FINEST®

Model 816
EV & HEV Automotive DMM

USER'S MANUAL

FINEST® a world leader in test & measurement

FINE INSTRUMENTS CORPORATION

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WARNING!

SOURCES LIKE SMALL HAND-HELD RADIO TRANSCEIVERS, FIXED STATION RADIO AND TELEVISION TRANSMITTERS, VEHICLE RADIO TRANSMITTERS AND CELLULAR PHONES GENERATE ELECTROMAGNETIC RADIATION THAT MAY INDUCE VOLTAGES IN THE TEST LEADS OF THE MULTIMETER. IN SUCH CASES THE ACCURACY OF THE MULTIMETER CANNOT BE GUARANTEED DUE TO PHYSICAL REASONS.

⚠ Warning

Read “Safety Information” before using this Meter.

CONTENTS

1. SAFETY INFORMATION

This manual contains information and warnings that must be followed for operating the meter safely and maintaining the meter in a safe operating condition.
If the meter is not used in a manner specified in this manual, the protection provided by the meter may be impaired.

This meter complies with IEC 61010-1 (2001), UL 61010B-1, EN 61010-1 (2002), CAN/CSA 22.2 No. 1010-1 ; Overvoltage 1000 V Category III and 600 V Category IV.

TERMS IN THIS MANUAL

A **Warning** identifies conditions and actions that could pose serious hazards to the user. A **Caution** identifies conditions and actions that could cause damage the meter or the vehicle under test. **Notes** are added to provide clarity and helpful tips.

INTERNATIONAL ELECTRICAL SYMBOLS


AC (Alternating Current)


DC (Direct Current)


Either DC or AC


Caution! Refer to the explanation in the manual.


Dangerous voltage (Risk of electric shock)


Earth (Ground)


Double insulation or Reinforced insulation


Fuse


Battery

WARNING

- Observe the proper safety precautions when working with voltages above 60 V DC or 25 V AC rms to avoid an electrical shock. These voltage levels pose a potential shock hazard to the user.
- Wear an ANSI eye shield when testing or repairing vehicles. Objects can be propelled by whirling engine components.
- Inspect test leads, connectors, and probes for damaged insulation or exposed metal before using the instrument. If any defects are found, replace them immediately.
- Never attempt a voltage measurement with the test leads inserted into the “A” terminal and the “COM” terminal. The “A” terminal is protected by a fuse. You might be injured or damage the meter.
- Turn the engine off before connecting or disconnecting inductive pickup to avoid a shock.

CAUTION

- Disconnect the test leads from the test points before changing functions to avoid damaging the meter when testing above 350 V AC.
- Choose the proper range and function for the measurement. Always set the meter to the highest range and work downward for an unknown value if you are using manual ranging mode.
- Do not try voltage or current measurements that may exceed the ratings marked on the input limit for switch or terminal.
- Use current probes to measure circuits exceeding 10 A.
- Disconnect the “live” test lead before disconnecting the “common” test lead.
- Do not test a recently recharged lead-acid battery.
- Disconnect the power and discharge all high-voltage capacitors before testing in the resistance, continuity, and diode functions.
- If the engine has been running, do not place the meter and its accessories near the engine or the exhaust manifold which might be hot and can damage the meter.

2. INTRODUCTION

This meter is a handheld and battery operated professional automotive multimeter designed to provide troubleshooting solutions to the most difficult problems encountered with today’s sophisticated electrical / electronic systems like the Integrated Starter Generator system or the Integrated Starter Alternator system of the modern electric vehicles. (EV or HEV or FCV, etc.)

*** EV = Electric Vehicle, HEV = Hybrid Electric Vehicle, FCV = Fuel Cell Vehicle**

For troubleshooting the electric or hybrid electric vehicles, current measurement (especially without interrupting the supply from the battery or other current carrying conductors) is more important and effective than voltage measurement from a technical, economical and process point of view.

The more important or essential checking points in electric or hybrid electric vehicles than those of the conventional vehicles are as follows:

- Battery leakage current (normally around 15 mA), when all systems are turned off, which is used as a quality indicator in an Electrical Check Out System for production line quality assurance testing or as a fault identifier for the diagnostic units in large service centers.
- Current drain of the ECU controlling the ISG (or ISA) system, which is as low as 10 mA when ignition is turned off, should be measured without disconnecting the battery cable to prevent the ECU from losing the stored data.
- Starting currents (or Cranking currents to the starter motor) or Alternator currents up to 400 to 800 A rms (or 1,250 to 1,350 A peak) in the ISG system.
- A lot of specially designed current sensors or transducers in the ISG system should be checked if they are working properly.

※ Basically, the ISG (or ISA) system is made of the following elements:
- A 3-Phase AC motor integrated into the internal combustion motor
- An AC/DC converter which rectifiers the AC generated by the 3-Phase motor
- A DC/AC converter that provides the required voltages
- The electronics driving the ISG system as a whole
- The energy management system (ECU) controlling the ISG

For these current measurements, we need a precision clamp-on low DC/AC current probe with 1 mA resolution (or better) and a reading accuracy of 1 % as well as a high DC/AC current probe with full-scale ranges of 400 A (100 mA resolution) and 1500 A (1 A resolution).
The specially designed high and low current probes equipped with this meter as standard accessories allow fast and precise current measurements without interrupt the circuit.

The User's Manual tells you how to use this meter. You may also need a manual that provides technical information for the vehicle you plan to test. The most important information resources are the vehicles repair service manuals generally available for purchase through automotive dealers. They are also available through a number of publishers that specialize in providing technical information manuals to the independent repair garages.

The User's Manual should be used as a guide to get you started in troubleshooting. Your real learning can best be accomplished through experience. As you become more proficient in using the automotive multimeters to troubleshoot, you will very quickly learn how certain electrical symptoms can relate to various driveability problems.

This meter is much more than a standard multimeter. This meter can replace the following several automotive testers.

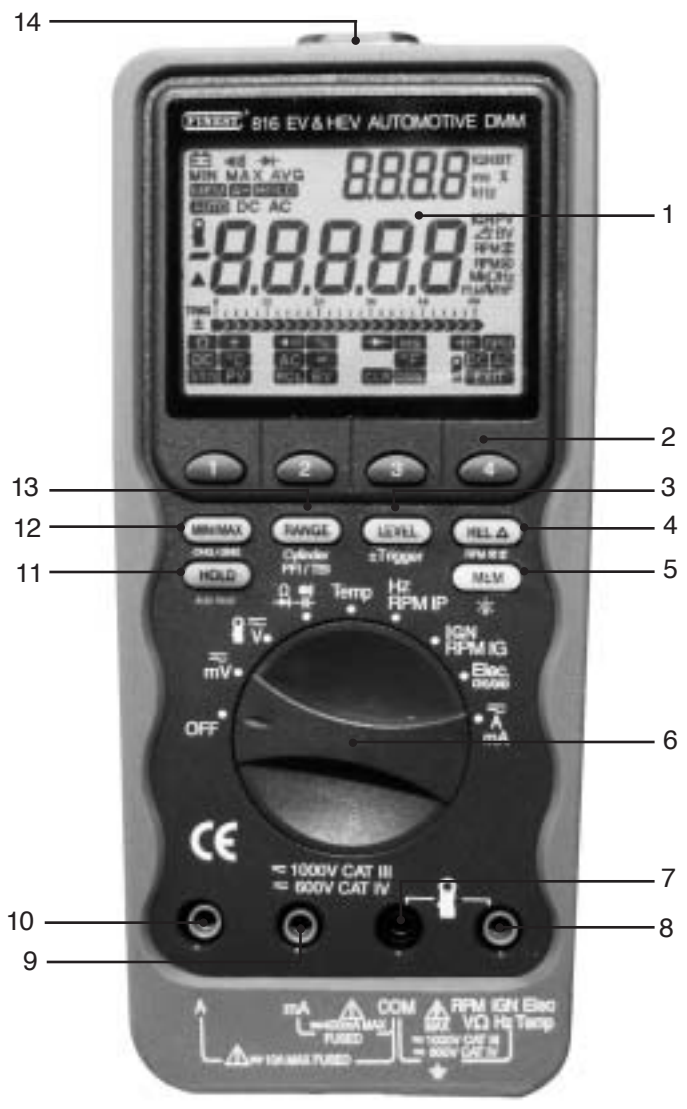
- Full Function Multimeter
- Automotive RPM Tester
- Electric Motor Tester for electric vehicles
- ECU (Electronic Control Unit) Tester
- Battery Leakage Current & Cranking Current Tester
- PFI type and TBI type Fuel Injection On-Time Tester
- kV Tester
- Sensor or Transducer Tester
- Charging System Tester

This meter has a bright LED backlight as well as enhanced LCD with larger digits, wide viewing angle and on screen menu selection. A battery access door allows users to replace the battery and fuse without voiding calibration seals. Overmolding technology in the case disperses various shock over more of the case than a conventional rubber boot design. Convenient closed case calibration allows adjustments to be made directly through the RS-232C port (compatible with a USB port of a PC by using the RS-232C to USB adaptor supplied).

FEATURES

- 4-4/5 digit, 50000 count (primary) and 3-4/5 digit, 5000 count (secondary) dual display with 26 segments bar-graph. (Frequency range : 49999 counts)
- Closed case calibration through the phototronic RS-232C serial port. (compatible with a USB port of a PC by using the RS-232C to USB adaptor supplied)
- Battery leakage current and Cranking current test function.
- Electric Motor tester for electric vehicles.
- ECU tester to measure the current drain when the ignition is turned off.
- PFI type or TBI type Fuel Injection On-Time test function.
- Ignition Peak Voltage measurement mode.
- Ignition Burn Voltage measurement mode.
- Ignition Burn Time measurement mode.
- Ground test to locate bad ground, voltage drops, intermittent connections, or any source of high resistance in automotive electrical circuits and grounds.
- Charging system test to diagnosis the battery and the alternator.
- Accurate RPM measurements for 4- and 2- stroke automotive engines with 1 to 12 Cylinders.
- Duty Cycle and direct Dwell reading for electronic fuel injection, feedback carburetors, and ignition systems.
- 4 steps adjustable triggers on 1 to 12 Cylinders, either 4- or 2- Cylinder for outboards, motorcycles and conventional engines.
- Measure temperature of fan switch and catalytic converts up to 1,300 °C (2,372 °F).
- Auto Hold, 50 ms highspeed MIN/MAX/AVG, and Relative mode.
- Memory store and recall (20 locations).
- Backlit display.
- Auto-power-off.
- RS-232C phototronic serial port (This RS-232C port is interfaceable with a USB port of a PC by using the RS-232C to USB adaptor supplied).
- High-Impact Overmolded case.
- CE-mark Certified.
- EN-61010-1; CAT III 1000 V and CAT IV 600 V rating.

3. CONTROLS AND INDICATORS



1. **LCD display** 4 ⁴/₅ digit, 50000 count (primary) and 5000 count (secondary) dual display with bar-graph.

2. ① ② ③ ④ On screen menu selection pushbuttons.

3. LEVEL ±Trigger — Press this pushbutton momentarily to select trigger levels. Press this pushbutton for more than 1 second to toggle between positive and negative trigger slopes.

4. REL Δ RPM — Press this pushbutton momentarily to select Relative Zero. Press this pushbutton for more than 1 second to toggle between **RPM** ④ and **RPM** ② in **RPM IP** and **RPM IG** function.

5. MEM — Press this pushbutton momentarily to select Memory mode. Press this pushbutton for more than 1 second to turn the LCD backlit on.

6. **Selector** Turn the power **On** or **Off** and select a test function.

7. **COM** Common (Ground reference) input terminal for all functions.

8. **RPM IGN Elec VΩ Hz Temp** Input terminal for all functions except **Current (A & mA)** functions.

9. **mA** Input terminal (+) for **mA** function.

10. **A** Input terminal (+) for **A** function.

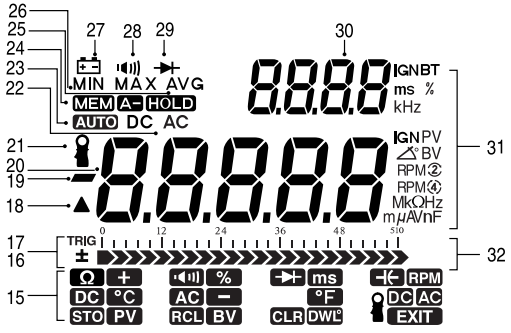
11. HOLD *Auto Hold* — Press this pushbutton momentarily to activate **HOLD** for simply freezing a reading.
Press this pushbutton for more than 1 second to activate **Auto Hold** for automatically capturing a stable reading, beeping to acknowledge, and holding it on the LCD.

12. MIN/MAX CHG / GND — Press this pushbutton momentarily to step through the minimum, maximum, and average readings on the LCD. Press this pushbutton for more than 1 second to exit this mode.

Press this pushbutton momentarily to toggle between Charging System Test and Ground Test in Elec. Function, when the MIN/MAX mode doesn't work.

13. (RANGE) Cylinder PFI / TBI — Press this pushbutton momentarily to select ranges in the manual ranging mode of most functions or number of cylinders on Dwell function. Press this pushbutton momentarily to toggle between the PFI mode and the TBI mode when measuring on-time of fuel injectors.
Press this pushbutton for more than 1 second to toggle Auto/Manual ranging.

14. **RS-232 Optical interface (This RS - 232C port is interfaceable with a USB port of a PC by using the RS - 232C to USB adaptor supplied).**



15. **Menu on screen**

16. **TRIG ±** — These annunciators indicate that a positive (+) or a negative (-) Trigger Slope is selected.

17. TRIG + 0 — The analog bar-graph with **TRIG ±** indicates trigger level status.

18. ▲ — This symbol indicates the Relative function is activated.

19. ▬ — This symbol indicates Negative Polarity.

20. **DATA** — Primary digital readings of data being measured.

21. This symbol indicates the Adaptor function is activated.
Set the Meter in the 30 A measurement range when using the DC/AC Clamp-on mA Current Probe. (The Meter defaults at 30 A range.)
Set the Meter in the 500 A range when measuring less than 500 A using the DC/AC Clamp-on High Current Probe by pressing the (RANGE) button.
Set the Meter in the 1000 A range when measuring higher than 500 A using the DC/AC Clamp-on High Current Probe by pressing the (RANGE) button.

22. **DC AC** — DC annunciator indicates direct current is selected.
AC annunciator indicates alternating current is selected.

23. AUTO — This annunciator indicates Autoranging.

24. MEM — This annunciator indicates the Memory function is activated.

25. A- HOLD — HOLD annunciator indicates the HOLD function is selected and A- HOLD annunciators indicate the Auto Hold function is selected.

26. **MIN MAX AVG** — These annunciators indicate MIN (Minimum), MAX (Maximum), or AVG (Average) reading is being displayed.

27. Low Battery alert. Replace the battery as soon as possible to ensure accuracy.

28. This symbol indicates the Continuity test function is selected.

29. This symbol indicates the Diode test function is selected.

30. **DATA** — Secondary display for Dual Display data.

31. **ING BT...** — These annunciators indicate the function being selected and/or the appropriate measurement units.

32. 48 510 — Analog bar-graph with scale.

4. BASIC METER FUNCTIONS

Making Measurements and Tests

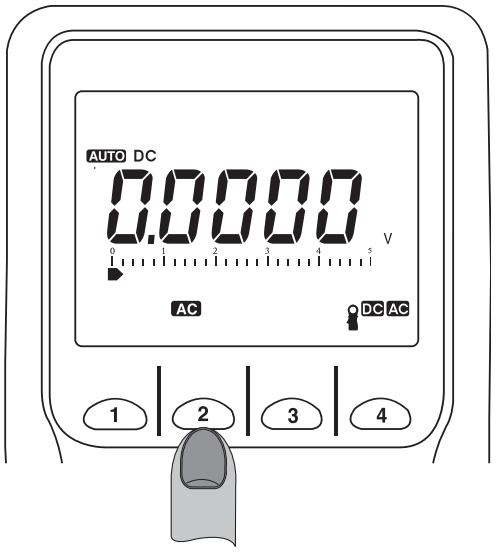
All measurements and tests are made by first setting the rotary selector switch to a function setting (so that the meter is put in the default measurement function) and then selecting a measurement from the menukeys. Note that not all function knob settings have corresponding menukeys settings.

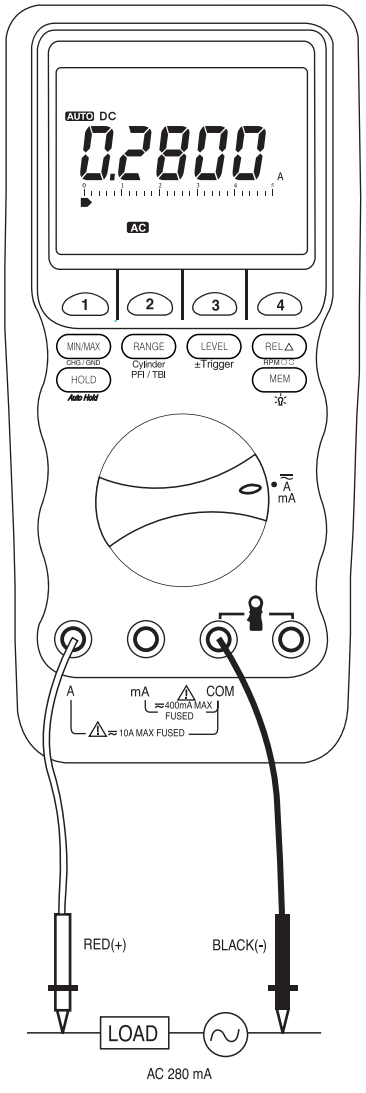
For example, the steps below show how to make an AC voltage measurement.

1. Set the rotary selector switch to $\overline{\underline{\sim}}$ V position for voltage measurements. Then, the meter is set to the default DC voltage measurement mode.

2. Select the menukey 2 for AC voltage measurement.

3. Connect the test leads to the measurement points.





4-1. DC or AC Current (A)

WARNING

Do not measure any circuit that draws more than the current rating of the installed fuse. Replace the defective fuse with a proper fuse only. Failure to do this may result in injury or damage to the meter. Do not attempt current measurements where the open circuit voltage is above 600 V.
For measuring circuits of more than 10 A, use voltage output current clamp adapters compatible with the meter Adapter function ( ).

1. Set rotary selector to $\overline{\underline{\sim}}$ A mA position. The meter defaults at DC current.

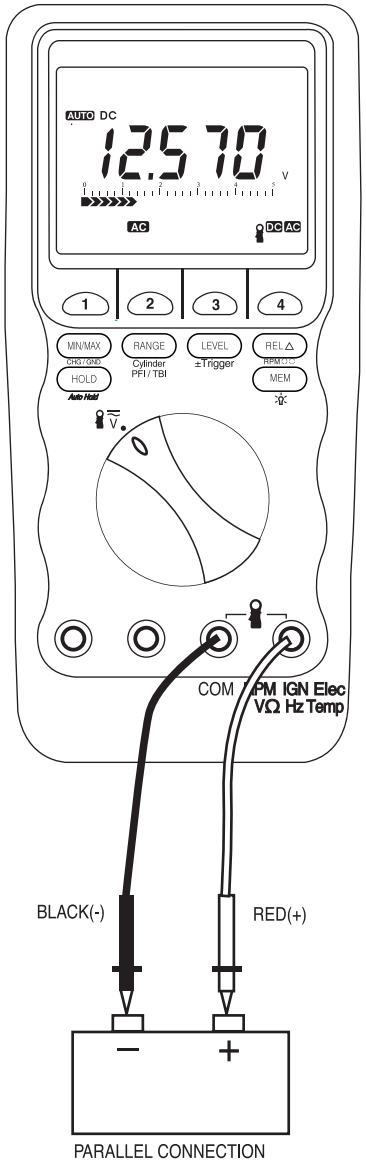
2. Press menukey 2 to select AC. Hz is displayed in the secondary display.

3. Insert black lead into COM terminal and red lead into A terminal (or red lead into mA terminal for current application below 400 mA).

4. Connect red lead probe to the side of the circuit closest to the power source.

5. Connect black lead probe to the side of the circuit closest to ground.

6. Turn the power ON and test. DO NOT crank the engine.



4-2. Voltage (V)

1. Set rotary selector to $\widetilde{\overline{V}}$ position. The meter defaults at DC.

2. Press menukey 2 momentarily to select AC. Hz is displayed in the secondary display.

3. Insert red lead into V terminal and black lead into COM terminal.

4. Touch black probe to ground or negative side of the circuit and touch red probe to positive side of the circuit coming from the power source.

5. Set rotary selector to $\widetilde{\overline{mV}}$ position for voltage application below 0.4 V with similar operation procedures.

NOTE: Voltage must be measured in parallel (red probe measuring circuit from power source).

The analog bar graph is easier to read when the data causes the digital display to rapidly change. It is also useful for trend setting or directional data.

4-3. Resistance (Ω)

CAUTION

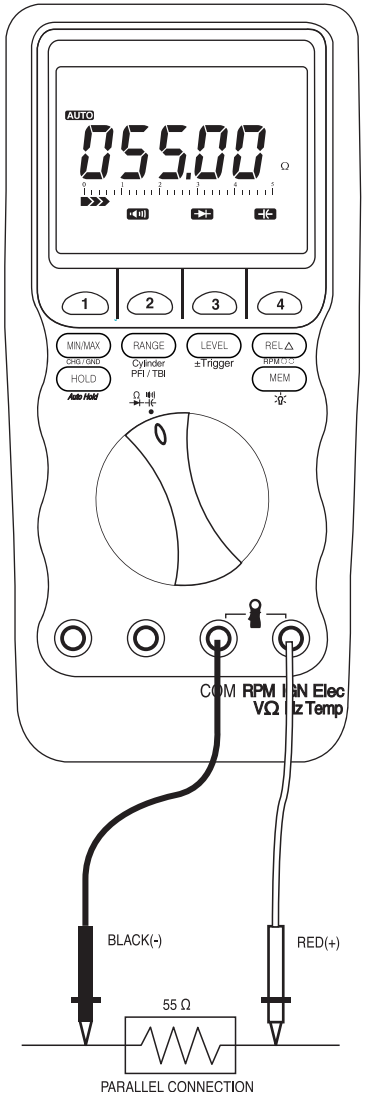
Turn off power and discharge all capacitors on circuit to be tested before attempting incircuit resistance measurements.
Accurate measurement is not possible if external or residual voltage is present.

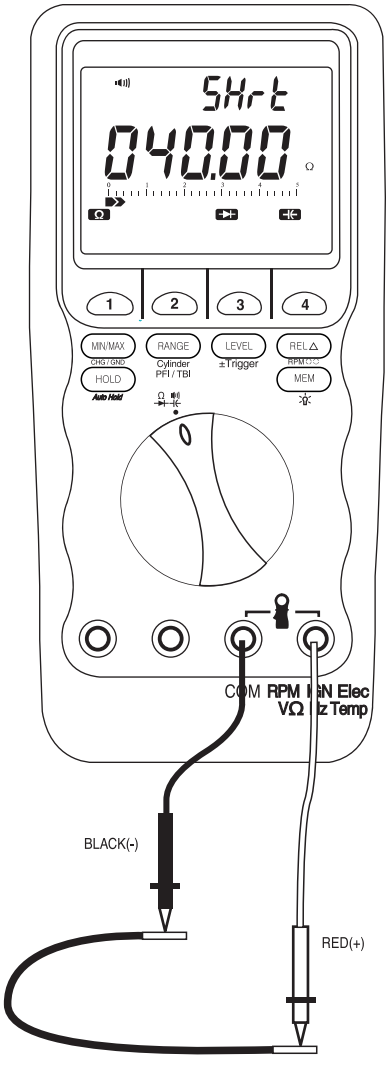
1. Set rotary selector to Ω position. The meter defaults at Ω function. OFL is displayed in the primary display.

2. Insert black lead into COM terminal and red lead into **Ω** terminal.

3. Touch the test lead probes across the resistance or circuit to be tested.

NOTE: The resistance in the test leads can affect accuracy in the 500Ω range. Short the leads together and press the (REL△) button to automatically subtract the test lead resistance from the measured resistance.





4-4. Continuity ( )

CAUTION

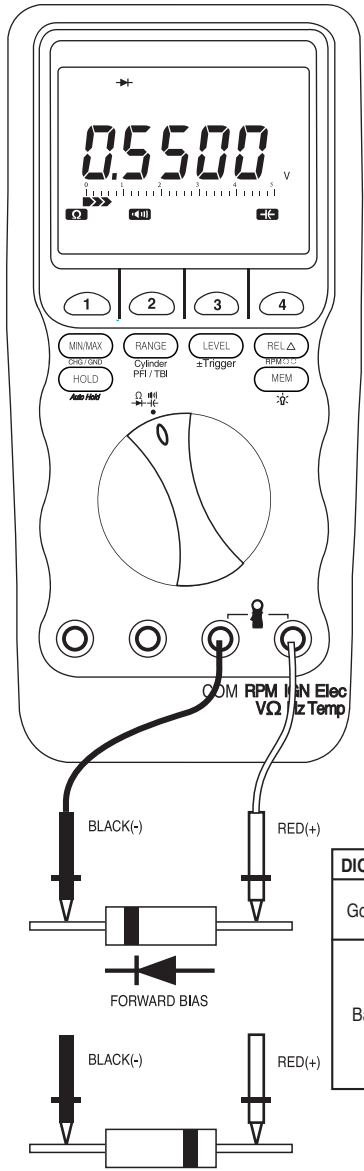
Turn the power OFF on the test circuit. A beeper tone does not necessarily mean zero resistance.

1. Set rotary selector to Ω position.
2. Press menukey 2 to select Continuity function. oFL is displayed in the primary display.
3. Insert black lead into COM terminal and red lead into Ω terminal.
4. Touch the test lead probes across the device being tested.

If the resistance of the device is below 70 Ω, there is a continuous beep tone and SHrt is displayed in the secondary display.

If the resistance of the device is more than 70 Ω, there is no beep tone and oPEn is displayed in the secondary display.

This is useful for checking wiring connections and operation of switches.



4-5. Diode ( ) Test

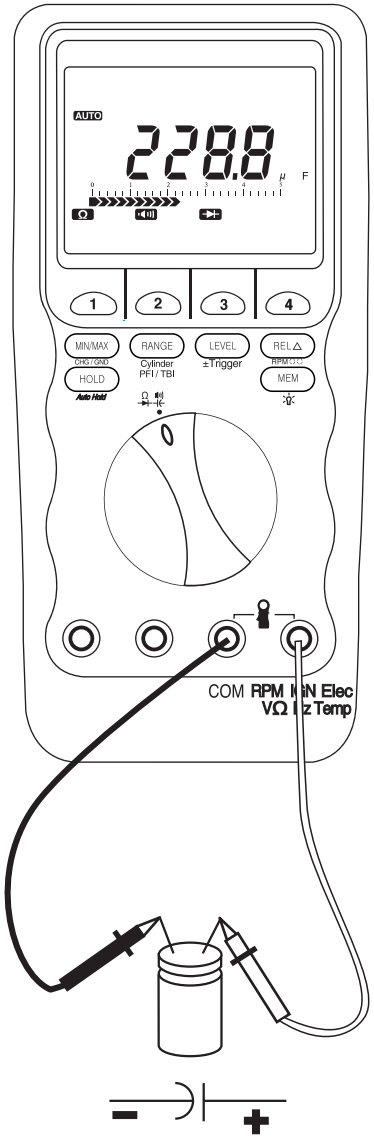
CAUTION

Turn the power OFF on the test circuit.

1. Set rotary selector to Ω position.
2. Press menukey 3 to select Diode Test function. oFL is displayed in the primary display.
3. Connect the test leads as shown and observe the digital display. Normal forward voltage drop (forward biased) for a good silicon diode is between 0.4 V to 0.9 V. A reading higher than that indicates a leaky diode (defective). A zero reading indicates a shorted diode (defective). An oFL indicates an open diode (defective).
4. Reverse the test leads connections (reverse biased) across the diode.
5. The primary display shows oFL if the diode is good. Any other readings indicate the diode is resistive or shorted (defective).

Use the table below to determine if the diode is Good or Bad.

DIODE	FORWARD BIAS( )	REVERSE BIAS( )
Good	0.4 to 0.9 V	OFL
	OFL	0.4 to 0.9 V
Bad	OFL	1.0 to 2.5 V
	1.0 to 2.5 V	OFL
	0.4 to 0.9 V	0.4 to 0.9 V
	OFL	OFL
	0.0000 V	0.0000 V



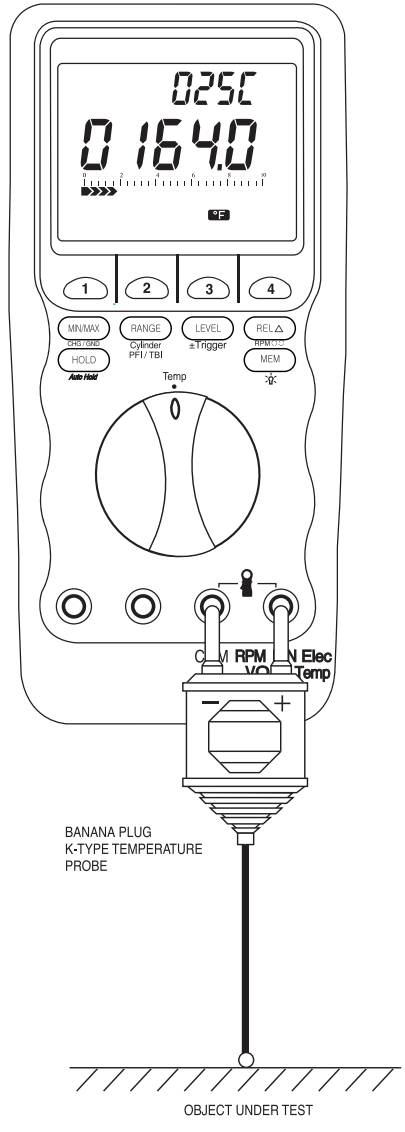
4-6. Capacitance (⊣( )

CAUTION

Turn off power and discharge all high voltage capacitance on the test circuit before measuring capacitance. Large value capacitors should be discharged through an appropriate resistance load.
Use the DC voltage function to confirm that the capacitor is discharged.

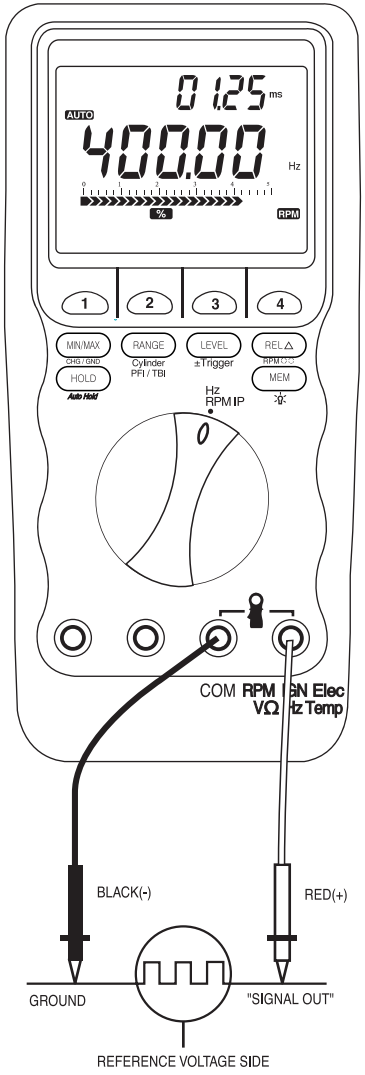
1. Set rotary selector to Ω ◄)) →| ⊣(position.
2. Press menukey 4 to select Capacitance function.
3. Insert black lead into COM terminal and red lead into Ω terminal.
4. Touch the test lead probes across the device being tested.

In 5 nF range, the readings are probably unstable due to environmentally induced electrical noise and floating capacity of the test leads. Therefore, directly connect the object to be measured to the input terminal.



4-7. Temperature

1. Set rotary selector to Temp position. The meter defaults at °C. The primary display will show ∝FL and the secondary display will show always show the meter's internal temperature in °C or °F alternatively matching with the selected primary display mode of °C or °F.
2. Press menukey 3 to select °F, if necessary.
3. Insert banana plug K-type temperature bead probe with correct +/- polarities.
4. Touch the end of the thermocouple probe to the measurement surface and read the primary display with °C (or °F).



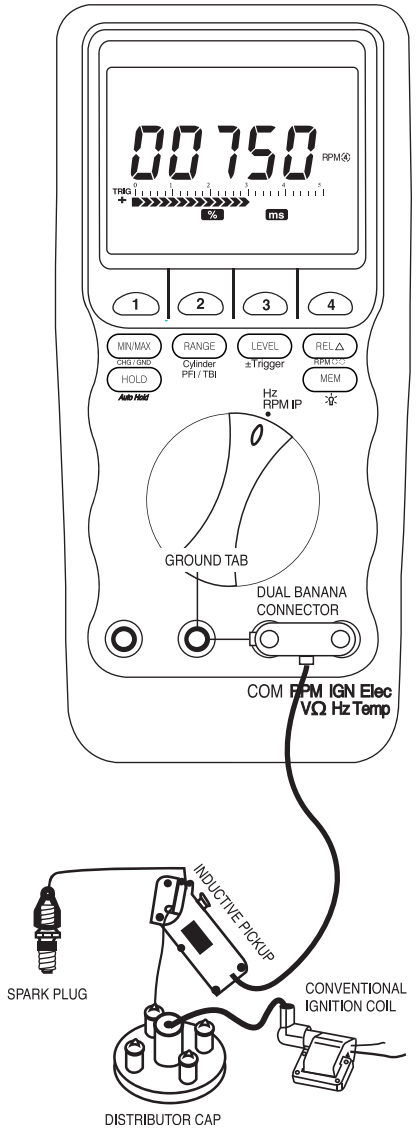
4-8. Frequency

1. Set rotary selector to Hz RPM IP position.

2. The primary display will show Hz and ms-Pulse is displayed in the secondary display.
   Refer to 4-13 convenient dual display Duty Cycle function and ms-Pulse function.

3. Insert black lead into COM terminal and red lead into Hz terminal.

4. Touch black probe to ground and touch red probe to the “Signal out” wire on the sensor.



4-9. RPM IP (RPM Measurements Using the Inductive Pickup)

WARNING

Be sure the inductive pickup is in the correct terminals when measuring RPM’s. If the pickup is in the wrong terminal, personal injury or meter damage may occur.
The ignition system can generate a potential shock hazard. Ensure that the engine is off before connecting or removing the inductive pickup.

1. Set rotary selector to Hz RPM IP position and press menukey 4 to select RPM IP function. The meter defaults at TRIG (trigger) level. Select the required trigger level by using the (LEVEL) button, if necessary.

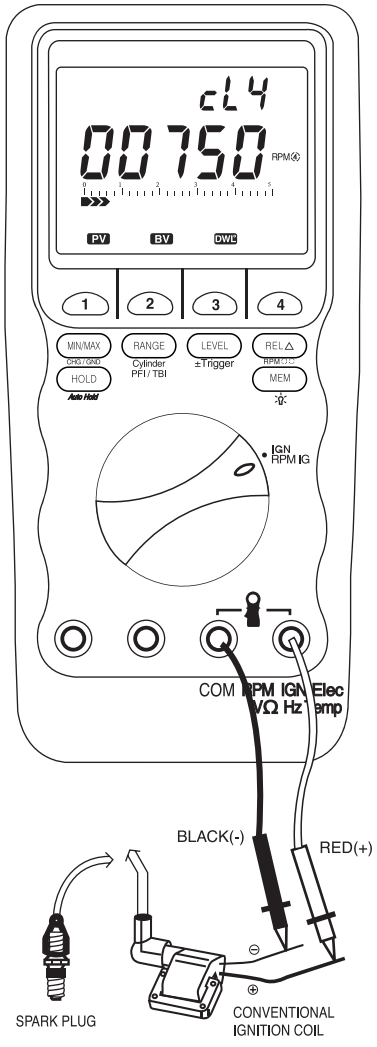
2. Press (REL Δ) (RPM ④ ②) button for more than 1 second to toggle between RPM ④ for 4-stroke engine and RPM ② for 2-stroke or DIS (Distributorless Ignition System) engine.

3. Insert the Dual Banana Connector into the COM and RPM terminals as shown. Ensure the plug with the Ground Tab goes into the COM terminal.

4. Clamp the inductive pickup around a spark plug wire with the arrow sign facing the spark plug as shown.
   Ensure the pickup jaws are completely closed.

5. Read RPM in the primary display.

6. To return to Hz function, press menukey 2 or 3.



4-10. RPM IG (RPM Measurements Using Test probes)

1. Set rotary selector to IGN RPM IG position.
2. Press menukey 4 to select RPM IG function. The meter defaults at 4-stroke engine (RPM ④) and 4 cylinders(cL4).
3. Press (REL △)(RPM④ ②) button for more than 1 second to toggle between RPM④ for 4-stroke engine and RPM② for 2-stroke or DIS engine.
4. Press (RANGE) (Cylinder) button momentarily and repeatedly to select the required number of cylinder and display the cylinder setting in the secondary display.
5. Insert black lead into COM terminal and red lead into RPM terminal.
6. Connect black probe to a good ground near the coil and red probe to the primary side of the ignition coil.
7. Read RPM in the primary display.

NOTE: Refer to the vehicle's service manual for information on the number of strokes and cylinders for specific engines.

4-11. Fuel Injection On-Time

Electronic fuel injectors are controlled by the ECU and influenced by a variety of operating conditions including engine load, temperature, and feedback from the O_2 sensor during colsed loop operation.
Fuel injection on-time can be expressed in ms pulse width and indicates the amount of fuel delivered to the cylinder. Greater pulse width means more fuel, provided the fuel pressure stays the same.
The ECU provides a ground path for the injector through a driver transistor. When the switching transistor, or driver, is "on", current flows through the injector winding and the transistor to ground, opening the injector valve.

There are three main fuel injector systems, each with its own method for controlling fuel injection. All injectors have some method for limiting the electrical flow through the injector - too much current flow could burn out the injector.

◆ Current Controlled (Peak Hold) Injector

Peck and Hold injector circuits actually use two circuits to energize the injectors. Both circuits come on to energize the injector, this sends a high initial current (about 4 A) to the injector allowing it to open quickly. Then, after the injector opens, one circuit releases, leaving the second circuit to hold the injector open through the duration of its on-time. This circuit adds a resistance to the circuit in order to reduce the current flow through the injector to a maximum of about 1 A. Generally, a solenoid requires 4 times more current to initiate mechanical movement than it does to hold the component in place. When the second circuit shuts off, the injector closes ending the injector's on-time.

◆ Throttle Body Injection (TBI) Injector

The throttle body assembly was designed to replace the carburetor. The pulse width represents the amount of time the injector is energized or "on". The pulse width is carried by the ECU in response to changes in engine operation and driving conditions.
The ECU continues to ground the circuit (in order to hold it at zero volts) until it detects about 4 A flowing through the injector winding. When the 4 A "Peak" is reached, the ECU cuts back the current to a maximum of 1 A, by switching in a current limiting resistor. This reduction in current causes the magnetic field in the injector to collapse partially, creating a voltage spike similar to an ignition coil waveform. The ECU continues the "Hold" operation for the desired injector on-time, then it shuts it off by opening the ground circuit completely. This creates the second spike at the right of the waveform.

NOTE : The “Peak” portion of the waveform usually doesn’t change its on-time.
This is because the time it takes to “flood” the injector with current and lift the pintle remains constant. The “Hold” portion of the waveform is where the ECU increases and decreases on-time. Therefore, you can see the second spike move to the right under acceleration, while the first spike remains stationary, by using a proper DSO. And also, if the engine is running extremely rich, you may see both spikes nearly on top of one another. This indicates the ECU is attempting to lean out the fuel mixture by shortening injector on-time as much as possible.

◆ Conventional (Saturated Switch) Injector

The injector driver (switching transistor) applies constant current to the injector. Some injectors use a resistor to limit the current flow, others have a high internal resistance. These injectors have a single rising edge. Conventional injector drivers are used primarily on multiport fuel injection (MFI, PFI, SFI) systems. It is not used very much, if at all, on Throttle Body Injection (TBI) systems. The injector on-time begins where the ECU grounds the circuit to turn it on and it ends where the ECU opens the control circuit. Since the injector is a coil (winding), when its electric field collapses from the ECU turning it off, it creates a spike.

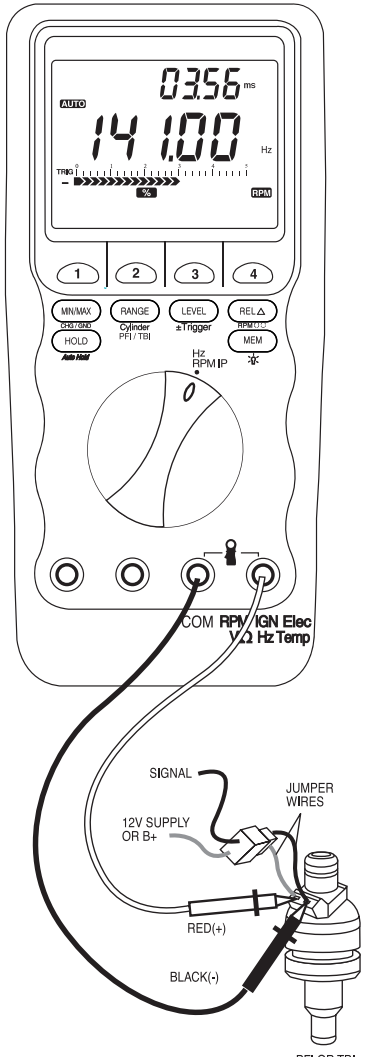
◆ Pulse Width Modulated Injector

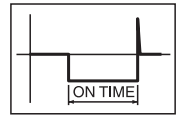
Pulse modulated injectors have a high initial current applied to energize the injector quickly. Then, after the injector is open, the ground begins pulsing on and off to extend injector on-time, while limitimg the current applied to the injector. Generally, this type injectors are pretty rare.

- Generally, the range of injector on-times runs from about 1 - 6 ms at idle to about 6 - 35 ms or more under cold cranking or Wide Open Throttle (WOT) operation.

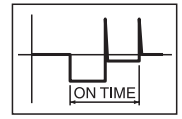
- Generally, the injector on-time only has to change from 0.25 ms to 0.50 ms while driving the system through its normal full rich to full lean range.

This Function applies to both Port Fuel Injectors (PFI) which operate with a single On-Time pulse and Throttle Body Injectors (TBI) which operate with twin pulses.





PORT FUEL INJECTION WAVEFORM



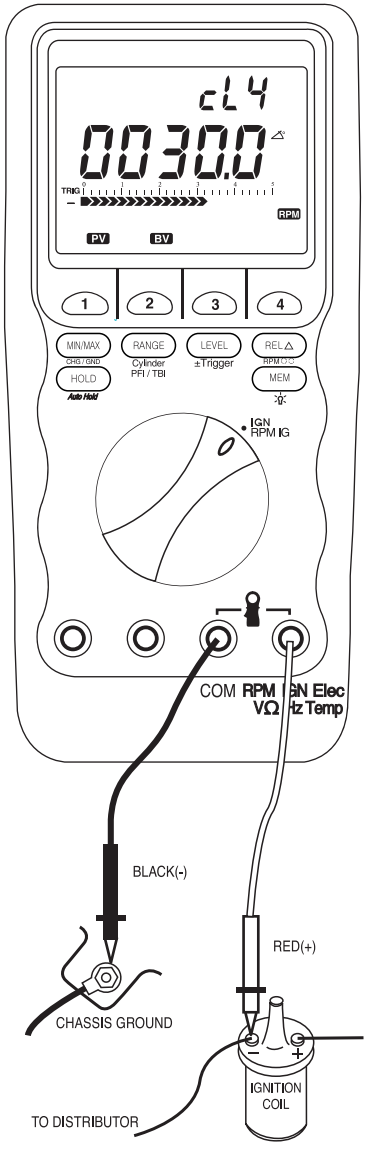
THROTTLE BODY INJECTION WAVEFORM

1. Set rotary selector to Hz RPM IP position, and then press the (RANGE) (PFI / TBI) button momentarily to toggle between the PFI mode (“ PFI ” appears in the primary display for 1 second.) and TBI mode (“ tbI ” appears in the primary display for 1 second.).
   4 trigger levels are selectable by pressing (LEVEL) (±Trigger) button momentarily in this function.

2. Insert black lead into COM terminal and red lead into Hz terminal.

3. Connect the test leads as shown and read On-Time in the secondary display and the fuel injection frequency in the primary display.

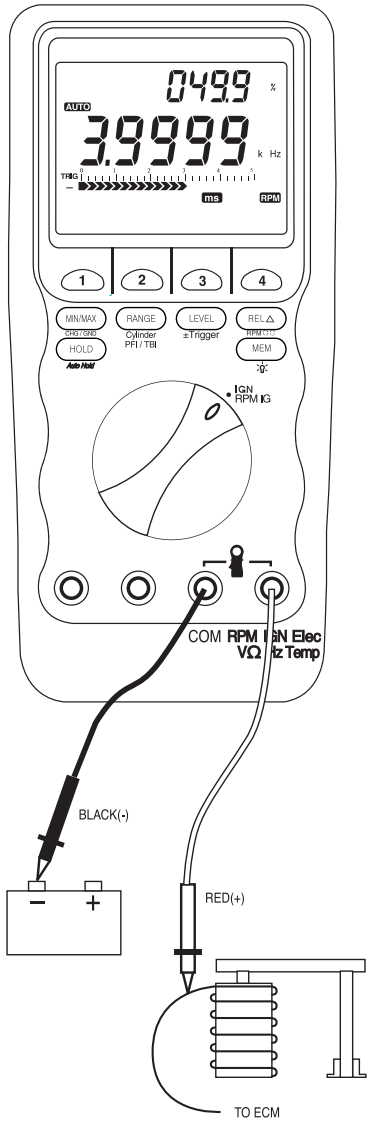
4. To return to Hz function, press the (RANGE) button for more than 1 second.



4-12. Dwell

1. Set rotary selector to IGN RPM IG position.
2. Press menukey 3 to select Dwell function. The meter defaults at 4 cylinder (cL4).
   Press (RANGE) (Cylinder) button momentarily and repeatedly to select the required number of cylinder and display the cylinder setting in the secondary display.
3. Insert black lead into COM terminal and red lead into RPM terminal.
4. Connect the test leads as shown and read Dwell angle in the primary display. Adjust trigger levels by pressing (LEVEL) (±Trigger) button momentarily, if necessary.
5. Adjust the dwell angle according to the procedures outlined in your vehicle service manual.

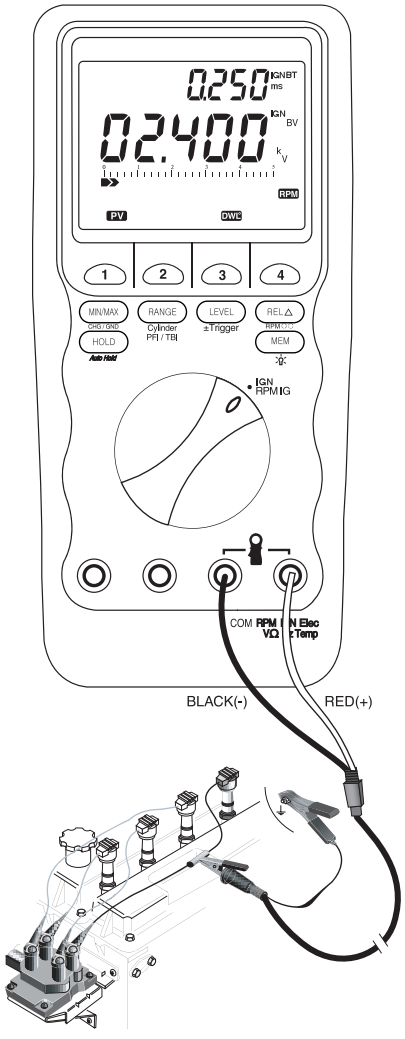
NOTE: Recheck the timing whenever the dwell angle has been adjusted.



4-13. Dual Display Duty Cycle

1. Set rotary selector to Hz RPM IP position.
2. Insert black lead into COM terminal and red lead into Hz terminal.
3. Connect the test leads as shown and read the duty cycle ms (Pulse Width) in the secondary display. Adjust trigger levels by pressing (LEVEL) (±Trigger) button momentarily, if necessary.
4. Press menukey 2 momentarily to display Duty Cycle reading in terms of percentage in the secondary display.

In the most applications, the negative trigger slope is assigned to display the percentage of time that the plunger is in the closed position (low duty cycle) during one duty cycle. The positive slope is assigned to display the percentage of time that the plunger is in the open position. Refer to the vehicle's service manual to verify slope assigned to position for each component.
Press the (LEVEL) (±Trigger) button for more than 1 second to toggle between the negative (-) slope and the positive (+) slope, if required.



4-14. Secondary Ignition

NOTE: It takes a special "capacitive type" pickup probe to connect this DMM to the ignition secondary. Connecting the test leads to an ignition secondary circuit can cause severe damage to the DMM or even personal injury.

BACKGROUND AND APPLICATION INFORMATION :

The IGN (Ignition) feature of this DMM displays three readings from both distributorless ignition systems (DIS) and conventional distributor systems ; Peak Voltage, Burn Voltage, and Burn Time. If necessary, the MIN / MAX function can be used for this feature.

- Peak Voltage is the peak voltage on the plug wire that occurs before the spark plug gap breaks down. (Typical Reading : 4 - 17 kV)
- Burn Voltage is the voltage seen across the spark plug gap when the ignition coil is discharging. (Typical Reading : 1.5 - 2.5 kV)
- Burn Time is the time that the ignition coil is discharging across the spark plug gap. (Typical Reading : 1.5 - 2.5 ms on single coil distributor ignition system, 1.0 - 2.0 ms on DIS, and 1.0 - 4.0 ms on multi-strike ignition system)
  Burn time is displayed on the secondary (small) display only with Burn Voltage.

⚠ Warning

To prevent electrical shock, do not connect or remove the spark plug wires while the engine is running.

QUICK TEST ON A CONVENTIONAL IGNITION SYSTEM

Test the ignition coil wire to the distributor first. The voltage taken on the coil / distributor wire is indicative of all cylinders. If there is more than 25% variation between maximum and minimum voltage at 2000 RPM, it will be necessary to check individual spark plug wires to determine which cylinder(s) is out of range.

CONNECT AND SETUP :

1. Set rotary selector to IGN RPM IG position. The meter defaults at Peak Voltage function.
2. Connect the Pickup into the COM and IGN terminal as shown.
3. Select Peak Voltage or Burn Voltage mode. These readings can be toggled throughout the test, while Burn Time will be displayed in the secondary display, simultaneously Burn Voltage will be displayed in the primary display.
4. Clamp the Pickup over the ignition wire located between the coil and distributor or over a spark plug wire.
5. Press the corresponding menukeys to toggle the primary display between IGN PV (Peak Voltage) and IGN BV (Burn Voltage) with IGN BT (Burn Time).
6. Check and note readings for each cylinder.

EXPECT THIS TEST RESULT :

◆ Peak Voltage

- If all readings are even (within 25% of each other) and between 5 - 15 kV, system is operating normally.
- If all readings are even (within 25% of each other) and below 5 kV, this could mean a possible rich fuel mixture, which would allow the spark to fire at a lower voltage.
- If all readings are even (within 25% of each other) and above 15 kV, this could mean a possible lean fuel mixture, wide plug gap, bad coil wire, or worn plugs.

- If kV readings are uneven (more than 25% of each other) and some above 15 kV, this could mean bad plugs or wires, poor fuel distribution or vacuum leak into the intake manifold near that cylinder.

◆ Burn Voltage

- A high kV indicates high resistance somewhere in the secondary ignition circuit for that cylinder (open plug wire, worn plugs, or corroded cap / terminals, etc.).
- A low kV indicates low resistance somewhere in the secondary ignition circuit for that cylinder (shorted plug wire, fouled plug, etc.).

◆ Burn Time

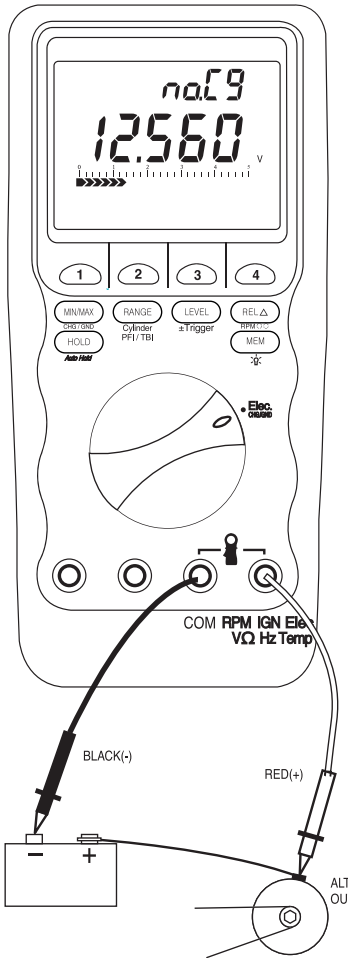
- Coil wire resistance (affects all cylinders)
- Spark plug wire resistance (affects individual cylinders)
- Spark plug gap
- Fuel Mixture
- Timing
- Compression
- Short Burn Time - High resistance or broken wires weaken the spark and shorted the duration. Check the coil wire, coil connection and rotor.
- Long Burn Time - Excessivey long burn times are usually caused by an excessively rich mixture, small spark plug gap, or a bridged spark plug gap due to carbon fouling.

◆ Possible Causes of Excessive kV :

- Spark Plug Gap - A wide spark plug gap or worn or damaged spark plug.
- Air / Fuel Ratio - Rich mixtures provide more conductive material between the spark plug gap resulting in a lower kV requirement, while lean mixture result in high kV.
- Ignition Timing - Higher cylinder pressure increases the firing kV demand. Ignition timing affects cylinder pressure when the spark fires before TDC (Top Dead Center). As ignition timing is retarded from TDC, firing kV will decrease.
- Circuit Resistance - Excessive resistance in the secondary ignition circuit increases kV, which can be caused by a burned rotor or damaged spark plug wire. Low resistance causes reduced kV, which can be caused by a wire that is shorted or by a fouled plug.

Secondary Ignition Circuit Trouble Shooting Guide

Location of Test on Vehicle	Vehicle Condition	Peak Voltage Readings (kV)	Burn Voltage Readings (kV)	Burn Time Readings (ms)
Plug wire	Normal plug and gap, on misfire noted	4.0 - 17.0	0.5 - 5.0	0.8 - 2.4
Plug wire	Grounded plug, fouled plug, misfire noted	4.0 - 6.0	0.2 - 2.0	1.5 - 5.0
Plug wire, before open	Open plug, misfire noted	35.0 - 50.0	5.0 - 15.0	0.0 - 1.0
Plug wire, after open	Open plug, misfire noted	0.0 - 2.0	0.0 - 1.0	0.0 - 1.0
Plug wire, before short in wire	Grounded plug wire, fouled plug, misfire noted	5.0 - 15.0	1.0 - 5.0	0.8 - 2.4
Plug wire, after short in wire	Grounded plug wire, fouled plug, misfire noted	0.0 - 2.0	0.0 - 1.0	0.0 - 1.0



4-15 . Charging System Test

Charging system problems often are identified with a No-Start complaint. The battery will have discharged and the starter won't crank the engine. To properly check the charging system, the battery must be fully charged.

WARNING

Be sure the battery to alternator connection and lead connections are all secure, or damage may result.

1. Set rotary selector to Elec position. The meter defaults at Charging System Test function.
2. Insert black lead into COM terminal and red lead into Elec terminal.

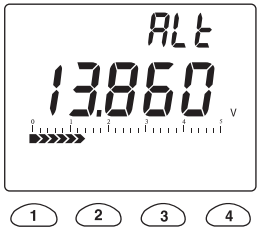
Battery Condition Test

1. Connect red lead probe to the alternator output.
2. Connect black lead probe to ground.
3. With engine Off, turn the headlights On low.
4. Read the secondary display to check the condition of the battery. Use the table below.

SECONDARY DISPLAY (Battery Condition)	PRIMARY DISPLAY
LbAt (Low Battery)	< 11.399 V
noCG (No Charge)	11.400 ~ 13.299 V
Good (Good)	13.300 ~ 15.599 V

- " noCG " not displayed : Check wiring and battery leads.
- " noCG " displayed : Good battery, proceed.
- " noCG " and " LbAt " displayed : Low Battery, correct before proceeding.

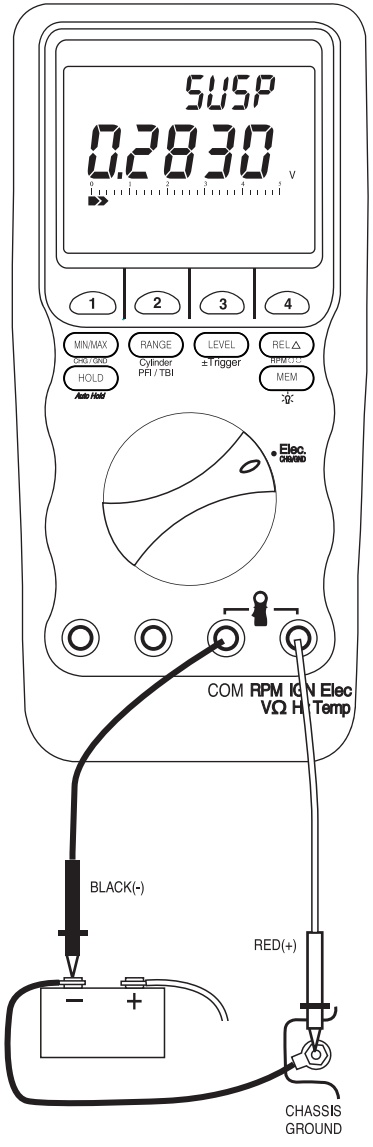
Alternator Charging Test



1. Connect red lead probe to the alternator output.
2. Connect black lead probe to ground.
3. Start engine and run at 1000 - 2000 rpm.
4. Turn the headlights On low.
5. Allow the secondary display to stabilize.
6. Read the secondary display to check the alternator charging conditions.
   A display " ALt " or " noCG " in the secondary display together with beep sound indicates that the alternator charging system is in bad condition.

- No display in the secondary display : System normal.
- " noCG " displayed : Suspect open field (current) or regulator.
- " noCG " or " ALt" displayed alternatively : Suspect bridge rectifier or grounded stator winding.
- " ALt" displayed : Suspect bridge rectifier or open stator winding.

NOTE: When the alternator and the associated rectifier diodes are in good condition, the ripple voltage of the alternator output signal should be less than 0.49 V AC (typical).



4-16. Ground Test

This function is designed to locate bad grounds, voltage drops, intermittent connections, or any source of high resistance in automotive electrical circuits and grounds.
It provides a very efficient check of a vehicle's electrical system condition.
This test works by measuring the voltage drop across any cable to which it is connected. The amount of voltage drop is displayed as " Good ", " SUSP ", " bAd ", and " oPEn " annunciators in the secondary display.

1. Set rotary selector to Elec position.
2. Press (MIN/MAX) (CHG/GND) button to select Ground Test function. " oFL " is displayed in the primary display and " oPEn " is displayed in the secondary display.
3. Insert black lead into COM terminal and red lead into Elec terminal.
4. Connect the two probes to the cable being tested. A good connection is indicated by the display of " Good " in the secondary display.
5. Apply power to the vehicle. The condition of the cable between the two probes is indicated by either " Good ", " SUSP ", or " bAd " in the secondary display.

SECONDARY DISPLAY	PRIMARY DISPLAY (Amount of Voltage Drop)
Good (Good)	< 0.1999 V
SUSP (Suspect)	0.2000 ~ 0.3999 V
bAd (Bad)	0.4000 ~ 1.9999 V
oPEn (Open)	≥ 2.0000 V

If either " SUSP " or " bAd " is displayed, check the cable closely for poor connections between the two test leads.
Make certain all connectors are clean and secure.

NOTE: ***When checking ground connections, always clean or scrape off the area of the chassis where the ground lead is being connected. Dirt, grease, and paint are insulators and will prevent the unit from making a good connection. If a ground connection is suspect, connect the unit to the chassis as close as possible. When testing charging or starting circuits from the battery, always make the first connection to the battery post, and not the battery connector. Corrosion on the battery post and connector surfaces can be the source of the problem very frequently.***

5. ADVANCED FEATURES

5-1. MIN/MAX Mode

Press the (MIN/MAX) button momentarily to activate MIN/MAX(Record) mode with LCD annunciators MAX MIN AVG turned on. Press this button momentarily to read throughout the Minimum(MIN), Maximum(MAX), and Average(AVG) readings in the primary display. Press this button for more than 1 second to exit MIN/MAX (Record) mode.

※ This mode doesn't work in the Elec (CHG/GND) mode.

With the Autoranging MIN/MAX (Record) mode, you can easily track intermittent signals, capture turn on/ turn off surges, and monitor line voltage changes over a much wider dynamic range with the best resolution. It surpasses manual ranging recording which is apt to be overflowed or to have insufficient resolution. The meter features a fast sampling speed of 50 ms for MIN, MAX and AVG readings. The faster the sampling speed, the more accurate the measurements will be. The true average (AVG) feature calculates all readings continually taken over time. The Auto - Power - off feature will be automatically disabled in this mode.

5-2. Manual and Auto Ranging

Press the (RANGE) button momentarily to select manual ranging, and the meter will remain in the range it was in, when the LCD annunciator **AUTO** turns off. Press this button momentarily again to step through the ranges. Press this button for more than 1 second to resume autoranging.

In Dwell(∠°) function, press this (RANGE) (Cylinder) button momentarily to display the cylinder setting on the secondary display. Default is cL4 (4 Cylinder). Press this button momentarily again to select the number of cylinders from 1 through 12 (1, 2, 3, 4, 5, 6, 8, 10, and 12 cylinders) to match the engine under test.

NOTE: The selected cylinder setting or RPM ④ ② setting is maintained until the meter is turned off.

5-3. Trigger Level and ±Trigger Slope Selection

This feature is available for PFI/TBI Injection On-Time, RPM IP, Dwell, ms-Pulse, or Duty measurement function. The meter is set at selected trigger level as power up default in individual function as follows :

FUNCTION	DEFAULT TRIGGER LEVEL
RPM IP	
PFI/TBI, Dwell, ms-Plulse, Duty	

However, vehicle signal levels under test may vary due to aging of components, abnormal conditions, and each car manufacturer's different design. Therefore, positive and/or negative 4 selectable trigger levels, which are carefully designed and tested to cover all the extreme conditions, are available in these functions to provide more flexibility to cope with your applications.

If your reading is unstable, select lower sensitivities (higher trigger level scale) by pressing the (LEVEL) (±Trigger) button momentarily. If your reading shows zero, select higher sensitivities (lower trigger level scale).

The 4 selectable trigger levels are cycled through as follows :

• RPM IP

• PFI/TBI, Dwell, ms-Pulse, Duty

In some cases, positive trigger levels may be required for measuring, Dwell, ms-Pulse, or Duty. Press the (LEVEL) (±Trigger) button for more than 1 second to toggle between positive (+) and negative (-) trigger slope for the selected trigger level.

NOTE: Positive (+) trigger or negative (-) trigger is to identify whether the On or Off portion of the signal under test is of measuring interest. For example, if you get a reading of 10 % Duty Cycle in the Positive (+) Trigger (On portion), you then will get a reading of 90 % Duty Cycle in the Negative (-) Trigger (Off portion).

5-4. RPM ④ ② Selection

In the RPM IP & IG function, the meter defaults to RPM ④ for conventional 4-stroke engine. Press the REL△ (RPM ④ ②) button for more than 1 second to toggle to RPM ② for 2-stroke or DIS engine.

5-5. Relative △ Mode

Press the REL△ button momentarily to select the Relative Zero (△) mode with LCD annunciator ▲ turned on. This feature allows the user to offset the measured value with a relative reference value.

Press the REL△ button momentarily to exit relative mode and resume normal measurements.

5-6. Hold or Auto Hold

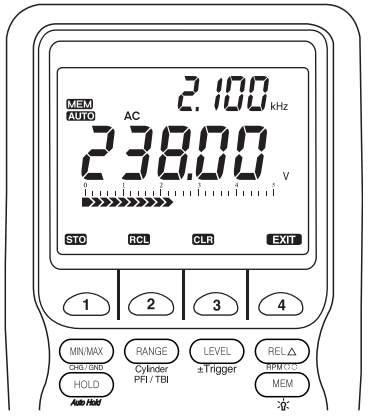
Press the HOLD button momentarily to activate the Hold function with LCD annunciator **HOLD** turned on. Press this button momentarily again to exit Hold function. This feature freezes the display for later view.

Press the HOLD (*Auto Hold*) button for more than 1 second to activate the Auto Hold function with LCD annunciators **A-** **HOLD** turned on. This feature automatically freezes the display and the meter beeps when the measurement reading is stabilized. The displayed value will be updated when a new measurement value is stabilized. This mode is very useful when it is impossible for you to press the HOLD button or see the meter display while probing and taking measurements. Press the HOLD (*Auto Hold*) button for more than 1 second to exit Auto Hold function.

5-7. Memory (Data Store, Recall & Clear) Mode

Press the MEM button momentarily to activate the Memory mode with LCD annunciators **MEM** and **HOLD** turned on. The menu screen shows four menu selections : **STO** (Store), **RCL** (Recall), **CLR** (Clear), and **EXIT** (Exit).

Store : Press the menukey 1 to store the displaying data. The available memory location number momentarily shows in the secondary display and " SAVE " momentarily shows in the primary display. If no memory location is available, " FULL " and " dATA " momentarily show in the primary display and in the secondary display respectively and nothing is stored, when you must clear all the memory locations by pressing the Clear menukey to secure memory locations. You can store up to 20 data. You can exit the store mode by pressing either the EXIT menukey or the MEM button momentarily.



Recall : Select Recall to review the stored data by pressing the menukey 2. When you press the menukey 2, the last memory location number used in the previous memory operation will momentarily show in the secondary display with four menu selections ; **+** , **—** , **CLR** and **EXIT** turned on in the menu screen. The required memory location can be selected by using the menukey 1 and the menukey 2, when the data stored at the selected memory location will show in the primary display. In the Recall mode, when you press the Clear menukey, the data stored at the recalled memory location only is erased. If no stored data is available in the Recall mode, when you press the Recall menukey, " dATA " and " no " momentarily show in the primary display and in the secondary display respectively and nothing is retrieved. You can exit the Recall mode by pressing either the EXIT menukey or the MEM button momentarily.

Clear : Select Clear to clear all stored data in the Store mode or only the data stored at the selected memory location in the Recall mode. In the Store mode, when you press the Clear menukey, " SUrE " and " YoU " continuously show in the primary display and in the secondary display respectively with two menu selections ; AC (All Clear) and EXIT turned on in the menu screen. When you press the menukey 2, " donE " momentarily shows in the primary display and all the stored data are erased. Press the EXIT menukey to exit the memory mode without erasing any stored data.

EXIT : Select EXIT to exit memory mode. You can also exit memory mode by pressing the MEM button momentarily or turning the rotary selector.

5-8. Backlight

Press the MEM (☼) button for more than 1 second to toggle the backlight On and Off. The backlight will also automatically be Off 30 seconds after each activation to extend the battery life.

5-9. Auto-Power-Off

The meter automatically turns off after approximately 30 minutes of no activities to extend battery life.

5-10. RS-232C and USB Interface

The meter equips with an optically isolated interface port at the top for the data communication. The RS-232C optical adaptor cable and the software CD are required to connect the meter to the PC. This RS-232C port is also interfaceable with a USB port of a PC by using the RS-232C to USB adaptor supplied. The meter comes with these standard accessories.

6. Automotive Applications of the DC/AC Clamp-on High and Low Cuttent Probes

This DMM is internally configured to accept the current probe's input without any modifications other than telling the DMM what probe's setting is.

The PC Interfacing software supplied with this DMM will display the measured values on your PC in the form of numerical table or a graph.

NOTE:
In general, when troubleshooting automotive vehicles, we can use a DMM or a DSO to measure some specific values from signals under test or a scan tool to read out some service data from the ECU's built in vehicles.

- A DMM can be used effectively for the signals that are not changed for more than 1 sec because a DMM is designed to show average values; for example, alternator charging current, fuel pump current, TPS main voltage, battery voltage, and battery leakage current, etc.
- A scan tool can read out some service data from the ECU's built in vehicles so the service data for the signals that are not changed for more than 1 sec are reliable; for example, service data for battery voltage, WTS (Water Temperature Sensor), ATS (Air Temperature Sensor), BPS (Barometric Pressure Sensor), and DC supplied switches, etc.
- A DSO should be used to measure the signals that are changed for less than 1 sec; for example, CKP (Crankshaft Position) sensor, No. 1 TDC sensor, VSS (Vehicle Speed Sensor), AFS (Air Flow Sensor), MAP (Manifold Absolute Pressure) sensor, and TPS (Throttle Position Sensor), etc.

These current probes can be used with a DMM or a DSO. However, we would like to recommend users to use them with a DSO when measuring the signals that are changed for less than 1 sec.

Merits of Current Measurement in Automotive Troubleshooting :

- Easier measurements.
- Decrease or excess of fuel pressure can be determined without direct measuring the fuel pressure by using a pressure gauge.
- We can easily determine if a problem belongs to the actuator (injector, motor, or solenoid, etc.) itself or to the circuits connected to the actuator.
- See if the measured current is lower than the reference (normal) current that can be obtained from the vehicle manufacturer's specifications or by your premeasurement of this current on the same vehicle model with the milage of under 10,000 km. If so, measure the voltages on the circuits connected to the actuator to find out any connection failure on the circuits.
- If the measured circuit is almost same as the reference current, we can say that the actuator itself has no problem at all.
- Current measurements on battery or alternator system can help us troubleshoot them in more depth and raise our service capabilities, especially, for electric or hybrid electric vehicles.
- In case of the cooling fan, we can determine even that the fan's distorted angle, which applies more load to the fan motor, can cause more current to flow through the cooling fan system.

Sample Case : How to Diagnose Injector Failures by Current Measurement using a DSO

We can diagnose an injector failure due to a bad connection between the injector and its ECU by measuring the spike voltage and the voltage of the on-time portion of the trace because generally, in this case, the spike voltage is about 5 V lower than that of the normal injector and the on-time portion voltage is more than 0.6 V. If only the spike voltage is about 5 V lower than that of the normal injector, we can suspect a failure of the injector itself or a failure on the battery power supplying circuit side components like engine key or relay switch, etc.
In this case, if the voltage between the battery positive side and the injector positive side is less than 1 V, we must suspect a failure on the injector itself and if the voltage is more than 1 V, we must suspect a connection failure on the relevant components.

However, the voltage measurements above cannot provide us with the information about the failure of the injector itself in details. On the contrary, current measurements on the injector circuit can provide us with the following information :

- If the peak (maximum) current (usually about 700 mA) is about 80 mA lower than that of a normal injector, the injector circuit under test may have a connection failure on the circuit.
- If the peak current is higher than that of the normal injector, the injector may not be a genuine injector specified for the same vehicle model.
- The current trace of a normal injector has a hump due to so called "Ineffective Injection Time". If the injector pintle moves heavily, this hump may be disappeared.
- If the current trace of the injector under test has no hump and also its peak current is lower than that of a normal injector, the injector pintle moves heavily and the injector circuit has bad connections.
- The hump on the current trace can be appeared earlier or later depending upon the degree of deterioration of the injector's internal spring connected to the pintle. The earlier, the weaker deterioration. The vehicle with an earlier hump consumes more fuel and its O_2 sensor voltage is higher generally.
- If the injector pintle does not move, the injector current trace has no hump at all. This faulty injector should be replaced with a new one immediately.

NOTE : The injector current traces of some normal vehicle models have no hump because the injector pintle's seat is designed to absorb the pintle shocks in various ways. Thus, obtaining the Reference Current Trace is very important.

Demerits :

The reference current traces should be prepared by the vehicle manufacturer's specifications or by your premeasurement of this current traces on the same vehicle model with the milage of under 10,000 km before comparing the measured current to this reference current.

Recommendable Useful Reference Current Traces to be prepared :

- Ignition Primary Coil Current Traces (at Idle, Cranking, Snap Acceleration)
- Injector On-Time Current Trace at Idle
- Starting Motor Current Trace at Cranking
- ST' terminal's Driving Current Trace at Cranking
- Cooling Fan's Current Traces at High or Low Speed
- Air-con Fan's Current Traces at High or Low
- Headlight High and Low Current Traces
- ISA valve's Current Trace
- Battery Charging Current Trace
- Battery Leakage Current (normally about 15 mA), when all systems are turned off
- ABS Hydraulic Solenoid's Driving Current Trace
- Autotransmission Solenoid's Driving Current Trace

6-1. High Resolution DC/AC Clamp-on mA Current Probe

6-1-1. Ignition Primary Coil Current Test

BACKGROUND AND APPLICATION INFORMATION :

When a shorted ignition coil and/or a faulty ignition module's switching transistor is suspected, there are several ways to approach the diagnosis. There are usually manufacturer's specifications available for ignition coil primary and secondary winding resistance ranges. This is a static test of the ignition coil's windings. A more accurate and dynamic test of an ignition coil's winding involves testing its current flow (amperage) during operation by analyzing its current trace or waveform. Additionally, the operation of the ignition module's switching transistor can be checked during the ignition coil's current flow test. A current flow test of "current limiting type" ignition modules can also confirm proper operation of the current limiting circuit in the ignition module's switching transistor.

The HR30 is required to perform this test. HR30 can be used to check any solenoid (injector, etc.), coil, or switched circuit.

CONNECT AND SETUP :

1. If your DSO has the capability to accept a current probe, consult the DSO's manual and set the DSO up with the Low Current Probe. Connect the current probe to the "CH1" and "COM" terminals on the DSO.
2. Clamp the current probe around the power feed wire to the ignition coil (the non-pulsing side). Use the wiring diagram for the vehicle being serviced to obtain the color of the wire.
3. Make sure the setting on the current probe matches the setting in the DSO.
4. Zero the current probe and begin the test.

FOLLOW THIS PROCEDURE :

Start the engine. Let it idle, accelerate the engine, or drive the vehicle to replicate the failure conditions.
If the engine won't start, crank the engine and watch the DSO display.

EXPECT THIS TEST RESULT :

As current begins to flow into the ignition coil, the coil's winding, with its specific resistance and inductance characteristics, causes the trace to rise at a certain rate. The rate of the trace's rise is critical. Generally, ignition coil's primary current trace will rise at about a 60 degree angle (at a 10 ms/div timebase).
Most modern ignition primary circuits generally flow up to 5 or 6 A (amps) into the ignition coil initially, then, when the maximum allowed current is reached (usually 5 or 6 A), the current limiting circuit in the ignition module is activated. This caused the current trace to flatten out on the top. The current trace will remain flat at the top for the duration of the coil's on-time (or dwell). The current trace then drops almost vertically as the ignition module shuts off current flow and the coil's current drains out to the zero level. This process repeats itself for every ignition cycle.

It's important to look for ignition coils whose current trace takes an almost vertical rise on its left side, when current is initially flowing into the winding. This indicates that the resistance of the coil's winding is too low (it's shorted), which can create driveability problem as well as damage to the ignition module's switching transistor.

IMPORTANT NOTE : The "initial rise" portion of the current trace usually doesn't change with regard to the time it takes to get to its "peak". This is because the time it takes to "flood" a good ignition coil with current remains constant (with slight variations for temperature). The "coil on-time (or dwell)" portion of the trace is where the PCM (through the ignition module) increases and decreases its on-time.

6-1-2. Diesel Glow Plug Current Draw Test

BACKGROUND AND APPLICATION INFORMATION :

Cold diesel engines do not start easily. Blow-by past the piston rings and terminal losses reduce the amount of compression possible. This produces lower peak compression temperatures. Starting the engine becomes impossible without the assistance of auxiliary air / fuel heating devices and systems.
Cold starting is improved by the additional of a sheathed element glow plug in the pre-combustion chamber, or on Direct-injection (DI) engines, in the main combustion chamber.

When current flows through the heating coil of the glow plug, a hot spot is formed in the subchamber or main combustion chamber. A portion of the fuel around the glow plug's hot tip is vaporized, assisting in igniting the air / fuel mixture.
Never glow plug systems continue to operate after engine startup for up to 3 minutes. This improves initial engine performance, reduces smoke, emissions, and combustion noise (knock).

Usually, a glow plug control unit supplies power to the glow plug during appropriate conditions. An effective method of testing glow plug operation is to measure the current flow through the glow plug or more specifically, through the heating element. Some newer glow plugs are designed with a heater element that changes resistance with temperature. The glow plug's resistance gets larger as the heating element gets hotter from when combustion temperature increases after startup. This increase in resistance reduces the current flow through the glow plug.

CONNECT AND SETUP :

1. If your DSO has the capability to accept a current probe, consult the DSO's manual and set the DSO up with the Low Current Probe. Connect the current probe to the " CH1 " and " COM " terminals on the DSO.

2. Clamp the current probe around the power feed wire to the glow plug (or bank of glow plugs) to be tested. Use the wiring diagram for the vehicle being serviced to obtain the color of the wire.

3. Make sure the setting on the current probe matches the setting in the DSO.

4. Zero the current probe and begin the test.

EXERCISE THE SENSOR :

With the engine stone cold, turn on the ignition key.
Watch the DSO display to :

- Make sure that the Critical Dimension of the current height is correct and consistent for the glow plug system being tested.
- Make sure that the operation of the glow plug controller follows the manufacturer's specific control strategies.

EXPECT THIS TEST RESULT :

Look for the current going through the glow plug to be at its maximum when the key is first turned on. Maximum current and operating current specifications may be available from the manufacturer of the vehicle being serviced. If the trace stays flat (at zero), suspect a faulty glow plug.

Most glow plugs will open circuit when they are overheated from a faulty controller that held them on too long, etc. No current flows through them and they do not get hot.

Possible defects and Critical Dimension violations to watch for are drop outs in the current trace, which would indicate an open circuit in the glow plug's heater element. This may be caused by heat, vibration, or fatigue related malfunctions.

6-1-3. DC Current Test

BACKGROUND AND APPLICATION INFORMATION :

This Low Current Probe can be applied to measure current in a lot of different automotive circuits, such as solenoids of all types (purge control, EGR control, transmission shift control. etc.), temperature switches, throttle switches, vacuum switches, light switches, brake switches, and cruise control switches, etc.

When a shorted solenoid winding and/or a faulty solenoid driver is suspected, there are several ways to go about the diagnosis. There are usually manufacturer's specifications available for electronic solenoid winding resistance ranges (cold and hot).
Ohm checking a solenoid winding is a static test of the electrical windings. A more accurate and dynamic test of a solenoid's electrical winding involves testing its current flow (amperage) during operation by analyzing its current trace. Additionally, the operation of the solenoid's driver (switching transistor in the PCM) can be checked during the solenoid current flow test. A current flow test of "current limiting type" solenoid drivers can also confirm proper operation of the current limiting circuit in the PCM's driver.

CONNECT AND SETUP :

1. Install the supplied PC Interfacing Software into your PC.
2. Connect the DMM to your PC via the RS-232C cable or the RS-232C to USB adaptor.
3. Connect the current probe to the terminals on the DMM.
4. Clamp the current probe around the power feed wire to the solenoid or circuit to be tested.
5. Make sure the setting on the current probe matches the setting in the DMM.
6. Zero the current probe and begin the test.
7. Review the current trace on your PC.

EXERCISE THE SOLENOID, DEVICE, OR CIRCUIT UNDER TEST :

Make sure power is switched on in the circuit so that the solenoid, device, or circuit is operational. Then exercise the solenoid, device, or circuit while paying particular attention to the amplitude of the current signal. It should stay within a predetermined current range for a given solenoid, device, or circuit. In most cases, the amplitude of the current trace should go up when the circuit is on, and go to zero level when the circuit is off or the switch is activated.

EXPECT THIS TEST RESULT :

As current begins to flow into a solenoid's winding, the solenoid's winding, with its specific resistance and inductance characteristics, causes the current trace to rise. Generally, most solenoids in today's vehicles operate in the range of 400 to 750 mA. Some solenoids may be operated at high speed (such as injectors, EGR solenoids, etc.), for which using a DSO is much better than using a DMM, and some may operate at low speed and be switched on and off for longer periods (such as TCC solenoids, etc.). Shorted solenoid windings will allow too much current to flow through the current trace making the trace exceed the maximum allowed amplitude. Switched circuits will produce stepped traces that will rise to a certain amplitude and stay there until the circuit is switched off.

6-2. DC/AC Clamp-on High Current Probe

6-2-1. Alternator Output Current Test

BACKGROUND AND APPLICATION INFORMATION :

Simultaneous measurement of the alternator's output voltage and current is a good test because it tests the alternator's ability to deliver the required charging system current while maintaining an acceptable level of charging system voltage.

An alternator is an AC generator with diode rectification, which converts the AC signal to a pulsating DC signal. The DC signal charges the vehicle's battery and supplies power to run the vehicle's electrical and electronic system. Field current is supplied to the rotor in the alternator to vary its output. As engine RPM increases, so does alternator output voltage.

Unless a regulator was employed in the charging system, the battery would explode. To prevent this, the alternator's output voltage is controlled by a solid state regulator, which is in some cases, the PCM. The regulator limits the charging voltage to a preset upper limit and varies the amount of the excitation current supplied to the field winding. The field winding excitation is varied according to the battery's need for charge and ambient temperature.

There are many factors to consider when analyzing the alternator output voltage and current. Check the manufacturer's specifications for the particular vehicle being serviced for the upper and lower limits of charging voltage permitted. Alternator maximum output current is usually listed on the alternator case. Alternators will not reach their maximum output current unless they are "full fielded" and run at sufficient RPM.

The battery is the critical reference point for the entire electrical system. To properly test the charging system, the battery must first be tested.

CONNECT AND SETUP :

1. Install the supplied PC Interfacing Software into your PC.
2. Connect the DMM to your PC via the RS-232C cable or the RS-232C to USB adaptor.
3. Connect the High Current Probe to the terminals on the DMM.
4. Clamp the current probe around the alternator B+ output wire.
5. Make sure the setting on the current probe matches the setting in the DMM.
6. Zero the current probe and begin the test.
7. Review the current trace on your PC.

FOLLOW THIS PROCEDURE :

Perform a visual inspection of all alternator and battery connections, cables and terminals. Check for a loose or worn alternator belt. Turn off all electrical loads and start the engine. Hold the engine at 2500 RPM for about 3 minutes and check the alternator's output current.

EXPECT THIS TEST RESULT :

The alternator's output current will vary depending on the electrical system's requirements from time to time. When large electrical loads are operating, the alternator output current will be high. Check the maximum current capacity for the alternator being tested. This can be obtained by finding the amperage capacity stamped on the alternator case or it can be obtained from vehicle manufacturer's repair information. If an undercharge condition is suspected, use a battery load tester to apply load to the battery while the engine is held at 2500 RPM. If the output current doesn't increase, suspect a problem.

6-2-2. Relative Cylinder Compression Test

BACKGROUND AND APPLICATION INFORMATION :

It is very helpful in some diagnosis to see if an engine has a weak cylinder due to low compression. A direct measurement of each cylinder's compression using a compression gauge can be somewhat labor intensive. A simple and effective relative cylinder compression test can be conducted using this high current probe on the DSO.
When the starter motor turns the crankshaft, its rotational speed is not constant. Every time a piston begins its compression stroke, the starter motor has to work harder to turn the crankshaft. The starter motor requires more current to do this and the starter motor slows down slightly. This repeated slowing down and speeding up, requiring more, then less current, is what comprises the distinctive sound of an engine cranking.

If an engine has a weak cylinder, the crankshaft speeds up instead of slowing down during the weak cylinder's compression stroke. The starter motor's current requirement is also much less than that of a cylinder with good compression. This high current probe enables easy viewing of the starter motor's current requirements during cranking. If all cylinders are relatively equal in compression, then the starter motor's current fluctuations, as displayed on your DSO, will be relatively equal as well.

CONNECT AND SETUP :

1. If your DSO has the capability to accept a current probe, consult the DSO's manual and set the DSO up with the High Current Probe. Connect the current probe to the " CH1 " and " COM " terminals on the DSO.
2. Clamp the current probe around the positive starter cable.
3. Choose the proper current probe setting.
   Make sure the setting on the current probe matches the setting in the DSO.
4. Zero the current probe and begin the test.

EXERCISE THE SENSOR :

Disable the ignition or fuel injection system to prevent the engine from starting. Crank the engine and watch your DSO's display.

EXPECT THIS TEST RESULT :

The DSO calculates the relative compression of the cylinders by measuring the current change created from each cylinder during cranking. This is a very useful test to determine compression differences between cylinders and identify a weak cylinder. From the compression graph on your DSO you cannot identify cylinder numbers, because there is no synchronization signal used for the test. Cylinder display on the compression graph is in firing order. This test will quickly identify any low compression cylinders causing problems.

IMPORTANT NOTE : The relative compression test can only be used in reciprocating piston engines. This test cannot be used on rotary (Wankel) engines. Also on odd fired engines, you may not be able to correctly interpret the results.

◆ Measurement Conditions :

- This test requires several conditions to get test results that can be interpreted properly and are not misleading. Verify test result by physical compression test prior to mechanical repair.
- Interpretation of test results is easier for engines with 6 cylinders or less. It becomes increasingly more difficult as the number of cylinders increase, due to more compression overlap and less difference in current draw of the starter motor.
- Disable engine run by momentarily interrupting the fuel supply. (Pull the fuel pump fuse or clamp the flexible fuel pressure line.)
- On some engines, holding the throttle wide open during cranking will give the best results to get an evenly distributed air intake.

7. MAINTENANCE AND REPLACEABLE PARTS

⚠ Warning

To avoid electrical shock or personal injury, remove the test leads and any input signals before replacing the battery or fuses. To prevent damage or injury, install only the same type of fuses or equivalents.

Cleaning and Storage

Periodically wipe the case with a damp cloth and mild detergent; do not use abrasives or solvents.

Clean the input terminals as follows :

1. Turn the meter off and remove all test leads.
2. Shake out any dirt that may be in the terminals.
3. Soak a new swab with alcohol and work the swab around in each terminal.

If the meter is not to be used for periods of longer than 60 days, remove the battery and store it separately.

Auto Fuse Detection

The meter automatically verifies the integrity of the internal fuses when you set the rotary function knob to $\widetilde{\underline{\underline{\frac{A}{mA}}}}$ and plug 1 test lead into either A terminal or mA terminal. In either case, if an open fuse is detected, the word " FUSE " shows on the primary display.

Battery and Fuse Replacement

The meter uses a single standard 9 V battery (NEDA 1604, JIS006P, IEC 6F 22), a 1000 V/440 mA IR 10 kA fast acting F fuse (F_{71}) for mA current input, and a 1000 V/11 A IR 10 kA fast acting F fuse (F_{72}) for A current input.

⚠ Warning

To avoid false readings, which could lead to possible electric shock or personal injury, replace the battery as soon as the low battery indicator appears.

Replace the battery or the fuses as follows :

1. Turn the rotary switch to OFF and remove the test leads from the input terminals.
2. Remove the battery door by using a screwdriver.
3. Replace the battery or the fuses with ONLY specified replacement battery or fuses.
4. Reinstall the battery door by using a screwdriver.

Trouble Shooting

If the meter fails to operate even with the battery or fuse replacements, check it twice over according to operating procedure as described in this manual.

If the meter's V/Ω input terminal has subjected to high voltage transient (caused by lightning or switching surge to the system) by accident or abnormal operating conditions, the series fusible resistors will be blown off like fuses in order to protect the user and the meter. Most measuring functions through this terminal will then be open circuit.
In this case, the series fusible resistors and the spark gaps should be replaced by qualified personnel.

8. GENERAL SPECIFICATIONS

Safety & Compliances

Maximum voltage between any Terminal and earth ground	: 1000 V DC/AC
Compliances	: Complies with CAN/CSA 22.2 No 1010-1, ANSI/ISA-S82 to 1000 V Overvoltage Category III and 600 V Overvoltage Category IV
Certifications	: CE-marking certificated
Surge Protection	: 8 kV peak per IEC 1010.1-92
⚠ Fuse Protection for mA input	: 1000 V / 440 mA IR 10 kA Fast fuse
⚠ Fuse Protection for A input	: 1000 V / 11 A IR 10 kA Fast fuse

Physical Specifications

Display (LCD)	: 4-4/5 digits 50000 counts primary and 3-4/5 digits 5000 counts secondary dual display LCD (with frequency range 49999 counts) 26 segments bar graph, Updates 40 times/sec
Operating Temperature	: 0 °C to 50 °C (32 °F to 122 °F)
Storage Temperature	: -20 °C to 60 °C (-4 °F to 140 °F)
Temperature Coefficient	: Nominal 0.15 x (specified accuracy) / °C @ (0 °C to 18 °C or 28 °C to 50 °C), or otherwise specified
Relative Humidity	: 0 % to 80 % @ 0 °C to 35 °C (32 °F to 95 °F) 0 % to 70 % @ 35 °C to 50 °C (95 °F to 122 °F)
Altitude	: Operating – up to 2000m Storage – 10000m
Auto Power Off	: 30 minutes
Battery Type	: Single 9 V battery - NEDA 1604, JIS 006P or IEC 6F22

Battery Life	: 60 hrs typical (with backlight off)
Shock Vibration	: Per MIL-T-PRF 28800 for a Style D, Class III instruments
Pollution Degree	: 2
Electromagnetic Compatibility (EMC)	: EN 61326-1 (2006)
Size (H x W x D)	: 8.19 in x 4.05 in x 2.13 in without mounted accessory
Weight	: Approx. 1.45 lbs (655 g)
Calibration Interval	: 1 year

Feature Summary

Backlight	: For clear readings in poorly lighted areas
Fast Autoranging	: Meter automatically selects the best range momentarily
Auto HOLD	: Automatically holds readings on display for later view
Continuity / Open test	: Beeper sounds
Fast Bar Graph	: 26 segments for peaking and nulling
Memory Locations	: 20
MIN/MAX Mode	: Record minimum, maximum and average values
Relative	: Relative zero
Trigger Level	: 4 selectable trigger levels

±Trigger	: Selectable Positive & Negative trigger slope
Cylinder	: 9 selectable number of cylinders in Dwell
RPM ④	: For 4-stroke engine application
RPM ②	: For DIS & 2-stroke engine application
ms-Pulse/Duty Cycle	: Measures the time signal is ON or OFF in milliseconds or in %
Injection On-time	: Measures the Injection On-time for PFI/TBI type injectors
Secondary Ignition	: Measures the Peak Voltage, Burn Voltage, and Burn Time
Elec.	: Battery Charging System Test and Ground Test
Closed Case Calibration	: No internal adjustments needed
Battery/Fuse Access Door	: Battery or fuse replaceable without voiding calibration
High-Impact Overmolded Case	: Protective holster features

9. ELECTRICAL SPECIFICATIONS

Accuracy is given as ± ([% of reading] + [number of digits]) at 64 °F to 82 °F (18 °C to 28 °C) with relative humidity up to 80 %, for a period of one year after calibration. True RMS responding accuracies are specified from 10 % to 100 % of range or otherwise specified; Crest Factor < 3:1 at full scale and < 6:1 at half scale.

DC Voltage

Range	Resolution	Accuracy
50.000 mV	1 uV	0.08 % + 10
500.00 mV	10 uV	
5.0000 V	100 uV	
50.000 V	1 mV	0.08 % + 2
500.00 V	10 mV	
1000.0 V	100 mV	0.1 % + 10

NMRR : >60 dB @ 50/60 Hz
CMRR : >120 dB @ DC 50/60 Hz, RS=1 KΩ
Input Impedance : 10 MΩ, 30 pF nominal (50 MΩ, 100 pF nominal for 500 mV range)

AC Voltage

Range	Resolution	Accuracy			
		40 Hz ~ 1 kHZ	1 kHz ~ 5 kHZ	5 kHz ~ 20 kHZ	20 kHz ~ 40 kHZ
500.00 mV	10 uV	0.3 % + 10	1.0 % + 10	2.0 % + 20	Unspecified
5.0000 V	100 uV	0.3 % + 10	0.5 % + 10	0.5 % + 10	0.8 % + 20
50.000 V	1 mV				
500.00 V	10 mV				
1000.0 V	100 mV	0.4 % + 10	0.5 % + 20	Unspecified	Unspecified

CMRR : > 60 dB @ DC to 60 Hz, Rs = 1 kΩ
Input Impedance : 10 MΩ, 30 pF nominal (50 MΩ, 100 pF nominal for 500 mV range)

DC / AC Current probe

Range	Resolution	Accuracy	Probe Output
30 A	1 mA	1.0 % + 2	100 mV/A
400 A	0.1 A	DC : 1.5 % + 5 AC : 2.5 % + 5	1 mV/A
1500 A	1 A	DC : 1.5 % + 5 AC : 2.5 % + 5	0.1 mV/A

DC Current

Range	Resolution	Accuracy
50.000 mA	1 uA	0.1 % + 5
500.00 mA	10 uA	
5.0000 A	100 uA	0.3 % + 10
10.000 A	1 mA	0.3 % + 20

AC Current

Range	Resolution	Accuracy	
		40 Hz ~ 1 kHz	1 kHz ~ 10 kHz
50.000 mA	1 uA	0.3 % + 5	0.8 % + 10
500.00 mA	10 uA		
5.0000 A	100 uA	0.4 % + 10	Unspecified
10.000 A	1 mA	0.4 % + 20	

Ohms

Range	Resolution	Accuracy
50.000 Ω	0.001 Ω	0.5 % + 20*1
500.00 Ω	0.01 Ω	0.2 % + 5*1
5.0000 kΩ	0.1 Ω	0.2 % + 1
50.000 kΩ	1 Ω	
500.00 kΩ	10 Ω	
5.0000 MΩ	100 Ω	0.3 % + 5
50.000 MΩ	1 kΩ	0.5 % + 20

Open Circuit Voltage : 1.3 Vdc
*1. Using Relative(△) mode

Diode Test

Range	Accuracy	Open Circuit Voltage
2.5000 V	2.0 % + 1	< 2.5 Vdc

Capacitance (5,000 Counts only)

Range	Resolution	Accuracy*1
5.000 nF	1 pF	1.0 % + 15*2
50.00 nF	10 pF	
500.0 nF	100 pF	
5.000 uF	1 nF	2.0 % + 3
50.00 uF	10 nF	3.0 % + 3
500.0 uF	100 nF	
5000 uF	1 uF	3.5 % + 5

* 1 Accuracy with film capacitor or better
* 2 Using Relative(△) mode

Temperature

Range	Resolution	Accuracy*1
-50 °C to 1300 °C	0.1 °C	± 3.0 °C
-58 °F to 2372 °F	0.1 °F	± 5.4 °F

* 1 With k-type thermocouple

Frequency

Range	Resolution	Accuracy
50.000 Hz	0.001 Hz	0.002 % + 3
500.00 Hz	0.01 Hz	
5.0000 kHz	0.1 Hz	
50.000 kHz	1 Hz	
500.00 kHz	10 Hz	

Minimum frequency : 0.5 Hz, Sensitivity : 250 mV

RPM IP

Mode	Range	Resolution	Accuracy
4 - stroke	120 - 20000 RPM	1 RPM	± 2 RPM
2 - stroke	60 - 10000 RPM	1 RPM	± 2 RPM

RPM IG

Mode	Range	Resolution	Accuracy
4 - stroke	60 - 20000 RPM	1 RPM	± 2 RPM
2 - stroke	30 - 10000 RPM	1 RPM	± 2 RPM

9 Selectable cylinders 1, 2, 3, 4, 5, 6, 8, 10, 12

Dwell

Range *	Resolution	Accuracy
0.0 ° - 356.4 °	0.1 °	1.2 ° / krpm + 2

4 Selectable trigger levels and ± trigger slopes
9 Selectable cylinders 1, 2, 3, 4, 5, 6, 8, 10, 12
* Specified ranges depend on ± trigger slopes, engine rpm

ms-Pulse and Duty cycle

Mode	Range	Accuracy
Multi-Point-Injection	0.50 ms - 250.00 ms	0.05 ms + 1
	0.0 % - 100.0 %	0.04 % / krpm + 2
Single-Point-Injection	0.50 ms - 250.00 ms	0.05 ms + 1
	0.0 % - 100.0 %	0.04 % / krpm / cyl + 2

Fuel Injection Detector (Both TBI & PFI)
4 Selectable trigger levels and ± trigger slopes
* Specified ranges depend on ± trigger slopes, engine rpm and number of cylinders

Audible Continuity Test

Application : For quick open-short test.
Threshold : The beeper turns on when the measured resistance is lower than 10 Ω, and turns off when greater than 70 Ω. Response time < 200 μS.

Ground Test

Application : Designed to locate bad grounds, voltage drops, intermittent connections, or any source of high resistance in an automotive electrical circuits and grounds.

Charging system test

Application : Designed to diagnose the battery and the alternator.

Battery Drain Tester

Application : Measures the vehicle's battery current when it is turned off.