RANGE ROVER 14cux Fuel Injection system

Note this is far from complete but based on my experiences that you wont find elsewhere- if you think something is wrong or want to add more information on the 14CUX, please drop me an email. Blitzracing@zoom.co.uk.

Note these notes are based on the 1992 ECU.

Overview

14CUX was the latest in a long line of fuel injection systems made by Lucas. Lucas licensed the designs from Bosch, the inventor of the system. Earlier iterations of this system were called 4CU, 13CU, and 13CUX. 14CUX is a fuel injection system only, meaning that it only controls the fuel injection on the engine - newer engine management systems do much more. These systems are pretty primitive in terms of diagnostics but they have the benefit of being serviced without special tools. They don’t have many sensors, and those sensors can be monitored with fairly common test gear and ss Lucas electrical systems go, these 14CUX systems are actually quite reliable. Sensor wise, these are air flow, fuel temperature, engine temperature, and throttle positions, road speed and on catalytic cars a lambda input. The "hot wire" air sensor gives an electrical signal depended on the amount of cooling air that passes over a preheated wire, that's then compared with a reference hot wire that has no cooling air flow. The various sensor inputs are then fed into the ECU, and converted into a digital signal that address's a pre determined fuel map held in a 27128 or 27256 type Eprom to give an injector pulse signal appropriate for the fuel requirements of the engine at that point. The ECU control's the fuel allowed to each cylinder by changing the time the injectors are open for (batch firing them) , combined with a variable fuel pressure regulator on the end of the fuel rail. This regulator alters the fuel pressure dependent on what the inlet vacuum is at any given moment and will vary from 24- 36 psi . This simply maintains the fuel pressure at at a set value above the pressure in the plenum chamber, so exact fuel metering can be maintained. To maintain a steady tick over, there is a stepper motor that controls an extra air path past the throttle body. The Fuel regulator is set to 2.5 bar or 37.5 psi if the inlet vacuum pipe is open to the atmosphere.

Initial start up sequence.

The sequence to restart the engine actually starts as you turn off the ignition switch. As the ignition voltage is removed from the ECU, the unit sends out a signal to the stepper motor attached to the plenum chamber to wind it fully backwards and allow maximum air into the plenum chamber. This can be heard as a buzz from the stepper motor as the engine dies. As the ignition voltage has now gone, the engine simply stops with the stepper motor in maximum air position.

On turning the ignition back on, a short pulse (about 1- 3 seconds) is sent to the fuel pump to pressurise the fuel rail. Once the starter motor starts to turn the engine, a 12v pulse is fed back to the ECU from the negative side of the coil as it the ignition amplifier switches. The ECU then turns on the fuel pump and energises the fuel relay that provides a fixed 12 volt supply to all the injectors. The transistors in the ECU starts to ground the injectors with a longer pulse than the normal idle pulse for about 3 seconds. This provides enough fuel to start the engine, combined with the stepper motor still being in its wide open position. Once the engine has fired, the air flow meter then takes over feeding the air flow volume back signal to the ECU and the injector pulse width is reduced to match the fuelling requirements for the engine at tick over. The stepper motor is also wound in to stabilise the idle at around 800 RPM. This system accounts for the short burst of higher RPM at tick over as the stepper goes from wide open to part closed during the start process.

One side effect of this system is if air leak develops any where in the inlet system, the engine will start and run for 3-4 seconds and then die. The initial over rich mixture will allow the engine to run, but once the air flow volume comes into play, (Now reduced because of the air leak) the injector pulse width is reduced to the point where the is insufficient fuel to keep the engine running, so it dies. The whole pipe work and breather system around the plenum chamber is pretty finely balanced and can be easily go out of tolerance should an air leak develop.

Fuel control system.

Once the engine is running the ECU then starts to take the various sensor inputs into account. These are:

Water and fuel temperature from 2 thermistors.

A variable voltage for the overall mass of air entering the system from the mass airflow sensor.

The engine RPM from a wire leading from the coil trigger.

The throttle position from a potentiometer mounted on the throttle butterfly.

Road speed from a "chopper disc" transducer that's inline with the throttle cable.

Fuel mixture from a lambda probe in each exhaust.

Although its of mid 1980 electronics and programming, its still quite smart with the Catalyst fueling maps. On starting the engine the lambda probe output is measured at tick over, and if it averages rich or lean the ECU alters a "base "setting in the ECU that either enrichens or leans off the entire fuel map, unit the idle mixture is correct. This takes around 15 seconds to achieve, and could roughly be described as a "leaning process". Once this base level is fixed, the normal closed loop part of the lambda control circuits then takes care of the "instantanous" mixture control throughout the rest of the fueling map above tick over. The ECU has the ability to alter the overall fueling over a wide range with this system, but if you start to deviate to far from its original "fixed" fuel map, the car can become hard to drive as the ECU constantly makes large corrections. When full power is needed at over about 3/4 throttle or about 3000 rpm, (both settings are programmable) the ECU goes open loop, and simply supplies a richer mixture, dependent on the fuel map values and fuel pressure.

There are 3 parts to lambda controlled fueling.

1) Tickover- Adjust the overall fuelling
2) Mid range - Closed loop control- small and rapid corrections
3) Full Power - Open loop, no lambda control, both probes should show .7 volts or more and remain there to show mixture is around 12:1 for maximum power and engine safety.

The other variable the ECU can "learn" is the voltages generated by the throttle position potentiometer over its maximum and minimum range.

Idle control.

This is a fairly crude affair, utilising a air bypass screw (called the base idle setting) and a simple stepper motor controlled air valve to keep the idle steady as the engine loads vary. The stepper motor has 180 different step positions, and each time the ignition is turned off, the stepper motor pulls the air valve wide open, by being pulsed 200 times. As only 180 steps are available, it will always reach a "home position", and from this point the ECU keeps track of its position by counting pulses from the home position. One weakness of this system, is if the stepper motor sticks, the ECU looses its correct position, as there is no feedback to say where it is which leads to an unstable idle. Another weakness is how it crudely controls the tick over. If the engine is running above the required RPM at tick over, a burst of pulses is sent to the stepper motor to reduce the air supply. The ECU then waits a few seconds for the mechanics of the engine to respond. This time "constant" depends on the engine dropping its RPM in a fairly controlled manner. Further tweeks then take place if the RPM is still outside tolerance. A problem occurs if the engine RPM drops faster than predicted due to fueling errors, or ignition problems, so the engine RPM drops too far. After the wait time the ECU detects the RPM is now too low, and winds the stepper motor back again and waits again, at which point the RPM goes too high. The process then repeats itself, so the idle remains very unstable.

Road Speed sensor.

This has the function of turning off idle control when the car is moving, so to maintain engine braking when slowing down, operating the fuel cut off on the over run, and in the case of of the 4x4 map, a top speed limit.

ECU Fuel maps.

The fuel map is held in a 27C128 or 27C256 type Eprom, dependent on the revision of ECU. Although the 27256 device has twice the storage capacity of the 27128 type device, it appears that you can still put the smaller device in place of the larger one as the highest address line is not used. The device itself contains multiple maps, such as catalyst, non catalyst, limp home, and some country specific ones for particular fuels. These are selectable with a plug in programming resistor found under the passenger dash board. The maps are referred to by the colour of covering plastic on the resistor wires, red, yellow, green, white and blue, and no resistor- (this defaults to the catalyst map.) Changing these values alters the base address used to find the relevant fuel map in the Eprom. On the early 14CUX units the Eprom device is soldered in, and does not have the classic quartz window in the chip. Later units have a plug socket, and plastic cover over the Eprom. To reprogram the early units the old device has to be cut out and the chip legs carefully removed one at a time. Its almost impossible to get the chip out in once piece, so once you have started there is no going back ! Its recommended that a “turned pin ” type chip socket is soldered into the board as these have better electrical connections in the harsh environment of a cars foot well where the ECU lives. Unfortunately due to the very restricted data available on this ECU, many people have simply given up trying to tune it, to switch to an after market fuel injections control unit like Emerald or Megasquirt, where programming data is freely available.

ECU trim values.

There are many values that can be altered such as the upper rev limit, the amount of cold start fuel supplied, the point at which the system goes open loop, plus the overall fueling levels of the map. It is virtually impossible to study the binary data in the EPROM, and tweak it manually,

If you are that way inclined the fuel maps can be studied by extracting the binary data with an EPROM programmer, and using a simple hex data editor to study the data. a suitable hex editor.

http://www.chmaas.handshake.de/delphi/freeware/xvi32/xvi32.htm

Memory map is 64K bytes big (16 address bits), and the program/calibration chip sits at address range C000-FFFF. Tune data is at the beginning of the chip, from chip address 0000-07FF. Program (but not entry point) officially starts after at 800h, although there are several 'hidden' calibrations (like overriding rev. limit) just after 07FF. Actual program entry point can be found from the reset vectors at the top end of the chip with reference to the 6803 processor data sheet.

Fuel maps are 2-axis maps 16 by 8 sites, speed versus load with 16 speed sites and 8 load sites. Load is calculated from the AFM reading by a formula which includes a scaling factor from the engine speed. This means that (maybe) 30 litres per second could give max load (site no.7) at 1000RPM, whereas it could take (maybe) 150 litres per second at 5000RPM to give the same load site. (Those figures are illustrative guesses!). Speed axis is a simple set of breakpoints with RPM. The breakpoints I believe have always been the same as follows:

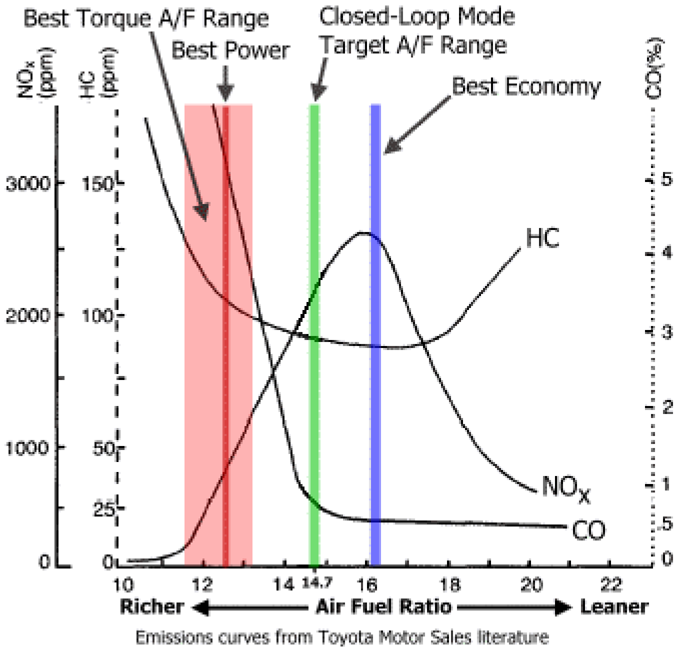
Site	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RPM	200	480	620	700	780	900	1100	1400	1750	2000	2700	3100	3750	4100	4752	5502

If you can adjust whatever you use to view the chip data to display 16 columns, the first map should be glaringly obvious. Since the data groups are not on 16-byte boundaries the others may be less so however, but the maps are almost identical so should be spottable. Directly after each map is the scaling factor applied to it, a 16-bit value usually of the order of (hex) 6590 or maybe 61AB. Fuel maps usually start with several instances of the same value, often (hex) 14 or 21. Each fuel map is at the start of a section of tune data applicable to that tune (as determined by the tune resistor) which extends down to the start of the next fuel map. Many things like acceleration enrichment, order of accessing analog inputs, cold start maps and other stuff are included on a per-tune basis, but some stuff found in the first (tune 0) area applies to all. There are six areas including tune zero. All are exactly the same size except zero.

To re program the 14cux, Lucas sold what was described as a "development box" that was basically a programmable ECU with a laptop interface and software. This unit replaces the standard ECU, and by using a rolling road and lambda probe outputs, the fuel map can be tweaked until the best conditions are reached. This modified map can been be programmed into a blank Eprom that then fits into a standard ECU. It is not possible to communicate with the stock ECU in anyway to alter the fuel mapping. One reason aftermarket chips are so expensive is the development units where very expensive, and now pretty rare, limiting the number of places that can genuinely change the fuel maps. As the fuel maps are on standard Eproms, they are pretty easy to copy given an Eprom copier although some aftermarket Eproms are sold with a scramble chip, that needs the correct address sequence to mimic the initial start up of the ECU CPU before the fuel map is unscrambled. A standard Eprom programmer will not follow this sequence so the data is scrambled.

After market performance chips.

It a light car like the G33 where the engine can rev easily, much more fuel is required through the higher rev and load range (4500 rpm plus) to prevent damage. The original leaning off of the mixture was a "feature" of the Range Rover to try and save a little fuel at higher revs and keep the emissions low. An evaluation by the magazine Car and car conversions found one G33 to be down to around 140 BHP (at the rear wheels), and by simply increasing the fuel pressure an extra 20bhp was gained. As already stated there is also a speed limiter plus a rev' limiter also built into the software, so there is good reason to upgrade the chip. At its most basic, simple modifications are to increase the injector pulse widths above 4500 rpm to provide more fuel, and remove the rev' and speed limiters. Beyond that there is also scope for improving the starting, mid range running and mid range fuel economy. Getting maximum power normally involves making the engine run at around 12:1 air /fuel ratio, but at this point both fuel economy drops, and emissions go up. So manufactures chose a compromise point of around 14.7:1, (shown as closed loop mode) when the engine will fill the emission requirements, and fuel economy even though power will drop a little. So the first step for more BHP is to re-chip to richen the mixture. A richer mixture also makes the engine run cooler, and its possible to advance the timing a a couple of degrees to make most use of the extra fuel with lower combustion temperatures.



Catalyst versus non catalyst fuel maps.

The 14CUX has all the hardware to use Lambda probes to keep the fueling spot on to best suit the catalysts, and keep the emissions low. Any G33 produced pre August 1992 however was not fitted with the lambda probes or catalysts as it was not a legal requirement, and not running a catalyst can have a slight performance advantages, by not restricting the exhaust gas flow. Having said that the catalyst map goes into open loop mode at anything more than 3/4 throttle or around 3000 rpm, so the fixed map section can be tweaked to run a bit richer in open loop as there is no lambda control. Its is not true to assume that running the ECU in fixed map will provide any more power than a correctly modified catalyst map. Things have moved on since the nineties when the G33 was produced, and TVR have done considerable work with the 3.9 engine fitted to the Chimaera with catalysts and have produced a very good fuel map, but it does require the installation of Lambda probes and wiring. Its worth noting that due to there being at least 5 maps in the Eprom, only one map may be modified. Don't assume that a TVR map switched to non cat will provide any performance advantage, as it may well be just a standard Range Rover map.

The catalyst fuel map has been rolling road tested (rear wheel figures) with the non cat G33 (read Range Rover) and TVR map and the results are as follows:

Max Power
Standard 179bhp
Modified 193bhp

Max Torque
Standard 198 ft-lbs
Modified 207 ft-lbs

Rev Limiter

Standard 5200 rpm

Modified 5680 rpm

The torque curves for both ECU's are virtually flat with max torque flat between 3200 and 3800 for the standard ECU and 2400 & 4000rpm for the modified map

Car ran to 84mph in 3rd with the modified map and 80mph with the standard.

Why bother switching to a catalyst maps over your fixed map ?

The standard fixed map needs its idle mixture set up accurately on the air flow meter adjustment to get the car to idle well and not cause problems with an unstable tick over. The normal procedure is to set the CO trim value to 1 -1.5 volts on the air flow meter for the non catalyst cars. Unfortunately any changes in the fuel pressure, fuel map, or valve timing (such as cam change) can throw these settings out, and the fixed system may not be able to cope, affecting the cars low speed drivability. By changing to the catalyst map these variances can be automatically compensated for by the ECU without a full and expensive remap. On the idle carbon monoxide settings I have tested from 0 - 3.5 volts on the CO trim value, and the system can cope within this range, without dropping out of "lambda range". From this I believe the CO trim value is ignored on the catalyst setting. On the fixed map, it really needs to be setup with a CO meter, as its quite possible to foul the plugs if this setting is out. Running the catalyst map is good for fuel economy, emissions and low speed drivability. Above about 3000 rpm, maximum power can still be maintained as long as an upgraded ECU chip is used such as the TVR Chimaera one already mentioned. The important thing here is you have nothing to loose as its the physical catalyst that reduces the power due to the restriction in gas flow, not the fueling map.

Lambda probes

These are fairly conventional units generating a voltage dependent on the amount of remaining oxygen in the exhaust after the burn has taken place. The voltage should be within the range of .3-.7 volts , with .3 being lean and .7 being rich. The only unique thing about them is the M12 thread, that allows the price to be kept up, as most generic units will not fit this thread. They also have a heater coil fitted that is powered from the fuel pump relay, so give a rapid warm up time. Once the ECU is powered on, will not modify the fueling until it receives its first changing signal from the probe, but from this point it expects the signal and if the signal fails or goes out of range it will generate fault codes showing fuel supply/ injector problems or lambda faults. If you source probes in the UK, they are VERY expensive at between £60 – 100 each. All is not lost however, as they can be sourced at around £14 each from the USA from a company called Global automotive:

http://stores.ebay.com/GLOBAL-AUTOMOTIVE

Search for Land Rover Oxygen sensor, and you will find them listed for the 3.9 engine.

To fit probes to the down tubes, you need to remove the pipe that connects the exhaust manifold to the first exhaust box. A hole big enough to take the probe tip needs to be drilled on the side or upper section of the pipe, as near the manifold as practical. Make sure you have sufficient clearance for the probe and wiring once its reassembled. Don’t install the probes on the lower parts of the pipes where condensation can run down into the probe sensor. You now need to weld a M12 fine nut (or half of one) to the down tube to hold the sensor.

Wiring the probes

The connections are already installed in the engine bay for the probes, and can be located jammed down amongst the wiring loom that runs along the engine bulkhead wit a pin circular connector for the left and right hand probe. As the probes come without the relevant connectors, you need to cut the connectors off and fit something suitable like bullet or spade connectors. I also left 3 test connectors free for subsequent testing. The Lambda control wire is screened, as the signal values are very low, and external electrical noise will interfere with the signal. If you need to extend the cables, its recommended that you use screened audio cable for this one signal.

Wire Colours

Loom	Function	Probe
White/orange	Heater	Red
Screened blue	Probe signal	Black
Black	Ground	White

Switching the ECUtune resistor.

You could simplybuy another plug in resistor pack, or just remove the original 470 ohm resistorreplace it with a 3900 ohm resistor (half or quarter watt). The leads are longenough to use a terminal block to join the connections if you don't have accessto a soldering iron. Alternatively a better bet to make a switch able option isto insert a simple on off switch in series with the tune resistor, and thensolder a 3.3k ohm resistor across it. Switching the switch "on" selects the noncat' map, whilst switching it "off" puts the resistors in series, switching tothe cat' map.

ECUmodifications

As alreadystated, the ECU will need the standard Range Rover fuel map chip removing, andan upgraded TVR chip fitting. There is little point in switching to the cat mapwithout this.

Testing.

You need preferably an analogue test meter, with a suitable range to measure up to 1 volt or over. With the engine running for a few minutes, the meter needs to be connected across the white and black connectors on the probe outputs. This should show a fluctuating voltage of between . 3 and .7 volts as the engine idles. If its not fluctuating, and sticks near 0 or 1 volts there's is a problem and the ECU is not compensating for the mixture variances, some sort of fueling problem or possibly a failed lambda sensor.

Further fueling adjustments.

Firstly and most important. Dont try to make any fueling adjustments without monitoring bothLambda probe outputs. It is impossible to guess what the fueling is doingwithout this, and could prove fatal to your engine if it runs lean underload.

The lambda probes have quite a narrow range of operation of around 15:1 air fuel to around 12:1 air fuel, but as long as the origional map is not too far out the readings will be good enough. In normal operation the voltages range around .3 - .7 volts, but even on a fully functioning system, you may see glitches as high as 1.2 volts. Due to the rapid response times, an LED bar graph display is the best item to make a cockpit gauge that can be viewed as the car is driven. Although you can buy such gauges "off the shelf" for around £25 (per probe), these will display only one side (or one probe) at a time. I found a low cost alternative (around £15) was to buy a stereo audio VU meter kit so both banks could be seen side by side in real time. The particular kit I purchased did require some tweeking of the input resistors to get it to give a full scale reading of 1.2 volts. I also managed to locate some old Lambda plugs and sockets that allowed the unit to plug in without splicing into the loom. It also conveniently provides the 12v supply needed to drive the gauges from the lambda heater supply rail.

A simple test box that monitors both lambda outputs

Viewing the normal fueling

This can give some interesting in site into how this ECU works. Firstly run the engine up until its warm, the disconnect the ECU for a few seconds to remove any fueling preset values. Reconnect the ECU, and start the engine and observe the results. The Lambda probes should already be hot, so the rising voltages should show rapidly BUT, with no fueling offset yet applied it may read very rich or lean. The ECU will then adjust the "base" mixture over a period of about 15 seconds, so the gauge should then start to fluctuate rapidly as a correct fueling point is reached. This short period can give you some idea of how much correction to the basic fuel map is applied by Lambda feedback, which is useful if you are adjusting the fuel pressure to minimise the amount of base correction applied.

Once out on the road in light to mid throttle, the lambda probes should hold the fueling close to the optimum point, and the gauge with constantly fluctuate. Once you go above around 3000 rpm or 3/4 throttle, Lambda control is released and the ECU goes open loop. At this point the gauge should rise to .7 volts or more and stay there. This is most important as any reduction from this value shows there is a problem with the basic fuel map, fuel pressure or fuel pump delivery. A lean mixture is very bad news as it causes the combustion temperatures to rise, and can lead to "micro" welds between the piston rings and bores, that can make a liner lift a fraction, which can destroy an engine block. YOU HAVE BEEN WARNED.

Adjusting the fuelling.

The first and foremost thing to remember is **Lambda feedback is king**, and the ECU will always try and keep the mixture correct whatever you do to the various inputs. In an ideal world, the unaltered part of the fuel map would be so near perfect, that very little correction has to take place, but this is rarely the case. The name of the game here is to alter a sensor input to try and minimise the amount of correction taking place. There are three methods I have found.

1) Fuel pressure.

By increasing (or decreasing) this by a couple of PSI will alter the fueling through the engines range. The ECU’s idle adjustment system will pick up this change in mixture, and alter the base setting to bring it back to lambda control range. If you go to far either way you will exceed the ECU’s compensation range, and it will go into a fault status. The cars will also become hard to drive before this point is reached, as the ecu battles to keep control. Once the ECU goes open loop near full throttle, the lambda control is ignored, so increasing the fuel pressure slightly can be used to provide more fuel under full load. The normal fuel pressure is 37 psi, and no more than 40-41 psi is recommended, as an optimum point for the standard fuel injectors.

	An adjustable cheap and cheerful variable fuel pressure regulator for around £40. You need a gauge with it, as adjusting the pressure blindly is an impossible task. Once the original pressure regulator is removed, you need a fuel line adaptor for the Rover V8 to allow a simple take off point for the new regulator. This can just bee seen as the brass item to the right of the regulator. Later 4 plus liter engines have the fuel rail position reversed over this 3.9.

Setting the basic pressure can be a little tricky, as without the engine running the fuel pump only runs for a few seconds. The best way to do this is to attach a 12 volt supply directly to the fuel pump (like a battery charger), with the ignition OFF. With the pump running then tweak the end adjustment to give a reading of 37 psi as a start point. If you have no access to the pump connections, you can try cycling the ignition, and try and tweak the pressure within the few seconds available to get it some where near. Then disconnect the vacuum pipe from the plenum chamber to the regulator , and block it to prevent air getting in to the plenum, and start the engine. Now adjust the pressure as quickly as possible. The engine at this point will be over fueling without the controlling plenum vacuum, and can put un burnt fuel into the catalysts, so speed (and preferably cold catalysts) is of the essence.

2) "Altering" engine temperature

Crude to say the least. The first problem is the resistance / temperature curve of the water temperature sensor is not linear, so by fitting extra fixed resistance distorts this curve. An additional 200 ohm resistor will make the engine temperature drop by an apparent (and approximate) 20 degrees at 80', or only about 10' degrees at 60'. The effect of this is to fool the ECU into thinking more fuel is needed as the engine is colder than it is, but much the same as changing the fuel pressure, but lambda control will have the same effect, pulling the mixture back to 14.5: until it goes open loop. Personally I prefer to alter the fuel pressure, as the results are more linear.

3) "Altering" the air flow output

There are case's with cam changes that the airflow meters output drops at low rpm due to reduced volumetric efficiency, and so the ECU makes the mixture too lean. This can be felt as a snatching at low rpm (say 1500) and in higher gears. It will disappear the moment the throttle is opened and the air flow increases. Although the ECU will go into fault if it detects the lambda probe outputs are consistently low, but, this is below the threshold the fault occurs at, but can still make the car very hard to drive. Its as if a small fueling "hole" appears in the mapping. From my experiments I found about an extra 200 mv is needed on the airflow output at 1500 rpm to provide enough extra fuel to reduce this considerably. This is not easy to achieve, but it can be done, but putting a small resistance into the earth wire of the airflow meter (red/ black wire). There is between 100 – 200 ma flowing down this wire, so by putting a 1 ohm resistor in this line, a 100 – 200 mv lift is applied to the overall airflow output, in relation to the ECU's earth point . The airflow meters body is not connected to this earth, so it does not matter if it is grounded. This system distorts the airflow much more at tick over and low rpm, than further than up the rev range. Examples are:

Tick over air flow out put 1.5 volts + 100 mv = 6.6 % increase

1500 rpm. Air flow output 1.7 volts +110mv = 6.4% increase

Full power Air flow output 7 volts +200 mv = 2,8% increase.

You will notice the additional voltage has changed, and this is due to the increased current flow thought the earth / resistor as the airflow output goes up. NOTE: THESE VALUE'S ARE EXAMPLES ONLY.

So this method will allow a small amount of extra fuel to be added when the air flows are low. The down side of this system is the ECU sets its basic fueling levels at tick over, so as an example 6% change will be added to its compensation throughout the closed loop area. The instantaneous fuelling correction that takes place via the lambda sensors may well cope with this, but the lambda probe outputs will need monitoring at tick over, to ensure the ECU can still keep the mixture within limits, and it is not simply too rich. I hit this point at 1.2 ohms, yet .8 ohms had no effect, so the values are very tight. AGAIN DO NOT TRY THIS WITHOUT MONITORING THE LAMBDA PROBES for a .3 - .7 volt switching output at tick over as an over rich mixture will damage catalysts.

These methods do give you some area for crude adjustment, if ECU mapping is not available or too expensive.

Air flow meteroverview (Electrically speaking)

This isfrequently seen as restrictive for best performance on the Rover V8, due to thesize of the restrictive area that forces air into the hot wire chamber, an theturbulence generated by it. This may be true on the 4.5 - 5 litre engines, buton a mildly tuned 3.9 its not a major problem, up to around 280 bhp. It also hasthe great advantage of measuring the exact and true air flow used by the engine,and can compensate for engine modifications (within limits), unlike most ECU'sthat would require a remap. It has only one adjustment, a hex head bolt thatsets a DC output voltage from the sensor that sets the idle carbon monoxidelevel (or mixture setting). Without lambda feed back this setting willsignificantly alter the mixture to the point of the engine running very lean orthe other way, carbon fouling the plugs and it can cause low speed runningproblems if its too far out. With the catalyst fuel map, this setting has noeffect as the ECU will trim the mixture to keep it within the correct range.The setting of the DC voltage has no effect on the overall voltages produced bythe air flow meter output for any given air flow.

Air flow meter adjustment.

Setting the Air flow sensor. Applicable to NON catalyst cars only. Using a voltmeter between red and black wire and blue and red wire check the voltage with the ignition on, but the engine not running. Recessed Hex head screw allows you to set the carbon monoxide base line with these voltages. NOTE these are base settings ONLY. Turn the adjustment screw clockwise to richen the mixture, and anticlockwise to lean the mixture. The screw has multiple turns, that will go from 0 volts to over 3.5 volts.

This unit has 4 connections:

Red/black. Ground

Blue/Green Air flow signal- should be .2-.7 volts (no air flow). Tick over on the 3.9 is about 1.7 volts It rises to around 7 volts maximum at full air flow.

Brown Orange +12v

Blue/red CO trim value. This is factory set 1.8 volts for catalyst engines, although I believe this setting is ignored with Lambda correction. Non cat cars are in the range of 1-1.5 volts, although accurate setting will require the use if an exhaust gas analyzer.

To test the air flow sensors output, connect the meter between the the ground (red black wire)and air flow sensor output (blue green wire). By removing the air filter and looking into the mouth of the air flow meter, a small hole will be seen in a cutout that runs around the edge of the air intake. By blowing gently into this hole the voltage should rise sharply on the airflow output. Not a scientific calibration, but a basic confidence check.

This small hole contains the hot wire sensor. Any small change in air flow through this hole (like blowing on it) will change the sensor output.

Bypass air valve (stepper motor) and its problems.

 The stepper motor is always the first culprit for unstable tick over, but due to a very crude "pulse and wait" system used by the ECU to stablise the tick over, other factors like wrong CO settings, air leaks and wrong timing can cause the the engine revs to rise and fall as if the stepper motor was sticking. If you have cleaned the stepper motor shaft (as below) then look else where before replacing the stepper motor

Air control valve. This comprises of a stepper motor, with a worm drive that moves a conical valve to control the amount of air by passing the throttle butterfly, and hence the tick over. Very prone to sticking, leading to erratic tick over.

Servicing the stepper motor.

Although the units appear to be sealed it is possible to strip the mechanics to clean them. The easiest option is to remove the unit, and clamp the head of conical valve in a vice. Now pull against the cone and rock the body of the stepper side to side at the same time, and with a bit of luck the cone and rod will pull out very slowly. Its on a screw thread (worm drive) so the motor has to spin as it pulls out. If it wont move, try soaking it in WD40 or the like to see if it will free. Assuming you can get the cone and shaft out, now clean the keyway and area behind the cone free of all carbon and muck. I found a bit of Chrome cleaner and a mini drill and rotary fibre brush did a good job, but you could probably use a stiff paint brush.

	Clamp the cone securely, then rock the motor side to side and pull.
	The component parts. Clean the cone, shaft and keyway.

Reassembly.

Firstly lightly lubricate the threaded area then refit the spring and screw the cone back into the motor, until the keyway just snags on its locating lug in the motor. Now reconnect the stepper into the car, and cycle the ignition on and off. The unit will wind the assembly back in as the ignition goes off. Disconnect and refit to the plenum chamber.

Reassembly is the same as above.

It is possible to disconnect the stepper motor completely, and rely on the base idle adjustment. The biggest problem with this is poor cold starting

If basic repairs or adjustments don't solve the problem, base idle speed can be adjusted.   Adjustment is made by turning a set screw that's normally hidden under a tamper-resistant plug on the Throttle body.

To access the screw, first drill a small hole (typically 1/8") in the tamper-resistant plug. Thread a sheet metal screw into the hole, and then pry the screw & plug out together. The main throttle butterfly is fully closed at idle, so there is a air bypass screw adjustment on the top of the plenum chamber that works together with the stepper motor. The screw adjustment is factory set, and sealed with a cap, **and normally will not need adjusting.** How ever the system will work quite happily without the stepper motor being connected at all, using just the base idle adjustment to bring the tick over up to 900 rpm when warm. This setting will need the engine to be rev'd slightly when cold to keep it running (for 30 seconds or so).

Setting the base idle for NO stepper motor operation.

	Base Idle adjustment screw.
	Make up a sealing plug with a M6 bolt and a bit of fuel hose. Tigtening the bolt will expand the hose to provide a good seal (see below).

Remove this pipe from the plenum chamber, and insert the sealing plug to make an air tight seal. Refit the pipe to prevent air reaching the air control valve. The base idle screw can be then adjusted with the engine warm and minimum load (ie no lights , fans or air con') for about 900rpm with a hex key. Leave the sealing plug in place.

Another trick used to help stablise an erratic tick over is to insert a metal plug into the air bypass hose, but with a 6mm hole in it with the stepper connected. This will allow enough air in to keep the tickover up, but prevent the engine from over revving.

Fuel Injection Fault Display (Note Never fitted to Ginetta's)

The Range Rover setup allows an ECU warning light to come on if the correct air fuel ratio cannot be maintained. Failure in one of the following sensors will cause the warning light to illuminate, and the ECU will drop into the "get you home " mode. This causes the ECU to default to a "fixed fueling" map, that can run without sensor inputs. This will limit the cars performance and tends to run a bit rich, until the fault can be cleared.

Failing sensors.

Airflow sensor.

Lambda sensor

Water temperature thermistor

Throttle potentiometer

To get a full diagnostic a fuel injection fault display has to be plugged into a socket in the wiring loom above the ECU that provides two-digit diagnostic codes.

.

These were available as a hand held unit from Lucas for around £125 but are now obsolete. There is an aftermarket unit available.

http://www.bespokeintelligentsystems.co.uk

For cars without Lambda sensors the fault codes are limited, but can at least point you in the correct direction. Modern Range Rover test equipment can still read the older units. To reset the unit after a fault has occurred, disconnect it from the battery for some minutes.

If multiple faults exist, the display shows the one that the ECU thinks is highest priority. Higher priority faults need to be "cleared" before lower priority faults will be displayed. A "blank" (dark) display usually indicates there are no faults.

Use this procedure to clear faults:

1. Switch "on" the ignition.
2. Disconnect the serial link mating plug, wait five seconds, and reconnect.
3. Switch "off" the ignition, and wait several seconds.
4. Switch "on" the ignition. The display should now reset.

Note: It should either show a lower priority fault code or appear dark.

Note: Fault code "02" will appear after a disconnected ECU is reconnected. Simply switch on the ignition to clear the display.

Fault codes

02 ECU Supply has been disconnected

Normal code to get after ECU has been reset. May indicate supply problems if ECU has not been reset recently. Code will be cleared if the ignition is turned on for 30 seconds or so

03 Data corrupted. Corrupted data in ECU. Reset ECU and test drive again.

12 Airflow meter out of range Possible faulty airflow meter or connection/wiring fault.

14 Coolant thermistor out of range. Possible faulty coolant thermistor or connection/wiring fault.

15 Fuel thermistor out of range. Possible faulty coolant thermistor or connection/wiring fault.

17 Throttle pot out of range. Possible faulty throttle potentiometer / incorrect setting or connection/wiring fault.

18 Throttle pot output too high with low airflow. Major air leak between airflow meter and intake plenum. Possible faulty airflow meter or throttle potentiometer or wiring/connections to either.

19 Throttle sensor output too low with high airflow. Possible faulty airflow meter or throttle potentiometer or wiring/connections to either.

21 Tune resistor out of range Tune resistor has become disconnected / damaged.

23 Low fuel pressure. Possible faulty fuel pump/ blocked filter or faulty fuel pressure regulator. VALID FOR CAT CARS ONLY.

25 Misfire at full load. A misfire has been detected while engine under heavy throttle and during high airflow meter readings. Check coil/plugs/leads/ distributor and ignition module. Code means that lambda sensors have detected a rich condition under load. Also see codes 40 and 50. VALID FOR CAT CARS ONLY.

28 Air leak. Air leak around intake plenum. Check all hoses/ injector seals etc.

29 Checksum error. ECU fault. Try resetting ECU and test driving again. If fault code returns ECU may be faulty. NOTE – any other codes generated should be ignored.

34 Fuelling fault in nearside injector bank. For cylinders 1-3-5-7 Possible injector, lambda sensor fault or wiring / connection fault to either. Blocked injector(s) or air leak at injector /inlet manifold. VALID FOR CAT CARS ONLY.

36 Fuelling fault in offside injector bank. For cylinders 2-4-6-8. Possible injector, lambda sensor fault or wiring / connection fault to either. Blocked injector(s) or air leak at injector /inlet manifold. VALID FOR CAT CARS ONLY.

40 Misfire on nearside bank. Misfire on 1-3-5-7 cylinders only. Nearside lambda sensor has detected a fault (or fault in lambda sensor circuit). VALID FOR CAT CARS ONLY

44 Offside lambda sensor out of range. Possible faulty lambda sensor or wiring/connection fault. See section 5 below for check. If in conjunction with code 45 then suspect lambda heater circuit. VALID FOR CAT CARS ONLY

45 Nearside lambda sensor out of range. Possible faulty lambda sensor or wiring/connection fault. See section 5 below for check. If in conjunction with code 44 then suspect lambda heater circuit. VALID FOR CAT CARS ONLY

48 Stepper motor fully open below 500rpm or fully closed above 750rpm. Possible faulty stepper motor or wiring connections. Stepper motor needs cleaning / is jammed. Incorrectly set idle adjustment screw. Incorrectly set throttle butterfly. Misfire or rough running because of other faults.

50 Misfire on offside bank Misfire on 2-4-6-8 cylinders only. Offside lambda sensor has detected a fault (or fault in lambda sensor circuit). VALID FOR CAT CARS ONLY

58 ECU cannot distinguish between codes 23 and 28. Fault maybe either due to code 23 or 28.

59 Same as 58 or fuel thermistor out of range. Documentation seems to vary here. Code either means same as 58, or faulty fuel thermistor or wiring / connector fault.

68 Road speed sensor too low at medium rpm and high airflow. Possible speed sensor or wiring/ connection fault.

88 Power-up check / purge valve fault. Sometimes shown on power up (CAT and NON-CAT CARS) or could also indicate purge valve fault with carbon canister system. (CAT CARS ONLY)

ECU urban myths.

Over the years various myths have risen up about this ECU, and not all of them are true.

Examples are:

You need to drive for 20 minutes to stablise the mixture after a ECU reset.

Untrue- it takes place in about 15 seconds at tick over.

You need to reset the stepper motor if you remove it.

Untrue. The stepper is reset every time the ignition is cycled off, but sending 200 pulses into a 180 step motor, so it will always reach "home".

You need an ECU reset to clear fault codes and reset the mixture.

True - The ECU contains no volatile memory, so a 30 second power off (as in unplug it or disconnect the battery) will remove any fault codes, and any stored fuel base settings. These will be re established once then engine is running at tick over.

The fuel map “stops” at 5400 rpm.

On the standard Range Rover fuel map does not increase the amount of fuel above 5400 rpm, but simply carries on fueling as if the engine was still at 5400 rpm. This can be overcome with aftermarket maps, where one of the alterable parameters in the fuel map, allows the entire fuel map to be moved up or down the RPM Range, so the upper limits can be moved to cover the higher RPM range.