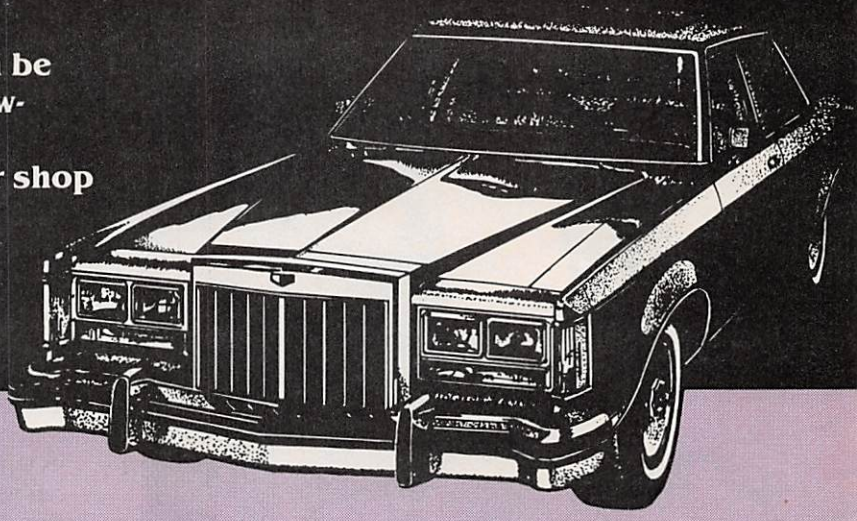
The cost of automotive repairs can be astronomical, but with a little know-how, you can forego some of the all-too-frequent visits to the repair shop

By Herb Friedman

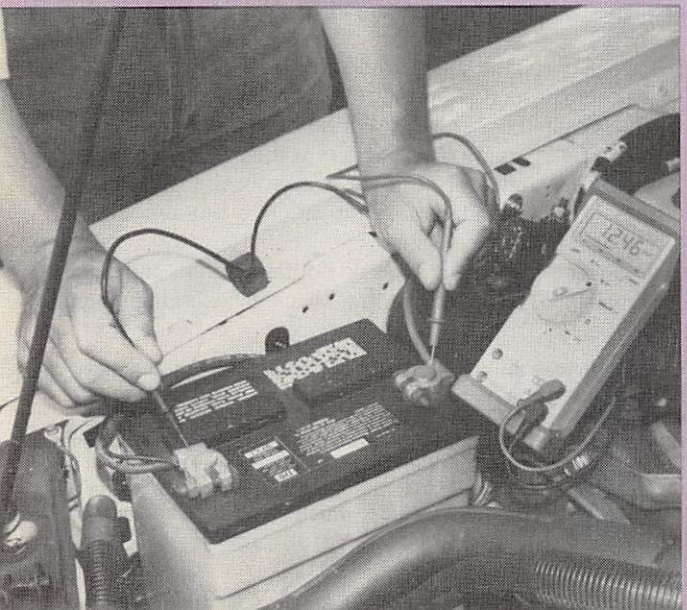


Use a DMM to Troubleshoot Your Car

THERE WAS A TIME WHEN A SIMPLE PUSH WAS ALL IT TOOK to start a car with a dead battery; when a squirt of "hot shot" (ether) starting fluid would kick the engine on a bitter cold morning; when almost any problem could be diagnosed by holding your ear against a screwdriver that was pressed against the engine. Today, you can't start a vehicle with an automatic transmission other than by the starter. You often can't "hot shot" start a car because computer sensors mounted above the carburetor aren't programmed for anything but gasoline; and a screwdriver pressed against the engine will tell you next to nothing because many modern-day car problems are electric and electronic rather than mechanical.

From the starting motor to the electronically-regulated battery charger; to the on-board computer that runs the fuel and engine systems; to electronic speed control, radiator fans, electronic radios, digital clocks, security systems; to power seats, windows, and even side-view mirrors, so much of the modern-day auto depends on electric and electronic systems that the ordinary service-grade multimeter is one of the most important troubleshooting tools.

While automotive electric/electronic circuits are usually so reliable that they are rarely given a second thought, they are extremely difficult and time-consuming for the average automobile mechanic to troubleshoot. Often they require the services of a specially trained and very expensive auto-electric specialist. Except for certain kinds of problems with an automotive computer system, most auto-electric problems can be easily resolved by the average electronics hobbyist using nothing more than a multimeter, and a few optional meter accessories. (That's if you want to get into the nitty-gritty of some of the obscure problems that can drive an auto mechanic to distraction.)



When checking the voltage of a battery, turn on a heavy load such as the bright lights and measure the voltage across the battery clamps, not the terminals. Corrosion between a battery terminal and its clamp can often serve as an insulator.

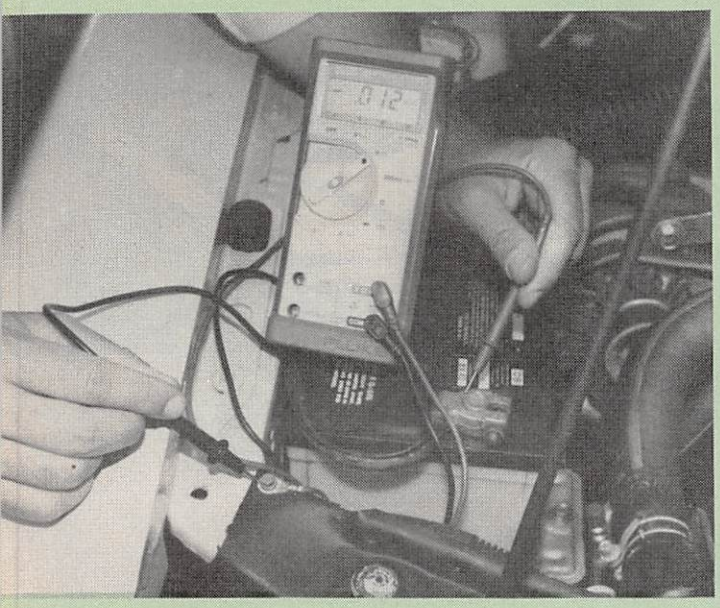
What Kind of Meter?

Any kind of multimeter can be used to troubleshoot auto-electric problems, but because many of the new autos are sensitive to small variations in operating current and voltages, the use of a digital meter is specifically recommended—particularly one also having an analog meter scale, so that you can see transient variations that might be concealed by a digital meter's sampling time.

To illustrate how to troubleshoot an auto-electric system we're going to use a Fluke model 23 digital meter, because it also has an analog indicator. And rather than use separate automotive-type, high-current sensors to test the charging system, and boiling pots of water to test thermostats, we'll use a temperature probe and an electronic current sensor that's specifically designed for use with a digital multimeter—the kind of equipment that might be found in a typical electronics hobbyist's shop.

Three Measurements

Electronics and electrical troubleshooting involves three measurements: voltage, current, resistance—and for some vehicles, temperature. The presence of voltage tells you that, at the very least, a component is receiving voltage. A current value tells you if a component is working properly. A resistance value primarily tells you if the wiring or a component is defective. Temperature combined with a resistance or current



Having electrical problems with lights, fans, etc.? Often the problem is a high resistance between the battery's negative terminal, and the chassis and engine block. Don't make resistance tests; they are worthless in this instance. Instead, turn on the maximum current load and measure the voltage drop between the battery's negative terminal and the chassis/body. It should be well under 1 volt—usually in the millivolts range.

measurement tells you if a thermostat—such as the one that controls a fan—is working properly.

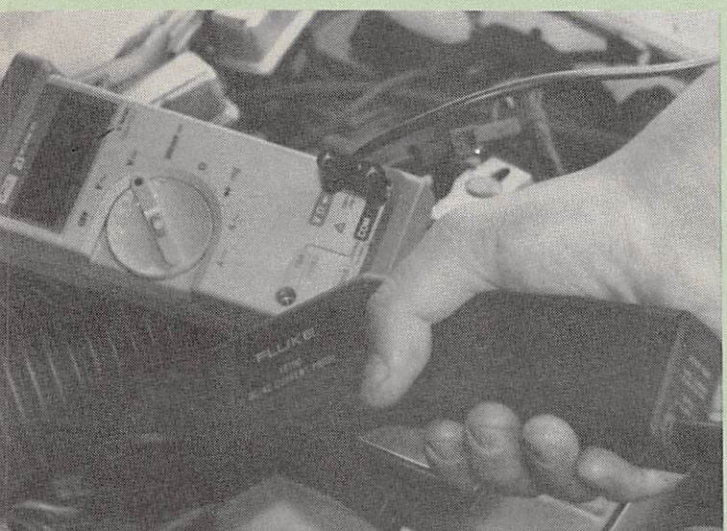
Creating Heavy-duty Battery Loads

Many auto-electric tests (at least those covered in service manuals) require the use of a "carbon pile" to apply a load to the battery, charging system, or whatever. A carbon pile is essentially a high wattage variable resistor that's adjusted for a desired test-current load. Since few, if any, hobbyists own or have access to a carbon pile, we're going to use a convenient substitute: the headlamps. In vehicles that have separate lamps for the low and high beams, the low-beam lamps average about 10 amperes; turning on the high beams (the "brights") increases the average load to 20 amperes.

For vehicles that have a single lamp providing both the low and high beams, the low beam is nominally 10 amperes; turning on the high beam increases the load to 15 amperes. In our tests, we're going to use the low and high beams as a carbon pile. It won't be as accurate, but it sure beats using nothing at all. And for extra heavy-current tests, you can add nominally 20 amperes from the air conditioner with the fan on high, and another 10 amperes for the rear window-defroster elements; the heating strips applied directly to the glass.

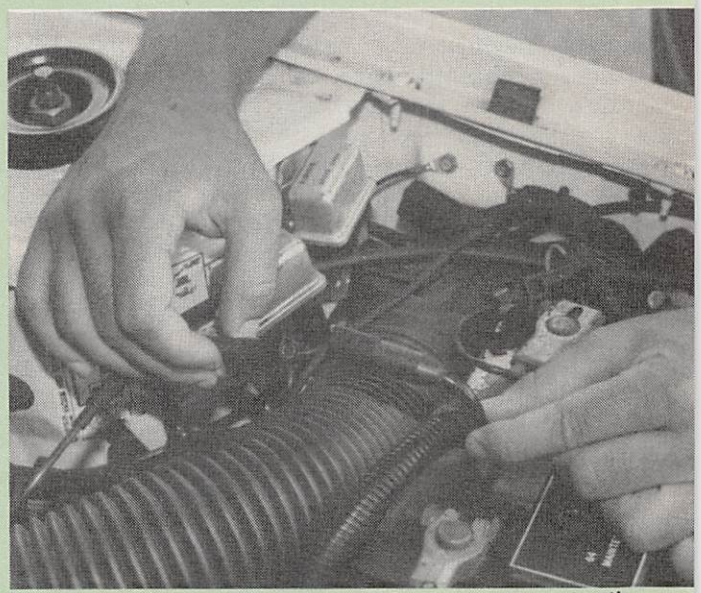
First Things First.

The first step in auto-electric troubleshooting is to test the



battery, because nothing is going to work without electric power. Usually, a hydrometer (a device that measures the specific gravity of the acid) is recommended. Unfortunately, not too many people own hydrometers, and even fewer want to handle sulphuric acid. And even if you wanted to, you can't use a hydrometer on the new sealed batteries. So, the most convenient battery test is simply to measure the voltage across its terminals. However, even a battery that's stone cold dead can indicate nominally 12.6 volts when not delivering current. For reliable measurements, the battery must be tested while delivering substantial current. We'll use the headlamp high beam to provide the current load.

Connect your meter's test probes across the clamps that secure the wires to the battery terminals, not to the terminals themselves, because corrosion can develop an insulating



Modern cars use connectors for just about every current path. So if you want to disconnect some equipment when taking current readings, it might be easier simply to open the appropriate battery connector than to start disconnecting wires at the particular device you want to disable.

surface between the battery and its clamp. When the battery is delivering substantial current, the drop across the insulation can be substantial—enough to disable the starting system and also prevent charging. If the battery voltage at the terminals is low with the lights on, dig the test probes into the battery terminals. If the voltage reading varies by any amount, the terminals should be cleaned.

If the readings are the same on both the clamps and battery terminals, and the voltage is low, check the charging system.

Current divides among the various wires going to the battery terminal, so if you use a current probe, make certain that you encircle all the wires going to the battery terminal. The current probe has been clamped around the thin wire that connects the negative battery terminal to the car body only, causing an incorrect reading because the main part of the current is going through the battery cable, which has not been clamped.

Start the car—using a jumper cable if necessary—and then check for battery charging. One way is to measure the voltage across the battery: It should be in the range of 13.2 to 14.4 volts, depending on the particular car manufacturer.

Unfortunately, the presence of a charging voltage doesn't mean that the battery is accepting the charge. A more accurate check of the battery's ability to accept a charge, as well as a check on the charging system, can be made with a *current probe*, an accessory for the digital multimeter that clamps around a wire and indicates the actual current flowing in the wire. If you can measure the specified charging voltage across the battery, but little or no charging current flows *into* the battery, then you know that it's time to replace the battery.

Battery Leakage

Be careful not to be confused or fooled by normal leakage current when testing the battery circuit. Before Detroit starting putting computers, digital clocks, and radios in cars, there was no current flow when the ignition was off. At most, there might be a minute current flow if the car was equipped with a clock. But digital computers, clocks, and radios in modern cars require a substantial amount of continuous current to keep their memories "alive."

It's not unusual for a computerized mid-size car to pull anywhere from 0.2 to 0.5 amperes with the ignition off. Looking at it another way, the drain is enough to run down a weak battery in a few days. Nevertheless, if you measure a substantial leakage current, don't be too quick to blame a defective diode in the alternator or a short in the wiring; the drain might be perfectly normal.

Checking the Charging System

As long as you have the current probe clamped around the battery cable, assuming that the battery is good, now is a good time to check out the charging system—the alternator and regulator. First, run the battery down by turning on the bright lights for about 15 minutes. Then start the car and bring up the engine to about 2000 rpm. If you don't have a tachometer, feed enough gas for a moderate, not fast, race. Turn on all electrical equipment: the air conditioner, the window wipers, the rear defogger, and the bright lights. (Do it fast, before the battery gets a chance to fully recharge.) Note the charging current into the battery. It might be small, perhaps just a couple of amperes; but there should be *some* amount of charging current, even if you have turned on the maximum electric load. If the maximum electric load results in current flowing out of the battery, the charging system is "weak."

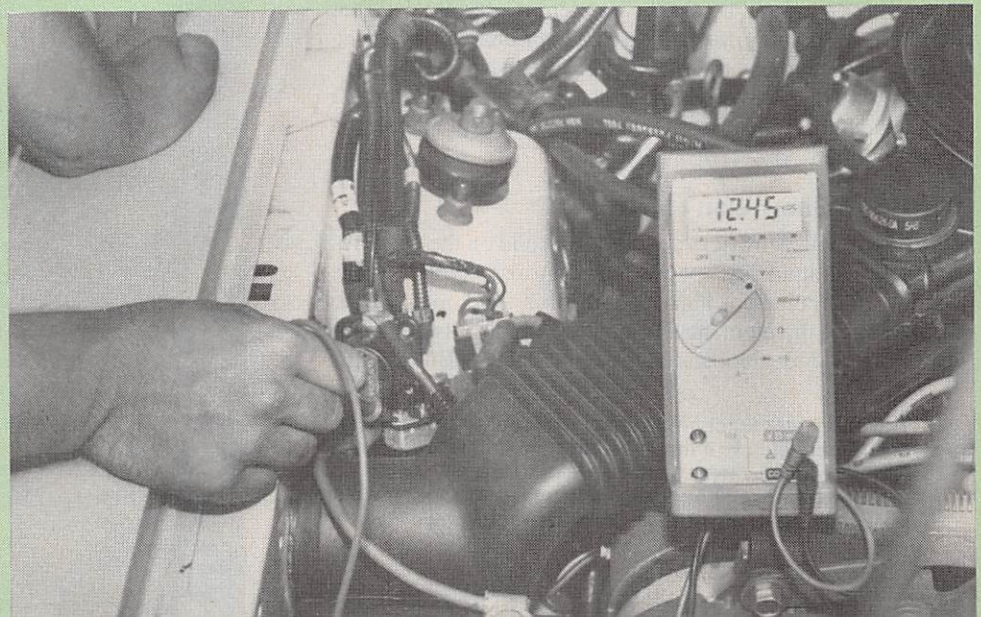
Connect the current probe around the alternator's output wire. If you can't reach it, or it's in a dangerous location, clamp the current probe around one of the battery wires. But take care: If more than one wire comes off a battery terminal, they must all be encircled by the probe. Next, disconnect the connector at the voltage regulator, and—depending on the kind of car you have—get set with an alligator clip to jump the connector's terminals. With the engine at a very low race (slightly above curb idle), jump the regulator connector so that the alternator is energized.

If the charging current surges to 20 amperes or more, and then almost instantly falls off, the charging problem is more than likely caused by a loose or worn drive belt. If the charging current surges to a high value and remains there, the problem is probably in the regulator—a relatively inexpensive item to replace. If the charging current is low, the problem is a "weak" alternator. Disconnect the wires from the alternator (of course, turn off the motor) and use the digital multimeter's resistance functions to test the alternator's internal rectifier diodes and the field winding's brush connections. (Take note that many of the new cars don't require removal of the alternator or its wiring, because they are connected into the vehicle's wiring through connectors. Simply opening the connectors, which are located in convenient locations near the battery, provide easy access to the alternator's connections. Check the service manual for your particular vehicle.)

High Resistance

The term "high resistance" is relative. In automobiles, as little as 0.06-ohm (that's right 6/100) can interfere with the starting or operation of the auto. The resistance of auto connections increase as the car ages; and it may, in fact, be caused by concealed battery-acid vapor dissolving wires in the battery cable under the insulation, or corrosion at terminal screws caused by road salts. The easiest way to locate bad or poor connections is to measure voltage drop, rather than resistance. That's because, in the final analysis, it is low voltage that affects the car.

With the engine running and all electric accessories turned on, the recommended limits for voltage drops from any point



If you have starter motor problems, use the voltmeter to check for DC voltage up to and through the starter relay to the starter itself, while turning over the starter motor. Be careful to keep away from all moving parts in case the engine starts.

The individual wires in the rear window defogger can be tested by connecting one probe of a voltmeter to the power connector on one side of the defogger and then sliding the other along each "ceramic wire." The voltage reading will decrease as the probe is moved along the wire. If the reading suddenly drops out, the probe has passed over a break in the "wire."

to any other point is 0.2 volt for wires and cables: 0.3 volt for switches (such as the starter switch when the starter is actually turning the engine over); and 0.1 volt between any two grounds (such as a fender and the engine block, or the engine block and the chassis, or the fender and the battery's negative terminal). Connections should have zero voltage drop; that is, there should be no voltage drop between the terminal itself and, say, the lug from a connecting wire.

Ignition

If the car coughs and sputters after it warms up, the problem could be within the ignition coil—possibly a winding opening. Check and compare both the hot and cold resistance value of both the primary and secondary connections with the values specified in the vehicle's service manual. If the resistance values don't match both the hot and cold specifications, a new coil is probably what's needed.

Condensers

Condensers (automotive shop-talk for capacitors) didn't vanish when electronic ignitions were substituted for the old distributor breaker points. Even the new cars have condensers; they're used as "radio noise" filters. A leaky condenser can either create hash in the radio or tape player, or actually disable an electric circuit by blowing the associated fuses. Use the multimeter's ohmmeter function to check condensers.

Usually, the meter will indicate a low resistance at the instant it's connected across the condenser's terminals. That value increases to infinity as the capacitor charges up. If the measurement settles at some moderate resistance value, it's best to replace the condenser. If the meter reading doesn't kick when the meter is first connected the condenser is probably open.

When The Snow Won't Melt

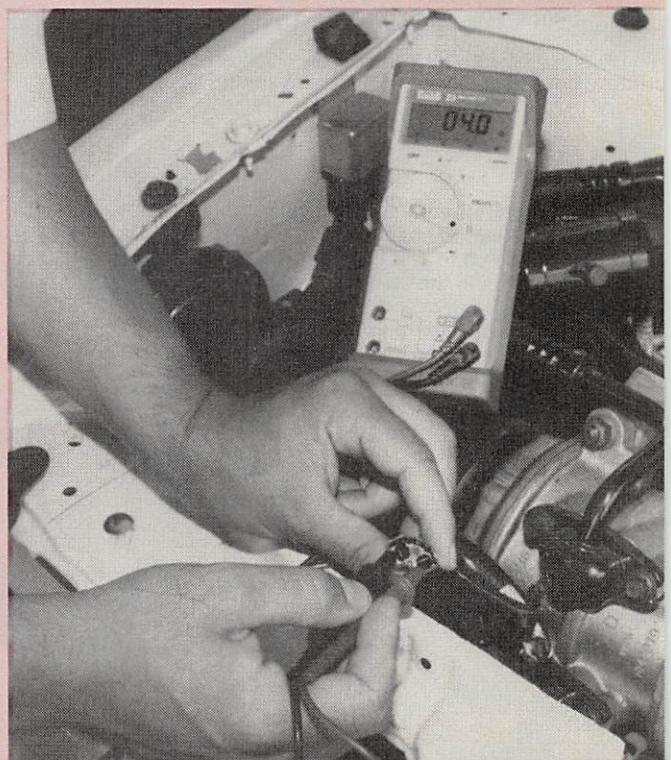
Rear window defrosters/defoggers depend on the heat produced by ceramic resistor elements (strips) applied to the window. If an element breaks, no heat is developed for the full length of the element. Fortunately, repair kits are available from both dealers and auto-supply stores. But the kits can only repair a length of an inch or so, and it's often most difficult to locate the break visually; a multitimeter can isolate the break within seconds.

Simply clip one meter probe to either of the defogger's battery connectors, turn on the defogger, place the other test probe gently on the opposite side of the element and then slide the probe toward the other probe. When both probes are on opposite sides of an element the meter indicates 12.6 volts. As the probe is moved, the indicated voltage will drop—6 volts will be measured when the probe is in the center of the element. Suddenly, the voltage reading will fall to zero; that's where the probe passes over the break in the resistance element; the place where you apply the repair kit.

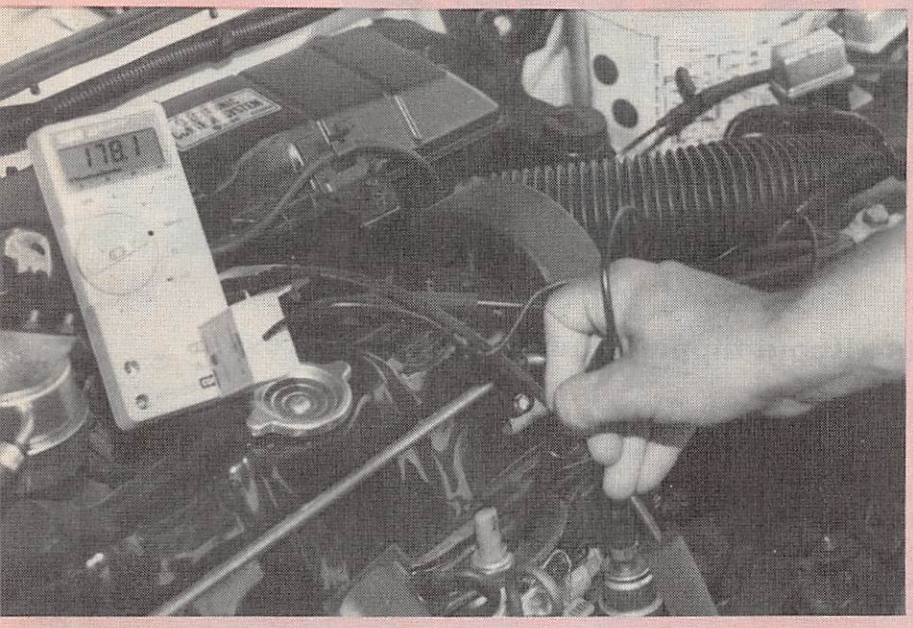
Is It Hot

Has the air conditioner pooped out? Is the compressor running? Is it the control switch that's defective? The compressor won't turn if the electric clutch is burned out or not receiving voltage. To check the clutch, just turn off the motor, disconnect the connector at the clutch, and measure the resistance across the terminals.

If you get an infinity reading, the clutch is open; if you get zero resistance, the clutch is shorted; if you get any value in



The ohmmeter function can be used for a quick test on the air conditioner clutch. If the resistance reading is very low (about 4 ohms), the clutch's coil is probably OK. And if there's no smoke or squealing when the A/C is on, the clutch is definitely OK; any A/C problems are someplace else.



Having heat problems with the engine, the radiator, the heater? You can track them down with a thermistor temperature probe (a device that converts temperature to a DC voltage that can be read on a DC voltmeter in terms of temperature). Here the probe shows that the engine temperature is too low, possibly indicating that a thermostat is stuck open.

between the clutch is probably OK. Next, insert the voltmeter's probes in the connector and turn on the ignition and the air-conditioner switch. If the meter doesn't indicate 12.6 to 14.2 volts, either the fuse is blown or the switch is defective. Either way, you've got a good idea of where the problem is.

How's The Fan?

In many vehicles, the fan is controlled by a heat-sensing switch that's built into the radiator. If the fan doesn't work, disconnect it first so that it doesn't start suddenly while your fingers are in reach of the blades. In some cars, the fans operate even when the ignition switch is set at OFF. Then bring the car up to temperature and check the switch. Since all modern radiators are meant to run sealed, you can't stick a thermometer in the coolant. But what you *can* do is the next best thing: Measure the temperature of the heat switch.

To do so, connect a temperature-sensing probe to your digital multimeter, place the tip of the probe on the sensor, and run the engine until the probe indicates that the sensor has reached the temperature where the fan should start. Quickly switch the meter function and measure the resistance across the sensor's terminals. If the sensor is working properly, you should read a short, which would start the fan (if the fan were connected). If the sensor is open, you have isolated the problem.

Resistance Checks

Naturally, resistance measurements can be made on any switch or wire; just be careful that you're not working on a "live" circuit. If necessary, disconnect the battery. Some of the latest cars use a quick-connector on the main battery wires—the ones that don't connect to the starting motor. Simply open the connector(s) and the battery is disconnected from everything except the starting motor. You can also locate certain radio-reception problems with resistance checks. Road salts often corrode or actually short-circuit the antenna.

To check the antenna installation, measure the resistance from the antenna mount to the fender itself: It should be less than 5 ohms. If the value is higher, look for corrosion inside the fender and under the antenna's mounting hardware. If you can, unplug the antenna lead from the radio and then measure the resistance from the antenna itself to the fender. It should be infinite (read as an open circuit). If it isn't, either replace the antenna or remove the corrosion, which is functioning like a partial short-circuit.

Dim Headlights

Are the headlights dim, or do they flicker? Check for any resistance between the lamp's ground terminal and the battery's negative terminal by measuring the voltage drop between the lamp and the battery when the lamp is on. If it's more than 0.2 volts, the wiring has excessive resistance; work the test probe back from the battery until you locate the wire or connector that's causing the excess resistance.

Summing Up

We've shown some of the most common practical examples of electric and electronic troubleshooting. You can extend the general principles we've covered to all the other electrical gear in the car. If you use a digital multimeter, most of the tests and checks are quick and easy, That's because a digital meter can detect minute variations that often point to

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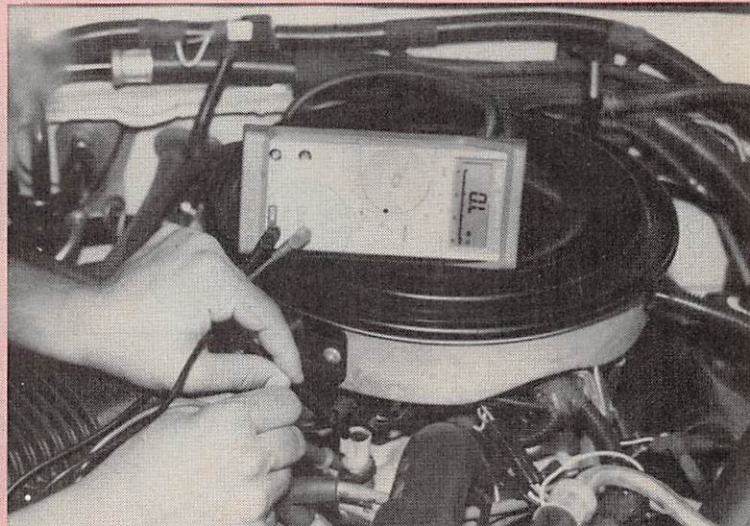

The ohmmeter can also be used to check out defective heat sensors used to control the radiator fan, computer, engine warning lights, etc. The car's service manual gives the sensor's resistance value for various operating conditions.

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serious problems, which are generally masked by the more conventional, analog multimeter.

When it comes to what accountants call "the bottom line," doing your own electric/electronic checks and tests pays off in big dividends because you can avoid paying for what you don't need. For example, replacing a worn alternator belt is a lot cheaper than replacing the alternator, and replacing a radiator's heat sensor yourself can easily save a shop charge of $50 for the diagnosis. The fact is, what you can save on a single electric/electronic repair can easily pay for a quality digital multimeter and its accessories. ■