Vehicle Multi-V

Want to monitor the battery voltage, the airflow meter or oxygen sensor signals in your car? This versatile voltage monitor can do it all and includes display dimming so the LEDs are not too bright at night. It also makes an ideal monitor for a battery charger.

There are many voltages within a vehicle that can be monitored simply by attaching a meter to the source of the signal (or voltage) to be measured. This can give the driver information about the operation of various sensors and voltages within the engine bay.

When monitoring these voltages, it is not usually necessary to obtain a precise value of the voltage but the general trend of the voltage is sufficient.

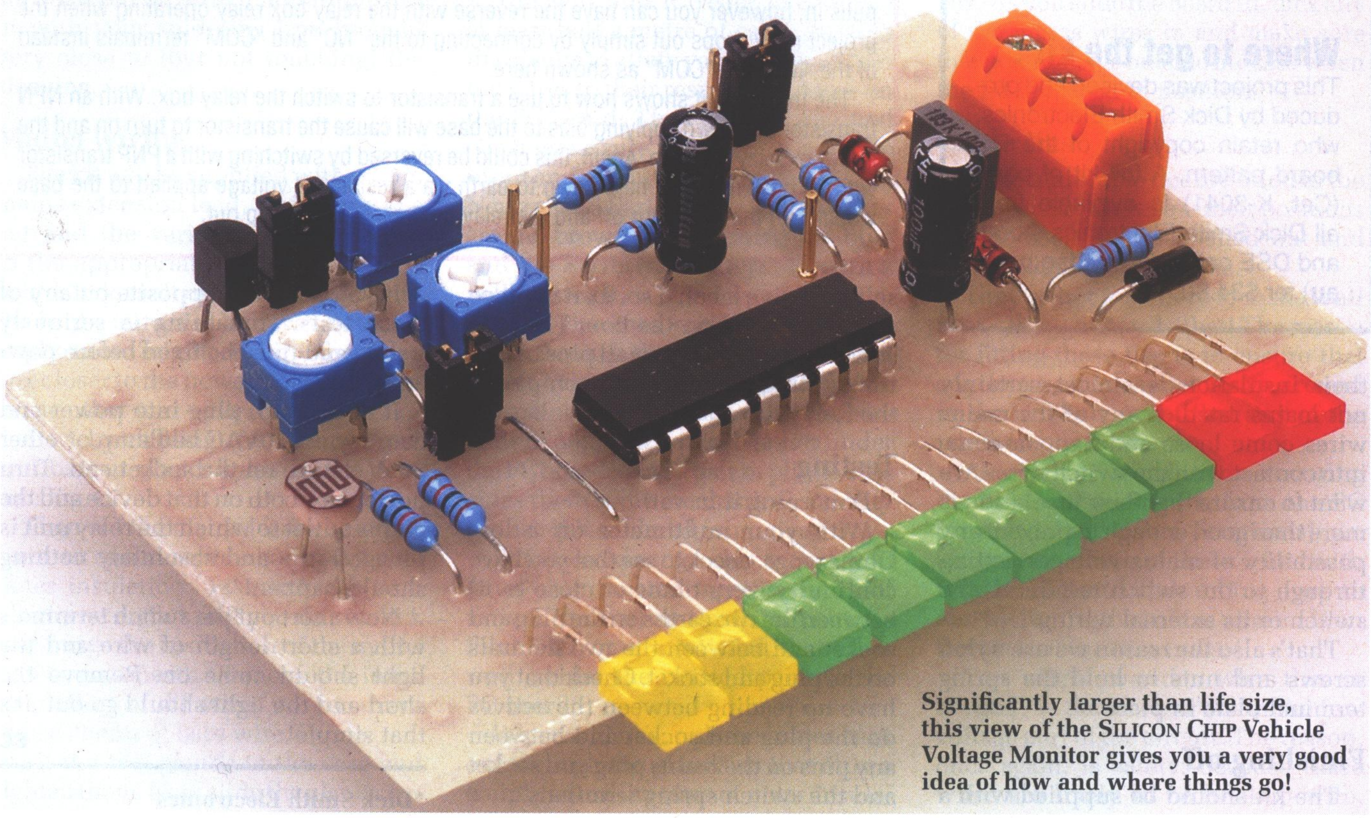
Our Voltage Monitor provides for monitoring some of the most common voltages within a car. A 10-step bargraph lights LEDs in response to the measured voltage.

With low voltages applied to the Voltage Monitor, the low LEDs light and for high voltages, the upper LEDs light. Voltages in between are shown by the middle LEDs.

Some sensor voltages will alter simply due to the loading of a meter. Therefore, these require a meter that does not present any appreciable load on the sensor.

For example, the oxygen sensor that is used to monitor the correct burning of the fuel, typically has a voltage output between 0 and 1V, with the mid-way voltages indicating that the fuel is burnt correctly. A low voltage (near to 0V) indicates that the air-fuel mixture is too lean and a high value (approaching 1V) indicates a too-rich mixture. The voltage from these sensors also changes at a rapid rate as the engine management system continually monitors and changes the air-fuel mixture to ensure it is running at the correct (stoichiometric) mixture.

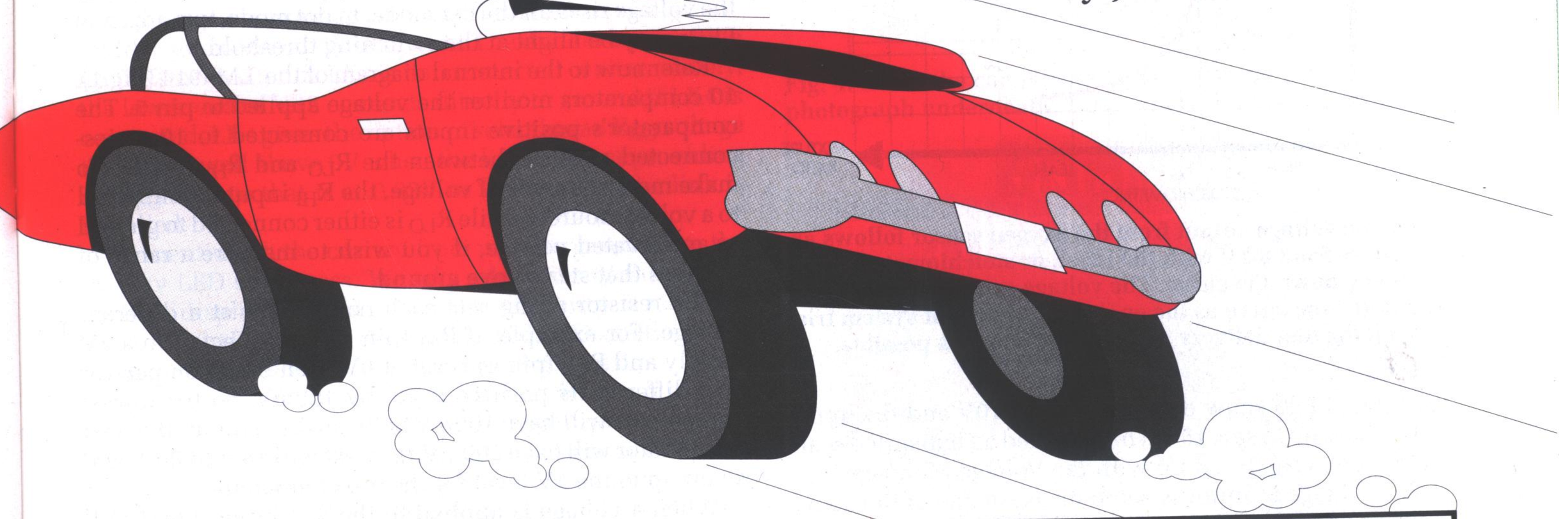
The SILICON CHIP Vehicle Voltage Monitor is easily set up to monitor a nominal 0-1V range. It also provides minimal loading on the sensor's output.



Significantly larger than life size, this view of the SILICON CHIP Vehicle Voltage Monitor gives you a very good idea of how and where things go!

Voltage Monitor

by John Clarke



A typical response curve is shown overleaf of an oxygen sensor for rich, lean and stoichiometric mixtures. The curve is very steep at the stoichiometric position and covers a voltage range that is typically 0.2V to 0.8V.

The stoichiometric mixture ratio is normally maintained by the engine management system to ensure minimum exhaust emissions when used in conjunction with a catalytic converter.

When the car is running you will see that the display will move rapidly up and down this steep part of the curve as the engine management unit maintains the correct mixture. On engine over-run, the mixture may go lean. When the engine is loaded, the mixture will go into the rich portion of the curve to provide more engine power.

Other sensors

Other sensors within a car have a 0-5V range. These include airflow meters, MAP sensors and some later model air/fuel ratio sensors. For these signals, the Voltage Monitor can be set to show the full range from 0V up to the maximum of 5V. It is also possible to narrow the voltage range that is measured and shown on the display.

For example, you may wish to monitor between 0.5V and 4.5V. To do this, it is just a simple adjustment of the upper and lower voltage limits with trimpots.

Other types of voltages that can be measured are those that do not normally drop to 0V but vary by a small amount from a typical fixed level. An example of this is the car battery. This is generally at 12V but can fall to around 10V when the starter motor is starting the engine and rise to 14.4V when the battery is fully charged.

When measuring this narrow voltage range we are not particularly interested in what is happening below, say, 10V because it should normally never happen.

So in this case it is best to set up the metering so that

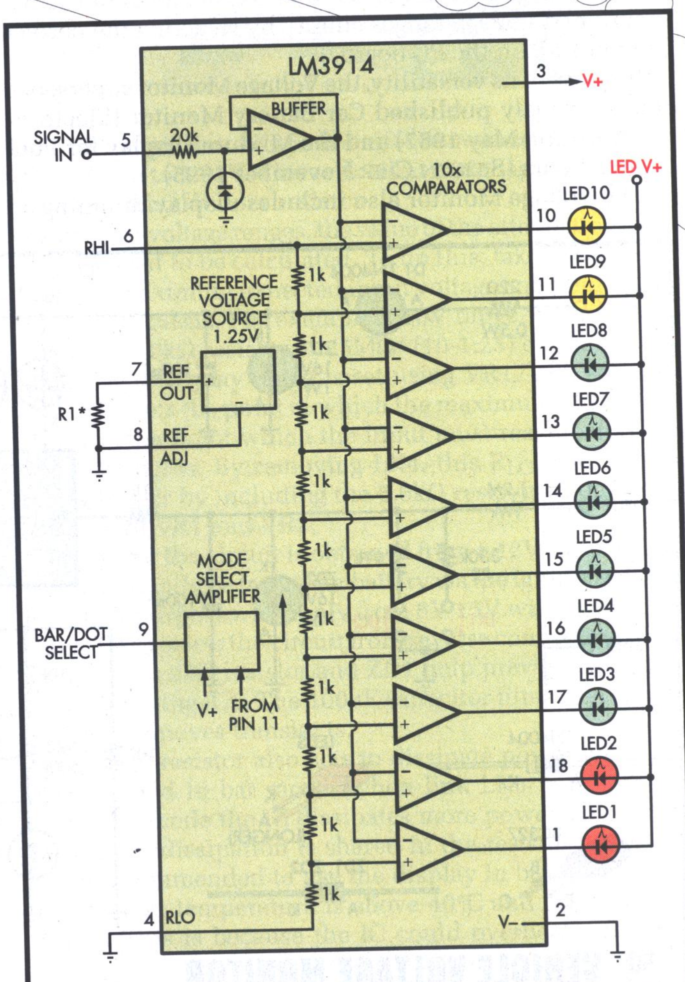


Fig.1: inside the LM3914 purpose-built LED driver IC.

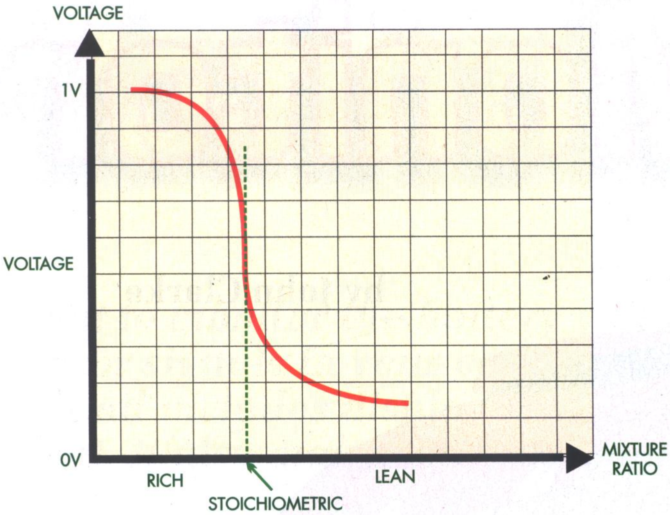


Fig.2: the voltage output from the oxygen sensor follows an "S" curve from 0-1V with the ideal, or stoichiometric, mix part-way down the curve. The voltage actually varies up and down the curve as the engine management system tries to keep the fuel delivery system as efficient as possible.

the lower LEDs show down to around 10V and the upper LEDs show up to say, 15V. This is called an expanded scale meter and is easily set up with the Voltage Monitor.

The Voltage Monitor is set to measure one of the above mentioned voltage ranges simply by selecting the correct jumper link on the PC board.

Because of its versatility, the Voltage Monitor supersedes the previously published Car Battery Monitor (Electronics Australia May 1987) and the Mixture Display for Fuel Injected Cars (Silicon Chip November 1995).

The Voltage Monitor also includes display dimming so that the display is not excessively bright at night.

The circuit

Circuitry for the Voltage Monitor is based around an LM3914 10-LED bargraph display chip. This drives 10 LEDs sequentially from the lowest LED, when the voltage measured is low, through to the highest LED when the upper voltage range is reached.

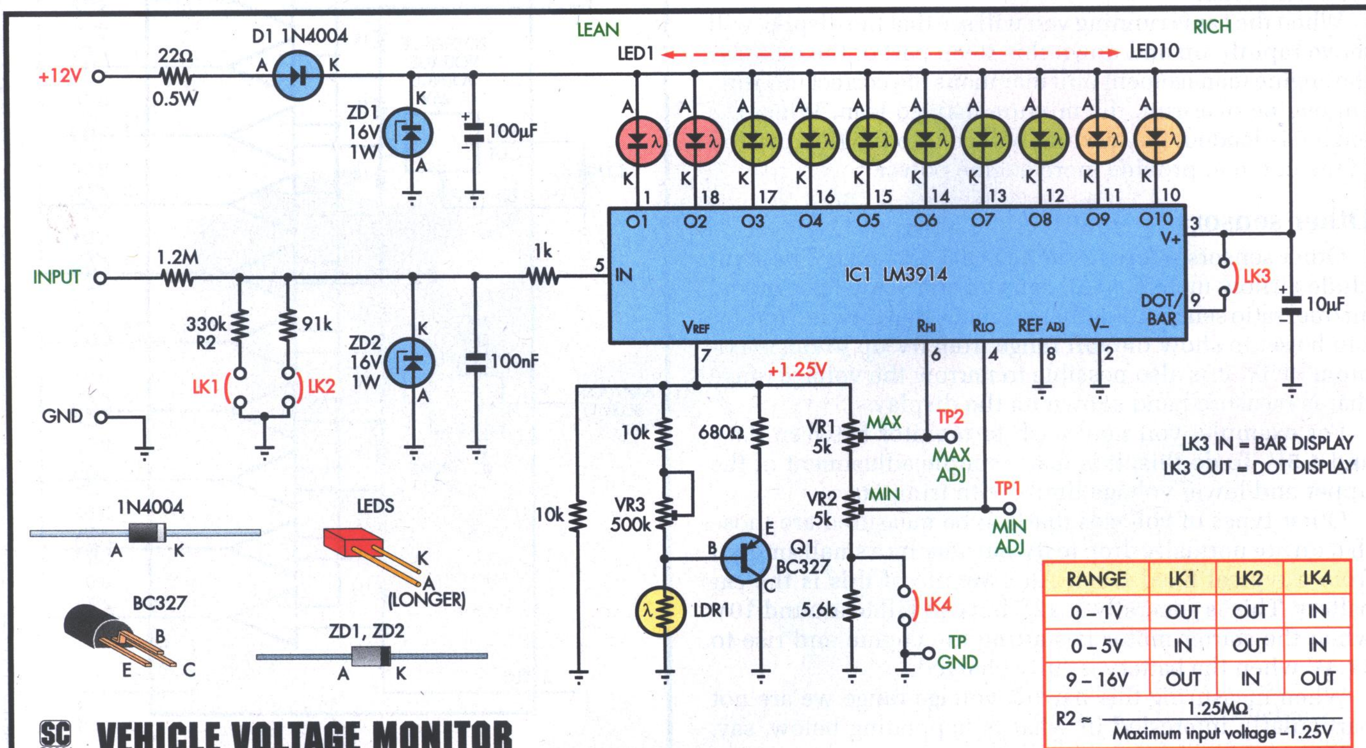
The IC gives the option of showing this as single LEDs (dot mode) or as a sequentially increasing number of lit LEDs as the voltage rises for the bar mode. In dot mode, two adjacent LEDs may be alight at the switching threshold.

Refer now to the internal diagram of the LM3914 (Fig.1). 10 comparators monitor the voltage applied to pin 5. The comparator's positive inputs are connected to 10 series-connected resistors between the R_{LO} and R_{HI} inputs. To make measurements of voltage, the R_{HI} input is connected to a voltage source, while R_{LO} is either connected to ground or an elevated voltage, if you wish to measure a range of voltages that start above ground.

The resistor string sets each comparator at a different voltage. For example, if R_{HI} (pin 6) is connected to a 1V supply and R_{LO} (pin 4) is set at 0V, then each comparator will differ at its positive input by 100mV. So the lowest comparator will have 100mV at its positive input, the next comparator will have 200mV, the next will have 300mV and so on up to the 1V level for the top comparator.

When a voltage is applied to the IC's input, LED1 will light for voltages above 100mV. At 200mV, LED2 will light and so on. Finally, LED10 will light at 1V. Whether the lower LEDs remain lit or extinguish as a higher LED lights depends on whether the IC is set to display in bar mode or dot mode.

The LM3914 includes a voltage reference which can be used to set the R_{HI} level. This reference has a nominal 1.25V



RANGE	LK1	LK2	LK4
0 – 1V	OUT	OUT	IN
0 – 5V	IN	OUT	IN
9 – 16V	OUT	IN	OUT

$$R2 \approx \frac{1.25M\Omega}{\text{Maximum input voltage} - 1.25V}$$

Fig.3: this circuit can be set to measure any voltage in a car up to 16V.

between pins 8 and 7. We can derive a 1.25V reference by connecting pin 8 to ground.

Incidentally, the current through the LEDs is set at about 10 times the current flow through R1. So if pin 7 is at 1.25V and we use a 1kΩ resistor for R1, there will be a 1.25mA current through R1. The LED current is therefore about 12.5mA. This current determines the brightness of the display.

All this is shown opposite in the circuit for the Voltage Monitor. R_{HI} and R_{LO} inputs are provided with voltage via trimpots VR1 and VR2 that form a divider across the 1.25V reference. The divider can include a 5.6kΩ resistor if link LK4 is not connected or alternatively, the lower end of VR2 connects directly to ground if LK4 is connected. LK4 gives the option of selecting an R_{LO} voltage that starts well above 0V when the link is out or providing an R_{LO} voltage that is at 0.63V or lower when the link is installed.

As mentioned, the current from pin 7 to ground sets the display LED brightness. We take advantage of this fact to include display dimming. Dimming circuitry is made up using a Light Dependent Resistor (LDR1), VR3 and the series 10kΩ resistor, transistor Q1 and the 680Ω resistor.

It works as follows: in bright light, LDR1 has a low resistance (around 10kΩ), so the base of Q1 is pulled toward the 0V rail. Since the emitter of Q1 is only 0.7V above the base, it follows that there will be somewhere around 0.55V across the 680Ω resistor (Reference voltage [1.25V]-0.7V=0.55V). This sets the current flow from pin 7 to ground at its maximum. Therefore the LEDs are at their brightest in bright light.

At low light levels, LDR1 has a high resistance, so the base voltage for Q1 moves substantially higher than it was under bright light. As a consequence, Q1 is almost switched off. Current through the 680Ω resistor is therefore minimal and the overall current from pin 7 to ground is set by the effective resistance still connected. This comprises the 10kΩ resistor and the VR1, VR2 and 5.6kΩ resistor string.

VR3 sets the dimming threshold. At its minimum resistance, the base of Q1 will not fall below about 1.25V/2 because of the voltage divider action of the 10kΩ resistor in series with VR3 and the 10kΩ light resistance of LDR1. Thus dimming will occur even at relatively bright levels. Winding VR3 for more resistance will set the base of Q1 lower at the bright ambient light levels to increase the brightness. In practice, VR3 is adjusted to start dimming as the ambient light falls.

Signal for the pin 5 input of IC1 is processed to keep the voltage to within the 1.25V maximum range set by V_{REF} at pin 7. For the 1V signal from an oxygen sensor, the signal is passed through a 1.2MΩ resistor to provide a high input impedance load, filtered with a 100nF capacitor. Pin 5 has a very small input current, typically 25nA, so there will be less than 30mV across the 1.2MΩ input resistor. The 16V zener ZD1 protects pin 5 from transients that could otherwise destroy the IC.

When measuring voltages above the 0-1V range, the input needs to be attenuated so that pin 5 still only sees a voltage within the 0-1.25V range. When measuring 0-5V, link LK1 is inserted so that the voltage is reduced using the 1.2MΩ series resistor and the 330kΩ resistor to ground. The division by these two resistors reduces the 0-5V signal at the input to a 0-1.08V range at pin 5. Similarly, when measuring

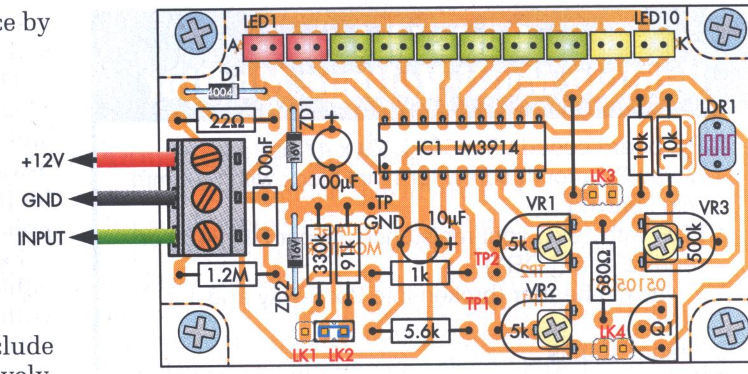
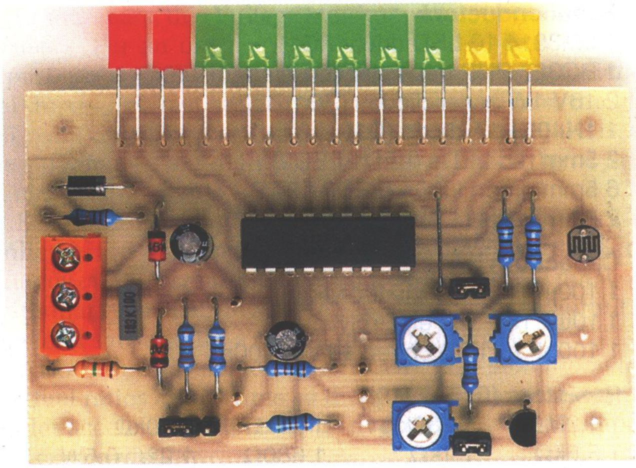


Fig. 4: here's the component layout diagram with matching photograph underneath. Take care when placing the LEDs!



the 16V range, link LK2 is installed to reduce the signal at pin 5 down to 1.13V. This reduction in voltage is achieved with the 91kΩ divider resistor.

For other voltage ranges, the value of the attenuating resistor will need to be calculated. To do this, take 1.25V away from the maximum expected input voltage and then divide this into 1.25MΩ. For example a 10V range will require a nominal 150kΩ resistor (1.25MΩ/ (10-1.25) or 142kΩ).

The final display range is set using VR1, VR2 and link LK4. VR1 sets the point at which the maximum LED lights. VR2 sets the point which the input must reach before the first LED lights. By removing LK4, this R_{LO} level can be raised higher by including the 5.6kΩ resistor in the series string with VR1 and VR2.

Power for the circuit is obtained from a 12V supply. This would normally be from a car battery via the ignition switch. For other purposes, a supply from 6V-15V will be suitable. Diode D1 protects the circuit from reverse connection of the supply. The 22Ω resistor and ZD1 help prevent transients from damaging IC1. The 100µF capacitor filters the supply and also removes transients.

The 22Ω resistor also acts to dissipate power when IC1 is connected in bar mode (when link LK3 is in circuit). In the bar mode the IC dissipates more power, so some of this power dissipation is shared in the resistor instead. It is not recommended to use the display in bar mode when the ambient temperature is above 40°C and the supply is at 15V. This is because the IC could overheat under the high temperatures and power dissipation. The IC can easily drive the display in dot mode even on the hottest of days in a vehicle.

Parts List – Vehicle Multi-Voltage Monitor

1 PC board coded 05105061, 79 x 47mm
1 3-way PC mount screw terminal block with 5.08mm pin spacing
1 LDR with 10kΩ light resistance Jaycar RD-3480 or equivalent) (LDR1)
1 7-way pin header (broken into 2 x 2-way and 1 x 3-way)
3 jumper shunts
3 PC stakes
1 50mm length of 0.7mm tinned copper wire

Semiconductors
1 LM3914 10-LED driver (IC1)
1 BC327 PNP transistor (Q1)
2 16V 1W zener diodes (ZD1,ZD2)
1 1N4004 1A diode (D1)
2 5mm red LEDs (LED1,LED2)
6 5mm green LEDs (LED3-LED8)
2 5mm yellow LEDs (LED9,LED10)

Capacitors
1 100µF 16V PC electrolytic
1 10µF 16V PC electrolytic
1 100nF (0.1µF) coded 104 or 100n

Resistors (0.25W, 1%)
1 1.2MΩ 1 330kΩ 1 91kΩ 2 10kΩ
1 5.6kΩ 1 1kΩ 1 680Ω 1 22Ω 0.5W
1 500kΩ horizontal trimpot (code 504) (VR3)
2 5kΩ horizontal trimpot (code 502) (VR1,VR2)

Miscellaneous
Automotive wire, solder.

Construction

The Vehicle Voltage Display is constructed using a PC board coded 05105061 and measuring 79 x 47mm. It can fit into a small plastic UB5 box measuring 83 x 54 x 31mm if required. However, our experience is that many constructors of the Fuel Mixture Meter and similar projects like to mount the LEDs behind the dash, so we are presenting the unit as a bare PC board.

Begin by checking the PC board for any possible shorts between tracks, breaks in the copper and for holes that are not drilled. Start by installing the wire link and resistors. The accompanying table shows the resistor colour codes but it's also advisable to check them with a digital multimeter, as some colours can be difficult to decipher.

The diodes, Q1, the capacitors and trimpots can go in next, along with IC1. Take care to orient the diodes, IC1 and the electrolytic capacitors as shown. Now install the 3-way terminal block and the two and three pin headers for the link shorting plugs. Also insert the PC stakes at test points TP1, TP2 and TP GND.

Finally, install the LDR and the LEDs. The LDR can go in either way, but the 10 bargraph LEDs must all be installed with their anodes (the longer of the two leads) to the left.

Depending on how you wish to install the display in the car or piece of equipment, you may wish to set the LEDs parallel to the PC board. This means that you need to bend the LED leads over at 90° so that they are in line with the edge of the PC board – see photo. Alternatively, you can mount the LEDs vertically so that they later protrude through a slot in the lid of a case.

Install the links (LK1-LK4) according to your application. A table showing the link connections for the 0-1V, 0-5V and 9-16V ranges is shown on the circuit diagram.

LED colours

Note that our prototype uses red LEDs for LEDs 1 & 2 and yellow LEDs for LEDs 9 & 10. This because we envisage that the most popular use for this project will be a fuel mixture meter, monitoring a vehicle's oxygen sensor. In this case, you want lean mixtures to be shown with red LEDs, indicating DANGER for your engine.

For other applications though, say monitoring your battery voltage, you might want to have red LEDs for LEDs 9 & 10, because in this case a battery voltage up around 15V indicates over-charging, another DANGER condition.

Installation

You will need to make three wiring connections to your car. It's easiest to do that at the ECU, so you will need to have a wiring diagram showing the ECU pin-outs. The four connections are: (1) +12V (ignition switched); (2) chassis (0V); and (3) sensor or car battery signal. The car battery signal is best taken at a point close to the battery for best accuracy without incurring voltage drops across the wiring in the vehicle.

Use the car's wiring diagram to find these connections and then use your multimeter to check that they're correct (eg, when you find the +12V supply, make sure that it switches off when you turn off the ignition).

In addition, you have to confirm that there is a fluctuating signal in the 0-1V range on the oxygen sensor lead (the car

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	1.2MΩ	brown red green brown	brown red black yellow brown
❑	1	330kΩ	orange orange yellow brown	orange orange black orange brown
❑	1	91kΩ	white brown orange brown	white brown black red brown
❑	2	10kΩ	brown black orange brown	brown black black red brown
❑	1	5.6kΩ	green blue red brown	green blue black brown brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	1	680Ω	blue grey brown brown	blue grey black black brown
❑	1	22Ω (0.5W)	red red black brown	red red black gold brown

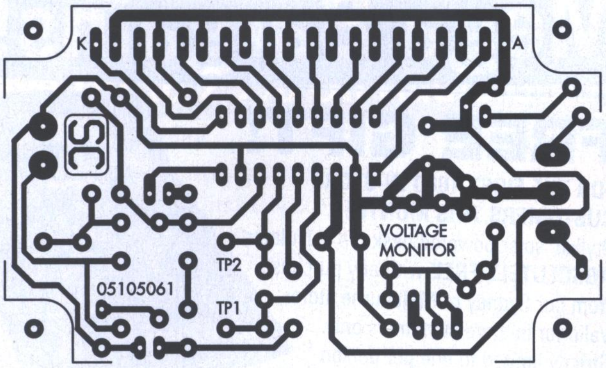


Fig. 5: full-size PC board pattern for etching your own board or checking a commercial board.

will need to be fully warmed up) or that the signal coming from the airflow meter, or MAP sensor changes when the throttle is blipped.

Note that the 0V connection for the Voltage Display should be made at the ECU or to a terminal that is secured directly to a chassis point.

Setting up for an oxygen sensor

Links LK1 and LK2 should be out and link LK4 installed.

(1) Set trimpot VR1 fully clockwise and trimpot VR2 fully anticlockwise.

(2) Start the car, let the oxygen sensor warm up and confirm that the LED display changes.

(3) Go for a drive and briefly use full throttle. The end yellow LED should light up. Back off sharply – the end red LED should light.

(4) Check that the LEDs travel back and forth when the engine is at idle.

(5) If the end yellow LED never lights, even at full throttle, adjust VR1 so that it lights when the mixtures are fully rich.

(6) In normal driving, the LED should move back and forth around the centre LED. If the oscillations are all down one end after adjusting VR1, adjust VR2 to centre the display.

Setting up for a 0-5V airflow sensor

Link LK1 should be installed and LK4 out.

(1) Set trimpot VR1 fully clockwise and trimpot VR2 fully anticlockwise.

(2) Adjust VR2 so that the lowest LED just lights on an engine over-run (when you are going downhill in gear with the engine slowing the car down).

(3) Adjust VR2 so the top LED just lights on maximum acceleration.

(4) Repeat the adjustments, since adjusting VR1 and VR2 will affect one another to a small degree.

Setting up for a battery monitor

Link LK2 should be installed and LK4 out.

(1) Use a multimeter to measure the battery voltage. Now with the engine running fast and with all accessories, lights, etc, off, set VR1 so that the top green LED lights at a measured 14.4V.

(2) Now stop the engine and switch on the lights. Wait until the battery falls to a measured 12V and set VR2 so that the lower green LED lights.

(3) Again, the adjustments will affect one another to a small extent so you may need to recheck the results at either end of the scale.

Adjusting the dimming

Turn the dimmer sensitivity trimpot (VR3) until the display dimming matches your preferences– clockwise will give a brighter display at night (so you need to fully cover the LDR to simulate night when you're setting it!). Note that when installing the Voltage Monitor, the LDR must be exposed to the ambient light in order for the display to dim. The LDR can be mounted off the PC board if necessary.

Note

In some cars, this Voltage Monitor will not work on some sensors. For an oxygen sensor, it needs a signal voltage from 0-1V, with the higher voltages corresponding to richer mixtures. The vast majority of cars produced over the last 15 years use this type of sensor but there are exceptions, so be sure to use your digital multimeter to check the oxygen sensor output signal before buying a kit.

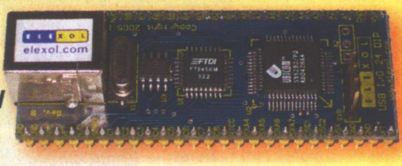
For other sensors, the output signal needs to vary in voltage. However, some airflow meters have a variable-frequency output signal and the Voltage Monitor will not work with that type of airflow meter. Again, check the output of the load sensor with a digital multimeter first.

Also note that some modern cars run stoichiometric air/fuel ratios all the time so the rich and lean indications under acceleration and engine overrun may not be apparent on the display. **SC**

www.elexol.com www.elexol.com www.elexol.com www.elexol.com

ELEXOL USBIO - 24 DIP

A Dual Inline Package version of our USB I/O 24 module – fits a standard 50 pin 900mil wide IC Socket. This makes the USB I/O 24 DIP ideal for rapid prototyping and development work



- Single module High-Speed Digital Input / Output solution.
- Integrated Type-B USB Connector.
- On-board unique serial number in EEPROM and custom programmable FLASH microcontroller.
- Both USB Enumeration information and Micro controller can be re-programmed.
- Module powered by the USB from the PC (default option) and can also be configured for Self powered.
- Virtual COM Port driver allows access as a regular serial port.

Great range of I/O-24 peripherals, too ...

OPTO INPUT BOARD Provides 8 Opto Isolated inputs for each of the I/O-24 pins with LED indication.

RELAY OUTPUT BOARD Provides 8 isolated relay contact outputs suitable for a variety of loads.

SWITCH/PUSH BUTTON BOARD Provides 8 switch/push buttons with LED indicators showing the status of the I/O pin.

CONNECTOR/LED BOARD Provides screw terminal connections plus optional either pull up or pull down resistors and LED port status indication.

Visit our web shop @ www.elexol.com

Elexol Pty Ltd

Ph: (07) 5574 3988 Fax: (07) 5574 3833
(PO Box 5972, Bundall, Qld 4217)

www.elexol.com www.elexol.com www.elexol.com www.elexol.com