DIAGNOSING VARIABLE DISPLACEMENT COMPRESSORS

By Tom Tillman

As vehicles have become more sophisticated, their air conditioning systems have also gotten more complicated. The variable displacement a/c compressor is one example of this increased complexity.

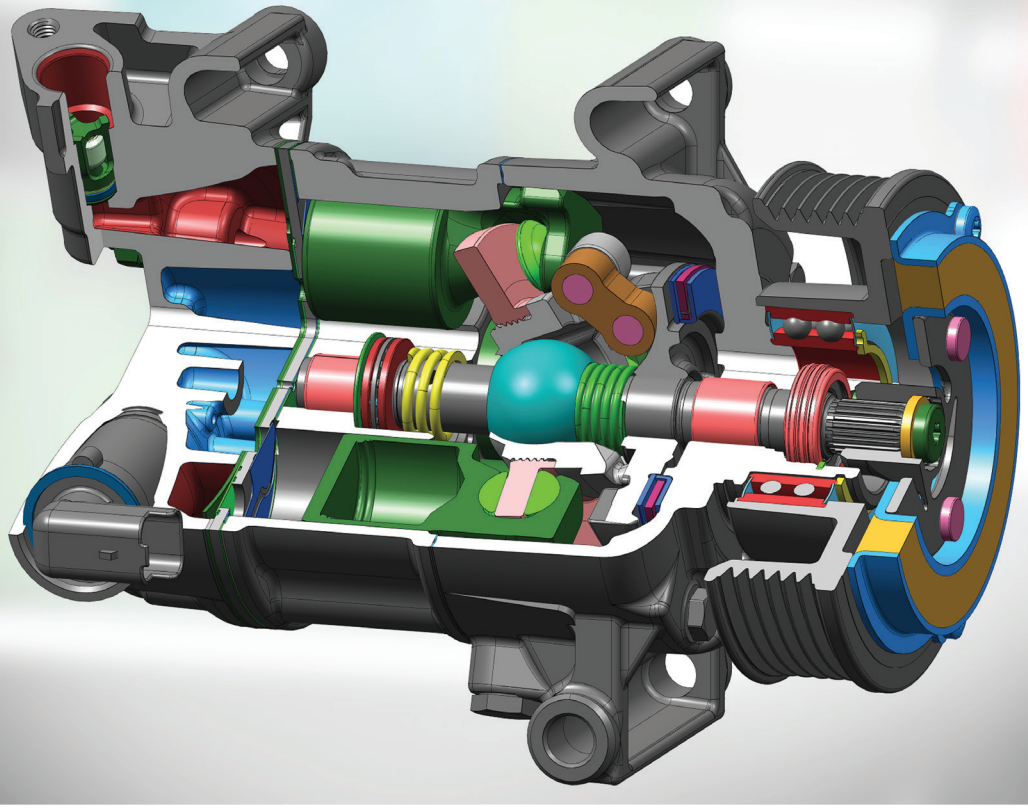


Illustration courtesy Delphi

In earlier air conditioning systems, the compressor ran at full capacity whenever its cycling clutch was engaged. If the engine was running and the clutch was engaged, the compressor was pumping. And the faster the engine turned, the more pressure the compressor developed. The only way to modulate the pressure produced by the compressor was to disengage the clutch and allow the compressor to rest for a while. Then, when the system pressure had dropped sufficiently, the clutch was reengaged, the compressor started pumping and the cycle was repeated.

The biggest disadvantage with this arrangement is that it forces the compressor to run at full capacity whenever it's running, regardless of the ambient temperature or the temperature demands being made by the vehicle's occupants. This wastes fuel and makes it more difficult to modulate the vehicle's interior temperature.

The variable displacement a/c compressor addresses some of these shortcomings by changing the way the a/c system operates. The system is controlled by a pulse-width modulated solenoid mounted in the compressor. This allows the pressure developed by the compressor to be applied gradually, rather than come on at full force. Also, when the vehicle's inside temperature is cool enough, there's no need for the compressor to operate at full capacity, and its output can be reduced.

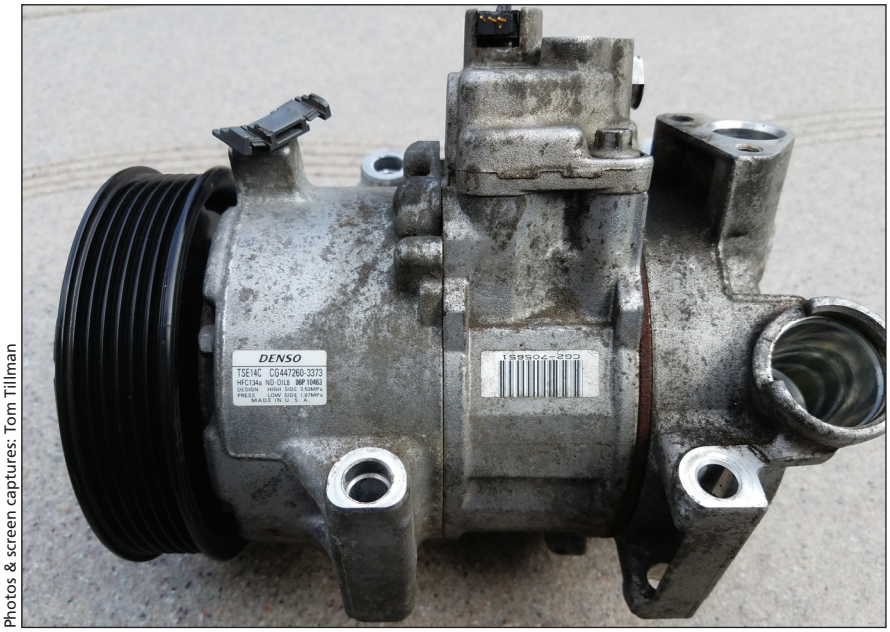
This is particularly helpful at highway speeds. This is when the compressor's pulse modulated on time can be dropped as much as 50%. A DVOM would register the on time as a voltage of between 6 to 7V at this point. Remember, a voltmeter averages the voltage reading only. The Min/Max record would show the highest and lowest voltage reading, whereas a scope would show a 50% pulse-width voltage signal (on time vs. off time).

There are several different variable displacement compressor manufacturers, but the diagnostic approach to each is very similar. There are two basic designs. The first type is a direct-drive compressor that's controlled by a pulse-width modulated voltage signal only. The second type is basically the same, but with the addition of a conventional electromagnetic clutch mounted on the compressor shaft.

The direct-drive compressor has at least one drawback. If the refrigerant leaks out of the system, there's no pressure to push the refrigerant oil through the system. There's no way to temporarily disengage the compressor, which is still being driven by the engine at this point. Catastrophic compressor failure may result. A compressor equipped with a clutch stands a better chance of survival because a low-pressure switch would signal the PCM to disengage the clutch.

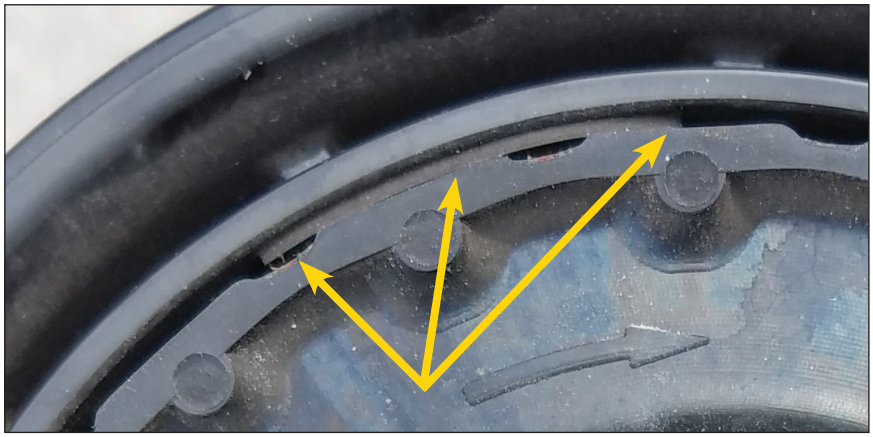
This is why locating refrigerant leaks on systems with direct-drive compressors has never been more important to the life of the compres-

The variable displacement control solenoid is used to control the flow of refrigerant through the system. This type of solenoid uses a pulse-width modulated signal to control the on time. This particular Toyota valve was stuck in the closed position, which prevented refrigerant from reaching the compressor, so it could not produce system pressure. The resistance specification for the solenoid is 10 to 14 ohms. This solenoid was within specification; however, it still failed to operate.



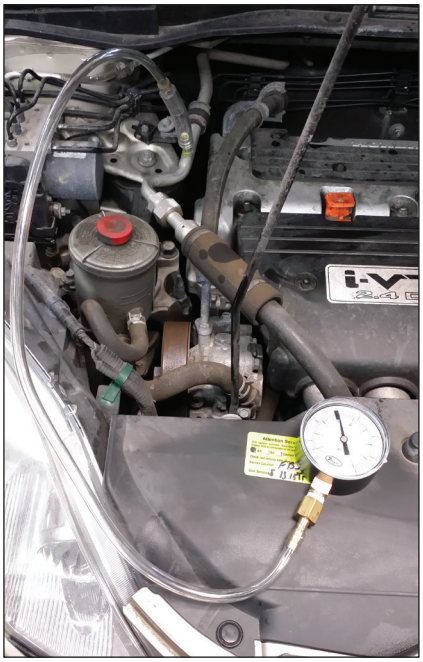
Photos & screen captures: Tom Tillman

The variable displacement direct-drive compressor is driven whenever the engine is running. This particular unit is from a Toyota. The variable displacement compressors used by some other manufacturers still have an electromagnetic clutch attached to the compressor shaft.



The direct-drive clutch is locked to the compressor shaft with a shear pin or hard rubber mount. This is a close-up view of the clutch on one such compressor. The hard rubber mounts are placed between the main hub and the outer ring of the clutch (arrows). If the compressor fails for any reason, these mounts will shear.

sor. When servicing the system, replace the Schrader valves, if possible. To check for leaks around the Schrader valves, I use an inches of water (in.-H_2O) pressure gauge connected to a hard-plastic hose. The same gauge is also used for evap testing. Even a very small leak will cause the gauge to continually rise. Using a spray solution to check for leaks should be avoided because it can contaminate the service valves.



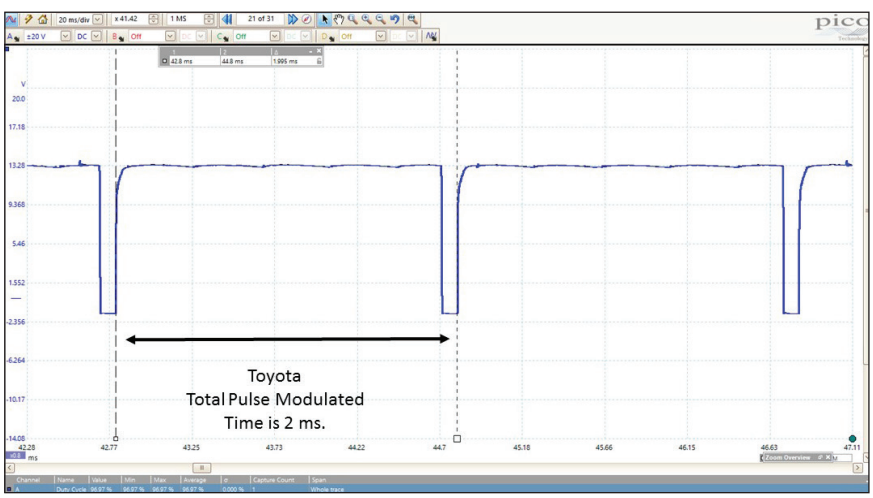
An in.-H_2O pressure gauge is used mainly for evap testing; however, it also works very well for locating a/c service port leaks. Schrader valves are very common locations for refrigerant leaks. An in.-H_2O pressure gauge can be used to determine if the valve is leaking. Make sure the hose makes a snug fit over the valve. If there is a leak, the gauge needle will rise slightly when the hose is connected to the service port.

Diagnosing variable displacement compressors is basically the same as with the old-style compressors. Check the refrigerant pressure first. If there's sufficient pressure to run the system, check the signals to the compressor. If the compressor has an electromagnetic clutch on the front, check to see that voltage is being supplied to the clutch and that it's applying properly. Next, check for variable voltage to the control solenoid on the back of the compressor. If the variable voltage is close to 12 to 13V (the scope pattern shows a 95% on time), then the compressor is being commanded to produce full pressure. The readings on the a/c manifold gauges should show normal pressures at this point.

While charging the system with refrigerant, monitor the variable voltage signal to the compressor. Some systems will display the compressor voltage/amperage applied on a scan tool. For example, on Toyotas, 0A = full off and .99A = full on. This will answer the question *Is the system working properly or is there a problem?*

If the cabin interior temperature gets cold enough, the system may start dropping off the control signal to the compressor. This will cause the high-side gauge pressure reading to drop as well. You might think you have a problem with refrigerant flow at that point. For example, the monitored voltage may start at 13.5V (95% on time), then after a while it could drop to 11V (80% on time).

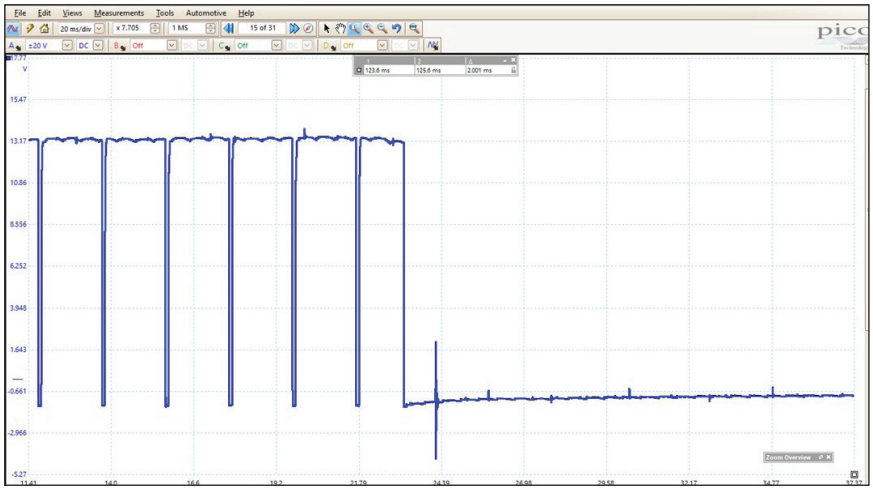
Suppose the cabin temperature has now dropped down to 45°F. The control module has commanded the



The total pulse-width modulated time on Toyota is 2mS. If the pulse time is 1mS on and 1mS off, then pulse time would equal 50% on time. A DVOM would display a reading between 6 and 7V.

compressor to drop off the pressure. Your manifold gauge pressures would also be affected. You might think there's a leak in the system. Adding refrigerant at this point could easily overcharge the system.

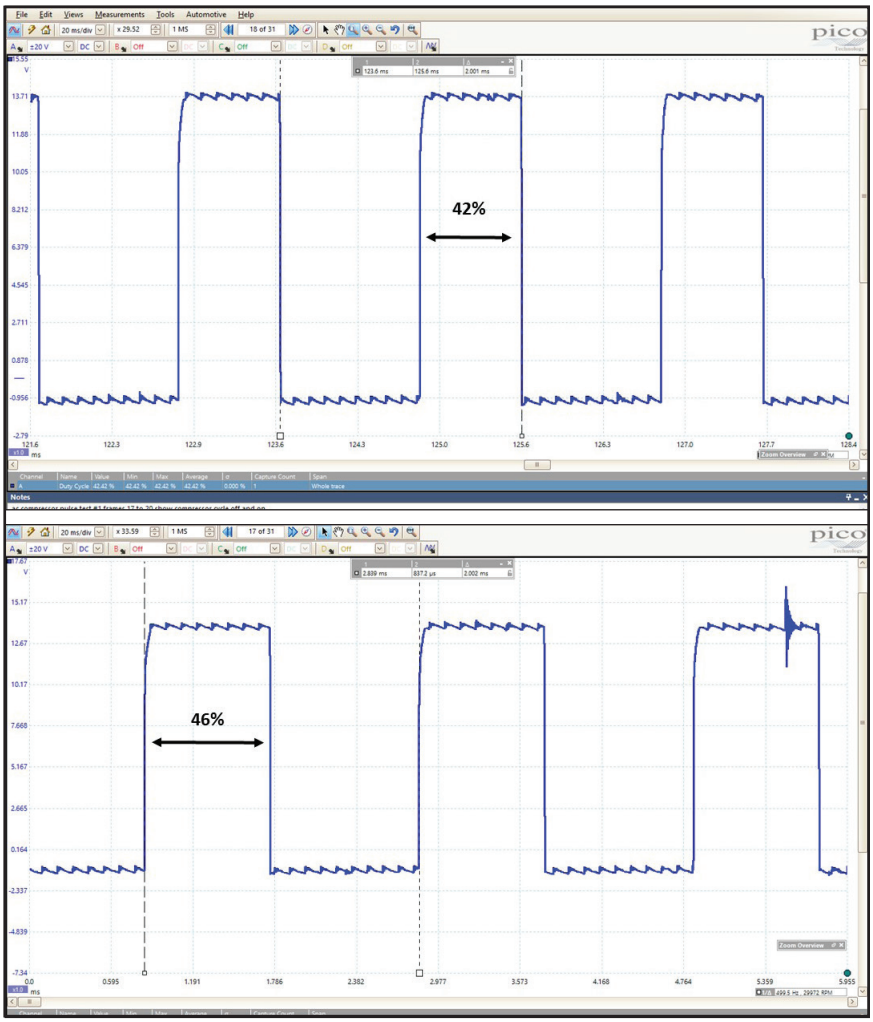
As stated previously, direct-drive compressors are constantly driven by the engine. As a safety feature, the compressor features a plastic shear pin or hard rubber clutch plate (similar to a harmonic balancer) to drive the compressor shaft. If the compressor suffers a catastrophic internal failure, the shear pin or clutch plate breaks, separating the seized compressor from any other driven components.



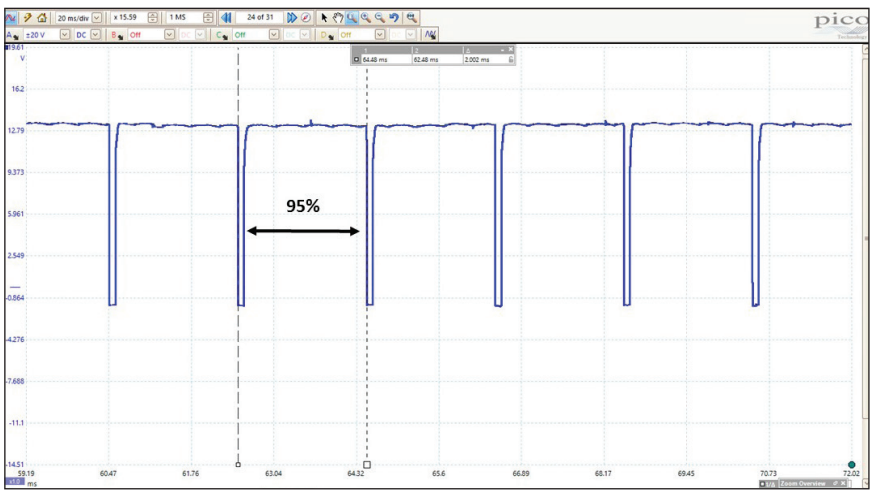
When the accelerator pedal is snapped to the floor, the pulse signal to the control solenoid will drop to zero. This momentarily shuts off the a/c compressor.

To check the clutch, remove the drive belt tension. Manually rotate the direct-drive clutch and feel for a slight resistance or drag. If the clutch freewheels and/or part of it doesn't turn, then the pin or the clutch rubber has sheared for some reason. Excessive pressure or a mechanical failure of the compressor has occurred.

Another type of problem that can cause the system to fail to operate is input signals to the a/c module. Some



Once the system restarts the compressor, the pressure is gradually increased by the pulse width. This keeps the compressor from coming back on at full force.



When the system is being commanded full on, the pulse-width modulated time will be at 95% on. A DVOM would display 12 to 13V with the engine running.

of the input sensors that must be checked include the evaporator temp sensor, the high/low pressure sensor, the ambient temperature sensor, the solar sensor and the engine coolant temp sensor.

If a sensor is totally out of range, a code will usually be set. However, a sensor that's stuck somewhere in its normal operating range could affect the operation of an a/c system. How many times have we seen the compressor fail to turn on due to a temperature sensor reporting an engine overheating problem?

If the variable voltage signal to the compressor is close to 0V, or 10% on time, then something is commanding the system off. Check the voltage signal at the pulse-width modulated compressor solenoid control wire at the a/c control module first. An open or grounded circuit in the wiring will prevent the system from operating. Next, check the a/c control module for codes. These codes must be addressed first. Some system modules have been programmed to disable the a/c system when certain codes are set.

To test the performance of the compressor's variable control solenoid, perform the following steps: 1. Connect a lab scope to the variable control solenoid on the compressor. Connect your a/c manifold pressure gauges at this point as well. 2. Start the vehicle, then adjust the a/c controls for maximum cooling and set the blower speed on High. 3. While watching the scope, jab the throttle to the floor. The pulse-width signal on the scope should momentarily drop to 0%, shutting off the compressor.

On some vehicles, the pulse-width on time may drop only to 10%. The important thing to note is that the control unit registered the rapid change in throttle opening and responded by reducing the compressor output. When the compressor is commanded back on, the scope pulse-width modulated signal may reach only 40%, then gradually rise to 95% on time. This would be considered normal operation.

Each manufacturer's control of the compressor may be slightly different. Again, it would be wise to monitor the pulse control signals to the compressor while servicing the system. It may add to the cost of the service, but will help prevent comebacks. M

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