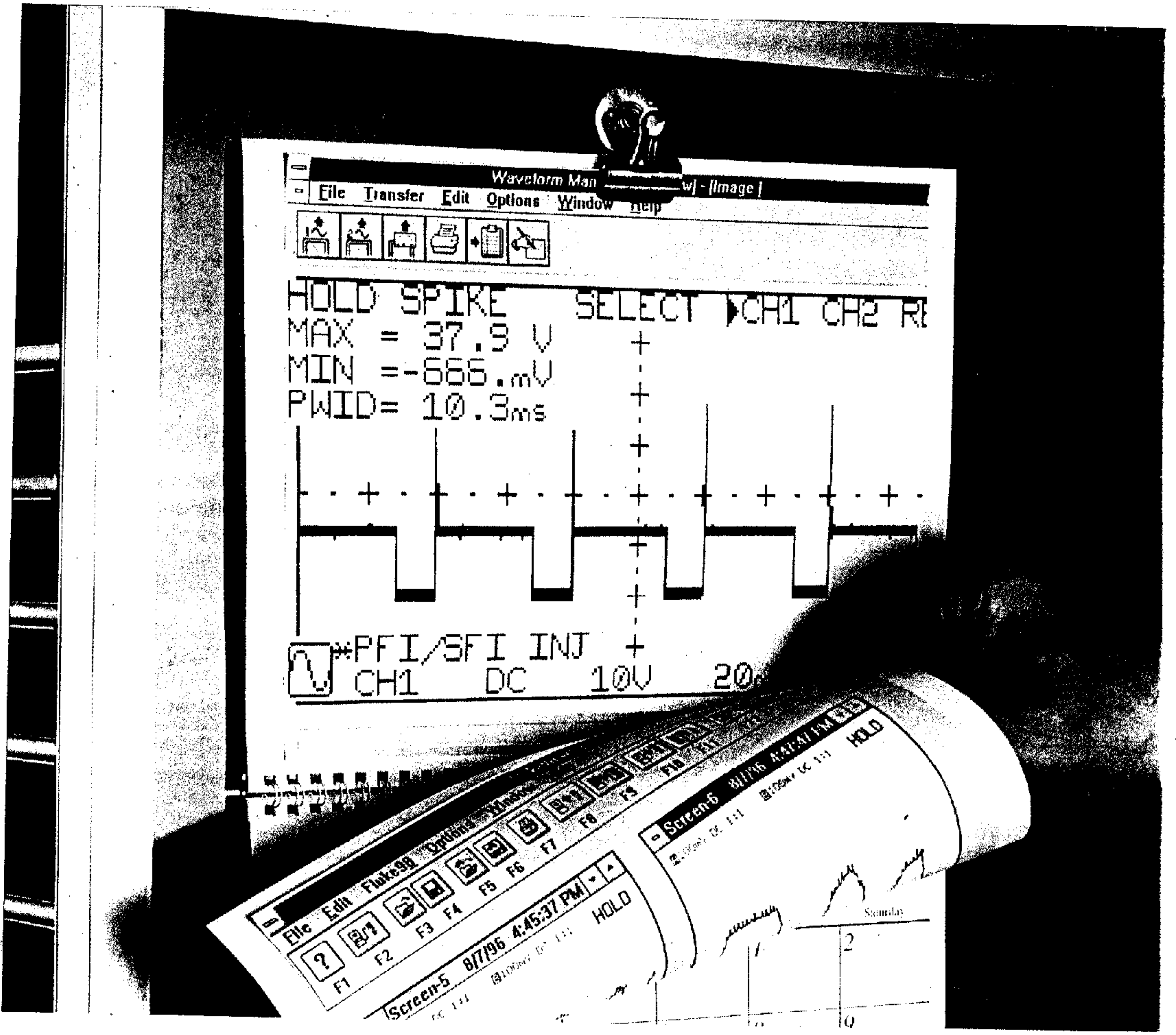


```
HOLD SPIKE    SELECT ▶CH1 CH2 RE
MAX = 37.9 V
MIN =-666.mV
PWID= 10.3ms
*PFI/SFI INJ
 CH1    DC    10V    20
```

Hall Sensors

When I decided to focus on Hall sensors for this article, my first thought was "They're pretty simple." When compared to all the activity of the Peak and Hold injectors we looked at last time, Hall sensors do seem pretty tame. But as it turns out, there's more to a Hall sensor circuit than meets the eye. There are many things to consider and discuss concerning these signal circuits.

Hall Sensors are used in many analog as well as digital applications. Compasses, position sensors, angle of rotation detectors, direction of rotation sensors, tachometers, isolated current, and voltage measuring devices all utilize Hall sensors.

Figure 1 is a block diagram that illustrates what' going on inside a typical Hall sensor. Before th Hall sensor chip can do its thing, many support circuits built into the sensor must also contribute These include:

- A voltage and current regulator that gives the Hall sensor chip a standard t work from.
- The Hall Sensor outputs its signal to a conditioning circuit, where it is changed from an analog to a digital signal.
- From the conditioning circuit, the signal is sent to the base of an NPN transistor, causing the transistor to act as a simple ON/OFF switch.

We've moved the magnifying glass back a bit in **Figure 2.** We can see that the Hall sensor needs a few support components on the outside as well. A magnet and a vane (shield) are used to interrupt the magnetic field. The interruption of the field is what causes the Hall device to switch. It's important to note that the slots in the vane are also the main factor in determining the shape of the Hall sensor's output signal.

The magnet and slots can be configured in different ways. For example the magnet and Hall Sensor can be installed in a single housing that is mounted to a gear with teeth. The teeth of the gear play the same role as the shield in our first example. For an example of the toothed gear-style Hall sensor application, take a look at a Chrysler SBEC system.

Figure 3 on page 28 shows a simplified wiring schematic of the working portion of the Hall sensor circuit. The diagram uses basic electronic symbols to represent the actual devices in the circuit. Let's take a look at each of these Hall sensor components.

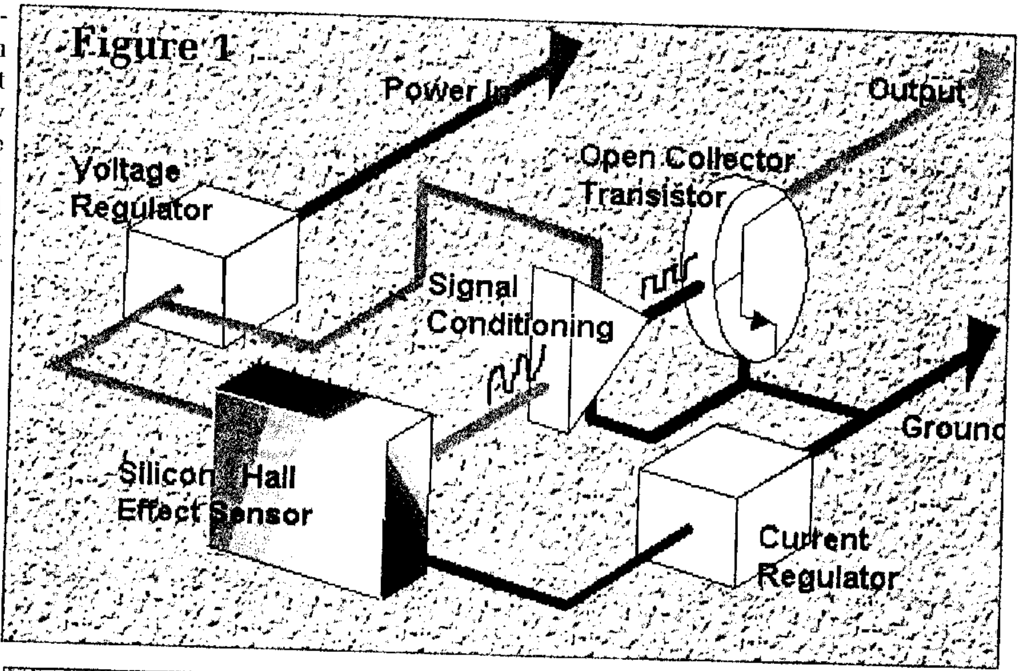


Figure 1

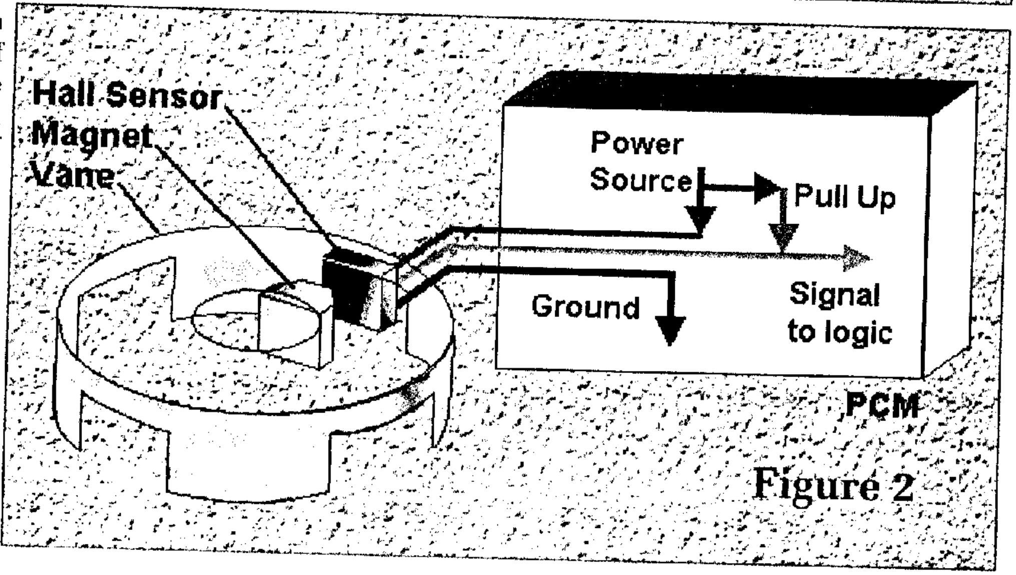


Figure 2

Sensor Power Source

The power source for this type of sensor might originate at the PCM or an ignition module. **Figure 1** shows that this voltage input is needed to supply the Hall sensor's onboard electronics. Please note that different systems use different supply voltages to their Hall sensors.

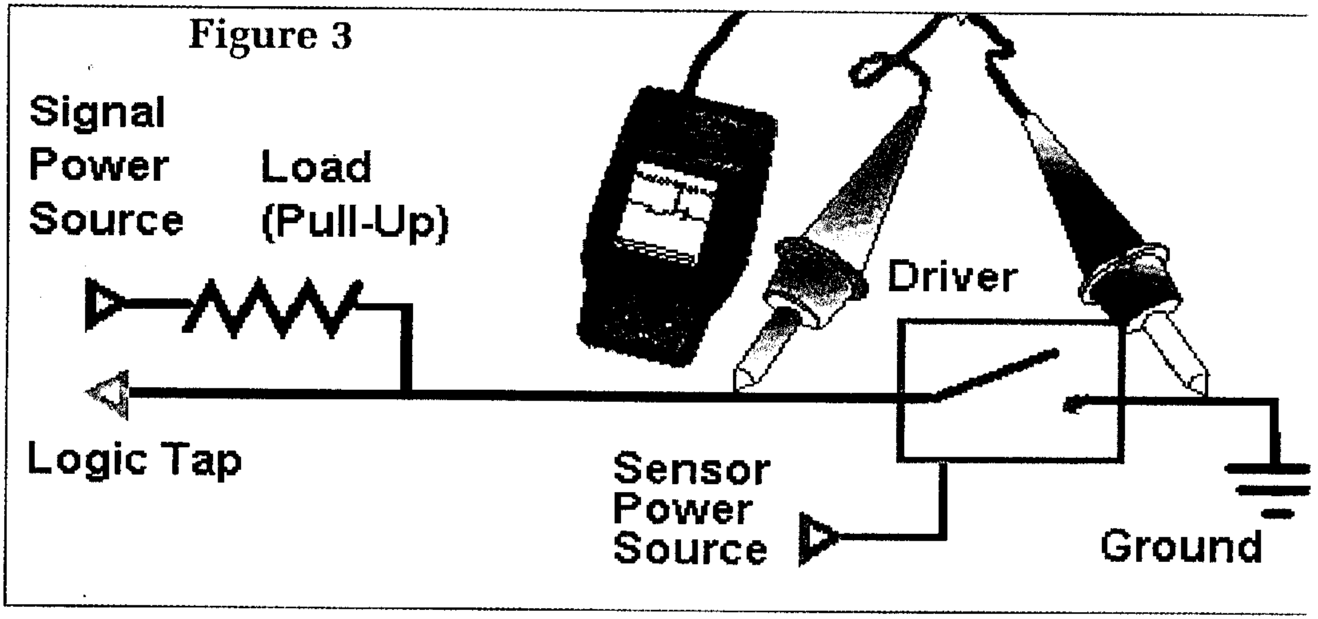
Signal Power Source

Closer examination of **Figure 1** reveals that the Hall sensor's circuit is not supplying any voltage to the output. It simply tells the transistor when to switch. The transistor is said to have an *open collector output*. This means that it is no more then a simple switch to ground. It is the signal power source that supplies the voltage to the transistor to create the signal.

Load (Pull-Up Resistor)

The pull-up resistor is used to control the amount of current that can flow in the circuit when the circuit is ON. The value of this resistor defines the load of the circuit. A higher value resistor means less current flow, and less load. A lower resistor value means more current flow, and a higher load circuit.

Figure 3



Because this is a sensor circuit, and not an actuator circuit, there is no need for high current flow. So the pull-up resistor usually has a high resistance value. One source reports values of more than 500 ohms, but usually less than 1 K ohms for the pull-up resistor.

Just remember, the Hall sensor is not a driver. It acts as a simple ON/OFF switch instead. Because the Hall sensor is not a driver, it is not designed to handle high current loads, like the loads that injector drivers must be able to handle.

Ground

The ground to the Hall sensor usually originates from the same source as the power for the sensor and the destination point for the Hall sensor signal. This destination point might be the PCM, so the Hall sensor's ground supply will probably come from the PCM, too. In the case of non-integrated engine management systems with separate electronic controls for the ignition and fuel systems, the Hall sensor ground might be found at the Ignition Module.

Logic Tap

The system's control module logic circuits need to read the output signal from the Hall sensor. This is accomplished by tapping into the signal wire between the load and the switch. The PCM is doing the same thing we do when we connect our lab scope to look at the Hall sensor's output signal.

To understand how the waveform is shaped, the first thing we need to do is consider what part of the circuit is between the test leads when we m a connection with our lab scope.

In **Figure 3,** the scope ground is attached to Hall sensor ground. You might chose to hook you scope to a different system ground, but we leave it where it is for the sake of this example.

So the big question is, "what is between" our leads? Look at the diagram in **Figure 3** and internals of the Hall sensor shown in **Figure 1**. can see that the switching transistor and any nections are between the scope's test leads.

Circuit Characteristics

The Hall sensor circuit has only two basic ope ing conditions. The circuit is either open or c plete. The condition of the circuit will control output we will see on our scope.

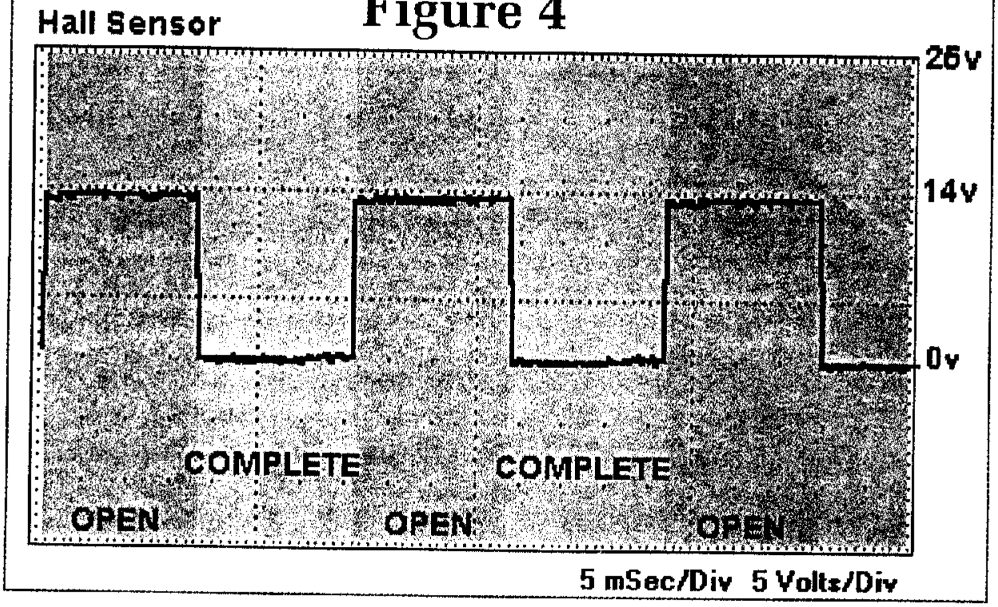
Transistor Open

When the transistor is open, the signal displ Signal Output Voltage. I did not say Signal Sou Voltage because it is very important to note tha some systems the Signal Source Voltage is at a dil ent level then the Sensor Output Voltage. One syst may send 8 volts to power the Sensor and the sen may output just 5 volts to the Signal Output Wire.

The main thing to remember is that the Sig Source Voltage will probably be different from tem to system. Different systems might use 5, 8 even 14 volts. Consult a service manual for re ence and don't attempt to keep all of the infor tion in your head. It can't be done, and there's shame in admitting it. Just remember to expect the unexpected.

Refer to **Figure 4** to see what the Hall sensor output signal looks like on a scope. As the scope trace begins, the circuit transistor is open and the resistance between the test leads is infinite. There is no current flow and the scope reads the source voltage level to the signal wire (14 volts).

Figure 4



Circuit Completed

We know current flows in the circuit when the transistor is ON and switched to ground. The transistor is between our test leads. When it is turned ON, the resistance between our test leads changes from infinite to a very low resistance value. There is very little current flow across the pull-up resistor, so there is really no indication of a voltage drop across the transistor. Therefore the signal goes to ground.

At this point, the resistance between the test leads is very low. The driver is closed. There is current flow through the circuit, but it is very small. The scope reads no voltage, as seen in **Figure 4** (Circuit Completed).

System Information

Most Hall Sensors are used as position and speed sensors. The signal carries its speed information in the form of a frequency signal. Position is usually delivered via a duty cycle change in the signal. I like to call this type of signal a unique ID.

In **Figure 5** on page 30, we see two waveform samples that depict both types of information. From what we have learned, if these systems use a vane to interrupt the magnetic field, we would expect it to have a unique shape that corresponded to these signals. In the Ford signal, notice the slight variations in the signal for the unique ID! Also, notice the peak voltages of these signals.

Diagnostic Tidbits

There are many things to consider when you are diagnosing a Hall sensor circuit:

- First, determine what is between the test leads.
- If you connect the scope ground to a system ground, you are testing the voltage drop across the transistor and connectors, the originating controller and connectors, and the control unit ground.
- Whenever you encounter a bad signal, you must ensure that the ground and power supply to that signal are good.
- Connect your scope to a system ground, then probe the sensor ground as you would any signal wire. A faulty ground here could affect the output at the signal line.
- If there is a problem in the power or ground side of the circuit, check the source. If the PCM is the source, are the PCM's power and ground supplies good?
- Always check the integrity of the signal power source. If this input is missing you may end up with a zero volt flat line signal. Pull the connector off the Hall Sensor and probe the signal wire! Many sensors have been mistakenly replaced before checking the originating power source.
- Check the physical condition of the Hall sensor and its components. Bushing wear may allow the vane wheel to contact the Hall sensor or its magnet. Physical contact between the vane and the magnet may have cracked the magnet. A cracked magnet can affect the characteristics of the Hall sensor's output signal.

Rounded Corners

Many technicians have reported seeing Hall sensor and other digital oscilloscope signals that appeared to have rounded corners. This characteristic

Illustrations by Jorge Menchu

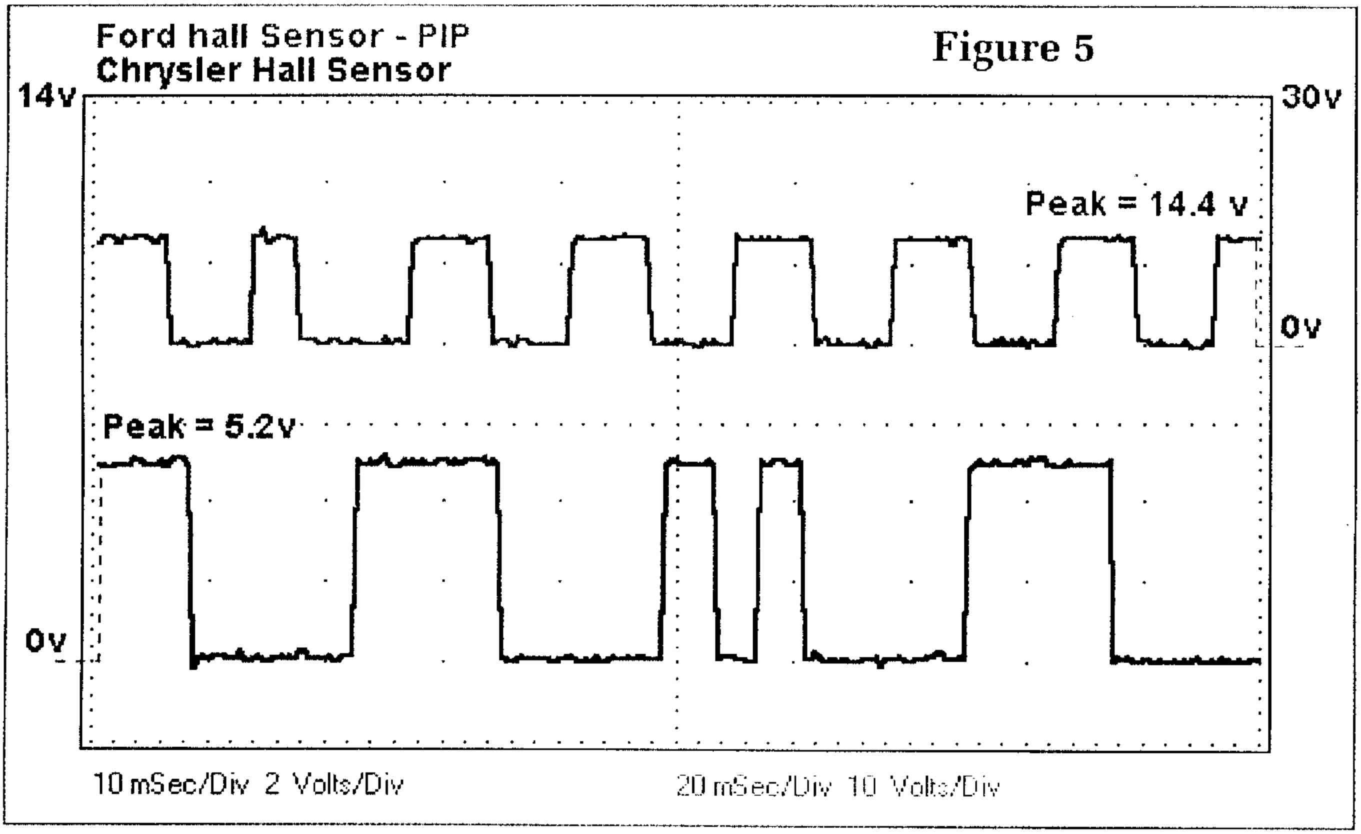


Figure 5

is often found at the top of the rising edge of the positive pulse. This signal characteristic does not seem to affect the performance of the circuit. In some cases it may have been intentionally placed there by the circuit designers.

My investigation reveals that a delay may be intentionally designed into some digital output circuits (like Hall effect sensors). The reason for the delay is to prevent signal noise. If you run into a signal with this characteristic, don't be too quick to condemn the circuit or the Hall sensor. Can you relate the characteristic you are seeing on your scope to the problem you are trying to solve?

The control units in most systems respond to the leading or trailing edge of the signal pulses produced by the Hall sensor. This is called the trigger point. The trigger window is usually within $^1/_3$- $^2/_3$ of the open circuit signal voltage.

Any events in the waveform that take place outside this area (like rounded corners on the scope pattern) might be ignored by the PCM. There's no point in getting worked up about something the PCM doesn't see, or is programmed to ignore.

Assignment

Take the information in this article, add your own experience, then make a trouble tree to diagnose this complete circuit. For example, can you answer these questions:

- If I test the sensor wire at the Hall Sensor and the signal is high during cranking, *what else* needs to be tested?
- If I test the sensor wire at the originating controller and the signal is high during cranking, *what else* needs to be tested?

Bottom Line

Thank goodness we have scopes to help us with our diagnosis. Hall sensor signals clearly show the need for a scope. With a scope, we can make the connection between the physical items that make up the circuit, then use a wiring diagram to understand the logic of the Hall sensor circuit. The scope gives us the ability to determine whether the circuit is performing as the circuit engineer intended.

Just remember to *always* expect the unexpected. *Always* verify the source and accuracy of your information. *Always* question what you read and hear. Don't let the technology master you. Strive to become a master of the technology.

—By Jórge Menchu