M220 Technical Specification
29T-068432TK-05

Release 2.9.0 (r2020-1)

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Chapter 1. Technical specification

This document is the technical specification for OpenECU part *01T-068432-05m03*. Within this document, that part is referred to as the *M220-000 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-068432 M220 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:

- M220D-000 — for development and testing, including full interactive calibration tool integration.

Table 1.1. Specification

Specification	Variant
	M220D-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	-
Sensor supplies	1
Inputs	20
Outputs	13
CAN buses	2
LIN buses	-
RS232 links	-
Connectors	1x46
Weight	520g

Specification	Variant
	M220D-000
Vibration	6g random RMS
Shock capability	- [c]
Enclosure	IP69K [d]
EMC	- [c]
Partial operating voltage	6 to 36V
Full operating voltage	7 to 32V [e]
Standby current (typical)	0.25mA at 12V [f]
Operating current (typical)	100mA at 12V [g]
Operating temperature range	-40 to +105°C
Storage temperature range (installation)	-40 to +105°C
Storage temperature range (shipping)	-40 to +85°C

[a] Target ECU available for general use.

[b] See list of possible memory configurations in section 'Memory - configuration'.

[c] Please contact Pi for details.

[d] Designed for chassis mounted applications.

[e] Designed for 12V or 24V vehicles.

[f] 1.75mA at 24V.

[g] 75mA 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	-	A2
ECU ground	1	-	A31
Sensor supply	1	-	A25
Module control, status			
Ignition sense	1	-	A26
Module control FEPS	1	-	A27
Module status Flash code	1	-	A27
Communication			
CAN buses	2	-	A23+A24, A28+A43
Inputs — time based			
Analogue	12	27	A3, A5, A7, A10, A12, A13, A14, A15, A18, A19, A20, A21
Digital	8	4	A4, A6, A11, A22, A26, A38, A39, A42

I/O type	External	Internal	Pins
Frequency	8	-	A4, A6, A8+A9, A11, A22, A38, A39, A42
PWM	7	-	A6, A8+A9, A11, A22, A38, A39, A42
Quadrature	7	-	A6, A8+A9, A11, A22, A38, A39, A42
Outputs — time based			
Digital	12	10	A16, A17, A29, A32, A33, A34, A35, A36, A37, A44, A45, A46
H-bridge	1	-	A30+A1
PWM	12	-	A16, A17, A29, A32, A33, A34, A35, A36, A37, A44, A45, A46
Inputs — angle based			
Crank-shaft primary	1	-	A8+A9
Cam-shaft	3	-	A4, A6, A11
Analogue	12	52	A3, A5, A7, A10, A12, A13, A14, A15, A18, A19, A20, A21
Analogue injector duration	12	-	A3, A5, A7, A10, A12, A13, A14, A15, A18, A19, A20, A21
Outputs — angle based			
Injector saturating	4	-	A17, A29, A32, A44
Ignition	4	-	A35, A36, A37, A46

Chapter 2. Connector pinout

The M220-000 variants have one ECU connector (pocket) named A, which has a pinout as given in the following table. 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

2.1. Pocket A

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

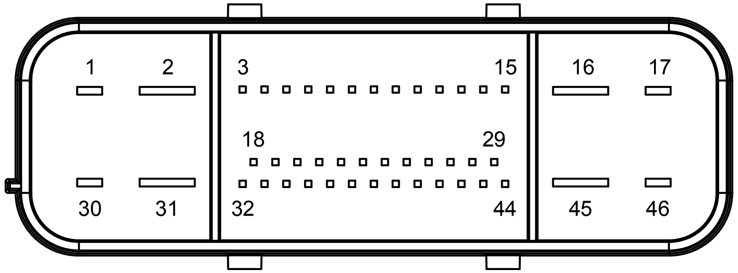


Table 2.1. Part numbers of the mating connector

Supplier	Part number	Part
TE	1326110-1	Cable mount connector (right handed)
	1326341-1	Cable mount connector (left handed)
	1326113-1	Cover

Table 2.2. Part numbers for the 6.3 mm pin

Supplier	Part number	Colour	Part
Yazaki	7116-4142-02	Tin	Female crimp contact
	7158-3081-50	Red	Seal (for wire 1.40 mm - 2.10 mm)
	7158-3082-90	Blue	Seal (for wire 2.18 mm - 3.00 mm)
	7158-3083	Black	
	7158-3080-60	Green	Plug for unused position
Pins A2, A16, A31 and A45			

Table 2.3. Part numbers for the 2.8 mm pin

Supplier	Part number	Colour	Part
TE	1326032-4	Tin	Female crimp contact
Yazaki	7158-3111-60	Green	Seal (for wire 1.19 mm - 1.90 mm)
	7158-3112-70	Yellow	Seal (for wire 1.88 mm - 2.10 mm)
	7158-3113-40	White	Seal (for wire 2.18 mm - 3.00 mm)
	7158-3114-90	Blue	Plug for unused position
Pins A17, A30+A1 and A46			

Table 2.4. Part numbers for the 0.64 mm pin

Supplier	Part number	Colour	Part
TE	0638551-1	Tin	Female crimp contact

Supplier	Part number	Colour	Part
Deutsch	0413-204-2005	Red	Plug for unused position
Pins A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15, A18, A19, A20, A21, A22, A23, A24, A25, A26, A27, A28, A29, A32, A33, A34, A35, A36, A37, A38, A39, A40+A41, A42, A43 and A44			

Table 2.5. Part numbers of the pin crimp tools

Supplier	Tool assembly part number	Die assembly part number	Part
TE	91338-1	91338-2	Crimp tool for the 0.64 mm female terminal, PRO-CRIMPER III Hand Tool
Diamond Die and Mold Company	088BR	-	Crimp tool for the 2.8 mm female terminal
	088BR-1		Crimp tool for the 6.3 mm female terminal

Table 2.6. Connector pinout — Pocket A

Main connector — Pocket A								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
A1		Digital	O	Y	H-bridge		5A	Outputs A1 and A30 are only supported in H-bridge mode. Independent configuration as a low-side or high-side output is not possible. Related to internal channels H-bridge Ready and Monitor (v).
A2		V_{PWR}	P	Y			40A	Related to internal channel AIN VPWR.
A3		Analogue	I		1k to V_{PSU1}	530Hz	0V to 5V	12-bit unsigned conversion.
A4		Analogue (VRS single-ended)	I		68K series	23.4kHz	TBD	VRS input. Related to internal channels DOT Hall input bias and DOT Hall-VRS Select.
		Digital (VRS single ended)					0 to +157V	Cam-shaft position sensor. Related to internal channels DOT Hall input bias and DOT Hall-VRS Select.
A5		Analogue	I		1k to V_{PSU1}	530Hz	0V to 5V	12-bit unsigned conversion.

Main connector — Pocket A

Pin	P	Function	I/O	M	Loading	Filter	Range	Notes
A6		Analogue (VRS single-ended)	I		68K series	23.4kHz	TBD	Single-ended VRS input. Pin not available as PWM input in the default build configuration. Related to internal channels DOT Hall input bias and DOT Hall-VRS Select.
		Digital (VRS single ended)					0 to +157V	Cam-shaft position sensor. Related to internal channels DOT Hall input bias and DOT Hall-VRS Select.
A7		Analogue	I		51k to V_{GND}	530Hz	0V to 5V	12-bit unsigned conversion.
A8		Analogue (VRS diff., +ve)	I		68K series	1.2kHz	±157V	Crank-shaft position sensor, see also: A9. Related to internal channels DOT Hall input bias and DOT Hall-VRS Select.
A9		Analogue (VRS diff., -ve)	I		68K series	1.2kHz	±157V	Differential VRS input, see also: A8. Related to internal channels DOT Hall input bias and DOT Hall-VRS Select.
A10		Analogue	I		1k to V_{PSU1}	530Hz	0V to 5V	12-bit unsigned conversion.
A11		Digital (Hall effect)	I		4k7 to V_{PWR}	9.58kHz	0V to V_{PWR}	Cam-shaft position sensor.
		Digital						
A12		Analogue	I		51k to V_{GND}	530Hz	0V to 5V	12-bit unsigned conversion.
A13		Analogue	I		51k to V_{GND}	530Hz	0V to 5V	12-bit unsigned conversion.
A14		Analogue	I		51k to V_{GND}	530Hz	0V to 5V	12-bit unsigned conversion.
A15		Analogue	I		1k to V_{PSU1}	530Hz	0V to 5V	12-bit unsigned conversion.
A16		Digital	O	Y	High side	n/a	15A	Related to internal channels Monitor (c), Monitor (ct) and Monitor (v).
A17		Digital (injector)	O	Y	Low side		2A	Related to internal channels Monitor (c) and Monitor (v).
		Digital				n/a		
A18		Analogue	I		1k to V_{PSU1}	530Hz	0V to 5V	12-bit unsigned conversion.
A19		Analogue	I		1k to V_{PSU1}	530Hz	0V to 5V	12-bit unsigned conversion.
A20		Analogue	I		1k to V_{PSU1}	530Hz	0V to 5V	12-bit unsigned conversion.
A21		Analogue	I		1k to V_{PSU1}	530Hz	0V to 5V	12-bit unsigned conversion.

Main connector — Pocket A

Pin	P	Function	I/O	M	Loading	Filter	Range	Notes
A22		Digital	I		4k7 to V_{PWR}	100Hz	0V to V_{PWR}	
A23		CAN+ (high)	C		124R			CAN bus 1 high (+ve), see also: A24. Related to internal channel DOT disable-CAN.
A24		CAN- (low)	C		124R			CAN bus 1 low (-ve), see also: A23. Related to internal channel DOT disable-CAN.
A25		Sensor supply	P	Y			5V, 250mA	Sensor supply 1. Can be turned on and off by the application for diagnostics purposes. Related to internal channels DOT enable-EXT-PSU1 and Monitor (v).
A26		Digital	I		4k7 to V_{GND}	100Hz	0V to V_{PWR}	Key position (ignition sense) input. Reads 0 when the external voltage at the pin is >= 4.73V and 1 when the external voltage at the pin is <= 3.44V. Related to internal channel DOT hold-PSU.
A27		FEPS	I		See notes	323Hz	±18V	Module flash programming control. 82K series input resistor followed by a bias voltage network with 10K to 5V and 11K to ground. Mutually exclusive use with Flash code output function. You can not connect both at the same time.
		Flash code	O		Low side		10mA	ECU status information. Mutually exclusive use with FEPS input function. You can not connect both at the same time.
A28		CAN+ (high)	C		No termination resistor			CAN bus 0 high (+ve), see also: A43. Related to internal channel DOT disable-CAN.
A29		Digital (injector)	O	Y	Low side		2A	Related to internal channels Monitor (c) and Monitor (v).
		Digital						
A30		Digital	O	Y	H-bridge		5A	Outputs A1 and A30 are only supported in H-bridge mode. Independent configuration as a low-side or high-side output is not possible. Related to internal channels H-bridge Ready and Monitor (v).
A31		V_{GND}	P				40A	
A32		Digital (injector)	O	Y	Low side		2A	Related to internal channels Monitor (c) and Monitor (v).
		Digital						

Main connector — Pocket A								
Pin	**P**	**Function**	**I/O**	**M**	**Loading**	**Filter**	**Range**	**Notes**
A33		Digital	O	Y	Low side		2A	Related to internal channels Monitor (c) and Monitor (v).
A34		Digital	O	Y	Low side		250mA	Related to internal channel Monitor (v).
A35		Digital	O	Y	Low side		250mA	Coil/spark (smart) driver. Related to internal channel Monitor (v). Related to internal channel Monitor (v).
A36		Digital	O	Y	Low side		100mA	Coil/spark (smart) driver. Related to internal channel Monitor (v). Related to internal channel Monitor (v).
A37		Digital	O	Y	Low side		100mA	Coil/spark (smart) driver. Related to internal channel Monitor (v). Related to internal channel Monitor (v).
A38		Digital	I		4k7 to V_{PWR}	100Hz	0V to V_{PWR}	
A39		Digital	I		4k7 to V_{PWR}	100Hz	0V to V_{PWR}	
A40		Sensor ground	P					A40 and A41 connected together internally.
A41		Sensor ground	P					A40 and A41 connected together internally.
A42		Digital	I		4k7 to V_{PWR}	100Hz	0V to V_{PWR}	
A43		CAN- (low)	C		No termination resistor			CAN bus 0 low (-ve), see also: A28. Related to internal channel DOT disable-CAN.
A44		Digital (injector) Digital	O	Y	Low side		2A	Related to internal channel Monitor (v).
A45		Digital	O	Y	Low side		15A	Related to internal channels Monitor (ct), Monitor (d) and Monitor (v).
A46		Digital	O	Y	Low side		2A	Coil/spark (smart) driver. Related to internal channel Monitor (v). Related to internal channel Monitor (v).

Chapter 3. Internal signals

Table 3.1. Internal signals

Signal	I/O	Signal type	Range	Notes
Analogue				
AIN 3.3V	I	Analogue	0V to 5V	Internal 3.3V supply monitor. 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 monitor				
Monitor (c) (pin A16)	I	Analogue	0A to 15.625A	Digital output current monitor. 12-bit unsigned conversion. For currents below 0.5A the relationship is non-linear (see the 'Digital output' sections for more information).
Monitor (c) (pin A17)	I	Analogue	-5A to 5A	Digital output current monitor (not populated as standard). 12-bit unsigned conversion. To convert voltage (V) to current (I) use the equation, I=(V-2.5)/0.185.
Monitor (c) (pin A29)	I	Analogue	-5A to 5A	Digital output current monitor (not populated as standard). 12-bit unsigned conversion. To convert voltage (V) to current (I) use the equation, I=(V-2.5)/0.185.
Monitor (c) (pin A32)	I	Analogue	-5A to 5A	Digital output current monitor (not populated as standard). 12-bit unsigned conversion. To convert voltage (V) to current (I) use the equation, I=(V-2.5)/0.185.

Signal	I/O	Signal type	Range	Notes
Monitor (c) (pin A33)	I	Analogue	-5A to 5A	Digital output current monitor (not populated as standard). 12-bit unsigned conversion. To convert voltage (V) to current (I) use the equation, I=(V-2.5)/0.185.
Current trip monitor				
Monitor (ct) (pin A16)	I	Digital	0 or 1	Digital output current trip.
Monitor (ct) (pin A45)	I	Digital	0 or 1	Digital input indicating current trip.
Digital				
DOT disable-CAN (pin A23 and A24)	O	Digital	0 or 1	Set to 0 to enable the CAN-2 transceiver, set to 1 to disable.
DOT disable-CAN (pin A28 and A43)	O	Digital	0 or 1	Set to 0 to enable the CAN-1 transceiver, set to 1 to disable.
DOT enable-EXT-PSU1 (pin A25)	O	Digital	0 or 1	Sensor supply switch. Set to one to turn on the power supply and to zero to turn it off.
DOT Hall input bias (pin A4)	O	Digital	0 or 1	For VRS-style input this has no effect. For Hall effect, set to 1 for slightly higher input voltage threshold.
DOT Hall input bias (pin A6)	O	Digital	0 or 1	For VRS-style input this has no effect. For Hall effect, set to 1 for slightly higher input voltage threshold.
DOT Hall input bias (pin A8 and A9)	O	Digital	0 or 1	For VRS-style input this has no effect. For Hall effect, set to 1 for slightly higher input voltage threshold.
DOT Hall-VRS Select (pin A4)	O	Digital	0 or 1	Set to 1 for Hall effect, 0 for VRS-style input.
DOT Hall-VRS Select (pin A6)	O	Digital	0 or 1	Set to 1 for Hall effect, 0 for VRS-style input.
DOT Hall-VRS Select (pin A8 and A9)	O	Digital	0 or 1	Set to 1 for Hall effect, 0 for VRS-style input.
DOT hold-PSU (pin A26)	O	Digital	0 or 1	Control power supply to ECU in conjunction with the key position (ignition sense) input. Set the output to 1 to enable power hold and 0 to disable it.
H-bridge Ready (pin A30 and A1)	I	Digital	0 or 1	H-bridge ready signal. 0 indicates H-bridge is in No Drive mode OR a fault when mode is NOT No Drive. 1 indicates H-bridge ready for use. See H-bridge outputs section.
Digital monitor				
Monitor (d) (pin A45)	I	Digital	0 or 1	Digital output state monitor.

Signal	I/O	Signal type	Range	Notes
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				
AIN VPWR (pin A2)	I	Analogue	0V to 40V	Switched power supply voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=V_m*8$.
Monitor (v) (pin A1)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A16)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A17)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A25)	I	Analogue	0V to 5V	Sensor supply voltage monitor. 12-bit unsigned conversion.
Monitor (v) (pin A29)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A30)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A32)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.

Signal	I/O	Signal type	Range	Notes
Monitor (v) (pin A33)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A34)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A35)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A36)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A37)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A44)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A45)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.
Monitor (v) (pin A46)	I	Analogue	-3.488V to 36.916V	Digital output voltage monitor. 12-bit unsigned conversion. To convert measured voltage (V_m) to actual voltage (V_a) use the equation, $V_a=(V_m-0.43169)*8.080808$.

Chapter 4. Operational details

4.1. ECU power

The power supply pin (V_{PWR} A2) and the ground pin (V_{GND} A31) are both rated to 40A.

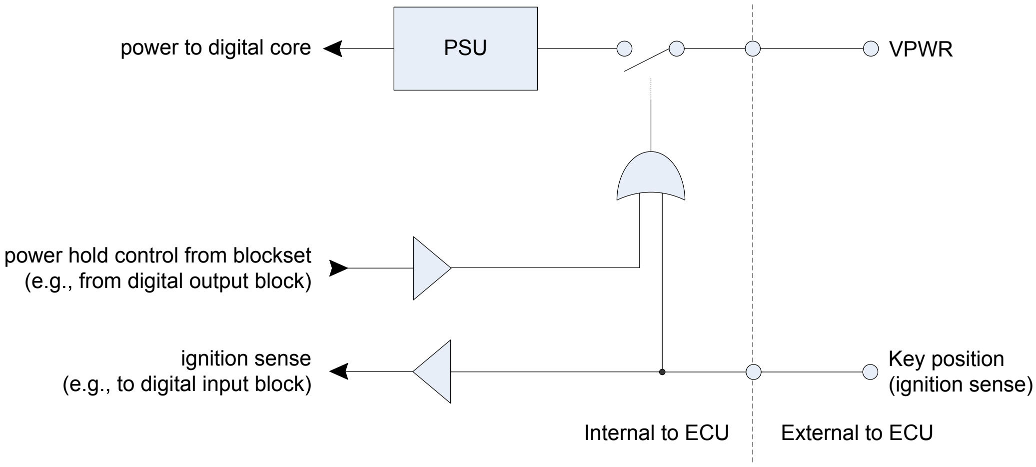
The ECU V_{GND} (pin A31) and sensor ground (pins A40+A41) are directly connected together via a ground plane in the ECU PCB. The ECU case is capacitively coupled to V_{GND}.

The ECU is designed for 12V or 24V vehicles, with various modes of operation based on the voltage (see Table 1.1, “Specification”). The ECU is protected against reverse supply connection. All inputs and outputs are protected against short-to-V_{PWR} or short-to-V_{GND} over normal operating range.

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} A2) and key position (ignition sense) input (pin A26) are asserted. The key position input (pin A26) 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 high will hold power when the key position input is opened, setting it low 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 high *as soon as* the external key position input (pin A26) is closed and only set low once all required shutdown tasks have completed.

4.3. ECU power — sensor supplies

The ECU provides one external sensor power supply (pin A25). The sensor supply can be switched off to allow the application software to perform intrusive diagnostics on sensors.

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

Table 4.1. PSU 1 monitor voltages

Voltage [a]	Meaning
-	Output short to battery [b]
4.85V - 5.00V	Normal operation
0.00V - 4.85V	Output over current or short to ground

[a] These voltages are based on absolute A/D counts (referenced to the ECU's internal 5V supply).

[b] A build option can be applied to allow the ECU to detect when the power supply is shorted to battery. Please contact Pi for further details.

4.4. Analogue inputs

The analogue inputs (pins A3, A5, A7, A10, A12, A13, A14, A15, A18, A19, A20 and A21) sample voltage with varying resolution and range. See the pin information for more details.

Note

Applying voltages greater than 5V to any analogue input with an internal 1K pull-up to 5V V_{REF} can induce measurement shifts in all analogue inputs with an internal 1K pull-up to 5V V_{REF}. The affected inputs are A3, A5, A10, A15, A18, A19, A20 and A21.

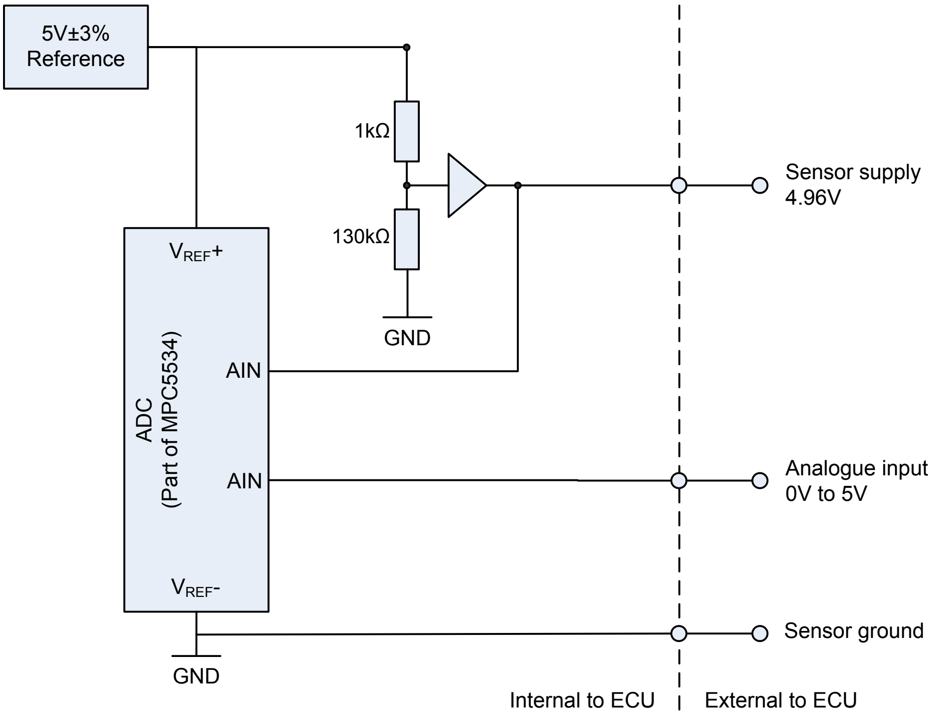
Note

If any of the pins A1, A16, A17, A29, A30, A32, A33, A34, A35, A36, A37, A44, A45 and A46 are not being used as digital outputs then it is possible for them to be used as an analogue input with a series input resistance of 300K followed by a bias network of 430K to 5V and 47K to V_{GND}, and a 630Hz filter. Providing the output transistor is switched off, the pin can be driven by an external source and the pin's voltage monitor will reflect the actual voltage on the pin.

4.5. Analogue inputs — relationship between V_{REF}, sensor supplies and inputs

The ECU power arrangement is shown in Figure 4.2, “VREF arrangement”. The figure shows the relationship between the internal 5V V_{REF} and ground, the external sensor supply and ground, and the analogue inputs.

Figure 4.2. V_{REF} arrangement



The internal low precision 5V reference supplies the reference pin on the ADC. The 5V reference is divided down to 4.95V to provide the external sensor supply. The exact voltage being produced can be read on a direct (unscaled) ADC channel. The sensor ground is a nominal 0V, but may be slightly above this due to voltage drop across the protection device.

The exact voltage on the analogue input pin can be read on a direct (unscaled) ADC channel. Standard 0-5V inputs are passed directly to the ADC with no scaling.

Some analogue input pins are internally pulled up to the sensor power supply (pin A25). If the sensor supply is not enabled, floating inputs will fluctuate when read by the ADC. The sensor supply must be enabled for resistance measurements made on any of these channels.

4.6. Analogue inputs — variable reluctance (VR)/Hall effect inputs

The analogue input pins A4, A6, A8 and A9 have conditioning circuitry for interfacing to *Variable Reluctance* (VR) sensors. The VR signal is amplified, processed to determine an adaptive threshold used in noise reduction, and then processed to determine zero crossings representing the center of teeth. The input chip is also capable of processing in Hall effect mode however.

Each of these inputs has a corresponding "Hall-VRS Select" internal digital output signal to select VR mode or Hall effect mode. Set to 1 for Hall effect, 0 for VRS-style input.

A second "Hall input bias" internal digital output signal is available for each of these inputs. For VRS-style input this has no effect and can be ignored. For Hall-effect, set to 1 for a slightly higher input voltage threshold.

> ### Note
>
> Reading a Hall effect sensor may require a pull up resistor. An external pull up can be used or an internal one can be added as a custom option by contacting Pi Innovo.

In VR mode, once the VR input signal voltage rises above an adaptive threshold, the zero crossing comparator is armed. Arming the comparator this way provides robust noise immunity to the input VR signal, preventing false triggers from occurring due to a broken tooth or an off-center tooth wheel.

The peak threshold level is set to a third of the peak of the previous cycle of the input VR signal. As the sensor signal peak voltage rises or falls, the adaptive peak threshold voltage also increases by the same ratio. If the input signal voltage remains lower than the adaptive peak threshold for more than 85ms, an internal watchdog timer drops the threshold level to a default minimum threshold. This ensures pulse recognition recovers even in the presence of intermittent sensor connection.

Once armed, the zero crossing detection logic generates a digital (rising) edge when the positive input signal falls below the negative input signal. For single-ended inputs (pins A4 and A6) this occurs when the input signals falls below ground. This zero crossing point corresponds to the center of the gear-tooth (provided the sensor is wired the right way round) and is the most reliable marker for position/angle-sensing applications.

The VR input circuitry introduces a phase offset as an artifact of signal filtering. The phase shift causes the digital tooth edge representing the tooth center to occur some time after the actual tooth center. The time between the digital tooth edge and the actual tooth center increases as the frequency of the input signal increases.

> ### Note
>
> The VRS input pins A4, A6, A8 and A9 low pass filters are specified in Chapter 2, *Connector pinout* above. Contact Pi Innovo to specify a customized input filter if the standard filter is not appropriate for your application.

Pins A8+A9 are a differential input pair. In order to use these as a single ended input, pin A9 should be connected to sensor ground (pins A40+A41).

The conditioning circuitry for pins A4, A6, A8 and A9 invert the logical sense of the inputs. In VRS mode, a logic 0 is reported from when the interface is armed until the zero-crossing point, and a logic 1 is reported from the zero-crossing point until the interface is next armed. In Hall effect mode, a logic 1 is reported if the signal is less than the threshold voltage and a logic 0 is reported if it is greater than the threshold voltage. For the differential input on pins A8+A9, the signal here means the positive input signal on pin A8 minus the negative input signal on pin A9.

The peak-to-peak voltage range for each VR input varies with temperature:

Table 4.2. VR input voltage range

Operating temperature	Input voltage range
-40°C to +85°C	±100mV to ±200V peak sine wave voltage
-40°C to 105°C	±100mV to ±157V peak sine wave voltage

These voltage limits are with full power loading of the outputs. The voltage limits will be higher with lighter load conditions.

> **Note**
>
> The default build option does not support measuring the single-ended VRS input A6 as a PWM input. Contact Pi for details.

> **Note**
>
> Pins A4 and A6 are available to use as secondary cam inputs only in modified units. Please request technical support if this modification is of interest.

4.7. Digital inputs

The digital inputs (pins A22, A38, A39 and A42, A11 and A26) sense the binary state based on the pin voltage and a threshold.

Not inverted
: For pins A22, A38, A39 and A42, the signal is not inverted: low if <= 2.32V and high if >= 4.75V (worst case).

Inverted
: For pins A11 and A26, the signal is inverted. For pin A26 the sense is low if the signal is >= 4.73V and high if <= 3.44V (worst case). For pin A11, the sense is low if the signal is >= 4.6V, and high if <= 2.6V.

> **Note**
>
> All external signals are low pass filtered to prevent signals of excessive frequency from tying up the target processor. See the pin information for more details.

> There is a potential issue when using earlier M220 revisions with later versions of OpenECU developer software. M220 revision 3 ECUs do not have circuitry to read pins A38, A39 and A42 as PWM inputs. Later versions of OpenECU developer software allow the application to read these pins as PWM inputs, regardless of ECU revision. To avoid high frequency EMI from tying up the target processor on M220 revision 3 ECUs, do not read these pins as PWM inputs. This is not an issue with more recent revisions of M220 ECUs (e.g., revision 4 or 5).

4.8. Digital outputs

The digital outputs (pins A16, A17, A29, A32, A33, A34, A35, A36, A37, A44, A45 and A46) reflect a mixture of high-side and low-side drivers. Pin A16 is configured as a high-side — the ECU switches this output pin to V_{PWR} and the actuator is connected to the output pin and ground.

On some variants of the M220-000, the digital outputs for pins A17, A29, A32 and A33 have current feedback channels populated. The current feedback channels can be read as analogue inputs, see Table 3.1, “Internal signals” for details.

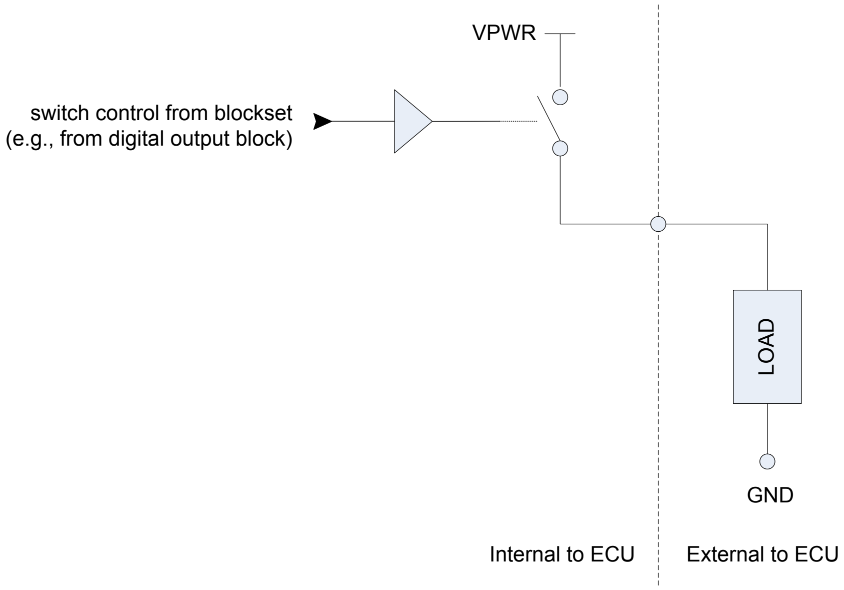
> ## Warning
>
> The digital outputs are not guaranteed to work properly when the ECU supply (battery) is outside 7V - 32V. It is recommended to monitor the ECU supply voltage on A2 and set the digital outputs to a safe state in your application software. The safe state depends on your application. In most applications, the safe state is to disable the outputs to protect the circuitry and to prevent unwanted output activation.

> ## Note
>
> The current feedback channels are not populated on the standard M220-000 ECU, but they can be populated with a build option.

> ## Note
>
> The underlying timer for the M220 I/O has a rate of 4MHz.

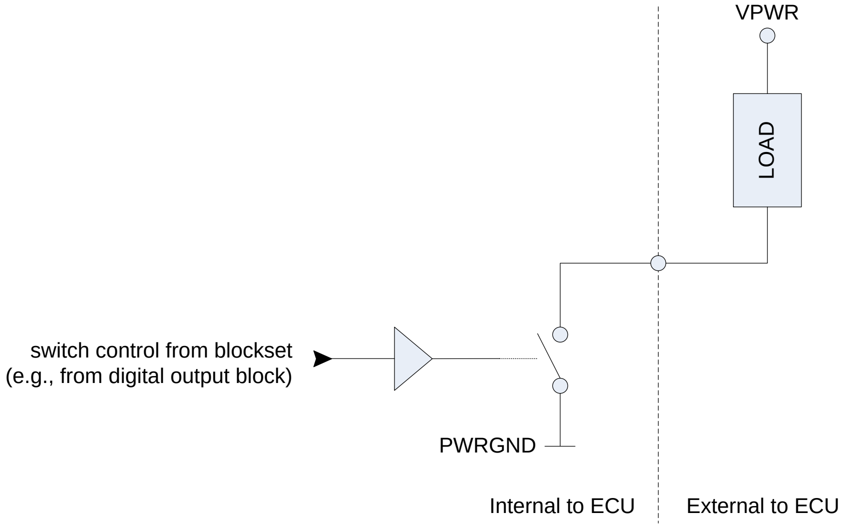
> ## Note
>
> Because the platform does not sample the current feedback signal synchronised to the 'on' stage of the PWM output, the application cannot easily derive an average current reading.

Figure 4.3. High-side switching arrangement for digital outputs



Pins A17, A29, A32, A33, A34, A35, A36, A37, A44, A45 and A46 are configured as low-side — the ECU switches the output pin to ground, the load is connected to the output pin and the battery.

Figure 4.4. Low-side 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 (V)	Typical Leakage Current (mA)
12	0.400
24	0.800

4.9. Digital output — state monitoring

The actual state of an output pin can be monitored using a corresponding internal *analogue monitor* channel. The analogue monitor channel measures the actual voltage at the pin after scaling.

When the pin is used as a PWM, there are two possible uses for such a feedback:

- Before starting a PWM, by reading the voltage on the pin and checking for open or short circuits.
- By reading the average voltage on a PWM output and comparing it with the demanded PWM width and the battery voltage reading, you can perform a consistency check that the PWM output is performing as expected. This method can be applied if the PWM frequency is higher than the filter cut off frequency (630Hz).

When the pin is used as a plain digital output, feedback is used as follows:

- Read the voltage on the pin and check for open or short circuits.

4.10. Digital output — high/low-side driver protection and diagnostics

The digital outputs apart from A16 and A45 are self protecting; in case of a fault the outputs will automatically switch off, and once they recover, switch on again.

Output A45 has an over-current trip state monitor. In normal operation the internal over-current trip channel will be one. 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 zero.

> ### Note
>
> The overcurrent trip circuit takes a short time to reach a steady state after power-up. If a strong load is driven by output A45 within 18.4 ms of the application starting, the circuit may trip at a lower-than-expected current. Avoid driving strong loads within this brief interval.

The over-current trip latch can be cleared and the tripped outputs enabled by the *pss_OvercurTripReset* Simulink block or by calling the *pss_overcur_trip_reset()* 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.

4.11. Digital output — high-side output diagnostics

The high-side output (pin A16) has a number of internal monitor signals (voltage, current and current trip). In normal operation the internal over-current trip channel will be one. 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 zero.

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

The relationship between the high-side output's (pin A16) current monitor and the ADC voltage is non-linear below 0.5A. Refer to Table 4.4, "High-side digital output current monitor" for correlation between current and voltage.

Table 4.4. High-side digital output current monitor

Current(A)	Voltage(V)	Current(A)	Voltage(V)
0	0.112	1	0.32
0.2	0.118	2	0.64
0.4	0.144	13	4.16
0.6 [a]	0.192	13.5 [b]	4.32
0.8	0.256		

[a] The minimum guaranteed detectable current.

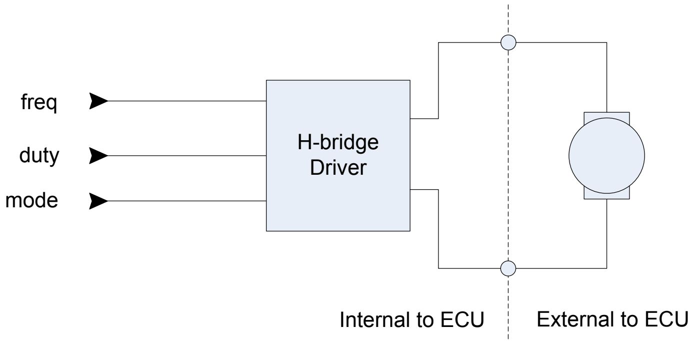
[b] The maximum guaranteed detectable current.

> **Note**
>
> High side output A16 has an over current protection threshold of 20Amps nominal. The current monitor associated with A16 has a dynamic range of 0 to 15A. Load currents above 15Amps will be reported as 15A by the A16 current monitor.

4.12. H-bridge outputs

The H-bridge outputs (pins A30+A1) are controlled through the *pdx_HBridge_Output* Simulink block or the *pdx_hbridge_output()* C-API function.

Figure 4.5. H-bridge arrangement



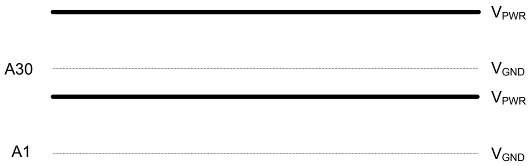
The H-Bridge can be driven in four modes:

No Drive

In *no-drive* mode, the H-bridge is turned off leaving the pins to float.

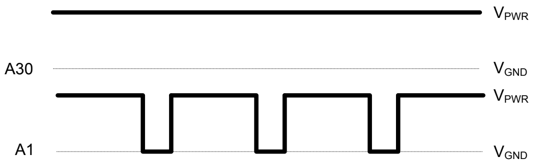
Brake

In *brake* mode, both pins of the H-bridge are driven to V_{PWR}.



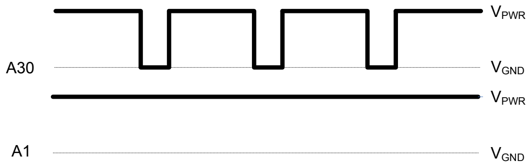
Forward

In *forward* mode, pin A30 is driven to V_{PWR} and pin A1 pulsed, resulting in a current flow the opposite from the reverse mode.



Reverse

In *reverse* mode, pin A1 is driven to V_{PWR} and pin A30 is pulsed, resulting in a current flow the opposite from the *forward* mode.



Warning

To avoid unexpected behavior, H-bridges should be set to NO DRIVE mode before flashing the ECU. This can be done by commanding the actuators to NO DRIVE any time the engine is not turning.

Warning

The digital outputs are not guaranteed to work properly when the ECU supply (battery) is outside 7V - 32V. It is recommended to monitor the ECU supply voltage on A2 and set the digital outputs to a safe state in your application software. The safe state depends on your application. In most applications, the safe state is to disable the outputs to protect the circuitry and to prevent unwanted output activation.

The frequency and the duty cycle of operation are controlled by the application. There are monitor inputs to check the output pin state.

4.13. H-bridge outputs — H-bridge ready signal

The H-bridge outputs include an H-bridge Ready signal which can be used to determine faults that are internal to the H-bridge IC.

The H-bridge Ready signal is interpreted as follows:

0 (logic low)
: In *no-drive* mode, H-bridge Ready is always 0.

If the mode is not *no-drive*, then H-bridge Ready will be 0 if the H-bridge IC encounters an over-temperature fault or an over-current fault.

An *over-current* fault will occur if the current exceeds 11A on the high-side of the H-bridge, or 8A on the low-side of the H-bridge.

An *over-temperature* fault will occur if the temperature of the H-bridge exceeds 175 degC.

1 (logic high)
: When H-bridge Ready is 1, this indicates that the H-bridge is NOT in *no-drive* mode, AND an over-current or over-temperature fault does not exist.

4.14. Communication — CAN

The CAN busses (pins A23+A24 and A28+A43) are implemented using high-speed CAN transceivers. CAN bus 1 (pins A23+A24) has terminating resistors fitted, CAN bus 0 (pins A28+A43) doesn't.

4.15. Memory — configuration

The ECU supports different memory configurations for application, calibration and RAM sizes, some of which require external calibration RAM (see Section 4.17, “Memory — calibration capabilities”).

Table 4.5. 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.

4.16. 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).

4.17. 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.

4.18. 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 selects which mode to enter when it is powered up by measuring the external *FEPS* A27 pin.

Table 4.6. System mode selection

FEPS (A27) Voltage	System mode
> +16V	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. [a]
Otherwise	Enter application mode if valid application software has previously been programmed, otherwise enter reprogramming mode.

[a] In early revisions of the hardware, using this negative may damage the ECU, please consult the errata associated to your revision before using this functionality.

> **Note**
>
> When reprogramming an M220 over CAN ensure that the unit is operating safely within the specified operating limits. Care should be taken to not reprogram at the specified extremes of temperature or voltage.

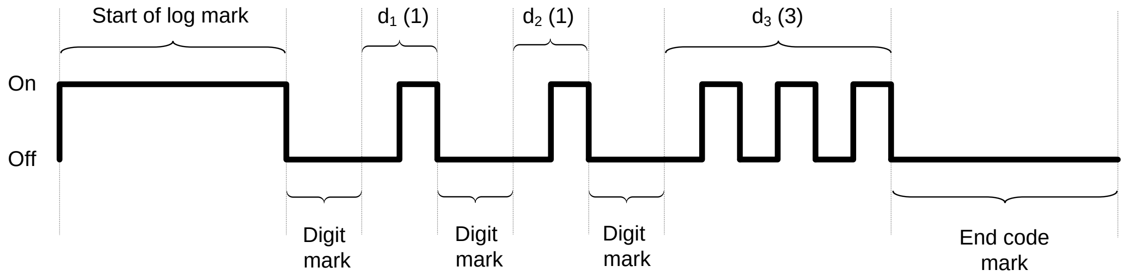
4.19. Flash codes

The ECU also uses the FEPS input (pin A27) as an output to flash an optional LED. The LED is connected between V_{PWR} (pin A2) and FEPS (pin A27). Note that the pin use as FEPS input or as lamp output is mutually exclusive.

> **Note**
>
> Pin A27 can supply up to 10mA, it is not capable of lighting a bulb.

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 of marks, or on and off pulses as follows:

Figure 4.6. Flash code sequence



Each of the marks lasts for a specific duration:

Table 4.7. 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 ON 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 4.8. Flash codes

Code	Meaning
111	In application mode — no other condition has been detected.

Code	Meaning
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.

4.20. 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 4.9. Floating point conditions

Condition	Result
Underflow	The result of a calculation underflow is ±*0*. The sign is based on the signs of the operands.
Overflow	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.
Divide by zero	

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

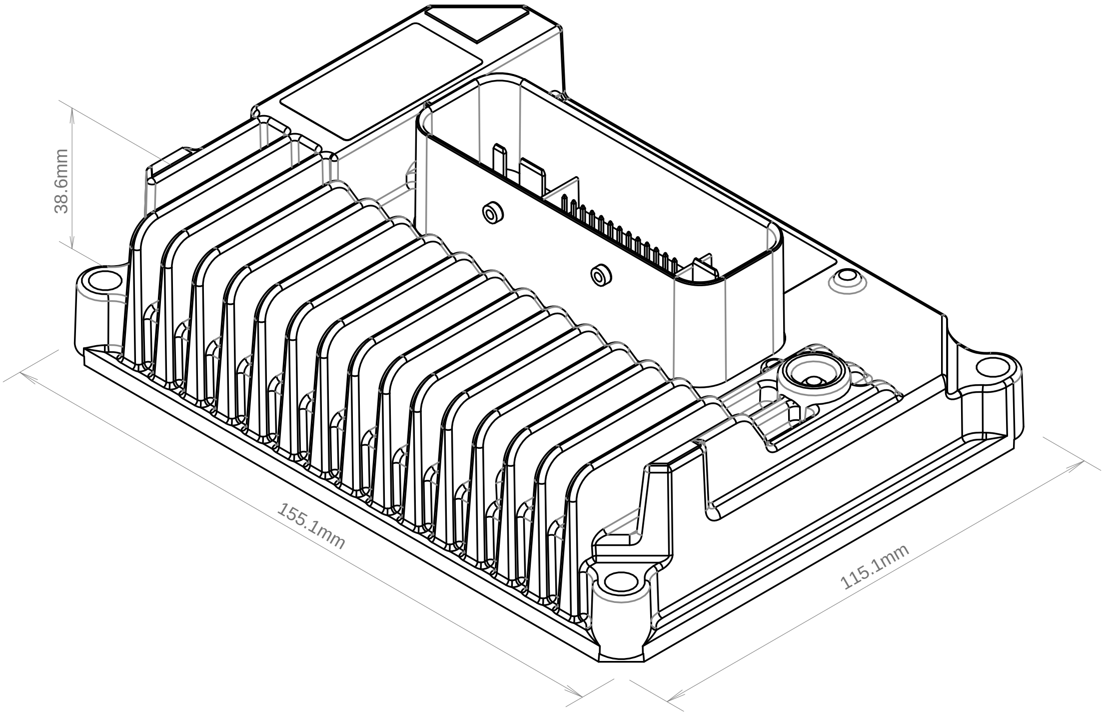
4.21. Customization — build options

To support a variety of sensors and actuators, the ECU is pre-populated with a default selection of components with varying voltage range, pull strengths, filtering and other characteristics. In some cases, the default component selection will not meet the requirements of all customers. Within design constraints, Pi can modify the ECU components to adjust these characteristics as *build options*. Contact Pi for further information.

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).