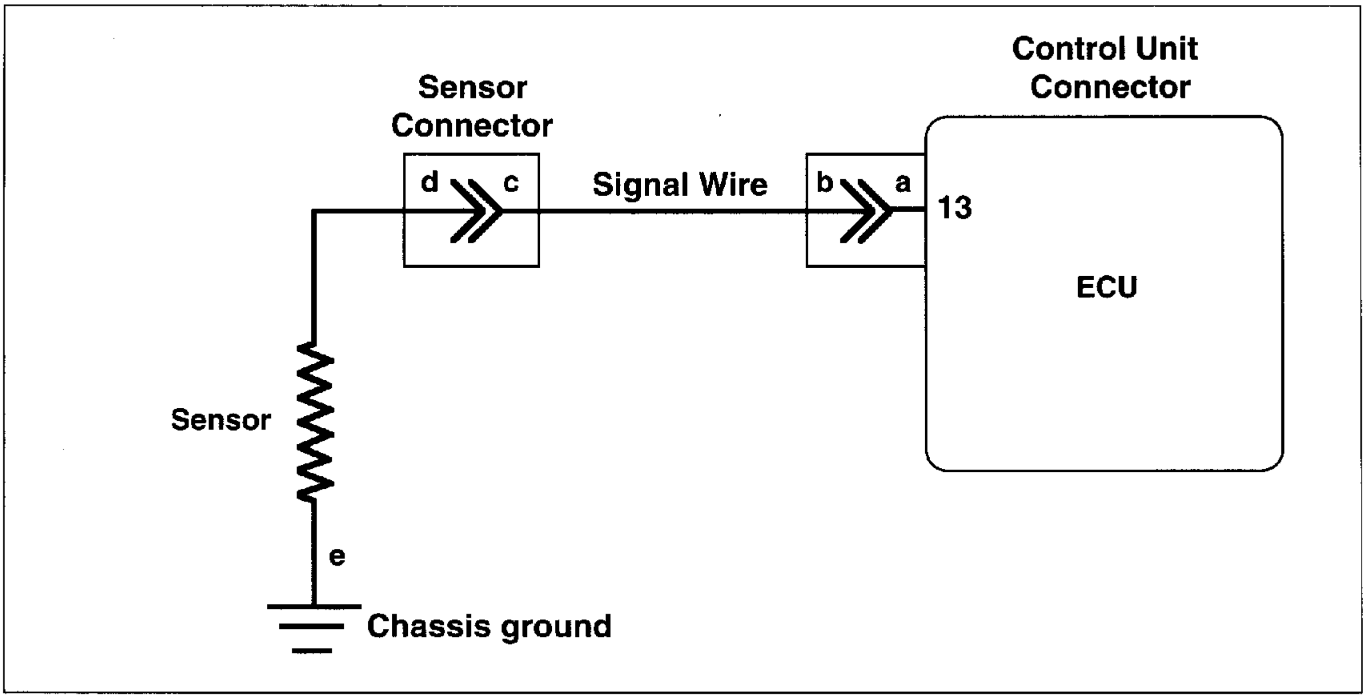


Problems in a single wire sensor circuit can occur in any of six areas .

1. **Control unit connector. (a-b)**
2. **Sensor contact terminals and plug. (c-d)**
3. **Ground connection. (e)**
4. **Broken signal wire.**
5. **Sensor failure.**
6. **Control unit. (ECU)**

The circuit shown above is typical for coolant, air, and exhaust gas temperature sensors. There really is no such thing as a single wire sensor circuit. Circuits always have at least two connections. In this case, a single wire I mean only one wire terminates at the ECU interface. The other side of the sensor is connected to chassis ground. Not all sensors are grounded in this way, however.

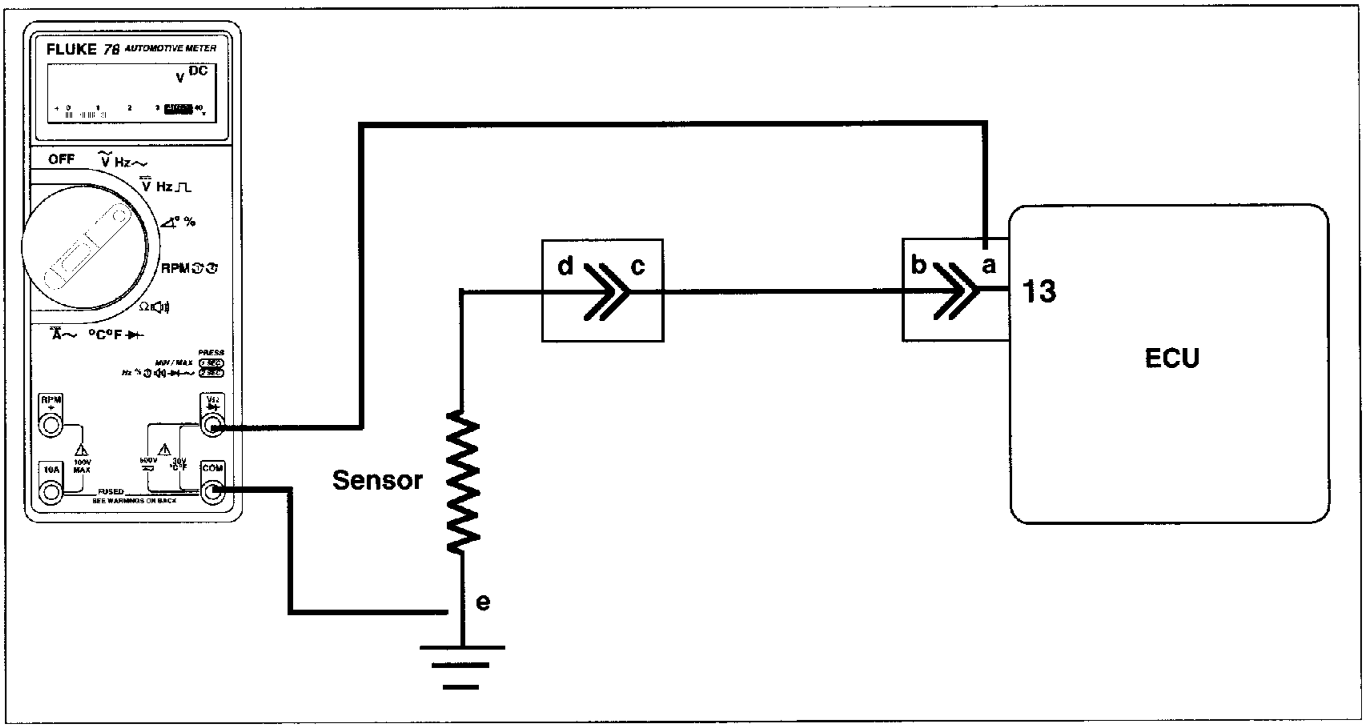
Let's examine the connections which could cause trouble. First we have the connection between "a" and "b" at the computer interface. This connection is the only one we recommend that you disconnect for troubleshooting at this point. The reasoning behind this is that if there isn't a problem in the circuit, there is no reason to disturb any connections. Doing so may compromise the integrity of the factory installation.

In other words never disconnect a sensor or actuator plug unless you are convinced that the problem lies in the connection or in the sensor or actuator. Try to eliminate all other possibilities before removing the plug from any sensor. Here's how:

* Always start at the computer interface. In the figure above we start at contacts "a" and "b."
* Remove this connector and look at the terminals in the plug. Make sure the contact terminals are where they are supposed to be, then make sure they are not bent or pushed back in the receptacle housing.
* Next, connect a breakout box. Backprobing should be avoided because tearing into the computer connectors may compromise the integrity of the factory installation.
* Once you are satisfied that the connector looks okay and you have connected the breakout box between ECU and harness plug, read the voltage at the breakout terminal "13" to the chassis ground terminal. The ignition key should be "on" for voltage tests. There are two possibilities for this test:

1. **The voltage is within specification.**
2. **The voltage is not within specification.**

If the first condition is true, you are done



with this test. Simple! If the second condition is true things get more complicated. If condition two is true, you will have one of three possible readings:

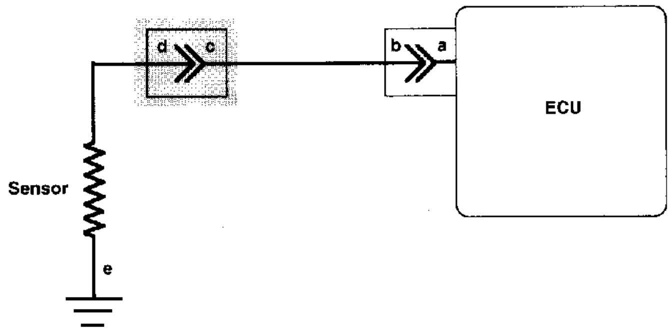
1. The reading is zero "0" volts.
2. The reading is at its maximum, say 4.5 V .
3. The reading is between "0" and "4.5" V, but not within specification.

Let's take the first condition of zero volts. It appears there could be a short circuit to ground. It's necessary to do some continuity tests. Turn off ignition, then disconnect the ECU from the breakout box adapter. Set your DMM to the ohms mode. (If you do not have auto ranging, switch your DMM to the 200 (scale.) There are three possibilities if the reading is "0" volts.

1. A shorted sensor wire.
2. A shorted sensor.
3. A bad control unit.

With the ECU disconnected and the DMM in the "ohms mode" you should read close to zero ohms if a short is present. If your resistance reading is normal for this circuit, it is more than likely that the ECU is bad. If you read close to "0" ohms, it is necessary to find the cause of the short.

At this point it is okay to disconnect the harness connector at the sensor. In our diagram, this is represented by the connection "c" to "d".



Don't pull on the wire when removing the plug. There are two possibilities when the sensor is disconnected:

1. When sensor connector is removed, the DMM goes to "OL". "OL" on a DMM means "over limit" and for all practical purposes you can assume an open circuit.

2. When the connector is removed the DMM still reads a short or some resistance value.

If DMM display reads "OL" after disconnecting the harness connector, the sensor is the source of the short. Replace the sensor and repeat the test.

If the short is still present after sensor plug connector has been removed, the sensor is probably okay. To verify whether the sensor is okay, use your DMM to check directly between the sensor terminal and chassis ground to measure the resistance. It should be within specification.

Dealing with a shorted wire in the harness is another matter because there could be many possibilities. I would start by connecting one DMM lead to sensor terminal "13." Now use the other probe to test for continuity to any of the other terminals in the entire ECU plug, using the breakout box .

If you don't find the short, inspect the wire for a possible insulation break that may be touching the engine block, causing a short to chassis ground. If the short is buried somewhere in the wire loom, it may be necessary to replace the wire loom. A cheaper fix would be to run a new wire from sensor to ECU. This procedure is frowned upon by the auto manufacturers, but the customer saves on his or her repair bill. It's your call.

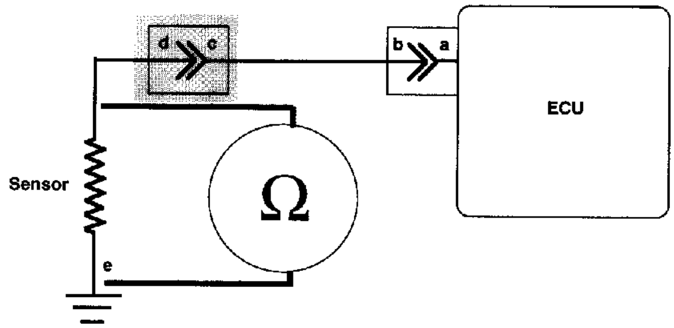
The second possibility is a voltage reading of 4.5 volts. This is a common reading for an open circuit or a faulty ECU. Many of the older control units may go as high as 10 volts when an open circuit is present. There are five possible causes for this condition:

1. **Bad sensor plug connection.**
2. **Broken wire.**
3. **Open circuited sensor.**
4. **Faulty ground connection.**
5. **Bad control unit.**

Set the DMM for the OHMS mode, then connect the DMM leads between pin "13" and ground on the breakout box. If you read a resistance that's within specification, there's nothing wrong with the circuit and the source of the problem is the computer. If you read "OL," the simplest way to test the sensor connector is to do a wiggle test.

Refer to the connection between "c" and "d" in the diagram on the preceding page, A loose terminal in the connector may not be making good contact. If the wiggle test does not expose the problem, check for a possible broken wire.

Disconnect the sensor plug. At this point you can measure the sensor resistance directly at the sensor terminals. Use the sensor case "e," not the engine block, for one probe connection. The other probe goes to the sensor contact "d" as shown in diagram below. If you get "OL" on the multimeter display replace the sensor.



If the sensor resistance is within normal readings, check the wiring. Short the terminal in the sensor connector to the chassis. If you get continuity, you can assume that the wiring is okay. If the multimeter displays an open circuit even while the sensor terminal "c" is connected to the chassis ground, you have a broken wire.

No matter how many sensors you replace, the problem will not be solved until you find the problem in the wiring.

If both of these tests don't remedy the problem, there are two other conditions which you can check quickly.

If you read a resistance value that agrees with the specifications when you were connected directly across sensor contacts, it's possible that the ground connection is bad. Remove the sensor and clean threads of both sensor and the threaded hole. Replace the sensor and test again.

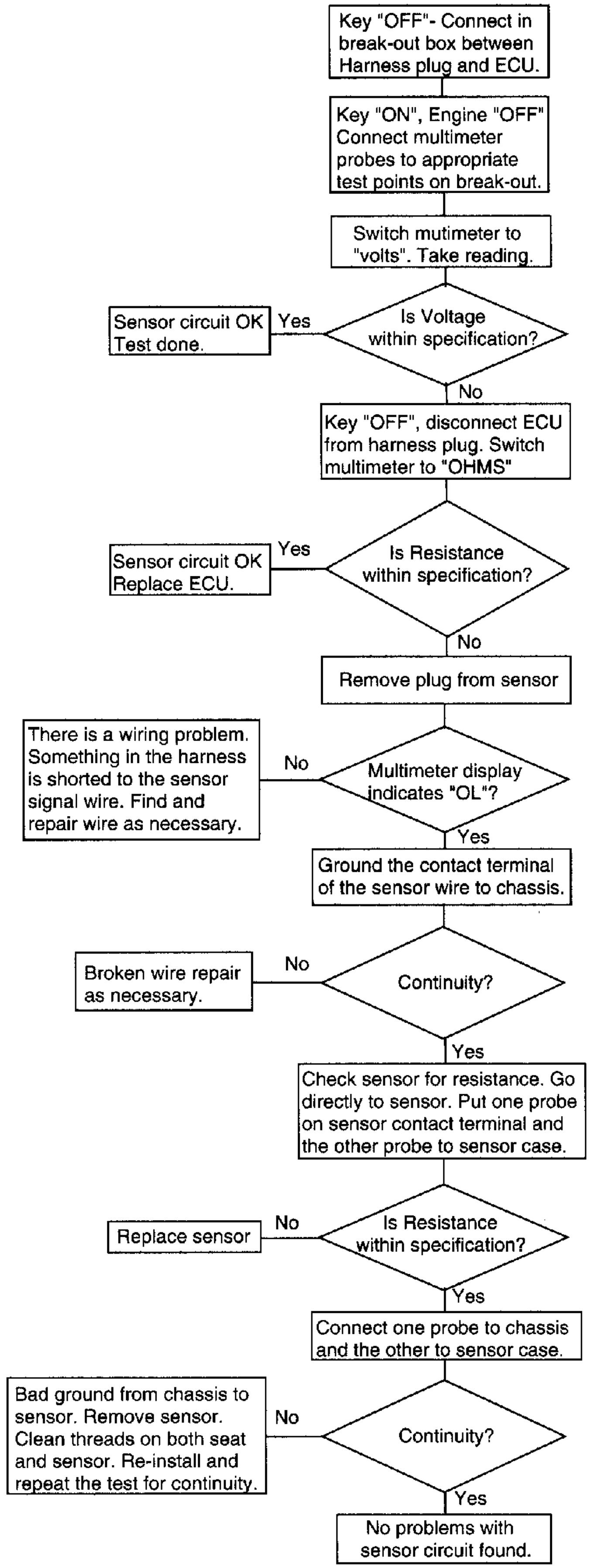
At this point you're probably thinking that this is a long-winded procedure just to test a simple circuit. You're right, but the simple circuit has many possible faults that can keep the circuit from operating properly.

Remember, on board diagnostics will not always tell you specifically what you must do to remedy a problem. It only points to a circuit. That's why the flow chart was invented. It shows with much less wording what your thought process should be when you are troubleshooting a circuit.

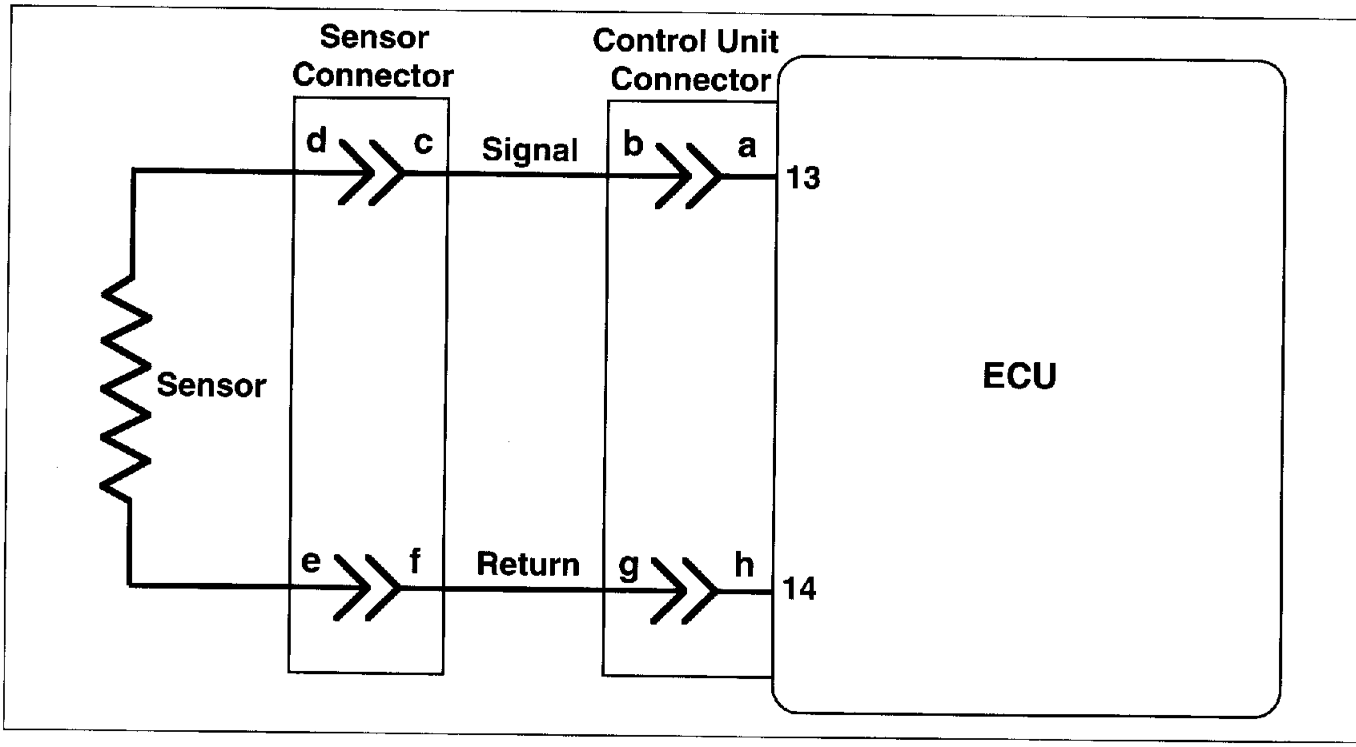
Refer to the flow chart to the right. This type of flow chart is used in the electronics field to locate a problem by a process of elimination. Notice that each rectangle gives you something to do. The diamond-shaped boxes ask a question after you have taken a measurement or have taken some action. There are always two paths to take based on your decision of either a "yes or "no" answer to the question in the diamond.

Flow charts are an easy way to break down a complicated circuit using logical step by step procedures. A flow chart is like a road map. You may know where you want to go, but you do not necessarily know how to get there without a map.

Once you learn the direction you need to go and the turns you must make, you won't need the map any more. If you make a wrong turn you can go back to a familiar place to start over. The same is true for a flow chart. The same precautions apply. If you make the wrong decision (turn) you could take the wrong path (road). If you take the wrong path, you will usually get conflicting results which makes no sense. If you are not sure where you're going, just back up and start over.



Flow chart for checking single wire sensor



Problems in a two wire sensor circuit can occur in any of six places.

1. **Control unit connector. (a-b) and (g-h)**
2. **Sensor connector. (c-d) and (e-f)**
3. **Signal wire continuity.**
4. **Return wire continuity.**
5. **Sensor fault.**
6. **Control unit fault.**

The circuit shown above represents a typical coolant temperature sensor or air temperature sensor circuit. Notice that the sensor has two wires going back to the ECU (the signal wire and the return wire). The return wire is usually a ground that the ECU provides to the sensor.

We'll begin with the connectors as a possible source of problems. Notice that there are two ECU connections - "a" to "b" and "g" to "h'. There are also two connections to the sensor "c" to "d" and "e" to "f".

All of the same procedures described for the single wire sensor are also true for this circuit. The difference is that you must check for continuity for both the signal wire and the return wire. Remember, this sensor does not get its ground directly from the chassis. The ECU provides the ground through the ECU connector and the sensor connector.

Let's assume we have a breakout box connected between the ECU and the harness plug. A DMM set to **VOLTS** is connected to #13 and #14. As we saw in the single wire sensor tests, there are just two possibilities for a voltage reading.

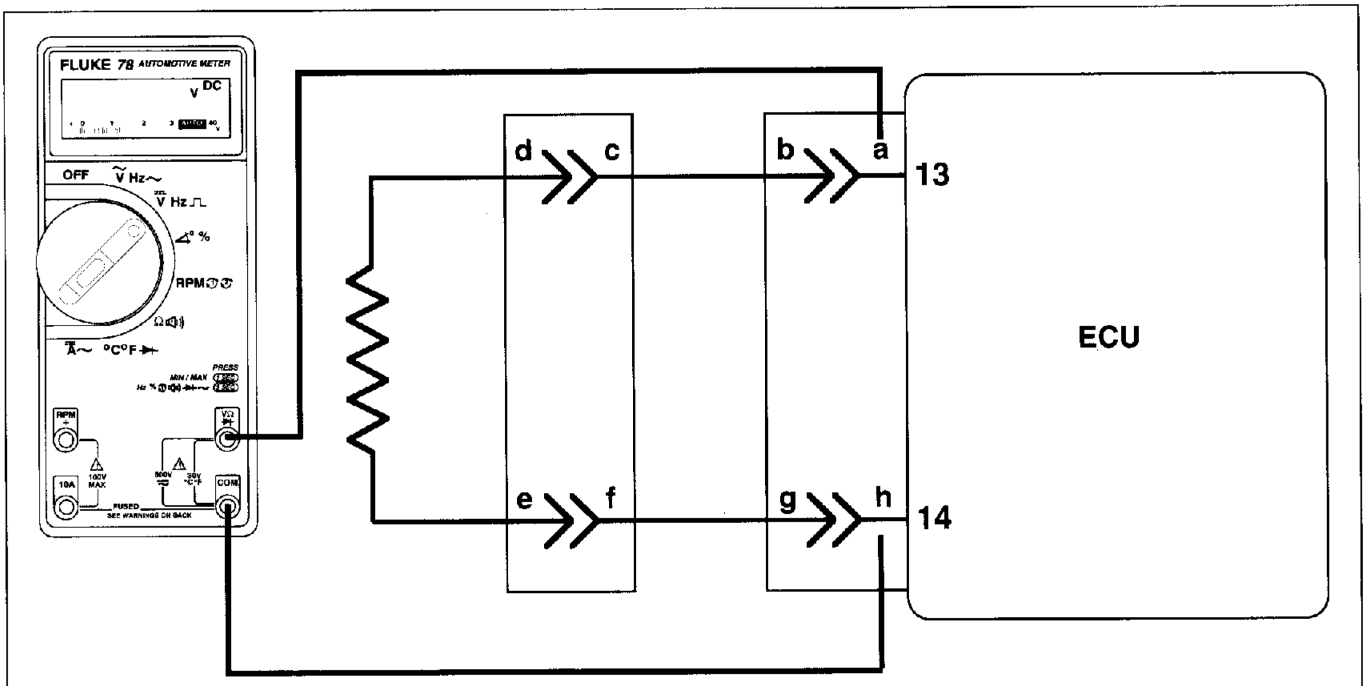
1. **The voltage is within specification.**
2. **The voltage is not within specification.**

If the first statement is true the test is done. If the second condition is true, more testing must be done to locate the source of the problem.

There are three possibilities if a fault exists in this circuit.

1. **The reading is "0" volts.**
2. **The reading is at it' maximum. We'll use 4.5 volts in this example.**
3. **The reading is between "0" and "4.5" volts but not within specification.**

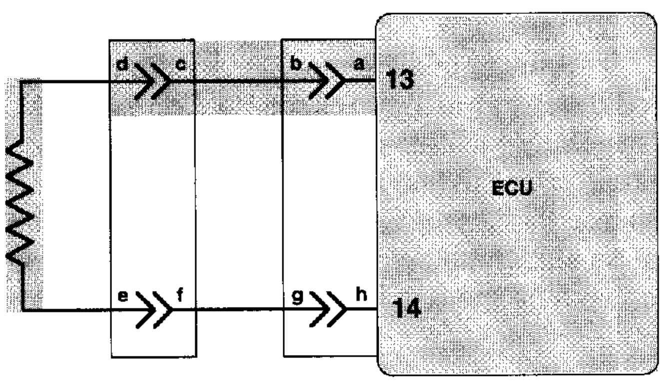
We'll test for each condition. The first



Connections for reading sensor voltage.

reading of "0" volts indicates three possible causes. Shaded area in diagram below indicates the fault areas.

1. Signal wire shorted to ground.
2. The sensor is shorted internally.
3. Control unit fault.



To locate the source of the problem, we start by testing for a shorted sensor signal wire. To set up this test:

1. Turn the ignition OFF.
2. Disconnect the ECU from breakout adapter.
3. Switch DMM to "ohms".

If the DMM reading indicates a sensor resistance within specification, there is nothing wrong with the circuit and the problem is in the control unit.

If the reading is showing at or near "0" ohms, it could be caused by a shorted signal wire or the sensor could be shorted internally. To find out which, disconnect the sensor connector. This will produce one of two possible meter readings:

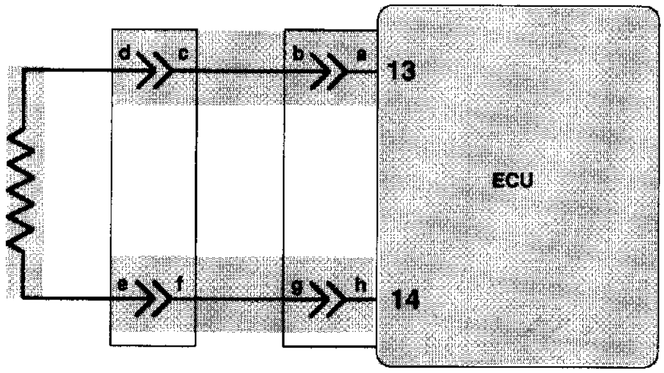
1. The meter reading goes to "OL" after the sensor connector is disconnected.
2. The meter reads the same after the sensor connector is disconnected.

If the meter goes to "OL," the sensor is faulty. If the reading stays the same, the signal wire is shorted. Finding a shorted wire is not easy since it could be anywhere in the harness. Inspect the signal wire for possible insulation damage or a bare wire touching the engine block. It might be necessary to replace the signal wire or the complete harness. This completes the tests for a "0" voltage reading.

The next possibility is a voltage reading of 4.5 or more. Here there are six possibilities:

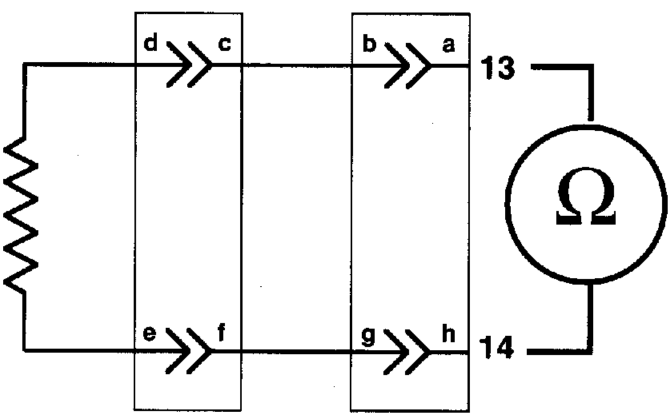
1. Signal wire open circuited.
2. Return wire open circuited.
3. Bad signal wire contact (a-b) or (c-d)

4. Bad return wire contact (e-f) or (g-h)
5. The sensor is opened internally.
6. Control unit faulty.



Remember to follow a line of thinking that will eliminate each potential problem until the fault is found. If you have eliminated all possibilities without finding the problem, the only component left is the control unit. Nobody likes to gamble on control units, so we must be certain that all other possibilities have been checked out first.

Start by reading the resistance in the circuit between terminals #13 and #14. If the resistance is within specification, the control unit is more than likely the source of the problem.

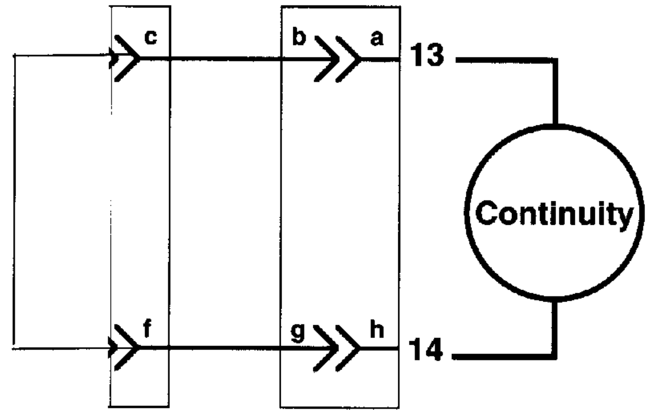


If an open circuit is indicated ("OL"), further testing must be done to find the fault.

Always remember when testing resistance values that the ignition key must be OFF and the ECU must be disconnected.

Follow these steps to test the circuit:

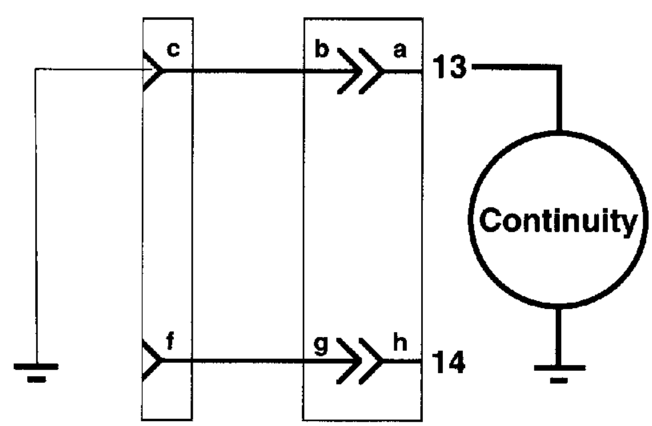
1. **Disconnect the harness connector from the sensor.**
2. **Short the contacts (c-f) in the sensor connector, using a paper clip.**
3. **Check for continuity, using the DMM.**



If the DMM reads continuity, the wiring is good. This means that either the sensor has an open circuit or the ECU is bad.

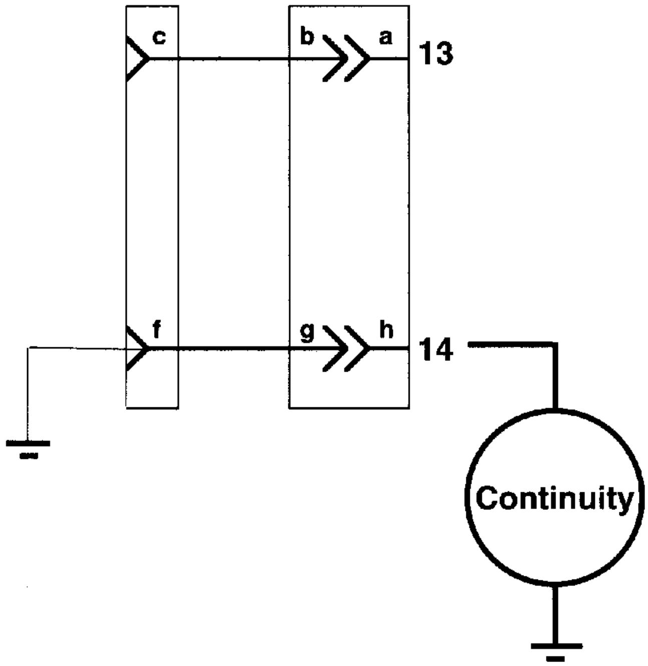
To test the sensor, go directly to the sensor terminals to measure the resistance value. If the DMM indicates "OL," the sensor is bad. If it reads a resistance consistent with known-good values, inspect the contacts on both the sensor and the sensor plug . You are looking for is possible bent contact or terminals that have been pushed back from their original position. Sometimes the wire may break at the point where it is crimped into the contact. Also look for corrosion that might be preventing a good contact to the sensor terminals.

A break in either the signal or return wire would show as an open circuit "OL" on the DMM. If the DMM indicates "OL" you must find which wire is open. To find which wire is open, ground the lead that was connected to #13, then ground "c" as shown below. The DMM should indicate continuity if there is no break in wire.



Now move #13 to #14 and ground to "f"

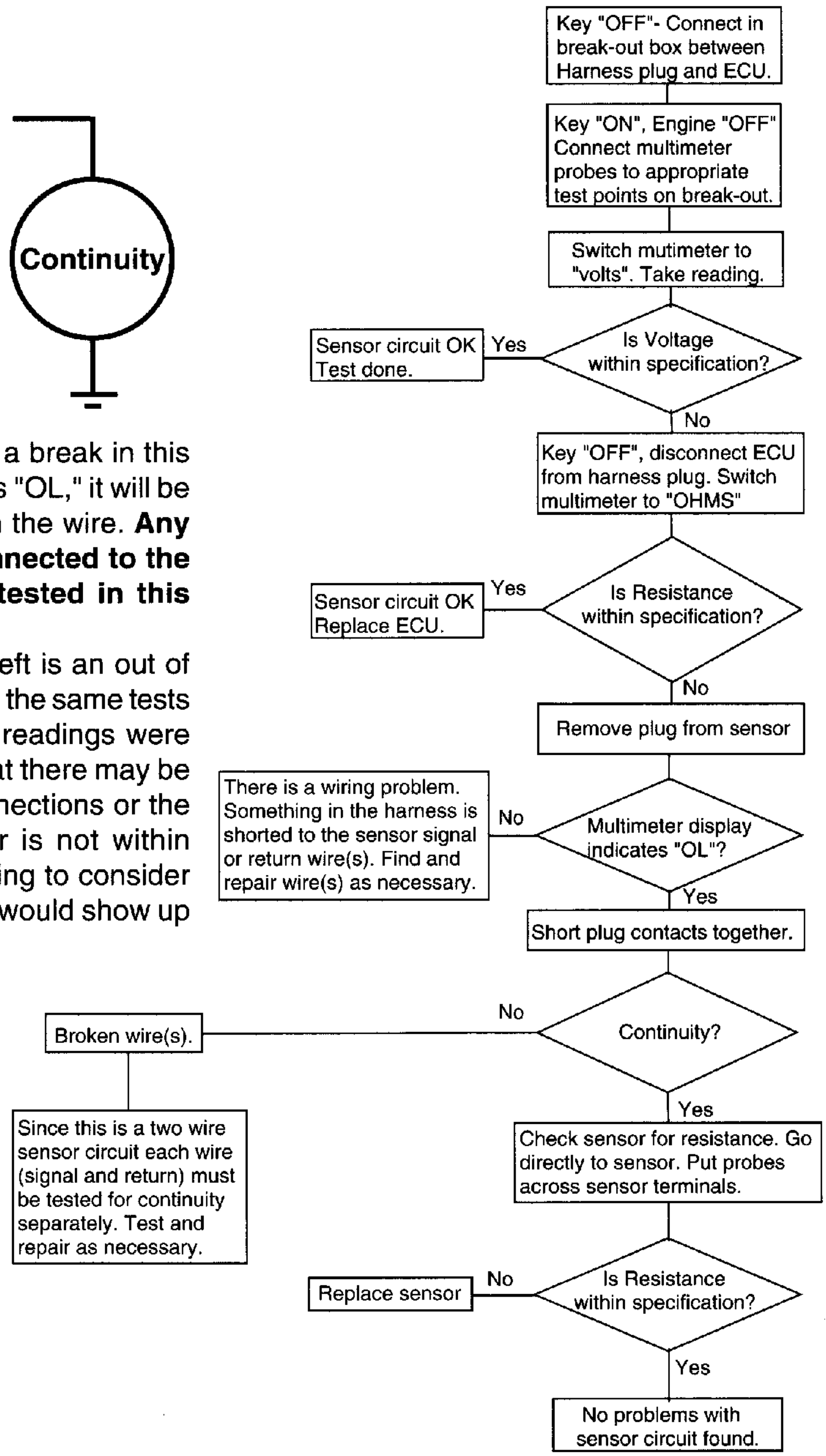
as shown below. The DMM should read continuity or close to "0" ohms.



If there is no continuity, there is a break in this wire. If either of these tests reads "OL," it will be necessary to repair the break in the wire. **Any sensor or actuator that is connected to the ECU with two wires can be tested in this manner.**

The only fault condition left is an out of specification reading. In this case the same tests should be made. If the voltage readings were too high, there is a possibility that there may be additional resistance in the connections or the resistance value of the sensor is not within known-good values. The last thing to consider is a bad ECU. These conditions would show up in the tests as outlined.

Flow chart for checking two wire sensor.



Three Wire Sensor Quick Test

There are a few quick voltage tests that can be used to test a three wire sensor. These voltage tests should be done with a breakout box to save time:

* First, read the voltage across terminals #13 and #15. It should be between 4.5 and 5.5 volts.
* If the voltage reading is correct, it does not necessary mean that the voltage is actually getting to the potentiometer through terminal #13. All it means is that the ECU is furnishing a reference voltage.
* To determine if the voltage is getting to the sensor, go to terminal #14. If you read between .3 and 1 volt, there is an excellent chance the reference voltage is getting to the sensor.
* Now move the wiper of the sensor. The voltage should increase smoothly toward the reference voltage.

There are two other unique readings you may see when you connect to terminal #14.

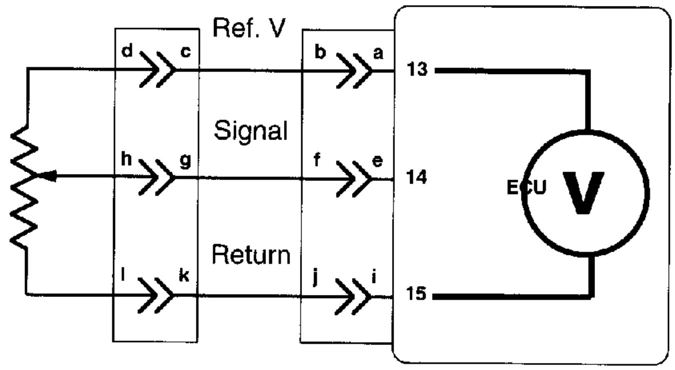
1. **No voltage reading.**
2. **A voltage reading that is the same as the reference voltage.**

If there is no voltage reading, it could mean there is a faulty contact, a broken wire in either the reference line or the signal line or a faulty sensor. **Be sure the main relay supplies power to the ECU.**

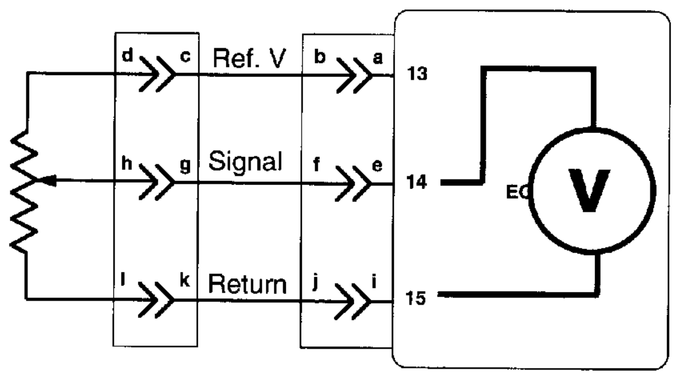
If the voltage reading is the same as the reference voltage, no matter what position the wiper is in, this could mean that the return line has either a faulty contact terminal, a broken wire or a faulty sensor.

This is a quick way to test the three wire sensor using the Voltage mode only. If you discover a problem, you can do the fault isolation checks using the Ohms mode as we will describe next. If you do not discover a problem, you don't need to do the time-consuming Ohms check. A breakout box should be used to perform voltage tests. To summarize:

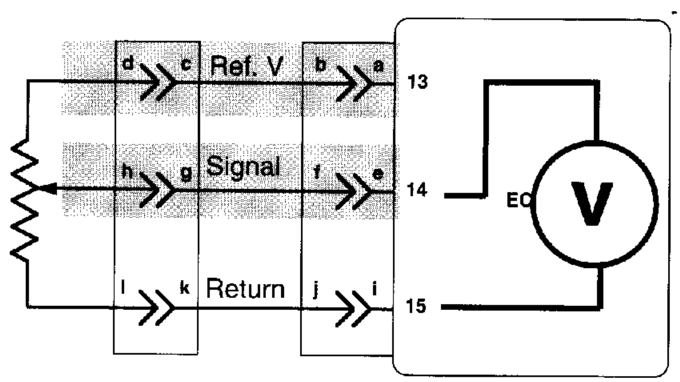
Step 1: Read voltage across the sensor reference and return terminals as shown below.



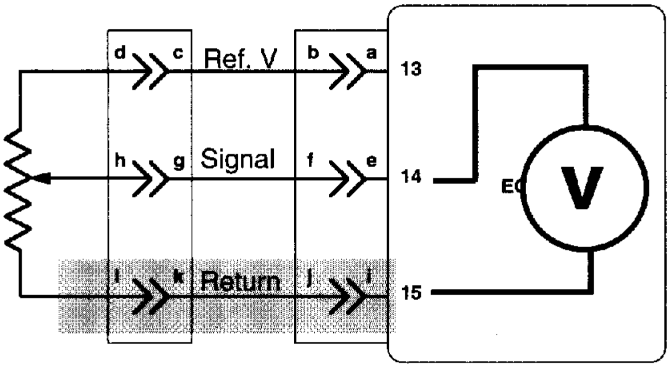
Step 2: Read voltage across the signal and return terminals as shown below. Move wiper and watch for a smooth increase in voltage.

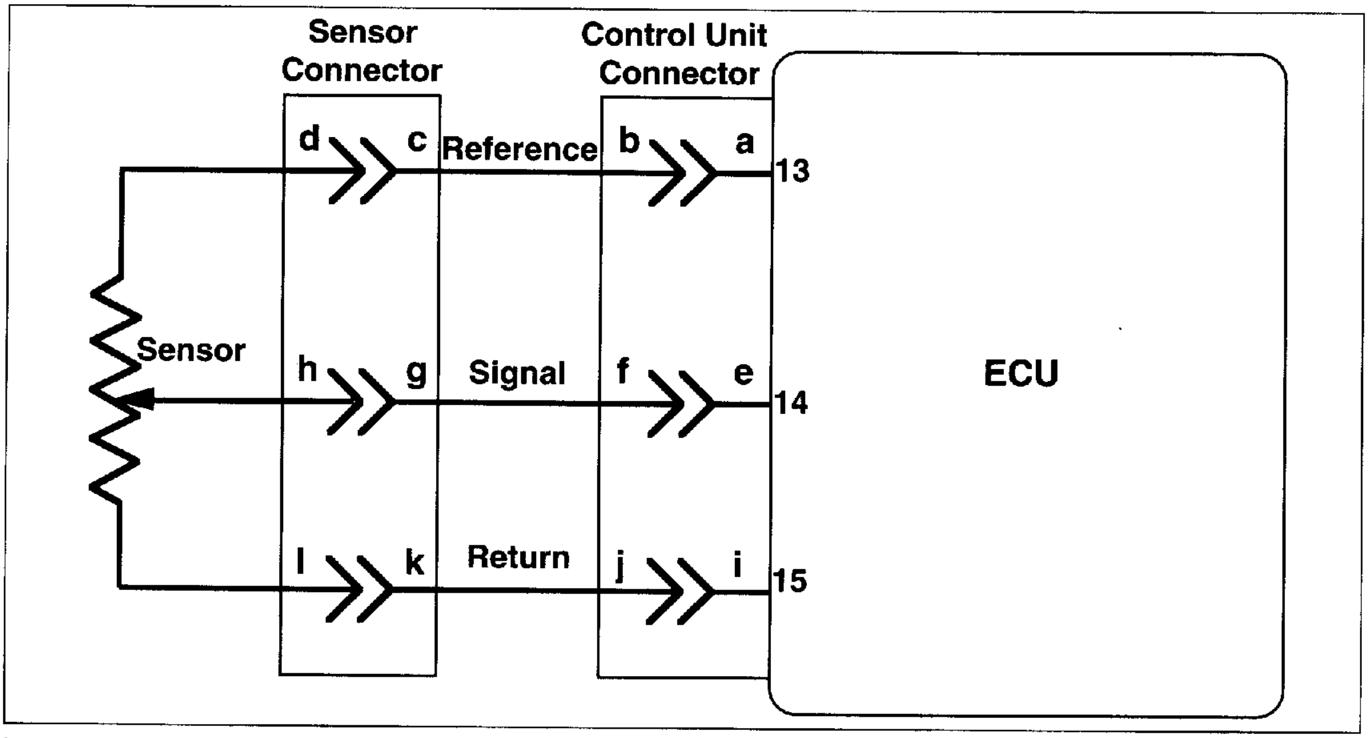


* If there is no voltage reading, check the shaded area as shown above. Include the sensor and the signal wire.



* If the reading on the signal or wiper is the same as the reference voltage check the shaded area of this circuit.





You may have noticed that we are adding a wire to the circuit as we proceed. If the quick tests reveals that the circuit has a problem, the following procedures are necessary to make the repair. The more wires, there are, the more complicated it gets to test and troubleshoot the circuit. That's why it is important to develop a discipline for troubleshooting. Even though the circuit shown is a bit more complicated, the same techniques can be used to find solutions to possible faults.

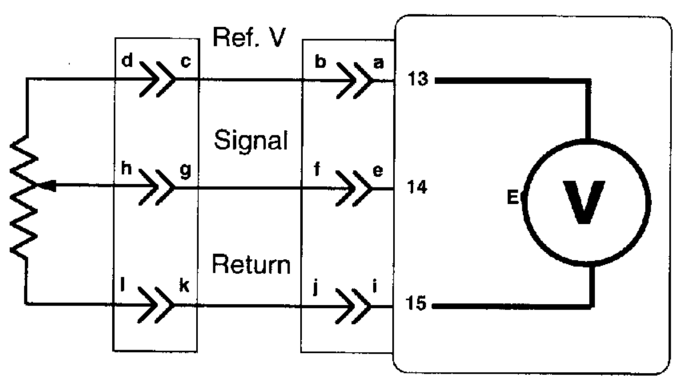
The only difference is that there is one additional wire added to our circuit. The possible problems with this circuit are the same as the previous circuits.

1. **Control unit connector. (a-b), (e-f) & (i-j)**
2. **Sensor connector. (c-d), (g-h) & (l-k)**
3. **Reference wire continuity.**
3. **Signal wire continuity.**
4. **Return wire continuity.**
5. **Sensor fault.**
6. **Control unit fault.**

Sensors that are connected to the ECU in this manner include throttle potentiometers, air flow sensors and altitude sensors. These sensors convert mechanical movement to a voltage which is proportional to that movement. For example, in the case of a throttle potentiometer, the voltage is proportional to throttle angle.

Begin with the harness connections as a possible source of a problem. Check the contacts to the ECU at "a" to "b", "e" to "f" and "i" to "j". There are also three connections at the sensor end which are "c" to "d", "g" to "h" and "l" to "k" respectively.

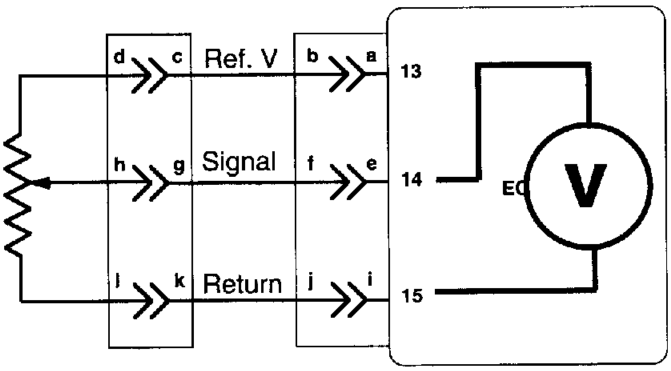
Perform a wiggle test first. Read the voltage between terminal "13 and "15". Turn the ignition key "ON," but don't start the engine. In most cases the reference voltage will be 5 volts plus or minus 10 percent.



There are three possible readings that you may see for these voltage tests:

1. The voltage is within range.
2. The reference voltage is not within range.
3. The signal voltage is not within range.

We aren't done with the three wire sensor test because we still have to test the signal terminal. If the voltage reading is not within specification, we must find the problem before going on to test the signal terminal. We will assume that the voltage is within specification and test the signal terminal. It should be pointed out that if the reference voltage is wrong, the signal voltage will also be wrong.



The voltage reading will be measured between terminals "14" and "15" as shown above. What should the reading be? Some conditions must be set first:

* The ignition key is still "ON" and engine is "OFF".
* If you are testing a throttle potentiometer, keep your foot off the accelerator pedal to prevent the reading from being affected.
* If this is an air flow sensor, the sensor flap will be in its at rest position because the engine is "OFF".
* The voltage measured will be between .3 and 1 volt.
* As the potentiometer is moved from fully closed to fully open, the voltage will increase smoothly toward the reference voltage.

For the second condition "reference voltage not within range," our measurement will be taken between terminals "13" and "15." There are three possible outcomes:

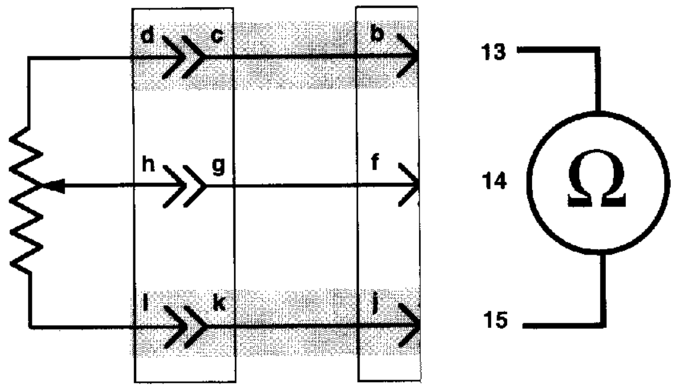
1. A bad sensor.
2. Faulty wires.
3. A defective ECU.

We'll test the sensor, then the wiring harness. If both are okay, we can assume that the ECU is faulty.

To test the sensor circuit :

1. Turn the ignition key OFF.
2. Disconnect the ECU harness connector.
3. Switch the DMM to "OHMS" mode.

Connect the DMM probes to terminal #13 and #15 as shown below.

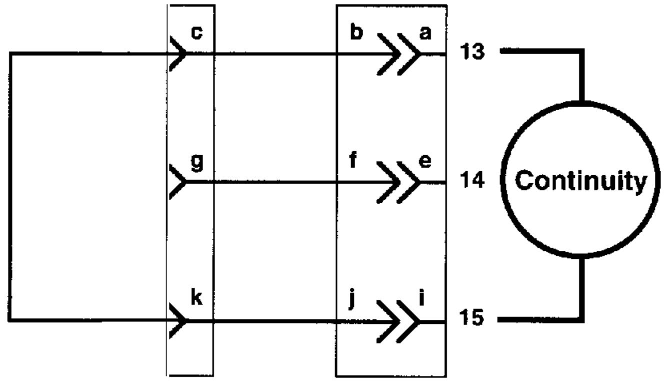


An ohm reading of 3000-5000 ohms would be considered a normal reading. If the reading is "OL," there are three possible causes:

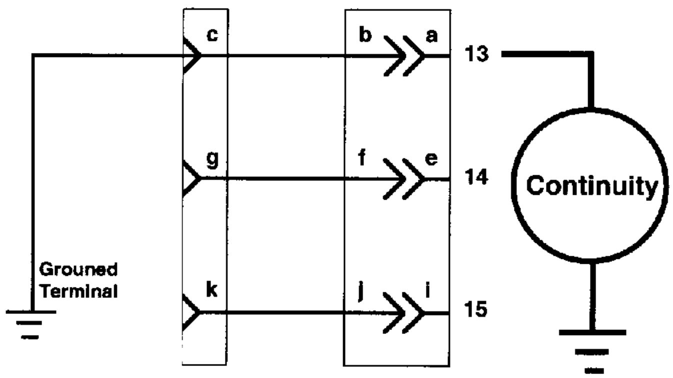
1. A broken reference wire or connection at terminal #13.
2. A broken return wire or connection at terminal #15.
3. A bad connection at the ECU harness con nector ("a" to "b") or ("j" to "i") or sensor harness connector ("c" to "d") or ("l" to "k"), as shown in the shaded area above.
4. The sensor is internally open-circuited.

To check the continuity of the wires at terminal #13 and #15, disconnect the sensor. Inspect the sensor connector for misaligned terminals or broken wires at the contact terminals at the back of the connector. After your inspection is complete, short the sensor harness connector terminals together as shown top of next page. **Remember, the ECU must be disconnected and the ignition must be "OFF".**

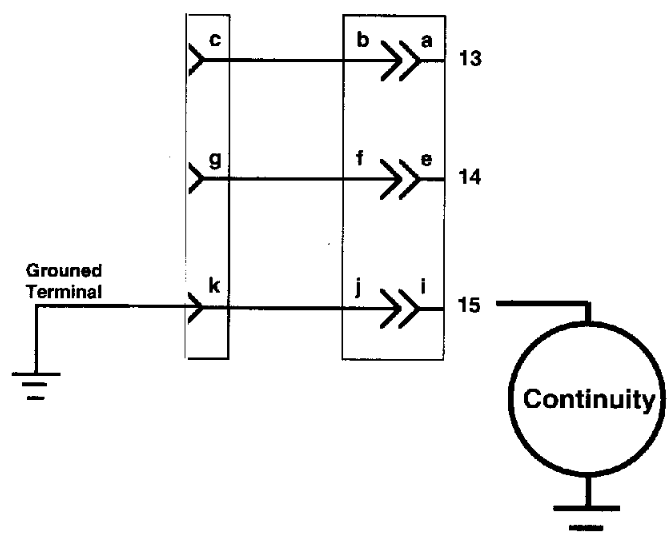
Read the continuity of the wires if the connections are okay. If there is no continuity, it will be necessary to separately check each wire for continuity. To do this, ground one of the wires on the sensor connector end, then attach one



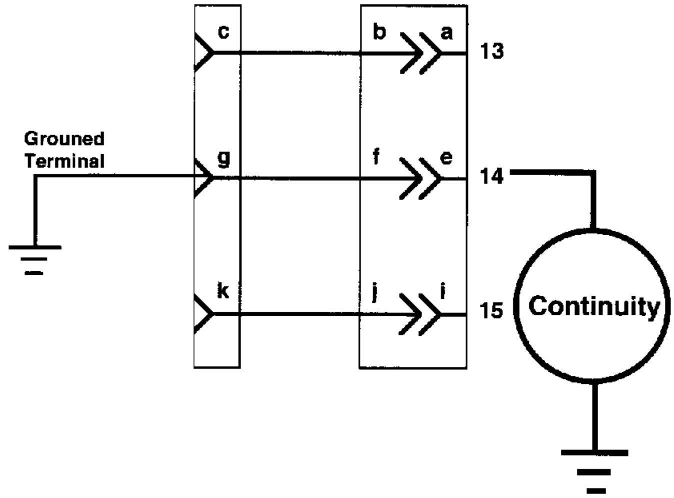
probe of the DMM to ground. Connect the other probe to the ECU harness terminal as shown below. Follow the color code to match what was grounded on the sensor connector end. You should read continuity if this wire is okay.



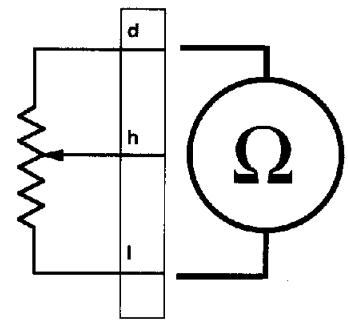
The same check is used for the other wires. Connections are shown below. You should read continuity on each of the remaining wires.



The last wire to test is the signal wire. To test, move the ground to terminal "g" and the probe to terminal #14 as shown above right.

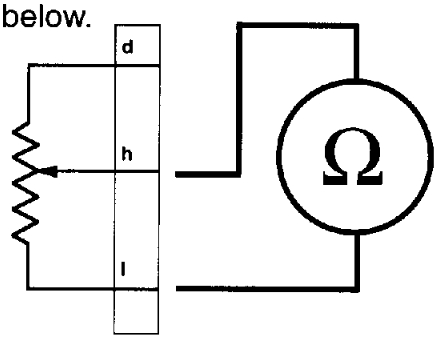


If the wires are okay or repairs have been made, the next test involves the sensor itself. Connect the DMM as shown below.



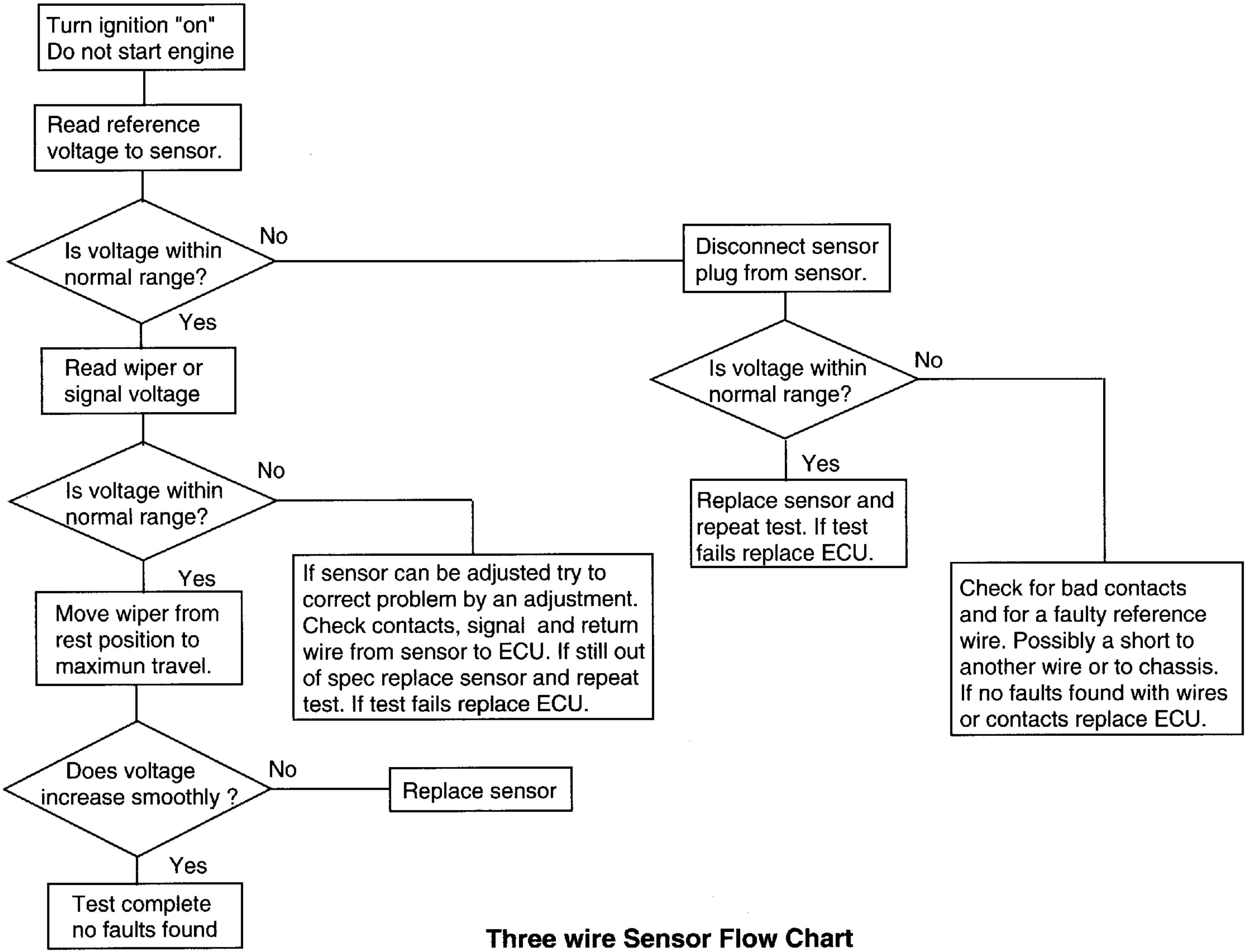
If you read "OL" or out of limits, the source of the problem would be the sensor. If no problem has been found after doing these tests, we need to test the signal terminal or the wiper of the sensor.

Move the probe from terminal "d" to "h as shown below.

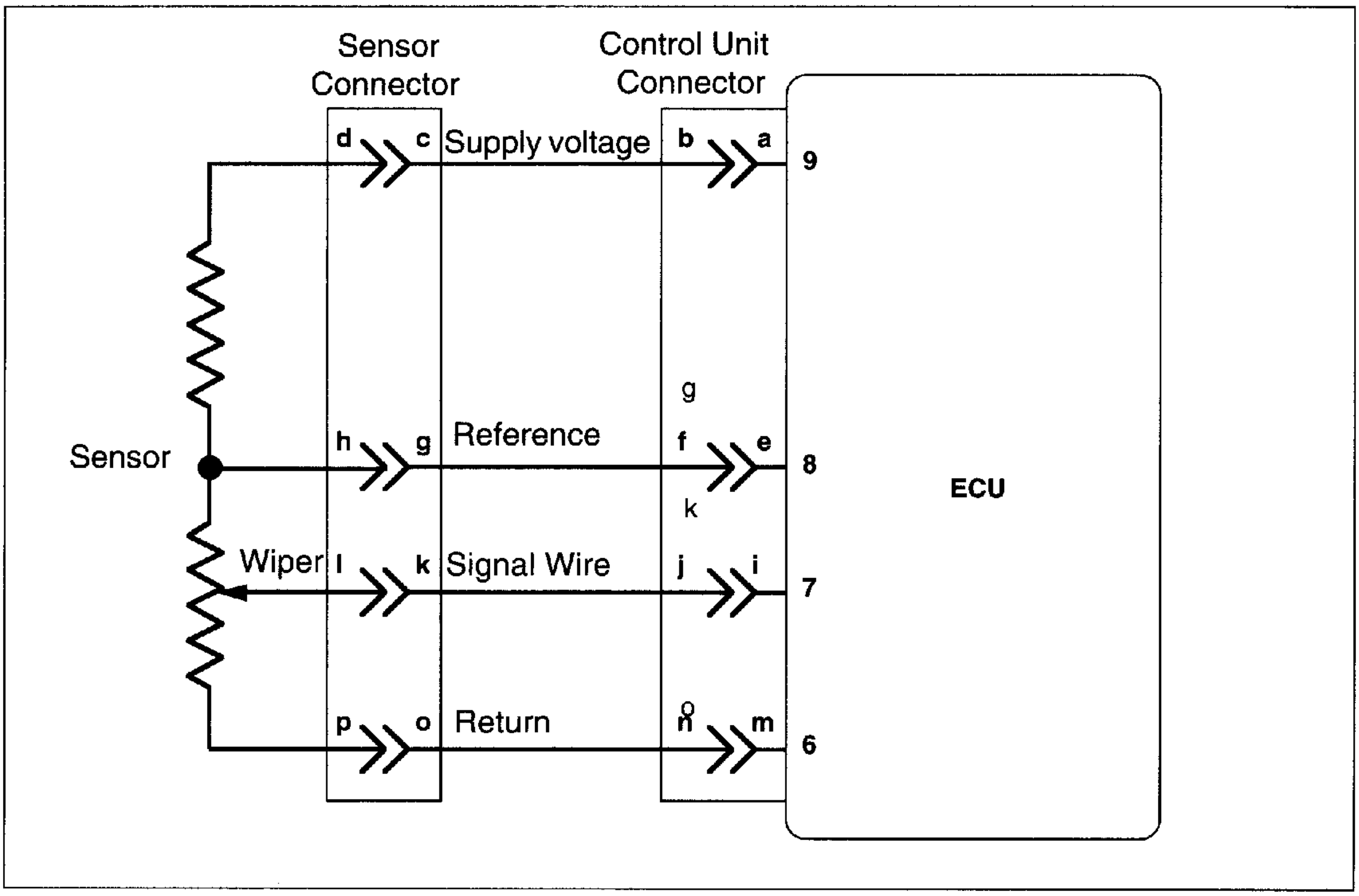


The resistance reading should be less than 1000 ohms. As the sensor wiper is moved, the resistance should increase toward the maximum value of 3-5000 ohms.

Make sure there are no intermittent readings. If the reading jumps randomly or goes to an "OL" and back to normal, the potentiometer is faulty and the sensor needs to be replaced. If no problems were found, the ECU may be faulty. This concludes the test.



Three wire Sensor Flow Chart



An example of the four wire sensor is an early Intake Air Sensor. Many vehicles that used this type of sensor are still driving around. On later systems, most have been replaced with the newer three wire versions or the hot wire Air Mass Meter that started to gain popularity around 1984. Jaguar used the basic four wire system until 1988 on some models. The Japanese also used this sensor type until the late 1980's.

The intake air sensor measures the volume of air entering the intake manifold. A flap opens as air rushes into the intake manifold. As engine load increases, the flap opening increases. Connected on the same pivot point as the flap is a wiper that moves in conjunction with the flap. The wiper picks off a voltage from a resistive substrate and sends this voltage to the ECU for load information.

The sensor flap should be tested for smoothness of movement as it is opened and closed . The flap should not hang up when it is released. Check the flap movement before doing any electrical tests.

We'll start by measuring voltages at the interface to test this sensor. If we get incorrect readings, we'll do our ohm and continuity tests.

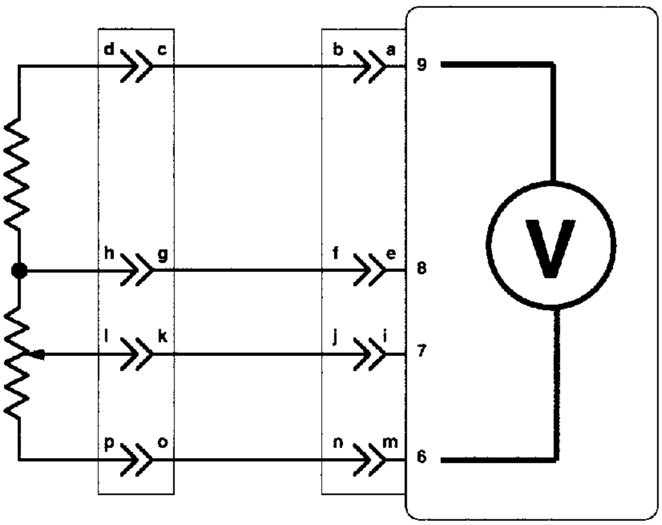
Some of problems you may encounter when testing this sensor are:

1. **Flap hangs up or jams.**
2. **Return spring is weak. Flap does not re turn to rest position.**
3. **Resistive sensor substrate worn.**
4. **Bad sensor contact terminals.**
5. **Bad sensor harness terminals.**
6. **Faulty wiring.**
7. **Bad ECU terminals.**
8. **Air leaks.**
8. **Defective ECU.**

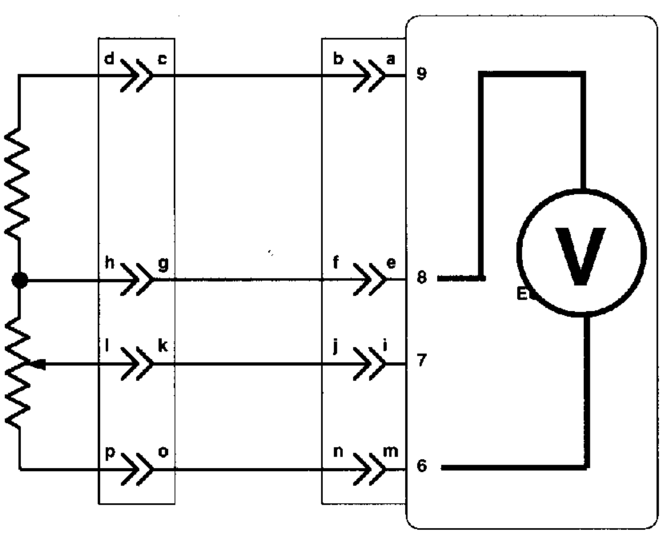
Use a breakout box to test the sensor for voltage. Begin by connecting your DMM to terminals #6 and #9. Be sure the DMM is on the voltage mode. Once connected, turn the ignition "ON". Do not start the engine.

Remember to check for the correct voltages first. If you encounter a problem, use continuity tests to isolate the fault. The pin numbers used here and in previous sections are arbitrary. Actual pin numbers for specific systems are listed in the data section of this book.

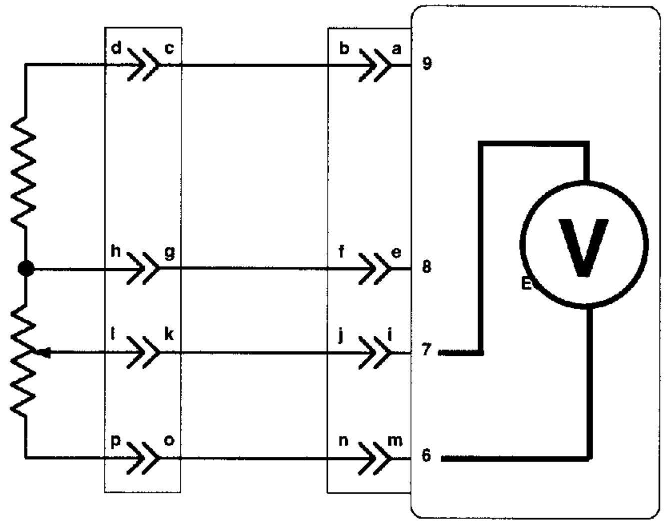
Make DMM connections as shown below. The voltage measured is being supplied by the ECU. **If no voltage is measured, make sure that power is being supply to the ECU by the main relay**. The voltage measurements at these points will be about 2 to 3 volts less than battery positive voltage.



Next move the DMM probe from terminal # 6 to #8 as shown below. This is the reference voltage and will vary, depending on the vehicle. Reference voltage will usually be 5 to 7 volts less than battery positive voltage.



The next measurement is taken at terminal #7. Move the probe from #8 to #7 as shown below. The voltage should be between 1.5 and 2.5 volts.



Next we must test for a varying voltage as the flap is moved from its rest position to the wide open position. Watch for a smooth increase in voltage as the flap moves toward full open. Random voltage fluctuations indicate a faulty sensor. The maximum voltage will be 6.5 to 8.5 volts when the flap is wide open.

There are two problems that we can quickly identify when performing these tests:

1. **If all measurements are equal to the supply voltage, a fault in the return line is indicated.**
2. **If all measurements are zero volts, a problem in the supply line is indicated.**

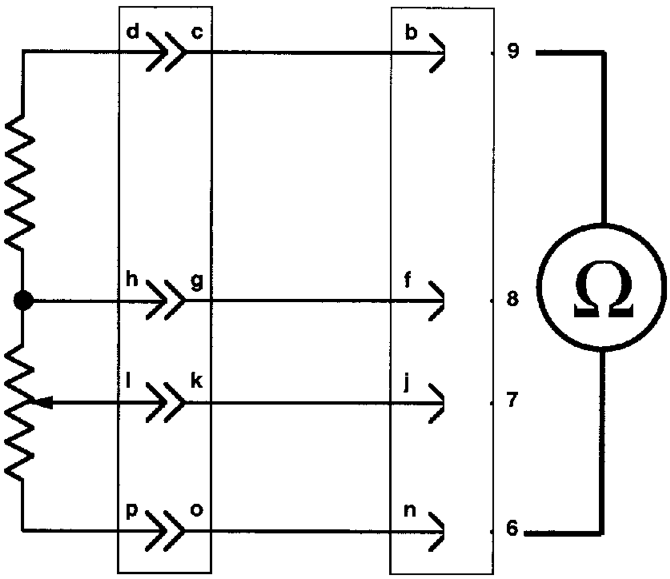
Both of these problems could be the result of a faulty ECU. It is necessary to check for faulty contact terminals and wiring problems before replacing the ECU.

To begin fault isolation testing, take the following steps:

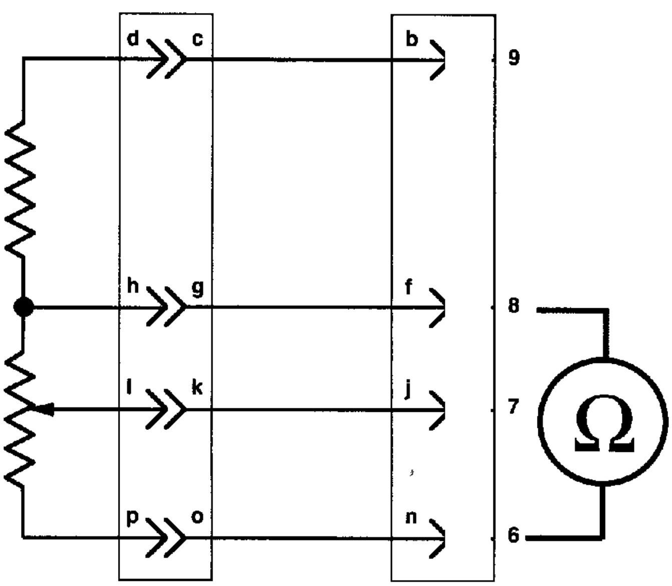
1. **Turn the ignition "OFF".**
2. **Disconnect the ECU harness connector.**
3. **Switch the DMM to the OHMS mode.**

* We will start by measuring the resistance from terminal #9 to terminal #6. If a problem is found it must be corrected before going to the next test.

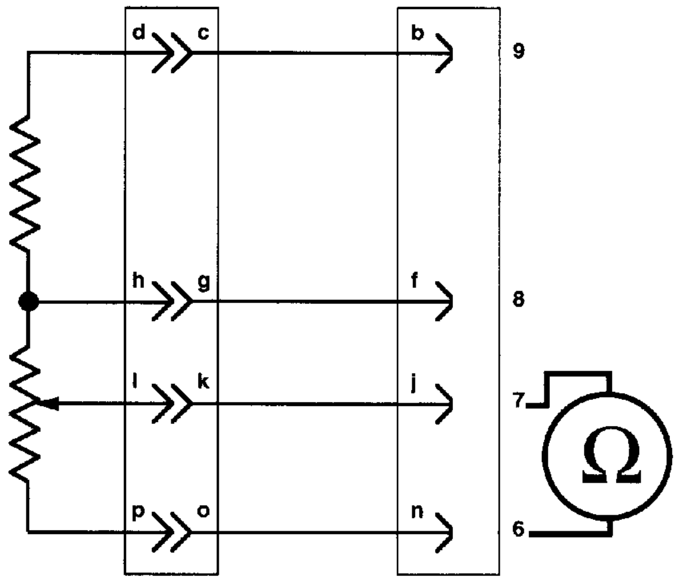
* Connect the DMM as shown below. The resistance reading will vary greatly, depending on the type of vehicle. A measurement between 400 and 1000 ohms usually indicates a good sensor. Most intake air sensors will fall within this range.



* Next move the probe from #9 to #8 as shown below. The resistance measurement should be about 300 to 900 ohms.



* The final resistance measurement is taken between terminal #8 and #7. Connect the DMM as shown above right. The resistance will be less than 100 ohms with the sensor flap closed.
* Next move the flap toward the full opened position while observing the readout on the DMM. The resistance will increase in steps. Watch for a meter reading that momentarily goes to an "OL" indication.
* If you get an "OL" indication, this means the

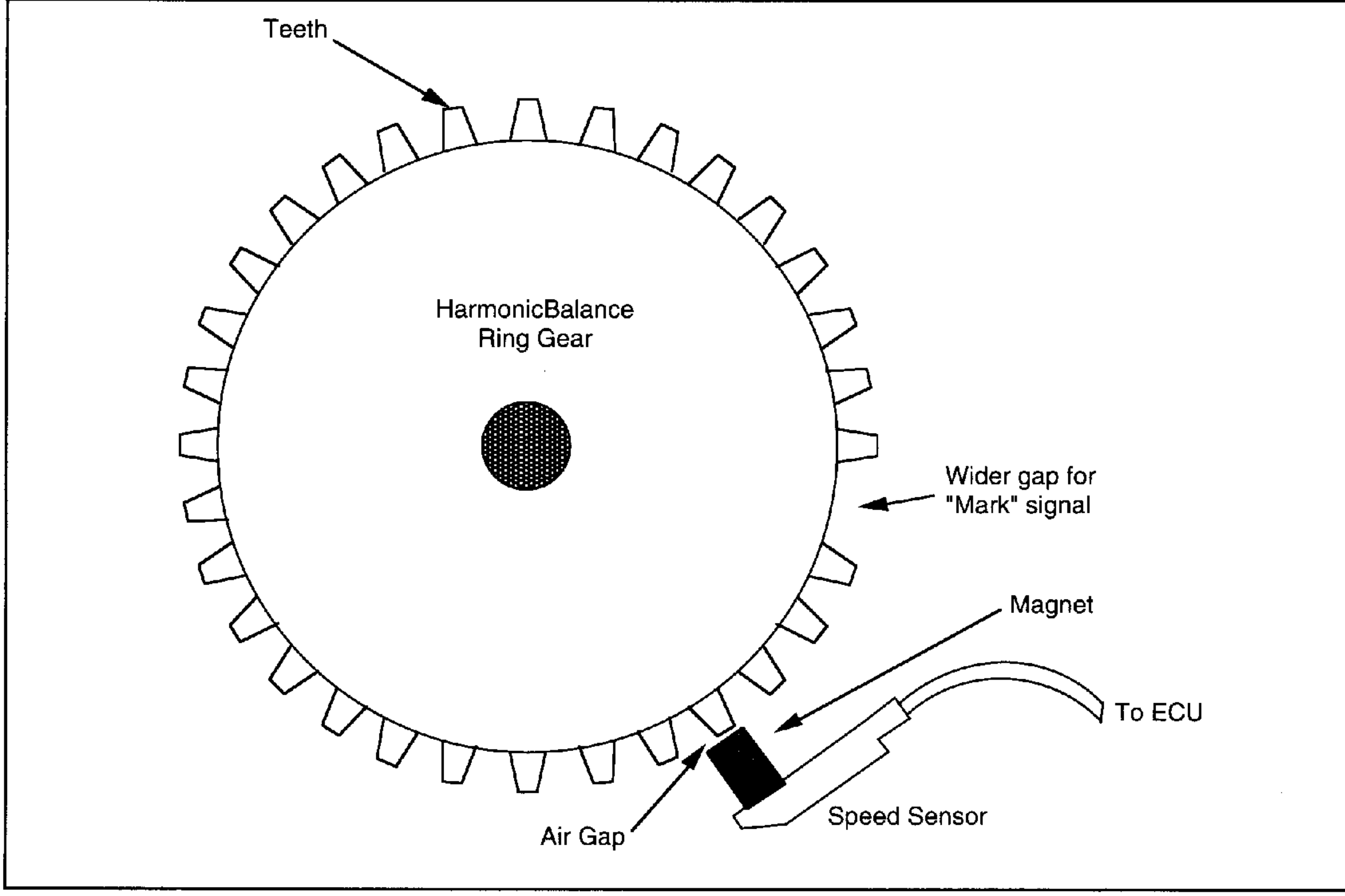


sensor's resistive substrate has worn spots on it. This problem may cause the engine to run rough and not accelerate smoothly.

If you get an open circuit indication at any time during these tests, remove the sensor connector and test the sensor directly. If the sensor checks out okay, check the wires and inspect the contacts in the harness connectors.

To check the wires, use the techniques that were described in earlier sections. Start with continuity tests for the sensor wires and inspect the ECU and sensor harness contacts. Once all the wires and contacts have been inspected and tested and any abnormalities corrected, reconnect everything and repeat the tests, starting with the voltage readings.

Remember, this is an intake air sensor it will be influenced by air leaks. Make sure that the fittings around the sensor are tight and the duct work has no cracks that could allow false air to enter the intake manifold. If all tests pass but the circuit does not operate as intended, replace the ECU.



As we mentioned previously, magnetic sensors are widely used in ignition timing applications and anti-lock braking systems. No matter where they are used, they all operate using the same basic principles:

***A magnetic sensor is placed close to a toothed wheel.**
***As the wheel turns, voltage is induced into the sensor's winding.**

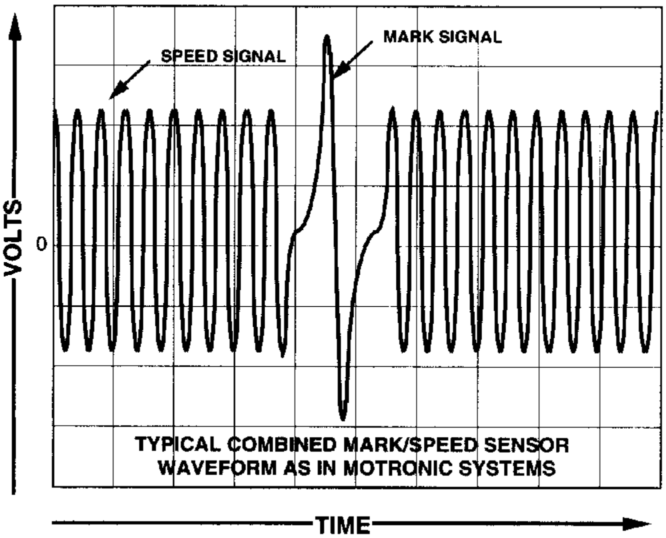
We need to understand how to test this circuit and know the kinds of problems we may encounter. Since this is an electromechanical sensor, testing for continuity and proper resistance measurements may not expose the problem. Electrical voltage tests are best done with a oscilloscope, not a DMM.

All the possible problems you may encounter with this circuit are the same as any other sensor, with a few more twists. Let's start with a list of possible faults, then we will cover the repair techniques for each case:

1. **Faulty connector contacts.**
2. **Faulty wiring.**
3. **Faulty shield wire.**
4. **Winding of sensor opened or shorted.**
5. **Weak magnetic field.**
6. **Air gap between sensor and wheel too wide.**
7. **Toothed wheel damaged.**
8. **Toothed wheel clogged with dirt and grime (ABS wheel speed sensor only).**

The most effective method of testing a speed sensor is to connect a scope to the sensor and monitor the waveform while cranking the engine. In the case of ABS, monitor the waveform while spinning the wheels. If no waveform is present, tests to isolate the problem are necessary. If a good waveform is observed, there's no need to waste time doing any further testing.

What is considered a good waveform? The waveform shown next page top left would be considered good for a Motronic system. The speed signal should be more than 1 volt peak to peak while cranking. Two pulses are generated for each tooth, one positive and one negative. The pulse will look something like the one shown below.



TYPICAL COMBINED MARK/SPEED SENSOR WAVEFORM AS IN MOTRONIC SYSTEMS

This alternating air gap from minimum to maximum causes the magnetic field to build and collapse. The reluctance of the magnetic field is changing as the toothed wheel or reluctor rotates. The reluctor must be made of a material that has magnetic properties, such as iron or steel.

The difference between the maximum and minimum air gap for a magnetic sensor is very small. The teeth are very small and a build up of dirt and grime between the teeth can make the wheel appear smooth. There will be no difference between the high and low points as the wheel rotates. This will cause a very small induced voltage, or none at all.

The larger Mark pulse should have an amplitude of more than 2 volts peak to peak while cranking. These voltages will increase as engine RPM increases.

Suppose there were no pulses or the pulses were too weak for the ECU to detect during cranking. Use the following tests to determine why this would occur:

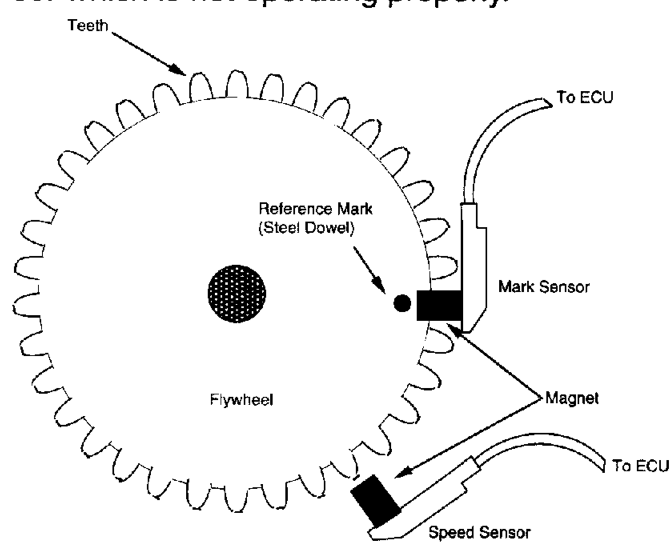
1. Wiggle the connectors at the sensor. You are looking for a bad or intermittent contact terminal.
2. Check for continuity.
3. Check the sensor resistance (800-1200 ohms) is considered a good value.
4. Check the shield wire and look for a possible short of the signal wire to the shield wire.

That's all there is to the static electrical tests. If no problem is found, there are a few more options you should be looking at.

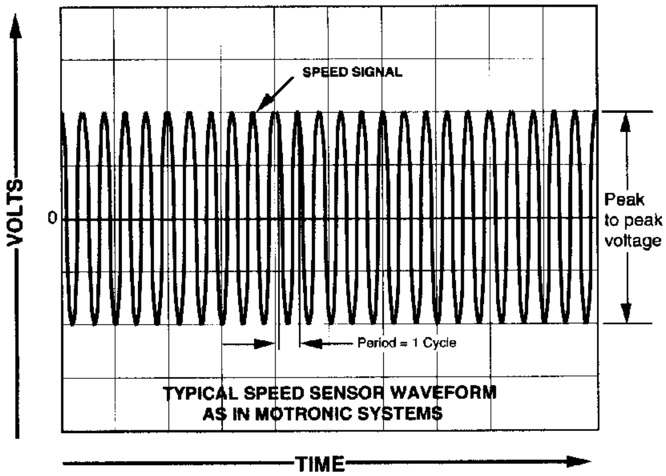
1. Make sure the sensor has not come loose. Remember the air gap distance from the tip of the toothed wheel to the sensor should be about 1.5 mm. If the air gap is more than 1.5 mm, the magnetic field will be weaker. If the air gap is too wide, the magnetic field will not sufficiently impinge on the toothed wheel and little no voltage will be induced into the sensor winding.

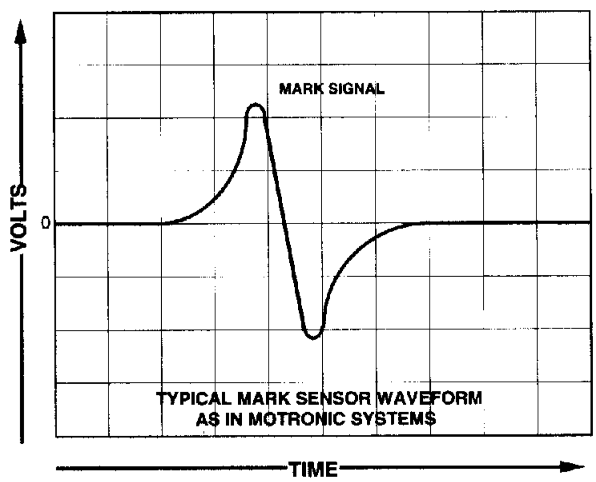
2. If the sensor is mounted correctly and the air gap is okay but the induced voltage is not great enough for the ECU to recognize it could be that the magnet in the sensor is weak. In other words the magnetic field strength is not what it was when the sensor was new. A device that could measure the magnetic field strength is called a gauss meter. It would be possible to measure the magnetic field of a new sensor and use its value for comparison purposes to older sensors. I don't know of anyone using a gauss meter to test these sensors but it is possible.

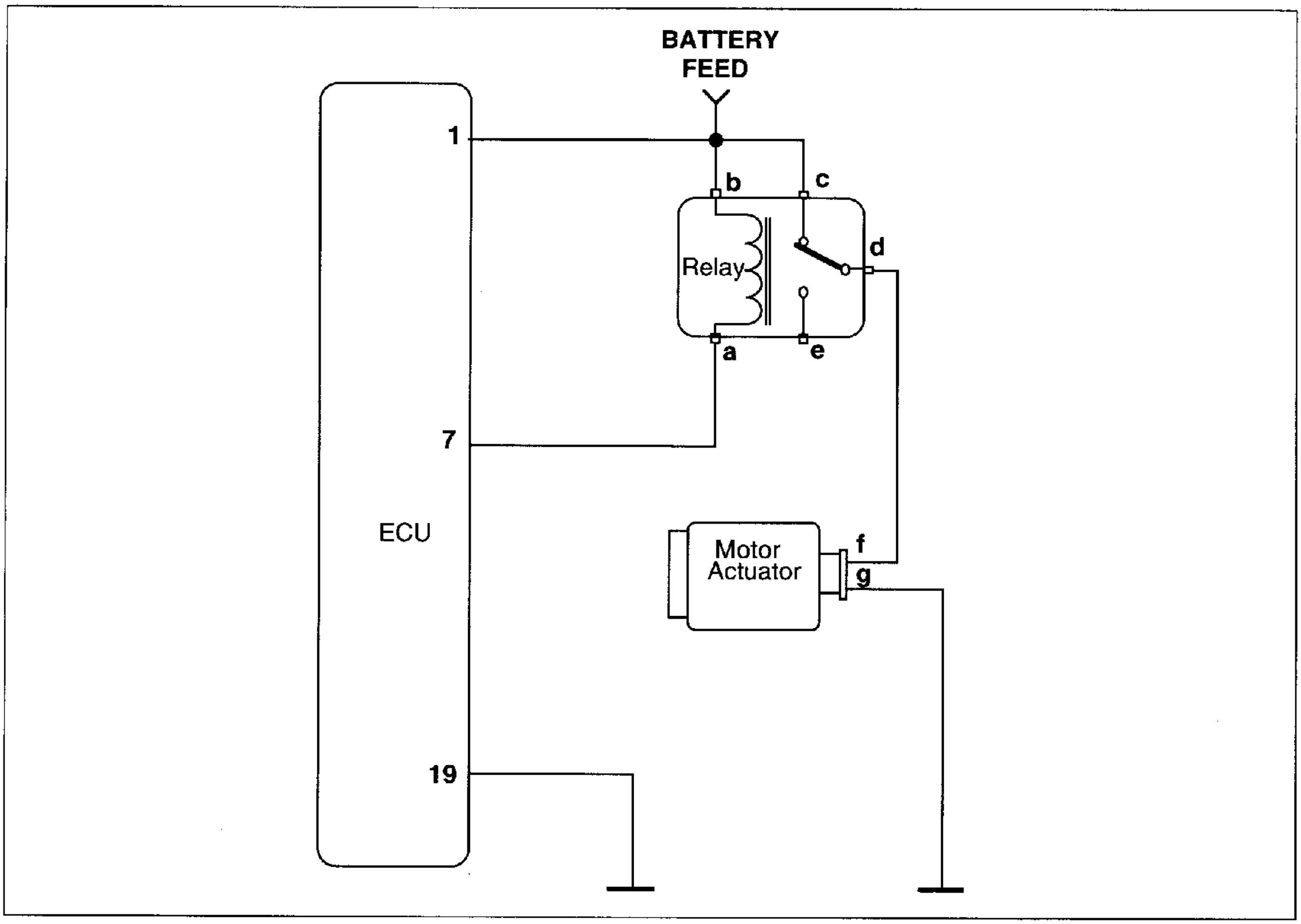
3. The final part that should be inspected is the toothed wheel, especially a wheel speed sensor which is not operating properly.



Look for tooth damage or a build up of grease mixed with dirt that may contain magnetic material. Also, for the "mark" sensor in Motronic systems make sure the steel dowel is not broken off or missing. The engine may start with the reference mark pulse missing but it will stall at about 1500 RPM when you try to accelerate. If the speed information is missing the Motronic System will not allow the engine to start. Below is an example of how the waveforms would look on a scope for the "mark and "speed sensor signals in an early Motronic system.







All computer controlled systems have inputs to the ECU and outputs from the ECU. A sensor is an input device to the control unit. The control unit would be of no use if all it did was receive voltage and process information. That's why we have actuators and relays. These devices are output devices under the control of the ECU. A relay can actually be both an input and an output device depending on its application. For example if the control unit is connected to the relay coil and is responsible for energizing it, the relay is an output device under the control of the computer. If on the other hand, the relay is controlled for example, by an ignition switch and the relay contacts provide power to the ECU the relay is an input device to the ECU. The conclusion is relays are both input and output devices to the ECU. It depends on the circuit connections.

For the circuit above, the relay is an output device under the control of the computer. The relay provides power to the motor. This circuit is quite common in many automotive schemes. It is important to understand how a circuit is supposed to operate in order to troubleshoot it.

In this case battery voltage is supplied to the relay at all times. There will be a fuse in the battery feed circuit. This is a good place to check first if no power is present. Usually when a relay is controlled by the ECU and that relay controls a motor, the motor is a high current device. The ECU can't control the motor directly. In this case the ECU must provide a ground through a transistor to energize the relay. The relay contact closes to battery voltage and current will flow through the motor to ground completing the circuit.

What if this circuit is not operating? The easiest way to check this circuit is with a breakout box. Since all the pins at the computer interface are at your finger tips when a breakout box is connected, you can do some simple simulations. With a breakout box connected and the

ECU disconnected, provide a ground on pin #7 of the circuit to see if and the motor will operate. If the motor works then you have a faulty ECU. Fast and simple right.

A word of caution! Sometimes motor and actuators are only activated under certain driving conditions. These conditions are sensed by an input device and sent to the ECU. If the ECU does not get proper information, it will fail to activate the relay. The ECU will be unaware of engine conditions due to sensor failure. So, even though you have verified that this circuit works when grounding pin #7 it does not necessarily mean that in every case the ECU will have to be replaced. Keep this in mind since an ECU is expensive to replace. This is where knowledge of how a system operates comes in handy.

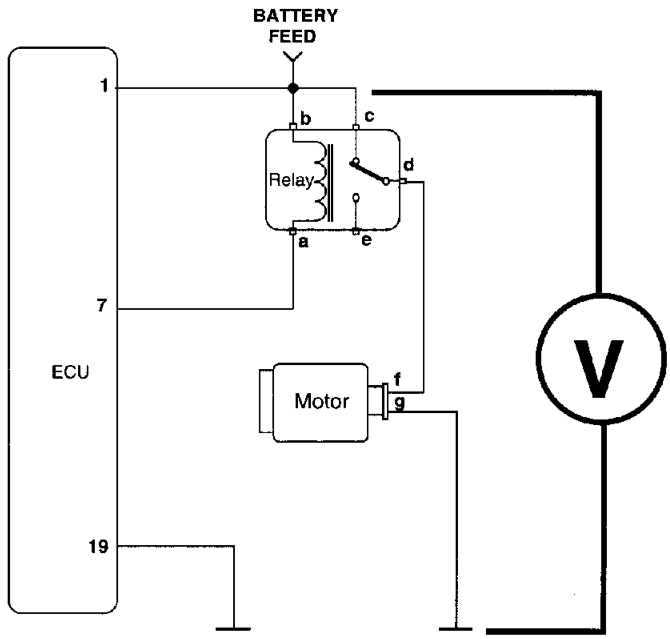
What happens if pin #7 is grounded but the motor does not activate? Check the following:

1. **Check that battery voltage is present at the relay terminal "b" and "c".**
2. **Check for a ground signal at from #7 to relay terminal "a" when pin #7 is jumped to ground.**
3. **Check the relay coil resistance.**
4. **Check for voltage from relay terminal "d" while pin #7 is grounded. The relay should be energized.**
5. **Check for voltage at terminal "f" while pin #7 is grounded.**
6. **Check motor winding for proper resistance.**
7. **Check the motor ground wire from "g" to chassis ground.**

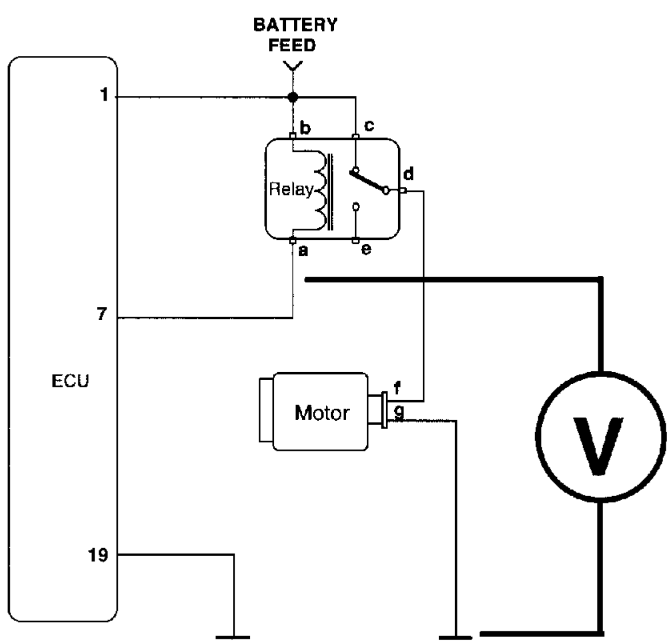
These seven items can be checked in any order but the order I listed them in is the way I would proceed. Sometimes it's best to start with the easy things first then proceed towards the more difficult items. It will vary from car to car and system to system.

The first check is to see if battery voltage is present at the relay terminals "b" and "c". To check for this put the DMM probes from terminal "d" and then to terminal "c" to chassis ground. If no voltage check for blown fuse. If still no voltage check wiring from relay to battery source. Notice that you need voltage at both relay terminals for this circuit to operate. Terminal "b" feeds the relay coil and terminal "c" feeds the relay contact. Refer to the circuit below.

Next you will check to see that a ground signal is present at relay terminal "a" when pin #7 is grounded..



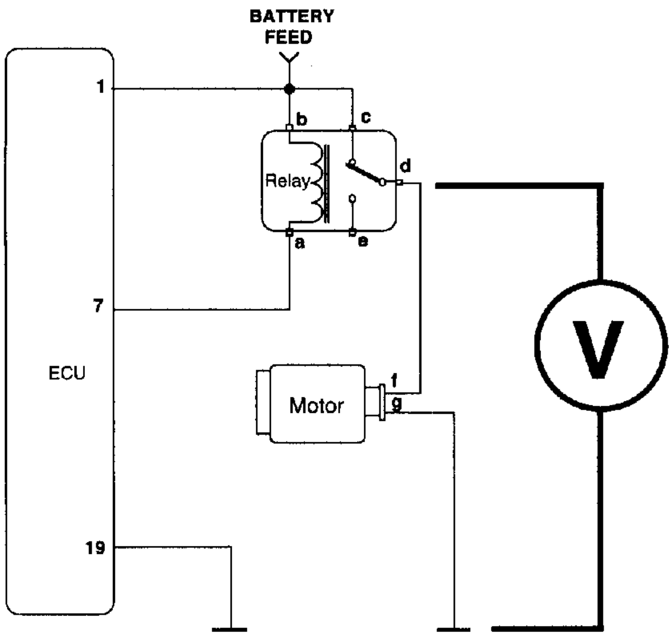
Refer to the circuit below. If we move the positive probe from terminal "c" to terminal "a" we should read "0" volts if the wire from #7 to terminal "a" is good.



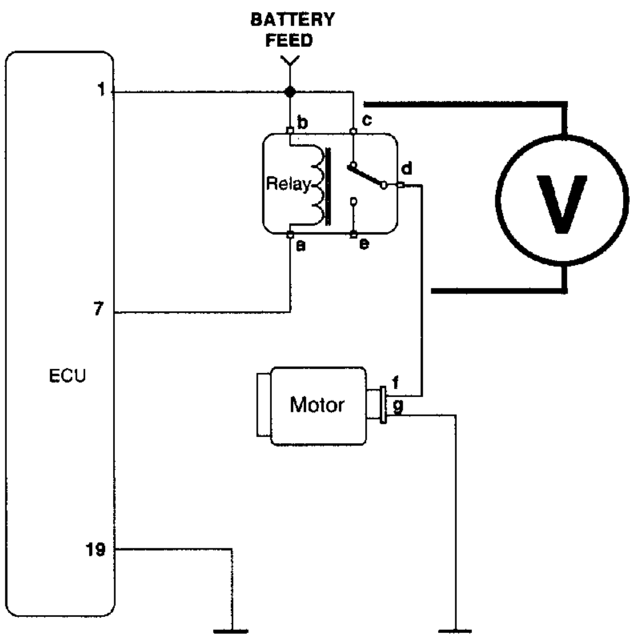
If the wire is not good you would read battery voltage assuming that test one was okay. If battery voltage is read the wire from the ECU #7 to relay terminal "a" is opened.

Test three measures the coil resistance between terminal "a and "b" usually it is should be around 80 to 120 ohms.

For test four we check to see if the relay contacts are good. Move the positive probe of the DMM to terminal "d". If the relay contacts are good the voltage should be equal to battery volts.



If the relay works, you should here a click each time pin #7 is grounded. If you do not here a click and you're not deaf you will not get battery voltage at relay terminal "d".



Another good method of checking the relay (especially for high current circuits) is to check the voltage drop across the relay contacts. To do this put the negative probe on relay terminal "d" and the positive probe on relay terminal "c" as shown below left. If the contacts are good you will see only a small voltage drop across the relay contacts (less than one tenth of a volt in most cases).

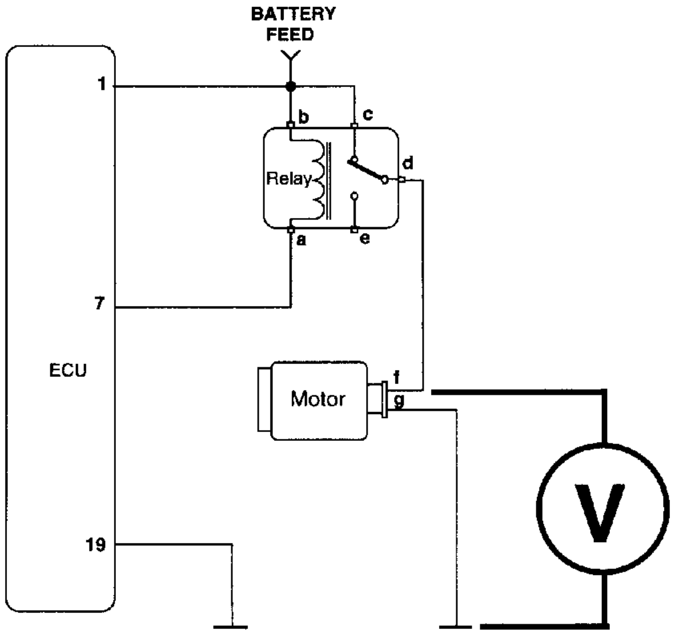
If the relay has 2 or 3 ohms resistance in the relay contacts and the motor draws 4 amps, the drop will be significant enough to prevent the motor from operating properly. Remember Ohm's Law? If you don't go to the appendix in the back of the book for Ohm's Law and you will see why the motor will not work as intended.

Checking voltage drops in a circuit is a good way to find bad connections when dealing with actuators, motors and relays. Doing continuity checks in a circuit that carries more than 1/2 amp may not be a good enough check. Remember the ohmmeter only loads the circuit with at most 100 milliampere when checking for continuity. If the wire is stranded and only few strands are making contact, the ohmmeter will indicate that the circuit is good.

A few strands of wire are not enough to carry 4 amps. What you will get is a voltage drop across the wire where only a few strands exist. In other words the wire turns into a resistor which keeps the proper amount of current from flowing .

At this point we only have three more places to check: the voltage at terminal "f" of the motor, the motor winding resistance, and the ground connection at terminal "g" of the motor.

* The voltage at terminal "f should be the same as the voltage at terminal "d" of the relay. If it is not the same there is a problem with the wire "d" to "f" or the connectors. Refer to diagram at the top of next page for placement of probes.



The last remaining part of the circuit to check is the ground wire. The same things that were true for the other parts of the circuit are also true here. The ground wire can be checked by moving the positive probe to motor terminal "g" and leaving the other probe on ground. The voltage drop across the ground wire should be almost "0" volts. If the reading is over a few tenths of a volt, check the connections to ground and to the motor terminal "g".

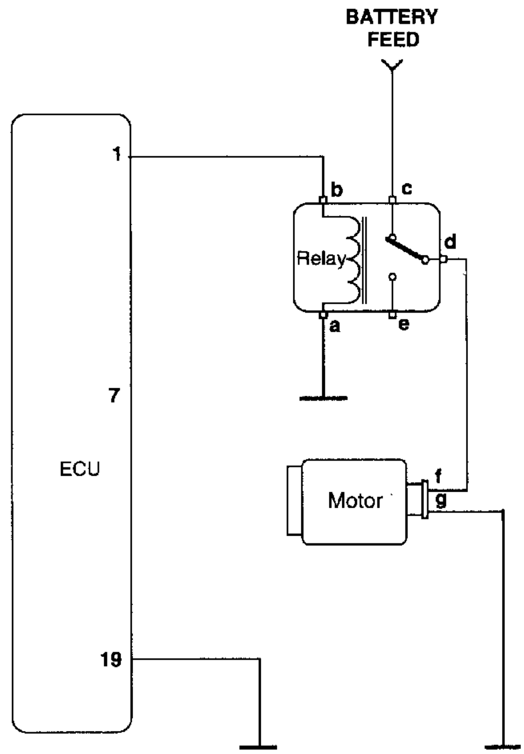
This is the way a circuit with relatively high current flow should be checked. The following circuit deals with some of the same concerns but with slightly different connections. The differences will become evident as you go through the troubleshooting procedures.

Next we come to the winding resistance. This is a simple measurement of the motor winding, but be careful. You can be fooled here also. For example, let's say that the resistance specification for the motor is 4 ohms. You measure 6 ohms. Is the motor good or bad?

At first glance, there is only a two ohm difference between the specification and the value read. What's two ohms? In a circuit that is 30 ohms, a 2 ohm difference is nothing to be concerned about. In a motor that is supposed to be 4 ohms and reads 6 ohms, we see 50 percent increase.

How will that effect the performance of the motor? Let's go back to Ohm's Law and see. We have a voltage of 12 volts in this circuit and the motor winding resistance is 4 ohms. What amount of current will the motor draw when it is running?

One form of Ohm's Law is $I = E/R$. If we substitute the numbers, we get $I = 12/4$ or 3 amps. But we measured 6 in our circuit. What will the current be? Again $I = E/R$, substituting we get $I = 12/6$ or 2 amps. The motor suffered a 33 percent loss in current. If this were a fuel pump motor, it would run at a reduced speed because DC motor speed is directly proportional to current. The volume of fuel pumped into the fuel rail would also be reduced. Engine performance would also suffer. High current circuits require a more acute awareness of the relationship of current to resistance in a given circuit.



The circuit diagram above is almost the same as the previous diagram. The difference is how the relay is energized. The high current side is actually identical. It is still possible to energize the relay by providing battery voltage at pin #1. Make sure that the ECU is disconnected. You don't want to put battery voltage on pin #1 with the ECU connected because it could damage the unit.

When the relay is energized, you will hear a clicking sound if all is well. If it does not energize, check the wire from pin #1 to relay terminal "b" and the wire from relay terminal "a" to ground. If the wiring is okay, check the coil resistance of the relay. It will usually be between 80 an 120 ohms. There are some Bosch automotive relays that may have a coil resistance as high as 400 ohms. The balance of the circuit can be checked using the same techniques as in the first example.

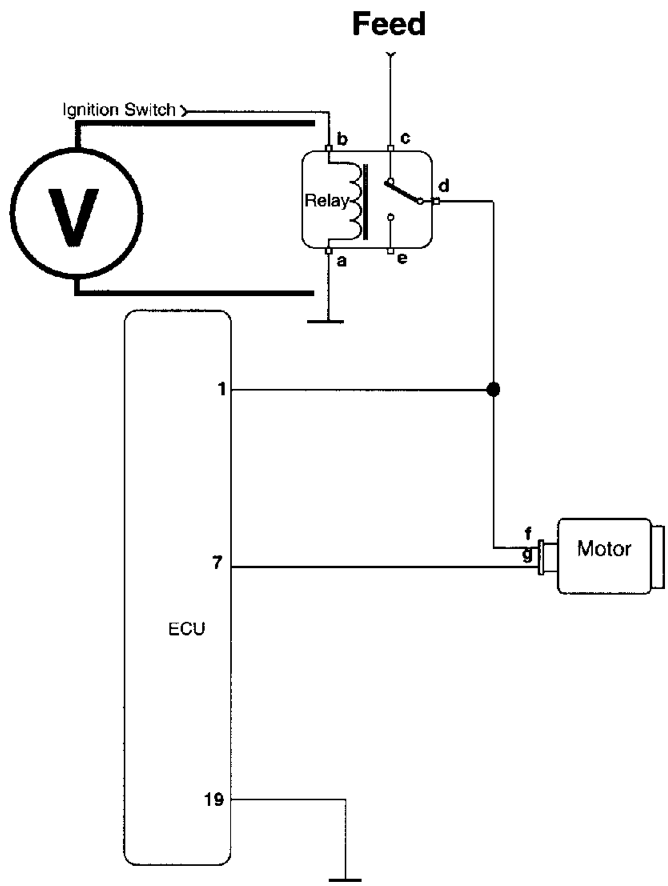
The next circuit example contains still another twist. In this case the relay is not operated by the computer, but by the ignition switch turned to the on position. It is important to know that the computer does not control the relay. If the relay fails you wouldn't replace the computer to remedy the problem. Unlike our first two examples, the computer could not be the cause in this case. Look at the diagram to the right. The relay is providing power to the ECU and the actuator. The actuator is controlled by the computer. What do you look for if this actuator does not operate? Let's make a list.

1. **Check whether ignition switch is getting battery voltage. Check fuses.**
2. **Check the ignition switch.**
3. **Check for power at the relay terminal "b" when ignition switch is on.**
4. **Check relay terminal "a" for ground connection.**
5. **Check relay coil resistance between relay terminals "a" and "b".**
6. **Check the battery feed to relay terminal "c". Check fuses.**
7. **Check relay contact "d" for battery voltage when relay is energized.**
8. **Check for battery voltage at ECU pin #1 with ignition switch in on position.**
9. **Check whether actuator terminal "f" receives battery voltage with ignition on.**
10. **Check actuator winding resistance.**
11. **Check wire from ECU terminal #7 to actuator terminal "g".**
12. **Check computer ground pin #19.**

That's all the checks that should be made when troubleshooting this circuit.

Most technicians have probably developed a method for checking the ignition switch because these switches have been installed on cars for so many years. So, the first two checks on our list needn't go into detail. It's enough to realize what you must check if this circuit doesn't operate.

Let's assume the ignition switch checked okay. For Test Three, check for battery voltage at relay terminal "b". Set the DMM to the voltage mode, then measure between relay terminals "a" and "b". Make sure you establish a good ground. Refer to the circuit below.



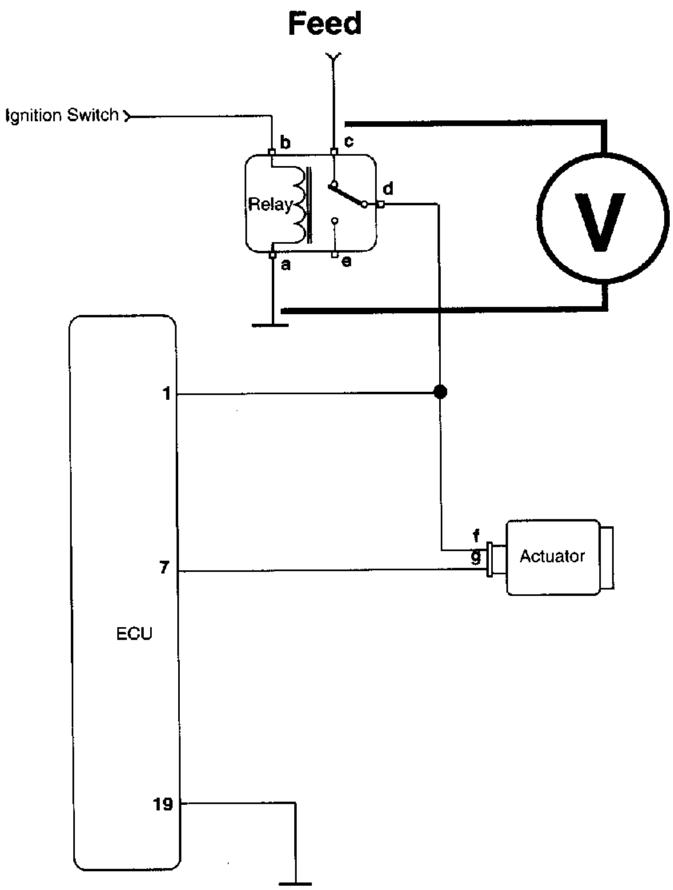
It's important to find a good ground source to attach your meter to. If there is no reading, you may think the relay is not receiving battery voltage at terminal " b". It might be that the ground reference you are using is not good.

If you do not get a voltage reading, you must find a break in the circuit wiring. Remember, we know the ignition switch is good at this point. If you get battery voltage with the key on but the relay is not energizing, go to test step 4.

Check for a ground at relay terminal "a". Just move the positive probe to relay terminal "a" if you read battery voltage, it means that the relay is not grounded. If you read no voltage, it means the relay is grounded or that the coil is opened.

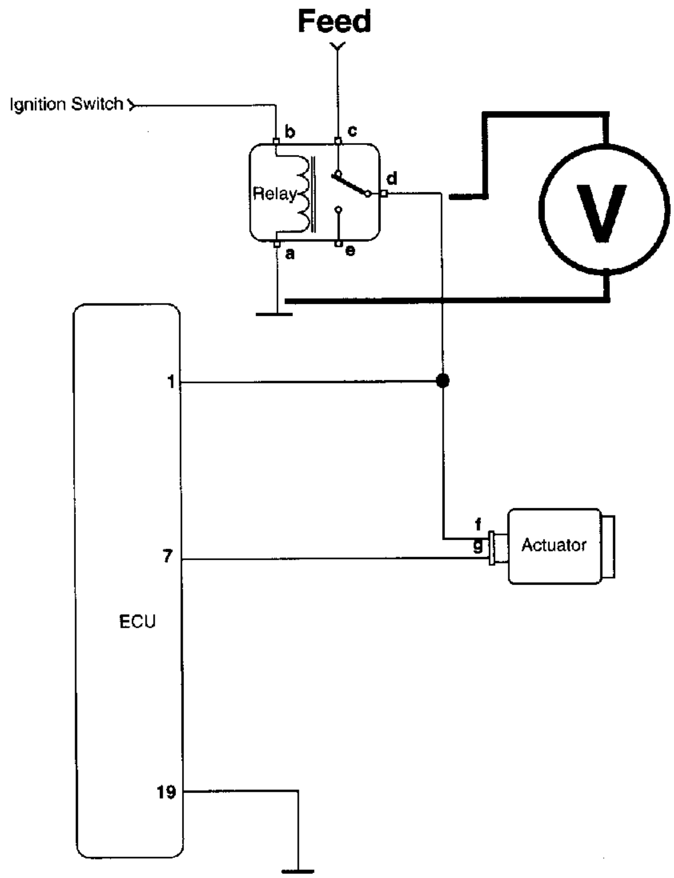
Test step five checks for an open relay winding. Connect probes to relay terminal "a" and "b," then put DMM in ohms mode. If resistance is okay, the relay coil circuit is good.

Step 1 through five completes the relay control side of the circuit. We're ready to move to the contact or relay output side of the circuit to see if power is being applied to the ECU and to the actuator. Connect probes as shown below (positive probe to terminal "c" and negative probe to ground).

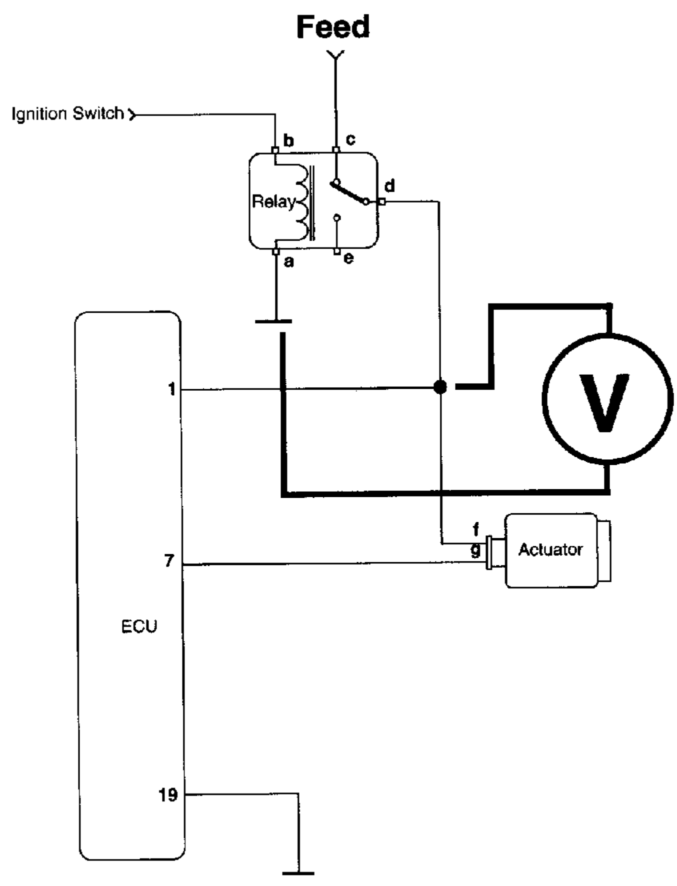


Battery voltage should be present at this terminal. If no voltage is present, check the wire from the feed circuit and related fuses.

The next step will be to check the voltage at terminal "d" when the relay is energized. Battery voltage should be present at terminal "d" (Refer to diagram top right). If no voltage appears here then it may be bad relay contacts. If the relay energizes and the contacts close but no voltage is present at terminal "d," take a chance and replace the relay.



The following tests are used to determine whether voltage is being provided to ECU ter minal #1 and also to actuator terminal "f".



If the voltage was present at "d," it should also be present at these terminals. If either terminal is missing the battery voltage the actuator will not operate. Terminal #1 is power to the ECU and terminal "f" is power to the actuator and both must have voltage present to operate.

Everything to this point has been concerned with the power distribution side of the circuit. If power is okay or any problems were repaired, it is time to test the actuator circuit that is controlled by the ECU.

It is possible to activate the actuator by grounding pin #7. Remember the ignition key must be in the ON position. The actuator will also click when it is energized. If no clicking sound is observed, check the actuator resistance. Actuators usually have between 10 ohms and 90 ohms of internal resistance, depending on the actuator. Here are some examples:
* An electronic fuel injector has about 16 ohms resistance, while a purge valve may be 30 to 60 ohms and an ISC valve between 4 and 22 ohms

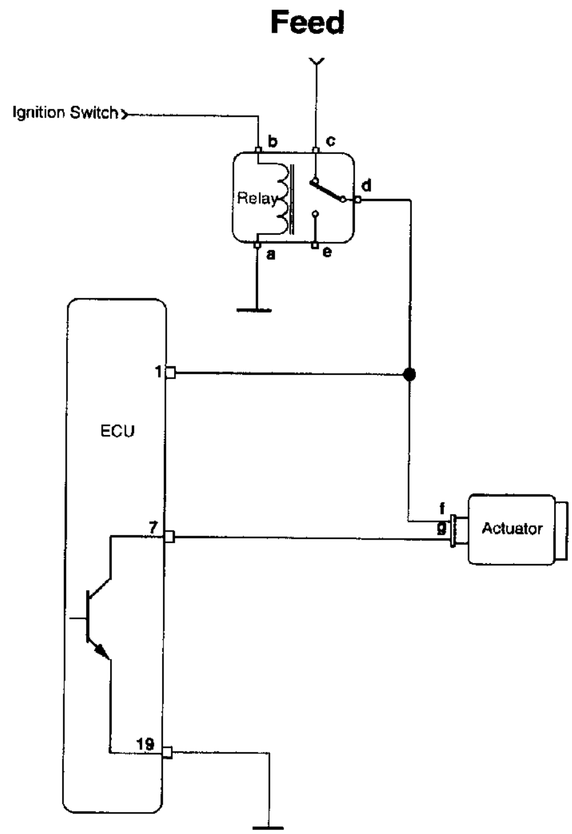
If the actuator does not work when pin #7 is grounded, check the wire from actuator terminal "g" to pin #7. If all circuits have checked out okay but the actuator fails to operate, it's safe to assume that the ECU is bad. Right?

Not exactly. There is really two more possibilities. The first is that the actuator may not operate because it is not receiving a signal from a sensor that alerts the ECU to activate the actuator. The other possibility is that the ECU controls the actuator by grounding pin #7. The ECU uses a transistor to make this switch to ground.

Look at the diagram to the right. The actuator is in the collector circuit of the transistor. When the transistor is switched by a signal on the base, current flows through the collector to the emitter to ground. What if the ground at pin #19 is bad? The circuit will not work! No matter how many ECUs you replace, the same results will be obtained.

It is very important to check all chassis grounds in a system when problems occur. In many cases you may not be aware of which ground is used for what transistor driver. That's why you should check all chassis ground wires to the ECU.

It is also a good practice to measure the ground side voltage drops using a known-good chassis ground. A poor chassis ground may sink significant amounts of current. Remember testing a circuit strictly with an ohmmeter will not always give the results you want when checking high current circuits. The acceptable voltage drop specifications listed in the data section of this book were collected while using a known good chassis ground as a reference.



CONCLUSION

Everyone who works on automobiles knows that it is important to have knowledge about different systems. With more knowledge, you will be better prepared to tackle the bewildering problems that occur from time to time. On-board diagnostics can be a great help, but it is only capable of providing information that you must be able to interpret. It can't tell you how to fix the problem.

Scan tool manufacturers make similar promises, but scanners are also unable to tell you what's specifically wrong with a circuit. They can only point in a general direction. You must know how to determine the specific problem in a circuit. As we saw in the troubleshooting section, an open circuit can be caused by a lot of different things.

It is not getting any easier to obtain information on many import systems. Many manufacturers have implemented dedicated computer diagnostic systems that cost tens of thousands of dollars. Much of the information that used to be published in shop manuals is no longer available or valid, unless you have access to these expensive computer systems. Some manufacturers have created special testers for their systems that are only available to their dealers. Less and less information is available in plain volt/ohm specifications. We have tried to close the gap somewhat with this book. We hope you find it to be useful.