Contents

1 General Description

1.1 Introduction

TTC 50 is a family of programmable electronic control units for sensor/actuator management. Many configurable I/Os allow its use with different sensor and actuator types. The control unit is part of a complete and compatible product family and designed specifically for vehicles and machines that function in rough environments and at extreme operating temperatures. Its robust die-cast aluminum housing protects against electromagnetic disturbance and mechanical stress.
An 80 MHz Infineon XC2287 integrated microprocessor provides the necessary processing power.

The TTC 50 family consists of the following variants:

- TTC 90: designed to fulfill safety requirements according to IEC 61508 SIL2 and ISO 13849 PL d
- TTC 60
- TTC 50

This document applies to all available variants TTC 50, TTC 60 and TTC 90. Throughout this document, any reference to TTC 50 includes all family members TTC 50, TTC 60 and TTC 90. Wherever specifications are not applicable for all variants, the differences are pointed out within this document.

1.2 Interfaces and I/Os

All TTC 50 inputs and outputs are protected against electrical surges and short circuits. In addition, internal safety measures allow the detection of open load, overload and short circuit conditions at the outputs.
Proportional hydraulic components can be connected directly to the current controlled PWM outputs.
The TTC 50 family is designed to support various analog and digital sensor types. Many SW-configurable input options can be selected to adapt to different sensor types.
The widely used group of individually configurable analog inputs, well known from TTC 200, is also supported by TTC 50. Additionally a group of analog inputs with voltage range from 0..5V to 0..32V is provided that can be set to different voltage ranges by software for achieving best analog accuracy and resolution.
The interfaces CAN, RS-232 and LIN are available for serial communication.

1.3 Safety and Certification

The variant TTC 90 was designed to comply with the IEC 61508 and ISO13849 international standards. The ECU fulfils SIL 2 (Safety Integrity Level) and PL d requirements respectively.

The requirements in the Safety Manual shall be followed if the TTC 90 is used in safety-critical applications.

1.4 Advanced Programming Possibilities

The unit may be programmed in C or CoDeSys. CoDeSys is one of the most common IEC 61131-3 programming systems that runs under Microsoft Windows®. Several editors are supported, including the Instruction List Editor, the Sequential Function Chart Editor and the Function Block Diagram Editor. CoDeSys produces native machine code for the main processor of TTC 50.

1.5 Features

System CPU

- XC2287 (XE167 family), 80MHz, 768KB internal Flash, 64kB int. + 512kB ext. RAM; 16 kBit EEPROM
- Watchdog CPU - 68HC908
- 1 x RS232 (1200-115200Bd), 1 x LIN (1200Bd – 20000Bd)
- 2 x CAN, 125 to 1000 kbit/s

Power supply

- Supply voltage: 9 to 32 V
- CPU operates down to 4V battery supply during cranking
- Load dump protection (max. steady state supply voltage 35V)
- Low current consumption: 0.15 A at 9 V
- 1 x (8.5 or 10 or 15V / 50mA) sensor supply, voltage selected by software
- 2 x (5V / 50mA) sensor supply
- Board temperature, sensor supply and battery monitoring

Inputs

- 8 x analog in 0 to 5 V or 0 to 20 mA or input for resistive sensors, 10 bit resolution, configured by software (individual setting per input)
- 8 x analog / digital in range selectable, 10 bit resolution,
  range settings 0 to 5V, 0 to 10V, 0 to 15V, 0 to 20V, 0 to 25V, 0 to 30V and 0 to 32V with full 10 bit resolution, voltage selectable by software in groups of 4 inputs
- 4 x digital in (4 counter 10 to 10.000 Hz) supporting sensors with different output stages (push pull, open collector, active high or low) as well as 7/14mA current loop (ABS-type) sensors
- 8 x digital in

Outputs

- 8 x digital out 2.0 A, PWM, short-circuit and open load detection
- current control loop for 4 PWM outputs
- internal safety switch for all 2A PWM outputs
- 8 x digital out 4 A, short-circuit and open load detection

Specifications

- Dimensions: 181 x 174 x 44 mm (with mounted connector)
- Weight: 550 g
- Ambient temperature: -40 °C to +85 °C
- IP67 rated die-cast aluminum housing and 80 pin connector
- Pressure adjusting with water barrier
- Operating altitude: 0 to 4000 m

2 Pin connection

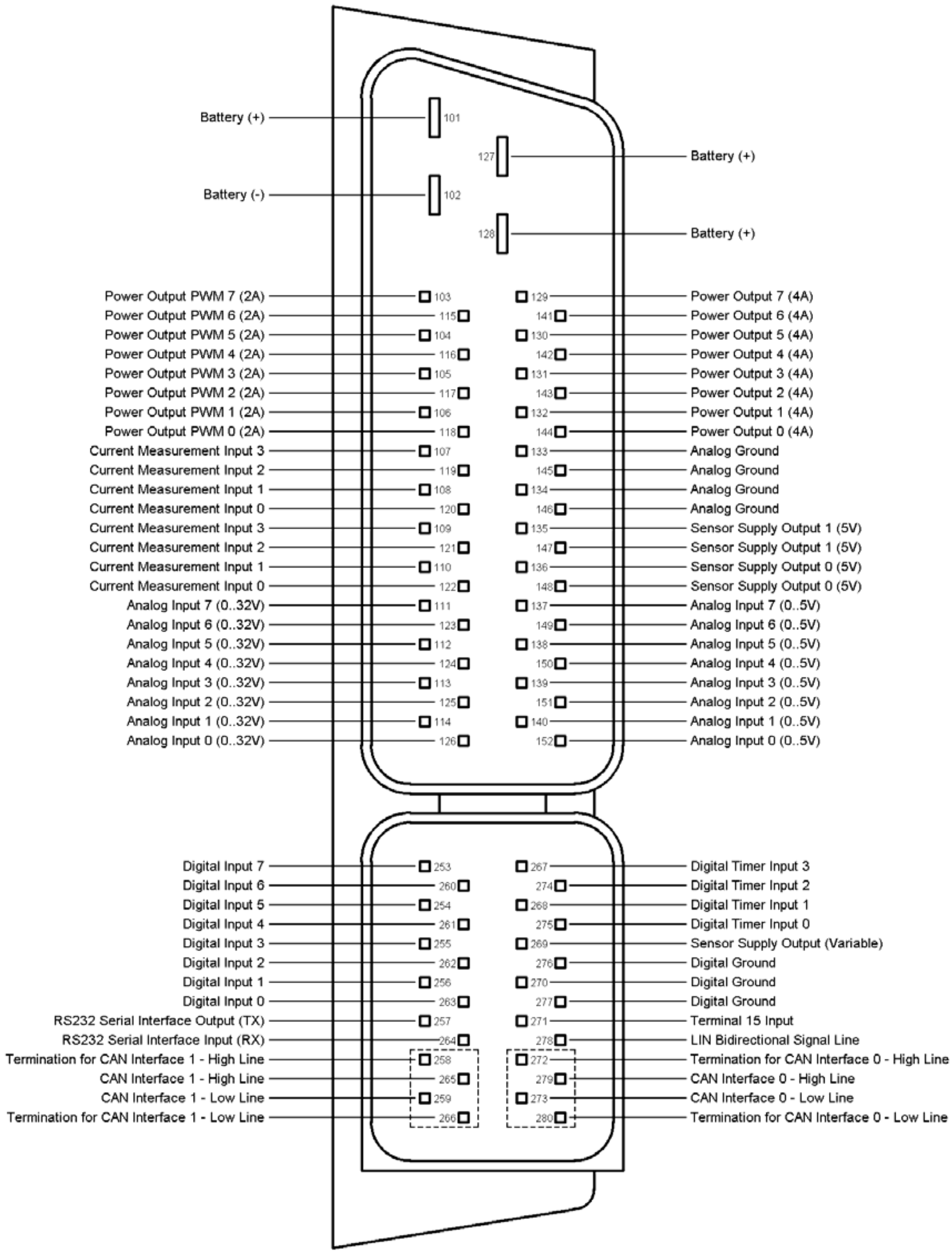


Figure 1: Connector front view

2.1 Pin connection part 1

Connector Pin Number	Pin description
P101	Battery (+) Supply Input for Internal Electronics
P102	Battery (-) Supply Input
P103	Power Output PWM 7 (2A)
P104	Power Output PWM 5 (2A)
P105	Power Output PWM 3 (2A)
P106	Power Output PWM 1 (2A)
P107	Current Measurement Input 3
P108	Current Measurement Input 1
P109	Current Measurement Input 3
P110	Current Measurement Input 1
P111	Analog Input 7 (0..32V)
P112	Analog Input 5 (0..32V)
P113	Analog Input 3 (0..32V)
P114	Analog Input 1 (0..32V)
P115	Power Output PWM 6 (2A)
P116	Power Output PWM 4 (2A)
P117	Power Output PWM 2 (2A)
P118	Power Output PWM 0 (2A)
P119	Current Measurement Input 2
P120	Current Measurement Input 0
P121	Current Measurement Input 2
P122	Current Measurement Input 0
P123	Analog Input 6 (0..32V)
P124	Analog Input 4 (0..32V)
P125	Analog Input 2 (0..32V)
P126	Analog Input 0 (0..32V)
P127	Battery (+) Supply Input for Power Stages
P128	Battery (+) Supply Input for Power Stages
P129	Power Output 7 (4A)
P130	Power Output 5 (4A)
P131	Power Output 3 (4A)
P132	Power Output 1 (4A)
P133	Analog Ground
P134	Analog Ground
P135	Sensor Supply Output 1 (5V)
P136	Sensor Supply Output 0 (5V)
P137	Analog Input 7 (0..5V)
P138	Analog Input 5 (0..5V)
P139	Analog Input 3 (0..5V)
P140	Analog Input 1 (0..5V)

P141	Power Output 6 (4A)
P142	Power Output 4 (4A)
P143	Power Output 2 (4A)
P144	Power Output 0 (4A)
P145	Analog Ground
P146	Analog Ground
P147	Sensor Supply Output 1 (5V)
P148	Sensor Supply Output 0 (5V)
P149	Analog Input 6 (0..5V)
P150	Analog Input 4 (0..5V)
P151	Analog Input 2 (0..5V)
P152	Analog Input 0 (0..5V)

2.2 Pin connection part 2

Connector Pin Number	Pin description
P253	Digital Input 7
P254	Digital Input 5
P255	Digital Input 3
P256	Digital Input 1
P257	RS232 Serial Interface Output (TX)
P258	Termination for CAN Interface 1 – High Line
P259	CAN Interface 1 – Low Line
P260	Digital Input 6
P261	Digital Input 4
P262	Digital Input 2
P263	Digital Input 0
P264	RS232 Serial Interface Input (RX)
P265	CAN Interface 1 – High Line
P266	Termination for CAN Interface 1 – Low Line
P267	Digital Timer Input 3
P268	Digital Timer Input 1
P269	Sensor Supply Output (Variable)
P270	Digital Ground
P271	Terminal 15 Input
P272	Termination for CAN Interface 0 – High Line
P273	CAN Interface 0 – Low Line
P274	Digital Timer Input 2
P275	Digital Timer Input 0
P276	Digital Ground
P277	Digital Ground
P278	LIN Bidirectional Signal Line
P279	CAN Interface 0 – High Line
P280	Termination for CAN Interface 0 – Low Line

3 Block Diagram

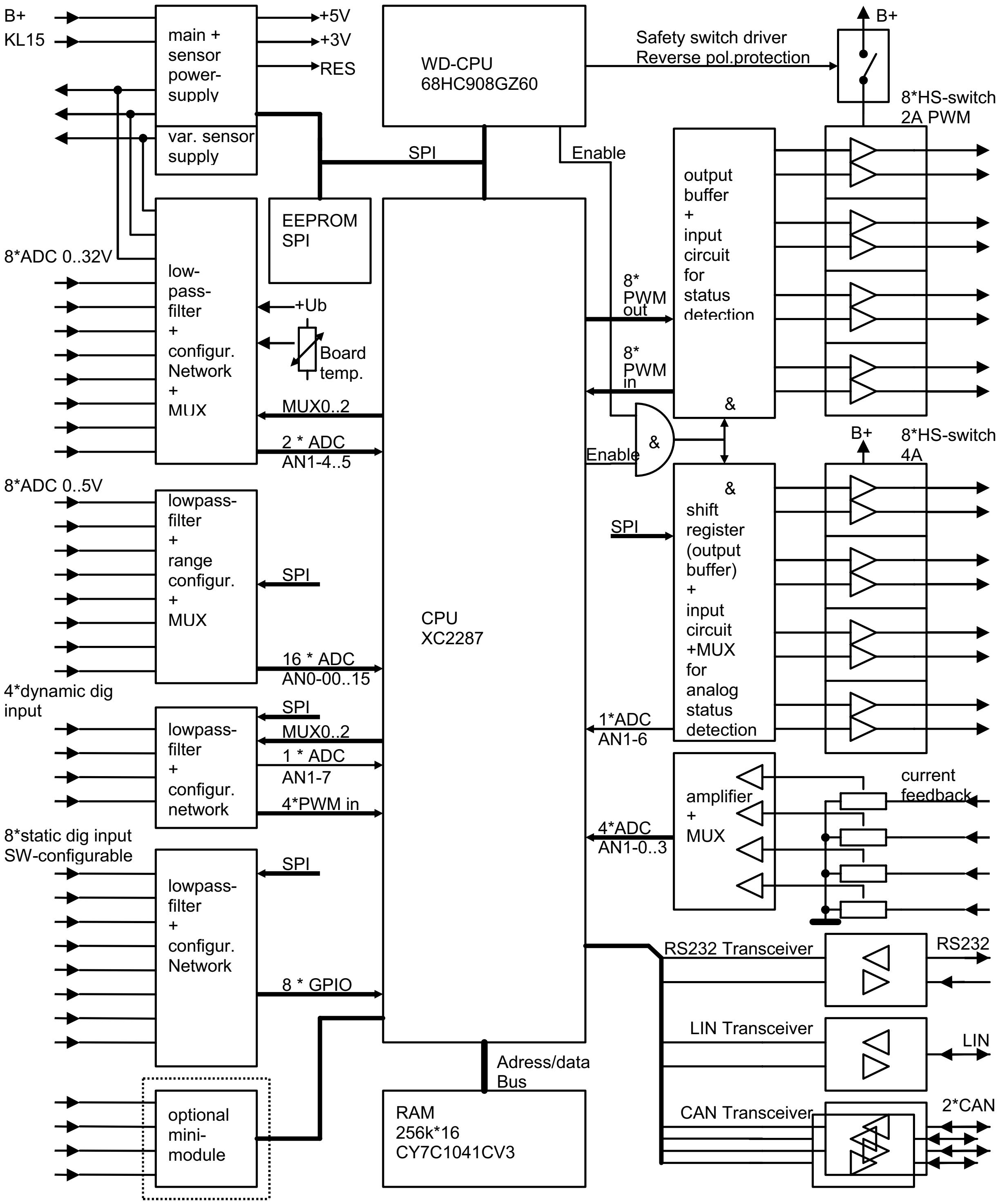
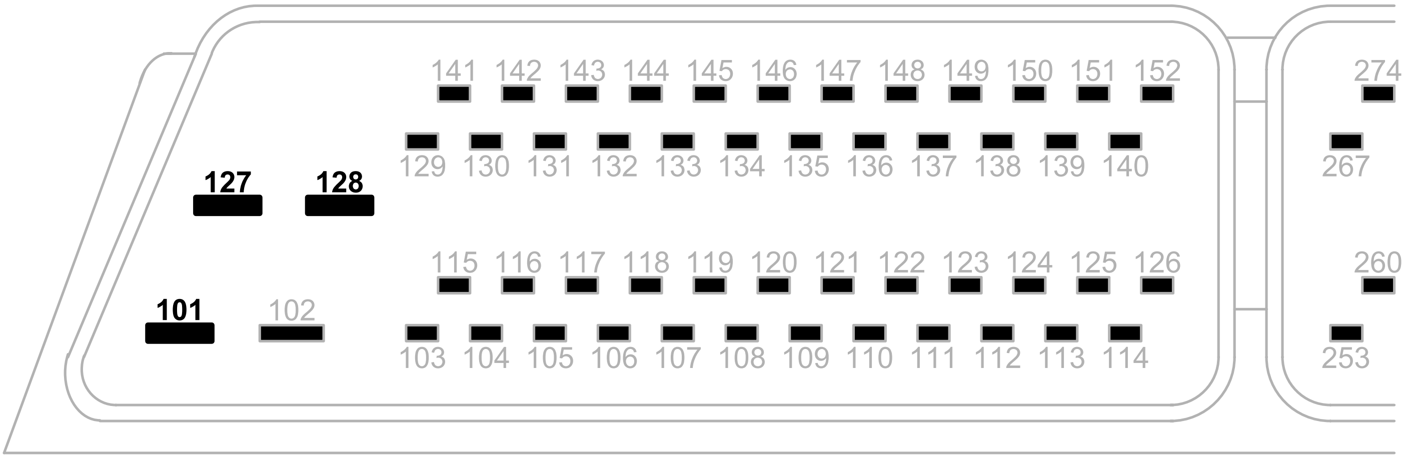


Figure 2: Block diagram

4 Specification of Inputs and Outputs

4.1 Positive power supply (BAT+

4.1.1 Pinout:



Connector Pin Number	Function
P101	Battery (+) Supply Input for Internal Electronics
P127	Battery (+) Supply Input for Power Stages
P128	Battery (+) Supply Input for Power Stages

4.1.2 Functional description:

Supply pins for positive supply.
One power pin to be used for supplying the internal electronics.
Two power pins to be used in parallel with 2.5mm² wires for total supply current of up to 30A.
For operation at least pin 101 and one of the pins 127 or 128 have to be connected. If the total load current of the power stages exceeds 17A both pins for power stage supply have to be used.
Nominal supply voltage for full operation is 9 .. 32V, including both supply voltage ranges for 12 and 24V battery operation. In this voltage range all I/Os work according to the user manual. For the Variable Senor Supply there is a different supply voltage spec. Transients exceeding this voltage range are suppressed up to the non-destructive limits found in the maximum ratings.
For 12V systems there is an option for operation during cranking. The CPU is working down to 4V battery supply (voltage drop until the starter motor makes its first turns, described in IS6736 Part1 for 12V systems). For safety reasons this function is limited to 1 second.

4.1.3 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Ratings for Pin 101, 127 and 128

Symbol	Parameter	Note	min	max	Units
U_{in-max}	permanent none-destructive supply voltage		-32	32	V
U_{in-lim}	peak none-destructive supply clamping voltage	1	-40	45	V
I_{in-lim}	peak none-destructive supply clamping current	1	-10	+100	A
T_d	Load dump protection according to ISO7636-2, Pulse 5, Level IV (superimposed 174V, R_i=2Ω)	1		350	ms

Ratings for Pin 127 and 128 only

$I_{in-max\_}$	Permanent input current (Pins 127 and 128 in parallel with symmetrical wire connection)			30	A
I_{in-max}	Permanent input current per pin			17	A

Note1: control unit is protected by transient suppressor diode, specified is clamp voltage, current and duration of voltage transient

4.1.4 Characteristics

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{in}	Capacitance load at input			500	µF
U_{in}	Supply voltage for full operation		9	32	V
U_{in}	Supply voltage for CPU operation		4	32	V
T_{crank}	Max. duration low battery voltage below 9V without CPU reset		1000		ms
$I_{in\text{-}idle}$	Supply current of unit without load	1		0.15	A
$I_{in\text{-}idle}$	Supply current of unit without load	2		0.11	A
$I_{in\text{-}idle}$	Supply current of unit without load	3		0.08	A
$I_{in\text{-}STBY}$	Standby supply current (KL15 off)	4		0.5	mA
$I_{in\text{-}STBY}$	Standby supply current (KL15 off)	5		1.0	mA

Note 1: at U_{Bat} = 9V
Note 2: at U_{Bat} = 12V
Note 3: at U_{Bat} = 24V
Note 4: at U_{Bat} = 27V / T_{ECU} = $T_{ambient}$ = -40°.. 85°C
These are worst case operating conditions during standby.
Note 5: at U_{Bat} = 32V / T_{ECU} = 85°.. 125°C
These are operating conditions during or immediately after switching to standby:
The battery voltage is higher than the maximum output voltage of the battery.
The ECU was internally heated up to an over temperature of 40K. After some minutes the ECU cools down and the internal temperature is equal to the ambient temperature (max. 85°C).

4.1.5 Voltage Monitoring

The battery voltage is connected to an ADC-input. Battery voltage measurement can be used for voltage compensation for PWM-controlled loads or for diagnostic purpose.
The input voltage is attenuated to a factor of 0.14826 (nom, or divided by 6.745) thus allowing voltage measurement up to 32.76V (nom.)

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{Out}	Scale factor (nom)	1	0.12466		
f_{g_LP}	Nominal battery supply range that can be measured	2	9	32.7	V
V_{Tol-M}	ADC voltage tolerance (of reading)	3	-4	+4	%
V_{Tol-0}	ADC voltage tolerance (offset)	3	-0.1	+0.1	V
f_{g_LP}	Cut off frequency of 1st order low pass filter	4	30	50	Hz

Note 1: 12V input voltage will be attenuated to 1.496 on the ADC input

Note 2: Low limit is given by minimum supply voltage of the ECU, high limit is full scale limit of ADC

Note 3: Total error is the sum of proportional error and zero reading error:

$$TUE = \pm \left| V_{Tol-M} * U_{Bat} \pm V_{Tol-0} \right|$$

Note 4: A low pass filter (1st order) is provided to remove glitches on the battery voltage from the ADC input

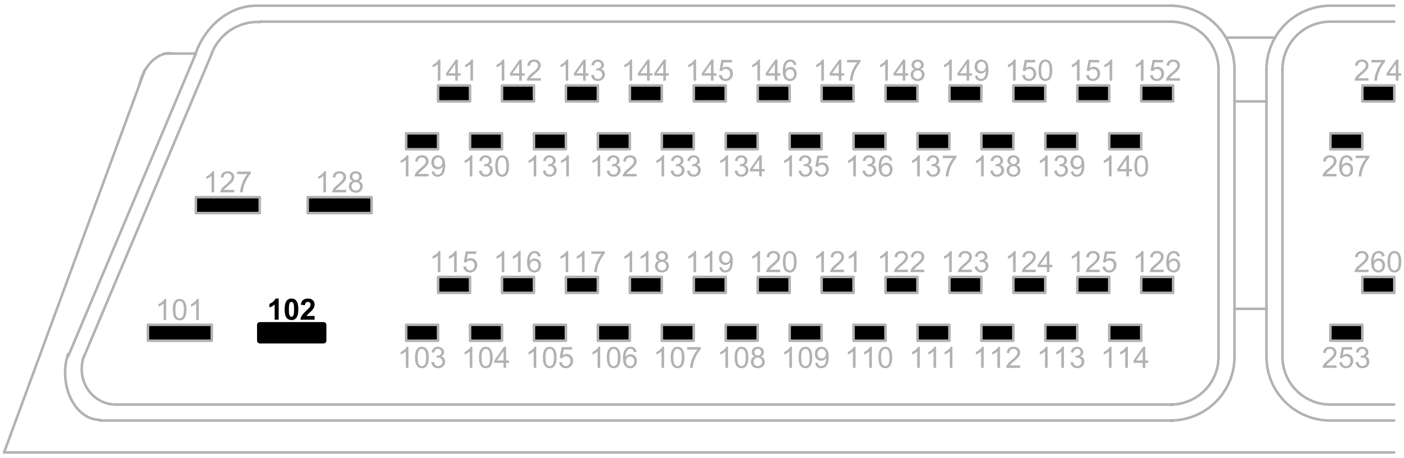
4.1.6 Wiring hints:

The ECU is limited to a total load current of 30A (maximum) for the power stages, connected to pins 127 and 128. When all loads are tied towards ground, the load current will be also carried by these supply pins. Each contact pin is thermally limited to 17A (maximum). 2 supply pins work in parallel for the power stages supply. So the system designer must be careful with the cable harness design to guarantee evenly distribution of supply current on all three pins.

Example: It is not ok to use one cable with a length of two meters and large diameter for a connection between a fuse box and the ECU and crimp it to 2 piggy tails with small diameter in the connector area. Small differences in the contact pressure can lead to a big imbalance. In worst case condition 1 contact carries most of the current load and is overloaded at maximum current. It is better to use 2 wires with the same total cross sectional area than this one thick cable. All wires must have exactly the same length and diameter. In this case an evenly distribution of current will be the case even with slightly different contact resistance.

4.2 Negative power supply (BAT-)

4.2.1 Pinout:



Connector Pin Number	Function
P102	Battery (-) Supply Input

4.2.2 Functional description:

Supply pin for negative supply.
Power pin to be used with 1.5mm² or 2.5mm² wires for total return current of 17A.

4.2.3 Maximum ratings

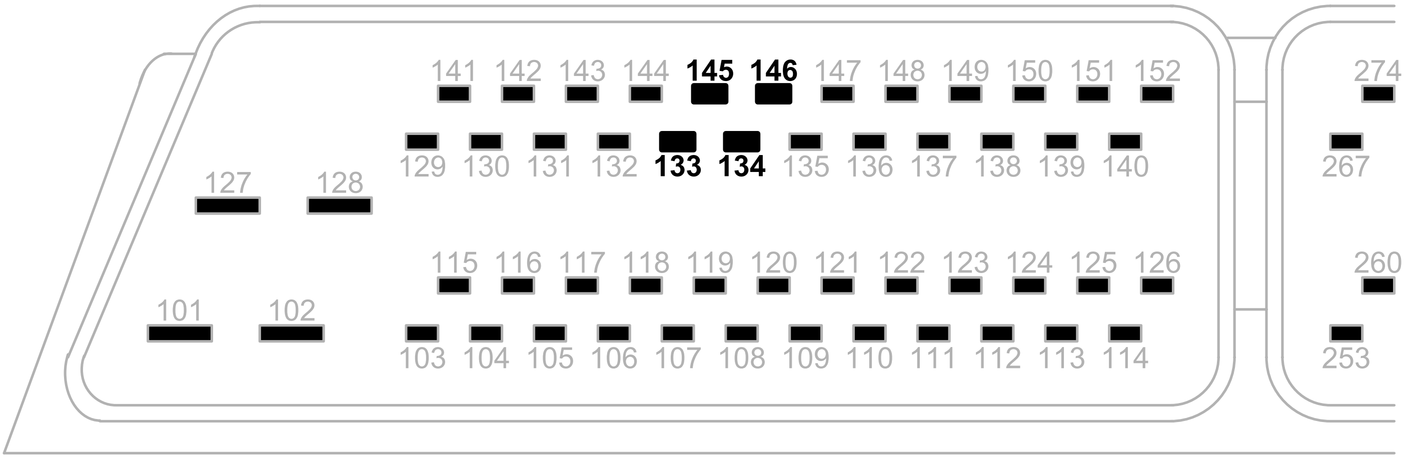
$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	Max	Units
$I_{in\text{-}max}$	Permanent supply current	1		17	A

Note 1: GND supply current in excess of 1A is produced by inductive loads during free wheeling. This is not a continues current but a pulsed current with a duty cycle. For high current values the duty cycle is smaller than 50%. Even with all PWM outputs on at rated current and 50% duty cycle the RMS value will be less than 10A. For calculation of voltage drops please observe the direction of the current. It is negative that means the voltage drop is negative, the over all supply voltage of the TTC50 is **increased** through this voltage drop.

4.3 GND Analog Ground

4.3.1 Pinout:



Connector Pin Number	Function
P133	Analog Ground
P134	Analog Ground
P145	Analog Ground
P146	Analog Ground

4.3.2 Functional description:

Supply pins for analog sensor GND connection.

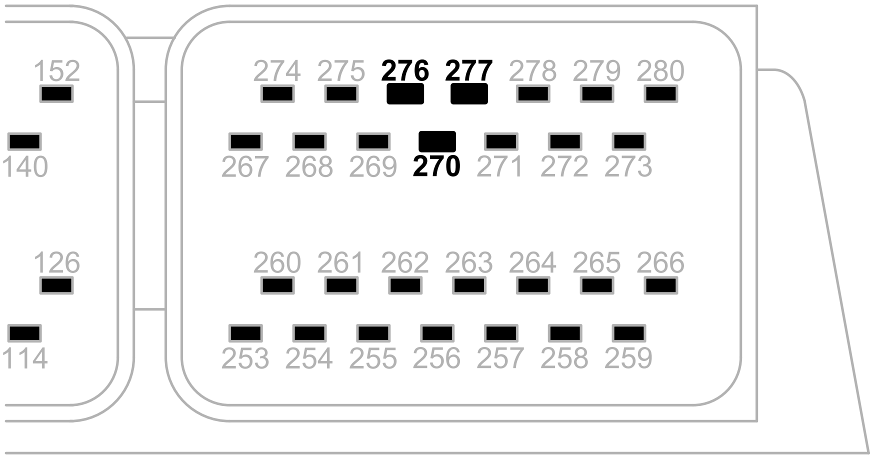
4.3.3 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
$I_{out-max}$	Permanent current per pin			2	A

4.4 GND Digital Ground

4.5 Pinout:



Connector Pin Number	Function
P270	Digital Ground
P276	Digital Ground
P277	Digital Ground

4.5.1 Functional description:

Supply pins for digital sensor GND connection or GND connections for switches.
Can be used as sensor supply GND or for light loads..

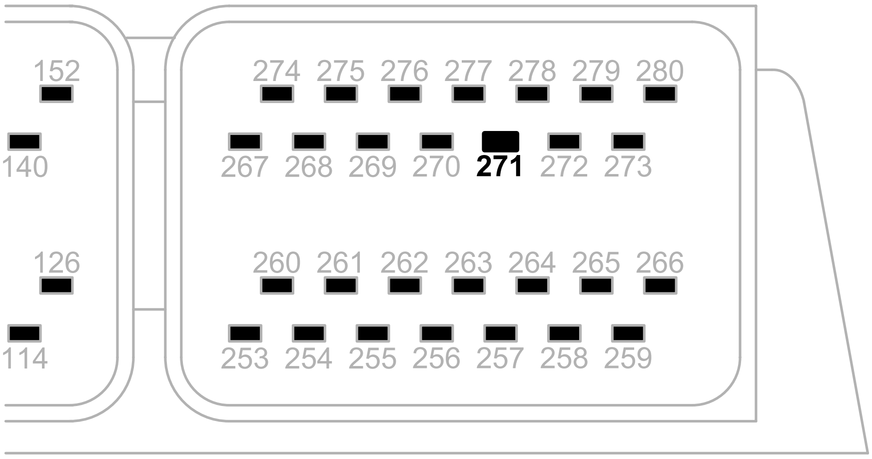
4.5.2 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
$I_{out-max}$	Permanent current per pin			2	A

4.6 Ignition on switch input / Terminal 15 (Klemme15)

4.6.1 Pinout:



Connector Pin Number	Function
P271	Terminal 15 Input

4.6.2 Functional description:

Only used for permanent supplied systems. When switched to positive supply, this input gives the command to power up the ECU. When switched off, the ECU performs activates its keep-alive functionality and switches off by software.
For systems with main power switch (not permanent supplied) this pin must be tied to the BAT+ pins (101, 127, 128).
This input can also be monitored via a digital input of the CPU.

4.6.3 Maximum ratings

T_{ambint} = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{in}	Permanent (DC) input voltage		-32	32	V
V_{in}	Transient peak input voltage 500ms		-50	50	V
V_{in}	Transient peak input voltage 1ms		-100	100	V

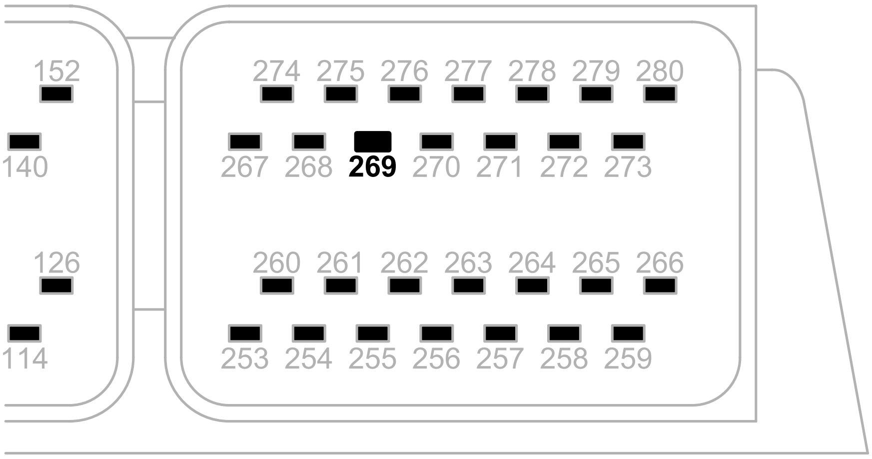
4.6.4 Characteristics

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		40	60	nF
R_{pu}	Pulldown resistor to GND		9.85	10.15	kΩ
V_{IL}	Input voltage for low level		-1	1.8	V
V_{IH}	Input voltage for high level		3.8	U_{Bat}	V
τ_{in}	Input low pass filter		0.4	0.6	ms

4.7 Variable Sensor supply

4.7.1 Pinout:



Connector Pin Number	Function
P269	Sensor Supply Output (Variable)

4.7.2 Functional description:

This sensor supply output is provided for sensors that operate at higher voltages than 5V. Examples are analog or digital current loop sensors that do not withstand direct connection to battery. In this case the sensor supply acts as voltage limiter.
The software can configure this output to one of the following nominal supply voltages:

- 8.5V
- 10.0V
- 14.5V

Typical sensors supplied with 14.5V are the current loop (ABS-type) speed sensors and analog transducers /e.g. pressure sensors) with current output.
The actual output voltage is read back by the ADC-unit for monitoring purposes.

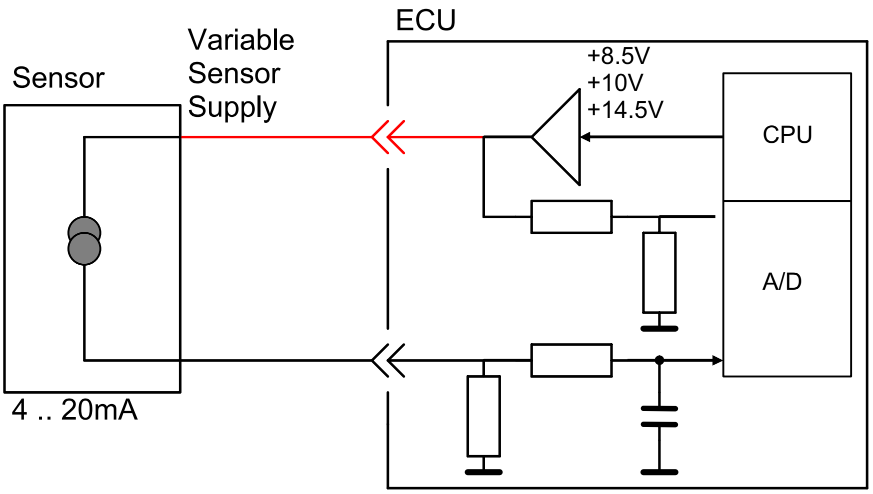


Figure 3: Variable sensor supply used for analog current loop sensor (4..20mA)

4.7.3 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{in}	Output voltage under overload conditions (i.e. short circuit to supply voltages)		-1	32	V

4.7.4 Characteristics

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{out}	Pin output capacitance		4	6	µF
V_{out}	Output voltage, at I_{load} and over $V_{Bat-min}$	1	8	9.2	V
V_{out}	Output voltage, at I_{load} and over $V_{Bat-min}$	2	9.4	10.8	V
V_{out}	Output voltage, at I_{load} and over $V_{Bat-min}$	3	13.8	15.2	V
$V_{Bat-min}$	Minimum voltage drop to allow nominal output voltage	4		0.3	V
I_{load}	Load current	5	0	30	mA
I_{load}	Load current 14.5V	6	0	40	mA

Note 1: Output setting to 8.5V
Note 2: Output setting to 10V
Note 3: Output setting to 14.5V
Note 4: This output is provided by a linear voltage regulator.
The battery voltage must be at lest 0.3V higher than the regulated output voltage.
Note 5: For all voltage settings and at highest supply voltage.
Note 6: For voltage setting to 14.5V and at highest supply voltage.

4.7.5 Sensor Supply Voltage Monitoring

$T_{ambient}$ = -40° .. 85°C

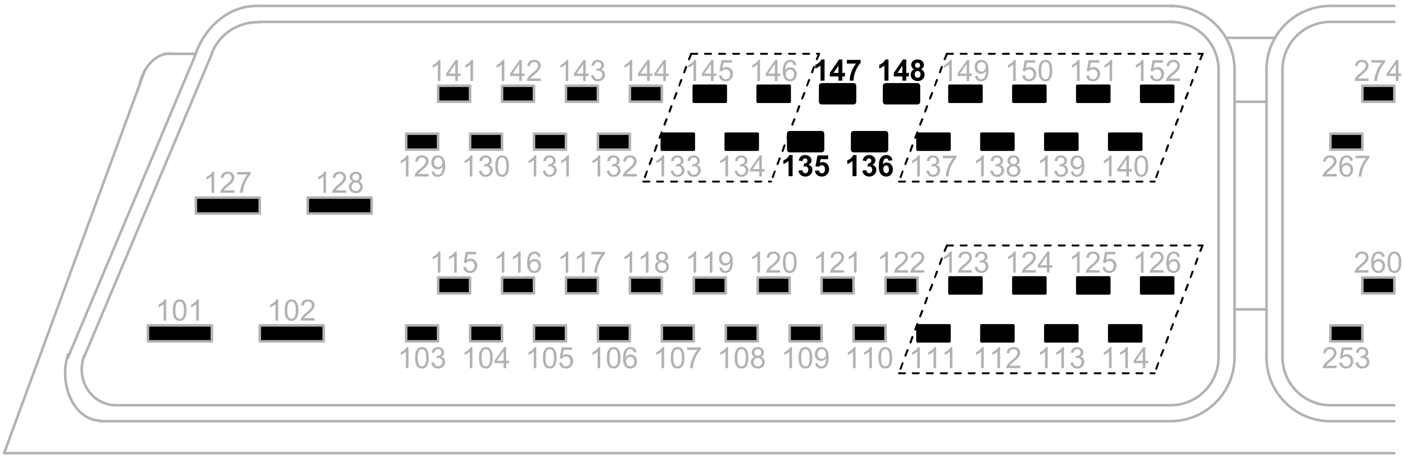
Symbol	Parameter	Note	min	max	Units
α_{UGEB}	Read back attenuation factor	1	0.3140	0.3236	
$V_{UG\text{-}SRC}$	Read back values normal operation 8.5V setting	2	2.462	3.037	V
$V_{UG\text{-}SRC}$	Read back values normal operation 10.0V setting	2	2.893	3.564	V
$V_{UG\text{-}SRC}$	Read back values normal operation 14.5V setting	2	4.247	4.990	V

Note 1: Supply is read back to allow ratiometric measurement. In order to guarantee that the read back input is always in the ADC operating range, an attenuating voltage divider (nom *0.3188) is inserted.

Note 2: Due to tolerances in the actual supply voltage of main- and sensor-supply the read back value may vary in the range specified.
Values outside this window indicate voltage failure in the sensor supply (short circuit or overload) and must set the sensor failure flag.

4.8 Sensor Supply 5V

4.8.1 Pinout:



Connector Pin Number	Function
P136	Sensor Supply Output 0 (5V)
P148	Sensor Supply Output 0 (5V)
P135	Sensor Supply Output 1 (5V)
P147	Sensor Supply Output 1 (5V)

4.8.2 Functional description:

Two independent sensor supplies are provided for 3-wire-sensors (i.e. potentiometers, pressure sensors etc.). For fully redundant sensors with 2 sensor supply connections both supplies must be connected to different sensor supplies.
Sensor Supply 1 is defined to be the redundant supply. For detecting short circuits between redundant analog inputs the sensor supply can be switched off by SW.

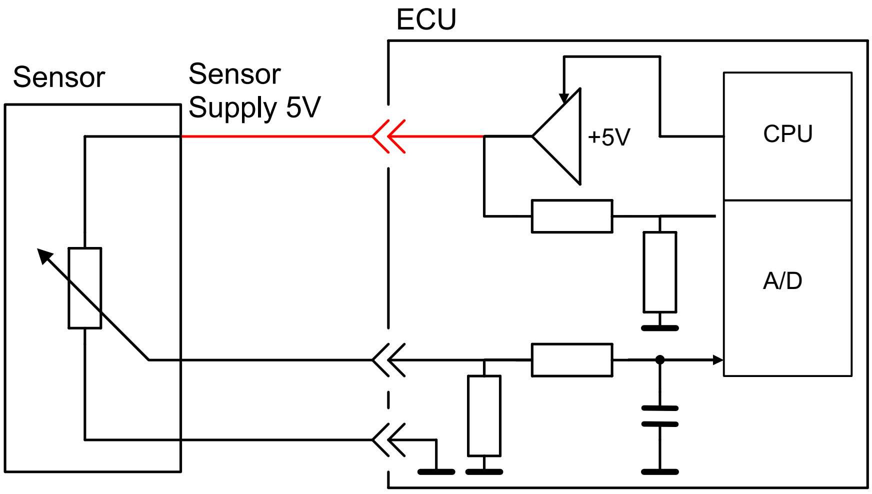


Figure 4: Sensor supply 5V

4.8.3 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{in}	Output voltage under overload conditions (i.e short circuit to supply voltages)		-1	32	V

4.8.4 Characteristics

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{out}	Pin output capacitance		4	6	µF
V_{out}	Output voltage, at I_{load}		4.9	5.1	V
V_{out}	Output voltage differential, at I_{load}	1	-25	+15	mV
I_{load}	Load current		0	50	mA

Note 1: This sensor supply is a tracking regulator to the internal 5V supply which is also the reference voltage of the ADC unit.

4.8.5 Supply Voltage Monitoring and Correction

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
α_{UGEB}	Read back attenuation factor	1	0.9780	0.9789	
$V_{UG\text{-}SRC}$	Read back values normal operation	2	4.865	4.910	V
k_{REF}	Reference correction value		4.8924		V

Note 1: Supply is read back to allow ratiometric measurement. Due to tolerances the sensor supply might be higher than the ADC reference thus exceeding the allowed voltage range. In order to guarantee that the read back input is always in the ADC operating range, an attenuating voltage divider (nom *0.9785) is inserted.

Note 2: When all parameters are nominal value the read back input (referred to ADC reference) will show 4.8924V. Due to tolerances in the actual supply voltage of main- and sensor-supply the read back value may vary in the range specified.
Please note that this window will not affect the measurement accuracy when using the correction formula below.
Values outside this window indicate voltage failure in the sensor supply (short circuit or overload) and must set the sensor failure flag.

4.8.6 Supply Voltage Correction Formula

Correction formula for ratiometric measurement:

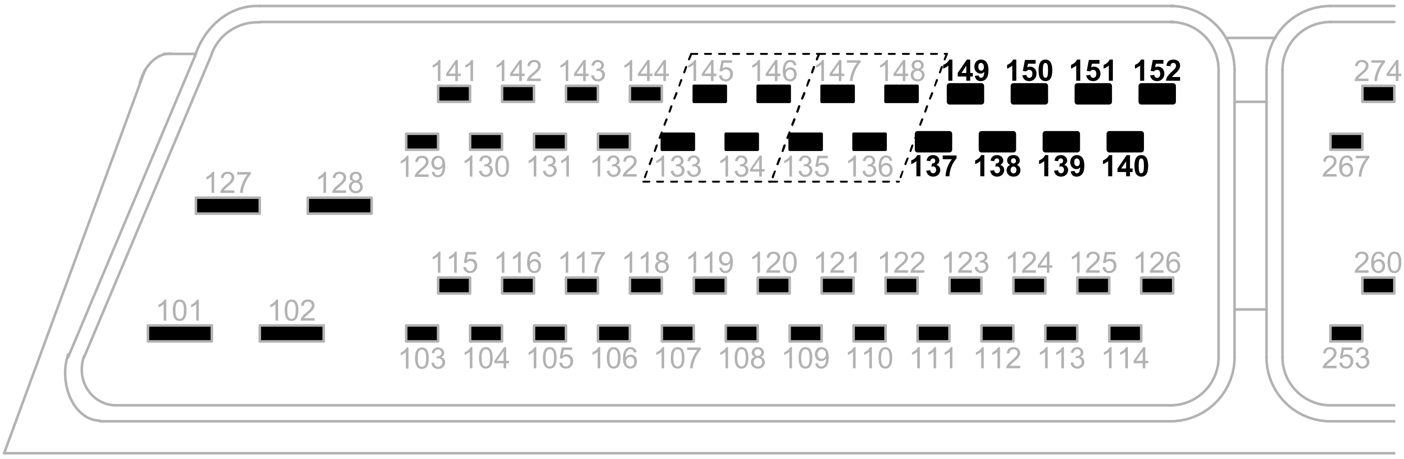
$$U_{IN-rat} = \frac{N_{ADC-ANx}}{N_{ADC-UGEBy}} * k_{REF} \quad [V]$$

$N_{ADC-UGEBy}$	ADC value of sensor supply voltage
$N_{ADC-ANx}$	ADC value of sensor input voltage
U_{IN-rat}	Ratiometric equivalent input voltage Result in volts calculated for a supply of exactly 5V. Example: An input voltage with 20% of sensor supply will show a result of 1.0V regardless of actual sensor supply voltage (within the normal operating range).

The software drivers for ADC 0..5V and ADC 0 .. 32V inputs use this calculation formula for the output result when set to ratiometric input mode.

4.9 Analog input 0..5V with SW- configuration

4.9.1 Pinout:



Connector Pin Number	Function 1	Function 2	Function 3
P152	Analog Input 0 0 .. 5V	Analog Input 0 0 .. 20mA	Analog Input 0 0 .. 100kΩ
P140	Analog Input 1 0 .. 5V	Analog Input 1 0 .. 20mA	Analog Input 1 0 .. 100kΩ
P151	Analog Input 2 0 .. 5V	Analog Input 2 0 .. 20mA	Analog Input 2 0 .. 100kΩ
P139	Analog Input 3 0 .. 5V	Analog Input 3 0 .. 20mA	Analog Input 3 0 .. 100kΩ
P150	Analog Input 4 0 .. 5V	Analog Input 4 0 .. 20mA	Analog Input 4 0 .. 100kΩ
P138	Analog Input 5 0 .. 5V	Analog Input 5 0 .. 20mA	Analog Input 5 0 .. 100kΩ
P149	Analog Input 6 0 .. 5V	Analog Input 6 0 .. 20mA	Analog Input 6 0 .. 100kΩ
P137	Analog Input 7 0 .. 5V	Analog Input 7 0 .. 20mA	Analog Input 7 0 .. 100kΩ

4.9.2 Functional description:

This kind of input can be set to 3 different operation modes individually by SW.
Fits to different types of sensors:

4.9.3 Mode 1: resistive sensors (i.e. NTC/PTC temperature sensors)

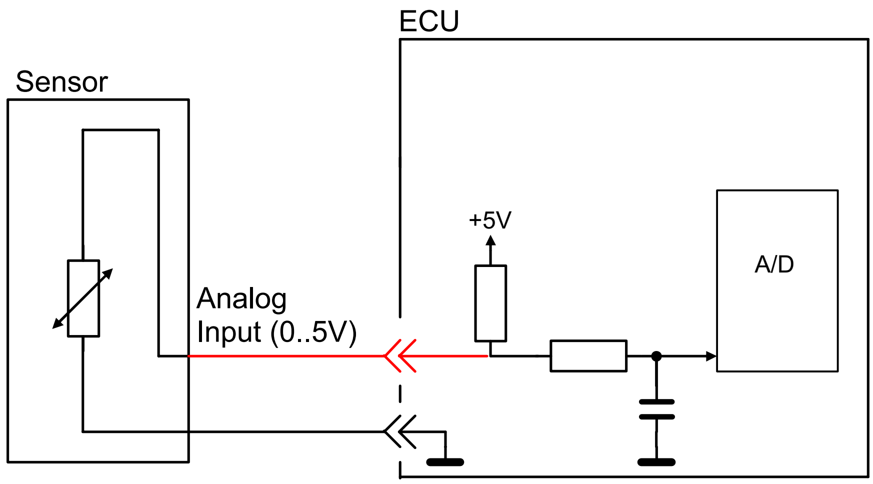


Figure 5: Resistive sensor

This mode may also be used as switch input with switches connected to ground.
The use of switches to BAT+ is not allowed.

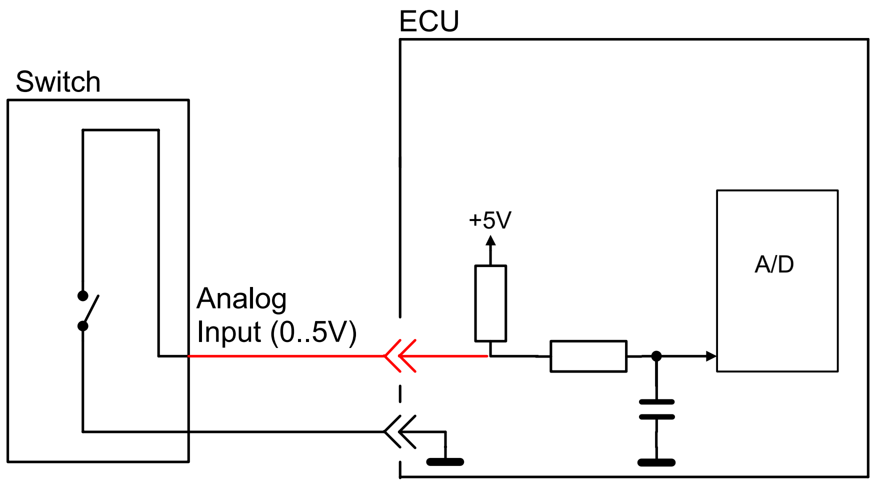


Figure 6: Switch input (only for switches to ground)

4.9.4 Mode 2: current loop active sensors (0..20mA)

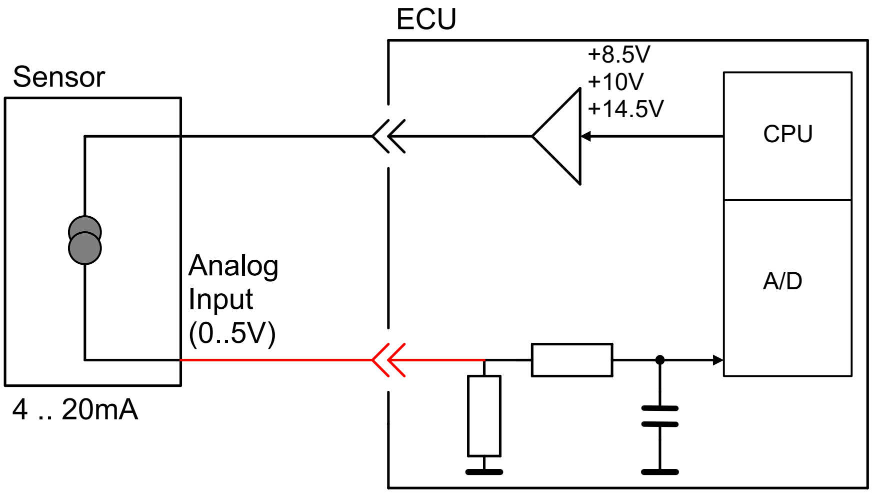


Figure 7: Current loop active sensor

4.9.5 Mode 3: ratiometric for potentiometric sensors (pedals, joystick etc)

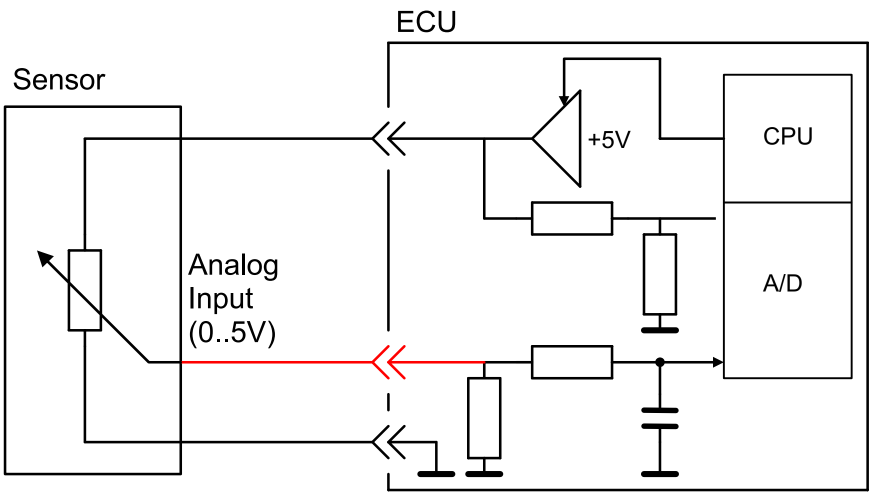


Figure 8: Potentiometric sensor

Most physical sensors (e.g. pressure transducers) are operated in this mode.
Please note that many sensors are offered in 2 variants:

- absolute: The output voltage is a fixed value and corresponds directly to a physical value. For example 2.5V corresponds to 1bar. Any tolerance in the sensor's and the ECU'S reference voltage **generates additional measurement inaccuracy**.
- ratiometric: The output voltage is a fixed percentage of the sensor supply, the ratio corresponds to a physical value. For example 50% corresponds to 1bar (or 2.5V if the sensor supply is exactly 5.00V). Any tolerance in the sensor's or the ECU'S reference voltage **is completely compensated and will not generate additional measurement inaccuracy.**

Due to the described behavior ratiometric sensors are generally preferred.

Function selection is done by software application for each input independently

4.9.6 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{in}	Input voltage under overload conditions	1	-1	32	V

Note 1: due to thermal reasons only one of the 8 inputs may be shorted to 32V at the same time. A connection to any supply voltage higher than 5V is not allowed for normal operation.

4.9.7 Characteristics

$T_{ambient}$ = -40° .. 85°C

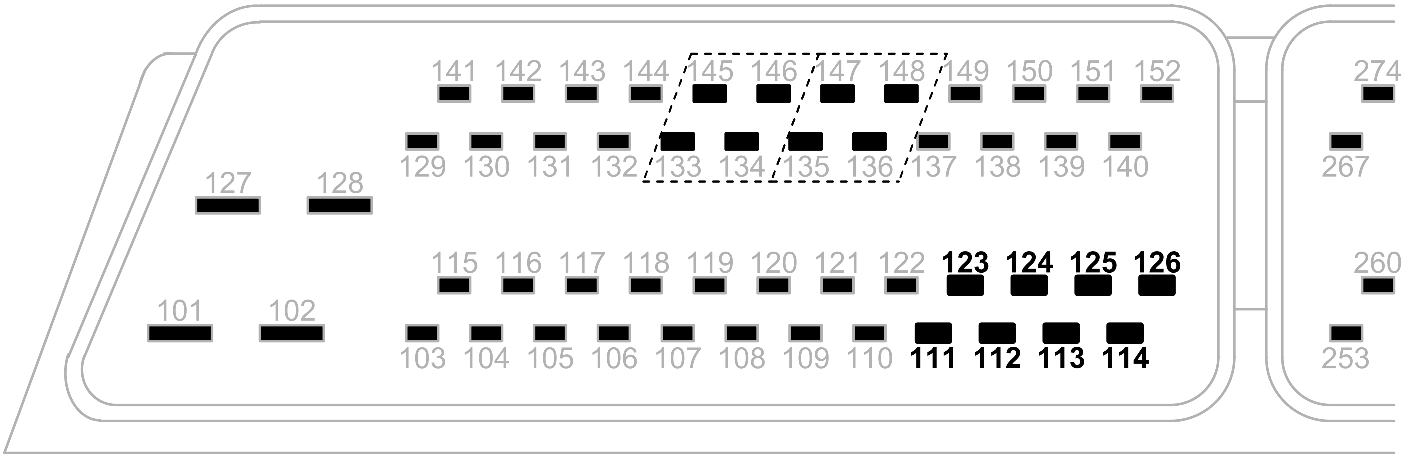
Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		4	6	nF
R_{in}	Input resistance to V_{CC}	1	1202	1250	Ω
R_{pu}	Reference resistor	1	1202	1238	Ω
R_{in}	Input resistance to GND	2	217	230	Ω
R_{pd}	Reference resistor	2	217	223	Ω
R_{in}	Input resistance to GND	3	99.7	102.7	kΩ
τ_{in}	Input low pass filter		0.7	1.3	ms
V_{CC}	ADC reference voltage		4.85	5.15	V
V_{In}	ADC input voltage range		0	V_{CC}	V
V_{Tol}	ADC voltage tolerance	4	-25	+25	mV
LSB	Nominal value of 1 LSB (Full scale / 1024)		4.88		mV

Note 1: configuration mode 1 (resistive sensor)
Note 2: configuration mode 2 (current loop sensor)
Note 3: configuration mode 3 (potentiometric sensor)
Note 4: V_{CC} is the reference voltage of the ADC. Therefore measurement is referred to V_{CC} . For total tolerance including sensor in mode 1 (ratiometric measuring) or mode 3 when using the built in sensor supply (by reading back the offset) V_{CC} is not a parameter in error calculation.

4.10 Analog and digital input with range select 0..32V

Note: The analog inputs with range select are only available on TTC 60 and TTC 90, not on TTC 50.

4.10.1 Pinout:



Connector Pin Number	Function
P126	Analog input (from 0..5 up to 0..32V) 0
P114	Analog input (from 0..5 up to 0..32V) 1
P125	Analog input (from 0..5 up to 0..32V) 2
P113	Analog input (from 0..5 up to 0..32V) 3
P124	Analog input (from 0..5 up to 0..32V) 4
P112	Analog input (from 0..5 up to 0..32V) 5
P123	Analog input (from 0..5 up to 0..32V) 6
P111	Analog input (from 0..5 up to 0..32V) 7

4.10.2 Functional description:

Eight multi purpose analog input with 10 bit resolution are provided, divided into 2 input groups, each with 4 pins.

The inputs are intended to be used with:

- analog sensors 0..5V ratiometric or with absolute reference.
- analog sensors with higher output voltage than 5V and absolute reference.
- each group can be adapted to different full scale voltages up to 0..32V per SW
- standard settings: 0..5V, 0..10V, 0..15V, 0..20V, 0..25V, 0..30V, 0..32V
- full 10bit resolution for any range.
- digital switch input with switches that may be connected either to ground or to battery supply.

The ADC values can be referenced either to internal supply or sensor supply (ratiometric mode) or to a internal accurate reference voltage (absolute reference) for each channel individually.

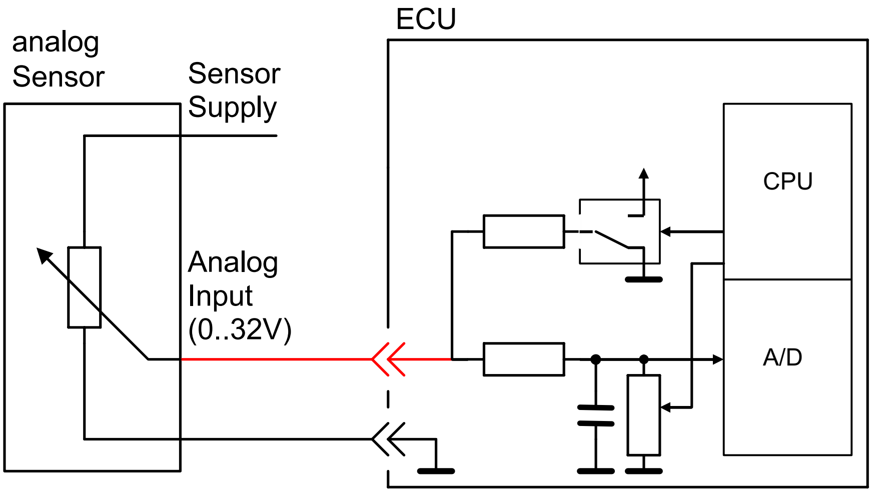


Figure 9: Analog sensor input 0..32V

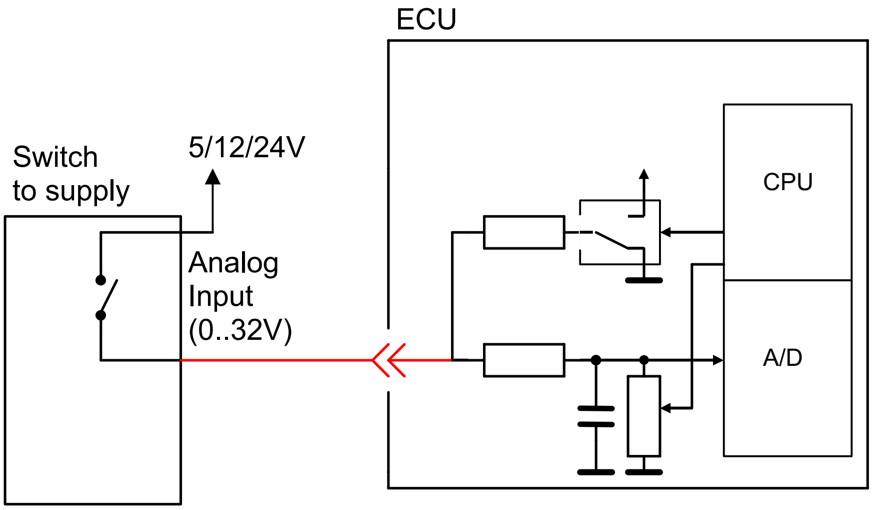


Figure 10: Switch to Sensor Supply or BAT+ connected to sensor input 0..32V

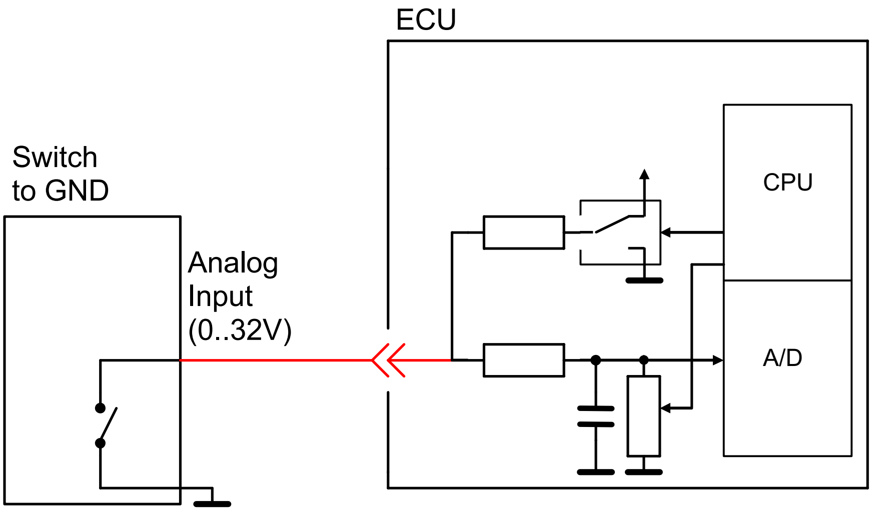


Figure 11: Switch to GND connected to sensor input 0..32V

4.10.3 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{in}	Input voltage under overload conditions		-1	32	V

4.10.4 Characteristics

$T_{ambient}$ = -40° .. 85°C

4.10.5 Parameters for 5V ratiometric setting

For 3 pin sensors that are supplied with one of the TTC50's sensor supplies and use this supply as reference for the output signal. Output voltages of these sensors are typically described as percentage of the supply voltage.
The software compares the input voltage with the actual sensor supply voltage. The calculated output value is a portion of the supply voltage. Any deviation of either sensor supply or internal supply voltage from the typical value (in the operating range) will **not** influence the output value. Therefore ratiometric measurement will be in most cases more accurate compared to measurement where sensor and ECU uses each there built in references. In this case the sum of the tolerance of both references has to be added to the ADC error.

Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		4	6	nF
R_{in}	Input resistance to V_{CC}	1	9.85	10.25	kΩ
R_{in}	Input resistance to GND	1	9.85	10.25	kΩ
τ_{in}	Input low pass filter		40	55	ms
V_{CC}	ADC reference voltage V_{CC}	2	4.85	5.15	V
V_{In}	ADC input voltage range		0	V_{CC}	V
V_{Tol-0}	ADC voltage tolerance (zero)	3	-25	+25	mV
V_{Tol-M}	ADC voltage tolerance (full scale)	3	-50	+25	mV

Note 1: Depending on SW-setting.
Note 2: V_{CC} is the reference voltage of the ADC. Therefore measurement is referred to V_{CC} .
Note 3: V_{CC} is the reference voltage of the ADC. Therefore measurement is referred to V_{CC} . For total tolerance including sensor with ratiometric measuring mode using the built in sensor supply (by reading back the offset) V_{CC} is not a parameter in error calculation.

4.10.6 Parameters for 5V absolute measurement setting

This setting is for sensors that work only with an internal reference. For this reason the TTC50 can make use of an internal precision reference with better accuracy than the ADC reference.

Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		4	6	nF
R_{in}	Input resistance to V_{CC}	1	9.85	10.25	kΩ
R_{in}	Input resistance to GND	1	9.85	10.25	kΩ
τ_{in}	Input low pass filter		40	55	ms
V_{CC}	ADC reference voltage V_{CC}	2	4.85	5.15	V
V_{In}	ADC input voltage range		0	4.85	V
$V_{Tol\text{-}0}$	ADC voltage tolerance (zero)	3	-25	+25	mV
$V_{Tol\text{-}M}$	ADC voltage tolerance (full scale)	3	-150	+125	mV
$V_{Tol\text{-}R}$	ADC voltage tolerance (full scale)	3	-3.0	+2.5	%
LSB	Nominal value of 1 LSB (Full scale / 1024)		4.88		mV

Note 1: Depending on SW-setting.
Note 2: V_{CC} is the reference voltage of the ADC. Therefore measurement is referred to V_{CC} .
Note 3: V_{CC} is the reference voltage of the ADC. Therefore measurement is referred to V_{CC} . For non-ratiometric sensors the ADC reference voltage tolerance is included in this oval all error calculation.

4.10.7 Parameters for voltage range 10 .. 32V absolute measurement setting

This setting is for sensors that work only with an internal reference. For this reason the TTC 50 can make use of an internal precision reference with better accuracy than the ADC reference.

Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		4	6	nF
R_{in}	Input resistance to V_{CC}	1	9.85	10.25	kΩ
R_{in}	Input resistance to GND	1	9.85	10.25	kΩ
τ_{in}	Input low pass filter		7	25	ms
V_{CC}	ADC reference voltage V_{CC}	2	4.85	5.15	V
10V setting for range selection					
V_{In}	ADC input voltage range		0	10	V
V_{Tol-R}	ADC voltage tolerance (zero)		-3	+3	LSB
V_{Tol-R}	ADC voltage tolerance (full scale)		-4.0	+4.0	%
LSB	Nominal value of 1 LSB (Full scale / 1024)		9.765		mV
15V setting for range selection					
V_{In}	ADC input voltage range		0	15	V
V_{Tol-R}	ADC voltage tolerance (zero)		-3	+3	LSB
V_{Tol-R}	ADC voltage tolerance (full scale)		-4.0	+4.0	%
LSB	Nominal value of 1 LSB (Full scale / 1024)		14.65		mV
20V setting for range selection					
V_{In}	ADC input voltage range		0	20	V
V_{Tol-R}	ADC voltage tolerance (zero)		-3	+3	LSB
V_{Tol-R}	ADC voltage tolerance (full scale)		-4.0	+4.0	%
LSB	Nominal value of 1 LSB (Full scale / 1024)		19.5		mV
25V setting for range selection					
V_{In}	ADC input voltage range		0	25	V
V_{Tol-R}	ADC voltage tolerance (zero)		-2	+2	LSB
V_{Tol-R}	ADC voltage tolerance (full scale)		-4.0	+4.0	%
LSB	Nominal value of 1 LSB (Full scale / 1024)		24.4		mV
30V setting for range selection					
V_{In}	ADC input voltage range		0	30	V
V_{Tol-R}	ADC voltage tolerance (zero)		-2	+2	LSB
V_{Tol-R}	ADC voltage tolerance (full scale)		-4.0	+4.0	%
LSB	Nominal value of 1 LSB (Full scale / 1024)		29.3		mV
32V setting for range selection					
V_{In}	ADC input voltage range	3	0	32	V
V_{Tol-R}	ADC voltage tolerance (zero)		-2	+2	LSB
V_{Tol-R}	ADC voltage tolerance (full scale)		-4.0	+4.0	%
LSB	Nominal value of 1 LSB (Full scale / 1024)		32.2		mV

Note 1: Depending on SW-setting.
Note 2: V_{CC} is the reference voltage of the ADC. Therefore measurement is referred to V_{CC} .
Note 3: nominal full scale value is 33.65V. This is higher than the max. permanent input voltage with 32V.

4.11 Board temperature sensor

4.11.1 Pinout:

Connector Pin Number	Function
No connector pin, internal sensor.	Board Temperature Sensor

4.11.2 Functional description:

On board PTC-type temperature sensor. Allows monitoring ECU internal temperature for diagnostic purpose and safety features (strategy to bring machine to safe state and switch off loads in case of over temperature detected)

4.11.3 Characteristics

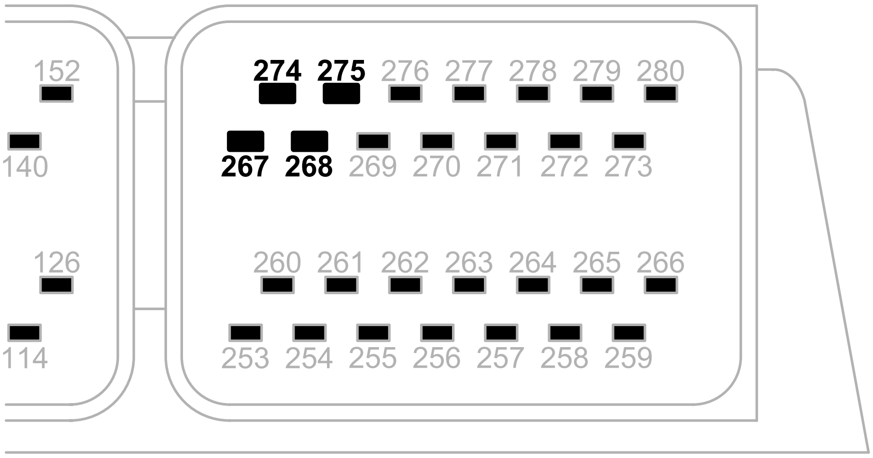
$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
T_{op}	measure temperature range		-40	+130	°C
α_{ADC}	Resolution per K at –40°C	1	1.54		LSB
α_{ADC}	Resolution per K at +20°C	1	1.68		LSB
α_{ADC}	Resolution per K at +130°C	1	1.12		LSB
V_{Tol-m}	Temperature tolerance at 120°C	3	-6	+6	K

Note 1: due to characteristic of the sensor the resolution (change of ADC value per degree K) will depend on actual temperature value. Characteristic values are listed for 3 different temperatures.

4.12 Digital input for frequency / timing measurement

4.12.1 Pinout:



Connector Pin Number	Function
P275	Digital Timer Input 0
P268	Digital Timer Input 1
P274	Digital Timer Input 2
P267	Digital Timer Input 3

4.12.2 Functional description:

Four digital inputs with timer function are provided to process input signals like frequency (rotational speed), pulse count and quadrature decoding (incremental length measurement), PWM etc.
The inputs can be configured with different pull-up / pull-down resistors and input thresholds by software individually to adapt to different sensor types like:
-3pin NPN-type sensors
-3pin PNP-type sensors
-2pin current loop sensors (ABS-type with 7 / 14mA output signal)
-2pin sensors with minimum load current requirement
The input is overload protected in all settings (including current input setting).

Additionally the inputs can also be set to standard digital or analog input with the same pull-up / pull-down options. Supported analog measurement modes are absolute and ratiometric.

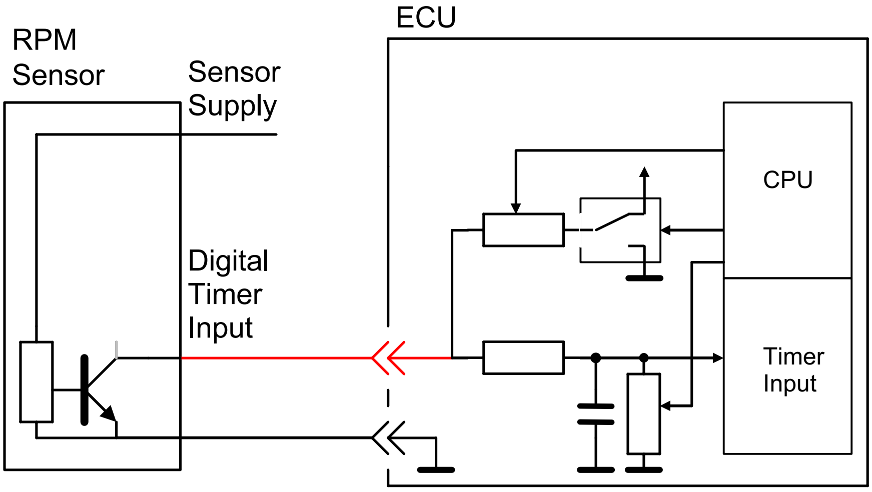


Figure 12: Digital input for frequency / timing measurement with NPN-type 3pole sensor

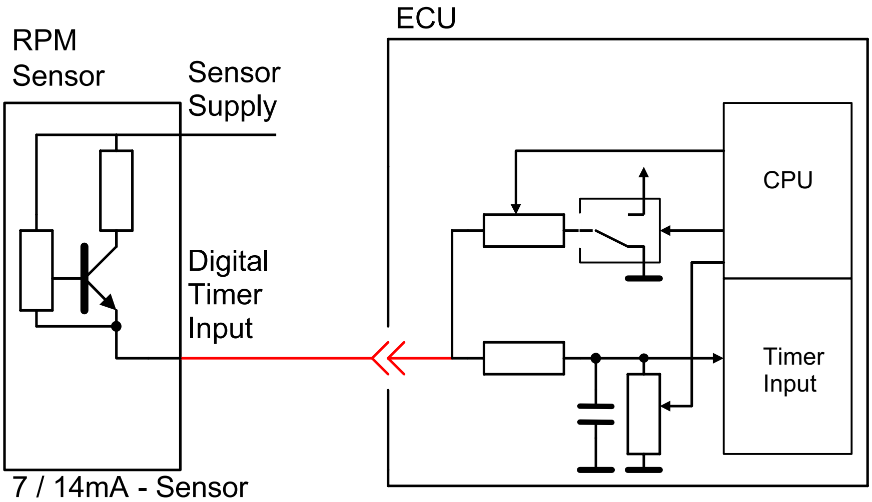


Figure 13: Digital input for frequency / timing measurement with ABS-type 7/14mA 2pole sensor

The quadrature decode function is an input function that uses two dedicated input channel pairs (Digital Timer Input 0+1 and 2 + 3) to decode a pair of out-of-phase signals in order to increment or decrement a (position) counter. It is particularly useful for decoding position and direction information from an encoder in motion control systems, thus replacing expensive external solutions.

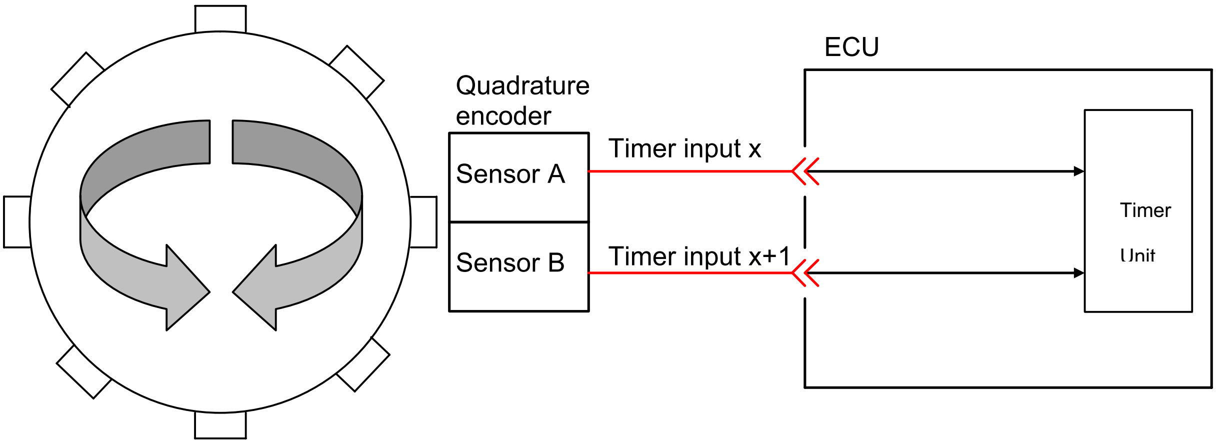


Figure 14: Digital input pair for quadrature encoder

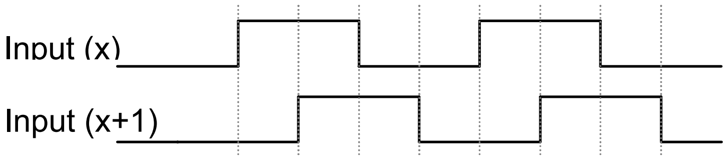


Figure 15: Direction A – channel X leading channel X+1

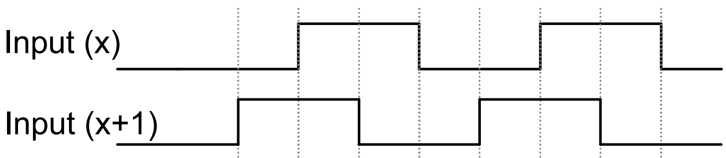


Figure 16: Direction B – channel X lagging channel X+1

4.12.3 Maximum ratings

T_{ambint} = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{in}	Input voltage under overload conditions		-1	32	V

4.12.4 Characteristics digital parameters

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		4	6	nF
R_{pu}	Pullup resistor to V_{CC}	1	9.00	9.25	kΩ
R_{pu}	Pulldown resistor to GND (standard)	2	9.00	9.25	kΩ
R_{pu}	Pulldown resistor to GND (strong)	3	1.75	1.80	kΩ
R_{pu}	Pulldown resistor to GND (current loop)	4	110	115	Ω
τ_{in}	Input low pass filter (digital path)		4	6	µs
F_{max}	Maximum input frequency range	5	10		kHz
F_{max}	Maximum input frequency range	6	20		kHz
F_{min}	Minimum input frequency	7	0.02		Hz
t_{min}	Minimum pulse / pause length to be measured by Timer unit	7	20		µs
V_{IL}	Input voltage for low level	8	-1	1.8	V
V_{IH}	Input voltage for high level	8	3.2	U_{Bat}	V
V_{IL}	Input voltage for low level	9	-1	1.1	V
V_{IH}	Input voltage for high level	9	1.3	U_{Bat}	V

Note 1: with software setting for pull up resistor
Note 2: with software setting for pull down resistor
Note 3: with software setting for strong pull down resistor
Note 4: with software setting for current loop sensors (for 7 / 14mA ABS-type sensors)
Note 5: limit for sensors with open drain / open collector output due to input capacitance
Note 6: limit for sensors with either push-pull or current loop output
Note 7: dependent on configuration of timer prescaler in software; due to the dynamic range of the timer there is a minimum frequency when timer overflow will occur. At lower frequencies the output value will be read as 0 Hz.
Note 8: with software setting for standard threshold
Note 9: with software setting for current loop sensors (for 7 / 14mA ABS-type sensors)

4.12.5 Characteristics analog parameters

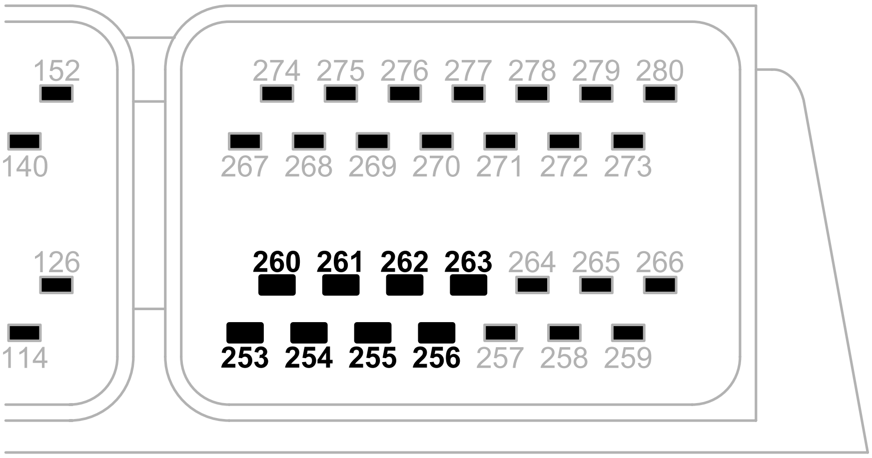
$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		4	6	nF
R_{pu}	Pullup resistor to V_{CC}	1	9.00	9.25	kΩ
R_{pu}	Pulldown resistor to GND (standard)	2	9.00	9.25	kΩ
R_{pu}	Pulldown resistor to GND (strong)	3	1.75	1.80	kΩ
R_{pu}	Pulldown resistor to GND (current loop)	4	110	115	Ω
$I_{7\text{-}14min}$	Input current 7/14mA sensor SRC low	5	4	5	mA
$I_{7\text{-}14max}$	Input current 7/14mA sensor SRC high	6	20	21	mA
V_{In}	ADC input voltage range		0	VCC	V
V_{In}	ADC input voltage range		0	VCC	V
V_{In}	ADC input voltage range		0	VCC	V
τ_{in}	Input low pass filter (analog path)		0.7	1.3	ms
V_{Tol}	ADC voltage tolerance	7	-25	+25	mV
LSB	Nominal value of 1 LSB (Full scale / 1024)		4.88		mV

Note 1: with software setting for pull up resistor
Note 2: with software setting for pull down resistor
Note 3: with software setting for strong pull down resistor
Note 4: with software setting for current loop sensors (for 7 / 14mA ABS-type sensors)
Note 5: failure detection window for defect 7/14mA sensor with too low current
Note 6: failure detection window for defect 7/14mA sensor with too high current
Note 7: V_{CC} is the reference voltage of the ADC. Therefore measurement is referred to V_{CC}. For total tolerance including sensor in mode 3 (ratiometric measuring) when using the built in sensor supply (by reading back the offset) V_{CC} is not a parameter in error calculation.

4.13 Digital inputs

4.13.1 Pinout:



Connector Pin Number	Function
P263	Digital Input 0
P256	Digital Input 1
P262	Digital Input 2
P255	Digital Input 3
P261	Digital Input 4
P254	Digital Input 5
P270	Digital Input 6
P253	Digital Input 7

4.13.2 Functional description:

General purpose digital input, typically used to read switch settings. The input can be tied to ground or supply voltage (Sensor Supply or BAT+) or left open.

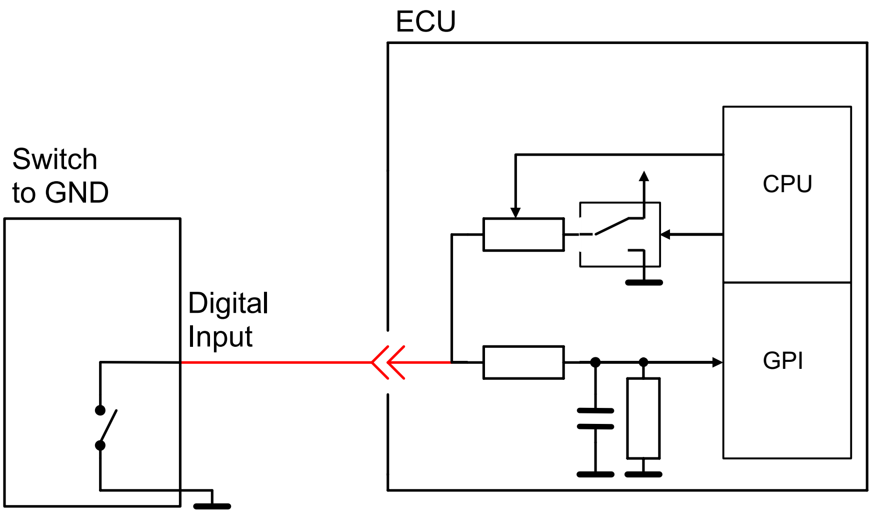


Figure 17: Digital input for reading switch connected to ground.

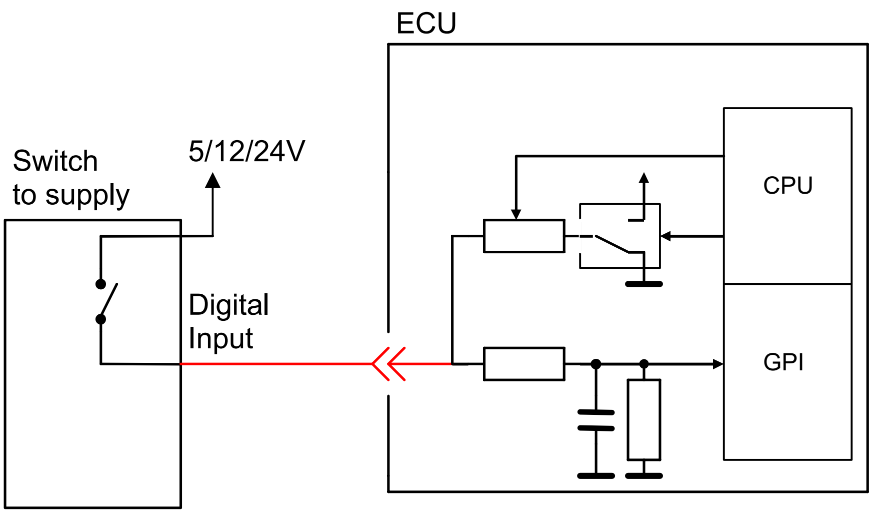


Figure 18: Digital input for reading switch connected to (battery) supply voltage

4.13.3 Maximum ratings

T_{ambint} = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{in}	Input voltage under overload conditions		-1	32	V

4.13.4 Characteristics

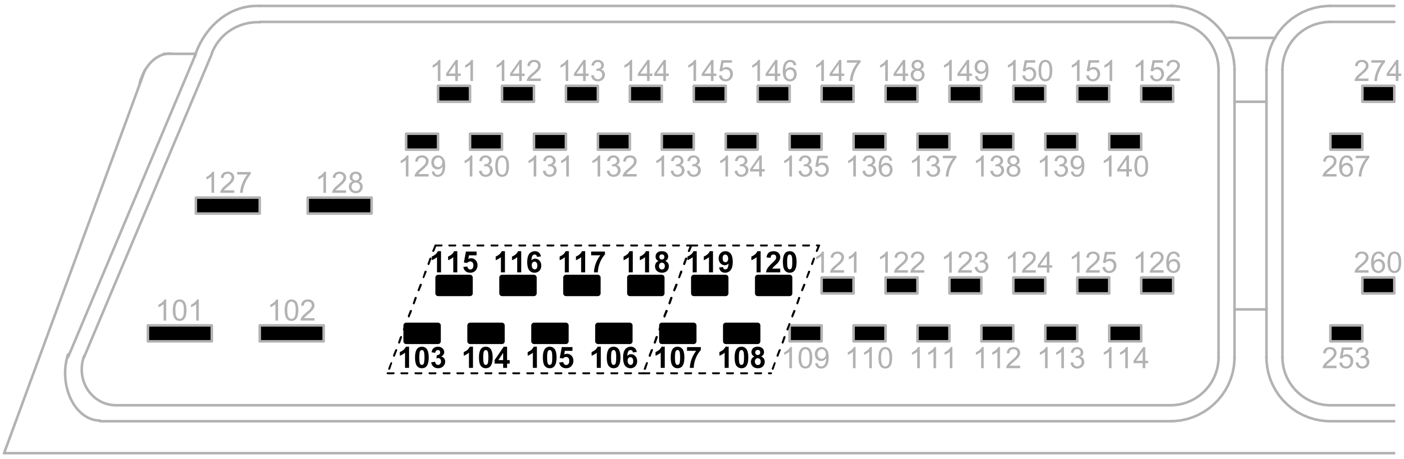
$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		4	6	nF
R_{pu}	Pullup resistor to V_{CC}	1	9.00	9.25	kΩ
R_{pu}	Pulldown resistor to GND (standard)	2	9.00	9.25	kΩ
R_{pu}	Pulldown resistor to GND (strong)	3	1.75	1.80	kΩ
τ_{in}	Input low pass filter		1	1.5	ms
V_{IL}	Input voltage for low level		-1	1.8	V
V_{IH}	Input voltage for high level		4.2	U_{Bat}	V

Note 1: with software setting for pull up resistor
Note 2: with software setting for pull down resistor
Note 3: with software setting for strong pull down resistor

4.14 Power output 2A high side with PWM-control

4.14.1 Pinout:



Connector Pin Number	Function
P118	Power Output PWM 0
P106	Power Output PWM 1
P117	Power Output PWM 2
P105	Power Output PWM 3
P116	Power Output PWM 4
P104	Power Output PWM 5
P115	Power Output PWM 6
P103	Power Output PWM 7
P120 (+ optional 122)	Current Measurement Input 0
P108 (+ optional 110)	Current Measurement Input 1
P119 (+ optional 121)	Current Measurement Input 2
P107 (+ optional 109)	Current Measurement Input 3

For optional pins please see section 4.18 Mini Module.

4.14.2 Functional description:

Power output stage with freewheeling diode for inductive loads with low-side connection.
Load current is controlled with PWM.
For better accuracy and diagnostics a current measurement/feedback loop is provided.

Output stage will be disabled (off state) by either watchdog CPU or main CPU if an error is detected in a safety-critical resource.

For diagnostic and safety reasons the actual PWM output signal is looped back to a timer input and the measured value is compared to the set value. For safety critical applications fast error detection is necessary. For this reason a permanent PWM output is available, setting a minimum pulse / pause to 250µs instead of 0 or 100% duty cycle. This means, there is a reliable periodical state change of the output allowing permanent load monitoring independent of the operation point. So even when the load is not powered a short on the load can be detected.

4.14.3 Alternate functions:

When the pulse width modulation is not needed, the output can be configured as simple digital output. Instead of comparing output PWM to loopback PWM value the static level is compared.

When the output is not used, the loop-back input can be used as timer input with frequency or pulse width measurement mode (see section *4.12 digital input for frequency / timing measurement*). The sensor's output stage shall be either open collector / open drain or push-pull type.

The current sense path can be used either for PWM load current measurement or as digital output. See chapter 4.14.9 Current Measurement Inputs.

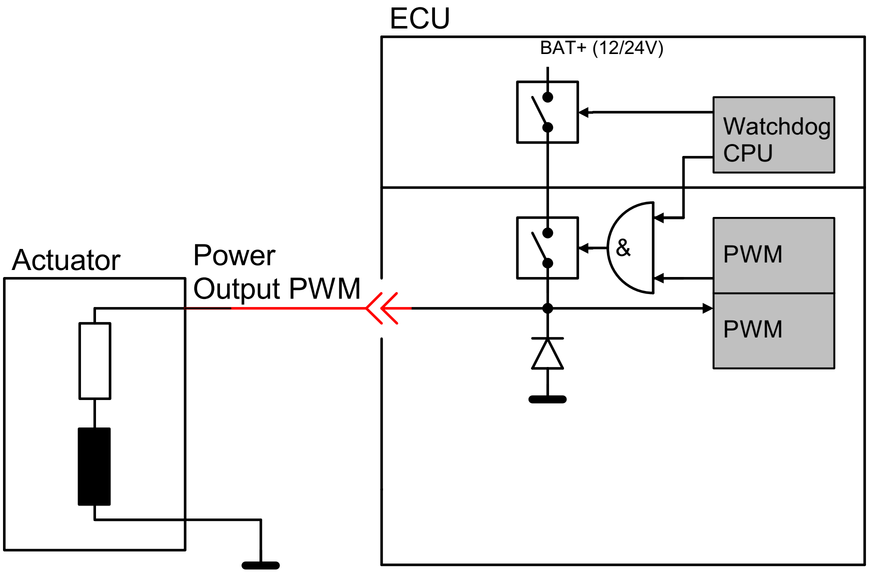


Figure 19: Power output 2A high side without current monitoring

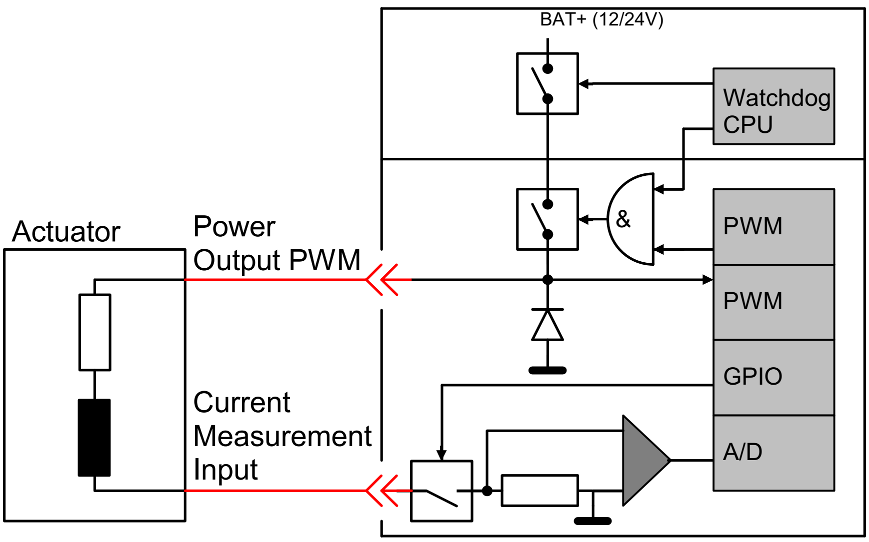


Figure 20: Power output 2A high side with current monitoring

4.14.4 Maximum ratings

T_{ambint} = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{in}	Input voltage under overload conditions		-0.5	U_{Bat}+0.5	V

4.14.5 Characteristics of PWM high side output stage

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{out}	Pin input capacitance		8	12	nF
f_{PWM}	PWM-frequency		10	200	Hz
f_{PWM}	PWM-frequency	1	50	200	Hz
$T_{min\text{-}PWM}$	Minimum pulse / pause	2	250		µs
R_{on}	On-resistance			200	mΩ
I_{load}	Nominal load current		0	2.0	A
$I_{load\text{-}lim}$	Internal current limitation for PTC-type loads	3	9		A

Note 1: For current control using the current measurement input the frequency shall be at least 50Hz.
Note 2: Instead of 0% resp. 100% output a minimum pulse resp. pause duration is inserted automatically when the output is configured to be safety critical. This is necessary for optimal load diagnostic.
Note 3: incandescent lamps with cold filament have a surge current 10 times higher than nominal current.

4.14.6 Characteristics of static (on/off) high side output stage

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{out}	Pin input capacitance		8	12	nF
R_{on}	On-resistance			200	mΩ
I_{load}	Nominal load current		0	2.0	A
I_{load}	Nominal load current	1	0	2.0	A
I_{load}	Nominal load current per output stage	2	0	4.0	A
$I_{load(sum)}$	Total load current for all PWM-type output stages	2		16.0	A
$I_{load\text{-}lim}$	Internal current limitation for PTC-type loads	3	9		A

Note 1: 2.0A is the maximum current per output stage. The load off all other output stages does not influence this value.
Note 2: Higher load current is possible (up to 4A) if the total current of all 8 outputs of this group (with a mix of outputs either used as PWM- or as static output) will be less than 16A.
For PWM operation the maximum current is 2A per output stage, in case of PWM operation on all PWM outputs the total current is in any case less than 16A (8*2A).
Note 3: incandescent lamps with cold filament have a surge current 10 times higher than nominal current.

4.14.7 Characteristics of frequency input (alternate function of output stage)

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		8	12	nF
R_{pu}	Pullup resistor to internal 5V supply		9.5	10.5	kΩ
V_{pu}	Internal supply for pull up		4.85	5.25	V
τ_{in}	Input low pass filter		3.5	6.5	µs
F_{max}	Maximum input frequency	1	5		kHz
F_{max}	Maximum input frequency	2	10		kHz
F_{min}	Minimum input frequency	3	10		Hz
t_{min}	Minimum pulse / pause length to be measured by timer input		50		µs
V_{IL}	Input voltage for low level		-0.5	1.8	V
V_{IH}	Input voltage for high level		4.2	U_{Bat}	V

Note 1: with open collector / open drain sensor output
Note 2: with push / pull sensor output stage or sensor internal pull-up of 10kΩ or below.
Note 3: due to the dynamic range of the timer there is a minimum frequency when timer overflow will occur. At even lower frequency the output value will be read as 0 Hz.

4.14.8 Load Diagnostic Function High Side Output

Load monitoring means detection of overload, external short circuits of the load output to positive or negative supply (BAT+ / BAT-) or any other power output and detection of loss of load.

Duty Cycle	Status Signal			
	Normal	Open Load	Short to GND	Short to U_{BAT}
0% < x < 100%	*Note 1*	1	0	1

Note 1: The status signal follows the output signal. Please note: if the duty cycle is 0% or 100% the status signal cannot be distinguished from the error condition

Under normal load conditions the status signal follows the corresponding PWM output. In case of a disconnected load (open load) the signal is pulled to 5V (high level) by an internal resistor. If a short circuit to ground exists, the status signal is constant zero (low level). A short circuit to U_{BAT} implicates that the status signal is also pulled to U_{BAT} (high level).

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
$R_{load-nom}$	Load resistance for proper operation (24V supplied system: V_{BATmax} =32V)	1	13 (0.5)	1700	Ω
$R_{load-nom}$	Load resistance for proper operation (12V supplied system: V_{BATmax} =16V)	1	6.5 (0.5)	1700	Ω
$R_{openload}$	Open load threshold	2		20	kΩ
$I_{load-OVL}$	Temperature limited current	3	4		A
$I_{load-lim}$	Internal current limitation for PTC-type loads	4	9		A
$I_{load-lim}$	Internal current limitation	5	2.30	2.60	A

Note 1: Resistance values in that range will neither generate overload (min-value) nor open load (max-value) detection.
Loads with any resistor value in that window will be detected as normal load.
For PWM current controlled inductive loads there is only a virtual lower limit (value in brackets) to keep the control loop stable.

Note 2: Resistance values higher than this threshold will be detected as open load.

Note 3: Overload is defined by chip temperature. Due to the thermal design of the ECU this limit will be influenced by the number of outputs activated with high current simultaneously and ambient temperature. This is the worst case value for maximum allowed over-all load and highest temperature.

Note 4: Internal current limit for short circuit protection to limit excessive power dissipation.
Overload protection is done typically by detecting over temperature.

Note 5: For protection of the current sense resistors the output duty cycle will be regulated by software to a maximum load current of 2.45A typ.

4.14.9 Current Measurement Inputs

For actuators requiring precision current control this type of input provides a measurement unit with overload protection. The current flows through a sensing resistor is amplified and low pass filtered to deliver an average value and suppress ripple current introduced by PWM-control.
In case of overload a switch disconnects the overloaded input for 1 second and then switches on again. 4 inputs of this type are available to support up to 8 PWM outputs. In case of 2 loads that will never be operated at the same time, 2 outputs can share 1 input, for example 2 proportional valves, one for forward, the other for backward movement. For that reason in standard configuration (without mini module) any current measurement input is connected to a pair of connector pins.

If a current input is not needed, it can be also used as low side switch with diagnostic function.

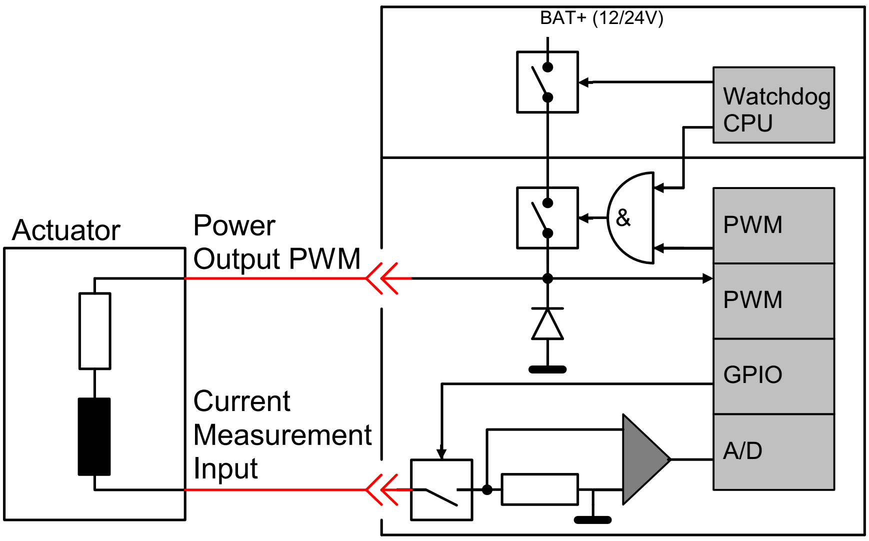


Figure 21: Power output 2A high side with current monitoring

4.14.10 Characteristics of Current Measurement Input

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{Out}	Shunt factor	1	2.00		V/A
I_{FS}	Full scale nominal current	1	2.50		A
I_{Tol-M}	Accuracy	2	-5	+5	%[FS]
	Proportional factor (at nominal load current)	2	-125	+125	mA
I_{Tol-0}	Accuracy	3	-2.0%	+2.0%	%[FS]
	Zero reading (no load current)	3	-50	+50	mA
$f_{g\ LP}$	Cut off frequency of 3rd order low pass filter	4	6	10	Hz

Note 1: current is measured with a ground referenced shunt, amplified and connected to an ADC input.
1A load current will bring 2V ADC input voltage.
Please note that 2.45A is the nominal current without any tolerance.
0 .. 2.30A is the nominal operating range for peak current.

Note 2: Current measurement gives absolute values and does not work ratiometric to the ADC's reference.
Therefore absolute tolerance of ADC supply is also included.

Note 3: The ADC can only measure positive values.
With a negative zero reading current a small output current of the same absolute value is necessary to get ADC-values greater than zero.

Total error is the sum of proportional error and zero reading error:

$$TUE = \pm\left|I_{Tol-M} * I_L \pm I_{Tol-0}\right|$$

Note 4: An active low pass filter (3rd order) is provided to remove current ripple from the ADC input

4.14.11 Alternate Function Low Side Output

If a current input is not needed, it can be also used as low side switch with diagnostic function. When using highly inductive loads operated at high current values the maximum switch-off energy must be calculated carefully not to overload the output clamping. For inductive actuators exceeding the dissipation limit an external freewheeling diode must be added.

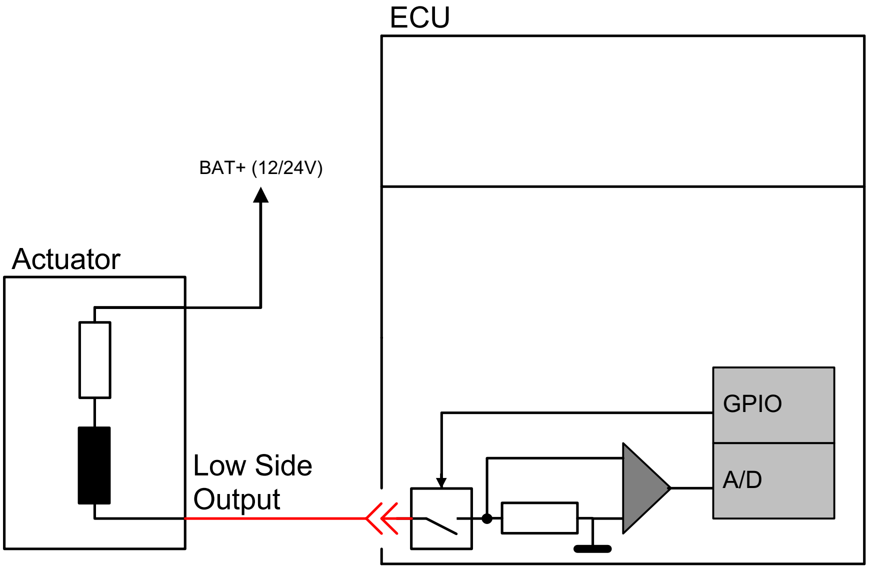


Figure 22: Power output 2A low side

4.14.12 Example for switch off energy calculation for inductive loads:

In this example an inductive load is operated at 24V and the actuator draws the maximum specified output current of 2A. When switching off the stored energy in the inductance, the output is driven to negative until the output stage clamps. In this example this happens at approx. 50V referred to GND. The current linearly decreases from 2A to 0 within 1ms at almost constant clamp voltage. So also the power dissipated in the output stage decreases, from 100W (2A*50V) down to 0. For a time of 1ms the average power in the clamping phase is 50W, which equals to 50mWs or 50mJ, which is well below the limit of 170mJ.

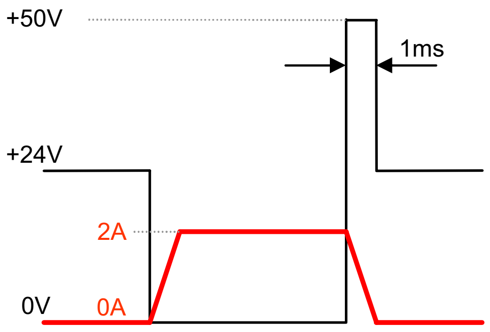


Figure 23: Power output 2A switch off waveform

4.14.13 Characteristics of Low Side Switch

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter (single power stage)	Note	min	max	Units
C_{out}	Pin input capacitance		8	12	nF
R_{on}	On-resistance			200	mΩ
I_{load}	Nominal load current		0	2	A
I_{load}	Permanent load current	1	0.03	2.3	A
$I_{load-lim}$	Internal current limitation for PTC-type loads	2	9		A
E_{AS}	Maximum switch off energy dissipation	3		170	mJ
Z_{l-max}	Maximum switchable inductive load	3		20	mH

Note 1: Load diagnostic is based on current measurement during on-phase.
The limits are the minimum / maximum permanent (DC) current that will not trigger low load detection or overload protection

Note 2: incandescent lamps with cold filament have a surge current 10 times higher than nominal current.

Note 3: with I_{load} = 2A, Z_L = 20mH, R_{DC} = 0Ω. Typical electromagnetic valves have R_{DC} in excess of 5Ω, thus reducing the energy to be clamped by the output stage.

4.14.14 Load Diagnostic Function

Load monitoring means detection of overload, external short circuits of the load output to positive or negative supply (BAT+ / BAT-) or any other power output and detection of loss of load.

Output Signal	Detection Status		
	Normal	Open Load	Short to U_{BAT}
0 (on)	o.k.	open-load	short-circuit
1 (off)	o.k.	o.k.	o.k.

With this output stage load diagnostic is based on current measurement. Therefore short circuit / open load detection is both made during on-phase. In case of excessive overload or short circuit to BAT+ the output switches off in order to protect the output stage.
$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter (single power stage)	Note	min	max	Units
$R_{load\text{-}nom}$	Load resistance for proper operation (24V supplied system: V_{BATmax} =32V)	1	16	800	Ω
$R_{load\text{-}nom}$	Load resistance for proper operation (12V supplied system: V_{BATmax} =16V)	1	8	400	Ω
$R_{openload}$	Open load threshold	2		5	kΩ
$I_{load\text{-}OVL}$	Protection limited current	3	2.3	2.5	A
$I_{load\text{-}lim}$	Internal current limitation for PTC-type loads	4	9		A

Note 1: Resistance values in that range will neither generate overload (min-value) nor open load (max-value) detection.
Loads with any resistor value in that window will be detected as normal load.

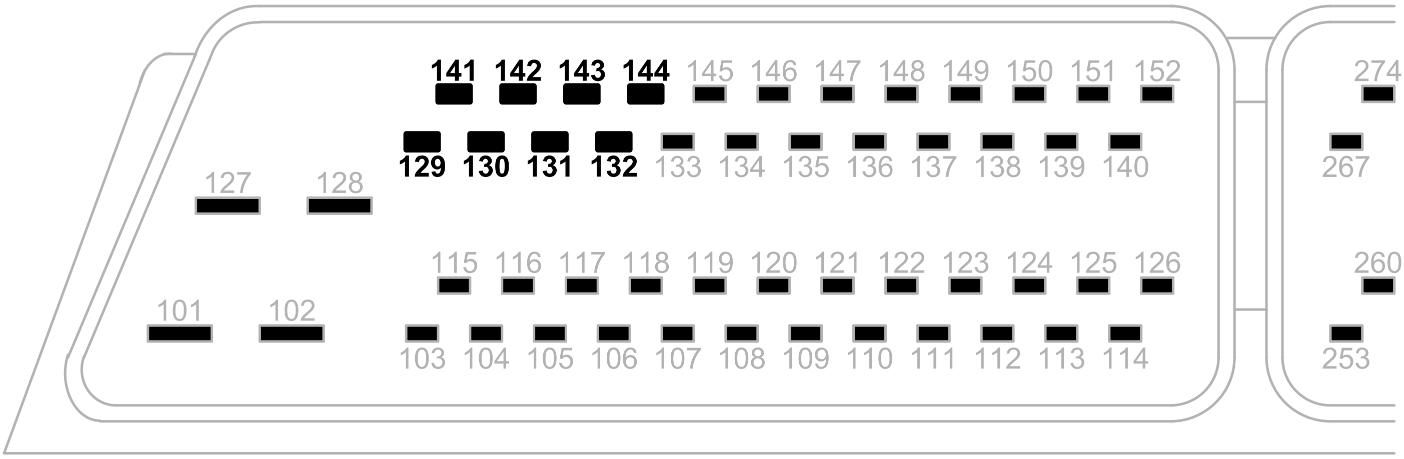
Note 2: Resistance values higher than this threshold will be detected as open load.

Note 3: After some milliseconds operated in or above this current range the internal overload protection will switch off the output.

Note 4: Internal current limit for short circuit protection to limit excessive power dissipation.

Power output 4A high side

4.14.15 Pinout:



Connector Pin Number	Function
P144	Power Output 0
P132	Power Output 1
P143	Power Output 2
P131	Power Output 3
P142	Power Output 4
P130	Power Output 5
P141	Power Output 6
P129	Power Output 7

4.14.16 Functional description:

Power output stage for resistive loads with low-side connection.
Suitable loads are lamps, valves, relays etc.
When using highly inductive loads operated at high current values the maximum switch-off energy must be calculated carefully not to overload the output clamping. For inductive actuators exceeding the dissipation limit an external freewheeling diode must be added.

Output stage will be disabled (off state) by either watchdog CPU or main CPU if an error is detected in a safety-critical resource.

For diagnostic reasons the output signal is looped back to the CPU and the measured value is compared to the set value. When the output is not used, the loop-back signal can be used as analog input with an internal 10kΩ pullup resistor. Absolute and ratiometric modes (referred to a sensor supply) are supported.

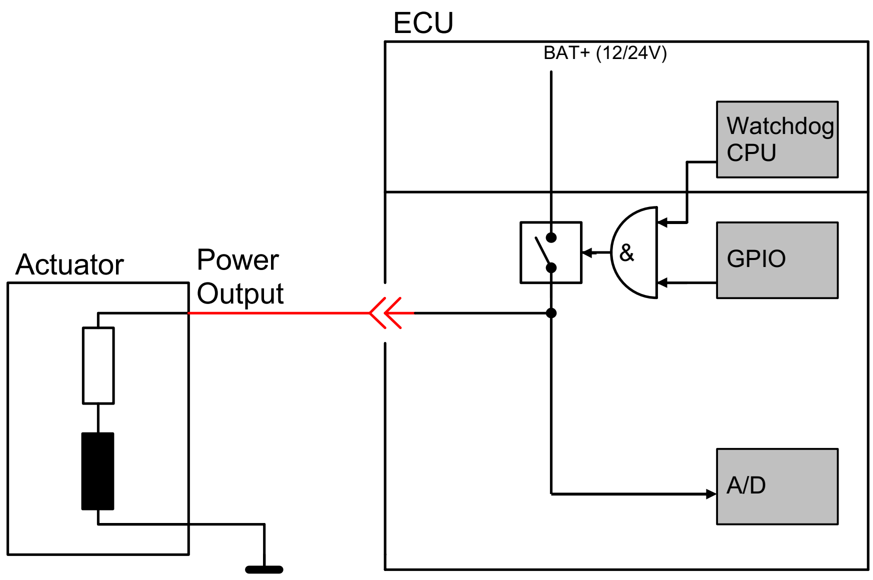


Figure 24: Power output 4A high side

4.14.17 Example for switch off energy calculation for inductive loads:

In this example an inductive load is operated at 24V and the actuator draws the maximum specified output current of 4A. When switching off the stored energy in the inductance, the output is driven to negative until the output stage clamps. In this example this happens at 50V (24+26V, referred to BAT+). The current linearly decreases from 4A to 0 within 1ms at almost constant clamp voltage. So also the power dissipated in the output stage decreases, from 200W (4A*50V) down to 0. For a time of 1ms the average power in the clamping phase is 100W, which equals to 100mWs or 100mJ, which is well below the limit of 170mJ.

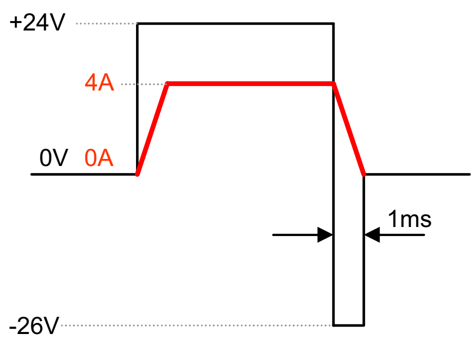


Figure 25: Power output 4A switch off waveform

4.14.18 Maximum ratings

T_{ambint} = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{in}	In-/output voltage under overload conditions	1	-1	U_{bat}+0.5	V

Note 1: inductive load negative transients will be clamped internally to <52V referred to BAT+.

4.14.19 Characteristics of output stage

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter (single power stage)	Note	min	max	Units
C_{out}	Pin input capacitance		8	12	nF
R_{on}	On-resistance			200	mΩ
I_{load}	Nominal load current		0	4	A
$I_{load-lim}$	Internal current limitation for PTC-type loads	1	9		A
E_{AS}	Maximum switch off energy dissipation	2		170	mJ
Z_{l-max}	Maximum switchable inductive load	2		20	mH

Note 1: incandescent lamps with cold filament have a surge current 10 times higher than nominal current.
Note 2: with I_{load} = 4A, Z_L = 20mH, R_{DC} = 0Ω . Typical electromagnetic valves have R_{DC} in excess of 5Ω, thus reducing the energy to be clamped by the output stage.

4.14.20 Characteristics of analog input (alternate function of output stage)

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{in}	Pin input capacitance		8	12	nF
R_{pu}	Pullup resistor to internal 5V supply		9.5	10.5	kΩ
V_{pu}	Internal supply for pull up		4.85	5.25	V
τ_{in}	Input low pass filter		0.7	1.3	ms
V_{CC}	ADC reference voltage		4.85	5.15	V
V_{CC}	ADC reference voltage		4.85	5.15	V
V_{In}	ADC input voltage range		0	V_{CC}	V
V_{Tol}	ADC voltage tolerance		-25	+25	mV
LSB	Nominal value of 1 LSB (Full scale / 1024)		4.88		mV

4.14.21 Load Diagnostic Function

Load monitoring means detection of overload, external short circuits of the load output to positive or negative supply (BAT+ / BAT-) or any other power output and detection of loss of load.

Output Signal	Status Signal			
	Normal	Open Load	Short to GND	Short to U_{BAT}
1	1	1	0	0
0	1	0	1	0

When the power stage is switched off the monitoring interface will read back high level if the load is properly connected or if a short circuit to ground exists. In case of open load or a short circuit to UBAT+ the monitoring interface will read back low level.

When the power stage is switched on, a high level will be read back in case of normal operation. In case of excessive overload or short circuit to ground the output switches off in order to protect the output stage. In this case the monitoring interface will read back a low-level.

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter (single power stage)	Note	min	max	Units
$R_{load-nom}$	Load resistance for proper operation (24V supplied system: V_{BATmax} =32V)	1	8	1700	Ω
$R_{load-nom}$	Load resistance for proper operation (12V supplied system: V_{BATmax} =16V)	1	4	1700	Ω
$R_{openload}$	Open load threshold	2		20	kΩ
$I_{load-OVL}$	Temperature limited current	3	4		A
$I_{load-lim}$	Internal current limitation for PTC-type loads	4	9		A

Note 1: Resistance values in that range will neither generate overload (min-Value) nor open load (max-value) detection.
Loads with any resistor value in that window will be detected as normal load.

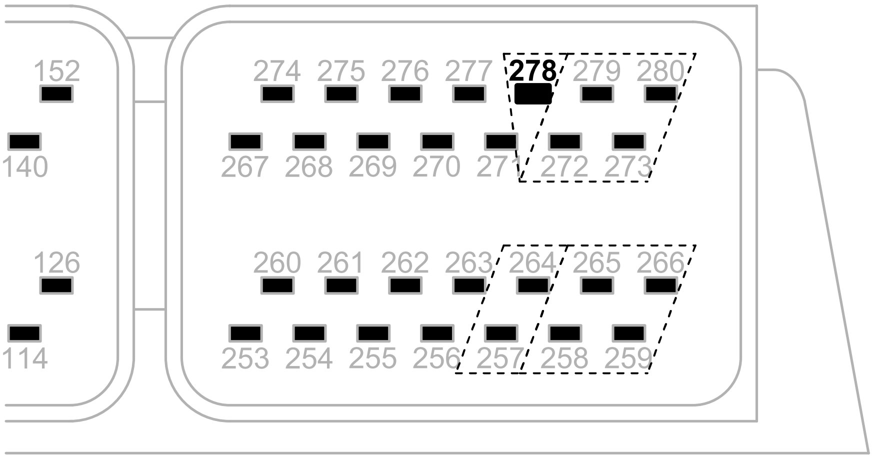
Note 2: Resistance values higher than this threshold will be detected as open load.

Note 3: Overload is defined by chip temperature. Due to the thermal design of the ECU this limit will be influenced by the number of outputs activated with high current simultaneously and ambient temperature. This is the worst case value for maximum allowed over-all load and highest temperature.

Note 4: Internal current limit for short circuit protection to limit excessive power dissipation.
Overload protection is done typically by detecting over temperature.

4.15 LIN interface

4.15.1 Pinout:



Connector Pin Number	Function
P278	Lin Bidirectional Signal Line

4.15.2 Functional description:

LIN[1] is a bidirectional half duplex serial bus for up to 10 nodes.

[1] Note1: The TTC 50 is the LIN master. The LIN standard is only defined for 12V supply.

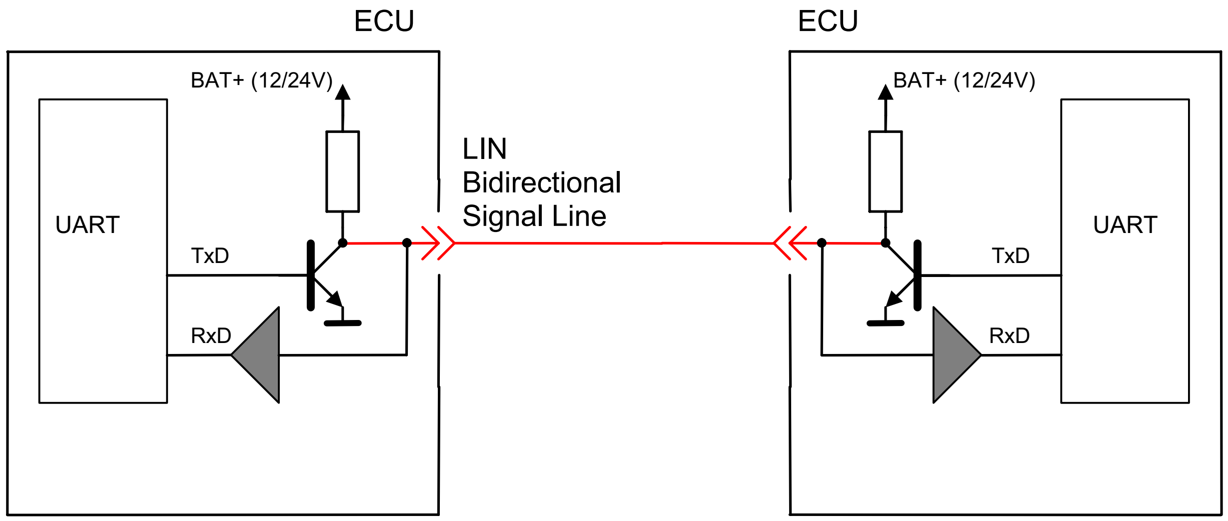


Figure 26: half duplex interface

Please note that a common ground (chassis) or a proper ground connection is necessary for LIN operation. In case of connecting via connectors (e.g. to a PC with LIN-interface) please make sure that the maximum voltage ratings are not violated when connecting to or disconnecting from the LIN-connection.

4.15.3 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{LIN}	Bus voltage under overload conditions (i.e short circuit to supply voltages)		-1	32	V

4.15.4 Characteristics

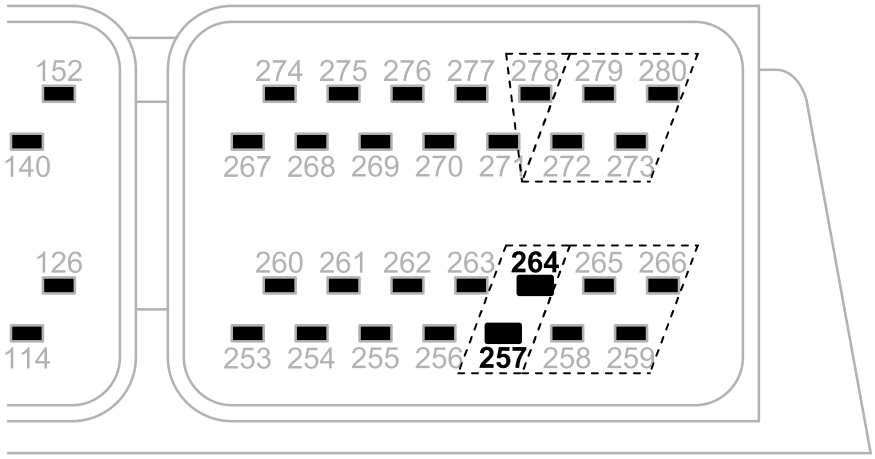
$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{out}	Pin output capacitance		100	150	pF
V_{IL}	Input voltage for low level		-1	0.3*U_{Bat}	V
V_{IH}	Input voltage for high level		0.7*U_{Bat}	U_{Bat}	V
V_{OL}	Output low voltage @ 10mA			1.1	V
V_{pu}	Pullup supply voltage	1	U_{Bat} –1.5	U_{Bat}	V
V_{pu}	Pullup supply voltage	2	13	15	V
R_{pu}	Pullup resistor		0.9	1.1	kΩ
S_{Tr}	Data-rate			20	kbd

Note 1: with reverse polarity protection diode, for battery supply voltage less than 14.5V
Note 2: with voltage limiter active, for battery supply voltage higher than 14.5V

4.16 RS232 interface

4.16.1 Pinout:



Connector Pin Number	Function
P257	RS232 Serial Interface Output (TX)
P264	RS232 Serial Interface Input (RX)

4.16.2 Functional description:

RS232 is used as a full duplex serial interface. Note that handshake lines (RTS, CTS, …) are not available.

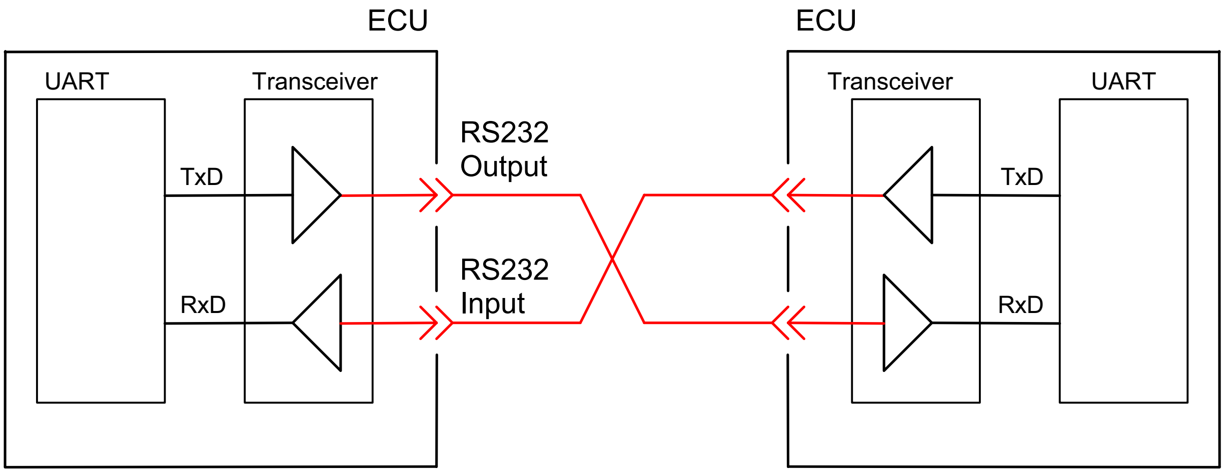


Figure 27: RS232 interface

Please note that a common ground (chassis) or a proper ground connection is necessary for RS232 operation. In case of connecting with an external device (e.g. PC with RS232-interface) please make sure that the maximum voltage ratings are not violated when connecting to or disconnecting from the RS232-connection.

4.16.3 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{RS232x}	Bus voltage under overload conditions (i.e short circuit to supply voltages)		-15	32	V

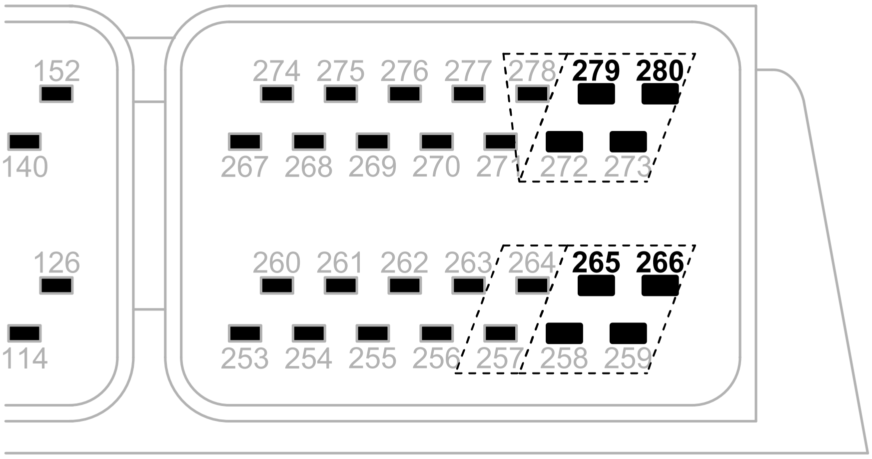
4.16.4 Characteristics

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{out}	Pin output capacitance		100	150	pF
V_{IL}	Input voltage for low level		-15	+0.8	V
V_{IH}	Input voltage for high level		+2.4	+15	V
R_{pd}	Input resistor (to GND)		3	7	kΩ
V_{OL}	Output voltage for low level		-9	-5	V
V_{OH}	Output voltage for high level		+5	+9	V
S_{Tr}	Data-rate			115	kbd

4.17 CAN interface ISO 11898

4.17.1 Pinout:



Connector Pin Number	Function
P279	CAN Interface 0 – High Line
P273	CAN Interface 0 – Low Line
P272	Termination for CAN Interface 0 – High Line
P280	Termination for CAN Interface 0 – Low Line
P265	CAN Interface 1 – High Line
P259	CAN Interface 1 – Low Line
P258	Termination for CAN Interface 1 – High Line
P266	Termination for CAN Interface 1 – Low Line

4.17.2 Functional description:

Bidirectional twisted pair bus.
Needs termination with 120Ω (2*60 Ω) in 2 control units whereas the others remain unterminated.
Termination must be fit at the ends of the bus line to prevent wave reflection and is necessary to enter the recessive state.
For easy configuration there are 2*2 pin-pairs for activating / deactivating termination.

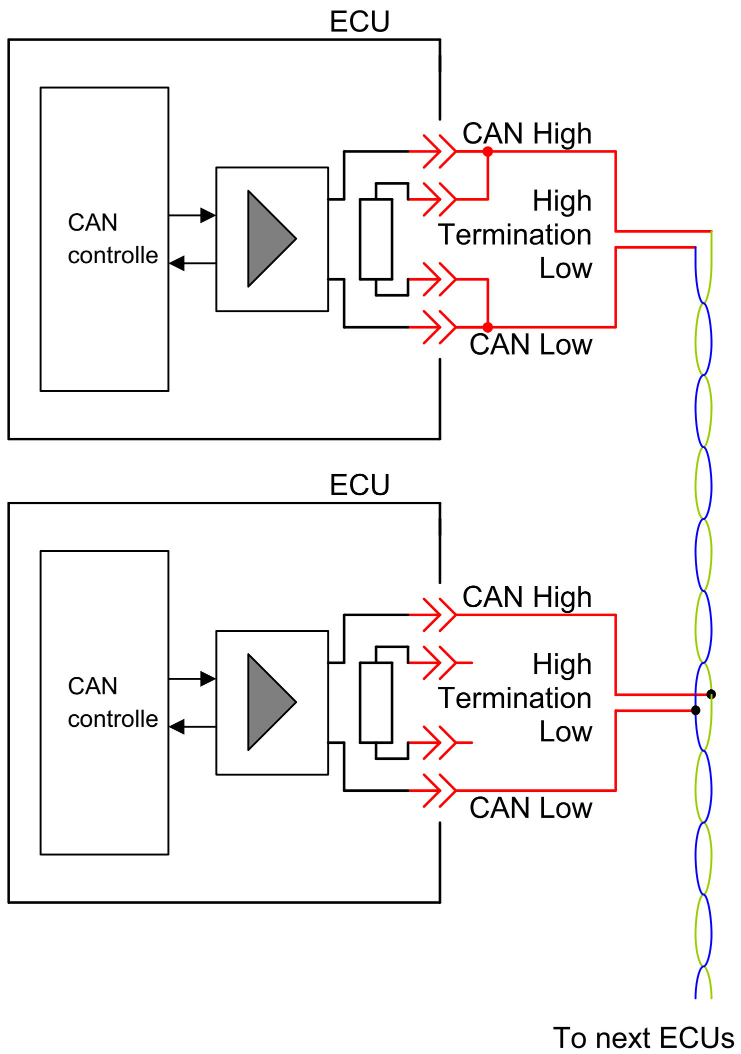


Figure 28: CAN interface

Please note that a common ground (chassis) or a proper ground connection is necessary for CAN operation. In case of connecting with an external device (e.g. PC with CAN-interface for downloading software) please make sure that the maximum voltage ratings are not violated when connecting to or disconnecting from the CAN-connection.

4.17.3 Maximum ratings

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
V_{CAN_CN} V_{CAN_CN}	Bus voltage under overload conditions (i.e. short circuit to supply voltages)		-20	40	V

4.17.4 Characteristics

$T_{ambient}$ = -40° .. 85°C

Symbol	Parameter	Note	min	max	Units
C_{out}	Pin output capacitance			100	pF
$V_{in\text{-}CMM}$	Input common mode range	1	-2	7	V
$V_{in\text{-}dif}$	Differential input threshold voltage (V_{CAN_CNH} - V_{CAN_CNL})		0.5	0.9	V
$V_{out\text{-}dif}$	Differential output voltage dominant state (V_{CAN_CNH} - V_{CAN_CNL})		1.5	3.0	V
$V_{out\text{-}dif}$	Differential output voltage recessive state (V_{CAN_CNH} - V_{CAN_CNL})		-0.1	+0.1	V
V_{CAN_CNL} V_{CAN_CNH}	Common mode idle voltage (recessive state)		2	3	V
I_{CAN_CNL}	Output current limit		-40	-200	mA
I_{CAN_CNH}	Output current limit		40	200	mA
S_{Tr}	Bit-rate	2		1000	kBit/s
S_{Tr}	Bit-rate	3		500	kBit/s
R_{Ter}	Termination resistance		115	125	Ω

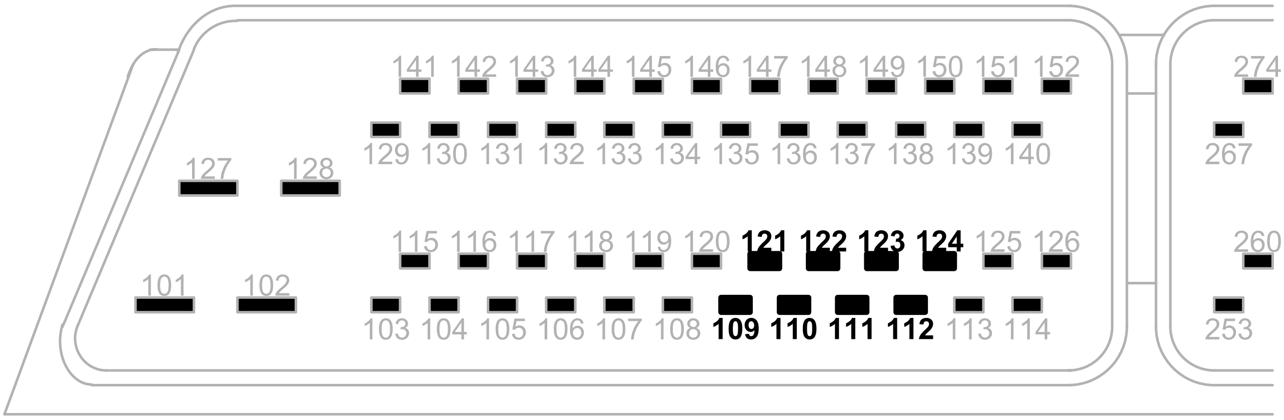
Note 1: due to high current in the wiring harness the individual ground potential of control units may differ up to several Volts. This difference will appear also between a transmitting and receiving control unit as common mode voltage and does not influence the differential bus signal as long as it is within the common mode limits.

Note 2: please observe the limitations of CAN. The arbitration process will allow 1Mbit/s operation only in small networks and reduced wire length. As example a so called “private CAN”, a short point to point connection (less than 10m) between only 2 nodes can be operated at 1MBit/s.

Note 3: for typical network size and topology (network with stub wires) and more than 2 nodes the practical limit is 500kBit/s.

4.18 Mini Module / Current measurement

4.18.1 Pinout:



Connector Pin Number	Function
P122	Mini Module Connection 0
	Current Measurement Input 0, 2nd connection pin
P110	Mini Module Connection 1
	Current Measurement Input 1, 2nd connection pin
P121	Mini Module Connection 2
	Current Measurement Input 2, 2nd connection pin
P109	Mini Module Connection 3
	Current Measurement Input 3, 2nd connection pin
P124	Mini Module Connection 4
	Analog input (from 0..5 up to 0..32V) 4
P112	Mini Module Connection 5
	Analog input (from 0..5 up to 0..32V) 5
P123	Mini Module Connection 6
	Analog input (from 0..5 up to 0..32V) 6
P111	Mini Module Connection 7
	Analog input (from 0..5 up to 0..32V) 7

The Mini Module shares connector pin with other I/Os.

4.18.2 Functional description:

Optionally a customer specific Mini Module may be mounted that can make use of up to 8 connector pins as listed in the table above.
On the Mini Module a microcontroller can be placed as well as small power stages or complex user specific circuits.

The Mini Module shares connector pins with other I/Os.
The current measurement inputs are routed to pin pairs. When using a mini module there are only single pins available. However, the current measurement function is still available.
If the Mini Module needs 5 ..8 connector pins the analog input (from 0..5 up to 0..32V) number 5 .. 8 are replaced by Mini Module connections.

4.18.3 Suitable functions for the Mini Module:

- user specific sensor interfaces
- user specific actuator interfaces
- user specific actuator/position feedback interface an control loop
- high resolution ADC-units
- analog outputs

…….

5 Application Notes

5.1 Wiring Harness

In order to enable a safe operation a few general rules for the layout of the wiring harness have to be obeyed.

For the dimensioning the power supply cables please refer to section 4.1.6 (wiring hints).

5.2 Load Distribution

The 16 power stages of the TTC 50 would theoretically deliver a total current of 48A if switched on concurrently. The TTC 50's permanent input current $I_{in\text{-}max}$ is 30A because there is a thermal and a contact current limit.

As the power stages have not negligible power dissipation each load current leads to a rise of temperature. To ensure proper operation of the TTC 50 in its temperature range (-40 °C to +85 °C) the total current driven by the power stages has to be limited and the load evenly distributed.

One first rule of thumb is that if two output states are mutually exclusive (e.g. output A is only activated in state 1, output B is only activated in state 2) these outputs should be driven by one double-channel power stage, so that only one channel is used at a time.

Another way to reduce the overall power dissipation is to drive different power stages in parallel for high currents.

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