Technion Control Unit
TEC172
Technical manual

Table of contest

1 Overview

This document specifies Technion Control Unit (TEC172) electrical and mechanical details and gives brief functional overview of the controller. The Control Unit user manual describes module usage more thoroughly and it is separate document.

2 Abbreviations and terminology

CAN	Controller Area Network
TBD	To Be Defined
CLAMP-15, cl15	Automotive power rail which is supplied when ignition switch is closed
CLAMP-30, cl30	Automotive power rail that has permanent power supply regardless of ignition switch state.
AI	Analog input
DI	Digital input
DO	Digital output
FI	Frequency input
PWM	Pulse width modulation. In this document this refers to digital output with pulse width modulation capability.
EMC	Electromagnetic compatibility
I/O	Input / Output
SW	Software
System SW	Software preprogrammed to device by Technion Oy
Application SW	Software customized by/for customer – i.e. CODESYS IEC-61131 program
Wetting current	Minimum current flow through switch to break any oxidation on the switch contacts

3 General

TEC172 is a general purpose controller for mobile vehicles. Mobile vehicles consist of but not limited to following utility, forest, construction, mining, load and container handling machinery. TEC172 is intended to be a part of the control system in vehicle. The control unit will control valves and other actuator, read different kind of sensors and communicate with other control units forming a complete control system. The TEC172 is intended for mounting directly to vehicle body or inside the cabin.

Functionality of application is developed by CODESYS V3 freely by customer. Technion offers supportive libraries for I/O mapping and field communication interfaces.

3.1 Limited Responsibility

The Manufacturer shall under no circumstances have responsibility of any direct or indirect consequences, that might occur when using the product. The machine builder or system integrator alone is responsible for making the final selection of the system and its components and assuring that all performance, safety and warning requirements of the application are met. In case claims based on product liability are brought against the Manufacturer for which claims the manufacturer may be liable, the manufacturer's liability is limited to the extent normally covered under normal product liability insurances.

4 Product data

4.1 Mechanics

Material: Aluminum casing,
Protection Class: IP67
Weight: 1.86 kg
Dimensions: 253 mm x 203 mm x 49 mm (W x L x H)
Mounting: 5 holes at module corners for M8 bolts.
Connectors: Straight mount, located at top side of the casing

Mechanical drawing is presented in Chapter 9.

4.2 Electrical connection

Module has six connectors. Connector types and usage is presented in Table 1. Connector orientation and location is presented in mechanical drawing (see Chapter 9).

Table 1- TEC172 connectors

Ref	Module connector	Contact plating	Mating connector	Usage
A	AMPSEAL 776230-5 BLUE	Tin	AMPSEAL 776164-5 BLUE	Analog inputs, digital inputs
B	AMPSEAL 776230-4 GRAY	Tin	AMPSEAL 776164-4 GRAY	Frequency inputs, CANs, RS232, RS485
C	AMPSEAL 1-776261-1 BLACK	Gold	AMPSEAL 776273-1 BLACK	Power input, CAN
D	AMPSEAL 776230-2 WHITE	Tin	AMPSEAL 776164-2 WHITE	Outputs, digital inputs
E	AMPSEAL 776230-1 BLACK	Tin	AMPSEAL 776164-1 BLACK	Outputs
F	M-12, D-coded	Gold		Ethernet
G	M-12, D-coded	Gold		Ethernet

Maximum current for single connector pin is MAX 8 A (for connectors A, B, D & E) and MAX 10 A (for connector C).

Note: Mating of tin coated contacts to gold coated contacts is not recommended. Tin-to-gold contacts are susceptible to fretting corrosion related failures. Lubrication of contacts improves reliability and prevents fretting corrosion for both tin-to-tin and gold-to-gold contacts. See references [1] – [2] for more details.

4.3 Marking

Product is marked with type label. Type label contains following information: Technion part number, serial number and production date.

4.4 Order options

TEC172 product family has several product variants. This documents covers following products.

Table 2 – TEC172 order codes covered by this manual

Order code	Description	FI_VR	FI_H	ETH
TEC172-001	VR sensor option	4	6	-
TEC172-002	VR sensor and Ethernet option	4	6	2 (*)
TEC172-003	Ethernet option	-	10	2 (*)
TEC172-004	Standard version, no additional options	-	10	-

*) 2 pcs of Ethernet ports with internal switch

5 Electrical data

5.1 System block diagram

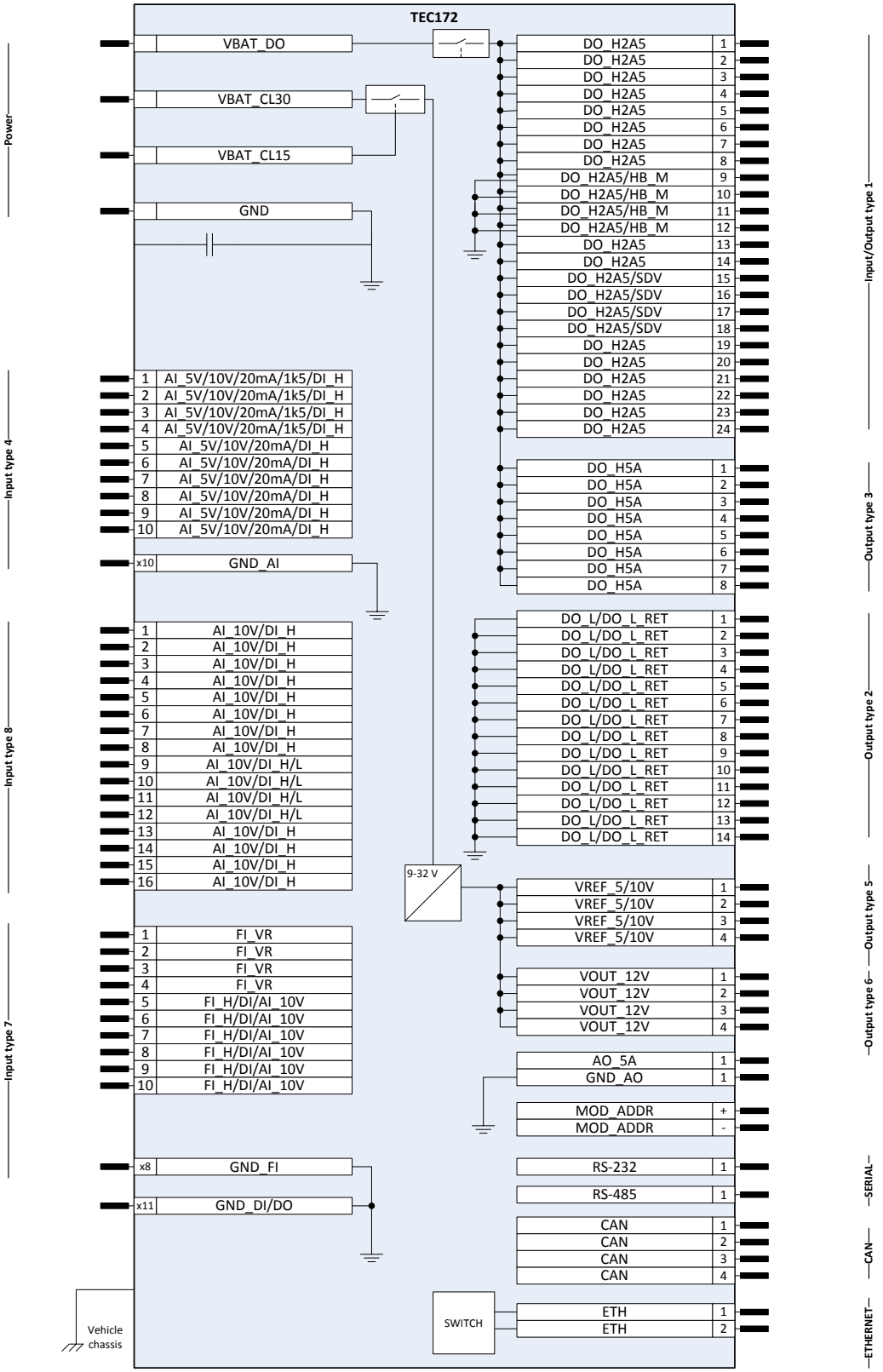


Figure 1 - TEC172 I/O block diagram

5.2 System properties

TEC172 has following system properties.

Memory	Size
CPU type	MPC5674F
CPU architecture	e200z7 Power Architecture
CPU performance	600 DMIPS

TEC172 memory resources are presented below.

Memory resources	Size
RAM (total)	1.25 MiB
RAM (application)	0.75 MiB
Program Flash (total)	4 MiB
Program Flash (application)	2 MiB
Data Flash (total)	16 MiB
Data Flash (application)	9.5 MiB
Retain data memory	3.5 KiB

CODESYS (IEC-61131) application is executed and located in "program flash (application)" memory. Data flash can be used to store for example application parameters and/or failure / diagnostics log. Retain data memory is a fast non-volatile memory. Data in retain data memory remain unaltered on power failure (unintended VBAT_cl30 power loss).

Retain data memory parameters:

Item		Min	Nom	Max	Unit	Notes
Endurance		25			years	
Data refresh time			10		ms	data is refreshed automatically
Data retention		10			years	TEC172 power-OFF time shall not exceed data retention time, otherwise data may be corrupted. During power-ON data is automatically refreshed

Module start-up time

Parameter	Time (min)	Time (nom)	Time (max)
Start-up time from power-up to application software start[1]		400 ms	

5.2.1 Internal system monitoring

TEC172 has external hardware watch-dog that monitors system software execution. External watch-dog time out period is maximum 750 ms. If watchdog is activated (maximum kick time is exceeded) all outputs are switched OFF (OFF is expected to be output safe state). System software is restarted automatically and SW failure information is forwarded to application software. Application software execution can be monitored using CODESYS task watch-dog. Application software programmer may decide if automatic application restart is accepted or not.

Controller monitors internal temperature. If internal temperature exceeds safe range all outputs are put to safe state (OFF) and program execution is halted. Internal temperature is readable in application SW. Controller will send critical warning to application before automatic output turn-off.

[1] Application software is located and executed from flash memory (simple application toggling digital output, system software v3.7.0.9).

Item		Min	Nom	Max	Unit	Notes
Internal temperature measurement range		-45		130	°C	
Accuracy				±5	°C	

5.3 Power supply

TEC172 module can operate either in 12V or 24V electrical system.

Item		Min	Nom	Max	Unit	Notes
Supply voltage	U_S	9	24	32	V	
Overvoltage 1				36	V	Controller operates normally during overvoltage (32 V – 36 V). Maximum overvoltage 1 duration that module withstands is 60 minutes. [2]
Overvoltage 2				48	V	Controller does not operate during overvoltage 2 (36 V – 48 V). If overvoltage 2 is exceeded module will be damaged.
Reverse voltage		-28			V	
Under voltage detection			8		V	Automatic shutdown after 60 seconds
Under voltage shutdown			5.4		V	
$VBAT_{cl15}$ threshold voltage			8	9		
$VBAT_{cl15}$ input pull-down resistance			3.3		kΩ	
Supply current: module/logic ($VBATcl_{30}$)			0.3		A	@ 28V, sensor supply output not included current
Standby Supply current: module ($VBATcl_{30}$ + $VBAT_{DO}$)			2.6		mA	$VBAT_{cl15}$ < 2 V, VBATcl30 ≈ 24 V, $VBAT_{DO}$ ≈ 24 V, module is turned to OFF state
Supply current: outputs ($VBAT_{DO}$)				30	A	

Controller has under and over voltage monitor. During $VBAT_{CL30}$ under voltage all outputs are switched off (i.e. safe state) and user application is shut down; during $VBAT_{DO}$ under voltage all outputs are switched off, but the user application remains active and output control can be restored if supply voltage reaches minimum value. Exceeding Overvoltage 1 maximum value causes immediate shutdown of the module. If Overvoltage 2 maximum value is exceeded module will be damaged permanently.

Module monitors $VBAT_{DO}$ total current. If maximum current is exceeded all outputs are switched OFF and power off-on cycle is required for returning to normal operation.

Power supply fault events are reported for user application.

5.3.1 Power supply input

Supply voltage must be within the module operating range. Module has two separate power inputs and one control input. Separate power inputs are for module logic ($VBAT_{CL30}$) and outputs ($VBAT_{DO}$) power. $VBAT_{CL30}$ supplies power to internal logic circuitry and input functions (including power supply for the sensors). $VBAT_{DO}$ power supply provides power for high-side outputs (DO_H), DC-motor (HB_M) and Sauer-Danfoss valve control (HB_{SDV}) outputs. Module power is controlled using one dedicated control signal $VBAT_{cl15}$. Module is started after $VBAT_{cl15}$ is activated. Power-off is controlled either from software or $VBAT_{cl15}$ signal. $VBAT_{cl15}$ signal can be used e.g. to implement delayed power-off functionality.

TEC172 power inputs $VBAT_{CL30}$ and $VBAT_{DO}$ voltage can be measured in application software.

[2] Some I/O functions do not tolerate overvoltage during short circuit to battery conditions. See detailed I/O specifications.

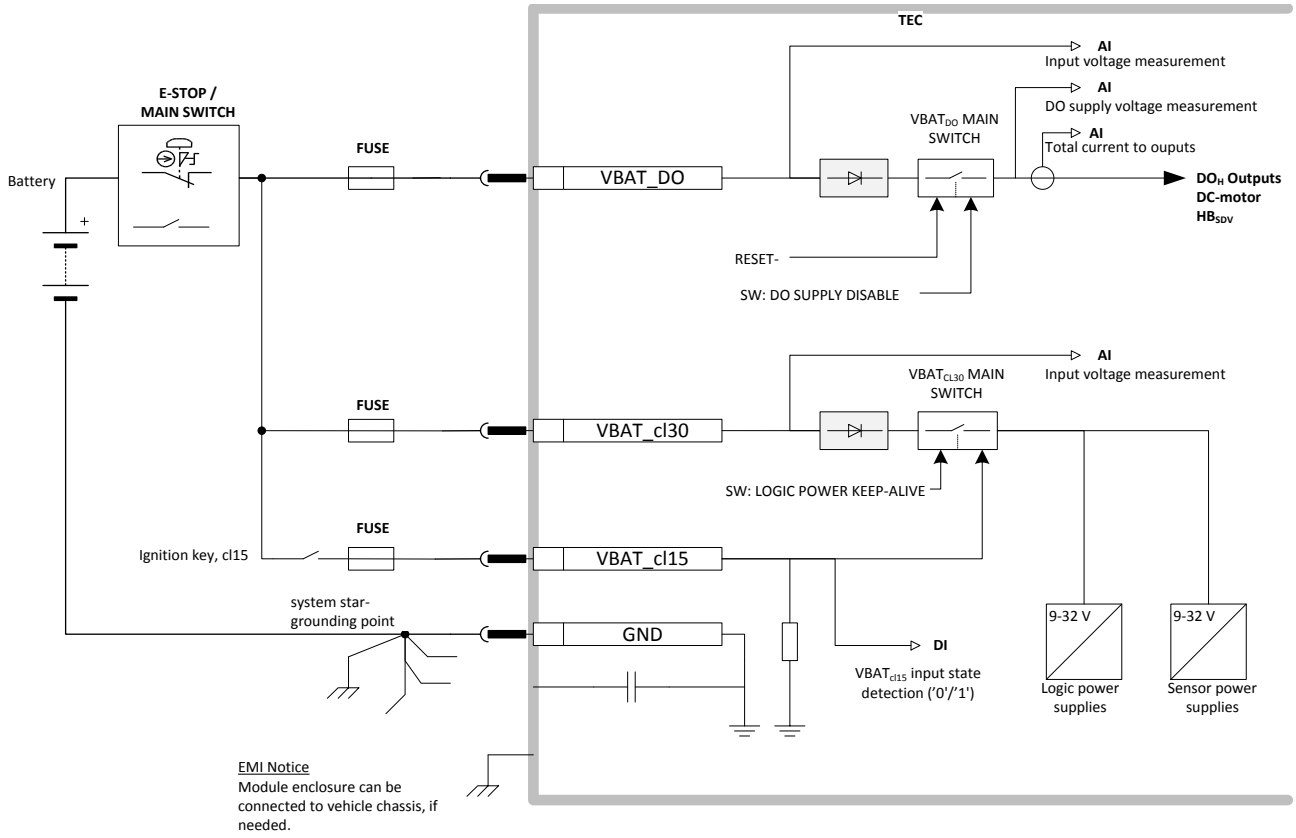


Figure 2 – VBAT power input topology

Table 3 – VBAT input diagnostics

Item		Min	Nom	Max	Unit	Notes
$VBAT_{CL30}$ & $VBAT_{DO}$ voltage measurement range		0		48	V	
Measurement accuracy % FS				±1	%FS	
Accuracy, typical			0.7+0.2		%	± (% of reading + % FS)

Table 4 - Functional specification

Item	Value	Notes
$VBAT_{cl30}$ main switch control	Power supply for logic and sensor supplies are supplied through internal "main switch". Logic operation is started when $VBAT_{cl15}$ is powered. Module is powered-down after both $VBAT_{cl15}$ is switched off and software control signal (logic power keep-alive) is negated.	
$VBAT_{DO}$ main switch control	Digital output (DO_H) outputs are supplied through single $VBAT_{DO}$ main switch. Main switch is enabled when: 1) Controller logic power supplies are stable (reset = '1') AND 2) Application SW asserts main switch control signal (do_supply_disable = '0')	
$VBAT_{DO}$ main switch reverse current protection	Main switch is reverse protected (i.e. short circuit to battery on DO_H cannot supply power to $VBAT_{DO}$ pin (=vehicle battery / cl30)	

Table 5 - Power input signals

Signal	Type	Description
$VBAT_{cl30}$	PWR	Power supply input for module logic functions and sensors
$VBAT_{DO}$	PWR	Power supply input for outputs (DO_H, HB_{SDV} and HB_M)
$VBAT_{cl15}$	IN	Control input for module power supply
GND	-	Ground for logic and output power supply

6 General I/O functionality

All I/O functions (every connector pin) have short circuit protection against system supply voltage (max 32V) and GND short circuit.

Sensor ground pins (GND_{AI} and GND_{FI}) are able to break maximum 10 A external fuse during short circuit to battery.

6.1 I/O List

TEC172 controller has versatile set of I/O types. Different I/O types/functions are presented in Table 6. Detailed description of the I/O types is provided in Chapters 6.2 and 6.3. TEC172 I/O pins can be configured to several I/O functions. I/O configuration is presented in Table 7. Configuration is mainly selected in SW. For some configurations there is separate HW version (i.e. order option e.g. FI_{VR}) (see ch. 4.4).

Table 6 - TEC172 I/O types

I/O Type	Abbreviation
Digital input PNP (high active)	DI_H
Digital input PNP/NPN (high or low active)	$DI_{H/L}$
Digital output high-side, PWM or ON/OFF 2,5 A	DO_{H2A5}
Digital output high-side, PWM or ON/OFF 5 A	DO_{H5A}
Digital output/input return signal (GND)	$GND_{DO/DI}$
Current measurement input for DO_H (current control operation mode) 1A / 2A range	$DO_{L\_RET1A/2A}$
Digital output low-side ON/OFF	DO_L
Half-Bridge output for DC-motor [2]	HB_M
Half-Bridge output for Sauer-Danfoss valve control (PVE actuator)	HB_{SDV}
Analog input - voltage measurement 0-5V Analog input - voltage measurement 0-10V	AI_{5V} AI_{10V}
Analog input - current measurement 4-20mA	AI_{20mA}
Analog input – resistance measurement (internal 1k5 pull-up)	$AI_{1.5k\Omega}$
Analog input – sensor ground	GND_{AI}
Voltage reference output 5 V / 10 V	$VREF_{5V/10V}$
Sensor power supply output 12 V	$VOUT_{12V}$
Sensor power supply ground	GND_{VOUT}
Frequency / pulse input high active	FI_H
Frequency / pulse input – variable reluctance sensor	FI_{VR+} FI_{VR-}
Analogue output 5V	AO_{5V}
Controller address input	MOD_{ADDR}
RS-232	RS-232
RS-485	RS-485
CAN	CAN
ETHERNET	ETH

Note 1: Each input/output can have several subtypes. Subtype number is shown after I/O-type e.g. $DI_{H.1}$ (i.e. Digital input, high-active, type 1)
Note 2: Half-bridge motor output is used for DC-motor drive. Two half-bridge outputs are always needed to drive one DC-motor.

Table 7 - TEC172-001 and TEC172-002 I/O configuration

TEC172-001 / TEC172-002			
I/O Group	**Pcs**	**I/O Types**	**Notes**
HIGH SIDE DIGITAL OUTPUTS (Configurable output #1) (24 pcs)	10	$DO_{H2A5.1}$	Digital output 2,5A, high side, PWM
	4	$DO_{H2A5.1}$ $HB_{M.1}$	Digital output 2,5A, high side, PWM Half bridge for DC-motor drive
	6	$DO_{H2A5.2}$(1	Digital output 2,5A, high side, PWM
	4	$DO_{H2A5.2}$(1 $HB_{SDV.1}$	Digital output 2,5A, high side, PWM Sauer-Danfoss valve control (PVE)
LOW SIDE DIGITAL OUTPUTS / PWM CURRENT CONTROL INPUTS (Configurable output #2)	14	$DO_{L.1}$ $DO_{L\_RET1A/2A.1}$	Digital output 1 A, low side Current measurement input (CC PWM with DO_{H2A5})
HIGH SIDE DIGITAL OUTPUTS (Configurable output #3)	8	$DO_{H5A.1}$	Digital output 5A, high side, PWM
HIGH PRECISION INPUTS (Configurable input #4) (10 pcs)	4	$AI_{5V.1}$ $AI_{10V.1}$ $AI_{20mA.1}$ $AI_{1k5\Omega.1}$ $DI_{H.1}$	Analog input 0-5 V Analog input 0-10 V Analog input 0-20 mA Analog input resistance Digital input (PNP / active high)
	6	$AI_{5V.1}$ $AI_{10V.1}$ $AI_{20mA.1}$ $DI_{H.1}$	Analog input 0-5 V Analog input 0-10 V Analog input 0-20 mA Digital input (PNP / active high
GND (for AI sensors)	10	GND_{AI}	
REFERENCE OUTPUTS (Configurable output #5)	4	$VREF_{5V.1}$ $VREF_{10V.1}$	Voltage reference output 5 V Voltage reference output 10 V
SENSOR SUPPLY VOLTAGE (Configurable output #6)	4	$VOUT_{12V.1}$	Sensor supply voltage 12 V
GND (for sensor supply voltage)	2	GND_{VOUT}	
PULSE INPUTS (Configurable input #7) (10 pcs)	6	$FI_{H.1}$ $DI_{H.3}$ $AI_{10V.3}$	Pulse input (active high) Digital input (PNP / active high) Analog input 0-10 V
	4	FI_{VR+} FI_{VR-}	Variable reluctance sensor pulse input
GND (for FI sensors)	4	GND_{FI}	
GENERAL PURPOSE INPUT (Configurable input #8) (16 pcs)	12	$DI_{H.2}$ $AI_{10V.2}$	Digital input (PNP / active high) Analog input 0-10 V
	4	$DI_{H/L.2}$ $AI_{10V.2}$	Digital input (PNP/NPN) Analog input 0-10 V
GND (for in-puts/outputs)	11	$GND_{DO/DI}$	
Analog output	1	$AO_{5V.1}$	Analog output 0 – 5 V
GND (for analog output)	1	GND_{AO}	
Controller Address	1	MOD_ADDR	Module address input
Module power supply	1 1 1	$VBAT_{cl15}$ $VBAT_{cl30}$ $VBAT_{OUT}$ GND	Power supply control signal Power supply for module logic and inputs Power supply for outputs (DO & PWM) VBAT ground
CAN	4	CAN	
RS-232	1	RS232	
RS-485	1	RS485	
ETHERNET(2	2	ETH	Internal 3-port switch (i.e. 2 external ports)

1) Limited open load detection capability
2) TEC172-002 variant only

Table 8 - TEC172-003 and TEC172-004 I/O configuration

TEC172-003 / TEC172-004			
I/O Group	**Pcs**	**I/O Types**	**Notes**
HIGH SIDE DIGITAL OUTPUTS (Configurable output #1) (24 pcs)	10	$DO_{H2A5.1}$	Digital output 2,5A, high side, PWM
	4	$DO_{H2A5.1}$ $HB_{M.1}$	Digital output 2,5A, high side, PWM Half bridge for DC-motor drive
	6	$DO_{H2A5.2}$(1	Digital output 2,5A, high side, PWM
	4	$DO_{H2A5.2}$(1 $HB_{SDV.1}$	Digital output 2,5A, high side, PWM Sauer-Danfoss valve control (PVE)
LOW SIDE DIGITAL OUTPUTS / PWM CURRENT CONTROL INPUTS (Configurable output #2)	14	$DO_{L.1}$ $DO_{L\_RET1A/2A.1}$	Digital output 1 A, low side Current measurement input (CC PWM with DO_{H2A5})
HIGH SIDE DIGITAL OUTPUTS (Configurable output #3)	8	$DO_{H5A.1}$	Digital output 5A, high side, PWM
HIGH PRECISION INPUTS (Configurable input #4) (10 pcs)	4	$AI_{5V.1}$ $AI_{10V.1}$ $AI_{20mA.1}$ $AI_{1k5\Omega.1}$ $DI_{H.1}$	Analog input 0-5 V Analog input 0-10 V Analog input 0-20 mA Analog input resistance Digital input (PNP / active high)
	6	$AI_{5V.1}$ $AI_{10V.1}$ $AI_{20mA.1}$ $DI_{H.1}$	Analog input 0-5 V Analog input 0-10 V Analog input 0-20 mA Digital input (PNP / active high
GND (for AI sensors)	10	GND_{AI}	
REFERENCE OUTPUTS (Configurable output #5)	4	$VREF_{5V.1}$ $VREF_{10V.1}$	Voltage reference output 5 V Voltage reference output 10 V
SENSOR SUPPLY VOLTAGE (Configurable output #6)	4	$VOUT_{12V.1}$	Sensor supply voltage 12 V
GND (for sensor supply voltage)	2	GND_{VOUT}	
PULSE INPUTS (Configurable input #7) (10 pcs)	10	$FI_{H.1}$ $DI_{H.3}$ $AI_{10V.3}$	Pulse input (active high) Digital input (PNP / active high) Analog input 0-10 V
GND (for FI sensors)	8	GND_{FI}	
GENERAL PURPOSE INPUT (Configurable input #8) (16 pcs)	12	$DI_{H.2}$ $AI_{10V.2}$	Digital input (PNP / active high) Analog input 0-10 V
	4	$DI_{H/L.2}$ $AI_{10V.2}$	Digital input (PNP/NPN) Analog input 0-10 V
GND (for in-puts/outputs)	11	$GND_{DO/DI}$	
Analog output	1	$AO_{5V.1}$	Analog output 0 – 5 V
GND (for analog output)	1	GND_{AO}	
Controller Address	1	MOD_ADDR	Module address input
Module power supply	1 1 1	$VBAT_{cl15}$ $VBAT_{cl30}$ $VBAT_{OUT}$ GND	Power supply control signal Power supply for module logic and inputs Power supply for outputs (DO & PWM) VBAT ground
CAN	4	CAN	
RS-232	1	RS232	
RS-485	1	RS485	
ETHERNET(2	2	ETH	Internal 3-port switch (i.e. 2 external ports)

1) Limited open load detection capability
2) TEC172-003 variant only

6.2 I/O definition

Every configurable I/O type has its own specification. Each specification part is divided to two parts:

1) electrical specification and
2) functional specification

I/O functions presented in following chapters have several protection and diagnostics functions to detect failures either in module, wiring or sensor/actuator. Failure mode diagnostic capability depends on I/O type. Failure types are presented in table below.

Table 9 - I/O protection features

Failure	Abbreviation
Open load	OL
Short circuit to ground	SC_G
Short circuit to battery	SC_B
Over Current	OC

Each IO-type is named according to Figure 3. TEC172 has several IO types that have same functionality and subtype but different electrical specification. Extra care has to be taken on electrical specification when selecting IO-type / pin for application.

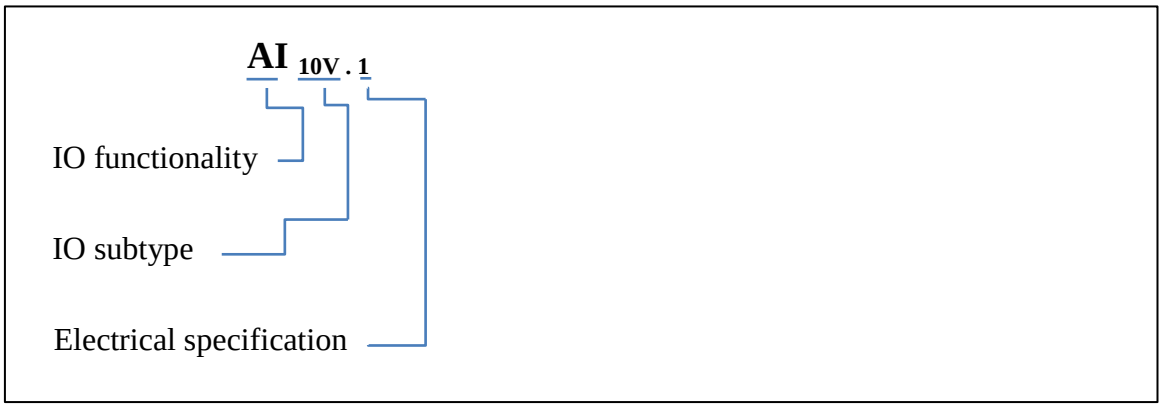


Figure 3 - IO-type naming

6.2.1 Input, PNP, [$DI_{H.1}$ / $DI_{H.2}$ / $DI_{H.3}$]

Active high i.e PNP digital input is used interface sensors / switches connected to battery voltage or TEC172 power supply outputs. For example following sensors can be connected to this input:

- Mechanical on/off switches
- Semiconductor switches
- Inductive proximity sensors

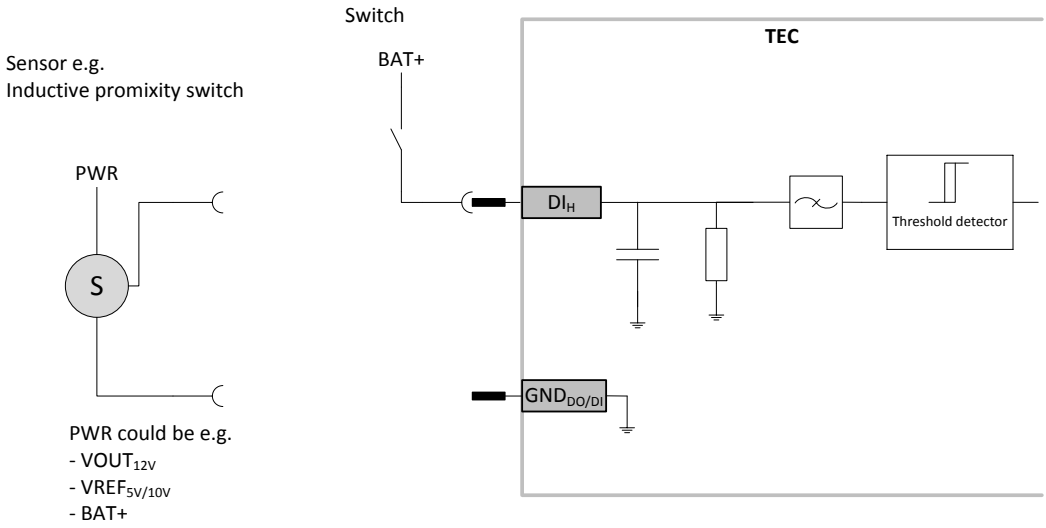


Figure 4- DI_H usage

Table 10 - Electrical specification $DI_{H.2}$

Item		Min	Nom	Max	Unit	Description	ID
Type	**$DI_{H.2}$** Digital input PNP, Active high, sw controlled threshold levels						
Voltage range	U_{in}	0		32	V		
Over voltage				36	V		
Threshold low	U_{low}	1	3	5	V	Software controlled	
Threshold high	U_{high}	2	7	9	V	Software controlled	
Threshold accuracy	U_{acc}		0.3		V		
Threshold adjustment resolution			0.1		V		
Hysteresis	U_{hyst}	*depends on threshold level*				MIN U_{hyst} = U_{high} - U_{low} - 2 * U_{acc}	
Cutoff frequency	f_{-3dB}		50		Hz	HW filter	
Wetting current	I_w		9.5		mA	at 28 V	
Pull-down resistance	R_{PD}		3		kΩ	U_{in} ≤ 10 V	
Input capacitance			4.7		nF		
Protection		SC_G, SC_B					

Table 11 - Electrical specification $DI_{H.1}$

Item		Min	Nom	Max	Unit	Description	ID
Type	**$DI_{H.1}$** Digital input PNP, Active high, sw controlled threshold levels, high input impedance						
Voltage range	U_{in}	0		32	V		
Over voltage				36	V		
Threshold low	U_{low}	1	3	5	V	Software controlled	
Threshold high	U_{high}	2	7	9	V	Software controlled	
Threshold accuracy	U_{acc}		0.3		V		
Threshold adjustment resolution			0.1		V		
Hysteresis	U_{hyst}	*depends on threshold level*				MIN $U_{hyst} = U_{high} - U_{low} - 2 * U_{acc}$	
Cutoff frequency	f_{-3dB}		1.6		kHz	HW filter	
Wetting current	I_w		1		mA	at 28 V	
Pull-down resistance	R_{PD}		50		kΩ	$U_{in} \leq 10$ V	
Input capacitance			4.7		nF		
Protection		SC_G, SC_B					

Table 12 - Electrical specification $DI_{H.3}$

Item		Min	Nom	Max	Unit	Description	ID
Type	**$DI_{H.3}$** Digital input PNP, Active high, sw controlled threshold levels, high input impedance						
Voltage range	U_{in}	0		32	V		
Over voltage				36	V		
Threshold low	U_{low}	1	3	5	V	Software controlled	
Threshold high	U_{high}	2	7	9	V	Software controlled	
Threshold accuracy	U_{acc}		0.3		V		
Threshold adjustment resolution			0.1		V		
Hysteresis	U_{hyst}	*depends on threshold level*				MIN $U_{hyst} = U_{high} - U_{low} - 2 * U_{acc}$	
Cutoff frequency	f_{-3dB}		50		Hz	HW filter	
Wetting current (@28V)	I_w		2.5		mA	at 28 V	
Pull-down resistance	R_{PD}		11		kΩ	$U_{in} \leq 10$ V	
Input capacitance			4.7		nF		
Protection		SC_G, SC_B					

Table 13 - Functional specification

Item	Value	Notes
Input refresh rate	100Hz	
Digital filter cutoff frequency f_{-3dB}	40Hz	Digital filter implemented in system software
Digital filter stop-band attenuation	Typical 20dB at f > 100Hz	

Table 14 - DI signals

Signal	Dir	Description
DI_H	In	Active high digital input
$GND_{DO/DI}$		Reference ground for DO/DI

6.2.2 Input, PNP/NPN, [$DI_{H/L.2}$]

SW configurable active high or low (i.e PNP/NPN) digital input is used for interface sensors / switches connected to battery voltage.

- Mechanical on/off switches
- Semiconductor switches
- Inductive proximity sensors

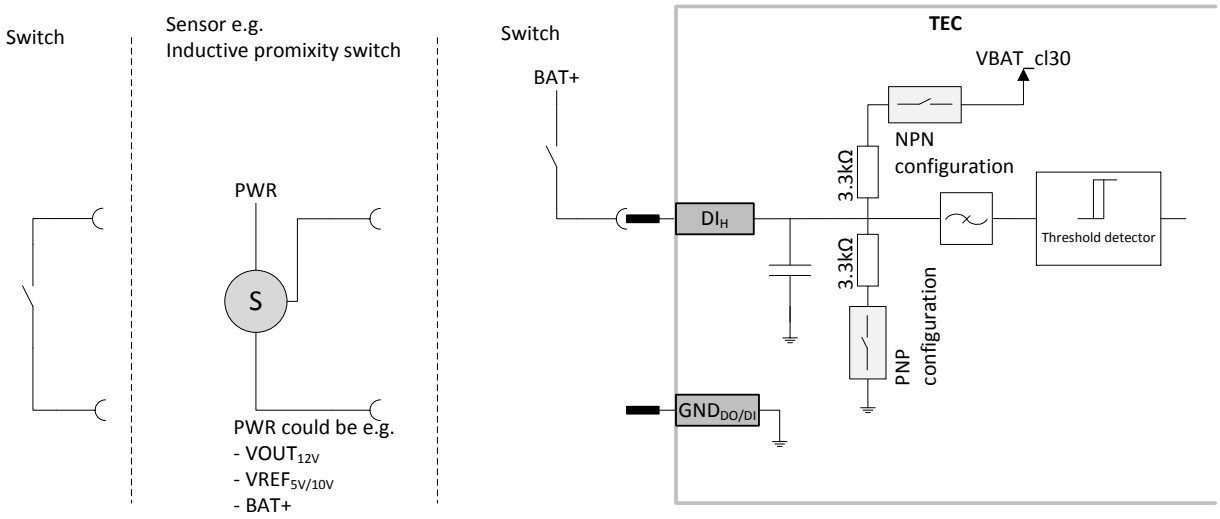


Figure 5- DI_H usage

Table 15 - Electrical specification

Item		Min	Nom	Max	Unit	Description	ID
Type	**$DI_{H/L.2}$** Digital input PNP/NPN, Active high, sw controlled threshold levels						
Voltage range	U_{in}	0		32	V		
Over voltage				36	V		
Threshold low	U_{low}	1	3	5	V	Software controlled	
Threshold high	U_{high}	2	7	9	V	Software controlled	
Threshold accuracy	U_{acc}		0.3		V		
Threshold adjustment resolution			0.1		V		
Hysteresis	U_{hyst}				V	MIN U_{high} - U_{low} - 2 * U_{acc}	
Cutoff frequency (HW)	f_{-3dB}		50		Hz		
Wetting current (@28V)	I_w		9.5		mA	at 28 V	
Pull-down resistance	R_{PD}		3		kΩ	SW controlled (PNP)	
Pull-up resistance	R_{PU}		3.3		kΩ	SW controlled (NPN)	
Input capacitance			4.7		nF		
Protection		SC_G, SC_B					

Table 16 - Functional specification

Item	Value	Notes
Input refresh rate	100Hz	
Digital filter cutoff frequency f_{-3dB}	40Hz	Digital filter implemented in system software
Digital filter stop-band attenuation	Typical 20dB at f > 100Hz	

Table 17 - DI signals

Signal	Dir	Description
$DI_{H/L}$	In	Active high/low digital input
$GND_{DO/DI}$		Reference ground for DO/DI

6.2.3 Input, Frequency / Pulse input [$FI_{H.1}$]

Configurable frequency input can be used to interface e.g following sensors:

- Incremental encoder (quadrature signals, push-pull or PNP output)
- Incremental encoder (direction and increment signals, push-pull or PNP output)
- Incremental encoder with index/reference signal (push-pull or PNP output)
- Inductive/HALL sensors (frequency / pulse counter, push-pull or PNP output)

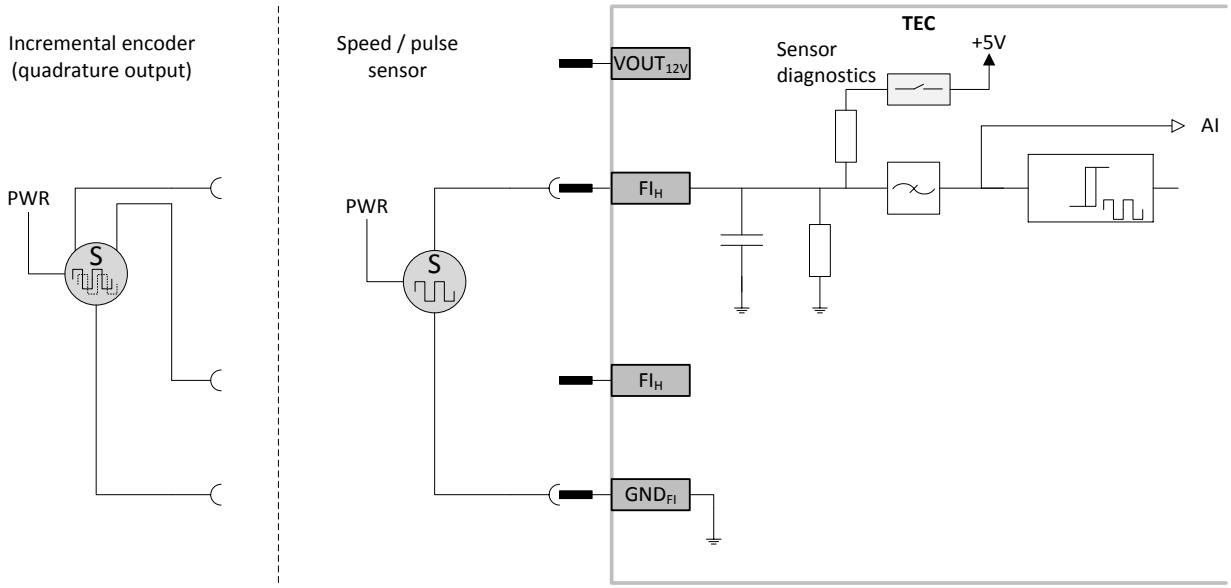


Figure 6- FI_H usage

Table 18 - FI_H Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type	**$FI_{H.1}$ Frequency/pulse input**						
Input frequency range		1		25000	Hz	Rising edge frequency at one channel	
Input voltage range		0		32	V		
Over voltage				36	V		
Threshold low				2	V		
Threshold high		4			V		
Hysteresis		0.2	0.5		V		
Cutoff frequency (HW)	f_{-3dB}		25		kHz	HW filter	
Input resistance			11		kΩ		
Input capacitance			4.7		nF		
Protection	SC_B, SC_G						

Table 19 - Functional specification

Item	Value	Notes
Incremental encoder mode	High resolution mode is supported (i.e. all edges of the quadrature signal are evaluated). Counter event frequency can be four times the single channel input signal frequency, i.e. counter value can change 40 000 times per second when individual encoder inputs receive 10 kHz signal. **Pins used as encoder inputs must be a sequential pair; e.g. $FI6_H$ and $FI7_H$**	
Pulse counter mode	Rising, falling or both edges can be counted (application specific configurability). Counter event frequency can be two times the input frequency (if both edges are counted).	
Frequency measurement mode	Resolution of frequency values: 1 Hz. Frequency evaluation interval: Maximum 1 second (software configurable). Polling interface: The last evaluated frequency value is given.	
Period or pulse length measurement mode	Measurement is configurable for rising or falling edge (pulse period measurement) or for either pulse high time or low time (pulse length measurement). Resolution: 1 microsecond. Polling interface: The last evaluated frequency value is given.	
Input capture mode	Input events (rising, falling or either edge) are time stamped. Resolution of timestamps: 1 microsecond. Polling interface: The last captured timestamp value is given.	
Digital input mode	State of frequency input pin is readable while in pulse counter / measurement modes.	

Table 20 – Frequency input interface signals

Signal	Dir	Description
FI_H	In	Configurable frequency input
GND_{FI}	In	FI reference grounds

6.2.4 Input, Frequency / Pulse input for variable reluctance sensors [FI_{VR}]

This input is dedicated for variable reluctance type sensor (VR). TEC172 VR sensor interface has electrically differential input to minimize interference from electrical system disturbances. Also the input filter is effective below intended maximum input frequency to maximize immunity to noise. This is possible because input signal amplitude is proportional to input frequency. Input can be used as pulse/frequency counter or incremental (quadrature) encoder input.

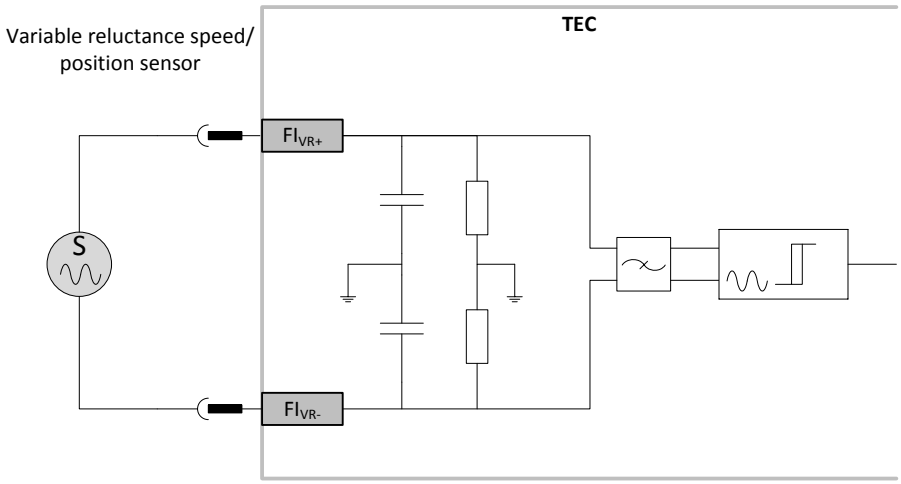


Figure 7- FI_{VR} usage

Table 21 - FI_{VR} Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type	**FI_{VR+} Frequency / Pulse input for Variable Reluctance-Sensor**						
Input frequency range		1		25000	Hz		
Input voltage range		-90		90	V		
Over voltage				90	V		
Minimum threshold voltage			50		mV		
Cutoff frequency (HW)	f_{-3dB} $f_{-6.5dB}$ $f_{-10.3dB}$		8 15 25		kHz kHz kHz	HW filter	
Input resistance			15		kΩ		
Input capacitance			4.7		nF		
Protection	SC_B, SC_G						

Table 22 - Functional specification

Item	Value	Notes
Pulse input filter length	1 µs (pulses shorter than filter length are ignored)	

Item	Value	Notes
Incremental encoder mode	High resolution is supported (i.e. all edges of the quadrature signal are evaluated). Counter event frequency can be four times the single channel input signal frequency, i.e. counter value can change 40 000 times per second when individual encoder inputs receive 10 kHz signal. **Pins used as encoder inputs must be a sequential pair; e.g. $FI1_{VR}$ and $FI2_{VR}$**	
Pulse counter mode	Rising, falling or both edges can be counted (application specific configurability). Counter event frequency can be two times the input frequency (if both edges are counted).	
Frequency measurement mode	Resolution of frequency values: 1Hz. Frequency evaluation interval: Maximum 1 second (software configurable). Impact of high frequency on CPU load is negligible. Polling interface: The last evaluated frequency value is given.	
Period or pulse length measurement mode	Measurement is configurable for rising or falling edge (pulse period measurement) or for either pulse high time or low time (pulse length measurement). Resolution: 1 microsecond. Impact of high frequency on CPU load is negligible. Polling interface: The last evaluated frequency value is given.	
Input capture mode	Input events (rising, falling or either edge) are time stamped. Resolution of timestamps: 1 microsecond. Polling interface: The last captured timestamp value is given.	

Table 23 – Frequency input interface signals

Signal	Dir	Description
FI_{VR+}	In	Differential sensor input+
FI_{VR-}	In	Differential sensor input-

Twisted-pair cable shall be used.

6.2.5 Input, Controller address [MOD_{ADDR}]

Controller address input is used to configure module ID-number / address in control system. ID-number can be used in application SW to identify each controller's intended functionality. Addressing supports 32 individual addresses. Resistor between two address pins defines the module address. Address resistor should be connected to mating AMPSEAL connector using short wires (< 0,1 m).

Module address pin configuration other than presented in Table 25 returns error code. If module address pins are shorted together module start-up time is increased by 1 second.

Table 24 - MOD_{ADDR} Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Address configu-ration resistor		0.22		82	kΩ	Value is selected from E12-series.	
Address resistor tolerance				1	%		
Address resistor temperature drift				100	ppm/K		
Address resistor power rating		125			mW		

Table 25 – Module address / resistor coding

Module address	Resistor value
1	220 Ω
2	270 Ω
3	330 Ω
4	390 Ω
5	470 Ω
6	560 Ω
7	680 Ω
8	820 Ω
9	1 kΩ
10	1,2 kΩ
11	1,5 kΩ
12	1,8 kΩ
13	2,2 kΩ
14	2,7 kΩ
15	3,3 kΩ
16	3,9 kΩ
17	4,7 kΩ
18	5,6 kΩ
19	6,8 kΩ
20	8,2 kΩ
21	10 kΩ
22	12 kΩ
23	15 kΩ
24	18 kΩ
25	22 kΩ
26	27 kΩ
27	33 kΩ
28	39 kΩ
29	47 kΩ
30	56 kΩ
31	68 kΩ
32	82 kΩ
No address	open (MOD_{ADDR} pins not connected) Module base address is used
Not valid	shorted (MOD_{ADDR} pins connected together)

Table 26 – Module address interface signals

Signal	Dir	Description
MOD_ADDR+	In	Module address resistor
MOD_ADDR-	In	Module address resistor reference

6.2.6 Input, High precision analog input, 0-5V / 0-10V / 0-20mA / Resistance, [$AI_{5V.1}$ / $AI_{10V.1}$ / $AI_{20mA.1}$ / $AI_{1k5\Omega.1}$]

Analog input type is software configurable. For example following sensors can be connected to input.

- Potentiometer (3-wire)
- Temperature sensors (PTC or NTC)
- Pressure sensors
- Variable resistance
- Voltage output sensors
- 4 – 20 mA current output sensors

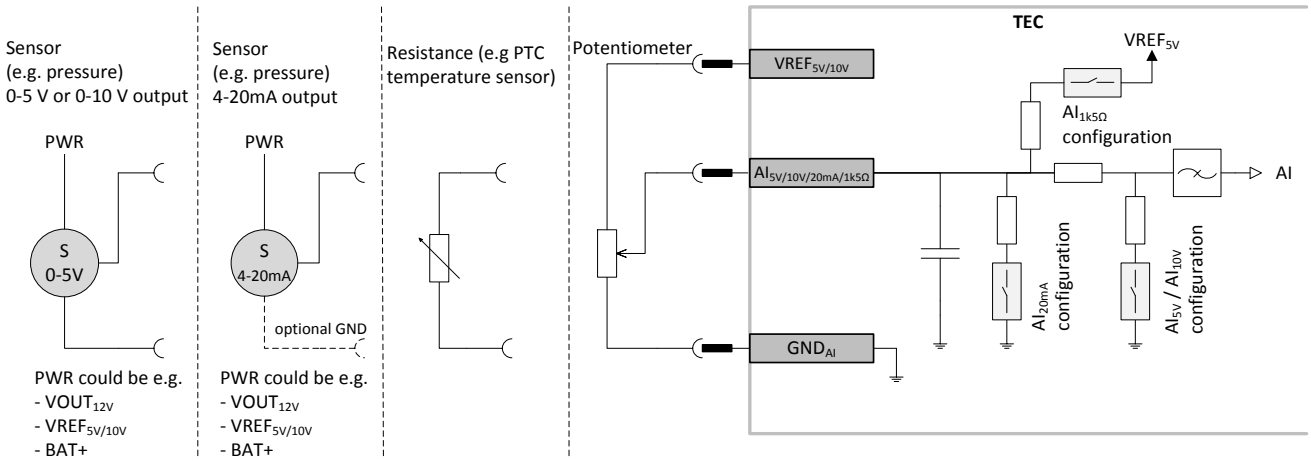


Figure 8 - AI usage

Table 27 - Analog input electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Resolution			12		bits		
Protection		SC_G, SC_B					
Type	**$AI_{5V.1}$ 0-5V Voltage input**						
Input voltage range		0		5	V	Voltage input	
Over voltage				32	V		
Accuracy % FS				±1	%FS		
Accuracy, typical			0.1+0.3		%	± (% of reading + % FS)	
Input resistance			47		kΩ		
Input capacitance			4.7		nF		
Input cut-off frequency	f_{-3dB}		0.9		kHz	HW filter	
Type	**$AI_{10V.1}$ 0-10V Voltage input**						
Voltage range		0		10	V	Voltage input	
Over voltage				32	V		
Accuracy % FS				±1	%FS		
Accuracy, typical			0.4+0.3		%	± (% of reading + % FS)	
Input resistance			50		kΩ		
Input capacitance			4.7		nF		
Input cut-off frequency	f_{-3dB}		1.6		kHz	HW filter	
Type	**$AI_{20mA.1}$ 0…20mA current input**						
Current range Nominal Actual		 4 0		 20 22.5	mA	 for diagnostics purposes	

Parameter		Min	Nom	Max	Unit	Description	ID
Over current protection				>22.5	mA	Input is switched to voltage mode	
Accuracy % FS				±1	%FS		
Accuracy, typical			0.5+0.3		%	± (% of reading + % FS)	
Input resistance			220		Ω		
Input capacitance			4.7		nF		
Input cut-off frequency	f_{-3dB}		1		kHz	HW filter	
Type	**$AI_{1k5\Omega.1}$ Resistance input**						
Accuracy				±1	%FS		
Accuracy, typical			0.6+0.3		%	± (% of reading + % FS)	
Input resistance (pull-up)			1.5		kΩ		
Pull-up reference voltage		4.97	5	5.03	V		
Input capacitance			4.7		nF		
Input cut-off frequency	f_{-3dB}		1		kHz	HW filter	

Table 28 - Analog input functional specification

Item	Value	Notes
Sampling interval	6.4 kHz	Unfiltered samples can be streamed to application at full sample rate (RAW sample rate)
Input refresh rate	800Hz	Digitally filtered (FAST sample rate).
Diagnostic evaluation interval	100Hz	
Digital filter cutoff frequency f_{-3dB}	320Hz	Digital filter implemented in system software
Digital filter stop-band attenuation	Typical 20dB at f > 800Hz	
Input configuration	Selected during device initialization	
Overcurrent handling in AI_{20mA} mode	Fault reporting: • Current exceeds measurement range • Overcurrent protection is active Automatic disabling of current measurement on overcurrent after 30ms. Automatic re-enabling of current measurement after 1 second cool-down period (SUSPENDED state). After 10 retry sequences, input is permanently disabled (SHUTDOWN state) until power off-on cycle is performed.	Application can reconfigure the channel to voltage measurement mode to prevent the fault condition from repeating.

Table 29 - AI signals

Signal	Dir	Description
AI	In	Configurable analog input
GND_{AI}		AI reference ground

6.2.7 Input, Precision analog input, 0-10V, [$AI_{10V.2}$ / $AI_{10V.3}$]

For example following sensors can be connected to input.

- Potentiometer (3-wire)
- Temperature transducers
- Pressure sensors
- Voltage output sensors

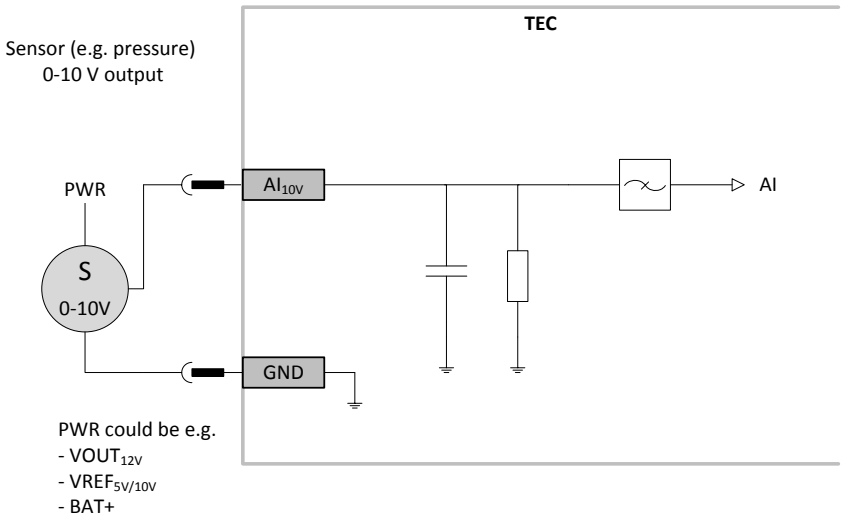


Figure 9 – $AI_{10V.2}$ / $AI_{10V.3}$ usage

Table 30 - Analog input electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Resolution			12		bits		
Protection		SC_G, SC_B					
Type	**$AI_{10V.2}$ 0-10V Voltage input**						
Input voltage range	U_{in}	0		10	V	Voltage input	
Over voltage				32	V		
Accuracy % FS				±3	%FS		
Accuracy, typical			2+0.5		%	± (% of reading + % FS)	
Input resistance			3		kΩ	U_{in} ≤ 10 V	
Input capacitance			4.7		nF		
Input cut-off frequency	f_{-3dB}		50		Hz	HW filter	

Table 31 - Analog input electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Resolution			12		bits		
Protection		SC_G, SC_B					
Type	**$AI_{10V.3}$ 0-10V Voltage input**						
Input voltage range		0		10	V	Voltage input	
Over voltage				32	V		
Accuracy % FS				±3	%FS		
Accuracy, typical			2+0.5		%	± (% of reading + % FS)	
Input resistance			11		kΩ	U_{in} ≤ 10 V	
Input capacitance			4.7		nF		
Input cut-off frequency	f_{-3dB}		50		Hz	HW filter	

Table 32 - Analog input functional specification

Item	Value	Notes
Sampling interval	800 Hz	Unfiltered samples can be streamed to application at full sample rate (RAW sample rate)
Input refresh rate	100Hz	Digitally filtered (NORMAL sample rate).
Digital filter cutoff frequency f_{-3dB}	40Hz	Digital filter implemented in system software
Digital filter stop-band attenuation	Typical 20dB at f > 100Hz	
Input configuration	Selected during device initialization	

Table 33 - AI signals

Signal	Dir	Description
AI	In	Configurable analog input
GND_{AI}		AI reference ground

6.2.8 Output, Sensor supply voltage 12 V [$VOUT_{12V.1}$]

Supply voltage for external sensors that are not tolerant to automotive power system.

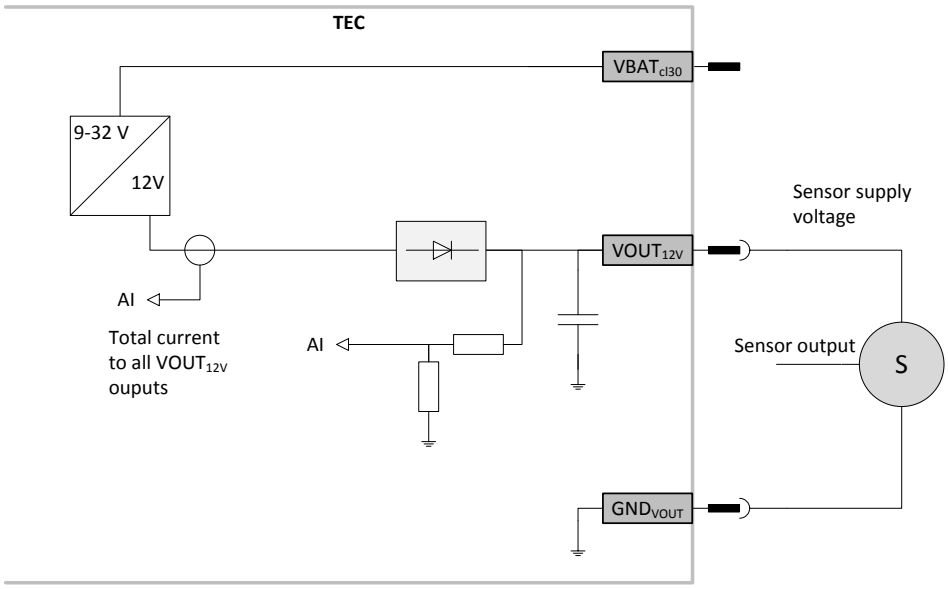


Figure 10- $VOUT_{12V}$ usage

Table 34 – $VOUT_{12V}$ Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type	**$VOUT_{12V.1}$ 12 V ± 15% Sensor supply output**						
Default state		OFF					
Output voltage	U_{out}	10.2	11.5	13.5	V		
Output over voltage				32	V	Output short circuit to battery	
Output current				250	mA		
Maximum capacitive load				50	µF		
Turn-on delay				40	ms		
Protection		SC_G, SC_B, OC					
Output voltage measurement range		0		13.8	V		
Output voltage measurement accuracy % FS				±3	%FS		

Table 35 - Functional specification

Item	Value	Notes
Supply state	Software controllable as digital state (‘0’ = supply off, ‘1’=supply on)	
Diagnostics	SC_G	
Overcurrent / short to ground handling	Automatic disabling of supply on fault detection. After 1 second of cool-down period (SUSPENDED state), application can turn the supply on again. After 100 repeated faults, the supply is permanently disabled (SHUTDOWN state).	
Short circuit to Battery handling	Fault reporting: Output voltage above threshold value.	

Table 36 – $VOUT_{12V}$ signals

Signal	Dir	Description
$VOUT_{12V}$	Out	Sensor supply voltage output
GND_{VOUT}		AI reference ground

6.2.9 Output, Voltage reference output 5 V / 10V [$VREF_{5V.1}$, $VREF_{10V.1}$]

Output can be used as reference voltage output for sensors (i.e. ratiometric measurement) or supply voltage source for external sensors.

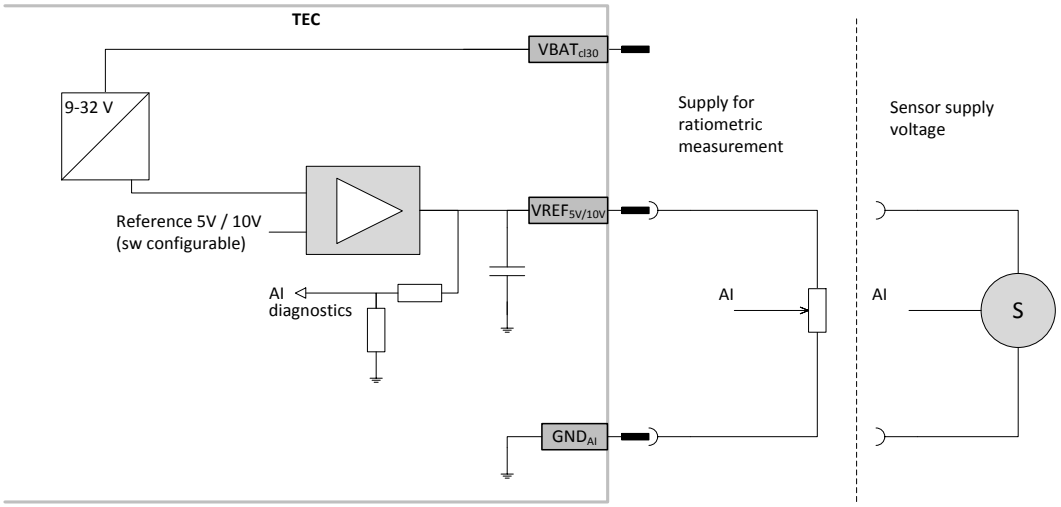


Figure 11- VREF usage

Table 37 – Voltage reference output electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type	$VREF_{5V.1}$, $VREF_{10V.1}$						
Default state		OFF					
Output voltage	U_{out}		5 10		V V	Software selectable	
Output accuracy % FS				±0,5	%FS		
Output over voltage		-3		32	V	Output short circuit to battery	
Output current				50	mA		
Protection		SC_G, SC_B, OC					

Parameter		Min	Nom	Max	Unit	Description	ID
Output voltage feedback measurement range		0		10.5	V		
Output voltage feedback measurement accuracy % FS				±1	%FS		

Table 38 - Functional specification

Item	Value	Notes
Supply state	Software controllable as digital state (‘0’ = supply off, ‘1’=supply on)	
Diagnostics	SC_G	
Overcurrent / short to ground handling	Automatic disabling of supply on fault detection. After 1 second of cool-down period (SUSPENDED state), application can turn the supply on again. After 100 repeated faults, the supply is permanently disabled (SHUTDOWN state).	
Short circuit to Battery handling	Fault reporting: Output voltage above threshold value.	

Table 39 – $VREF_{5V/10V}$ signals

Signal	Dir	Description
$VREF_{5V/10V}$	Out	Voltage reference output
GND_{AI}		AI reference ground

6.2.10 Output, high side PWM or ON/OFF with current feedback [$DO_{H2A5.1}$ / $DO_{H5A.1}$ / $DO_{L\_RET1A/2A.1}$]

TEC172 high-side outputs can be used either in open-loop PWM or current controller closed-loop mode. PWM output has integrated free-wheeling diode. Proportional valves with current controlled mode need both DO_{H2A5} and DO_{L_RET} outputs. DO_{H5A} can be used for high current loads (max. 5A)

TEC172 high-side output load examples:

- Proportional valve (current controlled)
- ON/OFF valve
- Solenoid
- Bulb lamp
- Led lamp
- Heaters (and other resistive loads)
- Relay

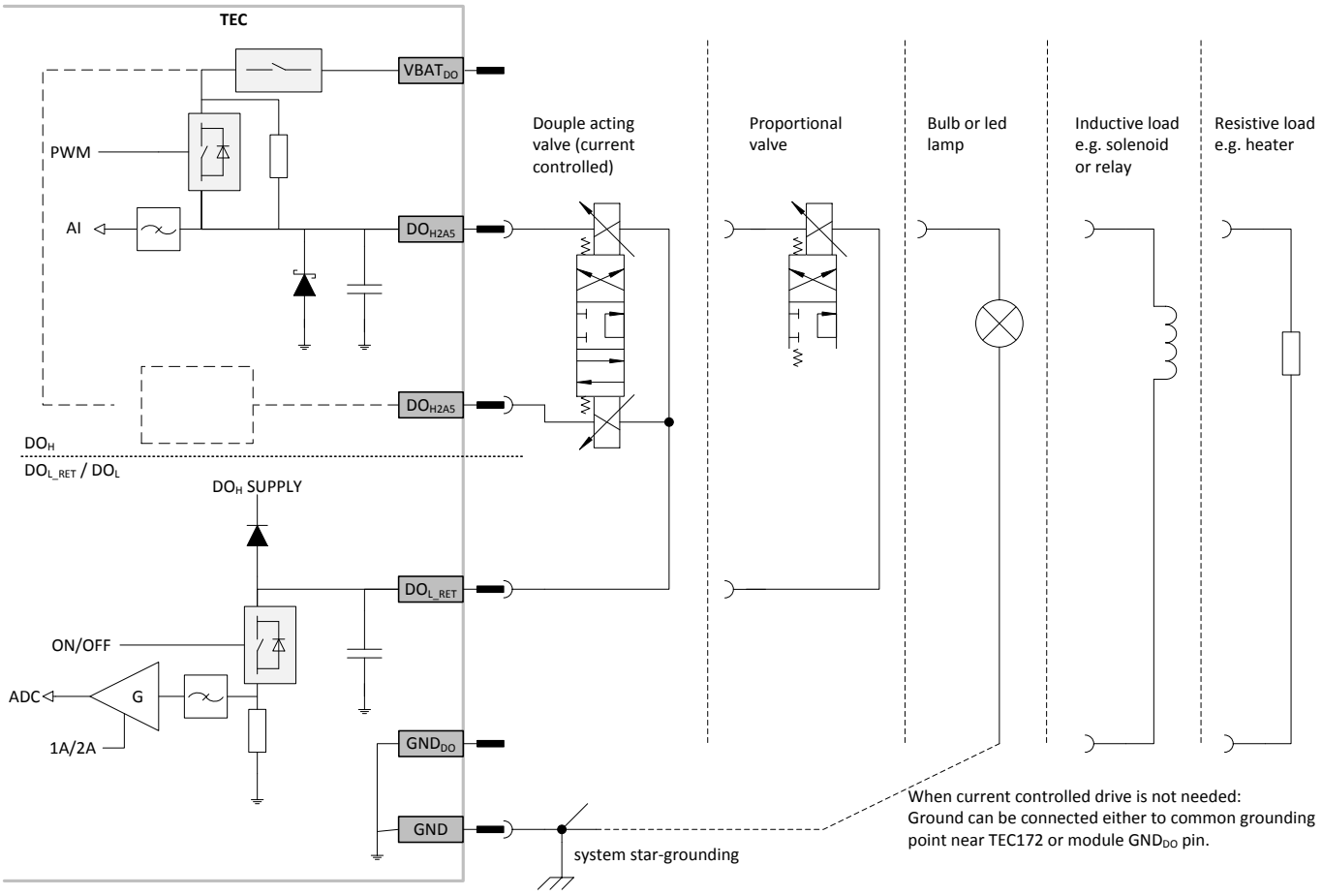


Figure 12 – DO_{H2A5} usage

Table 40- DO_{H2A5} Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type		**$DO_{H2A5.1}$ / $DO_{H2A5.2}$** High-side output					
Default state		OFF					
Voltage range		9		32	V		
Over voltage				48	V		
Output current				2.5	A	Parallel connection of the channels is allowed for higher output current in ON/OFF mode only with dedicated CODESYS block.	
Voltage drop load 1 A load 2.5 A				 0.1 0.3	 V V	$U(VBAT_{DO}) – U(DO_H)$	
Output current				2.5	A		
Freewheeling diode current				1	A	Average current	
Short circuit current limit				6.5	A		
Leakage current in off state		-2		*0.4*	mA	Leakage current from DOH (positive value outgoing from DOH), $VBAT_{DO}$ < 32V	
Pull-up resistance	R_{PU}		100		kΩ	only in $DO_{H2A5.1}$	
PWM frequency	f_{PWM}	10		1000	Hz		
PWM duty cycle resolution		0.1			%		
Dither frequency	f_{DITH}			500	Hz	Dither frequency can be set to $f_{DITH} = f_{PWM}$ / DIV , where DIV={2,4,6,8,…}	
Dither amplitude				50	%	PWM duty modulation depth. '*PWM duty*' ± '*Modulation depth*' must always be 0%...100%	
Protection	SC_G, SC_B, OC					Output voltage shall not exceed $VBAT_{DO}$ supply voltage in any conditions	

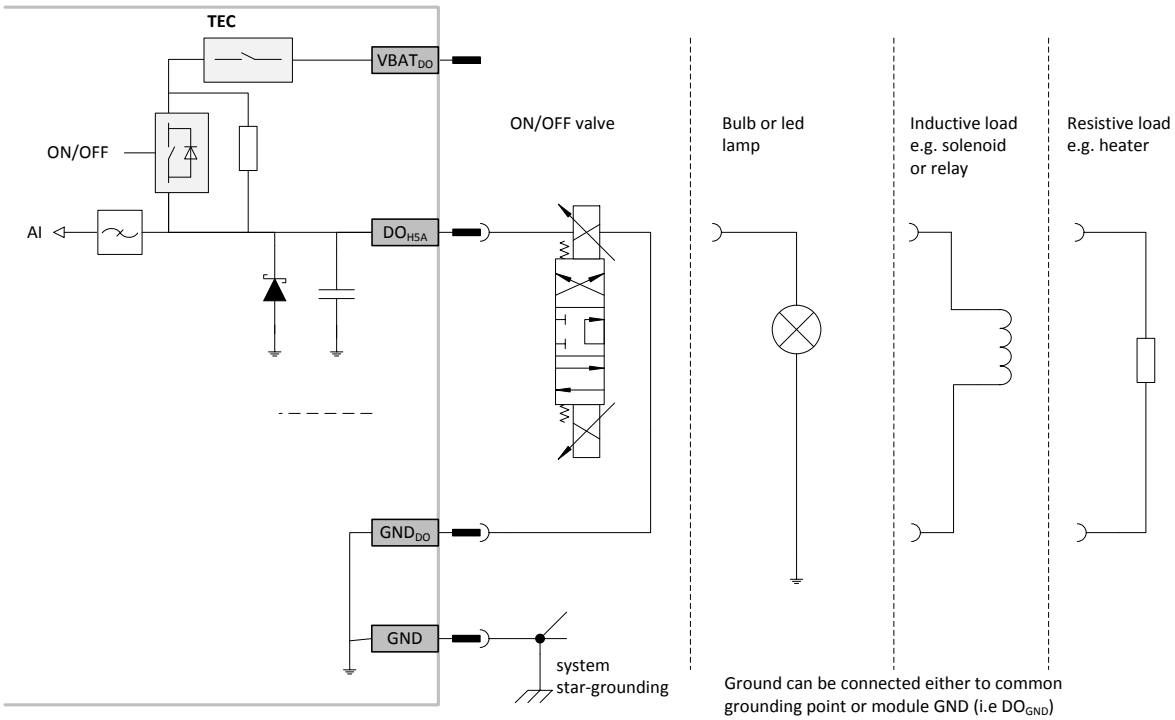


Figure 13 – DO$_{H5A}$ usage

Table 41- DO$_{H5A}$ Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type		**DO$_{H5A.1}$** High-side output					
Default state		OFF					
Voltage range		9		32	V		
Over voltage				48	V		
Output current				5	A	Parallel connection of the channels is allowed for higher output current in ON/OFF mode only with dedicated CODESYS block.	
Voltage drop load 1 A load 5 A				 0.1 0.4	 V V	V(VBAT$_{DO}$) – V(DO$_H$)	
Freewheeling diode current				1	A	Average current	
Short circuit current limit				8.5	A		
Leakage current in off state		-2		*0.4*	mA	Leakage current from DOH (positive value outgoing from DOH), VBAT$_{DO}$ < 32V	
Pull-up resistance	R_{PU}		100		kΩ		
PWM frequency		10		1000	Hz		
PWM duty cycle resolution		0,1			%		
Dither frequency	f_{DITH}			500	Hz	Dither frequency can be set to $f_{DITH} = f_{PWM}$ / DIV , where DIV={2,4,6,8,…}	
Dither amplitude				50	%	PWM duty modulation depth. '*PWM duty*' ± '*Modulation depth*' must always be 0%...100%	
Protection	SC_G, SC_B, OC					Output voltage shall not exceed VBAT$_{DO}$ supply voltage in any conditions	

6.2.10.1 Low-side output with current measurement [$DO_{L\_RET1A.1}$ / $DO_{L\_RET2A.1}$]

Low-side output with current measurement is used to closed loop current control for proportional hydraulic valves. Current measurement is used in conjunction with high-side PWM output (DO_{H2A5}). Two high-side outputs can be connected to same current measurement (DO_{L_RET}) channel if not used simultaneously (i.e for double acting valve). Current measurement range is software configurable to 0 – 1 A or 0 – 2 A. See Figure 12 for typical connections.

Table 42- DO_{L_RET1A} Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type		$DO_{L\_RET1A.1}$ return current measurement 0 – 1 A (for DO_{H2A5})					
Default state		OFF					
Voltage drop load 1 A				0.3	V	DO_{L_RET} – GND	
Output current				1	A		
Freewheeling diode current				0.5	A	Average current	
Short circuit current limit			1.2	1.3	A	$t_{measure}$ = 100 ms	
Current measurement range		0		1	A		
Current measurement accuracy				±1	% FS		
Current measurement accuracy, typical			0.6 + 0.2		%	± (% of reading + % FS)	
Current measurement resolution			1		mA		
Protection	SC_G, SC_B, OC						

Table 43- DO_{L_RET2A} Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type		$DO_{L\_RET2A.1}$ return current measurement 0 – 2 A (for DO_{H2A5})					
Default state		OFF					
Voltage drop load 2 A				0.6	V	DO_{L_RET} – GND	
Output current				2	A		
Freewheeling diode current				0.5	A	Average current	
Short circuit current limit			2.4	2.5	A	$t_{measure}$ = 100 ms	
Current measurement range		0		2	A		
Current measurement accuracy				±1	% FS		
Current measurement accuracy, typical			0.6 + 0.2		%	± (% of reading + % FS)	
Current measurement resolution			1		mA		
Protection	SC_G, SC_B, OC						

6.2.10.2 Functional specification

Table 44 - Functional specification

Item	Value	Notes
Dither modes	1) Direct PWM, PWM output without current control (i.e. open-loop control). 2) Current controlled output	1) PWM duty is modulated by dither depth value. 2) Current controller's target value is modulated by fraction of full scale feedback current
Direct PWM dither (amplitude and resolution)	Dither amplitude in PWM duty cycle deviation amount. Dither resolution 0.1%	
Current controlled dither (amplitude and resolution)	Dither amplitude is fraction of full scale feedback current. Dither resolution is 0.1%	
Turn-on/off ramp (soft-start) modes	1) Direct PWM 2) Current controlled output	
Turn-on/off ramp (soft-start)	Minimum ramp step time: One PWM period Ramp type: linear Dynamic ramp control: Ramp parameters can be controlled during ramp (see Figure 14)	
PID current control	Current controller loop time: One PWM period	
Double acting valve control	Single control value for two complementary channels.	
DO_H Over current / short circuit protection	Different overcurrent profiles for inductive and lamp loads Quick autoretry (< 100ms until output value is automatically restored after turn-off due to fault detection) After 10 autoretries, 1 second cool-down period (SUSPENDED state, output is disabled) after which application is allowed to turn on the output After 100 faults in total, output is disabled permanently (SHUTDOWN state) until power off-on cycle is performed	
DO_{L_RET} Over current / short circuit protection	Output is disabled for cool-down period of 1 s typical (SUSPENDED state) after overcurrent or short circuit, after which user application is allowed to turn on the output.	
Number of different PWM frequencies	Each channel can be configured independently.	
PWM frequency resolution	Period time of PWM must be multiple of 100µs	
Diagnostics	OC	Diagnostic functions available depends on load type
Diagnostics DO_{L_RET}	OC	

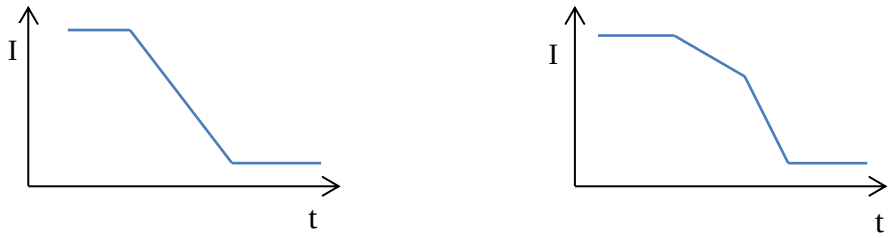


Figure 14 - Linear ramp control (left) and dynamic control (right)

Table 45 – DO_H & DO_{L_RET} signals

Signal	Dir	Description
DO_H	Out	High-side output
$DO_{L\ RET}$	In	Feedback current measurement
$GND_{DO/DI}$		DO reference ground

6.2.10.3 Parallel connection of DO_H outputs

Two DO_H outputs can be connected parallel to increase output current. When outputs are connected parallel only ON/OFF control of the outputs is possible (no PWM control). Parallel connection must be done using special CODESYS block. Otherwise outputs may not behavior correctly or TEC172 module may be damaged. When outputs are connected parallel maximum output current is doubled. However freewheeling current remains same as for one output and must not be exceeded.

Channels that can be connected parallel are presented in the Table 46. Other connections are not possible.

Table 46 – DO_H Parallel connections

#	CH A	CH B	Notes
1	E-1	E-13	DO_{H2A5}
2	E-14	E-15	DO_{H2A5}
3	E-31	E-32	DO_{H2A5}
4	E-33	E-34	DO_{H2A5}
5	E-35	E-23	DO_{H2A5}
6	E-11	E-12	DO_{H2A5}
7	D-4	D-3	DO_{H2A5}
8	D-2	D-1	DO_{H2A5}
9	D-13	D-24	DO_{H2A5}
10	D-25	D-26	DO_{H2A5}
11	D-31	D-32	DO_{H2A5}
12	D-33	D-34	DO_{H2A5}
13	D-35	E-24	DO_{H5A}
14	E-25	E-26	DO_{H5A}
15	E-27	E-28	DO_{H5A}
16	E-29	E-30	DO_{H5A}

6.2.11 Output, low side ON/OFF

TEC172 low side output load examples

- Relays
- ON/OFF valves
- Resistive loads

Maximum output current is 1 A.

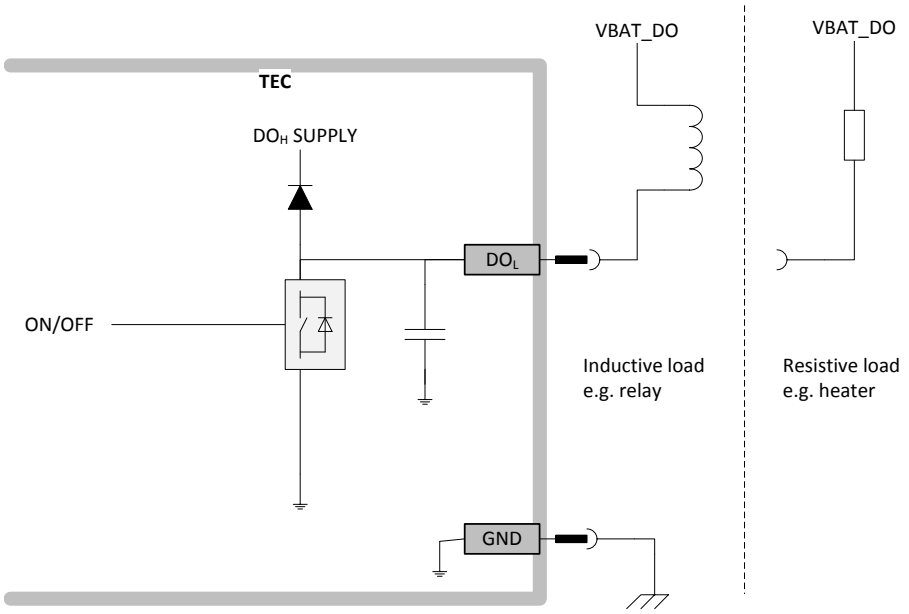


Figure 15 - DO_L usage

Table 47 - Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type		$DO_{L.1}$ Low-side output 1 A					
Default state		OFF					
Voltage range		9		32	V		
Over voltage				48	V		
Voltage drop load 1 A				0.3	V		
Output current				1	A		
Freewheeling diode current				*0.5*	A	Average current	
Short circuit current limit			1.2	1.3	A	$t_{measure}$ = 100 ms	
Leakage current in off state			10	100	µA		
Protection	SC_G, SC_B, OC						

Table 48 - Functional specification

Item		Value	Notes
Signal change rate		< 10Hz	
Diagnostics		OC	
Diagnostic evaluation interval		100Hz	
Overcurrent / short circuit to battery handling		Output is disabled for cool-down period of 1 s typical (SUSPENDED state) after overcurrent or short circuit, after which user application is allowed to turn on the output.	

Table 49 – Digital output, low side interface signals

Signal	Dir	Description
DO_L	Out	Digital output low side

6.2.12 Output, Sauer-Danfoss valve control [$HB_{SDV.1}$]

TEC172 Sauer-Danfoss valve control output is intended to be used with voltage controlled hydraulic valves (Sauer-Danfoss valves with PVE actuator e.g. PVG 32, PVG 100 and PVG 120). Dedicated half-bridge output produces high frequency and symmetric push-pull PWM output (HB_{SDV}). HB_{SDV} output is connected to valve signal input (U_S) to generate ratiometric control voltage (0,25…0,75)*U_{DC}. HB_{SDV} output must be used together with DO_H output. DO_H output provides supply voltage to PVE actuator. Valve signals US and UDC must connected to specific TEC172 I/O pins. TEC172 connection to PVE actuator is defined in Table 52.

TEC172 has internal monitoring to HB_{SDV} output voltage. If application software detects misbehavior at the HB_{SDV} output voltage DO_H shall be switched OFF to stop hydraulic valve. HB_{SDV} outputs have common overcurrent diagnostics. If overcurrent or short to ground is diagnosed at any HB_{SDV} output all channels should be disable i.e. DO_H should be turned off.

TEC172 HB_{SDV} usage:

- Voltage controlled U_S = (0,25…0,75)*U_{DC} hydraulic valves.

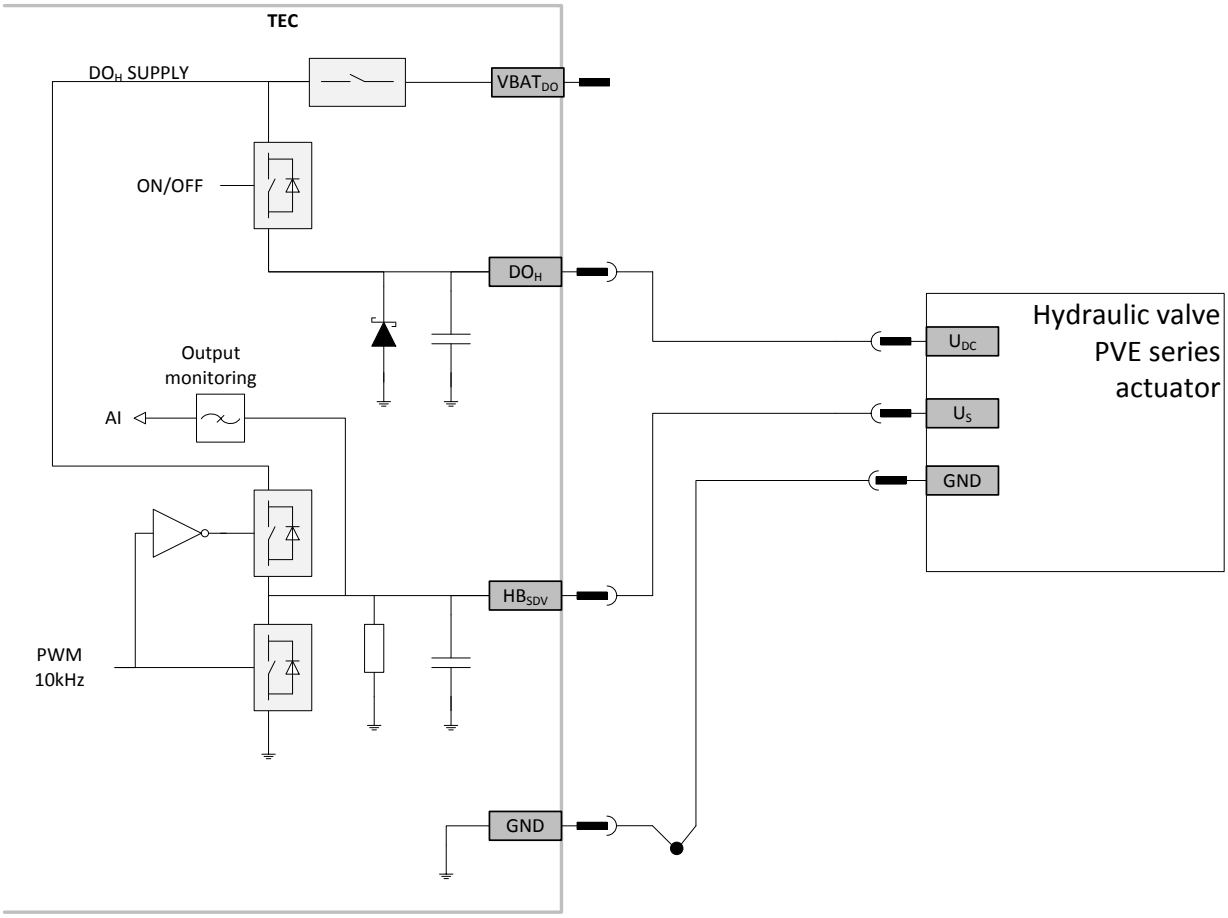


Figure 16 - HB_{SDV} usage

Table 50- HB_{SDV} Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type		$HB_{SDV.1}$ Half-bridge output for 12 kΩ resistive load					
Default state		pull-down 55 kΩ					
Voltage range		9		32	V		
Over voltage				48	V		
Voltage drop load 0.01 A				0.01	V	DO_H SUPPLY – HB_{SDV}	
Output current			0.02	0.1	A		
PWM frequency			10		kHz		
PWM duty cycle resolution		0,1			%		
Pull-down resistance	R_{PD}		55		kΩ		
Protection	SC_G, SC_B, OC					Output voltage shall not exceed $VBAT_{DO}$ supply voltage in any conditions	

Table 51 - Functional specification

Item	Value	Notes
Diagnostics	OC	
Diagnostic evaluation interval	100Hz	
Fault handling	DO_H channel providing supply to HB_{SDV} channel is turned off to prevent erratic control	Driver hardware has internal protection. Fault protection is shared by all HB_{SDV} channels – fault in one channel shuts down all HB_{SDV} channels

Table 52 – Sauer-Danfoss valve control interface signals

#	TEC172 Signal	Dir	TEC172 Pin	PVE	Description
1	DO_H	Out	D3	U_{DC}	Supply voltage to PVE actuator
1	HB_{SDV}	Out	D1	U_S	Signal voltage to actuator
1	GND		D21	GND	Ground
2	DO_H	Out	D4	U_{DC}	Supply voltage to PVE actuator
2	HB_{SDV}	Out	D2	U_S	Signal voltage to actuator
2	GND		D21	GND	Ground
3	DO_H	Out	D26	U_{DC}	Supply voltage to PVE actuator
3	HB_{SDV}	Out	D13	U_S	Signal voltage to actuator
3	GND		D21	GND	Ground
4	DO_H	Out	D25	U_{DC}	Supply voltage to PVE actuator
4	HB_{SDV}	Out	D24	U_S	Signal voltage to actuator
4	GND		D21	GND	Ground

6.2.13 Output, Analog output 0-5V

General purpose 0 – 5 V analog voltage output can be used to interface sensor and actuators.

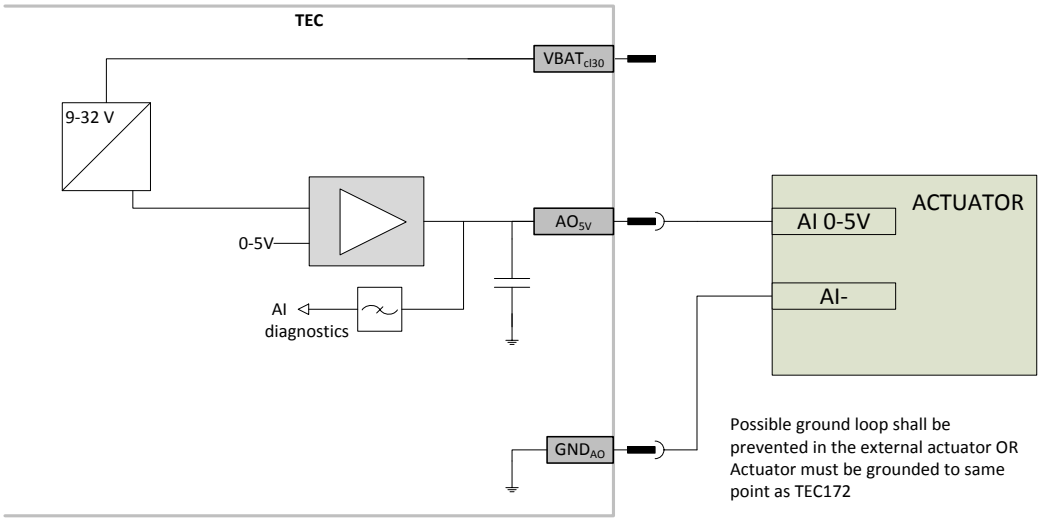


Figure 17- AO_{5V} usage

Table 53 - Analog output electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type	$AO_{5V.1}$, Analog output 0-5V						
Default state		0 V / OFF					
Output voltage	U_{out}	0		5	V		
Resolution				10	bit		
Output accuracy % FS			±0,1	±0,5	%FS		
Output over voltage		0		32	V	Output short circuit to battery	
Output current				5	mA	Minimum output load 1kΩ	
Maximum capacitive load				1	µF		
Protection		SC_G, SC_B					
Output voltage feedback measurement range		0		5.5	V		
Output voltage feedback measurement accuracy % FS				±1	%FS		

Table 54 - Functional specification

Item	Value	Notes
Supply state	Software controllable	
Diagnostics	OC	
Output update rate	Max. 100Hz	

Table 55 - AO signals

Signal	Dir	Description
AO_{5V}	Out	Analog output 0 – 5 V
GND_{AO}		AO reference ground

6.2.14 Output, DC-motor drive H-bridge [HB_M]

TEC172 H-bridge output consists of two HB_M half-bridge outputs. Two outputs (HB_M) are always needed to drive one DC-motor. Output configuration is presented in chapter 8. TEC172 motor drive topology is 2-quadrant unipolar PWM-drive. Both motor driving speed and direction can be controlled.

TEC172 H-bridge usage:

- DC-motor drive with direction and speed control
- Linear DC-motor drive with direction and speed control

Regenerative energy

Note!
DC-motor generates regenerative energy (motor acts as a generator) during braking or when external force spins the motor. Regenerative energy may break TEC172 module if following preventive actions are not handled in system side:

1) DC-motor must not be spin by any other device than TEC172
2) Battery must be connected directly to TEC172 $VBAT_{DO}$ pin always when motor is driven to provide sink for regenerative energy.

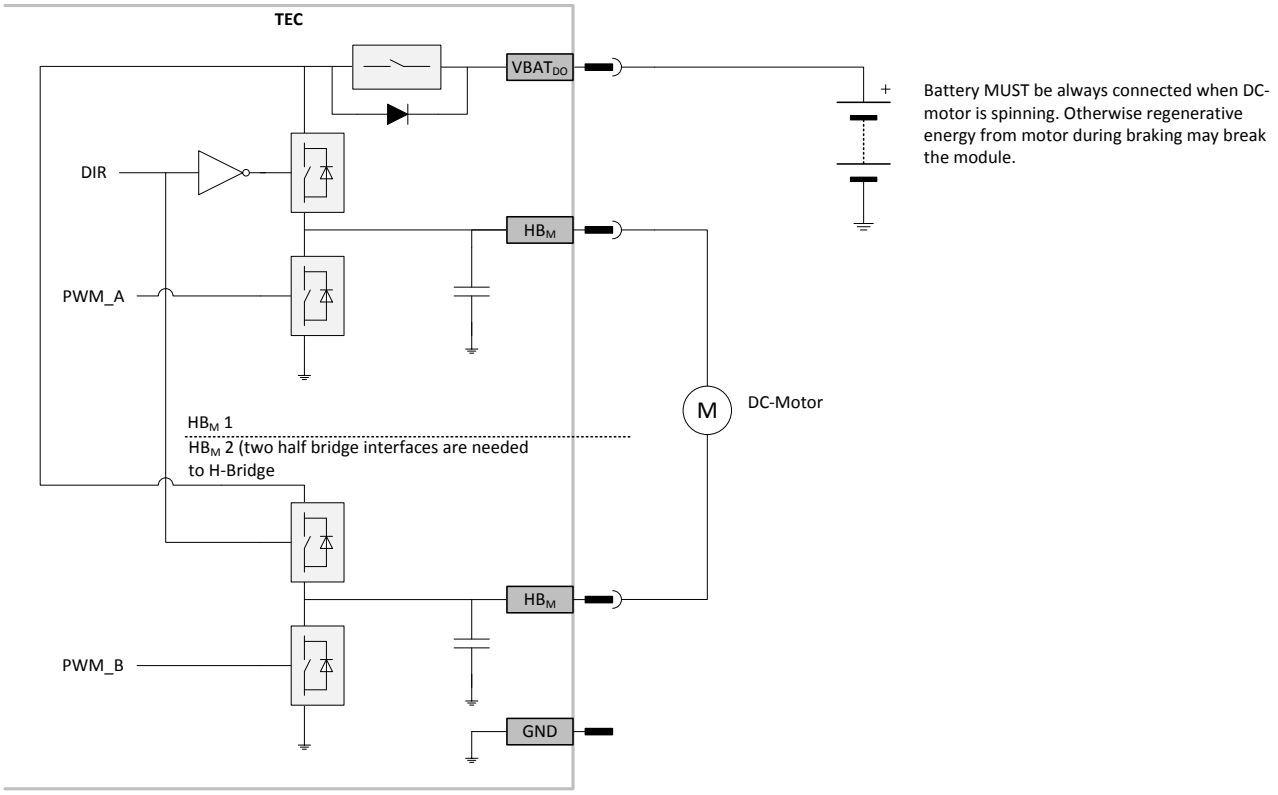


Figure 18 - HB_M usage

Table 56- HB_M Electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type		HB_M Half-bridge (PWM) output for motor control					
Default state		Hi-Z (before initialization), Low state (= STOP) after DC-motor mode is initialized					
Voltage range		9		32	V		
Over voltage				48	V		
Voltage drop load 2.5 A				0.5	V	$VBAT_{DO}$ – HB_M	
Output current				2.5	A	MAX continuous current	
Freewheeling current				*2*	A	Average current Note: Motor generator current has to be limited below this value.	
Short circuit current limit		14	17		A	Motor stall current must lower than this limit and t_{stall} < 50 ms	
PWM frequency		1		10	kHz		
PWM duty cycle		0		100	%		
PWM duty cycle resolution		0,1			%		
Protection	SC_G, OC					Output voltage shall not exceed $VBAT_{DO}$ supply voltage in any conditions	

Table 57 - Functional specification

Item	Value	Notes
Drive modes	• Stopped (not driving) • Forward (adjustable duty) • Reverse (adjustable duty) • Braking	
Short circuit protection		
PWM frequency resolution	Minimum 10 Hz	
Diagnostics for full H-bridge configuration	OC	

Signal	Dir	Description
HB_M	Out	Motor *x* + output
HB_M	Out	Motor *x* - output

6.2.15 IO GND (actuator / sensor return signal)

TEC172 module has several IO GND pins that can be used to connect load / actuators / sensor return signals. IO GND is internally connected to module GND pins.

It is essential to use strictly controlled grounding principle at system level. For example the use of dedicated analog ground signal prevents measurements errors caused by ground currents. Sensors and loads shall be grounded (IO GND pin or star-grounding near module GND pin) only in module side to prevent ground loops.

Table 58 – IO GND electrical specification

Parameter		Min	Nom	Max	Unit	Description	ID
Type	GND_{FI}, GND_{AI}, GND_{VOUT}, $GND_{DO/DI}$, GND_{RS232} Ground signal for sensors and actuators						
Input current				8	A		

6.2.16 System status LEDs

There are two LEDs that are visible to the user. LEDs are located on cover near main connector (see Figure 22). First (green) led indicates module operational or fault state other (yellow) is user application programmable. Module status LED (green) functionality is according to Table 59.

Table 59 - Status led operation

LED (green) state	Description
Constant ON	Power ON – system software not running
2 blinks	Application SW running
3 blinks	System SW running – application not started
4 blinks	Application / system SW reprogramming
5 blinks	HW fault
6 blinks	SW operation fault
OFF	Power failure

LED (yellow) state	Description
ON/OFF (default OFF)	Application specific, freely programmable

6.3 Communication definition

6.3.1 CAN

Module has four CAN 2.0 A/B communication interfaces. CAN physical layer is according to ISO 11898-2. CAN interface supports CANopen and other protocols implementable over CAN2.0 A/B. CAN bus can be terminated in the module using short wire loop (max 80 mm) between pins CAN_H_TERM and CAN_L_TERM.

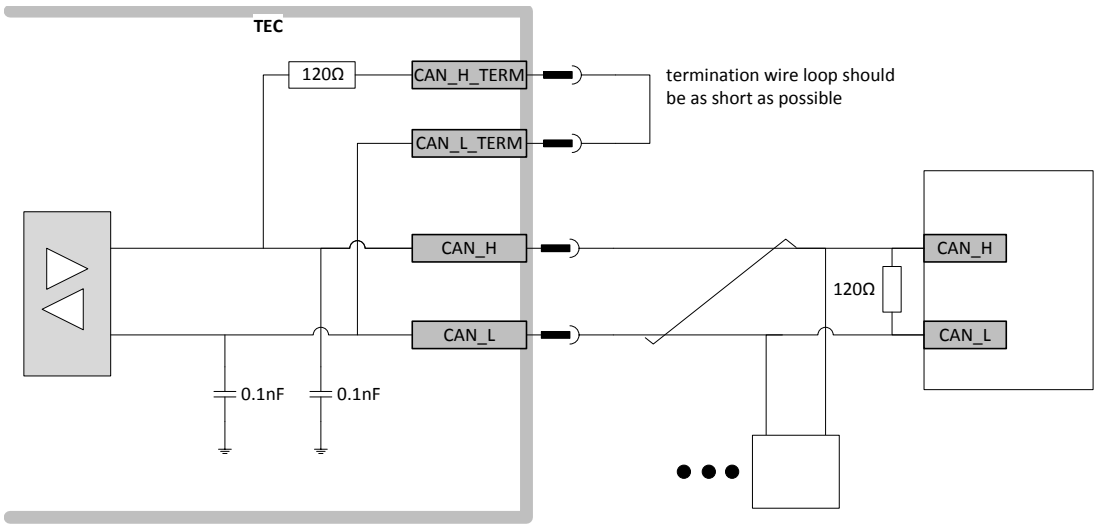


Figure 19- CAN usage

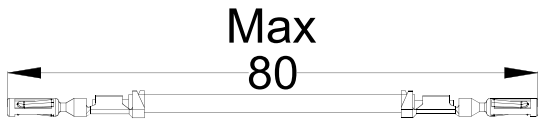


Figure 20- CAN termination wire loop maximum length

Table 60- CAN Electrical specification

Parameter		Value	Description
Physical layer		ISO 11898-2	High speed CAN
Termination resistor		120 Ω ± 5%	Termination resistor is connected using wire loop in connector
Communication speed		10 kbps – 1 Mbps	
Common mode voltage		-25 V …+25 V	
Short circuit protection		-28 V … +36 V	
CAN_H / CAN_L leakage current		5µA	Max leakage current during power-off, $U_{CAN\_H/CAN\_L} < 5$ V

Table 61 - CAN interface signals

Signal	Dir	Description
CAN_H	In / Out	CAN transmit / receive high
CAN_L	In / Out	CAN transmit / receive high
CAN_TERM_L	-	Termination resistor connection (internally connected to CAN_L)
CAN_TERM_R	-	Termination resistor connection (internally connected to termination resistor)

Twisted-pair cable shall be used.

6.3.2 Ethernet

Module has two Ethernet ports (connectors), which are connected to CPU through Ethernet switch. Ethernet ports can be used for:

- Software or application specific data download
- Industrial Ethernet type communication networks
- Diagnostic port

Table 62- Ethernet Electrical specification

Parameter		Value	Notes
Physical layer		10BASE-T / 100BASE-TX	IEEE 802.3i / 802.3u
Crossover support		Auto MDI/MDI-X	
Time synchronization		IEEE 1588	Software implementation

Table 63 - Ethernet interface signals

Signal	Dir	Description
ETH_TX+	Out	Transmit data +
ETH_TX-	Out	Transmit data -
ETH_RX+	In	Receive data +
ETH_RX-	In	Receive data -

6.3.3 RS-232

RS-232 interface can be used to communicate with external devices.

Table 64- RS-232 Electrical specification

Parameter		Value	Description
Communication speed		max. 115200 bps	
Input capacitance		typ. 1,5 nF	

Table 65 – RS-232 interface signals

Signal	Dir	Description
TXD	Out	RS-232 Transmit data
RXD	In	RS-232 Receive data
GND_{RS232}		Reference ground signal

6.3.4 RS485

RS-485 interface can be used to connect TEC172 to other ECUs. TEC172 supports MODBUS-RTU/ASCII protocol and other protocols based on standard RS-485 communication.

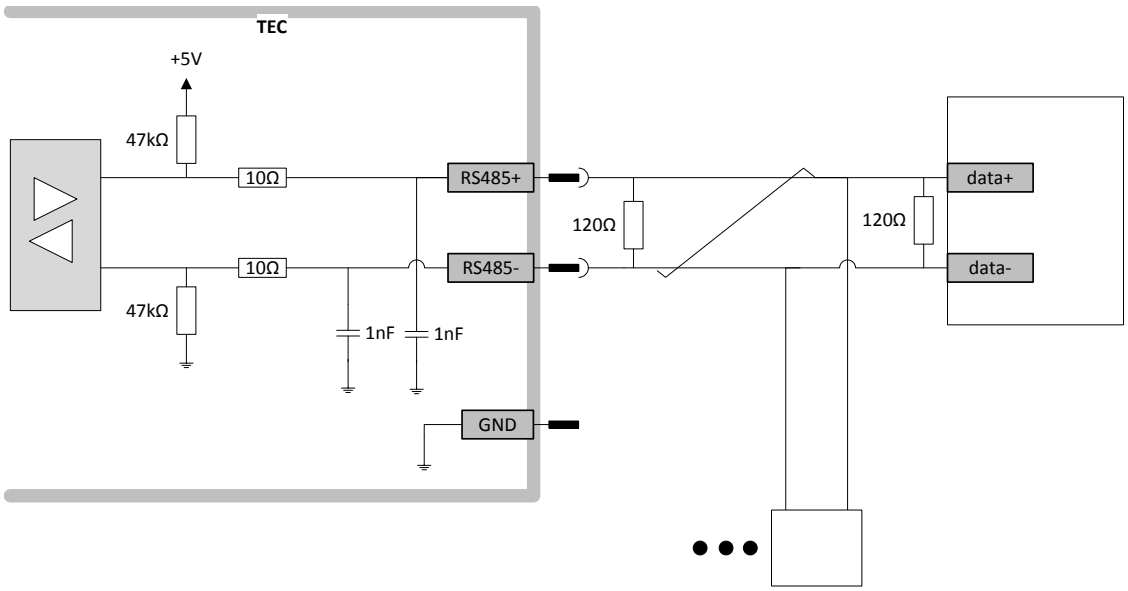


Figure 21- RS-485 usage

Table 66- RS-485 Electrical specification

Parameter		Value	Description
Physical layer		TIA/EIA-485	
Termination resistor		NA	external termination resistors shall be connected at the both ends of the bus
Communication speed		max. 115,2 kbps half-duplex	
Input common mode voltage		-10 V …+15 V	
Short circuit protection		-28 V … +36 V	
RS485+/RS485- leakage current		*250*µA	Max leakage current during power-off, $U_{RS485+/RS485-}$ < 5 V
RS485+/RS485- input capacitance		1 nF	

Table 67 - Functional specification

Item	Value	Notes
TX enable control	Transmitter enable signal is controlled by system software.	

Table 68 – RS-485 interface signals

Signal	Dir	Description
RS485+	In / Out	Non-inverted TX/RX data
RS485-	In / Out	Inverted TX/RX data

Twisted-pair cable shall be used.

6.4 Fault handling

Individual IO channels implement fault containment mechanisms which protect the hardware from breaking down. Recovery from situation can be attempted, unless allowed number of retries has been exhausted due to repeated failure. When no more retries are allowed, the affected IO channel is non-operational until a power off-on cycle is performed.
The recovery is performed in two stages:

- When the fault is initially detected, the output channel may enter RECOVERING state (implemented on some IO-types). The channel output is momentarily disabled, but will be automatically re-enabled with the value last set by application. If the fault is still present, recovery is attempted again.
- When a set limit of fault events for one IO channel has been reached, the channel is disabled for a longer cool-down time. This is SUSPENDED state. After cool-down time expires, normal operation is allowed. Note however, that the output will remain turned off unless application explicitly writes a control value for the output after exit from SUSPENDED state.
- When faults have repeated long enough, the channel is put to SHUTDOWN state. In this state, the channel is disabled and cannot return to normal operation until power off-on cycle is performed.

The application can read the diagnostic information from all outputs using the functions provided in the Technion IO library.

Table 69 - IO channel fault handling parameters

Parameter	Value	Notes
Number of fault events until IO channel is set to SUSPENDED state	10 1	DO_H outputs (fast auto-recovery through RECOVERING state) Other IO types
Number of entries into SUSPENDED state after which IO channel is set to SHUTDOWN state	10	All IO types
Minimum cool-down time in SUSPENDED state	1s	

Faults that affect the whole module, such as power supply issues, are reported to application using CODESYS system events mechanism. Where appropriate, the operation of the user application is forced to stop unless fault is removed.

7 Environmental specification

7.1 General

Electrical and environmental requirements are based on standard ISO 16750.

7.2 Ambient temperature

TEC172 is to be designed to operate mounted directly in vehicle body or inside the cabin.

Item		Min	Nom	Max	Unit	Notes
Operating temperature		-40	-	75	°C	
Storage temperature		-40	-	85	°C	

7.3 Functional safety

TEC172 is not a safety component according to the machine directive 2006/42/EC. TEC172 is not SIL classified.

8 Connector pin mapping

8.1 Connector locations

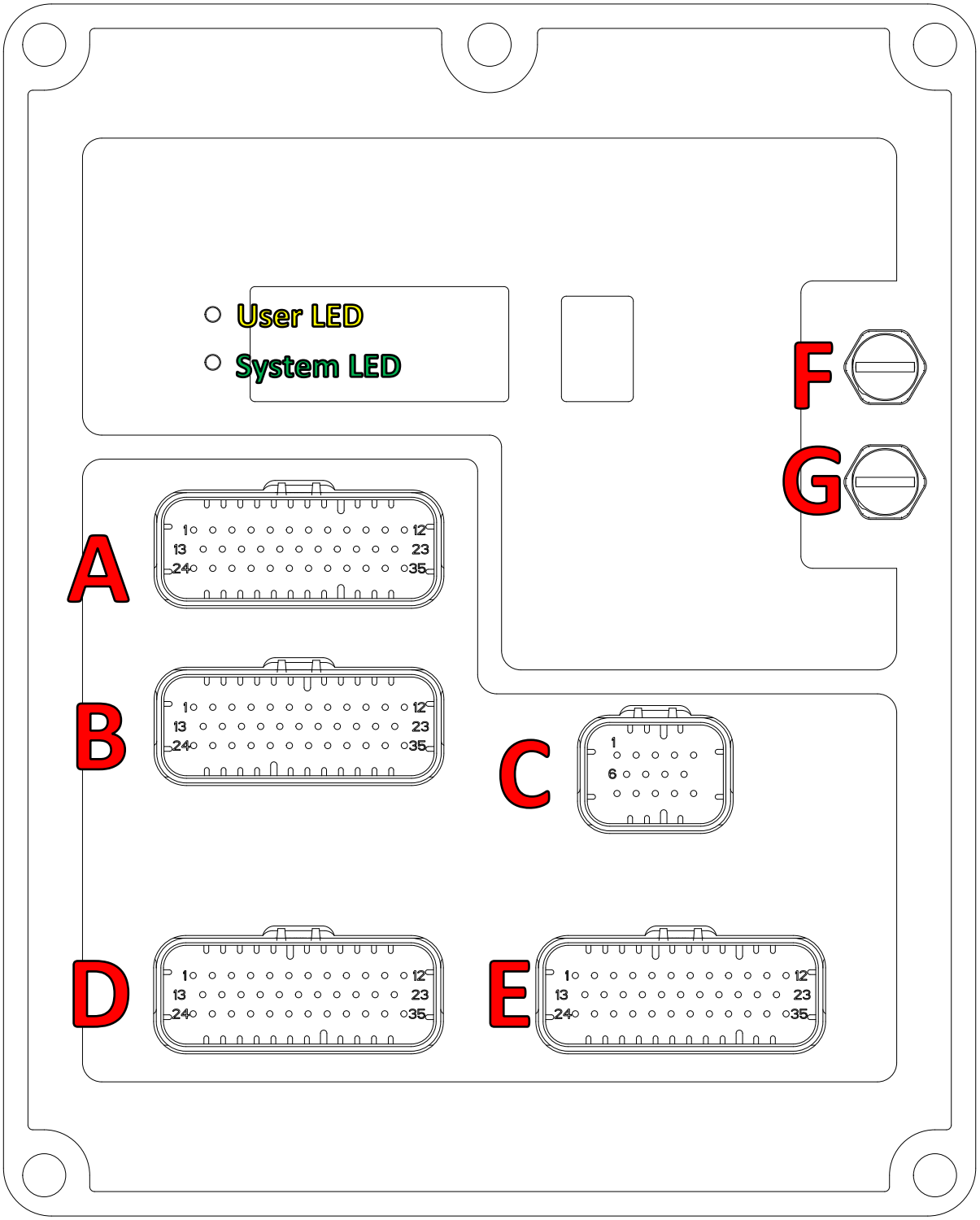


Figure 22 - Connector locations

8.2 Main connectors pin map (TEC172-001 / TEC172-002)

Table 70 – Connector A pinout (TEC172-001 / TEC172-002)

Connector A – TYCO AMPSEAL 776230-5 (BLUE), TEC172-001 / TEC172-002					
Pin		Dir	Function(s)	I/O Group	Notes
A	1	O	$VOUT_{12V.1}$	O_#6	+12V output
A	2	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $AI_{1k5.1}$, $DI_{H.1}$	I_#4a	High precision analog input
A	3	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $AI_{1k5.1}$, $DI_{H.1}$	I_#4a	High precision analog input
A	4	O	$VREF_{5V.1}$, $VREF_{10V.1}$	O_#5	5V/10V reference output
A	5	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	6	O	$VREF_{5V.1}$, $VREF_{10V.1}$	O_#5	5V/10V reference output
A	7	O	$VREF_{5V.1}$, $VREF_{10V.1}$	O_#5	5V/10V reference output
A	8	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	9	O	$VREF_{5V.1}$, $VREF_{10V.1}$	O_#5	5V/10V reference output
A	10	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	11	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	12	O	$VOUT_{12V.1}$	O_#6	+12V output
A	13	O	$VOUT_{12V.1}$	O_#6	+12V output
A	14	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $AI_{1k5.1}$, $DI_{H.1}$	I_#4a	High precision analog input
A	15		GND_{AI}		Analog ground
A	16	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $AI_{1k5.1}$, $DI_{H.1}$	I_#4a	High precision analog input
A	17	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	18		GND_{AI}		Analog ground
A	19		GND_{AI}		Analog ground
A	20	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	21		GND_{AI}		Analog ground
A	22		GND_{AI}		Analog ground
A	23	O	$VOUT_{12V.1}$	O_#6	+12V output
A	24	O	$AO_{5V.1}$	O_#9	0-5V analog output
A	25		GND_{AO}		Analog ground
A	26		GND_{AI}		Analog ground
A	27		GND_{AI}		Analog ground
A	28		GND_{AI}		Analog ground
A	29		GND_{AI}		Analog ground
A	30		GND_{AI}		Analog ground
A	31		GND_{DI}		Ground for digital inputs
A	32		GND_{VOUT}		Sensor power supply ground
A	33		GND_{VOUT}		Sensor power supply ground
A	34	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	Digital/Analog input
A	35	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	Digital/Analog input

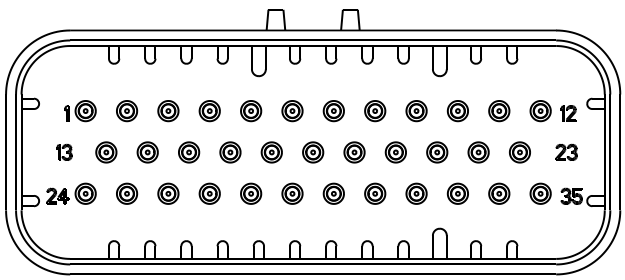


Figure 23- Connector A pinout

Table 71 – Connector B pinout (TEC172-001 / TEC172-002)

Connector B – TYCO AMPSEAL 776230-4 (GREY) , TEC172-001 / TEC172-002					
Pin		Dir	Function(s)	I/O Group	Notes
B	1	I	$FI1_{VR.1}$+	I_#7	Frequency/pulse input+
B	2	I	$FI3_{VR.1}$+	I_#7	Frequency/pulse input+
B	3	I	$FI4_{VR.1}$+	I_#7	Frequency/pulse input+
B	4	I	$FI6_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	5		GND_{FI}	-	Ground signal for FI_H
B	6	I	$FI9_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	7	O	TXD		RS-232 transmit signal
B	8	IO	RS485+		RS-485 TxD/RxD non-inverting
B	9	IO	CAN4_L		CAN interface 4 dominant low line
B	10	IO	CAN3_L		CAN interface 3 dominant low line
B	11	I	CAN2_L_TERM		CAN interface 2 bus termination (connect to B23)
B	12	IO	CAN2_H		CAN interface 2 dominant high line
B	13	I	$FI4_{VR.1}$-	I_#7	Frequency/pulse input-
B	14	I	$FI2_{VR.1}$+	I_#7	Frequency/pulse input+
B	15	I	$FI5_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	16	I	$FI7_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	17	I	$FI8_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	18	I	$FI10_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	19	I	RXD		RS-232 receive signal
B	20	IO	RS485-		RS-485 TxD/RxD inverting
B	21	IO	CAN4_H		CAN interface 4 dominant high line
B	22	IO	CAN3_H		CAN interface 3 dominant high line
B	23	I	CAN2_H_TERM		CAN interface 2 bus termination (connect to B11)
B	24	I	$FI1_{VR.1}$-	I_#7	Frequency/pulse input-
B	25	I	$FI2_{VR.1}$-	I_#7	Frequency/pulse input-
B	26	I	$FI3_{VR.1}$-	I_#7	Frequency/pulse input-
B	27		GND_{FI}		Ground signal for FI_H
B	28		GND_{FI}		Ground signal for FI_H
B	29		GND_{FI}		Ground signal for FI_H
B	30		GND_{RS323}		Ground signal for RS-232
B	31	I	CAN4_H_TERM		CAN interface 4 bus termination (connect to B32)
B	32	I	CAN4_L_TERM		CAN interface 4 bus termination (connect to B31)
B	33	I	CAN3_L_TERM		CAN interface 3 bus termination (connect to B34)
B	34	I	CAN3_H_TERM		CAN interface 3 bus termination (connect to B33)
B	35	IO	CAN2_L		CAN interface 2 dominant low line

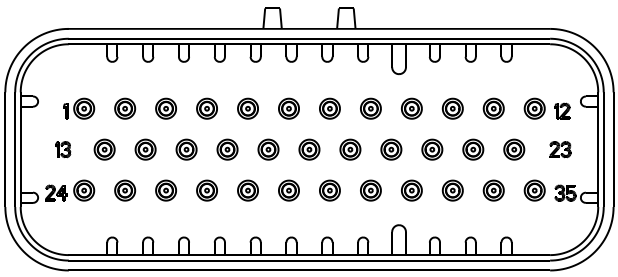


Figure 24- Connector B pinout

Table 72 – Connector C pinout (TEC172-001 / TEC172-002)

Connector C – TYCO AMPSEAL 1-776261-1 (BLACK) , TEC172-001 / TEC172-002					
Pin		**Dir**	**Function(s)**	**I/O Group**	**Notes**
C	1	PWR	$VBAT_{CL30}$		Power supply for logic and sensors
C	2	I	$VBAT_{CL15}$		Control input for logic power supply
C	3	GND(2	GND(2		Power Supply Ground
C	4	PWR(1	$VBAT_{DO}$		Power supply for outputs
C	5	PWR(1	$VBAT_{DO}$		Power supply for outputs
C	6	IO	CAN1_L		CAN interface 1 dominant low line
C	7	IO	CAN1_H		CAN interface 1 dominant high line
C	8	GND(2	GND(2		Power Supply Ground
C	9	PWR(1	$VBAT_{DO}$		Power supply for outputs
C	10	I	MOD_{ADDR-}		Module address resistor
C	11	I	MOD_{ADDR+}		Module address resistor
C	12	I	CAN1_L_TERM		CAN interface 1 bus termination (connect to C13)
C	13	I	CAN1_H_TERM		CAN interface 1 bus termination (connect to C12)
C	14	GND(2	GND(2		Power Supply Ground

1) *Several parallel pins are needed for output current rating, all pins must be connected*
2) *Several parallel pins are needed for output current rating, all pins must be connected*

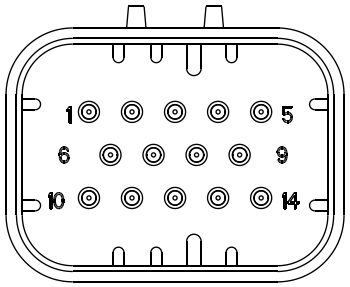


Figure 25- Connector C pinout

Table 73 – Connector D pinout (TEC172-001 / TEC172-002)

Connector D – TYCO AMPSEAL 776230-2 (WHITE) , TEC172-001 / TEC172-002					
Pin		Dir	Function(s)	I/O Group	Notes
D	1	O	$DO_{H2A5.2}$, $HB_{SDV.1}$	O_#1d	
D	2	O	$DO_{H2A5.2}$, $HB_{SDV.1}$	O_#1d	
D	3	O	$DO_{H2A5.1}$	O_#1a	
D	4	O	$DO_{H2A5.1}$	O_#1a	
D	5	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	6	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	7	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	8	I	$DI_{H/L.2}$, $AI_{10V.2}$	I_#8	
D	9	I	$DI_{H/L.2}$, $AI_{10V.2}$	I_#8	
D	10	I	$DI_{H/L.2}$, $AI_{10V.2}$	I_#8	
D	11	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	12	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	13	O	$DO_{H2A5.2}$, $HB_{SDV.1}$	IO_#1d	
D	14	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	15	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	16	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	17	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	18	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	19	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	20	I	$DI_{H/L.2}$, $AI_{10V.2}$	I_#8	
D	21		$GND_{DO/DI}$		Ground for digital outputs / inputs / SDV
D	22		$GND_{DO/DI}$		Ground for digital outputs / inputs
D	23	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	24	O	$DO_{H2A5.2}$, $HB_{SDV.1}$	O_#1d	
D	25	O	$DO_{H2A5.2}$	O_#1c	
D	26	O	$DO_{H2A5.2}$	O_#1c	
D	27	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	28	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	29	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	30	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	31	O	$DO_{H2A5.2}$	O_#1c	
D	32	O	$DO_{H2A5.2}$	O_#1c	
D	33	O	$DO_{H2A5.2}$	O_#1c	
D	34	O	$DO_{H2A5.2}$	O_#1c	
D	35	O	$DO_{H5A.1}$	O_#3	

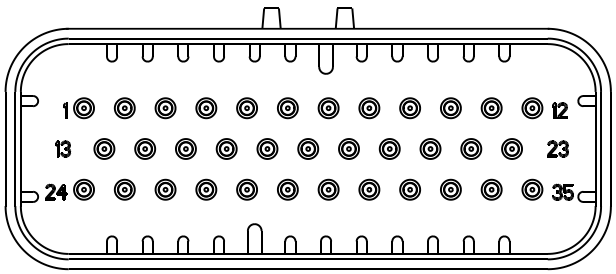


Figure 26- Connector D pinout

Table 74 – Connector E pinout (TEC172-001 / TEC172-002)

Connector E – TYCO AMPSEAL 776230-1 (BLACK) , TEC172-001 / TEC172-002					
Pin		**Dir**	**Function(s)**	**I/O Group**	**Notes**
E	1	O	$DO_{H2A5.1}$	O_#1a	
E	2	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	3	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	4	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	5	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	6	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	7	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	8	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	9	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	10		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	11	O	$DO_{H2A5.1}$, $HB_{M.1}$	O_#1b	Motor2+ (in DC-motor configuration)
E	12	O	$DO_{H2A5.1}$, $HB_{M.1}$	O_#1b	Motor2- (in DC-motor configuration)
E	13	O	$DO_{H2A5.1}$	O_#1a	
E	14	O	$DO_{H2A5.1}$	O_#1a	
E	15	O	$DO_{H2A5.1}$	O_#1a	
E	16		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	17		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	18		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	19		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	20		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	21		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	22		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	23	O	$DO_{H2A5.1}$, $HB_{M.1}$	O_#1b	Motor1- (in DC-motor configuration)
E	24	O	$DO_{H5A.1}$	O_#3	
E	25	O	$DO_{H5A.1}$	O_#3	
E	26	O	$DO_{H5A.1}$	O_#3	
E	27	O	$DO_{H5A.1}$	O_#3	
E	28	O	$DO_{H5A.1}$	O_#3	
E	29	O	$DO_{H5A.1}$	O_#3	
E	30	O	$DO_{H5A.1}$	O_#3	
E	31	O	$DO_{H2A5.1}$	O_#1a	
E	32	O	$DO_{H2A5.1}$	O_#1a	
E	33	O	$DO_{H2A5.1}$	O_#1a	
E	34	O	$DO_{H2A5.1}$	O_#1a	
E	35	O	$DO_{H2A5.1}$, $HB_{M.1}$	O_#1b	Motor1+ (in DC-motor configuration)

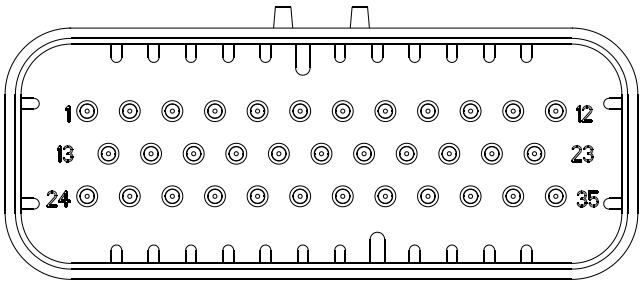


Figure 27- Connector E pinout

8.3 Main connectors pin map (TEC172-003 / TEC172-004)

Table 75 – Connector A pinout (TEC172-003 / TEC172-004)

Connector A – TYCO AMPSEAL 776230-5 (BLUE), TEC172-003 / TEC172-004					
Pin		Dir	Function(s)	I/O Group	Notes
A	1	O	$VOUT_{12V.1}$	O_#6	+12V output
A	2	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $AI_{1k5.1}$, $DI_{H.1}$	I_#4a	High precision analog input
A	3	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $AI_{1k5.1}$, $DI_{H.1}$	I_#4a	High precision analog input
A	4	O	$VREF_{5V.1}$, $VREF_{10V.1}$	O_#5	5V/10V reference output
A	5	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	6	O	$VREF_{5V.1}$, $VREF_{10V.1}$	O_#5	5V/10V reference output
A	7	O	$VREF_{5V.1}$, $VREF_{10V.1}$	O_#5	5V/10V reference output
A	8	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	9	O	$VREF_{5V.1}$, $VREF_{10V.1}$	O_#5	5V/10V reference output
A	10	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	11	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	12	O	$VOUT_{12V.1}$	O_#6	+12V output
A	13	O	$VOUT_{12V.1}$	O_#6	+12V output
A	14	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $AI_{1k5.1}$, $DI_{H.1}$	I_#4a	High precision analog input
A	15		GND_{AI}		Analog ground
A	16	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $AI_{1k5.1}$, $DI_{H.1}$	I_#4a	High precision analog input
A	17	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	18		GND_{AI}		Analog ground
A	19		GND_{AI}		Analog ground
A	20	I	$AI_{5V.1}$, $AI_{10V.1}$, $AI_{20mA.1}$, $DI_{H.1}$	I_#4b	High precision analog input
A	21		GND_{AI}		Analog ground
A	22		GND_{AI}		Analog ground
A	23	O	$VOUT_{12V.1}$	O_#6	+12V output
A	24	O	$AO_{5V.1}$	O_#9	0-5V analog output
A	25		GND_{AO}		Analog ground
A	26		GND_{AI}		Analog ground
A	27		GND_{AI}		Analog ground
A	28		GND_{AI}		Analog ground
A	29		GND_{AI}		Analog ground
A	30		GND_{AI}		Analog ground
A	31		GND_{DI}		Ground for digital inputs
A	32		GND_{VOUT}		Sensor power supply ground
A	33		GND_{VOUT}		Sensor power supply ground
A	34	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	Digital/Analog input
A	35	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	Digital/Analog input

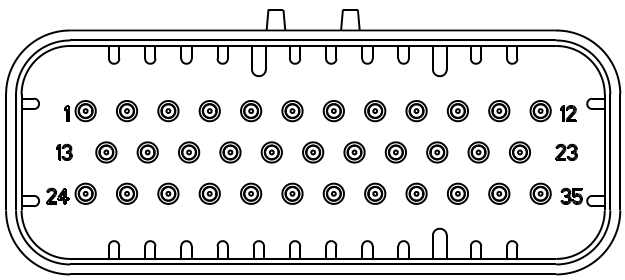


Figure 28- Connector A pinout

Table 76 – Connector B pinout (TEC172-003 / TEC172-004)

Connector B – TYCO AMPSEAL 776230-4 (GREY) , TEC172-003 / TEC172-004					
Pin		**Dir**	**Function(s)**	**I/O Group**	**Notes**
B	1	I	$FI1_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	2	I	$FI3_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	3	I	$FI4_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	4	I	$FI6_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	5		GND_{FI}	-	Ground signal for FI_H
B	6	I	$FI9_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	7	O	TXD		RS-232 transmit signal
B	8	IO	RS485+		RS-485 TxD/RxD non-inverting
B	9	IO	CAN4_L		CAN interface 4 dominant low line
B	10	IO	CAN3_L		CAN interface 3 dominant low line
B	11	I	CAN2_L_TERM		CAN interface 2 bus termination (connect to B23)
B	12	IO	CAN2_H		CAN interface 2 dominant high line
B	13		GND_{FI}	I_#7	Ground signal for FI_H
B	14	I	$FI2_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	15	I	$FI5_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	16	I	$FI7_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	17	I	$FI8_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	18	I	$FI10_{H.1}$, $AI_{10V.3}$, $DI_{H.3}$	I_#7	Frequency/pulse, analog or digital input
B	19	I	RXD		RS-232 receive signal
B	20	IO	RS485-		RS-485 TxD/RxD inverting
B	21	IO	CAN4_H		CAN interface 4 dominant high line
B	22	IO	CAN3_H		CAN interface 3 dominant high line
B	23	I	CAN2_H_TERM		CAN interface 2 bus termination (connect to B11)
B	24		GND_{FI}	I_#7	Ground signal for FI_H
B	25		GND_{FI}	I_#7	Ground signal for FI_H
B	26		GND_{FI}	I_#7	Ground signal for FI_H
B	27		GND_{FI}	I_#7	Ground signal for FI_H
B	28		GND_{FI}	I_#7	Ground signal for FI_H
B	29		GND_{FI}	I_#7	Ground signal for FI_H
B	30		GND_{RS232}		Ground signal for RS-232
B	31	I	CAN4_H_TERM		CAN interface 4 bus termination (connect to B32)
B	32	I	CAN4_L_TERM		CAN interface 4 bus termination (connect to B31)
B	33	I	CAN3_L_TERM		CAN interface 3 bus termination (connect to B34)
B	34	I	CAN3_H_TERM		CAN interface 3 bus termination (connect to B33)
B	35	IO	CAN2_L		CAN interface 2 dominant low line

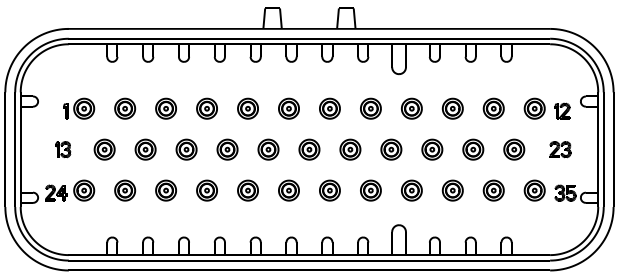


Figure 29- Connector B pinout

Table 77 – Connector C pinout (TEC172-003 / TEC172-004)

Connector C – TYCO AMPSEAL 1-776261-1 (BLACK) , TEC172-003 / TEC172-004					
Pin		Dir	Function(s)	I/O Group	Notes
C	1	PWR	$VBAT_{CL30}$		Power supply for logic and sensors
C	2	I	$VBAT_{CL15}$		Control input for logic power supply
C	3	GND(2	GND(2		Power Supply Ground
C	4	PWR(1	$VBAT_{DO}$		Power supply for outputs
C	5	PWR(1	$VBAT_{DO}$		Power supply for outputs
C	6	IO	CAN1_L		CAN interface 1 dominant low line
C	7	IO	CAN1_H		CAN interface 1 dominant high line
C	8	GND(2	GND(2		Power Supply Ground
C	9	PWR(1	$VBAT_{DO}$		Power supply for outputs
C	10	I	MOD_{ADDR-}		Module address resistor
C	11	I	MOD_{ADDR+}		Module address resistor
C	12	I	CAN1_L_TERM		CAN interface 1 bus termination (connect to C13)
C	13	I	CAN1_H_TERM		CAN interface 1 bus termination (connect to C12)
C	14	GND(2	GND(2		Power Supply Ground

1) *Several parallel pins are needed for output current rating, all pins must be connected*
2) *Several parallel pins are needed for output current rating, all pins must be connected*

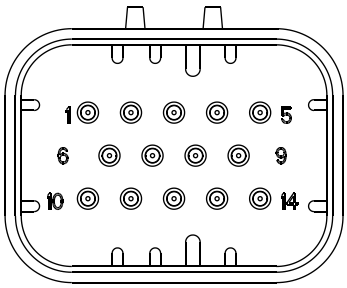


Figure 30- Connector C pinout

Table 78 – Connector D pinout (TEC172-003 / TEC172-004)

Connector D – TYCO AMPSEAL 776230-2 (WHITE) , TEC172-003 / TEC172-004					
Pin		Dir	Function(s)	I/O Group	Notes
D	1	O	$DO_{H2A5.2}$, $HB_{SDV.1}$	O_#1d	
D	2	O	$DO_{H2A5.2}$, $HB_{SDV.1}$	O_#1d	
D	3	O	$DO_{H2A5.1}$	O_#1a	
D	4	O	$DO_{H2A5.1}$	O_#1a	
D	5	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	6	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	7	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	8	I	$DI_{H/L.2}$, $AI_{10V.2}$	I_#8	
D	9	I	$DI_{H/L.2}$, $AI_{10V.2}$	I_#8	
D	10	I	$DI_{H/L.2}$, $AI_{10V.2}$	I_#8	
D	11	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	12	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	13	O	$DO_{H2A5.2}$, $HB_{SDV.1}$	IO_#1d	
D	14	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	15	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	16	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	17	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	18	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	19	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	20	I	$DI_{H/L.2}$, $AI_{10V.2}$	I_#8	
D	21		$GND_{DO/DI}$		Ground for digital outputs / inputs / SDV
D	22		$GND_{DO/DI}$		Ground for digital outputs / inputs
D	23	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
D	24	O	$DO_{H2A5.2}$, $HB_{SDV.1}$	O_#1d	
D	25	O	$DO_{H2A5.2}$	O_#1c	
D	26	O	$DO_{H2A5.2}$	O_#1c	
D	27	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	28	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	29	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	30	I	$DI_{H.2}$, $AI_{10V.2}$	I_#8	
D	31	O	$DO_{H2A5.2}$	O_#1c	
D	32	O	$DO_{H2A5.2}$	O_#1c	
D	33	O	$DO_{H2A5.2}$	O_#1c	
D	34	O	$DO_{H2A5.2}$	O_#1c	
D	35	O	$DO_{H5A.1}$	O_#3	

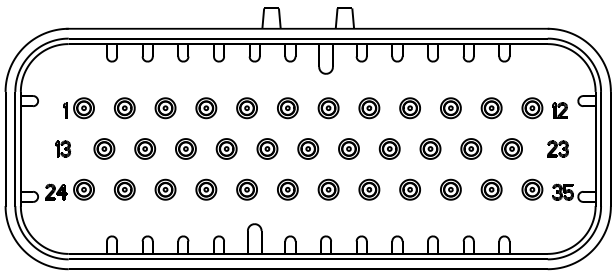


Figure 31- Connector D pinout

Table 79 – Connector E pinout (TEC172-003 / TEC172-004)

Connector E – TYCO AMPSEAL 776230-1 (BLACK) , TEC172-003 / TEC172-004					
Pin		**Dir**	**Function(s)**	**I/O Group**	**Notes**
E	1	O	$DO_{H2A5.1}$	O_#1a	
E	2	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	3	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	4	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	5	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	6	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	7	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	8	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	9	IO	$DO_{L\_RET1A/2A.1}$, $DO_{L.1}$	IO_#2	
E	10		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	11	O	$DO_{H2A5.1}$, $HB_{M.1}$	O_#1b	Motor2+ (in DC-motor configuration)
E	12	O	$DO_{H2A5.1}$, $HB_{M.1}$	O_#1b	Motor2- (in DC-motor configuration)
E	13	O	$DO_{H2A5.1}$	O_#1a	
E	14	O	$DO_{H2A5.1}$	O_#1a	
E	15	O	$DO_{H2A5.1}$	O_#1a	
E	16		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	17		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	18		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	19		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	20		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	21		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	22		$GND_{DO/DI}$		Ground for digital outputs / inputs
E	23	O	$DO_{H2A5.1}$, $HB_{M.1}$	O_#1b	Motor1- (in DC-motor configuration)
E	24	O	$DO_{H5A.1}$	O_#3	
E	25	O	$DO_{H5A.1}$	O_#3	
E	26	O	$DO_{H5A.1}$	O_#3	
E	27	O	$DO_{H5A.1}$	O_#3	
E	28	O	$DO_{H5A.1}$	O_#3	
E	29	O	$DO_{H5A.1}$	O_#3	
E	30	O	$DO_{H5A.1}$	O_#3	
E	31	O	$DO_{H2A5.1}$	O_#1a	
E	32	O	$DO_{H2A5.1}$	O_#1a	
E	33	O	$DO_{H2A5.1}$	O_#1a	
E	34	O	$DO_{H2A5.1}$	O_#1a	
E	35	O	$DO_{H2A5.1}$, $HB_{M.1}$	O_#1b	Motor1+ (in DC-motor configuration)

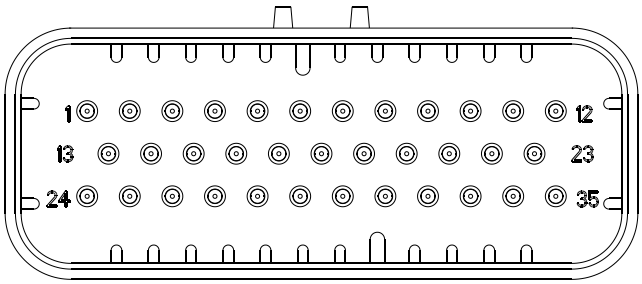


Figure 32- Connector E pinout

8.4 Ethernet M12 (Female, D-coded)

Table 80 – Connector F pinout

Connector F – M-12 D-CODED (female)					
Pin		**Dir**	**Function(s)**	**Spec / type**	**Notes**
F	1	O	$ETH1_{TX+}$		Transmit data +
F	2	I	$ETH1_{RX+}$		Receive data +
F	3	O	$ETH1_{TX-}$		Transmit data -
F	4	I	$ETH1_{RX-}$		Receive data -
F			Shield		Connector body is connected to module enclosure

Table 81 – Connector G pinout

Connector G – M-12 D-CODED (female)					
Pin		**Dir**	**Function(s)**	**Spec / type**	**Notes**
G	1	O	$ETH2_{TX+}$		Transmit data +
G	2	I	$ETH2_{RX+}$		Receive data +
G	3	O	$ETH2_{TX-}$		Transmit data -
G	4	I	$ETH2_{RX-}$		Receive data -
G			Shield		Connector body is connected to module enclosure

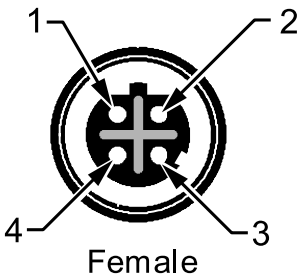
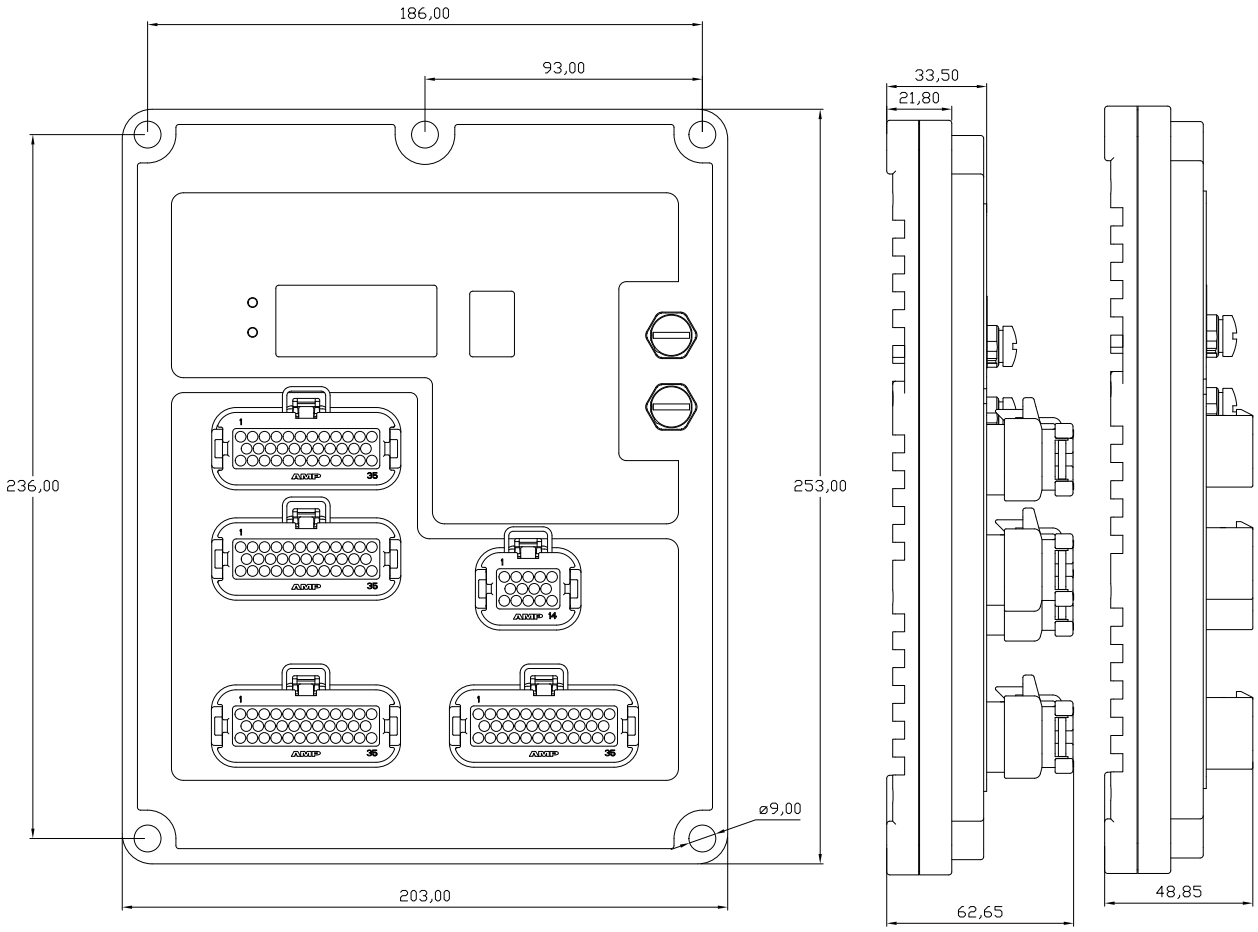


Figure 33 – Ethernet connector pin numbering from front view of the connector

9 Mechanical drawings

All measurements in millimeters (mm).



10 Software environment

User applications for TEC172 are developed as IEC 61131-3 applications, using CODESYS V3 programming environment. By default, CAN1 is used as development port for communication between the module and the development PC. The CODESYS tool is compatible with USB-to-CAN interfaces provided by Kvaser and PEAK-System Technik. The firmware of TEC172 supporting development of user applications consists of the Boot loader and the System software.

10.1 Boot loader

The boot loader is the first program running after power-up of the device, and it provides facilities for updating the system software and user application over CAN using CANopen-based download protocol. Technion offers a software tool for Windows-based PCs for performing the download. The software tool is compatible with USB-to-CAN interfaces provided by Kvaser and PEAK-System Technik.

10.2 System software

The system software of TEC172 manages the I/O features of the module, and implements CODESYS V3 Runtime System, necessary for creating user applications with CODESYS. Main features provided by the runtime system for application development are:

- On-line monitoring and writing of application variables
- Pre-emptive multitasking scheduler for application tasks
- Exception processing for handling application programming errors
- Support for CAN interfaces
- Support for Ethernet Socket interface
- Support for file access on data flash
- Support for RS232/485 interfaces
- Retain variables support
- Support for configuring all analog and digital I/O interfaces of TEC172

Documentation on how to access these features can be found in built-in help system of CODESYS.

11 Reference documents

Item	Document name	Description	Rev
[1]	Technical Report: The Tin Command-ments:Guidelines For The Use Of Tin On Connector Contacts, AMP Incorporated	http://www.te.com/documentation/whitepapers/pdf/sncomrep.pdf	7/31/96
[2]	Technical Report: Golden Rules: Guide-lines For The Use Of Gold On Connector Contacts, AMP Incorporated	http://www.te.com/documentation/whitepapers/pdf/aurulrep.pdf	7/29/96

12 Version History

Version	Date	Description	Author	Approval
1.4	29.1.2015	Technical manual initial public release	TA,TS	AP