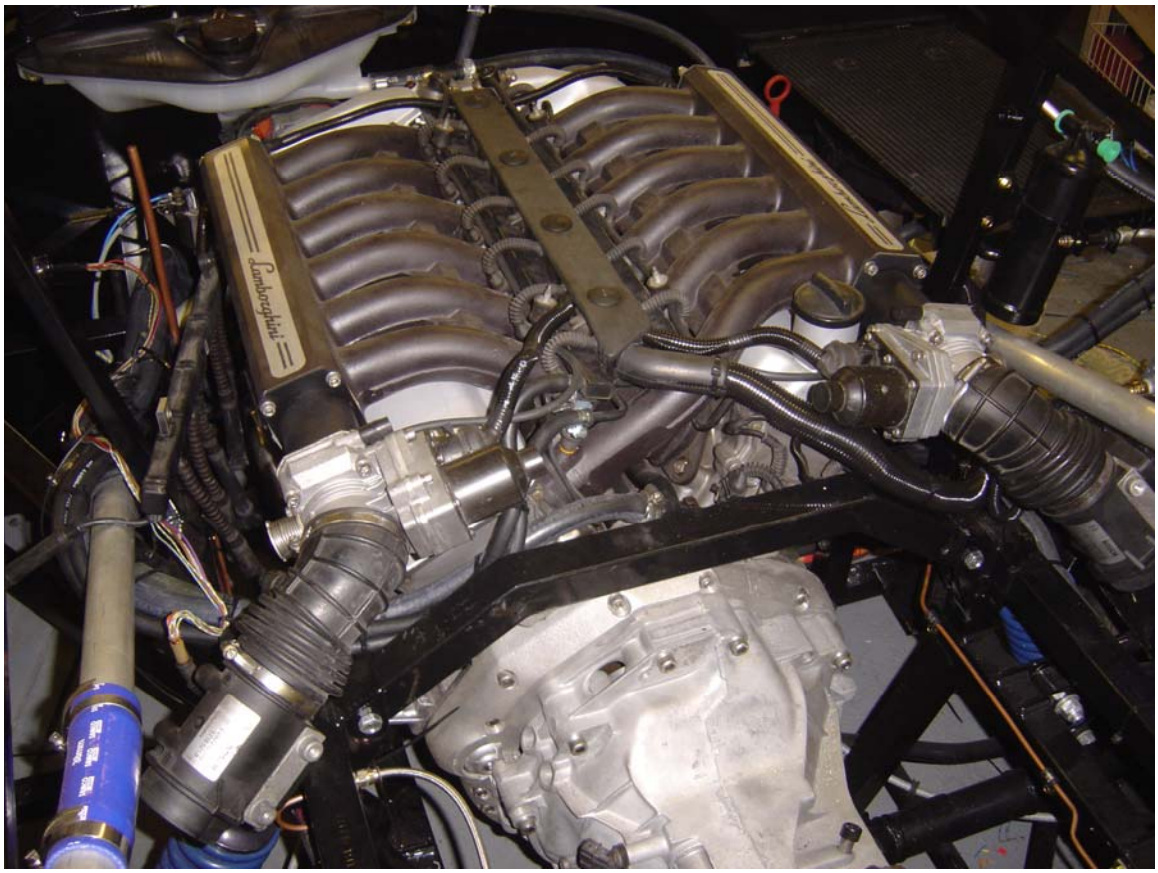
Re-using the BMW M70 engine management system



Re-using the BMW M70 engine management system

The engine control system uses three ECU's to control fuelling and ignition timing. One DME is used per bank of six cylinders for ignition timing, a third module; the EML controls fuelling and reads the position of the throttle potentiometer, the drive by wire system. Additional ECU's can communicate with these three modules and include traction control, transmission control, active suspension, climate control and anti-theft devices. This document is only concerned with the three main ECU's, these being referred to as the two DME's and EML.

The original ECU system used with the V12 M70 engine used in the 7 and 8 series BMW's can be reused and made to work in a non standard installation. To do this you will need some or all of the following:

a) Schematic diagram of the donor vehicle. Emule has diagrams for the 1989/90 models of the 750iL.
b) Access to a full function code reader that has the capability to erase fault codes.
c) A donor vehicle that operates correctly with an EML light that extinguishes after the engine has started.
d) A high quality soldering iron, cables of different gauges and colours. Heat shrink insulation, cable binding, insulation tape and split sheathing.
e) A fire extinguisher. Keep one handy when you fire up the engine for the first time.

This is not a simple process. You will need to extend or rejoin almost two hundered individual conductors. If you are any doubt as to your competence or ability to solder to perform this coversion, do not start; buy a kit from your car manufacturer instead.

The first thing that is required is to make sure your donor engine is running correctly with no faults. If you do not have a correctly working engine, it's pointless even beginning this. Ensure that if your vehicle is so equipped, that you have the anti-theft code switched off. This is done using the on board computer located above the climate controls. Refer to your manual for how to do this. BMW documents state with the battery disconnected, the code is disabled after 45 minutes. It is however better to be safe than sorry.

Once you are sure your engine is working correctly, you can begin to remove it!

Easier said than done, usual time with being careful is about ten to fifteen hours for a novice. Disconnect all cables, labelling those going to your ignition coils, crank sensors, air mass sensors and DK motors. You will need to record the position of these sensors and actuators to ensure you do not get the banks crossed over when it comes to reconnect everything. Before you start work, disconnect the battery.

Engine before removal, there is a lot of work here!

Once you have the engine out, you will have the main engine cable loom hanging in the engine compartment. Begin by taking out the ECU's and remove its compartment; you will need to cut the thick rubber grommet to manipulate the connectors through the case's cable entry. Place the ECU's in a safe place until you need them again, and try to follow static-safe handling procedures. I.e. ground yourself before handling the ECU's, and try not to touch the signal pins with your hands.

Remove the engine compartment fuse and relay box, this has two bolts holding it down to the right hand side front wheel arch. If your vehicle is equipped with ABS, you will need to cut the cables to the hydraulic actuator, as the connections to this device are usually badly corroded and difficult to remove otherwise.

Gradually pull the loom forward, disconnecting and plugs and sockets as you go. Eventually you will end up with three points of connection. These are the front power distribution block, and two circular connectors referred to on the schematic as X21, and X20. These are the main connecting points from the engine to the rest of the vehicles systems and connect the electronics through to the instrumentation and other ECU's. After you disconnect these points, you should be able to lift the loom clear.

Engine bay after loom and engine removal

Before you begin to reassemble the engine and cables, you will need to recondition the DK throttle bodies. These are unavailable as spare parts and are likely to have dry bearings. Erratic idle and poor acceleration problems can be solved by simple dismantling, re-lubrication and cleaning.

You can test these motors after you have reassembled them by applying DC six volts between pins two and five. Make sure you either limit the current or have a current limited power supply. The throttle butterfly should snap open quickly, and close fully when the power is removed. Pin numbers are indicated next to the pins, inside the connector shroud.

Try reverse polarity if the butterfly valve does not open. Do not connect the supply for any longer than necessary to check the motor, they are not designed to carry DC voltage for long periods of time. Once you are sure they are working correctly, put them in a safe place and continue through to the next stage.

Parts of a stripped DK motor before cleaning

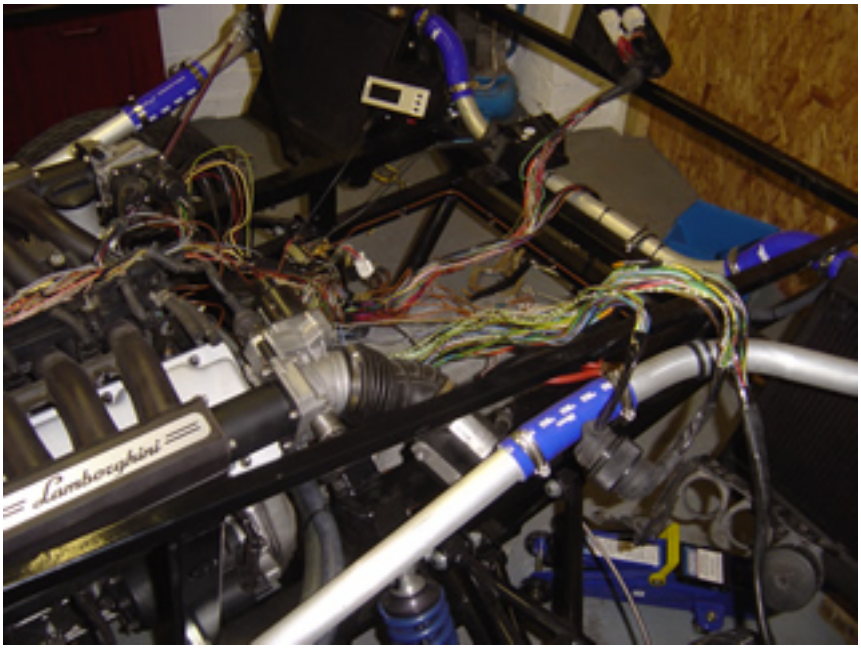
Your next job is to strip all of the insulation material from the cable loom. This process is required because the insulation will have degraded through heat in the engine compartment, and because you need to separate the redundant ABS cables and those going to the transmission and traction control ECU's. Be careful as you remove the insulation as it is very easy to cut cables or damage insulation. If you damage a cable, repair it at once. The cables will be very sticky, with a nasty black residue covering the insulation. Use isopropanol alcohol to remove it without damaging the insulation.

You will now have a less-sticky wiry mess all over your workshop floor. It will look untidy, nasty and you may be asking yourself if you will ever get it working again. Relax; it looks a lot worse than it actually is.

The next job is to reconnect all of the connectors to the engine's components. Some like the main alternator cables are not required for this stage. You should concentrate on only connecting the engine connectors. Things like the A/C clutch drive and ignition coils are not needed at this stage. Things that need to be connected are the fuel injectors, manifold inlet temperature sensors, crank sensors, ignition lead pick ups, DKM motors and the air-mass sensors. Basically everything on the top of the engine.

The most wonderful thing about the M70 engine is the inlet manifolds. Although they do not look it, they are identical. They interlock cleverly, and the DK motors and inlet manifold temperature senders can be mounted at either end. You need to rotate the whole inlet manifold system 180 degrees for a Lamborghini installation.

You will need to extend the air inlet temperature sensors as the leads to them will now be too short. You do not need to shorten the cables to the DK motors, this will happen when you run the cables through to the passenger compartment.



Cables all connected before cutting the loom

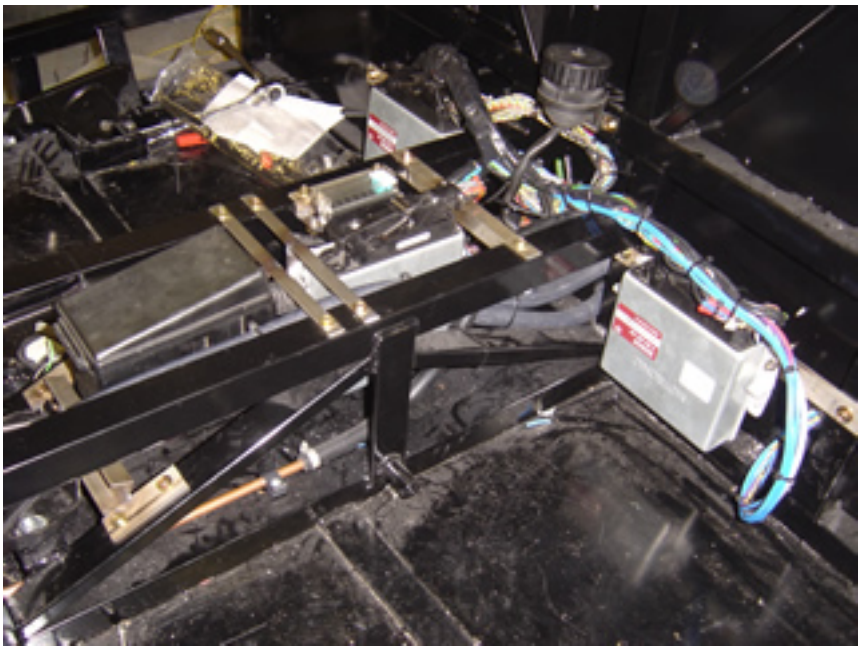
Once you have done this, bundle the cables as they exit the rear of the engine together with two tie wraps approx six inches apart. Between the wraps, label the multi core cables with two labels. I used masking tape, and then cut each cable between the two labels. You can use letters or numbers, it makes no difference, and all you are looking to do here is to label the leads so they can be reconnected in the right order again.

The rest of the cables can be snipped at this point as they are all different, both in gauge and colours. Try to snip them at different points between the two ties as this will make your joins not all line up, thus reducing the chances of shorts between joined cables.

Depending on the year of your donor vehicle, the loom may route differently to the air-mass sensors. If it does not route with all the other top-of-engine electronics, simply leave them disconnected for the minute.

At the rear of the engine are three coolant temperature senders. One for each of the DME's, and another one (on the extreme right, looking at the rear of the engine) which is for instrumentation. If you are using the VDO gauge set, this last sender will need to be changed. Make allowances when you extend the cables for this change.

You should now have a whole mess of wiring which is separate from the cables on top of the engine. The next stage is to mount the two DME's and the EML computers in the passenger compartment. The best position I have found, for mounting these is to place a DME each side of the tunnel on the rear bulkhead, and the EML inside the central tunnel. You will need to fabricate brackets for these items, and ensure that you have a good earth connection between the cases of the ECU's and the chassis, as the ECU's derive some of their earths from their cases.



Suggested locations of ECU's, as in my installation

Once you have the ECU's mounted, remove the relays from the front power distribution box and mount this somewhere too. You will need an additional fuse box for the DME's, fuel pump and cooling fan control. I have mounted both this components inside the tunnel as well.

At this stage you will have a fairly neat loom exiting the rear of the engine, mounted ECU's and a whole mess of cables for the wiring between the ECU's. You can separate the cables for the Traction control and ABS computers at this point and terminate the loose ends which would go into the EML & DME's to prevent them shorting out on anything.

Plug the connectors for the ECU's in. They have polarized connectors to make sure you do not plug the EML connector into a DME computer and vice-versa. The connectors for the two DME's can go to either DME, it does not matter, but it makes sense to put them closer to the bank of cylinders they are responsible for, than to cross them over.

Next stage is to set up the equivalent of a pin board to loom your cables back from the rear of the engine to your ECU's. Place a tie-wrap at each location loose where your cables will change direction. This is where you will run your cables through to ensure they all end up at about the same length. When you come to bundle the cables together, you will find this simple step will save you considerable time and effort.

Begin with individual cables, running them from the engine to the ECU's one at a time. Do it this way to prevent cables becoming confused and cross wired. Make sure you use either the same gauge or a higher gauge for each cable extension to ensure you will not have any cables carrying too higher a load. Solder each end carefully, make sure there are no solder spikes present and insulate each connection with heat shrink sleeving. Try not to pull the cables too hard if at all possible; you can always shorten a cable if it is too long. You want to minimise the number of joins to reduce the opportunity for failure.

Solder joints and their quality are key to this project. If you cannot solder, enlist help who can.

Here the wire is being heated using a 'third hand' to hold the wire. Apply heat to the wire with the iron, and then add the solder to the wire, not the iron. When you have 'tinned' both ends of the cable you intend to join. You can then attach the two cables together.

Carry on until you have terminated each of the individual cables. Once you have completed these, you can then begin on the multi core cables which go to the DK motors and the crank sensor pick ups. You can buy special cable to extend these, but you will find the necessary cables are expensive and difficult to obtain. The best alternative to use is shielded mains cable of the type using for medical appliances. It is able to carry the required current and is of sufficient quality and flexibility to carry the signals back to the ECU's. A 25 metre roll is about £40 and you will find you have plenty left over. You will also find that this cable is thicker than that which you are extending. Make allowances for this when it comes to making holes in the bulkhead to pass cables through. The colour codes will not match those used in the original wiring loom, make yourself a chart showing the colour translations and stick too it.

Typical type of cable you can use to extend the DK motors and crank sensors. Costs £34.69, carry's seven amps per conductor on a 100 metre drum. Order code 3894757 from Farnell.

Use plenty to tie-wraps as you run the cables to make sure everything stays tidy, you can cut the extraneous wraps off when you are ready to wrap the loom up with insulation tape. Remember that whenever a cable passes through a bulkhead, that you must protect the cables against chaffing and potential shorting. Use rubber grommets and plenty of insulation tape and split sleeving. If a cable is secured correctly, it cannot move, therefore it cannot chafe. Use plenty of clips and heavy duty plastic tie-wraps where clips are not practical.

Soon you will arrive at the stage where all the cables are run from the engine to the ECU's. The next stage is to tidy up the cables in the passenger compartment and try to make them neater. You should reinstall the relays into the front power and relay distribution box at this point to help with this.

Two more multi cored cables with shield need to be run from the EML and DME's through to the ignition coils, run these now.

If you are going to retain the standard BMW diagnostic socket (and you are, aren't you?), you can sort the cables for this out now. Once the diagnostic socket is dealt with, wrap the cables with insulation tape and secure it out of the way. There is a feed to the exciter on the alternator present on this socket you may want to run for the sake of completeness. I do not know if any code reader or exerciser requires this, but you may want to trigger the starter remotely, so this will help.

You may have cables designed to run oxygen sensors on your car. If your donor did not have these, terminate these leads. There may also be emission control equipment which also needs to be terminated. If your car had oxygen sensors, you will need to reinstall them as your engine management computer will expect to see them. There may also be SVA issues in removing emission control equipment on engines which have this fitted as standard.

Your mess should now start to look a little less scary at this point. Take the two connectors X20 & X21, and tie-wrap these in such a way as to loom them correctly from the ECU's. Label each bundle of cables and cut the connectors from the end, they are not required anymore. You can wire the electronic throttle potentiometer now; this will get rid of at least six cables straight away.

You may have noticed I have not given colour codes for any of the cables in the following sections. The reason for this is simple; the colour codes change from year to year. I cannot therefore guarantee that the cable colours I give may not match your own, and if this is the case, and you connect your cables up incorrectly, best case it will not work. Worst case and 'magic smoke' might escape from your ECU's. You must have a schematic for your year of vehicle. I have tried to refer to these signal cables with the same language that BMW themselves have used.

Using your schematic, isolate the EML and check engine light feeds and run those through to your dashboard location. A common fault is to ignore these and leave them disconnected; your engine will only run in limp home mode if you do this. The EML feed expects to see two low wattage 12 volt bulbs wired in parallel. The check engine light is only one bulb. The other side of the bulbs connects to the switched positive feed from your ignition.

There are several other cables that run along X20 & X21 you will want to run forward at this point too. One is an ignition signal which you can use to run a tachometer, the others are for cruise control should you have an automatic gearbox, and ignition advance/retard signals from a gearbox for gear change control. You can terminate these and leave them disconnected if not required. The advance/retard is used to signal the engine that it should reduce output power to prevent damage to the gearbox during gearshifts.

A quick note on terminating unused signal cables it that they should not be tied to either ground or the 12 volt lines unless I specify this. Many of these lines already contain what are called pull-up or pull-down resistors in the ECU which ensure correct operation if the line is disconnected. If you ground or connect a line incorrectly, the result could be erratic or undesirable operation, or damage to the sensitive electronics in the ECU's.

I have terminated unused cables by trimming the end and crimping a join directly over the insulation. You can then wrap the crimp in insulation, or use heat shrink sleeving to provide further electrical isolation.

The TX/RX lines for diagnostics should be terminated also as they are not required. The two fuel pump control lines need to be routed through your fuse box to the pumps, as well as the DME feed which would normally route through the Park/Neutral switch. Another line which must be dealt with is the brake safety sensor. This line is used to detect if the driver has their foot on the accelerator and the brake simultaneously. This in an automatic car would be a bad situation and is designed to either shut the engine down or prevent it from starting. If you leave the line disconnected, the engine will not start. You must either ground this line (in a manual car installation), or connect it to the non-earthy side of your brake lights (for an automatic gearbox).

At this stage the cables should look a lot neater now. You can run a supply from the battery to the distribution point inside the front relay box now. This line can be fused if required with a 50 amp unit. The cable you use should be of at least a gauge capable of carrying up to 63 amps. Run the ignition feeds to your ignition switch and cable up your starter motor. Make sure that both the engine and chassis have very good earth connections.

You need to make sure your earth and supply connections are clean and secure. Poor connections exposed to corrosion or low battery supplies will cause the sensitive electronics to malfunction. If the battery voltage is allowed to drop below 12 volts, the ECU's will begin to exhibit unusual behaviour and it may not be possible to clear their fault code memory's.

This is the Snap-On MT2500 scanner I used to debug my system. Any code reader capable of reading a BMW 7 or 8 series can be used, although the better ones like this, allow you to test certain parts of the system such as the fuel injectors and can give valuable diagnostic information

You are almost at the point of being able to try and start your engine now. First thing to do is to connect your battery, and switch your ignition to position 2 or run. Do not try to start it yet. Check the EML light. Did it come on and then go off? If it did not come on or stayed on permanently, switch the key off and check your

cabling. If there are no faults visible, follow the instructions with your code reader and try and get the fault codes from the engine ECU's.
Remember that the ECU's have separate fault memory's. Any faults are most likely to be found in the EML computer. Fault codes 00 or 60 are usually because the engine management system does not have any calibration data. Do not worry about these codes if present, they do not prevent the EML light from going out. Check also that the fuel pumps are both working, and that you have the connections to them the correct way round.

Connect a light or multimeter, set to the continuity range, to the oil pressure switch now. Disable the DME's by removing the Park/Neutral fuse. This will prevent the engine starting prematurely. Turn the engine over, and check your multimeter or light to ensure you have oil pressure. If you do not have oil pressure, go back, check your engine and rectify this fault before proceeding further. You can now replace the DME fuse.

Once you have the EML light extinguishing after a few seconds of switching the ignition to run, you are ready to start the engine. You will need at least a gallon of fuel, almost half a gallon is required to prime the fuel pumps, filters and fuel rails. Make sure you have a dry-powder fire extinguisher handy at this point, just in case there is a problem. Prime the pumps by switching the ignition to run and waiting for the pumps to switch off. Turn the key off, wait five seconds and try the key again. The sound the fuel pumps make will become much quieter when the pumps are primed correctly. You should also see overpressure fuel being returned from the fuel rails when they are full of fuel. The check engine light at this point will not extinguish, it will remain on until the two DME's have synchronised.

It may take several attempts to start the engine. It may cough and splutter initially, run and stall or idle badly. Keep trying, making sure your battery voltage does not drop below 12 volts off load, and do not turn the starter for longer than ten second bursts. If the starter motor becomes hot, wait a few minutes for it too cool and start again. If you cannot get the engine to fire at all, check your connections, and use your code reader to see if any faults have been stored.

If your engine has been rebuilt, and you are still having problems starting it, the usual suspect is valve timing. Check you have compression by removing a spark plug and attaching a compression tester. A rebuilt engine should exhibit a pressure of over 100lbs before running in. If you have no pressure, a very much lower pressure or pressure which leaks away instantly, you have a valve and/or timing problem. Check your timing!

If you can get your engine to start, the two DME computers will need to be synchronised. If you do not do this, the engine will idle badly, rock alarmingly when you accelerate, and limit your engines output power and revs to output 3000rpm. Let the engine reach operating temperature, check for water leaks and

make sure your cooling fans are working correctly. When the engine has reached the operating temperature, rev the engine up to three thousand RPM's for a few seconds, or better still, take the vehicle for a short drive. If you have rebuilt your engine, it may be slow to respond initially as everything may be a little tight. Do not stress your engine if this is the case. Let it idle for a period of time, and slowly increase the RPM's incrementally over a matter of time. You do not want to damage a bore or bearing do you? This procedure will allow the computers to store typical operating conditions and to calibrate the sensors. After you come back from your test run, leave the car idling for a few minutes before switching it off. Check that your check engine light has gone out, meaning the engine is now synchronised, and connect your fault code reader and check for any faults which may have occurred. Bear in mind that it is a good idea to repeat this synchronisation procedure after the engine is run in to get the optimum performance from it. If you disconnect the battery, you will need to repeat the synchronisation exercise to get the engine to run correctly.

If you have rebuilt your engine, change the oil and filter after 50 miles or a few hours of static tests. Even in a clean build environment, there may be debris floating around the engine or oil lines. This will reduce oil filter performance and could potentially block a filter and hence cut off oil feeds if the filter becomes blocked.

You should have a fully functional BMW M70 engine now. You can rest assured that you have the pinnacle of late 1980's automotive technology at your disposal, with advanced engine controls and standard BMW diagnostic for when things don't behave as they should! Revel in the massive 415fl/lb of torque and 340 BHP that this standard engine produces. Once you have your engine running, you may desire more performance. The easiest way to produce this is to increase the throttle body's diameter. You can then investigate high lift cams, gas porting and turbo charging. The BMW engine management system is adaptive, and can accommodate these changes without requiring modification to the ECU's. If you want you can change the DME eproms to a more aggressive profile, and change the EML eprom to remove or change the rev limiter. Whatever modifications you make, bear in mind that these will affect fuel economy and engine longevity, but then again, you didn't buy a V12 and go to all this effort to save the planet did you?

About the Author

Simon Appleby is a engineer with a major test equipment manufacturer.

In-between building Lamborghini replicas and writing documents like these. He is jetting around the world producing all sorts of meaningful stuff for the good of mankind.

You can view his build progress at http://www.v12diablo.co.uk