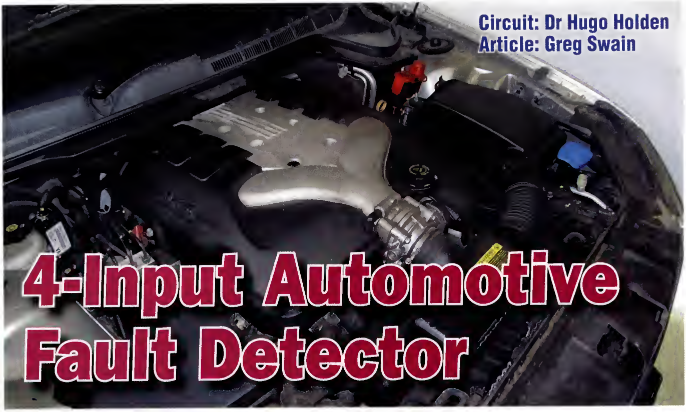


Circuit: Dr Hugo Holden
Article: Greg Swain

4-Input Automotive Fault Detector

Got a car engine that cuts out suddenly and unexpectedly? Does the car have an intermittent bug or gremlin in its electrical system? This 4-Input Automotive Fault recorder is just the shot for tracking down an elusive fault that's missed by the onboard diagnostics.

ONE OF OUR regular contributors, Dr Hugo Holden, recently sent in a Serviceman's Log story describing how he tracked down an elusive, intermittent engine fault in a 1993 Holden Berlina. At unpredictable times, after it had been running for a while, the car's engine would suddenly cut out and could only be restarted again after about 10 minutes. The dealer he bought the car from hadn't been able to fix it, so he devised a clever method of solving the problem himself.

The car's ECU (engine control unit) and ignition timing pick-up had already been replaced by the dealer, so that eliminated those two possibilities. So was it a fuel pump problem, a sudden failure of the injector pulses or were the HT pulses to the spark plugs going AWOL? Or was there some other obscure bug? Once the engine had cut out, the ECU shut everything down so it was impossible to tell.

Hugo Holden's initial approach was to assume that it was an electrical problem and so he designed a simple 4-Input Fault Detector with indicator LEDs. This circuit was then used to monitor four control signals: (1) the ECU's output to the fuel pump relay; (2) the fuel pump relay's output (ie, the voltage driving the fuel pump); (3) fuel injector drive pulses and (4) the HT ignition pulses to one of the spark plugs.

While ever these circuits all functioned normally, the detector's four indicator LEDs were all off. However, if one circuit developed a fault, its corresponding indicator LED would light and (simultaneously) the other three would be "locked out", so that they would not light as the engine was quitting. And that would be the "gotcha" moment, as the lit LED would indicate the system that brought it to a halt.

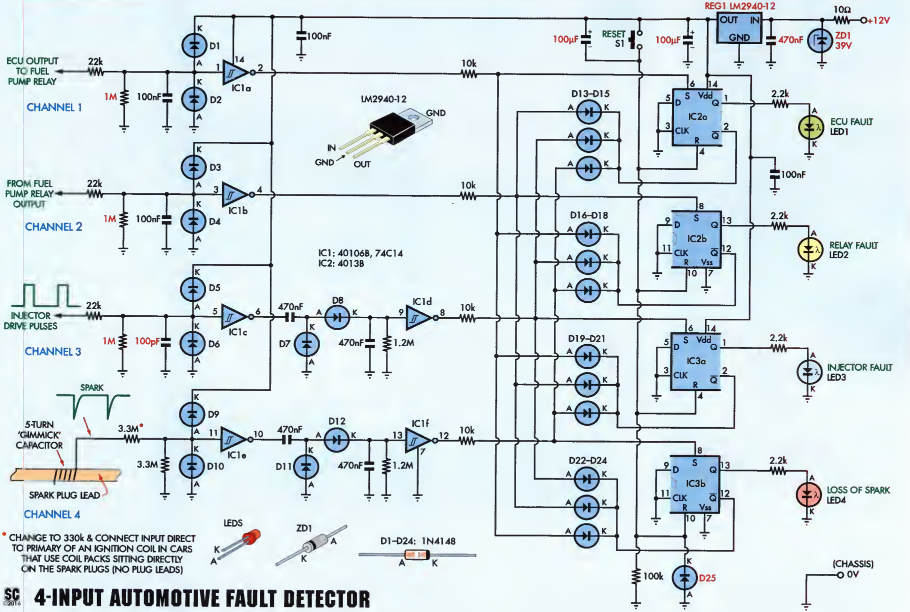
If you haven't read Dr Holden's story in this month's Serviceman's Log then take a look at it now (see "Fault Detector Solves Difficult Intermittent In A Holden Berlina"). It gives the background and describes how he tracked down an elusive (and potentially dangerous) fault in his car. We won't spoil the mystery by telling you what it was here; it's all in the Serviceman's Log.

Along with the story, Dr Holden also sent in the full circuit details of his fault detector. We liked the idea so much that we decided to design a PCB for it, so that anyone can easily build it.

Circuit details

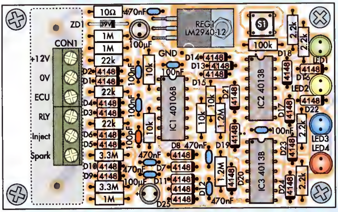
Fig.1 shows the circuit devised by Dr Holden, with just a few minor enhancements (the parts labelled in red). First, we've added more protection to the supply line in the form of zener diode ZD1 and an LM2940-12 automotive voltage regulator (REG1). The addition of REG1 also allowed us to reduce the 1000μF filter capacitor originally used to 100μF.

Other changes to the original circuit include the addition of 1MΩ pull-down resistors on three of the inputs (channels 1-3), to ensure that the device would "notice" if any of the signals went momentarily open-circuit, and a 100pF filter capacitor across the injector pulse input circuit to filter any spikes which may be induced by the ignition system. We also added a 100μF capacitor across switch S1, to



SC ©2016 **4-INPUT AUTOMOTIVE FAULT DETECTOR**

Fig.1: the circuit uses a 40106B hex Schmitt trigger IC to monitor four inputs: the ECU's output to the fuel pump relay, the fuel pump relay output, a set of injector pulses and the HT pulses to one spark plug. If an input signal ceases, the Set input of its associated 4013B flipflop is pulsed high and its output LED lights. At the same time, diodes D13-D24 ensure that the Set inputs of the remaining flipflops are latched low, so that their LEDs stay off.



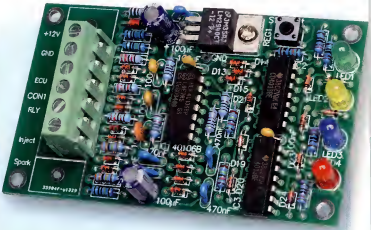


Fig.2: follow this parts layout diagram and the photo to build the PCB. Be careful not to get the ICs mixed up and note that the LEDs should be mounted horizontally if you intend installing the unit in a box (see text).

provide an automatic power-on reset.

Previously, it was necessary to press S1 to reset the circuit after power-on, to ensure that all LEDs were initially off. This meant that the unit had to be mounted inside the cabin, so that the reset switch could be reached. Including the automatic power-on reset means that the circuit can now be mounted under the bonnet; there's no longer any need to run wires through the firewall and into the cabin. With this arrangement, it's simply a matter of opening the bonnet after the engine cuts out to see which LED is lit.

As shown in Fig.1, the circuit uses just three ICs: a 40106B hex Schmitt trigger inverter (IC1) and two 4013B dual-D flipflops (IC2 & IC3). LEDs1-4 are the output status indicators.

IC2a, IC2b, IC3a and IC3b all have their D (data) and CLK (clock) inputs connected to ground so that they operate as Set/Reset (or RS) flipflops. Their reset (R) pins are connected in parallel and are normally pulled low via a 100kΩ resistor. When power is applied, these reset pins are all briefly pulled high via the 100µF capacitor (or when S1 is pressed), and so the flipflops are all reset, with their Q outputs low and Q-bar outputs high. This ensures that LEDs1-4 are all initially off.

Moving now to the inputs, channel 1 monitors the ECU's drive to the fuel pump relay, while channel 2 monitors the line from the fuel pump relay to the pump itself. These two channels are identical, so we'll just concentrate on channel 1.

When the engine is running, the pump relay signal from the ECU will be high (ie, at +12V). This signal is filtered and fed to pin 1 of Schmitt trigger inverter IC1a. IC1a's pin 2 output will thus be low and so flipflop IC2a will remain in the reset state, with its Q output low and LED1 off.

However, if the ECU's output suddenly fails, pin 1 of IC1a switches low (aided by a 1MΩ pull-down resistor) and so its pin 2 output goes high. This pulls IC2a's Set input (pin 6) high and forces its outputs to the set state, with Q high and Q-bar low. As a result, LED1 lights to indicate an ECU fault.

At the same time, the signal to the Set inputs of the other three flipflops are pulled low by IC2a's Q-bar output via diodes D13, D14 & D15. This ensures that these flipflops remain reset and so LEDs2-4 stay off. This effectively prevents these LEDs from turning on when their respective channel inputs go low as the engine stops.

This means that only the LED associated with the fault that initiated the engine shut-down can light. The others are effectively locked out. The same scheme is used for the other three flipflops, utilising diodes D16-D24.

Diodes D1 & D2 are included to protect IC1a by clamping the input signal to the supply rails.

Channel 2 operates in exactly the same manner. It turns on LED2 if the output from the fuel pump relay suddenly fails while the engine is running.

Injector & ignition pulses

Channel 3 is used to monitor the drive pulses to one of the fuel injectors. First, the signal is filtered and inverted by IC1c. IC1c then drives a charge pump circuit consisting of diodes D7 & D8 and two 470nF capacitors.

When injector pulses are present, the square-wave signal couples through the series 470nF capacitor, charging the subsequent capacitor via D8 and

Injector & Ignition Pulses Can Cease During Engine Over-Run

This Event Recorder was initially developed to troubleshoot a problem in a 1993 vehicle. However, most modern cars switch off the injectors and the ignition when the engine is in over-run and the throttle is closed. This typically occurs during a downhill run and is done to save fuel.

This condition would cause either LED3 or LED4 in the Fault Detector to light, so you need to keep this in mind when using this unit. In fact, it may be necessary to mount the reset switch inside the cabin so that the unit can be manually reset if this occurs.

In some cases, it may be possible to alter the driving style to prevent this from happening. Normally, the injectors switch off only if the engine speed exceeds about 1500RPM and the throttle is closed.

Finally, note that many modern cars don't have spark-plug leads. Instead, they use an ignition coil pack which is fitted directly to the spark-plugs.

If so, it may be possible to detect ignition pulses in a lead that connects to the primary of one of the coils (eg, near the connector). In that case, the input is connected directly to the primary lead (instead of via a gimmick capacitor) and the input resistor is changed to 330kΩ (see Fig.1).

Low-Side Switching

On many cars, the ECU's output to the fuel pump relay will employ low-side switching, ie, it switches the relay coil's negative lead. Similarly, the relay's output may switch the negative side of the fuel pump.

If so, an additional inverter stage will be required after IC1a and/or IC1b. This can be done by piggy-backing another 40106B (with all but its supply pins splayed out) on top of IC1. The relevant PCB tracks can then be cut and the connections run using short lengths of wire.

so pin 9 of IC1d is high and its output remains low. IC3a is thus held in the reset state and LED3 is off. However, if the injector pulses suddenly cease, the 470nF capacitor discharges through its parallel 1.2MΩ resistor (in around 500ms) and IC1d's pin 8 pulls the Set input of IC3a high. IC3a then turns on LED3 to indicate an injector fault.

The other three LEDs are latched off in exactly the same manner as before.

Channel 4 monitors the HT pulses to one of the spark plugs. As shown, the HT pulses are picked up by winding five turns of wire around one of the plug leads to form a "gimmick" capacitor. The resulting capacitively-induced pulses are then fed to pin 11 of IC1e.

IC1e drives a charge pump circuit which operates in exactly the same manner as for channel 3. If the ignition pulses suddenly cease, IC1f's output switches high and drives LED4 via flipflop IC3b.

Building it

All parts are mounted on a double-sided PCB coded 05109161 and measuring 89 x 53.5mm. Fig.2 shows the parts layout on the board.

Begin the assembly by installing the resistors, diodes and zener diodes. Pushbutton switch S1 and the three ICs can then be installed, followed by the capacitors. Don't get the ICs mixed up; they all have 14 pins but IC1 is a 40106B while IC2 & IC3 are both 4013B types. Make sure that they are all orientated correctly.

Regulator REG1 can now go in. It's installed flat on the PCB with its leads bent down through 90° some 8mm from its body so that they go through their respective holes. Fasten REG1's metal tab to the PCB using an M3 x 6mm machine screw, washer and nut before soldering its leads.

LEDs1-4 are next. Take care with their orientation; the flat (K) side of each LED body goes towards the bottom edge of the PCB.

If you going to mount the unit in a box, you should install the four indicator LEDs horizontally. That's done by bending each LED's leads down through 90° about 2mm from its body, then soldering it in place so that it sits slightly proud of the board's top surface. The LEDs can then protrude through holes drilled in the side of the box. In this case, you should also use a chassis-mounted momentary pushbutton switch in place of reset switch S1, in case you need to manually reset the unit once it's in place.

Connector CON1 is fitted last. You can either use a 6-way PCB-mount terminal barrier strip or two 3-way screw terminal blocks. The barrier strip makes it somewhat easier to terminate leads but will be too tall to fit inside the specified case (in which case screw terminal blocks will have to be used).

If you're using the specified case, the PCB is mounted using the tapped spacers and machine screws specified in the parts list. While not strictly necessary, we've also listed parts so that you can make a connection between the pad marked GND on the PCB and the earthed metal case, ie, using a solder lug, machine screw, washer, nut, length of wire and a PCB stake.

The six wires going to CON1 can pass through a cable gland fitted on the end of the box.

Fitting it

Mounting the unit in the engine bay will usually be the best approach. In most cars, this will give easy access to the main fusebox, so that you can access power and the fuel pump relay. It also makes it easy to make the connections to one of the spark leads and a fuel injector signal lead.

Be sure to install any wiring in a professional manner, so that you don't compromise the car's existing wiring and cause further problems. For example, if you need to penetrate any insulation to make a connection, make sure the connection is waterproof so that you don't have problems in wet or humid weather and so that corrosion will not be encouraged.

Note that this circuit may not work in all respects with all cars. There are lots of different vehicle wiring configurations, so check carefully before fitting this unit.

Note also that the outputs won't latch until about 10s after powering on or resetting the unit, due to the 100µF capacitor on the reset line. **SC**

Parts List

1 double-sided PCB, code 05109161, 89 x 53.5mm
1 6-way PCB-mount terminal barrier, 8.25mm-spacing* (CON1, Altronics P2106) ***OR***
2 3-way screw terminal blocks, 6mm spacing (CON1)
1 4-pin tactile pushbutton switch (S1)
1 M3 x 6mm machine screw & nut

Semiconductors
1 40106B or 74C14 hex schmitt trigger (IC1)
2 4013B dual flip flops (IC2,IC3)
1 LM2940-12 automotive low-dropout regulator (REG1)
1 green 5mm LED (LED1)
1 yellow 5mm LED (LED2)
1 blue 5mm LED (LED3)
1 red 5mm LED (LED4)
1 39V 1W zener diode (ZD1)
25 1N4148 diodes (D1-D25)

Capacitors
2 100µF 16V electrolytic
5 470nF multi-layer ceramic
4 100nF ceramic disc or multi-layer ceramic
1 100pF ceramic disc

Resistors (all 0.25W, 1%)

2 3.3MΩ	3 22kΩ
2 1.2MΩ	4 10kΩ
3 1MΩ	4 2.2kΩ
1 100kΩ	1 10Ω

Additional parts for box mounting
1 diecast aluminium case, 111 x 60 x 30mm (Jaycar HB5062)
1 cable gland to suit 3-6mm cable
8 M3 x 5mm machine screws
1 M3 x 10mm machine screw, star washer and nut
1 solder lug
1 1mm diameter PCB stake
4 M3 x 6.3mm tapped Nylon spacers
1 short length green hook-up wire

* Note: terminal barrier is too tall to fit in the specified diecast case – see text

4-Input Automotive Fault Detector, September 2016: the 3-way screw terminal blocks that make up CON1 have 5mm pin spacing, not 6mm as stated in the parts list.