Basic Electronics Damage Analysis

Self-study Narrations

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Module 1 - Basic Electronics Damage Analysis

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Learning Objectives

The learning objectives for this course include:

- identifying the basic requirements for a circuit.
- identifying circuit values and how they are measured.
- identifying other parts of a circuit and what they are designed to do.
- identifying collision damage to wiring and the possibilities for repair.
- identifying the tools and steps required when troubleshooting an electrical circuit problem.

This course will begin with a discussion on how to begin analysis on a vehicle with electrical damage. Some terms for electrical flow will be identified in order to discuss how circuits are tested, and some of the different testing equipment that is available will be highlighted. The three most common problems with electrical circuits will be identified. There will be a focus on problems that can occur with electrical systems during a collision, what it takes to diagnose the problems, and how the problems should be corrected.

Communication Tool

There is value for damage appraisers and estimators to have a working knowledge of basic electricity and electrical circuits. One of the biggest reasons is communication. Insurance appraisers need to be able to communicate with vehicle owners intelligently on what might be wrong with the electrical system on their vehicle and why an electrical system is not working. They also must be able to make an accurate assessment of damage. Estimators need to be able to communicate at a competent level with repair facility technicians on what needs to be done to diagnose and repair electrical problems.

As an auto physical damage appraiser or estimator, you do not have to perform the diagnostics, testing, or repairs. You should, however, have a basic understanding of how common electrical repair processes are done.

The Collision Advantage

An extremely valuable strategy for finding electrical problems, and one that is helpful to auto physical damage appraisers, estimators, and collision repair technicians, is the collision advantage. What is the collision advantage and why is it so valuable?

Finding an electrical problem can be a challenge. Circuits run behind and under panels. After a collision, where would be the most likely place for a cut or pinched wire or a damaged sensor? It would be in the area of the collision. This is the collision advantage, a perfectly logical starting point for finding the source of an electrical problem. If a vehicle is brought into a mechanical repair facility with an electrical problem, the entire vehicle may need to be diagnosed. Collision repair technicians, auto physical damage appraisers, and damage estimators know where to start.

Knowing How To Look

Finding electrical damage is all in knowing how to look. Auto physical damage appraisers and estimators should use the most valuable tool available to them, their eyes. Look in the area of the damage, using the collision advantage. If the vehicle can be started, or if the battery has enough charge, try all of the electrical loads:

- Turn the lights on and off.
- Try the horn.
- Turn on the radio.
- Switch the cooling fan and the heater to all the settings.
- Operate all the switches in the doors.
- Turn on and off interior accessory lamps.
- Operate all of the power accessories.

Also, note any lit warning lamps on the instrument panel. Take note of what does work and what does not. Loads that do not work may have something in common.

The I-CAR Troubleshooting Flowchart

Even though damage analysis will not require knowing how to do all the steps for troubleshooting and fixing electrical problems, it is helpful to know the systematic method of how this is done. The I-CAR Troubleshooting Flowchart lists five commonsense steps to finding the source of an electrical problem. These steps are:

1. Define the problem.
2. Know the system.
3. Find the cause.
4. Make the repair.
5. Check the system.

This is a diagnostic flowchart, not for damage analysis purposes, but lessons can be learned if we keep these steps in mind throughout this course.

Circuits And Systems

Repairing electrical damage does not start with replacing parts. It is true that electrical parts can go bad suddenly without warning. Knowing that the vehicle recently underwent a violent jarring in a collision only reinforces that belief. But an old adage holds true, especially with anything electrical, "it is not always as it seems."

Electrical parts do not work alone. They are connected into a continuous path of wiring that could stretch the entire length of the vehicle. One opening in that path, or a problem in another part of that same path, can cause a window regulator, lamp, or horn to malfunction.

Basic Parts Of A Circuit

There are three basic parts necessary for a circuit to be a complete working circuit: power source, load, and path.

Without one of those three, there is no circuit. On a vehicle, the power source storage device is the battery. When the vehicle is running, the alternator becomes the power source and the recharging battery becomes a load.

Loads include bulbs, motors, computers, and solenoids, in other words, the parts that do the work.

The paths for the different circuits are the wires, terminals, and connectors bundled into wiring harnesses. Parts that carry electrical flow, or electrons through the circuit, are called conductors. All metals are conductors, including the metal chassis and engine block, which are a part of all circuit paths. Copper is used the most, but aluminum, silver, and even gold are used for conductors on vehicles. Most wiring and terminal ends are copper. Connectors have a plastic housing but metal contacts inside.

Must Be A Complete Path

A circuit path must be complete. If there is a break or open anywhere in the path, the flow stops and the load will not work. If there is a restriction or unwanted resistance in the path, such as a pinched or partially broken wire, the load may partially work or not work at all.

Circuit Protectors And Controls

There are other parts in most circuits besides the necessary power source, load, and path. Every circuit on a vehicle has at least one protection device to protect from overloads, which can result in damage to other system parts or can even result in a fire.

Every circuit also has some type of circuit control. Control can be a simple push switch that opens and closes a lamp circuit to turn on and off the lamp. Switches usually have two or more sets of contacts. Opening these contacts opens the circuit. Closing these contacts completes the circuit.

Circuit Protector Locations

Fuses and other circuit protectors may be located in fuse blocks, which may be under the instrument panel, behind kick panels, under the rear seat, or in multiple areas underhood. The inside cover of the fuse block usually labels the location, rating, and use of each circuit protector contained in the block.

Larger circuit protectors, called maxi-fuses, fusible links, and fuse elements, are designed to carry larger amounts of flow than fuses. They are used in high-powered circuits, such as the main battery feed, and may be grouped together near the battery.

Ground

Every circuit flows through the battery, and that flow is in one direction. Benjamin Franklin guessed that direction to be from positive to negative. This became known as "conventional flow." Later it was discovered that electrons actually flow from negative to positive, what became known as "electron flow." Current flow does not start and end at the battery, it flows through the battery.

All circuits are not physically wired to the negative battery post, that is the purpose of common ground. Ground is the common meeting place for electrical flow to the battery. The negative terminal of the battery is connected to the vehicle's frame, metal body, or engine block. With this battery ground, a common ground connection is available anywhere there is a metal-to-metal connection to the frame, metal body, or engine block.

Hot And Ground Side Of A Circuit

There are two sides to every circuit, the hot side and the ground side. The hot side of a circuit is from the power source up to one side of the load. The ground side of a circuit is from the other side of the load to ground. A switch can be located in the ground side of a circuit. A switch in the ground side of the circuit completes the connection to ground when it is turned on. An example is most horns. Pressing the horn button closes the ground connection, sounding the horn.

Ground Connection

The connection to ground is made in several ways, including:

- multiple circuits connected to a single bolt, which is attached to the frame or body.
- bolting the metal case of a part to the frame or body, called a case ground.
- attaching a ground strap from the part to the frame or body.

A bad or open ground connection, making the circuit incomplete, is one of the more frequent problems with electrical circuits after a collision. What might appear to be a part problem could be a simple ground connection problem instead. For example, during damage analysis it is discovered that a power door window does not move. The first assumption may be that the power door motor should be replaced, or the power door window switch, but it is more likely a wiring problem, like a bad ground connection.

Three Most Common Circuit Problems
A bad ground connection is one of the more frequent problems with electrical circuits after a collision. There are two others:

- Opens
- Shorts

Actually, these three are the most common faults even if a vehicle has not been in a collision.

Shorts
Opens have already been described as a break in the circuit flow path, but what is a short? It is a shortcut the electron flow takes instead of the intended path. Electron flow will always take the easiest path, and will also seek every available path. A short is often caused by insulation scraped off a wire, allowing the wire to touch another bare wire or ground. The exposed wires may touch only from vehicle movement or engine vibration, causing intermittent flickering of a bulb or sounding of a buzzer. If the two wires involve another circuit, it is a short to power causing another load not to work as it was designed. The wipers moving when the headlamps are switched on is an example of a short to power.

A short to ground causes different problems depending on where the short occurs. If the circuit is grounded before the load, the load will be taken out of the circuit and the fuse will likely blow. A short to ground after the load may show no problem at all, but since the circuit is not correctly wired at that point, there may be a problem in another circuit that is difficult to find.

Voltage, Current, And Resistance
When a technician checks the operation of a circuit, more than just a visual inspection may be required when the circuit is not working properly. It may require measuring circuit values, called voltage, current, and resistance.

Voltage

Voltage is electrical pressure. Voltage is the pushing force that moves electrons through a circuit. Voltage can be measured as a number of volts, often shown abbreviated with a capital "V." A fully charged conventional storage battery on a vehicle measures between 12.4V and 12.6V.

Current

The electron flow itself is called current, which can be measured in amperage as a number of amperes or amps. Amps is often shown abbreviated with a capital "A." Current that flows in one direction only is called direct current (DC). Current that flows both ways is called alternating current (AC).

Current from a household electrical outlet is AC. Automotive circuits are mostly DC, because batteries store only DC. An alternator produces AC, but it is changed to DC in order to charge the battery and power the vehicle circuits.

Resistance

Resistance is what resists the current flow, and is measured in a number of ohms. Ohms is often shown as the Greek letter omega.

The Need For Resistance

When looking for circuit problems, resistance is often referred to as unwanted, in the way of the circuit being able to do its job. But resistance has an important role in a circuit, and is just as essential as voltage and current. The illustration shown would never be called a circuit, since it is missing a load. If there actually was a cable connected directly across the battery posts, the cable would quickly burn because of too much current flow. The battery would quickly discharge and be unusable.

The load can be considered the main resistance in the circuit. By consuming most of the supplied voltage to operate, the load is resisting the flow of current. Though there is some resistance in the length of the wire and the connectors, it is not enough. A more substantial resistance, the load, is required. Every circuit on the vehicle requires voltage to push current through the path, and substantial resistance to use most of the voltage being supplied.

Digital Volt-Ohm Meter (DVOM)

Volts, amps, and ohms can all be measured with a meter, the most common being a digital volt-ohm meter, or DVOM. A DVOM is able to read the different circuit values by turning a dial to the appropriate scale. The leads, red for positive and black for negative, are positioned in the circuit to make the measurements. To measure voltage or resistance, the leads are placed across the part being measured. To measure current, the current must flow through the meter, so an opening is made in the circuit and the leads are used to complete the circuit.

A DVOM is better for measuring circuit values than an analog-type meter or a test lamp, because it has an internal resistance that makes it virtually invisible to the circuit being measured. This makes a DVOM accurate, and not harmful to sensitive electronic circuits.

Ohm's Law

It is not necessary for the technician to measure all circuit values whenever testing. There is a relationship between voltage, current, and resistance called Ohm's law, which states that current and resistance are directly proportional. Think of this relationship as a seesaw, with the seesaw base voltage and resistance and current on opposite sides of the seesaw. If resistance increases, current decreases an equal amount. Therefore, it is not necessary to measure both values. If the resistances in the circuit are as expected, there will be a correct amount of current flowing through the circuit to allow the load to work as it should. If resistance should become too high, current will be too low, causing a lamp to be dim or a motor to run slowly.

Parallel Circuit Flow

Automotive circuits are mostly wired in what is called a parallel setup, where even though there may be several loads branching off one wiring harness, each circuit branch has its own complete path. Each branch has access to full source voltage. In a parallel circuit, if there is a cut wire or open in one of the branches, only the load in that branch is affected.

Series Circuit Flow

Another type of setup is wiring a circuit in series, where there is only one path for more than one load, requiring each load to share the available voltage. All of the bulbs in the circuit shown are 12-volt bulbs all sharing the one 12-volt source, which is why they are all dim compared to the parallel circuit. Also with a series circuit, all it takes is one open to shut down the entire circuit. An example is a type of Christmas light strand, where if one bulb burns out, the entire string does not work. An example on a vehicle is a blower motor circuit, where the speed of the motor changes with each switch setting. This is because there is a different level of resistance in series at each setting. The more resistance there is in the series, the lower the motor speed. At the highest setting, there is no resistance in series with the blower motor.

Voltage Most Common Measurement

Measuring voltage is the most common measurement done in a circuit. This is because even though voltage remains consistent at the source, voltage:

- can be measured anywhere in the circuit.

- is designed to be mostly used, or "dropped," across the load. If a voltage measurement shows that nearly full voltage is not dropped across the load, there is likely trouble somewhere in the circuit.

Measuring Voltage
To measure voltage, the circuit must be powered, or turned on. After selecting the proper scale on the DVOM, the two leads are positioned across any two points in the circuit. The measurement on the meter is the number of volts between those two points.

Measuring Across A Battery
A common voltage measurement that technicians will do is across the battery terminals, which checks the state of charge of the battery, and also shows the full available voltage, also called full source voltage. If the measurement is:

- 12.66 volts, the state of charge is 100%.
- 12.45 volts, the state of charge is 75%.
- 12.24 volts, the state of charge is 50%.
- 12.06 volts, the state of charge is 25%.
- 11.89 volts, the state of charge is 0%.

For a more accurate reading, remove the surface charge from the battery. To do this, turn on a load, such as the headlamps, for a short time with the ignition in the OFF position.

Voltage Across An Open
This measurement shows full source voltage across an open ground. The DVOM will always show full source voltage across an open no matter where it occurs, in the hot or ground side of the circuit. When there is an open in the circuit, voltage does not get used by the load. On a vehicle, this is one way of detecting an open in a circuit.

What Voltage Drops Reveal
A voltage measurement can be taken anywhere in a live circuit, and those measurements can be revealing. For example, the 11-volt measurement across the headlamp means a dim bulb and a problem somewhere else in the circuit. A voltage drop measurement of about 2 volts across a connector would reveal a problem within the connector. It could be corrosion on the connector contacts or perhaps a loose terminal.

A voltage drop test may also reveal:

- a few wire strands broken inside a wire sheathing.

- hidden corrosion under a bolt.
- hidden corrosion on a switch.

Any one of these problems could cause a dim or flickering bulb, a slow running motor, or the load not working at all. It should also be pointed out that if these same areas were checked for resistance with the DVOM set to ohms, the measurement may show zero ohms, or no resistance problem at all.

Voltage On Hybrid Electric And Pure-Electric Vehicles

On hybrid electric vehicles, plug-in hybrid electric vehicles, and pure-electric vehicles, the 12-volt battery serves as an auxiliary battery for providing voltage to the vehicle accessories. The main power source is a high voltage battery that may carry as much as 300 volts and higher. It is typically located in the rear seat or trunk area of the passenger compartment. If the 12-volt battery is not disabled, all of the power accessories can be turned on to check for their operation. Before looking under the hood, turn off and remove the ignition key, which will power down the vehicle.

The voltage in these vehicles is high enough to kill. Technicians and those doing damage analysis should always approach a damaged electric and hybrid electric vehicle assuming that the high voltage system is energized. The high voltage system is controlled by the 12-volt system. On most hybrids, if the 12-volt battery is disconnected, then the high voltage system will be disabled. Although the high voltage system is disabled, and the electric motor will not operate, disconnecting the 12-volt battery does not isolate the high voltage to the high voltage battery. There is still high voltage present in the bright orange cables connected to the high voltage systems on the vehicle. The only way to disconnect the high voltage from the cables and isolate the voltage to the high voltage battery is with the service disconnect located on the high voltage battery. This is a simple procedure, though it differs slightly for just about every vehicle and requires insulated lineman's gloves to avoid electric shock. The procedure should only be done by a trained technician in a repair facility.

Why Resistance Measurements Are Uncommon

Resistance measurements are uncommon when looking for circuit problems. This is because to measure resistance, the circuit part has to be isolated, and no power can be applied. For example, if two sides of a wire connector are measured for resistance with the connector wired into the circuit, the meter will show the resistance of the entire circuit. Even if a part is isolated, a resistance measurement provides little information since the resistance may be correct, or the part may be damaged. A step in a diagnostic flowchart may say to measure resistance across two points, or across a part such as an impact sensor. This specific measurement is used in the flowchart to determine how to proceed. Other than a specific direction like that, it is not very helpful to take a resistance measurement.

Continuity Check
What is helpful with a resistance measurement is that it can be used to check for a continuous path with no break, or open, in the path. This is called a continuity check and can be done on individual wires within a wiring harness. It is difficult to find an open wire within a wiring harness by visual inspection alone. Individual wires are coated with insulation, and several wires are usually grouped together within an insulated covering. Some DVOMs have a separate setting for a continuity check.

To check for continuity in a circuit, a voltage drop test is used. Zero or near zero voltage drop is continuity.

Collision Damage To Switches
Common problems with a switch after a collision include:

- cracked casings.
- loose internal contacts.
- loose or damaged connections.

In most of these cases, the switch should be replaced. If the problem is not visible, switches can be tested. Voltage drop testing is the best test to determine the condition of the switch contacts. A continuity check can be done on simple on / off switches once the switch is isolated from the circuit.

Computer-Controlled Switches
Think of a computer, or control module, as a switch. The control module may switch several circuits within a related system. Just like manually operated switches, computer-controlled switches turn on and off the current flow. The control module makes decisions based on inputs from various sensors and other switches. The passive restraints control module, for example, uses information from impact sensors and other sensors to determine whether to trigger an airbag deployment.

Wiring Issues
Wiring issues are usually at the forefront of collision damage. Wires get pinched or cut, including wiring harnesses. This means that several wires are cut in one location. Wiring harnesses are several sizes, and it is often more practical to replace a small, isolated wiring harness.

What if the damage is in a large wiring harness? Is this a repairable situation or does the entire wiring harness have to be replaced? This decision is based on several factors, with the vehicle maker's service information having the final say. There will be general statements on wire repair recommendations, usually found in the mechanical/electrical service information, or it may be found in technical service bulletins (TSBs).

Offset Splice Locations

A repair to a cut wire is called a splice. Many vehicle makers allow multiple splices, but the splices must be offset to avoid a bulk of repairs in one location. There may be a recommended distance between the splices in the wiring, which may dictate how many splices can actually be made. If there is not enough room to complete the splices, the harness may require replacement. General Motors, for example, specifies 40 mm between splices. If there are six cut wires in a portion of a wiring harness that is 200 mm long, there may not be enough room for repairs to that harness.

Wire repairs should not be performed in an area of the harness that will continually flex, such as a doorjamb. This would be prone to failure. The harness may require replacement, or if repairs are allowed, splices may be made at a location where it does not constantly flex. If replacing a portion of a wire, it is important to match the same wire thickness, or gauge. Splicing in a different gauge wire affects the resistance of the wiring, affecting the current flow, therefore changing the circuit design.

Wire Repair Kits

Most vehicle makers offer wire repair kits, which contain the tools and materials required for wiring repairs. The kit may contain splice sleeves or heat-shrink tubing, which is melted over the soldered splice. Some vehicle makers will not honor warranties on their vehicles if their wire repair kits are not used.

Passive Restraint System Wiring

Use caution when inspecting passive restraint systems. Even if an airbag looks fully deployed, it may be capable of a second deployment. Disabling the system is commonly done by disconnecting and isolating the negative battery cable and allowing time to pass to allow the system to fully discharge.

There may be a special kit just for repairs to passive restraint system wiring. Due to the safety concerns, some vehicle makers do not recommend any repairs to passive restraint system wiring. Other vehicle makers, however, have detailed repair procedures. There may be limitations. Ford Motor Company, for example, does not allow wiring repairs if the damaged passive restraint system harness is a stand-alone wiring harness, rather than part of a large main wiring harness. Volvo recommends only one splice per circuit with passive restraint system wiring, and one splice per wire with other circuits. Connectors for passive restraint wiring may be yellow for visibility, but not all yellow connectors are for the passive restraint system. Passive restraint system wiring may also be yellow. Yellow connectors and wiring are not universally used among vehicle makers. When wire repairs are done, document that OEM procedures are used.

There are two I-CAR Advantage articles that discuss passive restraint wiring repairs, one discussing General Motors' recommendations. The other article discusses Chrysler recommendations.

Use caution when inspecting passive restraint systems. Even if an airbag looks fully deployed, it may be capable of a second deployment. Disabling the system is commonly done by disconnecting and isolating the negative battery cable and allowing time to pass to allow the system to fully discharge.

Wiring Pigtails

A wiring pigtail refers to a small section of wire that is either integral with a part, such as a clock spring pigtail, or directly connected to a part via a connector, such as on driver airbag modules or occupant classification sensor (OCS) systems. Many vehicle makers do not allow repairing these pigtails on passive restraint parts, but there are exceptions to every rule. Ford Motor Company, for example, has pigtail repair kits specifically for the passive restraint system wiring. The damaged passive restraint system wiring must be part of a main vehicle wiring harness. If the restraint system wiring is contained in a stand-alone wiring harness, the harness must be replaced.

Spilled Battery Acid On Wiring

Spilled battery acid, which is sulfuric acid, causes problems with wiring and connectors. The acid corrodes what it touches, burning away wiring insulation and connector housings and exposing wires. Acid must be neutralized, such as with a baking soda and water solution, or it will remain active. The exposed battery acid could be neutralized, but battery acid is a liquid so it naturally wicks into areas that cannot be seen or treated. If the acid dries it is inactive, but only until rain or other moisture reactivates it. There is a special grease available, called dielectric grease, that can be applied to wiring and terminals to keep them waterproof, but this is not a solution to spilled battery acid. Again, this will protect what can be seen, but what about what cannot be seen? Typically replacement of the wiring harness is the only fix. It may be possible to replace only part of a wiring harness.

Battery acid on wiring and connectors is not the only problem. Where else did the acid go? Any part under the hood is vulnerable to sulfuric acid exposure.

Dead Battery

The battery may be the first encounter with a vehicle electrical system for damage appraisers and estimators. This is because if the battery has a low charge or there is wiring damage that stops the electrical flow, none of the lights or power accessories can be checked. It is likely the odometer will not be able to be read. Provided the problem is only a partially discharged battery, a jumper pack can be used but it is important to know the safety precautions when doing this.

Battery Safety Terminals
Some vehicle makers, first BMW and now some others, have a safety device installed in the positive battery cable on some vehicles. This battery safety terminal (BST) is a self-contained explosive-type device. It deploys during a collision to create an open in the positive cable connection. This prevents a short circuit in the high amperage starter circuit. The BST is supposed to deploy when the front airbags deploy. The entire cable or a section of the cable requires replacement following the BST activation.

Headlamp Circuits
Headlamps are often damaged in a frontal collision and questions often arise about whether the entire assembly must be replaced. The wiring harness is typically available separately, but what about the headlamp bulb and other related parts? Composite headlamps use a replaceable halogen bulb, and the bulb can be replaced separately.

High-Intensity Discharge Headlamps
Use caution when inspecting these types of headlamps. High amounts of voltage are used to light this type of headlamp, so serious injury may occur from incidental contact.

High-intensity discharge (HID) headlamps, also called xenon headlamps, may have separate parts available. The HID bulb is usually available separately. The ballast, or electronic control unit, may be available separately depending on the application. Data from your information provider should indicate this. If only one headlamp is out, the two assemblies are not side-specific, so the technician could try swapping the bulbs, then the ballast side to side to see if the problem is one of these units.

Use caution when inspecting these types of headlamps. High amounts of voltage are used to light this type of headlamp, so serious injury may occur from incidental contact.

LED Lamp Assemblies
Headlamps and tail lamps may consist of a series of light emitting diodes (LEDs), which cannot be replaced separately, only as an assembly. LED assemblies may wrap around rear body panels, be used as turn signals by being turned on in succession, or be combined with conventional bulbs in one assembly. The wiring and connectors to LED assemblies are the same as any other lamp assembly, it is just the appearance of the lamp that is different.

Know The System
The second step in the troubleshooting flowchart is to know the system, and this requires looking at the vehicle maker service information. A visual inspection can only go so far. Even a very simple circuit, such as the horn, could have some complicated subsystems, like an alarm system, routed in with the horn circuit.

There are several diagrams and other information for electrical circuits. One of these is a wiring diagram, which is basically a road map of how the parts are connected together. A wiring diagram will help in understanding a circuit, but there are limitations to wiring diagrams. The diagram only shows what makes up the circuit path. It does not show the size of parts, the length of wires, or the location of anything.

Part Locator Diagram
Part locator diagrams may be available on the service website. Part locator diagrams are line arts or even photos of where the parts of the circuit are located, including:

- the load.
- switches.
- connectors.
- ground locations.
- circuit protector locations.
- wiring harness routing.

Part locator diagrams are helpful after a collision, because it is an opportunity to use the collision advantage. What parts or wiring that are parts of the malfunctioning circuit are located at or near the site of the collision? That is where to start looking for problems.

Power And Ground Distribution Diagrams
Two other especially helpful diagrams for knowing the system after a collision are power and ground distribution diagrams. These diagrams typically show where the power is coming from, and the circuits that share common grounds.

Knowing which circuits share common power feeds and common grounds will dictate what other loads to check. For example, if the horn, dome light, and cigarette lighter are all powered by one fuse and the horn does not work, what about the dome light and the cigarette lighter? If all of these are not working, perhaps the fuse is blown. If these three share one ground location, try the same. If all three are not working, the problem may have been found. Is the ground location in the area of the collision? The collision advantage has just made this diagnosis a whole lot easier.

Diagnostic Flowcharts
Troubleshooting a complex, computer-controlled system is not a seek-and-you-shall-find type of process. Generally, it requires the technician to follow a diagnostic flowchart from the vehicle maker service information. Flowcharts contain steps directing the technician to perform specific tasks, such as making electrical measurements. When doing the steps, the technician should always ask why the test is being called for.

TSBs may be a valuable tool as well, as many times the subject of a TSB will be a common electrical problem with a particular make or model. The TSB may include a short explanation of how to correct the problem.

Diagnostic flowcharts and TSBs do not take into account the fact that the vehicle was just involved in a collision. Before turning to a diagnostic flowchart, the collision technician should use the collision advantage and their eyes to inspect the area that was damaged for pinched or broken wires, loose grounds, and possible shorts. In the end, no matter how complicated the circuit, the problem is usually an open, short, or bad ground.

Scan Tools

Besides a DVOM, a diagnostic flowchart may also require the use of a scan tool to find problems. A scan tool may have to be model-specific for some diagnostics. A scan tool will allow the technician to:

- monitor input and output information from control modules.
- turn parts on and off to check for proper operation.
- check for diagnostic trouble codes, which directs the technician to specific circuits and maybe even the specific part that is affected.

Electricity And Magnetism

There are some electrical parts that take advantage of the close relationship electricity has with magnetism. Whenever there is current flowing through a circuit, there is a magnetic field present around the path. It is called an electromagnetic field because it only exists when current is flowing. The higher the current flow there is, the larger the electromagnetic field.

Automotive parts that use electromagnetic fields to work include:

- solenoids.
- relays.
- motors.
- magnetic pickups.

Solenoids

Solenoids are used to perform several functions on a vehicle, such as:

- remotely opening a fuel filler door or deck lid.
- opening some door locks.
- recirculating some of the exhaust gases back through the combustion process as part of the exhaust gas recirculation system.

- opening and closing a valve that controls fuel delivery, called a fuel injector solenoid.
- controlling brake fluid system pressure on an anti-lock brake system.
- engaging an air compressor clutch.
- engaging the starter with the flywheel.

Solenoids can be physically damaged in a collision. Replacement is the only option. If a solenoid does not appear damaged, solenoids can also be tested for proper operation.

Relays
A relay is a type of switch that is opened or closed using an electromagnet. A relay uses a low current circuit to control a high current circuit. It also can provide electrical isolation of the control circuit. The low current side usually has thinner wires than the circuit being controlled. Using a relay eliminates the need to run heavy wires into the passenger compartment.

Relays may be located in blocks, just like fuses. In fact, they are often grouped together with fuses in the same block. The inside cover of the block may list the locations of the relays and their use. Relays may also be found alone in various locations.

Relays can be inspected and tested for:

- proper resistance.
- contact continuity when energized.
- mechanical movement.
- freely moving contacts.

Faulty relays should be replaced.

Unwanted Electromagnetic Fields
The fact that there is an electromagnetic field around any wire or cable when current is flowing can cause problems when the electromagnetic field is not wanted. A starter circuit, for example, has 300-500 amps flowing when the vehicle is being started. If those high current wires are routed wrong, the surrounding electromagnetic field can damage another circuit. This can lead to intermittent problems or, in the case of a control module, even permanent part failure. The same goes for the large electromagnetic field around welding cables when making a weld. This applies to both GMA (MIG) welders and spot welders. The cables should never be routed near electronic parts. The GMA (MIG) weld ground clamp should be attached as close as possible to where the weld is being made, and never near electronic parts.

Twisted / Shielded Wires

Some circuits or parts that cannot tolerate any unwanted electromagnetic fields have twisted wiring harnesses and shields on the wires to break the magnetic fields. These shielded wires are common on anti-lock brake system wheel speed sensors, parts of the distributor, and antenna leads.

Twisted and shielded wires may be repairable depending on the location, application, and vehicle maker recommendations. If repairs are possible, there are offset requirements for multiple wires cut in one location, just like with conventional wire repairs.

5-Volt Systems

It has already been pointed out that a computer, or control module, switches circuits on and off based on sensor input. It has just been pointed out that computers are sensitive to electromagnetic fields, and can actually be destroyed by a poorly routed cable. The reason for this is that many computer-controlled circuits operate on lower voltage and current levels, usually 5 volts as opposed to 12 volts.

This is one of the key differences between electrical and electronic circuits. The 12-volt battery power source is reduced to 5 volts for electronic circuits. Amperage is far lower than 12-volt electrical circuits. A soldering gun, even static electricity, can also damage or destroy control modules.

Electrical Vs. Electronic Systems

A control module, all of the parts it controls, and parts that gather information for the control module, are generally grouped together and called an electronic system. The passive restraints system, for example, consists of the various airbags, seat belt pre-tensioners, crash sensors, safing sensors, and the passive restraints control module. The electronic stability control system (ESC) consists of the ESC module, wheel speed sensors, yaw rate sensor, steering wheel angle sensor, and the anti-lock brake system (ABS) module.

More information on analyzing damage on advanced electronic systems can be found in the live I-CAR "Advanced Electronic Systems Damage Analysis (DAM07)" training course.

Fiber-Optic Cables

Information between sensors and the control module may travel through fiber-optic cables. Fiber-optic cables transmit signals using light instead of current through a wire.

A fiber-optic cable looks the same as any other wire, and may even be bundled in with other wires in a wiring harness. The difference can be seen when looking at the connector or cable end. There will be a hole in the connector body instead of a terminal cavity. The end of the cable will be hollow, so light can pass through. If a fiber-optic cable is damaged, the only repair is replacement of the cable between connectors. Special tools are required.

Module Summary

This training course was an introduction to basic electrical and electronic systems. It is meant to be a communication tool, to give damage appraisers and estimators knowledge of how electrical and electronic systems are designed to work and what can be done when there is damage to these systems. Use this course as a handy reference when looking at the electrical system on a vehicle.

Information discussed in this course included:

- the basic requirements for a circuit.
- circuit values and how they are measured.
- other parts of a circuit and what they are designed to do.
- collision damage to wiring and the possibilities for repair.
- the tools and steps required when troubleshooting an electrical circuit problem.

This course is just an overview on electrical systems. If you want more electrical and electronics training, including hands-on diagnostic training, reference the I-CAR course catalog.