

Section 2

Electrical Circuits

Types of Circuits A circuit is a complete path for current when voltage is applied. There are three basic types of circuits:

- Series
- Parallel
- Series-parallel

All circuits require the same basic components:

- Power source
- Protection device
- Conductors
- Load
- Control device
- Ground

Components of a Circuit

All circuits have these basic components.

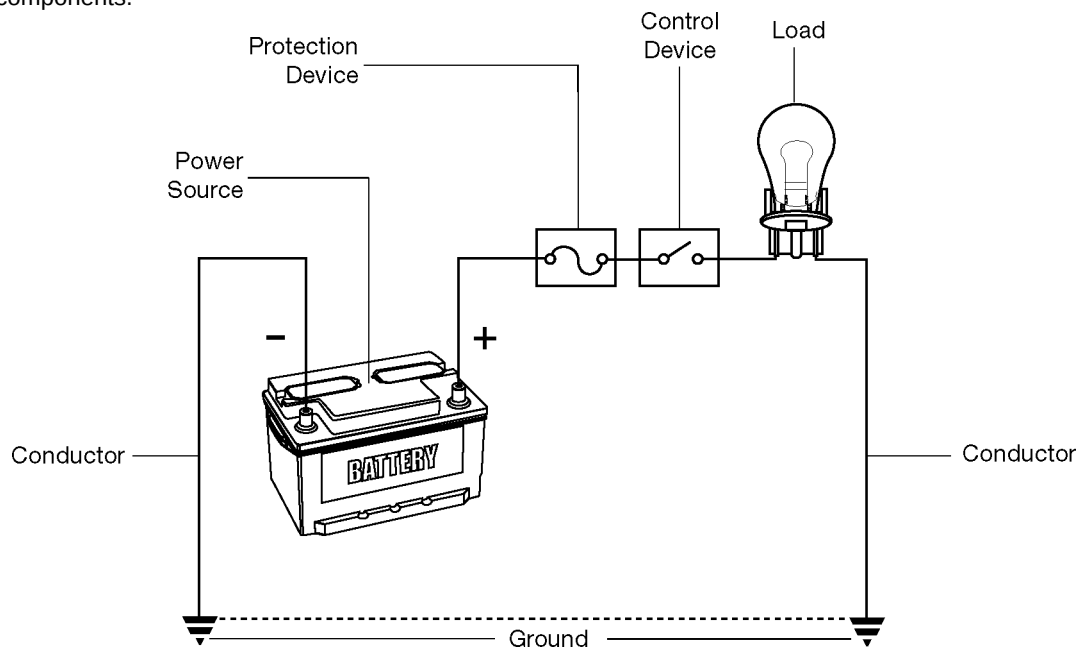


Fig. 2-01
TL623f201

Power source - In automotive circuits, the source is typically the battery.

Protection device - Circuits require protection from excessive current. Excessive current generates heat and can damage wires, connectors, and components. Fuses, fusible links, and circuit breakers protect circuits by opening the circuit path when there is too much current.

Load - The load can be any component that uses electricity to do work:

- Light
- Coil
- Motor

Control device - The simplest control device is a switch. A switch opens or closes the path for current. Close the switch and current is present to operate the load. Open the switch and current stops. The load no longer operates.

A control device can do more than just turn the load on or off. It can also regulate how the load works by varying the amount of current in the circuit. A dimmer is an example of such a control device.

There are other types of control devices:

- Relays
- Transistors
- ECUs

Ground - The connection to ground provides a “shortcut” back to the source. Ground is typically any major metal part of a vehicle. You can think of ground as a zero voltage reference. Ground provides a common connection that all circuits can use so that they do not have to be wired all the way back to the battery.

The circuit type is determined by how the power source, protection devices, conductors, loads, control devices, and grounds are connected.

Simple Series Circuit

This diagram shows a simple series circuit. Battery voltage is applied through the fuse to the control device (switch). When the switch closes, there is current in a single path through the load (lamp) to ground.

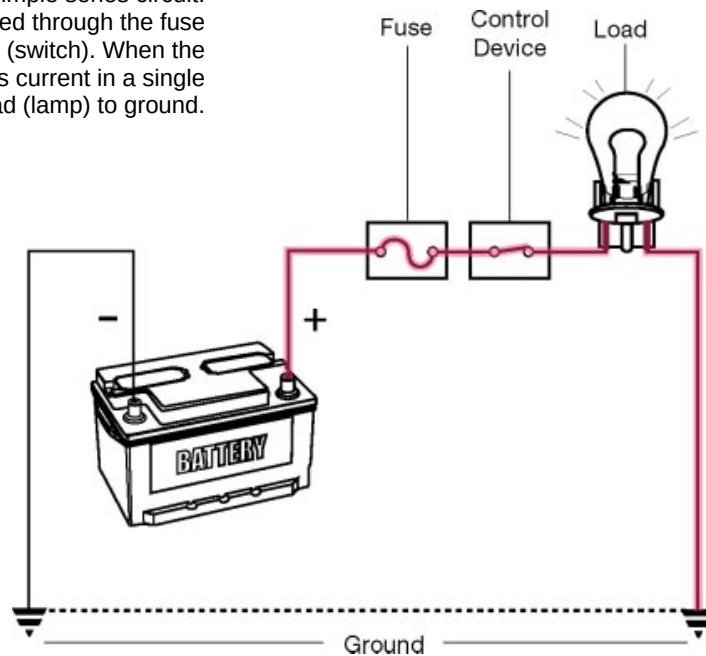


Fig. 2-02
TL623f202c

Key Features A series circuit has these key features:

- Current is the same in every part of the circuit.
- The sum of all the individual resistances equals the total resistance in the circuit.
- The sum of the individual voltage drops in the circuit equals the source voltage.

Series Circuits A series circuit has only one path for current. That means current is the same through every part of the circuit. If any part of the circuit is broken or disconnected, the whole circuit will stop working. No current is present in a series circuit unless there is continuity through the entire circuit.

Applying Ohm's Law You can use Ohm's Law to predict the behavior of electricity in a circuit.

For series circuits, apply Ohm's Law as follows:

- Total circuit resistance (R_T) equals the sum of the individual load resistances ($R_1 + R_2$).
 - $R_T = R_1 + R_2$
- Circuit current (I) equals voltage (E) divided by total resistance (R).
 - $I = E/R$
- Voltage drop (E_{R1} , E_{R2}) across each load equals current (I) times load resistance (R_1 , R_2).
 - $E_{R1} = I \times R_1$
 - $E_{R2} = I \times R_2$

NOTE In most modern texts, current is represented as “I” and voltage as “E.” You may also see these represented as “A” for amperage, instead of “I” for current, and “V” instead of “E” for voltage. When using that terminology, the Ohm's Law equation looks like this: $A = V/R$.

Ohm's Law in Series Circuits

When troubleshooting, use Ohm's Law to predict the behavior of a series circuit.

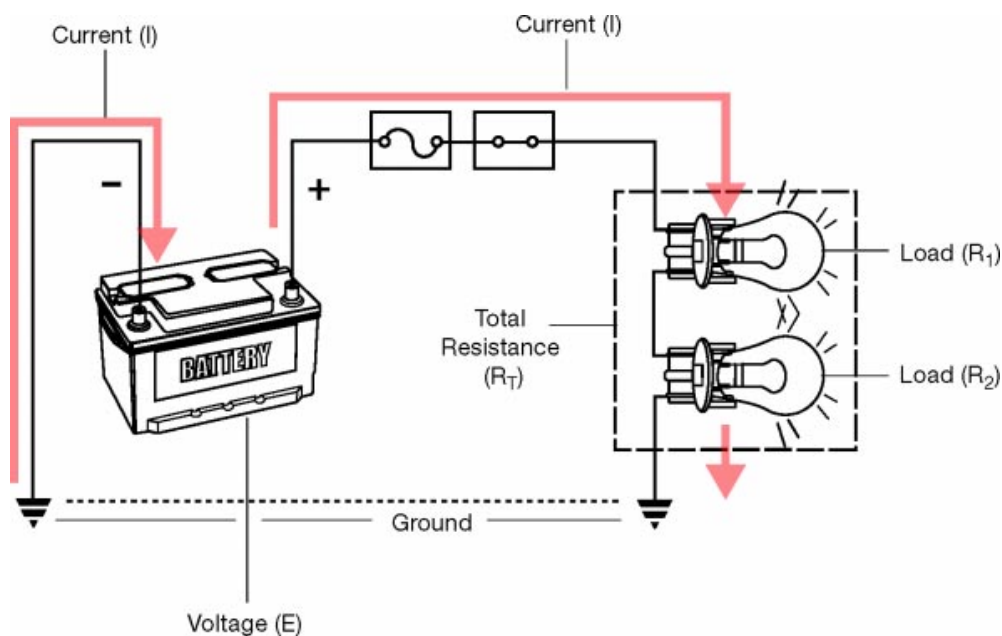


Fig. 2-03
TL623f203c

Use Ohm's Law to troubleshoot series circuits:

- Poor connections and faulty components can increase resistance.
- Since $E/R = I$, more resistance means less current.
- Less current affects the operation of the loads (dim lamps, slow running motors).
- There is no current if there is a break (open circuit) anywhere in the current path.
- Since $E/R = I$, lower voltage also means less current and higher voltage means more current.
- High voltage increases current and can also affect circuit operation (blown fuses, premature component failure).

Voltage Drops in a Series Circuit

Troubleshoot by taking voltage measurements with a digital multimeter.

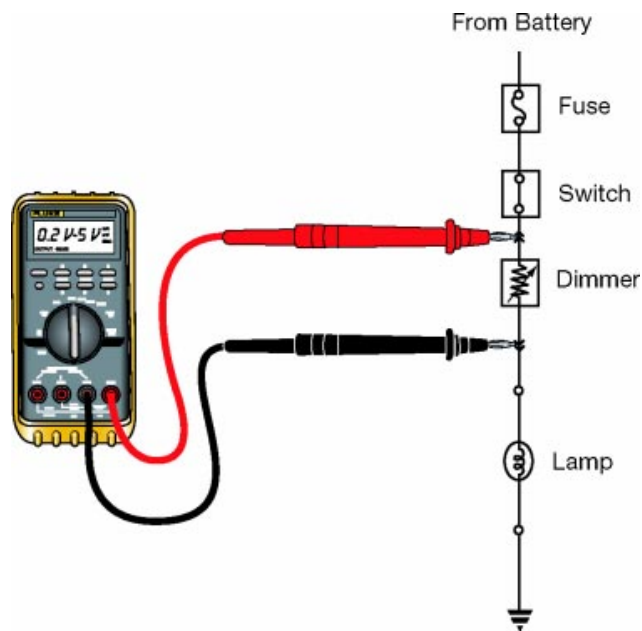


Fig. 2-04
TL623f204c

Voltage drops in a series circuit - Every element in a circuit that has resistance generates a voltage drop.

- The load in this circuit (lamp) generates the largest voltage drop.
- The dimmer generates a smaller, variable voltage drop to control the brightness of the lamp.
- Other components also generate even smaller voltage drops.
 - Fuse and fuse connectors
 - Wiring
 - Harness connectors
- The sum of all the voltage drops is equal to the source voltage.

Current in a Series Circuit

When practical, remove the fuse to measure current in a circuit.

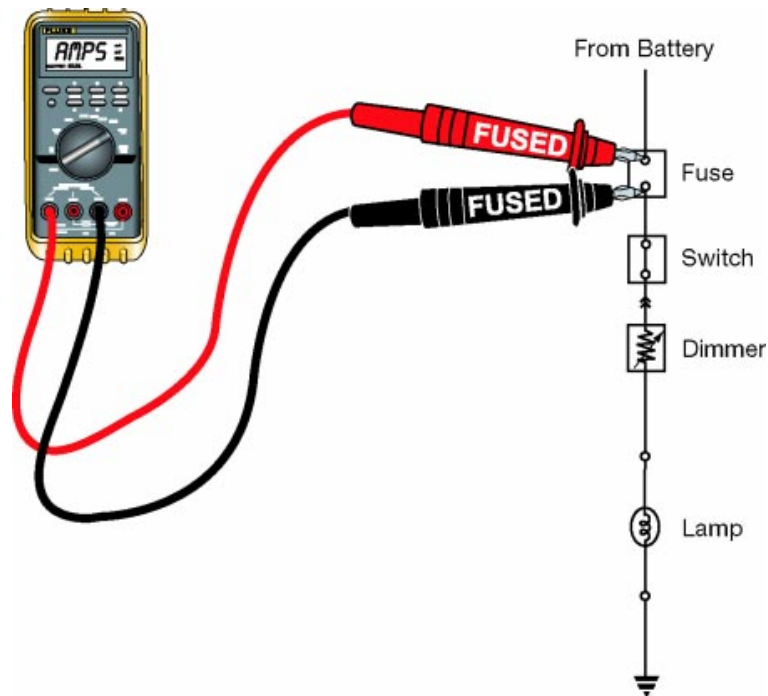


Fig. 2-05
TL623f205c

Current in a series circuit - Current in a series circuit is the same at every point in the circuit.

- Measure current by opening the circuit and inserting the meter in series.
- The circuit now includes the DMM in series with the circuit.
- Use a fused lead if removing the circuit fuse.

Measuring Resistance in a Series Circuit

Remove the fuse before beginning resistance measurements. To test the dimmer, disconnect it from the circuit.

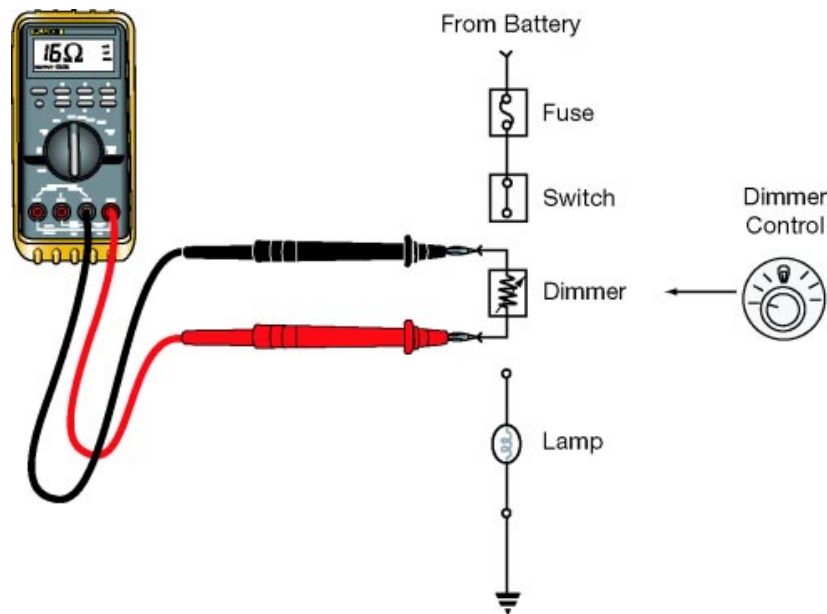


Fig. 2-06
TL623f206c

Resistance in a series circuit - To make resistance measurements:

- Remove power from the circuit (turn it off or pull the circuit fuse).
- Isolate components to be tested from the rest of the circuit (disconnect or remove the component).
- Test suspect components one at a time.

EXAMPLE In the series circuit above, isolate the dimmer for resistance testing.

- Resistance varies as the dimmer knob turns.
- Resistance is highest with the dimmer turned all the way to “Dim.”
- Resistance is lowest with the dimmer turned all the way to “Bright.”

Open Circuit

This open circuit between the dimmer and the lamp means the lamp does not operate at all (a break in the current path).

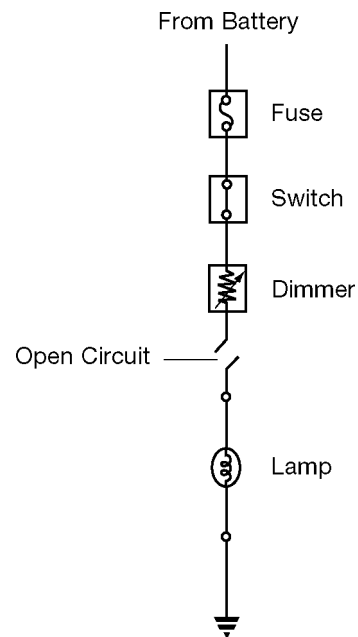


Fig. 2-07
TL623f207

Open circuit - Any break (open) in the current path of a series circuit makes the whole circuit inoperative. Open circuits can be caused by:

- Broken or loose connections
- Cut wire
- Faulty component

Find an Open Circuit

Look for an open circuit by testing for voltage in the circuit. Start with the point closest to the power source (battery) and move toward the circuit ground.

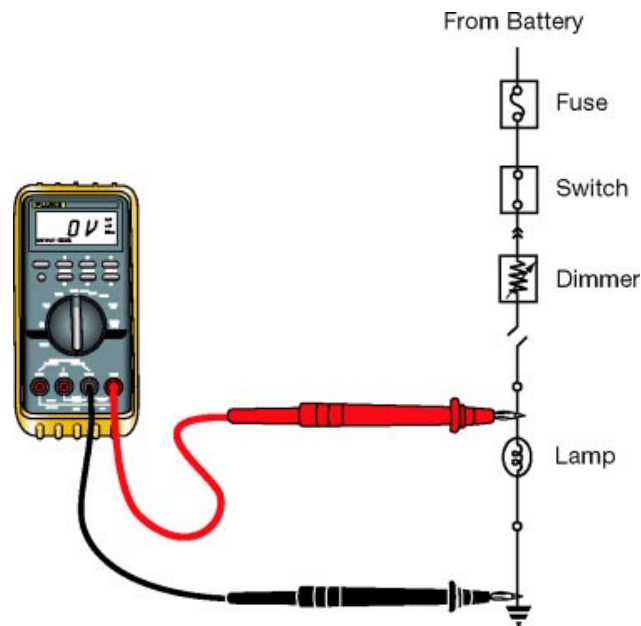


Fig. 2-08
T623f208c

Testing for available voltage - Find the fault in an open circuit by testing for available voltage.

- Begin at the fuse.
- Work your way point by point toward the circuit ground.
- Proceed until you find a point where voltage is no longer present.
- The open circuit is between your last two test points.

Split - Half Method

Circuits with easy access to components can use the split-half method to isolate the problem.

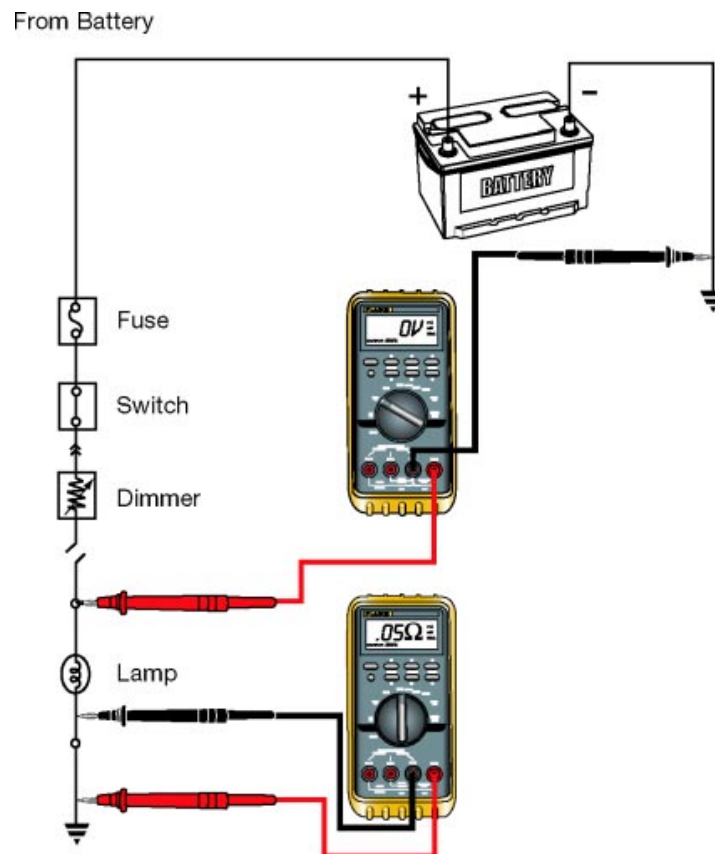


Fig. 2-09
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Split-Half Method - You can use the split-half method on circuits where access to the related components is good. The split-half method works as follows:

- Locate the middle area of the circuit that has the problem.
- Determine if the source (battery +) or ground side of that section of the circuit is bad by the following:
 - Check for available voltage on the source side.
 - Check for continuity to ground on the ground side.
- Split the bad section you found in step 2 in half and repeat the same tests.
- Continue splitting the circuit into smaller halves repeating steps 2 and 3 until you isolate the cause of the problem.

Continuity Check to Find an Open Circuit

Look for an open circuit by testing for continuity. In a logical sequence, check individual segments of the circuit.

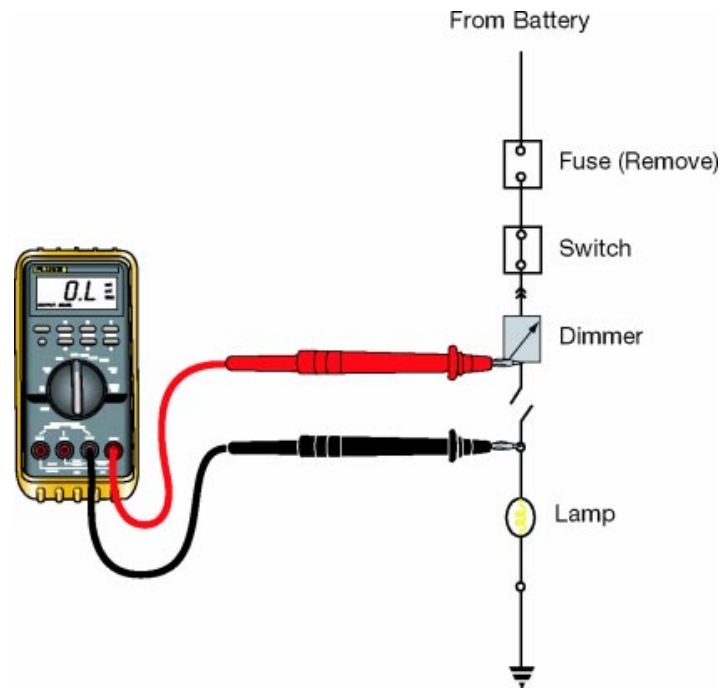


Fig. 2-10
T623f210c

Testing for continuity - The preferred method of testing a circuit is with power applied and checking for voltage drop.

When that is not possible, find the fault in an open circuit by testing for continuity as follows:

- Remove power from the circuit (turn it off or pull the circuit fuse).
- Refer to the wiring diagram to choose individual sections of the circuit for continuity checks.
- Use a DMM to check each section. Isolate components and sections as needed (by disconnecting or removing wires or components).
- Proceed until you find a section that does not show continuity (very high resistance). The open circuit will be in that section.

Short Circuit

The short circuit shown in this diagram is before the load. It provides an unwanted path for current to flow to ground.

In most cases, a short like this increases current so much that it blows the circuit fuse.

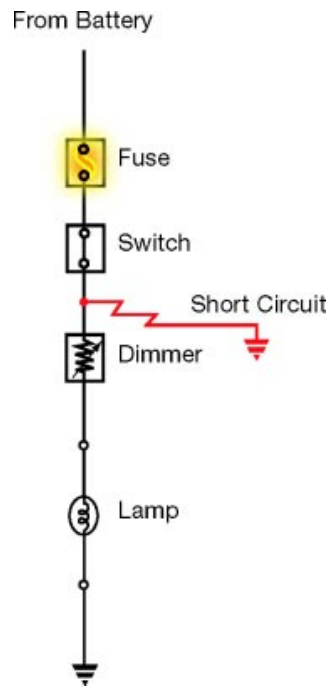


Fig. 2-11
TL623f211c

Short circuit - A short circuit is a fault in the current path. A short can be:

- an unwanted path between two parts of a circuit.
- an unwanted path between part of a circuit and ground.
- an unwanted current path inside a component.
- an unwanted path between two separate circuits.

Excessive current - Short circuits may cause excessive current.

- This typically blows the circuit fuse.
- It may not be possible to troubleshoot the circuit under power.

Isolate a short circuit - To isolate a short circuit, disconnect sections or components of the circuit one at a time.

- Refer to the electrical wiring diagram to determine a logical sequence of testing.
- Use continuity checks to find and isolate unwanted current paths.

Isolating a Short Circuit

You can troubleshoot a short circuit with continuity checks, or you can use a sealed beam headlight in the isolation method shown here.

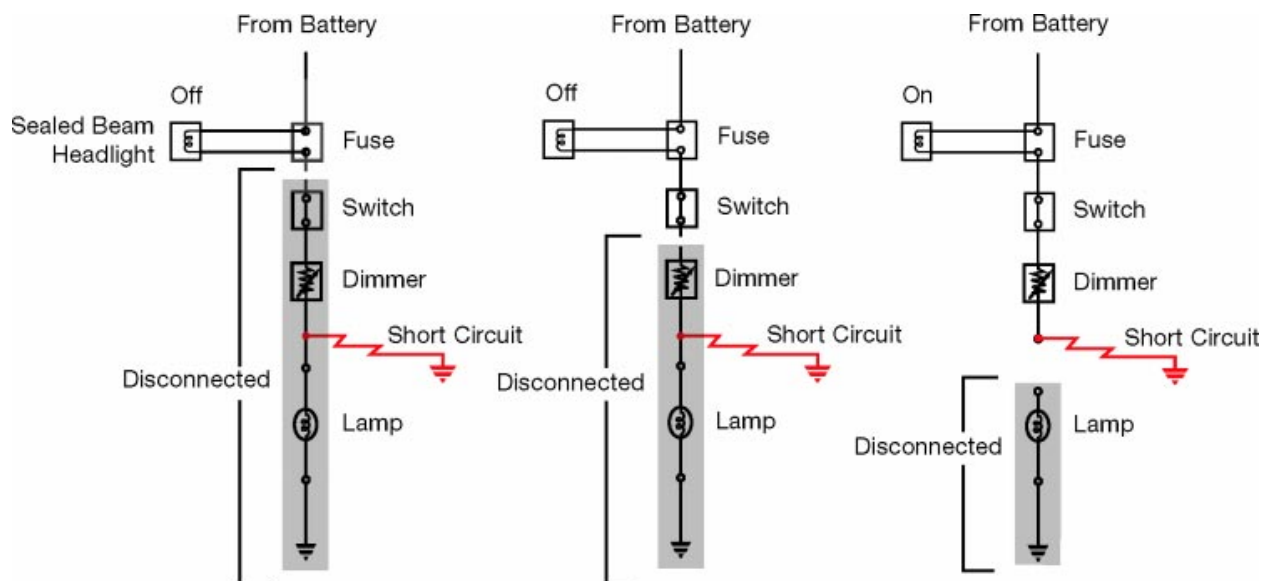


Fig. 2-12
TL623f212c

Isolating a short circuit - Circuit breakers and short detectors may damage some circuits. The following method works well for locating most short circuits:

- Remove the related fuse.
- Jumper in a sealed beam headlight to the fuse connections (the headlight becomes the load in the circuit allowing you to isolate the area with the short).
- Apply power to the circuit and the headlight will illuminate.
- Isolate sections of the circuit until the headlight turns off. This pinpoints what section of the circuit the short is in.
- Inspect that section of the circuit to locate the cause of the short.
- Repair the cause of the short.
- Remove the headlamp and reinstall the fuse.
- Verify proper circuit operation.

Parallel Circuit

In this diagram, each lamp is in its own parallel branch of the circuit. This makes it possible for one lamp to operate while the other is inoperative.

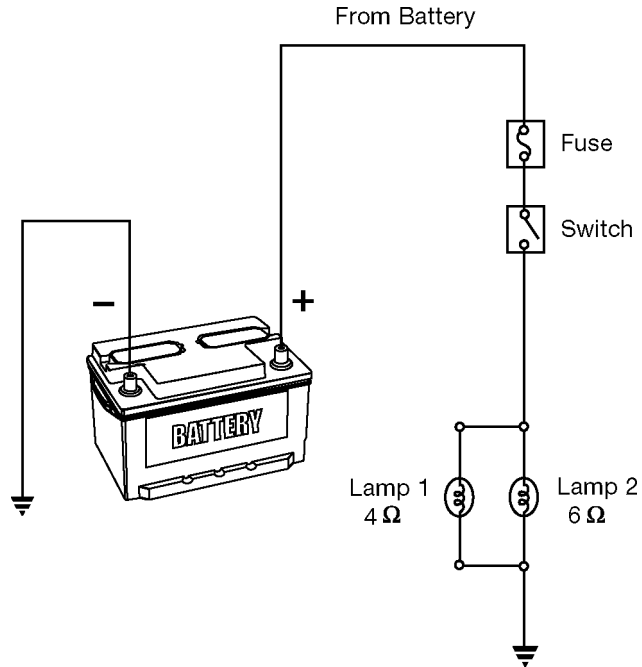


Fig. 2-13
TL623f213

Key Features A parallel circuit has these key features:

- Total current equals the sum of the branch currents.
- Resistance of each branch determines the current through each branch.
- If the branch resistances are the same, branch currents will be the same.
- If the branch resistances are different, the current in each branch will be different.
- The voltage drop across each load resistance is the same. This is because the source voltage is applied equally to each branch.
- The equivalent resistance of the circuit is less than the smallest branch resistance.

Parallel circuit operation - The circuit shown above resembles an automotive brake light circuit.

- When the switch is open, voltage is applied to the open contact of the switch. No current flows.
- When the switch is closed, current flows through the switch and both lamps to ground. The lamps light.

Parallel Circuit Elements

Parallel Circuit

A parallel circuit has a source, protection device, loads with dedicated current path, control device and ground.

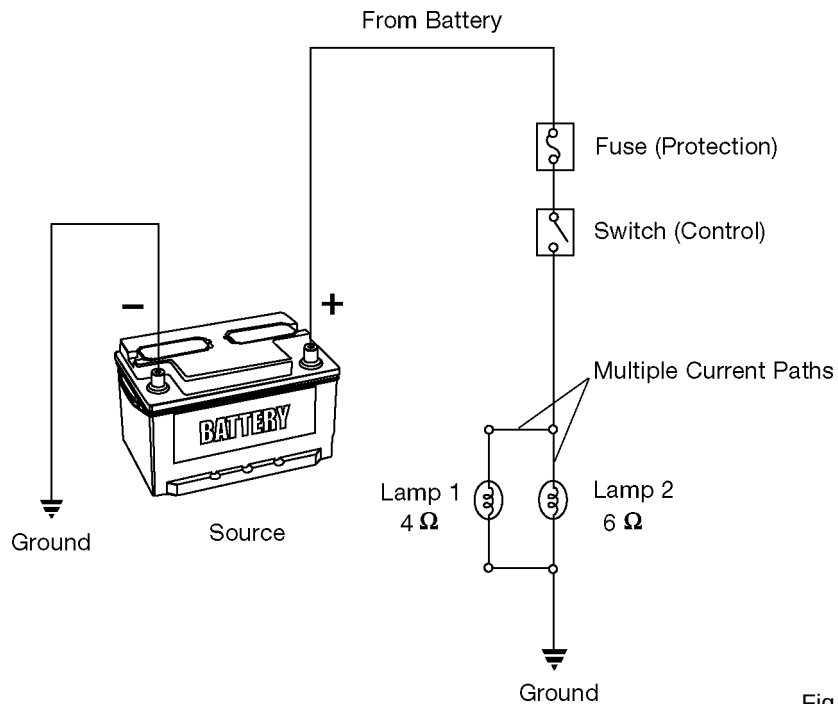


Fig. 2-14
TL623f214

A parallel circuit contains all the elements of a series circuit:

- Power source
- Protection device
- Load
- Control device
- Ground

However, a parallel circuit has more than one path for current. It typically has two or more loads, and it may have multiple control devices.

The circuit loads are connected in parallel paths called “branches.” Each branch operates independently of the others. In a parallel circuit, it is possible for one load to be inoperative while other loads continue to operate.

Ohm's law in Parallel Circuits

You can use Ohm's law to predict circuit behavior. Total resistance is less than the smallest branch resistance. Voltage drop in each branch equals source voltage.

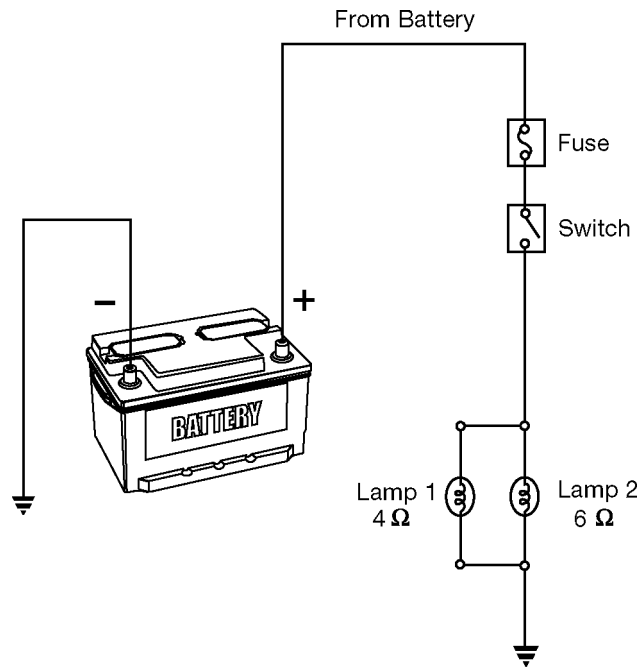


Fig. 2-15
TL623f215

Applying Ohm's Law - You can use Ohm's Law to predict the behavior of electricity in a circuit.

For parallel circuits, apply Ohm's Law as follows:

- The total (or equivalent) resistance (R) is less than the smallest branch resistance.

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

- When you add a branch resistance to a parallel circuit, the equivalent resistance of the circuit decreases.
- When you remove a branch, the equivalent resistance increases.
- Voltage drop across each branch in the circuit is the same.

Use Ohm's Law to troubleshoot circuits:

- If there is an open circuit in one or more of the branches, the increased equivalent resistance will reduce current.
- Increasing resistance in one branch may affect only the component operation in that branch. However, if the resistance goes high enough to create an open circuit, the circuit effectively loses a branch. In that case, equivalent resistance increases and current decreases for the entire circuit.
- Increased resistance in the series segment of the circuit can also reduce current. Low source voltage can also reduce current.
- As in series circuits, high source voltage or a short circuit to ground before the load can increase current, blow fuses, and damage components.

Current in Parallel Circuits

Total current in the circuit equals the sum of current in each branch.

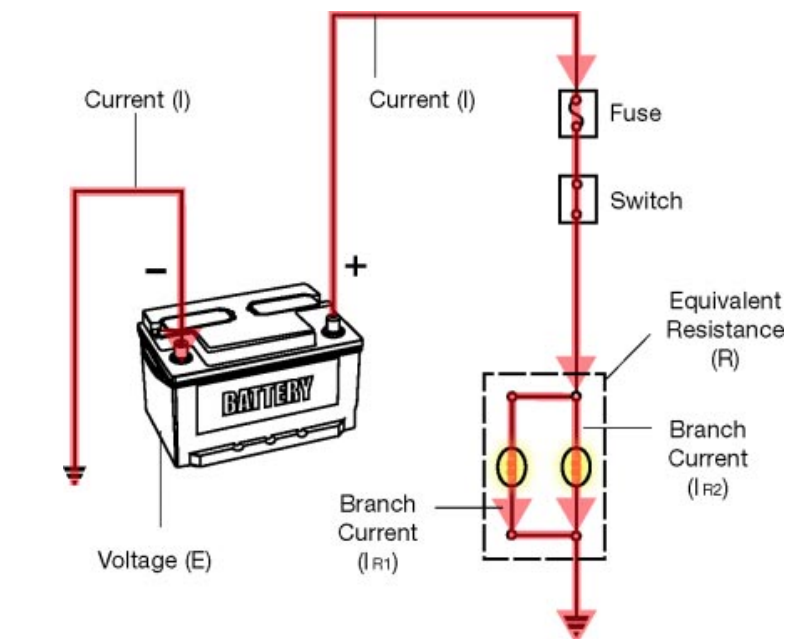


Fig. 2-16
TL623f216c

Current - Current in a parallel circuit behaves differently than it does in a series circuit.

- Current through the fuse and the switch is the same.

Current through the lamps is split.

- If the lamps have equal resistance, current through the lamps is identical.
- If the lamps have unequal resistance, the lamp with lower resistance conducts more current than the lamp with higher resistance.
- If one lamp fails, the other lamp will still work and conduct the same amount of current as before.
- Total current in the circuit does change when one bulb fails.

Parallel Circuit Tests

Diagnose parallel circuits using the DMM to measure voltage, amperage, and resistance.

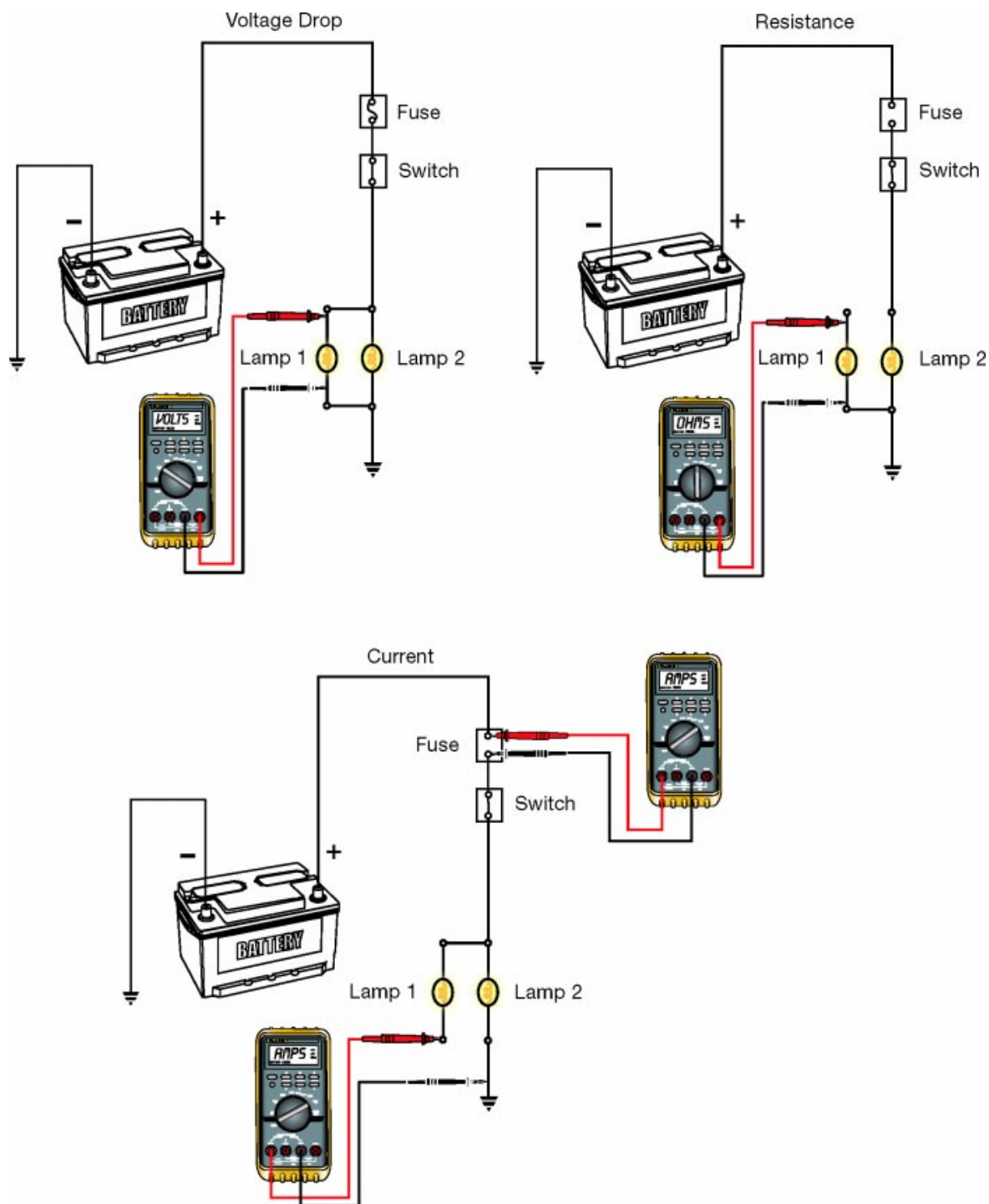


Fig. 2-17
TL623f217c

Parallel circuit tests - Use these guidelines to measure current, voltage, and resistance in parallel circuits:

- Voltage drops across parallel components and branches will be equal, even if their resistance is different.
- Measure total circuit current in a parallel circuit just as you would measure it in a simple series circuit.
- Measure branch current by inserting the DMM into a point in the branch to be measured (branch current will flow through the DMM to be measured).
- Isolate branches when checking continuity or measuring resistance (this avoids inaccurate measurement results).
- Total circuit resistance will be less than the lowest resistance branch in that circuit.

Parallel circuit troubleshooting - Observe the operation of a parallel circuit to gain clues about the fault.

- If one lamp works and the other doesn't ...
 - You know the battery, fuse, and switch are all operating correctly.
 - The fault is in the parallel branch that contains the non-functioning lamp.
- If neither lamp works ...
 - The most likely location for the fault is in the series portion of the circuit (between the battery and the point where the current paths split for the lamps).
 - It is possible that both lamps are burnt out, but this is not the most likely fault.

Series-Parallel Circuits

These are the three basic circuit types. The series-parallel circuit combines a series segment (fuse, switch, dimmer) with two parallel branches (lamps).

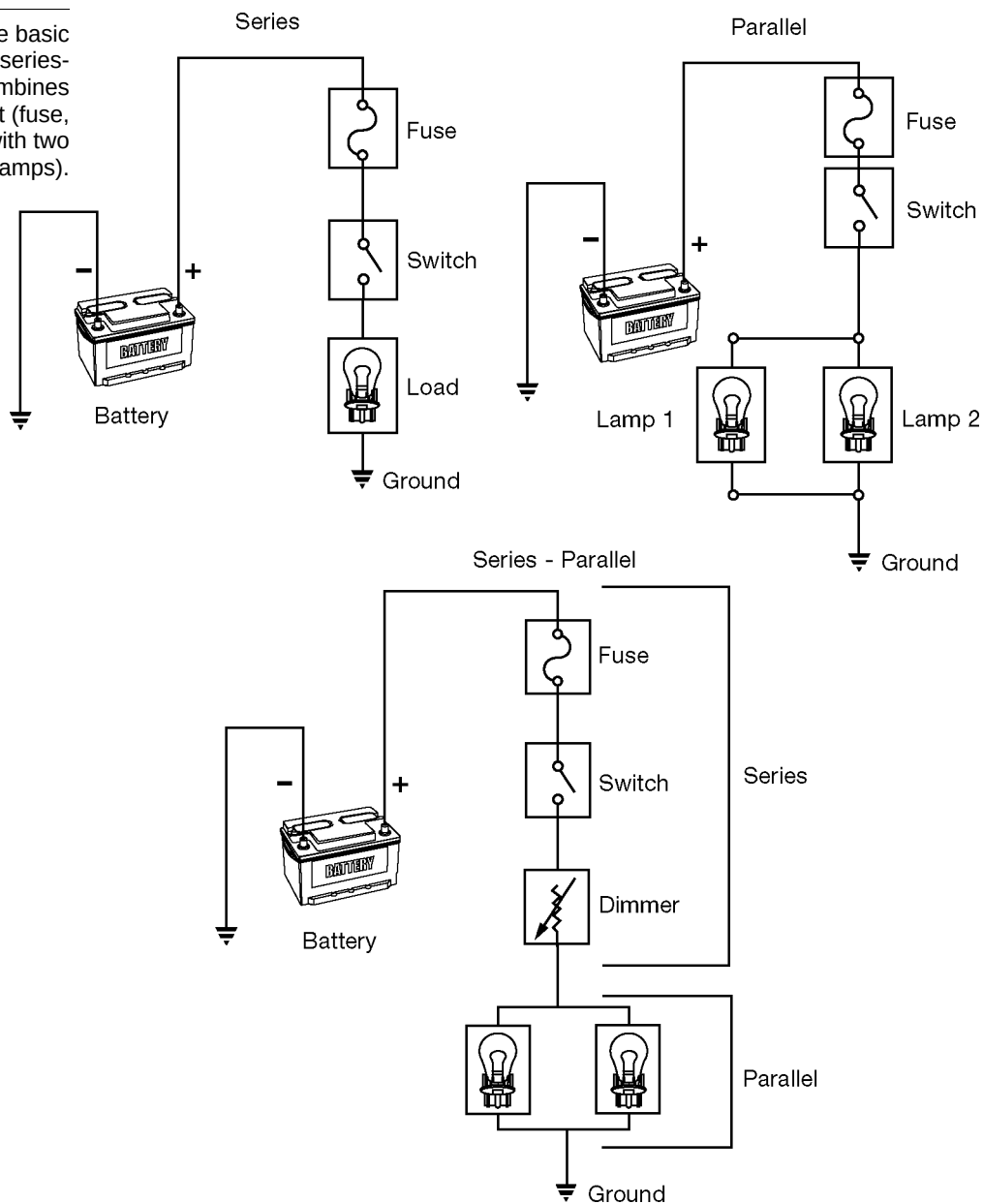


Fig. 2-18
TL623f218

Key Features A series-parallel circuit has these key features:

- Current in the series segment equals the sum of the branch currents.
- Circuit resistance is the sum of the parallel equivalent resistance plus any series resistances.
- Voltage applied to the parallel branches is the source voltage minus any voltage drop across loads in the series segment of the circuit.

Series-Parallel Circuits

Combinations - Most automotive circuits combine series and parallel segments.

- A series circuit has a single path for current.
- A parallel circuit has multiple paths for current.
- A series-parallel circuit combines both series and parallel sections.

Current - In a series-parallel circuit, current flows through the series segment and then splits to flow through the parallel branches of the circuit.

Applying Ohm's Law - You can use Ohm's Law to predict the behavior of electricity in a circuit.

For series-parallel circuits, apply Ohm's Law as follows:

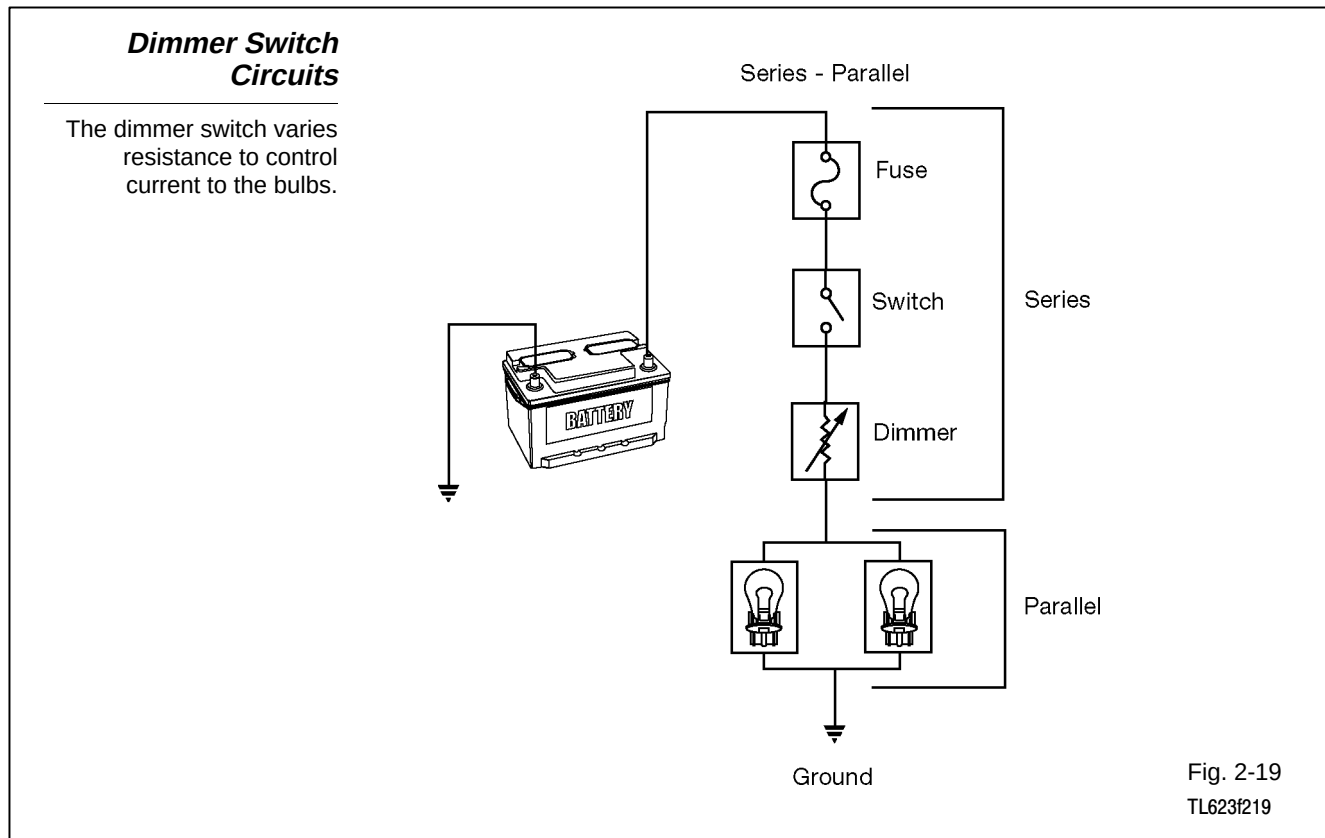
- Calculate the circuit resistance.
 - Calculate the equivalent resistance of the parallel branches.
 - Add any series resistances to the equivalent resistance.
- Calculate current (I) by dividing the source voltage (E) by the circuit resistance (R).
 - $I = E/R$
- Calculate individual voltage drops by multiplying the current times the load resistance.
 - $E = I \times R$

Use Ohm's Law to troubleshoot series-parallel circuits:

- Faults in the series segment of the circuit will affect operation of the entire circuit.
- Increasing resistance in one branch may affect only the component operation in that branch. However, if the resistance goes high enough to create an open circuit, the circuit effectively loses a branch. In that case, equivalent resistance increases and current decreases for the entire circuit.
- Increased resistance in the series segment of the circuit can also reduce current. Low source voltage can also reduce current.
- High source voltage or a short circuit to ground before the load can increase current, blow fuses, and damage components.

Dimmer switch circuit - The simplified instrument panel wiring diagram shown here is typical of series-parallel circuits.

- The dimmer switch controls instrument panel bulb brightness.
- Equal currents flow through the two back-up lights to ground.



Circuit connections - Various devices connect components in series and parallel segments:

- Splices
- Connectors
- Junction blocks

Circuit Connections

Splices, connectors, and junction blocks connect components and wires to form circuits.

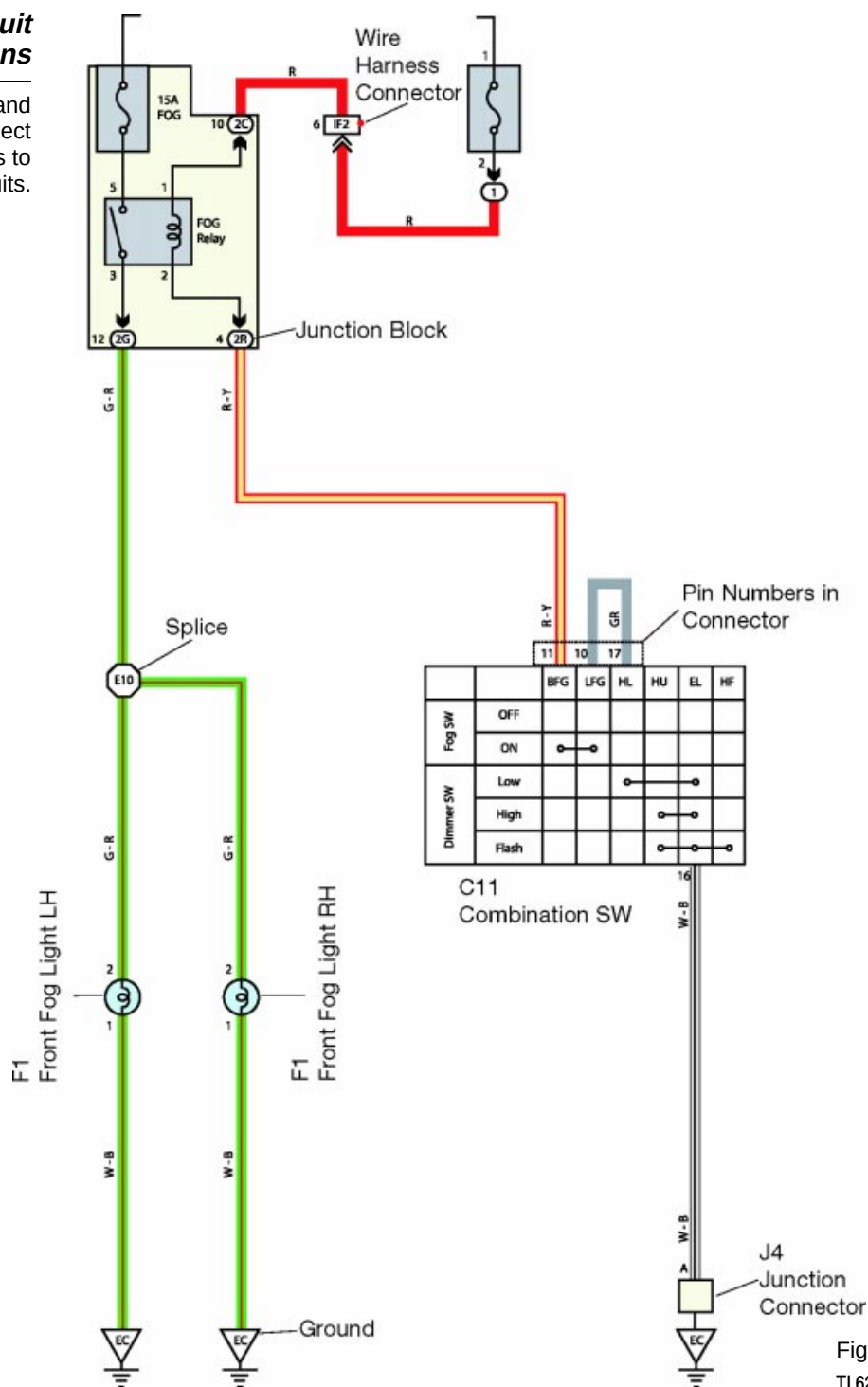


Fig. 2-20
TL623f220c

**Load Control
Source or Ground**

Switching devices control current in circuits:

- Relays
- Diodes
- Transistors
- Electronic components
- Switches

These switching devices can be placed to control the source side or the ground side of a circuit:

- Source side - control device between the voltage source and the load.
- Ground side - control device between the load and ground.

The back-up lights circuit shown here is an example of a source control circuit.

**Source Control
Circuit**

Switches, diodes, relays, transistors, and other electronic components can interrupt the flow of current to control a load. The switch in this circuit controls power to the back-up lights.

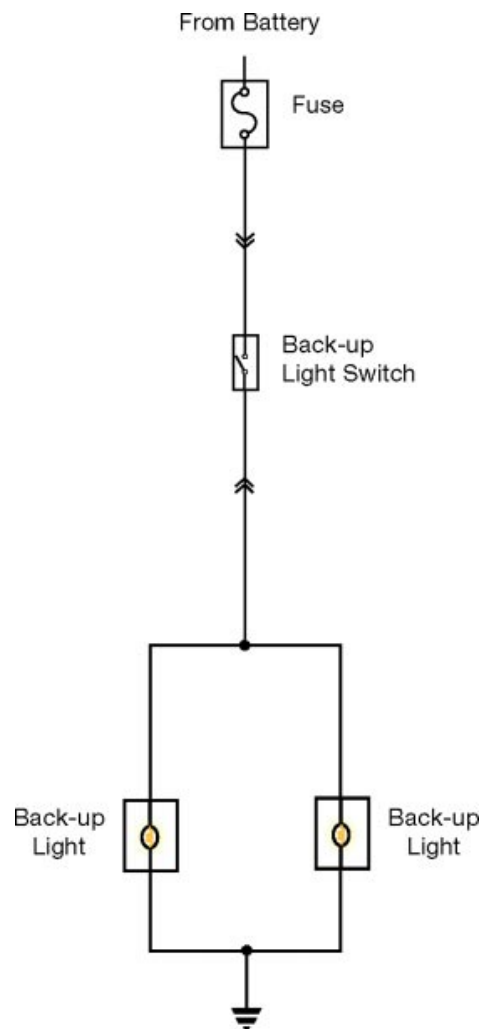


Fig. 2-21
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Ground Control Circuit

The switch in this circuit controls current from the relay coil to ground.

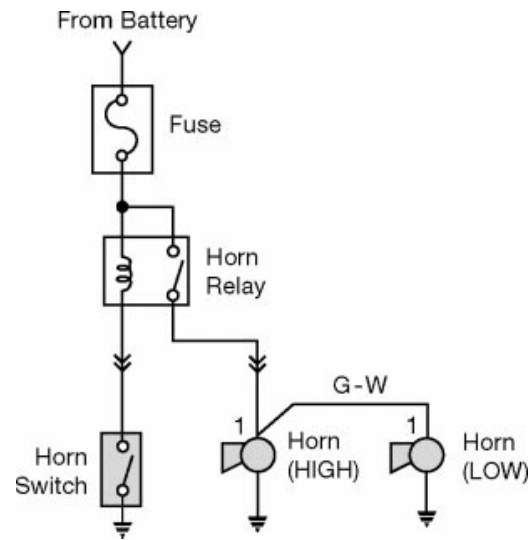


Fig. 2-22
TL623f222

Ground control - The horn circuit shown here is an example of a ground control circuit.

Electrical Symbols

Electrical Symbols

These are some of the symbols used in Toyota Electrical Wiring Diagrams.

GLOSSARY OF TERMS AND SYMBOLS

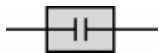
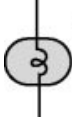
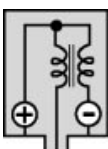
	BATTERY Stores chemical energy and converts it into electrical energy. Provides DC current for the auto's various electrical circuits.		GROUND The point at which wiring attaches to the body, thereby providing a return path for an electrical circuit; without a ground, current cannot flow.
	CAPACITOR (Condenser) A small holding unit for temporary storage of electrical voltage.		HEADLIGHTS Current flow causes a headlight filament to heat up and emit light. A headlight may have either a single (1) filament or a double (2) filament.
	CIGARETTE LIGHTER An electric resistance heating element.		1. SINGLE FILAMENT 2. DOUBLE FILAMENT
	CIRCUIT BREAKER Basically a reusable fuse, a circuit breaker will heat and open if too much current flows through it. Some units automatically reset when cool, others must be manually reset.		HORN An electric device which sounds a loud audible signal.
	DIODE A semiconductor which allows current flow in only one direction.		IGNITION COIL Converts low-voltage DC current into high-voltage ignition current for firing the spark plugs.

Fig. 2-23
TL623f223

Standardized electrical symbols allow wiring diagrams to efficiently convey information about automotive electrical and electronic circuits.

Technicians must understand these symbols to use the electrical wiring diagrams for troubleshooting Toyota vehicles. Toyota Electrical Wiring Diagram (EWD) manuals incorporate a “How to Use this Manual” section. Refer to this section if there are any questions about using electrical wiring diagrams.

Wiring Diagrams Wiring diagrams let you see the fuses, components, wires, and connectors, as well as the power and ground connections that make up each circuit.

Each diagram's layout helps you to quickly understand how the circuit works and how you can troubleshoot electrical faults.

Typical Toyota Wiring Diagram

This wiring diagram has been simplified to show more clearly the basic elements (components, wires, connectors, power and ground connections).

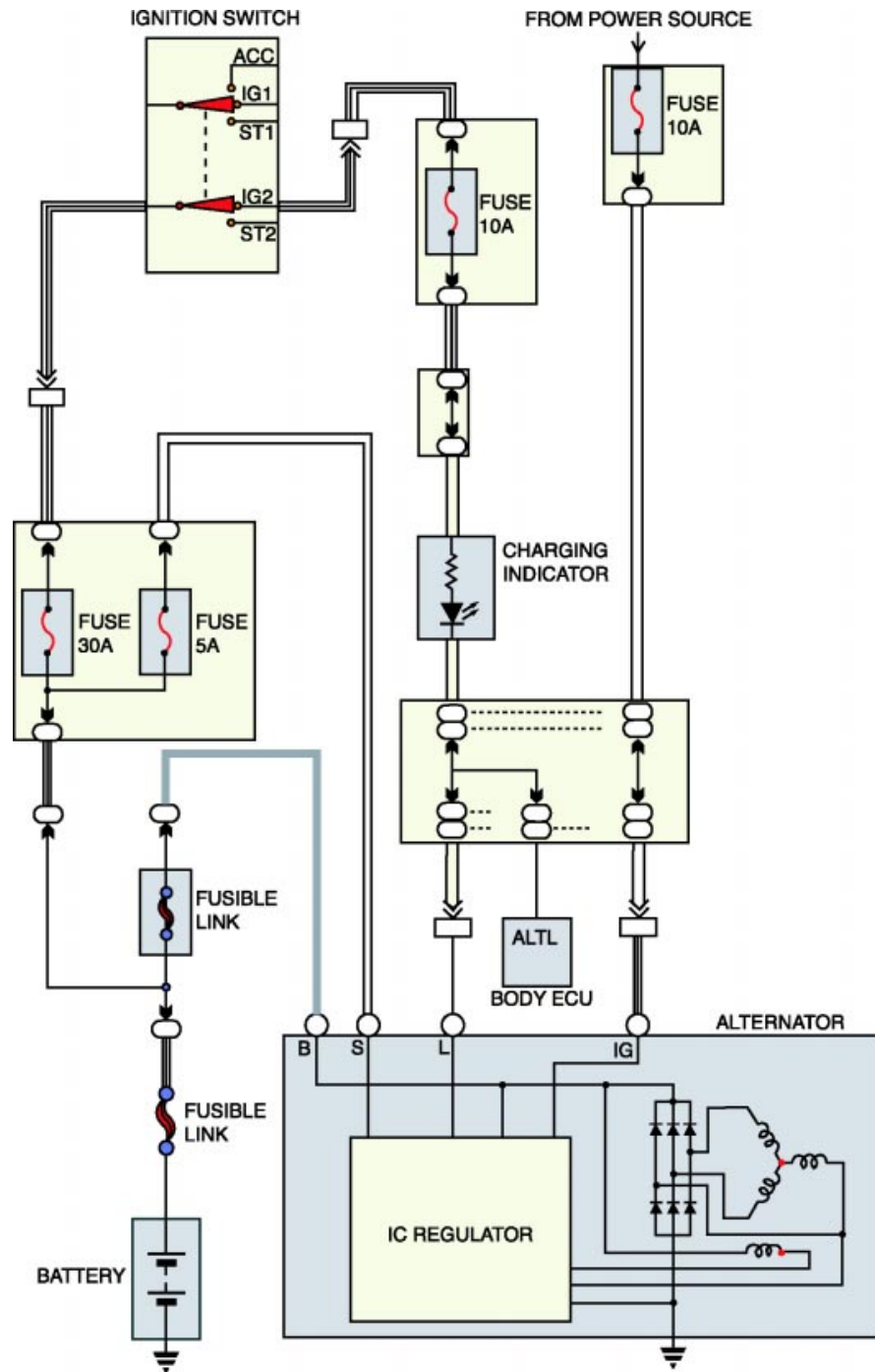


Fig. 2-24

TL623f224c

You must know how to read Toyota wiring diagrams in order to effectively diagnose and repair electrical systems on Toyota vehicles.

Skilled technicians use electrical wiring diagrams to:

- Determine how a particular system operates.
- Predict voltage or resistance values for selected test points.
- Find the locations of components, relays, fuses, junction blocks, terminals, and connectors.
- Identify pin assignments in connectors and junction blocks.
- Determine wire colors and locations.
- Check for common points using the power source and ground points diagrams.

Inductors

Inductors

These components are inductors. They all use electromagnetism to work.

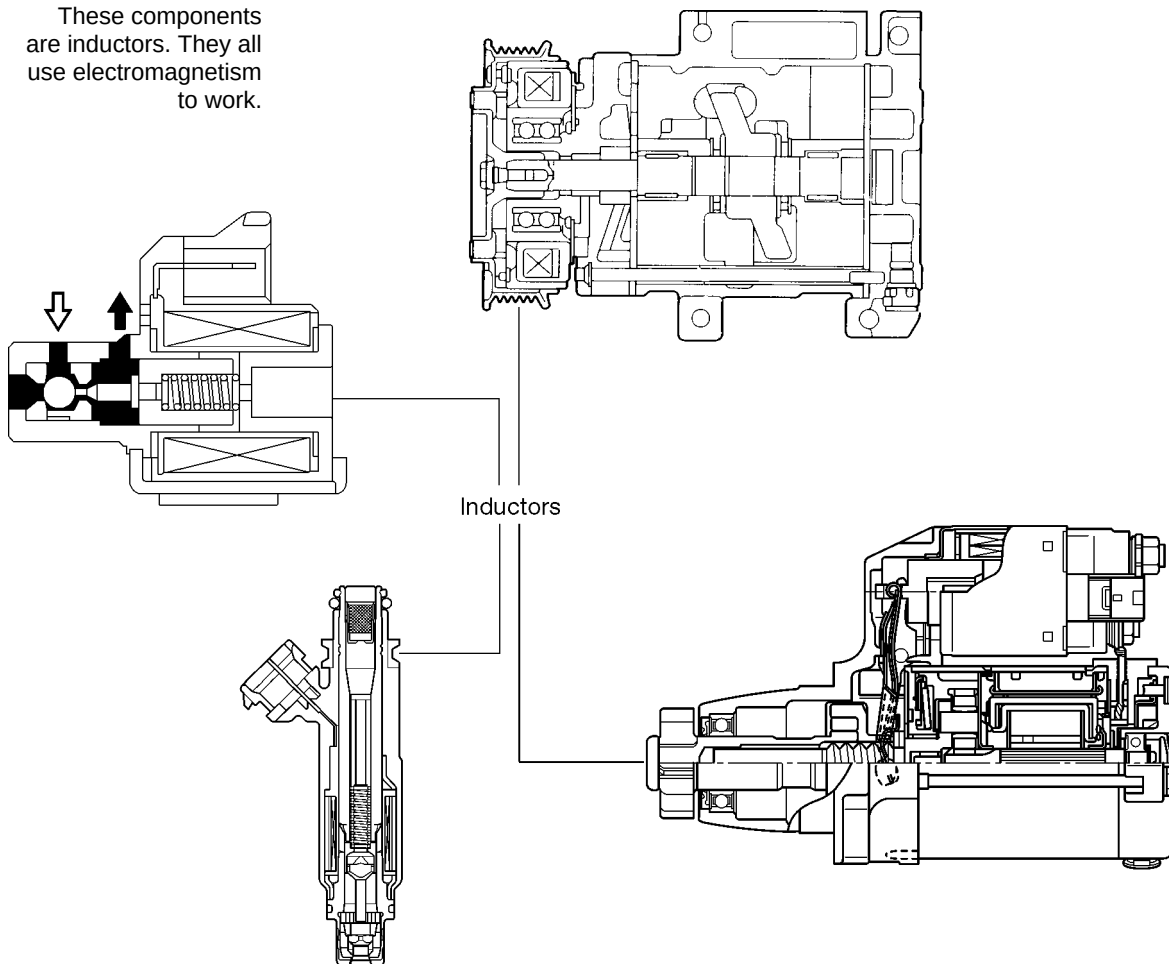


Fig. 2-25
TL623f225

Solenoids, relays, motors, and coils:

- Are in a class of devices called “inductors.”
- Use electromagnetism to do work.

A Simple Electromagnet

A simple electromagnet can be made from a length of wire, a battery, and a nail. Depending on the size of the battery, this circuit might require some added resistance to keep excess current from burning the wire.

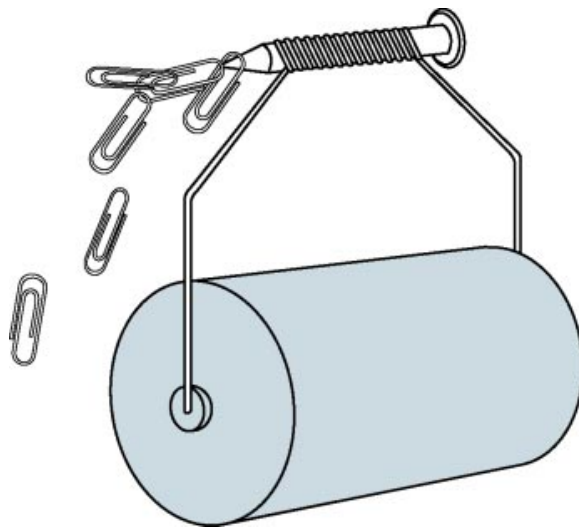


Fig. 2-26

TL623f226

Electromagnetism - Electricity can create magnetism.

- Current flowing through a conductor creates a magnetic field.
- It is possible to concentrate that magnetic field by wrapping the conductor into a coil.

You can create a simple electromagnet:

- Wrap an insulated wire around a nail (or a metal rod).
- Connect a battery to the wire.
- When current flows through the nail, you will see that it behaves like a magnet.

Applications of Electromagnetism

Motors, solenoids, and coils all use windings of wire.

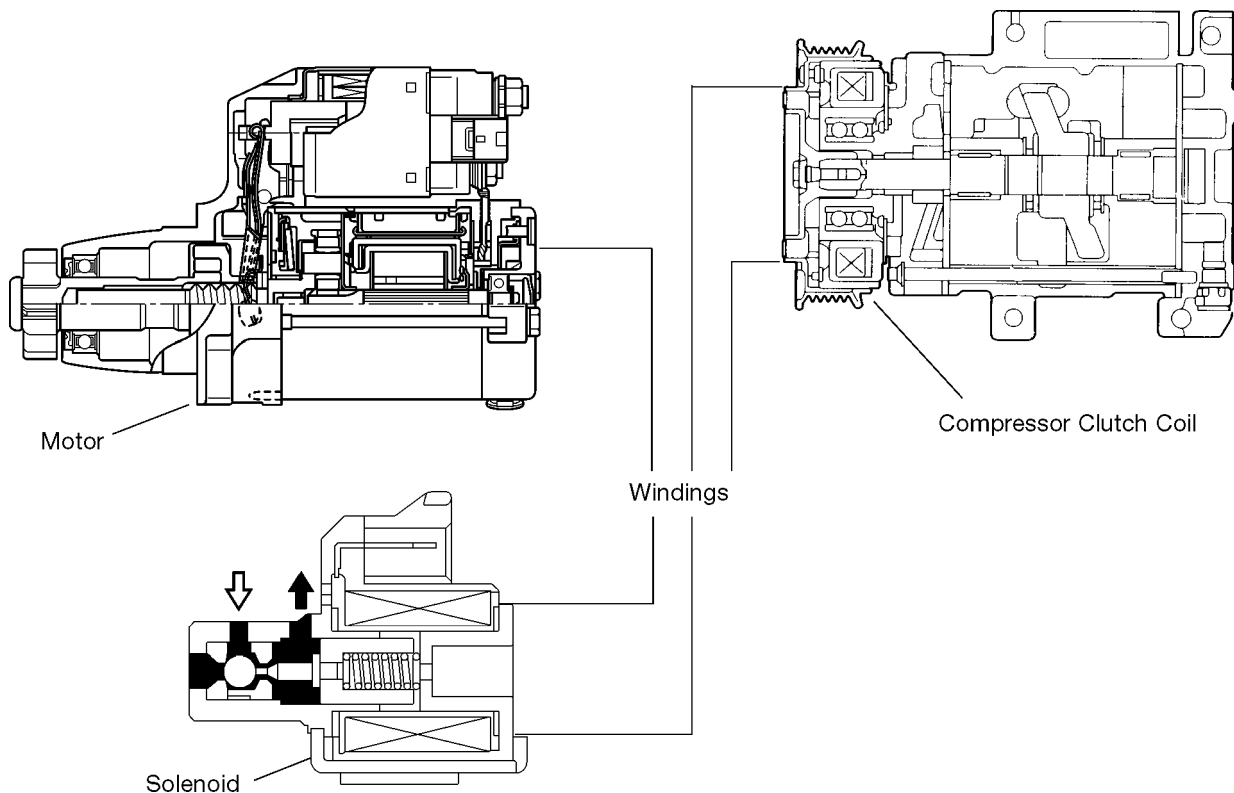


Fig. 2-27
TL623f227

Applications of electromagnetism - Automotive electrical systems use electromagnetism in various ways:

- A solenoid uses a coil of wire to generate a magnetic field that moves a plunger.
- A relay incorporates a coil to open and close one or more switch contacts.
- A generator uses windings to create current.
- A motor uses windings to create motion.

Voltage Generated by Induction

When a current flowing through a coil is cut off, the collapsing magnetic field generates a voltage spike.

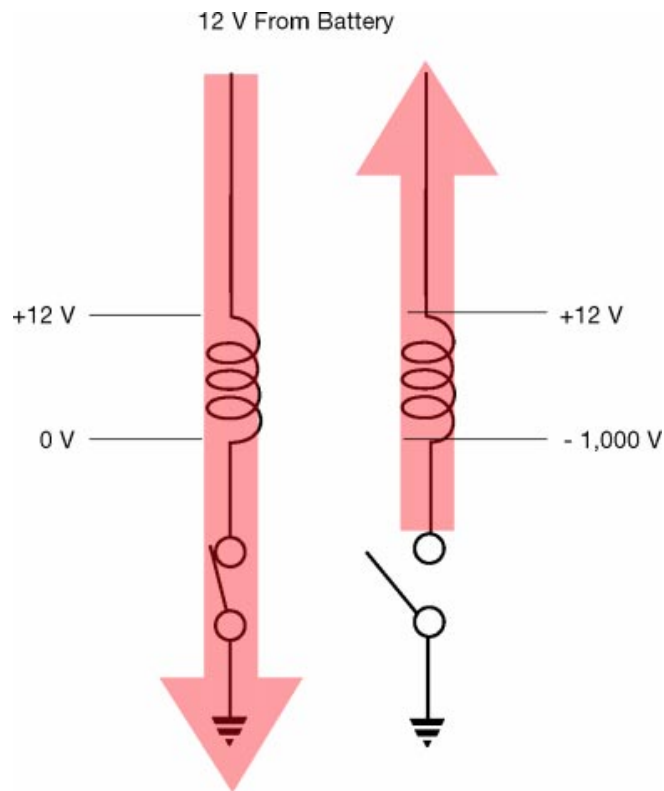


Fig. 2-28
TL623f228c

Inductor coil control devices - These control devices can turn coils on and off as needed to control solenoids and relays:

- Switch
- Transistor
- Electronic control unit (ECU)

Voltage spikes - Coils can generate voltage spikes as they are turned off.

- An inductor coil generates a magnetic field when current is present.
- This magnetic field starts to collapse the instant current stops.
- The collapsing magnetic field produces a large momentary voltage called a *transient* or a voltage spike.
- The voltage spike can be powerful enough to damage electronic components.

EXAMPLE A 12-volt relay can generate a voltage spike of 1000 to 1500 volts as its coil is switched off.

Suppression diode/resistor - A diode or resistor wired in parallel with a coil suppresses voltage spikes.

Ignition Coil

An ignition coil takes advantage of the collapsing magnetic field to generate a high voltage pulse for the spark plugs.

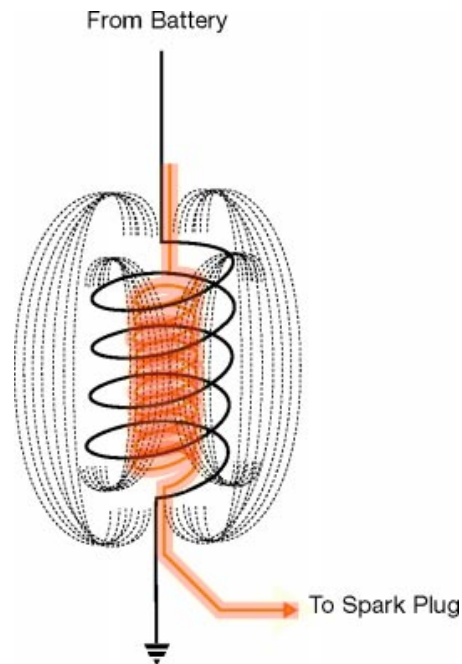


Fig. 2-29
TL623f229c

Ignition coil - An ignition coil is one type of inductor.

- An ignition coil contains two windings:
 - Primary
 - Secondary
- The secondary winding has hundreds of times more turns than the primary.
- Current flows from the battery through the primary winding of the ignition coil to ground.
- The primary winding generates a magnetic field that encompasses the secondary winding.
- When current through the primary winding is cut off, its magnetic field collapses rapidly.
- The collapsing magnetic field induces a very high voltage (up to 100,000 volts) in the secondary winding. The voltage is so high because of the number of turns in the secondary winding.
- The secondary winding delivers this high voltage to the spark plug(s).

Relay

A relay uses an electromagnetic coil to move a set of contacts.

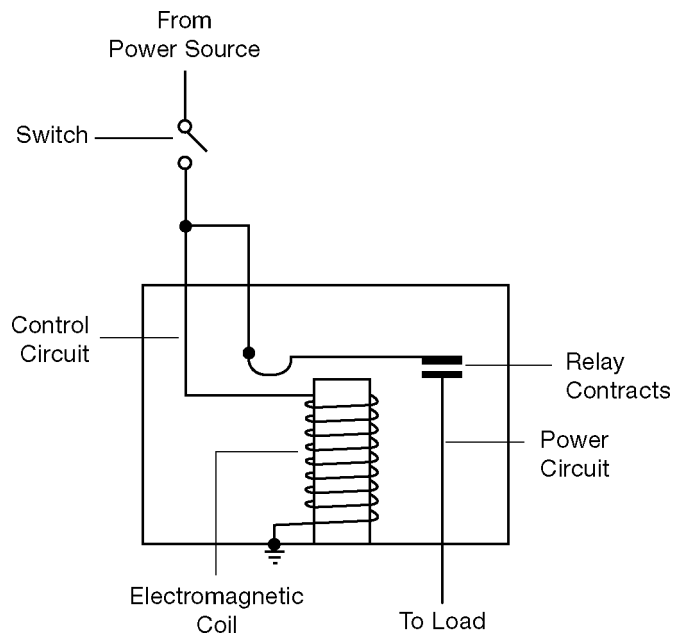


Fig. 2-30
T623f230

Relay - A relay functions as a remote-control switch. It uses a small current to control a larger current. A typical application for a relay is to control a load that requires a large current with a switch that controls a small current. Using a relay for remote switching has these advantages:

- Relay coil can be operated with a small current.
- Relay contacts can control (switch) a large current.
- Relay allows use of a switch to operate a component that is some distance away from where the switch needs to be (horn, for example).
- The small current control circuit saves weight and reduces wire size in wiring harnesses.

Current typically flows through two separate paths in the relay.

- Control circuit (small current)
- Power circuit (larger current)

The control circuit contains the relay's electromagnetic coil. It is typically controlled by a switch in the current path between the power source and the coil or between the coil and ground (more common in Toyota circuits). The power circuit contains one or more relay contacts. When the relay coil is energized, it moves the contacts. Depending on the relay type, the contacts may open or close as the relay coil energizes:

- Normally open contacts - close when relay coil energizes.
- Normally closed contacts - open when relay coil energizes.

Engine Compartment Relay Block

Most relays are grouped into relay blocks. This one is located in the engine compartment.

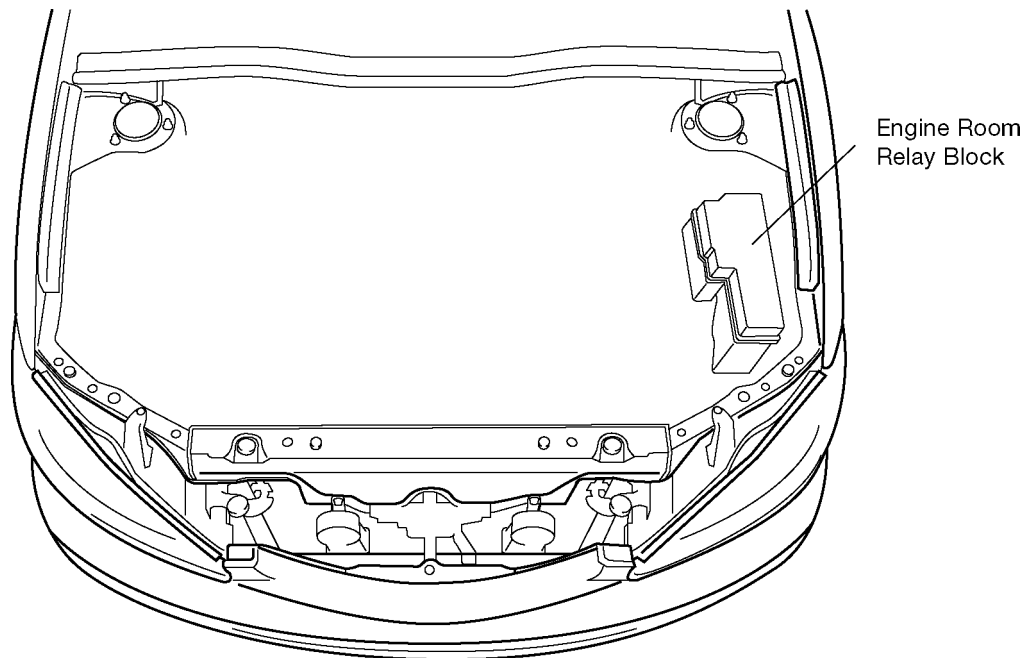


Fig. 2-31
TL623f231

Relay location - Relay blocks are found at various locations in Toyota vehicles:

- In the engine compartment
- Behind the right or left kick panel
- Under the dash

Refer to the appropriate EWD or TIS for specific relay identification and location.

Relay checks - There are a number of ways you can check a relay:

- **CONTINUITY** - Use an ohmmeter or DMM to confirm that the relay contacts are open (no continuity) and closed (continuity) as required.
- **VOLTAGE** - Use a voltmeter or DMM to confirm that the relay contacts block voltage and pass voltage as required.
- **OPERATIONAL** - If the relay controls more than one load, determine if other loads operate when relay closes the circuit.

Refer to the appropriate wiring diagram to determine whether the contacts are normally open or closed.

DMM limitations - A typical DMM has very high internal resistance.

- This high resistance means the meter puts out a very small test current (normally an advantage).
- Small test current can cause inaccurate test results with relay contacts.
- If the contacts are partially burned or corroded, the DMM may show good continuity or voltage and yet the relay may not operate correctly.

NOTE

Many relays produce an audible click as the coil closes or opens the contacts. This is not a reliable test for proper operation. Even a malfunctioning relay may produce a click.

Relay Operational Check

A DMM should measure voltage at the relay's (normally open) output contact when the relay coil is energized.

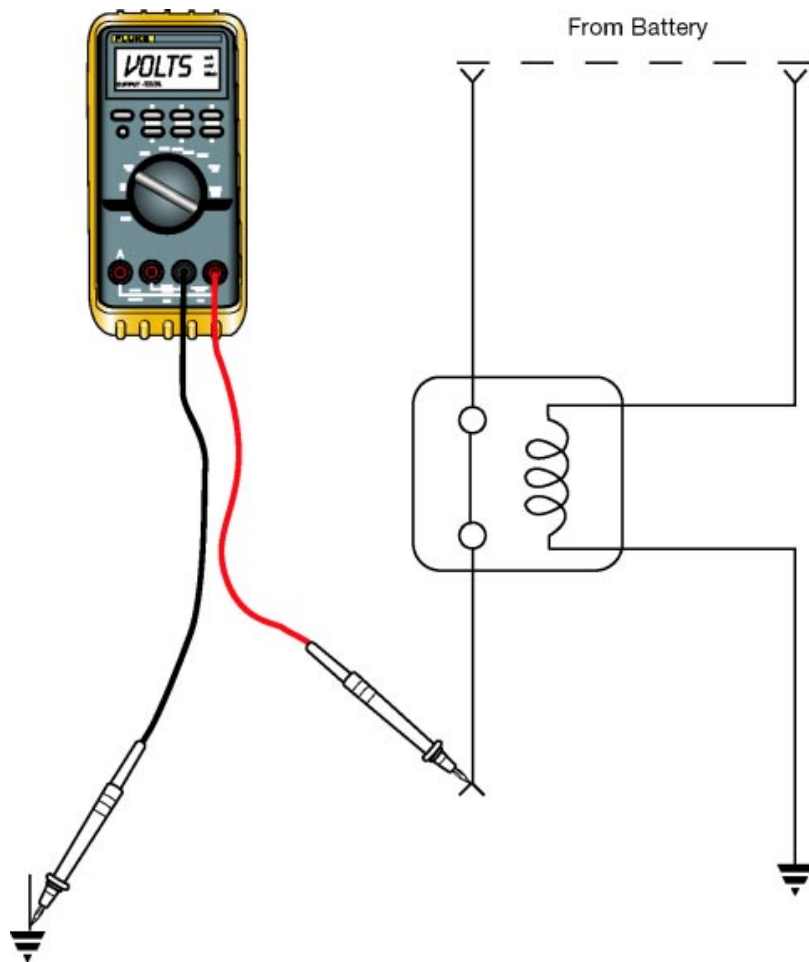


Fig. 2-32
TL623f232c

Inductors Controlled by Electronic Components

Components with electromagnetic coils are sometimes called “actuators” when they are controlled by an ECU.

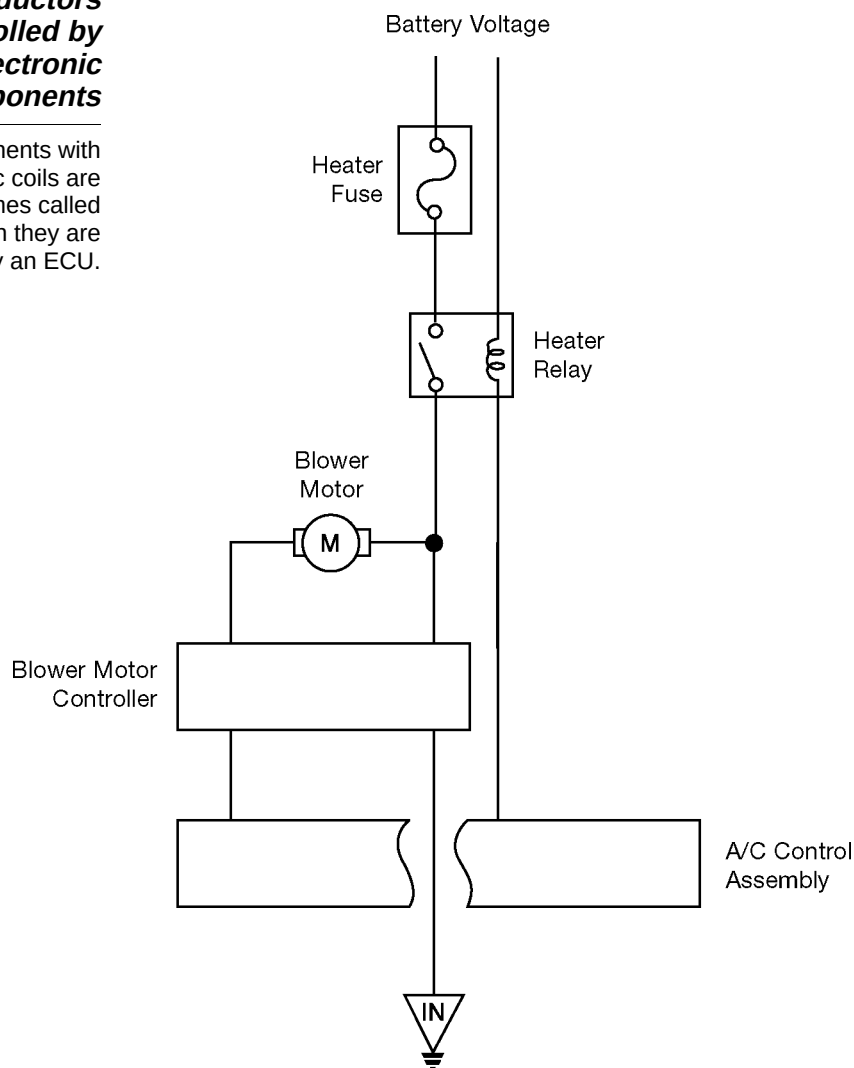


Fig. 2-33
TL623f233

Inductors controlled by electronic components - Components with electromagnetic coils are sometimes called “actuators” when they are controlled by an Electronic Control Unit (ECU). Keep these things in mind when dealing with actuators:

- A short circuit in an actuator can allow excess current to flow in the circuit.
- Excess current can damage electronic components, such as ECUs.
- Any time an ECU has failed, confirm that all actuators under its control are operating correctly and are not shorted.

NOTE

Diagnostic procedures for electronic components are covered in detail in Courses 652 and 852.

Vehicle Wiring Terminal and Connector Repair

Conductors

Conductors carry current from the power source to the load and then to ground. There are several different designs used depending on the current load required and packaging/space limitations.

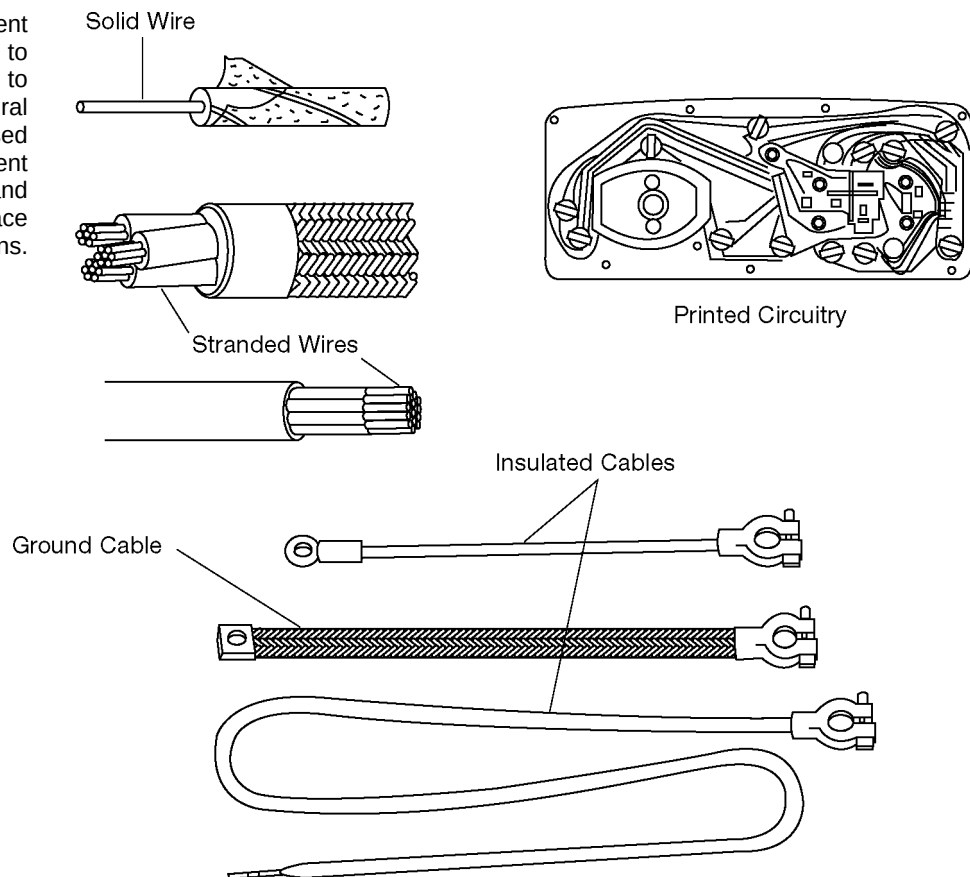


Fig. 2-34
TL623f234

Conductors Conductors allow electrical current to flow from the power source to the working devices and back to the power source.

Power or Insulated Conductors Conductors for the power or insulated current path may be solid wire, stranded wire, or printed circuit boards. Solid, thin wire can be used when current is low. Stranded, thick wire is used when current is high. Printed circuitry — copper conductors printed on an insulating material with connectors in place — is used where space is limited, such as behind instrument panels.

Special wiring is needed for battery cables and for ignition cables. Battery cables are usually very thick, stranded wires with thick insulation. Ignition cables usually have a conductive carbon core to reduce radio interference.

Ground Paths Wiring is only half the circuit in Toyota electrical systems. This is called the “power” or insulated side of the circuit. The other half of the path for current flow is the vehicle’s engine, frame, and body. This is called the ground side of the circuit. These systems are called single-wire or ground-return systems.

A thick, insulated cable connects the battery’s positive (+) terminal to the vehicle loads. As insulated cable connects the battery’s negative (-) cable to the engine or frame. An additional grounding cable may be connected between the engine and body or frame.

Resistance in the insulated side of each circuit will vary depending on the length of wiring and the number and types of loads. Resistance on the ground side of all circuits must be virtually zero. **This is especially important:** ground connections must be secure to complete the circuit. Loose or corroded ground connections will add too much resistance for proper circuit operation.

Ground Paths

The ground path in an automobile is the chassis. The negative cable of the battery is connected to the chassis, as are all other circuit ground points. This eliminates the need to run wires back to the negative side of the battery.

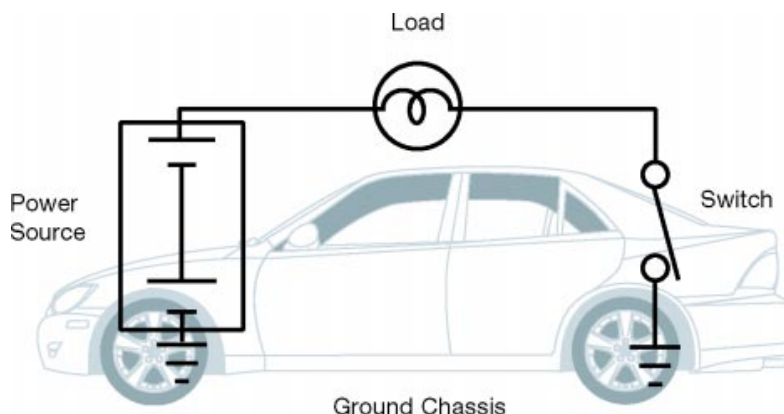


Fig. 2-35
L623f235

System Polarity System polarity refers to the connections of the positive and negative terminals of the battery to the insulated and ground sides of the electrical system. On Toyota vehicles, the positive (+) battery terminal is connected to the insulated side of the system. This is called a **negative ground system having positive polarity**.

Knowing the polarity is extremely important for proper service. Reversed polarity may damage alternator diodes, cause improper operation of the ignition coil and spark plugs, and may damage other devices such as electronic control units, test meters, and instrument-panel gauges.

Harnesses Harnesses are bundles of wires that are grouped together in plastic tubing, wrapped with tape, or molded into a flat strip. The colored insulation of various wires allows circuit tracing. While the harnesses organize and protect wires going to common circuits, don't overlook the possibility of a problem inside.

Harnesses

A harness is a group of wires inside a protective covering. These wires supply current to several components often in the same general area of the vehicle.

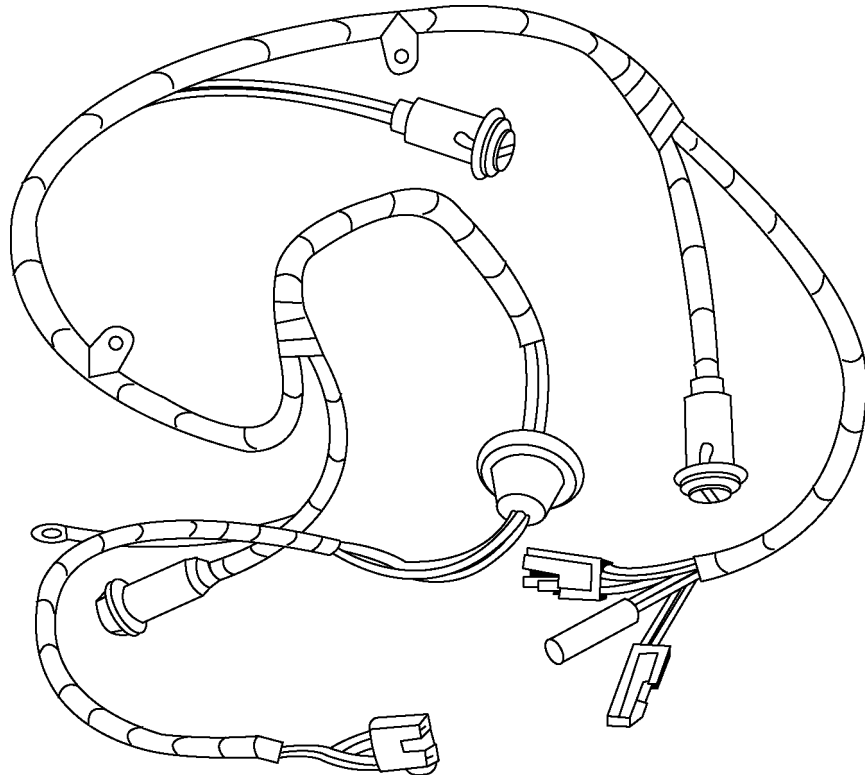


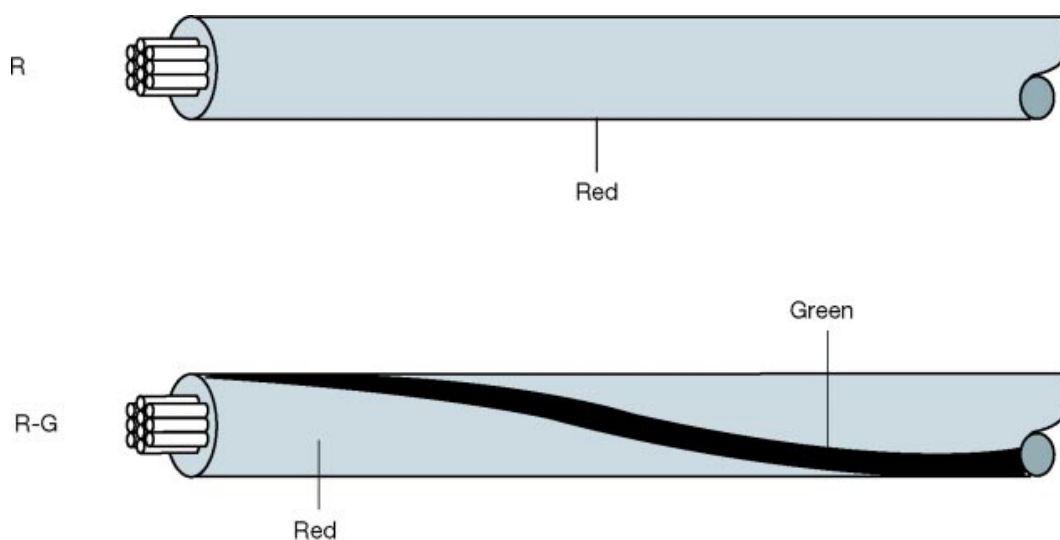
Fig. 2-36
TL623f236

Wire Insulation Conductors must be insulated with a covering or “jacket.” This insulation prevents physical damage, and more important, keeps the current flow in the wire. Various types of insulation are used depending on the type of conductor. Rubber, plastic, paper, ceramics, and glass are good insulators.

Wire Insulation

Wires are insulated to protect from moisture, dirt, and other contaminants.

The wires must also be shielded from other wires, and the chassis ground, to prevent short circuits.



Wiring Color Code

Wire Colors are indicated by an alphabetical code.

B = Black	L = Blue	R = Red
BR = Brown	LG = Light Green	V = Violet
G = Green	O = Orange	W = White
GR = Gray	P = Pink	Y = Yellow

The first letter indicates the basic wire color and the second letter indicates the color of the stripe.

Fig. 2-37
TL623f237

Connectors Various types of connectors, terminals, and junction blocks are used on Toyota vehicles. The wiring diagrams identify each type used in a circuit. Connectors make excellent test points because the circuit can be “opened” without need for wire repairs after testing. However, never assume a connection is good simply because the terminals seem connected. Many electrical problems can be traced to loose, corroded, or improper connections. These problems include a missing or bent connector pin.

Connectors

Connectors join wiring harnesses together or connect the wiring to specific components.

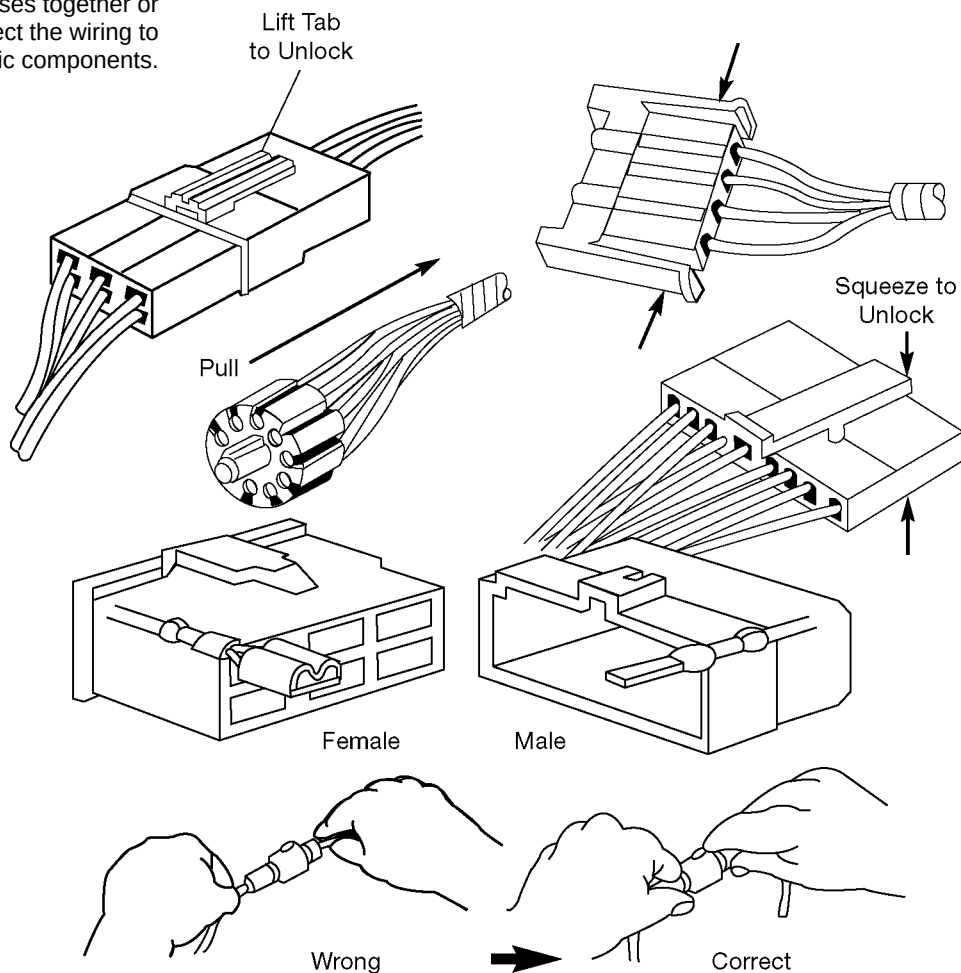


Fig. 2-38
TL623f238

SRS Harness Components

Supplemental Restraint System (SRS) airbag harness insulation and the related connectors are usually color coded yellow or orange. Do not connect any accessories or test equipment to SRS related wiring.

Warning: Supplemental Restraint System (SRS) airbag harness components, including wiring, insulation and connectors, are not repairable. Any SRS harness component damage requires replacement of the related harness. Refer to the service information in TIS or the Repair Manual when diagnosing SRS.

SRS Wiring

Supplemental Restraint System wiring, harnesses and connectors are identified by yellow or orange connectors or insulation wrapping. Do not repair any SRS wiring or connectors. Replace any damaged components with a new harness.



Fig. 2-39
TL623f239

Connector Repair The repair parts now in supply are limited to those connectors having common shapes and terminal cavity numbers. Therefore, when there is no available replacement connector of the same shape or terminal cavity number, please use one of the alternative methods described below. Make sure that the terminals are placed in the original order in the connector cavities, if possible, to aid in future diagnosis.

1. When a connector with a **different number of terminals** than the original part is used, select a connector having more terminal cavities than required, and replace both the male and female connector parts.

EXAMPLE You need a connector with six terminals, but the only replacement available is a connector with eight terminal cavities. Replace both the male and female connector parts with the eight-terminal part, transferring the terminals from the old connectors to the new connector.

2. When several **different type terminals** are used in one connector, select an appropriate male and female connector part for each terminal type used, and replace both male and female connector parts.

EXAMPLE You need to replace a connector that has two different types of terminals in one connector. Replace the original connector with two new connectors, one connector for one type of terminal, another connector for the other type of terminal.

3. When a different shape of connector is used, first select from available parts a connector with the appropriate number of terminal cavities, and one that uses terminals of the same size as, or larger than, the terminal size in the vehicle. The wire lead on the replacement terminal must also be the same size as, or larger than, the nominal size of the wire in the vehicle. ("Nominal" size may be found by looking at the illustrations in the back of this book or by direct measurement across the diameter of the insulation). Replace all existing terminals with the new terminals, then insert the terminals into the new connector.

EXAMPLE You need to replace a connector that is round and has six terminal cavities. The only round replacement connector has three terminal cavities. You would select a replacement connector that has six or more terminal cavities and is not round, then select terminals that will fit the new connector. Replace the existing terminals, then insert them into the new connector and join the connector together.

Conductor Repairs

Conductor repairs are sometimes needed because of wire damage caused by electrical faults or by physical abuse. Wires may be damaged electrically by short circuits between wires or from wires to ground. Fusible links may melt from current overloads. Wires may be damaged physically by scraped or cut insulation, chemical or heat exposure, or breaks caused during testing or component repairs.

Conductor Damage

Wires may be damaged by repeated movement or being cut by road debris for example. Short circuits may overheat wiring causing additional damage.

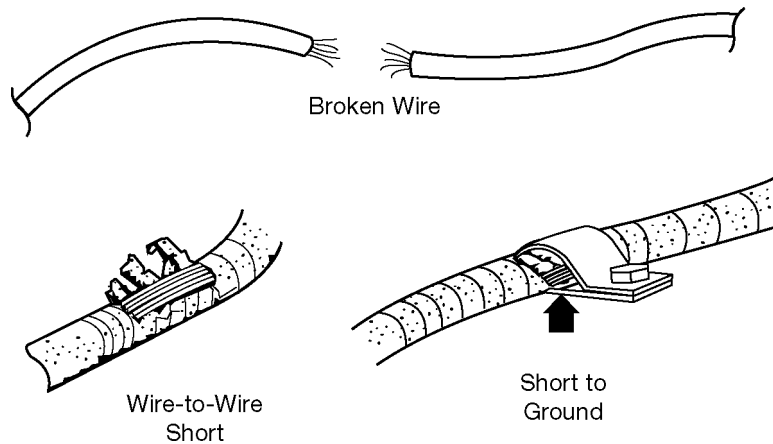


Fig. 2-40
TL623f240

Wire Size Choosing the proper size of wire when making circuit repairs is critical. While choosing wires too thick for the circuit will only make splicing a bit more difficult, choosing wires too thin may limit current flow to unacceptable levels or even result in melted wires. Two size factors must be considered: **wire gauge number** and **wire length**.

American Wire Gauge Sizes

Gauge Size	Conductor Diameter (Inch)	Cross Section Area (Circular Mils)
20	.032"	1,020
16	.051"	2,580
12	.081"	6,530
8	.128"	16,500
2	.258"	66,400
0	.325"	106,000
2/0	.365"	133,000

AWG Size	Metric Size (mm ²)
20	0.5
18	0.8
16	1.0
14	2.0
12	3.0
10	5.0
8	8.0
6	13.0
4	19.0

Wire Gauge Number Wire gauge numbers are determined by the conductor's cross-section area.

In the American Wire Gauge system, “gauge” numbers are assigned to wires of different thicknesses. While the gauge numbers are not directly comparable to wire diameters and cross-section areas, higher numbers (16, 18, 20) are assigned to increasingly thinner wires and lower numbers (1, 0, 2/0) are assigned to increasingly thicker wires. The chart shows AWG gauge numbers for various thicknesses.

Wire cross-section area in the AWG system is measured in circular mils. A mil is a thousandth of an inch (0.001). A circular mil is the area of a circle 1 mil (0.001) in diameter.

In the metric system used worldwide, wire sizes are based on the cross-section area in square millimeters (mm²). These are not the same as AWG sizes in circular mils. The chart shows AWG size equivalents for various metric sizes.

NWS - Nominal Wiring Size is used in the wire repair kit charts.

Wire Length Wire length must be considered when repairing circuits because resistance increases with longer lengths. For instance, a 16-gauge wire can carry an 18-amp load for 10 feet without excessive voltage drop. But, if the section of wiring being replaced is only 3-feet long, an 18-gauge wire can be used. Never use a heavier wire than necessary, but, more important, never use a wire that will be too small for the load.

Wire Repairs

- Cut insulation should be wrapped with tape or covered with heat-shrink tubing. In both cases, overlap the repair about $1\frac{1}{2}$ inch on either side.
- If damaged wire needs replacement, make sure the same or larger size is used. Also, attempt to use the same color. Wire strippers will remove insulation without breaking or nicking the wire strands.
- When splicing wires, make sure the battery is disconnected. Clean the wire ends. Crimp and solder them using rosin-core, **not acid-core** solder.

Wire Stripper

A wire stripper is used to correctly remove the insulation from the wire. Other methods often result in damage to the wire itself which can affect the current carrying capacity of the wire.

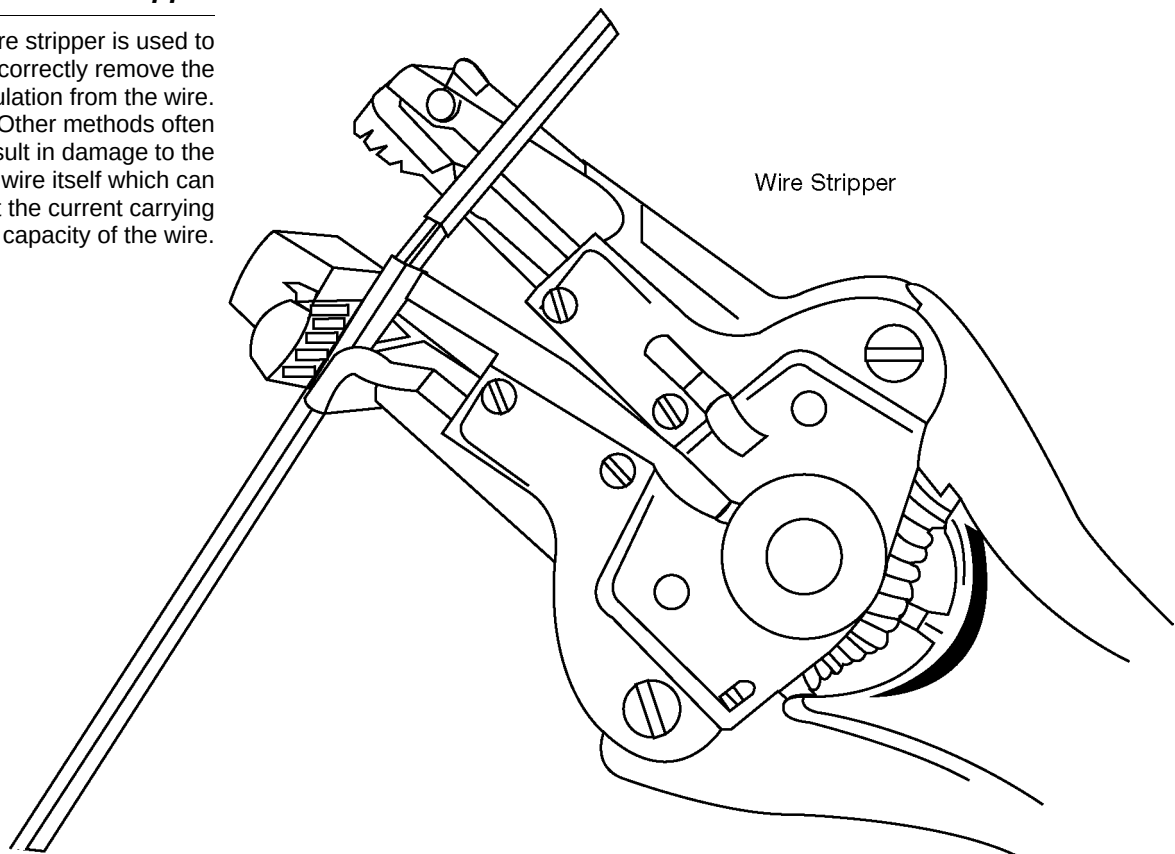


Fig. 2-41
TL623f241

Soldering Soldering joins two pieces of metal together with a lead and tin alloy.

In soldering, the wires should be spliced together with a crimp. The less solder separating the wire strands, stronger the joint.

Solder Solder is a mixture of lead and tin plus traces of other substances.

Flux core wire solder (wire solder with a hollow center filled with flux) is recommended for electrical splices.

Soldering Flux Soldering heats the wires. In so doing, it accelerates oxidization, leaving a thin film of oxide on the wires that tends to reject solder. Flux removes this oxide and prevents further oxidation during the soldering process.

Rosin or resin-type flux **must be used for all electrical work**. The residue will not cause corrosion, nor will it conduct electricity.

Soldering Irons The soldering iron should be the right size for the job. An iron that is too small will require excessive time to heat the work and may never heat it properly. A low-wattage (25-100 W) iron works best for wiring repairs.

Soldering Iron

A soldering iron or soldering gun is used to melt solder. The solder is like an electrical weld holding both sections together.

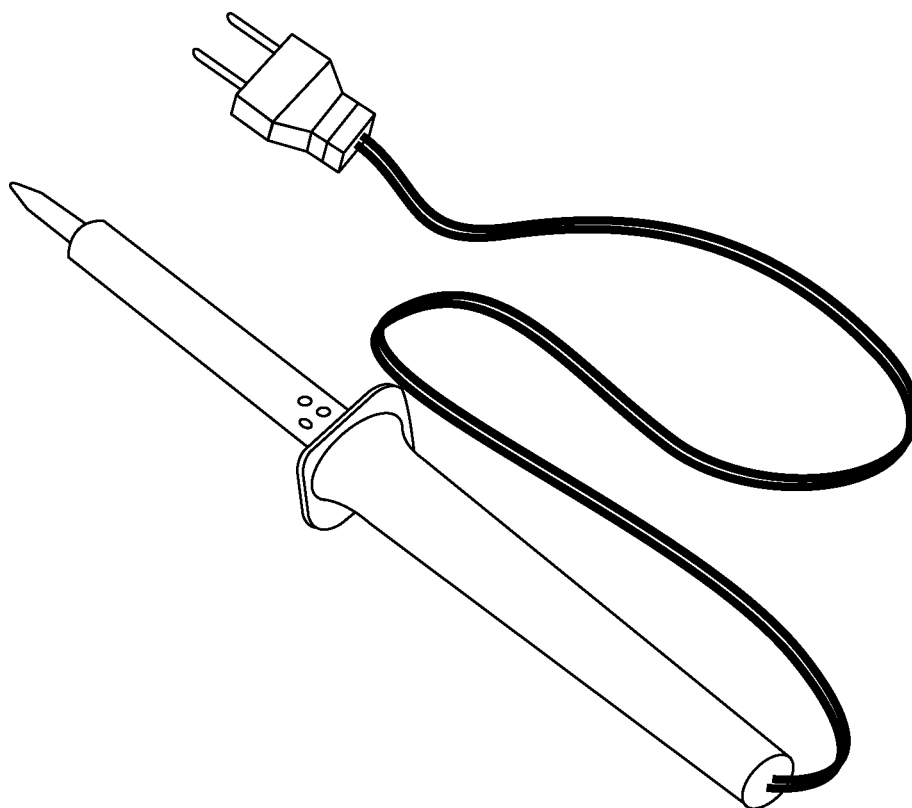


Fig. 2-42
TL623f242

Cleaning Work All traces of paint, rust, grease, and scale must be removed. **Good soldering requires clean, tight splices.**

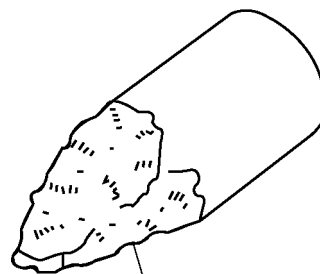
Tinning the Iron The soldering iron tip is made of copper. Through the solvent action of solder and prolonged heating, it will pit and corrode. An oxidized or corroded tip will not satisfactorily transfer heat from the iron to the work. It should be cleaned and tinned. Use a file and dress the tip down to the bare copper. File the surfaces smooth and flat.

Then, plug the iron in. When the tip color begins to change to brown and light purple, dip the tip in and out of a can of soldering flux (rosin type). Quickly apply rosin core wire solder to all surfaces.

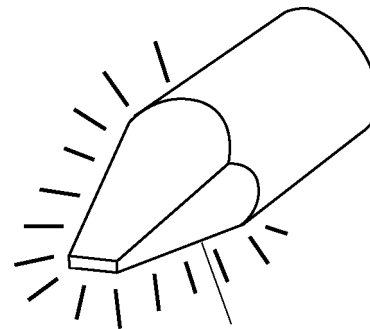
The iron must be at operating temperature to tin properly. When the iron is at the proper temperature, solder will melt quickly and flow freely. **Never try to solder until the iron is properly tinned.**

Soldering Iron Tip

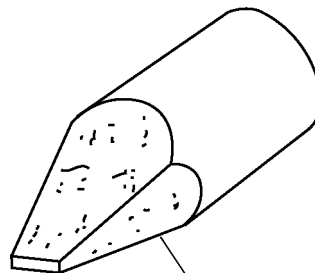
The soldering iron tip must be in good condition for creation of a good solder joint. Tin the tip with a thin layer of solder before soldering wires together.



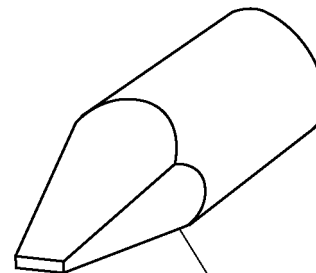
Tip Badly Corroded



Filed Clean and Smooth



Poor Tinning Job



Correctly Tinned

Fig. 2-43
TL623f243

Soldering Wire Splices

Apply the tip flat against the splice. Apply rosin-core wire solder to the flat of the iron where it contacts the splice. As the wire heats, the solder will flow through the splice.

Rules for Good Soldering

1. Clean wires.
2. Wires should be crimped together.
3. Iron must be the right size and must be hot.
4. Iron tip must be tinned.
5. Apply full surface of soldering tip to the splice.
6. Heat wires until solder flows readily.
7. Use rosin-core solder.
8. Apply enough solder to form a secure splice.
9. Do not move splice until solder sets.
10. Place hot iron in a stand or on a protective pad.
11. Unplug iron as soon as you are finished.

Soldering Wires

Heat the wire with the soldering iron. Apply a thin layer of rosin-core solder so it flows into the wiring and forms a strong, conductive bond.

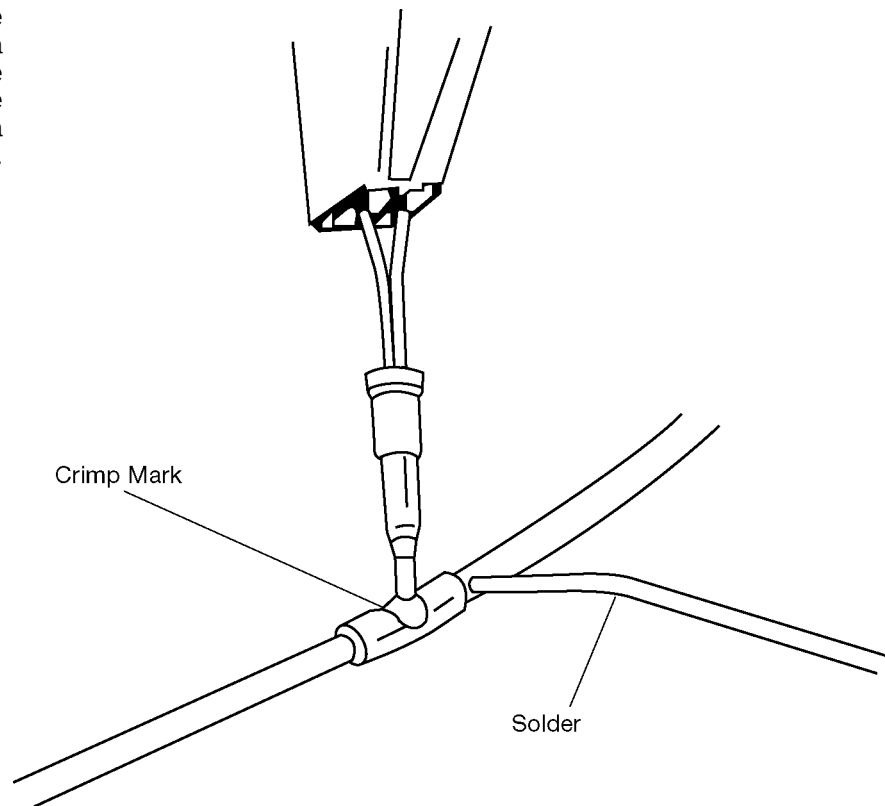


Fig. 2-44
TL623f244

Terminal Replacement

These steps must be followed when replacing a terminal.

Terminal Replacement

Terminal repair requires you follow these steps for a proper repair.

Step 1. Identify the connector and the terminal type.



Step 2. Remove the terminal from the connector.



Step 3. Replace the terminal.



Step 4. Install the terminal into the connector.

Fig. 2-45
TL623f245

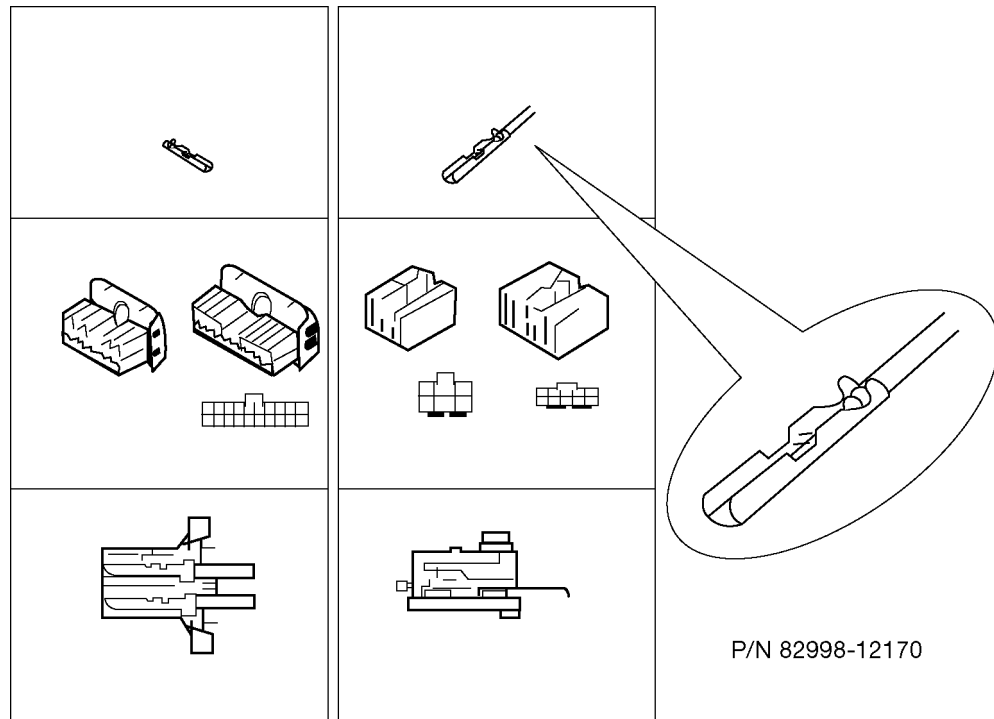
Step 1. Identify the connector and terminal type.

1. Replacing Terminals

- a) Identify the connector name, position of the locking clips, the unlocking direction and terminal type from the pictures provided on the charts.

Identify the Connector and Terminal

Many different types of connectors and related terminals are used. A successful repair depends on identifying the correct part required.



P/N 82998-12170

Fig. 2-46
TL623f246

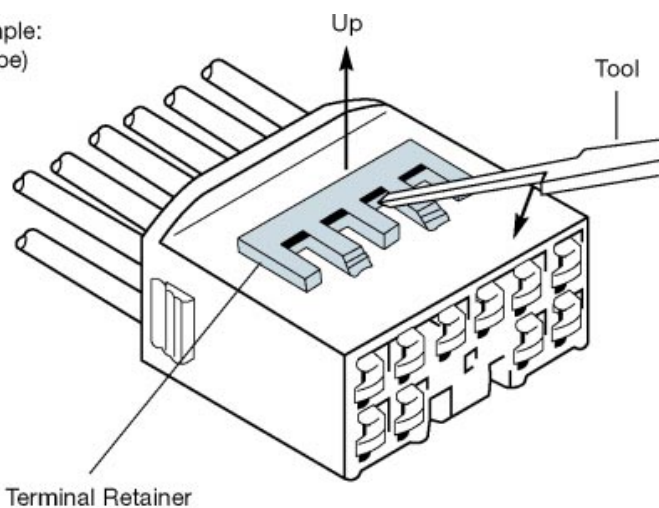
Step 2. Remove the terminal from the connector.

1. Disengage the secondary locking device or terminal retainer.
 - a) Locking device must be disengaged before the terminal locking clip can be released and the terminal removed from the connector.
 - b) Use a miniature screwdriver or the terminal pick to unlock the secondary locking device.

Terminal Lock

Open the lock on the terminal using an appropriate tool.

Example:
(A Type)



(B Type)

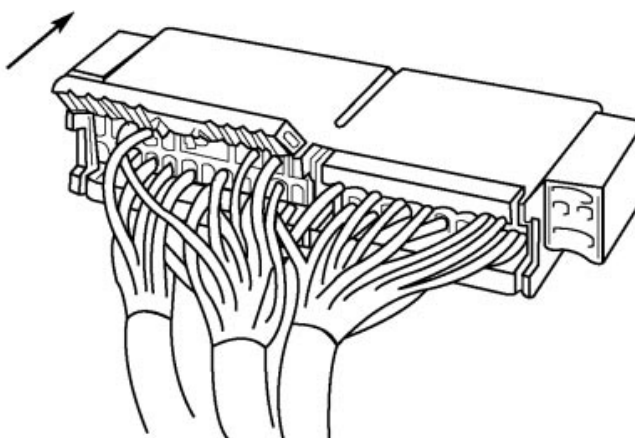


Fig. 2-47
TL623f247

2. Determine the primary locking system from the charts.
 - a) Lock located on terminal
 - b) Lock located on connector
 - c) Type of tool needed to unlock
 - d) Method of entry and operation

Terminal Locks

Use the appropriate tool to depress the terminal lock so you can remove it from the connector.

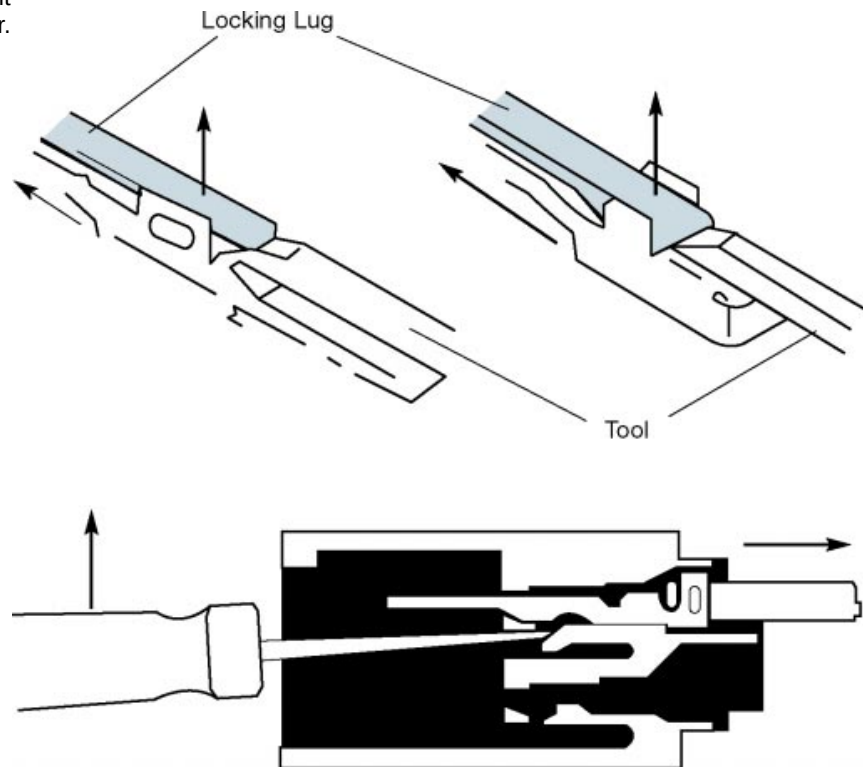


Fig. 2-48
TL623f248

3. Remove terminal from connector by releasing the locking clip.
 - a) Push the terminal gently into the connector and hold it in this position.

Terminal Removal

Push in on the wire to release an tension against the terminal lock.

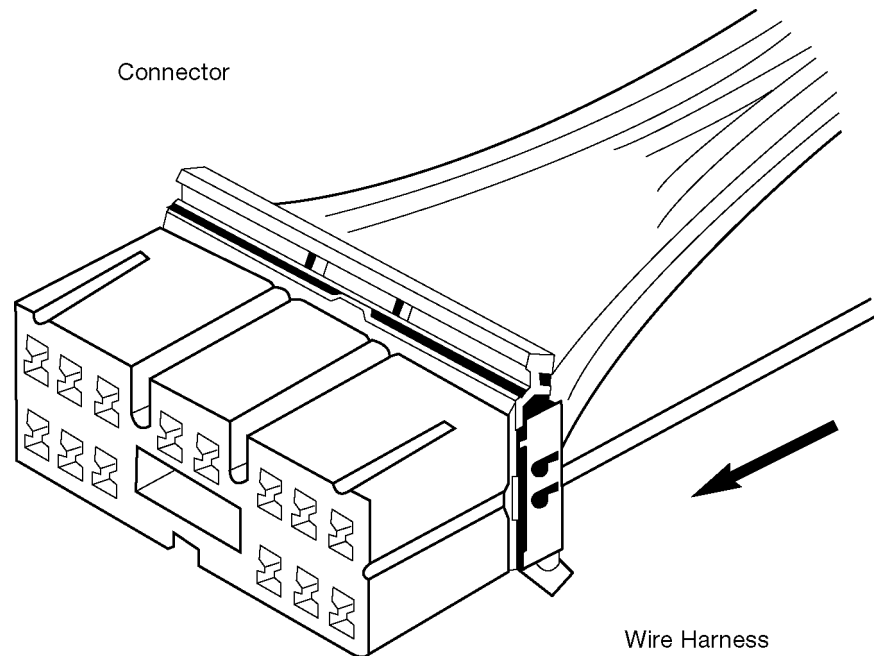


Fig. 2-49
TL623f249

- b) Insert the terminal pick into the connector in the direction shown in the chart.
- c) Move the locking clip to the unlock position and hold it there.

NOTE Do not apply excessive force to the terminal. Do not pry on the terminal with the pick.

- d) Carefully withdraw the terminal from the connector by pulling the lead toward the rear of the connector.

NOTE Do not use too much force. If the terminal does not come out easily, repeat steps a) through d).

Terminal Pick

Use the terminal pick to release the terminal lock.
Pull the wire out of the connector.

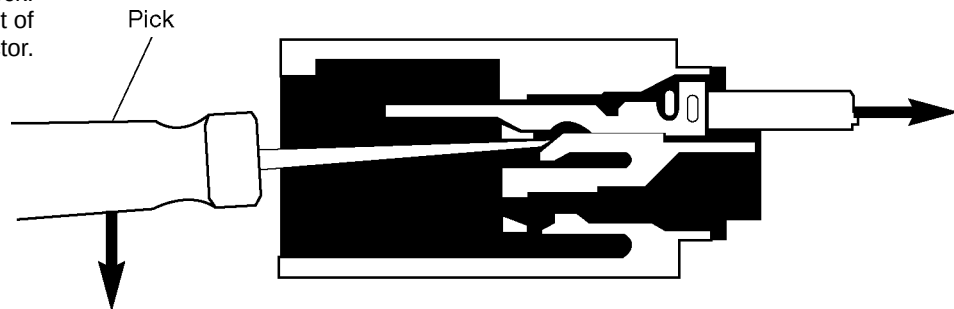


Fig. 2-50
TL623f250

4. Measure “nominal” size of the wire lead by placing a measuring device, such as a micrometer or Vernier Caliper, across the diameter of the insulation on the lead and taking a reading.

Wire Size

Measure the wire size to ensure selecting the correct replacement terminal.

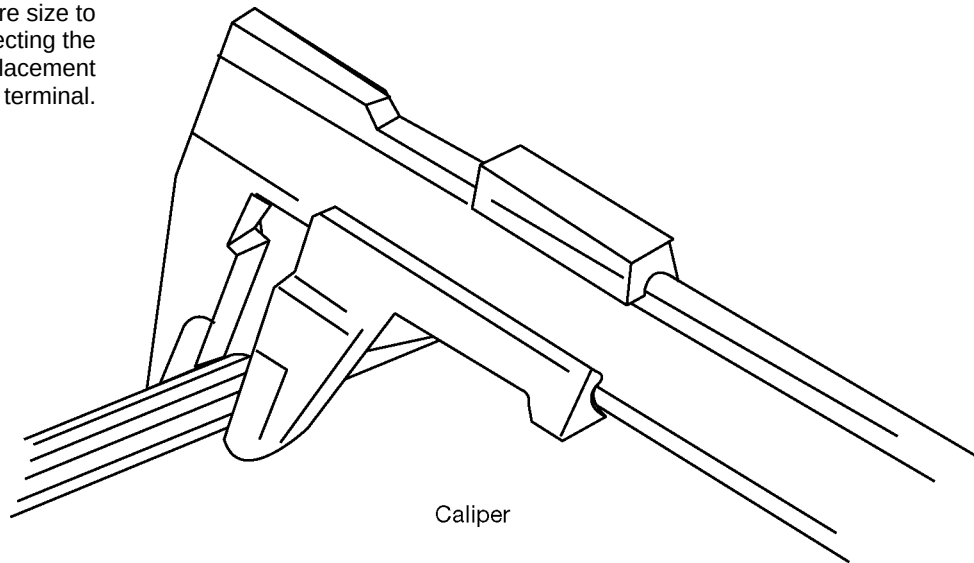


Fig. 2-51
TL623f251

5. Select the correct replacement terminal, with lead, from the repair kit.

Terminal Kit

Select the correct size and type terminal from the repair kit.

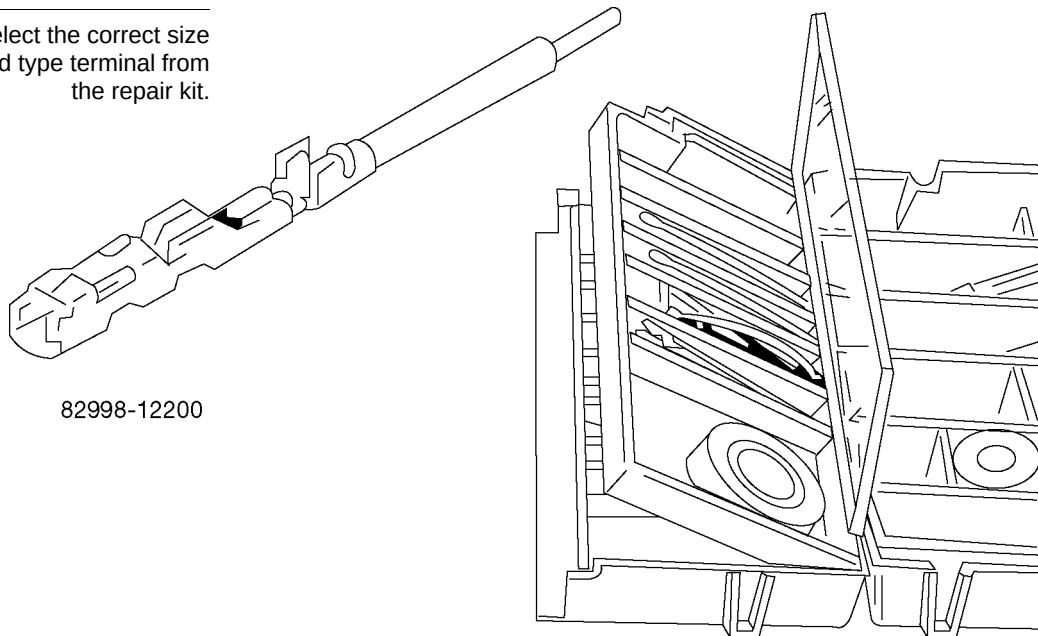


Fig. 2-52
TL623f252

6. Cut the old terminal from the harness.

a) Use the new wire lead as a guide for proper length.

NOTE If the length of wire removed is not approximately the same length as the new piece, the following problems may develop:

Too short - tension on the terminal, splice, or the connector, causing an open circuit.

Too long - excessive wire near the connector, may get pinched or abraded, causing a short circuit.

NOTE If the connector is of a waterproof type, the rubber plug may be reused.

Terminal Replacement

Remove the damaged terminal and wire from the harness and replace with a new wire cut to the same length. Too much or too little length can cause future problems.

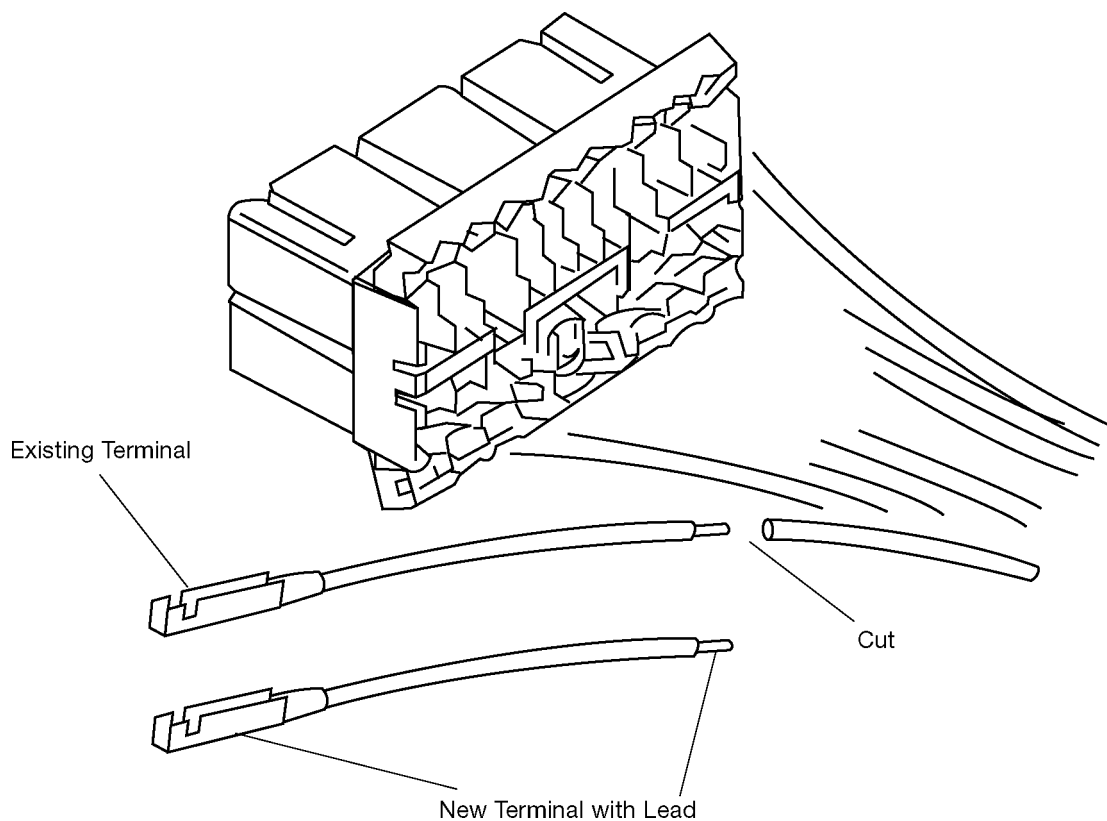


Fig. 2-53
TL623f253

7. Strip insulation from wire on the harness and replacement terminal lead.

- a) Strip length should be approximately 8 to 10 mm ($\frac{3}{8}$ in.).

NOTE Strip carefully to avoid nicking or cutting any of the strands of wire.

Wire Repair

Strip approximately 8 to 10 mm of insulation from each wire.

Stripped insulation length (A) approximately 8 to 10 mm ($\frac{3}{8}$ in.)

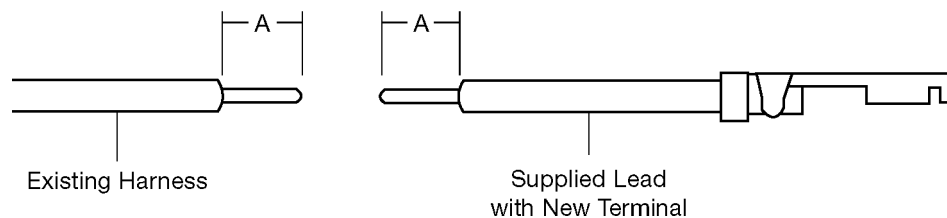


Fig. 2-54
TL623f254

NOTE If heat shrink tube is to be used, it must be installed at this time, sliding it over the end of one wire to be spliced. (See Step 3, 4. B. 1. for instructions on how to use heat shrink tube.)

NOTE If the connector is a waterproof type, the rubber plug should be installed on the terminal end at this time.

Insulation

Use heat shrink tubing to seal the repair. Also install a new water-proof rubber plug if required.

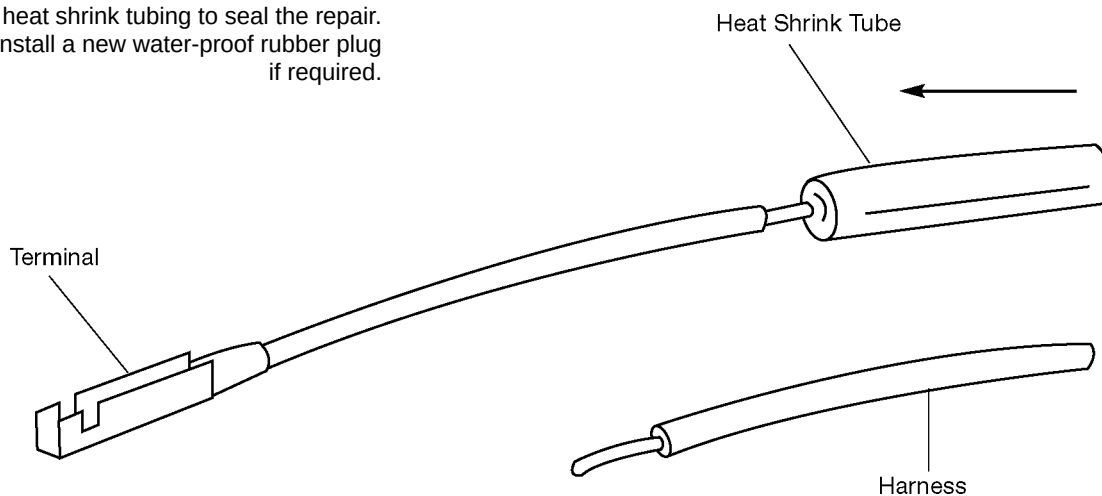


Fig. 2-55
TL623f255

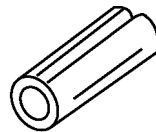
Step 3. Replace the terminal.

1. Select correct size of splice from the repair kit.
 - a) Size is based on the nominal size of the wire (three sizes are available).

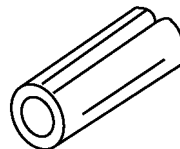
	<u>Part Number</u>	<u>Wire Size</u>
Small	00204-34130	16-22 AWG 1.0 - 0.2 mm
Medium	00204-34137	14-16 AWG 2.0 - 1.0 mm
Large	00204-34138	10-12 AWG 5.0 - 3.0 mm

Splices

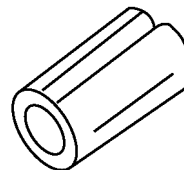
Select the appropriate size splice for the wire repair from the repair kit.



Small: 00204-34130



Medium: 00204-34137



Large: 00204-34138

Fig. 2-56
TL623f256

2. Crimp the replacement terminal lead to the harness lead.
 - a) Insert the stripped ends of both the replacement lead and the harness lead into the splice, overlapping the wires inside the splice.

NOTE Do not place insulation in the splice, only stripped wire.

Using the Splice

Place both wires into the splice. Do not place the insulated portion in the splice.

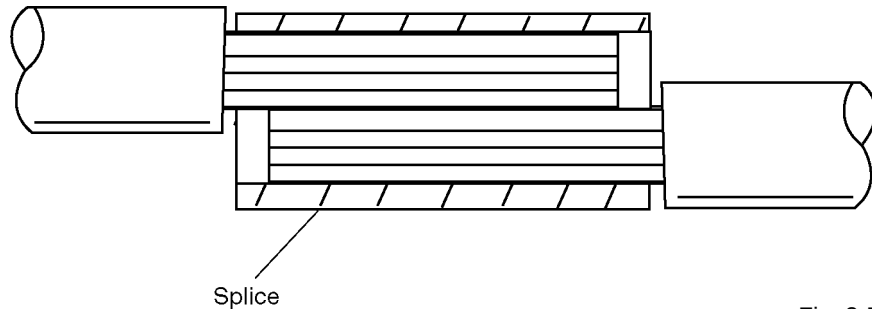


Fig. 2-57-1
TL623f257-1

- b) Do not use position marked "INS."
- (1) The crimping tool has positions marked for insulated splices (marked "INS") that should not be used, as they will not crimp the splice tightly onto the wires.

Crimp the Splice

Crimp the splice using the appropriate tool. Do not use the insulated (INS) portion of the tool.

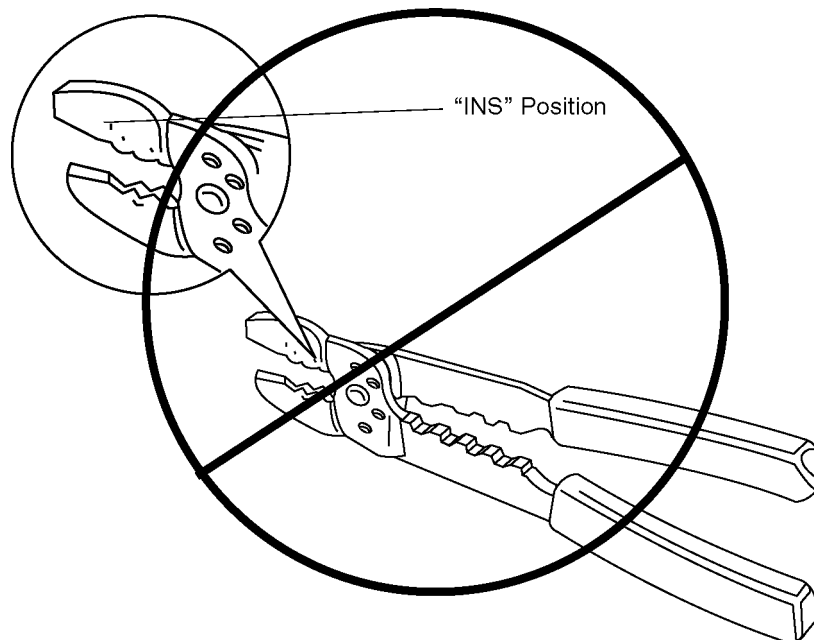


Fig. 2-57-2
TL623f257-2

c) Use only position marked “NON INS.”

- (1) With the center of the splice correctly placed between the crimping jaws, squeeze the crimping tool together until the contact points of the crimper come together.

NOTE Make sure the wires and the splice are still in the proper position before closing the crimping tool ends. Use steady pressure in making the crimp.

- (2) Make certain that the splice is crimped tightly.

Crimp the Splice (Cont.)

Crimp the splice in several locations to ensure good contact with the wire and that it does not pull apart.

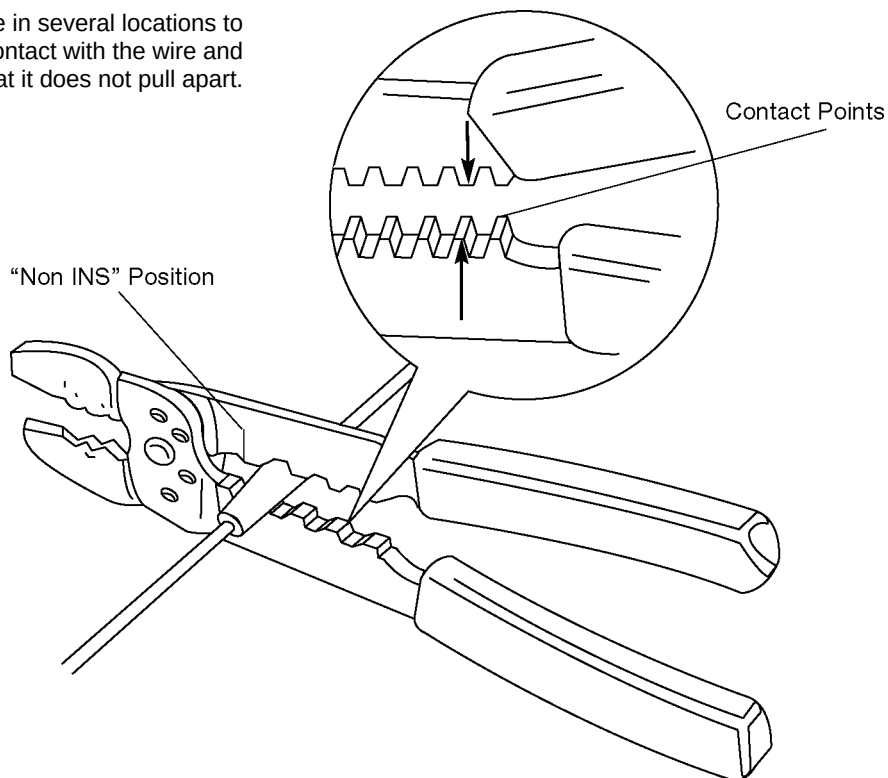


Fig. 2-57-3
TL623f257-3

3. Solder the completed splice using **only** rosin core solder.
 - a) Wires and splices **must** be clean.
 - b) A good mechanical joint **must** exist, because the solder will not hold the joint together.
 - c) Heat the joint with the soldering iron until the solder melts when pressed onto the joint.
 - d) Slowly press the solder into the hot splice on one end until it flows into the joint and out the other end of the splice.

NOTE

Do not use more solder than necessary to achieve a good connection. There should not be a “glob” of solder on the splice.

- e) When enough solder has been applied, remove the solder from the joint and then remove the soldering iron.

Solder the Splice

Solder the splice using rosin-core solder.

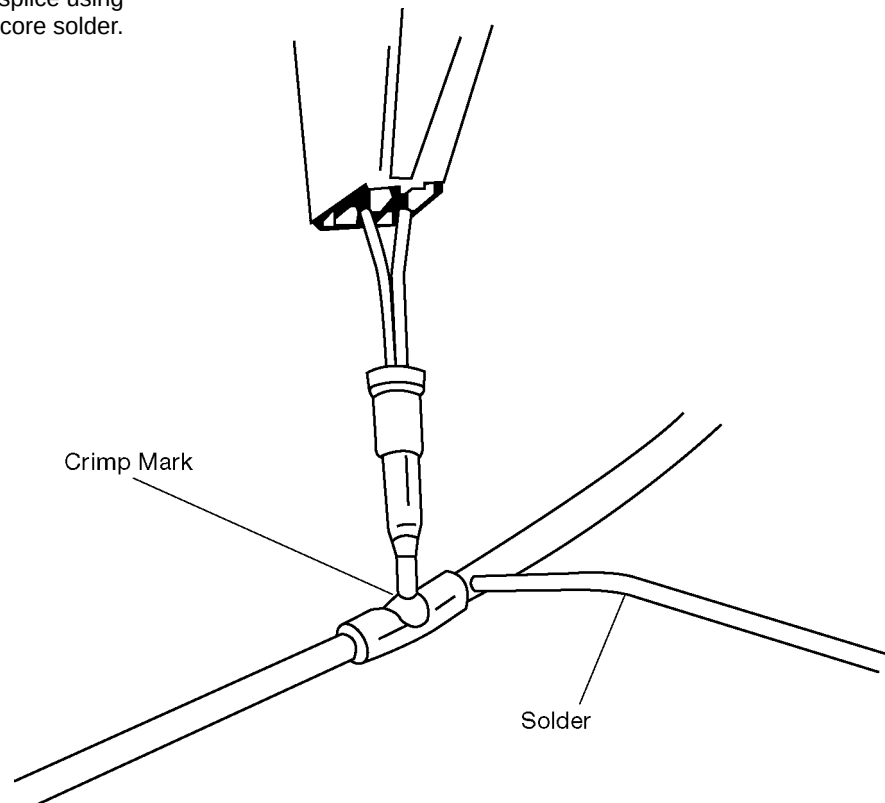


Fig. 2-58
TL623f258

4. Insulate the soldered splice using one of the following methods:
 - a) Silicon tape (provided in the wire repair kit).
 - (1) Cut a piece of tape from the roll approximately 25 mm (1 in.) long.
 - (2) Remove the clear wrapper from the tape.

NOTE The tape will not feel “sticky” on either side.

- (3) Place one end of the tape on the wire and wrap the tape tightly around the wire. You should cover one-half of the previous wrap each time you make a complete turn around the wire. (When stretched, this tape will adhere to itself.)
- (4) When completed, the splice should be completely covered with the tape and the tape should stay in place. If both of these conditions are not met, remove the tape and repeat steps 1 through 4.

NOTE If the splice is in the engine compartment or under the floor, or in an area where there might be abrasion on the spliced area, cover the silicon tape with vinyl tape.

Splice Insulation

Insulate with shrink tubing and/or silicon tape. Cover with vinyl tape also if the wiring is in a high abrasion area.

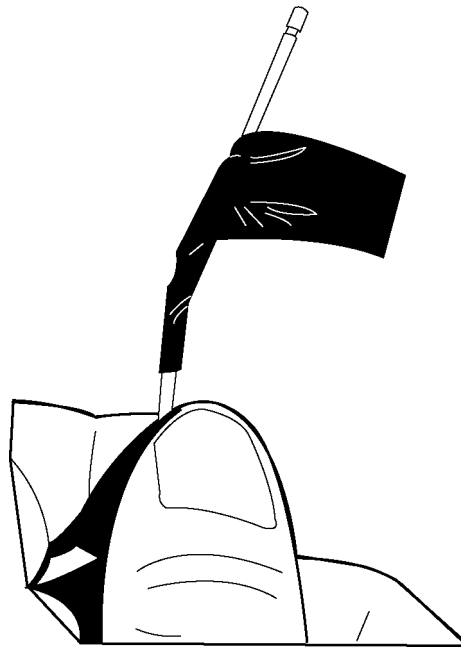
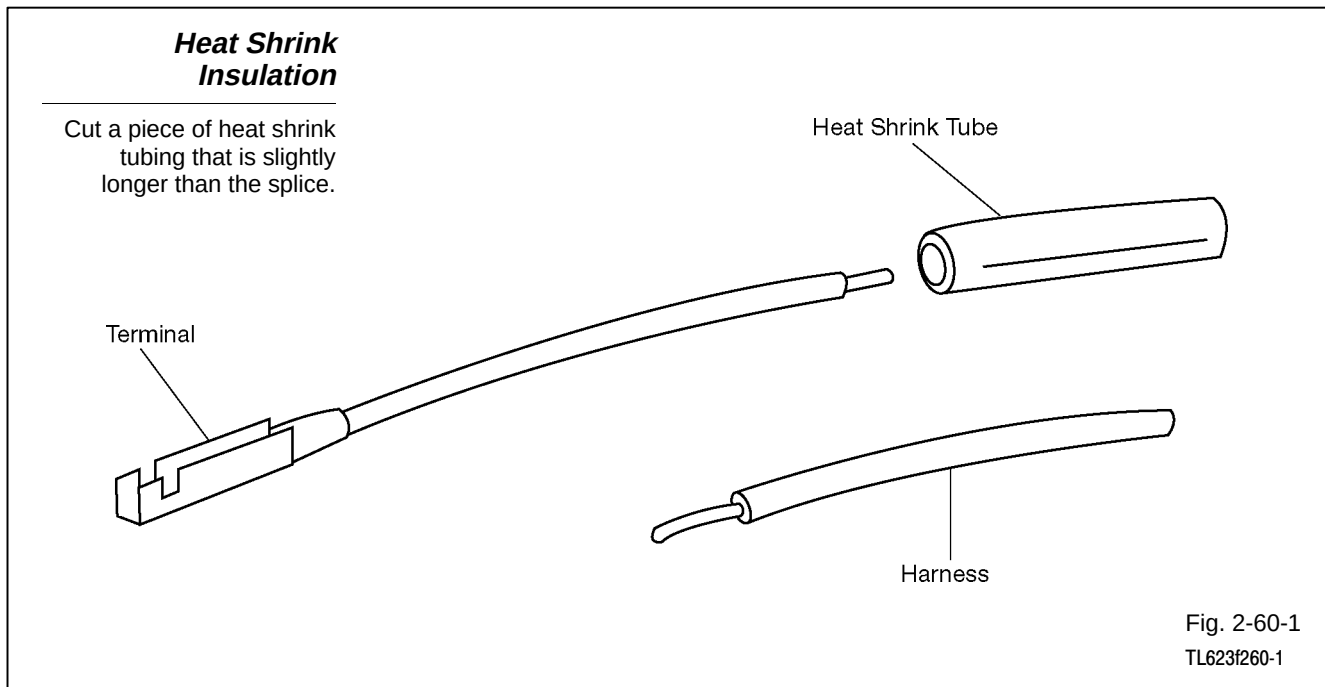


Fig. 2-59
TL623f259

- b) Apply heat shrink tube (provided in the wire repair kit).
- (1) Cut a piece of the heat shrink tube that is slightly longer than the splice, and slightly larger in diameter than the splice.



- (2) Slide the tube over the end of one wire to be spliced. (THIS STEP **MUST** BE DONE PRIOR TO JOINING THE WIRES TOGETHER!)
- (3) Center the tube over the soldered splice.
- (4) Using a source of heat, such as a heat gun, gently heat the tubing until it has shrunk tightly around the splice.

NOTE

Do not continue heating the tubing after it has shrunk around the splice. It will only shrink a certain amount, and then stop. It will not continue to shrink as long as you hold heat to it, so be careful not to melt the insulation on the adjoining wires by trying to get the tubing to shrink further.

***Heat Shrink
Insulation (Cont.)***

Use a heat gun to shrink the tubing over the repair/splice.

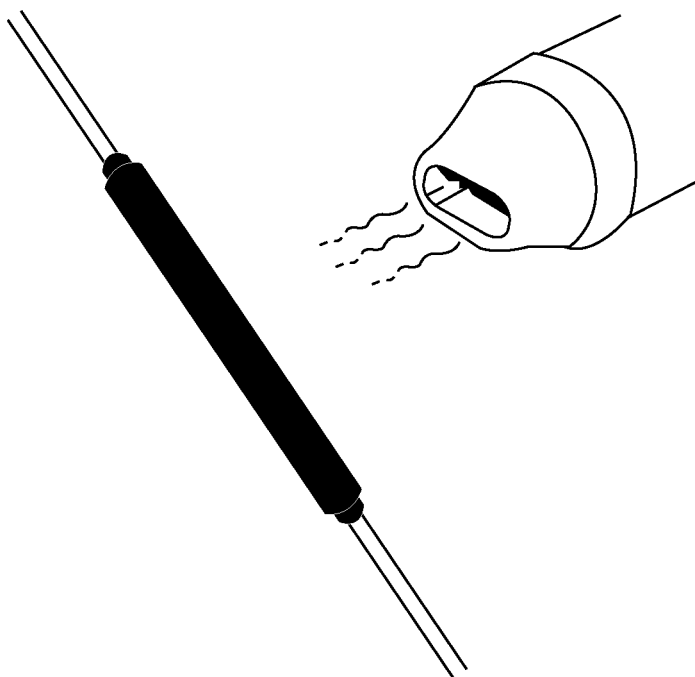


Fig. 2-60-2
TL623f260-2

Step 4. Install the terminal into the connector.

1. If reusing a terminal, check that the locking clip is still in good condition and in the proper position.
 - a. If it is on the terminal and not in the proper position, use the terminal pick to gently bend the locking clip back to the original shape.
 - b. Check that the other parts of the terminal are in their original shape.

Locking Clip

Verify the locking clip is in good condition if reusing the terminal.

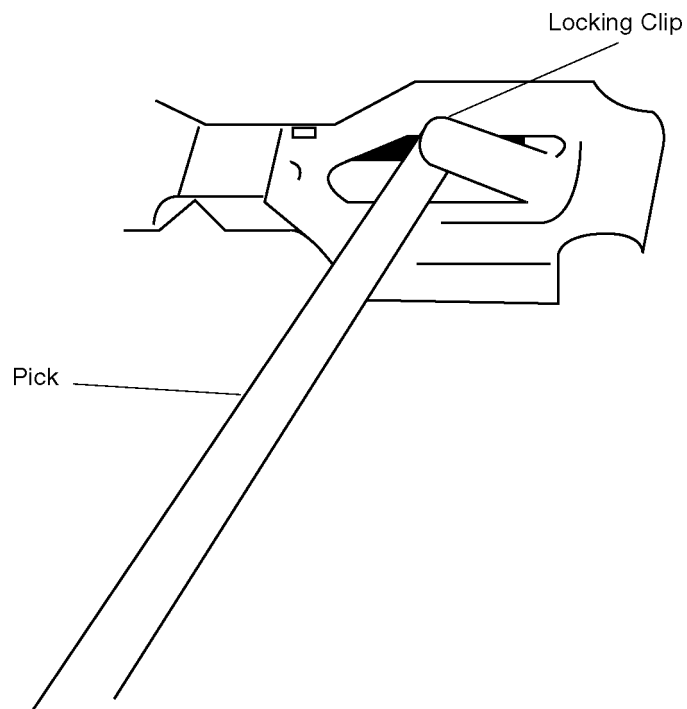


Fig. 2-61
TL623f261

2. Push the terminal into the connector until you hear a “click.”

NOTE Not all terminals will give an audible “click.”

Terminal Insertion

Insert the terminal into the connector until you hear a click as it locks into place.

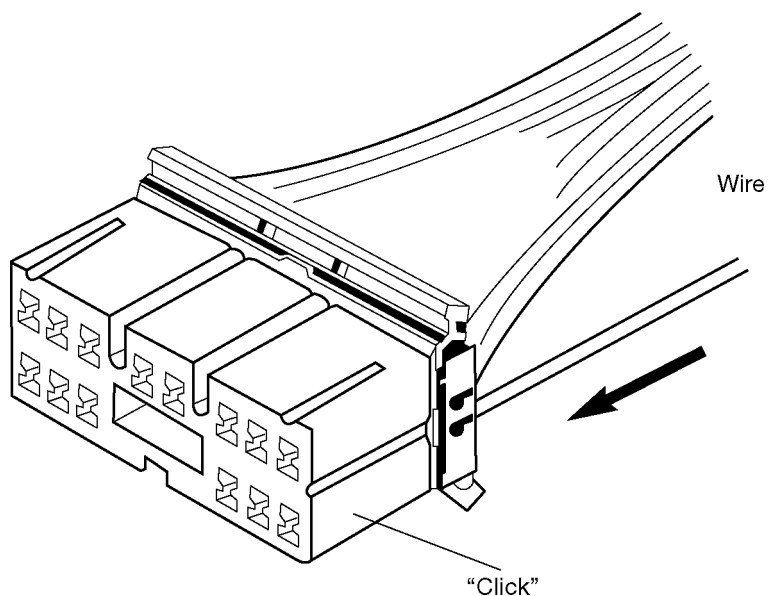


Fig. 2-62
TL623f262

- a) When properly installed, pulling gently on the wire lead will prove the terminal is locked in the connector.

Verify Terminal is Locked

Gently pull on the wire to verify the terminal has locked into the connector. Reinsert and recheck if required.

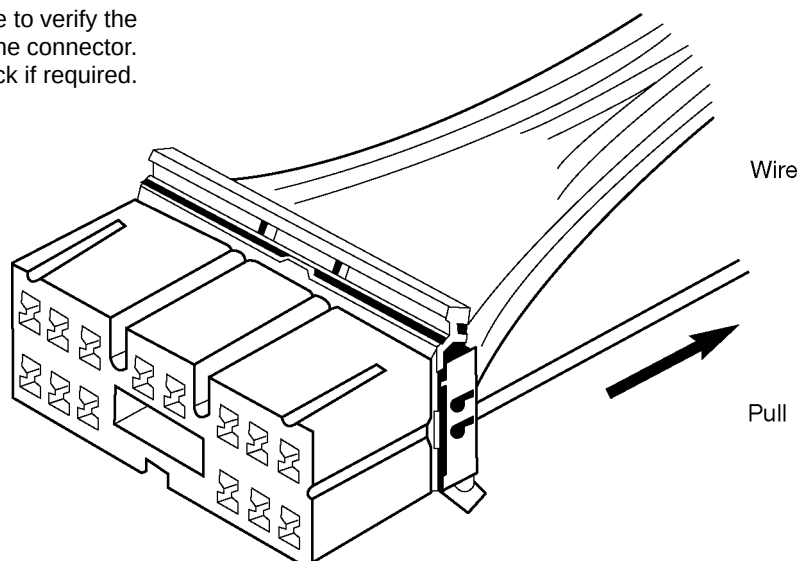


Fig. 2-63
TL623f263

3. Close terminal retainer or secondary locking device.
 - a) If the connector is fitted with a terminal retainer, or a secondary locking device, return it to the lock position.

Terminal Lock

Close the terminal lock to ensure all terminals now remain in place.

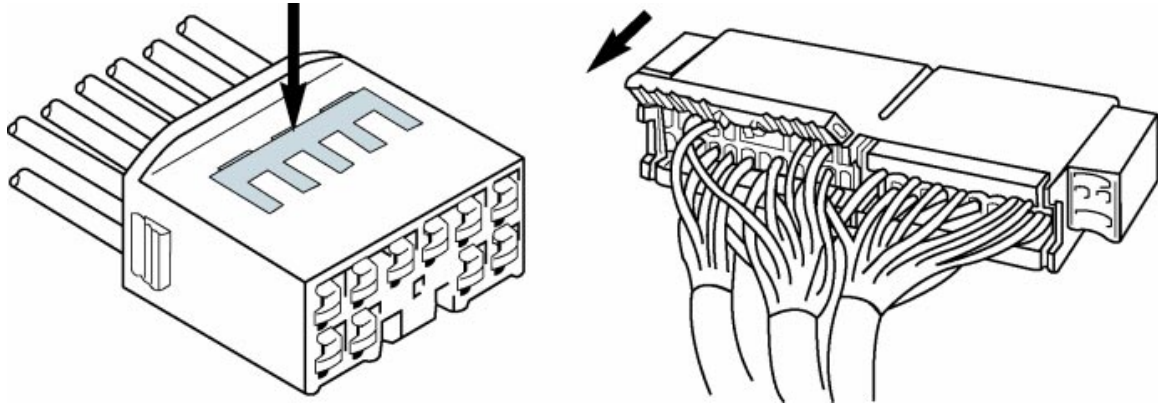


Fig. 2-64
TL623f264

4. Secure the repaired wire to the harness.
 - a) If the wire is not in the conduit, or secured by other means, wrap vinyl tape around the bundle to keep it together with the other wires.

Secure the Repaired Wire

Secure the repaired wire using silicon or vinyl tape if necessary.

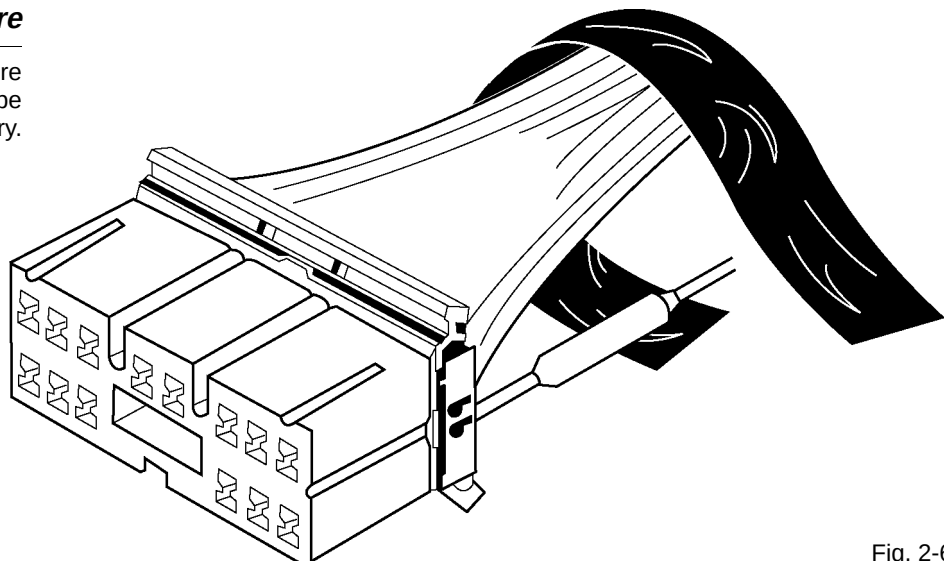


Fig. 2-65
TL623f265



Notes