ≥ 10μF	35V	≤ 3.5%	≤ 10%	0805≥2.2μF; 1210 ≥ 10μF	25V	≤ 3.5%	≤ 5%	0201 ≥ 0.01μF;0805 ≥ 1μF; 1210 ≥ 10μF	≤ 7%	0603 ≥ 0.33μF; 1206 ≥ 4.7μF	≤ 10%	0402 ≥ 0.10μF;0603 ≥ 0.47μF; 0805 ≥ 2.2μF; 1206 ≥ 6.8μF ; 1210 ≥ 22μF ; TT series	16V	≤ 3.5%	≤ 5%	0201 ≥ 0.01μF;0402 ≥ 0.033μF; 0805 ≥ 0.68μF;1206 ≥ 2.2μF;1210 ≥ 4.7μF	≤ 10%	0402 ≥ 0.22μF; 0603 ≥ 0.68μF;0805 ≥ 2.2μF; 1206 ≥ 4.7μF; 1210 ≥ 22μF; TT series	≤ 10%	0201 ≥ 0.012μF;0402 ≥ 0.33μF;0603 ≥ 0.33μF; 0805 ≥ 2.2μF; 1206 ≥ 2.2μF;1210 ≥ 22μF; TT series	10V	≤ 5%	≤ 15%	0201 ≥ 0.1μF; 0402 ≥ 1μF	---	---	6.3V	≤ 10%	≤ 15%	0201 ≥ 0.1μF;0402 ≥ 1μF;0603 ≥ 10μF; 0805 ≥ 4.7μF; 1206 ≥ 47μF :1210 ≥ 100μF; TT series	4V	≤ 15%	---	---	---	---
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			Rated vol.	D.F. ≤	Exception of D.F. ≤																																														
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10V	12.5%	---	---																																																
6.3V	20%	---	---																																																
4.	Dielectric Strength	* To apply voltage (≤100V) 250%. Duration: 1 to 5 sec. Charge and discharge current less than 50mA.	* No evidence of damage or flash over during test.																																																
5.	Insulation Resistance	To apply rated voltage for max. 120 sec.	10GΩ or RxC ≥ 500Ω·F whichever is smaller. Class II (X7R, X5R, Y5V) <table><tr><th>Rated voltage</th><th>Insulation Resistance</th></tr><tr><td>100V: X7R</td><td rowspan="7">10GΩ or RxC ≥ 100 Ω·F whichever is smaller.</td></tr><tr><td>50V:0603≥1μF;0805≥1μF;1206≥4.7μF;1210≥4.7μF</td></tr><tr><td>35V:0805≥2.2μF;1210 ≥ 10μF</td></tr><tr><td>25V:0402≥1μF;0603≥2.2μF;0805≥2.2μF;1206≥10μF;1210≥10μF</td></tr><tr><td>16V:0402≥0.22μF;0603≥1μF;0805≥2.2μF;1206≥10μF;1210≥47μF</td></tr><tr><td>10V:0201≥47nF;0402≥0.47μF;0603≥0.47μF;0805≥2.2μF; 1206≥4.7μF;1210≥47μF</td></tr><tr><td>6.3V ; 4V</td></tr></table>	Rated voltage	Insulation Resistance	100V: X7R	10GΩ or RxC ≥ 100 Ω·F whichever is smaller.	50V:0603≥1μF;0805≥1μF;1206≥4.7μF;1210≥4.7μF	35V:0805≥2.2μF;1210 ≥ 10μF	25V:0402≥1μF;0603≥2.2μF;0805≥2.2μF;1206≥10μF;1210≥10μF	16V:0402≥0.22μF;0603≥1μF;0805≥2.2μF;1206≥10μF;1210≥47μF	10V:0201≥47nF;0402≥0.47μF;0603≥0.47μF;0805≥2.2μF; 1206≥4.7μF;1210≥47μF	6.3V ; 4V																																						
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6.3V ; 4V																																																			
6.	Temperature Coefficient	With no electrical load. <table><tr><th>T.C.</th><th>Operating Temp</th></tr><tr><td>NPO</td><td>-55~125℃ at 25℃</td></tr><tr><td>X7R</td><td>-55~125℃ at 25℃</td></tr><tr><td>X5R</td><td>-55~ 85℃ at 25℃</td></tr><tr><td>Y5V</td><td>-25~ 85℃ at 20℃</td></tr></table>	T.C.	Operating Temp	NPO	-55~125℃ at 25℃	X7R	-55~125℃ at 25℃	X5R	-55~ 85℃ at 25℃	Y5V	-25~ 85℃ at 20℃	<table><tr><th>T.C.</th><th>Capacitance Change</th></tr><tr><td>NPO</td><td>Within ±30ppm/℃</td></tr><tr><td>X7R</td><td>Within ±15%</td></tr><tr><td>X5R</td><td>Within ±15%</td></tr><tr><td>Y5V</td><td>Within +30%/-80%</td></tr></table>	T.C.	Capacitance Change	NPO	Within ±30ppm/℃	X7R	Within ±15%	X5R	Within ±15%	Y5V	Within +30%/-80%																												
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No.	Item	Test Condition	Requirements															
7.	Adhesive Strength of Termination	* Pressurizing force : 5N (≤0603) and 10N (>0603) * Test time: 10±1 sec.	* No remarkable damage or removal of the terminations.															
8.	Vibration Resistance	* Vibration frequency: 10–55 Hz/min. * Total amplitude: 1.5mm * Test time: 6 hrs. (Two hrs each in three mutually perpendicular directions.) * Measurement to be made after keeping at room temp. for 24±2 hrs.	* No remarkable damage. * Cap change and Q/D.F.: To meet initial spec.															
9.	Solderability	* Solder temperature: 235±5°C * Dipping time: 2±0.5 sec.	95% min. coverage of all metalized area.															
10.	Bending Test	* The middle part of substrate shall be pressurized by means of the pressurizing rod at a rate of about 1 mm per second until the deflection becomes 1 mm and then the pressure shall be maintained for 5±1 sec. * Measurement to be made after keeping at room temp. for 24±2 hrs.	* No remarkable damage. * Cap change : NP0: within ±5% or 0.5pF whichever is larger X7R, X5R: within ±12.5% Y5V: within ±30% (This capacitance change means the change of capacitance under specified flexure of substrate from the capacitance measured before the test.)															
11.	Resistance to Soldering Heat	* Solder temperature: 260±5°C * Dipping time: 10±1 sec * Preheating: 120 to 150°C for 1 minute before immerse the capacitor in a eutectic solder. * Before initial measurement (Class II only): Perform 150+0/-10°C for 1 hr and then set for 24±2 hrs at room temp. * Measurement to be made after keeping at room temp. for 24±2 hrs.	* No remarkable damage. * Cap change: NP0: within ±2.5% or 0.25pF whichever is larger X7R, X5R: within ±7.5% Y5V: within ±20% * Q/D.F., I.R. and dielectric strength: To meet initial requirements. * 25% max. leaching on each edge.															
12.	Temperature Cycle	* Conduct the five cycles according to the temperatures and time.<table><tr><th>Step</th><th>Temp. (°C)</th><th>Time (min.)</th></tr><tr><td>1</td><td>Min. operating temp. +0/-3</td><td>30±3</td></tr><tr><td>2</td><td>Room temp.</td><td>2~3</td></tr><tr><td>3</td><td>Max. operating temp. +3/-0</td><td>30±3</td></tr><tr><td>4</td><td>Room temp.</td><td>2~3</td></tr></table> * Before initial measurement (Class II only): Perform 150+0/-10°C for 1 hr and then set for 24±2 hrs at room temp. * Measurement to be made after keeping at room temp. for 24±2 hrs.	Step	Temp. (°C)	Time (min.)	1	Min. operating temp. +0/-3	30±3	2	Room temp.	2~3	3	Max. operating temp. +3/-0	30±3	4	Room temp.	2~3	* No remarkable damage. * Cap change : NP0: within ±2.5% or 0.25pF whichever is larger X7R, X5R: within ±7.5% Y5V: within ±20% * Q/D.F., I.R. and dielectric strength: To meet initial requirements.
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4	Room temp.	2~3																

No.	Item	Test Condition	Requirements																																																																																												
13.	Humidity (Damp Heat) Steady State	* Test temp.: 40±2℃ * Humidity: 90~95% RH * Test time: 500+24/-0hrs. * Before initial measurement (Class II only): Perform 150+0/-10℃ for 1 hr and then set for 24±2 hrs at room temp. * Measurement to be made after keeping at room temp. for 24±2 hrs.	* No remarkable damage. * Cap change: - NP0: within ±5% or 0.5pF whichever is larger - X7R, X7E, X5R: ≥10V**, within ±12.5%; 6.3V within ±25%; TT series & C≥ 1uF, within ±25% **10V: 0603 ≥ 4.7μF; 0402 ≥ 1μF; 0201 ≥ 0.1μF, within ±25%; - Y5V: ≥10V, within ±30%; 6.3V, within +30/-40% * Q/D.F. value: - NP0: More than 30pF Q≥350, 10pF≤C≤30pF, Q≥275+2.5C - Less than 10pF Q≥200+10C X7R, X5R: <table><tr><th>Rated vol.</th><th>D.F. ≤</th><th colspan="2">Exception of D.F. ≤</th></tr><tr><td rowspan="3">≥ 50V</td><td rowspan="3">≤ 3%</td><td>≤ 6%</td><td>0201(50V); 0603 ≥ 0.047μF; 0805 ≥ 0.18μF; 1206 ≥ 0.47μF</td></tr><tr><td>≤ 10%</td><td>1210 ≥ 4.7μF</td></tr><tr><td>≤ 20%</td><td>0603 ≥ 1μF; 0805 ≥ 1μF; 1206 ≥ 4.7μF; 1210 ≥ 10μF</td></tr><tr><td>35V</td><td>≤ 5%</td><td>≤ 20%</td><td>0805 ≥ 2.2μF; 1210 ≥ 10μF</td></tr><tr><td rowspan="3">25V</td><td rowspan="3">≤ 5%</td><td>≤ 10%</td><td>0201 ≥ 0.01μF; 0805 ≥ 1μF; 1210 ≥ 10μF</td></tr><tr><td>≤ 14%</td><td>0603 ≥ 0.33μF; 1206 ≥ 4.7μF</td></tr><tr><td>≤ 15%</td><td>0402 ≥ 0.10μF; 0603 ≥ 0.47μF; 0805 ≥ 2.2μF; 1206 ≥ 6.8μF; 1210 ≥ 22μF</td></tr><tr><td rowspan="2">16V</td><td rowspan="2">≤ 5%</td><td>≤ 10%</td><td>0603 ≥ 0.15μF; 0805 ≥ 0.68μF; 1206 ≥ 2.2μF; 1210 ≥ 4.7μF</td></tr><tr><td>≤ 15%</td><td>0201 ≥ 0.01μF; 0402 ≥ 0.033μF; 0603 ≥ 0.68μF; 0805 ≥ 2.2μF; 1206 ≥ 4.7μF; 1210 ≥ 22μF</td></tr><tr><td rowspan="2">10V</td><td rowspan="2">≤ 7.5%</td><td>≤ 15%</td><td>0201 ≥ 0.012μF; 0402 ≥ 0.33μF; 0603 ≥ 0.33μF; 0805 ≥ 2.2μF; 1206 ≥ 2.2μF; 1210 ≥ 22μF</td></tr><tr><td>≤ 20%</td><td>0201 ≥ 0.1μF; 0402 ≥ 1μF</td></tr><tr><td>6.3V</td><td>≤ 15%</td><td>≤ 30%</td><td>0201 ≥ 0.1μF; 0402 ≥ 1μF; 0603 ≥ 10μF; 0805 ≥ 4.7μF; 1206 ≥ 47μF; 1210 ≥ 100μF</td></tr><tr><td>4V</td><td>≤ 20%</td><td>---</td><td>---</td></tr></table> Y5V: <table><tr><th>Rated vol.</th><th>D.F. ≤</th><th colspan="2">Exception of D.F. ≤</th></tr><tr><td>≥ 50V</td><td>7.5%</td><td>10%</td><td>0603 ≥ 0.1μF; 0805 ≥ 0.47μF; 1206 ≥ 4.7μF</td></tr><tr><td>35V</td><td>10%</td><td>---</td><td>---</td></tr><tr><td rowspan="2">25V</td><td rowspan="2">7.5%</td><td>10%</td><td>0402 ≥ 0.047μF; 0603 ≥ 0.1μF; 0805 ≥ 0.33μF; 1206 ≥ 1μF; 1210 ≥ 4.7μF</td></tr><tr><td>15%</td><td>0402 ≥ 0.068μF; 0603 ≥ 0.47μF; 1206 ≥ 4.7μF; 1210 ≥ 22μF</td></tr><tr><td>16V (C<1.0μF)</td><td>10%</td><td>12.5%</td><td>0402 ≥ 0.068μF; 0603 ≥ 0.68μF</td></tr><tr><td></td><td></td><td>20%</td><td>0402 ≥ 0.22μF</td></tr><tr><td>16V (C ≥ 1.0μF)</td><td>12.5%</td><td>20%</td><td>0603 ≥ 2.2μF; 0805 ≥ 3.3μF; 1206 ≥ 10μF; 1210 ≥ 22μF; 1812 ≥ 47μF;</td></tr><tr><td>10V</td><td>20%</td><td>30%</td><td>0402 ≥ 0.47μF</td></tr><tr><td>6.3V</td><td>30%</td><td>---</td><td>---</td></tr></table> *I.R.: ≥10V, 1GΩ or 50 Ω·F whichever is smaller. Class II (X7R, X5R, Y5V) <table><tr><th>Rated voltage</th><th>Insulation Resistance</th></tr><tr><td>100V: X7R</td><td rowspan="7">1GΩ or RxC ≥ 10 Ω·F whichever is smaller.</td></tr><tr><td>50V: 0603 ≥ 1μF; 0805 ≥ 1μF; 1206 ≥ 4.7μF; 1210 ≥ 4.7μF</td></tr><tr><td>35V: 0805 ≥ 2.2μF; 1210 ≥ 10μF</td></tr><tr><td>25V: 0402 ≥ 1μF; 0603 ≥ 2.2μF; 0805 ≥ 2.2μF; 1206 ≥ 10μF; 1210 ≥ 10μF</td></tr><tr><td>16V: 0402 ≥ 0.22μF; 0603 ≥ 1μF; 0805 ≥ 2.2μF; 1206 ≥ 10μF; 1210 ≥ 47μF</td></tr><tr><td>10V: 0201 ≥ 47nF; 0402 ≥ 0.47μF; 0603 ≥ 0.47μF; 0805 ≥ 2.2μF; 1206 ≥ 4.7μF; 1210 ≥ 47μF</td></tr><tr><td>6.3V ; 4V</td></tr></table>	Rated vol.	D.F. ≤	Exception of D.F. ≤		≥ 50V	≤ 3%	≤ 6%	0201(50V); 0603 ≥ 0.047μF; 0805 ≥ 0.18μF; 1206 ≥ 0.47μF	≤ 10%	1210 ≥ 4.7μF	≤ 20%	0603 ≥ 1μF; 0805 ≥ 1μF; 1206 ≥ 4.7μF; 1210 ≥ 10μF	35V	≤ 5%	≤ 20%	0805 ≥ 2.2μF; 1210 ≥ 10μF	25V	≤ 5%	≤ 10%	0201 ≥ 0.01μF; 0805 ≥ 1μF; 1210 ≥ 10μF	≤ 14%	0603 ≥ 0.33μF; 1206 ≥ 4.7μF	≤ 15%	0402 ≥ 0.10μF; 0603 ≥ 0.47μF; 0805 ≥ 2.2μF; 1206 ≥ 6.8μF; 1210 ≥ 22μF	16V	≤ 5%	≤ 10%	0603 ≥ 0.15μF; 0805 ≥ 0.68μF; 1206 ≥ 2.2μF; 1210 ≥ 4.7μF	≤ 15%	0201 ≥ 0.01μF; 0402 ≥ 0.033μF; 0603 ≥ 0.68μF; 0805 ≥ 2.2μF; 1206 ≥ 4.7μF; 1210 ≥ 22μF	10V	≤ 7.5%	≤ 15%	0201 ≥ 0.012μF; 0402 ≥ 0.33μF; 0603 ≥ 0.33μF; 0805 ≥ 2.2μF; 1206 ≥ 2.2μF; 1210 ≥ 22μF	≤ 20%	0201 ≥ 0.1μF; 0402 ≥ 1μF	6.3V	≤ 15%	≤ 30%	0201 ≥ 0.1μF; 0402 ≥ 1μF; 0603 ≥ 10μF; 0805 ≥ 4.7μF; 1206 ≥ 47μF; 1210 ≥ 100μF	4V	≤ 20%	---	---	Rated vol.	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14	Humidity (Damp Heat) Load	* Test temp.: 40±2℃ * Humidity: 90~95%RH * Test time: 500+24/-0 hrs. * To apply voltage : rated voltage. * Before initial measurement (Class II only): To apply test voltage for 1hr at 40℃ and then set for 24±2 hrs at room temp. * Measurement to be made after keeping at room temp. for 24±2 hrs.	* No remarkable damage. Cap change: NP0: ±7.5% or 0.75pF whichever is larger. X7R, X7E, X5R: ≥10V**,within ±12.5%;6.3V within ±25%; TT series & C≥ 1uF,within ±25% **10V:0603 ≥ 4.7μF;0402 ≥ 1μF;0201 ≥ 0.1μF, within ±25%; Y5V: ≥10V, within ±30%; 6.3V, within +30/-40% Q/D.F. value: NP0: C≥30pF,Q≥200;C<30pF, Q≥100+10/3C X7R, X5R: <table><tr><th>Rated vol.</th><th>D.F. ≤</th><th colspan="2">Exception of D.F. ≤</th></tr><tr><td rowspan="3">≥ 50V</td><td rowspan="3">≤ 3%</td><td>≤ 6%</td><td>0201(50V);0603 ≥ 0.047μF; 0805 ≥ 0.18μF; 1206 ≥ 0.47μF</td></tr><tr><td>≤ 10%</td><td>1210 ≥ 4.7μF</td></tr><tr><td>≤ 20%</td><td>0603 ≥ 1μF; 0805 ≥ 1μF;1206 ≥ 4.7μF; 1210 ≥ 10μF</td></tr><tr><td>35V</td><td>≤ 5%</td><td>≤ 20%</td><td>0805≥2.2μF;1210 ≥ 10μF</td></tr><tr><td rowspan="3">25V</td><td rowspan="3">≤ 5%</td><td>≤ 10%</td><td>0201 ≥ 0.01μF;0805 ≥ 1μF; 1210 ≥ 10μF</td></tr><tr><td>≤ 14%</td><td>0603 ≥ 0.33μF;1206 ≥ 4.7μF</td></tr><tr><td>≤ 15%</td><td>0402 ≥ 0.10μF;0603 ≥ 0.47μF;0805 ≥ 2.2μF;1206 ≥ 6.8μF; 1210 ≥ 22μF</td></tr><tr><td rowspan="2">16V</td><td rowspan="2">≤ 5%</td><td>≤ 10%</td><td>0603 ≥ 0.15μF;0805 ≥ 0.68μF;1206 ≥ 2.2μF;1210 ≥ 4.7μF</td></tr><tr><td>≤ 15%</td><td>0201 ≥ 0.01μF;0402 ≥ 0.033μF;0603 ≥ 0.68μF;0805 ≥ 2.2μF 1206 ≥ 4.7μF; 1210 ≥ 22μF</td></tr><tr><td rowspan="2">10V</td><td rowspan="2">≤ 7.5%</td><td>≤ 15%</td><td>0201 ≥ 0.012μF;0402 ≥ 0.33μF; 0603 ≥ 0.33μF; 0805 ≥ 2.2μF; 1206 ≥ 2.2μF; 1210 ≥ 22μF</td></tr><tr><td>≤ 20%</td><td>0201 ≥ 0.1μF ;0402 ≥ 1μF</td></tr><tr><td>6.3V</td><td>≤ 15%</td><td>≤ 30%</td><td>0201 ≥ 0.1μF;0402 ≥ 1μF;0603 ≥ 10μF; 0805 ≥ 4.7μF;1206 ≥ 47μF;1210 ≥ 100μF</td></tr><tr><td>4V</td><td>≤ 20%</td><td>---</td><td>---</td></tr></table> Y5V: <table><tr><th>Rated vol.</th><th>D.F. ≤</th><th colspan="2">Exception of D.F. ≤</th></tr><tr><td>≥ 50V</td><td>7.5%</td><td>10%</td><td>0603 ≥ 0.1μF; 0805 ≥ 0.47μF; 1206 ≥ 4.7μF</td></tr><tr><td>35V</td><td>10%</td><td>---</td><td>---</td></tr><tr><td rowspan="2">25V</td><td rowspan="2">7.5%</td><td>10%</td><td>0402 ≥ 0.047μF;0603 ≥ 0.1μF; 0805 ≥ 0.33μF;1206 ≥ 1μF; 1210 ≥ 4.7μF</td></tr><tr><td>15%</td><td>0402 ≥ 0.068μF;0603 ≥ 0.47μF; 1206 ≥ 4.7μF; 1210 ≥ 22μF</td></tr><tr><td>16V (C<1.0μF)</td><td>10%</td><td>12.5% 20%</td><td>0402 ≥ 0.068μF; 0603 ≥ 0.68μF 0402 ≥ 0.22μF</td></tr><tr><td>16V (C ≥ 1.0μF)</td><td>12.5%</td><td>20%</td><td>0603 ≥ 2.2μF; 0805 ≥ 3.3μF; 1206 ≥ 10μF;1210 ≥ 22μF; 1812 ≥ 47μF;</td></tr><tr><td>10V</td><td>20%</td><td>30%</td><td>0402 ≥ 0.47μF</td></tr><tr><td>6.3V</td><td>30%</td><td>---</td><td>---</td></tr></table> *I.R.: ≥10V, 500MΩ or 25 Ω-F whichever is smaller. Class II (X7R, X5R, Y5V) <table><tr><th>Rated voltage</th><th>Insulation Resistance</th></tr><tr><td>100V: X7R</td><td rowspan="7">500MΩ or RxC ≥ 5 Ω-F whichever is smaller.</td></tr><tr><td>50V:0603≥1μF;0805≥1μF;1206≥4.7μF;1210≥4.7μF</td></tr><tr><td>35V:0805≥2.2μF;1210 ≥ 10μF</td></tr><tr><td>25V:0402≥1μF;0603≥2.2μF;0805≥2.2μF;1206≥10μF;1210≥10μF</td></tr><tr><td>16V:0402≥0.22μF;0603≥1μF;0805≥2.2μF;1206≥10μF;1210≥47μF</td></tr><tr><td>10V:0201≥47nF;0402≥0.47μF;0603≥0.47μF;0805≥2.2μF; 1206≥4.7μF;1210≥47μF</td></tr><tr><td>6.3V ; 4V</td></tr></table>	Rated vol.	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15.	High Temperature Load (Endurance)	Test temp. : NP0, X7R/X7E: 125±3℃ X5R, Y5V: 85±3℃ Test time: 1000+24/-0 hrs. To apply voltage: (1) 6.3V or C≥10μF or TT series: 150% of rated voltage. (2) 10V≤Ur<500V: 200% of rated voltage. (3) 500V: 150% of rated voltage. (4) Ur≥630V: 120% of rated voltage. (5) 100% of rated voltage for below range.	* No remarkable damage. Cap change: NP0: ±3.0% or ±0.3pF whichever is larger X7R, X7E, X5R: ≥10V**, within ±12.5%; 6.3V within ±25%; TT series & C≥1uF, within ±25% **10V: 0603≥4.7μF; 0402≥1μF; 0201≥0.1μF, within ±25%; Y5V: ≥10V, within ±30%; 6.3V, within +30/-40% Q/D.F. value: NP0: More than 30pF, Q≥350 10pF≤C<30pF, Q≥275+2.5C Less than 10pF, Q≥200+10C X7R, X5R:																																																																							
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(6) 150% of rated voltage for below range.	<table><tr><th>Size</th><th>Dielectric</th><th>Rated voltage</th><th>Capacitance range</th></tr><tr><td rowspan="2">0402</td><td>X5R/X7R</td><td>10V, 16V, 25V</td><td>C≥0.22μF</td></tr><tr><td>Y5V</td><td>16V</td><td>C≥0.47μF</td></tr><tr><td rowspan="2">0603</td><td>X5R/X7R</td><td>10V, 16V</td><td>C≥1.0μF</td></tr><tr><td>Y5V</td><td>16V</td><td>C≥2.2μF</td></tr><tr><td rowspan="2">0805</td><td>X5R/X7R</td><td>10V</td><td>C≥4.7μF</td></tr><tr><td>Y5V</td><td>16V</td><td>C≥4.7μF</td></tr></table>	Size	Dielectric	Rated voltage	Capacitance range	0402	X5R/X7R	10V, 16V, 25V	C≥0.22μF	Y5V	16V	C≥0.47μF	0603	X5R/X7R	10V, 16V	C≥1.0μF	Y5V	16V	C≥2.2μF	0805	X5R/X7R	10V	C≥4.7μF	Y5V	16V	C≥4.7μF	Y5V: <table><tr><th>Rated vol.</th><th>D.F. ≤</th><th colspan="2">Exception of D.F. ≤</th></tr><tr><td>≥50V</td><td>7.5%</td><td>10%</td><td>0603≥0.1μF; 0805≥0.47μF; 1206≥4.7μF</td></tr><tr><td>35V</td><td>10%</td><td>---</td><td>---</td></tr><tr><td rowspan="2">25V</td><td rowspan="2">7.5%</td><td>10%</td><td>0402≥0.047μF; 0603≥0.1μF; 0805≥0.33μF; 1206≥1μF; 1210≥4.7μF</td></tr><tr><td>15%</td><td>0402≥0.068μF; 0603≥0.47μF; 1206≥4.7μF; 1210≥22μF</td></tr><tr><td>16V (C<1.0μF)</td><td>10%</td><td>12.5%</td><td>0402≥0.068μF; 0603≥0.68μF</td></tr><tr><td rowspan="2">16V (C≥1.0μF)</td><td rowspan="2">12.5%</td><td>20%</td><td>0402≥0.22μF</td></tr><tr><td>20%</td><td>0603≥2.2μF; 0805≥3.3μF; 1206≥10μF; 1210≥22μF; 1812≥47μF;</td></tr><tr><td>10V</td><td>20%</td><td>30%</td><td>0402≥0.47μF</td></tr><tr><td>6.3V</td><td>30%</td><td>---</td><td>---</td></tr></table>	Rated vol.	D.F. ≤	Exception of D.F. ≤		≥50V	7.5%	10%	0603≥0.1μF; 0805≥0.47μF; 1206≥4.7μF	35V	10%	---	---	25V	7.5%	10%	0402≥0.047μF; 0603≥0.1μF; 0805≥0.33μF; 1206≥1μF; 1210≥4.7μF	15%	0402≥0.068μF; 0603≥0.47μF; 1206≥4.7μF; 1210≥22μF	16V (C<1.0μF)	10%	12.5%	0402≥0.068μF; 0603≥0.68μF	16V (C≥1.0μF)	12.5%	20%	0402≥0.22μF	20%	0603≥2.2μF; 0805≥3.3μF; 1206≥10μF; 1210≥22μF; 1812≥47μF;	10V	20%	30%	0402≥0.47μF	6.3V	30%	---	---											
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*Before initial measurement (Class II only): To apply test voltage for 1hr at test temp. and then set for 24±2 hrs at room temp.																																																																										
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			*I.R.: ≥10V, 1GΩ or 50 Ω-F whichever is smaller. Class II (X7R, X5R, Y5V)																																																																							
			<table><tr><th>Rated voltage</th><th>Insulation Resistance</th></tr><tr><td>100V: X7R</td><td rowspan="7">1GΩ or RxC ≥10 Ω-F whichever is smaller.</td></tr><tr><td>50V: 0603≥1μF; 0805≥1μF; 1206≥4.7μF; 1210≥4.7μF</td></tr><tr><td>35V: 0805≥2.2μF; 1210≥10μF</td></tr><tr><td>25V: 0402≥1μF; 0603≥2.2μF; 0805≥2.2μF; 1206≥10μF; 1210≥10μF</td></tr><tr><td>16V: 0402≥0.22μF; 0603≥1μF; 0805≥2.2μF; 1206≥10μF; 1210≥47μF</td></tr><tr><td>10V: 0201≥47nF; 0402≥0.47μF; 0603≥0.47μF; 0805≥2.2μF; 1206≥4.7μF; 1210≥47μF</td></tr><tr><td>6.3V ; 4V</td></tr></table>	Rated voltage	Insulation Resistance	100V: X7R	1GΩ or RxC ≥10 Ω-F whichever is smaller.	50V: 0603≥1μF; 0805≥1μF; 1206≥4.7μF; 1210≥4.7μF	35V: 0805≥2.2μF; 1210≥10μF	25V: 0402≥1μF; 0603≥2.2μF; 0805≥2.2μF; 1206≥10μF; 1210≥10μF	16V: 0402≥0.22μF; 0603≥1μF; 0805≥2.2μF; 1206≥10μF; 1210≥47μF	10V: 0201≥47nF; 0402≥0.47μF; 0603≥0.47μF; 0805≥2.2μF; 1206≥4.7μF; 1210≥47μF	6.3V ; 4V																																																													
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APPENDIXES

■ Tape & reel dimensions

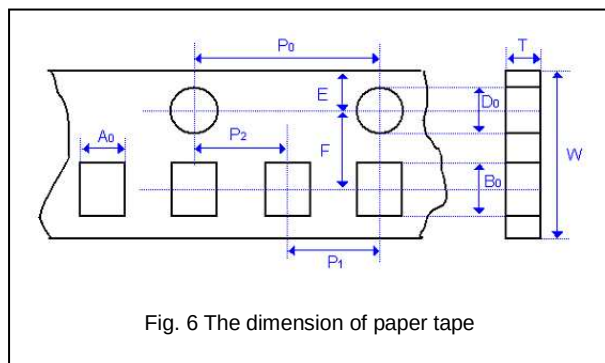


Fig. 6 The dimension of paper tape

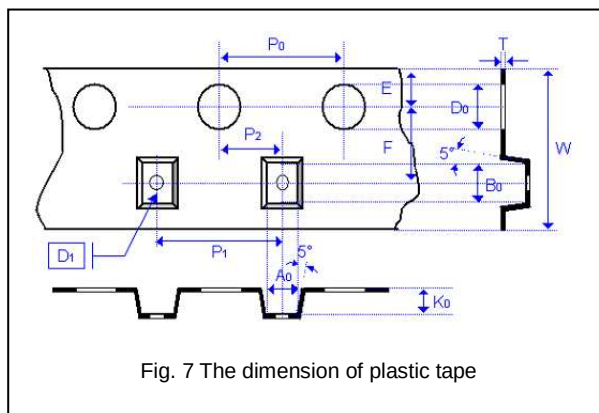


Fig. 7 The dimension of plastic tape

Size	0402	0603	0805			1206			1210			1812		
Thickness	N	S, X	A	B	C, D, I	B	C, J, D	G, P	C, D	G, K	M	D, K	M	U
A ₀	0.62±0.05	1.02±0.05	1.50±0.10	1.50±0.10	<1.57	2.00±0.10	<1.85	<1.95	<2.97	<2.97	<2.97	<3.81	<3.81	<3.90
B ₀	1.12±0.05	1.80±0.05	2.30±0.10	2.30±0.10	<2.40	3.50±0.10	<3.46	<3.67	<3.73	<3.73	<3.73	<5.30	<5.30	<5.30
T	0.60±0.05	0.95±0.05	0.75±0.05	0.95±0.05	0.23±0.05	0.95±0.05	0.23±0.05	0.23±0.05	0.23±0.05	0.23±0.05	0.23±0.05	0.25±0.05	0.25±0.05	0.25±0.05
K ₀	-	-	-	-	<2.50	-	<2.50	<2.50	<2.50	<2.50	<3.00	<2.50	<3.00	<3.50
W	8.00±0.10	8.00±0.10	8.00±0.10	8.00±0.10	8.00±0.10	8.00±0.10	8.00±0.10	8.00±0.10	8.00±0.10	8.00±0.10	8.00±0.10	12.0±0.20	12.0±0.20	12.0±0.20
P ₀	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10
10xP ₀	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.10	40.0±0.20
P ₁	2.00±0.05	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	4.00±0.10	8.00±0.10	8.00±0.10	8.00±0.10
P ₂	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05	2.00±0.05
D ₀	1.55±0.05	1.55±0.05	1.55±0.05	1.55±0.05	1.50±0.05	1.50±0.05	1.50±0.05	1.50±0.05	1.50±0.05	1.50±0.05	1.50±0.05	1.50±0.05	1.50±0.05	1.50±0.10
D ₁	-	-	-	-	1.00±0.10	-	1.00±0.10	1.00±0.10	1.00±0.10	1.00±0.10	1.00±0.10	1.50±0.10	1.50±0.10	1.50±0.10
E	1.75±0.05	1.75±0.05	1.75±0.05	1.75±0.05	1.75±0.10	1.75±0.10	1.75±0.10	1.75±0.10	1.75±0.10	1.75±0.10	1.75±0.10	1.75±0.10	1.75±0.10	1.75±0.10
F	3.50±0.05	3.50±0.05	3.50±0.05	3.50±0.05	3.50±0.05	3.50±0.05	3.50±0.05	3.50±0.05	3.50±0.05	3.50±0.05	3.50±0.05	5.50±0.05	5.50±0.05	5.50±0.05

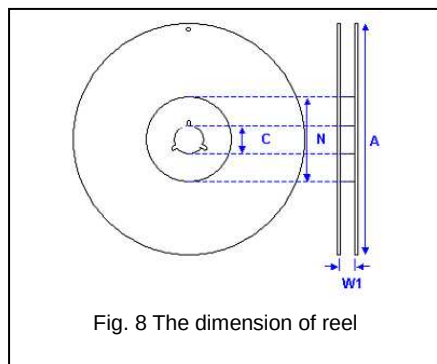
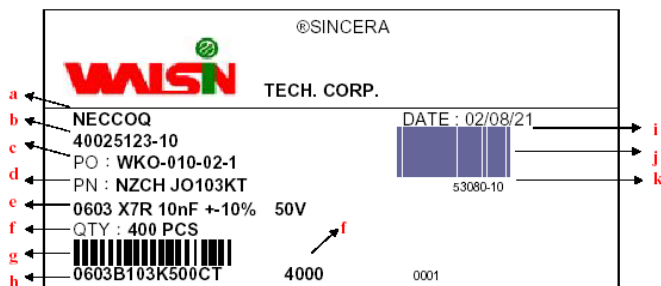


Fig. 8 The dimension of reel

Size	0402, 0603, 0805, 1206, 1210			1812
Reel size	7"	10"	13"	7"
C	13.0+0.5/-0.2	13.0+0.5/-0.2	13.0+0.5/-0.2	13.0+0.5/-0.2
W ₁	8.4+1.5/-0	8.4+1.5/-0	8.4+1.5/-0	12.4+2.0/-0
A	178.0±0.10	250.0±1.0	330.0±1.0	178.0±0.10
N	60.0+1.0/-0	100.0±1.0	100±1.0	60.0+1.0/-0

■ Description of customer label



- a. Customer name
- b. WTC order series and item number
- c. Customer P/O
- d. Customer P/N
- e. Description of product
- f. Quantity
- g. Bar code including quantity & WTC P/N or customer
- h. WTC P/N
- i. Shipping date
- j. Order bar code including series and item numbers
- k. Serial number of label

■ Constructions

No.	Name		X7R, X5R, Y5V
①	Ceramic material		BaTiO ₃ based
②	Inner electrode		Ni
③	Termination	Inner layer	Cu
④		Middle layer	Ni
⑤		Outer layer	Sn (Matt)

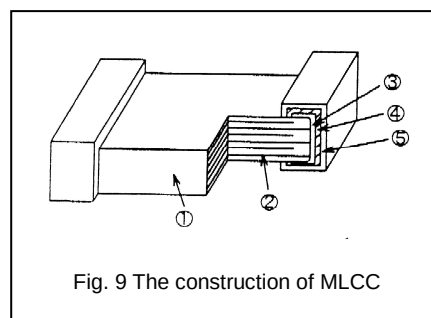


Fig. 9 The construction of MLCC

■ Storage and handling conditions

- (1) To store products at 5 to 40°C ambient temperature and 20 to 70% related humidity conditions.
- (2) The product is recommended to be used within one year after shipment. Check solderability in case of shelf life extension is needed.

Cautions:

- a. The corrosive gas reacts on the terminal electrodes of capacitors, and results in the poor solderability. Do not store the capacitors in the ambience of corrosive gas (e.g., hydrogen sulfide, sulfur dioxide, chlorine, ammonia gas etc.)
- b. In corrosive atmosphere, solderability might be degraded, and silver migration might occur to cause low reliability.
- c. Due to the dewing by rapid humidity change, or the photochemical change of the terminal electrode by direct sunlight, the solderability and electrical performance may deteriorate. Do not store capacitors under direct sunlight or dewing condition. To store products on the shelf and avoid exposure to moisture.

■ Recommended soldering conditions

The lead-free termination MLCCs are not only to be used on SMT against lead-free solder paste, but also suitable against lead-containing solder paste. If the optimized solder joint is requested, increasing soldering time, temperature and concentration of N₂ within oven are recommended.

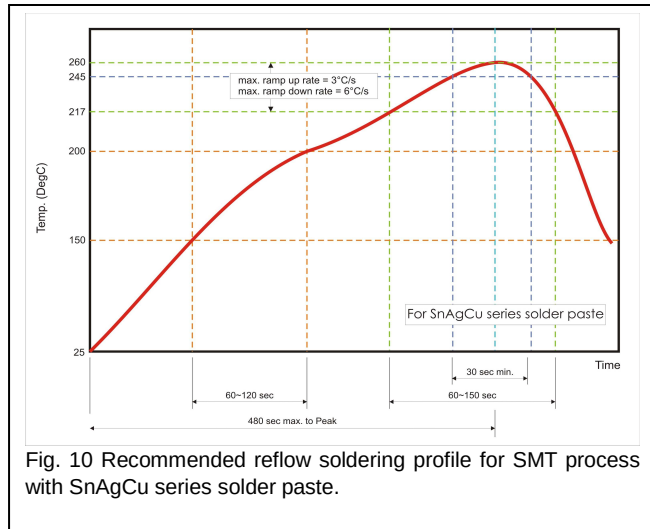


Fig. 10 Recommended reflow soldering profile for SMT process with SnAgCu series solder paste.

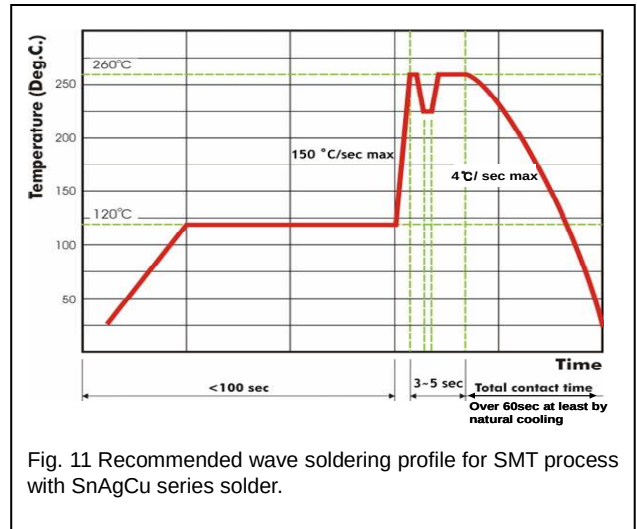


Fig. 11 Recommended wave soldering profile for SMT process with SnAgCu series solder.