Probing Auto Electronics

Help your neighbor identify his car's problem and be an electronics hero!

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Being a ham, you're expected to know everything about electronics regardless of the application. So have you ever had some neighbors drop over and indicate that they needed your help with their car? Chances are, they've indicated that it won't start or runs poorly, or that the battery is dead.

In most cases, the symptoms described seldom fit the actual situation. But because you're a ham, you're looked upon to be "the neighborhood electronics resource." So how do you approach the problem?

Do you agree to take a look? Or do you shine them on and suggest that they go see the local mechanic? Let's assume that you're at least willing to take a look at the problem to help sort out the details, which may lead to a solution if the problem is electrical. And if it's mechanical, you may have to suggest the mechanic after all.

Electrical problems and solutions in older cars were usually easy to sort out, but the computers used in modern cars make the problems more difficult for a ham to diagnose. In fact, the things that one might be able to do are limited to only a few things, but those could have an identifiable solution within your grasp.

Three situations are discussed here that can help solve many aggravating problems that cars experience and are not under computer control. These situations involve the spark plugs and HV wiring, alternator and battery, and current leakage paths that run a battery down unexpectedly. The test equipment for troubleshooting these three situations is typically available on a ham's workbench: oscilloscope; digital voltmeter/ammeter; and #1157 (or #1034) taillight bulb. So there is very little financial investment required, beyond what a ham normally has available.

Most hams have had some exposure to Ohm's law problems as part of their electronics training. The logic and circuitry involved in Ohm's law problems is exactly the same as that required for solving electrical problems in a car's electrical system. Troubleshooting then becomes a matter of developing a plan or procedure to follow in sorting out the various measurements and symptoms.

Spark plugs

Being able to diagnose a problem in an automobile's high voltage ignition system is both interesting and satisfying. Because of the pulse nature of the system, it can be analyzed dynamically. Using an oscilloscope provides a means of looking at the HV pulses for one or all of the cylinders. Observed conditions can be related to inequality of spark, weak spark, shorted spark plug, defective plug wiring, or intermittent plug firing.

In the case of a standard ignition system (points and capacitor), the point's dwell time can also be observed to determine if coil saturation is being achieved. Dwell time is not a factor in electronic ignition systems. The oscilloscope display can be focused for detailed analysis on one or all of the spark plugs to help sort out differences between them.

To make up an engine analyzer using an oscilloscope, it will be necessary to make up a couple of interface boards to be used as scope probes as shown in **Figs. 1** and **2**. Sync for the horizontal of the scope is obtained from the high voltage using the circuit shown in **Fig. 1**. A wire cuff or broadfaced spring clip is used to provide a capacitive coupling to the HV wire, as a direct connection is not desirable. The circuit integrates the HV pulse to create a single con-

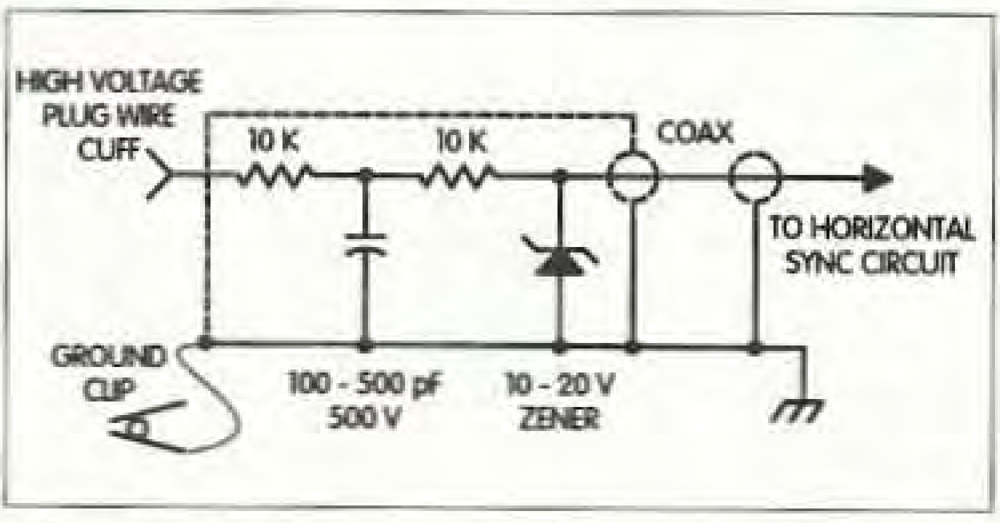

Fig. 1. Sync input circuit.

stant amplitude (a zener diode is used as an amplitude limiter) trigger pulse suitable for synching the scope.

The HV pulse train to be analyzed is obtained from the primary side of the ignition coil using the circuit shown in **Fig. 2** and is applied to the vertical input of the scope. All HV sensing is done in the primary of the coil, not in the actual HV circuit. All of the system's performance is viewable in the primary more so than in the secondary, or HV side, of the coil. A small amount of integration is performed by the interface board, but only enough to make the pulse visible on the screen.

The amplitude pot is used to bring the vertical signal amplitude within the control range of the scope's input attenuator. The pot remains fixed after the initial adjustment. In modern engines, there is a separate ignition coil for each pair of cylinders. Therefore, it will be necessary to move the vertical scope probe from one coil to another to view the next pair of cylinders.

Construction of the probes indicated in **Figs. 1** and **2** is not critical. Some shielding is recommended to keep stray signals from entering the scope, but even unshielded boards have been used successfully. The minimum construction should entail placing each circuit within a plastic box to prevent the circuit from shorting to an engine component.

Test preparation includes connecting the interface circuits to and starting the engine, and running the engine at idle. In operation, the scope sweep is adjusted to approximately 20 ms/cm when displaying all of the plugs at once. Attaching the HV pickup (sync) to plug #1 will allow all of the plugs to be viewed in the order in which they fire (only when one coil is used for all of the cylinders).

Adjust the sweep timing to display four, six, or eight pulse sequences as

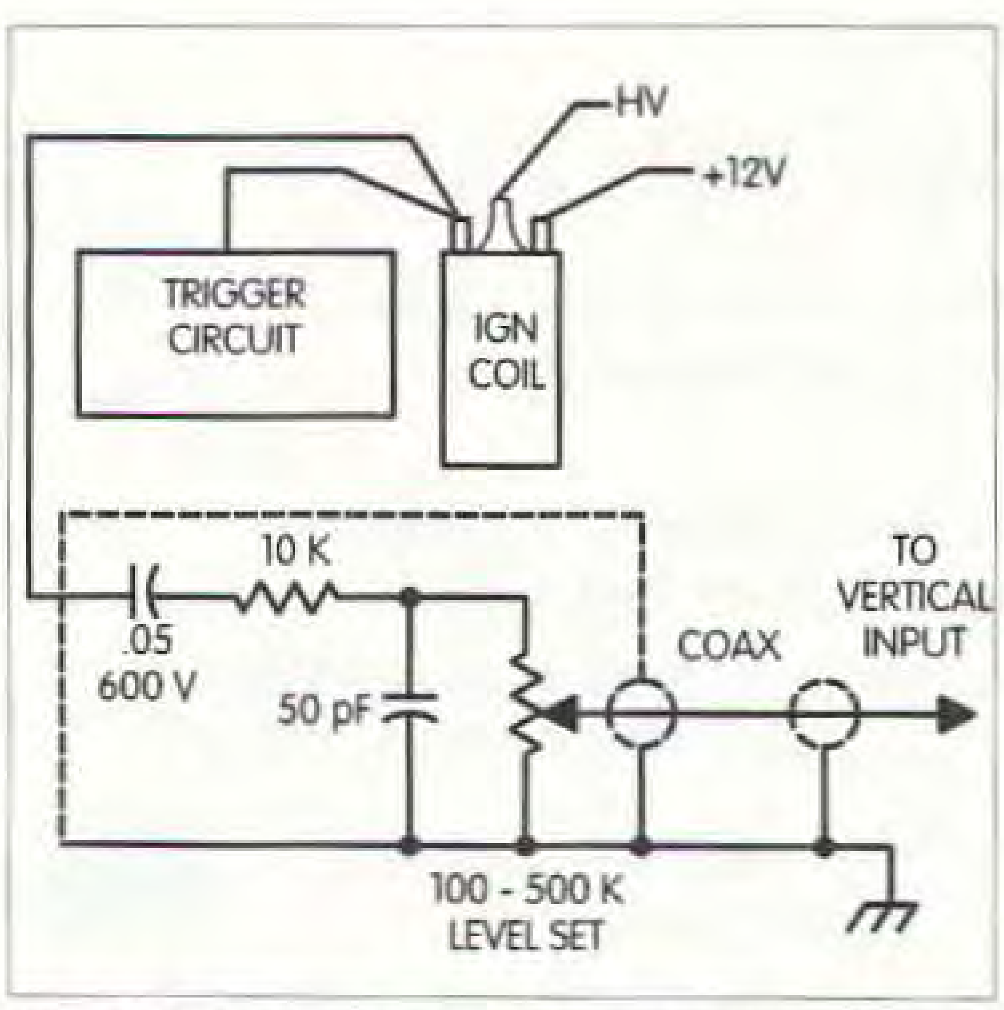

***Fig. 2.** Pulse input circuit to vertical amplifier.*

determined by the number of cylinders present (only two cylinders at a time can be viewed when an ignition coil is provided for each pair of cylinders). To view a single plug, attach the HV pickup to the plug to be viewed and adjust the sweep to approximately 1 ms/cm or until one pulse sequence is observed. Move the HV pickup from one plug wire to another to make pulse comparisons.

Typical waveforms suitable for comparison are shown in **Fig. 3.** Because the waveforms obtained vary somewhat from one engine to another, it is necessary to identify a "norm" waveform for the engine being analyzed. A norm can be determined by looking first at all plugs firing (typical sweep of 20 ms/cm) and observing the similarity as a norm. Then note any differences in the plug patterns observed for a potential problem. Obtain a closer analysis of individual plugs using a sweep of about 1 ms/cm to provide clues as to the health of the ignition system.

To aid in the analysis, look for the series of HV pulses that occurs during a plug firing, then look for the short delay before the next firing. The right-hand end of the delay indicates the beginning of the firing cycle and the left-hand end of the next delay indicates the completion of the firing cycle.

The pulse waveform between the delay periods provides the clues for comparison to the examples shown. A shorted plug wire can be simulated by holding a screwdriver between the engine block and the top of a spark plug while observing the waveform. It is *not* recommended, however, to simulate an open HV wire by removing a plug wire—as electronic ignition systems are subject to damage when an open HV wire occurs.

Alternator and battery

Troubleshooting a battery and/or alternator problem is fairly easy with a digital voltmeter, and the short time that it takes could satisfy your neighbors and make you a hero. The use of a digital voltmeter is preferred, but an analog voltmeter will work with a little less satisfaction in determining specific voltage values. But the general function of "what's happening" can be displayed with an analog voltmeter.

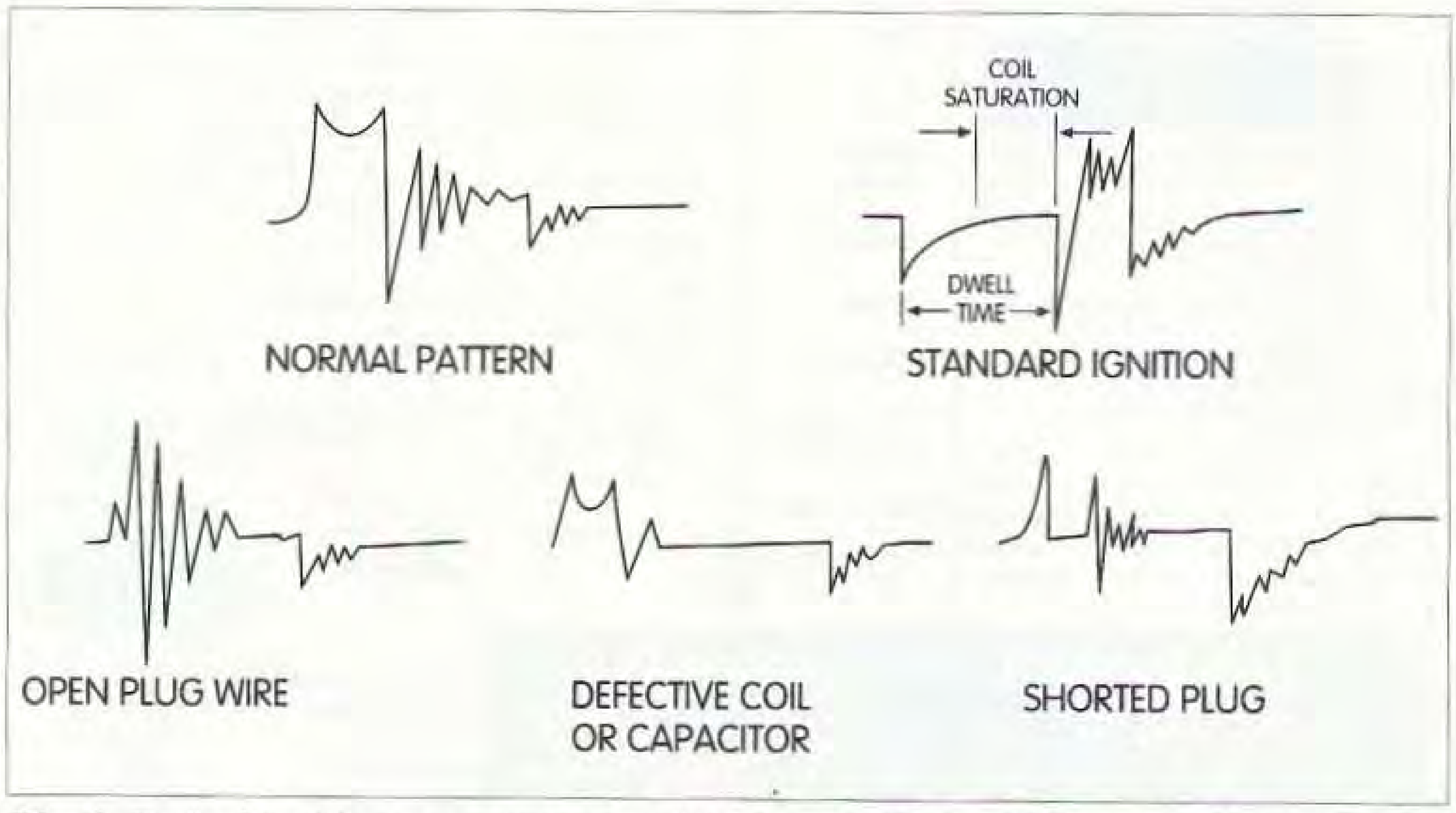

***Fig. 3.** Typical ignition wave patterns exhibiting specific conditions. Dwell time pattern is specific to a standard ignition system.*

Test conditions involve the logic of what happens during static and dynamic conditions where static conditions occur when the engine is turned off. During this period both loaded and unloaded tests can be performed on the battery to determine its present health regarding being charged or discharged.

What you may not know at this time is whether the battery has been charged recently or discharged due to an inadvertent current leakage path. But the first test involves performing a load test which begins by placing the voltmeter across the battery terminals and noting the voltage indication, which should be approximately 13.5 V. While observing the meter, the headlights are turned on. Typically, if the battery is healthy, the voltage indication will remain above 12.6 V and the lights will be fairly bright. The small voltage drop between the load and no-load test indicates the battery to be healthy. If the battery has not been charged recently, perhaps if the alternator has failed, then the voltage differential would be higher—making the battery suspect. But before installing another battery, the alternator will require testing. Because the battery and alternator together make up the power system for the automobile, they must be tested as a system.

Test conditions

I.A. To determine if a battery is capable of starting the engine, you need only to engage the starter. Assume first that the solenoid just clicks, with the starter failing to turn. This indicates one of three conditions:

1. The battery charge is low.
2. The battery is defective.
3. The starter is defective.

B. Two tests are required for an evaluation of the battery, because if the battery is good and the solenoid still just clicks, then the starter is suspect. The starter and solenoid are both suspect if the battery is fully charged and the solenoid fails to click. The first test of the battery involves measuring the terminal voltage under load (headlights *on*) with the engine *off*. Record the voltage readings. Then, after charging the battery, the load/no-load tests are repeated and the voltage values compared.

C. Expected results:

1. If the battery will retain a charge, the terminal voltage will be above 12.6 V for both load and no-load tests.

2. If the battery terminal voltage is below 12.6 V after being charged, then the battery is suspect, as it may be defective.

II.A. Determining the status of an alternator is much easier and considerably faster than testing a battery. Alternator testing is always done with the engine running. With one exception, the engine should not be running when checking for alternator diode leakage.

1. To perform a diode leakage test on an alternator, the following procedure is used. With engine off, the battery cable is removed from the alternator and a voltmeter is placed between the terminal and the cable. Because of the high reverse resistance of the diodes, a voltage indication of less than 12.8 V should be expected. If the leakage is more than might be expected, a #1157 (or #1034) light bulb with pigtails attached to one filament may be placed between the cable and terminal as an additional test method. The light bulb should not exhibit any filament glow. If the bulb filament does glow, then suspect leaky diodes in the alternator. Another symptom of a bad alternator/regulator (particularly if the filament glows during the light bulb test) will be a dead battery after a few hours of non-use.

2. Dynamic tests on the alternator will also check the regulator, brushes, and diode conduction. The terminal voltage across the battery with the engine running at or above idle should yield a voltage between 13.2 and 14.7 V. The voltage value should remain approximately the same whether or not the headlights are turned *on*.

VOLTAGE	CONDITION
15.2	Overcharging
13.2 – 14.7	Normal Range
13.0	Not Charging
12.7	Possible Open/Defective Diode
11.5	Low Battery

Table 1. *Expected battery terminal voltage values based upon typical system conditions.*

B. Expected results:

1. If the terminal voltage remains fairly constant at a value between 13.2–14.7 V with or without a load, then the alternator and regulator are functioning OK.

2. If the terminal voltage is at 12.8 V or below with or without a load, suspect the alternator/regulator as being defective.

3. If the voltage appears to be regulated but hangs at about 12.7 V, then suspect an open diode in the alternator.

C. **Table 1** provides a guide for making diagnostic decisions regarding an automobile's electrical system. Because of the cost factor of replacing a battery or alternator, replacement decisions should be based upon as many symptoms and available test data results as possible. It is best to perform all of the tests and compare the results of each to identify the bad component.

III.A. One of the most difficult electrical problems to diagnose is a current leakage path that tends to run down the battery during a short period of unuse—24–48 hours, perhaps. Because of the elusiveness of the problem, only a few hints can be provided as to how you would go about solving it. Hams have a solution for almost all electronic problems, even those involving cars. The best suggestion is to consider the car's electrical system as an Ohm's law problem in which there is one voltage source feeding a great number of parallel current paths. It will then be necessary to determine the current flow in each path when each is intended to be *open* circuited.

B. Before starting a troubleshooting process, make sure that all lights including the glove box, trunk, engine compartment, map light, etc., are turned off. It may be necessary to temporarily remove them from their sockets to make sure they are completely turned *off*. It's also a good idea to remove the cigarette lighter from its socket. It must be recognized that the clock and computer will draw some current, but the value should be relatively small in comparison to what a glove box light might draw.

C. The first step in chasing a leakage problem is to determine the magnitude of the leakage path. This can be done by removing the battery cable from the battery. This operation can wipe out the theft code on some electrical devices, such as the radio, within the vehicle, so you must be prepared to re-enter the proper codes following the troubleshooting process. Otherwise, do not remove the battery cable from the battery.

D. Assuming that the above items have been accounted for and found to not be a problem, a DVM and a #1157 (or #1034) light bulb can be used as diagnostic tools for tracing current paths.

1. Remove the battery cable and place the light bulb between the cable and battery terminal. If the bulb filament glows, then take note of the brilliance as a reference for later measurements. Place a DVM set on the amps scale and measure the current value. Anything greater than about 50 mA is considered suspect. The measured value is essentially the current value that must be traced to the suspected branch circuit causing the leakage path. It is assumed here that the alternator and regulator have been found to be OK and checked as in step number II above.

2. Circuits that do not normally go through the fuse block are the headlights, computer, transmission shift indicator, temperature sensors, starter, alternator, etc. If no problem is found in the fuse block test (below), then each of these circuits will require an examination. Each of the circuits listed will have a switch or relay that provides power to the circuit. It will be necessary to examine each.

3. Reconnect the battery cable to the battery and move to the fuse block. Each fuse is to be removed, one at a time, and the current measured in that path. Either the light bulb or ammeter may be used as a current indicator.

E. Expected results:

1. The current in each circuit path should be zero if the circuit is open.

2. The circuit containing the high

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leakage path should exhibit a current value similar to the value determined as a reference at the battery terminal.

F. Taking note of the circuit and the current measured at each fuse position (circuit branch) will provide a clue as to which circuit contains the excessive leakage path.

There is an alternate test method that may be used when two people are available, one to perform the test and the other to watch the light bulb. If the light bulb filament glows when connected between the battery terminal and cable, then leave the bulb connected and open each fuse circuit and potential circuit path. The light bulb will cease to glow when the leakage path has been opened.

Following the logic of an Ohm's law problem analysis will provide the clues necessary to diagnose automotive electrical systems. Help your neighbor identify his automobile's electrical problem and be a hero!