4-1. EVALUATING CABLE AND CONNECTION VOLTAGE DROPS

NOTES

1. Circuits that handle high current levels commonly found in automotive starting and charging systems are adversely affected by high resistance connections and inadequate wiring diameter. The high current demanded by automotive circuits can cause high voltage drops to occur at various points in the circuit. These voltage drops represent a voltage loss to the circuit load, such as the starter motor or battery. A voltage drop is developed from the resistance of a dirty connection or a corroded cable in the path of high current. Needless to say, voltage drops cause poor performance.

2. For example, with 200 amps of starter motor current flowing through 0.01 ohm of resistance, a voltage drop of 2.0 volts is produced. The desired voltage drop should ideally be 0.0 volt. If the resistance is merely 0.02 ohm, the voltage drop is 4.0 volts. This illustrates that even the slightest resistance in a starter motor feed circuit can cause a significant voltage drop, resulting in poor starter motor performance.

3. The unwanted voltage drop consumes voltage needed for proper circuit performance. A voltage drop of just two volts needed by the starter motor, due to dirty connections and wiring, will greatly hamper starter motor performance. If replacing the starter motor doesn't solve the problem of a sluggish starter motor, an undesired voltage drop is frequently the problem.

4. OHM'S LAW explains the voltage drop principle. Remember from Section One, paragraph 1-21, the basic form of Ohm's Law, E = I x R. The current, I, multiplied by the resistance, R, equals the voltage drop, E.

For circuits that carry high currents, it is best to have no resistance, or 0.0 ohms, in the connections and wiring. Looking at Ohm's Law explains why.

E = 1 amp x 0.0 ohms resistance
E = 0.0 volt, or no voltage drop

E = 100 amps x 0.0 ohms resistance
E = 0.0 volt, or no voltage drop

Notice that when there is no resistance in the circuit, there is no voltage drop, whether there is one amp of current or one hundred amps of current.

5. When a small resistance develops in the path of current, Ohm's Law again explains how much voltage drop is developed.

I x R	= E
1 amp x 1 ohm	= 1.0 volt dropped
200 amp x 0.01 ohm	= 2.0 volts dropped
200 amp x 0.02 ohm	= 4.0 volts dropped

NOTES

Small resistances of 0.01 or 0.02 of an ohm cannot be measured without the use of laboratory accurate instruments. The typical service ohmmeter cannot accurately measure 0.01 or 0.02 of an ohm, so some other method is needed to detect resistance in the connections and wiring of high current circuits. In addition, according to Ohm's Law, the resistance only appears when high current is flowing. The technique to detect a high resistance connection in a high current circuit is to measure the voltage drop across the connection or wire when high current is flowing. Use a digital voltmeter that has a DC accuracy of $\pm 0.5\%$ or less. If excessive voltage drop is found, it indicates resistance is present.

6. The voltage drop measured is a direct result of the connection's resistance to high current. The higher the resistance, the higher the voltage drop present. It is also possible to measure the voltage drop of a length of cable to be sure it hasn't developed undesired resistance.

7. When measuring circuit connections and cables for a voltage drop, some voltage drop may be found. It therefore becomes necessary to establish what is an acceptable voltage drop and what is not. The Society for Automotive Engineers, S.A.E., has established the maximum voltage drop that is permissible for automotive electrical circuit components.

0.0 volt for small wire connections

0.1 volt high current grounds

0.2 volt for battery/starter cables

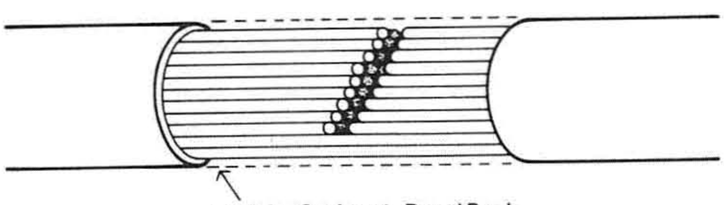
0.3 volt for switches or solenoid contacts

Before applying the voltage-drop troubleshooting technique to actual circuits a more detailed description of voltage drops in cables and connections will help in understanding the principle.

4-2. VOLTAGE DROPS IN CABLES

A heavy duty cable is shown with a break in the individual wires of the cable. Notice several strands are not making contact. This greatly reduces the high current-handling capability of the cable because there are less paths for current to pass through the cable.

Broken Heavy Duty Cable

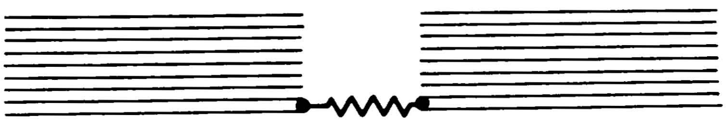


NOTES

1. In the illustration only two strands are left to pass the high current. The interrupted paths, represented by the broken wires, force the current to flow through the remaining strands. This presents substantial resistance to high current levels passing through the remaining cable strands.

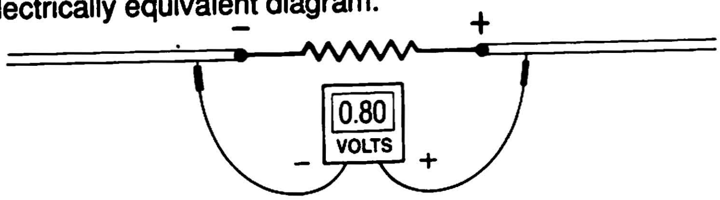
2. An ohmmeter cannot detect these broken wires because either of the two remaining strands can easily pass the ohmmeter test current. The ohmmeter will read 0.0 ohms. This explains why the ohmmeter is not a valid test to look for cable resistance that would produce voltage drops.

3. Here is how a cable with broken strands electrically appears to high current.



The resistance offered by the two remaining strands, as it tries to handle the high current demands of the circuit, develops a voltage drop. It can be detected by a digital voltmeter as long as the normal high current of the circuit is flowing when the voltage drop measurement is made.

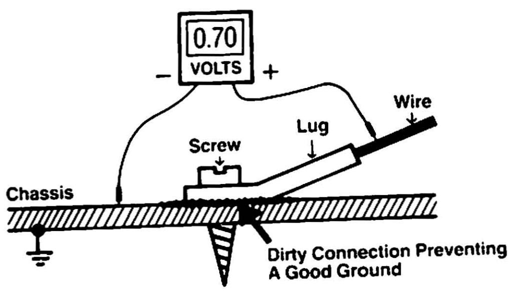
Measuring across the cable with the digital voltmeter reveals a voltage drop directly proportional to the resistance present in the cable. This is shown below with an electrically equivalent diagram.

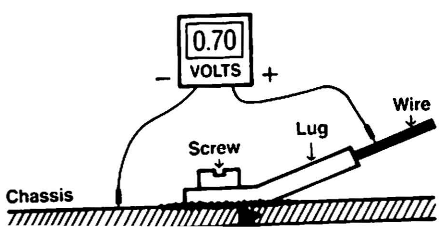


"Bad Cable"

4-3. VOLTAGE DROPS IN CONNECTIONS

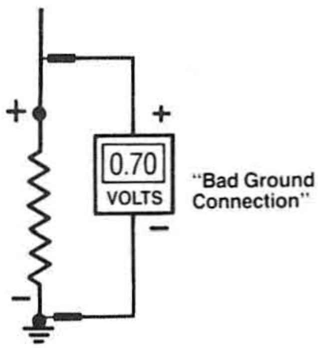
The diagram below shows a dirty ground connection. At any point where the lug surface contacts the chasis, an electrical connection exists. Corrosion or other foreign material, such as paint or grease, can prevent a good electrical connection.





The corroded connection presents a resistance to high circuit current. The resistance can be detected by a voltage drop measured with a digital voltmeter. An ohmmeter may not reveal any resistance being present because the very small ohmmeter test current is able to pass through the corroded connection with no resistance.

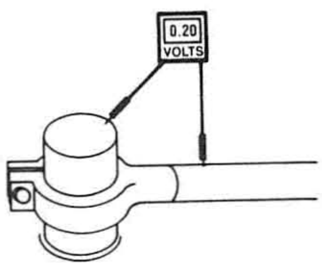
Here is what the corroded connection looks like electrically when high current is flowing. The bad connection is represented by the resistance symbol. The voltage drop developed by the connection's resistance is detected by the digital voltmeter.



The resistance is detected by measuring the voltage drop completely across the ground connection. Measure from the wire itself to the metal chassis. Remember, when testing with an ohmmeter, the ground connection will probably check good since the small ohmmeter test current can pass through the ground connection without encountering resistance.

4-4. VOLTAGE DROPS AT BATTERY POSTS

The voltage drop across the battery post and connection should not exceed 0.2 volt. Notice the digital voltmeter leads measure the voltage drop of the connection between the cable clamp and battery post, as well as the connection of the battery cable where it enters the battery cable clamp. This is necessary because a bad connection can exist at either point.

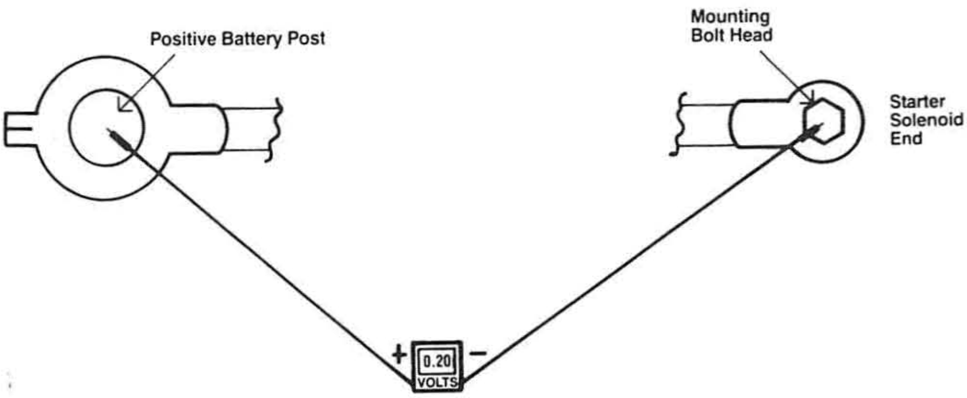


If the voltage drop exceeds 0.20 volt, clean the battery post and inside area of the battery clamp. Measure the voltage drop with the starter motor engaged. This puts the highest current load through the battery cables. Without high current, the voltage drop may not be measurable. After the voltage drop has been eliminated, cover the entire metal connection with a high temperature grease.

NOTES

4-5. HOW TO CHECK VOLTAGE DROP OF BATTERY CABLE

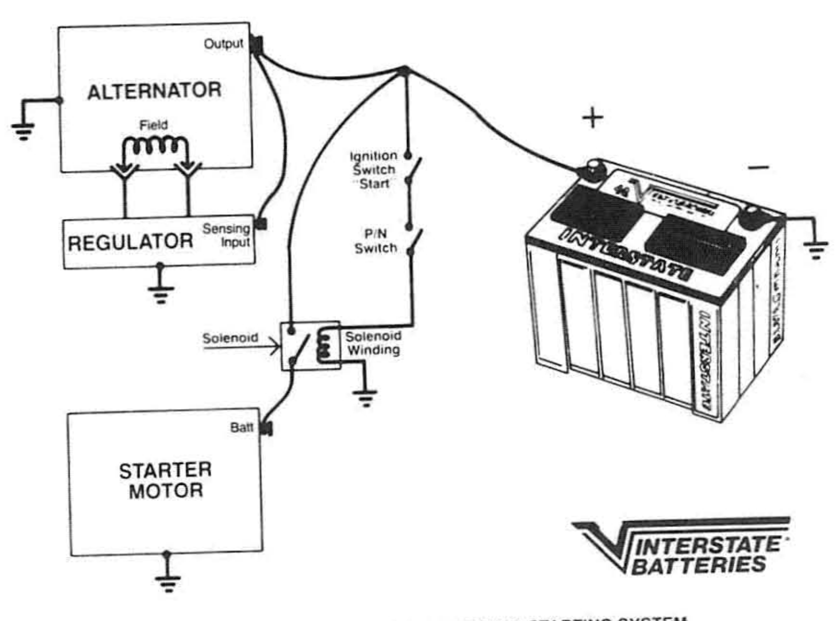
Notice the digital voltmeter test leads are connected between the positive battery post itself, and to the connecting bolt at the starter solenoid connection.



The voltage drop of the cable should not exceed 0.20 volt with the engine cranking and normal starter motor current draw flowing. A note of caution performing this voltage test: Remove at least one voltmeter test lead before the starter motor is turned off. Sometimes the starter motor can generate a spike voltage and damage the voltmeter.

4-6. CHECKING VOLTAGE DROPS IN THE CHARGING SYSTEM

The schematic shown below is a block diagram of a typical charging and starting system.



BLOCK DIAGRAM OF TYPICAL CHARGING-STARTING SYSTEM WITH NEGATIVE GROUND

NOTES

NOTES

Let's apply the measuring of voltage drop technique to the charging system to find unwanted resistance to current. The diagram of the charging and starting system is very similar to the same diagram shown at the end of Section Three, this time with the starting system added.

The battery, alternator, regulator, starter motor, switches and relays are connected to form the electrical charging and starting system. The wiring cables and connections must transport high current levels throughout this system without any voltage losses in the form of voltage drops.

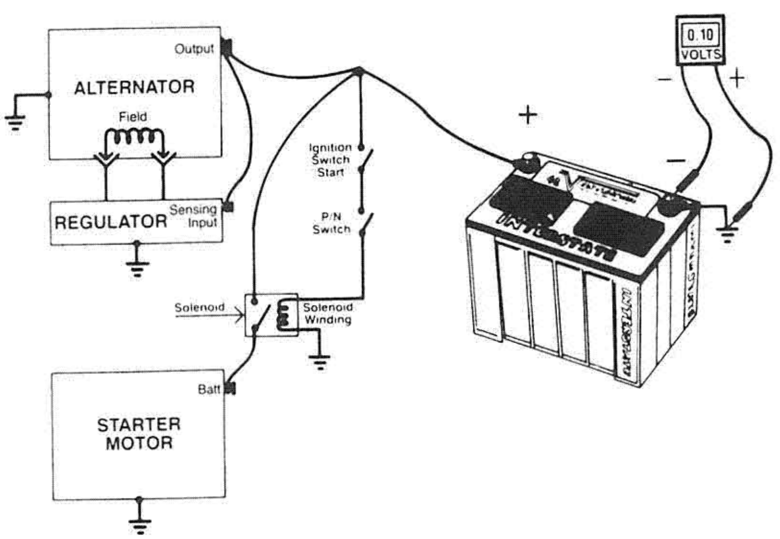
The reduction of normal current levels is the result of resistance developing in connections, or cables that can only be detected by measuring the voltage dropped across each connection and cable. If the measured voltage drop exceeds S.A.E. specified limits given in paragraph 4-1, a repair is necessary to remove the unwanted resistance.

Following in Paragraphs 4-7, 4-8 and 4-9 are three examples of voltage drop measurement applied to the charging system. Each shows how to test for critical voltage drops that could hinder proper battery charging or vehicle accessory operation. Note the placement of the digital voltmeter test leads and the maximum permissible reading.

4-7. MEASURING BATTERY GROUND CABLE AND GROUND CONNECTION RESISTANCE

There are two battery grounds on most vehicles. One ground connects to the engine block to ground the starter motor and the alternator. The other connects all accessories to the fender well, to ground them to the chassis. The voltage drop method to check both ground cables is the same and is illustrated in the diagram below. Follow the correct procedures below.

CHECKING BATTERY GROUND CABLES IS THE FIRST CHECK TO MAKE ON A CAR WITH ELECTRICAL OR ELECTRONIC SYSTEM PROBLEMS.



NOTES

The procedure to check each ground is different. The following steps are given to check both under conditions that will send maximum current through each ground cable to reveal a problem.

CHECKING THE ENGINE GROUND:

STEP 1: Ignition key off.

STEP 2: Place voltmeter black test lead on battery negative post, voltmeter red test lead on the engine block.

STEP 3: Crank engine and read the engine block ground voltage drop. Remove one test lead, THEN stop engine from cranking. Remove voltmeter. Voltage drop should not exceed 0.1 volt.

CHECKING THE ACCESSORY GROUND:

STEP 1: Ignition key off.

STEP 2: Place voltmeter black test lead on negative battery post, voltmeter red test lead on the fender well or other suitable chassis ground connection (metal frame).

STEP 3: Turn ignition key to on position, engine NOT running.

STEP 4: Turn on all accessories, such as high-beam headlights, high speed blower, windshield wipers, depress brake pedal, activate turn signals, open driver door to activate courtesy lights, turn on radio, etc.

STEP 5: Read the voltage drop of accessory ground. Turn all accessories off and disconnect the voltmeter. Voltage drop should not exceed 0.1 volt.

TEST CONDITIONS: To run the voltage drop tests for Paragraph 4-8 and 4-9 (on the next page) the charging system should be placed under a load. Use one of the following two methods:

1. Place a load tester across the battery terminals while the engine is running. Adjust the load tester for 75% of the maximum current rating of the alternator.

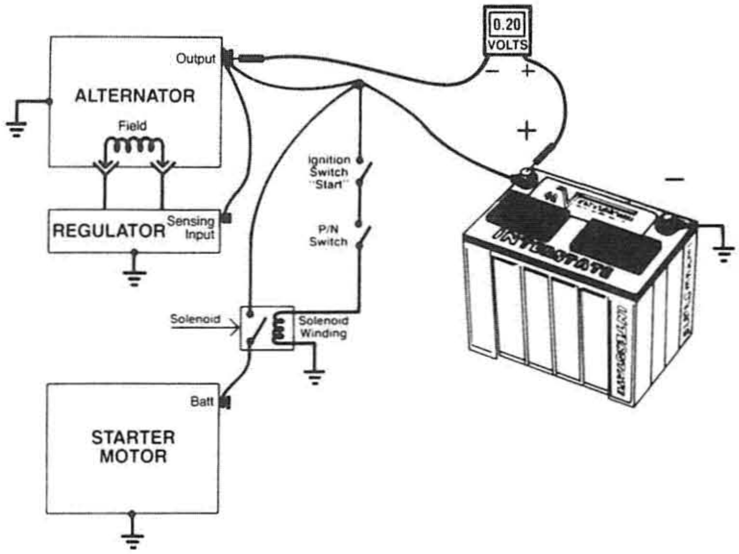
2. Place the digital voltmeter test leads on the vehicle where the voltage drop measurement is to be made. Start the engine and note the voltage drop as soon as the engine begins running and the alternator output is giving the battery its initial recharge.

Any voltage drop that exceeds that shown in the diagram should be investigated and repaired. In many cases, cleaning the connection or replacing the cable is sufficient to correct the problem.

For the most accurate reading, it is recommended that a digital voltmeter with at least a ±0.5% DC accuracy, set to the two volt range, be used to measure these very small voltage drops.

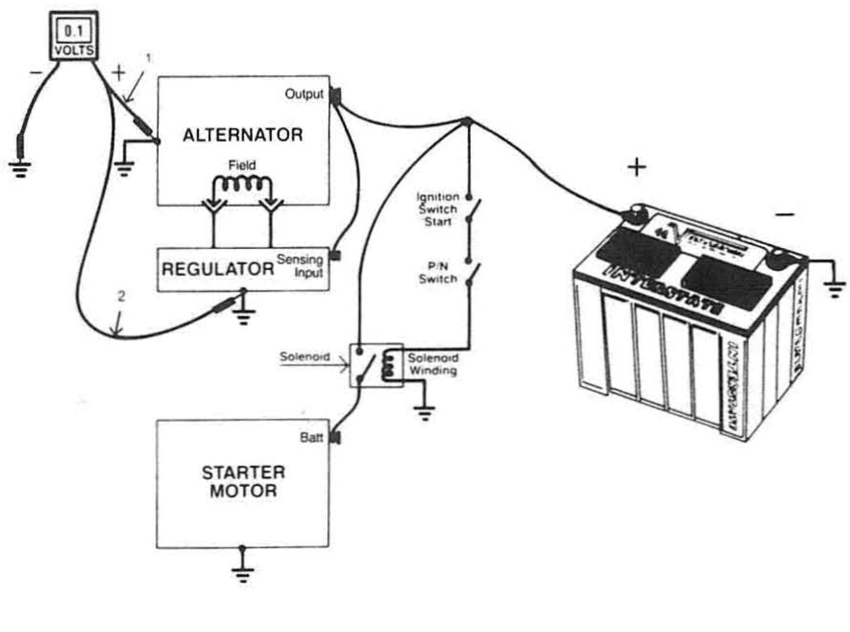
4-8. MEASURING VOLTAGE DROPS OF CHARGING CIRCUIT

Engine running at 2,000 rpm and high-beams turned on. The voltage drop should not exceed 0.2 volt. A reading above 0.2 volt should be serviced. Clean connections at both ends. Measure voltage drop again. If still too high, replace cable.



4-9. MEASURING VOLTAGE DROP OF GROUND CONNECTIONS FOR THE ALTERNATOR AND REGULATOR

Engine running at 2,000 rpm and high-beams turned on. In Step 1, the voltage drop of the alternator ground is measured. The reading should not exceed 0.1 volt. In Step 2, the digital voltmeter's positive test lead is moved to the voltage regulator ground. The reading should not exceed 0.1 volt. Any reading above 0.1 volt should be serviced by cleaning the connections involved or installing new wire.



NOTES

4-10. BATTERY DRAIN, IGNITION KEY OFF

NOTES

1. Even with a good battery and a properly functioning electrical charging system a car battery can be drained overnight. The battery is discharged when the ignition key-off battery drain exceeds the manufacturer's specifications by a significant amount. The current drain is caused by an electrical or electronic system failure that allows excessive battery current to flow with the ignition key off.

2. Normal key-off drain should not exceed 25 milli-amps (.025 amps) for most cars. On some 1986 or higher models with large electronic systems, the key off drain approaches 50 milli-amps (.050 amps). A good battery can handle 25 - 50 milli-amp drain over a long period.

3. The key-off current drain is necessary to "keep alive" computer memory circuits, such as diagnostic memory. There also is a very small current drain through the alternator, regulator and digital clock. As long as the drain is within "specs", there is no problem. If current drain is too high, from a defective solid-state component on the car, the battery could be drained dead overnight. The service technician must be able to detect and measure the amount of key-off drain to find the problem.

4. Key-off drain problems only show up when the car is parked overnight or over the weekend. It also depends on the amount of current drain and length of time he car is not driven. It only takes 25 hours to drain a 100 ampere-hour battery with a key-off current drain of 4.0 amps. If the car is never left parked for long periods of time, a key-off drain problem may not be detected. These cars may have a history of the battery needing water more than usual.

5. Other circuits can contribute to key-off drain. A typical example is a courtesy light left on in the trunk, or under the hood and a dome light that doesn't go off when the doors are closed. When key-off battery drain is excessive, suspect any electrical component that has battery voltage applied with the ignition key "OFF".

6. Problem faced by the auto service technician:

   a. Measuring key-off drain

   b. Confirming the repair has corrected the problem

There is a method to quickly and accurately measure ignition key-off battery drain, but before we explain the recommended method, the following are some ways that DO NOT work.