AVI

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PARASITIC CURRENT DRAW

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PARASITIC CURRENT DRAW

WHAT IS PARASITIC CURRENT DRAW?

In review and in automotive terms, a parasitic current draw is an electrical load that draws current from the battery when the ignition is turned off. Some are considered normal, some above normal. Regarding what's normal, we have the various electronic devices sometimes "affectionately" referred to as F.R.E.D.s. (Frustrating Ridiculous Electronic Device) connected to hot all-the-time battery power circuits ebbing away in tiny amounts on the battery. FREDs often draw a few mA (milliamps) because of something called KAM (Keep Alive Memory). Whether it's the clock in the radio or the last known position of the memory mirrors, these tiny amounts of KAM induced current typically will only add up to 20 or 30 mA at most. That means the vehicle can sit parked for days, even a few weeks without any problems of excessive battery drain that might prevent starting.

As long as the vehicle is driven periodically in order for the alternator to recharge the battery there is no problem. A problem may occur, however, in situations such as new vehicles in dealer stock, long term airport parking situations, the driver who parks the sports car for the winter or the retiree who leaves their "northern car" parked in the garage while a second car gets used in more winter friendly place.

To get down to really "techie" terms, you can calculate just exactly how long your customer's battery will keep its head above water, electrolyte-ly speaking of course. It all boils down to the actual parasitic drain, the reserve capacity (in minutes) of the vehicle's battery and the amount of parking time.

As noted in a typical TSB for a late model GM vehicle, the Reserve Capacity (RC) rating multiplied by 0.6 gives the approximate available ampere-hours (AH) from full charge to complete rundown. Somewhere between full charge and complete rundown, the battery will reach a point at which it can no longer power the starter. Using up about 40% of the total available AH will usually take a fully-charged battery to a no-start condition at moderate temps of 25°C (77°F). Put another way, for a typical battery in a storage situation, depleting the available AH by 20 to 30 AH will result in a no-start situation.

Important: If the battery begins storage at 90% of full charge, reduce the available AH accordingly.

Although the maximum rule of thumb recommended parasitic drain is around 30 mA (0.030 amps) a typical drain usually falls into the 7-12 mA range, even though some luxury vehicles do approach the maximum. Multiply the drain (in amps) by the time (in hours) the battery sits without being recharged. The result is the amount of AH consumed by the parasitic drain. The actual drain may be small, but over time the battery grows steadily weaker.

Here's an example: A vehicle with a 30 mA drain and a fully-charged 70 RC battery will last 3 weeks. But if that battery is at only 65% of full charge it is going to last only 2 weeks before giving the customer that "click click click" complaint. The parasitic drain will be fairly constant over a range of temperatures. The important temperature is that of the vehicle at the time a start is attempted. Colder temperature raises the threshold of a no-start by increasing the residual power needed. When the temperature falls to 0°C (32°F), the battery will be able to put out only about 85% of its normally available starting power, and the engine may need as much as 165% of the usual power to start.

PARASITIC CURRENT DRAW

WHAT IS PARASITIC CURRENT DRAW?

The combined effect of these two factors is to reduce the number of days the battery can put up with a parasitic drain. At 0°C (32°F), the battery can last only half as long as it could at 25°C (77°F). And at -19°C (0°F), the days are reduced to 25 percent of the days it could have lasted in warmer temperatures. Now go the other direction, and summer days of 25°C (77°F) or greater increase the battery's self discharge. If the vehicle is located where the temperature is averaging 32°C (90°F), an additional 5% to 10% of the available ampere-hours will be lost in a month due to self-discharge within the battery. At temperatures below the moderate range, self-discharge is unnoticeable compared to the parasitic loss.

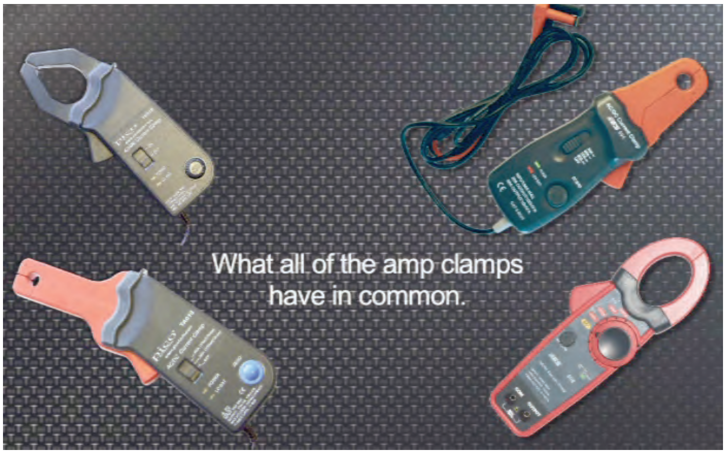
How much should each module's parasitic drain be on the battery? While following chart certainly is not a set of exact specifications to pass or fail "FREDs" it does give good estimates for the parasitic drains of various devices.

Component	Normal Draw	Maximum Draw	Time-Out (Minutes)
Anti-Theft System	0.4	1.0	...
Auto Door Lock	1.0	1.0	...
Body Control Module	3.6	12.4	20
Central Processing System	1.6	2.7	20
Electronic Control Module	5.6	10.0	...
Electronic Level Control	2.0	3.3	20
Heated Windshield Module	0.3	0.4	...
HVAC Power Module	1.0	1.0	...
Illuminated Entry	1.0	1.0	1
Light Control Module	0.5	1.0	...
Oil Level Module	0.1	0.1	...
Multi-Function Chime	1.0	1.0	...
Pass Key Decoder Module	0.75	1.0	...
Power Control Module	5.0	7.0	...
Retained Accessory Power	3.8	3.8	...
Radio	7.0	8.0	15
Twilight Sentinel Module	1.0	1.0	...
Voltage Regulator	1.4	2.0	...

Intermittent parasitic lad can occur because of a memory device that does not power down with ignition off. With an intermittent parasitic load, battery draw can be greater than 1.0 amp.

TOOLS OF THE TRADE

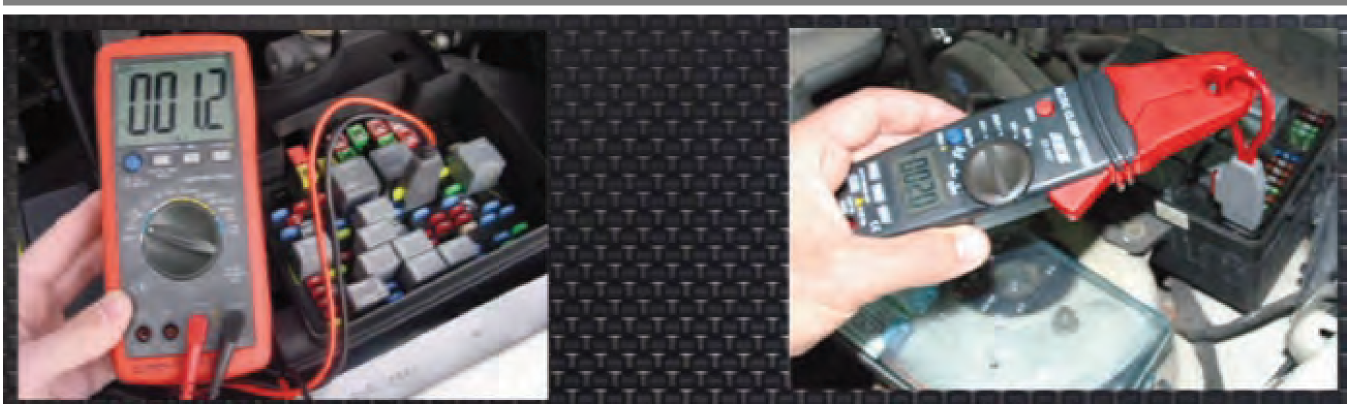
AMP CLAMPS



Question: What do the AMP Clamps pictured left all have in common? Answer: All of them take a magnetic field that is traveling through a wire and turn that magnetic field, also known as current, into a millivolt reading. Also, they all are capable of plugging into a Digital Multi Meter (DMM).

Another question to ask is how they all differ from one another. The amp clamps with the larger openings fit great over larger cables such as the battery cables but they are not suitable for parasitic current draw testing. This is a key issue you need to know and understand when testing for parasitic current draw. These types of amp clamps are great for testing 30-100 amps in situations such as alternator output and charge rate or starter draw testing, but for parasitic current draw testing, you want to use an amp clamp that can measure as low as 2 – 3 milliamps. To measure milliamps in this low of a range, you want to use the amp clamp with the smaller opening.

THE FUSE BUDDY



Using an amp clamp and/or DMM to diagnose a parasitic current draw does present one simple problem. If the parasitic draw was present when you connected the battery cable into series with the meter, and if you had a good fuse in the meter…and you didn't forget and leave the meter in series with the cable when you opened the door (a 2 amp dome light trying to make it's circuit path through a ½ amp meter fuse) or worse yet, tried to start the engine. The latter scenario would be a starter trying to source 200 amps through the meter's ½ amp fuse. You could connect the meter leads into the battery cable circuit via the meter's 10 amp ammeter circuit and it least it could source the dome light when you opened the door without a problem.

If you did forget and try to start the engine, you might see the meter's 10 amp fuse pop or you might be looking at a toasted meter. Some meters don't fuse their higher current ammeter section. Often times, as in the case of Fluke, the fuses for both the low current (300 mA) and high current (10 amps) sections are fused. The problem is, the fuses are expensive relatively hard to locate.

TOOLS OF THE TRADE

THE FUSE BUDDY

Here is the solution to all of this. Connect an inline fuse into series with your meter's leads. Have a fuse slightly smaller than your meter's low end rating (200 mA) when you are testing for low current parasitic drains and another inline fuse dedicated to putting in series with your meter's leads when it's in the high current setting (8 amps) so that if you open the door or crank the motor, you only have to replace an automotive fuse and not an exotic and expensive Fluke fuse or a very expensive meter.

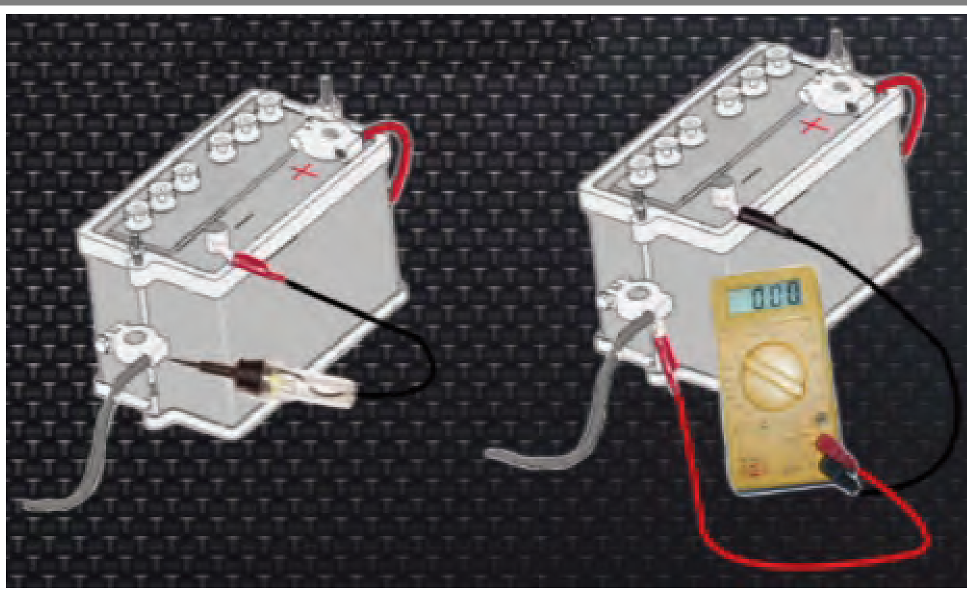
If you think this sounds like a hassle, it is. The alternative is of course a low current inductive amp probe. Beware of the inductive amp probe. It must be accurate enough to measure current as low as 10 mA, which would be a realistic normal parasitic current draw for some vehicles.

TOOLS OF THE TRADE

THE FUSE BUDDY

Along with the two types of fuse buddies shown on the previous page are the fuse buddies with a meter built right into them(pictured right). This type of fuse buddy does not rely on the use of an amp clamp connected to a DMM. This has the DMM built right into the tool simplifying the circuit isolation process.

THE KNIFE SWITCH

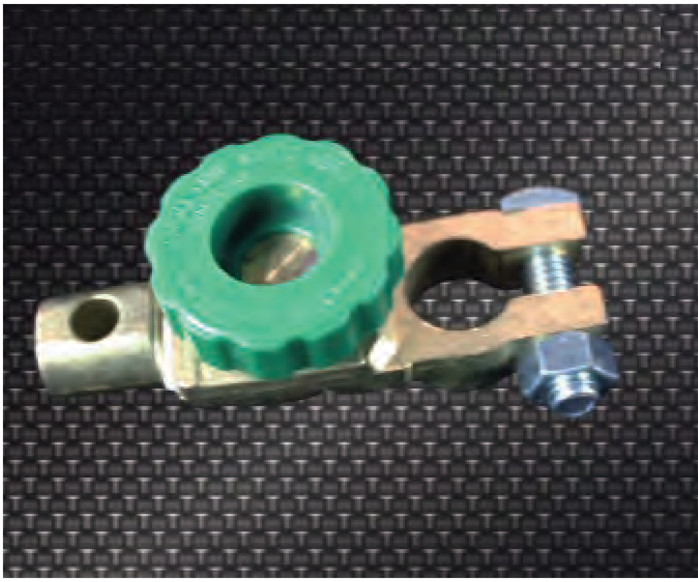


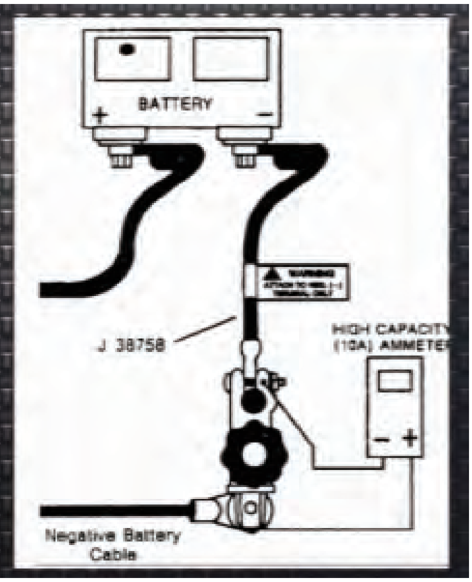
Connecting a DMM to read amps in series with the battery cable could mean a possible loss of an intermittent condition. The vehicles produced today have an array of modules all using KAM can and do have intermittent problems.

When you disconnect the battery cable then reconnect it through the DMM, the intermittent problem will oftentimes disappear. This means that when you have an intermittent parasitic current draw, the last thing you want to do is disconnect anything from the power source. Disconnecting the power source from the vehicle will cause the control modules within the vehicle to reset.

TOOLS OF THE TRADE

THE KNIFE SWITCH





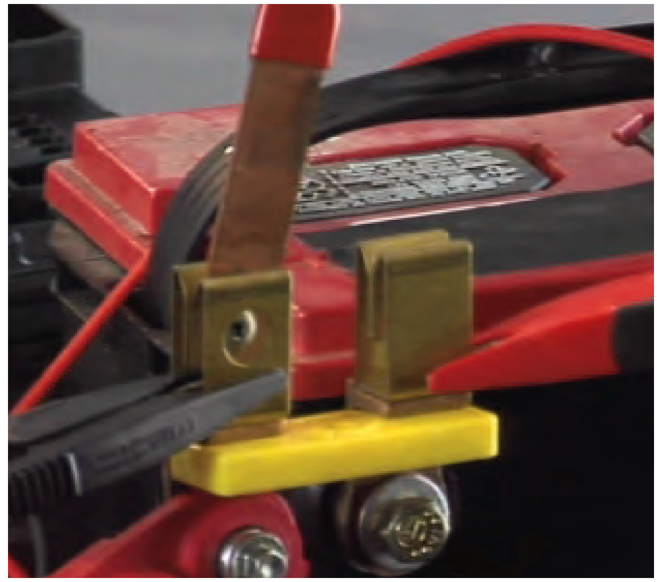
The answer to this problem is to install what is commonly known as a Knife Switch or battery disconnect switch. A knife switch is a type of switch used to control the flow of electricity in a circuit. It is composed of a hinge which allows a metal lever, or knife, to be lifted from or inserted into a slot or jaw. The hinge and jaw are both fixed to an insulated base, and the knife has an insulated handle to grip at one end. Current flows through the switch when the knife is pushed into the jaw. Knife switches can take several forms, including single throw, in which the "knife" engages with only a single slot, and double throw, in which the knife hinge is placed between two slots and can engage with either one.

For the most part a battery disconnect switch is usually installed on a travel trailer or RV to prevent battery drainage. Although travel trailers do not use a battery for powering an engine, the trailer uses a battery, or set of batteries, for powering auxiliary power, like lighting and appliances. During trailer storage periods, any electrical devices plugged into outlets can slowly drain the connected battery's power, even if the device is switched off. The device acts as a load on the battery, slowly trickling power from the battery to the device until the battery is completely drained. A battery disconnect switch creates a separation between the connected battery and the device, effectively blocking any current flow and preserving battery power.

Some switches have different features, including switching to another battery bank. This switch disconnects one battery and activates another without stopping the power supply to appliances. This feature prevents a temporary power loss to appliances in use when switching battery sources. Another switch variation comes with a key. Removing the key activates the battery disconnect switch, blocking current flow. The key is especially helpful when the travel trailer is in storage. No mischievous person can activate the switch without the key. For our purposes we will be using the knife switch to diagnose intermittent parasitic current draws.

TOOLS OF THE TRADE

THE KNIFE SWITCH



By installing a knife switch to the vehicle you will be able to test the vehicle for parasitic draw without having to disconnect the battery. Yes, you do need to disconnect the battery to install the knife switch but after it is installed you can simply return the car to the customer and have them drive the vehicle as they normally would for a few days then return it to you for further testing.

Once the vehicle is returned to you with the knife switch still installed you can begin testing. When you are ready to begin testing all you need to do is connect the leads to the appropriate jacks on your meter, then to the battery. Connect one lead to one side of the switch, and the remaining lead to the other side of the switch. It does not matter what lead you connect to what side, just make sure they are connected to opposite sides of the switch.

As we all know, the current will follow the path of least resistance. With the switch closed the path of least resistance will be through the knife switch rather than the high impedance meter. When you open the switch, the current has no other choice than to travel through the meter. At this point you can leave the meter connected and observe the meter reading as things within the vehicle begin to power down or “go to sleep”.

With everything at rest you should see something in the range of 15 – 40 milliamps of current draw. If you see something like 150 milliamps, you have some type of parasitic draw. This is the simplest way of testing if you do not want to use an inductive amp clamp.

ELECTRICAL REVIEW

BASIC AUTOMOTIVE ELECTRICAL THEORY

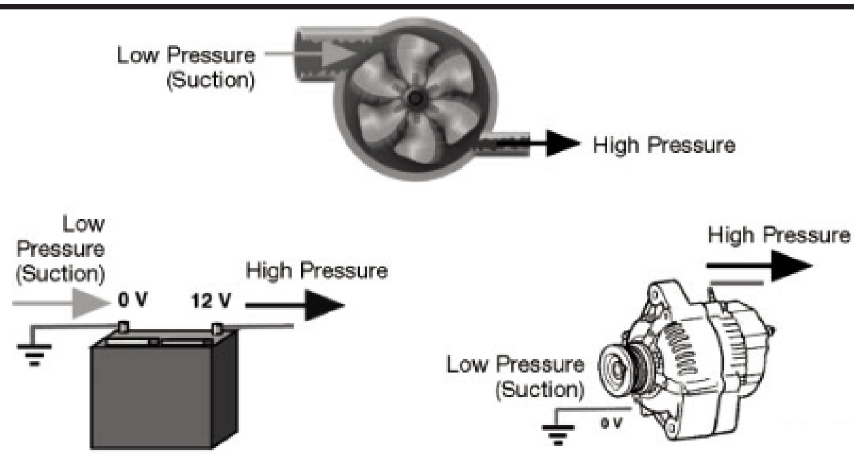
VOLTAGE

The first step in being able to effectively diagnose electrical problems is to have a good understanding of basic electrical principles. We will be reviewing each of them with emphasis to their on-car applications and how these concepts are applied when you are diagnosing an electrical problem.

Simply put, think of voltage as electrical pressure or pressure differential. The difference in pressure that makes any hydraulic pump work is virtually the same for electrons. The pressure differential provided by the positive and negative terminals of the battery causes the electrons in a conductor to move when the two terminals are connected together. This movement or flow of electrons is used to perform useful work. Whenever work is done, pressure is used up. We can measure where work is done in an electrical circuit by measuring where voltage is used up.

Voltage as Pressure

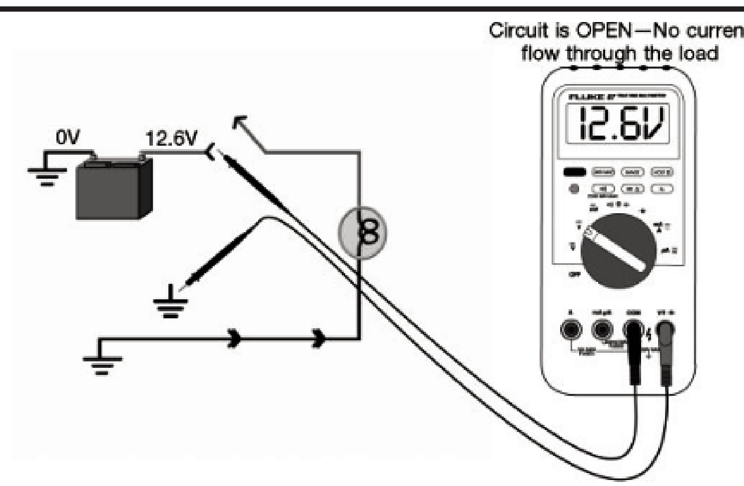
Like the pressure/suction that a pump provides a fluid, a battery or alternator provides for an electrical circuit.



When working with on-car electrical problems, there are two different methods of voltage measurement. A Technician can either measure an open circuit voltage or a voltage drop. Open circuit voltage is measured when there is no current flow through the circuit. A voltage drop is measured dynamically while there is current flow through the circuit. Both open circuit voltage and voltage drop testing have their place in the diagnostic process. Information from each measurement can be helpful if used appropriately.

Measuring Open Circuit Voltage

This measurement tells you if there is voltage present at a terminal. It cannot tell you if there is any circuit resistance up to that point.



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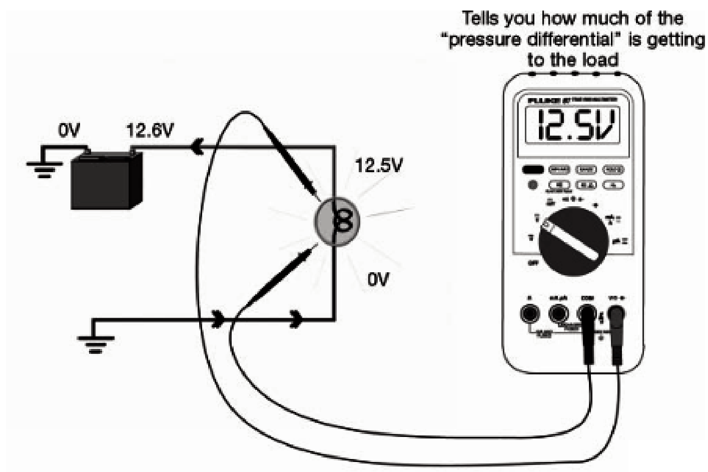
BASIC AUTOMOTIVE ELECTRICAL THEORY

VOLTAGE

Measuring Voltage Drop

This measurement can only be done if there is current flow in the circuit. It accurately tells you how much voltage is actually available at the load, or the amount of voltage lost across connections or wiring on either the ground or power side of the circuit.



NOTES

ELECTRICAL REVIEW

BASIC AUTOMOTIVE ELECTRICAL THEORY

VOLTAGE DROP

Whenever current passes through any component, voltage is used up. The voltage used up is called Voltage Drop (ΔV). (ΔV) is the Greek letter delta. The symbol delta means “change in”. When we use the abbreviated D V it indicates “change in voltage” or Voltage Drop. The voltage drop (ΔV) of a component is directly proportional to the resistance of the component. The greater the resistance the greater the voltage drop (ΔV). Low resistance components like fuses, switches, wires and connectors should have very low ΔV. As a general rule the maximum ΔV allowed for these components is less than 0.1V per component or connector.

Higher resistance components are usually referred to as loads. Loads use their resistance to convert current into work (light, heat, motion). This conversion causes voltage drop (ΔV) as the electrical pressure is used up. Typical loads include lamps, motors, relay coils and most sensors. Voltage drop (Δ V) is always proportional to resistance. The higher the resistance, the higher the ΔV. In any electrical circuit, all the voltage will always be used up. Adding up all the voltage drops in a circuit will always equal source voltage.

CURRENT FLOW

Current is the term used to describe the flow of electrons through the circuit. It is this flow of electrons that does the “work" in the circuit. The unit for measuring the amount of current flow is the Ampere or Amp (A). One Amp equals 628 billion electrons per second flowing through a circuit.

Current will only flow if there is a complete circuit between a source of higher voltage (power) and a lower voltage (ground). Voltage is the pressure that pushes the electrons through the circuit and Amperes is a measure of the number of electrons flowing. The combination of amperage with voltage determines the amount of power that is being used at the load in the circuit. Power is measured in Watts (W). The amount of power that is being used by a load can be determined by multiplying the amperage through the load by the voltage drop across the load.

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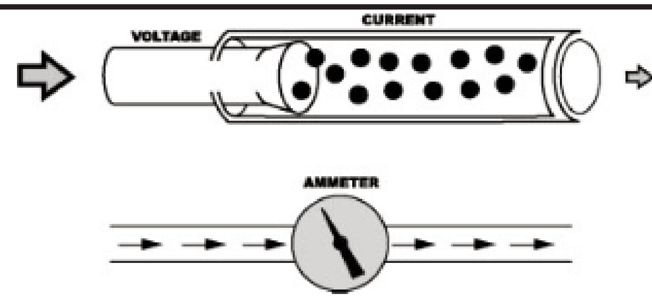
CURRENT FLOW

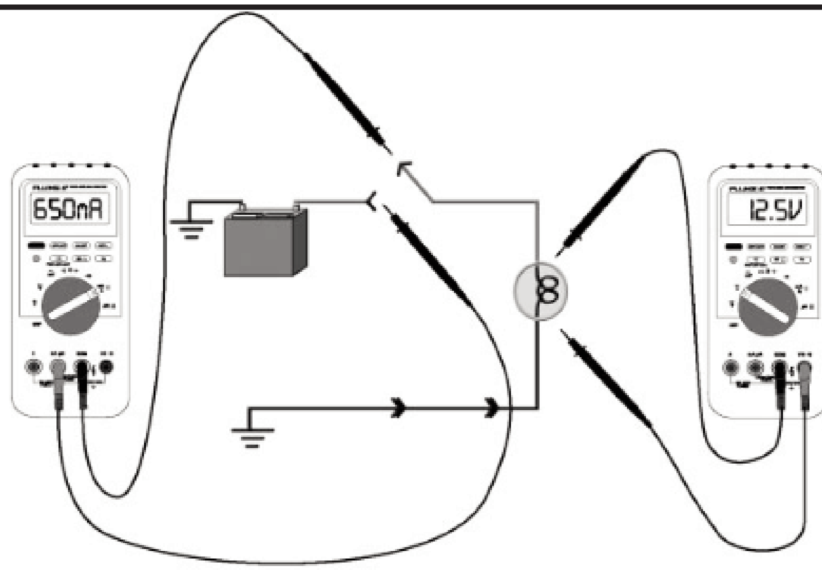
Current Flow

Measured in Amps (A) or milliamps (mA), current flow is caused when a voltage or pressure differential exists at both ends of a conductor.



Measuring Amperage

Note that the ammeter is connected in series. The circuit must be "broken" so that the meter could be placed "in-line" with the circuit. The wattage of the light bulb can be determined by multiplying the amperage and the voltage drop.



Amps x Voltage Drop = Watts

0.650A x 12.5V = 8.125W

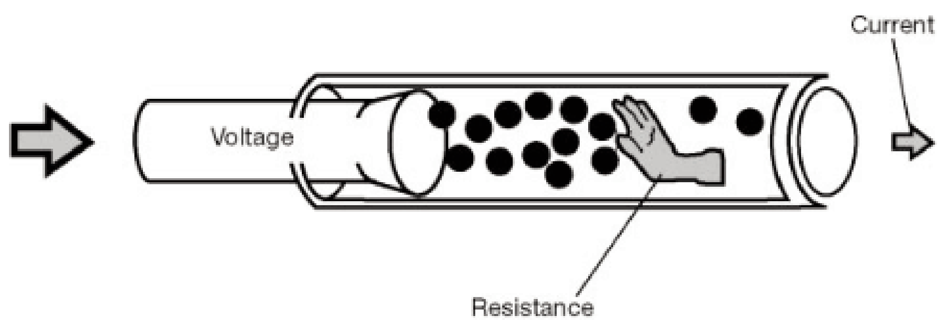
ELECTRICAL REVIEW

BASIC AUTOMOTIVE ELECTRICAL THEORY

RESISTANCE

Resistance

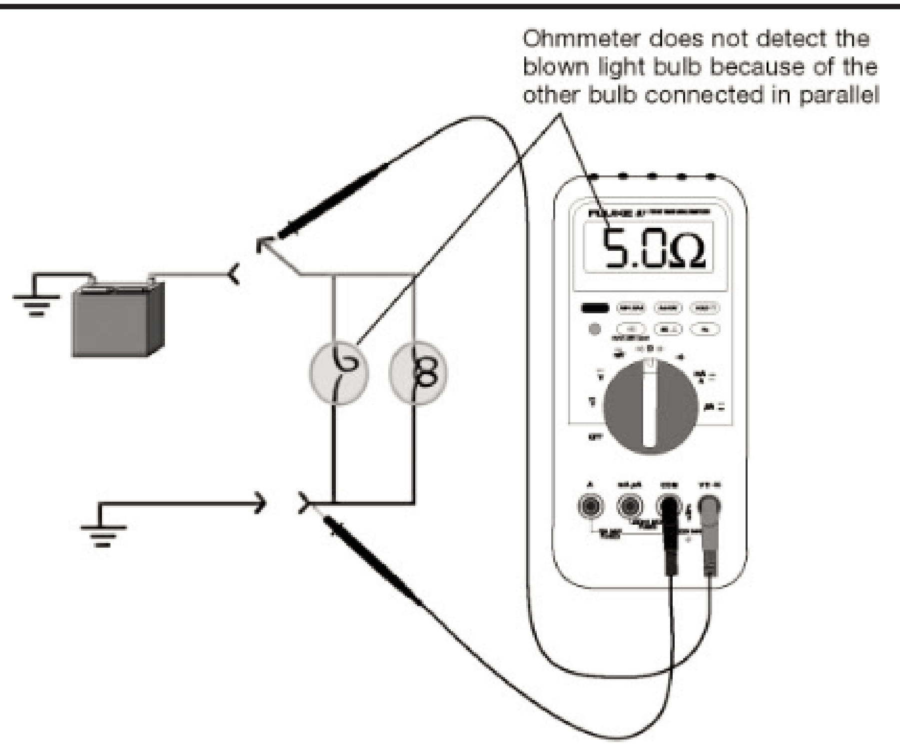
Resistance is the opposition to current flow. Resistance determines the amount of current flow as long as the voltage stays constant. In theory, the load should be the only resistance in the circuit.



Electrical resistance describes how much something opposes current flow. This opposition to current is measured in Ohms (Ω) or in thousands of Ohms (kΩ). In every circuit, resistance regulates current. In a “perfect" circuit, the only resistance would be the load you are operating with the circuit. But even the best of conductors (materials which allow the flow of electrons) have a certain amount of electrical resistance. Materials which have an extremely high resistance are called insulators.

Using an Ohmmeter

When using an ohmmeter, disconnect the component from the circuit to isolate the measurement from other current flow paths or voltage sources. In this case, the ohmmeter does not measure the open circuit at the burned out light bulb.



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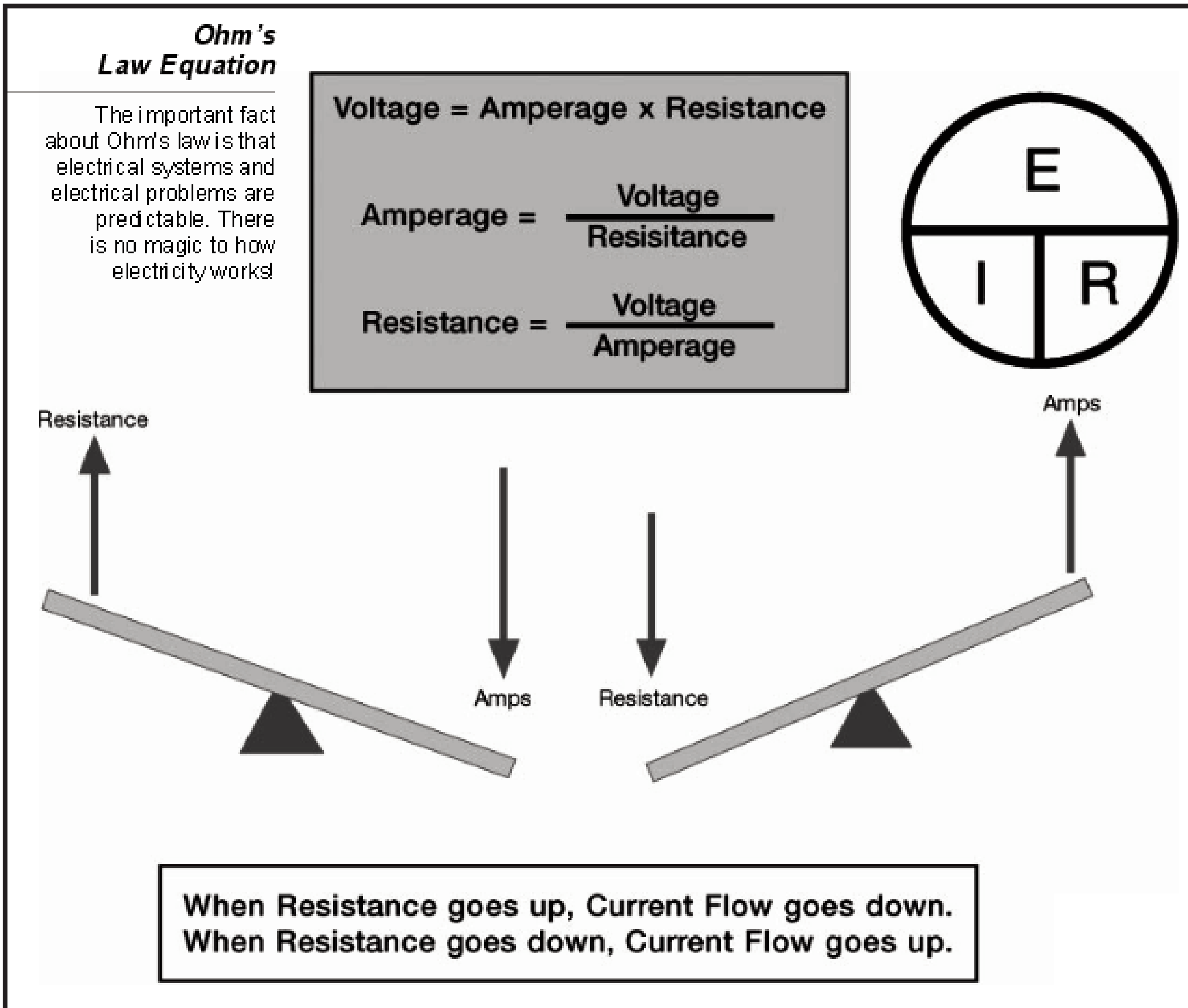
BASIC AUTOMOTIVE ELECTRICAL THEORY

OHMS LAW

In short, Ohm's law states that current in a circuit will always be proportional to the voltage and resistance present. Voltage, amperage, and resistance in a circuit work in proportion to each other. Mathematically, we can always predict what electricity is going to do in a circuit, as long as we know what any two of the three values are. So, for example, if you knew what the voltage and resistance were in a circuit, you could easily determine exactly how much current there would be in the circuit.



ELECTRICAL REVIEW

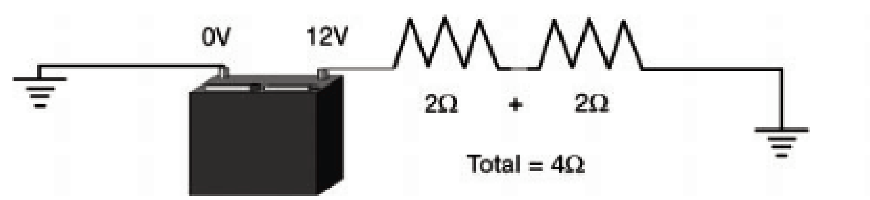
BASIC AUTOMOTIVE ELECTRICAL THEORY

OHMS LAW

One of the more difficult concepts concerning Ohm's Law has to do with calculating resistance in a circuit. Series circuit resistance is probably the easiest concept to understand because it is simply an adding up of all the resistances in a circuit in order to get the total resistance.

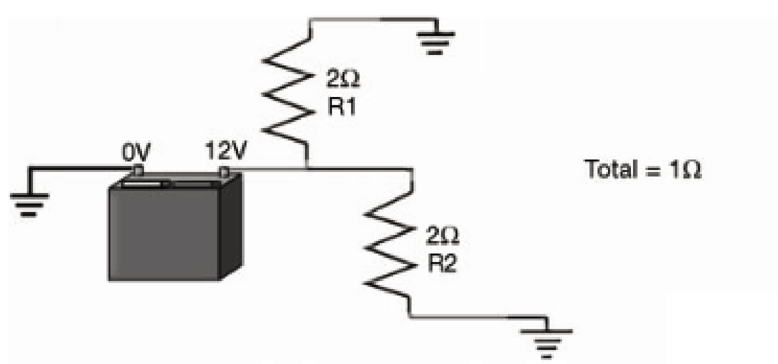
The total resistance is the sum of all resistances in the circuit. This resistance will affect the number of amps which can flow through the circuit. Ohm's Law says that amps can be found by dividing ohms into voltage. In this case: 12V divided by 4 Ω equals 3A.

Series Resistance



In the next figure, we have a parallel resistance rule at work. The total circuit resistance will always be less than the smallest resistance. To find total resistance you must treat each branch as an individual series circuit. 12V divided by 2 Ω equals 6A current per branch. Adding the branch currents, 6A plus 6A equals 12A total current. Dividing 12V by 12A equals a total parallel circuit resistance of 1Ω. Notice that this number is smaller than the smallest branch resistance.

Parallel Resistance



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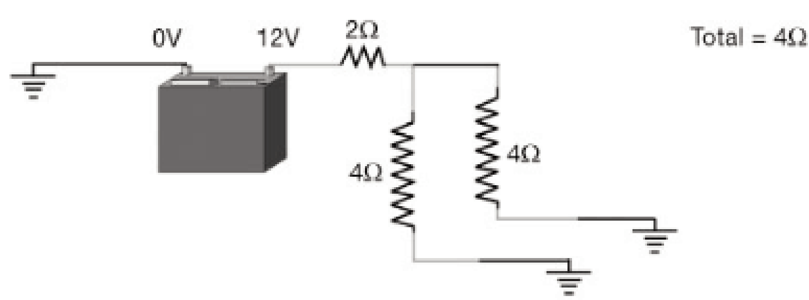
BASIC AUTOMOTIVE ELECTRICAL THEORY

OHMS LAW

Series/parallel circuits are the most difficult calculation. The first step is to calculate the total resistance of the parallel portion of the circuit. The formula is:

$$\frac{1}{\frac{1}{R1} + \frac{1}{R2}}$$



Using values from the example, Adding the total resistance of the parallel portion, 2 Ω ohms, to the 2 Ω from the series portion equals 4 Ω total circuit resistance.

$$\frac{1}{\frac{1}{4} + \frac{1}{4}} = \frac{1}{0.25 + 0.25} = \frac{1}{0.5} = 2\Omega$$

Knowing the formulas that arise out of Ohm's Law is not necessarily helpful for repairing automobiles. A person can know theory, but not know how to apply it in the real world. However, a knowledge of the relationships between these elements is essential to a Technician. You need to be able to predict what should be as opposed to what is in a problem vehicle. We are going to use the concept of voltage drop in this class to make this kind of diagnosis quicker and easier. Later, as you become more familiar with electrical theory and concepts, there may be an opportunity to do more advanced calculations like the ones we have discussed here.

The “math" side of Ohm's Law is important if we are designing a circuit. But because we are in the business of repairing electrical problems, what we need to know about Ohm's law can be summarized. Since most circuits (and basically all body electrical circuits) work on what is called 12V power (which is actually more like 12.6 -

ELECTRICAL REVIEW

BASIC AUTOMOTIVE ELECTRICAL THEORY

OHMS LAW

13.6V) we will look at Ohm's law with the voltage held constant. Assuming this fixed voltage, we can summarize Ohm's law as:

• When resistance goes up, current goes down. When resistance goes down, current goes up." This is the heart of Ohm's law when it comes to servicing a vehicle. Knowing the principle of Ohm's law plays an important role when diagnosing an electrical problem. However, a Technician will rarely use a calculator to fix an electrical problem. The importance of Ohm's law is that it provides the foundation for being able to understand and predict how an electrical circuit will respond.

• If a circuit is inoperative, and there is no current in the circuit, it means that there is an infinite amount of resistance or an open somewhere in the circuit.

• If the circuit is partially working (such as when a bulb is dim), and the load is not receiving full battery voltage, it is probable that there is excessive resistance in the circuit. The excessive resistance can be located either in the circuit itself or in series somewhere in the circuit. Or, the battery may not be delivering 12V. If the battery voltage is low, more than one circuit will be affected.

• If a 20A fuse is blown, we know that a lot of current must have been flowing in the circuit. In order to get a 20A fuse to blow at 12V, there must be very little resistance (0.6 Ω) in the circuit. This condition is caused by too many loads connected to the fuse, aftermarket accessories or a possible short-to-ground.

Shorts-to-ground provide no or very low resistance path to ground before the load, allowing current to flow unregulated. In this case, the resistance of the load has been removed. Because of Ohm's law the actual circuit does not need to operate in order for us to know how much current (if any) there will be or where it is going to flow. Ohm's law makes current predictable. So instead of checking every component, connector or wire on the vehicle, a Technician can use the System Circuit Diagram to determine where current flow should be, and which specific area could be causing the problem. This type of diagnosis eliminates unnecessary checks during the repair process. It saves the Technician time.

FRANKLINS FLUID FLOW CONCEPT

In 1752 Benjamin Franklin began studying electricity. He rejected Dufay's model of two electrical fluids, stating that there was only one fluid and its positive or negative nature depended on the excess or deficiency of the fluid. A neutral object would have the proper amount of electrical fluid. An excess of the fluid would be called positive electricity and a deficiency of the fluid would be called negative electricity.

Franklin was the first person to use the terms positive and negative.

Positively and negatively charged objects would attract, according to Franklin, because the positive object has excess electrical fluid that it can give to the deficient negatively charged object. As the electrical fluid drains from one object to the other, eventually both objects have the proper or natural amount of fluid and become neutral.

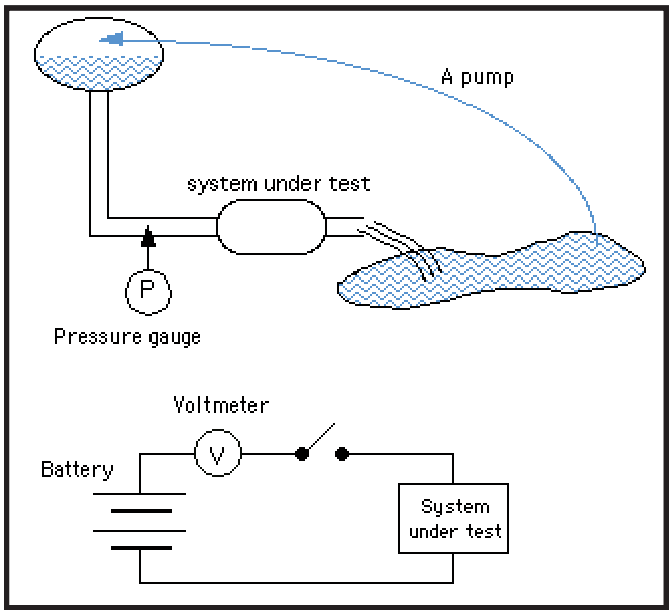
ELECTRICAL REVIEW

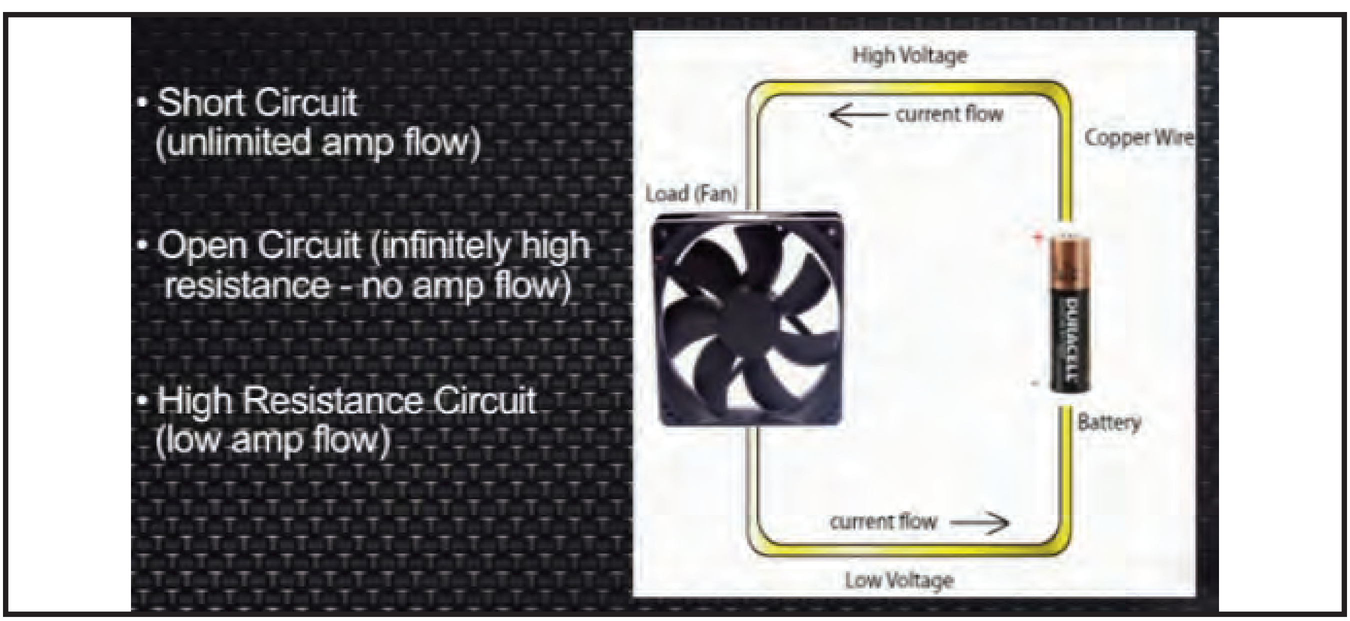
BASIC AUTOMOTIVE ELECTRICAL THEORY

FRANKLINS FLUID FLOW CONCEPT

Franklin also believed like charges repel because an object with excess electric fluid does not accept any more fluid from another object with excess fluid. Similarly, an object with a deficiency of fluid does not combine with (attract) another object having a deficiency of fluid because neither one is able to give fluid to the other.

Today, scientists have a different understanding about the nature of static electricity but they still use the concept of positive and negative electrical charge.



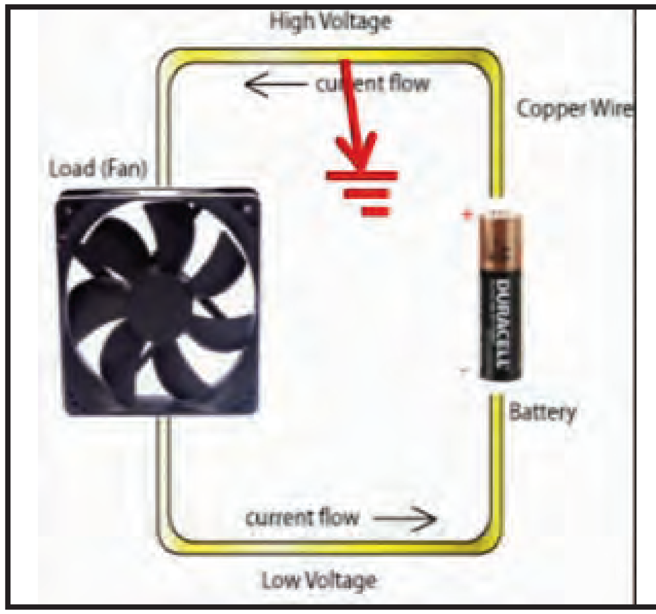


ELECTRICAL REVIEW

BASIC AUTOMOTIVE ELECTRICAL THEORY

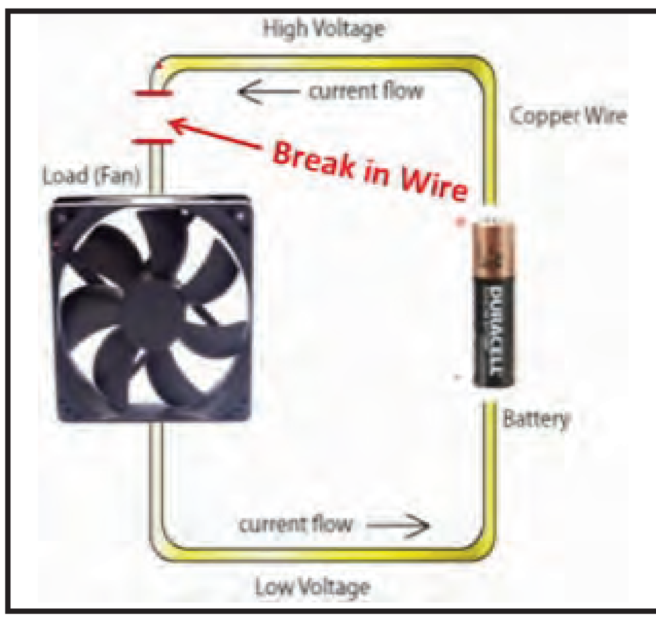
FRANKLINS FLUID FLOW CONCEPT

A short circuit is an abnormal connection between two nodes of an electric circuit intended to be at different voltages. This results in an excessive electric current/overcurrent limited only by the Thévenin equivalent resistance of the rest of the network and potentially causes circuit damage, overheating, fire or explosion. Although usually the result of a fault, there are cases where short circuits are caused intentionally, for example, for the purpose of voltage-sensing crowbar circuit protectors.



In circuit analysis a short circuit is a connection between two nodes that forces them to be at the same voltage. In an ideal short circuit, this means there is no resistance and no voltage drop across the short. In real circuits, the result is a connection with almost no resistance. In such a case, the current that flows is limited by the rest of the circuit.

Open-circuit voltage (abbreviated as OCV or VOC) is the difference of electrical potential between two terminals of a device when disconnected from any circuit. There is no external load connected and no external electric current flows between the terminals. It is sometimes given the symbol Voc.

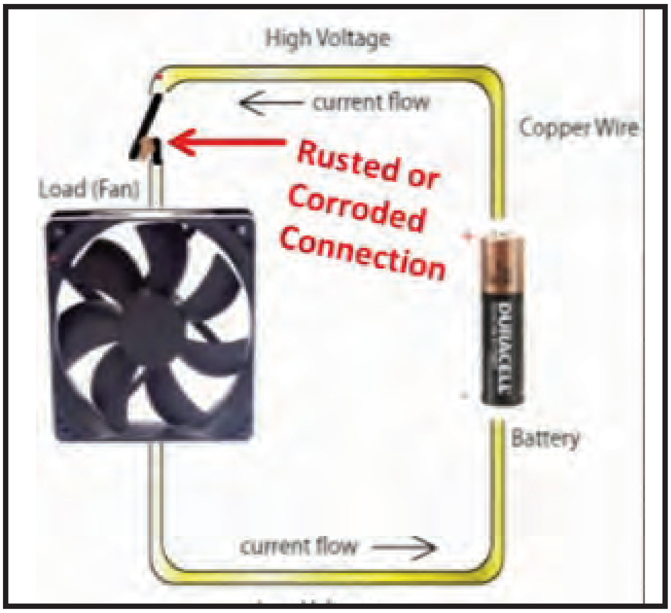


The open-circuit voltages of batteries and solar cells are often quoted under particular conditions (state-of-charge, illumination, temperature, etc.).

ELECTRICAL REVIEW

BASIC AUTOMOTIVE ELECTRICAL THEORY

FRANKLINS FLUID FLOW CONCEPT



A High Resistance Connection (HRC) is a problem that results from loose or poor connections in traditional electrical accessories and switchgear which can cause heat to develop, capable of starting a fire. Safety devices such as fuses and Residual-current devices (RCDs) are unable to detect thermal rise and disconnect the electrical supply because they cannot sense HRC.

A safety device to prevent HRC operates by effectively monitoring for abnormal thermal rise and will prevent ignition, smoke or burning odor of the electrical accessory or electrical installation.

NOTES

ELECTRICAL REVIEW

BASIC AUTOMOTIVE ELECTRICAL THEORY

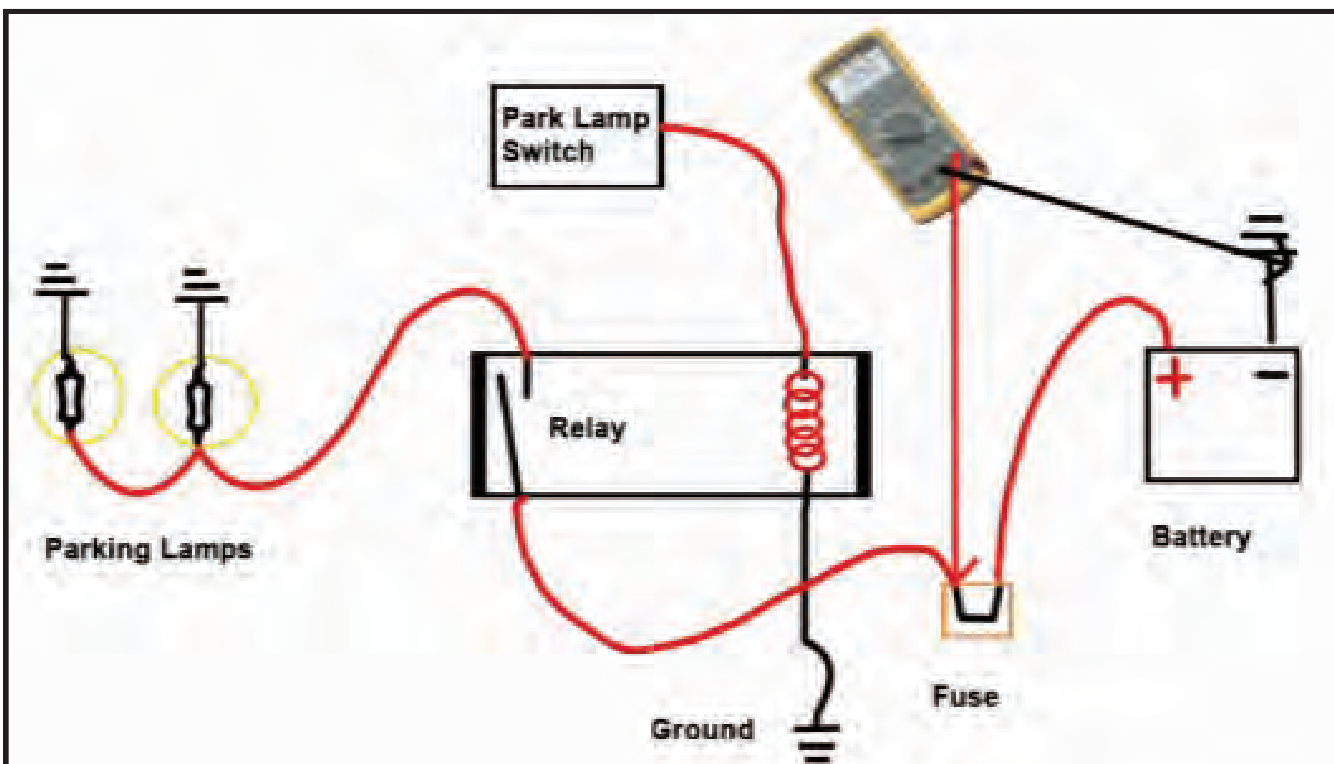
VOLTAGE DROP TESTING

Voltage drop describes how the supplied energy of a voltage source is reduced as electric current moves through the passive elements (elements that do not supply voltage) of an electrical circuit. Voltage drops across internal resistances of the source, across conductors, across contacts, and across connectors are undesired; supplied energy is lost (dissipated). Voltage drops across loads and across other active circuit elements are desired; supplied energy performs useful work. Recall that voltage represents energy per unit charge. For example, an electric space heater may have a resistance of ten ohms, and the wires which supply it may have a resistance of 0.2 ohms, about 2% of the total circuit resistance. This means that approximately 2% of the supplied voltage is lost in the wire itself. Excessive voltage drop may result in unsatisfactory operation of, and damage to, electrical and electronic equipment.

A voltage drop occurs when current flows through a component in a circuit. The resistance created by the device produces a corresponding drop in voltage which can be calculated using Ohms Law if you know the resistance of the component and current flow.

VOLTAGE DROP = RESISTANCE x CURRENT

You can measure voltage drop in a circuit or across a connection with a digital voltmeter. The voltmeter's leads are connected on either side of the circuit component or connection that is being tested. If a connection is loose or corroded, it will create resistance in the circuit and restrict the flow of current causing an excessive voltage drop.



ELECTRICAL REVIEW

BASIC AUTOMOTIVE ELECTRICAL THEORY

VOLTAGE DROP TESTING

As a rule of thumb, a voltage drop MORE than one tenth volt (0.1v) across a low voltage or low amperage connection means trouble. Circuits that handle higher voltages or currents (such as the voltage output circuit for the charging system) can tolerate voltage drops up to half a volt (0.5 volts), but 0.1 volts or less is best.

Measuring voltage drop is an effective means to quickly pinpoint automotive electrical circuit problems such as loose or corroded connectors, wires, switches, etc. It's more accurate than just measuring voltage in a circuit or using a simple test light to see if there is power or not because it tells you if there is excessive resistance that might restrict the current in the circuit.
Whenever working with sensitive components like a PCM use the recommended settings on the voltage meter. Be careful not to short one pin to another and when using any meter make sure the tool has the proper impedance. An analog vs. digital meter question may show up on your test. Analog meters are not recommended for use with ECM's.

Use a digital voltmeter to find a poor or corroded ground connection. Turn the ignition key on KOEO (key on engine off). Use a service manual to find the key points to be probed and set the meter to 1 volt. Connect the negative probe to the battery's negative terminal and back probe the PCM connection at the proper ground wires with the positive probe to identify any corroded, faulty, or poor ground wires and connections. The typical voltage drop for this type of circuit is below or between 1 and 2 volts. Anything over 3 volts is considered unacceptable and further inspection of this ground circuit is required. Always consult manufacturers specifications as voltage tolerance may vary from one model to another.

As you can see a voltage drop test is a great way to find excessive resistance in a circuit. This test is just a typical example and can be performed on many of the PCM's sensor circuits as well. These tests require the appropriate service manual for procedures, specifications, sensor, and pin locations.

Measuring Voltage Drop — Step-by-Step

• The step-by-step method is most useful for isolating excessive drops in low voltage systems (such as those in “Computer Controlled Systems”).

• Circuits in the “Computer Controlled System” operate on very low amperage.

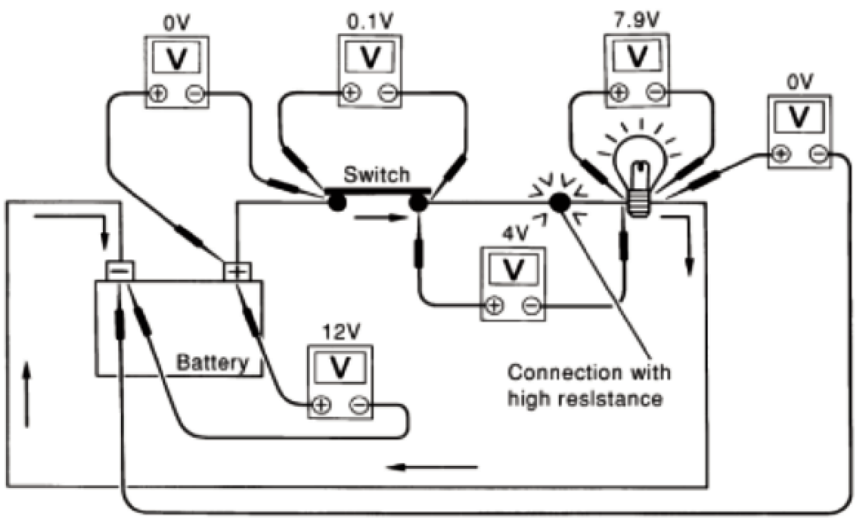
• The (Computer Controlled) system operations can be adversely affected by any variation in resistance in the system. Such resistance variation may be caused by poor connection, improper installation, improper wire gauge or corrosion.

• The step by step voltage drop test can identify a component or wire with too much resistance.

ELECTRICAL REVIEW

BASIC AUTOMOTIVE ELECTRICAL THEORY

VOLTAGE DROP TESTING



1. Connect the DMM as shown, starting at the battery and working your way around the circuit.
2. An unusually large voltage drop will indicate a component or wire that needs to be repaired, As you can see the illustration above, the poor connection causes a 4 volt drop.

The chart that follows illustrates some maximum allowable voltage drops. These values are given as a guideline, the exact value for each component may vary.

COMPONENT	VOLTAGE DROP
Wire	negligible < .001 volts
Ground Connections	Approx. 0.1 volts
Switch Contacts	Approx. 0.3 volts

NOTES

GETTING STARTED

AUTOMOTIVE BATTERY BASICS

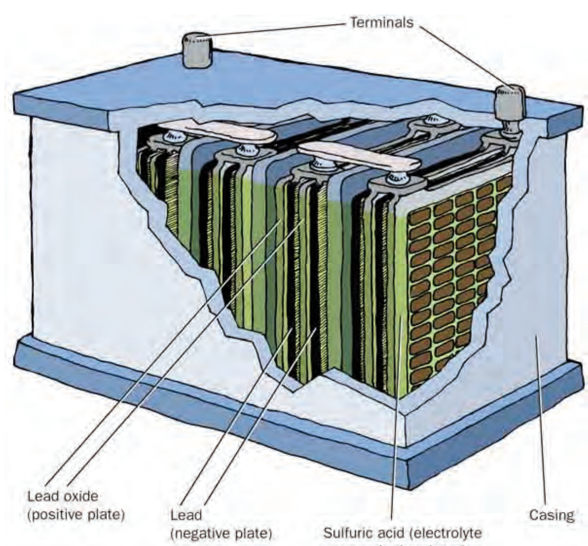
Determining if you have excessive battery drain will consist on several variables. The first variable is the battery itself and the amount of resistance that is within the circuit between positive and ground with all accessories OFF and all of the vehicles control modules “asleep”. If we know the specifications of the battery in the vehicle, we can closely determine how long it should take for the battery to drain.

An automotive battery is a type of rechargeable battery that supplies electric energy to an automobile. Usually this refers to an SLI battery (starting, lighting, ignition) to power the starter motor, the lights, and the ignition system of a vehicle's engine.

Automotive SLI batteries are usually lead-acid type, and are made of six galvanic cells in series to provide a 12 volt system. Each cell provides 2.1 volts for a total of 12.6 volt at full charge. Heavy vehicles such as highway trucks or tractors, often equipped with diesel engines, may have two batteries in series for a 24 volt system, or may have parallel strings of batteries.

Lead-acid batteries are made up of plates of lead and separate plates of lead dioxide, which are submerged into an electrolyte solution of about 38% sulfuric acid and 62% water. This causes a chemical reaction that releases electrons, allowing them to flow through conductors to produce electricity. As the battery discharges, the acid of the electrolyte reacts with the materials of the plates, changing their surface to lead sulfate. When the battery is recharged, the chemical reaction is reversed: the lead sulfate reforms into lead dioxide and lead. With the plates restore to their original condition, the process may now be repeated.

Lead-acid batteries for automotive use are made with slightly different construction techniques, depending on the application of the battery. The "flooded cell" type, indicating liquid electrolyte, is typically inexpensive and long-lasting, but requires more maintenance and can spill or leak. Some flooded batteries have removable caps that allow for the electrolyte to be tested and maintained.



Flooded or Wet Cell Batteries

Flooded or "wet cell" batteries are the most commonly used batteries on the market today. Flooded batteries come in the widest variety of shapes and sizes due to their widespread usage in a multitude of industries and applications.

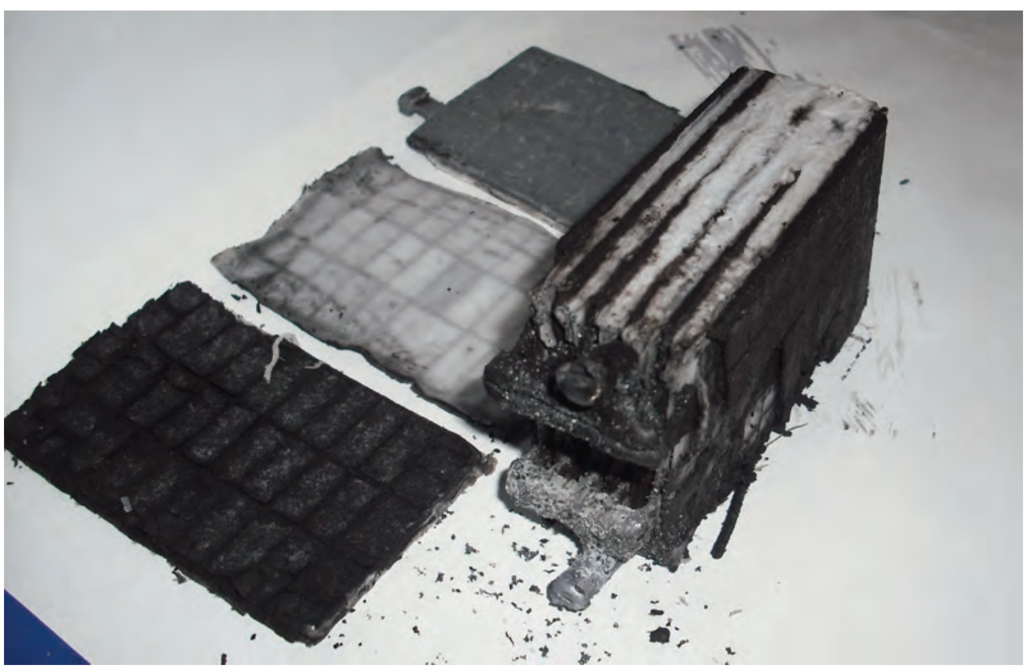
GETTING STARTED

AUTOMOTIVE BATTERY BASICS

Flooded batteries again use lead plates, a sulfuric acid electrolyte, and plate separators but that is where it stops. Usually flooded batteries are not sealed, and do not recombine the gases to liquids internally. Instead, these gases are vented externally. Internal gases produced are released directly to the environment. Through these same vents can flow acid, steam, and condensation, leading to maintenance.

Flooded batteries do require maintenance, in the form of water, to routinely replenish lost electrolyte through the vents. Lead plates start to deteriorate when they touch the atmosphere, so if you fail to maintain your batteries, they will corrode and fail. Flooded batteries hold very good rates of charge for the price, but require more work. Unfortunately due to the internal construction, flooded batteries have the weakest internal construction, and some very high internal resistance statistics.

These batteries also acid "mist" during charging and discharging. This leads to the corrosion of their terminals, and often acid damage to surrounding surfaces. VRLA Flooded batteries must be installed upright, can leak that acid, and require regular watering. Should they fail to be watered, they will not perform to spec. That all being said, they are also the least expensive type and therefore are the choice of many renewable and RV owners.



Absorbent Glass Material (AGM) Flat Plate or Spiral Cell Batteries (Dry)

AGM batteries differ from flooded lead acid batteries in that the electrolyte is held in the glass mats, as opposed to freely flooding the plates. Very thin glass fibers are woven into a mat to increase surface area enough to hold sufficient electrolyte on the cells for their lifetime. The fibers that compose the fine glass mat do not absorb nor are affected by the acidic electrolyte. These mats are wrung out 2–5% after being soaked in acids, prior to manufacture completion and sealing.

The plates in an AGM battery may be any shape. Some are flat, others are bent or rolled. AGM batteries, both deep cycle and starting, are built in a rectangular case to BCI battery code specifications.

GETTING STARTED

AUTOMOTIVE BATTERY BASICS

AGM technology became popular in the early 1980s as a sealed lead acid battery for military aircraft, vehicles and UPS to reduce weight and improve reliability. The acid is absorbed by a very fine fiberglass mat, making the battery spill-proof. This enables shipment without hazardous material restrictions. The plates can be made flat to resemble a standard flooded lead acid pack in a rectangular case; they can also be wound into a cylindrical cell.

AGM has very low internal resistance, is capable to deliver high currents on demand and offers a relatively long service life, even when deep-cycled. AGM is maintenance free, provides good electrical reliability and is lighter than the flooded lead acid type. It stands up well to low temperatures and has a low self-discharge. The leading advantages are a charge that is up to five times faster than the flooded version, and the ability to deep cycle. AGM offers a depth-of-discharge of 80 percent; the flooded, on the other hand, is specified at 50 percent DoD to attain the same cycle life. The negatives are slightly lower specific energy and higher manufacturing costs then the flooded. AGM has a sweet spot in midsize packs from 30 to 100Ah and is less suitable for large UPS system.

AGM batteries are commonly built to size and are found in high-end vehicles to run power-hungry accessories such as heated seats, steering wheels, mirrors and windshields. NASCAR and other auto racing leagues choose AGM products because they are vibration resistant. AGM is the preferred battery for upscale motorcycles. Being sealed, AGM reduces acid spilling in an accident, lowers the weight for the same performance and allows installation at odd angles. Because of good performance at cold temperatures, AGM batteries are also used for marine, motor home and robotic applications.

Ever since Cadillac introduced the electric starter motor in 1912, lead acid became the natural choice to crank the engine. The classic flooded type is, however, not robust enough for the start-stop function and most batteries in a micro-hybrid car are AGM. Repeated cycling of a regular flooded type causes a sharp capacity fade after two years of use. See Heat, Loading and Battery Life.

As with all gelled and sealed units, AGM batteries are sensitive to overcharging. These batteries can be charged to 2.40V/cell (and higher) without problem; however, the float charge should be reduced to between 2.25 and 2.30V/cell (summer temperatures may require lower voltages). Automotive charging systems for flooded lead acid often have a fixed float voltage setting of 14.40V (2.40V/cell), and a direct replacement with a sealed unit could spell trouble by exposing the battery to undue overcharge on a long drive. See Charging Lead Acid.

AGM and other sealed batteries do not like heat and should be installed away from the engine compartment. Manufacturers recommend halting charge if the battery core reaches 49°C (120°F). While regular lead acid batteries need a topping charge every six months to prevent the buildup of sulfation, AGM batteries are less prone to this and can sit in storage for longer before a charge becomes necessary. Table 1 spells out the advantages and limitations of AGM.

Advantages	Spill-proof through acid encapsulation in matting technology
	High specific power, low internal resistance, responsive to load
	Up to 5 times faster charge than with flooded technology
	Better cycle life than with flooded systems
	Water retention (oxygen and hydrogen combine to produce water)
	Vibration resistance due to sandwich construction
	Stands up well to cold temperature
Disadvantages	Higher manufacturing cost than flooded (but cheaper than gel)
	Sensitive to overcharging (gel has tighter tolerances than AGM)
	Capacity has gradual decline (gel has a performance dome)
	Low specific energy
	Must be stored in charged condition (less critical than flooded)
	Not environmentally friendly (has less electrolyte, lead that flooded)

GETTING STARTED

AUTOMOTIVE BATTERY BASICS

Gel Battery (also known as a "gel cell") or VRLA

A gel battery (also known as a "gel cell") is a VRLA battery with a gelified electrolyte; the sulfuric acid is mixed with silica fume, which makes the resulting mass gel-like and immobile. Unlike a flooded wet-cell lead-acid battery, these batteries do not need to be kept upright. Gel batteries reduce the electrolyte evaporation, spillage (and subsequent corrosion issues) common to the wet-cell battery, and boast greater resistance to extreme temperatures, shock, and vibration.

Chemically they are almost the same as wet (non-sealed) batteries except that the antimony in the lead plates is replaced by calcium, and gas recombination can take place. More importantly, real gas recombination was used to make batteries that were not "watered" and could be called maintenance-free. The one-way valves were set at 2 psi, and this was high enough to have full recombination take place.

At the end of charge when oxygen was evolved from overcharge on the positive plate it traveled through the shrink cracks in the gel directly to the negative plate made from high surface area pure lead and "burned" up as fast as it was made. This oxygen gas and the hydrogen adsorbed on the surface of the sponge lead metal negative plate combined to make water that was retained in the cell.

This sealed, non-spill feature made it possible to make very small VRLA batteries (1 –12 Amp hr. range) that fit into the growing portable electronics market. A large market for inexpensive smaller sealed Pb/Acid batteries was generated quickly. Portable TV, light for news cameras, children's toy riding cars, emergency lighting, and the growing market for UPS systems for computer back-up, to name a few, were powered with small sealed VRLA.

TEMPERATURE COMPENSATED BATTERY STATE-OF-CHARGE (SoC) TABLE

Electrolyte Temperature		Wet Low Maintenance (Sb/Ca) or Wet Standard (Sb/Sb) Battery										Wet "Mainteneance Free" (Ca/Ca) or AGM/Gel Cell VRLA (Ca/Ca) Battery				
		Specific Gravity Reading					Open Circuit Voltage Reading					Open Circuit Voltage Reading				
Degrees Fahrenheit	Degrees Celsius	100% SoC	75% SoC	50% SoC	25% SoC	0% SoC	100% SoC	75% SoC	50% SoC	25% SoC	0% SoC	100% SoC	75% SoC	50% SoC	25% SoC	0% SoC
120	48.9	1.249	1.209	1.174	1.139	1.104	12.663	12.463	12.253	12.073	11.903	12.813	12.613	12.413	12.013	11.813
110	43.3	1.253	1.213	1.178	1.143	1.108	12.661	12.461	12.251	12.071	11.901	12.811	12.611	12.411	12.011	11.811
100	37.8	1.257	1.217	1.182	1.147	1.112	12.658	12.458	12.248	12.068	11.898	12.808	12.608	12.408	12.008	11.808
90	32.2	1.261	1.221	1.186	1.151	1.116	12.655	12.455	12.245	12.065	11.895	12.805	12.605	12.405	12.005	11.805
80	**26.7**	**1.265**	**1.225**	**1.190**	**1.155**	**1.120**	**12.650**	**12.450**	**12.240**	**12.060**	**11.890**	**12.800**	**12.600**	**12.400**	**12.000**	**11.800**
70	21.1	1.269	1.229	1.194	1.159	1.124	12.643	12.443	12.233	12.053	11.883	12.793	12.593	12.393	11.993	11.793
60	15.6	1.273	1.233	1.198	1.163	1.128	12.634	12.434	12.224	12.044	11.874	12.784	12.584	12.384	11.984	11.784
50	10.0	1.277	1.237	1.202	1.167	1.132	12.622	12.422	12.212	12.032	11.862	12.772	12.572	12.372	11.972	11.772
40	4.4	1.281	1.241	1.206	1.171	1.136	12.606	12.406	12.196	12.016	11.846	12.756	12.556	12.356	11.956	11.756
30	-1.1	1.285	1.245	1.210	1.175	1.140	12.588	12.388	12.178	11.998	11.828	12.738	12.538	12.338	11.938	11.738
20	-6.7	1.289	1.249	1.214	1.179	1.144	12.566	12.366	12.156	11.976	11.806	12.716	12.516	12.316	11.916	11.716
10	-12.2	1.293	1.253	1.218	1.183	1.148	12.542	12.342	12.132	11.952	11.782	12.692	12.492	12.292	11.892	11.692
0	-17.8	1.297	1.257	1.222	1.187	1.152	12.516	12.316	12.106	11.926	11.756	12.666	12.466	12.266	11.866	11.666

As a battery discharges, the electrolyte contains more and more water and less acid. Since water is lighter than acid, the weight of electrolyte decreases as the battery discharges.

As the battery charges, the acid content of the electrolyte increases. Electrolyte in a charged battery weighs more by volume than electrolyte in a discharged battery.

GETTING STARTED

AUTOMOTIVE BATTERY BASICS

We can use a hydrometer to test Specific Gravity and State of Charge in batteries with removable caps. Here's how:

* Remove the battery caps. Check the electrolyte level. Make sure all cells are covered but not overfilled.
* Insert the hydrometer into each cell and draw electrolyte into the glass cylinder with the squeeze ball. Draw just enough acid into the cylinder to make the float rise. Hold the hydrometer vertical as each sample is drawn. Note the exact level at which the fluid level intersects the measurement scale on the float and record it.
* Repeat the test at each of the remaining cells. Record the reading for each cell. Compare readings to the chart on this page to determine state of charge.
* If the battery is below 75 percent state of charge, recharge it before load testing.

Temperature Correction
If the temperature of the electrolyte is below 80 degrees F, subtract .004 (4 points) from the actual reading for each 10 degree change. Add 4 points for each 10 degree change above 80 degrees F.

For example, if the actual specific gravity reading is 1.265, but the electrolyte temperature is only 30 degrees F, then the true, corrected specific gravity is 1.245 (1.265-.020 = 1.245). Why? Because the higher 1.265 specific gravity reading at 30 degrees F is the result of the increased density of colder electrolyte, not because the sample contains a higher concentration of acid.

Testing State of Charge in Sealed Batteries
The Open Circuit Voltage Test

If the battery has a sealed top, you cannot perform a specific gravity test to determine the battery state of charge since there is no way to take samples of the electrolyte.

To determine battery state of charge in sealed-top batteries, you must perform an Open Circuit Voltage test across the battery posts using an accurate digital voltmeter; analog voltmeters are not accurate enough for this test. Open Circuit Voltage (OCV) refers to voltage measured across the battery posts with no electrical loads turned on.

Adjust your digital multimeter to the 20 or 40 Volt SC scale and place the meter leads across the battery posts.

Take the voltage reading and compare it to the chart below. The chart combines specific gravity and OCV test standards.

There is a direct relationship between specific gravity and open-circuit voltage measured across the battery posts. Batteries below 75% of full charge must be recharged before performing a load test.

BATTERY TERMS

Cold Cranking Amps (CCA)
Cold cranking amperes (CCA) is the amount of current a battery can provide at 0 °F (−18 °C). The rating is defined as the current a lead-acid battery at that temperature can deliver for 30 seconds and maintain at least 1.2 volts per cell (7.2 volts for a 12-volt battery). It is a more demanding test than those at higher temperatures. This is the most widely used cranking measurement for comparison purposes.

GETTING STARTED

AUTOMOTIVE BATTERY BASICS

Cranking Amps (CA)

Cranking amperes (CA), also sometimes referred to as marine cranking amperes (MCA), is the amount of current a battery can provide at 32 °F (0 °C). The rating is defined as the number of amperes a lead-acid battery at that temperature can deliver for 30 seconds and maintain at least 1.2 volts per cell (7.2 volts for a 12 volt battery).

Reserve Capacity (RC)

Reserve capacity minutes (RCM), also referred to as reserve capacity (RC), is a battery's ability to sustain a minimum stated electrical load; it is defined as the time (in minutes) that a lead-acid battery at 80 °F (27 °C) will continuously deliver 25 amperes before its voltage drops below 10.5 volts.

Marine Cranking Amps (MCA)

Marine Cranking Amps - The amount of amps a battery can produce at 32°F.

European Norm (EN)

The European Norm is an agreement between the countries in Europe to consolidate the specification of standards to enhance the efficiency of commerce. In Europe, EN Standards are gradually being adopted as a more uniform alternative to many different national standards. This EN Standard has been applied to automotive batteries.

Deutsche Industrial Norm (DIN)

Recognized by the German Federal Government as Germany's national standards body, DIN has been a member of the International Organization for Standardization (ISO) since 1951. While these standards were developed for Germany, many of their automotive standards have been used to develop EN standards but they are not always the same. It is important to remember that EN standards are for all of Europe and not just for one country. It is also important to note that there are some DIN battery part numbers, originally for German manufactured cars, that don’t have a corresponding EN part number.

Japanese Industry Standard (JIS)

Asian manufacturers conform to the Japanese JIS standard, while the Battery Council International (BCI) maintains the standards and specifications for North American battery manufacturers.

International Electrical Code (IEC)

The International Electrotechnical Commission (IEC), founded in London in 1906, is the leading global organization that prepares and publishes international standards for all electrical, electronic and related technologies.

International Standards Organization (ISO)

A network of national standards institutes from 148 countries, founded in 1946, working in partnership with international organizations, governments, industry, business and consumer representatives.

GETTING STARTED

MAKING SENSE OF BATTERY SPECIFICATIONS

North American Region

BATTERY SPECIFICATION CHART

Printed on: 8/24/2012

GM Part Number	BCI Group Size	ACDelco Part #	GM Part Number	Description (See Footer)	Terminal / Post Type	Terminal / Post Positive Position	Volts	Amps for Load Test	Cpacity Ratings Reserve Capacity (minutes)	Cpacity Ratings Ah_{20}	Cold Cranking Amps @ 0°F (-18°C)	Cranking Amps @ 32°F (0°C)	Maximum Dimensions Length (inches)	Width (inches)	Height (inches)	Weight (pounds)	Maximum Dimension Length (mm)	Width (mm)	Height(mm) (Top of Post)
PASSENGER CAR / LIGHT TRUCK COMMERCIAL BATTERIES																			
19002044	24	24-5YR	19002044	MF / H	TP	L.H.	12	230	90	**50**	475	590	10.0	6.8	8.8	36.1	254.5	173	223.5
19002045		24-6YR	19002045	MF / H	TP	L.H.	12	270	100	**55**	550	685	10.0	6.8	8.8	37.8	254.5	173	223.5
19001591		24-7YR	19001591	MF / H	TP	L.H.	12	330	110	**61**	660	825	10.0	6.8	8.8	39.2	254.5	173	223.5
19001594	24R	24R5YR	19001594	MF / H	TP	R.H.	12	230	90	**50**	475	590	10.0	6.8	8.8	36.1	254.5	173	223.5
19002046		24R6YR	19002046	MF / H	TP	R.H.	12	270	100	**55**	550	685	10.0	6.8	8.8	37.8	254.5	173	223.5
19002047		24R7YR	19002047	MF / H	TP	R.H.	12	330	110	**61**	660	825	10.0	6.8	8.8	39.2	254.5	173	223.5
19001595	25	25-6YR	19001595	MF	TP	L.H.	12	280	110	**61**	560	700	9.1	6.8	8.8	36.1	230.3	173	223.5
19001597	26	26-5YR	19001597	MF / H	TP	L.H.	12	220	70	**39**	450	560	8.1	6.8	8.0	27.7	206.3	173	203.1
19001596		26-6YR	19001596	MF / H	TP	L.H.	12	270	80	**44**	550	685	8.1	6.8	8.0	28.8	206.3	173	203.1
19001599	26R	26R5YR	19001599	MF / H	TP	R.H.	12	220	70	**39**	450	560	8.1	6.8	8.0	27.7	206.3	173	203.1
19001598		26R6YR	19001598	MF / H	TP	R.H.	12	270	80	**44**	550	685	8.1	6.8	8.0	28.8	206.3	173	203.1
19002048	27	27-7YR	19002048	MF / H	TP	L.H.	12	350	110	**61**	700	875	12.1	6.8	8.8	44.0	306.2	173	223.5
89021960	27F	27R7YR	89021960	MF	TP	R.H.	12	350	110	**61**	700	875	12.1	6.8	8.8	44.0	306.2	173	223.5
19001600	34	34-6YR	19001600	MF	TP	L.H.	12	260	110	**61**	535	665	10.3	6.8	8.0	35.2	260.5	173	203.5
89022223		34H6YR	89022223	MF	TP	L.H.	12	300	110	**61**	600	665	10.3	6.8	8.0	35.2	260.5	173	203.5
19002055		34-7YR	19002055	MF	TP	L.H.	12	350	115	**63**	700	875	10.3	6.8	8.0	38.1	260.5	173	203.5
89022222		34H7YR	89022222	MF	TP	L.H.	12	375	120	**70**	750	875	10.3	6.8	8.0	38.1	260.5	173	203.5
19001602	35	35-6YR	19001602	MF	TP	R.H.	12	280	110	**61**	560	700	9.1	6.8	8.8	36.1	230.3	173	223.5
89020663	36	36R6YR	89020663	MF	TP	R.H.	12	325	130	**72**	650	810	10.4	7.2	8.1	36.1	263	183	206
89020664	40	40R6YR	89020664	MF / H	TP	R.H.	12	300	120	**66**	650	810	10.9	6.9	6.9	38.2	276	174	176
19001604	41	41-6YR	19001604	MF	TP	R.H.	12	260	95	**61**	525	655	11.5	6.9	6.9	32.3	293	175	175
19001603		41-7YR	19001603	MF	TP	R.H.	12	320	105	**58**	650	810	11.5	6.9	6.9	35.4	293	175	175
19001606	42	42-5YR	19001606	MF / H	TP	R.H.	12	230	70	**39**	460	575	9.5	6.8	6.9	26.6	241	172	174
19002050	45 / 46	45-5YR	19002050	MF	TP	R.H.	12	230	70	**39**	470	585	8.9	5.5	8.7	26.8	226	138.9	220.5
~~19001608~~	~~47 / 90~~	~~47/90-6YR~~	~~19001608~~	MFLA	TP	R.H.	12	250	100	**50**	510	630	~~9.7~~	~~6.9~~	~~6.9~~	~~33.0~~	~~246~~	~~174~~	~~175~~
89022164	47	47-6YR	89022164	MF	TP (LN2)	R.H.	12	300	95	**55**	600	760	9.5	6.9	7.5		242	175	190
89022165		47-7YR	89022165	MF	TP (LN2)	R.H.	12	320	115	**63**	650	810	9.5	6.9	7.5		242	175	190
19001609	91	91-6YR	19001609	MF / H	TP	R.H.	12	350	110	**61**	700	840	10.9	6.9	6.9	41.6	277	175	175
89022168	48	48-6YR	89022168	MF	TP (LN3)	R.H.	12	350	110	**61**	700	840	10.9	6.9	7.5		278	175	190
89022169		48-7YR	89022169	MF	TP (LN3)	R.H.	12	380	120	**66**	770	960	10.9	6.9	7.5		278	175	190
19001610	49 / 93	49/93-6YR	19001610	MF / H	TP	R.H.	12	410	150	**83**	825	1000	13.9	6.9	6.9	51.3	354	175	175
89022166	49	49-6YR	89022166	MF	TP (LN5)	R.H.	12	420	130	**66**	850	1050	13.9	6.9	7.5		354	175	190
89022167		49-7YR	89022167	MF	TP (LN5)	R.H.	12	480	150	**83**	975	1170	13.9	6.9	7.5		354	175	190
88900702	50	50-6YR	88900702	MF / H	TP	L.H.	12	300	108	**58**	600	760	13.3	5.5	8.7	43.0	337	140	220
19001611	51	51-5YR	19001611	MF	TP	L.H.	12	220	75	**82**	440	550	9.4	5.1	8.8	27.1	238	129	223.5
19001612	51R	51R5YR	19001612	MF / H	TP	R.H.	12	220	75	**41**	440	550	9.2	5.1	8.8	27.9	234	129	223.5
19001613	55 / 56	55-6YR	19001613	MF / H	TP	R.H.	12	290	85	**47**	580	725	8.9	6.1	8.3	28.6	225	154	210.5
19001615	58	58-5YR	19001615	MF / H	TP	L.H.	12	210	70	**39**	430	535	9.5	7.2	6.9	26.2	241	182.9	174
19001614		58-6YR	19001614	MF / H	TP	L.H.	12	280	75	**41**	560	700	9.5	7.2	6.9	27.1	241	182.9	174
19001616	58R	58R6YR	19001616	MF / H	TP	R.H.	12	290	100	**55**	585	730	9.5	7.2	6.9	30.1	241	182.9	174
89020665	59	59-6YR	89020665	MF	TP	L.H.	12	270	100	**55**	540	650	10.0	7.6	7.7		255	193	196
19001617	62	62-6YR	19001617	MF	TP	R.H.	12	250	90	**50**	510	635	8.9	6.4	8.8	28.6	226	162	224
19001618	64	64-6YR	19001618	MFLA	TP	R.H.	12	300	120	**66**	610	760	11.7	6.4	8.9	40.9	296	162	225
19001620	65	65-6YR	19001620	MF / H	TP	L.H.	12	320	150	**83**	650	810	11.9	7.4	7.6	42.7	303.4	188.9	193.1
19001619		65-7YR	19001619	MF / H	TP	L.H.	12	420	160	**88**	850	1000	11.9	7.5	7.6	45.5	303.4	189.9	193.1
19001622	70	70-5YR	19001622	MF / H	ST	L.H.	12	220	70	**39**	445	555	8.5	6.9	7.3	27.5	215.5	174	185
19001621		70-6YR	19001621	MF / H	ST	L.H.	12	270	80	**44**	550	685	8.5	6.9	7.3	28.6	215.5	174	185
19001624	70DT	70DT5YR	19001624	MF / H	DT	L.H.	12	230	75	**41**	460	575	8.5	6.8	8.0	29.0	215.5	173	202.8
19002051		70DT6YR	19002051	MF / H	DT	L.H.	12	270	90	**50**	555	690	8.5	6.8	8.0	31.7	215.5	173	202.8
19001623		70DT7YR	19001623	MF / H	DT	L.H.	12	330	90	**50**	675	840	8.5	6.8	8.0	32.8	215.5	173	202.8

D=Dry. W= Wet, MF=Maint. Free (non-accesible), MF/H - MF w/ Handle, MFLA - MF Limited Access,
DT=Dual Term., ST=Side Term., TP=Top Post, TP/WN=Top Post Wing Nut,TS=Top Stud, TSM=Top Stud Marine, D@1= Dry w/Acid Pack

Highlighted: Ser. 60 Lineup

GETTING STARTED

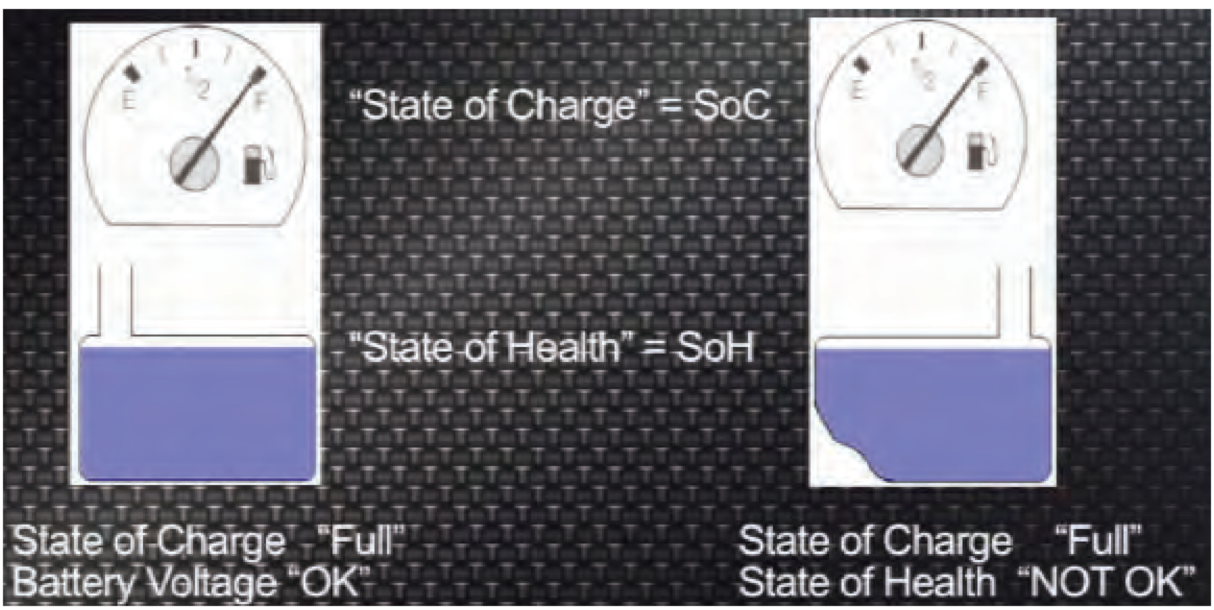
MAKING SENSE OF BATTERY SPECIFICATIONS

Illustrated on the previous page is the AC Delco Battery Group/Specification chart. If we take a closer look at a BCI Group 36 battery we can see that the Reserve Capacity (minutes) is 130 and the AH capacity is 72. If we compare this battery to a BCI Group 24 battery, we can see the reserve capacity (90 – 110), and the AH (50 – 61) are much less. This tells us that if there is a drain on the battery, the group 24 battery will not last nearly as long as the group 36 battery.

A good way to look at this from an automotive standpoint is this: if you had a 50 AH battery and a parasitic drain of 0.25 amps, without charging the battery, the battery would be completely drained in 2,000 hours or 82 days. 50AH/0.25amps = 2,000 hours. Conversely, if you had 50AH of parasitic current draw, the battery would be dead in 1,000 hours or 41 days. 50AH/0.50amps = 1,000 hours. A larger parasitic current draw such as a glove box light being left on can drain the battery in a matter of 100 hours. 50AH/0.5amps = 100 hours.

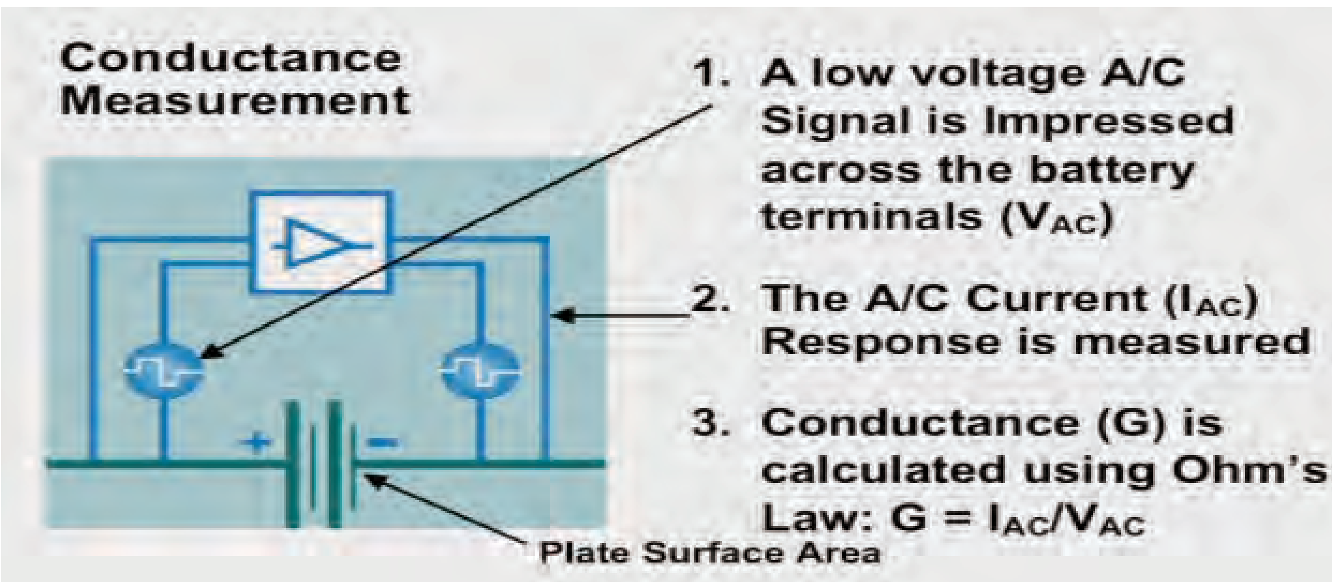
What will further effect how long it takes to drain the battery are the ambient temperature and/or the temperature of the battery itself. In colder temperatures we will see the battery deplete energy faster than you would at warmer temperatures.

STATE OF CHARGE (SOC) VS. STATE OF HEALTH (SOH)



GETTING STARTED

STATE OF CHARGE (SOC) VS. STATE OF HEALTH (SOH)



The purpose of SOC is to provide an indication of the performance which can be expected from the battery in its current condition or to provide an indication of how much of the useful lifetime of the battery has been consumed and how much remains before it must be replaced. In critical applications such as standby and emergency power plant the SOC gives an indication of whether a battery will be able to support the load when called upon to do so. Knowledge of the SOH will also help the plant engineer to anticipate problems to make fault diagnosis or to plan replacement. This is essentially a monitoring function tracking the long term changes in the battery.

If the recorded usage history of the battery is used to determine the SOH, as in the Log Book Function below, then this same data can be also used to validate warranty claims. This is particularly useful for assessing the condition of high cost EV and HEV batteries which may have been subject to abuse.

Any parameter which changes significantly with age, such as cell impedance or conductance, can be used as a basis for providing an indication of the SOH of the cell. Changes to these parameters will normally signify that other changes have occurred which may be of more importance to the user. These could be changes to the external battery performance such as the loss of rated capacity or increased temperature rise during operation or internal changes such as corrosion.

Because the SOH indication is relative to the condition of a new battery, the measurement system must hold a record of the initial conditions or at least a set of standard conditions. Thus if cell impedance is the parameter being monitored, the system must keep in memory as a reference, a record of the initial impedance of a fresh cell. If counting the charge / discharge cycles of the battery is used as a measure of the battery usage, the

GETTING STARTED

STATE OF CHARGE (SOC) VS. STATE OF HEALTH (SOH)

expected battery cycle life of a new cell would be used as the reference. In a Lithium ion battery, since the cell capacity deteriorates fairly linearly with age or cycle life, the expired, or remaining cycle life, depending on the definition used, is often used as a crude measure of the SOH.

Battery manufacturers have their own definitions and conventions for Impedance and Conductance based on the test method used. Though not strictly correct they serve their purpose.

The test method involves applying a small AC voltage "E" of known frequency and amplitude across the cell and measuring the in phase AC current "I" that flows in response to it.

The Impedance "Z " is calculated by Ohm's Law to be Z=E/I

The Conductance "C" is similarly calculated as C=I/E (the reciprocal of the impedance)

Note that the impedance increases as the battery deteriorates while the conductance decreases. Thus C correlates directly with the battery's ability to produce current where as Z gives an inverse correlation. The conductance of the cell therefore provides an indirect approximation to the State of Health of the cell. This measurement can be refined by taking other factors into account.
In addition to impedance and conductance these tests will obviously detect cell defects such as shorts, and open circuits.

These test methods can be used with different cell chemistries however different calibration factors must be built into the test equipment to take into account differences in the aging profiles of the different chemistries.

Impedance and conductance testing are reliable, safe, accurate, fast and they don't affect the battery performance. They can be carried out while the battery is in use or they can be used to continuously monitor the battery performance, avoiding the need for load testing or discharge testing.

Load testing is used to verify that the battery can deliver its specified power when needed. The load is usually designed to be representative of the expected conditions in which the battery may be used. It may be a constant load at the C rate or pulsed loads at higher current rates or in the case of automotive batteries, the load may be designed to simulate a typical driving pattern. Low power testing is usually carried out with resistive loads. For very high power testing with variable loads other techniques may be required.

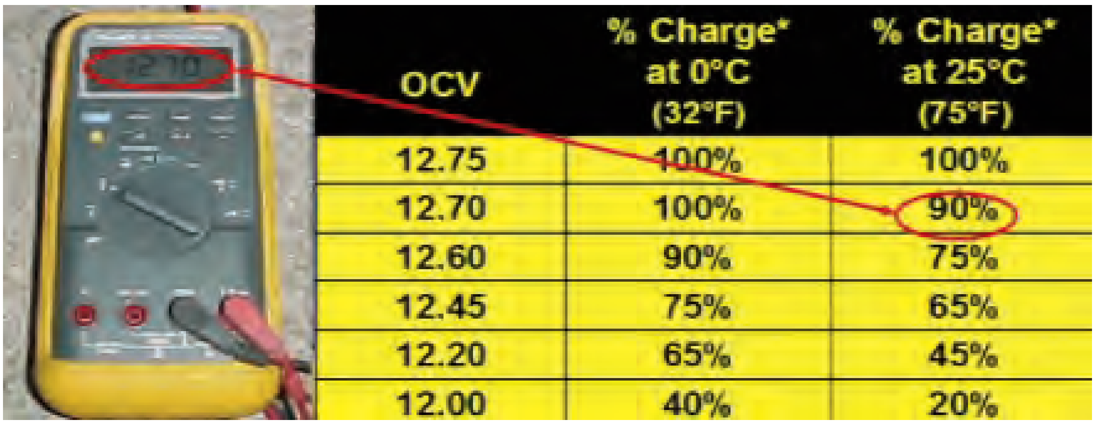
Note that the battery may appear to have a greater capacity when it is discharged intermittently than it may have when it is discharged continuously. This is because the battery is able to recover during the idle periods between heavy intermittent current drains. Thus testing a battery capacity with a continuous high current drain will not necessarily give results which represent the capacity achievable with the actual usage profile.

Load testing is often required to be carried out with variable load levels. This may simply be pulsed loads or it could be more complex high power load profiles such as those required for electric vehicle batteries. Standard load profiles such as the Federal Urban Driving Schedule (FUDS), the Dynamic Stress Test (DST) specified by the United Sates Advanced Battery Consortium (USABC), the United Nations Economic Commission for Europe specification (ECE-15) and the Extra Urban Driving Cycle (EUDC) in Europe have been developed to simulate driving conditions and several manufacturers have incorporated these profiles into their test equipment.

GETTING STARTED

THE FIVE STEP PROCEDURE

STEP 1: DETERMINE THE BATTERY SOH & SOC



OCV	% Charge* at 0°C (32°F)	% Charge* at 25°C (75°F)
12.75	100%	100%
12.70	100%	90%
12.60	90%	75%
12.45	75%	65%
12.20	65%	45%
12.00	40%	20%

The first step in this process is to determine the battery state of health (SOH) and state of charge (SOC). What is the battery voltage and what is the battery condition? If you have determined both of these battery conditions are good, you can continue your testing.

If you find the battery SOC is low, charge the battery THEN test the battery SOH. If the battery SOH is bad, replace the battery and begin your testing.

STEP 2: ELIMINATE ANY CHARGING SYSTEM PROBLEMS

The second step in the process is to eliminate any charging system problems. The charging system MUST be functioning correctly BEFORE any testing can begin. Remember, it is possible to have a parasitic current draw when the engine is off, all accessories are off and all of the modules are asleep. If the charging system is not functioning correctly, you will have a symptom of a parasitic current drain because the battery is running down.

Also, with the modern automotive charging systems being used today, if there is a fault, a DTC can be set. Make sure you diagnose and repair ANY DTC before beginning any testing.

STEP 3: SET UP THE VEHICLE FOR PARASITIC DRAW TESTING

The third step in this process is to set the vehicle up for parasitic draw testing. You need to make sure all of the accessories are OFF. The best way to do this is to simply turn the vehicle off and REMOVE the key from the vehicle and place it in a safe place away from your work area. Vehicles that use “Smart Key” technology have oscillators and transponders in the vehicle and a key that communicates with each other. This can cause a bit of a parasitic load on the vehicle battery. This situation should not happen but it does on a regular basis. Manufacturers are beginning to release TSBs on the subject along with steps to correct this situation.

Once you have the key safely stored, you need to close the door to the vehicle and wait until all of the control modules go to sleep or power down. How long can this take? The answer depends on the year, make, and model of vehicle and how many modules the vehicle is equipped with. It could be as little as 30 minutes or even up to 4 hours!

GETTING STARTED

THE FIVE STEP PROCEDURE

STEP 3: SET UP THE VEHICLE FOR PARASITIC DRAW TESTING

Typical Parasitic Current Draw Values

2005 Model Year Parasitic Load Measurements

Mal	Model	Model Ye	Options	Parasitic Load (mA) 0.5 mi	1 min	5 min	10 mi	20 mi	Comments
Buick	Rainier	2005	6-CD W/Rear Audio						Key Out
			Onstar & XM Radio	108	108	108	108	108	Key In
			Sunroof & Heated Seats						
Buick	LeSabre Custom	2004	Traction Control	150	7	7	7	7	Key Out
			am/fm cassette / CD	302	168	11	11	11	Key In
Buick	LeSabre Custom	2004		293	161	7	7	7	Key Out
				299	164	7	7	7	Key In
Buick	LaCrosse(Uplevel)	2005	Onstar	987	856	481	18	18	Key Out/In - Parasitic doesn't chang
	AGM Battery		Remote Start	981	856	480	18	18	Key In
			Monsoon 6 Cd/MP3						*Chime off with door ajar
Buick	LaCrosse(Base)	2005	Onstar	856	791	469	16	16	Key Out
	Flooded Battery		Side Impact	879	802	471	17	16	Key In
			CD w/XM Radio						*Chime off with door ajar
Buick	Regal GS	2004	Onstar	108	16	16	16	16	Key Out
			Side Impact	124	16	16	16	16	Key In
									*Chime off with door ajar
Buick	Rendezvous	2005	Onstar	10	10	10	10	10	Key Out
			Heated Seats	10	10	10	10	10	Key In
									*Chime off with door ajar
Buick	Park Avenue	2005	Head-up Display	958	668	172	127	31	Key Out
			Radio CD/Cassette	976	625	216	128	31	Key In
			Memory Package						*Chime off with door ajar
									Vehicle Build Date 4/04

STEP 4: MAKE YOUR MEASUREMENT

Step four is to make your measurement. Determine if you have an excessive current drain on the vehicle. As we discussed earlier, there are two types of AMP clamps you can use to measure current draw. They are large jaw and small jaw amp clamps. Large jaw amp clamps are great for testing 30-100 amps in situations such as alternator output and charge rate or starter draw testing, but for parasitic current draw testing, you want to use an amp clamp that can measure as low as 2 – 3 milliamps. To measure milliamps in this low of a range, you want to use the amp clamp with the smaller opening.

Once you have chosen the tool you want to use to perform the test, a good practice to get into is validating your tool. To validate your tool, turn on a load in the vehicle that you know what the current draw specification is. Make sure you DO NOT turn on a load that your equipment cannot handle or you risk damage to your tool.

GETTING STARTED

THE FIVE STEP PROCEDURE

STEP 5: GENERALIZE THEN LOCALIZE THE BATTERY DRAIN

The fifth and final step in the process is to generalize and then localize the battery drain. The generalization step we discussed earlier is determining if you do actually have an excessive battery drain. You need to determine if the excessive battery drain is enough to warrant the customer complaint.

Once we have generalized the excessive battery drain we need to localize it. We need to test the vehicle circuits to narrow down where the fault is happening. As a technician you already have a fair amount of experience in doing this. Look for the usual suspects such as lights of all kinds, sticky relays, electronic modules that will not power down, aftermarket accessories, high resistance shorts to ground on B+ circuits, electronic ride control modules and sensors, leaky alternator diodes, etc.

HINT! Generalize at the fuse panel(s) first. Use a DVOM and test each fused circuit then localize down to the wiring branch and/or actual component draining the battery. Keep in mind we are not looking for a large voltage drop, we are looking for a voltage drop of ANY type. When testing, you should see 0.00V. If you see 0.081V (or any voltage), you know you have a problem. If the vehicle is powered down, there should be no load going across the fused circuit.

NOTES

CHOOSE YOUR WEAPON

As you can see in the illustration above we have a multitude of tools we will be using during the hands on portion of the presentation. We have everything from DMMs, both types of amp clamps, a Midtronics battery tester, the Bosch BAT 151 and the Delphi flasher/scan tool.

CHOOSE YOUR WEAPON

DELPHI SCAN TOOL

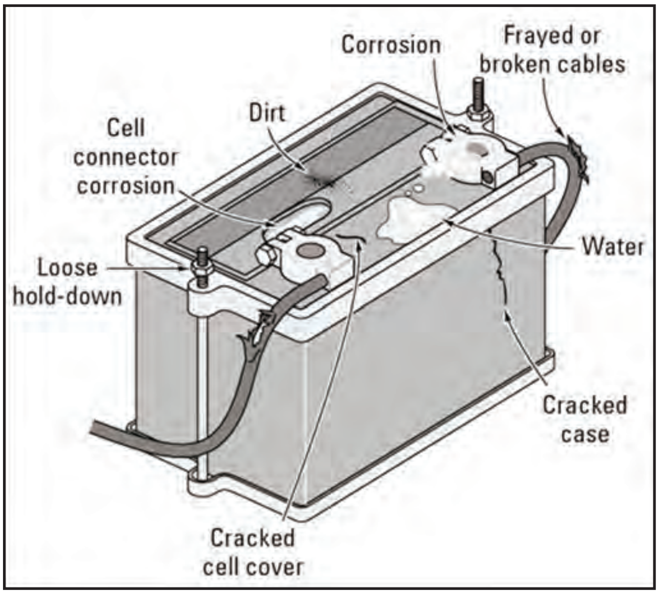
We have connected the Delphi scan tool to the vehicle's Data Link Connector (DLC), and then connected the tool to the laptop. Once the scanner communicated with the vehicle we were able to scan the modules on the vehicles communication network for DTCs.

After the scan we found there were 12 modules on the network and a total of eight DTCs stored in the modules memory. Keep in mind that any one of these codes or a combination of these codes can be the cause of the parasitic drain the vehicle is experiencing. The best thing to do when you run into a situation where there are multiple codes is to save the data. This could be the difference in solving an intermittent condition or not.

After saving the data we can clear the codes and retest the system to see if any DTCs reset. After retesting the system we see that only four of the original DTCs have returned. Before moving on to the next step in the five step process, you need to diagnose and repair the remaining DTCs. By doing so, it will help you to determine if the problem indicated by the DTC was the actual problem causing the parasitic drain.

CHOOSE YOUR WEAPON

BATTERY SOC & SOH INSPECTION



A battery, like other parts of your vehicle, is subject to wear and tear and should be checked regularly. In particular, pay attention to the battery's trouble spots, shown here. A battery that is kept clean with good connections will last longer than a battery that is neglected.

Never work on a battery with a lit cigarette in your mouth. Batteries are filled with sulfuric acid that generates hydrogen gas. If you get acid deposits on your skin or clothes, wash them off with water immediately.

Disconnect the battery whenever you work on it and be sure to shut the engine off first! On most modern vehicles, computers control functions of the engine, fuel and ignition systems, automatic transmissions, and other stuff. Be extremely careful not to inadvertently send a shot of unwanted voltage into one of the computers and destroy it.

Always remove the negative cable from the battery if you plan to work on wiring under the hood. This prevents you from possibly damaging electrical components or receiving a shock.

When removing and replacing both battery cables, always remove the negative cable first and replace it last. If you attempt to remove the positive clamp first and your wrench slips and touches something metal, your wrench can fuse to the part like an arc welder.

Tie the cables back while you work on the battery. Don't allow anything made of metal to connect the terminal posts; this can damage the battery. If the cables are connected to the posts when something else interferes, you can destroy the on-board computers.

Clean off powdery deposits on the positive and negative terminals. The deposits that form in lovely colors on the top of your terminals are made by battery acid. Before you clean it, remove the cables (negative first) from both terminals by undoing the nut on each cable clamp and wiggling the cable until the clamp comes off the terminal post.

To brush the deposits off the terminal posts and cable clamps, sprinkle some baking soda onto each terminal, dip an old toothbrush or disposable brush in water, and scrub the deposits away.

CHOOSE YOUR WEAPON

BATTERY SOC & SOH INSPECTION

If your cables and clamps won't clean up completely with baking soda and water, rotate an inexpensive battery terminal brush on each terminal to shine it and ensure a good, solid electrical connection. You can also shine the insides of the cable clamps with the clamp cleaner that's usually sold as one unit with the brush. A soapless steel wool pad may also do the job.

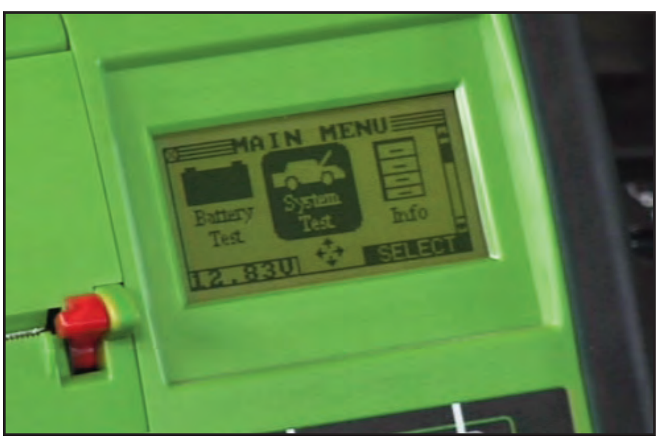
Dry everything with a clean, disposable, lint-free rag. Try to avoid getting the powdery stuff on your hands or clothes. If you do, wash it off with water right away.

Reconnect the terminals to the battery, replacing the positive cable first and the negative cable last. After the battery terminals are reconnected, coat the terminals with thick automotive grease or petroleum jelly to prevent corrosive deposits from forming again.

Examine the battery cables and clamps to see whether they're frayed or corroded. If the damage looks extensive, the cables and clamps may need to be replaced; otherwise, the battery may short-circuit, which could damage on-board computers.

If you've been having trouble starting your engine, your headlights seem dim, or if the battery is old, check to see whether the electrolyte in the battery is strong enough. If it's weak, the battery may need to be recharged or replaced before it dies and leaves you stranded.

Check the battery case and the terminals. If you see major cracks in the battery case or obvious terminal damage, replace the battery regardless of its electrical performance.



Once all of the cables have been either cleaned or replaced we can begin testing the battery using the Bosch BAT 151 battery tester. As you can see we have connected the BAT 151 to the vehicle battery and we are showing 12.83V on the tools display.

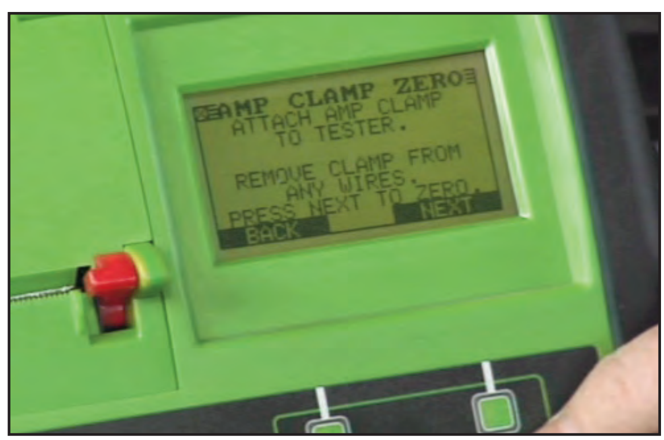
CHOOSE YOUR WEAPON

BATTERY SOC & SOH INSPECTION

The next screen to appear after we click the “next” option is to select whether we will be using the amp clamp. We will be using the amp clamp for our testing so we will be selecting the amp clamp available option and clicking next.

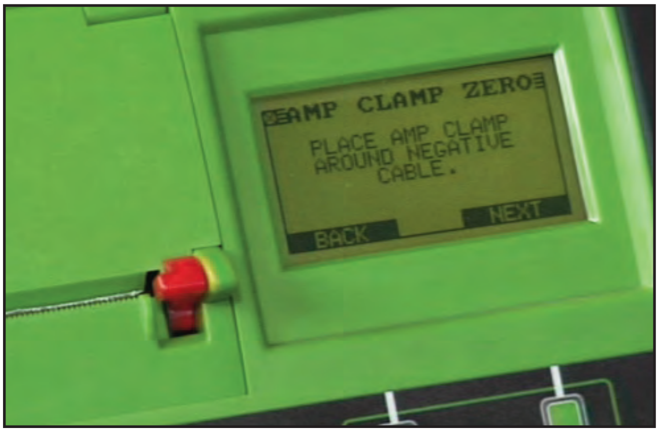
The next screen to appear after we click the “next” option is to select whether we will be using the amp clamp. We will be using the amp clamp for our testing so we will be selecting the amp clamp available option and clicking next.

Then next screen tells us we need to zero the amp clamp and connect it to the tester. To do this we must remove the clamp from any wires, and then press next on the BAT 151 to continue.

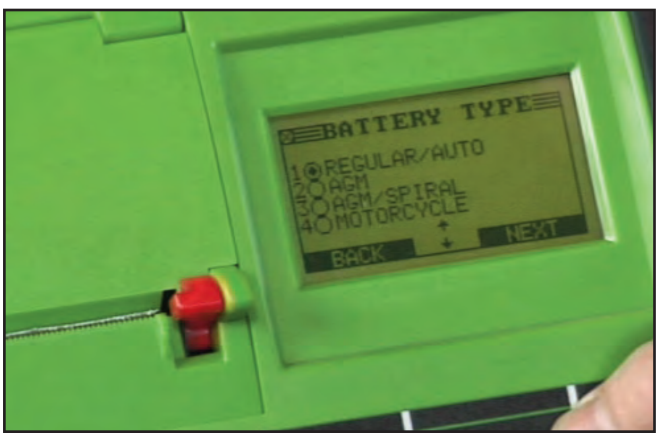


CHOOSE YOUR WEAPON

BATTERY SOC & SOH INSPECTION



Once the tool has zeroed the amp clamp we are prompted to place the amp clamp around the negative cable of the battery. Our vehicle is equipped with three cables coming from the negative terminal of the battery. ALL of these cables MUST be clamped by the amp clamp.



After clamping all of the cables and clicking “next” on the tool, we will be prompted to enter the date on the battery, battery type, rating units (CCA), and temperature of the battery.

Once all of the above information has been entered into the tool, the tool will begin testing the conductance of the battery.

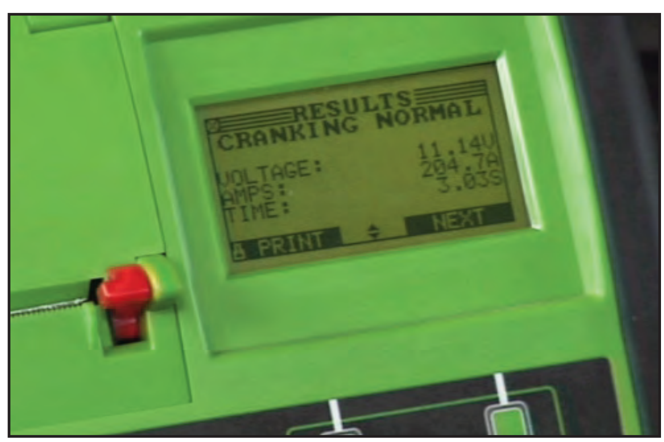
CHOOSE YOUR WEAPON

BATTERY SOC & SOH INSPECTION

When the test is complete the tool will display the results within the monitor window. As you can see the results are voltage 12.81V, the measured CCA was 569 and the temperature was 77°F. Due to the low CCA, this battery is at a marginal level and should be replaced.

For the next part of the test the tool is prompting us to start the engine.

The results of the cranking test show the starter required 11.14V and drew 204.7 amps and the starter did its job in 3.03 seconds.



CHOOSE YOUR WEAPON

BATTERY SOC & SOH INSPECTION

The next thing we need to do is check the alternator for proper function. We select "next" on the tool and are prompted to turn all vehicle loads off and idle the engine. The tool then prompts us to increase the RPM of the engine with the loads off for five seconds.

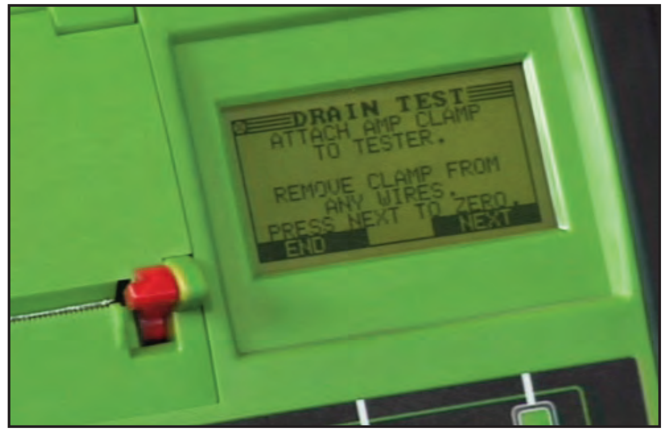
Once the tool has gathered the data from the high rpm test, we are instructed to return the engine to idle then turn on the high beams and blower motor. Once the tool has gathered the data from the high rpm test, we are instructed to return the engine to idle then turn on the high beams and blower motor. Once we have turned on the specified loads, the tool instructs us to rev the engine with the loads on for five seconds.

Once both tests are complete the tool reports the results as follows: With the No Load conditions the charging system is operating at 13.84 volts and 7.6 amps. Loaded, the charging system is operating at 13.83 volts and 6.4 amps. The tool is also reporting the charging system has passed both tests and is operating correctly.

CHOOSE YOUR WEAPON

BATTERY SOC & SOH INSPECTION

After completing the charging test the tool prompts us to begin the drain test. We are instructed to attach the amp clamp to the tester and remove the clamp from any wires it may be connected to.



After zeroing the amp clamp and clamping it around all of the negative battery cables, we click “next” and begin the drain test. The results of the drain test reveal a 1.26 amp drain prompting the tool to give us a “suspect” result.

The suspect result in this case is not surprising. We just turned engine off so some of the modules and control heads have not gone into their power down mode. They are still drawing current from the battery.

NOTES

CHOOSE YOUR WEAPON

AMMETER

As you can see in the illustration we have installed a knife switch. As we discussed earlier, a knife switch is a type of switch used to control the flow of electricity in a circuit. It is composed of a hinge which allows a metal lever, or knife, to be lifted from or inserted into a slot or jaw. The hinge and jaw are both fixed to an insulated base, and the knife has an insulated handle to grip at one end. Current flows through the switch when the knife is pushed into the jaw. Knife switches can take several forms, including single throw, in which the "knife" engages with only a single slot, and double throw, in which the knife hinge is placed between two slots and can engage with either one.

After we installed the knife switch we connected the amp clamp to the ammeter and selected one of the three negative cables to test. Our initial reading was 3 milliamps. However, as we moved the amp clamp around the wire and changed its position, the reading changes as we move it. One of the last readings we saw as 6 milliamps. Remember, we need to add a zero at the end of our reading to convert to milliamps!

Not really excessive but also not very stable.

When we move the amp clamp the third negative cable we see we have almost 90 milliamps which is quite excessive. You may be thinking our amp clamp has a bad battery or has been damaged. We used another amp clamp on the same wires and the results were the same. This tells us that the amp clamp may not be the best tool to use in this case. This vehicle has a large amount of electronics and we may be better off using a Digital Multi Meter to test the system.

CHOOSE YOUR WEAPON

AMMETER

After disconnecting the amp clamp we connected the DMM leads to the knife switch. As you can see, we have roughly 13 milliamps of current draw. Keep in mind we did let the vehicle rest until all of the modules went into sleep mode. The original customer complaint was the battery runs down after a week. Thirteen amps is not enough parasitic current draw to run a battery down in a week.

What we did find is a pulse in the current draw. The current draw would jump from 13 milliamps to 30 milliamps for just a fraction of a second. All things considered, 30 milliamps is still not enough to validate the customer complaint.

After examining this power surge even further, we found the cause to be in the passive anti theft system. Every time the red light on the dash would pulse, there would be a spike in the current draw. This is a normal function of the vehicle and was not the cause of the parasitic drain.

NOTES

CHOOSE YOUR WEAPON

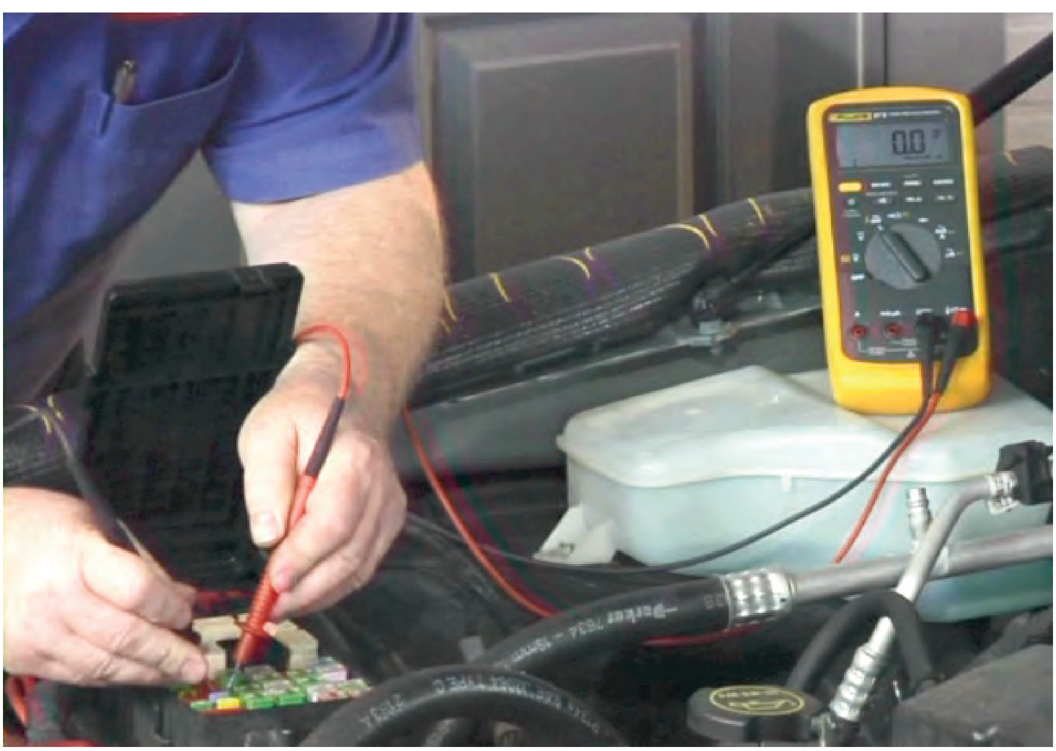
VOLTAGE DROP TEST

After a brief road test, we pulled the vehicle back into the service bay and reconnected the DMM to the knife switch. We let the vehicle rest for approximately 30 minutes and watched the current draw drop on the meter as the accessories of the vehicle turned off and the modules powered down. However, as you can see the DMM is now reading 141.9 millivolts. Why is this? The answer is we have confirmed the customer complaint. We can be very confident this vehicle has a parasitic current draw. We do not yet know where the draw is or what it is related to, but we know we have one.

This level of parasitic current draw would definitely run this battery down within a week. If we were in a colder climate or the battery state of health was bad, it would run itself down even faster, probably within a few days.

Now that we have determined the vehicle does in fact have a parasitic current drain we need to go find out what the cause is. There are many ways to do this. We could use the amp clamp and test every single circuit coming from the fuse panels but this would take forever on this type of vehicle. We could go to the fuse panel and pull each fuse while monitoring the DMM for the correct readings to determine when the problem goes away but this comes with its own set of problems.

Much like removing the battery cables from the battery, when you remove a fuse from the fuse panel, you run the risk of resetting a module thus not being able to find the intermittent problems.



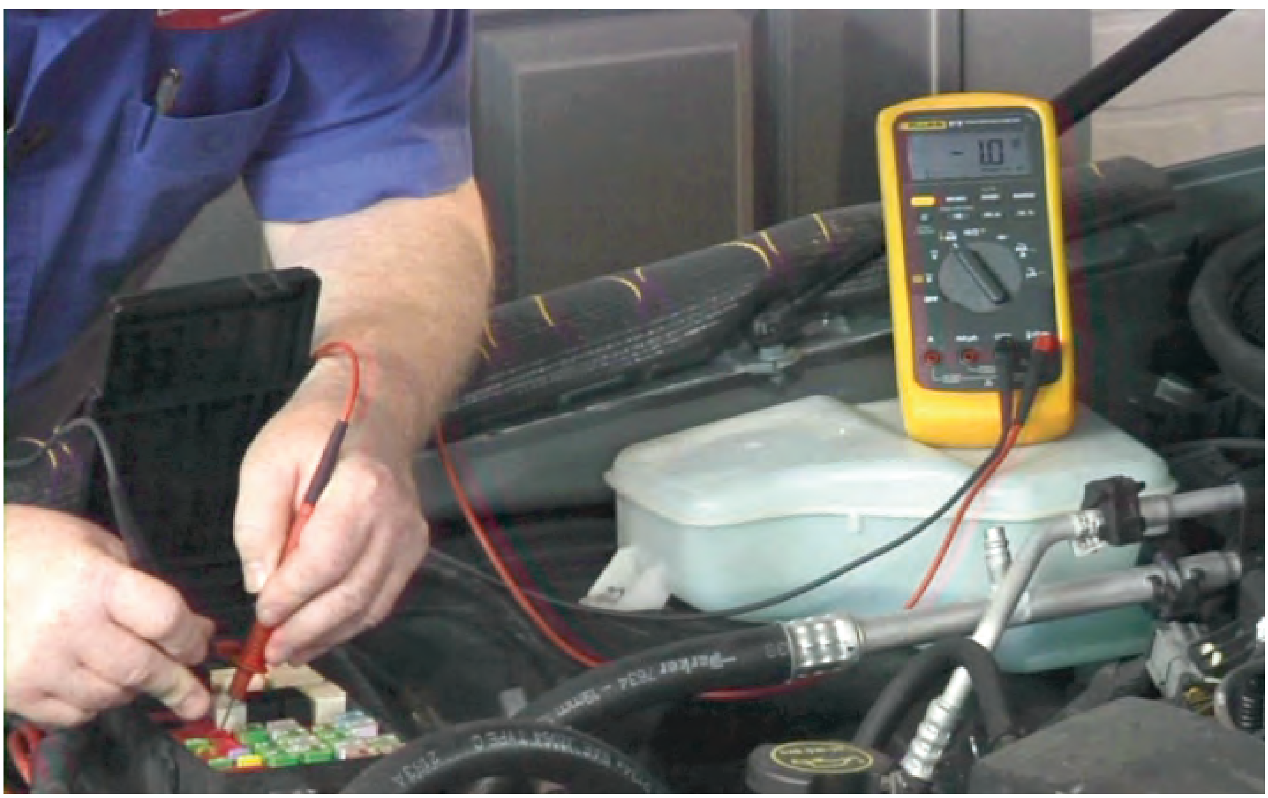
CHOOSE YOUR WEAPON

VOLTAGE DROP TEST

The last and best way to test for this type of condition is a voltage drop test across the fuse. At this point in the presentation we all know voltage drops are a bad thing. In a perfect world a good electrical connection would have no voltage drop if there were no current flowing through it and we would always see “0.00” on the meter. This of course is not true. Even the best circuits have some degree of voltage drop when current is flowing through it.

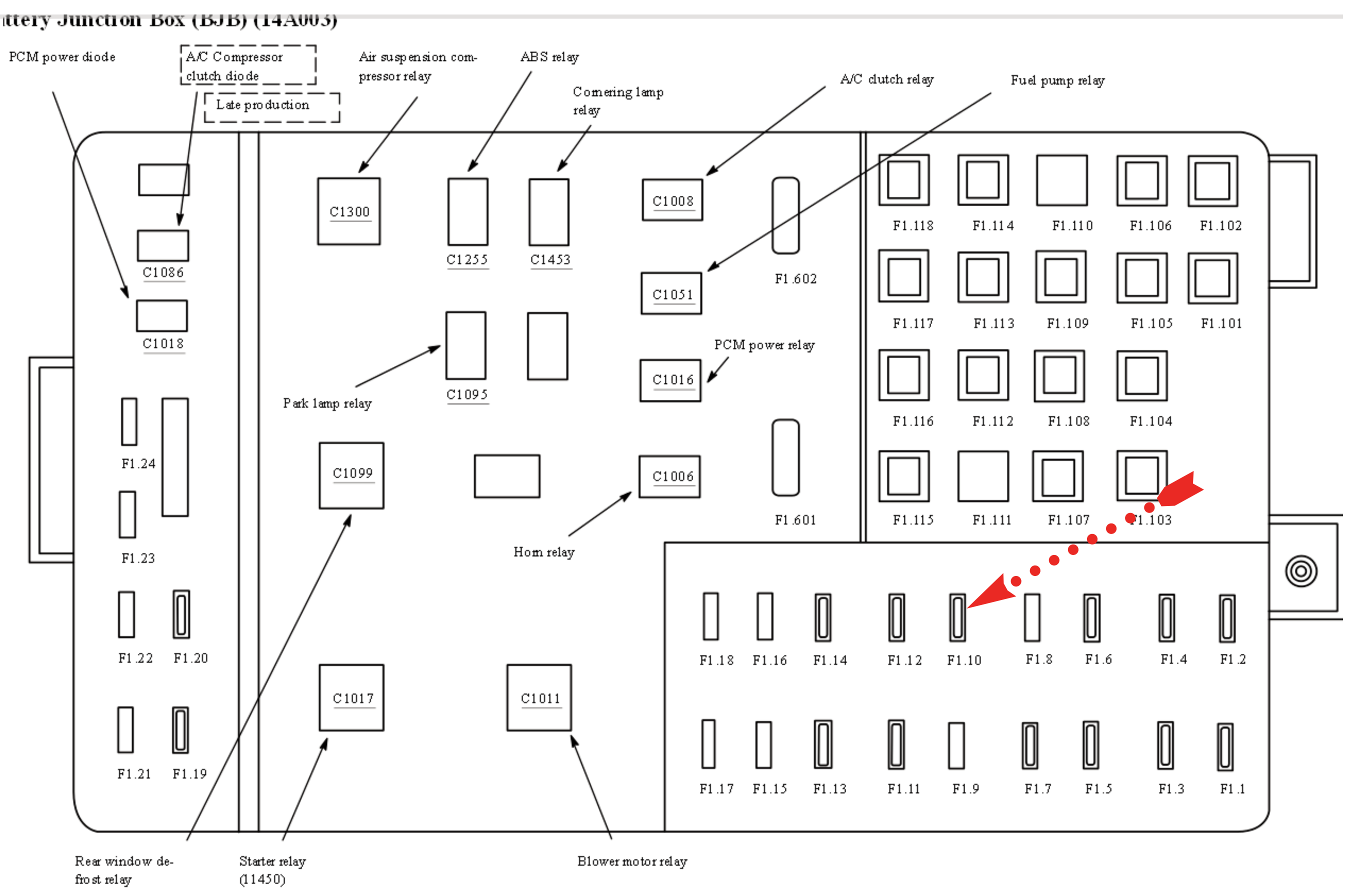
Notice we keep saying “if there is current flowing through it”. This is because when we perform a voltage drop test to find parasitic draw, we are looking for current.

As we begin to test the fuses within the fuse panel we begin to see what you would expect to see. So far each fuse is reading 0.00 milliamps on the meter indicating no current is flowing through the circuit we are testing. This testing goes fine until we test a 10 amp fuse and the meter reads 1.0 milliamps.



CHOOSE YOUR WEAPON

VOLTAGE DROP TEST



Once we determined the 10 amp fuse had a current draw, we need to know what circuit that particular fuse is powering. To do this we need to refer to the appropriate diagram of the battery junction box. As you can see, the 10 amp fuse in question is fuse F1.10. Looking further into the service information we see that F1.10 is powering the air suspension module.

This problem is quite common to this vehicle and the cause can be any number of things such as a stuck relay, bad sensor or a leveling motor that will not turn off. Have we determined EXACTLY what the fault is? No, but we have determined which circuit has the parasitic current draw. This gives us a good diagnostic path to go down as we continue our diagnostic process.

TECH TIP! There really is no need to test every single fuse if you do not have to. Use a test light to determine which fuses have power going to them, THEN test them with your DMM!

PARASITIC DRAW TESTING

1987 CORVETTE TOTAL DRAW

Our next subject vehicle is a 1987 Chevrolet Corvette, a classic car with classic problems. As most of you know, these cars are stored for long periods of time without driving them leading to dead batteries due to parasitic current draw. To combat this, owners of these vehicles have taken steps such as a battery disconnect switch or a trickle charger. The customer complaint is the vehicles battery dies within a matter of days. Not weeks or months, days.

The purpose of this exercise is to compare the current draw readings on the DMM V.S. the amp clamp. As always we want to follow the five steps we talked about earlier to prepare the vehicle for testing. We have verified the battery is good, the starting and charging systems are functioning properly, all of the accessories and modules have been powered down and there are no DTCs in memory that need to be diagnosed and/or repaired.

After connecting a knife switch to the battery cable we tested for parasitic battery drain and found there was a current draw of approximately 53 millivolts. Although this is a little high, it is not enough to kill the battery within a couple days but it is enough to kill it within a month or so. At this point we want to start the vehicle and put it through a few key cycles, open the doors and a few other loads just to see if they wake up and go back to sleep.

1987 CORVETTE DIAGNOSIS & REPAIR

After waiting approximately 20 minutes for the modules and accessories to power down we did find the vehicle had an excessive parasitic current draw. As we probed the fuses that were powered we found we had a parasitic draw on the courtesy lamp circuit. As you can see in the illustration, the meter is reading approximately 260 milliamps. This type of parasitic current draw is definitely enough to run the battery down in this vehicle in a matter of a day or two.

Now that we have determined what circuit is causing the parasitic current drain we need to determine what component(s) on the circuit are the culprit(s). This particular circuit power not only the courtesy lights but the clock, the KAM for the radio, the Bose sound system relay and the power antenna.

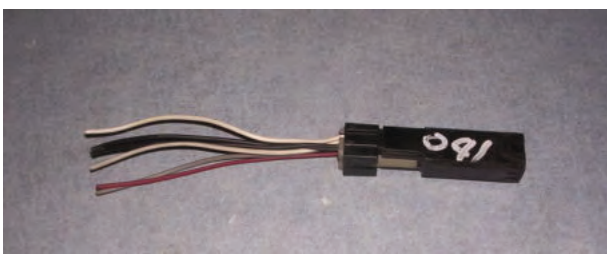
We took a closer look at the components on the circuit and found the courtesy lights are functioning correctly, the clock and radio are functioning correctly and the Bose relay is also functioning correctly. What isn't functioning correctly is the power antenna. The power antenna is staying extended no matter if the key is on, off or if the radio is on or off. This could be the problem and we need to take a closer look at the antenna to make sure.

PARASITIC DRAW TESTING

1987 CORVETTE DIAGNOSIS & REPAIR

Upon further inspection we also checked the power antenna relay and found it to be functioning correctly as well. At this point we have tested every probable suspect powered by this circuit and found all of them to be good. However, as you can see we still have a parasitic drain of 125 milliamps.

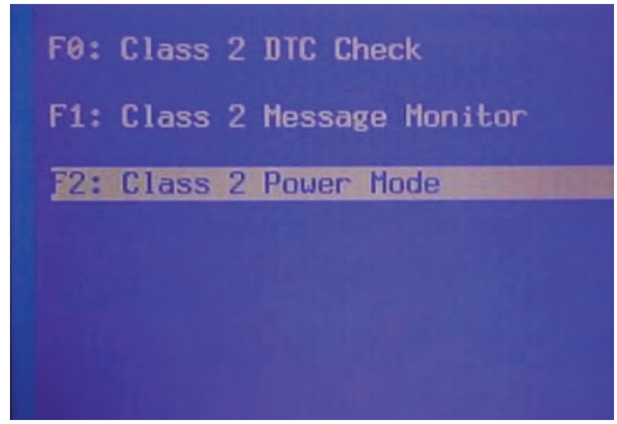
At this point we were literally stumped as to what the problem could be so we began inspecting the circuit piece by piece and found a connector in the trunk (GM part number 12033874), which happens to be the rear courtesy lamp control module. When we unplugged this module the parasitic drain disappeared.



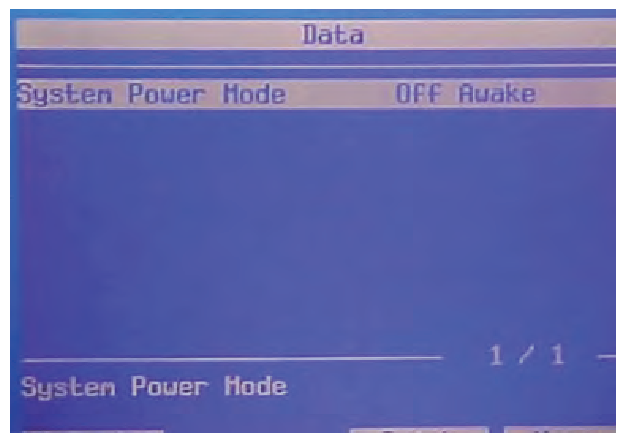
ADVANCED FORMS OF PARASITIC DRAW TESTING

GM TECH 2 PARASITIC DRAW TESTING

You may need more than the battery disconnect switch for some stubborn cases. You may need to watch the meter for an extended period of time to see if any solid state modules are waking up and drawing excess current. But who has time to baby sit their ammeter? In the case of a GM vehicle with a class 2 data bus, if you have a Tech 2 scanner, you have the ultimate parasitic drain babysitter ready to work while you make money on something else.

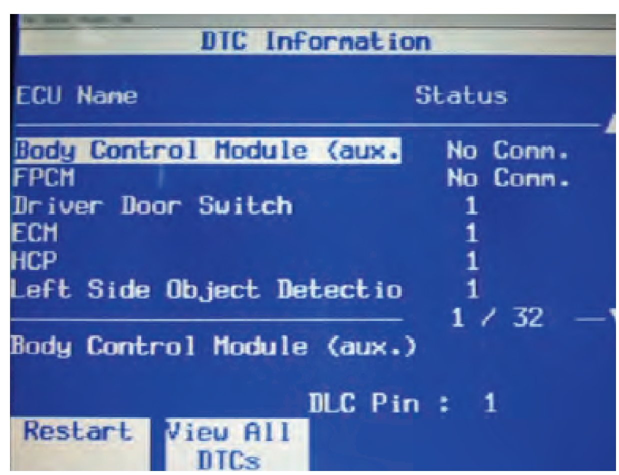


It's rather simple yet ingenious to do. First, set up your phantom parasitic drain test via the battery disconnect and ammeter arrangement mentioned previously. Next, remove the fuse that powers pin 16 of the DLC (12 volt supply for your scanner) so that when you connect your Tech 2, you won't be seeing its power demand on the ammeter. The fuse is often the same fuse as the 12 volt accessory / cigar lighter fuse. Next, power your Tech 2 with an alternative power source such as the 110V / 12V power supply that comes with the tool. Finally, build the vehicle with the Tech 2 setup menu. When you get to the main diagnostic menu (Powertrain / Body / Chassis / Diagnostic Circuit Check) select Diagnostic Circuit Check.



From there you can go into Class 2 Message Monitor and see all the modules that are on the BUS. Turn the ignition switch on one last time (with the battery disconnect switch closed) and watch the state listed next to each module on the bus display the word "Active". Next to the word "Active will be an odd number like 1, 3, 5, etc.

Turn the ignition off and watch the states for the modules to all go to "Inactive". It may take a few seconds / minutes. As they do, their previous odd number (1 for example) will increment up to an even number (2) as each module goes to sleep on the BUS and quits drawing any more current than the typical KAM current. Each module if it was a "2" next to the status of "Inactive" should remain a 2. You can now monitor bus activity by watching module status on the Tech 2. If a module won't go to "Inactive" (sleep state) or wakes back up to "Active" state (along with a state number change) you may well have narrowed down your problem.



Since the BCM is usually the bus power mode master device you may see it wake up first followed by other modules it might be waking up. The Tech 2 even allows you to put the modules all to sleep to hurry up the process in

ADVANCED FORMS OF PARASITIC DRAW TESTING

GM TECH 2 PARASITIC DRAW TESTING

testing. You can also leave the Tech 2 alone and allow it to monitor the status of the bus. If you leave the Tech 2 “baby sitting” the vehicle while you are off on another job and come back to find that the Driver Door Module (for example) incremented it’s status number from a 2 (Inactive) to a 6 (still inactive) you can guess what happened…the Driver Door Module (DDM) woke up (the status would have incremented to a 3) and went back to sleep (now a 4) and then woke up still yet another time (now a 5) and finally went back to sleep, which gave it the status of “Inactive” but at 6 which you now see on the tool.

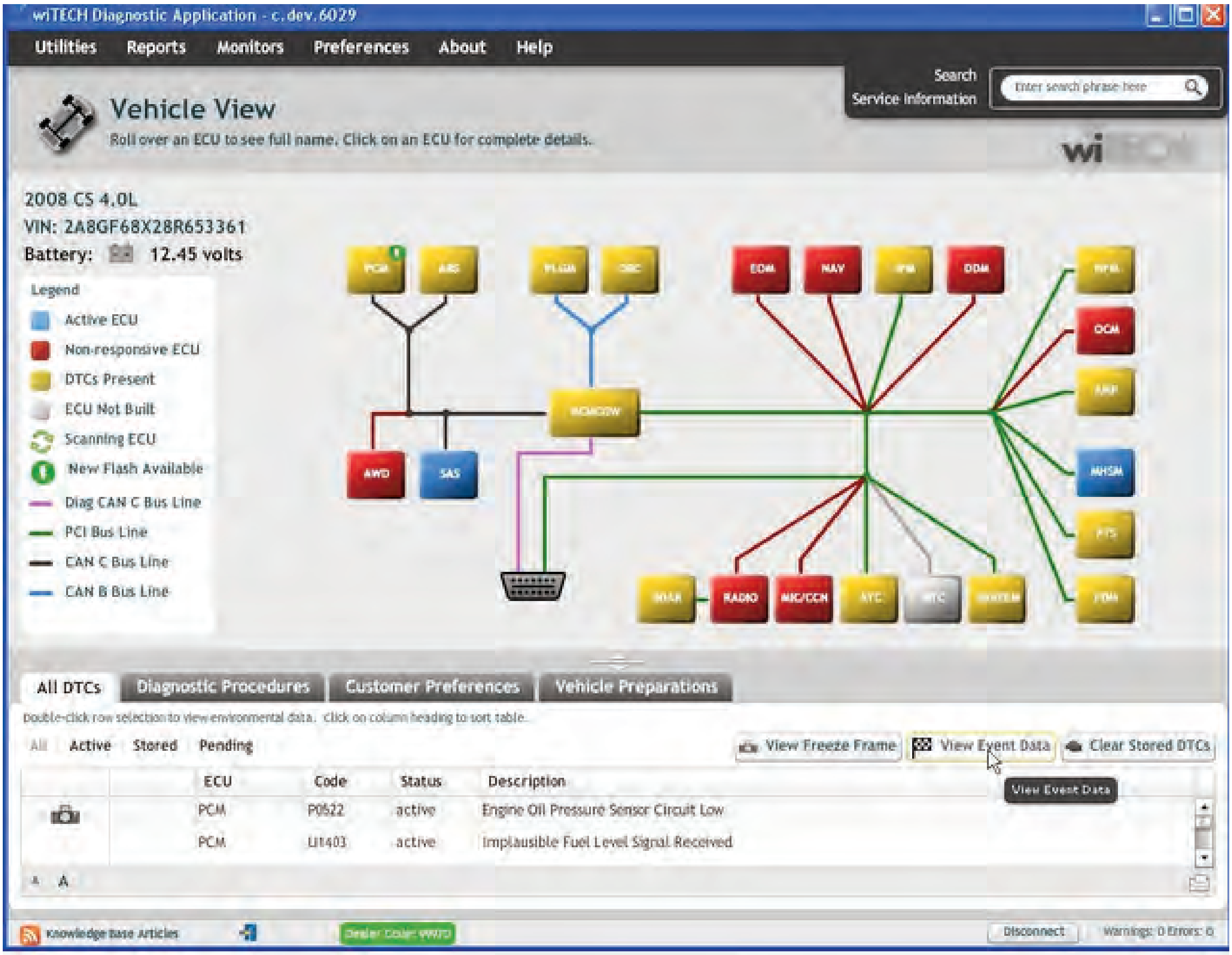
Keep in mind, an OnStar may need to turn on and wake up periodically due to the nature of its mission on the vehicle, but something like a DDM shouldn’t be waking up unless you touch the door handle or wake up the RKE. (Remote Keyless Entry) Pretty sneaky, that blasted DDM. But not sneaky enough to outsmart the Tech 2! And the best part is you let the Tech 2 do the job while you worked on something else.

Parameter	System State	Expected Value	Description
Operating Conditions: Ignition in the ON position. Bright Light Applied to the DRL ambient light sensor. Park brake not set. Headlamp Switch in the OFF position. I/P lamp switch in the OFF position. Fog lamp switch in the OFF position.			
Accy/RAP Relay Command	--	On	The scan tool displays On or Off. This is the state of the Accy/RAP relay.
Ambient Light Sensor	--	3.8 Volts	The scan tool displays Volts. When the ambient light is high the voltage is high.
Ambient Light Status	--	Day	The scan tool displays Night/Day/Unknown/Invalid. This is the status of the ambient light
Auto Hdlp. Disable Sw.	--	Inactive	The scan tool displays Inactive/Active. The scan tool only displays active when the switch in rotated and held in position. When the switch is rotated, the scan tool displays active for auto lts. ON and for auto lts. OFF.
Battery Current	--	Varies	This displays amps. This numeric value is the battery amperage.
Battery Voltage	--	Varies	The scan tool displays 0-20 Volts. The scan tool displays the voltage as received by the Module.
Batt. Low at Start	--	No	The scan tool displays Yes or No. Yes is displayed if the state of the battery charge is low during cranking.
Batt. Open Ckt. Tested	--	No	The scan tool displays Yes or No. Yes is displayed if the BCM senses an open battery circuit.
Batt. Open Ckt. Voltage	--	Varies	This displays Volts.
Battery Sulfation Mode	--	Inactive	The scan tool displays Active or Inactive. This is the state of the battery sulfation mode.
Battery Voltage High Res.	--	Varies	This displays Volts.
Backup Lamps	--	OFF	The scan tool displays On/Off. On is displayed when the backlamps are commanded on.
Brake Applied Output Signal	--	ON	The scan tool displays On/Off. This output of the BCM is displayed as ON when the brake pedal is applied.

SAMPLE TECH 2 MODULE PARAMETERS AND DESCRIPTIONS

ADVANCED FORMS OF PARASITIC DRAW TESTING

CHRYSLER



Advanced diagnosis of a parasitic drain within a Chrysler vehicle using the WiTech scan tool is somewhat similar to that of the Tech 2 on a GM vehicle. First you need to see which modules respond on the BUS with the ignition off as illustrated above. As the key is turned off, you should see modules go to sleep over a period of time.

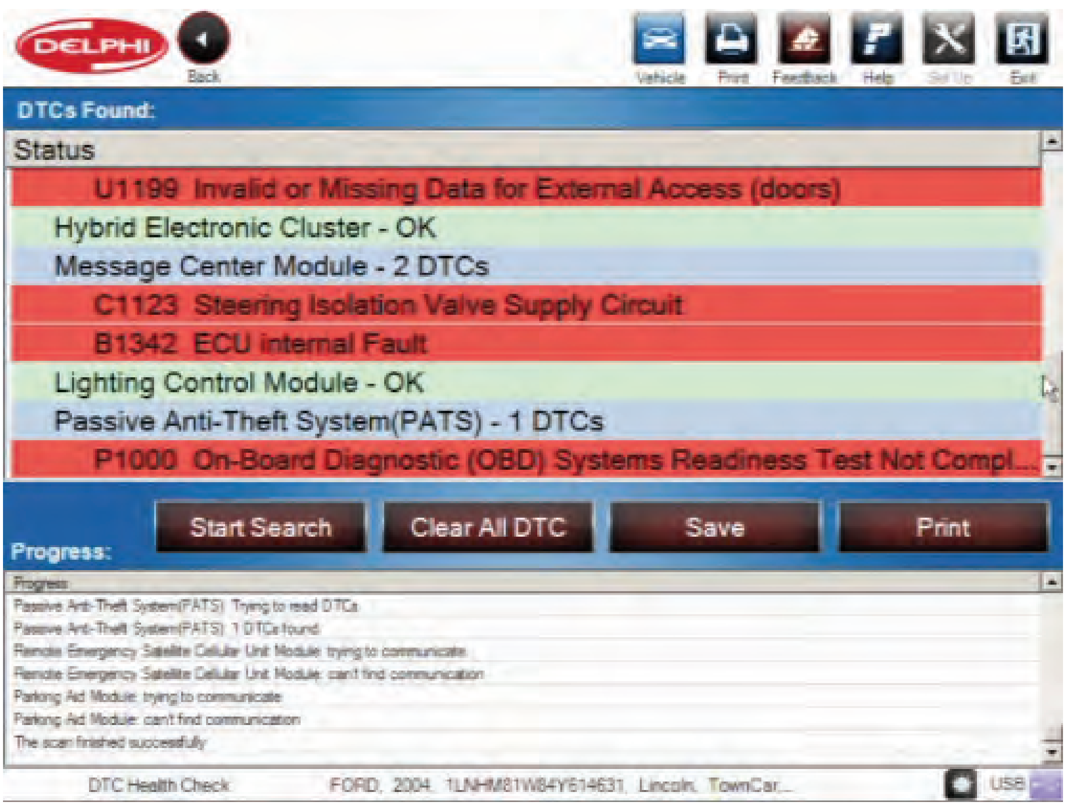
One important item of note, you need to be aware that the DLC may only have a single BUS within it. If you want to monitor other busses, you will need to use a lab scope at one of the modules on each of the non DLC busses.

ADVANCED FORMS OF PARASITIC DRAW TESTING

2010 CADILLAC CTS

Our case study vehicle is a 2010 Cadillac CTS that was purchased with a salvage title after GM repurchased the vehicle from the original owner due to a battery run down problem that could not be solved quickly enough to satisfy the customer. The vehicle was stored at the dealer while multiple service technicians and engineers diagnosed and solved the problem. Or so they thought. The vehicle was then put back on the sales lot and sold to another customer only to have the vehicle come back to the dealership two weeks later with the same problem as before.

Once we were involved we tested the systems for parasitic draw and found a very intermittent condition that was captured only momentarily. One item we did find very suspicious were the DTCs. Of course there were the normal DTCs displayed in memory when a battery runs down but after clearing the DTCs, we had one continue to come back over and over again.

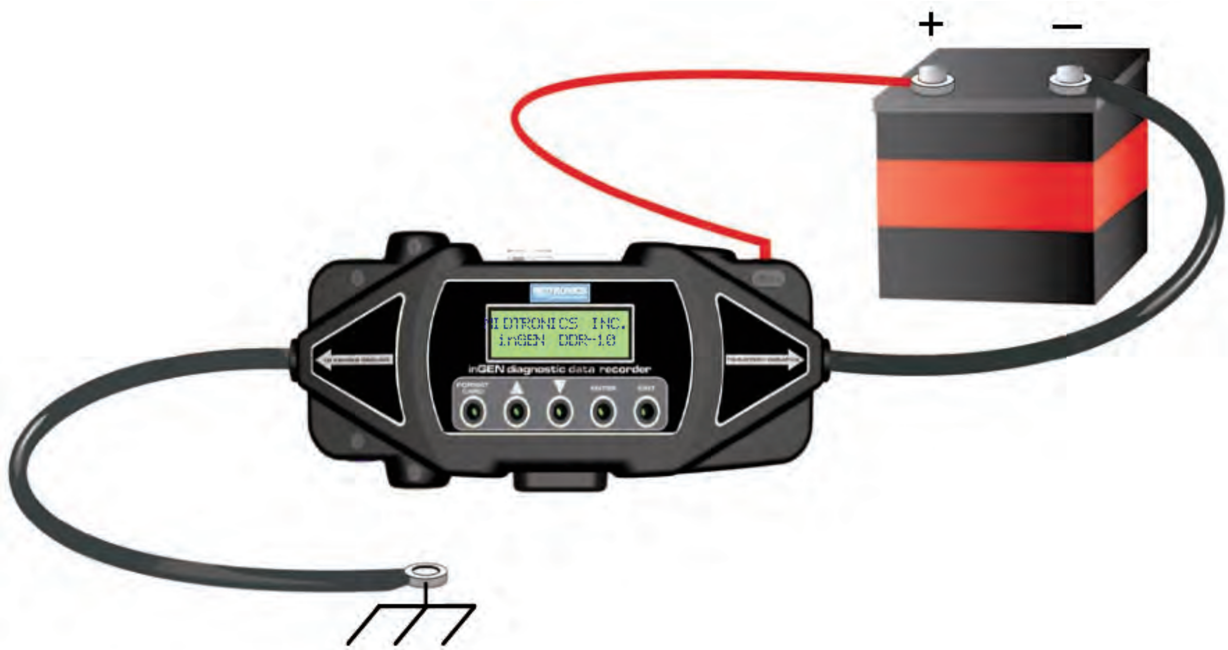


The DTC in question was B1342: ECU INTERNAL FAULT as illustrated above. The interesting thing about this code is that it was constantly set with the key OFF. This raised the possibility of this being the cause of the parasitic drain because a module such as the ABS module will not normally throw any DTCs with the key off. Remember, a DTC is nothing more than the computer telling you a certain module has failed a certain test and an ABS module does not perform any tests on the ABS system while the key is off.

We replaced the ABS module and retested the system and found that fixed the cause of the parasitic current draw. The moral to this story is to always read the DTCs on the vehicle. Even DTCs that you may not think have anything to do with the parasitic draw problem, may in fact lead you down the diagnostic path to solve the problem.

ADVANCED FORMS OF PARASITIC DRAW TESTING

MONITORING BATTERY DRAINS OVER AN EXTENDED PERIOD OF TIME



The DDR-10 DAS Diagnostic System is two interrelated tools: the inGEN™ Diagnostic Data Recorder (DDR-10) and the inGEN Diagnostic Analysis Software (DAS). The DDR-10 is an under-hood monitor for vehicle electrical systems that collects information on current drain, stalling, and no-start conditions—problems that would require time-consuming and costly trial-and-error troubleshooting without the benefits of the Diagnostic System. The DDR-10 connects to the battery and the vehicle ground to provide in-line testing, display, and recording of voltage, amperage, and temperature. The Diagnostic System includes accessories for monitoring additional current and voltage channels.

At the heart of the Diagnostic System is the Diagnostic Analysis Software. The software directs how the DDR-10 measures and records data according to your specifications and enables you to upload data via a data card to your computer for display and analysis. The DAS runs on a PC with Windows ® XP, and a data card reader is included that connects to a USB port.

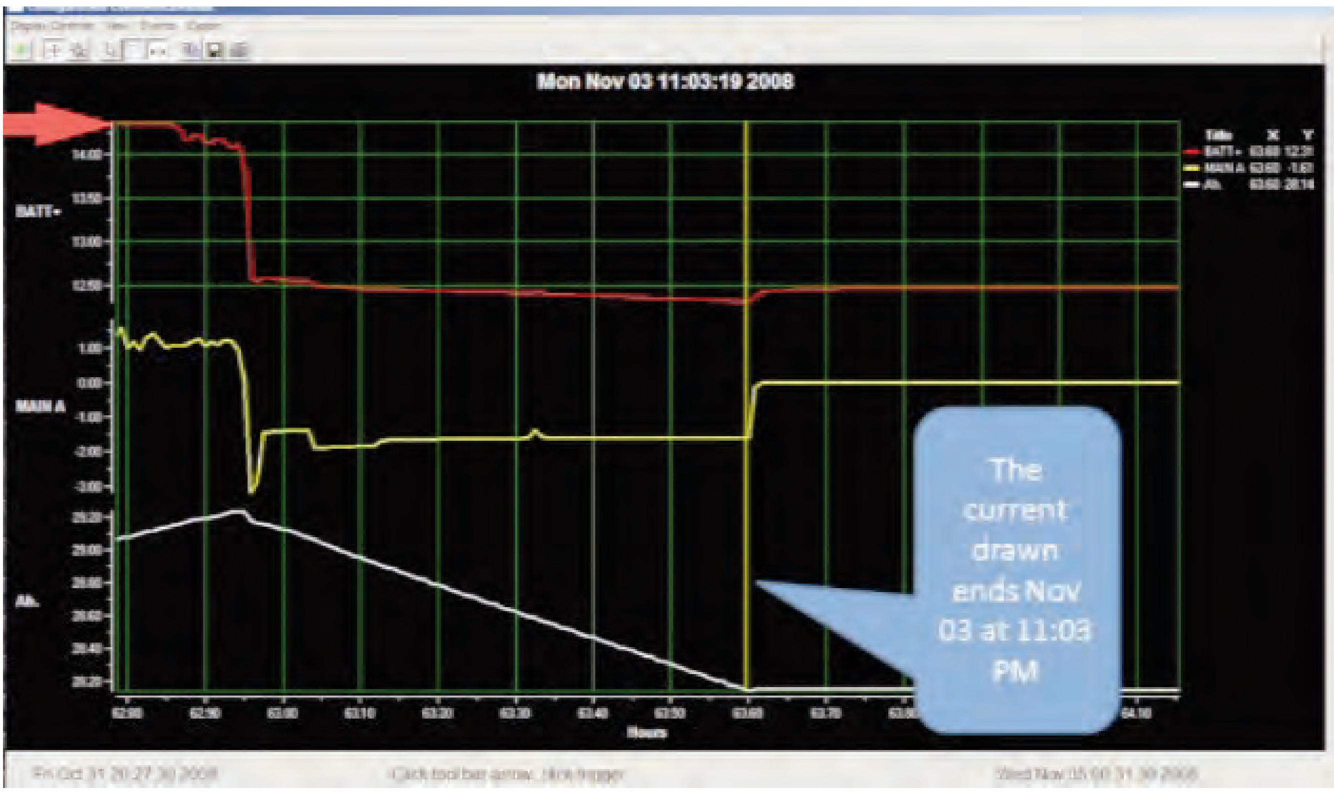
The DDR-10 can measure and record or log voltage at five different sources. Battery voltage is measured through the BATT + connection, which also supplies power to the DDR-10. You can connect up to four auxiliary test leads to determine when electrical components are switched on or off. Charge and discharge current is measured through the DDR-10’s series connection. An auxiliary current source is measured at the AUX A connection through which you can isolate a vehicle system by connecting to a fuse holder or other source. This channel has a maximum current capability of 30 A. The DDR-10 also has a built-in sensor that approximates system temperature, which is logged with the voltage and current measurements.

The DAS does much more than its name indicates. The DAS gives you the ability to determine at what point in the vehicle electrical system the DDR-10 collects data and when it collects it. The configuration file you edit using the DAS works with the DDR-10’s firmware, hardware, and cable connections. The configuration file specifies conditions or triggers, such as changes in voltage and current, that control at what intervals the DDR-10 collects and logs data on its removable data card. Additionally, in the configuration file you can regulate the DDR-10’s power consumption by adjusting the transition thresholds of its three power modes: Full Power, Low Power, and Deep Sleep Mode.

ADVANCED FORMS OF PARASITIC DRAW TESTING

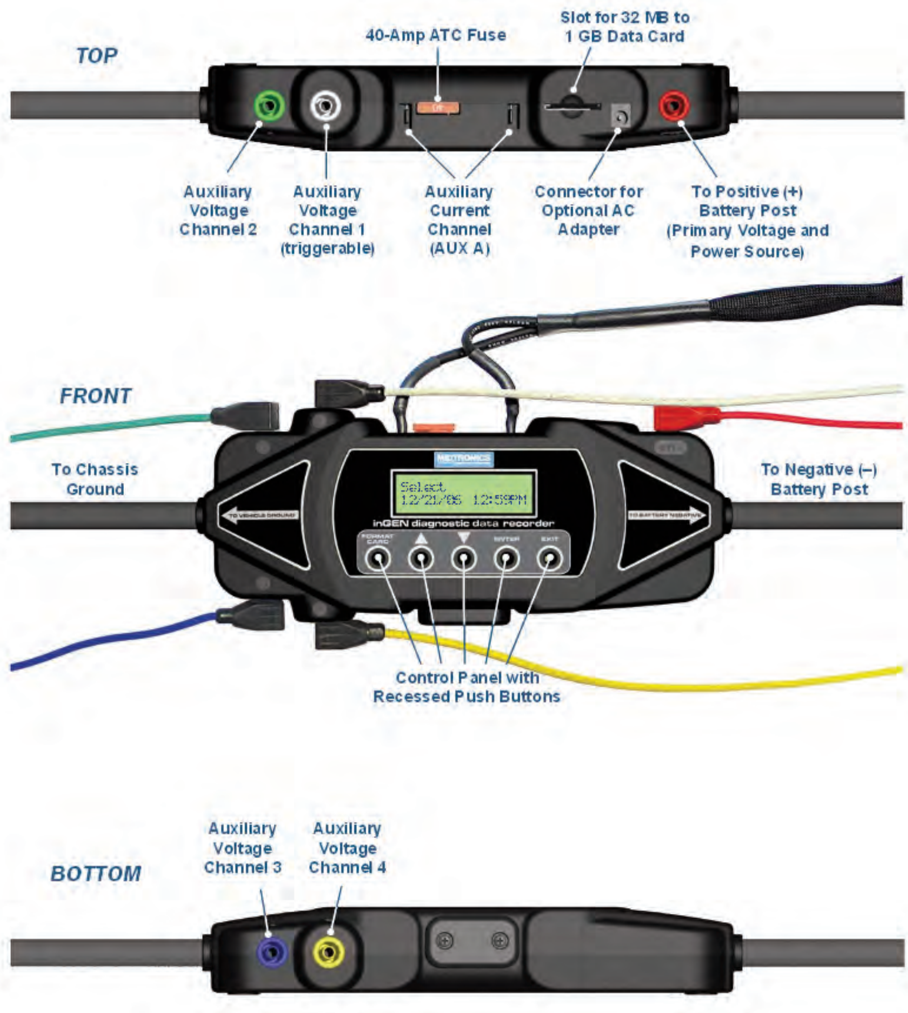
MONITORING BATTERY DRAINS OVER AN EXTENDED PERIOD OF TIME

The DAS graphs data with measurements along the vertical axis and time along the horizontal axis. The measurements are labeled with the channel name and color coded to match the DDR-10’s connectors and cables. Data can be scaled, panned, and zoomed for clarity. To highlight specific events, such as a reached set point or a change in one or more graphed measurements, you use Boolean operators (AND, OR) and mathematical symbols, and save the formula to be used again. The DAS also enables you to compare the graph to a reference graph of benchmark measurements. Graphs can be printed or exported to spreadsheets and databases.



ADVANCED FORMS OF PARASITIC DRAW TESTING

MONITORING BATTERY DRAINS OVER AN EXTENDED PERIOD OF TIME



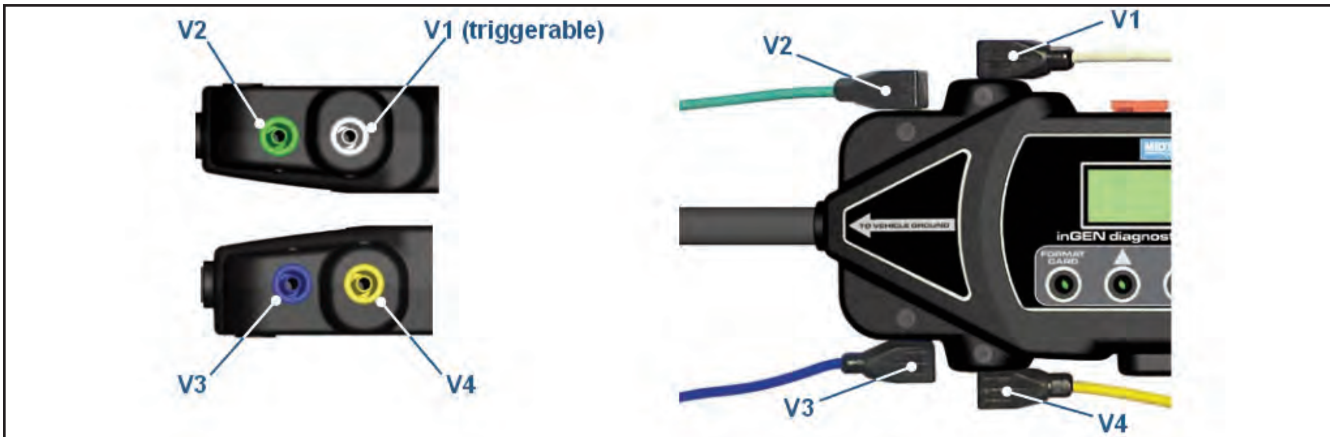
DAS CONNECTIONS AND DATA PORTS

ADVANCED FORMS OF PARASITIC DRAW TESTING

MONITORING BATTERY DRAINS OVER AN EXTENDED PERIOD OF TIME

The auxiliary current cable (AUX A) is connected through a fuse adapter to fuse holders inside the vehicle and under the hood. Secure the connection between the auxiliary current cable and the fuse adapter with a nylon strap or electrical tape.

To safeguard the vehicle electrical system as well as the auxiliary current cable:
- Monitor the auxiliary current only when the vehicle is not being driven.
- Keep the auxiliary current cable away from door and hood hinges and from the fenders.
- Do not let unconnected wires touch metal on the vehicle or anything that can conduct electricity.
- Make sure all connections are fused.
- Secure all wiring with cable clamps or electrical tape.
- Insulate all wires and do not allow any bare wiring to remain exposed.



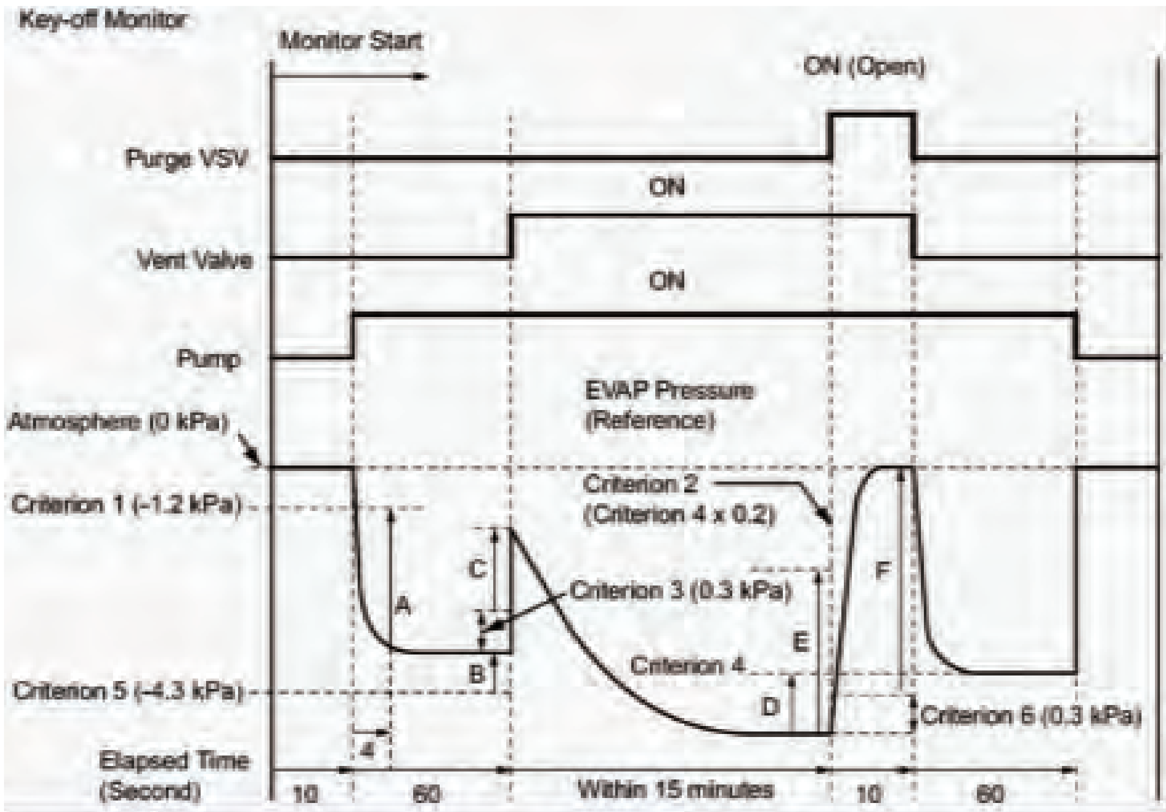
CONNECTION AT DASHBOARD FUSE PANEL

CONNECTION AT FUSE PANEL AT BATTERY

ADVANCED FORMS OF PARASITIC DRAW TESTING

MONITORING BATTERY DRAINS OVER AN EXTENDED PERIOD OF TIME

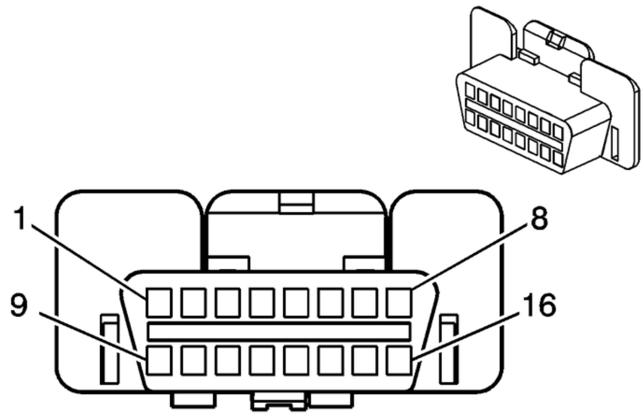
Be advised! Sometimes a draw you see is a false alarm such as any Key OFF EVAP monitors as illustrated below!



NOTES

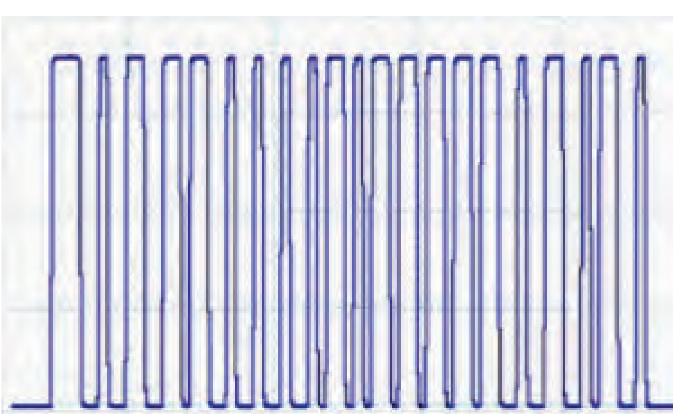
ADVANCED FORMS OF PARASITIC DRAW TESTING

USING THE DLC



Pin 1 – GMLAN Low Speed	Pin 9 – Discretionary
Pin 2 – J1850 (Class 2)	Pin 10 – Bus – J1850
Pin 3 – Discretionary	Pin 11 – Discretionary
Pin 4 – Chassis Ground	Pin 12 – Discretionary
Pin 5 – Signal Ground	Pin 13 - Discretionary
Pin 6 – CAN High	Pin 14 – CAN Low
Pin 7 – KW 200	Pin 15 – L-Line /KWP
Pin 8 – Discretionary	Pin 16 – Unswitched B+

The DLC within a vehicle has a lot of information it can tell you regarding a parasitic current draw if you access it correctly. By scoping the BUS, you will find sleeping modules do not put out serial data as square wave forms. Also, you can monitor the voltage between pins 16 and 5 and monitor BUS activity as well. If BUS activity is present a module is awake and drawing current. Conversely, if the vehicle has had enough time for all of the modules to go to sleep and there are no EVAP tests in progress, you should see no activity along the BUS.



Pictured left is a waveform that indicates a module on the BUS is awake. If you see this type of waveform, you can be sure a module on the BUS is awake and drawing current.

ADVANCED FORMS OF PARASITIC DRAW TESTING

2013 CHEVROLET MALIBU

Our next subject vehicle is a 2013 Chevrolet Malibu which we will be employing the five step process of parasitic draw testing. We have already determined that the battery state of health (SOH) and state of charge (SOC) are both within good specification. The objective of this hands on demonstration is to determine if we have a normal parasitic draw or an excessive parasitic draw. If the parasitic draw is excessive, we will then need to diagnose and repair the cause.

DLC BREAKOUT BOX

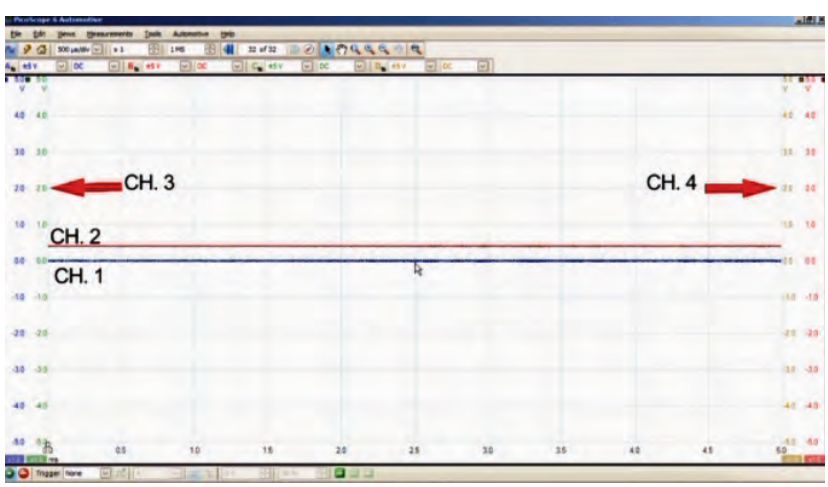
As we have already stated, we have completed step 1 by determining the battery is good. Step 2 requires us to inspect the vehicle charging and starting system. This will be done using a total approach using not only a volt/amp test but we will also test the DLC and monitor all of the modules on the vehicle and retrieve all of the DTCs on the vehicle if there are any.

Step 3 requires us to set up the vehicle for the test by installing a knife switch and making sure all of the devices within the vehicle are either off or asleep. You would definitely want to review the OEM chart for how long certain modules need before they go to sleep to determine how long you want to leave the vehicle static before testing. Also, it is a good practice to check to see if there have been any TSBs issued for this vehicle regarding possible parasitic current draws.

The fourth step is to actually test the vehicle to see if there is a parasitic draw by selecting the tools we want to use and begin taking measurements to generalize and localize the fault. If there is a parasitic draw we want to move to step five in which we isolate the circuit, then the component and repair the system.

After we have generalized and localized the possible cause of the parasitic drain we want to monitor the modules on the CAN BUS to determine if they are awake, how long they are awake and when they go to sleep.

One of the best ways to do this is with the use of a DLC breakout box as illustrated. We have connected the breakout box to the DLC and scoped four channels. Channel 1 is the blue trace, channel 2 is the red trace, channel 3 is the green trace and channel 4 is the tan trace.

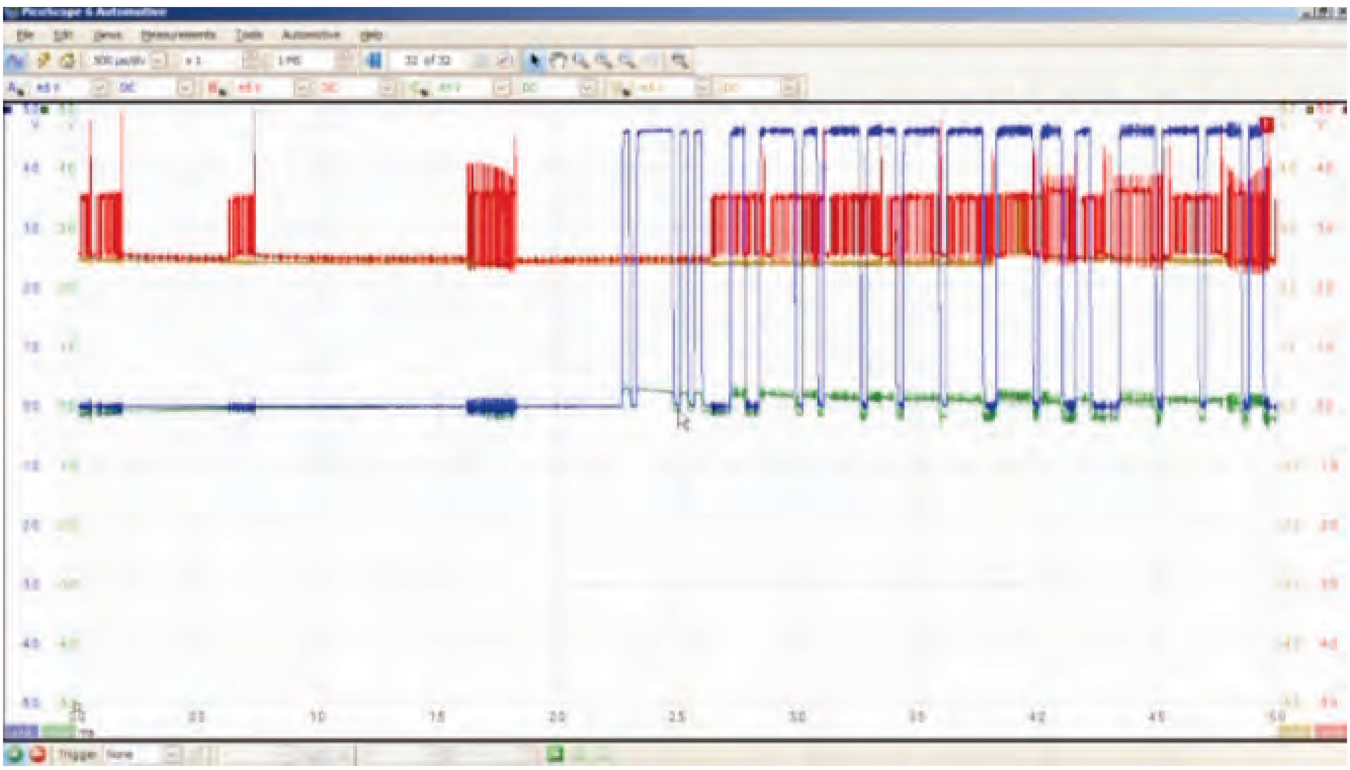


ADVANCED FORMS OF PARASITIC DRAW TESTING

2013 CHEVROLET MALIBU

Channel 1 is displaying one of the most usual suspects of a parasitic current draw and that is the Body BUS. The body BUS is the circuit that stays active the most and the longest once the key is turned off and it has the most modules reporting on it as well. Channel 3-4 will be monitoring the CAN BUS circuits.

As the vehicle sits right now not much is going on. However, when the vehicle wakes up, you can see we have activity on all four channels indicating modules are communicating across the BUS.



For this vehicle this is normal activity after the vehicle has been off for an extended period of time. This GM vehicle will perform an EVAP test after the vehicle has been off. Also, the OnStar system will activate and report every 10 minutes. These are all normal activities and should not cause a parasitic drain.

CLOSING

Parasitic current draw has been a problem for as long as cars have been on the road. As time has gone on and vehicles have gotten more complex, diagnosing these problems has become tougher and tougher. We hope this training program has helped you find new and more effective ways to diagnose and fix parasitic battery drains. We encourage you to perform these methods on known good vehicles as well as faulty ones to become more proficient, accurate and fast at diagnosing them. These methods will lead to faster diagnosis, accurate repair, happier customers and more dollars in your pocket.

NOTES

VOLTAGE DROP ACROSS FUSE CHART

Using the Vd Chart Example

Voltage Drop Across a Mini Fuse

Measurement mV	Mini 5 Amp	Mini 7.5 Amp	Mini 10 Amp	Mini 15 Amp	Mini 20 Amp	Mini 25 Amp
0.1	6	10	14	22	29	40
0.2	12	20	28	44	57	80
0.3	18	30	43	67	86	120
0.4	24	40	57	89	114	160
0.5	30	50	71	[illegible]	143	200
0.6	36	60	85	[illegible]	171	240
0.7	42	70	99	[illegible]	200	280
0.8	48	80	[illegible]	178	229	320
0.9	54	90	128	200	257	360
1	60	100	142	222	286	400
1.1	66	110	156	244	314	440

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This is only an example of using the chart and doe not pertain to our test readings.

The specification charts for Vd across a fuse are in the back of the student manual. The values in these charts are based on a fully charged battery (12.6 V)

In this example, we are testing a 15 amp mini fuse. The voltage drop across the fuse is 0.8 mV. This is only an example and has nothing to do with the values we measured on our test vehicle.

To use the Voltage Drop Across a Fuse chart:

1. Select the fuse rating. This is the rating stamped on the fuse being tested.
2. Perform a voltage drop test across the fuse and record the reading
3. Find the Vd value in the "Measurement mV" column.
4. Locate the intersecting cell of the column and row
5. This is the current draw through the fuse in milliamps (mA). If the value is 178, the draw is 178 mA or 0.178 amps

This chart is not all inclusive, the voltage drop measurements range from 0.1 mV to 10 mV. However, if a technician has a reading of, let's say 27.0 mV during the Vd test, he would simply take the 2.7 mV value and multiply by 10. Although not exact, the values will be very close.

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VOLTAGE DROP ACROSS FUSE CHART

Voltage Drop Across a Mini Fuse

Measurement mV	Mini 5 Amp	Mini 7.5 Amp	Mini 10 Amp	Mini 15 Amp	Mini 20 Amp	Mini 25 Amp	Mini 30 Amp
0.1	6	10	14	22	29	40	50
0.2	12	20	28	44	57	80	100
0.3	18	30	43	67	86	120	150
0.4	24	40	57	89	114	160	200
0.5	30	50	71	111	143	200	250
0.6	36	60	85	133	171	240	300
0.7	42	70	99	156	200	280	350
0.8	48	80	114	178	229	320	400
0.9	54	90	128	200	257	360	450
1	60	100	142	222	286	400	500
1.1	66	110	156	244	314	440	550
1.2	72	120	171	267	343	480	600
1.3	78	130	185	289	371	520	650
1.4	84	140	199	311	400	560	700
1.5	90	150	213	333	429	600	750
1.6	96	160	227	356	457	640	800
1.7	102	169	242	378	486	680	850
1.8	108	179	256	400	514	720	900
1.9	114	189	270	422	543	760	950
2	120	199	284	444	571	800	1000
2.1	126	209	296	467	600	840	1050
2.2	132	219	313	489	629	880	1100
2.3	138	229	327	511	657	920	1150
2.4	144	239	341	533	686	960	1200
2.5	150	249	355	556	714	1000	1250
2.6	156	259	369	578	743	1040	1300
2.7	162	269	384	600	771	1080	1350
2.8	168	279	398	622	800	1120	1400
2.9	174	289	412	644	829	1160	1450
3	180	299	426	667	857	1200	1500
3.1	186	309	441	689	886	1240	1550
3.2	192	319	455	711	914	1280	1600
3.3	198	329	469	733	943	1320	1650
3.4	204	339	483	756	971	1360	1700
3.5	210	349	497	778	1000	1400	1750
3.6	216	359	512	800	1029	1440	1800
3.7	222	369	526	822	1057	1480	1850
3.8	228	379	540	844	1086	1520	1900
3.9	234	389	554	867	1114	1560	1950
4	240	399	568	889	1143	1600	2000

Current in milliamps (mA)

VOLTAGE DROP ACROSS FUSE CHART

Voltage Drop Across a Mini Fuse

Measurement mV	Mini 5 Amp	Mini 7.5 Amp	Mini 10 Amp	Mini 15 Amp	Mini 20 Amp	Mini 25 Amp	Mini 30 Amp
4.1	246	409	583	911	1171	1640	2050
4.2	252	419	597	933	1200	1680	2100
4.3	258	429	611	956	1229	1720	2150
4.4	264	439	625	978	1257	1760	2200
4.5	270	449	639	1000	1286	1800	2250
4.6	276	459	654	1022	1314	1840	2300
4.7	282	469	668	1044	1343	1880	2350
4.8	288	479	682	1067	1371	1920	2400
4.9	294	488	696	1089	1400	1960	2450
5	300	498	711	1111	1429	2000	2500
5.1	306	508	725	1133	1457	2040	2550
5.2	312	518	739	1156	1486	2080	2600
5.3	318	528	753	1178	1514	2120	2650
5.4	324	538	767	1200	1543	2160	2700
5.5	330	548	782	1222	1571	2200	2750
5.6	336	558	796	1244	1600	2240	2800
5.7	342	568	810	1267	1629	2280	2850
5.8	348	578	824	1289	1657	2320	2900
5.9	354	588	838	1311	1686	2360	2950
6	360	598	853	1333	1714	2400	3000
6.1	366	608	867	1356	1743	2440	3050
6.2	372	618	881	1378	1771	2480	3100
6.3	378	628	895	1400	1800	2520	3150
6.4	384	638	909	1422	1829	2560	3200
6.5	390	648	924	1444	1857	2600	3250
6.6	396	658	938	1467	1886	2640	3300
6.7	402	668	952	1489	1914	2680	3350
6.8	408	678	966	1511	1943	2720	3400
6.9	414	688	981	1533	1971	2760	3450
7	420	698	995	1556	2000	2800	3500
7.1	426	708	1009	1578	2029	2840	3550
7.2	432	718	1023	1600	2057	2880	3600
7.3	438	728	1037	1622	2086	2920	3650
7.4	444	738	1052	1644	2114	2960	3700
7.5	450	748	1066	1667	2143	3000	3750
7.6	456	758	1080	1689	2171	3040	3800
7.7	462	768	1094	1711	2200	3080	3850
7.8	468	778	1108	1733	2229	3120	3900
7.9	474	788	1123	1756	2257	3160	3950
8	480	798	1137	1778	2286	3200	4000

Current in milliamps (mA)

VOLTAGE DROP ACROSS FUSE CHART

Voltage Drop Across a Mini Fuse

Measurement mV	Mini 5 Amp	Mini 7.5 Amp	Mini 10 Amp	Mini 15 Amp	Mini 20 Amp	Mini 25 Amp	Mini 30 Amp
8.1	486	807	1151	1800	2314	3240	4050
8.2	492	817	1165	1822	2343	3280	4100
8.3	498	827	1179	1844	2371	3320	4150
8.4	504	837	1194	1867	2400	3360	4200
8.5	510	847	1208	1889	2429	3400	4250
8.6	516	857	1222	1911	2457	3440	4300
8.7	522	867	1236	1933	2486	3480	4350
8.8	528	877	1251	1956	2514	3520	4400
8.9	534	887	1265	1978	2543	3560	4450
9	540	897	1279	2000	2571	3600	4500
9.1	546	907	1293	2022	2600	3640	4550
9.2	552	917	1307	2044	2629	3680	4600
9.3	558	927	1322	2067	2657	3720	4650
9.4	564	937	1336	2089	2686	3760	4700
9.5	570	947	1350	2111	2714	3800	4750
9.6	576	957	1364	2133	2743	3840	4800
9.7	582	967	1378	2156	2771	3880	4850
9.8	588	977	1393	2178	2800	3920	4900
9.9	594	987	1407	2200	2829	3960	4950
10	600	997	1421	2222	2857	4000	5000

Current in milliamps (mA)

VOLTAGE DROP ACROSS FUSE CHART

Voltage Drop Across a Standard Fuse

Measurement mV	Standard 5 Amp	Standard 10 Amp	Standard 15 Amp	Standard 20 Amp	Standard 25 Amp	Standard 30 Amp
0.1	7	13	23	30	47	62
0.2	13	27	45	61	94	123
0.3	20	40	68	91	141	185
0.4	26	54	91	122	188	246
0.5	33	67	113	152	235	308
0.6	40	80	136	183	281	370
0.7	46	94	158	213	328	431
0.8	53	107	181	244	375	493
0.9	59	120	204	274	422	554
1	66	134	226	305	469	616
1.1	73	147	249	335	516	677
1.2	79	161	272	366	563	739
1.3	86	174	294	396	610	801
1.4	92	187	317	427	657	862
1.5	99	201	340	457	704	924
1.6	106	214	362	487	751	985
1.7	112	228	385	518	797	1047
1.8	119	241	407	548	844	1109
1.9	125	254	430	579	891	1170
2	132	268	453	609	938	1232
2.1	139	281	475	640	985	1293
2.2	145	294	498	670	1032	1355
2.3	152	308	521	701	1079	1417
2.4	158	321	543	731	1126	1478
2.5	165	335	566	762	1173	1540
2.6	172	348	589	792	1220	1601
2.7	178	361	611	823	1267	1663
2.8	185	375	634	853	1313	1725
2.9	192	388	656	884	1360	1786
3	198	401	679	914	1407	1848
3.1	205	415	702	944	1454	1909
3.2	211	428	724	975	1501	1971
3.3	218	442	747	1005	1548	2032
3.4	225	455	770	1036	1595	2094
3.5	231	468	792	1066	1642	2156
3.6	238	482	815	1097	1689	2217
3.7	244	495	837	1127	1736	2279
3.8	251	509	860	1158	1782	2340
3.9	258	522	883	1188	1829	2402
4	264	535	905	1219	1876	2464

Current in milliamps (mA)

VOLTAGE DROP ACROSS FUSE CHART

Voltage Drop Across a Standard Fuse

Measurement mV	Standard 5	Standard 10	Standard 15	Standard 20	Standard 25	Standard 30
4.1	271	549	928	1249	1923	2525
4.2	277	562	951	1280	1970	2587
4.3	284	575	973	1310	2017	2648
4.4	291	589	996	1341	2064	2710
4.5	297	602	1019	1371	2111	2772
4.6	304	616	1041	1401	2158	2833
4.7	310	629	1064	1432	2205	2895
4.8	317	642	1086	1462	2252	2956
4.9	324	656	1109	1493	2298	3018
5	330	669	1132	1523	2345	3080
5.1	337	683	1154	1554	2392	3141
5.2	343	696	1177	1584	2439	3203
5.3	350	709	1200	1615	2486	3264
5.4	357	723	1222	1645	2533	3326
5.5	363	736	1245	1676	2580	3387
5.6	370	749	1268	1706	2627	3449
5.7	376	763	1290	1737	2674	3511
5.8	383	776	1313	1767	2721	3572
5.9	390	790	1335	1798	2768	3634
6	396	803	1358	1828	2814	3695
6.1	403	816	1381	1858	2861	3757
6.2	409	830	1403	1889	2908	3819
6.3	416	843	1426	1919	2955	3880
6.4	423	857	1449	1950	3002	3942
6.5	429	870	1471	1980	3049	4003
6.6	436	883	1494	2011	3096	4065
6.7	442	897	1517	2041	3143	4127
6.8	449	910	1539	2072	3190	4188
6.9	456	923	1562	2102	3237	4250
7	462	937	1584	2133	3284	4311
7.1	469	950	1607	2163	3330	4373
7.2	475	964	1630	2194	3377	4434
7.3	482	977	1652	2224	3424	4496
7.4	489	990	1675	2255	3471	4558
7.5	495	1004	1698	2285	3518	4619
7.6	502	1017	1720	2315	3565	4681
7.7	508	1030	1743	2346	3612	4742
7.8	515	1044	1766	2376	3659	4904
7.9	522	1057	1788	2407	3706	4866
8	528	1071	1811	2437	3753	4927

Current in milliamps (mA)

VOLTAGE DROP ACROSS FUSE CHART

Voltage Drop Across a Standard Fuse

Measurement	Standard	Standard	Standard	Standard	Standard	Standard
mV	**5**	**10**	**15**	**20**	**25**	**30**
8.1	535	1084	1833	2468	3800	4989
8.2	541	1097	1856	2498	3846	5050
8.3	548	1111	1879	2529	3893	5112
8.4	555	1124	1901	2559	3940	5174
8.5	561	1138	1924	2590	3987	5235
8.6	568	1151	1947	2620	4034	5297
8.7	575	1164	1969	2651	4081	5358
8.8	581	1178	1992	2681	4128	5420
8.9	588	1191	2015	2712	4175	5482
9	594	1204	2037	2742	4222	5543
9.1	601	1218	2060	2772	4269	5605
9.2	608	1231	2082	2803	4316	5666
9.3	614	1245	2105	2833	4362	5728
9.4	621	1258	2128	2864	4409	5789
9.5	627	1271	2150	2894	4456	5851
9.6	634	1285	2173	2925	4503	5913
9.7	641	1298	2196	2955	4550	5974
9.8	647	1312	2218	2986	4597	6036
9.9	654	1325	2241	3016	4644	6097
10	660	1338	2263	3047	4691	6159

Current in milliamps (mA)

VOLTAGE DROP ACROSS FUSE CHART

Voltage Drop Across a Cartridge Fuse

Measurement mV	Cartridge 20 Amp	Cartridge 30 Amp	Cartridge 40 Amp	Cartridge 50 Amp
0.1	100	67	100	200
0.2	200	133	200	400
0.3	300	200	300	600
0.4	400	267	400	800
0.5	500	333	500	1000
0.6	600	400	600	1200
0.7	700	467	700	1400
0.8	800	533	800	1600
0.9	900	600	900	1800
1	1000	667	1000	2000
1.1	1100	733	1100	2200
1.2	1200	800	1200	2400
1.3	1300	867	1300	2600
1.4	1400	933	1400	2800
1.5	1500	1000	1500	3000
1.6	1600	1067	1600	3200
1.7	1700	1133	1700	3400
1.8	1800	1200	1800	3600
1.9	1900	1267	1900	3800
2	2000	1333	2000	4000
2.1	2100	1400	2100	4200
2.2	2200	1467	2200	4400
2.3	2300	1533	2300	4600
2.4	2400	1600	2400	4800
2.5	2500	1667	2500	5000
2.6	2600	1733	2600	5200
2.7	2700	1800	2700	5400
2.8	2800	1867	2800	5600
2.9	2900	1933	2900	5800
3	3000	2000	3000	6000
3.1	3100	2067	3100	6200
3.2	3200	2133	3200	6400
3.3	3300	2200	3300	6600
3.4	3400	2267	3400	6800
3.5	3500	2333	3500	7000
3.6	3600	2400	3600	7200
3.7	3700	2467	3700	7400
3.8	3800	2533	3800	7600
3.9	3900	2600	3900	7800
4	4000	2667	4000	8000

Current in milliamps (mA)

VOLTAGE DROP ACROSS FUSE CHART

Voltage Drop Across a Cartridge Fuse

Measurement mV	Cartridge 20 Amp	Cartridge 30 Amp	Cartridge 40 Amp	Cartridge 50 Amp
4.1	4100	2733	4100	8200
4.2	4200	2800	4200	8400
4.3	4300	2867	4300	8600
4.4	4400	2933	4400	8800
4.5	4500	3000	4500	9000
4.6	4600	3067	4600	9200
4.7	4700	3133	4700	9400
4.8	4800	3200	4800	9600
4.9	4900	3267	4900	9800
5	5000	3333	5000	10000
5.1	5100	3400	5100	10200
5.2	5200	3467	5200	10400
5.3	5300	3533	5300	10600
5.4	5400	3600	5400	10800
5.5	5500	3667	5500	11000
5.6	5600	3733	5600	11200
5.7	5700	3800	5700	11400
5.8	5800	3867	5800	11600
5.9	5900	3933	5900	11800
6	6000	4000	6000	12000
6.1	6100	4067	6100	12200
6.2	6200	4133	6200	12400
6.3	6300	4200	6300	12600
6.4	6400	4267	6400	12800
6.5	6500	4333	6500	13000
6.6	6600	4400	6600	13200
6.7	6700	4467	6700	13400
6.8	6800	4533	6800	13600
6.9	6900	4600	6900	13800
7	7000	4667	7000	14000
7.1	7100	4733	7100	14200
7.2	7200	4800	7200	14400
7.3	7300	4867	7300	14600
7.4	7400	4933	7400	14800
7.5	7500	5000	7500	15000
7.6	7600	5067	7600	15200
7.7	7700	5133	7700	15400
7.8	7800	5200	7800	15600
7.9	7900	5267	7900	15800
8	8000	5333	8000	16000

Current in milliamps (mA)

VOLTAGE DROP ACROSS FUSE CHART

Voltage Drop Across a Cartridge Fuse

Measurement mV	Cartridge 20 Amp	Cartridge 30 Amp	Cartridge 40 Amp	Cartridge 50 Amp
8.1	8100	5400	8100	16200
8.2	8200	5467	8200	16400
8.3	8300	5533	8300	16600
8.4	8400	5600	8400	16800
8.5	8500	5667	8500	17000
8.6	8600	5733	8600	17200
8.7	8700	5800	8700	17400
8.8	8800	5867	8800	17600
8.9	8900	5933	8900	17800
9	9000	6000	9000	18000
9.1	9100	6067	9100	18200
9.2	9200	6133	9200	18400
9.3	9300	6200	9300	18600
9.4	9400	6267	9400	18800
9.5	9500	6333	9500	19000
9.6	9600	6400	9600	19200
9.7	9700	6467	9700	19400
9.8	9800	6533	9800	19600
9.9	9900	6600	9900	19800
10	10000	6667	10000	20000

Current in milliamps (mA)

NOTES