OBJECTIVES

- Describe and show how to identify “Positive Switching” circuits
- Describe and show how to identify “Negative Switching” circuits
- Describe and show how to identify “Reverse Polarity Switching” circuits

INTRODUCTION

This lesson will address applications of vehicle electrical switching and control systems. The lesson material will provide an overview of important vehicle electrical circuits that commonly require interfacing to aftermarket mobile electronic equipment. These circuits will include positive, negative and reversing polarity switching systems. Some of the more popular alternative control systems will also be covered.

Vehicle Electrical System

Brief Review

This section serves as a preface to the core topics in this lesson. Topics reviewed in this section can be found in greater detail in prior lessons. For more detailed information regarding circuit elements and electrical basics, please review the following lessons.

1. DC Electricity Lessons
2. Series and Parallel Circuit Lessons
3. Introduction to Charging and Electrical System

Elements in a Circuit

There are four basic elements to any DC vehicle electrical circuit. Each element is necessary for the circuit to function and for control over WHEN the circuit functions.

Element 1 - A Voltage Source

Typically, the voltage source in a vehicle’s electrical system is the battery and, when the vehicle is running, the alternator. A circuit MUST have a voltage source before any electrical current will flow.

Element 2 - A Circuit Path (Supply and Return Path)

The supply portion of the circuit path is often called the “power” wiring or connection. This comes from the battery or a distribution point connected to the battery such as the vehicles fuse panel(s). A fuse or circuit breaker placed somewhere in the circuit path serves as circuit protection. The return portion of the circuit path is often called the “ground” wiring or connection. This portion of the circuit uses the vehicle body and chassis as the return path back to the vehicle’s voltage source (i.e. battery and alternator).
Element 3 - A Control Method

The control method is a switch of some sort. It can be automated, manual or electromechanical in nature. Nearly every vehicle circuit requires a switch to control WHEN it operates. Some advanced electrical systems use small microprocessor controlled “computers” to control vital electronic circuits.

Element 4 - A Load (Electrical Work to be Done)

Electrical loads are basically any item that uses electrical power to operate. Most often in vehicle electrical circuits, these are light bulbs, relays, sensors, and motors.

Simple Control Methods

The basic two types of control methods are to switch or “control” EITHER the (+) positive side of the circuit OR the (-) negative side of the circuit. This simple concept is illustrated in the diagram below.

Notice that the "LOAD" has nothing to do with the switching type

Switching most electrical circuits is necessary because they don’t need to be connected and operational all of the time. Door locks or headlights, for example, only need be active for the duration of time that the switch is active. This not only extends the life of the electrical components, but also reduces the constant electrical demands on the vehicle electrical supply (the battery and alternator).

It is important to recognize that with simple methods of controlling current flow in a circuit, the method of control (switching the (+) positive side of the circuit OR the (-) negative side of the circuit) has no effect on the load. The load in the circuit is independent of which polarity is switched. It’s only important that the circuit have control of current flowing to the load.

In another example, circuit protection could also be installed on either side of the circuit. An installer could fuse a ground connection with the same effect as installing a fuse on the positive connection. The reason that the (+) positive side of the circuit is generally fused is that the remainder of the metal in the vehicle is connected to (-) negative ground through the body and chassis. Any short circuit would bypass the fuse if the ground wire that was fused became shorted to any metal point on the vehicle. In a vehicle environment, a fuse may not only protect the circuit, but also the length of wire that runs through the car. This is the reason most vehicles are fused on the (+) positive side of the circuit because the chassis and body metal are (-) negative polarity.
**What is a “load”, exactly?**

An electrical “load” is simply a shortened way of saying electrical workload. Essentially everything that is considered a load consumes a certain amount of electrical power to accomplish it’s given task.

Virtually EVERYTHING electrically controlled in a vehicle electrical system is considered a load. Some of the examples listed include very common items such as light bulbs and power window motors. If a load is connected to an electrical supply, the control function (the switch) must be capable of passing adequate current flow to the electrical load. This is why there are fundamental differences in many switches within a vehicle. Some are large and “industrial” feeling, while others have a small and tidy appearance with easy one finger operation.

Examples within this lesson will show switches controlling a load directly and switches that send commands to “control modules” which handle the responsibility of connecting and disconnecting the circuit.

**Positive Switching Systems**

Positive Switching Systems are characterized by the (+) positive portion of the electrical circuit connecting through a switch that determines whether the circuit is open (no current flow) or closed (current CAN flow).

**Identifying Positive Switching**

Before a technician can diagnose the circuit operation, he/she must FIRST identify the switching type. To identify a positive switching system, follow the directions listed.
Directions

A Multimeter is required to identify a Positive Switching System properly. In addition to probing wires in a circuit, the installer must also VERIFY that the circuit does not exhibit characteristics of another switching type (such as Reversing Polarity).

Step 1

Plug the RED probe into the “Volts/Ohms (V/Ω)” socket of the Multimeter. Plug the BLACK probe into the “COM” socket of the Multimeter. Set the Multimeter to the appropriate range on DC Volts. The meter is “looking” for DC voltage when the circuit under test is activated.

Step 2

Attach the BLACK probe to a reliable source of GROUND so it can reference the (-) negative side of the circuit. Installers may prefer to use reliable ground points with an extension of wire where necessary (such as the negative battery post or a grounded metal support behind the dash). See the examples shown.

Step 3

Have a piece of paper and a writing implement (such as a pen or pencil) handy to take down the results of wire locations and colors that will be under test.

Step 4

Expose the back of the switch, the wires within a harness, or the harness plug that will be probed.

Step 5

Carefully separate the wire to be probed from other surrounding wires. It may be necessary to probe several wires to find the appropriate one. In cases where a Molex type plug is present, many pin locations can be easily probed at the plug itself. This method avoids having to break the insulation of the wire.
Step 6

If you are testing at the switch such as in this example (rather than on wires within a harness) look for a constant source of 12 volts at the switch. This will indicate that there is 12 volts of supply to the switch and probably connects to 12 volt outputs depending on the position of the switch. Remember that to “enable” the supply voltage, you MAY need to turn the ignition key to “ACC” or “RUN” for certain circuits.

Step 7

With the RED the probe attached to the wire or switch contact, activate the switch and watch the display on meter. A reading or +12 volts (or higher) while the switch is being activated is the initial indication of the wire under test being part of the positive switched circuit.

Remember that you need to check all of the possibilities to make certain that the wire you’re testing ACTUALLY functions as you think it does. Continue with the following sections to understand more about common Positive Switching circuit testing variables.

Verifying Circuit Operation

Sometimes switches can have “lockout” features or can be disabled during certain times. Other switching operations may be enabled only if certain events have taken place prior to activating the circuit. These precautions are generally for increased safety and security.
Verification Example #1

Headlight switches often appear to show a parking light output on the dimmer wire so the installer must operate the dimmer switch to monitor any change in voltage on the wire. If the voltage changes, then that wire is part of the dimmer circuit and NOT the correct park light wire for a security system interface. A dimmer circuit is often found in the headunit wiring harness and may be useful when interfacing an aftermarket headunit with dimmer controlled illumination capabilities. Double check the measurement on the Resistance mode of the Multimeter. If it is truly an illumination wire, there should be SOME resistance present (typically 2-25 ohms) across the filament of the light bulb(s).

In the “ON” position shown above, the dimmer switch is wide open and the full voltage is available to the wire under test

In the “OFF” position shown above, the dimmer switch has completely closed the circuit and NO voltage (or just a very small amount) is available to the wire under test

Verification Example #2

Reversing Polarity circuits such as certain power door lock applications, most power window motors and even power sunroof applications often exhibit the initial characteristic of a Positive Switching circuit, but the condition of the circuit at rest (when the switch is NOT engaged) is also important to test.

For more detail on the testing and verification conditions for Reversing Polarity Switching, please read the Reversing Polarity Switching section in this Lesson.

Most power window and sunroof motors may appear at first to be Positive Switching, but are typically Reversing Polarity Switching when verified with a Multimeter
Determining (+) Positive Switching

Testing the target wire when the switch is "ON"

0 Volts when the circuit is "OFF" (Open Circuit)

1. Extension Wire to (-) Negative Battery Post OR Ground probe to Vehicle Body Sheet Metal or Dash Area Metal

2. RED Probe is "looking" for a (+) positive voltage to complete the measurement

Example Shown - Parking Light Circuit

Extension Wire from BLACK probe to (-) Negative Battery Post terminal OR Ground probe to the vehicle body sheetmetal or grounded dash area sheetmetal

RED Probe is “looking” for (+) positive polarity to complete the measurement
Variations of Positive Switching

Many times the Positive Switching system described in the previous section may have some slight variables. In situations where a control module is present in the circuit, the wiring at the switch may have some subtle differences, or may have some major differences that even reduce the amount of wires present at the switch. The majority of circuits that use a variation of the standard Positive Switching type are bi-directional motor switching circuits (such as power door locks, power windows, or power sunroofs), or incandescent lighting circuits.

Positive Switching that Rests NEAR (-) Ground

In some cases, typically involving a control module or incandescent lighting, the positive switched wire can appear to “rest” at ground. When this is the case, the wire under test MAY show continuity to ground when the circuit is NOT operating, yet the actual resistance to ground may be 2-25 Ohms. This amount of resistance is enough to account for the resistive filament of a light bulb, relay coil, or windings in a door lock or older type of window motor. It’s always important to check the RESISTANCE with the switch position in the “At Rest” position.

Example - Most GM and Ford Truck Dimmer Circuits

In these GM and Ford trucks (as well as MANY OTHER TYPES of common vehicles), the circuit controlled by the dimmer switch APPEARS as a ground with the switch or dimmer at rest. As many factory installed headunits have matching illumination with other dashboard componentry, the dimmer circuit wire is usually present with the headunit wiring harness located at the back of the headunit. Many installers make the mistake of connecting this wire as a headunit ground only to discover that the fuse for the parking lights blows the first time the lights are switched on.

When tested “at rest”, this circuit appears to show ground by beeping on the CONTINUITY meter setting. Testing the actual resistance should yield several ohms (typically 2-25 Ohms) of resistance across the light bulb(s). It’s not until it becomes active (with the parking lights switched “ON”) that the circuit goes to a positive polarity showing a voltage (which is displayed on the meter as a difference of electrical potential in the DC Volts mode).

Testing these circuits in the DC Voltage mode (while at rest) typically show MORE THAN ZERO Volts because of the additional resistance of the lighting filament. It’s reasons such as this that it is important to check the wiring with the switch position both “ON” and “At Rest”. Virtually all dimmer circuits directly controlled by the switch (rather than through a lighting control module) exhibit this electrical characteristic.

Mistaken Identity - Reversing Polarity Switching Applications

In most power windows, sunroofs, and convertible tops, Positive Switching in a Reversing Polarity circuit is used. Many power door lock systems also use this type of switching (often referred to as “5 wire door locks”). The thing that differs these switching applications from Positive Switching applications is that, although the switching polarity is in fact positive, the circuit “rests” at the opposing polarity. In these cases the opposing polarity is negative (also termed “rest at ground”).

To correctly identify and verify these types of applications, the installer must determine BOTH the switched and the “at rest” condition of the circuit. True “rest at ground” applications have 0 volts.
of potential difference between probes if measuring in the DC Volts mode and typically have less than 1 ohm of resistance when in the DC Resistance mode. For more detail on the testing and verification, please read the Reversing Polarity Switching section in this lesson.

Positive Switching with Isolated Multiple Outputs

In some cases where Positive Switching is used, it may be necessary to allow the positive supply to switch multiple circuits but not to have any of the multiple circuits affect one another. This is the concept of “isolation” in electrical circuits. Allowing multiple loads to feed off a single supply, but each load may only be active at select positions of the control cycle or switch.

Example #1 European Lighting Systems

The basis of the isolated multiple outputs in a European vehicle to which this type of circuit applies is to allow only ONE SIDE of the parking lights to turn on WITHOUT turning on the other side. This feature was created to allow European vehicles to park on small roads and (due to the frequent fog in Winter months) allow the vehicle side nearest the traffic path on the street to remain lit as a warning to passers by. As these lights were intended to sometimes be left on all night, isolating the left and right sides effectively cuts the current draw on the vehicle battery virtually in half.

An installer can easily identify a vehicle with European style, isolated outputs by taking a close look at the headlight/parklight switch. If there is a position for “Left”, then “Right”, followed by normal parklamps (all switched on), and finally the headlamps, the vehicle likely features these isolated multiple outputs.

Example #2 Ignition Switch Wiring

In the example of an ignition switch, the outputs are isolated and operate independently even though all circuits typically share a common supply wire. The vast majority of ignition circuits in a vehicle are positive switching circuits. In an ignition switch circuit, there are four fundamental switch positions and there may be FOUR OR MORE isolated outputs. The fundamental switch positions are:

1) OFF (No activity or key turned)
2) ACC (Accessory, usually the first turn of the key switch in most Asian and European vehicles OR the position turned “back” toward the driver in many American vehicles)
3) RUN (Usually the second position of the key switch in most Asian and European vehicles OR the first position turned “forward” toward the dash in many American vehicles)
4) START (Active only while held in this position)
Accessory (ACC)

Accessory (ACC) - Accessory outputs control accessory devices in a vehicle (better described as creature comforts) that don’t necessarily require the engine to be running for operation. Typical accessories include the audio system, which becomes enabled with the key in the ACC position.

True accessory circuits operate while the key is in the ACC and RUN positions, but an accessory circuit MOMENTARILY LOSES POWER for the duration of time the key is in the START POSITION.

Ignition #1 (IGN 1)

Ignition #1 (Ign #1, Primary Ignition, or “True” Ignition) - Ignition #1 (or Primary Ignition) circuits are fundamental circuits that the vehicle must have to start and run the engine. These are circuits which are critical to the engine control, fuel delivery, and ignition systems. Typical components powered by these circuits are ECU’s (Engine Control Computers), Fuel Injectors, Electronic Fuel Pumps, and Electronic Ignition Coil Packs.

True Ignition #1 (or Primary Ignition) circuits operate while the key is in the RUN and START position. Unlike an Accessory circuit, the Ignition #1 (or Primary Ignition) STAYS POWERED for the duration of time the key is in the START POSITION. It is important to identify the function of the circuit with a Multimeter to verify proper circuit identity. This is the circuit that security system control modules require connection to on the “Ignition Powered” wire.

The fundamental reason it is so important to identify the ignition switch circuits correctly is because the circuit that controls the starter interrupt function of most security systems must remain capable of controlling the “interrupt” function if the vehicle is attempting to start.

Ignition #1 circuits may go by other names than listed in this lesson, but the importance for any installer becomes understanding the way the circuit operates and identifying it properly with a Multimeter.

Ignition #2 (IGN 2)

Ignition #2 (Ign #2, Secondary Ignition, or Heater-A/C) - Ignition #2 (or Secondary Ignition) circuits are deemed for powering devices that generally require the vehicle be running to operate properly. Most notably, the heater and air conditioning systems are powered on this circuit (hence the occasional use of Heater-A/C as an alternative term for Ignition 2). Although it’s generally necessary for
the vehicle to be running for these Ignition 2 powered devices to operate, it is NOT REQUIRED to power them while the vehicle is cranking over. This is the reason the heater or A/C blower will shut down momentarily while the vehicle cranks over to start the engine.

True Ignition #2 (or Secondary Ignition) circuits have power ONLY IN THE RUN POSITION of the ignition switch, but NOT IN ACC or START positions. Once again, it is important to identify the function of the circuit with a Multimeter to verify proper circuit identity.

Start (START)

Start (START) - The Start circuit generally has a single function in a vehicle, which is to power the starter solenoid for the duration the key is held in the start position. Many modern vehicle electrical systems may also feature additional start circuits for other electronically controlled items such as on-board computers or control modules. The START circuit is the one which most installers choose to interrupt when performing a security system installation on an automatic transmission vehicle that includes a starter interrupt device (also called a “starter kill relay”).

True START circuits are active ONLY WHILE THE KEY IS IN THE START POSITION. As mentioned previously, it is extremely important to identify the function of the circuit with a Multimeter to verify proper circuit identity. Never assume that an ignition switch wire under test is the correct wire to interrupt (for security system installations) until tested and verified.

The ignition switch performs the task of selectively powering certain specific circuits while others are not powered. All of these functions are automatically incorporated within a single complex switch. Though each function of the switch is a Positive Switching circuit, the isolated nature of the outputs allows the unique circuits to receive power when needed without having any unnecessary electrical power wasted on things that don’t matter. The most important of these isolations is perhaps the starting function where all but the starter and necessary Ignition #1 electrical circuits are momentarily shut down to allow as much electrical power as possible to be dedicated for starting the vehicle.

Single Wire Variable (Positive) Voltage Switching

Single Wire / Variable Voltage switching systems are characterized by the change in voltage on a single output wire to designate the command of a particular function. The advantage of this type of system is a reduction of copper wire. Reductions of wire reduce manufacturing costs and overall vehicle weight.

Example - Chrysler JA/JX/LH Body Door Lock Systems

Many Chrysler, Dodge, Plymouth, and Eagle branded vehicles made 1993 and later use the single wire, variable voltage system. It’s actually two wires (sometimes three wires) at the switch; one supply wire that reads +12v constant and the other that reads a different voltage depending on which way the switch is pressed. Lock produces one voltage while unlock produces a totally different voltage. Each voltage produced is less than 12v because the switch contains resistors in series with the supply wire. The brains of the door locking system (generally housed within a control module such as a Body Control Module or BCM) interprets the unique voltage generated as the appropriate command to lock or unlock. The control module then commands the door lock motors to move in the appropriate direction.

These systems are easily identified by containing only two wires at the door lock switch. One
for supply, the other to send variable voltages to the door lock controller (or BCM).

A similar circuit with opposite polarity (negative switching) also exists. For more information on that circuit type refer to the “Variations of Negative Switching Systems” section in this lesson.

Specific applications for the Single Wire Variable (Positive) Voltage door lock circuit include:

- Dodge Cirrus
- Plymouth Breeze
- Dodge Intrepid
- Eagle Vision
- Chrysler Concorde
- Dodge Stratus
- Chrysler Sebring
- Dodge LHS
- Chrysler 300M
- 1989-96 Ford Probe

**Negative Switching Systems**

Negative Switching Systems are characterized by the (-) negative portion of the electrical circuit connecting through a switch that determines whether the circuit is open (no current flow) or closed (current CAN flow).

![Negative Switching Circuit](image)

**Identifying Negative Switching**

Before a technician can diagnose the circuit operation, he/she must FIRST identify the switching type. To identify a Negative Switching System, follow the directions listed.

**Directions (Using The Voltage Scale)**

A Multimeter is required to identify a Negative Switching System properly. In addition to probing wires in a circuit, the installer must also VERIFY that the circuit does not exhibit characteristics of another switching type (such as Reversing Polarity).

**Step 1**

Plug the RED probe into the “Volts/Ohms (V/Ω)” socket of the Multimeter. Plug the BLACK probe into the “COM” socket of the Multimeter. Set the Multimeter to the appropriate range on DC voltage.
Step 2

Attach the RED probe to a reliable source of +12 volts so it can reference the (+) positive side of the circuit. Installers may prefer to use reliable power points with an extension of wire where necessary (such as the positive battery post, a large gauge power feed under the dash, or a constant powered cigarette lighter). See the examples shown.

Referencing a source of (+) positive voltage at the positive battery post (2a) or at a high current feed under the dashboard area (2b and 2c).

Step 3

You may want to use the (-) negative battery post or a known good ground point connected to the BLACK probe if you’re “looking” for the reliable source of +12 volts under the dash area. This way, when the display on the meter reads 12 volts (or so), you will have verified that the RED probe is correctly connected while using the BLACK probe to look for a (-) negative switch trigger to complete the circuit in subsequent steps.

Once a reliable source of (+) positive voltage is located, remove the BLACK probe from the ground point of reference. You will now attach this probe to the wire(s) intended for testing.

Step 4

Have a piece of paper and a writing implement (such as a pen or pencil) handy to take down the results of wire locations and colors that will be under test.

Step 5

Expose the back of the switch, the wires within a harness, or the harness plug that will be probed. Carefully separate the wire to be probed from other surrounding wires. It may be necessary to probe several wires to find the appropriate one.
Attach the BLACK probe to the wire intended for testing. (In some cases, the Piercing Clip probe accessory shown may be easier to test multiple wires in a harness).

This photo shows a Piercing Clip accessory probing wires under a steering column harness. This probe accessory is connected to the BLACK probe of the Multimeter in this example.

Some circuits MAY require the ignition key switch to be active in order to function properly.

Step 6

If you are testing at the switch (rather than on wires within a harness as demonstrated here) look for a constant ground at the switch. This will indicate that there is (-) negative supply to the switch and probably connects to (-) negative outputs depending on the position of the switch. Remember that to “enable” the input ground to the switch, you MAY need to turn the ignition key to “ACC” or “RUN” for certain circuits.

Step 7

With the BLACK probe attached to the wire or switch contact, activate the switch and watch the display on meter. A reading or +12 volts while the switch is being activated is the initial indication of the wire under test being part of the negative switched circuit.

Remember that you need to check all of the possibilities to make certain that the wire you’re testing ACTUALLY functions as you think it does. Continue with the following sections to understand more about common Negative Switching circuit testing variables.

Notes on Resistance and Continuity Testing Methods

Any time DC Resistance (or Continuity) measurements are taken, the circuit is intended to be disconnected from the supply voltage. Resistance (or Continuity) measurements taken while the circuit
is powered will yield inaccurate resistance measurements. Due to the relatively low voltages used in the mobile electronics installation field, this may only present a problem on occasion. It’s important to understand the limitations of any type of measurement so the most accurate result can be obtained.

When testing Negative Switching circuits, many installers prefer to begin the test with the CONTINUITY method. While this is certainly an acceptable method, the continuity threshold (usually accompanied by a buzzer or beep tone) in most Multimeters is about 250-400 ohms. That means that there could be several hundred ohms of resistance (as much as 400 ohms) between the negative battery terminal and the circuit under test even if the meter responds with a beep. Remember, the most accurate result is preferred in ANY measurement.

The voltage testing method demonstrated in the “Identifying Negative Switching” section is much more reliable with respect to consistent accuracy of measurements. It is for this reason the testing method using voltage is preferred. The voltage testing method simply reverses the roles for the probes and configures the BLACK probe to “look” for (-) negative polarity while the RED probe is connected to a source of (+) positive polarity for reference.

**Verifying Circuit Operation**

As mentioned in the Positive Switching section earlier in this lesson, lock-out buttons, safety switches, dimmer switches, and bi-directional motors can sometimes present a circuit test that appears to be the correct wire but is affected when the safety, dimmer, or opposite motor direction is engaged. Always verify the wire(s) under test do not change state whenever the aforementioned features are engaged or introduced into the circuit.

For more detail on the testing and verification conditions for Reversing Polarity Switching (which applies to bi-directional motors), please read the Reversing Polarity Switching section in this lesson.
Determining (-) Negative Switching

Testing the target wire when the switch is "ON"

1. Extension Wire to (+) Positive Battery Post OR +12v connection inside the vehicle

2. BLACK Probe is "looking" for a (-) negative voltage to complete the measurement

Example Shown - Parking Light Circuit

0 Volts when the circuit is "OFF" (Open Circuit)

BLACK Probe is "looking" for a (-) negative polarity to complete the measurement

Extension Wire from RED probe to (+) Positive Battery Post terminal

OR......locate a high current "constant +12v" feed under the dash or fuse panel area

BLACK Probe is “looking” for (-) negative polarity to complete the measurement
Variations of Negative Switching

Many times the Negative Switching system described in the previous section may have some slight variables. In situations where a control module is present in the circuit, the wiring at the switch may have some subtle differences, or may have some major differences that even reduce the amount of wires present at the switch. The majority of circuits that use a variation of the standard Negative Switching type are applications where a control “module” is present and one of several events can trigger the circuit.

An example of a variation of Negative Switching that is commonly found with control module applications may be a modern Body Control Module (BCM) that has multiple ways to lock and unlock the vehicle doors. The module may react from any of the lock/unlock switches in the car, from the drivers or passengers front door key cylinders or from a keyless entry command given by the keyless entry module. In some cases these negative outputs MAY appear to rest at (+) positive or at an open circuit during certain states of the circuit. Some Asian vehicles are particularly likely to exhibit these conditions from model to model, though it may not appear across an entire brand.

Negative Switching that Rests NEAR (+) Positive

Variations on Negative Switching systems that rest near (+) positive are less likely to be found as the opposite type (Positive Switching that rests NEAR ground) because there are three possible ways that the (-) negative trigger could be “processed”.

Negative triggered dome light circuits are the most common application for showing near (+) positive at rest due to the lighting filament within the bulb. When the doors in these applications are closed (and the circuit is OPEN), the wire under test may show +12volts. This is very simply caused by the “supply” side of the bulb passing across the conductive filament of the light bulb. As soon as a ground is introduced into the circuit when the door is opened (and the circuit becomes CLOSED), the two polarities meet across the resistive load of the bulb filament and the resulting electrical work is light.

Besides simple dome lighting circuits, the nature of (-) negative switching systems in MOST applications is a very low current trigger to drive a control module that controls the actual circuit function. This is evident when the wires at the switch driving the module and the wires at the module itself are primarily low current, small gauge wires (say 20 gauge or smaller). This indicates that low current is used to control higher circuit current inside the module.

Example - Control Module Applications

Low current control is generally done with one of three devices in most automotive control modules. An Integrated Circuit (known as an IC), a transistor, or a relay. Without getting too technical, the IC and the transistor are generally isolated from showing an “at rest” position on the input wire. The relay control may show a rest near (+) positive condition as it references positive voltage through opposite side of the relay coil. Depending on the method by which the relay in the module is activated on the (+) positive side of the coil, the wire under test may show +12v (or 11 point “something”) when the switch is in the “at rest” position.

In summary, the Negative Switching that rests near (+) Positive is certainly possible to see, but not as likely as simple straight forward Negative Switching as described previously in this lesson.

Negative Switching with Isolated Multiple Outputs

In some cases where Negative Switching is used, it may be necessary to allow the Negative supply to switch multiple circuits but not to have any of the multiple circuits affect one another. This is the concept of “isolation” in electrical circuits. Allowing multiple loads to feed off a single supply, but each load may only be active at select positions of the control cycle or switch.
Single Wire Variable (Negative) Voltage Switching

Single Wire / Variable Voltage switching systems are characterized by the change in voltage on a single output wire to designate the command of a particular function. The advantage of this type of system is a reduction of copper wire. Reductions of wire reduce manufacturing costs and overall vehicle weight.

Example - Some Chrysler/Dodge/Plymouth Mini Van Door Lock Systems

Many Chrysler, Dodge, and Plymouth mini-vans from 1996 and on, switch variable negative voltage (rather than positive as on other Chrysler products). In a similar way to the Variable (Positive) Voltage Switching, a change in voltage will cause the door lock controller (or BCM) to operate the locks appropriately “up” or “down”. The change in voltage is introduced by resistance built into the switch. In this example, the only major difference is that the POLARITY of the variable voltage is negative rather than positive as in the previous variable voltage switching example.

These systems are easily identified because they typically contain only two wires at the door lock switch. One for supply, the other to send variable voltages to the door lock controller (or BCM). This type of system may also be present in certain Mazda vehicles and in 1999 and newer Pontiac Grand Am and Oldsmobile Alero.

Negative Pulse - Open Circuit Switching

This is a popular method of controlling door locks in several Asian vehicles. It involves a special switch and two wires. There is a supply wire and a single output (or control) wire. The single wire receives a (-) negative pulse to perform one function while the other function involves opening the circuit between control and supply wires. The switch that is connected to the control module provides an “at rest” state to the control wire. When the “at rest” state is interrupted by the switch, the control module knows to operate a function.

Example - “One Wire” Door Lock Systems in Select Nissan Vehicles

Often called a “One Wire” negative pulse door lock system, many Asian vehicles have used this circuit type. Most notably, Nissan 300ZX (1992 and on), some 240SX, and some Sentras used this type of door locking circuit. Depending on the application, the circuit is (-) negative pulse to lock, open circuit to unlock OR reversed so that a (-) negative pulse operates the unlock function and an open circuit operates lock.

Besides these Nissan applications, other vehicles known to have used this type of circuit are:

Some Mitsubishi Vehilces
Some Mazda MPV Vans

Reversing Polarity Switching

Reversing Polarity Switching Systems are characterized by BOTH the (+) positive portion AND the (-) negative portion of the electrical circuit connecting through a switch that determines whether the circuit is open (no current flow) or closed (current CAN flow). In addition to the characteristics of simple (+) positive or (-) negative switching systems, a reversing polarity circuit also has an “at rest” characteristic of the circuit.

*Note - This circuit is shown with the switches in the “at rest” position
Identifying Reversing Polarity Switching

Reverse Polarity Rest at Ground Systems

Before a technician can diagnose the circuit operation, he/she must FIRST identify the switching type. For the purpose of this lesson, the default (or most common type of) Reversing Polarity Switching System is called “Reverse Polarity Rest at Ground”. This indicates that the target wire(s) in the circuit switch (+) positive polarity but show (-) negative polarity (or ground) when the switch is at rest. To identify a Reversing Polarity Switching System, follow the directions listed.

Directions

A Multimeter is required to identify a Reversing Polarity Switching System properly. In addition to probing wires in a circuit, the installer must also VERIFY that the circuit does not exhibit characteristics of another switching type (such as simple Positive Switching). Please be sure to have read the “Positive Switching Systems” section in this lesson prior to proceeding with this section.

Step 1

Plug the RED probe into the “Volts/Ohms (V/Ω)” socket of the Multimeter. Plug the BLACK probe into the “COM” socket of the Multimeter. Set the Multimeter to the appropriate range on DC Volts. The meter is “looking” for DC voltage when the circuit under test is activated.

Step 2

Attach the BLACK probe to a reliable source of GROUND so it can reference the (-) negative side of the circuit. Installers may prefer to use reliable ground points with an extension of wire where necessary (such as the negative battery post or a grounded metal support behind the dash). See the examples shown.

Step 3

Have a piece of paper and a writing implement (such as a pen or pencil) handy to take down the results of wire locations and colors that will be under test.
Step 4

Exposé the back of the switch, the wires within a harness, or the harness plug that will be probed. Carefully separate the wire to be probed from other surrounding wires. It may be necessary to probe several wires to find the appropriate one. Remember that Reversing Polarity circuits are typically power windows, sunroof and SOME power door lock systems.

Step 5

Certain circuits enabled by the ignition key switch (such as power windows or sunroof) may require turning the key to the “RUN” position to enable power to the circuit.

Step 6

With the RED probe attached to the wire or switch contact, activate the switch and watch the display on meter. A reading or +12 volts while the switch is being activated is the INITIAL indication of the wire under test being part of the positive switched circuit. To verify that the circuit is a Reversing Polarity (Rest at Ground) type, proceed to the next steps.

Step 7

Release the switch and leave it in the “OFF” or “At Rest” position. Leave BOTH of the test probes in place. Check to see if the display reads “0.00 v” at this point.

Verifying Circuit Operation

Step 8

The next step is to turn the Multimeter to the “Continuity” scale. If the Multimeter has no Continuity scale, use the lowest scale of resistance (Ω). Using this method, the installer need not change the location of the test probes. Changing the meter setting makes changes in what the meter is now “looking” for.
**Step 9**

With the Multimeter set in the Continuity mode, the meter will indicate a low resistance to ground if the circuit is resting at ground (and most Multimeters will verify this with a “BEEP” tone). The meter reading with continuity to ground should be 000.1-000.2 or so. (A measurement of exactly 0000.0 is nearly impossible because there is still some very small amount of resistance in the test probes themselves.) The reading should be LESS THAN 2 Ohms though.

If the wire or circuit shows CONTINUITY to ground, the display will look something like the picture to the left. Remember that this measurement is taken with the switch in the “AT REST” position. The display shows 000.2 ohms which means the circuit is showing a ground in the current switch position. Remember that ABOVE 2 Ohms may indicate a Positive Switching System that is reading across a resistance such as a light bulb filament.

If there is high resistance (more than 30 ohms and the Multimeter emits NO “BEEP” tone), this indicates that the circuit is NOT a “Rest at Ground” type. If there is no continuity to ground, the meter reading should display “OL”.

If the wire or circuit shows NO CONTINUITY to ground, the display will look something like the picture to the left. Remember that this measurement is taken with the switch in the “AT REST” position. The display shows “OL” which means the circuit is showing a very high (or infinite) resistance to ground in the current switch position.

**Step 10**

For a final verification, press the switch in the SAME POSITION as in Step 6. If the wire under test showed +12 volts in Step 6, then continuity to ground in Step 9, the final test is to activate the switch as Step 6 to VERIFY that the wire under test breaks continuity to ground for the duration the switch is pressed.

If each of these conditions is met, the system is a Reversing Polarity (Rest at Ground) System. On the following pages, the system is diagramed for better understanding. Remember that Reversing Polarity Systems (no matter which type) are used in bi-directional motor control circuits such as power door locks, power windows, power sunroofs and robotics projects.
Determining Reversing Polarity Switching
Testing the target wire when the switch is "ON"

Example Shown - Power Window Circuit

Extension Wire to (-) Negative Battery Post OR Ground probe to Vehicle Body Sheet Metal

RED Probe is "looking" for a (+) positive voltage to complete the measurement

Extension Wire from BLACK probe to (-) Negative Battery Post terminal

OR.....Ground probe to the vehicle body sheetmetal or grounded dash area sheetmetal

RED Probe is “looking” for (+) positive polarity to complete the measurement
Variations of Reversing Polarity Switching

Many times the Reversing Polarity Switching System described in the previous section may have some variables. Since the nature of a Reversing Polarity System is such that it "switches" one type of polarity while "resting" at another type, there are really only two variations on the Reversing Polarity Switching Systems found in automotive electrical applications. Once again, the majority of circuits that use a variation of the Reversing Polarity Switching System type are bi-directional motor switching circuits such as power door locks, power windows, power sunroofs or robotics.

Reverse Polarity Switching that Rests at (+) Positive

Before a technician can diagnose the circuit operation, he/she must FIRST identify the switching type. The default (or most common type of) Reversing Polarity Switching System is called “Reverse Polarity Rest at Ground”. This indicates that the target wire(s) in the circuit switch (+) positive voltage but show (-) negative voltage when the switch is at rest.

The type discussed in this section is called Reverse Polarity Rest at (+) Positive where the “At Rest” condition is (+) positive rather than (-) negative. As such, the switching type is then (-) negative in polarity. Although applications that use this type of Reversing Polarity Switching in automotive electrical circuits are limited, from time to time an installer may run into one. Essentially, it’s exactly OPPOSITE of the “Rest at Ground” type of Reversing Polarity systems.

Example - Some Mercedes-Benz Power Window Circuits

Many Mercedes-Benz vehicles use power window control circuits that are switching (-) negative polarity and rest at (+) positive polarity. In fact, the circuit actually works only after the ignition switch is in the RUN position because the (+) positive voltage “At Rest” is not constant +12v, but IGN +12v instead. This is how the windows remain operational only while the key is switched on just as other vehicles do.

Reverse Polarity Switching that Rests Open Circuit

Before a technician can diagnose the circuit operation, he/she must FIRST identify the switching type. The default (or most common type of) Reversing Polarity Switching System is called “Reverse Polarity Rest at Ground”. The other somewhat common type is essentially OPPOSITE but accomplishes the same task and is called Reverse Polarity Rest at (+) Positive.

The type discussed in this section is called Reverse Polarity Rest at Open Circuit where the “At Rest” condition is NEITHER (+) POSITIVE NOR (-) NEGATIVE. As such, the switching type could be EITHER (+) positive or (-) negative in polarity, but the switch will create the “At Rest” condition of the inactive side of the circuit when the active side of the circuit operates. Applications that use this type of Reversing Polarity Switching in automotive electrical circuits are VERY LIMITED.

Example - Some GM Vehicle Power Window Systems

Some select GM vehicles (particularly F-Body cars like Camaro, Firebird, and Trans-Am in certain years) use power window control circuits that are switching (+) positive polarity and rest at an open circuit. When the switch is pressed in one direction (UP for example), the circuit will receive (+) polarity and the opposite side of the circuit will then require (-) negative polarity if it is to operate properly. The switch in that particular position not only provides the (+) positive polarity for the UP function, it also provides the (-) negative polarity to the opposite motor wire as the “At Rest” condition.

In the opposite direction (DOWN for example) the polarity delivered to the SAME motor wires has been reversed. For the opposing motor direction, the output wire that was (+) positive in the previ-
ous example is now (-) negative polarity because it is performing the “At Rest” condition for the motor. Similarly, the wire that had been (-) negative in the previous example is now (+) positive to enable the opposing motor direction (in this example DOWN).

When these circuits are truly at rest (meaning no switch being pressed) both motor wires show no connection to either (+) positive or (-) negative. This characteristic is why the circuit is called reversing polarity, rest at open circuit. Though it does in fact use a reversal of polarity to switch a bi-directional window motor, the engineers at GM for some reason chose to leave the circuit open while the switches were at rest.

Power window interface with a security system and the appropriate window control modules typically requires an additional relay for each motor direction that the window control module will operate.

**Alternative Control Systems**

Many modern vehicles use some alternatives for circuit control that are different than traditional means of discrete switching on a (+) positive or (-) negative polarity.

**Vacuum Controlled Door Locking Systems**

A common characteristic of German vehicles built after the 1985 model year is vacuum operated door lock motors. The characteristic is not common to every brand of German car, but is most common on Mercedes Benz, Audi and some Volkswagen vehicles. Porsche and BMW typically use other types of electrically operated (more traditional) door lock motors.

**Example - Many 1985 and later Mercedes Benz vehicles**

In many Mercedes Benz vehicles made after the 1985 model year, the door locking system is operated by a vacuum pump (either under the rear seat or in the trunk) and each locking motor is operated by the vacuum or pressure of the pump. These vehicles have vacuum lock motors on all doors as well as the trunk and fuel door. In these applications, the key switch in either front door (driver or passenger) or the key switch for the trunk will command the pump to lock and unlock all vacuum operated motors connected to the pump.

Since the vacuum or pressure operation of each actuator motor is staggered (they don’t all move at once), a more lengthy output command from a Keyless Entry or Security System control module is required, typically about 3 seconds. Most security and convenience products offer this option as a programmable feature. As the system depends on sealed vacuum lines to operate, no lines to the motors themselves can be cut. This will render the door locking system inoperable and the vehicle will face a costly repair. The correct interface procedure is to electrically command the vacuum control motor to create vacuum to lock or pressure to unlock each motor, just like the key switch in either front door or the trunk does.

**Multiplexed Control Systems**

It is increasingly common for luxury vehicles that have hundreds and hundreds of electrical circuits to turn to multiplexing techniques for greater circuit control without increasing the amount of wires required to do so. Multiplexing is very simply MORE THAN ONE FUNCTION or COMMAND on a SINGLE wire (or single pair of wires in some cases). Some aftermarket mobile electronic product manufacturers refer to multiplexing systems as MUX systems for short.

Though variable voltages on a single wire can technically be considered an application of multiplexing, the vast majority of those systems are still able to interface with an aftermarket security or convenience system by combinations of resistances in series with a (+) positive or (-) negative electrical supply. On occasion, an “at rest” condition must be interrupted to emulate a switching function rather than applying a specific voltage to the circuit such as in the Nissan 300ZX example given earlier in this lesson. These variable voltage systems use simple integrated circuits (IC’s) in a controller called “comparators” to compare an input voltage with a reference voltage. If the voltage is at the appropriate level, the comparator gives
an output that can control the desired function.

The more difficult and advanced multiplexing control systems use serial data messaging from one vehicle “module” to another. These systems are increasing in application as the challenge to increase the number of functions in the vehicle without added weight or electrical strain continues to plague vehicle designers and manufacturers.

Example - 1996 and newer Jeep Grand Cherokee Door Locks

These Jeep vehicles use two peripheral modules that communicate with a main Body Control Module (BCM) within the vehicle. One controller is located in each front door. The peripheral modules are typically labeled as the Drivers Door Module (DDM) and the Passenger Door Module (PDM). Each “communicates” back and forth to the BCM using unique serial data messaging to operate keyless entry and power door locking functions. The serial data protocol is Chrysler’s proprietary Chrysler Collision Detection (CCD) protocol. Though CCD is used in many Damiler-Chrysler vehicles, these Jeep Grand Cherokee examples use the protocol to communicate between more vehicle modules than most others in the Damiler-Chrysler family.

For this type of door locking system to interface with an aftermarket security system, a vehicle specific module is available from Directed Electronics, Inc. which allows virtually any security system to communicate door lock and unlock commands just as the DDM or PDM does. The module part number is 455T.