ESCUELA UNIVERSITARIA POLITÉCNICA

DE LA ALMUNIA DE DOÑA GODINA (ZARAGOZA)

# ANEXOS

# Banco de ensayos multipropósito para caracterizar baterías de LiPo

# Multipurpose test bench to typify LiPo batteries

[424.18.54]


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Fecha: 27/112019

# INDICE DE CONTENIDO

**(**Documentación Técnica)

# ANEXO 1. (DOCUMENTACIÓN TÉCNICA)

## 1.1. (BATERÍA)

| Electric Power | Doc. No. | EP171019033 |
|---|---|---|
| | Rev. | V.1.0 |
| | Model No. | EPA096190SP |

**1、范围**

**Scope**

本规格书描述了由香港明達實業有限公司生产的高倍率聚合物锂离子蓄电池有关参考技术指标及测试方法、使用要求。

This specification describes the technical parameter, testing method and using requirement of polymer Li-ion battery manufactured by Hongkong Mingda Industrial Co., Ltd

**2、主要技术参数**

**Main Technical Parameter**

2.1 电芯和电池组规格参数 Technical Parameter Of Cell and Pack:

| 项目<br>Item | 电芯<br>Cell | 成品<br>Pack | 备注<br>Remark |
|---|---|---|---|
| 1. 主要化学成分 Cell Chemistry | LiCoO2 | N/A | |
| 2. 标称容量<br>Rated Capacity | 20000mAh | N/A | 电芯标准充电后 0.2C 放电至 2.75V<br>Fully Discharge to 2.75V @ 0.2C. after the cell standard charge |
| 3. 额定电压<br>Rated Voltage | 3.7V | N/A | 平均放电电压<br>Average Discharge Voltage (discharged at 1CmA) |
| 4. 内阻<br>Internal Resistance | ≤1.5mΩ | N/A | 通过电芯组合后总的正负极耳测试<br>Measure the resistance with the overall cathode and anode tab |
| 5. 最大连续放电电流<br>Max. Constant Discharge Current | 300A | N/A | 15C |
| 6. 最大峰值放电电流<br>Max. Peak Current | 600A | N/A | 30C |
| 7. 峰值电流放电时间<br>Time for peak discharge current | 5S | N/A | |
| 8. 放电截止电压<br>Discharge Cut-off Voltage | 2.75V | N/A | 2.75V/Cell |
| 9. 最大持续充电电流<br>Max. Constant Charge Current | 100A | N/A | 5CmA |
| 10. 最大峰值充电电流<br>Max. Peak Charge Current | 200A | N/A | 10CmA |
| 11. 最大峰值电流充电时间<br>Time for peak charge current | 5S | N/A | |
| 12. 充电截止电压<br>Charging Cut-off Voltage | 4.2V | N/A | 4.2V/Cell |
| 13. 尺寸 Product Size | N/A | N/A | |
| 14. 重量 Weight | 420g | N/A | ±3% |
| 15. 工作温度范围<br>Range of Work Temperature | 充电 Charge | | 0~+45℃<br>*Can be charged at 60°C, but may cause swell.* |
| | 放电 Discharge | | -20~+60℃ |

| 项目<br>Item | 测试方法<br>Testing method | 要求<br>Requirement |
| --- | --- | --- |
| 1. 开路电压<br>Open-circuit voltage | 标准充电后，24 小时内测量开路电压<br>Measure the open-circuit voltage of the battery within 24 hours after the Standard Charge | ≥4.1V |
| 2. AC 内阻<br>AC Resistance | 充半电后，在 23±2℃采用交流法测量内阻（正负极耳测试）<br>After half charge, measure he resistance with the cathode and anode tab at AC 1KHz ,23±2℃ | 电池总内阻<br>≤1.5mΩ<br>Resistance of Cells≤1.5mΩ |
| | 充半电后，在 23±2℃采用交流法测量内阻（通过放电线两端测试）<br>After half charge, measure the resistance with the discharge wires at AC 1KHz ,23±2℃ | 成品组合内阻<br>≤/mΩ<br>Resistance of Battery Pack≤/mΩ |
| 3. 容量<br>Capacity | 充满电后，搁置 30min，0.2CmA 放电至 2.75V<br>Discharge the battery at a constant current of 0.2CmA to 2.75V after Standard Charge and rest 30min | 放电容量<br>Discharge Capacity≥ 98%（Nominal Capacity） |
| 4. 倍率放电特性<br>C-rate Discharge Characteristics | 电池在标准充电后，用标称最大连续放电电流 300A 进行恒流放电到 2.75V 截止<br>Discharge the battery at a constant current of 300A to 2.75V after Standard Charge | 放电容量<br>Discharge Capacity≥85%（1C） |
| 5. 放电温度特性<br>Temperature Dependence of the Discharge Capacity | 电池在 23±2℃标准充电，然后在 30 分钟内冷却或加热到测试温度。放电前电池在此温度下保持 2 小时，放电电流为 1.0CmA(20000mA)，做完一个温度实验后，电池在室温下放置 2h 然后进行充电（23±2℃）<br>Heat or cool the battery to the testing temperature within 30min and rest for 2 hours after standard charge at 23±2℃, then discharge at 1.0CmA（20000mA . When a test finished, charge the battery after rested 2 hours at room temperature（23±2℃） | -20℃ ≥60%<br>25℃ ≥100%<br>60℃ ≥95% |
| 6. 循环性能<br>Cycle Life characteristics | 标准充电后，搁置 30min，1C 放电至 3V，搁置 30min，重复上述步骤进行循环，直至电池放电容量连续 3 次≤80%（1C），测试温度 23±2℃（影响电池循环性能的重要参数）<br>Measure capacity under the cycle conditions described below, until the discharge capacity ≤80% (1C) for three times. Cycle conditions: Standard Charge（CC-CV，20000mA, 4.2V），Rest for 30min;Discharge at 1C to 3V cut-off. Testing temperature is 23±2℃ | 循环次数≥300 次<br>Cycle Life≥300 cycles<br>放电容量<br>Discharge Capacity≥80%（1C） |

4.2 储存特性
Storage Characteristics

| 项目<br>Item | 测试方法<br>Testing method | 要求<br>Requirement |
| --- | --- | --- |

| Electric Power | Doc. No. | EP171019033 |
|---|---|---|
| | Rev. | V.1.0 |
| | Model No. | EPA096190SP |

| | | | |
|---|---|---|---|
| 常温贮存 General Temperature Storage Characteristics | 1 | 标准充电后电池在 23±2℃的环境中贮存 30 天，测试 1.0CmA 放电容量（保持容量）<br>Store the battery, which is charged at standard charge condition, for 30 days at 23±2℃.Measure the remaining capacity of the battery at 1.0CmA discharge | 容量保持≥85%C1.0<br>Remaining Capacity≥85% C1.0 |
| | 2 | 1.0CmA 循环 3 次，测试恢复容量（3 周循环的最大放电容量）<br>Charge and discharge at 1.0CmA for 3 cycles. Measure the recovery capacity (the max. discharge capacity for three cycles) | 容量恢复≥90%C1.0<br>Recovery Capacity≥90% C1.0 |
| 高温贮存 High Temperature Storage Characteristics | 1 | 标准充电后电池在 60±2℃的环境中贮存 7 天，测试 1.0CmA 放电容量（保持容量）<br>Store the battery, which is charged at standard charge condition, for 7 days at 60±2℃.Measure the remaining capacity of the battery at 1.0CmA discharge | 容量保持≥60%<br>C1.0 Remaining Capacity≥60% C1.0 |
| | 2 | 1.0CmA 循环 3 次，测试恢复容量（3 周循环的最大放电容量）<br>Charge and discharge at 1.0CmA for 3 cycles. Measure the recovery capacity (The max. discharge capacity for three cycles) | 容量恢复≥80%<br>C1.0 Recovery Capacity≥80% C1.0 |
| 长期贮存性能 Long-term Storage Characteristics | | 贮存前给电池充入 50%的容量，然后开路搁置 365 天，在 23±2℃的环境条件下 1.0CmA 循环 3 次，测试恢复容量（3 周循环的最大放电容量）<br>Store the battery at 23±2℃ for 365 days after charging the battery with 50% capacity, then charge and discharge the battery at 1.0CmA, at 23±2℃ for 3 cycles. Measure the recovery capacity (The Max. discharge capacity for three cycles) | 容量恢复≥85%<br>C1.0 Recovery Capacity≥85% C1.0 |

4.3 机械特性
Mechanical Performance

| 项目<br>Item | 测试方法<br>Testing method | 要求<br>Requirement |
|---|---|---|
| 恒定湿热性能 Constant humidity and temperature test | 标准充电后，将电池放入 40±2℃，相对湿度为 90%~95%的恒温恒湿箱中搁置 48h，取出电池在环境温度 23±2℃条件下，搁置 2h，若外观无明显变化则以 1.0CmA 放电至 2.75V<br>Put the battery into an oven of constant humidity (90%~95%) and constant temperature (40±2℃), rest for 48 hours, take it out and rest for 2 hours at 23±2℃, then discharge at 1.0CmA to 2.75V cut-off | 放电容量≥80% C1.0<br>Discharge Capacity≥80% C1.0 |
| 振动 Vibration test | 标准充电后，将电池安装在振动台上，在 X、Y、Z 三个垂直方向进行实验，振动频率在 10~55Hz 间以 1Hz/min 的速度变化，往复振动 30min<br>振动频率：10~30Hz　位移振幅：0.38mm<br>振动频率：30~55Hz　位移振幅：0.19mm<br>Fix the battery on a vibration table, vibrate it at X, Y, Z orientation. Change the frequency of vibration with 1Hz/min from 10Hz to 55Hz, redo it for 30min | 电池外观无明显损伤、漏液、冒烟或爆炸，电池电压≥4.0V<br>The battery has no obvious defaced, no leakage, no smoking or no explosion. The voltage of battery |

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| | Rev. | V.1.0 |
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| | | |
|---|---|---|
| | Frequency: 10~30Hz Swing distance: 0.38mm<br>Frequency: 30~55Hz Swing distance: 0.19mm | ≥4.0V |
| 自由跌落<br>Free drop test | 电池振动试验结束后按下列条件进行自由跌落试验:<br>跌落高度：1.0m<br>承接物：18~20mm 厚硬木板<br>跌落方向：沿水平方向正反面各跌落一次<br>将电池以 1.0CmA 恒流放电至 3V,然后进行 3 次循环<br>Do the free drop test according to the condition described below after finished the vibration test<br>Altitude: 1.0m<br>Receiver: a hard board of 18~20mm<br>Orientation: two sides of battery at horizontal<br>Discharge the battery to 3V at 1.0CmA, then charge-discharge the battery 3 cycles, measure the discharge capacity | 电池外观无明显损伤、漏液、冒烟或爆炸<br>容量保持率≥85% C1.0<br>容量恢复率≥90% C1.0<br>The battery has no obvious defaced, no leakage, no smoking or no explosion<br>Remaining Capacity≥85% C1.0.<br>Recovery capacity≥90% C1.0 |

**5、储存及运输要求**

**Storage and Shipment Requirement**

| 项目<br>Item | 要求<br>Requirement | 备注 1<br>Remark1 | 备注 2<br>Remark2 |
|---|---|---|---|
| 1、贮存温度<br>Storage temperature | -20℃~+35℃ | 小于 1 个月<br>Less than 1 month | 运输时推荐贮存温度为 23±5℃<br>The best temperature in shipment is 23±5℃ |
| | -20℃~+35℃ | 超过 6 个月<br>More than 6 months | |
| 2、湿度<br>Humidity | ≤75%RH | | |
| 3、荷电量<br>Charged Capacity | 30-60% | Cell 电压 3.75-3.90V<br>Cell Voltage 3.75-3.90V | Pack 电压 3.75-3.90V<br>Pack Voltage 3.75-3.90V |

**6、电池保质期**

**Warranty period of battery**

电池保质期为从工厂发货起半年期限内，如果确实证明电池没有经受过异常使用而是因为本身的材料或制造过程导致的品质问题，明達實業免费赔偿等值的新电池。

The warranty period of a battery is half year after shipment. However, if the battery is unusual within this period, Mingda Industrial will replace a new battery for free as long as it is clear that the problem is the failure of material or manufacturing process and the battery is not used abnormally。

**7、免责条款**

**Exemption from Warrantee**

对超出说明书外的误操作导致的问题，明達實業不承担任何责任。

如因保护电路、电池组、RC 模型和充电器的匹配使用不当导致的问题，明達實業不承担任何责任。

对超出保质期的产品，明達實業不承担任何责任。

产品已经验收合格，在客户端装配过程导致的电池损坏，明達實業不承担任何责任。

Mingda Industrial will not be responsible for trouble occurred by handling outside of the

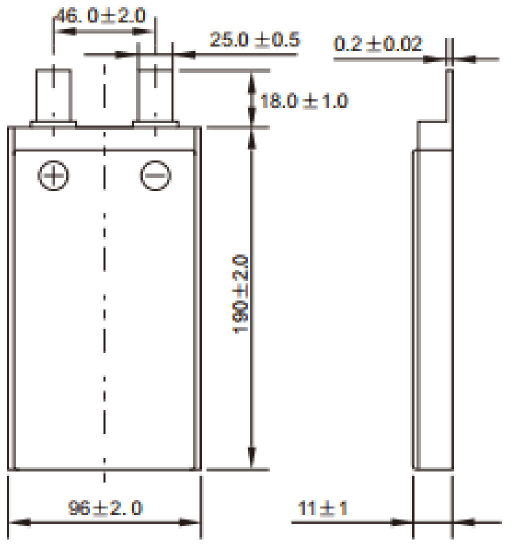
Electric Power

# Data Sheet for EPA096190SP 20000mAh 3.7V 15C

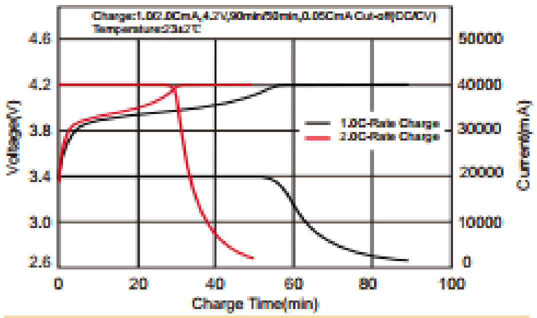
## Specifications

| | | |
|---|---|---|
| Model | | EPA096190SP |
| Nominal Capacity | | 20000mAh |
| Nominal Voltage | | 3.7V |
| Weight(Approx.g) | | 420±10g |
| AC-Impedance(mΩ) at 1KHz | | Max 1.5mΩ |
| Dimensions | Thickness | 11±1mm |
| | Width | 96±2mm |
| | Length | 190±2.0mm |
| Nominal Charge Condition | Current | 20000mA(1C) |
| | Voltage | 4.2V |
| | Cut-off Current | 10000mA(C/20) |
| | Ending Time | 1.5h |
| Nominal Discharge | Current | 20000mA(1C) |
| | Cut-off Voltage | 3.0V |
| Max. Conti. Charge Current | | 100A(5C) |
| Max Discharge Current | Continuous | 300A(15C) |
| | Burst | 600A(30C) |
| Temperature Condition | Charge | 0~45℃ |
| | Discharge | -20~60℃ |
| | Storage | -20~45℃ |

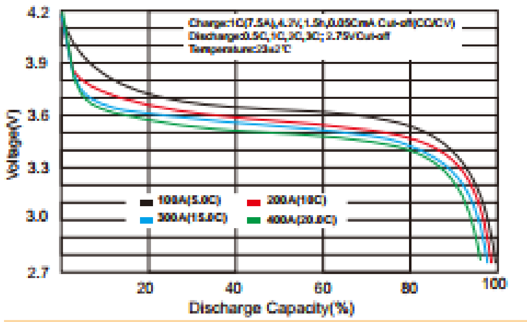
## Dimensions(mm)



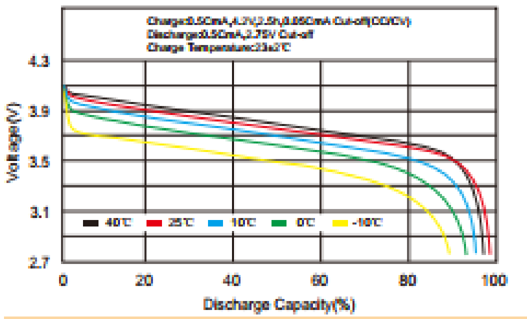

## Charge Characteristics



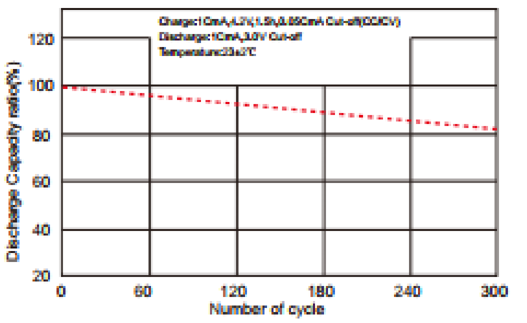

## Discharge Rate Characteristics




## Discharge Temperature Characteristics




## Cycle Life Characteristics



## 1.2. (FUENTE)

MW MEAN WELL

350W Single Output Switching Power Supply **SE-350 series**

■ Features :
- AC input range selectable by switch
- Protections: Short circuit / Overload / Over voltage/ Over temperature
- Forced air cooling by built-in DC fan
- Withstand 300vac surge input for 5 second
- Built-in cooling Fan ON-OFF control
- Built-in constant current limiting circuit
- 100% full load burn-in test
- LED indicator for power on
- Fixed switching frequency at 90KHz
- Low cost,high reliability
- 2 years warranty

**SPECIFICATION**

| MODEL | | SE-350-3.3 | SE-350-5 | SE-350-7.5 | SE-350-12 | SE-350-15 | SE-350-24 | SE-350-27 | SE-350-36 | SE-350-48 |
|---|---|---|---|---|---|---|---|---|---|---|
| OUTPUT | DC VOLTAGE | 3.3V | 5V | 7.5V | 12V | 15V | 24V | 27V | 36V | 48V |
| | RATED CURRENT | 60A | 60A | 46A | 29A | 23.2A | 14.6A | 13A | 9.7A | 7.3A |
| | CURRENT RANGE | 0 ~ 60A | 0 ~ 60A | 0 ~ 46A | 0 ~ 29A | 0 ~ 23.2A | 0 ~ 14.6A | 0 ~ 13A | 0 ~ 9.7A | 0 ~ 7.3A |
| | RATED POWER | 198W | 300W | 345W | 348W | 348W | 350.4W | 351W | 349.2W | 350.4W |
| | RIPPLE & NOISE (max.) Note.2 | 150mVp-p | 150mVp-p | 150mVp-p | 150mVp-p | 150mVp-p | 150mVp-p | 200mVp-p | 240mVp-p | 240mVp-p |
| | VOLTAGE ADJ. RANGE | 2.97 ~ 3.7V | 4.5 ~ 5.6V | 6 ~ 9V | 10 ~ 13.5V | 13.5 ~ 18V | 20 ~ 26.4V | 26 ~ 32V | 32~40V | 41 ~ 56V |
| | VOLTAGE TOLERANCE Note.3 | +3%,-4.5% | ±3.0% | ±2.0% | ±1.5% | ±1.0% | ±1.0% | ±1.0% | ±1.0% | ±1.0% |
| | LINE REGULATION | ±0.5% | ±0.5% | ±0.5% | ±0.5% | ±0.5% | ±0.5% | ±0.5% | ±0.5% | ±0.5% |
| | LOAD REGULATION | ±2.5% | ±2.0% | ±2.0% | ±1.0% | ±0.5% | ±0.5% | ±0.5% | ±0.5% | ±0.5% |
| | SETUP, RISE TIME | 1000ms, 50ms/230VAC 1000ms,50ms/115VAC at full load | | | | | | | | |
| | HOLD UP TIME (Typ.) | 20ms/230VAC 16ms/115VAC at full load | | | | | | | | |
| INPUT | VOLTAGE RANGE Note.4 | 90 ~ 132VAC / 180 ~ 264VAC by switch 254 ~ 370VDC | | | | | | | | |
| | FREQUENCY RANGE | 47 ~ 63Hz | | | | | | | | |
| | EFFICIENCY (Typ.) | 74% | 78% | 80% | 83% | 84% | 87% | 88% | 87.5% | 87.5% |
| | AC CURRENT (Typ.) | 7A/115VAC 4A/230VAC | | | | | | | | |
| | INRUSH CURRENT (Typ.) | 40A/115VAC 60A/230VAC | | | | | | | | |
| | LEAKAGE CURRENT | <3.5mA / 240VAC | | | | | | | | |
| PROTECTION | OVER LOAD | 105 ~ 135% rated output power | | | | | | | | |
| | | Protection type : Constant current limiting, recovers automatically after fault condition is removed | | | | | | | | |
| | OVER VOLTAGE | 3.8 ~ 4.6V | 5.75 ~ 7.5V | 9.4 ~ 11.25V | 13.8 ~ 16.2V | 18 ~ 21V | 27.6 ~ 32.4V | 33.7 ~ 39.2V | 41.4~46.8V | 57.6 ~ 67.2V |
| | | Protection type :Shut down O/P voltage, re-power on to recover | | | | | | | | |
| | OVER TEMPERATURE | 90℃ ±5℃(3.3~7.5V); 85℃ ±5℃(12~15V); 80℃ ±5℃(24V);75℃ ±5℃(27~48V) (TSW1) Detect on case | | | | | | | | |
| | | Protection type : Shut down O/P voltage, recovers automatically after temperature goes down | | | | | | | | |
| FUNCTION | FAN ON/OFF CONTROL(Typ.) | RTH2≧50℃ FAN ON, ≦45℃ FAN OFF (3.3 ~ 7.5V) | | | | | | | | |
| | | RTH2≧55℃ FAN ON, ≦50℃ FAN OFF (12 ~ 48V) | | | | | | | | |
| ENVIRONMENT | WORKING TEMP. | -20 ~ +60℃ (Refer to output load derating curve) | | | | | | | | |
| | WORKING HUMIDITY | 20 ~ 90% RH non-condensing | | | | | | | | |
| | STORAGE TEMP., HUMIDITY | -20 ~ +85℃, 10 ~ 95% RH | | | | | | | | |
| | TEMP. COEFFICIENT | ±0.03%/℃ (0 ~ 50℃) | | | | | | | | |
| | VIBRATION | 10 ~ 500Hz, 5G 10min./1cycle, 60min. each along X, Y, Z axes | | | | | | | | |
| SAFETY | SAFETY STANDARDS | UL60950-1 approved | | | | | | | | |
| | WITHSTAND VOLTAGE | I/P-O/P:3KVAC I/P-FG:2KVAC O/P-FG:0.5KVAC | | | | | | | | |
| | ISOLATION RESISTANCE | I/P-O/P, I/P-FG, O/P-FG:100M Ohms/500VDC / 25℃/ 70% RH | | | | | | | | |
| OTHERS | MTBF | 234.3K hrs min. MIL-HDBK-217F (25℃) | | | | | | | | |
| | DIMENSION | 215*115*50mm (L*W*H) | | | | | | | | |
| | PACKING | 1.07Kg; 12pcs/13.5Kg/0.92CUFT | | | | | | | | |
| NOTE | 1. All parameters NOT specially mentioned are measured at 230VAC input, rated load and 25℃ of ambient temperature.<br>2. Ripple & noise are measured at 20MHz of bandwidth by using a 12" twisted pair-wire terminated with a 0.1uf & 47uf parallel capacitor.<br>3. Tolerance : includes set up tolerance, line regulation and load regulation.<br>4. Please connect positive pole of input voltage with mark "L" of terminal block, connect negative pole of input voltage with mark "N" of terminal block, using DC voltage for input voltage. | | | | | | | | | |

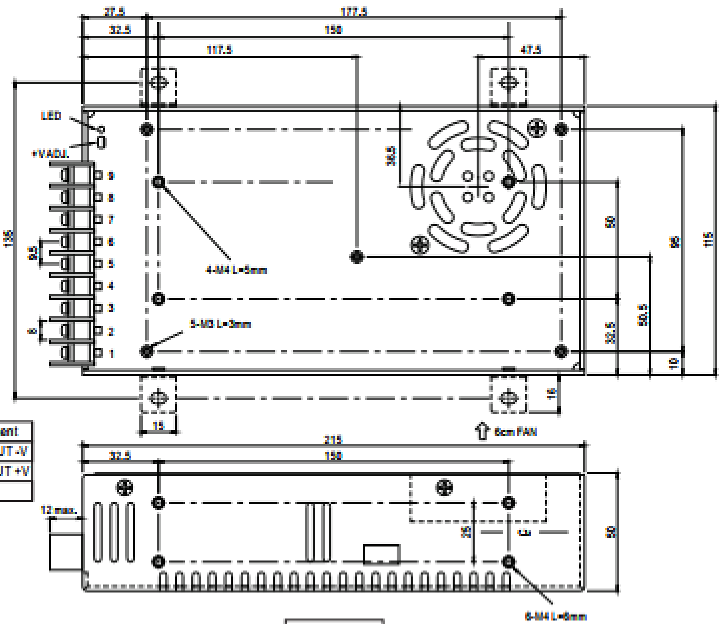
File Name:SE-350-SPEC 2013-08-19

MEAN WELL

350W Single Output Switching Power Supply **SE-350 series**

## Mechanical Specification

Case No. 912C Unit:mm

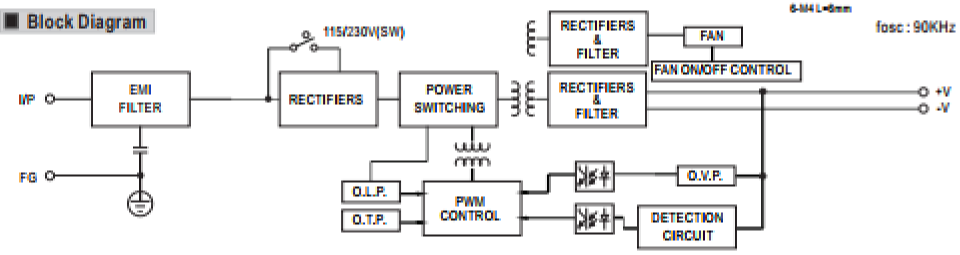



Terminal Pin No. assignment :

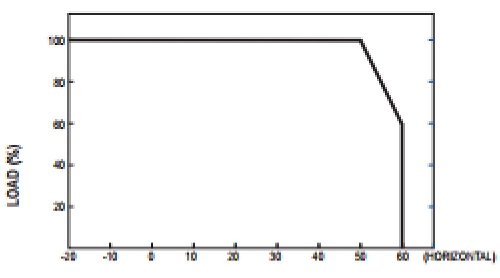
| Pin No. | Assignment | Pin No. | Assignment |
|---|---|---|---|
| 1 | AC/L | 4~6 | DC OUTPUT -V |
| 2 | AC/N | 7~9 | DC OUTPUT +V |
| 3 | FG ⏚ | | |

## Block Diagram

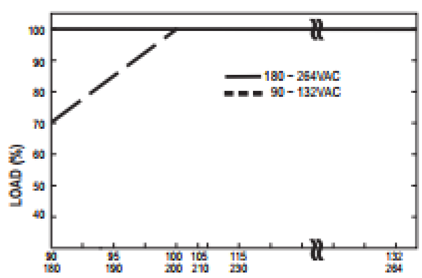
fosc : 90KHz




## Derating Curve




## Static Characteristics




File Name:SE-350-SPEC 2013-08-19

# 1.3. (RESISTENCIAS)

## HS Aluminium Housed Resistors

ARCOL

Manufactured in line with the requirements of MIL 18546 and IEC 115, designed for direct heatsink mounting with thermal compound to achieve maximum performance.

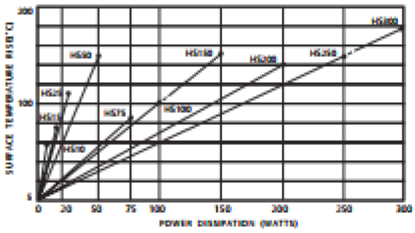
- High Power to volume
- Wound to maximise High Pulse Capability
- Values from R005 to 100K
- Custom designs welcome
- RoHS Compliant

### Characteristics

| | |
|---|---|
| Tolerance (Code): | Standard ±5% (J) and ±10% (K). Also available ±1% (F), ±2% (G) and ±3% (H) |
| Tolerance for low Ω values: | Typically ≥ R05 ±5% ≤ R047 ±10% |
| Temperature coefficients: | Typical values < 1K 100ppm Std. > 1K 25ppm Std. For lower TCR's please contact Arcol |
| Insulation resistance (Dry): | 10,000 MΩ minimum |
| Power dissipation: | At high ambient temperature dissipation derates linearly to zero at 200°C |
| Ohmic values: | From R005 to 100K depending on wattage size |
| Low inductive (NHS): | Specify by adding N before HS Series code, e.g. NHS50 |
| NHS ohmic value: | Divide standard HS maximum value by 4 |
| NHS working volts: | Divide standard HS maximum working voltage by 1.414 |

### Temp. Rise & Power Dissipation

Surface temperature of resistor related to power dissipation. The resistor is standard heatsink mounted using a proprietary heatsink compound.




### Heat Dissipation

Heat dissipation: Whilst the use of proprietary heat sinks with lower thermal resistances is acceptable, uprating is not recommended. For maximum heat transfer it is recommended that a heat sink compound be applied between the resistor base and heat sink chassis mounting surface. It is essential that the maximum hot spot temperature of 200°C is not exceeded, therefore, the resistor must be mounted on a heat sink of correct thermal resistance for the power being dissipated.

### Ordering Procedure

Standard Resistor. To specify standard: Series, Watts, Ohmic Value, Tolerance Code, e.g.: HS25 2R2 J
Non Inductive Resistor. To specify add N, e.g.: NHS100 10R J

ARCOL UK Limited,
Threemilestone Ind. Estate,
Truro, Cornwall, TR4 9LG, UK.
T +44 (0) 1872 277431
F +44 (0) 1872 222002
E sales@arcolresistors.com

www.arcolresistors.com

The information contained herein does not form part of a contract and is subject to change without notice. ARCOL operate a policy of continual product development, therefore, specifications may change.

It is the responsibility of the customer to ensure that the component selected from our range is suitable for the intended application. If in doubt please ask ARCOL.

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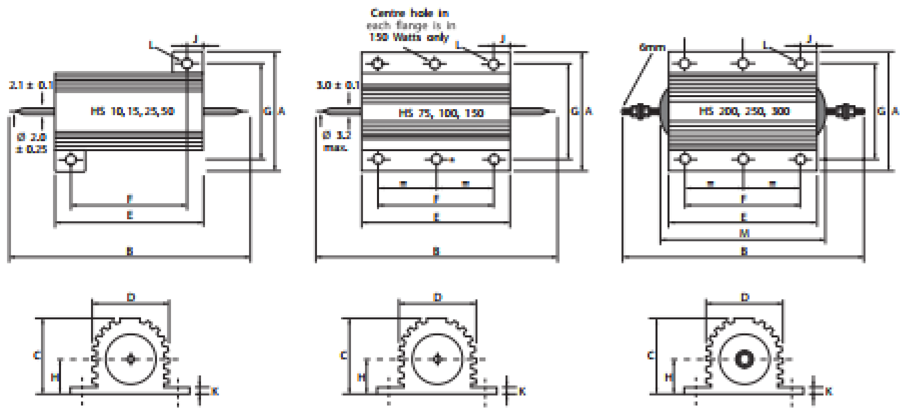
# HS Aluminium Housed Resistors

ARCOL

## Electrical Specifications

| Size | Style MIL-R 18546 | Power rating on std. heatsink @25°C | Watts with no heatsink @25°C | Resistance range | Limiting element voltage | Voltage proof AC Peak | Voltage proof AC rms. | Approx weight gms | Typical surface rise HS mounted | Standard heatsink | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | cm² | Thickness mm |
| HS10 | RE 60 | 10 | 5 | R005-10K | 160 | 1400 | 1000 | 4 | 5.8 | 415 | 1 |
| HS15 | RE 65 | 15 | 7 | R005-10K | 265 | 1400 | 1000 | 7 | 5.1 | 415 | 1 |
| HS25 | RE 70 | 25 | 9 | R005-36K | 550 | 3500 | 2500 | 14 | 4.2 | 535 | 1 |
| HS50 | RE 75 | 50 | 14 | R01-86K | 1250 | 3500 | 2500 | 32 | 3.0 | 535 | 1 |
| HS75 | | 75 | 24 | R01-50K | 1400 | 6363 | 4500 | 85 | 1.1 | 995 | 3 |
| HS100 | | 100 | 30 | R01-70K | 1900 | 6363 | 4500 | 115 | 1.0 | 995 | 3 |
| HS150 | | 150 | 45 | R01-100K | 2500 | 6363 | 4500 | 175 | 1.0 | 995 | 3 |
| HS200 | | 200 | 50 | R01-50K | 1900 | 7070 | 5000 | 475 | 0.7 | 3750 | 3 |
| HS250 | | 250 | 55 | R01-50K | 2200 | 7070 | 5000 | 600 | 0.6 | 4765 | 3 |
| HS300 | | 300 | 60 | R01-68K | 2500 | 7070 | 5000 | 700 | 0.6 | 5780 | 3 |

## HS10-HS300 Standard Resistor




## Dimensions (mm)

| Size | A Max | B Max | C Max | D Max | E Max | F±0.3 | G±0.3 | H Max | J Max | K Max | L ±0.25* | M Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HS10 | 16.5 | 30.0 | 8.8 | 8.5 | 15.9 | 11.3 | 12.4 | 4.5 | 2.4 | 1.8 | 2.4 | |
| HS15 | 21.0 | 36.5 | 11.0 | 11.2 | 19.9 | 14.3 | 15.9 | 5.5 | 2.8 | 1.8 | 2.4 | |
| HS25 | 28.0 | 51.0 | 14.8 | 14.2 | 27.3 | 18.3 | 19.8 | 7.7 | 5.2 | 2.6 | 3.2 | |
| HS50 | 28.0 | 72.5 | 14.8 | 14.2 | 49.1 | 39.7 | 21.4 | 8.4 | 5.2 | 2.6 | 3.2 | |
| HS75 | 47.5 | 72.0 | 24.1 | 27.3 | 48.7 | 29.0 | 37.0 | 11.8 | 10.4 | 3.7 | 4.4 | |
| HS100 | 47.5 | 88.0 | 24.1 | 27.3 | 65.2 | 35.0 | 37.0 | 11.8 | 15.4 | 3.7 | 4.4 | |
| HS150 | 47.5 | 121.0 | 24.1 | 27.3 | 97.7 | 58.0 | 37.0 | 11.8 | 20.4 | 3.7 | 4.4 | |
| HS200 | 72.5 | 145.7 | 41.8 | 45.5 | 89.7 | 70.0 | 57.2 | 20.5 | 10.4 | 5.5 | 5.1 | 103.4 |
| HS250 | 72.5 | 167.0 | 41.8 | 45.5 | 109.7 | 89.0 | 57.2 | 20.5 | 10.4 | 5.5 | 5.1 | 122.4 |
| HS300 | 72.5 | 184.4 | 41.8 | 45.5 | 127.7 | 104.0 | 59.0 | 20.5 | 12.4 | 5.5 | 6.6 | 141.4 |

* HS200-HS300 Watts is ± 0.45

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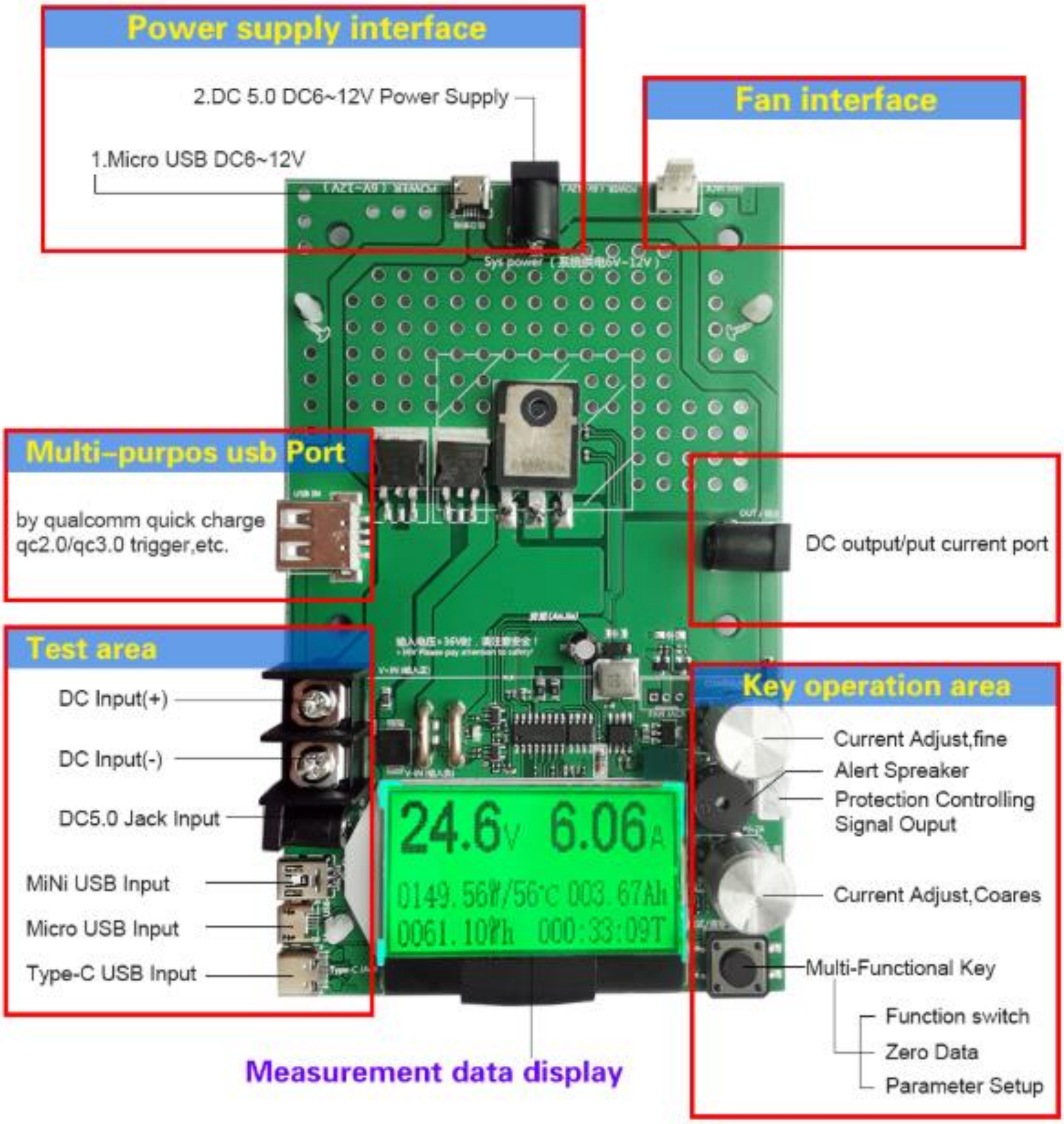
## 1.4. (CARGA ELECTRÓNICA)

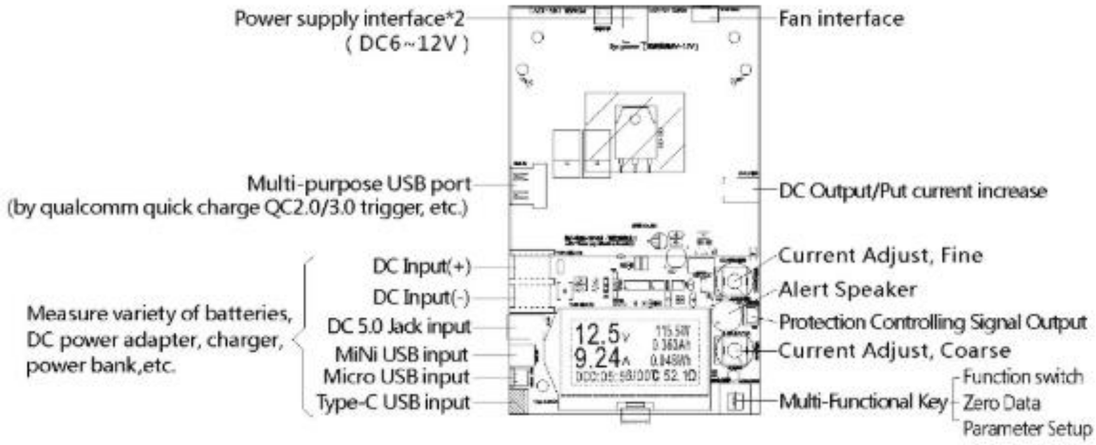

Power supply interface
2.DC 5.0 DC6~12V Power Supply
1.Micro USB DC6~12V
Fan interface
Multi-purpos usb Port
by qualcomm quick charge qc2.0/qc3.0 trigger,etc.
DC output/put current port
Test area
DC Input(+)
DC Input(-)
DC5.0 Jack Input
MiNi USB Input
Micro USB Input
Type-C USB Input
Key operation area
Current Adjust,fine
Alert Spreaker
Protection Controlling Signal Ouput
Current Adjust,Coares
Multi-Functional Key
Function switch
Zero Data
Parameter Setup
Measurement data display
24.6V 6.06A

# Battery Capacity/Dc Power Multi-function Tester

## —Usage introduction—

**Prevent burning warning:** when the input voltage battery and large power test, access must be before using two current adjustment knob counterclockwise to the minimum to zero, then the access, according to the priority according to current power to slowly adjust current knob, must not instantly transferred in full, so there are excessive instantaneous power load discharge tube burnt huge risk! Please use the special attention to this point, thank you!

## Interface function instruction:




### Description for Function Key :

1) Keep Press long time the key: Zero all data(mAh,Wh,00:00:00)
2) Double-click the key: for the Capacity data reset to zero
3) Three-click the key for the electric quantity data reset to zero
4) Four-click the key: for the time data reset to zero
5) Five-click the key: Auto-Standby Mode & Timer for discharge alert
6) Single-click to change the window, entering the setup window for high&Low Voltage background light, adjust the parameters by double-clicking or three-clicking, click-holding for continuous and quick adjust.
7) Without load,quickly click the key for 7 times, for current data reset to zero(0.00A). It is for Precise calibration in local circumstance, so that the small current could be precisely measured.
8) Keep pressing the key when power-off, then power-on, entering the Background setup window for High&Low Voltage over-load, single-click or double-click to adjust the parameters, keep press the key long time to reset to the default setup
(Note: Please don't calibrate the voltage or current if without standard instruments)

### Instruction for Connection and Operation :

1) Open the package, insert the power adapter into the end of the product and supply the power.
2) Anti-clockwise rotate the two current knobs to the lower limit.
3) Connecting the Power Supply under test to the product according to the diagram above, and the current Input Voltage value will be read out. Keep pressing the key to reset all data to zero;
4) Slowly clockwise rotate the two current knobs (coarse&fine) to adjust the current to the rating value of the Power Supply(The current should be slowly adjusted, using the fine knob priority, the coarse knob could be only used under large current condition.)
5) When testing the battery, Low voltage discharge limit should be set up, to avoid the possible damage caused by over discharging while discharge capacity test of the battery.

### SPECIFICATIONS:

Supply Voltage/ Interface : DC6~12V / DC5.0 or Micro USB
Voltage measure Range : 0.00V~200V Accuracy : 0.05V
Current Adjustable Range : 0.00A~20A Accuracy : 0.05A
Capacity measure Range : 0~999.999Ah Accuracy : 0.01Ah
Power cumulative range : 0~99999.9Wh Accuracy : 0.01Wh
Power measure Range : 0~2999.99 W Accuracy : 0.01W
Impedance measure Range : 1~999.9 ohm Accuracy : 0.01
Temperature Range : 0~99℃ Accuracy : 1℃
Max Timing : 999H59M59S Accuracy : 1S
Cooling Fan Power : <150W/<180W (Fan could be changed for different cooling power)
Fan controlling gate: The cooling fan auto-started while the current>0.5A or the Temperature >45℃
Input/Output : 20A biting screw + USB
Refresh time : >500mS/time
measure rate : about 2s/time
Over voltage and over current alert method : Display warning window and voice warning
Protecting Voltage setting Range : 1~300V
Low Voltage setting Range : 0~149V
Protecting Current setting Range : 0.2~100A
Protecting Power setting Range : 185W
Display Type : Micro power consumption, LCM module, black font, green backlit, Chinese&English
Size : 160x95x60mm
Consumption Current : <1.5A
Operating Temp. : -10~+60℃
Operating Humidity : : 10~80℃ Condensation )
Operating Pressure : 80~106kPa

### Warning:

1) The two current knobs should be set at the lower limit before using(Counterclockwise Adjust to the end Double current knobs to 0.00A)! Then increase the current slowly.
2) When the voltage >36V, please attention to safety! Avoid electric shock
3) Several Powers should not be connected at the same time, avoid the over voltage or current to damage your power supply.
4) Slowly adjust the current while observing the displayed value, avoid the instant large current overloaded.
5) Be sure to obey the law of conservation of energy, the product of the voltage and the current should less than 150W.

## 1.5. AUTOTRANSFORMADOR

**2.- CARACTERÍSTICAS.**

**Tensión de entrada Up:**
Tensión de alimentación para la cual el autotransformador-variador ha sido proyectado. La tensión monofásica normalizada es 230 V.
La tensión trifásica normalizada es 3 x 400 V.

**Tensión de salida Us:**
La tensión de salida se obtiene a través de las escobillas, pudiendo tomar tantos valores como espiras dispone el núcleo del autotransformador. La tensión máxima se obtiene con el cursor situado en el extremo opuesto a la entrada.
Us = 0 ÷ Up.

**Corriente nominal In:**
Es la corriente que puede suministrar para cualquier tensión de salida.

**Corriente máxima Imax:**
Es la corriente que puede suministrar para la tensión nominal de red (fig. 1).

**Potencia nominal Pn:**
Pn = In x Us máx.

**Sobrecargas momentáneas admisibles Ks:**
La corriente nominal del autotransformador-variador puede ser sobrepasada durante intervalos muy bajos de tiempo; la curva de la fig. 2 muestra los valores de coeficientes ks en función de la duración de la sobrecarga. Corriente de sobrecarga:
Is = In x Ks.

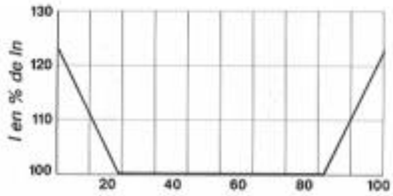


Fig. 1 Us en % de Up

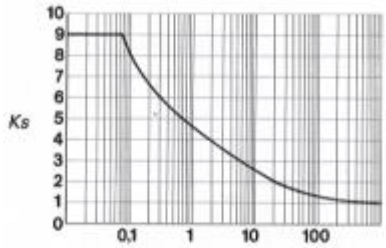


Fig. 2 Tiempo en segundos

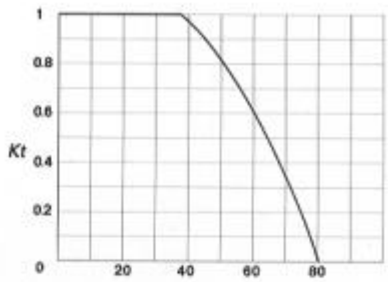


Fig. 3 T. amb. en °C

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**Coeficiente de ambiente Kt**:
Si la temperatura ambiente sobrepasa los 40 °C, la corriente nominal In viene afectada, según la fig. 3, por un coeficiente de reducción Kt.
It = In x Kt.

**Caídas de tensión Us**:
En la fig. 4 se muestran los valores aproximados en porcentaje de la tensión de alimentación Up.

**Conforme a la Norma IEC 989:1991.**
Las características particulares del modelo, tensión, corriente y bornes de conexión, vienen detallados en la placa de bornes del aparato.
Los aparatos motorizados tienen un tiempo de recorrido total según modelo.

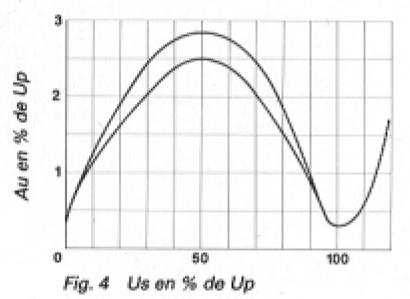


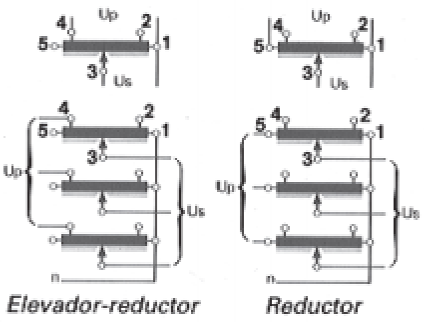
*Fig. 4 Us en % de Up*

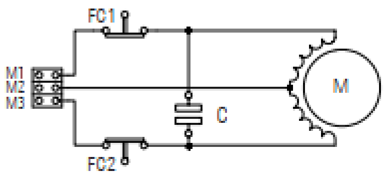
**MONOFÁSICOS**
Entrada 230 V / Salida 0 ÷ 250 V, 50 ÷ 60 Hz.

| Modelo | Potencia (VA) | Intensidad (A) | Tiempo de recorrido (s) |
|---|---|---|---|
| ARC 3-2 | 625 | 2,5 | 7 |
| ARC 3A-2 | 800 | 3,2 | 7 |
| ARC 4-2 | 1.250 | 5 | 7 |
| ARC 4A-2 | 1.650 | 6,5 | 7 |
| ARC 5-2 | 2.500 | 10 | 7 |
| ARC 6-2 | 3.000 | 12 | 7 |
| ARC 7-2 | 4.000 | 16 | 10 |
| ARC 9-2 | 5.500 | 22 | 10 |
| P2ARC 7-2 | 8.000 | 32 | 10 |
| P2ARC 9-2 | 11.000 | 44 | 10 |
| P3ARC 9-2 | 16.500 | 66 | 10 |
| P4ARC 9-2 | 22.000 | 88 | 10 |

**TRIFÁSICOS** (Conexión en estrella)
Entrada 3 x 400 V + N/ Salida 3 x 0÷440 V, 50 ÷ 60 Hz.

| Modelo | Potencia (VA) | Intensidad (A) | Tiempo de recorrido (s) |
|---|---|---|---|
| 3ARC 3-2 | 1.875 | 2,5 | 7 |
| 3ARC 3A-2 | 2.400 | 3,2 | 7 |
| 3ARC 4-2 | 3.750 | 5 | 7 |
| 3ARC 4A-2 | 4.875 | 6,5 | 7 |
| 3ARC 5-2 | 7.500 | 10 | 7 |
| 3ARC 6-2 | 9.000 | 12 | 7 |
| 3ARC 7-2 | 12.000 | 16 | 10 |
| 3ARC 9-2 | 16.500 | 22 | 10 |




M: ........................................ Motor bifásico, 230 V 50 Hz.
C: ........................................ Condensador.
FC1, FC2: ............................ Finales de carrera.
Giro a derechas: ................. Bornes M1-M2.
Giro a izquierdas: ............... Bornes M2-M3.

**Fig. 5**

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# 1.6. DIODOS

**IXYS** **MDD44-12N1B**

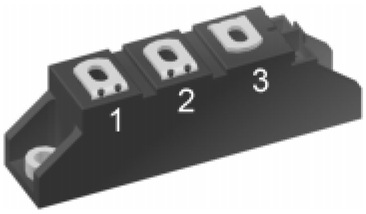
## Standard Rectifier Module

$V_{RRM}$ = 2x 1200 V
$I_{FAV}$ = 59 A
$V_F$ = 1.26 V

Phase leg

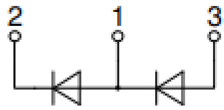
**Part number**

**MDD44-12N1B**




Backside: isolated

E72873




**Features / Advantages:**
- Package with DCB ceramic
- Improved temperature and power cycling
- Planar passivated chips
- Very low forward voltage drop
- Very low leakage current

**Applications:**
- Diode for main rectification
- For single and three phase bridge configurations
- Supplies for DC power equipment
- Input rectifiers for PWM inverter
- Battery DC power supplies
- Field supply for DC motors

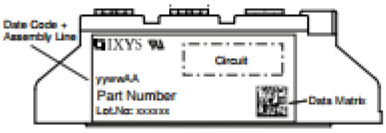
**Package:** TO-240AA
- Isolation Voltage: 3600 V~
- Industry standard outline
- RoHS compliant
- Height: 30 mm
- Base plate: DCB ceramic
- Reduced weight
- Advanced power cycling

**IXYS** **MDD44-12N1B**

| **Rectifier** | | | | | **Ratings** | | |
|---|---|---|---|---|---|---|---|
| **Symbol** | **Definition** | **Conditions** | | **min.** | **typ.** | **max.** | **Unit** |
| $V_{RSM}$ | *max. non-repetitive reverse blocking voltage* | | $T_{VJ}$ = 25°C | | | 1300 | V |
| $V_{RRM}$ | *max. repetitive reverse blocking voltage* | | $T_{VJ}$ = 25°C | | | 1200 | V |
| $I_R$ | *reverse current* | $V_R$ = 1200 V | $T_{VJ}$ = 25°C | | | 100 | µA |
| | | $V_R$ = 1200 V | $T_{VJ}$ = 150°C | | | 10 | mA |
| $V_F$ | *forward voltage drop* | $I_F$ = 100 A | $T_{VJ}$ = 25°C | | | 1.30 | V |
| | | $I_F$ = 200 A | | | | 1.60 | V |
| | | $I_F$ = 100 A | $T_{VJ}$ = 125°C | | | 1.26 | V |
| | | $I_F$ = 200 A | | | | 1.67 | V |
| $I_{FAV}$ | *average forward current* | $T_C$ = 100°C | $T_{VJ}$ = 150°C | | | 59 | A |
| $I_{F(RMS)}$ | *RMS forward current* | 180° sine | | | | 100 | A |
| $V_{F0}$ | *threshold voltage* } *for power loss calculation only* | | $T_{VJ}$ = 150°C | | | 0.80 | V |
| $r_F$ | *slope resistance* | | | | | 4.3 | mΩ |
| $R_{thJC}$ | *thermal resistance junction to case* | | | | | 0.59 | K/W |
| $R_{thCH}$ | *thermal resistance case to heatsink* | | | | 0.20 | | K/W |
| $P_{tot}$ | *total power dissipation* | | $T_C$ = 25°C | | | 212 | W |
| $I_{FSM}$ | *max. forward surge current* | t = 10 ms; (50 Hz), sine | $T_{VJ}$ = 45°C | | | 1.15 | kA |
| | | t = 8,3 ms; (60 Hz), sine | $V_R$ = 0 V | | | 1.24 | kA |
| | | t = 10 ms; (50 Hz), sine | $T_{VJ}$ = 150°C | | | 980 | A |
| | | t = 8,3 ms; (60 Hz), sine | $V_R$ = 0 V | | | 1.06 | kA |
| $I^2t$ | *value for fusing* | t = 10 ms; (50 Hz), sine | $T_{VJ}$ = 45°C | | | 6.62 | kA²s |
| | | t = 8,3 ms; (60 Hz), sine | $V_R$ = 0 V | | | 6.40 | kA²s |
| | | t = 10 ms; (50 Hz), sine | $T_{VJ}$ = 150°C | | | 4.80 | kA²s |
| | | t = 8,3 ms; (60 Hz), sine | $V_R$ = 0 V | | | 4.63 | kA²s |
| $C_J$ | *junction capacitance* | $V_R$ = 400 V; f = 1 MHz | $T_{VJ}$ = 25°C | | 27 | | pF |

## IXYS MDD44-12N1B

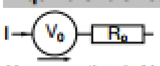
| Package TO-240AA | | | | Ratings | | | |
|---|---|---|---|---|---|---|---|
| Symbol | Definition | Conditions | | min. | typ. | max. | Unit |
| $I_{RMS}$ | *RMS current* | per terminal | | | | 200 | A |
| $T_{VJ}$ | *virtual junction temperature* | | | -40 | | 150 | °C |
| $T_{op}$ | *operation temperature* | | | -40 | | 125 | °C |
| $T_{stg}$ | *storage temperature* | | | -40 | | 125 | °C |
| **Weight** | | | | | 76 | | g |
| $M_D$ | *mounting torque* | | | 2.5 | | 4 | Nm |
| $M_T$ | *terminal torque* | | | 2.5 | | 4 | Nm |
| $d_{Spp/App}$ | *creepage distance on surface / striking distance through air* | *terminal to terminal* | 13.0 | 9.7 | | | mm |
| $d_{Spb/Apb}$ | | *terminal to backside* | 16.0 | 16.0 | | | mm |
| $V_{ISOL}$ | *isolation voltage* | t = 1 second; 50/60 Hz, RMS; $I_{ISOL} \leq 1$ mA | | 3600 | | | V |
| | | t = 1 minute | | 3000 | | | V |




| Ordering | Ordering Number | Marking on Product | Delivery Mode | Quantity | Code No. |
|---|---|---|---|---|---|
| Standard | MDD44-12N1B | MDD44-12N1B | Box | 36 | 458023 |

| Similar Part | Package | Voltage class |
|---|---|---|
| MDD44-08N1B | TO-240AA | 800 |
| MDD44-14N1B | TO-240AA | 1400 |
| MDD44-16N1B | TO-240AA | 1600 |
| MDD44-18N1B | TO-240AA | 1800 |

**Equivalent Circuits for Simulation** * *on die level* $T_{VJ} = 150$ °C

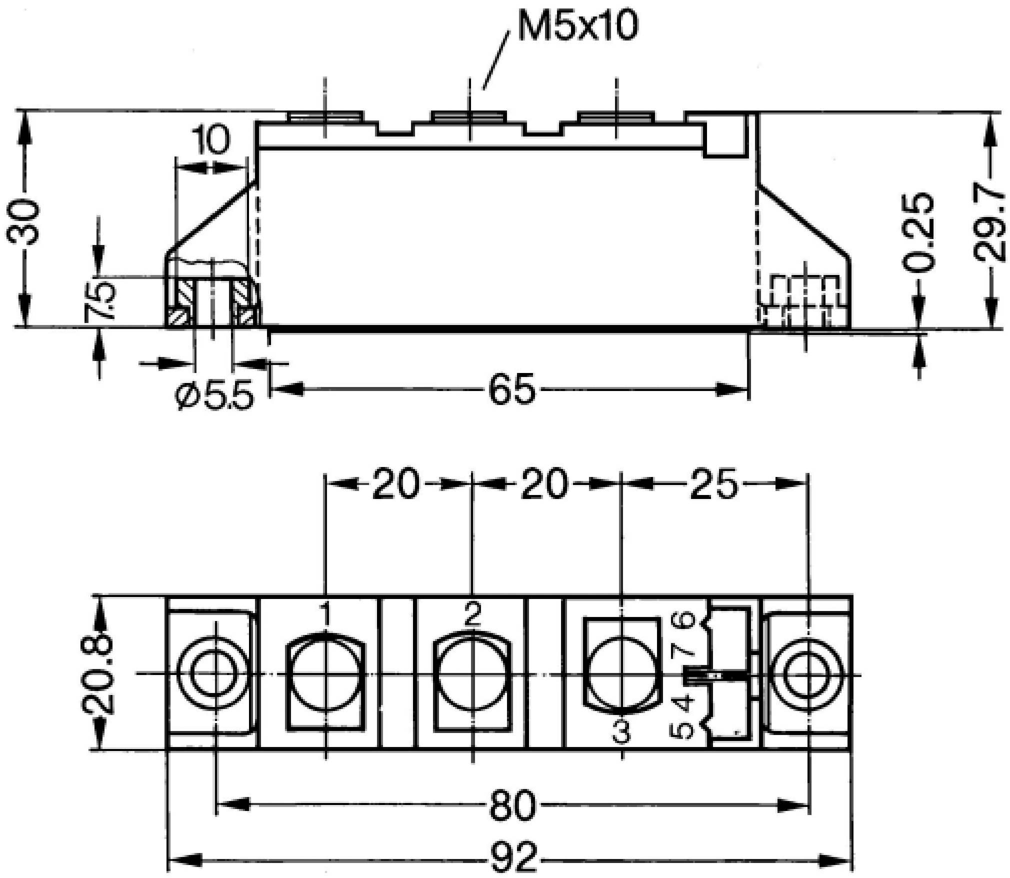


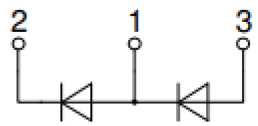

**Rectifier**

| | | | |
|---|---|---|---|
| $V_{0\,max}$ | *threshold voltage* | 0.8 | V |
| $R_{0\,max}$ | *slope resistance ** | 3.1 | mΩ |

IXYS **MDD44-12N1B**

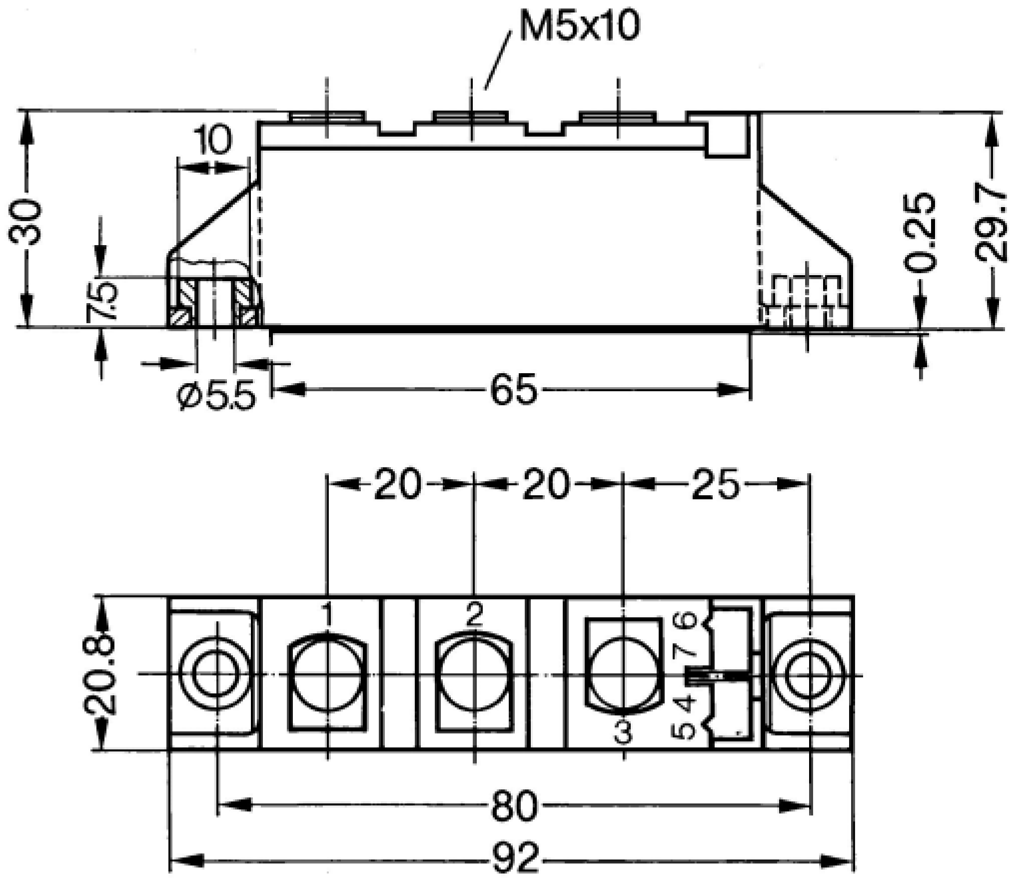
**Outlines TO-240AA**

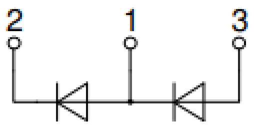


**IXYS** **MDD44-12N1B**

**Outlines TO-240AA**



IXYS **MDD44-12N1B**

**Rectifier**

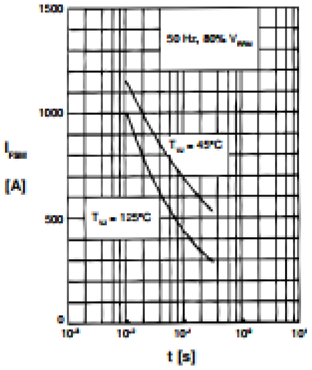



Fig. 1 Surge overload current
$I_{FSM}$, $I_{FSM}$: Crest value, t: duration

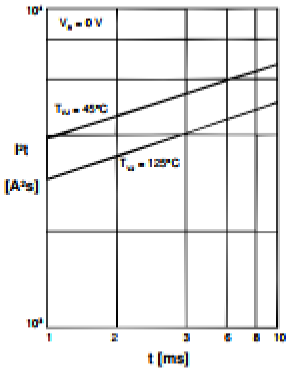



Fig. 2 $I^2t$ versus time (1-10 ms)

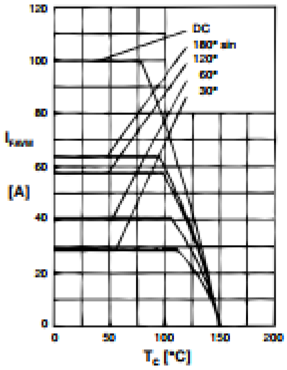



Fig. 3 Maximum forward current at case temperature

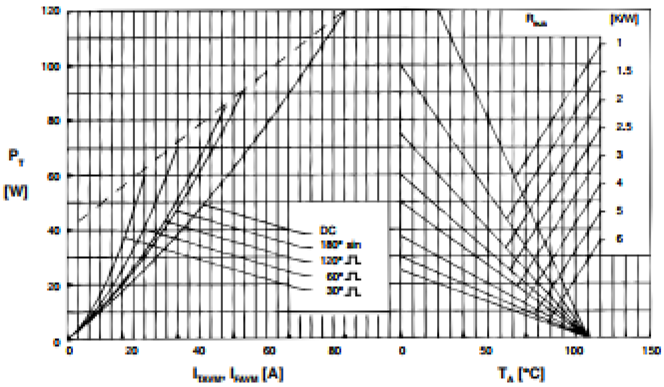



Fig. 4 Power dissipation vs. onstate current and ambient temperature (per diode)

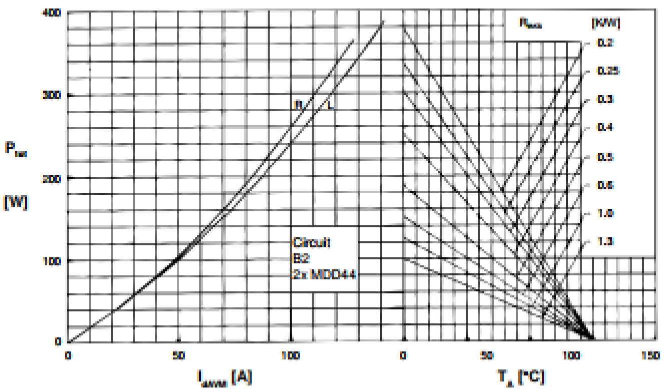



Fig. 6 Single phase rectifier bridge: Power dissipation versus direct output current and ambient temperature; R = resistive load, L = inductive load

IXYS **MDD44-12N1B**

**Rectifier**

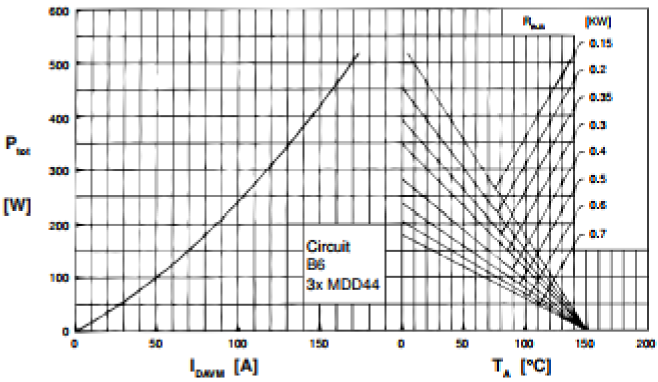



Fig. 6 Three phase rectifier bridge: Power dissipation versus direct output current and ambient temperature

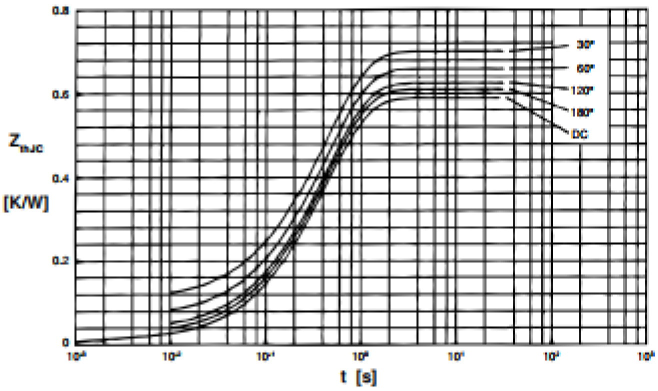



Fig. 7 Transient thermal impedance junction to case (per diode)

$R_{thJC}$ for various conduction angles d:

| d | $R_{thJC}$ [K/W] |
|---|---|
| DC | 0.59 |
| 180° | 0.61 |
| 120° | 0.63 |
| 60° | 0.66 |
| 30° | 0.70 |

Constants for $Z_{thJC}$ calculation:

| i | $R_{thi}$ [K/W] | $t_i$ [s] |
|---|---|---|
| 1 | 0.012 | 0.0012 |
| 2 | 0.045 | 0.0950 |
| 3 | 0.533 | 0.4550 |

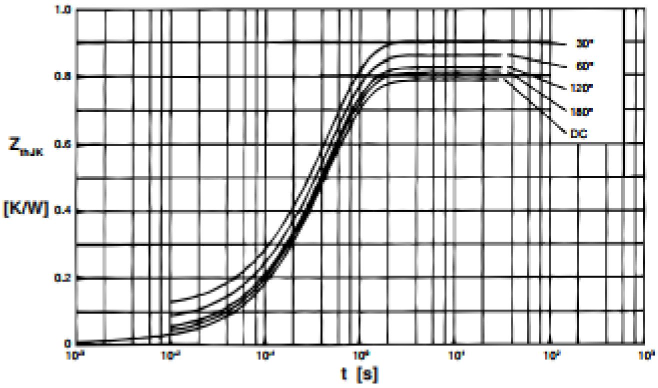



Fig. 8 Transient thermal impedance junction to heatsink (per thyristor)

$R_{thJK}$ for various conduction angles d:

| d | $R_{thJK}$ [K/W] |
|---|---|
| DC | 0.79 |
| 180° | 0.81 |
| 120° | 0.83 |
| 60° | 0.86 |
| 30° | 0.90 |

Constants for $Z_{thJK}$ calculation:

| i | $R_{thi}$ [K/W] | $t_i$ [s] |
|---|---|---|
| 1 | 0.012 | 0.0012 |
| 2 | 0.045 | 0.0950 |
| 3 | 0.533 | 0.4550 |
| 4 | 0.200 | 0.4950 |

## 1.7. SUPERCONDESADORES

**PowerStor**

# Supercapacitors

**HV Series**

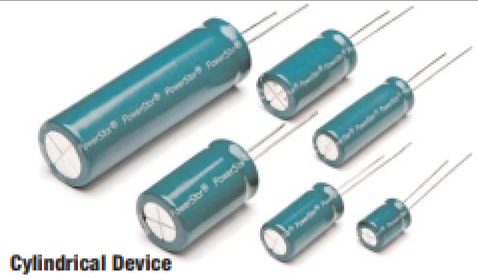
HALOGEN HF FREE — Pb — RoHS 2002/95/EC

### Description

Cooper Bussmann® PowerStor® supercapacitors are unique, ultra-high capacitance devices utilizing electrochemical double layer capacitor (EDLC) construction combined with new, high performance materials. This combination of advanced technologies allows Cooper Bussmann to offer a wide variety of capacitor solutions tailored to specific applications that range from a few micro-amps for several days to several amps for milliseconds.

### Features & Benefits

- Ultra low ESR for high power density
- Large capacitance for high energy density



**Cylindrical Device**

| Specifications | |
|---|---|
| Working Voltage | 2.7V |
| Surge Voltage | 3.0V |
| Capacitance | 1.0F to 100F |
| Capacitance Tolerance | -10% to +30% (20°C) |
| Operating Temperature Range | -40°C to 65°C |
| Extended Operating Temperature Range | -40°C to 85°C (with linear voltage derating to 2.1V @ 85°C) |

**Standard Product**

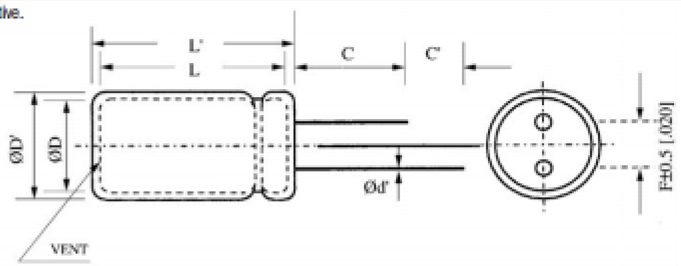
| Capacitance (F) | Part Number | Maximum ESR (Ω) (Equivalent Series Resistance) Measured @ | | Nominal Leakage Current (μA) After 72 Hrs. @ 20°C | Nominal Dimensions (mm) | | Typical Mass (grams/piece) |
|---|---|---|---|---|---|---|---|
| | | 1kHz | 100Hz | | Diameter | Length | |
| 1 | HV0810-2R7105-R | 0.15 | 0.20 | 10 | 8 | 10 | 1.2 |
| 3 | HV0820-2R7305-R | 0.060 | 0.080 | 15 | 8 | 20 | 1.4 |
| 5 | HV1020-2R7505-R | 0.038 | 0.040 | 20 | 10 | 20.5 | 2.3 |
| 6 | HV0830-2R7605-R | 0.038 | 0.040 | 20 | 8 | 30 | 2.1 |
| 10 | HV1030-2R7106-R | 0.032 | 0.034 | 23 | 10 | 30 | 3.2 |
| 15 | HV1325-2R7156-R | 0.028 | 0.030 | 23 | 13 | 26 | 4.5 |
| 25 | HV1625-2R7256-R | 0.025 | 0.027 | 45 | 16 | 25 | 7.3 |
| 35 | HV1635-2R7356-R | 0.022 | 0.024 | 98 | 16 | 35 | 9.3 |
| 60 | HV1840-2R7606-R | 0.016 | 0.018 | 110 | 18 | 40 | 13 |
| 100 | HV1860-2R7107-R | 0.010 | 0.012 | 260 | 18 | 60 | 20 |

**Performance**

| Parameter | Capacitance Change (% of initial specified value) | ESR (% of initial specified value) |
|---|---|---|
| Life (1000 hrs @ 65°C @ 2.7Vdc) | ≤ 30 % | ≤ 200 % |
| Storage - Low and High Temperature (1000 hrs @ -40°C and 85°C) | ≤ 30 % | ≤ 200 % |

| Dimensions (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Part Number | D | D' | L | L' | F | d | C | C' |
| HV0810-2R7105-R | 8.0 | 8.5 | 13.0 | 13.5 | 3.5 | 0.50 | 20.0 | 5.0 |
| HV0820-2R7305-R | 8.0 | 8.5 | 20.5 | 21.0 | 3.5 | 0.50 | 20.0 | 5.0 |
| HV1020-2R7505-R | 10.0 | 10.5 | 21.8 | 22.3 | 5.0 | 0.60 | 20.0 | 5.0 |
| HV0830-2R7605-R | 8.0 | 8.5 | 30.5 | 31.0 | 3.5 | 0.60 | 20.0 | 5.0 |
| HV1030-2R7106-R | 10.0 | 10.5 | 31.0 | 31.5 | 5.0 | 0.60 | 20.0 | 5.0 |
| HV1325-2R7156-R | 13.0 | 13.5 | 27.9 | 28.4 | 5.0 | 0.60 | 20.0 | 5.0 |
| HV1625-2R7256-R | 16.0 | 16.5 | 27.9 | 28.4 | 7.5 | 0.80 | 20.0 | 5.0 |
| HV1635-2R7356-R | 16.0 | 16.5 | 37.5 | 38.0 | 7.5 | 0.80 | 20.0 | 5.0 |
| HV1840-2R7606-R | 18.0 | 18.5 | 41.5 | 42.0 | 7.5 | 0.80 | 20.0 | 5.0 |
| HV1860-2R7107-R | 18.0 | 18.5 | 59.5 | 61.0 | 7.5 | 0.80 | 20.0 | 5.0 |
| *Tolerances* | Maximum | | | | ± 0.5 | ± 0.02 | Minimum | |

Note: Longer lead is positive.




| Part Numbering System | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HV | □ | □ | □ | □ | – | □ | R | □ | □ | □ | □ |
| Series Code | Dimensions (mm) | | | | | Voltage (V) R is Decimal | | | Capacitance (µF) | | |
| | | | | | | | | | Value | | Multiplier |
| HV Series | Diameter | | Length | | | 2R7 = 2.7V | | | Example: 106 = 10 x 10⁶µF or 10F | | |

## Packaging Information

Packaging:
- Standard packaging: Bulk, 100 units per bag.
- Larger bulk packages available on request.

## Part Marking

Manufacturer
Capacitance (F)
Nominal Working Voltage (V)
Series Code (or part number)
Polarity

North America
Cooper Bussmann
1225 Broken Sound Parkway NW
Suite F
Boca Raton, FL 33487-3533
Tel: 1-561-998-4100
Fax: 1-561-241-6640
Toll Free: 1-888-414-2645

Cooper Bussmann
P.O. Box 14460
St. Louis, MO 63178-4460
Tel: 1-636-394-2877
Fax: 1-636-527-1607

Europe
Cooper Bussmann
Cooper (UK) Limited
Burton-on-the-Wolds
Leicestershire • LE12 5TH UK
Tel: +44 (0) 1509 882 737
Fax: +44 (0) 1509 882 786

Cooper Bussmann
Avda. Santa Eulalia, 290
08223
Terrassa, (Barcelona), Spain
Tel: +34 937 362 812
+34 937 362 813
Fax: +34 937 362 719

Asia Pacific
Cooper Bussmann
1 Jalan Kilang Timor
#06-01 Pacific Tech Centre
Singapore 159303
Tel: +65 278 6151
Fax: +65 270 4160

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COILTRONICS Bussmann PowerStor
COOPER Bussmann

## 1.8. RELÉS

# DG85 series
## automotive / industrial relays

DURAKOOL

- General purpose automotive or industrial relays
- High inrush capabilities
- PCB Mounting option
- Ideal for DC Motor Control
- High continuous DC current capacity
- Industry standard size and footprint
- DG85F optimised for 24VDC switching
- RoHS Compliant

| | | | | | | |
|---|---|---|---|---|---|---|
| **Contacts** | | | | | | |
| Contact number & arrangement | | SPST-NO (1 Form A); SPDT (1 Form C) | | | | |
| Contact material | | AgNI0.15; AgNI90/10; AgSnOInO; AgCdO | | | | |
| Max. switching voltage | DC | 30VDC (current dependent - see Figs 5 & 6 ); DG85F 24VDC | | | | |
| | | DG85A | DG85B | DG85C | DG85D | DG85F |
| Max. continuous current | SPST-NO | 40A | 60A | 80A | 100A | 60A |
| | SPDT (NO/NC) | 40A/30A | 60A/40A | 80A/60A | - | 60A/40A |
| Max. switching current - make | SPST-NO | 120A | 120A | 240A | 240A | 120A |
| | SPDT (NO/NC) | 120A/45A | 120A/45A | 240/180A | - | 120A/45A |
| Max. switching current - break | SPST-NO | 40A | 60A | 80A | 100A | 60A |
| | SPDT (NO/NC) | 40A/30A | 60A/40A | 80A/60A | - | 60A/40A |
| Min. switching current | | 0.1A 12VDC | 0.5A 12VDC | 0.5A 12VDC | 0.5A 12VDC | 0.5A 24VDC |
| Contact gap | | >0.5mm | >0.5mm | >0.5mm | ≤1.0mm | >1.0mm |
| Initial contact resistance | | <100mΩ, max. at 0.1A/6VDC | | | | |
| **Coil** | | | | | | |
| Rated voltage | DC | 6...24V | | | | |
| Must release voltage | | ≥0.1Un | | | | |
| Operating range of supply voltage | | See coil table 1 | | | | |
| Rated power consumption | DC | 1.6W; 1.81W with resistor; DG85F, 2.3W | | | | |
| **Insulation** | | | | | | |
| Insulation resistance | | 100MΩ at 500VDC, 50%RH | | | | |
| Dielectric strength | | | | | | |
| | coil to contact | 500Vrms, 1min | | | | |
| | contact to contact | 500Vrms, 1min | | | | |
| **General Data** | | | | | | |
| Operating time (typical) | mS | ≤ 7mS | | | | |
| Release time (typical) | mS | ≤ 2 mS | | | | |
| Electrical Life | ops | 1 x $10^5$, 5 x $10^4$ (DG85F only) (see Note 2) | | | | |
| Mechanical life | ops | 1 x $10^7$, 5 x $10^5$ (DG85F only) | | | | |
| Dimensions | L x W x H | various - see dimensional drawings | | | | |
| Weight | | 40g approx. depending on style and mounting | | | | |
| Ambient temperature | storage | -40 to 155°C | | | | |
| | operating | -40 to 125°C | | | | |
| Shock resistance | | Functional: 20g 11mS; Destructive: 100g | | | | |
| Vibration resistance | | DA 1.27mm 10-40Hz / 40-70Hz:5g / DA 0.5mm 100-500Hz: 10g | | | | |

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Ref: DG85 062310JHM

# DG85 series
## automotive / industrial relays

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Coil Data — Table 1

| Model | Coil voltage code | Nominal voltage (VDC) | Coil resistance (Ω) ±10% | Must operate voltage Max. (VDC) | Allowable voltage (VDC)* | Must release voltage min. (VDC) |
|---|---|---|---|---|---|---|
| DG85A DG85B DG85C DG85D | 1006 | 6 | 22 | 3.6 | 10.1 | 0.6 |
| | 1012 | 12 | 90 | 7.2 | 20.5 | 1.2 |
| | 1024 | 24 | 330 | 14.4 | 39.1 | 2.4 |
| DG85F | 1006 | 6 | 15.6 | 3.6 | 6.4 | 0.6 |
| | 1012 | 12 | 62.5 | 7.2 | 14.8 | 1.2 |
| | 1024 | 24 | 250 | 14.4 | 28.8 | 2.4 |

* At ambient temperature of 85°C, maximum allowable voltage should be reduced by 28%

Ordering codes

Type: D G 8 5 _ - Contact material _ _ Contact arrangement _ _ - Cover protection and mounting _ _ - Coil code _ _ _ _ - Options _ _ _ _

Series

| | | |
|---|---|---|
| A | - | 40/30A |
| B | - | 60/40A |
| C | - | 80/60A |
| D | - | 100A |
| F | - | 60/40A |

Contact material

| | | |
|---|---|---|
| 10 | - | AgCdO (std for DG85B) |
| 20 | - | AgNi (std for DG85A) |
| 70 | - | AgSnOInO (std for DG85C, D, & F) |
| 80 | - | AgNi0.15 |

Contact arrangement

| | | |
|---|---|---|
| 11 | - | SPDT (1 C/O, 1 Form C) |
| 21 | - | SPST-NO (1N/O, 1 Form A) |

Cover protection category

| | | |
|---|---|---|
| 3 | - | in cover, sealed - IP67 (not available for DG85C & DG85D, nor for any metal mounting bracket) |
| 7 | - | in cover, dust cover - IP54 |
| 9 | - | Cover with mounting bracket |

Connection mode

| | | |
|---|---|---|
| 5 | - | for PCB |
| 6 | - | Flat Blades |
| D | - | Double 87 flat blades (DG85A, DG85B & DG85F only |

Coil code: see Table 1

Options 1

| | | |
|---|---|---|
| Nil | - | No options |
| M1 | - | Metal bracket |
| M2 | - | Bent metal bracket |
| S1 | - | Skirted cover & metal bracket |
| S2 | - | Skirted cover & bent metal bracket |

Options 2

| | | |
|---|---|---|
| Nil | - | No options |
| R | - | Integral resistor |
| D | - | Integral diode +85, -86 |
| DR | - | Integral diode reversed -85, +86 |
| BD | - | Bi-directional diode |

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# DG85 series
## automotive /industrial relays

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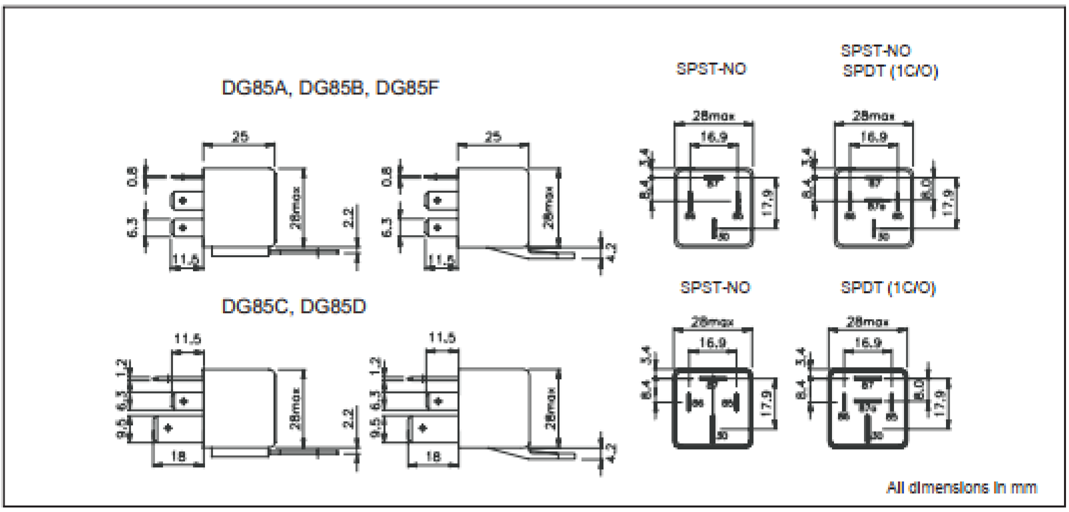
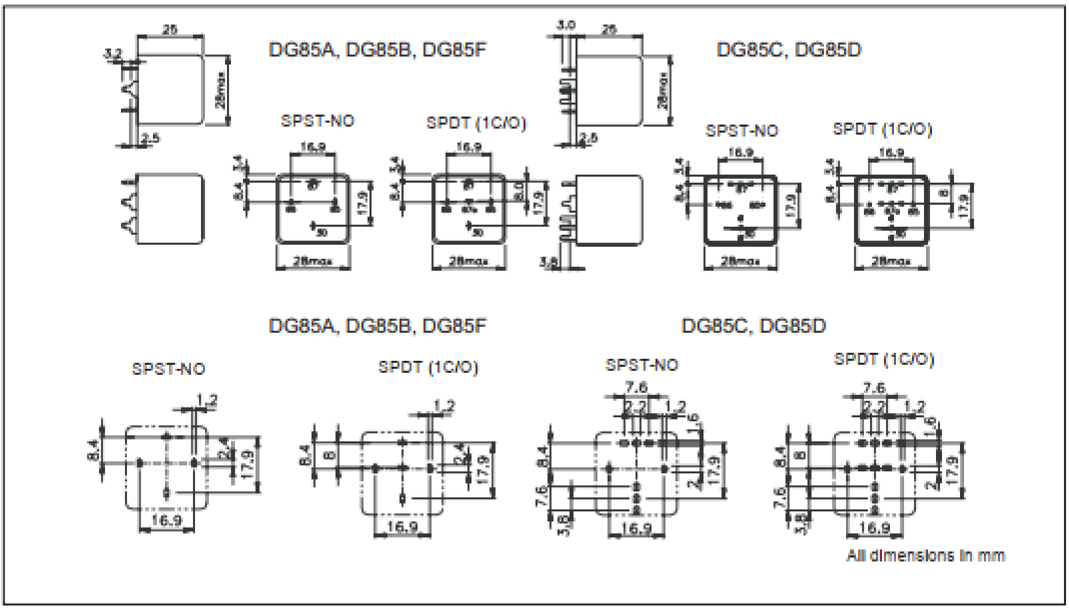
Overall Dimensions - Plug-in Types Fig. 1




Overall Dimensions - PCB Types Fig. 2

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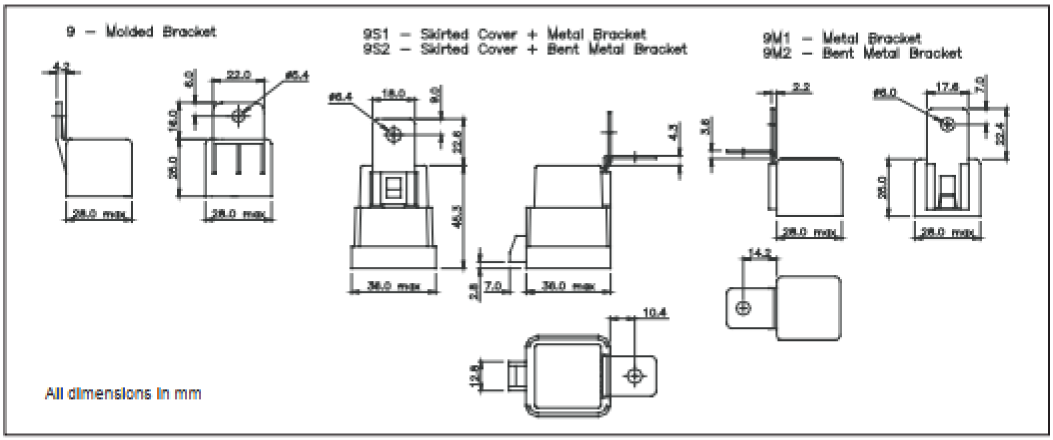
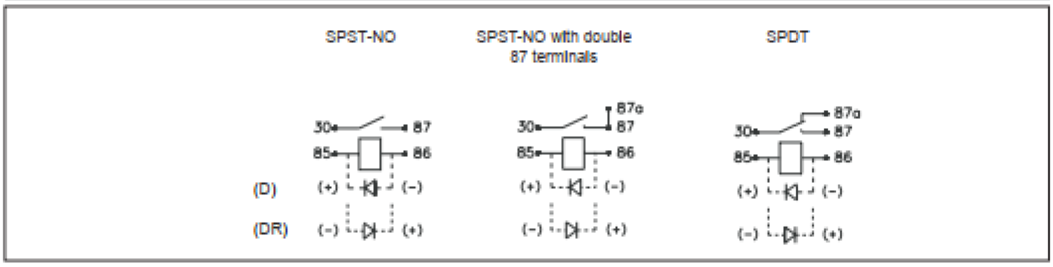
# DG85 series
## automotive / industrial relays

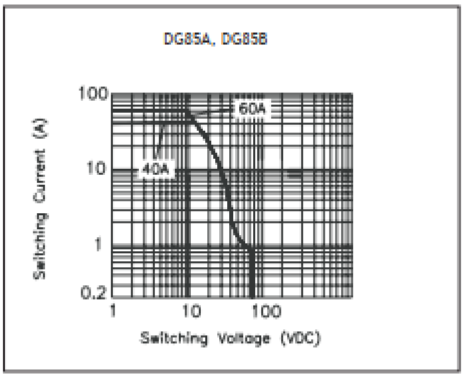
Overall Dimensions - Plug-in types with optional brackets & skirts | Fig. 3



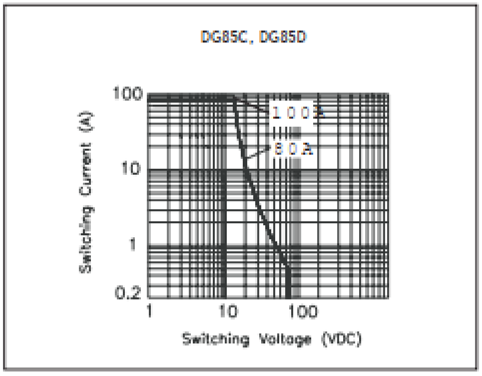

Wiring Diagrams | Fig. 4




Max. DC resistive load breaking capacity | Fig. 5




Max. DC resistive load breaking capacity | Fig. 6




Notes:
1: All parameters, unless otherwise specified, are measured at ambient temperature of 23°C.
2: Electrical life obtained at resistive or inductive load at 40A, 15VDC with suitable arc suppression circuit attached and with operating frequency of 1 op/sec.
3: Maximum make current refers to lamp load inrush current.

Specifications are liable to change without notice. E&OE.

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# 1.9. MLX90614

## MLX90615
*Infra Red Thermometer*

### Features and Benefits

- Small size, low cost
- Easy to integrate
- Factory calibrated in wide temperature range:
  -40…85˚C for sensor temperature and
  -40…115˚C for object temperature
- High accuracy of 0.5°C over wide temperature range (0…+50°C for both $T_A$ and $T_O$ )
- High (medical) accuracy calibration
- Measurement resolution of 0.02°C
- SMBus compatible digital interface
- Power saving mode
- Customizable PWM output for continuous reading
- Embedded emissivity compensation
- 3V supply voltage

### Applications Examples

- High precision non-contact temperature measurements
- Hand-held thermometers
- Ear thermometers
- Home appliances with temperature control
- Healthcare
- Livestock monitoring
- Multiple zone temperature control – up to 127 sensors can be read via common 2 wires

### Ordering Information

| Part No. | Temperature Code | Package Code | - Option Code - X X X | Standard part | Packing form |
|---|---|---|---|---|---|
| MLX90615 | S (-20°C...85°C) | SG (TO-46) | (1) (2) (3) | -000 | -TU |

(1) Accuracy
D – medical accuracy

(2) Specifics:
A – straight pins for thru hole mounting

(3) Package options:
A – 100° FOV
G – 80° FOV

**Example:**
MLX90615SSG-DAA-000-TU

### *1 Functional diagram*

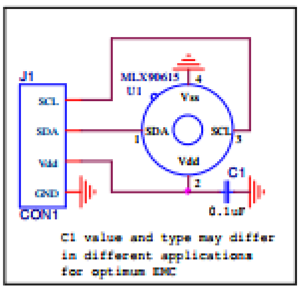


Figure 1 Typical application schematics – MLX90615 connection to SMBus

### *2 General description*

The MLX90615 is an Infra Red thermometer for non contact temperature measurements. Both the IR sensitive thermopile detector chip and the signal conditioning chip are integrated in the same TO-46 can package.

Thanks to its low noise amplifier, 16-bit ADC and powerful DSP unit, a high accuracy and resolution of the thermometer is achieved.

The thermometer is factory calibrated with the digital SMBus compatible interface enabled. Readout resolution is 0.02°C.

3901090615
Rev 005

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Data Sheet
08 November 2013

Melexis
Microelectronic Integrated Systems

**MLX90615**
***Infra Red Thermometer***

## *7 Electrical Specification*

All parameters are valid for $T_A$ = 25 ˚C, $V_{DD}$ =3V (unless otherwise specified)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| | | | | | | |
| Supplies | | | | | | |
| External supply | $V_{DD}$ | | 2.6 | 3 | 3.4 | V |
| Supply current | $I_{DD}$ | No load | | 1.3 | 1.5 | mA |
| Supply current (programming) | $I_{DDpr}$ | No load, erase / write EEPROM operations | | 1.5 | | mA |
| Power-down supply current | Isleep | No load, SCL and SDA high | | 1.1 | 3 | µA |
| Power On Reset | | | | | | |
| POR level | $V_{POR}$ | Power-up, power-down and brown-out | 0.8 | 1.5 | 1.9 | V |
| $V_{DD}$ rise time | $T_{POR}$ | Ensure POR signal | | | 20 | ms |
| Output valid | Tvalid | After POR | | 0.5 | | s |
| EEPROM | | | | | | |
| Data retention | | $T_A$ = +85°C | 10 | | | years |
| Erase/write cycles | | $T_A$ = +25°C | 100,000 | | | Times |
| Erase/write cycles | | $T_A$ = +85°C | 40,000 | | | Times |
| Erase cell time | Terase | | | 5 | | ms |
| Write cell time | Twrite | | | 5 | | ms |
| Pulse width modulation | | | | | | |
| PWM resolution | PWMres | Data band | | 10 | | bit |
| PWM output period | $PWM_{T,H,def}$ | Factory default high frequency PWM, HFO factory calibrated | | 1.024 | | ms |
| PWM output period | $PWM_{T,L}$ | Low frequency PWM, HFO factory calibrated | | 102.4 | | ms |
| PWM period stability | $dPWM_T$ | Internal oscillator factory calibrated, over the entire operation range and supply voltage | -15 | | +15 | % |
| Output low Level | $PWM_{LO}$ | $I_{sink}$ = 2 mA | | | VSS+0.2 | V |
| Output sink current | $Isink_{PWM}$ | Vout,L = 0.5V | | 10 | | mA |

Table 4 Electrical specification parameters of the MLX90615

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| SMBus compatible 2-wire interface* | | | | | | |
| Input high voltage | $V_{IH}(T_A,V)$ | Over temperature and supply | VDD-0.1 | | | V |
| Input low voltage | $V_{IL}(T_A,V)$ | Over temperature and supply | | | 0.6 | V |
| Output low voltage | $V_{OL}$ | Over temperature and supply, Isink = 2mA | | | 0.2 | V |
| SCL,SDA leakage | $I_{leak}$ | $V_{SCL}=V_{DD}$, $V_{SDA}=V_{DD}$, $T_A=+85°C$ | | | 0.25 | µA |
| SCL capacitance | $C_{SCL}$ | | | | 10 | pF |
| SDA capacitance | $C_{SDA}$ | | | | 10 | pF |
| Slave address | SA | Factory default | | 5B | | hex |
| WakeUp Request | $t_{wake}$ | SCL low | 21 | | 39 | ms |
| SMBus Request | $t_{REQ}$ | SCL low | 39 | | | ms |
| Timeout, low | $T_{imeout,L}$ | SCL low | 21 | | 39 | ms |
| Timeout, high | $T_{imeout,H}$ | SCL high | 52 | | 78 | µs |
| Acknowledge setup time | Tsuac(MD) | 8-th SCL falling edge, Master | | | 1.5 | µs |
| Acknowledge hold time | Thdac(MD) | 9-th SCL falling edge, Master | | | 1.5 | µs |
| Acknowledge setup time | Tsuac(SD) | 8-th SCL falling edge, Slave | | | 2.5 | µs |
| Acknowledge hold time | Thdac(SD) | 9-th SCL falling edge, Slave | | | 1.5 | µs |

Table 5 Electrical specification parameters of the MLX90615 (continued)

*Notes: All the communication and refresh rate timings are given for the nominal calibrated HFO frequency and will vary with this frequency's variations.*

**SMBus compatible interface is described in details in the SMBus detailed description section. Maximum number of MLX90615 devices on one bus is 127, higher pull-up currents are recommended for higher number of devices, faster bus data transfer rates, and increased reactive loading of the bus.*

*MLX90615 is always a slave device on the bus. MLX90615 can work in both low-power and high-power SMBus communication.*

*All voltages are with respect to the Vss (ground) unless otherwise noted.*

MLX90615
*Infra Red Thermometer*

## 8 Detailed description

### 8.1 Block diagram

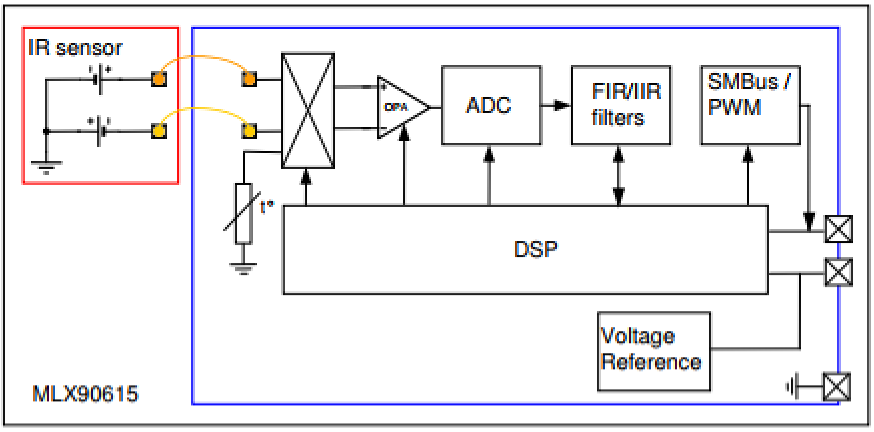


Figure 3: Block Diagram

### 8.2 Signal processing principle

A DSP embedded in the MLX90615 controls the measurements, calculates object and ambient temperatures and does the post-processing of the temperatures to output them through SMBus compatible interface or PWM (whichever activated).

The output of the IR sensor is amplified by a low noise, low offset chopper amplifier with programmable gain, then converted by a Sigma Delta modulator to a single bit stream and fed to the DSP for further processing. The signal passes a FIR low pass filter with fixed length of 65536. The output of the FIR filter is the measurement result and is available in the internal RAM. Based on results of the above measurements, the corresponding ambient temperature $T_A$ and object temperatures $T_O$ are calculated. Both calculated temperatures have a resolution of 0.02 °C.

An additional IIR LPF is programmable in EEPROM and allows customization of the thermometer output in order to trade-off noise versus settling time (refresh rate of the data in the RAM remain constant).

The IIR filter can also limit effect of spurious objects that may appear in the FOV in some applications.

The PWM output can be enabled in EEPROM as the POR default. Linearized temperatures ($T_O$ or $T_A$, selectable in EEPROM) are available through the free-running PWM output.

### 8.3 Block description

#### 8.3.1 Amplifier

A low noise, low offset amplifier with programmable gain is used for amplifying the IR sensor voltage. By a careful design of the input modulator and balanced input impedance, the max offset of the system is

## 9 Performance Graphs

### 9.1 Temperature accuracy of the MLX90615

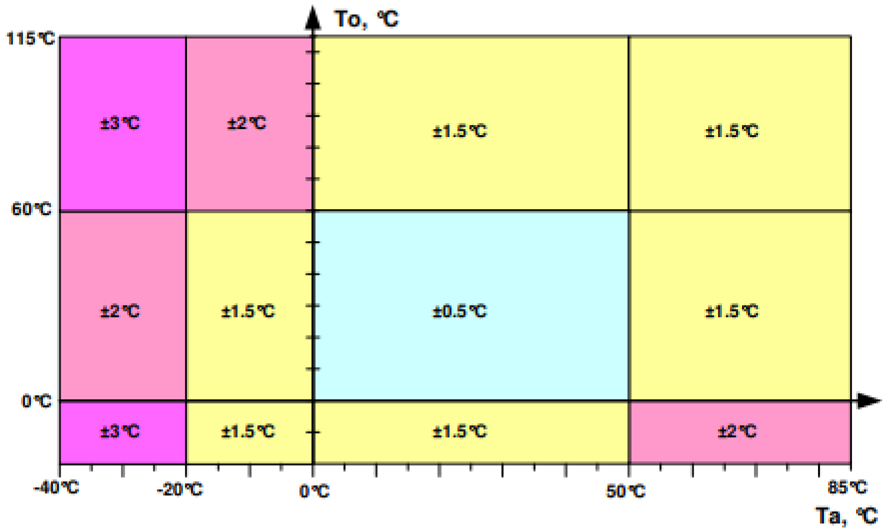


Figure 16: Accuracy of MLX90615 ($T_A$, $T_O$)

All accuracy specifications apply under settled isothermal conditions only and nominal supply voltage.

**The accuracy for the MLX90615SSG-DAX in the range $T_A$ =16°C …40°C and $T_O$= 32°C …42°C is shown in diagram below. The accuracy for the rest ranges is same as in previous diagram.**

## 10 Applications Information

### 10.1 Use of the MLX90615 thermometer in SMBus configuration

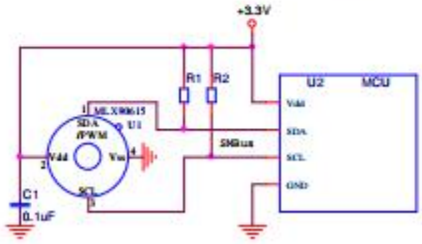


Figure 20: Connection of MLX90615 to SMBus.

MLX90615 has diode clamps SDA/SCL to Vdd so it is necessary to provide MLX90615 with power in order not to load the SMBus lines.

### 10.2 Use of multiple MLX90615s in SMBus configuration

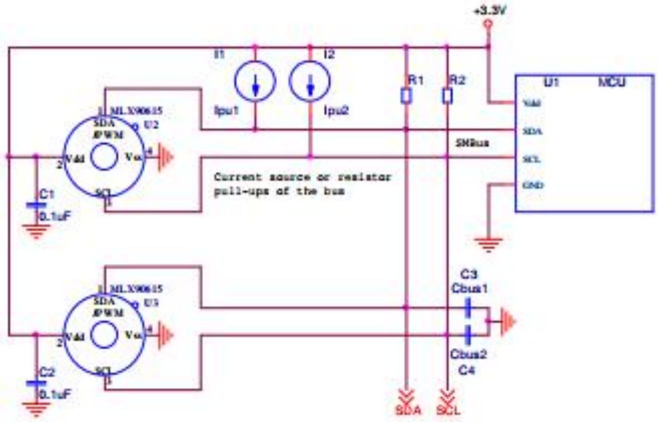


Figure 21: Use of multiple MLX90615 devices in SMBus network

The MLX90615 supports a 7-bit slave address in EEPROM, thus allowing up to 127 devices to be read via two common wires. Current source pull-ups may be preferred with higher capacitive loading on the bus (C3 and C4 represent the lines' parasitic), while simple resistive pull-ups provide the obvious low cost advantage.

### *10.3 PWM output*

With PWM output configuration MLX90615 can be read via single wire. Output is open drain NMOS (with a weak pull-up, 300kΩ typ). Therefore external pull-up is required for high level state on the line with longer wires. Simple level shifting is possible with a single resistor. ESD protective clamp on the SDA pin consists of 4 diodes to Vdd, thus allowing high level to go up to 5V disregarding the MLX90615 supply voltage value.

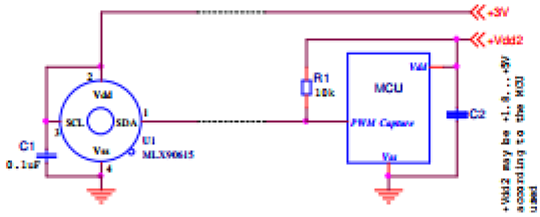


Figure 22: Using MLX90615 PWM output

In EEPROM two PWM periods can be programmed – 102.4 or 1 ms (typ). With remote installation (wires)

PWM is recommended as more robust to EMI than the SMBus and the high PWM period would be also preferred. As a factory default, once PWM is enabled, output will cover 0…50°C object temperature range (as 12.5 … 62.5% duty cycle) at 1 kHz frequency.

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**MLX90615**
***Infra Red Thermometer***

### *15 Package Information*

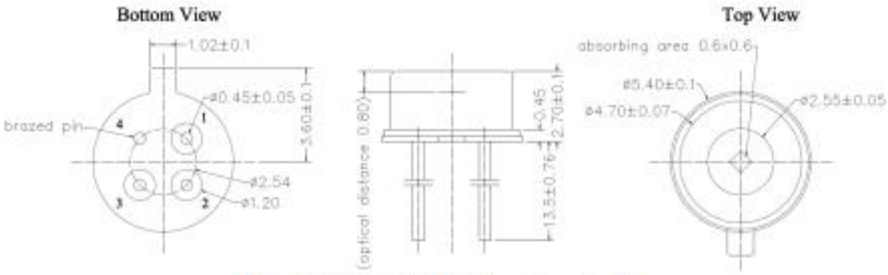


Figure 23: MLX90615SSG-DAA package drawing

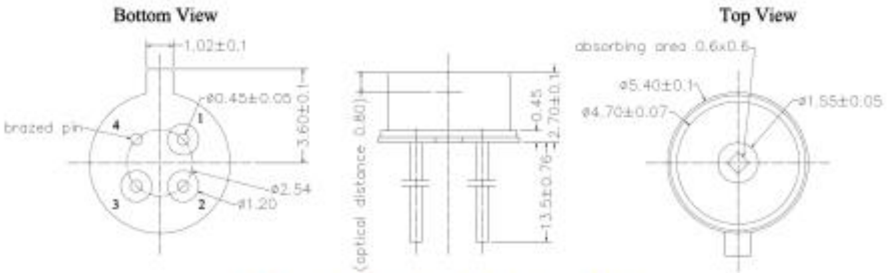


Figure 24: MLX90615SSG-DAG package drawing

### *16 Part marking*

No part marking is foreseen for this product

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Data Sheet
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# 1.10. ADS1115

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TEXAS INSTRUMENTS

**ADS1113, ADS1114, ADS1115**

SBAS444D – MAY 2009 – REVISED JANUARY 2018

## ADS111x Ultra-Small, Low-Power, I²C-Compatible, 860-SPS, 16-Bit ADCs With Internal Reference, Oscillator, and Programmable Comparator

### 1 Features

- Ultra-Small X2QFN Package: 2 mm × 1.5 mm × 0.4 mm
- Wide Supply Range: 2.0 V to 5.5 V
- Low Current Consumption: 150 µA (Continuous-Conversion Mode)
- Programmable Data Rate: 8 SPS to 860 SPS
- Single-Cycle Settling
- Internal Low-Drift Voltage Reference
- Internal Oscillator
- I²C Interface: Four Pin-Selectable Addresses
- Four Single-Ended or Two Differential Inputs (ADS1115)
- Programmable Comparator (ADS1114 and ADS1115)
- Operating Temperature Range: –40°C to +125°C

### 2 Applications

- Portable Instrumentation
- Battery Voltage and Current Monitoring
- Temperature Measurement Systems
- Consumer Electronics
- Factory Automation and Process Control

### 3 Description

The ADS1113, ADS1114, and ADS1115 devices (ADS111x) are precision, low-power, 16-bit, I²C-compatible, analog-to-digital converters (ADCs) offered in an ultra-small, leadless, X2QFN-10 package, and a VSSOP-10 package. The ADS111x devices incorporate a low-drift voltage reference and an oscillator. The ADS1114 and ADS1115 also incorporate a programmable gain amplifier (PGA) and a digital comparator. These features, along with a wide operating supply range, make the ADS111x well suited for power- and space-constrained, sensor measurement applications.

The ADS111x perform conversions at data rates up to 860 samples per second (SPS). The PGA offers input ranges from ±256 mV to ±6.144 V, allowing precise large- and small-signal measurements. The ADS1115 features an input multiplexer (MUX) that allows two differential or four single-ended input measurements. Use the digital comparator in the ADS1114 and ADS1115 for under- and overvoltage detection.

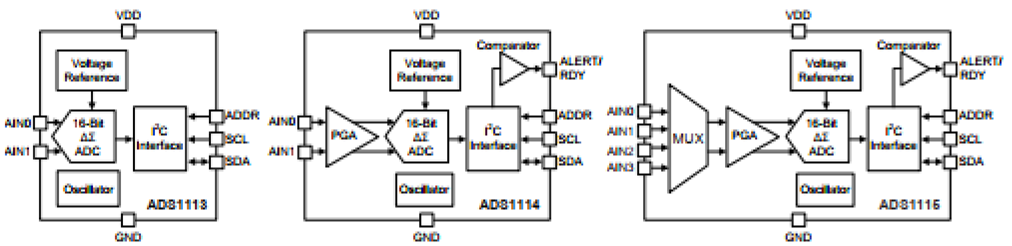
The ADS111x operate in either continuous-conversion mode or single-shot mode. The devices are automatically powered down after one conversion in single-shot mode; therefore, power consumption is significantly reduced during idle periods.

**Device Information(1)**

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| ADS111x | X2QFN (10) | 1.50 mm × 2.00 mm |
| | VSSOP (10) | 3.00 mm × 3.00 mm |

(1) For all available packages, see the package option addendum at the end of the data sheet.

**Simplified Block Diagrams**

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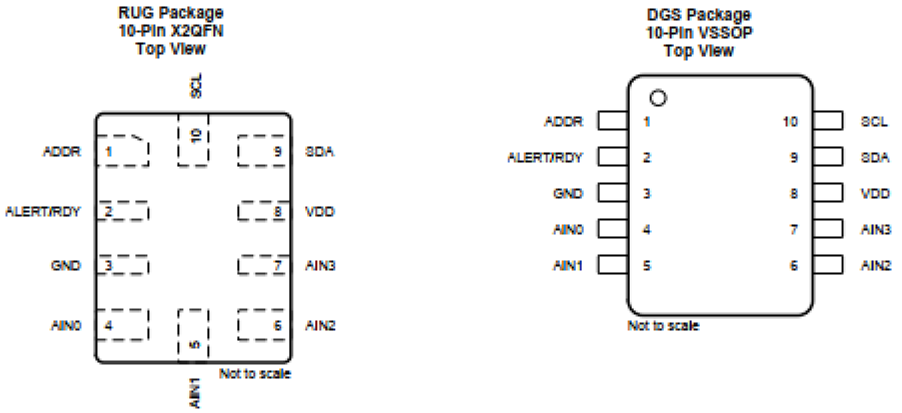
## 5 Device Comparison Table

| DEVICE | RESOLUTION (Bits) | MAXIMUM SAMPLE RATE (SPS) | INPUT CHANNELS Differential (Single-Ended) | PGA | INTERFACE | SPECIAL FEATURES |
|---|---|---|---|---|---|---|
| ADS1115 | 16 | 860 | 2 (4) | Yes | I²C | Comparator |
| ADS1114 | 16 | 860 | 1 (1) | Yes | I²C | Comparator |
| ADS1113 | 16 | 860 | 1(1) | No | I²C | None |
| ADS1015 | 12 | 3300 | 2 (4) | Yes | I²C | Comparator |
| ADS1014 | 12 | 3300 | 1 (1) | Yes | I²C | Comparator |
| ADS1013 | 12 | 3300 | 1 (1) | No | I²C | None |
| ADS1118 | 16 | 860 | 2 (4) | Yes | SPI | Temperature sensor |
| ADS1018 | 12 | 3300 | 2 (4) | Yes | SPI | Temperature sensor |

## 6 Pin Configuration and Functions




**Pin Functions**

| PIN(1) | | | | TYPE | DESCRIPTION |
|---|---|---|---|---|---|
| NAME | ADS1113 | ADS1114 | ADS1115 | | |
| ADDR | 1 | 1 | 1 | Digital input | I²C slave address select |
| AIN0 | 4 | 4 | 4 | Analog input | Analog input 0 |
| AIN1 | 5 | 5 | 5 | Analog input | Analog input 1 |
| AIN2 | — | — | 6 | Analog input | Analog input 2 (ADS1115 only) |
| AIN3 | — | — | 7 | Analog input | Analog input 3 (ADS1115 only) |
| ALERT/RDY | — | 2 | 2 | Digital output | Comparator output or conversion ready (ADS1114 and ADS1115 only) |
| GND | 3 | 3 | 3 | Analog | Ground |
| NC | 2, 6, 7 | 6, 7 | — | — | Not connected |
| SCL | 10 | 10 | 10 | Digital input | Serial clock input. locks data on SDA |
| SDA | 9 | 9 | 9 | Digital I/O | Serial data. Transmits and receives data |
| VDD | 8 | 8 | 8 | Analog | Power supply. Connect a 0.1-μF, power-supply decoupling capacitor to GND. |

(1) See the *Unused Inputs and Outputs* section for unused pin connections.

## 7 Specifications

### 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| Power-supply voltage | VDD to GND | –0.3 | 7 | V |
| Analog input voltage | AIN0, AIN1, AIN2, AIN3 | GND – 0.3 | VDD + 0.3 | V |
| Digital input voltage | SDA, SCL, ADDR, ALERT/RDY | GND – 0.3 | 5.5 | V |
| Input current, continuous | Any pin except power supply pins | –10 | 10 | mA |
| Temperature | Operating ambient, $T_A$ | –40 | 125 | °C |
| | Junction, $T_J$ | –40 | 150 | |
| | Storage, $T_{stg}$ | –60 | 150 | |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 7.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1) | ±2000 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101(2) | ±500 | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 7.3 Recommended Operating Conditions

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| **POWER SUPPLY** | | | | | |
| | Power supply (VDD to GND) | 2 | | 5.5 | V |
| **ANALOG INPUTS(1)** | | | | | |
| FSR | Full-scale input voltage range(2) ($V_{IN} = V_{(AINP)} – V_{(AINN)}$) | ±0.256 | | ±6.144 | V |
| $V_{(AINx)}$ | Absolute input voltage | GND | | VDD | V |
| **DIGITAL INPUTS** | | | | | |
| $V_{DIG}$ | Digital input voltage | GND | | 5.5 | V |
| **TEMPERATURE** | | | | | |
| $T_A$ | Operating ambient temperature | –40 | | 125 | °C |

(1) AINP and AINN denote the selected positive and negative inputs. AINx denotes one of the four available analog inputs.
(2) This parameter expresses the full-scale range of the ADC scaling. No more than VDD + 0.3 V must be applied to the analog inputs of the device. See Table 3 more information.

### 7.4 Thermal Information

| THERMAL METRIC(1) | | ADS111x | | UNIT |
|---|---|---|---|---|
| | | DGS (VSSOP) | RUG (X2QFN) | |
| | | 10 PINS | 10 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 182.7 | 245.2 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 67.2 | 69.3 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 103.8 | 172.0 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 10.2 | 8.2 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 102.1 | 170.8 | °C/W |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | N/A | N/A | °C/W |

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

### 7.5 Electrical Characteristics

At VDD = 3.3 V, data rate = 8 SPS, and full-scale input voltage range (FSR) = ±2.048 V (unless otherwise noted). Maximum and minimum specifications apply from $T_A$ = –40°C to +125°C. Typical specifications are at $T_A$ = 25°C.

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **ANALOG INPUT** | | | | | | |
| | Common-mode input impedance | FSR = ±6.144 V(1) | | 10 | | MΩ |
| | | FSR = ±4.096 V(1), FSR = ±2.048 V | | 6 | | |
| | | FSR = ±1.024 V | | 3 | | |
| | | FSR = ±0.512 V, FSR = ±0.256 V | | 100 | | |
| | Differential input impedance | FSR = ±6.144 V(1) | | 22 | | MΩ |
| | | FSR = ±4.096 V(1) | | 15 | | |
| | | FSR = ±2.048 V | | 4.9 | | |
| | | FSR = ±1.024 V | | 2.4 | | |
| | | FSR = ±0.512 V, ±0.256 V | | 710 | | kΩ |
| **SYSTEM PERFORMANCE** | | | | | | |
| | Resolution (no missing codes) | | 16 | | | Bits |
| DR | Data rate | | | 8, 16, 32, 64, 128, 250, 475, 860 | | SPS |
| | Data rate variation | All data rates | –10% | | 10% | |
| | Output noise | | | See *Noise Performance* section | | |
| INL | Integral nonlinearity | DR = 8 SPS, FSR = ±2.048 V(2) | | | 1 | LSB |
| | Offset error | FSR = ±2.048 V, differential inputs | –3 | ±1 | 3 | LSB |
| | | FSR = ±2.048 V, single-ended inputs | | ±3 | | |
| | Offset drift over temperature | FSR = ±2.048 V | | 0.005 | | LSB/°C |
| | Long-term Offset drift | FSR = ±2.048 V, $T_A$ = 125°C, 1000 hrs | | ±1 | | LSB |
| | Offset power-supply rejection | FSR = ±2.048 V, DC supply variation | | 1 | | LSB/V |
| | Offset channel match | Match between any two inputs | | 3 | | LSB |
| | Gain error(3) | FSR = ±2.048 V, $T_A$ = 25°C | | 0.01% | 0.15% | |
| | Gain drift over temperature(3) | FSR = ±0.256 V | | 7 | | ppm/°C |
| | | FSR = ±2.048 V | | 5 | 40 | |
| | | FSR = ±6.144 V(1) | | 5 | | |
| | Long-term gain drift(3) | FSR = ±2.048 V, $T_A$ = 125°C, 1000 hrs | | ±0.05 | | % |
| | Gain power-supply rejection | | | 80 | | ppm/V |
| | Gain match(3) | Match between any two gains | | 0.02% | 0.1% | |
| | Gain channel match | Match between any two inputs | | 0.05% | 0.1% | |
| CMRR | Common-mode rejection ratio | At DC, FSR = ±0.256 V | | 105 | | dB |
| | | At DC, FSR = ±2.048 V | | 100 | | |
| | | At DC, FSR = ±6.144 V(1) | | 90 | | |
| | | $f_{CM}$ = 60 Hz, DR = 8 SPS | | 105 | | |
| | | $f_{CM}$ = 50 Hz, DR = 8 SPS | | 105 | | |
| **DIGITAL INPUT/OUTPUT** | | | | | | |
| $V_{IH}$ | High-level input voltage | | 0.7 VDD | | 5.5 | V |
| $V_{IL}$ | Low-level input voltage | | GND | | 0.3 VDD | V |
| $V_{OL}$ | Low-level output voltage | $I_{OL}$ = 3 mA | GND | 0.15 | 0.4 | V |
| | Input leakage current | GND < $V_{DIG}$ < VDD | –10 | | 10 | µA |

(1) This parameter expresses the full-scale range of the ADC scaling. No more than VDD + 0.3 V must be applied to the analog inputs of the device. See Table 3 more information.
(2) Best-fit INL; covers 99% of full-scale.
(3) Includes all errors from onboard PGA and voltage reference.

### Electrical Characteristics (continued)

At VDD = 3.3 V, data rate = 8 SPS, and full-scale input voltage range (FSR) = ±2.048 V (unless otherwise noted).
Maximum and minimum specifications apply from $T_A$ = –40°C to +125°C. Typical specifications are at $T_A$ = 25°C.

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| **POWER-SUPPLY** | | | | | | | |
| $I_{VDD}$ | Supply current | Power-down | $T_A$ = 25°C | | 0.5 | 2 | µA |
| | | | | | | 5 | |
| | | Operating | $T_A$ = 25°C | | 150 | 200 | |
| | | | | | | 300 | |
| $P_D$ | Power dissipation | VDD = 5.0 V | | | 0.9 | | mW |
| | | VDD = 3.3 V | | | 0.5 | | |
| | | VDD = 2.0 V | | | 0.3 | | |

### 7.6 Timing Requirements: I²C

over operating ambient temperature range and VDD = 2.0 V to 5.5 V (unless otherwise noted)

| | | FAST MODE | | HIGH-SPEED MODE | | |
|---|---|---|---|---|---|---|
| | | MIN | MAX | MIN | MAX | UNIT |
| $f_{SCL}$ | SCL clock frequency | 0.01 | 0.4 | 0.01 | 3.4 | MHz |
| $t_{BUF}$ | Bus free time between START and STOP condition | 600 | | 160 | | ns |
| $t_{HDSTA}$ | Hold time after repeated START condition. After this period, the first clock is generated. | 600 | | 160 | | ns |
| $t_{SUSTA}$ | Setup time for a repeated START condition | 600 | | 160 | | ns |
| $t_{SUSTO}$ | Setup time for STOP condition | 600 | | 160 | | ns |
| $t_{HDDAT}$ | Data hold time | 0 | | 0 | | ns |
| $t_{SUDAT}$ | Data setup time | 100 | | 10 | | ns |
| $t_{LOW}$ | Low period of the SCL clock pin | 1300 | | 160 | | ns |
| $t_{HIGH}$ | High period for the SCL clock pin | 600 | | 60 | | ns |
| $t_F$ | Rise time for both SDA and SCL signals(1) | | 300 | | 160 | ns |
| $t_R$ | Fall time for both SDA and SCL signals(1) | | 300 | | 160 | ns |

(1) For high-speed mode maximum values, the capacitive load on the bus line must not exceed 400 pF.

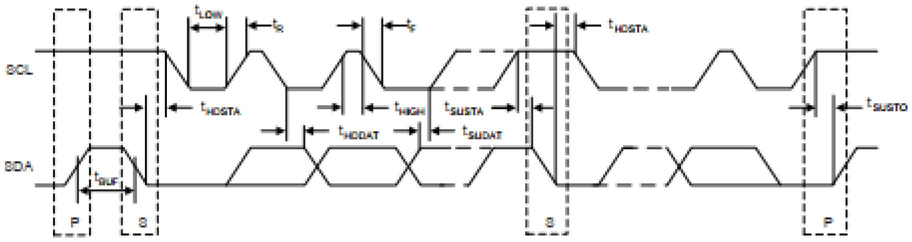



**Figure 1. I²C Interface Timing**

### 7.7 Typical Characteristics

at $T_A$ = 25°C, VDD = 3.3 V, FSR = ±2.048 V, DR = 8 SPS (unless otherwise noted)

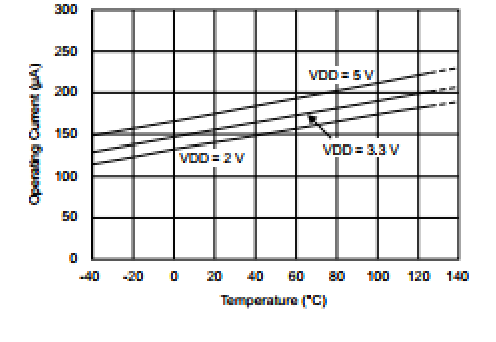



Figure 2. Operating Current vs Temperature

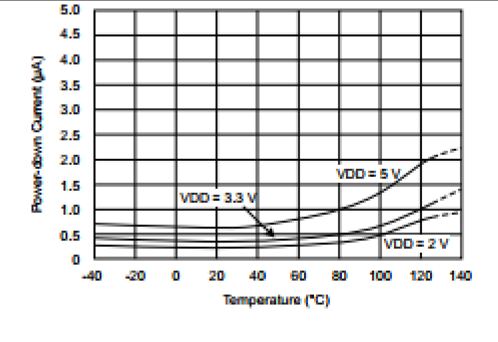



Figure 3. Power-Down Current vs Temperature

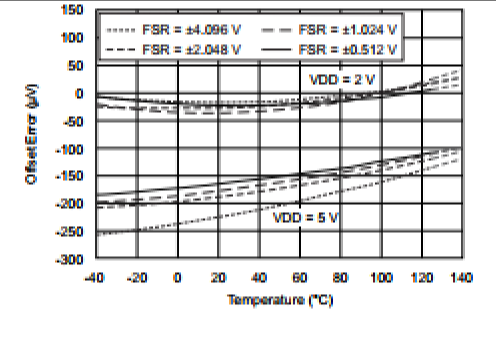



Figure 4. Single-Ended Offset Error vs Temperature

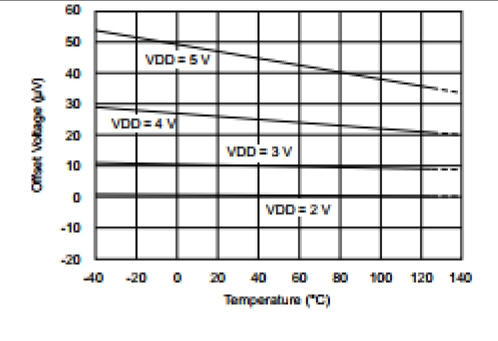



Figure 5. Differential Offset vs Temperature

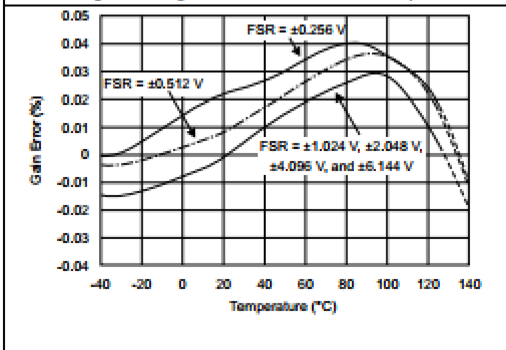



Figure 6. Gain Error vs Temperature

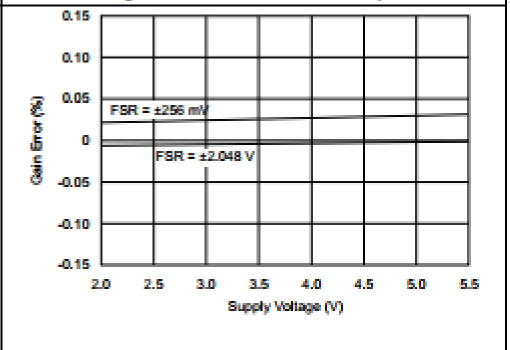



Figure 7. Gain Error vs Supply Voltage

### Typical Characteristics (continued)

at $T_A$ = 25°C, VDD = 3.3 V, FSR = ±2.048 V, DR = 8 SPS (unless otherwise noted)

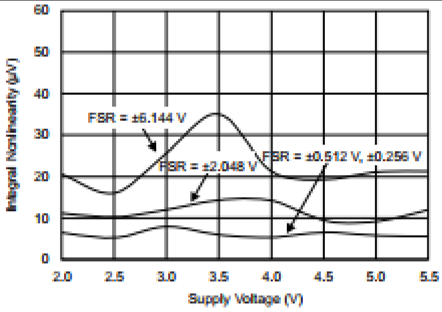
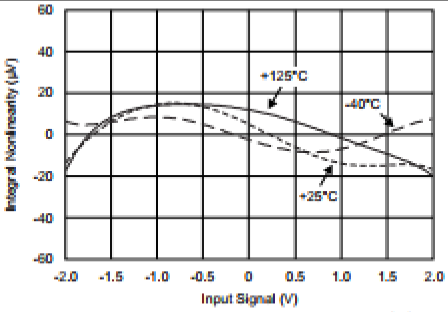
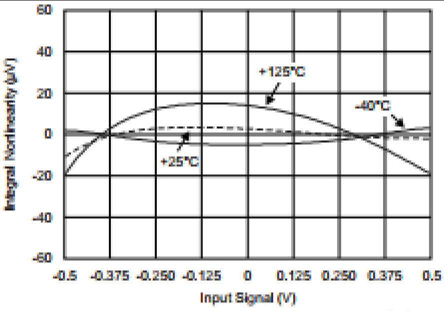



Figure 8. INL vs Supply Voltage



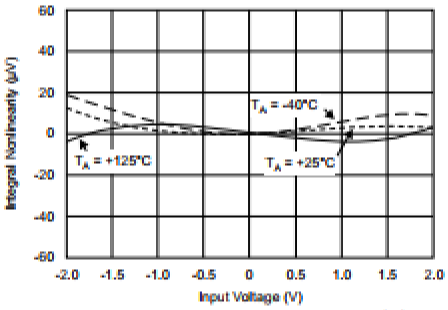

VDD = 3.3 V, FSR = ±2.048 V, DR = 8 SPS, best fit

Figure 9. INL vs Input Signal



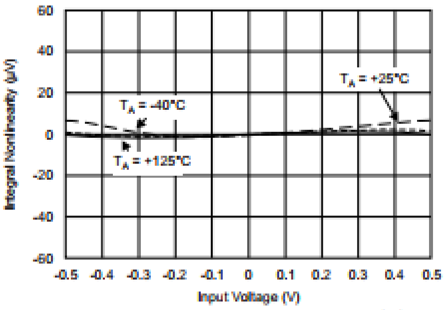

VDD = 3.3 V, FSR = ±0.512 V, DR = 8 SPS, best fit

Figure 10. INL vs Input Signal




VDD = 5 V, FSR = ±2.048 V, DR = 8 SPS, best fit

Figure 11. INL vs Input Signal




VDD = 5 V, FSR = ±0.512 V, DR = 8 SPS, best fit

Figure 12. INL vs Input Signal

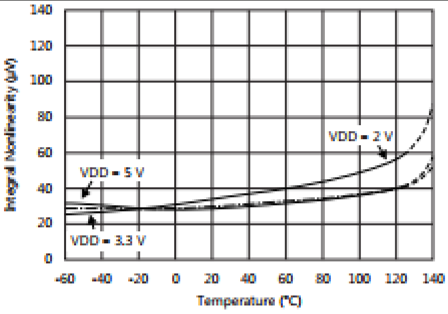
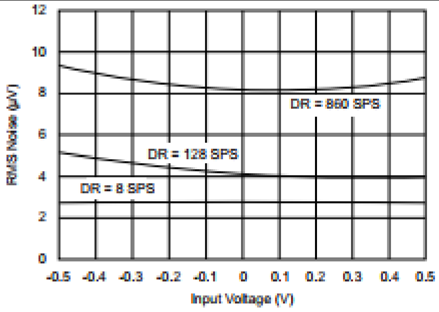



Figure 13. INL vs Temperature

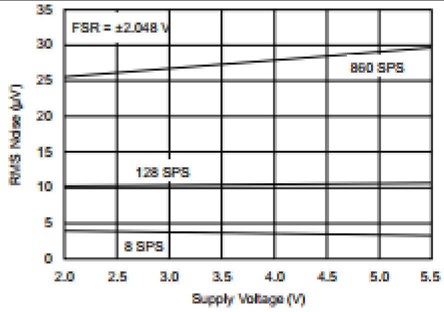
### Typical Characteristics (continued)

at $T_A$ = 25°C, VDD = 3.3 V, FSR = ±2.048 V, DR = 8 SPS (unless otherwise noted)



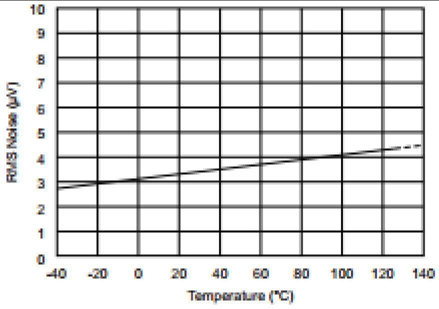

FSR = ±0.512 V

**Figure 14. Noise vs Input Signal**



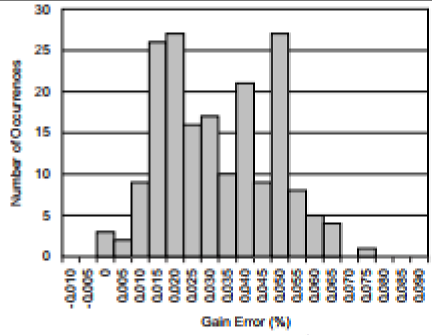

FSR = ±2.048 V

**Figure 15. Noise vs Supply Voltage**



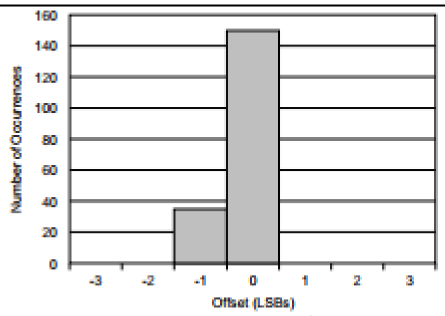

FSR = ±2.048 V, DR = 8 SPS

**Figure 16. Noise vs Temperature**



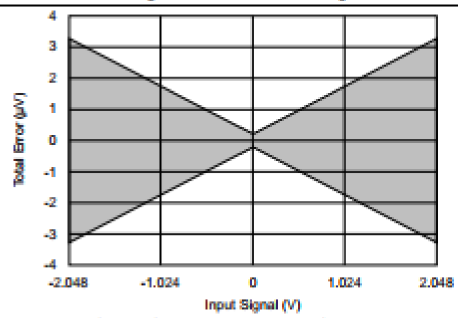

FSR = ±2.048 V, 185 units

**Figure 17. Gain Error Histogram**




FSR = ±2.048 V, 185 units

**Figure 18. Offset Histogram**




Differential Inputs; Includes noise, offset and gain error

**Figure 19. Total Error vs Input Signal**

## 8 Parameter Measurement Information

### 8.1 Noise Performance

Delta-sigma (ΔΣ) analog-to-digital converters (ADCs) are based on the principle of oversampling. The input signal of a ΔΣ ADC is sampled at a high frequency (modulator frequency) and subsequently filtered and decimated in the digital domain to yield a conversion result at the respective output data rate. The ratio between modulator frequency and output data rate is called *oversampling ratio* (OSR). By increasing the OSR, and thus reducing the output data rate, the noise performance of the ADC can be optimized. In other words, the input-referred noise drops when reducing the output data rate because more samples of the internal modulator are averaged to yield one conversion result. Increasing the gain also reduces the input-referred noise, which is particularly useful when measuring low-level signals.

Table 1 and Table 2 summarize the ADS111x noise performance. Data are representative of typical noise performance at $T_A$ = 25°C with the inputs shorted together externally. Table 1 shows the input-referred noise in units of $\mu V_{RMS}$ for the conditions shown. Note that $\mu V_{PP}$ values are shown in parenthesis. Table 2 shows the effective resolution calculated from $\mu V_{RMS}$ values using Equation 1. The noise-free resolution calculated from peak-to-peak noise values using Equation 2 are shown in parenthesis.

$$\text{Effective Resolution} = \ln(FSR / V_{RMS\text{-}Noise}) / \ln(2) \quad (1)$$

$$\text{Noise-Free Resolution} = \ln(FSR / V_{PP\text{-}Noise}) / \ln(2) \quad (2)$$

**Table 1. Noise in $\mu V_{RMS}$ ($\mu V_{PP}$) at VDD = 3.3 V**

| DATA RATE (SPS) | FSR (Full-Scale Range) | | | | | |
|---|---|---|---|---|---|---|
| | ±6.144 V | ±4.096 V | ±2.048 V | ±1.024 V | ±0.512 V | ±0.256 V |
| 8 | 187.5 (187.5) | 125 (125) | 62.5 (62.5) | 31.25 (31.25) | 15.62 (15.62) | 7.81 (7.81) |
| 16 | 187.5 (187.5) | 125 (125) | 62.5 (62.5) | 31.25 (31.25) | 15.62 (15.62) | 7.81 (7.81) |
| 32 | 187.5 (187.5) | 125 (125) | 62.5 (62.5) | 31.25 (31.25) | 15.62 (15.62) | 7.81 (7.81) |
| 64 | 187.5 (187.5) | 125 (125) | 62.5 (62.5) | 31.25 (31.25) | 15.62 (15.62) | 7.81 (7.81) |
| 128 | 187.5 (187.5) | 125 (125) | 62.5 (62.5) | 31.25 (31.25) | 15.62 (15.62) | 7.81 (12.35) |
| 250 | 187.5 (252.09) | 125 (148.28) | 62.5 (84.03) | 31.25 (39.54) | 15.62 (16.06) | 7.81 (18.53) |
| 475 | 187.5 (266.92) | 125 (227.38) | 62.5 (79.08) | 31.25 (56.84) | 15.62 (32.13) | 7.81 (25.95) |
| 860 | 187.5 (430.06) | 125 (266.93) | 62.5 (118.63) | 31.25 (64.26) | 15.62 (40.78) | 7.81 (35.83) |

**Table 2. Effective Resolution from RMS Noise (Noise-Free Resolution from Peak-to-Peak Noise) at VDD = 3.3 V**

| DATA RATE (SPS) | FSR (Full-Scale Range) | | | | | |
|---|---|---|---|---|---|---|
| | ±6.144 V | ±4.096 V | ±2.048 V | ±1.024 V | ±0.512 V | ±0.256 V |
| 8 | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (16) |
| 16 | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (16) |
| 32 | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (16) |
| 64 | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (16) |
| 128 | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (16) | 16 (15.33) |
| 250 | 16 (15.57) | 16 (15.75) | 16 (15.57) | 16 (15.66) | 16 (15.96) | 16 (14.75) |
| 475 | 16 (15.49) | 16 (15.13) | 16 (15.66) | 16 (15.13) | 16 (14.95) | 16 (14.26) |
| 860 | 16 (14.8) | 16 (14.9) | 16 (15.07) | 16 (14.95) | 16 (14.61) | 16 (13.8) |

# 9 Detailed Description

## 9.1 Overview

The ADS111x are very small, low-power, 16-bit, delta-sigma (ΔΣ) analog-to-digital converters (ADCs). The ADS111x consist of a ΔΣ ADC core with an internal voltage reference, a clock oscillator and an I²C interface. The ADS1114 and ADS1115 also integrate a programmable gain amplifier (PGA) and a programmable digital comparator. Figure 22, Figure 23, and Figure 24 show the functional block diagrams of ADS1115, ADS1114, and ADS1113, respectively.

The ADS111x ADC core measures a differential signal, $V_{IN}$, that is the difference of $V_{(AINP)}$ and $V_{(AINN)}$. The converter core consists of a differential, switched-capacitor ΔΣ modulator followed by a digital filter. This architecture results in a very strong attenuation of any common-mode signals. Input signals are compared to the internal voltage reference. The digital filter receives a high-speed bitstream from the modulator and outputs a code proportional to the input voltage.

The ADS111x have two available conversion modes: single-shot and continuous-conversion. In single-shot mode, the ADC performs one conversion of the input signal upon request, stores the conversion value to an internal conversion register, and then enters a power-down state. This mode is intended to provide significant power savings in systems that only require periodic conversions or when there are long idle periods between conversions. In continuous-conversion mode, the ADC automatically begins a conversion of the input signal as soon as the previous conversion is completed. The rate of continuous conversion is equal to the programmed data rate. Data can be read at any time and always reflect the most recent completed conversion.

## 9.2 Functional Block Diagrams

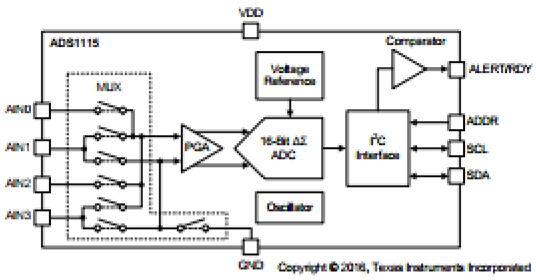



Figure 22. ADS1115 Block Diagram

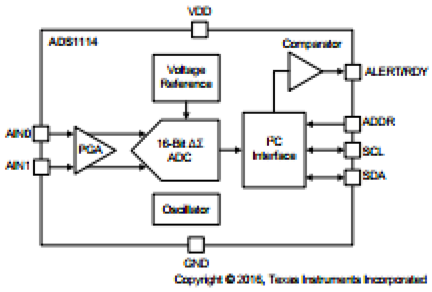



Figure 23. ADS1114 Block Diagram

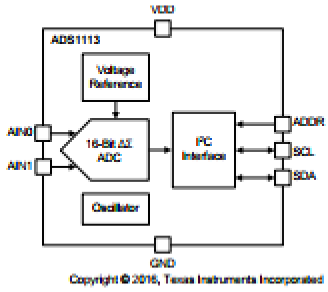



Figure 24. ADS1113 Block Diagram

## 9.3 Feature Description

### 9.3.1 Multiplexer

The ADS1115 contains an input multiplexer (MUX), as shown in Figure 25. Either four single-ended or two differential signals can be measured. Additionally, AIN0 and AIN1 may be measured differentially to AIN3. The multiplexer is configured by bits MUX[2:0] in the Config register. When single-ended signals are measured, the negative input of the ADC is internally connected to GND by a switch within the multiplexer.

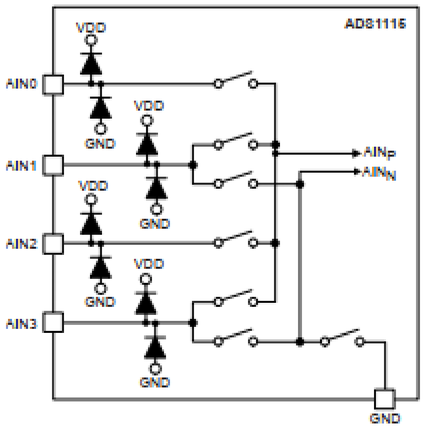



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**Figure 25. Input Multiplexer**

The ADS1113 and ADS1114 do not have an input multiplexer and can measure either one differential signal or one single-ended signal. For single-ended measurements, connect the AIN1 pin to GND externally. In subsequent sections of this data sheet, $AIN_P$ refers to AIN0 and $AIN_N$ refers to AIN1 for the ADS1113 and ADS1114.

Electrostatic discharge (ESD) diodes connected to VDD and GND protect the ADS111x analog inputs. Keep the absolute voltage of any input within the range shown in Equation 3 to prevent the ESD diodes from turning on.

$$GND - 0.3\ V < V_{(AINX)} < VDD + 0.3\ V \quad (3)$$

If the voltages on the input pins can potentially violate these conditions, use external Schottky diodes and series resistors to limit the input current to safe values (see the *Absolute Maximum Ratings* table).

**Feature Description (continued)**

### 9.3.2 Analog Inputs

The ADS111x use a switched-capacitor input stage where capacitors are continuously charged and then discharged to measure the voltage between $AIN_P$ and $AIN_N$. The frequency at which the input signal is sampled is called the sampling frequency or the modulator frequency ($f_{MOD}$). The ADS111x has a 1-MHz internal oscillator that is further divided by a factor of 4 to generate $f_{MOD}$ at 250 kHz. The capacitors used in this input stage are small, and to external circuitry, the average loading appears resistive. Figure 26 shows this structure. The capacitor values set the resistance and switching rate. Figure 27 shows the timing for the switches in Figure 26. During the sampling phase, switches $S_1$ are closed. This event charges $C_{A1}$ to $V_{(AINP)}$, $C_{A2}$ to $V_{(AINN)}$, and $C_B$ to $(V_{(AINP)} - V_{(AINN)})$. During the discharge phase, $S_1$ is first opened and then $S_2$ is closed. Both $C_{A1}$ and $C_{A2}$ then discharge to approximately 0.7 V and $C_B$ discharges to 0 V. This charging draws a very small transient current from the source driving the ADS111x analog inputs. The average value of this current can be used to calculate the effective impedance ($Z_{eff}$), where $Z_{eff} = V_{IN} / I_{AVERAGE}$.

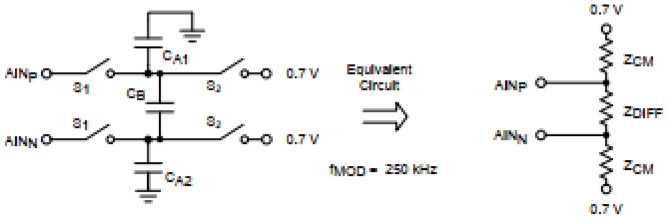



**Figure 26. Simplified Analog Input Circuit**

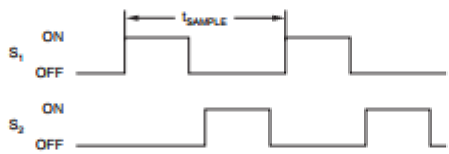



**Figure 27. $S_1$ and $S_2$ Switch Timing**

The common-mode input impedance is measured by applying a common-mode signal to the shorted $AIN_P$ and $AIN_N$ inputs and measuring the average current consumed by each pin. The common-mode input impedance changes depending on the full-scale range, but is approximately 6 MΩ for the default full-scale range. In Figure 26, the common-mode input impedance is $Z_{CM}$.

The differential input impedance is measured by applying a differential signal to $AIN_P$ and $AIN_N$ inputs where one input is held at 0.7 V. The current that flows through the pin connected to 0.7 V is the differential current and scales with the full-scale range. In Figure 26, the differential input impedance is $Z_{DIFF}$.

Make sure to consider the typical value of the input impedance. Unless the input source has a low impedance, the ADS111x input impedance may affect the measurement accuracy. For sources with high-output impedance, buffering may be necessary. Active buffers introduce noise, and also introduce offset and gain errors. Consider all of these factors in high-accuracy applications.

The clock oscillator frequency drifts slightly with temperature; therefore, the input impedances also drift. For most applications, this input impedance drift is negligible, and can be ignored.

## Feature Description (continued)

### 9.3.3 Full-Scale Range (FSR) and LSB Size

A programmable gain amplifier (PGA) is implemented before the ΔΣ ADC of the ADS1114 and ADS1115. The full-scale range is configured by bits PGA[2:0] in the Config register and can be set to ±6.144 V, ±4.096 V, ±2.048 V, ±1.024 V, ±0.512 V, ±0.256 V. Table 3 shows the FSR together with the corresponding LSB size. Equation 4 shows how to calculate the LSB size from the selected full-scale range.

$$LSB = FSR / 2^{16} \quad (4)$$

**Table 3. Full-Scale Range and Corresponding LSB Size**

| FSR | LSB SIZE |
|---|---|
| ±6.144 V(1) | 187.5 μV |
| ±4.096 V(1) | 125 μV |
| ±2.048 V | 62.5 μV |
| ±1.024 V | 31.25 μV |
| ±0.512 V | 15.625 μV |
| ±0.256 V | 7.8125 μV |

(1) This parameter expresses the full-scale range of the ADC scaling. Do not apply more than VDD + 0.3 V to the analog inputs of the device.

The FSR of the ADS1113 is fixed at ±2.048 V.

Analog input voltages must never exceed the analog input voltage limits given in the *Absolute Maximum Ratings*. If a VDD supply voltage greater than 4 V is used, the ±6.144 V full-scale range allows input voltages to extend up to the supply. Although in this case (or whenever the supply voltage is less than the full-scale range; for example, VDD = 3.3 V and full-scale range = ±4.096 V), a full-scale ADC output code cannot be obtained. For example, with VDD = 3.3 V and FSR = ±4.096 V, only signals up to $V_{IN}$ = ±3.3 V can be measured. The code range that represents voltages $|V_{IN}|$ > 3.3 V is not used in this case.

### 9.3.4 Voltage Reference

The ADS111x have an integrated voltage reference. An external reference cannot be used with these devices. Errors associated with the initial voltage reference accuracy and the reference drift with temperature are included in the gain error and gain drift specifications in the *Electrical Characteristics* table.

### 9.3.5 Oscillator

The ADS111x have an integrated oscillator running at 1 MHz. No external clock can be applied to operate these devices. The internal oscillator drifts over temperature and time. The output data rate scales proportionally with the oscillator frequency.

### 9.3.6 Output Data Rate and Conversion Time

The ADS111x offer programmable output data rates. Use the DR[2:0] bits in the Config register to select output data rates of 8 SPS, 16 SPS, 32 SPS, 64 SPS, 128 SPS, 250 SPS, 475 SPS, or 860 SPS.

Conversions in the ADS111x settle within a single cycle; thus, the conversion time is equal to 1 / DR.

### 9.3.7 Digital Comparator (ADS1114 and ADS1115 Only)

The ADS1115 and ADS1114 feature a programmable digital comparator that can issue an alert on the ALERT/RDY pin. The COMP_MODE bit in the Config register configures the comparator as either a traditional comparator or a window comparator. In traditional comparator mode, the ALERT/RDY pin asserts (active low by default) when conversion data exceeds the limit set in the high-threshold register (Hi_thresh). The comparator then deasserts only when the conversion data falls below the limit set in the low-threshold register (Lo_thresh). In window comparator mode, the ALERT/RDY pin asserts when the conversion data exceed the Hi_thresh register or fall below the Lo_thresh register value.

### 9.3.8 Conversion Ready Pin (ADS1114 and ADS1115 Only)

The ALERT/RDY pin can also be configured as a conversion ready pin. Set the most-significant bit of the Hi_thresh register to 1 and the most-significant bit of Lo_thresh register to 0 to enable the pin as a conversion ready pin. The COMP_POL bit continues to function as expected. Set the COMP_QUE[1:0] bits to any 2-bit value other than 11 to keep the ALERT/RDY pin enabled, and allow the conversion ready signal to appear at the ALERT/RDY pin output. The COMP_MODE and COMP_LAT bits no longer control any function. When configured as a conversion ready pin, ALERT/RDY continues to require a pullup resistor. The ADS111x provide an approximately 8-µs conversion ready pulse on the ALERT/RDY pin at the end of each conversion in continuous-conversion mode, as shown in Figure 29. In single-shot mode, the ALERT/RDY pin asserts low at the end of a conversion if the COMP_POL bit is set to 0.

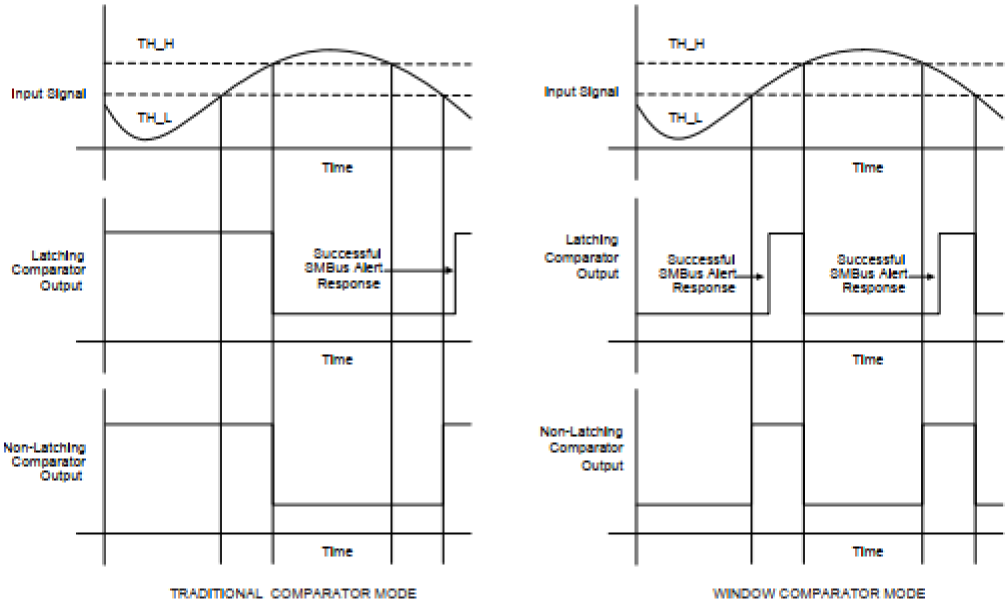



**Figure 28. ALERT Pin Timing Diagram**

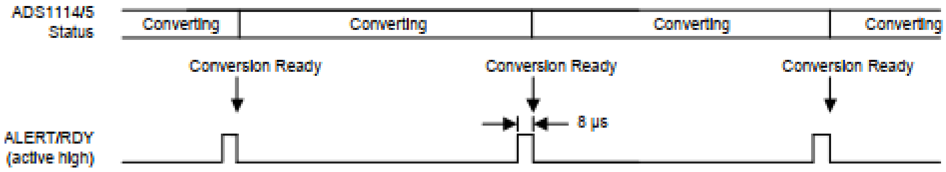



**Figure 29. Conversion Ready Pulse in Continuous-Conversion Mode**

### 9.6 Register Map

The ADS111x have four registers that are accessible through the I²C interface using the Address Pointer register. The Conversion register contains the result of the last conversion. The Config register is used to change the ADS111x operating modes and query the status of the device. The other two registers, Lo_thresh and Hi_thresh, set the threshold values used for the comparator function, and are not available in the ADS1113.

#### 9.6.1 Address Pointer Register (address = N/A) [reset = N/A]

All four registers are accessed by writing to the Address Pointer register; see Figure 30.

**Figure 34. Address Pointer Register**

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | P[1:0] | |
| W-0h | W-0h | W-0h | W-0h | W-0h | W-0h | W-0h | |

LEGEND: R/W = Read/Write; R = Read only; W = Write only; -n = value after reset

**Table 6. Address Pointer Register Field Descriptions**

| Bit | Field | Type | Reset | Description |
|---|---|---|---|---|
| 7:2 | Reserved | W | 0h | Always write 0h |
| 1:0 | P[1:0] | W | 0h | **Register address pointer**<br>00 : Conversion register<br>01 : Config register<br>10 : Lo_thresh register<br>11 : Hi_thresh register |

#### 9.6.2 Conversion Register (P[1:0] = 0h) [reset = 0000h]

The 16-bit Conversion register contains the result of the last conversion in binary two's complement format. Following power-up, the Conversion register is cleared to 0, and remains 0 until the first conversion is completed.

**Figure 35. Conversion Register**

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
|---|---|---|---|---|---|---|---|
| D15 | D14 | D13 | D12 | D11 | D10 | D9 | D8 |
| R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

**Table 7. Conversion Register Field Descriptions**

| Bit | Field | Type | Reset | Description |
|---|---|---|---|---|
| 15:0 | D[15:0] | R | 0000h | 16-bit conversion result |

## 12 Layout

### 12.1 Layout Guidelines

Employ best design practices when laying out a printed-circuit board (PCB) for both analog and digital components. For optimal performance, separate the analog components [such as ADCs, amplifiers, references, digital-to-analog converters (DACs), and analog MUXs] from digital components [such as microcontrollers, complex programmable logic devices (CPLDs), field-programmable gate arrays (FPGAs), radio frequency (RF) transceivers, universal serial bus (USB) transceivers, and switching regulators]. An example of good component placement is shown in Figure 48. Although Figure 48 provides a good example of component placement, the best placement for each application is unique to the geometries, components, and PCB fabrication capabilities employed. That is, there is no single layout that is perfect for every design and careful consideration must always be used when designing with any analog component.

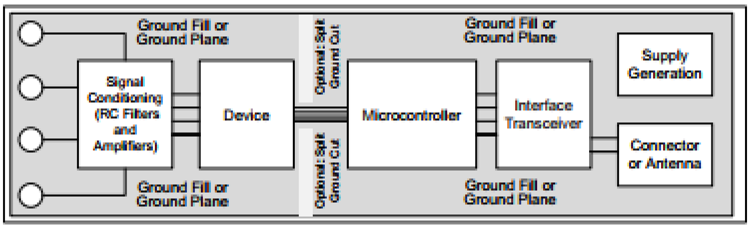



**Figure 48. System Component Placement**

The following outlines some basic recommendations for the layout of the ADS111x to get the best possible performance of the ADC. A good design can be ruined with a bad circuit layout.

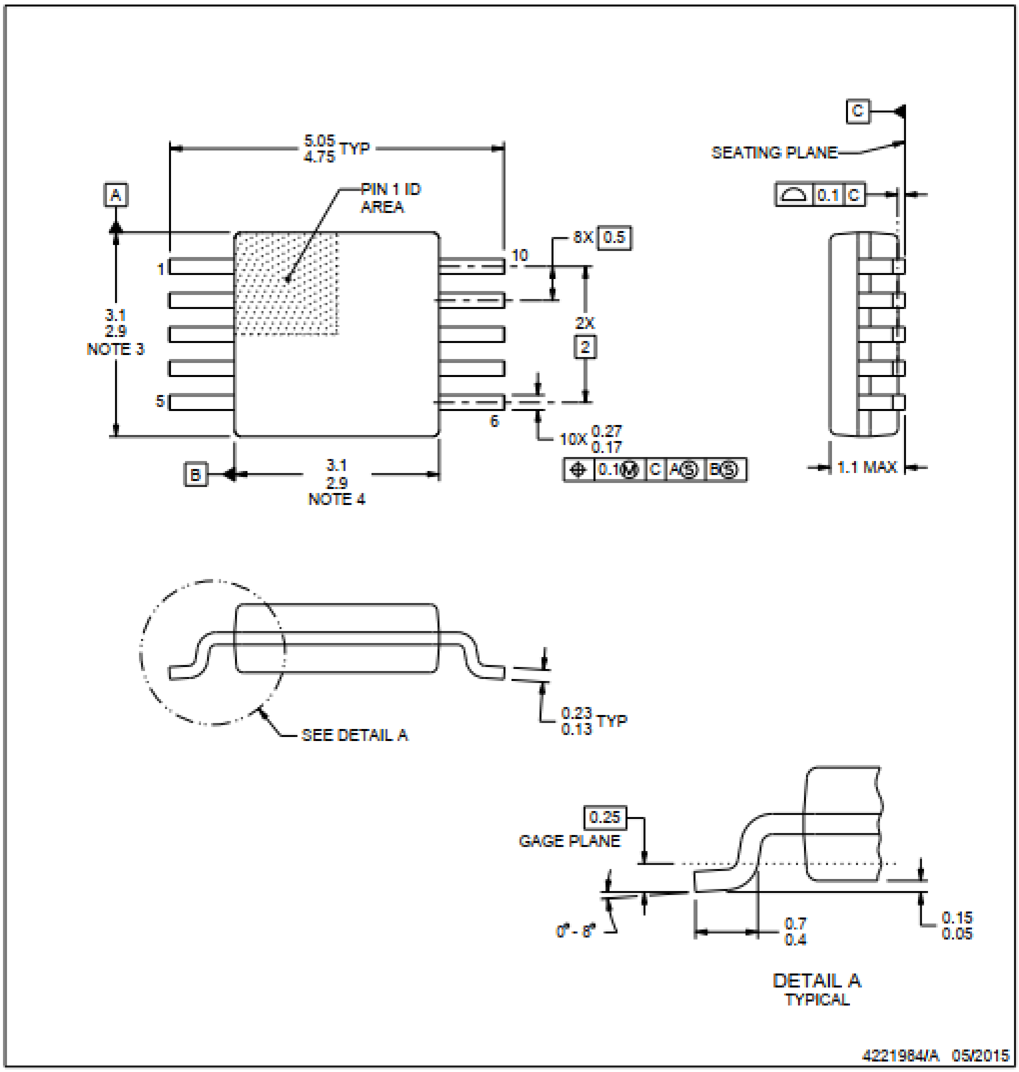
- Separate analog and digital signals. To start, partition the board into analog and digital sections where the layout permits. Route digital lines away from analog lines. This prevents digital noise from coupling back into analog signals.
- Fill void areas on signal layers with ground fill.
- Provide good ground return paths. Signal return currents flow on the path of least impedance. If the ground plane is cut or has other traces that block the current from flowing right next to the signal trace, it has to find another path to return to the source and complete the circuit. If it is forced into a larger path, it increases the chance that the signal radiates. Sensitive signals are more susceptible to EMI interference.
- Use bypass capacitors on supplies to reduce high-frequency noise. Do not place vias between bypass capacitors and the active device. Placing the bypass capacitors on the same layer as close to the active device yields the best results.
- Consider the resistance and inductance of the routing. Often, traces for the inputs have resistances that react with the input bias current and cause an added error voltage. Reduce the loop area enclosed by the source signal and the return current in order to reduce the inductance in the path. Reduce the inductance to reduce the EMI pickup, and reduce the high frequency impedance seen by the device.
- Differential inputs must be matched for both the inputs going to the measurement source.
- Analog inputs with differential connections must have a capacitor placed differentially across the inputs. Best input combinations for differential measurements use adjacent analog input lines such as AIN0, AIN1 and AIN2, AIN3. The differential capacitors must be of high quality. The best ceramic chip capacitors are C0G (NPO), which have stable properties and low-noise characteristics.

**DGS0010A**

**PACKAGE OUTLINE**

**VSSOP - 1.1 mm max height**

SMALL OUTLINE PACKAGE




NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187, variation BA.

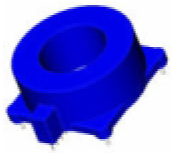
# 1.11. SENSOR HALL

LEM

## Current Transducer HTFS 200..800-P/SP2

## $I_{PN}$ = 200 - 400 - 800 A

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 kΩ

### Electrical data

| Primary nominal current rms $I_{PN}$ (A) | Primary current measuring range $I_{PM}$ (A) | Type | RoHS since date code |
|---|---|---|---|
| 200 | ± 300 | HTFS 200-P/SP2 | 45326 |
| 400 | ± 600 | HTFS 400-P/SP2 | 45060 |
| 800 | ± 1200 | HTFS 800-P/SP2 | 45060 |

| | | | |
|---|---|---|---|
| $V_{OUT}$ | Output voltage (Analog) @ $I_P$ | $V_{REF}\pm(1.25 \cdot I_P/I_{PN})$ | V |
| | $I_P = 0$ | $V_{REF}$ ± 0.025 | V |
| $V_{REF}$ | Reference voltage [1] - Output voltage | $1/2V_C$ ± 0.025 | V |
| | $V_{REF}$ Output Impedance | typ. 200 | Ω |
| | $V_{REF}$ Load Impedance | ≥ 200 | kΩ |
| $R_L$ | Load resistance | ≥ 2 | kΩ |
| $R_{OUT}$ | Output internal resistance | < 10 | Ω |
| $C_L$ | Capacitive loading < 1 | µF | |
| $V_C$ | Supply voltage (± 5 %) | 5 | V |
| $I_C$ | Current consumption @ $V_C$ = 5 V | 22 | mA |

### Accuracy - Dynamic performance data

| | | | |
|---|---|---|---|
| X | Accuracy [2] @ $I_{PN}$ , $T_A$ = 25°C | ≤ ± 1 | % of $I_{PN}$ |
| $\varepsilon_L$ | Linearity error 0 .. 1.5 x $I_{PN}$ | ≤ ± 0.5 | % of $I_{PN}$ |
| $TCV_{OE}$ | Temperature coefficient of $V_{OE}$ @ $I_P$ = 0 | ≤ ± 0.3 | mV/K |
| $TCV_{REF}$ | Temperature coefficient of $V_{REF}$ | ≤ ± 0.01 | %/K |
| $TCV_{OUT}/V_{REF}$ | Temperature coefficient of $V_{OUT}/V_{REF}$ @ $I_P$ = 0 | ≤ ± 0.2 | mV/K |
| $TCV_{OUT}$ | Temperature coefficient of $V_{OUT}$ | ≤ ± 0.05% of reading/K | |
| $V_{OM}$ | Magnetic offset voltage @ $I_P$ = 0, after an overload of 3 x $I_{PNDC}$ | < ± 0.5 | % of $I_{PN}$ |
| $t_{ra}$ | Reaction time @ 10 % of $I_{PN}$ | < 3 | µs |
| $t_r$ | Response time to 90 % of $I_{PN}$ step | < 7 | µs |
| di/dt | di/dt accurately followed | > 100 | A/µs |
| $V_{no}$ | Output voltage noise (DC ..10 kHz) | < 15 | mVpp |
| | (DC .. 1 MHz) | < 40 | mVpp |
| BW | Frequency bandwidth (-3 dB) [3] | DC .. 20 | kHz |

### General data

| | | | |
|---|---|---|---|
| $T_A$ | Ambient operating temperature | - 40 .. + 105 | °C |
| $T_S$ | Ambient storage temperature | - 40 .. + 105 | °C |
| m | Mass | 60 | g |
| | Standards | EN 50178: 1997 | |

Notes : [1] It is possible to overdrive $V_{REF}$ with an external reference voltage between 2 - 2.8 V providing its ability to sink or source approx. 2.5 mA.
[2] Excluding offset.
[3] Small signal only to avoid excessive heatings of the magnetic core.

#### Features

- Hall effect measuring principle
- Galvanic isolation between primary and secondary circuit
- Low power consumption
- Single power supply +5V
- Ratiometric offset
- $T_A$ = -40..+105 °C
- PCB fixation by 4 Ø1 pins
- Insulated plastic case recognized according to UL 94-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

- Forklift drives
- 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

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## Current Transducer HTFS 200..800-P/SP2

### Isolation characteristics

| | | | |
|---|---|---|---|
| $V_b$ | Rated isolation voltage rms<br>with IEC 61010-1 standards and following conditions<br>- Single insulation<br>- Over voltage category III<br>- Pollution degree 2<br>- Heterogeneous field | 150 | V |
| $V_b$ | Rated isolation voltage rms<br>with EN 50178 standards and following conditions<br>- Reinforced insulation<br>- Over voltage category III<br>- Pollution degree 2<br>- Heterogeneous field | 150 | V |
| $V_d$ | Rms voltage for AC isolation test, 50 Hz, 1 min | 2.5 | kV |
| $V_e$ | Partial discharge extinction voltage rms @ 10pC | > 1 | kV |
| $\hat{V}_w$ | Impulse withstand voltage 1.2/50 µs | 4 | kV |
| dCp | Creepage distance | > 4 | mm |
| dCI | Clearance distance | > 4 | mm |
| CTI | Comparative tracking index (Group IIIa) | > 220 | |

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 | 300V CAT III |
| HAR 05 | 400V CAT III |
| HAR 07 | 500V 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.

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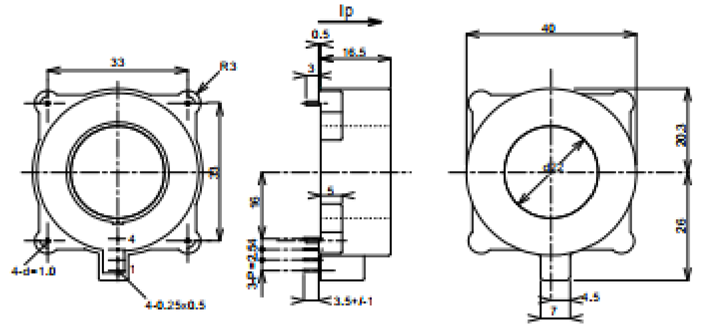
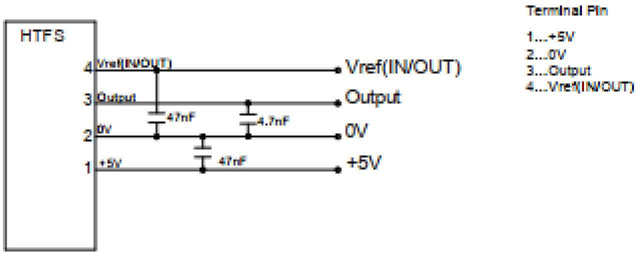
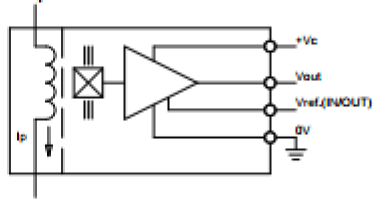
**Dimensions HTFS 200..800-P/SP2** (in mm. 1 mm = 0.0394 inch)




**Required Connection Circuit**




**Operation Principle**




**Mechanical characteristics**

| | |
|---|---|
| • General tolerance | ± 0.2 mm |
| • Fixation | 4 pins x Ø 1.0 |
| • Recommended PCB hole | Ø 1.2 mm |
| • Fastening & connection of secondary | 4 pins 0.5 x 0.25 |
| Recommended PCB hole | Ø 0.7 mm |

**Remarks**

- $V_{OUT}$ is positive when $I_p$ flows in the direction of the arrow.
- Temperature of the primary conductor should not exceed 120°C.

# 1.12. MAX 31856

EVALUATION KIT AVAILABLE

**MAX31856** **Precision Thermocouple to Digital Converter with Linearization**

## General Description

The MAX31856 performs cold-junction compensation and digitizes the signal from any type of thermocouple. The output data is formatted in degrees Celsius. This converter resolves temperatures to 0.0078125°C, allows readings as high as +1800°C and as low as -210°C (depending on thermocouple type), and exhibits thermocouple voltage measurement accuracy of ±0.15%. The thermocouple inputs are protected against overvoltage conditions up to ±45V.

A lookup table (LUT) stores linearity correction data for several types of thermocouples (K, J, N, R, S, T, E, and B). Line frequency filtering of 50Hz and 60Hz is included, as is thermocouple fault detection. A SPI-compatible interface allows selection of thermocouple type and setup of the conversion and fault detection processes.

## Applications

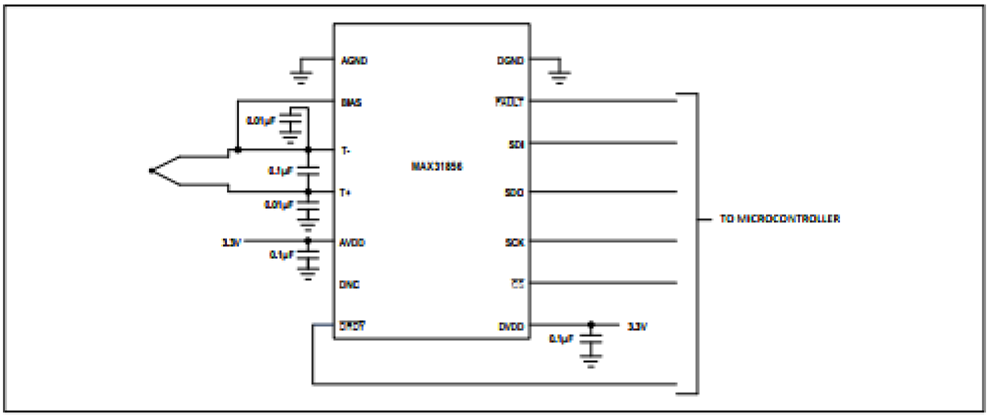
- Temperature Controllers
- Industrial Ovens, Furnaces, and Environmental Chambers
- Industrial Equipment

*Ordering Information appears at end of data sheet.*

## Benefits and Features

- Provides High-Accuracy Thermocouple Temperature Readings
  - Includes Automatic Linearization Correction for 8 Thermocouple Types
  - ±0.15% (max, -20°C to +85°C) Thermocouple Full-Scale and Linearity Error
  - 19-Bit, 0.0078125°C Thermocouple Temperature Resolution
- Internal Cold-Junction Compensation Minimizes System Components
  - ±0.7°C (max, -20°C to +85°C) Cold-Junction Accuracy
- ±45V Input Protection Provides Robust System Performance
- Simplifies System Fault Management and Troubleshooting
  - Detects Open Thermocouples
  - Over- and Undertemperature Fault Detection
- 50Hz/60Hz Noise Rejection Filtering Improves System Performance
- 14-Pin TSSOP Package

## Typical Application Circuit




*19-7534; Rev 0; 3/15*

maxim integrated

MAX31856 Precision Thermocouple to Digital Converter with Linearization

## Absolute Maximum Ratings

AVDD, DVDD ........ -0.3V to +4.0V
T+, T-, Bias ........ ±45V
T+, T-, Bias ........ ±20mA
All Other Pins ........ -0.3V to ($V_{DVDD}$ + 0.3V)
Continuous Power Dissipation ($T_A$ = +70°C)
TSSOP (derate 9.1mW/°C above +70°C) ........ 727.3mW
ESD Protection (All pins, Human Body Model) ........ 2000V
Operating Temperature Range ........ -55°C to +125°C
Junction Temperature ........ +150°C
Storage Temperature Range ........ -65°C to +150°C
Lead Temperature (soldering, 10s) ........ +300°C
Soldering Temperature
(reflow) ........ See IPC/JEDEC J-STD-020A Specification

*Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

## Package Thermal Characteristics (Note 1)

TSSOP
Junction-to-Ambient Thermal Resistance ($\theta_{JA}$) ........ 110°C/W
Junction-to-Case Thermal Resistance ($\theta_{JC}$) ........ 30°C/W

**Note 1:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to www.maximintegrated.com/thermal-tutorial.

## Recommended DC Operating Conditions

($T_A$ = -55°C to +125°C, unless otherwise noted.)(Notes 2 and 4)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Power-Supply Voltage | $V_{AVDD}$, $V_{DVDD}$ | | 3.0 | 3.3 | 3.6 | V |
| AVDD-DVDD | | | -100 | | +100 | mV |
| Cable Resistance | $R_{CABLE}$ | Per lead | | | 40 | kΩ |
| Input Logic 0 | $V_{IL}$ | | | | 0.8 | V |
| Input Logic 1 | $V_{IH}$ | | 2.1 | | | V |

## Electrical Characteristics

(3.0V ≤ $V_{DD}$ ≤ 3.6V, $T_A$ = -55°C to +125°C, unless otherwise noted.)(Notes 2, 3, and 4)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Supply Current | $I_{DD}$ | Standby | | 5.25 | 10 | µA |
| | | Active conversion | | 1.2 | 2 | mA |
| Thermocouple Temperature Resolution | | | | 19 | | Bits |
| | | | | 0.0078125 | | °C |
| Cold-Junction Temperature Data Resolution | | | | 0.015625 | | °C |
| Thermocouple Input Bias Current | $I_{TCBIAS}$ | $T_A$ = +25°C | -10 | | +10 | nA |
| | | $T_A$ = -40°C to +85°C | -10 | | +65 | |
| | | $T_A$ = -55°C to +105°C | -20 | | +110 | |
| | | $T_A$ = -55°C to +125°C | -20 | | +400 | |

## Electrical Characteristics (continued)

($3.0V \le V_{DD} \le 3.6V$, $T_A$ = -55°C to +125°C, unless otherwise noted.)(Notes 2, 3, and 4)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Thermocouple Input Differential Bias Current (Note 4) | $I_{TCIDBIAS}$ | $T_A$ = +25°C | | ±0.2 | | nA |
| | | $T_A$ = -40°C to +85°C | -4 | | +4 | |
| | | $T_A$ = -55°C to +105°C | -5.5 | | +5.5 | |
| | | $T_A$ = -55°C to +125°C | -10 | | +10 | |
| Input-Referred Noise | $V_N$ | AV = 8 | | 1.3 | | $\mu V_{RMS}$ |
| | | AV = 32 | | 0.4 | | |
| Power-Supply Rejection | PSR | Cold-junction sensor | | 0.15 | | °C/V |
| Power-On-Reset Voltage Threshold | $V_{POR}$ | | | 2.7 | 2.85 | V |
| Power-On-Reset Voltage Hysteresis | $V_{HYST}$ | | | 0.1 | | V |
| Bias Voltage | $V_{BIAS}$ | | | 0.735 | | V |
| BIAS Output Resistance | $R_{BIAS}$ | | | 2 | | kΩ |
| Input Common-Mode Range | | | 0.5 | | 1.4 | V |
| Full-Scale and INL Error (Note 6) | | $T_A$ = +25°C | -0.05 | | +0.05 | %FS |
| | | $T_A$ = -20°C to +85°C | -0.15 | | +0.15 | |
| | | $T_A$ = -40°C to +105°C | -0.2 | | +0.2 | |
| | | $T_A$ = -40°C to +125°C | -0.3 | | +0.3 | |
| | | $T_A$ = -55°C to +125°C | -0.35 | | +0.35 | |
| Input Offset Voltage (Note 7) | | $T_A$ = +25°C | -0.01 | | +0.01 | %FS |
| | | $T_A$ = -20°C to +85°C | -0.015 | | +0.015 | |
| | | $T_A$ = -40°C to +105°C | -0.017 | | +0.017 | |
| | | $T_A$ = -55°C to +125°C | -0.02 | | +0.02 | |
| Input Offset Voltage | | AV = 8, $T_A$ = +25°C | -7.8 | | +7.8 | µV |
| | | AV = 8, $T_A$ = -20°C to +85°C | -11.7 | | +11.7 | |
| | | AV = 8, $T_A$ = -40°C to +105°C | -13.3 | | +13.3 | |
| | | AV = 8, $T_A$ = -55°C to +125°C | -15.6 | | +15.6 | |
| | | AV = 32, $T_A$ = +25°C | -2.0 | | +2.0 | |
| | | AV = 32, $T_A$ = -20°C to +85°C | -2.9 | | +2.9 | |
| | | AV = 32, $T_A$ = -40°C to +105°C | -3.3 | | +3.3 | |
| | | AV = 32, $T_A$ = -55°C to +125°C | -3.9 | | +3.9 | |
| Cold-Junction Temperature Error | | $T_A$ = -20°C to +85°C | -0.7 | | +0.7 | °C |
| | | $T_A$ = -40°C to +105°C | -1 | | +1 | |
| | | $T_A$ = -55°C to +125°C | -2 | | +2 | |
| Overvoltage Rising Threshold (Note 8) | | | $V_{AVDD}$ − 0.1 | $V_{AVDD}$ + 0.17 | $V_{AVDD}$ + 0.35 | V |
| Overvoltage Hysteresis | | | | 0.09 | | V |

## Electrical Characteristics (continued)

($3.0V \leq V_{DD} \leq 3.6V$, $T_A$ = -55°C to +125°C, unless otherwise noted.)(Notes 2, 3, and 4)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Undervoltage Falling Edge Threshold (Note 8) | | | -0.3 | -0.17 | 0 | V |
| Undervoltage Hysteresis | | | | 0.09 | | V |
| Thermocouple Linearity Correction Error | | Type B, $T_A$ = 0 to 125°C, $T_{TC}$ = 95°C to +1798°C | -0.24 | | +0.25 | °C |
| | | Type E, $T_A$ = -55°C to +125°C $T_{TC}$ = -200°C to +1000°C | -0.14 | | +0.06 | |
| | | Type J, $T_A$ = -55°C to +125°C $T_{TC}$ = -210°C to +1200°C | -0.11 | | +0.10 | |
| | | Type K, $T_A$ = -55°C to +125°C $T_{TC}$ = -200°C to +1372°C | -0.13 | | +0.12 | |
| | | Type N, $T_A$ = -55°C to +125°C $T_{TC}$ = -200°C to +1300°C | -0.09 | | +0.08 | |
| | | Type R, $T_A$ = -50°C to +125°C $T_{TC}$ = -50°C to +1768°C | -0.19 | | +0.17 | |
| | | Type S, $T_A$ = -50°C to +125°C $T_{TC}$ = -50°C to +1768°C | -0.16 | | +0.20 | |
| | | Type T, $T_A$ = -55°C to +125°C $T_{TC}$ = -200°C to +400°C | -0.07 | | +0.07 | |
| Temperature Conversion Time (Thermocouple + Cold Junction) | $t_{CONV}$ | 1-Shot conversion or first conversion in auto-conversion mode (60Hz) | | 143 | 155 | ms |
| | | 1-Shot conversion or first conversion in auto-conversion mode (50Hz) | | 169 | 185 | |
| | | Auto conversion mode, conversions 2 through n (60Hz) | | 82 | 90 | |
| | | Auto conversion mode, conversions 2 through n (50Hz) | | 98 | 110 | |

MAX31856 Precision Thermocouple to Digital Converter with Linearization

## Electrical Characteristics (continued)

($3.0V \leq V_{DD} \leq 3.6V$, $T_A$ = -55°C to +125°C, unless otherwise noted.)(Notes 2, 3, and 4)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Common-Mode Rejection | CMR | $0.5V \leq V_{CM} \leq 1.4V$ | | 70 | | dB |
| 50/60Hz Noise Rejection | | Fundamental and harmonics | | 91 | | dB |
| **SERIAL INTERFACE** | | | | | | |
| Input Leakage Current | $I_{LEAK}$ | (Note 5) | -1 | | +1 | µA |
| Output High Voltage | $V_{OH}$ | $I_{OUT}$ = -1.6mA | $V_{CC}$ - 0.4 | | | V |
| Output Low Voltage | $V_{OL}$ | $I_{OUT}$ = 1.6mA | | | 0.4 | V |
| Input Capacitance | $C_{IN}$ | | | 8 | | pF |
| Serial Clock Frequency | $f_{SCL}$ | | | | 5 | MHz |
| SCK Pulse High Width | $t_{CH}$ | | 100 | | | ns |
| SCK Pulse Low Width | $t_{CL}$ | | 100 | | | ns |
| SCK Rise and Fall Time | $t_R$, $t_F$ | $C_L$ = 10pF | | | 200 | ns |
| $\overline{CS}$ Fall to SCK Rise | $t_{CC}$ | $C_L$ = 10pF | 100 | | | ns |
| SCK to $\overline{CS}$ Hold | $t_{CCH}$ | $C_L$ = 10pF | 100 | | | ns |
| $\overline{CS}$ Rise to Output Disable | $t_{CDZ}$ | $C_L$ = 10pF | | | 40 | ns |
| Data to SCLK Setup | $t_{DC}$ | | 35 | | | ns |
| SCLK to Data Hold | $t_{CDH}$ | | 35 | | | ns |
| SCK Fall to Output Data Valid | $t_{CDD}$ | $C_L$ = 10pF | | | 80 | ns |
| $\overline{CS}$ Inactive Time | $t_{CWH}$ | (Note 3) | 400 | | | ns |

**Note 2:** All voltages are referenced to GND. Currents entering the IC are specified positive, and currents exiting the IC are negative.
**Note 3:** All Serial Interface timing specifications are guaranteed by design.
**Note 4:** Specification is 100% tested at $T_A$ = +25°C. Specification limits over temperature ($T_A$ = $T_{MIN}$ to $T_{MAX}$) are guaranteed by design and characterization; not production tested.
**Note 5:** For all pins except T+ and T- (see the Thermocouple Input Bias Current parameter in the *Electrical Characteristics* table.
**Note 6:** Using a common-mode voltage other than $V_{BIAS}$ will change this specification. See the *Typical Operating Characteristics* for details.
**Note 7:** Input-referred full-scale voltage is 78.125mV when AV = 8 and is 19.531mV when AV = 32.
**Note 8:** Overvoltage and undervoltage limits apply to T+, T-, and BIAS pins.

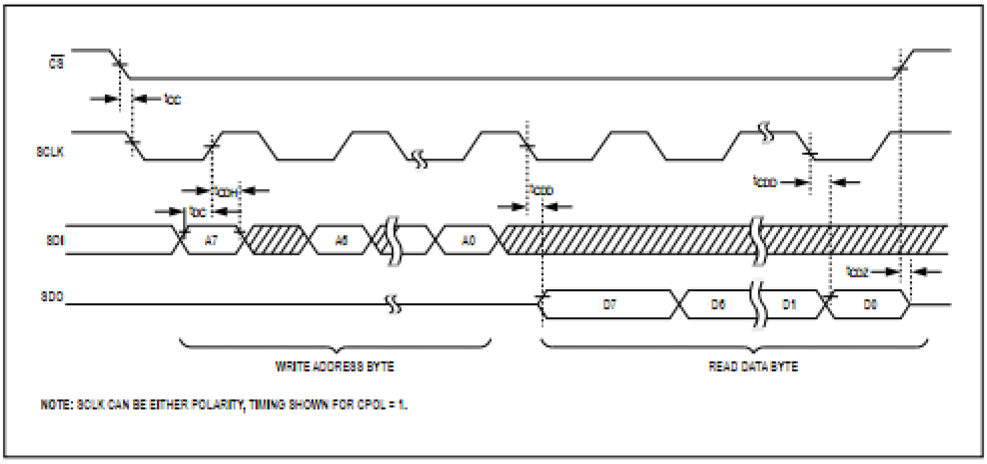



*Figure 1. Timing Diagram: SPI Read Data Transfer*

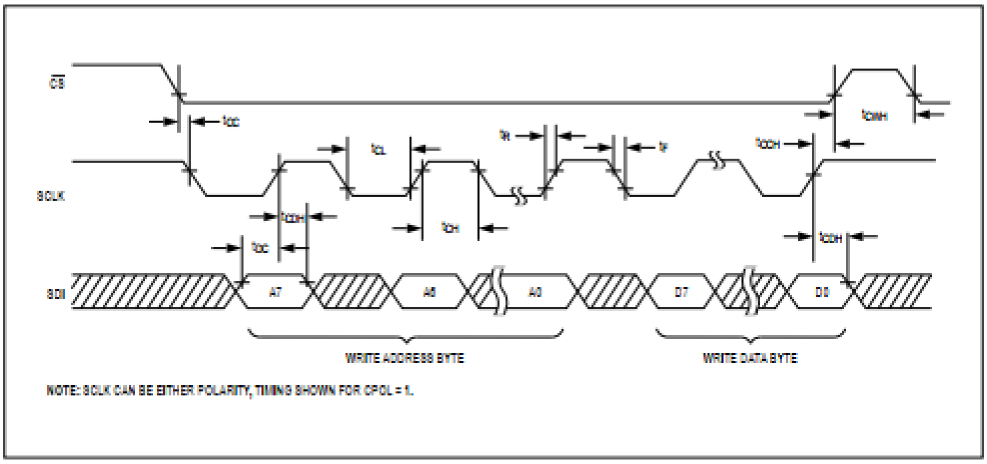
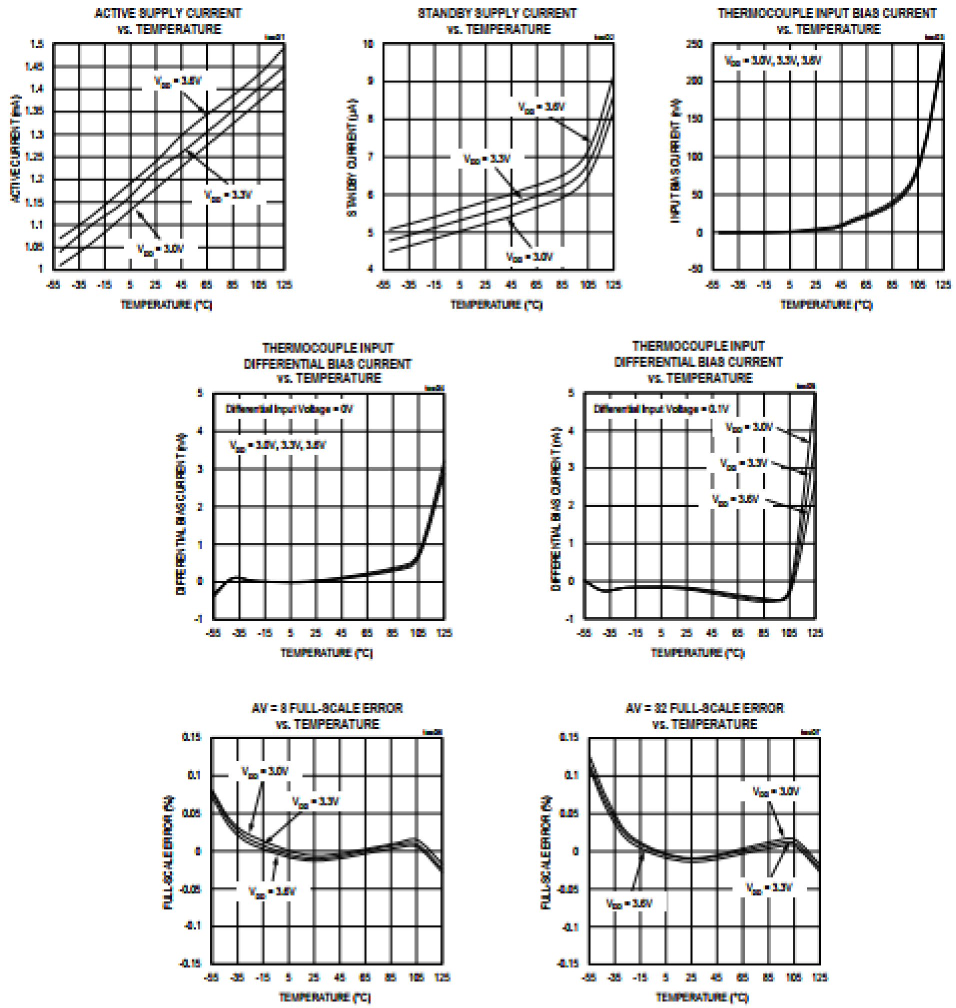



*Figure 2. Timing Diagram: SPI Write Data Transfer*

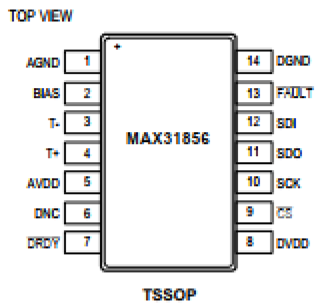
## Typical Operating Characteristics

($V_{CC}$ = 3.3V and $T_A$ = +25°C, unless otherwise noted.)



MAX31856 Precision Thermocouple to Digital Converter with Linearization

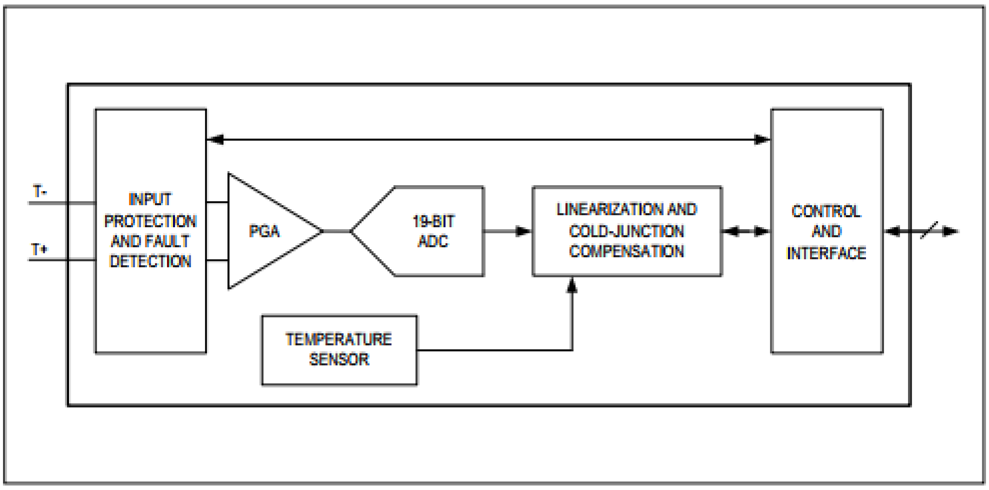
## Pin Configuration




## Pin Description

| PIN | NAME | FUNCTION |
|---|---|---|
| 1 | AGND | Analog Ground |
| 2 | BIAS | Bias Voltage Source. Nominally 0.735V. This pin is floating when no conversions are taking place. |
| 3 | T- | Thermocouple Negative Input. See Table 1. |
| 4 | T+ | Thermocouple Positive Input. See Table 1. |
| 5 | AVDD | Analog Positive Supply. Bypass with a 0.1µF capacitor to AGND. |
| 6 | DNC | Do Not Connect |
| 7 | DRDY | Data Ready Output |
| 8 | DVDD | Digital Positive Supply. Bypass with a 0.1µF capacitor to DGND. |
| 9 | CS | Chip Select. Set CS low to enable the serial interface. |
| 10 | SCK | Serial Clock Input |
| 11 | SDO | Serial Data Output |
| 12 | SDI | Serial Data Input |
| 13 | FAULT | Cable, thermocouple, or temperature fault output |
| 14 | DGND | Digital Ground |

## Block Diagram




## Detailed Description

The MAX31856 is a sophisticated thermocouple-to-digital converter with a built-in 19-bit analog-to-digital converter (ADC). Internal functions include correction for thermocouple nonlinearity, input protection, cold-junction compensation sensing and correction, a digital controller, a SPI-compatible interface, and associated control logic.

In the simplest configuration, the thermocouple wires connect directly to inputs T- and T+, with a common-mode bias voltage provided by the BIAS output. Additional filtering and/or protection components may be added if needed, as discussed in the *Applications Information* section. Operation is controlled by two configuration bytes and four bytes that contain over- and undertemperature detection thresholds.

### Temperature Conversion

The temperature conversion process consists of five steps as described in the sections below. The input amplifier and ADC amplify and digitize the thermocouple's voltage output. The internal temperature sensor measures the cold-junction temperature. Using the internal lookup table (LUT), the ADC code corresponding to the cold-junction temperature for the selected thermocouple type is determined. The thermocouple code and the cold-junction code are summed to produce the code corresponding to the cold-junction compensated thermocouple temperature. Finally, the LUT is used to produce a cold-junction compensated output code in units of °C.

### Thermocouple Voltage Conversion

T+ and T- are the thermocouple inputs. T- is biased to approximately 0.735V by the BIAS output. The amplifier provides gain to the μV- and mV-level thermocouple signals to make the amplitude appropriate for the ADC's full-scale input range. Two amplifier gains provide full-scale input ranges of ±78.125mV and ±19.531mV to accommodate higher- and lower-sensitivity thermocouples.

Because long thermocouple wires may pick up noise from a variety of sources, including AC power cables, the amplified signal is lowpass filtered before being applied to the ADC. The ADC provides further digital lowpass and notch filtering to attenuate input noise. The notch frequencies are either 50Hz and its harmonics or 60Hz and its harmonics, selectable using bit 0 of the Configuration 0 register (00h). In addition, bits D6:4 of the Configuration 1 register (01h) enable an averaging mode that provides additional filtering with an associated increase in conversion time. 2, 4, 8, or 16 samples may be averaged using this mode.

The conversion mode can be either continuous or "normally off", as selected by bit 7 of the Configuration 0 register (00h). When in the normally off mode, a single "1-shot" conversion may be selected using bit 6 of the Configuration 0 register (00h).

Thermocouple type is user-selectable using bits D3:0 of the Configuration 1 register (01h). Thermocouple types K, J, N, R, S, T, B, and E are supported by automatic cold-junction compensation and linearization. (To use a different thermocouple type, use bits D3:0 to select a gain of either 8 or 32. The linearization and cold-junction compensation calculations may then be done externally using the cold-junction temperature and thermocouple voltage data.)

### Cold-Junction Temperature Sensing

The function of the thermocouple is to sense a difference in temperature between two ends of the thermocouple wires. The thermocouple's sensing junction (often called the "hot" junction regardless of its temperature) can be measured across its rated operating temperature range (see Table 1 for supported thermocouple temperature ranges).

Additional thermocouples are created where the thermocouple wires make contact with different metals, usually at a connector or at the point where they are soldered to a PCB (the "cold junction"). To compensate for the errors due to these additional thermocouples, the temperature at the cold junction must be measured. This is done with the internal precision temperature sensor, which has accuracy better than ±0.7°C from -20°C to +85°C. By placing the MAX31856 near the cold junction, the cold-junction temperature can be measured and used to compensate for cold-junction effects.

The MAX31856 stores the cold-junction temperature data in registers 0Ah and 0Bh. When the cold-junction temperature sensor is enabled, these registers are read-only and contain the measured cold-junction temperature plus the value in the Cold-Junction Offset register. Reading the register with the cold-junction temperature sensor enabled will reset the $\overline{DRDY}$ pin high. Both bytes of this register should be read as a multibyte transfer to ensure both bytes are from the same temperature update. When the cold-junction temperature sensor is disabled, these registers become read-write registers that contain the most recent measured temperature value. If desired, data from an external temperature sensor may be written to these registers when the internal cold-junction sensor is disabled. The maximum cold-junction temperature is clamped at 128°C and the minimum is clamped at -64°C. See Table 2 for the Reference Junction (Cold Junction) Temperature Data Format.

If desired, a temperature offset may be written to the Cold-Junction Offset register (09h). The value stored in registers 0Ah and 0Bh will then be equal to the measured

**Table 1. Supported Thermocouples and Temperature Ranges**

| TYPE | T- WIRE | T+ WIRE | TEMP RANGE | NOMINAL SENSITIVITY (µV/°C) | COLD-JUNCTION TEMP RANGE |
|---|---|---|---|---|---|
| B | Platinum/Rhodium | Platinum/Rhodium | 250°C to 1820°C | 10.086 (+500°C to +1500°C) | 0 to 125°C |
| E | Constantan | Chromel | -200°C to +1000°C | 76.373 (0°C to +1000°C) | -55°C to +125°C |
| J | Constantan | Iron | -210°C to +1200°C | 57.953 (0°C to + 750°C) | -55°C to +125°C |
| K | Alumel | Chromel | -200°C to +1372°C | 41.276 (0°C to + 1000°C) | -55°C to +125°C |
| N | Nisil | Nicrosil | -200°C to +1300°C | 36.256 (0°C to +1000°C) | -55°C to +125°C |
| R | Platinum | Platinum/Rhodium | -50°C to +1768°C | 10.506 (0°C to +1000°C) | -50°C to +125°C |
| S | Platinum | Platinum/Rhodium | -50°C to +1768°C | 9.587 (0°C to +1000°C) | -50°C to +125°C |
| T | Constantan | Copper | -200°C to +400°C | 52.18 (0°C to +400°C) | -55°C to +125°C |

MAX31856 Precision Thermocouple to Digital Converter with Linearization

**Register 00h/80h: Configuration 0 Register (CR0) (continued)**

| BIT | NAME | DESCRIPTION |
|---|---|---|
| 7 | CMODE | Conversion Mode<br>0 = Normally Off mode (default)<br>1 = Automatic Conversion mode. Conversions occur continuously every 100ms (nominal). |
| 6 | 1SHOT | One-Shot Mode<br>0 = No conversions requested (default)<br>1 = This causes a single cold-junction and thermocouple conversion to take place when Conversion Mode bit =0 (normally off mode). The conversion is triggered when CS goes high after writing a 1 to this bit. Note that if a multi-byte write is performed, the conversion is triggered when CS goes high at the end of the transaction. A single conversion requires approximately 143ms in 60Hz filter mode or 169ms in 50Hz filter mode to complete. This bit self clears to 0. |
| 5:4 | OCFAULT[1:0] | These bits enable/disable open-circuit fault detection and select fault detection timing.<br>See *Open-Circuit Fault Detection* section and Table 4 for operation of these bits. |
| 3 | CJ | Cold-Junction Sensor Disable<br>0 = Cold-junction temperature sensor enabled (default)<br>1 = Cold-junction temperature sensor disabled. Data from an external temperature sensor may be written to the cold-junction temperature register. When this bit changes from 0 to 1, the most recent cold-junction temperature value will remain in the cold-junction temperature register until the internal sensor is enabled or until a new value is written to the register. The overall temperature conversion time is reduced by 25ms (typ) when this bit is set to 1. |
| 2 | FAULT | Fault Mode<br>0 = Comparator Mode. The FAULT output and respective fault bit reflects the state of any non-masked faults by asserting when the fault condition is true, and deasserting when the fault condition is no longer true. There is a 2°C hysteresis when in comparator mode for threshold fault conditions. (default)<br>1 = Interrupt Mode. The FAULT output and respective fault bit asserts when a non-masked fault condition is true and remain asserted until a 1 is written to the Fault Status Clear bit. This deasserts FAULT and respective fault bit until a new fault is detected (note that this may occur immediately if the fault condition is still in place). |
| 1 | FAULTCLR | Fault Status Clear<br>0 = Default<br>1 = When in interrupt mode, returns all Fault Status bits [7:0] in the Fault Status Register (0Fh) to 0 and deasserts the FAULT output. This bit has no effect in comparator mode. Note that the FAULT output and the fault bit may reassert immediately if the fault persists. To prevent the FAULT output from reasserting, first set the Fault Mask bits. The fault status clear bit self-clears to 0. |
| 0 | 50/60Hz | 50Hz/60Hz Noise Rejection Filter Selection<br>0= Selects rejection of 60Hz and its harmonics (default)<br>1= Selects rejection of 50Hz and its harmonics<br>**Note:** Change the notch frequency only while in the "Normally Off" mode – not in the Automatic Conversion mode. |

**Register 01h/81h: Configuration 1 Register (CR1)**

The Configuration 1 register selects the averaging time for the thermocouple voltage conversion averaging mode and also selects the thermocouple type being monitored.

Default Value: 03h

| MEMORY ACCESS | N/A | R/W | R/W | R/W | R/W | R/W | R/W | R/W |
|---|---|---|---|---|---|---|---|---|
| 01h/81h | Reserved | $AVGSEL_2$ | $AVGSEL_1$ | $AVGSEL_0$ | TC $TYPE_3$ | TC $TYPE_2$ | TC $TYPE_1$ | TC $TYPE_0$ |
| | Bit 7 | | | | | | | Bit 0 |

| BIT | NAME | DESCRIPTION |
|---|---|---|
| 7 | Reserved | Reserved. |
| 6:4 | AVGSEL[2:0] | Thermocouple Voltage Conversion Averaging Mode<br>000 = 1 sample (default)<br>001 = 2 samples averaged<br>010 = 4 samples averaged<br>011 = 8 samples averaged<br>1xx = 16 samples averaged<br>Adding samples increases the conversion time and reduces noise.<br>Typical conversion times:<br>1-shot or first conversion in Auto mode:<br>= $t_{CONV}$ + (samples -1) x 33.33mS (60Hz rejection)<br>= $t_{CONV}$ + (samples -1) x 40mS (50Hz rejection)<br>2 thru n conversions in Auto mode<br>= $t_{CONV}$ + (samples -1) x 16.67mS (60Hz rejection)<br>= $t_{CONV}$ + (samples -1) x 20mS (50Hz rejection)<br><br>The Thermocouple Voltage Conversion Averaging Mode settings should not be changed while conversions are taking place. |
| 3:0 | TC TYPE[3:0] | Thermocouple Type<br>0000 = B Type<br>0001 = E Type<br>0010 = J Type<br>0011 = K Type (default)<br>0100 = N Type<br>0101 = R Type<br>0110 = S Type<br>0111 = T Type<br>10xx = Voltage Mode, Gain = 8. Code = 8 x 1.6 x $2^{17}$ x $V_{IN}$<br>11xx = Voltage Mode, Gain = 32. Code = 32 x 1.6 x $2^{17}$ x $V_{IN}$<br>Where Code is 19 bit signed number from TC registers and $V_{IN}$ is thermocouple input voltage |

**Register 02h/82h: Fault Mask Register (MASK)**

The Fault Mask Register allows the user to mask faults from causing the FAULT output from asserting. Masked faults will still result in fault bits being set in the Fault Status register (0Fh). Note that the FAULT output is never asserted by thermocouple and cold-junction out-of-range status.

Default Value: FFh

| MEMORY ACCESS | N/A | N/A | R/W | R/W | R/W | R/W | R/W | R/W |
|---|---|---|---|---|---|---|---|---|
| 02h/82h | Reserved | Reserved | CJ High FAULT Mask | CJ Low FAULT Mask | TC High FAULT Mask | TC Low FAULT Mask | OV/UV FAULT Mask | Open FAULT Mask |
| | Bit 7 | | | | | | | Bit 0 |

| BIT | NAME | DESCRIPTION |
|---|---|---|
| 7:6 | Reserved | Reserved. |
| 5 | CJ High FAULT Mask | Cold-Junction High Fault Threshold Mask<br>0 = FAULT output asserted when the Cold-Junction Temperature rises above the Cold-Junction Temperature high threshold limit value<br>1 = FAULT output masked (default) |
| 4 | CJ Low FAULT Mask | Cold-Junction Low Fault Threshold Mask<br>0 = FAULT output asserted when the Cold-Junction Temperature falls below the Cold-Junction Temperature low threshold limit value<br>1 = FAULT output masked (default) |
| 3 | TC High FAULT Mask | Thermocouple Temperature High Fault Threshold Mask<br>0 = FAULT output asserted when the Thermocouple Temperature rises above the Thermocouple Temperature high threshold limit value<br>1 = FAULT output masked (default) |
| 2 | TC Low FAULT Mask | Thermocouple Temperature Low Fault Threshold Mask<br>0 = FAULT output asserted when the Thermocouple Temperature falls below the Thermocouple Temperature low threshold limit value<br>1 = FAULT output masked (default) |
| 1 | OV/UV FAULT Mask | Over-voltage or Undervoltage Input Fault Mask<br>0 = FAULT output asserted when an over- or undervoltage condition is detected<br>1 = FAULT output masked (default) |
| 0 | Open FAULT Mask | Thermocouple Open-Circuit Fault Mask<br>0 = FAULT output asserted when a thermocouple open condition is detected<br>1 = FAULT output masked (default) |

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# ANEXO 2. LIBRERÍAS

En este apartado se exponen las librerías utilizadas en el código puesto que están modificadas.

## 2.1. MLX90614

A continuación, se expone la librería del sensor de temperatura por infrarrojos

### *2.1.1. MLX90614.h*

```
/***************************************************
This is a library for the MLX90614 Temp Sensor

Designed specifically to work with the MLX90614 sensors in the
adafruit shop
----> https://www.adafruit.com/products/1748
----> https://www.adafruit.com/products/1749

These sensors use I2C to communicate, 2 pins are required to
interface
Adafruit invests time and resources providing this open source code,
please support Adafruit and open-source hardware by purchasing
products from Adafruit!

Written by Limor Fried/Ladyada for Adafruied in any redistribution
****************************************************/


#if (ARDUINO >= 100)
#include "Arduino.h"
#else
#include "WProgram.h"
#endif
#include "Wire.h"


#define MLX90614_I2CADDR 0x5A

// RAM
```

```
#define MLX90614_RAWIR1 0x04
#define MLX90614_RAWIR2 0x05
#define MLX90614_TA 0x06
#define MLX90614_TOBJ1 0x07
#define MLX90614_TOBJ2 0x08
// EEPROM
#define MLX90614_TOMAX 0x20
#define MLX90614_TOMIN 0x21
#define MLX90614_PWMCTRL 0x22
#define MLX90614_TARANGE 0x23
#define MLX90614_EMISS 0x24
#define MLX90614_CONFIG 0x25
#define MLX90614_ADDR 0x0E
#define MLX90614_ID1 0x3C
#define MLX90614_ID2 0x3D
#define MLX90614_ID3 0x3E
#define MLX90614_ID4 0x3F


class Adafruit_MLX90614 {
public:
Adafruit_MLX90614(uint8_t addr = MLX90614_I2CADDR);
boolean begin();
uint32_t readID(void);

double readObjectTempC(void);
double readAmbientTempC(void);
double readObjectTempF(void);
double readAmbientTempF(void);

private:
float readTemp(uint8_t reg);

uint8_t _addr;
uint16_t read16(uint8_t addr);
void write16(uint8_t addr, uint16_t data);
};
```

### 2.1.2. MLX90614.cpp

```
/***************************************************
This is a library for the MLX90614 Temp Sensor

Designed specifically to work with the MLX90614 sensors in the
adafruit shop
----> https://www.adafruit.com/products/1748
----> https://www.adafruit.com/products/1749

These sensors use I2C to communicate, 2 pins are required to
interface
Adafruit invests time and resources providing this open source code,
please support Adafruit and open-source hardware by purchasing
products from Adafruit!

Written by Limor Fried/Ladyada for Adafruit Industries.
BSD license, all text above must be included in any redistribution
****************************************************/

#include "Adafruit_MLX90614.h"

Adafruit_MLX90614::Adafruit_MLX90614(uint8_t i2caddr) {
_addr = i2caddr;
}


boolean Adafruit_MLX90614::begin(void) {
Wire.begin();

/*
for (uint8_t i=0; i<0x20; i++) {
Serial.print(i); Serial.print(" = ");
Serial.println(read16(i), HEX);
}
*/
```

```
return true;
}

//////////////////////////////////////////////////////


double Adafruit_MLX90614::readObjectTempF(void) {
return (readTemp(MLX90614_TOBJ1) * 9 / 5) + 32;
}


double Adafruit_MLX90614::readAmbientTempF(void) {
return (readTemp(MLX90614_TA) * 9 / 5) + 32;
}

double Adafruit_MLX90614::readObjectTempC(void) {
return readTemp(MLX90614_TOBJ1);
}


double Adafruit_MLX90614::readAmbientTempC(void) {
return readTemp(MLX90614_TA);
}

float Adafruit_MLX90614::readTemp(uint8_t reg) {
float temp;

temp = read16(reg);
temp*= .02;
temp-= 273.15;
return temp;
}

/*********************************************************************/

uint16_t Adafruit_MLX90614::read16(uint8_t a) {
uint16_t ret;

```

```
Wire.beginTransmission(_addr); // start transmission to device
Wire.write(a); // sends register address to read from
Wire.endTransmission(false); // end transmission

Wire.requestFrom(_addr, (uint8_t)3);// send data n-bytes read
ret= Wire.read(); // receive DATA
ret |= Wire.read() << 8; // receive DATA

uint8_t pec = Wire.read();

return ret;
}

```

## 2.2. ADS1115

A continuación, se expone la librería del conversor analógico digital de 4 canales diferenciales ADS1115.

### 2.2.1. ADS1115.h

```
s // I2Cdev library collection - ADS1115 I2C device class header file
// Based on Texas Instruments ADS1113/4/5 datasheet, May 2009 (SBAS444B, revised October 2009)
// Note that the ADS1115 uses 16-bit registers, not 8-bit registers.
// 8/2/2011 by Jeff Rowberg <jeff@rowberg.net>
// Updates should (hopefully) always be available at https://github.com/jrowberg/i2cdevlib
//
// Changelog:
// 2013-05-05 - Add debug information. Clean up Single Shot implementation
// 2011-10-29 - added getDifferentialx() methods, F. Farzanegan
// 2011-08-02 - initial release


/* ============================================
I2Cdev device library code is placed under the MIT license
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furnished to do so, subject to the following conditions:

```

```
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LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN
THE SOFTWARE.
===============================================
*/

#ifndef _ADS1115_H_
#define _ADS1115_H_

#include "I2Cdev.h"

// -----------------------------------------------------------------------------
// Arduino-style "Serial.print" debug constant (uncomment to enable)
// -----------------------------------------------------------------------------
//#define ADS1115_SERIAL_DEBUG

#define ADS1115_ADDRESS_ADDR_GND 0x48 // address pin low (GND)
#define ADS1115_ADDRESS_ADDR_VDD 0x49 // address pin high (VCC)
#define ADS1115_ADDRESS_ADDR_SDA 0x4A // address pin tied to SDA pin
#define ADS1115_ADDRESS_ADDR_SCL 0x4B // address pin tied to SCL pin
#define ADS1115_DEFAULT_ADDRESS ADS1115_ADDRESS_ADDR_GND

#define ADS1115_RA_CONVERSION 0x00
#define ADS1115_RA_CONFIG 0x01
#define ADS1115_RA_LO_THRESH 0x02
#define ADS1115_RA_HI_THRESH 0x03

#define ADS1115_CFG_OS_BIT 15
#define ADS1115_CFG_MUX_BIT 14
#define ADS1115_CFG_MUX_LENGTH 3
#define ADS1115_CFG_PGA_BIT 11
#define ADS1115_CFG_PGA_LENGTH 3
#define ADS1115_CFG_MODE_BIT 8
#define ADS1115_CFG_DR_BIT 7
#define ADS1115_CFG_DR_LENGTH 3
#define ADS1115_CFG_COMP_MODE_BIT 4
#define ADS1115_CFG_COMP_POL_BIT 3
#define ADS1115_CFG_COMP_LAT_BIT 2
#define ADS1115_CFG_COMP_QUE_BIT 1
#define ADS1115_CFG_COMP_QUE_LENGTH 2


#define ADS1115_MUX_P0_N1 0x00 // default
#define ADS1115_MUX_P0_N3 0x01
#define ADS1115_MUX_P1_N3 0x02
#define ADS1115_MUX_P2_N3 0x03
#define ADS1115_MUX_P0_NG 0x04
#define ADS1115_MUX_P1_NG 0x05
#define ADS1115_MUX_P2_NG 0x06
```

```
#define ADS1115_MUX_P3_NG 0x07

#define ADS1115_PGA_6P144 0x00
#define ADS1115_PGA_4P096 0x01
#define ADS1115_PGA_2P048 0x02 // default
#define ADS1115_PGA_1P024 0x03
#define ADS1115_PGA_0P512 0x04
#define ADS1115_PGA_0P256 0x05
#define ADS1115_PGA_0P256B 0x06
#define ADS1115_PGA_0P256C 0x07

#define ADS1115_MV_6P144 0.187500
#define ADS1115_MV_4P096 0.125000
#define ADS1115_MV_2P048 0.062500 // default
#define ADS1115_MV_1P024 0.031250
#define ADS1115_MV_0P512 0.015625
#define ADS1115_MV_0P256 0.007813
#define ADS1115_MV_0P256B 0.007813
#define ADS1115_MV_0P256C 0.007813

#define ADS1115_MODE_CONTINUOUS 0x00
#define ADS1115_MODE_SINGLESHOT 0x01 // default

#define ADS1115_RATE_8 0x00
#define ADS1115_RATE_16 0x01
#define ADS1115_RATE_32 0x02
#define ADS1115_RATE_64 0x03
#define ADS1115_RATE_128 0x04 // default
#define ADS1115_RATE_250 0x05
#define ADS1115_RATE_475 0x06
#define ADS1115_RATE_860 0x07

#define ADS1115_COMP_MODE_HYSTERESIS 0x00 // default
#define ADS1115_COMP_MODE_WINDOW 0x01

#define ADS1115_COMP_POL_ACTIVE_LOW 0x00 // default
#define ADS1115_COMP_POL_ACTIVE_HIGH 0x01

#define ADS1115_COMP_LAT_NON_LATCHING 0x00 // default
#define ADS1115_COMP_LAT_LATCHING 0x01

#define ADS1115_COMP_QUE_ASSERT1 0x00
#define ADS1115_COMP_QUE_ASSERT2 0x01
#define ADS1115_COMP_QUE_ASSERT4 0x02
#define ADS1115_COMP_QUE_DISABLE 0x03 // default

// -----------------------------------------------------------------------------
// Arduino-style "Serial.print" debug constant (uncomment to enable)
// -----------------------------------------------------------------------------
//#define ADS1115_SERIAL_DEBUG


class ADS1115 {
public:
ADS1115();
ADS1115(uint8_t address);

```

```
void initialize();
bool testConnection();
// SINGLE SHOT utilities
bool pollConversion(uint16_t max_retries);
void triggerConversion();
// Read the current CONVERSION register

int16_t getConversion(bool triggerAndPoll=true);
// Differential

int16_t getConversionP0N1();
int16_t getConversionP0N3();
int16_t getConversionP1N3();
int16_t getConversionP2N3();
// Single-ended

int16_t getConversionP0GND();
int16_t getConversionP1GND();
int16_t getConversionP2GND();
int16_t getConversionP3GND();
// Utility

getMilliVolts(bool triggerAndPoll=true);
getMvPerCount();


// CONFIG register
bool isConversionReady();
uint8_t getMultiplexer();
void setMultiplexer(uint8_t mux);
uint8_t getGain();
void setGain(uint8_t gain);
bool getMode();
void setMode(bool mode);
uint8_t getRate();
void setRate(uint8_t rate);
bool getComparatorMode();
void setComparatorMode(bool mode);
bool getComparatorPolarity();
void setComparatorPolarity(bool polarity);
bool getComparatorLatchEnabled();
void setComparatorLatchEnabled(bool enabled);
```

```
uint8_t getComparatorQueueMode();
void setComparatorQueueMode(uint8_t mode);
void setConversionReadyPinMode();
// *_THRESH registers
int16_t getLowThreshold();
void setLowThreshold(int16_t threshold);
int16_t getHighThreshold();
void setHighThreshold(int16_t threshold);
// DEBUG
void showConfigRegister();
private:
uint8_t devAddr;
uint16_t buffer[2];
bool devMode;
uint8_t muxMode;
uint8_t pgaMode;
};
#endif /* _ADS1115_H_ */
```

### 2.2.2. ADS1115.cpp

```
// I2Cdev library collection - ADS1115 I2C device class
// Based on Texas Instruments ADS1113/4/5 datasheet, May 2009 (SBAS444B, revised October 2009)
// Note that the ADS1115 uses 16-bit registers, not 8-bit registers.
// 8/2/2011 by Jeff Rowberg <jeff@rowberg.net>
// Updates should (hopefully) always be available at https://github.com/jrowberg/i2cdevlib
//
// Changelog:
// 2013-05-05 - Add debug information. Rename methods to match datasheet.
// 2011-11-06 - added getVoltage, F. Farzanegan
// 2011-10-29 - added getDifferentialx() methods, F. Farzanegan
// 2011-08-02 - initial release
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copies of the Software, and to permit persons to whom the Software is
furnished to do so, subject to the following conditions:
```

```

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LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING
FROM,
OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN
THE SOFTWARE.
===============================================
*/

#include "ADS1115.h"

/** Default constructor, uses default I2C address.
* @see ADS1115_DEFAULT_ADDRESS
*/
ADS1115::ADS1115() {
devAddr = ADS1115_DEFAULT_ADDRESS;
}

/** Specific address constructor.
* @param address I2C address
* @see ADS1115_DEFAULT_ADDRESS
* @see ADS1115_ADDRESS_ADDR_GND
* @see ADS1115_ADDRESS_ADDR_VDD
* @see ADS1115_ADDRESS_ADDR_SDA
* @see ADS1115_ADDRESS_ADDR_SDL
*/
ADS1115::ADS1115(uint8_t address) {
= address;

/** Power on and prepare for general usage.
* This device is ready to use automatically upon power-up. It defaults to
* single-shot read mode, P0/N1 mux, 2.048v gain, 128 samples/sec, default
* comparator with hysterysis, active-low polarity, non-latching comparator,
* and comparater-disabled operation.
*/
void ADS1115::initialize() {
setMultiplexer(ADS1115_MUX_P0_N1);
setGain(ADS1115_PGA_2P048);
setMode(ADS1115_MODE_SINGLESHOT);
setRate(ADS1115_RATE_128);
setComparatorMode(ADS1115_COMP_MODE_HYSTERESIS);
setComparatorPolarity(ADS1115_COMP_POL_ACTIVE_LOW);
setComparatorLatchEnabled(ADS1115_COMP_LAT_NON_LATCHING);
```

```
setComparatorQueueMode(ADS1115_COMP_QUE_DISABLE);
}

/** Verify the I2C connection.
* Make sure the device is connected and responds as expected.
* @return True if connection is valid, false otherwise
*/
bool ADS1115::testConnection() {
return I2Cdev::readWord(devAddr, ADS1115_RA_CONVERSION, buffer) == 1;
}

/** Poll the operational status bit until the conversion is finished
* Retry at most 'max_retries' times
* conversion is finished, then return true;
* @see ADS1115_CFG_OS_BIT
* @return True if data is available, false otherwise
*/
bool ADS1115::pollConversion(uint16_t max_retries) {
for(uint16_t i = 0; i < max_retries; i++) {
if (isConversionReady()) return true;
}
return false;
}

/** Read differential value based on current MUX configuration.
* The default MUX setting sets the device to get the differential between the
* AIN0 and AIN1 pins. There are 8 possible MUX settings, but if you are using
* all four input pins as single-end voltage sensors, then the default option is
* not what you want; instead you will need to set the MUX to compare the
* desired AIN* pin with GND. There are shortcut methods (getConversion*) to do
* this conveniently, but you can also do it manually with setMultiplexer()
* followed by this method.
*
* In single-shot mode, this register may not have fresh data. You need to write
* a 1 bit to the MSB of the CONFIG register to trigger a single read/conversion
* before this will be populated with fresh data. This technique is not as
* effortless, but it has enormous potential to save power by only running the
* comparison circuitry when needed.
```

```
*
* @param triggerAndPoll If true (and only in singleshot mode) the conversion trigger
* will be executed and the conversion results will be polled.
* @return 16-bit signed differential value
* @see getConversionP0N1();
* @see getConversionPON3();
* @see getConversionP1N3();
* @see getConversionP2N3();
* @see getConversionP0GND();
* @see getConversionP1GND();
* @see getConversionP2GND();
* @see getConversionP3GND);
* @see setMultiplexer();
* @see ADS1115_RA_CONVERSION
* @see ADS1115_MUX_P0_N1
* @see ADS1115_MUX_P0_N3
* @see ADS1115_MUX_P1_N3
* @see ADS1115_MUX_P2_N3
* @see ADS1115_MUX_P0_NG
* @see ADS1115_MUX_P1_NG
* @see ADS1115_MUX_P2_NG
* @see ADS1115_MUX_P3_NG
*/
int16_t ADS1115::getConversion(bool triggerAndPoll) {
if (triggerAndPoll && devMode == ADS1115_MODE_SINGLESHOT) {
triggerConversion();
pollConversion(I2CDEV_DEFAULT_READ_TIMEOUT);
}
I2Cdev::readWord(devAddr, ADS1115_RA_CONVERSION, buffer);
return buffer[0];
}
/** Get AIN0/N1 differential.
* This changes the MUX setting to AIN0/N1 if necessary, triggers a new
* measurement (also only if necessary), then gets the differential value
* currently in the CONVERSION register.
* @return 16-bit signed differential value
* @see getConversion()
*/
```

```
ADS1115::getConversionP0N1() {
(muxMode != ADS1115_MUX_P0_N1) setMultiplexer(ADS1115_MUX_P0_N1);
return getConversion();
}

/** Get AIN0/N3 differential.
* This changes the MUX setting to AIN0/N3 if necessary, triggers a new
* measurement (also only if necessary), then gets the differential value
* currently in the CONVERSION register.
* @return 16-bit signed differential value
* @see getConversion()
*/
ADS1115::getConversionP0N3() {
(muxMode != ADS1115_MUX_P0_N3) setMultiplexer(ADS1115_MUX_P0_N3);
return getConversion();
/** Get AIN1/N3 differential.
* This changes the MUX setting to AIN1/N3 if necessary, triggers a new
* measurement (also only if necessary), then gets the differential value
* currently in the CONVERSION register.
* @return 16-bit signed differential value
* @see getConversion()
*/
ADS1115::getConversionP1N3() {
(muxMode != ADS1115_MUX_P1_N3) setMultiplexer(ADS1115_MUX_P1_N3);
return getConversion();
}

/** Get AIN2/N3 differential.
* This changes the MUX setting to AIN2/N3 if necessary, triggers a new
* measurement (also only if necessary), then gets the differential value
* currently in the CONVERSION register.
* @return 16-bit signed differential value
* @see getConversion()
*/
ADS1115::getConversionP2N3() {
(muxMode != ADS1115_MUX_P2_N3) setMultiplexer(ADS1115_MUX_P2_N3);
return getConversion();
```

```
}

/** Get AIN0/GND differential.
* This changes the MUX setting to AIN0/GND if necessary, triggers a new
* measurement (also only if necessary), then gets the differential value
* currently in the CONVERSION register.
* @return 16-bit signed differential value
* @see getConversion()
*/
int16_t ADS1115::getConversionP0GND() {
if (muxMode != ADS1115_MUX_P0_NG) setMultiplexer(ADS1115_MUX_P0_NG);
return getConversion();
}
/** Get AIN1/GND differential.
* This changes the MUX setting to AIN1/GND if necessary, triggers a new
* measurement (also only if necessary), then gets the differential value
* currently in the CONVERSION register.
* @return 16-bit signed differential value
* @see getConversion()
*/

ADS1115::getConversionP1GND() {
(muxMode != ADS1115_MUX_P1_NG) setMultiplexer(ADS1115_MUX_P1_NG);
return getConversion();
}
/** Get AIN2/GND differential.
* This changes the MUX setting to AIN2/GND if necessary, triggers a new
* measurement (also only if necessary), then gets the differential value
* currently in the CONVERSION register.
* @return 16-bit signed differential value
* @see getConversion()
*/
int16_t ADS1115::getConversionP2GND() {
if (muxMode != ADS1115_MUX_P2_NG) setMultiplexer(ADS1115_MUX_P2_NG);
return getConversion();
}
/** Get AIN3/GND differential.
* This changes the MUX setting to AIN3/GND if necessary, triggers a new
* measurement (also only if necessary), then gets the differential value
```

```
 * currently in the CONVERSION register.
 * @return 16-bit signed differential value
 * @see getConversion()
 */

ADS1115::getConversionP3GND() {
(muxMode != ADS1115_MUX_P3_NG) setMultiplexer(ADS1115_MUX_P3_NG);
return getConversion();
}

/** Get the current voltage reading
 * Read the current differential and return it multiplied
 * by the constant for the current gain. mV is returned to
 * increase the precision of the voltage
 * @param triggerAndPoll If true (and only in singleshot mode) the conversion trigger
 * will be executed and the conversion results will be polled.
 */
float ADS1115::getMilliVolts(bool triggerAndPoll) {

(pgaMode) {
ADS1115_PGA_6P144:

(getConversion(triggerAndPoll) * ADS1115_MV_6P144);
case ADS1115_PGA_4P096:

(getConversion(triggerAndPoll) * ADS1115_MV_4P096);
case ADS1115_PGA_2P048:

(getConversion(triggerAndPoll) * ADS1115_MV_2P048);
case ADS1115_PGA_1P024:

(getConversion(triggerAndPoll) * ADS1115_MV_1P024);
case ADS1115_PGA_0P512:

(getConversion(triggerAndPoll) * ADS1115_MV_0P512);

ADS1115_PGA_0P256:
ADS1115_PGA_0P256B:
ADS1115_PGA_0P256C:

(getConversion(triggerAndPoll) * ADS1115_MV_0P256);
}
}
```

```
/**
* Return the current multiplier for the PGA setting.
*
* This may be directly retreived by using getMilliVolts(),
* but this causes an independent read. This function could
* be used to average a number of reads from the getConversion()
* getConversionx() functions and cut downon the number of
* floating-point calculations needed.
*
*/

float ADS1115::getMvPerCount() {

(pgaMode) {
ADS1115_PGA_6P144:

ADS1115_MV_6P144;
case ADS1115_PGA_4P096:
return ADS1115_MV_4P096;
break;
case ADS1115_PGA_2P048:
return ADS1115_MV_2P048;
break;
case ADS1115_PGA_1P024:
return ADS1115_MV_1P024;
break;
case ADS1115_PGA_0P512:

ADS1115_MV_0P512;

ADS1115_PGA_0P256:
ADS1115_PGA_0P256B:
ADS1115_PGA_0P256C:

ADS1115_MV_0P256;
}

// CONFIG register

/** Get operational status.
* @return Current operational status (false for active conversion, true for inactive)
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_OS_BIT
```

```
*/
bool ADS1115::isConversionReady() {
I2Cdev::readBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_OS_BIT, buffer);
return buffer[0];
}
/** Trigger a new conversion.
* Writing to this bit will only have effect while in power-down mode (no conversions active).
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_OS_BIT
*/
void ADS1115::triggerConversion() {
I2Cdev::writeBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_OS_BIT, 1);
}
/** Get multiplexer connection.
* @return Current multiplexer connection setting
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_MUX_BIT
* @see ADS1115_CFG_MUX_LENGTH
*/
uint8_t ADS1115::getMultiplexer() {
I2Cdev::readBitsW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_MUX_BIT, ADS1115_CFG_MUX_LENGTH, buffer);
muxMode = (uint8_t)buffer[0];
return muxMode;
}
/** Set multiplexer connection. Continous mode may fill the conversion register
* with data before the MUX setting has taken effect. A stop/start of the conversion
* is done to reset the values.
* @param mux New multiplexer connection setting
* @see ADS1115_MUX_P0_N1
* @see ADS1115_MUX_P0_N3
* @see ADS1115_MUX_P1_N3
* @see ADS1115_MUX_P2_N3
* @see ADS1115_MUX_P0_NG
* @see ADS1115_MUX_P1_NG
* @see ADS1115_MUX_P2_NG
* @see ADS1115_MUX_P3_NG
```

```
 * @see ADS1115_RA_CONFIG
 * @see ADS1115_CFG_MUX_BIT
 * @see ADS1115_CFG_MUX_LENGTH
 */
void ADS1115::setMultiplexer(uint8_t mux) {
if (I2Cdev::writeBitsW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_MUX_BIT,
ADS1115_CFG_MUX_LENGTH, mux)) {
muxMode = mux;
if (devMode == ADS1115_MODE_CONTINUOUS) {
// Force a stop/start
setMode(ADS1115_MODE_SINGLESHOT);
getConversion();
setMode(ADS1115_MODE_CONTINUOUS);
}
}

}
/** Get programmable gain amplifier level.
 * @return Current programmable gain amplifier level
 * @see ADS1115_RA_CONFIG
 * @see ADS1115_CFG_PGA_BIT
 * @see ADS1115_CFG_PGA_LENGTH
 */
uint8_t ADS1115::getGain() {
I2Cdev::readBitsW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_PGA_BIT,
ADS1115_CFG_PGA_LENGTH, buffer);
pgaMode=(uint8_t)buffer[0];
return pgaMode;
}
/** Set programmable gain amplifier level.
 * Continous mode may fill the conversion register
 * with data before the gain setting has taken effect. A stop/start of the conversion
 * is done to reset the values.
 * @param gain New programmable gain amplifier level
 * @see ADS1115_PGA_6P144
 * @see ADS1115_PGA_4P096
 * @see ADS1115_PGA_2P048
 * @see ADS1115_PGA_1P024
 * @see ADS1115_PGA_0P512
```

```
* @see ADS1115_PGA_0P256
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_PGA_BIT
* @see ADS1115_CFG_PGA_LENGTH
*/
void ADS1115::setGain(uint8_t gain) {
if (I2Cdev::writeBitsW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_PGA_BIT,
ADS1115_CFG_PGA_LENGTH, gain)) {
pgaMode = gain;
if (devMode == ADS1115_MODE_CONTINUOUS) {
// Force a stop/start
setMode(ADS1115_MODE_SINGLESHOT);
getConversion();
setMode(ADS1115_MODE_CONTINUOUS);
}
}
}
/** Get device mode.
* @return Current device mode
* @see ADS1115_MODE_CONTINUOUS
* @see ADS1115_MODE_SINGLESHOT
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_MODE_BIT
*/
bool ADS1115::getMode() {
I2Cdev::readBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_MODE_BIT, buffer);
devMode = buffer[0];
return devMode;
}
/** Set device mode.
* @param mode New device mode
* @see ADS1115_MODE_CONTINUOUS
* @see ADS1115_MODE_SINGLESHOT
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_MODE_BIT
*/
void ADS1115::setMode(bool mode) {
if (I2Cdev::writeBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_MODE_BIT, mode)) {
```

```
devMode = mode;
}
}
/** Get data rate.
* @return Current data rate
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_DR_BIT
* @see ADS1115_CFG_DR_LENGTH
*/
uint8_t ADS1115::getRate() {
I2Cdev::readBitsW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_DR_BIT, ADS1115_CFG_DR_LENGTH, buffer);
return (uint8_t)buffer[0];
}
/** Set data rate.
* @param rate New data rate
* @see ADS1115_RATE_8
* @see ADS1115_RATE_16
* @see ADS1115_RATE_32
* @see ADS1115_RATE_64
* @see ADS1115_RATE_128
* @see ADS1115_RATE_250
* @see ADS1115_RATE_475
* @see ADS1115_RATE_860
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_DR_BIT
* @see ADS1115_CFG_DR_LENGTH
*/
void ADS1115::setRate(uint8_t rate) {
I2Cdev::writeBitsW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_DR_BIT, ADS1115_CFG_DR_LENGTH, rate);
}
/** Get comparator mode.
* @return Current comparator mode
* @see ADS1115_COMP_MODE_HYSTERESIS
* @see ADS1115_COMP_MODE_WINDOW
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_COMP_MODE_BIT
*/
```

```
bool ADS1115::getComparatorMode() {
I2Cdev::readBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_COMP_MODE_BIT, buffer);
return buffer[0];
}
/** Set comparator mode.
* @param mode New comparator mode
* @see ADS1115_COMP_MODE_HYSTERESIS
* @see ADS1115_COMP_MODE_WINDOW
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_COMP_MODE_BIT
*/
void ADS1115::setComparatorMode(bool mode) {
I2Cdev::writeBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_COMP_MODE_BIT, mode);
}
/** Get comparator polarity setting.
* @return Current comparator polarity setting
* @see ADS1115_COMP_POL_ACTIVE_LOW
* @see ADS1115_COMP_POL_ACTIVE_HIGH
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_COMP_POL_BIT
*/
bool ADS1115::getComparatorPolarity() {
I2Cdev::readBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_COMP_POL_BIT, buffer);
return buffer[0];
}
/** Set comparator polarity setting.
* @param polarity New comparator polarity setting
* @see ADS1115_COMP_POL_ACTIVE_LOW
* @see ADS1115_COMP_POL_ACTIVE_HIGH
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_COMP_POL_BIT
*/
void ADS1115::setComparatorPolarity(bool polarity) {
I2Cdev::writeBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_COMP_POL_BIT, polarity);
}
/** Get comparator latch enabled value.
* @return Current comparator latch enabled value
* @see ADS1115_COMP_LAT_NON_LATCHING
```

```
 * @see ADS1115_COMP_LAT_LATCHING
 * @see ADS1115_RA_CONFIG
 * @see ADS1115_CFG_COMP_LAT_BIT
 */
bool ADS1115::getComparatorLatchEnabled() {
I2Cdev::readBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_COMP_LAT_BIT, buffer);
return buffer[0];
}
/** Set comparator latch enabled value.
 * @param enabled New comparator latch enabled value
 * @see ADS1115_COMP_LAT_NON_LATCHING
 * @see ADS1115_COMP_LAT_LATCHING
 * @see ADS1115_RA_CONFIG
 * @see ADS1115_CFG_COMP_LAT_BIT
 */
void ADS1115::setComparatorLatchEnabled(bool enabled) {
I2Cdev::writeBitW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_COMP_LAT_BIT, enabled);
}
/** Get comparator queue mode.
 * @return Current comparator queue mode
 * @see ADS1115_COMP_QUE_ASSERT1
 * @see ADS1115_COMP_QUE_ASSERT2
 * @see ADS1115_COMP_QUE_ASSERT4
 * @see ADS1115_COMP_QUE_DISABLE
 * @see ADS1115_RA_CONFIG
 * @see ADS1115_CFG_COMP_QUE_BIT
 * @see ADS1115_CFG_COMP_QUE_LENGTH
 */
uint8_t ADS1115::getComparatorQueueMode() {
I2Cdev::readBitsW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_COMP_QUE_BIT, ADS1115_CFG_COMP_QUE_LENGTH, buffer);
return (uint8_t)buffer[0];
}
/** Set comparator queue mode.
 * @param mode New comparator queue mode
 * @see ADS1115_COMP_QUE_ASSERT1
 * @see ADS1115_COMP_QUE_ASSERT2
 * @see ADS1115_COMP_QUE_ASSERT4
 * @see ADS1115_COMP_QUE_DISABLE
```

```
* @see ADS1115_RA_CONFIG
* @see ADS1115_CFG_COMP_QUE_BIT
* @see ADS1115_CFG_COMP_QUE_LENGTH
*/
void ADS1115::setComparatorQueueMode(uint8_t mode) {
I2Cdev::writeBitsW(devAddr, ADS1115_RA_CONFIG, ADS1115_CFG_COMP_QUE_BIT,
ADS1115_CFG_COMP_QUE_LENGTH, mode);
}

// *_THRESH registers

/** Get low threshold value.
* @return Current low threshold value
* @see ADS1115_RA_LO_THRESH
*/
int16_t ADS1115::getLowThreshold() {
I2Cdev::readWord(devAddr, ADS1115_RA_LO_THRESH, buffer);
return buffer[0];
}
/** Set low threshold value.
* @param threshold New low threshold value
* @see ADS1115_RA_LO_THRESH
*/
void ADS1115::setLowThreshold(int16_t threshold) {
I2Cdev::writeWord(devAddr, ADS1115_RA_LO_THRESH, threshold);
}
/** Get high threshold value.
* @return Current high threshold value
* @see ADS1115_RA_HI_THRESH
*/
int16_t ADS1115::getHighThreshold() {
I2Cdev::readWord(devAddr, ADS1115_RA_HI_THRESH, buffer);
return buffer[0];
}
/** Set high threshold value.
* @param threshold New high threshold value
* @see ADS1115_RA_HI_THRESH
*/
```

```
void ADS1115::setHighThreshold(int16_t threshold) {
I2Cdev::writeWord(devAddr, ADS1115_RA_HI_THRESH, threshold);
}

/** Configures ALERT/RDY pin as a conversion ready pin.
* It does this by setting the MSB of the high threshold register to '1' and the MSB
* of the low threshold register to '0'. COMP_POL and COMP_QUE bits will be set to
'0'.
* Note: ALERT/RDY pin requires a pull up resistor.
*/
void ADS1115::setConversionReadyPinMode() {

ADS1115_RA_HI_THRESH, 15, 1);
ADS1115_RA_LO_THRESH, 15, 0);

}

// Create a mask between two bits
unsigned createMask(unsigned a, unsigned b) {
unsigned mask = 0;
for (unsigned i=a; i<=b; i++)
mask |= 1 << i;
return mask;


shiftDown(uint16_t extractFrom, int places) {
(extractFrom >> places);
}


uint16_t getValueFromBits(uint16_t extractFrom, int high, int length) {
int low= high-length +1;
uint16_t mask = createMask(low ,high);
return shiftDown(extractFrom & mask, low);
}

/** Show all the config register settings
*/
void ADS1115::showConfigRegister() {
```

```
I2Cdev::readWord(devAddr, ADS1115_RA_CONFIG, buffer);
uint16_t configRegister =buffer[0];

#ifdef ADS1115_SERIAL_DEBUG
Serial.print("Register is:");
Serial.println(configRegister,BIN);

Serial.print("OS:\t");
Serial.println(getValueFromBits(configRegister,
ADS1115_CFG_OS_BIT,1), BIN);
Serial.print("MUX:\t");
Serial.println(getValueFromBits(configRegister,
ADS1115_CFG_MUX_BIT,ADS1115_CFG_MUX_LENGTH), BIN);
Serial.print("PGA:\t");
Serial.println(getValueFromBits(configRegister,
ADS1115_CFG_PGA_BIT,ADS1115_CFG_PGA_LENGTH), BIN);
Serial.print("MODE:\t");
Serial.println(getValueFromBits(configRegister,
ADS1115_CFG_MODE_BIT,1), BIN);
Serial.print("DR:\t");
Serial.println(getValueFromBits(configRegister,
ADS1115_CFG_DR_BIT,ADS1115_CFG_DR_LENGTH), BIN);
Serial.print("CMP_MODE:\t");
Serial.println(getValueFromBits(configRegister,
ADS1115_CFG_COMP_MODE_BIT,1), BIN);
Serial.print("CMP_POL:\t");
Serial.println(getValueFromBits(configRegister,
ADS1115_CFG_COMP_POL_BIT,1), BIN);
Serial.print("CMP_LAT:\t");
Serial.println(getValueFromBits(configRegister,
ADS1115_CFG_COMP_LAT_BIT,1), BIN);
Serial.print("CMP_QUE:\t");
Serial.println(getValueFromBits(configRegister,
ADS1115_CFG_COMP_QUE_BIT,ADS1115_CFG_COMP_QUE_LENGTH), BIN);
#endif
};
```

## 2.3. MCP342X

En este apartado se presenta la librería del conversor analógico digital que se utiliza con el sensor de efecto hall

## *2.3.1. MCP342X.h*

```
#ifndef _MCP342X_H_
#define _MCP342X_H_

#ifdef ARDUINO
#if ARDUINO < 100
#include "WProgram.h"
#else
#include "Arduino.h"
#endif
#else
#include "ArduinoWrapper.h"
#endif

#include <Wire.h>

// I2C Address of device
// MCP3421, MCP3425 & MCP3426 are factory programed for any of 0x68 thru 0x6F
#define MCP342X_DEFAULT_ADDRESS 0x68

// MCP3422, MCP3423, MCP3424, MCP3427 & MCP3428 addresses are controlled by address lines A0 and A1
// each address line can be low (GND), high (VCC) or floating (FLT)
#define MCP342X_A0GND_A1GND 0x68
#define MCP342X_A0GND_A1FLT 0x69
#define MCP342X_A0GND_A1VCC 0x6A
#define MCP342X_A0FLT_A1GND 0x6B
#define MCP342X_A0VCC_A1GND 0x6C
#define MCP342X_A0VCC_A1FLT 0x6D
#define MCP342X_A0VCC_A1VCC 0x6E
#define MCP342X_A0FLT_A1VCC 0x6F


// Conversion mode definitions
#define MCP342X_MODE_ONESHOT 0x00
```

```
#define MCP342X_MODE_CONTINUOUS 0x10


// Channel definitions
// MCP3421 & MCP3425 have only the one channel and ignore this param
// MCP3422, MCP3423, MCP3426 & MCP3427 have two channels and treat 3 & 4 as repeats of 1 & 2 respectively
// MCP3424 & MCP3428 have all four channels
#define MCP342X_CHANNEL_1 0x00
#define MCP342X_CHANNEL_2 0x20
#define MCP342X_CHANNEL_3 0x40
#define MCP342X_CHANNEL_4 0x60
#define MCP342X_CHANNEL_MASK 0x60


// Sample size definitions - these also affect the sampling rate
// 12-bit has a max sample rate of 240sps
// 14-bit has a max sample rate of 60sps
// 16-bit has a max sample rate of 15sps
// 18-bit has a max sample rate of 3.75sps (MCP3421, MCP3422, MCP3423, MCP3424 only)
#define MCP342X_SIZE_12BIT 0x00
#define MCP342X_SIZE_14BIT 0x04
#define MCP342X_SIZE_16BIT 0x08
#define MCP342X_SIZE_18BIT 0x0C
#define MCP342X_SIZE_MASK 0x0C


// Programmable Gain definitions
#define MCP342X_GAIN_1X 0x00
#define MCP342X_GAIN_2X 0x01
#define MCP342X_GAIN_4X 0x02
#define MCP342X_GAIN_8X 0x03
#define MCP342X_GAIN_MASK 0x03


// /RDY bit definition
#define MCP342X_RDY 0x80

```

```

class MCP342X {
public:
MCP342X();
MCP342X(uint8_t address);

bool testConnection(void);

// Set/Get the configuration bits for the ADC
void configure(uint8_t config);
uint8_t getConfigRegShdw(void);
//float getStepSize(); // returns step size based on configRegShdw

// Start a conversion
bool startConversion(void);
bool startConversion(uint8_t channel);

// Read the ADC result
uint8_t getResult(int16_t *data);
uint8_t getResult(int32_t *data);

// Non-blocking Read the ADC result
uint8_t checkforResult(int16_t *data);
uint8_t checkforResult(int32_t *data);

private:
uint8_t devAddr;
uint8_t configRegShdw;
//float stepSizeTbl[];
};

#endif /* _MCP342X_H_ */

```

## 2.3.2. MCP342X.cpp

```
/**************************************************************************/
/*!
```

```
@license BSD (see license.txt)

This is part of an Arduino library to interface with the Microchip
MCP47X6 series of Analog-to-Digital converters which are connected
via the I2C bus.

MCP342X I2C device class
Based on Microchip datasheets for the following part numbers
MCP3421, MCP3422, MCP3423, MCP3424, MCP3425, MCP3426, MCP3427, MCP3428
These parts share a common programming interface

(c) Copyright 2013 by Chip Schnarel <schnarel@hotmail.com>
Updates should (hopefully) always be available at
https://github.com/uchip/MCP342X

@section HISTORY

2013-Dec-24 - First release, C. Schnarel
*/
/**************************************************************************/

#include "MCP342X.h"

/* static float stepSizeTbl[] = {

0.00003125, // 14-bit, 8X Gain
0.0000625, // 16-bit, 1X Gain
0.00003125, // 16-bit, 2X Gain

};
*/

/******************************************
* Default constructor, uses default I2C address.
* @see MCP342X_DEFAULT_ADDRESS
*/
MCP342X::MCP342X() {

= MCP342X_DEFAULT_ADDRESS;

```

```
/******************************************
* Specific address constructor.
* @param address I2C address
* @see MCP342X_DEFAULT_ADDRESS
* @see MCP342X_A0GND_A1GND, etc.
*/
MCP342X::MCP342X(uint8_t address) {
devAddr = address;
}


/******************************************
* Verify the I2C connection.
* Make sure the device is connected and responds as expected.
* @return True if connection is valid, false otherwise
*/
bool MCP342X::testConnection() {
Wire.beginTransmission(devAddr);
return (Wire.endTransmission() == 0);
}



/******************************************
* Set the configuration shadow register
*/
void MCP342X::configure(uint8_t configData) {
= configData;

/******************************************
* Get the configuration shadow register
*/
uint8_t MCP342X::getConfigRegShdw(void) {
return configRegShdw;
}


/******************************************
* Get the step size based on the configuration shadow register
*/
/*float MCP342X::getStepSize(void) {
```

Librerías

```
uint8_t select = configRegShdw & (MCP342X_SIZE_MASK | MCP342X_GAIN_MASK);
return stepSizeTbl[select];
}*/

/*****************************************
* Start a conversion using configuration settings from
* the shadow configuration register
*/
bool MCP342X::startConversion(void) {
Wire.beginTransmission(devAddr);
Wire.write(configRegShdw | MCP342X_RDY);
return (Wire.endTransmission() == 0);
}


/*****************************************
* Start a conversion using configuration settings from
* the shadow configuration register substituting the
* supplied channel
*/
bool MCP342X::startConversion(uint8_t channel) {
Wire.beginTransmission(devAddr);
configRegShdw = ((configRegShdw & ~MCP342X_CHANNEL_MASK) |
(channel & MCP342X_CHANNEL_MASK));
Wire.write(configRegShdw | MCP342X_RDY);
return (Wire.endTransmission() == 0);
}


/*****************************************
* Read the conversion value (12, 14 or 16 bit)
* Spins reading status until ready then
* fills in the supplied location with the 16-bit (two byte)
* conversion value and returns the status byte
* Note: status of -1 "0xFF' implies read error
*/
uint8_t MCP342X::getResult(int16_t *dataPtr) {
uint8_t adcStatus;
```

```
if((configRegShdw & MCP342X_SIZE_MASK) == MCP342X_SIZE_18BIT) {
return 0xFF;
}

do {
if(Wire.requestFrom(devAddr, (uint8_t) 3) == 3) {
((char*)dataPtr)[1] = Wire.read();
((char*)dataPtr)[0] = Wire.read();
adcStatus = Wire.read();
}
else return 0xFF;
} while((adcStatus & MCP342X_RDY) != 0x00);
return adcStatus;
}


/******************************************
* Check to see if the conversion value (12, 14 or 16 bit)
* is available. If so, then
* fill in the supplied location with the 16-bit (two byte)
* conversion value and status the config byte
* Note: status of -1 "0xFF' implies read error
*/
uint8_t MCP342X::checkforResult(int16_t *dataPtr) {
uint8_t adcStatus;
if((configRegShdw & MCP342X_SIZE_MASK) == MCP342X_SIZE_18BIT) {
return 0xFF;
}

if(Wire.requestFrom(devAddr, (uint8_t) 3) == 3) {
((char*)dataPtr)[1] = Wire.read();
((char*)dataPtr)[0] = Wire.read();
adcStatus = Wire.read();
}
else return 0xFF;
return adcStatus;
}

```

```

/******************************************
* Read the conversion value (18 bit)
* Spins reading status until ready then
* fills in the supplied location (32 bit) with
* the 24-bit (three byte) conversion value
* and returns the status byte
* Note: status of -1 "0xFF' implies read error
*/
uint8_t MCP342X::getResult(int32_t *dataPtr) {
uint8_t adcStatus;
if((configRegShdw & MCP342X_SIZE_MASK) != MCP342X_SIZE_18BIT) {
return 0xFF;
}

    do {
if(Wire.requestFrom((uint8_t) devAddr, (uint8_t) 4) == 4) {
((char*)dataPtr)[3] = Wire.read();
((char*)dataPtr)[2] = Wire.read();
((char*)dataPtr)[1] = Wire.read();
adcStatus = Wire.read();
}
else return 0xFF;
} while((adcStatus & MCP342X_RDY) != 0x00);
*dataPtr = (*dataPtr)>>8;
return adcStatus;
}


/******************************************
* Check to see if the conversion value (18 bit)
* is available. If so, then
* fill in the supplied location (32 bit) with
* the 24-bit (three byte) conversion value
* and return the status byte
* Note: status of -1 "0xFF' implies read error
*/
uint8_t MCP342X::checkforResult(int32_t *dataPtr) {
```

```
uint8_t adcStatus;
if((configRegShdw & MCP342X_SIZE_MASK) != MCP342X_SIZE_18BIT) {
return 0xFF;
}

if(Wire.requestFrom((uint8_t) devAddr, (uint8_t) 4) == 4) {
Wire.read();
Wire.read();
Wire.read();
adcStatus = Wire.read();
}
else return 0xFF;

*dataPtr = (*dataPtr)>>8;
return adcStatus;
}
```

## 2.4. MAX31856

Se expone la librería utilizada para programar el amplificador universal de termopares.

### *2.4.1. MAX 31856.h*

```
// This is a library for the Maxim MAX31856 thermocouple IC
// http://datasheets.maximintegrated.com/en/ds/MAX31856.pdf
//
// Written by Peter Easton (www.whizoo.com)
// Released under CC BY-SA 3.0 license
//
// Look for the MAX31856 breakout boards on www.whizoo.com and eBay (madeatrade)
// http://stores.ebay.com/madeatrade
//
```

```
// Looking to build yourself a reflow oven? It isn't that difficult to
// do! Take a look at the build guide here:
// http://www.whizoo.com
//
// Change History:
// 25 June 2015 Initial Version
// 31 July 2015 Fixed spelling and formatting problems

#ifndef MAX31856_H
#define MAX31856_H

#include "Arduino.h"

// MAX31856 Registers
// Register 0x00: CR0
#define CR0_AUTOMATIC_CONVERSION 0x80
#define CR0_ONE_SHOT 0x40
#define CR0_OPEN_CIRCUIT_FAULT_TYPE_K 0x10 // Type-K is 10 to 20 Ohms
#define CR0_COLD_JUNCTION_DISABLED 0x08
#define CR0_FAULT_INTERRUPT_MODE 0x04
#define CR0_FAULT_CLEAR 0x02
#define CR0_NOISE_FILTER_50HZ 0x01
// Register 0x01: CR1
#define CR1_AVERAGE_1_SAMPLE 0x00
#define CR1_AVERAGE_2_SAMPLES 0x10
#define CR1_AVERAGE_4_SAMPLES 0x20
#define CR1_AVERAGE_8_SAMPLES 0x30
#define CR1_AVERAGE_16_SAMPLES 0x40
#define CR1_THERMOCOUPLE_TYPE_B 0x00
#define CR1_THERMOCOUPLE_TYPE_E 0x01
#define CR1_THERMOCOUPLE_TYPE_J 0x02
#define CR1_THERMOCOUPLE_TYPE_K 0x03
#define CR1_THERMOCOUPLE_TYPE_N 0x04
#define CR1_THERMOCOUPLE_TYPE_R 0x05
#define CR1_THERMOCOUPLE_TYPE_S 0x06
#define CR1_THERMOCOUPLE_TYPE_T 0x07
#define CR1_VOLTAGE_MODE_GAIN_8 0x08
#define CR1_VOLTAGE_MODE_GAIN_32 0x0C
```

```
// Register 0x02: MASK
#define MASK_COLD_JUNCTION_HIGH_FAULT 0x20
#define MASK_COLD_JUNCTION_LOW_FAULT 0x10
#define MASK_THERMOCOUPLE_HIGH_FAULT 0x08
#define MASK_THERMOCOUPLE_LOW_FAULT 0x04
#define MASK_VOLTAGE_UNDER_OVER_FAULT 0x02
#define MASK_THERMOCOUPLE_OPEN_FAULT 0x01
// Register 0x0F: SR
#define SR_FAULT_COLD_JUNCTION_OUT_OF_RANGE 0x80
#define SR_FAULT_THERMOCOUPLE_OUT_OF_RANGE 0x40
#define SR_FAULT_COLD_JUNCTION_HIGH 0x20
#define SR_FAULT_COLD_JUNCTION_LOW 0x10
#define SR_FAULT_THERMOCOUPLE_HIGH 0x08
#define SR_FAULT_THERMOCOUPLE_LOW 0x04
#define SR_FAULT_UNDER_OVER_VOLTAGE 0x02
#define SR_FAULT_OPEN 0x01
// Set/clear MSB of first byte sent to indicate write or read
#define READ_OPERATION(x) (x & 0x7F)
#define WRITE_OPERATION(x) (x | 0x80)
// Register numbers
#define REGISTER_CR0 0
#define REGISTER_CR1 1
#define REGISTER_MASK 2
#define NUM_REGISTERS 12 // (read/write registers)

// Errors
#define FAULT_OPEN 10000 // No thermocouple
#define FAULT_VOLTAGE 10001 // Under/over voltage error. Wrong thermocouple type?
#define NO_MAX31856 10002 // MAX31856 not communicating or not connected
#define IS_MAX31856_ERROR(x) (x == FAULT_OPEN && x <= NO_MAX31856)
#define CELSIUS 0
#define FAHRENHEIT 1


class MAX31856
{
public:
```

```
MAX31856(int, int, int, int); // SDI, SDO, CS, CLK (DRDY and FAULT are not used)

void writeRegister(byte, byte);
double readThermocouple(byte unit);
double readJunction(byte unit);
private:
long readData();
void writeByte(byte);
double verifyMAX31856();
int _sdi, _sdo, _cs, _clk;
byte _registers[NUM_REGISTERS]; // Shadow registers. Registers can be restored if power to MAX31855 is lost
};
#endif // MAX31856_H

```

## 2.4.2. MAX 31856.cpp

```


//
// Written by Peter Easton (www.whizoo.com)
// Released under CC BY-SA 3.0 license
//
// Look for the MAX31856 breakout boards on www.whizoo.com and eBay (madeatrade)
// http://stores.ebay.com/madeatrade
//
// Looking to build yourself a reflow oven? It isn't that difficult to
// do! Take a look at the build guide here:
// http://www.whizoo.com
//
// Library Implementation Details
```

```
// ==============================
// DRDY and FAULT lines are not used in this driver. DRDY is useful for low-power mode so samples are only taken when
// needed; this driver assumes power isn't an issue. The FAULT line can be used to generate an interrupt in the host
// processor when a fault occurs. This library reads the fault register every time a reading is taken, and will
// return a fault error if there is one. The MAX31856 has sophisticated usage scenarios involving FAULT. For
// example, low and high temperature limits can be set, and the FAULT line triggers when these temperatures are
// breached. This is beyond the scope of this sample library. The assumption is that most applications will be
// polling for temperature readings - but it is good to know these features are supported by the hardware.
//
// The MAX31856 differs from earlier thermocouple IC's in that it has registers that must be configured before
// readings can be taken. This makes it very flexible and powerful, but one concern is power loss to the IC. The IC
// should be as close to the cold junction as possible, which might mean there is a cable connecting the breakout
// board to the host processor. If this cable is disconnected and reconnected (MAX31856 loses power) then the
// registers must be reinitialized. This library detects this condition and will automatically reconfigure the
// registers. This simplifies the software running on the host.
//
// A lot of configuration options appear in the .H file. Of particular note is the line frequency filtering, which
// defaults to 60Hz (USA and others). If your line voltage is 50Hz you should set CR0_NOISE_FILTER_50HZ.
//
// This library handles the full range of temperatures, including negative temperatures.
//
//
// Change History:
// 25 June 2015 Initial Version
```

```
// 31 July 2015 Fixed spelling and formatting problems
#include "MAX31856.h"
// Define which pins are connected to the MAX31856. The DRDY and FAULT outputs
// from the MAX31856 are not used in this library.
MAX31856::MAX31856(int sdi, int sdo, int cs, int clk)
{
_sdi = sdi;
_sdo = sdo;
_cs = cs;
pinMode(_sdi, OUTPUT);
pinMode(_cs, OUTPUT);
pinMode(_clk, OUTPUT);
// Use a pullup on the data line to be able to detect "no communication"
pinMode(_sdo, INPUT_PULLUP);
// Default output pins state
digitalWrite(_cs, HIGH);
digitalWrite(_clk, HIGH);
// Set up the shadow registers with the default values
byte reg[NUM_REGISTERS] = {0x00,0x03,0xff,0x7f,0xc0,0x7f,0xff,0x80,0,0,0,0};
for (int i=0; i<NUM_REGISTERS; i++)
_registers[i] = reg[i];
}
// Write the given data to the MAX31856 register
void MAX31856::writeRegister(byte registerNum, byte data)
{
// Sanity check on the register number
if (registerNum >= NUM_REGISTERS)
return;
```

```
// Select the MAX31856 chip
digitalWrite(_cs, LOW);

// Write the register number, with the MSB set to indicate a write
writeByte(WRITE_OPERATION(registerNum));

// Write the register value
writeByte(data);

// Deselect MAX31856 chip
digitalWrite(_cs, HIGH);

// Save the register value, in case the registers need to be restored
_registers[registerNum] = data;
}


// Read the thermocouple temperature either in Degree Celsius or Fahrenheit. Internally,
// the conversion takes place in the background within 155 ms, or longer depending on the
// number of samples in each reading (see CR1).
// Returns the temperature, or an error (FAULT_OPEN, FAULT_VOLTAGE or NO_MAX31856)
double MAX31856::readThermocouple(byte unit)
{
double temperature;
long data;

// Select the MAX31856 chip
digitalWrite(_cs, LOW);
// Read data starting with register 0x0c
writeByte(READ_OPERATION(0x0c));
// Read 4 registers
data = readData();
// Deselect MAX31856 chip
digitalWrite(_cs, HIGH);
// If there is no communication from the IC then data will be all 1's because
// of the internal pullup on the data line (INPUT_PULLUP)
```

```
if (data == 0xFFFFFFFF)
return NO_MAX31856;
// If the value is zero then the temperature could be exactly 0.000 (rare), or
// the IC's registers are uninitialized.
if (data == 0 && verifyMAX31856() == NO_MAX31856)
return NO_MAX31856;
// Was there an error?
if (data & SR_FAULT_OPEN)
temperature = FAULT_OPEN;
else if (data & SR_FAULT_UNDER_OVER_VOLTAGE)
temperature = FAULT_VOLTAGE;
else {
// Strip the unused bits and the Fault Status Register

data = data >> 13;
// Negative temperatures have been automagically handled by the shift above
:-)


// Convert to Celsius
temperature = (double) data * 0.0078125;
// Convert to Fahrenheit if desired
if (unit == FAHRENHEIT)
temperature = (temperature * 9.0/5.0)+ 32;
}
// Return the temperature
return (temperature);
}



// Read the junction (IC) temperature either in Degree Celsius or Fahrenheit.
// This routine also makes sure that communication with the MAX31856 is working and
// will return NO_MAX31856 if not.
double MAX31856::readJunction(byte unit)
{
double temperature;
long data, temperatureOffset;

// Select the MAX31856 chip
digitalWrite(_cs, LOW);
```

```
// Read data starting with register 8
writeByte(READ_OPERATION(8));

// Read 4 registers
data = readData();
// Deselect MAX31856 chip
digitalWrite(_cs, HIGH);
// If there is no communication from the IC then data will be all 1's because
// of the internal pullup on the data line (INPUT_PULLUP)
if (data == 0xFFFFFFFF)
return NO_MAX31856;
// If the value is zero then the temperature could be exactly 0.000 (rare), or
// the IC's registers are uninitialized.
if (data == 0 && verifyMAX31856() == NO_MAX31856)
        return NO_MAX31856;
// Register 9 is the temperature offset
temperatureOffset = (data & 0x00FF0000) >> 16;

// Is this a negative number?
if (temperatureOffset & 0x80)
temperatureOffset |= 0xFFFFFF00;
// Strip registers 8 and 9, taking care of negative numbers
if (data & 0x8000)
data |= 0xFFFF0000;
else
data &= 0x0000FFFF;
// Remove the 2 LSB's - they aren't used
data = data >> 2;
// Add the temperature offset to the temperature
temperature = data + temperatureOffset;
// Convert to Celsius
temperature *= 0.015625;

// Convert to Fahrenheit if desired
if (unit == FAHRENHEIT)
```

```
temperature = (temperature * 9.0/5.0)+ 32;

        // Return the temperature
return (temperature);
}


// When the MAX31856 is uninitialzed and either the junction or thermocouple temperature is read it will return 0.
// This is a valid temperature, but could indicate that the registers need to be initialized.
double MAX31856::verifyMAX31856()
{
        long data, reg;
// Select the MAX31856 chip
digitalWrite(_cs, LOW);

// Read data starting with register 0


// If there is no communication from the IC then data will be all 1's because


NO_MAX31856;
// Are the registers set to their correct values?
reg = ((long)_registers[0]<<24) + ((long)_registers[1]<<16) + ((long)_registers[2]<<8) + _registers[3];
if (reg == data)
return 0;
// Communication to the IC is working, but the register values are not correct
// Select the MAX31856 chip
digitalWrite(_cs, LOW);
// Start writing from register 0
writeByte(WRITE_OPERATION(0));

```

```
// Write the register values
for (int i=0; i< NUM_REGISTERS; i++)
writeByte(_registers[i]);
// Deselect MAX31856 chip
digitalWrite(_cs, HIGH);
// For now, return an error but soon valid temperatures will be returned
return NO_MAX31856;
}


// Read in 32 bits of data from MAX31856 chip. Minimum clock pulse width is 100 ns
// so this could be made faster (using NOP). However, make sure it works on all
// microcontrollers
long MAX31856::readData()
{
long data = 0;
unsigned long bitMask = 0x80000000;

// Shift in 32 bits of data
while (bitMask)
{
digitalWrite(_clk, LOW);
delayMicroseconds(2);

// Store the data bit
if (digitalRead(_sdo))
data += bitMask;
digitalWrite(_clk, HIGH);
delayMicroseconds(2);

bitMask >>= 1;
}
return(data);
}


// Write out 8 bits of data to the MAX31856 chip. Minimum clock pulse width is 100 ns
// so this could be made faster (using NOP). However, make sure it works on all
```

```
// microcontrollers
void MAX31856::writeByte(byte data)
{
byte bitMask = 0x80;

// Shift out 8 bits of data
while (bitMask)

{
// Write out the data bit. Has to be held for 35ns
digitalWrite(_sdi, data & bitMask? HIGH: LOW);
digitalWrite(_clk, LOW);
delayMicroseconds(2);
digitalWrite(_clk, HIGH);
delayMicroseconds(2);
bitMask >>= 1;
}
}
```

# Relación de documentos

(_) Memoria ..........................................137 páginas

(X) Anexos ............................................119 páginas

La Almunia, a 27 de noviembre de 2019

Firmado: Igor Martos Iza