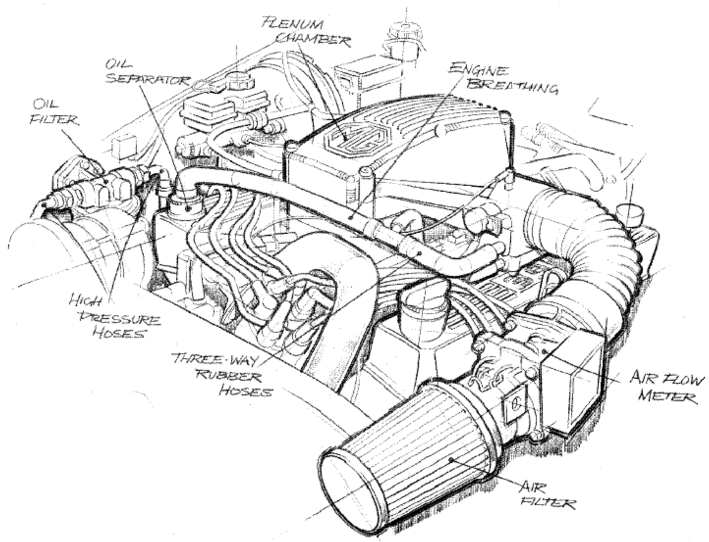


Understanding the RV8 Engine Management System

Mark Leitiger from Germany sought help with fault finding for the fuel injection on his RV8. He was having trouble with achieving a consistent idle, especially when coming to a halt but was unable to understand how the fuel injection management system was performing. Dave Morris, John Anthistle and John Hale offered assistance and it seemed like a good opportunity to update RV8 owners about the operation and maintenance of the 'brain' behind their fuel injection system.

In this article we delve into some of the details of the engine management system, fault detection and diagnosis. We also explore the options for owners who want to upgrade their cars by 'chipping' or 'remapping' their engines. Some basic knowledge is assumed so anyone unfamiliar with **Electronic Fuel Injection** and **Engine Management Systems** and their terminology should first read Nic Houslip's excellent article introducing the ECU in the RV8.

Introducing the 14CUX

Unlike earlier generations of the Rover V8 engine the RV8 came with electronic fuel injection based on the Lucas 'hot-wire' system used widely by Rover for their 3.9litre V8 engine. The 14CUX was the most sophisticated in a line of Lucas **engine management systems (EMS)** following on from the flap-valve systems in the Rover SD1 and eventually succeeded by the Bosch based GEMS system used in Range Rovers from 1995 on.

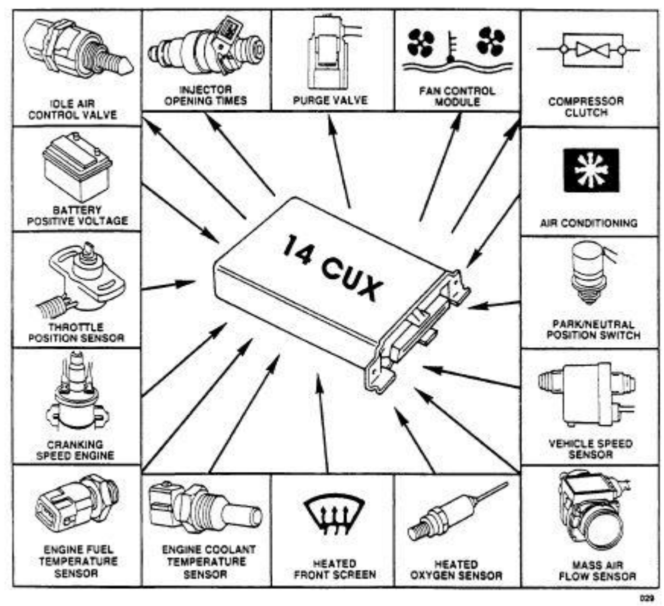
The 14CUX ECU in the RV8 is very similar to that used in contemporary Land Rover vehicles, for example, the Classic Range Rover and Mark 1 Discovery. It was also used, often with some modification, by specialist sports car manufacturers, notably Ginetta, Morgan and TVR. This article therefore gives some basic information on the 14CUX as fitted to the RV8, its main sensors and operation. It also explains how to obtain, connect and use the Rovergauge program to check for fuel injection errors and running conditions.

What is the 14CUX and what does it do?

The 14CUX differs from most modern EMS because it only controls the fuel system, it does not control the ignition system which is completely separate. It does however rely on some of the other safety and security systems on the car which we will come to later.

Neither does the 14CUX come with what would now be considered standard **On Board Diagnostics** (OBD). Consequently interrogating an RV8 ECU has until fairly recently been a specialised task. Fortunately for us Colin and Dan Bourassa in the US and Mark Thompson of Blitz Racing in the UK have pioneered the development and use of the **Rovergauge software** that is very helpful for all RV8 owners who want to see inside the fuel injection system.

Like all EMS the 14CUX ECU (or ECM in Rover terminology) uses input signals from engine sensors to control the fuel injection system to optimise performance, fuel economy and emissions.



The main inputs and outputs are clearly shown in this diagram from the Land Rover fuel injection manual and, although not all of these are used in the RV8, the main elements should be recognisable to anyone who has looked under their RV8 bonnet.

During **normal running** the ECU monitors air flow, throttle opening, road speed and engine revs to determine the correct fuelling and adjust injector opening time. The basic fuel requirement is stored in a table or fuel map which is then moderated according to the sensor inputs. In fact because the system had to operate differently in different markets it is equipped with a **tune resistor** which tells the ECU which particular map to use. For RV8s, which have catalytic converters and lambda probes, the system operates in 'closed-loop' mode and uses the 'white' tune resister. The 14CUX stores several of these fuel maps and it is possible to change between them by changing the tune resistor, but that's another story…

During the period in which it was manufactured the software in the 14CUX was modified and improved. This resulted in a number of different versions of the software being developed for different vehicles, engine sizes and markets. These revisions of the software are known as 'tunes' and can be identified by version number when interrogating the ECU. This 'tune' is not to be confused with the fuel maps selected by the 'tune resister'!

In addition to normal driving there are certain engine conditions where the ECU goes through a special control sequence. It is worth knowing about these in order to be able to recognise what the system is doing and identify problems if they occur:

On **startup** the ECU runs the fuel pump for a few seconds to pressurise the fuel pipework. The pump is stopped if the engine is not started and powered on again when it picks up a trigger signal from the distributor as the engine is rotated with the starter. The idle valve stepper motor, which has been fully opened by the ECU at shut down, is set at maximum for a cold start, and is adjusted rapidly during warm up to reduce the air flow and maintain idle.

At **idle** the ECU monitors engine speed, temperature and electrical load and moderates the idle valve to maintain a consistent idle. It is important that the idle air valve operates properly and the base idle is correctly set otherwise this idle system will not function correctly. When the engine is shut down the stepper motor is driven to the fully open position to be ready for the next start up.

On the **overrun** the ECU shuts off fuel flow to reduce fuel consumption. Road speed is monitored to enable a smooth transition either back to driving or idle. If the road speed signal is incorrect or absent idle speed control will become erratic and the engine will tend to stall when the car comes to a halt.

Please be aware that this is just a brief summary of 14CUX operation. For a more complete description reference should be made to the RV8 Workshop Manual (MG RV8 Repair Manual AKM153ENG) and other sources listed at the end of this Note.

Troubleshooting & diagnosis

Fortunately for RV8 owners the 14CUX system is largely robust and reliable. In a well maintained car with all of the input and output devices working to specification there is no reason why it should not give many years of good service. But if problems are experienced and, especially, if the **Malfunction Indicator Lamp (MIL)** illuminates it is natural to want to try and understand what has gone wrong and why.

As always understanding and fixing engine problems benefits from a methodical and systematic approach, it is best to check each basic system to isolate the fault and proceed from there. Do not jump to the conclusion that every problem is ECU related – it usually isn't!

There are a nevertheless a few known issues which can give the impression of an ECU or fuel injection fault which are worth mentioning here:

- **Failure of the fuel pump or starter motor** to operate on the key can occur even when there is no fault with these items. If so it is worth checking that all wiring and earth connections are intact, the immobiliser has reset and the fuel pump relay is operating. The fuel pump relay is hidden under the centre console and is a little prone to corroded contacts.
- **Erratic idle, hunting or stalling on the overrun** can result from several causes which can be difficult to distinguish. Sticking idle air valves are relatively common; cleaning is straightforward, see **RV8NOTE283**. Air leaks downstream of the **MAF** can cause similar symptoms. Check for perished vacuum pipes and seals. Check also that the road speed sensor is properly connected and working.

If the **ECU detects an error** it will set a **fault code** in its memory and, on UK cars, illuminate the MIL. Note that Japanese specification cars do not have the MIL light, which is replaced on the centre console by the Catalyst Overheat warning. In some cases, but not all, the ECU will compensate for a sensor failure by using a default value or switch to 'limp-home' mode. The **fault codes** give a pretty good indication of the likely cause of the problem as they are specific to individual systems or sensors as shown in the **table below**.

Interrogation of the fault codes

Interrogation of the fault codes is possible with the right equipment and MG Rover used a hand held code reader for their **Testbook** system for this purpose. Unfortunately not many workshops still have Testbook and it is out of the scope of most DIY enthusiasts. Land Rover did fit a fault code display (PRC7067) to some Range Rovers which can be used to show 14CUX fault codes but so far I've not seen one on an RV8.

An aftermarket alternative sold as **ECUmate** was available until recently but is now out of production. If you are lucky you might find one second-hand or be able to beg, borrow or steal one from a friend! The alternative for the enthusiast is to get hold of a copy of **Rovergauge**, I shall discuss this in a bit more detail in the next section.

Normal operating ranges of the sensors

Sensor	Signal
MAF (Mass air flow)	
	0.32 – 0.34V with ignition on, rising to 1.6v at idle, approx 4.5V under load at full throttle. Error generated if signal <122mV or >4.96V at idle
TPS (Throttle position)	
	0.085-0.545V throttle closed, rising to 4.2-4.9V wide open. Error generated if signal < 78mV
ECTS (Engine coolant)	
	Normally 0.15 – 4.9V. Resistance reduces with rising temperature and should be approximately 2400-2600 Ohms at 20^{o}C and 300-400 Ohms at 80^{o}C. Fuel temperature sensor is similar.
Lambda probes	
	Also known as heated oxygen sensors. Should have battery voltage input, 13V on the red heater wire. Output signal is 0-1.1V
Engine speed (revs)	
	0-7V. Pulse from coil required to energise fuel pump. Coil signal used to monitor engine speed (rpm)
VPS (Vehicle speed)	
	0-2.0V and 10.5-13.0V. Signals when road speed >3mph.The signal should go up and down between 0-2.0 Volts and 10.5-13.0 Volts, changing every 4-5 metres. The signal is 8000 pulses per mile.

In the absence of a fault code reader it is possible to check most of the input sensors with a multimeter and identify any that are out of range. The normal operating ranges are shown in the table below. Obviously any sensors that are not producing the right signals will need to be repaired or changed.

14 CUX Fault codes

Code	Description	Comments
02	Live feed to ECU interrupted	Normal if ECU has been disconnected to clear codes, should clear if ignition turned off for 30 seconds then on again
03	Stored data corrupted	No useful information stored. Test drive & try again
12	Air flow meter	Possible air leak wiring or sensor fault.
14	Coolant thermistor	Faulty sensor or wiring
15	Fuel thermistor	Faulty sensor or wiring.
17	Throttle sensor	Sensor needs adjustment, is faulty or has wiring fault. This can cause low speed misfires
18	Throttle sensor output high when air flow low	Large air leak or faulty throttle sensor or A/F meter
19	Throttle sensor output low when air flow high	Faulty A/F meter or throttle sensor.
21	Tune resistor	Check tune resistor resistance
23	Fuel supply	Blocked fuel filter, faulty pump or pressure regulator
25	Misfire at full load	Lambda sensors have indicated an emission fault. Can be caused by almost anything within the engine's ignition and injection system from faulty plugs to a leaking head gasket. Check for a second code, if this is 40 or 50 it may indicate which side of the engine is at fault.
26	Very lean mixture	Indicates a very lean mixture or a misfire. Possible causes are a faulty lambda sensor or ignition fault. *(This code is used on the Jaguar version of the 14CUX ECU and is not listed under MG fault codes)*
28	Intake system air leak	Check for air leaks in the following areas: • Hose, air flow meter to plenum • Breather system hoses to plenum • Brake servo hose • Vacuum reservoir hose • Distributor vacuum advance • Purge valve to plenum • Injector seals
29	Checksum error	The ECU has failed its internal self-test. If detected all other fault codes are unreliable. Reset the ECU by disconnecting it, then reconnect it and repeat test as this fault can be caused by a faulty connection
34	Fuelling fault, nearside	Injector or Lambda sensor wiring fault, faulty injectors, air leak at injector seals or inlet manifold, blocked injectors
36	Fuelling fault, offside	As 34 above but for cylinders 2-4-6-8 only
40	Misfire on nearside	A misfire has occurred for cylinders 1-3-5-7 only
44	Nearside Lambda sensor	Faulty or lead-poisoned sensor or sensor wiring fault. If both code 44 and 45 appear then the likely culprit is the heater supply to both Lambda sensors
45	Offside Lambda sensor	
48	Stepper motor fully open above 500 rpm or fully closed above 750 rpm	Sticking stepper valve, incorrect base idle speed adjustment, incorrect stepper motor or throttle butterfly adjustment. A faulty road speed input can also cause this problem.
50	Misfire on offside	A misfire has occurred for cylinders 2-4-6-8 only
58	ECU unable to diagnose	Fault occurred for insufficient time for ECU to distinguish between faults 23 and 28
59	Fuel thermistor	Fuel thermistor fault. *(Note: in some documents code 59 is described as the same as 58!)*
68	Road speed sensor	Output too low at medium rpm and high air flow. Possible sensor or wiring fault
88	Power-up check	For cat equipped indicates a purge valve fault with the carbon canister system.
Note: This table has been drawn from several sources, not all of these error codes are listed in Rovergauge or MG references		

Interrogating the ECU

A lot of useful information about engine condition and performance can be obtained from the ECU. Fortunately for us a piece of software is now available that will not only identify fault codes but will also allow the operation of the ECU and it's sensors to be seen and logged in real time.

Rovergauge is available free of charge but you will need a laptop (or similar) on which to run it and a special lead to convert the ECU serial output to USB. You can make your own or they can be purchased from Mark Thompson at Mark@blitzracing.co.uk or through the classifieds on Pistonheads or Ebay. Just make sure you purchase the lead which is designed for the RV8 as the plugs for TVRs and Land Rovers are different.

If you purchase a lead from BlitzRacing it comes with a CD with Rovergauge, very good instructions and lots of other interesting information. Otherwise you can download Rovergauge from here: https://github.com/colinbourassa/rovergauge/releases/download/0.8.8/rovergauge-0.8.8-Windows.zip

Your lead will look something like this. . .

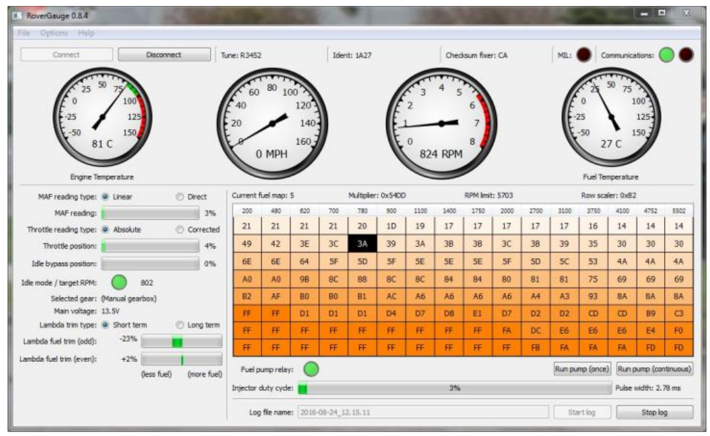
and it plugs in to the data link plug (DLC) in the passenger footwell:

The **basic Rovergauge screen** provides information on the status and operation of the engine and the ECU, summarised in the picture below. If the MIL lamp is on you will be able to see the fault codes in the options menu and by activating the logging facility you can store the data in a file which can then be imported into Excel and analysed.

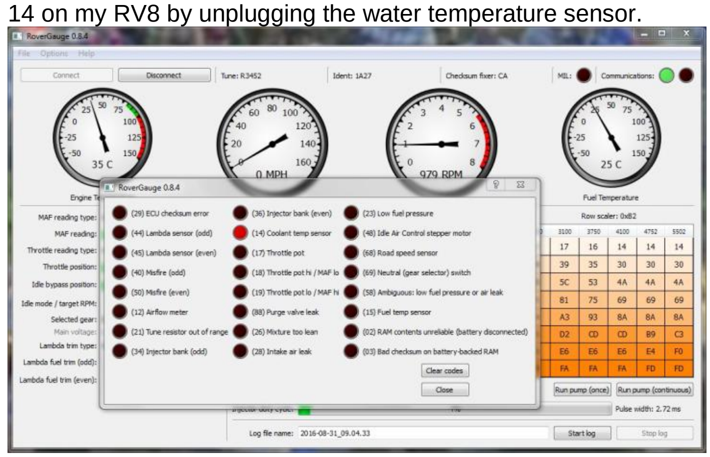
Finding the plug

The plug can be a bit difficult to find as it is up by the glove box near the bonnet release in the passenger footwell. On air conditioned cars it is a bit tricky to get to, but it can be done! Connecting your computer to Rovergauge can also be a bit tricky so follow the instructions that come with the lead carefully and then press the connect button. Once you are connected via the DLC the screen will show you some basic data about the ECU, which version of the firmware you have and whether any faults have been stored. The fault screen includes most of the fault codes listed in the table above so will give you a good idea of which sensor has caused the problem. You can also choose to clear the fault code to check if it recurs. Just be aware that fault codes do not tell the whole story as the ECU can be confused if the engine is not running normally.

With the engine running the screen will show the state of the main sensors and which part of the fuel map is in use:

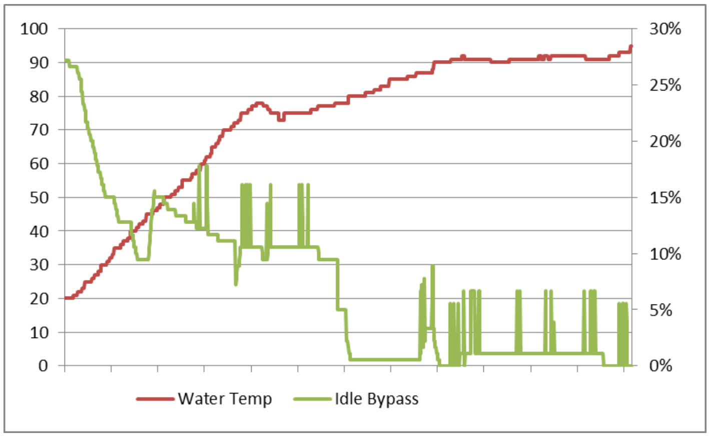


And this one shows the **fault code screen** – I generated code 14 on my RV8 by unplugging the water temperature sensor.



Pressing the **Start Log** button will record the ECU data in a file on your hard disk. It is then quite straightforward to import the data into a spreadsheet and analyse the parts you are interested in.

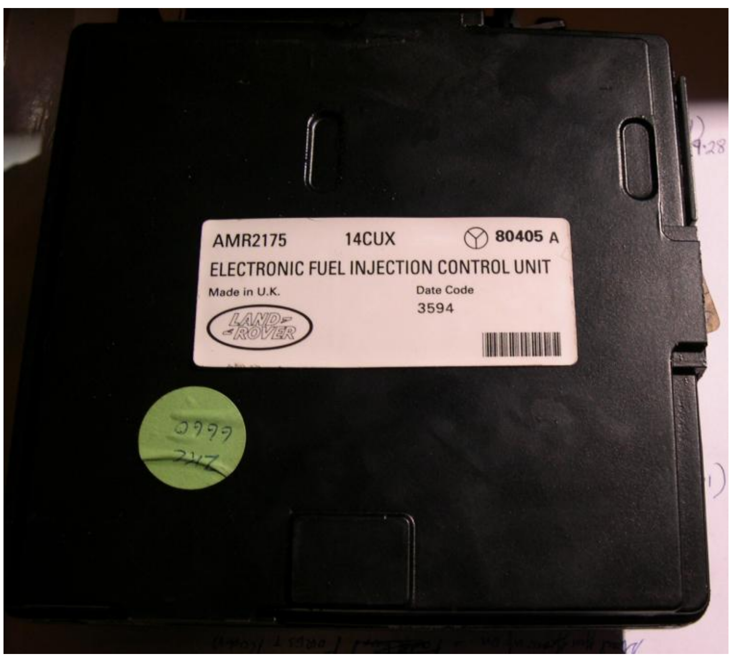
Typically Rovergauge records the data a couple of times per second so you can get a very detailed picture of how the parameters are changing. As a simple example the graph below shows how the idle bypass position changes during warm up on my car:



This is pretty much what is expected and shows that the idle system is working properly.

Chipping and remapping

The 14CUX was the last of a line of Lucas fuel-control-only microprocessors used by MG Rover and Land-Rover and consists of integrated circuits and components mounted on printed circuit boards within a strong aluminium case. Connection to the vehicle's main wiring harness is by a 40-pin multi-plug and in the MG it is located within the passenger foot-well.



It is important to repeat that although this ECU does not control the ignition system the performance of the ignition system does have a strong influence on how the ECU reacts.

A key component of the ECU is the microchip and it's **'Firmware'**. This carries specific information on how the injection system should interpret and react to data being fed to it from the various sensors on and around the engine. **This Firmware, known as 'tune'** in MG-Rover speak, holds target engine idle speeds at various coolant and fuel temperatures, and critically, a digital 'map' of how much fuel the injectors should deliver at various engine speeds and loads. It also holds the self-checking routines which generate the fault codes shown above.

You can see the **fuel map** as the orange coloured table in the centre of the Rovergauge screen. The map lists engine speed (horizontal) and load (vertical) and each intersection shows a 'cell' with a digital 'instruction' on fuel quantity to be injected, this quantity being controlled by how long the injectors are held open. The ECU reads the engine speed from the ignition coil and calculates 'load' from sensor data such as throttle position, throttle position speed-of-change and air flow into the engine.

The Firmware chip takes the form of an **Erasable, Programmable, Read Only Memory (EPROM)** and the data it holds can be altered by the use of specialised equipment and software. The Firmware used in the RV8 is derived from that used by Land-Rover in the early 1990s when one of the primary concerns was compliance with Exhaust Emission Regulations and this resulted in some cautious setting of, for example, ignition timing and idle speed. Land Rover continued to develop the 14CUX Firmware until the mid-1990s with various 'tunes' being issued. These have a reference number in the form Rnnnn with R3452 typical for later RV8s although there may be others. There is a school of thought that suggests the use of basic data pertaining to a large, heavy, 4x4 was not ideal for a light sports car, resulting in unnecessary use of fuel, particularly under cruising conditions, plus restricted engine rpm and road-speed.

This thinking has led to **re-mapping and re-chipping** the 14CUX to achieve maps more suited to sports car operation. The most popular of these have proved to be the **Optimax and Tornado** chips developed by Mark Adams of Tornado Systems and used in many RV8s plus other sports cars such as Ginetta and Morgan.

Of these **Optimax** has been the most widely adopted being particularly suitable for unmodified engines, Tornado being marketed more as a 'performance' option. The principle claims are improved part-throttle economy, lower idle speed and a freer revving engine. Feedback from those owners who have taken the step of re-chipping does suggest that these claims have been fulfilled.

In practice the **re-chipping and re-mapping** options for the RV8 are limited as the closed loop control on catalyst equipped cars will force the fuelling back to an emissions compliant mixture. Having said that some functions, like idle speed, cold start fuelling, extending the RPM table, lifting the rev limit and removal of the speed limiters on 4x4 maps, are possible without altering the closed loop fuelling. Importantly for performance minded owners full power fuelling can also be changed as the ECU is open loop above 3400 RPM.

Changing a 'Chip'

If you decide **a 'chip' change** is for you, the initial approach should be to a reputable tuning supplier such as Mark Adams 'Tornado Systems' (www.tornadosystems.com) or RPi Engineering (www.v8engines.com) who market these upgrades. Both companies have many years of experience with these 'chips' and will need details from you of the EPROM currently fitted to your vehicle. These details may well necessitate removal and opening of the ECU to identify the 'chip' currently fitted. Early models of the 14CUX had the chip soldered rather than pressed into place so replacement is a little more difficult although sockets can be retrofitted.

As mentioned above, the ECU is fitted in the RV8 passenger footwell and is released by removal of fixing bolts or nuts and removal of the multi plug. Access is easy on UK specification cars but it is tucked away in front of the air-conditioning unit on

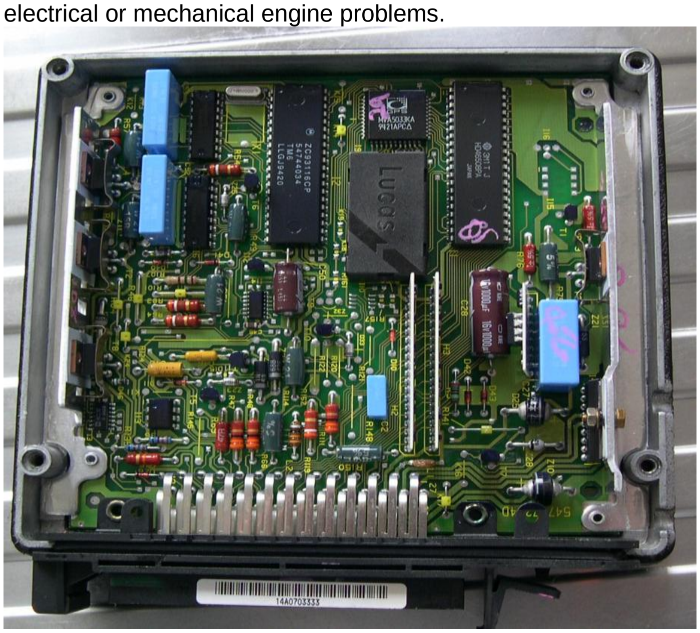
Japanese models and requires some athleticism. Make sure that the vehicle battery is disconnected before commencing work.

The new chips are supplied with detailed fitting instructions but briefly the work entails the following major steps:

- To avoid static electrical discharges, ensure you and the ECU are earthed – wearing a computer engineer's wrist strap connected to a stainless-steel household sink is ideal.
- Remove the ECU lid (Torx T20 bolts)
- Pull off the cover from the EPROM chip
- Lever the old chip from its socket
- Press the new chip into place
- Replace the lid

The work requires careful attention to detail but is not beyond the scope of the home enthusiast.

With the ECU lid in place, the unit can be refitted in its original position, the plug reinserted, the vehicle battery reconnected and the engine started. No other work is necessary, though advancing the ignition timing to 8 – 12 deg. BTDC and resetting the base idle is advised. The re-chip will not of course solve any underlying electrical or mechanical engine problems.



Your insurance company should be informed of the change, though most insurers seem to accept the Optimax chip on unaltered terms.

Writing Your Own 'Chip'

Thanks to work done by enthusiastic owners of, in particular, TVRs with the Rover V8 engine, it is possible to 'write' your own bespoke EPROM 'chip'. This is of course a much more serious undertaking and outside the scope of this article as selecting an incorrect fuel map on a catalyst equipped car like the RV8 can destroy the cats or worse!

There is a lot more scope for **remapping** the non-catalyst green tune, but it will fail emissions compliance on road cars, so this should only be considered on track cars with the catalysts removed. Alternatively it is possible to carry out a specific remap on a rolling road. A Derbyshire company has gained a good reputation for full rolling road 14CUX remaps: http://www.kitsandclassics.co.uk/, although there may be others.

There are now **multiple fuel maps** available free of charge on the web, based on TVR maps these can be copied onto a suitable EPROM before fitting. The TVR 4L maps are a good place to start for the RV8 for those wishing to experiment, if you are interested have a look at www.stevesprint.com/remap-14cux .

Summary & conclusion

Thanks to the availability of Rovergauge and accurate, low cost digital multimeters, there is no reason why fuel injection should be considered a 'black art'. Indeed with these tools any enthusiastic RV8 owner is able to diagnose, repair and even improve the fuel injection system of their car. Anyone who wishes to can now go further than that and remap their own 14CUX using readily available software tools and instructions – although I suggest that this is not a task to be undertaken lightly!

For anyone who wants to know more than I have covered in this brief article I would recommend a look through:

- The RV8 Repair Manual (AKM153ENG)
- Land Rover Fuel Injection Systems manual.
- Mark Thompson's very informative web site: http://www.g33.co.uk/
- Mark Adams' blog on the ACT Products web site http://www.actproducts.co.uk/2011/lucas-14cux-fuel-injection-system-%e2%80%93-installation-and-diagnostic-notes/
- And: http://www.britishv8.org/Articles/Rover-14CUX-EFI.htm
- Searching on Pistonheads for '14CUX' and 'Rovergauge'

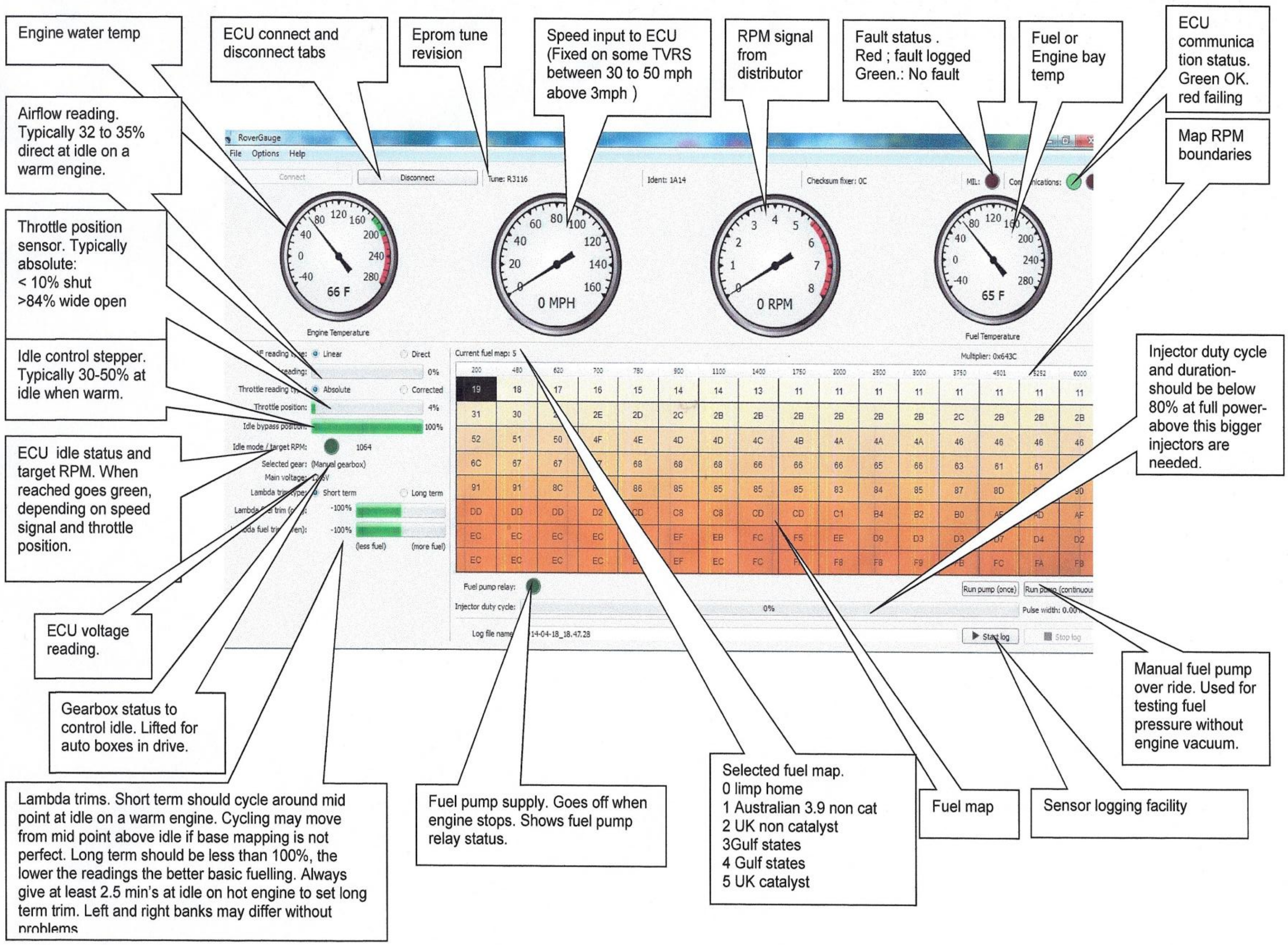
Acknowledgements

Many thanks to Mark Thompson, Steve Sprint and Steve Heath for permission to use their material. To Mark Thompson for providing the connector to fit the RV8 and for his helpful comments and of course to Colin & Dan Bourassa for developing Rovergauge.

Glossary

14CUX – The code name for a particular engine management computer produced by Lucas and used by MG Rover with the Rover 3.9L V8 engine.
Chip – An integrated circuit or microchip used in computers and electronic devices, in this case shorthand for the EEPROM containing the 14CUX firmware.
ECU- An engine control unit (ECU) is an electronic control unit that controls a series of actuators on an internal combustion engine to ensure optimal engine performance.
ECUmate – A commercially available hand held device for reading 14CUX fault codes, unfortunately no longer in production.
EMS – the engine management system is the ECU and all of its associated sensors which are used to control the engine.
Fuel map – A conceptual table of engine speed and load which allows the ECU to maintain the correct air fuel ratio.
Firmware – The set of instructions and data coded into the chip, firmware because it can only be changed by physically changing the chip.
Rovergauge – A program developed by Colin and Dan Bourassa which allows users to interrogate the 14CUX ECU made freely available on the internet.
Testbook – ECU fault diagnosis system used by Rover dealers and specialists to interrogate the 14CUX and other EMS (see RV8NOTE115 for more details).

Any feedback will be welcome by Dave Morris.



Engine water temp
ECU connect and disconnect tabs
Eprom tune revision
Speed input to ECU (Fixed on some TVRS between 30 to 50 mph above 3mph)
RPM signal from distributor
Fault status . Red ; fault logged Green.: No fault
Fuel or Engine bay temp
ECU communica tion status. Green OK. red failing
Map RPM boundaries
Airflow reading. Typically 32 to 35% direct at idle on a warm engine.
Throttle position sensor. Typically absolute: < 10% shut >84% wide open
Idle control stepper. Typically 30-50% at idle when warm.
ECU idle status and target RPM. When reached goes green, depending on speed signal and throttle position.
Injector duty cycle and duration- should be below 80% at full power- above this bigger injectors are needed.
ECU voltage reading.
Gearbox status to control idle. Lifted for auto boxes in drive.
Manual fuel pump over ride. Used for testing fuel pressure without engine vacuum.
Lambda trims. Short term should cycle around mid point at idle on a warm engine. Cycling may move from mid point above idle if base mapping is not perfect. Long term should be less than 100%, the lower the readings the better basic fuelling. Always give at least 2.5 min's at idle on hot engine to set long term trim. Left and right banks may differ without problems
Fuel pump supply. Goes off when engine stops. Shows fuel pump relay status.
Selected fuel map.
0 limp home
1 Australian 3.9 non cat
2 UK non catalyst
3Gulf states
4 Gulf states
5 UK catalyst
Fuel map
Sensor logging facility
RoverGauge
File Options Help
Connect
Disconnect
Tune: R3116
Ident: 1A14
Checksum fixer: 0C
66 F
Engine Temperature
0 MPH
0 RPM
65 F
Fuel Temperature
Current fuel map: 5
Multiplier: 0x643C
Fuel pump relay:
Injector duty cycle:
Run pump (once)
Start log
Stop log