

# Phase 1 Workshop Home Study Guide

## Vehicle Electrical-Electronics Troubleshooting Training

Written and Developed by  
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## Phase 1 Workshop Home Study Guide

This study guide will take you through the Phase 1 Workshop curriculum in 9 Study Blocks using the same training aids and books taught by Vince Fischelli in the “Phase 1 – *Hands-On Vehicle Electrical-Electronics Troubleshooting Workshop.*”

### The Three Training Materials Used in the Phase 1 Workshop

#### (1) Text Book “Vehicle Electrical Troubleshooting **SHORTCUTS**”

This 250 page book is divided into 7 sections and this is explained before Page 1-1. When reference is made to this book in the Study Guide it will simply be referred to as **SHORTCUTS**.

#### (2) Module H-III A, The Starter Kit

This module contains a Power Board, H-PCB01A and a Lamp Board, H-PCB02A, a 12 volt power supply, H-PS01 (USA) or a UK or Euro Power supply for countries using 220V main line voltage. A Resistor Bag H-RB01 contains resistors needed for problem insertion.

##### Two books are included in H-111A.

- The Student Workbook, **H-WB111A** contains detailed directions, circuit explanations, exercises and step-by-step instructions.
- The Instructor Guide, **H-IG111A**, contains the answers to exercises and troubleshooting problems as well as easy to follow instructions to insert electrical problems on the bottom of the circuit boards.

#### (3) **FIRST THINGS FIRST**

A laminated flip-chart that tests a vehicle’s primary electrical system consisting of the battery, primary ground circuits (engine ground and accessory ground) and the charging system. The first series of tests are performed with a cold engine then a quick retest after the engine warms up. Entire test sequence consisting of 14 voltage measurements can be accomplished in less than 5 minutes with a little practice.

##### A Few Comments Before You Get Started

- Set aside a convenient and comfortable Study Station (place to study) where your study materials will easily remain available so you can start and stop studying without the hassle of packing up or unpacking materials each time.
- Your Study Station should have easy access to line voltage (wall plug) for the Power Supply. The Power Supply has no ON/OFF switch. It is controlled by plugging it in to turn it ON and unplugging it to turn it OFF or use the ON/OFF switch on a power strip to control the Power Supply.



## 9 Study Blocks - Study in Numerical Order

(Check Off each item when completed)

### Block 1

#### Study Section 1 in *SHORTCUTS* – Essential Electrical Principles

\_\_\_ Study 1-1 to 1-23. This section covers essential electrical principles that explain the laws and principles needed to understand electrical circuit operation.

\_\_\_ Completed Section 1

\_\_\_ Review Questions Pages 1-24 to 1-26. (Answers in the back of *SHORTCUTS*.)

### Block 2

#### Study Section 2 in *SHORTCUTS* – Working With Digital Multimeters

Read Section 2 in *SHORTCUTS*. Important concepts to focus on are listed below and should be checked off when completed and understood.

\_\_\_ Page 2-4 covers conversions between volts, (V) and millivolts (mV). This is very important to understand the readings on your DMM and technical explanations throughout this training program.

\_\_\_ Pages 2-5 to 2-11 explains DMM voltage ranges and important concepts using your DMM to measure voltage. Have your DMM in front of you to see how your DMM compares with the examples given.

\_\_\_ Pages 2-15 to 2-15 explains concepts of measuring electron current. This will be important for hands-on vehicle testing of electron current with a Current Clamp in Section 4.

\_\_\_ Pages 2-15 to 2-20 explains ohmmeter principles, ohmmeter ranges and measuring resistance of circuit components. Ohmmeters are an important tool to test solid-state components like diodes, transistors, solid-state relays and vehicle circuits such as the CAN Bus network.

\_\_\_ Pages 2-21 to 2-22 explains continuity testing, why it is both a good test and a bad test.

\_\_\_ Pages 2-23 to 2-27 explains semiconductor (solid-state) diodes, diode testing using the Diode Test of a DMM.

\_\_\_ Pages 2-28 to 2-30 explains using a Current Clamp which will be used extensively in Sections 4, 5 and 6 while studying *SHORTCUTS*. There will be a reminder in the Study Guide to review the Current Clamp when it is needed.

\_\_\_ Completed Section 2

\_\_\_ Section 2 Review Questions Pages 2-33 to 2-34 (Answers in back of the book.)



## Block 3

### Begin H-111A, The Starter Kit Hands-On Training Program

The Starter Kit, **H-111A**, comes in a white flip-top box with two circuit boards, a power supply and two books, Student Workbook **H-WB111A** has all the curriculum and the Instructor Guide **H-IG111A** has all the answers. Set up the two circuit boards and prepare the Power Supply to be connected to line voltage (wall socket or power strip).

#### Initial Set-Up Procedure

Connect the red and black wires to the red and black posts on the Power Board BEFORE plugging in (turning "ON") the Power Supply. The Power Supply does not have an ON/OFF Switch. Unplug to turn "OFF" the Power Supply.

\_\_\_ Wires connected. PLEASE READ CAUTION STATEMENT BELOW.

THE POWER SUPPLY, H-PS01 (USA) or UK or EURO style) SHOULD BE TURNED "ON" ONLY WHEN THE RED AND BLACK WIRES ARE CONNECTED TO THE RED AND BLACK POSTS ON THE POWER BOARD. **DO NOT ALLOW THE RED AND BLACK WIRES TO MAKE CONTACT IF THE POWER SUPPLY IS "ON." THIS WILL DESTROY THE POWER SUPPLY.** BEFORE DISCONNECTING THE RED AND BLACK WIRES FROM THE RED AND BLACK POSTS VERIFY THAT THE POWER SUPPLY IS TURNED "OFF" (UNPLUGGED). Adding a fuse to the red or black wire will NOT protect the Power Supply. There is a solid-state rectifier circuit inside the Power Supply. The rectifier will instantly fail if the red and black wire tips short together while the Power Supply is "ON" because the rectifier fails BEFORE the fuse can blow. That is why many electronic components are not fused for protection. A fuse will fail before the fuse can blow. That is basic electronics "101."

\_\_\_ I HAVE READ AND UNDERSTAND CAUTION STATEMENT

**Begin reading Workbook H-WB111A at Page 1.** Follow pages in numerical order.

Check answers to exercises in the Instructor Guide, H-IG111A.

\_\_\_ Read and study all exercises Pages 1 to 31. Answers to exercises in H-IG111A.

\_\_\_ Read Pages 38 to 40 to prepare to troubleshoot 28 electrical problems.

\_\_\_ In Instructor Guide, H-IG111A read Pages 1 to 3.

\_\_\_ In Instructor Guide, H-IG111A read Page 6 to verify no problems are inserted on the bottom of the PCBs.

\_\_\_ In Instructor Guide, H-IG111A read Pages 7-8 for directions inserting problems.

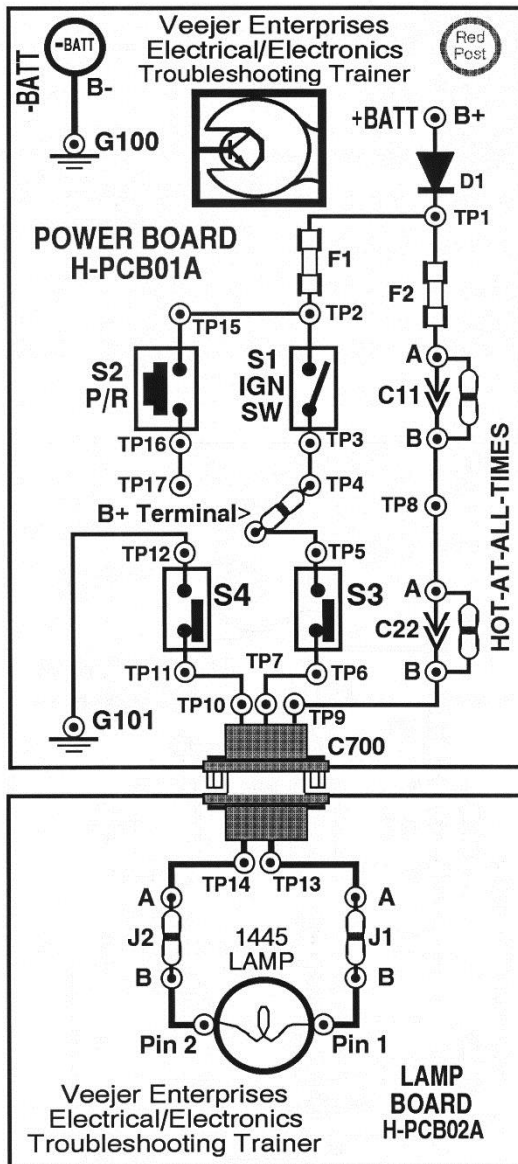
\_\_\_ Designate someone to insert problems for you so you won't have any hint what is wrong with each problem before you start troubleshooting.

\_\_\_ Explain to your assistant how to insert problems in numerical order starting on Page 9 of H-IG111A.



## Check List of 28 H-111A Troubleshooting Problems

Check off when each problem is completed on this page or on Page 71 of Student Workbook H-WB111A. Keep track of which problems have been completed. These 28 problems are either an OPEN circuit or a Vd [voltage drop]. Problems may appear on the voltage side or the ground side. Remove the previous problem before inserting the next problem.



- \_\_\_ Completed Problem #1.
- \_\_\_ Completed Problem #2.
- \_\_\_ Completed Problem #3.
- \_\_\_ Completed Problem #4.
- \_\_\_ Completed Problem #5.
- \_\_\_ Completed Problem #6.
- \_\_\_ Completed Problem #7.
- \_\_\_ Completed Problem #8.
- \_\_\_ Completed Problem #9.
- \_\_\_ Completed Problem #10.
- \_\_\_ Completed Problem #11.
- \_\_\_ Completed Problem #12.
- \_\_\_ Completed Problem #13.
- \_\_\_ Completed Problem #14.
- \_\_\_ Completed Problem #15.
- \_\_\_ Completed Problem #16.
- \_\_\_ Completed Problem #17.
- \_\_\_ Completed Problem #18.
- \_\_\_ Skip #19 (Short-to-Ground Problem)
- \_\_\_ Skip #20 (Short-to-Ground Problem)
- \_\_\_ Completed Problem #21.
- \_\_\_ Completed Problem #22.
- \_\_\_ Completed Problem #23.
- \_\_\_ Completed Problem #24.
- \_\_\_ Skip #25 (Short-to-Ground Problem)
- \_\_\_ Completed Problem #26.
- \_\_\_ Skip #27 (Short-to-Ground Problem)
- \_\_\_ Completed Problem #28.
- \_\_\_ Completed Problem #29.
- \_\_\_ Completed Problem #30.
- \_\_\_ Completed Problem #31.
- \_\_\_ Completed Problem #32.



After completing the 28 problems consisting of OPEN connections and Vds (voltage drops) you are ready to tackle short-to-ground problems. You are still working in the Student Workbook H-WB111A.

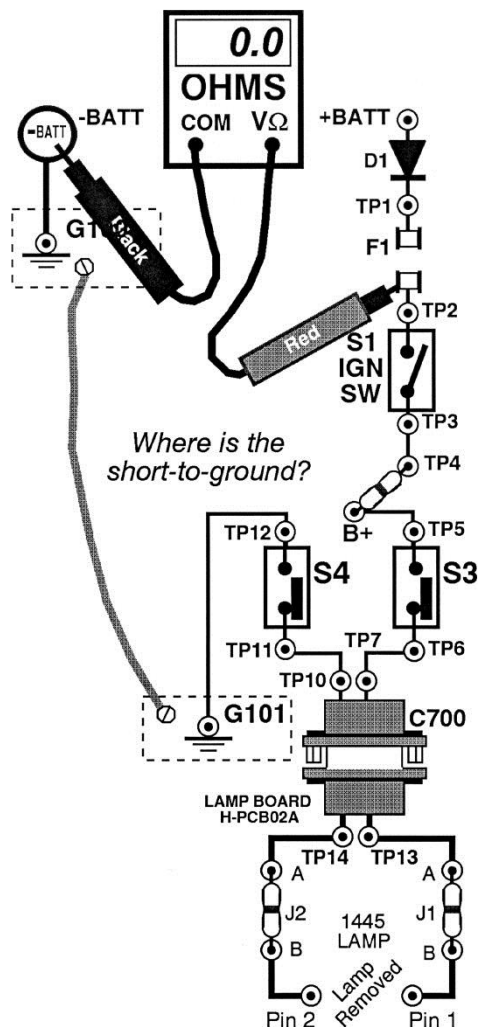
\_\_\_ Workbook H-WB111A read Pages 32 to 36 explaining short-to-ground problems.

\_\_\_ Workbook H-WB111A read Pages 63 to 66 explaining ohmmeter readings that indicate a “short is present.”

You are now ready to practice troubleshooting short-to-ground problems.

- UNPLUG THE POWER SUPPLY.
- DISCONNECT THE RED AND BLACK WIRES FROM THE RED/BLACK POSTS.

## Short-to-Ground Problems



Have your assistant install “short-to-ground” problems from H-IG111A, Page 12. A zero ohm resistor is placed in a U-NOx jumper location listed on Page 12 to create the “short” condition.

DO THIS:

- Remove Fuse F1
- Remove Lamp from Lamp socket
- Close Switches S1, S3 and S4.
- Insert zero ohm resistor
- Troubleshoot problem with the ohmmeter and determine where the “short” exists in the circuit.

Check off when completed.

- \_\_\_ Page 66 Problem 19
- \_\_\_ Page 67 Problem 20
- \_\_\_ Page 68 Problem 25
- \_\_\_ Page 69 Problem 27

**Final exercise in Workbook H-WB111A.**

\_\_\_ Read Page 37 explains measuring circuit electron current at a fuse location.

Continue reading “**Vehicle Electrical Troubleshooting SHORTCUTS**” beginning with Block 4, Study Section 3 in **SHORTCUTS** – How Electrical Circuits Work



## Block 4

### Read Section 3 in **SHORTCUTS – How Electrical Circuits Work**

Why study electrical circuit principles?

\_\_\_ Understand Water hoses in a series connection / Hose water current / Electrical series circuit / The law of electron current in a series circuit

\_\_\_ Understand Impact of resistance R1

\_\_\_ Understand Current takes the path of least resistance

\_\_\_ Understand Measuring electron current in a series circuit

\_\_\_ Understand Voltage in a series circuit

\_\_\_ Understand How much should a Vd (Voltage Drop) be?

\_\_\_ Understand Vd of components in a circuit

\_\_\_ Understand Law of voltage in a series circuit

\_\_\_ Understand The voltage drop of the voltage side

\_\_\_ Understand The voltage drop of the ground side

\_\_\_ Understand Law of resistance in a series circuit

\_\_\_ Understand Load resistance

\_\_\_ Understand Starter Kit H-111 troubleshooting training

\_\_\_ Understand Two water hoses in parallel

\_\_\_ Understand Electrical parallel circuit

\_\_\_ Understand Law of current in parallel circuits

\_\_\_ Understand Current takes the path of least resistance / Measuring total electron current in a parallel circuit / Measuring individual parallel branch electron current / Law of voltage in parallel circuits / Measuring voltage inside a branch / Law of resistance in parallel circuits / Example of resistors in parallel / Compound circuit Voltage measurement techniques / Measuring B+ / Measuring Vd of the voltage side Measuring voltage drop of the ground side / Putting it all together /

H-113 Troubleshooting DC Motor Circuits Troubleshooting Trainer (Studied in Phase 2 Curriculum.)

\_\_\_ Completed Section 3

\_\_\_ Answered Review Questions



## Block 5

### Read Section 4 in **SHORTCUTS - Quick Troubleshooting Batteries**

Introduction to batteries / Battery voltage / What happens in a battery / Battery during discharge / Battery discharge circuit / Battery changes during discharge / Battery recharge circuit / The battery during recharge / Testing batteries / Cycle testing electrical circuits

\_\_\_ Read about battery voltage test called Open Circuit Voltage (O.C.V.)

Perform this test on some vehicle batteries and/or batteries in storage.

Vehicle \_\_\_\_\_ O.C.V. \_\_\_\_\_ V %State of Charge \_\_\_\_\_

Vehicle \_\_\_\_\_ O.C.V. \_\_\_\_\_ V %State of Charge \_\_\_\_\_

Vehicle \_\_\_\_\_ O.C.V. \_\_\_\_\_ V %State of Charge \_\_\_\_\_

\_\_\_ Understand when battery O.C.V. is 12.66V

\_\_\_ Understand when battery O.C.V. suddenly drops down to 10.55V

\_\_\_ Understand when battery O.C.V. is suddenly drops to almost zero volt

\_\_\_ Understand when battery O.C.V. is over 13.00V

\_\_\_ Understand Battery Cranking Voltage Test

Perform the **Cranking Voltage Test** on some vehicles.

Vehicle \_\_\_\_\_ Cranking Voltage \_\_\_\_\_ V Ambient Temp \_\_\_\_\_ °F

Vehicle \_\_\_\_\_ Cranking Voltage \_\_\_\_\_ V Ambient Temp \_\_\_\_\_ °F

Vehicle \_\_\_\_\_ Cranking Voltage \_\_\_\_\_ V Ambient Temp \_\_\_\_\_ °F

\_\_\_ Summary of cranking voltage test

\_\_\_ Understand Battery cranking electron current test

Perform the **Cranking Amps Test** on some vehicles.

Vehicle \_\_\_\_\_ Cranking Amps \_\_\_\_\_ A Ambient Temp \_\_\_\_\_ °F

Vehicle \_\_\_\_\_ Cranking Amps \_\_\_\_\_ A Ambient Temp \_\_\_\_\_ °F

Vehicle \_\_\_\_\_ Cranking Amps \_\_\_\_\_ A Ambient Temp \_\_\_\_\_ °F

\_\_\_ Understand Battery Recharge Electron Current Test

Perform **Battery Recharge Electron Current Test** (Single battery negative cable)

Vehicle \_\_\_\_\_ Recharge Amps \_\_\_\_\_ A Time running \_\_\_\_\_ min.

Vehicle \_\_\_\_\_ Recharge Amps \_\_\_\_\_ A Time running \_\_\_\_\_ min.

Vehicle \_\_\_\_\_ Recharge Amps \_\_\_\_\_ A Time running \_\_\_\_\_ min.

\_\_\_ Understand Carbon pile battery load test not suitable for service bay diagnostics

Battery bounce-back test (used only in conjunction with carbon pile test)

Determine remaining battery life (compare cranking voltage with ambient temp.)

Overview of 5-Step Battery test procedure / Practice on vehicles and record readings.

\_\_\_ Completed Section 4

\_\_\_ Answered Review Questions





## Block 6

### Read Section 5 in **SHORTCUTS - Quick Troubleshooting Cranking**

Some of these tests repeat from the previous Block 5 on Batteries. That is due to the close interrelationship of the battery and the cranking motor working together. The starter motor is used to test the battery cranking voltage under load. The battery is used to test the performance of the starter motor circuit cranking the engine. Once the individual concepts of battery performance and starter operation are understood separately they can be easily combined for an overall test of starter circuit performance as each component does its job.

Introduction to cranking circuits / Basic cranking circuit /

- Understand starter motor current
- Overview of troubleshooting cranking circuit problems
- Measure cranking current or starter motor draw
- Measure battery cranking voltage
- Understand 3-Step cranking circuit test procedure
- Understand when starter draw is too high
- Understand when starter draw is too low
- Understand if there is a bad connection in the wiring?
- Understand a resistance problem in the starter motor?
- Understand how to pinpoint a bad connection or cable on voltage side.
- Understand how to perform 3 Step QUICK cranking circuit test on a vehicle
- Vehicle \_\_\_\_\_ Cranking Volts \_\_\_\_\_ V Cranking Current Test \_\_\_\_\_ A
- Vehicle \_\_\_\_\_ Cranking Volts \_\_\_\_\_ V Cranking Current Test \_\_\_\_\_ A
- Vehicle \_\_\_\_\_ Cranking Volts \_\_\_\_\_ V Cranking Current Test \_\_\_\_\_ A
  
- Understand cranking circuit control
- Understand testing the solenoid control circuit
- Understand simple cranking circuit
- Understand failure to crank
- Understand cranking control circuit.

Starter Relay Circuit - H-115 Troubleshooting Relay Circuits (Studied in Phase 2)

Troubleshooting starter relay circuit / A true story.

- Completed Section 5
- Answered Review Questions



## Block 7

### Read Section 6 in *SHORTCUTS - Quick Troubleshooting Charging Systems*

Introduction to generator/charging systems / Overview of the charging system / Inside a generator / What a generator does / Interpreting the charging voltage /

- Understand Three factors that affect the charging voltage
- Understand Generator voltage tests
- Understand Generator electron current tests
- Understand The charging voltage test
- Understand When charging voltage is too high or too low
- Understand generator/battery current test
- Understand Measuring battery recharge electron current
- Understand Factors that determine battery recharge current
- Understand How to measure battery recharge current
- Understand what's good - what's bad
- Understand Read the DMM correctly
- Understand Determining if a battery is defective when recharging
- Try this simple experiment
- Understand The conclusion of measuring battery recharge current
- Understand Generator ripple voltage test
- Understand Lab scope test of generator output
- Understand Overview of testing vehicle charging system
- Understand Evaluating charging voltage test results
- Understand The wrong way to test a generator
- Understand Two major problems with the generator load test
- Understand Computer controlled generator
- Understand How an onboard computer controls the generator
- Here's the problem
- Understand Testing resistance of rotor/field winding
- Understand Hot and cold resistance
- Understand Evaluating/calculating rotor/field winding condition
- Understand rotor/field windings may be internally grounded
- Understand Introduction to PWM (pulse-width-modulation)
- Understand PWM duty cycle
- Understand PWM rotor/field winding control
- Completed Section 6
- Answered Review Questions



**Block 8**

**FIRST THINGS FIRST™**

This is a laminated flip-chart that tests a vehicle's primary electrical system consisting of the battery, primary grounds circuits (engine ground and accessory ground) and the charging system. The first series of voltage tests are performed with a cold engine; then running and then a quick retest after the engine warms up. Entire test sequence consisting of 14 voltage measurements can be accomplished in less than 5 minutes with a little practice. Each test step is explained and illustrated on its own laminated page.



Technicians are going through **FIRST THINGS FIRST** for the first time. Each test step is fully explained on the left side of the page and an illustration of the DMM test leads connected to the vehicle is shown on the right side of the page for added clarity. These tests will reveal a weak or undercharged battery, a faulty engine or accessory (sheet metal) ground circuit, and a poor performing charging system.

Simply follow instructions to proceed through the test sequence. Record test readings on The Test Results Form printed on the back cover of the flip-chart.

**Vehicle Electrical System Analysis**

<b>FIRST THINGS FIRST™ TEST RESULTS</b>		Expected Normal	Problem Noted	Corrected Reading
1	Battery Open Circuit Voltage (OCV)	Range of 12.5-12.8V	_____	_____
2	Evaluate O.C.V. Reading			
3	Accessory Ground Voltage Drop	0.10V	_____	_____
4	Battery Terminal Cranking Voltage	Range of 10.0-11.5V	_____	_____
5	Engine Ground Voltage Drop, Cranking	Range of 0.1-0.5V	_____	_____
6	Charging Volts at Battery Terminals	Range of 13.8-15.1V	_____	_____
7	Charging (+) Side Voltage Drop	0.2V or less	_____	_____
8	Charging (-) Side Voltage Drop	0.1V or less	_____	_____
9	Engine Ground Voltage Drop, Warm	0.1V or less	_____	_____
10	Accessory Ground Volt Drop, Warm	0.1V or less	_____	_____
11	Charging (+) Side Volt Drop, Warm	0.2V or less	_____	_____
12	Charging (-) Side Volt Drop, Warm	0.1V or less	_____	_____
13	Charging Volts At Batt. Term., Warm	Range of 13.8-15.1V	_____	_____
14	Final Chrg. Voltage for Undercharge	Above +3.5V	_____	_____
15	Final Chrg. Voltage for Overcharge	Below 15.1V	_____	_____
16	Trouble Codes No ___ Yes ___			
Customer Name _____ Date _____ Mileage _____				
Make _____ Model/Color _____ Year _____				
Lic. Plate # _____ Phone _____				
VIN _____				

The Test Results Form may be copied on any copy machine and used to record test results. A copy can be given to the customer. There is a place to paste your business card at the bottom so the customer knows who did the electrical system analysis.

Date Tested: \_\_\_\_\_  
Service Technician \_\_\_\_\_

Paste a business card in this box and make copies of this page to record test results. Give the customer a copy of this report to build good public relations and customer loyalty. Repair shops can charge the customer 0.5-1.0 hour to perform these tests. If a bad connection is found add from 0.5-1.0 hour to repair the bad connection and note the repair and the corrected DMM reading on this form.



## Block 9

### Study Section 7 in **SHORTCUTS** – Reading Schematic Diagrams

- How to read a schematic or schemation diagram
- Understand What a schematic or “schemation” diagram can do
- Understand What a diagram cannot do
- Understand “Schemation” of a vehicle's primary electrical system
- Understand Inventory a circuit diagram
- Understand Trace the path of electron current
- Understand Measure the voltage around the circuit
- Understand Physically trace the circuit lines
- Completed Exercise 7-3
- Understand Reading a relay controlled cooling fan circuit diagram
- Understand How the circuit works
- Understand Troubleshooting the circuit on paper
- Completed Exercise 7-4
- Understand Reading a relay controlled cranking circuit diagram
- Understand How the circuit works
- Understand Troubleshooting the circuit on paper
- Completed Exercise 7-5
- Understand Reading a relay controlled horn circuit diagram
- Understand How the circuit works
- Understand Troubleshooting the circuit on paper
- Completed Exercise 7-6
- Reading a rear compartment relay controlled lid release circuit diagram
- Understand How the circuit works
- Understand Troubleshooting the circuit on paper
- Completed Exercise 7-7
- Reading a relay controlled window defogger circuit diagram
- Understand How the circuit works
- Understand Troubleshooting the circuit on paper
- Completed Exercise 7-8
- Understand Reading a relay controlled wiper/washer pump motor circuit diagram
- Understand How the circuit works
- Understand Troubleshooting the circuit on paper / Conclusion

*Congratulations on completing the “Phase 1 – “Hands-On Vehicle Electrical-Electronics Troubleshooting Workshop.” May you have great success and make more money,  
Vince Fischelli*