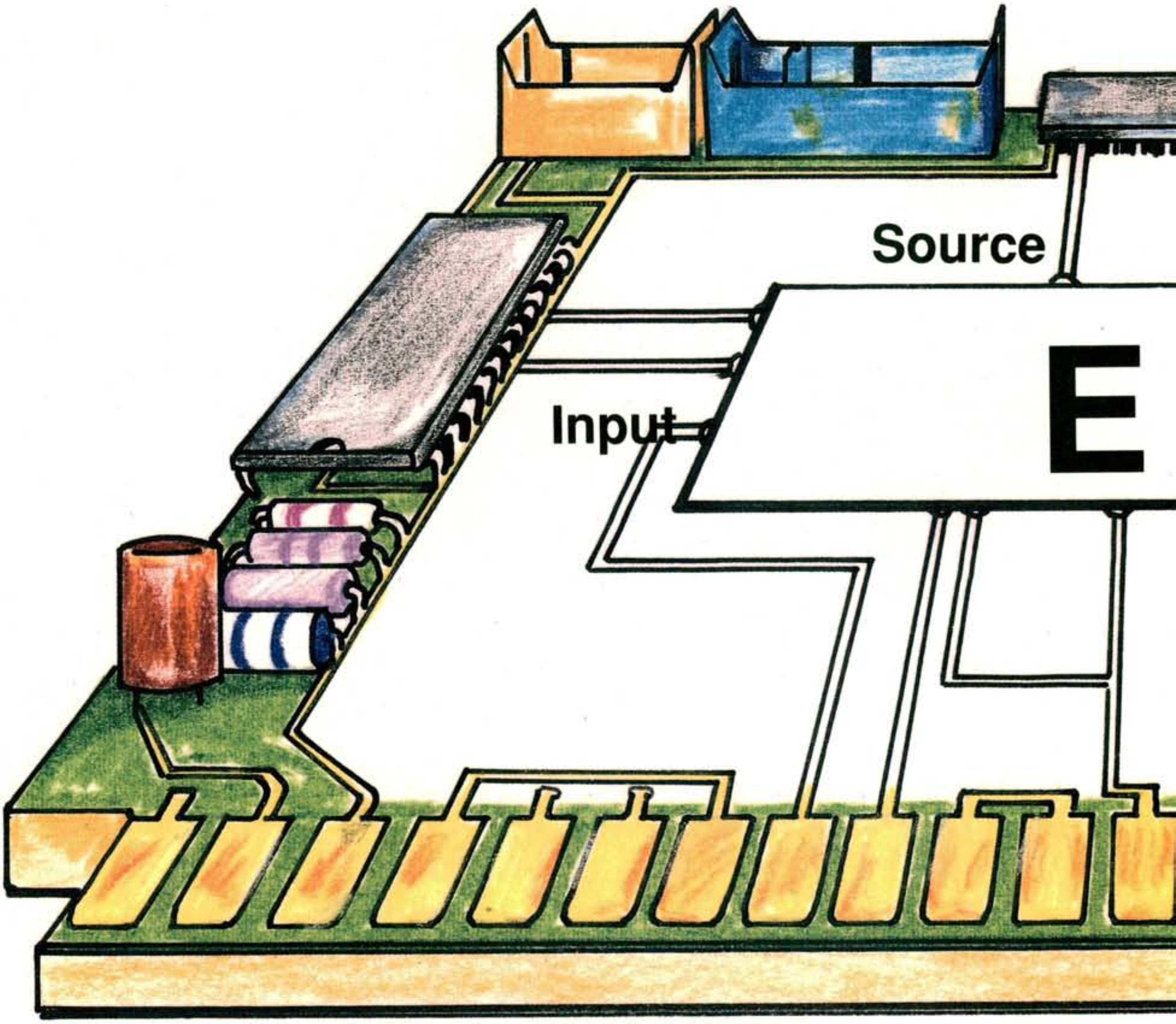
Tour Guide II

Electronic Schematics



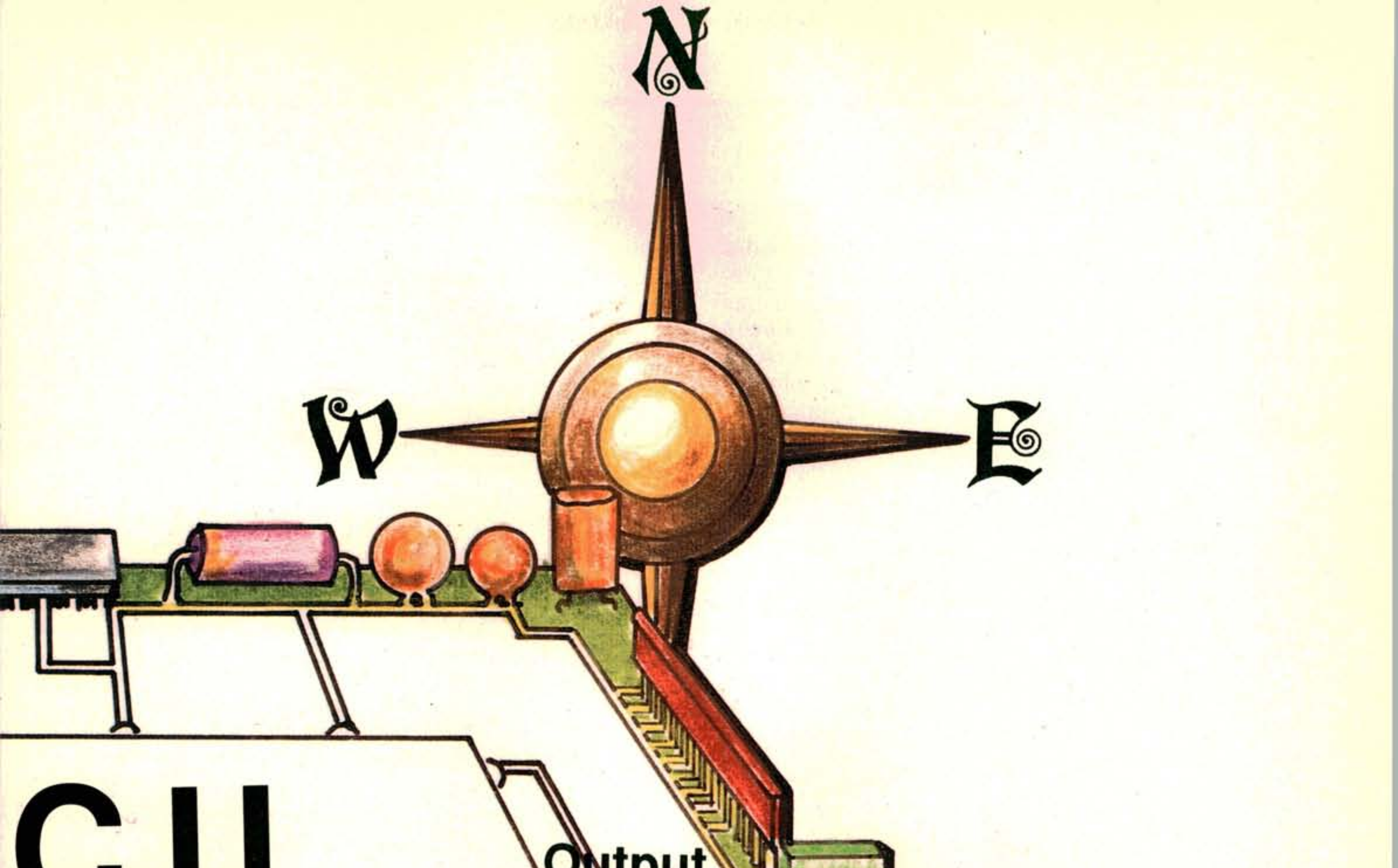
Back in August we ran an article about schematics—electrical schematics to be exact. This follow-up article will take us to the next step and discuss the use of electronic schematics.

What's the difference between electrical and electronic systems? Good question, because there is a difference.

• **Electrical systems do not contain semiconductor components.** Electrical systems have three important jobs: generating electricity (alternators), controlling and distributing electricity (wiring harnesses), and storing electricity (batteries).

• **Electronic systems are different because they contain semiconductor circuits.** These circuits use transistors and integrated circuits like the ones found in ECUs.

In automobiles, as in most electronic technologies, the electronic system can only do



its job if the electrical system is working properly. The electronic system in an automobile is built on the foundation of a properly operating electrical system which can generate, store, and then distribute electrical energy to meet the needs of various electronic components.

So before we start to troubleshoot any electronic system, we need to be sure that the basic electrical system is working properly.

January's "16 Minutes" article covered quick checks of the car's battery, cranking, and charging circuits. Thorough voltage drop testing of both grounds and voltage supplies in the charging and starting circuits of the electrical system come first. Then we can move on to the electronic components.

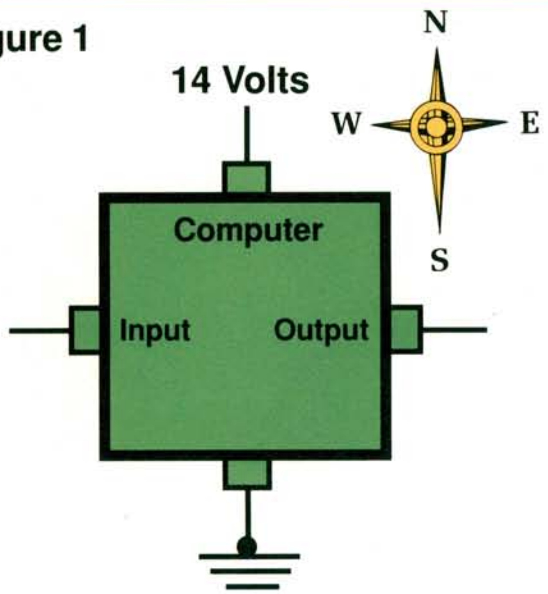
Remember, it still takes voltage and ground to operate a computer (electronics), just as it does to operate a light bulb (electrical).

The Good, The Bad, and The In-Between

Schematics, like the automobiles they represent, come in varying degrees of quality. Some are good, some bad, and others are—well, they're mediocre. But even the worst of them will contain a lot of useful information. Reading electronic schematics is similar to reading electrical schematics, but with a few wrinkles.

In **Figure 1** we see a familiar block diagram showing voltage applied at the top, and ground applied at the bottom. There are two new wrinkles, however. The addition of the input and output terminals suggest that there are semiconductor components inside the box.

Figure 1



When a circuit is asked to process input information in order to control outputs, you can bet that semiconductor components are involved.

The Basic Electronic Circuit

There are four dimensions to an electronic circuit. Two are electrical in nature, two are electronic. Let's group them by function to make it easier for you to identify them.

The electrical part of the circuit:

A. Voltage—Operating voltage is required to power the electronic circuits. Let's designate the top of our simple schematic as the northern border, just as we would with a map. The top, or northern terminal is the operating voltage. It will usually be in the range of 12.6 volts (engine off) to about 14.5 volts with the engine running.

B. Ground—The southern boundary is reserved for the ground connection. Voltage measured here should be less than 0.1 volt when the electronic circuit is in operation. Some computer systems now require that the ground side voltage drop should be less than 0.05 volts. A voltage drop greater than that can affect sensitive electronic circuits inside the computer.

Electronics can be very, very touchy.

Electrical or electronic, we still need voltage and ground to make a circuit work.

The Electronic Portion of the Circuit

Let's look east and west on our diagram as we discuss inputs and outputs in an electronic system:

C. Inputs—Inputs are shown on the western border of our schematic. While our illustration shows only one input, there may be several inputs to an electronic system:

- Sensors generate voltages to indicate different engine conditions and modes of operation.
- Switches may be opened or closed to signal the computer about changes in engine operating modes.

• Position sensors warn the computer that various components have changed their positions. They may tell the computer that the throttle has opened. Or maybe they'll tell the computer about the position of the camshaft or crankshaft.

Information from these inputs is used by the computer to make a plan of action. Then the computer uses that plan of action to control outputs.

D. Outputs—Outputs are located on the eastern border of our schematic. There can be several outputs. Here are some examples:

• Solenoids can receive a ground signal which tells them to open a fuel injector.

• Relays are sent a voltage level, and act as switching devices in high current circuits.

• On cars equipped with serial data capabilities, data stream information is sent to diagnostic connectors. That information is then interpreted by hand held scanners.

Once the computer has made its decision, it uses transistors to provide the switching current or ground to activate these loads.

This is clearly the electronic portion of the circuit. Transistors and integrated circuits are working with the electrical system of the car to control all sorts of devices to improve fuel economy and reduce emissions.

The Next Step

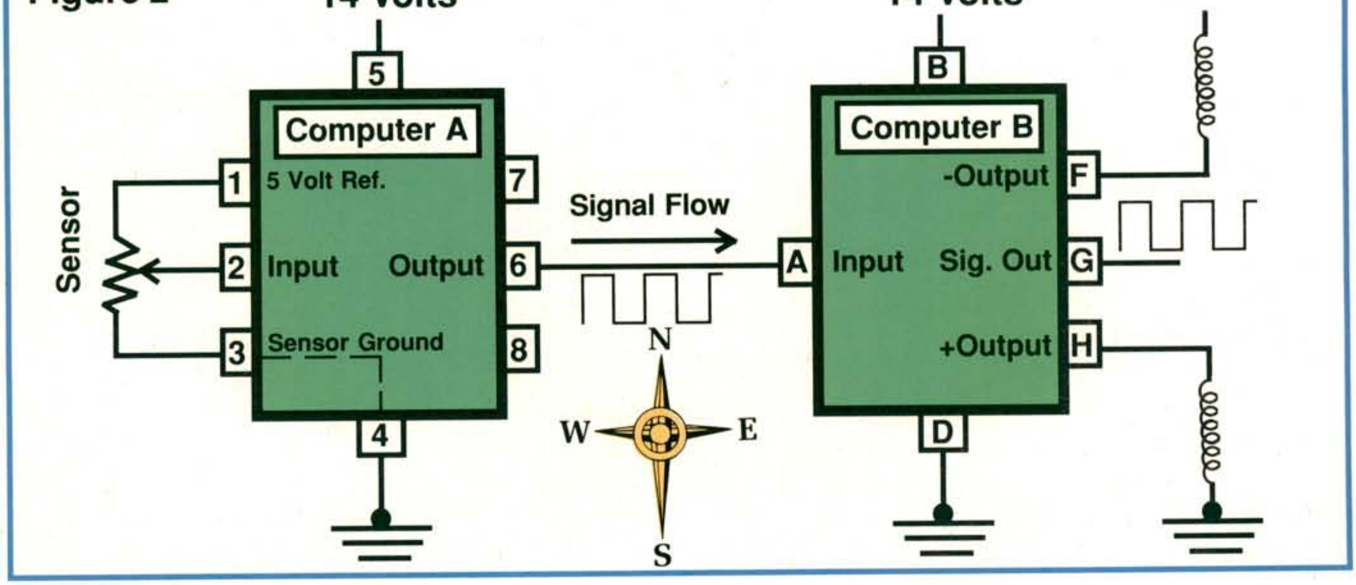
Let's use our simple electronic device to control a more complicated circuit.

Figure 2 shows a different diagram, but the north-south-east-west approach will simplify things in a big hurry. Our illustration shows computer A and computer B connected together.

The voltage side of the computer is north, just as it was in **Figure 1**. The same thing applies to ground. In this figure the ground is still on the southern border.

With power and ground located, we can focus on the western and eastern borders—the inputs and outputs. Computer A has a sensor input with three wires on its western border.

Figure 2



• The top wire (connected to terminal 1) provides 5 volts of reference voltage to power the sensor.

• The bottom wire (connected to terminal 3) grounds through the master ground circuit of the computer.

• The middle wire (connected to terminal 2) is connected to a wiper arm. The wiper arm is also connected to some moving part of the car. In this case, let's say that the wiper arm is inside a throttle position sensor (TPS). The TPS is connected to the throttle.

As the throttle moves, it moves the wiper arm in the TPS. A variable DC voltage is "seen" by the computer at terminal 2. Depending on the voltage the computer "sees," it knows about changes in throttle position.

With this small amount of information, we already know quite a bit about the sensor's operation. We have identified the pin connectors, so we know where to test with our DVOM if there's a problem. Once we know the reference voltage value, (normally about 5 volts), we can track sensor performance.

Here's an example: Let's say we test the sensor's ground pin (pin number 3). We find that the voltage drop at the pin is greater than 0.1 volt. But the main computer ground tests good. This can only mean that there's a bad internal ground circuit in the computer. The ground circuit path from pin 3, through the computer to ground, has high resistance.

It happens.

Although not shown in this figure, there are other possible sensor inputs. A coolant sensor has only two wires, and one of them is grounded, usually inside the computer. Switch inputs have only one wire. The switch will be tied to either ground or voltage, depending on the message it sends to the computer.

Looking Over His Shoulder

Computer A has several outputs on its eastern border. One is of particular interest to us. That's output terminal 6. This output is data stream information being sent by a direct connection to computer B.Computer B is looking over computer A's shoulder and sharing information.

Both computer A and computer B are watching information sent by the wiper arm in the TPS.

Correct operation of the TPS and the TPS wiring circuit become doubly important in this case. Two devices are counting on the TPS to send along truthful information. Look for this type of circuit to be used more in the future.

Looking at Computer B, we see that it has some outputs of its own to control. But in addition to its own sensors, it's using shared information about the wiper arm position in the TPS. (If the TPS goes bananas and starts lying its head off, both computers will suffer.) Let's go over to the eastern end of computer B and look at outputs.

• **Pin F grounds a solenoid.** We call this a switch-to-ground circuit because the computer is providing the ground to operate the solenoid. The other end of the solenoid winding is permanently connected to voltage. We know all this by looking at the diagram.

• **Pin H powers a solenoid.** We call this a switch-to-voltage, because the computer provides the voltage to operate the solenoid. The other end of this solenoid's winding is permanently connected to ground. The schematic tells us this as well. If one end of a solenoid winding is permanently hot, then the computer output controlling the solenoid is a switch-to-ground.

If one end of a solenoid winding is permanently grounded, then the computer output controlling the solenoid is a switch-to-voltage.

Unfortunately, many schematics fail to give us a recommended resistance value for a solenoid winding. Our only option at that point is to check a known-good solenoid.

• **Finally, Pin G provides a data stream to be used by a diagnostic scanner.**

What We Don't Know— What They Don't Tell Us

While these schematics tell us a great deal about how circuit components are operated by the computer, we may not know the right combination of inputs needed to activate an electronic component inside "the box." It's a little like trying to open a safe without the right combination.

Without the combination, we are sometimes forced to check all inputs, because we don't know which ones combine to dial in the correct combination. That is an entirely different story, and we'll be forced to save it for another day.

When It Gets Complicated—Keep It Simple

The samples we showed in **Figures 1 and 2** are simpler than the ones you'll be forced to work with. Life in the real world is seldom as simple as **Figures 1 and 2** might lead you to believe. Some manufacturer's diagrams are needlessly complicated and confusing. Others are simplified, but leave out very important pieces of information we need to complete a repair.

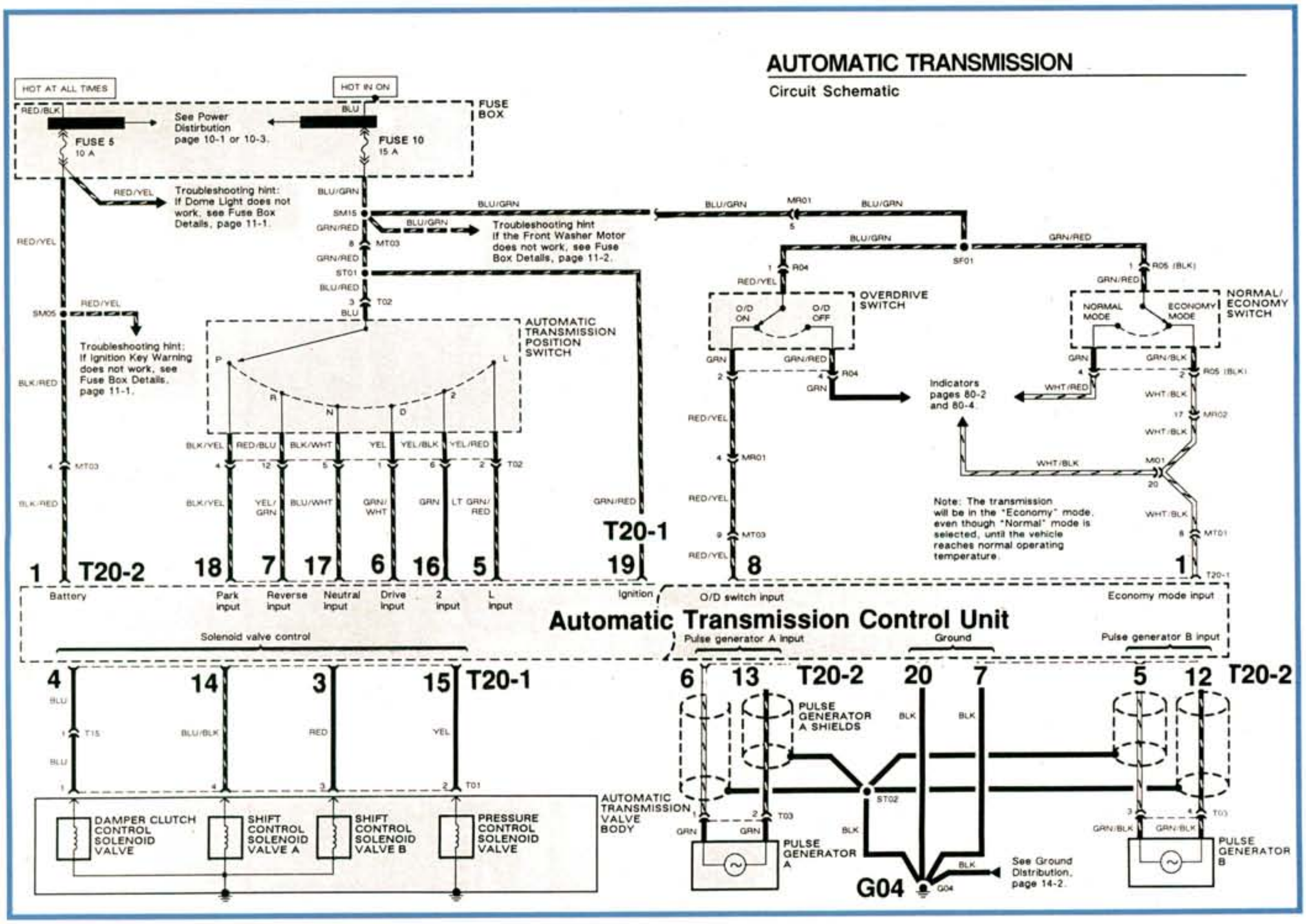
We'll look at a real example. In the meantime, remember that we have four things to keep track of in any electronic circuit: (1) voltage supplies, (2) grounds, (3) inputs, and (4) outputs.

No matter how many wires go in and out of an electronic component, each must fall into one these classifications.

A Real Example

Let's look at some schematics from Hyundai. **Figure 3** shows part of the Automatic Transmission Control Unit (ATCU) for a 1990 Excel. This isn't the entire circuit, but the example will show how to track voltage supplies and grounds, inputs and outputs.

- **In the upper left we see a box marked power distribution.** That's handy, because it allows us to quickly identify the main power supplies to the ATCU. We see that there are two power supplies, one at terminal 1 of connector T20-2, and the other a key ON at terminal 19 of connector T20-1.
- **On the southern border we see the main grounds.** They have a common grounding point at connection G04. At this point, we've already located and identified source voltage and main ground connectors.



Inputs and Outputs

Next, we need to identify inputs. Hyundai has been kind enough to mark inputs with the word "input." But even if they hadn't, we would be able to find them. Remember that inputs are sensors or switches which provide information to the control unit. Three of the inputs in this section of the schematic are selected by the driver of the vehicle.

(1) When the driver changes gears by moving the shift lever, a voltage signal tells the ATCU which gear has been selected.

(2) If the driver doesn't want the overdrive to engage, he can turn it off with the overdrive switch.

(3) The driver can also choose between Normal and Economy shift points with the Normal/Economy switch.

You'll notice that there are two pulse generators connected to ATCU. Too bad they aren't identified. More on this in a moment.

Finally, we get to our outputs. In this case, the outputs are permanently grounded solenoids. Switch-to-Voltage circuits inside the control unit turn the solenoids ON and OFF. These solenoids are located in the transmission valve body.

Testing Your Skills

Look at **Figure 3** and see if you can answer the following questions.

Question: How many voltage feeds to the ATCU are shown?

Answer: There are two voltage feeds at pins 1 and 19.

Question: How many switch-to-voltage inputs are there?

Answer: There are eight. Reading from left to right along the northern border of the ATCU, we have switch-to-voltage inputs at pins 18, 7, 17, 6, 16, 5, 8, and 1.

Question: How many computer loads are shown?

Answer: The four solenoids in the transmission valve body are output loads.

Question: Are the computer loads Switch-to-Ground, or Switch-to-Voltage?

Answer: Since the solenoids are permanently grounded, the loads are switch-to-voltage.

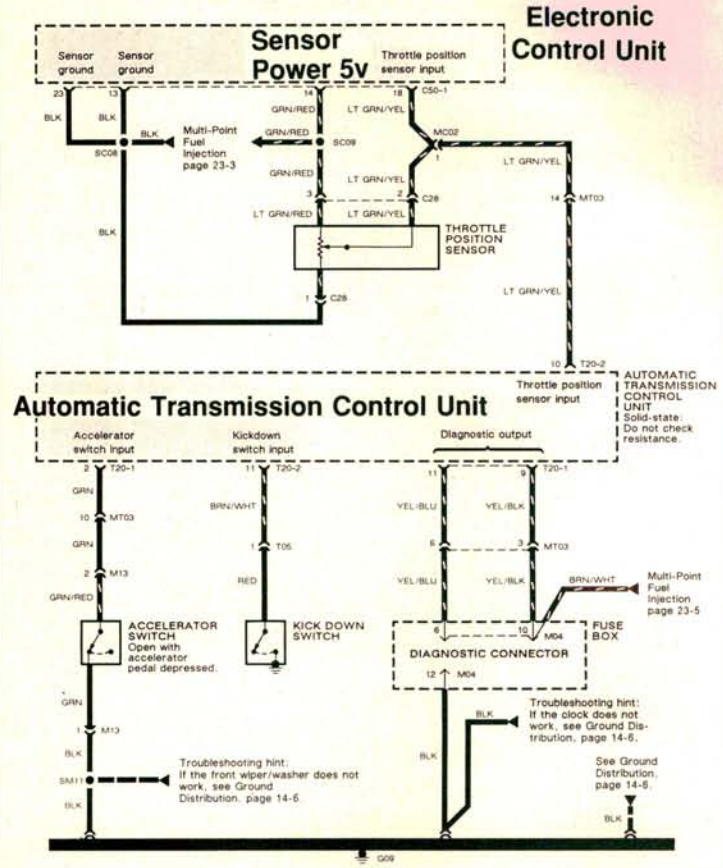
Question: What is the specified normal resistance of the Pressure Control Solenoid?

Answer: We don't know, because the schematic doesn't tell us. If you've ever been frustrated with us for telling you to check a "known good" part, now you know the reason. We get frustrated having to say that. But incomplete information in a schematic leaves us no choice.

Question: How many signal inputs does the ATCU receive in this diagram?

Answer: Two, from pulse generators A and B.

Figure 4



Now look at **Figure 4.** This is a continuation of the same Excel ATCU circuit we've been using. It points out a very important fact of operation concerning the Throttle Position Sensor.

The asterisk in each multiple choice selection indicates the correct answer.

Question: The ECU and ATCU share TPS voltage by
a. dividing the voltage in half
b. direct connection *

Question: Which computer provides the ground for the TPS?
a. The ECU *
b. The ATCU

Question: Which computer provides the 5 volt reference voltage to the TPS?
a. The ECU *
b. The ATCU

Question: What color is the TPS feedback voltage wire?
a. Lt Grn/Red
b. Blk
c. Lt Grn/Yel *

Thumbs Up, Thumbs Down

Okay, so the Hyundai schematic is easy enough to read. But we don't work in a vacuum do we. The schematic is a tool which we need to use on a real car with a real problem.

Here are some nice touches which make this schematic more useful:

1) It marks inputs.

2) It's open enough that we have room to jot down test values as we go along.

3) It offers helpful hints about other components which share the same power supplies. For example, the dome light is powered by the same 10 amp fuse which supplies battery voltage to the ATCU. A dead dome light may lead us to an open fuse.

Here are some things missing from the Hyundai schematic that would help us when we troubleshoot:

1) The two pulse generators aren't identified, either by name, or by location. And there aren't any test values listed for either one listed in the schematic. We end up searching through other sections of the repair manual.

2) We aren't given any resistance values for the solenoid windings in the valve body.

3) The schematic suggests that the transmission won't shift from Economy to Normal until the engine is warm, but doesn't mention how that signal is sent to the ATCU. Two pages farther on in the wiring schematic we found an engine oil temperature sensor input to the ATCU.

This leads us to our final observation about using schematics. Since all of the information needed to complete a diagnosis and repair may not be included in the schematic, you may need to do some digging in other parts of the repair manual.

• Most schematic sections in the shop manual will include separate schematics for a power distribution and ground distribution circuits. In our Hyundai schematic, the main ground G04 isn't identified. Instead we are sent to another page which tells us the location of G04.

• Some manufacturer's really make you hunt for connectors. In some cases, a side view of the connector will show the location of each pin in the connector. They may also identify the connector by color and give you its location. Connector and component locators are often listed on separate pages.

• The pulse generators which are not identified in this schematic are described in the automatic transmission troubleshooting section. It takes practice to learn all the variations, but even the worst electronic schematics can be a big time saver. The initial time and effort required to learn their "ins" and "outs" can pay handsome dividends.

—By Vince Fischelli