ONLINE WIRING DIAGRAM EXERCISE

This wiring diagram exercise is an extension to the TDR article about "How to Read Wiring Diagrams." As mentioned in the article it takes practice using a wiring diagram to become proficient at diagnosing electrical problems. The wiring diagram for this exercise is from a 2009 Dodge RAM 2500 truck with a 6.7-liter Turbo Diesel engine. The diagram has been modified for this exercise.

The diagram is typical of examples found online for Mitchel 1, Haynes, Alldata and OEM factory service manuals. Individual components are identified and some have location references. All wires are identified using colors either by the actual color, or labels, i.e., RD=red, PK/GY=pink with grey stripe, BR/YL= brown with yellow strip etc. A word of caution, don't count on red wires as having power and black wires depicting grounds as there are exceptions. Grounds are depicted as a dot with a horizontal line under it and all ground symbols connect to the battery's negative terminal.

Notes about the Diagram

The notes provide some general knowledge about how the circuits/sensor within the wiring diagram operate. This information would normally be found in a service manual and a basic understanding of how and when the intake air heater is turned on will help in reading the wiring diagram.

The "RELAY-INTAKE AIR HEATER" looks like a starter solenoid and works like the relays in the "How to Read Wiring Diagrams" article and even has the same terminal numbers.

The "SENSOR INTAKE AIR TEMPERATURE" sensor works as follows: The control module sends a 5-volt reference signal (aka bias voltage) on pin 47 to the Intake air temp sensor (IAT) which is grounded through the sensor return circuit on pin 24 of the control module.

When the intake air temperature is low, the sensor's resistance is high causing the intake air temp signal voltage to be high (close to 5-volts). As the intake manifold heats up, the temperature sensor's resistance is lowered causing the IAT signal voltage to decrease (close to 1-volt). For reference intake manifold temperature vs. IAT voltage and resistance values are listed:

Intake Manifold Temperature	IAT Signal Voltage	IAT Resistance in Ohms
0° F	4.70v	85,000
40° F	4.11v	23,900
60° F	3.67v	13,300
80° F	3.08v	10,500
100° F	2.51v	4,900
180° F	0.86v	1,450
220° F	0.48v	600

The “HEATER-INTAKE AIR” grid operates as follows. The intake air heater element/grid is used to heat air entering the intake manifold to aid in cold engine starting and/or to improve drivability when outside temperatures are cold.

When the intake manifold temperature is above 66° F. the instrument panel wait-to-start lamp (not shown in the diagram) will not illuminate and the intake air heater will not be activated. At 32° F. the wait-to-start lamp and heater grid will operate for 10 seconds and at 0° F. operation will last for 30 seconds.

Wiring Diagram Questions

Voltage readings for the exercise are determined using an imaginary digital voltmeter. Most readings will require the black voltmeter lead be connected to battery ground and the red lead used to probe various wires or control module/relay pins in the diagram.

Answering the questions about the wiring diagram will help you understand what voltage values are present when circuits are operating correctly. It will also demonstrate the logic behind using wiring diagrams to determine how to diagnose electrical problems. Practice reading wiring diagrams will help you when faced with real electrical problems on your truck. Remember the “Three Things”—Power, Load Device and Ground Return. The key to solving electrical problems is to figure out which of the three are missing (electrically speaking) in a faulty circuit.

WIRING DIAGRAM EXERCISE QUESTIONS

Scenario 1 Questions:
The check engine light in your truck is on and after plugging in a scan tool you read a PO113 code (Intake Air Temperature Sensor). A new sensor cost $82. You have read on the TDR Forum that the sensor's circuit should be tested before replacing it but you ignore this advice and buy a new sensor. You install it, clear the code and after a few short miles the check engine light comes back on setting a PO113 code—again. The only thing different is that your wallet is $82 lighter. (I guess you should have taken the TDR Forum's advice and tested the IAT circuit.)

1A) How can you isolate the IAT from the engine control module; test the IAT circuit and the wires going to the module?

1B) Using a digital voltmeter how can you test the IAT sensor?

1C) Can you measure resistance of the IAT sensor? Is this a better test than measuring voltage?

1D) How can you use a hair dryer (or heat gun) to test the IAT sensor?

Scenario 2 Questions:
The intake air heater relay looks like a remote starter solenoid and operates just like the relays in the TDR article *How to Read Wiring Diagrams.* You suspect that the relay on your truck is bad but want to test it before replacement.

2A) What are the wire colors and terminal numbers for the intake air heater relay? With the intake air heater off, what voltage values should be on each of the relay's four terminals with all wires connected?

2B) What should the relay voltage values be if the intake heater in operation?

3B) How can you use a jumper wire (short length of wire with alligator clips at each end) to test the relay and the wire connecting it to the control module?

Scenario 3 Questions:
The intake air heater on your truck will not operate even when the temperature is below 40° F. You have determined that the intake air heater relay, intake heater grid and intake manifold temperature sensor are working correctly. You suspect that the engine control module has a problem—however, a new one costs $989. (A Ram Dodge dealership would simply swap the module in the truck with a good one from their parts department to see if it was at fault. You don't have that luxury.) You need to make sure that the module is really bad before spending $982.

3A) If the intake air heater doesn't work how can you "test" the engine control module?

3B) Before replacing the control module, what values should each of the module pins have with the ignition key on?

Wiring Diagram Exercise
Answers to Questions:

Scenario 1 Questions:

1A) How can you isolate the IAT from the engine control module; test the IAT circuit and the wires going to the module?

1B) Using a digital voltmeter how can you test the IAT sensor?

1C) Can you measure resistance of the IAT sensor? Is this a better test than measuring voltage?

1D) How can you use a hair dryer (or heat gun) to test the IAT sensor?

Answers:

1A) Unplug the connector at the IAT sensor and turn the ignition key to the run position. Connect the red lead of the voltmeter to the DB/VT (dark blue/violet) wire and the black lead to the DB/DG (dark blue/dark green) wire. A reading around 4.8-volts indicates that the engine control module is sending the 5-volt reference signal to the IAT and that the ground return wire is connected to the control module. This test verifies that the wires from the engine control module to the IAT are good and that the control module has power (if it didn't there would be no 5-volt signal present).

1B) With the IAT connected to the control module, back probe the DB/VT wire (back probing the signal wire allows you to read voltage with the sensor plugged in—you can use a safety pin inserted into the connector). Estimate the ambient temperature and take a voltage reading at the IAT signal wire. If the ambient temperature is between 60° F to 80° F signal wire voltage should be 3.60 to 3.08 volts. This test verifies that the IAT and control module are working.

1C) Yes, you can measure resistance of the IAT sensor. Unplug the sensor and turn your voltmeter into an ohmmeter. Connect the leads to the IAT sensor (doesn't matter which lead goes where). Estimate the ambient temperature and read the resistance. This procedure is not a test for accuracy of the sensor—it's more of go/no-go test. Reading IAT signal voltage with the sensor plugged into the control module is a better test as voltage is what the control module reads in operation—not resistance. The sensor could have the correct resistance at a particular temperature, but a PO113 code could still be set if there is something wrong with the IAT circuit.

1D) Heating the sensor will decrease the IAT voltage at pin 47 of the engine control module. If voltage decreases as the sensor heats up it is working correctly. This is not a test for accuracy of the sensor—it's more of go/no-go test. An alternative method to determine if the sensor is working is the use of a scan tool to view IAT temperature. Heating the sensor should cause the reading to increase. CAUTION: Be careful heating the sensor as hair dryers and heat guns get really hot—don't melt the sensor!

Scenario 2 Questions:

2A) What are the wire colors and terminal numbers for the intake air heater relay? With the intake air heater off, what voltage values should be on each of the relay's four terminals with all wires connected?

2B) What should the relay voltage values be if the intake heater in operation?

3B) How can you use a jumper wire (short length of wire with alligator clips at each end) to test the relay and the wire connecting it to the control module?

Answers:

2A) Relay terminal 30 (RD/YL) should have 12-volts, terminal 87 (BK) should show 0-volts (ground through the heater), terminals 85 (BR/YL) and 86 (BK) should have 0-volts.

2B) Terminals 30, 87 and 85 should be 12-volts, Terminal 86 should be 0-volts.

2B) To bypass the engine control module, test the relay and the wire connecting the control module to the relay (BR/YL, terminal 85), unplug the wiring harness connector from the module. Connect one end of a jumper wire to battery positive and touch the other end to the BR/YL wire at the control module wiring harness connector (not the control module). The relay should click and there should be power on relay terminal 87 (black wire) going to the intake air heater. CAUTION: Don't leave the jumper wire connected too long as the intake air heater uses up to 200 amps and will drain the battery quickly.

Scenario 3 Questions:

3A) If the intake air heater doesn't work how can you "test" the engine control module?

3B) Before replacing the control module, what values should each of the module pins have with the ignition key on?

Answers:

3A) A bi-directional scan tool is required to test the engine control module. These scan tools have functional tests that check operation of solid-state controllers. For example, within the scan tool's menu there is a test for the intake heater relay. When selected, the scan tool commands the engine control module to turn on the intake air heater relay. If the module can't perform this test it should be replaced. Bi-directional scan tools are available for as little as $100 with the more expensive scan tools able to perform more functional tests.

If you don't have a scan tool there is an alternative test for the control module. The test is deductive and works as follows: If the module has the correct input/output voltage values, and all the wires are intact, it should be capable of operating the intake air heater. This also assumes that the ambient temperature is below 66° F. If the heater will not operate, then the module is probably bad and needs to be replaced. If any voltage values at the module are missing, fix these first BEFORE purchasing a new module.

3B) With the control module plugged in, turn the ignition key to the on position; back probe the wires at the module with the red lead of the voltmeter and connect the black lead to ground. Here are the voltage values for each module terminal/pin:

Pin #	Voltage	Notes
32	12.0v	With the ign. key in the run or start positions—if not, check fuse 28
20	12.0v	Power all the time—if not, check fuse 42
30	12.0v	Power all the time—if not, check fuse 42
40	12.0v	Power all the time—if not, check fuse 42
47	0.1 to 4.7v	Reference voltage for IAT sensor, voltage depends on intake temperature (see voltage vs. temperature chart)
24	0.0v	Ground for IAT sensor, should be close to zero volts
6	0.0 / 12.0 v	Intake manifold temp above 66° F = 0v; temp below 66° F =12v (only on for 10 to 30 seconds depending on temp)
21	0.0v	Module ground, should be close to 0-volts, higher voltage indicates a bad ground
49	0.0v	Same as above (pin 21)
50	0.0v	Same as above (pin 21)

A “real” engine control module will have way more pins that the ten used in this exercise (more like 50) however the logic for testing remains the same. If all the module inputs are correct, and the wires going to the various actuators/controls are intact, then the only thing left is a bad module.

Independent repair shops have used this logic for testing solid state components before bi-directional scan tools were available. A competent repair shop will always test, and not guess before replacing black boxes (control modules) because like you, they can’t return them to an parts store if a new module didn’t fix the problem.

Here are some additional tricks for testing solid-state/black boxes/control modules. With a voltmeter connected to suspect pins, try lightly tapping on the module with a screwdriver handle. If the vibration changes voltage readings the module is bad. Also, try gently heating the module with a hair dryer/heat gun. If voltage readings change when heat is applied the module is bad. Don’t overheat the module!