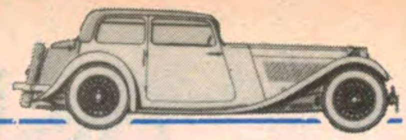


Analog fuel consumption meter

Featuring a 20-LED bar graph display, this unique circuit displays instantaneous fuel consumption in both litres/100km and litres/h. The principle is simple: the more LEDs that light up, the more it's costing you. Build it for your car and save petrol!

by JEFF SKEEN & GREG SWAIN

Whether you own a traditional Australian six-cylinder car or a more economical four-cylinder car, the price of petrol has become a significant factor in everyday motoring. Who would have thought, just a few years ago, that motorists in the "lucky country" would have to pay 45c/litre (or more) for petrol? Motorists in New Zealand are even worse off – the price there is currently about 70c/litre!.

With petrol prices like these, it makes good sense to strive for the lowest possible fuel consumption. Fairly obviously, the fuel consumption that you get from your car will depend largely on your driving habits. The driver who accelerates away from traffic lights like a startled rabbit, who brakes heavily, or who drives at excessive speed needlessly wastes petrol.

In fact, two different drivers can obtain widely different fuel consumption figures for the same car! It's all a matter of driver technique. The trick is not to emulate Starsky and Hutch, but to drive as smoothly as possible. The good driver carefully reads the traffic ahead and avoids heavy acceleration and braking as much as possible.

The role of the driver in obtaining good fuel economy is well recognised by car makers, several of whom now fit economy gauges as standard equipment. A typical device is the vaccum gauge as fitted to the Holden Commodore, which monitors inlet manifold pressure. The idea here is that the less the throttle is opened, the lower the manifold pressure and the lower the fuel consumption.

In practice, a vacuum gauge is a fairly useless device, since the only information it gives the driver is a rough indication of how wide the throttle is opened. It doesn't tell him what he really wants to know – ie, the instantaneous fuel consumption – so its use as an economy aid is rather limited.

That's where out new Fuel Consumption Meter comes in. It uses eleven readily available integrated circuits and works in conjunction with fuel flow and distance sensors to give the driver a bar graph readout of instantaneous fuel consumption in either litres/100km (l/100km) or litres/hour (l/h). The device is easy to build and install, and its compact size (129x131x40mm) ensures that it can be fitted to the dashboard of any model car.

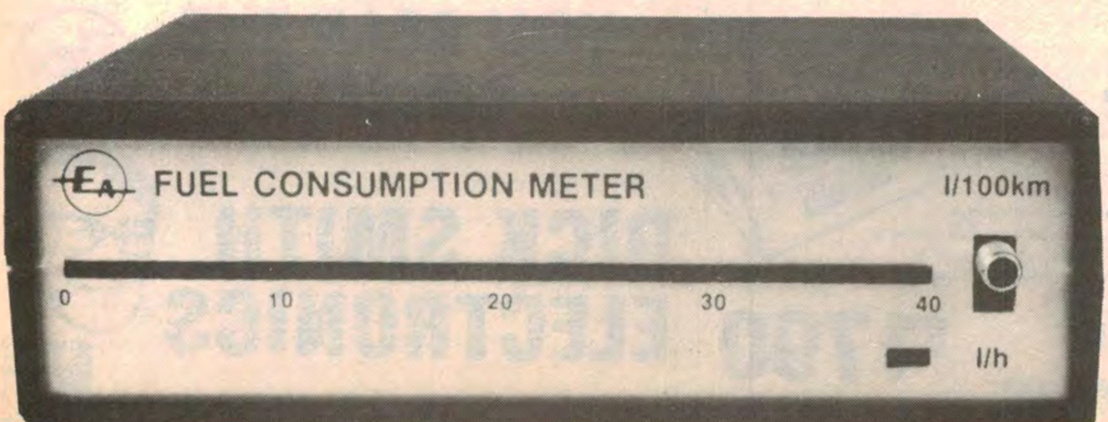
Once the unit is installed, you will find that you can easily modify your driving habits to obtain better fuel economy. In particular, you will be able to monitor the effects of rapid acceleration, gear selection and vehicle speed. The more LEDs that light up, the more it's costing you!

Out on the highway you can quickly determine the difference in fuel consumption between driving at, say, 100km/h and 120km/h. As you will discover, 100km/h is far more economical.

Bar graph display

Perhaps the most important feature of our Fuel Consumption Meter is the bar graph display. This is formed by 20 rectangular LEDs arranged side by side and, in this application, has several important advantages over the digital display used in the Car Computer. In particular, an analog display has virtually instantaneous response and you can tell what it is doing by merely glancing at it. It is not necessary to read and interpret numbers.

There is only one front panel control: a two-position slide switch that allows the



Watch the LEDs light up when you plant the right foot! The Fuel Consumption Meter can measure fuel consumption to 40l/100km or 40l/h.

unit to be switched from the l/100km mode to l/h as required. In addition, the unit automatically switches from l/100km to l/h when the vehicle stops (ie, when no pulses are being received from the disance sensor). The reason for this is that, when the vehicle is stationary, the l/100km mode becomes meaningless.

To understand why, consider what happens as the vehicle is brought to a stop. Initially, as the vehicle slows, the fuel consumption in l/100km decreases, then increases dramatically just before the vehicle stops. This is because, at very low speeds, the distance travelled between fuel pulses progressively decreases while the fuel flow rate remains fairly constant.

The limiting case is obviously at standstill, when fuel is used but no distance is travelled. The l/100km value then becomes infinite. Our Fuel Consumption Meter overcomes this problem by automatically switching to the l/h consumption mode about one second after the vehicle has stopped.

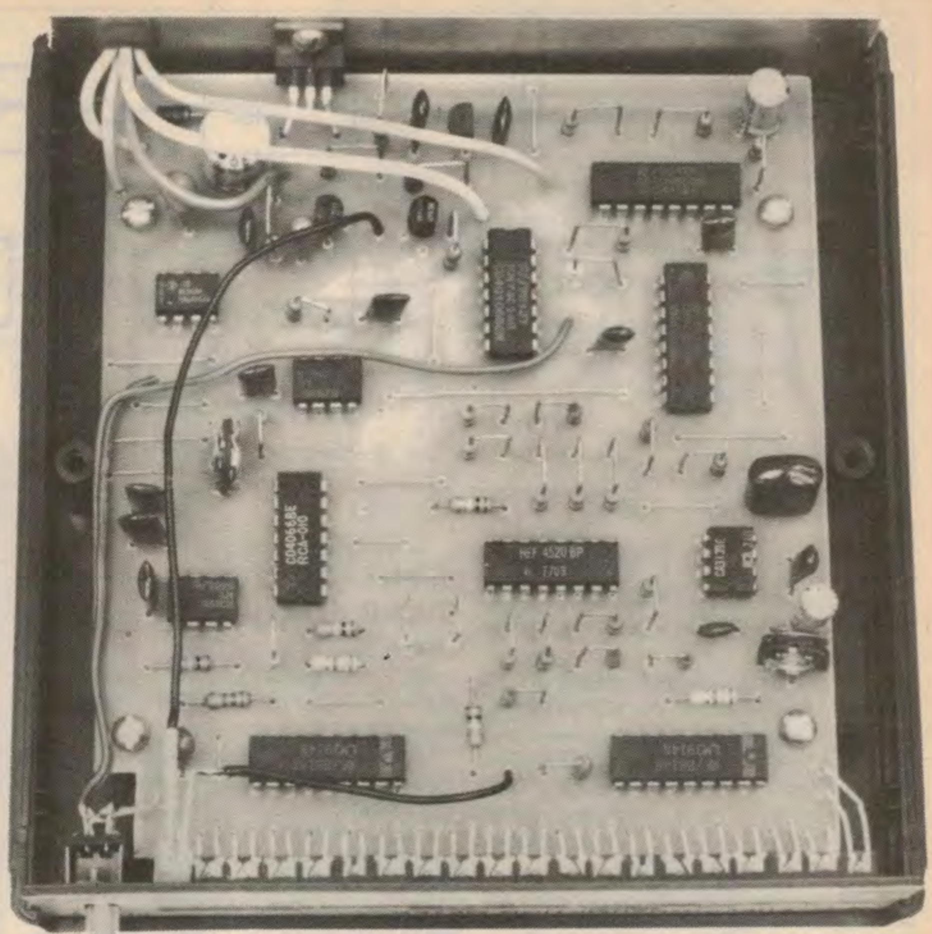
A green LED on the front panel provides visual indication that the meter is in the l/h mode. This LED operates regardless of whether the changeover is initiated manually or automatically.

As can be seen on the photograph, our prototype also features a "0-40" scale adjacent to the LED bar graph display. Despite this, accurate calibration of the unit is not really necessary since we are mainly interested in fuel consumption trends during driving rather than the exact instantaneous value. The value is of little importance as fuel consumption can vary quite rapidly from one instant to the next during everyday driving.

Is there a catch to any of this? Are there no disadvantages with our new Fuel Consumption Meter? Well, we have to admit to one problem area in designing a suitable unit.

Due to the action of the needle valve in the carburettor, petrol flow through the fuel sensor tends to occur in short spurts rather than as a continuous flow. At times the needle valve may cut off fuel flow completely (depending upon the float level), thus giving readings of 0l/100km. At other times, the valve may open fully, even at light throttle openings, giving flow rates much higher than normal and causing full scale display readings.

This effect is much more pronounced in small cars (1.6 litres or less) than in big cars with three to four litres engine capacity. There is also a driver condition which upsets the operation of the device. We refer to this as the "three-second syndrome" and it applies to drivers who, in heavy traffic, accelerate, ease off, gaze at the traffic, and then accelerate again, and so on. Many drivers who have this habit are unaware of it (government bus-drivers, please note!).



Contruction is easy, with virtually all components mounted on a small PC board. Note that the board is mounted upside down in the case (see text).

For obvious reasons, this upsets operation since it is difficult to obtain a steady reading. Not only is the habit bad as far as the Fuel Consumption Meter is concerned, but it also promotes excessive fuel consumption. Even so, our circuit largely overcomes the effects of needle valve action and the "three-second syndrome" as we shall see later on in the circuit description.

Fuel and distance sensors

The fuel flow and distance sensors used in this project are exactly the same as those used in the EA Car Computer. In fact, both projects can share the same sensors if required – all you have to do is wire them in parallel.

The fuel flow sensor is branded "Moray" and consists of a miniature turbine with multiple vanes that interrupt a beam of infrared light to a phototransistor. It delivers around 17,000 pulses per litre, the exact figure varying somewhat from unit to unit, and is inserted in the fuel line between the fuel pump and the carburettor.

Two different types of distance sensor can be used: (1) a magnetic pick-up using a coil and rotating magnets; or (2) a speedometer cable sensor that uses vanes to chop an infrared beam to a phototransistor. Generally speaking, the magnetic pick-up system will suit rear-wheel drive cars as the tailshaft is an ideal place to mount the magnets. The speedometer cable sensor is more applicable to front-wheel drive cars.

Block diagram

Let's now discuss the general circuit features by referring to the block diagram (Fig. 1). We will consider the l/100km mode of operation first.

Pulses from the fuel flow sensor are first multiplied by 64 and the resultant signal used to clock the input of a digital-to-analog converter (DAC). At the same time, the distance sensor pulses are squared up and passed to a monostable. The output of the monostable is a train of narrow positive going pulses which perform the reset function for the DAC.

At the heart of the circuit is the digital-to-analog converter. It functions as follows: initially, the output of the DAC is reset to zero and the device begins counting clock pulses from the x64 multiplier. As shown on Fig. 1 the output of the DAC is a staircase waveform which increments one step each time a clock pulse is received. This staircase waveform continues to increment until a reset pulse is received, at which time the

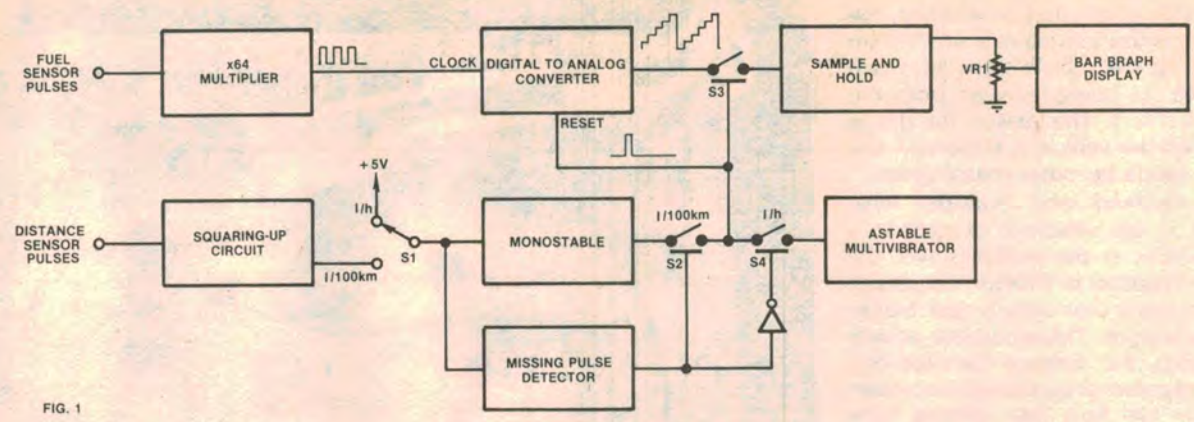


FIG. 1

output of the DAC is "frozen" and transferred to a sample-and-hold circuit. The DAC is then reset to zero ready for the next count.

In other words, the DAC counts up the number of pulses from the x64 multiplier between successive reset pulses, and converts the resultant binary number to an equivalent analog voltage. This analog voltage is then transferred to the sample-and-hold circuit, which in turn drives the bar graph display.

Since we are effectively using distance sensor pulses to gate through fuel sensor pulses, the voltage on the wiper of trimpot VR1 will be directly proportional to fuel consumption as a function of the distance travelled. By suitably adjusting VR1, we can get the display to read directly in l/100km.

Note that switch S3 is closed only during the reset pulse so that data can be transferred from the DAC to the sample and hold circuit. The switch is open at other times to ensure that the DAC has no effect on the sample and hold circuit during counting.

The sample and hold circuit, by the way, does exactly what its name implies – it samples the voltage at the output of the DAC, and holds that voltage until the next reset pulse arrives and the signal is updated (or re-sampled).

l/h mode

The l/h mode functions in similar fashion with the difference that reset pulses are now derived from an astable multivibrator. That's where the missing pulse detector circuit comes in. It detects the absence of distance sensor pulses when the vehicle stops, and automatically switches in the astable multivibrator via CMOS switch S4. At the same time, S2 opens to disconnect the monostable output (which will be low) from the reset line.

Switch S1 allows the circuit to be manually switched to the l/h mode by connecting the input of the missing pulse detector to the +5V supply rail.

Circuit details

The circuit is quite straightforward and uses 11 integrated circuits to carry out the various circuit functions referred to in the block diagram.

The output of the fuel sensor is connected to a x64 multiplier formed by a 4046 phase locked loop (IC1) and a 4020 14-stage binary counter (IC2). Operation of the PLL is as follows: Inside the 4046 is a phase comparator and a voltage controlled oscillator (VCO). One input of the phase comparator (pin 14) monitors the fuel flow pulses while the other (pin 3) is fed from the output of IC2. The comparator output (pin 13) drives a lag-lead filter network and is fed back to the input of the VCO (pin 9) via a 100kΩ resistor.

What happens is that the VCO adjusts its frequency so that its output after division by the 4020 is the same as the input frequency at pin 14. In other words the VCO output frequency at pin 4 is equal to the input frequency from the fuel flow sensor multiplied by the division factor of the 4020.

Result – the input signal from the fuel flow sensor is multiplied by 64, the division ratio of the 4020. This provides a large difference between the apparent pulse rates of the two sensors and improves the resolution of the meter.

Output pulses from the x64 multiplier are fed to the clock input of IC5, a dual synchronous up counter. This IC contains two binary up counters which we have connected in series to form a single 8-bit counter. An R:2R ladder network is connected to the Q1-Q8 outputs and converts the binary output of the 4520 to an equivalent analog voltage.

IC5 and the resistive ladder network thus form the required digital-to-analog converter.

Note that all the 47kΩ resistors in the ladder network should ideally be 50kΩ. In practice, any errors caused by using the 47kΩ values remain insignificant until the Q7 output is reached. At this point, it is necessary to use the correct value of 50kΩ (2x100kΩ in parallel) in order to avoid non-linearity problems.

Because it is quite possible to have very high fuel consumption under some conditions, it is necessary to include an over-range halt to prevent the possibility of ambiguous display readings. This function is performed by IC10f which disables the clock input of the 4520 when the Q8 output goes high. The 4520 counter then remains "frozen" at maximum count until the next reset pulse.

At other times, D4 is reverse biased and IC10f has no effect on circuit operation.

Let's assume first of all that the reset pulses are derived from the distance sensor (ie, the unit is measuring l/100km). Our circuit diagram shows a coil and rotating magnet assembly as the distance sensor, although the speedometer cable sensor can also be used.

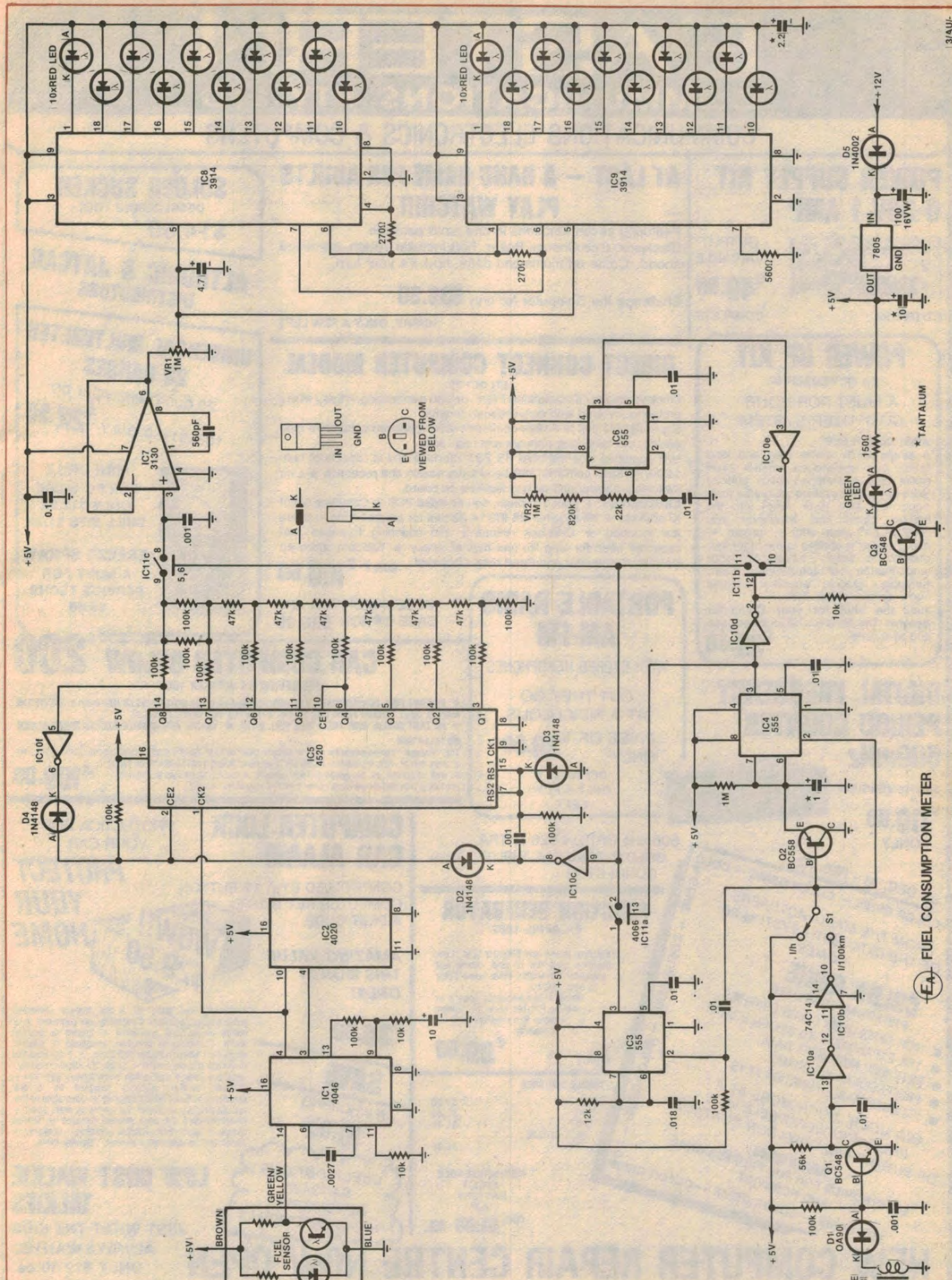
As the magnets rotate, they induce a signal voltage in the coil. This signal is half-wave rectified by germanium diode D1 and filtered by a .001μF capacitor. A BC548 transistor (Q1) provides the necessary gain and, after further filtering by a .01μF capacitor, the resulting waveform is squared up by Schmitt triggers IC10a and IC10b.

Note that if you elect to use the speedometer cable sensor, the sensor signal should be applied directly to pin 13 of IC10a. The diode, .001μF capacitor, 100kΩ and 56kΩ resistors, and transistor

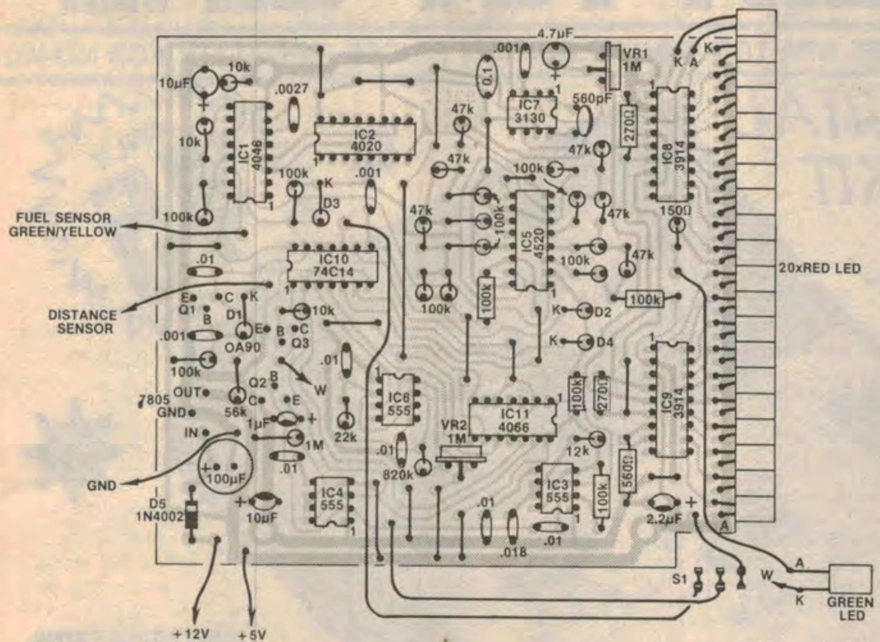
We estimate that the current cost of parts for this project is approximately

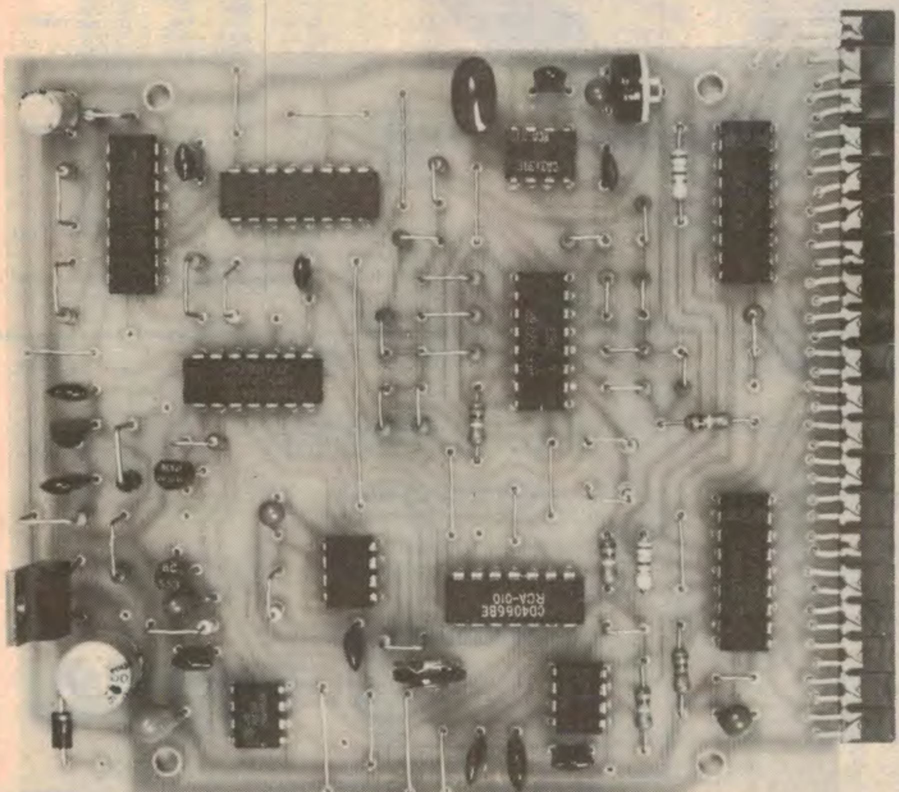
$50

This includes sales tax, but does not include the cost of the fuel and distance sensors.



FUEL CONSUMPTION METER





Part overlay diagram and life-size view of the assembled PC board. Not that the final version differs slightly from the unit shown in the photograph.

Q1 can then be deleted. The .01μF capacitor should be left in circuit.

The output of IC10b is passed via switch S1 and a .01μF capacitor to the trigger input of IC3, a 555 timer IC. IC3 is wired as a monostable and triggers on the negative going edge of a distance sensor pulse to produce a brief output pulse on pin 3. This output pulse – about 0.2ms long – passes via CMOS switch IC11a (which will be closed at this time), and forms the reset pulse.

The reset pulse does two things. Firstly, it causes pin 8 of IC10c and hence the clock enable (CE2) input of the 4520 to go low, thus preventing the 4520 from counting further clock pulses. Secondly, it closes CMOS switch IC11c to connect the output of the ladder network to the sample and hold circuit. Note that because the 4520 is inhibited while its CE2 input is low, the sample-and-hold circuit is presented with a fixed voltage to sample.

IC7, a 3130 FET-input op amp, forms the sample-and-hold circuit and is wired as a unity gain buffer. It works like this: When IC11c is closed by the reset pulse, the DAC output voltage is transferred to the .001μF capacitor at the non-inverting input of IC7. At the end of the reset pulse, IC11c opens again to isolate the capacitor from the DAC during counting.

Because the unity gain buffer has an extremely high input impedance, it follows that the voltage across the .001μF capacitor, and hence the output of IC7, will remain constant between reset pulses.

As well as opening switch IC11c, the end of the reset pulse also forces the output of IC10c to go high again. This transition causes a positive pulse to be delivered by the differentiating network on pin 7 and 15 of the 4520, and this resets the 8-bit counter to zero. Diode D3 clips the large negative going spike produced by the differentiating network at the beginning of a reset pulse, and is included as a precautionary measure.

The high output from IC10c also reverse biases diode D2, and so the clock enable input (CE2) of the 4520 is pulled high by the 100kΩ pull-up resistor. This allows the 4520 to begin counting clock pulses from the x64 multiplier again and so the cycle is repeated.

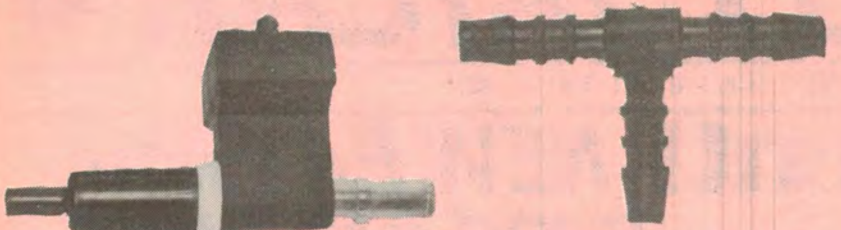
The sample and hold circuit drives the bar graph display via a 1MΩ calibration trimpot. IC8 and IC9 are bar graph display drivers, each capable of driving 10 LEDs. They are cascaded together to form a 20 LED display which covers the most used portion of the fuel consumption range – ie, 0 to 40 litres/100km or 0 to 40 litres per hour, depending upon the setting of the calibration trimpot.

LED current is set at 20mA by the 560Ω resistor and the two 270Ω resistors. This ensures adequate display brightness even in daylight.

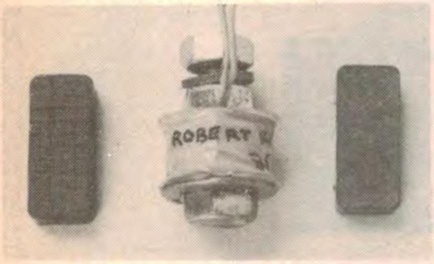
Earlier on, we described how needle valve action in the carburettor could upset the operation of the Fuel Consumption Meter, particularly on cars with small four-cylinder engines. In most cases, however, this effect can be eliminated by filtering the output of the sample and hold circuit, and this is the job of the 4.7μF electrolytic capacitor connected to the wiper of VR1.

Note that the value of the capacitor

Fuel consumption meter



Moray fuel flow sensor (left) and matching T-piece (right). The T-piece is used only in cars which have recirculating fuel systems.



Distance sensors: magnetic pick-up sensor (above) and speedometer cable sensor (right).

may have to be varied to suit individual model cars. There is a limit, however – if the capacitor value is made too large it will also filter out the effects of fuel consumption changes!

The missing pulse detector consists of a 555 (IC4) wired as a monostable, with a PNP transistor (Q2) connected across the timing capacitor. As stated earlier, its job is to detect the absence of distance sensor pulses and then automatically switch the circuit to the l/h mode.

When the car is moving, pulses from the distance sensor trigger the monostable and also turn on Q2, which discharges the timing capacitor so that the monostable cannot complete its timing cycle. Thus, the pin 3 output of IC4 remains high and the meter remains in the l/100km mode while ever the time between distance sensor pulses is shorter than the monostable timing period (about 1s).

When the car stops, however, there are no distance sensor pulses to turn on transistor Q2, and so the 1μF capacitor is able to charge via the 1MΩ resistor. After about one second, the monostable completes its timing cycle and the pin 3 output of IC4 is forced low. This opens CMOS switch IC11a and at the same time, closes CMOS switch IC11b via inverter IC10d. Reset pulses to the 4520 and to IC11c are now supplied by IC6.

IC6 is a 555 timer wired as an astable multivibrator and has been arranged so that its duty cycle is almost 100%. When the output is inverted by IC10e, the result is a series of short positive reset pulses about 0.2ms long as before. Trimpot VR2 provides adjustment of the output frequency (nominally 100Hz) and allows the unit to be calibrated to suit different fuel flow sensors.

Transistor Q3 is controlled by the output of IC10d. It turns on to drive the green indicator LED when the unit switches to the l/h mode (ie, when the output of IC10d is high).

Manual changeover to the l/h mode is accomplished by using S1 to switch the base of Q2 to the +5V rail, thus turning Q3 hard off and allowing IC4 to complete its timing cycle.

Power for the Fuel Consumption Meter is derived from the 12V battery. A diode and a 100μF capacitor filter the battery voltage and a 7805 three-terminal regulator supplies +5V directly to the circuit. The 10μF tantalum capacitor provides supply decoupling and ensures stability of the regulator.

Construction

The circuit is built on a printed circuit (PCB) coded 83fc2 and measuring 116x105mm. Before commencing assembly, a small piece should be cut out of one corner of the PCB as shown on the parts overlay diagram. The boundaries for the cut-out are the edge of the +5V track and the dotted line.

This done, assemble the PCB according to the parts overlay diagram but do not mount the three-terminal regulator at this stage. Pay particular attention to the

PARTS LIST

1 printed circuit board, code 83fc2, 116x105mm
1 Scotchcal front panel, 121x33mm
1 instrument case, Cadin/Clift Model IC-1 or Pactec model CM5-125
1 SPDT slide switch
1 rubber grommet
4 12mm plastic PCB standoffs
1 Utilux 12-way line socket and panel plug
1 fuel flow sensor
1 distance sensor (see text)
1 piece of aluminium, 121 × 33 × 1mm
4 12mm self-tapping screws

SEMICONDUCTORS
3 555 timer ICs
1 4046 CMOS phase locked loop
1 4020 CMOS 14-stage binary counter
1 4520 CMOS dual synchronous up counter
1 74C14 or 40106 CMOS hex Schmitt trigger
1 4066 CMOS quad bilateral switch
1 3130 Fet-input op amp
2 LM3914 LED display drivers
1 7805 3-terminal +5V regulator
2 BC547, BC548 or BC549 transistors
1 BC557, BC558 or BC559 transistor
1 OA90 germanium diode
1 1N4002 diode
3 1N4148 diodes
20 rectangular red LEDs
1 rectangular green LED

CAPACITORS
1 100μF 16VW PC mounting electrolytic
1 10μF 25VW tantalum or LL type
1 10μF 10VW PC mounting electrolytic
1 4.7μF 10VW PC mounting electrolytic
1 2.2μF 35VW tantalum or LL type
1 1μF 35VW tantalum or LL type
1 0.1μF greencap
1 .018μF greencap
6 .01μF greencaps
1 .0027μF greencap
3 .001μF greencaps
1 560pF ceramic

RESISTORS (all ¼W, 5%)
1 × 1MΩ, 1 × 820kΩ, 16 × 100kΩ, 1 × 56kΩ, 6 × 47kΩ, 1 × 22kΩ, 1 × 12kΩ, 3 × 10kΩ, 1 × 560Ω, 2 × 270Ω, 1 × 150Ω, 2 × 1MΩ miniature vertical trimpots

MISCELLANEOUS
Machine screws and nuts, rainbow cable, light duty hook-up wire, solder, mounting brackets, etc.

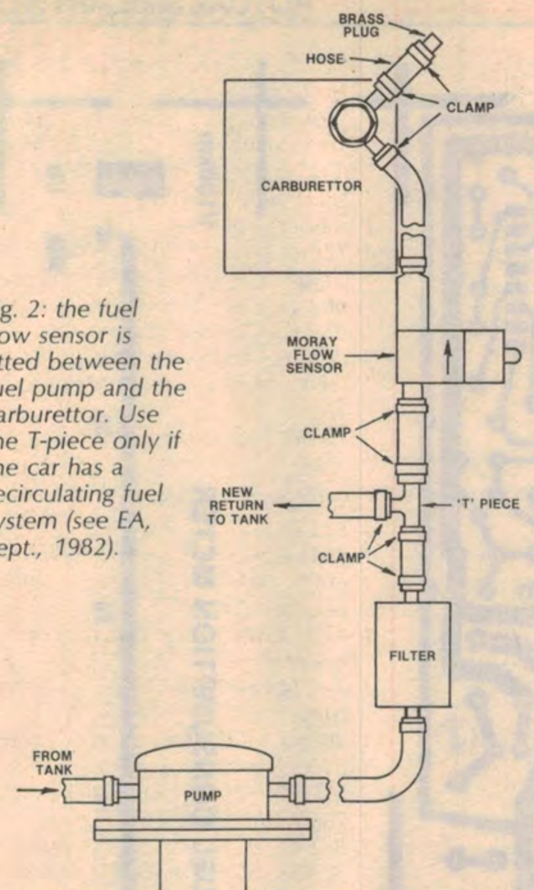


Fig. 2: the fuel flow sensor is fitted between the fuel pump and the carburettor. Use the T-piece only if the car has a recirculating fuel system (see EA, Sept., 1982).

Fig. 2

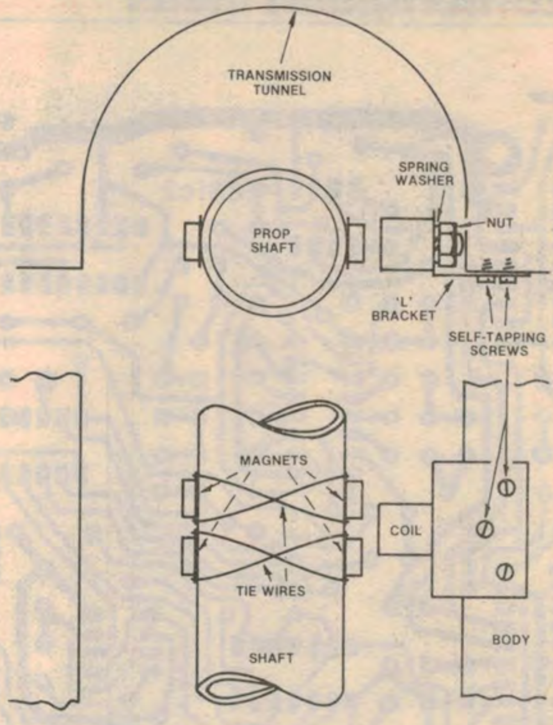


Fig. 3

Figs. 3 & 4 show how the magnetic pick-up sensor is installed in rear-wheel drive and front-wheel drive cars respectively, while Fig. 5 shows the wiring for the 12-pin Utilux socket (as viewed from the front).

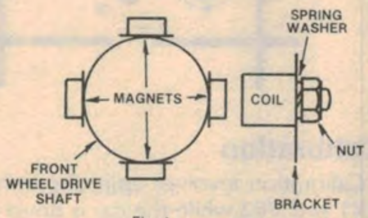


Fig. 4

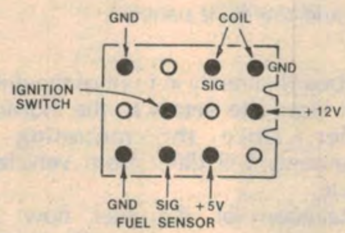


Fig. 5

orientation of polarised components and note that some of the resistors and diodes are stood on end to conserve board space. The LEDs are mounted side by side, with their leads bent through 90° and with the back edge of each LED butted against the edge of the PCB.

Make sure that the LEDs all line up and that you mount them the right way round – the anode lead is the longer of the two.

Several of the ICs (IC1, 2, 5, 10 & 11) are CMOS devices, so the usual precautions apply when soldering them into circuit. Earth the barrel of your soldering iron to the earth track on the PCB using a small clip lead and solder the power supply pins first to enable the internal static protection circuitry. No special precautions are required for the remaining ICs other than to ensure correct orientation.

A standard plastic case measuring 129x131x40mm (WxDxH) is used to house the PCB. We used a Model IC-1 case manufactured by Cadin/Clift Electronics (2a Cromwell St, Burwood, Victoria), but you can also use the Pactec Model CM5-125 case. A front-panel label made from self-adhesive Scotchcal material was used to provide an attractive finish.

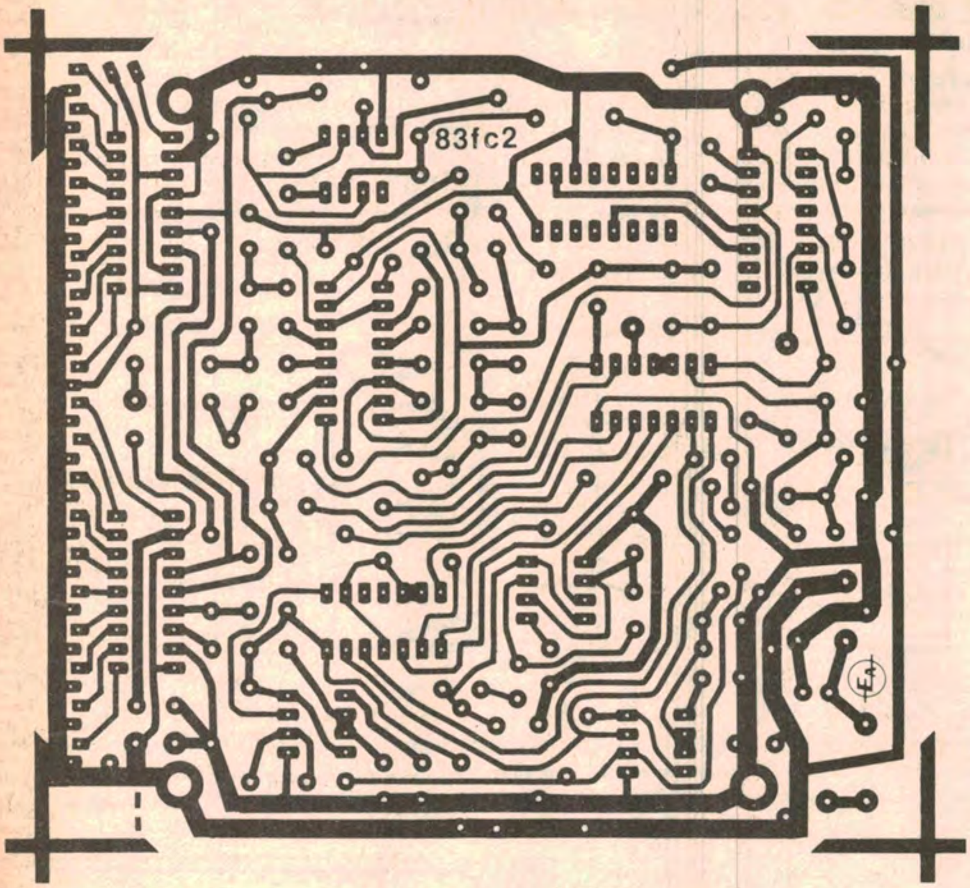
Spray the Scotchcal label with a hard-setting lacquer (eg, "Estapol") to prevent scratches, then carefully trim it to size using a sharp knife to score along the edges. The label can now serve as a template to make the front panel cutout for the slide switch.

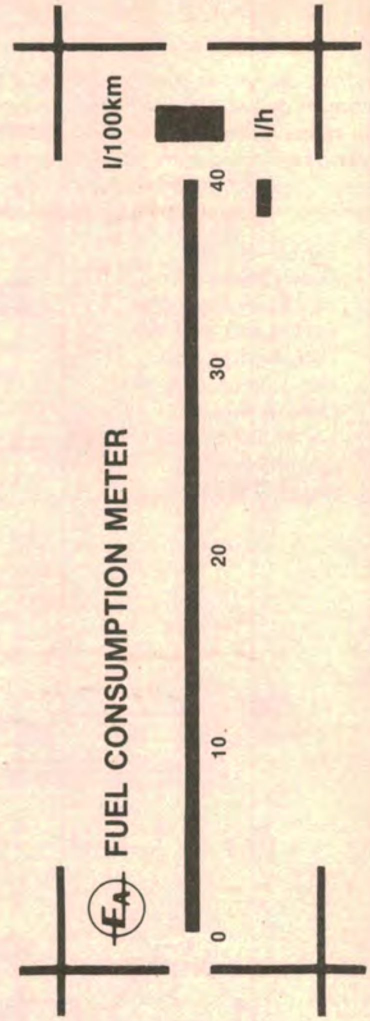
The slide switch is mounted using two countersunk cheese-head screws hidden behind the Scotchcal label. Cut out the switch actuator area on the Scotchcal label using a sharp knife, then using the Scotchcal as a template, mark the switch cutout area on the plastic panel. The switch cutout is now made by using a drill to remove most of the material and then filing to a neat rectangular shape.

Next drill and countersink the switch mounting holes and screw the switch into position. The Scotchcal label should now be carefully fixed to the front panel and holes drilled and filed to shape to take the LED bar graph display and the indicator LED. Proceed carefully with this step, periodically offering the front panel to the bar graph display so that you can judge how much progress is being made. The job is admittedly tedious but requires care to ensure that the LED bar graph is a tight fit in the front panel cutout.

The PCB assembly is mounted upside down in the case. Carefully push the LED display into the front panel cutout so that the LEDs sit slightly proud of the surface, then position the assembly in the lid of the case so that the PCB mounting holes line up with the case pillars. You are now ready to mount the regulator IC.

To do this, first bend the leads forward so that they make an angle of 90° with the body of the regulator. The leads are then bent down 90° so that, when the regulator is mounted on the PCB, its metal tab sits flush against the back panel (see photograph). Once the cor-





Here are actual size artworks for the PC board and the front panel.

rect mounting arrangement has been determined, the PCB can be removed from the case and the regulator soldered permanently in position.

Heatsinking for the regulator is provided by replacing the plastic back panel with an aluminium panel. Two holes must be drilled in this panel: one to accept the regulator mounting bolt and another through which to pass external leads. The latter should be fitted with a small rubber grommet.

The remaining wiring can now be completed according to the parts layout diagram. We used rainbow cable for the wiring connections to the switch and front panel indicator LED, and light duty hook-up wire for external connections to the power supply and sensors. These external connections are terminated in a Utilux line socket wired in exactly the same manner as for the EA Car Computer.

Finally, the whole assembly can be fitted to the lid of the case and secured using suitable plastic standoffs and 12mm-long self-tapping screws. Note that it may be necessary to trim the standoffs slightly so that they will fit between the PCB and the case pillars.

Ideally, the Fuel Consumption Meter should be installed on top of the dashboard, directly in front of the driver. We'll leave the details to the individual reader, since the mounting arrangements will differ from vehicle to vehicle.

Installation of the fuel flow and distance sensors was covered in detail in the September 1982 issue as part of our description of the EA Car Computer. Fitting is straightforward and will be largely self-evident from the accompanying diagrams. Even so, readers should refer to the September issue as there are a number of important guidelines that must be followed.

Fig. 5 shows the recommended wiring for the 12-pin Utilux socket, as viewed from the front. The leads from the sensors are passed through the firewall and terminated to the appropriate mating pins on the matching plug. Make sure that you get these connections right, otherwise the circuitry could be damaged.

The +12V supply should be switched by the ignition switch, and can be obtained from the fusebox. Check the voltage available with a multimeter before actually connecting the +12V lead, and make the connection to the fused side. The ground connection can be made at any suitable chassis point.

Calibration

Calibration involves adjusting trimpots VR1 and VR2 while the car is driven at a steady 50km/h along a straight level road. In the interests of safety, we strongly recommend that you carry out these adjustments with the aid of an assistant.

If you have a Car Computer fitted, it is simply a matter of switching to the l/100km mode and adjusting VR1 to give the same reading as the Car Computer. The Fuel Consumption meter is then switched to the l/h mode and VR2 adjusted so that the display shows half the previous l/100km reading.

If you don't have a Car Computer, the procedure is to adjust VR1 so that the display shows the average fuel consumption of the car (for a steady 50km/h). The unit is then switched to the l/h mode and VR2 adjusted for half the previous reading as before. Note: it is important that the car be maintained at a steady 50k/mh during these adjustments.

That's it! Your Fuel Consumption Meter is now ready to show you what a lead-footed "petrol-head" you really are.