



Diagnosing GM DRAC and Speed Sensor Circuits

Understanding and Testing the System

If you have a 1991 to 1995 General Motors rear wheel drive truck or van in your shop with no upshift, no speedometer, DTC 24, or DTC 72, you're more than likely going to be diagnosing the DRAC/Vehicle Speed Buffer and related circuits. In this issue of *GEARS*, we're going to cover some DRAC/Vehicle Speed Buffer basics, as well as some quick diagnostic tests that will help you pinpoint the problem.

The DRAC (Digital Ratio Adapter Controller), or Vehicle Speed Buffer is used in most rear wheel drive General Motors cars, trucks and vans from 1991 to about 1995, and in some 1996-and-newer commercial trucks and vans. In this article we'll refer to this device as the DRAC.

The function of the DRAC is to take the AC voltage signal generated by vehicle speed sensor (or transmission output sensor in 4L80E applications) and convert it into separate DC pulse signals for the PCM and speedometer to read.

We're going to look at a 1995 C1500 Chevrolet pickup truck with a 5.7L engine and a 4L60E transmission. GM DRAC systems are all very similar; the main difference is component location. Some PCM pin locations and wire colors vary, so consult a wiring diagram and an electrical component location chart for the vehicle you're working on.

On our truck, removing the glove compartment provides access to the

DRAC and PCM. Most of the testing and diagnostic procedures will be performed at the DRAC and PCM connector terminals, so moving the PCM and DRAC out into the open provides free access to these components (figure 1).

The DRAC will typically have two connector cavities (figure 2). The larger, 9-pin connector cavity is used for power, ground, and the main input and output signals. The smaller, 4-pin connector may be empty on vehicles without cruise control, as those terminals are reserved for cruise control module vehicle speed signal circuits.

Figure 3 shows a basic DRAC wiring diagram. With an overview of what the DRAC does, let's take a look at the signals the DRAC needs to operate:

1. Switched battery + (hot with ignition switch on) at terminal C9
2. Ground at terminal C8
3. A clean AC voltage signal of sufficient amplitude from the speed sensor between terminals C7 and C12

Power and Ground

Battery + and ground are necessary for the DRAC to function properly. With the ignition switch on, you should have system voltage at terminal C9. Terminal C8 should provide the DRAC with a good engine ground.

Open the hood and look around. The DRAC ground is typically connected to the engine, so it's sometimes left loose or disconnected during

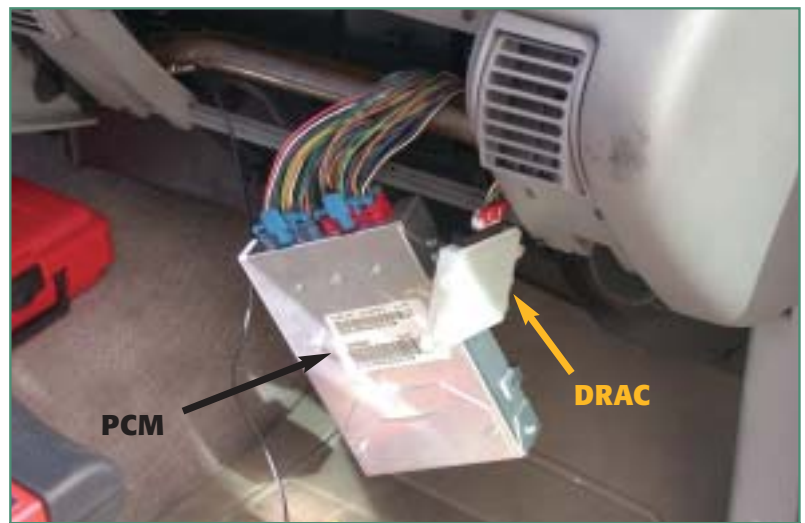


Figure 1: Accessing the DRAC and PCM



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engine service work. On our test vehicle, the DRAC ground (G134) is bolted to the thermostat housing (figure 4). This location makes it susceptible to corrosion, and to being left loose or disconnected after engine or cooling system service.

Quick Test: Eliminate problems with the power and ground by jumping battery + to DRAC terminal C9 with a 2-amp, fused jumper wire from the positive battery terminal, and a jumper between DRAC terminal C8 and the negative battery terminal. By connecting these jumpers, you'll bypass any power or ground problems, and can road test the vehicle to see if the condition goes away.

Vehicle Speed Sensor or Output Speed Sensor Signal

Okay, so we have power and ground to the DRAC; what's next? For the Vehicle Speed Buffer to send speed signals to the speedometer or PCM, it must first receive a signal from the Vehicle Speed Sensor (4L60E), or Output Speed Sensor (4L80E). The signal from the speed sensor is an AC (alternating current) signal. There are three main characteristics of the speed sensor signal that affect how the DRAC receives and processes the signal:

1. Amplitude
2. Signal quality
3. Frequency

Amplitude

Amplitude is the voltage "strength" of the signal. You can measure the AC voltage with a multimeter for a quick check. To check signal quality and look for interference or dropout, you'll need an oscilloscope.

On an oscilloscope, amplitude is the peak-to-peak height of the

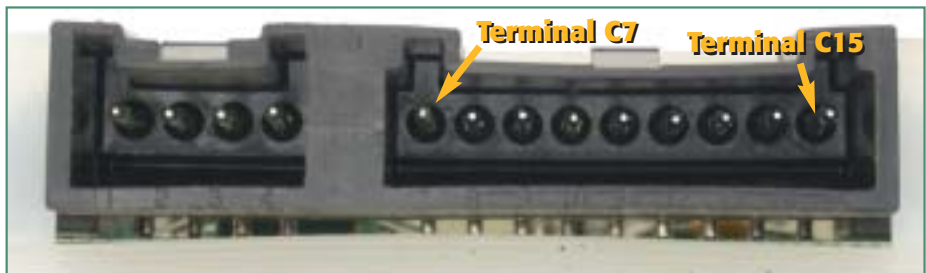


Figure 2: The 9 pin connector on the DRAC is where the power, ground, and main input/output signal connections are made

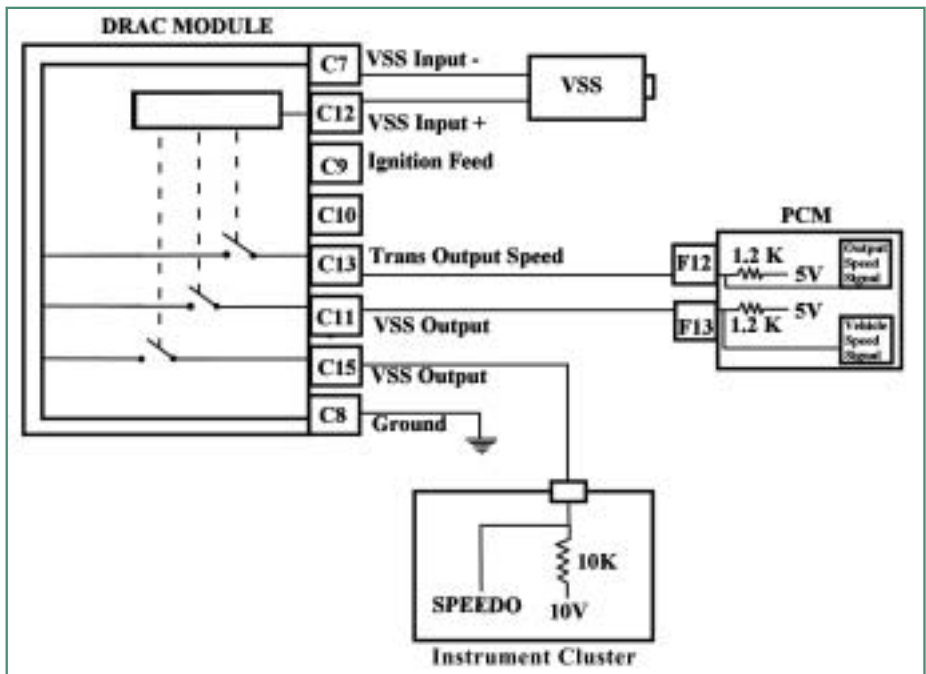


Figure 3: DRAC wiring diagram



Figure 4: DRAC ground (G134) on thermostat housing bolt



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waveform. Figure 5 shows the Vehicle Speed Sensor signal at the DRAC on our 1995 pickup, measured between DRAC terminals C12 (+) and C7 (-). This signal is taken at about 12 MPH. The signal is about 20 volts peak-to-peak, and is a regular, clean, even, repeating pattern.

There's no hard specification on for the AC voltage, but some factory test procedures say you should have 7 volts AC (about 10 volts peak) at 10 MPH. The DRAC needs more than 4 volts peak-to-peak to function reliably.

Automotive module circuits typically use what's called a "zero crossing detector" circuit to process the AC signal from a speed sensor. The zero crossing detector allows the module's logic circuits or microprocessor to detect precisely when the AC signal voltage crosses zero volts. By counting zero crossings and precisely measuring the time between zero crossings, a microprocessor can figure out the speed of a shaft in RPM, or the vehicle speed in MPH, etc.

Amplitude is very important because, to recognize a zero crossing event, voltage must first reach the "arming" amplitude; in other words, before it can recognize a negative-going, zero crossing event, the positive amplitude must first reach the arming voltage level.

In simpler terms, the zero crossing detector first verifies that the voltage reached a minimum level before counting a zero crossing. This reduces, if not entirely eliminates, any low voltage AC noise from being interpreted as a valid speed sensor signal, *as long as the noise amplitude is below the voltage threshold of the zero crossing detector!* Basically, we don't want any low level AC noise taking cuts in line and triggering our zero crossing detector.

Signal Quality

Signal quality is how clean and consistent the waveform looks on an oscilloscope. Referring to figure 5, the waveform should be a clean line, sweeping up and down evenly from a positive to a negative peak, centered on 0 volts (ground), repeating continuously (when the vehicle is moving). Any fuzziness or jagged appearance of the

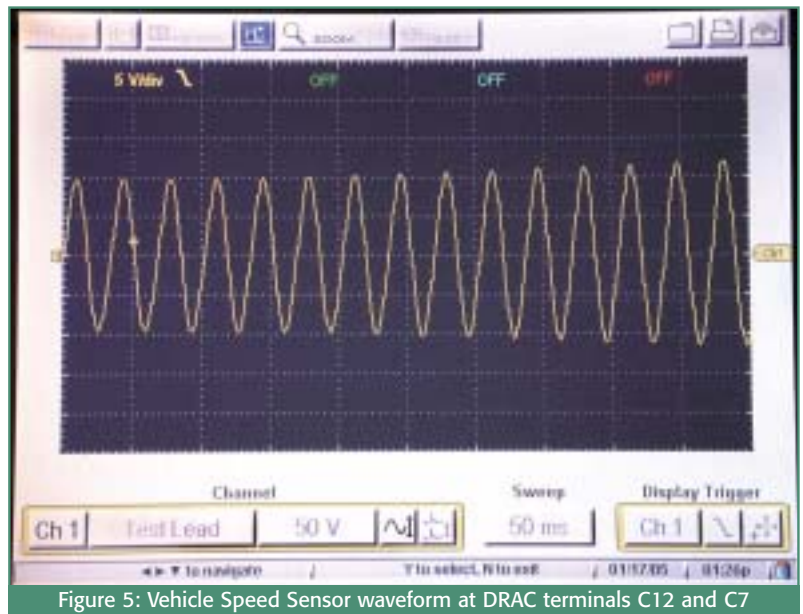


Figure 5: Vehicle Speed Sensor waveform at DRAC terminals C12 and C7

line indicates noise or signal dropout. You really shouldn't see more than 300 millivolts (0.300 volts) of noise or signal variation on a speed sensor circuit.

With the vehicle stopped, you shouldn't have any signal or waveform showing on the oscilloscope (the oscilloscope should display a flat line indicating 0 volts). You may have a blip or brief series of voltage pulses when you shift the transmission in or out of gear at a stop. This is completely normal, caused by the output shaft moving a fraction of a revolution because of normal slack in the driveline and rear end. This brief movement will cause the sensor to send out a few pulses during engagement or disengagement.

Otherwise, if you rev the engine in park or neutral, or stall test the vehicle, you shouldn't see more than 300 millivolts (0.300 volts) of amplitude if the vehicle isn't moving.

Quick Test: If you see noise in park, neutral, or during a stall test, there are 3 main possibilities:

1. Ignition system interference — typically this interference will look like short spikes, increasing in frequency with engine speed. This indicates secondary ignition breakdown interference.
2. Faulty alternator/charging system interference — this is fairly simple to identify; discon-

nect the wires at the alternator and tape them up so they can't short out, then run the vehicle and see if the interference goes away.

3. A bad connection in any of the DRAC circuits, aggravated by engine vibration when you rev the engine or perform a stall test (check grounds!)

Frequency

The signal must have a regular period (frequency) to provide sufficient amplitude and acceptable signal quality. Unless there's a speed calibration problem caused by the wrong gear ratio or damaged reluctor wheel teeth (you would see the latter as an irregular pattern on an oscilloscope), there isn't much reason to be concerned with frequency, if the amplitude and signal quality are good.

Diagnostic Tip: Just because you get a frequency reading from the speed sensor circuit on your DMM, it doesn't mean that the VSS signal is okay. A DMM can measure the frequency of a very weak signal. Most DMMs are capable of measuring the frequency of a signal that has only a few *millivolts* of amplitude. We need a couple of *volts* of amplitude for the DRAC to recognize and process the VSS signal.

Quick test: At this point, if you are having a problem with the AC voltage

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signal coming from the vehicle Speed/Output Speed sensor, you are going to have a problem with the sensor or the wiring (as long as there are reluctor teeth inside of the transmission for the sensor to pick up off of). You can test the sensor for AC voltage output right at its connector, or substitute a good sensor. To eliminate a wiring problem, you can cut the two wires at the sensor, cut them at the DRAC (C7 and C12), and run new wires. This will bypass and eliminate any problems in the harness.

DRAC Output Circuits

Once you're sure the DRAC has the basic signals it needs to do its job — good power, good ground, and a good signal from the VSS/OSS — you're ready to look at what the DRAC needs to transmit its speed signals to the PCM and instrument cluster.

1. 5-volt pull-up sources from the PCM for Output Speed and VSS Output signals (DRAC terminals C11 and C13)
2. 10- to 12-volt pull-up source from the instrument cluster (DRAC terminal C15)

Output and VSS Signals to PCM and Speedometer

You might ask: "What the heck is a 5- or 10-volt pull-up source?" To answer this question, let's briefly go over the function of the Output and VSS circuits, and how the signals are transmitted from the DRAC to the Speedometer and PCM.

Figure 3 shows a wiring diagram of a typical DRAC and its related circuits. PCM terminal F12 is connected

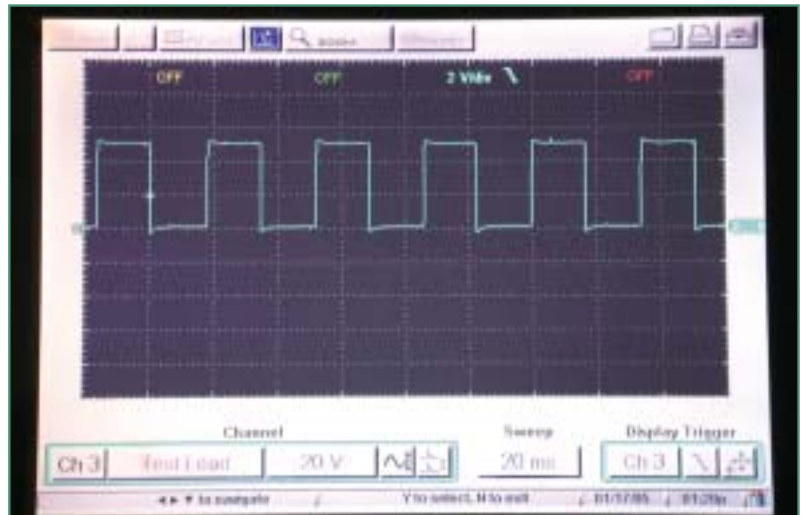


Figure 6: DRAC Output Speed Signal Waveform at DRAC terminal C13

to 5 volts inside the PCM through a 1.2k-ohm (1200 ohm) pull-up resistor. PCM terminal F12 is also connected to the DRAC terminal C13.

Figure 6 shows the Output Speed signal at DRAC terminal C13, with the vehicle at about 12 MPH. When the DRAC sends the transmission output speed signal to the PCM, it grounds and ungrounds terminal C13 at regular intervals. The result is a square wave that toggles up and down continuously from 5 volts to 0 volts and back to 5 volts. If the DRAC doesn't have 5 volts supplied to it through a pull-up resistor, the PCM won't receive the speed signal from the DRAC.

The DRAC *can't* send out a speed signal without a pull-up voltage supplied by the PCM. *Failure to understand this is one of the main reasons for misdiagnosis!*

The DRAC is *grounding* terminal

C13 to pull the voltage to zero, then *ungrounding* terminal C13 to let it return to 5 volts. The key word here is *ground*; if the DRAC itself doesn't have a good ground at terminal C8, it won't be able to pull the Vehicle Speed, Output Speed, or Speedometer signal lines all the way to ground. The DRAC doesn't have another magical ground circuit to toggle the Vehicle Speed, Output Speed, or Speedometer signal lines with; DRAC terminal C8 is the be-all, end-all ground. *Make sure DRAC terminal C8 has a good connection to engine ground!*

Quick Test: With the DRAC harness connector unplugged, you should have 5 volts on terminals C11 and C13 (figure 7). According to Ohm's Law, grounding C11 or C13 should develop about 4.2 mA of current (figure 8) in the circuit, because the 5 volts is supplied through a 1.2k resistor inside the PCM.



Figure 7: Check DRAC harness connector terminal C13 (Output Speed Signal) for 5 Volt Pull-Up



Figure 8 : Grounding DRAC harness connector terminal C13 to check DC current

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Figure 9: Check DRAC harness connector terminal C15 (Speedometer Signal) for 10 -12 volt pull up

You should have 10 to 12 volts on harness connector terminal C15 (Speedometer Signal; figure 9).

With the DRAC connector still unplugged:

- Probe harness connector terminal C15 with a jumper wire.
- Turn the ignition switch on.
- Rapidly tap the other end of the jumper wire against a good ground.

You should be able to get a 10 to 20 MPH reading on the speedometer. This verifies the speedometer can create a reading if the DRAC is doing its job.

You can perform the same test on DRAC harness connector terminals C11 and C13 while watching the Vehicle Speed and Output Speed readings on the scan tool, but this isn't a conclusive test. Even if everything is okay, you may not get a steady reading for Vehicle Speed. The Output Speed may only read a low value and will come and go. This is because the frequency of the Output Speed signal is pretty fast and difficult to duplicate by hand.

Using a Digital Storage Oscilloscope

A DMM will tell you if there's a consistent problem most or all the time. But catching intermittent DRAC system glitches with a DMM can be a hit-and-miss proposition.

By connecting a scan tool to the vehicle you can check Vehicle Speed and Output RPM through scan data. You can also record a movie of scan data when a problem is occurring to see

if the PCM is losing one or both of the signals.

A DSO (digital storage oscilloscope) allows you to view waveforms, record them over a period of time, and store them for future reference. The length of time is limited by the memory or buffer size of the DSO. Using a DSO with a good size buffer can let you record waveforms over a relatively long time, so you can review them to look for signal dropouts or glitches.

We're going to use the Snap-on MODIS in lab scope mode. We can monitor the VSS input, Speedometer output, Output speed, and Vehicle Speed signals using the 4 channel DSO (figure 10). When viewing a stored waveform, you can zoom out (figure 11) to view some of the slower signal components (figure 12). This is helpful if you suspect a faulty PCM or EPROM. If the PCM is always getting a good Vehicle Speed and Output Speed signal at its terminals when a signal loss problem is occurring, the DRAC is doing its job; which means there's a good possibility the PCM or EPROM may have lost a couple of marbles.



Figure 10: Viewing the signals on a 4 channel digital storage oscilloscope:

- Channel 1- Vehicle Speed Sensor
- Channel 2- Vehicle Speed signal
- Channel 3- Output Speed signal
- Channel 4- Speedometer signal



Figure 11: Selecting the 'Zoom Out' 8x function to view slower signal components.

A Tip for Successful Diagnosis

Of course, the circuit tests we've discussed here are all fine and dandy if there's a *hard fault*; one that's occurring *right now*. But if you have an intermittent problem, remember: the only valid diagnostic information you'll get is from tests performed *when the problem is occurring*.

In other words, if the truck comes in with a DTC 24, and the customer says that once every three weeks the truck drops into neutral at highway speed and the MIL lights, there's a good chance that everything's going to test okay. You aren't going to find the source of the problem unless you can:

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When viewing a stored waveform, you can zoom out to view some of the slower signal components (figure 12). This is helpful if you suspect a faulty PCM or EPROM.

1. Find a marginal problem, such as a poor ground or intermittent connection.
2. Duplicate the problem while performing the tests.

This is why it's important to quiz the vehicle owner. Ask whether any work has been performed on the vehicle. If so, check the area where the work was performed for loose grounds, damaged harness, etc. Ask about the driving conditions and what's happening when the problem occurs:

- Is the engine cold or warm?
- What speed?
- Towing a trailer?
- Does the speedometer drop out?

And so on, so you can try to duplicate the failure.

Don't forget to check the basics: charging system, powertrain ground, chassis ground (July 2004 GEARS; *Check the Grounds!*), terminal tension, battery condition, etc. Before you start throwing parts at the car, you need to cover the basics, especially with an intermittent problem.

The GM DRAC system has a few things to take into consideration before diagnosis can begin, but once you get the basics down it's just a process of elimination. Besides, it just gets easier as time goes on; on most 1996-and-later GM vehicles, they eliminated the external DRAC; the vehicle speed sensor signal goes straight to the VCM (Vehicle Control Module, or what they used to call the PCM). Isn't it nice when new technology actually becomes easier to diagnose?



Figure 12: After zooming out, we can view more cycles of the Vehicle Speed and Speedometer signal waveforms

Watch Out for the Ground Loop!

Whenever you're using an oscilloscope, DMM, or any other type of test equipment that's powered by the vehicle's battery, cigarette lighter, or OBD-II diagnostic connector, be careful. Some externally-powered test equipment will have its negative or ground test probe connected internally to the tool's power source ground. This means that the negative test probe is already connected to the vehicle's ground.

The GM DRAC VSS terminal C7 is also connected to ground internally (to C8). So if you're probing the VSS AC signal input to the DRAC with test equipment that's powered by the vehicle, and you have your negative test probe connected to DRAC terminal C12, you can essentially short out the VSS signal, giving you a false test result. To avoid this type of ground loop problem, always connect your negative test probe to DRAC terminal C7 and positive test probe to DRAC terminal C12 to check this signal.

Remember this when testing any other circuits on a vehicle; you can short out circuits and possibly damage the vehicle or your test equipment.

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