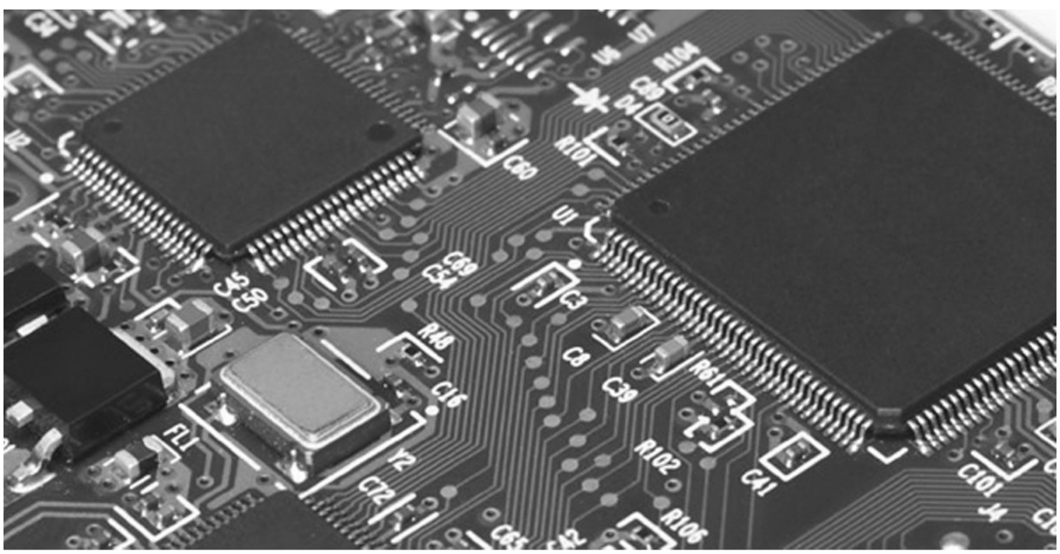
CDC 2W151A

Aircraft Armament Systems Journeyman

Volume 3. Electronic Principles, Troubleshooting, and Maintenance



Air Force Career Development Academy

The Air University

Air Education and Training Command

2W151A 03 1702, Edit Code 07

AFSC 2W151

Author: MSgt Matthew A. Perry
363 Training Squadron
Aircraft Armament Systems School (AETC)
363 TRS/TTW (AETC)
520 Missile Road
Sheppard Air Force Base, Texas 76311-2261
DSN: 736–7401
E-mail address: matthew.perry.4@us.af.mil or
363TRSCDCWriters@us.af.mil

Instructional Systems Specialist: Timothy Sackie

Editor: Elizabeth Melton

Air Force Career Development Academy (AFCDA)
The Air University (AETC)
Maxwell-Gunter Air Force Base, Alabama 36118–5643

Material in this volume is reviewed annually for technical accuracy, adequacy, and currency. For SKT purposes the examinee should check the *Weighted Airman Promotion System Catalog* to determine the correct references to study.

THIS CAREER development course (CDC) consists of three volumes. When you have completed this course, you'll have covered administration, management, and publications in volume 1; safety and security in volume 2; and electronic principles, troubleshooting, and maintenance in volume 3. This is the last volume in a three-volume series. This volume rounds out the knowledge you need to perform basic aircraft troubleshooting in a safe and professional manner. Unit 1 is primarily a refresher on electricity and electrical circuits, which plays an important part in maintaining weapons systems. Unit 2 covers the basic electrical maintenance principles to help you prevent damage from occurring. Lastly, unit 3 introduces you to the use of measuring devices and shows you how to use them when troubleshooting.

A glossary is included for your use.

Code numbers on figures are for preparing agency identification only.

The use of a name of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force.

To get a response to your questions concerning subject matter in this course, or to point out technical errors in the text, unit review exercises, or course examination, call or write the author using the contact information on the inside front cover of this volume.

NOTE: Do not use the IDEA Program to submit corrections for printing or typographical errors.

If you have questions that your supervisor, training manager, or education/training office cannot answer regarding course enrollment, course material, or administrative issues, please contact Air University Educational Support Services at http://www.aueducationsupport.com. Be sure your request includes your name, the last four digits of your social security number, address, and course/volume number.

This volume is valued at 12 hours and 4 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Unit 1. Fundamentals of Electricity and Circuits

THIS UNIT is primarily a refresher on the fundamentals of electricity. Your knowledge of electricity and electrical circuits will play an important part in maintaining aircraft weapons systems. To really understand your maintenance tasks, you must be familiar with the construction of basic circuits, electrical symbols and values, and the circuit-controlling devices in electrical circuits.

1–1. Nature of Electricity

To understand the nature of electricity as it relates to your job as a 2W1, you must first look at the different electrical terms, magnetic theories, and sources of current.

401. Electrical and magnetic theory, components, and terms

All matter consists of atoms made up of electrons, protons, and neutrons. These particles in proper combinations can produce electrical charges. This doesn’t mean all materials are practical for generating or transmitting electricity. Let’s look at the properties of some of the materials we use in electrical circuits.

Insulators

Insulators are substances with tightly bound orbiting electrons held firmly in place by the nucleus. Substances such as wood, plastic, rubber, and glass are good examples of insulators.

Conductors

Conductors are substances with electrons bound loosely to the nucleus of an atom and are easily freed by a suitable force. Platinum, gold, silver, and copper are all good conductors.

Semi-conductors

Semi-conductors are used in solid-state devices; their resistance and conductivity fall between insulators and conductors. Germanium and silicon are the most common semiconductors. A good conductor offers little opposition to electron flow, whereas insulators offer a great deal of opposition. Semi-conductors aren’t good conductors, but they’re better conductors than insulators are. There’s no such thing as a perfect conductor. Any substance is, to some degree, a good conductor or a poor conductor; a good insulator or a poor insulator.

Electromotive force

Electron movement occurs anytime there’s a difference in electrical potential between two points of a conductor—whenever there are more electrons at one point than at the other. The difference in the number of electrons is the determining factor for the amount of pressure that is present; the greater difference in the number of electrons the larger the force of electrical pressure.

The electrical pressure that makes electrons flow through a conductor is called electromotive force (EMF). You can consider EMF as an "electron-moving force." EMF and potential difference are just two ways of saying the same thing—electrical pressure. The unit of measurement of electrical pressure is the volt. Therefore, an electrical circuit has a certain amount of voltage. The symbol for volt is V, and the symbol for EMF is E.

Electrical current

Electrical current is the movement of electrons through a conductor. The unit of measurement for current is the ampere (amp). One ampere of current is the flow (across a certain point) of one coulomb (pronounced "cool ohms") of electrons in one second. One coulomb is equal to 6.28×10^{18} electrons. Amperage refers to the intensity of the current flow in a conductor. The standard symbol for current is I.

To be specific about how much current is flowing in a circuit, let's establish definitions concerning the "amount" of electron flow. The term *current* refers to the quantity of electrons flowing past a given point during one second. Technicians measure the amount of electrons moving in units called coulombs. We refer to the measure of the quantity of electrons flowing past a given point in one second as an "ampere," or "amp" (A). One amp of current is equal to the flow of one coulomb of electrons passing a given point in 1 second. The amount of current flow a technician can then determine by other factors such as the amount of resistance in the circuit and the amount of energy used in moving the electrons.

Electrical resistance

We said earlier there's no such thing as a perfect conductor or insulator—all conductors and insulators offer at least some opposition to current flow. Since all substances have different electron arrangements, they all offer different amounts of resistance to current flow. A length of copper wire offers less resistance than an iron wire of the same dimensions. The type of material is one of the factors that determines a conductor's resistance; temperature and size are the others. For most materials, the hotter the material, the more resistance it offers. The colder the material is, the less resistance. The amount of resistance change in relation to temperature change is known as temperature coefficient. If a temperature increase raises its resistance, the material has a positive temperature coefficient. It has a negative coefficient if a temperature increase decreases the resistance.

The amount of resistance present is measured in ohms. Its symbol is the Greek letter omega (Ω). The letter R represents resistance. There is a definite relationship between resistance, current, and electromotive force. By using different resistors, you can control current flow. The other factor that controls current flow is the voltage applied, or difference in potential.

Electromagnetism

The fact that magnetism and electricity are closely linked can be most readily seen in the phenomenon of electro magnetism. Any time a conductor serves as the path for electrons to flow through, a magnetic field develops around the conductor (fig. 1–1). Science has shown us how to take this phenomenon and shape it to perform a myriad of tasks in the field of electronics. The left-hand rule is used to determine the direction of the magnetic field and is illustrated in figure 1–2. If the thumb of the left hand is extended in the direction of current flow and the fingers clenched, then the rough circles formed by the fingers indicate the direction of the magnetic field.

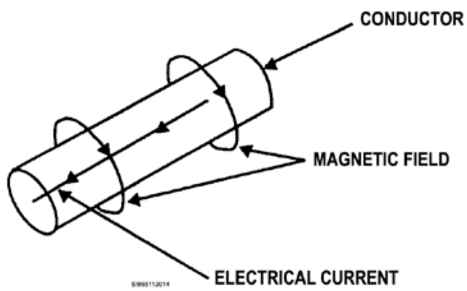


Figure 1–1. Electromagnetism.

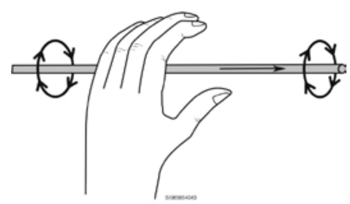


Figure 1–2. Left hand rule.

Magnetic field about a straight wire

Figure 1–3 shows one way to prove the existence of a magnetic field surrounding a direct current (DC) conductor. Note that a straight piece of wire is passed through a hole in a piece of glass and connected to a DC source through a rheostat and switch. If you sprinkle iron filings over the glass and then tap it gently, the filings will arrange themselves in circles about the wire. If you place two magnetic compasses on the glass, their needles will point in the direction of the magnetic lines of force. The north pole of each compass (A and B) indicates the direction of magnetic lines of force. In this experiment the magnetic lines of force travel counterclockwise. This experiment shows that a magnetic field does exist about a current-carrying conductor and that the field also has direction. If you reverse the battery, the direction of the current reverses and both compass needles change direction by 180°. Thus, a change in current direction changes the magnetic field's direction. The important point to remember about this experiment is when an electric current is flowing, there's a magnetic field.

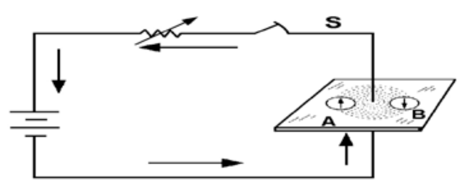


Figure 1–3. Lines of force around a conductor.

Magnetic field about a coil of wire

Now let's form that straight wire into a loop (fig. 1–4). With current flowing in it, the loop of wire acts like a short bar magnet and the magnetic lines around it are as they're shown here. The face of the loop the lines enter is the *south pole* and the face they leave is the N*orth Pole*. If you wind several loops to form a coil, you'll get a more powerful magnetic field. Inside the coil, the lines are concentrated to form a more powerful field, while outside the coil they're spread out.

A coil with current flowing in it (fig. 1–5) is the equivalent to a bar magnet. The coil's magnetic field has the same shape as the field of a bar magnet, and it obeys the same laws of magnetism that a bar magnet obeys; that is, the unlike poles of two coils attract each other and the like poles repel. If the coil is free to rotate in a horizontal plane and placed in a magnetic field, it will rotate, as will a compass needle, to arrange its force lines parallel to the lines of the field.

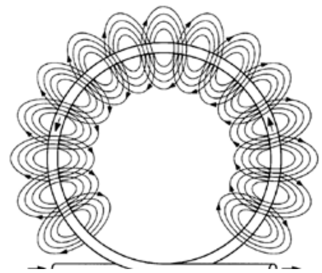


Figure 1-4. Lines of force around a loop.

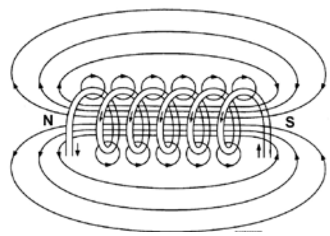


Figure 1–5. Lines of force around a coil.

Electromagnets

An electromagnet is an electrically excited magnet capable of exerting mechanical force. Present day examples of electromagnets include the starter solenoid on an automobile, electromechanical input-output devices used with computers, and the simple doorbell. Each of these devices operates on the principle of a current-carrying conductor wrapped around a soft iron core. Very strong electromagnets can be made by winding the coil around a piece of iron or steel. The reluctance of iron or steel is so much lower than air that the same electric current in the coil sets up thousands of times more lines of magnetism than it would with an air core. Of course the larger the electric current, the more lines will be set up in the core and, thus, strengthen the magnetic field. The strength can be produced by using many turns of wire carrying a small current or by using a few turns of wire carrying a larger current. Thus, an electric current of 2 amps flowing in a coil of 5,000 turns produce the same number of lines as a current of 20 amps flowing in a coil of 500 turns. The product of the number of turns in a coil and the number of amps flowing in the coil is called the coil's ampere-turns. Two coils with identical cores and the same number of ampere-turns produce magnetic fields of the same strength. The same product of amperes and turns gives the same effect, no matter what the separate values of current and turns may be.

If you continually increase the current in a coil with an iron core, you eventually reach a point where further current increases add so few flux lines that it's uneconomical and impractical to add more lines. At this point, the core is said to be saturated. Sometimes the current is deliberately made large enough to saturate the core but it's usually not desirable.

A bar of iron or soft steel in a coil's magnetic field will be magnetized. Since the bar has less reluctance than air, magnetic lines flow through it. If the field is strong enough, the tendency of magnetic lines to shorten themselves pulls the bar into the coil until its center is near the center of the coil, where the field is most intense. If you place the bar on the other side of the coil, it also will be drawn into the coil.

402. Sources of current

We need to start our conversations of electricity at its sources. There are many different methods of generating current, but there are only three sources of current applicable to the 2W1 community. These sources are batteries, generators, and generators of static current.

Batteries

Batteries are common throughout the systems we work in. A battery by definition is a device that converts chemical energy into electrical energy, typically through a chemical reaction called a redox reaction. Chemical batteries generally consist of three parts: an anode, cathode, and an electrolyte (fig. 1–6).

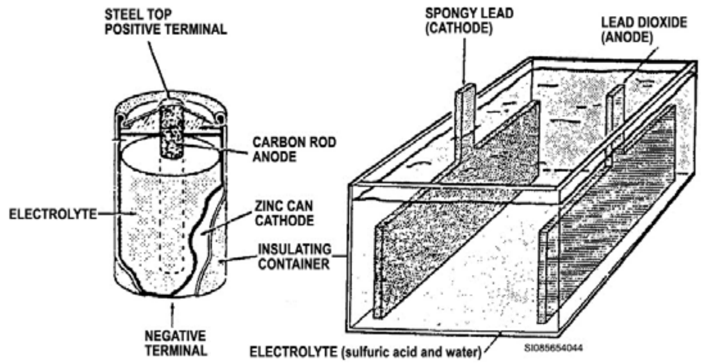


Figure 1–6. Common batteries.

At one electrode (the anode), a chemical reaction can occur that produces an excess of electrons. This reaction will fail to occur if excess electrons have no way of moving out of the reaction site. This process results in the anode generating a negative charge or a desire to remove electrons. At the other electrode (the cathode) another chemical reaction can occur but only if free electrons are available. This results in a positive charge being generated in the cathode or a desire or attraction to electrons. So, in a battery the only way for the anode to remove this excess of electrons is for it to be connected to a positively charged cathode. This movement of electrons is how a battery generates current. This reaction (and the current it produces) will continue to occur as long as a continuous path for electrons is available (a closed circuit) and there are sufficient chemicals present for the reaction to continue.

NOTE: The flow of electrons in a battery is *always* from the anode to the cathode; it *never* changes direction. This is the reason batteries are only capable of generating direct current.

Generators

A generator by definition is a device that converts mechanical energy into electrical energy, typically through the interactions that conductors have with magnets. We mentioned earlier that a conductor carrying an electrical current develops a magnetic field. The opposite is also true; if a conductor is passed through a magnetic field so that it will pass through the magnetic lines of force, it will generate an electric current. This is the basic theory of how a generator works.

The direction of the flow of electrons is determined by which side of the conductor is passing through a given section of the magnetic field. The electrons in the conductor will be drawn *towards* the side of the coil closest to the *north pole* of the magnetic field *from* the side of the conductor that is nearest the *south pole* of the field. As the conductor rotates within the field, the sides closest to either pole will switch. When this happens, the direction of the flow will reverse or alternate.

Figure 1–7 shows a very basic alternating current (AC) generator, with a one-wire conductor. **NOTE:** that the conductor is a loop located in a magnetic field between the poles of a permanent magnet. When one side of the loop is traveling up, the other side is moving down. As the conductor (armature) first moves through the magnetic field, a voltage is induced into the conductor (A). Then as the loop rotates to a vertical position there are no lines of force cut, current decreases to zero (B and D). As the loop continues to rotate, force lines are again cut, but in the opposite direction (C). The loop has now completed one full cycle. During half of the revolution, the current in a closed loop rotating in a magnetic field flows in one direction; during the other half, it flows in the reverse direction. Slip rings attached to the two ends of the loop then transmit the current to the brushes which, in turn, let it flow to an external circuit.

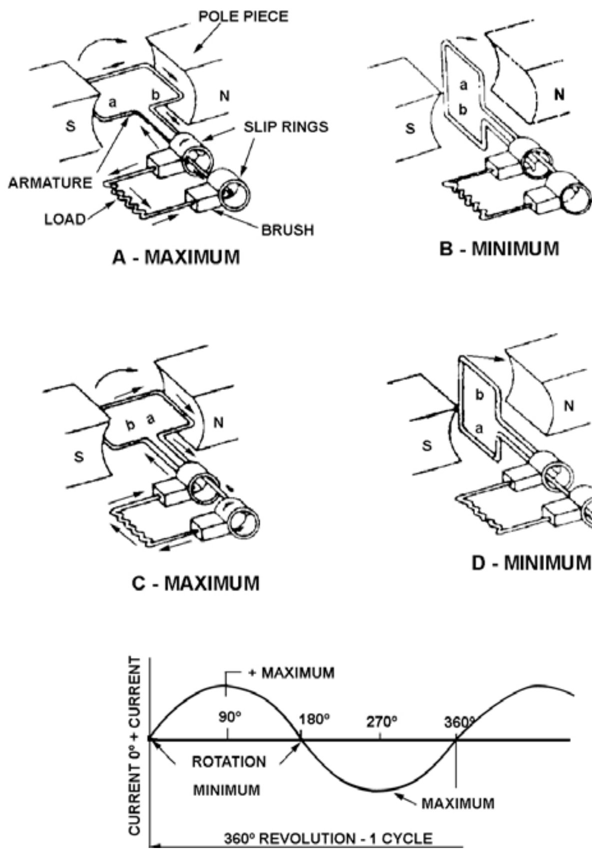


Figure 1–7. Simple AC generator.

Static electricity

While static electricity is not a usable or reliable source of electricity, it is one that is constantly around us and is inseparable for our environment. These things we refer to as a "discharge of static electricity." The word *static* means "at rest," and that's exactly what static electricity is—electricity at rest. When an object gains or loses a large amount of electrons, it develops a "static" charge (keep in mind the rule of repulsion and attraction). As two differently charged bodies come close to one another, the attraction becomes stronger. When they are physically close enough, they will "balance out," resulting in a spark—the spark between you and the doorknob or, on a larger scale, lightning.

If you connect a wire to a metallic object and hold it in your hand while moving across the rug, you would not get a spark. This is because the wire supplies a continuous path to ground that allows the current (electrons) to equalize (balance), and you would have a harmless non-sparking discharge of static. Realize, though, there will only be a momentary flow of current, and it ceases as soon as the unbalanced charge is equalized. Static charges held in insulators tend to remain in the localized area of contact for long periods.TEST Charges on conductors are rapidly distributed over the surfaces. Static electricity may be found in items you work with or around daily. Typical static charge sources or generators of static electricity are as follows:

- Work surfaces (waxed, painted, or varnished surfaces and also common vinyl or plastics).
- Floors (sealed concrete and common vinyl tile or sheeting).
- Clothes (synthetic personal garments and virgin cotton).
- Packaging and handling materials (common plastic bags, wraps, and envelopes and common bubble pack, foam, and plastic trays such as parts bins).
- Electronic equipment repair areas (plastic solder suckers and solvent brushes).

Electrostatic voltage levels generated with these types of areas or surfaces can be very high since they are not readily distributed over the entire surface of the substance. The conductivity of some insulators is increased by the absorption of moisture under high-humidity conditions, which tends to dissipate static charges. Electrostatic voltage levels are generated in every activity you perform. For example, depending upon the humidity of the area, sitting at a workbench generates between 100 and 6,000 electrostatic volts. Opening a vinyl envelope or folder having aircraft forms generates between 600 and 7,000 electrostatic volts. Picking up a common poly bag from a workbench generates between 1,200 and 20,000 electrostatic volts, and sitting in a work chair can generate between 1,500 and 18,000 electrostatic volts. Now combine a few of those activities and think about why it is so important to ground yourself, your test equipment, and the aircraft/equipment you are working on.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

401. Electrical and magnetic theory, components, and terms

1. What is the definition of an insulator?

2. What is the unit of measurement of electrical pressure?

3. Define electrical current.

4. Define temperature coefficient.

5. What is the “left-hand rule”?

402. Sources of current

1. What are the three basic parts of a battery?

2. What is the definition of a generator?

3. What has happened in an object that contains a static charge?

1–2. Electrical Components

To understand how electricity can do all the jobs it does, you must know the different types of components and how they interact with each other within a circuit.

403. Electrical resistance and resistors

There is no such thing as a "perfect" conductor. All good conductors offer at least some opposition to current flow. The opposition a conductor or insulator offers to the flow of electrons scientists call *resistance*. Semiconductors have a high resistance to electron flow. When used in circuits, their principal function is to oppose current flow. We use these materials when it's desirable to add resistance to a circuit at a given point. All circuits are designed to withstand a certain (maximum) amount of current flow. If current flow exceeds this limit, the circuit will burn up (due to the heat built up by the movement of electrons). Circuit designers use resistors to control the current flow and to keep it below the maximum limit of the circuit. Resistors are designed to offer a predetermined amount of opposition within a circuit. They are made of many different materials and are constructed in many different forms. The most common material used in the manufacture of resistors is carbon.

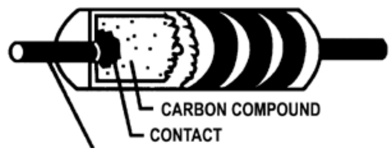


Figure 1–8. Typical carbon resistor.

Carbon-composition resistors

Carbon-composition resistors are the most common type used in electronics. Figure 1–8 shows a carbon-composition resistor. It is made from a mixture of powdered carbon and a cement-like material used to hold the carbon together. The resistance value is governed by the mixture of carbon and cement contained in the glass capsule that makes up the housing of the resistor. A minute variation in the composition can have a major effect in the resistance value of the completed resistor. Their method of construction also prevents them from being tested or adjusted during the manufacturing process. The manufacturer has to complete the process and then test the completed product, either rejecting or approving of the final product with no adjustments possible. Carbon-composition resistors are not extremely accurate; the actual value of the resistors can vary by 5-to-20 percent. They are commonly found with power ratings of ¼ to 2 watts. The larger the physical size, the larger the wattage rating is.

Wire-wound resistors

Wire-wound resistors are generally used in a circuit where the power requirements exceed 5 watts. They're usually large because of the great amount of power they must dissipate, and because they are constructed of many turns (length = resistance) of high-resistance wire around ceramic material. The wire used has a specific amount of resistance per foot. Since the resistance is known and easily calculated, the total resistance of the completed resistor can be controlled to a very high degree of accuracy, down to 1 percent, simply by adjusting the length of the conductor during the manufacturing process. Because of their accuracy, wire-wound resistors are also used in low-power circuits where an accurate resistance is required. Normally, the design of these resistors is either fixed or variable.

Fixed

Fixed resistors have a constant fixed value of total resistance. They are not constructed with a provision for selecting a desired portion of the total resistance. You find them used on circuit cards, in bomb racks, and just about everywhere. They are the most commonly used type of resistor.

Variable

Resistors that provide a means of selecting some desired portion of their total resistance scientists call variable resistors or rheostats.

Figure 1–9 shows two types of variable resistors. As you can see, the carbon resistive element of the variable resistor (fig. 1–9, B) is molded in a circle. The wiper arm contact is used to control the resistor element. Between contacts 1 and 3, the resistor is not variable, but it is the maximum value of the carbon resistor. For example, if the variable resistor is a 1 K ohm, or kilohm (kΩ), control, then the resistance between terminals 1 and 3 in figure 1–9, B, will always equal 1 K ohm. However, the resistance between either of the end terminals and the wiper arm contact 1 (fig. 1–9, B, index 2) will vary, depending upon the position of the wiper arm. Positioning the wiper arm in the center of the carbon element divides the resistance in half (500 ohms). Figure 1–9, A, illustrates a tapped resistor. This type of cylindrical resistor consists of a resistive wire wrapped around a ceramic insulating body. It can be used in a semi-fixed application.

Once a technician adjusts the tap (fig. 1–9, A, index 2) by sliding the collar to the desired resistance value, he or she seldom readjusts the value. With this arrangement, we have the capability of any resistance similar to the variable type or a fixed resistance from terminals 1 and 3.

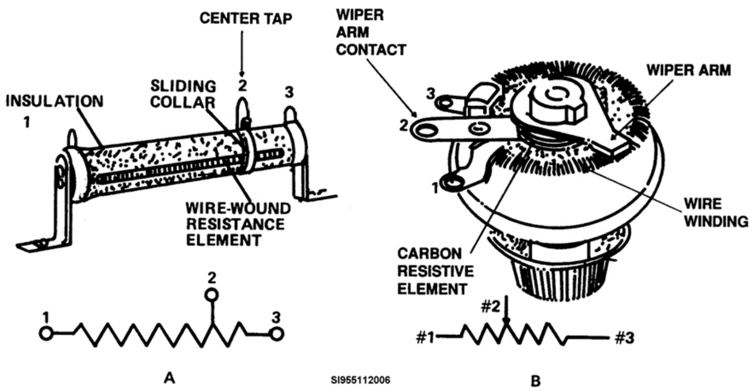


Figure 1–9. Wire-wound resistors.

The rheostat is a two-terminal variable resistor (fig. 1–10). It is used to vary current in a circuit and is shown in a simple circuit in figure 1–10. As you adjust the rheostat, you increase or decrease the total resistance within the circuit. This changes the amount of current flowing in the circuit. Therefore, in the circuit shown in figure 1–10, you can make the lamp dim or bright by varying the adjustment of the rheostat.

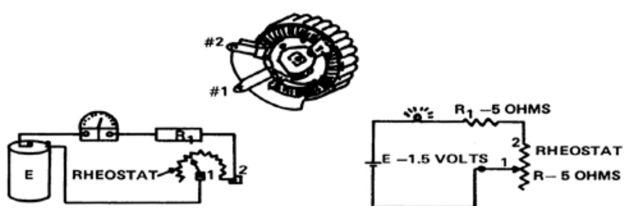


Figure 1–10. Rheostat.

A potentiometer is a three-terminal variable resistor used to control voltage as shown in figure 1–11. The fixed maximum resistance of the control between indexes 1 and 3 (fig. 1–11) is connected across the voltage source (battery). The variable wiper arm, index 2, is used to vary the voltage being sent or fed to another circuit or device. You can see that all three terminals in this illustration are used in the application.

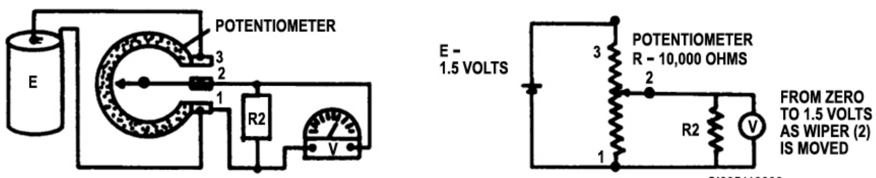


Figure 1–11. Potentiometer.

404. Switches

It would be hard to count the amount of times you use an electrical switch on any given day. They surround you in both your life and the systems that it's your job to maintain. This lesson looks at the individual pieces of switches and how they work.

A switch is a mechanical device used to connect and disconnect a circuit at will. They exist in a myriad of forms and are limited in their construction and form only by the number of applications that people can think up. Even with all of the variations in the types of switches they all share two common components. These components are called the contacts and the actuator.

Contacts

The contacts of a switch are the location where the switch makes contact to complete the circuit and they need to be positioned with sufficient space between them to prevent the unintentional flow of electricity in the circuit. The actual construction of the contacts and the materials used in their construction vary widely depending on their use and application in the circuit that is being controlled by their use.

Actuator

The actuator is the moveable part of the switch that is manipulated to complete or open the electrical circuit or circuits to allow or inhibit the flow of electrons. The forms that the actuator can take are basically limitless, from the familiar toggle switch that controls almost every lighting system that you are familiar with to exotic mercury switches to control tilt.

Types of switches

Switches are classified according to the arrangement of their contacts. Some contacts are normally open until closed by operation of the switch, while others are normally closed and opened by the switch action. The terms pole and throw are used to describe switch contact configurations. A pole is a set of contacts that belong to a single circuit. A throw is one of two or more positions that the switch can adopt. In single throw multiple pole switches the activation of a single actuator is responsible for connecting or disconnecting multiple contacts or circuits with a single action. An example of this would be the master switch in a power strip. The activation of a single switch allows current to flow in multiple outlets.

Biased switch

A biased switch is one containing a spring or some other restoring force that returns the actuator to a certain position. The on-off notation can be modified by placing parentheses around all positions other than the resting position. For example, an (on)-off-(on) switch can be switched on by moving the actuator in either direction away from the center, but returns to the central off position when the actuator is released.

Momentary push-button switch

The momentary push-button switch is another type of biased switch. The most common type is a push-to-make switch, which completes the circuit when the button is pressed and breaks when the button is released. A push-to-break switch, on the other hand, breaks contact when the button is pressed and makes contact when it is released. An example of a push-to-break switch is a refrigerator with an internal light, when the door depresses the switch the circuit is broken and the light goes out, when the door is opened the spring pushes the button out and the contact is closed.

Rotary switch

Another common type of switch you will encounter is the rotary switch (fig. 1–12). In a rotary switch there is a single contact usually located in the center that is surrounded by a series of contacts arranged around the outside. An example of a rotary switch would be the function switch on a multimeter. As you rotate the switch on the multimeter, you complete the circuit that activates different functions on the meter while disabling other functions.

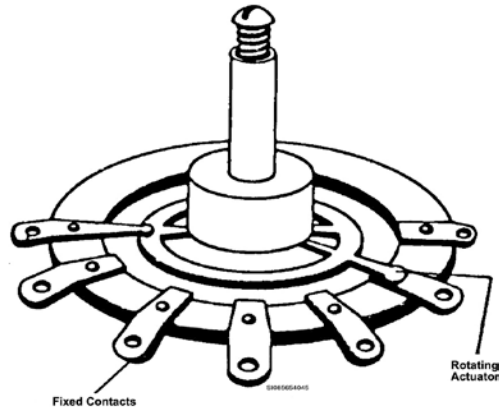


Figure 1–12. Rotary switch.

405. Circuit-limiting devices

Safe, efficient operation of an electrical system can be maintained only with the proper control and protective equipment. The starting, stopping, varying, and reversing of this current necessitates the use of many different kinds of control equipment. The problem of protecting electrical equipment is also very important. The directing of electric current to a particular piece of equipment requires controlling devices. In this lesson, we consider electrical devices that both control and protect electrical circuits.

Fuses

Fuses are the oldest protective devices used in electrical systems (fig. 1–13). Many circuits today still incorporate fuses as the circuit protector. Inside the fuse container is a metallic link designed to normally conduct no more than a specified current. If the current exceeds this specified amount, the heating effect of the greater current on the metallic link will cause it to melt. Once the link has melted, the circuit is broken. When the link melts and opens the circuit, the fuse is said to have “blown.”

Fuses are rated according to the ampere load they can carry without blowing. Fuses come in two types: regular and slow-blow. The regular type blows immediately when the circuit exceeds its rated capacity, but the slow-blow type can carry a normal overload for a short time before it opens the circuit. When you replace a fuse, be careful to use a fuse of the same type and ampere rating. The fuse link is completely enclosed in the case and, in some instances, is surrounded with some material that will dampen any arc produced when the conducting link parts. Because the fuse link actually melts, it destroys itself and has to be replaced after it is overloaded. Some fuses are constructed with a stretched spring attached to one end of the conducting link so that when the unit melts, the spring draws the two fuse segments apart. This is necessary in high-voltage circuits to overcome the possibility of current arcing across the open fuse. Always replace blown fuses with new fuses.

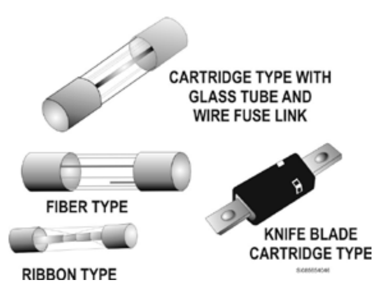


Figure 1–13. Common fuses.

Circuit breakers

Circuit breakers (CB) are used more extensively today than fuses, since they can be easily reset an indefinite number of times. This eliminates the need for replacement as in the case of fuses.

Magnetic circuit breakers

The magnetic type of circuit breaker is arranged so the current of the circuit flows through a coil within the breaker housing (fig. 1–14, A). If the current through the coil exceeds the value that the unit was factory-adjusted to carry, the coil, which is wound on an iron core, attracts a trip lever and, thus, breaks the circuit (fig. 1–14, B).

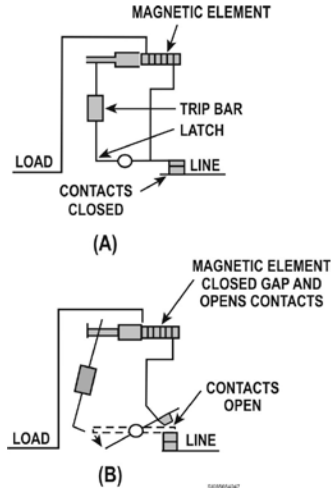


Figure 1–14. Typical magnetic CB operation.

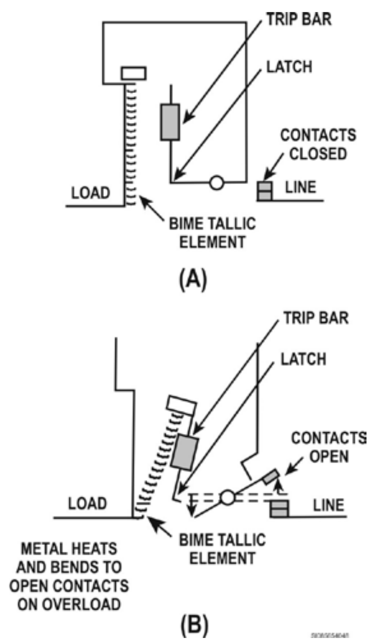


Figure 1–15. Typical thermal CB operation.

Thermal circuit breakers

The thermal type of circuit breaker that is used in some circuits does the breaking action through the use of a bimetallic strip (fig. 1–15, A). When excess current heats the circuit, the distortion of the bimetallic strip opens it (fig. 1–15, B). One type of thermal circuit breaker is the push-to-reset type. When the breaker is closed, the operator cannot open it. Another type of thermal circuit breaker is the switch type. This type of circuit breaker may be opened as well as closed by the operator. Externally, it appears to be similar to the toggle switch we mentioned previously. This type of breaker may be used as a single-throw switch to complete a circuit as well as a circuit breaker to protect it.

Realizing it is necessary at times for a circuit breaker to be opened manually, manufacturers have designed another type of thermal breaker known as a push-pull breaker. This unit is similar to the push-to-reset type, with a provision for manually opening the circuit at will. These breakers are equipped with a colored collar surrounding the operating shaft to indicate when the breaker is in the OPEN position. When the breaker circuit is closed, the colored indicator collar is inside the mechanism. This gives a quick means of visually checking any circuit breaker panel for any open breakers. The push-pull circuit breakers are small, and their external projection from the panel is designed to reduce the possibility of accidentally catching on them and opening circuit breakers.

406. Relays and solenoids

Relays and solenoids are present in various systems that you will come in contact with no matter where you work on aircraft. They are grouped together because they use similar principles in their operation. In this lesson we'll try to build on the knowledge you already have on these components.

Relays

In most aircraft, there are many types of relays used in many different scenarios. Whatever purpose they are serving, their principle of operation is the same. A current is sent through a coil, which may or may not contain an iron core. This current creates an electromagnetic field, which causes the movement of an iron bar toward the end of the electromagnet. This action causes one or more circuits to close.

A common device designed and built to incorporate the knowledge of magnetism is the relay switch. A relay is an electrically controlled magnetic device used for mechanically switching electrical circuits on or off. The circuit switched by the relay is called the *controlled* circuit, and the circuit energizing the relay is called the *actuating* or *primary* circuit. There are many different types and purposes of relays. However, their basic principles of operation and structural features are similar. Look at figure 1–16, views A and B, to familiarize yourself with the relay while we discuss it.

The basic relay consists essentially of a coil of insulated wire wrapped around an iron core and an iron bar (armature) (fig. 1–16, A). Current flows through the coil and begins to build up a strong magnetic field around the coil. The magnetic field attracts the armature and pulls it toward the core, and contacts A and C are closed (fig. 1–16, B). The movement of the armature serves to open and close one or more circuits. Basic relays are made to operate on a very small amount of current. The amount of current flowing in the secondary circuit is limited only by the power of the electrical source. In essence, a very weak current can be made to control the operation of a circuit with large current flow.

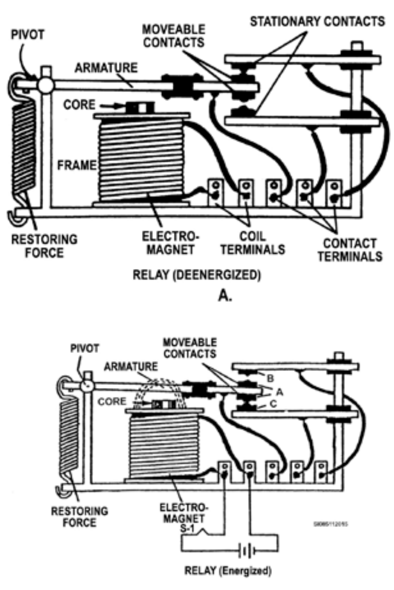


Figure 1–16. Basic relay.

Latching relays

Another common relay is called the latching relay. Unlike the more common simple relays, a latching relay has two de-energized states. These are also called ‘keep’ or ‘stay’ relays. When the current is switched off, the relay remains in its last state. This is achieved with a solenoid operating a ratchet mechanism, or by having two opposing coils with an over-center spring or permanent magnet to hold the armature and contacts in position while the coil is de-energized. In the ratchet and cam example, the first pulse to the coil turns the relay on and the second pulse turns it off. In the two coil example, a pulse to one coil turns the relay on and a pulse to the opposite coil turns the relay off. This type of relay has the advantage that it consumes power only for an instant, while it is being switched.

In our example (fig. 1–17), you can see an example of a latching relay. If the coil (6) is energized it will attract the armature (2) and it will make a connection with contact (3). At the same time that the armature moves it will cause the armature to slip under the catch located on a thin piece of metal that acts like a spring (5). Once the armature is captured by the catch on the spring the coil can be de-energized and the contact will remain in its current position. When the control circuit is energized again power will flow to the opposite coil (7). This will attract the lever positioned over the armature (4) causing it to pivot. When it pivots it will push the spring with the catch on it (5) to move out of the way and allow the contact to move back into the original position so that the armature (2) restores contact with the original contact (1).

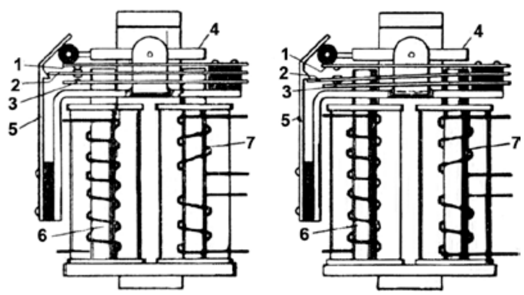


Figure 1–17. Latching relay.

Reed relays

Reed relays, like basic relays, have physical contacts that are mechanically actuated to open/close a path. For reed relays, however, the contacts are much smaller than those used in electromechanical relays. Reed relays are made of coils wrapped around reed switches. The reed switch is composed of two overlapping blades made of a material that reacts to magnets like steel or nickel (called reeds) sealed within a glass capsule that is filled with an inert gas to prevent corrosion. The reeds have contacts on their overlapping ends. When the coil is energized, the two reeds are drawn together by the magnetic lines of force so that their contacts complete a path through the relay (fig.1–18, a). When the coil is de-energized, the spring force in the reeds pulls the contacts apart (fig. 1–18, b).

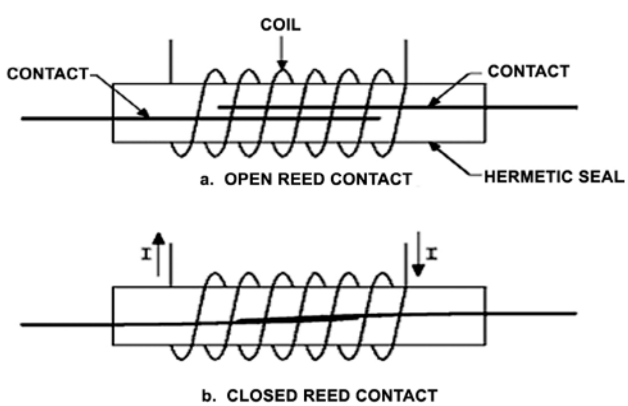


Figure 1–18. Reed relay.

Solenoids

First, let's do a refresher on the basics of solenoids. Solenoids operate similarly to relays in the fact that they rely on the interaction of magnetic fields to metals that are reactive to them. The inner shaft of a solenoid is a piston like cylinder made of iron or steel, called the *plunger*. The magnetic field then applies a force to this plunger, either attracting or repelling it. When the magnetic field is turned off, a spring then returns the plunger to its original state (fig. 1–19).

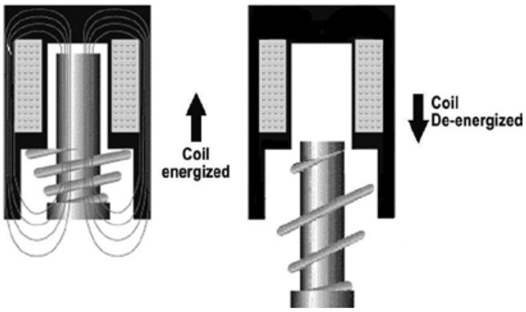


Figure 1–19. Solenoid operation.

As a 2W1, you will see solenoids in various pieces of equipment. For example, nearly every bomb rack uses solenoids to hold the loops that allow the pilot to release munitions in either an armed condition or in an unarmed state. Solenoids are also common features in aircraft gun systems for actuating levers that allow cam path selection to allow or prevent firing of rounds.

407. Schematic symbols

In the study of electronics, circuit designers use many symbols to enable us to understand complex circuits. Just as a road map designers use lines and symbols to allow us to visualize highway networks, circuit designers use lines and symbols to diagram the road or path of electronic circuits.

Throughout your career, you'll be working with schematics and wiring diagrams containing symbols used to simplify the reading of these circuits. All aircraft and munitions depend on electronic circuits for arming, releasing, and performing the task they were designed to do. Your understanding of these circuits depends on your ability to read and learn the language of schematic symbols and diagrams.

An electrical circuit must be *a complete path for current to flow*. A circuit always consists of a power source, a load (operating unit), and conductors (wires). Figure 1–20 shows the pictorial and schematic diagrams of a very simple circuit, like the one we just discussed. As you can see, it's a circuit operating a lamp. Using a pictorial diagram, although easy to understand, is not practical for large circuits; for this reason, schematic symbols and schematic diagrams were devised. Review figure 1–20 closely and note the similarities in the two diagrams; also note the difference in their sizes.

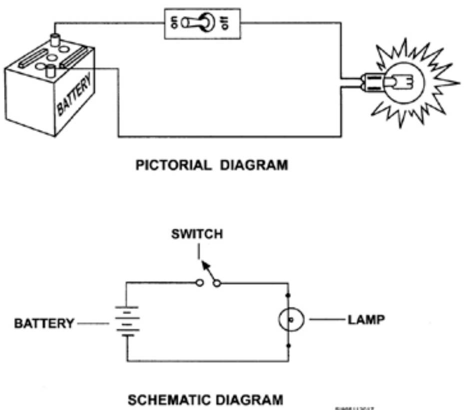


Figure 1-20. Simple circuit

Obviously, schematic diagrams are a lot more convenient and easier to understand if you know what the symbols mean. See figure 1–21.The clarity provided by symbols would be very apparent if you compared a pictorial diagram of an F–15 with its schematic diagram. To help you save time by using symbols instead of pictures, we've compiled numerous commonly used symbols with their explanations in the following table.

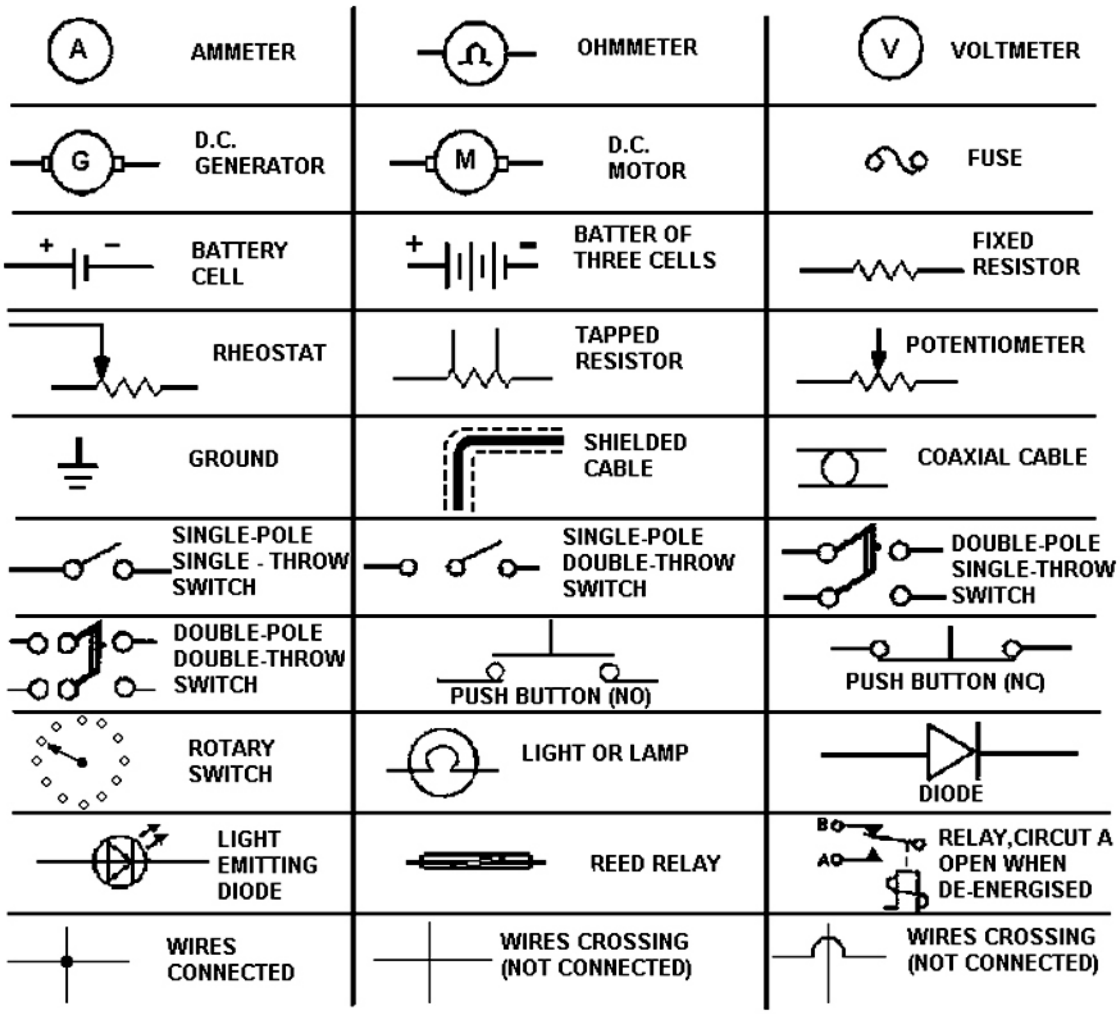
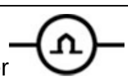
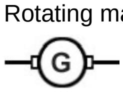
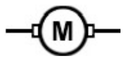
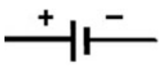
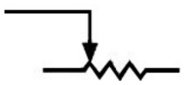
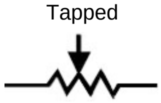
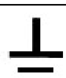
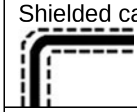
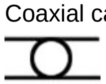
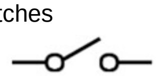
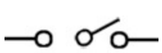


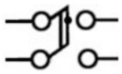
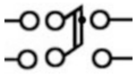
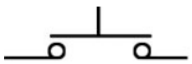
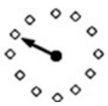
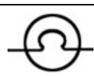
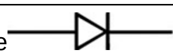
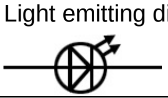
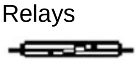
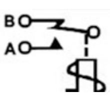
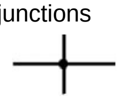
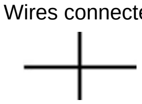
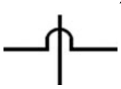
Figure 1–21. Schematic symbols.

Common Schematic Diagram Symbols	
Symbol	**Explanation**
Ammeter 	An ammeter measures current flow in amps.
Ohmmeter 	An ohmmeter measures resistance to current flow.
Voltmeter 	This component measures voltage in volts.
Rotating machines  DC generator	A generator converts mechanical energy to electrical energy. A motor converts electrical energy to mechanical energy.

Common Schematic Diagram Symbols

Symbol	Explanation
 DC motor	
Fuse 	A fuse is a protective device for its circuit.
Batteries  Battery cell  Battery of three cells	In the single- or multi-cell battery, the short line represents the negative terminal and the longer line represents the positive terminal. The negative terminal of one cell is connected to the positive terminal of another cell, and so on. In instances where the schematic symbol represents a multi-cell battery, it can mean either multiple cells in a single case (e.g., a 12-volt car battery) or an array of single cell batteries arranged to function like a multi-cell battery (e.g., a flashlight that contains multiple batteries in the handle).
Resistors  Fixed  Rheostat  Tapped  Potentiometer	There are several varieties of resistors. The fixed resistor is the most common and comes in a wide range of ohm values. The rheostat is a variable resistor that's usually wire-wound and available only in low-ohm values. Another wire-wound device is the tapped resistor. Different amounts of opposition are sensed at its various taps. The potentiometer is either made of carbon or wire-wound, and it's also available in a wide range of ohmic values.
Ground 	A ground is a point in a circuit used as a common reference point from which to measure positive and negative voltages. You are probably familiar with the electrical ground on an automobile; the chassis is the common reference point.
Shielded cable 	Shielded cable has a protective jacket around the conductors to prevent interference from outside sources called "noise".
Coaxial cable 	This is wire or cable that you are familiar with carrying television or other signals. This cable is commonly used in application where signals of some sort are to be carried between pieces of equipment.
Switches  Single-pole, single throw  Single-pole, double throw	A switch is a circuit-controlling device or simply a means of turning the circuit power ON and OFF. There are numerous switch combinations that you'll learn by association. The following switches are illustrated here: 1. Single-pole, single-throw (SPST) – You are familiar with the standard light switch. 2. Single-pole, double-throw (SPDT) – This switch has two possible settings it can be on, for example forward or reverse on an electric drill.

Common Schematic Diagram Symbols

Symbol	Explanation
 Double-pole, single throw  Double-pole, double throw  Push button (NO)  Push button (NC)  Rotary	3. The double-pole, single throw (DPST) and the double-pole, double-throw (DPDT) are simply the same switches as above, but multiple circuits are affected by the switch position. 4. Push button switches are shown in their normal or biased positions. On push button switches the "NO" stands for normally open. 5. The "NC" stands for normally closed. 6. Rotary switches have a single central contact with a series of contacts arrange around it.
Lamp 	A lamp can be used as a loading device or to indicate a circuit condition.
Diode 	A diode is a device placed in a circuit to control the direction of current flow.
Light emitting diode 	A diode that during its normal operation emits light is a light emitting diode; it is used *primarily* as a status indicator as opposed to a light source in weapons applications. The light may be visible spectrum, infra red, or ultraviolet.
Relays  Reed relay  Relay, circuit A open when de-energized	These are electrically operated switches. They will be represented in their de-energized state if possible.
Wire junctions  Wires connected  Wires crossing (not connected)  Wires crossing (not connected)	When two wires cross, they will be connected together and will offer another path for current. When two wires cross, but not connected, it will not offer another path for current. If they are merely crossing over each other, no electrical contact between the circuits occurs.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

403. Electrical resistance and resistors

1. What do circuit designers use resistors for?

2. What is the *most* common material used to make resistors?

3. What are the common power ratings for carbon-composition resistors?

4. Where are wire-wound resistors used?

404. Switches

1. What are the two common components shared by all switches?

2. What does the term “throw” refer to in relation to switches?

3. Briefly explain the construction of a rotary switch.

405. Circuit-limiting devices

1. What happens in a fuse when it “blows”?

2. Fuses come in what two types?

3. Which are used more commonly, fuses or circuit breakers? Why?

406. Relays and solenoids

1. What is the term used to identify a circuit that is switched by a relay?

2. What type of relay has two de-energized states?

3. What type of relay is sealed in a glass capsule?

407. Schematic symbols

1. What three things are required to form a circuit?

2. Match the following terms in column A with the schematic symbols from figure 1–22 by writing the letter of the symbol in the blank preceding the term in column A.

Column A

____ (1) Fuse.
____ (2) Diode.
____ (3) Tapped resistor.
____ (4) Battery.
____ (5) Rheostat.
____ (6) Potentiometer.
____ (7) Lamp.
____ (8) Ground.
____ (9) Coaxial cable.
____ (10) Rotary switch.

Column B

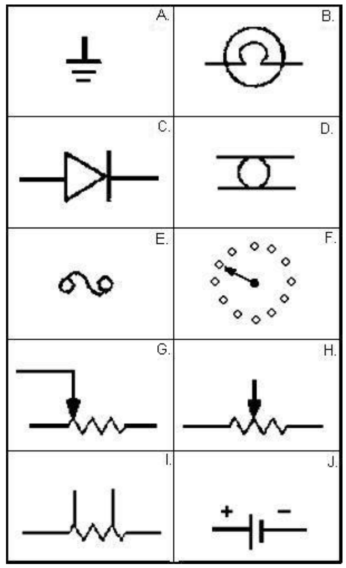


Figure 1–22. Schematic symbols.

Answers to Self-Test Questions

401

1. Substances with tightly bound orbiting electrons held firmly in place by the nucleus.
2. The volt (V).
3. The movement of electrons through a conductor.
4. The amount of resistance change in relation to temperature.
5. If the thumb of the left hand is extended in the direction of current flow and the fingers clenched, then the rough circles formed by the fingers indicate the direction of the magnetic field.

402

1. An anode, a cathode, and an electrolyte.
2. A device that converts mechanical energy into electrical energy.
3. The object has gained or lost a large amount of electrons.

403

1. To control the current flow and keep it below the maximum limit of the circuit.
2. Carbon.
3. ¼ to 2 watts.
4. In circuits where the power requirement exceeds 5 watts.

404

1. Contacts and actuators.
2. One of two or more positions that the switch can adopt.

3. In a rotary switch there is a single contact usually located in the center that is surrounded by a series of contacts arranged around the outside.

405

1. The link melts and opens the circuit.
2. Regular and slow-blow.
3. Circuit breakers. They can be easily reset an indefinite number of times.

406

1. The controlled circuit.
2. A latching relay.
3. A reed relay.

407

1. A circuit always consists of a power source, an operating unit (load), and conductors (wires).
2. (1) E.
   (2) C.
   (3) I.
   (4) J.
   (5) G.
   (6) H.
   (7) B.
   (8) A.
   (9) D.
   (10) F.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Unit Review Exercises**Note to Student:** Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (401) Which of the following substances is an insulator?
   a. Iron.
   b. Gold.
   c. Glass.
   d. Silver.

2. (401) What is the unit of measure for movement of electrons through a conductor?
   a. Volt.
   b. Watt.
   c. Amp.
   d. Ohm.

3. (401) What does the term *current* refer to?
   a. Total resistance present in a circuit.
   b. Amount of electrical pressure in the circuit.
   c. Amount of power being transmitted through a conductor in 1 second.
   d. Quantity of electrons flowing past a given point during 1 second.

4. (401) What is the unit of measurement for resistance to current flow?
   a. Volt.
   b. Watt.
   c. Amp.
   d. Ohm.

5. (401) Any time that a conductor serves as the path for electrons to flow, it
   a. becomes ionized.
   b. develops a static charge.
   c. develops a magnetic field.
   d. temperature coefficient changes.

6. (401) What effect does arranging the conductor into a coil have on the magnetic lines of force?
   a. It forces them to cross.
   b. They are weakened.
   c. They are concentrated.
   d. A coil has no effect on magnetic lines of force.

7. (401) What effect will increasing the current have on an electromagnet?
   a. Strengthens the magnetic field.
   b. Raises the temperature coefficient.
   c. Lowers the temperature coefficient.
   d. Raises the resistance offered by the conductor.

8. (402) Which component of a battery generates the negative charge during operation?
   a. Cathode.
   b. Anode.
   c. Diode.
   d. Electrolyte.

9. (402) The flow of electrons in a battery is *always* from the
   a. cathode to the anode.
   b. anode to the cathode.
   c. diode to the anode.
   d. anode to the diode.

10. (402) If a conductor is passed through a magnetic field so that it will pass through the magnetic lines of force, it will generate
    a. electrical current.
    b. electrical resistance.
    c. magnetic resonance.
    d. thermal coefficient changes.

11. (402) In a generator, the electrons in the conductor nearest the south pole will be drawn *towards* the side of the coil that is closest to the
    a. magnetic dipole.
    b. source of current.
    c. north pole of the magnetic field.
    d. south pole of the magnetic field.

12. (402) Static electricity refers to
    a. electricity at rest.
    b. variable electricity.
    c. balanced electricity.
    d. continually moving electricity.

13. (402) Static charges tend to remain in the localized area of contact for long periods in
    a. resistors.
    b. insulators.
    c. capacitors.
    d. conductors.

14. (402) The conductivity of some insulating materials is increased by the absorption of
    a. air under low-humidity conditions.
    b. heat under high-humidity conditions.
    c. moisture under high-humidity conditions.
    d. moisture under low-humidity conditions.

15. (403) Which electrical component is designed to offer a predetermined amount of opposition to current flow in a circuit?
    a. Filter.
    b. Diode.
    c. Resistor.
    d. Capacitor.

16. (403) The actual value of carbon-composition resistors can vary from
    a. 1 to 5 percent.
    b. 5 to 10 percent.
    c. 1 to 15 percent.
    d. 5 to 20 percent.

17. (403) Wire-wound resistors are normally used in circuits where power requirements exceed
    a. 2 watts.
    b. 3 watts.
    c. 5 watts.
    d. 10 watts.

18. (403) Wire-wound resistors are more accurate than carbon-composition resistors because of their
    a. large size.
    b. extreme cost.
    c. large current carrying capacity.
    d. adjustable wire length capability during manufacture.

19. (403) A three-terminal variable resistor is a
    a. rheostat.
    b. fixed resistor.
    c. potentiometer.
    d. tapped resistor.

20. (404) What are the two basic components of a switch?
    a. Contacts and levers.
    b. Contacts and throws.
    c. Actuators and levers.
    d. Contacts and actuators.

21. (404) What is the moveable part of the switch that is manipulated to complete or open the electrical circuit or circuits to allow or inhibit the flow of electrons?
    a. Actuator.
    b. Contact.
    c. Throw.
    d. Lever.

22. (404) Which term refers to one of two or more positions that the switch can adopt?
    a. Pole.
    b. Throw.
    c. Position.
    d. Direction.

23. (404) Which manual switch contains a spring or some other restoring force that returns the actuator to a certain position?
    a. Polled.
    b. Biased.
    c. Governed.
    d. Controlled.

24. (405) Fuses in electrical systems are rated according to the
    a. power they dissipate for the circuit.
    b. resistance they produce in the circuit.
    c. voltage load they can carry without blowing.
    d. ampere load they can carry without blowing.

25. (405) Which type of circuit breaker is opened by a coil when the current exceeds the value set at the factory?
    a. Thermal.
    b. Magnetic.
    c. Fast-blow.
    d. Slow-blow.

26. (405) Which type of thermal circuit breaker can be opened as well as closed by the operator?
    a. Toggle.
    b. Switch.
    c. Magnetic.
    d. Bimetallic strip.

27. (406) Which electrical device is used to mechanically switch electrical circuits?
    a. Relay.
    b. Diode.
    c. Resistor.
    d. Capacitor.

28. (406) Circuit designers call a circuit switched by a relay the
    a. primary circuit.
    b. actuating circuit.
    c. secondary circuit.
    d. controlled circuit.

29. (406) Relays are made to operate on a
    a. small amount of current.
    b. large amount of current.
    c. small amount of voltage.
    d. large amount of resistance.

30. (406) What part does the magnetic force of a solenoid apply to?
    a. Armature.
    b. Actuator.
    c. Plunger.
    d. Slide.

31. (406) What restores a solenoid to its de-energized state?
    a. Spring.
    b. Counter weight.
    c. Re-loading mechanism.
    d. Pressurized gas cartridges.

32. (407) What three components are found in all circuits?
    a. Power source, load, and resistors.
    b. Power source, load, and conductor.
    c. Power source, wires, and conductors.
    d. Power source, resistors, and conductor.

33. (407) Light emitting diodes are *primarily* used in weapons system applications as
    a. current restrictors.
    b. heating elements.
    c. status indicators.
    d. light sources.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. Electrical Inspection, Maintenance, and Repair

YOU MAY have seen burnt wires or broken electronic components. In the process of working with electrical equipment, there is always the potential of damaging electrical equipment or injuring personnel. This unit covers basic electrical maintenance principles to help you prevent damage from occurring.

2–1. Inspection, Maintenance, and Repair

Electronic equipment must be inspected and maintained to operate properly. It must also be repaired when necessary. Technicians should not attempt to repair electrical equipment unless they are authorized to do so and have received the proper training. As most people have found out from experience, electricity can hurt if handled improperly.

408. Electrical inspection and cleaning

In today's military, aircraft electrical wiring systems can no longer be considered a subsystem of another major component. Normal operational environments, maintenance, modifications, and conversions can and do contribute to wiring system stress, deterioration, and deficiencies. These wiring systems which are comprised of individual wires, cables, groups, bundles, and harnesses located throughout the entire airframe have necessitated the establishment of inspection criteria.

Electrical inspection

Visually inspect all electronic equipment following any repair action before testing. The intent of this inspection is to detect obvious defects that could cause additional damage to equipment if power is applied. The visual inspection consists of, but is not limited to, checking for the following conditions in the table below.

Electronic Equipment Visual Inspection Guidance	
Condition	**Description**
Overheating of electronic components.	Evidence can include discoloration, warping of plastic or other non-metallic components, build up of carbon or other deposits, or even the "burned" smell common to electrical overheating.
Loose or missing mechanical hardware.	Wear from loose parts may be evident by worn paint or other protective coatings. Components may wiggle when touched or have a rattling sound when moved.
Proper mechanical operation of controls.	Common control issues are failure of detents to hold their proper settings or binding of controls necessitation "forcing" of controls into settings.
Frayed, burnt, pinched, or broken wires.	Use care when inspecting wires to look for signs of damage evidence such as broken or frayed outer braided coverings or distortions in insulative coverings.
Securely mounted chassis-mounted components and printed circuit cards.	A key indicator of this can be rattling of components during handling.

Electronic Equipment Visual Inspection Guidance	
Condition	**Description**
Secure and serviceable mechanical, crimped, and soldered connections.	The easiest way to discover this is lightly tugging on components. The force applied must not be enough to damage the components, just enough to detect loose components.
Missing, damaged, recessed, or bent connector contacts and serviceable insulation.	Careful visual inspection is the only way to detect these defects. Take your time and look carefully at all components in the effort to detect damage.
Mechanical integrity of case.	A warped or cracked case damages the environmental countermeasures built into systems and can subject them to harsh environments that they were never intended to encounter.

You can find further guidance for the inspection of electrical components in Technical Order (TO 1–1A–14, *Installation and Repair Practices Aircraft and Electronic Wiring*. This TO not only carries information on inspections but also repair information that is applicable across all aircraft wiring systems.

Electrical cleaning

Any technician that has spent even a little time in an operational environment is intimately familiar with the inherent "dirtiness" of aircraft. Your systems are surrounded with lubricants (oils and grease), environmental contaminants (sand and dust), residue from wear susceptible parts (brake dust), and even biological agents (mold or bird strike residue) that will constantly need to be removed from components as a normal part of maintenance.

You must use only approved cleaning solvents to clean electrical equipment, components, or devices. Remove electrical power and install proper lockout devices to prevent energizing the item prior to the completion of cleaning. Vacuuming is considered an effective method for cleaning dust and debris from circuit devices. Consider the use of compressed air for cleaning *only* as a last resort. Don't allow the maximum pressure to exceed 30 pounds per square inch (psi).

409. Chafing awareness and prevention

Wires and wiring harnesses in aircraft take a great deal of punishment on a daily basis. If you stop and think about it, they are constantly twisted, turned, scraped, and pulled in some form or fashion. In your job as an aircraft armament systems journeyman, you deal with some type of wires or wiring harness in almost every task you perform. For example, during pylon removal and installation, you connect and disconnect harnesses. During loading operations, you check for security of the bomb rack wiring harness to the pylon. The examples are endless. A question you should be asking yourself every time you do one of these tasks is, "Are the harnesses damaged due to chafing?" Chafing is becoming a very serious problem with aircraft wiring today. You should know what causes chafing, what kind of problems chafing can cause, and how to prevent chafing.

What is chafing?

Chafing is nothing more than some type of constant friction (rubbing, scraping, etc.) between wiring harnesses and electrical components or between wiring harnesses and the structure to which they are attached. A noninsulated splice inside a wire bundle that rubs against an adjacent wire, can cause the insulation to wear off. Also, improperly installed wiring harness that rub back and forth against the hinge of an access door in the aircraft are common examples of chafing problems. Chafing can occur regardless of whether an aircraft is on the ground or in the air. The damage caused by something as simple as wire chafing could have minimal or catastrophic results depending upon the situation. In all cases, chafing is costly and can be prevented.

Chafing indicators

You can recognize or identify a chafing problem in two different ways. First you may see exterior damage to a single wire or wiring harness in the form of a cut to the insulation or just worn insulation. This should alert you to investigate the damage further, identify the cause of the damage, and repair as necessary. Exterior damage is probably the *most* obvious form of chafing. Secondly, you may encounter a malfunction of a system during a functional or electrical check. This can be caused by a wire shorted out against some component or against another wire. The unserviceable condition of any wiring component should alert you to a potential chafing problem.

Chafing causes

Chafing can have many causes ranging from improper wire routing during aircraft wiring installation to the failure of the components used to secure a wiring harness. We will not attempt to cover all these areas here, but we will address the two most common causes of chafing—excessive slack and improper fasteners.

Slack

Chafing can occur if excessive slack is allowed to exist between support points, such as cable clamps, when single wires or wire bundles are installed. Excess slack allows a wire or wire bundle to rub against the surface of the aircraft or another component and causes wear. Normally, do not let slack between support points exceed ½ inch (fig. 2–1). You can exceed this requirement if the wire bundles are thin and the clamps are positioned far apart, but never let the slack be so great the wiring can touch another **surface** and chafe. Slack can be allowed near each end of any wiring bundle for any or all of the following reasons:

1. Permit ease of maintenance.
2. Allow replacement of terminals at least twice.
3. Prevent mechanical strain on the wires, cables, junctions, and supports.
4. Permit free movement of shock-and-vibration-mounted equipment.
5. Permit shifting of equipment for purposes of maintenance while installed in the aircraft.

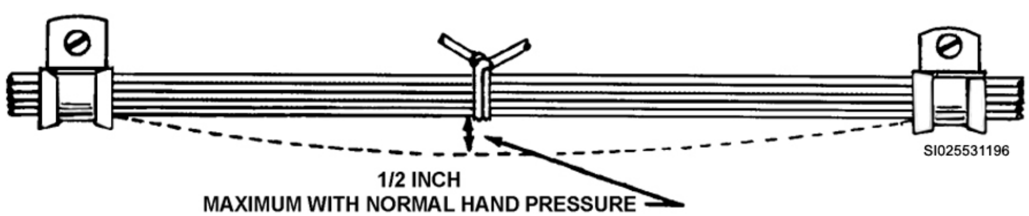


Figure 2–1. Slack between supports.

Improper fasteners

Clamps are a common method of anchoring aircraft wiring. These items must be installed properly and the correct clamp used; otherwise, chafing occurs. Clamps normally come with a rubber grommet; a missing grommet can cause chafing by allowing the metal edges of the clamp to contact the wiring. Loose-fitting clamps are another cause, because they allow wiring to move and rub on the aircraft structure, causing them to wear.

Preventing chafing

There are no real set cures for preventing chafing other than adhering to proper maintenance procedures. What we attempt to do here is explore things you can do to ensure the aircraft wiring is mechanically and electrically sound.

Proper routing and installation of wires and harnesses goes a long way in preventing chafing. The following is a list of general precautions for you to observe when routing and installing aircraft wiring or bundles:

1. Wherever practical, route wires and/or bundles parallel with, or at right angles to, ribs of the aircraft, as shown in figure 2–2.
2. Route coaxial cable as directly as possible. Avoid unnecessary bends in the cable.
3. Do *not* permit wire or wire bundles to have movement or frictional contact with any other object.
4. Route coaxial cable as directly as possible. Avoid unnecessary bends in the cable.
5. Do *not* permit wire or wire bundles to have movement or frictional contact with any other object.

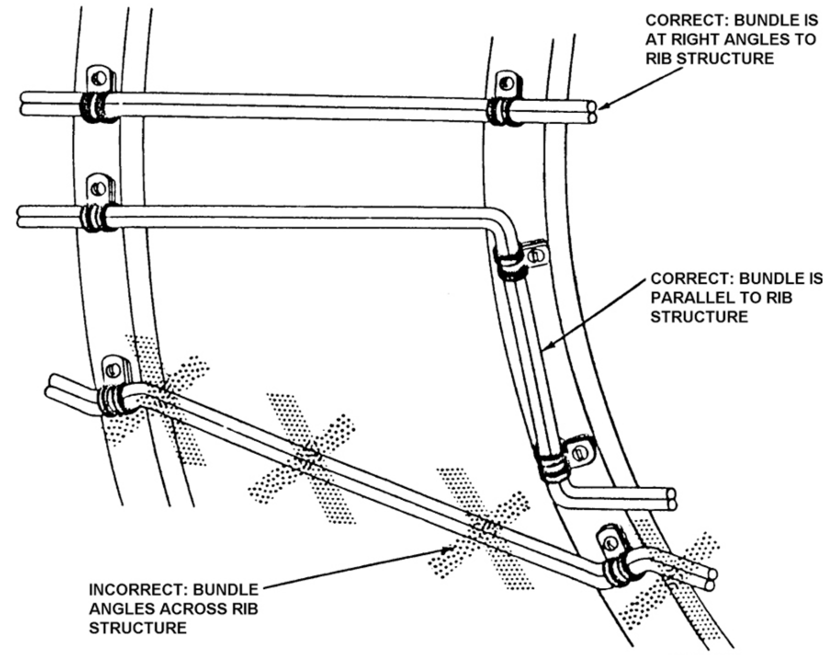


Figure 2–2. Routing bundles.

6. Do *not* permit wire or wire bundles to contact sharp edges of structure, holes, and so forth.
7. Do *not* use any installation tools other than those specifically authorized.
8. Do *not* damage threads of attaching hardware by overtightening or cross threading.
9. Do *not* subject wire bundles to sharp bends during installation.
10. Do *not* allow dirt, chips, loose hardware, lacing tape, scraps, etc., to accumulate in enclosures or wire bundles.
11. Do *not* hang tools on wire bundles as this could cause excess slack or pull the bundle loose at the connector.
12. Do *not* compensate for wires that are too long by folding them back on themselves and hiding the fold inside a bundle.
13. Ensure you use the proper hardware to install harnesses and you are aware of the dos and don’ts in figure 2–3.
14. Ensure wires or wire bundles do not come within ¼ inch of the edge of a hole when routed through a bulkhead opening and when a suitable grommet and clamp is installed. The ¼-inch criterion may vary according to the particular application, but generally, not closer than ¼ inch is a good criterion to follow.

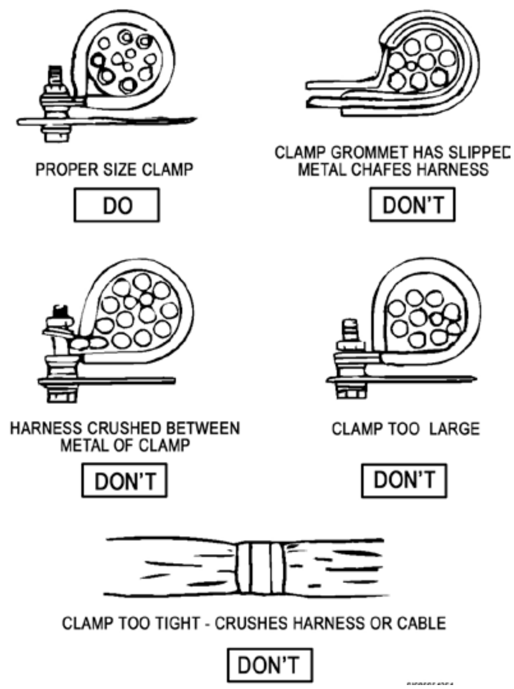


Figure 2–3. Typical clamp installation conditions.

Just remember, there is no set cure to stop chafing, except following proper maintenance procedures.

Chafing awareness program

Chafing awareness program is a mandatory program for all fighter aircraft units and other mission design series (MDS) according to applicable MDS technical data. Quality assurance (QA) monitors and tracks instances of wire, harness, and metal lines/tube chafing. When notification is received of a potential chafing problem involving like aircraft model, lot number or block of aircraft exists, 10 percent of assigned aircraft are inspected

Based off the 10 percent findings, the chief QA inspector *must* recommend initiating a one-time inspection (OTI) if the sampled aircraft indicate a chafing problem or the detected chafing is an operational safety hazard. QA *must* use a database for the purpose of tracking wire and harness chafing problems identified though OTIs and maintenance cross-tell reports.

NOTE: It is all of our duties to be aware chafing is a problem, and our duty to properly document the required forms, as well as, notify the correct individuals when we detect a potential hazard.

410. Coaxial cable maintenance

Coaxial cable assemblies are used more and more in today's aircraft systems and modern test equipment. Basically, they are used to carry radio frequency (RF) power from one point to another.

Cable assembly description

You will find coaxial cable being used as part of the air-to-ground missile (AGM)–65 video systems and the military standard (MIL–STD)–1760 cables used with the newer munitions. This means if the cable or connector breaks during loading, you repair it. A coaxial cable assembly consists of two RF connectors and the coaxial cable itself. The RF connectors used on coaxial cables are either pin-contact type plugs or socket-contact type plugs (fig. 2–4). These are bayonet nut connector (BNC)-series connectors and are preferred for use in Air Force applications. These are small, lightweight, bayonet-type, quick-connect/disconnect connectors used with small coaxial cables.

Coaxial cable, itself, is really quite different from any other type of wiring. It consists of an inner (center) conductor separated from the outer conductor, usually called a *shield*, by an insulating dielectric. The cable is protected against moisture and abrasion by a tough outer jacket. Figure 2–5 shows typical coaxial cables.

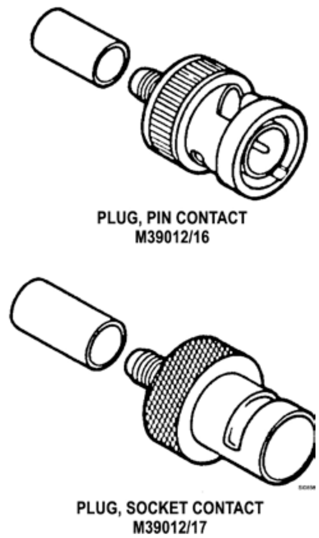


Figure 2–4. Quick-connect/disconnect coaxial connectors.

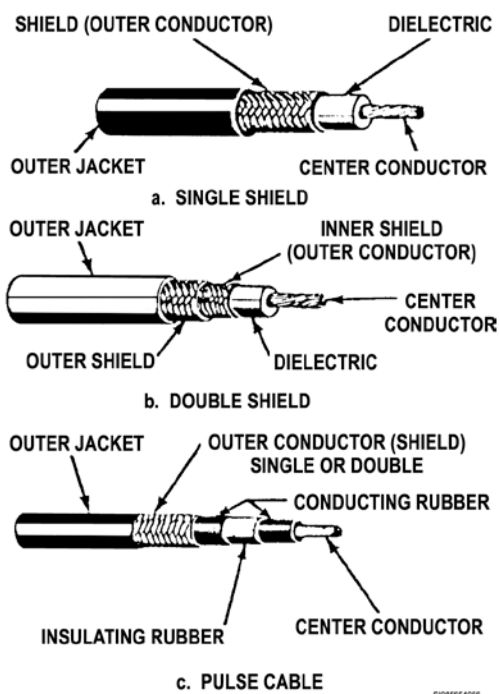


Figure 2–5. Typical coaxial cables.

The inner conductor of coaxial cable is normally copper, either solid or stranded, and may be bare, tin-plated, or silver-plated. The outer conductor (shield) is usually a copper braid that may be bare, tin-plated, or silver-plated (fig.2–5, A). This braid is woven over the dielectric. Some coaxial cables you come across may have a double outer conductor (double shield) to provide extra shielding (fig. 2–5, B). The dielectric of the cable has two primary functions:

1. To provide low loss insulation between the inner conductor and the outer conductor.
2. To maintain the relative position of the inner conductor inside the outer conductor and, therefore, keep the capacitance between the two at a constant value.

The most common materials used in the construction of the dielectric are polyethylene (PE), polypropylene (PP), fluorinated ethylene propylene (FEP), and polytetrafluoroethylene (PTFE). You can interchange cables with different types of dielectric if they are of the same physical and electrical characteristics.

Triaxial wire is used for video signals and serial digital transfer. Connectors are assembled in the same manner as coaxial connectors except there is an extra shield. Figure 2–6 shows a typical triaxial connection.

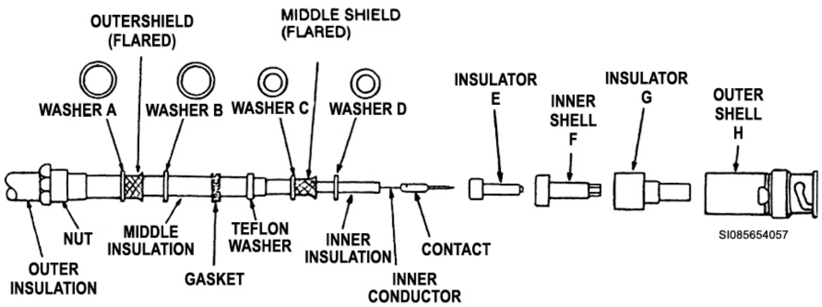


Figure 2–6. Triaxial connector assembly.

Military Standard–1760

Weapons troops for decades have wandered into the back of dusty and cobweb filled storage locations looking for cables to connect various stores or launchers to aircraft. Almost universally, all have said, “Why do we need all of these different cables?” In the past, most every cable/connection in the inventory was a custom made component created specifically for a particular system on a particular aircraft. While it would do a single job well in a particular situation, it was useless in every other application.

With a new generation of Global Positioning System (GPS)-guided munitions and launchers coming online in the early 1990s, the services operating combat aircraft realized there was a potential for saving considerable amounts of money and work if all services and contractors could agree on a single interface for future munitions. The interface that incorporated the standards they settled on became the military standard (MIL–STD)–1760. Figure 2–7 shows a typical MIL–STD–1760 compliant cable and figure 2–8 shows the typical MIL–STD–1760 compliant connector face. This standard defines implementation requirements for the aircraft/store electrical (and fiber optic) interconnection system (AEIS) in aircraft and stores. This interconnection system provides a common interfacing capability for the operation and employment of stores on aircraft. While this standard does not completely eliminate the need for different cables required for configuration of aircraft, it does lessen the burden on you and other maintainers.

Figure 2–7. Generic MIL–STD–1760 compliant cable.

Figure 2–8. Generic MIL–STD–1760 compliant connector face.

However, for the MIL–STD–1760 to be so versatile, it needs to be more complicated. In the past, cables have been little more than multi-wire extension cords for the equipment or munition. The MIL–STD–1760 compliant cable incorporates its own electronic components to properly relay signals between the aircraft and stores (fig. 2–9). As you can see from the figure, the cable contains its own electronic components to perform its job. Because of this increased level of sophistication contained in these cables, they need to be handled by maintainers in a sufficiently cautious manner to avoid damage.

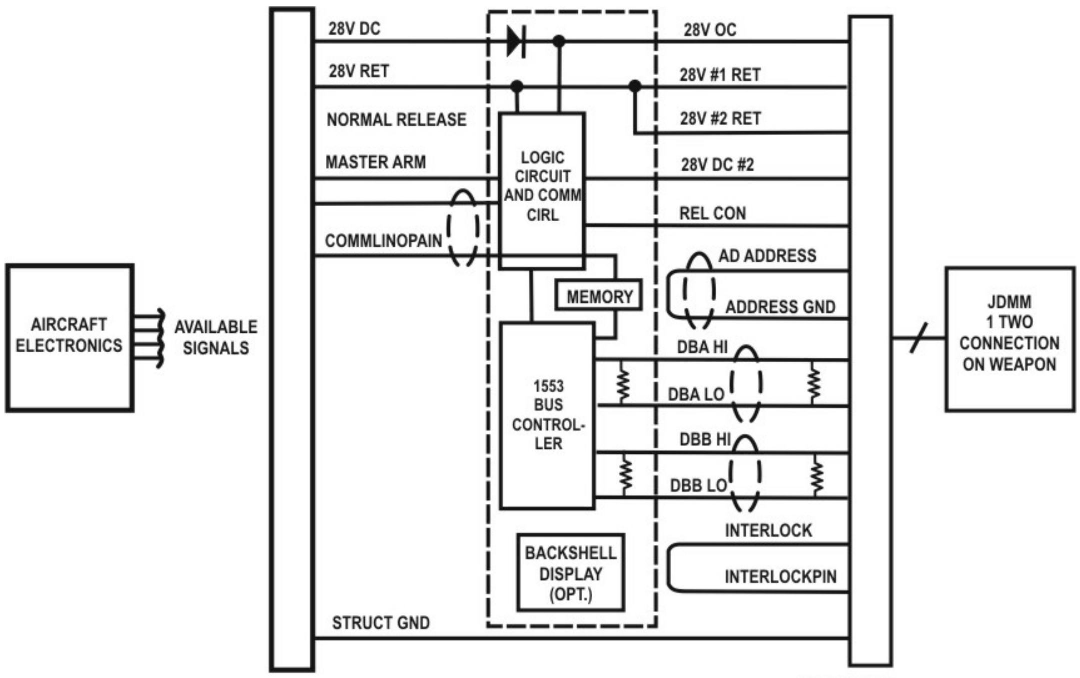


Figure 2–9. MIL–STD–1760 compliant cable schematic.

Cable handling precautions

A good connection depends on holding coaxial and triaxial cable and connectors to their original design dimensions. Any change in dimensions causes added losses to the RF or video signal carried in the cable and can cause radiation interference in the circuit. It is important you follow the directions of each type of connection made to the coaxial or triaxial cable to avoid any future problems. The following precautions are common to all triaxial cable assemblies and coaxial RF connectors:

1. When working with coaxial cable, *never* step on the cable, set anything heavy on it, or bend it sharply. This will flatten the cable and change its electrical characteristics. Handle coaxial cable carefully at all times. Anything that damages it or may lead to it being damaged later reduces the efficiency of the system.
2. Do *not* use pliers to assemble or disassemble RF connectors.
3. Do *not* misplace the pins and sockets for the RF connectors which are usually packed, unassembled.
4. Use care when starting the braid clamp nut into a plug or jack body to prevent cross threading.
5. Keep your soldering iron clean, smooth, and well tinned at all times if the center pin is to be soldered in place during assembly or repair.

General repair procedures

Just like conventional wiring, coaxial cables or their connectors can break or become damaged and require repair. Normal procedures involve replacing the entire coaxial assembly if the cable actually breaks. Only attempt splicing coaxial cable in an emergency situation. Follow the procedures in TO 1–1A–14.

411. Electrical repairs

We work with wire bundles extensively in equipment and on the aircraft. When we have a malfunction, we may have to break into wire bundles to repair the cause. Only competent, qualified personnel should do electrical repairs. As an aircraft armament systems technician, you need to learn how to handle electrical circuits properly and how to work on aircraft and suspension equipment safely. ~~Air Force Instruction (AFI) 91–203, *Air Force Consolidated Occupational Safety Instruction*~~, chapter 8, states the general guidelines on safety while working with electrical equipment.

CAUTION: Generally, disconnect electrical items from the power source when you are performing maintenance on the item.

In some cases, electrical power may need to be applied for testing, troubleshooting, and adjustment. In cases where electrical power is to remain on, take precautions to prevent accidental shock. If the voltage applied to an item exceeds 300 volts, a safety observer is required. Complete the task only when authorized to do so by the applicable TO, the manufacturer's guidelines, or other approved procedures or directives.

Do *not* use lead pencils, screwdrivers, or other unapproved tools to test any piece of electrical equipment. Use only items authorized for use by technical data or manufacturer's guidelines for adjustment or repair of electrical items.

CAUTION: Do *not* hold meters in your hands while performing measurements on energized circuits or equipment.

When it is necessary to handhold meters or meter cables, wear gloves or use effective personal protective equipment. When performing tests, keep the workbenches clean at all times. When voltage is applied to equipment being repaired or tested, personnel must remove all tools and equipment that are not essential to the test from the bench. Ground any metal workbench when you use it for repairing and testing of electronic equipment. Workbench stools should be made of wood, fiberglass, or other non-conducting materials.

412. Cable repair

On the end of every cable assembly/wire bundle (fig. 2–10) is some type of connector. Knowing this, let's say a pin in the connector was bent or broken and needed repair; you cannot repair it until you remove the protective boot from the cable assembly or wire bundle. Let's also suppose you have a broken wire under the bundle braid that needs to be repaired. This leads you into removing and repairing the braid bundle and splicing the wire. Therefore, before we even think about our initial connector problem, you must be familiar with the maintenance used on a cable assembly or wire bundle.

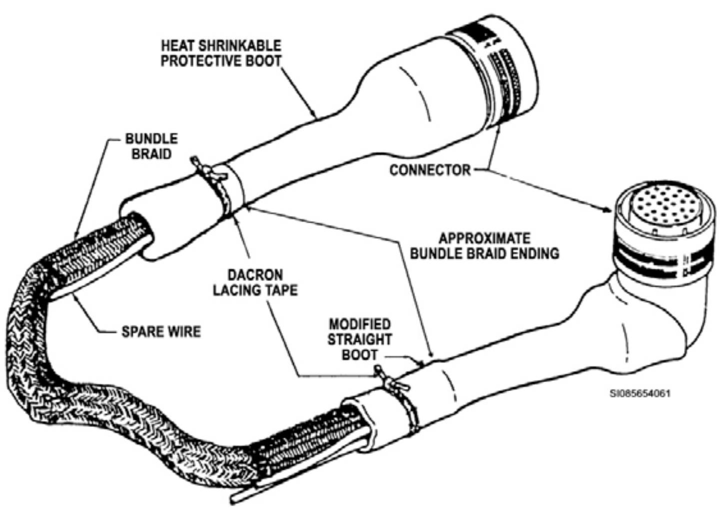


Figure 2–10. Typical cable assembly.

Removing and installing protective boots

A protective boot, as its name implies, is used to cover or protect the exposed-wire access area between the rear of a connector and the end of the bundle braid on cable assemblies or wire bundles.

Removing

The removal of this item normally allows you direct access to the connector so you can repair it if you need to. If it is at all possible to salvage a protective boot, do so. You remove the boot by using a small-blade screwdriver to pry the boot from the connector. You also have to cut a spot tie from the braid end of the boot and slide the boot back over the bundle. If you find it is not possible to save the boot when trying to remove it, it is permissible to cut it off. However use extreme care during this process so as not to damage the wiring underneath the boot.

Installing

When you install a salvaged protective boot, first wash the inside of the boot and connector potting with a solvent, such as Mozel no. 18, to remove the old adhesive. Allow the boot to dry thoroughly and then apply a thin film of adhesive, such as Silastic no. 140, to the washed and dried surfaces. Slide the boot in place and make a spot tie on the boot within ½ inch of the braid with Dacron lacing tape.

Essentially, installing a *new* protective boot includes the same procedures as installing a salvaged protective boot. Follow these seven steps:

1. Wash the boot with solvent and apply the same type of adhesive you used on the salvaged boot.
2. Position the new boot so, after it shrinks, the entire connector potting is covered, but do not let the boot restrict the connector coupling.
3. Using an approved heat source, apply heat to the boot starting at the connector.
4. Starting at the connector causes the boot to grip the connector firmly so the boot remains positioned during the remainder of the shrinking process.
5. Continue the shrinking process slowly, working from the connector to the braid end of the boot.
6. Apply heat evenly around the circumference and to each section of the boot before proceeding to the next section or distortion will result.
7. After completing the shrinking process, make a spot tie of Dacron lacing tape on the boot within ½ inch of the braid.

CAUTION: If you are using the heat-shrinking process on fueled aircraft, the heat source must be explosion proof. Do *not* use heat guns with electric motors, because the brushes of their motors produce sparks while they are operating. A compressed air/nitrogen heat gun kit is the *only* heat gun presently authorized around fueled aircraft.

If you require more information on this process or you need to know how to fabricate a protective boot from materials like silicone tape, refer to TO 1–1A–14.

Removing and repairing bundle braid

Bundle braid is removed to incorporate modifications or to inspect for wire damage if the braid has been damaged. You use a soldering iron with a braid cutter adapter (an ordinary tip with the sharp edges removed) to cut braid. Make a lengthwise cut along the bundle to expose the damaged/repair area and then cut the braid around the circumference of the bundle at each end of the lengthwise cut. Remove the cut section from the bundle. The cutting operation causes a ridge to form at the braid ends. Smooth off this ridge using the flat side of your soldering iron tip.

Braid repair consists of covering the exposed area of the bundle with silicone self-bonding tape. Wrap the silicone tape around the braid for one complete turn beginning within ½ inch of the braid end (fig. 2–11). Using one continuous length of tape, spiral wrap, with a 50 percent overlap, a single layer over the wires and onto the opposite braid end for a minimum of ½ inch. End the tape by wrapping it a full turn around the braid. Make a spot tie of Dacron lacing tape at both ends of the silicone tape. Another method by which you can repair the bundle braid is by using heat-shrink tubing. If you require any further information on this type of repair, refer to TO 1–1A–14.

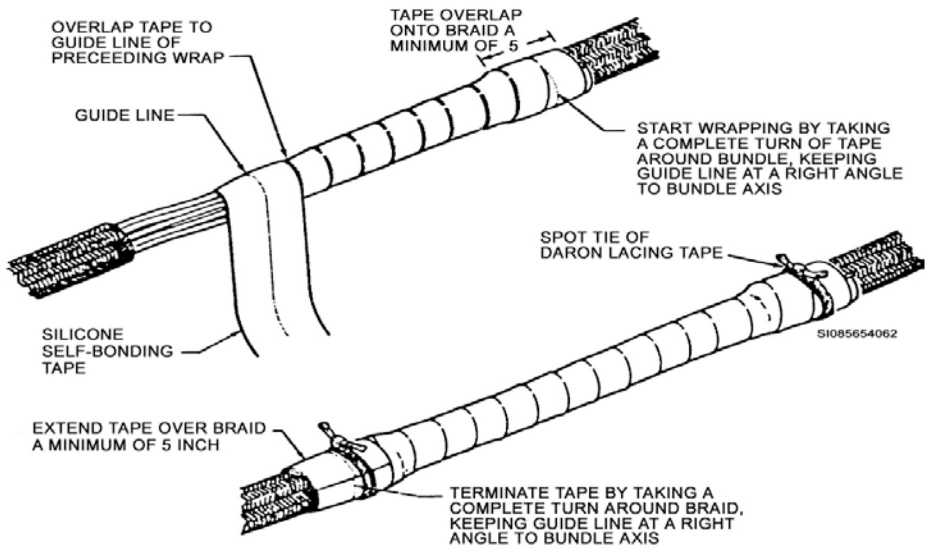


Figure 2–11. Braid repair.

Splicing wires

You *cannot* use splices on firing or control circuits associated with ordnance or explosive subsystems.

Splicing braided shielding

There may come a time when you need to do repairs on braided shielding or repair braided shielding to complete a repair on the conductor inside. This is not a particularly difficult procedure, but it requires particular techniques unique to this type of repair.

Virtually all braided shields are covered by a protective jacket of some sorts. When removing this jacket, it's important to note that you do not cut all the way through the jacket to remove it. All that is required is to score the outside of the jacket. After scoring, you must flex the jacket until it separates. The reason behind this is that the braided shield is easily damaged by sharp objects. Once the jacket is split and separated from the shield, you may use diagonal cutters or small scissors to remove sufficient jacket material to facilitate your repairs. Ensure enough jacket material is removed as to leave ½ inch undamaged braid material on both ends of the repair area available to accept a splice. To remove braid material, simply insert the nose of diagonal cutters into the holes of the braid material and cut enough of the braid away to do the required repairs. Ensure that when you are cutting away the braid material you are not cutting any of the wires contained inside the shielding itself.

At some point during the repair procedures a free end of cable must be created. This is because braided shielding is repaired using a tube consisting of replacement braid material that has been impregnated with solder and covered with a heat shrink sleeve to both seal it and secure it in place. When you create a free end of cable, you need to slide the sleeve over the exposed end to an area outside of where you are performing your repairs then continue with your repairs.

Once the required repairs are complete, slide the braid repair sleeve over the damaged area ensuring the solder impregnated ends of the replacement sleeve overlap the ½ inch undamaged braid sections you left when removing your braid material from the repair area. Heat one end of the repair sleeve using an approved heat gun with a terminal sleeve reflector. This "U" shaped device ensures that the tube receives an even distribution of heat all the way around the area you are heating. Apply heat to the overlapping shield area until the impregnated solder melts and the sleeve shrinks down onto the cable. Continue to heat the repair area until solder flows into the original cables braid strands. Heat down the length of the repair sleeve to shrink the remainder of the tube and repeat the procedure from the end you started on the terminal end of the splice. Allow the sleeve to cool undisturbed until solder solidifies.

Repairing solderless connectors

Most of our aircraft today use solderless-type connectors for termination of wire bundles or cable assemblies. We show examples of solderless connectors in figure 2–12. Many different commercial brands of solderless connectors are in aircraft armament systems. Each brand has its own repair procedures, and the tools used with each are not always the same. We do not attempt to discuss all of the various types, but our discussion does include the more common ones we use. Always refer to TO 1–1A–14 when you perform these procedures.

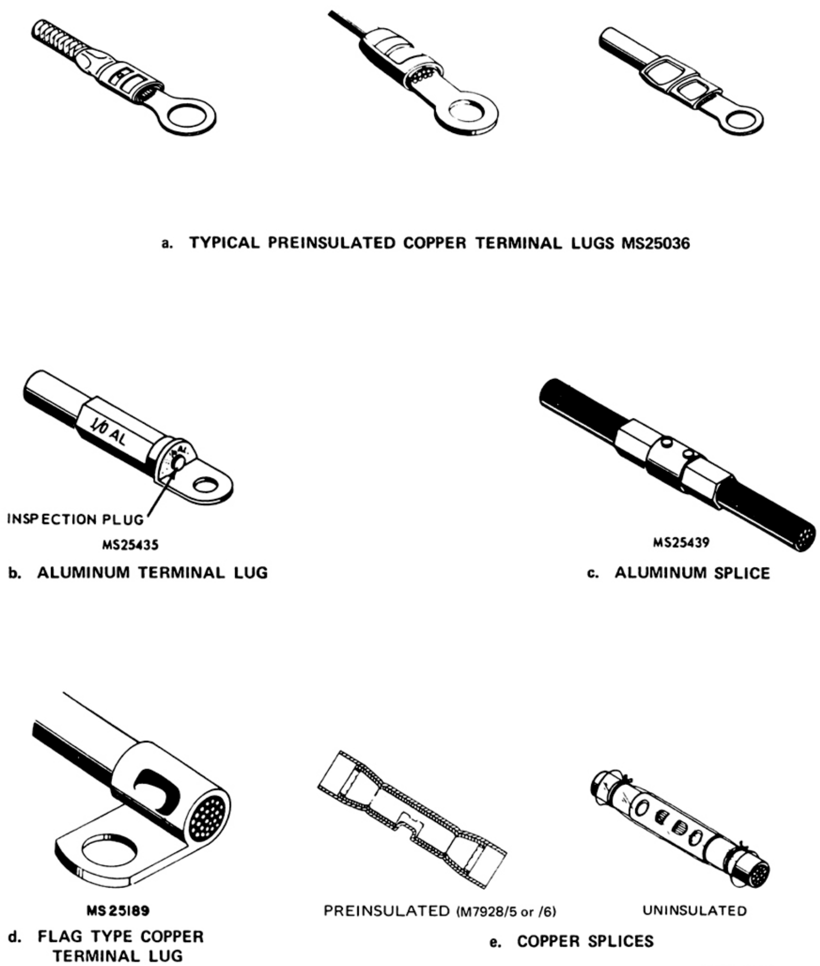
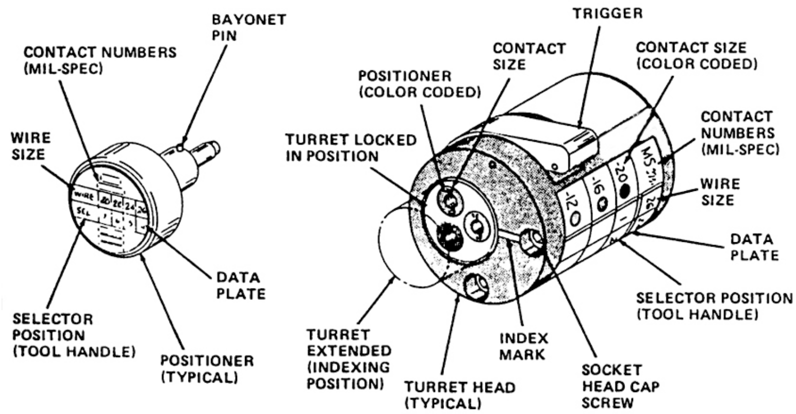


Figure 2–12. Typical solderless connectors.

Multiple-pin connectors

The pins in these type connectors are actually crimp-type contacts because they are crimped to the wires before their installation into the connector. The tools used to crimp these contacts is shown in figure 2–13. It is capable of crimping wire sizes ranging from 12 to 32 gauges. The contacts are normally installed through the rear of the connector and are removed, using special tools, by pushing from the front to the rear. The method of crimping these contacts to wires is essentially the same for all the different types of solderless connectors. The following paragraphs briefly describe procedures for crimping contacts and their insertion into and extraction from connectors.



TYPICAL POSITIONER AND TURRET HEAD

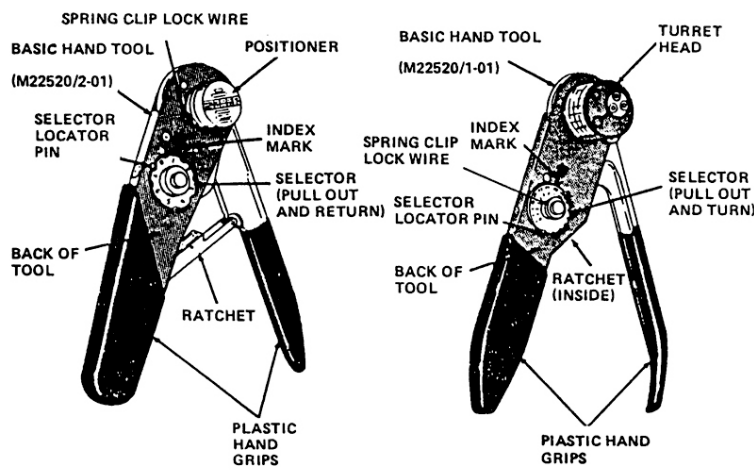


Figure 2–13. M22520 crimping tools.

Contact crimping

The first thing you need to do is select the proper positioning head to be used for the contacts being crimped. If the head you use is a turret head, first depress the turret trigger to release the turret portion into the indexing or extended position, as shown in figure 2–13. Once this is completed, place the head over the retaining ring on the back of the tool (selector side) and seat it against the tool body; secure the $^{9}/_{64}$-socket head screws with an Allen wrench. The turret-type positioning head has three separate color-coded positioners, and they are marked with the contact size accommodated by each individual positioner. The color code and contact size correspond to the information contained on the data plate. Refer to this data plate to select the proper positioner to use for the contact being crimped. After you select the correct positioner, rotate the turret until it is lined up with the index mark on the turret head and push the turret in until it snaps into the locked position.

Next refer to the data plate again for the correct selector setting for the wire size being used. Then, with the handles fully open, remove the spring clip lock wire from the selector knob, lift and rotate the selector knob (or slide the thumb button) to the correct setting and release (fig. 2–13), and reinstall the spring clip lock wire.

After the crimping tool is properly set, you are ready to insert the wire into the contact and crimp. Insert the stripped wire into the wire barrel of the contact until you can’t see the end of the wire through the inspection hole. The insulation must be between 0.016 and 0.031 inch from the end of the contact. Insert the wire and contact through the indenters on the front side of the tool (opposite from the selector side) until it bottoms out and fully seats in the positioner (fig. 2–14). Once you insert the contact in the positioner, hold the wire and contact in place, then squeeze the tool handles until they fully close and the ratchet releases, allowing the handles to automatically return to the open position. Remove the crimped contact and inspect it. Make sure the wire strands are visible through the inspection hole in the contact wire barrel, as shown in figure 2–15.

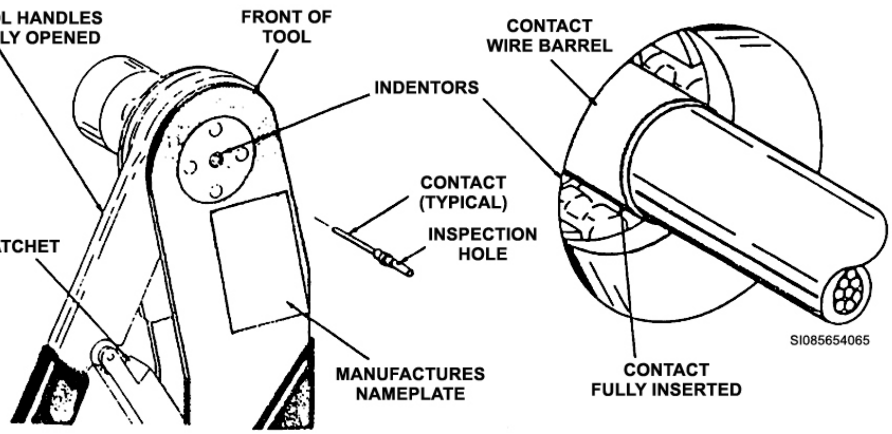


Figure 2–14. Contact crimping.

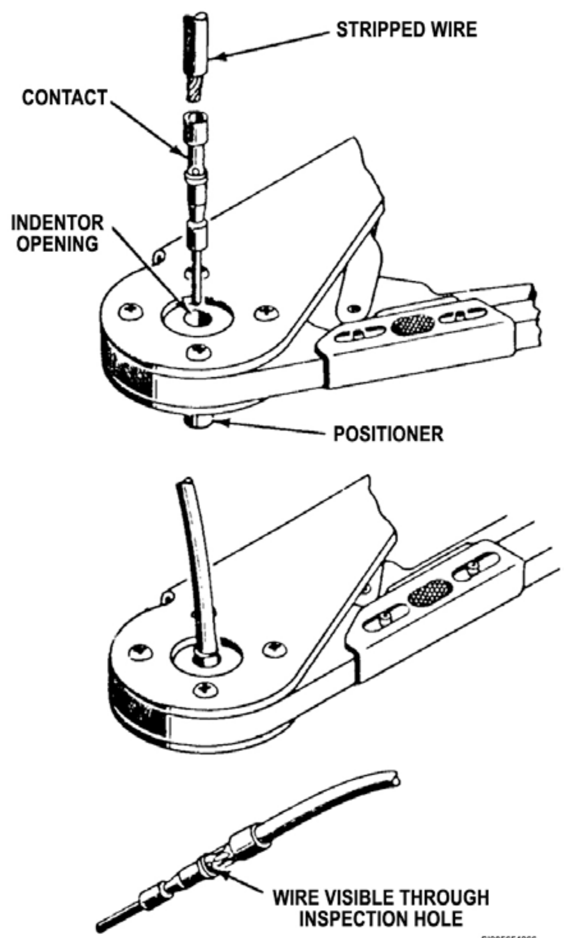


Figure 2–15. Assembling wires to crimp.

Contact insertion

Use the special tools shown in figure 2–16 for inserting the assembled wire and contact into front-release solderless connectors. There is a separate size for each contact size. An indicating band on the working end of the tool determines the correct depth to insert the tool. Never use tools with burrs or sharp edges. Burrs or sharp edges can cut through the grommet wire sealing webs and destroy the environmental sealing capabilities of a connector.

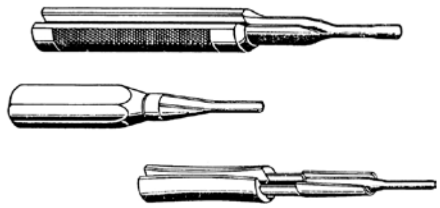


Figure 2–16. Insertion tools.

Once you select the correct insertion tool, insert the crimped end of the contact into the hollow end of the insertion tool and lay the wire into the slot in the tool handle, as shown in figure 2–17. Guide the contact into the grommet hole in the rear face of the insert and feed the contact carefully into the hole in the rear of the connector. Push the tool straight in at a right angle to the grommet surface until the contact is fully seated (fig. 2–17). As the indicator band on the tool enters the grommet hole, the contact retention clip will snap into place on the contact with a slight click. Withdraw the tool, keeping it perpendicular to the grommet face. It would be wise at this point to pull on the wire GENTLY to make sure the contact is properly seated and is held in place. If, by chance, a contact does not seat properly, do not attempt to reseat it once you have removed the insertion tool. If this was the case, you remove the contact and start over again. If you try to reseat a contact, you can very well cause the insertion tool to shear the barrel inside the grommet. The sharp edges of the sheared barrel will cut through the grommet web and cause a short circuit. Fill all unused holes of a connector with unwired contacts and sealing plugs. There are alternate procedures for installing contacts that we do not cover here. If you need information on these procedures, refer to TO 1–1A–14.

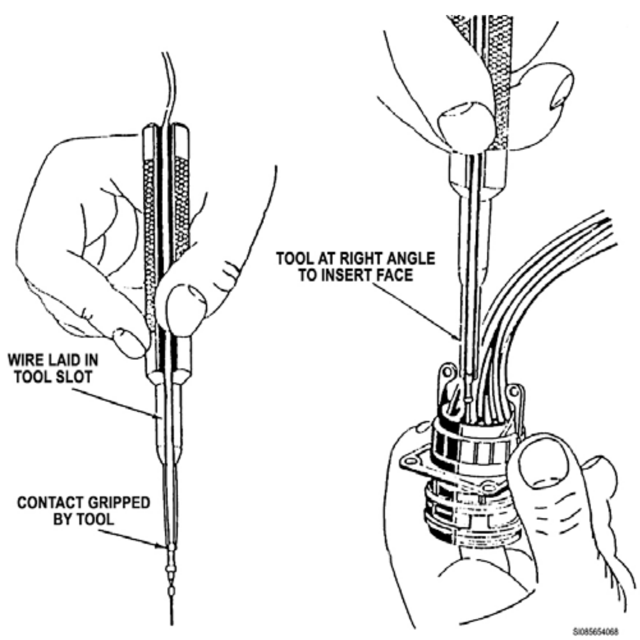


Figure 2–17. Installing crimp type contacts.

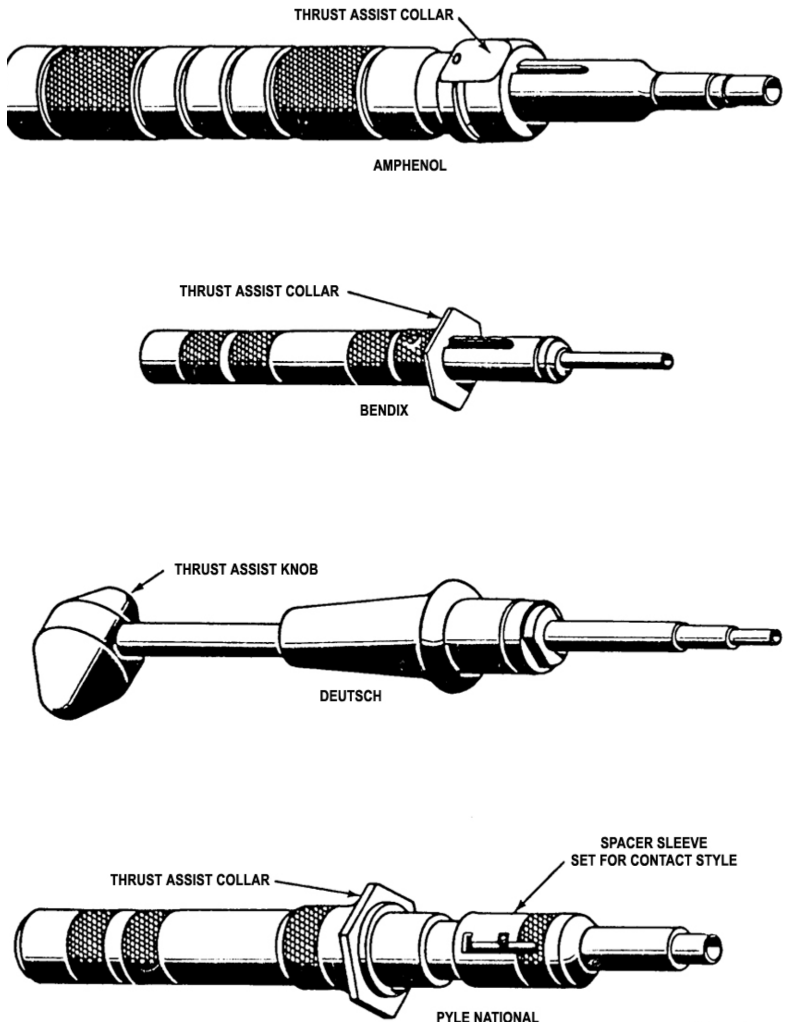


Figure 2–18. Extraction tools.

Contact removal

Use the special tools shown in figure 2–18 when it is necessary to remove crimped contacts from front-release solderless connectors. Like the insertion tools, they come in different sizes for each contact size. The extraction tool has a hollow cylindrical probe, which fits snugly over the pin or socket end of the contact and releases the insert retention clip when pushed over the contact. Two indicating bands determine the correct depth. The band nearest the working end of the tool is for pin contacts; the other is for socket contacts. The extraction tool has a thrust assist collar (or slide), which is pushed forward to eject the contact from the insert retention clip by means of an internal plunger. We show a rear-release contact insertion/removal tool in figure 2–19.

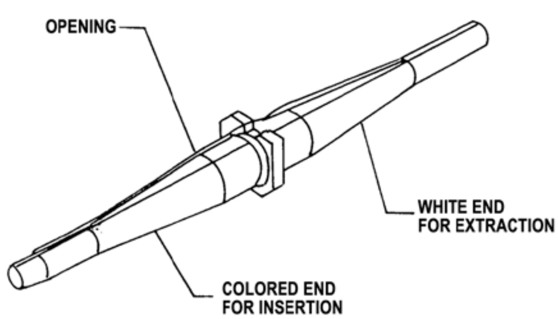


Figure 2–19. Insertion and extraction tool (rear-release type).

Removal of contacts is the opposite of installation. First you determine if the contacts are removed from the front or rear of the connectors; then you select the proper contact extraction tool. Front- and rear-release contacts are removed differently. We will discuss both of them.

Front release

With the front-release contacts, the pin contact removal tool has a hole to accept the pin contact. The socket removal tool has a pin tip to insert in the socket. Next grasp the tool by the handle and locate the contact to be removed. Now mate the tool with the contact, holding the tool at a right angle to the connector face, and push against the tip of the contact until the contact appears at the rear of the connector. The tools are designed to bottom against the connector face when the contacts are completely released and pushed out. The wire and contact can now be removed from the connector. Using the proper tool for each contact is the only way to remove the contact without damaging a connector. If you are in question as to what tool to use, refer to TO 1–1A–14.

Rear release

Rear-release contacts are removed a little differently than the front-release type. To remove them, you must start with the rear of the connector facing you. Next you lay the wire of the contact along the slot of the tool and snap the wire into the tool. Now slide the tool down along the wire and into the rear cavity of the connector. You should feel a positive resistance. When this happens, the contact retaining mechanism is unlocked. Finally press the wire of the contact against the separation of the extraction tool and pull both the tool and the contact out of the connector.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

408. Electrical inspection and cleaning

1. What must you do prior to performing electrical testing following an electronic equipment repair action?

2. What is the intent of performing an electrical inspection?

3. List some of the items a visual inspection consists of?

4. What type of cleaning solvent is authorized for cleaning electrical equipment?

5. When cleaning an electrical item, what do you install to prevent energizing the item?

6. What is an effective method of cleaning debris from circuit devices?

7. When using compressed air for cleaning, what is the *maximum* pressure you can use?

409. Chafing awareness and prevention

1. What is chafing?

2. What the first indication of chafing?

3. What is the *most obvious* form of chafing?

4. List the two *most common* causes of chafing.

5. Normally, how much slack is allowed between cable support points?

6. Name two procedures or practices that go a long way toward the prevention of chafing.

7. What does QA monitor and track?

410. Coaxial cable maintenance

1. What types of RF connectors are used on coaxial cable?

2. What insulates the inner (center) conductor of coaxial cable from the outer conductor?

3. When may you interchange coaxial cables with different types of dielectric?

4. When can you splice coaxial cables?

411. Electrical repairs

1. Who can do electrical repairs?

2. What precautions *must* you take to prevent accidental shock when power that exceeds 300 volts is to remain on during testing?

3. What items can you use for repair and adjustment of electrical items?

4. What should workbench stools be made of?

412. Cable repair

1. What do you use to spot tie a protective boot?

2. When installing a new protective boot, how do you position it after it shrinks?

3. What is involved in braid repair?

4. How far do you insert a stripped wire into a contact before you crimp it?

5. What is the purpose of the indicating band on the working end of an insertion tool?

6. What do you do to all unused holes in a connector?

7. What two types of contact releases are provided for crimped contacts?

8. At what angle do you keep an insertion or extraction tool to the grommet face of the connector?

9. What indicates a rear-release contact retaining mechanism is unlocked during contact removal?

Answers to Self-Test Questions

408

1. A visual inspection.
2. To detect obvious defects that could cause additional damage to equipment if power is applied.
3. The inspection consists the following:
   (1) Overheating of electronic components.
   (2) Loose or missing mechanical hardware.
   (3) Proper mechanical operation of controls.
   (4) Frayed, burnt, pinched, or broken wires.

(5) Securely mounted chassis-mounted components and printed circuit cards.

(6) Secure and serviceable mechanical, crimped, and soldered connections.

(7) Missing, damaged, recessed, or bent connector contacts and serviceable insulation.

(8) Mechanical integrity of case.

4. Only approved cleaning solvents.
5. Lockout devices.
6. Vacuuming.
7. 30 psi.

409

1. The constant interaction (rubbing, scraping, etc.) between wiring system components themselves or between these components and the structure to which they are attached.
2. Exterior damage to a single wire or wiring harness in the form of cut or damaged insulation or a system malfunction either in-flight or on the ground.
3. Exterior damage to a cable.
4. (1) Excessive slack.
   (2) Improper fasteners.
5. Slack should not exceed ½ inch.
6. (1) Proper routing.
   (2) Proper installation of wiring harnesses or bundles.
7. Instances of wire, harness, and metal line/tube chafing.

410

1. Either pin-contact type plugs or socket-contact type plugs.
2. Dielectric.
3. When they are of the same physical and electrical characteristics.
4. In emergency situations only.

411

1. Only competent, qualified personnel.
2. Use a safety observer.
3. Only items authorized for use by technical data or manufacturer’s guidelines.
4. Wood, fiberglass, or nonconducting material.

412

1. Dacron lacing tape.
2. So it covers the entire connector potting while ensuring the connector coupling is not restricted.
3. Covering the exposed area with silicone self-bonding tape or using heat-shrink tubing.
4. Until you can’t see the end of the wire through the inspection hole.
5. To determine the correct depth to insert the tool.
6. Fill them with unwired contacts and sealing plugs.
7. (1) Front.
   (2) Rear.
8. Right angle.
9. You’ll feel positive resistance as you slide the extraction tool into the rear cavity of the connector.

Complete the unit review exercises before going to the next unit

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

34. (408) You must visually inspect equipment before testing and following repair actions to
    a. document actions taken.
    b. check for obvious defects.
    c. establish a maintenance record.
    d. ensure the job was completed on time.

35. (408) Which technical order contains inspection and repair information that applies across all aircraft wiring systems?
    a. 1–1A–14.
    b. 14–1A–1.
    c. 1–11A–14.
    d. 11–1A–14.

36. (408) What do you use to clean electrical equipment?
    a. Any dry chemical cleaner.
    b. Fast-dry alcohol solution.
    c. Only approved cleaning solvents.
    d. Only approved dry chemical cleaners.

37. (408) When do you use compressed air for cleaning electrical equipment?
    a. Only as a last resort.
    b. After using dry cleaners.
    c. Only when oil is applied.
    d. After using chemical cleaners.

38. (409) What is chafing?
    a. Electrical movement.
    b. Movement of components.
    c. Constant friction (rubbing) between electrons and the insulation sleeve.
    d. Constant friction (rubbing) between wiring harnesses and the structure to which they are attached.

39. (409) What is the *most* obvious indication of chaffing?
    a. Electrical malfunctions.
    b. Mechanical malfunctions.
    c. Exterior damage to cables.
    d. Cannot duplicate malfunctions.

40. (409) To prevent chafing, the slack in a wiring harness between two support points normally should *not* exceed
    a. ¼ inch.
    b. ⅜ inch.
    c. ½ inch.
    d. ⅝ inch.

41. (409) Which condition is a cause of chafing?
    a. Insulated clamps.
    b. Loose-fitting clamps.
    c. Tight-fitting connectors.
    d. Loose-fitting connectors.

42. (409) Which method is *not* an acceptable way to prevent possible chaffing problems?
    a. Routing coaxial cables in the most direct way possible.
    b. Routing wires or bundles parallel to the ribs of the aircraft.
    c. Routing wires and bundles at right angles to the ribs of the aircraft.
    d. Routing wires and bundles back on themselves and placing the fold inside a bundle.

43. (409) When installing aircraft wiring, you must ensure wires or wire bundles do *not* come within
    a. ½ inch of the edge of a hole when routed without a grommet and/or clamp installed.
    b. 1 inch of the edge of a hole when routed through a bulkhead opening and when a suitable grommet and clamp is installed.
    c. ½ inch of the edge of a hole when routed through a bulkhead opening and when a suitable grommet and clamp is installed.
    d. ¼ inch of the edge of a hole when routed through a bulkhead opening and when a suitable grommet and clamp is installed.

44. (410) The dielectric of a coaxial cable is *normally* made of what type of material?
    a. Rayon.
    b. Copper.
    c. Polyethylene.
    d. Dacron.

45. (410) Which standard defines implementation requirements for the Aircraft/Store Electrical (and fiber optic) Interconnection System (AEIS) in aircraft and stores?
    a. MIL-STD–1760.
    b. MIL-STD–1670.
    c. MIL-STD–1060.
    d. MIL-STD–760.

46. (410) When working with coaxial cable, you must *never* step on it, set anything heavy on it, or bend it sharply because doing so will
    a. begin a weak point for future chaffing to occur.
    b. cause a weak point for future corrosion to occur.
    c. cause a weak point for radio frequency intrusion.
    d. flatten the cable and change its electrical characteristics.

47. (410) When installing a connector on coaxial cable, you *must* use care in starting the braid clamp nut into a plug or jack body to prevent
    a. cross-threading.
    b. damage to the center pin.
    c. damage to the center socket.
    d. damage to the cable dielectric.

48. (411) Who should do electrical repairs?
    a. Anyone.
    b. Degreed personnel only.
    c. Qualified personnel only.
    d. Certified mechanical experts.

49. (411) As a *general* rule, when you are working on electrical items, they should have the power
   a. off for testing and on for maintenance.
   b. on for testing only.
   c. off.
   d. on.

50. (411) When performing measurements on energized circuits, meters should
   a. *not* be used.
   b. be held by a helper.
   c. *not* be held in your hand.
   d. be placed on the equipment under test.

51. (411) When voltage is applied to equipment being repaired, personnel must
   a. stay away from the workbench.
   b. remove all nonessential tools from the workbench.
   c. keep all tools on hand next to the equipment being repaired.
   d. remove essential tools from the equipment being repaired.

52. (412) What device is used to cover or protect the exposed-wire access area between the rear of a connector and the end of the bundle braid on cable assemblies or wire bundles?
   a. Protective boot.
   b. Wire terminal cover.
   c. Cable environmental cover.
   d. Cable environmental sealing/isolation assembly.

53. (412) What do you use to make a spot tie on protective boots during installation?
   a. Plastic pull-ties.
   b. Nylon lacing tape.
   c. Dacron lacing tape.
   d. Waxed lacing string.

54. (412) When shrinking a protective boot for wiring, work slowly from the
   a. inside to the outside.
   b. connector to the braid end.
   c. braid end to the connector.
   d. middle of the connector to either end.

55. (412) What is the *only* heat gun presently authorized around fueled aircraft?
   a. Electric motor driven heat guns.
   b. Soldering gun mounted fan/heat pump.
   c. Compressed air/nitrogen heat gun kit.
   d. Positive pressure, fully contained flame units.

56. (412) When using self-bonding silicone tape to repair damaged bundle braid, how much overlap must you maintain during the wrapping procedure?
   a. 25 percent.
   b. 40 percent.
   c. 50 percent.
   d. 75 percent.

57. (412) What do you use to make a spot tie on silicone tape when repairing a wire braid?
   a. Plastic pull-ties.
   b. Dacron lacing tape.
   c. Nylon lacing tape.
   d. Waxed lacing string.

58. (412) The indicating band on the working end of the solderless connector insertion tool determines the
    a. correct gauge wire to use.
    b. proper size crimp to be made.
    c. correct depth to insert the tool.
    d. proper length to strip the insulation off the wire.

59. (412) You must *never* use pin insertion tools with burrs or sharp edges because they
    a. can damage the insulation of the wire attached to the pin you are trying to install.
    b. present a hazard to the operator possibly causing laceration to the fingers or other parts of the hands.
    c. can cut through the grommet wire sealing webs and destroy the environmental sealing capabilities of a connector.
    d. can scrape off the letter or number marking on the back of the connector making it more difficult to ensure correct pin insertion.

60. (412) Similar to contact insertion tools, extraction tools for solderless connectors are
    a. of solid construction.
    b. for pin contacts only.
    c. for socket contacts only.
    d. of different sizes for each contact.

61. (412) You can tell if a solderless connector contact is completely released and pushed out of the connector because the extraction tool will bottom against the
    a. contact face.
    b. connector rim.
    c. connector face.
    d. contact shoulder.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Electrical Measuring Devices and Troubleshooting

SINCE WE CANNOT see or hear electrical current flowing through conductors and it is extremely uncomfortable, if not fatal, to feel this current, we must exploit one or more of its effects as a means of measurement. How do we observe the effects of electrical currents? By using multimeters, we can observe voltage, current, resistance, and the frequency of any given circuit. Also we can troubleshoot various malfunctions encountered in electrical circuits. Therefore, in this unit, we introduce you to the Fluke 8025A digital multimeter and show you how to put it to use in troubleshooting.

3–1. Precision Test Equipment

As an aircraft armament systems journeyman, you'll be required to troubleshoot various circuits while becoming skilled in the measurement of current, voltage, resistance, and frequency. An accurate measurement of such parameters is critical and requires a variety of precision test equipment to perform these routine tasks.

413. Fluke 8025A digital multimeter

The type of testing device you use most frequently is the Fluke 8025A (digital) multimeter. This multimeter is designed to meet the challenge of harsh military and industrial environments. In this lesson, we cover its description, operation, and function.

Fluke 8025A digital multimeter description

The Fluke 8025A is a rugged water- and chemical-resistant multimeter. It is versatile enough to use at any of our bases and can withstand water, dust, dirt, humidity, airborne particles, and even accidental dropping. A unique feature of this meter is that it can withstand a severe electrical overload without being damaged. The 8025A combines the performance and accuracy of a digital meter with the dynamic capability of an analog meter. All controls and connectors are located on the front panel, beneath the display window, as shown in figure 3–1.

The digital display of information consists of four functional categories (fig. 3–2):

1. Digital display.
2. Various annunciators.
3. Bar graph display.
4. Range indicator.

The annunciators are used to distinguish among ohms, kilohms, and megohms.TEST Other annunciators are displayed when the meter is set to the "ohms" function. These annunciators display information about the polarity, the condition of the meter's battery, whether you're in manual or auto range, and negative annunciator for the bar graph.STQ The analog bar graph is located just below the digital display. The range indicators are located between the analog bar graph and the digital display. A 3-, 30-, or 300-range indicator is displayed just below the decimal point in the digital display. The number displayed indicates the range in use for each of the decimal point positions. No decimal point is displayed in the 1,000 V or 3,200 microamperes (μA) range.

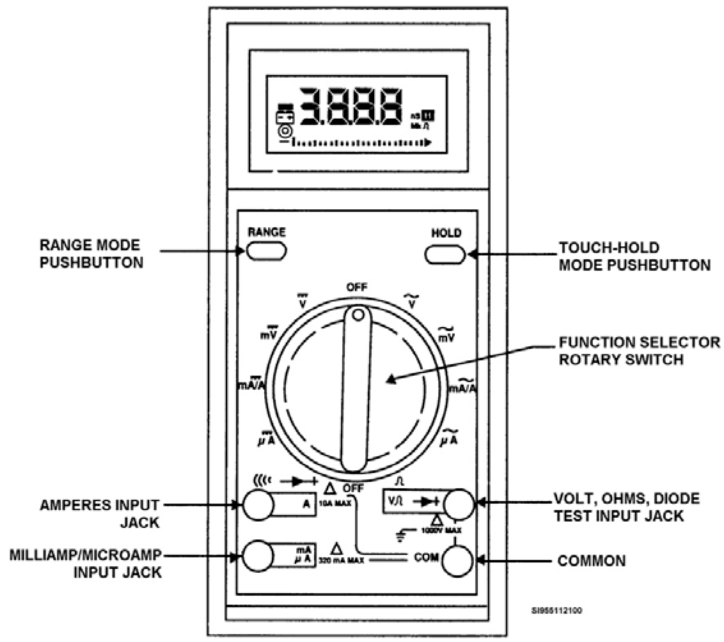


Figure 3–1. 8025A (Fluke) controls and connectors.

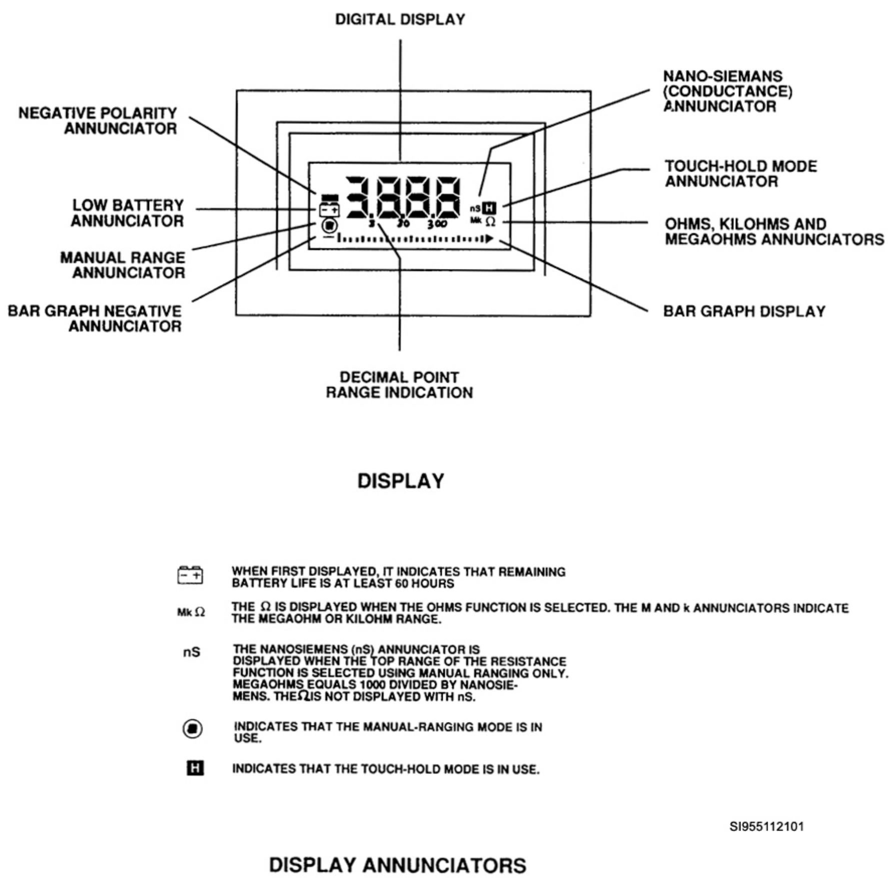


Figure 3–2. 8025A display and display controls.

Operation

Operation of the 8025A is provided in two modes. You can actuate the two modes, RANGE and HOLD, with their respective push buttons.

RANGE

Use the RANGE push button to initiate the manual range operating mode, change ranges while in the manual mode, and return to the auto range mode. You must press the RANGE push button for more than 1 second to exit the manual mode.

HOLD

In the touch-hold mode, operators can make a measurement in a delicate, hazardous, or difficult-to-reach circuit without taking their eyes from the test leads. The 8025A beeper indicates when a stable measurement is held in the display; then the operator can look at the measurement when convenient.

Function selection

In selecting the function, you use a single rotary switch to select all of the available functions. Listed below are the functions:

1. Volts DC.
2. Millivolts DC.
3. Milliamps/amps DC.
4. Microamps DC.
5. Diode test. DC.
6. Volts AC.
7. Millivolts AC.
8. Milliamps/amps AC.
9. Microamps AC.
10. Ohms. AC

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

413. Fluke 8025A digital multimeter

1. What information do the annunciators display?

2. What are the *two* modes of operation?

3. What mode of the 8025A is most useful when taking measurements in a circuit where it may be necessary to keep your eyes on the test leads after they are positioned?

3–2. Basic Electrical Troubleshooting

Up to this point, from the flow of an electron, through the various types of circuits, and the intricacies of logic principles and devices, you have learned a great deal of information. As a 2W1, you need to know how this information relates to our career field and us. How can we use this information to enhance not only our knowledge but also the efficiency of the Air Force? The answer is clear—solve electrical malfunctions of an aircraft weapons system by applying theories and techniques previously learned. In any situation, you should be able to isolate the problem, fix it, and understand what caused the problem. Identifying and locating troubles is an exciting and thought-provoking process.

414. Causes and types of electrical troubles

We have all experienced certain troubles that repeat themselves in the same location or piece of equipment. Usually, we become so familiar with these types of troubles that we know exactly what to do to get them fixed. On the other hand, an unfamiliar problem soon occurs and then the troubleshooting begins.

Common causes

The two most common causes of electrical troubles are careless maintenance practices and weather conditions. Also, continued use and frequent maintenance operations may cause worn insulation, loose connections, broken wires, and loosening of units so they do not operate properly. Weather conditions may cause corroded terminals and wires, thus increasing the resistance and decreasing the current to the devices.

Types of troubles

Three general types of electrical troubles may develop from careless maintenance practices, weather conditions, or other causes those of us in the electronic arena classify as (1) open circuits, (2) short circuits, and (3) grounded circuits.

Open circuits

When we discussed a “switch” in a circuit, we said the switch had to be “closed” in order for current to flow through the circuit. An open in a circuit has the same result as opening a switch—no current flows. Should one of the wires attached to a switch become broken, the circuit would break and stop the movement of the electrons. Another example of this is a main conductor coming loose from the main armament bus in an aircraft; in which case, no unit in the system would operate.

Short circuits

Accidental contact between two normally insulated conductors or points is not uncommon. Shorts often produce the opposite effect of an open. That is, instead of current flow being stopped (as in an open), a short across a series component produces a larger than normal current flow by reducing resistance. Often short circuits occur because of improper installation of electrical connections to a unit, or they are the result of poor maintenance practices. There are several places where shorts are commonly encountered. Cannon plugs often acquire a short because there are so many individual wires positioned so close together. We constantly install and remove these devices; eventually, the wires rub through their insulation and cause a short.

Another place where a short can develop is in a junction box. A junction box is a metal container housing a number of insulating strips. Each of the strips has a number of stud-type points where wire end terminals are joined together. When you tighten the nut, hold the wire with your free hand to prevent rotation of the terminals as you tighten the nut and draw it down. Follow this same precaution when connecting wires to any unit having stud-type connector panels. Be sure each terminal end has insulation over the barrel of the terminal to prevent accidental short circuits between terminals attached to adjacent studs.

The systematic analysis of the circuit should include not only a check of the wiring and controls but also a check of the internal circuits of the equipment. In the handbook covering the operation and maintenance of each piece of equipment, the manufacturer of the equipment often gives the resistance values between certain accessible reference points for circuit testing. Check these values during troubleshooting procedures, because no piece of equipment is foolproof. The trouble may be inside the operating mechanism and not in the wires leading to it. Check carefully and thoroughly.

Many times when working on the wires or terminals inside a junction box, maintenance personnel will drop a screw, nut, or other small object into the bottom of the box. Oftentimes this object will lie there unnoticed when the work is finished. During flight or other movement, the loose part may be thrown about in the box. The possibility of it making electrical contact between two points and causing a short circuit is very great. The time used in extracting any loose parts from any piece of electrical equipment is time well spent when we consider the value of the equipment and human lives that might otherwise be lost.

Grounded circuits

In certain wiring installations, you may find one or more negative connections from each piece of equipment fastened directly to the basic frame or structure. This method of wiring uses the metallic parts of the structure as a conductor and, reduces the total number of wires required for the installation. Systems wired with the structure as the second conductor are called grounded systems. For example, your car uses this system.

Accidental contact between a positive lead and the structure or frame is commonly referred to as a grounded out circuit. In reality, this arrangement constitutes a short circuit, as we discussed in the preceding paragraphs. Because the structure is included in the circuit as a ground, we elect to call it a grounded circuit to differentiate between the two troubles.

When the positive lead touches the structure, a circuit is made from the negative terminal of the source of power through the structure to the point of contact and through the positive lead back to the source of power, as illustrated in figure 3–3. This circuit has little or no resistance; consequently, very large currents flow through it. A burnt wire is a good indication of a short to ground. Most equipment and tester power circuits use fuses or have a special ground-fault circuit to prevent the possibility of fire should this condition develop.

WARNING: Disconnect both ends of a circuit that has a short to ground before you do any troubleshooting inspections.

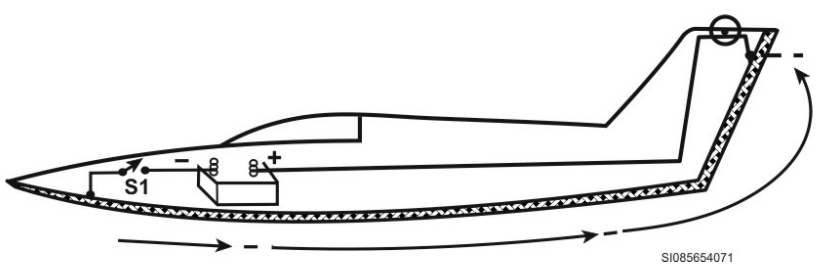


Figure 3–3. System ground.

Intermittent contact between a power cable and the basic structure causes the voltage throughout the system to vary over a wide range. In addition, it causes a large shower of sparks every time the circuit is completed. This shower of sparks is much hotter than the arc of an electric welder and may burn a hole in the structure or wire bundle. You must perform an inspection to determine if you have to replace any other wire(s) at this time to reduce the possibility of future troubles.

Other electrical troubles

The preceding paragraphs have dealt with three of the most common troubles we encounter in electrical circuits. In addition, an alert maintenance person can eliminate several other troubles with methodical work.

Improper soldering is responsible for creating many electrical troubles. Before you solder anything, use a cleaning agent (flux) to remove the oxidation from the conductor and to ensure good fusing between the solder and the conductor.

NOTE: There are many brands of flux available but use only rosin-base fluxes on aircraft electrical wiring. Use flux sparingly and apply it only to the actual area to be joined. When you complete the soldering operation, clean the joint with alcohol to remove any surplus flux. Acid fluxes tend to promote corrosion over a period and may have a harmful effect upon the insulating material. The application of excessive flux may allow the individual strands of the conductor to be fused together to form a solid conductor, which will not withstand excessive vibration.

Keep the tip of your copper soldering iron tinned and in the proper shape at all times. Just because the copper is hot enough to melt the solder is no indication it is ready to use. The iron must be hot enough so when you touch it to the material to be soldered, sufficient heat is transferred to the material itself, and the material melts the solder. If the soldering iron is *not* hot enough when contact is made, the heat transferred will be insufficient, and the solder will set before it fuses with the material being joined. The connection may appear to be satisfactory to the eye, but electrically it is a weak joint. Unless there is complete fusing between the solder and the two or more parts to be joined, this kind of joint will cause trouble in the future.

Another possible source of trouble when using rosin flux is the flux itself (and not the solder) may bind the joint. Technicians call this type rosin a joint; it is not electrically solid. Also, the application of too much heat can cause trouble. Heat has a tendency to cause charring of some of the various types of insulation and future deterioration of others. Thus, the electrical insulating value of the substance is reduced causing another possible source of irritating troubles. To prevent this, heat the bare parts to be joined and protect the other parts from excessive heating as much as possible. Excessive heating of the soldering iron promotes oxidation of the tip and materially shortens its working life. Experience is the best teacher of just how much heat is necessary to do the job without damaging any of the components.

Another cause of trouble is loose connections. When checking a circuit, you may frequently find it necessary to disconnect terminals at various points in the electrical circuit. Take extreme care to reconnect the wires in the proper order and make sure the connections is secure. Loose connections can cause a piece of equipment to function only part of the time. Every time the terminals separate, an arc is produced. In time, this could cause an assembly or subassembly to need replacement. In most cases, the replacement is not a difficult job, but it is costly in dollars and man-hours. Furthermore, loose electrical connections may lead to the development of a short circuit or open circuit.

415. Basic troubleshooting procedures

When malfunctions or troubles occur in a circuit, you must know how to locate them quickly and systematically. Troubleshooting usually begins with a visual check of the circuit for broken wires, loose connections, or other obvious damage/defects. The conditions of fuses and other circuit safety devices are important factors in determining the type of trouble and the most appropriate method to use in locating the trouble.

Getting started

A good fuse or circuit breaker in a malfunctioning circuit normally indicates an open in the circuit. A blown or popped circuit breaker is usually an indication of a short to ground or an overloaded circuit. If your visual inspection does not reveal the trouble, then you must locate the trouble by using electrical measuring instruments, test lamps, or a continuity tester.

Troubleshooting with a voltmeter

One of the measuring instruments you can use to troubleshoot open circuits is the voltmeter. By checking the voltage at various points along the circuit, you can determine where the open is located. At a point where you do not get the proper readings, there is a fault.

Let us look at the circuitry in diagram A of figure 3–4. In this figure, all three lamps are alike; they have the same resistance, and they have ceased to operate. It is up to you to troubleshoot the circuit. You have made a physical check and found no broken wires, no loose connections, or any other faulty conditions. The fuse is also good, so there appears to be an open in the circuit. You are now ready to troubleshoot with the voltmeter.

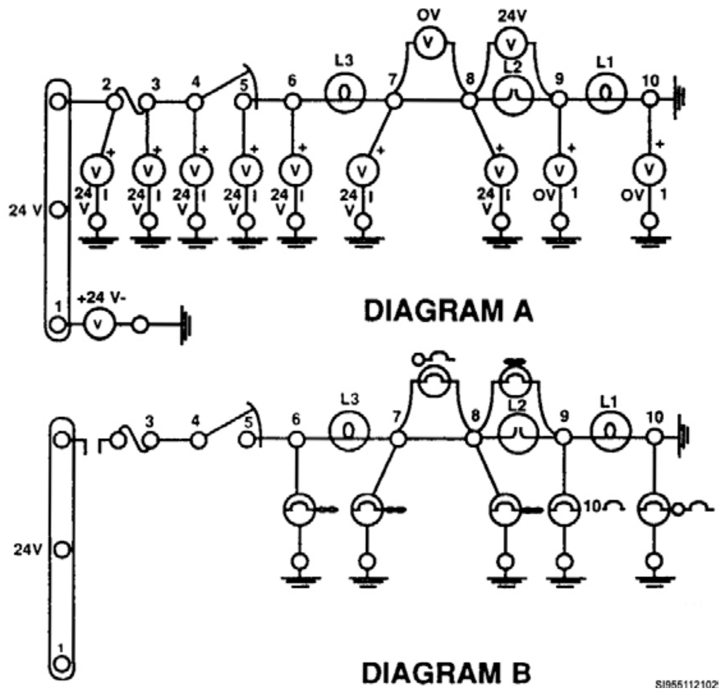


Figure 3–4. Troubleshooting opens.

You begin at the source of voltage—the bus bar, point 1, in the top circuit. Note the positive lead of the voltmeter is at this point in the circuit, while the negative lead is at ground.

At point 1, you get a reading of 24 volts. This proves you are getting voltage to your bus bar. Next go to point 2, where you find the same situation. This is also correct. Since there is only one wire between point 2 and the bus bar and there is no resistive unit, you are still measuring the voltage across the bus bar. The same will be true at points 3, 4, 5, and 6. Remember fuses and switches do not offer resistance in a circuit.

At point 7, there is a lightbulb, L3, offering resistance in the circuit from ground to the bus bar. The voltmeter across L3 (point 7 to ground) should then have a reading of less than 24 volts (16 volts), since the three lamps are alike and have the same resistance; however, the voltmeter reads 24 volts.

Here is our first sign of trouble; so let's stop and analyze it. We know that up to point 6, there is nothing faulty; therefore, the trouble must be somewhere past it.

You can't have a short because the other lamps are not operating, and you can't have a short to ground between points 6 and 7 because the fuse would have burned out. If the fuse were out, then you would get a reading of zero at points 3, 4, 5, 6, and 7 (as far as we have gone), because there would be no completed circuits. Therefore, the trouble can't be L3 or between points 6 and 7. Let us proceed further and see what happens.

At point 8, you get another 24-volt reading indicating there is nothing faulty up to that point. At point 9, you get a reading of zero. Now you should really see the trouble, since you should be getting an 8-volt reading. Remember our voltmeter is still across the high and low potential points. Let's analyze this situation.

Assuming there was nothing faulty with the circuit at all, the voltmeter should read 8 volts at point 9, but it doesn't. Therefore, since L3 gives us a 24-volt reading, the trouble must lie with L2. To make certain this is so, let us proceed to check point 10. Here you also get a zero reading. The open must be between points 8 and 9, or L2. We remove L2 and inspect it—the filament is broken—so there's our trouble.

This may seem like a long, drawn-out process, but actually an experienced person can locate the trouble in a few minutes. All he or she must do is attach the negative meter lead to the ground terminal and then move the positive meter lead from point to point through the circuit, as shown in diagram A (fig. 3–4).

To verify whether this analysis is correct, we can pursue a second method of using the voltmeter. This method checks each wire and device in the circuit by connecting the voltmeter across or in parallel with each wire or device, as shown in diagram A (fig. 3–4), and across points 7 and 8, and 8 and 9. Except for point 1, when any reading other than zero is indicated on the voltmeter, you have found the open.

The reason for such a reading is that with the circuit open, there will be no current flowing anywhere in the circuit either through the electrical devices or in the wires. Therefore, with the voltmeter across a good wire or electrical device, there must be a zero reading. For example, in diagram A of figure 3–4, with the voltmeter across points 6 and 7, we get a zero reading.

However, with the voltmeter across an open wire or electrical device, the voltmeter completes the circuit permitting current to flow. The voltmeter then measures the difference of potential between the two points, high and low, and we get a source voltage reading. For example, in figure 3–4, diagram A, with the voltmeter across points 8 and 9, we get a 24-volt reading.

This second method may seem easier to you, but it cannot be used to locate more than one open in a circuit. Another open prevents any circuit from being completed by the voltmeter and, with the exception of point 1, gives all zero readings instead of 24-volt readings along the circuit.

To illustrate this point, let us look again at circuit diagram A in figure 3–4. Assuming L3 was also open, we would now have two opens. Using this second method, except for point 1, you get zero readings across points 2 and 3, 3 and 4, 4 and 5, 5 and 6, 6 and 7, 7 and 8, 8 and 9, and 9 and 10. Therefore, we cannot tell where the opens were located.

However, with the first method, point-to-ground, it makes no difference how many opens there are. Up to the first open, you get a source voltage reading. After the first open, you get a zero reading. If you repair and close the first open, you complete the circuit and get a source voltage reading up to the second open. After the second open, you get a zero reading. Repeat the process until you locate all the opens.

For example, in diagram A of figure 3–4, let's assume you have another open in L3. Using the first method, you get 24-volt readings up to point 6. At point 7, you get a zero reading indicating an open at L3. Replace L3 with a good lamp. With the voltmeter connected to point 7 and ground, you have a complete circuit, and you get a 24-volt reading as at the previous points.

Then continue on to point 8, where we get a 24-volt reading. However, at point 9, you are confronted again with a zero reading, which indicates an open this time at L2. Replace L2 with a good lamp. Keep right on down the line until you locate all the opens and repair them, thus producing a complete and fully operating circuit. This takes care of troubleshooting with a voltmeter. Now let's see the process of troubleshooting with an ohmmeter.

Troubleshooting with an ohmmeter

You can use the ohmmeter to troubleshoot nearly all types of electrical malfunctions, but you generally use it to locate short circuits (commonly called shorts) not only in circuits but also in electrical devices.

Open circuit

Let's see how you would use an ohmmeter to locate the open shown in diagram B of figure 3–4. However, before proceeding with the troubleshooting, you must first disconnect the open circuit from its voltage source. Next you must zero the ohmmeter. Place one meter lead on the ground terminal and the other meter lead on point 10 in the bottom circuit. You get a reading of 0 ohms. This is correct, since the circuit is completed through ground and there is no resistive unit from there to ground. Then move the lead from point 10 to point 9. Suppose you get a reading of 10 ohms. This is also correct, since L1 completes the circuit to ground and it is a 10-ohm resistive unit.

You should have a 20-ohm (10 + 10 = 20) reading at point 8, since the ohmmeter is now measuring the resistance across two lamps, L1 and L2. However, you don't. Instead, you get an infinity reading. This means you have infinite resistance or no continuity. Therefore, the open must exist between points 9 and 8. Another reading, taken at points 7 and 6, verifies this by giving us another infinity reading when there should be a 10-ohm reading at point 7 and a 30-ohm (10 + 10 + 10 = 30) reading at point 6.

You can also use the other method, as you did with the voltmeter, by connecting the ohmmeter across, or in parallel with each wire or device and then taking the respective readings. Across point 10 and a ground, you get a zero reading since the wire alone is considered to have no resistance. With this ohmmeter method, you can locate more than one open in a circuit since there is no external source of voltage entering the picture.

Short circuit

Now let's see how you can use the ohmmeter to locate shorts. As we stated earlier, if for some reason the fuse in a circuit blows or burns out, it is an indication you have a short to ground. The best way to locate a short is to take resistance measurements with a multimeter. First, as always disconnect the source of voltage and zero the ohmmeter function of the multimeter. Then disconnect and separate each wire and device in the circuit, as shown in figure 3–5. Now let us proceed to troubleshoot the circuit in figure 3–5, using the multimeter point-to-ground method.

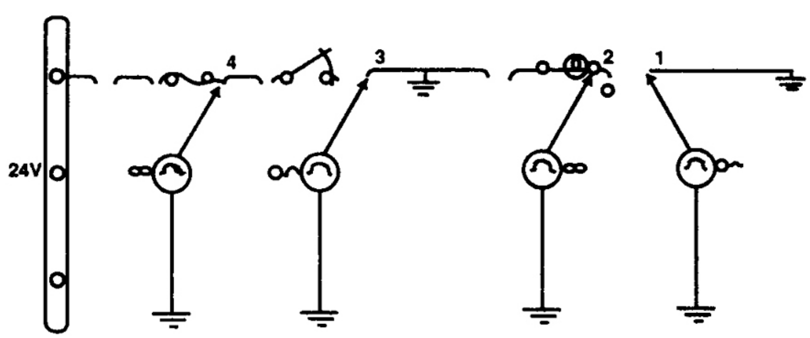


Figure 3–5. Troubleshooting shorts.

At point 1, you get a zero reading. This is correct, since the wire should make a complete circuit to ground. At point 2, you get an infinity reading. That, too, is correct, since there is an open circuit. At point 3, you get a zero reading, which is not correct because the reading indicated a completed or closed circuit and you have an open circuit at this point. Obviously, you have our short right here. Checking into it, you find the wire is making contact with ground when it should not. (The dashed ground symbol indicates a hidden ground.) The ohmmeter infinity reading at point 4 illustrates what the correct reading should be if the wire at point 3 were not grounded.

Although we have illustrated only one cause of a short circuit, there are many causes. For example, in a connector (multiple-wire plug), one strand of wire from one conductor could contact another bare wire and, thus, short the circuit; or because of excessive solder between the two soldering cups, contact could occur with each other and cause a short circuit.

A good rule to follow when troubleshooting is to make a thorough visual check first. Then proceed using the proper meter as outlined above.

416. Component testing procedures

We mentioned in our discussion about diodes and transistors that we would discuss and recommend some troubleshooting procedures later. If you suspect a diode is bad, you can check it in various ways. The most convenient and quickest way of testing a diode is with an ohmmeter, as shown in figure 3–6.

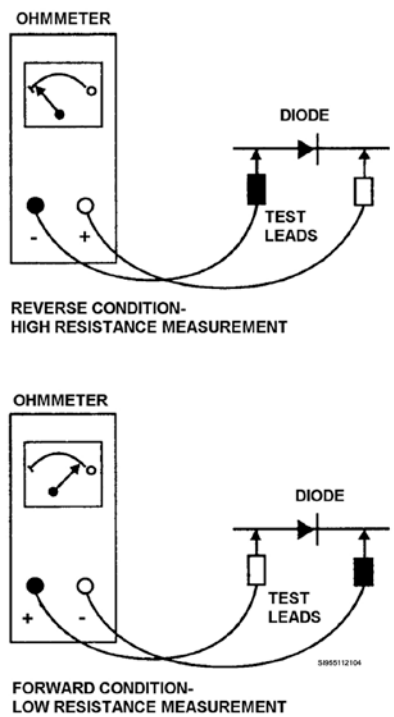


Figure 3–6. Checking a diode with an ohmmeter.

To make this check, simply disconnect one of the diode leads from the circuit wiring and make resistance measurements across the leads of the diode. The resistance measurements obtained naturally depend upon the test-lead polarity of the ohmmeter; therefore, you must make two measurements.

Take the first measurement with the test leads connected to either end of the diode, and take the second measurement with the test leads reversed on the diode. The larger resistance value should be the reverse-biased resistance of the diode, while the smaller should be the forward-biased resistance. You can make measurements of another identical-type diode you know to be good for comparison purposes. Two high-value resistance measurements indicate a diode is open or has a high forward resistance; two low-value resistance measurements indicate the diode is shorted or has a low reverse resistance. A normal set of measurements shows a high resistance in the reverse direction and a low resistance in the forward direction. The diode’s efficiency is determined by how low the forward resistance is, as compared with the reverse resistance; or it is desirable to have as great a ratio as possible between the reverse and forward resistance measurements. However, a small signal diode has a ratio of several hundred to 1, while the standard for a regular diode used in a rectifier can operate satisfactorily with a ratio of 10 to 1.

One thing to keep in mind about the ohmmeter check is that it is not conclusive. It is possible for a diode to check “good” under this test, but it may break down when replaced in the circuit. The problem is the meter used to check the diode uses a lower voltage than the voltage in the circuit. Another important point to remember is that you don’t condemn a diode because two ohmmeters give different readings. This could occur due to the different internal resistances of the ohmmeters and the different states of charge on the ohmmeter batteries.

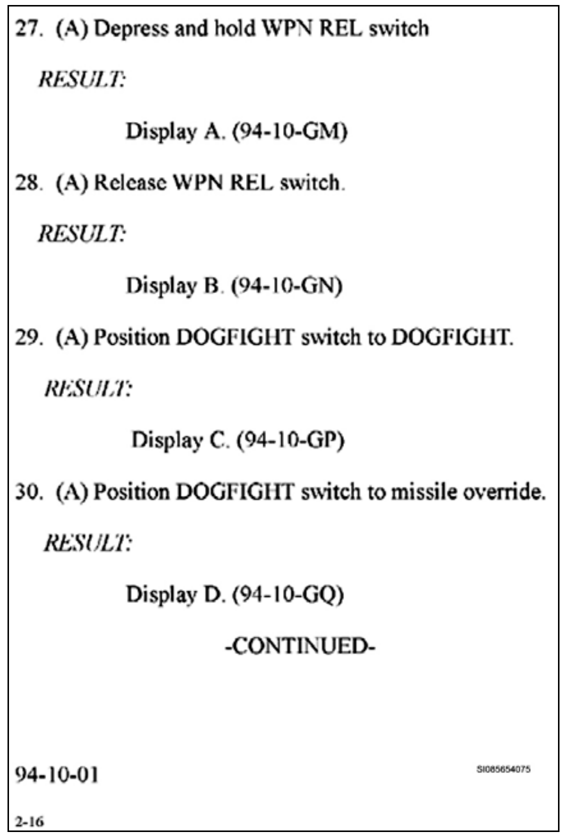
Another way of checking a diode is to substitute a diode known to be good for the questionable one. Use this technique only after you have made voltage and resistance measurements to make certain there is no circuit defect to damage the substitution diode. If more than one defective diode is present in the equipment section where you’ve localized trouble, this method becomes cumbersome since you may have to replace several diodes before you correct the trouble. In conclusion, the only valid check of a diode is a dynamic electrical test to determine the diode’s forward current (resistance) and reverse current (resistance).

417. Troubleshooting aircraft systems

Troubleshooting is a systematic approach to finding the cause of a fault or abnormal indication. Troubleshooters should be able to take a fault or abnormal indication and isolate the fault using their knowledge and technical data of the system. Troubleshooters are people who take the self-initiative to learn the system and use the technical data to find faults. Troubleshooters are not born, but they are made. Tracking a fault begins with an improper indication. You match the indication to your knowledge of the system workings to start the troubleshooting process. If our knowledge of the system is limited, then we have to rely solely on technical guidance to find the probable cause. In this lesson, we are going to look at the process of troubleshooting using the technical data sources.

Job guides

The job guides are TOs with step-by-step procedures for maintenance tasks and functional or operational checks. Figure 3–7 is a sample of a job guide functional check for the F–16. Notice for each step there is a *result*. If the result is not met, then you are referred to a number in parenthesis. Notice in figure 3–7, step 29 refers to a display in the cockpit, and then in parenthesis, it says "94–10–GP." When the result does not match, refer to the fault isolation (FI) TO or fault isolation table for help.



27. (A) Depress and hold WPN REL switch

RESULT:

Display A. (94-10-GM)

28. (A) Release WPN REL switch.

RESULT:

Display B. (94-10-GN)

29. (A) Position DOGFIGHT switch to DOGFIGHT.

RESULT:

Display C. (94-10-GP)

30. (A) Position DOGFIGHT switch to missile override.

RESULT:

Display D. (94-10-GQ)

-CONTINUED-

94-10-01 SI085654075

2-16

Figure 3–7. F–16 job guide.

Fault isolation

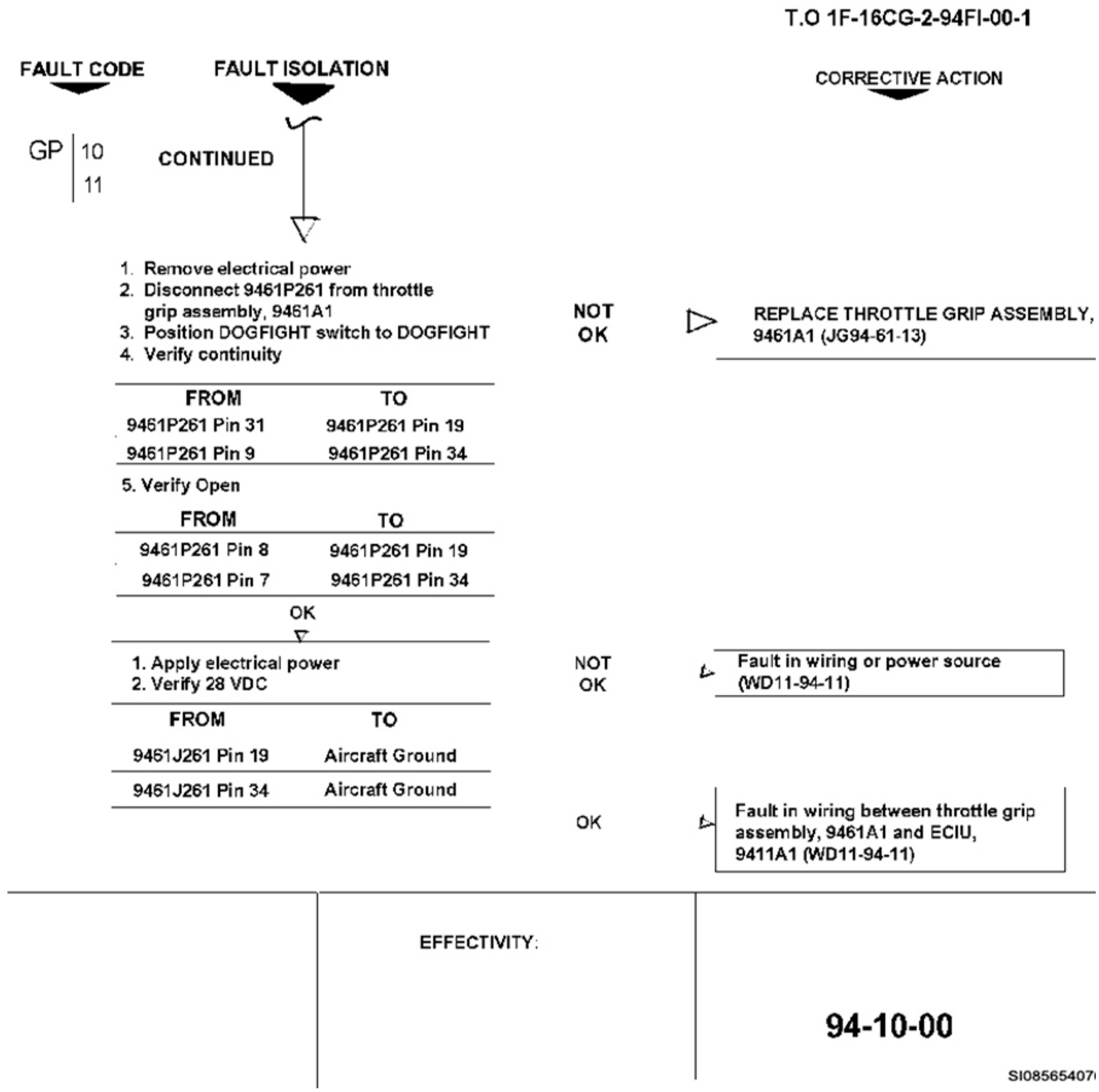
Figure 3–8 is the FI table for fault 94–10–GP. We are on page 94–10–00 and the fault code at the top left of the page is GP. When referring to the FI technical data, go to the section of the FI starting with the first two characters of the number, then the second two. This reading continues until you have the exact fault code. Most FIs contain troubleshooting trees to isolate malfunctions. We often refer to this step-by-step isolation as a troubleshooting tree. This is where we now begin to isolate the malfunction. You must keep in mind what switch positions you used before the fault occurred. Those switch positions should be used somewhere in the fault isolation procedure; if not, double-check your steps. You were positioning the dogfight switch to DOGFIGHT, so you should be working with the dogfight switch when you are troubleshooting the malfunction.

In figure 3–8, the box tells us to remove electrical power, disconnect a plug from the throttle grip assembly, and position the dogfight switch to DOGFIGHT. Then you are to check for continuity and opens (no continuity) on some of the plugs and pins. When our indications for an open or continuity are not present, then you go to the NOT OK arrow, and you would replace the throttle grip assembly. When all the conditions match, you would go to the OK arrow and perform those tasks.

Wiring diagrams

When you reach the end of a troubleshooting tree, you usually replace an item or fix a broken wire. Remember the wiring on which you have performed continuity or voltage checks so you can narrow your tracing area. Earlier, we talked about the need to be knowledgeable of the system you are working on; you can start here in that process. When you perform a continuity check, trace the wiring on the schematic to see why you are checking for voltage and where the source of voltage is coming from.

This process greatly increases your knowledge of the system you are working on and your ability to perform troubleshooting tasks.


T.O 1F-16CG-2-94FI-00-1

FAULT CODE — FAULT ISOLATION — CORRECTIVE ACTION

GP 10 / 11 — CONTINUED

1. Remove electrical power
2. Disconnect 9461P261 from throttle grip assembly, 9461A1
3. Position DOGFIGHT switch to DOGFIGHT
4. Verify continuity

FROM	TO
9461P261 Pin 31	9461P261 Pin 19
9461P261 Pin 9	9461P261 Pin 34

5. Verify Open

FROM	TO
9461P261 Pin 8	9461P261 Pin 19
9461P261 Pin 7	9461P261 Pin 34

NOT OK — REPLACE THROTTLE GRIP ASSEMBLY, 9461A1 (JG94-61-13)

OK

1. Apply electrical power
2. Verify 28 VDC

FROM	TO
9461J261 Pin 19	Aircraft Ground
9461J261 Pin 34	Aircraft Ground

NOT OK — Fault in wiring or power source (WD11-94-11)

OK — Fault in wiring between throttle grip assembly, 9461A1 and ECIU, 9411A1 (WD11-94-11)

EFFECTIVITY:

94-10-00

SI08565407

Figure 3–8. F–16 fault isolation table.

In figure 3–8, at the bottom of the tree and in the “NOT OK” branches, you were told there is a fault in the wiring or power source. The easiest thing to check is the power source. While performing the tasks in our fault tree, look at the wiring diagram in figure 3–9 and see where the voltage is coming from. This greatly aids you in learning about the aircraft you are working on. In this example, you are looking for voltage between pin 19 of 9461J261 and aircraft ground (the last fault isolation block of figure 3–7). You can trace this in the wiring diagram. Look in the upper middle section of figure 3–9 for the indication THROTTLE DISC; this is a cannon plug where you are checking for voltage. Follow the lead out of pin 19 and it goes through the L CONSOLE DISC plug and then to WT17, a splice area. The splice is connected to STA 158 L DISC by wire W1509–838–22. This wire continues through to the AFT EQPT BAY DC PWR PNL. This is the source of our power and is a 28 volts, direct current (VDC) power supply.

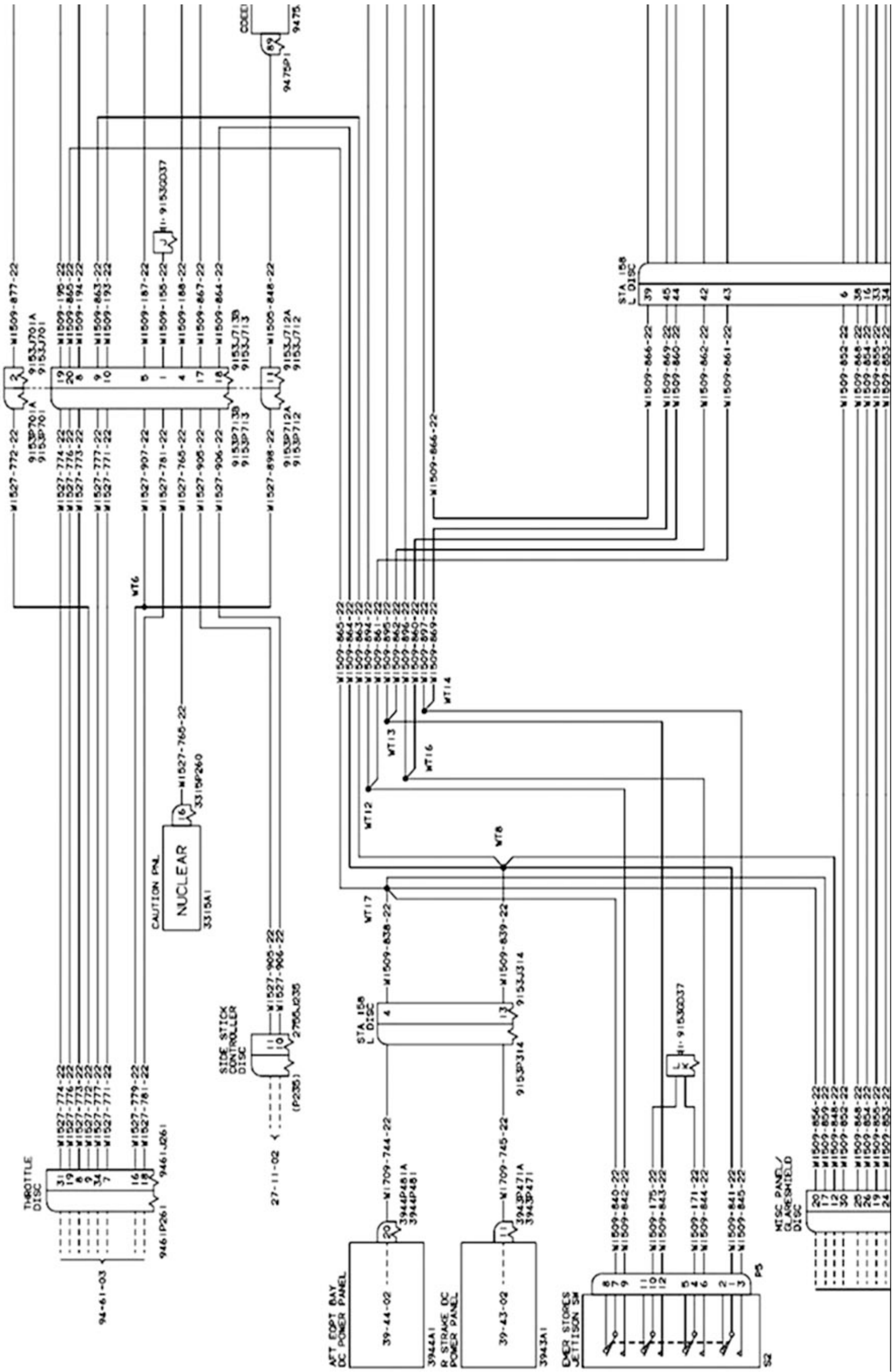
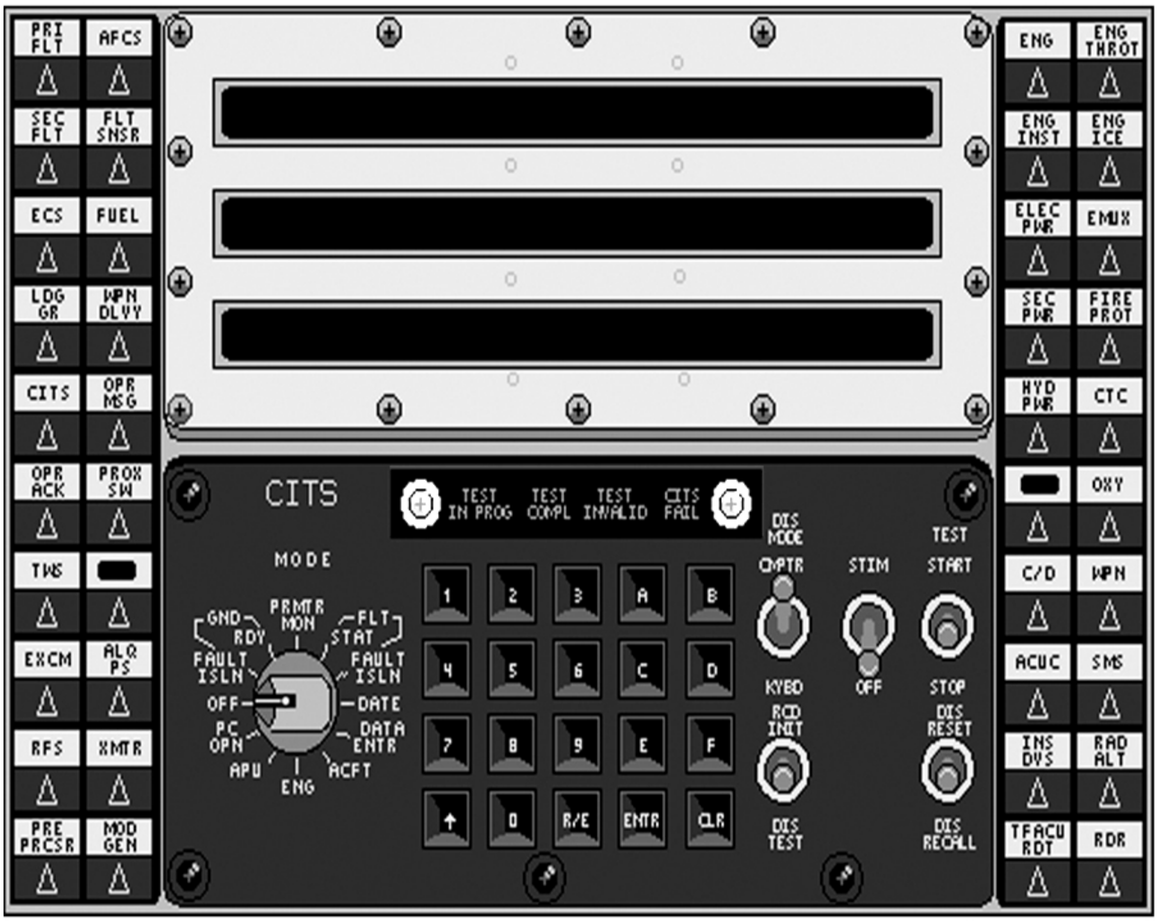


Figure 3–9. F–16 wiring diagram.

Now that you know where your power is coming from, you can place your positive meter lead to pin 19. The negative meter lead would be connected to an aircraft ground. It is very important to have a good ground when testing for voltage. The surface should be unpainted and clean of corrosion and oils. If power is applied and you touch the lead to a good ground, you should get 28 VDC. If you get 28 VDC, you would perform the steps in the OK box. If 28 VDC is not present, perform the NOT OK steps. Let’s look at another type of troubleshooting guide, how to use it, and see how you are to troubleshoot.

The B–1 system has the central integrated test system (CITS) and uses this system to identify faults for troubleshooting. The system displays a maintenance code you use to find the fault code and fault description. Figure 3–10 is a sample code displayed on the CITS control and display (CCD) panel of the B–1.



SI085654072

Figure 3–10. CITS control and display.

The CITS maintenance code (CMC) is taken from the CCD and referenced to the technical data (fig. 3–11). Take the CMC code 94035 and move to the column titled *Fault Code* and you find it to be 94–90–CE–01. The description of the fault is PROX SNCR L AFT, FWD BAY, FWD BAY DR CLOSED WRONG OUTPUT. This should match the procedure you are performing.

TO IB-IB-2-94GS-00-1

FAULT CODE INDEX PART I - (Continued)

CMC	FAULT CODE	DESIGNATOR	REFERENCE	FAULT DESCRIPTION
9402B	94-91-YY	2452A04KD47	FWD BAY DOOR FULL OPEN ALTN PWR RELAY RLY STATUS DISAGREES WITH CMD	
9402C	94-91-13-2	9491A04	PWR DRIVE UNIT - BAY DOOR, FWD BAY NORM BRAKE FAILED TO RELEASE	
9402D		94-91-13-2	9491A04PWR DRIVE UNIT - BAY DOOR, FWD BAY NORM BRAKE FAILED TO ENGA	
9402E	94-91-13-2	949IA04	PWR DRIVE UNIT - BAY DOOR, FWD BAY ALTN BRAKE FAILED TO RELEASE	
94030	94-91-13-2	9491A04	PWR DRIVE UNIT - BAY DOOR, FWD BAY NORM BRAKE FAILED TO ENGA	
94031	94-91-13-2	949IA04	PWR DRIVE UNIT - BAY DOOR, FWD BAY ALTN SIDE FAILED TO ENGA	
94032	94-90-AH-01		9491MC04 L DOOR DRIVE FWD BAY ROTARY ACTUATORS LOSS OF TORQUE	
		9491MC03	L DOOR DRIVE FWD BAY ROTARY ACTUATORS LOSS OF TORQUE	
		9491MC01	L DOOR DRIVE FWD BAY R ANGLE GEARBOX LOSS OF TORQUE	
		9491MC05	L DOOR DRIVE FWD BAY ROTARY ACTUATORS LOSS OF TORQUE	
94034	94-90-CC-01	9491S12	PROX SNSR R FWD, FWD BAY DR FULL OPEN WRONG OUTPUT	
94035	94-90-CE-01		9491S07 PROX SNSR L AFT, FWD BAY, FWD BAY DR CLOSED - WRONG OUTPUT	
94036	94-90-CE-01		9491S05PROX SNSR L FWD, FWD BAY DR CLOSED WRONG OUTPUT	
94037	94-90-CE-01		9491S06 PROX SNSR R AFT, FWD BAY DR CLOSED WRONG OUTPUT	
94038	94-90-CE-01		9491S04PROX SNSR R FWD, FWD BAY DR CLOSED WRONG OUTPUT	
94039	94-90-CA-01		9491S11 PROX SNSR L AFT, FWD BAY DR HALF OPEN WRONG OUTPUT	

94-00-00

SI085654078

Change 13

Figure 3–11. Fault code index.

Figure 3–12 is a sample of a B–1 troubleshooting tree from the B–1 general system (GS) technical order. In the previous discussion, we referred to a system that was dependent on an external test set for testing the armament portions of the system, but the B–1 is different. The B–1 system has an internal checkout system to test itself, but you have to provide external inputs (e.g., a launcher test set, simulator plug, etc.) to provide the needed signal for system testing. The process may seem different, but the way the items are derived is the only difference.

Once you have the fault code, go to the fault tree for fault isolation. Figure 3–12 is the page you would refer to for troubleshooting. Note the page is marked with the fault code, and the fault code is posted at the beginning of the fault tree. Notice this is a go/no-go block structure like the one for the F–16. Move through the steps until you have the fault isolated. Notice in block 7 of the figure you are told to troubleshoot the system and you are referred to the technical data for the wiring diagram

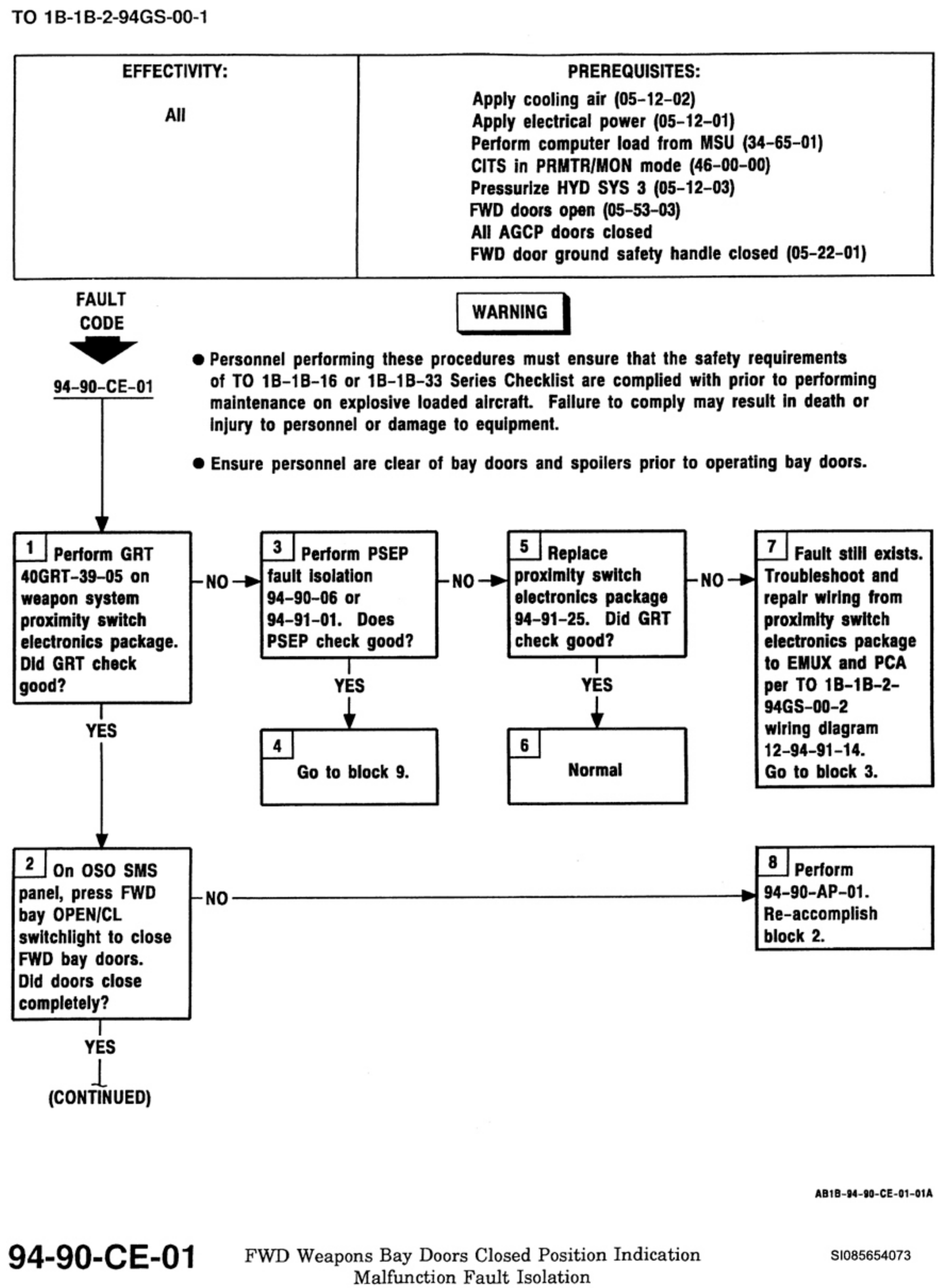


Figure 3–12. B–1 fault isolation.

Figure 3–13 is the wiring diagram you would have to refer to for troubleshooting. As a technician, you have to know what job the item does in the system and what steps you performed before being referred to this wiring diagram. You are told in block 7 of figure 3–13 to troubleshoot wiring between the proximity switch electronics package and the electrical multiplex (EMUX).

In figure 3–13, you can see the proximity switch electronics package and the EMUX at the top of the diagram. You can trace these wires by disconnecting the plugs 9492P14 on the proximity switch electronics package and any of the other plugs (e.g., 9221P132, 9221P134, etc.) on the EMUX. These two items can be next to each other or on opposite sides of the aircraft. You have to be aware of the aircraft components and their location. Earlier in this section, we discussed needing system knowledge to become a good troubleshooter. This you can achieve by following the troubleshooting steps with the wiring diagram and by reading the system description. You may not always have the time to follow along with the wiring diagram; if so, note what was done and refer to the system description later.

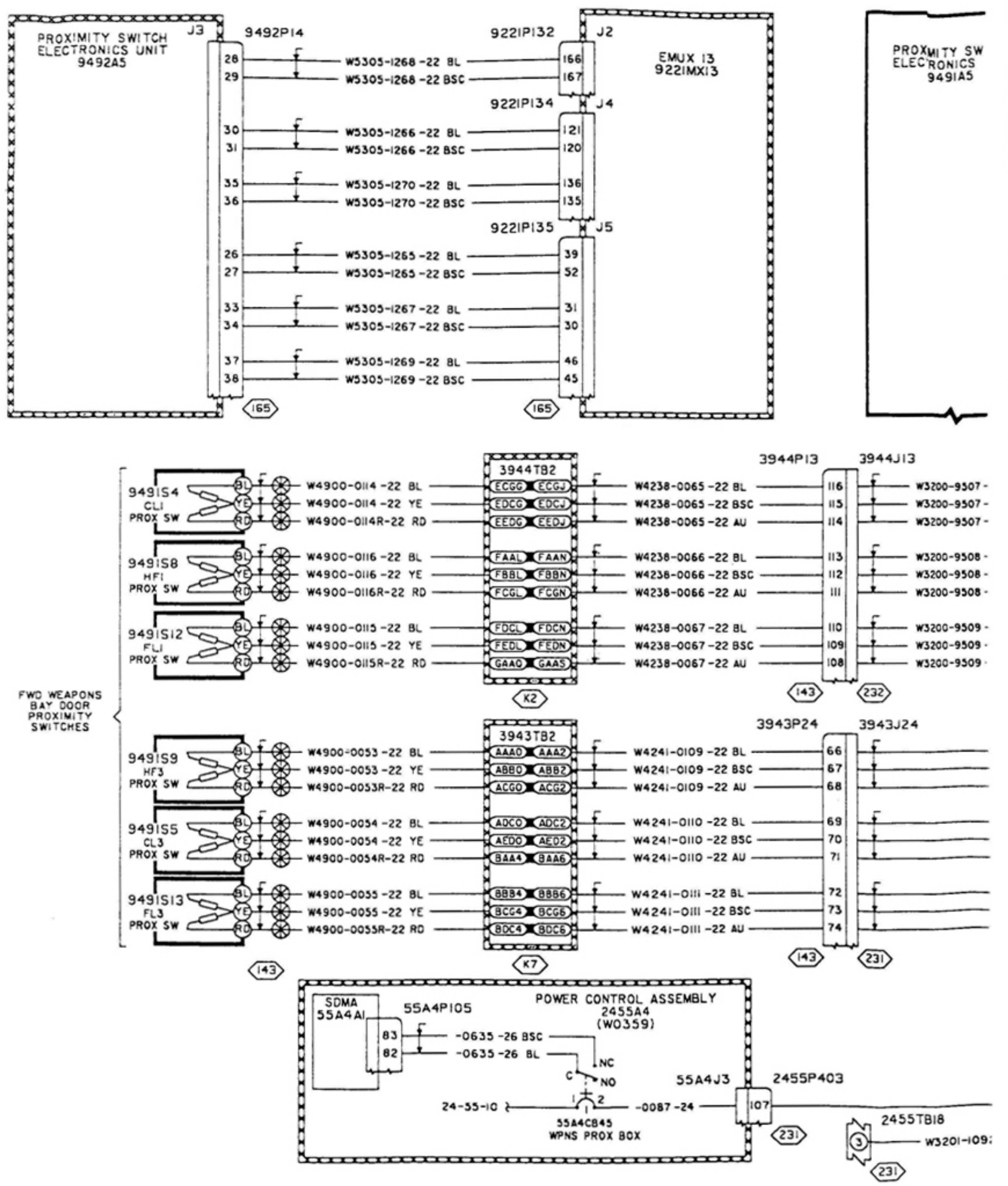


Figure 3–13. B–1 wiring diagram.

418. Electrostatic discharge control

Current trends in solid-state technology are producing greater circuit complexity, smaller components, and increased density in solid-state devices. This produces thinner dielectrics between the active elements, resulting in increased vulnerability to damage from electrostatic discharges (ESD).

Electrostatic discharge sensitive components

Various electronic parts are now more electrostatic discharge sensitive (ESDS) than others and can be damaged by ESD levels commonly generated when you are testing, handling, repairing, and assembling electronic components. You may not even be aware a discharge of static electricity has occurred, but it could have happened.

Many ESD electronic devices such as semiconductors, thick and thin film resistors, chips, and hybrid devices can be destroyed by ESD levels of a few hundred volts, far below our threshold of awareness (around 4,000 volts). Several more types of components are susceptible to electrostatic damage such as the following:

- Metal-oxide semiconductor field-effect transistors (MOSFET).
- Programmable read-only memory (PROM) circuits.
- Read-only memory (ROM) circuits.
- Random-access memory (RAM) circuits.
- Complementary MOSFETs (CMOS).
- Piezoelectric crystals.

Consider any assembly or line replaceable unit (LRU) containing these components to be ESDS. ESDS equipment should be marked with the following ESDS caution symbol and statement:

CAUTION: This equipment contains parts sensitive to damage by electrostatic discharge (ESD). Use ESD precautionary procedures when touching, removing, or inserting parts or assemblies.

Levels of ESDS

ESD components are grouped into two levels arranged by their sensitivity ranges: level 1, sensitive, and level 2, supersensitive.

Level 1 (sensitive)

This level ranges from 0 to 16,000 volts. This level includes microcircuits and integrated circuits, crystal oscillators and piezoelectronic crystals, thick and thin film resistors, resistor chips and resistor networks (*except* wire-wound or carbon resistors), MOSFETs, junction field-effect transistors (JFET), bipolar transistors, input protection circuits on discrete MOSFETs, and MOS integrated circuits (IC).

Level 2 (supersensitive)

This level ranges from 0 to 1,000 volts. This level includes parts or components with voltage sensitivity between 0 and 1,000 volts. The gate density in a transistor or the dielectric thickness also contributes to the device being classified as supersensitive.

ESDS failures

ESDS-related failures are not always easy to identify. An ESD can cause electronic equipment to exhibit total, an intermittent, or delayed failure. Total failure of the equipment is easily identified. Intermittent failures are another matter. These units return to the shop continuously for the same malfunction on the aircraft. Each time the equipment enters the shop, a different technician is assigned to repair it. Each time, the failure is not duplicated. The equipment becomes known as a *bad actor*. What this means is the equipment might appear to act normally when checked out, but it malfunctions when installed in the aircraft and subjected to extreme temperatures, vibration, high G forces, or hard landings. This type is sent to depot for repair due to its poor history. The delayed type of failure is just as frustrating for the technician as the intermittent failure. The damaged component is at the point of malfunctioning but remains operational for the duration of the checkout. Just as you complete the test, the unit malfunctions and troubleshooting has to begin.

ESDS precautions

There are specific precautions you must follow when working with ESDS equipment in the shop. Most of the precautions are outlined in the TOs you use to test the equipment. In your work area, you generally have an ESDS work station. The most important precaution is to ensure you and the equipment are properly grounded before you begin maintenance on any ESDS equipment. Attach the grounding straps of the workstation to the LRU, the test equipment, and your wrist. This equalizes the electrostatic potentials between you and the equipment. The use of a floor mat is optional, but the mat helps reduce the generation of static charges. The mat should have a resistance of at least 1,000,000 ohms for personal protection. Correct handling of ESDS LRUs results in increased reliability and decreased life-cycle costs. You can find further guidance on this subject in TO 00–25–234, *General Shop Practice Requirements for the Repair, Maintenance, and Test of Electrical Equipment (ATOS).*

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

414. Causes and types of electrical troubles

1. What are the two *most common* causes of electrical troubles?

2. What are the *three* general types of electrical troubles?

3. What is the difference between an *open* circuit and a *short* circuit?

4. What type of problem is indicated by burnt wiring?

5. What precaution must you take when troubleshooting a short to ground?

6. What type of problem can a loose connection eventually cause?

415. Basic troubleshooting procedures

1. What is usually the *first* step in troubleshooting?

2. When troubleshooting a circuit, what does a good circuit breaker normally indicate?

3. Referring to diagram A of figure 3–3, assume you had an additional open between points 5 and 6. Using the point-to-ground method, what would the reading be at each point?

4. Referring to diagram B of figure 3–3, assume the same opens are present as in question 3. Using the parallel method, what would the reading be across points 2 and 3, 3 and 4, 4 and 5, 5 and 6, 6 and 7, 7 and 8, 8 and 9, and 9 and 10?

416. Component testing procedures

1. When checking a diode with an ohmmeter, what is indicated by two high-resistance measurements?

2. What does a normal set of measurements from a diode show?

3. What is the desired ratio between the forward and reverse biases of a regular diode?

417. Troubleshooting aircraft systems

1. What are job guides?

2. You are using the job guide and a task fails. What do you do with the fault code for that task?

3. What must you remember when you begin the fault finding process?

4. When performing the fault isolation process, why do you follow along in the wiring diagrams?

5. What component of the B–1 aircraft identifies the faults for troubleshooting?

6. How do you use the maintenance code that is displayed on the CITS?

418. Electrostatic discharge control

1. List the types of ESDS components.

2. What are the sensitivity ranges for the two levels of ESD components?

3. List the *three* types of failures you might encounter because of electrostatic damage.

4. When you've tested a unit numerous times in the shop and can't find a malfunction with it, what type of failure is it?

5. What is the *most* important procedure when you're involved in repairing an ESD unit?

Answers to Self-Test Questions

413

1. The polarity, the condition of the meter's battery, whether you are in manual or auto range, and negative annunciator for the bar graph.
2. (1) RANGE.
   (2) HOLD.
3. HOLD mode.

414

1. (1) Careless maintenance.
   (2) Weather conditions.
2. (1) Open circuits.
   (2) Shorted circuits.
   (3) Grounded circuits.
3. An open circuit is a break in the circuit or a circuit in which no current flows. A short circuit is an accidental contact between two normally insulated conductors or points.
4. Grounded circuit (short to ground).
5. Disconnect both ends of the circuit under inspection.
6. Short or open circuits.

415

1. A visual check of the circuit for broken wires, loose connections, or other conditions that are apparent.
2. An open in the circuit.
3. Point 1, 24 V; point 6, 0 V; point 2, 24 V; point 7, 0 V; point 3, 24 V; point 8, 0 V; point 4, 24 V; point 9, 0 V; point 5, 24 V; point 10, 0 V.
4. Points 2–3, 0 ohms; points 6–7, 10 ohms; points 3–4, 0 ohms; points 7–8, 0 ohms; points 4–5, 0 ohms; points 8–9, infinity; points 5–6, infinity; points 9–10, 10 ohms.

416

1. The diode is open or has a high forward resistance.
2. A low resistance in the forward direction and high resistance in the reverse direction.
3. 10 to 1.

417

1. Abbreviated TOs with step-by-step functional or operational checks for systems within a particular job.
2. Refer to the FI TO or table for the task being performed.
3. The switches you used before the fault occurred.
4. Because, doing so will greatly increase your knowledge of the system and the reasoning behind the tasks that are performed.
5. The CITS.
6. To find the fault code and fault description in the fault code index.

418

1. (1) Semiconductors.
   (2) Thick and thin film resistors.
   (3) Chips.
   (4) Hybrid devices.
   (5) MOSFETs.
   (6) PROMs.
   (7) RAMs.
   (8) CMOSs.
   (9) Piezoelectric crystals.
2. (1) Level 1 sensitive: 0 to 16,000 volts.
   (2) Level 2 supersensitive: 0 to 1,000 volts.
3. (1) Total.
   (2) Intermittent.
   (3) Delayed.
4. Intermittent.
5. Ensuring you and the equipment are properly grounded.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

62. (413) The annunciators displayed on the Fluke 8025A digital multimeter are used to distinguish among
    a. ohms, kilohms, and megohms.
    b. ohms, milliohms, and kilohms.
    c. amps, ohms, and millivolts.
    d. ohms, volts, and amps.

63. (413) What are the two operational modes of the Fluke 8025A digital multimeter?
    a. AC and DC.
    b. Range and hold.
    c. Auto and manual.
    d. Continuous and momentary.

64. (413) To return the Fluke 8025A digital multimeter meter to the auto range mode, you *must* depress the RANGE push button for
    a. less than 1 second.
    b. more than 1 second.
    c. more than 3 seconds.
    d. between 4 and 5 seconds.

65. (414) What are the three general types of electrical troubles that develop in electrical circuits?
    a. Open, crossed, and grounded circuits.
    b. Closed, short, and grounded circuits.
    c. Open, short, and grounded circuits.
    d. Closed, short, and open circuits.

66. (414) Accidental contact between two normally insulated conductors *most* likely results in
    a. an open circuit.
    b. a grounded circuit.
    c. a shorted circuit.
    d. an overloaded circuit.

67. (414) Loose metal hardware is a special area of concern when dealing with junction boxes because it can
    a. jam controls within the junction box.
    b. damage the structural hardware inside the box.
    c. damage the environmental integrity of the junction box.
    d. shift during flight making untended electrical contact causing short circuits.

68. (414) What do you use to remove oxidation from conductors to ensure a good solder joint?
    a. Flux.
    b. Alcohol.
    c. Gum eraser.
    d. Rubber eraser.

69. (414) What is the *only* kind of flux usable on aircraft electrical wiring?
    a. Paste.
    b. Liquid.
    c. Rosin based.
    d. Petroleum based.

70. (414) What must the technician use to remove excess flux after completing a solder joint?
    a. Alcohol.
    b. Gum eraser.
    c. Wire brush.
    d. Petroleum based cleaner.

71. (414) What happens if the soldering iron is *not* hot enough when contact is made to transfer sufficient heat to the component being soldered?
    a. Heat related corrosion can result in the two joined materials.
    b. Excessive oxidation of the flux may occur, which leads to corrosion.
    c. The solder will “set” before it fuses with the material being joined causing a weaker than expected joint.
    d. The soldering iron will need to remain in the joining longer possibly damaging the components through excessive heating.

72. (415) What is usually the *first* step in troubleshooting an electrical circuit?
    a. Isolate the voltage source.
    b. Make a visual check for obvious defects.
    c. Disconnect the source of power from the circuit.
    d. Calibrate the instrument to be used during troubleshooting procedures.

73. (415) A good fuse or circuit breaker in a malfunctioning circuit *normally* indicates
    a. a grounded circuit.
    b. an open in the circuit.
    c. a short in the circuit.
    d. an open-grounded circuit.

74. (415) If for some reason, the fuse in a circuit blows or burns out, it is an indication that you have
    a. a ruptured circuit.
    b. an open in the circuit.
    c. an open-grounded circuit.
    d. a short to ground in the circuit.

75. (416) When testing a diode, how many measurements *must* you take?
    a. One.
    b. Two.
    c. Three.
    d. Four.

76. (416) Two high-value resistance measurements indicate a diode is
    a. open.
    b. shorted.
    c. grounded.
    d. a low reverse-bias diode.

77. (416) A standard diode used in a rectifier should have a reverse-to-forward bias ratio of
    a. 5 to 1.
    b. 10 to 1.
    c. 50 to 1.
    d. 100 to 1.

78. (417) Troubleshooting is a
    a. scheme of wire tracing.
    b. systematic approach to finding a fault.
    c. method used to functionally check a system.
    d. method used to operationally check systems.

79. (417) What are job guides?
    a. Step-by-step isolation technical data.
    b. Wire tables with fault isolation data.
    c. Step-by-step operational procedures.
    d. A list of fault trees.

80. (417) Where do you find troubleshooting trees?
    a. Job guides.
    b. Wiring diagrams.
    c. General technical data.
    d. Fault isolation technical data.

81. (417) What are troubleshooting trees?
    a. A list of operational data.
    b. Step-by-step operational data.
    c. Wire splicing and fault isolation data.
    d. Step-by-step troubleshooting procedures.

82. (418) How many levels of electrostatic discharge (ESD) components are there?
    a. One.
    b. Two.
    c. Three.
    d. Four.

83. (418) What is the sensitivity range of level 1 electrostatic discharge (ESD) components?
    a. 0 to 500 volts.
    b. 0 to 16,000 volts.
    c. 1,000 to 4,000 volts.
    d. 1,000 to 15,000 volts.

84. (418) What is the *most important* precaution the technician can take *before* handling electrostatic discharge (ESD) components?
    a. Using insulated gloves.
    b. Using floor mats to reduce generation of static charges.
    c. Ensuring that they and their equipment are grounded.
    d. Ensuring benches, seating, and technicians are insulated from all grounding sources.

85. (418) *At least*, how many ohms of resistance should a floor mat at a workstation have for proper personnel protection?
    a. 1,000.
    b. 10,000.
    c. 100,000.
    d. 1,000,000.

Student Notes

Glossary Abbreviations and Acronyms

μA	microampere
Ω	ohm
kΩ	kilohm
A	ampere
AC	alternating current
AEIS	aircraft/store electrical (and fibre optic) interconnection system
~~**AFI**~~	~~Air Force instruction~~
AGM	air-to-ground missile
BNC	bayonet nut connector
CB	circuit breaker
CCD	CITS control and display
CITS	central integrated test system
CMC	CITS maintenance code
CMOS	complementary MOSFET
DC	direct current
DPDT	double-pole, double-throw
DPST	double-pole single throw
EMF	electromotive force
EMUX	electrical multiplex
ESD	electrostatic discharge
ESDS	electrostatic discharge sensitive
FEP	fluorinated ethylene propylene
FI	fault isolation
GPS	global positioning system
GS	general system
I	current
IC	integrated circuit
JFET	junction field-effect transistor
LRU	line replaceable unit
mA	microampere
MDS	mission design series
MIL–STD	military standard
MOSFET	metal-oxide semiconductor field-effect transistor

OTI	one-time inspection
PE	polyethyleve
PP	polypropylene
PROM	programmable read-only memory
psi	pounds per square inch
PTFE	polytetrafluoroethylene
QA	quality assurance
R	resistance
RAM	random-access memory
RF	radio frequency
ROM	read-only memory
SPDT	single-pole, double-throw
SPST	single-pole, single-throw
TO	technical order
V	volt
VDC	volts, direct current

Student Notes

AFSC 2W151
2W151A 03 1702
Edit Code 07