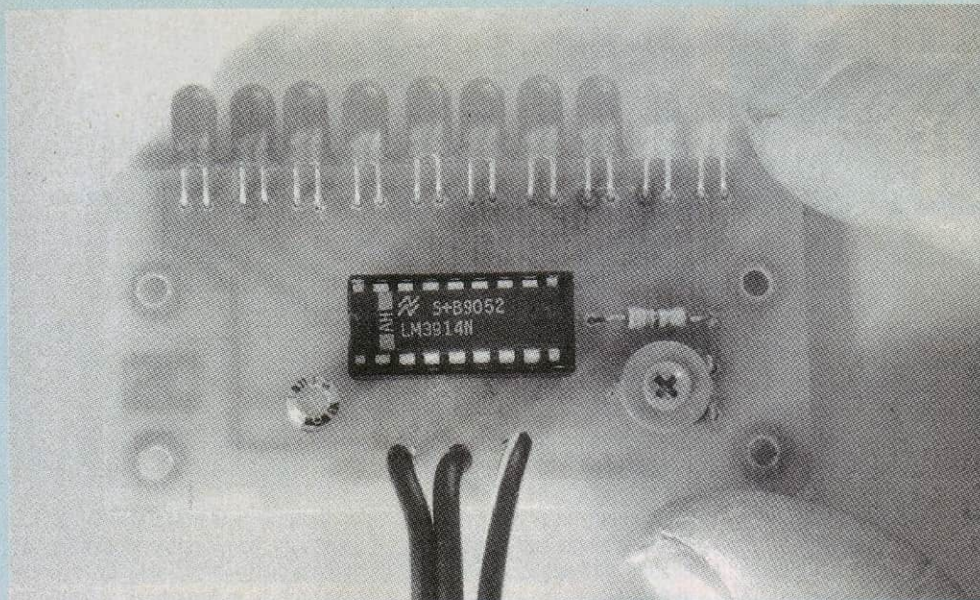
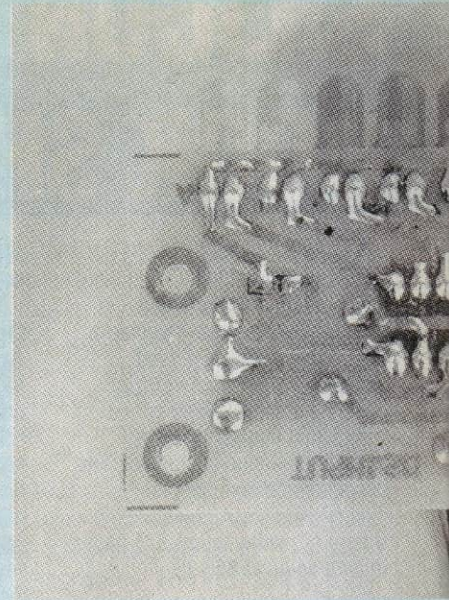




A mixture display for fuel injected cars

This simple project allows you to monitor the fuel mixtures being run by your car. You can use it as a tuning tool, to help in vehicle modification, or simply to see the behaviour of the engine control module. It is based on an LM3914 chip and 10 LEDs.

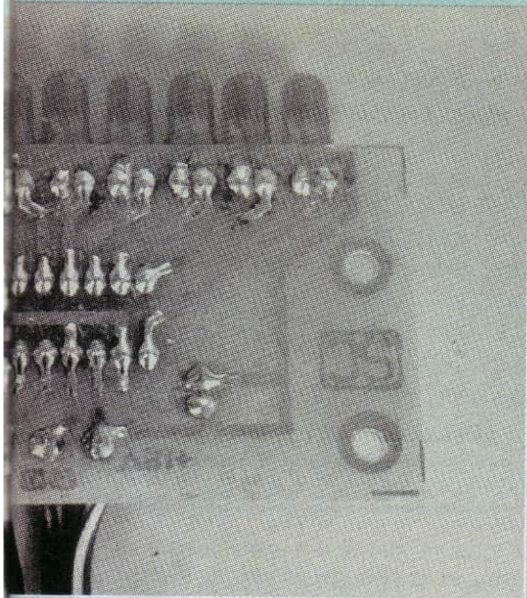
By JULIAN EDGAR

One aspect which makes engine-managed cars very different to their earlier carby brethren is the use of a number of sensors to measure various engine parameters. For example, inlet airflow, coolant temperature and throttle position all have sensors to measure their values. One of the most interesting sensors is the exhaust gas oxygen (EGO) sensor. As the name suggests, this sensor is mounted in the exhaust flow, usually in the exhaust manifold. Specifically, it measures the oxygen content in the exhaust gas (relative to air) and generates a voltage which is dependent on the air-fuel mixture. It does this to determine whether the air-fuel ratio is rich, stoichiometric, or lean.

The most commonly used EGO sensor generates its own voltage output which varies between zero and 1 volt. In round terms, if the sensor output is about 200mV or less the mixture is lean and if the output voltage is over 800mV it is rich. However, the precise value of the output voltage is less important than its relative value. In other words, 'rich' and 'lean' are only meaningful terms when compared with stoichiometric ratios and the sensor has been designed so that its output changes very rapidly around this point. Fig.6 shows the response curve of a typical oxygen sensor.

Monitoring the sensor output can be done with a digital multimeter but the response time of the typical multimeter is too slow to keep up with mixture fluctuations. The mixtures fluctuate in a rapid rich-lean-rich-lean sequence as the ECM responds to the EGO sensor's output. Depending on the particular EFI system (and the health of the EGO sensor), this can occur at frequencies as high as 10Hz.

The rapidly varying output of the EGO sensor means that it is easiest to read on a bargraph. Hence this project uses 10 coloured LEDs in a bargraph. Two red LEDs are used to indicate lean mixtures, six green LEDs to show mixtures in a normal range and two yellow LEDs to show rich mixtures.



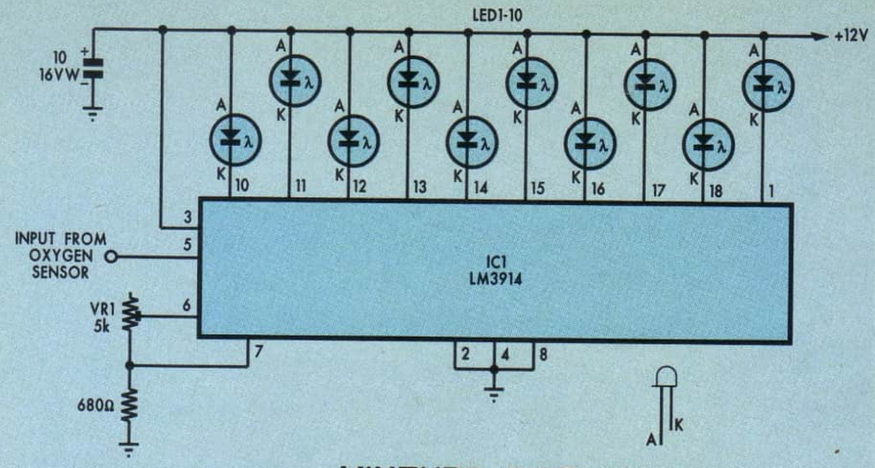


Fig.1: the signal from the oxygen sensor is monitored by an LM3914 dot/bar display driver in dot mode. Different coloured LEDs are used to highlight the signal changes.

Above: the Mixture Meter uses just a single IC and three other components, in addition to the 10 LEDs. The two LEDs at the extreme left are red, the two on the far right are yellow and the middle six are green. Make sure that no solder bridges are formed between the tracks, especially at the IC and LED connections.

Incidentally, depending on the application of the Mixture Display, you may wish to reduce the number of green LEDs and substitute more red and yellow ones. It is important that coloured LEDs be used (as opposed to an all-red bargraph display, for example), because it is far easier to see at a glance the mixture strength by simply looking at the LED colour, rather than its position in the display.

Circuit details

The circuit presented here is identical to that featured in "Electronic Engine Management: Pt.5" on oxygen sensors, in the February 1994 issue of SILICON CHIP. It is based on a National Semiconductor LM3914 dot/bar display driver. In dot mode, it drives the LEDs so that as the input voltage to its pin 5 is increased, it turns on progressively higher LEDs. For example, at the lowest input voltage, LED1 is alight; at midrange voltages, LED4 or LED5 may be lit; and at the highest input voltage, LED10 will be lit.

In bar mode, the LM3914 operates as a bargraph display driver, turning on more LEDs for higher input voltages. Hence, for the lowest input voltage, only LED1 will be lit; for midrange voltages all LEDs up to LED4 or LED5 may be lit; and for the highest input voltage, all 10 LEDs will be lit.

The circuit is shown in Fig.1 and as you can see, there is the LM3914, the 10 LEDs and little else. The 680Ω resistor connected to pin 7 (the internal 1.25V voltage reference) sets the current through the LEDs, while trimpot VR1 acts as a sensitivity control. Not shown on the circuit is pin 9 which is left open circuit to operate in dot mode or connected to the +12V line for bargraph mode.

Construction

The Mixture Display is built on a small PC board measuring 74 x 36 mm and coded 05111951. The component layout is shown in Fig.2.

Start the construction process by making sure that you can identify all the components and then check the PC board to ensure that there aren't any breaks in the copper pattern or unwanted bridges between the tracks.

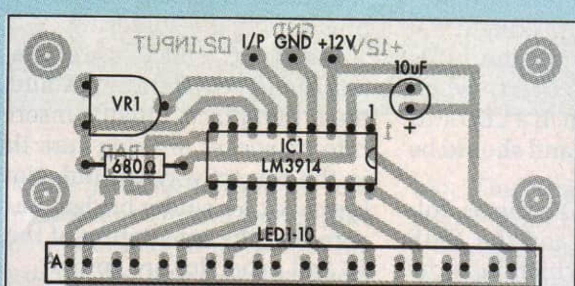


Fig.2: the parts layout for the PC board. Note that you can use the 680Ω resistor and a 6V or 9V battery to check the LEDs before they are installed.

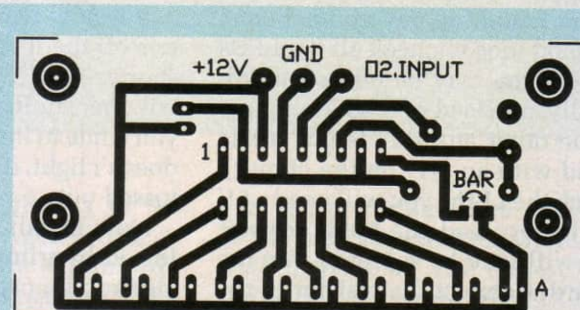
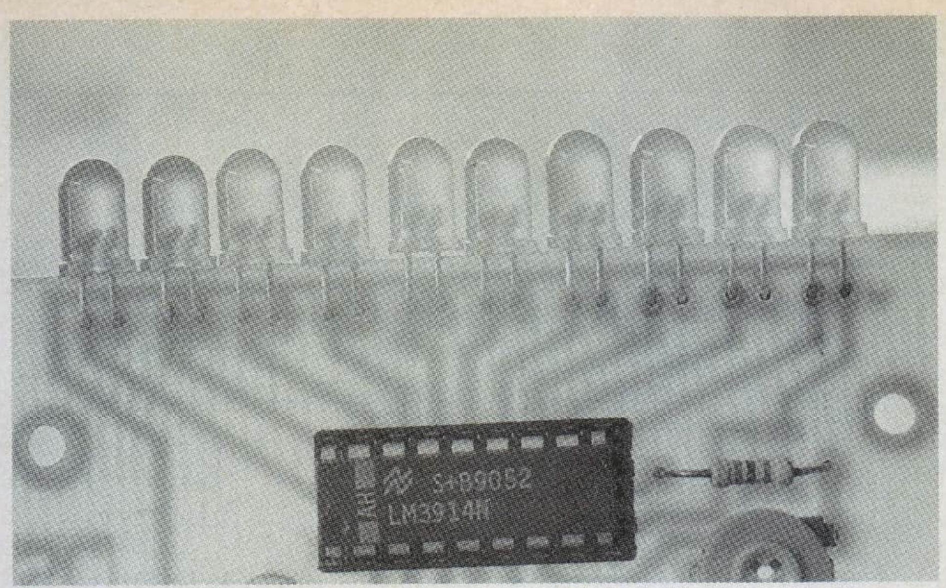
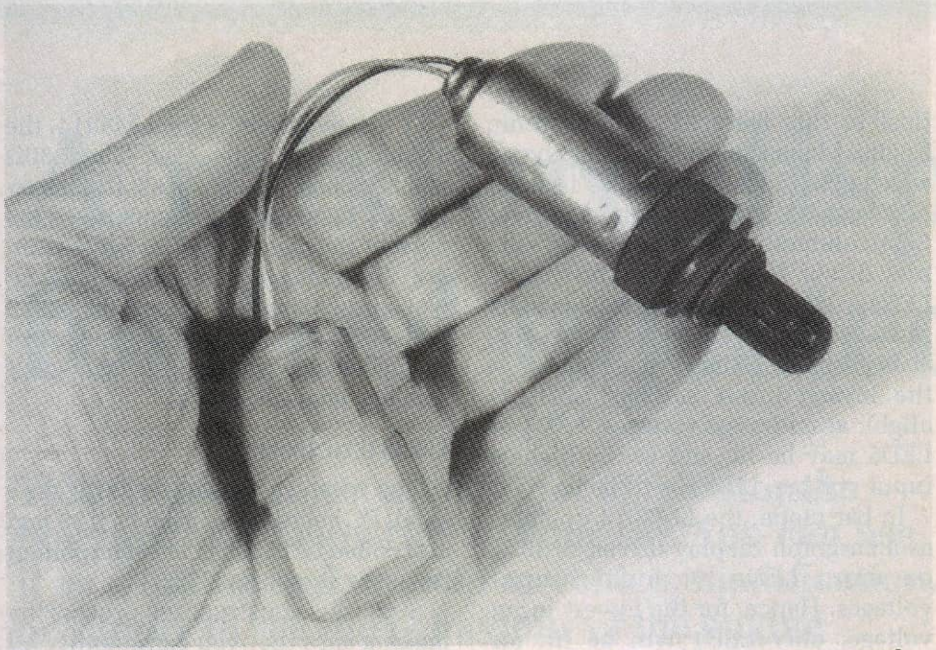


Fig.3: this is the full-size etching pattern for the PC board. Check the board carefully before installing any of the parts.



The LEDs should be oriented so that their internals look like this. If their connections are reversed they won't work!



This is a Nissan 3-wire oxygen sensor. In this type of sensor, two wires provide power for an internal heating element, while the third wire is the signal output.

If any are found, they should be fixed before proceeding further.

Before installing any components, it is a good idea to check all the LEDs because some may be non-standard. Normally, one lead of a LED is longer than the other and this is the anode (marked with an "A" on the circuit). To check the LEDs, you will need a 6V or 9V battery and the 680Ω resistor which will later be soldered into the PC board. Connect the resistor to the positive battery terminal and the longer (anode) lead of the LED to the free end of the resistor. The other LED lead goes to the battery negative. If the LED lights, it is a standard type; if it doesn't, reverse the LED leads.

If it now lights, cut a few millimetres off the longer lead, making it the shorter one. This way, all the LEDs will be similar (and correct) when you come to install them. If a LED still doesn't light, it is a dud and should be tossed out.

Now install the 680Ω resistor, followed by trimpot VR1 and the 10µF electrolytic capacitor which must be installed with correct polarity; ie, negative lead furthest from the LEDs. The LEDs are also polarised and so must be soldered in the correct way around if they're to work. With the board orientated so that the LEDs are at the top and the PC tracks are facing downwards, the LEDs are inserted with their longest wire on the right.

Start by inserting the two red LEDs, which go at the lefthand end of the board (when viewed with the LEDs at the top). When soldering the LEDs into place make sure that a solder bridge isn't formed between the two leads, as their solder pads are quite close together.

Continue with the six green LEDs and then the two yellow LEDs. Making them line up neatly will be easier if their leads are bent so that the LED bodies are hard up against the edge of the PC board. With all the LEDs in place, hold the board up to the light and check that the internals of the LEDs show that they are all lined up the same way.

Next solder in the IC socket. The socket has a small cutout at one end which shows the correct orientation to insert the IC. The notch in the socket should be at the opposite end to the 680Ω resistor. Make sure that bridges aren't formed between the IC socket pins during the soldering.

Insert PC stakes into the holes marked I/P, GND and +12V and solder them into place. Finally, insert the IC into its socket, making sure that it is in the correct way around. Now double check for solder bridges and make sure that the orientation of the LEDs, IC and capacitor are correct.

Connecting the board

The Mixture Display is powered from an ignition-switched +12V rail

PARTS LIST

- 1 PC board, 74 x 36mm, code 05111951
- 1 LM3914 dot/bar display driver (IC1)
- 1 18-pin IC socket
- 2 red LEDs (LED1,2)
- 6 green LEDs (LED3-8)
- 2 yellow LEDs (LED9-10)
- 1 680Ω 1% 0.25W resistor
- 1 5kΩ trimpot (VR1)
- 1 10µF 16VW PC electrolytic capacitor

Miscellaneous

Hook-up wire, solder, PC stakes

How does an EGO sensor work?

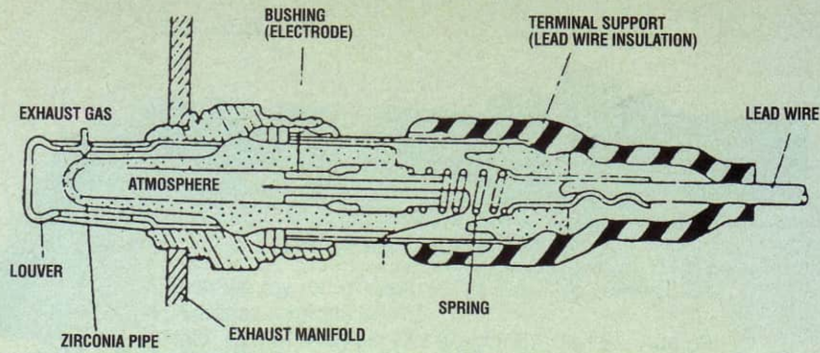


Fig.4: cross-section of a typical zirconia EGO sensor.

There are two types of oxygen sensor in general use, one based on Zirconium Oxide (also known as Zirconia, ZrO_2) and the other based on Titanium Oxide (TiO_2). The Zirconium Oxide type is the most common as it generates a voltage directly and does not need to be connected in a bridge circuit.

By the way, EGO sensors are also often referred to as Lambda sensors, from the Greek symbol λ which is used in the equation:

λ = air-fuel ratio/air-fuel ratio at stoichiometry

When the air-fuel mixture has too much air (ie, lean), λ is greater than one ($\lambda > 1$). Conversely, when the air-fuel mixture has too much fuel (ie, rich), λ is less than one ($\lambda < 1$).

Fig.4 shows the cross-section of a typical zirconia EGO sensor. In essence, this uses a thimble-shaped section of zirconia (a ceramic-like material) with platinum electrodes on the inside and outside.

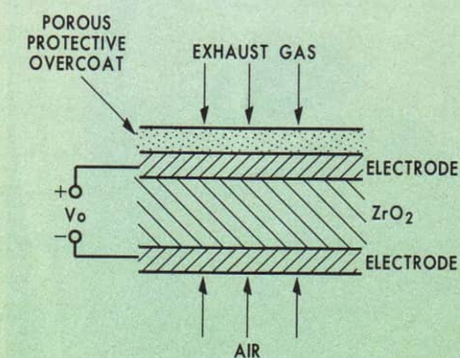


Fig.5: the inside platinum electrode is exposed to air while the outside is exposed to the hot exhaust gas, via a porous protective layer.

The EGO sensor actually generates a voltage due to the vastly different concentrations of oxygen ions at either electrode. Oxygen ions are negatively charged. The zirconia has a tendency to attract the oxygen ions and they accumulate on the surface just inside the platinum electrodes. The platinum electrode exposed to air has a much higher concentration of oxygen than the exhaust electrode and therefore it becomes electrically negative.

In practice, the air electrode is connected to chassis and so the exhaust electrode is positive. The magnitude of the voltage depends on the concentration of oxygen ions in the exhaust gas and the temperature of the sensor.

Fig.6 shows the sharp response of a typical EGO sensor as the air-fuel mixture varies from rich to lean and back again. Note that the response is slightly different from rich to lean than from lean to rich. The difference is the hysteresis of the sensor.

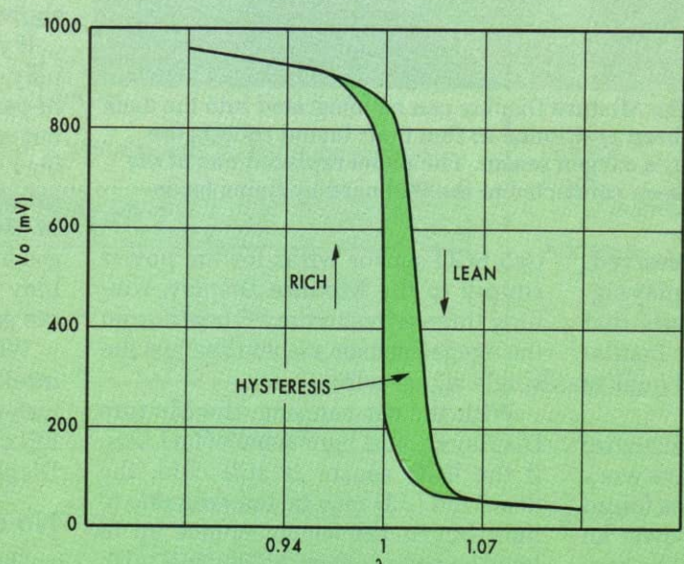
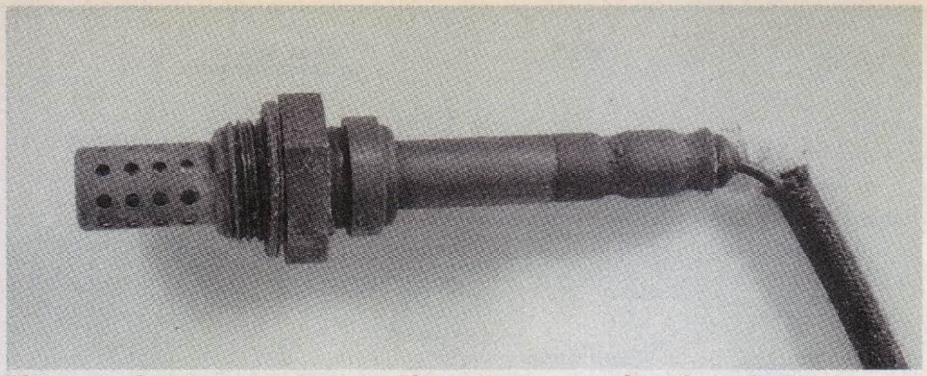


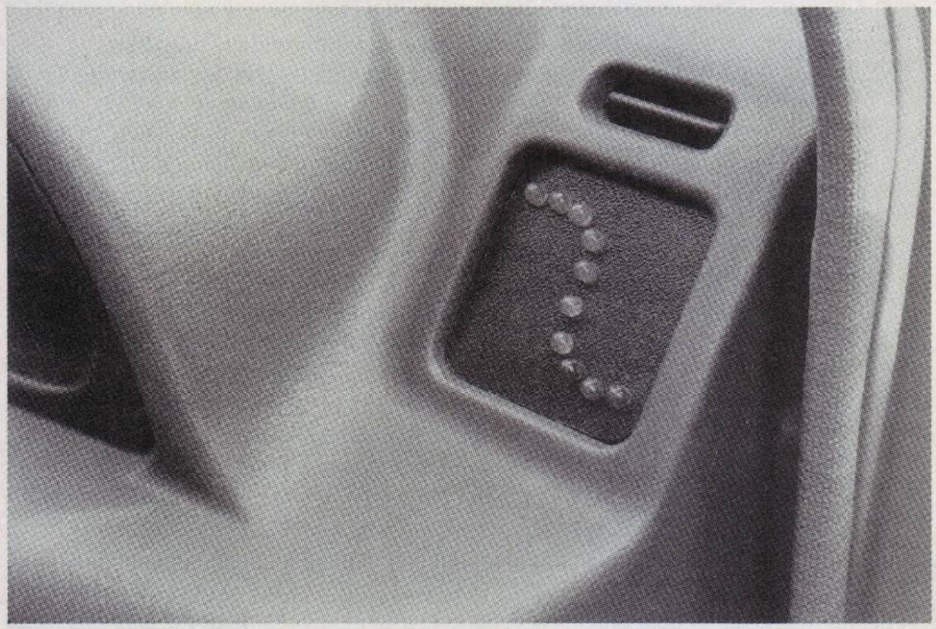
Fig.6: the voltage output of the sensor changes very quickly around the stoichiometric mixture point. This means that mixtures which are only a little rich or lean can be easily seen. This sensor response is obtained at operating temperatures of 360°C and above.

which could be accessed from the fuse panel or another switched device (like the radio). Connect this rail to the +12V pin on the board and connect the GND pin to chassis. Make sure that these wires are connected the right way around otherwise you will damage the IC and possibly the LEDs too. The final connection is to the signal output of the oxygen sensor.

Oxygen sensors are commonly available in single or 3-wire configurations. If your car is fitted with a single-wire sensor, simply connect the signal lead from the Mixture Display to this wire. Don't disconnect the oxygen sensor output from the vehicle ECM; instead wire the Mixture Display in parallel. The easiest way of doing this is to access the EGO sensor wiring near to the sensor itself. Push a pin right through the centre of the lead and bend it over and twist the leads together. This way, the integrity



This is single-wire oxygen sensor. This wire connects directly to the Mixture Display's I/P lead.



If you want to be really fancy, the Mixture Display can be integrated into the dash of the car. Here the LEDs have been positioned so that their layout reflects the shape of the response curve of the oxygen sensor. The panel replaced one of the dash vents and the LEDs have been connected to the PC board by flying leads.

of the oxygen sensor lead is preserved.

Now solder the Mixture Display signal lead to the pin, making sure that you don't damage the lead's insulation. Wrap the join with good quality insulation tape.

If your car's sensor is the 3-wire type, then a little more detective work will be needed. The extra wires found in this type of sensor are to power an internal heater, which brings the sensor up to temperature faster than solely by heat transfer from the exhaust gas. With the car running and up to operating temperature, one wire will be +12V, another 0V and the final wire 0.4-0.6V. It is the latter which is the EGO sensor output and this must be connected to the I/P terminal on the Mixture Display board.

Incidentally, if yours is a 3-wire type, you can also access the other two EGO sensor wires for the power supply to the Mixture Display, running three wires to the PC board from the oxygen sensor, rather than just the single signal wire.

With the car running, the Mixture Display should light some of its LEDs. If the EGO sensor is still cold, the 'lean' red LED may be the only one to light but as the sensor comes up to temperature, other LEDs will also light. With the sensor up to temperature, a blip on the throttle should cause the lit LED to run up and down the scale.

If all the LEDs light at once – and there is a burning smell coming from the display – switch off the ignition immediately and check the orientation of the IC. If no LEDs light, check the polarity of the power supply wiring and if you find that you had wrongly connected the Mixture Display, buy another IC and try again! If one or two LEDs fail to light, check for solder bridges between their leads.

Using the mixture display

There are two ways of calibrating the Mixture Display: (1) on the road; and (2) on a chassis dyno. The easiest is on the road, although note that this won't be appropriate in a car which has already been highly modified.

With an assistant in the passenger seat and with the engine up to operating temperature, drive at a constant speed, say 60km/h, with a steady throttle opening. The lit LED should start oscillating up and down the display, as the ECM makes the mixtures alternately rich and lean in closed loop operation. Adjust trimpot VR1 so that the oscillations in either direction are symmetrical around the middle LED.

Now, use full throttle and watch what happens to the Mixture Display. It should instantly show a rich mixture (either of the two yellow LEDs lit) and this mixture should be constantly held. Lift the throttle abruptly and the display should blank, as the injectors reduce their flow on the overrun – and so the mixture goes full lean. At idle, the Mixture Display should again show the closed loop oscillations.

If you're installing the Mixture Display on a highly modified engine then in-car calibration can still be done – but with the proviso that the mixtures may be all wrong to start with. The safest approach with this type of car is to use a chassis dyno and an exhaust gas analyser so that the Mixture Display can be calibrated according to the gas analyser's readout.

Whether to help in tuning, to allow intelligent modification, or simply so that you can see the way in which the EFI computer is working, the Mixture Display is a cheap and effective tool.

No oxygen sensor?

Note that if you have an engine which runs on leaded petrol (either carby or EFI), it will not have a factory installed exhaust gas oxygen sensor. The way around this is to source a sensor from a wrecker and install it in the exhaust manifold yourself. However, running leaded petrol will soon poison the sensor and so this approach should be used only for tuning purposes, with the sensor then removed for everyday use. **SC**