WELLS Counter Point
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The Triangle Of Doom

Hybrid repairs may be coming your way. Is your shop ready for this rapidly emerging technology?

This issue's case study was contributed by "G" Jerry Truglia.

The following challenge involves a 2001 Toyota Prius hybrid with 98K on the odometer. While driving, the owner noticed a warning light on the dash. The warning light was shaped like an exclamation point inside a red triangle. It looked serious, so the owner decided to take the vehicle to the Toyota dealer. The service adviser listened to the owner's complaints and checked the vehicle dash for the illuminated triangle. His next step was to write up the repair order (RO) and assign the shop's certified hybrid technician.

In order to solve this problem, the technician performed visual and scan tool diagnostic procedures. Results indicated a HV (high voltage) battery problem that was identical to a Toyota TSB concerning early Prius vehicles. The repair involved removing the HV battery from the vehicle, cleaning and sealing the battery terminals, along with changing the battery terminal strips. The technician performed the repair, cleared the DTC and sent the vehicle on its way.

As the Prius owner was driving home, she heard an unusual noise coming from the front of the vehicle. Since she had not heard this noise before the vehicle's repair, she returned the Prius to the dealer for further diagnosis. The vehicle was assigned to the same hybrid technician for an undercarriage inspection. After an hour of diagnosis and test drives, he determined that the noise was coming from the drivetrain. As you can imagine, a drivetrain problem on a hybrid vehicle would not be cheap.

Remember, the vehicle came to the shop because of a warning light, not a transaxle noise. The service adviser started his conversation with the Prius owner by reminding her that the diagnosis and repair of the HV battery was performed at no charge. He explained that the noise was coming from the transaxle and would not be covered under warranty. The owner questioned why the noise appeared after the repair and wanted to know how much the repair was going to cost. The service adviser told her the repair estimate was $5,500 because it involved replacing the entire transaxle unit. Toyota only sells the transaxle as a complete unit since it has two high voltage motor generators inside its casing. The Prius owner did not have confidence in the dealer's diagnosis, so she decided to take the vehicle to a transmission shop for another opinion.

Before we move on, a word of caution is in order. We need to make sure that you understand what is needed before attempting any diagnosis or repairs on hybrid vehicles.

Precautions must be taken before attempting to diagnose or repair any component that has orange wires connected to it. The equipment needed is as follows: a CAT III meter and scope that is capable of handling 1,000 volts, accurate vehicle service information, 1,000-volt gloves with protective liners and safety glasses.

The Prius hybrid system uses two electric motor generators (MGs): MG 1 and MG 2. Both provide electric power to the HV battery, while MG 2 delivers power to the drive wheels. The motor generators are three-phase AC electric motors that generate voltage in the 500-volt range. The HV battery consists of six 1.2-volt nickel metal hydride (Ni-MH) batteries that are connected to form a module. There are a total of 38 modules divided into two holders on the 2001-03 Toyota Prius. The battery stores a total of 273.6 volts. 2004 and newer Prius vehicles store 201.6 volts and have 28 battery modules.

The transmission technician checked and diagnosed the vehicle, confirming a transaxle problem. As he scanned the ECU, the technician came upon DTC P1636 (HV ECU Malfunction). The technician thought this DTC might be connected to the transaxle because it involved high voltage. The transmission shop was confident they could repair the vehicle, so they provided the Prius owner with a couple of options. One was to purchase a new replacement unit from Toyota and the other was to purchase a unit from a salvage yard. The Prius owner wanted the least expensive way out.

Before the transmission technicians decided to replace the transaxle, they came over to the training center to consult with me. I provided them with accurate service information and reviewed all of the safety requirements.

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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, L.P., P.O. Box 70, Fond du Lac, WI 54936-0070 or e-mail him at technical@wellsmfgcorp.com. We'll send you a very nice Wells golf shirt if your question is published. So please include your shirt size with your question.

We received several responses to our coverage of flex fuel vehicles in the Winter, 2007 issue of *Counter Point*. Readers requested additional information on the alcohol sensor that is used to detect the presence of and determine the concentration of ethanol in the fuel tanks of flex fuel vehicles.

For proper engine operation, these vehicles must accurately measure the alcohol/gasoline ratio of the fuel that is injected into the combustion chamber. A vehicle may have a fuel tank that's filled with 100% gasoline, a 100% E85 ethanol blend, or anything in between those two extremes. To further complicate the problem, alcohol and gasoline can physically separate in the gas tank. This can cause the actual alcohol/gasoline ratio to change very rapidly over a few minutes or even faster. Therefore, the ratio must be quickly determined on a continuous basis.

The alcohol sensor is mounted in the fuel line and uses infrared spectrometry measuring techniques to determine the ratio of light absorption of the alcohol/gasoline mixture. The alcohol/gasoline mixture is measured at two discrete wavelengths within the near-infrared spectrum. At one of the infrared wavelengths, alcohol is strongly absorbing while the gasoline exhibits very little absorption. At the second wavelength, both the alcohol and the gasoline are essentially non-absorbing.

An alternating current is used to switch the light beam between two power settings. This varies the intensity of the transmitted light at both wavelengths. The light beam is transmitted through the alcohol/gasoline fuel mixture so that the two discrete wavelengths traverse the same optical path. Two adjacent detectors receive the emitted light from each wavelength after their transmission through the alcohol/gasoline fuel mixture. Once the signals corresponding to the two wavelengths are obtained, the ratio of the absorbances of the fuel mixture at both wavelengths is computed. The concentration of alcohol in the fuel is determined from this ratio, after factoring in the temperature of the fuel mixture.

A variety of other techniques have previously been proposed for measuring the alcohol/gasoline ratio. These methods have measured various properties of the gasoline mixture, including the dielectric constant, thermal conductivity, index of refraction, change in the speed of sound through the mixture and microwave absorption. The disadvantages of these methods were their added expense and the fact that they were strongly dependent on the temperature and/or the detailed properties of the gasoline used. The composition of a particular gasoline mixture may vary considerably even within a single name brand. Consequently, these methods failed to provide the reliability required for automotive engine control applications.

An alcohol sensing device based on infrared spectroscopy generally avoids the problems associated with these previous methods, including the strong dependence on temperature and/or gasoline composition. Infrared spectroscopy is an analytical technique which measures the relative absorption of various infrared wavelengths by a particular specimen and is dependent on the molecular constitution of the specimen.

In the last issue, Chuck Wright had an overcharging problem with a 2001 Honda Civic. He found the alternator hanging loose, then replaced the mounting bolts, alternator, and battery and tightened them to specifications. After starting the engine, the charging voltage was too high at 16.5 volts.

This charging system has an internal voltage regulator in the alternator that I will assume was replaced with the alternator. However, unlike traditional charging systems, this vehicle also incorporates an Electrical Load Detector (ELD). The alternator signals the PCM during charging mode. The PCM then controls the voltage generated by the alternator according to electrical load. The electrical load is determined by the ELD and driving mode. This process reduces the load on the engine and improves fuel economy. So this system does have a voltage regulator, but the charging output is ultimately controlled by the PCM.

When the alternator mounting bolts are loose or broken, a high risk of of PCM damage will occur. Check the wiring between the alternator and PCM. If wiring checks good, replace the PCM. The wiring checked okay, so Chuck replaced the PCM to correct the overcharging problem.

The first readers with the correct answer were:

Patrick and Alan
Community Motors
St. Thomas, U.S. Virgin Islands

Ken Gutierrez
Wakefield Auto Electric
Bronx, NY

Diagnose The Problem Win A Shirt

I am working on a 1994 Olds 98 with about 96,000 miles. The vehicle came into the shop idling at about 2800 RPM. I have replaced the air injection system (AIS) motor, upper intake manifold gaskets and the throttle body gasket. I have thoroughly checked the engine for any vacuum leaks, blocked off the PCV and the EGR. I have also checked the throttle plate and it is closing completely at idle. Nothing I've don has had any effect on the idle speed. I don't understand what else could be affecting the idle speed. Please help.

Fred Ludden
Ft. Wayne, IN

If you have the answer, please use the following contact information:

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Quality Points

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manufacture of every applicable sensor. Low pressure molding is a breakthrough technology for all types of components that require added protection from moisture, dust, vibration and strain, during and after the manufacturing process. Because of the low pressures employed during the plastic molding process, the risk of damaging the delicate circuit board during manufacturing is virtually eliminated.

In addition to pioneering this low pressure molding process, Wells also utilizes a polyamide plastic material that is UL94-VO rated. This plastic is known for its exceptional hardness, impact strength, sealing capabilities and superior abrasion resistance. Even the OE manufacturers do not always require these high standards. The result of Wells' care in manufacturing and materials selection are a sensor that is stronger and performs better, while offering a longer service life right out of the box. Low pressure molding — yet another reason to make Wells Engine Management your brand. WELLS

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The Triangle Of Doom

Replacement of the transaxle went well, from powering down the vehicle to installing the used transaxle. Starting the vehicle was another story. Can you guess what came back? Well as luck would have it, the red triangle warning light was lit again. I like to call this warning light the Triangle of Doom because when it lights, it usually indicates big trouble. The replacement unit did not make any noise, but it did illuminate the Triangle of Doom.

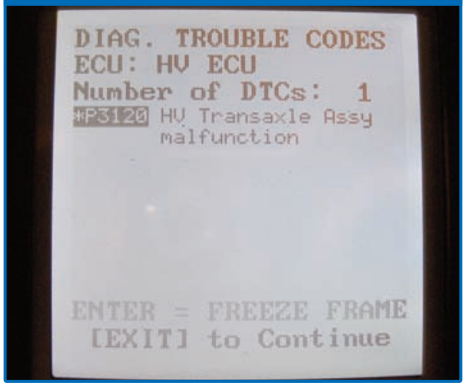
Figure 1: Checking voltage between HTE+ and HTE-

Two DTCs were set: P1636 (HV ECU Malfunction) and P3002 (HV Serial Communication Abnormality). Since both DTCs had to do with HV, the transmission shop decided to drive the vehicle over to the training center for me to diagnose. My dealer-level scan tool allowed me to extract the following DTCs: P1636 (HV ECU Malfunction), P3002 (HV Serial Communication Abnormality), P3120 (HV Transaxle Assembly Malfunction) and sub system 253 Generator Resolver Interphase Short, C1213 (HV System Communication Circuit Malfunction).

Figure 2: Installing battery pack on AGM battery

My plan of attack was to record the DTC data, clear the DTCs, start the engine and test drive the vehicle. I wasn't long into the test drive before the Triangle reappeared, along with the same four DTCs and one sub system DTC. Now it was time for me to look up information for the vehicle hybrid system. Armed with this information, I was able to continue my diagnosis.

Figure 3: DTC P3120 HV Transaxle Assy Malfunction



The first DTC concerning me was P1636 (HV ECU Malfunction). The flowchart for this DTC involves the HV ECU and communications. I thought this would be the most logical DTC to start with because it could be the root cause of all the DTCs.

Following the Toyota flowchart and checking voltage between HTE + and HTE – of the ECM, I came up with a reading of 1.49 volts and a waveform that matched Toyota's example (Figure 1). The Toyota flowchart then states that the ECM should be replaced. I've been around awhile, and it's hard for me to swallow replacing an ECM without first checking every sensor and component that is associated with it. I think that flowcharts should be renamed "trouble charts" because in many cases that's what you will find yourself in.

Figure 4: Hybrid transaxle with shorted MG windings

Since the flowchart did not make sense to me, I decided to get back to the basics and test the 12-volt battery. I found that the vehicle's absorbed glass mat (AGM) 12-volt battery was below specification. A word of caution is in order concerning this battery. Be careful when charging the AGM 12-volt battery because it can and will be damaged if the charging current surpasses 3.5 amps.

As you can see in Figure 2, I installed a battery pack and retested the ECM just to verify I was testing with the correct voltage. While retesting, I captured the identical meter and scope readings, with one difference: the DTC P1636 was gone.

DTC P3002 (HV Serial Communication Abnormality) deals with a communication problem to the HV ECU. This DTC was coming back even with the 12-volt AGM battery fully charged. I knew this vehicle now had a hard problem in the HV system but I proceeded to check the other DTCs. P3120 (HV Transaxle Assembly Malfunction) (Figure 3) confirmed the DTC HV P3002, but I had to look into the sub system DTC 253 Generator Resolver Inter-Phase Short. The sub system DTC lead me to the cause of my HV problem. The MG had a shorted winding that I confirmed with my megohm meter (Figure 4 - Bad & Figure 5 - Good.)

Figure 5: Second transaxle with good MG windings

I was on my last DTC: C1213 (HV System Communication Circuit Malfunction). This DTC is related to the antilock brake/traction control system. After researching the information on the DTC, I had a better understanding of why this DTC had set. The HV system is linked to the ABS system for charging purposes and the information listed HV problems as a major cause of this DTC.

I was confident with my diagnosis and recommended replacing the salvage yard transaxle. We waited three weeks for the salvage yard to locate a replacement. When it arrived, we made sure to check the unit for visible damage and/or shorted windings. The transaxle was replaced for the second time, test driven and checked for DTCs, all without any problems. The Prius was ready to be returned to the customer, minus the Triangle of Doom.

"G" Jerry Truglia is an experienced automotive instructor with Automotive Technician Training Services, Inc. He provides training programs and materials on Hybrid vehicles and many other topics. His new Hybrid book will be available in late 2007. You can reach G at gt@attstraining.com or (845) 628-1062.

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Quality Points

Low Pressure Molding

Moore's Law of 1965 predicted that computer operating speeds would double every two years, and they have. The same holds true for automotive onboard systems. Today's automotive computer systems are blazingly fast and accurate when compared to the first OBD II technologies.

However, a vehicle's onboard computer system is only as accurate as the sensor inputs it receives. A sensor's input must remain clear and extremely accurate in spite of the diverse environmental conditions it operates in. Today's sensors use densely populated printed circuit boards and are fast and accurate, but they are still extremely sensitive to environment effects. They are constantly surrounded by dust and moisture, as well as extremes of heat and cold. In addition, they are subjected to relentless vibration, a source of tremendous strain.

Aside from the vehicle operating environment, one of the most vulnerable times for a sensor's circuit board is during the plastic molding manufacturing process. The high temperatures and compression stress during the molding process can, and sometimes does damage a circuit board before it ever leaves the factory. For these reasons, Wells once again has stepped up to the plate by incorporating a state of the art low pressure molding technology into the

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