ESCUELA UNIVERSITARIA POLITÉCNICA

DE LA ALMUNIA DE DOÑA GODINA (ZARAGOZA)

ANEXOS

Banco de ensayos para regulador de motor brushless

424.16.25

Autor: Daniel Suñén Angós

Director: Jesús García Millán

Fecha: 29-11-2016

INDICE DE CONTENIDO

1. HEINZMANN PMS 150

1.1. DATASHEET

PERM Motor GmbH Im Brand 24/1 79677 Schönau	Datenblatt / Datasheet PMS Motoren / PGS Generatoren	PERM MOTOR Member of the HEINZMANN Group

Motor	PMS 150 - WB 340
Maschinentyp / Type	PMS 150
Luftspalt	2,1 mm
Betriebsart / Duty contition	S1 (100%)
Kühlung / cooling	Luftkühlung mit mind. 5 m/s - Air cooling with minimum 5 m/s

Nennleistung / Nominal Power [kW]	13,00	kW
Schaltung / Stator winding connection	Dreieck / Delta	
Spannung / Voltage [V AC]	64,87	V AC
Strom / Current [A rms]	149,5	A rms
Drehzahl / Speed [rpm]	6000	rpm
Drehmoment / Torque [Nm]	20,70	Nm
Spannungskonstante Ke (ph-ph) / Voltage constant ke (ph-ph) [V/1000 rpm]	9,133	V / 1000 rpm
Drehmomentkonstante / Torque constant [Nm/A]	0,1385	Nm / A
Polzahl / number of pole	8	
Frequenz / Frequenzy [Hz]	400	Hz
Wicklungswiderstand Ru-v bei 20°C / resistance at 20°C Ru-v	0,016	Ohm
Induktivität / inductance Lu-v [mH]	0,04633	mH

1.2. CURVA CARACTERÍSTICA

HEINZMANN®

PMS 150, ID 490

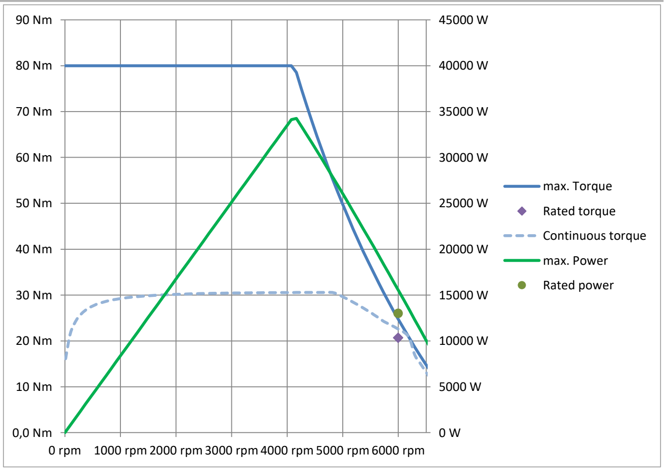
Torque-Speed Characteristic

2015-09-28

Motor data		
Motor		PMS 150
Motor ID		ID 490
Winding-No.		WB 340
Cooling		Air-cooled with at least 5m/s
DC link voltage	U_{dc}	96 V DC
Operational mode		S1
Rated motor voltage	U_n	66,6 V AC
Nominal Speed	n_n	6000 rpm
Rated torque	M_n	20,7 Nm
Rated power	P	13 kW
Rated AC current	I_n	143 A
Controller		-

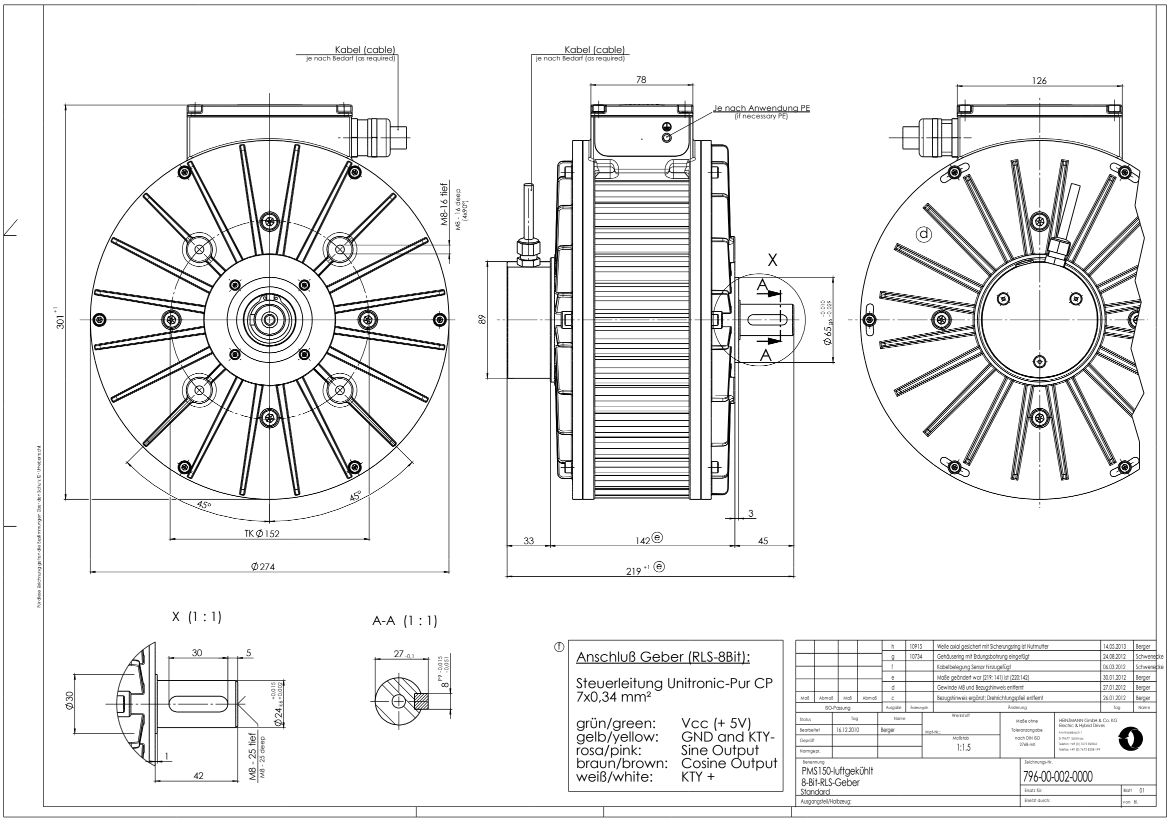
Please note

Operation points with a higher torque demand than the rated continuous torque are not suited for continuous operation (S1).



Heinzmann GmbH & Co. KG
Electric & Hybrid Drives
Am Haselbach 1 • D-79677 Schönau/Germany • Tel. +49 7673 8208 – 0 • Fax +49 7673 8208 - 799
E-Mail: info@heinzmann.de • www.heinzmann.com

1.3. PLANO MECÁNICO



1.4. SONDA DE TEMPERATURA. KTY84

KTY84 series

Silicon temperature sensors

Rev. 06 — 8 May 2008 — Product data sheet

1. Product profile

1.1 General description

The temperature sensors in the KTY84 series have a positive temperature coefficient of resistance and are suitable for use in measurement and control systems. The sensors are encapsulated in the SOD68 (DO-34) package.

Other special selections are available on request.

CAUTION

This device is sensitive to ElectroStatic Discharge (ESD). Therefore care should be taken during transport and handling.

1.2 Features

- High accuracy and reliability
- Positive temperature coefficient; fail-safe behavior
- Temperature range −40 °C to +300 °C
- Long-term stability
- Virtually linear characteristics
- Nickel plated leads

1.3 Quick reference data

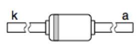
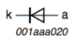
Table 1. Quick reference data

T_{amb} = 100 °C; in liquid; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
R_{100}	sensor resistance	$I_{sen(cont)}$ = 2 mA				
		KTY84/130	970	-	1030	Ω
		KTY84/150	950	-	1050	Ω
		KTY84/151	950	-	1000	Ω

2. Pinning information

Table 2. Pinning

Pin	Description	Simplified outline	Graphic symbol
1	cathode (k)		
2	anode (a)		

6. Characteristics

Table 6. Characteristics

T_{amb} = 100 °C; in liquid; unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
R_{100}	sensor resistance	$I_{sen(cont)}$ = 2 mA					
		KTY84/130		970	-	1030	Ω
		KTY84/150		950	-	1050	Ω
		KTY84/151		950	-	1000	Ω
TC	temperature coefficient			-	0.61	-	%/K
R_{250}/R_{100}	resistance ratio	T_{amb} = 250 °C and 100 °C		2.111	2.166	2.221	
R_{25}/R_{100}	resistance ratio	T_{amb} = 25 °C and 100 °C		0.595	0.603	0.611	
τ_{th}	thermal time constant	in still air	[1]	-	20	-	s
		in still liquid	[1]	-	1	-	s
		in flowing liquid	[1]	-	0.5	-	s

[1] The thermal time constant is the time taken for the sensor to reach 63.2 % of the total temperature difference. For example, if a sensor with a temperature of 25 °C is moved to an environment with an ambient temperature of 100 °C, the time for the sensor to reach a temperature of 72.4 °C is the thermal time constant.

Table 7. Ambient temperature, corresponding resistance, temperature coefficient and maximum expected temperature error for KTY84/130 and KTY84/150

$I_{sen(cont)}$ = 2 mA.

Ambient temperature		Temperature coefficient	KTY84/130				KTY84/150			
(°C)	(°F)	(%/K)	Resistance (Ω)			Temperature error (K)	Resistance (Ω)			Temperature error (K)
			Min	Typ	Max		Min	Typ	Max	
−40	−40	0.84	340	359	379	±6.48	332	359	386	±8.85
−30	−22	0.83	370	391	411	±6.36	362	391	419	±8.76
−20	−4	0.82	403	424	446	±6.26	394	424	455	±8.7
−10	14	0.80	437	460	483	±6.16	428	460	492	±8.65
0	32	0.79	474	498	522	±6.07	464	498	532	±8.61
10	50	0.77	514	538	563	±5.98	503	538	574	±8.58
20	68	0.75	555	581	607	±5.89	544	581	618	±8.55
25	77	0.74	577	603	629	±5.84	565	603	641	±8.54
30	86	0.73	599	626	652	±5.79	587	626	665	±8.53
40	104	0.71	645	672	700	±5.69	632	672	713	±8.5
50	122	0.70	694	722	750	±5.59	679	722	764	±8.46
60	140	0.68	744	773	801	±5.47	729	773	817	±8.42
70	158	0.66	797	826	855	±5.34	781	826	872	±8.37
80	176	0.64	852	882	912	±5.21	835	882	929	±8.31
90	194	0.63	910	940	970	±5.06	891	940	989	±8.25
100	212	0.61	970	1000	1030	±4.9	950	1000	1050	±8.17
110	230	0.60	1029	1062	1096	±5.31	1007	1062	1117	±8.66
120	248	0.58	1089	1127	1164	±5.73	1067	1127	1187	±9.17
130	266	0.57	1152	1194	1235	±6.17	1128	1194	1259	±9.69
140	284	0.55	1216	1262	1309	±6.63	1191	1262	1334	±10.24
150	302	0.54	1282	1334	1385	±7.1	1256	1334	1412	±10.8
160	320	0.53	1350	1407	1463	±7.59	1322	1407	1492	±11.37
170	338	0.52	1420	1482	1544	±8.1	1391	1482	1574	±11.96
180	356	0.51	1492	1560	1628	±8.62	1461	1560	1659	±12.58
190	374	0.49	1566	1640	1714	±9.15	1533	1640	1747	±13.2
200	392	0.48	1641	1722	1803	±9.71	1607	1722	1837	±13.85
210	410	0.47	1719	1807	1894	±10.28	1683	1807	1931	±14.51
220	428	0.46	1798	1893	1988	±10.87	1760	1893	2026	±15.19
230	446	0.45	1879	1982	2085	±11.47	1839	1982	2125	±15.88
240	464	0.44	1962	2073	2184	±12.09	1920	2073	2226	±16.59
250	482	0.44	2046	2166	2286	±12.73	2003	2166	2329	±17.32
260	500	0.42	2132	2261	2390	±13.44	2087	2261	2436	±18.15
270	518	0.41	2219	2357	2496	±14.44	2172	2357	2543	±19.36
280	536	0.38	2304	2452	2600	±15.94	2255	2452	2650	±21.21
290	554	0.34	2384	2542	2700	±18.26	2333	2542	2751	±24.14
300	572	0.29	2456	2624	2791	±22.12	2404	2624	2844	±29.05

Table 8. Ambient temperature, corresponding resistance, temperature coefficient and maximum expected temperature error for KTY84/151

$I_{sen(cont)}$ = 2 mA.

Ambient temperature		Temperature coefficient (%/K)	KTY84/151			
			Resistance (Ω)			Temperature error (K)
(°C)	(°F)		Min	Typ	Max	
−40	−40	0.84	332	350	368	±5.97
−30	−22	0.83	362	381	399	±5.84
−20	−4	0.82	394	414	433	±5.72
−10	14	0.80	428	449	469	±5.62
0	32	0.79	464	486	507	±5.51
10	50	0.77	503	525	547	±5.41
20	68	0.75	544	566	589	±5.31
25	77	0.74	565	588	611	±5.25
30	86	0.73	587	610	633	±5.2
40	104	0.71	632	656	679	±5.08
50	122	0.70	679	704	728	±4.96
60	140	0.68	729	754	778	±4.83
70	158	0.66	781	806	831	±4.68
80	176	0.64	835	860	885	±4.53
90	194	0.63	891	916	942	±4.37
100	212	0.61	950	975	1000	±4.19
110	230	0.60	1007	1036	1064	±4.58
120	248	0.58	1067	1099	1131	±4.99
130	266	0.57	1128	1164	1199	±5.41
140	284	0.55	1191	1231	1271	±5.84
150	302	0.54	1256	1300	1345	±6.3
160	320	0.53	1322	1372	1421	±6.77
170	338	0.52	1391	1445	1500	±7.25
180	356	0.51	1461	1521	1581	±7.75
190	374	0.49	1533	1599	1664	±8.27
200	392	0.48	1607	1679	1751	±8.81
210	410	0.47	1683	1761	1839	±9.36
220	428	0.46	1760	1846	1931	±9.93
230	446	0.45	1839	1932	2024	±10.51
240	464	0.44	1920	2021	2121	±11.11
250	482	0.44	2003	2112	2220	±11.73
260	500	0.42	2087	2205	2321	±12.42
270	518	0.41	2172	2298	2424	±13.37
280	536	0.38	2257	2391	2525	±14.79
290	554	0.34	2335	2479	2622	±16.98
300	572	0.29	2406	2558	2710	±20.61

2. DATASHEET SEVCON GEN4

Gen4

Applications Reference Manual

DOCUMENT NO:

177/52701

REV. 3.0

TECH/OPS SEVCON®

Partner with Performance™

DATASHEET SEVCON GEN4

Sevcon Ltd
Kingsway South
Gateshead, NE11 0QA
England
Tel +44 (0)191 497 9000
Fax +44 (0)191 482 4223
sales.uk@sevcon.com

Sevcon, Inc.
155 Northboro Road
Southborough, MA 01772
USA
Tel (508) 281 5500
Fax (508) 281 5341
sales.us@sevcon.com

Sevcon SA
12 Rue Jean Poulmarch
95100 Argenteuil
France
Tel +33 (0)1 34 10 95 45
Fax +33 (0)1 34 10 61 38
sales.fr@sevcon.com

Sevcon Japan
4-12-1 Shinbashi
Minato-Ku, Tokyo 105-0004
Japan
Tel +81 (0) 3 (5408) 5670
Fax +81 (0) 3 (5408) 5677
sales.jp@sevcon.com

Sevcon Asia Ltd
4th Floor, Eun-Hyae Building
463-1, Sang-dong
Wonmee-gu, Bucheon City
Kyunggi-do 420-030
Korea
Tel +82 (0)32 215 5070
Fax +82 (0)32 215 8027
sales.kr@sevcon.com

www.sevcon.com

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DATASHEET SEVCON GEN4

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Appendices 1

Chapter 1:
Introduction

About Gen4 documentation

THIS VERSION OF THE MANUAL

This version of the Gen4 manual replaces all previous versions. Sevcon has made every effort to ensure this document is complete and accurate at the time of printing. In accordance with our policy of continuing product improvement, all data in this document is subject to change or correction without prior notice.

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SCOPE OF THIS MANUAL

The Application Reference Manual provides important information on configuring lift and traction drive systems using Gen4 controllers as well as details on sizing and selecting system components, options and accessories.

The manual also presents important information about the Gen4 product range.

RELATED DOCUMENTS

The following documents are available from Sevcon:

- The Object Dictionary providing important information about CANopen communication with Gen4.
- Device Configuration Files (DCF) and Electronic Data Sheets (EDS) for each Gen4 model and revision.

DRAWINGS AND UNITS

Orthographic illustrations in this manual are drawn in Third Angle Projection. SI units are used throughout this manual.

WARNINGS, CAUTIONS AND NOTES

Special attention must be paid to the information presented in Warnings, Cautions and Notes when they appear in this manual. Examples of the style and purpose of each are shown below:

A WARNING is an instruction that draws attention to the risk of injury or death and tells you how to avoid the problem.

A CAUTION is an instruction that draws attention to the risk of damage to the product, process or surroundings.

A NOTE indicates important information that helps you make better use of your Sevcon product.

SEVCON

Product identification label

If you have a customized product your unique identifier will appear at the end of the Type number. When discussing technical issues with Sevcon always have your product's Type number, Part number and Serial number available. Figure 1 shows a typical product identification label.

Figure 1 Product identification label

Technical support

For technical queries and application engineering support on this or any other Sevcon product please contact your nearest Sevcon sales office listed on the inside front cover of this manual. Alternatively you can submit enquiries and find the details of the nearest support center through the Sevcon website, www.sevcon.com.

Product warranty

Please refer to the terms and conditions of sale or contract under which the Gen4 was purchased for full details of the applicable warranty.

Chapter 2:
About the Gen4

Introduction

Sevcon Gen4 controllers are designed to control 3-phase AC induction motors and Permanent Magnet AC (PMAC) motors in battery powered traction and pump applications. A range of models is available to suit a wide number of applications and cooling regimes.

The controller adapts its output current to suit the loading conditions and the ambient in which it is operating (temporarily shutting down if necessary). It will also protect itself if incorrectly wired.

Signal wiring and power connections have been designed to be as simple and straight forward as possible. Analog and digital signal inputs and outputs are provided for switches, sensors, contactors, hydraulic valves and CAN communications. These electrical signals can be mapped to Gen4's software functions to suit a wide range of traction and pump applications.

Given Gen4's mapping versatility it is important to ensure you map your application signals to the correct software functions (see 'Manual object mapping' on page 6-10). A common configuration is supplied by default which may suit your needs or act as a starting point for further configuration.

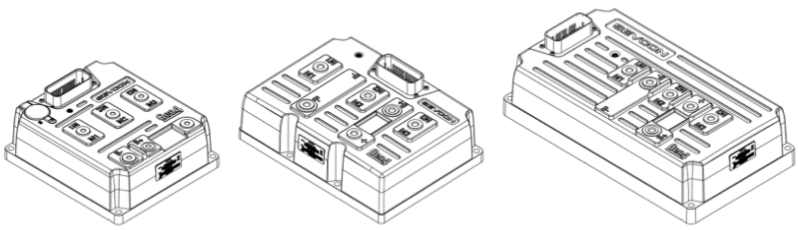
Configuration and control of Gen4 is fully customizable using Sevcon's Calibrator handset or DriveWizard, an intuitive Windows based configuration software tool.

A single green LED is provided to give a visual indication of the state of the controller. This signal can be replicated on a dashboard mounted light for example.

Standard features and capabilities

Available options

There are three mechanical package options (Figure 2) for the Gen4 controller at various voltage and current ratings.



Size 2 models   Size 4 models   Size 6 models

Figure 2 Mechanical package options

Intended use of the Gen4

The Gen4 motor controller can be used in any of these main applications for both pump and traction control:

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DATASHEET SEVCON GEN4

- Counterbalanced, warehouse and pedestrian fork lift trucks (Classes 1 to 3, FLT1, 2 & 3)
- Airport ground support (AGS), including tow tractors
- Utility vehicles
- Burden carriers
- Sweepers and scrubbers
- Golf buggies/carts
- Neighborhood electric vehicles (NEV)
- Scooters
- Marine

AVAILABLE ACCESSORIES

The following accessories are available from Sevcon

- Loose equipment kit (connectors and pins) for Gen4
- Gen4 cooling kit
- CANopen Calibrator Handset
- SmartView™ display
- ClearView™display
- Hourmeters
- Contactors
- Fuses
- Drive Wizard - PC based configuration tool
- SCWiz – PC based motor characterisation tool

SEVCON

Overview of a truck drive system

Each traction or pump application requires a number of system components. The main components (excluding control inputs such as throttle and seat switch) are shown in Figure 3. In this example there are two controllers, a traction motor and a hydraulic pump, however all the main components would be the same if controller 2 was also powering a traction motor.

Communication between the controllers is achieved using the CANopen protocol. This protocol also allows Gen4 to communicate with other non-Sevcon, CANopen compliant devices.

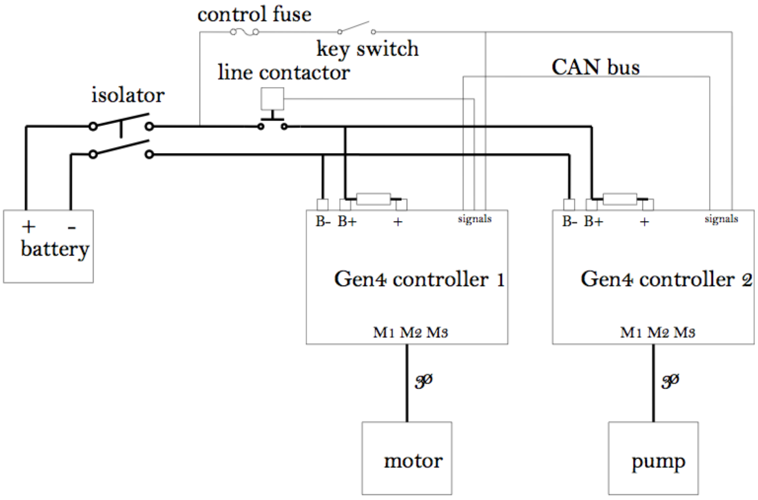

Figure 3 Truck system components

Signal power for the internal control circuits and software is derived from the battery via the control fuse and key switch as shown. No external in-rush current limiting is needed as long as Gen4 is used to control the line contactor and hence the timing of its closure. The software controls the start up sequence in this order:

1. Charge the input capacitors to within a user definable percentage (using 5820_h) of battery voltage (via the key switch signal line).
2. Close line contactor.
3. Generate output to the motor as demanded.

A line input fuse can be mounted on the body of the controller. The 'B+' terminal is a dummy terminal. If the fuse is mounted elsewhere, connections from the battery positive are made to the controller '+' terminal see "On-board fuse mounting" section.

Principles of operation

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DATASHEET SEVCON GEN4

FUNCTIONAL DESCRIPTION

The main function of Gen4 is to control the power to 3-phase squirrel-cage AC induction or PMAC motors in electric vehicles. Four-quadrant control of motor torque and speed (driving and braking torque in the forward and reverse directions) is allowed without the need for directional contactors. Regenerative braking is used to recover kinetic energy which is converted into electrical energy for storage in the battery.

In a traction application control commands are made by the driver using a combination of digital controls (direction, foot switch, seat switch, etc.) and analog controls (throttle and foot brake). The controller provides all the functions necessary to validate the driver's commands and to profile the demand for speed and torque according to stored parameters.

Throttle inputs can be configured as speed or torque demands with throttle-dependent speed limits: in either case, a torque demand is continually calculated to take account of pre-set limits on the level and rate-of-change of torque. The torque demand is used to calculate current demands; that is, the controller calculates what currents will be required within the motor to generate the required torque.

There are two distinct components of the current, known as the d-q axis currents, which control current flow in the motor. The d-axis current is responsible for producing magnetic flux, but does not by itself produce torque. The q-axis current represents the torque-producing current.

When a vehicle is ready to drive, but no torque is being demanded by the driver, the d-axis or magnetizing current will be present in the motor so that the vehicle will respond immediately to a torque demand. To save energy the magnetizing current is removed if the vehicle is stationary and no torque has been demanded after a set period.

Measured phase currents and current demands i_d and i_q, the d-q axis currents, are used as part of a closed-loop control system to calculate the necessary voltage demands for each phase of the motor. Voltage demands are then turned into PWM demands for each phase using the Space Vector Modulation (SVM) technique. SVM ensures optimum use of the power semiconductors.

POWER CONVERSION SECTION

The power conversion section of Gen4 employs a 6-switch MOSFET bridge operating at an effective frequency of either 16 kHz or 24kHz (the PWM frequency is set using 5830_h). Excellent electrical and thermal efficiency is achieved by:

- Minimization of thermal resistances.
- Use of the latest MOSFET technology
- Internal thermal protection (if temperatures are excessive, output torque is reduced).
- Overcurrent protection using device characteristics.
- Internal measurement of output current.
- Overvoltage trip in the event of regenerative braking raising battery voltage to unsafe levels.

DUAL TRACTION MOTOR

In the case of dual traction motors, there is additional processing of the associated steering signal (from a potentiometer or switches) in order to generate separate torque demands for the left and right motors of the vehicle. This allows the two motors to be operated at different speeds, which greatly assists in turning the vehicle and prevents wheel scrub. After the torque demands have been generated, the operation of each motor control system is as described in the case of a single traction motor.

PUMP MOTORS

Pump motor control is similar to traction motor control, although motion is requested using a different combination of switches.

INTERFACES

In addition to its motor control functions, Gen4 offers many other functions designed to interface with electric vehicles. A variety of digital and analog input sources are supported, as listed in 'Signal connections' on page 3-11.

Voltage and current control of up to three contactors or proportional valves is provided by Gen4, and includes built-in freewheeling diodes for spike suppression. All I/O on the Gen4 controller is protected against short-circuit to the battery positive and negative terminals.

Connectivity and interoperability with other system devices (for example another Gen4 controller) using a CANbus and the CANopen protocol is provided. In addition to in-service operation, the CANopen protocol allows the controller to be commissioned using the Calibrator handset or Sevcon's DriveWizard tool. In addition Sevcon's SCWiz PC based tool provides the function to self-characterise most induction motors and hence simplify the process of putting a new motor into service.

For simple visual diagnosis of system faults and to monitor system status, a green LED is provided on the body of the controller. It is continuously lit when there is no fault but flashes a different number of times, in a repeated pattern, when there is a fault. The number of flashes indicates the type of fault (see " on page 1).

MASTER-SLAVE OPERATION

The Gen4 controller contains both master and slave functions as shown in Figure 4. They operate as follows:

- **Slave function:** implements the CANopen Generic I/O Profile (DS401) and the Drives and Motion Control Profile (DSP402).
- **Master function:** implements vehicle functionality (traction and pump control) and CANopen network management.

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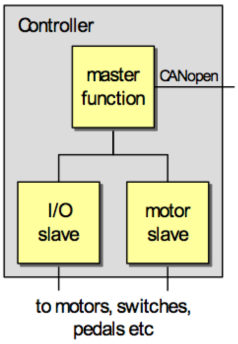

Figure 4 Single controller

TORQUE MODE

In this mode Gen4 maintains the motor torque output at a constant value for a given throttle position. This is similar to DC motors (in particular, series wound DC motors) and provides a driving experience like a car. To prevent excessive speed when the load torque is low, for example when driving down hill, a maximum vehicle speed can be set.

SPEED MODE

Speed mode (or speed control) is not recommended for on-highway vehicles as it can cause the traction motor/wheel to remain locked or brake severely if the wheel is momentarily locked due to loss of traction on a slippery surface and/or mechanical braking.

In this mode Gen4 maintains the motor at a constant speed for a given throttle position as long as sufficient torque is available. Speed mode differs from torque mode in that the torque value applied to the motor is calculated by the controller based on the operator's requested speed (determined by throttle position) and the vehicle's actual speed. This mode is useful where accurate speed control is required irrespective of the motor torque.

Safety and protective functions

GENERAL

Electric vehicles can be dangerous. All testing, fault-finding and adjustment should be carried out by competent personnel. The drive wheels should be off the floor and free to rotate during the following procedures. The vehicle manufacturer's manual should be consulted before any operation is attempted.

The battery must be disconnected before replacing the controller. After the battery has been disconnected wait 30 seconds for the internal capacitors to discharge before handling the controller.

Never connect the controller to a battery with vent caps removed as an arc may occur due to the controller's internal capacitance when it is first connected.

As blow-out magnets are fitted to contactors (except 24V) ensure that no magnetic particles can accumulate in the contact gaps and cause malfunction. Ensure that contactors are wired with the correct polarity to their power terminals as indicated by the + sign on the top molding.

Do not attempt to open the controller as there are no serviceable components. Opening the controller will invalidate the warranty.

Use cables of the appropriate rating and fuse them according to the applicable national vehicle and electrical codes.

Where appropriate use of a suitable line contactor should be considered.

Electric vehicles are subject to national and international standards of construction and operation which must be observed. It is the responsibility of the vehicle manufacturer to identify the correct standards and ensure that their vehicle meets these standards. As a major electrical control component the role of the Gen4 motor controller should be carefully considered and relevant safety precautions taken. The Gen4 has several features which can be configured to help the system integrator to meet vehicle safety standards. Sevcon accepts no responsibility for incorrect application of their products.

2-8

On-Highway Vehicles

General

This applies to all on-highway vehicles, such as motorcycles and cars.

The installer must ensure an appropriate controller configuration is set to ensure that the vehicle remains in a safe condition, even in the event of a fault.

Inputs

Always ensure drive inputs have adequate protection. Inputs such as the throttle should have appropriate wire-off detection configured. Single point failures should never cause an unsafe condition.

Gen4 supports wire-off detection on all analogue inputs, and it contains various safety interlocks to prevent unexpected drive due to a wiring fault (e.g. FS1 switch, dual throttle inputs).

Sevcon recommends that the following features are enabled for all applications:

- Wire-off detection on analogue inputs, particularly the throttle.
- A valid analogue input voltage which is more than 0.5V from wire off limits
- Appropriate safety interlocks to ensure a single point of failure cannot cause an unsafe driving condition.

Refer to sections Analog inputs (page 6-14) and Vehicle performance configuration (page 6-17) for more information.

Notes on Features

The Gen4 is a generic motor controller intended for use in both highway AND non-highway industrial applications. Not all of the controller features are suitable for an on-highway vehicle. Some features, if activated, could lead to the controller forcing a motor condition that is not directly requested by the throttle, such as undesired drive or harsher than expected braking.

Sevcon recommends that the following features are DISABLED for any on-highway applications:

- Proportional Speed Limit[1].
- Hill Hold[1].
- Controlled Roll-Off[1].
- Speed mode (or speed control)[1].
- Electromechanical Brake output[1].
- Inching[2].
- Belly switch[2].
- Unused Driveability Profiles[3].

NOTES:

1. These features can cause the traction motor/wheel to remain locked or brake severely if the wheel is momentarily locked due to loss of traction on a slippery surface and/or mechanical braking.
2. These features can cause unexpected drive if accidentally activated.
3. This feature can cause a sudden reduction in maximum speed if a driveability profile is accidentally activated and is incorrectly configured.

In addition, the following features must be configured correctly

- Steering map, if used to reduce maximum outer wheel speed with steering angle.

FAULT DETECTION AND HANDLING

There are five categories of faults as described in Table 1. For a detailed list of faults see Table 8 on page 7-9.

Fault severity	Controller latched off until	Consequences
Return to base (RTB)	Cleared by Sevcon personnel	Immediate shut down of the system with the exception of the power steering if needed. Power is removed to nearly all external components.
Very severe (VS)	Cleared by authorized service personnel	Immediate shut down of the system with the exception of the power steering if needed. Power is removed to nearly all external components.
Severe (S)	Keyswitch recycled (turned off then on)	Immediate shut down of the system with the exception of the power steering if needed. Power is removed to nearly all external components.
Drive-inhibit (DI)	User deselects all drive switches before reselecting	Neutral brakes or coasts the traction motor(s) to a stop. The fault prevents the operator initiating drive, but does not inhibit braking function, in particular, controlled roll-off braking.
Information (I)	Not latched	Information faults do not require immediate action, although some cutback of power or speed may occur.

Table 1 Fault categories

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Chapter 3: Installation

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Mounting Gen4

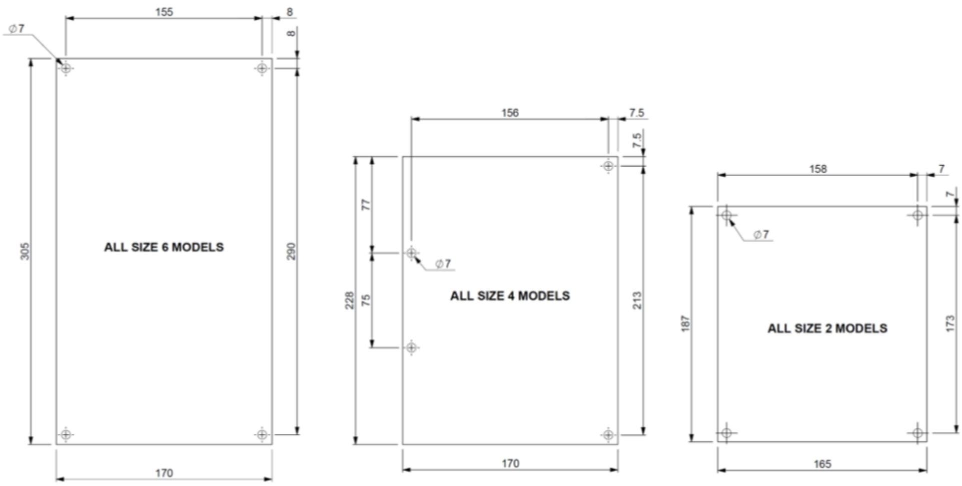
Orientation

The controller can be mounted in any orientation.

Clearance for LED access

If you want an operator of your vehicle to be able to view the onboard LED, it is advisable to consider the line of sight to the LED at this time.

Mounting hole pattern



Flatness of mounting surfaces: 0.2mm

Failure to comply with this flatness specification can cause deformation of the frame and damage to the product.

Equipment required:

- 4 x M6 socket cap head bolts, nuts and spring washers. Bolts need to be long enough to pass through 12 or 20 mm of Gen4 baseplate (depending on controller type) and your mounting surface thickness.
- T hand-socket wrench or Allen key
- Thermal grease

Recommended torque setting: 10 Nm ± 2 Nm

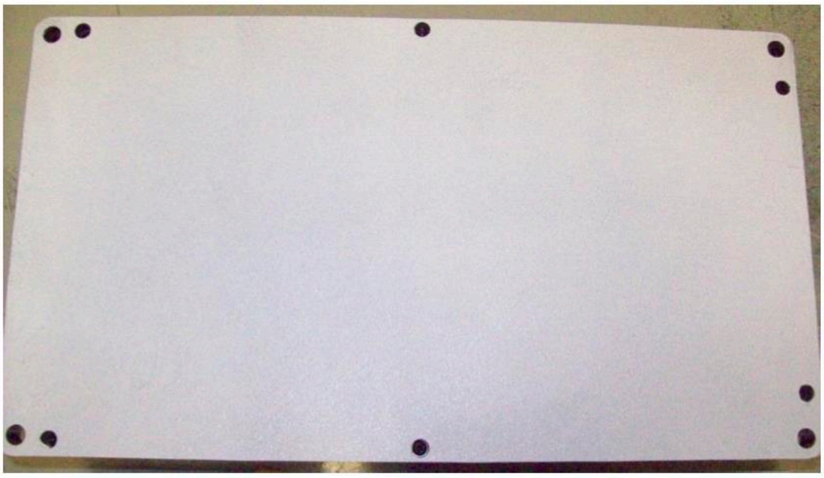
3-2

Thermal grease application

Spread a layer of thermal grease (such as Dow Corning 340) as described below, before bolting to your mounting surface.

- Thermal compound should be applied with a small soft paint roller to ensures an even spread of thermal compound.
- The most appropriate thickness will look white but with a greyish colour still showing through from the controller base or vehicle mounting face material. *It should be noted that too little thermal compound will not fill all gaps left the flatness mismatch of the contact surfaces, but too much thermal compound may prevent the gap from closing up when tightening.*
- It is recommended that thermal compound is applied to both the Controller base and the vehicle/panel/boost plate surfaces.
- The controller should then be placed onto the vehicle/panel/heatsink.
- It is important that the two surfaces are then rubbed together in order to help transfer the thermal compound between the two surface.
- The entire assembly is then bolted together at all mounting holes.

An example of a good thermal compound spreading can be seen in the photo below:-



How effective the spreading technique is can be checked by removing the controller and inspecting the paste residue left on the mounting faces. On a well applied paste application, the controller will be difficult to remove and a rippled surface will be left on the paste surface as shown (magnified) below:-

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Cooling requirements

To ensure you get the maximum performance from your Gen4 controller:

- Keep it away from other heat generating devices on the vehicle
- Maintain its ambient operating temperature below the specified maximum (see 'Operating environment' on page 4–6)

To obtain maximum performance it is important to keep Gen4's base plate within the operating temperature range. To do this, mount Gen4 to a surface capable of conducting away the waste heat. Finned heatsinks are considerably better at doing ths than flat plates. For example, a finned heatsink used at Sevcon has a footprint of 330mm x 200mm and thermal resistance of 0.3°C/W, whereas a plate approximately 420 mm x 270 mm x 9.5 mm will give approximately the same thermal performance (0.3°C/W). Ratings achievable with conductive heatsinking are shown in Figure 11 on page 4–3.

In Sevcon's experience the thermal resistance of the stand-alone Gen4 packages and achievable thermal resistances to ambient using conductive heatsinking are as shown in the table below. These are given as a guide: actual performance in an application must be verified.

Gen4 Size	Thermal resistance without additional heatsinking (°C/W)	Thermal resistance achievable with finned heatsink (°C/W)	Dimension of finned heatsink (W x L)
Size 2	0.7	0.5	250mm x 180mm
Size 4	0.6	0.3	330mm x 200mm
Size 6	0.5	0.2	330mm x 280mm

Cooling performance is affected by mounting surface flatness and the thermal transfer between mounting surface and Gen4. Ensure your application of thermal grease is effective and your mounting surface meets the flatness figures as described in the 'Mounting' section above.

EMC guidelines

The following guidelines are intended to help vehicle manufacturers to meet the requirements of the EC directive 89/336/EEC for Electromagnetic Compatibility. Any high speed switch is capable of generating harmonics at frequencies that are many multiples of its basic operating frequency. It is the objective of a good installation to contain or absorb the resultant emissions. All wiring is capable of acting as a receiving or transmitting antenna. Arrange wiring to take maximum advantage of the structural metal work inherent in most vehicles. Link vehicle metalwork with conductive braids.

Power cables

Route all cable within the vehicle framework and keep as low in the structure as is practical - a cable run within a main chassis member is better screened from the environment than one routed through or adjacent to an overhead guard. Keep cables short to minimize emitting and receiving surfaces. Shielding by the structure may not always be sufficient - cables run through metal shrouds may be required to contain emissions.

Parallel runs of cables in common circuits can serve to cancel emissions - the battery positive and negative cables following similar paths is an example. Tie all cables into a fixed layout and do not deviate from the approved layout in production vehicles. A re-routed battery cable could negate any approvals obtained.

Signal cables

Keep all wiring harnesses short and route wiring close to vehicle metalwork. Keep all signal wires clear of power cables and consider the use of screened cable. Keep control wiring clear of power cables when it carries analogue information - for example, accelerator wiring. Tie all wiring securely and ensure it always follows the same layout.

Controller

Thermal and EMC requirements tend to be in opposition. Additional insulation between the controller assembly and the vehicle frame work reduces capacitive coupling and hence emissions but tends to reduce thermal ratings. Establish a working balance by experiment. Document the complete installation, in detail, and faithfully reproduce on it all production vehicles. Before making changes, consider the effect on EMC compliance. A simple cost reduction change could have a significant negative effect on the EMC compliance of a vehicle.

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Connecting power cables

See also 'EMC guidelines' on page 3-5.

Battery and motor connections

Cables carrying high AC currents are subject to alternating forces and may require support in the cable harness to avoid long-term fatigue.

Equipment required for **size 4 or 6 models**:

- Cables sized to suit the controller and application (see table below)
- M8 crimp ring lugs
- Crimp tool
- M8 wrench

Torque setting: 11 Nm ± 2 Nm

Equipment required for **size 2 models**:

- Cables sized to suit the controller and application (see table below)
- M6 crimp ring lugs
- Crimp tool
- M6 wrench

Torque setting: 7 Nm ± 1 Nm

Consider cable routing before making connections.

- Keep cable runs short
- Minimize current loops by keeping positive and negative cables as close together as possible.
- Route cables away from the LED if you intend to make this visible under normal operating conditions.

Connect your power cables using the bolts supplied. They are sized to clamp one ring lug thickness. Use a longer bolt if you are fastening more than one ring lug. You need thread engagement of at least 10 mm and the maximum penetration is 15 mm.

If you use a bolt which is too long, damage to the terminal and overheating of the connection may occur. If you use a bolt which is too short and there isn't enough thread engagement you may damage the threads.

Cable sizes

When deciding on power cable diameter, consideration must be given to cable length, grouping of cables, the maximum allowable temperature rise and the temperature rating of the chosen cable.

The following table gives guidance on the cable size needed for various currents in welding cable, not grouped with other cables, in 25°C ambient with 60°C temperature rise on the cable surface.

Gen4 average (rms) current	Cable sizes	
	metric	US (approx equivalent)
180 A	25 mm²	4 AWG
225 A	35 mm²	2 AWG
280 A	50 mm²	1 AWG
350 A	70 mm²	2/0 AWG

On-board fuse mounting

You can mount your main input protection fuse directly onto the controller body as shown below . Select the appropriate fuse from the table below. Connect the battery positive cable to the B+ terminal. Connecting to the end marked '+' (or un-named in the case of size 2) will leave your installation without a fuse unless located elsewhere in the system. The B+ terminal is a dummy terminal to allow fuse connection only and has no internal connection.

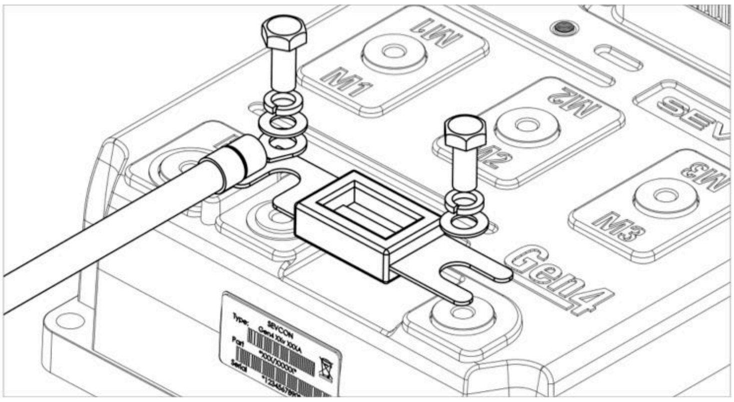

Figure 5 On-board fuse mounting – size 2 models

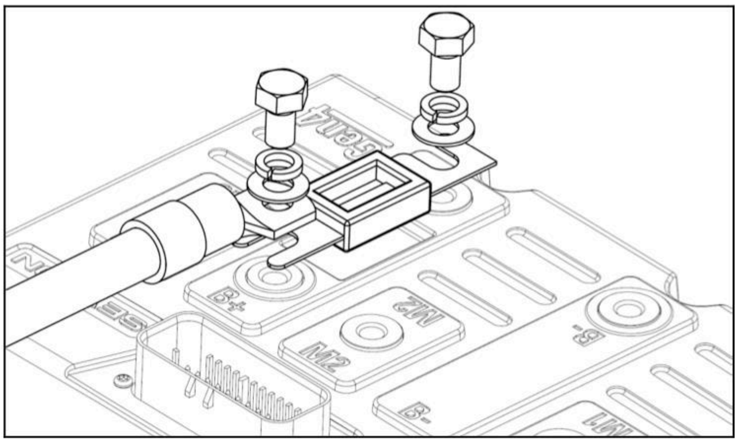

Figure 6 On-board fuse mounting – size 4 models

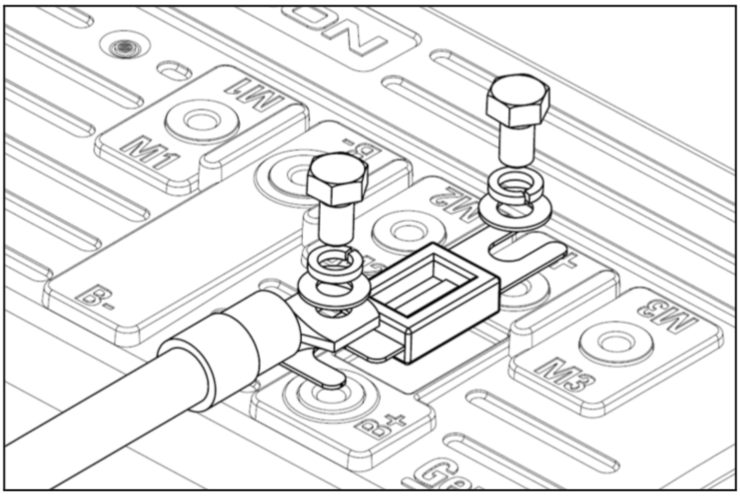

Figure 7 On-board fuse mounting – size 6 models

Fuse rating and selection

On-board fuse dimensions are in accordance with DIN43560/1

Gen4 input voltage	Gen4 peak output current	Fuse rating	Sevcon part number
24V/36 V	300 A	325 A	858/32044
	450 A	425 A	858/81990
	650 A	750 A	858/33021
36V/48 V	275 A	250 A	858/29043
	450 A	425 A	858/81990
	650 A	750 A	858/33021
72V/80 V	180 A	200 A	858/83339
	350 A	355 A	858/32045
	550 A	500 A	858/32043

Signal wiring

Assemble your wiring harness using wire of the sizes recommended below and the Sevcon loose connector kit (P/N 661/27091). The use of twisted pair and in some cases twisted-screened cables is recommended for the speed sensor and CANbus wiring.

To make a connection, gently push the connector housing onto the appropriate mating half on the Gen4. Never force a connector. Connectors are keyed to prevent incorrect insertion.

Twisted, shielded wire is recommended. Keep signals away from power cables to avoid interference. See also 'EMC guidelines' on page 3-5.

Signal wire sizes

Use wire between 0.5 mm² (20 AWG) and 1.5 mm² (16 AWG) for all signal wiring. Single twisted pair cable is readily available in 0.5 mm² (20 AWG).

CANbus termination

See also 'EMC guidelines' on page 3-5.

If your system has more than one CAN node, connect the nodes in a 'daisy chain' arrangement (Figure 8) and terminate the connections of the two end nodes with a 120 Ω resistor. If the end node is a Gen4, link pins 2 and 24 on the customer connector, a 120 Ω resistor is built into the controller. If you have a single node system the termination resistor should be connected so that the bus operates correctly when configuration tools are used.

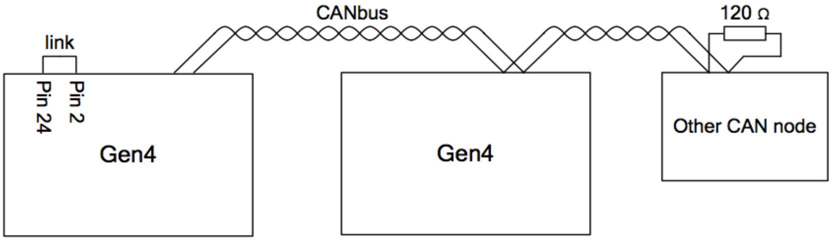

Figure 8 CAN node termination

Signal connections

Signal connections are made to Gen4 via a 35 way AMPSeal connector.

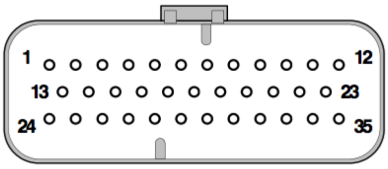

Figure 9 Customer Connector

Pins are protected against short-circuits to the battery positive or negative terminals.

Inserting contacts into connector housing pierces the sealing diaphragm to make the seal to the wire. To maintain IP rating, unused positions must be sealed with appropriate hardware (available from Tyco) if a contact is inserted and then subsequently removed.

Pin	Name	Type	What to connect	Maximum rating	Comment
1	Key switch in	Power	From 'dead' side of key switch via suitable fuse	7A (Total of all contactor output currents plus 1.0A)	This input supplies power from the battery for all the logic circuits. The unit cannot operate without "Key switch in" supply. Pins 1 and 6 (and 10 on Size 4 & 6 models) are connected together internally and can be used individually or in parallel.
2	CAN termination	Comms	To terminate a Gen4 CAN node link pin 2 to pin 24. This connects a 120Ω termination resistor, mounted inside the controller, across the CANbus.		Make the connection only if the Gen4 is physically at the end of the CANbus network (see 'CANbus termination' on page 3-10.
3	Contactor out 1	Out	To the switched low side of contactor or valve coil. Contactor out 1 usually drives the line contactor. (DO NOT USE WITH CAPACITIVE LOADS).	2.0A per output, subject to a limit of 6A for the total of all the outputs. V = Vb	This output provides low side voltage or current control to the load depending on configuration. The output goes low or is chopped to activate the load. It goes high (to Vb) to de-activate the load.
4	Output 1 Supply +	Power	To one end (high side) of a contactor to be controlled by Contactor out 1	2A	This output feeds power to the contactors. The output is at battery voltage.
5	Encoder "U"	Digital pulse	Position encoder	10V	Use in conjunction with "V" and "W" for PMAC motors.

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Pin	Name	Type	What to connect	Maximum rating	Comment
6	Key-switch in	Power	From 'dead' side of key switch via suitable fuse	7A (Total of all contactor output currents plus 1.0A)	This input supplies power from the battery for all the logic circuits. The unit cannot operate without "Key switch in" supply. Pins 1 and 6 (and 10 on Size 4 & 6 models) are connected together internally and can be used individually or in parallel.
7	Contactor out 2	Out	To the switched low side of contactor or valve coil. (DO NOT USE WITH CAPACITIVE LOADS).	2.0A per output, subject to a limit of 6A for the total of all the outputs. V = Vb	This output provides low side voltage or current control to the load depending on configuration. The output goes low or is chopped to activate the load. It goes high (to Vb) to de-activate the load.
8	Output 2 Supply +	Power	To one end (high side) of a contactor to be controlled by Contactor out 2	2A	This output feeds power to the contactors. The output is at battery voltage.
9	Digital Input 6	Digital	From digital switch input 6.	Type B V = Vb See Table 3	See note to Table 3
10	Size 2 models: 5V supply output	Power	5Vsupply output	I = 100mA. V = 5V	This output can be used to power transducers or similar devices at 5V and up to 100mA.
10	Size 4 & 6 models: Key switch input	Power	From 'dead' side of key switch via suitable fuse	7A (Total of all contactor output currents plus 1.0A)	This input supplies power from the battery for all the logic circuits. The unit cannot operate without "Key switch in" supply. Pins 1, 6 and 10 are connected together internally and can be used individually or in parallel.
11	Contactor out 3	Out	To the switched low side of contactor or valve coil. (DO NOT USE WITH CAPACITIVE LOADS).	2.0A per output, subject to a limit of 6A for the total of all the outputs. V = Vb	This output provides low side voltage or current control to the load depending on configuration. The output goes low or is chopped to activate the load. It goes high (to Vb) to de-activate the load.

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Installation

Pin	Name	Type	What to connect	Maximum rating	Comment
12	Output 3 Supply +	Power	To one end (high side) of a contactor to be controlled by Contactor out 3	2A	This output feeds power to the contactors. The output is at battery voltage.
13	CAN High	Comms	CANbus High signal	V = 5 V	Maximum bus speed 1 Mbits/sec Alternative connection to pin 16
14	Encoder A Input	Digital pulse	From the speed encoder A channel	I = 25 mA (internally limited) V = 8 V (for current-source encoders) V = 2.5V or 5V (for open-collector encoders)	Check the speed encoder signals have the correct number of pulses per revolution. Check Gen4 is configured for the type of encoder you are using (open-collector or current-source)
15	Encoder power supply -	Power	To the negative supply input (0 V) of the speed encoder	I = 100 mA V = 0.5 V	We recommend the use of screened cable for the encoder wiring. Connect the screen to this pin only along with the negative supply.
16	CAN High	Comms	CANbus High signal	V = 5 V	Maximum bus speed 1 Mbits/s. Alternative connection to pin 13
17	Encoder "V"	Digital pulse	Position encoder	10V	Use in conjunction with "U" and "W" for PMAC motors.
18	Digital Input 1	Digital	From digital switch input 1. In a basic configuration this is usually the forward switch.	Type A V = Vb See Table 3	See note to Table 3
19	Digital Input 3	Digital	From digital switch input 3. In a basic configuration this is usually the foot switch (FS1).	Type A V = Vb See Table 3	See note to Table 3
20	Digital Input 5	Digital	From digital switch input 5.	Type B V = Vb See Table 3	See note to Table 3

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Pin	Name	Type	What to connect	Maximum rating	Comment
21	Digital Input 8	Digital	From digital switch input 8.	Type B V = Vb See Table 3	See note to Table 3. Alternative: Sin input from Sin-Cos analogue encoder, only if specified in h/w build
22	Pot. 1 wiper in	Analog	From potentiometer 1 wiper.	V = 9.5 V Zin = 82 kΩ (24V/36V and 36V/48V models) Zin = 100 kΩ (24V/36V and 36V/48V models)	Suitable for potentiometers in the range 500 Ω to 10 kΩ, or voltage-output device (e.g. Sevcon linear accelerator) 0 to 5 V or 0 to 10 V. Ensure that at least 0.5V margin exists between the maximum valid throttle and the wire-off threshold
23	Pot. 2 wiper in	Analog	From potentiometer 2 wiper.	V = 9.5 V Zin = 82 kΩ (24V/36V and 36V/48V models) Zin = 100 kΩ (24V/36V and 36V/48V models)	Suitable for potentiometers in the range 500 Ω to 10 kΩ, or voltage-output device (e.g. Sevcon linear accelerator) 0 to 5 V or 0 to 10 V. Ensure that at least 0.5V margin exists between the maximum valid throttle and the wire-off threshold
24	CAN Low	Comms	CANbus Low signal	V = 5 V	Maximum bus speed 1 Mbits/s. Alternative connection to pin 27
25	Encoder B Input	Digital pulse	From the speed encoder B channel	I = 25 mA (internally limited) V = 8 V (for current-source encoders) V = 2.5V or 5V (for open-collector encoders)	
26	Encoder power supply +	Power	To the positive supply input of the speed encoder	I = 100 mA V = 5V or 10V software selectable	Check the speed encoder you use is compatible with Gen4. See page 6-12 for configuration details.

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Pin	Name	Type	What to connect	Maximum rating	Comment
27	CAN Low	Comms	CANbus Low signal	V = 5 V	Maximum bus speed 1 Mbits/s. Alternative connection to pin 24
28	CAN power supply +	Power	To CAN device requiring external supply	V = 24 V I = 100 mA	Check that the CAN device power supply requirement is suitable for Gen4.
29	Encoder "W"	Digital pulse	Position encoder	10V	Use in conjunction with "U" and "V" for PMAC motors.
30	Digital Input 2	Digital	From digital switch input 2. In a basic configuration this is usually the reverse switch.	Type A V = Vb See Table 3	See note to Table 3
31	Digital Input 4	Digital	From digital switch input 4. In a basic configuration this is usually the seat switch.	Type A V = Vb See Table 3	See note to Table 3
32	Digital Input 7	Digital	From digital switch input 7.	Type B V = Vb See Table 3	See note to Table 3
33	Motor thermistor in	Analog	From a thermistor device mounted inside the motor	V = 5 V (via 2.2 kΩ internal pull-up resistor)	A NTC thermistor having a resistance of approximately 2.2 kΩ at 100°C will give best sensitivity. Connect the other lead of the thermistor to the B- terminal of the Gen4 controller. Can also be used as an additional analog input
34	Pot. 1 power supply +	Power	Supply feed to potentiometer 1. In a basic configuration this is the throttle.	V = 10 V I = 15 mA	Suitable for potentiometers in the range 500 Ω to 10 kΩ
35	Pot. 2 power supply +	Power	Supply feed to potentiometer 2.	V = 10 V I = 15 mA	Suitable for potentiometers in the range 500 Ω to 10 kΩ. Alternative: Cos input from Sin-Cos analogue encoder, only if specified in h/w build

Table 2 Connector A pin out and wiring information

Controller voltage	Digital Input Type	Impedance to B+	Impedance to B-
24V/36V	A	9k	9k
	B	13k	9k
36V/48V	A	16k	16k
	B	24k	16k
72V/80V	A	44k	44k
	B	66k	44k

Table 3: Impedance at Digital Input Pins

Note to Table 3:

Configure the digital input switches as active-high (switched to Vb) or active-low (switched to battery negative). Configuration applies to all digital input switches (1 to 8) i.e. they are all active-high or all active-low. See section Digital inputs (page 6-14) for more details.

When a switch is open the digital input pin sits at 0.5 x Vb. The input sinks current in active-high configurations and sources current in active-low configurations.

Calibrator connections (Size 2 models only)

Calibrator connections are made to Gen4 via a 6 way Minifit Junior connector accessed by lifting rubber cover. **Ensure cover is fully engaged after use to maintain IP rating**.

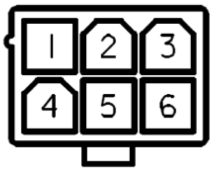

Figure 10 Calibrator Connector

Pin 1 and pin 3 – 6 are protected against short-circuits to the battery positive or negative terminals.

Pin	Name	Type	What to connect	Maximum rating	Comment
1	CAN Term.	Comms	Normally no connection. This pin can be connected to pin 3 if the controller wiring does not terminate the bus on the 35-way connector and the equipment being connected via the calibrator port does require termination.	V = 5 V	Internally connected to CANH via 120Ohm.
2	0V	0V	Connects the controller 0V to the 0V of the calibrator.		Internally connected to the B- terminal.
3	CAN Low	Comms	Normally no connection. This pin can be connected to pin 1 if the controller wiring does not terminate the bus on the 35-way connector and the equipment being connected via the calibrator port does require termination.	V = 5 V	Maximum bus speed 1 Mbits/s.
4	CAN power supply +	Power	To CAN device requiring 24V supply	V = 24 V I = 100 mA	Check that the CAN device power supply requirement is suitable for Gen4.
5	CAN High	Comms	CANbus High signal	V = 5 V	Maximum bus speed 1 Mbits/s.
6	CAN Low	Comms	CANbus Low signal	V = 5 V	Maximum bus speed 1 Mbits/s.

Table 4 Connector B pin out and wiring information

Chapter 4: Specification

Electrical

INPUT VOLTAGE

	24V only (Size 2 24V)	24/36V controllers	36/48V controllers	72/80V controllers
Conventional working voltage range (Note 1)	16.8V to 28.8V	16.8V to 43.2V	25.2V to 57.6V	50.4V to 96V
Working voltage limits (Note 2)	12.7V to 34.8V	12.7V to 52.2V	19.3 V to 69.6 V	39.1 V to 116 V
Non-operational overvoltage limits:	39.6V	59.4V	79.2 V	132 V
Battery voltage droop:	Vnom to 0.5 x Vnom for 100 ms			
Input protection:	Input protected against reverse connection of battery			

Note 1: Conventionally the controller may be set to operate without cutback in the range 70% to 120% of the nominal battery voltage, although cutback parameters may be used to set cutbacks higher or lower than this range. Cutbacks are set by the user for various reasons, including:

- Battery protection against high current in deep discharge condition
- Providing smoothly reducing performance at extremes of working voltage range, rather than a sudden loss of function

Note 2: Working voltage range outside which the controller will be non-operational.

OUTPUT PROTECTION

Output current:	Reduced automatically from peak to continuous rating depending on the time a peak load is applied to the controller (see Figure 11 on page4-3). Reduced automatically if operated outside normal temperature range.
Short-circuit:	Protected against any motor phase to B- or B+ at power-up. Protected against any motor phase to another motor phase at any time during operation. At switch-on Gen4 detects valid output loads are present before applying drive current.

Repetitive short circuits may damage the controller.

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OUTPUT RATINGS

Input (Vdc)	Function	Short term rating* (A rms)	Continuous rating** (A rms)
24	Single traction size 2	300	120
24/36	Single traction size 4	450	180
	Single traction size 6	650	260
36/48	Single traction size 2	275	110
	Single traction size 4	450	180
	Single traction size 6	650	260
72/80	Single traction size 2	180	75
	Single traction size 4	350	140
	Single traction size 6	550	210

*2 minute rating (lower ratings are possible for longer periods; see example in Figure 11)
** 1 hour minimum without forced-air cooling
Size 2 long-term rating achievable with finned heatsink approx 250mm x 180mm, 0.5°C/W
Size 4 long-term rating achievable with finned heatsink approx 330mm x 200mm, 0.3°C/W
Size 6 long-term rating achievable with finned heatsink approx 330mm x 280mm, 0.2°C/W

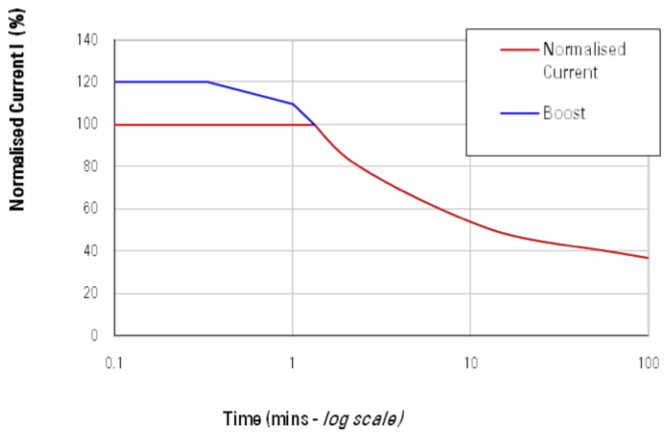

Figure 11 Output current available for various durations of sustained current demand

SEVCON

CAN INTERFACE

CAN protocol:	CANopen profiles DS301, DS401 and DSP402 are supported. Physical layer uses ISO11898-2.
Baud rates supported:	1 Mbits/s (default), 500 kbits/s, 250 kbits/s, 125 kbits/s, 100 kbits/s, 50 kbits/s and 20 kbits/s.

CONTROL INPUTS AND OUTPUTS

Digital inputs:	8 digital switch inputs (software configurable polarity). 24/36V controllers: Active low inputs < 2.6V, active high inputs > Vb – 2.6 V 36/48V controllers: Active low inputs < 2.9V, active high inputs > Vb – 2.9 V 72/80V controllers: Active low inputs < 4.4V, active high inputs > Vb – 4.4 V
Analog inputs:	2 general purpose inputs which can be used for 2-wire potentiometers, or as supplies for the 3-wire potentiometer wiper inputs. Motor thermistor input All analog inputs can also be used as digital inputs.
Potentiometer wiper inputs:	Two 3-wire protected inputs.
Inductive drive outputs: (DO NOT USE WITH CAPACITIVE LOADS).	3 configurable PWM outputs. Use in voltage or current control mode. Voltage-controlled: Continuous sink current = 2A Peak current limited to < 2.5A Open-circuit detection (Iout < 0.1 A) is a configurable option Short-circuit detection (Iout >0.2 A) when drive is in "off" state Voltage-controlled (PWM) mode allows contactors with a rating less than Vnom to be used (range 24 V to Vnom). Current-controlled: Current output configurable between 0 and 2A
Motor speed sensor inputs:	Quadrature AB encoder signal inputs provided for control of induction motors UWV digital position sensor or sin-cos analogue position sensor inputs provided for control of permanent magnet motors

ISOLATION

Any terminal to the case:	Withstands 2 kV d.c. Meets EN1175-1:1998 and ISO3691 Complies with IEC-60664

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Specification

EMC

Radiated emissions:	EN12895 (Industrial Trucks – Electromagnetic Compatibility) EN 55022:1998, 6, class B EN 12895:2000, 4.1 Emissions. When part of a system with a motor operating, FCC Part 15, Radiated Emissions. Meets the standards given in FCC Part 15, Section 15.109:
Conducted emissions:	No mains port, therefore not required
Susceptibility:	Performance level A (no degradation of performance) or level B (degradation of performance which is self-recoverable) subject to the additional requirement that the disturbances produced do not: • affect the driver's direct control of the truck • affect the performance of safety related parts of the truck or system • produce any incorrect signal that may cause the driver to perform hazardous operations • cause speed changes outside limits specified in the standard • cause a change of operating state • cause a change of stored data
Radiated RF field:	EN 61000-4-3, 5.1 Test Level: user-defined test level of 12 V/m EN 12895:2000, 4.2 Immunity EN 61000-4-6, Table 1 - Test Levels
Electrical fast transient:	EN 61000-4-4, Table 1 - Test Levels, Level 2
Electrostatic discharge:	EN 12895:2000, 4.2 Electrostatic Discharge 4 kV contact discharge 8 kV air discharge
Electrical surge:	EN 61000-4-5:1995, Table A.1 – Selection of Test Levels, Class 3

REGULATORY COMPLIANCE

Designed to meet:	EN1175-1:1998 (which covers EN1726 for the controller) ISO 3691 UL583 ASME/ANSI B56.1:1993

SEVCON

Mechanical

OPERATING ENVIRONMENT

Operating temperature:	-30°C to +25°C (no current or time derating) +25°C to +80°C (no current derating, but reduced time at rated operating point) +80°C to +90°C and -40°C to -30°C (with derating)
Non-operation temperature:	-40°C to +85°C (can be stored for up to 12 months in this ambient range)
Humidity:	95% at 40°C and 3% at 40°C
Ingress of dust and water:	IP66 rated (IP54 when 35-way connector unmated – size 2 models only)

SHOCK AND VIBRATION

Thermal shock:	EN60068-2-14, Test Na
Repetitive shock:	50 g peak 3 orthogonal axes, 3+ and 3– in each axis, 11 ms pulse width
Drop test:	BS EN 60068-2-32:1993 Test Ed: Free fall, appendix B, Table 1
Bump:	40 g peak, 6 ms, 1000 bumps in each direction repetition rate 1 to 3 Hz.
Vibration:	3 g, 5 Hz to 500 Hz
Random vibration:	20 Hz to 500 Hz, acceleration spectral density 0.05 g^2/Hz (equivalent to 4.9 g_{rms})

WEIGHT

	Controller weight
Case size 2:	1.3kg
Case size 4:	2.7kg
Case size 6:	4.6kg

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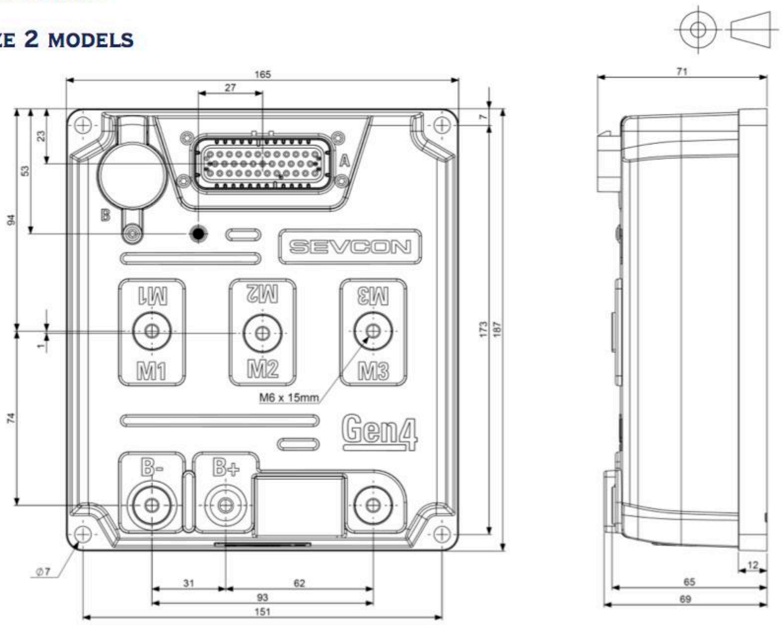
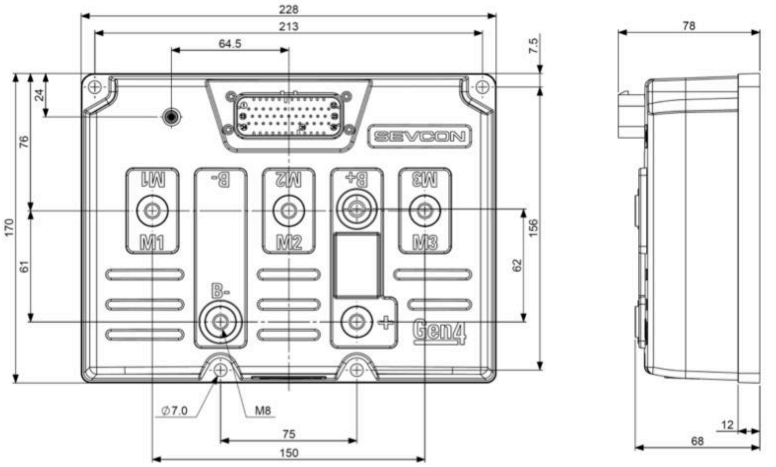
Dimensions

Size 2 models

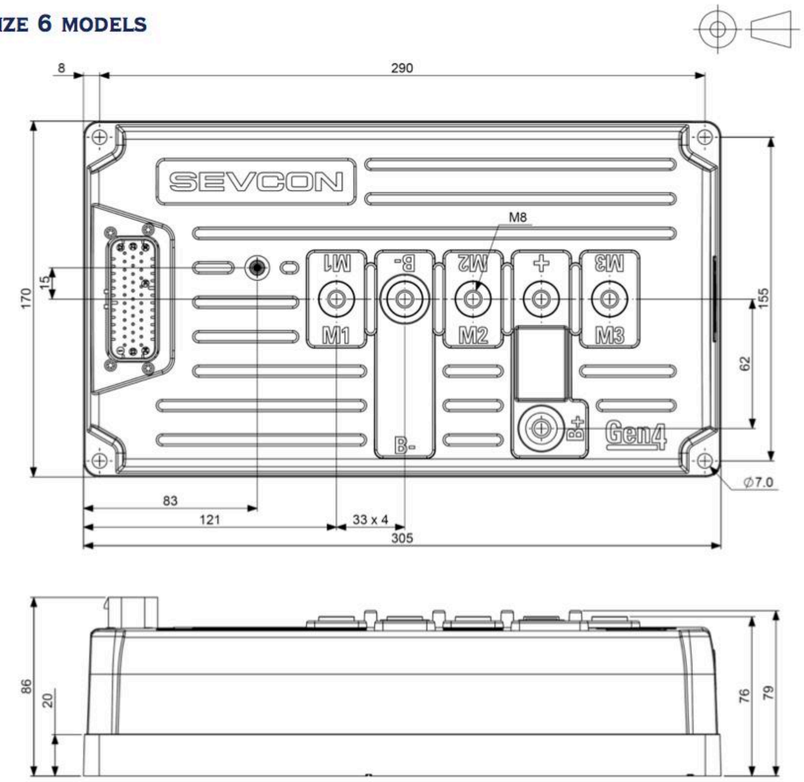


Size 4 models



SEVCON

SIZE 6 MODELS



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Chapter 5:
System design

Sizing a motor

Information required about the application

To select an appropriate induction motor for an application find or estimate the following information:

- Minimum battery voltage
- Maximum motor speed required
- Peak torque required at base speed
- Peak torque required at maximum motor speed
- Continuous (average) motor power output required to perform the work cycle
- Peak motor power output required and duration

Include inertia and friction contributed by the motor, as well as any gearing in the drive chain, when calculating torque and load requirements. If replacing a DC motor with an AC motor in an existing application, the DC motor torque vs. speed curve is a good starting point to determine the required ratings.

Motor maximum speed

Determine the maximum motor speed using the required vehicle or pump maximum speeds and the ratio of any gear box or chain between the motor and the load. Most motor manufacturer rate induction motors at synchronous speed which is 1,500 and 1,800 rpm for a 4-pole motor when operated from 50 Hz and 60 Hz line frequencies respectively.

The maximum speed an induction motor can be used at is determined by the limit of the mechanical speed, typically 4,000 to 6,000 rpm, and the reduction in useful torque at higher speeds. Increasing losses in the iron of the motor at higher speeds may further limit the maximum speed. Always check the maximum speed with the motor manufacturer. Check also any limitations imposed by the maximum frequency of the encoder input signal (see 'Motor speed sensor (encoder)' on page 5-10).

Torque required between zero and base speed

Calculate the torque required by the application. Use figures for the work that needs to be done against friction and gravity, plus those required to accelerate the load inertia and momentum. Up to rated speed the peak torque that can be supplied when using a correctly specified Gen4 is equal to the breakdown torque. Select a motor with a breakdown torque rating greater than the peak torque required.

System design

Torque required at maximum speed

Calculate the torque as above. As speed increases beyond base speed the maximum torque an induction motor can supply falls as defined by the following two equations:

In the constant power region;

$$T = \frac{T_{\max}}{\left(\dfrac{\omega}{\omega_{rated}}\right)}$$

In the high speed region;

$$T = \frac{T_{\max}}{\left(\dfrac{\omega}{\omega_{rated}}\right)^2}$$

This is shown in Figure 12. Select a motor with a torque rating greater than the peak torque required.

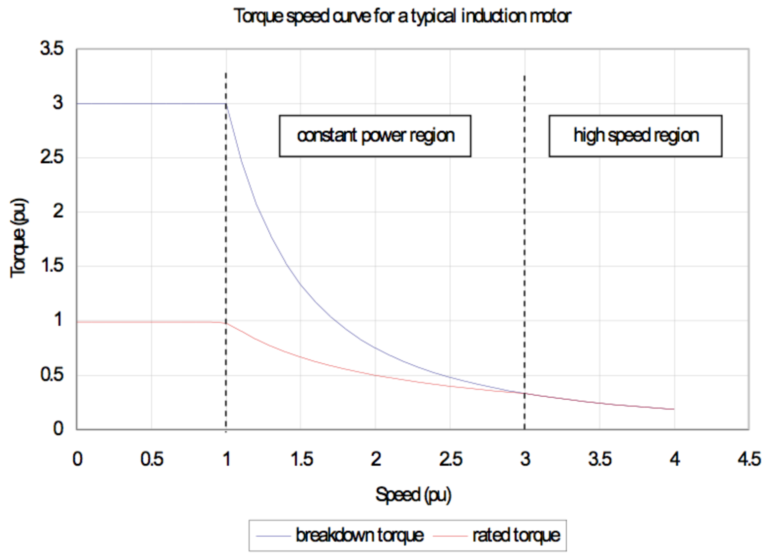

Figure 12 Torque speed curve

Continuous power rating

The required continuous power rating of the motor is governed by the application load cycle over a shift. Use the maximum RMS current over a period of one hour to determine the motor rating required. The motor manufacturer will typically specify a 1 hour or continuous rating. Select a motor whose ratings are equal to or greater than your calculated load over 1 hour.

SEVCON

PEAK POWER RATING

The peak power rating required for the application is actually determined by the peak torque required, as this determines the motor current required. Motor manufacturers will provide S1, S2 or S3 duty cycle ratings for the motors.

Selecting the Gen4 model

Matching motor and controller ratings is not an exact exercise and therefore you may need to perform iterative calculations. The main considerations when choosing an appropriate Gen4 controller are described below.

CURRENT AND POWER RATINGS CONSIDERATIONS

Consider the following when choosing the appropriate Gen4 controller:

- Ensure the controller chosen matches or exceeds the peak current and average current requirements of the motor(s) in the application.
- Ensure the application can dissipate the waste heat generated by the controller. If the controller gets too hot it reduces its output, limiting vehicle performance.

POWER OUTPUT RESTRICTIONS AT MOTOR AND DRIVE OPERATING TEMPERATURE LIMITS

A controller protects itself by reducing the current and hence torque available when its temperature limit is reached (Figure 13).

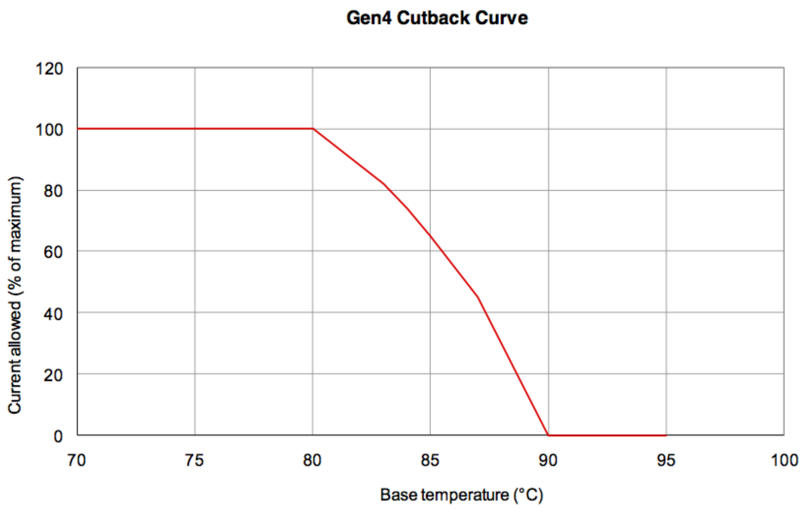

Figure 13 Current allowed vs. controller base temperature

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Circuit configuration

Once motor size is determined the application circuit configuration can be defined. A basic single traction configuration (Figure 14) is provided as a starting point for new designs. Given the flexibility of the I/O it is possible to configure a wide range of systems. Refer to 'Signal connections' on page 3-11 to see what each I/O signal is capable of doing as you design your system. For pump applications a basic single pump system is shown in Figure 15.

SEVCON

SINGLE TRACTION WIRING DIAGRAM

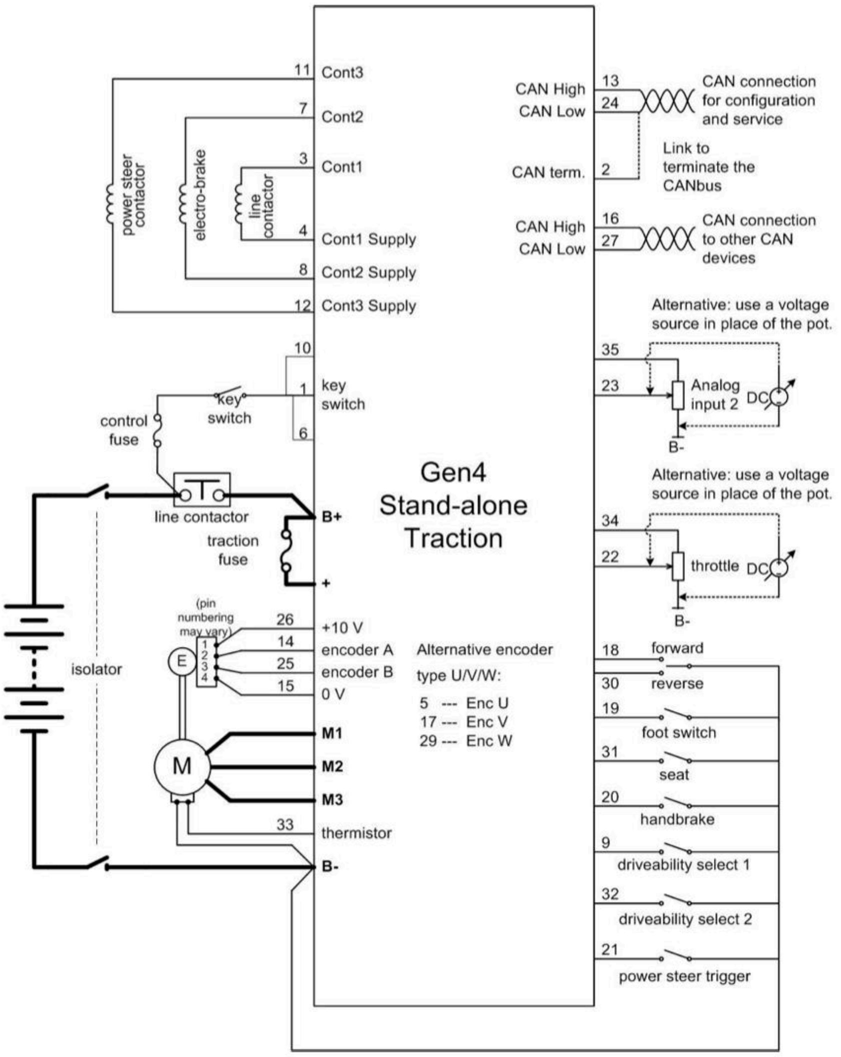

Figure 14 Single traction wiring diagram

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System design

SINGLE PUMP WIRING DIAGRAM

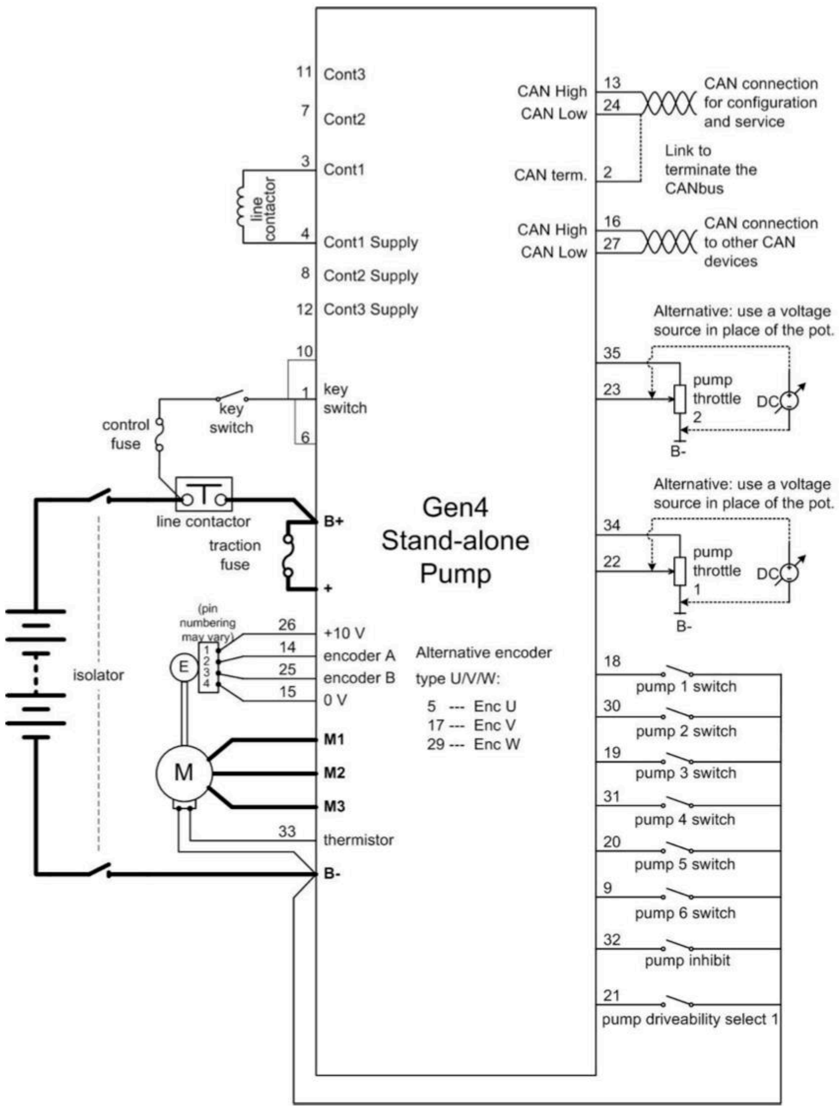

Figure 15 Stand-alone pump wiring diagram

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Twin motor systems

A twin motor system may be powered by two Gen4 controllers operating in master–slave configuration. In this case the necessary commands are transmitted by the master node to the slave node via the CANbus.

Motors may be operated independently in a combined traction-pump application or operated in tandem where each motor drives a separate wheel. In this latter case the controller (where there are two controllers, the controller configured as master):

- Assists in the steering of a vehicle by adjusting the torque of each motor dependent on the steering angle.
- Reverses the direction of the inner wheel in order to provide a smaller turning circle. The speed of the outer wheel is also limited during a turn.

An example of possible wiring for Gen4 traction controllers operating in master-slave configuration is shown in Figure 16.

Auxiliary components

Main contactor

Select the appropriate contactor line contactor from Table 5. A line contactor used at its rated coil voltage must be rated 'continuous'. Contactor coil voltage chopping allows the use of coils rated 'intermittent', provided the manufacturer's conditions are met.

Gen4 peak output current	Coil	Sevcon P/N	Manufacturer	Notes
Up to 450 A	24 V	828/37024	Albright SW200-29	See paragraph below
	48 V	828/57026	Albright SW200-20	
	80 V	828/67010	Albright SW200-460	
Up to 650 A	24 V	828/39001	Albright SW200	Chop at 17 V (intermittent coil)

Table 5 Main contactor rating

The controller can drive any contactor with coil voltages from 12 V to Vb. It is worth considering the use of 24 V contactors with the contactor drive output set to voltage-control mode. This allows you to use one type of contactor for any battery voltage (24 V to 80 V). Pull-in voltage, pull-in time and hold-in voltage values are all configurable.

Contactor coils must not be wired to the supply side of the key switch. Use the Output 1 Supply / Output 2 Supply / Output 3 Supply pins provided (see Table 2).

35 Way AMPSeal Connector Kit

Kit consists of Gen4 mating 35 way AMPSeal connector and pins, Sevcon p/n 661/27901

Emergency stop switch

Refer to the appropriate truck standards.

On-board fuse

See 'On-board fuse mounting' on page 3-8.

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System design

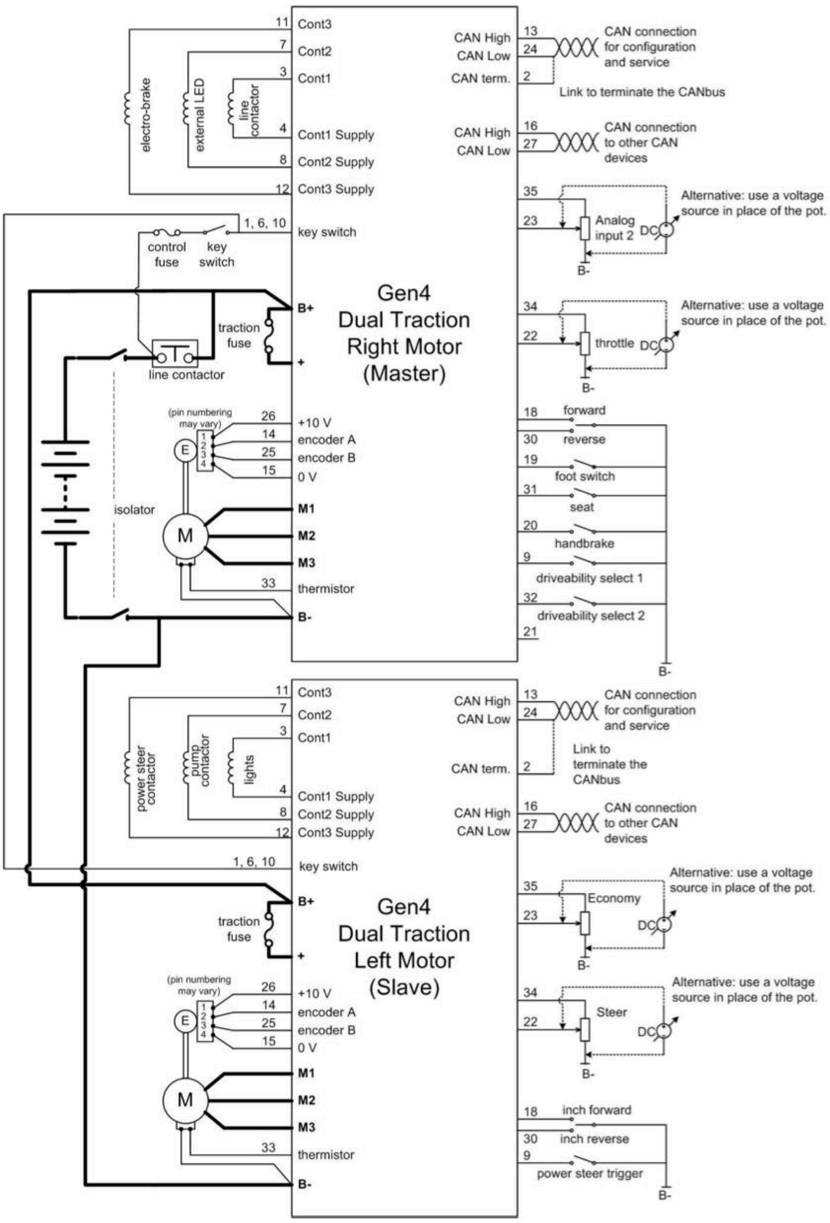

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Figure 16 Dual traction wiring diagram

KEY SWITCH FUSE F2

Use a fuse rated for the larger of: A) the sum of the drive currents plus 1A for internal circuits, and B) the capacitor pre-charge circuit. In the following example there are two contactors each drawing 2 A:

	Device	Current
A	Line contactor	2 A
	Pump contactor	2 A
	Gen4 control circuits	1 A
B	Pre-charge circuit	7 A

Fuse choice: 7A.

MOTOR SPEED SENSOR (ENCODER)

A 4-wire connection is provided for open-collector or current-source quadrature pulse encoder devices (software configurable). These types of encoder are optimized for accurate speed measurement, required for efficient control of induction motors.

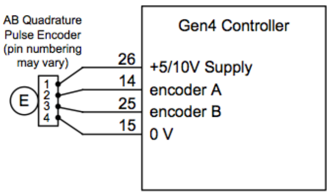

Figure 17 - Sample wiring for an AB quadrature speed encoder

You can use the following types of encoder, or equivalents:

Type	Output	Supply	Specification
Bearing Type (SKF and FAG)	Open collector	5 to 24 V DC	64 and 80 pulses per revolution Dual quadrature outputs Output low = 0 V (nominal)
HED Type (Thalheim)	Constant current	10 V nominal	80 pulses per revolution Dual quadrature outputs Output low = 7 mA Output high = 14 mA

The number of encoder pulses per revolutions (**n**) and the maximum motor speed (**N**) are related to, and limited by, the maximum frequency of the encoder signal (f_{max}). The following table shows the maximum motor speed for a given encoder on a 4-pole motor.

Encoder ppr	Maximum motor speed (rpm)
128	6000
80	10000

64	10000

For other types of encoder and motor use the formulae:

$$f_{\max}(Hz) = \frac{n(per\ revolution) \times N(rpm)}{60}$$

with $\mathbf{f}_{max}$ limited to 13.3 kHz.

and

$$N_{\max}(rpm) = \frac{20000(rpm)}{(p/2)}$$

Encoder PPR is set at 6090_h. Additional encoder configuration (pull-up, supply, etc) is set at 4630_h.

Motor commutation sensor

UVW Commutation Sensors

Commutation sensors are designed to measure the position of the rotor shaft within the motor, rather than its rotational speed. Rotor position information is used for control of permanent magnet motors, as it allows the controller to energise the motor phases appropriately based on the measured position of the magnets on the rotor.

The Gen4 controller provides inputs for both digital UVW style position sensors and analogue sin-cos sensors. Either of these can be used for control of permanent magnet motors.

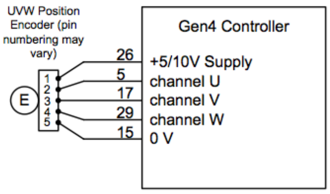

Figure 18 - Sample wiring for a UVW commutation sensor

3 digital inputs are provided for UVW encoders. The encoder should provide one pulse on each channel per electrical cycle of the motor, and each pulse should be 120° out of phase with the others and have a 50% duty cycle:

DATASHEET SEVCON GEN4

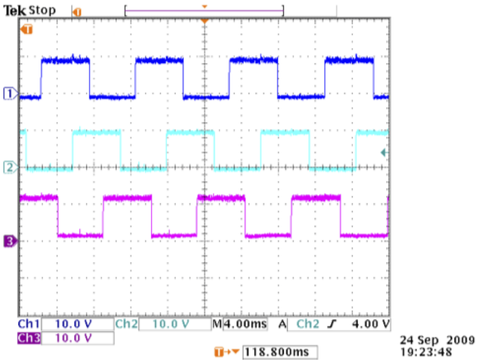

Figure 19 - Example pulse train from a UVW commutation sensor

SIN-COS COMMUTATION SENSOR

Analogue sin-cos encoders should provide one sine wave and one cosine wave per mechanical rotation of the motor. Peak and trough signal voltages must have a minimum of 1V difference.

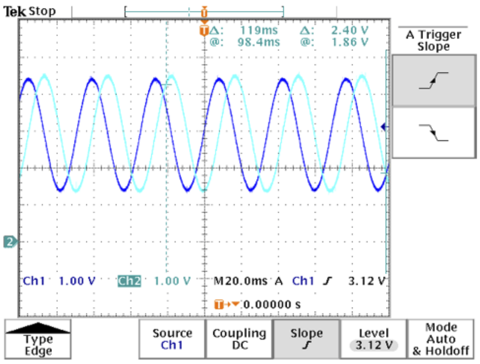

Figure 20 - Example of signals from a sin-cos position sensor

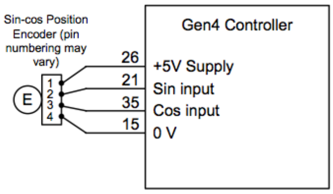

Figure 21 - Sample wiring for a sin-cos commutation sensor

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Sin-cos encoders are typically powered by a 5V supply. Therefore it is important to ensure that the controller is configured to supply 5V on pin 26. This should be done by setting the encoder configuration object dictionary entry at 4630_h.

The standard Gen4 build does not provide inputs for the sin and cos signals. Therefore, if operation with a sin-cos analogue encoder is required then this must be specified as a hardware build option. Controllers built for use with sin-cos encoders have the functions of pins 31 and 35 reassigned from digital and analogue inputs to sin and cos signal inputs respectively. Please contact your local dealer for more information on the sin-cos encoder build option.

Initial power up sequence

Incorrectly wired or configured vehicles may behave in unexpected ways. At the end of the following procedure, only lower the drive wheels to the ground after correct operation of the motor and encoder has been confirmed.

Checks prior to power up

Follow this checklist prior to applying power to your system:

- Jack up the vehicle so that the drive wheels are clear of the ground.
- Confirm all connections are tightened to specified level.
- Ensure all plugs are fully inserted.
- Confirm power wiring connections are made to the correct terminals (B+, B-, +, M1, M2 and M3).
- Ensure the controller is securely mounted (from a mechanical and thermal perspective).
- Ensure there is adequate and correctly ducted airflow for the fan cooled version.
- Check the routing of cables is safe with no risk of short circuit, overheating or cable insulation wear due to rubbing.

Checks after power is applied

Apply power and do the following:

- Use DriveWizard (see page 6-2) or any configuration tool to complete the configuration process which starts on page 6-7.
- Using the drive controls ensure the wheels rotate in the expected direction. If they do not, check the motor wiring, encoder wiring and encoder configuration (page 6-12).

It should now be safe to lower the vehicle to the ground and test drive. Proceed with caution.

SEVCON

Chapter 6: Configuration

Introduction

This section covers what you need to do to configure Gen4's software once you have designed and installed your hardware. All of Gen4's parameters have a default value and the amount of configuration needed is dependent on your particular system.

The main topics are:

- DriveWizard configuration tool: installation and use
- CANopen: an introduction to the protocol and its use in Sevcon products
- An overview of the configuration process outlining what needs to be done and the order in which it must be done
- The configuration steps

DriveWizard configuration tool

DriveWizard (Figure 22) is Sevcon's proprietary configuration tool. It allows the user, subject to a secure login process, to monitor, configure and duplicate the parameters of any Sevcon CANopen node such as the Gen4 controller. DriveWizard can also be used to monitor and configure the parameters of any 3rd party CANopen node. The information presented here is an overview only. For more information see DriveWizard's on-screen help system.

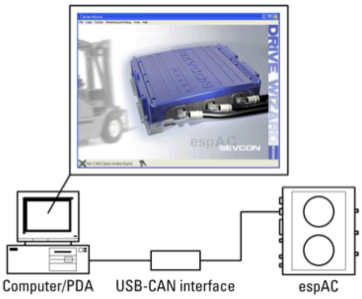

Figure 22 DriveWizard and hardware

DriveWizard functionality with lowest access level

The lowest access level allows you to review or monitor:

- DCF files on disk
- the contents of the Object Dictionary (applies also to 3rd party nodes)
- the mapping of CANopen PDO communication objects
- system logs
- fault logs

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- counters
- operational logs
- real time data (applies also to 3rd party nodes).

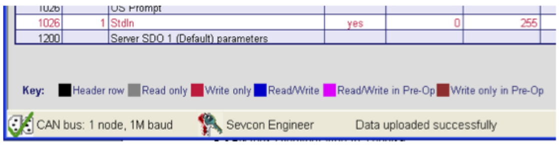
You can also change the baud rate and Node ID of a connected node. To write information to a Sevcon CANopen node you will need a higher level of access.

Status bars

User controls are invisible when DriveWizard is busy reading/writing.

User prompts are displayed in the top left of the screen as shown below:

The bottom right area of the status bar shows what DriveWizard is doing if busy and sometimes the result of DriveWizard's action if this is not clear from the main display area.



The bottom left status bar in the above example shows how many CAN nodes are connected and the access level of the person using DriveWizard.

When viewing the Object Dictionary in DriveWizard, parameters are color coded and the key is shown in the lower portion of the screen.

Saving, duplicating and restoring a node's configuration

You can use DriveWizard to:

- Save a node's configuration. This can be used at some later date to clone the node's configuration.
- Duplicate a node's configuration, in real time, to another node on the CANbus.
- Restore a configuration to a node.

Data monitoring

You can use DriveWizard to monitor data or parameters of a Sevcon or 3rd party node in real time.

CANopen

This section assumes you have an understanding of CAN and are familiar with its use. If you are new to CAN or CANopen please refer to the CiA (CAN in Automation) website, www.can-cia.org for further information.

The following information provides an introduction to the important CANopen terminology used in this manual and how it relates to the configuration of your Gen4 controller.

CANOPEN PROTOCOL

CANopen is a CAN higher layer protocol and is defined in the DS301 'Application Layer and Communication Profile' specification. All CANopen devices must adhere to this standard. To provide greater standardization and interoperability with 3rd party devices, Gen4 is designed to use the CANopen protocol for communication on its CANbus and meets V4.02 of DS301.

CANopen also supports standardized profiles, which extend the functionality of a device. The controller supports the following CANopen standardized profiles:

- DS401 (V2.1) – Device Profile for Generic I/O Modules
- DSP402 (V2.X) – Device Profile for Drives and Motion Control

OBJECT DICTIONARY

Any device connected to the CANopen network is entirely described by its Object Dictionary. The Object Dictionary defines the interface to a device. You setup, configure and monitor your Gen4 controller by reading and writing values in its Object Dictionary, using a configuration tool such as Sevcon's DriveWizard (see page 6-2).

There are two important text files associated with the Object Dictionary. These are:

EDS (ELECTRONIC DATA SHEET)

An EDS is a text file representation of the Object Dictionary structure only. It contains no data values. The EDS is used by configuration software such as Sevcon's DriveWizard to describe the structure of a node's Object Dictionary. An EDS for each Gen4 model and software version, is available from Sevcon. The EDS file format is described in the DSP306 – Electronic Data Sheet Specification.

Each Object Dictionary matches a particular Gen4 software revision, and its structure is hard coded into the controller software.

DCF (DEVICE CONFIGURATION FILE)

This is a text file similar to an EDS except that it contains data values as well as the Object Dictionary structure.

DCFs are used to:

- Download a complete pre-defined configuration to a node's Object Dictionary.
- Save the current configuration of a node's Object Dictionary for future use.

COMMUNICATION OBJECTS

These are SDO (service data object) and PDO (process data object) as described below. There is a third object, VPDO (virtual PDO), used by Gen4 which is not a CANopen object. It is described here because its function is important and similar to that of a PDO.

SDO (SERVICE DATA OBJECT)

SDOs allow access to a single entry in the Object Dictionary, specified by index and sub-index. They use the client–server communication model, where the client accesses the data and the server owns the target Object Dictionary.

SDOs are typically used for device configuration (e.g. via DriveWizard) or for accessing data at a very low rate.

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PDO (Process Data Object)

PDOs are used by connected nodes (for example in a twin motor configuration) to exchange real time data during operation. PDOs allow up to 8 bytes of data to be transmitted in one CAN message.

They use the producer-consumer communication model, where one node (the producer) creates and transmits the PDO for any connected nodes (consumers) to receive. Transmitted PDOs are referred to as TPDOs and received PDOs as referred to as RPDOs.

VPDO (Virtual Process Data Object)

VPDOs do a similar job as PDOs for data exchange, but internal to a single Sevcon node. They are unique to Sevcon and are not part of CANopen.

Network Configuration

The easiest way to configure a CANopen network is to use the auto-configuration feature. See section, Automatic Configuration Mapping (page 6-12) for more information.

General

If auto-configuration cannot be used or if additional, non-Sevcon nodes need to be added, use the following procedure to setup the network:

1. Set node ID and baudrate in 5900_h to the required values. Node IDs must be unique, and the baudrate must be the same for each node.
2. Set SYNC COB-ID in 1005_h to 0x40000080 for the master node, or to 0x00000080 for all slave nodes. Bit 30 is set to indicate to a node if it is the SYNC producer. Only one node in the network should be configured as the SYNC producer. This should normally be the master. On the SYNC producer, set the SYNC rate in 1006_h.
3. Set the EMCY message COB-ID to 0x80 + node ID in 1014_h.

EMCY COB-IDs must be configured correctly to ensure the master handles EMCYs from slaves correctly.

4. Configure the heartbeat producer rate in 1017_h. This is the rate at which this node will transmit heartbeat messages.
5. Configure the heartbeat consumer rate in 1016_h. A consumer should be configured for each node to be monitored.

Heartbeats must be configured correctly for correct network error handling. The master node should monitor heartbeats from all slave nodes. Slave nodes should, at a minimum, monitor heartbeats from the master node.

Loss of CANbus communication from any one node must cause a heartbeat fault to occur.

6. On standalone systems with non-CANopen nodes attached, hardware CANbus fault detection should be enabled at 5901_h. CANbus fault detection is automatically enabled for multi-node CANopen systems.
7. Configure additional SDO servers. An SDO server allows another CANopen device to SDO read/write from a node's object dictionary. Each node has one default SDO server (1200_h) which is reserved for communication with configuration tools like DriveWizard or the

calibrator. Another 3 SDO servers can be configured at 1201_h to 1203_h. These should be used as follows:

a. On slave nodes, configure a server to allow the master node to communicate.

b. If there is a display in the system, configure a server to allow the display access.

8. On the master node, configure SDO clients at 1280_h to 1286_h. There must be one client for each slave node. The SDO clients must be configured to match the corresponding SDO server on each slave.
9. On the master node, list all slave node IDs at 2810_h.
10. Configure RPDOs (1400_h to $17FF_h$) and TPDOs (1800_h to $1BFF_h$) appropriately for the system. See section, Manual object mapping (page 6-10), for more information.
11. Configure the RPDO timeout function if required. See section PDO mapping (page 6-11) for more information.

3RD Party CANopen Devices

At power up, the Gen4 master will communicate with all slave nodes to identify which nodes are Sevcon devices and which are not using the vendor ID in 1018_h. This instructs the Gen4 how to handle EMCY messages from each node.

Gen4 knows how to react to EMCYs (faults) from Sevcon slaves and can take appropriate action. Gen4 does not know how to react to EMCYs from 3rd party devices, so the required fault reaction to 3rd party device EMCYs must be set at 2830_h.

Configuration process overview

Electric vehicles can be dangerous. All testing, fault-finding and adjustment should be carried out by competent personnel. The drive wheels should be off the floor and free to rotate during the following procedures.

We recommend saving parameter values by creating a DCF, before making any alterations so you can refer to, or restore the default values if necessary. Do this using DriveWizard.

This part of the manual assumes you have a vehicle designed and correctly wired up with a CANopen network setup. Before you can safely drive your vehicle it is necessary to go through the following process in the order presented:

Step	Stage	Page
1	Motor characterization	6-8
2	I/O configuration	6-9
3	Vehicle performance configuration	6-17
4	Vehicle features and functions	6-32

Access authorization

To prevent unauthorized changes to the controller configuration there are 5 levels of accessibility: (1) User, (2) Service Engineer, (3) Dealer, (4) OEM Engineering and (5) Sevcon Engineering. The lowest level is (1), allowing read only access, and the highest level is (5) allowing authorization to change any parameter.

To login with DriveWizard, select User ID and password when prompted.

To login with other configuration tools write your password and, optionally, a user ID to object 5000_h sub-indices 2 and 3. The access level can be read back from sub-index 1. The password is verified by an encryption algorithm which is a function of the password, user ID and password key (5001_h).

The password key allows passwords to be made unique for different customers. The user ID also allows passwords to be made unique for individuals.

How NMT state affects access to parameters

Some important objects can only be written to when the controller is in the pre-operational state. DriveWizard takes Gen4 in and out of this state as required.

If you are not using DriveWizard you may need to request the CANopen network to enter pre-operational before all objects can be written to.

To enter pre-operational, write '1' to 2800_h on the master node.

To restore the CANopen network to operational, write '0' to 2800_h.

The controller may refuse to enter pre-operational if part of the system is active: for example, if the vehicle is being driven. The request is logged in the EEPROM however, so if power is recycled the system won't enter operational and remains in pre-operational after powering up.

The NMT state can be read at 5110_h where 05 = operational and 7F = pre-operational.

SEVCON

Motor characterization

Ensure you have completed the CANopen network setup process.

DETERMINING MOTOR PARAMETERS

To provide optimum motor performance Gen4 needs the basic motor information normally found on the name plate as well as the following information:

- A value for each of the electrical parameters of the induction motor as shown in Figure 23.
- The magnetic saturation characteristics of the motor in the constant power and high speed regions.
- Current and speed control gains.

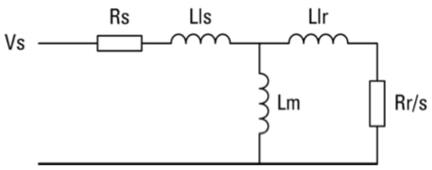


Figure 23 AC motor single-phase equivalent circuit

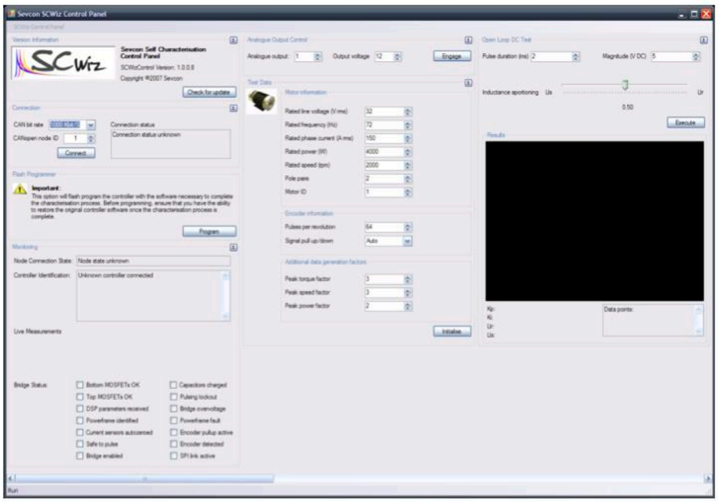
To determine these parameters use one of the following methods:

1. Ask the motor manufacturer to provide the data and enter it in the Object Dictionary at 4640_h and 4641_h. Also enter encoder data at 4630_h and 6090_h and motor maps at 4610_h to 4613_h.
2. Use the motor name plate data and the self characterization routine provided by Gen4 and DriveWizard (described below).

SELF CHARACTERIZATION

The self characterization function will cause the motor to operate. Ensure the vehicle is jacked up, with the driving wheels off the ground and free to turn, before starting the test.

The motor self-characterisation process allows a user to determine the electrical parameters required for efficient control of AC induction motors using a Gen4 controller connected to a PC or laptop running characterisation software. For further information, please contact your local Sevcon representative.



I/O configuration

Ensure you have completed the CANopen network setup and Motor Characterization processes described above.

The individual characteristics and mapping of the I/O in your application need to be setup. This can be done manually, or one of a selection of predefined setups can be selected. Predefines setups exist for many of the common vehicle functions such as standalone traction, standalone pump and twin traction.

For manual configuration, it is necessary to use PDOs and VPDOs to map application objects on the master node (2000_h to $24FF_h$) to the hardware I/O objects on all other nodes (6800_h to $6FFF_h$). Auto configurations will create the required PDO and VPDO mappings depending on which pre-defined I/O configuration has been selected, but additional PDO mappings can be added if desired.

To configure I/O:

- **Either** configure PDOs and VPDOs to map application objects on the vehicle master node to hardware I/O objects on other nodes, **or** select a pre-defined configuration and use auto-configuration to set up PDOs and VPDOs
- Setup each hardware I/O object, including wire-off protection.

MANUAL OBJECT MAPPING

To enable the controller to perform the functions required in your system it is necessary to map object to object (e.g. a measured input signal mapped to a steer operation).

This is achieved by setting up PDOs (node to node mapping) and VPDOs (internal mapping on each controller) as described below.

Apply mapping to Gen4 as follows:

- Standalone controllers: setup VPDOs only
- Networked controllers: setup VPDOs and PDOs

Before starting the mapping process it is a good idea to draw out a map of what you want to do. The amount of mapping required depends on the electrical wiring of your vehicle. Check to see if the default settings satisfy your needs before making changes.

VPDO MAPPING

VPDO mapping is defined by objects in the range 3000_h to $3FFF_h$ as shown in the table below. Use DriveWizard, or any other configuration tool, to access these objects.

Feature	Object indices	Notes
Motor	3000h	Used to map the master to the type of local motor
Input mapping	3300h	Used to map digital input signals to application inputs
	3400h	Used to map analog input signals to application inputs
Output mapping	3100h	Used to map application outputs to digital output signals
	3200h	Used to map application outputs to analog output signals

To help understand how to map internal objects an example VPDO mapping is shown in Figure 24. A digital switch input is mapped to the seat switch function to control the traction application, i.e. with no seat switch input the vehicle is prevented from moving.

6-10

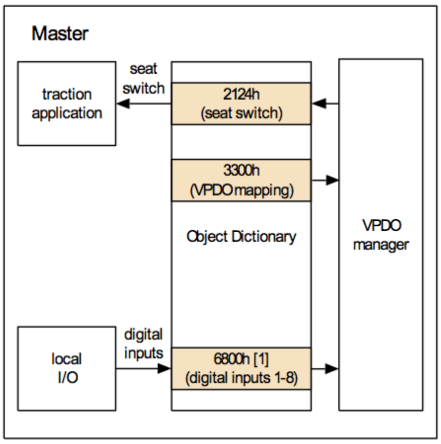


Figure 24 Example of a digital input mapped to the seat switch via VPDO

The number of sub-indices of each VPDO object depends on the amount of I/O on the device. For example, 3300_h has 14 sub-indices on a device with 8 digital inputs and 5 analog inputs. Sub-index 0 gives the number of I/O channels in use. In 3300_h sub-indices 1 to 8 correspond to the digital inputs and sub-indices 9 to 14 correspond to the digital state of analog inputs.

To map the local I/O to an application signal object, set the appropriate VPDO sub-index to the application signal object index. If the seat switch shown in the above diagram was connected to digital input 4 (bit 3 in 6800_h,1), sub-index 4 of 3300_h would be set to 2124_h.

Some further examples are:

- Map FS1 to read the value of digital input 8 (connector A, pin 11): at 3300_h sub-index 8 enter the value 2123_h.
- Map the electromechanical brake signal to be applied to analog output 2 (customer connector, pin 7): at 3200_h sub-index 2 enter the value 2420_h.

The data flow direction between the application signal objects and the local I/O objects depends on whether they are inputs or outputs. For inputs, the flow is from the local I/O to application objects, and vice versa for outputs.

Motor VPDOs are slightly different. There are six parameters for each motor, some of which flow from application to local I/O (controlword, target torque and target velocity) and some of which flow from local I/O to application (statusword, actual torque and actual velocity).

PDO MAPPING

The controller supports 5 RPDOs (receive PDOs) and 5 TPDOs (transmit PDOs). Up to 8 Object Dictionary entries can be mapped to each PDO. Every PDO must have a unique identifier (COB-ID).

Setup RPDOs and TPDOs to transmit and receive events between nodes, and map I/O from one node to applications in another node.

The easiest way to do this is using DriveWizard. If you are using a 3rd party configuration tool, the relevant Object Dictionary indices are listed in Table 6.

Feature	Object indices	Notes
Input mapping	1400h-15FFh	RPDO communication parameters
	1600h-17FFh	RPDO mapping
Output mapping	1800h-19FFh	TPDO communication parameters
	1A00h-1BFFh	TPDO mapping

Table 6 Objects associated with mapping

An example mapping (Figure 25) shows the movement of PDOs in a master-slave configuration in which a digital input to the slave has been mapped to the seat switch object in the master.

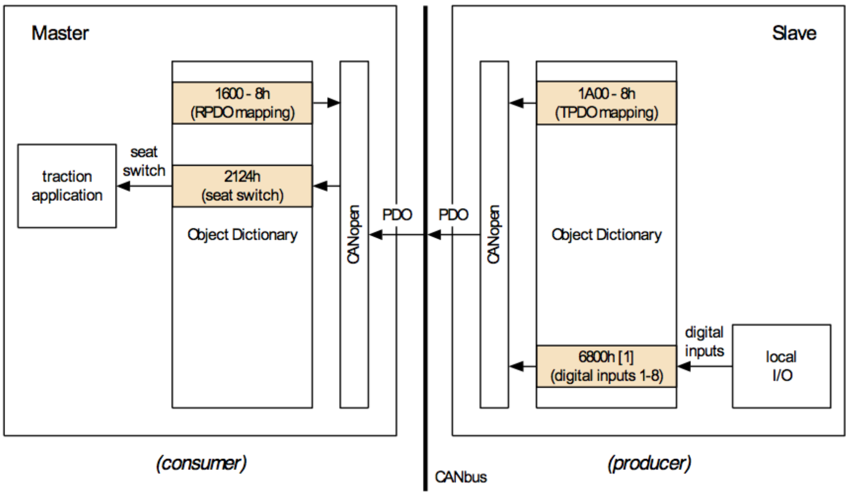


Figure 25 Example of a digital input mapped to the seat switch object via PDO and the CANbus

Gen4 supports RPDO timeout fault detection. This can set a warning, drive inhibit or severe fault depending on the configuration in 5902_h.

RPDO timeout can be used for non-CANopen systems which do not support heartbeating. By default, RPDO timeout is disabled, and normal CANopen heartbeating protocol (see section Network Configuration (page 6-5)) is assumed to be used.

Automatic Configuration Mapping

The auto-configuration feature allows the user to select their vehicle I/O from a list of pre-defined configurations. The principle is identical to the manual process described above, but the PDO and VPDO mappings are created by each controller automatically at start up as well as CANopen network configuration settings. This feature provides an easy and reliable method of setting up both single and

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multi node systems, providing they match one of a selection of pre-defined setups (refer to page 1 for details on the available configurations).

To enable auto configuration on all nodes set 5810_h sub-index 1 to $0CFF_h$ (This corresponds to "Enabled"/"Both VPDO and PDO" for all IO auto configuration options in Drive Wizard). This enables the auto configuration of local and remote (via CANopen) analogue IO, digital IO and motor control. This is the default state for automatic configuration. It is possible to disable individual parts of the configuration to allow for user customization via the methods described above.

Digital input, analogue input and analogue output configurations can be selected from the predefined tables and their numbers entered into sub-indices 3, 5 and 6. This need only be set on the master controller if a multimode system is being configured.

CAN node function and configuration can also be defined via the auto configure feature. For each node the following should be specified:

- If it is Master or Slave in the CANBus system
- On the Master node, specify it's function, e.g. Traction, right side controller and also which other nodes are present as slaves, e.g. Pump, Power steer.
- On the Slave node, simply specify that it is a slave and which type of slave it is, e.g. Pump.

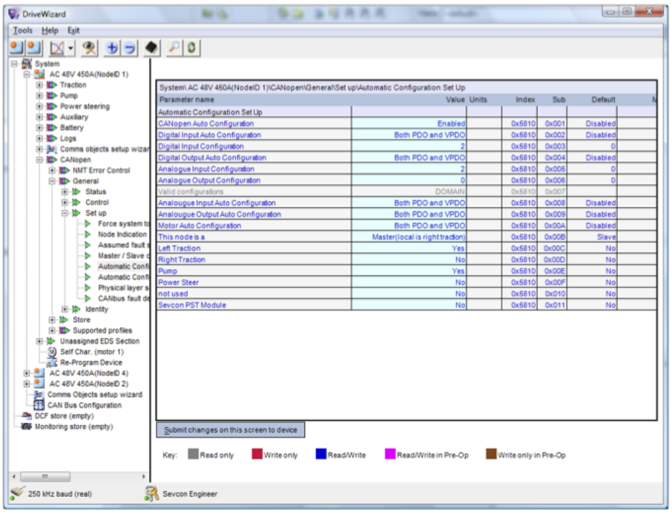

Figure 26 - DriveWizard screen showing automatic object mapping

SEVCON

Encoder

It is important that the number of encoder pulses per revolution is entered correctly. If this information is not correct, the controller may not be able to brake the motor effectively.

To configure the encoder:

1. Enter the resolution pulses/rev at 6090_h.
2. Check whether the encoder requires controller pull ups enabled (e.g. open-collector type) and enable pull-ups if needed at 4630_h. The default setting is no pull-ups, which is suitable for current source encoder types.
3. Select the required encoder supply voltage (10V or 5V) at 4630_h.

To change the encoder polarity (if required) change the setting at $607E_h$ (reverses the forward and reverse speed measurements).

Digital inputs

The state of the digital inputs can be read at object 6800_h.

Digital inputs are either all active low (switch return to battery negative) or all active high (switch return to battery positive). A mixture of active low and active high inputs is not possible. The default setting is active low.

To configure digital inputs:

- Set active high/low logic at 4680_h.
- Set wire off protection at 4681_h. Any two digital inputs can be configured with wire-off protection. See Table 2 Connector A pin out and wiring information on page 3-15 (pins 14 and 15) for more details.
- Set digital input polarity at 6802_h. This is used to configure normally closed/open switches.

Analog inputs

The analog input voltages can be read at object $6C01_h$. Voltages are 16-bit integer values with a resolution of 1/256 V/bit.

Although each input is usually assigned a specific task by default, any of the inputs can accept a variable voltage or a potentiometer. Analog inputs can also be used as additional digital inputs.

The following table summarises the analog inputs and any special features:

Name	Object	Pin	Usage
Wiper Input 1	$6c01_h$,1	22	Input from external voltage source or 3-wire pot wiper. Use pin 34 as supply for 3-wire pot.
Wiper Input 2	$6c01_h$,2	23	Input from external voltage source or 3-wire pot wiper. Use pin 35 as supply for 3-wire pot.
Analog Input 1 or Supply for Wiper Input 1	$6c01_h$,3	34	Use for 2-wire pot input or as a supply for wiper input 1. Has internal pull-up.
Analog Input 2 or Supply for Wiper Input 2	$6c01_h$,4	35	Use for 2-wire pot input or as a supply for wiper input 2. Has internal pull-up.
Motor thermistor	$6c01_h$,5	33	Use for motor thermistor input or 2-wire pot input.

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			Has internal pull-up.

Wire-off detection

Enable wire-off detection at $46C0_h$ to $46C4_h$. For each input specify the allowable range of input voltages. To disable, set the ranges to maximum.

Motor thermistor input

You can connect a thermistor sensor to the Motor thermistor input or a switch to any digital input.

Type	Specification
PTC Silistor	Philips KTY84 or equivalent
Switch	Connected to a general purpose digital input

To setup go to object 4620_h:

- Configure as none, switch or PTC thermistor
- For KTY84 thermistors, set the PTC type to KTY84.
- For non-KTY84 PTC thermistors, set the PTC type to User Defined and then set the expected voltages at 100°C (high temperature voltage) and 0°C (low temperature voltage). The Gen4 will linearly interpolate temperature with voltage.
- If you are using a switch select the digital input source

Read the measured motor temperature (PTC) or switch operation at object 4600_h.

Analog inputs configured as digital inputs

Each analog input can also be used as a digital input.

To configure an analog input as a digital input, set the high and low trigger voltages at object 4690_h.

The digital input status object, 6800_h, contains enough sub-indices for the digital and analog inputs. Sub-index 1 is the states of the digital inputs, and sub-index 2 is the states of the analog inputs converted to digital states.

Analog (contactor) outputs

There are 3 analog outputs which you may have mapped to one or more contactor functions such as: line contactor, pump, power steer, electro-brake, external LED, alarm buzzer and horn.

Configure each of the outputs used in your system:

- Choose voltage control or current control for each analog output at $46A1_h$.
  (At the time of writing, current controlled devices can only be operated from Gen4 by mapping a signal input to the controller from an external 3rd party node).
- Set the frequency of each output to a fixed value of 16 kHz or any value between 40 Hz and 1 kHz at $46A2_h$ and $46A3_h$. You can have only one low frequency setting per controller. Low frequencies are normally used with current-controlled outputs.
- Set the analog output values at object $6C11_h$. The value is either a voltage or current depending on whether the output is voltage controlled or current controlled. Values are 16-bit integers with a resolution of 1/256 V/bit or A/bit.

SEVCON

ERROR CONTROL

It is important that analog outputs on nodes other than the master must have appropriate error configuration to protect against CANbus faults. This section explains how to configure the outputs to go to a safe state in the event of a CANbus fault. It is the installers responsibility to define what a safe state is for each output.

In a CANopen network, the slave node on which the analog (contactor) outputs reside can be different to the master node which calculates the output value. If the CANbus fails, the master node is no longer able to control the slave outputs. In this situation, the outputs may need to change to a safe value. This is achieved with error control.

To configure error control:

- Set each output at object $6C43_h$ to use its last set value or the value at $6C44_h$ if the CANbus fails.
- Set values if needed at $6C44_h$ for each output. These values are 32-bit integers, but the the bottom 16-bits are ignored. The top 16-bits give the error value in 1/256 V/bit (or A/bit for current controlled outputs).

Some examples of typical configurations may be:

- Electro-mechanical brake on slave node. If CANbus communication is lost, it may be desirable to apply the electro-mechanical brake on the slave device. In this case, enable error control in $6C43_h$ and set the error value in $6C44_h$ to 0.
- Power steer contactor on slave node. If CANbus communication is lost, it may be desirable to leave the power steer output in its previous state. In this case, disable error control in $6C43_h$.
- CANbus communication error lamp on slave node. If CANbus communication is lost, it may be desirable to activate an output on the slave device. In this case, enable error control in $6C43_h$ and set the error value in $6C44_h$ to an appropriate voltage for the lamp.

The above examples are for illustration purposes only. It is the responsilbity of the installer to decide on the required state for each output in the event of a CANbus failure.

Vehicle performance configuration

Ensure you have completed the CANopen network setup, Motor Characterization and I/O Configuration processes described above.

SAFETY INTERLOCKS

FS1

The FS1 switch is normally part of the throttle assembly. It closes when the throttle is pressed. The throttle voltage is ignored until FS1 is closed.

FS1 features are configured at 2914_h:

- SRO (static return to off): inhibits drive if FS1 is closed for the SRO delay without any direction (forward or reverse) being selected.
- FS1 recycle: forces the operator to lift their foot off the throttle before allowing drive after a direction change.

DEADMAN

The deadman switch operates similar to the FS1 switch, whereby, it inhibits drive until it is active. However, the deadman switch applies the electro-mechanical brake immediately on deactivation, whereas FS1 waits for the vehicle to stop before applying the brake.

SEAT

The seat switch indicates operator presence on the vehicle. Drive is not allowed if this switch is open. If the seat switch opens during drive for a period longer than the seat switch delay, a fault is set, disabling drive. To clear a seat fault, close the seat switch, open FS1 and deselect the forward/reverse switch.

Set the seat switch delay at object 2902_h.

HANDBRAKE

If mapped to a digital input, the handbrake switch inhibits drive if the vehicle handbrake is applied. Controlled roll-off detection is still active when the handbrake is applied in case the brake fails.

SEQUENCE FAULT MASKING

If an application does not require it, sequence fault checking can be disabled on selected drive inputs. This is set at 2918_h.

Similarly, drive inputs can be masked when clearing drive inhibit faults. This is set at $291A_h$.

These masks must only be applied if the application has other adequate means of protection. It is the responsibility of the installer to ensure this.

TORQUE MODE/SPEED MODE

Speed mode (or speed control) is not recommended for on-highway vehicles as it can cause the traction motor/wheel to remain locked or brake severely if the wheel is momentarily locked due to loss of traction on a slippery surface and/or mechanical braking.

SEVCON

The Gen4 controller provides both torque and speed control modes. Objects 2900_h and 6060_h are used to set which mode to use. The default setting is torque mode.

Always ensure 2900_h on the master node and 6060_h on all the traction nodes (master and slaves) match otherwise motor signals between the master and slaves may be misinterpreted.

The speed control (speed mode) or speed limit (torque mode) is controlled using PI loops. These loops are configured at 4651_h. The following parameters can be configured:

- Standard proportional and integral gains (4651_h, 1+2). Used to configure the loops during normal operation.
- Low speed proportional and integral gains (4651_h, 3+5). Used to configure the loops at low speeds (<50 RPM) and during hill hold. These are normally set lower than the standard gains to dampen oscillation as the vehicle comes to a stop.
- Roll back integral gain (4651_h, 4). Used to boost the integral term to prevent vehicle roll-off down inclines, particularly when Hill Hold is enabled. Normally, this gain is higher than the standard integral gain.
- dw/dt gain (4651_h, 6). For speed mode this is used to boost the torque output when a large increase in speed demand occurs. For torque mode this is used to apply compensatory torque to damped oscillations induced from the vehicle drivetrain.
- Integral initialization factor (4651_h, 7). Used to initialize the integral term on entry to speed limit in torque mode. This factor is multiplied by the actual torque to set the integral term. Not used in speed mode.

These settings affect how driver demands are interpreted by the controller. In torque mode, the throttle push translates into a torque demand, which is applied to the traction motor. In speed mode, the throttle push translates to a speed demand. The controller then calculates the torque required to maintain this speed.

The difference between these control methods is most apparent when driving on an incline. In torque mode, when the vehicle is driven uphill, the vehicle speed will decrease due to the increased load. The operator must apply more throttle demand in order to maintain speed. In speed mode, the controller will apply additional torque in order to maintain the operator's speed demand, without the operator having to increase throttle demand.

THROTTLE

GENERAL

The controller can use 2 or 3 wire throttle inputs of the following types:

- Linear potentiometer in the range 470 Ω to 10 kΩ
- Voltage source in the range 0V to 10V: compliant with the standard 0..5 V, 0..10 V or 3.5..0 V ranges

To setup throttle inputs see 'Analog inputs' on page 6-14. The throttle voltage (2220_h) must be mapped to an analog input.

It is recommended that inputs with wire-off detection are used for the throttle input to detect wiring faults. This is especially important if a wire-off sets maximum throttle. See section Analog inputs (page 6-14) for more information.

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Configuration

Setup the characteristics of the throttle at 2910h, sub-indices 2 to 20.

- Define the throttle voltage input: this is the relationship between the throttle voltage and the throttle value. Separate relationships can be specified for forward and reverse. Each relationship has two points, a start and an end. The points are configured differently for standard and directional throttles as shown in Figure 27 and Figure 28 respectively.

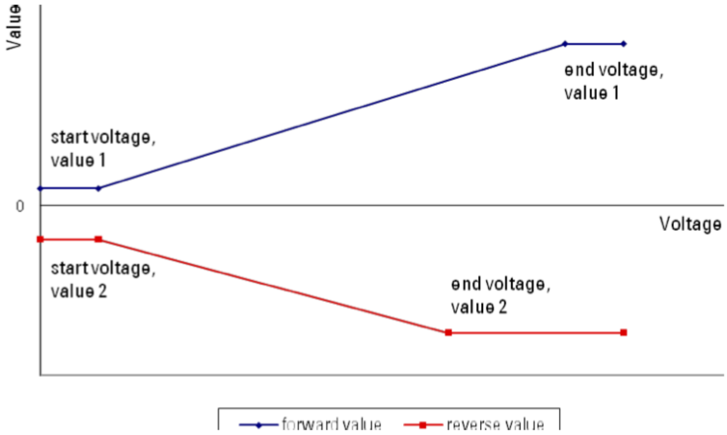

Figure 27 Standard throttle configuration

If the reverse characteristic is the same as the forward characteristic, just set all the reverse throttle parameters to 0 in 2910h.

SEVCON

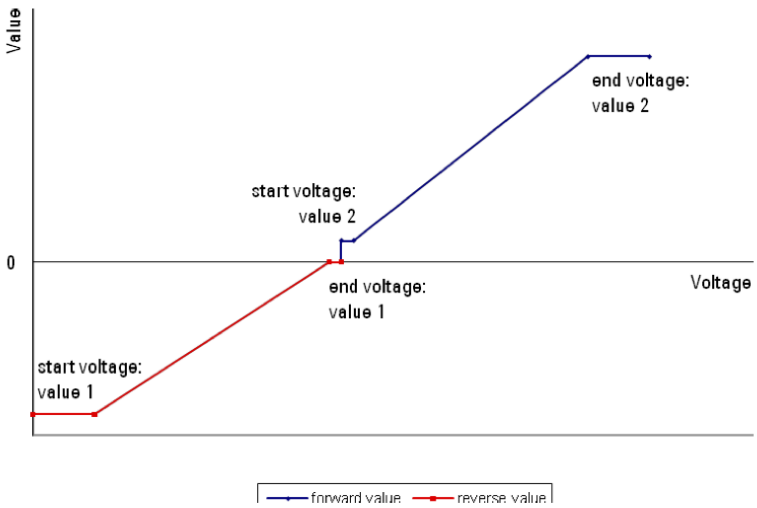

Figure 28 Directional throttle configuration

- Define the input characteristic: this is a profile to the throttle value and can be linear, curved, crawl or user-defined as shown in Figure 29. The curved and crawl characteristics give greater throttle control at low speeds.

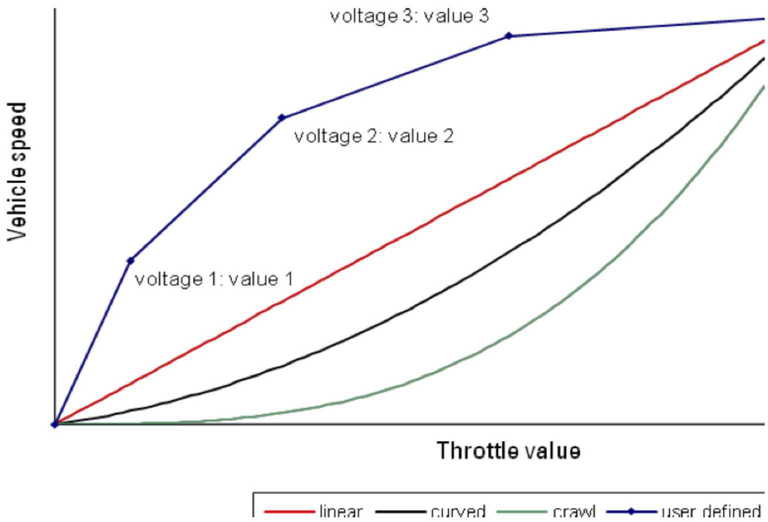

Figure 29 Input characteristics

6-20

The throttle value calculated from the voltage can be read at 2620_h.

Dual Throttle Inputs

Single and dual throttle inputs are supported.

Single throttle inputs are normally used with other interlock inputs (eg FS1, deadman, etc) and use a single input voltage to determine driver demand.

Dual throttle inputs use two separate input voltages, each of which is converted to a throttle value using 2910_h, subindices 3 to 6 (throttle input 1) and subindices 7 to 10 (throttle input 2). If the throttle values differ by more than 5%, a throttle fault is set and the system will not drive.

To enable dual throttle functionality, map a second analog input to 2224_h. The throttle value for the second throttle input can be read at 2626_h.

Dual throttle systems allow a virtual FS1 feature, which can be used instead of an actual FS1 switch. This feature can be enabled on dual throttle systems using 2910_h, 1.

The voltage input characteristics of the two analogue throttle inputs must be different.

Creep Torque

Creep torque allows a small amount of torque to be applied as soon as the throttle is closed. This can be used on some vehicles to overcome the friction required to achieve initial vehicle movement.

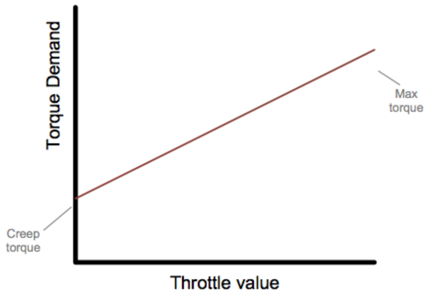

Figure 30 – Illustration showing behaviour of creep torque

Increasing the creep torque level can improve how the vehicle feels when drive is first selected and the vehicle starts to move. However, too much creep torque can make the vehicle uncontrollable at low speeds.

Creep torque will be applied as soon as drive is selected and the throttle is closed. Do not increase the creep torque value to a level that would cause unexpected high levels of torque output for comparatively low levels of throttle push. If in doubt, set the creep torque level to 0%.

Driveability Features

These features are used to configure how the system uses throttle information and how it handles speed limits (in torque mode). The installer must ensure these features are configured appropriately.

Set the following driveability features at $2910_h,1$:

- Enable/disable proportional braking. If enabled, the braking torque during direction braking is proportional to the throttle.
- Enable/disable directional throttle. If configured as a directional throttle, the throttle voltage indicates the direction as well as the speed demand. This removes the need for forward and reverse direction switches.
- Proportional speed limit enable/disable. If enabled, speed limit is proportional to the throttle, otherwise speed limit is fixed at the forward or reverse maximum speed. Only used in torque mode.

Proportional Speed Limit is not recommended for on-highway vehicles as it can cause the traction motor/wheel to remain locked or brake severely if the wheel is momentarily locked due to loss of traction on a slippery surface and/or mechanical braking.

- Braking directional throttle enable/disable. If enabled, a directional throttle can be used to demand a drive or braking torque in conjunction with the direction switches. Only used in torque mode.
- Reverse speed limit encoding. Controls how reverse speed limits are handled in torque mode. Must always be enabled on Slip control systems, and must always be disabled on flux vector and PMAC systems.
- Handbrake fault. If enabled, a handbrake fault is set when a direction is selected whilst the handbrake input is active.
- Proportional speed limit during braking enable/disable. If enabled, speed limit is proportional to throttle only in drive states. Maximum speed limit is allowed in braking states. Only used in torque mode.
- Driveability Consolidation. Normally, driveability profiles are only used to reduce vehicle performance, however, if this is enabled, an active driveability profiles over-writes the baseline. This allows vehicle performance to increase when a profile is active. Note, that this feature is not available in all software builds.
- Allow step change in steering angle. If enabled, steering angle can change instantly with steering voltage. If disabled, steering angle is rate limited to 90°/s which prevents sudden steering angle changes in the event of a steering sensor wire-off.
- Virtual FS1 enable/disable. If enabled, this sets up a virtual FS1 feature on systems with dual throttle inputs configured.

An s-curve profile can be applied to the speed target (in speed mode) or maximum speed (in torque mode). This can be set at $290A_h$.

ACCELERATION AND BRAKING

See 'Driveability profiles' for more information on page 6-25.

Some vehicles can exhibit shock due to the rapid reversal of torque after a direction change. 2909_h can be set to force the vehicle to remain stationary for a period before driving in the new direction.

To prevent early exit from neutral braking, a debounce timer can be set at $290D_h$. Neutral braking only finishes when the vehicle has been stopped for longer than this time. This can help prevent early exit of neutral braking due to motor oscillation caused by under damped suspension.

On vehicles with gearbox meshing issues, a slower rate of torque ramp up at low speeds can be configured at $291C_h$. This slow rate of change of torque lessens shock due to gear meshing. Used in torque mode only.

Brake feathering reduces neutral and foot braking torques as the vehicle speed approaches 0 to prevent any roll-back in the opposite direction. This is set at $290E_h$. Used in torque mode only.

FOOTBRAKE

The controller can use a switch or analog voltage as the footbrake input. If a footbrake switch is mapped, it applies maximum foot braking when the switch is closed. The footbrake switch object (2130_h) must be mapped to a digital input.

If the footbrake input is an analog voltage, configure the voltage levels in the same way as the throttle. The footbrake voltage (2221_h) must be mapped to an analog input.

Configure the characteristics of the footbrake at 2911_h:

- Drive/foot braking priority. If the throttle and footbrake are pressed at the same time, this setting determines whether the system attempts to drive or brake.
- Minimum speed for braking. Foot braking stops when the vehicle speed drops below this level.
- Footbrake voltage input and Input characteristic. These settings are similar to those for the throttle. Refer to the Throttle section above for more information.
- Footbrake priority timeout allows the configured priority to change after a timeout period. Setting zero will disable this feature.

The footbrake value calculated from the voltage can be read at 2621_h.

STEERING INPUTS – TWIN DRIVING MOTOR SYSTEMS

Loss of steering information can make a vehicle operate erratically. The analog input use for the steering sensor should have suitable wire-off protection configured.

Twin motor systems, which use the drive motors for turning, require some means of determining the angle of the steering wheel.

To do this use one of these options:

- A steering potentiometer to give an analog voltage which is a linear function of the steering angle. The steer potentiometer voltage (2223_h) must be mapped to an analog input.
- Four digital inputs representing 'inner left', 'inner right', 'outer left' and 'outer right'. The inner switches indicate the steering angle where torque to the inner wheel motor is removed. The outer switches indicate the steering angle where inner wheel motor changes direction. The outer switches are optional. The steer switches ($212B_h$ to $212E_h$) must be mapped to digital inputs.
- Steering angle from 3rd party CAN device. This can be received via RPDO on object 2624_h in 0.01°/bit resolution.

To configure steering inputs go to index 2913_h in the Object Dictionary:

- Setup the voltages corresponding to fully left, fully right and straight ahead. Using this information, Gen4 calculates the steering angle based on the voltage from a steering potentiometer.
- Setup the steering map. This map defines the relationship between the inner and outer wheel speeds and the steering angle. Each map has 4 user definable points as shown in Figure 31.

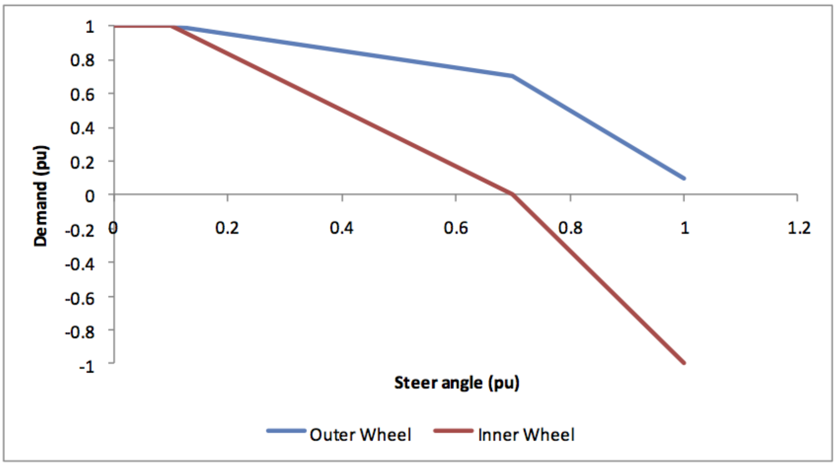

Figure 31 Graph of speed vs. steering angle

The speed and steering angle are normalized. Speed is normalized to maximum vehicle speed and the steering angle to 90°.

In speed mode, outer wheel speed target and maximum torque is scaled according the outer wheel map. Inner wheel speed target and maximum torque is scaled to the outer wheel demands according to the inner wheel map.

In torque mode, both inner and outer wheel maximum speeds are scaled according the outer wheel map. The outer wheel target torque comes from the throttle. The inner wheel target torque is scaled to the outer wheel actual torque according the inner wheel map.

In object 2913_h, 0 to 1 is represented by values in the range 0 to 32767. The inner wheel is scaled according to the outer wheel. Where a demand (pu) of -1 is shown at 90° for the inner wheel, this means the inner wheel demand will be equal and opposite to the outer wheel.

The calculated steering angle can be read at 2623_h. An angle value of -32767 indicates full steering to the left, +32767 full steering to the right and 0 is straight ahead.

If steering switches are used instead of a steering potentiometer, only part of the steering map is used as shown in Table 7.

Value	Description
2913_h,9	Outer wheel speed during inner wheel cutback
2913_h,11	Outer wheel speed during inner wheel reversal
2913_h,17	Inner wheel cutback speed
2913_h,19	Inner wheel reverse speed

Table 7 Objects to set when using steering switches

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During a turn the inner wheel speed is slowed by power reduction instead of braking to prevent the outer wheel motor working against the inner wheel motor.

DRIVEABILITY PROFILES

Ensure driveability profiles are disabled when not required. Activation of a driveability profile can cause driving parameters to change.

Driveability profiles allow you to set maximum values for speed, torque, acceleration and deceleration for use in a range of operational situations. In addition, in torque mode, there are ramp rates for speed limits as well. and Figure 33 show the change in speed and torque target under various driving conditions over a period of time.

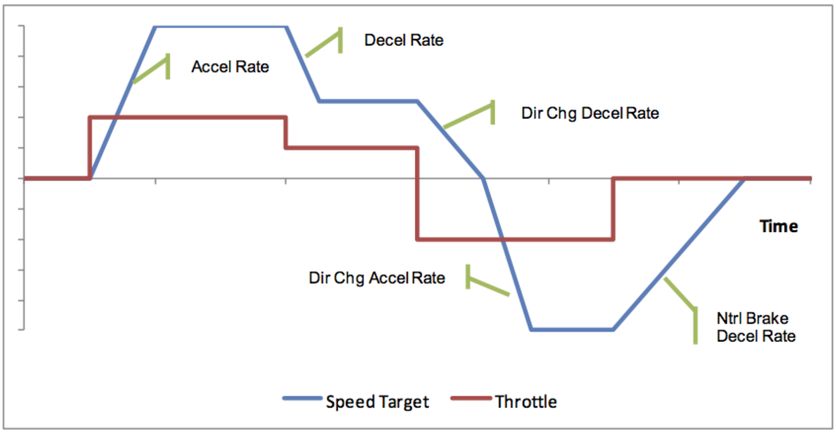

Figure 32 Speed mode acceleration/deceleration

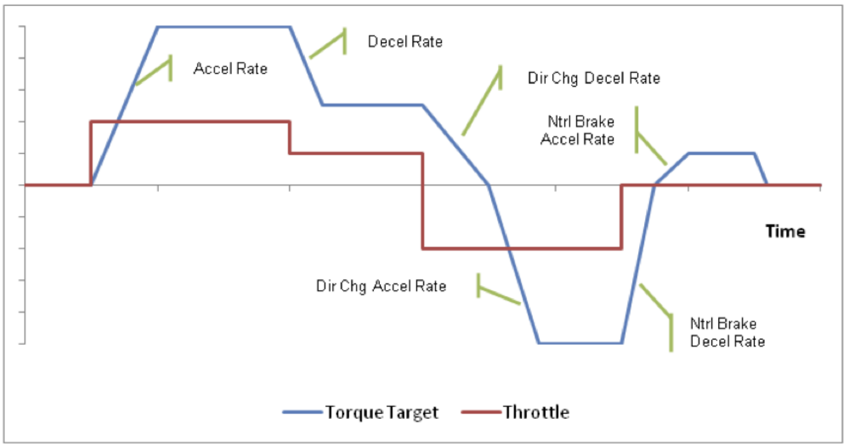

Figure 33 Torque mode acceleration/deceleration

In Torque mode, the acceleration and deceleration rates control the rate of change of torque. In Speed mode, the acceleration and deceleration rates control the rate of change of speed.

You can select reverse while driving in the forward direction with your foot still on the throttle. In this situation the controller applies braking in the form of a direction change deceleration rate down to zero speed. It then applies a direction change acceleration rate to increase the vehicle's speed in the reverse direction up to the set maximum speed as shown above.

Configure the following drivability profiles to suit your application (each containing the same set of parameters):

- Traction baseline profile: the default and highest set of values (2920_h).
- Drivability select 1 profile: invoked when drivability select 1 switch is active (2921_h) or an alternative trigger is active (see below).
- Drivability select 2 profile: invoked when drivability select 2 switch is active (2922_h) or an alternative trigger is active (see below).

The traction baseline profile contains the default maximum values. All of the remaining profiles apply lower, modifying values to the baseline profile. BDI and service profiles, when configured, are automatically applied by the software under preset conditions. For example you may want to limit the acceleration and maximum speed of a vehicle when the battery gets low to maximize the operating time before recharge. The remaining profiles are applied by the driver with a switch.

Drivability profiles can also be invoked by internal software triggers, such as BDI low, service required or low speed. These can be selected to suit specific application requirements. Set the profile triggers in 2931_h.

Where more than one profile is active, the lowest value(s) are used by the software.

Speeds in driveability profiles are scaled according to the vehicle gear ratio (2915_h). This is used to convert speed in RPM to any other preferred unit such as KPH or MPH. To remove this scaling and leave driveability profile speeds in RPM, set 2915_h,3 to 1.

Torques in driveability profiles are in 0.1%/bit resolution. These are converted to Nm using the motor rated torque value at object 6076_h.

Ramp rates in driveability profiles are in either RPM/s for speed mode, or %/s for torque mode. In speed mode, RPM/s becomes "User Defined Units" / s if the gear ratio is used to rescale the driveability profile speeds.

Speed limit ramp rates are only used in torque mode and are in RPM/s (or user defined units / s).

In addition to the speed limit ramp rates in the profiles, $291E_h$ can be used to configure safety limits on speed limit ramping. The installer should set these ramp rates to suitable levels to ensure speed limits can not ramp faster than could actually happen on a vehicle. This can protect against harsh braking if traction wheels are momentarily locked.

Preventing Wheel Lock Scenarios

For certain vehicle types, particularly on-highway vehicles or electric motorcycles, the possibility of wheel locking during drive must be considered.

During braking, the controller will maintain a speed limit to ensure the vehicle does not overspeed if entering braking whilst travelling downhill. If proportional speed limit is set then the speed limit will follow actual speed toward zero whenever actual speed is dropping rapidly, usually due to some external influence such as application of mechanical brakes.

If the brakes are applied too harshly, then there is possibility to lock the drive wheels. In these circumstances, the normal reaction of the driver is to release the brake to allow the wheels to rotate again. The correct operation of the controller in this scenario is to allow the wheels to continue to rotate, and not impose a speed limit.

The maximum rate at which the speed limit can increase or decrease is specified in object 291E $_h$. By limiting the rate at which the speed limit can decrease, we can ensure that if the brakes are released after they had locked the drive wheels, the controller's speed limit will allow them to rotate again. The operation of this is shown in Figure 34 below.

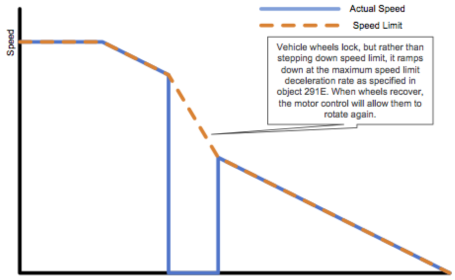

Figure 34 - Example of behaviour of speed limit when drive wheels are locked

It is important to consider the behaviour of the vehicle under all drive conditions, including when traction is lost due to locking of the drive wheels. When testing a vehicle, check that the vehicle behaves in a safe manner when performing harsh braking on low-friction surfaces such as gravel.

CONTROLLED ROLL-OFF

Controlled Roll-Off is not recommended for on-highway vehicles as it can cause the traction motor/wheel to remain locked or brake severely if the wheel is momentarily locked due to loss of traction on a slippery surface and/or mechanical braking.

Controlled roll-off limits a vehicle to a slow, safe speed if it starts to move without any operator input. Primarily, it is to prevent uncontrolled movement if a vehicle's brakes fail on an incline. Controlled roll-off operates whether the operator is present or not.

Configure the following at object 2930$_h$:

- Enable/disable controlled roll-off
- Set a roll-off maximum speed
- Set a roll-off maximum torque

Alternatively, Gen4 can apply an electromagnetic brake if one is mapped and roll-off is detected. Refer to 'Electro-mechanical brake' on page 6-32 for more information.

HILL HOLD

Hill Hold is not recommended for on-highway vehicles as it can cause the traction motor/wheel to remain locked or brake severely if the wheel is momentarily locked due to loss of traction on a slippery surface and/or mechanical braking.

A vehicle on a hill can be held at a standstill for a configurable time when the operator selects neutral. At the end of this time or if the seat switch indicates the operator is not present, hill hold terminates and the vehicle can start to move if parked on an incline. If enabled, the system will enter controlled roll-off after hill hold.

You can set the hill hold delay at object 2901_h. Set the hill hold delay to 0 to disable this feature.

In speed mode, drive torque is disabled whilst neutral braking to stop. However, drive torque must be re-enabled when entering Hill Hold to allow torque to be applied to hold on the incline. Set the speed to re-enable drive torque at 2908_h.

Inching

Ensure inch switches are only mapped to digital inputs when required. Activation of these inputs can cause a drive condition to occur.

Inching allows an operator to maneuver a vehicle, at low speeds, towards a load. Inching can be initiated with one switch. A time-out is used to prevent the vehicle from continuing to drive indefinitely if the switch gets stuck or goes short circuit.

To configure inching:

- Ensure forward and reverse inching switches have been mapped to two digital inputs.
- Specify an inching speed (0% to 25% of the full speed of the vehicle) at 2905_h sub-index 1. This is either a speed target in speed mode, or maximum speed in torque mode.
- Specify an inching throttle (0 to 100%) at 2905_h sub-index 3. This gives a torque target in torque mode. This is not used in speed mode.
- Specify a time-out (0.1 s to 5.0 s) at 2905_h sub-index 2.

Belly Switch

Ensure the belly switch is only mapped to a digital input when required. Activation of this input can cause a drive condition to occur.

The belly switch is normally connected to the end of the tiller arm on class 3 vehicles. When activated it forces a drive condition in forward at a user specified throttle value and maximum speed for a specified time.

To configure belly:

- Ensure the belly switch is mapped to a digital input.
- Specify the maximum belly speed at $290C_h$ sub-index 2.
- Specify a belly throttle at $290C_h$ sub-index 1. This will determine the torque demand in torque mode or speed demand in speed mode.
- Specify a belly time out at $290C_h$ sub-index 3. The belly function will cease after this time has expired.

Drivability Select Switches

Ensure the driveability switches are only mapped to digital inputs when required. Activation of these inputs can cause driving parameters to change.

There are two drivability select switches (2126_h and 2127_h).

To enable either of these they must be mapped to digital inputs. When they are active, the corresponding drivability profiles (2921_h and 2922_h) are applied.

See Driveability profiles (page 6-25) for more information.

ECONOMY

The economy input is an analog input which can be used to increase vehicle efficiency and extend battery life. It is normally controlled using a potentiometer mounted on the vehicle's dashboard. The economy voltage (2222_h) must be mapped to an analog input.

Efficiency is improved by reducing the acceleration rate or the maximum torque.

Configure the economy input at object 2912_h as follows:

- Economy function: select acceleration or torque.
- Economy voltage input: These settings are similar to those for the throttle (see page 6-18).

The economy value calculated from the voltage can be read at 2622_h.

PUMP CONFIGURATION

The controller can use a mixture of switch and analog voltages as the pump input. In addition, the power steer function can be used as an extra input to the pump if the pump motor is required to supply pump and power steering.

Pump motors always run in speed mode. Ensure the motor slave is also configured for speed mode in 6060_h.

GENERAL SETUP

Configure the pump features at $2A00_h$:

- Inhibit pump when BDI drops below cutout level. If already operating when the cutout occurs, the pump will continue to operate until all pump inputs are inactive.
- Drive Enable switch and/or Seat switch input disables pump.
- Ignore Line Contactor state. Allows the pump to operate if it is not connected to the battery through the line contactor. Should be set if the pump also supplies power steering and the power steer is required to operate when the line contactor is open.
- Use Power Steer target velocity as pump input, if pump also supplies power steering.
- Enable minimum pump speed. Enable this to force the pump to run at minimum speed ($2A01_h$, 2) even when there is no trigger. Can be used to maintain minimum pump pressure.
- Pump to stop on Low Battery. Enable to force pump to stop immediately on low battery condition.
- Use power steer demand to minimum pump speed. Enable this to force the pump to use power steer demand as a minimum speed. Can be used to maintain minimum pump pressure for power steering.

Set the pump minimum and maximum speed, maximum torque, acceleration and deceleration at $2A01_h$. The pump speed is calculated as the value from the inputs multiplied by the maximum speed.

PRIORITY/ADDITIVE INPUTS

Each pump input can be configured as a priority input or an additive input. When calculating the pump demand, the controller selects the demand from the highest priority active input, and then adds the demand from all the active additive inputs.

Configure priority/additive levels in $2A10_h$ and $2A11_h$, and $2A20_h$ to $2A26_h$.

Pump throttles

There are 2 pump throttle inputs, which can be configured independently at $2A10_h$ and $2A11_h$. The pump throttles allow proportional control of the pump speed.

Configure inputs as priority or additive and set the voltage levels in the same way as the traction throttle. The pump throttles must be mapped to analog inputs.

Pump switches

There are 7 pump switch inputs. Configure each input as priority or additive and assign it a value at $2A20_h$ to $2A26_h$. The pump switches must be mapped to digital inputs.

Pump Driveability Profiles

Pumps have configurable driveability profiles. Profiles are triggered by pump driveability select switches (2152_h and 2153_h). One or more of these switches must be mapped to enable pump profiles.

Each profile allows the installer to reduce acceleration and deceleration rates, throttle and switch values and maximum torque.

Set pump driveability profiles at $2A30_h$ and $2A31_h$

Power steer configuration

General

Power steering can be provided using:

- Contactor. Map the power steer contactor drive object to an analog output.
- Pump motor controller. Configure pump to provide power steering. Power steer demand is added to pump demand.
- Dedicated motor controller. Map power steer application motor object to motor control slave.

Power steer motors always run in speed mode. Ensure the motor slave is also configured for speed mode in 6060_h.

-

The power steer can be triggered by a number of events:

- Vehicle moving
- FS1 switch activating
- Direction selected.
- Seat switch activating
- Footbrake activating

The power steering function will always attempt to execute, even if the line contactor is open due to a fault condition. This is to ensure power steering continues to operate at all times.

Set the power steer motor speed, acceleration and deceleration at $2B01_h$. This is not required if the power steer motor is operated by a contactor.

VARIABLE ASSIST POWER STEERING

Gen4 supports a variable assist power steering algorithm which can be used to reduce the power steering speed as vehicle traction speed increases to a user configurable level. Set the reduction factor and traction speed in $2B02_h$. This allows power steering effort to be reduced as vehicle speed increases to prevent steering becoming too light.

Vehicle features and functions

Ensure you have completed the CANopen network setup, Motor Characterization, I/O Configuration and Vehicle Performance Configuration processes described above.

CONTACTORS

Ensure voltage control has been selected (see 'Analog (contactor) outputs' on page 6-15).

To configure any contactor:

- Set pull-in voltage, pull-in time and hold-in voltage at $2D00_h$
- Enable each output to operate at the pull-in voltage or at the maximum voltage at $2D01_h$
- If required enable each output to reduce to the hold voltage level at $2D02_h$

LINE CONTACTOR

The line contactor object (2400_h) must be mapped to an analog output.

The line contactor is used to isolate controllers and motors from the battery during power down or in case of a serious fault. It is normally closed all the time the vehicle is powered, but it can be configured to open when the vehicle has been stationary for a period of time.

Configure line contactor dropout at object 2820_h. See also 'Contactors' above.

The controller has a capacitor pre-charge feature used to protect line contactor tips from damage due to in-rush currents when the contactor closes.

Writing to 5180_h starts a pre-charge cycle. The pre-charge circuit can only supply enough current to charge the capacitors of one controller. Where more than one controller is present, the pre-charge circuit on each must be used. If an Gen4 is configured as the vehicle master, it controls the pre-charge of all slave nodes automatically.

Pre-charge the capacitors once only before closing the line contactor. Repeated pre-charging can damage the circuit.

The pre-charge level is configurable between 50% and 90%. The level can be adjusted by object 5820_h.

ELECTRO-MECHANICAL BRAKE

Electro-mechanical brakes are not recommended for on-highway vehicles as they can cause the traction motor/wheel to remain locked or brake severely if the wheel is momentarily locked due to loss of traction on a slippery surface and/or mechanical braking. Also, electro-mechanical brakes normally fail to the applied state, meaning any loss of power, or wiring fault can cause the brakes to be applied.

The electro-mechanical brake object (2420_h) must be mapped to an analog output.

Set the conditions under which it is applied at 2903_h.

The brake can be applied when the vehicle stops or when roll-off is detected. If the brake is configured to apply when the vehicle stops, it is not applied until the vehicle has been stationary for more than the brake delay time.

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To prevent vehicle roll away on inclines, the electro-mechanical brake normally does not release until the traction motor(s) are producing torque. This feature can be disabled using $2903_h,3$.

External LED

This mirrors the operation of the controller's on board diagnostic LED. The external LED object 2401_h can be mapped to an analog output to drive a lamp on a vehicle dashboard.

Alarm buzzer

The alarm buzzer object (2402_h) must be mapped to an analog output.

Configure the alarm buzzer output, if required, to be activated by one or more of these conditions at 2840_h:

- forward motion or forward direction selected
- reverse motion or reverse direction selected
- faults other than information faults
- controlled roll-off
- BDI low.

A different cadence for each of the above conditions can be configured.

Brake Lights

A brake light output object is available (2404_h) and can be mapped to an analog output. The brake lights will illuminate whenever the footbrake is pressed (providing either an analog or digital footbrake input is available) or the system is in direction change braking.

Horn

Ensure a digital input switch is mapped to the horn switch object (2101_h) and an analog output is mapped to the horn object (2403_h).

Vehicle Speed Calculation

The controller can be configured to calculate vehicle speed from motor speed by setting a configurable ratio between these values in object 2915_h.Calculated vehicle speed can then be transmitted to the CANbus for use with compatible displays, or used to keep a log of total distance travelled by the vehicle.

The convention is to calculate vehicle speed as a signed number in 12.4 format in kph. This is required for compatibility with ClearView displays and the odometer. In case a custom display is used whose units are different, a user speed calculation is also provided whose units are independent from all other features.

Two sets of ratios are provided for calculation of a vehicle and user speeds, located in object 0x2915. While vehicle speed is a signed value, the option to have unsigned user speeds is also provided (an absolute value will be calculated).

The ratio between motor speed and vehicle speed will be dependent on vehicle drivetrain parameters such as gearbox ratio and wheel size. However, the ratio should be calculated such than when it is multiplied by motor speed (which is in rpm), the result is vehicle speed in kph 12.4 format. To do this, the following equation can be used:

- Set the divisor (object 2915_h sub index 2) to a known speed point of the motor
- Set the multiplier (object 2915_h sub index 1) to the corresponding scaled vehicle speed for the known motor speed.

For example, if it is known that 1000rpm on the motor results in a vehicle speed of 5kph, then the divisor should be set to 1000, and the multiplier should be set to 0x0050, which is 5kph in 12.4 format.

The same process should be repeated for the user speed ratio, setting the multiplier for the user speed in the desired custom format. Both the vehicle and user speeds, objects 0x2921 and 0x2922, can be mapped to TPDO for transmission to other devices via CAN if required.

Distance Calculation

Total vehicle distance and trip distance counters are available at objects 0x29A0 and 0x29A1. Counters will operate and will be accurate provided that the vehicle speed calculated at object 0x2721 is in kph in 12.4 format. Counters are available in the following formats:

- Distance travelled in km in 24.8 format
- Distance travelled in km in 0.1km/bit increments
- Distance travelled in miles in 0.1mile/bit increments

Both distance counters objects can be mapped to TPDOs for monitoring over the CANbus, or for use by a dashboard display. The trip distance counter can be reset by holding the reset switch, object 0x217D, closed for 1 second. The total vehicle distance counter cannot be reset by the user.

Service Indication

The controller can reduce vehicle performance and indicate to the operator when a vehicle service is required. The interval between services is user-configurable.

Configure the following at object 2850_h:

- Service indication: via an analog (contactor) output (e.g. to drive a dashboard lamp) and/or Gen4's LED.
- Source hours counter: selects the hours counter and is used to determine when a service is required.
- Service interval: hours between vehicle services. Can be used by the reset function (see below) or for information only.
- Next service due: Servicing is required when the source-hours counter reaches this time. This can be set manually, or automatically using the reset function; see below.
- Reset function: write to the reset sub-index at 2850_h to automatically reset the service timer for the next service. The next service due time is calculated as the source hours counter time plus the service interval.

Service profile

This is a drivability profile where you can set maximum torques, speeds and acceleration rates to be applied when a vehicle needs servicing (2925_h). See 'Driveability profiles' on page 6-25.

Traction motor cooling fan

This object can be used to drive a motor cooling fan when the operator is present on the vehicle (as indicated by the seat switch). The cooling fan object (2421_h) must be mapped to an analog output.

Controller heatsink / motor cooling fan

An external fan to cool the controller heatsink or a motor may be connected to one of the analogue outputs. The fan will be turned on by the controller when either the heatsink temperature or the motor temperature exceed a specified temperature. The fan turns off when the nominated temperature is cold. The temperatures at which the fans should turn on and off, the analogue output to use for the fan, the fan voltage and the temperature source (heatsink or motor) can be programmed using the heatsink fan object ($5A01_h$). Note that the contactor driver outputs may be damaged if connected to capacitive loads. It is quite common for fans to incorporate capacitive elements, in which case a relay should be used to isolate the fan from the contactor driver output.

The temperature set-point to turn on the fans should be higher than the set-point to turn off the fans

The fans will not operate if another function is configured to run on the specified analogue output.

MOTOR OVER-TEMPERATURE PROTECTION

The controller protects motors from over-temperature. It maintains a motor temperature estimate and can also accept a direct temperature measurement via an analog input (for a thermistor) or a digital input (for an over-temperature switch).

The temperature estimate is calculated by monitoring current to the motor over time. The estimate is configured at 4621_h.

The estimate is always applied, since it can detect increases in motor temperature more quickly then the direct measurement. Direct measurement is normally done on the motor casing, which lags behind the internal temperature.

MOTOR OVER-SPEED PROTECTION

A facility to protect the motor or vehicle powertrain due to damage by overspeeding is available on the controller. A maximum speed can be configured at object 4624_h. Under normal operation the controller should output braking torque to prevent the overspeeding initially, if the measured speed exceeds this limit then the controller will shut down and a fault will be set.

The trip speed offers a final level of protection for the vehicle mechanics, and should be set to a level that would not be expected to be reached under normal operation.

BATTERY PROTECTION

The nominal battery voltage must be set at $2C00_h$.

OVER VOLTAGE

Battery over voltage usually occurs during regenerative braking.

To provide protection set values for these parameters at $2C01_h$:

- Over voltage start cutback: the value at which the braking effort is linearly reduced to limit voltage increase.
- Over voltage limit: the value at which the controller cutouts out. A fault is set if the voltage exceeds the cutout voltage.

UNDER VOLTAGE

To prevent excessive battery discharge, set values for these parameters at $2C02_h$:

- Under voltage start cutback: the value at which the current drawn from the battery is reduced to limit voltage decrease.
- Under voltage limit: the value at which the controller cutouts out. A fault is set if the voltage drops below the cutout voltage for longer than the protection delay
- Protection delay: the time it takes for the controller to cutout after the under voltage limit has been reached (2C03h).

BATTERY DISCHARGE INDICATOR (BDI)

Monitor battery voltage using Gen4's Battery Discharge Indicator (BDI). The BDI presents the driver with a percentage remaining charge figure and has become an industry standard in recent years.

The BDI is not a measure of the absolute battery charge remaining and therefore we recommend you regularly check the absolute value in accordance with the battery manufacturer's instructions.

To use the BDI, configure the following parameters at $2C30_h$ in the Object Dictionary:

- Cell count: this is the number of battery cells and is normally half the battery voltage, as cells are usually 2 volts each.
- Reset voltage (V): set this to the cell voltage when the batteries have just been charged. This resets the BDI back to 100%.
- Discharge voltage (V): set this to the cell voltage when the battery is discharged.
- Cutout level (%): this is the level at which the vehicle adopts the low battery drivability profile.
- Discharge rate (s/%): this is the rate at which the BDI remaining charge value discharges. Set to 0 to use default value of 16.8s to reduce by 1%. This default should suit most lead-acid battery types, however, this can be increased/decreased for different battery technologies.

Setting the warning and cut-out levels to 0% disables the warning and cut-out functionality

Read the percentage remaining charge value from 2790_h sub-index 1 in the Object Dictionary.

BATTERY CURRENT LIMIT

Battery current can be limited by the controller for the purposes of efficiency or to protect batteried that are sensitive to high levels of current flow. Charge and discharge currents can be limited independently.

If limiting the discharge current flow, this can extend the time taken for the vehicle to reach top speed. Note that limiting the charge current flow back to the battery can impede the performance of regenerative braking.

Object 2870_h controls how the battery current limit is calculated. Sub-index 1 of this object can be set to one of the following values to specify how the current limit behaves:

Value	Mode
0x00	Master control of battery current limit disabled. To completely disable battery current limit, object 4623_h sub index 3 must also be set to 0x0000.
0x01	Battery current limit set by object 4623_h sub index 2 and 3.
0x02	Battery current limit controlled by compatible BMS
0x03	Battery current limit set by object 4623_h sub index 2 and 3, but the drive current limit is multiplied down by factors set in sub index 4 and 5 when driveability profiles are activated
0x04	Battery current limit is calculated to maintain a power limit as set in sub index 6 and 7.

Object 4623_h shows the current limits that are in effect. Sub index 3 of this object allows you to specify the cutback aggressiveness and a measurement correction factor. Setting this to zero. Battery current flow can be monitored at object 5100_h.

Note that regen currents flowing back to the battery are specified as negative numbers.

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DISPLAYS

Gen4 is compatible with Smartview and Clearview displays.

Clearview displays use the CANopen protocol. To use, set up TPDOs to transmit the required data for the display.

Smartview displays use Sevcon's proprietary CAN protocol. To use set the CAN baudrate to 100kHz at 5900_h, enable Smartview and select hours counter at $2E00_h$.

SEVCON

Chapter 7:
Monitoring Gen4

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Reading status variables

All status variables are in Gen4's object dictionary. They can be accessed using SDOs. Some can be mapped to PDOs for continuous transmission to remote nodes such as displays and logging devices.

Motor measurements

The following status objects can be read:

- Motor slip frequency, currents, voltages and temperature at object 4600_h.
- Additional motor debug information is available at 4602_h.
- Motor torque, speed, etc. at objects 6000_h to $67FF_h$.

Heatsink temperature

Read the heatsink temperature at object 5100_h, sub-index 3.

Identification and version

Read identification and version information at:

- 1008_h – Controller name.
- 1009_h – Hardware version.
- $100A_h$ – Software version.
- 1018_h – Identity object. Contains CANopen vendor ID, product code, CANopen protocol revision, and controller serial number.
- 5500_h – NVM (EEPROM) format.
- 5501_h – Internal ROM checksum.

Battery monitoring

The controller measures actual battery voltage at two points:

- Battery voltage; measured at keyswitch input and read at 5100_h sub-index 1.
- Capacitor voltage; measured at the B+ terminal and read at 5100_h sub-index 2.

The controller also has a battery discharge indicator (BDI), which can be read at 2790_h.

Hours counters

The controller supports many different hours counters for various functions. Some counters run on all units and some only run on the Gen4 configured as the vehicle master.

Hours counters are preserved with a minimum resolution of 15 seconds when the system is powered down.

Local hours counters

Local hours counters which run on all units are:

- Controller key hours: increments while the keyswitch is in the ON position (5200_h).
- Controller pulsing hours: increments when the controller is powering its connected motor (4601_h).

Vehicle hours counters

Vehicle hours counters which run only on the Gen4 configured as the vehicle master are:

- Vehicle key hours: increments as controller key hours (2781_h).
- Vehicle traction hours: increments when the vehicle is driving or braking (2782_h).
- Vehicle pump hours: increments when the pump motor is running (2783_h).
- Vehicle power steer hours: increments when the power steer motor is running (2784_h).
- Vehicle work hours: increments when the traction, pump or power steer motors are running (2785_h).

Since these hours are specific to the vehicle, they are writeable so that they can be reset to known good values if the master controller is replaced.

Logging

The controller can log events in the system (along with additional event-related information) and minimum and maximum levels of important parameters. You need different levels of access to clear the contents of the logs.

Logs are normally reset individually. However, to reset all logs at once write to 4000_h.

FIFO event logs

Events are recorded by these two separate FIFOs (first in, first out logs), which operate identically:

- System: this FIFO is 20 elements deep and is used for events such as software upgrades, user logins and some hardware upgrades (4100_h to 4102_h).
- Faults: this FIFO is 40 elements deep and is used for fault logging (4110_h to 4112_h).

At object $41X0_h$:

- Reset the FIFO
- Read its length

You can access the FIFO using objects $41X1_h$ and $41X2_h$. The FIFO index is entered at $41X1_h$ and the data is read from $41X2_h$.

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Event counters

The controller provides 10 event counters at 4200_h to $420A_h$. Each event counter can record information about occurrences of one event. The allocation of event counters to events is user-configurable however Gen4 will automatically count important events in unused counters. The information recorded in each event counter is:

- The time of the first occurrence
- The time of the most recent occurrence
- The number of occurrences

Operational monitoring

At objects 4300_h and 4301_h, Gen4 monitors and records the minimum and maximum values of these quantities:

- Battery voltage
- Capacitor voltage
- Motor current
- Motor speed
- Controller temperature

Two instances of the operational monitoring log are maintained. Service engineers can access and clear the first log; the second is accessible and clearable only by Sevcon engineers. The Customer copy is normally recorded and reset each time the vehicle is serviced. The Sevcon copy records data over the controller's entire working life.

CANopen abort code

The controller will sometimes respond with a CANopen General Abort Error (08000000_h) when the object dictionary is accessed. This can occur for many reasons. Object 5310_h gives the exact abort reason. These are:

0	None	12	Invalid value	24	Cannot read from DSP
1	General	13	EEPROM write failed	25	Peek time out
2	Nothing to transmit	14	Unable to reset service time	26	Reserved for future use
3	Invalid service	15	Cannot reset log	27	Reserved for future use
4	Not in pre-operational	16	Cannot read log	28	Reserved for future use
5	Not in operational	17	Invalid store command	29	Reserved for future use
6	Cannot go to pre-operational	18	Bootloader failure	30	Reserved for future use
7	Cannot go to operational	19	DSP update failed	31	Reserved for future use
8	Access level too low	20	GIO module error failed	32	Checksum calculation failed
9	Login failed	21	Backdoor write failed	33	PDO not copied
10	Range underflow	22	Reserved for future use		
11	Range overflow	23	Cannot write to DSP		

Faults and warnings

INTRODUCTION

In the event of a fault Gen4 takes the following action:

1. Protects the operator and vehicle where possible (e.g. inhibits drive).
2. Sends out an EMCY message on the CANbus.
3. Flashes the LED in a pattern determined by the fault type and severity.
4. Logs the fault for later retrieval.

FAULT IDENTIFICATION

You can identify a fault as follows:

- Check the number of LED flashes and use below to determine what action can be taken. A complete and comprehensive fault identification table will be available from Sevcon in due course.
- Pick up the EMCY on the CANbus and read the fault condition using configuration software
- Interrogate the fault on the node directly using DriveWizard or other configuration software.

LED FLASHES

Use below to determine the type of fault from the number of LED flashes. The LED flashes a preset number of times in repetitive sequence (e.g. 3 flashes – off – 3 flashes – off – and so on). Only the faulty node in a multi-node system flashes its LED. Possible operator action is listed in the right hand column of the table.

LED flashes	Fault	Level	Set conditions	Operator action
0 (off)	Internal hardware failure	RTB	Hardware circuitry not operating.	
1	Configuration item out of range	VS	At least one configuration items is outside its allowable range.	Set configuration item to be in range. Use 5621_h to identify out of range object.
1	Corrupt configuration data	VS	Configuration data has been corrupted.	
1	Hardware incompatible with software or invalid calibration data	VS	Software version is incompatible with hardware. Calibration data for sensors invalid.	
2	Handbrake fault	I	Direction selected with handbrake switch active.	Release handbrake
2	Sequence fault	DI	Any drive switch active at power up.	Reset drive switches
2	SRO fault	DI	FS1 active for user configurable delay without a direction selected.	Deselect FS1 and select drive
2	FS1 recycle	DI	FS1 active after a direction change	Reset FS1

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LED flashes	Fault	Level	Set conditions	Operator action
2	Seat fault	DI	Valid direction selected with operator not seated or operator is not seated for a user configurable time in drive.	Must be seated with switches inactive
2	Belly fault	DI	Set after belly function has activated.	
2	Inch sequence fault	DI	Inch switch active along with any drive switch active (excluding inch switches), seat switch indicating operator present or handbrake switch active.	
2	Invalid inch switches	DI	Inch forward and inch reverse switches active simultaneously.	Both inch switches inactive.
2	Two direction fault	DI	Both the forward and reverse switches have been active simultaneously for greater than 200 ms.	Reset switches
2	Invalid steer switch states	VS	Steering switches are in an invalid state, for example, both outer switches are active.	Check steer switches.
3	Fault in electronic power switching circuit	VS	Fault in electronic power switching circuit (e.g. MOSFET s/c).	
3	Hardware over voltage activated	VS	Hardware over voltage circuit activated	Investigate and reduce battery voltage below user defined maximum level. Ensure suitable over voltage is configured in $2C01_h$ and 4612_h.
3	Hardware over current trip activated	VS	Hardware over current circuit activated	Check motor load and wiring. Check motor parameters are correct.
4	Line contactor welded	S	Line contactor closed at power up or after coil is de-energized.	Check line contactor condition/wiring.
4	Line contactor did not close	S	Line contactor did not close when coil is energized.	Check line contactor condition/wiring.
5	PST fault	DI	Fault detected on PST power steer module.	Check PST condition.
5	Motor open circuit	S	Unable to establish current in motor.	Check motor condition/wiring.
6	Throttle pressed at power up	DI	Throttle demand is greater than 20% at power up.	Reduce demand
6	Analog input wire-off	VS	Analog input voltage is outside allowable range.	Check analog input wiring

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Monitoring

LED flashes	Fault	Level	Set conditions	Operator action
6	Analog output fault (over/under current, failsafe, short circuit driver)	VS	Analog output fault caused by over current (>4A), under current if actual current < 50% target (current mode only), failsafe circuit fault, short circuit driver MOSFET.	Check analog output wiring.
7	BDI warning or cutout	I	BDI remaining charge is less than warning or cutout levels.	Charge battery.
7	Battery low voltage protection	I	Battery voltage or capacitor voltage is below a user definable minimum battery level for a user definable time.	Increase battery voltage above user defined level
7	Controller low voltage protection	I	Battery voltage or capacitor voltage is below the minimum level allowed for the controller.	Increase battery voltage above minimum level
7	Controller high voltage protection with line contactor closed.	I	Battery voltage or capacitor voltage is above the maximum level allowed for the controller with line contactor closed.	Investigate and reduce battery voltage below maximum level.
7	Battery high voltage protection	I	Battery voltage or capacitor voltage is above a user definable maximum battery level for a user definable time.	Investigate and reduce battery voltage below user defined maximum level.
7	Motor low voltage protection	I	Capacitor voltage has entered the motor low voltage cutback region defined in 4612_h.	Increase battery voltage above start of motor low voltage cutback region.
7	Motor high voltage protection	I	Capacitor voltage has entered the motor high voltage cutback region defined in 4612_h.	Reduce battery voltage below start of motor high voltage cutback region.
7	Controller high voltage protection with line contactor open.	S	Battery voltage or capacitor voltage is above the maximum level allowed for the controller with line contactor open.	Isolate controller and investigate high battery voltage
7	Battery voltage below critical level for controller.	S	Battery voltage is below the absolute minimum voltage at which the controller hardware is guaranteed to operate.	Increase battery voltage.
7	Precharge failure	VS	Capacitor voltage is less than 5V after pre-charge operation is complete.	Check controller wiring to ensure there are no short circuits between B+ and B-.

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LED flashes	Fault	Level	Set conditions	Operator action
8	Controller too hot	I	Controller has reduced power to motor(s) below maximum specified by user settings due to controller over temperature.	Remove loading to allow controller to cool down.
8	Controller too cold	I	Controller has reduced power to motor(s) below maximum specified by user settings due to controller under temperature.	Allow controller to warm up to normal operating temperature.
8	Motor over temperature	I	Controller has reduced power to motor(s) below maximum specified by user settings due to motor over temperature.	Reduce load to motor to allow it to cool down.
8	Motor too cold	I	Motor thermistor reports less than -30°C.	Allow motor to warm up. Check motor thermistor.
8	Heatsink over temperature	VS	Heatsink temperature measurement has exceed absolute maximum for controller and system has powered down.	Remove loading to allow controller to cool down.
10	Pre-Operational	I	Controller is in pre-operational state.	Use DriveWizard to put controller into operational state.
10	I/O initializing	I	Controller has not received all configured RPDOs within 5s of power up.	Check CANbus wiring and PDO configuration.
10	RPDO Timeout	I / DI / S	One or more RPDOs have not been received within 3s at power up or within 500ms during operation.	Check CANbus wiring and PDO configuration.
11	Encoder fault	VS	Speed measurement input wire-off is detected.	Check encoder wiring
11	Over current	VS	Software has detected an over current condition	Check motor load and wiring. Check motor parameters are correct.
11	Current Control fault	VS	Software is unable to control currents on PMAC motor.	Check motor load and wiring. Check motor parameters are correct.
12	Communication error	S	Unrecoverable network communication error has been detected.	Check CANbus wiring and CANopen configuration.
13	Internal software fault	RTB	Software run time error captured	
13	Current sensor auto-zero fault	RTB	Current sensor voltage out of range with no current.	

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LED flashes	Fault	Level	Set conditions	Operator action
13	DSP parameter error	RTB	Motor parameter written to while motor control is operational.	Recycle keyswitch to allow parameters to be reloaded correctly.
14	3rd Party Anonymous Node EMCY received	I / DS / RTB	3rd party node has transmitted an EMCY message.	Check CANbus wiring and 3rd party node status.
15	Vehicle service required	I	Vehicle service interval has expired.	Service vehicle and reset service hours.

Table 8 Fault identification

FAULT LIST

Use DriveWizard to access the Fault list. If you don't have DriveWizard you can use any configuration tool as follows:

1. Object 5300_h gives information about all active faults. Read sub-index 1 to get the number of active faults. Write to sub-index 2 to select one of the active faults (0 = highest priority) and read back sub-index 3 to read the fault ID at that index.
3. Object 5610_h can be used to read a text description of the fault. Write the fault ID to sub-index 1 and read back the fault description from sub-index 2.

Upgrading the controller software

It is possible to field update the firmware of the Gen4 controller , typically using Sevcon's DriveWizard configuration tool.

Please contact Sevcon for assistance with this process.

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DATASHEET SEVCON GEN4

Appendices

Automatic Configuration Tables

This section lists the pre-defined digital and analogue input and output configurations that can be used with the CANopen automatic object mapping (see page 6-12).

The entries in the tables refer to the pin a particular function is connected to. MX refers to a pin on the master node, SR refers to a pin on the slave node driving the right traction motor, and SP refers to a pin on the slave node driving the pump motor. For example, analogue input configuration number 3 has throttle and footbrake inputs going to pins 22 and 34 on the master node, and an economy input going to pin 22 on the right traction slave node.

Digital Inputs

IO Selection→		0	1	2	3	4	5	6	7	8	9	10
Key switch	2100h											
Horn switch	2101h											
Drive enable switch	2120h						MX20					MX31
Forward Switch	2121h	MX18	MX18	MX18	MX18	MX18	MX18		MX18	MX18	MX18	MX18
Reverse Switch	2122h	MX30	MX30	MX30	MX30	MX30	MX30		MX30	MX30	MX30	MX30
FS1 switch	2123h	MX19	MX19	MX19	MX19		MX19		MX19	MX19	MX19	MX19
Seat switch	2124h		MX31	MX31	MX31		MX31		MX31	MX31	MX31	
Handbrake/Tiller switch	2125h		MX32	MX21	MX20	MX19	MX9		MX20	MX20	MX21	MX20
Driveability Select 1 switch	2126h			MX20	MX9	MX31	MX20		MX9	MX9		MX9
Driveability Select 2 switch	2127h				MX32				MX32	MX32		MX32
Inch forward switch	2129h	MX32				MX20			SR18	SR18		
Inch reverse switch	212Ah	MX21				MX9			SR30	SR30		
Inner left Steer switch	212Bh								SR19			
Outer left Steer switch	212Ch								SR31			
Inner right Steer switch	212Dh								SR20			
Outer right Steer switch	212Eh								SR9			
High speed switch	212Fh											

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IO Selection→		0	1	2	3	4	5	6	7	8	9	10
Footbrake switch	2130h			MX32			MX32				MX32	
Traction Inhibit	2137h											
Belly	2139h					MX32						
Pump 1 switch	2140h		SP18	SP18			SP18	MX18			SP18	
Pump 2 switch	2141h		SP30	SP30			SP30	MX30			SP30	
Pump 3 switch	2142h		SP31	SP19			SP19	MX19			SP19	
Pump 4 switch	2143h						SP31	MX31				
Pump 5 switch	2144h						SP20	MX20				
Pump 6 switch	2145h						SP9	MX9				
Pump 7 switch	2146h						SP32					
Pump Inhibit switch	2150h							MX32				
Pump Drivability 1 switch	2152h							MX21				
Pump Drivability 2 switch	2153h											
Power Steer trigger switch	2160h				MX21	MX21		MX35	SR32	SR9		

Analogue Inputs

IO Selection→		0	1	2	3	4	5	6
Throttle Input Voltage	2220h	MX22		MX22	MX22	MX22	MX22	MX22
Footbrake Pot Input Voltage	2221h				MX34	MX34	SR34	
Economy Input Voltage	2222h				SR22	SR22	SR23	
Steer Pot Input Voltage	2223h			SL22		SR34	MX34	
Motor temp thermister	2224h							
Pump Throttle 1 Input Voltage	2240h		MX22	SP22				SP22
Pump Throttle 2 Input Voltage	2241h		MX34					

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Monitoring

Analogue Outputs

IO Selection→		0	1	2	3	4	5	6	7	8	9	10	11	12
Line contactor	2400h	MX3	MX11	MX3	MX3	MX3	MX3	MX3	MX3	SL3	MX3	MX3	MX3	MX3
Line contactor	2400h			SP3		SP3								
External LED	2401h									SL7	MX7	MX7		
Alarm buzzer	2402h											SP3	MX7	MX7
Horn	2403h									SR3		SR3		
Lights	2404h								MX7		SR3	SP7		
Service Due	2405h						MX7			SR7		SR7		
Electro-mechanical brake	2420h	MX7		MX7	MX7			MX7		MX11	MX11	MX11		MX11
Traction Motor Cooling Fan	2421h											SP7		
Motor Isolation Contactor	2422h													
High / Low Speed Indication	2423h											SP11		
Pump contactor	2440h							MX11			SR7			
Power Steer contactor	2460h	MX11	MX3		MX11		MX11		MX11	SR11	SR11			

Suggested Sample Configurations

This table lists suggested digital input, analogue input and analogue output configuration schemes for common vehicle configurations.

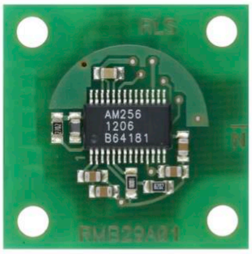
Vehicle Type	Suggested Configuration Scheme		
	Digital Inputs	Analogue Inputs	Analogue Ouptuts
Golf car or light urban vehicle	0	0	0
Generic standalone traction system	3	0	0
Walkie or palette truck	4	0	6
Generic standalone pump	6	1	1
Dual traction with digital steer switches	7	3	0
Dual traction with analogue steer angle sensor	8	4	0

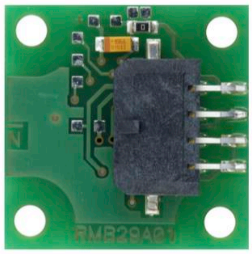
DATASHEET SEVCON GEN4

3. Datasheet RLS RMB29AC

Data sheet
RMB29D01_02
Issue 2, 31st March 2014

RMB29AC01SS1 – Analogue sine/cosine encoder





The RMB29 encoder module is designed for direct integration to high volume OEM applications. The low cost 29 mm square PCB is provided with a connector for easy installation.

The encoder module consists of a magnetic actuator and a separate sensor board. Rotation of the magnetic actuator is sensed by a custom encoder chip mounted on the sensor board, and processed to give one sine/cosine wave per revolution.

The RMB29 can be used in a wide range of applications including motor control and industrial automation.

- **29 mm square module**
- **Low cost for OEM integration**
- **5 V power supply version**
- **High speed operation to 60,000 rpm**
- **Analogue sine/cosine output**
- **Accuracy to ±0.5°**
- **RoHS compliant (lead free)**
- **Conformal coated**

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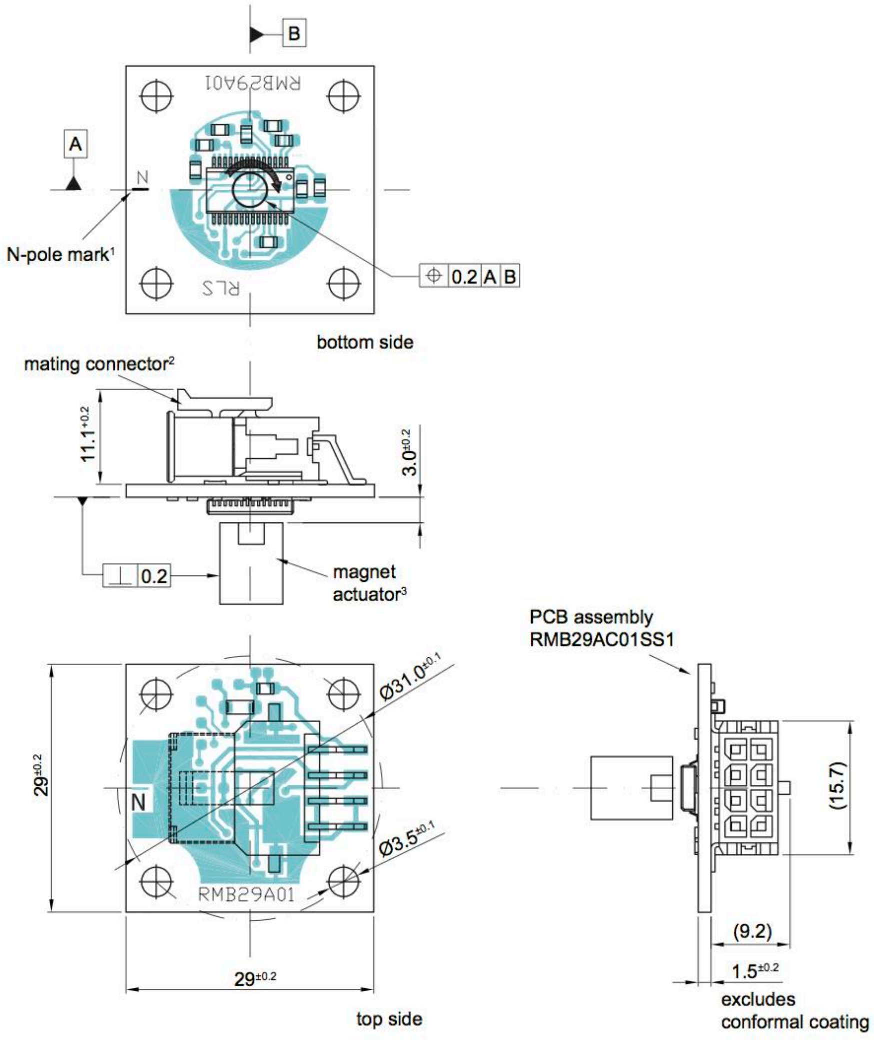
Data sheet
RMB29D01_02

RMB29 installation drawing



[1] When N-pole marks of the magnet actuator and the PCB are aligned sine output = mid level and cosine output = max. level.
[2] Not supplied. See page 3 for details.
[3] See page 4 for options.

Clockwise (CW) rotation of magnet

2

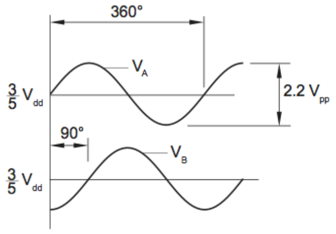
Datasheet RLS RMB29AC

RMB29AC – Analogue sinusoidal

Power supply	V_{dd} = 5 V ± 5 %
Resolution	one sine/cosine wave per revolution
Power consumption	13 mA
Sin/Cos outputs	Signal amplitude: 1.1 V ± 0.2 V
Operating temperature	-40 °C to +105 °C (limited by connector) All other components used are specified for operation from -40 °C to +125 °C.
Maximum speed	60,000 rpm
Accuracy*	±0.7°
Hysteresis	0.45°

* Worst case within operational parameters including magnet position and temperature.

Timing diagram

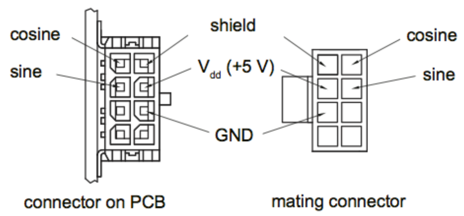


V_B leads V_A for clockwise rotation of magnet.

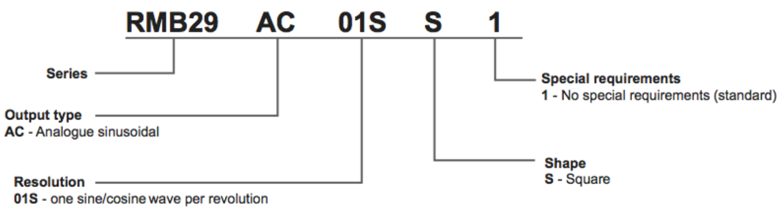
Conformal coating type - Polyurethane

Connections

Connector on board: MOLEX 43045-0810
Mating connector:
Shell: MOLEX 43025-0800
8 pin crimp: MOLEX 43030-0010



RMB29 ordering code



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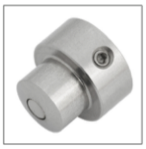
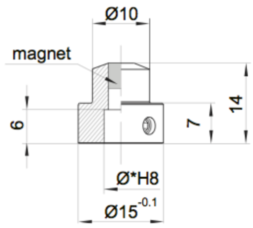
Data sheet
RMB29D01_02

Magnetic actuator and magnet ordering information

Actuator for integration onto shaft





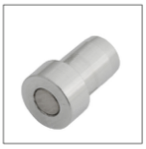
Shaft = Ø*h7
Fixing: Grub screw provided

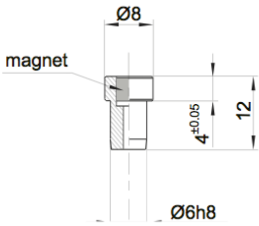
Part numbers:

For resolutions up to 9 bit absolute (512 cpr incremental)
RMA04A2A00 – Ø4 mm shaft
RMA05A2A00 – Ø5 mm shaft
RMA06A2A00 – Ø6 mm shaft
RMA08A2A00 – Ø8 mm shaft
RMA10A2A00 – Ø10 mm shaft
RMA19A2A00 – Ø3/16" shaft
RMA25A2A00 – Ø1/4" shaft
RMA37A2A00 – Ø3/8" shaft

For resolutions from 10 bit absolute (800 cpr incremental) and above
RMA04A3A00 – Ø4 mm shaft
RMA05A3A00 – Ø5 mm shaft
RMA06A3A00 – Ø6 mm shaft
RMA08A3A00 – Ø8 mm shaft
RMA10A3A00 – Ø10 mm shaft
RMA19A3A00 – Ø3/16" shaft
RMA25A3A00 – Ø1/4" shaft
RMA37A3A00 – Ø3/8" shaft

Actuator for integration into shaft





Hole = Ø6G7
Fixing: Glue (recommended – LOCTITE 648)

Part numbers:

For resolutions up to 9 bit absolute (512 cpr incremental)
RMH06A2A00

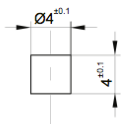
For resolutions from 10 bit absolute (800 cpr incremental) and above
RMH06A3A00

With N-pole marker scribed to a ± 5° accuracy:

For resolutions up to 9 bit absolute (512 cpr incremental)
RMH06A2A02

For resolutions from 10 bit absolute (800 cpr incremental) and above
RMH06A3A02

Magnet for direct recessing in non-ferrous shafts



Fixing: Glue (recommended – LOCTITE 648)

Part numbers:

For resolutions up to 9 bit absolute (512 cpr incremental)
RMM44A2A00 (individually packed) – for sample quantities only
RMM44A2C00 (packed in tubes)

For resolutions from 10 bit absolute (800 cpr incremental) and above
RMM44A3A00 (individually packed) – for sample quantities only
RMM44A3C00 (packed in tubes)

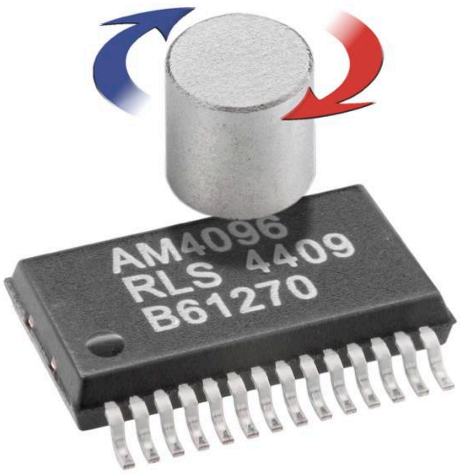
4

4. DATASHEET RLS AM4096

Data sheet
AM4096D02_04
Issue 4, 2nd June 2016

RLS®

AM4096 – 12 bit angular magnetic encoder IC



The AM4096 uses Hall sensor technology for sensing the magnetic field.

A circular array of sensors detects the perpendicular component of the magnetic field. The signals are summed then amplified. Sine and cosine signals are generated when the magnet rotates. The sine and cosine signals are factory calibrated for optimum performance.

From the sine and cosine values the angular position is calculated with a fast 12 bit interpolator. The calculated position is then output in various digital and analogue formats.

An inbuilt voltage regulator ensures stable conditions for the core of the chip and a more flexible power supply voltage. All inputs and outputs are related to the external supply voltage.

The AM4096 has many different setting options which are defined by the contents of internal registers. The zero position can be also set with an external pin. The settings of the chip are stored in an integrated EEPROM.

The registers and the EEPROM can be accessed through a serial two wire interface TWI.

With its compact size the AM4096 is especially suitable for different applications, including motor motion control and commutation, robotics, camera positioning, various encoder applications, battery powered devices and other demanding high resolution applications.

Output options:
- Incremental
- Serial SSI
- Serial two wire interface (TWI)
- UVW commutation output
- Linear voltage
- Tacho
- Analogue sinusoidal

- **Contactless angular position encoding over 360°**
- **12 bit absolute encoder**
- **Presetable zero position**
- **High speed operation to 60,000 rpm**
- **Power save mode for low current consumption**
- **5 V or 3 V power supply**
- **Integrated EEPROM**
- **SMD package SSOP28**
- **RoHS compliant (lead free)**

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Block diagram

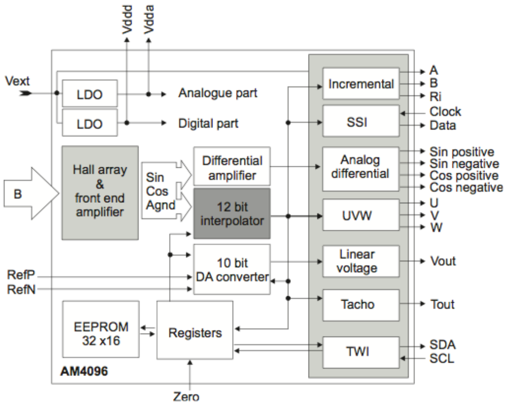

Fig. 1: AM4096 block diagram

Pin description

Some pins have more than one function. The function of those pins can be selected over the two wire serial interface and stored in the chip. All digital input pins all have a pull-down resistor except PSM pin.

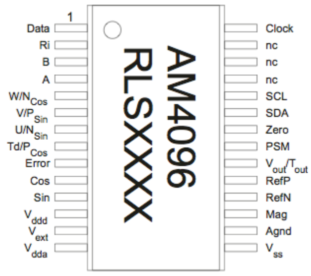

Fig. 2: Pin description for AM4096

Pin 1 (Data) is a digital output for serial SSI communication.

Pin 2 (Ri) is the quadrature incremental reference mark output.

Pin 3 (B) is the quadrature incremental output B.

Pin 4 (A) is the quadrature incremental output A.

Pin 5 (W/N_{Cos}) is the commutation digital output W or analogue differential buffered Cosine negative output.

Pin 6 (V/P_{Sin}) is the commutation digital output V or analogue differential buffered Sine positive output.

Pin 7 (U/N_{Sin}) is the commutation digital output U or analogue differential buffered Sine negative output.

Pin 8 (Td/P_{Cos}) is the tacho direction digital output or analogue differential buffered Cosine positive output.

Pin 9 (Error) is the analogue output signal. It can monitor the axial misalignment between the AM4096 and the magnet or it can monitor the signal amplitude.

Pin 10 (Cos) is the single-ended cosine analogue output for filtering.

Pin 11 (Sin) is the single-ended sine analogue output for filtering.

Pin 12 (V_{ddd}) is the pin for filtering the power supply of the digital part of the chip. The power supply voltage is selectable between 3 V and 3.3 V.

Pin 13 (V_{ext}) is the external power supply pin (3 V to 5.5 V).

Pin 14 (V_{dda}) is the pin for filtering the power supply of the analogue part of the chip. The power supply voltage is selectable between 3 V and 3.3 V.

Pin 15 (V_{ss}) is the power supply pin 0 V.

Pin 16 (Agnd) is the pin for filtering analogue reference voltage (1.55 V).

Pin 17 (Mag) is the digital output for monitoring the magnet presence. If the output is high than the magnet distance is OK. If the distance is too small or too large, then the output voltage is low.

Pin 18 (R_{efN}) is the reference voltage input for defining the minimum output value of the linear voltage output.

Pin 19 (R_{efP}) is the reference voltage input for defining the maximum output value of the linear voltage output.

Pin 20 (V_{out}/T_{out}) is the linear voltage output or tacho output.

Pin 21 (PSM) is the digital input pin for power save mode operation. The input is floating and it must have defined input. When the input is low, the power save mode is inactive.

Pin 22 (Zero) is the digital input for zeroing the output position with internal 10k pull-down resistor. The zeroing is done at transition from low to high.

Pin 23 (SDA) is the data line for the two wire serial interface (TWI).

Pin 24 (SCL) is the clock line for the two wire serial interface (TWI).

Pins 25, 26 and 27 are test pins and must be left unconnected.

Pin 28 (Clock) is the digital clock input for SSI communication with internal 10k pull-down resistor.

Pin	Name	Pin description
1	Data	SSI data output
2	Ri	Incremental output Ri
3	B	Incremental output B
4	A	Incremental output A
5	W/N_{Cos}	Commutation output W/Cosine negative output
6	V/P_{Sin}	Commutation output V/Sine positive output
7	U/N_{Sin}	Commutation output U/Sine negative output
8	Td/P_{Cos}	Tacho direction output/Cosine positive output
9	Error	Analogue error or amplitude output
10	Cos	Cosine analogue output for filtering
11	Sin	Sine analogue output for filtering
12	V_{ddd}	Digital power supply 3.0 / 3.3 V
13	V_{ext}	Power supply input 5 V
14	V_{dda}	Analogue power supply 3.0 / 3.3 V
15	V_{ss}	Power supply 0 V
16	Agnd	Analogue reference voltage
17	Mag	Output, that indicates magnet presence
18	R_{efN}	Lower reference input for voltage output
19	R_{efP}	Upper reference input for voltage output
20	V_{out}/T_{out}	Linear voltage output/Tacho output
21	PSM	Power save mode input
22	Zero	Zeroing input
23	SDA	TWI serial interface data line
24	SCL	TWI serial interface clock line
25	NC	Factory test
26	NC	Factory test
27	NC	Factory test
28	Clock	SSI clock input

Absolute maximum ratings

T_A = 22 °C unless otherwise noted.

Parameter	Symbol	Min.	Max.	Unit	Note
Supply voltage	V_{ext}	–0.3	5.5	V	
Input pin voltage	V_{in}	–0.3	5.5	V	
Input current (latch-up immunity)	I_{scr}	–100	100	mA	
Electrostatic discharge	ESD		2	kV	*
Operating junction temperature	T_j	–40	140	°C	
Storage temperature range	T_{st}	–40	150	°C	
Moisture sensitivity level		3			

* Human Body Model

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Operating range conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
General						
Temperature range	T_O	–40	125		°C	
Temperature range for EEPROM write	T_{OE}	–40	115		°C	
Supply voltage	V_{ext}	3	5	5.5	V	
Supply current	I_{dd}	*	26	30	mA	*
Power-up time	t_p		1.5	2	ms	
Interpolator delay	t_{di}		0.7		µs	
Sensors delay	t_{ds}		10		µs	
Filtering delay	t_{df}		20		µs	**
Oscillator						
Oscillator frequency	f_{osc}	8	10	12	MHz	
Oscillator frequency temperature drift	TC_{osc}		–0.006		% / K	
f_{osc} power supply dependence	VC_{osc}		3		% / V	***
Digital outputs						
Saturation voltage hi ($V_{ext} – V_{out}$)	V_{shi}	137		490	mV	I_{load} = 2mA
Saturation voltage lo	V_{slo}	124		339	mV	I_{loa} = 2mA
Rise time	t_r	4		12	ns	C_{load} = 15+3pF
Fall time	t_f	3		9	ns	C_{load} = 15+3pF
Digital inputs						
Threshold voltage hi	Vt_{hi}	0.39	0.5	0.59	V_{ext}	
Threshold voltage lo	Vt_{lo}	0.30	0.38	0.45	V_{ext}	
Hysteresis	Vt_{hys}	0.08	0.12	0.15	V_{ext}	

* When in power-save mode the average supply current is significantly reduced.
** Typical time delay is calculated for filter capacitors 10 nF.
*** Due to internal supply regulator only 3 V or 3.3 V is possible.

AM4096 programming

The AM4096 can be programmed over the two-wire serial interface (TWI) which is compatible with I²C protocol with a 400 kbps bit rate speed.

The TWI protocol allows the to interconnect up to 128 individually addressable devices using only two bi-directional bus lines, one for clock (SCL) and one for data (SDA). The only external hardware needed to implement the bus is a single pull-up resistor for each of the TWI bus lines. All devices connected to the bus have individual addresses, and mechanisms for resolving bus contention are inherent in the TWI protocol.

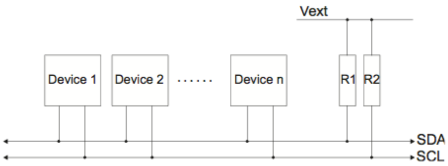

Fig. 3: TWI bus interconne

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The TWI bus is a multi-master bus where one or more devices, capable of taking control of the bus, can be connected. Only Master devices can drive both the SCL and SDA lines while a Slave device is only allowed to issue data on the SDA line. Data transfer is always initiated by a Bus Master device. A high to low transition on the SDA line while SCL is high is defined to be a START condition (or a repeated start condition).

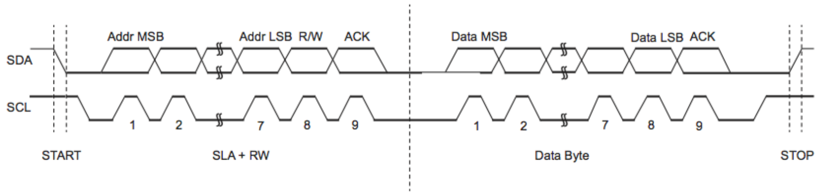

Fig. 4: TWI Address and Data Packet Format

A START condition is always followed by the (unique) 7 bit slave addresses and then by a Data Direction bit. The Slave device addressed now acknowledges to the Master by holding SDA low for one clock cycle. If the Master does not receive any acknowledge the transfer is terminated. Depending of the Data Direction bit, the Master or Slave now transmits 8 bit of data on the SDA line. The receiving device then acknowledges the data. Multiple bytes can be transferred in one direction before a repeated START or a STOP condition is issued by the Master. The transfer is terminated when the Master issues a STOP condition. A STOP condition is defined by a low to high transition on the SDA line while the SCL is high. If a Slave device cannot handle incoming data until it has performed some other function, it can hold SCL low to force the Master into a wait-state. All data packets transmitted on the TWI bus are 9 bits long, consisting of one data byte and an acknowledge bit. During a data transfer, the master generates the clock and the START and STOP conditions, while the receiver is responsible for acknowledging the reception. An Acknowledge (ACK) is signaled by the receiver pulling the SDA line low during the ninth SCL cycle. If the receiver leaves the SDA line high, a NACK is signaled.

The AM4096 has a default slave address of 00h. This address can be changed for each device. The functionality of the device can be programmed on the addresses between 0 and 55 with 16 bit long words.

Address	Functionality
00–31	Read/Write EEPROM
32–35	Read registers for reading the output data
40–41	Write registers for factory tests
48–55	Read / Write registers with settings

The AM4096 device acts as a slave and supports two modes:

1. Master transmits to slave. This mode is used to write to the AM4096 address space. The 16 bit data word is divided into two 8 bit data frames. The ACK acknowledges are provided by the slave.

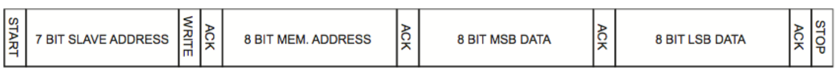

Fig. 5: Write data packet

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After the EEPROM write packet (memory address 00 h – 1 Fh) the slave device can not be addressed for a time of 10 ms. In this time the slave is performing the internal EEPROM write process. If the device is addressed, no ACK is returned.

2. Combined format mode is used to read the AM4096 address space. If the EEPROM address space is addressed (00 h – 1 Fh), then the slave uses clock stretching during the internal EEPROM read time (minimum 20 µs).

START	7 BIT SLAVE ADDRESS	WRITE	ACK	8 BIT MEM. ADDRESS	ACK	SR	7 BIT SLAVE ADDRESS	READ	ACK	CLK stretching min. 20 µs	8 BIT MSB DATA	ACK	8 BIT LSB DATA	ACK	STOP

Fig. 6: EEPROM read data packet, with clock stretching

If the R or R/W registers are addressed, then the device response is immediate. After the two DATA packets the ACK is not verified.

START	7 BIT SLAVE ADDRESS	WRITE	ACK	8 BIT MEM. ADDRESS	ACK	SR	7 BIT SLAVE ADDRESS	READ	ACK	8 BIT MSB DATA	ACK	8 BIT LSB DATA	ACK	STOP

Fig. /: Register read data packet

Memory address space

		ADR	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EEPROM	R/W	0	Pdint	AGCdis	-	Slowint	Pdtr		Pdie	Reg35	-	Addr						
		1	Abridis	Bufsel	Monsel	Sign	Zin											
		2	Nfil								Daa	Hist						
		3	Dact	Dac		SSIcfg		-	-	Sth			UVW			Res		
	R	4	Factory settings data. This part of EEPROM is locked.															
		5																
		6																
		7																
	R/W	8	Free EEPROM space															
		9																
		10																
		...																
		28																
		29																
	R	30	Device identification number. This part of EEPROM is locked.															
		31																
REGISTERS	R	32	SRCH	-	-	-	Rpos											
		33	SRCH	-	-	-	Apos											
		34		Weh	Wel	-												
		35	AGCgain				-	Thof	Tho									
		...	Not available															
	R/W	40	Only for testing. For normal operation must be zeros.															
		41																
		...	Not available															
	R/W	48	Pdint	AGCdis	-	Slowint	Pdtr		Pdie	Reg35	-	Addr						
		49	Abridis	Bufsel	Monsel	Sign	Zin											
		50	Nfil								Daa	Hist						
		51	Dact	Dac		SSIcfg		-	-	Sth			UVW			Res		
	R	52	Factory settings data. Those registers are locked.															
		53																
		54																
		55																

AM4096 has EEPROM and registers with 16 bit word organization. AM4096 operates according to the contents in registers. When the chip is powered-on the EEPROM contents from address 0 to 7 is copied to the registers from 48 to 55. This is also done with every change in the EEPROM. Registers from 48 to 51 can be accessed for fast non-permanent setting changes. Registers from 32 to 35 can be used for fast readings of the measured data.

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Description of parameters:

Parameter	Length	Description	Logic	Note
Pdint	1	Interpolator power	0 = on, 1 = off	Interpolator power can be switched off, if only analogue outputs are used.
AGCdis	1	AGC disable	0 = AGC on, 1 = AGC off	
Slowint	1	Interpolator delay	0 = on, 1 = off	It must always be set to 1. Currently it is not allowed to use value 0.
Pdtr	2	Internal power down rate	00 = 1:128, 01 = 1:256, 10 = 1:512, 11 = 1:1024	See power save mode description.
Pdie	1	Internal power down	0 = disabled, 1 = enabled	See power save mode description.
Reg35	1	Regulator voltage	0 = 3 V, 1 = 3.3 V	
Adr	7	Device address	From 0 to 127	Default address is set to 0.
Abridis	1	Enabling A B Ri outputs	0 = enabled, 1 = disabled	Incremental output can be disabled if not used.
Bufsel	1	Selects the output on pins U/N_{Sin}, V/P_{Sin}, W/N_{Cos}, Td/P_{Cos}	0 = UVW, Tacho direction 1 =Sinusoidal differential	Interpolator may not work properly when sinusoidal differential analogue outputs are on.
Monsel	1	Selects the output on Error pin	0 = error signal, 1 = amplitude level signal	
Sign	1	Selects the output direction	0 = positive, 1 = negative	
Zin	12	Zero position data	0 = 0°, 4,095 = 360°	
Nfil	8	Test parameters		Must be zeros.
Daa	1	Output position selection	0 = relative, 1 = absolute	Absolute position is not affected by zeroing while relative position is.
Hist	7	Digital hysteresis value in LSB at 12 bit resolution	From 0 to 127	
Dact	1	Select the output on V_{out}/T_{out} pin	0 = position data on V_{out}/T_{out} pin 1 = tacho data on V_{out}/T_{out} pin	
Dac	2	Linear voltage period selection	00 = 360°, 01 = 180°, 10 = 90°, 11 = 45°	
SSIcfg	2	SSI settings		See SSI description.
Sth	3	Tacho measuring range		See table in tacho output description.
UVW	3	UVW number of periods/turn	000 = 1, 001 = 2, 010 = 3, 011 = 4, ..., 111 = 8	
Res	3	Interpolation factor rate	000 = 4,096, 001 = 2,048, ... 110 = 64, 111 = 32	
SRCH	1	Output position data valid	0 = valid data 1 = data not valid yet,	
Rpos	12	Relative position inf.	0 = 0°, 4,095 = 360°	
Apos	12	Absolute position inf.	0 = 0°, 4,095 = 360°	
Weh	1	Magnet too far status	0 = magnet distance ok, 1 = magnet is too far	
Wel	1	Magnet too close status	0 = magnet distance ok, 1 = magnet is too close	
Thof	1	Tacho overflow info	0 = speed in range, 1 = speed out of range	
Tho	10	Tacho output data	0 = 0, 1,023 = full measuring range	

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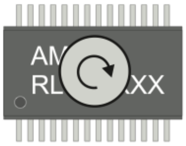
3/5 V operation mode

The AM4096 can operate with power supply voltage from 3 V to 5.5 V. The outputs and inputs are supplied with the external voltage. The core of the chip is always powered with the regulated voltage from the LDO voltage regulator. The voltage of the regulator can be selected with the "Reg35" parameter between 3 V and 3.3 V. When the external power supply is from 3 V to 3.3 V the regulator voltage should be set to 3 V. When the external power supply voltage is from 3.3 V to 5.5 V the regulator voltage should be set to 3.3 V.

Outputs direction

The direction of the outputs can be changed by changing the "Sign" parameter. The arrow in picture shows clockwise (CW) rotation of the magnet. The picture is a top view of the magnet placed above the AM4096.



Sinusoidal analogue outputs for filtering

Agnd is an internally generated reference voltage. It is used as a zero level for the analogue signals, the voltage is typically 1.55 V. Pins 10 and 11 are unbuffered sinusoidal analogue outputs used for filtering and for testing purposes.

Unbuffered sinusoidal outputs:

Parameter	Symb.	Min	Typ	Max	Unit
Internal serial impedance	R_n		2		kΩ

The chart below shows the timing diagram for CW rotation of the recommended magnet.
Sinusoidal outputs produce one period of sine and cosine signal per turn with phase difference of 90°. Each signal has the same amplitude and minimum offset with respect to Agnd.
AGC controls the amplitude of the signals within 20%. AGC can be disabled if "AGCdis" parameter is set to 1.

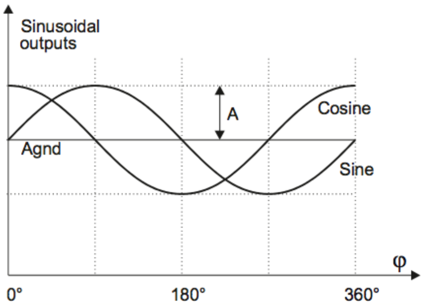


Fig. 8: Timing diagram for analogue output

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Amplitude	A	0.5	0.83	1.1	V	*
Vref voltage	V_{Vref}		1.55		V	
Max. frequency	f_{Max}		1000		Hz	

* Amplitude = 1/2 of peak to peak value.

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Sinusoidal differential analogue outputs

Sinusoidal signals can be output as sinusoidal differential signals when the "BufSel" parameter is set to 1. The interpolator may not work properly when the differential analogue outputs are on. If analogue outputs are not needed then the "BufSel" parameter should be set to 0.

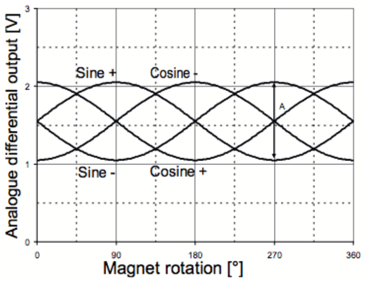

Fig. 9: Timing diagram for differential analogue output

Pin name	Pin function
"W/N_{Cos}"	Cosine negative
"V/P_{Sin}"	Sine positive
"U/N_{Sin}"	Sine negative
T_d/P_{Cos}	Cosine positive

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Amplitude	A	1	1.66	2.2	V	*
Amplitude difference	d_A		0	0.5	%	
Phase difference	d_{Ph}	89.8	90	90.2	°	
Sine offset	S_{offs}	–5	0	5	mV	
Cosine offset	C_{offs}	–5	0	5	mV	
Max. frequency	f_{Max}		1000		Hz	

* Amplitude = 1/2 of peak to peak value of the difference between the positive and negative signal.
The distance to the magnet and the temperature are within tolerances. To prevent saturation of the signals, the amplitude must never exceed 2.2 V.

AGC

Automatic gain control is enabled when the "AGCdis" parameter is set to 0. If the magnetic signal is changing the AGC is able to control the output signal amplitude in range between 0.8 V and 1 V. When the amplitude is less than 0.8 V, the gain is increased. When the amplitude is more than 1 V, the gain is decreased. The AGC gain has 16 levels and the range is from 0.5 to 2. Level 8 is at normal magnetic conditions.

Interpolator

When the magnet is rotated for 360° the sensors generates two perfect sinusoidal signals with phase difference of 90°. The interpolator is using those sinusoidal signals to calculate the current angle position and the angle position is output in various output formats. The calculation is performed is less than 1µs. The interpolation rates is selectable from 64 to 4096.

"Res" value	Interpolation rate	Resolution	Max. input freq.
0 0 0	4,096	0.0879°	500 Hz
0 0 1	2,048	0.1758°	1000 Hz
0 1 0	1,024	0.3516°	1000 Hz
0 1 1	512	0.7031°	1000 Hz
1 0 0	256	1.4062°	1000 Hz
1 0 1	128	2.8125°	1000 Hz
1 1 0	64	5.625°	1000 Hz
1 1 1	32	11.25°	1000 Hz

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Zeroing

The output angle position data can be zeroed at any angle with resolution of 0.0879°. The relative output position is a difference between absolute position and data in zero register. The value in zero register can be changed by writing a desired value with TWI interface or with using a “Zero” input pin. With low to high transition of a signal on “Zero” pin the current absolute value is stored in zero register. When zeroing the relative position the chip must not be in power-save mode as the EEPROM is not accessible.

Incremental output

There are three signals for the incremental output: A, B and Ri. Signals A and B are quadrature signals, shifted by 90°, and signal Ri is a reference mark. The reference mark signal is produced once per revolution. The width of the Ri pulse is 1/4 of the quadrature signal period and it is synchronized with the A and B signals. The position of the reference mark is at zero.

The chart below shows the timing diagram of A, B and Ri signals with CW rotation of the magnet and positive counting direction. B leads A for CW rotation. The counting direction can be changed by programming the EEPROM with the “Sign” parameter.

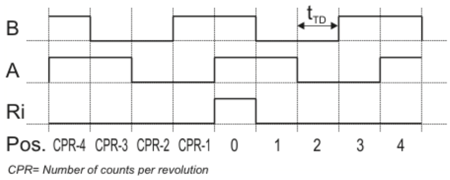

Fig. 10: Timing diagram for incremental output

The transition distance (t_{TD}) is the time between two output position changes. The transition distance time is limited by the interpolator and the limitation is dependent on the output resolution. The counter must be able to detect the minimum transition distance to avoid missing pulses.

Binary synchronous serial output SSI

Serial output data is available in up to 12 bit natural binary code through the SSI protocol. With positive counting direction and the CW magnet rotation, the value of the output data increases.

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Clock period	t_{CL}	0.25		2 × tm	μs	
Clock high	t_{CHI}	0.1		tm	μs	
Clock low	t_{CLO}	0.1		tm	μs	
Monoflop time	t_m	15	19	25	μs	

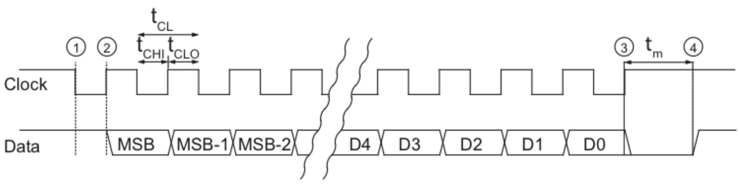

Fig. 11: SSI timing diagram with monoflop timeout

The controller interrogates the AM4096 for its positional value by sending a pulse train to the Clock input. The Clock signal must always start from high. The first high/low transition (point 1) stores the current position data in a parallel/ serial converter and the monoflop is triggered. With each transition of Clock signal (high/low or low/high) the monoflop is retriggered. At the first low/high transition (point 2) the most significant bit (MSB) of the binary code is transmitted through the Data pin to the controller. At each subsequent low/high transition of the Clock the next bit is transmitted to the controller. While reading the data the t_{CHI} and t_{CLO} must be less than t_{mMin} to keep the monoflop set. After the least significant bit (LSB) is output (point 3) the Data goes to low. The controller must wait longer than t_{mMax} before it can read updated position data. At this point the monoflop time expires and the Data output goes to high (point 4).

SSIcfg	Descripion
0 0	No ring register operation
0 1	Ring register operation data length according to the resolution, data is not refreshed
1 0	No ring register operation
1 1	Ring register operation data length according to the resolution, data is refreshed

If the number of clocks is more than the data length than the behaviour of the SSI can be as defined with the SSIcfg parameter. If the "SSIcfg" parameter is set to 00 then the data is output only once (chart below).

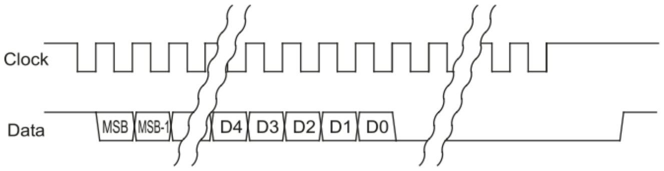

Fig. 12: SSI single read, SSIcfg is set to 00

To enlarge the reliability of reading the controller can read the same data more than once. The "SSIcfg" parameter must be set to "10" and the controller must continue sending the Clock pulses after the data is read without waiting for Tm (chart below). The same data will be output again and between the two outputs one logic zero will be output. The length of the data is depended of the resolution settings.

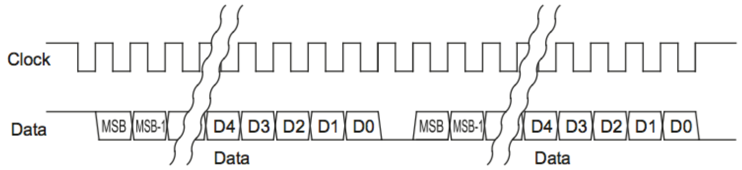

Fig. 13: SSI multi-read of the same position data, "SSIcfg" is set to 10

To speed-up the position reading of AM4096 the controller can constantly read the data. The "SSIcfg" parameter must be set to "11" and the controller must continue sending the Clock pulses after the data is read without waiting for Tm (chart below). Each data will be output as fresh position information and between the two outputs one logic zero will be output. The length of the data is depended of the resolution settings.

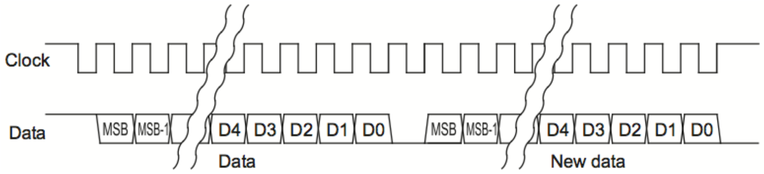

Fig. 14: SSI fast position read, SSIcfg is set to 11

Data sheet
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Two wire interface (TWI) output

The output data can be read with the TWI interface which is described in the beginning of the data sheet. The available data are relative position, absolute position, magnet out of range and tacho output.

Data	Symbol	Adress	Position
Relative position	Rpos	32	<11:0>
Absolute position	Apos	33	<11:0>
Magnet too far	Weh	34	<14>
Magnet too close	Wel	34	<13>
Tacho overflow	Thof	35	<10>
Tacho out	Tho	35	<9:0>

Tacho output

The tacho output provides information of the current rotating speed. The rotating speed is calculated and output on the "V_{out}/T_{out}" pin when the "Dact" parameter is set to 1. The speed information is also available in the registers on address 35. The measuring range can be selected with the "Sth" parameter. The update time depends on the "Sth" parameter and selected resolution ("Res").

"Sth" value	Measuring range [Hz]	Measuring range [rpm]	Update time [ms]
0 0 0	2,048	122880	0.125 × 4096/Res
0 0 1	1,024	61440	0.25 × 4096/Res
0 1 0	512	30720	0.5 × 4096/Res
0 1 1	256	15360	1 × 4096/Res
1 0 0	128	7680	2 × 4096/Res
1 0 1	64	3840	4 × 4096/Res
1 1 0	32	1920	8 × 4096/Res
1 1 1	16	960	16 × 4096/Res

The "V_{out}/T_{out}" pin is an output from the 10 bit DA converter. The DA converter output voltage range is defined by the voltages on the "RefN" and "RefP" pins. See the linear voltage output description for detailed description of DA converter properties.

UVW output

UVW outputs can be output as digital signals when the "BufSel" parameter is set to 0. The number of pole pairs can be selected with "UVW" parameter. The number of signal periods (P) equals number of pole pairs. The timing diagram shows the signals when the position data is increasing. The U signal always starts at zero position regardless the signal period length. The resolution should be set to 4096 to ensure accurate transitions of the signals.).

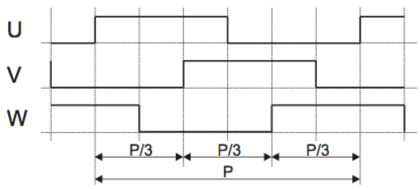

Fig. 15: UVW timing diagram for CW magnet rotation

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"Uvw" value	Number of pole pairs	Signal period length [°]
0 0 0	1	360
0 0 1	2	180
0 1 0	3	120
0 1 1	4	90
1 0 0	5	72
1 0 1	6	60
1 1 0	7	51,4
1 1 1	8	45

Pin name	Pin function
"U/N_{Sin}"	U
"V/P_{Sin}"	V
"W/N_{Cos}"	W

Linear voltage output

The digital relative angular position information is converted into linear voltage with a 10 bit DA converter. The linear output voltage is a sawtooth shape and lies within thresholds defined with the two external pins RefP and RefN. The number of periods per revolution can be selected with the "Dac" parameter. The interpolator resolution setting should be more than 10 bit.

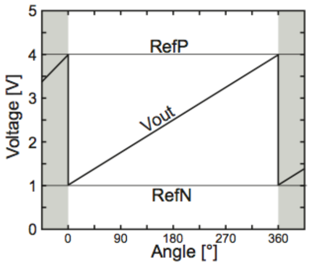

Fig. 16: One period per revolution ("Dac"= 0 0)

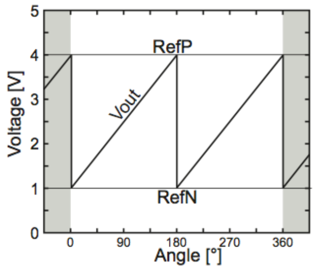

Fig. 17: Two periods per revolution ("Dac"= 0 1)

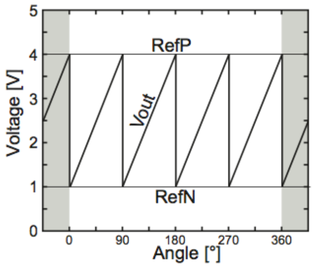

Fig. 18: Four periods per revolution ("Dac"= 1 0)

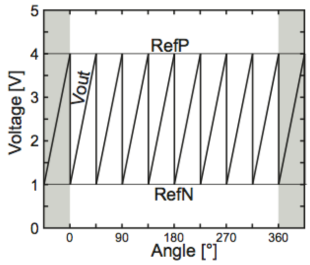

Fig. 19: Eight periods per revolution ("Dac"= 1 1)

Terminology:

RELATIVE ACCURACY: For the DAC, Relative Accuracy or Integral Nonlinearity (INL) is a measure of the maximum deviation in LSBs, from a straight line passing through the actual endpoints of the DAC transfer function.

OFFSET ERROR: This is a measure of the offset error of the DAC and the output amplifier. It is the difference between the output and the RefN voltage when the digital input value is 0. The units are in LSB.

GAIN ERROR: This is a measure of the span error of the DAC (including any error in the gain of the buffer amplifier). It is the deviation in slope of the actual DAC transfer characteristic from the ideal expressed in LSB.

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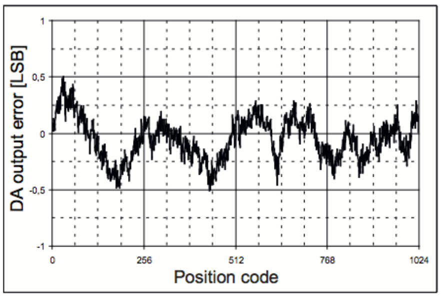

Fig. 20: Typical relative accuracy plot of the DAC

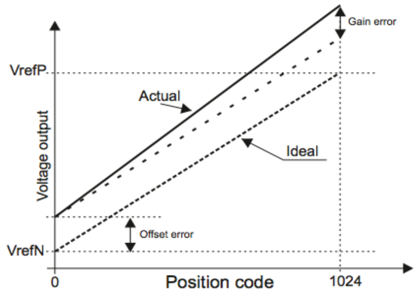

Fig. 21: Offset and Gain error of the DAC

DAC reference inputs characteristics:

Parameter	Min.	Typ.	Max.	Note
RefN internal pull down resistor		4.4 kΩ		
RefP internal pull up resistor		4.4 kΩ		
V_{RefN} input range	V_{ss}		Vext/2	
V_{RefP} input range	Vext/2		Vext	
V_{RefN} default value		7.4 % (Vext)		if RefN pin is not connected
V_{RefP} default value		92.7 % (Vext)		if RefP pin is not connected

DAC voltage output characteristics:

Parameter	Min.	Typ.	Max.	Note
Minimum output voltage		0 V		
Maximum output voltage		Vext-10 mV		Unloaded output
Output impedance		42 Ω		

DAC characteristics:

Parameter	Min.	Typ.	Max.	Units	Note
Resolution		10		bit	
Relative accuracy		±2		LSB	
Offset error		10		LSB	
Gain error		5		LSB	

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Hysteresis

Hysteresis is the difference of the output position at the same magnet position when rotating direction is changed. Hysteresis can be separated into static and dynamic. Static hysteresis is independent of rotational speed, whilst dynamic hysteresis is directly related. The AM4096 uses an electrical and digital hysteresis (static) when converting analogue signals to digital. The hysteresis must always be larger than the peak noise to assure a stable digital output. Electrical hysteresis is set to 0.17°. Digital hysteresis can be set with the "Hist" parameter from 0 to 127 units. By default the digital hysteresis is set to 0. Each unit equals 360°/4096.

Dynamic hysteresis is caused by filter delay. Analogue signals are filtered with an RC filter (2 kΩ, 10 nF). The delay of such filter is 20 µs.

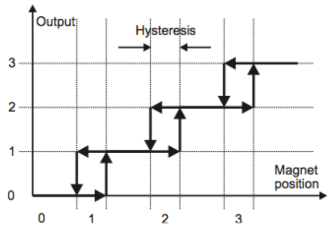

Fig. 22: Hysteresis

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Electrical hysteresis	$Hyst_e$	0.14	0.17	0.21	deg	*
Digital hysteresis	$Hyst_d$	0	0	11.16	deg	

* Measured at slow movement to avoid delay caused by filtering.

Nonlinearity

Nonlinearity is defined as the difference between the actual angular position of the magnet and the angular position output from the AM4096. There are different types of nonlinearity.

Differential nonlinearity is the difference between the measured position step and the ideal position step. The position step is the output position difference between any two neighbouring output positions, while the ideal position step is 360° divided by the resolution. Differential nonlinearity is mainly caused by noise. Differential nonlinearity is always less than one position step because there is a system that prevents missing codes. Chart on the left side shows a typical differential nonlinearity plot of the AM4096 with 12 bit resolution, 10 nF filtering and default parameters.

Integral nonlinearity is the total position error of the AM4096 output. Integral nonlinearity includes all position errors but does not include the quantisation error. Integral nonlinearity is minimised during production to better than ±0.2°. Chart on the right side shows a typical integral nonlinearity plot of the AM4096 with 12 bit resolution, a perfectly aligned magnet, 10 nF filtering and default parameters. Integral nonlinearity can increase if the default parameters are changed.

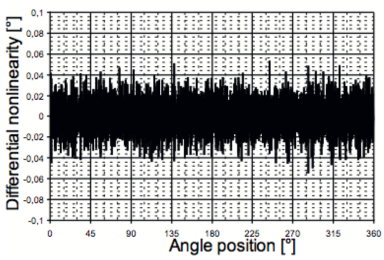

Fig. 23: Typical differential nonlinearity

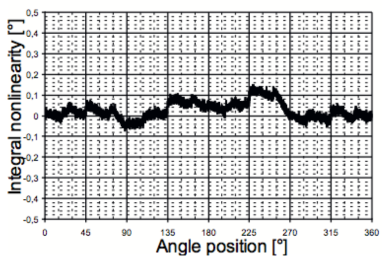

Fig. 24: Typical integral nonlinearity at optimal parameters

Power save mode

The AM4096 can operate in power save mode to minimise current consumption when position data update rate is not critical. Two types of power save mode are available, externally triggered and autonomous power save mode. It is recommended that when power save mode is used, the internal voltage regulator is not used and the voltage supply is 3.3 V.

Externally triggered power save mode can be done with "PSM" pin. While the "PSM" pin is high, the chip is operating in stand-by mode with no current consumption. When the "PSM" pin is switched to low the chip starts to operate normally and after 6ms the correct position data is available. When the position data is no longer needed, the chip can be put to sleep again.

Autonomous power save mode can be activated with "Pdie" parameter. If "Pdie" is set to 1 then the chip starts to sleep with periodically 1ms wake-up time. The length of sleep time can be selected with "Pdtr" parameter.

"PSM" pin *	Operation	Note
Low	AM4096 operates normally	
High	AM4096 sleeps	**

* PSM pin is the only digital input that does not have internally pull-down resistor and it must not be left open.
** No communication with the chip is available.

"Pdie" value	Operation	Note
0	AM4096 operates normally	
1	AM4096 cyclically awakes according to the "Pdtr" parameter	*

* When autonomous power save mode is selected, the "PSM" pin should be low

"Pdtr" value	Active time	Inactive time	Units	Note
0 0	0.94	120	ms	
0 1	0.94	240	ms	
1 0	0.94	480	ms	
1 1	0.94	960	ms	

"Pdee" value	Available outputs	Note
0	All outputs are available	*
1	Only SSI and TWI outputs are available	**

* After PSM is switched from high to low it takes 6 ms before output information is usable.
** SSI and TWI data is available all the time. Position information is updated according to the "Pdtr" parameter.

Recommended magnet

The AM4096 can be supplied with a pre-selected magnet to ensure that optimum performance is achieved. Alternatively, magnets can be sourced from other suppliers but they must conform to the following guidelines.

To select a suitable magnet it is important to know the properties of the sensors. Hall Sensors are only sensitive to the perpendicular component of the magnetic flux density (B). The AM4096 has a Hall sensor array arranged in a circle with 1 mm radius. The sensors are located on the surface of the silicon. The nominal distance between the sensors and the magnet surface is 1.6 mm.

Magnets must be cylindrical in shape and diametrically polarized. The main criterion for magnet selection is the modulation of the perpendicular component of magnetic flux density at the location of the sensors (B_n) and a low offset of magnet modulation.

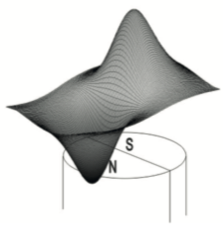

Fig. 25: Distribution of the perpendicular component of B

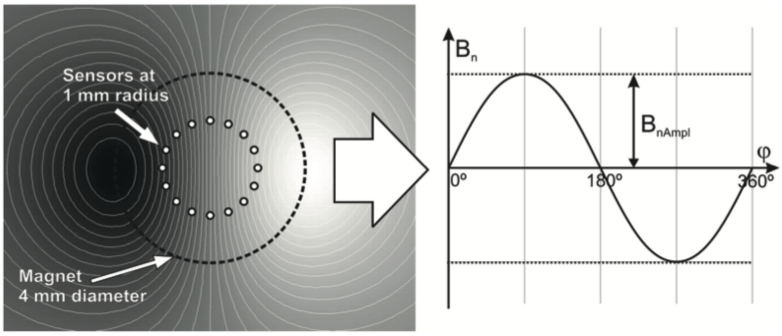

Fig. 26: Distribution of B_n and its modulation if the magnet is rotated through 360°

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Amplitude of B_n modulation	B_{nAmpl}		50		mT	*
Offset of B_n modulation	$B_{nOffset}$	–1		1	mT	**

* Typical value of B_{nAmpl} will give an analogue signal output with an amplitude of 0.68 V. The amplitude of the signal is proportional to the B_{nAmpl}.
1 Tesla equals 10,000 Gauss.

** Bad quality magnets offset the Bn modulation which results in increased integral nonlinearity when the magnet is not aligned correctly with respect to the chip.

We recommend that a magnet with the following parameters is used to provide the necessary modulation:

Parameter	Typ.	Unit	Note
Diameter	4	mm	
Length	4	mm	
Material	Sm2Co17		*
Material remanence	1.05	T	
Temperature coefficient	–0.03	% / °C	
Curie temperature	720	°C	

* Rare earth material magnets SmCo are recommended; however, NdFeB magnets can be used but they have different characteristics.

Magnet quality and the nonlinearity error

Each AM4096 is optimized during the production to give best performance with an ideal magnet when perfectly aligned.

An ideal magnet would have the polarization border exactly in the middle of the magnet. If the polarization is not exactly in the middle of the magnet then the modulation of the magnetic field has an offset.

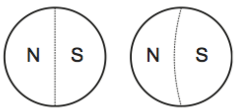

Fig. 27: Ideally polarized magnet and not ideally polarized magnet

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The offset represents a mean value of Bn when the magnet is rotated trough 360° and B_n is measured at 1.6 mm distance from the magnet surface and at 1 mm radius.

Offset will cause larger than normal integral nonlinearity errors if the sensors center placement is not in the center of the magnet rotation. Chart below shows an additional integral nonlinearity error caused by misalignment of the AM4096 for ideal and recommended magnets. Total integral nonlinearity is the summation of integral nonlinearity and the additional integral nonlinearity error caused by magnet displacement.

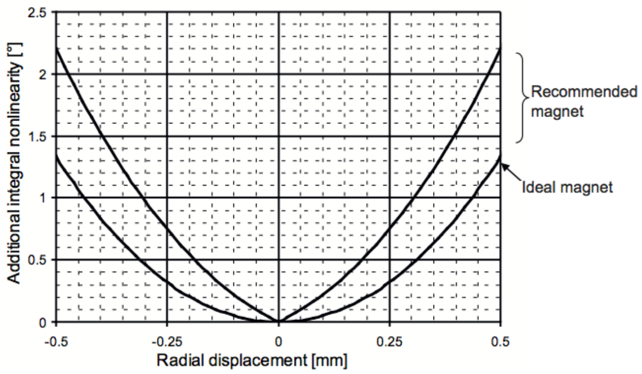

Fig. 28: Additional integral nonlinearity error caused by magnet displacement and quality

It is important that magnetic materials are not close to the magnet because they can increase the integral nonlinearity. They should ideally be at least 3 centimetres away from the chip. The magnet should be mounted in a non-magnetic carrier.

Magnet position

Magnet must be positioned above the AM4096 in the centre of hall sensor array. The centre of the sensor array is not in the centre of the AM4096.

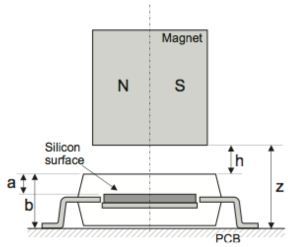

Fig. 29: AM4096 and the magnet with dimensions

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Distance sensors – chip surface	a		0.75		mm	
Distance PCB plane– chip surface	b		1.86		mm	*
Distance chip surface – magnet	h	0.50	1.00	1.50	mm	
Distance PCB plane – magnet	z	2.36	2.86	3.36	mm	*

* For typical 40 μm copper thickness of PCB

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Mounting instructions

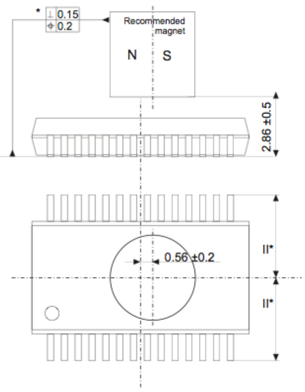


Fig. 30: Mounting instructions

Application scheme

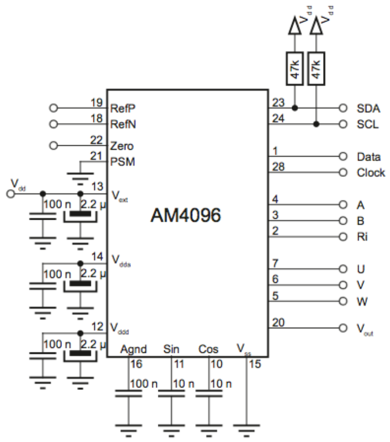


Fig. 31: Typical application scheme

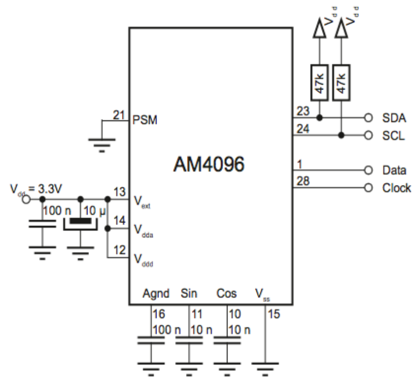


Fig. 32: Application scheme for autonomous power save mode

SSOP28 package dimensions

Dimensions:

Symbol	Min.	Typ.	Max.	Unit
A			2	mm
A1	0.05			mm
A2	1.65	1.75	1.85	mm
b	0.22		0.38	mm
c	0.09		0.25	mm
D	9.9	10.2	10.5	mm
E	7.4	7.8	8.2	mm
E1	5	5.3	5.6	mm
e		0.65		mm
K	0		10	deg
L	0.55	0.75	0.95	mm

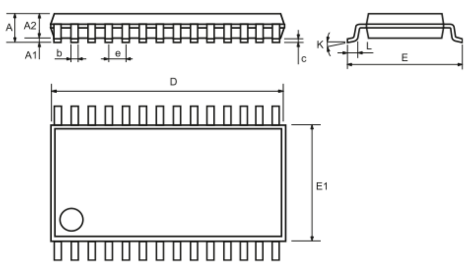


Fig. 33: Dimensional drawing

Data sheet
AM4096D02_04

Ordering information

1. Angular magnetic Encoder IC

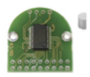
Part Number	Description
AM4096PT 	AM4096 Angular Magnetic Encoder IC with default functionality Output options: - SSI - Incremental - Linear voltage - UVW - TWI Programmable: - Differential buffered Sine/Cosine - Tacho SSOP28 plastic package Delivered in tubes (48 units per tube)

NOTE: Order quantity must be a multiple of 48 (one tube).
NOTE: Can be delivered in reels (special order)
NOTE: Magnet must be ordered separately! The Angular Magnetic Encoder IC part number does not include a magnet.

2. Magnet

Part Number	Description
RMM44A3C00 	Diametrically polarized magnet Dimensions: Ø4 mm × 4 mm

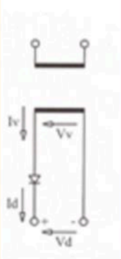
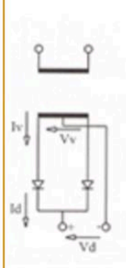
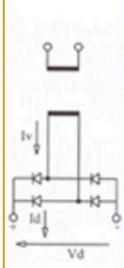
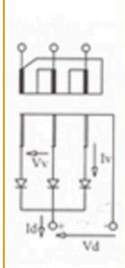
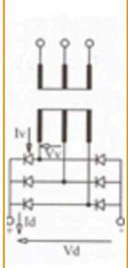
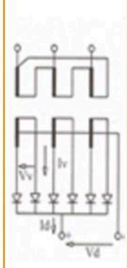
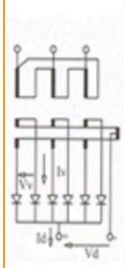
3. Sample Kits

Part Number	Description
RMK4 	AM4096 Angular Magnetic Encoder IC, on a PCB with all necessary components and a magnet, delivered in an antistatic box Output options: SSI, Incremental, Linear voltage, UVW, TWI Programmable: Differential buffered Sine/Cosine, Tacho

4. Interfaces

Part Number	Description
UPRGAM4096 	The UPRGAM4096 is a programming interface for use with AM4096 rotary magnetic encoder chip and RMK4 evaluation board. It connects simply to a computer via a USB port. The package includes USB 2.0 A-B mini cable and a ribbon cable with the appropriate connector for the RMK4 board

5. TABLAS PARA EL CÁLCULO DE RECTIFICADORES

Circuito							
Denominación del circuito	Circuito de rama única	Circuito con toma media	Circuito monofásico en puente	Circuito trifásico en estrella	Circuito trifásico en puente	Circuito hexafásico	Circuito doble trifásico en estrella
Signo abreviado del circuito según IEC	E1 ...	M2 ...	B2 ...	M3 ...	B6 ...	M6 ...	(M3..)2
Número de ramas	1	2	4	3	6	6	6
Frecuencia fr de la tensión alterna sobrepuesta en relación a la frecuencia de trabajo fo $\frac{fr}{fo}$	1	2	2	3	6	6	6
Tensión continua en vacío $\frac{Vdi}{Vvo}$	0.45	0.45	0.90	0.67	1.35	0.67	0.67 ***1)***

Factor de forma de la corriente continua $f=\frac{V_{dRMS}}{V_d}$	1.57	1.11	1.11	1.017	1.001	1.001	1.001
Rizado de la corriente continua $W=100\cdot\sqrt{f^2-1}$	121%	48%	48%	18.3%	4.2%	4.2%	4.2%
Corriente media por rama $\frac{I_{AAV}}{I_d}$	1	0.5	0.5	0.33	0.33	0.1666	0.1666
Corriente eficaz por rama $\frac{I_{ARMS}}{I_d}$	1.57	0.79	1.11	0.59	0.82	0.41	0.29
Corriente eficaz del secundario del transformador $\frac{I_{VRMS}}{I_d}$	1.57	0.79	1.11	0.59	0.82	0.41	0.29
Potencia del secundario del transformador $\frac{P_S}{V_{di}\cdot I_d}$	3.50	1.75	1.23	1.48	1.05	1.81	1.48
Potencia del primario del transformador $\frac{P_P}{V_{di}\cdot I_d}$	2.68	1.23	1.23	1.22	1.05	1.29	1.05
Potencia nominal del transformador $\frac{P_N}{V_{di}\cdot I_d}$	3.09	1.49	1.23	1.35	1.05	1.55	1.26

ESCUELA UNIVERSITARIA POLITÉCNICA

DE LA ALMUNIA DE DOÑA GODINA (ZARAGOZA)

PLANOS

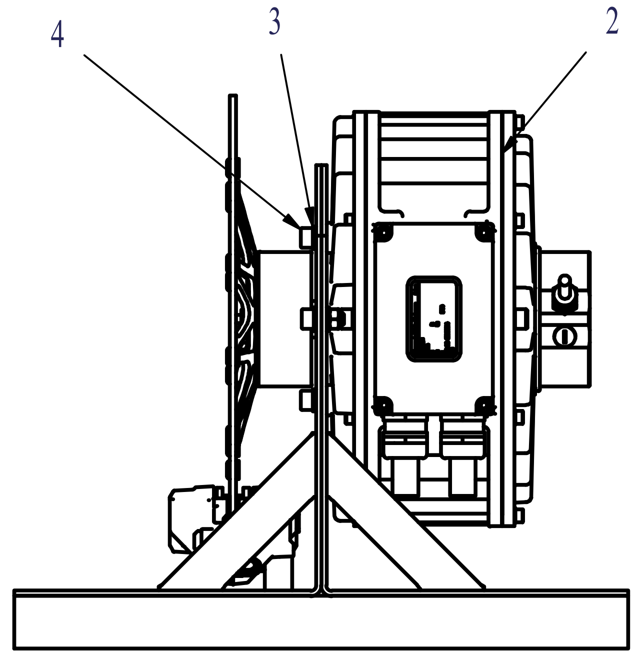
Banco de ensayos para regulador de motor brushless

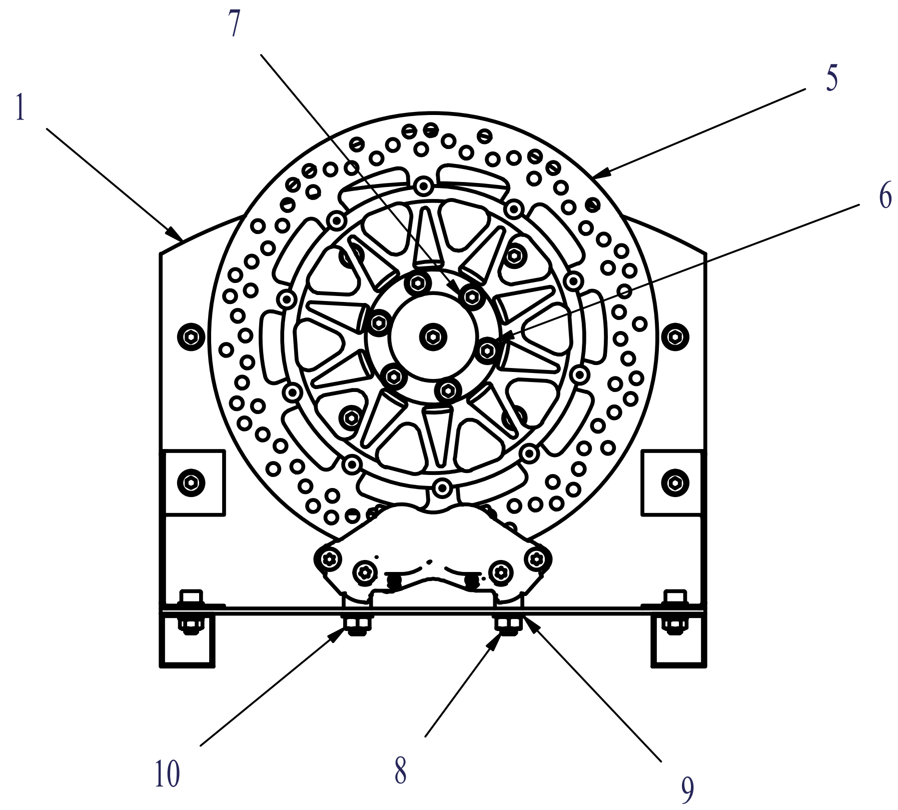
424.16.25

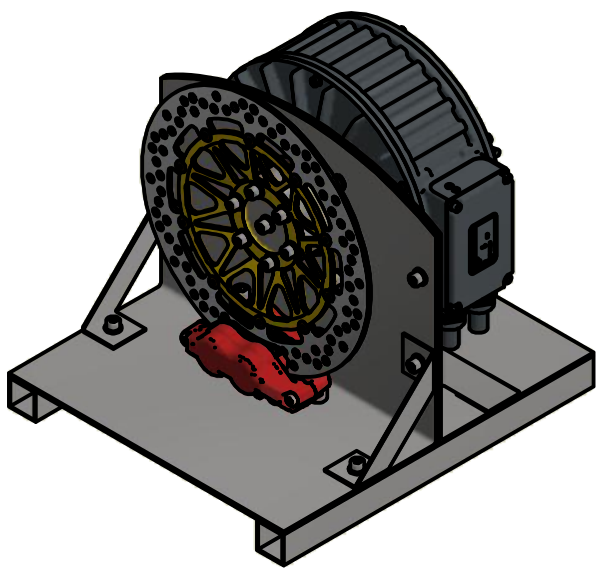
Autor: Daniel Suñén Angós

Director: Jesús García Millán

Fecha: 29-11-2016







MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
10	2	Tuerca hexagonal	ISO 4032 - M10DIN EN	Acero inoxidable, 440C
9	2	Arandela	DIN 126 - 11	Acero, suave
8	2	Tornillo cabeza Allen	DIN EN ISO 4762 - M10 x 80	Acero inoxidable, 440C
7	6	Tornillo cabeza Allen	DIN EN ISO 4762 - M8 x 30	Acero inoxidable, 440C
6	6	Arandela	DIN 126 - 9	Acero, suave
5	1	Sistema Frenado	424.16.25.030	-
4	4	Tornillo cabeza Allen	DIN EN ISO 4762 - M8 x 20	Acero inoxidable, 440C
3	4	Arandela Grower	AS 1968 - 1976 - 8	Acero, suave
2	1	Sistema Motríz	424.16.25.020	-
1	1	Estructura	424.16.25.010	-

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V3

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D. Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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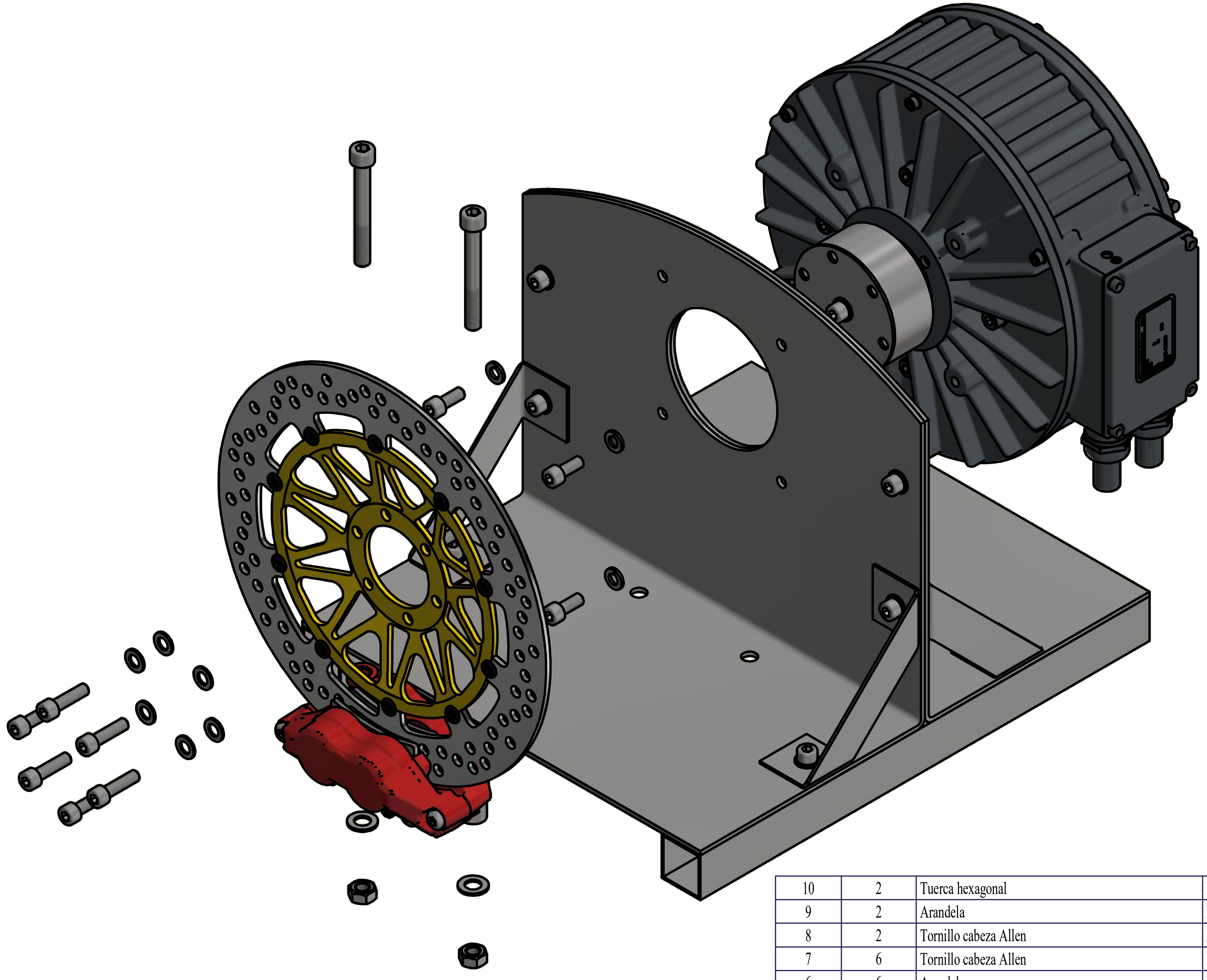
ESCUELA UNIVERSITARIA POLITECNICA
La Almunia de Dª Godina -ZARAGOZA-

ESCALA
1:5

Ensamblaje general
BANCO DE ENSAYOS
PLANO DE CONJUNTO

Nº P.: 424.16.25.000
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.000.idw



MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
10	2	Tuerca hexagonal	ISO 4032 - M10DIN EN	Acero inoxidable, 440C
9	2	Arandela	DIN 126 - 11	Acero, suave
8	2	Tornillo cabeza Allen	DIN EN ISO 4762 - M10 x 80	Acero inoxidable, 440C
7	6	Tornillo cabeza Allen	DIN EN ISO 4762 - M8 x 30	Acero inoxidable, 440C
6	6	Arandela	DIN 126 - 9	Acero, suave
5	1	Sistema Frenado	424.16.25.030	-
4	4	Tornillo cabeza Allen	DIN EN ISO 4762 - M8 x 20	Acero inoxidable, 440C
3	4	Arandela Grower	AS 1968 - 1976 - 8	Acero, suave
2	1	Sistema Motríz	424.16.25.020	-
1	1	Estructura	424.16.25.010	-

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless.
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V1

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D. Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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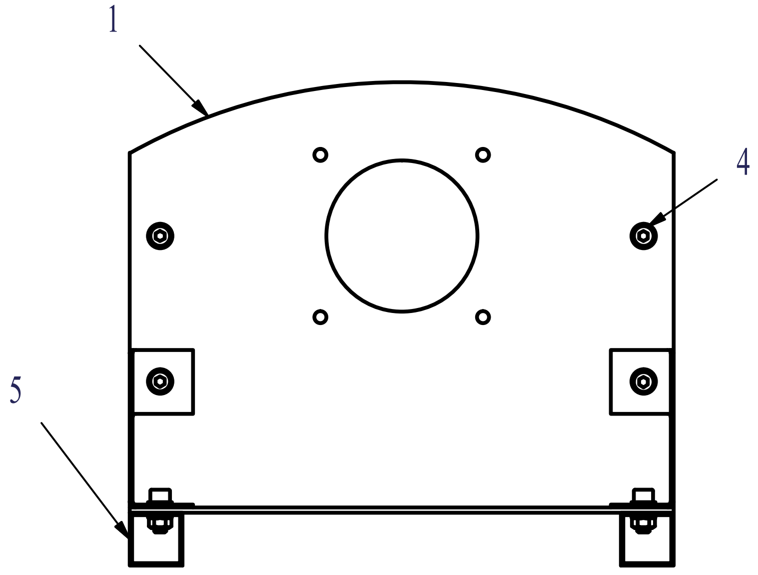
La Almunia de Dª Godina -ZARAGOZA-

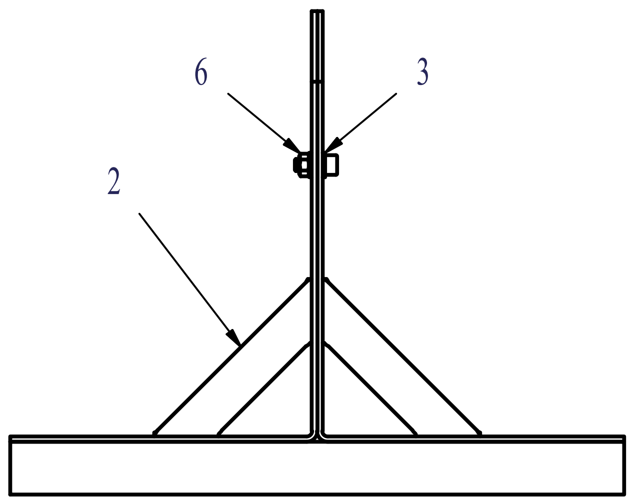
ESCALA

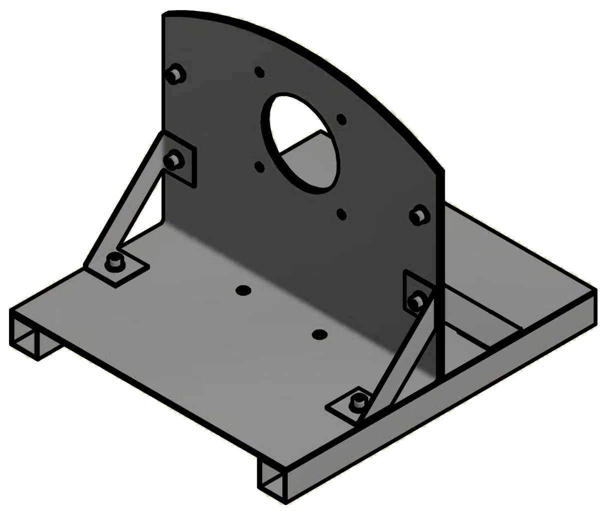
Ensamblaje general

BANCO DE ENSAYOS
PERSPECTIVA ESTALLADA

Nº P.: 424.16.25.000.1
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.000.1.idw







MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
6	8	Tuerca hexagonal	ISO 4032 - M8DIN EN	Acero inoxidable, 440C
5	2	Vigueta	424.16.25.013	AISI 304 35x35x1000mm
4	8	Tornillo cabeza Allen	DIN EN ISO 4762 - M8 x 20	Acero inoxidable, 440C
3	16	Arandela	DIN 126 - 9	Acero, suave
2	4	Cartela	424.16.25.012	Chapa acero estructural SJ275 250x80mm
1	2	Soporte Motor	424.16.25.011	Chapa acero estructural SJ275 360x500mm

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V3

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D. Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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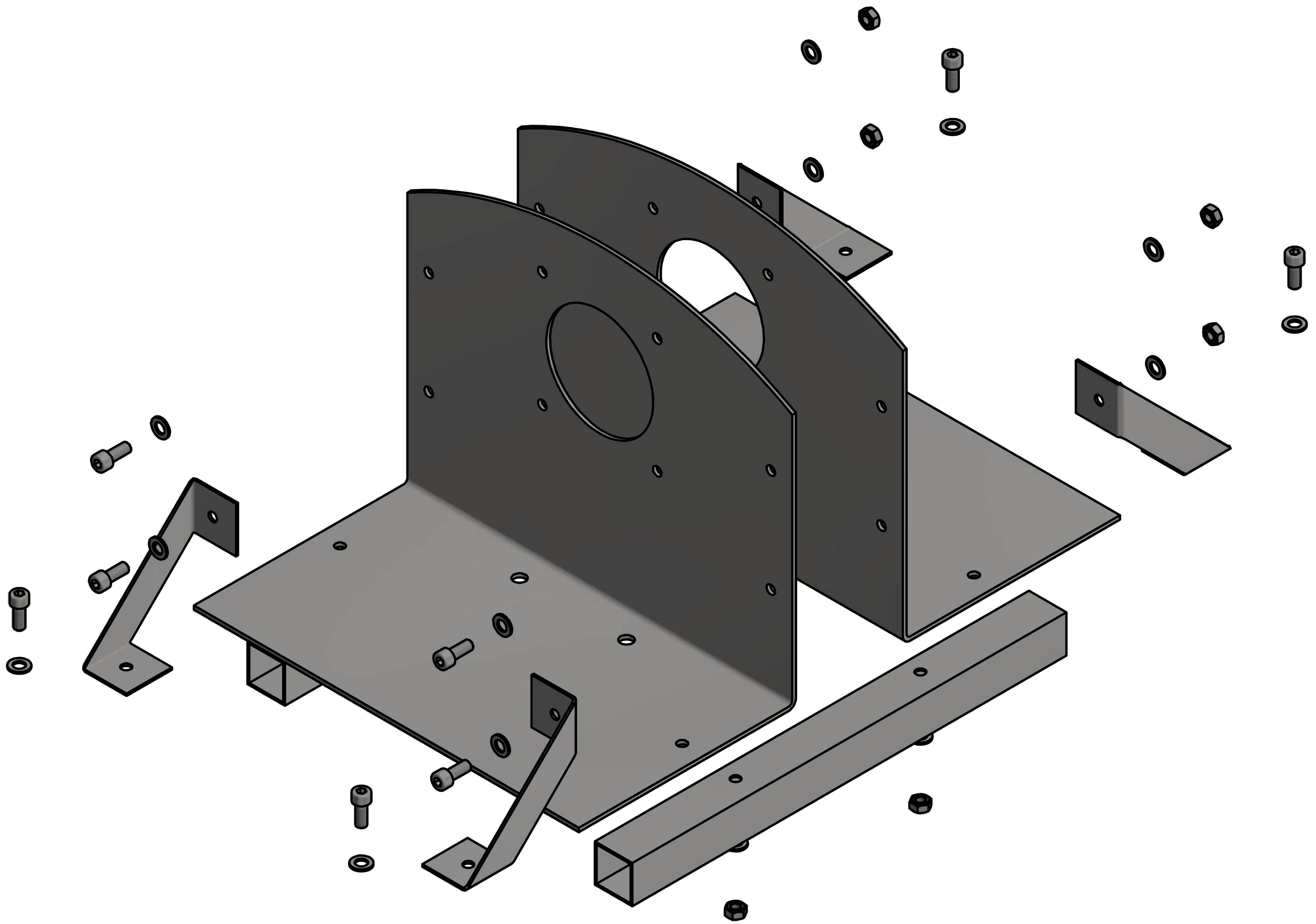
ESCUELA UNIVERSITARIA POLITECNICA
La Almunia de Dª Godina -ZARAGOZA-

ESCALA
1:5

Ensamblaje de grupo
ESTRUCTURA
PLANO DE CONJUNTO

Nº P.: 424.16.25.010
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.010.idw



MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
6	8	Tuerca hexagonal	ISO 4032 - M8DIN EN	Acero inoxidable, 440C
5	2	Vigueta	424.16.25.013	AISI 304 35x35x1000mm
4	8	Tornillo cabeza Allen	DIN EN ISO 4762 - M8 x 20	Acero inoxidable, 440C
3	16	Arandela	DIN 126 - 9	Acero, suave
2	4	Cartela	424.16.25.012	Chapa acero estructural SJ275 250x80mm
1	2	Soporte Motor	424.16.25.011	Chapa acero estructural SJ275 360x500mm

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless

Palabras clave:

Empresa: EUPLA

Estado del proyecto: En curso

Versión: V2

Observaciones de plano

Plano nº: 1 **de:** 1

Formato: A3

Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D.Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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ESCUELA UNIVERSITARIA POLITECNICA

La Almunia de Dª Godina -ZARAGOZA-

ESCALA

Ensamblaje de grupo

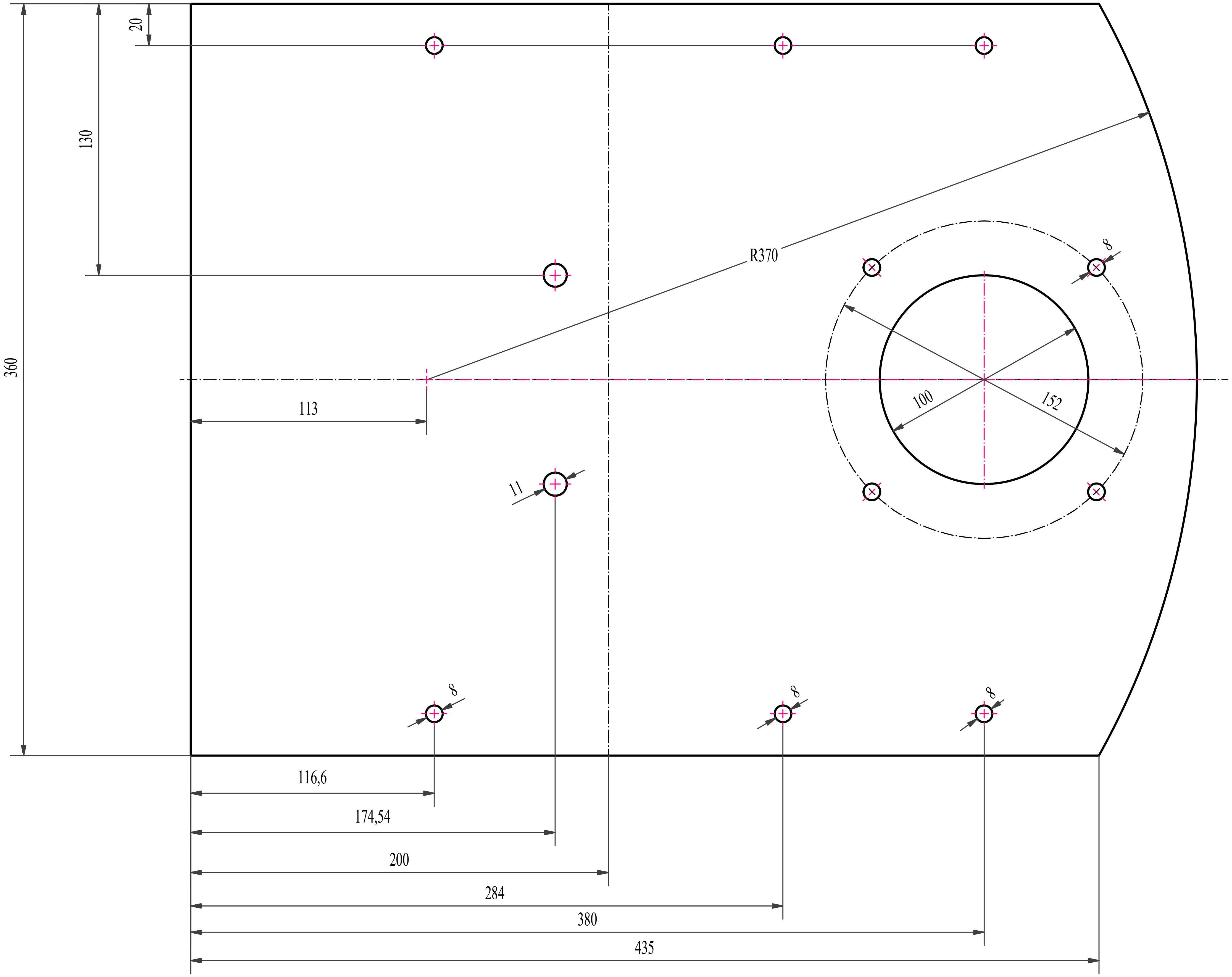
ESTRUCTURA

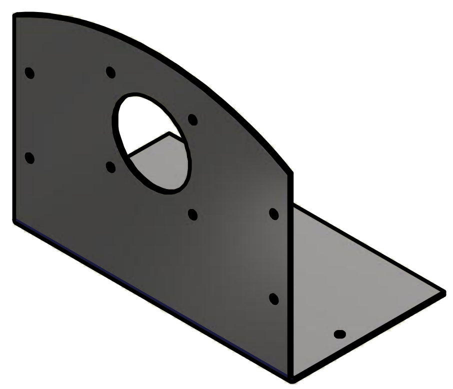
PERSPECTIVA ESTALLADA

Nº P.: 424.16.25.010.1

Nº O.: 424.16.25

Nom.Ar.: 424.16.25.010.1.idw





1	2	Soporte mesa	424.16.25.010	Chapa 2mm acero estructural SJ270 360x500
MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless

Palabras clave:

Empresa: EUPLA

Estado del proyecto: En curso

Versión: V6

Observaciones de plano

Plano nº: 1 **de:** 1

Formato: A3

Coment: Pliegue a 90º

	Fecha	Nombre
Dibujado	15/06/2016	D.Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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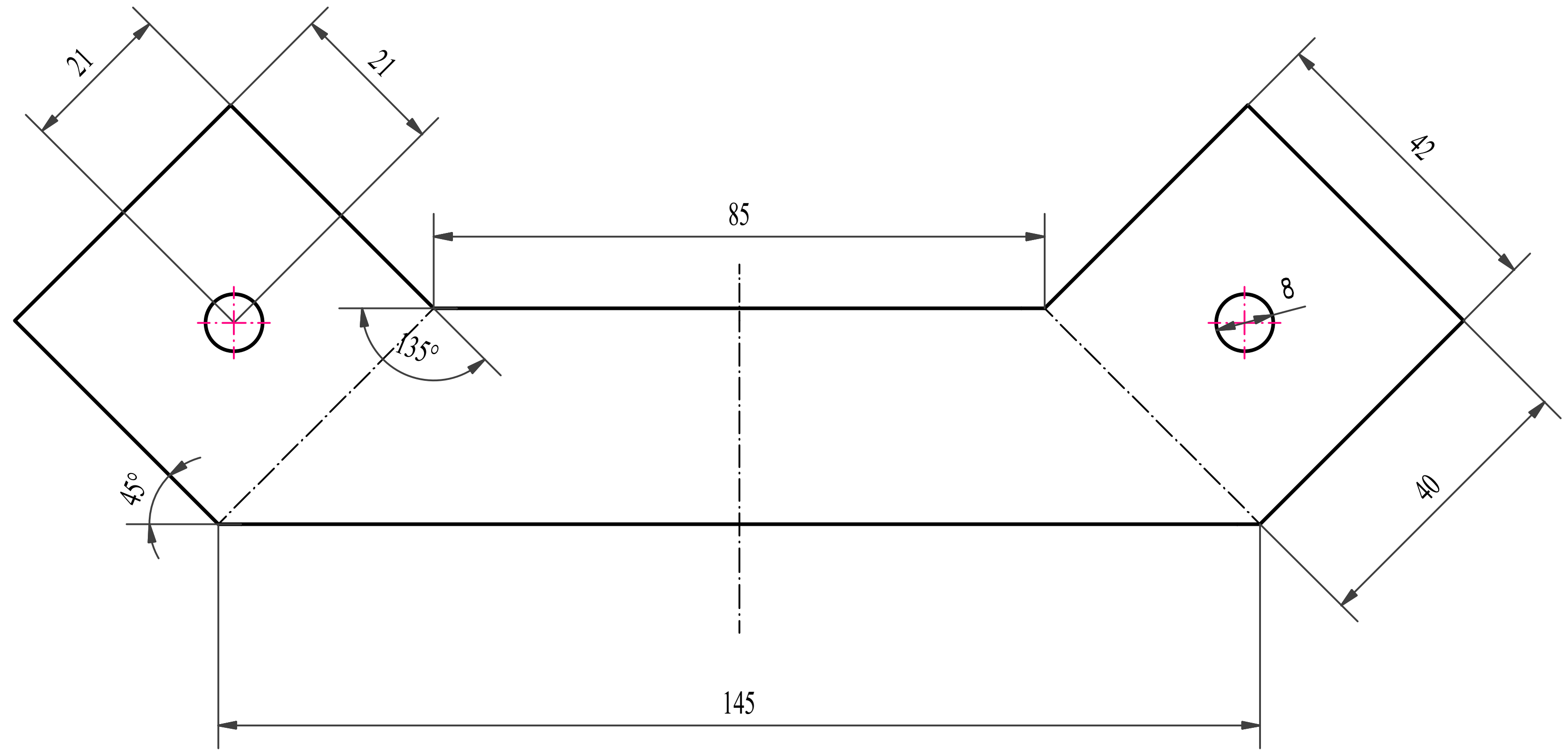
ESCUELA UNIVERSITARIA POLITECNICA
La Almunia de Dª Godina -ZARAGOZA-

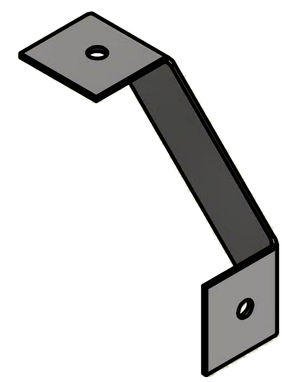
ESCALA
1:2

Soporte motor
ESTRUCTURA
SOPORTE MOTOR

Nº P.: 424.16.25.011
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.011.idw

N8





MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
1	4	Cartela	424.16.25.010	Chapa 2mm acero estructural SJ275 250x80

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V4

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment: Todos los pliegues a 90º

	Fecha	Nombre
Dibujado	15/06/2016	D.Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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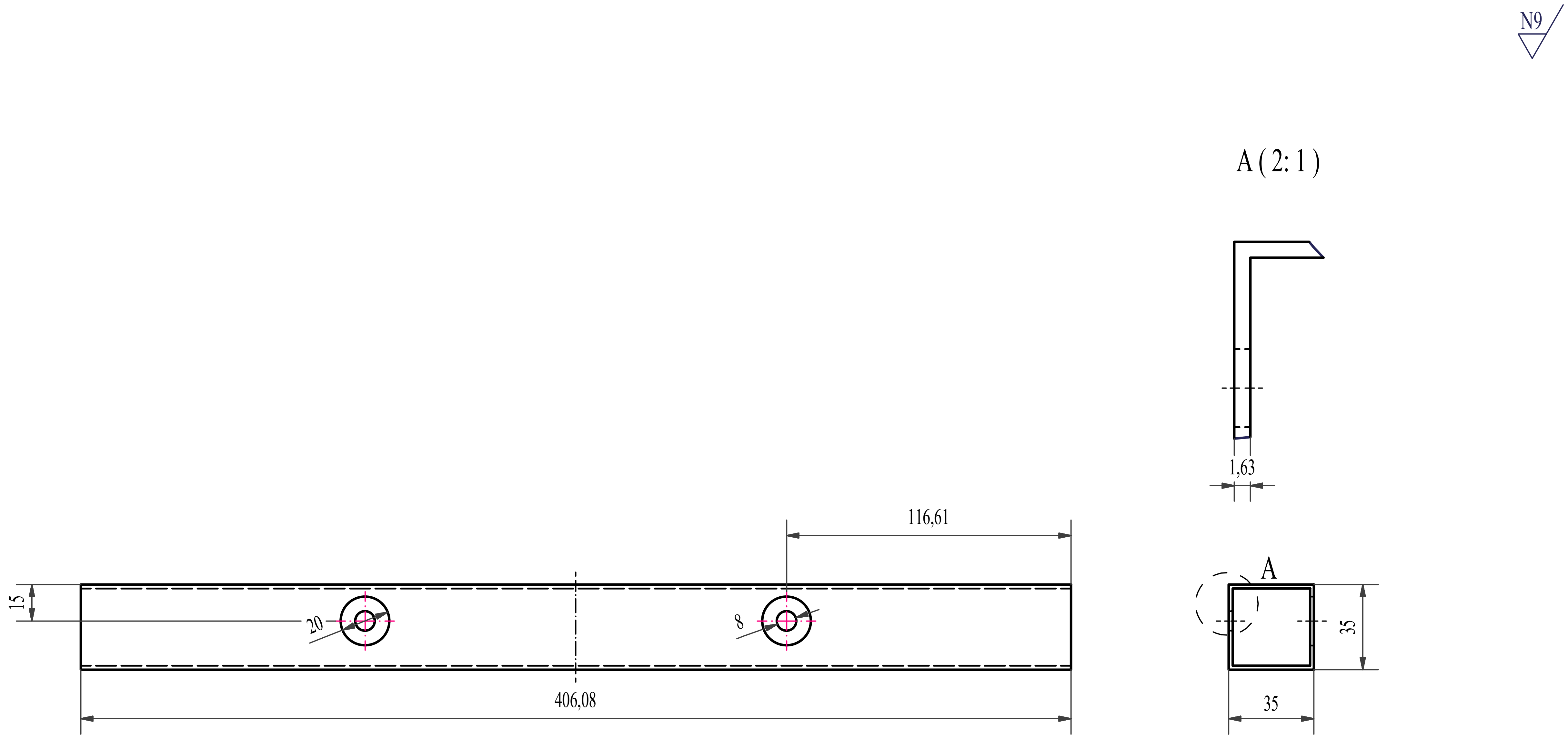
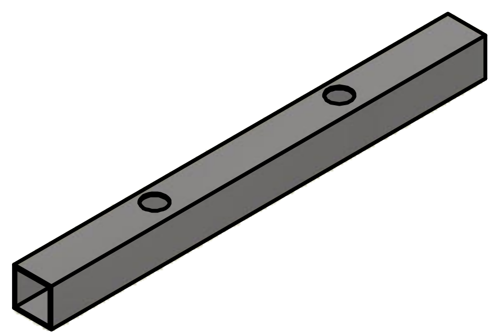
La Almunia de Dª Godina -ZARAGOZA-

ESCALA
1:1

Cartela
ESTRUCTURA
CARTELA

Nº P.: 424.16.25.012
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.012.idw





1	1	Vigueta	424.16.25.010	AISI 304 35x35x1000mm
MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V4

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D. Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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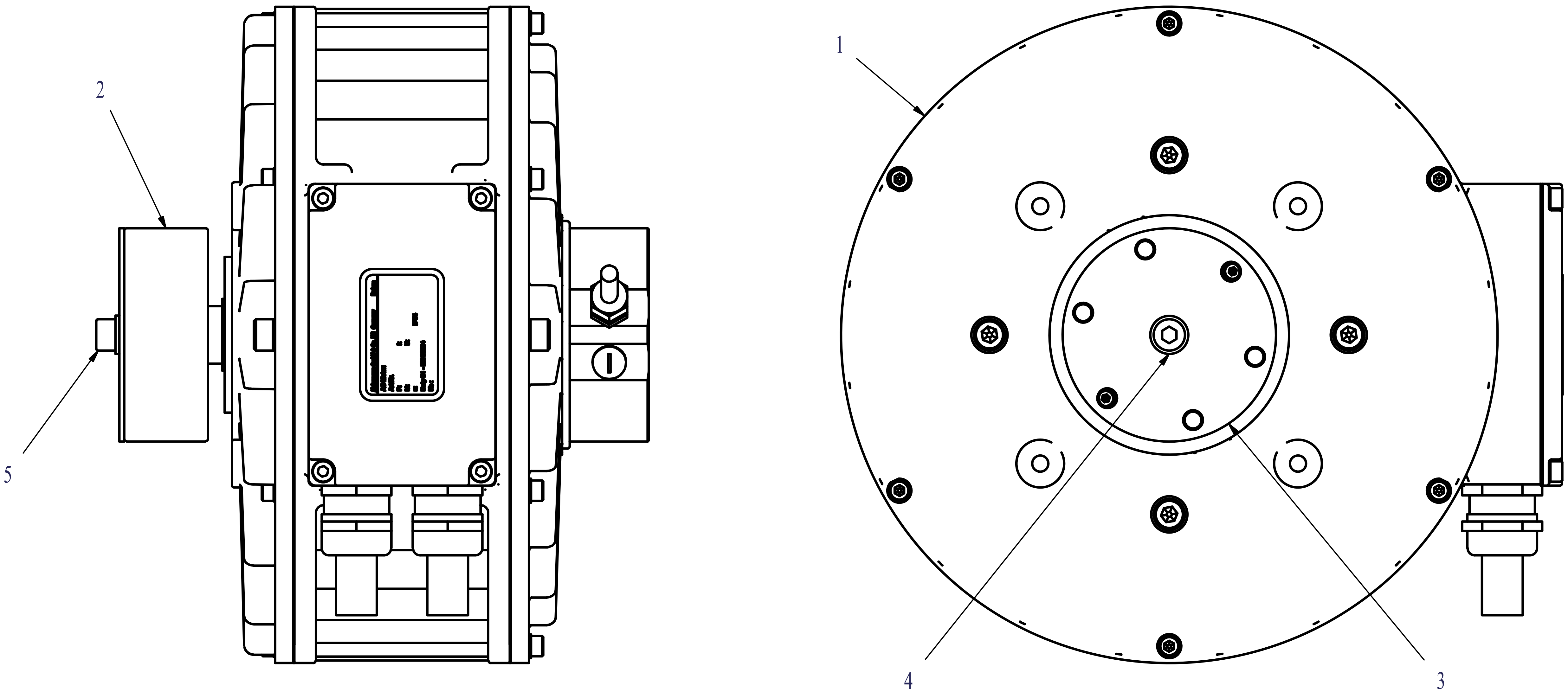
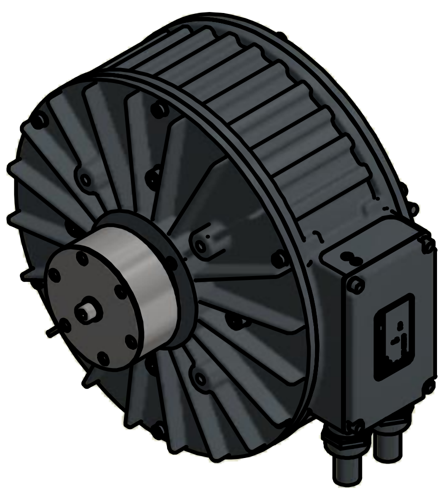
ESCUELA UNIVERSITARIA POLITECNICA
La Almunia de Dª Godina -ZARAGOZA-

ESCALA
1:2

Vigueta
ESTRUCTURA
VIGUETA

Nº P.: 424.16.25.013
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.013.idw





MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
5	1	Tornillo cabeza Allen	DIN EN ISO 4762 - M8 x 25	Acero inoxidable, 440C
4	1	Arandela	DIN 126 - 9	Acero, suave
3	1	Arandela acoplamiento disco	424.16.25.022	Chapa 2mm acero AISI 304 Ø100
2	1	Acoplamiento disco freno	424.16.25.021	Acero SJ275 Ø100x40
1	1	Motor	Heinzmann PMS 150	-

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless.
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V7

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D. Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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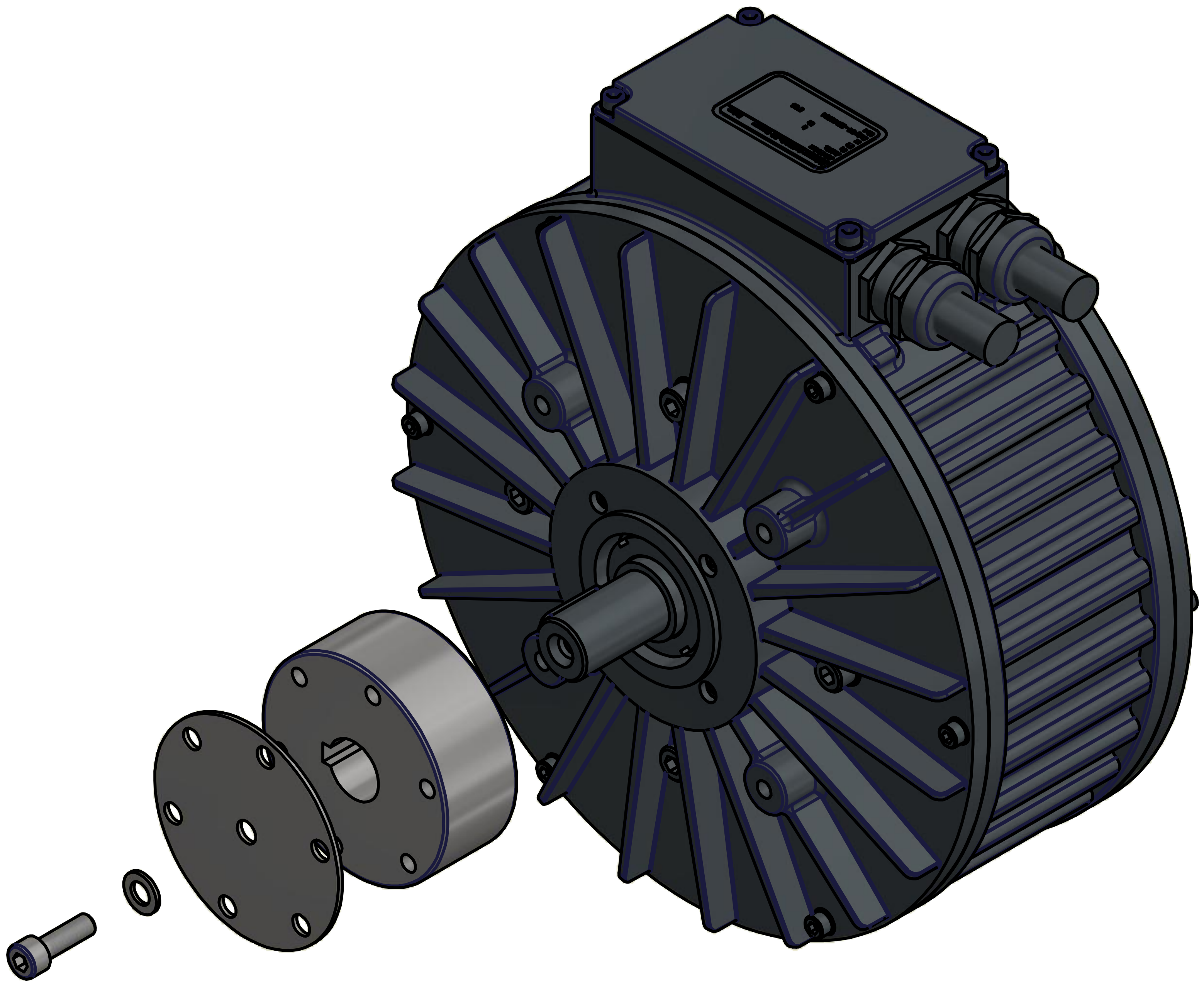
ESCUELA UNIVERSITARIA POLITECNICA
La Almunia de Dª Godina -ZARAGOZA-

ESCALA 1:2

Plano de grupo
SISTEMA MOTRIZ
PLANO DE GRUPO

Nº P.: 424.16.25.020
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.020.idw



MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
5	1	Tornillo cabeza Allen	DIN EN ISO 4762 - M8 x 25	Acero inoxidable, 440C
4	1	Arandela	DIN 126 - 9	Acero, suave
3	1	Arandela acoplamiento disco	424.16.25.022	Chapa 2mm acero AISI 304 Ø100
2	1	Acoplamiento disco freno	424.16.25.021	Acero SJ275 Ø100x40
1	1	Motor	Heinzmann PMS 150	-

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless

Palabras clave:

Empresa: EUPLA

Estado del proyecto: En curso

Versión: V4

Observaciones de plano

Plano nº: 1 **de:** 1

Formato: A3

Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D.Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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ESCUELA UNIVERSITARIA POLITECNICA

La Almunia de Dª Godina -ZARAGOZA-

ESCALA

Plano de grupo

SISTEMA MOTRIZ

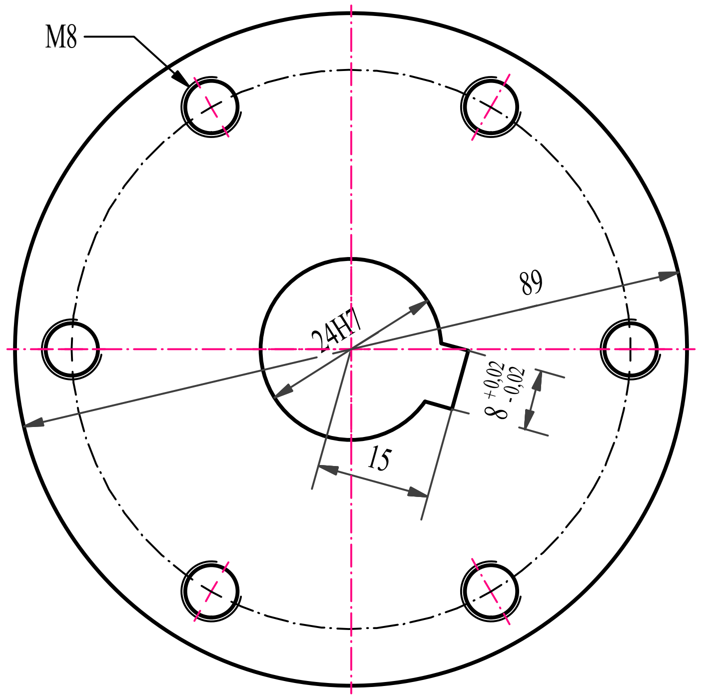
PERSPECTIVA ESTALLADA

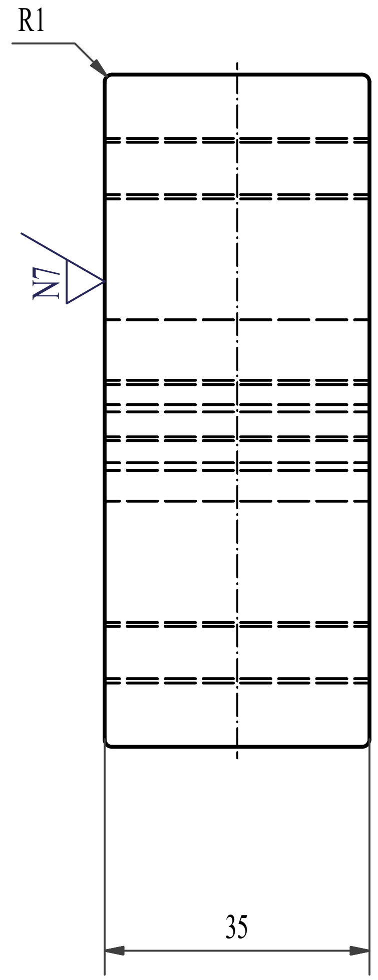
Nº P.: 424.16.25.020.1

Nº O.: 424.16.25

Nom.Ar.: 424.16.25.020.1.idw

N8 (N7)





MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
1	1	Acoplamiento disco de freno	424.16.25.020	Acero SJ275 Ø100x40

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V5

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D.Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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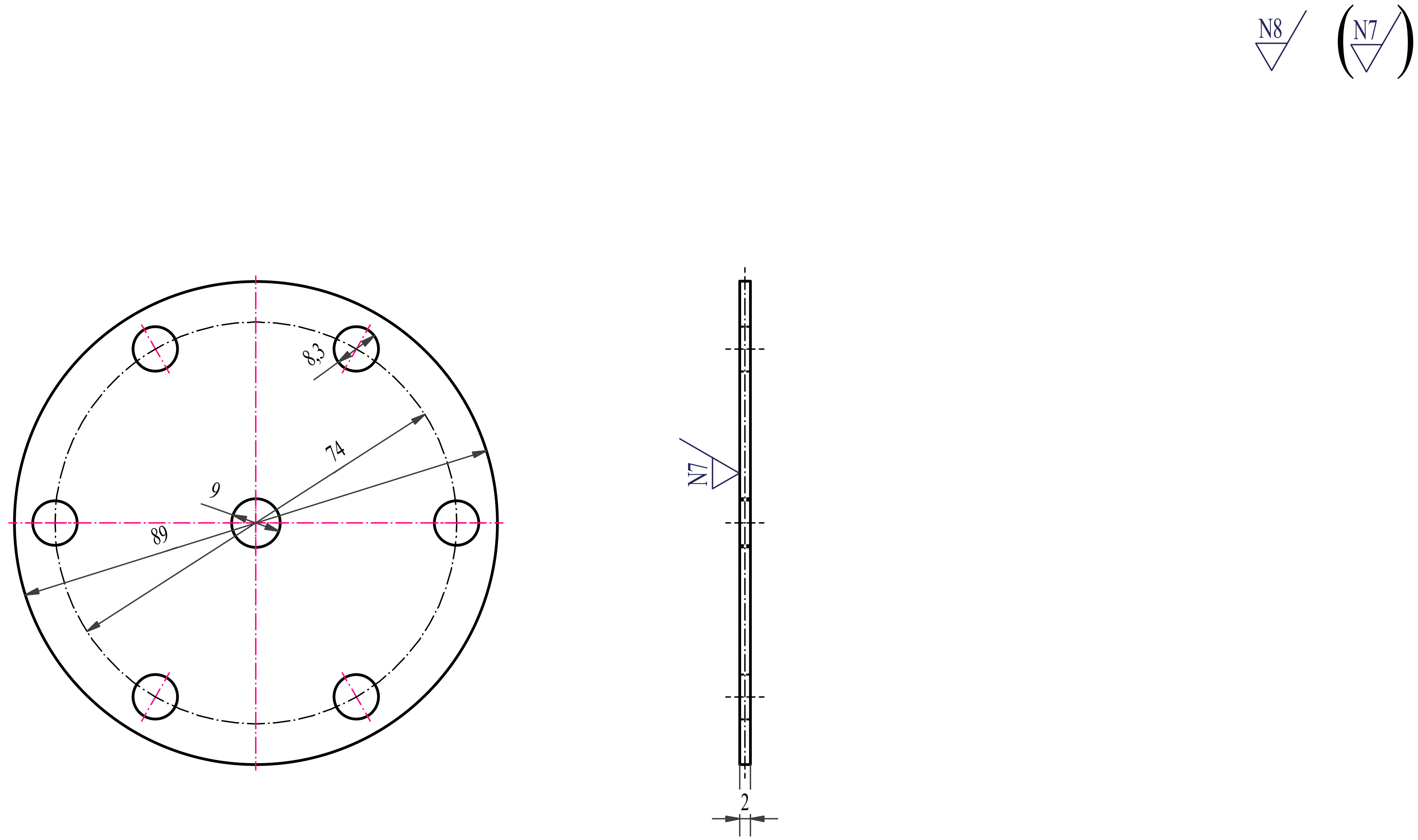
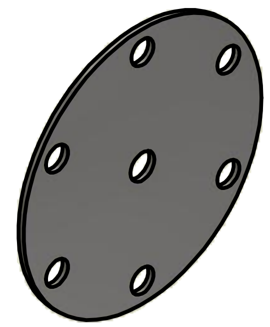
ESCUELA UNIVERSITARIA POLITECNICA
La Almunia de Dª Godina -ZARAGOZA-

ESCALA 1:1

Acoplamiento disco de freno
SISTEMA MOTRIZ
ACOPLAMIENTO DISCO FRENO

Nº P.: 424.16.25.021
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.021.idw





1	1	Arandela acoplamiento disco	424.16.25.020	Chapa 2mm acero AISI 304 Ø100
MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V2

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

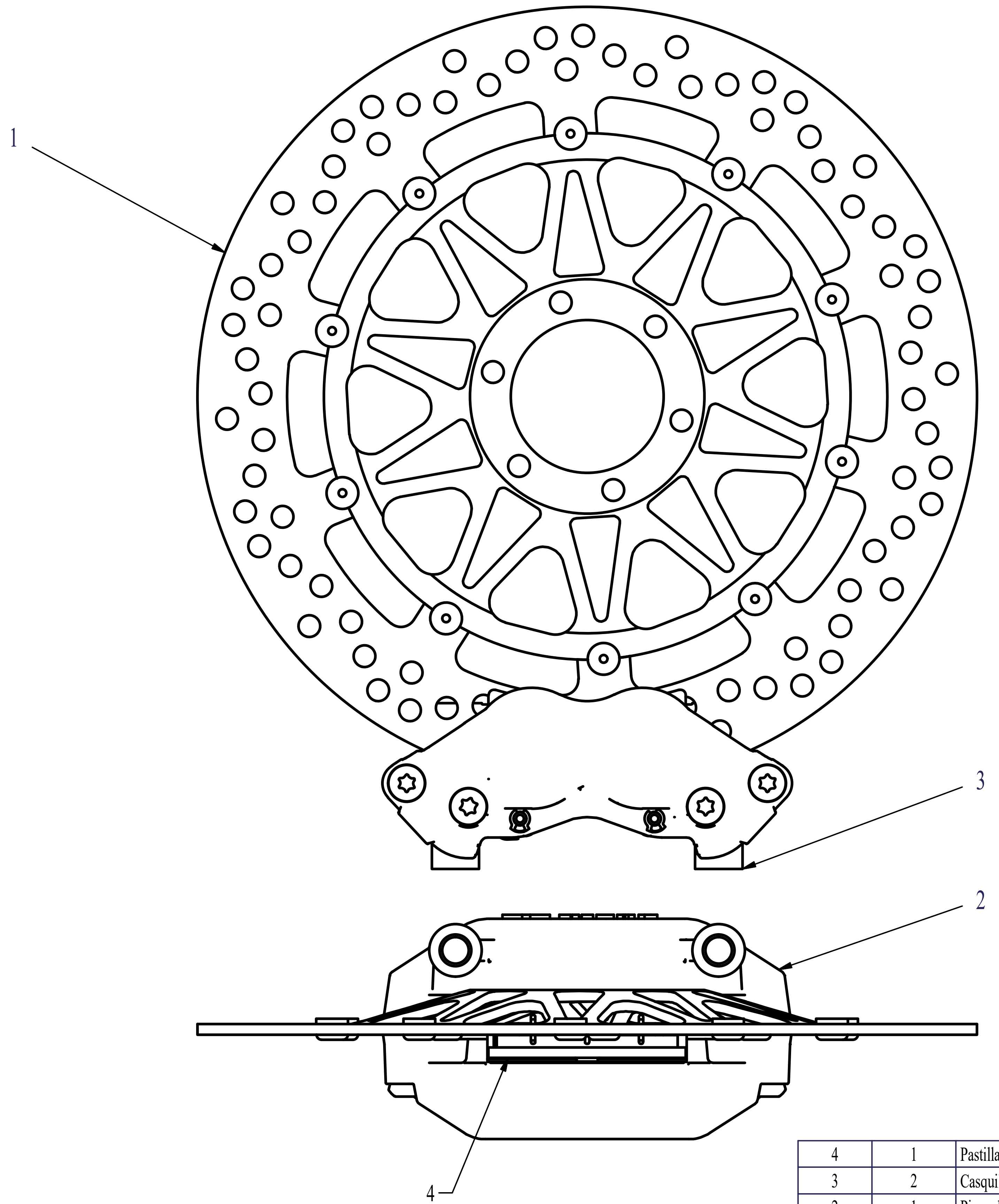
	Fecha	Nombre
Dibujado	15/06/2016	D. Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

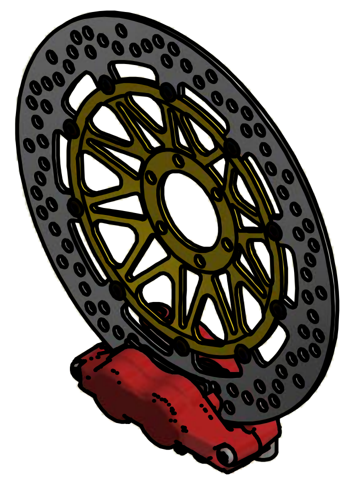
ESCUELA UNIVERSITARIA POLITECNICA
La Almunia de Dª Godina -ZARAGOZA-

ESCALA 1:1

Arandela acoplamiento disco
SISTEMA MOTRIZ
ARANDELA ACOPLAMIENTO DISCO

Nº P.: 424.16.25.022
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.022.idw





MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
4	1	Pastilla de freno	SBS-SI-90HH	-
3	2	Casquillo pinza	424.16.25.031	Acero AISI 304 Ø20x25
2	1	Pinza de freno	JJUAN IID0007-13-FCRH1	-
1	1	Disco de freno	NG Brake 216	-

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V1

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D. Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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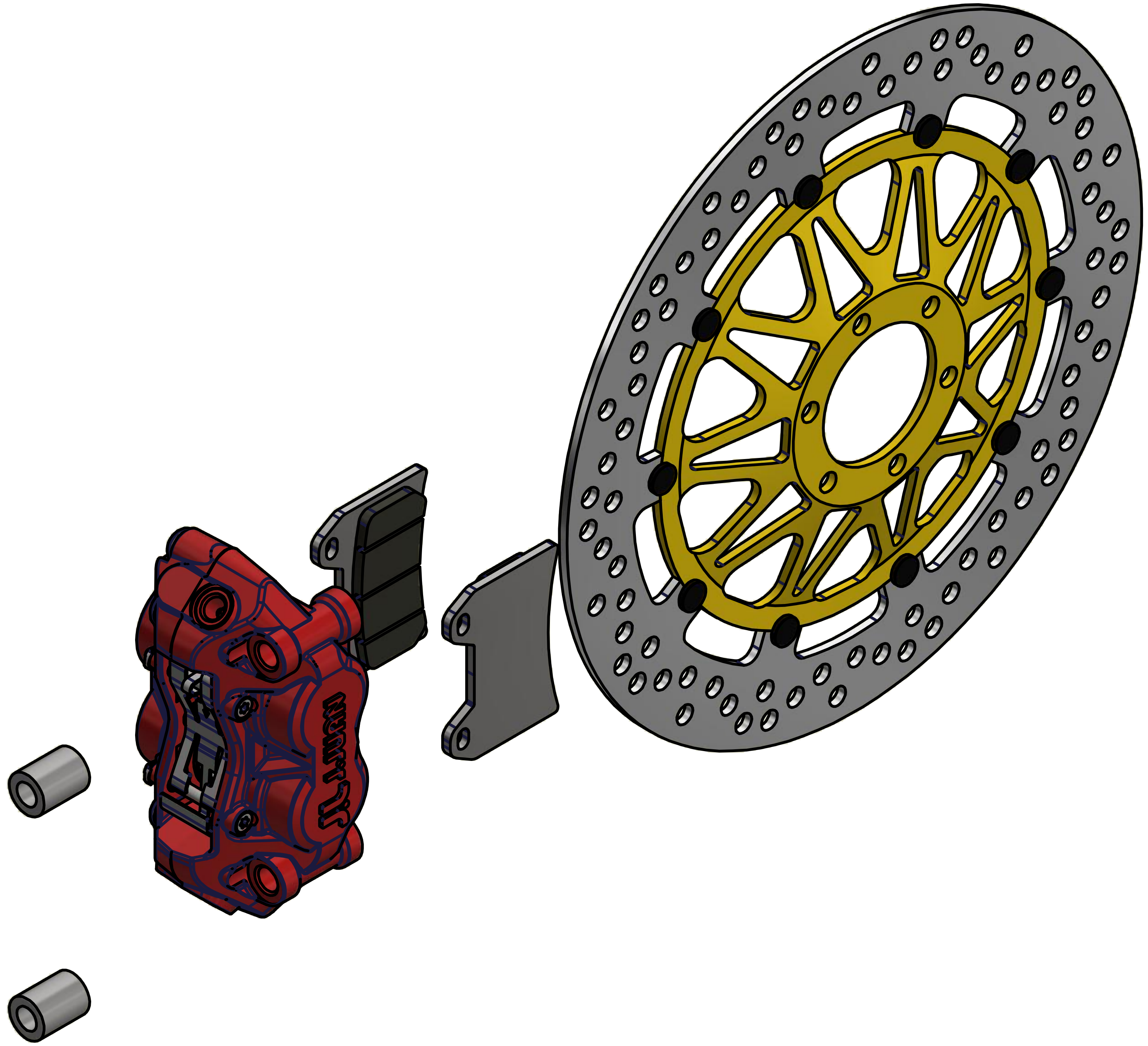
ESCUELA UNIVERSITARIA POLITECNICA
La Almunia de Dª Godina -ZARAGOZA-

ESCALA
1:2

Plano de grupo
SISTEMA FRENADO
PLANO DE GRUPO

Nº P.: 424.16.25.030
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.030.idw



MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES
4	1	Pastilla de freno	SBS-SI-90HH	-
3	2	Casquillo pinza	424.16.25.031	Acero AISI 304 Ø20x25
2	1	Pinza de freno	JJUAN IID0007-13-FCRH1	-
1	1	Disco de freno	NG Brake 216	-

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless.
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V1

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D. Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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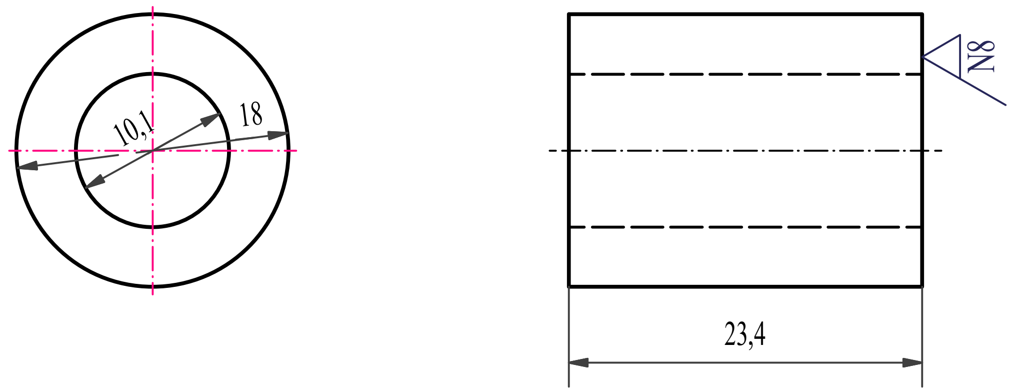
ESCUELA UNIVERSITARIA POLITECNICA
La Almunia de Dª Godina -ZARAGOZA-

ESCALA

Plano de grupo
SISTEMA FRENADO
PERSPECTIVA ESTALLADA

Nº P.: 424.16.25.030.1
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.030.1.idw

N9 (N8)



1	1	Casquillo pinza de freno	424.16.25.030	Acero AISI 304 Ø20x25
MARCA	CTDAD	DENOMINACIÓN Y CARACTERISTICAS	Nº PLANO / ABRE. NORMA	MATERIAL/OBSERVACIONES

Observaciones Generales

Proyecto: Banco de ensayos. Regulador motor brushless
Palabras clave:
Empresa: EUPLA
Estado del proyecto: En curso
Versión: V1

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment:

	Fecha	Nombre
Dibujado	15/06/2016	D.Suñén
Comprobado	02/12/2016	Tribunal 2
Idem.s.normas		UNE-EN

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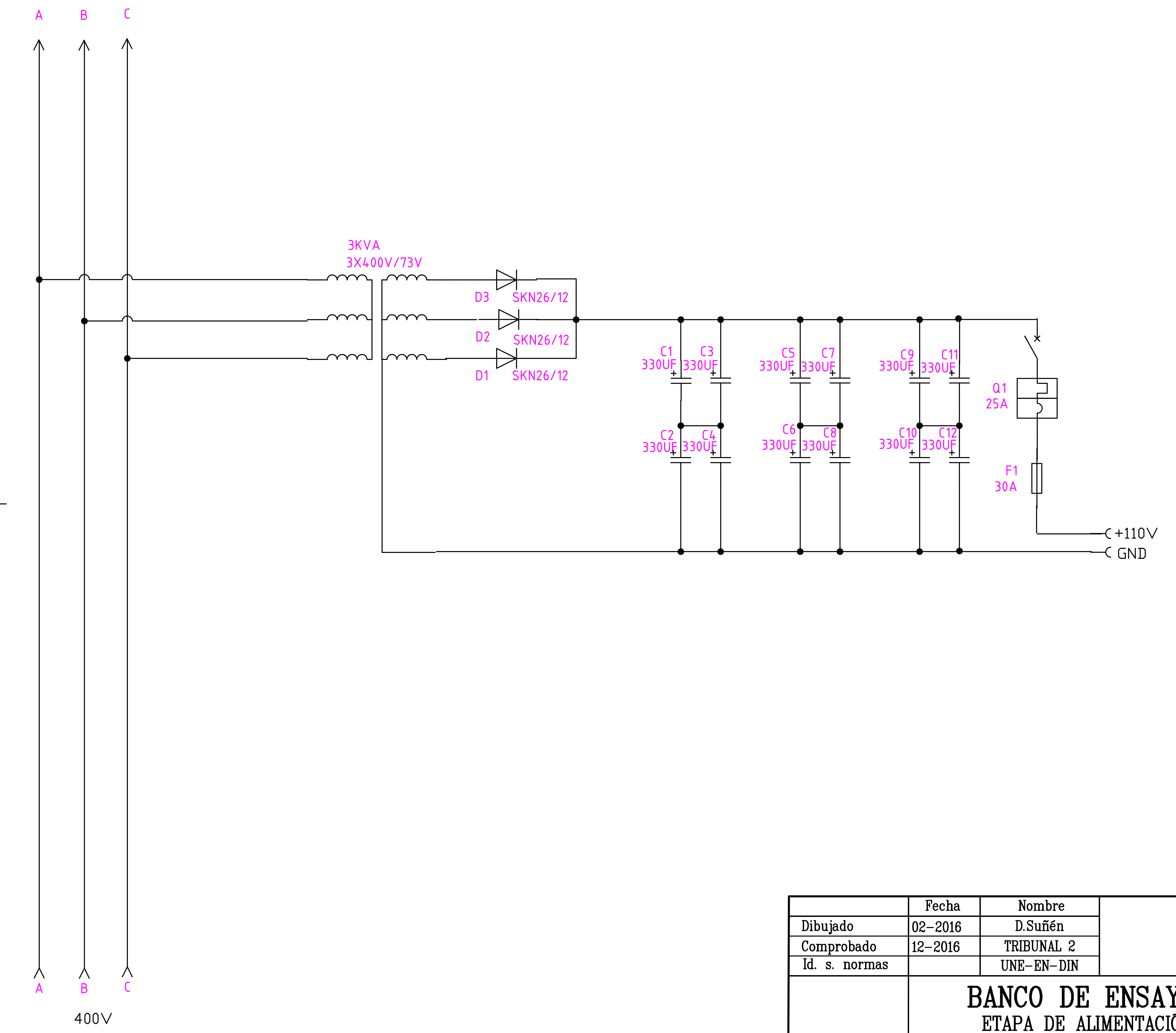
2:1

Casquillo pinza de freno
SISTEMA DE FRENADO
CASQUILLO PINZA

Nº P.: 424.16.25.031
Nº O.: 424.16.25
Nom.Ar.: 424.16.25.031.idw



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Dibujado	02-2016	D.Suñén
Comprobado	12-2016	TRIBUNAL 2
Id. s. normas		UNE-EN-DIN

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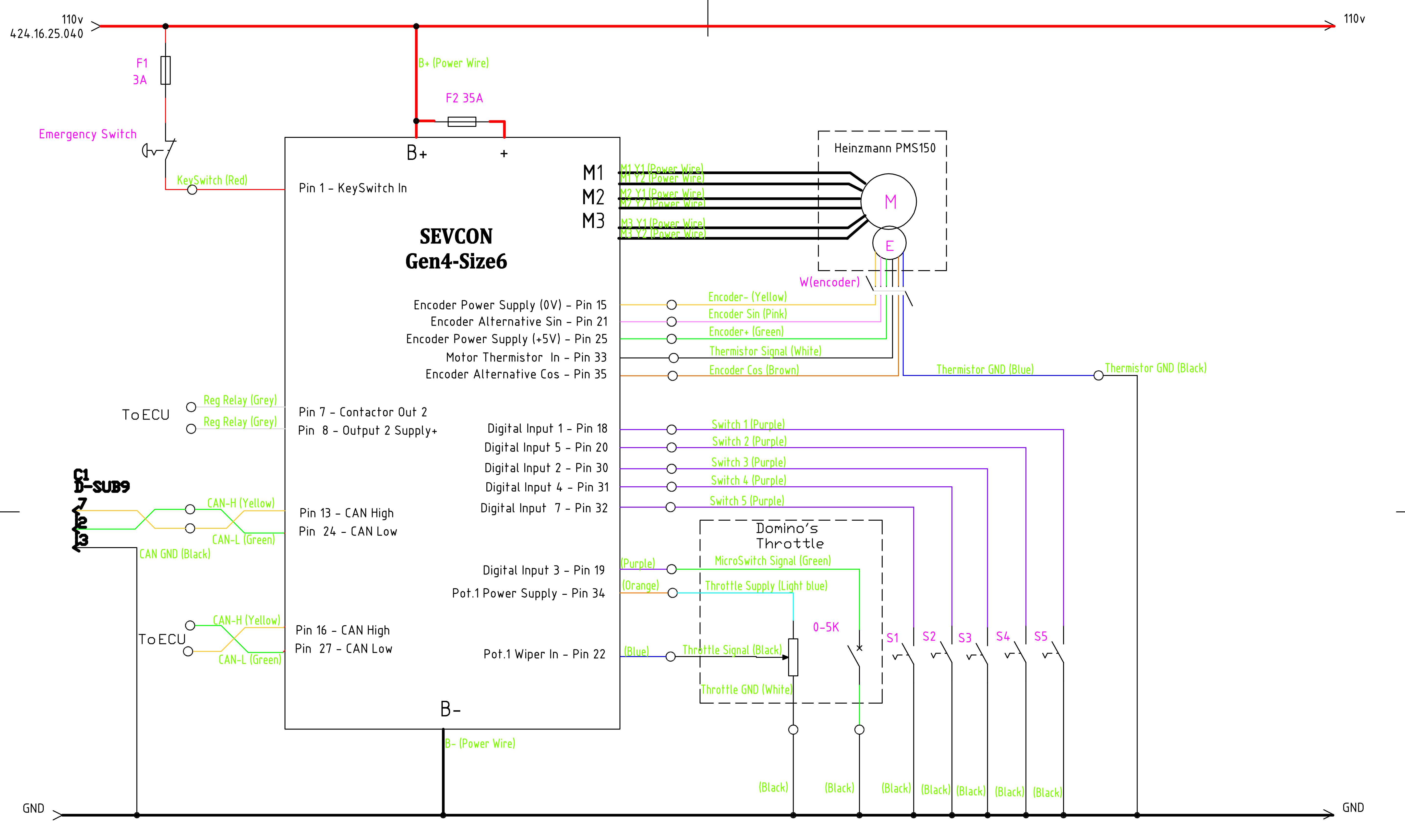
BANCO DE ENSAYOS
ETAPA DE ALIMENTACIÓN
FUENTE ALIMENTACIÓN BANCO

Nº P. :424.16.25.040
Nº O. :424.16.25
Nom. Arch:



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Dibujado	03-2016	D.Suñén
Comprobado	12-2016	TRIBUNAL 2
Id. s. normas		UNE-EN-DIN

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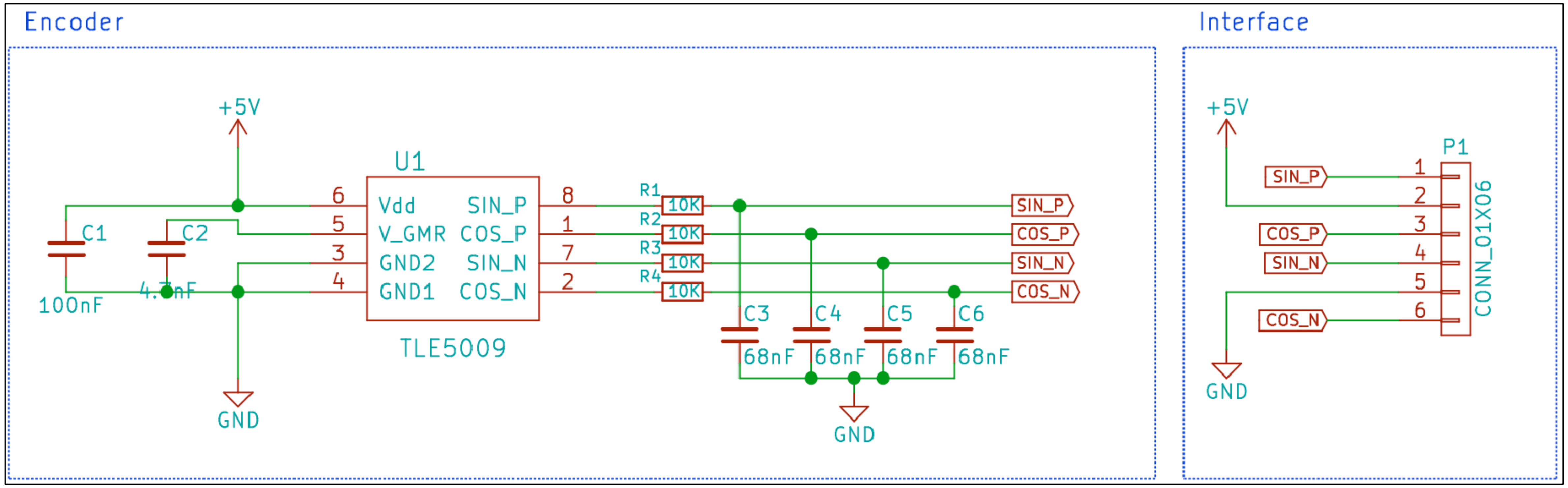
BANCO DE ENSAYOS
ETAPA DE CONTROL
CABLEADO REGULADOR

Nº P. :424.16.25.040
Nº O. :424.16.25
Nom.Arch:



	Fecha	Nombre
Dibujado	05–2016	D.Suñén
Comprobado	12–2016	TRIBUNAL 2
Id. s. normas		UNE–EN–DIN

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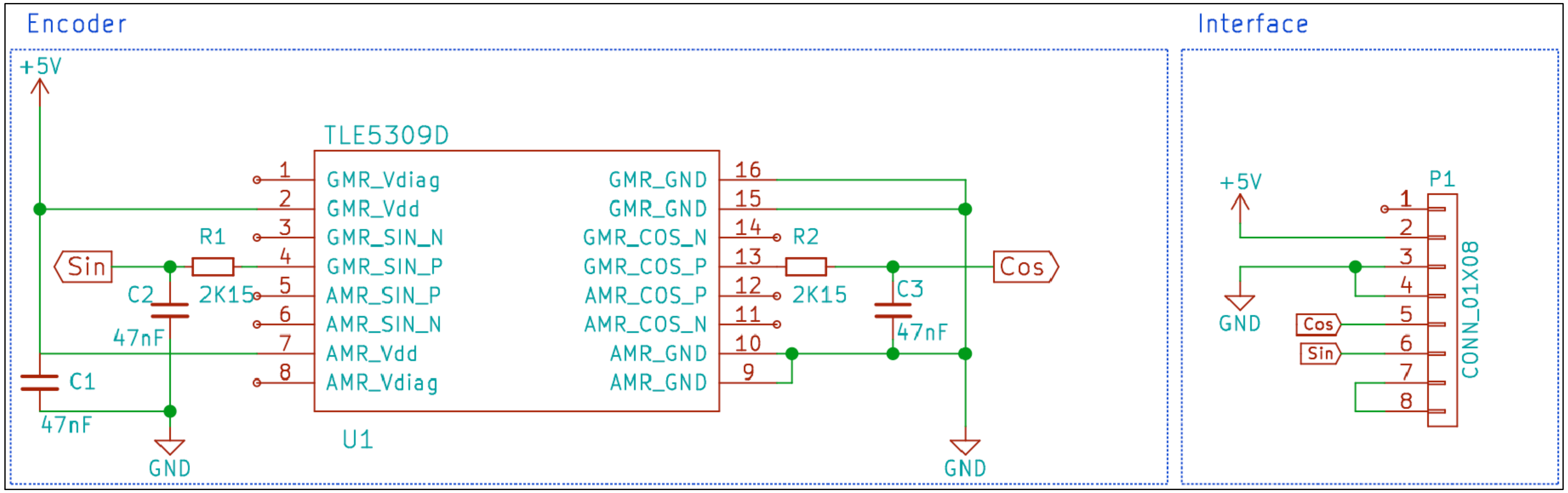
BANCO DE ENSAYOS
ENSAYOS ENCODER
INFINEON TLE5009

Nº P. : 424.16.25.061
Nº O. : 424.16.25
Nom. Arch:



	Fecha	Nombre
Dibujado	05-2016	D.Suñén
Comprobado	12-2016	TRIBUNAL 2
Id. s. normas		UNE-EN-DIN

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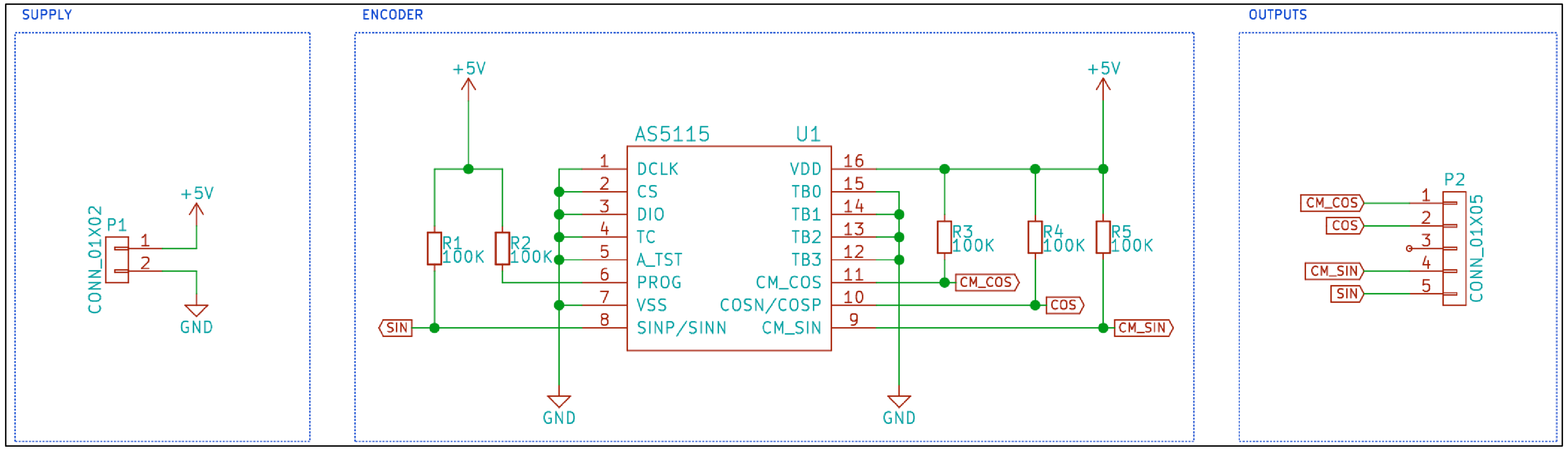
BANCO DE ENSAYOS

ENSAYOS ENCODER

INFINEON TLE5309D

Nº P. :424.16.25.062
Nº O. :424.16.25
Nom. Arch:



	Fecha	Nombre
Dibujado	05-2016	D.Suñén
Comprobado	12-2016	TRIBUNAL 2
Id. s. normas		UNE-EN-DIN

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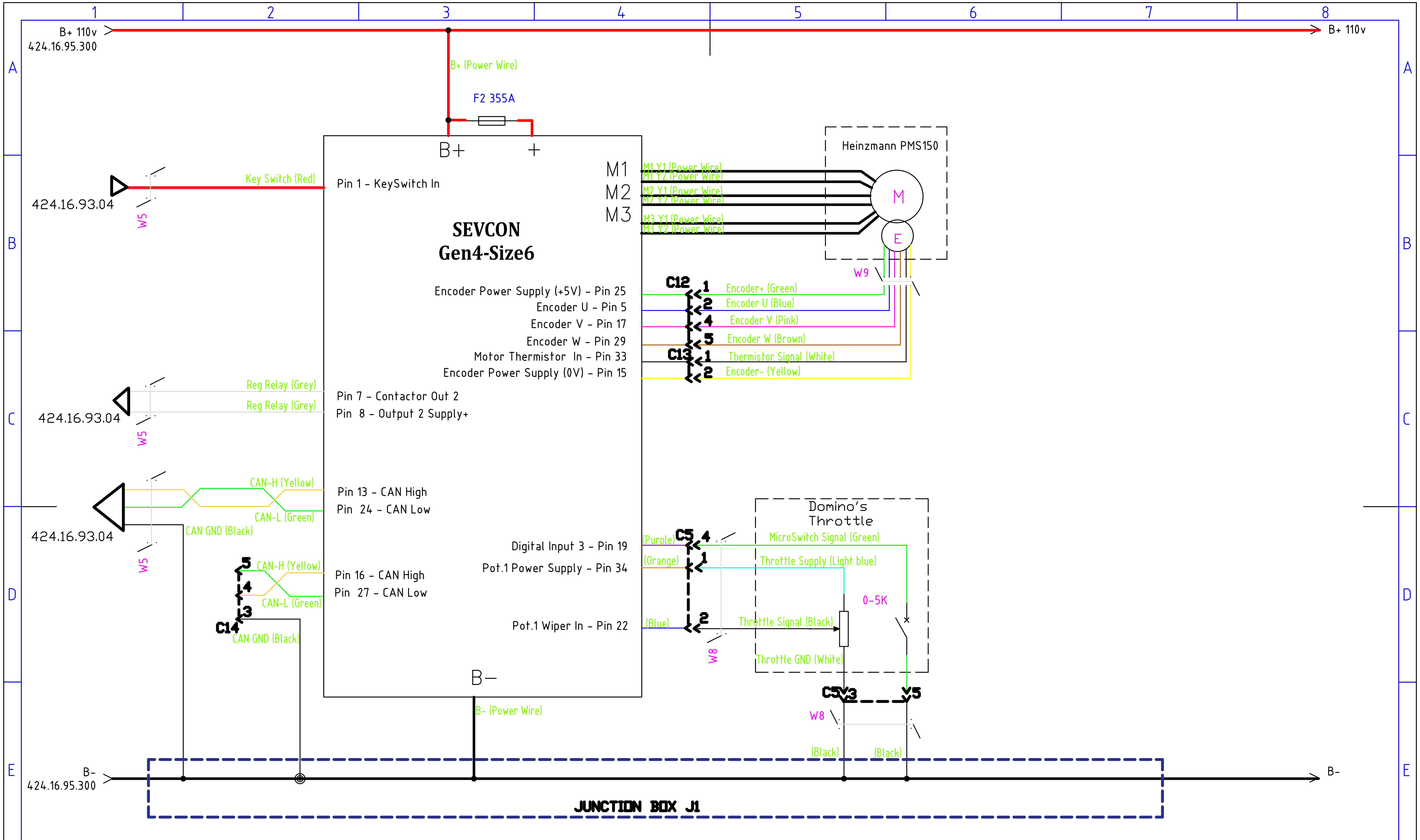
BANCO DE ENSAYOS
ENSAYOS ENCODER
AMS AS5115

Nº P. :424.16.25.063
Nº O. :424.16.25
Nom. Arch:



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Dibujado	06-2016	D.Suñén
Comprobado	12-2016	TRIBUNAL 2
Id. s. normas		UNE-EN-DIN

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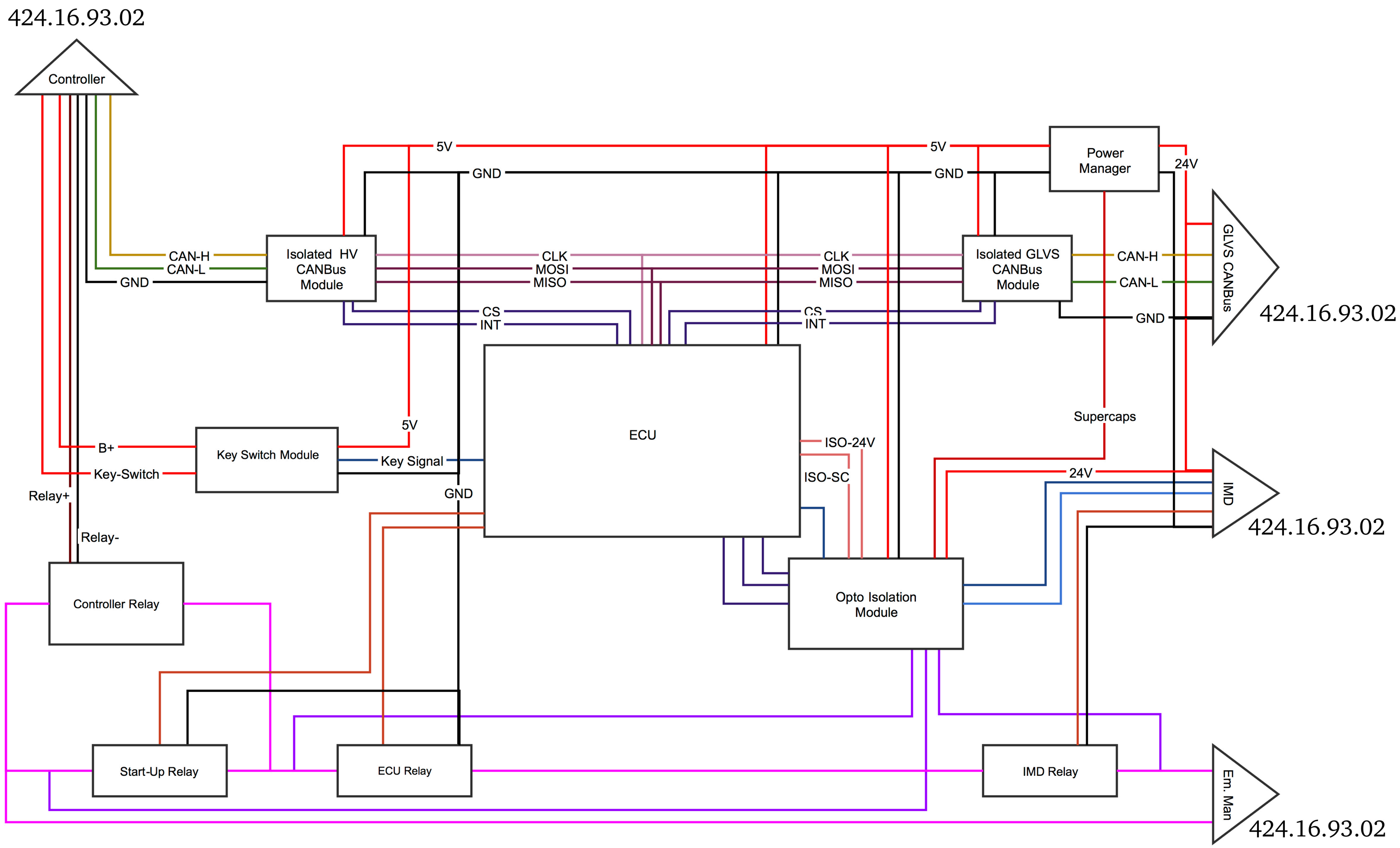
ERT Motostudent Electric
ETAPA DE CONTROL
CABLEADO REGULADOR

Nº P. :424.16.25.070
Nº O. :424.16.25
Nom. Arch:



Esquema de conexionado general de la moto en el plano nº 424.16.93.02
Esquema de bloques de la ECU en el plano nº 424.16.93.03
Esquema electrónico de la ECU en el plano 424.16.93.05

Observaciones Generales

Proyecto: ECU para EV mediante MCU y CPU
Palabras clave:
Empresa: EUPLA
Estado del proyecto: Lanzado
Versión: V1

Observaciones de plano

Plano nº: 1 **de:** 1
Formato: A3
Coment: Esquema de Conexionado entre subsuistemas de la ECU

	Fecha	Nombre
Dibujado	26/11/2016	Javier Martinez
Comprobado		
Idem.s.normas		UNE-EN

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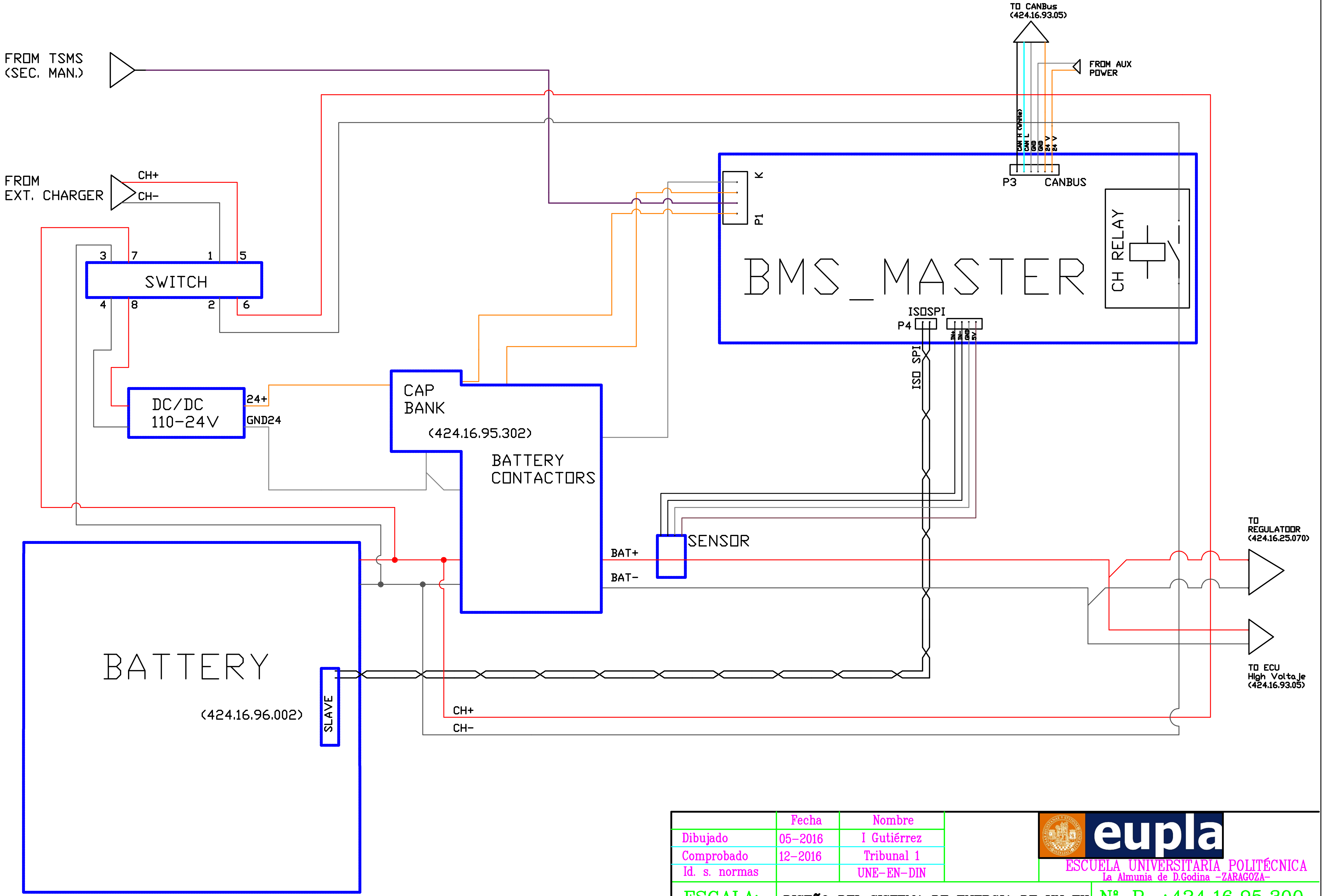
ESCALA

ECU para EV mediante MCU y CPU

Esquemas de Bloques
Esquema de Conexinoado entre subsistemas de la ECU

Nº P.: 424.16.93.04
Nº O.: 424.16.93
Nom.Ar.: Esq_Con_ECU.idw



	Fecha	Nombre
Dibujado	05-2016	I Gutiérrez
Comprobado	12-2016	Tribunal 1
Id. s. normas		UNE-EN-DIN

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1:1

DISEÑO DEL SISTEMA DE ENERGIA DE UN EV
BATERÍA
Plano general

Nº P. :424.16.95.300
Nº O. :
Nom. Arch: Batería.dwg