TTControl
HYDAC INTERNATIONAL

HY-TTC 500

System Manual

Programmable ECU for Sensor-Actuator Management

Product Version 02.00

Original Instructions

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1 Introduction

The HY-TTC 500 is a family of programmable electronic control units for sensor/actuator management. Lots of configurable I/Os allow the use of HY-TTC 500 with different sensor and actuator types. Being part of a complete and compatible product family, the control unit is specifically designed for vehicles and machines that operate in rough environments and at extreme operating temperatures. The robust die-cast aluminum housing of HY-TTC 500 provides protection against electromagnetic disturbances and mechanical stress. A 180 MHz TI TMS570-integrated microprocessor provides the necessary processing power. To provide individual features that are scalable to system integrator needs, the HY-TTC 500 family is available in several variants, with different assembly options. See Section 1.5 on the facing page for variants overview.

1.1 Inputs and Outputs

All inputs and outputs of each HY-TTC 500 variant 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 directly connected to the current-controlled PWM outputs. The HY-TTC 500 family is designed to support a variety of analog and digital sensor types. Many software-configurable input options can be selected to adapt to different sensor types. A group of individually configurable analog inputs with a voltage ranging from 0. . . 5V to 0. . . 32V are provided. Those analog inputs can be set to different voltage ranges by software in order to achieve the best analog accuracy and resolution. The analog inputs can also be configured as a current input or for resistive measurements.

1.2 Communication Interfaces

On the fully equipped variant HY-TTC 580, 7 x CAN (according to CAN 2.0B), 1x RS-232 and 1x LIN interface are available for serial communication. Additionally a 10/100 Mbit/s Ethernet interface for high speed communication, application download, and debug purpose is provided.

1.3 Safety and Certification

The HY-TTC 500 family is designed to comply with the international standards IEC 61508 [8], ISO 13849 [24], and ISO 25119 [25]. For information regarding ISO 26262 [26] compliance, or for any further queries, please contact TTControl at support@ttcontrol.com.

1.4 Programming Options

The unit may be programmed in C or CODESYS. CODESYS is one of the most common IEC 61131-3 programming systems [10] running under Microsoft Windows. CODESYS supports several editors, including the **Instruction List Editor**, **Sequential Function Chart Editor**, and **Function Block Diagram Editor**. CODESYS produces native machine code for the main processor of HY-TTC 500.

1.5 HY-TTC 500 Variants

The following HY-TTC 500 variants are described in this System Manual:

- **HY-TTC 580**
- **HY-TTC 540**
- **HY-TTC 520 (customer-specific variant only)**
- **HY-TTC 510**
- **HY-TTC 590E**
- **HY-TTC 590**
- **HY-TTC 508**

The main difference of the listed HY-TTC 500 variants is the amount of available I/Os, whereas the HY-TTC 580 is the most powerful variant with the maximum number of I/Os. See Chapter 3 on page 42 which main- and alternative functions are available on which variant.

Unless other specified in Chapter 4 on page 96, the functionality of the available main- and alternative functions do not differ between each variants.

1.5.1 HY-TTC 500 FPGA Variants

The following 3 tables Table 1 on the next page, Table 2 on page 5 and Table 3 on page 6 define the main features and I/Os of three different hardware executions: Spartan-6 XA6SLX9 FPGA, Spartan-6 XA6SLX16 FPGA and Spartan-6 XA6SLX25 FPGA based

Feature		HY-TTC 580	HY-TTC 540	HY-TTC 520	HY-TTC 510	HY-TTC 590E	HY-TTC 590	HY-TTC 508
CPU								
	32-bit TI TMS570	x	x	x	x	x	x	x
	Int. FLASH	3 MB	3 MB	3 MB	3 MB	3 MB	3 MB	3 MB
	Int. RAM	256 kB	256 kB	256 kB	256 kB	256 kB	256 kB	256 kB
Memory								
	Ext. FLASH	8 MB	-	-	-	64 MB	32 MB	16 MB
	Ext. RAM	2 MB	2 MB	2 MB	2 MB	2 MB	2 MB	2 MB
	Ext. EEPROM	64 kB	64 kB	64 kB	64 kB	-	-	64 kB
	Ext. FRAM	-	-	-	-	32 kB	32 kB	-
Interface								
	CAN	7	4	4	3	7	7	3
	CAN1 is ISOBUS Compliance	-	-	-	-	x	x	x
	CAN bus termination	4	4	4	3	4	4	3
	Ethernet	1	-	-	-	-	-	-
	100BASE-T1 Ethernet	-	-	-	-	1	1	1
	LIN	1	-	-	1	1	1	-
	RS232	1	-	-	-	1	1	-
	Real time clock	1	-	-	-	1	1	1
Outputs								
	High-Side PWM with CM	36	28	18	16	36	36	10
	High-Side digital	8	8	8	8	8	8	8
	High-Side digital, PVG, VOUT	8	-	-	8	8	8	6
	Low-Side digital	8	8	8	8	8	8	8
Inputs								
	Analog input 3 modes (V)(I)(R)	8	8	8	8	8	8	8
	Analog input 2 modes (V)(I)	16	16	16	16	16	16	16
	Analog input (V)	-	8	-	-	-	-	-
	Timer input	12	20	20	20	12	12	20
	Terminal 15	1	1	1	1	1	1	1
	Wake-Up	1	1	1	1	1	1	1
Sensor supply								
	+5V/500mA	2	2	2	2	2	2	1
	+5-10V/2.5W	1	1	1	1	1	1	-
Safety Switch								
	Nr. of secondary shut-off path	3	2	2	2	3	3	2

Table 1: Variants overview for the Spartan-6 XA6SLX16 FPGA

Feature	HY-TTC 580	HY-TTC 540	HY-TTC 520	HY-TTC 510	HY-TTC 590E	HY-TTC 590	HY-TTC 508
CPU							
32-bit TI TMS570	x	x	x	x	x	x	x
Int. FLASH	3 MB	3 MB	3 MB	3 MB	3 MB	3 MB	3 MB
Int. RAM	256 kB	256 kB	256 kB	256 kB	256 kB	256 kB	256 kB
Memory							
Ext. FLASH	8 MB	-	-	-	64 MB	32 MB	16 MB
Ext. RAM	2 MB	2 MB	2 MB	2 MB	2 MB	2 MB	2 MB
Ext. EEPROM	64 kB	64 kB	64 kB	64 kB	-	-	64 kB
Ext. FRAM	-	-	-	-	32 kB	32 kB	-
Interface							
CAN	4	4	4	3	4	4	3
CAN1 is ISOBUS Compliance	-	-	-	-	x	x	x
CAN bus termination	4	4	4	3	4	4	3
Ethernet	1	-	-	-	-	-	-
100BASE-T1 Ethernet	-	-	-	-	1	1	1
LIN	1	-	-	1	1	1	-
RS232	1	-	-	-	1	1	-
Real time clock	1	-	-	-	1	1	1
Outputs							
High-Side PWM with CM	36	28	18	16	36	36	10
High-Side digital	16	8	8	8	16	16	8
High-Side digital, PVG, VOUT	0	-	-	8	0	0	6
Low-Side digital	8	8	8	8	8	8	8
Inputs							
Analog input 3 modes (V)(I)(R)	8	8	8	8	8	8	8
Analog input 2 modes (V)(I)	16	16	16	16	16	16	16
Analog input (V)	-	8	-	-	-	-	-
Timer input	12	20	20	20	12	12	20
Terminal 15	1	1	1	1	1	1	1
Wake-Up	1	1	1	1	1	1	1
Sensor supply							
+5V/500mA	2	2	2	2	2	2	1
+5-10V/2.5W	1	1	1	1	1	1	-
Safety Switch							
Nr. of secondary shut-off path	3	2	2	2	3	3	2

Table 2: Variants overview for the Spartan-6 XA6SLX9 FPGA

Feature	HY-TTC 580	HY-TTC 590E	HY-TTC 590
CPU			
32-bit TI TMS570	x	x	x
Int. FLASH	3 MB	3 MB	3 MB
Int. RAM	256 kB	256 kB	256 kB
Memory			
Ext. FLASH	8 MB	64 MB	32 MB
Ext. RAM	2 MB	2 MB	2 MB
Ext. EEPROM	64 kB	-	-
Ext. FRAM	-	32 kB	32 kB
Interface			
CAN	7	7	7
CAN1 is ISOBUS Compliance	-	x	x
CAN bus termination	7	7	7
Ethernet	1	-	-
100BASE-T1 Ethernet	-	1	1
LIN	1	1	1
RS232	1	1	1
Real time clock	1	1	1
Outputs			
High-Side PWM with CM	36	36	36
High-Side digital	8	8	8
High-Side digital, PVG, VOUT	8	8	8
Low-Side digital	8	8	8
Inputs			
Analog input 3 modes (V)(I)(R)	8	8	8
Analog input 2 modes (V)(I)	16	16	16
Analog input (V)	-	-	-
Timer input	12	12	12
Terminal 15	1	1	1
Wake-Up	1	1	1
Sensor supply			
+5V/500mA	2	2	2
+5-10V/2.5W	1	1	1
Safety Switch			
Nr. of secondary shut-off path	3	3	3

Table 3: Variants overview for the Spartan-6 XA6SLX25 FPGA

1.5.2 HY-TTC 580 Variant

Note 1 For any FPGA variant differences please refer to Table 1 on page 4, Table 2 on page 5 and Table 3 on the facing page.

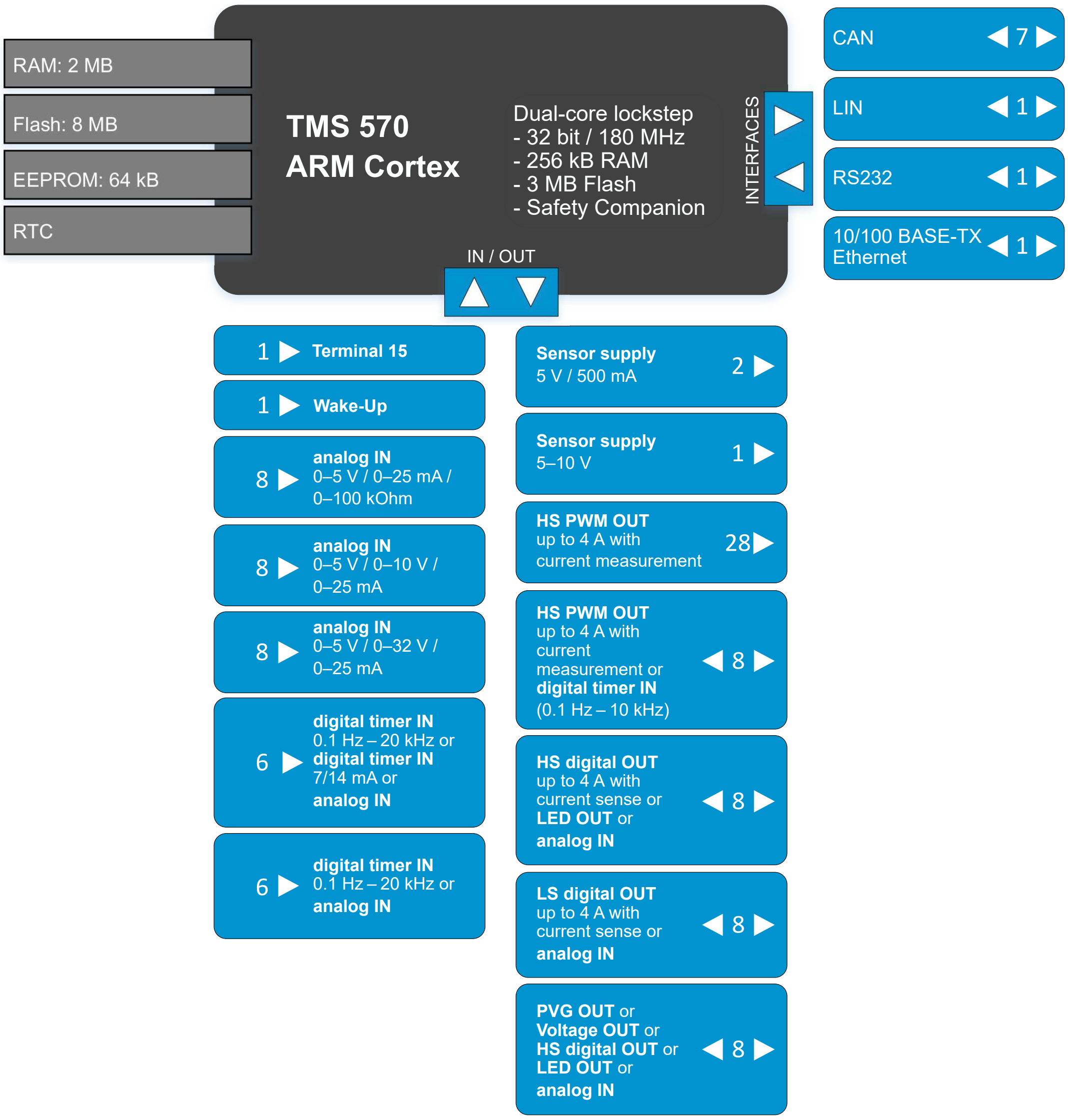

Figure 1: HY-TTC 580 Variant

System CPU

- TMS570LS3137 CPU running at 180 MHz, 3 MB internal Flash, 256 kB internal RAM, 64 kB configuration Flash
- Safety companion
- 12 bit ADC with 5 V reference voltage
- Real Time Clock (RTC)

Memory

External EEPROM	64 kB More than 1,000,000 write cycles. More than 40-year data retention.
External Flash	8 MB More than 100,000 write/erase cycles per block. More than 20-year data retention.
Internal Flash	3 MB Program Flash. More than 1000 write/erase cycles. More than 15-year data retention.
Configuration Flash	64 kB More than 100,000 write/erase cycles. More than 15-year data retention.
External SRAM	2 MB
Internal SRAM	256 kB

Communication Interfaces

Note 1 For any FPGA variant differences please refer to Table 1 on page 4, Table 2 on page 5 and Table 3 on page 6.

- 7 x CAN (50 to 1000 kbit/s)
- 1 x LIN (up to 20 kBd)
- 1 x RS232 (up to 115 kBd)
- 1 x Ethernet (10/100 Mbit/s)

Power Supply

- Supply voltage: 8 to 32 V
- Separate supply pins for CPU subsystem and I/O subsystem
- Load dump protection
- Low current consumption: 0.4 A at 12 V
- 2 x 5 V / 500 mA sensor supply
- 1 x 5 to 10 V / 2.5 W sensor supply, voltage selected by software
- Board temperature, sensor supply and battery monitoring

Inputs

8 x analog input 3 modes	Voltage measurement: 0 to 5 V Current measurement: 0 to 25 mA Resistor measurement: 0 to 100 kΩ
16 x analog input 2 modes	Voltage measurement: 8 x 0 to 5 V/ 0 to 10 V Voltage measurement: 8 x 0 to 5 V/ 0 to 32 V Current measurement: 16 x 0 to 25 mA
6 x timer input	Frequency and pulse width measurement Input pair as encoder Voltage measurement 0 to 32 V
6 x timer input	Frequency and pulse width measurement Input pair as encoder Digital (7/14 mA) current loop speed sensor Voltage measurement 0 to 32 V

All modes are configurable in software. The analog inputs provide 12-bit resolution. Each voltage input can be configured as a digital input with an adjustable threshold.

Outputs

Note 1 For any FPGA variant differences please refer to Table 1 on page 4, Table 2 on page 5 and Table 3 on page 6.

36 x PWM-controlled HS Outputs	PWM mode (50 Hz to 1 kHz)
	Nominal current 4 A
	Digital output mode with current feedback
when used as an input	Digital input
	8 PWM-controlled HS outputs can be alternatively used as frequency or pulse width measurement input
8 x digital HS outputs	Digital output mode
	Nominal current 4 A with voltage feedback
when used as an input	Voltage measurement 0 to 32 V
	Digital input
8 x digital LS outputs	Digital output mode
	Nominal current 4 A
when used as an input	Voltage measurement 0 to 32 V
	Digital input
8 x HS outputs	Digital output mode
	PVG output
	Voltage output (VOUT)
when used as an input	Voltage measurement 0 to 32 V
	Digital input

Specifications

Dimensions	See [28]
Weight	See [28]
Operating ambient temperature	-40 °C to +85 °C[1]
Storage temperature	-40 °C to +85 °C
Housing	IP67- and IP6k9k-rated die-cast aluminum housing and 154-pin connector
	Pressure equalization with water barrier
Operating altitude	0 to 4000 m

[1] For the Spartan-6 XA6SLX25 FPGA variant the operating ambient temperature decreases to -40 °C to +80 °C

1.5.3 HY-TTC 540 Variant

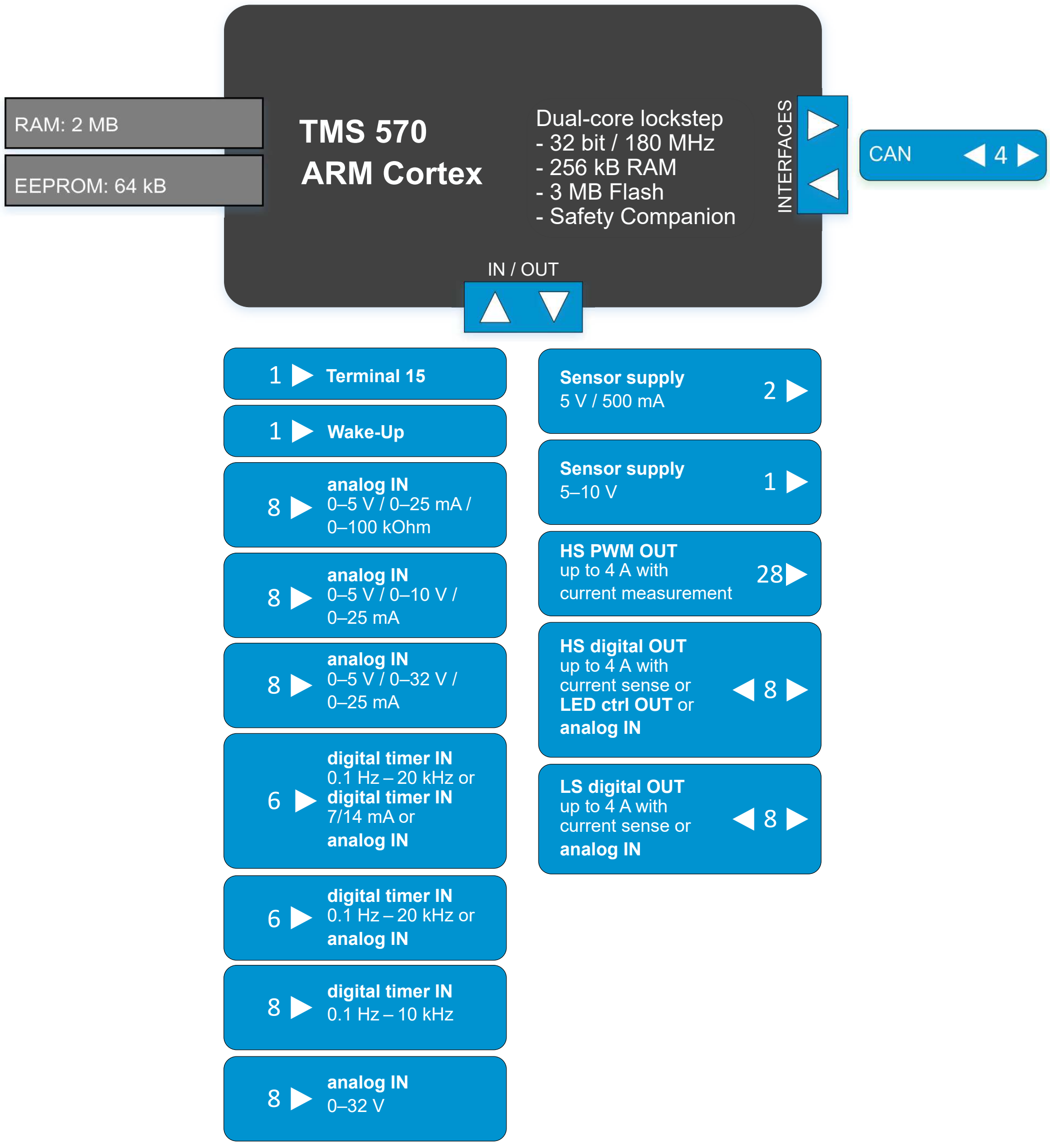

Figure 2: HY-TTC 540 Variant

System CPU

- TMS570LS3137 CPU running at 180 MHz, 3 MB internal Flash, 256 kB internal RAM, 64 kB configuration Flash
- Safety companion
- 12 bit ADC with 5 V reference voltage

Memory

External EEPROM	64 kB More than 1,000,000 write cycles. More than 40-year data retention.
Internal Flash	3 MB Program Flash. More than 1000 write/erase cycles. More than 15-year data retention.
Configuration Flash	64 kB More than 100,000 write/erase cycles. More than 15-year data retention.
External SRAM	2 MB
Internal SRAM	256 kB

Communication Interfaces

- 4 x CAN (50 to 1000 kbit/s)

Power Supply

- Supply voltage: 8 to 32 V
- Separate supply pins for CPU subsystem and I/O subsystem
- Load dump protection
- Low current consumption: 0.4 A at 12 V
- 2 x 5 V / 500 mA sensor supply
- 1 x 5 to 10 V / 2.5 W sensor supply, voltage selected by software
- Board temperature, sensor supply and battery monitoring

Inputs

8 x analog input 3 modes	Voltage measurement: 0 to 5 V Current measurement: 0 to 25 mA Resistor measurement: 0 to 100 kΩ
16 x analog input 2 modes	Voltage measurement: 8 x 0 to 5 V/ 0 to 10 V Voltage measurement: 8 x 0 to 5 V/ 0 to 32 V Current measurement: 16 x 0 to 25 mA
6 x timer input	Frequency and pulse width measurement Input pair as encoder Voltage measurement 0 to 32 V
6 x timer input	Frequency and pulse width measurement Input pair as encoder Digital (7/14 mA) current loop speed sensor Voltage measurement 0 to 32 V
8 x timer input	Frequency and pulse width measurement
8 x analog input	0 to 32 V

All modes are configurable in software. The analog inputs provide 12-bit resolution. Each voltage input can be configured as a digital input with an adjustable threshold.

Outputs

28 x PWM-controlled HS Outputs	PWM mode (50 Hz to 1 kHz) Nominal current 4 A Digital output mode with current feedback
when used as an input	Digital input
8 x digital HS outputs	Digital output mode Nominal current 4 A with voltage feedback
when used as an input	Voltage measurement 0 to 32 V Digital input
8 x digital LS outputs	Digital output mode Nominal current 4 A
when used as an input	Voltage measurement 0 to 32 V Digital input

Specifications

Dimensions	See [28]
Weight	See [28]
Operating ambient temperature	-40 ℃ to +85 ℃
Storage temperature	-40 ℃ to +85 ℃
Housing	IP67- and IP6k9k-rated die-cast aluminum housing and 154-pin connector
	Pressure equalization with water barrier
Operating altitude	0 to 4000 m

1.5.4 HY-TTC 520 Variant (Customer-specific variant only)

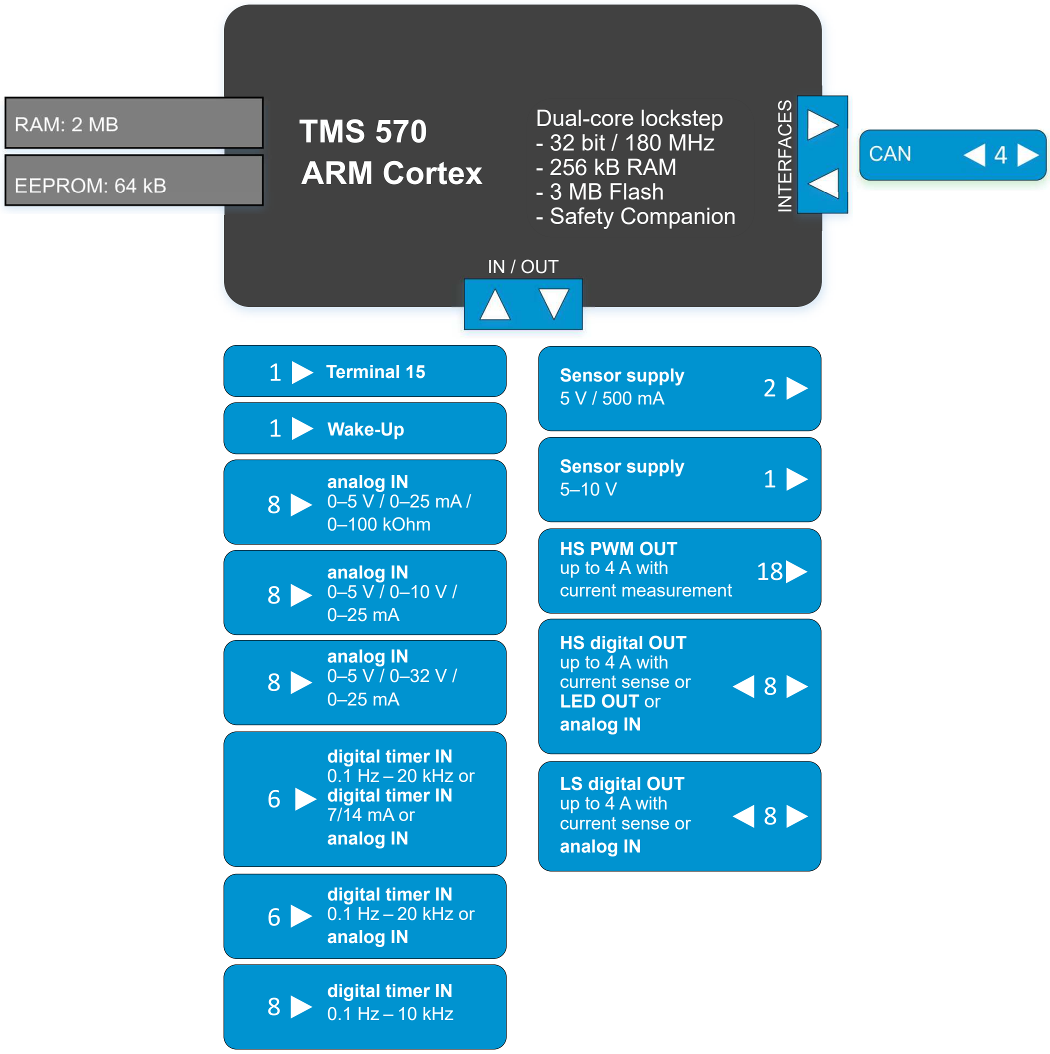

Figure 3: HY-TTC 520 Variant

System CPU

- TMS570LS3137 CPU running at 180 MHz, 3 MB internal Flash, 256 kB internal RAM, 64 kB configuration Flash
- Safety companion
- 12 bit ADC with 5 V reference voltage

Memory

External EEPROM	64 kB More than 1,000,000 write cycles. More than 40-year data retention.
Internal Flash	3 MB Program Flash. More than 1000 write/erase cycles. More than 15-year data retention.
Configuration Flash	64 kB More than 100,000 write/erase cycles. More than 15-year data retention.
External SRAM	2 MB
Internal SRAM	256 kB

Communication Interfaces

- 4 x CAN (50 to 1000 kbit/s)

Power Supply

- Supply voltage: 8 to 32 V
- Separate supply pins for CPU subsystem and I/O subsystem
- Load dump protection
- Low current consumption: 0.4 A at 12 V
- 2 x 5 V / 500 mA sensor supply
- 1 x 5 to 10 V / 2.5 W sensor supply, voltage selected by software
- Board temperature, sensor supply and battery monitoring

Inputs

8 x analog input 3 modes	Voltage measurement: 0 to 5 V Current measurement: 0 to 25 mA Resistor measurement: 0 to 100 kΩ
16 x analog input 2 modes	Voltage measurement: 8 x 0 to 5 V/ 0 to 10 V Voltage measurement: 8 x 0 to 5 V/ 0 to 32 V Current measurement: 16 x 0 to 25 mA
8 x timer input	Frequency and pulse width measurement
6 x timer input	Frequency and pulse width measurement Input pair as encoder Voltage measurement 0 to 32 V
6 x timer input	Frequency and pulse width measurement Input pair as encoder Digital (7/14 mA) current loop speed sensor Voltage measurement 0 to 32 V

All modes are configurable in software. The analog inputs provide 12-bit resolution. Each voltage input can be configured as a digital input with an adjustable threshold.

Outputs

18 x PWM-controlled HS Outputs	PWM mode (50 Hz to 1 kHz) Nominal current 4 A Digital output mode with current feedback
when used as an input	Digital input
8 x digital HS outputs	Digital output mode Nominal current 4 A with voltage feedback
when used as an input	Voltage measurement 0 to 32 V Digital input
8 x digital LS outputs	Digital output mode Nominal current 4 A
when used as an input	Voltage measurement 0 to 32 V Digital input

Specifications

Dimensions	See [28]
Weight	See [28]
Operating ambient temperature	-40 ℃ to +85 ℃
Storage temperature	-40 ℃ to +85 ℃
Housing	IP67- and IP6k9k-rated die-cast aluminum housing and 154-pin connector
	Pressure equalization with water barrier
Operating altitude	0 to 4000 m

1.5.5 HY-TTC 510 Variant

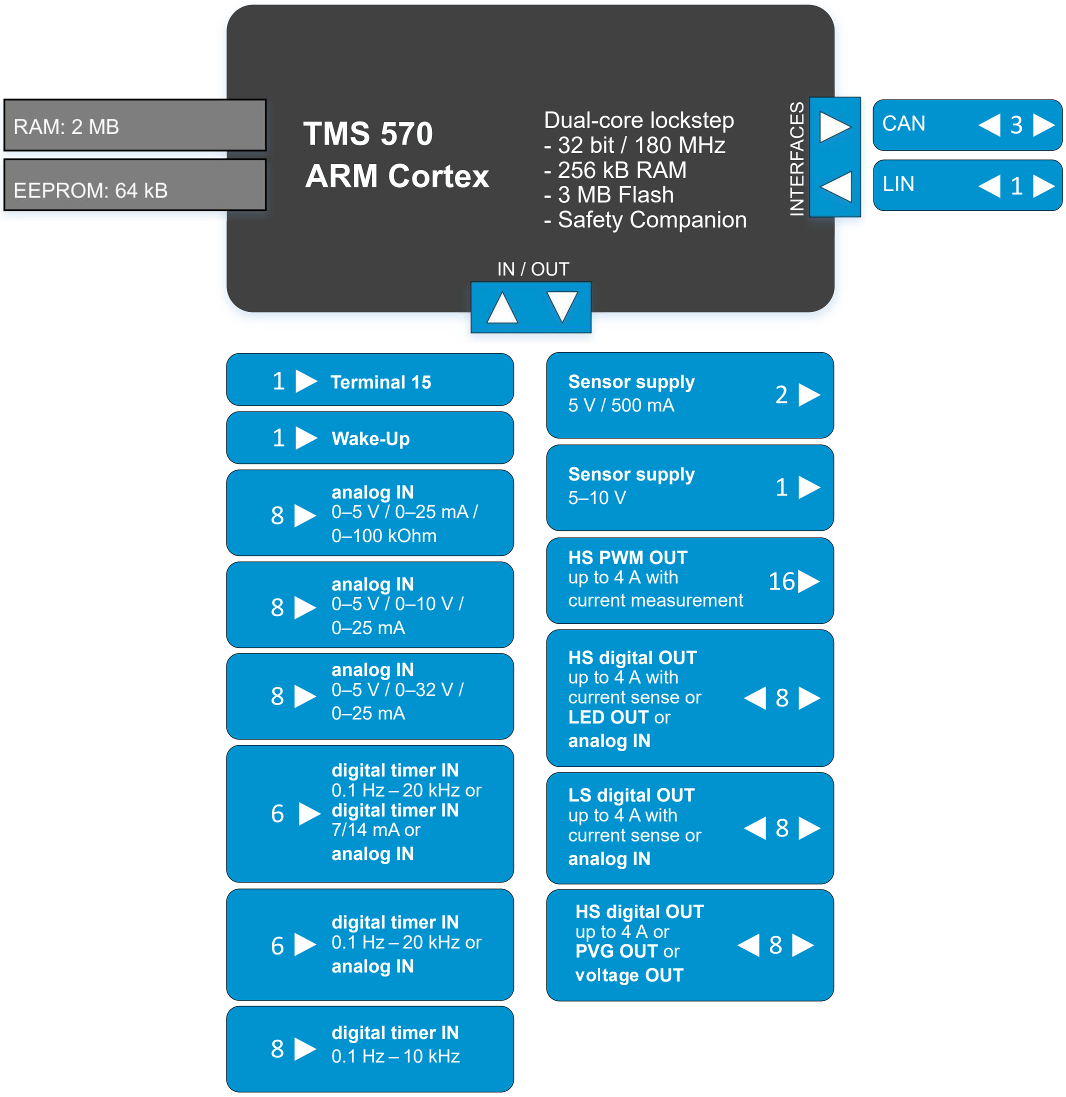

Figure 4: HY-TTC 510 Variant

System CPU

- TMS570LS3137 CPU running at 180 MHz, 3 MB internal Flash, 256 kB internal RAM, 64 kB configuration Flash
- Safety companion
- 12 bit ADC with 5 V reference voltage

Memory

External EEPROM	64 kB More than 1,000,000 write cycles. More than 40-year data retention.
Internal Flash	3 MB Program Flash. More than 1000 write/erase cycles. More than 15-year data retention.
Configuration Flash	64 kB More than 100,000 write/erase cycles. More than 15-year data retention.
External SRAM	2 MB
Internal SRAM	256 kB

Communication Interfaces

- 3 x CAN (50 to 1000 kbit/s)
- 1 x LIN (up to 20 kBd)

Power Supply

- Supply voltage: 8 to 32 V
- Separate supply pins for CPU subsystem and I/O subsystem
- Load dump protection
- Low current consumption: 0.4 A at 12 V
- 2 x 5 V / 500 mA sensor supply
- 1 x 5 to 10 V / 2.5 W sensor supply, voltage selected by software
- Board temperature, sensor supply and battery monitoring

Inputs

8 x analog input 3 modes	Voltage measurement: 0 to 5 V Current measurement: 0 to 25 mA Resistor measurement: 0 to 100 kΩ
16 x analog input 2 modes	Voltage measurement: 8 x 0 to 5 V/ 0 to 10 V Voltage measurement: 8 x 0 to 5 V/ 0 to 32 V Current measurement: 16 x 0 to 25 mA
8 x timer input	Frequency and pulse width measurement
6 x timer input	Frequency and pulse width measurement Input pair as encoder Voltage measurement 0 to 32 V
6 x timer input	Frequency and pulse width measurement Input pair as encoder Digital (7/14 mA) current loop speed sensor Voltage measurement 0 to 32 V

All modes are configurable in software. The analog inputs provide 12-bit resolution. Each voltage input can be configured as a digital input with an adjustable threshold.

Outputs

16 x PWM-controlled HS Outputs	PWM mode (50 Hz to 1 kHz) Nominal current 4 A Digital output mode with current feedback
when used as an input	Digital input
8 x digital HS outputs	Digital output mode Nominal current 4 A with voltage feedback
when used as an input	Voltage measurement 0 to 32 V Digital input
8 x digital LS outputs	Digital output mode Nominal current 4 A
when used as an input	Voltage measurement 0 to 32 V Digital input
8 x HS outputs	Digital output mode PVG output Voltage output (VOUT)
when used as an input	Voltage measurement 0 to 32 V Digital input

Specifications

Dimensions	See [28]
Weight	See [28]
Operating ambient temperature	-40 ℃ to +85 ℃
Storage temperature	-40 ℃ to +85 ℃
Housing	IP67- and IP6k9k-rated die-cast aluminum housing and 154-pin connector
	Pressure equalization with water barrier
Operating altitude	0 to 4000 m

1.5.6 HY-TTC 590E Variant

Note 1 For any FPGA variant differences please refer to Table 1 on page 4, Table 2 on page 5 and Table 3 on page 6.

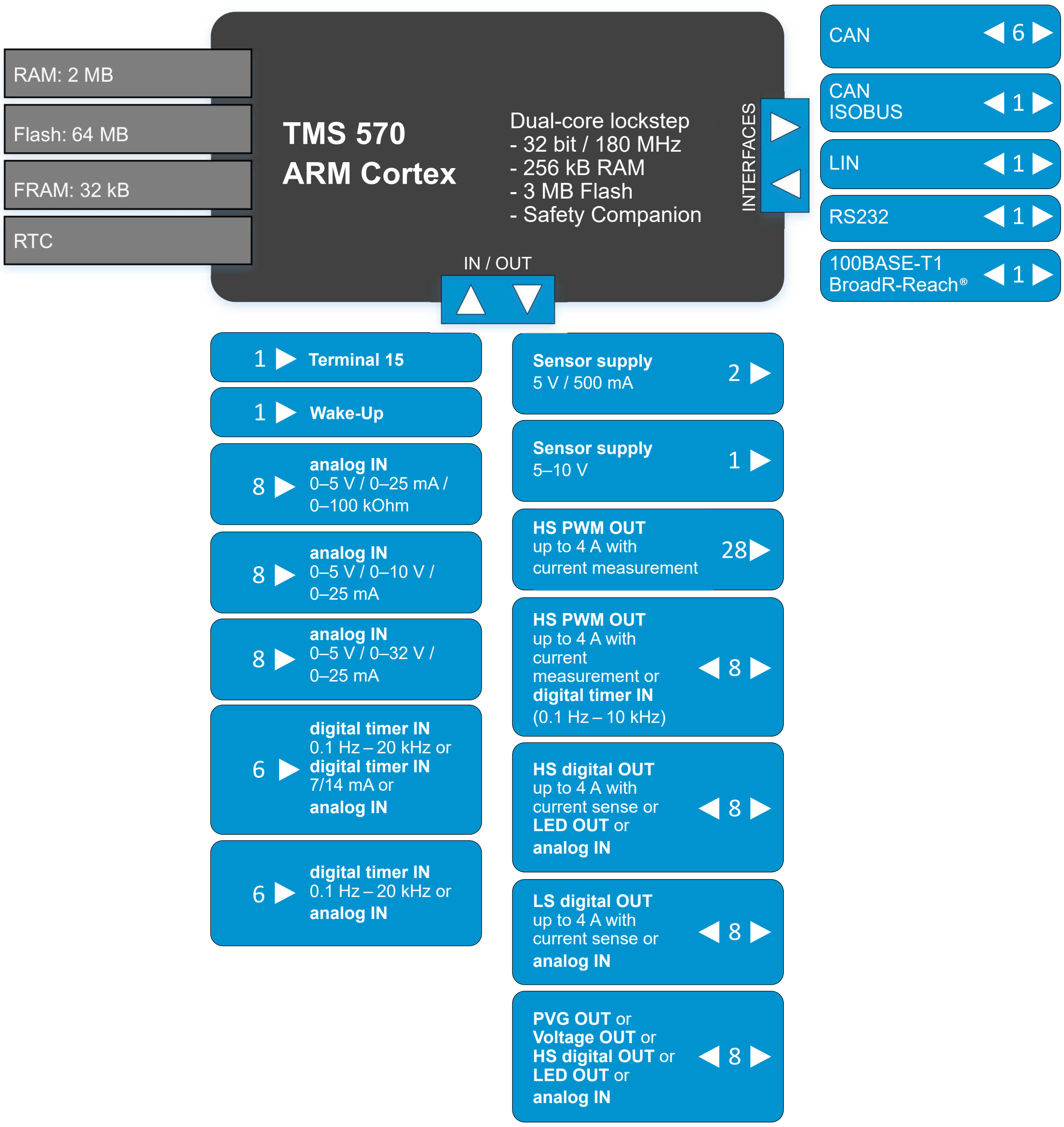

Figure 5: HY-TTC 590E Variant

System CPU

- TMS570LS3137 CPU running at 180 MHz, 3 MB internal Flash, 256 kB internal RAM, 64 kB configuration Flash
- Safety companion
- 12 bit ADC with 5 V reference voltage
- Real Time Clock (RTC)

Memory

External FRAM	32 kB More than 10 trillion (10^{13}) write cycles. More than 121-year data retention.
External Flash	64 MB More than 100,000 write/erase cycles per block. More than 20-year data retention.
Internal Flash	3 MB Program Flash. More than 1000 write/erase cycles. More than 15-year data retention.
Configuration Flash	64 kB More than 100,000 write/erase cycles. More than 15-year data retention.
External SRAM	2 MB
Internal SRAM	256 kB

Communication Interfaces

Note 1 For any FPGA variant differences please refer to Table 1 on page 4, Table 2 on page 5 and Table 3 on page 6.

- 7 x CAN (50 to 1000 kbit/s) (CAN1 is ISOBUS compliant)
- 1 x LIN (up to 20 kBd)
- 1 x RS232 (up to 115 kBd)
- 1 x 100BASE-T1 BroadR-Reach® (100 Mbit/s)

Power Supply

- Supply voltage: 8 to 32 V
- Separate supply pins for CPU subsystem and I/O subsystem
- Load dump protection
- Low current consumption: 0.4 A at 12 V
- 2 x 5 V / 500 mA sensor supply
- 1 x 5 to 10 V / 2.5 W sensor supply, voltage selected by software
- Board temperature, sensor supply and battery monitoring

Inputs

8 x analog input 3 modes	Voltage measurement: 0 to 5 V Current measurement: 0 to 25 mA Resistor measurement: 0 to 100 kΩ
16 x analog input 2 modes	Voltage measurement: 8 x 0 to 5 V/ 0 to 10 V Voltage measurement: 8 x 0 to 5 V/ 0 to 32 V Current measurement: 16 x 0 to 25 mA
6 x timer input	Frequency and pulse width measurement Input pair as encoder Voltage measurement 0 to 32 V
6 x timer input	Frequency and pulse width measurement Input pair as encoder Digital (7/14 mA) current loop speed sensor Voltage measurement 0 to 32 V

All modes are configurable in software. The analog inputs provide 12-bit resolution. Each voltage input can be configured as a digital input with an adjustable threshold.

Outputs

Note 1 For any FPGA variant differences please refer to Table 1 on page 4, Table 2 on page 5 and Table 3 on page 6.

36 x PWM-controlled HS Outputs	PWM mode (50 Hz to 1 kHz) Nominal current 4 A Digital output mode with current feedback
when used as an input	Digital input 8 PWM-controlled HS outputs can be alternatively used as frequency or pulse width measurement input
8 x digital HS outputs	Digital output mode Nominal current 4 A with voltage feedback
when used as an input	Voltage measurement 0 to 32 V Digital input
8 x digital LS outputs	Digital output mode Nominal current 4 A
when used as an input	Voltage measurement 0 to 32 V Digital input
8 x HS outputs	Digital output mode PVG output Voltage output (VOUT)
when used as an input	Voltage measurement 0 to 32 V Digital input

Specifications

Dimensions	See [28]
Weight	See [28]
Operating ambient temperature	-40 ℃ to +85 ℃[1]
Storage temperature	-40 ℃ to +85 ℃
Housing	IP67- and IP6k9k-rated die-cast aluminum housing and 154-pin connector
	Pressure equalization with water barrier
Operating altitude	0 to 4000 m

[1] For the Spartan-6 XA6SLX25 FPGA variant the operating ambient temperature decreases to -40 ℃ to +80 ℃

1.5.7 HY-TTC 590 Variant

Note 1 For any FPGA variant differences please refer to Table 1 on page 4, Table 2 on page 5 and Table 3 on page 6.

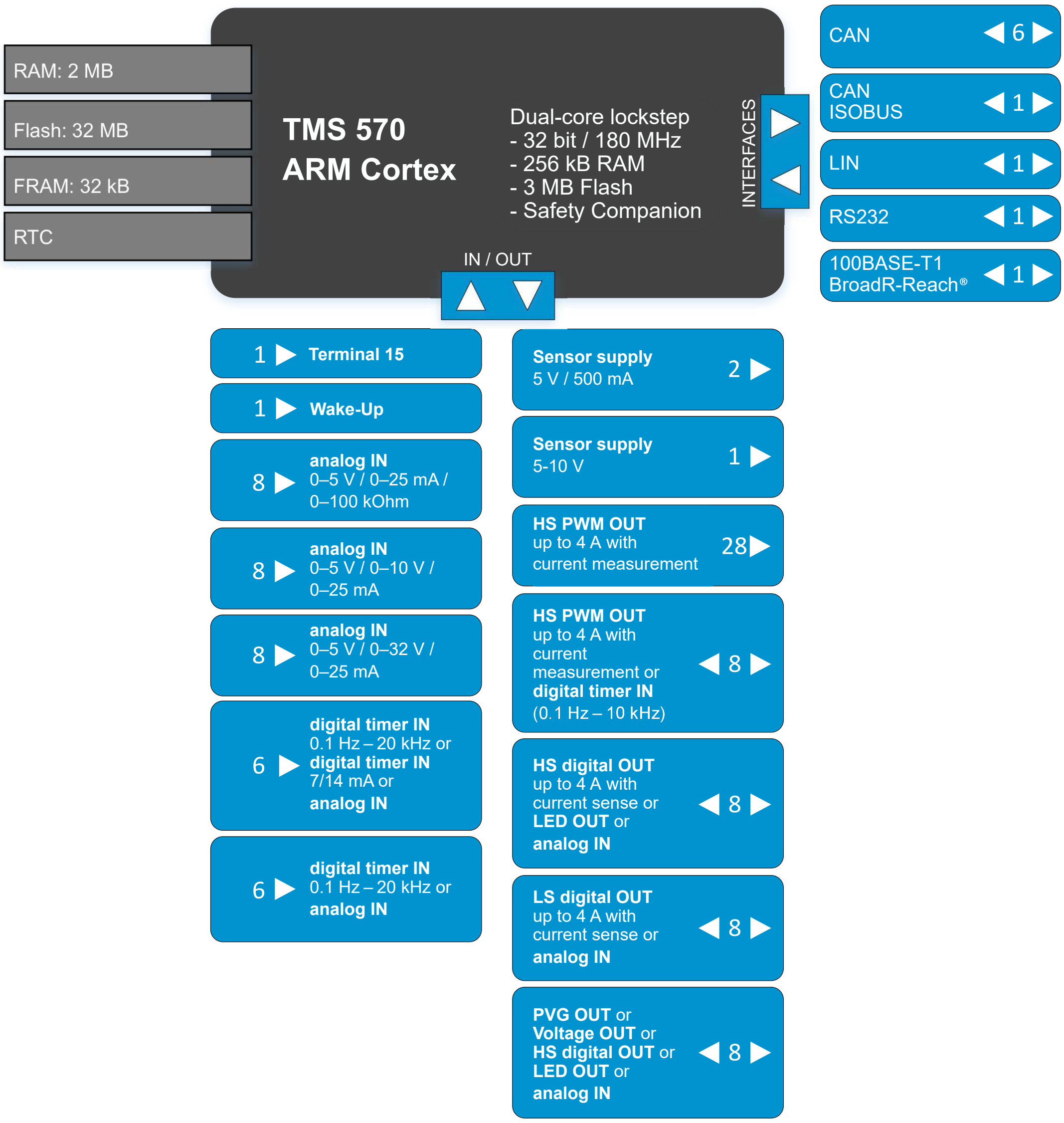

Figure 6: HY-TTC 590 Variant

System CPU

- TMS570LS3137 CPU running at 180 MHz, 3 MB internal Flash, 256 kB internal RAM, 64 kB configuration Flash
- Safety companion
- 12 bit ADC with 5 V reference voltage
- Real Time Clock (RTC)

Memory

External FRAM	32 kB More than 10 trillion (10^{13}) write cycles. More than 121-year data retention.
External Flash	32 MB More than 100,000 write/erase cycles per block. More than 20-year data retention.
Internal Flash	3 MB Program Flash. More than 1000 write/erase cycles. More than 15-year data retention.
Configuration Flash	64 kB More than 100,000 write/erase cycles. More than 15-year data retention.
External SRAM	2 MB
Internal SRAM	256 kB

Communication Interfaces

Note 1 For any FPGA variant differences please refer to Table 1 on page 4, Table 2 on page 5 and Table 3 on page 6.

- 7 x CAN (50 to 1000 kbit/s) (CAN1 is ISOBUS compliant)
- 1 x LIN (up to 20 kBd)
- 1 x RS232 (up to 115 kBd)
- 1 x 100BASE-T1 BroadR-Reach® (100 Mbit/s)

Power Supply

- Supply voltage: 8 to 32 V
- Separate supply pins for CPU subsystem and I/O subsystem
- Load dump protection
- Low current consumption: 0.4 A at 12 V
- 2 x 5 V / 500 mA sensor supply
- 1 x 5 to 10 V / 2.5 W sensor supply, voltage selected by software
- Board temperature, sensor supply and battery monitoring

Inputs

8 x analog input 3 modes	Voltage measurement: 0 to 5 V Current measurement: 0 to 25 mA Resistor measurement: 0 to 100 kΩ
16 x analog input 2 modes	Voltage measurement: 8 x 0 to 5 V/ 0 to 10 V Voltage measurement: 8 x 0 to 5 V/ 0 to 32 V Current measurement: 16 x 0 to 25 mA
6 x timer input	Frequency and pulse width measurement Input pair as encoder Voltage measurement 0 to 32 V
6 x timer input	Frequency and pulse width measurement Input pair as encoder Digital (7/14 mA) current loop speed sensor Voltage measurement 0 to 32 V

All modes are configurable in software. The analog inputs provide 12-bit resolution. Each voltage input can be configured as a digital input with an adjustable threshold.

Outputs

Note 1 For any FPGA variant differences please refer to Table 1 on page 4, Table 2 on page 5 and Table 3 on page 6.

36 x PWM-controlled HS Outputs	PWM mode (50 Hz to 1 kHz) Nominal current 4 A Digital output mode with current feedback
when used as an input	Digital input 8 PWM-controlled HS outputs can be alternatively used as frequency or pulse width measurement input
8 x digital HS outputs	Digital output mode Nominal current 4 A with voltage feedback
when used as an input	Voltage measurement 0 to 32 V Digital input
8 x digital LS outputs	Digital output mode Nominal current 4 A
when used as an input	Voltage measurement 0 to 32 V Digital input
8 x HS outputs	Digital output mode PVG output Voltage output (VOUT)
when used as an input	Voltage measurement 0 to 32 V Digital input

Specifications

Dimensions	See [28]
Weight	See [28]
Operating ambient temperature	-40 ℃ to +85 ℃[1]
Storage temperature	-40 ℃ to +85 ℃
Housing	IP67- and IP6k9k-rated die-cast aluminum housing and 154-pin connector
	Pressure equalization with water barrier
Operating altitude	0 to 4000 m

[1] For the Spartan-6 XA6SLX25 FPGA variant the operating ambient temperature decreases to -40 ℃ to +80 ℃

1.5.8 HY-TTC 508 Variant

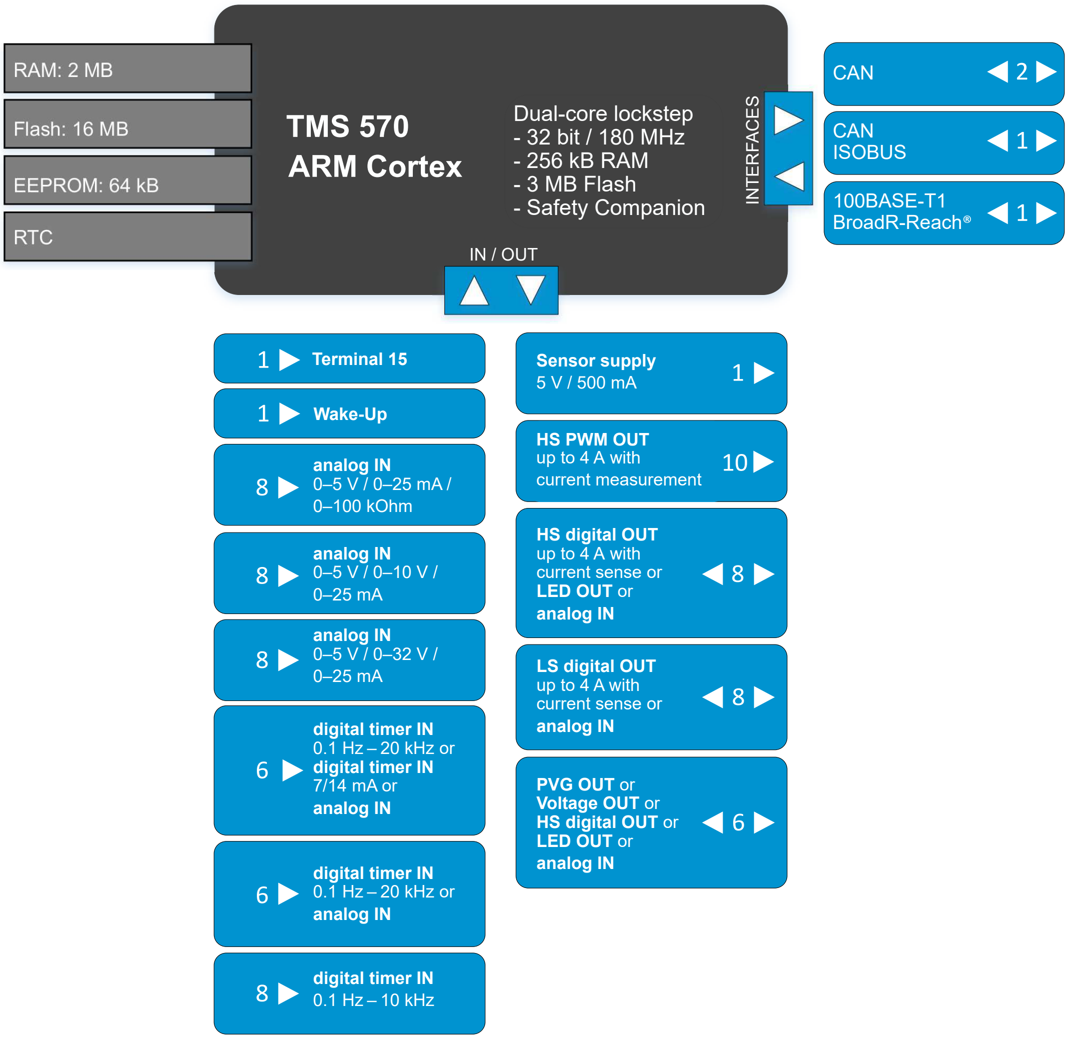

Figure 7: HY-TTC 508 Variant

System CPU

– TMS570LS3137 CPU running at 180 MHz, 3 MB internal Flash, 256 kB internal RAM, 64 kB configuration Flash
– Safety companion
– 12 bit ADC with 5 V reference voltage
– Real Time Clock (RTC)

Memory

External EEPROM	64 kB More than 1,000,000 write cycles. More than 40-year data retention.
External Flash	16 MB More than 100,000 write/erase cycles per block. More than 20-year data retention.
Internal Flash	3 MB Program Flash. More than 1000 write/erase cycles. More than 15-year data retention.
Configuration Flash	64 kB More than 100,000 write/erase cycles. More than 15-year data retention.
External SRAM	2 MB
Internal SRAM	256 kB

Communication Interfaces

– 3 x CAN (50 to 1000 kbit/s) (CAN1 is ISOBUS compliant)
– 1 x 100BASE-T1 BroadR-Reach® (100 Mbit/s)

Power Supply

– Supply voltage: 8 to 32 V
– Separate supply pins for CPU subsystem and I/O subsystem
– Load dump protection
– Low current consumption: 0.4 A at 12 V
– 2 x 5 V / 500 mA sensor supply
– 1 x 5 to 10 V / 2.5 W sensor supply, voltage selected by software
– Board temperature, sensor supply and battery monitoring

Inputs

8 x analog input 3 modes	Voltage measurement: 0 to 5 V Current measurement: 0 to 25 mA Resistor measurement: 0 to 100 kΩ
16 x analog input 2 modes	Voltage measurement: 8 x 0 to 5 V/ 0 to 10 V Voltage measurement: 8 x 0 to 5 V/ 0 to 32 V Current measurement: 16 x 0 to 25 mA
6 x timer input 6 x timer input	Frequency and pulse width measurement Input pair as encoder Voltage measurement 0 to 32 V Frequency and pulse width measurement Input pair as encoder Digital (7/14 mA) current loop speed sensor Voltage measurement 0 to 32 V
8 x timer input	Frequency and pulse width measurement

All modes are configurable in software. The analog inputs provide 12-bit resolution. Each voltage input can be configured as a digital input with an adjustable threshold.

Outputs

10 x PWM-controlled HS Outputs	PWM mode (50 Hz to 1 kHz) Nominal current 4 A Digital output mode with current feedback
8 x digital HS outputs when used as an input	Digital output mode Nominal current 4 A with voltage feedback Voltage measurement 0 to 32 V Digital input
8 x HS outputs when used as an input	Digital output mode PVG output Voltage output (VOUT) Voltage measurement 0 to 32 V Digital input
8 x digital LS outputs when used as an input	Digital output mode Nominal current 4 A Voltage measurement 0 to 32 V Digital input

Specifications

Dimensions	See [28]
Weight	See [28]
Operating ambient temperature	-40 ℃ to +85 ℃
Storage temperature	-40 ℃ to +85 ℃
Housing	IP67- and IP6k9k-rated die-cast aluminum housing and 154-pin connector
	Pressure equalization with water barrier
Operating altitude	0 to 4000 m

1.6 Standards and Guidelines

The HY-TTC 500 was developed to comply with several international standards and guidelines. This section lists the relevant standards and guidelines and the applied limits and severity levels.

Environmental Criteria – ISO 16750 Code:

CODE: ISO 16750 (B[1] F[2]), L, G, D, Z, (IP6k7; IP6k9k)

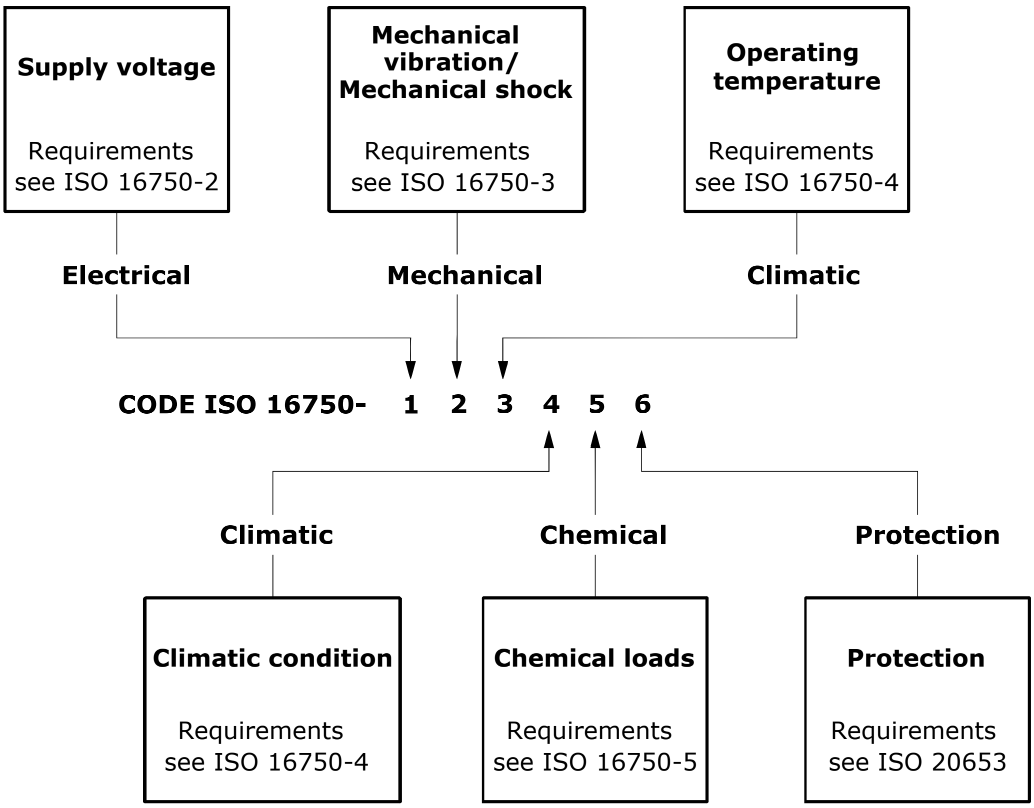

Figure 8: ISO 16750-1:2006 [13], Figure 1 – Code allocation

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[0] According to ISO 16750-2:2012 [22], Table 3, *Starting profile values for systems with 12 V nominal voltage*, functional status C at level II test-pulse can be achieved.

[0] According to ISO 16750-2:2012 [22], Table 4, *Starting profile values for systems with 24 V nominal voltage*, functional status A at level II and functional status B at level III test-pulse can be achieved.

1.6.1 Electrical Capability

ISO 16750-2:2012 [22]

ISO 7637-2:2011 [20]	Electrical transient conduction along supply lines. Test pluse: 1: -600 V, 1 ms 2a: +50 V, 50 μs 2b: +20 V, 200 ms 3a: -200 V, 0.1 μs 3b: +200 V, 0.1 μs 4: 12 V system, -6V drop (6 V remaining voltage) 24 V system, -18 V drop (6 V remaining voltage) 5a: +174 V, 2 Ω, 350 ms
ISO 7637-3:2007 [14]	Electrical transient transmission along signal lines. Tested for 24 V parameters, severity I

1.6.2 Mechanical Capability

ISO 16750-3:2012 [23]	Free fall tests, 1 m high, 6 falls per side Random vibration, broad-band 3 axes, 32 h per axis 57.9 m/s^2 -10 Hz to 2 kHz, temperature profile superimposed Shock, half-sine 3 axes, 60 shocks 500 m/s^2, 6 ms

1.6.3 Climatic Capability

ISO 16750-4:2012 [18]	Humid Heat Cyclic, DIN EN 60068-2-30:2006-06 [3], DIN EN 60068-2-38:2009 [5] Damp Heat, DIN EN 60068-2-78:2014-02[9]

Salt spray,
DIN EN 60068-2-11:2000-02 [2],
DIN EN 60068-2-38:1996-10 [5]

1.6.4 Chemical Capability

The list of applied chemical agents for tests according to **IEC 16750-5:2010**[19] is given in Table 4 on the current page.

ID	Chemical Agent	Application Method
AA	Diesel fuel	III. Wiping
AB	“Bio” diesel	III. Wiping
AC	Petrol/gasoline unleaded	III. Wiping
AE	Methanol	III. Wiping
BA	Engine oil	II. Brushing
BB	Differential oil	II. Brushing
BC	Transmission fluid	II. Brushing
BD	Hydraulic fluid	II. Brushing
CA	Battery fluid	III. Wiping
CB	Brake fluid	III. Wiping
CC	Antifreeze fluid	III. Wiping
CE	Cavity prodection	III. Wiping
CF	Protective lacquer	II. Brushing
CG	Protective lacquer remover	III. Wiping
DA	Windscreen washer fluid	II. Brushing
DB	Vehicle washing chemicals	II. Brushing
DC	Interior cleaner	III. Wiping
DD	Glass cleaner	III. Wiping
DE	Wheel cleaner	II. Brushing
DF	Cold cleaning agent	II. Brushing
DK	Denatured alcohol	III. Wiping
ED	Refreshment containing caffeine and sugar	III. Wiping
YYA	Gasoline with 15% methanol	III. Wiping
YYB	FAM test fuel	III. Wiping

Table 4: List of chemical agents

1.6.5 Ingress Protection Capability

ISO 20653:2013 [17]	IP6k7 and IP6k9k

1.6.6 ESD and EMC Capability for Road Vehicles

UNECE 10.4	Uniform provisions concerning the approval of vehicles with regard to EMC
DIN EN 13309:2010-12 (E) [4]	Construction machinery – Electromagnetic compatibility of machines with internal power supply
ISO 14982:1998 [11]	Agricultural and forestry machinery – Electromagnetic compatibility – Test methods and acceptance criteria
ISO 11452-2:2004 [12]	100 V/m, 20 MHz to 3 GHz
CISPR 25 ED. 3.0 B:2008 [1]	Conducted emissions, Class 3
ISO 10605:2008 [15]	ESD powered and unpowered ±6 kV contact discharge ±8 kV air discharge

1.6.7 ESD and EMC Capability for Industrial Applications

IEC 61000-6-2:2005 [6]	Immunity for industrial environments. Conformance to surge immunity is only given if signal line wire length is less than 30 m.
IEC 61000-6-4:2007 [7]	Radiated emission for industry

1.6.8 Functional Safety

ISO 13849:2015 [16]	Safety of machinery – Safety-related parts of control systems
IEC 61508:2010 [8]	Functional safety of electrical/electronic/programmable electronic safety-related systems (E/E/PE, or E/E/PES), Safety Integrity Level 2 (SIL 2)
ISO 25119:2018 [25]	Tractors and machinery for agriculture and forestry – Safety-related parts of control systems
ISO 26262:2018 [26]	Road vehicles – Functional safety

1.7 Instructions for Safe Operation

For safe operation of the HY-TTC 500 family ECUs, the following rules have to be obeyed:

1.7.1 General

- The HY-TTC 500 System Manual is written for a specific product version, for example 02.00. Make sure this document corresponds with the product version of the ECU. The *Product Version* on the title page of this document must match the *Version* on the label of the ECU. The following figure shows an example of an ECU label:

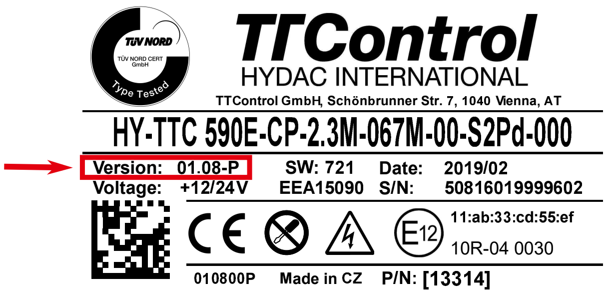

Figure 9: ECU label with Version field

- Please check regularly if there are updated documents (System Manual, Release Notes, . . .) for your specific product version on the `https://www.ttcontrol.com/service-area/` website.
- Carefully read the instructions and specifications listed in this document before operating the ECU.
- The ECU has to be operated by using the type of connectors specified in section section 3.2 on page 43.
- It is not allowed to use any other connector or cable harness than one of the specified ones.
- It is not allowed to operate the ECU in an environment that violates the specified operational range.
- The ECU has to be operated by skilled personnel only.
- When operating the ECU in an environment close to humans, it has to be considered that the ECU contain power electronics and therefore the housing can have high temperatures.
- It is not allowed to open a sealed ECU.
- It is not allowed to operate an unsealed ECU outside the laboratory.
- It is not allowed to operate a prototype ECU in a production environment (no matter if it is sealed or unsealed).
- Only skilled and trained personnel is allowed to operate a prototype ECU (no matter if it is sealed or unsealed).
- The ECU does not require maintenance activities by the user/system integrator. The only maintenance activity allowed for the user is exchanging the ECU (for example after it has reached its specified lifetime).

1.7.2 Checks to be done before commissioning the ECU

- Check the supply voltage before connecting the ECU.
- Check the ECU connector and the cable harness to be free of defects.
- Check the correct dimensioning of the wires in the cable harness.
- Be sure that the ECU is mounted in a way that humans are not directly exposed to it and physical contact is avoided.
- Be sure to choose a mounting location for the ECU that eliminates the possibility of operation temperatures greater than the maximum temperature allowed for the ECU (see MRD [27]).
- The power supply of the ECU has to be secured with a fuse. The fuse trip current has to match to the maximum specified input current of the ECU and the cable harness. See Section 3.4 on page 48 for more information.

1.7.3 Intended use

The HY-TTC 500 is a family of programmable general-purpose control units for safety-related sensor/actuator management to be used in mobile machinery for construction, agricultural, forestry and municipal applications.

Always operate the product within the electrical and environmental specifications and follow the handling and mounting instructions provided by TTControl GmbH.

Usage of the product outside the specifications may result in hazard to persons or property.

1.7.4 Improper use

Any use of the product other than as described in Section 1.7.3 on this page (Intended use) is considered to be improper. Use in explosive areas is not permissible.

TTControl GmbH is not liable for damages resulting from improper use.

2 Mounting and Label

2.1 Mounting Requirements

Any requirements for mounting, temperature and air flow conditions are defined in the Mounting Requirements Document (MRD) [27]. Furthermore, product dimensions and tolerances are defined in the Product Drawing [28].

2.2 Label Information

Any information about the label and its content is defined in the Product Drawing [28].

3 Pinning and Connector

3.1 Connector

Figure 10 on the current page shows the main connector of HY-TTC 500 ECU, which has 154 pins and divided into two segments.

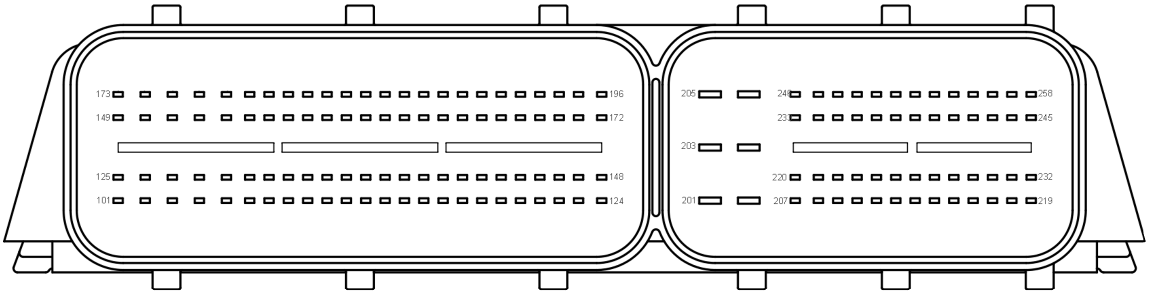

Figure 10: Main connector

Note: The main connector is numbered from 1 to 96 (left connector) and 1 to 58 (right connector). This correspond to pins 101 to 196 and 201 to 258, respectively, in this System Manual.

3.2 Mating Connector

The listed part numbers can be ordered from HERTH+BUSS, KOSTAL or BOSCH with a minimum quantity of, for example, 100 pieces.

For lower quantities, TTControl GmbH provides complete kits with BOSCH connectors, crimp contacts and sealings.

TTControl Order Numbers	Description
10619	Connector kit for HY-TTC 500, 58-positions
10620	Connector kit for HY-TTC 500, 96-positions

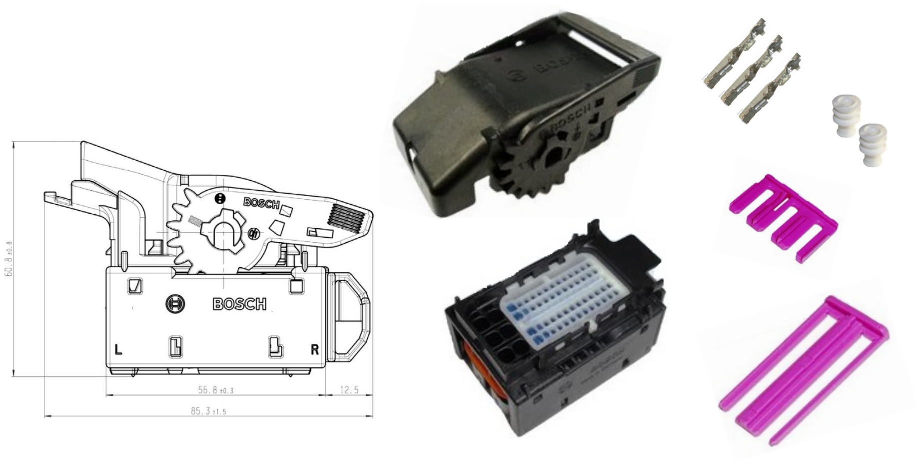

Figure 11: 58 terminal plug housing set

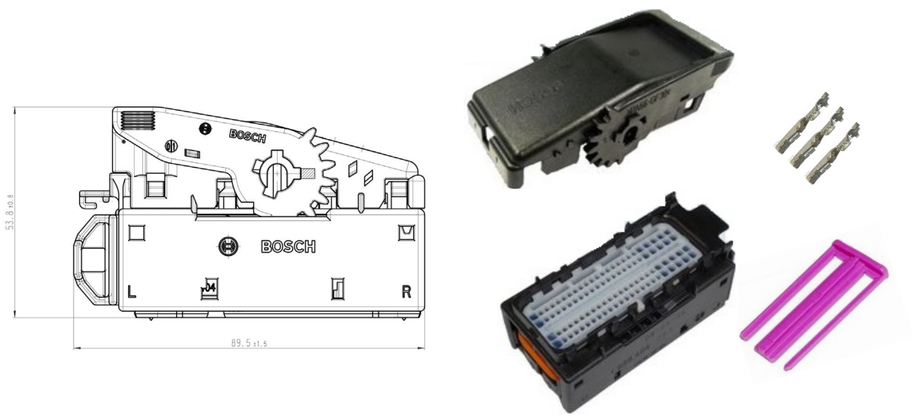

Figure 12: 96 terminal plug housing set

3.2.1 KOSTAL Mating Connector

Please follow the Process Specification below for the right handling of the KOSTAL mating connector:

Process Specification DOC00105005,
Receptacle Housing 58-way and 96-way for control units

3.2.1.1 Mating Connector 96-positions

KOSTAL Part Number	HERTH+BUSS Part Number	Description	Note	Quantity
9409601	50390395	Plug housing		1
10400794061	50390397	Holder		1
10400794071	50390398	Secondary lock		1
22400794081	50390399	Cover cap (cable exit on the left side)		1
22400172011	50390567	Cover cap (cable exit on the upper right side)		1
10800794051	50282066 (discontinued)	Sealing-/protection plug	1	1
10204225	50282099	Sealing-/protection plug	1	1

Table 5: KOSTAL / HERTH+BUSS part numbers

Note 1 In order to achieve the specified IP rating each single wire must be populated either with a single-, blind- or a total protection-plug.

3.2.1.2 Mating Connector 58-positions

KOSTAL Part Number	HERTH+BUSS Part Number	Description	Note	Quantity
9405801	50390396	Plug housing		1
10400758951	50390400	Holder		1
10400758991	50390401	Secondary lock		1
22400794001	50390402	Cover cap (cable exit on the right side)		1
22400172001	50390449	Cover cap (cable exit on the upper left side)		1
10800758941	50282065	Sealing-/protection plug	1	1
-	50282062	High power pin single sealing-/protection plug	1	6
10800472631	50282030	High power pin single blind-sealing-/protection plug	1	-

Table 6: KOSTAL / HERTH+BUSS part numbers

Note 1 In order to achieve the specified IP rating each single wire must be populated either with a single-, blind- or a total protection-plug.

3.2.1.3 Crimp Contacts

<table>
<tr><th>For I/O pins (148)
KOSTAL
Part Number</th><th>HERTH+BUSS
Part Number</th><th>Note</th><th>Description</th></tr>
<tr><td>22140734080</td><td>50253445</td><td>1</td><td rowspan="2">KKS MLK 1.2 m, crimp contact tinned, wire size 0.75 mm^2 to 1 mm^2</td></tr>
<tr><td>32140734080</td><td>50253445088</td><td>2</td></tr>
<tr><td>22140734070</td><td>50253443</td><td>1</td><td rowspan="2">KKS MLK 1.2 m, crimp contact tinned, wire size 0.5 mm^2 to 0.75 mm^2</td></tr>
<tr><td>32140734070</td><td>50253443088</td><td>2</td></tr>
<tr><td>22140734060</td><td>50253441</td><td>1</td><td rowspan="2">KKS MLK 1.2 m, crimp contact tinned, wire size 0.35 mm^2 to 0.5 mm^2</td></tr>
<tr><td>32140734060</td><td>50253441088</td><td>2</td></tr>
<tr><td>22140734050</td><td>50253439</td><td>1</td><td rowspan="2">KKS MLK 1.2 m, crimp contact tinned, wire size 0.1 mm^2 to 0.25 mm^2</td></tr>
<tr><td>32140734050</td><td>50253439088</td><td>2</td></tr>
<tr><th>For High Power pins (6)
KOSTAL
Part Number</th><th>HERTH+BUSS
Part Number</th><th>Note</th><th>Description</th></tr>
<tr><td>22140499580</td><td>50253230</td><td>1</td><td rowspan="2">KKS SLK 2.8 ELA, crimp contact tinned, wire size 1mm^2 to 2.5mm^2</td></tr>
<tr><td>32140499580</td><td>50253230088</td><td>2</td></tr>
<tr><td>22140499570</td><td>50253229</td><td>1</td><td rowspan="2">KKS SLK 2.8 ELA, crimp contact tinned, wire size 0.5mm^2 to 0.75 mm^2</td></tr>
<tr><td>32140499570</td><td>50253229088</td><td>2</td></tr>
</table>

Table 7: KOSTAL / HERTH+BUSS part numbers

Note 1 Loose crimp contact order code, minimum 50 pieces per packing unit.
Note 2 Strip (reel) crimp contact order code, minimum 4000 pieces per packing unit.

3.2.1.4 Tools

KOSTAL Part Number	HERTH+BUSS Part Number	Description
80411002	95942166	Crimping pliers without inserts
80411504	95942167	Crimping pliers insert set for MLK 1,2
80411631	95942169	Crimping pliers insert set for SLK 2,8
80495003	95945400	Unlocking tool for MLK 1,2
-	95945402	Unlocking tool for SLK 2,8

Table 8: KOSTAL / HERTH+BUSS part numbers

3.2.2 BOSCH Mating Connector

Please follow the assembly instruction and technical customer information below for the right handling of the BOSCH mating connector:

Assembly Instruction 1 928 A00 48M

Technical Customer Information 1 928 A00 45T

3.2.2.1 Mating Connector 96-positions

BOSCH Part Number	Description	Quantity
1 928 404 781	Plug housing	1
1 928 404 927	Plug housing, 90-degree angled (alt.)	-
1 928 404 773	Cover cap	1
1 928 404 762	Secondary lock	1

Table 9: BOSCH part numbers

3.2.2.2 Mating Connector 58-positions

BOSCH Part Number	Description	Note	Quantity
1 928 404 916	Plug housing		1
1 928 404 780	Plug housing, 90-degree angled (alt.)		-
1 928 404 917	Cover cap		1
1 928 404 760	Secondary lock		1
1 928 404 761	Secondary lock		1
1 928 300 600	High power pin single sealing-/protection plug	1	6
1 928 300 601	High power pin single blind-sealing-/protection plug	1	-

Table 10: BOSCH part numbers

Note 1 In order to achieve the specified IP rating each single wire must be populated either with a single protection-, blind protection-, or a total protection-plug.

3.2.2.3 Crimp Contacts

For I/O pins (148) BOSCH Part Number	Description
1 928 498 679	Matrix 1.2 m, crimp contact tinned, wire size 0.35 mm^2 to 0.5 mm^2
1 928 498 137 (alt.)	
1 928 498 680	Matrix 1.2 m, crimp contact tinned, wire size 0.75 mm^2 to 1.0 mm^2
1 928 498 138 (alt.)	
For High Power pins (6) BOSCH Part Number	**Description**
1 928 498 057	BDK 2.8, crimp contact tinned, wire size 1.5mm^2 to 2.5mm^2

Table 11: BOSCH crimp contacts part numbers

3.2.2.4 Tools

BOSCH Part Number	Description
1 928 498 161	Crimping pliers / BDK / BSK 2,8 / 0,5 - 1 mm^2
1 928 498 162	Crimping pliers / BDK / BSK 2,8 / 1,5 - 2,5 mm^2
1 928 498 212	Crimping pliers / Matrix 1,2 / 0,35 - 0,5 mm^2
1 928 498 213	Crimping pliers / Matrix 1,2 / 0,75 - 1,0 mm^2
1 928 498 167	Unlocking tool for BDK / BSK 2,8
1 928 498 168	Unlocking tool spare pin for BDK / BSK 2,8
1 928 498 218	Unlocking tool for Matrix 1,2
1 928 498 219	Unlocking tool spare pin for Matrix 1,2

Table 12: BOSCH Tools part numbers

3.3 Cable Harness

Description	Variants
Cable Harness for HY-TTC 500, 3 m, open end	HY-TTC 580, HY-TTC 540, HY-TTC 520, HY-TTC 510
Cable Harness for HY-TTC 500 family, 1.5 m	
Cable Harness for HY-TTC 500, BRR, 3 m, OE	HY-TTC 590E, HY-TTC 590, HY-TTC 508
Cable Harness for HY-TTC 500, BRR, 1.5 m	

Note: Make sure you use a cable harness fitting to the variant as listed in the table above. Usage of improper cable harness may damage the device.

3.4 Fuse

For cable harness protection, it is recommended to protect each power supply path by a dedicated fuse. Please take note that the selected fuse type has to match to the current capability of the cable harness.

Symbol	Parameter	Note	Min.	Max.	Unit
BAT+ CPU	Fuse trip current of Positive Power Supply of Internal Electronics		2		A
BAT+ Power	Fuse trip current of Positive Power Supply of Power Stages	1		60	A

Note 1 The maximum fuse trip current is dependent on the specific customer application. The maximum total load current must be considered, see Section 4.1.3 on page 97

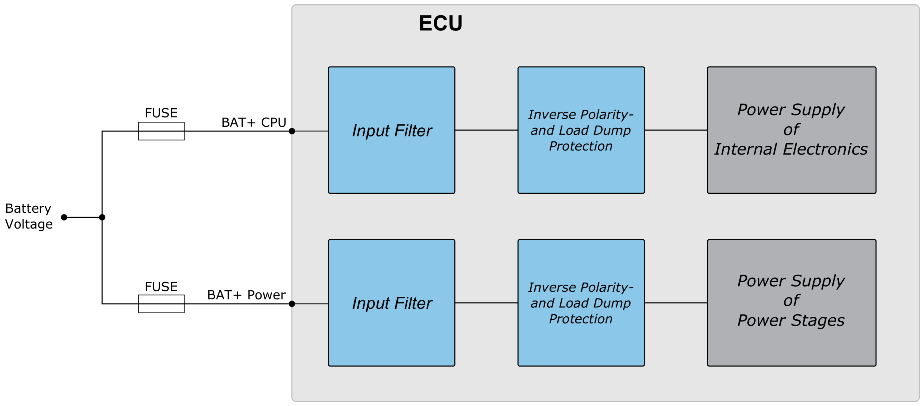

Figure 13: Battery Supply - Fuse

3.5 HY-TTC 500 Family Pinning

The following subsections describe the HY-TTC 500 family variant dependent main- and the respective alternative functions on connector pin-level.
Each hardware function in the table, e.g. Pin 101 - HS PWM Output, is referenced to its main- (*IO_PWM_28*) and alternative (*IO_DO_44, IO_PWD_12, IO_DI_28*) function. *IO_xx_yy* represents the software define for each function. For more information about API documentation, please refer to Chapter 8 on page 226.

Please take note that the main function shall be used preferably and the technical specifications must particularly be regarded when alternative functions are to be used. See Chapter 4 on page 96 for limits and restrictions.

3.5.1 HY-TTC 580 Variant

		Alternative Function													
Pin No.	Main Function	HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P101	HS PWM Output IO_PWM_28	IO_DO_44	IO_PWD_12 IO_DI_28												
P102	HS PWM Output IO_PWM_32	IO_DO_48	IO_PWD_16 IO_DI_32												
P103	Analog Voltage Input IO_ADC_00												IO_ADC_00	IO_ADC_00	IO_DI_48
P104	Analog Voltage Input IO_ADC_02												IO_ADC_02	IO_ADC_02	IO_DI_50
P105	Analog Voltage Input IO_ADC_04												IO_ADC_04	IO_ADC_04	IO_DI_52
P106	Analog Voltage Input IO_ADC_06												IO_ADC_06	IO_ADC_06	IO_DI_54
P107	Analog Voltage Input IO_ADC_08										IO_ADC_08	IO_DI_56			
P108	Analog Voltage Input IO_ADC_10										IO_ADC_10	IO_DI_58			
P109	Analog Voltage Input IO_ADC_12										IO_ADC_12	IO_DI_60			
P110	Analog Voltage Input IO_ADC_14										IO_ADC_14	IO_DI_62			
P111	Analog Voltage Input IO_ADC_16										IO_ADC_16	IO_DI_64			
P112	Analog Voltage Input IO_ADC_18										IO_ADC_18	IO_DI_66			
P113	Analog Voltage Input IO_ADC_20										IO_ADC_20	IO_DI_68			
P114	Analog Voltage Input IO_ADC_22										IO_ADC_22	IO_DI_70			
P115	Timer Input IO_PWD_00						IO_PWD_00	IO_ADC_24 IO_DI_36							
P116	Timer Input IO_PWD_02						IO_PWD_02	IO_ADC_26 IO_DI_38							
P117	Timer Input IO_PWD_04						IO_PWD_04	IO_ADC_28 IO_DI_40							
P118	BAT-														
P119	BAT-														
P120	BAT-														
P121	BAT-														
P122	Timer Input IO_PWD_06							IO_ADC_30 IO_DI_42							
P123	Timer Input IO_PWD_08							IO_ADC_32 IO_DI_44							

Pin No.	Main Function	HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
		Alternative Function													
P124	Timer Input IO_PWD_10							IO_ADC_34 IO_DI_46							
P125	HS PWM Output IO_PWM_29	IO_DO_45	IO_DI_29 IO_PWD_13												
P126	HS PWM Output IO_PWM_33	IO_DO_49	IO_PWD_17 IO_DI_33												
P127	Analog Voltage Input IO_ADC_01												IO_ADC_01	IO_ADC_01	IO_DI_49
P128	Analog Voltage Input IO_ADC_03												IO_ADC_03	IO_ADC_03	IO_DI_51
P129	Analog Voltage Input IO_ADC_05												IO_ADC_05	IO_ADC_05	IO_DI_53
P130	Analog Voltage Input IO_ADC_07												IO_ADC_07	IO_ADC_07	IO_DI_55
P131	Analog Voltage Input IO_ADC_09										IO_ADC_09	IO_DI_57			
P132	Analog Voltage Input IO_ADC_11										IO_ADC_11	IO_DI_59			
P133	Analog Voltage Input IO_ADC_13										IO_ADC_13	IO_DI_61			
P134	Analog Voltage Input IO_ADC_15										IO_ADC_15	IO_DI_63			
P135	Analog Voltage Input IO_ADC_17										IO_ADC_17	IO_DI_65			
P136	Analog Voltage Input IO_ADC_19										IO_ADC_19	IO_DI_67			
P137	Analog Voltage Input IO_ADC_21										IO_ADC_21	IO_DI_69			
P138	Analog Voltage Input IO_ADC_23										IO_ADC_23	IO_DI_71			
P139	Timer Input IO_PWD_01						IO_PWD_01	IO_ADC_25 IO_DI_37							
P140	Timer Input IO_PWD_03						IO_PWD_03	IO_ADC_27 IO_DI_39							
P141	Timer Input IO_PWD_05						IO_PWD_05	IO_ADC_29 IO_DI_41							
P142	BAT-														
P143	BAT-														
P144	BAT-														
P145	BAT-														
P146	Timer Input IO_PWD_07							IO_ADC_31 IO_DI_43							
P147	Timer Input IO_PWD_09							IO_ADC_33 IO_DI_45							

				Alternative Function											
						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P148	Timer Input IO_PWD_11							IO_ADC_35 IO_DI_47							
P149	HS Digital Output IO_DO_00								IO_ADC_36 IO_DI_72						
P150	HS PWM Output IO_PWM_30	IO_DO_46	IO_PWD_14 IO_DI_30												
P151	HS PWM Output IO_PWM_34	IO_DO_50	IO_PWD_18 IO_DI_34												
P152	HS Digital Output IO_DO_02								IO_ADC_38 IO_DI_74						
P153	HS PWM Output IO_PWM_00	IO_DO_16	IO_DI_00												
P154	HS PWM Output IO_PWM_14	IO_DO_30	IO_DI_14												
P155	HS Digital Output IO_DO_04								IO_ADC_40 IO_DI_76						
P156	HS PWM Output IO_PWM_02	IO_DO_18	IO_DI_02												
P157	HS PWM Output IO_PWM_16	IO_DO_32	IO_DI_16												
P158	HS Digital Output IO_DO_06								IO_ADC_42 IO_DI_78						
P159	HS PWM Output IO_PWM_04	IO_DO_20	IO_DI_04												
P160	HS PWM Output IO_PWM_18	IO_DO_34	IO_DI_18												
P161	HS Digital Output IO_DO_52			IO_PVG_00	IO_VOUT_00	IO_ADC_52 IO_DI_88									
P162	HS PWM Output IO_PWM_07	IO_DO_23	IO_DI_07												
P163	HS PWM Output IO_PWM_21	IO_DO_37	IO_DI_21												
P164	HS Digital Output IO_DO_55			IO_PVG_03	IO_VOUT_03	IO_ADC_55 IO_DI_91									
P165	HS PWM Output IO_PWM_09	IO_DO_25	IO_DI_09												
P166	HS PWM Output IO_PWM_23	IO_DO_39	IO_DI_23												
P167	HS Digital Output IO_DO_57			IO_PVG_05	IO_VOUT_05	IO_ADC_57 IO_DI_93									
P168	HS PWM Output IO_PWM_11	IO_DO_27	IO_DI_11												
P169	HS PWM Output IO_PWM_25	IO_DO_41	IO_DI_25												
P170	HS Digital Output IO_DO_59			IO_PVG_07	IO_VOUT_07	IO_ADC_59 IO_DI_95									

		Alternative Function													
Pin No.	Main Function	HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P171	HS PWM Output IO_PWM_13	IO_DO_29	IO_DI_13												
P172	HS PWM Output IO_PWM_27	IO_DO_43	IO_DI_27												
P173	HS Digital Output IO_DO_01								IO_ADC_37 IO_DI_73						
P174	HS PWM Output IO_PWM_31	IO_DO_47	IO_PWD_15 IO_DI_31												
P175	HS PWM Output IO_PWM_35	IO_DO_51	IO_PWD_19 IO_DI_35												
P176	HS Digital Output IO_DO_03								IO_ADC_39 IO_DI_75						
P177	HS PWM Output IO_PWM_01	IO_DO_17	IO_DI_01												
P178	HS PWM Output IO_PWM_15	IO_DO_31	IO_DI_15												
P179	HS Digital Output IO_DO_05								IO_ADC_41 IO_DI_77						
P180	HS PWM Output IO_PWM_03	IO_DO_19	IO_DI_03												
P181	HS PWM Output IO_PWM_17	IO_DO_33	IO_DI_17												
P182	HS Digital Output IO_DO_07								IO_ADC_43 IO_DI_79						
P183	HS PWM Output IO_PWM_05	IO_DO_21	IO_DI_05												
P184	HS PWM Output IO_PWM_19	IO_DO_35	IO_DI_19												
P185	HS Digital Output IO_DO_53			IO_PVG_01	IO_VOUT_01	IO_ADC_53 IO_DI_89									
P186	HS PWM Output IO_PWM_06	IO_DO_22	IO_DI_06												
P187	HS PWM Output IO_PWM_20	IO_DO_36	IO_DI_20												
P188	HS Digital Output IO_DO_54			IO_PVG_02	IO_VOUT_02	IO_ADC_54 IO_DI_90									
P189	HS PWM Output IO_PWM_08	IO_DO_24	IO_DI_08												
P190	HS PWM Output IO_PWM_22	IO_DO_38	IO_DI_22												
P191	HS Digital Output IO_DO_56			IO_PVG_04	IO_VOUT_04	IO_ADC_56 IO_DI_92									
P192	HS PWM Output IO_PWM_10	IO_DO_26	IO_DI_10												
P193	HS PWM Output IO_PWM_24	IO_DO_40	IO_DI_24												

					Alternative Function										
						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P194	HS Digital Output IO_DO_58			IO_PVG_06	IO_VOUT_06	IO_ADC_58 IO_DI_94									
P195	HS PWM Output IO_PWM_12	IO_DO_28	IO_DI_12												
P196	HS PWM Output IO_PWM_26	IO_DO_42	IO_DI_26												
P197															
P198															
P199															
P200															
P201	BAT+ Power														
P202	BAT+ Power														
P203	BAT+ Power														
P204	BAT+ Power														
P205	BAT+ Power														
P206	BAT+ Power														
P207	Terminal 15 IO_ADC_K15														
P208	LIN IO_LIN														
P209	CAN 0 Low IO_CAN_CHANNEL_0														
P210	CAN 1 Low IO_CAN_CHANNEL_1														
P211	CAN 2 Low IO_CAN_CHANNEL_2														
P212	CAN 3 Low IO_CAN_CHANNEL_3														
P213	CAN 4 Low IO_CAN_CHANNEL_4														
P214	CAN 5 Low IO_CAN_CHANNEL_5														
P215	CAN 6 Low IO_CAN_CHANNEL_6														
P216	CAN Termination 3L														
P217	Sensor GND														
P218	Ethernet TD+ IO_DOWNLOAD, IO_UDP														
P219	Ethernet TD- IO_DOWNLOAD, IO_UDP														
P220	Wake-Up IO_ADC_WAKE_UP														
P221	Sensor Supply Var. IO_ADC_SENSOR_SUPPLY_2														

Pin No.	Main Function	Alternative Function													
		HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P222	CAN 0 High IO_CAN_CHANNEL_0														
P223	CAN 1 High IO_CAN_CHANNEL_1														
P224	CAN 2 High IO_CAN_CHANNEL_2														
P225	CAN 3 High IO_CAN_CHANNEL_3														
P226	CAN 4 High IO_CAN_CHANNEL_4														
P227	CAN 5 High IO_CAN_CHANNEL_5														
P228	CAN 6 High IO_CAN_CHANNEL_6														
P229	CAN Termination 3H														
P230	Sensor GND														
P231	Ethernet RD- IO_DOWNLOAD														
P232	Ethernet RD+ IO_DOWNLOAD														
P233	RTC_BACKUP_BAT														
P234	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_1														
P235	CAN Termination 0L														
P236	CAN Termination 1L														
P237	CAN Termination 2L														
P238	LS Digital Output IO_DO_09									IO_ADC_45 IO_DI_81					
P239	LS Digital Output IO_DO_11									IO_ADC_47 IO_DI_83					
P240	LS Digital Output IO_DO_13									IO_ADC_49 IO_DI_85					
P241	LS Digital Output IO_DO_15									IO_ADC_51 IO_DI_87					
P242	RS232 TXD IO_UART														
P243	Sensor GND														
P244	Sensor GND														
P245	Sensor GND														
P246	BAT+ CPU IO_ADC_UBAT														
P247	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_0														
P248	CAN Termination 0H														
P249	CAN Termination 1H														

Pin	Function			Alternative Function: A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P250	CAN Termination 2H												
P251	LS Digital Output IO_DO_08							IO_ADC_44 IO_DI_80					
P252	LS Digital Output IO_DO_10							IO_ADC_46 IO_DI_82					
P253	LS Digital Output IO_DO_12							IO_ADC_48 IO_DI_84					
P254	LS Digital Output IO_DO_14							IO_ADC_50 IO_DI_86					
P255	RS232 RXD IO_UART												
P256	Sensor GND												
P257	Sensor GND												
P258	Sensor GND												

Table 13: Pinning of HY-TTC 580

3.5.2 HY-TTC 540 Variant

Pin No.	Main Function	Alternative Function: HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P101	HS PWM Output		IO_PWD_12 IO_DI_28												
P102	HS PWM Output		IO_PWD_16 IO_DI_32												
P103	Analog Voltage Input IO_ADC_00												IO_ADC_00	IO_ADC_00	IO_DI_48
P104	Analog Voltage Input IO_ADC_02												IO_ADC_02	IO_ADC_02	IO_DI_50
P105	Analog Voltage Input IO_ADC_04												IO_ADC_04	IO_ADC_04	IO_DI_52
P106	Analog Voltage Input IO_ADC_06												IO_ADC_06	IO_ADC_06	IO_DI_54
P107	Analog Voltage Input IO_ADC_08										IO_ADC_08	IO_DI_56			
P108	Analog Voltage Input IO_ADC_10										IO_ADC_10	IO_DI_58			
P109	Analog Voltage Input IO_ADC_12										IO_ADC_12	IO_DI_60			
P110	Analog Voltage Input IO_ADC_14										IO_ADC_14	IO_DI_62			
P111	Analog Voltage Input IO_ADC_16										IO_ADC_16	IO_DI_64			
P112	Analog Voltage Input IO_ADC_18										IO_ADC_18	IO_DI_66			
P113	Analog Voltage Input IO_ADC_20										IO_ADC_20	IO_DI_68			
P114	Analog Voltage Input IO_ADC_22										IO_ADC_22	IO_DI_70			
P115	Timer Input IO_PWD_00						IO_PWD_00	IO_ADC_24 IO_DI_36							
P116	Timer Input IO_PWD_02						IO_PWD_02	IO_ADC_26 IO_DI_38							
P117	Timer Input IO_PWD_04						IO_PWD_04	IO_ADC_28 IO_DI_40							
P118	BAT-														
P119	BAT-														
P120	BAT-														
P121	BAT-														
P122	Timer Input IO_PWD_06							IO_ADC_30 IO_DI_42							
P123	Timer Input IO_PWD_08							IO_ADC_32 IO_DI_44							

				Alternative Function									
			A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P124	Timer Input IO_PWD_10				IO_ADC_34 IO_DI_46							
P125	HS PWM Output	IO_DI_29 IO_PWD_13										
P126	HS PWM Output	IO_PWD_17 IO_DI_33										
P127	Analog Voltage Input IO_ADC_01									IO_ADC_01	IO_ADC_01	IO_DI_49
P128	Analog Voltage Input IO_ADC_03									IO_ADC_03	IO_ADC_03	IO_DI_51
P129	Analog Voltage Input IO_ADC_05									IO_ADC_05	IO_ADC_05	IO_DI_53
P130	Analog Voltage Input IO_ADC_07									IO_ADC_07	IO_ADC_07	IO_DI_55
P131	Analog Voltage Input IO_ADC_09							IO_ADC_09	IO_DI_57			
P132	Analog Voltage Input IO_ADC_11							IO_ADC_11	IO_DI_59			
P133	Analog Voltage Input IO_ADC_13							IO_ADC_13	IO_DI_61			
P134	Analog Voltage Input IO_ADC_15							IO_ADC_15	IO_DI_63			
P135	Analog Voltage Input IO_ADC_17							IO_ADC_17	IO_DI_65			
P136	Analog Voltage Input IO_ADC_19							IO_ADC_19	IO_DI_67			
P137	Analog Voltage Input IO_ADC_21							IO_ADC_21	IO_DI_69			
P138	Analog Voltage Input IO_ADC_23							IO_ADC_23	IO_DI_71			
P139	Timer Input IO_PWD_01			IO_PWD_01	IO_ADC_25 IO_DI_37							
P140	Timer Input IO_PWD_03			IO_PWD_03	IO_ADC_27 IO_DI_39							
P141	Timer Input IO_PWD_05			IO_PWD_05	IO_ADC_29 IO_DI_41							
P142	BAT-											
P143	BAT-											
P144	BAT-											
P145	BAT-											
P146	Timer Input IO_PWD_07				IO_ADC_31 IO_DI_43							
P147	Timer Input IO_PWD_09				IO_ADC_33 IO_DI_45							

				Alternative Function									
				A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	Timer Input IO_PWD_11					IO_ADC_35 IO_DI_47							
	HS Digital Output IO_DO_00						IO_ADC_36 IO_DI_72						
			IO_PWD_14 IO_DI_30										
P151	HS PWM Output		IO_PWD_18 IO_DI_34										
P152	HS Digital Output IO_DO_02						IO_ADC_38 IO_DI_74						
P153	HS PWM Output IO_PWM_00	IO_DO_16	IO_DI_00										
P154	HS PWM Output IO_PWM_14	IO_DO_30	IO_DI_14										
P155	HS Digital Output IO_DO_04						IO_ADC_40 IO_DI_76						
P156	HS PWM Output IO_PWM_02	IO_DO_18	IO_DI_02										
P157	HS PWM Output IO_PWM_16	IO_DO_32	IO_DI_16										
P158	HS Digital Output IO_DO_06						IO_ADC_42 IO_DI_78						
P159	HS PWM Output IO_PWM_04	IO_DO_20	IO_DI_04										
P160	HS PWM Output IO_PWM_18	IO_DO_34	IO_DI_18										
P161	HS Digital Output			IO_ADC_52 IO_DI_88									
P162	HS PWM Output IO_PWM_07	IO_DO_23	IO_DI_07										
P163	HS PWM Output IO_PWM_21	IO_DO_37	IO_DI_21										
P164	HS Digital Output			IO_ADC_55 IO_DI_91									
P165	HS PWM Output IO_PWM_09	IO_DO_25	IO_DI_09										
P166	HS PWM Output IO_PWM_23	IO_DO_39	IO_DI_23										
P167	HS Digital Output			IO_ADC_57 IO_DI_93									
P168	HS PWM Output IO_PWM_11	IO_DO_27	IO_DI_11										
P169	HS PWM Output IO_PWM_25	IO_DO_41	IO_DI_25										
P170	HS Digital Output			IO_ADC_59 IO_DI_95									

Alternative Function

				A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P171	HS PWM Output IO_PWM_13	IO_DO_29	IO_DI_13										
P172	HS PWM Output IO_PWM_27	IO_DO_43	IO_DI_27										
P173	HS Digital Output IO_DO_01						IO_ADC_37 IO_DI_73						
P174	HS PWM Output		IO_PWD_15 IO_DI_31										
P175	HS PWM Output		IO_PWD_19 IO_DI_35										
P176	HS Digital Output IO_DO_03						IO_ADC_39 IO_DI_75						
P177	HS PWM Output IO_PWM_01	IO_DO_17	IO_DI_01										
P178	HS PWM Output IO_PWM_15	IO_DO_31	IO_DI_15										
P179	HS Digital Output IO_DO_05						IO_ADC_41 IO_DI_77						
P180	HS PWM Output IO_PWM_03	IO_DO_19	IO_DI_03										
P181	HS PWM Output IO_PWM_17	IO_DO_33	IO_DI_17										
P182	HS Digital Output IO_DO_07						IO_ADC_43 IO_DI_79						
P183	HS PWM Output IO_PWM_05	IO_DO_21	IO_DI_05										
P184	HS PWM Output IO_PWM_19	IO_DO_35	IO_DI_19										
P185	HS Digital Output			IO_ADC_53 IO_DI_89									
P186	HS PWM Output IO_PWM_06	IO_DO_22	IO_DI_06										
P187	HS PWM Output IO_PWM_20	IO_DO_36	IO_DI_20										
P188	HS Digital Output			IO_ADC_54 IO_DI_90									
P189	HS PWM Output IO_PWM_08	IO_DO_24	IO_DI_08										
P190	HS PWM Output IO_PWM_22	IO_DO_38	IO_DI_22										
P191	HS Digital Output			IO_ADC_56 IO_DI_92									
P192	HS PWM Output IO_PWM_10	IO_DO_26	IO_DI_10										
P193	HS PWM Output IO_PWM_24	IO_DO_40	IO_DI_24										

				Alternative Function				
				A/D Input (HS Output/PVG/VOUT)	Current Loop Input A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M Digital Input 2M	Analog Current Input 3M Analog Resistance Input 3M Digital Input 3M
	HS Digital Output			IO_ADC_58 IO_DI_94					
	HS PWM Output IO_PWM_12	IO_DO_28	IO_DI_12						
	IO_PWM_26	IO_DO_42	IO_DI_26						
P197									
P198									
P199									
P200									
P201	BAT+ Power								
P202	BAT+ Power								
P203	BAT+ Power								
P204	BAT+ Power								
P205	BAT+ Power								
P206	BAT+ Power								
P207	Terminal 15 IO_ADC_K15								
P208									
P209	CAN 0 Low IO_CAN_CHANNEL_0								
P210	CAN 1 Low IO_CAN_CHANNEL_1								
P211	CAN 2 Low IO_CAN_CHANNEL_2								
P212	CAN 3 Low IO_CAN_CHANNEL_3								
P213									
P214									
P215									
P216	CAN Termination 3L								
P217	Sensor GND								
P218									
P219									
P220	Wake-Up IO_ADC_WAKE_UP								
P221	Sensor Supply Var. IO_ADC_SENSOR_SUPPLY_2								
P222	CAN 0 High IO_CAN_CHANNEL_0								
P223	CAN 1 High IO_CAN_CHANNEL_1								
P224	CAN 2 High IO_CAN_CHANNEL_2								

			Alternative Function									
			A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P225	CAN 3 High IO_CAN_CHANNEL_3											
P226												
P227												
P228												
P229	CAN Termination 3H											
P230	Sensor GND											
P231												
P232												
P233												
P234	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_1											
P235	CAN Termination 0L											
P236	CAN Termination 1L											
P237	CAN Termination 2L											
P238	LS Digital Output IO_DO_09						IO_ADC_45 IO_DI_81					
P239	LS Digital Output IO_DO_11						IO_ADC_47 IO_DI_83					
P240	LS Digital Output IO_DO_13						IO_ADC_49 IO_DI_85					
P241	LS Digital Output IO_DO_15						IO_ADC_51 IO_DI_87					
P242												
P243	Sensor GND											
P244	Sensor GND											
P245	Sensor GND											
P246	BAT+ CPU IO_ADC_UBAT											
P247	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_0											
P248	CAN Termination 0H											
P249	CAN Termination 1H											
P250	CAN Termination 2H											
P251	LS Digital Output IO_DO_08						IO_ADC_44 IO_DI_80					
P252	LS Digital Output IO_DO_10						IO_ADC_46 IO_DI_82					
P253	LS Digital Output IO_DO_12						IO_ADC_48 IO_DI_84					
P254	LS Digital Output IO_DO_14						IO_ADC_50 IO_DI_86					
P255												
P256	Sensor GND											

				Alternative Function									
				A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P257	Sensor GND												
P258	Sensor GND												

Table 14: Pinning of HY-TTC 540

3.5.3 HY-TTC 520 Variant (Customer-specific variant only)

		Alternative Function													
Pin No.	Main Function	*HS Digital Output*	*Timer Input*	*PVG Output*	*VOUT Output*	*A/D Input (HS Output/PVG/VOUT)*	*Current Loop Input*	*A/D Input (Timer Input)*	*A/D Input (HS Digital Output)*	*A/D Input (LS Digital Output)*	*Analog Current Input 2M*	*Digital Input 2M*	*Analog Current Input 3M*	*Analog Resistance Input 3M*	*Digital Input 3M*
P101	HS PWM Output		IO_PWD_12 IO_DI_28												
P102	HS PWM Output		IO_PWD_16 IO_DI_32												
P103	Analog Voltage Input IO_ADC_00												IO_ADC_00	IO_ADC_00	IO_DI_48
P104	Analog Voltage Input IO_ADC_02												IO_ADC_02	IO_ADC_02	IO_DI_50
P105	Analog Voltage Input IO_ADC_04												IO_ADC_04	IO_ADC_04	IO_DI_52
P106	Analog Voltage Input IO_ADC_06												IO_ADC_06	IO_ADC_06	IO_DI_54
P107	Analog Voltage Input IO_ADC_08										IO_ADC_08	IO_DI_56			
P108	Analog Voltage Input IO_ADC_10										IO_ADC_10	IO_DI_58			
P109	Analog Voltage Input IO_ADC_12										IO_ADC_12	IO_DI_60			
P110	Analog Voltage Input IO_ADC_14										IO_ADC_14	IO_DI_62			
P111	Analog Voltage Input IO_ADC_16										IO_ADC_16	IO_DI_64			
P112	Analog Voltage Input IO_ADC_18										IO_ADC_18	IO_DI_66			
P113	Analog Voltage Input IO_ADC_20										IO_ADC_20	IO_DI_68			
P114	Analog Voltage Input IO_ADC_22										IO_ADC_22	IO_DI_70			
P115	Timer Input IO_PWD_00						IO_PWD_00	IO_ADC_24 IO_DI_36							
P116	Timer Input IO_PWD_02						IO_PWD_02	IO_ADC_26 IO_DI_38							
P117	Timer Input IO_PWD_04						IO_PWD_04	IO_ADC_28 IO_DI_40							
P118	BAT-														
P119	BAT-														
P120	BAT-														
P121	BAT-														
P122	Timer Input IO_PWD_06							IO_ADC_30 IO_DI_42							
P123	Timer Input IO_PWD_08							IO_ADC_32 IO_DI_44							

			Alternative Function									
			A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	Timer Input IO_PWD_10				IO_ADC_34 IO_DI_46							
	HS PWM Output	IO_DI_29 IO_PWD_13 IO_PWD_17 IO_DI_33										
P127	Analog Voltage Input IO_ADC_01									IO_ADC_01	IO_ADC_01	IO_DI_49
P128	Analog Voltage Input IO_ADC_03									IO_ADC_03	IO_ADC_03	IO_DI_51
P129	Analog Voltage Input IO_ADC_05									IO_ADC_05	IO_ADC_05	IO_DI_53
P130	Analog Voltage Input IO_ADC_07									IO_ADC_07	IO_ADC_07	IO_DI_55
P131	Analog Voltage Input IO_ADC_09							IO_ADC_09	IO_DI_57			
P132	Analog Voltage Input IO_ADC_11							IO_ADC_11	IO_DI_59			
P133	Analog Voltage Input IO_ADC_13							IO_ADC_13	IO_DI_61			
P134	Analog Voltage Input IO_ADC_15							IO_ADC_15	IO_DI_63			
P135	Analog Voltage Input IO_ADC_17							IO_ADC_17	IO_DI_65			
P136	Analog Voltage Input IO_ADC_19							IO_ADC_19	IO_DI_67			
P137	Analog Voltage Input IO_ADC_21							IO_ADC_21	IO_DI_69			
P138	Analog Voltage Input IO_ADC_23							IO_ADC_23	IO_DI_71			
P139	Timer Input IO_PWD_01			IO_PWD_01	IO_ADC_25 IO_DI_37							
P140	Timer Input IO_PWD_03			IO_PWD_03	IO_ADC_27 IO_DI_39							
P141	Timer Input IO_PWD_05			IO_PWD_05	IO_ADC_29 IO_DI_41							
P142	BAT-											
P143	BAT-											
P144	BAT-											
P145	BAT-											
P146	Timer Input IO_PWD_07				IO_ADC_31 IO_DI_43							
P147	Timer Input IO_PWD_09				IO_ADC_33 IO_DI_45							

				Alternative Function									
				A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P148	Timer Input IO_PWD_11					IO_ADC_35 IO_DI_47							
P149	HS Digital Output IO_DO_00						IO_ADC_36 IO_DI_72						
P150	HS PWM Output		IO_PWD_14 IO_DI_30										
P151	HS PWM Output		IO_PWD_18 IO_DI_34										
P152	HS Digital Output IO_DO_02						IO_ADC_38 IO_DI_74						
P153	HS PWM Output IO_PWM_00	IO_DO_16	IO_DI_00										
P154	HS PWM Output IO_PWM_14	IO_DO_30	IO_DI_14										
P155	HS Digital Output IO_DO_04						IO_ADC_40 IO_DI_76						
P156	HS PWM Output IO_PWM_02	IO_DO_18	IO_DI_02										
P157	HS PWM Output IO_PWM_16	IO_DO_32	IO_DI_16										
P158	HS Digital Output IO_DO_06						IO_ADC_42 IO_DI_78						
P159	HS PWM Output IO_PWM_04	IO_DO_20	IO_DI_04										
P160	HS PWM Output IO_PWM_18	IO_DO_34	IO_DI_18										
P161													
P162	HS PWM Output IO_PWM_07	IO_DO_23	IO_DI_07										
P163	HS PWM Output IO_PWM_21	IO_DO_37	IO_DI_21										
P164													
P165	HS PWM Output IO_PWM_09	IO_DO_25	IO_DI_09										
P166													
P167													
P168													
P169													
P170													
P171													
P172													
P173	HS Digital Output IO_DO_01						IO_ADC_37 IO_DI_73						
P174	HS PWM Output		IO_PWD_15 IO_DI_31										

				Alternative Function									
				A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	HS PWM Output		IO_PWD_19 IO_DI_35										
	HS Digital Output IO_DO_03						IO_ADC_39 IO_DI_75						
	IO_PWM_01	IO_DO_17	IO_DI_01										
P178	HS PWM Output IO_PWM_15	IO_DO_31	IO_DI_15										
P179	HS Digital Output IO_DO_05						IO_ADC_41 IO_DI_77						
P180	HS PWM Output IO_PWM_03	IO_DO_19	IO_DI_03										
P181	HS PWM Output IO_PWM_17	IO_DO_33	IO_DI_17										
P182	HS Digital Output IO_DO_07						IO_ADC_43 IO_DI_79						
P183	HS PWM Output IO_PWM_05	IO_DO_21	IO_DI_05										
P184	HS PWM Output IO_PWM_19	IO_DO_35	IO_DI_19										
P185													
P186	HS PWM Output IO_PWM_06	IO_DO_22	IO_DI_06										
P187	HS PWM Output IO_PWM_20	IO_DO_36	IO_DI_20										
P188													
P189	HS PWM Output IO_PWM_08	IO_DO_24	IO_DI_08										
P190													
P191													
P192													
P193													
P194													
P195													
P196													
P197													
P198													
P199													
P200													
P201	BAT+ Power												
P202	BAT+ Power												
P203	BAT+ Power												
P204	BAT+ Power												
P205	BAT+ Power												

			Alternative Function									
			A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P206	BAT+ Power											
P207	Terminal 15 IO_ADC_K15											
P208												
P209	CAN 0 Low IO_CAN_CHANNEL_0											
P210	CAN 1 Low IO_CAN_CHANNEL_1											
P211	CAN 2 Low IO_CAN_CHANNEL_2											
P212	CAN 3 Low IO_CAN_CHANNEL_3											
P213												
P214												
P215												
P216	CAN Termination 3L											
P217	Sensor GND											
P218												
P219												
P220	Wake-Up IO_ADC_WAKE_UP											
P221	Sensor Supply Var. IO_ADC_SENSOR_SUPPLY_2											
P222	CAN 0 High IO_CAN_CHANNEL_0											
P223	CAN 1 High IO_CAN_CHANNEL_1											
P224	CAN 2 High IO_CAN_CHANNEL_2											
P225	CAN 3 High IO_CAN_CHANNEL_3											
P226												
P227												
P228												
P229	CAN Termination 3H											
P230	Sensor GND											
P231												
P232												
P233												
P234	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_1											
P235	CAN Termination 0L											
P236	CAN Termination 1L											
P237	CAN Termination 2L											

			Alternative Function									
			A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	LS Digital Output IO_DO_09						IO_ADC_45 IO_DI_81					
	LS Digital Output IO_DO_11						IO_ADC_47 IO_DI_83					
	LS Digital Output IO_DO_13						IO_ADC_49 IO_DI_85					
	LS Digital Output IO_DO_15						IO_ADC_51 IO_DI_87					
P242												
P243	Sensor GND											
P244	Sensor GND											
P245	Sensor GND											
P246	BAT+ CPU IO_ADC_UBAT											
P247	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_0											
P248	CAN Termination 0H											
P249	CAN Termination 1H											
P250	CAN Termination 2H											
P251	LS Digital Output IO_DO_08						IO_ADC_44 IO_DI_80					
P252	LS Digital Output IO_DO_10						IO_ADC_46 IO_DI_82					
P253	LS Digital Output IO_DO_12						IO_ADC_48 IO_DI_84					
P254	LS Digital Output IO_DO_14						IO_ADC_50 IO_DI_86					
P255												
P256	Sensor GND											
P257	Sensor GND											
P258	Sensor GND											

Table 15: Pinning of HY-TTC 520

3.5.4 HY-TTC 510 Variant

		Alternative Function													
Pin No.	Main Function	HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P101	HS PWM Output		IO_PWD_12 IO_DI_28												
P102	HS PWM Output		IO_PWD_16 IO_DI_32												
P103	Analog Voltage Input IO_ADC_00												IO_ADC_00	IO_ADC_00	IO_DI_48
P104	Analog Voltage Input IO_ADC_02												IO_ADC_02	IO_ADC_02	IO_DI_50
P105	Analog Voltage Input IO_ADC_04												IO_ADC_04	IO_ADC_04	IO_DI_52
P106	Analog Voltage Input IO_ADC_06												IO_ADC_06	IO_ADC_06	IO_DI_54
P107	Analog Voltage Input IO_ADC_08										IO_ADC_08	IO_DI_56			
P108	Analog Voltage Input IO_ADC_10										IO_ADC_10	IO_DI_58			
P109	Analog Voltage Input IO_ADC_12										IO_ADC_12	IO_DI_60			
P110	Analog Voltage Input IO_ADC_14										IO_ADC_14	IO_DI_62			
P111	Analog Voltage Input IO_ADC_16										IO_ADC_16	IO_DI_64			
P112	Analog Voltage Input IO_ADC_18										IO_ADC_18	IO_DI_66			
P113	Analog Voltage Input IO_ADC_20										IO_ADC_20	IO_DI_68			
P114	Analog Voltage Input IO_ADC_22										IO_ADC_22	IO_DI_70			
P115	Timer Input IO_PWD_00						IO_PWD_00	IO_ADC_24 IO_DI_36							
P116	Timer Input IO_PWD_02						IO_PWD_02	IO_ADC_26 IO_DI_38							
P117	Timer Input IO_PWD_04						IO_PWD_04	IO_ADC_28 IO_DI_40							
P118	BAT-														
P119	BAT-														
P120	BAT-														
P121	BAT-														
P122	Timer Input IO_PWD_06							IO_ADC_30 IO_DI_42							
P123	Timer Input IO_PWD_08							IO_ADC_32 IO_DI_44							

			Alternative Function									
			A/D Input (HS Output/PVG/VOUT)	*Current Loop Input*	*A/D Input (Timer Input)*	*A/D Input (HS Digital Output)*	*A/D Input (LS Digital Output)*	*Analog Current Input 2M*	*Digital Input 2M*	*Analog Current Input 3M*	*Analog Resistance Input 3M*	*Digital Input 3M*
	Timer Input IO_PWD_10				IO_ADC_34 IO_DI_46							
	HS PWM Output	IO_DI_29 IO_PWD_13										
	HS PWM Output	IO_PWD_17 IO_DI_33										
	Analog Voltage Input IO_ADC_01									IO_ADC_01	IO_ADC_01	IO_DI_49
P128	Analog Voltage Input IO_ADC_03									IO_ADC_03	IO_ADC_03	IO_DI_51
P129	Analog Voltage Input IO_ADC_05									IO_ADC_05	IO_ADC_05	IO_DI_53
P130	Analog Voltage Input IO_ADC_07									IO_ADC_07	IO_ADC_07	IO_DI_55
P131	Analog Voltage Input IO_ADC_09							IO_ADC_09	IO_DI_57			
P132	Analog Voltage Input IO_ADC_11							IO_ADC_11	IO_DI_59			
P133	Analog Voltage Input IO_ADC_13							IO_ADC_13	IO_DI_61			
P134	Analog Voltage Input IO_ADC_15							IO_ADC_15	IO_DI_63			
P135	Analog Voltage Input IO_ADC_17							IO_ADC_17	IO_DI_65			
P136	Analog Voltage Input IO_ADC_19							IO_ADC_19	IO_DI_67			
P137	Analog Voltage Input IO_ADC_21							IO_ADC_21	IO_DI_69			
P138	Analog Voltage Input IO_ADC_23							IO_ADC_23	IO_DI_71			
P139	Timer Input IO_PWD_01			IO_PWD_01	IO_ADC_25 IO_DI_37							
P140	Timer Input IO_PWD_03			IO_PWD_03	IO_ADC_27 IO_DI_39							
P141	Timer Input IO_PWD_05			IO_PWD_05	IO_ADC_29 IO_DI_41							
P142	BAT-											
P143	BAT-											
P144	BAT-											
P145	BAT-											
P146	Timer Input IO_PWD_07				IO_ADC_31 IO_DI_43							
P147	Timer Input IO_PWD_09				IO_ADC_33 IO_DI_45							

Pin No.	Main Function	Alternative Function													
		HS Digital Output	*Timer Input*	*PVG Output*	*VOUT Output*	*A/D Input (HS Output/PVG/VOUT)*	*Current Loop Input*	*A/D Input (Timer Input)*	*A/D Input (HS Digital Output)*	*A/D Input (LS Digital Output)*	*Analog Current Input 2M*	*Digital Input 2M*	*Analog Current Input 3M*	*Analog Resistance Input 3M*	*Digital Input 3M*
P148	Timer Input IO_PWD_11							IO_ADC_35 IO_DI_47							
P149	HS Digital Output IO_DO_00								IO_ADC_36 IO_DI_72						
P150	HS PWM Output		IO_PWD_14 IO_DI_30												
P151	HS PWM Output		IO_PWD_18 IO_DI_34												
P152	HS Digital Output IO_DO_02								IO_ADC_38 IO_DI_74						
P153	HS PWM Output IO_PWM_00	IO_DO_16	IO_DI_00												
P154	HS PWM Output IO_PWM_14	IO_DO_30	IO_DI_14												
P155	HS Digital Output IO_DO_04								IO_ADC_40 IO_DI_76						
P156	HS PWM Output IO_PWM_02	IO_DO_18	IO_DI_02												
P157	HS PWM Output IO_PWM_16	IO_DO_32	IO_DI_16												
P158	HS Digital Output IO_DO_06								IO_ADC_42 IO_DI_78						
P159	HS PWM Output IO_PWM_04	IO_DO_20	IO_DI_04												
P160	HS PWM Output IO_PWM_18	IO_DO_34	IO_DI_18												
P161	HS Digital Output IO_DO_52			IO_PVG_00	IO_VOUT_00	IO_ADC_52 IO_DI_88									
P162	HS PWM Output IO_PWM_07	IO_DO_23	IO_DI_07												
P163	HS PWM Output IO_PWM_21	IO_DO_37	IO_DI_21												
P164	HS Digital Output IO_DO_55			IO_PVG_03	IO_VOUT_03	IO_ADC_55 IO_DI_91									
P165															
P166															
P167	HS Digital Output IO_DO_57			IO_PVG_05	IO_VOUT_05	IO_ADC_57 IO_DI_93									
P168															
P169															
P170	HS Digital Output IO_DO_59			IO_PVG_07	IO_VOUT_07	IO_ADC_59 IO_DI_95									
P171															
P172															

							Alternative Function								
						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	HS Digital Output IO_DO_01								IO_ADC_37 IO_DI_73						
	HS PWM Output		IO_PWD_15 IO_DI_31												
	HS PWM Output		IO_PWD_19 IO_DI_35												
	HS Digital Output IO_DO_03								IO_ADC_39 IO_DI_75						
P177	HS PWM Output IO_PWM_01	IO_DO_17	IO_DI_01												
P178	HS PWM Output IO_PWM_15	IO_DO_31	IO_DI_15												
P179	HS Digital Output IO_DO_05								IO_ADC_41 IO_DI_77						
P180	HS PWM Output IO_PWM_03	IO_DO_19	IO_DI_03												
P181	HS PWM Output IO_PWM_17	IO_DO_33	IO_DI_17												
P182	HS Digital Output IO_DO_07								IO_ADC_43 IO_DI_79						
P183	HS PWM Output IO_PWM_05	IO_DO_21	IO_DI_05												
P184	HS PWM Output IO_PWM_19	IO_DO_35	IO_DI_19												
P185	HS Digital Output IO_DO_53			IO_PVG_01	IO_VOUT_01	IO_ADC_53 IO_DI_89									
P186	HS PWM Output IO_PWM_06	IO_DO_22	IO_DI_06												
P187	HS PWM Output IO_PWM_20	IO_DO_36	IO_DI_20												
P188	HS Digital Output IO_DO_54			IO_PVG_02	IO_VOUT_02	IO_ADC_54 IO_DI_90									
P189															
P190															
P191	HS Digital Output IO_DO_56			IO_PVG_04	IO_VOUT_04	IO_ADC_56 IO_DI_92									
P192															
P193															
P194	HS Digital Output IO_DO_58			IO_PVG_06	IO_VOUT_06	IO_ADC_58 IO_DI_94									
P195															
P196															
P197															
P198															
P199															

		Alternative Function													
Pin No.	Main Function	HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P200															
P201	BAT+ Power														
P202	BAT+ Power														
P203	BAT+ Power														
P204	BAT+ Power														
P205	BAT+ Power														
P206	BAT+ Power														
P207	Terminal 15 IO_ADC_K15														
P208	LIN IO_LIN														
P209	CAN 0 Low IO_CAN_CHANNEL_0														
P210	CAN 1 Low IO_CAN_CHANNEL_1														
P211	CAN 2 Low IO_CAN_CHANNEL_2														
P212															
P213															
P214															
P215															
P216															
P217	Sensor GND														
P218															
P219															
P220	Wake-Up IO_ADC_WAKE_UP														
P221	Sensor Supply Var. IO_ADC_SENSOR_SUPPLY_2														
P222	CAN 0 High IO_CAN_CHANNEL_0														
P223	CAN 1 High IO_CAN_CHANNEL_1														
P224	CAN 2 High IO_CAN_CHANNEL_2														
P225															
P226															
P227															
P228															
P229															
P230	Sensor GND														
P231															
P232															
P233															

			Alternative Function					
			A/D Input (HS Output/PVG/VOUT)	Current Loop Input / A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M / Digital Input 2M	Analog Current Input 3M / Analog Resistance Input 3M / Digital Input 3M
	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_1							
P235	CAN Termination 0L							
P236	CAN Termination 1L							
P237	CAN Termination 2L							
P238	LS Digital Output IO_DO_09					IO_ADC_45 IO_DI_81		
P239	LS Digital Output IO_DO_11					IO_ADC_47 IO_DI_83		
P240	LS Digital Output IO_DO_13					IO_ADC_49 IO_DI_85		
P241	LS Digital Output IO_DO_15					IO_ADC_51 IO_DI_87		
P242								
P243	Sensor GND							
P244	Sensor GND							
P245	Sensor GND							
P246	BAT+ CPU IO_ADC_UBAT							
P247	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_0							
P248	CAN Termination 0H							
P249	CAN Termination 1H							
P250	CAN Termination 2H							
P251	LS Digital Output IO_DO_08					IO_ADC_44 IO_DI_80		
P252	LS Digital Output IO_DO_10					IO_ADC_46 IO_DI_82		
P253	LS Digital Output IO_DO_12					IO_ADC_48 IO_DI_84		
P254	LS Digital Output IO_DO_14					IO_ADC_50 IO_DI_86		
P255								
P256	Sensor GND							
P257	Sensor GND							
P258	Sensor GND							

Table 16: Pinning of HY-TTC 510

3.5.5 HY-TTC 590E Variant

		Alternative Function													
Pin No.	Main Function	HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P101	HS PWM Output IO_PWM_28	IO_DO_44	IO_PWD_12 IO_DI_28												
P102	HS PWM Output IO_PWM_32	IO_DO_48	IO_PWD_16 IO_DI_32												
P103	Analog Voltage Input IO_ADC_00												IO_ADC_00	IO_ADC_00	IO_DI_48
P104	Analog Voltage Input IO_ADC_02												IO_ADC_02	IO_ADC_02	IO_DI_50
P105	Analog Voltage Input IO_ADC_04												IO_ADC_04	IO_ADC_04	IO_DI_52
P106	Analog Voltage Input IO_ADC_06												IO_ADC_06	IO_ADC_06	IO_DI_54
P107	Analog Voltage Input IO_ADC_08										IO_ADC_08	IO_DI_56			
P108	Analog Voltage Input IO_ADC_10										IO_ADC_10	IO_DI_58			
P109	Analog Voltage Input IO_ADC_12										IO_ADC_12	IO_DI_60			
P110	Analog Voltage Input IO_ADC_14										IO_ADC_14	IO_DI_62			
P111	Analog Voltage Input IO_ADC_16										IO_ADC_16	IO_DI_64			
P112	Analog Voltage Input IO_ADC_18										IO_ADC_18	IO_DI_66			
P113	Analog Voltage Input IO_ADC_20										IO_ADC_20	IO_DI_68			
P114	Analog Voltage Input IO_ADC_22										IO_ADC_22	IO_DI_70			
P115	Timer Input IO_PWD_00						IO_PWD_00	IO_ADC_24 IO_DI_36							
P116	Timer Input IO_PWD_02						IO_PWD_02	IO_ADC_26 IO_DI_38							
P117	Timer Input IO_PWD_04						IO_PWD_04	IO_ADC_28 IO_DI_40							
P118	BAT-														
P119	BAT-														
P120	BAT-														
P121	BAT-														
P122	Timer Input IO_PWD_06							IO_ADC_30 IO_DI_42							
P123	Timer Input IO_PWD_08							IO_ADC_32 IO_DI_44							

				Alternative Function									
				A/D Input (HS Output/PVG/VOUT)	*Current Loop Input*	*A/D Input (Timer Input)*	*A/D Input (HS Digital Output)*	*A/D Input (LS Digital Output)*	*Analog Current Input 2M*	*Digital Input 2M*	*Analog Current Input 3M*	*Analog Resistance Input 3M*	*Digital Input 3M*
	Timer Input IO_PWD_10					IO_ADC_34 IO_DI_46							
	HS PWM Output IO_PWM_29	IO_DO_45	IO_DI_29 IO_PWD_13										
	HS PWM Output IO_PWM_33	IO_DO_49	IO_PWD_17 IO_DI_33										
	Analog Voltage Input IO_ADC_01										IO_ADC_01	IO_ADC_01	IO_DI_49
P128	Analog Voltage Input IO_ADC_03										IO_ADC_03	IO_ADC_03	IO_DI_51
P129	Analog Voltage Input IO_ADC_05										IO_ADC_05	IO_ADC_05	IO_DI_53
P130	Analog Voltage Input IO_ADC_07										IO_ADC_07	IO_ADC_07	IO_DI_55
P131	Analog Voltage Input IO_ADC_09								IO_ADC_09	IO_DI_57			
P132	Analog Voltage Input IO_ADC_11								IO_ADC_11	IO_DI_59			
P133	Analog Voltage Input IO_ADC_13								IO_ADC_13	IO_DI_61			
P134	Analog Voltage Input IO_ADC_15								IO_ADC_15	IO_DI_63			
P135	Analog Voltage Input IO_ADC_17								IO_ADC_17	IO_DI_65			
P136	Analog Voltage Input IO_ADC_19								IO_ADC_19	IO_DI_67			
P137	Analog Voltage Input IO_ADC_21								IO_ADC_21	IO_DI_69			
P138	Analog Voltage Input IO_ADC_23								IO_ADC_23	IO_DI_71			
P139	Timer Input IO_PWD_01				IO_PWD_01	IO_ADC_25 IO_DI_37							
P140	Timer Input IO_PWD_03				IO_PWD_03	IO_ADC_27 IO_DI_39							
P141	Timer Input IO_PWD_05				IO_PWD_05	IO_ADC_29 IO_DI_41							
P142	BAT-												
P143	BAT-												
P144	BAT-												
P145	BAT-												
P146	Timer Input IO_PWD_07					IO_ADC_31 IO_DI_43							
P147	Timer Input IO_PWD_09					IO_ADC_33 IO_DI_45							

Pin No.	Main Function	*HS Digital Output*	*Timer Input*	*PVG Output*	*VOUT Output*	*A/D Input (HS Output/PVG/VOUT)*	*Current Loop Input*	*A/D Input (Timer Input)*	*A/D Input (HS Digital Output)*	*A/D Input (LS Digital Output)*	*Analog Current Input 2M*	*Digital Input 2M*	*Analog Current Input 3M*	*Analog Resistance Input 3M*	*Digital Input 3M*
		Alternative Function													
P148	Timer Input IO_PWD_11							IO_ADC_35 IO_DI_47							
P149	HS Digital Output IO_DO_00								IO_ADC_36 IO_DI_72						
P150	HS PWM Output IO_PWM_30	IO_DO_46	IO_PWD_14 IO_DI_30												
P151	HS PWM Output IO_PWM_34	IO_DO_50	IO_PWD_18 IO_DI_34												
P152	HS Digital Output IO_DO_02								IO_ADC_38 IO_DI_74						
P153	HS PWM Output IO_PWM_00	IO_DO_16	IO_DI_00												
P154	HS PWM Output IO_PWM_14	IO_DO_30	IO_DI_14												
P155	HS Digital Output IO_DO_04								IO_ADC_40 IO_DI_76						
P156	HS PWM Output IO_PWM_02	IO_DO_18	IO_DI_02												
P157	HS PWM Output IO_PWM_16	IO_DO_32	IO_DI_16												
P158	HS Digital Output IO_DO_06								IO_ADC_42 IO_DI_78						
P159	HS PWM Output IO_PWM_04	IO_DO_20	IO_DI_04												
P160	HS PWM Output IO_PWM_18	IO_DO_34	IO_DI_18												
P161	HS Digital Output IO_DO_52			IO_PVG_00	IO_VOUT_00	IO_ADC_52 IO_DI_88									
P162	HS PWM Output IO_PWM_07	IO_DO_23	IO_DI_07												
P163	HS PWM Output IO_PWM_21	IO_DO_37	IO_DI_21												
P164	HS Digital Output IO_DO_55			IO_PVG_03	IO_VOUT_03	IO_ADC_55 IO_DI_91									
P165	HS PWM Output IO_PWM_09	IO_DO_25	IO_DI_09												
P166	HS PWM Output IO_PWM_23	IO_DO_39	IO_DI_23												
P167	HS Digital Output IO_DO_57			IO_PVG_05	IO_VOUT_05	IO_ADC_57 IO_DI_93									
P168	HS PWM Output IO_PWM_11	IO_DO_27	IO_DI_11												
P169	HS PWM Output IO_PWM_25	IO_DO_41	IO_DI_25												
P170	HS Digital Output IO_DO_59			IO_PVG_07	IO_VOUT_07	IO_ADC_59 IO_DI_95									

					Alternative Function										
						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P171	HS PWM Output IO_PWM_13	IO_DO_29	IO_DI_13												
P172	HS PWM Output IO_PWM_27	IO_DO_43	IO_DI_27												
P173	HS Digital Output IO_DO_01								IO_ADC_37 IO_DI_73						
P174	HS PWM Output IO_PWM_31	IO_DO_47	IO_PWD_15 IO_DI_31												
P175	HS PWM Output IO_PWM_35	IO_DO_51	IO_PWD_19 IO_DI_35												
P176	HS Digital Output IO_DO_03								IO_ADC_39 IO_DI_75						
P177	HS PWM Output IO_PWM_01	IO_DO_17	IO_DI_01												
P178	HS PWM Output IO_PWM_15	IO_DO_31	IO_DI_15												
P179	HS Digital Output IO_DO_05								IO_ADC_41 IO_DI_77						
P180	HS PWM Output IO_PWM_03	IO_DO_19	IO_DI_03												
P181	HS PWM Output IO_PWM_17	IO_DO_33	IO_DI_17												
P182	HS Digital Output IO_DO_07								IO_ADC_43 IO_DI_79						
P183	HS PWM Output IO_PWM_05	IO_DO_21	IO_DI_05												
P184	HS PWM Output IO_PWM_19	IO_DO_35	IO_DI_19												
P185	HS Digital Output IO_DO_53			IO_PVG_01	IO_VOUT_01	IO_ADC_53 IO_DI_89									
P186	HS PWM Output IO_PWM_06	IO_DO_22	IO_DI_06												
P187	HS PWM Output IO_PWM_20	IO_DO_36	IO_DI_20												
P188	HS Digital Output IO_DO_54			IO_PVG_02	IO_VOUT_02	IO_ADC_54 IO_DI_90									
P189	HS PWM Output IO_PWM_08	IO_DO_24	IO_DI_08												
P190	HS PWM Output IO_PWM_22	IO_DO_38	IO_DI_22												
P191	HS Digital Output IO_DO_56			IO_PVG_04	IO_VOUT_04	IO_ADC_56 IO_DI_92									
P192	HS PWM Output IO_PWM_10	IO_DO_26	IO_DI_10												
P193	HS PWM Output IO_PWM_24	IO_DO_40	IO_DI_24												

						Alternative Function									
						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	HS Digital Output IO_DO_58			IO_PVG_06	IO_VOUT_06	IO_ADC_58 IO_DI_94									
	HS PWM Output IO_PWM_12	IO_DO_28	IO_DI_12												
	HS PWM Output IO_PWM_26	IO_DO_42	IO_DI_26												
P197															
P198															
P199															
P200															
P201	BAT+ Power														
P202	BAT+ Power														
P203	BAT+ Power														
P204	BAT+ Power														
P205	BAT+ Power														
P206	BAT+ Power														
P207	Terminal 15 IO_ADC_K15														
P208	LIN IO_LIN														
P209	CAN 0 Low IO_CAN_CHANNEL_0														
P210	CAN 1 Low IO_CAN_CHANNEL_1 ISOBUS CAN														
P211	CAN 2 Low IO_CAN_CHANNEL_2														
P212	CAN 3 Low IO_CAN_CHANNEL_3														
P213	CAN 4 Low IO_CAN_CHANNEL_4														
P214	CAN 5 Low IO_CAN_CHANNEL_5														
P215	CAN 6 Low IO_CAN_CHANNEL_6														
P216	Sensor GND														
P217	do not connect														
P218	CAN Termination 3H														
P219	CAN Termination 3L														
P220	Wake-Up IO_ADC_WAKE_UP														
P221	Sensor Supply Var. IO_ADC_SENSOR_SUPPLY_2														
P222	CAN 0 High IO_CAN_CHANNEL_0														

			Alternative Function									
			A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P223	CAN 1 High IO_CAN_CHANNEL_1 ISOBUS CAN											
P224	CAN 2 High IO_CAN_CHANNEL_2											
P225	CAN 3 High IO_CAN_CHANNEL_3											
P226	CAN 4 High IO_CAN_CHANNEL_4											
P227	CAN 5 High IO_CAN_CHANNEL_5											
P228	CAN 6 High IO_CAN_CHANNEL_6											
P229												
P230	do not connect											
P231	BRR/100BASE-T1 TRX- IO_DOWNLOAD, IO_UDP											
P232	BRR/100BASE-T1 TRX+ IO_DOWNLOAD, IO_UDP											
P233	RTC_BACKUP_BAT											
P234	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_1											
P235	CAN Termination 0L											
P236	CAN Termination 1L											
P237	CAN Termination 2L											
P238	LS Digital Output IO_DO_09						IO_ADC_45 IO_DI_81					
P239	LS Digital Output IO_DO_11						IO_ADC_47 IO_DI_83					
P240	LS Digital Output IO_DO_13						IO_ADC_49 IO_DI_85					
P241	LS Digital Output IO_DO_15						IO_ADC_51 IO_DI_87					
P242	RS232 TXD IO_UART											
P243	Sensor GND											
P244	Sensor GND											
P245	Sensor GND											
P246	BAT+ CPU IO_ADC_UBAT											
P247	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_0											
P248	CAN Termination 0H											
P249	CAN Termination 1H											
P250	CAN Termination 2H											

						Alternative Function									
						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	LS Digital Output IO_DO_08									IO_ADC_44 IO_DI_80					
	LS Digital Output IO_DO_10									IO_ADC_46 IO_DI_82					
	LS Digital Output IO_DO_12									IO_ADC_48 IO_DI_84					
P254	LS Digital Output IO_DO_14									IO_ADC_50 IO_DI_86					
P255	RS232 RXD IO_UART														
P256	Sensor GND														
P257	Sensor GND														
P258	Sensor GND														

Table 17: Pinning of HY-TTC 590E

3.5.6 HY-TTC 590 Variant

		Alternative Function													
Pin No.	Main Function	HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P101	HS PWM Output IO_PWM_28	IO_DO_44	IO_PWD_12 IO_DI_28												
P102	HS PWM Output IO_PWM_32	IO_DO_48	IO_PWD_16 IO_DI_32												
P103	Analog Voltage Input IO_ADC_00												IO_ADC_00	IO_ADC_00	IO_DI_48
P104	Analog Voltage Input IO_ADC_02												IO_ADC_02	IO_ADC_02	IO_DI_50
P105	Analog Voltage Input IO_ADC_04												IO_ADC_04	IO_ADC_04	IO_DI_52
P106	Analog Voltage Input IO_ADC_06												IO_ADC_06	IO_ADC_06	IO_DI_54
P107	Analog Voltage Input IO_ADC_08										IO_ADC_08	IO_DI_56			
P108	Analog Voltage Input IO_ADC_10										IO_ADC_10	IO_DI_58			
P109	Analog Voltage Input IO_ADC_12										IO_ADC_12	IO_DI_60			
P110	Analog Voltage Input IO_ADC_14										IO_ADC_14	IO_DI_62			
P111	Analog Voltage Input IO_ADC_16										IO_ADC_16	IO_DI_64			
P112	Analog Voltage Input IO_ADC_18										IO_ADC_18	IO_DI_66			
P113	Analog Voltage Input IO_ADC_20										IO_ADC_20	IO_DI_68			
P114	Analog Voltage Input IO_ADC_22										IO_ADC_22	IO_DI_70			
P115	Timer Input IO_PWD_00						IO_PWD_00	IO_ADC_24 IO_DI_36							
P116	Timer Input IO_PWD_02						IO_PWD_02	IO_ADC_26 IO_DI_38							
P117	Timer Input IO_PWD_04						IO_PWD_04	IO_ADC_28 IO_DI_40							
P118	BAT-														
P119	BAT-														
P120	BAT-														
P121	BAT-														
P122	Timer Input IO_PWD_06							IO_ADC_30 IO_DI_42							
P123	Timer Input IO_PWD_08							IO_ADC_32 IO_DI_44							

				Alternative Function									
				A/D Input (HS Output/PVG/VOUT)	*Current Loop Input*	*A/D Input (Timer Input)*	*A/D Input (HS Digital Output)*	*A/D Input (LS Digital Output)*	*Analog Current Input 2M*	*Digital Input 2M*	*Analog Current Input 3M*	*Analog Resistance Input 3M*	*Digital Input 3M*
	Timer Input IO_PWD_10					IO_ADC_34 IO_DI_46							
	HS PWM Output IO_PWM_29	IO_DO_45	IO_DI_29 IO_PWD_13										
	HS PWM Output IO_PWM_33	IO_DO_49	IO_PWD_17 IO_DI_33										
P127	Analog Voltage Input IO_ADC_01										IO_ADC_01	IO_ADC_01	IO_DI_49
P128	Analog Voltage Input IO_ADC_03										IO_ADC_03	IO_ADC_03	IO_DI_51
P129	Analog Voltage Input IO_ADC_05										IO_ADC_05	IO_ADC_05	IO_DI_53
P130	Analog Voltage Input IO_ADC_07										IO_ADC_07	IO_ADC_07	IO_DI_55
P131	Analog Voltage Input IO_ADC_09								IO_ADC_09	IO_DI_57			
P132	Analog Voltage Input IO_ADC_11								IO_ADC_11	IO_DI_59			
P133	Analog Voltage Input IO_ADC_13								IO_ADC_13	IO_DI_61			
P134	Analog Voltage Input IO_ADC_15								IO_ADC_15	IO_DI_63			
P135	Analog Voltage Input IO_ADC_17								IO_ADC_17	IO_DI_65			
P136	Analog Voltage Input IO_ADC_19								IO_ADC_19	IO_DI_67			
P137	Analog Voltage Input IO_ADC_21								IO_ADC_21	IO_DI_69			
P138	Analog Voltage Input IO_ADC_23								IO_ADC_23	IO_DI_71			
P139	Timer Input IO_PWD_01				IO_PWD_01	IO_ADC_25 IO_DI_37							
P140	Timer Input IO_PWD_03				IO_PWD_03	IO_ADC_27 IO_DI_39							
P141	Timer Input IO_PWD_05				IO_PWD_05	IO_ADC_29 IO_DI_41							
P142	BAT-												
P143	BAT-												
P144	BAT-												
P145	BAT-												
P146	Timer Input IO_PWD_07					IO_ADC_31 IO_DI_43							
P147	Timer Input IO_PWD_09					IO_ADC_33 IO_DI_45							

						Alternative Function									
						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P148	Timer Input IO_PWD_11							IO_ADC_35 IO_DI_47							
P149	HS Digital Output IO_DO_00								IO_ADC_36 IO_DI_72						
P150	HS PWM Output IO_PWM_30	IO_DO_46	IO_PWD_14 IO_DI_30												
P151	HS PWM Output IO_PWM_34	IO_DO_50	IO_PWD_18 IO_DI_34												
P152	HS Digital Output IO_DO_02								IO_ADC_38 IO_DI_74						
P153	HS PWM Output IO_PWM_00	IO_DO_16	IO_DI_00												
P154	HS PWM Output IO_PWM_14	IO_DO_30	IO_DI_14												
P155	HS Digital Output IO_DO_04								IO_ADC_40 IO_DI_76						
P156	HS PWM Output IO_PWM_02	IO_DO_18	IO_DI_02												
P157	HS PWM Output IO_PWM_16	IO_DO_32	IO_DI_16												
P158	HS Digital Output IO_DO_06								IO_ADC_42 IO_DI_78						
P159	HS PWM Output IO_PWM_04	IO_DO_20	IO_DI_04												
P160	HS PWM Output IO_PWM_18	IO_DO_34	IO_DI_18												
P161	HS Digital Output IO_DO_52			IO_PVG_00	IO_VOUT_00	IO_ADC_52 IO_DI_88									
P162	HS PWM Output IO_PWM_07	IO_DO_23	IO_DI_07												
P163	HS PWM Output IO_PWM_21	IO_DO_37	IO_DI_21												
P164	HS Digital Output IO_DO_55			IO_PVG_03	IO_VOUT_03	IO_ADC_55 IO_DI_91									
P165	HS PWM Output IO_PWM_09	IO_DO_25	IO_DI_09												
P166	HS PWM Output IO_PWM_23	IO_DO_39	IO_DI_23												
P167	HS Digital Output IO_DO_57			IO_PVG_05	IO_VOUT_05	IO_ADC_57 IO_DI_93									
P168	HS PWM Output IO_PWM_11	IO_DO_27	IO_DI_11												
P169	HS PWM Output IO_PWM_25	IO_DO_41	IO_DI_25												
P170	HS Digital Output IO_DO_59			IO_PVG_07	IO_VOUT_07	IO_ADC_59 IO_DI_95									

					Alternative Function										
						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	HS PWM Output IO_PWM_13	IO_DO_29	IO_DI_13												
	HS PWM Output IO_PWM_27	IO_DO_43	IO_DI_27												
	HS Digital Output IO_DO_01								IO_ADC_37 IO_DI_73						
P174	HS PWM Output IO_PWM_31	IO_DO_47	IO_PWD_15 IO_DI_31												
P175	HS PWM Output IO_PWM_35	IO_DO_51	IO_PWD_19 IO_DI_35												
P176	HS Digital Output IO_DO_03								IO_ADC_39 IO_DI_75						
P177	HS PWM Output IO_PWM_01	IO_DO_17	IO_DI_01												
P178	HS PWM Output IO_PWM_15	IO_DO_31	IO_DI_15												
P179	HS Digital Output IO_DO_05								IO_ADC_41 IO_DI_77						
P180	HS PWM Output IO_PWM_03	IO_DO_19	IO_DI_03												
P181	HS PWM Output IO_PWM_17	IO_DO_33	IO_DI_17												
P182	HS Digital Output IO_DO_07								IO_ADC_43 IO_DI_79						
P183	HS PWM Output IO_PWM_05	IO_DO_21	IO_DI_05												
P184	HS PWM Output IO_PWM_19	IO_DO_35	IO_DI_19												
P185	HS Digital Output IO_DO_53			IO_PVG_01	IO_VOUT_01	IO_ADC_53 IO_DI_89									
P186	HS PWM Output IO_PWM_06	IO_DO_22	IO_DI_06												
P187	HS PWM Output IO_PWM_20	IO_DO_36	IO_DI_20												
P188	HS Digital Output IO_DO_54			IO_PVG_02	IO_VOUT_02	IO_ADC_54 IO_DI_90									
P189	HS PWM Output IO_PWM_08	IO_DO_24	IO_DI_08												
P190	HS PWM Output IO_PWM_22	IO_DO_38	IO_DI_22												
P191	HS Digital Output IO_DO_56			IO_PVG_04	IO_VOUT_04	IO_ADC_56 IO_DI_92									
P192	HS PWM Output IO_PWM_10	IO_DO_26	IO_DI_10												
P193	HS PWM Output IO_PWM_24	IO_DO_40	IO_DI_24												

Alternative Function

						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P194	HS Digital Output IO_DO_58			IO_PVG_06	IO_VOUT_06	IO_ADC_58 IO_DI_94									
P195	HS PWM Output IO_PWM_12	IO_DO_28	IO_DI_12												
P196	HS PWM Output IO_PWM_26	IO_DO_42	IO_DI_26												
P197															
P198															
P199															
P200															
P201	BAT+ Power														
P202	BAT+ Power														
P203	BAT+ Power														
P204	BAT+ Power														
P205	BAT+ Power														
P206	BAT+ Power														
P207	Terminal 15 IO_ADC_K15														
P208	LIN IO_LIN														
P209	CAN 0 Low IO_CAN_CHANNEL_0														
P210	CAN 1 Low IO_CAN_CHANNEL_1 ISOBUS CAN														
P211	CAN 2 Low IO_CAN_CHANNEL_2														
P212	CAN 3 Low IO_CAN_CHANNEL_3														
P213	CAN 4 Low IO_CAN_CHANNEL_4														
P214	CAN 5 Low IO_CAN_CHANNEL_5														
P215	CAN 6 Low IO_CAN_CHANNEL_6														
P216	Sensor GND														
P217	do not connect														
P218	CAN Termination 3H														
P219	CAN Termination 3L														
P220	Wake-Up IO_ADC_WAKE_UP														
P221	Sensor Supply Var. IO_ADC_SENSOR_SUPPLY_2														
P222	CAN 0 High IO_CAN_CHANNEL_0														

			Alternative Function									
			A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P223	CAN 1 High IO_CAN_CHANNEL_1 ISOBUS CAN											
P224	CAN 2 High IO_CAN_CHANNEL_2											
P225	CAN 3 High IO_CAN_CHANNEL_3											
P226	CAN 4 High IO_CAN_CHANNEL_4											
P227	CAN 5 High IO_CAN_CHANNEL_5											
P228	CAN 6 High IO_CAN_CHANNEL_6											
P229												
P230	do not connect											
P231	BRR/100BASE-T1 TRX- IO_DOWNLOAD, IO_UDP											
P232	BRR/100BASE-T1 TRX+ IO_DOWNLOAD, IO_UDP											
P233	RTC_BACKUP_BAT											
P234	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_1											
P235	CAN Termination 0L											
P236	CAN Termination 1L											
P237	CAN Termination 2L											
P238	LS Digital Output IO_DO_09						IO_ADC_45 IO_DI_81					
P239	LS Digital Output IO_DO_11						IO_ADC_47 IO_DI_83					
P240	LS Digital Output IO_DO_13						IO_ADC_49 IO_DI_85					
P241	LS Digital Output IO_DO_15						IO_ADC_51 IO_DI_87					
P242	RS232 TXD IO_UART											
P243	Sensor GND											
P244	Sensor GND											
P245	Sensor GND											
P246	BAT+ CPU IO_ADC_UBAT											
P247	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_0											
P248	CAN Termination 0H											
P249	CAN Termination 1H											
P250	CAN Termination 2H											

Pin	Main Function		Alternative Function: A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	LS Digital Output IO_DO_08						IO_ADC_44 IO_DI_80					
	LS Digital Output IO_DO_10						IO_ADC_46 IO_DI_82					
	LS Digital Output IO_DO_12						IO_ADC_48 IO_DI_84					
	LS Digital Output IO_DO_14						IO_ADC_50 IO_DI_86					
P255	RS232 RXD IO_UART											
P256	Sensor GND											
P257	Sensor GND											
P258	Sensor GND											

Table 18: Pinning of HY-TTC 590

3.5.7 HY-TTC 508 Variant

Pin No.	Main Function	Alternative Function: *HS Digital Output*	*Timer Input*	*PVG Output*	*VOUT Output*	*A/D Input (HS Output/PVG/VOUT)*	*Current Loop Input*	*A/D Input (Timer Input)*	*A/D Input (HS Digital Output)*	*A/D Input (LS Digital Output)*	*Analog Current Input 2M*	*Digital Input 2M*	*Analog Current Input 3M*	*Analog Resistance Input 3M*	*Digital Input 3M*
P101	HS PWM Output		IO_PWD_12 IO_DI_28												
P102	HS PWM Output		IO_PWD_16 IO_DI_32												
P103	Analog Voltage Input IO_ADC_00												IO_ADC_00	IO_ADC_00	IO_DI_48
P104	Analog Voltage Input IO_ADC_02												IO_ADC_02	IO_ADC_02	IO_DI_50
P105	Analog Voltage Input IO_ADC_04												IO_ADC_04	IO_ADC_04	IO_DI_52
P106	Analog Voltage Input IO_ADC_06												IO_ADC_06	IO_ADC_06	IO_DI_54
P107	Analog Voltage Input IO_ADC_08										IO_ADC_08	IO_DI_56			
P108	Analog Voltage Input IO_ADC_10										IO_ADC_10	IO_DI_58			
P109	Analog Voltage Input IO_ADC_12										IO_ADC_12	IO_DI_60			
P110	Analog Voltage Input IO_ADC_14										IO_ADC_14	IO_DI_62			
P111	Analog Voltage Input IO_ADC_16										IO_ADC_16	IO_DI_64			
P112	Analog Voltage Input IO_ADC_18										IO_ADC_18	IO_DI_66			
P113	Analog Voltage Input IO_ADC_20										IO_ADC_20	IO_DI_68			
P114	Analog Voltage Input IO_ADC_22										IO_ADC_22	IO_DI_70			
P115	Timer Input IO_PWD_00						IO_PWD_00	IO_ADC_24 IO_DI_36							
P116	Timer Input IO_PWD_02						IO_PWD_02	IO_ADC_26 IO_DI_38							
P117	Timer Input IO_PWD_04						IO_PWD_04	IO_ADC_28 IO_DI_40							
P118	BAT-														
P119	BAT-														
P120	BAT-														
P121	BAT-														
P122	Timer Input IO_PWD_06							IO_ADC_30 IO_DI_42							
P123	Timer Input IO_PWD_08							IO_ADC_32 IO_DI_44							

			Alternative Function									
			A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	Timer Input IO_PWD_10				IO_ADC_34 IO_DI_46							
	HS PWM Output	IO_DI_29 IO_PWD_13										
	HS PWM Output	IO_PWD_17 IO_DI_33										
	Analog Voltage Input IO_ADC_01									IO_ADC_01	IO_ADC_01	IO_DI_49
P128	Analog Voltage Input IO_ADC_03									IO_ADC_03	IO_ADC_03	IO_DI_51
P129	Analog Voltage Input IO_ADC_05									IO_ADC_05	IO_ADC_05	IO_DI_53
P130	Analog Voltage Input IO_ADC_07									IO_ADC_07	IO_ADC_07	IO_DI_55
P131	Analog Voltage Input IO_ADC_09							IO_ADC_09	IO_DI_57			
P132	Analog Voltage Input IO_ADC_11							IO_ADC_11	IO_DI_59			
P133	Analog Voltage Input IO_ADC_13							IO_ADC_13	IO_DI_61			
P134	Analog Voltage Input IO_ADC_15							IO_ADC_15	IO_DI_63			
P135	Analog Voltage Input IO_ADC_17							IO_ADC_17	IO_DI_65			
P136	Analog Voltage Input IO_ADC_19							IO_ADC_19	IO_DI_67			
P137	Analog Voltage Input IO_ADC_21							IO_ADC_21	IO_DI_69			
P138	Analog Voltage Input IO_ADC_23							IO_ADC_23	IO_DI_71			
P139	Timer Input IO_PWD_01			IO_PWD_01	IO_ADC_25 IO_DI_37							
P140	Timer Input IO_PWD_03			IO_PWD_03	IO_ADC_27 IO_DI_39							
P141	Timer Input IO_PWD_05			IO_PWD_05	IO_ADC_29 IO_DI_41							
P142	BAT-											
P143	BAT-											
P144	BAT-											
P145	BAT-											
P146	Timer Input IO_PWD_07				IO_ADC_31 IO_DI_43							
P147	Timer Input IO_PWD_09				IO_ADC_33 IO_DI_45							

Pin No.	Main Function	Alternative Function													
		HS Digital Output	*Timer Input*	*PVG Output*	*VOUT Output*	*A/D Input (HS Output/PVG/VOUT)*	*Current Loop Input*	*A/D Input (Timer Input)*	*A/D Input (HS Digital Output)*	*A/D Input (LS Digital Output)*	*Analog Current Input 2M*	*Digital Input 2M*	*Analog Current Input 3M*	*Analog Resistance Input 3M*	*Digital Input 3M*
P148	Timer Input IO_PWD_11							IO_ADC_35 IO_DI_47							
P149	HS Digital Output IO_DO_00								IO_ADC_36 IO_DI_72						
P150	HS PWM Output		IO_PWD_14 IO_DI_30												
P151	HS PWM Output		IO_PWD_18 IO_DI_34												
P152	HS Digital Output IO_DO_02								IO_ADC_38 IO_DI_74						
P153	HS PWM Output IO_PWM_00	IO_DO_16	IO_DI_00												
P154	HS PWM Output IO_PWM_14	IO_DO_30	IO_DI_14												
P155	HS Digital Output IO_DO_04								IO_ADC_40 IO_DI_76						
P156	HS PWM Output IO_PWM_02	IO_DO_18	IO_DI_02												
P157	HS PWM Output IO_PWM_16	IO_DO_32	IO_DI_16												
P158	HS Digital Output IO_DO_06								IO_ADC_42 IO_DI_78						
P159	HS PWM Output IO_PWM_04	IO_DO_20	IO_DI_04												
P160															
P161	HS Digital Output			IO_PVG_00	IO_VOUT_00	IO_ADC_52 IO_DI_88									
P162															
P163															
P164	HS Digital Output			IO_PVG_03	IO_VOUT_03	IO_ADC_55 IO_DI_91									
P165															
P166															
P167	HS Digital Output			IO_PVG_05	IO_VOUT_05	IO_ADC_57 IO_DI_93									
P168															
P169															
P170															
P171															
P172															
P173	HS Digital Output IO_DO_01								IO_ADC_37 IO_DI_73						
P174	HS PWM Output		IO_PWD_15 IO_DI_31												

				Alternative Function											
						A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	HS PWM Output		IO_PWD_19 IO_DI_35												
	HS Digital Output IO_DO_03								IO_ADC_39 IO_DI_75						
	HS PWM Output IO_PWM_01	IO_DO_17	IO_DI_01												
	HS PWM Output IO_PWM_15	IO_DO_31	IO_DI_15												
P179	HS Digital Output IO_DO_05								IO_ADC_41 IO_DI_77						
P180	HS PWM Output IO_PWM_03	IO_DO_19	IO_DI_03												
P181	HS PWM Output IO_PWM_17	IO_DO_33	IO_DI_17												
P182	HS Digital Output IO_DO_07								IO_ADC_43 IO_DI_79						
P183	HS PWM Output IO_PWM_05	IO_DO_21	IO_DI_05												
P184															
P185	HS Digital Output			IO_PVG_01	IO_VOUT_01	IO_ADC_53 IO_DI_89									
P186															
P187															
P188	HS Digital Output			IO_PVG_02	IO_VOUT_02	IO_ADC_54 IO_DI_90									
P189															
P190															
P191	HS Digital Output			IO_PVG_04	IO_VOUT_04	IO_ADC_56 IO_DI_92									
P192															
P193															
P194															
P195															
P196															
P197															
P198															
P199															
P200															
P201	BAT+ Power														
P202	BAT+ Power														
P203	BAT+ Power														
P204	BAT+ Power														
P205	BAT+ Power														
P206	BAT+ Power														

Pin No.	Main Function	HS Digital Output	Timer Input	PVG Output	VOUT Output	A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
P207	Terminal 15 IO_ADC_K15														
P208															
P209	CAN 0 Low IO_CAN_CHANNEL_0														
P210	CAN 1 Low IO_CAN_CHANNEL_1 ISOBUS CAN														
P211	CAN 2 Low IO_CAN_CHANNEL_2														
P212															
P213															
P214															
P215															
P216	Sensor GND														
P217	do not connect														
P218															
P219															
P220	Wake-Up IO_ADC_WAKE_UP														
P221															
P222	CAN 0 High IO_CAN_CHANNEL_0														
P223	CAN 1 High IO_CAN_CHANNEL_1 ISOBUS CAN														
P224	CAN 2 High IO_CAN_CHANNEL_2														
P225															
P226															
P227															
P228															
P229															
P230	do not connect														
P231	BRR/100BASE-T1 TRX- IO_DOWNLOAD, IO_UDP														
P232	BRR/100BASE-T1 TRX+ IO_DOWNLOAD, IO_UDP														
P233	RTC_BACKUP_BAT														
P234															
P235	CAN Termination 0L														
P236	CAN Termination 1L														
P237	CAN Termination 2L														

				Alternative Function									
				A/D Input (HS Output/PVG/VOUT)	Current Loop Input	A/D Input (Timer Input)	A/D Input (HS Digital Output)	A/D Input (LS Digital Output)	Analog Current Input 2M	Digital Input 2M	Analog Current Input 3M	Analog Resistance Input 3M	Digital Input 3M
	LS Digital Output IO_DO_09							IO_ADC_45 IO_DI_81					
	LS Digital Output IO_DO_11							IO_ADC_47 IO_DI_83					
	LS Digital Output IO_DO_13							IO_ADC_49 IO_DI_85					
	LS Digital Output IO_DO_15							IO_ADC_51 IO_DI_87					
P242													
P243	Sensor GND												
P244	Sensor GND												
P245	Sensor GND												
P246	BAT+ CPU IO_ADC_UBAT												
P247	Sensor Supply 5 V IO_ADC_SENSOR_SUPPLY_0												
P248	CAN Termination 0H												
P249	CAN Termination 1H												
P250	CAN Termination 2H												
P251	LS Digital Output IO_DO_08							IO_ADC_44 IO_DI_80					
P252	LS Digital Output IO_DO_10							IO_ADC_46 IO_DI_82					
P253	LS Digital Output IO_DO_12							IO_ADC_48 IO_DI_84					
P254	LS Digital Output IO_DO_14							IO_ADC_50 IO_DI_86					
P255													
P256	Sensor GND												
P257	Sensor GND												
P258	Sensor GND												

Table 19: Pinning of HY-TTC 508

4 Specification of Inputs and Outputs

4.1 Positive Power Supply of Power Stages (BAT+ Power)

4.1.1 Pinout

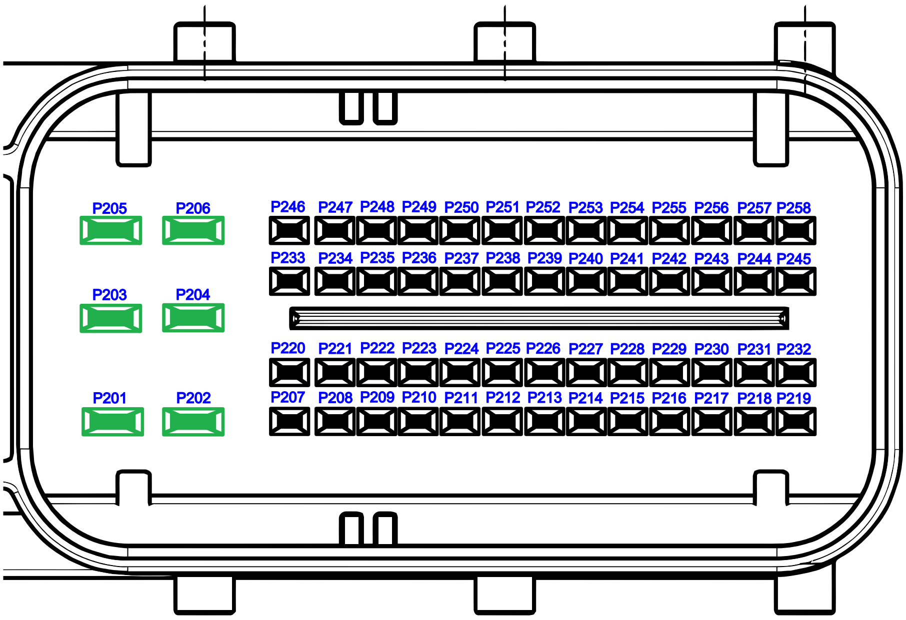

Figure 14: Pinout of BAT+ Power

Pin No.	Function
P201	Battery (+) Supply of Power Stages / BAT+ Power
P202	Battery (+) Supply of Power Stages / BAT+ Power
P203	Battery (+) Supply of Power Stages / BAT+ Power
P204	Battery (+) Supply of Power Stages / BAT+ Power
P205	Battery (+) Supply of Power Stages / BAT+ Power
P206	Battery (+) Supply of Power Stages / BAT+ Power

4.1.2 Functional Description

Supply pins for power stage supply.

The nominal supply voltage for full operation is between 6 and 32 V, including supply voltage ranges for 12 and 24 V battery operation. In this voltage range, all the I/Os work, as described in the system manual. BAT+ Power pins are equipped with inverse polarity protection.

TTControl GmbH recommends to use these pins in parallel and the maximum possible wire size (FLRY type) in case of maximum load current to reduce voltage drop and prevent overheating of the crimp contact.

4.1.3 Maximum Ratings

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
$BAT+_{max}$	Permanent non-destructive supply voltage	1	-32	32	V
$BAT+_{lim}$	Peak non-destructive supply clamping voltage <1 ms	1, 2	-40	45	V
$I_{in\text{-}lim}$	Peak non-destructive supply clamping current <1 ms	1, 2	-10	+100	A
T_d	Load dump protection time according to ISO 7637-2 [20], Pulse 5, Level IV (superimposed 174 V, R_i = 2 Ω)	1		350	ms
$I_{in\text{-}max}$	Permanent battery supply current (all 6 pins in parallel with symmetrical wire connection))	3		60	A
$I_{in\text{-}max}$	Permanent battery supply current per pin	3		10	A
$I_{in\text{-}total}$	Total load current, 12 V and 24 V battery operation	4		45	A
$I_{in\text{-}total}$	Total load current, 12 V and 24 V battery operation	4,5		60	A

Note 1 The control unit is protected by a transient suppressor, specified by clamp voltage, current and duration of voltage transient

Note 2 1 ms pulse width, non-repetitive. The pulse width is defined as the point at which the peak current decreases to 50 % of the maximum value.

Note 3 This battery supply current is related to the total load current of all high-side power-stages. In worst case, all outputs are in non-PWM mode or with maximum duty cycle operated, the battery current equals the total load current. With typical PWM-operation the battery supply current is significant lower than the total load current. For more details please see Section 6.2.2 on page 193.

Note 4 HY-TTC 500 variant-dependent, see Section 6.2.2 on page 193

Note 5 T_{ECU} = -40...+85 °C

4.1.4 Characteristics

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance			250	µF
BAT+	Supply voltage for full operation		6	32	V

4.2 Positive Power Supply of Internal Electronics (BAT+ CPU)

4.2.1 Pinout

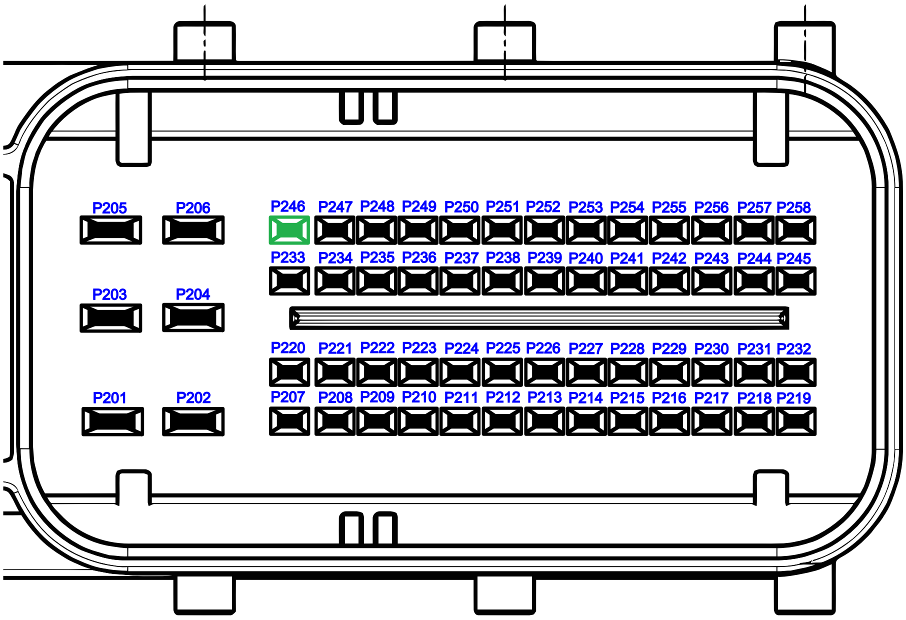

Figure 15: Pinout of BAT+ CPU

Pin No.	Function	SW-define
P246	Battery supply of internal electronics	IO_ADC_UBAT

4.2.2 Functional Description

Supply pin for positive power supply of internal electronics, sensor supply and PVG/V_{out} output stages.

As the output voltage of the PVG/V_{out} outputs is defined as a percentage value in relation to the battery voltage, the voltage drop on the wire to this pin has a direct influence on the accuracy of the PVG output voltage.

BAT+ CPU pin is equipped with inverse polarity protection.

TTControl GmbH recommends to use the maximum possible wire size (FLRY type) in case of maximum load current to reduce voltage drop and prevent overheating of the crimp contact.

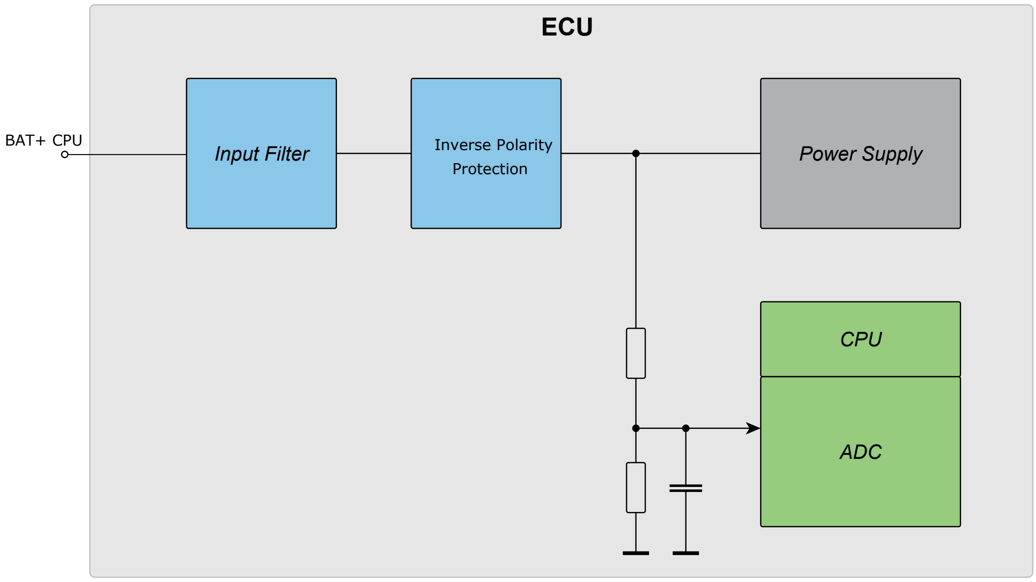

Figure 16: Supply pin for the internal ECU logic

4.2.3 Maximum Ratings

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
$U_{in\text{-}max}$	Permanent non-destructive supply voltage	1	-32	32	V
$U_{in\text{-}lim}$	Peak non-destructive supply clamping voltage <1 ms	1,2	-40	45	V
$I_{in\text{-}lim}$	Peak non-destructive supply clamping current <1 ms	1,2	-10	+100	A
T_d	Load dump protection time according to ISO 7637-2 [20], Pulse 5, Level IV (superimposed 174 V, $R_i = 2\ \Omega$)	1		350	ms
$I_{in\text{-}max}$	Permanent input current	3		3	A

Note 1 The control unit is protected by a transient suppressor, specified by clamp voltage, current and duration of voltage transient.

Note 2 1 ms pulse width, non-repetitive. The pulse width is defined as the point at which the peak current decreases to 50 % of the maximum value.

Note 3 Current internally self-limited

4.2.4 Characteristics

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance			250	µF
BAT+	Supply voltage for start-up	1	8	32	V
BAT+	Supply voltage for full operation	2	6	32	V
$I_{in\text{-}idle}$	Supply current of unit without load (8 V)			600	mA
$I_{in\text{-}idle}$	Supply current of unit without load (12 V)			400	mA
$I_{in\text{-}idle}$	Supply current of unit without load (24 V)			200	mA
$I_{in\text{-}STBY}$	Standby supply current (Terminal 15 and Wake-Up off)			1	mA
$I_{in\text{-}STBY}$	Standby supply current (Terminal 15 and Wake-Up off)	3		<0.5	mA

Note 1 8 V is the initial voltage for start-up at the beginning of the drive cycle

Note 2 See Section 4.2.5 on the next page

Note 3 T_{ECU} = -40...+85 °C

4.2.5 Low-Voltage Operation

The HY-TTC 500 core system is designed for full operation after start-up between 6 V and 32 V, including supply voltage ranges for 12 V and 24 V battery operation and cold-start cranking according to ISO 16750-2 [22]. The initial minimum supply voltage at the beginning of the drive cycle is 8 V. After start-up, the CPU will remain operational down to 6 V, e.g. during cold-start cranking.

The minimum supply voltage during cold-start cranking is defined by ISO 16750-2:2012 (see Table 3, *Starting profile values for systems with 12 V nominal voltage,* U_N, and Table 4, *Values for systems with 24 V nominal voltage,* U_N). The HY-TTC 500 core system complies with ISO 16750-2:2012, level I, II (functional status C), III and IV for 12-V systems and level I, II (functional status A) and III (functional status B) for 24-V systems, see Table 20 on page 103 and Table 21 on page 103.

Restrictions during cold-start cranking apply also for sensor supplies. For more information, see Section 4.7 on page 112 and Section 4.8 on page 114.

HY-TTC 500 ISO 16750 code specification see Section 1.6 on page 35.

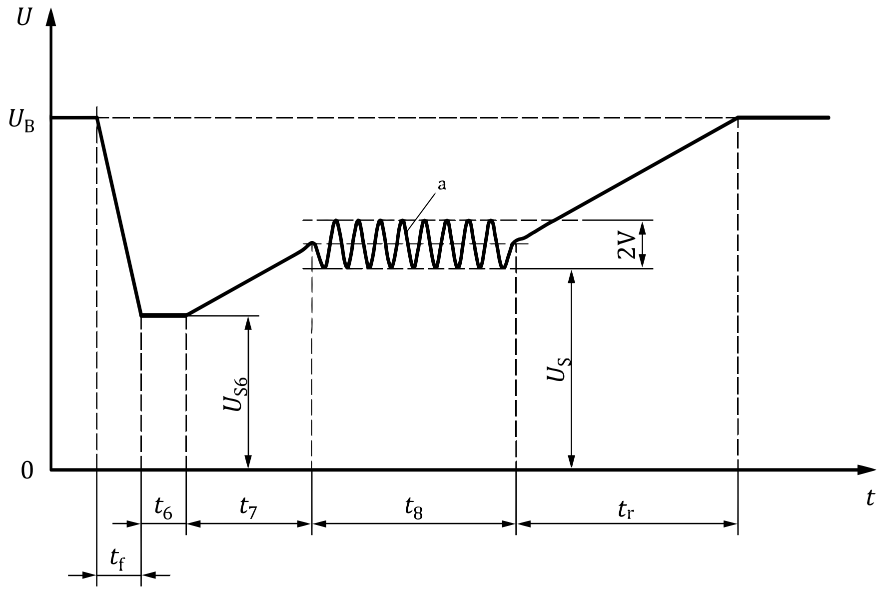

Figure 17: ISO 16750-2, Figure 7 – Starting profile

Key

t	time
U	test voltage
t_f	falling slope
t_r	rising slope
t_6, t_7, t_8	duration parameters (in accordance with Table 3 and Table 4 of ISO 16750-2)
U_B	supply voltage for generator not in operation (see ISO 16750-1 [13])
U_S	supply voltage
U_{S6}	supply voltage at t_6
a	f = 2 Hz

4.2.5.1 HY-TTC 500 ISO 16750 functional status

ISO 16750-2:2012 starting profile - functional status for 12 V system nominal voltage

	Functional Status		
	A	B	C
Level I	X		
Level II			X
Level III			X
Level IV		X	

Table 20: ISO 16750 functional status for 12 V systems

ISO 16750-2:2012 starting profile - functional status for 24 V system nominal voltage

	Functional Status		
	A	B	C
Level I	X		
Level II	X		
Level III		X (after start-up)	

Table 21: ISO 16750 functional status for 24 V systems

4.2.6 Voltage Monitoring

The battery voltage on pin BAT+ CPU is connected to an ADC input. Battery voltage measurement can be used for diagnostic purposes.

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
τ_{in}	First order low pass filter		1.5	2.5	ms
V_{nom}	Nominal battery supply range	1	0	33	V
$V_{tol\text{-}0}$	Zero reading error		-80	+80	mV
$V_{tol\text{-}0}$	Zero reading error	2	-67	+67	mV
$V_{tol\text{-}p}$	Proportional error		-1.2	+1.2	%
$V_{tol\text{-}p}$	Proportional error	2	-1	+1	%
LSB	Nominal value of 1 LSB		-	13.4	mV

Note 1 The nominal battery supply range is only a value to calculate the actual voltage.

Note 2 T_{ECU} = -40. . . +85 ℃

4.3 Negative Power Supply (BAT-)

4.3.1 Pinout

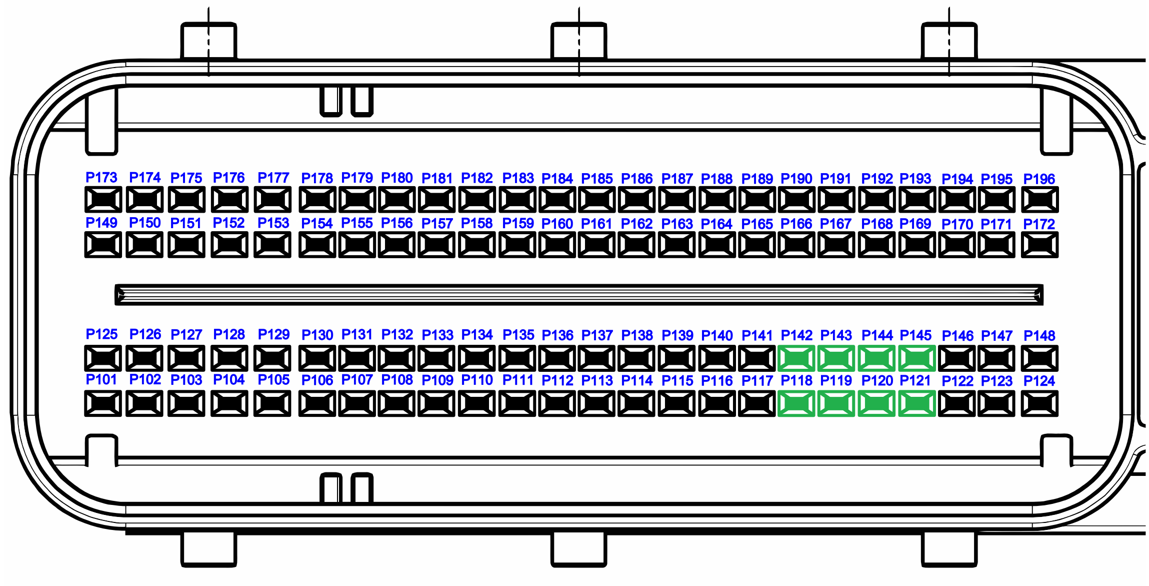

Figure 18: Pinout of BAT-

Pin No.	Function
P118	Negative Power Supply (BAT-)
P119	Negative Power Supply (BAT-)
P120	Negative Power Supply (BAT-)
P121	Negative Power Supply (BAT-)
P142	Negative Power Supply (BAT-)
P143	Negative Power Supply (BAT-)
P144	Negative Power Supply (BAT-)
P145	Negative Power Supply (BAT-)

4.3.2 Functional Description

Supply pins for BAT- connection.

The HY-TTC 500 housing is not directly connected to BAT-, for more information see Section 6.4 on page 195.

TTControl GmbH recommends to use these pins in parallel and the maximum possible wire size (FLRY type) in case of maximum load current to reduce voltage drop and prevent overheating of the crimp contact.

4.3.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
$I_{out\text{-}max}$	Permanent current per pin			4	A
$I_{out\text{-}max}$	Permanent current all pins			28	A

4.4 Sensor GND

4.4.1 Pinout

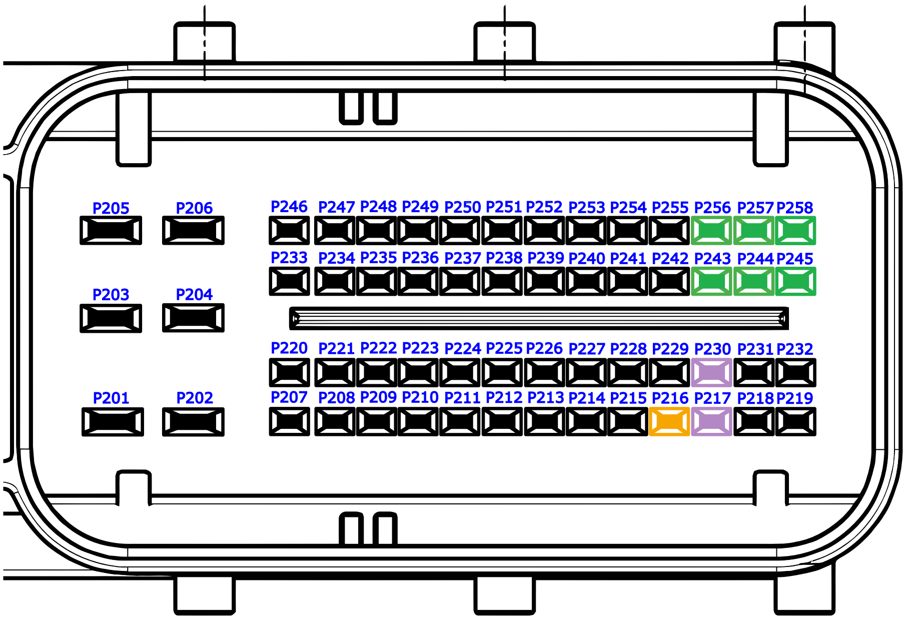

Figure 19: Pinout of sensor GND

Pin No.	Function	Applicable to variants
P216	Sensor GND	HY-TTC 590E, HY-TTC 590, HY-TTC 508
P217	Sensor GND	HY-TTC 580, HY-TTC 540, HY-TTC 520, HY-TTC 510
P230	Sensor GND	HY-TTC 580, HY-TTC 540, HY-TTC 520, HY-TTC 510
P243	Sensor GND	all
P244	Sensor GND	all
P245	Sensor GND	all
P256	Sensor GND	all
P257	Sensor GND	all
P258	Sensor GND	all

4.4.2 Functional Description

Supply pins for analog sensor GND connection.

These pins can also be used as GND connection for digital sensors.

4.4.3 Maximum Ratings

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
$I_{out\text{-}max}$	Permanent current per pin	1		1	A

Note 1 It is recommended to use all sensor ground pins simultaneously to ensure load distribution and minimize voltage drop on the external wiring.

4.5 Terminal 15

4.5.1 Pinout

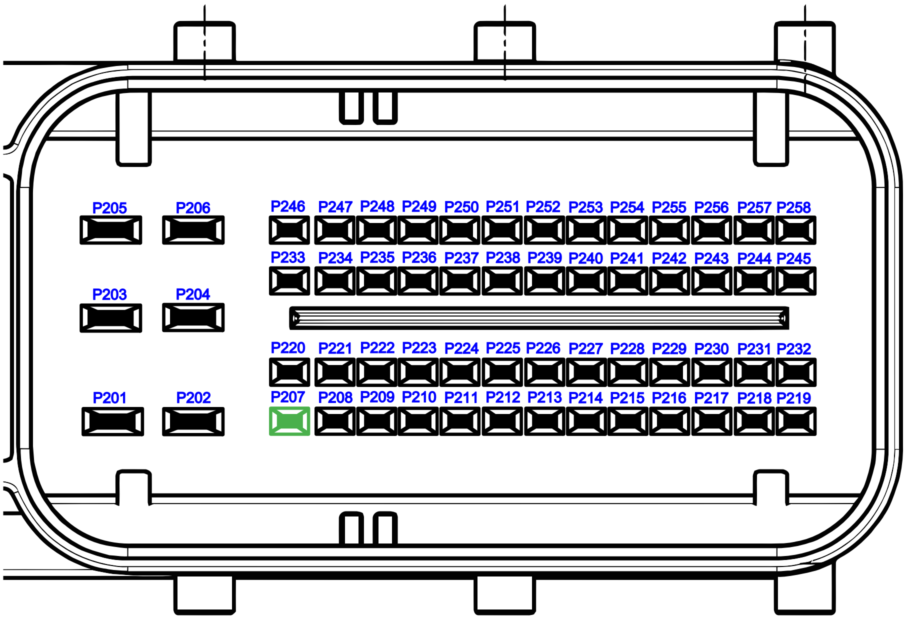

Figure 20: Pinout of terminal 15

Pin No.	Function	SW-define
P207	Terminal 15 Input	IO_ADC_K15

4.5.2 Functional Description

This is the power control input for permanently supplied systems. When switched to positive supply, this input gives the command to power up the ECU, regardless of the `Wake-Up` pin status. When switched off, the ECU can activate its keep-alive functionality (if keep-alive functionality is enabled by SW) and is finally switched off by software after a user-defined period of time.

This input is monitored by the CPU via an ADC input.

For correct pin wiring, see Section 6.6.1.1 with wiring examples. See also Section *POWER - Driver for ECU power functions* of the API documentation [30].

4.5.3 Maximum Ratings

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Permanent (DC) input voltage		-33	+33	V
V_{in}	Transient peak input voltage 500 ms		-50	+50	V
V_{in}	Transient peak input voltage 1ms		-100	+100	V

4.5.4 Characteristics

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		6.5	11.5	kΩ
I_{in}	Input current	1	2	2.5	mA
I_{in}	Input current	2	4	4.5	mA
V_{il}	Input voltage for low level		0	6	V
V_{ih}	Input voltage for high level	3	8	32	V
τ_{in}	Input low pass filter		180	280	µs

Note 1 at 16 V input voltage
Note 2 at 32 V input voltage
Note 3 8 V is the initial voltage for start-up at the beginning of the drive cycle

4.6 Wake-Up

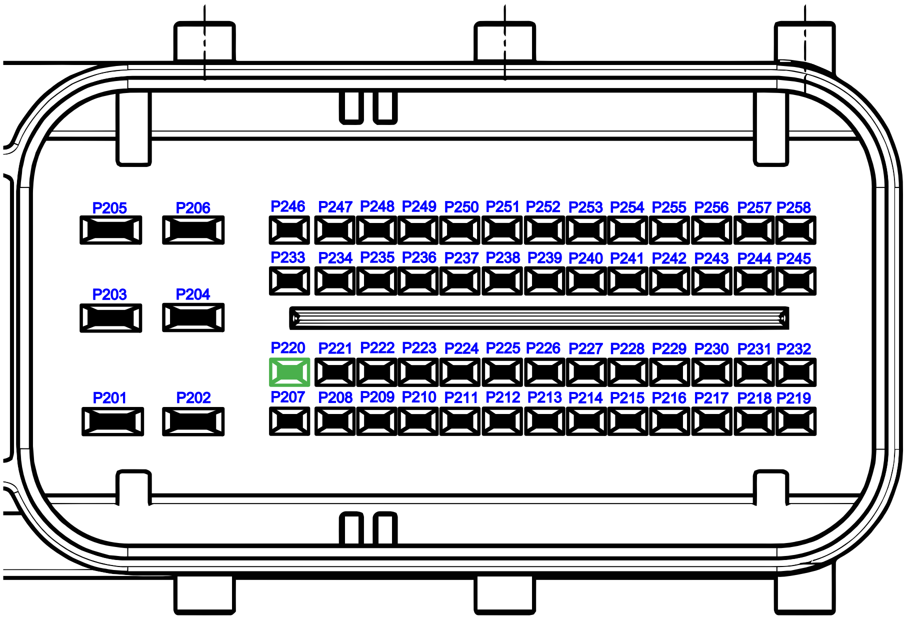

Figure 21: Pinout of Wake-Up

Pin No.	Function	SW-define
P220	Wake-Up input	IO_ADC_WAKE_UP

4.6.2 Functional Description

This is the `Wake-Up` input for permanently supplied systems. When switched to positive supply (rising edge triggered), this input gives the command to power up the ECU, regardless of the `Terminal 15` pin status. When switched off, the ECU can activate its keep-alive functionality (provided that keep-alive functionality is enabled by SW) and finally switches off by software after a user-defined period of time. The application software can command the ECU to switch off even if the `Wake-Up` pin is high, but only if `Terminal 15` is off. This input is monitored by the CPU via an ADC input.

Use case pre-boot sequence

For example, it is possible to start the boot sequence of the ECU by opening the vehicle door by connecting the `Wake-Up` pin with the vehicle door contact. When the driver enters the vehicle and turns the ignition key on (`Terminal 15` to high), the ECU boot process is already finished. With this feature the ECU is ready for operation without any delay.

If the `Wake-Up` pin is in a continuous high state (e.g. vehicle door is left open) and `Terminal 15` pin is not switched on, the application software shall power down the ECU after an application dependent timeout.

After forcing the ECU shutdown via application software, it is necessary to externally toggle the `Wake-Up` pin or activate `Terminal 15` pin to restart the ECU.

See also section *POWER - Driver for ECU power functions* of the API documentation [30].

4.6.3 Maximum Ratings

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Permanent (DC) input voltage		-33	33	V
V_{in}	Transient peak input voltage 500 ms		-50	50	V
V_{in}	Transient peak input voltage 1 ms		-100	100	V

4.6.4 Characteristics

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		6.5	11.5	kΩ
I_{in}	Input current	1	2	2.5	mA
I_{in}	Input current	2	4	4.5	mA
V_{il}	Input voltage for low level		0	6	V
V_{ih}	Input voltage for high level		8	32	V
τ_{in}	Input low pass filter		180	280	µs

Note 1 at 16 V input voltage
Note 2 at 32 V input voltage
Note 3 8 V is the initial voltage for start-up at the beginning of the drive cycle

4.7 Sensor Supplies 5 V

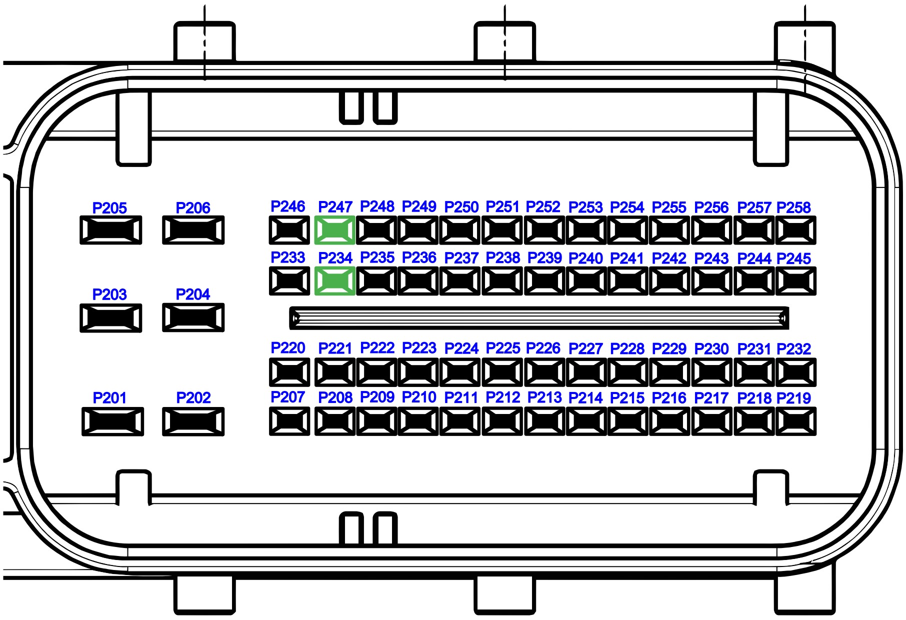

Figure 22: Pinout of sensor supply 5 V

Pin No.	Function	SW-define
P247	Sensor Supply 0	IO_ADC_SENSOR_SUPPLY_0
P234	Sensor Supply 1	IO_ADC_SENSOR_SUPPLY_1

4.7.2 Functional Description

Two independent sensor supplies 5 V for 3-wire sensors (e.g. potentiometers, pressure sensors etc.).

For fully redundant sensors with 2 sensor-supply connections, both supplies must be connected to different sensor supplies.

If the input voltage on the BAT+ CPU pin is lower than typically 6 V (at 5 mA sensor supply load current), the sensor supply output voltage will be out of specification. One example of such low input voltage situations may be cold-start cranking in 12/24 V systems where the supply voltage can drop below 6 V. If the sensor supply output voltage drops below 4.7 V, the application software will be informed about this error situation after glitch filtering.

TTControl GmbH recommends to use the maximum possible wire size (FLRY type) in case of maximum load current to reduce voltage drop and prevent overheating of the crimp contact.

See also section *POWER - Driver for ECU power functions* of the API documentation [30].

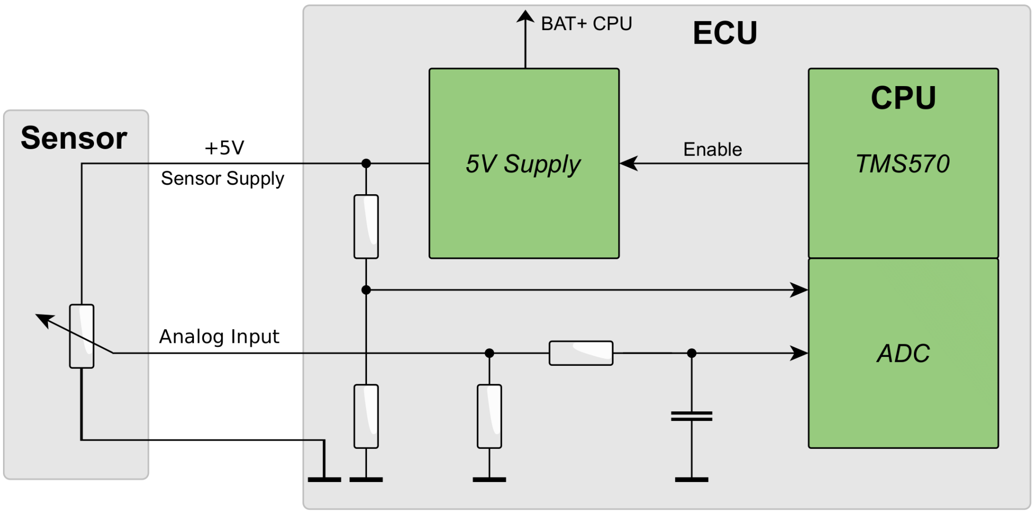

Figure 23: Sensor supply 5 V

4.7.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Output voltage under overload conditions (e.g. short circuit to supply voltage)		-1	+33	V

4.7.4 Characteristics

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{out}	Pin output capacitance		0.8	1.2	µF
V_{out}	Output voltage, at I_{load}		4.85	5.15	V
I_{load}	Load current		0	500	mA

4.8 Sensor Supply Variable

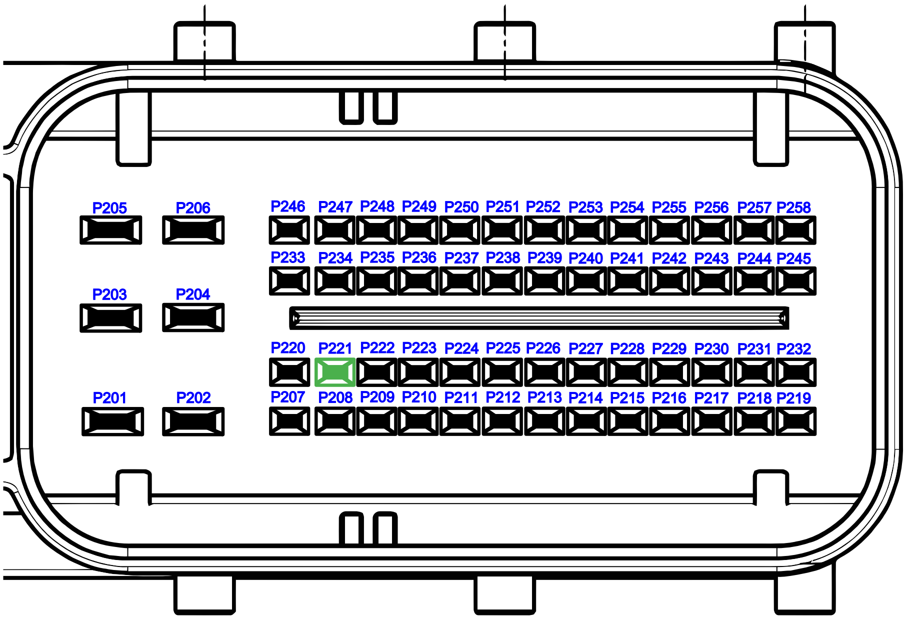

Figure 24: Pinout of sensor supply variable

Pin No.	Function	SW-define
P221	Sensor Supply 2	IO_ADC_SENSOR_SUPPLY_2

4.8.2 Functional Description

One independent sensor supply with variable output voltage, configurable in 1 V steps, is provided for 3-wire sensors (e.g. potentiometers, pressure sensors etc.).

As already described in Section 4.7 on page 112, 5 V sensor supply, Functional Description, the BAT+ CPU pin voltage must be at least 1 V higher than the required sensor supply output voltage VSSUP. If the BAT+ CPU pin voltage is lower than VSSUP -1 V, the sensor supply output voltage will be out of specification.

TTControl GmbH recommends to use the maximum possible wire size (FLRY type) in case of maximum load current to reduce voltage drop and prevent overheating of the crimp contact.

See also section *POWER - Driver for ECU power functions* of the API documentation [30].

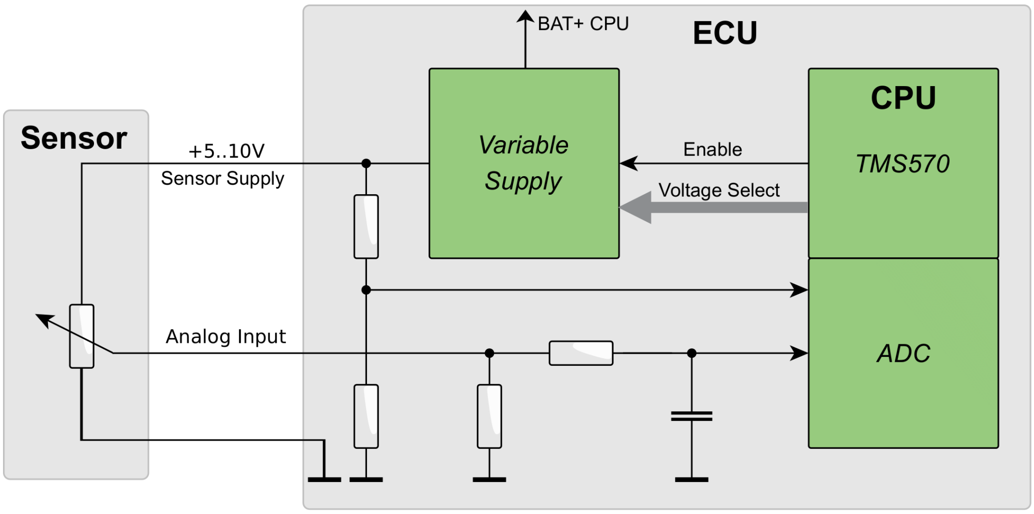

Figure 25: Sensor supply variable

4.8.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Output voltage under overload conditions (e.g. short circuit to supply voltages)		-1	33	V

4.8.4 Characteristics

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{out}	Pin output capacitance		0.8	1.2	µF
V_{out}	Output voltage, 5-V setting		4.85	5.15	V
V_{out}	Output voltage, 6-V setting		5.80	6.20	V
V_{out}	Output voltage, 7-V setting		6.75	7.25	V
V_{out}	Output voltage, 8-V setting		7.70	8.30	V
V_{out}	Output voltage, 9-V setting		8.65	9.35	V
V_{out}	Output voltage, 10-V setting		9.60	10.40	V
P_{load}	Maximum output power, 5-V. . . 10-V setting			2.5	W

4.9 Analog Input 3 Modes

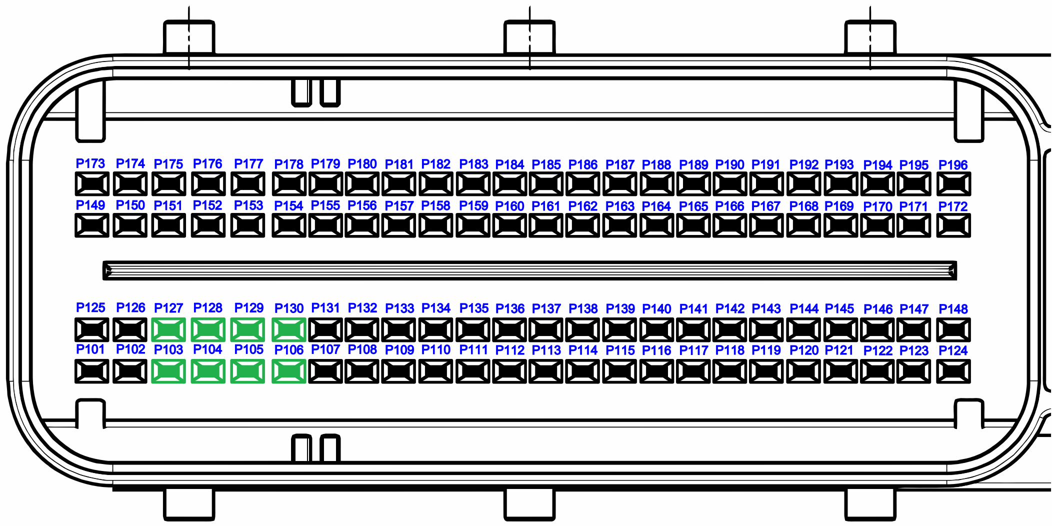

Figure 26: Pinout of analog input 3 mode

Pin No.	Function 1	Function 2	Function 3	SW-define
P103	Analog 0. . . 5 V Input	Analog 0. . . 25 mA Input	Analog 0. . . 100 kΩ Input	IO_ADC_00
P127	Analog 0. . . 5 V Input	Analog 0. . . 25 mA Input	Analog 0. . . 100 kΩ Input	IO_ADC_01
P104	Analog 0. . . 5 V Input	Analog 0. . . 25 mA Input	Analog 0. . . 100 kΩ Input	IO_ADC_02
P128	Analog 0. . . 5 V Input	Analog 0. . . 25 mA Input	Analog 0. . . 100 kΩ Input	IO_ADC_03
P105	Analog 0. . . 5 V Input	Analog 0. . . 25 mA Input	Analog 0. . . 100 kΩ Input	IO_ADC_04
P129	Analog 0. . . 5 V Input	Analog 0. . . 25 mA Input	Analog 0. . . 100 kΩ Input	IO_ADC_05
P106	Analog 0. . . 5 V Input	Analog 0. . . 25 mA Input	Analog 0. . . 100 kΩ Input	IO_ADC_06
P130	Analog 0. . . 5 V Input	Analog 0. . . 25 mA Input	Analog 0. . . 100 kΩ Input	IO_ADC_07

4.9.2 Functional Description

8 multipurpose analog inputs with 12-bit resolution.

The inputs can be configured to 3 different operation modes individually by software:

- Analog Voltage Input: 8 x 0 to 5 V, ratiometric or with absolute reference
- Analog Current Input: 8 x 0 to 25 mA, analog current loop sensors
- Analog Resistance Input: 8 x 0 to 100 kΩ

All inputs are short-circuit protected, independent of application software (included in low-level driver software). Each input is provided with a first-order low pass filter with 3 ms time constant, allowing 2 ms sample rate.

See also section *ADC - Analog to Digital Converter driver* of the API documentation [30].

4.9.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Input voltage under overload conditions	1	-1	+33	V

Note 1 Due to thermal reasons only one of the 8 inputs may be shorted to 33 V at the same time. A connection to any supply voltage higher than 5 V is not allowed for normal operation.

4.9.4 Analog Voltage Input

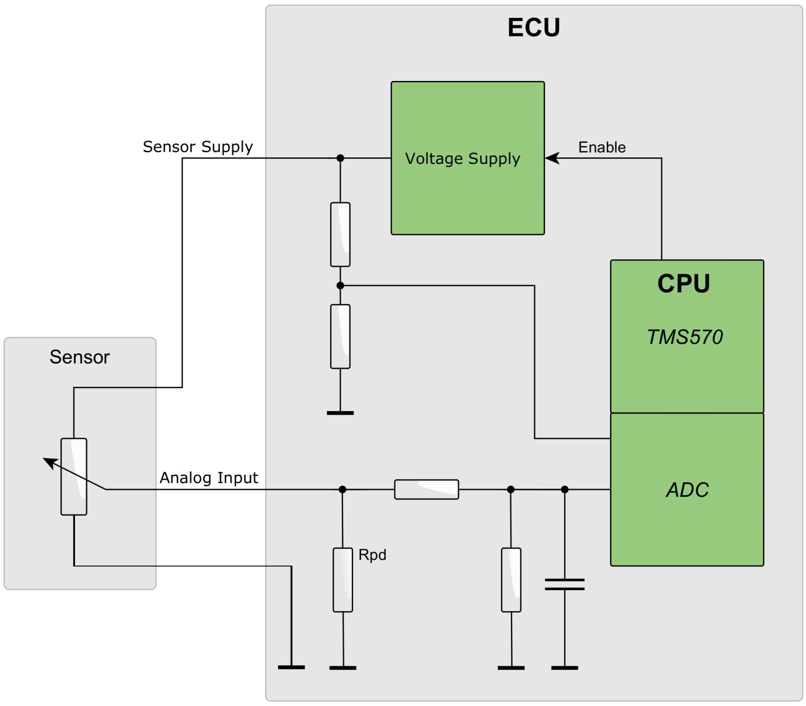

Figure 27: Analog voltage input (ratiometric)

Absolute vs. ratiometric voltage measurement:

Many sensor types are available in absolute or ratiometric measurement variant.

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

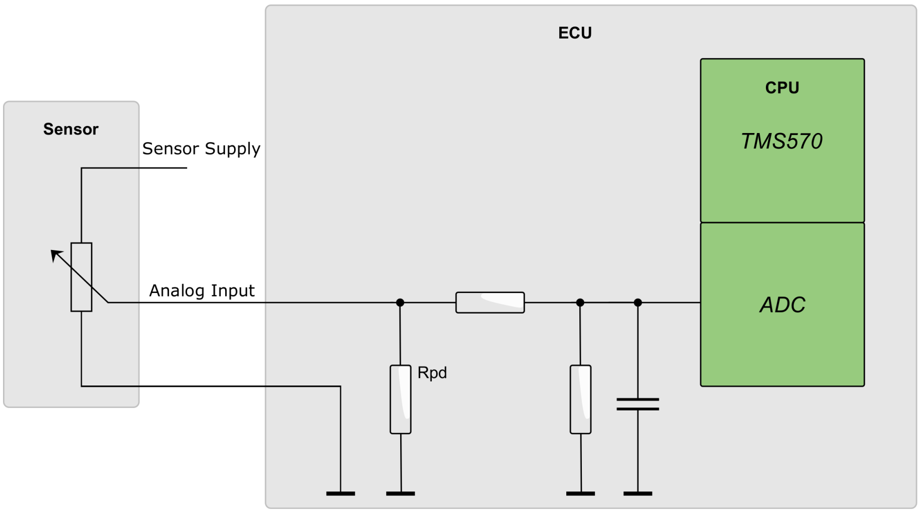

Figure 28: Analog voltage input

Due to the described behavior, it is generally recommended to use ratiometric sensors. Absolute or ratiometric function selection is done by software for each input individually.

4.9.4.1 Characteristics of 5 V Input (Ratiometric)

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		98	107	kΩ
τ_{in}	Input low pass filter		2.2	3.8	ms
V_{nom}	Nominal input voltage range		0	5	V
V_{In}	Input voltage range	1	0.2	4.8	V
$V_{tol\text{-}0}$	Zero reading error	4,5	-15	+15	mV
$V_{tol\text{-}0}$	Zero reading error	2,4,5	-10	+10	mV
$V_{tol\text{-}p}$	Proportional error	4,5	-0.2	+0.2	%
$V_{tol\text{-}p}$	Proportional error	2,4,5	-0.2	+0.2	%
LSB	Nominal value of 1 LSB		-	1.2207	mV

4.9.4.2 Characteristics of 5 V Input (Absolute)

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		98	107	kΩ
τ_{in}	Input low pass filter		2.2	3.8	ms
V_{nom}	Nominal input voltage range		0	5	V
V_{in}	Input voltage range	1	0.2	4.8	V
$V_{tol\text{-}0}$	Zero reading error	3,5	-15	+15	mV
$V_{tol\text{-}0}$	Zero reading error	2,3,5	-10	+10	mV
$V_{tol\text{-}p}$	Proportional error	3,5	-0.8	+0.8	%
$V_{tol\text{-}p}$	Proportional error	2,3,5	-0.6	+0.6	%
LSB	Nominal value of 1 LSB		-	1.2207	mV

4.9.4.3 Characteristics of 5 V Digital Input

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pu}	Pull-up resistor		4.8	5	kΩ
V_{pu}	Pull-up voltage		4.9	5.1	V
τ_{in}	Input low pass filter		2.2	3.8	ms
V_{il}	Input voltage for low level		0	●	V
V_{ih}	Input voltage for high level		●	5	V
LSB	Nominal value of 1 LSB		-	1.2207	mV

Note 1 For full accuracy

Note 2 T_{ECU} = -40. . . +85 °C

Note 3 Absolute measurement. This includes the conversion error of the HY-TTC 500 only. For the calculation of the total measurement error, it is necessary to sum the error of HY-TTC 500 and the absolute sensor error (measurement tolerance plus tolerance of external sensor reference).

Note 4 Ratiometric mode. This includes the conversion error of the HY-TTC 500 and the sensor supply error. For the calculation of the total measurement error, the error of HY-TTC 500 and the error of the ratiometric sensor (measurement tolerance) must be added.

Note ● Configuration by application software

Note 5 The total measurement error is the sum of zero reading error and the proportional error.

4.9.5 Analog Current Input

Analog input for 0. . . 25mA sensor measurement.

Due to the wider measurement range of the input compared to the output range of popular sensors with 4. . . 20 mA, short to GND, short to BAT+ and cable defects can be easily detected.

In case of an overload situation, the pin is switched to a high impedance state. The protection mechanism tries re-enabling the output 10 times per drive cycle.

During power down (`Terminal 15` off), the ECU does not disconnect the current sensor input. It is not recommended to supply the sensors permanently in order to prevent battery discharge.

TTControl GmbH recommends one of the following 2 options:

1. **Option 1**: Use a digital output for supplying the sensor. When the device is switched off, the ECU can perform an application-controlled shutdown, e. g., in order to operate a cooling fan to cool down an engine until the temperature is low enough or to store data in the non-volatile memory of the ECU. If the application controlled shut-down is finished, the ECU switches off and consumes less than 1 mA of battery current (including sensors).
2. **Option 2**: `Terminal 15` is used to supply the current loop sensor directly.
   Note that `Terminal 15` is often used to switch relays or other inductive loads directly. This may cause transients in excess of ±50 V, for which the sensor must be specified.

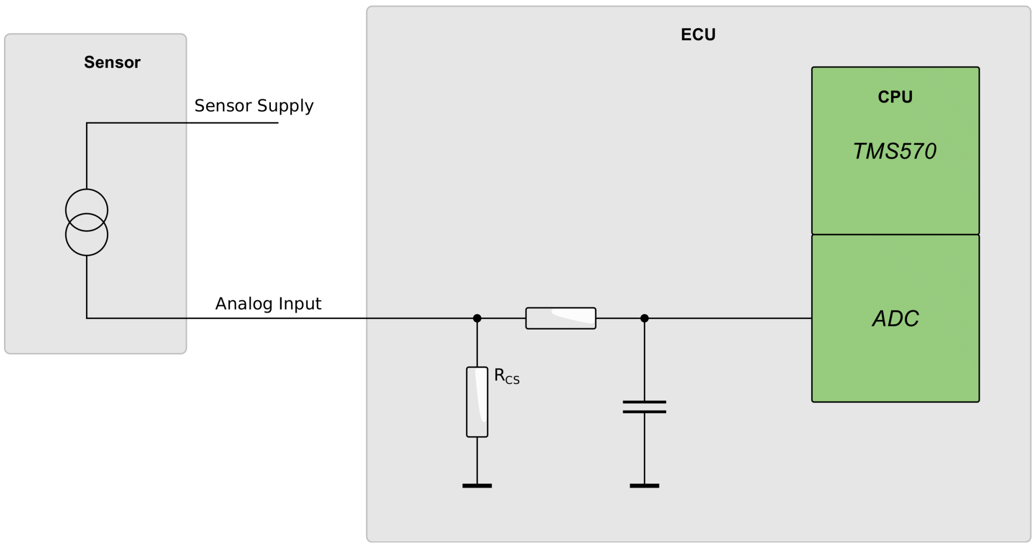

Figure 29: Analog current input

4.9.5.1 Characteristics of Analog Current Input

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{CS}	Current sense resistor	1	177	185	Ω
τ_{in}	Input low pass filter		2.2	3.8	ms
I_{in}	Input current range		0	25	mA
LSB	Nominal value of 1 LSB		-	6.78	µA
$I_{tol\text{-}0}$	Zero reading error	3	-70	+70	µA
$I_{tol\text{-}0}$	Zero reading error	2,3	-40	+40	µA
$I_{tol\text{-}p}$	Proportional error	3	-2.5	+2.5	%
$I_{tol\text{-}p}$	Proportional error	2,3	-2.0	+2.0	%

Note 1 This is the load resistor value for the current loop sensor.

Note 2 T_{ECU} = -40...+85 °C

Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.9.6 Analog Resistance Input

Input for 0...100kΩ resistance sensor measurement.

Resistive sensors are for example NTC or PTC resistors for temperature measurement.

The actual resistor value of the sensor is computed from the measured input voltage together with the known reference resistor value. Be aware that this measurement setup has the highest accuracy and resolution if the sensors resistance is in the magnitude of the reference resistors value.

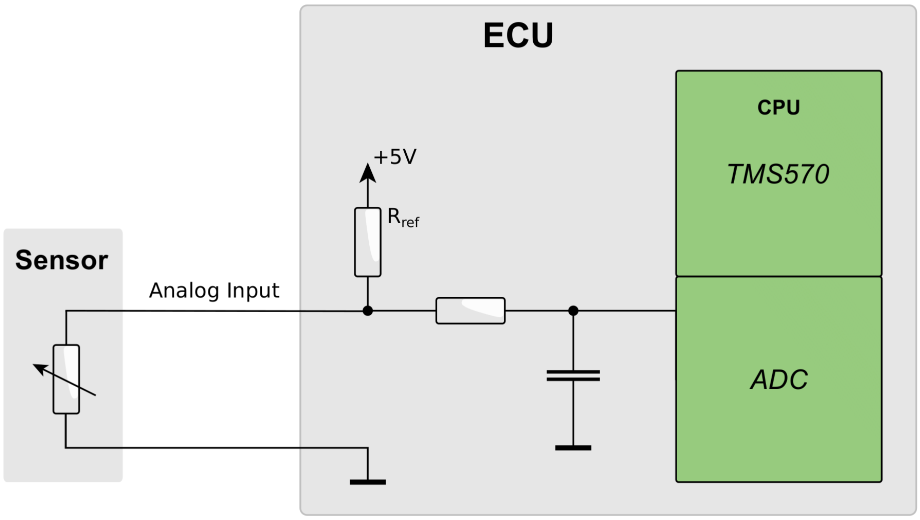

Figure 30: Analog resistance input

The resistance mode may also be used as digital input with switches connected to ground, see Figure 32 on the current page. The use of switches to BAT+ is not allowed.

To enhance the diagnostic coverage, use switches of type Namur. With a Namur-type switch sensor, short to ground, short to BAT+ and cable defects can be easily detected.

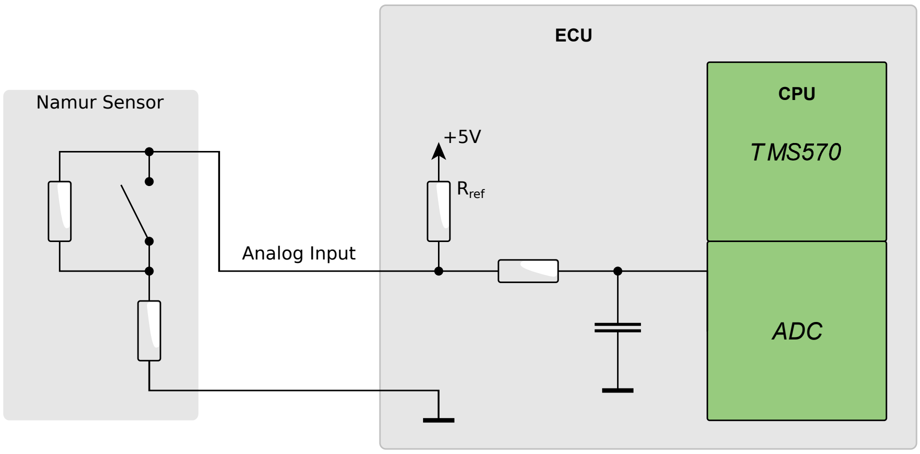

Figure 31: Namur type sensor (only for switches to ground)

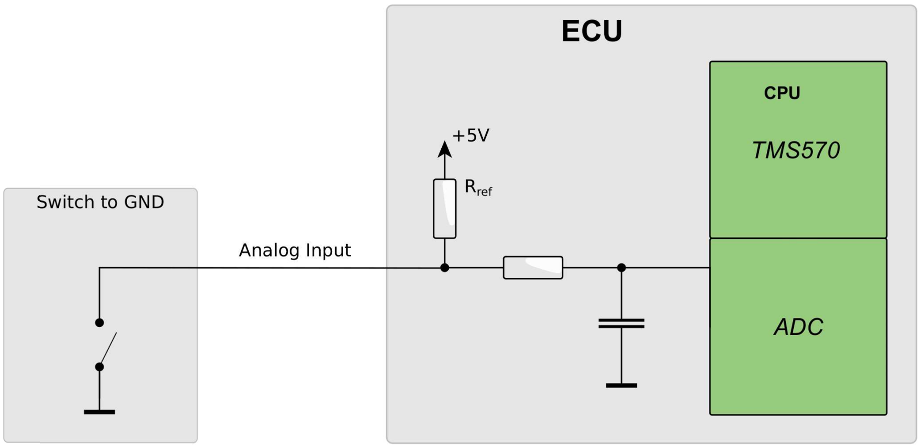

Figure 32: Switch input (only for switches to ground)

4.9.6.1 Characteristics of Analog Resistance Input

Resistance sensors are, e. g., PTC resistors for temperature measurement.

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{ref}	Reference resistor		4831	4929	Ω

Symbol	Parameter	Note	Min.	Max.	Unit
τ_{in}	Input low pass filter		2.2	3.8	ms
R_{ext_range}	Resistance measurement range		0	100	kΩ

T_{ECU} = -40...+85 °C

Symbol	Parameter	Note	Min.	Max.	Unit
R_{tol-m}	Measurement tolerance for 0...99 Ω		-5	+5	Ω
R_{tol-m}	Measurement tolerance for 100 Ω		-5	+5	%
R_{tol-m}	Measurement tolerance for 200 Ω		-4	+4	%
R_{tol-m}	Measurement tolerance for 500 Ω		-2.5	+2.5	%
R_{tol-m}	Measurement tolerance for 1 k...20 kΩ		-2	+2	%
R_{tol-m}	Measurement tolerance for 50 kΩ		-3	+3	%
R_{tol-m}	Measurement tolerance for 100 kΩ		-4	+4	%

T_{ECU} = +85...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
R_{tol-m}	Measurement tolerance for 0...99 Ω		-10	+10	Ω
R_{tol-m}	Measurement tolerance for 100 Ω		-10	+10	%
R_{tol-m}	Measurement tolerance for 200 Ω		-6	+6	%
R_{tol-m}	Measurement tolerance for 500 Ω...20 kΩ		-3	+3	%
R_{tol-m}	Measurement tolerance for 50 kΩ		-4	+4	%
R_{tol-m}	Measurement tolerance for 100 kΩ		-5	+5	%

The resistance measurement tolerance is given at specific sensor resistance value. Any value in between needs to be linear interpolated.

4.10 Analog Input 2 Modes

4.10.1 Pinout

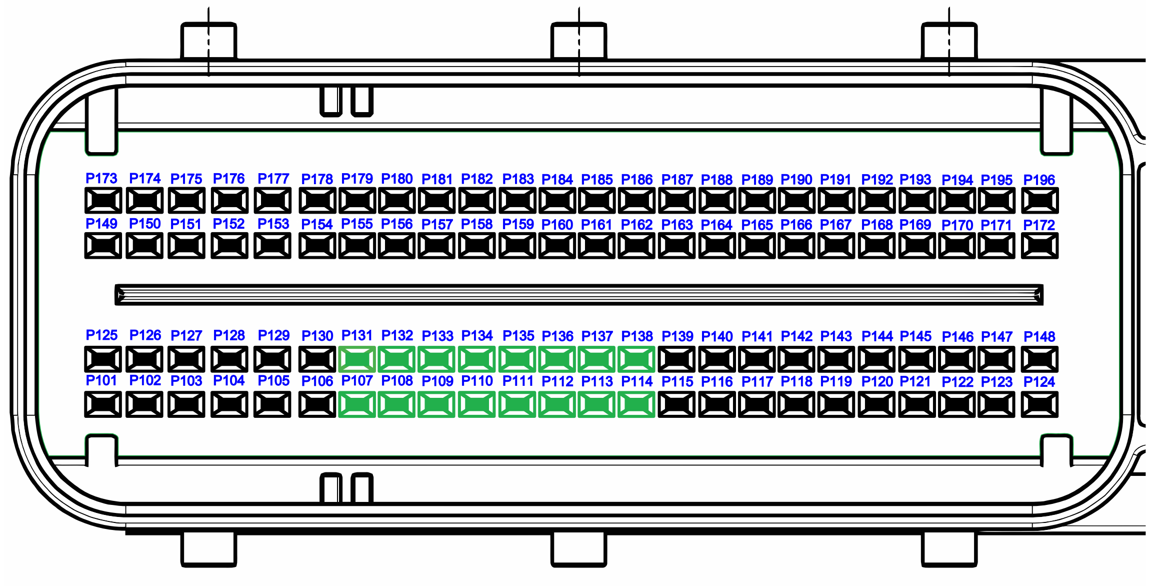

Figure 33: Pinout of analog input 2 mode

Pin No.	Function 1	Function 2	SW-define
P107	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_08
P131	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_09
P108	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_10
P132	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_11
P109	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_12
P133	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_13
P110	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_14
P134	Analog 0. . . 5 V, 0. . . 10 V Input	Analog 0. . . 25 mA Input	IO_ADC_15
P111	Analog 0. . . 5 V, 0. . . 32 V Input	Analog 0. . . 25 mA Input	IO_ADC_16
P135	Analog 0. . . 5 V, 0. . . 32 V Input	Analog 0. . . 25 mA Input	IO_ADC_17
P112	Analog 0. . . 5 V, 0. . . 32 V Input	Analog 0. . . 25 mA Input	IO_ADC_18
P136	Analog 0. . . 5 V, 0. . . 32 V Input	Analog 0. . . 25 mA Input	IO_ADC_19
P113	Analog 0. . . 5 V, 0. . . 32 V Input	Analog 0. . . 25 mA Input	IO_ADC_20
P137	Analog 0. . . 5 V, 0. . . 32 V Input	Analog 0. . . 25 mA Input	IO_ADC_21
P114	Analog 0. . . 5 V, 0. . . 32 V Input	Analog 0. . . 25 mA Input	IO_ADC_22
P138	Analog 0. . . 5 V, 0. . . 32 V Input	Analog 0. . . 25 mA Input	IO_ADC_23

4.10.2 Functional Description

16 multipurpose analog inputs with 12-bit resolution.

The inputs can be configured to 3 different operation modes individually by software:

- Analog Voltage Input: 8 x 0 to 5 V/ 0 to 10 V, ratiometric or with absolute reference.
- Analog Voltage Input: 8 x 0 to 5 V/ 0 to 32 V, ratiometric or with absolute reference.
- Analog Current Input: 16 x 0 to 25 mA, analog current loop sensors.

All inputs are short-circuit protected, independent of application software (included in low-level driver software). Each input is provided with a first-order low pass filter with 3 ms time constant, and converted with 2 ms sample rate.

See also section *ADC - Analog to Digital Converter driver* of the API documentation [30].

4.10.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Input voltage	1	-1	+33	V

Note 1 Due to thermal reasons only one of 8 inputs (except 32 V setting) may be shorted to 33 V at the same time. A connection to any supply voltage higher than the configured voltage setting (5 V, 10 V or 32 V) is not allowed for normal operation.

4.10.4 Analog Voltage Input

See Section 4.9.4 on page 117 for more information.

4.10.4.1 Characteristics of 5 V Input (Ratiometric)

Ratiometric mode: This includes the conversion error of the HY-TTC 500 and the sensor supply error. For the calculation of the total measurement error, the error of HY-TTC 500 and the error of the ratiometric sensor (measurement tolerance) must be added.

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		98	107	kΩ
τ_{in}	Input low pass filter		2.2	3.8	ms
V_{nom}	Nominal input voltage range		0	5	V
V_{in}	Input voltage range	1	0.2	4.8	V
$V_{tol\text{-}0}$	Zero reading error	4,5	-15	+15	mV
$V_{tol\text{-}0}$	Zero reading error	2,4,5	-10	+10	mV
$V_{tol\text{-}p}$	Proportional error	4,5	-0.2	+0.2	%
$V_{tol\text{-}p}$	Proportional error	2,4,5	-0.2	+0.2	%
LSB	Nominal value of 1 LSB		-	1.2207	mV

4.10.4.2 Characteristics of 5 V Input (Absolute)

Absolute measurement: This includes the conversion error of the HY-TTC 500 only. For the calculation of the total measurement error the error of the HY-TTC 500 and the error of the absolute sensor (measurement tolerance plus tolerance of external sensor reference) must be added.

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		98	107	kΩ
τ_{in}	Input low pass filter		2.2	3.8	ms
V_{nom}	Nominal input voltage range		0	5	V
V_{in}	Input voltage range	1	0.2	4.8	V
$V_{tol\text{-}0}$	Zero reading error	3,5	-15	+15	mV
$V_{tol\text{-}0}$	Zero reading error	2,3,5	-10	+10	mV
$V_{tol\text{-}p}$	Proportional error	3,5	-0.8	+0.8	%
$V_{tol\text{-}p}$	Proportional error	2,3,5	-0.6	+0.6	%
LSB	Nominal value of 1 LSB		-	1.2207	mV

4.10.4.3 Characteristics of 10 V Input (Absolute)

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		19	22.5	kΩ
τ_{in}	Input low pass filter		2.2	3.8	ms
V_{nom}	Nominal input voltage range		0	10	V
V_{in}	Input voltage range	1	0.2	10	V
$V_{tol\text{-}0}$	Zero reading error	3,5	-18	+18	mV
$V_{tol\text{-}0}$	Zero reading error	2,3,5	-13	+13	mV
$V_{tol\text{-}p}$	Proportional error	3,5	-1.8	+1.8	%
$V_{tol\text{-}p}$	Proportional error	2,3,5	-1.6	+1.6	%
LSB	Nominal value of 1 LSB		-	2.57	mV

4.10.4.4 Characteristics of 32 V Input (Absolute)

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		14.7	15.3	kΩ
τ_{in}	Input low pass filter		2.2	3.8	ms
V_{nom}	Nominal input voltage range		0	32	V
V_{in}	Input voltage range	1	0.2	32	V
$V_{tol\text{-}0}$	Zero reading error	5	-50	+50	mV
$V_{tol\text{-}0}$	Zero reading error	2,5	-45	+45	mV
$V_{tol\text{-}p}$	Proportional error	3,5	-4	+4	%
$V_{tol\text{-}p}$	Proportional error	2,5	-3	+3	%
LSB	Nominal value of 1 LSB		-	8.59	mV

4.10.4.5 Characteristics of 32 V Digital Input

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		14.7	15.3	kΩ
τ_{in}	Input low pass filter		2.2	3.8	ms
V_{il}	Input voltage for low level		0	●	V
V_{ih}	Input voltage for high level		●	32	V
LSB	Nominal value of 1 LSB		-	8.59	mV

Note 1 For full accuracy

2 T_{ECU} = -40. . . +85 ℃

Note

Note 3 Absolute measurement. This includes the conversion error of the HY-TTC 500 only. For the calculation of the total measurement error, it is necessary to sum the error of HY-TTC 500 and the absolute sensor error (measurement tolerance plus tolerance of external sensor reference).

Note 4 Ratiometric mode. This includes the conversion error of the HY-TTC 500 and the sensor supply error. For the calculation of the total measurement error, the error of HY-TTC 500 and the error of the ratiometric sensor (measurement tolerance) must be added.

Note 5 The total measurement error is the sum of zero reading error and the proportional error.

Note ● Configuration by application software

4.10.5 Analog Current Input

See Section 4.9.5 on page 120 for more information.

4.10.5.1 Characteristics of Analog Current Input

T_{ECU} = -40...+125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{CS}	Current sense resistor	1	177	185	Ω
τ_{in}	Input low pass filter		2.2	3.8	ms
I_{in}	Input current range		0	25	mA
LSB	Nominal value of 1 LSB		-	6.78	µA
$I_{tol\text{-}0}$	Zero reading error	3	-70	+70	µA
$I_{tol\text{-}0}$	Zero reading error	2,3	-40	+40	µA
$I_{tol\text{-}p}$	Proportional error	3	-2.5	+2.5	%
$I_{tol\text{-}p}$	Proportional error	2,3	-2.0	+2.0	%

Note 1 This is the load resistor value for the current loop sensor.

Note 2 T_{ECU} = -40...+85 ℃

Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.11 Timer Inputs

4.11.1 Pinout

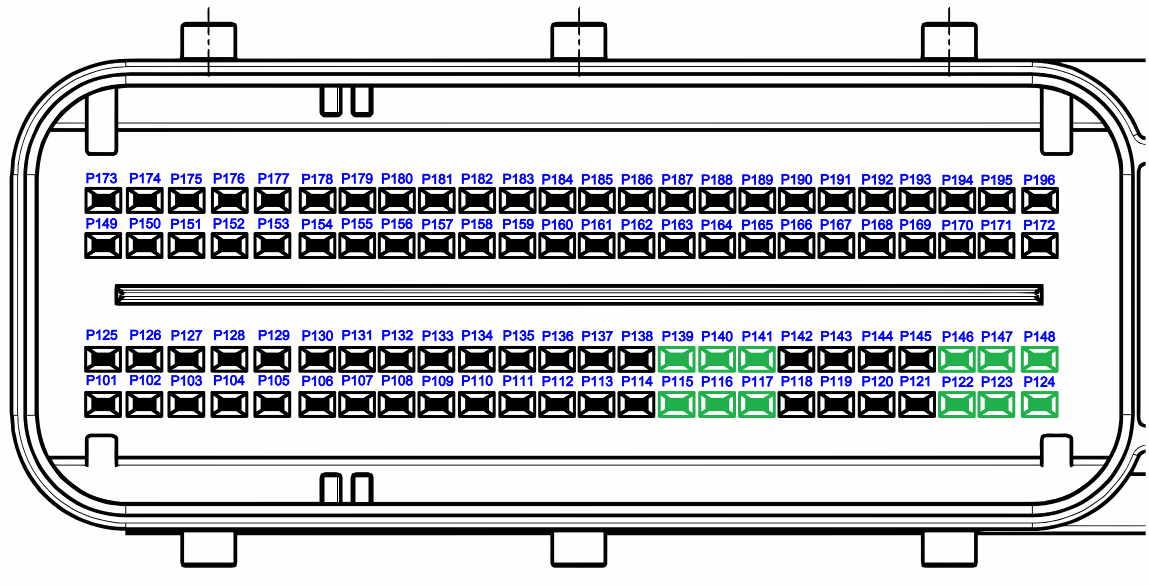

Figure 34: Pinout of timer input

Pin No.	Function	SW-define
P115	Timer Input	IO_PWD_00
P139	Timer Input	IO_PWD_01
P116	Timer Input	IO_PWD_02
P140	Timer Input	IO_PWD_03
P117	Timer Input	IO_PWD_04
P141	Timer Input	IO_PWD_05
P122	Timer Input	IO_PWD_06
P146	Timer Input	IO_PWD_07
P123	Timer Input	IO_PWD_08
P147	Timer Input	IO_PWD_09
P124	Timer Input	IO_PWD_10
P148	Timer Input	IO_PWD_11

4.11.2 Functional Description

12 digital inputs with timer function to process input signals such as frequency (rotational speed), pulse count and quadrature decoding (incremental length measurement), PWM etc.

6 out of 12 inputs can be alternatively used as digital (7/14 mA) current loop speed sensors.

The inputs can be individually configured by software with a pull-up/pull-down resistor to adapt them to different sensor types,

The timer input can be used as an analog voltage input as well. For diagnosis, it is possible to measure the analog voltage and frequency at the same channel at the same time.

See also sections *PWD - Pulse Width Decode and digital timer input driver* and *DIO - Driver for digital inputs and outputs* of the API documentation [30].

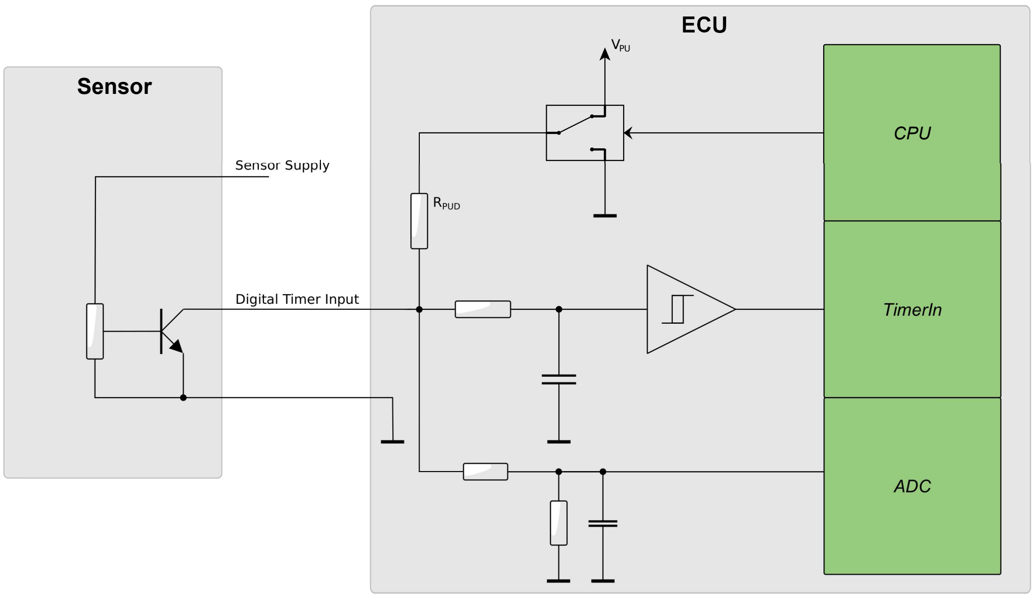

Figure 35: Digital input for frequency/timing measurement with NPN-type 2-pole sensor

4.11.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Input voltage under overload conditions		-1	+33	V

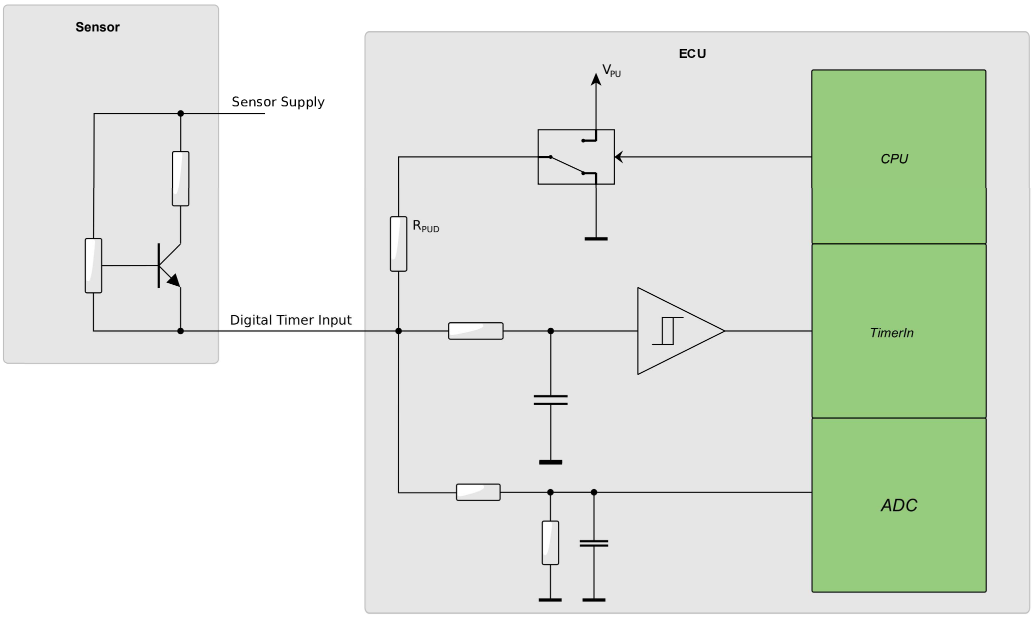

Figure 36: Digital input for frequency/timing measurement with PNP-type 2-pole sensor

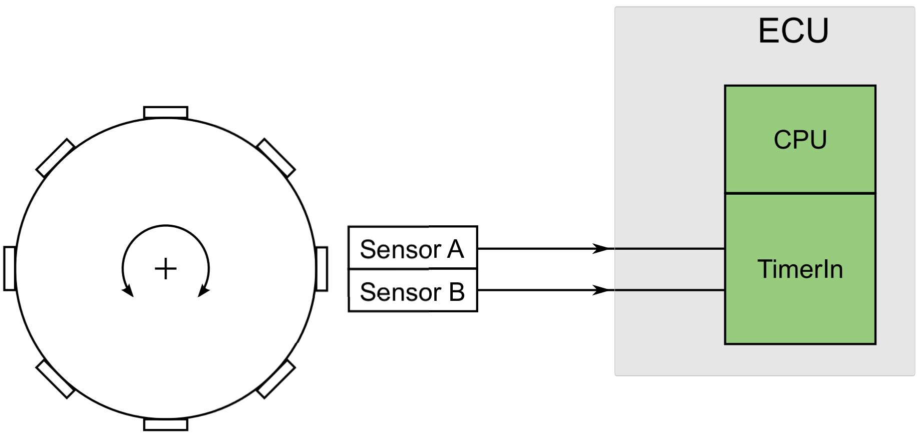

Figure 37: Digital input pair for encoder and direction

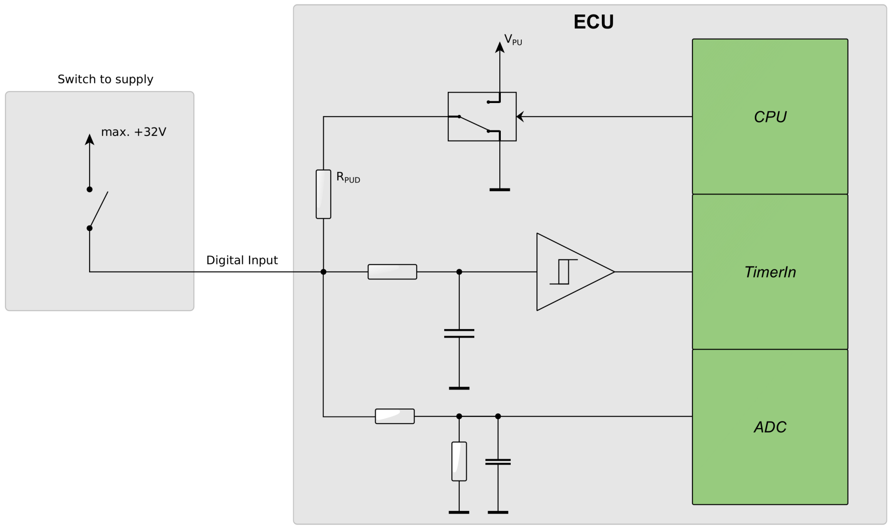

Figure 38: Digital input for switch connected to (battery) supply voltage

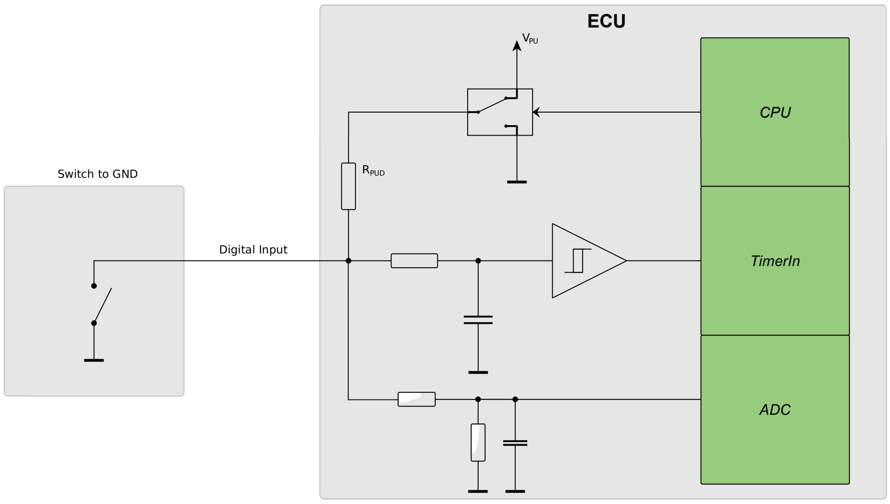

Figure 39: Digital input for switch connected to ground

4.11.4 Timer and Current Loop Inputs

4.11.4.1 Characteristics of Timer Input

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
R_{pud}	Pull-up/pull-down resistor		7.5	10	kΩ
V_{pu}	Pull-up voltage (open load)	1	4.25	4.8	V
τ_{in}	Input low pass filter		1.4	3.4	µs
F_{max}	Maximum input frequency range			20	kHz
F_{min}	Minimum input frequency		0.1		Hz
τ_{min}	Minimum on/off time to be measured by timer unit		20		µs
V_{il}	Input voltage for low level		0	2	V
V_{ih}	Input voltage for high level		3	32	V
t_{res}	Timer resolution	2	2	2	µs
t_{res}	Timer resolution	3	0.5	0.5	µs

Note 1 This is the input voltage with pull-up setting, without the sensor connected.
Note 2 IO_PWD_00 - IO_PWD_05
Note 3 IO_PWD_06 - IO_PWD_11

4.11.4.2 Characteristics of Current Loop Input

The timer input IO_PWD_00 to IO_PWD_05 can be alternatively also used as digital (7/14 mA) current loop sensor inputs. See Figure 40 on the facing page.

During power down (`Terminal 15` off), the ECU does not disconnect the timer and current loop sensor inputs. It is not recommended to supply the sensors permanently in order to prevent battery discharge.

TTControl GmbH recommends one of the following 2 options:

1. **Option 1**: Use a digital output for supplying the sensor. When the device is switched off, the ECU can perform an application-controlled shutdown, e. g., in order to operate a cooling fan to cool down an engine until the temperature is low enough or to store data in the non-volatile memory of the ECU. If the application controlled shut-down is finished, the ECU switches off and consumes less than 1 mA of battery current (including sensors).
2. **Option 2**: `Terminal 15` is used to supply the current loop sensor directly.
   Note that `Terminal 15` is often used to switch relays or other inductive loads directly. This may cause transients in excess of ±50 V, for which the sensor must be specified.

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
R_{pdc}	Pull-down resistor (current loop config.)	1	88	93	Ω
R_{pud}	Pull-up/pull-down resistor		7.5	10	kΩ
V_{pu}	Pull-up voltage (open load)		4.25	4.8	V
τ_{in}	Input low pass filter		1.4	1.6	µs
F_{max}	Maximum input frequency range			20	kHz
F_{min}	Minimum input frequency		0.1		Hz
τ_{min}	Minimum on/off time to be measured by timer unit		20		µs
I_{il}	Input current for low level(current loop config.)		4	8.5	mA
I_{ih}	Input current for high level (current loop config.)		11	20	mA
$I_{il\ SRC}$	Input current (7/14 mA) sensor SRC too low	2	0	4	mA
$I_{ih\ SRC}$	Input current (7/14 mA) sensor SRC too high	3	20		mA
t_{res}	Timer resolution		2	2	µs

Note 1 With software setting for digital (7/14 mA) current loop sensor inputs (ABS-type sensors).

Note 2 Fault detection window for defect digital (7/14 mA) current loop sensor inputs with too low current.

Note 3 Fault detection window for defect digital (7/14 mA) current loop sensor inputs with too high current. If the current exceeds the maximum input current, then overload protection gets active.

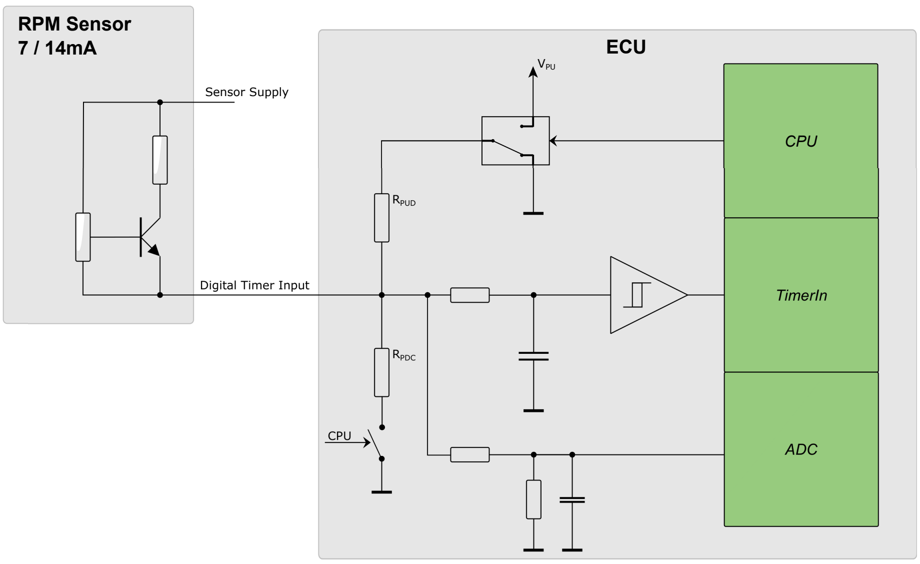

Figure 40: Digital input for frequency measurement with ABS-type 7/14 mA, 2 pole sensor

4.11.5 Analog and Digital Inputs

4.11.5.1 Characteristics of Analog Voltage Input

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
	Resolution		12	12	bit
R_{pud}	Pull-up/pull-down resistor		7.5	10	kΩ
V_{pu}	Pull-up voltage (open load)	2	4.25	4.8	V
V_{in}	Input voltage range		0	32	V
τ_{in}	Input low pass filter (analog path)		8	12	ms
$V_{tol\text{-}0}$	Zero reading error	3	-55	+55	mV
$V_{tol\text{-}0}$	Zero reading error	1,3	-50	+50	mV
$V_{tol\text{-}p}$	Proportional error	3	-4	+4	%
$V_{tol\text{-}p}$	Proportional error	1,3	-3	+3	%
LSB	Nominal value of 1 LSB		-	8.00	mV

4.11.5.2 Characteristics of Digital Input

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
R_{pud}	Pull-up/pull-down resistor		7.5	10	kΩ
V_{pu}	Pull-up voltage (open load)	2	4.25	4.8	V
V_{in}	Input voltage range		0	32	V
τ_{in}	Input low pass filter		2.8	3.2	µs
V_{il}	Input voltage for low level		0	2	V
V_{ih}	Input voltage for high level		3	32	V

Note 1 T_{ECU} = -40. . . +85 ℃
Note 2 This is the input voltage with pull-up setting, without the sensor connected.
Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.12 High-Side PWM Outputs

4.12.1 Pinout

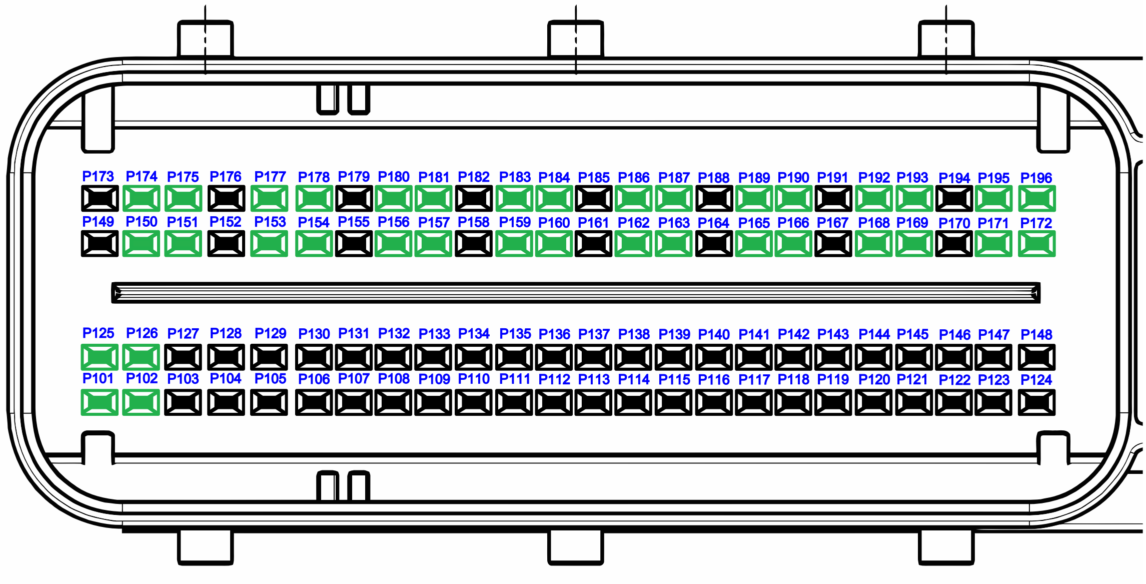

Figure 41: Pinout of high-side PWM outputs

The following table depicts the high-side PWM outputs together with their corresponding external and secondary shut-off group/paths and power stages.

Pin No.	Function	SW-define	Ext./Second. Shut-off	Power stage
P153	High-Side PWM Output	IO_PWM_00	A	a
P177	High-Side PWM Output	IO_PWM_01	A	a
P156	High-Side PWM Output	IO_PWM_02	A	b
P180	High-Side PWM Output	IO_PWM_03	A	b
P159	High-Side PWM Output	IO_PWM_04	A	c
P183	High-Side PWM Output	IO_PWM_05	A	c
P186	High-Side PWM Output	IO_PWM_06	A	d
P162	High-Side PWM Output	IO_PWM_07	A	d
P189	High-Side PWM Output	IO_PWM_08	A	e
P165	High-Side PWM Output	IO_PWM_09	A	e
P192	High-Side PWM Output	IO_PWM_10	A	f
P168	High-Side PWM Output	IO_PWM_11	A	f
P195	High-Side PWM Output	IO_PWM_12	A	g
P171	High-Side PWM Output	IO_PWM_13	A	g
P154	High-Side PWM Output	IO_PWM_14	B	h
P178	High-Side PWM Output	IO_PWM_15	B	h
P157	High-Side PWM Output	IO_PWM_16	B	i

Pin No.	Function	SW-define	Ext./Second. Shut-off	Power stage
P181	High-Side PWM Output	IO_PWM_17	B	i
P160	High-Side PWM Output	IO_PWM_18	B	j
P184	High-Side PWM Output	IO_PWM_19	B	j
P187	High-Side PWM Output	IO_PWM_20	B	k
P163	High-Side PWM Output	IO_PWM_21	B	k
P190	High-Side PWM Output	IO_PWM_22	B	l
P166	High-Side PWM Output	IO_PWM_23	B	l
P193	High-Side PWM Output	IO_PWM_24	B	m
P169	High-Side PWM Output	IO_PWM_25	B	m
P196	High-Side PWM Output	IO_PWM_26	B	n
P172	High-Side PWM Output	IO_PWM_27	B	n
P101	High-Side PWM Output	IO_PWM_28	C	o
P125	High-Side PWM Output	IO_PWM_29	C	o
P150	High-Side PWM Output	IO_PWM_30	C	p
P174	High-Side PWM Output	IO_PWM_31	C	p
P102	High-Side PWM Output	IO_PWM_32	C	q
P126	High-Side PWM Output	IO_PWM_33	C	q
P151	High-Side PWM Output	IO_PWM_34	C	r
P175	High-Side PWM Output	IO_PWM_35	C	r

4.12.2 Functional Description

Power output stages with freewheeling diodes for inductive loads with low-side connection.
The load current is controlled with PWM. For better accuracy and diagnostics, a current measurement/feedback loop is provided.

If an error is detected in a safety-critical system, the watchdog or the main CPU can disable the output stage (off state), triggered by the application software.

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 on/off time to 100/200 µs instead of 0 or 100 % duty cycle. This means, there is a reliable periodical state change of the output allowing permanent load monitoring that is independent of the operation point. So, even when the load is switched off, a short on the load can be detected.

TTControl GmbH recommends to use the maximum possible wire size (FLRY type) in case of maximum load current to reduce voltage drop and prevent overheating of the crimp contact.

See also section *PWM - Pulse Width Modulation driver* of the API documentation [30].

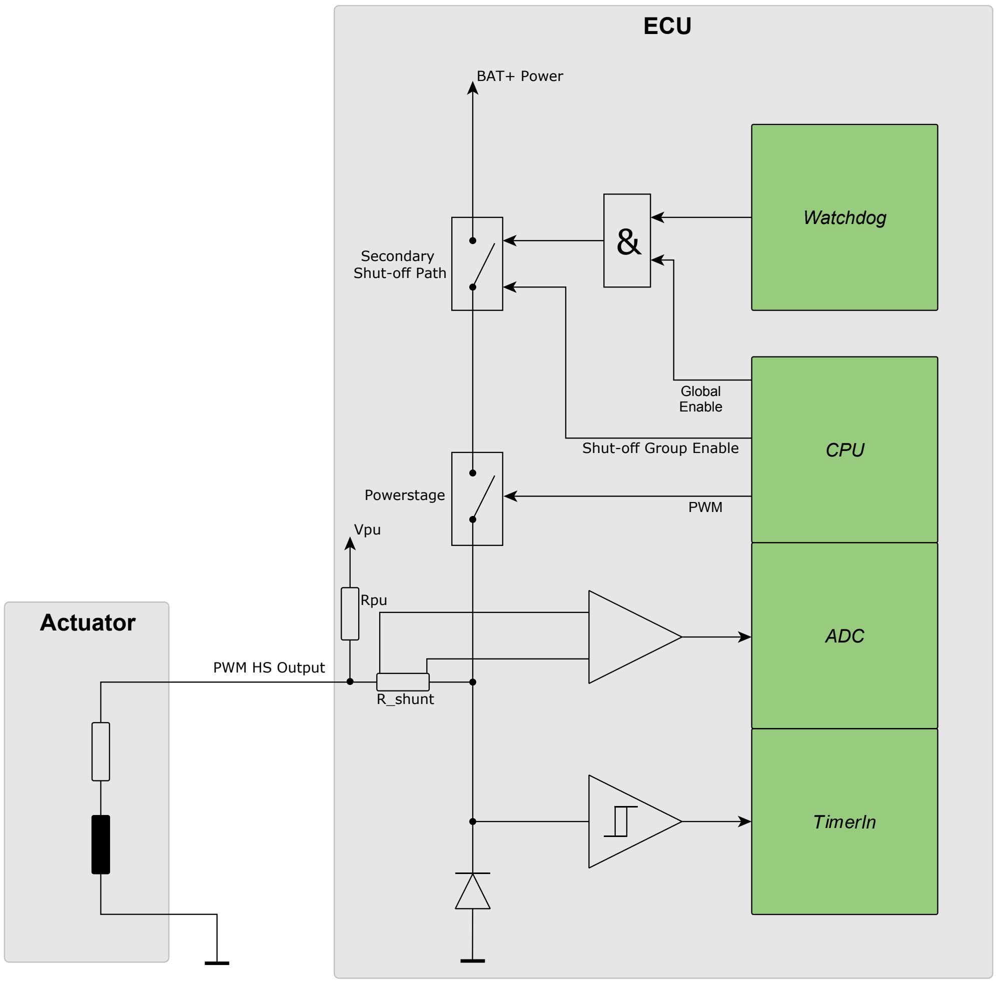

Figure 42: High-side output stage with PWM functionality

4.12.2.1 Power Stage Pairing

If outputs shall be used in parallel, always combine two channels from the same double-channel power stage and use the digital output mode. See Section 4.12.1 on page 137 for using the right power stage outputs in parallel.

Due to thermal limits, the resulting total load current of this output pair has to be de-rated by a factor of 0.85 (e.g. combining two 3 A outputs would result in a total load current of 3 A x 2 x 0.85 = 5.1 A). The application software has to make sure that both outputs are switched on at the same point in time, otherwise the over-current protection may trip.

For balanced current distribution through each of the pin pairs, the cable routing shall be symmetrical if pin-pairs or multiple pins shall be wired parallel to support higher load currents.

4.12.2.2 Mutual Exclusive Mode

The HY-TTC 500 uses double-channel high-side power stages. For load leveling it is a benefit if loads, which are switched on mutually exclusive (which means either load A, or load B is on, but not A and B at the same time), are connected to the same double-channel power stage. This reduces the thermal stress of the components. The power stage pairing is given in Section 4.12.1 on page 137.

For HS PWM output stage operating in 444–1000 Hz mode, the current limit is increased to 1 A if used in mutual exclusive mode, see Section 4.12.4.1 on the next page.

4.12.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Input voltage under overload conditions	1	-0.5	32	V
V_{in}	Input voltage under overload conditions	1	-0.5	BAT+ Power +0.5	V

Note 1 The input voltage may go up to 32 V but must never exceed battery supply voltage.

4.12.4 High-Side PWM Outputs

4.12.4.1 Characteristics of High-Side PWM Output

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{out}	Pin input capacitance		15	25	nF
R_{pu}	Pull-up resistor		4	5	kΩ
V_{pu}	Pull-up voltage (open load)		4.2	4.8	V
f_{PWM}	PWM frequency	1	50	1000	Hz
T_{min-on}	Minimum on time	2	100		µs
$T_{min-off}$	Minimum off time	2	200		µs
R_{on}	On-resistance			150	mΩ
I_{max}	Maximum load current (f = 50. . . 200 Hz)			3	A
I_{max}	Maximum load current (f = 50. . . 200 Hz)	3		4	A
I_{max}	Maximum load current (f = 210. . . 400 Hz)			1.2	A
I_{max}	Maximum load current (f = 444. . . 1000 Hz)			0.1	A
I_{max}	Maximum load current (f = 444. . . 1000 Hz)	4		1	A
I_{peak}	Peak load current limit	5		5.5	A
R_{load_min}	Minimum coil resistance (12 V)	6	2		Ω
R_{load_min}	Minimum coil resistance (24 V)	6	4		Ω
R_{load_max}	Maximum load resistance	7		1	kΩ

Note 1 Not all values for PWM frequency are possible, see section *PWM - Pulse Width Modulation driver* of the API documentation [30] for supported frequency values

Note 2 Instead of 0 % or 100 % output, minimum on/off time is inserted automatically when the output is configured to be safety critical. This is necessary for optimal load diagnostics.

Note 3 T_{ECU} = -40. . . +85 °C

Note 4 HS power stage used in mutual exclusive mode

Note 5 For t < 5 ms

Note 6 Additionally to observing the maximum load current limit, there is also a minimum load resistance limit, depending on the battery supply voltage.

Note 7 Exceeding this value will trigger open load detection.

4.12.4.2 Diagnostic Functions

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

The diagnostic functions are different between PWM and digital operation:

- **PWM-operated high-side output (duty cycle 0 % < X < 100 %)**:
  Under normal load conditions, the feedback signals to the timer unit and the ADC follow the corresponding PWM output. In case of a disconnected load (open load), the output is pulled to 5 V by an internal resistor. If there is a short circuit to ground, the feedback signals are

constantly low. A short circuit to BAT+ implicates that the feedback signals are pulled to 5 V, which also results in a constantly high level. By merging the measurement results from the timer and the ADC unit, it is possible to differentiate the diagnostic functions, as shown in the table below.

Output Signal	Status Signal			
	Normal	Open Load	Short to GND	Short to U_{BAT}
0 % < X < 100 %	●	●	●	●

● = detected

- **Digitally operated high-side output (true duty cycle of 0 or 100 %, without min. and max. pulses)**:
  When the power stage is switched off, the monitoring interface will read back low level if the load is properly connected or if there is a short circuit to ground. In case of open load or short circuit to BAT+ the monitoring interface will read back high 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. The possible diagnostic functions of the digital operation are shown in the table below.

Output Signal	Status Signal			
	Normal	Open Load	Short to GND	Short to U_{BAT}
On	●	×	●	×
Off	●	●	×	●

● = detected
× = not detected

4.12.4.3 Characteristics of Current Measurement

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
I_{tol-p}	Proportional error	1,2	-2.5	+2.5	%
I_{tol-p}	Proportional error	4,2	-2.0	+2.0	%
I_{tol-0}	Zero reading error	1,2	-40	+40	mA
I_{tol-0}	Zero reading error	1,2,4	-35	+35	mA
LSB	Nominal value of 1 LSB		-	1	mA
f_{g_LP}	Cut off frequency of 3rd order low pass filter	3	30	50	Hz

Note 1 The measured value is clipped in software if below zero. So at some devices a small output current is necessary to get ADC-values greater than zero.

Note 2 The total error (I_{tol}) is the sum of proportional error and zero reading error:
$I_{\text{tol}} = \pm\left(I_{tol-p} \cdot I_{load} + I_{tol-0}\right)$

Note 3 An active low pass filter (3rd order) is provided to reduce current ripple from the ADC input. Further digital filtering is applied to eliminate the current ripple completely and provide a stable measurement value for the application.

Note 4 T_{ECU} = -40. . . +85 ℃

4.12.5 High-Side Digital Outputs

When pulse width modulation is not necessary, the output can be configured as a simple digital output. This output mode is only allowed for non-safety critical applications, otherwise the high-side PWM mode needs to be used.

4.12.5.1 Characteristics of High-Side Digital Output

T_{ECU} = -40...+125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{out}	Pin input capacitance		15	25	nF
R_{pu}	Pull-up resistor		4	5	kΩ
V_{pu}	Pull-up voltage (open load)		4.2	4.7	V
R_{on}	On-resistance			150	mΩ
I_{max}	Maximum load current			3	A
I_{max}	Maximum load current	1		4	A
I_{peak}	Peak load current limit	2		5.5	A
R_{load_min}	Minimum coil resistance (12 V)	3	2		Ω
R_{load_min}	Minimum coil resistance (24 V)	3	4		Ω
R_{load_max}	Maximum load resistance	4		1	kΩ

Note 1 T_{ECU} = -40...+85 ℃

Note 2 For $t < 5$ ms

Note 3 Additionally to observing the maximum load current limit, there is also a minimum load resistance limit, depending on the battery supply voltage.

Note 4 Exceeding this value will trigger open load detection.

See Section 4.12.4.3 on page 142 for characteristics of current measurement.

4.12.6 Digital and Frequency Inputs

If a high-side output is not needed on IO_PWM_00 - IO_PWM_35, the loop-back path of these output stages can be alternatively used as a digital or frequency input.

External switches which are directly switching to battery voltage must not be used with alternative inputs.

See Section 6.6 on page 218 for more information on using the alternative digital and frequency input function of the High-Side PWM Outputs.

4.12.6.1 Characteristics of Digital Input

The alternative digital input function (use case: external switch connected to GND) is available for high-side PWM channels IO_PWM_00 - IO_PWM_35.

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		15	25	nF
τ_{in}	Input low pass filter		1.4	3.4	µs
R_{pu}	Pull-up resistor		4	5	kΩ
V_{pu}	Pull-up voltage		4.2	4.8	V
V_{il}	Input voltage for low level		0	2	V
V_{ih}	Input voltage for high level	1	3	32	V
V_{in}	Input voltage range	1	-0.5	BAT+ Power +0.5	V

Note 1 The input voltage may go up to 32 V but must never exceed battery supply voltage.

4.12.6.2 Characteristics of Timer Input

The alternative timer input function is only available for high-side PWM channels IO_PWM_28 - IO_PWM_35.

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		15	25	nF
τ_{in}	Input low pass filter		1.4	3.4	µs
R_{pu}	Pull-up resistor		4	5	kΩ
V_{pu}	Pull-up voltage		4.25	4.8	V
f_{max}	Maximum input frequency	1		2	kHz
f_{max}	Maximum input frequency	2		10	kHz
f_{min}	Minimum input frequency	3	0.1		Hz
t_{res}	Timer resolution		1	1	µs
t_{min}	Minimum on/off time to be measured by timer input		20		µs
V_{il}	Input voltage for low level		0	2	V
V_{ih}	Input voltage for high level	4	3	32	V
V_{in}	Input voltage range	4	-0.5	BAT+ Power +0.5	V

Note 1 With open collector sensor output.

Note 2 With push-pull sensor output stage.

Note 3 Due to the dynamic range of the timer, there is a minimum frequency when a timer overflow occurs. Even at a lower frequency the output value will be read as 0 Hz.

Note 4 The input voltage may go up to 32 V but must never exceed battery supply voltage.

4.12.7 Secondary Shut-off Paths

The available PWM output stages are allocated to three independent secondary shut-off paths (=Safety switches). See Section 4.12.1 on page 137, column *Ext./Second. Shut-Off* of pinout table. For safety-critical applications, these paths allow to selectively activate/deactivate a set of specific PWM outputs in case of a detected actuator failure. Thus, the ECU can be operated in a reduced (limp home) mode that allows the vehicle to be safely driven to the repair shop.

Figure 43 on the current page shows the detailed distribution of the PWM output stages to the shut-off paths.

See Section 5.1.1 on page 188 for safety concept overview.

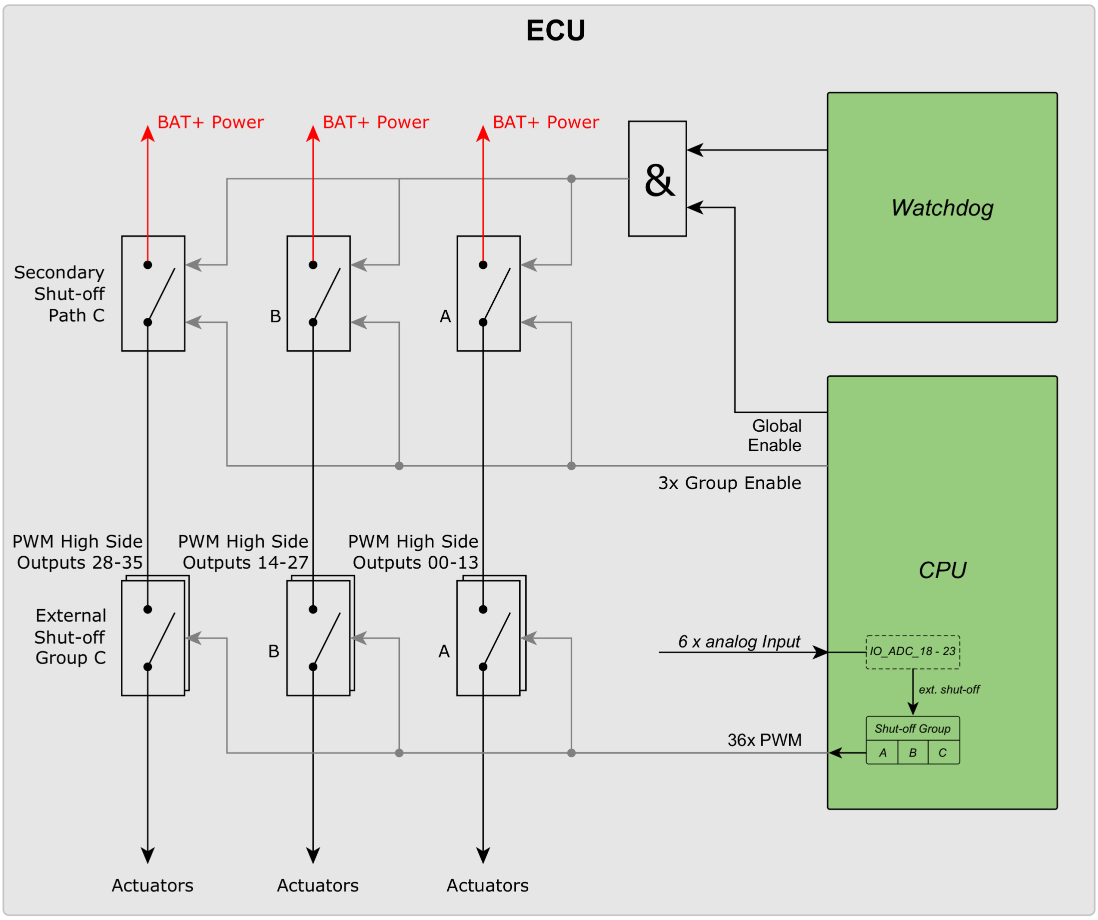

Figure 43: Distribution of PWM output stages to shut-off groups/paths

4.12.8 External Shut-off Groups

6 analog inputs can be configured acting as external activating or deactivating switch input for shut-off groups A, B and C, see Figure 43 on the preceding page.

The external analog input pins can deactivate the shut-off groups independently of the watchdog functionality and the application software as well.

List of analog input pins to shut-off group mapping:

Pin No.	Function	SW-define	Shut-Off Group
P112	0...32 V Input	IO_ADC_18	A
P136	0...32 V Input	IO_ADC_19	A
P113	0...32 V Input	IO_ADC_20	B
P137	0...32 V Input	IO_ADC_21	B
P114	0...32 V Input	IO_ADC_22	C
P138	0...32 V Input	IO_ADC_23	C

Depending on the voltage level on the external pin(s), the software driver switches the corresponding shut-off group ON or OFF within the previously configured failure reaction time. 2 Analog Inputs have to be used in parallel for each shut-off group to guarantee SIL 2 Level.

4.12.8.1 Characteristics of External Shut-off

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pd}	Pull-down resistor		14.7	15.3	kΩ
V_{in}	Input voltage range		0	32	V
V_{il}	Input voltage level to signal a low level input		0	4	V
V_{ih}	Input voltage level to signal a high level input		6	32	V
$V_{tol\text{-}0}$	Zero reading error	2	-50	+50	mV
$V_{tol\text{-}0}$	Zero reading error	1,2	-45	+45	mV
$V_{tol\text{-}p}$	Proportional error	2	-4	+4	%
$V_{tol\text{-}p}$	Proportional error	1,2	-3	+3	%
LSB	Nominal value of 1 LSB		-	8.59	mV

Note 1 T_{ECU} = -40...+85 °C

Note 2 The total measurement error is the sum of zero reading error and the proportional error.

4.12.9 Tertiary Shut-off Path

4.12.9.1 Functional description

Loads on safety-critical high-side PWM channels can be connected to the ground as shown in Figure 42 on page 139 or to a low-side digital output as shown in Figure 44 on the current page.

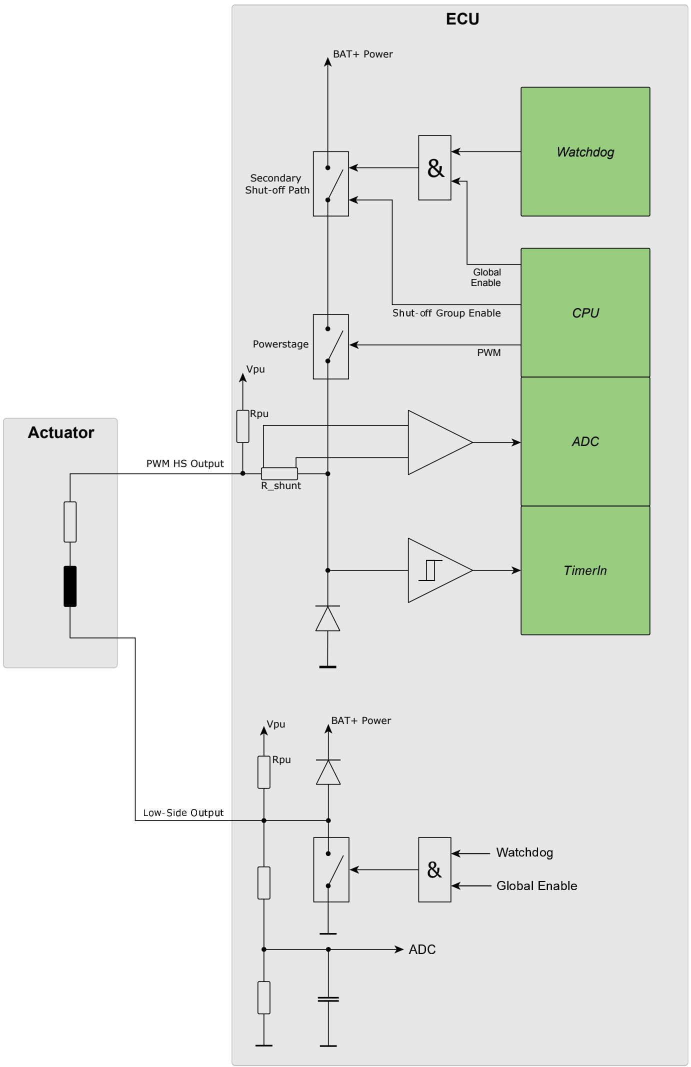

Figure 44: Tertiary Shut-off Path

With the tertiary shut-off configuration shown in 44 the HY-TTC 500 is able to switch off the high-side PWM channels even if the load has a short circuit to the positive battery supply.

Please refer to section *PWM - Pulse Width Modulation driver* of the API documentation [30] for more information how to configure such an output.

4.13 High-Side Digital Outputs

4.13.1 Pinout

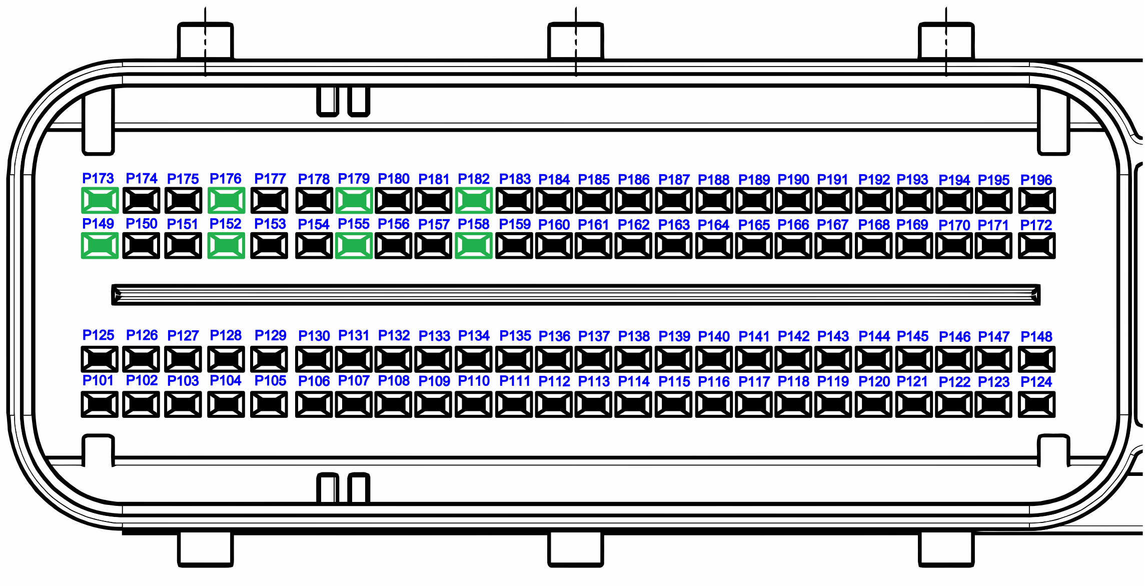

Figure 45: Pinout of high-side digital outputs

Pin No.	Function	SW-define	Power stage
P149	High-Side Digital Output	IO_DO_00	a
P173	High-Side Digital Output	IO_DO_01	a
P152	High-Side Digital Output	IO_DO_02	b
P176	High-Side Digital Output	IO_DO_03	b
P155	High-Side Digital Output	IO_DO_04	c
P179	High-Side Digital Output	IO_DO_05	c
P158	High-Side Digital Output	IO_DO_06	d
P182	High-Side Digital Output	IO_DO_07	d

4.13.2 Functional Description

Eight power output stages with freewheeling diodes for inductive and resistive loads with low-side connection.

Suitable loads are lamps, valves, relays etc.

If an error is detected in a safety-critical resource, the watchdog CPU or the main CPU will disable the output stage (off state).

For diagnostic reasons, the output signal is looped back to the CPU, and the value measured is compared with the value set. When the output is not used, the loop-back signal can be used as an analog input or as a digital input.

TTControl GmbH recommends to use the maximum possible wire size (FLRY type) in case of maximum load current to reduce voltage drop and prevent overheating of the crimp contact.

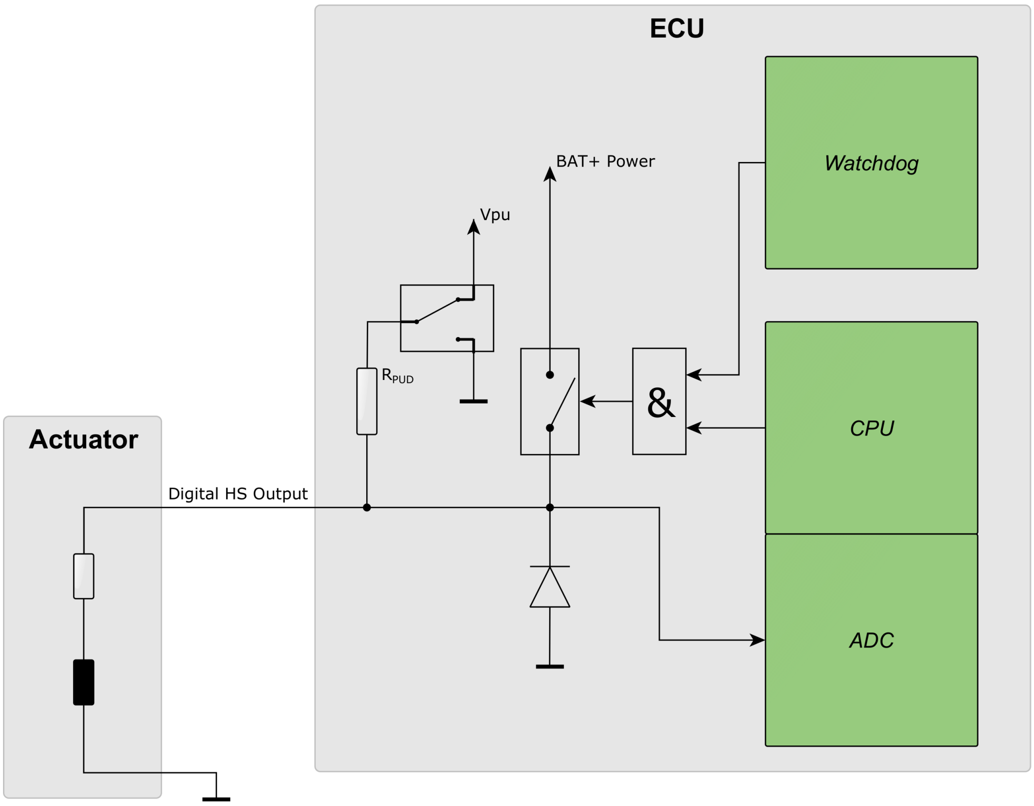

Figure 46: Digital high-side power stage

4.13.2.1 Power Stage Pairing

If outputs shall be used in parallel, always combine two channels from the same double-channel power stage and use the digital output mode. See Section 4.13.1 on page 149 for using the right power stage outputs in parallel.

Due to thermal limits, the resulting total load current of this output pair has to be de-rated by a factor of 0.85 (e.g. combining two 3 A outputs would result in a total load current of 3 A x 2 x 0.85 = 5.1 A). The application software has to make sure that both outputs are switched on at the same point in time, otherwise the over-current protection may trip.

For balanced current distribution through each of the pin pairs, the cable routing shall be symmetrical if pin-pairs or multiple pins shall be wired parallel to support higher load currents.

4.13.2.2 Mutual Exclusive Mode

The HY-TTC 500 uses double-channel high-side power stages. For load leveling it is a benefit if loads, which are switched on mutually exclusive (which means either load A, or load B is on, but not A and B at the same time), are connected to the same double-channel power stage. This reduces the thermal stress of the components. The power stage pairing is given in Section 4.13.1 on page 149.

4.13.3 Diagnostic Functions

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

Output Signal	Status Signal			
	Normal	Open Load	Short to GND	Short to U_{BAT}
On	●	×	●	×
Off	●	●	×	●

● = detected
× = not detected

4.13.4 Maximum Ratings

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Input/output voltage under overload conditions		-0.5	BAT+ Power +0.5	V

4.13.5 High-Side Digital Outputs

4.13.5.1 Characteristics of High-Side Output

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pud}	Pull-up/pull-down resistor		7.5	10	kΩ
V_{pu}	Pull-up voltage (open load)		4	4.5	V
R_{on}	On-resistance			100	mΩ
I_{load}	Nominal load current		0	3	A
I_{load}	Nominal load current	1	0	4	A
I_{peak}	Peak load current	2	0	6	A
$I_{tol\text{-}p}$	Proportional error	3	-14	+14	%
$I_{tol\text{-}p}$	Proportional error	1,3	-10	+10	%
$I_{tol\text{-}0}$	Zero reading error	3	-150	+150	mA
$I_{tol\text{-}0}$	Zero reading error	1,3	-150	+150	mA

Note 1 T_{ECU} = -40. . . +85 °C

Note 2 Peak current for not more than 100 ms. Exceeding this value will trigger the overload protection and switch off the power stage. Steady state operation goes only up to 3 A/4 A depending on temperature.

Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.13.6 Analog and Digital Inputs

External switches which are directly switching to battery voltage must not be used with alternative inputs.

See Section 6.6 on page 218 for more information.

4.13.6.1 Characteristics of Analog Voltage Input

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
τ_{in}	Input low pass filter (analog path)		1.5	2.5	ms
R_{pud}	Pull-up/pull-down	1	7.5	10	kΩ
V_{pu}	Pull-up voltage (open load)		4	4.5	V
	Resolution		12	12	bit
$V_{tol\text{-}0}$	Zero reading error	3	-55	+55	mV
$V_{tol\text{-}0}$	Zero reading error	1,3	-50	+50	mV
$V_{tol\text{-}p}$	Proportional error	3	-4	+4	%
$V_{tol\text{-}p}$	Proportional error	1,3	-3	+3	%
LSB	Nominal value of 1 LSB		-	13.4	mV
V_{in}	Input voltage measurement range	2	0	32	V
V_{in}	Input voltage range	2	-0.5	BAT+ Power +0.5	V

Note 1 T_{ECU} = -40...+85 °C

Note 2 The input voltage may go up to 32 V but must never exceed battery supply voltage.

Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.13.6.2 Characteristics of Digital Input

T_{ECU} = -40...+125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
τ_{in}	Input low pass filter		1.5	2.5	ms
R_{pud}	Pull-up/pull-down resistor		7.5	10	kΩ
V_{pu}	Pull-up voltage (open load)		4	4.5	V
	Resolution		12	12	bit
V_{il}	Input voltage for low level		0	●	V
V_{ih}	Input voltage for high level	1	●	32	V
V_{in}	Input voltage range	1	-0.5	BAT+ Power +0.5	V

Note ● Configuration by application software

Note 1 The input voltage may go up to 32 V but must never exceed battery supply voltage.

4.14 High-Side Digital/PVG/VOUT Outputs

4.14.1 Pinout

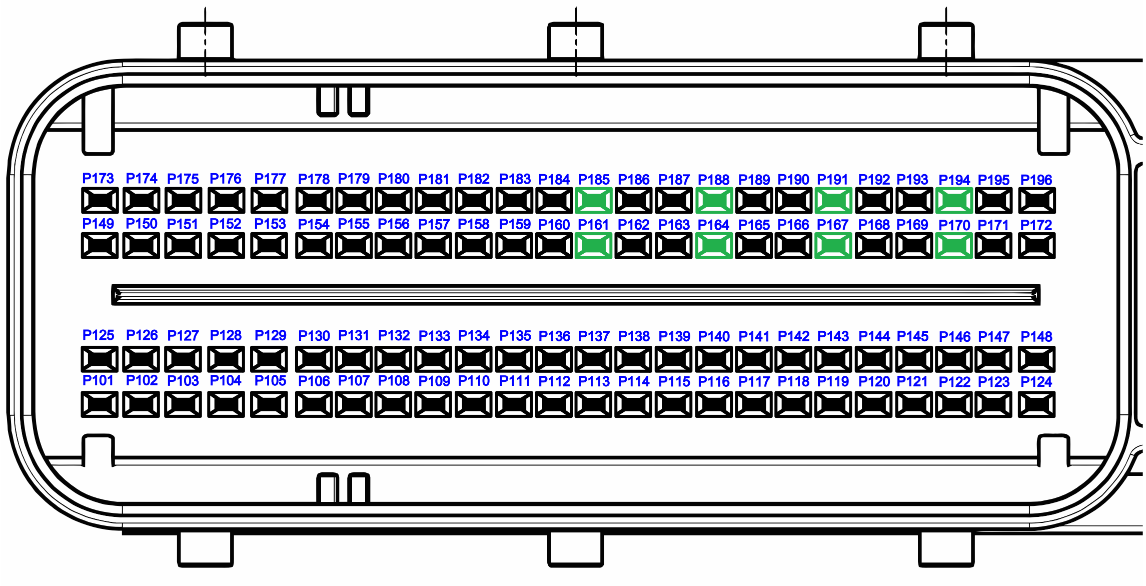

Figure 47: Pinout of High-side digital/PVG/VOUT outputs

Pin No.	Function	SW-define	Power stage
P161	High-Side Digital Output/PVG/V_{OUT}	IO_PVG_00	a
P185	High-Side Digital Output/PVG/V_{OUT}	IO_PVG_01	a
P188	High-Side Digital Output/PVG/V_{OUT}	IO_PVG_02	b
P164	High-Side Digital Output/PVG/V_{OUT}	IO_PVG_03	b
P191	High-Side Digital Output/PVG/V_{OUT}	IO_PVG_04	c
P167	High-Side Digital Output/PVG/V_{OUT}	IO_PVG_05	c
P194	High-Side Digital Output/PVG/V_{OUT}	IO_PVG_06	d
P170	High-Side Digital Output/PVG/V_{OUT}	IO_PVG_07	d

4.14.2 Functional Description

Output stages for interfacing to PVG type hydraulic valve groups (PVG mode), for low power analog voltage loads (V_{OUT} mode) or for high power inductive/resistive loads (HS mode).

All eight outputs can be configured independently of each other.

TTControl GmbH recommends to use the maximum possible wire size (FLRY type) in case of maximum load current to reduce voltage drop and prevent overheating of the crimp contact.

See also section *PVG - Proportional Valve output driver* of the API documentation [30].

4.14.2.1 Power Stage Pairing

If outputs shall be used in parallel, always combine two channels from the same double-channel power stage and use the digital output mode. See Section 4.14.1 on the previous page for using the right power stage outputs in parallel.

Due to thermal limits, the resulting total load current of this output pair has to be de-rated by a factor of 0.85 (e.g. combining two 3 A outputs would result in a total load current of 3 A x 2 x 0.85 = 5.1 A). The application software has to make sure that both outputs are switched on at the same point in time, otherwise the over-current protection may trip.

For balanced current distribution through each of the pin pairs, the cable routing shall be symmetrical if pin-pairs or multiple pins shall be wired parallel to support higher load currents.

4.14.2.2 Mutual Exclusive Mode

The HY-TTC 500 uses double-channel high-side power stages. For load leveling it is a benefit if loads, which are switched on mutually exclusive (which means either load A, or load B is on, but not A and B at the same time), are connected to the same double-channel power stage. This reduces the thermal stress of the components. The power stage pairing is given in Section 4.14.1 on the preceding page.

4.14.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Input/output voltage under overload conditions		-0.5	BAT+ Power +0.5	V

4.14.4 High-Side Digital Outputs

Eight power output stages with freewheeling diodes for inductive and resistive loads with low-side connection.

Suitable loads are lamps, valves, relays etc.

If an error is detected in a safety-critical resource, the watchdog CPU or the main CPU can disable the output stage (off state).

For diagnostic reasons the output signal is looped back to the CPU, and the value measured is compared with the value set. When the output is not used, the loop-back signal can be used as an analog input or as a digital input.

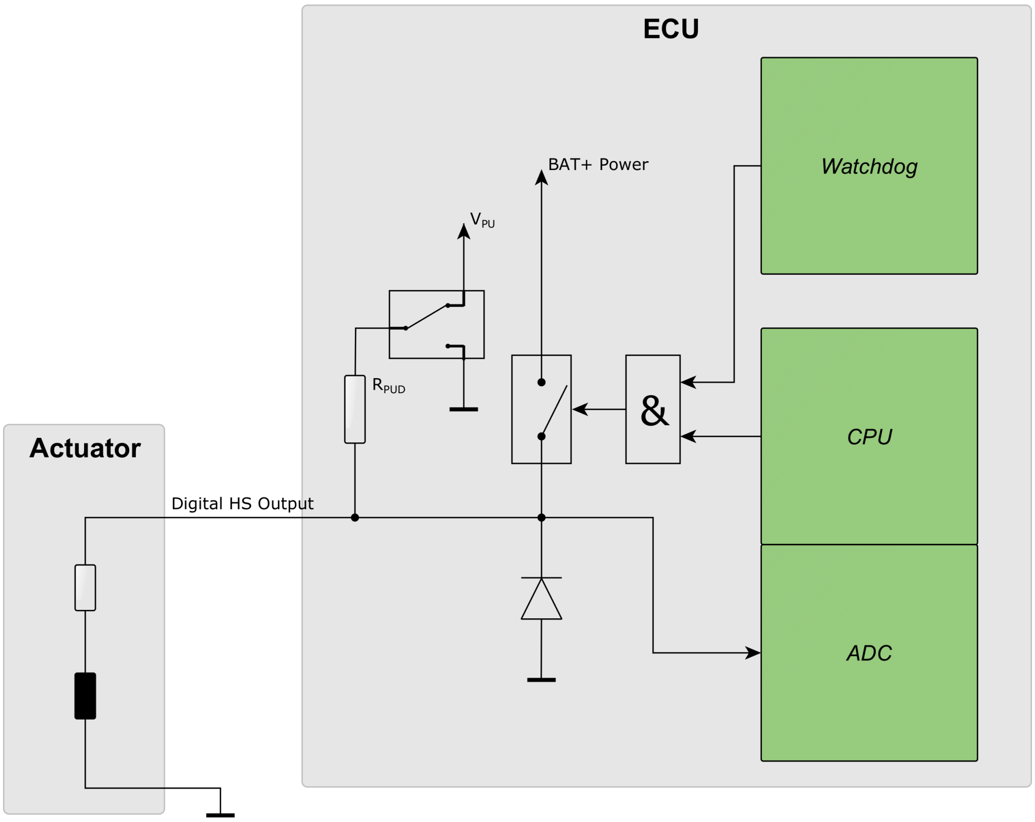

Figure 48: Digital high-side power stage

4.14.4.1 Diagnostic Functions

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

Output Signal	Status Signal			
	Normal	Open Load	Short to GND	Short to U_{BAT}
On	●	×	●	×
Off	●	●	×	●

● = detected
× = not detected

4.14.4.2 Characteristics of High-Side Digital

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pud}	Pull-up/pull-down resistor		2.5	2.6	kΩ
V_{pu}	Pull-up voltage (open load)		2.15	2.45	V
R_{on}	On-resistance			100	mΩ
I_{load}	Nominal load current		0	3	A
I_{max}	Maximum load current	1		4	A
I_{peak}	Peak load current	2	0	6	A
I_{tol-p}	Proportional error	3	-14	+14	%
I_{tol-p}	Proportional error	1,3	-10	+10	%
I_{tol-0}	Zero reading error	3	-150	+150	mA
I_{tol-0}	Zero reading error	1,3	-150	+150	mA

Note 1 T_{ECU} = -40. . . +85 ℃

Note 2 Peak current for maximal 100 ms. Exceeding this value will trigger overload protection and switch off the power stage.Steady state operation goes only up to 3 A/4 A depending on temperature.

Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.14.5 PVG Outputs

Proportional Valve Groups (PVG) are a group of hydraulic load-sensing valves with integrated electronics allowing advanced flow controllability, e.g., for load-independent flow control.

For diagnostic reasons in output mode, the output signal is looped back to the CPU, and the measured value is compared to the set value. If the difference between these two values is above a fixed limit, an overload is detected, and the output is disabled. The protection mechanism tries re-enabling the output 10 times per drive cycle. It is not allowed to use two outputs in parallel to increase driving strength.

The PVG output can be used to control PVG valves of the types PVEA, PVEH and PVES. These types of valves apply a low pass filter to the input signal and use the resulting DC voltage in relation to the valves supply voltage (BAT+) as a parameter for flow control.

The HY-TTC 500 uses the BAT+ CPU pin as a reference voltage input. The principle schematic is shown in Figure 49 on the current page. The output is open loop controlled. The ADC input is for diagnostic purposes only and can be evaluated by the application software.

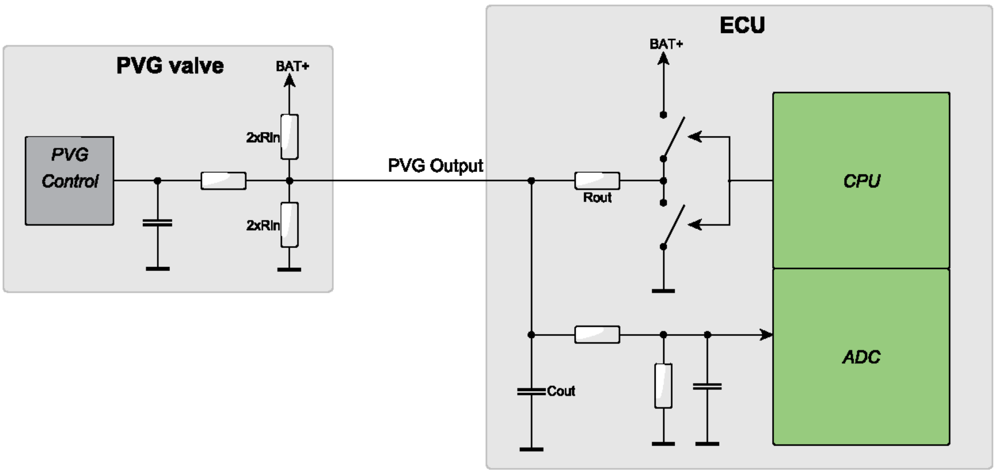

Figure 49: Output stage in PVG mode

4.14.5.1 Characteristics of PVG

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{out}	Pin capacitance		430	530	nF
R_{out}	Output resistance		2.5	2.6	kΩ
V_{nom}	Nominal voltage range (BAT+ = 8. . . 32 V, nominal load resistance)	1,2	0.1 · BAT+	0.9 · BAT+	V
$V_{tol\text{-}p}$	Proportional error (BAT+ = 8. . . 32 V, nominal load resistance)	1,3	-2	+2	%
$V_{tol\text{-}0}$	Zero reading error (BAT+ = 8. . . 32 V, nominal load resistance)	1,3	-100	+100	mV

Note 1 The PVG valves use a voltage divider with 2 · 24 k Ω between ground and BAT+. This is equivalent to 1 · 12 k Ω against 50 % of BAT+.

Note 2 The standard PVG valves are controllable between 25 % and 75 % of BAT+. This specification parameter is to show the HW-related control limits only.

Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.14.6 VOUT Outputs

In V_{OUT} mode, the outputs generate a DC voltage that can be used to connect to any high-impedance analog input. The load resistance of the receiving device defines the maximum possible output voltage.

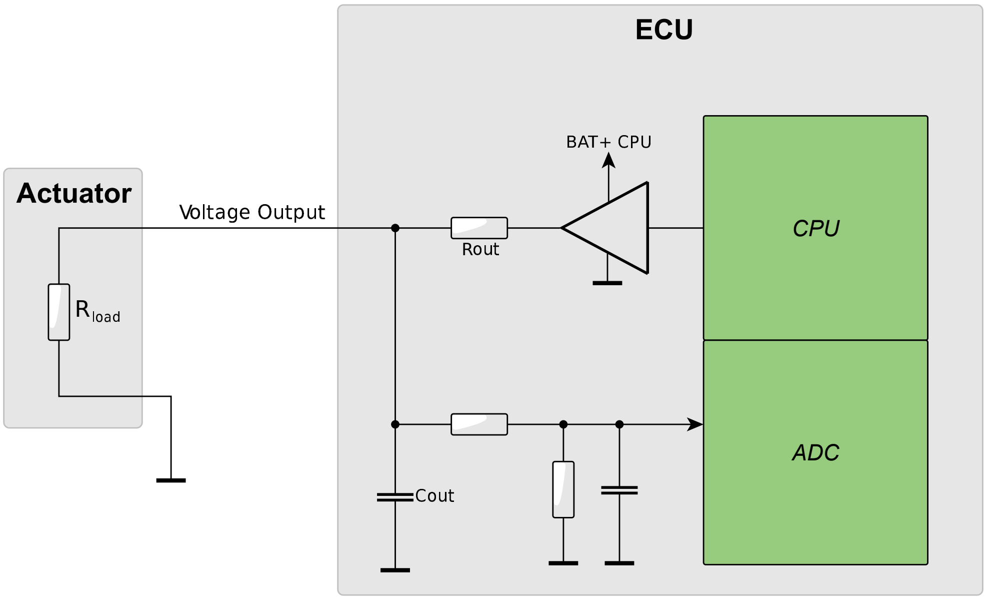

Figure 50: Output stage in V_{OUT} mode

In PVG mode, PVG valves have a well-defined input resistance, and the output signal settings can be calculated in advance by considering the characteristics of the output stage. In voltage mode, however, a PID controller must be applied to generate the desired output voltage. This results in a certain settling time, which depends on the parameter set of the PID controllers.

The V_{OUT} mode output can be used to control PVG valves of the type PVEU or other generic resistive loads.

For diagnostic reasons, the output signal is looped back to the CPU in output mode, and the measured value is compared to the set value. If the difference between these two values is above a fixed limit, an overload is detected and the output is disabled. The protection mechanism tries to re-enable the output 10 times per drive cycle. It is not allowed to use two outputs in parallel to increase driving strength.

4.14.6.1 Characteristics of VOUT

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{out}	Pin capacitance		430	530	nF
R_{out}	Output resistance		2.5	2.6	kΩ
I_{load}	Nominal load current		0	5	mA
V_{nom}	Nominal voltage range (open load), BAT+ = 8. . . 32 V	1	0.0 · BAT+	0.99 · BAT+	
$V_{tol\text{-}p}$	Proportional error (BAT+ = 8. . . 32 V)	3	-2	+2	%
$V_{tol\text{-}p}$	Proportional error (BAT+ = 8. . . 32 V)	2,3	-1.5	+1.5	%
$V_{tol\text{-}0}$	Zero error (BAT+ = 8. . . 32 V)	3	-300	+300	mV
$V_{tol\text{-}0}$	Zero error (BAT+ = 8. . . 32 V)	2,3	-200	+200	mV

Note 1 In the VOUT setting, the open load voltage is only open loop controlled. The load creates a voltage divider with the well-defined output resistance (Rout) of the VOUT stage. This effect must be considered in the application SW. To get a desired (loaded) output voltage the proper open load voltage must be calculated and set to a (higher) open load voltage level. For example, with a load RL = 10 kΩ to ground the open load voltage (Vset) must be set to 12.55 V ($Vset = Vout \frac{RL+2.55\ kohm}{RL}$) to get an output voltage of 10 V.

Note 2 T_{ECU} = -40. . . +85 °C

Note 3 The total error is the sum of zero error and the proportional error.

4.14.7 Analog and Digital Inputs

This input type is suitable for low impedance switches and sensors only. For standard analog senors please use Analog Input 2 Modes (Section 4.10 on page 124) and Analog Input 3 Modes (Section 4.9 on page 116).

External switches which are directly switching to battery voltage must not be used with alternative inputs.

See Section 6.6 on page 218 for more information.

4.14.7.1 Characteristics of Analog Voltage Input

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		384	576	nF
τ_{in}	Input low pass filter		8	12	ms
R_{pud}	Pull-up/pull-down resistor		2.5	2.6	kΩ
V_{pu}	Pull-up voltage (open load)		4.7	5.1	V
	Resolution		12	12	bit
$V_{tol\text{-}0}$	Zero reading error	3	-55	+55	mV
$V_{tol\text{-}0}$	Zero reading error	1,3	-50	+50	mV
$V_{tol\text{-}p}$	Proportional error	3	-4	+4	%
$V_{tol\text{-}p}$	Proportional error	1,3	-3	+3	%
LSB	Nominal value of 1 LSB		-	8	mV
V_{in}	Input voltage measurement range	2	0	32	V
V_{in}	Input voltage range	2	-0.5	BAT+ Power +0.5	V

Note 1 T_{ECU} = -40. . . +85 ℃

Note 2 The input voltage may go up to 32 V but must never exceed battery supply voltage.

Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.14.7.2 Characteristics of Digital Input

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		384	576	nF
τ_{in}	Input low pass filter		8	12	ms
R_{pud}	Pull-up/pull-down resistor		2.5	2.6	kΩ
V_{pu}	Pull-up voltage (open load)		4.7	5.1	V
	Resolution		12	12	bit
V_{il}	Input voltage for low level		0		V

Symbol	Parameter	Note	Min.	Max.	Unit
V_{ih}	Input voltage for high level	1	●	32	V
V_{in}	Input voltage range	1	-0.5	BAT+ Power +0.5	V

Note ● Configuration by application software

Note 1 The input voltage may go up to 32 V but must never exceed battery supply voltage.

4.15 Low-Side Digital Outputs

4.15.1 Pinout

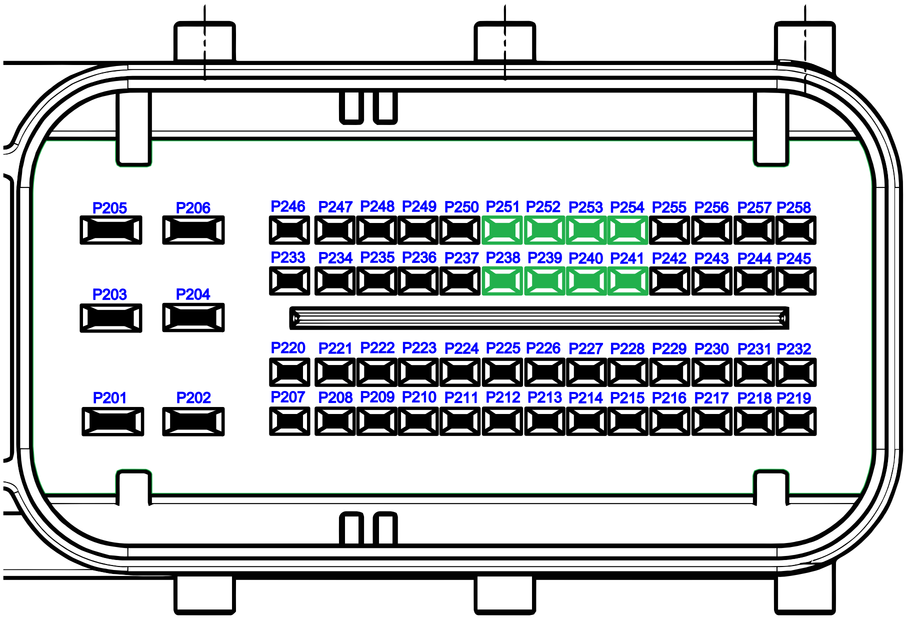

Figure 51: Pinout of low-side digital outputs

Pin No.	Function	SW-define
P251	Low-Side Digital Output	IO_DO_08
P238	Low-Side Digital Output	IO_DO_09
P252	Low-Side Digital Output	IO_DO_10
P239	Low-Side Digital Output	IO_DO_11
P253	Low-Side Digital Output	IO_DO_12
P240	Low-Side Digital Output	IO_DO_13
P254	Low-Side Digital Output	IO_DO_14
P241	Low-Side Digital Output	IO_DO_15

4.15.2 Functional Description

Eight low-side switches with freewheeling diodes to a clamping structure for inductive and resistive loads.

The current through the low-side switch is monitored and triggers the opening in case of over-current. Short-circuit and overload protection is included in low-level driver software. Before a tripped channel can be re-enabled, the overload situation has to be removed.

TTControl GmbH recommends to use the maximum possible wire size (FLRY type) in case of maximum load current to reduce voltage drop and prevent overheating of the crimp contact.

See also section *DIO - Driver for digital inputs and outputs* of the API documentation [30].

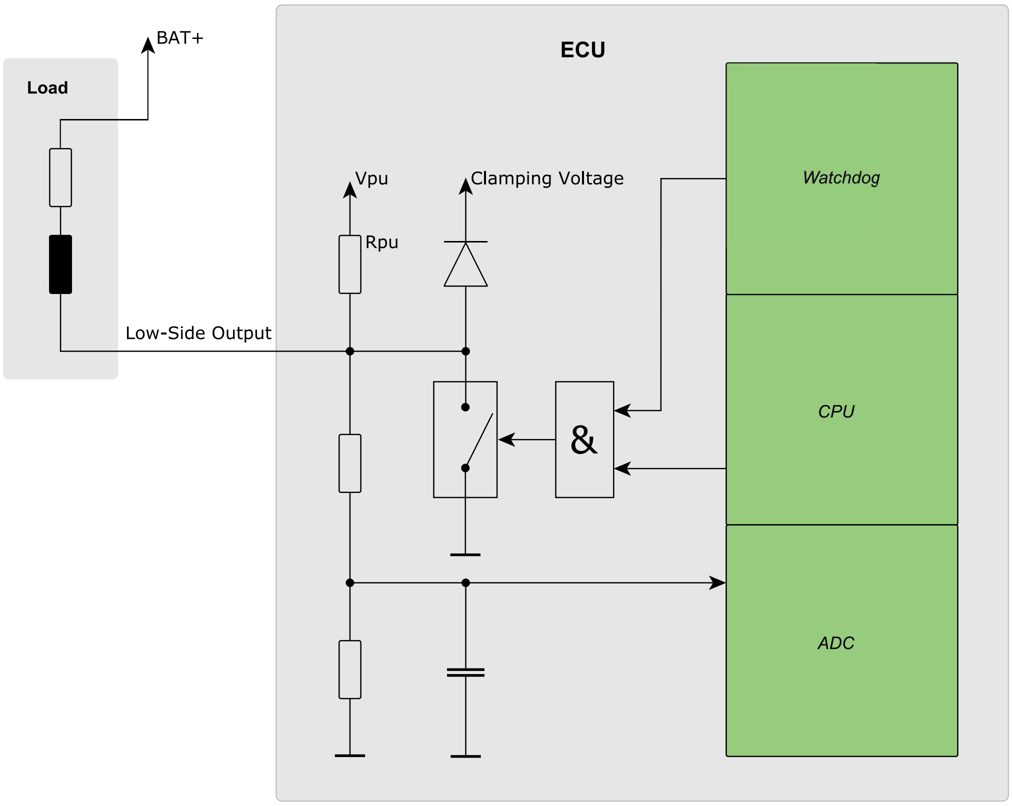

Figure 52: Low-side switch for resistive and inductive loads

4.15.2.1 Power Stage Pairing

If higher load current is needed, the output stages can be used in parallel.

Due to thermal limits, the resulting total load current of this output pair has to be de-rated by a factor of 0.85 (e.g. combining two 3 A outputs would result in a total load current of 3 A x 2 x 0.85 = 5.1 A). The application software has to make sure that both outputs are switched on at the same point in time, otherwise the over-current protection may trip.

For balanced current distribution through each of the pin pairs, the cable routing shall be symmetrical if pin-pairs or multiple pins shall be wired parallel to support higher load currents.

4.15.3 Diagnostic Functions

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

Output Signal	Status Signal			
	Normal	Open Load	Short to GND	Short to U_{BAT}
On	●	×	×	●
Off	●	●	●	×

● = detected
× = not detected

4.15.4 Maximum Ratings

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Input/output voltage under overload conditions		-0.5	BAT+ Power +0.5	V
V_{out}	Output voltage under overload conditions	1	-1	33	V
W_{max}	Inductive clamping Energy ($\frac{LI^2}{2}$)	2		450	mJ
f_{max}	Maximum combined switching rate	3		11	Hz
P_{max}	Maximum combined clamping power	3		5	W

Note 1 Inductive load transients will be clamped internally to <33 V referred to GND.

Note 2 With 3 A load current in a system with 32 V supply voltage, this corresponds to a maximum inductivity of 100 mH. For higher inductivities see Section 6.3 on page 195.

Note 3 This is the sum of all inductive switch-off events on all eight low side outputs. With lower energy, faster switching is possible as the limit is the average power.

4.15.5 Characteristics of Low-Side Digital Output

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
R_{pu}	Pull-up resistor		8	12	kΩ
V_{pu}	Pull-up voltage		4	4.5	V
R_{on}	On-resistance			50	mΩ
I_{load}	Nominal load current		0	3	A
I_{max}	Maximum load current	1		4	A
I_{peak}	Peak load current	2	0	6	A
$I_{tol\text{-}0}$	Zero reading error	3	-400	+400	mA
$I_{tol\text{-}0}$	Zero reading error	1,3	-300	+300	mA
$I_{tol\text{-}p}$	Proportional error	3	-14	+14	%
$I_{tol\text{-}p}$	Proportional error	1,3	-10	+10	%

Note 1 T_{ECU} = -40. . . +85 ℃.

Note 2 Peak current for not more than 100 ms. Exceeding this value will trigger overload protection and switch off the power stage. Steady state operation goes only up to 3 A/4 A depending on temperature

Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.15.6 Analog and Digital Inputs

4.15.6.1 Characteristics of Analog Voltage Input

T_{ECU} = -40...+125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
τ_{in}	Input low pass filter		1.5	2.5	ms
R_{pu}	Pull-up resistor		8	12	kΩ
V_{pu}	Pull-up voltage		4	4.5	V
	Resolution		12	12	bit
$V_{tol\text{-}0}$	Zero reading error	3	-55	+55	mV
$V_{tol\text{-}0}$	Zero reading error	1,3	-50	+50	mV
$V_{tol\text{-}p}$	Proportional error	3	-4	+4	%
$V_{tol\text{-}p}$	Proportional error	1,3	-3	+3	%
LSB	Nominal value of 1 LSB		-	13.4	mV
V_{in}	Input voltage measurement range	2	0	32	V
V_{in}	Input voltage range	2	-0.5	BAT+ Power +0.5	V

Note 1 T_{ECU} = -40...+85 ℃

Note 2 The input voltage may go up to 32 V but must never exceed battery supply voltage.

Note 3 The total measurement error is the sum of zero reading error and the proportional error.

4.15.6.2 Characteristics of Digital Input

T_{ECU} = -40...+125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
τ_{in}	Input low pass filter		1.5	2.5	ms
R_{pu}	Pull-up resistor		8	12	kΩ
V_{pu}	Pull-up voltage		4	4.5	V
	Resolution		12	12	bit
V_{il}	Input voltage for low level		0	●	V
V_{ih}	Input voltage for high level		●	32	V

Note ● Configuration by application software

4.16 LIN

4.16.1 Pinout

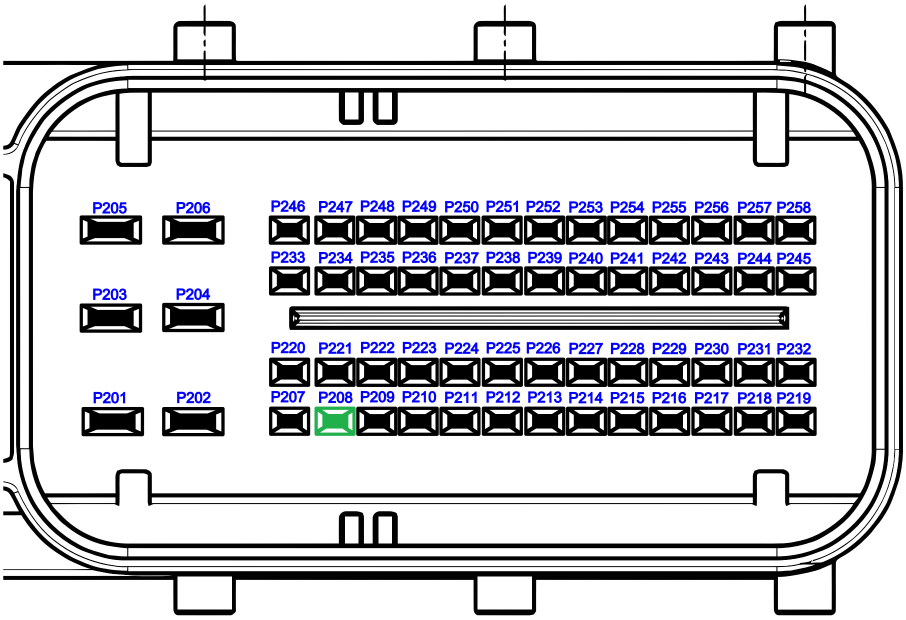

Figure 53: LIN pinout

Pin No.	Function	SW-define
P208	LIN	IO_LIN

4.16.2 Functional Description

LIN is configured in master mode.

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

Note: A common ground (chassis) or a proper ground connection is necessary for LIN operation. If you connect to an external device (e.g., to a PC with a LIN interface), make sure not to violate the maximum voltage ratings when connecting to the LIN connection.

See also section *LIN - Local Interconnect Network driver* of the API documentation [30].

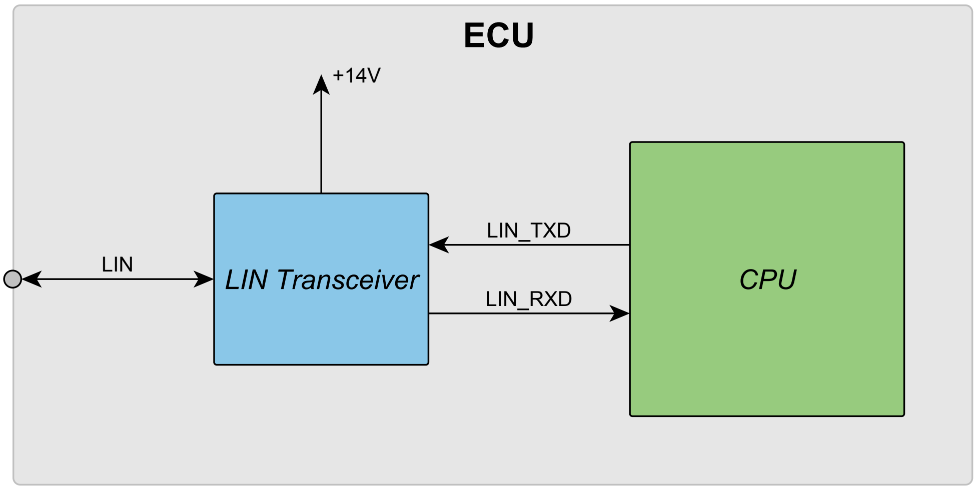

Figure 54: LIN interface

4.16.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{LIN}	Bus voltage under overload conditions		-1	+33	V

4.16.4 Characteristics

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{out}	Pin output capacitance		0.8	1.2	nF
V_{BUSdom}	Receiver dominant state			$0.4 \cdot V_{Bat\_LIN}$	V
V_{BUSrec}	Receiver recessive state		$0.6 \cdot V_{Bat\_LIN}$	–	V
V_{OL}	Output low voltage			2.0	V
V_{Bat_LIN}	LIN supply voltage	1	13	15	V
R_{pu}	Pull-up resistor		0.95	1.05	kΩ
S_{Tr}	Baud rate			20	kBd

Note 1 For battery voltages higher than V_Bat_LIN +0.5 V

4.17 RS232

4.17.1 Pinout

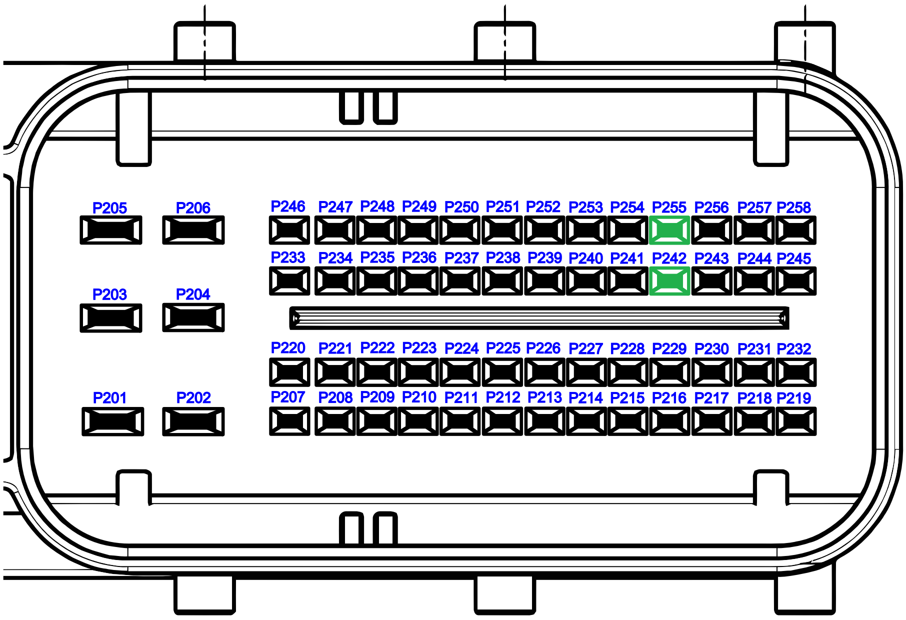

Figure 55: RS232 pinout

Pin No.	Function	SW-define
P242	RS232 Serial Interface Output(TX)	IO_UART
P255	RS232 Serial Interface Output(RX)	

4.17.2 Functional Description

RS232 is used as a full duplex serial interface.

Note: Handshake lines (RTS, CTS) are not available. A common ground (chassis) or a proper ground connection is necessary for RS232 operation. If you connect to an external device (e.g., to a PC with an RS232 interface), make sure not to violate the maximum ratings.

See also section *UART - Universal Asynchronous Receiver Transmitter driver* of the API documentation [30].

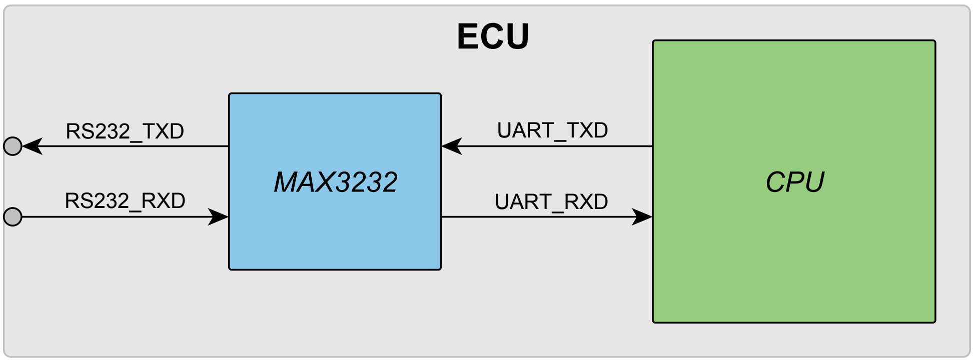

Figure 56: RS232 interface

4.17.3 Maximum Ratings

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
V_{RS232x}	Bus voltage under overload conditions (e.g. short circuit to supply voltages)		-15	+33	V

4.17.4 Characteristics

T_{ECU} = -40. . . +125 °C

Symbol	Parameter	Note	Min.	Max.	Unit
C_{out}	Pin output capacitance		100	150	pF
V_{il}	Input voltage for low level		-22	0.8	V
V_{ih}	Input voltage for high level		2.4	22	V
V_{ol}	Output voltage for low level		-5		V
V_{oh}	Output voltage for high level		+5		V
S_{Tr}	Baud rate			115	kBd

4.18 CAN

4.18.1 Pinout

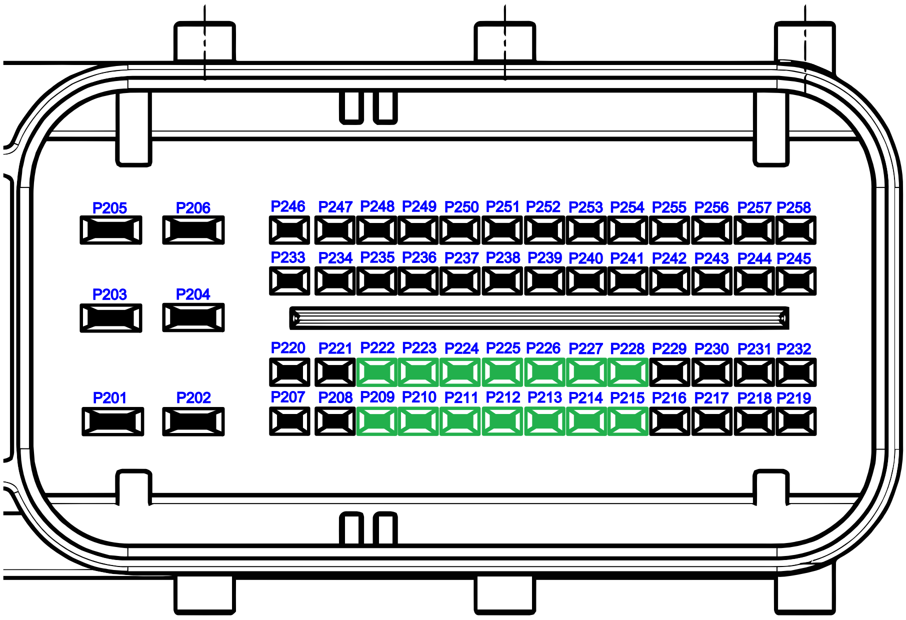

Figure 57: CAN pinout

Pin No.	Function	SW-define
P209	CAN Interface 0 – Low Line	IO_CAN_CHANNEL_0
P222	CAN Interface 0 – High Line	
P210	CAN Interface 1 – Low Line	IO_CAN_CHANNEL_1
P223	CAN Interface 1 – High Line	
P211	CAN Interface 2 – Low Line	IO_CAN_CHANNEL_2
P224	CAN Interface 2 – High Line	
P212	CAN Interface 3 – Low Line	IO_CAN_CHANNEL_3
P225	CAN Interface 3 – High Line	
P213	CAN Interface 4 – Low Line	IO_CAN_CHANNEL_4
P226	CAN Interface 4 – High Line	
P214	CAN Interface 5 – Low Line	IO_CAN_CHANNEL_5
P227	CAN Interface 5 – High Line	
P215	CAN Interface 6 – Low Line	IO_CAN_CHANNEL_6
P228	CAN Interface 6 – High Line	

4.18.2 Functional Description

CAN is a bidirectional twisted pair bus. Needs termination with 120 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. Termination is necessary to enter the recessive state. See Figure 58 on the facing page for details.

Note: 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 bus.

The CAN interface is ISO 11898-2/-5 compliant except for the input resistance. This input resistance is lower due to an RF termination, which drastically improves EMC immunity and is used, required and proven for it's performance in the automotive industry for many years. The differential internal resistance is given in table 4.18.4.

See also section *CAN - Controller Area Network driver* of the API documentation [30].

4.18.2.1 CAN1 on HY-TTC 590E, HY-TTC 590, and HY-TTC 508

Due to the requirements of the ISOBUS standard [21], CAN1 has a lower EMC protection than the other CAN interfaces. The high impedance RF termination is removed. To achieve equivalent RF immunity it is recommended to use CAN1 with a termination. That is, CAN1 should be connected at the terminated end of the CAN bus line. It is recommended to use either an internal CAN termination or an equivalent circuit according to Figure 60 on page 180.

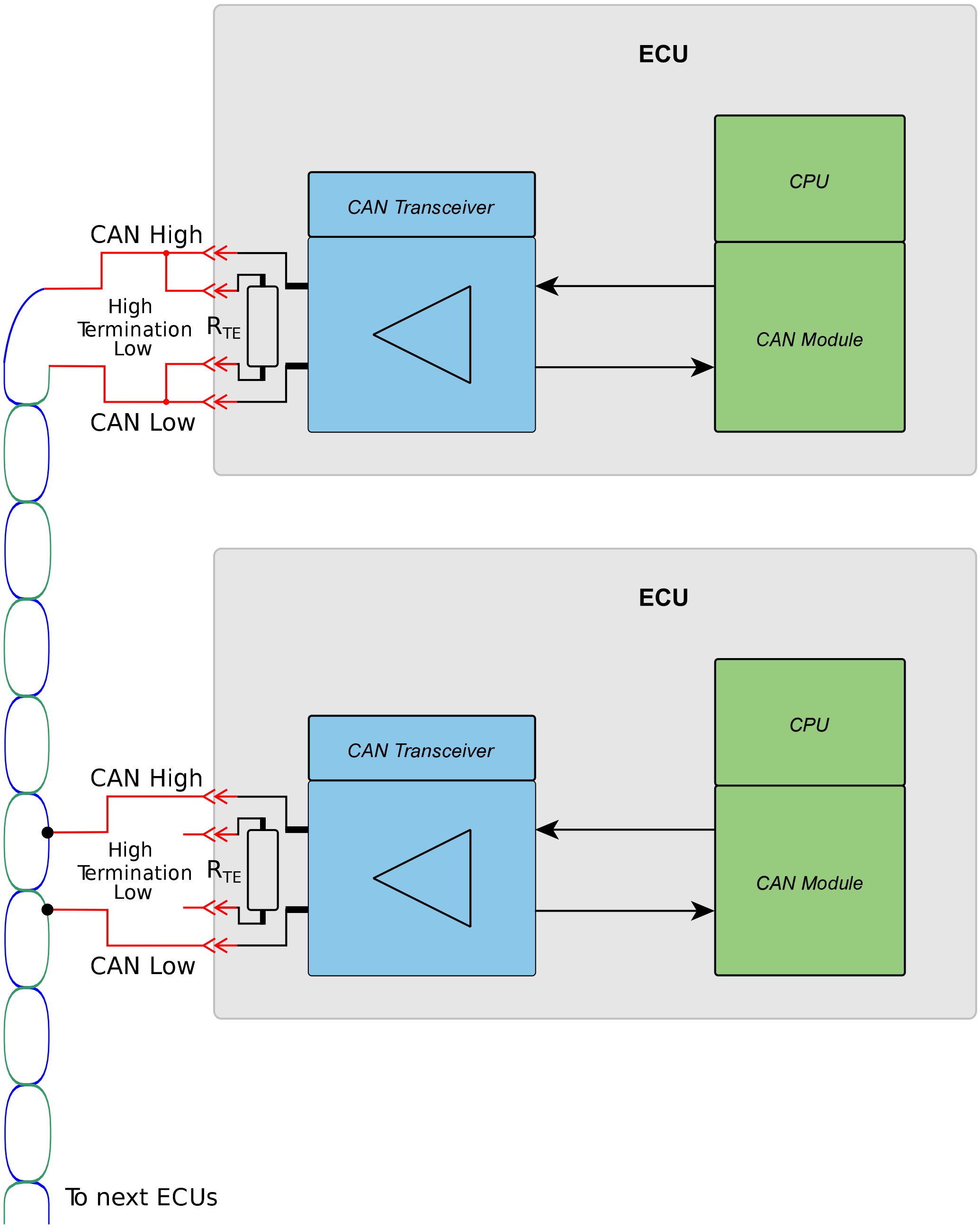

Figure 58: CAN interface

4.18.3 Maximum Ratings

T_{ECU} = -40...+125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
V_{CAN_H}, V_{CAN_L}	Bus voltage under overload conditions (e.g. short circuit to supply voltages)		-25	+33	V

4.18.4 Characteristics

T_{ECU} = -40...+125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin output capacitance			100	pF
$V_{in\text{-}CMM}$	Input common mode range	1	-12	12	V
$V_{in\text{-}dif}$	Differential input threshold voltage (V_{CAN_H} - V_{CAN_L})		0.5	0.9	V
$V_{out\text{-}dif}$	Differential output voltage dominant state (V_{CAN_H} - V_{CAN_L})		1.5	3	V
$V_{out\text{-}dif}$	Differential output voltage recessive state (V_{CAN_H} - V_{CAN_L})		-0.1	+0.1	V
V_{CAN_L}, V_{CAN_H}	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	2,3,4	20	1000	kbit/s
R_{diff}	Differential internal resistance	5	27	29	kΩ
R_{diff}	Differential internal resistance		3.7	3.9	kΩ

Note 1 Due to high current in the cable harness, the individual ground potential of the control units can differ up to several V. This difference will also appear as common mode voltage between a transmitting and a receiving control unit and not influence the differential bus signal, as long as it is within the common mode limits.

Note 2 Pay attention to the limitations of CAN. The arbitration process allows 1 Mbit/s operation only in small networks and reduced wire length. By way of example, a so-called “private CAN”, which is a short point-to-point connection (less than 10 m) between two nodes only, can be operated at 1 MBit/s.

Note 3 For typical network sizes and topologies (networks with stub wires) and more than two nodes, the practical limit is 500 kbit/s.

Note 4 Any value that conforms to CAN protocol standard definition is valid.

Note 5 ISOBUS CAN variant.

4.19 CAN Termination

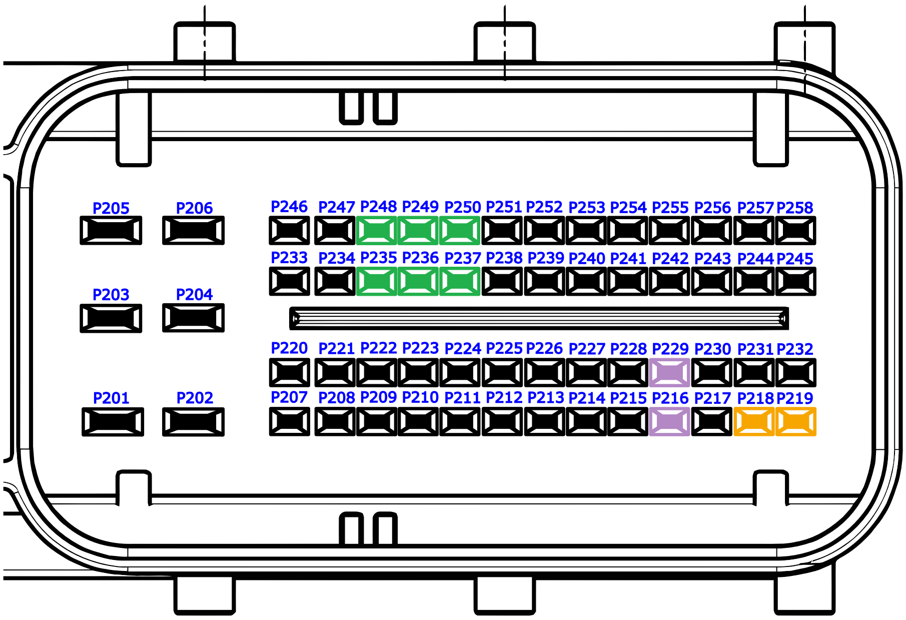

Figure 59: Pinout of CAN termination

Pin No.	Function	Applicable to variants
P235	120 Ω CAN Termination 0 Low	all
P248	120 Ω CAN Termination 0 High	all
P236	120 Ω CAN Termination 1 Low	all
P249	120 Ω CAN Termination 1 High	all
P237	120 Ω CAN Termination 2 Low	all
P250	120 Ω CAN Termination 2 High	all
P216	120 Ω CAN Termination 3 Low	HY-TTC 580, HY-TTC 540, HY-TTC 520, HY-TTC 510
P229	120 Ω CAN Termination 3 High	HY-TTC 580, HY-TTC 540, HY-TTC 520, HY-TTC 510
P218	120 Ω CAN Termination 3 High	HY-TTC 590E, HY-TTC 590, HY-TTC 508
P219	120 Ω CAN Termination 3 Low	HY-TTC 590E, HY-TTC 590, HY-TTC 508

4.19.2 Functional Description

For easy termination of the CAN bus, there are four built in 120 Ω termination resistors on the HY-TTC 500 which are accessible via 2 connector pins each. They can be used for any CAN port.

The 120 Ω termination of a control unit is realized with two serial 60 Ω resistors (split termination). To get an impedance of 60 Ω on the whole bus, a termination resistor of 120 Ω is required in two control units.

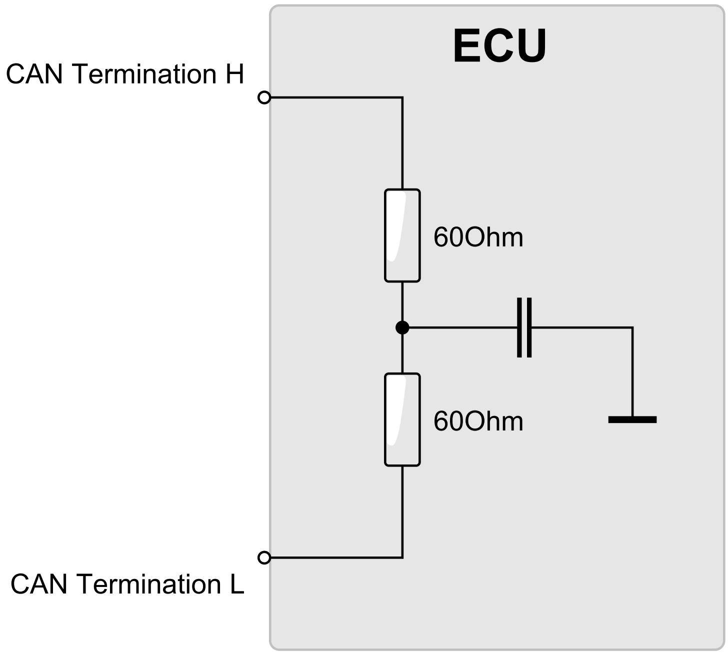

Figure 60: Optional CAN termination

4.20 Ethernet

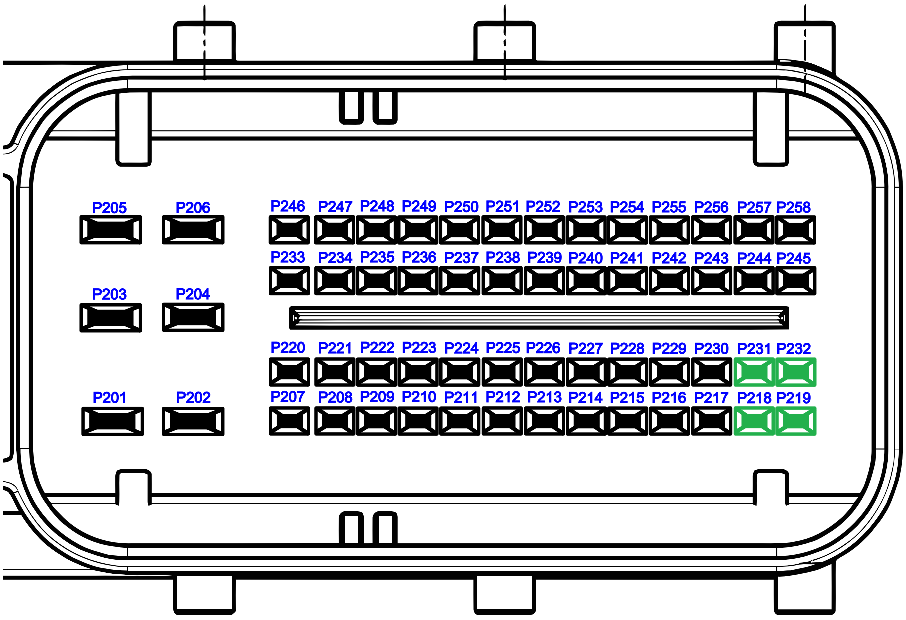

Figure 61: Ethernet pinout

Pin No.	Function	SW-define	Applicable to variants
P218	Ethernet Differential Transmit – TD+	IO_DOWNLOAD, IO_UDP	HY-TTC 580
P219	Ethernet Differential Transmit – TD-		HY-TTC 580
P231	Ethernet Differential Receive – RD-		HY-TTC 580
P232	Ethernet Differential Receive – RD+		HY-TTC 580

4.20.2 Functional Description

The Ethernet interface supports application download and the UDP communication protocol.

The 10/100 Mbit/s full duplex Ethernet port is designed for IEEE 802.3 compliance. However, there is no standard Ethernet connector provided, the Ethernet signals are located on the main connector.

Make sure to use appropriate cabling according to the Ethernet standard. Use at least an Ethernet CAT3 cable for a transmission speed of 10 Mbit/s and an Ethernet CAT5 cable for a transmission speed of 100 Mbit/s. In a noisy environment, it is recommended to use shielded cables.

See also sections *IO_UDP* and *IO_DOWNLOAD* in the API documentation [30].

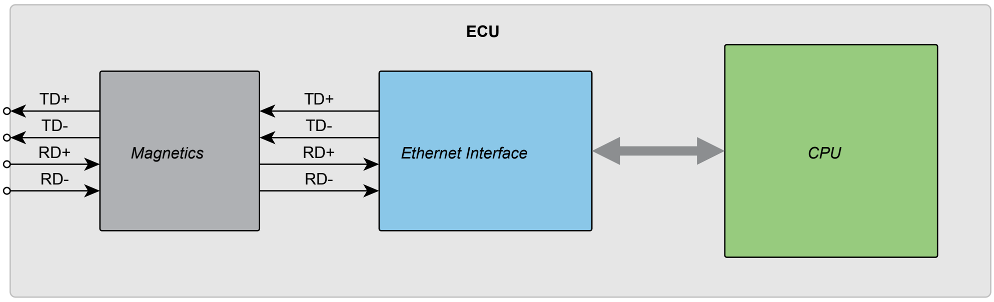

Figure 62: Ethernet interface

4.20.3 Maximum Ratings

T_{ECU} = −40...+125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
$V_{in\text{-}CMM}$	Input common mode voltage range 50/60 HZ AC, 60 s test duration		0	750	V_{RMS}

4.21 BroadR-Reach®

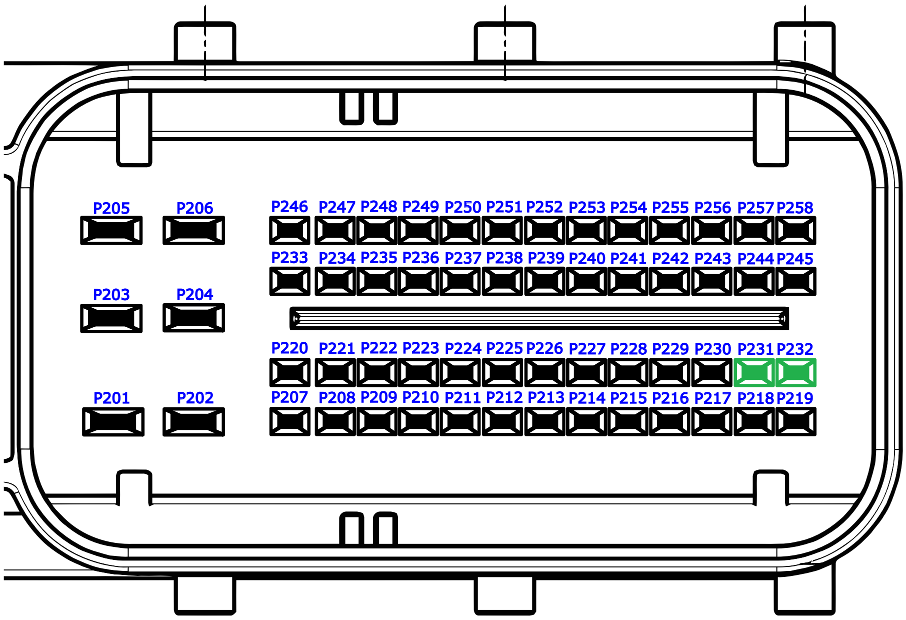

Figure 63: 100BASE-T1 Ethernet pinout

Pin No.	Function	SW-define	Applicable to variants
P231	100BASE-T1 Ethernet TRX-	IO_DOWNLOAD, IO_UDP	HY-TTC 590, HY-TTC 590E, HY-TTC 508
P232	100BASE-T1 Ethernet TRX+		HY-TTC 590, HY-TTC 590E, HY-TTC 508

4.21.2 Functional Description

The standardized BroadR-Reach® (also known as 100BASE-T1 Ethernet) link is an advancement of the IEEE 802.3 100Base-TX Fast Ethernet standard and was standardized by OPEN ALLIANCE. It uses a single unshielded twisted pair cable (UTP) and is therefore low in costs. The 100BASE-T1 Ethernet link is capable of 100 MBit/s full-duplex transmission rate.

Typical applications are

- IP-based camera links
- driver assistance systems
- in-vehicle backbone
- infotainment

4.21.3 Maximum Ratings

$T_{ECU} = -40...+125$ ℃

Symbol	Parameter	Note	Min.	Max.	Unit
V_{BRR}	Bus voltage under overload conditions (i.e., short circuit to supply voltages)		-32	+32	V

4.21.4 Characteristics

$T_{ECU} = -40...+125$ ℃

Symbol	Parameter	Note	Min.	Max.	Unit
$V_{in\text{-}CMM}$	Input common mode range		-32	+32	V
$V_{out\text{-}dif}$	Differential output voltage		-1	+1	V
V_{BRR_P}, V_{VBRR_M}	Common mode idle voltage		-0.1	+0.1	V
S_{Tr}	Bit rate			100	Mbit/s
$R_{in\_AC\_dif}$	Input resistance AC		90	110	Ω
$R_{in\_DC\_dif}$	Input resistance DC		1.8	2.2	kΩ

4.22 Real-Time Clock (RTC)

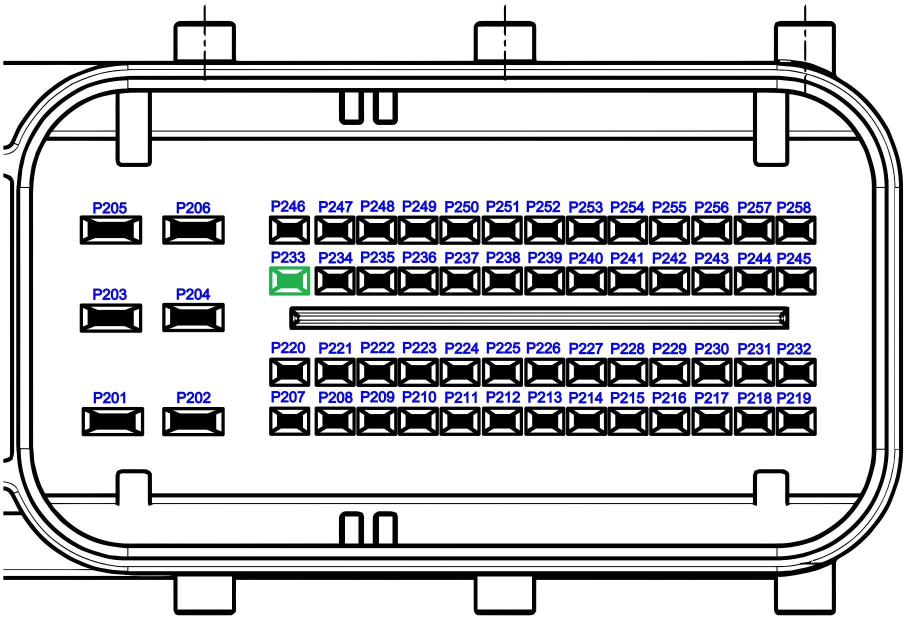

Figure 64: RTC pinout

Pin No.	Function	SW-define
P233	Real-Time Clock Backup Battery	IO_RTC

4.22.2 Functional Description

The HY-TTC 500 includes a real-time clock with a backup power system for exact system time- and date-keeping after every power cycle.

The real-time clock module is either supplied by the internal 5 V supply, vehicle battery, or by the external RTC battery pin.

When HY-TTC 500 is connected to the vehicle battery via the BAT+ CPU pin, the RTC is supplied by the vehicle battery independent of whether the device is operational or in power-off mode. When both the RTC backup battery and BAT+ CPU are disconnected, the real-time clock is supplied by an internal capacitor. The capacitor provides approximately 10 minutes of backup time when fully charged. Charging an empty capacitor takes at least 5 minutes.

See also section *RTC - Real Time Clock driver* of the API documentation [30].

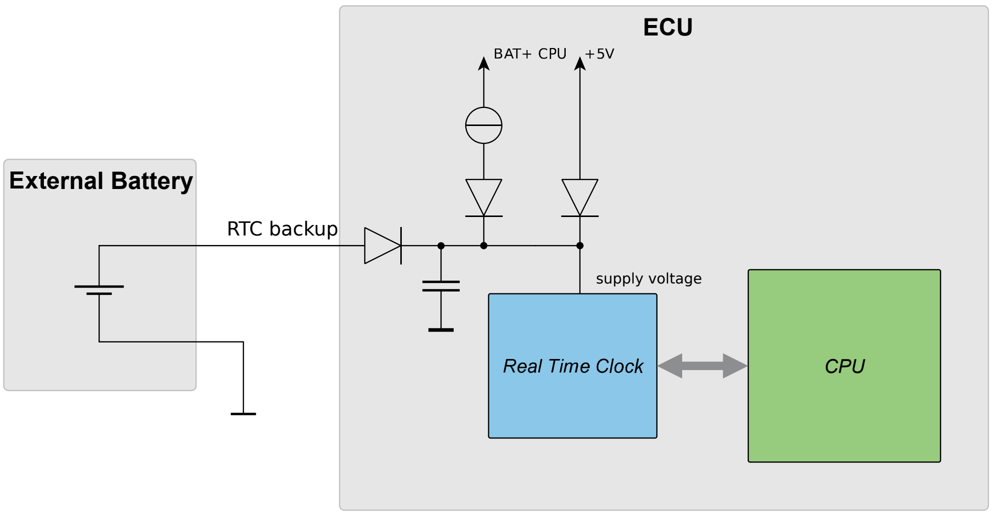

Figure 65: Voltage supply of real-time clock

4.22.3 Maximum Ratings

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
V_{in}	Input voltage		-1	+33	V

4.22.4 Characteristics

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
C_{in}	Pin input capacitance		8	12	nF
I_{in}	Steady state input current (after 1 min, 3.6 V)			10	µA
I_{in}	Steady state input current for high voltage operation (after 1 min, 16 V)			260	µA
I_{in}	Steady state input current for high voltage operation (after 1 min, 32 V)			600	µA
V_{in}	Input voltage		2.5	32	V
V_{in}	Input voltage	1	1.8	32	V
Δ t/day	Time variation per day at +25 ℃			± 1.5	s/day
RTC_{res}	Real-time clock resolution		1		s

Note 1 T_{ECU} = -40. . . +85 ℃

5 Internal Structure

5.1 Safety Concept

If HY-TTC 500 is used in safety-critical applications, you must follow the requirements specified in the Safety Manual [29].

5.1.1 Overview Safety Concept

The following picture descibes all possible (application-controlled) enable/disable paths for the HY-TTC 500 powerstages.

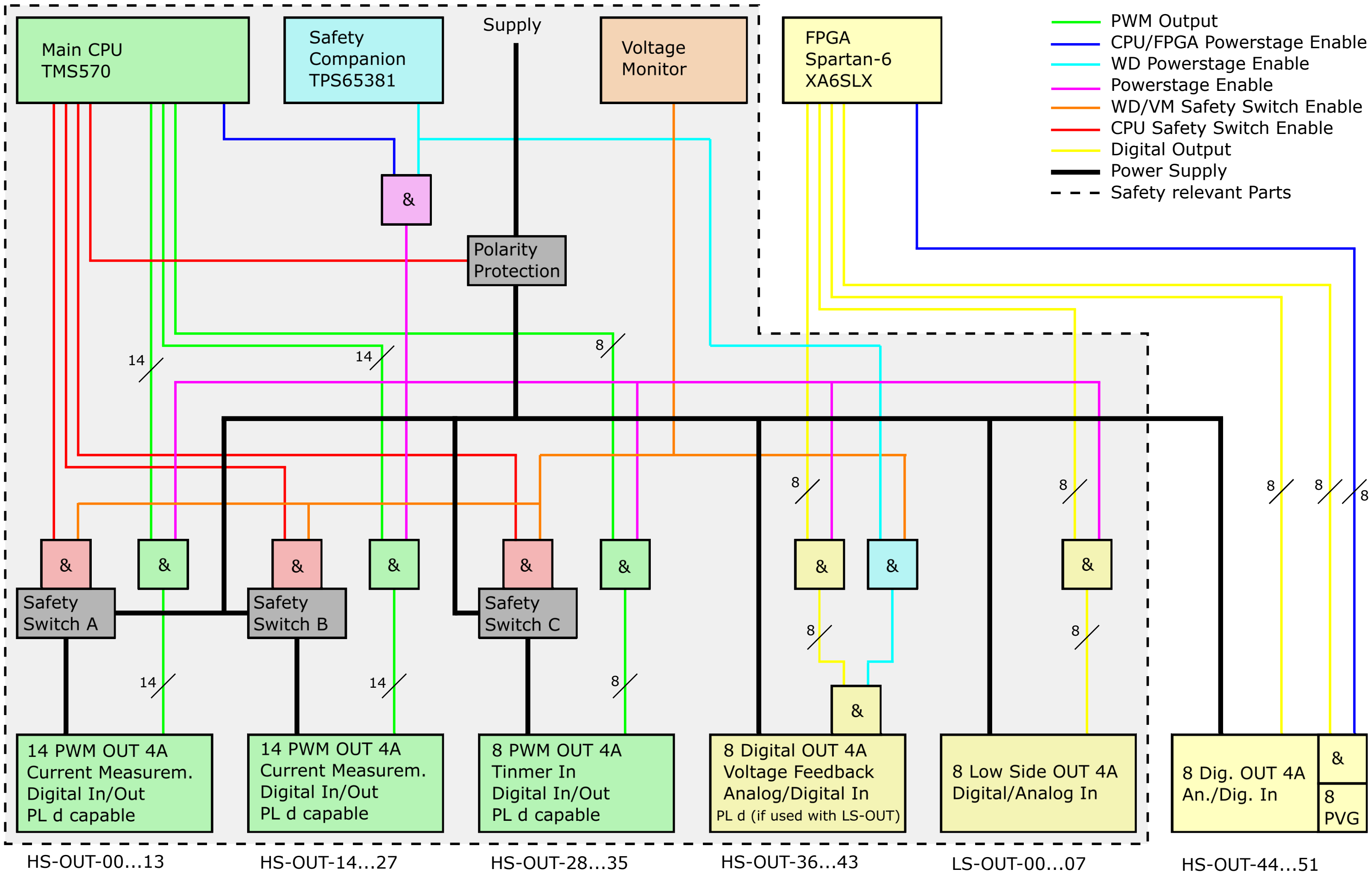

Figure 66: Overview safety concept HY-TTC 500

5.2 Thermal Management

5.2.1 Board Temperature Sensor

5.2.1.1 Pinout

Pin No.	Function	SW-define
No connector pin	Internal board temperature sensor	IO_ADC_BOARD_TEMP

5.2.1.2 Functional Description

To measure the temperature T_{ECU} within the housing, there is a temperature sensor located on the printed circuit board. This sensor allows monitoring of the internal board temperature for diagnostic purposes and monitoring of safety features.

Dependent on the T_{ECU} board temperature, the maximum current limit for High- and Low-side output stages is adjusted, see e.g. Section 4.12.4.1 on page 141. This is a strategy to allow higher current consumption at lower temperatures and to bring the ECU immediately to a safe state and switch off loads if over temperature is detected. See Section 5.2.2 on the next page for temperature limits triggering the safe state.

All input/output tolerance characteristics stated in this System Manual are worst case tolerances and are respected to the internal worst ECU temperature T_{ECU}. At lower $T_{ECU}/T_{ambient}$ temperature and/or lower loads, the tolerances are better.

The (internal) ECU temperature T_{ECU} is close to ambient temperature, when there is no load driven by the power stages at all. The ECU temperature may rise by 40 K above ambient temperature, when there is significant output load (many outputs activated with high load current at the same time) and no airflow supports cooling of the housing. Many applications tend to be somewhere in the middle. Reading out the ECU temperature during system development is a useful feature to analyze the application-specific thermal load and mounting situation. For more information please ask your local sales representative.

5.2.2 Characteristics

T_{ECU} = -40. . . +125 ℃

Symbol	Parameter	Note	Min.	Max.	Unit
T_m	Temperature measurement range		-40	+125	℃
$T_{tol\text{-}m}$	Temperature tolerance at 120 ℃		-3	+3	K
$T_{safe\ state}$	Temperature limit	1	-40	+125	℃

Note 1 A temperature (including measurement tolerance) below or above the specified limits immediately triggers the safe state

6 Application Notes

6.1 Cable Harness

The following general layout rules for the cable harness must be obeyed to enable safe operation of HY-TTC 500.

The ECU is limited to a total load current for the power stages connected to the BAT+ Power pins. When all loads are tied toward ground, the load current will be carried by these supply pins as well. As each contact pin is thermally limited to 10 A, multiple supply pins work in parallel for the power stages supply. So, the system designer must be careful with the cable harness design to ensure an even supply current distribution on all pins.

Example: Do not use a cable with a length of two meters and a large diameter for a connection between a fuse box and the ECU and do not crimp it to some piggy tails with a small diameter in the connector area. Small differences between the contact pressure can lead to a big imbalance. In the worst case, one contact carries most of the current load and is overloaded at maximum current. It is necessary to use six wires with the same total cross sectional area as one thick cable. All wires must have the same length and diameter. In this case, an even current distribution can be achieved, even with slightly different contact resistances.

6.2 Handling of High-Load Current

6.2.1 Load Distribution

The permanent input current of the HY-TTC 500 $I_{in\text{-}max}$ is limited due to thermal limits and contact current limits. As the power stages do not have negligible power dissipation, each load current leads to a rise in temperature within the device. To ensure proper operation of the HY-TTC 500 in its temperature range (-40 ℃ to +85 ℃) the total current $I_{in\text{-}total}$ driven by the power stages must be limited and the load must be evenly distributed. If two output stages are operated in mutually exclusive states (e.g. output channel 00 is only activated in state 1 and output channel 01 is only activated in state 2; never activated at the same time), then, as a rule of thumb, these outputs should be driven by a double-channel high-side power stage due to only one active channel at a time.

6.2.2 Total Load Current

Operating all power stages ON with maximum rated current (4 A) that would result in a load current $I_{in\text{-}total}$ in excess of 200 A, which is far beyond any allowed limit to ensure no violation of the allowed contact current limit as well as overall thermal limits.

Therefore, the maximum allowed load current, which can be controlled simultaneously with different power stages, is separately given as the maximum total load current $I_{in\text{-}total}$. This value can only be applied if an equal load distribution over different power stages is ensured - which implicit a different $I_{in\text{-}total}$ limit set by the different number of power stages in each HY-TTC 500 variant, e.g. the same current distributed over 52 output stages cannot be driven with 38 output stages due to the square rise of the power dissipation of the output stages and the respective thermal limit.

Maximum total load current $I_{in\text{-}total}$ for each variant at different T_{ECU}:

Variant	$I_{in\text{-}total}$ [A], T_{ECU} = -40...+85 ℃	$I_{in\text{-}total}$ [A], T_{ECU} = -40...+125 ℃
HY-TTC 580	60	45
HY-TTC 540	50	40
HY-TTC 520	40	30
HY-TTC 510	40	30
HY-TTC 590E	60	45
HY-TTC 590	60	45
HY-TTC 508	40	30

Table 23: Total Load Current $I_{in\text{-}total}$

6.2.2.1 Calculation of the battery supply current

For the PWM- and digital output stage supply pins BAT+ Power, up to 6 pins can be used in parallel to increase the overall current capability.

For the maximum battery supply current of 60 A, all 6 pins must be used in parallel with the maximum possible wire size (FLRY type) to reduce voltage drop and prevent overheating of the crimp contact. To define a proper cabling, it is important to calculate the maximum average battery supply current first.

For a single digital output power stage it is simply calculated as:

$$I_{\text{bat}} = I_{\text{power-stage}} \tag{1}$$

If for example one power stage is loaded with 2 A, it will also load the battery supply with 2 A.

For PWM output stages with inductive load it is calculated as:

$$I_{\text{bat}} = \frac{I_{\text{power-stage}} * (duty\ cycle)}{100} \tag{2}$$

Example: A load current of 2 A with a duty cycle of 25 % results in an average battery current of 0.5 A. More precisely explained: a single power stage with 100 Hz PWM frequency will draw 2.5 s in duration 2 A out of the battery followed by 7.5 ms with 0 A. The average current is 0.5 A, the rms current is higher.

However, with a couple of used PWM power stages, there is no significant difference between average and rms current, due to different phase operation of the individual power stages.

Once, the maximum battery supply current for the individual application is calculated, the required minimum number of battery supply wires and/or cabling diameter can be defined.

6.3 Inductive Loads

6.3.1 Inductive Loads at PWM Outputs

Inductive loads in PWM operation generate current through the freewheeling diodes, but these diodes have, at the same current, a power dissipation that is several times greater than the high-side switches themselves.

Therefore the duty cycle has a great influence on the power dissipation of the output devices. The duty cycle results from the relationship between coil resistance and supply voltage. A low resistance at a high supply voltage is the worst combination, because it results in a low duty cycle and, thus, in a long conduction time of the diodes.

6.3.2 Inductive Loads at Low Side Switches

For load inductivities >100 mH, either the current has to be lower or an external freewheeling diode or clamping device parallel to the coil has to be used. The clamping device has to clamp below 50 V.

Examples for clamping devices are: varistor, bidirectional Transzorb® diode, Zener diode with anti-serial diode or a suitably sized resistor.

A resistor can be calculated as 50 V/(maximum possible coil current). It can be a cost-effective solution. But it increases steady state power dissipation, so it may not be suitable in all cases.

6.4 Ground Connection of Housing

The HY-TTC 500 housing is not directly connected to ground. In case of chassis mounting this prevents ground loops or excessive current flow through the Negative Power Supply (BAT-) pins and cables in case of partly power connection loss in the negative supply rail of the vehicle.

Instead of direct connection, the housing is capacitively connected to BAT-. In order to discharge static electricity, a 1 MΩ resistor is equipped between housing and BAT-.

Note: It is allowed to mount the housing without any additional isolation directly to the vehicle chassis.

6.5 Motor Control

This application note describes control options for directly driving a DC-motor with outputs of the HY-TTC 500.

6.5.1 Motor Types supported

- Standard brushed DC-motors with defined power rating
- Motors with end position switches and diodes for rotation direction dependent automatic stop at full excursion.
- Motors with integrated electronic control (including brushless DC-motors) up to a well-defined current limit and a maximum input capacitance.

Motors running at different speed by using different windings are not supported.

6.5.2 Direct Control Options

The following control options are described into details in the following chapters:

6.5.2.1 Depending on Direction

- Unidirectional drive
- Bidirectional drive

6.5.2.2 Depending on Single Motor / Motor Group

- Single motor drive
- Motor cluster

6.5.2.3 Depending on Control

- PWM operation
- Steady state operation

6.5.2.4 Depending on stalled Motor Current

- 0 to 2 A max. motor current
- 2 to 4 A max. motor current
- 4 to 16 A max. motor current
- 16 A and higher

6.5.3 Motor Details

6.5.3.1 Start Current

A typical standard (brushed) DC-motor is driven by a current through the rotor winding and permanent magnets in the stator. The rotor winding is normally made out of copper wire with a well-defined DC-resistance. The DC-resistance defines the maximum possible current, when the motor does not rotate (stalled motor). The same current shows as peak current in the moment when supply voltage is switched on the motor. By taking up speed the motor builds up an electro motoric force (EMF) that works against the voltage applied on the motor terminals thus reducing the virtual voltage on the winding -> the current drops. When the motor stabilizes at nominal speed (depending on motor voltage) and the motor runs idle (no mechanical load) the current drops to a value 10 to 100 times smaller than the start current, depending on motor friction in the bearings and other constructive details.

This stall current (= max. motor current with blocked motor) is required to classify the motor power. This has a main impact on possible motor control options and even number of paralleled power stages, if required.

6.5.3.2 Start Current at low Temperatures

The motor windings are made out of copper. The winding resistance goes down towards lower temperature, by approx. 0.4 % / K. This means that at -40 ℃ the winding resistance is lower than the nominal value at +25 ℃ by 26 %. Depending on the lowest operating temperature this effect needs to be considered. In our example that turns a 2 A motor (@+25 ℃) into a 2.7 A motor (@-40 ℃).

6.5.3.3 Battery Voltage Impact

The start current increases proportionally with higher battery voltage. In our assumption the battery voltage of a 12 V system stays below 14 V and for a 24 V system below 28 V. Often the DC resistance of the motor is not specified but the maximum current at nominal voltage. Any maximum current rating of the motor for a nominal voltage needs to be modified for the maximum voltage that the system actually can have.

6.5.3.4 Motors with Limit Switch

Some motor assemblies are fitted with an limit switch turning off the motor power when a maximum position is reached. To allow reversing the motor to move out of this position a diode is placed in parallel to the switch. Operating these kinds of motors is no problem. Care should be taken that diagnostics may detect an open load in the end position which is intended with this kind of operation and no failure.

6.5.3.5 Motors with Electronics Inside

There is no general do or don't with that kind of motors. Essential is only the maximum start current in excess of 50 ms (to be found in chapter Motor classification) and the maximum capacitive load of the motor electronics:

- Max 5 μF when used with H-bridge
- Max 200 μF when used with a single high side power stage (unidirectional supply)

6.5.3.6 Unidirectional Motor Drive

This uses in the simplest case just one high side power stage.

6.5.3.7 Bidirectional Motor Drive

By configuring an H-bridge out of 4 power stages a reverse operation of the motor is possible.

6.5.3.8 Active Motor Brake

With bidirectional motor drive active braking by shorting the motor terminals is supported.

6.5.3.9 Motors Reversing with / without Braking

Motor reversing out of full speed can lead to unexpected high motor current. The cause is that for example a 24 V motor running at nominal speed has a back EMF of almost 24 V with the same sign as the voltage applied. By sudden revering the EMF-voltage adds to the terminal voltage, which means the motor current is as high as with starting at 48 V battery voltage. In other words, the peak motor current is doubled by sudden reverse. For small motors this is neither a problem to the motor nor to the driving power stages. For bigger motors a braking phase needs to be inserted first followed by the reversing command.

6.5.3.10 PWM Operation / steady State Control

In general PWM operation is not recommended as the PWM frequency for high efficient motors often require frequencies in excess of 10 kHz. A PWM frequency so high would cause lots of unacceptable electromagnetic noise (EMI) or dramatic switching losses or both. For small motors we can use a 200 Hz PWM instead. This causes a significant torque ripple which might be desirable for slow positioning of the motor with the need to prevent static friction.

As mentioned in section 6.5.3.9 above, motors produce a back EMF when running. With PWM controlled motors the motor is essentially free running between the PWM pulses. Depending on operating voltage and motor speed this back EMF can sometimes lead to false diagnostic errors.

6.5.3.11 Maximum Average Current (PWM and Digital Power Stages)

The maximum steady state motor current is 4 A (up to +85 °C internal ECU temperature) or 3 A (over +85 °C). This comes from the limits of the power stage used. Normally the start current limits the choice of suitable motors and not the supply current, when the motor is running. The motor current is measured in the ECU and can be used for control / diagnostic purposes.

6.5.3.12 Peak Current Bidirectional Drive (Digital Power Stages only)

The digital (non-PWM) power stages tolerate inrush current of up to 6 A for 100 ms. Fast accelerating motors show first an inrush current peak followed by a reduction in current to less than 50 % of the initial current after 20 ms. In other words, most motors that start with 6 A drop to less than 4 A in 100 ms. Motors with that kind of fast acceleration will work properly even with a winding resistance that is lower by a factor of 1.5 (stall current 6 A instead of 4 A).

6.5.3.13 Peak Current Unidirectional Drive (Digital Power Stages only)

Single high side power stages tolerate an inrush current that linearly declines from 16 to 6 A in 50 ms. Fast accelerating motors show after an initial current peak a reduction in current to less than 50 % after 20 ms. Motors with that kind of fast acceleration may have a winding resistance that is lower by a factor of 4 (stall current 16 A instead of 4 A).

6.5.4 Motor Classification

6.5.4.1 Independent from Speed Class

The most conservative limits apply for slow accelerating motors, found in the following section:

6.5.4.1.1 Tiny Motors (0 to 2 A)

This class gives the widest choice of control options.

	12 V System	24 V System
Max. battery voltage [1]	14 V	28 V
Motor blocked current	0 to 2 A	
DC-resistance	>=7.0 Ω	>=14.0 Ω
Unidirectional drive	yes	yes
Bidirectional drive	yes	yes
Active motor braking	yes	yes
Reverse without brake	yes	yes
PWM operation	yes	yes
Suitable high side power stages	PWM power stages, digital HS power stages	

[1] For other max. battery voltage please recalculate winding resistance (R = U / I).

6.5.4.1.2 Small Motors (2 to 4 A)

For this class some restrictions apply.

	12 V System	24 V System
Max. battery voltage [1]	14 V	28 V
Motor blocked current	2 to 4 A	
DC-resistance	>=3.5 Ω	>=7.0 Ω
Unidirectional drive	yes	yes
Bidirectional drive	yes	yes
Active motor braking	yes	yes
Reverse without brake	no	no
PWM operation	no	no
Suitable high side power stages	PWM power stages, digital HS power stages	
Maximum periodic DC peak current [2]	4 A (T_{ECU} < +85 °C)	
Maximum periodic DC peak current [2]	3 A (T_{ECU} > +85 °C)	

[1] For other max. battery voltage please recalculate winding resistance (R = U / I).

[2] Some motors draw a significant ripple current. The highest periodic peaks shall be below that limit.

6.5.4.1.3 Medium Power Motors (4 to 14 A) This class needs paralleled power stages. In the example below each switch utilizes 4 power stages in parallel for each switch. This in theory quadruples the power rating. In practice depending on close-to-perfect cabling a de-rating of maximum current (14 A instead of 16 A) is foreseen.

	12 V System	24 V System
Max. battery voltage [1]	14 V	28 V
Motor blocked current	4 to 14 A	
DC-resistance	>=1.0 Ω	>=2.0 Ω
Unidirectional drive	yes	yes
Bidirectional drive	yes	yes
Active motor braking	yes	yes
Reverse without brake	no	no
PWM operation	no	no
Suitable high side power stages	digital HS power stages only	
Maximum periodic DC peak current [2]	12 A (T_{ECU} < +85 °C)	
Maximum periodic DC peak current [2]	10 A (T_{ECU} > +85 °C)	

[1] For other max. battery voltage please recalculate winding resistance (R = U/I).
[2] Some motors draw a significant ripple current. The highest periodic peaks shall be below that limit.

6.5.4.2 Fast Accelerating Motors only

Higher inrush current,is allowed for fast accelerating motors. Most actuator motors fall into this category. Depending on operation mode different limits apply:

6.5.4.2.1 Bidirectional (max. 6 A)

For this class some restrictions apply.

	12 V System	24 V System
Max. battery voltage [1]	14 V	28 V
Motor blocked current	<6 A	
DC-resistance	>=2.35 Ω	>=4.7 Ω
Unidirectional drive	yes	yes
Bidirectional drive	yes	yes
Active motor braking	yes	yes
Reverse without brake	no	no
PWM operation	no	no
Suitable high side power stages	digital HS power stages only	
Maximum periodic DC peak current [2]	4 A (T_{ECU} < +85 ℃)	
Maximum periodic DC peak current [2]	3 A (T_{ECU} > +85 ℃)	
Inrush current drops after 50ms to	<6 A	
Inrush current drops after 50ms to	<4 / 3 A (depending on ECU temperature)	

[1] For other max. battery voltage please recalculate winding resistance (R = U/I).
[2] Some motors draw a significant ripple current. The highest periodic peaks shall be below that limit.

6.5.4.2.2 Bidirectional (max. 16 A) For this class each low side switch is built out of 4 switches working in parallel to increase current handling. The high side switches are still single switches.

	12 V System	24 V System
Max. battery voltage [1]	14 V	28 V
Motor blocked current	<16 A	
DC-resistance	>=0.88 Ω	>=1.75 Ω
Unidirectional drive	yes	yes
Bidirectional drive	yes	yes
Active motor braking	yes	yes
Reverse without brake	no	no
PWM operation	no	no
Suitable high side power stages	digital HS power stages only	
Maximum periodic DC peak current [2]	4 A (T_{ECU} < +85 °C)	
Maximum periodic DC peak current [2]	3 A (T_{ECU} > +85 °C)	
Inrush current drops after 50ms to	<6 A	
Inrush current drops after 50ms to	<4 / 3 A (depending on ECU temperature)	

[1] For other max. battery voltage please recalculate winding resistance (R = U/I).
[2] Some motors draw a significant ripple current. The highest periodic peaks shall be below that limit.

6.5.4.2.3 Bidirectional (max. 20 A) For this class each high and low side switch is built out of 4 switches working in parallel to increase current handling. This in theory quadruples the power rating. In practice depending on close-to-perfect cabling a de-rating of maximum current (20 A instead of 24 A) is foreseen.

	12 V System	24 V System
Max. battery voltage [1]	14 V	28 V
Motor blocked current	<20 A	
DC-resistance	>=0.7 Ω	>=1.4 Ω
Unidirectional drive	yes	yes
Bidirectional drive	yes	yes
Active motor braking	yes	yes
Reverse without brake	no	no
PWM operation	no	no
Suitable high side power stages	digital HS power stages only	
Maximum periodic DC peak current [2]	12 A (T_{ECU} < +85 °C)	
Maximum periodic DC peak current [2]	10 A (T_{ECU} > +85 °C)	
Inrush current drops after 50ms to	<12 / 10 A (depending on ECU temperature)	

[1] For other max. battery voltage please recalculate winding resistance (R = U/I).
[2] Some motors draw a significant ripple current. The highest periodic peaks shall be below that limit.

	12 V System	24 V System
Max. battery voltage [1]	14 V	28 V
Motor blocked current	<16 A	
DC-resistance	>=0.88 Ω	>=1.75 Ω
Unidirectional drive	yes	yes
Bidirectional drive	no	no
Active motor braking	no	no
Reverse without brake	no	no
PWM operation	no	no
Suitable high side power stages	digital HS power stages only	
Maximum periodic DC peak current [2]	4 A (T_{ECU} < +85 °C)	
Maximum periodic DC peak current [2]	3 A (T_{ECU} > +85 °C)	
Inrush current drops after 50ms to	<6 A	
Inrush current drops after 50ms to	<4 / 3 A (depending on ECU temperature)	

6.5.4.2.4 Unidirectional (max. 16 A)

[1] For other max. battery voltage please recalculate winding resistance (R = U/I).
[2] Some motors draw a significant ripple current. The highest periodic peaks shall be below that limit.

6.5.4.2.5 Unidirectional (max. 32 A)

For this class two digital high side power stages are operated in parallel.

	12 V System	24 V System
Max. battery voltage [1]	14 V	28 V
Motor blocked current	<32 A	
DC-resistance	>=0.4 Ω	>=0.8 Ω
Unidirectional drive	yes	yes
Bidirectional drive	no	no
Active motor braking	no	no
Reverse without brake	no	no
PWM operation	no	no
Suitable high side power stages	digital HS power stages only	
Maximum periodic DC peak current [2]	8 A (T_{ECU} < +85 °C)	
Maximum periodic DC peak current [2]	6 A (T_{ECU} > +85 °C)	
Inrush current drops after 50ms to	<12 A	
Inrush current drops after 50ms to	<8 / 6 A (depending on ECU temperature)	

[1] For other max. battery voltage please recalculate winding resistance (R = U/I).
[2] Some motors draw a significant ripple current. The highest periodic peaks shall be below that limit.

6.5.5 Connection

6.5.5.1 Unidirectional Single Power Stage

Figure 67 on this page shows the battery wiring for maximum total load current. This kind of wiring is used to increase output current capability. It is strongly recommended to support equal distribution of current between the power supply pins. This implies to use cables of same diameter and same wire length in parallel. In this example all power supply pins (BAT+ and GND) are connected to cable of maximum diameter supported by the appropriate connector pin. The cables in parallel are going to a distribution point (for example in the fuse box) and from there with a bigger diameter all the way to the battery.

The return pin of the motor is connected not direct to the ECU ground but to somewhere else, perhaps to the chassis. In this case significant voltage drops may occur between ECU and motor ground connection. This can lead to unexpected fluctuations in motor voltage and motor current.

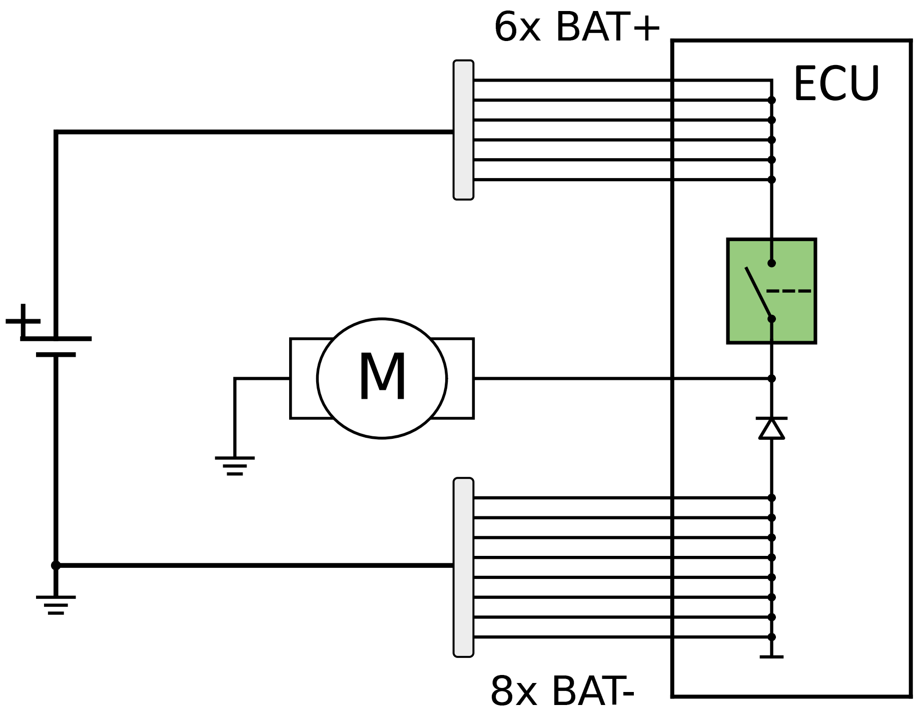

Figure 67: Unidirectional Single Power Stage

A better solution for achieving less voltage drop in the return path shows the Figure 68 on the current page.

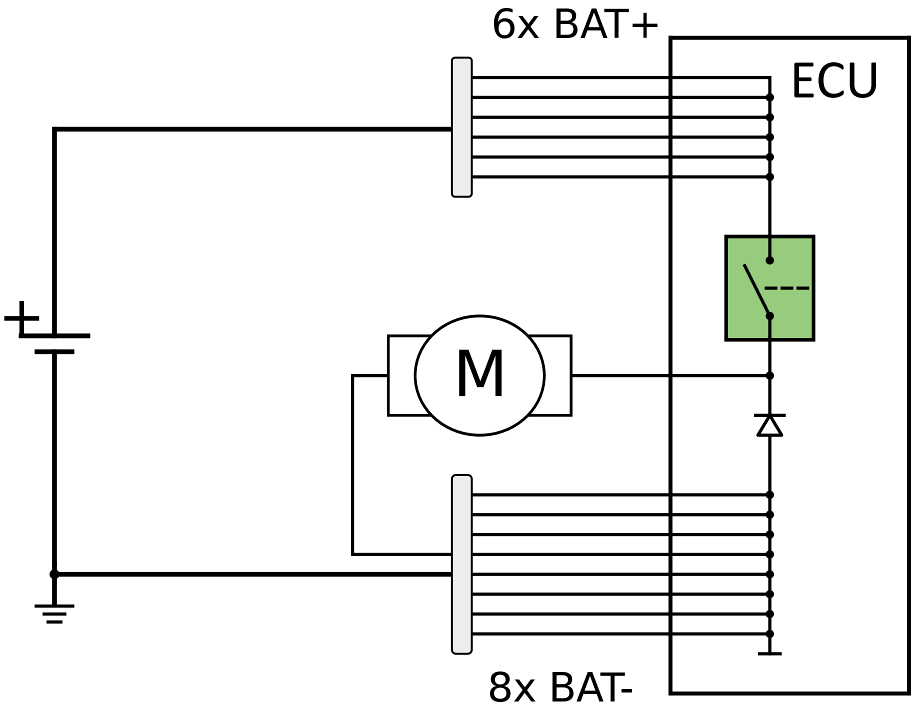

Figure 68: Unidirectional Single Power Stage

6.5.5.2 Unidirectional Double Power Stage

Higher current can be achieved by paralleling output stages, see Figure 69 on this page. Please observe the use of cables of same diameter and same wire length in parallel on the power stages as well.

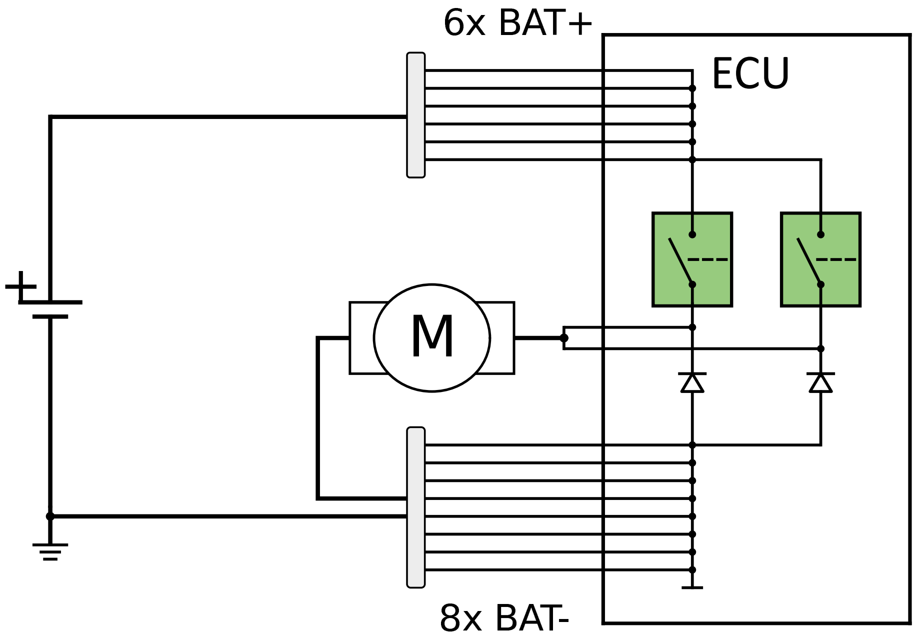

Figure 69: Unidirectional Double Power Stage

6.5.5.3 Bidirectional H-bridge (Single Power Stages)

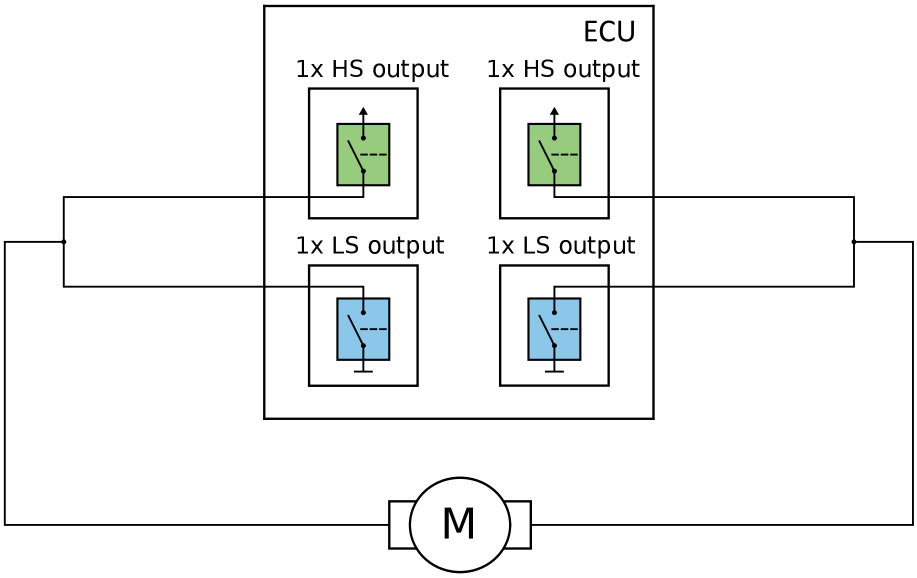

Figure 70: Bidirectional H-bridge (Single Power Stages)

6.5.5.4 Bidirectional H-bridge (Multiple Low Side Power Stages)

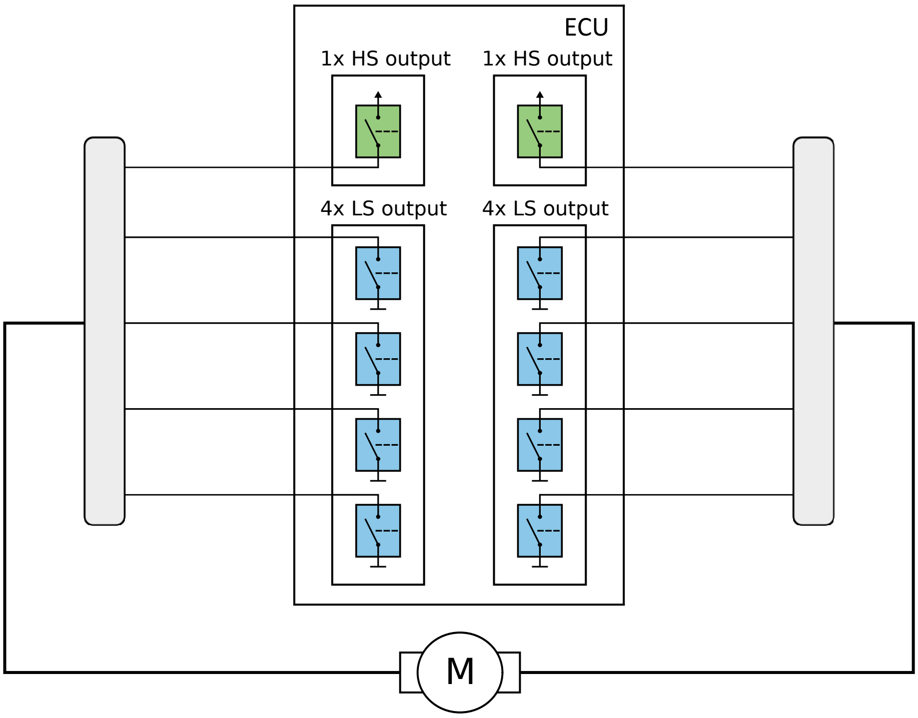

Figure 71: Bidirectional H-bridge (Multiple Low Side Power Stages)

6.5.5.5 Bidirectional H-bridge (Multiple High and Low Side Power Stages)

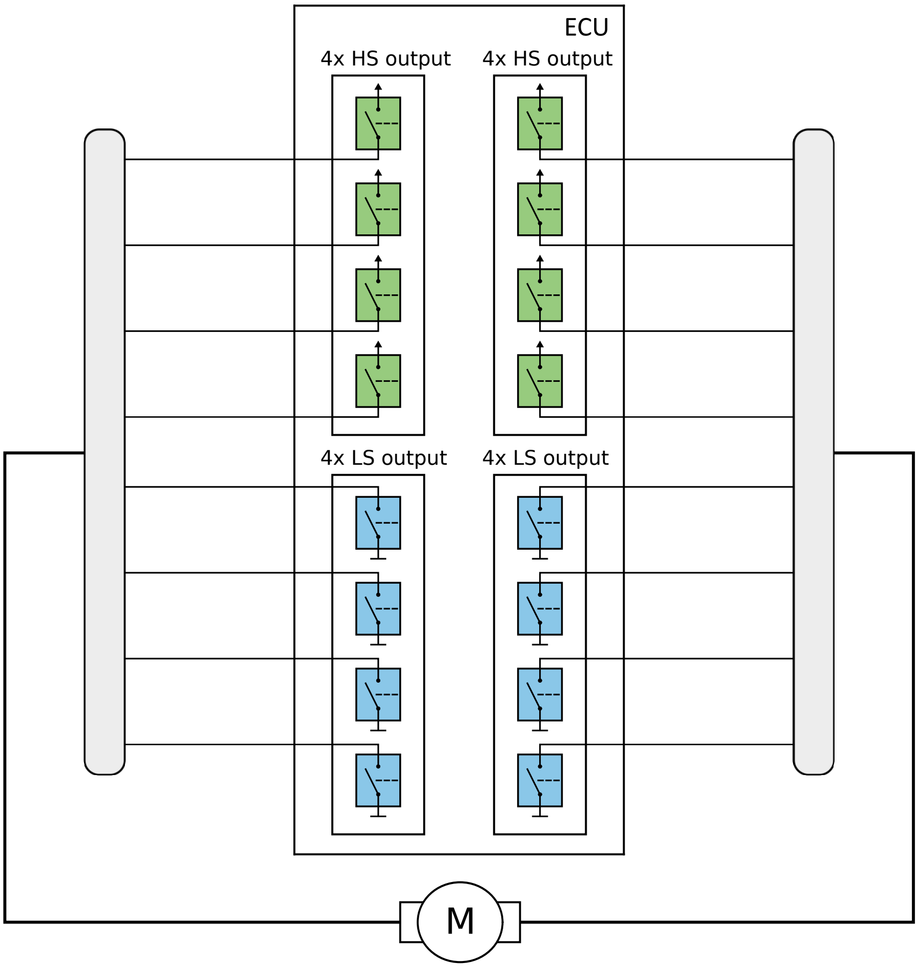

Figure 72: Bidirectional H-bridge (Multiple High and Low Side Power Stages)

6.5.5.6 Motor Cluster

This is a usual configuration to control 2 motors, that are never operated at the same time, with 3 half bridges (3 x high side + 3 x low side power stage).

Example: Outside mirror control

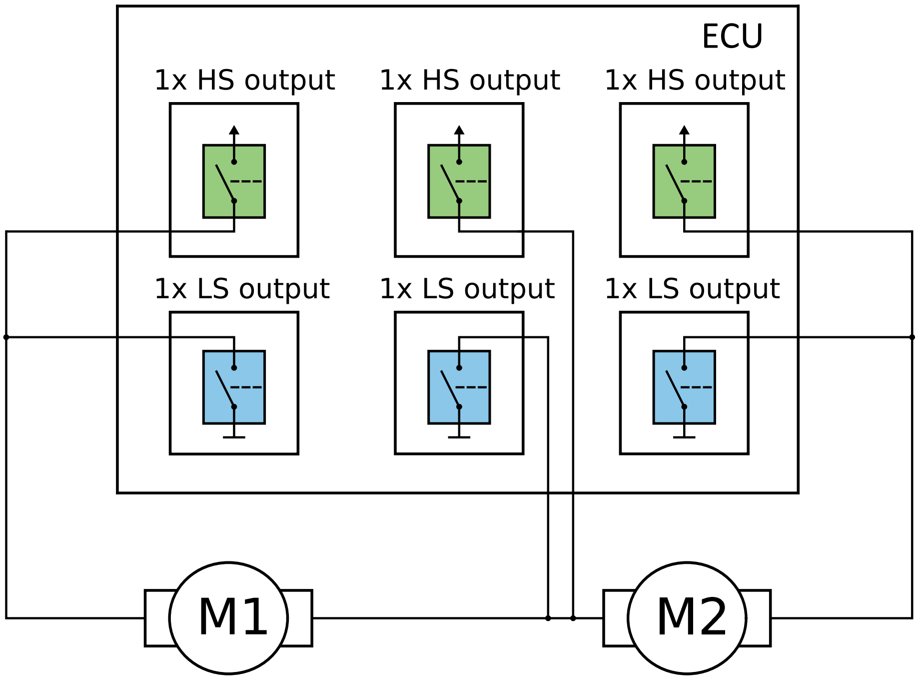

Figure 73: Motor Cluster (Example: Outside Mirror Control)

6.5.6 Power Stages for Motor Control

6.5.6.1 High Side Power Stages for PWM Operation

Depending on the HY-TTC 500 variant, up to 36 high side PWM power stages are provided:

- HY-TTC 580: HS channel 00...35
- HY-TTC 540: HS channel 00...27
- HY-TTC 520: HS channel 00...09, 14...21
- HY-TTC 510: HS channel 00...07, 14...21
- HY-TTC 590E: HS channel 00...35
- HY-TTC 590: HS channel 00...35
- HY-TTC 508: HS channel 00...05, 14...17

6.5.6.2 High Side Power Stages for Static Operation

Depending on the HY-TTC 500 variant, up to 16 digital high side power stages are provided:

- HY-TTC 580: HS channel 36...51
- HY-TTC 540: HS channel 36...43
- HY-TTC 520: HS channel 36...43
- HY-TTC 510: HS channel 36...51
- HY-TTC 590E: HS channel 36...51
- HY-TTC 590: HS channel 36...51
- HY-TTC 508: HS channel 36...49

6.5.6.3 Low Side Power Stages

8 digital low side power stages are provided independent from the HY-TTC 500 variant:

- HY-TTC 580: LS channel 00...07
- HY-TTC 540: LS channel 00...07
- HY-TTC 520: LS channel 00...07
- HY-TTC 510: LS channel 00...07
- HY-TTC 590E: LS channel 00...07
- HY-TTC 590: LS channel 00...07
- HY-TTC 508: LS channel 00...07

6.5.7 Parallel Operation of Power Stages

This kind of wiring is used to increase output current capability. It is strongly recommended to support equal distribution of current between those power stages. This implies to use cables of same diameter and same wire length in parallel as well as to use matched power stages inside the ECU. Matched power stages are always grouped in pairs of even and following odd signal number. For example a good pair is HS-OUT-36 and 37. See Section 4.15.2.1 on page 167 for more information about Power Stage Pairing.

6.5.8 Cabling

The cable resistance adds to the rotor resistance of the motor. While the impact of a small voltage drop is negligible for normal operation it can be helpful to reduce inrush current when switching on the motor. If there is significant cable length used for motor cabling, please add the wire resistance to the motor current classification to relax need of paralleling power stages.

For power stages operated in parallel please observe that this cable resistance also helps to equally distribute the load current over the power stages. On the other hand, if there is significant difference in wire length of paralleled output stages this enhances non-symmetric load, which means one power stage might carry significant more load current than the others. This ends up in reduced power capability.

4 power stages of the HY-TTC 500 would theoretically deliver a total current of 16 A if switched on concurrently.

So the system designer must be careful with the cable harness design to guarantee evenly distribution of supply current on all 4 pins. For example, it is not OK to use 1 cable with large diameter to connect from a fuse box to the ECU for, let's say 2 meters and crimp it to 4 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 2 contacts carry almost the full current load and are overloaded at maximum current. It is better to use 4 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.

6.5.9 Control Sequence for Bidirectional Drive

The complexity of SW control for bidirectional motor operation depends more or less on the motor type. Up to 2 A peak current a sudden reverse is still limited to 4 A maximum current, which is below the over load threshold of the power stages.

Above 2 A an active braking sequence close to speed 0 must be inserted prior to reversing the motor.

6.5.9.1 Motor Running

Forward or backward rotation is managed by diagonally switch on a high side and a low side power stage simultaneously. Always switch on low side first followed by high side. Never switch on high side first and then switch on low side.

6.5.9.2 Motor Breaking

Motor braking is managed by switching on both high side power stages simultaneously.

Always switch off low side first before switching on high side. Never switch on high side while low side is still on.

Please observe that the high side power stages can only measure current in positive direction (out of the terminal towards ground)

While the high side power stages are actively braking, one power stage (this one that was operated before entering brake mode) shows a high current (close to start current) declining to 0 A, while the other is reverse operated and does not show any current at all.

The brake sequence is considered to be finished when the brake current falls below 1 A. By using multiple power stages the limit is 1 A per power stage.

A reverse motor run now can be started.

6.5.9.3 Paralleled High Side Power Stage Control

This configuration can be needed for to increasing inrush current capability. However, in case of a short circuit this also dramatically increases the peak current that might be drawn out of the battery terminals. It is strongly recommended to first switch on only one single power stage and measure the output voltage. If the output voltage is > 0.75xVBAT this indicates that no short circuit is on the motor terminals and the other 1 to 3 high side power stages working in parallel can be switched on. The time that only one single power stage is working shall be limited to <= 20 ms. Important: this sequencing applies only on the high side power stages. The low side outputs needs to be switched on first.

6.6 Power Stage Alternative Functions

This application note describes the DO and DON'TS when using the alternative functions of HY-TTC 500 high- and low-side power stages.

6.6.1 High-Side Output Stages

High-side power stages can alternatively used as analog, digital or frequency inputs.

BAT+Power +0,5 V
In all high-side power stages there is a parasitic diode that conducts if the output voltage or, in case of alternative input function, the input voltage is externally driven higher than the voltage on the BAT+Power supply pins. The input voltage on all high-side stages, including the alternative input functions, must never exceed the power stage supply BAT+ Power +0,5 V. This application requirement is valid in active, standby and power-off state of the ECU.

To counteract such fault scenarios, maximum ratings and specified wiring examples must be followed and are essential for safe operation.

6.6.1.1 Wiring examples

Attention!
In many applications external switches (open collector, open drain (NPN) or a push-pull type), push-buttons or analog sensors have to be monitored by an alternative input of the ECU. Switches which are directly switching to battery voltage must not be used with alternative inputs.

For safety critical applicactions, however, additional restrictions apply, see the following sections.

Workarounds for safety critical applications:

- Usage of external switches connected to GND.
  Short circuits to battery supply needs to be excluded in the system architecture.
- Battery supplied switches and sensors need to be supplied via a digital output of the HY-TTC 500.

6.6.1.1.1 Valid Wiring Examples The following wiring examples for external switches and analog sensors connected to battery supply (PWM/digital high-side output) and to GND are allowed and can help avoiding system fault scenarios:

Switch connected to GND:

Usage of external switches connected to GND.
Short circuits to battery supply needs to be excluded in the system architecture.

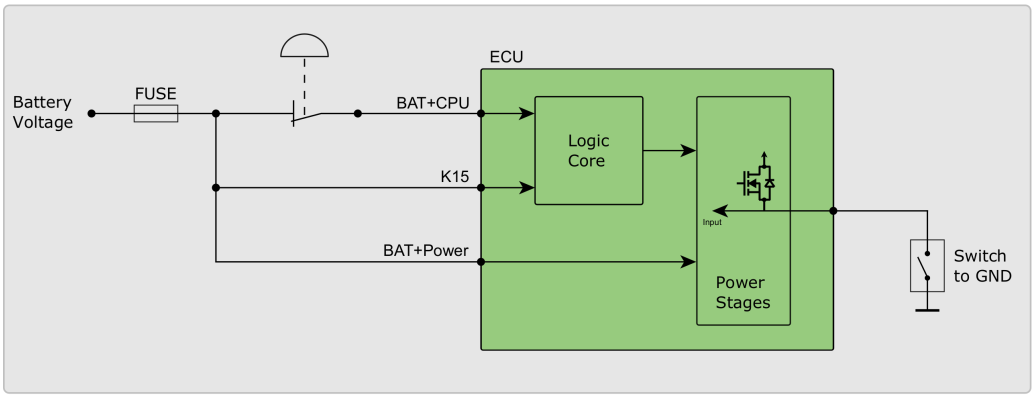

Figure 74: Switch connected to GND

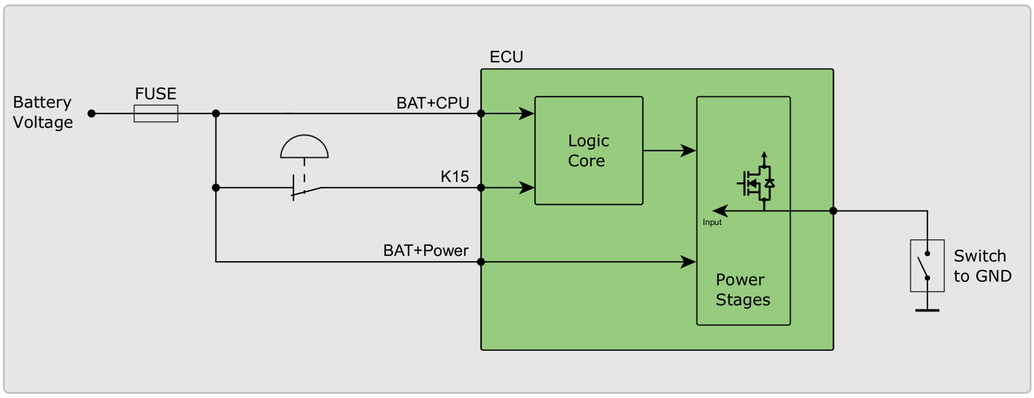

Figure 75: Switch connected to GND

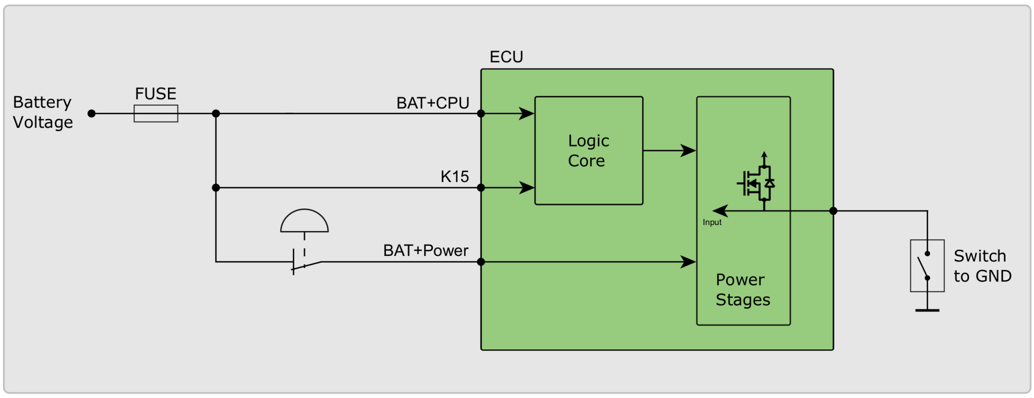

Figure 76: Switch connected to GND

Switches connected to PWM high-side output stage:

Digital switches and analog sensors are supplied via an HY-TTC 500 PWM high-side output pin, the switch/sensor output is monitored by an alternative (PWM high-side) input.

Caution! - The sourcing PWM high-side output stage (IO_PWM_00 - IO_PWM_35) must be out of the same secondary shut-off path (A, B or C) as the alternative input pin. For example IO_PWM_00 (output/source) supplies the digital sensor and the sensor output is monitored by IO_PWM_13 (input), both IO's are out of secondary shut-off path A. See Table 22 on page 138 for secondary shut-off paths and their relation to the alternative inputs.

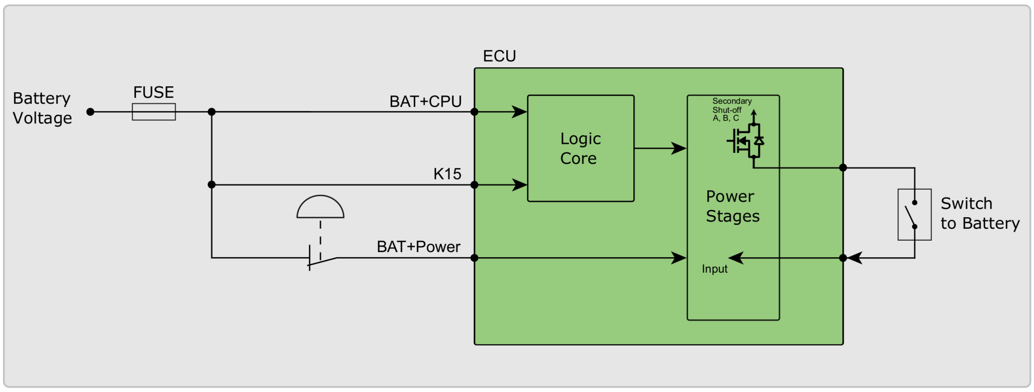

Figure 77: Switch connected to PWM high-side output stage

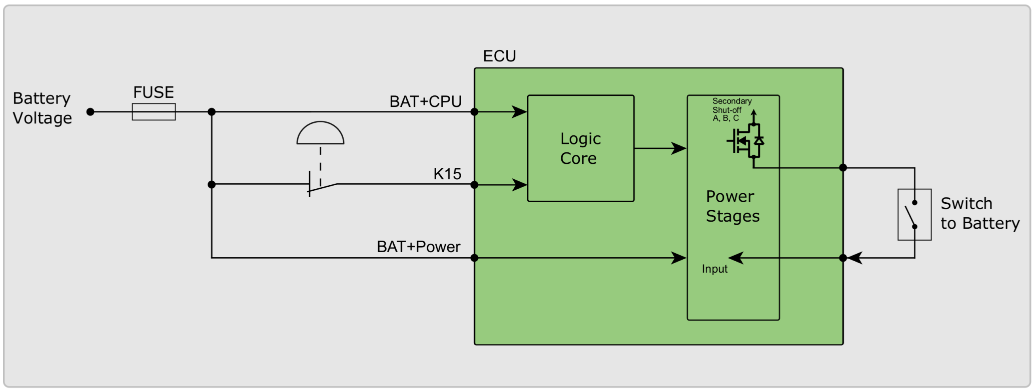

Figure 78: Switch connected to PWM high-side output stage

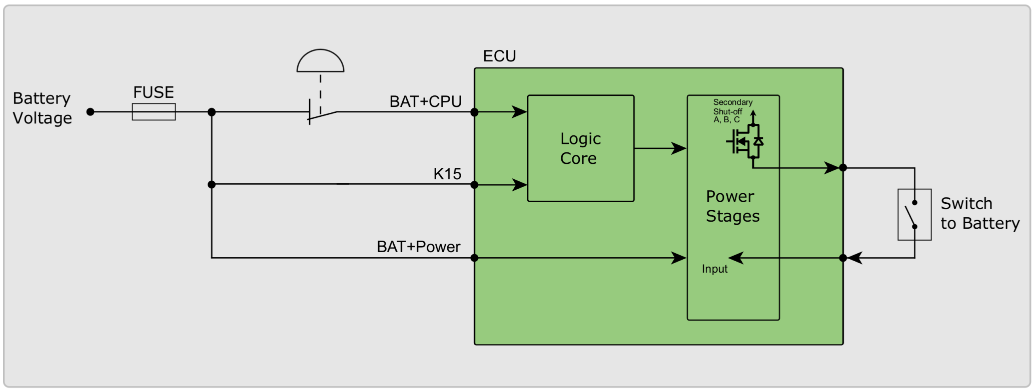

Figure 79: Switch connected to PWM high-side output stage

Switches connected to digital high-side output stage:

Digital switches and analog sensors are supplied via an HY-TTC 500 digital high-side output pin, the switch/sensor output is monitored by an alternative (digital high-side) input.

IO_DO_00 - IO_DO_07 and IO_PVG_00 - IO_PVG_07 are not equipped with an secondary shut-off paths. These high-side output stages can by themselves not be used for safety critical applications.

If the alternative input function of IO_DO_00 - IO_DO_07 and IO_PVG_00 - IO_PVG_07 shall be used, the connected sensor must be supplied by an digital output stage out of these outputs.

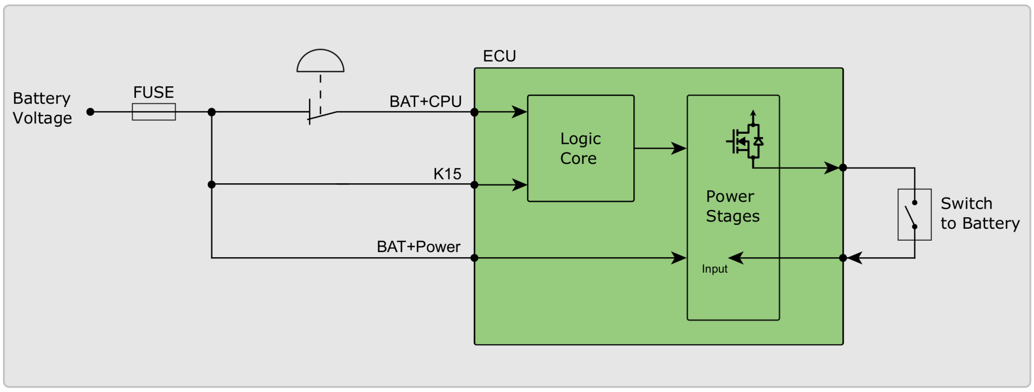

Figure 80: Switch connected to digital high-side output stage

6.6.1.1.2 Invalid Wiring Examples The following wiring examples of external switches or analog sensors connected to battery supply are not allowed and must be avoided for safety critical systems.

Nonconforming wiring can lead to destruction of the HY-TTC 500.

Stop switch / blown fuse / K15 wiring

Digital switches and analog sensors are supplied directly from the battery.

If for example the fuse is blown, BAT+Power is disconnected (loose connection) or the stop switch is pressed, digital switches or analog sensors are still supplied. The current flows over the closed switch and the parasitic body diode of the output stage used as input. All the load current of all other outputs now flows via the body diode of this single output stage. This may overload and even destroy this output stage.

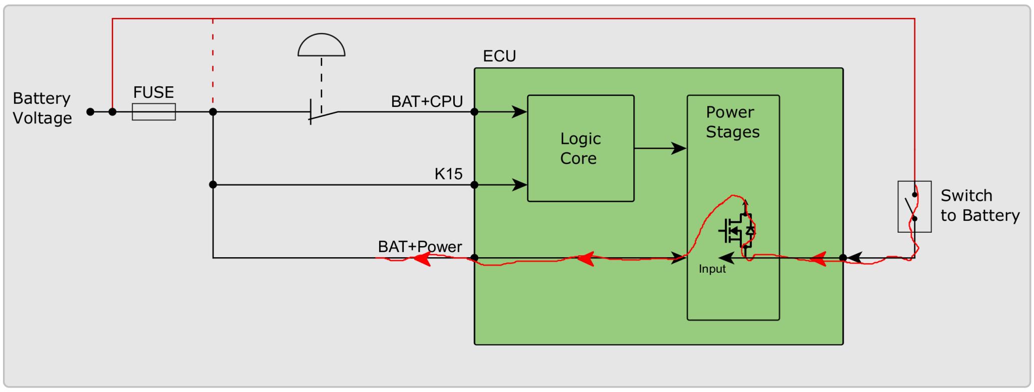

Figure 81: Switch connected to battery supply

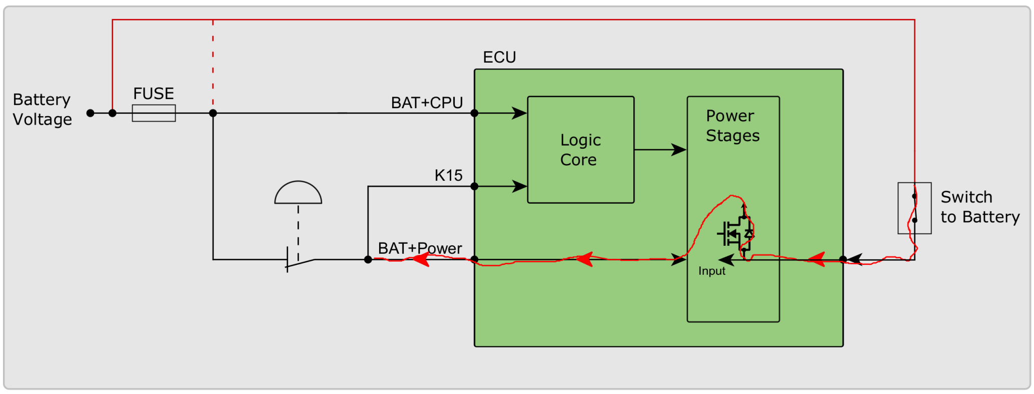

Figure 82: Switch connected to battery supply

7 Debugging

7.1 Functional Description

After connecting the HY-TTC 500 and the Lauterbach Debugging Device with the TTC JTAG-Adapter Board (for the connector pinning, see Figure 83 on the current page), open the Trace32 Software for ARM CPUs. Double-click the batch file `flash.cmm`, which is located in the corresponding template directory. When prompted by the dialog whether to flash the application or to load only the symbols for debugging, click **Yes** to start the flashing procedure.

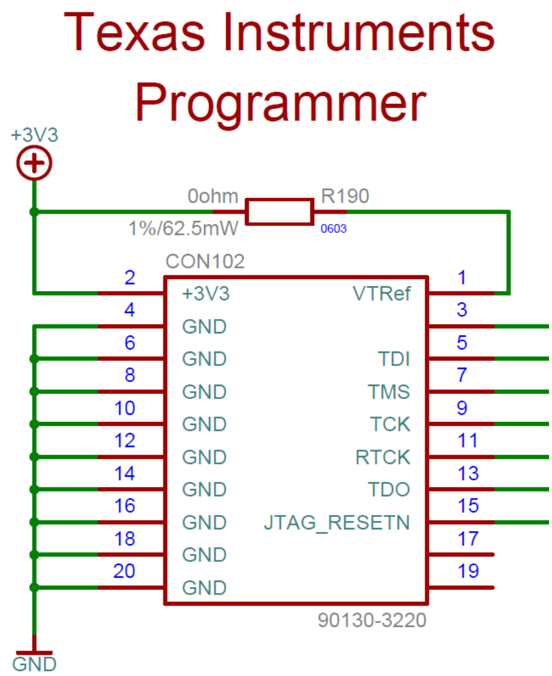

Figure 83: Pinning of JTAG Connector on the TTC JTAG-Adapter Board

Manufacturer:	TE CONNECTIVITY / AMP
Manufacturer Article Code:	2-1634689-0
Farnell Order Number:	8396027

Table 32: Order code of JTAG connector on the TTC JTAG-Adapter Board

For debugging details, see [31].

Software Description

8 API Documentation

Please refer to [30] for the API documentation of the HY-TTC 500 I/O driver.

Entry	Description
2M	2 Mode
3M	3 Mode
A/D	Analog and Digital
ADC	Analog-to-Digital Converter
API	Application Programming Interface
CAN	Controller Area Network
CPU	Central Processing Unit
CTS	Clear to Send
DC	Direct Current
DI	Digital Input
DOUT	Digital Output
DO	Digital Output
ECU	Electronic Control Unit
EEPROM	Electrically Erasable Programmable Read-Only Memory
EMC	Electromagnetic Compatibility
Flash	Nonvolatile computer storage
GND	Ground
HS	High Side
HW	Hardware
I/O	Input and Output
IN	Input
LIN	Local Interconnect Network
LSB	Least Significant Bit
LS	Low Side

Entry	Description
MRD	Mounting Requirements Document
Max.	Maximal
Min.	Minimal
OUT	Output
PC	Personal Computer
PD	Pull Down
PID	Proportional Integral Differential
PL	Performance Level
PU	Pull Up
PVG	Proportional Valve Group
PWD	Pulse Width Demodulation
PWM	Pulse With Modulation
RTC	Real-Time Clock
RTS	Request to Send
SIL	Safety Integrity Level
SRC	Signal Range Check
SSUP	Sensor Supply
SW	Software
TBD	To Be Defined
$T_{ambient}$	Ambient Temperature
Terminal 15	Battery+ from ignition switch
UNECE	United Nations Economic Commission for Europe
U_{bat}	Battery Voltage
VOUT	Voltage Output

References

[1] ANSI. CISPR 25 ED. 3.0 B:2008, vehicles, boats and internal combustion engines – radio disturbance characteristics – limits and methods of measurement for the protection of on-board receivers. American National Standard, American National Standards Institute, Inc., 2008.

[2] DIN. DIN EN 60068-2-11:2000-02, Umweltprüfungen – Teil 2: Prüfungen; Prüfung Ka: Salznebel (IEC 60068-2-11:1981 . European Standard, Deutsches Institut für Normung (DIN), 2000.

[3] DIN. DIN EN 60068-2-30:2006-06, Umgebungseinflüsse – Teil 2-30: Prüfverfahren - Prüfung Db: Feuchte Wärme, zyklisch (12 + 12 Stunden) (IEC 60068-2-30:2005) . European Standard, Deutsches Institut für Normung (DIN), 2006.

[4] DIN. DIN EN 13309:2010-12 (E), *Construction machinery – Electromagnetic compatibility of machines with internal power supply* . European Standard, Deutsches Institut für Normung (DIN), 2010.

[5] DIN. DIN EN 60068-2-38:2010-06, Umgebungseinflüsse – Teil 2-38: Prüfverfahren – Prüfung Z/AD: Zusammengesetzte Prüfung, Temperatur/Feuchte, zyklisch (IEC 60068-2-38:2009) . European Standard, Deutsches Institut für Normung (DIN), 2010.

[6] IEC. IEC 61000-6-2:2005, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments (2nd ed.)* . International Standard, International Electrotechnical Commission (IEC), 2005.

[7] IEC. IEC 61000-6-4:2007, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments* . International Standard, International Electrotechnical Commission (IEC), 2007.

[8] IEC. IEC 61508:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems*. International Standard, International Electrotechnical Commission (IEC), 2010.

[9] IEC. IEC 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Tests - Test Cab: Damp heat, steady state* . International Standard, International Electrotechnical Commission (IEC), 2012.

[10] IEC. IEC 61131-3:2013, *Programming languages (3rd ed.)*. International Standard, International Electrotechnical Commission (IEC), 2013.

[11] ISO. ISO 14982:1998, *Agricultural and forestry machinery – Electromagnetic compatibility – Test methods and acceptance criteria*. International Standard, International Organization for Standardization (ISO), 1998.

[12] ISO. ISO 11452-2:2004 , *Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 2: Absorber-lined shielded enclosure*. International Standard, International Organization for Standardization (ISO), 2004.

[13] ISO. ISO 16750-1:2006, *Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 1: General (2nd ed.)*. International Standard, International Organization for Standardization (ISO), 2006.

[14] ISO. ISO 7637-3:2007, *Road vehicles – Electrical disturbances from conduction and coupling – Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines*. International Standard, International Organization for Standardization (ISO), 2007.

[15] ISO. ISO 10605:2008, *Road vehicles – Test methods for electrical disturbances from electrostatic discharge*. International Standard, International Organization for Standardization (ISO), 2008.

[16] ISO. ISO 13849:2008-12, *Safety of machinery – Safety-related parts of control systems*. International Standard, International Organization for Standardization (ISO), 2008.

[17] ISO. ISO 20653:2013, Road vehicles – Degrees of protection (IP code) – Protection of electrical equipment against foreign objects, water and access. International Standard, International Organization for Standardization (ISO), 2008.

[18] ISO. ISO 16750-4:2010, *Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 4: Climatic loads (3rd ed.)*. International Standard, International Organization for Standardization (ISO), 2010.

[19] ISO. ISO 16750-5:2010, *Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 5: Chemical loads (2nd ed.)*. International Standard, International Organization for Standardization (ISO), 2010.

[20] ISO. ISO 7637-2:2011, *Road vehicles – Electrical disturbances from conduction and coupling – Part 2: Electrical transient conduction along supply lines only (2nd ed.)*. International Standard, International Organization for Standardization (ISO), 2011.

[21] ISO. ISO 11783-2:2012(E), *Tractors and machinery for agriculture and forestry – Serial control and communications data network – Part 2: Physical Layer (2nd ed.)*. International Standard, International Organization for Standardization (ISO), 2012.

[22] ISO. ISO 16750-2:2012, *Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 2: Electrical loads (4th ed.)*. International Standard, International Organization for Standardization (ISO), 2012.

[23] ISO. ISO 16750-3:2012, *Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 3: Mechanical loads (3rd ed.)*. International Standard, International Organization for Standardization (ISO), 2012.

[24] ISO. ISO 13849:2015, *Safety of machinery – Safety-related parts of control systems*. International Standard, International Organization for Standardization (ISO), 2015.

[25] ISO. ISO 25119:2018, *Tractors and machinery for agriculture and forestry – Safety-related parts of control systems*. International Standard, International Organization for Standardization (ISO), 2018.

[26] ISO. ISO 26262:2018, Road vehicles – Functional safety. International Standard, International Organization for Standardization (ISO), 2018.

[27] TTControl. HY-TTC 500 Mounting Requirements Document. User Documentation D-TTC5F-M-02-004, TTTech, Off-Highway-Services.

[28] TTControl. HY-TTC 500 Product Drawing. User Documentation D-TTC5F-C-20-007, TTTech, Off-Highway-Services.

[29] TTControl. HY-TTC 500 Safety Manual. User Documentation D-TTC5F-M-02-002, TTTech, Off-Highway-Services.

[30] TTControl GmbH. HY-TTC 500 I/O Driver Manual. S-TTC5F-G-20-001.

[31] TTControl GmbH. HY-TTC 500 Quick Start Guide - C Programming. User Documentation D-TTC5F-G-20-004, TTTech, BU Off-Highway, Services & Operations.

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Disposal

NOTICE
If disposal has to be undertaken after the life span of the device, the respective applicable country-specific regulations are to be observed.

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