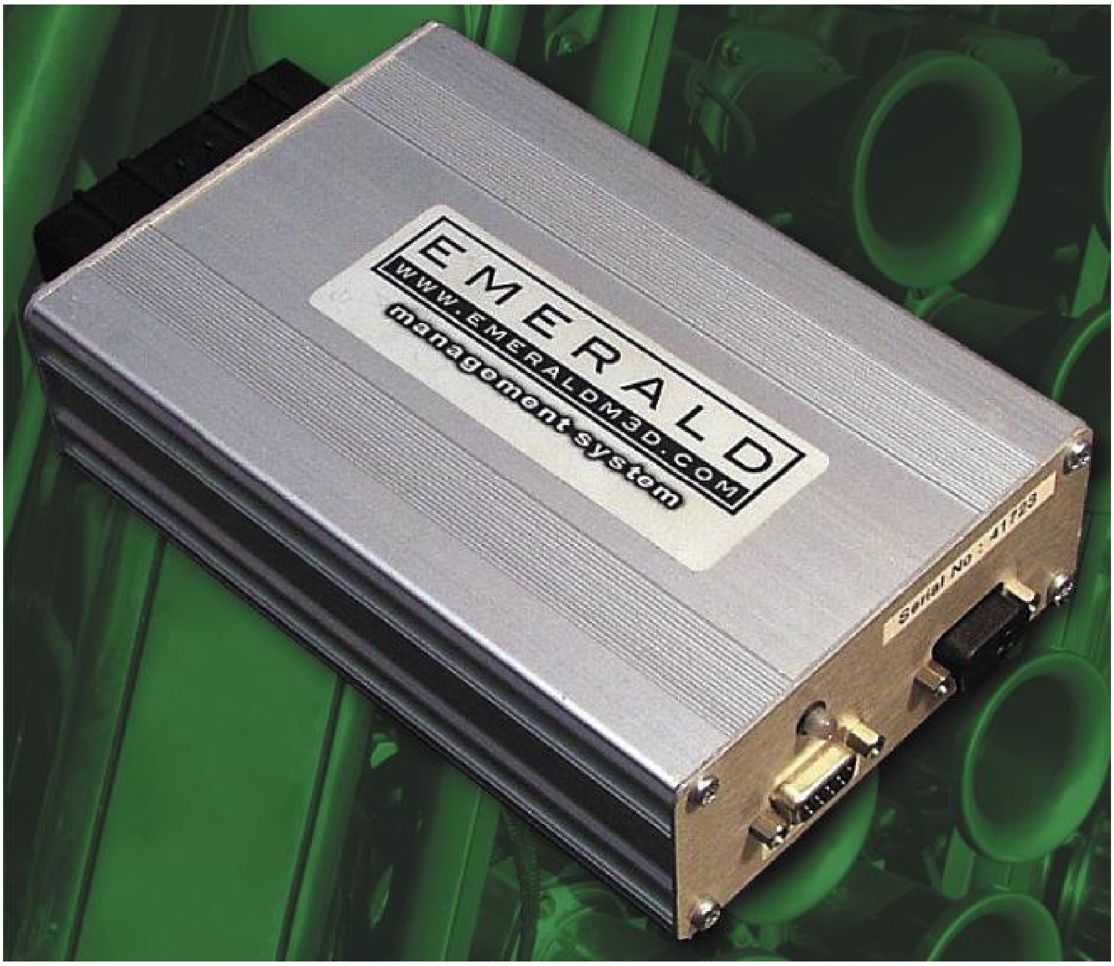
Emerald K3

Engine management system

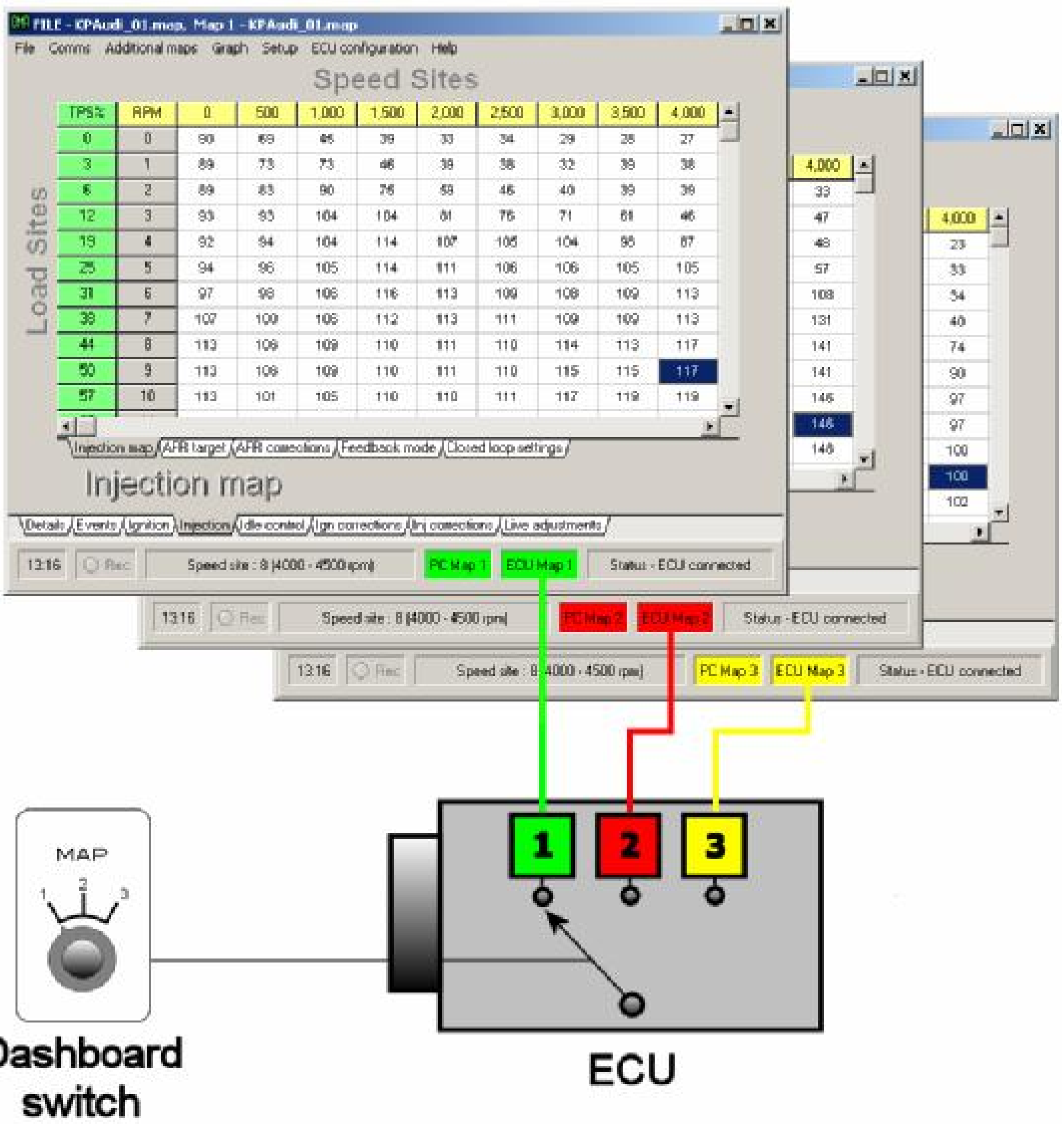


Operating manual

Draft v0.51

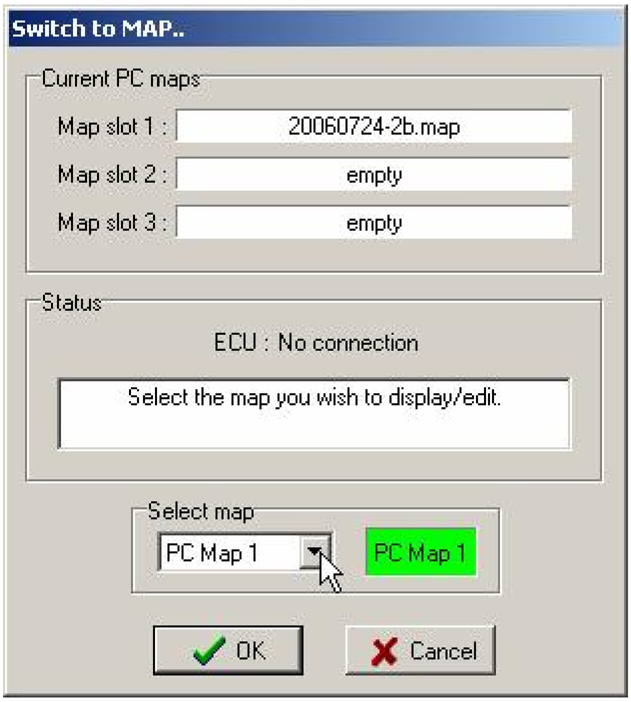
Map switching

- The ECU can store up to three completely separate maps.
- If set to do so the ECU will allow you to freely switch between maps on-the-fly.
- The mapping software also holds three maps in memory and will switch maps in sync with the ECU.
- The mapping software uses a new file format that allows three maps be to stored within the one file.
- A 0-5 volt signal via an analogue input can be used to instruct the ECU which map to use. A simple two position on-off switch can be used to provide a high-low signal that will enable you to switch between two maps. To switch between three maps a rotary multi-position or potentiometer can be used.



Map switching – software

The K3 ECU has the ability to retain three totally separate maps within the ECU. The laptop or PC also has three map screens available. For as long as the PC is communicating with the ECU it will automatically switch the maps displayed to stay in sync. If you want to work on a map that is not currently selected without using the ECU to switch maps you can power down the ECU (or unplug the communications lead) and select 'Switch to map' from the 'File' menu.



There is a short cut to this map selection screen by clicking the PC map box at the bottom of the main screen.

Note: *To prevent confusion the PC will not allow you to switch maps when linked to the ECU.*

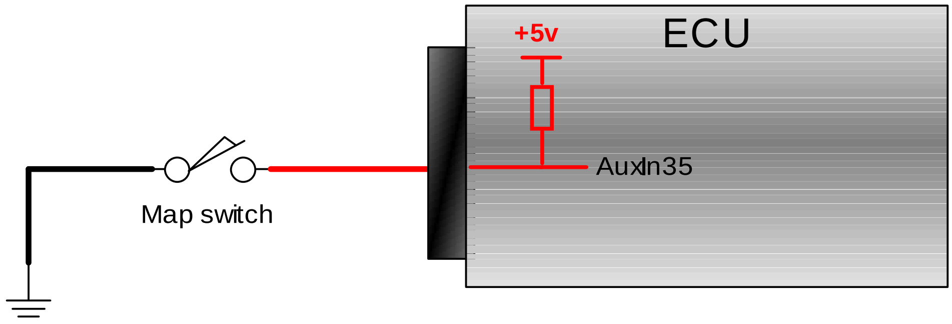
For example: if mapping on a rolling road you can alter the fuel and ignition settings on map 1 (green map) via the live mapping page (F8) and then, via a switch on the dash, switch to map 2 (red map). The PC will bring the red map to the front of the screen and you can alter fuel and ignition timing again via the live mapping screen exactly as before. Switch the ECU to map 3 (yellow map) and repeat the mapping process.

Map switching - configuration

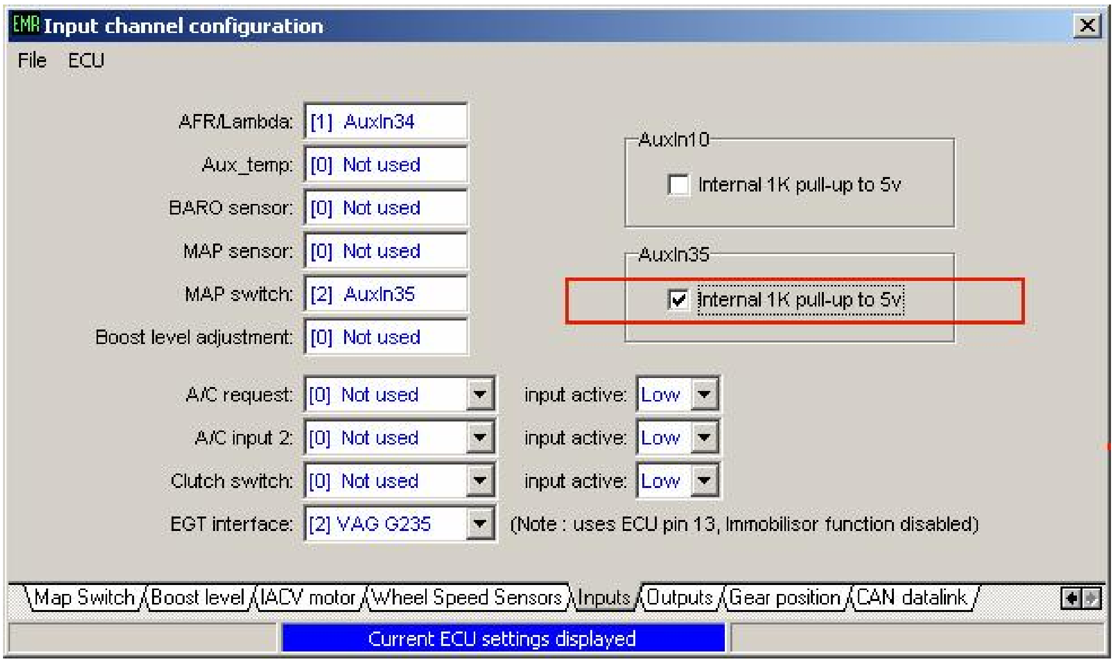
There are various ways of setting up the ECU to read the switching signal. Below are two examples.

Example 1

The ECU is to switch between two maps according to a user activated switch. In this particular case AuxIn35 is unused so it is available as an input source for the map switching function. By enabling the internal pull-up resistor on the AuxIn35 input we can change maps using a simple switch to earth.

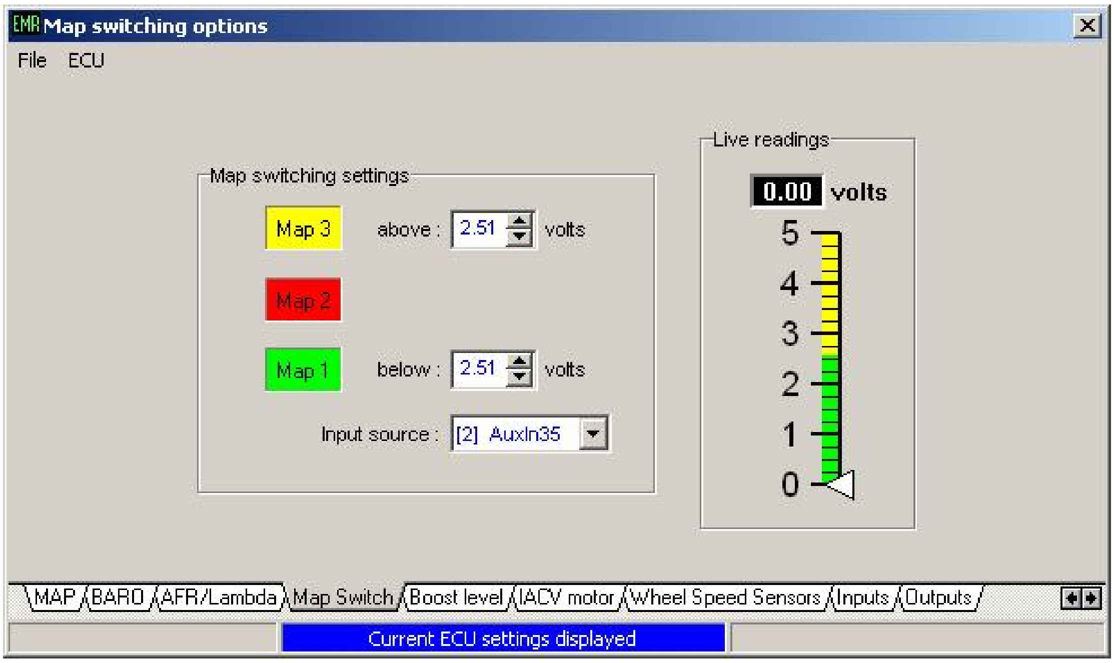


With the switch in the open position the internal pull-up resistor results in the ECU reading 5v at the AuxIn35 input. With the switch in the closed position the ECU will read 0v at the AuxIn35 input. The internal pull-up to +5v for AuxIn35 must be enabled in the 'Input channels' section of the 'ECU configuration' as shown below.



To configure the map switching function select 'Map switching' from the 'ECU configuration' menu.

In this example we have two voltage levels, 0v and 5v, at AuxIn35 depending on the position of a switch.



The input source has been set to AuxIn35. Two voltage levels are used to determine which map the ECU should be using. Map 1 is selected if the voltage is ***below*** a certain threshold and Map 3 is selected if the voltage is ***above*** a certain threshold. Map 2 is selected if the input voltage lies between the ***above*** and the ***below*** thresholds.

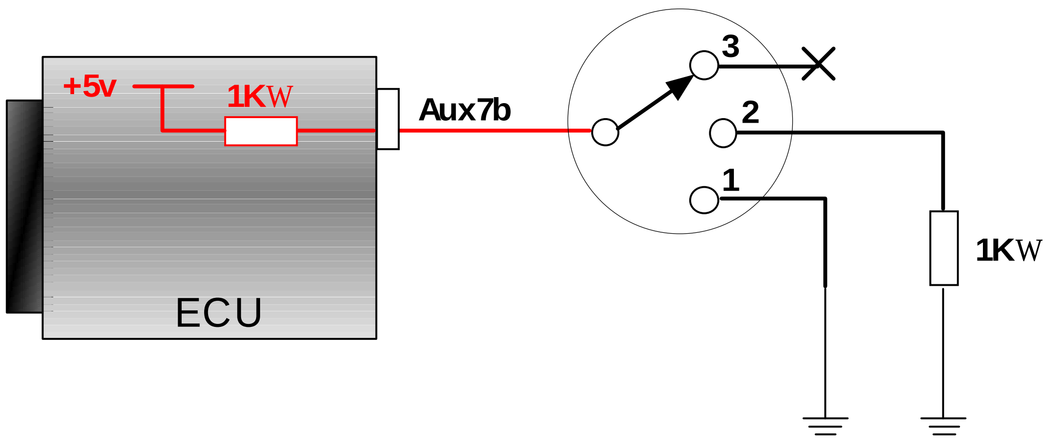
For this example the mid-point voltage of 2.51 volts is used as the above and below thresholds. Map 1 is selected if the voltage at AuxIn35 is below 2.51 volts (switch is in the closed position) and Map 3 is selected if the voltage at AuxIn35 is above 2.51 volts (switch is in the open position). Map 2 is not used and cannot be activated.

When the ECU is connected the live readings panel shows the real-timeinput voltage used for the map switching function. The bar graph has a vertical scale that presents 0 to 5 volts and is also colour coded to show the voltage to map selection relationship. The vertical colour coding of the bar graph is colour coded according to the map switching settings.

Example 2

The ECU is to switch between the three maps according to a 3-way rotary position switch mounted on the dash board.

As with the previous example, using an analogue input that has an internal pull-up resistor simplifies the map switch wiring. Using such an input gives us two voltage levels with a switch to earth (open = 5 volts, closed = 0 volts). By switching this input to earth via a resistor we create a potential divider circuit which will result in a third voltage level of between 0 volts and 5 volts (depending on the value of the resistor used). As the ECU uses 1KΩ internal pull-up resistors we can switch the input to earth via another 1KΩ resistor to give a mid-point voltage level of 2.5 volts.



In this example Aux7b is free so will be assigned to the map switching function.

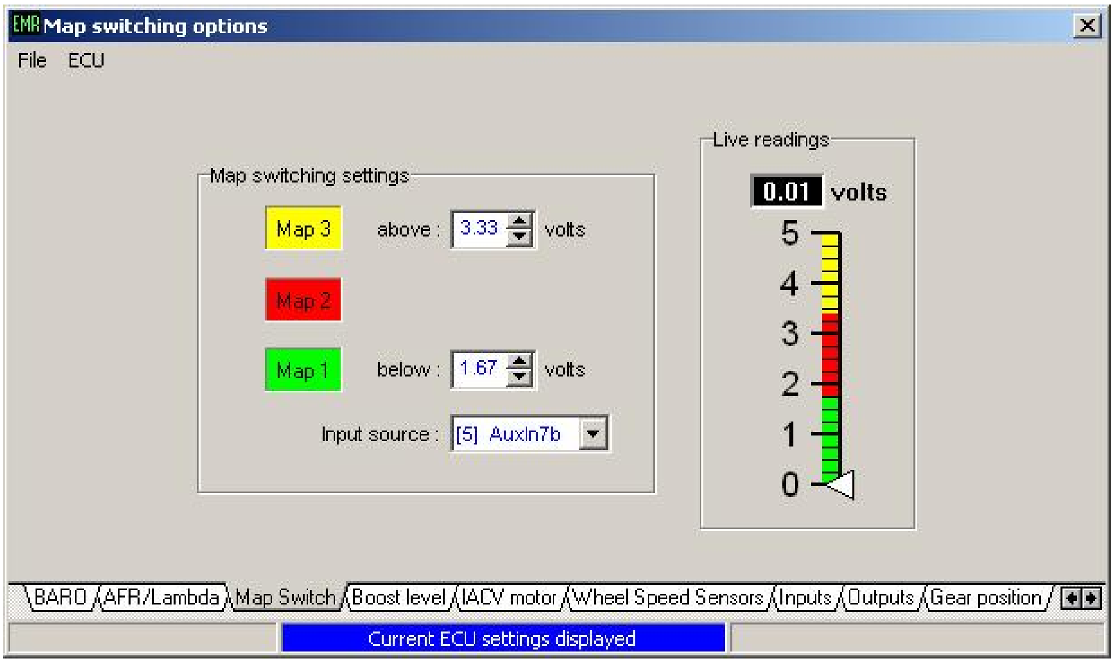
Aux7b, Aux8b and Aux9b have fixed internal 1KΩ pull-up resistors.

With the rotary position switch at position 1 Aux7b is connected to earth which results in an input voltage of 0 volts.

At position 2 Aux7b is connected to earth via a 1KΩ resistor resulting in 2.5 volts at Aux7b.

At position 3 Aux7b is unconnected so will be at 5 volts due to the internal pull-up resistor.

The ECU configuration for this example is shown below.



Here the map switch thresholds have been set so that the boundaries are spaced evenly give more than enough room for error.

The map switching function monitors the input voltage approximately 5 times per second. Before changing maps the ECU will re-evaluate the new map according to the current running conditions to ensure the change is seamless. This process takes approximately 1- 2mS.

The ECU will switch maps on-the-fly regardless of engine rpm or load.

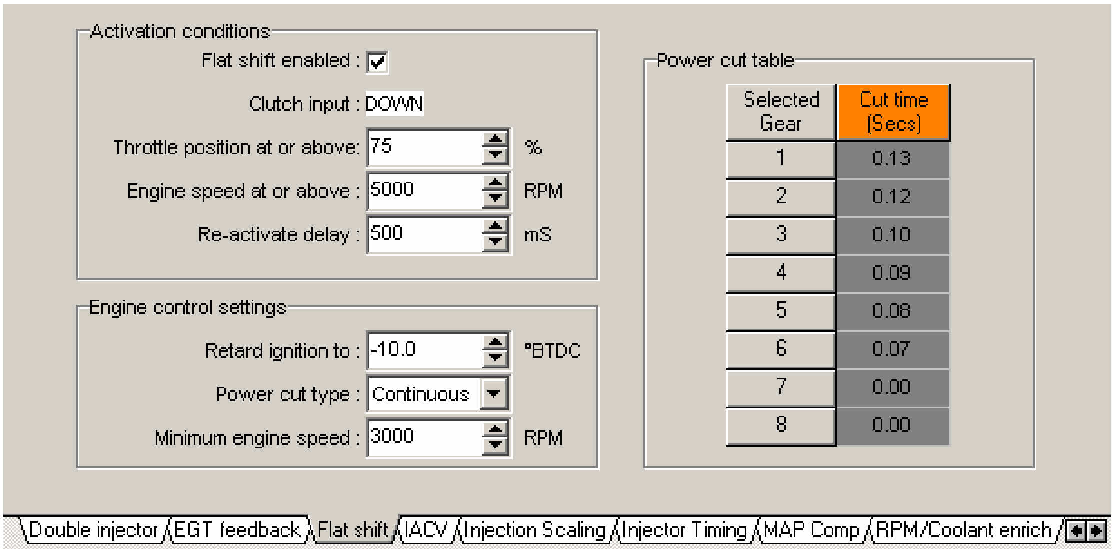
Full throttle gear shift (Flat shift)

This function is used to interrupt/reduce engine power so that a fast gear change can be made without lifting the throttle. Engine power is reduced by retarding the ignition to a set position. This ignition timing can be negative (After TDC). If turbo-charged, this retarded ignition timing during a gear change can provide a form of anti-lag.

The flat shift function will be activated if certain user adjustable conditions are met and a user assigned input is activated.

This flat shift function can be configured according to the gear box type used.

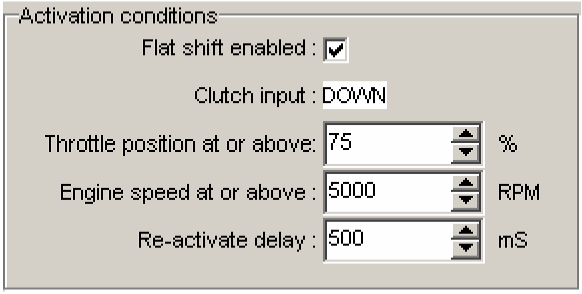
- Sequential gearbox.
  The user assigned input can be wired a gear lever movement switch or clutch switch. The flat shift function can be configured to interrupt power for a specific amount of time according to the gear selected.
- H-pattern gearbox.
  The user assigned input can be wired to a clutch position or pressure switch. The flat shift function can be configured to interrupt power for as long as the input is activated, i.e. until the clutch pedal is released.



Select 'full throttle gear shift' from the 'Additional maps' menu to access the settings page for this function. The settings are grouped into 3 areas on the screen; *Activation conditions*, *Engine control settings* and *Power cut table*.

Activation conditions

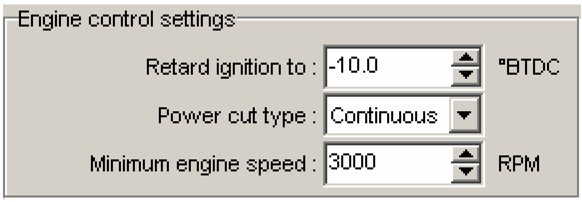
The activation conditions determine how and when the gear shift function can be activated.



- Flat shift enabled: Sets whether this function is enabled or not.
- Clutch input: Shows the current clutch switch status .
- Throtte position at or above: Throttle position must be above this before the flat shift function will activate.
- Engine speed at or above: The flat shift function will only activate above this rpm.
- Re-activate delay: How long the ECU will wait before allowing this function to activate again.

Engine control settings

This engine control settings determine how the engine power is cut and how low the engine rpm is allowed to drop.



- Retard ignition to: Sets the fixed ignition timing during the gear change. You can retard as far as -30 °BTDC (30 °ATDC).
- Power cut type: Continuous for a power cut for as long as the input switch is activate or Timed for a timed cut according to the gear table.
- Minimum engine speed: When activate this function will not allow the engine rpm to fall below this setting.

Power cut table

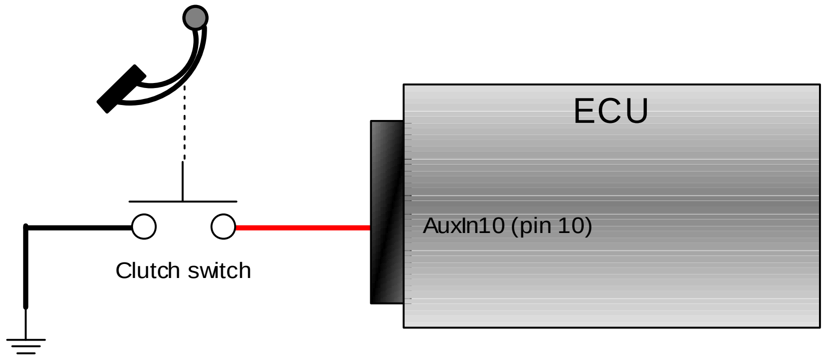
This table is only used when the power cut type is set to 'timed'. A timed power cut is usually only used if you have a sequential gear box.

Power cut table

Selected Gear	Cut time (Secs)
1	0.13
2	0.12
3	0.10
4	0.09
5	0.08
6	0.07
7	0.00
8	0.00

Set the cut time according to the selected gear. If the cut-time is set to zero, the function will not activate.

Clutch switch wiring example

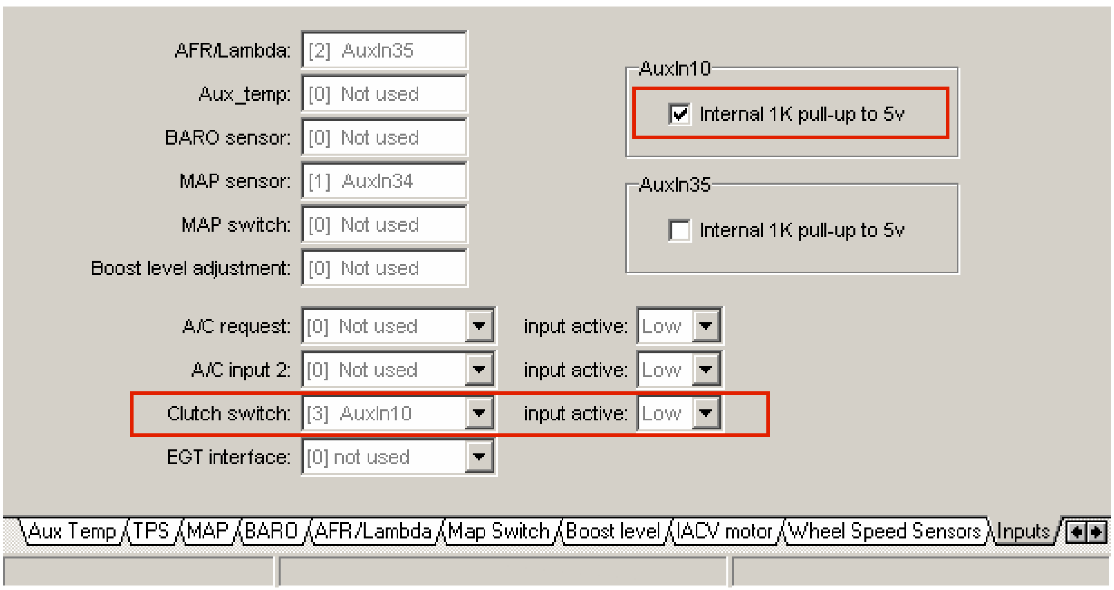


Any spare analogue input can be used to activate the full throttle gear shift function. This example uses ECU pin 10 (AuxIn10), with the internal pull-up enabled, wired to a switch on the clutch pedal.

When the clutch pedal is up (not pressed) the clutch switch contacts are open. The internal pull-up resistor sets the input level ‘high’. When the clutch pedal is down the switch contacts are closed, the AuxIn10 input is connected to earth which sets the input ‘low’.

In this example the clutch input is active low, i.e. the signal at AuxIn10 is low when the clutch is pressed. The ECU should be configured to read AuxIn10 as the clutch signal and also set to recognise that the clutch is down/pressed when the signal level is low.

Select ‘Input channels’ from the ‘ECU configuration’ menu. As shown below, the clutch switch channel has been set to **AuxIn10**, the input active has been set to **Low** and the **internal 1K pull-up to 5v** has been enabled. ECU inputs AuxIn10 and AuxIn35 have switchable internal pull-up resistors. If another input connection where to be used instead, e.g. AuxIn34 or AuxIn36, an external pull-up resistor would need to be fitted. The AuxIn7b, AuxIn8b and AuxIn9b inputs have internal pull-ups.

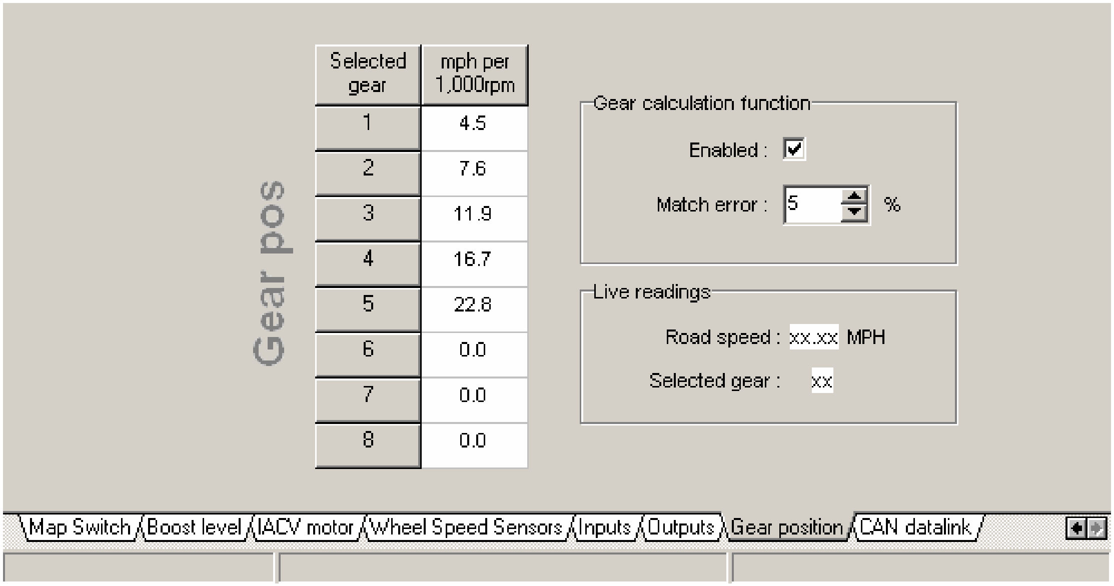


example clutch switch configuration settings

Gear position

The ECU is able to calculate the selected gear by using engine rpm, road speed and a gear position look-up table.

Select 'Gear position' from the 'ECU configuration' menu to access the gear position calculation settings…



Gear calculation function

- Enabled: Sets whether this function is enabled or not.
- Match error: Sets how close the ECU's calculations must be to the figures set in the gear pos table.

Gear pos table

For each of the forward gears set the speed (mph/kmh) per 1,000rpm in the table.

The easiest method to determine these values is to set the PC data logger to record engine rpm and road speed. Drive for a short amount of time in each gear and then use the data logger trace to determine the table settings.

For example in 3rd gear, at a road speed of 38.0mph, with an engine speed of 3,193rpm :-

$$\text{Mph per 1,000rpm} = \frac{38.0}{3193} \times 1000 = \mathbf{11.9}$$

Note: gear position calculations are suspended while the clutch switch input is active (clutch = down). If a clutch switch is not fitted ensure that input is disabled.

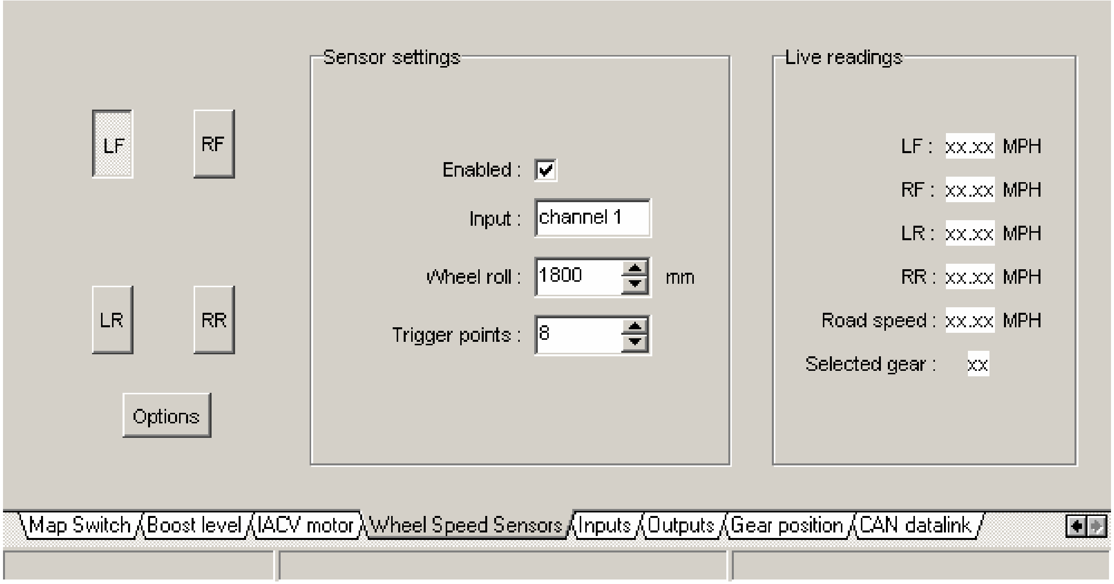
Road speed measurement

The ECU has 4 wheel speed (frequency measurement) input channels via Aux port B.

These input channels can be wired directly to inductive wheel speed sensors or a digital speed signal.

For speed measurement only one wheel speed signal is needed. If this measurement is used to calculate the selected gear the signal must be from a driven wheel.

Select 'Wheel Speed Sensors' from the 'ECU configuration' menu to access the wheel speed sensor settings.



The four wheel speed input channels are identified as follows

Input	Label	Aux Port B pin number
Channel 1	LF (**L**eft **F**ront)	2
Channel 2	RF (**R**ight **F**ront)	3
Channel 3	LR (**L**eft **R**ear)	4
Channel 4	RR (**R**ight **R**ear)	5

LF, RF, LR, RR sensor settings

Each channel is enabled and configured independently from the other channels. This flexibility allows differing wheel sizes and/or sensor set ups on each of the four wheels.

Click the label button (LF, RF, LR, RR) to access the settings for that input channel.

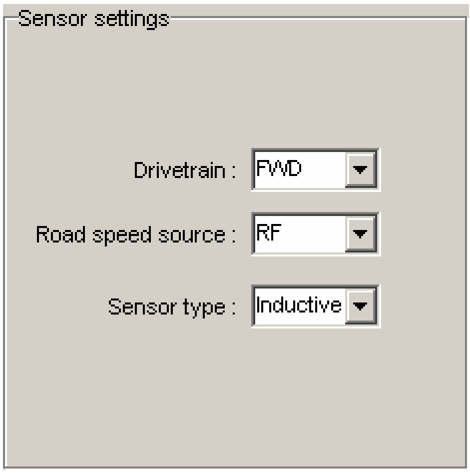
Each channel has the following settings :

- Enabled: Tick the enable box if this channel is used.
- Wheel roll: Distance travelled for one rotation of the wheel.
- Trigger points: Number of pulses per wheel rotation

The trigger points setting can be determined by counting the number of teeth/points that will pass the wheel speed sensor in one revolution of the wheel.

A quick/simple method to determine the wheel roll setting is to put a chalk mark at the bottom of the tyre (at the 6 o'clock position) and mark the ground at the same point. Roll the car forwards so the wheel rotates once and mark the ground in line with the tyre mark. The distance between the two ground chalk marks, in mm, is the 'wheel roll'. A rolling road can be used to compare actual and measured road speeds - adjust the wheel roll value if necessary.

Options

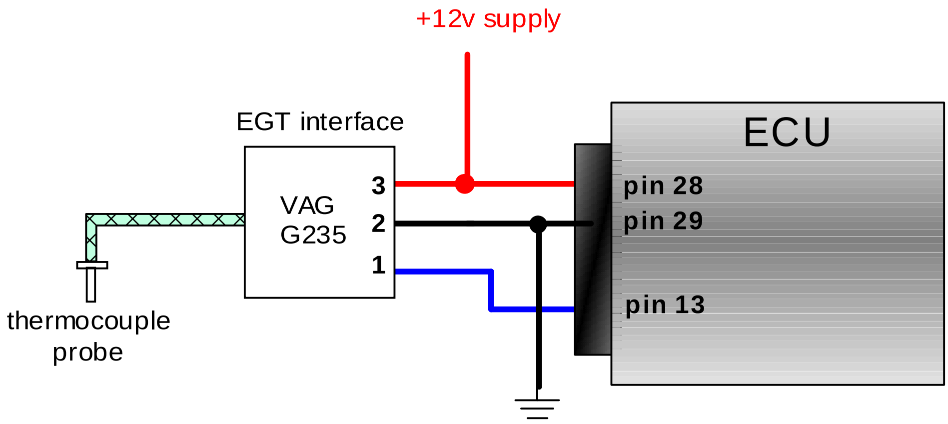


- Drivetrain: This setting is not currently used.
- Road speed source: Set to the channel you wish to measure road speed from
- Sensor type: Global setting for wheel speed sensors, inductive or digital. Open collector digital sensors will require a pull-up resistor.

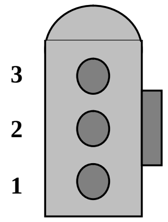
Exhaust Gas Temperature

The Emerald K3 is able to read EGT via an external signal conditioning unit. To ensure the best accuracy the exhaust gas temperature reading is transmitted digitally between the signal conditioning unit and the ECU.

The VAG G235 exhaust gas temperature interface combines a thermocouple probe, suitable for pre-turbo gas temperature measurements, along with a combined amplifier and serial data output. The serial data output line from the G235 should be wired to ECU pin 13.

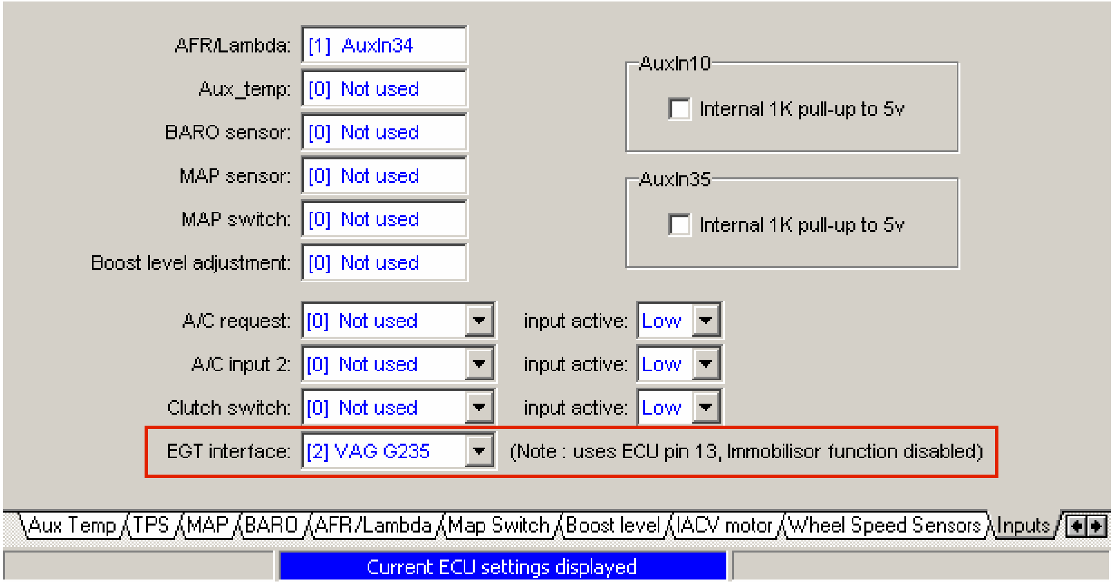


VAG G235 to Emerald K3 connection diagram

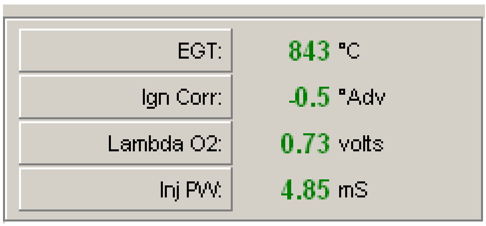


Wire side of G235 loom connector

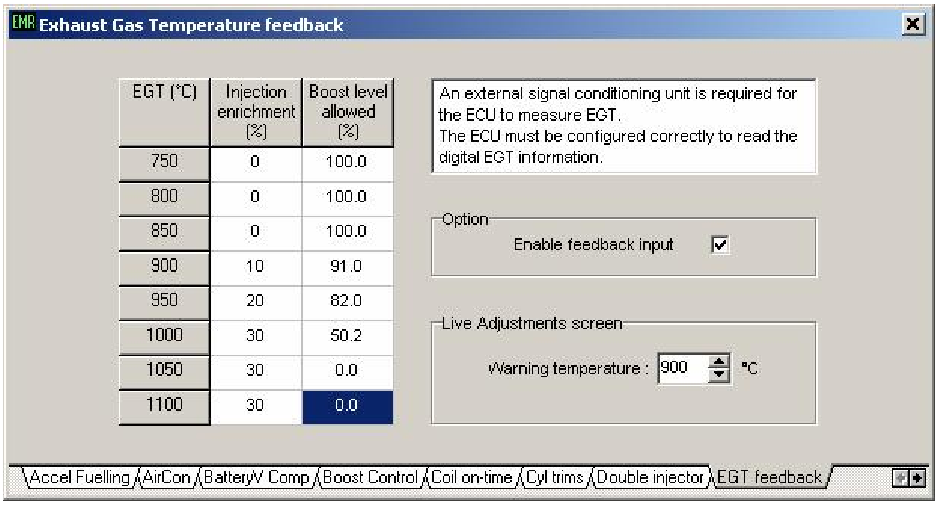
To set the ECU to read the G235 exhaust gas temperature serial data the ‘EGT interface’ setting in the ‘Input channels’ section of the ECU configuration should be to ‘[2] VAG G235’ as shown below..



Once configured to read EGT from the G235 this EGT measurement can be displayed on the ‘live adjustments’ screen. This EGT reading can also be recorded, along with other readings, into the data-logger.



The EGT can be used, in conjunction with the feedback table, to adjust the fuelling and/or boost pressure.



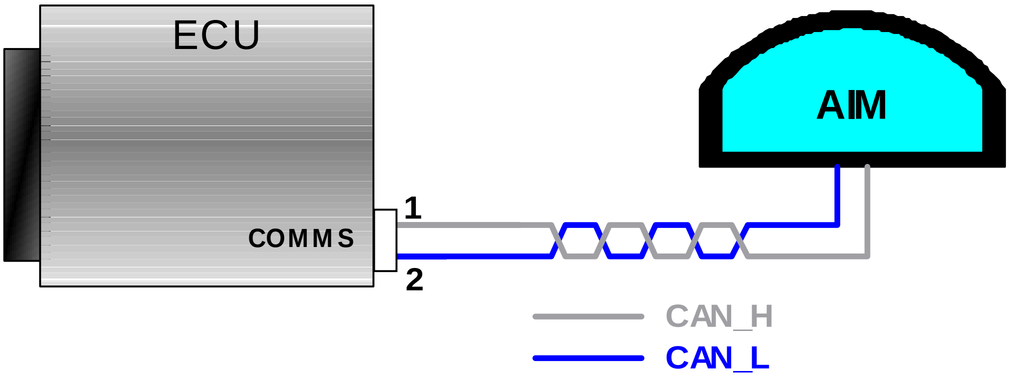
CAN data-link

The K3 ECU can be configured to set transmit data to external devices, such as dashboards, using it's **C**ontroller **A**rea **N**etwork interface.

The CAN was originally developed by Bosch Gmbh as a robust serial communications protocol to pass information between controllers on an automotive network. Communication speeds can be up to 1 Mbit/s between multiple devices sharing the same 2-wire CAN bus.

The CAN bus wiring should be a twisted-pair cable and, if required, shielded. The CAN bus must be terminated at each end by a 120Ω resistor. The K3 ECU, with it's internal 120Ω termination resistor, provides one end of the CAN bus. When connecting another device/s you must ensure that the CAN bus is correctly terminated with another 120Ω resistor. This termination resistor must be at the other end of the CAN bus. Some devices (e.g. the AIM MXL dash logger) also have an internal termination resistor so an external resistor is not required.

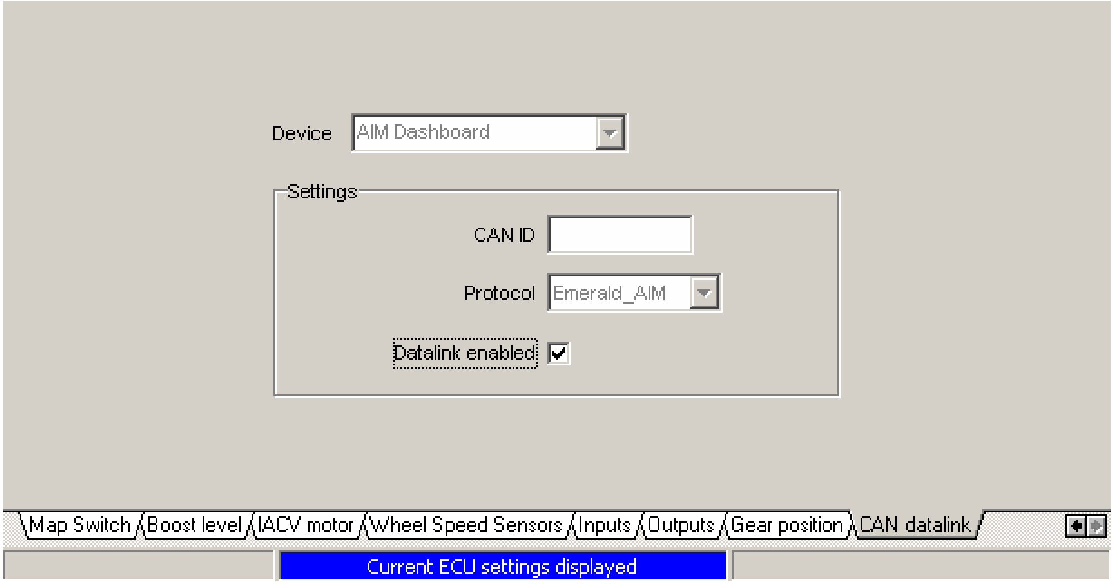
AIM dash logger connection



Refer to the 'Communications port' section of the manual for further details of the communications port.

K3 CAN configuration

Select 'CAN data-link' from the 'ECU configuration' menu.



From the 'Device' drop down menu select 'AIM dashboard'. To enable this K3 to AIM data-link ensure the 'data-link' check box is ticked.

Before configuration changes can take effect the ECU must be updated, select 'Update ECU configuration' from the 'ECU' menu.

AIM MXL configuration

Using the AIM Race Studio 2 software select 'System manager'.

Retrieve the current configuration from the AIM dash by clicking the 'Receive' button. Click the 'ECU manufacturer' entry for the current configuration and set to 'AIM'. Click the 'ECU model' entry for the current configuration and set to 'PROT_CAN'.

If you wish to change how/what data from the ECU is displayed on the AIM dash click the 'System configuration' tab and set accordingly. Once you are happy with your channel / display settings update the AIM dash by clicking the 'Transmit' button.

Refer to your AIM manual for detailed information.

Connection to a wideband lambda

Although the K3 cannot directly control a wideband lambda sensor it can read a 0-5v analogue signal that relates to AFR/lambda. Many wideband lambda sensor controllers produce a 0-5v signal for use with ECU's or data-loggers.

This AFR data can be recorded in the Emerald data-logger, displayed in the live adjustments screen and used by the ECU for closed loop and/or adaptive fuelling functions.

The 0-5v signal is converted to AFR by a user adjustable look-up table in the ECU configuration. This table must be set to match the AFR/voltage of your lambda signal conditioning unit.

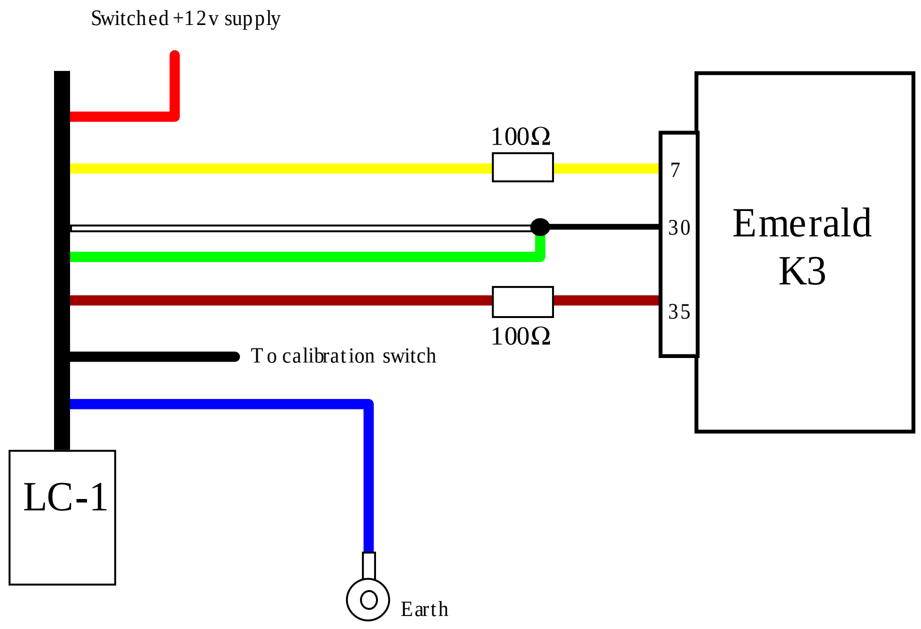
Emerald K3 to Innovate LC-1 connection example

An Innovate LC-1 is used in this example but the principles can be applied to many other wideband lambda controllers.

The Innovate LC-1 manual should be read carefully before installation.
It is absolutely essential that the correct sensor calibration routine is followed - this is detailed in the Innovate manual.

Wiring

LC-1	Function	Wire to..
Red	+12v supply	Ignition controlled +12v
Blue	Heater ground	Good chassis ground or battery (-) terminal
White	System ground	**Join** with Green wire to ECU pin 30
Yellow	Analogue out 1 (narrow band lambda signal)	ECU pin 7 via inline resistor. See **note 1**
Brown	Analogue out 2 (AFR signal)	Any spare analogue ECU input via an inline resistor. (see **note 2**). AuxIn35 (ECU pin 35) is used in this example.
Green	Analogue ground	**Join** with White wire to ECU pin 30
Black	Calibration wire	Calibration button



Note 1:

Narrow band lambda signal. This connection is optional. If used ensure the LC-1 is set to output a 0-1v narrow band simulated signal on analogue 1. The LC-1 is normally set to do this by default. A 100Ω resistor* should be fitted inline between the yellow analogue out 1 wire and the ECU pin 7.

Note 2:

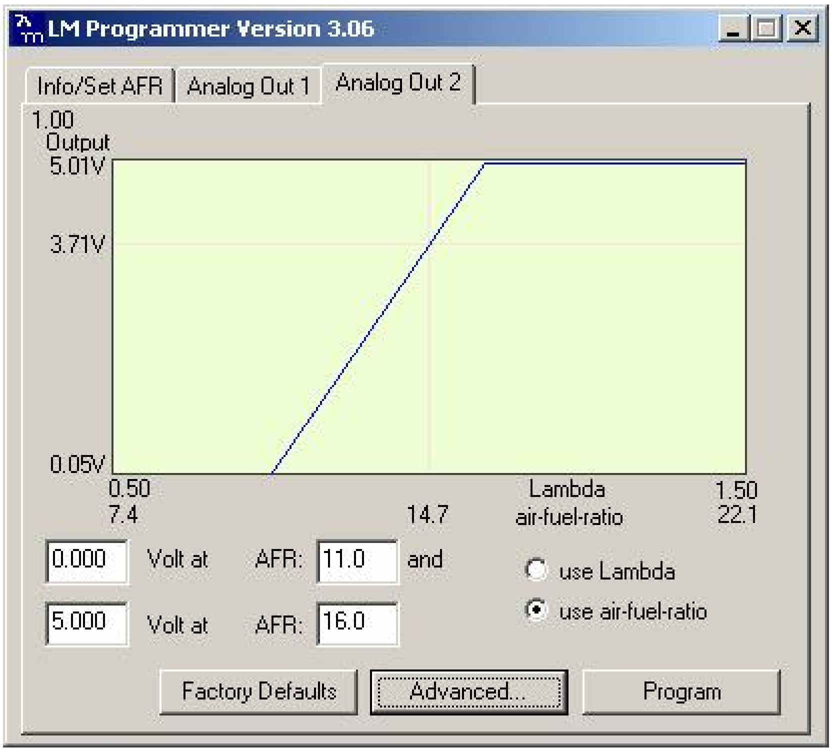
Wide band AFR signal. A 100Ω resistor* should be fitted inline between the brown analogue out 2 wire and the ECU analogue input pin (AuxIn35, pin 35 in this example)

*The LC-1 outputs are quite sensitive and can become unstable if connected to a capacitive load. The inline resistor buffers the LC-1 from the ECU input signal filters.

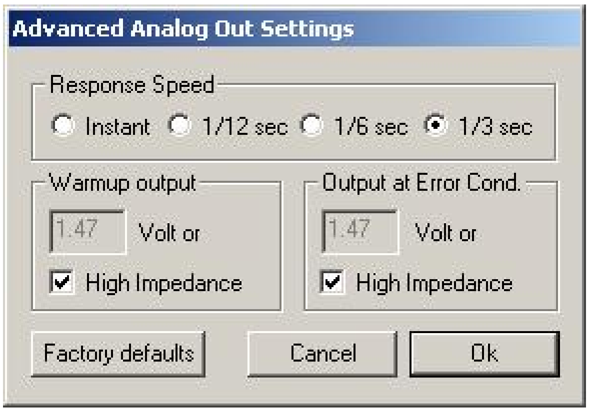
LC-1 configuration

The LC-1 output configuration should match the Emerald K3 input configuration.

We recommend narrowing the AFR range so the 0-5v signal spans a more useful 11.0:1 to 16.0:1. Doing this will mean any noise or voltage offset errors have less of an impact on the AFR readings.



If the AFR signal appears to be noisy you may find setting the LC-1's output response speed to '1/3 sec' helps…



K3 AFR/Lambda input calibration

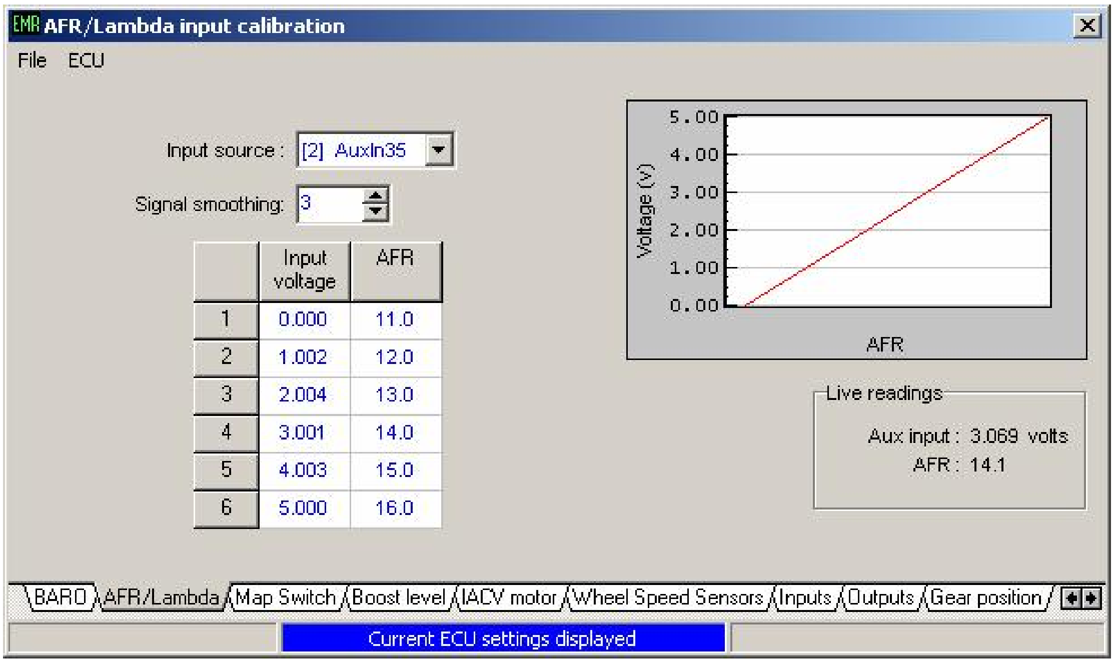
Any spare analogue input on the ECU can be used to read the LC-1 analogue AFR signal. AuxIn35 is often spare and is used for this example.

To convert from a voltage to an AFR value a look up table is used.

This table is accessed via the 'AFR/Lambda input' page of the 'ECU configuration'.

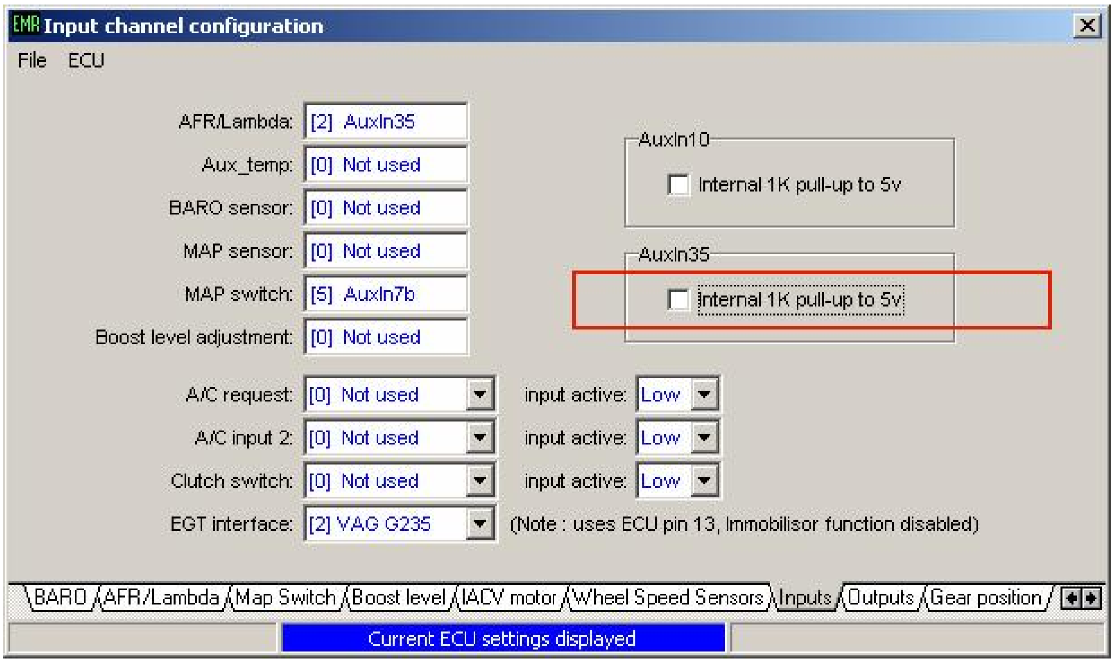
Select the input source to suit the analogue input you wish to use and set the table to match the LC-1 output as shown below.

The 'live readings' box will show the current voltage and AFR conversion readings but note that the AFR readings will not be correct until the ECU has been updated with the new table settings.



AuxIn10 and AuxIn35 analogue inputs have switchable internal pull-up resistors. As we have used AuxIn35 in this example you must ensure that the pull-up resistor is switched off otherwise the analogue AFR signal will be distorted.

From the ‘inputs’ page of the ‘ECU configuration’ screen ensure that the pull-up for the used input is switched off.



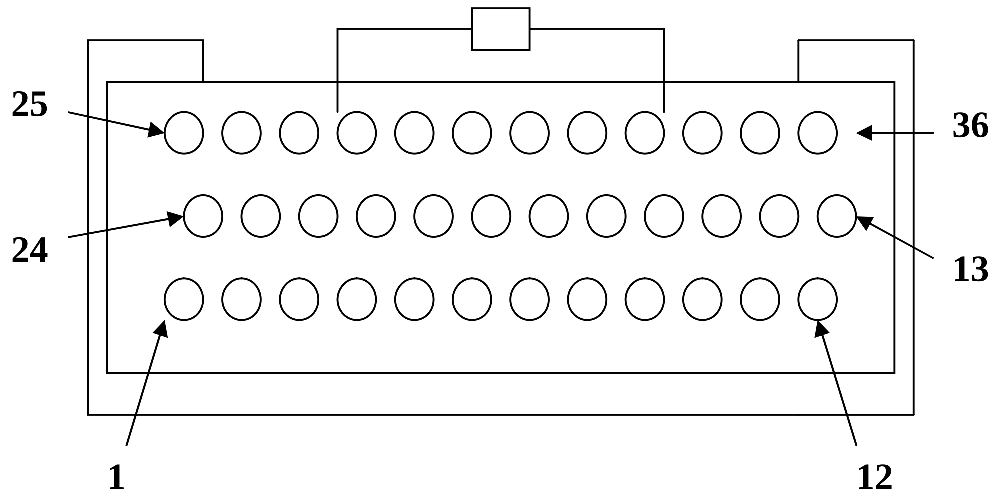
The ‘inputs’ screen confirms that the AFR/Lambda input has been set to AuxIn35 and that the AuxIn35 internal pull-up is switched off.

Update the ECU with these new settings by clicking ‘Update ECU configuration’ from the ‘ECU’ drop down menu.

The AFR information will now be displayed in the ‘Live adjustments’ screen as an LED bar display and in numerical form to the right of this.

The data-logger channel can also be set to record this AFR data by selecting ‘AFR/Lambda’ in the data-logger options screen.

K3 36-way loom connector

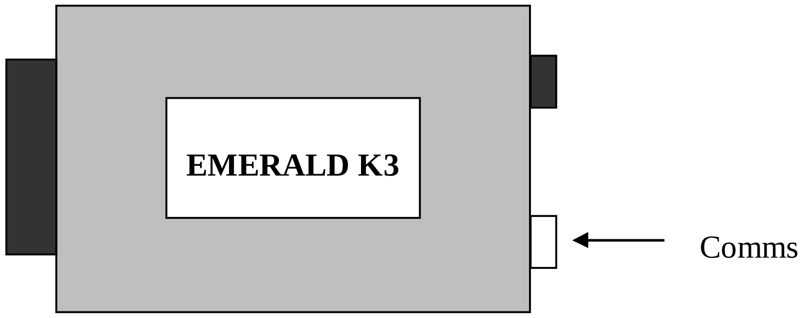


Rear view of connector
(wire side)

Pin no.	Connection	Comments
1	Injector driver 4 / AuxOut1	Injector driver 4 or user assigned output
2	IACV2 / AuxOut2	IACV stepper motor channel 2 or user assigned outputt
3	IACV1 / IACV-PWM / AuxOut3	IACV stepper motor channel 1, IACV pwm control or user assigned output
4	Ignition driver 3 / Main Relay Control	Ignition driver 3 or main relay control output according to ECU configuration
5	Ignition driver 2 / AuxOut5	Ignition driver 2 or user assigned output
6	Cooling fan relay control	Output switches to earth to activate relay & fan
7	Oxygen sensor signal input	0-1v input from narrow band sensor
8	Throttle pot signal input	0-5v input from throttle position sensor
9	+5v sensor supply	5v output, 100mA max supply for sensors such as TPS, MAP, etc
10	AuxIn10	User assigned 0-5v input. An internally switched pull-up resistor can be enabled on this input.
11	Ignition sense input	+12v supply via ignition switch
12	Tacho output signal	0-12v pulsed output
13	Immobilisor/EGT digital input	Digital input from a Lucas 5AS immobilisor or VAG EGT sensor interface
14	+8v sensor supply	+8v supply for external sensors
15	Cam phase or custom input	Cam sensor input (if required)
16	Air temperature signal input	NTC temperature sensor input
17	Injector driver 5 / Ignition driver 4 / AuxOut17	Injector driver 5, Ignition driver 4 or user assigned output according to ECU configuration
18	Oxygen sensor signal earth	
19	Shift-light driver / AuxOut19	Shift-light output (switched earth) or user assigned output according to ECU configuration
20	Fuel pump relay driver	Switched earth
21	Injector driver 6 / AuxOut3	Injector driver 6 or user assigned output
22	IACV3 / AuxOut22	IACV stepper motor control or user assigned output
23	Injector driver 2	
24	Injector driver 1	
25	Ignition driver 1	
26	Injector driver 3 / AuxOut26	Injector driver 3 or user assigned output
27	IACV 4 / AuxOut27	IACV stepper motor control or user assigned
28	+12v Ignition supply	Supply from main relay **or** common with pin 11
29	ECU earth	Good earth (direct to battery)
30	Sensor earth	Common earth for air, coolant & throttle sensors
31	Main trigger signal input	Crank sensor or digital distributor input signal
32	Main trigger sensor earth	Earth return for main/cam trigger sensors
33	Coolant temp signal input	NTC temperature sensor input
34	AuxIn34	User assigned 0–5v input
35	AuxIn35	User assigned 0-5v input. An internally switched pull-up resistor can be enabled on this input for temperature sensors.
36	AuxIn36 / AuxOut36	User configurable input or output pin

Note : *Apart from the Tacho output, all ECU driver outputs are switched earths*

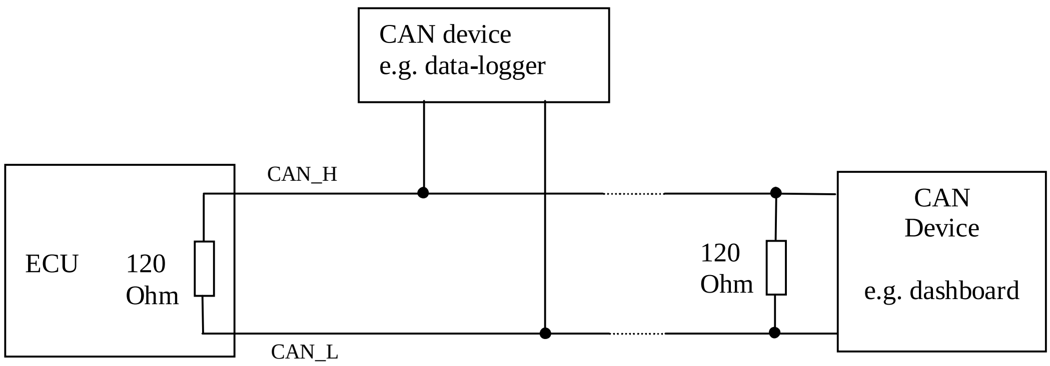
Communications port



Pin number	Connection	Comments
1	CAN_H	CAN bus interface[1]
2	CAN_L	CAN bus interface[1]
3	-	Not used
4	-	Not used
5	earth	Signal earth
6	-	Not used
7	Rx	RS232 serial interface, data receive
8	Tx	RS232 serial interface, data transmit
9	CTS	RS232 serial interface, clear to send

Notes:

1. The CAN bus must be terminated with two 120 Ohm resistors. The ECU's CAN interface includes a 120 Ohm internal termination resistor.
When connecting devices to the CAN bus confirm that the external CAN bus is terminated with a 120 Ohm resistor (either an external 120 Ohm resistor or by a device that has an internal terminating resistor). See example below…



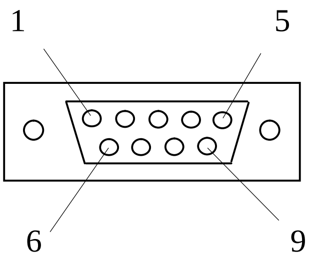
Emerald serial communications lead

The serial communications lead for connection to the PC is ***NOT*** a standard a standard RS-232 serial lead.

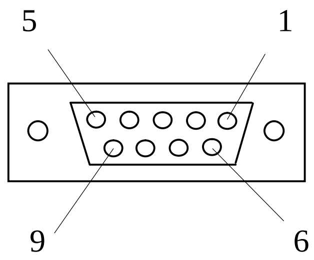
Warning: Use of a standard RS-232 lead could lead to damage of either the PC or ECU.

A serial communications lead is supplied with each ECU at no extra charge. The lead information is included below if you wish to repair / extend or construct a new lead.

PC 9-way D-type socket	**Wire colour**	**ECU** 9-way D-type plug
2	Yellow	8
3	White	7
5	Black	5
8	Red	9
Cable shield not connected	-	Cable shield soldered to outer casing

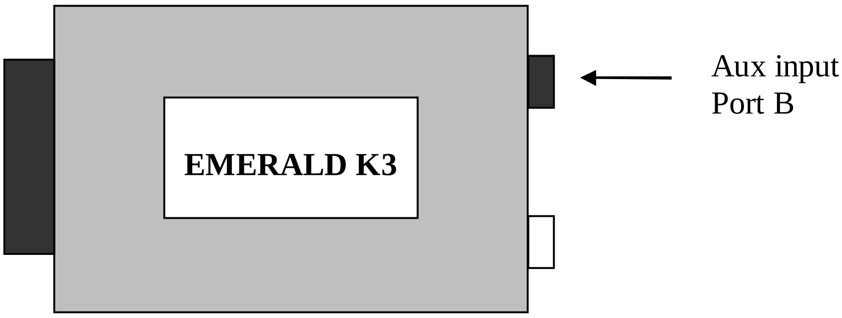


cable side of PC comms lead socket



cable side of ECU comms lead plug

Aux input, port B



Pin number	Connection	Comments
1	Earth	Common earth point for wheel speed sensors / switch inputs
2	WSS_LF	Signal input from **L**eft **F**ront wheel speed sensor [1]
3	WSS_RF	Signal input from **R**ight **F**ront wheel speed sensor [1]
4	WSS_LR	Signal input from **L**eft **R**ear wheel speed sensor [1]
5	WSS_RR	Signal input from **R**ight **R**ear wheel speed sensor [1]
6	Status_LED	LED control output. [2]
		Direct anode connection (no current limit resistor needed)
7	AuxIn7b	Level switch input [3]
8	AuxIn8b	Level switch input [3]
9	AuxIn9b	Level switch input [3]

Notes:

1. Wheel speed sensor input signals can be analogue or digital (inductive or hall sensor). Global inductive/digital setting in software applies to all WSS inputs. If the hall/digital sensor has an open-collector output a suitable pull-up resistor should be connected to the input line (e.g. 4.7K Ohm to +12v).

2. ECU provides direct control of the status LED. The output is a switched +5v signal via an internal 470 ohm current limiting resistor. Connect this output to anode of LED, cathode to earth.

3. Analogue input with internal 1K Ohm pull-up to +5v. Use a switch to earth for simple on/off control.