

A Practical Guide to 'Free Energy' Devices

Devices Part 17: Last updated: 7th August 2007

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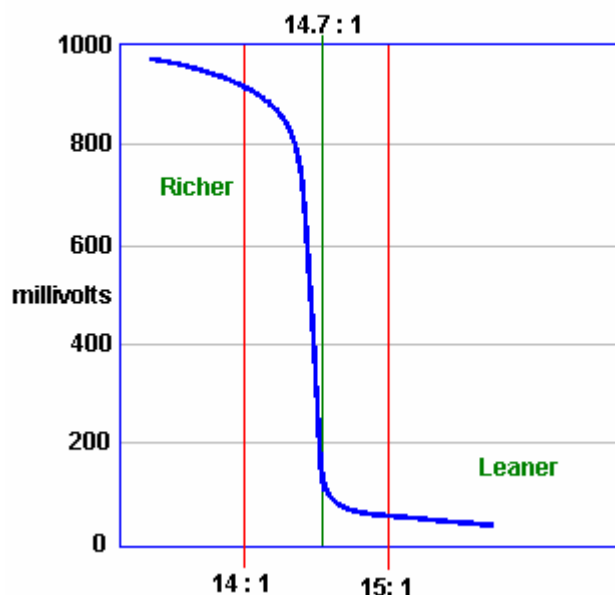
Dealing with the Vehicle Computer

When an mpg. improving device such as an electrolyzer is fitted to a vehicle, the result does not always produce better mpg. figures. Older vehicles which are fitted with a carburettor will see an immediate improvement. This is not the case for more recent vehicles which come with computer control of the fuel sent to the engine.

When an electrolyzer is attached to the engine, it causes the fuel burn inside the cylinders to be greatly improved, with a corresponding improvement in engine performance. Unfortunately, the fuel computer is expecting the same amount of unburnt oxygen to come out of the engine, and when it doesn't detect it, the computer increases the fuel flow rate in an attempt to get back to it's normal, inefficient method of running. That action cancels the mpg improvement produced by the electrolyzer unless something is done to adjust the operation of the computer.

In the most simple terms, most vehicles which have an Electronic Control Unit ("ECU") to control the fuel flow are fitted with one of two types of exhaust sensor. The majority have a "narrowband" sensor while the remainder have a "wideband" sensor. The ideal mix of air to fuel is considered to be 14.7 to 1. A narrowband sensor only responds to mixtures from about 14.2 to 1 through 14.9 to 1. The sensor operates by comparing the amount of oxygen in the exhaust gas to the amount of oxygen in the air outside the vehicle and it generates an output voltage which moves rapidly between 0.2 volts where the mixture is too lean, and 0.8 volts when it passes below the 14.7 to 1 air/fuel mix point where the mixture is too rich (as indicated by the graph shown below). The ECU increases the fuel feed when the signal level is 0.2 volts and decreases it when the signal voltage is 0.8 volts. This causes the signal voltage to switch regularly from high to low and back to high again as the computer attempts to match the amount of "too lean" time to the amount of "too rich" time.

Sensor Output Graph



A simple control circuit board can be added to alter the sensor signal and nudge the fuel computer into producing slightly better air/fuel mixes. Unfortunately, there is a severe downside to doing this. If, for any reason, the fuel mix is set too high for an extended period, then the excess fuel being burnt in the catalytic converter can raise the temperature there high enough to melt the internal components of the converter. On

the other hand, if the circuit board is switched to a mix which is too lean, then the engine temperature can be pushed high enough to damage the valves, which is an expensive mistake.

Over-lean running can occur at different speeds and loads. Joe Hanson recommends that if any device for making the mix leaner is fitted to the vehicle, then the following procedure should be carried out. Buy a “type K” thermocouple with a 3-inch stainless steel threaded shank, custom built by ThermX Southwest of San Diego. This temperature sensor can measure temperatures up to 1,800 degrees Fahrenheit (980 degrees Centigrade). Mount the thermocouple on the exhaust pipe by drilling and tapping the pipe close to the exhaust manifold, just next to the flange gasket. Take a cable from the thermocouple into the driver’s area and use a multimeter to show the temperature.

Drive the vehicle long enough to reach normal running temperature and then drive at full speed on a highway. Note the temperature reading at this speed. When a leaner mix is used, make sure that the temperature reading under exactly the same conditions does not exceed 180 degrees Fahrenheit (100 degrees Centigrade) above the pre-modification temperature.


David Andruczyk recommends an alternative method of avoiding engine damage through over-lean fuel/air mixtures, namely, replacing the narrowband oxygen sensor with a wideband sensor and controller. A wideband oxygen sensor reads a very wide range of Air/Fuel ratios, from about 9 to 1 through 28 to 1. A normal car engine can run from about 10 to 1 (very rich) to about 17.5 to 1 (pretty lean). Maximum engine power is developed at a mix ratio of about 12.5 to 1. Complete fuel combustion takes place with a mix of about 14.7 to 1, while the mix which gives minimum exhaust emissions is slightly leaner than that.

Unlike narrowband sensors, wideband sensors need their own controller in order to function. There are many of these units being offered for sale for retro-fitting to existing vehicles which have just narrowband oxygen sensor systems. David’s personal recommendation is the Innovate Motorsports LC-1 which is small, and uses the very reasonably priced LSU-4 sensor. This wideband controller can be programmed. Most controllers have the ability to output two signals, the wideband signal suitable for running to a gauge or new ECU, plus a synthesised narrowband signal which can feed an existing ECU. The trick is to install a wideband sensor, with the LC-1 controller and then reprogram it to **shift** the narrowband output to achieve a leaner mix as shown here:

Actual Air/Fuel Mix	Wideband Output	Original Narrowband Output	Shifted Narrowband Output
9 to 1	9 to 1	Mix is too Rich	Mix is too Rich
10 to 1	10 to 1	Mix is too Rich	Mix is too Rich
11 to 1	11 to 1	Mix is too Rich	Mix is too Rich
12 to 1	12 to 1	Mix is too Rich	Mix is too Rich
13 to 1	13 to 1	Mix is too Rich	Mix is too Rich
14 to 1	14 to 1	Mix is too Rich	Mix is too Rich
14.6 to 1	14.6 to 1	Mix is too Rich	Mix is too Rich
14.8 to 1	14.8 to 1	Mix is too Lean	Mix is too Rich
15 to 1	15 to 1	Mix is too Lean	Mix is too Rich
15.5 to 1	15.5 to 1	Mix is too Lean	Mix is too Lean
16 to 1	16 to 1	Mix is too Lean	Mix is too Lean
18 to 1	18 to 1	Mix is too Lean	Mix is too Lean

This system allows you to set the narrowband “toggle point” very precisely on an exact chosen air/fuel ratio. This is something which it is nearly impossible to do accurately with a circuit board which just shifts a narrowband oxygen signal as you just do not know what the air/fuel ratio really is with a narrowband sensor.

However, for anyone who wants to try adding a circuit board to alter a narrowband sensor signal to produce a leaner mix on a vehicle, the following description may be of help. It is possible to buy a ready-made circuit board, although using a completely different operating technique, from the very reputable Eagle Research, via their website: <http://www.eagle-research.com/products/pfuels.html> where the relevant item is shown like this:



DON'T WANT TO
BUILD IT?
JUST INSTALL AND GO!

[ORDER THIS DEVICE](#)

Note: The EFIE Device is a plastic covered circuit board that can be applied 'as is' OR you can put it in a box with a switch and LED's as per the EFIE Manual.

EFIE DEVICE

We now sell completely assembled EFIE device. All you have to do is hook it up and drive!

The EFIE connects directly to your oxygen sensor and is compatible with ALL oxygen sensors.

The EFIE allows you to retain all your power and performance while taking advantage of increased mileage.

No matter what fuel saver device or method you use on your fuel injected vehicle, you'll need the EFIE to unleash the full potential of the fuel saver.

The EFIE alone can save 5% - 10% on your fuel bill, simply by 'leaning' your fuel mixture. We do not consider it as a fuel saver on it's own. It is designed as an ASSIST for fuel savers.

Vehicles with more than one oxygen sensor need an EFIE on each oxygen sensor.

Note: Your actual mileage gains will depend on the capability of the fuel saver(s) you apply to your vehicle.

SKU ER1-78-0020

This unit generates a small voltage, using a 555 timer chip as an oscillator, rectifying the output to give a small adjustable voltage which is then added to whatever voltage is being generated by the oxygen sensor. This voltage is adjusted at installation time and is then left permanently at that setting. Eagle Research also offer for sale, a booklet which shows you how to build this unit from scratch if you would prefer to do that.

I understand that at the present time, the purchase price of this device is approximately US \$50, but that needs to be checked if you decide to buy one. Alternatively, instructions for building a suitable equivalent circuit board are provided later on in this document.

If you wish to use a circuit board with a narrowband oxygen sensor, then please be aware that there are several versions of this type of sensor. The version is indicated by the number of connecting wires:

- Those with **1** wire, where the wire carries the signal and the case is ground (zero volts)
 - Those with **2** wires, where one wire carries the signal and the other wire is ground.
 - Those with **3** wires, where 2 (typically slightly thicker) wires are for a sensor heater, and
1 for the signal while the case is ground.
 - Those with **4** wires (the most common on current model cars), where there are
2 (slightly heavier) for the sensor heater,
1 for the signal, and
1 for the signal ground.
- (Sensors with **5** wires are normally wideband devices.)

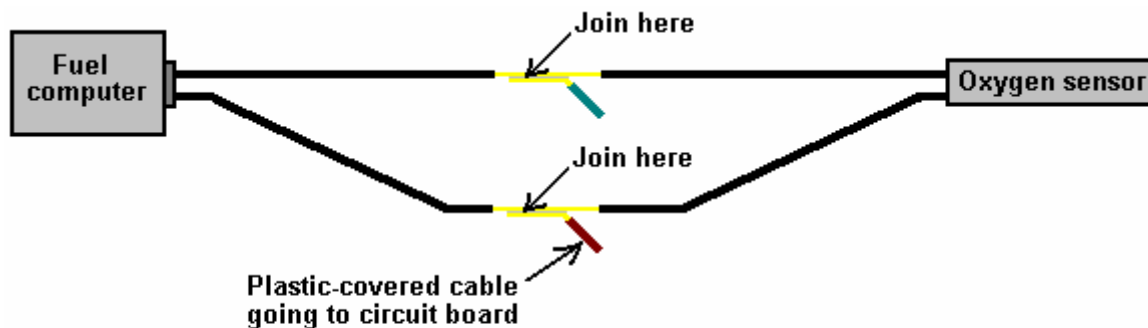
Look in the engine compartment and locate the oxygen sensor. If you have difficulty in finding it, get a copy of the Clymer or Haynes Maintenance Manual for your vehicle as that will show you the position. We need to identify the sensor wire which carries the control signal to the fuel control computer. To do this, make sure that the car is switched off, then

For **3** and **4** wire sensors:

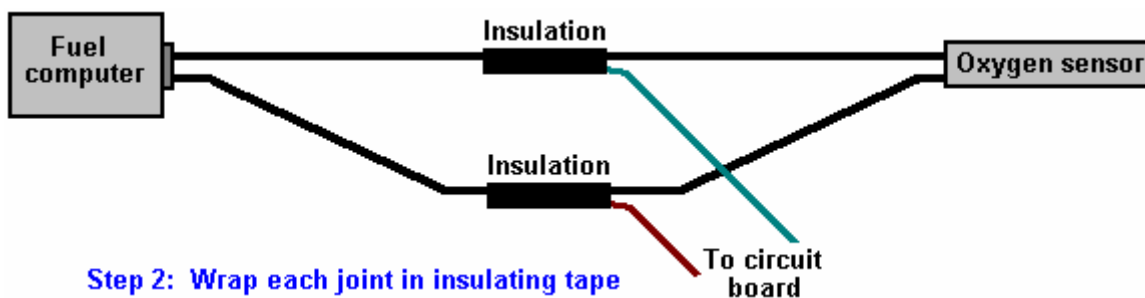
- Disconnect the oxygen sensor wiring harness,
- Set a multimeter to a DC voltage measurement range of at least 15 volts,
- Turn on the ignition and probe the socket looking for the two wires that provide 12 volts.
- These are the heater wires, so make a note of which they are,
- Shut the ignition off, and reconnect the oxygen sensor.

The two remaining wires can now be treated the same as the wires from a 2-wire sensor, one will carry the sensor signal and one will be the signal ground (for a single wire sensor, the signal ground will be the engine block). Jesper Ingerslev points out that the Ford Mustang built since 1996 has 2 oxygen sensors per catalytic converter, one before the converter and one after. Some other vehicles also have this arrangement. With a vehicle of this type, the circuit board described here should be attached to the sensor closest to the engine.

Find a convenient place along the wires. Don't cut these wires, you will cut the sensor wire here at a later time, but not now. Instead, strip back a small amount of the insulation on each wire. Be careful to avoid the wires short-circuiting to each other or to the body of the vehicle. Connect the DC voltmeter to the wires (the non-heater wires). Start the engine and watch the meter readings. When the engine is warmed up, if the oxygen sensor is performing as it should (i.e. no engine check lights on), the voltage on the meter should begin toggling between a low value near zero volts and a high value of about 1 volt. If the meter reading is going negative, then reverse the leads. The black multimeter lead is connected to the signal 'ground' (zero volts) and the red lead will be connected to the wire which carries the signal from the sensor. Connect a piece of insulated wire to the stripped point of the sensor wire and take the wire to the input of your mixture controller circuit board. Connect a second insulated wire between the signal 'ground' wire, or in the case of a 1-wire sensor, the engine block, and the circuit board zero-volts line. Insulate all of the stripped cables to prevent any possibility of a short-circuit:



Step 1: Remove a small piece of insulation and join the new cable to the original wire without cutting the original wire

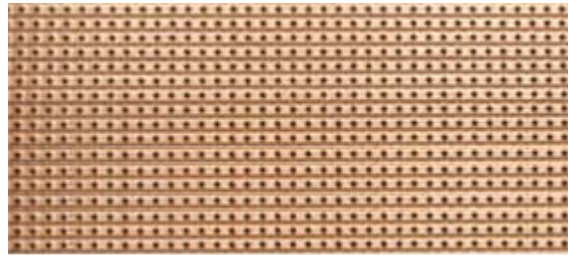


Step 2: Wrap each joint in insulating tape

Construction

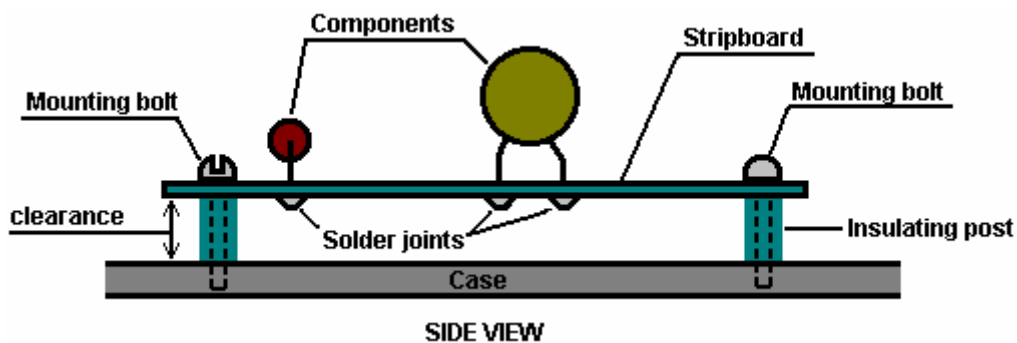
If you wish to build an oxygen sensor controller circuit, then here is a suggestion as to how you might do it. This description assumes very little knowledge on the part of the reader, so I offer my apologies to those of you who are already expert in these matters. There are many different ways to design and construct any electronic circuit and each electronics expert will have his own preferred way. In my opinion, the way shown here is the easiest for a newcomer to understand and build with the minimum of tools and materials.

The circuit shown here, is taken from the website <http://better-mileage.com/memberadx.html>, and is discussed here in greater detail. This circuit can be constructed on a printed circuit board or it can be built on a simple single-sided stripboard as shown here:



Stripboard (often called “Veroboard”), has copper strips attached to one side of the board. The copper strips can be broken where it is convenient for building the circuit. Component leads are cut to length, cleaned, inserted from the side of the board which does not have the copper strips, and the leads attached to the copper strips using a solder joint. Soldering is not a difficult skill to learn and the method is described later in this document.

When all of the components have been attached to the stripboard and the circuit tested, then the board is mounted in a small plastic case as shown here:



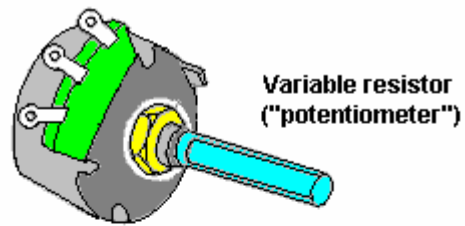
Insulating posts can be made from a short pieces of plastic rod with a hole drilled through its length. The mounting bolt can self-tap into a hole drilled in the case, if the hole is slightly smaller than the diameter of the bolt threads. Alternatively, the holes can be drilled slightly larger and the bolt heads located outside the case with nuts used to hold the board in place. This style of mounting holds the circuit board securely in place and gives some clearance between the board and the case.



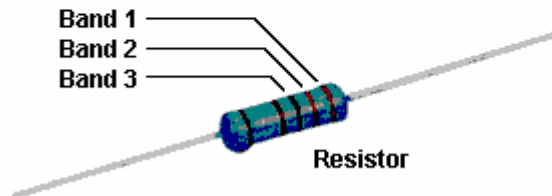
You will need building equipment, namely, a soldering iron, a 12 volt power supply such as a battery pack and an accurate digital volt meter for this project. If the 12 volt supply is a main-powered unit, then it needs to be a well-filtered, voltage-stabilised unit. Lastly, you will need a variable voltage source that can go from 0 to 1 volt to imitate the output from the vehicle's oxygen sensor when testing the completed circuit board. This is simple enough to make, using a resistor and a variable resistor.



Digital Voltmeter



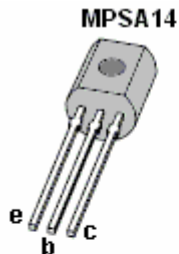
Variable resistor ("potentiometer")



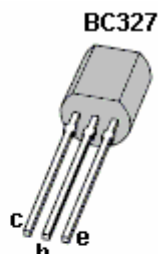
Resistor

A series of components will be needed for the circuit itself. These can be bought from a number of different suppliers and the ordering details are shown later in this document. Shown above is a resistor. The value of the resistor is indicated by a set of three colour bands at one end of the body. The reason for doing this rather than just writing the value on the resistor, is that when the resistor is soldered in place, its value can be read from any angle and from any side. The component list shows the colour bands for each of the resistors used in this circuit. If you want more information on basic electronics, then read the Electronics Tutorial which can be found at <http://panaceauniversity.org/D17.pdf>

Other components which you will be using, look like this:



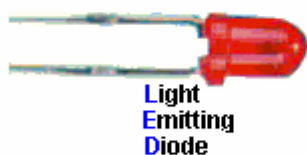
MPSA14



BC327



1N4007 Diode



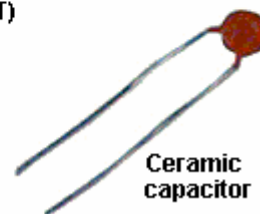
Light Emitting Diode



Double Pole Double Throw Switch (DPDT)



Electrolytic capacitor



Ceramic capacitor

The MPSA14 and the BC327 devices are transistors. They each have a "Collector", a "Base" and an "Emitter" wire coming out of them. Please notice that the two packages are not identical, and take care that the right wire is placed in the correct hole in the stripboard before soldering it in place.

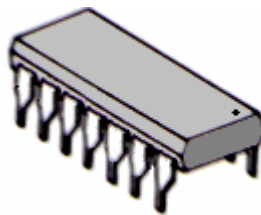
The 1N4007 diode has a ring marked at one end of the body. The ring indicates the flat bar across the symbol as shown on the circuit diagram, and in that way it identifies which way round the diode is placed on the stripboard.

The Light-Emitting Diode (the “LED”) will be familiar to most people as it is used so extensively in equipment of all types.

The toggle switch has six contacts - three on each side. The centre contact is connected to one of the two outer contacts on its side, which one, depends on the position of the switch lever.

The two capacitors (which are called “condensers” in very old literature) look quite different from each other. The electrolytic capacitor has its + wire marked on the body of the capacitor, while the ceramic has such a small value that it does not matter which way round it is connected.

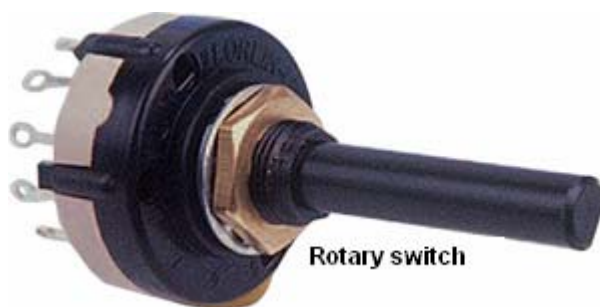
The main component of the circuit, is an integrated circuit or “chip”. This is a tiny package containing a whole electronic circuit inside it (resistors, capacitors, diodes, whatever,). Integrated circuit chips generally look like this:



A very common version of this package has two rows of seven pins each and it goes by the grandiose name of “Dual In Line” which just means that there are two rows of pins, each row having the pins in a straight line. In our particular circuit, the chip has eighteen pins, in two rows of nine.

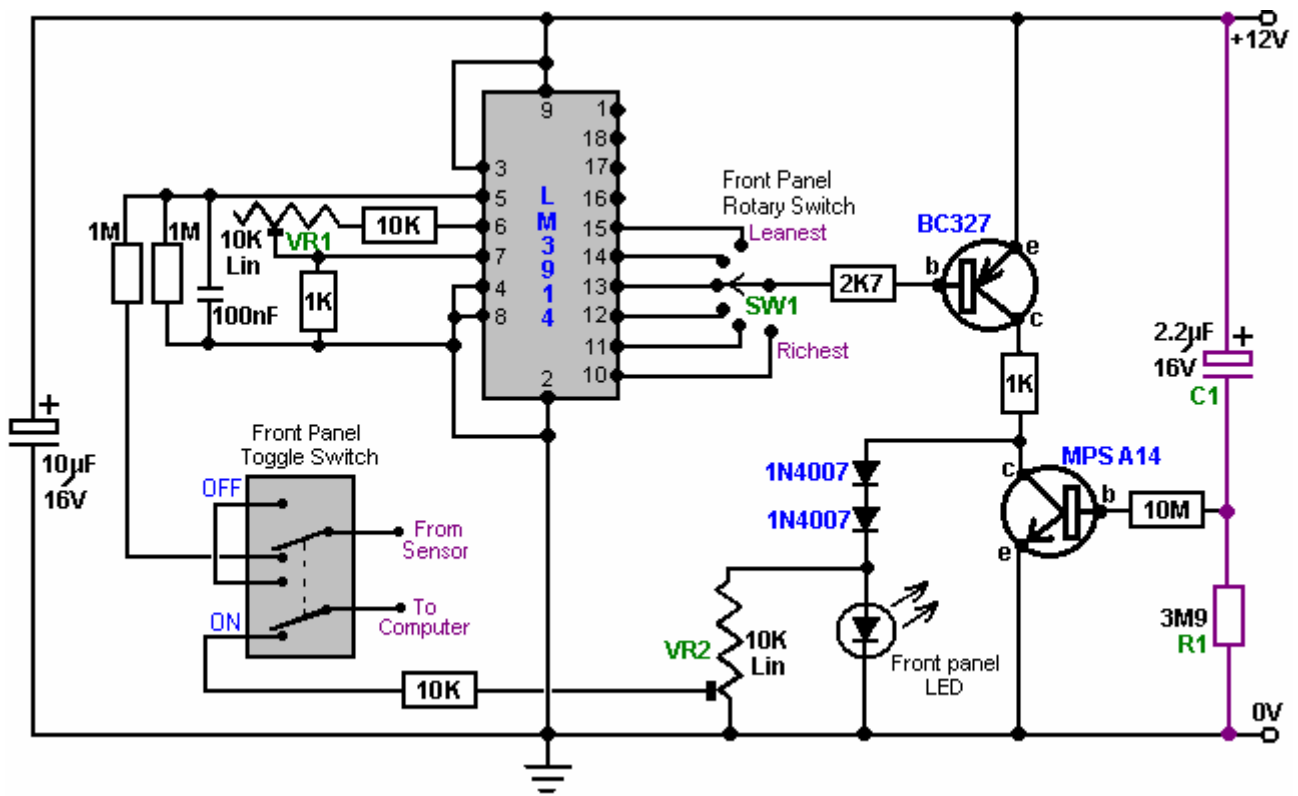
Now to the circuit itself. If you find it hard to follow, then take a look at the electronics tutorial on the web site as it shows the circuit diagram symbol for each component and explains how each device works.

The circuit contains three capacitors, eight resistors, two diodes, one LED, one IC chip, two transistors, one toggle switch and two types of component not yet described, namely: two preset resistors and one rotary switch.



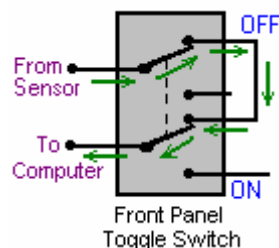
The preset resistor is very small and is adjusted using a flat bladed screwdriver. It is used for making an adjustable setting which is then left unchanged for a long time. The Rotary switch has a central contact which is connected to a row of outer contacts in turn when the shaft is rotated from position to position. The switch shaft is made of plastic and so can easily be cut to the length needed to make a neat installation, and the knob is locked in place by tightening its grub screw against the flat face of the shaft, although some knobs are designed just to push tightly on to the shaft. There is a wide range of knob styles which can be used with this switch, so the choice of knob is dictated by personal taste.

This is the circuit diagram:



Electronic circuits are normally “read” from left to right, so we will look at this circuit that way. The first component is the 10 microfarad, 16 volt electrolytic capacitor. This is put there to help iron out any little variations in the voltage supply, caused by surges in the current drawn by the circuit when it switches from one state to another.

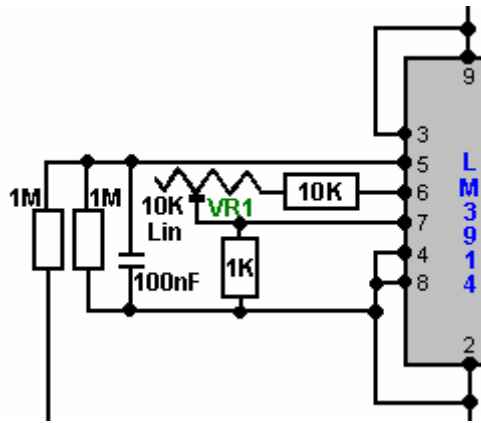
The next item is the On/Off dashboard switch. When switched to its Off position as shown here:



the connection from the oxygen sensor is passed straight through to the vehicle’s fuel computer, bypassing the circuit board completely. This switch allows the whole circuit to be switched Off should you want to do this for any reason.

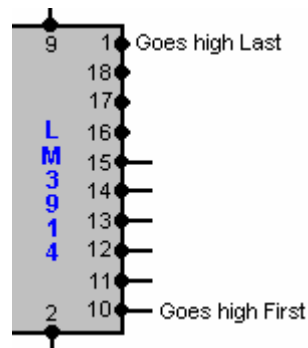
In it’s On position, as shown in the circuit diagram, the varying voltage signal coming from the oxygen sensor is passed into the circuit, and the output voltage from the circuit is passed back to the fuel computer, instead of the original sensor voltage. This allows the circuit to manipulate the voltage sent to the fuel computer.

The next set of components (three resistors, one ceramic capacitor and one preset resistor) shown here:



are needed to feed the incoming sensor voltage to the Integrated Circuit chip, and make the chip operate in the way that we want, (the chip manufacturer allows more than one way for the chip to work). You can just ignore these components for now, just understand why they are there.

The Integrated Circuit chip has ten outputs, coming out through Pins 1 and 10 through 18 inclusive:



If the input voltage coming from the oxygen sensor is low, then all of these ten outputs will have low voltages on them. When the input voltage rises a little, the voltage on Pin 10 suddenly rises to a high value, while the other output pins still have low voltages.

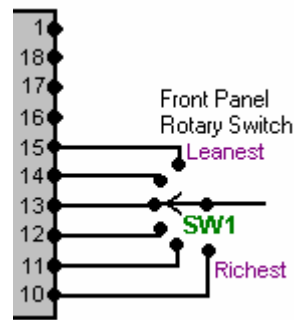
If the input voltage rises a little higher, then suddenly the voltage on Pin 11 rises to a high value. At this point, both Pin 10 and Pin 11 have high voltage on them and the other eight output pins remain at low voltage.

If the input voltage rises a little higher again, then suddenly the voltage on Pin 12 rises to a high value. At this point, Pin 10, Pin 11 and Pin 12 all have high voltage on them and the other seven output pins remain at low voltage.

The same thing happens to each of the ten output pins, with the voltage on Pin 1 being the last to get a high voltage on it. The circuit is arranged so that Pin 10 provides the output signal for the richest air/fuel mixture for the vehicle, and the mix gets progressively leaner as the output on Pins 11, 12, ... etc. are selected to be fed to the fuel computer.

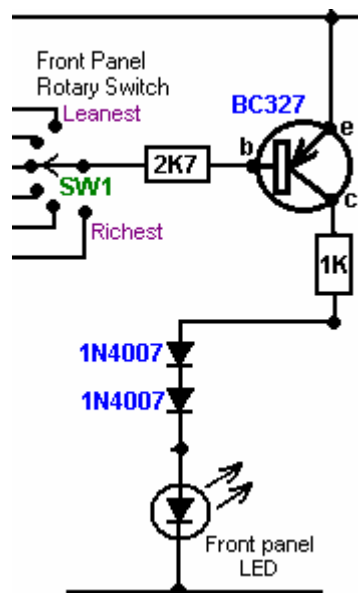
As there is the possibility of engine damage if the fuel mix is too lean, only six of the outputs are taken on into the circuit. However, if the engine is being fed hydroxy gas from an electrolyzer to improve both the miles per gallon performance and reduce emissions to zero, then it is likely that the engine will run cooler than before and engine damage is most unlikely to occur. It is quite safe to leave the remaining output pins of the Integrated Circuit chip unconnected. However, if this unit is to be used with the Nitrogen Hydroxide cell described in the D18.pdf document, then it is quite safe to connect Pins 16, 17, 18 and 1 and set the rotary switch to ten positions.

The output pin to be used by the remainder of the circuit is selected by the rotary switch mounted on the dashboard:



A standard single-pole rotary wafer switch has twelve positions but the switch operation can be restricted to any lesser number of positions by placing the end-stop lug of the switch just after the last switch position required. This lug comes as standard, fits around the switch shaft like a washer, and is held in place when the locking nut is tightened on the shaft to hold the switch in place. The lug projects down into the switch mechanism and forms an end-stop to prevent the switch shaft being turned any further. With six switch positions, the circuit provides five levels of leaner air/fuel mix which can be selected. This should be more than adequate for all practical purposes.

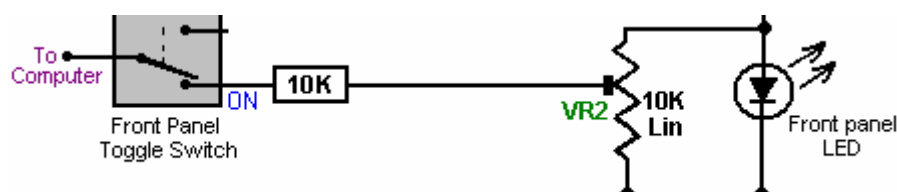
The next section of the circuit is the BC327 transistor amplifier stage which provides the output current for the fuel computer:



Here, the switch "SW1" connects to one of the output pins of the Integrated Circuit. When the voltage on that pin goes low, it causes a current to flow through the transistor Base/Emitter junction, limited by the 2.7K (2,700 ohm) resistor. This current causes the transistor to switch hard On, which in turn alters the voltage on its Collector from near 0 volts to near +12 volts. The 2.7K resistor is only there to limit the current through the transistor and to avoid excessive loading on the output pin of the IC.

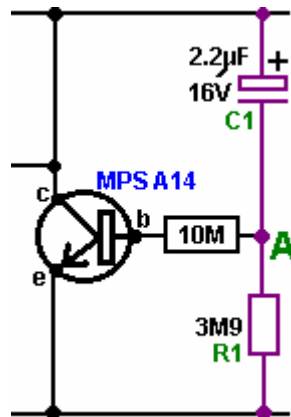
The transistor now feeds current to the LED via the two 1N4007 diodes and the 1K (1,000 ohm) resistor. This causes the Light Emitting Diode to light brightly. The 1K resistor is there to limit the amount of current flowing through this section of the circuit.

Part of the voltage across the LED is fed back to the fuel computer:



By moving the slider contact on the preset resistor "VR2", any output voltage can be fed to the fuel computer. This voltage can be anything from the whole of the voltage across the LED, down to almost zero volts. We will use VR2 to adjust the output voltage when we are setting the circuit up for use. In this circuit, VR2 is acting as a "voltage divider" and it is there to allow adjustment of the output voltage going from the circuit to the fuel computer.

The final section of the circuit is the MPSA14 transistor and its associated components:



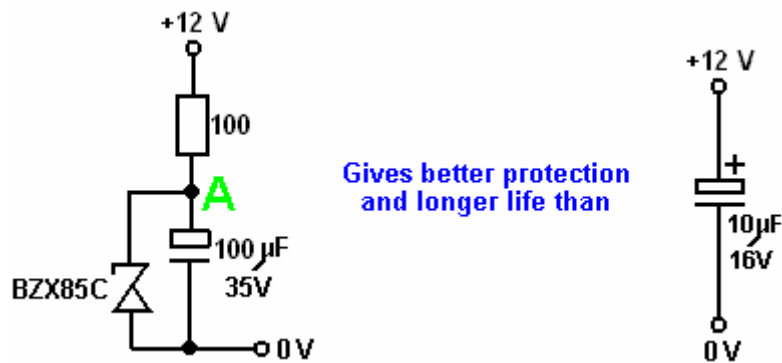
This circuit is a timer. When the circuit is first powered up (by the vehicle's ignition key being turned), the tantalum 2.2 microfarad capacitor "C1" is fully discharged (if it isn't, then the oxygen sensor will already be hot). As it is discharged and one side is connected to the +12 volt line, then the other side (point "A") looks as if it is also at +12 volts. This provides a tiny current to the Base/Emitter junction of the MPSA14 transistor, through the very high resistance 10M (10,000,000 ohm) resistor. The MPSA14 transistor has a very high gain and so this tiny current causes it to switch hard on, short-circuiting the LED and preventing any voltage developing across the LED.

As time passes, the tiny current flowing through the MPSA14 transistor, along with the tiny current through the 3.9M (3,900,000 ohm) resistor "R1", cause a voltage to build up on capacitor "C1". This in turn, forces the voltage at point "A" lower and lower. Eventually, the voltage at point "A" gets so low that the MPSA14 transistor gets starved of current and it switches off, allowing the LED to light and the circuit to start supplying an output voltage to the fuel computer. The purpose of the section of the circuit is to shut off the output to the fuel computer until the oxygen sensor has reached it's working temperature of 600 degrees Fahrenheit. It may be necessary to tailor this delay to your vehicle by altering the value of either "R1" or "C1". Increasing either or both will lengthen the delay while reducing the value of either or both, will shorten the delay.

Changes:

Having examined this circuit, Nigel Duckworth has recommended some alterations. Firstly, the capacitor placed across the battery supply lines is shown as 10 microfarad, which comes from the manufacturer's specification sheet for the Integrated Circuit. While this will be sufficient for many applications, this circuit will be working in what is effectively a hostile environment, with the battery supply being liable to have severe voltage spikes and surges superimposed on it. Consequently, it would be advisable to increase the value of this capacitor to, say, 100 microfarad in order to help it cope with these difficult conditions. Also, electrolytic capacitors perform much better and have a much longer life if their voltage rating is higher than the average working voltage they are expected to encounter. For vehicle circuits, a minimum of 35 volts is recommended. This has no significant effect on the cost or size of the capacitor, so it is a good idea to increase the rating as recommended.

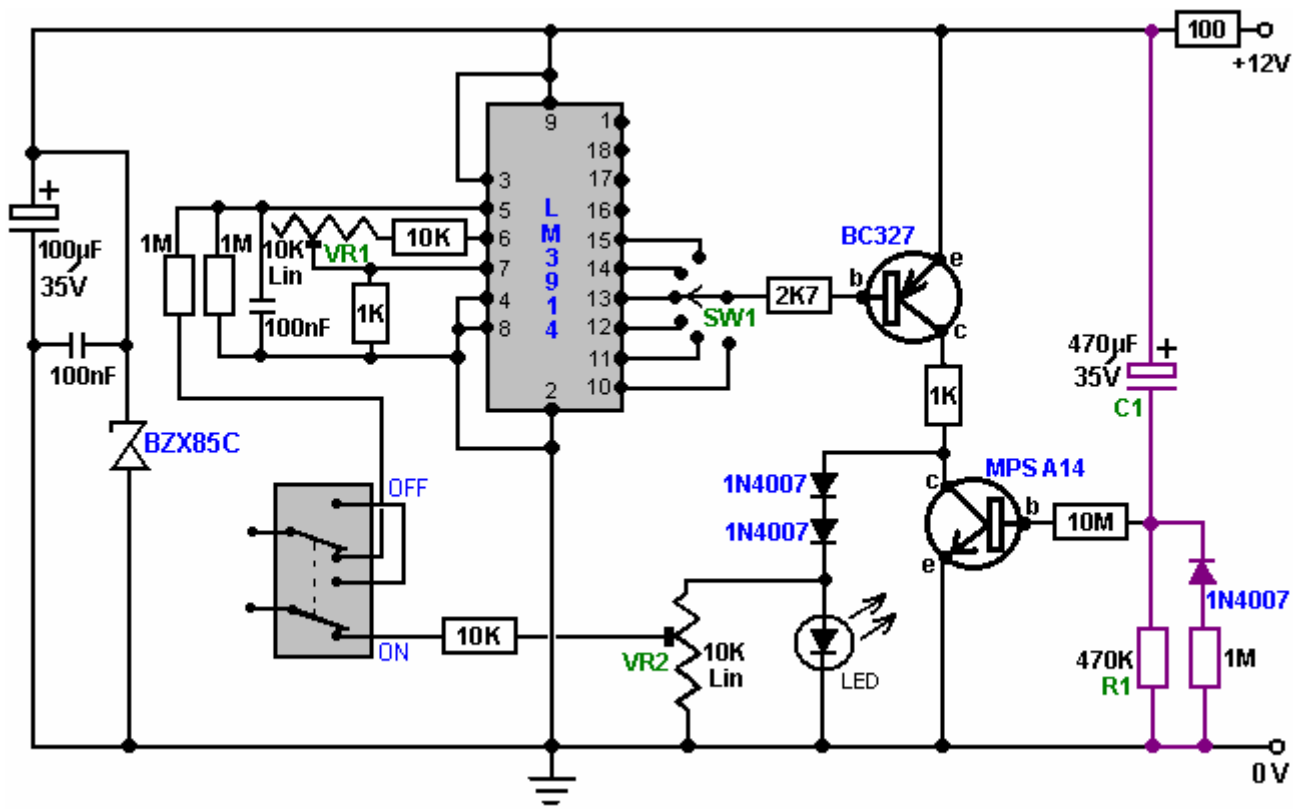
One other very important point is that the Integrated Circuit has an absolute maximum voltage rating of 25 volts and this can easily be exceeded in vehicle environments. To protect against this, it is worth adding a current-limiting resistor and a 24 volt zener diode as shown here:



With this modification, if the nominal +12 volt supply gets a spike on it which briefly takes the voltage up to, say, 40 volts, the voltage at point "A" starts to rise rapidly. When it reaches 24 volts, the BZX85C zener diode starts to conduct heavily, collapsing the spike and pinning down point "A", preventing the voltage exceeding 24 volts. One additional protection option is to put a 0.1 microfarad capacitor across the 100 microfarad capacitor. This looks unusual if you have not seen it before, but is a standard method of trapping very sharp spikes on the supply line, as a capacitor as small as that acts like a short-circuit to high frequency spikes. Also, to make adjustment of the circuit easier, an additional 10K resistor has been inserted between VR1 and Pin 6 of the integrated circuit. This makes the circuit:

The next point of concern is the timing circuit of "C1" and "R1". Contrary to what the website suggests, using the values shown here, capacitor C1 will charge up fully in nine seconds through R1 alone, and not the "few minutes" quoted. That neglects the current flowing through the Base/Emitter junction of the MPSA14 transistor and its 10 megohm resistor, which will shorten the nine second period quite substantially. If this part of the circuit is to generate a realistic delay period, then capacitor C1 needs to be very much larger, say a capacitor of 470 microfarad capacity. That will be an electrolytic capacitor, and they tend to have quite large leakage currents which will prevent them charging fully unless the current being fed into them is reasonably large. For that reason, we should change resistor R1 to 470K (470,000 ohms) which, with a 470 microfarad capacitor for C1, should give a delay time of about three and a half minutes.

effect when the circuit is powered up, but it will discharge the capacitor when the circuit is powered down. We can slow down the rate of discharge by putting a high-value resistor in series with the discharge diode and that would make the circuit:



Circuit Operation:

Now that we have looked at each part of the circuit separately, let us look again at the way that the circuit operates. The main component is the LM3914 integrated circuit. This device is designed to light a row of Light Emitting Diodes ("LEDs"). The number of LEDs lit is proportional to the input voltage reaching it through its Pin 5. In this circuit, the integrated circuit is used to provide a reduced voltage to be fed to the fuel computer, rather than to light a row of LEDs. When the operating switch is set in its ON position, the sensor voltage is fed to Pin 5 through a 1 megohm resistor.

The sensitivity of this circuit is adjusted, so that when 500 millivolts (0.5 volts) is applied to Pin 5, the output on Pin 10 is just triggered. This is done by adjusting the 10K linear preset resistor "VR1" while placing a test voltage of 500 millivolts on Pin 5. This LM3914 Integrated Circuit is normally switched so that it samples the sensor voltage. The LM3914 chip provides ten separate output voltage levels, and the circuit is arranged so that any one of several of these can be selected by the rotary switch "SW1". These output voltages range from 50 millivolts on Pin 1 to 500 millivolts on Pin 10, with each output position having a 50 millivolt greater output than its neighbouring pin. This allows a wide range of control over the sensor feed passed to the fuel computer.

The input resistor/capacitor circuit provides filtering of the sensor signal. Because this circuit draws very little current, it is easily knocked out of correct operation through its input line picking up stray electrical pulses produced by the engine, particularly the vehicle's ignition circuit. When the exhaust sensor heats up, the signal becomes cleaner and then the circuit starts operating correctly. The circuit includes a delay so that after start up, the output is held low for a few minutes to simulate a cold sensor. The sensor must be operating correctly before we send signals to the computer. The most common problem, if we don't have this delay, is that the output will be high simply from the noise on the signal line. The computer will think the sensor is working, because it is high, and will cut back the fuel to make the signal go low. If that were to happen, we would end up with an over-lean fuel input to the engine, producing very poor acceleration.

The front panel LED is not just to show that the device is operating, but forms a simple voltage regulator for the output signal to the computer. When the engine is warmed up and running normally, the LED is lit when the output is high, and not lit when the output is low, so this LED should be flashing on and off.

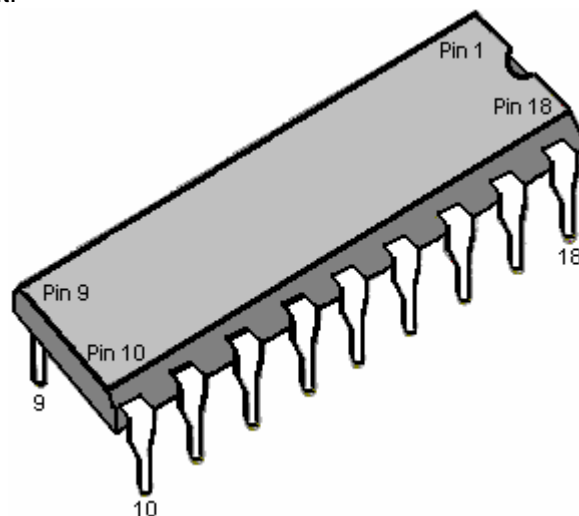
The earth connection for the oxygen sensor is the exhaust system, which is firmly bolted to the engine. The computer earth is the vehicle body. A difference of just 0.5 volts can make a large difference to the mixture. If the engine is not securely earthed to the vehicle body, then a voltage difference can exist between the two, and in this situation a voltage difference of just 0.5 volts would normally go unnoticed. We can't afford to have that sort of voltage difference when trying to control the mixture accurately, so some investigation and adjustment is needed.

To do this, start the engine, switch the headlights on to high beam, then measure the voltage between the engine and the body. Use a digital volt meter. Any more than 50 millivolts (0.05 volts) means that there is a bad earth connection which needs cleaning and tightening. Modern cars usually have more than one connection so look around. If you have trouble achieving a really good connection, then earth your circuit board directly on the engine rather than connecting it to a point on the bodywork of the vehicle. The most important item is to have a good quality signal voltage coming from the sensor, since the operating range consists of quite low voltages. The components and tools needed for building this circuit are shown later, but for now, consider the setting up and testing of the unit so as to understand better what is needed.

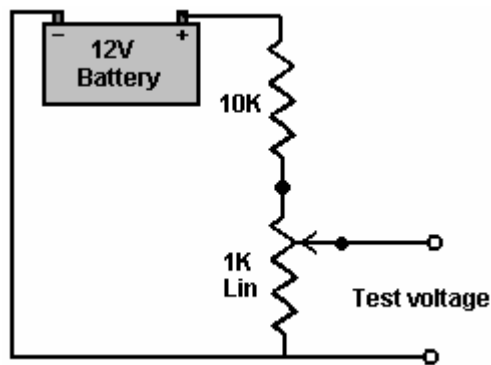
Adjusting on the Bench

When the circuit has been constructed to the testing stage, that is, with all components in place except for the timing capacitor "C1", and before the power is turned on, plug the Integrated Circuit chip into its socket mounted on the board. Be very careful doing this as the chip can be destroyed by static electricity picked up by your body. Professionals wear an electrical earth wrist strap when handling these devices, so it would be a good idea to touch a good earth point such as a metal-pipe cold water system just before handling the chip.

It is vital that you install the IC chip, the correct way round or it may be damaged. The circuit board layout shows which way round it goes. The chip has a semi-circular indentation at one end to show which end is which, so be careful that the indentation is positioned as shown on the board layout in the section which shows how the board is built. Some manufacturers use a dot rather than a semi-circular indentation to mark the end of the chip which has Pin 1 in it.



Make up the test voltage device. We need something to give us an adjustable voltage in the range 0 to 1 volt. A very easy way to get this is to use a 10K resistor and a 1K variable resistor (called a "potentiometer" by some people) and connect them across the 12 volt battery, as shown here:



This gives us a voltage in the correct range when the shaft of the variable resistor is turned. Power up the circuit board by switching the 12 volt battery through to the board. Adjust the test-voltage source to 500 millivolts (0.5 volts) and apply it to the board's input (where the sensor connection will be made when it is installed in the vehicle). Set the switch to the "Richest" position, that is, with the switch connected to Pin 10 of the chip.

Now, using a flat-blade screwdriver, adjust the sensitivity control preset resistor "VR1" so that the output LED is just lit. Leave the preset resistor in that position and adjust the test voltage lower and higher to test that the LED turns on and off in response to the varying voltage at the input to the circuit. The LED should come on at 0.5 volts, and go off just below 0.5 volts. The other outputs, which can be selected by the rotary switch "SW1", will be about 50 millivolts lower for each position of the switch away from its "Richest" setting on Pin 10.

Now, with the output high and the LED lit, use a flat-bladed screwdriver to adjust the preset resistor "VR2" to set the output voltage being sent to the computer to about 1.0 volts. When this has been set, lower the input voltage so that the LED goes out. The output voltage should now be at zero volts. If this is what happens, then it shows that the circuit is operating correctly.

If this board is not in place, the sensor will cause the fuel computer to make the fuel mixture richer so as to maintain a 500 millivolt voltage from the sensor. With the circuit in place and set to its "Richest" setting, exactly the same thing happens. However, if the rotary switch is moved to its next position, the fuel computer will maintain the fuel feed to maintain a 450 millivolt output, which is a leaner fuel-to-air mixture. One step further around and the fuel computer will make the mix even leaner to maintain a 400 millivolt output from the circuit board, which the fuel computer thinks is coming from the exhaust oxygen sensor.

If your circuit board does not operate as described, then power it down and examine the circuit board again, looking for places where the solder connections are not perfect. There may be somewhere where the solder is bridging between two of the copper strips, or there may be a joint which looks as if it is not a good quality joint. If you find one, don't solder anywhere near the IC chip as the heat might damage the chip. If necessary, earth yourself again, remove the chip and put it back into the anti-static packaging it came in, before repairing the board. If the components are all correctly positioned, the copper tracks broken at all the right places and all solder joints looking good and well made but the board still is not working correctly, then it is likely that the IC chip is defective and needs to be replaced.

Next, install the delay capacitor "C1". Set the test voltage above 500 millivolts and turn the power on again. It should take about three minutes for the LED to come on. If you want to shorten this delay, then change the timing resistor "R1" for a resistor of a lower value. To lengthen the delay, replace the timing capacitor "C1" with a capacitor of larger value. If you find that the oxygen sensor heats up quickly, then you can reduce the length of the delay. Having too long a delay is not ideal, since the computer will be adding extra fuel to make the mixture richer.

It is suggested that the rotary switch should be set to have only six switch positions (by moving its end-stop lug washer), so initially, connect the IC chip output pins 10 through 15 to the switch. You can choose to connect the wires to the switch so that the mixture gets richer when you turn the knob clockwise, or if you prefer, you can wire it in the reverse order so that the mixture gets richer when you turn the knob counter-clockwise.

Testing in the Car

You can now test the device in the vehicle but don't install it yet. Look in the engine compartment and locate the oxygen sensor. If you have difficulty in finding it, get a copy of the Clymer or Haynes Maintenance Manual

Start the vehicle and allow the oxygen sensor to warm up for a couple of minutes. Remember that there is a delay built in to the circuit, so after a few minutes you should see the LED start to flash. Rev the engine and the LED will stay on. When you release the throttle, the LED will go out for a while. A flashing LED is what you want to see. The rate of flashing will be somewhere between 1 and 10 times per second, most likely around 2 per second. Confirm that the LED goes out when you switch off the circuit board On/Off switch mounted on the dashboard.

Fuel computer

Permanent joint on the earth wire

Oxygen sensor

Male crimp connector

Female crimp connector

Sensor wire

Circuit board Input

Circuit board earth

Circuit board Output

Installing the Controller

It is important that there should be no hesitation in the engine performance and no knocking or “pinking” as that is an indication that the mix is too lean and the engine is liable to overheat. This circuit is intended for use with an electrolyzer, so your electrolyzer should be set up and working for these tests. The electrolyzer will tend to make the engine run cooler and offset any tendency towards overheating.

Page 16 of 22

Although the above information has been presented as if the board has already been built, the actual construction details have been left until now, so that you will already have an understanding of what the circuit is intended to do and how it is used.

It is likely that you will know somebody (neighbour, friend, relative,...) who has the necessary equipment and skills. If so, borrow the equipment, or better still, recruit the person to help with the construction. It is very likely that anybody owning the equipment would be very interested in your project and more than willing to help out.

However, the rest of this document will be written on the assumption that you cannot find anybody to help and have had to buy all of the necessary equipment. This project is not difficult to build, so you will almost certainly be successful straight off.

The tools which you will need, are:

1. A soldering iron with a fine conical tapering tip (probably 15 watts power rating)
2. Some "Multicore" resin solder. This is special solder for electronics construction work and is quite different from plumber's solder which is not suitable for this job.
3. A pair of long-nosed pliers (for holding component wires when soldering them in place)
4. Something for cutting and cleaning wires and stripping off insulation coverings. I personally prefer a pair of "nail" scissors for this job. Others prefer a pair of wire cutters and some sandpaper. You get whatever you feel would be the best tool for doing these tasks.
5. A 1/8 inch (3 mm) drill bit (for making bolt holes in the stripboard and for breaking the copper strips where needed) and a 3/8 inch (9 mm) drill and bit for mounting the switches on the plastic box.
6. A coping-saw or similar small saw for cutting the rotary switch shaft to the optimum length.
7. A small screwdriver (for tightening knob grub screws).
8. A crimping tool and some crimp connectors.
9. A multimeter (preferably a digital one) with a DC voltage measuring range of 0 to 15 volts or so.
10. (Optional) a magnifying glass of x4 or higher magnification (for very close examination of the soldering)

Soldering

Many electronic components can be damaged by the high temperatures they are subjected to when being soldered in place. I personally prefer to use a pair of long-nosed pliers to grip the component leads on the upper side of the board while making the solder joint on the underside of the board. The heat running up the component lead then gets diverted into the large volume of metal in the pair of pliers and the component is protected from excessive heat. On the same principle, I always use an Integrated Circuit socket when soldering a circuit board, that way, the heat has dissipated fully before the IC is plugged into the socket. It also has the advantage that the IC can be replaced without any difficulty should it become damaged.

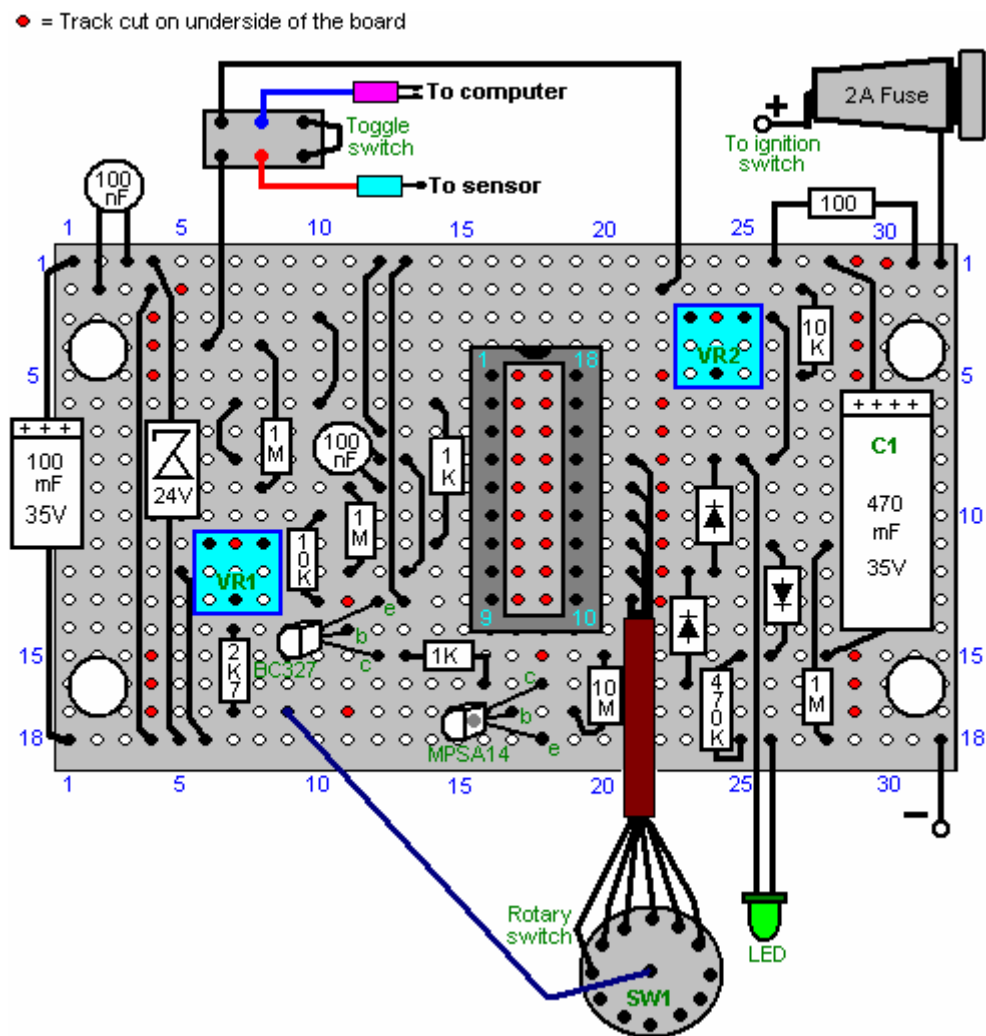
If you are using CMOS integrated circuits in any construction, you need to avoid static electricity. Very high levels of voltage build up on your clothes through brushing against objects. This voltage is in the thousands of volts range. It can supply so little current that it does not bother you and you probably do not notice it. CMOS devices operate on such low amounts of current that they can very easily be damaged by your static electricity. Computer hardware professionals wear an earthing lead strapped to their wrists when handling CMOS circuitry. There is no need for you to go that far. CMOS devices are supplied with their leads embedded in a conducting material. Leave them in the material until you are ready to plug them into the circuit and then only hold the plastic body of the case and do not touch any of the pins. Once in place in the circuit, the circuit components will prevent the build up of static charges on the chip.

Soldering is an easily-acquired skill. Multi-cored solder is used for electronic circuit soldering. This solder wire has flux resin contained within it and when melted on a metal surface, the flux removes the oxide layer on the metal, allowing a proper electrical and mechanical joint to be made. Consequently, it is important that the solder is placed on the joint area and the soldering iron placed on it when it is already in position. If this is done, the flux can clean the joint area and the joint will be good. If the solder is placed on the soldering iron and then the iron moved to the joint, the flux will have burnt away before the joint area is reached and the resulting joint will not be good.

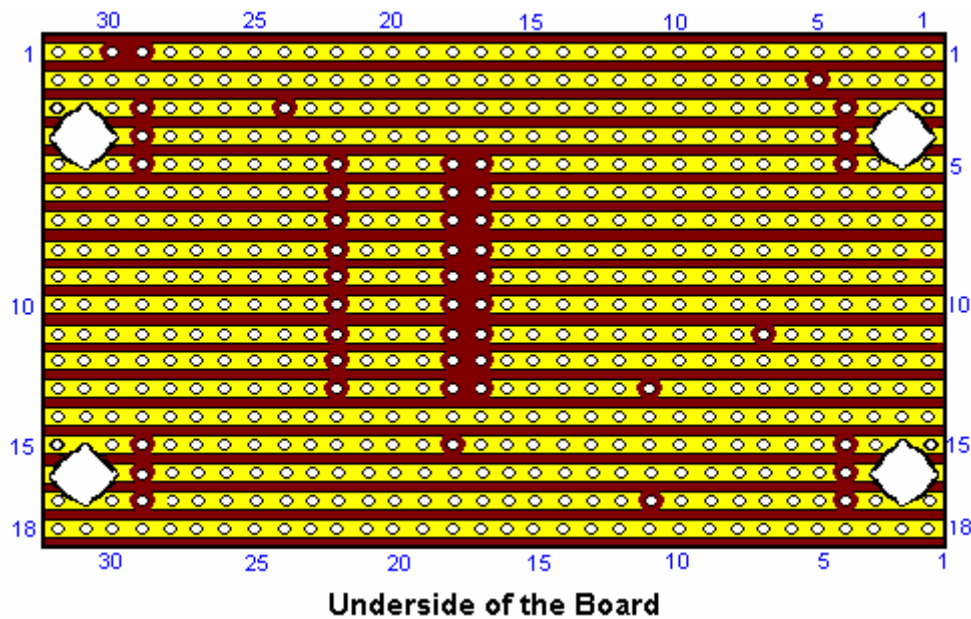
A good solder joint will have a smooth shiny surface and pulling any wire going into the joint will have no effect as the wire is now solidly incorporated into the joint. Making a good solder joint takes about half a second and certainly not more than one second. You want to remove the soldering iron from the joint before an excessive amount of heat is run into the joint. It is recommended that a good mechanical joint be made before soldering when connecting a wire to some form of terminal (this is often not possible).

The technique which I use, is to stand the solder up on the workbench and bend the end so that it is sloping downwards towards me. The lead of the component to be soldered is placed in the hole in the stripboard and gripped just above the board with long-nosed pliers. The board is turned upside down and the left thumb used to clamp the board against the pliers. The board and pliers are then moved underneath the solder and positioned so that the solder lies on the copper strip, touching the component lead. The right hand is now used to place the soldering iron briefly on the solder. This melts the solder on the joint, allowing the flux to clean the area and producing a good joint. After the joint is made, the board is still held with the pliers until the joint has cooled down.

Nowadays, the holes in the stripboard are only 1/10 inch (2.5 mm) apart and so the gaps between adjacent copper strips is very small indeed. If you solder carefully, there should be no problem. However, I would recommend that when the circuit board is completed, that you use a magnifying glass to examine the strip side of the board to make quite sure that everything is perfectly ok and that solder does not bridge between the copper strips anywhere. Before powering up the circuit, double-check that all of the breaks in the copper strips have been made correctly. Here is a possible layout for the components on the stripboard:



If this board is turned over horizontally, the underside will look like this:



This shows where the breaks in the copper strips need to be made using a 1/8 inch (3 mm) drill bit.

To construct this circuit, cut a piece of stripboard which has 18 strips, each with 32 holes. That is a board size of about two inches (50 mm) by just over three inches (85 mm). Mount the components on the board, working from one end as the installation is easier if you have a clear board to work across. If you are right-handed, then start at the left hand side of the board and work towards the right, installing all components as you go. If you are left-handed, then mount the components starting with the right hand side of the board and working towards the left hand side.

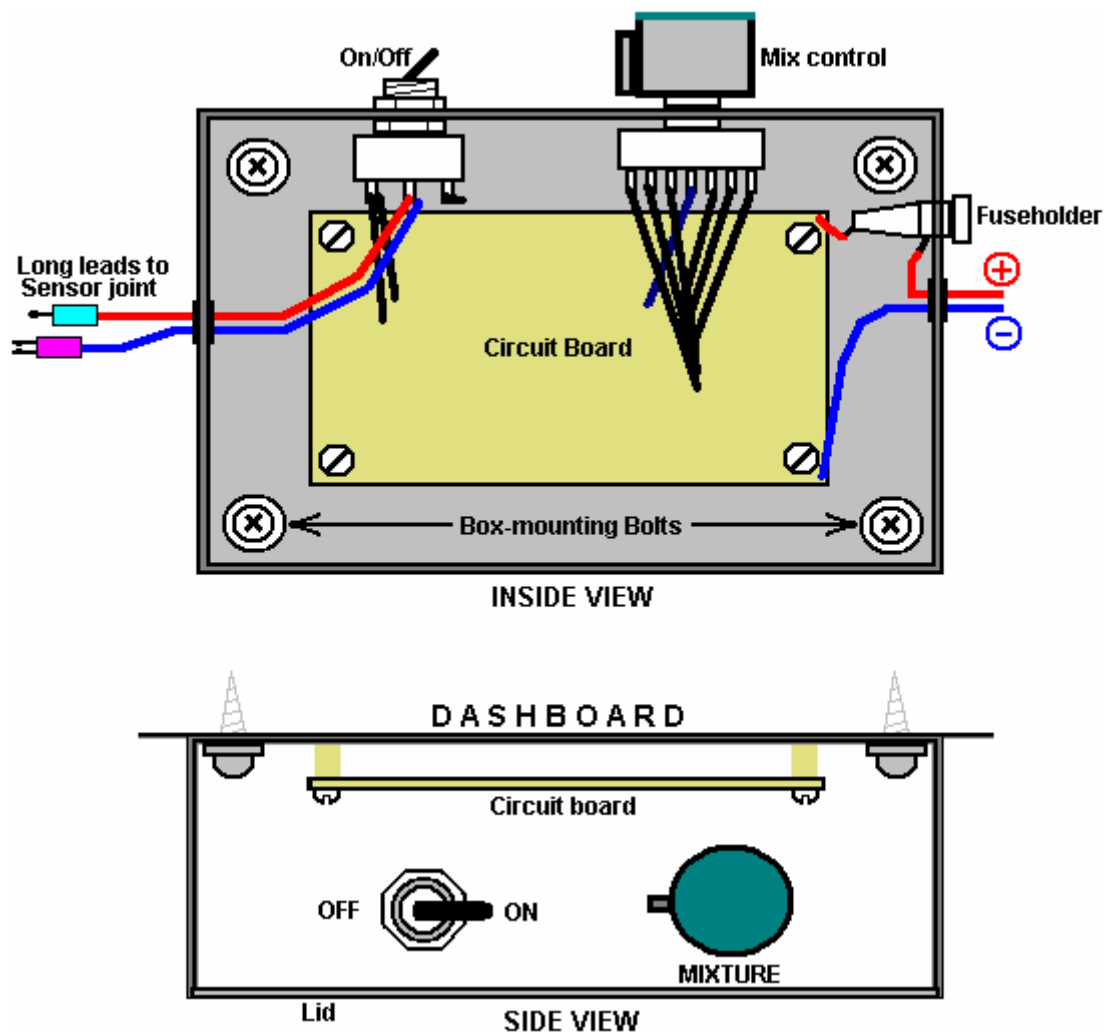
Having said that, it is probably easier if you put all of the wire jumpers in place as the first step. The best wire for this is solid core wire of the type used in telephone wiring, as it is easy to cut, easy to remove the insulation and it lies flat on the board, clear of all of the other holes. So, start with the wire jumpers and then install the electronic components working across the board.



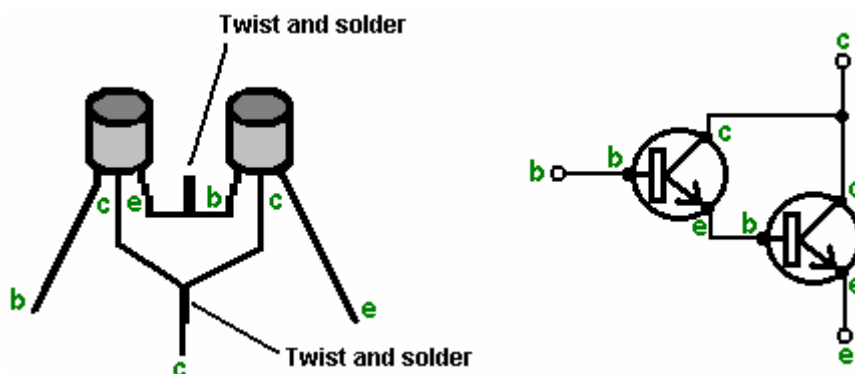
The jumper wires lie flat on the board, and like the other components, have about 2 mm of clean wire projecting through the copper strip before the solder joint is made.

The wires coming off the board should be of the type which have several thin wires inside the insulation, as these are more flexible and withstand the vibration of a vehicle in motion, better than solid core wire. If you have just one reel of wire, then be sure to label the far end of each piece mounted on the board, the moment you have soldered it in place. These labels will help avoid errors when mounting in the case, if you do not have different coloured wires.

The completed circuit board can be mounted in a small plastic box of the type which has a lid held in place by screws. It may be convenient to screw or bolt the case to the underside of the dashboard and then screw the lid in place, covering the mounting screws:



The components in this circuit are not critical and any near-match alternatives can be used. In the event that the MPSA14 Darlington-pair transistor is not available, then two general-purpose high-gain silicon transistors like the BC109 or 2N2222A can be substituted. Just connect them like this:



The emitter of the first transistor is connected to base of the second and the two collectors are connected together. If the transistors have metal cases, then make sure the emitter/base connection cannot touch either case as the cases are often connected internally to the collectors. If each transistor has a gain of only 200, then the pair will have a combined gain of 40,000 times. That means that the base current need only be 40,000 times less than the collector current of the second transistor.

The BC327 transistor can be replaced by almost any other silicon PNP transistor in this circuit as the gain does not need to be great and the power rating is very small. The following is a list of the main electronic components needed for the construction of this circuit as described here. There are several suppliers who are able to supply all of these components and the most suitable depends on where you are located. If there is

any difficulty, try an internet search, and if that fails, ask for help in one or more of the Yahoo enthusiast groups such as 'watercar', 'hydroxy' or any of the electronics Groups.

Component	Qty.	US Supplier	Code
Black plastic box with lid, size about 4" x 3" x 2"	1	Radio Shack	270-1803
Stripboard: 18 strips, 32 holes	1	Electronix Express	0302PB16
Double Pole Double Throw toggle switch	1	Radio Shack	275-636
Fuseholder, panel mounting, 1.25"	1	Radio Shack	270-364
Fuse, 2 amp slow-blow 1.25"	1	Radio Shack	270-1262 ?? (3 A)
Rotary wafer switch, 12-way single pole	1	Electronix Express	17ROT1-12
Knob for the rotary switch	1	Radio Shack	274-424
LED, any colour, 5 mm diameter	1	Radio Shack	276-041
IC socket, 18 pin DIL	1	Radio Shack	276-1992
Miniature preset resistor, 10K linear	2	Radio Shack	271-282
LM3914 LED bar driver Integrated Circuit	1	Electronix Express	LM3914
BC327 PNP transistor	1	Electronix Express	2N2905
MPSA14 Darlington pair transistor	1	Electronix Express	MPSA14
1N4007 Diode or equivalent	3	Radio Shack	276-1103 (2 pack)
BZX85C zener diode, 24 volt version	1	Electronix Express	1N5359
470 microfarad, 35 volt (or higher) axial lead aluminium foil electrolytic capacitor	1	Radio Shack	272-1018
100 microfarad, 35 volt (or higher) axial lead aluminium foil electrolytic capacitor	1	Radio Shack	272-1016
100 nF (0.01 microfarad) ceramic disc capacitor	2	Radio Shack	272-135 (2 pack)
10 megohm 1/4 watt carbon resistor (Bands: Brown,Black,Blue)	1	Radio Shack	271-1365 (5 pack)
1 megohm 1/4 watt carbon resistor (Bands: Brown,Black,Green)	3	Radio Shack	271-1356 (5 pack)
470K 1/4 watt carbon resistor (Bands: Yellow,Purple,Yellow)	1 or 1	(Radio Shack) Radio Shack	use two 1M in parallel or 271-1133 (5 pack 1/2 watt)
10K 1/4 watt carbon resistor (Bands: Brown,Black,Orange)	1	Radio Shack	271-1335 (5 pack)
2.7K 1/4 watt carbon resistor (Bands: Red,Purple,Red)	1	Radio Shack	271-1328 (5 pack) [use 3.3K]
1K 1/4 watt carbon resistor (Bands: Brown,Black,Red)	2	Radio Shack	271-1321 (5 pack)
100 ohm 1/4 watt carbon resistor (Bands: Brown,Black,Brown)	1	Radio Shack	271-1311 (5 pack)
Connecting wire: stranded and solid core		Local supplier	

Electronix Express <http://www.elexp.com/index.htm>
Radio Shack <http://www.radioshack.com/home/index.jsp>

And for a UK supplier:

Component	Qty.	European Supplier	Code
Black plastic box with lid, size about 4" x 3" x 2"	1	ESR	400-555
Stripboard: 18 strips, 32 holes	1	ESR	335-010
Double Pole Double Throw toggle switch	1	ESR	218-028
Fuseholder, panel mounting 31 mm	1	ESR	187-115
Fuse, 2 amp 31 mm	1	ESR	190-220
Rotary wafer switch, 12-way single pole	1	ESR	210-012
Knob for the rotary switch	1	ESR	060-22X
LED, any colour, 5 mm diameter	1	ESR	711-540
IC socket, 18 pin DIL	1	ESR	110-180
Miniature preset resistor, 10K linear	2	ESR	998-310
LM3914 LED bar driver Integrated Circuit	1	ESR	LM3914
BC327 PNP transistor	1	ESR	BC327
MPSA14 Darlington pair transistor	1	ESR	MPSA13
1N4007 Diode or equivalent	3	ESR	1N4007
BZX85C zener diode, 24 volt version	1	ESR	726-240
470 microfarad, 35 volt (or higher) axial lead aluminium foil electrolytic capacitor	1	ESR	810-104
100 microfarad, 35 volt (or higher) axial lead aluminium foil electrolytic capacitor	1	ESR	810-096
100 nF (0.01 microfarad) ceramic disc capacitor	2	ESR	871-061
10 megohm 1/4 watt carbon resistor (Bands: Brown,Black,Blue)	1	ESR	906-610
1 megohm 1/4 watt carbon resistor (Bands: Brown,Black,Green)	3	ESR	906-510
470K 1/4 watt carbon resistor (Bands: Yellow,Purple,Yellow)	1	ESR	906-447
10K 1/4 watt carbon resistor (Bands: Brown,Black,Orange)	1	ESR	906-310
2.7K 1/4 watt carbon resistor (Bands: Red,Purple,Red)	1	ESR	906-227
1K 1/4 watt carbon resistor (Bands: Brown,Black,Red)	2	ESR	906-210
100 ohm 1/4 watt carbon resistor (Bands: Brown,Black,Brown)	1	ESR	906-110
Reel of multi-strand connecting wire 6 amp Red	1	ESR	054-112
Reel of multi-strand connecting wire 6 amp Blue	1	ESR	054-116
Reel of solid core (or local phone wire)	1	ESR	055-111

ESR <http://www.esr.co.uk> Tel: 01912 514 363

While the components listed above are the parts needed to construct the electronics board, the following items may be needed in addition when testing and installing the board in a vehicle:

Component	Use
Rubber or plastic grommets	To protect wires from rubbing against the edges of the holes in the box
Crimp "bullet" connectors	Male and female, one pair for each sensor wire cut
Mounting bolts, nuts and spacers	To hold the circuit board securely, clear of the box.
Double-sided adhesive tape	For mounting the box on the dash. Alternatively, hardware items for this.
Fuse-box connector	For connecting to the fuse box to give an ignition-switched 12V supply
10K resistor and 1K Linear variable resistor	For bench testing with voltages of up to 1 volt, if these components are not already to hand
Multimeter	For general checking of voltages, continuity, etc.

I should like to express my sincere thanks to the various members of the 'watercar' Group who provided the technical information and patient support which made this document possible.