In the circuit shown in *Figure 4-74, View A*, the SCR is connected in the familiar half-wave arrangement. Current will flow through the load resistor (R_L) for one alternation of each input cycle. Diode CR1 is necessary to ensure a positive trigger voltage.

In the circuit shown in *Figure 4-74, View B* with the triac inserted in the place of the SCR, current flows through the load resistor during both alternations of the input cycle. Because either alternation will trigger the gate of the triac, CR1 is not required in the circuit. Current flowing through the load will reverse direction for half of each input cycle. To clarify this difference, a comparison of the waveforms seen at the input, gate and output points of the two devices is shown in *Figure 4-75*.

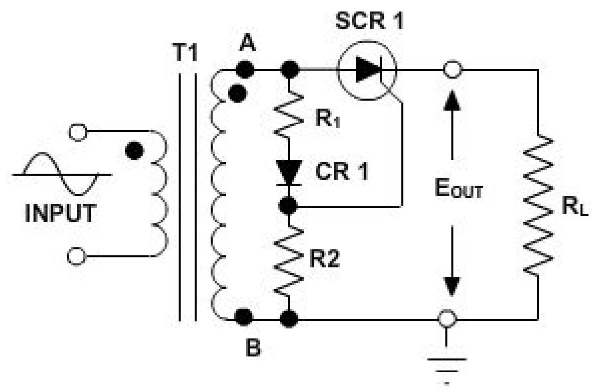

Figure 4-74 – Comparison of SCR and triac circuits

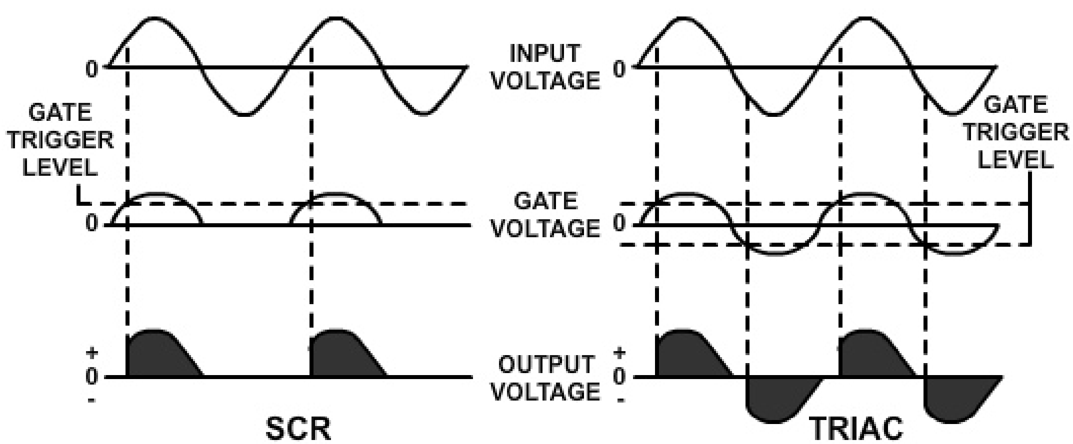

Figure 4-75 – Comparison of SCR and triac waveforms.

10.0.0 DIAC

A diac operated with a dc voltage across it behaves exactly the same as a Shockley diode. With ac, however, the behavior is different from what you might expect. Because alternating current repeatedly reverses direction, diacs will not stay latched longer than one half cycle. If a diac becomes latched, it will continue to conduct current only as long as voltage is available to push enough current in that direction. When the ac polarity reverses, as it must twice per cycle, the diac will drop out due to insufficient current, necessitating another breakover before it conducts again. The result is the current waveform in *Figure 4-76*. Diacs are almost never used alone, but in conjunction with other thyristor devices.

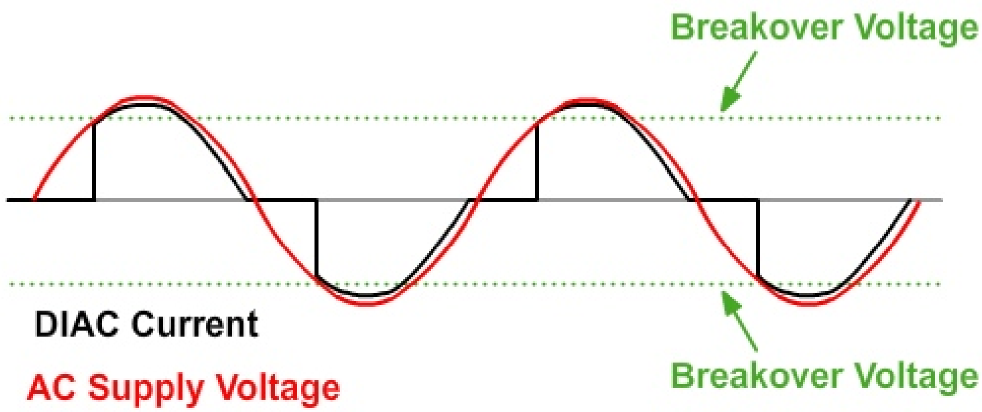

Figure 4-76 – DIAC waveform.

11.0.0 UNIJUNCTION TRANSISTOR (UJT)

The ***unijunction transistor (UJT)***, originally called a double-based diode, is a three-terminal, solid-state device that has several advantages over conventional transistors. It is very stable over a wide range of temperatures and allows a reduction of components when used in place of conventional transistors. A comparison is shown in *Figure 4-77*. *Figure 4-77, View A* is a circuit using conventional transistors, and *Figure 4-77, View B* is the same circuit using the UJT. As you can see, the UJT circuit has fewer components. Reducing the number of components reduces the cost, size, and probability of failure.

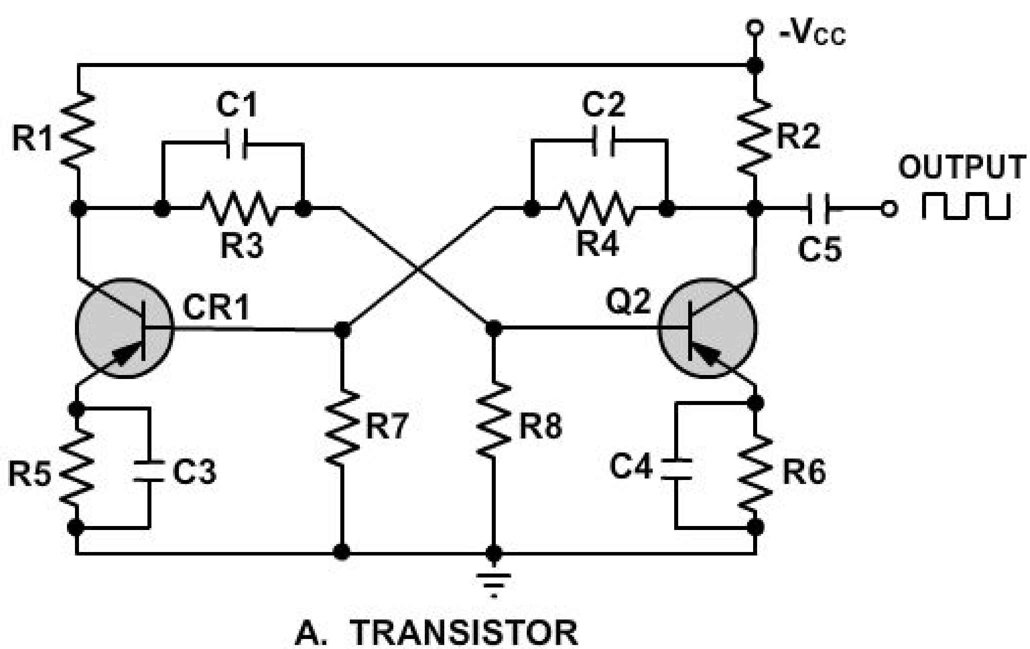

Figure 4-77 — Comparison of conventional transistors and UJT circuits.

The physical appearance of the UJT is identical to that of the common transistor. As shown in *Figure 4-78*, both have three leads and the same basic shape. The tab on the case indicates the emitter on both devices. The UJT, however, has a second base instead of a collector.

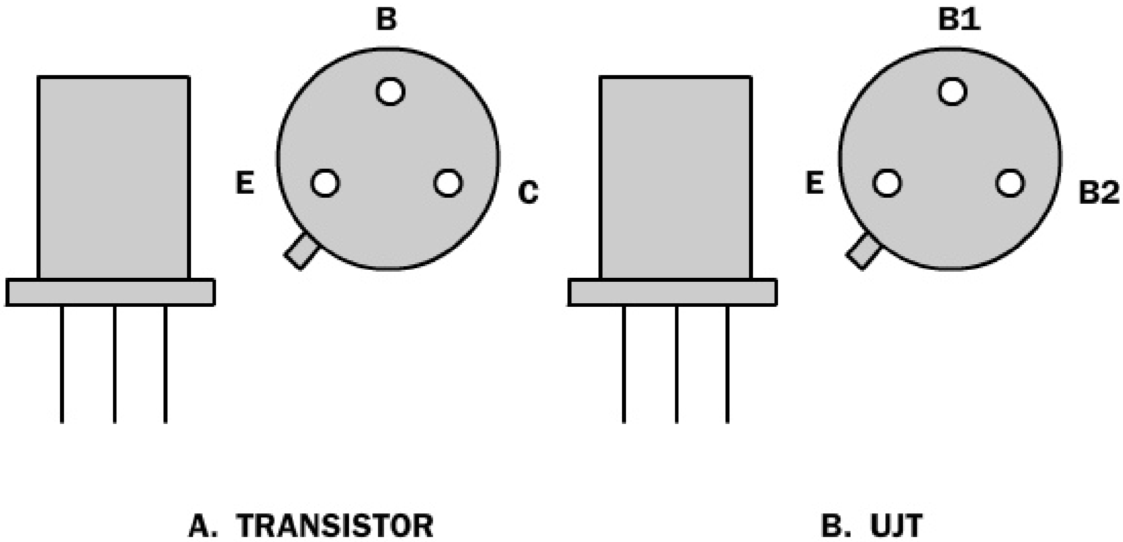

Figure 4-78 — Transistor and UJT.

As indicated in the block diagram shown in *Figure 4-79, Views A* and *B*, the lead differences are even more pronounced. Unlike the transistor, the UJT has only one PN junction. The area between base 1 and base 2 acts as a resistor when the UJT is properly biased. A conventional transistor needs a certain bias level between the emitter, base, and collector for proper conduction. The same principle is true for the UJT. It needs a certain bias level between the emitter and base 1, and also between base 1 and base 2 for proper conduction.

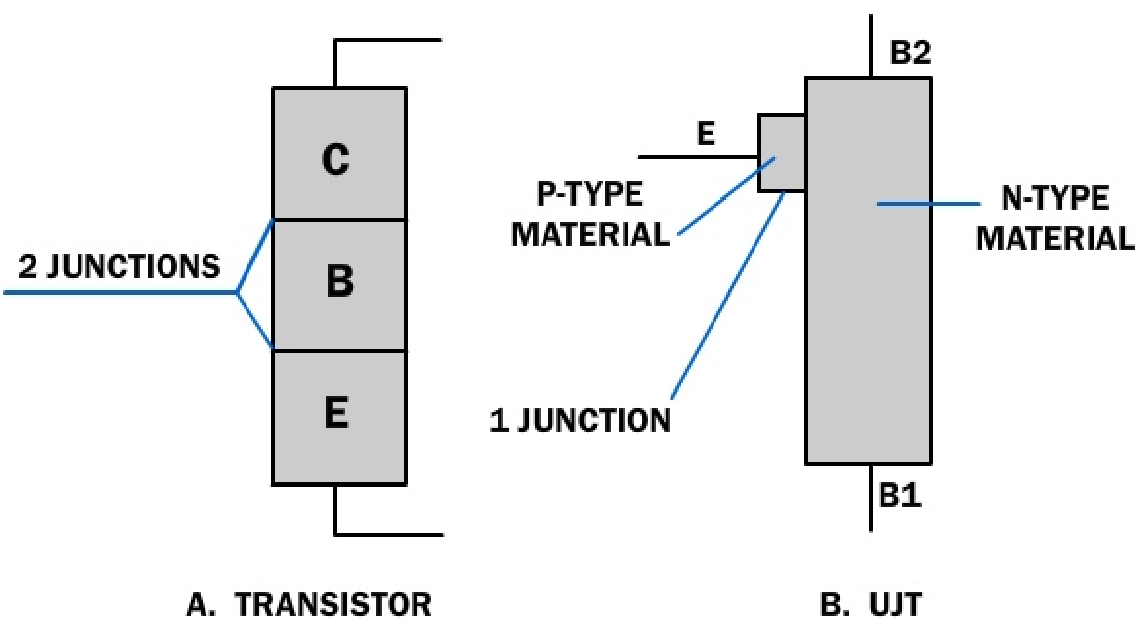

Figure 4-79 — Transistor and UJT structure.

The normal bias arrangement for the UJT is illustrated in *Figure 4-80, View A*. A positive 10 volts is placed on base 2 and a ground on base 1. The area between base 1 and base 2 acts as a resistor. If a reading were taken between base 1 and base 2, the meter would indicate the full 10 volts, as shown in *Figure 4-80, View B*. Theoretically, if one meter lead were connected to base 1 and the other lead to some point between base 1 and base 2, the meter would read some voltage less than 10 volts. This concept is illustrated in *Figure 4-81, View A*. *Figure 4-81, View B* is an illustration of the voltage levels at different points between the two bases. The sequential rise in voltage is called a voltage gradient.

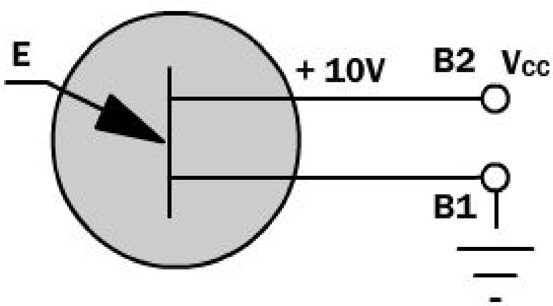

Figure 4-80 – UJT biasing.

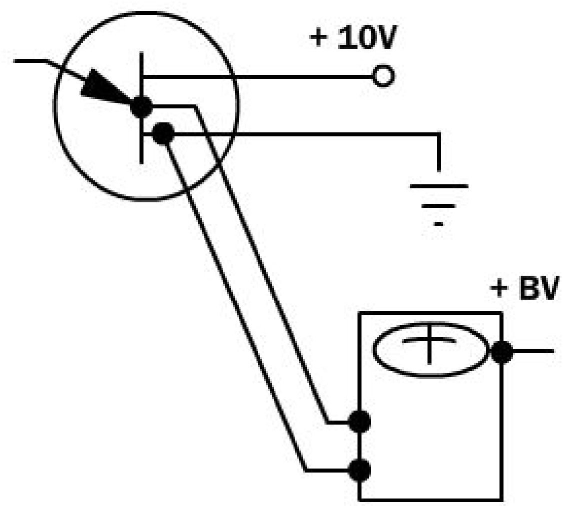

Figure 4-81 – UJT voltage gradient.

The emitter of the UJT can be viewed as the wiper arm of a variable resistor. If the voltage level on the emitter is more positive than the voltage gradient level at the emitter-base material contact point, the UJT is forward biased. The UJT will conduct

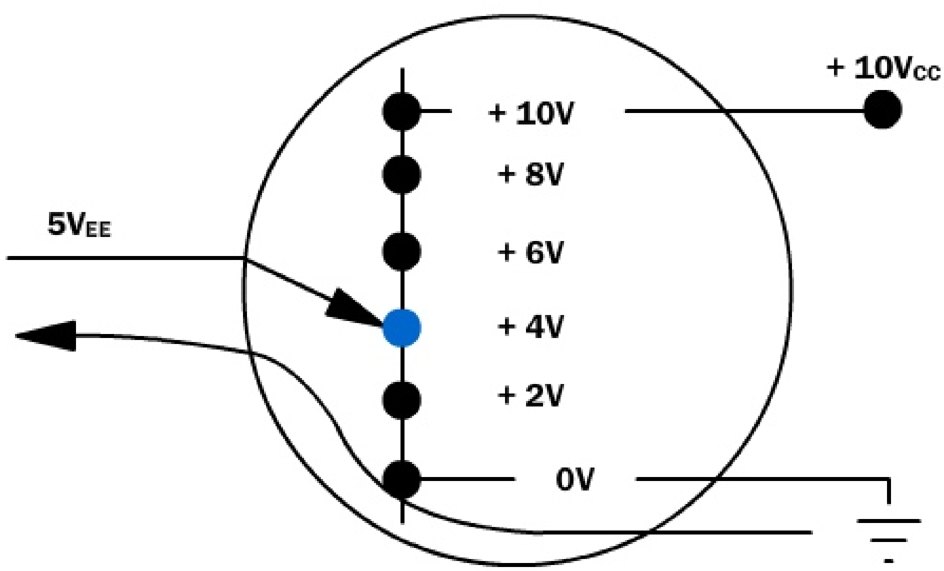

Figure 4-82 — Forward bias point on UJT voltage gradient.

heavily (almost short circuit) from base 1 to the emitter. The emitter is fixed in position by the manufacturer. The level of the voltage gradient therefore depends upon the amount of bias voltage, as shown in *Figure 4-82*.

If the voltage level on the emitter is less positive than the voltage gradient opposite the emitter, the UJT is reverse biased. No current will flow from base 1 to the emitter. However, a small current, called reverse current, will flow from the emitter to base 2. The reverse current is caused by the impurities used in the construction of the UJT and is in the form of minority carriers.

12.0.0 TRANSDUCERS

The broad definition of a transducer is a device that changes energy from one type into another. However, most transducers change between electricity and another energy type. Transducers also have other names depending on their usage, such as probe, detector, pickup, sensor, gauge, and electrode. *Figure 4-83* is a typical transducer diagram.

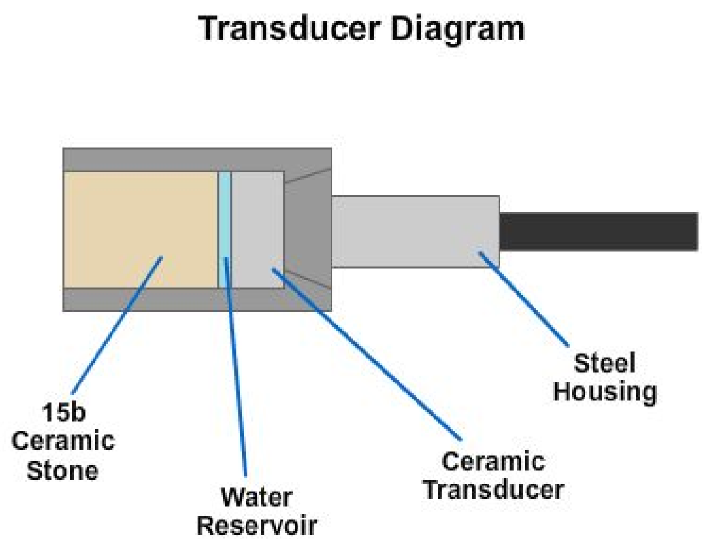

Figure 4-83 — Transducer diagram.

12.1.0 Electromagnetic Transducers

The antenna is the most basic transducer and can be made from a single piece of wire. It converts electromagnetic energy into electricity when it receives signals and does the opposite when it transmits. The head used in tape players is another type of electromagnetic transducer that converts the magnetic patterns on the tape into electrical signals. Tape heads have been largely replaced by laser diodes which turn electricity into light, and photo-detectors, which turn light into electricity.

12.2.0 Mechanical Transducers

Strain gauges have a long thin wire attached to a foil backing that is glued to an object. When the object changes shape, the strain gauge also changes shape, and its resistance changes. The amount of stress or strain in the object is calculated from this change in resistance. Another type of mechanical transducer is the accelerometer, which converts the change in position of mass into an electrical signal. Accelerometers measure the force of acceleration and deceleration. They are used in car airbags, stability control, hard drives, and many electronic gadgets.

12.3.0 Pressure Transducers

The most common types of pressure transducer are the microphone and speaker. Microphones convert sound pressure waves into electrical current, while speakers convert electrical current into sound pressure waves. Other types of pressure transducers include the geophone, hydrophone, and pickup needle. The geophone measures vibration in the earth and helps to predict earthquakes. The hydrophone detects water pressure waves and is used in sonar equipment. The pickup needle on a record player uses a piezoelectric crystal to produce an electrical current proportional to the variations in the record tracks.

Figure 4-84 – Pressure transducer.

12.4.0 Thermal Transducers

Thermocouples, thermistors, and resistance thermometers are all types of thermal transducers. They change the resistance proportionally to their temperature, but this relationship is different for each probe, and the meter needs to be calibrated for the type of probe being used. Thermal transducers are used in practically every device that measures temperature electronically.

13.0.0 INTEGRATED CIRCUIT (IC)

An ***integrated circuit*** is a device that integrates (combines) both active components (transistors, diodes, and so forth) and passive components (resistors, capacitors, and so forth) of a complete electronic circuit in a single chip which is a tiny slice or wafer of semiconductor crystal or insulator.

Integrated circuits (ICs) have almost eliminated the use of individual electronic components (resistors, capacitors, transistors, and so forth) as the building blocks of electronic circuits. Instead, tiny chips have been developed whose functions are not that of a single part, but of dozens of transistors, resistors, capacitors, and other electronic elements, all interconnected to perform the task of a complex circuit. Often these elements comprise a number of complete conventional circuit stages, such as a multistage amplifier (in one extremely small component). These chips are frequently mounted on a printed circuit board that plugs into an electronic unit (*Figure 4-85*).

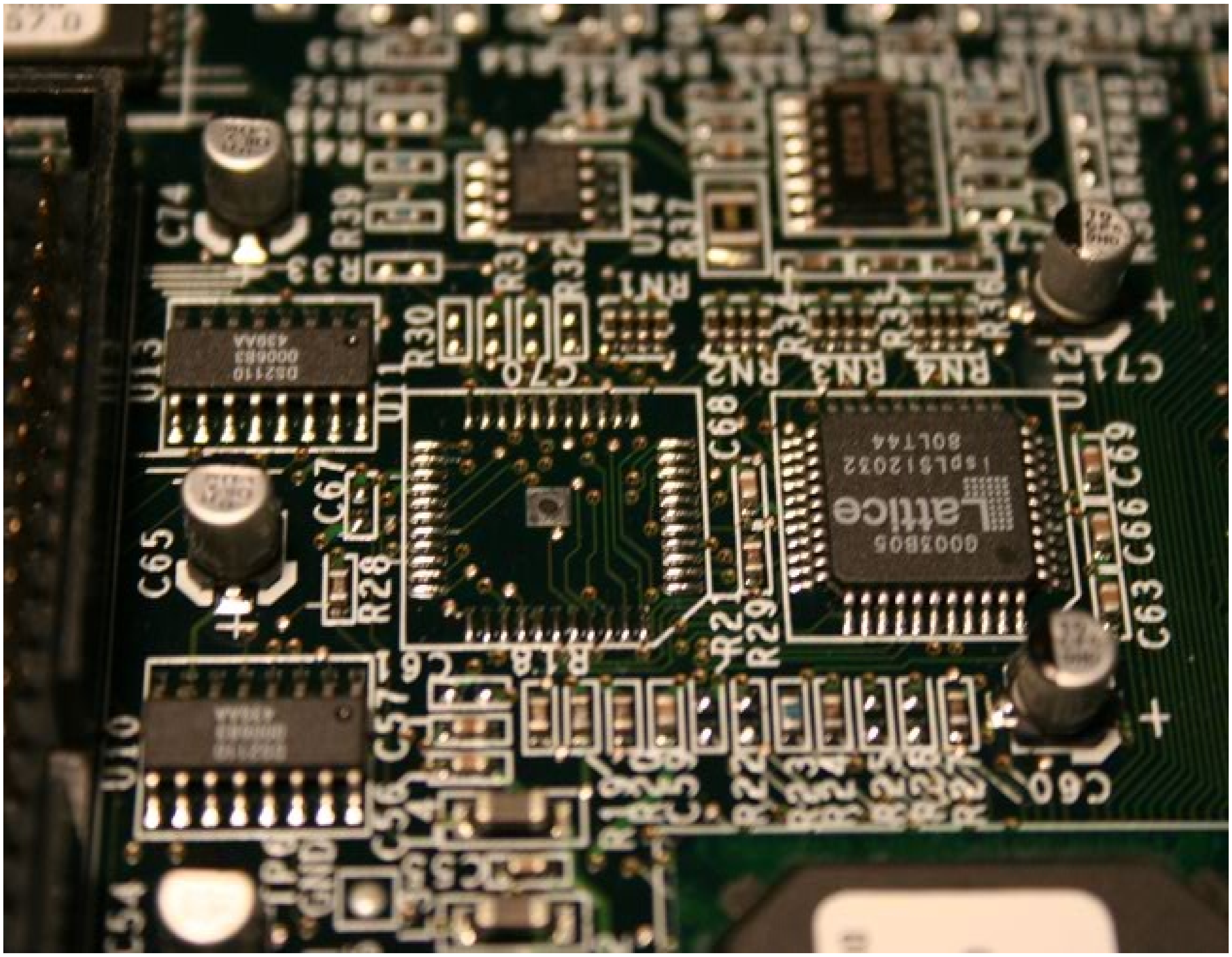

Figure 4-85 – ICs on a printed circuit board.

Integrated circuits have several advantages over conventional wired circuits of discrete components. These advantages include: (1) a drastic reduction in size and weight, (2) a large increase in reliability, (3) lower cost, and (4) possible improvement in circuit performance. However, integrated circuits are composed of parts so closely associated with one another that repair becomes almost impossible. In case of trouble, the entire circuit is replaced as a single component.

Basically, there are two general classifications of integrated circuits: ***Hybrid*** and ***Monolithic.*** In the monolithic integrated circuit, all elements (resistors, transistors, and so forth) associated with the circuit are fabricated inseparably within a continuous piece of material (called the substrate), usually silicon. The monolithic integrated circuit is made very much like a single transistor. While one part of the crystal is being doped to form a transistor, other parts of the crystal are being acted upon to form the associated resistors and capacitors. Thus, all the elements of the complete circuit are created in the crystal by the same processes and in the same time required to make a single transistor. This produces a considerable cost savings over the same circuit made with discrete components by lowering assembly costs.

Hybrid integrated circuits are constructed somewhat differently from the monolithic devices. The passive components (resistors and capacitors) are deposited onto a substrate (foundation) made of glass, ceramic, or other insulating material. Then the active components (diodes and transistors) are attached to the substrate and connected to the passive circuit components on the substrate using very fine (.001 inch) wire. The term hybrid refers to the fact that different processes are used to form the passive and active components of the device.

Hybrid circuits are of two general types: (1) thin film and, (2) thick film. Thin and thick film refers to the relative thickness of the deposited material used to form the resistors and other passive components. Thick film devices are capable of dissipating more power, but are somewhat more bulky.

Integrated circuits are being used in an ever-increasing variety of applications. Small size and weight and high reliability make them ideally suited for use in airborne equipment, missile systems, computers, spacecraft, and portable equipment. They are often easily recognized because of the unusual packages that contain the integrated circuit. A typical packaging sequence is shown in *Figure 4-86*. These tiny packages protect and help dissipate heat generated in the device. One of these packages may contain one or several stages, often having several hundred components. Some of the most common package styles are shown in *Figure 4-87*.

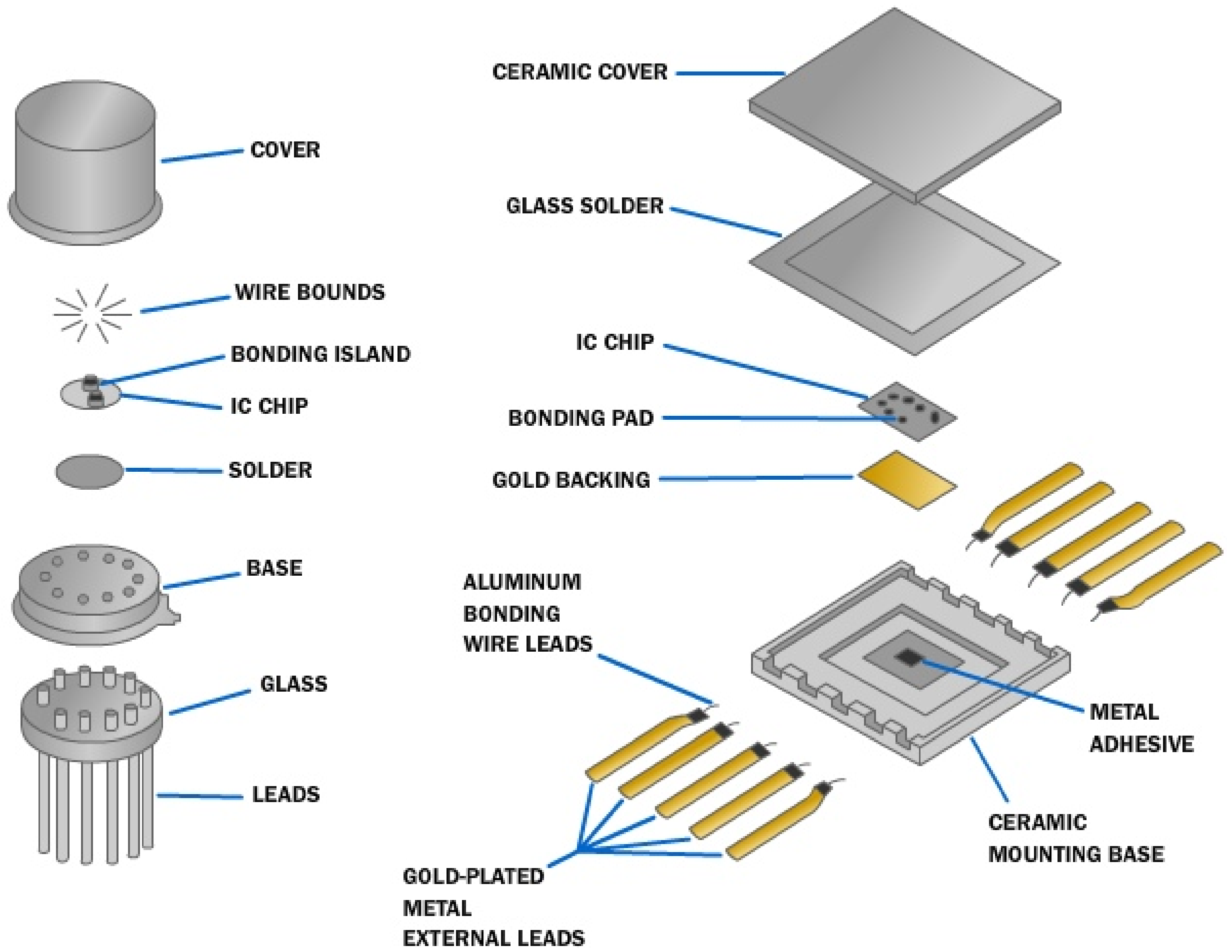

Figure 4-86 – Typical integrated circuit packaging sequence.

All of the above information was presented to give you a brief introduction into integrated circuits. More detailed information may be needed by you and is available in the Navy Electricity and Electronics Training Series, Module 7.

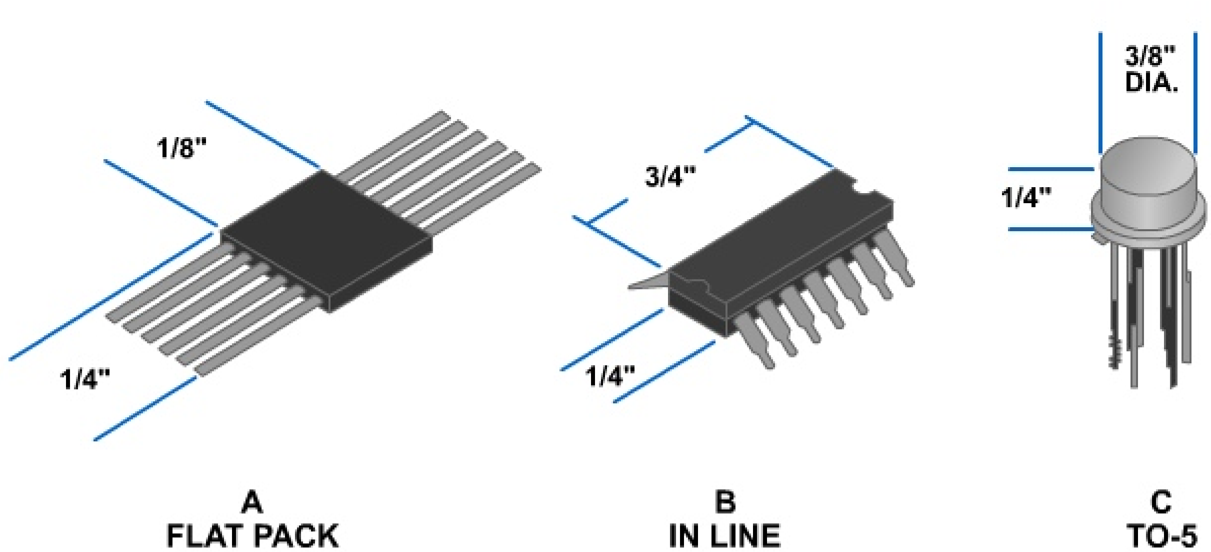

Figure 4-87 — Common IC packaging styles.

14.0.0 PRINTED CIRCUITS

A printed circuit board is a flat insulating surface upon which printed wiring and miniaturized components are connected in a predetermined design and attached to a common base. *Figure 4-88, View A* and *View B* shows a typical printed circuit board. Notice that various components are connected to the board and the printed wiring is on the reverse side. With this technique, all interconnecting wiring in a piece of equipment, except for the highest power leads and cabling, is reduced to lines of conducting material (copper, silver, gold, and so forth) deposited directly on the surface of an insulating circuit board. Since printed circuit boards are readily adapted as plug-in units, the elimination of terminal boards, fittings, and tie points, not to mention wires, results in a

Figure 4-88 — Typical printed circuit board (PCB).

substantial reduction in the overall size of electronic equipment

After the printed circuit boards were perfected, efforts to miniaturize electronic equipment were then shifted to assembly techniques, which led to ***modular circuitry***. In this technique, printed circuit boards are stacked and connected together to form a module. This modular circuitry increases the packaging density of circuit components and results in a considerable reduction in the size of electronic equipment. Because the module can be designed to perform any electronic function, it is also a very versatile unit.

However, the drawback to this approach was that the modules required a considerable number of connections that took up too much space and increased costs. In addition, tests showed the reliability was adversely affected by the increase in the number of connections; therefore, a new technique was required to improve reliability and further increase packaging density. The solution was integrated circuits.

Summary

Your knowledge and understanding of solid-state devices is very important for the safe conduct and completion of your job as a Construction Electrician. With the United States Navy becoming more and more dependent upon technology as it relates to diodes, filter circuits, transistors, and the ever-increasing amount of micro-circuitry, it is very important for you as Construction Electrician to be very familiar with this subject matter. During your career as a Construction Electrician, you will apply what has been presented in this chapter in your work on virtually a daily basis.

Review Questions (Select the Correct Response)

1. What are two of the most widely known semiconductors in use today?

   A. Transistor and transducer
   B. Junction diode and transducer
   C. Junction diode and transistor
   D. Transistor and simple capacitor

2. What is the maximum allowable voltage for a transistor?

   A. 200
   B. 300
   C. 400
   D. 500

3. **(True or False)** Hole flow is very similar to electron flow except that the holes move toward a negative potential and in an opposite direction to that of the electron.

   A. True
   B. False

4. A very efficient method of increasing current flow in semiconductors is by adding very small amounts of selected additives to them. These additives are called impurities and the process of adding them to crystals is referred to as ________.

   A. Bonding
   B. Valence
   C. Doping
   D. Covalent

5. What type of device can you obtain if you join a section of N-type semiconductor material with a similar section of P-type semiconductor material?

   A. N junction
   B. P junction
   C. Diode rectifier
   D. PN junction

6. **(True or False)** Conduction in the N-type semiconductor, or crystal, is similar to conduction in a copper wire.

   A. True
   B. False

7. Concerning current flow in P-type material, conduction in the P material is by __________ holes, instead of _________ electrons.

   A. Negative, positive
   B. Positive, negative
   C. Negative, negative
   D. Positive, positive

8. What is the term used when an external voltage is applied to a PN junction?

   A. Bias
   B. Forward bias
   C. Reverse bias
   D. None of the above

9. **(True or False)** If a battery is connected across the junction so that its voltage aids the junction, it will increase the junction barrier and thereby offer a high resistance to the current flow through the junction and is known as reverse bias.

   A. True
   B. False

10. What item(s) make up the simplest rectifier circuit which is a half-wave rectifier?

   A. Diode
   B. AC power source
   C. Load resistor
   D. All of the above

11. There are many known metal-semiconductor combinations that can be used for contact rectification. What are the most popular?

   A. Copper oxide
   B. Selenium
   C. Lead
   D. Both A and B

12. In addition to diodes being used as simple rectifiers, they are used as mixers and detectors, and to open or close a circuit. Diodes used for these purposes are commonly known by what name?

   A. Anode
   B. Signal
   C. Light-emitting
   D. Zener

13. **(True or False)** Manufacturers of various rectifier diodes specify operating parameters and characteristics with letter symbols. The letter symbol for DC blocking voltage is [V_F].

   A. True
   B. False

14. If you have a semiconductor diode that is identified as 1N345A, what does the letter A signify?

    A. Transistor
    B. Cathode end of diode
    C. Anode end of diode
    D. Improved version of the semiconductor diode type 345

15. Which of the following is/are considered as a basic type of filter circuit?

    A. LC choke-input filter
    B. LC capacitor-input filter (pi-type)
    C. RC capacitor-input filter (pi-type)
    D. All of the above

16. A capacitor is considered fully charged after how many RC time constants?

    A. Two
    B. Three
    C. Five
    D. Seven

17. **(True or False)** An inductor opposes any change in current.

    A. True
    B. False

18. What is the most basic type of power supply filter?

    A. RC capacitor-input filter (pi-type)
    B. Simple capacitor filter
    C. LC choke-input filter
    D. LC capacitor-input filter (pi-type)

19. Which type of filter is used in high power applications such as those found in radars and communication transmitters?

    A. Simple capacitor filter
    B. LC choke-input filter
    C. LC capacitor-input filter (pi-type)
    D. RC capacitor-input filter (pi-type)

20. How many times does conduction occur during each cycle for a full-wave rectifier?

    A. One
    B. Two
    C. Four
    D. Six

21. **(True or False)** The RC capacitor-input filter is limited to applications in which the load current is small.

    A. True
    B. False

22. What is the most commonly used filter?

    A. Simple capacitor filter
    B. LC choke-input filter
    C. LC capacitor-input filter (pi-type)
    D. RC capacitor-input filter (pi-type)

23. What are two disadvantages of the LC capacitor-input filter?

    A. Cost and size
    B. Size and lack of capability
    C. Lack of capability and cost
    D. Voltage surges and cost

24. **(True or False)** Semiconductor devices that have three or more elements are called transistors.

    A. True
    B. False

25. **(True or False)** To use a transistor as an amplifier, each junction must be modified by some external bias voltage.

    A. True
    B. False

26. **(True or False)** N-material on one side of the forward-biased junction is less heavily doped than the P-material.

    A. True
    B. False

27. What are the majority current carriers in the PNP transistor?

    A. Electrons
    B. Neutrons
    C. Holes
    D. None of the above

28. In the reverse-biased junction the _________ voltage on the collector and the positive voltage on the base block the _________ current carriers from crossing the junction.

A. Positive, minority
B. Negative, majority
C. Negative, minority
D. Positive, electron

29. **(True or False)** Although current flow in the external circuit of the PNP transistor is opposite in direction to that of the NPN transistor, the majority carriers always flow from the collector to the emitter.

A. True
B. False

30. What are the names of the two classifications of transistors?

A. NPN and MPN
B. MPN and NNN
C. NPN and PNP
D. None of the above

31. Which of the following are classes of amplifier operations.

A. A
B. AB
C. B
D. All of the above

32. If the base in a PNP transistor becomes positive with respect to the emitter, holes will be repelled at the PN junction and no current can flow in the collector circuit. What is this condition known as?

A. Cutoff
B. Saturation
C. Output
D. Input

33. When the base in a PNP transistor becomes so negative with respect to the emitter that changes in the signal are not reflected in the collector-current flow, what is the condition is known as?

A. Cutoff
B. Saturation
C. Output
D. Input

34. What class of operated amplifier is used as an audio-frequency and radio-frequency amplifier in radio, radar, and sound systems?

    A. A
    B. AB
    C. B
    D. C

35. What class of operated amplifier is commonly used as a push-pull amplifier to overcome crossover distortion?

    A. A
    B. AB
    C. B
    D. C

36. What class of operated amplifier is used extensively for audio amplifiers that require high-power outputs?

    A. A
    B. AB
    C. B
    D. C

37. **(True or False)** The term fidelity used in conjunction with amplifiers is the faithful reproduction of a signal.

    A. True
    B. False

38. To which of the following basic configurations may a transistor be connected?

    A. Common-emitter
    B. Common-base
    C. Common-collector
    D. All of the above

39. Which, if any, transistor configuration is the only one that provides a phase reversal?

    A. Common-emitter
    B. Common-base
    C. Common-collector
    D. None of the above

40. What term is used to describe current gain in the common-emitter circuit?

    A. Beta (β)
    B. Delta (Δ)
    C. Pi (π)
    D. Gamma (γ)

41. What term is used to describe current gain in the common-base circuit?

    A. Beta (β)
    B. Delta (Δ)
    C. Alpha (α)
    D. Gamma (γ)

42. What term is used to describe the current gain in the common-collector circuit configuration?

    A. Beta (β)
    B. Delta (Δ)
    C. Alpha (α)
    D. Gamma (γ)

43. **(True or False)** The four basic tests required for transistors in practical troubleshooting are gain, leakage, breakdown, and switching time.

    A. True
    B. False

44. When testing a transistor's junction resistance with an ohmmeter, it will reveal which of the following problems?

    A. Leakage
    B. Shorts
    C. Opens
    D. All of the above

45. **(True or False)** A Zener diode is a PN junction designed to operate in the forward-bias breakdown region.

    A. True
    B. False

46. According to Dr. Carl Zener, what is the process called when electrical breakdown in solid dielectrics occurs?

    A. Quantum-mechanical tunneling
    B. Conduction band
    C. Valence band
    D. Forbidden energy band

47. What is the name of the gap that exists between the valence band energy level and the conduction band energy level?

    A. Conduction band
    B. Valence band
    C. Zener band
    D. Forbidden energy band

48. **(True or False)** The tunneling phenomenon only takes place in heavily doped diodes, such as Zener diodes.

A. True
B. False

49. What is the basic purpose of the silicon controlled rectifier (SCR)?

A. To gain voltage in a transistor
B. To serve as a mechanical regulator
C. To serve as a switch that can turn on or off power
D. To take the place of a Zener diode

50. How many terminals does a triac device contain?

A. One
B. Two
C. Three
D. Four

51. **(True or False)** Diacs are almost never used alone, but in conjunction with other thyristor devices.

A. True
B. False

52. What are the advantages of using a unijunction transistor (UJT) in place of conventional transistors?

A. More components and larger size
B. Very stable and allows a reduction of components
C. Smaller size and more components
D. More components and greater cost

53. What is the most basic transducer that can be made from a single piece of wire?

A. Accelerometer
B. Microphone
C. Speaker
D. Antenna

54. **(True or False)** An integrated circuit is a device that combines both active components and passive components of a complete electronic circuit in a single chip, which is a tiny slice of wafer of semiconductor crystal or insulator.

A. True
B. False

Trade Terms Introduced in this Chapter

Junction diode	A two-terminal device containing a single crystal of semiconducting material, which ranges from P-type at one terminal to N-type at the other
Transistor	A semiconductor device with three or more elements
Solid-state device	An electronic device that operates by the movement of electrons within a solid piece of semiconductor material
Zener diode	A PN-junction diode designed to operate in the reverse-bias breakdown region
Light-emitting diode	A PN-junction diode that emits visible light when it is forward biased; depending on the material used to make the diode, the light may be red, green, or amber
Field effect transistor	A transistor consisting of a source, a gate, and a drain, in which current flow is controlled by the transverse electric field under the gate
Integrated circuit	A circuit in which many elements are fabricated and interconnected by a single process (into a single chip), as opposed to a nonintegrated circuit, in which the transistors, diodes, resistors, and other components are fabricated separately and then assembled
Quanta	In simple terms, energy is required in definite units to move electrons from one shell to the next higher shell. These units are called ***quanta*** (for example 1, 2, or 3 quanta)
Ionization	If a sufficient amount of energy is absorbed by an electron, it is possible for that electron to be completely removed from the influence of the atom. This is called ***ionization***
Negative ion	An atom having more than its normal amount of electrons that acquires a negative charge
Positive ion	The atom that gives up some of its normal electrons and is left with fewer negative charges than positive charges
Conduction band	A partially filled energy band in which electrons can move freely
Forbidden band	The energy band in an atom lying between the conduction band and the valence band; electrons are never found in the forbidden band but may travel back and forth through it; determines whether a solid material will act as a conductor, a semiconductor, or an insulator

Valence band	The last band composed of a series of energy levels containing valence electrons that are more tightly bound to the individual atom than the electrons in the conduction band, but can still be moved to the conduction band with the application of energy, usually thermal energy
Intrinsic	A condition of the semiconductor where no impurities exist, a term used to distinguish the pure semiconductor from one containing impurities
Doping	The process of adding impurities to semiconductor crystals to increase the number of free charges that can be moved by an external, applied voltage produces an N-type or P-type material
Extrinsic	A semiconductor in which impurities have been added to create certain changes carrier concentrations
Pentavalent	A type of impurity which contains five valence electrons and denotes one electron to the doped material; also called donor impurity
Trivalent	Acceptor impurities containing only three valence electrons
Bias	An external voltage applied to a PN junction
Electromotive force (**CEMF)**	The rate of the charge for the capacitor that is limited by the low impedance of the ac source (the transformer), by the small resistance of the diode, and by the counter ***electromotive force*** (***CEMF)*** developed by the coil
Cutoff	In a PNP transistor, for example, if the base becomes positive with respect to the emitter, holes will be repelled at the PN junction and no current can flow in the collector circuit. This condition is known as cutoff
Saturation	Condition in which the base becomes so negative with respect to the emitter that changes in the signal are not reflected in collector-current flow
Fidelity	A faithful reproduction of a signal; the accuracy with which a system reproduces a signal at its output that faithfully maintains the essential characteristics of the input signal
Efficiency	The ratio of output-signal power compared to the total input power
Beta (β)	The ratio of a change in collector current to a corresponding change in base current, when the collector voltage is constant in a common-emitter circuit.
Gamma (γ)	The emitter-to-base current ratio in a common-collector configuration

Breakdown	The phenomenon occurring in a reverse-biased semiconductor diode
Zener effect	A reverse breakdown effect in diodes in which breakdown occurs at reverse voltage below 5 volts; a breakdown that is produced by the presence of a high energy field at the junction of a semiconductor
Avalanche effect	A reverse breakdown effect in diodes that occurs at reverse voltage beyond 5 volts; the released of electrons that are accelerated by the electric field, which results in a release of more electrons in a chain or avalanche effect
Quantum-mechanical tunneling	When an electron is able to cross a PN junction because of tunnel effect
Silicon controlled rectifier	A semiconductor device that functions as an electrically controlled switch
Triac	A three-terminal device that is similar to two SCRs back to back with a common gate and common terminals
Unijunction transistor (UJT)	A three-terminal, solid-state device that resembles a transistor but is stable over a wide range of temperatures and allows a reduction of components when used in place of a transistor
Hybrid	The use of different processes to form the passive and active components of the device
Monolithic	A circuit in which all elements (resistors, transistors, and so forth) associated with the circuit are fabricated inseparably within a continuous piece of material, usually silicon
Modular circuitry	A technique where printed circuit boards are stacked and connected together to form a module

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

NAVEDTRA 14174 Navy Electricity and Electronics Training Series, Module 7.

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APPENDIX I

MATHEMATICS

The purpose of this mathematics appendix is twofold; first, it is a refresher for the Seabees who have encountered a time lapse between his or her schooling in mathematics; second, and more important, this section applies mathematics to the tasks that can not be accomplished without the correct use of mathematical equations.

Linear Measurement

Measurements are most often made in feet (ft) and inches (in). It is necessary that a Seabee know how to make computations involving feet and inches.

Changing Inches to Feet and Inches

To change inches to feet and inches, divide inches by 12. The quotient will be the number of feet, and the remainder will be inches.

Changing Feet and Inches to Inches

To change feet and inches to inches, multiply the number of feet by 12 and add the number of inches. The results will be inches.

Changing Inches to Feet in Decimal Form

To change inches to feet in decimal form, divide the number of inches by 12 and carry the result to the required number of places.

Changing Feet to Inches in Decimal Form

To change feet in decimal form to inches, multiply the number of feet in decimal form by 12.

Addition of Feet and Inches

A Seabee often finds it necessary to combine or subtract certain dimensions which are given in feet and inches.

Arrange in columns of feet and inches and add separately. If the answer in the inches column is more than 12, change to feet and inches and combine feet.

Subtraction of Feet and Inches

Arrange in columns with the number to be subtracted below the other number. If the inches in the lower number are greater, borrow 1 foot (12 Inches) from the feet column in the upper number. Subtract as in any other problem.

Multiplication of Feet and Inches

Arrange in columns. Multiply each column by the required number. If the inches column is greater than 12, change to feet and inches then add to the number of feet.

Division of Feet and Inches

In dividing feet and inches by a given number, the problem should be reduced to inches unless the number of feet will divide by the number evenly.

To divide feet and inches by feet and inches, change to inches or feet (decimals).

Angles

When two lines are drawn in different directions from the same point, an angle is formed.

Angles are of four types:

- Right angle is a 90° angle.
- Acute angles are angles less than 90°.
- Obtuse angles are angles greater than 90°, but less than 180°.
- Reflex angle is an angle greater than 180°.

Measurement of Angles

Observe that two straight lines have been drawn to form four right angles. Refer to *Figure A-1*.

In order to have a way to measure angles, a system of angle-degrees has been established. Assume that each of the four right angles is divided into 90 equal angles. The measure of each is 1 angle degree; therefore, in the four right angles, there are 4 x 90°, or 360 angle degrees. For accurate measurement, degrees have been subdivided into minutes and minutes into seconds.

1 degree= 60 minutes (’).

1 minute= 60 seconds (“).

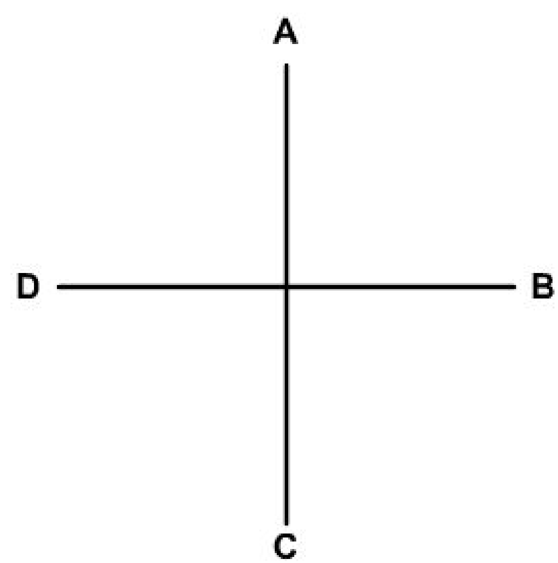


Figure A-1 — Right angles.

Relationship of Angles

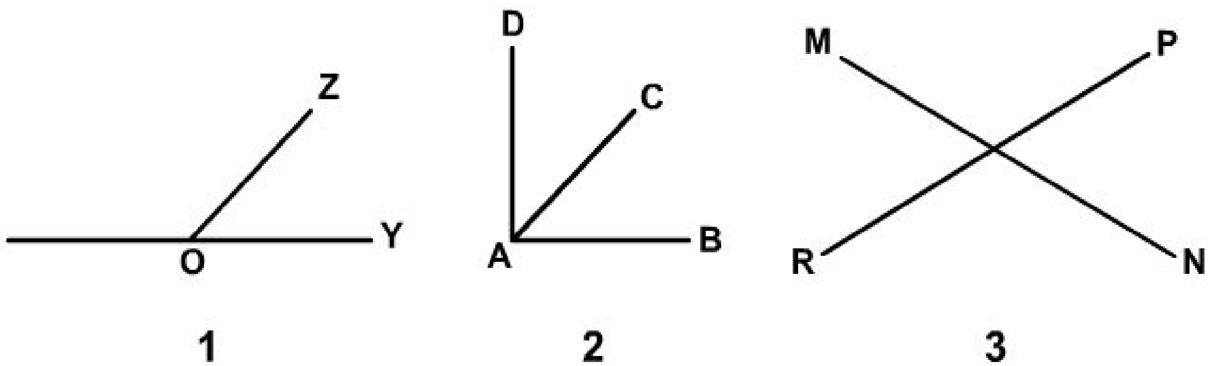


Figure A-2 — Relationship of angles.

1. $\angle$ZOY and $\angle$ZOX are supplementary angles and their total measure in degrees is equal to 180°. When one straight line meets another, two supplementary angles are formed. One is the supplement of the other. Refer to *Figure A-2, View 1*.

2. $\angle$DAC and $\angle$CAB are complementary angles and their total is a right angle or 90°. Refer to *Figure A-2, View 2*.

Two angles whose sum is 90° are said to be complementary, and one is the complement of the other.

3. $\angle$MOP and $\angle$RON are a pair of vertical angles and are equal. Refer to *Figure A-2, View 3*.

When two straight lines cross, two pairs of vertical angles are formed. Pairs of vertical angles are equal.

Bisecting Angles

To bisect an angle merely means to divide the angle into two equal angles. This may be done by use of a compass.

Perpendicular Lines

Lines are said to be perpendicular when they form a right angle (90°).

Parallel Lines

Two lines are said to be parallel if they are equidistant (equally distant) at all points.

Facts about parallel lines:

Two straight lines lying in the same plane either intersect or are parallel.

Through a point there can be only one parallel drawn to a given line.

If two lines are perpendicular to the third, and in the same plane, they are parallel.

Plane Shapes

A plane shape is a portion of a plane bounded by straight or curved lines or a combination of the two.

The number of different types of plane shapes is infinite, but we are concerned with those which are of importance to you as a Seabee. We will cover the circle, triangle, quadrilateral, other polygons, and ellipses.

Circles

Definitions:

A CIRCLE is a closed curved line in which any point on the curved line is equidistant from a point called the center. (Circle O). Refer to *Figure A-3*.

A RADIUS is a line drawn from the center of a circle to a point on a circle. (As OA, OB, OX, and OY). Refer to *Figure A-3.*

A DIAMETER is a line drawn through the center of a circle with its ends lying on the circle. Refer to *Figure A-3*.

A DIAMETER is twice the length of a radius. (AB is a diameter of circle O) Refer to *Figure A-3*.

A CHORD is a line joining any two points lying on a circle. (CD is a chord of circle O.) Refer to *Figure A-3*.

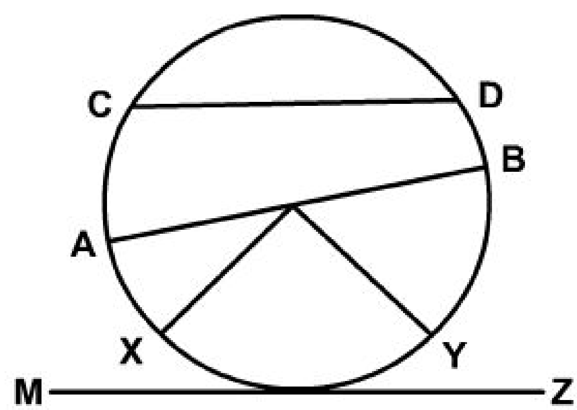


Figure A-3 — Circle.

An ARC is a portion of the closed curved lines which forms the circle. It is designated by CD. An arc is said to be subtended by a chord. Chord CD subtends arc CD. Refer to *Figure A-3*.

A TANGENT is a straight line which touches the circle at one and only one point. (Line MZ is a tangent to circle O.) Refer to *Figure A-3*.

A CENTRAL ANGLE is an angle whose vertex is the center of a circle and whose side are radii of the circle. (As XOY, YOA, and XOB.) Refer to *Figure A-3*.

CONCENTRIC CIRCLES are circles having the same center and having different radii.

The CIRCUMFERENCE of a circle is the distance around the circle. It is the distance on the curve from C to A to X to Y to B to D and back to C. Refer to *Figure A-3*.

Triangles

A triangle is a plane shape having 3 sides. Its name is derived from its three (tri) angles.

1. Equilateral - all sides are equal, all angles are equal, and all angles are 60°. Refer to *Figure A-4*.
2. Isosceles - two sides are equal and two angles are equal. Refer to *Figure A-4.*
3. Scalene - all sides are unequal and all angles are unequal. Refer to *Figure A-4.*
4. Right - one right angle is present. Refer to *Figure A-4*.

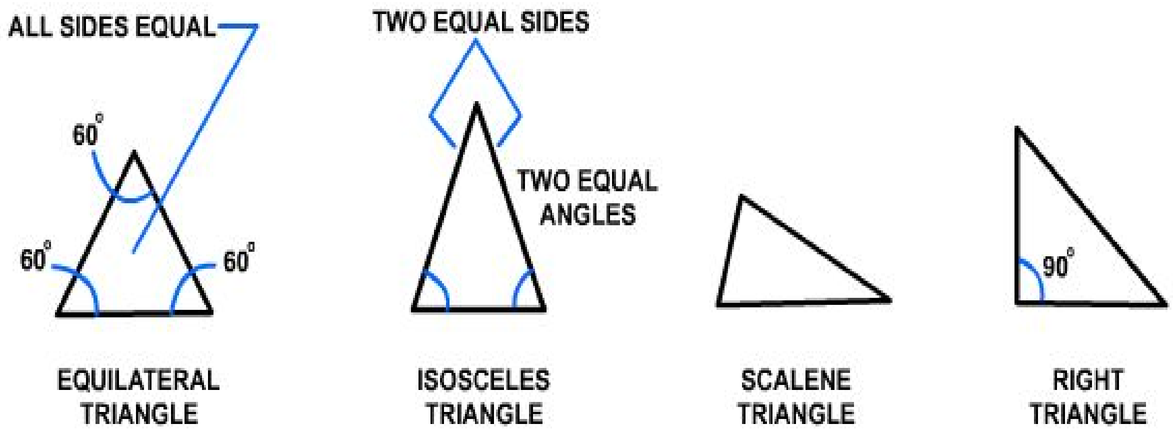


Figure A-4 — Types of triangles.

Altitudes and Medians

The altitude and median of a triangle are not the same; the difference is pointed out in the following definitions:

1. The altitude of a triangle is a line drawn from the vertex, perpendicular to the base. Refer to *Figure A-5, View 1*.
2. The median of a triangle is a line drawn from the vertex to the midpoint of the base. Refer to *Figure A-5, View 2*.

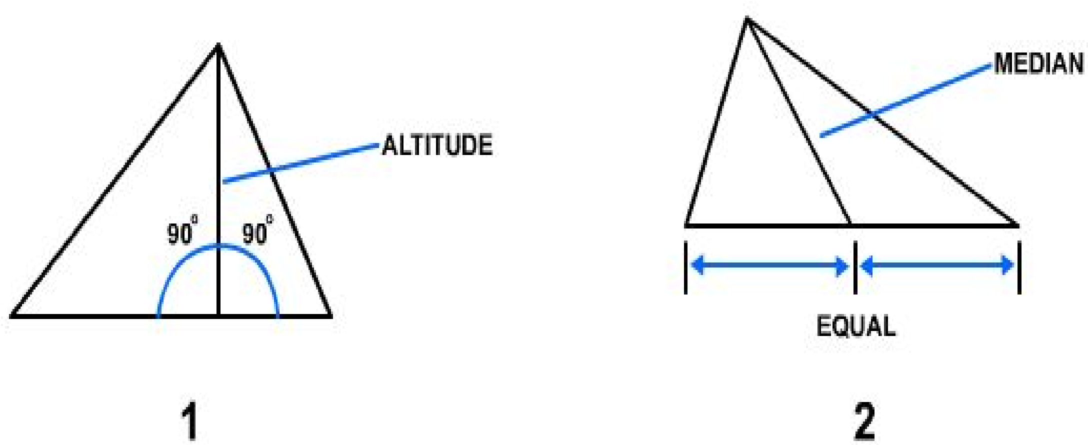


Figure A-5 — Altitude and median of a triangle.

Construction of Triangles

There are many ways to construct a triangle, depending upon what measurements are known to you. The following definitions will assist you.

1. A triangle may be constructed if the lengths of three sides are known.
2. A triangle may be constructed if two sides and the included angle (angle between the sides) are known.
3. A triangle may be constructed if two angles and the included side are given.
4. A right triangle may be constructed if the two sides adjacent to the right angle are known.
5. A right triangle may be constructed by making the sides 3, 4, and 5 inches or multiples or fractions thereof.

Quadrilaterals

A quadrilateral is a four-sided plane shape. There are many types, but only the trapezoid, parallelogram, rectangle, and square are described here.

Trapezoid is a quadrilateral having only two sides parallel. If the other two sides are equal, it is an isosceles trapezoid. BF is the altitude of the trapezoid. See *Figure A-6*.

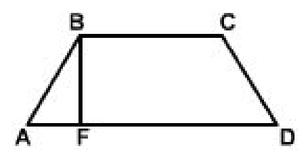


Figure A-6 — Trapezoid.

Parallelogram is a quadrilateral having opposite sides parallel. Refer to *Figure A-7*.

1. AB is parallel to CD.
2. AC is parallel to BD.
3. AD and CB are diagonals.
4. Diagonals bisect each other so CO = OB and AO = OD.
5. Opposite angles are equal. ACD = DBA and CAB = BDC.
6. If two sides of a quadrilateral are equal and parallel, the figure is a parallelogram.
7. A parallelogram may be constructed if two adjoining sides and one angle are known.

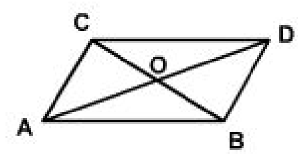


Figure A-7 — Parallelogram.

Rectangle is a parallelogram having one right angle. Refer to *Figure A-8*.

1. ABCD is a parallelogram having one right angle. This, of course, makes all angles right angles.
2. AC and BD are diagonals.
3. O is the midpoint of AC and BD and OB = OC = OD = OA.
4. O is equidistant from BC and AD and is also equidistant from AB and CD.
5. A rectangle may be constructed if two adjoining sides are known.

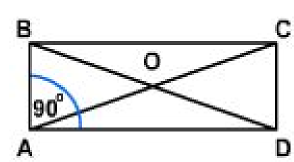


Figure A-8 — Rectangle.

Square is a rectangle having its adjoining sides equal. Refer to *Figure A-9*.

1. ABCD is a square.
2. AC and BD are diagonals.
3. O is the geometric center of the square. AO = OC = OB = OD.
4. O is equidistant from all sides.
5. A square may be constructed if one side is known.

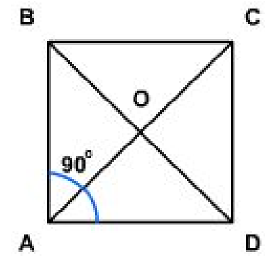


Figure A-9 — Square.

Polygons

A polygon is a many-sided plane shape. It is said to be regular if all sides are equal and irregular when they are not. Only regular polygons are described here.

Triangles and quadrilaterals fit the description of a polygon and have been covered previously. Three other types of regular polygons are shown in *Figure A-10*. Each one is inscribed in a circle. This means that all vertices of the polygon lie on the circumference of the circle.

Note that the sides of each of the inscribed polygons are actually equal chords of the circumscribed circle. Since equal chords subtend equal arcs, by dividing the circumference into an equal number of arcs, a regular polygon may be inscribed in a circle. Also note that the central angles are equal because they intercept equal arcs. This gives a basic rule for the construction of regular polygons inscribed in a circle as follows:

To inscribe a regular polygon in a circle, create equal chords of the circle by dividing the circumference into equal arcs or by dividing the circle into equal central angles.

Dividing a circle into a given number of parts has been discussed, so construction should be no problem. Since there are 360 degrees around the center of the circle, you should have no problem in determining the number of degrees to make each equal central angle.

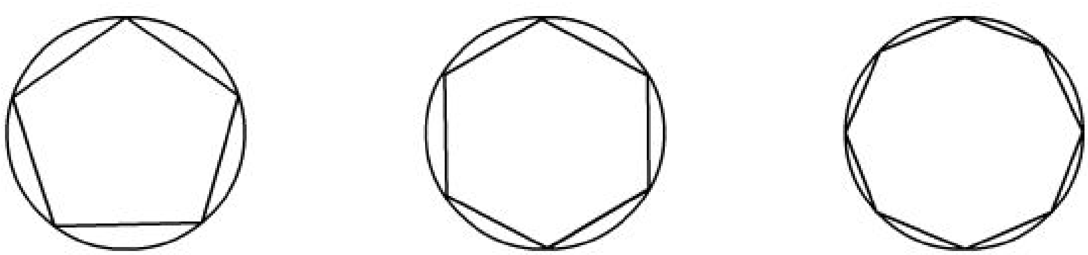


Figure A-10 — Types of polygons.

Methods for Constructing Polygons

The three methods for constructing polygons described here are the pentagon, hexagon, and octagon.

The Pentagon is a developed by dividing the circumference into 5 equal parts.

The Hexagon is developed by dividing the circumference into 6 equal parts.

The Octagon method has been developed by creating central angles of 90° to divide a circle into 4 parts and bisecting each arc to divide the circumference into 8 equal parts.

Ellipses

An ellipse is a plane shape generated by point P, moving in such a manner that the sum of its distances from two points, F_1 and F_2, is constant. Refer to *Figure A-11.*

$BF_1 + PF_2 = C =$ (a constant)

AE is the major axis.

BD is the minor axis.

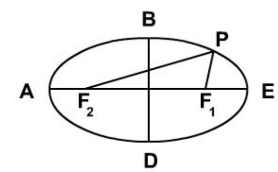


Figure A-11 — Ellipses.

Perimeters and Circumferences

Perimeter and circumference have the same meaning; that is, the distance around. Generally, circumference is applied to a circular object and perimeter to an object bounded by straight lines.

Perimeter of a Polygon

The perimeter of a triangle, quadrilateral, or any other polygon is actually the sum of the sides.

Circumference of a Circle

Definition of Pi: Mathematics have established that the relationship of the circumference to the diameter of a circle is a constant called Pi and written as π. The numerical value of this constant is approximately 3.141592653. For our purposes 3.1416 or simply 3.14 will suffice.

The formula for the circumference of a circle is $C = 2\pi D$ where C is the circumference and D is the diameter since D = 2R where R is the radius, the formula may be written as $C = 2\pi R$.

Areas

All areas are measured in squares.

The area of a square is the product of two of its sides and since both sides are equal, it may be said to be square of its side.

NOTE

The area of any plane surface is the measure of the number of squares contained in the object. The unit of measurement is the square of the unit which measures the sides of the square.

Area of Rectangle

$$A = L \times W$$

Where:

A = area of a rectangle

L = length of a rectangle

W = width of a rectangle

Area of a Cross Section

The cross section of an object is a plane figure established by a plane cutting the object at right angles to its axis. The area of this cross section will be the area of the plane figure produced by this cut.

The area of the cross section is L x W.

The most common units are square inches, square feet, square yards and in roofing, “squares.”

1 square foot = 144 square inches

1 square yard = 9 square feet

1 square of roofing = 100 square feet

Common Conversions

1. To convert square inches to square feet, divide square inches by 144.
2. To convert square feet to square inches, multiply by 144.
3. To convert square feet to square yards, divide by 9.
4. To convert square yards to square feet, multiply by 9.
5. To convert square feet to squares, divide by 100.

Conversion of Units of Cubic Measure

It is often necessary to convert from one cubic measure to another. The conversion factors used are as follows:

1. 1 cubic foot = 1,728 cubic inches
2. 1 cubic yard = 27 cubic feet
3. 1 cubic foot = 7.48 US gallons (liquid measure)
4. 1 us gallon (liquid measure) = 231 cubic inches
5. 1 bushel (dry measure) = 2,150.42 cubic inches

Area of a Circle

The formula for the area of a circle is:

$$A = \pi r^2$$

Where:

A = area of circle

r = radius of circle

π = 3.1416

Since r = d/2 where d is the diameter of a circle, the formula for the area of a circle in terms of its diameter is:

$$A = \pi(\frac{d^2}{2}) = \frac{\pi d^2}{4}$$

Geometric Solids

In describing plane shapes, you use only two dimensions: width and length; there is no thickness. By adding the third dimension, you describe a solid object.

Consider the solids described below.

Prism - is a figure whose two bases are polygons, alike in size and shape, lying in parallel planes and whose lateral edges connect corresponding vertices and are parallel and equal in length. A prism is a right prism if the lateral edge is perpendicular the base. The altitude of a prism is the perpendicular distance between the bases.

Cone - is a figure generated by a line moving in such a manner that one end stays fixed at a point called the “vertex.” The line constantly touches a plane curve which is the base of the cone. A cone is a circular cone if its base is a circle. A circular cone is a right circular cone if the line generating it is constant in length. The altitude of a cone is the length of a perpendicular to the plane of the base drawn from the vertex.

Pyramid - is a figure whose base is a plane shape bounded by straight lines and whose sides are triangular plane shapes connecting the vertex and a line of the base. A regular pyramid is one whose base is a regular polygon and whose vertex lays on a perpendicular to the base at its center. The altitude of a pyramid is the length of a perpendicular to the plane of the base drawn from the vertex.

Circular Cylinder - is a figure whose bases are circles lying in parallel planes connected by a curved lateral surface. A right circular cylinder is one whose lateral surface is perpendicular to the base. The altitude of a circular cylinder is the perpendicular distance between the planes of the two bases.

Measurement of Volume

Volume is measured in terms of cubes.

Common Volume Formulas

All factors in the formulas must be in the same linear units. As an example, one term could not be expressed in feet while other terms are in inches.

Volume of a Rectangular Prism

$$V = L \times W \times H$$

Where:

V = Volume in cubic inches

W = Width of the base in linear units

L = Length of base in linear units

H = Altitude of the prism in linear units

Volume of a Cone

$$V = \frac{A x h}{3}$$

Or

$$V = \frac{\pi r^2 h}{3}$$

Or

$$V = \frac{\pi d^2 h}{12}$$

Where:

V= Volume of a cone in cubic units

A = Area of the base in square units

h = Altitude of a cone in linear units

r = Radius of the base

d = Diameter of the base

Volume of a Pyramid

$$V = \frac{Ah}{3}$$

Where:

V = Volume in cubic units

A = Area of base in square units

h = Altitude in linear units

Volume of a Cylinder

$$V = Ah$$

Or

$$V = \pi r^2 h$$

Or

$$V = \frac{\pi d^2 h}{4}$$

Where:

V = Volume in cubic units

A = Area of the base in square units

h = Altitude in linear units

r = Radius of the base

d = Diameter of the base

Volume of the Frustum of a Right Circular Cone

The frustum of a cone is formed when a plane is passed parallel to the base of the cone. The frustum is the portion below the plane. The altitude of the frustum is the perpendicular distance between the bases.

$$V = 1/3\,\pi h\left(r^2 + R^2 + Rr\right)$$

Where:

h = Altitude in linear units

r = Radius of the upper base in linear units

R = Radius of the lower base in linear units

Volume of a Frustum of a Regular Pyramid

A frustum of a pyramid is formed when a plane is passed parallel to the base of the pyramid. The frustum is the portion below the plane. The altitude is the perpendicular distance between the bases.

$$V = 1/3h\,(B + b + \sqrt{Bb}\,)$$

Where:

V = Volume of the frustum in cubic units

h = Altitude in linear units

B = Area of the lower base in square units

b = Area of the upper base in square units

Ratio

The ratio of one number to another is the quotient of the first, divided by the second. This is often expressed as a:b, which is read as the ratio of a to b. More commonly, this expressed as the fraction a/b.

Ratio has no meaning unless both terms are expressed in the same unit by measurement.

Percentage

Percentage (%) is a way of expressing the relationship of one number to another. In reality, percentage is a ratio expressed as a fraction in which the denominator is always one hundred.

Proportion

Proportion is a statement of two ratios which are equal.

Example: 1/3 = 5/15 or 1:3 = 5:15

Solving proportions is done by cross multiplying.

Example: $\frac{a}{b} = \frac{c}{d}$ = a x d = b x c

Law of Pythagoras

The Law of Pythagoras is the square of the hypotenuse of a right triangle equals the sum of the two legs. It is expressed by the formula $a^2 + b^2 = c^2$.

Right Triangle: a triangle having one right angle

Hypotenuse: The hypotenuse of a right triangle is the side opposite the right angle

Leg: The leg of a right triangle is a side opposite and acute angle of a right triangle.

METRIC CONVERSION TABLES

Length Conversion

When You Know:	You Can Find:	If You Multiply By:
inches	millimeters	25.4
inches	centimeters	2.54
feet	centimeters	30
feet	meters	0.3
yards	centimeters	90
yards	meters	0.9
miles	kilometers	1.6
miles	meters	1609
millimeters	inches	0.04
centimeters	inches	0.4
centimeters	feet	0.0328
meters	feet	3.3
centimeters	yards	0.0109
meters	yards	1.1
meters	miles	0.000621
kilometers	miles	0.6
meters	nautical miles	0.00054
nautical miles	meters	1852

Weight Conversion

When You Know:	You Can Find:	If You Multiply By:
ounces	grams	28.3
pounds	kilograms	0.45
short tons (2000 lbs)	megagrams (metric tons)	0.9
grams	ounces	0.0353
kilograms	pounds	2.2
megagrams (metric tons)	short tons (2000 lbs)	1.1

Temperature Conversion

When You Know:	You Can Find:	If You Multiply By:
Degrees Fahrenheit	Degree Celsius	Subtract 32 then multiply by 5/9
Degrees Celsius	Degree Fahrenheit	Multiply by 9/5 then add 32
Degrees Celsius	Kelvins	Add 273.15°

Volume Conversion

When You Know:	You Can Find:	If You Multiply By:
teaspoons	milliters	5
tablespoons	milliters	1 5
fluid ounces	milliters	3 0
cups	liters	0.24
pints	liters	0.47
quarts	liters	0.95
gallons	liters	3.8
milliters	teaspoons	0.2
milliters	tablespoons	0.067
milliters	fluid ounces	0.034
liters	cups	4.2
liters	pints	2.1
liters	quarts	1.06
liters	gallons	0.26
cubic feet	cubic meters	0.028
cubic yards	cubic meters	0.765
cubic meters	cubic feet	35.3
cubic meters	cubic yards	1.31

Area Conversions

When You Know:	You Can Find:	If You Multiply By:
Square inches	Square centimeters	6.45
Square inches	Square meters	0.000 6
Square feet	Square centimeters	929
Square feet	Square meters	0.0929
Square yards	Square centimeters	8.360
Square yards	Square meters	0.836
Square miles	Square kilometers	2.6
Square centimeters	Square inches	0.155
Square meters	Square inches	1550
Square centimeters	Square feet	0.001
Square meters	Square feet	10.8
Square centimeters	Square yards	0.00012
Square meters	Square yards	1.2
Square kilometers	Square miles	0.4

Table A-1 — Decimal Equivalents.

Fraction	16th	32nd	64th	Decimal	Fraction	16th	32nd	64th	Decimal
			1	.015625				33	.515625
		1	2	.03125			17	34	.53125
			3	.046875				35	.54875
	1	2	4	.0625		9	18	36	.5625
			5	.078125				37	.578125
		3	6	.09375			19	38	.59375
			7	.109375				39	.609375
1/8	2	4	8	.125	5/8	10	20	40	.625
			9	.140625				41	.640625
		5	10	.15625			21	42	.65625
			11	.171875				43	.671875
	3	6	12	.1875		11	22	44	.6875
			13	.203125				45	.703125
		7	14	.21875			23	46	.71875
			15	.234375				47	.734375
1/4	4	8	16	.25	3/4	12	24	48	.75
			17	.265625				49	.765625
		9	18	.28125			25	50	.78125
			19	.296875				51	.796875
	5	10	20	.3125		13	26	52	.8125
			21	.328125				53	.818225
		11	22	.34375			27	54	.84375
			23	.359375				55	.859375
3/8	6	12	24	.375	7/8	14	28	56	.875
			25	.390623				57	.890625
		13	26	.40625			29	58	.90625
			27	.421875				59	.921875
	7	14	28	.4375		15	30	60	.9375
			29	.453125				61	.953125
		15	30	.46875			31	62	.96875
			31	.484375				63	.984375
1/2	8	16	32	.5	1	16	32	64	1.0

Table A-2 — Metric measures of length.

10 millimeters	=	1 centimeter (cm)
10 centimeters	=	1 decimeter (dm)
10 decimeters	=	1 meter (m)
10 meters	=	1 decameter (dkm)
10 decameters	=	1 hectometer (hm)
10 hectometers	=	1 kilometer (km)

Table A-3 — Conversion of inches to millimeters.

Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters
1	25.4	26	660.4	51	1295.4	76	1930.4
2	50.8	27	685.8	52	1320.8	77	1955.8
3	76.2	28	711.2	53	1346.2	78	1981.2
4	101.6	29	736.6	54	1371.6	79	2006.6
5	127	30	762	55	1397	80	2032
6	152.4	31	787.4	56	1422.4	81	2057.4
7	177.8	32	812.8	57	1447.8	82	2082.8
8	203.2	33	838.2	58	1473.2	83	2108.2
9	228.6	34	863.6	59	1498.6	84	2133.6
10	254	35	889	60	1524	85	2159
11	279.4	36	914.4	61	1549.4	86	2184.4
12	304.8	37	939.8	62	1574.8	87	2209.8
13	330.2	38	965.2	63	1600.2	88	2235.2
14	355.6	39	990.6	64	1625.6	89	2260.6
15	381	40	1016	65	1651	90	2286
16	406.4	41	1041.4	66	1676.4	91	2311.4
17	431.8	42	1066.8	67	1701.8	92	2336.8
18	457.2	43	1092.2	68	1727.2	93	2362.2
19	482.6	44	1117.6	69	1752.6	94	2387.6
20	508	45	1143	70	1778	95	2413
21	533.4	46	1168.4	71	1803.4	96	2438.4
22	558.8	47	1193.8	72	1828.8	97	2463.8
23	584.2	48	1219.2	73	1854.2	98	2489.2
24	609.6	49	1244.6	74	1879.6	99	2514.6
25	635	50	1270	75	1905	100	2540

Table A-4 — Conversions of fractions and decimals to millimeters.

Fraction of inch (64ths)	Decimal of Inch	Millimeters	Fraction of inch (64ths)	Decimal of Inch	Millimeters
1	.015625	.3968	33	.515625	13.0966
2	.03125	.7937	34	.53125	13.4934
3	.046875	1.1906	35	.546875	13.8903
4 (1/16”)	.0625	1.5875	36	.5625	14.2872
5	.078125	1.9843	37	.578125	14.6841
6	.09375	2.3812	38	.59375	15.0809
7	.109375	2.7780	39	.609375	15.4778
8 (1/8”)	.125	3.1749	40 (5/8”)	.625	15.8747
9	.140625	3.5817	41	.640625	16.2715
10	.15625	3.9686	42	.65625	16.6684
11	.171875	4.3655	43	.671875	17.0653
12	.1875	4.7624	44	.6875	17.4621
13	.203125	5.1592	45	.703125	17.8590
14	.21875	5.5561	46	.71875	18.2559
15	.234375	5.9530	47	.734375	18.6527
16 (1/4”)	.25	6.3498	48 (3/4”)	.75	19.0496
17	.265625	6.7467	49	.765625	19.4465
18	.28125	7.1436	50	.78125	19.8433
19	.296875	7.5404	51	.796875	20.2402
20	.3125	7.9373	52	.8125	20.6371
21	.328125	8.3342	53	.818225	21.0339
22	.34375	8.7310	54	.84375	21.4308
23	.359375	9.1279	55	.859375	21.8277
24 (3/8”)	.375	9.5248	56 (7/8”)	.875	22.2245
25	.390623	9.9216	57	.890625	22.6214
26	.40625	10.3185	58	.90625	23.0183
27	.421875	10.7154	59	.921875	23.4151
28	.4375	11.1122	60	.9375	23.8120
29	.453125	11.5091	61	.953125	24.2089
30	.46875	11.9060	62	.96875	24.6057
31	.484375	12.3029	63	.984375	25.0026
32 (1/2”)	.5	12.6997	64 (1”)	1.0	25.3995

Table A-5 Conversions of measurements.

Conversion Chart for Measurement								
inches								centimeters
Cm							inches	
Feet						meters		
Meters					feet			
Yards				meters				
Meters			yards					
Miles		kilometers						
km	miles							
1	0.62	1.61	1.09	0.91	3.28	0.30	0.39	2.54
2	1.21	3.22	2.19	1.83	6.56	0.61	0.79	5.08
3	1.86	4.83	3.28	2.74	9.81	0.91	1.18	7.62
4	2.49	6.44	4.37	3.66	13.12	1.22	1.57	10.16
5	3.11	8.05	5.47	4.57	16.40	1.52	1.97	12.70
6	3.73	9.66	6.56	5.49	19.68	1.83	2.36	15.24
7	4.35	11.27	7.66	6.4	22.97	2.13	2.76	17.78
8	4.97	12.87	8.75	7.32	26.25	2.44	3.15	20.32
9	5.59	14.48	9.84	8.23	29.53	2.74	3.54	22.86
10	6.21	16.09	10.94	9.14	32.81	3.05	3.93	25.40
12	7.46	19.31	13.12	10.97	39.37	3.66	4.72	30.48
20	12.43	32.19	21.87	18.29	65.62	6.10	7.87	50.80
24	14.91	38.62	26.25	21.95	78.74	7.32	9.45	60.96
30	18.64	48.28	32.81	27.43	98.42	9.14	11.81	76.20
36	22.37	57.94	39.37	32.92	118.11	10.97	14.17	91.44
40	24.37	64.37	43.74	36.58	131.23	12.19	15.75	101.60
48	29.83	77.25	52.49	43.89	157.48	14.63	18.90	121.92
50	31.07	80.47	54.68	45.72	164.04	15.24	19.68	127.00
60	37.28	96.56	65.62	54.86	196.85	18.29	23.62	152.40
70	43.50	112.65	76.55	64	229.66	21.34	27.56	177.80
72	44.74	115.87	78.74	65.84	236.22	21.95	28.35	182.88

Table A-6 — Cubic conversion chart.

Cubic Conversion Chart					
Cubic Meters				Cubic Feet	Cubic Yard
Cubic Yard			Cubic Meters		
Cubic Feet		Cubic Meters			
Cubic Inches	Cubic Centimeters				
1	16.39	0.028	0.76	35.3	1.31
2	32.77	0.057	1.53	70.6	2.62
3	49.16	0.085	2.29	105.9	3.92
4	65.55	0.113	3.06	141.3	5.23
5	81.94	0.142	3.82	176.6	6.54
6	98.32	0.170	4.59	211.9	7.85
7	114.71	0.198	5.35	247.2	9.16
8	131.10	0.227	6.12	282.5	10.46
9	147.48	0.255	6.88	317.8	11.77
10	163.87	0.283	7.65	353.1	13.07
20	327.74	0.566	15.29	706.3	26.16
30	491.61	0.850	29.94	1059.4	39.24
40	655.48	1.133	30.58	1412.6	52.32
50	819.35	1.416	38.23	1765.7	65.40
60	983.22	1.700	45.87	2118.9	78.48
70	1174.09	1.982	53.52	2472.0	91.56
80	1310.96	2.265	61.16	2825.2	104.63
90	1474.84	2.548	68.81	3178.3	117.71
100	1638.71	2.832	76.46	3531.4	130.79

Example: 3 cu. Yd = 2.29 cu. M
Volume: The cubic meter is the only common dimension used for measuring the volume of solids in the metric system.

Table A-7 — Gallon and liter conversion chart.

Gallon	Liter	Gallon	Liter	Gallon	Liter
.1	.38	1	3.79	10	37.85
.2	.76	2	7.57	20	57.71
.3	1.14	3	11.36	30	113.56
.4	1.51	4	15.14	40	151.42
.5	1.89	5	18.93	50	189.27
.6	2.27	6	22.71	60	227.12
.7	2.65	7	26.50	70	264.98
.8	3.03	8	30.28	80	302.83
.9	3.41	9	34.07	90	340.69
NOTE: 1 us Gallon = 3.785412 Liters 100 us Gallons = 378.5412 Liters					

Table A-8 — Weight conversion chart.

Weight Conversion Chart						
Ounces						Grams
Grams					Ounces	
Pounds				Kilograms		
Kilograms			Pounds			
Short Ton		Metric Ton				
Metric Ton	Short Ton					
1	1.10	0.91	2.20	0.45	0.04	28.1
2	2.20	1.81	4.41	0.91	0.07	56.7
3	3.31	2.72	6.61	1.36	0.11	85.0
4	4.41	3.63	8.82	1.81	0.14	113.4
5	5.51	4.54	11.02	2.67	0.18	141.8
6	6.61	5.44	13.23	2.72	0.21	170.1
7	7.72	6.35	15.43	3.18	0.25	198.4
8	8.82	7.26	17.64	3.63	0.28	226.8
9	9.92	8.16	19.81	4.08	0.32	255.2
10	11.02	9.07	22.05	4.54	0.35	283.5
16	17.63	14.51	35.27	7.25	0.56	453.6
20	22.05	18.14	44.09	9.07	0.71	567.0
30	33.07	27.22	66.14	13.61	1.06	850.5
40	44.09	36.29	88.14	18.14	1.41	1134.0
50	55.12	45.36	110.23	22.68	1.76	1417.5
60	66.14	54.43	132.28	27.22	2.12	1701.0
70	77.16	63.50	154.32	31.75	2.17	1981.5
80	88.18	72.57	176.37	36.29	2.82	2268.0
90	99.21	81.65	198.42	40.82	3.17	2551.5
100	110.20	90.72	220.46	45.36	3.53	2835.0
NOTE: 1 pound = 0.4535925 KG; 1 US Short Ton = 2,000 pounds; and 1 Metric Ton = 1,000 KG						

FORMULAS

Conversion Factors and Constants

$\pi = 3.14$	$2\pi = 6.28$
$\pi^2 = 9.87$	$(2\pi)^2 = 39.5$
$\varepsilon = 2.718$	$\sqrt{2} = 1.414$
$\sqrt{3} = 1.732$	LOG = 0.497

Sinusoidal Voltages and Currents

Effective Value	=	0.707 x Peak Value
Average Value	=	0.637 x Peak Value
Peak Value	=	1.414 x Effective Value
Effective Value	=	1.11 x Average Value
Peak Value	=	1.57 x Average Value
Average Value	=	0.9 x Effective Value

Temperature

(F to C) C = 5/9 (F – 32)

(C to F) F = 9/5 C = 32

(C to K) K = C + 73

Power

1 kilowatt = 1.341 horsepower

1 horsepower = 746 watts

Trigonometric Formulas

sin A = $\frac{a}{c} = \frac{\text{Opposite Side}}{\text{Hypotenuse}}$

cos A = $\frac{b}{c} = \frac{\text{Adjacent Side}}{\text{Hypotenuse}}$

tan A = $\frac{a}{b} = \frac{\text{Opposite Side}}{\text{Adjacent Side}}$

cot A = $\frac{b}{a} = \frac{\text{Adjacent Side}}{\text{Opposite Side}}$

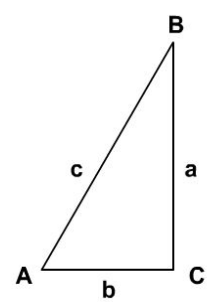


Figure A-12 — Trapezoid.

Ohm's Law- Direct Current

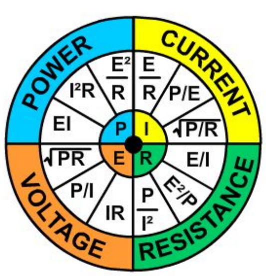


Figure A-13 — Direct Current.

Ohm's Law- Alternating Current

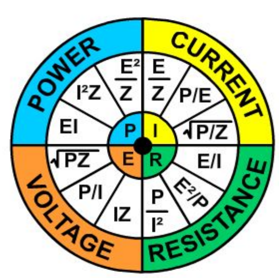


Figure A-14 — Alternating Current.

Speed vs. Poles Formulas

F = $\frac{NP}{120}$ N = $\frac{F\ 120}{P}$ P = $\frac{F\ 120}{N}$

F = frequency

N= speed of rotation

P = number of poles

120 = time constant

Power Factor

PF = $\frac{\text{actual power}}{\text{apparent power}} = \frac{\text{watts}}{\text{volts x amperes}} = \frac{\text{kW}}{\text{kVA}} = \frac{R}{Z}$

Single-Phase Circuits

kVA = $\frac{EI}{1{,}000} = \frac{kW}{PF}\ kW = kVA \times PF$

I = $\frac{P}{E \times PF}\ E = \frac{P}{I \times PF}\ PF = \frac{P}{E \times I}$

P = E x I x PF

Two-Phase Circuits

I =

$\frac{P}{2 \times E \times PF}\ E = \frac{P}{2 \times I \times PF}\ PF = \frac{P}{E \times I}$

kVA = $\frac{2 \times E \times I}{1{,}000}\ \frac{kW}{PF}\ kW = kVA \times PF$

P = 2 x E x I x PF

Three-Phase Circuits, Balanced Wye

I phase = I line

$E_L = \sqrt{3}\ E_P = 1.73\ E_P$

$E_P = \frac{E_L}{\sqrt{3}} = 0.577\ E_L$

Three-Phase Circuits, Balanced Wye

E phase = E line

$I_L = \sqrt{3}\ I_P = 1.73\ I_P$

$I_P = \frac{I_L}{\sqrt{3}} = 0.577\ I_L$

Power: Three-Phase Balanced Wye or Delta Circuits

P = 1.732 x E x I x PF VA = 1.732 x E x I

E = $\frac{P}{PF\ x 1.73\ x\ I} = \frac{0.577\ x\ P}{PF\ x\ I}$

I = $\frac{P}{PF\ x 1.73\ x\ E} = \frac{0.577\ x\ P}{PF\ x\ E}$

PF = $\frac{P}{PF\ x 1.73\ x\ E} = \frac{0.577\ x\ P}{I\ x\ E}$

VA = apparent power (volt-amperes)

P = actual power (watts)

E = line voltage (volts)

I = line current (amperes)

WEIGHTS AND MEASURES

Dry Measure

2 cups = 1 quart (pt)

2 pints = 1 quart (pt)

4 quarts = 1 gallon (gal)

8 quarts = 1 peck (pk)

4 pecks = 1 bushel (bu)

Liquid Measure

3 teaspoons (tsp) = 1 tablespoon (tbsp)

16 tablespoons = 1 cup

2 cups = 1 pint

16 fluid ounces (oz) = 1 pint

2 pints = 1 quart

4 quarts = 1 gallon

31.5 gallons = 1 barrel (bbl)

231 cubic inches = 1 gallon

7.48 gallons = 1 cubic foot (cu ft)

Weight

16 ounces = 1 pound (lb)

2,000 pounds = 1 short ton

2,240 pounds = 1 long ton

Distance

12 inches = 1 foot (ft)

3 feet = 1 yard (yd)

5-1/2 yards = 1 rod (rd)

16-1/2 feet = 1 rod

1,760 yards = 1 statute mile (mi)

5,280 feet = 1 statute mile

Area

144 square inches = 1 square foot (sq ft)

9 square feet = 1 square yd (sq yd)

30- ¼ square yards = 1 square rod

160 square rods = 1 acre (A)

640 acres = 1 square mile (sq mi)

Volume

1,728 cubic inches = 1 cubic foot

27 cubic feet = 1 cubic yard (CU yd)

Counting Units

12 units = 1 dozen (doz)

12 dozen = 1 gross

144 units = 1 gross

24 sheets = 1 quire

480 sheets = 1 ream

Equivalents

1 cubic foot of water weighs 62.5 pounds (approx) = 1,000 ounces

1 gallon of water weighs 8-1/3 pounds (approx)

1 cubic foot = 7.48 gallons

1 inch = 2.54 centimeters

1 foot = 30.4801 centimeters

1 meter = 39.37 inches

1 liter = 1.05668 quarts (liquid) = 0.90808 quart (dry)

1 nautical mile = 6,080 feet (approx)

1 fathom = 6 feet

1 shot of chain = 15 fathoms

Feet	x.00019	= miles
Feet	x 1.5	= links
Yards	x .9144	= meters
Yards	x .0006	= miles
Links	x .22	= yards
Links	x .66	= feet
Rods	x 25	= links
Rods	x 16.5	= feet
Square inches	x .007	= square feet
Square inches	x 6.451	= square centimeters
Square centimeters	x 0.1550	= square inches
Square feet	x .111	= square yards
Square feet	x .0929	= centares (square meters)
Square feet	x 929	= square centimeters
Square feet	x 144	= square inches
Square yards	x .0002067	= acres
Acres	x 4840.0	= square yards
Square yards	x 1,296	= square inches
Square yards	x 9	= square feet
Square yards	x 0.8362	= centares
Square miles, statute	x 640	= acres
Square miles, statute	x 25,900	=ares
Square miles, statute	x 259	= hectares
Square miles, statute	x 2,590	= square kilometers
Cubic inches	x .00058	= cubic feet
Cubic feet	x .03704	= cubic yards
Tons (metric)	x 2,204.6	= pounds (avoirdupois)
Tons (metric)	x 1,000	= kilograms
Tons (short)	x 2,000	= pounds (avoirdupois)

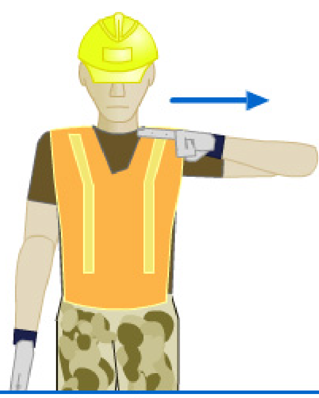
Tons (short)	x 0.9072	= metric tons
Tons (long)	x 2,240	= pounds (avoirdupois)
Tons (long)	x 1.016	= metric tons
π	= 3.14592654	
1 radian	= 180°/ π = 57.2957790°	= approx. 57° 17' 44.8"
1 radian	= 1018.6 miles	
1 degree	= 0.0174533 radian	
1 minute	= 0.0002909 radian	
1 mil	= 0.0009817	
π radians	= 180°	
π /2 radians	= 90°	
Radius	= arc of 57.2957790°	
Arc of 1° (radius $= 1$)	= .017453292	
Arc of $1'$ (radius $= 1$)	= .000290888	
Arc of $1''$ (radius $= 1$)	= .000004848	
Area of sector of circle	= ½ Lr	(L= length of arc; r = radius)
Area of segment of parabola	= 2/3 cm	(c = chord; m = mid. ord.)
Area of segment of circle	= approx 2/3	
Arc – chord length	= 0.02 foot per 11 ½ miles	
Curvature of earth's surface	= approx. 0.667 foot per mile	

APPENDIX II

Hand Signals

Emergency Stop
Stop all motion as quickly as possible.

Stop



Kill Engine
Secure engine as prescribed

Manuever Forward Slowly
When manuevering in close quarters or to move a foot or two at a time.

Slow Down

Guide On Me
Hand open and palm facing inward.

Increase Speed

Raise Hoist Slowly
Hurry up and move out, double time, etc.

Lower Hoist Slowly

Raise Load

Lower Load

Raise Boom

Lower Boom

Raise Boom and Hold Load

Lower Boom and Hold Load

Lower Boom Slowly