WELLS Counter Point

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THE ELECTRONIC, DIAGNOSTIC AND DRIVEABILITY RESOURCE.

Fuel Injectors…And Further More

Today's electronic fuel injection systems provide more effective and reliable fuel delivery systems than the carburetors they replaced.

In Part One, we provided information on how electronic fuel injectors work and explained some of the ways they may decide to malfunction. We'll continue with our fuel injector troubleshooting analysis, but first, more information about fuel injector types.

Four of a Kind

Rather than stating that there are four different types of electronic fuel injectors, it would be more accurate to say there are four different types of fuel injector *circuits*. For while the electrical construction of the fuel injectors vary little from one application to the next, the switching transistors or drivers which control the fuel injectors can be quite different. The four types of fuel injector circuits are:

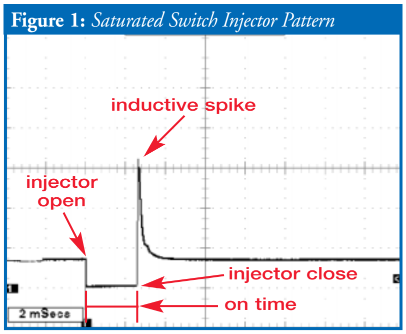
- Saturated Switch Type
- Peak and Hold Type
- Bosch-type Peak and Hold Type
- PNP Type

Saturated Switch

The saturated switch fuel injector driver is the type most commonly used. Fuel injectors in these systems are fired either sequentially or in groups.

The oscilloscope pattern produced by a saturated switch fuel injector circuit is shown in **Figure 1**. The fuel injector windings are provided with positive voltage when the ignition switch is in the ON position. The injector driver completes the circuit by providing a ground. This is when the oscilloscope trace drops to zero volts.

Figure 1: *Saturated Switch Injector Pattern*



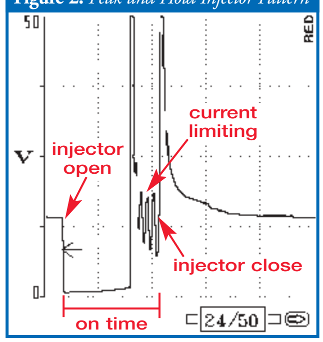
When the fuel injector driver turns the circuit OFF by removing the ground, an inductive spike is produced as the magnetic field surrounding the fuel injector windings collapses. This spike is captured by the oscilloscope as a vertical line. A fuel injector with shorted windings will shorten the spike (reduced amplitude). Injector pulse width, or ON time, can be determined by measuring the time the oscilloscope trace remains at 0 volts.

Peak and Hold

Peak and hold fuel injectors are often found on throttle body injector (TBI) systems and low resistance fuel injector circuits. An electrical solenoid (like a fuel injector) takes four times more current to get the injector pintle in motion than it does to hold the pintle in place once it's open.

Rather than continuing to provide four amps to the injector when only one is required to keep it open, the peak and hold injector driver electrically limits the flow of current. This type of fuel injector control produces an oscilloscope pattern as in **Figure 2**.

Figure 2: *Peak and Hold Injector Pattern*



The fuel injector driver opens the fuel injector by holding the circuit to ground until the injector has 3.5-4.0 amps flowing through it.

When the predetermined current peak is reached, the PCM cuts back the current to a maximum of one amp by switching to a current limiting resistor. This reduction in current causes the magnetic field surrounding the fuel injector windings to partially collapse, which causes the first inductive spike seen in the oscilloscope pattern.

The fuel injector driver circuit is still providing one amp to the fuel injector, so the injector stays open and fuel continues to flow. Finally, the fuel injector driver completely removes the ground from the circuit, producing the last inductive spike that signals the end of the injector ON time.

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Fine Tuning

***Fine Tuning** questions are answered by Mark Hicks, Technical Services Manager. Please send your questions to: Mark Hicks c/o **Wells Manufacturing Corp., P.O. Box 70, Fond du Lac, WI 54936-0070** or e-mail him at **technical@wellsmfgcorp.com.** We'll send you a Wells shirt if your question is published. So please include your shirt size with your question.*

Q: "I have a 1995 Chevrolet K1500 Truck with a 5.7L engine. There are no driveability problems until the truck is driven over 45 mph for 4-5 minutes. At that time, the engine service light activates but no code is stored. I can shut off the engine and let it sit for 10 seconds. Upon restart, the light will be out. It will stay out until I reach 45 mph and start to cruise again. I have replaced the thermostat but it didn't help. Next, I am going to look at the O2 sensor. What do you think?"

Richard Alsip, Technical Services/Information Services and Technology, University of Manitoba, Winnipeg, Manitoba, Canada

Yes, the next step would be to look at the O2 sensor. When I have run into this problem in the past the engine was running lean, rich or the O2 sensor was defective. I would also look at the cap, rotor, ignition wires, spark plugs and coil. If the engine has a miss, the O2 sensor will sense a lean condition. Also check for any vacuum leaks.
Results: The cause was a very slight leak in the EGR vacuum diaphragm. Replaced it and the problem was solved.

Q: "I have a 1993 Pontiac Grand Am with a 2.3L quad 4. I have noticed a lot of carbon tracking on the module/coils. Everything seems to check out okay on the secondary side of the ignition system, but where do these tracks come from?"

Rob Gunwall, Glendale, CO

The tracks are normal. They occur as a result of the high secondary voltage passing down the conductor. The RFI, as a result of the high voltage, causes the air to ionize and become conductive. The stray voltage will find a path to ground, causing these tracks. This is why the ground strap under the cover needs to be in place. However, it is common for these covers to burn out one or more of the conductors to the spark plugs. Use an ohmmeter to check for continuity from each coil tower to the spark plug terminal.

Q: "I have been working on a 1997 Ford Ranger with a 4.0L engine. The engine surges at idle and codes P0171 and P0174 are stored. I have gone through the diagnostic procedures for each of these codes and no problem was found. A friend at the dealership suggested cleaning the mass air flow wire. I took it out and it was clean. Do you have any ideas?"

Joe Stanicke at Joe's Repair, Escanaba, MI

Codes P0171 and P0174 are activated because the left and right O2 sensors are staying lean too long. The cross counts are minimal. If the spark plugs, wires and coil are in good shape, I would look for a vacuum leak. We also found Ford TSB #98-6-8, which refers to a vacuum leak under the intake manifold caused by a defective gasket. It explains how the gasket can become drawn in and supplies a new gasket number for replacement.
Results: The old gasket was replaced with the new number and the vehicle is running like a champ.

Diagnose The Problem Win A Shirt

I have been working on a 1994 Chevrolet Lumina with a 3.1L engine for several days. It has a misfire on Cylinder #5. I have replaced the spark plugs, ignition wires and coils with no change. I did notice that all the plugs were white except # 5 — it was black. Next, I ohm-tested the injectors. They were all at 12 ohms, which is within specs. However, I still replaced #5. Still no help. I took the plenum back off to check for a vacuum leak. No leak was found. I then swapped the coils and module for known good ones. Still no better. I talked to the dealership and they suggested a compression check. All the cylinders had from 145-160 psi. Please help. I am at the end of my rope!

The first reader to respond with the most accurate answer via e-mail or fax, and the first reader to respond with the most accurate answer via snail-mail, will receive a Wells golf shirt. The answer will appear in the next issue.

Last issue's question regarding a '96 Mercury Grand Marquis with a P0121 DTC was called in by Patrick Juliana of Patrick's Automotive, Kenosha, WI

When the PCM determines a code P0121 on this vehicle, it looks at MAF, TPS, and RPM inputs. In this case, the RPM was too high for the position of the TPS and the output of the MAF. Unmetered air is entering the intake, causing this to occur. The culprit this time was a crack in the PCV elbow.

The first correct answer received by e-mail was from John McDaniel of Partners Garage Inc., Huntington Station, NY. The first correct answer received by regular mail was from Countryside Transmission, Cromwell, KY.

Congratulations and thank you all for the many responses we received.

Quality Points

Wells Quality Assurance Department Updates Its Facility

Thanks to the Wells Quality Assurance Department, a technician installing a Wells product can be confident that the part will meet or exceed original equipment specifications and performance. Recently, the Quality Assurance Department was updated, incorporating many technological advancements.

The all-new environmentally-controlled facility is located directly adjacent to the Wells Manufacturing Corp. production area. This allows Wells Quality Assurance personnel to closely monitor the manufacturing process and maintain the high levels of quality that have been a Wells benchmark since 1903.

The new location makes the Quality Assurance Department more accessible to other departments as well. The Tool Room can easily bring in dies and molds for review before production runs and Design Engineering can use the Quality Assurance Department for assistance with Research and Development of new products.

American Society for Quality Certified Technicians utilize a Direct Computer Controlled Coordinate Measuring Machine (DCC CMM) and Vision System to perform OE and aftermarket product analyses, reverse engineering and calibration of shop floor gauging. The measurement capability of this equipment exceeds .0001 inch — less than 1/25 of a human hair.

DCC CMM

With industry standards becoming increasingly stringent, maintaining QS-9000 registration requires cutting edge facilities, equipment and personnel. As a fully QS-9000 certified company, Wells Manufacturing Corp. can ensure a top quality product that is second to none.

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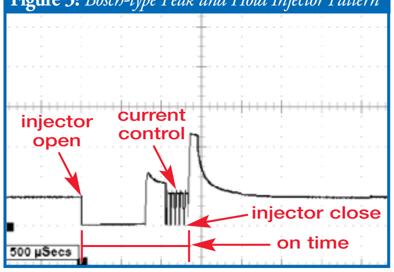
Fuel Injectors...And Further More

Bosch-type Peak and Hold

The Bosch-type peak and hold injector driver circuit can be found on some European multi-point fuel injection (MFI) systems, as well as some Asian MFI systems. Rather than reducing the current flow through the circuit to one amp after the injector opens, Bosch-type peak and hold systems rapidly pulse the current to the fuel injector OFF and ON. This takes place so quickly that the fuel injector remains open and fuel continues to flow. The fuel injector finally closes when the fuel injector driver completely removes the ground from the circuit.

The Bosch-type peak and hold injector driver circuit produces an oscilloscope pattern as seen in **Figure 3**. On some Asian systems, there may be two or three release spikes that look very similar to the pattern produced by conventional peak and hold injector drivers. The total fuel injector ON time is determined by measuring from the point where the signal trace drops to 0 volts to the final upward inductive spike.

Figure 3: *Bosch-type Peak and Hold Injector Pattern*

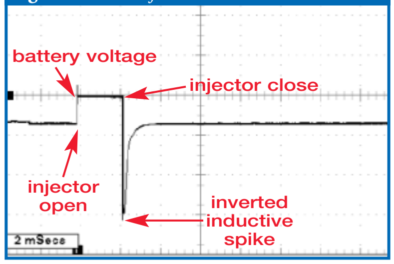


PNP Fuel Injector Driver

The PNP injector driver is named after the Positive-Negative-Positive (PNP) switching transistor that controls the operation of this fuel injector circuit. The fuel injector driver controls the circuit by opening and closing the positive side of the circuit. PNP fuel injector drivers pulse the power to an already grounded fuel injector to turn it ON.

When viewed on an oscilloscope as in **Figure 4**, the trace from this type of circuit looks 'upside down.' When the fuel injector driver turns the fuel injector ON, the trace moves upward toward battery voltage, rather than downward toward ground. When the fuel injector driver turns the fuel injector OFF, the trace spikes downward as the magnetic field surrounding the fuel injector coil winding collapses. Total fuel injector ON time is determined by measuring from the point where the signal trace rises to battery voltage to the final downward inductive spike.

Figure 4: *PNP Injector Pattern*



Injector Testing

Fuel injectors are relatively simple electrical devices. In fact, they have more in common with the lowly starter solenoid than with just about any other electrical device found under the hood. When an electrical current is supplied to the fuel injector, it flows through the fuel injector's windings. The magnetic field surrounding the fuel injector's windings then converts electrical energy into the mechanical energy needed to move the pintle off its seat.

Problems can develop for a number of reasons. As we explained in Part One, a fuel injector may become clogged or worn, preventing efficient operation. Or its windings may become shorted or open. That's about as complicated as it gets. But it *can* get complicated when it comes time to determine *which* injector is defective and *why* it failed.

All electronic fuel injectors contain coils of electrically insulated copper wire. The fuel injector's wire coil produces the solenoid effect needed to open the injector pintle. A specific number of turns and a specific gauge of wire are used for each injector type. These specifications give the injector its operating characteristics.

A simple way to check a fuel injector's electrical integrity is to measure the resistance of its coil windings. The reading should be taken when the fuel injector is at operating temperature. Shorted or open windings may not show up if the resistance is checked while the fuel injector is sitting on the bench at room temperature. An injector that reads significantly lower than specifications may be internally shorted. An injector that reads infinity on the ohmmeter has open windings.

Some injectors are hidden in inaccessible locations. It may be necessary to measure the combined resistance of a group of injectors on an engine by tapping into the wiring harness at a more convenient location. The combined resistance of four or more injectors wired in parallel will actually be *less* than a single injector when measured alone.

The combined resistance of the circuit is determined by dividing the resistance value of a single fuel injector by the total number of fuel injectors in the parallel circuit. So a group of four injectors with an individual resistance specification of 14 ohms should have a combined resistance value of 3.5 ohms ($14 \div 4 = 3.5$). The combined resistance reading would change if one or more injectors in the group were either shorted or open.

A static fuel injector resistance test may be only a partially effective method of detecting a defective fuel injector. Some fuel injectors will only fail when they are doing actual work. There are two methods of simulating these conditions. The first involves the use of a dedicated fuel injector tester. The tester is attached to the fuel injector's electrical connectors and a specified electrical load is applied to simulate injector operation. With actual current applied to the fuel injector, heat is produced within the fuel injector windings. This may reveal internal shorts or opens that could remain hidden during a static fuel injector winding resistance test.

The second method of dynamic fuel injector testing involves the use of an oscilloscope. By attaching the oscilloscope leads directly to the fuel injector circuit, it is possible to observe the electrical components of the circuit 'in action,' with actual circuit loads applied. With the engine running, the oscilloscope's fast sampling rate allows it to capture any glitches which may be caused by intermittent shorts or opens in the fuel injector circuit. An experienced 'scope user can spot a fuel injector that has begun to fail, but has yet to fail completely.

OBD II DTC Misdirection

We plan to devote future *Counter Point* articles to OBD II diagnosis and repair. However, there is a particular type of OBD II failure that has a direct connection to this month's topic of fuel injector diagnosis. As you know, OBD II has dramatically increased the number of diagnostic trouble codes (DTCs) available to pinpoint engine management problems. We'd have to say this is a good thing. But there are occasions when OBD II DTCs can lead you down the wrong diagnostic path.

Suppose you're confronted with a cylinder misfire DTC. OBD II can actually tell you which cylinder has the misfire. But the problem might reside elsewhere.

On many fuel injection systems, injectors are fired in groups, rather than sequentially. A partially shorted injector will grab the lion's share of the current, and the remaining injectors may not receive enough current to open. If an injector fails to open or only partially opens, that cylinder may misfire. This produces a misfire code. While OBD II correctly identifies the effect, in this case it misses the cause.

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INSIDE: Fuel Injectors

Hot off the Wire

Wells Introduces 2001 Wire, Cable and Battery Accessories Catalog

The new 2001 Wire, Cable and Battery Accessories Catalog is now available from Wells Manufacturing Corp. This year's catalog features a dramatic increase in overall product offerings. In all, over 687 new part numbers have been added, including:

- 33 new premium quality lifetime warranty ignition wire sets
- 268 new battery cables
- 181 new battery terminals
- 205 various new battery accessories.

Among the new battery accessories offered are:

- Hold Downs
- Protector Boots
- Premium Primary Wire
- Heat Shrink Tubing
- Duplex, Triplex and Quadraplex Wire
- Speaker Wire
- Trailer Lighting Cable
- Bonded Parallel Trailer Wire
- Nylon Loom
- Solder Connector-Type Battery Terminals
- Marine Cable
- Welding Cable
- Starter Cable
- Tools

The layout of the Wire Set application information has been reformatted for easier look-up. Application look-up data has also been added for battery cables. Cable part numbers for cars, trucks, tractors and combines are covered on these pages.

For information on obtaining copies of the new catalog, contact your nearest Wells distributor or representative.

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