M460 Technical Specification
29T-068144TK-03

Release 2.9.0 (r2020-1)

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Chapter 1. Technical specification

This document is the technical specification for OpenECU part *01T-068144-000 Issue 1*. Within this document, that part is referred to as the *M460-000 ECU*.

> **Note**
>
> For a list of issues and possible work arounds for this ECU, found after publication of this document, please refer to the hardware errata for this ECU (named *29T-068144ER-xE M460 Technical Spec Errata*).

Specific option control may exist for this part. In that case, parts of this document will be overridden by an option control specific technical specification. Please refer to the option control technical specification for more information.

1.1. Overview

This technical specification relates to the following ECU variant:

- M460D-000 — for development and testing, including full interactive calibration tool integration.

Table 1.1. Specification

Specification	Variant
	M460D-000
Status	Available [a]
Processor	MPC5534
Rate	80MHz
Code space	up to 768KiB [b]
RAM space	up to 832KiB [b]
Calibration space	up to 256KiB [b]
Calibratable	Y
Reprogrammable	Y
Power control relays	-
Actuator supplies	4
Sensor supplies	2
Inputs	38
Outputs	15
CAN buses	2
LIN buses	-
RS232 links	-
Connectors	2x40

Specification	Variant
	M460D-000
Weight	1.5Kg
Vibration	6g random RMS
Shock capability	TBC
Enclosure	IP68 [c]
EMC	SAE J1455 [d]
Partial operating voltage	7 to 36V
Full operating voltage	8 to 32V [e]
Standby current (typical)	0.15mA at 12V [f]
Operating current (typical)	200mA at 12V [g]
Operating temperature range	-40 to +105°C
Storage temperature range (installation)	-40 to +125°C
Storage temperature range (shipping)	TBC

[a] Target ECU available for general use.
[b] See list of possible memory configurations in section 'Memory - configuration'.
[c] Designed for under bonnet(hood)/chassis mounting.
[d] Load dump protection to SAE J1455 specification.
[e] Designed for 12V or 24V vehicles.
[f] 0.3mA at 24V.
[g] 150mA at 24V. When running idle task with I/O disconnected.

1.2. Function reference

Various input and output functionality is supported where some pins may be capable of more than one function. Some functions require a combination of pins but not all pin combinations are possible.

Table 1.2. Function reference

I/O type	External	Internal	Pins
Power			
ECU supply	1	-	A9+A10+A20+A30
ECU ground	1	-	C1+C2+C11+C12+C38
Actuator supply	4	-	A19, A29, A39, A40
Sensor supply	2	-	C8, C18
Module control, status			
Ignition sense	1	-	A12
Module control FEPS	1	-	A2
Module status Flash code	1	-	A27
Communication			
CAN buses	2	-	A37+A36, C37+C36
Inputs — time based			

I/O type	External	Internal	Pins
Analogue	32	29	A6, A8, A13+A3, A14+A4, A16, A22, A23, A24, A28, A32, A33, A34, C3, C4, C6, C7, C13, C14, C16, C17, C21, C22, C23, C24, C25, C27, C31, C32, C33, C35, C39, C40
Digital	11	26	A8, A12, A26, C7, C27, C28, C29, C30, C34, C39, C40
Frequency	11	14	A8, A12, A26, C7, C27, C28, C29, C30, C34, C39, C40
PWM	11	-	A8, A12, A26, C7, C27, C28, C29, C30, C34, C39, C40
Quadrature	10	-	A8, A26, C7, C27, C28, C29, C30, C34, C39, C40
Outputs — time based			
Digital	12	3	A5, A7, A15, A17, A18, A25, A31, A35, C5, C10, C15, C20
PWM	12	8	A5, A7, A15, A17, A18, A25, A31, A35, C5, C10, C15, C20
PWM synchronised	4	-	A1, A11, A21, A31
Inputs — angle based			
None	-	-	
Outputs — angle based			
None	-	-	

Chapter 2. Connector pinout

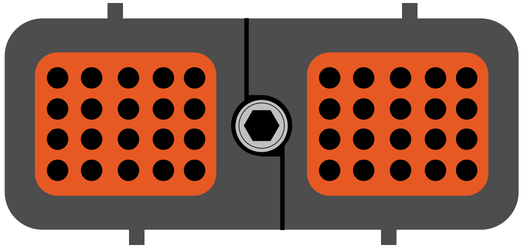
The M460-000 variants have two ECU connectors (pockets) named A and C, which have pinouts as given in the following tables. Currents listed are RMS unless otherwise stated.

The following abbreviations are used in the pinout tables below:

C	Communication
I	Input
M	Monitor
O	Output
P	Power
CT	Current trip
GND	Ground
PSU	Power supply
PWR	Power
RTD	Resistance temperature detector

2.1. Pocket A

Connector packs can be ordered from Pi. Individual connector components can be ordered from Pi or from various manufacturers.



Note: the protrusions visible here, on the back of the connector shell, do not line up with those on the mating side, which fit into receiving channels on the ECU connector.

Table 2.1. Part numbers for the mating connector

Supplier	Part number	Part
Deutsch	DRC26-40SA	Connector with A keyway

Table 2.2. Part numbers for the turned pin

Supplier	Part number	Part
Deutsch	0462-201-20141	Pin
	0413-204-2005	Plug for unused position
	HDT-48-00	Crimper
Pins A1, A2, A3, A4, A5, A6, A7, A8, A9+A10+A20+A30, A11, A12, A13, A14, A15, A16, A17, A18, A19, A21, A22, A23, A24, A25, A26, A27, A28, A29, A31, A32, A33, A34, A35, A36, A37, A38, A39 and A40		

Table 2.3. Part numbers for the formed pin

Supplier	Part number	Part
Deutsch	1062-20-0122	Pin
	0413-204-2005	Plug for unused position

Supplier	Part number	Part
	DTT-20-00	Crimper
Pins A1, A2, A3, A4, A5, A6, A7, A8, A9+A10+A20+A30, A11, A12, A13, A14, A15, A16, A17, A18, A19, A21, A22, A23, A24, A25, A26, A27, A28, A29, A31, A32, A33, A34, A35, A36, A37, A38, A39 and A40		

Table 2.4. Connector pinout — Pocket A

Main connector — Pocket A								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
A1		Digital (injector)	O	Y	Low side		5.8A peak/1.6A hold	Related to internal channels DOT injector-clock, Monitor (d) and Monitor (v).
A2		FEPS	I		82k to 2.6V		-16V to +17V	Module flash programming control.
A3		Thermo-couple (type K, +ve)	I					One pin from a pair, making a thermocouple input, see also: A13. Related to internal channel AIN cold-junction-temp.
A4		Thermo-couple (type K, +ve)	I					One pin from a pair, making a thermocouple input, see also: A14. Related to internal channel AIN cold-junction-temp.
A5		Digital	O	Y	Low side		8A	Nominal DC over-current trip 11A. Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).
A6		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
A7		Digital	O	Y	Low side		100mA	Related to internal channels Monitor (d) and Monitor (v).
A8		Analogue	I		37k to V_{GND}	22Hz	0V to 5V	12-bit unsigned conversion.
		Digital				6.9kHz		
A9		V_{PWR}	P				7A	Maximum of 28A in total when all V_{PWR} pins connected in parallel. Related to internal channel AIN VPWR.
A10		V_{PWR}	P				7A	Maximum of 28A in total when all V_{PWR} pins connected in parallel. Related to internal channel AIN VPWR.
A11		Digital (injector)	O	Y	Low side		5.8A peak/1.6A hold	Related to internal channels DOT injector-clock, Monitor (d) and Monitor (v).
A12		Digital	I		4k5 to V_{GND}	6.9kHz	0V to V_{PWR}	Key position (ignition sense) input. Related to internal channel DOT hold-PSU.

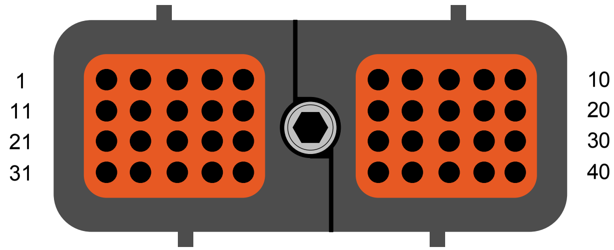
Main connector — Pocket A								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
A13		Thermo-couple (type K, -ve)	I					One pin from a pair, making a thermocouple input, see also: A3. Related to internal channel AIN cold-junction-temp.
A14		Thermo-couple (type K, -ve)	I					One pin from a pair, making a thermocouple input, see also: A4. Related to internal channel AIN cold-junction-temp.
A15		Digital	O	Y	Low side		8A	Nominal DC over-current trip 11A. Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).
A16		Analogue	I		51k to V_{GND}	22Hz	0V to 5V	12-bit unsigned conversion.
A17		Digital	O	Y	Low side		100mA	Related to internal channels Monitor (d) and Monitor (v).
A18		Digital	O	Y	Low side		2A	Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).
A19		Actuator supply	P	Y	High side		7A	High side actuator power. Maximum of 26A in total when all high side actuator pins connected in parallel (A19, A29, A39 and A40). The high side actuator pins are electrically one node internal to the ECU, and can only be turned on/off together. Related to internal channels Monitor (ct) and Monitor (v).
A20		V_{PWR}	P				7A	Maximum of 28A in total when all V_{PWR} pins connected in parallel. Related to internal channel AIN VPWR.
A21		Digital (injector)	O	Y	Low side		5.8A peak/1.6A hold	Related to internal channels DOT injector-clock, Monitor (d) and Monitor (v).
A22		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
A23		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
A24		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
A25		Digital	O	Y	Low side		8A	Nominal DC over-current trip 11A. Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).
A26		Digital	I		4k7 to V_{PWR}	6.9kHz	0V to V_{PWR}	

Main connector — Pocket A								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
A27		Flash code	O		Low side		100mA	ECU status information.
A28		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
A29		Actuator supply	P	Y	High side		7A	High side actuator power. Maximum of 26A in total when all high side actuator pins connected in parallel (A19, A29, A39 and A40). The high side actuator pins are electrically one node internal to the ECU, and can only be turned on/off together. Related to internal channels Monitor (ct) and Monitor (v).
A30		V_{PWR}	P				7A	Maximum of 28A in total when all V_{PWR} pins connected in parallel. Related to internal channel AIN VPWR.
A31		Digital (injector)	O	Y	Low side		5.8A peak/1.6A hold	The pin function (injector or digital) is selected using an internal channel. Related to internal channels DOT injector-clock, Monitor (ct), Monitor (d) and Monitor (v).
		Digital					5.8A	
A32		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
A33		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
A34		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
A35		Digital	O	Y	Low side		2A	Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).
A36		CAN+ (high)	C		124R			CAN bus 0 high (+ve).
A37		CAN- (low)	C		124R			CAN bus 0 low (-ve).
A38		CAN shield	C					CAN bus 0 shield.
A39		Actuator supply	P	Y	High side		7A	High side actuator power. Maximum of 26A in total when all high side actuator pins connected in parallel (A19, A29, A39 and A40). The high side actuator pins are electrically one node internal to the ECU, and can only be turned on/off together. Related to internal channels Monitor (ct) and Monitor (v).

Main connector — Pocket A								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
A40		Actuator supply	P	Y	High side		7A	High side actuator power. Maximum of 26A in total when all high side actuator pins connected in parallel (A19, A29, A39 and A40). The high side actuator pins are electrically one node internal to the ECU, and can only be turned on/off together. Related to internal channels Monitor (ct) and Monitor (v).

2.2. Pocket C

Connector packs can be ordered from Pi. Individual connector components can be ordered from Pi or from various manufacturers.



Note: the protrusions visible here, on the back of the connector shell, do not line up with those on the mating side, which fit into receiving channels on the ECU connector.

Table 2.5. Part numbers for the mating connector

Supplier	Part number	Part
Deutsch	DRC26-40SC	Connector with C keyway

Table 2.6. Part numbers for the turned pin

Supplier	Part number	Part
Deutsch	0462-201-20141	Pin

Supplier	Part number	Part
	0413-204-2005	Plug for unused position
	HDT-48-00	Crimper
Pins C1+C2+C11+C12+C38, C3, C4, C5, C6, C7, C8, C9, C10, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31, C32, C33, C34, C35, C36, C37, C39 and C40		

Table 2.7. Part numbers for the formed pin

Supplier	Part number	Part
Deutsch	1062-20-0122	Pin
	0413-204-2005	Plug for unused position
	DTT-20-00	Crimper
Pins C1+C2+C11+C12+C38, C3, C4, C5, C6, C7, C8, C9, C10, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31, C32, C33, C34, C35, C36, C37, C39 and C40		

Table 2.8. Connector pinout — Pocket C

Main connector — Pocket C								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
C1		V_{GND}	P					C1, C2, C11, C12 and C38 connected together internally.
C2		V_{GND}	P					C1, C2, C11, C12 and C38 connected together internally.
C3		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
C4		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
C5		Digital	O	Y	Low side		2A	Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).
C6		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
C7		Analogue	I		37k to V_{GND}	22Hz	0V to 5V	12-bit unsigned conversion.
		Digital				6.9kHz		

Main connector — Pocket C								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
C8		Sensor supply	P	Y			5V, 250mA	Sensor supply 3. Can be turned on and off by the application for diagnostics purposes, see also: C9. Related to internal channels DOT disable-EXT-PSU3 and Monitor (v).
C9		Sensor ground	P					Sensor ground 3. The sensor ground pins, C9 and C19, are electrically one node internal to the ECU, connected to the negative battery input by a MOSFET, see also: C8. Related to internal channel AIN extern-gnd.
C10		Digital (ignition)	O	Y	Low side		2A	IGBT with a saturation voltage of approximately 1.8V. Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).
C11		V_{GND}	P					C1, C2, C11, C12 and C38 connected together internally.
C12		V_{GND}	P					C1, C2, C11, C12 and C38 connected together internally.
C13		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
C14		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
C15		Digital (ignition)	O	Y	Low side		8A	IGBT with a saturation voltage of approximately 1.8V. Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).
C16		Analogue	I		51k to V_{GND}	22Hz	0V to 5V	12-bit unsigned conversion.
C17		Analogue	I		51k to V_{GND}	22Hz	0V to 5V	12-bit unsigned conversion.
C18		Sensor supply	P	Y			5V, 250mA	Sensor supply 4. Can be turned on and off by the application for diagnostics purposes, see also: C19. Related to internal channels DOT disable-EXT-PSU4 and Monitor (v).
C19		Sensor ground	P					Sensor ground 4. The sensor ground pins, C9 and C19, are electrically one node internal to the ECU, connected to the negative battery input by a MOSFET, see also: C18. Related to internal channel AIN extern-gnd.
C20		Digital (ignition)	O	Y	Low side		2A	IGBT with a saturation voltage of approximately 1.8V. Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).

Main connector — Pocket C								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
C21		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
C22		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
C23		Analogue (RTD)	I		10k to 5V	124Hz	0V to 0.454545V	12-bit unsigned conversion.
C24		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	Can be treated as an individual input, or as a differential input with C25. 12-bit unsigned conversion. Related to internal channel AIN diff..
C25		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	Can be treated as an individual input, or as a differential input with C24. 12-bit unsigned conversion. Related to internal channel AIN diff..
C26		No function						This pin is tied internally to ground of the ECU and should be left open circuit in the wire harness.
C27		Analogue	I		37k to V_{GND}	22Hz	0V to 5V	12-bit unsigned conversion.
		Digital				6.9kHz		
C28		Digital	I		4k7 to V_{PWR}	6.9kHz	0V to V_{PWR}	
C29		Digital	I		4k7 to V_{PWR}	6.9kHz	0V to V_{PWR}	
C30		Digital	I		4k7 to V_{PWR}	6.9kHz	0V to V_{PWR}	
C31		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
C32		Analogue	I		51k to V_{GND}	22Hz	0V to 5V	12-bit unsigned conversion.
C33		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
C34		Digital	I		4k7 to V_{PWR}	6.9kHz	0V to V_{PWR}	
C35		Analogue	I		51k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
C36		CAN+ (high)	C		124R			CAN bus 1 high (+ve).
C37		CAN- (low)	C		124R			CAN bus 1 low (-ve).

Main connector — Pocket C								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
C38		V_{GND}	P					C1, C2, C11, C12 and C38 connected together internally.
C39		Analogue	I		37k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
		Digital				6.9kHz		
C40		Analogue	I		37k to V_{GND}	42Hz	0V to 5V	12-bit unsigned conversion.
		Digital				6.9kHz		

Chapter 3. Internal signals

Table 3.1. Internal signals

Signal	I/O	Signal type	Range	Notes
Analogue				
AIN cold-junction-temp (pin A3, A4, A13 and A14)	I	Analogue	0V to 5V	Cold junction temperature: 0.251V @ -40°C; 1.31525V @ +125°C. 12-bit unsigned conversion.
AIN diff. (pin C24 and C25)	I	Analogue	0V to 5V	Differential input. 12-bit unsigned conversion.
AIN extern-gnd (pin C9 and C19)	I	Analogue	0V to 5V	Common sensor ground voltage monitor. 12-bit unsigned conversion.
AIN PSU+3V3	I	Analogue	0V to 5V	Internal 3.3V power supply. 12-bit unsigned conversion.
AIN PSU+5VD	I	Analogue	0V to 6V	Internal 5V power supply. 12-bit unsigned conversion.
AIN VPWR (pin A9, A10, A20 and A30)	I	Analogue	0V to 40V	Power supply voltage. 12-bit unsigned conversion.
AIN VRH	I	Analogue	0V to 5V	5V reference for analogue input conversions. 12-bit unsigned conversion.
AIN VRH-VRL 25%	I	Analogue	0V to 5V	1.25V reference for analogue input conversions. 12-bit unsigned conversion.
AIN VRH-VRL 50%	I	Analogue	0V to 5V	2.5V reference for analogue input conversions. Will read as 2.48V due to 20mV offset in processor implementation. 12-bit unsigned conversion.
AIN VRH-VRL 75%	I	Analogue	0V to 5V	3.75V reference for analogue input conversions. 12-bit unsigned conversion.
AIN VRL	I	Analogue	0V to 5V	0V reference for analogue input conversions. 12-bit unsigned conversion.
Current trip monitor				
Monitor (ct) (pin A15)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.
Monitor (ct) (pin A18)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.

Signal	I/O	Signal type	Range	Notes
Monitor (ct) (pin A19, A29, A39 and A40)	I	Digital	0 or 1	Digital input indicating current trip for the high side actuator power (safety switch). Serial input.
Monitor (ct) (pin A25)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.
Monitor (ct) (pin A31)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.
Monitor (ct) (pin A35)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.
Monitor (ct) (pin A5)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.
Monitor (ct) (pin C10)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.
Monitor (ct) (pin C15)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.
Monitor (ct) (pin C20)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.
Monitor (ct) (pin C5)	I	Digital	0 or 1	Digital input indicating current trip. Serial input.
Digital				
DOT disable-EXT-PSU3 (pin C8)	O	Digital	0 or 1	Sensor supply switch. Set to zero to turn on the power supply and to one to turn it off.
DOT disable-EXT-PSU4 (pin C18)	O	Digital	0 or 1	Sensor supply switch. Set to zero to turn on the power supply and to one to turn it off.
DOT hold-PSU (pin A12)	O	Digital	0 or 1	Control power supply to ECU in conjunction with the key position (ignition sense) input.
DOT injector-clock (pin A1)	O	Digital	0 or 1	PWM clock signal for injector.
DOT injector-clock (pin A11)	O	Digital	0 or 1	PWM clock signal for injector.
DOT injector-clock (pin A21)	O	Digital	0 or 1	PWM clock signal for injector.
DOT injector-clock (pin A31)	O	Digital	0 or 1	PWM clock signal for injector.
Digital monitor				
Monitor (d) (pin A1)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin A11)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin A15)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin A17)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.

Signal	I/O	Signal type	Range	Notes
Monitor (d) (pin A18)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin A21)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin A25)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin A31)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin A35)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin A5)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin A7)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin C10)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin C15)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin C20)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Monitor (d) (pin C5)	I	Digital	0 or 1	Digital output state monitor. V_{LH} >= 6.95V V_{HL} <= 3.25V.
Memory check				
Monitor (counter eTPU background task)	I	Digital data	0 to 65535	Cyclic counter providing number of times the eTPU background task runs. Its rate of increase can be used to determine the rate of the background task.
Monitor (fc SDM-checksum)	I	Digital data	0 to 65535	Saturating counter providing number of times the eTPU module's data memory failed a checksum test.
Voltage monitor				
Monitor (v) (pin A1)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A11)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A15)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A17)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A18)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A19, A29, A39 and A40)	I	Analogue	0V to 33V	Voltage monitor for the high side actuator power (safety switch). 12-bit unsigned conversion.
Monitor (v) (pin A21)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.

Signal	I/O	Signal type	Range	Notes
Monitor (v) (pin A25)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A31)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A35)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A5)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A7)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin C10)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin C15)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin C18)	I	Analogue	0V to 5V	Sensor supply voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin C20)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin C5)	I	Analogue	0V to 39V	Digital output voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin C8)	I	Analogue	0V to 5V	Sensor supply voltage monitor. 12-bit unsigned conversion.

Chapter 4. Operational details

4.1. ECU power

The power supply pins (V_{PWR} A9+A10+A20+A30) are connected internally in parallel. Similarly for the ground pins (V_{GND} C1+C2+C11+C12+C38).

The power supply pins are each individually rated to 7A and can be connected in parallel to provide a higher rating (e.g., using two pins gives 14A, three pins gives 21A, etc.). The maximum supply is 28A. All power supply pins are connected internally in parallel (similarly for the ground pins).

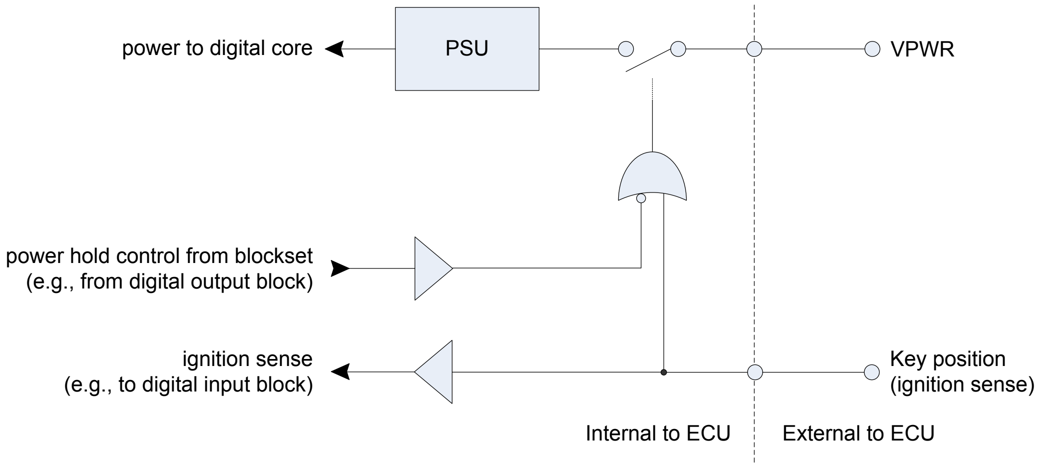
The ECU is designed for 12V or 24V vehicles. Some ECU functionality (e.g., output drivers) work only between 7.5V and 32V. The ECU is protected against reverse supply connection. All inputs and outputs are protected against short-to-V_{PWR} or short-to-$_{GND}$ over normal operating range.

> **Note**
>
> M460 power inputs (V_{PWR} A9+A10+A20+A30) should be connected to a permanent supply with module power controlled using the ignition input (pin A12). M460s revisions prior to Rev 1 Mod 4 may experience damage when exposed to repetitive power input switching or negative transients at the power inputs. Applications requiring switching power inputs or operation in the presence of negative power transients must utilize a minimum revision of Rev 1 Mod 4, or optionally provide negative power transient suppression external to the M460.

4.2. ECU power — control

The ECU power arrangement is shown in Figure 4.1, “Switching arrangement for main power supply”.

Figure 4.1. Switching arrangement for main power supply



The ECU is powered up when the power supply pins (V_{PWR} A9+A10+A20+A30) and key position (ignition sense) input (pin A12) are asserted. The key position input (pin A12) can be read as a digital input.

This arrangement allows for the ECU application software to hold the ECU on after the external key position input is opened, allowing, for example, non-volatile memory processing to occur. For the ECU to hold power the internal DOT hold-PSU channel needs to be asserted. Setting this internal channel low will hold power when the key position input is opened, setting it high will allow the ECU to power off when the key position input is opened.

> **Note**
>
> When using the 'power hold' functionality, it is best to set the internal DOT hold-PSU channel low *as soon as* the external key position input (pin A12) is closed and only set high once all required shutdown tasks have completed.

4.3. ECU power — actuator supplies

The ECU can provide power to actuators through a set of high side power pins, A19, A29, A39 and A40. These pins are electrically one node internal to the ECU. The ECU can control whether those pins are asserted or not through a single control switch. See Section 4.12, “Digital output — high side output control” for further details.

4.4. ECU power — sensor supplies

The ECU provides two external sensor power supplies (pins C8 and C18). The sensors supplies can be individually switched off to allow the application software to perform intrusive diagnostics on sensors.

Each output is monitored by an internal analogue input channel which can be used to check for short circuits and measure the exact output voltage for use with ratio-metric sensors.

The output voltage is guaranteed to never reach full scale in normal operation, hence a full scale indication should be taken to indicate a suspected short to battery. The value read from the voltage monitor when the corresponding PSU is enabled should be interpreted as follows:

Table 4.1. PSU 3 and 4 monitor voltages

Voltage	Meaning
> 4.97V	Output shorted to battery

Voltage	Meaning
4.85V - 4.95V	Normal operation
< 4.85V	Output over current or short to ground

The value read from the common sensor ground voltage monitor should be interpreted as follows:

Table 4.2. Sensor ground monitor voltage

Voltage	Meaning
0mV - 20mV	Normal Operation
> 20mV	Output over current or short to battery

The sensor ground feedback can also be used in normal operation by the application software to provide a precision ground reference for ratio-metric measurements.

4.5. Analogue inputs

The analogue inputs (pins A6, A8, A13+A3, A14+A4, A16, A22, A23, A24, A28, A32, A33, A34, C3, C4, C6, C7, C13, C14, C16, C17, C21, C22, C23, C24, C25, C27, C31, C32, C33, C35, C39 and C40) sample voltage with varying resolution and range. See the pin information for more details. Some of the analogue inputs have additional characteristics, as detailed in the following sections.

> **Note**
>
> If any of the pins A1, A5, A7, A11, A15, A17, A18, A21, A25, A31, A35, C5, C10, C15 and C20 are not being used as digital outputs then it is possible for them to be used as analogue inputs with a range of 0V to 33V, a loading of 41.5K to ground and a filter of 104Hz. Providing the output transistor is switched off, the pin can be driven by an external source and pin's voltage monitor will reflect the actual voltage on the pin.

4.6. Analogue inputs — thermocouple sensors

The voltages measured on the two thermocouple inputs (pins A13+A3 and A14+A4) correspond to the temperature difference between the thermocouple tip and the cold junction (internal channel AIN cold-junction-temp). The cold junction is the point where the special thermocouple wires join onto other metals and, for this ECU, is the pin(s) of the external connector. To get the absolute temperature of the thermocouple it is necessary to add on the temperature of the internal AIN cold-junction-temp channel. The cold junction temperature is measured by a semiconductor temperature sensor, placed at a point as close to the connector pins as possible.

The relationship between the input voltage and the ADC voltage (V_{ADC}) and ADC counts (C_{ADC}) for the thermocouple inputs is:

$$V_{ADC} = V_{TC} \times 100 + \frac{5}{11}$$

$$C_{ADC} = V_{TC} \times 20460 + 93$$

This gives an approximate range for a type K thermocouple of -134°C to +1109°C. The relationship between Temperature and V_{TC} depends on the type of thermocouple, it is approximately 42uV/°C for a type K thermocouple.

The relationship between temperature and the ADC voltage (V_{ADC}) and ADC counts (C_{ADC}) for the internal temperature sensor is:

$$V_{ADC} = T_{CJ} \times 0.00645 + 0.509$$

$$C_{ADC} = T_{CJ} \times 5.28255 + 416.871$$

over a range of -40°C to +125°C.

4.7. Analogue inputs — differential input

There is a single differential input (pin C24+C25) which is provided for use with a MAF sensor. The value reported by the internal AIN diff. channel is the voltage difference between the input signals.

4.8. Digital inputs

The digital inputs (pins A8, A26, C7, C27, C28, C29, C30, C34, C39 and C40) sense the binary state based on the pin voltage and a threshold. The sense state is low if the external pin voltage is >= 2.8V and high if <= 2.5V (i.e., the sensed state is inverted).

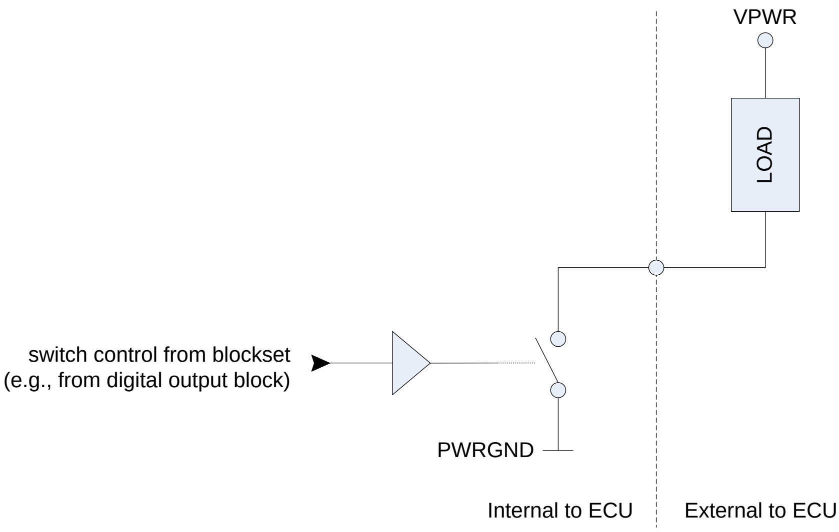
> **Note**
>
> The external digital signals are all low pass filtered to prevent signals of excessive frequency from tying up the target processor (e.g. to prevent spurious interrupts occurring from high frequency noise coupling).

> **Note**
>
> If any of the pins A1, A5, A7, A11, A15, A17, A18, A21, A25, A31, A35, C5, C10, C15 and C20 are not being used as digital outputs then it is possible for them to be used as digital inputs with a loading of 41.5K to ground and no input filter. Providing the output transistor is switched off, the pin can be driven by an external source and the pin's digital monitor will reflect the actual state of the pin. The digital monitor signal is not inverted: low if <= 3.3V and high if >= 6.9V.

4.9. Digital outputs

The digital outputs (pins A5, A7, A15, A17, A18, A25, A31, A35, C5, C10, C15 and C20) are low-side drivers. That is, the ECU switches the output pin to ground, the actuator is connected to the output pin and the battery (or to the ECU's high side power pins, A19, A29, A39 and A40, see Section 4.12, “Digital output — high side output control” for further details).

Figure 4.2. Switching arrangement for digital outputs



The low-side digital outputs contain internal monitoring circuitry that provides diagnostic information. However, as a consequence a small leakage current will flow through the actuator when the low-side output driver is turned off. Refer to Table 4.3, "Low-side digital output leakage current" for typical leakage currents at specified operating voltages.

Table 4.3. Low-side digital output leakage current

Supply Voltage	Typical Leakage Current
12V	0.4mA
24V	0.8mA

> **Note**
>
> If the battery voltage falls below 7.5V and any of the following outputs are on: A1, A5, A11, A15, A18, A21, A25, A31, A35, C5, C10, C15 and C20, then the ECU may become damaged. To prevent this, the platform software turns the outputs off if the measured battery voltage is less that 7.5V, and re-enables the outputs when the measured battery voltage is greater than 7.75V. The platform software performs this task every 10 milliseconds.

> **Note**
>
> The coil outputs (pins C10, C15 and C20) should be connected directly to *VPWR* (as shown above) and not through the high side pins A19, A29, A39 and A40 (see Section 4.12, "Digital output — high side output control").

4.10. Digital output — state monitoring

The actual state of an output pin can be monitored using a corresponding internal *digital monitor* and internal *analogue monitor* channel. The digital monitor channel simply reflects the on or off state of the actual output. The analogue monitor channel measures the actual voltage at the pin after scaling.

4.11. Digital output — driver protection

The over-current trip state of an output pin can be monitored using a corresponding internal *over-current monitor* channel. In normal operation the internal over-current trip channel will be 1. If the output channel experiences an over-current, the output channel will be forced off by the ECU and the over-current trip channel will be set to 0.

The over-current trip latch can be cleared and the tripped outputs enabled by the *pss_OvercurTripReset_DiagnEnable* Simulink block or by calling the *pss_overcur_trip_reset_and_diagn_enable_state()* C-API function.

> **Note**
>
> To help component heat dissipation and to help prevent component stress, the platform software ensures there is at least 50ms between each request to clear the over current trip latches.

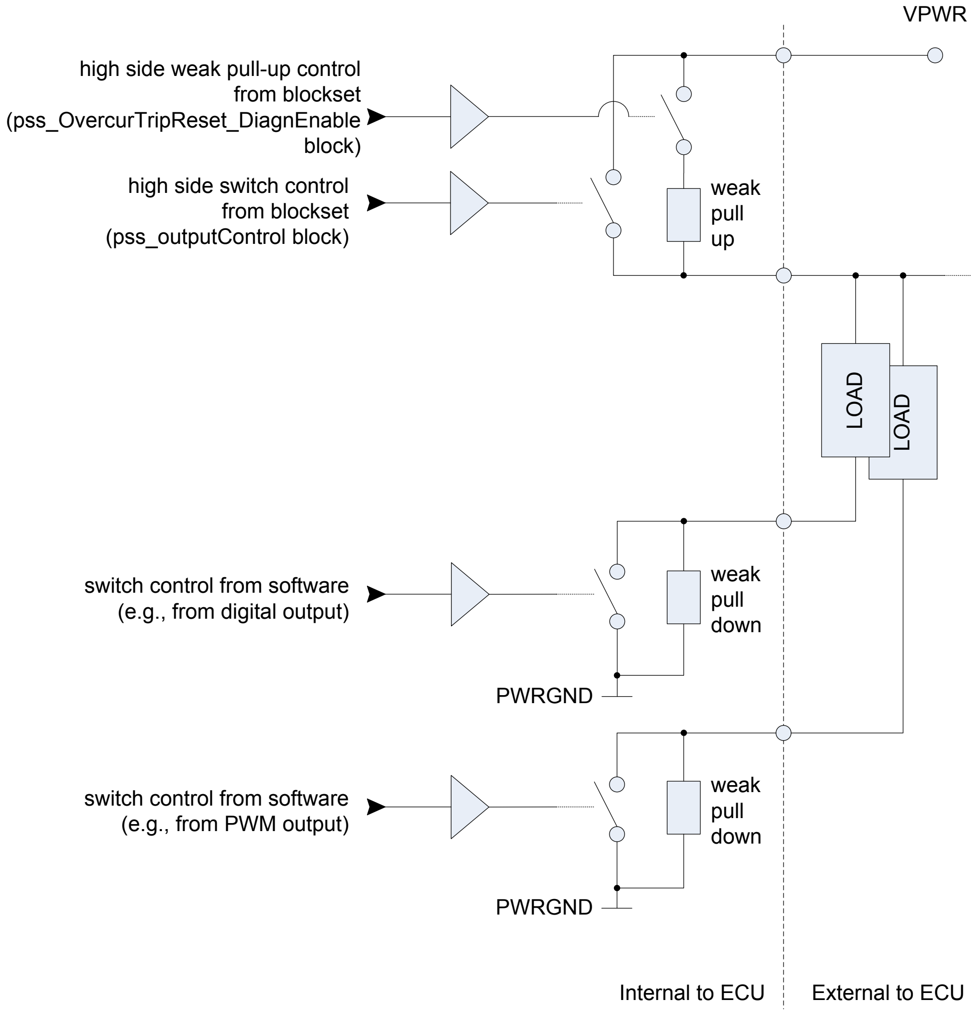
> **Note**
>
> The over current trip channel has no function when a channel is an injector or configured as an injector. In this state, reading the channel will give undefined results.

4.12. Digital output — high side output control

The high side output arrangement provides for a single switch to turn on or off actuators controlled by the ECU.

> **Note**
>
> When using the high-side actuator output control, all loads controlled by a low-side drive output must be supplied by the high-side actuator output. If the system includes loads controlled by low-side drive outputs supplied by the high-side actuator output and others supplied directly from battery positive, there is a potential for a sneak path to provide power to some actuators even if the module is powered off. If it is desirable to connect loads controlled by low-side outputs directly to battery positive, then do not use the high-side actuator output to control power to other loads controlled by low-side outputs.

Figure 4.3. Switched output control for digital outputs



The high side actuator supply pins (pins A19, A29, A39 and A40) are each individually rated to 7A and can be connected in parallel to provide a higher rating (e.g., using two pins gives 14A, three pins gives 21A, etc.). The maximum supply is 26A. All high side actuator supply pins are connected internally in parallel (similarly for the ground pins).

Note

If the battery voltage falls below 7.5V and any of the following outputs are on: A1, A5, A11, A15, A18, A21, A25, A31, A35, C5, C10, C15 and C20, then the ECU may become damaged. To prevent this, the platform software turns the outputs off if the measured battery voltage is less that 7.5V and re-enables the outputs when the measured battery voltage is greater than 7.75V. The platform software performs this task every 10 milliseconds.

Note

The coil outputs (pins C10, C15 and C20) should be connected directly to *VPWR* (as shown in Section 4.9, “Digital outputs”) and not through the high side switch.

Note

The underlying timer for the M460 I/O has a rate of 4MHz.

4.13. Digital output — high side output diagnostic

The high side output circuit provides a mechanism to diagnose shorts in the circuit. The mechanism allows faults to be detected without risk of unintentional operation of a load.

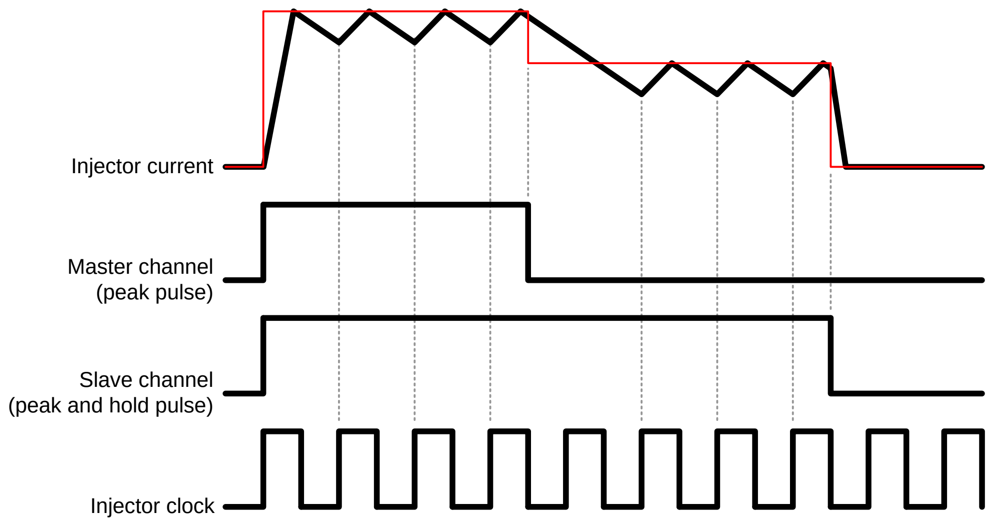
With the high side switch and all the low side outputs off, the weak pull-up resistor works in conjunction with the permanent weak pull-down resistors in parallel with all the low side switches to cause all the outputs to float at a voltage of somewhere around half battery.

The floating voltage can be verified by reading the corresponding internal *voltage monitor* channels. If any output is shorted to battery or ground, or if any load is open circuit, the measured voltages will show a clear bias.

4.14. Digital output — injector operation

The injector outputs (pins A1, A11, A21 and A31) allow the injector current to be regulated at two different levels, called the peak and the hold currents. The application software must provide two digital signals, one for the duration of the peak current and one for the duration of the peak and hold current. The application software must provide a clock for the injector current modulation (see internal channels A1, A11, A21 and A31).

Figure 4.4. Injector operation



The internal *injector clock* channel must be configured to output a continuous 50% duty cycle square wave at an application determined frequency. This will typically be in the range 100Hz to 10KHz.

The peak and hold digital signals can be generated through the use of the *pdx_PWMSynchronisedOutput* Simulink block or the *pdx_spwm_output()* C-API function The master channel corresponds to the peak signal, and the slave channel corresponds to the peak and hold signal. The master and slave channels must have identical frequency and the slave delay must be set to zero. The injector clock signal can be generated through the use of the *pdx_PWMOutput* or *pdx_PWMVariableFrequencyOutput* Simulink blocks, or the *pdx_pwm_output()* C-API function.

> **Note**
>
> If the battery voltage falls below 7.5V and any of the following outputs are on: A1, A5, A11, A15, A18, A21, A25, A31, A35, C5, C10, C15 and C20, the ECU may become damaged. To prevent this, the platform software ensures that the outputs are turned off if the measured battery voltage is less that 7.5V. The platform software re-enables the outputs when the measured battery voltage is greater than 7.75V. The platform software performs this task every 10 milliseconds.

> **Note**
>
> The over current trip channel has no function when a channel is an injector or configured as an injector. In this state, reading the channel will give undefined results.

> **Note**
>
> When operating in injector mode, the hardware switches the recirculation diode into circuit when the *peak and hold pulse* is high and out of circuit when low. This results in a slow decay of the current during the off periods of the hardware generated PWM and a rapid decay of the current flow at the end of the injection period (to ensure the fastest possible closing of the injector).

4.15. Digital output — configurable injector output

One of the injector outputs, A31 can be either an injector output or a PWM output. The output type is selected by the *pcfg_ConfigM460* Simulink block or by calling the *pcfg_setup_m460()* C-API function.

When A31 is configured as an injector channel, the corresponding internal *current trip monitor* channel will give undefined results.

> **Note**
>
> The configuration must be set once during the start of the application software and not changed thereafter.

4.16. Serial inputs and outputs

Some of the internal and external inputs and outputs are classed as serial. The connector pinout tables and internal channel tables above specify whether a pin or channel is serial or not.

When a serial input is read, the measurement reflects the value of the input taken last time the application task ended. I.e., the value of the input is delayed by one cycle of the task period. When a serial output is set, the driven state is updated at the end of the current application task. I.e., there is a delay between requesting a change in the output state, and the output state honoring that request.

4.17. Communication — CAN

The CAN buses (pins A37+A36 and C37+C36) are implemented using high-speed CAN transceivers. Each CAN bus has terminating resistors fitted. Fleet and developer ECUs support two CAN buses (see the pin details for more information).

4.18. Memory — configuration

The ECU supports different memory configurations for application, calibration and RAM sizes, some of which require external calibration RAM (see Section 4.20, "Memory — calibration capabilities").

Table 4.4. Memory configurations supported

Configuration	App size (KiB)	Cal size (KiB)	RAM size (KiB)	External RAM required?	Run-time calibration supported?
A [a]	512	256	64	N	N
	512	256	64	Y	Y
B	512	256	832	Y	Y
C	640	128	192	Y	Y
D	768	64	768	Y	Y

[a] If an OpenECU target that supports memory configuration is loaded with an application in which no such configuration has been specified, then configuration A will be used as the default.

4.19. Memory — non-volatile storage and lifetime

The ECU supports non-volatile memory storage in Flash. Battery backed RAM is not supported.

The processor's Flash memory is split into small and large memory blocks. The application and calibration are stored in large blocks, whilst DTC information, freeze frames and so on are stored in small blocks.

The largest Flash block can take up to approximately 7.5 seconds to erase. This occurs in an environment where the Flash has been erased and programmed many times at its temperature extreme. The typical erase time is smaller, especially at ambient temperatures. Reprogramming an ECU (where many large blocks would be erased), or storing DTC information across power cycles, can therefore take some time. Users and applications should take this into consideration.

The minimum number of erase cycles is approximately 1,000 for large Flash blocks and 100,000 for small Flash blocks. This occurs in an environment where the Flash has been erased and programmed many times at its temperature extreme. The typical number of erase cycles is larger, especially at ambient temperatures.

The minimum data retention is approximately 5 years for blocks which have been erased less than 100,000 times, and approximately 20 years for blocks which have been erased less than 1,000 times.

The information about the Flash has been taken from Freescale's MPC5534 Microcontroller Data Sheet document, revision 4 (dated Mar 2008).

4.20. Memory — calibration capabilities

The ECU supports both offline calibration (where all of the ECU's calibration memory is reprogrammed whilst the application is stopped) and online calibration (where individual calibrations can be modified whilst the application runs). These calibration capabilities are supported through two ECU types:

- Developer ECUs — Supports offline and online calibration Uses an external RAM device to map calibrations, normally stored in non-volatile memory, to RAM to support modifications of calibration whilst the application runs. This provides all of the processor's RAM for the application and platform library, whilst adding additional RAM to support calibration.
- Fleet ECUs — Does not provide external RAM or the ability to calibrate whilst the application runs (offline calibration is still supported). These units are lower-cost and intended for fleet trials or production.

4.21. System modes

The ECU can run in one of two system modes: reprogramming mode and application mode. In *reprogramming* mode, the ECU can be reprogrammed with application software from a calibration tool. In *application* mode, the ECU runs the programmed application software. The ECU enters reprogramming mode either by measuring the external *FEPS* A2 pin at power up, or when attempting to reflash over CCP when the application is not inhibiting reflashing.

Table 4.5. System mode selection

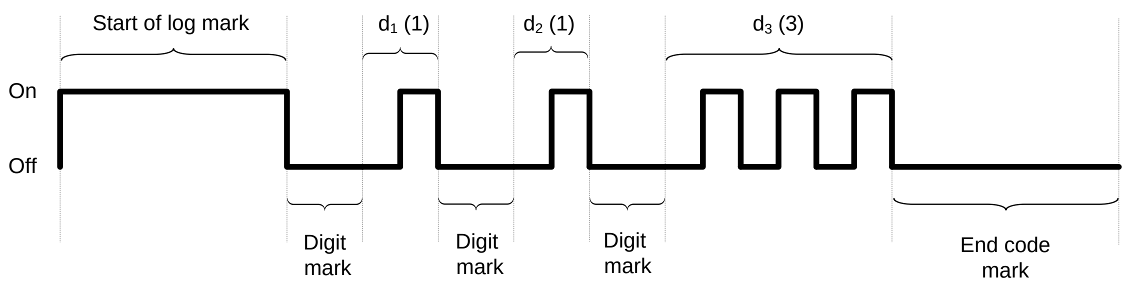
Voltage	System mode
> +17V	Enter reprogramming mode. If valid application software has previously been programmed, then use the CCP settings from that application, otherwise use the default CCP settings.
< -16V	Enter reprogramming mode. Use the default CCP settings.
Otherwise	Enter application mode if valid application software has previously been programmed, otherwise enter reprogramming mode.

4.22. Flash codes

The ECU provides a dedicated output (pin A27) for flashing a lamp. The flash sequence represents a set of codes. Each code is a three digit number, where each digit is flashed a number of times equal to its value.

An example would be the flash sequence for code *113*. The flash sequence is broken down into a series on marks, or on and off pulses as follows:

Figure 4.5. Flash code sequence



Each of the marks lasts for a specific duration:

Table 4.6. Flash code example

Mark	Duration and meaning
Start of log mark	3s — marks the start of the flash code list
Digit mark	1s — marks the start of a digit
d_n	*n*s — *n* digits, where the output is turned off for 0.5 second, then for 0.5 seconds, *n* times
End code mark	3s — marks the end of a code (i.e., end of 3 digits)

After the *end code mark*, the ECU will either flash the next code, or return to the start of the list and flash the first code. The ECU always has at least one code to flash.

Each code represents information about the ECU state. If there is no flash sequence, or a malformed flash sequence, then the ECU is malfunctioning. Otherwise, the flash sequence will represent one of the following codes:

Table 4.7. Flash codes

Code	Meaning
111	In application mode — no other condition has been detected.
112	In reprogramming mode with the FEPS pin negative.
113	In reprogramming mode with the FEPS pin high.
114	In reprogramming mode via a FEPS-less reprogramming request.
115	In reprogramming mode because no valid application software exists.
116	In reprogramming mode due to FEPS pin electrical failure.
117	In reprogramming mode due to repeated reset during application mode.
118	In reprogramming mode due to failed application checksum tests.
128	In reprogramming mode due to failed memory check tests.
119	In reprogramming mode due to a FEPS-less ISO reprogramming request.
121	In reprogramming mode due to an unknown failure.
123	In reprogramming mode due to a watchdog reset.
222	In reprogramming mode due to the application not having a valid license.

4.23. Calibration capabilities

Developer units have the capability to accept calibration changes while the application software is running. Fleet units do not have this capability.

4.24. Floating point capabilities

The ECU closely adheres to the IEEE-754 for floating point numbers.

When using Simulink, floating point Simulink models are supported — all calculations are performed using single-precision (even if the model uses double-precision, the ECU performs calculations using single-precision).

When using the C-API, floating point applications are supported — all calculations are performed using single or double precision, as determined by the application code (although double precision will incur some software overhead — see the compiler reference manual for further details).

The rounding mode is set to *round-to-nearest*. In some conditions, the ECU will not adhere to the IEEE-754 standard:

Table 4.8. Floating point conditions

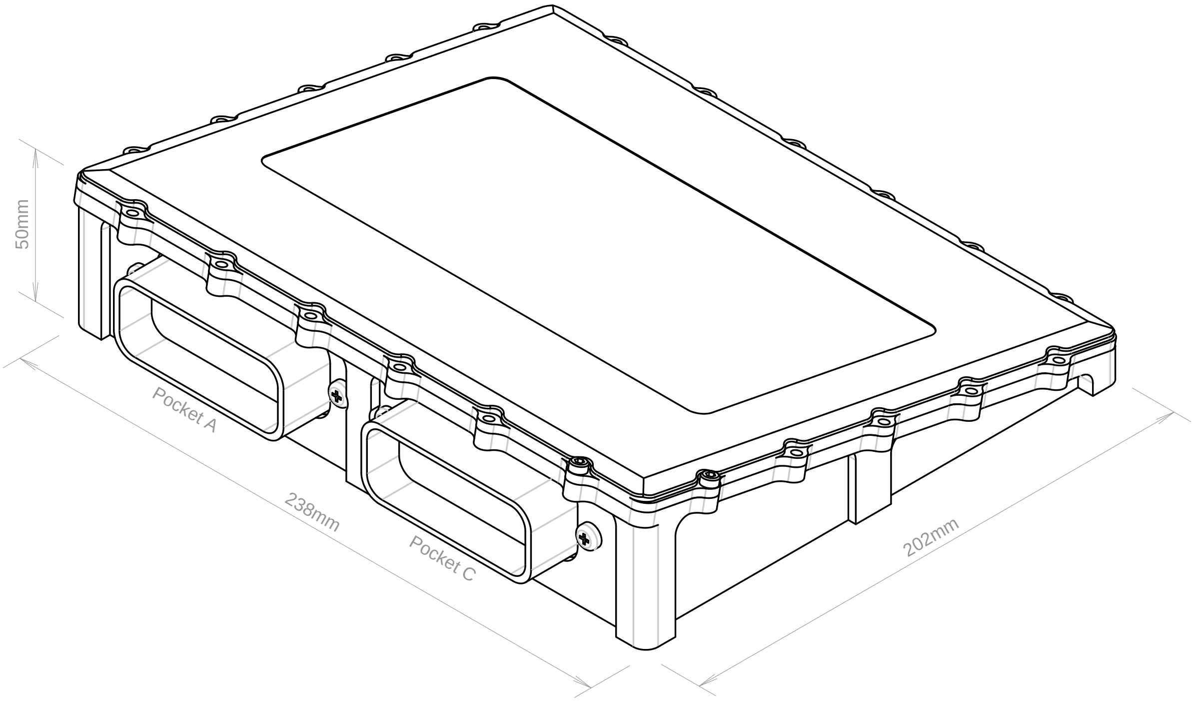
<table>
<tr><th>Condition</th><th>Result</th></tr>
<tr><td>Underflow</td><td>The result of a calculation underflow is ±0. The sign is based on the signs of the operands.</td></tr>
<tr><td>Overflow</td><td rowspan="2">The result of a calculation overflow is ±max where max is approximately 3.4×10^{38}. The sign is based on the signs of the operands.</td></tr>
<tr><td>Divide by zero</td></tr>
</table>

The ECU does not generate ±*Inf*, *NaN* or a denormalised number as the result of a calculation.

Chapter 5. Dimensions

The ECU has the following dimensions:

Figure 5.1. Outline of physical dimensions



Appendix A. Contact information

If you have questions, or are experiencing issues with OpenECU please see the FAQ website:

website
: Support.OpenECU.com [http://Support.OpenECU.com]

If you still have questions after searching through the FAQ, or want to discuss sales or proposals, you can contact main office:

Tel
: +1 734 656 0140

Fax
: +1 734 656 0141

during normal working hours (Mon to Fri, 0930 to 1700 EST).