Automotive Electrical & Engine Performance 8/E
Chapter 9 Wiring Schematics & Circuit Testing
Opening Your Class

KEY ELEMENT	EXAMPLES
Introduce Content	This Automotive Electrical & Engine Performance 8th edition provides complete coverage of automotive areas pertaining vehicle electrical systems and engine performance. It correlates material to task lists specified by ASE and ASEEducation (NATEF) and emphasizes a problem-solving approach. Chapter features include Tech Tips, Frequently Asked Questions, Case Studies, Videos, and Animations that are listed in this Lesson Plan. This Lesson Plan also references ASEEducation (NATEF) Task Sheets available from Jim's web site.
Motivate Learners	Explain how the knowledge of how something works translates into the ability to use that knowledge to figure why the engine does not work correctly and how this saves diagnosis time, which translates into more money.
State the learning objectives for the chapter or course you are about to cover and explain this is what they should be able to do as a result of attending this session or class.	Explain the chapter learning objectives to the students. 1. Interpret wiring schematics and explain the procedure to identify relay terminals. 2. Locate shorts, grounds, opens, and resistance problems in electrical circuits, and determine necessary action. 3. Explain the different methods to locate a short circuit, and the procedure to troubleshoot an electrical problem. **This chapter will help you prepare for the ASE Electrical/Electronic Systems (A6) certification test content area "A" (General Electrical/Electronic System Diagnosis).**
Establish the Mood or Climate	Provide a *WELCOME,* Avoid put downs and bad jokes.
Complete Essentials	Restrooms, breaks, registration, tests, etc.
Clarify and Establish Knowledge Base	Do a round robin of the class by going around the room and having each student give their backgrounds, years of experience, family, hobbies, career goals, or anything they want to share.

NOTE: This lesson plan is based on Automotive Electrical & Engine Performance 8th Edition Chapter Images found on Jim's web site @ www.jameshalderman.com

DOWNLOAD Chapter 09 Chapter Images: From http://www.jameshalderman.com/books_a8.html#anchor2

ICONS	Ch09 Wiring Schematics & Circuit Testing

1. **SLIDE 1 CH09 WIRING SCHEMATICS & CIRCUIT TESTING**

Check for ADDITIONAL VIDEOS & ANIMATIONS @ http://www.jameshalderman.com/

WEB SITE IS CONSTANTLY UPDATED

Videos

At the beginning of this class, you can download the crossword puzzle & Word Search from Jim's web site to familiarize your class with terms in this chapter & then discuss them, see below:

HTTP://WWW.JAMESHALDERMAN.COM/BOOKS_A8.HTML#ANCHOR2

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CROSSWORD PUZZLE (MICROSOFT WORD) (PDF)

WORD SEARCH PUZZLE (MICROSOFT WORD) (PDF

DISCUSSION: TALK ABOUT CIRCUIT INFORMATION ON A WIRING DIAGRAM. HOW IS A WIRING DIAGRAM SIMILAR TO A ROADMAP? DISCUSS CHART 9-1 typical abbreviations used on schematics to show wire color. Some OEMS use two letters to represent a wire Color. Check service information for color abbreviations used.

2. **SLIDE 2** EXPLAIN **Figure 9-1** The center wire is a solid color wire, meaning that the wire has no other identifying tracer or stripe color. The two end wires could be labeled "BRN/WHT," indicating a brown wire with a white tracer or stripe.
3. **SLIDE 3** EXPLAIN **Figure 9-2** Typical section of a wiring diagram. Notice that 2 wire color changes at connection C210. 2 ".8" represents 2 metric wire size in square **millimeters**.

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	4. **SLIDE 4** EXPLAIN **Figure 9-3** Electrical/electronic symbols used in automotive wiring & circuit diagrams.
	**DEMONSTRATION: PROCURE A WIRING HARNESS TO SHOW STUDENTS VARIOUS COLORS OF WIRES IN HARNESS**
	**DISCUSSION: HAVE THE STUDENTS TALK ABOUT THE VARIOUS COLORS OF THE WIRES IN A WIRING HARNESS. WHAT IS THE SIGNIFICANCE OF DIFFERENT COLORS?**
	**DISCUSSION: HAVE STUDENTS DISCUSS THE SYMBOLS USED TO INDICATE MALE AND FEMALE CONNECTORS. WHY IS BATTERY SIDE OF CONNECTOR FEMALE & NOT MALE? HAVE STUDENTS STUDY CHART 9–3 TO BECOME FAMILIAR WITH SYMBOLS USED IN WIRING DIAGRAMS. WHAT DO SHORTER AND LONGER LINES ON BATTERY SYMBOL MEAN? HOW IS WIRING SHOWN?**
	**EXPLAIN TECH TIP:** ***Read the Arrows:*** **Wiring diagrams indicate connections by symbols that look like arrows. • SEE FIGURE 9–4. Do not read these "arrows" as pointers showing direction of current flow. Also observe that power side (positive side) of circuit is usually female end of connector. If a connector becomes disconnected, it is difficult for circuit to become shorted to ground or to another circuit because wire is recessed inside connector.**
	5. **SLIDE 5** EXPLAIN **FIGURE 9-4** In this typical connector, note that positive terminal is usually a female connector**.** 6. **SLIDE 6** EXPLAIN **Figure 9-5** symbol for a battery. The positive plate of a battery is represented by the longer line and the negative plate by the shorter line. The voltage of the battery is usually stated next to the symbol

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7. **SLIDE 7 EXPLAIN Figure 9-6** ground symbol on the left represents earth ground. The ground symbol on the right represents a chassis ground.

8. **SLIDE 8 EXPLAIN Figure 9-7** Starting at top, wire from ignition switch is attached to terminal B of connector C2, wire is 0.5 mm^2 (20 gauge AWG), and yellow. Circuit number is 5. Wire enters connector C202 at terminal B3.
9. **SLIDE 9 EXPLAIN Figure 9-8** electrical terminals are usually labeled with a letter or number
10. **SLIDE 10 EXPLAIN Figure 9-9** Two wires that cross at the dot indicate that the two are electrically connected.

DEMONSTRATION: PROCURE A WIRING HARNESS WITH SPLICES. OPEN IT UP TO SHOW SPLICES IN HARNESS AND EXPLAIN THE NEED FOR SPLICES.

11. **SLIDE 11 EXPLAIN Figure 9-10** Wires that cross, but do not electrically contact each other, are shown with one wire bridging over the other.
12. **SLIDE 12 EXPLAIN Figure 9-11** Connectors (C), grounds (G), and splices (S) are followed by a number, generally indicating the location in the vehicle. For example, G209 is a ground connection located under dash.

DISCUSSION: TALK ABOUT NUMBERS USED TO INDICATE GENERAL AREAS FOR CONNECTION LOCATIONS. WHY IS THERE NEED TO SEPARATE VEHICLE INTO DIFFERENT AREAS TO SIMPLIFY REPAIRS? WHAT IS DIFFERENCE BETWEEN EVEN & ODD NUMBERED CONNECTORS?

13. **SLIDE 13 EXPLAIN Figure 9-12** ground for the battery is labeled G305 indicating the ground connector is located in the passenger compartment of the vehicle. The ground wire is black (BLK), the circuit number is 50, and the wire is 32 mm^2 (2 gauge AWG).
14. **SLIDE 14 EXPLAIN Figure 9-13** The symbol for light bulbs shows the filament inside a circle, which represents the glass ampoule of the bulb

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15. **SLIDE 15 EXPLAIN Figure 9-14** An electric motor symbol shows a circle with the letter M in the center and two black sections that represent the brushes of the motor. This symbol is used even though the motor is a brushless design
16. **SLIDE 16 EXPLAIN Figure 9-15** Resistor symbols vary depending on the type of resistor.

17. **SLIDE 17 EXPLAIN Figure 9-16** rheostat uses only two wires—one is connected to a voltage source and the other is attached to the movable arm
17. **SLIDE 18 EXPLAIN Figure 9-17** Symbols used to represent capacitors. If one of the lines is curved, this indicates that the capacitor being used has a polarity, while the one without a curved line can be installed in the circuit without concern about polarity.
19. **SLIDE 19 EXPLAIN Figure 9-18** grid like symbol represents an electrically heated element. Symbol represents a cigarette lighter or heated rear window
20. **SLIDE 20 EXPLAIN Figure 9-19** Dashed outline represents a portion (part) of a component

DISCUSSION: DISCUSS SYMBOLS USED TO REPRESENT CAPACITORS ON WIRING DIAGRAMS. WHY ARE 2 DIFFERENT SYMBOLS NEEDED FOR CAPACITORS?

21. **SLIDE 21 EXPLAIN Figure 9-20** Solid box represents an entire component
22. **SLIDE 22 EXPLAIN Figure 9-21** Symbol represents a component that is case grounded.

DEMONSTRATION: SHOW STUDENTS HOW TO USE A COPY OF A WIRING DIAGRAM AND HIGHLIGHTER TO TRACE CIRCUITS FOR TESTING OR REPAIR.

23. **SLIDE 23 EXPLAIN Figure 9-22** (a) A symbol for a single-pole, single-throw (SPST) switch. This type of switch is normally open (N.O.) because nothing is connected to the terminal that the switch is contacting in its normal position. (b) A single-pole, double-throw (SPDT) switch has three terminals. (c) A double-pole, single-throw (DPST) switch has two positions (off and on) and can control two separate circuits. (d) A double-pole, double-throw (DPDT)

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	switch has six terminals—three for each pole. Note: Both (c) and (d) also show a dotted line between the two arms indicating that they are mechanically connected, called a "ganged switch."
	24. SLIDE 24 EXPLAIN **Figure 9-23 (a)** symbol for a normally open (N.O.) momentary switch **(b)** symbol for a normally closed (N.C.) momentary switch.
	**EXPLAIN TECH TIP:** ***Color-Coding Is Key to Understanding*** **Whenever diagnosing an electrical problem, it is common practice to print out the schematic of the circuit and take it to the vehicle. A meter is then used to check for voltage at various parts of the circuit to help determine if there is a fault. The diagnosis can be made easier if the parts of the circuit are first color-coded using markers or color pencils. The colors represent voltage conditions in various parts of a circuit. Once the circuit has been color-coded, it can be tested using the factory wire colors as a guide.● SEE FIGURE 9–24.**
	**25. SLIDE 25** EXPLAIN **FIGURE 9-24** Using a marker and color-coding the various parts of the circuit makes the circuit easier to understand and helps diagnosing electrical problems easier.
	**26. SLIDE 26** EXPLAIN **Figure 9-25** relay uses a movable arm to complete a circuit whenever there is a power at terminal 86 and a ground at terminal 85. A typical relay only requires about 1/10 ampere through the relay coil. The movable arm then closes the contacts (#30 to #87) and can relay 30 amperes or more.
	27. SLIDE 27 EXPLAIN **Figure 9-26** cross-sectional view of a typical 4-terminal relay. Current flowing through coil (terminals 86 and 85) causes movable arm (called armature) to be drawn toward coil magnet. Contact points complete electrical circuit connected to terminals 30 & 87.
	28. SLIDE 28 EXPLAIN **Figure 9-27** typical relay showing the schematic of the wiring in the relay

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<u>DISCUSSION:</u> **HAVE STUDENTS TALK ABOUT OPERATION OF NORMALLY OPEN AND NORMALLY CLOSED RELAYS. WHAT ARE THE APPLICATIONS FOR NORMALLY OPEN RELAYS? WHAT ARE THE APPLICATIONS FOR NORMALLY CLOSED RELAYS?**

<u>EXPLAIN TECH TIP</u>: *Divide Circuit in Half:* When diagnosing any circuit that has a relay, start testing at relay and divide circuit in half.

- **High-current portion: Remove the relay and check that there are 12 volts at the terminal 30 socket. If there is, the power side is okay. Use an ohmmeter and check between terminal 87 socket and ground. If load circuit has continuity, there should be some resistance. If OL, the circuit is electrically open.**
- **Control circuit (low current): With relay removed from the socket, check that there are 12 volts to terminal 86 with ignition on and control switch on. If not, check service information to see if power should be applied to terminal 86, and continue troubleshooting switch power and related circuit.**
- **Check relay itself: Use an ohmmeter and measure for continuity and resistance between terminals 85 and 86 (coil), there should be 60 to 100 ohms. If not, replace the relay.**
- **Between terminals 30 and 87 (high-amperage switch controls), there should be continuity (low ohms) when there is power applied to terminal 85 and a ground applied to terminal 86 that operates the relay. If OL is displayed on the meter set to read ohms, the circuit is open, which requires that the relay be replaced.**

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- **Between terminals 30 and 87a (if equipped), with the relay turned off, there should be low resistance (less than 5 ohms).**

29. **SLIDE 29 EXPLAIN FIGURE 9.28** All schematics are shown in their normal, non-energized position
30. **SLIDE 30 EXPLAIN Figure 9-29** typical horn circuit. Note that relay contacts supply the heavy current to operate horn when horn switch simply completes a low-current circuit to ground, causing relay contacts to close.
31. **SLIDE 31 EXPLAIN Figure 9-30** When relay or solenoid coil current is turned off, the stored energy in coil flows through clamping diode and effectively reduces voltage spike.
32. **SLIDE 32 EXPLAIN Figure 9-31** resistor used in parallel with the coil windings is a common spike reduction method used in many relays

DISCUSSION: ASK STUDENTS TO TALK ABOUT CONTROLLING RELAY VOLTAGE SPIKES. HOW DOES DIODE USED IN A RELAY COIL CIRCUIT ELIMINATE VOLTAGE SPIKES?

DISCUSS FREQUENTLY ASKED QUESTION: *WHAT IS THE DIFFERENCE BETWEEN A RELAY AND A SOLENOID?* OFTEN, THESE TERMS ARE USED DIFFERENTLY AMONG OEMS, WHICH CAN LEAD TO SOME CONFUSION.

RELAY: a relay is an electromagnetic switch that uses a movable arm. Because a relay uses a movable arm, it is generally limited to current flow not exceeding 30 amperes.

SOLENOID: a solenoid is an electromagnetic switch that uses a movable core. Because of this type of design, a solenoid is capable of handling 200 amperes or more. It is used in the

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	starter motor circuit and other high-amperage applications, such as in the glow plug circuit of diesel engines.
	**AN INOPERATIVE CIRCUITINVOLVING A RELAY CAN BE DIVIDED IN ½ FOR TESTING. HIGH-CURRENT AND LOW-CURRENT SIDES CAN BE TESTED SEPARATELY TO DETERMINE WHICH SIDE OF CIRCUIT IS INOPERATIVE.**
	**LAB HANDS-ON TASK: STUDENTS COMPLETE WORKSHEET ON HIGHLIGHTING WIRING DIAGRAMS**
	33. **SLIDE 33** EXPLAIN **Figure 9-32** typical wiring diagram showing multiple switches & bulbs powered by one fuse.
 	**DISCUSS CASE STUDY: *THE ELECTRIC MIRROR FAULT STORY*** **A customer noticed that electric mirrors stopped working. The service technician checked all electrical components in the vehicle and discovered that the interior lights were also not working. The interior lights were not mentioned by the customer as being a problem most likely because the driver only used the vehicle in daylight hours. The service technician found the interior light and power accessory fuse blown. Replacing the fuse restored proper operation of the electric outside mirror and interior lights. However, what caused the fuse to blow? Visual inspection of the dome light, next to the electric sunroof, showed an area where a wire was bare. Evidence showed bare wire had touched metal roof, which could cause the fuse to blow. The technician covered bare wire with a section of vacuum hose and then taped hose with electrical tape to complete the repair.** **SUMMARY:** • **Complaint—electric power mirrors stopped working.**

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	• Cause—blown fuse due to a fault in wiring at dome light. • Correction—repaired wiring at the dome light, which restored proper operation of electric mirrors that shared the same fuse as dome light. **ASEEDUCATION Task Sheet A7. Use wiring diagrams during the diagnosis (troubleshooting) of electrical/electronic circuit problems.** **DEMONSTRATION: USE TRAINER FOR AN OPEN CIRCUIT. HAVE STUDENTS WORK THROUGH CIRCUIT TROUBLESHOOTING PROCEDURE WITH YOU. EXPLAIN REASON FOR TESTING SIMPLE THINGS FIRST. TRY OUT THIS EXERCISE BEFORE CLASS TO MAKE SURE IT WORKS PROPERLY FOR DEMONSTRATING TO STUDENTS.** **EXPLAIN TECH TIP: *Do It Right—Install a Relay*** **Often the owners of vehicles, especially owners of pickup trucks and sport utility vehicles (SUVs), want to add additional electrical accessories or lighting. It is tempting in these cases to simply splice into an existing circuit. However, when another circuit or component is added, the current that flows through the newly added component is also added to the current for the original component. This additional current can easily overload the fuse and wiring. Do not simply install a larger amperage fuse; the wire gauge size was not engineered for the additional current and could overheat. The solution is to install a relay, which uses a small coil to create a magnetic field that causes a movable arm to switch on a higher current circuit. The typical relay coil has 50 to 150 ohms (usually 60 to 100 ohms) of resistance and requires just 0.24 to 0.08 ampere when connected to a 12-**

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	volt source. This small additional current is not enough to overload the existing circuit. • SEE FIGURE 9–33 for an example of how additional lighting can be added.
	34. **SLIDE 34** EXPLAIN **FIGURE 9-33** To add additional lighting, simply tap into an existing light wire & connect a relay. Whenever the existing light is turned on, the coil of the relay is energized. The arm of the relay then connects power from another circuit (fuse) to auxiliary lights without overloading the existing light circuit.
	35. **SLIDE 35** EXPLAIN **Figure 9-34** Always check simple things first. Check fuse for circuit you are testing. Maybe a fault in another circuit controlled by same fuse could have caused fuse to blow. Use a test light to check that both sides of fuse have voltage
	**DISCUSS FREQUENTLY ASKED QUESTION:** ***WHERE TO START?*** **The common question is, where does a technician start troubleshooting when using a wiring diagram (schematic)?** **Hint 1 circuit contains a relay, start your diagnosis at relay. Entire circuit can be tested at terminals of relay.** **Hint 2 easiest first step is to locate unit on schematic that is not working or not working.** • **Trace where unit gets its ground connection.** • **Trace where the unit gets its power connection. Often a ground is used by more than one component.** **Therefore, ensure that everything else is working correctly. If not, the fault may lie at the common ground (or power) connection.**

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	Hint 3 divide the circuit in half by locating a connector or a part of the circuit that can be accessed easily. Then check for power and ground at this midpoint. This step could save you time. **Hint 4 use a fused jumper wire to substitute a ground or a power source to replace a suspected switch or section of wire.**
	**DISCUSSION: DISCUSS CIRCUIT BREAKER METHOD OF TESTING FOR A SHORT-TO-GROUND CIRCUIT. WHY IS THIS A BETTER ALTERNATIVE THAN FUSE REPLACEMENT METHOD?**
	36. **SLIDE 36** EXPLAIN: **Figure 9-35 (a)** After removing the blown fuse, a pulsing circuit breaker is connected to the terminals of fuse. 37. **SLIDE 37** EXPLAIN: **Figure 9-35 (b)** circuit breaker causes current to flow, then stop, then flow again, through circuit up to point of the short-to-ground. By observing the Gauss gauge, location of short is indicated near where the needle stops moving due to the magnetic field created by the flow of current through the wire.
	38. **SLIDE 38** EXPLAIN **Figure 9-36** Gauss gauge can be used to determine the location of a short circuit even behind a metal panel. 39. **SLIDE 39** EXPLAIN **Figure 9-37** tone generator-type tester used to locate open circuits and circuits that are shorted-to-ground. Included with this tester is a transmitter (tone generator), receiver probe, and headphones for use in noisy shops. 40. **SLIDE 40** EXPLAIN **Figure 9-38** To check for a short-to-ground using a tone generator, connect black transmitter lead to a good chassis ground & red lead to load side of fuse terminal. Turn the transmitter on and check for tone signal with the receiver. Using a wiring diagram, follow strongest signal to short-to-ground. There will be no signal

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beyond the fault, either a short-to-ground as shown or an open circuit

EXPLAIN TECH TIP: ***Heat or Movement***: **Electrical shorts are commonly caused either by movement, which causes insulation around the wiring to be worn away, or by heat melting the insulation. When checking for a short circuit, first check the wiring that is susceptible to heat, movement, and damage.**

1. **Heat. Wiring near heat sources, such as the exhaust system, cigarette lighter, or alternator**
2. **Wire movement. Wiring that moves, such as in areas near the doors, trunk, or hood**
3. **Damage. Wiring subject to mechanical injury, such as in the trunk, where heavy objects can move around and smash or damage wiring can also occur as a result of an accident or a previous repair**

EXPLAIN TECH TIP: ***Wiggle Test:*** **Intermittent electrical problems are common, yet difficult to locate. To help locate these hard-to-find problems, try operating circuit and start wiggling the wires and connections that control the circuit. If in doubt where the wiring goes, try moving all the wiring starting at the battery. Pay particular attention to wiring running near the battery or the windshield washer container. Corrosion can cause wiring to fail, and battery acid fumes and alcohol-based windshield washer fluid can start or contribute to the problem. If you notice any change in the operation of the device being tested while wiggling wiring, look closer in the area you were wiggling until you locate and correct the actual problem.**

DEMONSTRATION: SHOW STUDENTS HOW A GAUSS GAUGE WORKS. HAVE THEM USE GAUSS GAUGE TO CHECK FOR A SHORTED WIRE.

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DISCUSSION: **HAVE STUDENTS DISCUSS FOUR METHODS OF TESTING FOR A SHORT-TO-GROUND CIRCUIT. WHICH METHOD WOULD BE EASIEST, & WHICH WOULD BE MOST DIFFICULT? WHY?**

DEMONSTRATION: **RAISE A VEHICLE ON A LIFT. HAVE STUDENTS INSPECT & LOCATE AREAS WHERE POTENTIAL ELECTRICAL OR ELECTRONIC PROBLEMS COULD OCCUR FROM HEAT OR MOVEMENT OF A WIRING HARNESS.**

DISCUSS CASE STUDY: *SHOCKING EXPERIENCE*

A customer complained that after driving for a while, he got a static shock whenever he grabbed the door handle when exiting the vehicle. The customer thought that there must be an electrical fault and that the shock was coming from the vehicle itself. In a way, the shock was caused by the vehicle, but it was not a fault. The service technician sprayed the cloth seats with an antistatic spray and the problem did not reoccur. Obviously, a static charge was being created by the movement of the driver's clothing on the seats and then discharged when the driver touched the metal door handle. • SEE FIGURE 9–39.

SUMMARY:

- **Complaint–vehicle owner complained that he got shocked when the door handle was touched.**
- **Cause–static electricity was found to be the cause, not a fault with the vehicle.**
- **Correction–the seats and carpet were sprayed with an anti-static spray and this corrected the concern.**

41. **SLIDE 41** EXPLAIN **FIGURE 9-39** Antistatic spray can be used by customers to prevent being shocked when they touch a metal object like the door handle

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	**ASEEDUCATION TASK SHEET: A4.** **DEMONSTRATE KNOWLEDGE OF THE CAUSES AND EFFECTS FROM SHORTS, GROUNDS, OPENS, AND RESISTANCE PROBLEMS IN ELECTRICAL/ELECTRONIC CIRCUITS.**