



AVIATION MECHANIC SERIES

# AIRFRAME SYSTEMS



Original Text by Dale Crane  
**FIFTH EDITION**

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**FIFTH EDITION**

Original Text by Dale Crane  
Keith Anderson, Technical Editor



AVIATION SUPPLIES & ACADEMICS, INC.  
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*Aviation Mechanic Series: Airframe Systems*

Fifth Edition

Based on the original text by Dale Crane

Aviation Supplies & Academics, Inc.

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# Preface

Aviation maintenance technology has undergone tremendous changes in the past decades. Modern aircraft, with their advanced engines, complex flight controls and environmental control systems, are some of the most sophisticated devices in use today, and these marvels of engineering must be maintained by knowledgeable technicians. The Federal Aviation Administration, recognizing this new generation of aircraft, has updated the requirements for maintenance technicians and for the schools that provide their training. The FAA has also instituted an Aviation Maintenance Technician Awards Program to encourage technicians to update their training.

New technologies used in modern aircraft increase the importance of maintenance technicians having a solid foundation in such basic subjects as mathematics, physics, and electricity. The Aviation Mechanic Series has been produced by ASA to provide the needed background information for this foundation and to introduce the reader to aircraft structures, powerplants, and systems.

These textbooks have been carefully designed to assist a person in preparing for FAA technician certification, and at the same time serve as valuable references for individuals working in the field. The subject matter is organized into categories used by the FAA for the core curriculum in 14 CFR Part 147, Aviation Maintenance Technician Schools, and for the Subject Matter Knowledge Codes used in the written tests for technician certification. In some cases in the ASA series, these categories have been rearranged to provide a more logical progression of learning.

This textbook is part of the ASA series of coordinated maintenance technician training materials. The series consists of the Aviation Mechanic Series textbooks, *General*, *Airframe Structures*, *Airframe Systems*, and *Powerplant* textbooks with study questions, the test guides for aviation mechanics, exam software for Aviation Maintenance Technician tests, the *Aviation Mechanic Oral and Practical Exam Guide*, the *Dictionary of Aeronautical Terms*, and the *Aviation Mechanic Handbook*.

To supplement this fundamental training material, ASA reprints the FAA Advisory Circulars (ACs) 43.13-1 and 43.13-2 in *Aircraft Inspection, Repair, and Alterations: Acceptable Methods, Techniques, and Practices*, as well as the FAR-AMT, excerpts from the Federal Aviation Regulations that are applicable to the aviation maintenance technician.

*Dale Crane*

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# About the Editorial Team

## Fifth Edition

Based on the original text by Dale Crane

**Dale Crane** (1923–2010), the original author of this series, was involved in aviation for more than 50 years. He began his career in the US Navy as a mechanic and flight engineer in PBYS. After World War II, he attended Parks Air College. After college, he worked as an instrument overhaul mechanic, instrument shop manager, and flight test instrumentation engineer. Later he became an instructor and then director of an aviation maintenance school.

Dale was active as a writer of aviation technical materials, and as a consultant in developing aviation training programs. ATEC presented to Dale Crane their special recognition award for “his contribution to the development of aviation technicians as a prolific author of specialized maintenance publications.” He also received the FAA’s Charles Taylor “Master Mechanic” award for his years of service in and contributions to the aviation maintenance industry, and the recognition of his peers for excellence as a leader and educator in aircraft maintenance, and aviation safety advocate



**Keith Anderson** has over 40 years of experience in aviation as an A&P mechanic, authorized inspector (IA), commercial pilot, flight instructor, and aeronautical engineer. He has worked in Part 91, 121, and 135 operations, has held multiple DOM (director of maintenance) positions, and has taught at the university level. His pilot/mechanic experience includes 10 years of living and working in Central and South America and Africa. Keith has worked as a design engineer in aircraft design and certification and has held multiple leadership roles including engineering director and vice president positions that have included STC certifications and the type certification (TC) of a single-engine turboprop airplane.



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## An Introduction to Aircraft Electrical Systems

An aviation mechanic (also referred to as an aviation maintenance technician or AMT) must have a solid foundation in basic electrical principles and a good working knowledge of the way these principles apply to complex systems. Electrical systems provide the muscle for retracting landing gears and starting engines and serve as the brains for *electronic* flight control and monitoring systems.

Basic electrical principles are covered in the *General* textbook of the Aviation Mechanic Series. In the *General* text, electricity is discussed from a theoretical point of view, with emphasis on its laws. Circuit analysis considers the variables in both AC and DC circuits.

The *Airframe Structures* and *Airframe Systems* textbooks of the Aviation Mechanic Series take up where the *General* text leaves off, including a brief review of electrical terms and facts, followed by the practical application of basic electrical principles to aircraft electrical systems.

The *Powerplant* textbook of the Aviation Mechanic Series covers practical aspects of the generation of electricity and some of the heavy-duty applications, such as engine starting systems.

Aircraft electrical systems covered here range from the simplest component schematics to logic flow charts used for systematic troubleshooting. The intent of this section is to present aircraft electrical systems in their most practical form.

No specific aircraft electrical schematics are used in this text, but the systems used have been adapted from actual aircraft. The procedures discussed are general in their nature, and this text must be considered as a reference document, not a service manual. Information issued by the aircraft manufacturer takes precedence over any procedure mentioned in this text.

One of the fundamental rules of aviation maintenance is that you must use the latest approved information, such as that furnished by the aircraft manufacturer when servicing any part of an aircraft. This is particularly true of electrical systems, as these systems and their components are far too expensive to risk damage as the result of improper servicing procedures. There are limits as to what an aircraft mechanic or technician can do in the repair of certain electrical or electronic components. Some of these can be repaired only by the manufacturer or by a repair station specifically authorized for this work.

To begin this study, we will examine the requirements for an aircraft electrical system and then review some terms and facts.

### **Electrical System Requirements**

Title 14 of the Code of Federal Regulations, Part 23—*Airworthiness Standards: Normal Category Airplanes*—provides requirements and guidance for the certification of electrical systems in general aviation aircraft. The Normal Category includes aircraft of up to 19 passengers and maximum certificated takeoff weights of 19,000 pounds or less. Basic requirements for aircraft electrical systems include:

- A power generation system that will supply the required power during all intended operating conditions.

- Design considerations so that no single failure of any power supply, distribution path, or system component will prevent the system from providing essential power for a continued safe flight and landing.
- Sufficient system capacity so that, should the primary power generation source fail, the essential loads will continue to operate long enough for a continued safe flight and landing.
- Lights that are installed so that they do not interfere with the flight crew.
- Position lights that are of the correct colors and intensities to provide sufficient visibility to allow other aircraft time to avoid collisions.
- Taxi and landing lights that allow for safe night operation.
- Riding lights on seaplanes and amphibian aircraft that include a white light that is visible in clear weather.
- Built-in lightning protection for critical systems.
- Electrical protection from high-intensity radiated fields (HIRF), which can occur near ground-based radio transmitters.

## Review of Terms

Though by now you have a working knowledge of basic electricity, a brief review of some of the terms most commonly used in aircraft electrical systems should prove useful.

*bus*—A point in an aircraft electrical system supplied with power from the battery or the generator/alternator and from which the various circuits get their power.

*conductor*—A material that allows electrons to move freely from one atom to another within the material.

*current*—The assumed flow of electricity that is considered to move through an electrical circuit from the positive side of a battery to its negative side. This is opposite to the flow, or movement, of electrons. Current is measured in amperes (amps) and its symbol is the letter I. Current follows the arrowheads in the diode and transistor symbols.

*When current flows through a conductor, three things happen: heat is produced in the conductor, a magnetic field surrounds the conductor, and voltage is dropped across the conductor.*

*diode*—A solid-state device that acts as an electron check valve. Electrons can flow through a diode in one direction, but cannot flow through it in the opposite direction.

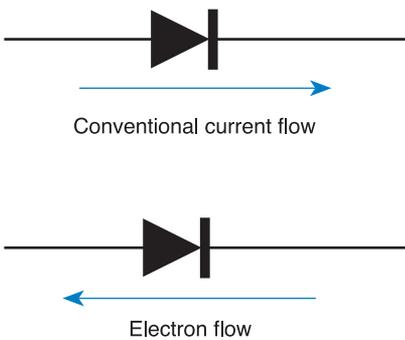
*electrons*—Invisible negative electrical charges that actually move in an electrical circuit.

*resistance*—Opposition to the flow of current. The unit of resistance is the ohm, and its symbol is R.

*voltage*—Electrical pressure. The unit of voltage is the volt, and its symbol is either V (used in this text) or E (electromotive force).

*voltage drop*—The decrease in electrical pressure that occurs when current flows through a resistance.

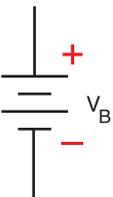
**electron current.** The actual flow of electrons in a circuit. Electrons flow from the negative terminal of a power source through the external circuit to its positive terminal. The arrowheads in semiconductor symbols point in the direction opposite to the flow of electron current.



**Figure 1-1.** Conventional current flows in the direction of the arrowheads of semiconductor diodes. Electron flow is in the opposite direction.

**conventional current.** An assumed flow of electricity that is said to flow from the positive terminal of a power source, through the external circuit to its negative terminal. The arrowheads in semiconductor symbols point in the direction of conventional current flow.

**schematic diagram.** A diagram of an electrical system in which the system components are represented by symbols rather than drawings or pictures of the actual devices.



**Figure 1-2.** Battery, or voltage source.



**Figure 1-3.** Resistor, or an electrical load.

## Direction of Current Flow

One of the things that adds confusion to the study of electricity is the way electricity flows in a circuit.

Before much was known about electricity, its flow was compared to the flow of water in a river and was therefore called “current.” As water currents flow from high to low, electrical current was considered to flow from positive (+) to negative (–). This was a reasonable conclusion, but was later determined to be wrong. Negatively charged electrons actually flow from negative to positive. This discovery was made only after countless textbooks about electricity had been written and symbols had been decided upon. Because of this, electrons in a circuit actually flow in the *opposite* direction to the way the arrowheads in the diode symbols point. This can be quite confusing.

In the *General* textbook, the term “electron flow” or “electrical current” was used to explain the basic principles of electricity. This *Airframe Systems* textbook (and many other modern texts on practical electricity) uses “conventional current,” or simply “current.” This is an assumed flow rather than an actual flow, and it travels from positive to negative, which allows us to visualize the flow in the direction of the arrowheads in the diode and transistor symbols. Considering the flow in this direction makes aircraft electrical systems much easier to understand. See Figure 1-1.

## Electrical System Components

The most important tool for understanding an aircraft electrical system is the schematic diagram. This road map of the electrical system uses standardized symbols to represent the various components, arranged in a logical sequence with regard to the circuit operation. However, their placement in the schematic tells nothing about their physical location in the aircraft.

This text uses standard symbols to show the way aircraft electrical circuits are built. Chapter 1’s Appendix A, beginning on page 90, shows the most common symbols used in schematic diagrams of aircraft electrical systems.

### DC Power Source

Figure 1-2 is the symbol for a battery. Conventional current leaves the positive (+) end and flows through the circuit to the negative (–) end. The long line is always the positive end of the battery.

### Electrical Load

Figure 1-3 is the symbol for a resistor, or an electrical load. It may be an actual component, or it may be part of some other device. The filament in a light bulb and the heater element in a soldering iron are both resistances.

When current flows through a circuit, three things happen:

- A magnetic field surrounds the conductors that carry the current.
- Some of the energy used to push the current through the load is changed into heat, light, and/or mechanical energy.
- Some of the voltage is dropped across the load.

All conductors have some resistance, but in this study, the resistance of the system conductors is disregarded.

## Basic Electrical Circuit

Figure 1-4 shows a complete electrical circuit. The battery ( $V_B$ ) supplies an electrical pressure (voltage) that forces current through the resistor (R). The arrows in the diagram show the direction of conventional current.

*Note:* In the symbols used in electricity, voltage is normally represented by the letter E, for electromotive force, but modern practice is to use the symbol V for voltage. As stated earlier, this text uses V, so don't be disturbed when you see E used for voltage in other books. The subscript B denotes battery voltage.

The current furnished by the battery follows the arrows. The resistor gets hot, and all of the voltage, or electrical pressure, from the battery is used up (dropped) across the resistor.

All electrical circuits must have three things:

- A source of electrical energy—the battery
- A load to change the electrical energy into mechanical energy, heat, and/or light—the resistor
- Conductors, or wires, that join the source and the load

In addition to these components, switches and fuses may be added for current control and circuit protection.

## Circuit Control Devices

Circuit control devices are those components which start or stop the flow of current, direct it to various parts of the circuit, or increase or decrease the amount of its flow. These components may be mechanical, or—more frequently the case—semiconductor devices.

### Switches

Figure 1-5 shows the symbols for some of the more common switches used in aircraft electrical systems. When a switch is open, current cannot flow in the circuit, but when it is closed, current can flow.

In Figures 1-6 and 1-7, the symbol for a light bulb has replaced the resistor as the electrical load. Rays coming from the bulb show that current is flowing. When there are no rays, current is not flowing.

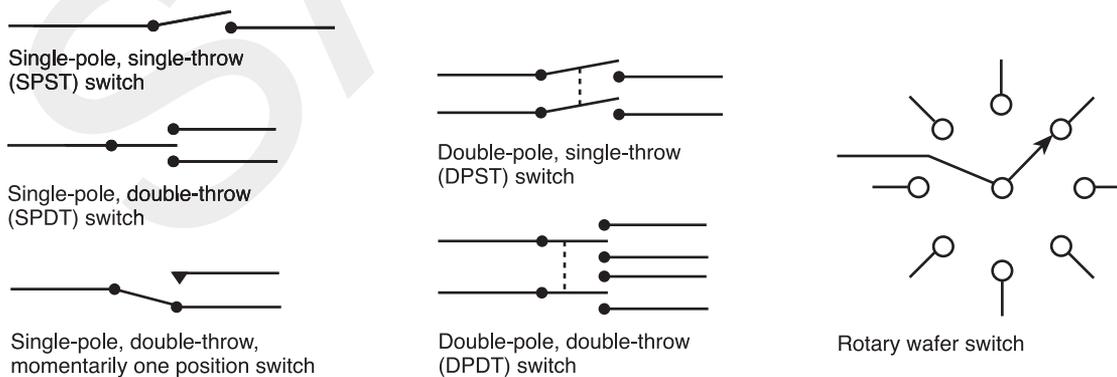


Figure 1-5. Switch symbols.

**electromotive force (EMF).** The force that causes electrons to move from one atom to another within an electrical circuit. Electromotive force is an electrical pressure, and it is measured in volts.

**current.** A general term used in this text for conventional current. See conventional current.

**conductor.** A material that allows electrons to move freely from one atom to another within the material.

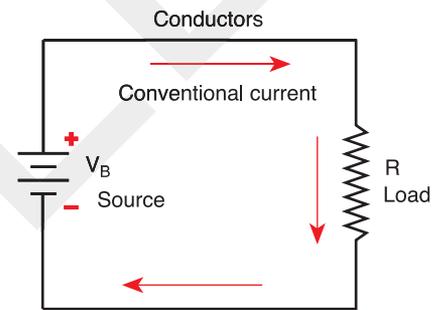
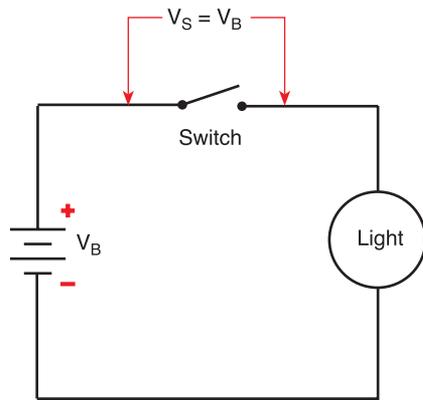
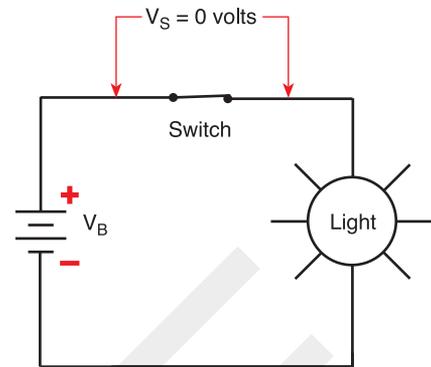


Figure 1-4. A complete electrical circuit.



**Figure 1-6.** This is an open circuit. No current is flowing and the light is off. All of the battery voltage is dropped across the open switch.



**Figure 1-7.** This is a closed circuit. The circuit is complete, current is flowing, and the light is lit. No voltage is dropped across the closed switch. All of the voltage is dropped across the light.

**semiconductor diode.** A two-element electrical component that allows current to pass through it in one direction, but blocks its passage in the opposite direction. A diode acts in an electrical system in the same way a check valve acts in a hydraulic system.

**forward bias.** A condition of operation of a semiconductor device such as a diode or transistor in which a positive voltage is connected to the P-type material and a negative voltage to the N-type material.

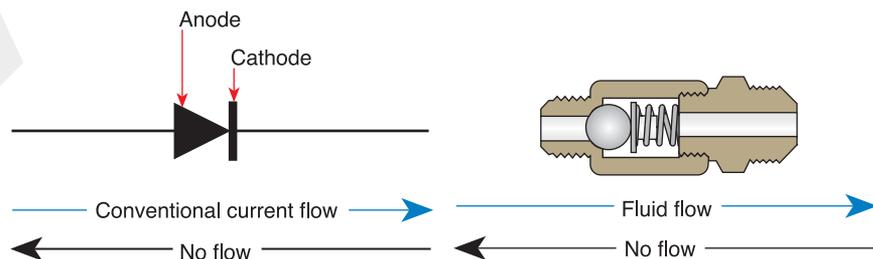
**reverse bias.** A voltage placed across the PN junction in a semiconductor device with the positive voltage connected to the N-type material and the negative voltage to the P-type material.

### Semiconductor Diodes

A semiconductor diode is an electron check valve that allows electrons to flow through it in one direction but blocks their flow in the opposite direction. Conventional current follows the direction of the arrowheads in the symbol. See Figure 1-8.

When a diode is installed in a circuit in such a way that its anode is more positive than its cathode, it is forward-biased and current can flow through it. A diode causes a voltage drop across it as current flows through it, but, unlike with a resistor, this voltage drop does not change with the amount of current. A silicon diode has a relatively constant voltage drop of approximately 0.7 volt across it when current flows through it (Figure 1-9). The voltage drop across a germanium diode is about 0.3 volt.

When a diode is installed in a circuit in such a way that its anode is more negative than its cathode, it is reverse-biased and current flow is blocked (Figure 1-10). No current can flow through it until the voltage across it reaches a value, called the “peak inverse voltage.” At this voltage, the diode breaks down and conducts current in its reverse direction. When this happens, an ordinary diode is normally destroyed.



**Figure 1-8.** A semiconductor diode controls current flow in an electrical circuit in the same way a check valve controls fluid flow in a hydraulic system. It allows flow in one direction but prevents its flow in the opposite direction. Conventional current flows through a diode in the direction shown by the arrowhead.



# AIRFRAME SYSTEMS

Also in the **Aviation Mechanic Series:**



*Airframe Systems*, the third textbook in Dale Crane's four-part Aviation Mechanic Series, covers the various systems involved with the airframe: electrical, fuel, cabin atmospheric control, aircraft instruments, communication and navigation, ice control and rain removal, fire protection, and potable water and waste systems, as well as aircraft inspections. The content meets FAA aviation maintenance technician school curriculum requirements and prepares applicants for the systems-related subjects tested on the Airframe FAA Knowledge Exam.

This new fifth edition features updated content reflecting new regulations and changes affecting aviation mechanic certification. Originally written by Dale Crane in 1994, this textbook has been reviewed and updated by an editorial team consisting of aviation mechanics, university professors, and pilots.

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