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ABSTRACT

This curriculum guide provides materials for basic training in electrical and electronic theory to enable participants to analyze circuits and use test equipment to verify electrical operations and to succeed in the beginning electrical and electronic courses in the Lakeshcre Technical College (Wisconsin) electronics programs. The course includes the study of logical and analytical skills as well as transferable practical skills, such as measuring voltage, current, and resistance; checking and replacing fuses; and making simple repairs on electrical appliances. Designed especially for helping women acquire the background to be successful in electrical and electronics courses, the course contains handouts and activities for six sessions that cover the following topics: (1) safety in the laboratory; (2) hand tools and special test equipment; (3) soldering and desoldering; (4) electronic components and direct current circuits; (5) alternating current and voltage; and (6) digital electronics. Suggestions for instructors and student handouts are provided for each session. The lessons are illustrated with line drawings; a glossary of terms is included. (KC)

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1993-94 PERKINS PROGRAM IMPROVEMENT PRODUCTS

LAKESHORE TECHNICAL COLLEGE

DEVELOPING BASIC ELECTRONICS APTITUDES

ABSTRACT ...provides basic training in electrical and electrical theory to enable participants to analyze circuits, utilize test equipment, to verify electrical operations, and prepare to succeed in the beginning electrical/electronic courses in any of LTC's electronics programs. Includes the study of logical and analytical skills as well as transferable practical skills, such as measuring voltage, current, resistance; checking/replacing fuses; and making simple repairs on electrical appliances.

DEVELOPING ELECTRICAL/MECHANICAL APTITUDES

INSTRUCTOR GUIDELINE

First Session

1. Video tapes: Intro to Safety in the Lab
   CPR Adult
2. Handouts: The Fatal Current
   Ground Fault Circuit Interrupters
   Lab Safety Check List
3. Activities: Discuss handouts as presented.
   Question and answer period.
   Compare fatal current to something common.
   (100W light bulb draws approximately 800 mA.)

Second Session
(handout on hand tools and special test equipment)

1. Discussion on electrical hand tools and test equipment. "Show and tell" on types of switches, receptacles, types and sizes of wires.
2. Proper procedure for stripping wire and attaching wire to different types of electrical components.
3. "Break"
4. Lab time for actual stripping, tinning and attaching wire to electrical components.

Third Session
(handout on soldering---desoldering)

1. Proper procedure on solderless connectors, soldering and desoldering. Discussion on soldering and desoldering equipment. Examine different types of printed circuit boards. Explain what the students will be doing during lab time.

2. "Break"

3. Actual soldering and desoldering on printed circuit boards. Students will be given a board and various components to solder.

4. Given a variety of solderless connectors, the students will "crimp" the connectors to wires. After the students are through with this project, the instructor should check for neatness and tightness of the connectors.

Fourth Session
(Handout on Electronic Components and D.C. Circuits)

1. Discuss various types of electronic components and the symbol used for each component. Explain the resistor color code and do some exercises involving the color code. Explain the lab assignment for this session.

2. "Break"

3. Lab assignment to include more resistor color codes, ohm's law formula and solving simple series circuits using ohm's law. Student to set up circuit shown on the back of handout.

4. Discussion on lab activities and question and answer period.

Fifth Session
(Handout on Alternating Current and Voltage)

1. Cover A.C. Glossary and some of the more common A.C. formulas.

2. Do Waveform Analysis Worksheet. (this tends to scare some of the students.) Explain lab assignments for this session.

3. "Break"

4. Using a Function Generator, have the students "listen" to A.C. and explain the difference between D.C. and A.C. Using an oscilloscope, show what an A.C. waveform looks like at different frequencies. If time permits, show other applications of the scope. (composite waveform from TV???)

Sixth Session
(Handout on Digital Electronics

1. Explain to the students what an IC is and show them some examples of what a "chip" looks like. Discuss the various types of gates and how they function. Compare the types of gates with series and parallel circuits. Explain lab assignments for this session.

2. "Break"

3. Using the Digital Trainers, have the students hook up the various IC's and compare the outcome with their lecture notes. Have the Students write the truth tables for the connected gates. Question and answer period for the entire program and of course, a plug for the Electronic Programs at LTC.

DEVELOPING ELECTRICAL/MECHANICAL APTITUDES

LTC CLEVELAND CAMPUS

Tuesday/Thursday
5:30 to 8:30 p.m.

April 5 to May 12, 1994
or
April 26 to June 2, 1994

INSTRUCTORS

Joe Belisle, Electrical
Bob Moore, Mechanical

HANDOUT
THE FATAL CURRENT

Strange as it may seem, most fatal electric shocks happen to people who should know better. Here are some electro-medical facts that should make you think twice before taking that last chance.

IT'S THE CURRENT THAT KILLS

Offhand it would seem that a shock of 10,000 volts would be more deadly than 100 volts. But this is not so! Individuals have been electrocuted by appliances using ordinary house current of 110 volts and by electrical apparatus in industry using as little as 42 volts direct current. The real measure of shock's intensity lies in the amount of current (amperes) forced through the body, and not the voltage. Any electrical device used on a house wiring circuit can, under certain conditions transmit a fatal current.

While any amount of current over 10 milliamps (0.01 amp) is capable of producing painful to servere shock, currents between 100 and 200 ma (0.1 to 0.2 amp) are lethal.

Currents above 200 milliamps (0.2 amp), while producing severe burns and unconsciousness do not usually cause death if the victim is given immediate attention. Resuscitation, consisting of artifical respiration, will usually revive the victim.

DANGER--LOW VOLTAGE!

It is common knowledge that victims of high-voltage shock usually respond to artifical respiration more readily than the victims of low-voltage shock. The reason may be the merciful clamping of the heart, owing to the high current densities associated with high voltages. However, least these details be misinterpreted, the only reasonable conclusion that can be drawn is that 75 volts is just as lethal as 750 volts.

The actual resistance of the body varies depending upon the points of contact and the skin condition (moist or dry). Between the ears, for example, the internal resistance (less than skin resistance) is only 100 ohms, while from hand to foot it is closer to 500 ohms. The skin resistance may vary from 1000 ohms for wet skin to over 500,000 ohms for dry skin.

When working around electrical equipment, move slowly. Make sure feet are firmly placed for good balance. Don't lunge after falling tools. Kill all power, and ground all high-voltage points before touching wiring. Make sure that power cannot be accidentally restored. Do not work on underground equipment.

Above all, do not touch electrical equipment while standing on metal floors, damp concrete or other well grounded surfaces. Do not handle electrical equipment while wearing damp clothing (particularly wet shoes) or while skin surface are damp.

Do not work alone! Remember, the more you know about electrical equipment, the more heedless you're apt to become. Don't take unnecessary risks.

WHAT TO DO FOR VICTIMS--

Cut voltage and/or remove victim from contact as quickly as possible--but without endangering your own safety. Use a length of dry wood, rope, blanket, ect. to pry or pull the victim loose. Don't waste valuable time looking for the power switch. The resistance of the victim's contact decreases with time. The fatal 100 to 200-milliampere level may be reached if action is delayed.

If the victim is unconscious and has stopped breathing, start artificial respiration at once. Don't stop resuscitation until medical authority pronounces the victim beyond help. It may take as long as eight hours to revive the patient. There may be no pulse and a condition similar to rigor mortis may be present; however, these are the manifestations of shock and are not an indication the victim has succumbed.

HANDOUT

GROUND FAULT CIRCUIT INTERRUPTERS

WHAT'S A GROUND FAULT?

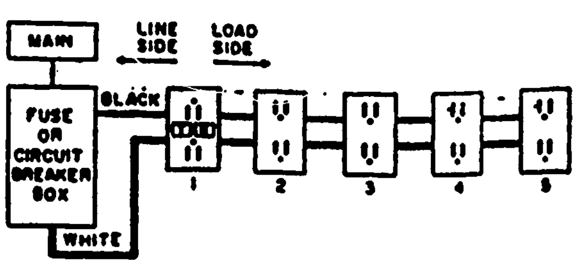
A ground fault is a failure in an electrical circuit that permits current to flow from a hot wire to ground. Faults occur as a result of worn insulation, moisture, or in tools or appliances that have deteriorated from age and abuse. Because failures of this type usually remain undetected, ground fault shock is the most common form of electrical accident. Faults are most dangerous when people are in their path. The human body can complete an electrical circuit. The Ground Fault Circuit Interrupter was developed to protect persons against this hazard.

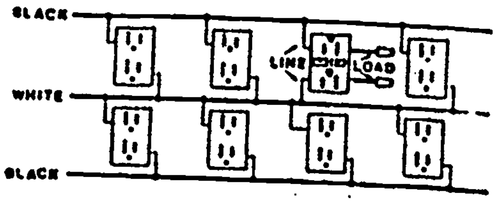
WHY USE A GROUND FAULT CIRCUIT INTERRUPTER?

Exposure to small amounts of electrical current can be hazardous . . even lethal to persons. As little as 6 milliamperes . . that's 6/1000 of one ampere . . is all it takes to "freeze" a child or woman to a circuit and 9 mA for men. At 18 mA, breathing may stop, and at 50mA the pulse may stop. But, with the use of a Ground Fault Circuit Interrupter leakage current of 4-6mA is detected and opens the circuit before bodily harm can occur. When the device "trips" a red button pops out, exposing the word TRIP which indicates that the power is off on that circuit. Power is restored by pressing the red RESET button back in. There's also a yellow TEST button which is used to chect the GFI (Ground Fault Interrupter) at regular intervals to assure continuity of protection.

HOW ARE GROUND FAULT CIRCUIT INTERRUPTERS INSTALLED?

The Ground Fault Interrupters can replace receptacles or circuit breakers. When using the ground fault receptacle, it is installed as the first receptacle from the panel or fuse-box and it will provide ground fault protection to itself and all downstream receptacles on the same circuit. It can also be used for "one-outlet-only" protection on multi-wire circuits. Color coding and simple instructions make it easy to install as a standard receptacle. GFI can also be of the circuit breaker type. The circuit breaker GFI is located at the distribution panel and protects the entire circuit.





Most electrical equipment, including wiring, has a small amount of current leakage. Over a long circuit the cumulative leakage of all lights, fans and appliances may equal the minimum, trip level of the GFI, causing it to open the circuit even though no actual hazard exists. This "nuisance tripping" is most common when the GFI is located at the panel board, as are GFI circuit breakers. Because the GFI receptacle is located at or near the point of use, nuisance tripping is elimated.

WHERE ARE GROUND FAULT CIRCUIT INTERRUPTERS NORMALLY USE?

The 1978 National Electrical Code dictate ground fault protection for residential bathrooms and outdoor receptacles. The Code requires protection for receptacles for electrical equipment for storable swimming pools and decorative fountains, of receptacles between ten and fifteen feet from swimming pools, underwater swimming pool fixtures operating at more that 15 volts, of receptacles in normally wet patient-care areas and in temporary power receptacles at construction sites where an assured grounding program has not been implemented.

The Code recognizes the installation of ground fault protection in kitchens, home workshops, garages, basements, assembly lines, public buildings . . virtually everyplace where a hazardous condition exists.

HOW DOES THE GROUND FAULT CIRCUIT INTERRUPTER WORK?

As mentioned previously GFCI's are available in different forms, including a circuit breaker type, and a receptacle type. An explanation of the receptacle type is the most useful because it is the most commonly used type of GFCI. The principle of operation of other types of GFCIs is identical.

The circuitry that follows is the internal circuitry of a typical receptacle-type GFCI. The current flowing in the line conductor is directed through a current transformer sensor and to the appropriate slot on the receptacle face. The return current on the grounded (neutral) conductor is also passed through the current sensor. An electronic circuit compares the current in each. When the differential current exceeds 6mA (5mA + or - 1mA) for a Class A GFCI, the solid-state circuitry magnifies the current and opens the circuit by means of a shunt-trip solenoid.

LAB SAFETY CHECK LIST

BE AWARE OF SHOCK HAZARD

- One hand in pocket
- Don't wear conductive jewelry
- Don't work while wet or barefoot
- Don't bring drinks into lab

NEVER WORK ALONE IN THE LAB

- Know what to do to help shock victim
- Get help lifting heavy objects

WORK WITH YOUR INSTRUCTOR

- Report all accidents to him/her

BE FAMILIAR WITH YOUR EQUIPMENT

- Be sure it's in safe condition
- Use the right tool for the job
- Know where burn and fire hazards exist and where fire extinguishers are
- Use caution around moving machinery (watch for cooling fans)

U(EXTREME CAUTION WHILE WORKING ON LIVE CIRCUITRY

- Work on live equipment only when absolutely necessary
- Use Insulated tools (keep one hand in pocket)

KEEP YOUR WORK AREA NEAT

- Shut off all equipment when leaving

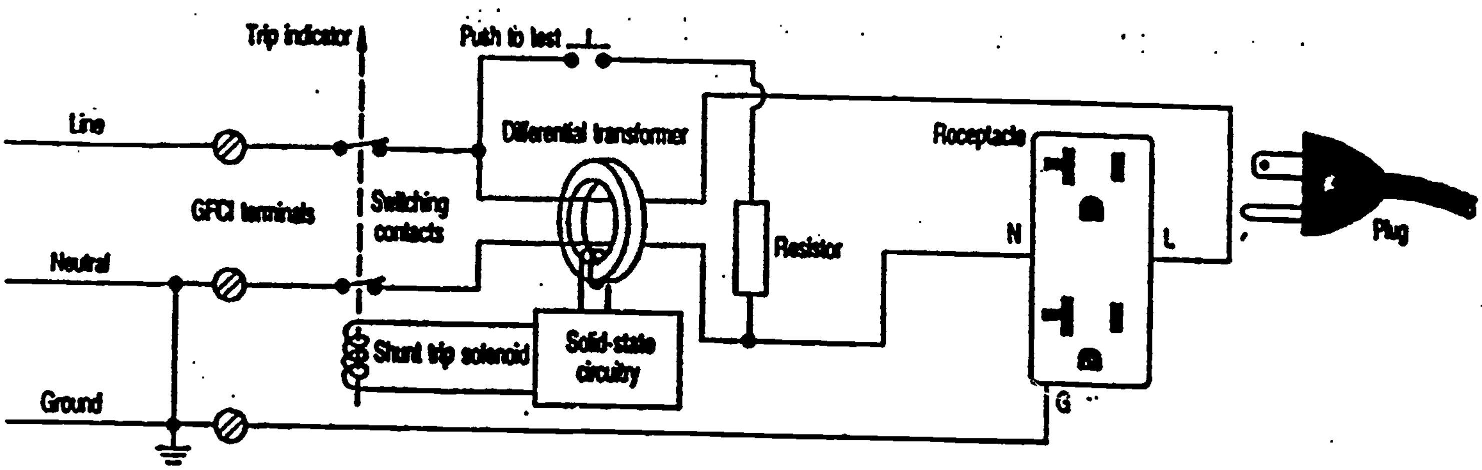
NO HORSEPLAY IN LAB

- Don't distract other students

BE CAREFUL

- Take your time
- Think first
- Plan ahead
- Consider the consequences

A push-to-test circuit is included in a receptacle-type GFCI as a means of checking that the sensor, electronic circuitry, and solenoid are in good operating order. The pushbutton circuit bypasses the CT sensor. Return current flows through a calibrated resistor and then through the CT sensor. This current is immediately recognized as being "unbalanced," and the solid-state circuitry will open the switching contacts.



DEVELOPING ELECTRICAL/MECHANICAL APTITUDES

HAND TOOLS and SPECIAL TEST EQUIPMENT

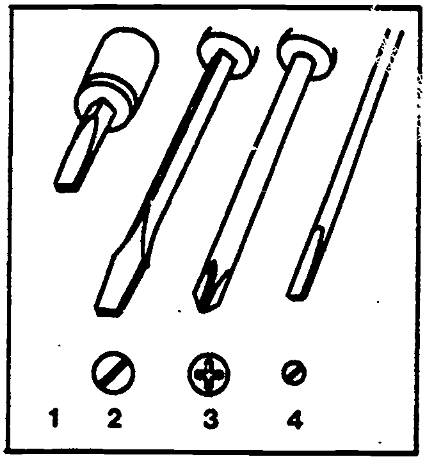


Figure 1-13 Typical screwdriver assemblies. (The Hand Tool Institute)

1. Stubby screwdriver for working in close quarters.

2. Screwdriver with a square shank to which a wrench can be applied to remove stubborn screws.

3. Screwdriver for Phillips screws.

4. Cabinet screwdriver has a thin shank to reach and drive screws in deep, counterbored holes.

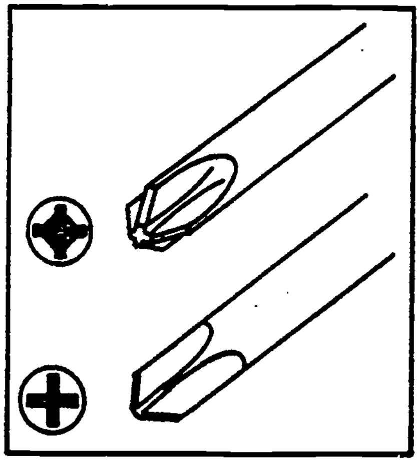


Figure 1-14 The Reed & Prince screw head and its matching screwdriver (bottom) somewhat resembles the Phillips type (top), but there is a difference. The slots in a Phillips screw end in a slight curve at their intersection, unlike the Reed & Prince screw, whose slots meet at an exact right angle. (The Hand Tool Institute)

1. Make sure that the tip fits the slot of the screw not too loose and not too tight.

2. Do not use a screwdriver as a cold chisel or punch.

3. Do not use a screwdriver near live wires (do not use any other tool, for that matter).

4. Do not expose a screwdriver to excessive heat.

5. Redress a worn tip with a file in order to regain a good straight edge.

6. Discard a screwdriver that has a worn or broken handle.

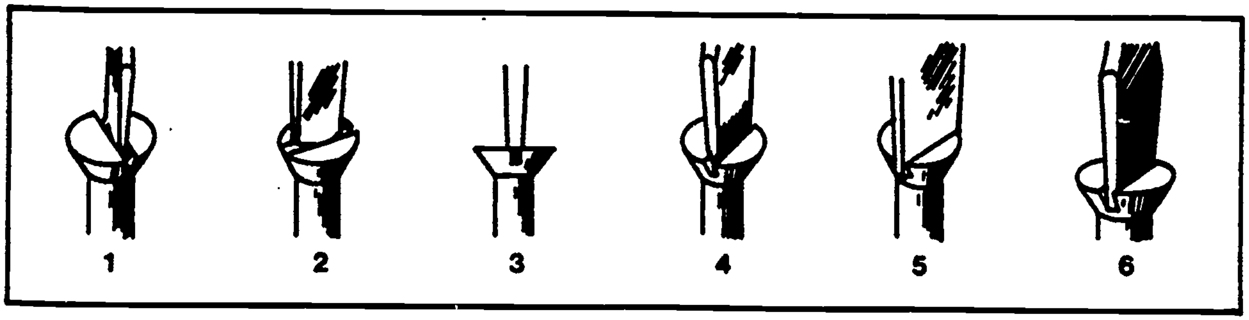


Figure 1-15 Proper and improper use of flathead screwdrivers. (The Hand Tool Institute)

1. This tip is too narrow for the screw slot; it will bend or break under pressure.

2. A rounded or worn tip. Such a tip will ride out of the slot as pressure is applied.

3. This tip is too thick. It will only serve to chew up the slot of the screw.

4. A chisel ground tip will also ride out of the screw slot. Best to discard it.

5. This tip fits, but it is too wide and will tear the wood as the screw is driven home.

6. The right tip. This tip is a snug fit in the slot and does not project beyond the screw head.

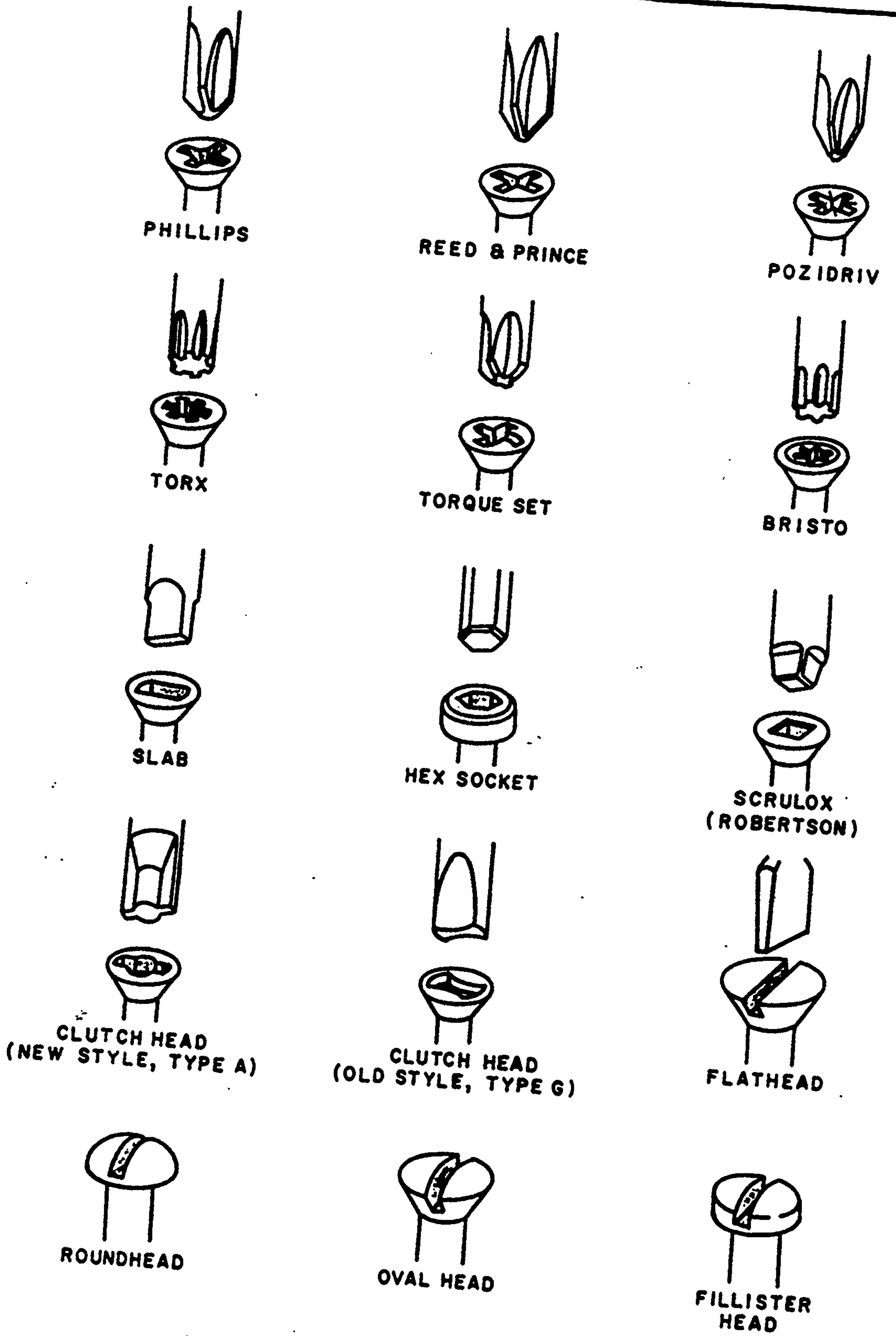


Figure 1-12 Typical screw head configurations. (The Hand Tool Institute)

FLATHEAD OFFSET SCREWDRIVER

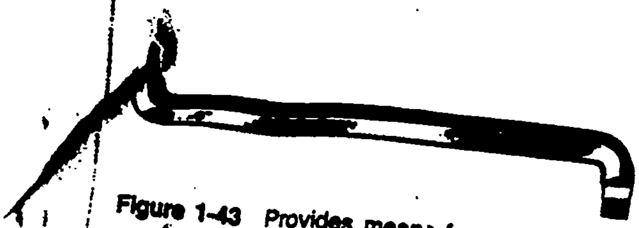


Figure 1-43 Provides means for reaching difficult flathead screws. (Vaco Products Company)

LONG NEEDLE-NOSE PLIERS AND CUTTER

Figure 1-44 Appropriate for bending wire, cutting wire and positioning small components. (Vaco Products Company)

LINEMAN'S SIDE CUTTING PLIERS

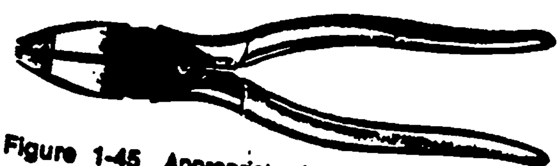


Figure 1-45 Appropriate for cutting cable, removing knockouts, twisting wire and deburring conduit. (Ideal Industries, Inc.)

UTILITY PLIERS

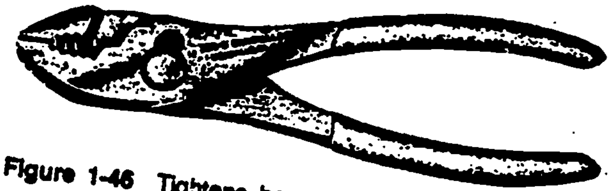


Figure 1-46 Tightens box connectors, lock nuts, and small size conduit couplings. (Channellock, Inc.)

SLIP JOINT PLIERS

Figure 1-47 Used for a wide range of service involving gripping, turning, and bending. (Vaco Products Company)

DIAGONAL SIDE-CUTTING PLIERS

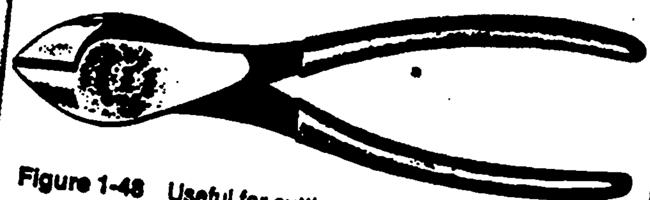


Figure 1-48 Useful for cutting cables and wires too difficult for side cutting pliers. (Courtesy of The Ridge Tool Company)

END-CUTTING PLIERS

Figure 1-49 Used for cutting wire, nails, rivets, etc., close to work (Channellock, Inc.)

TOOL CABINET

Figure 1-35 Used to organize and store a variety of tools and materials in one location. (Kennedy Manufacturing Company)

TOOL BOX

Figure 1-36 Used to organize, store, and carry tools. (Courtesy of The Ridge Tool Company)

TOOL POUCH AND ELECTRICIAN'S BELT

Figure 1-37 Used to safely transport and store many small electrical hand tools and instruments. (Klein Tools, Inc.)

FLATHEAD SCREWDRIVER

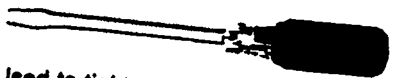


Figure 1-38 Used to tighten or loosen flathead screws. Be sure slot fits screw head. (Vaco Products Company)

PHILLIPS SCREWDRIVER

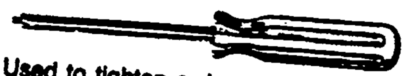


Figure 1-39 Used to tighten or loosen Phillips screws. Be sure that the screwdriver fits the screw head. (Vaco Products Company)

PHILLIPS OFFSET SCREWDRIVER

Figure 1-40 Provides means for reaching difficult Phillips head screws. (Vaco Products Company)

PHILLIPS SCREW-HOLDING DRIVER

Figure 1-41 Used to hold Phillips screws in place while working in tight spots. Once started, screw is released and tightened with standard screwdriver. (Vaco Products Company)

FLATHEAD SCREW-HOLDING DRIVER

Figure 1-42 Used to hold flathead screws in place when working in tight spots. Once started, screw is released and tightened with a standard screwdriver. (Vaco Products Company)

SLEDGE HAMMER

Figure 1-57 Medium sized (5 lb) hammer used for driving stakes and other heavy duty pounding. (Courtesy of The Ridge Tool Company)

POCKET TORPEDO LEVEL

Figure 1-61 Useful in leveling electrical control panels and conduit bends. (Klein Tools, Inc.)

BALL PEEN HAMMER

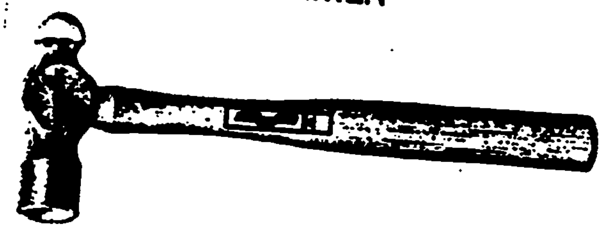


Figure 1-58 Ball peen hammers of the proper size are designed for striking chisels and punches. They also may be used for riveting, shaping, and straightening unhardened metal. (Channellock, Inc.)

24-INCH LEVEL

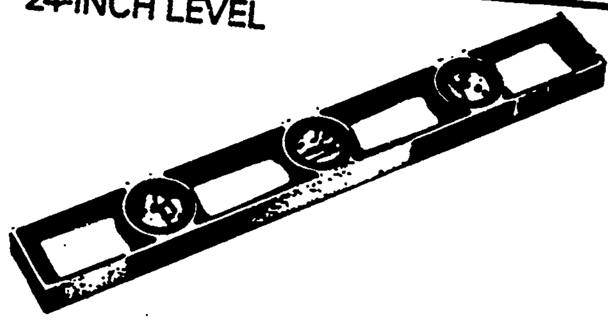


Figure 1-62 Useful in leveling long conduit runs and bus bar installations. (Courtesy of The Ridge Tool Company)

FOLDING RULE

Figure 1-59 Works better than tapes for measuring layout work. (Klein Tools, Inc.)

POWER RETURN STEEL TAPE

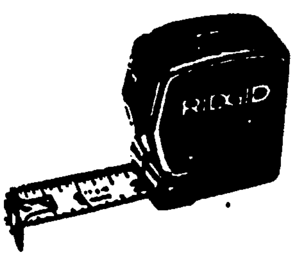


Figure 1-60 Used for rapid layout in measurements. Should be as wide as possible for easy extension. (Courtesy of The Ridge Tool Company)

FISH TAPE WITH HOLDER

Figure 1-63 Useful to pull wire through conduit and "fish" wires around obstructions in walls. (Ideal Industries, Inc.)

ELECTRICIAN'S KNIFE

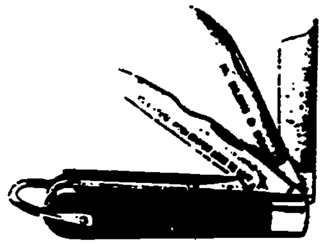


Figure 1-50 Removes insulation from cables and service conductors. Keep cutting blade sharp. (Klein Tools, Inc.)

SKINNING KNIFE

Figure 1-51 Removes insulation from cables and service conductors. Keep cutting blade sharp. (Klein Tools, Inc.)

CABLE STRIPPER

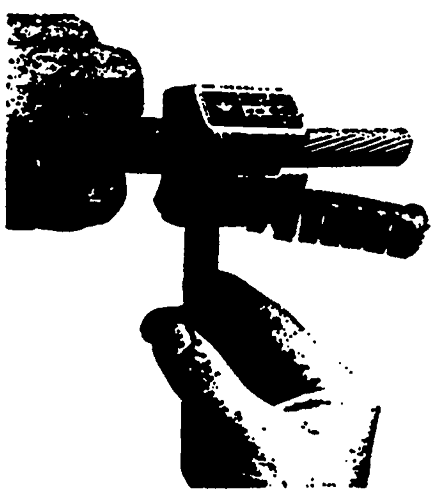


Figure 1-52 Removes insulation from heavy duty cables. (Ideal Industries, Inc.)

WIRE STRIPPERS

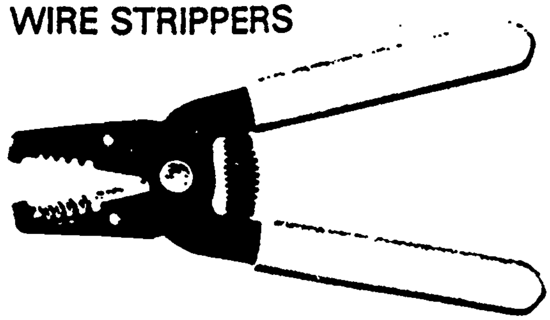


Figure 1-53 Removes insulation from small diameter wire. (Ideal Industries, Inc.)

COMBINATION WIRE STRIPPER, BOLT CUTTER AND CRIMPER

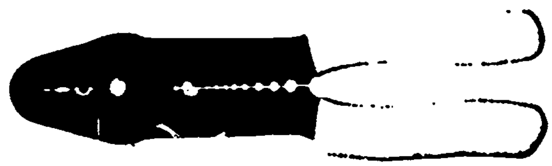


Figure 1-54 Removes insulation from small diameter wire, secures crimp type connectors, and cuts small bolts to given lengths. (Vaco Products Company)

CABLE CUTTER

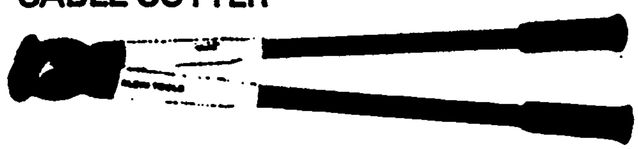


Figure 1-55 Provides shear-type cable cutting for relatively large diameter cables. Makes a clean, even cut for ease in fitting lugs and terminals. (Klein Tools, Inc.)

ELECTRICIAN'S HAMMER

Figure 1-56 Can be used to mount electrical boxes and drive nails. Can also be used to determine height of receptacle box since most hammers are 12" in length from head to end of handle, or can be so marked. (Klein Tools, Inc.)

NUT DRIVER SET

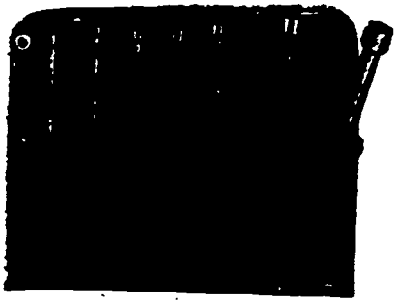


Figure 1-70 Used to tighten positive sized hex head nuts and screws. (Vaco Products Company)

HACKSAW

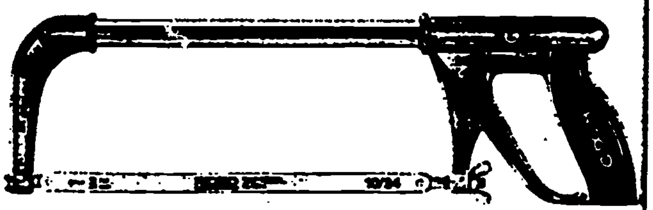


Figure 1-71 Cuts heavy cable, pipe, and conduit. (Courtesy of The Ridge Tool Company)

SOCKET WRENCH SET

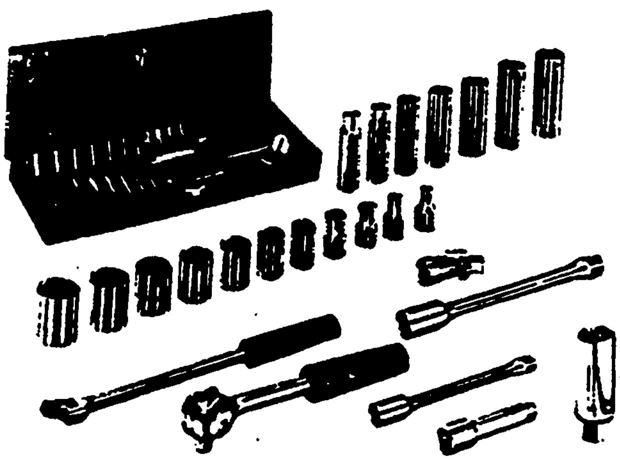


Figure 1-72 Used to tighten a variety of positive sized items such as hex head lag screws, bolts, and various electrical connectors. (Klein Tools, Inc.)

RIGID CONDUIT HICKEY

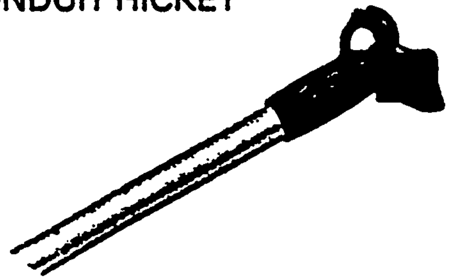


Figure 1-73 Used to bend rigid conduit to a variety of shapes. Available for different size conduits. (Courtesy of The Ridge Tool Company)

HAND THREADER

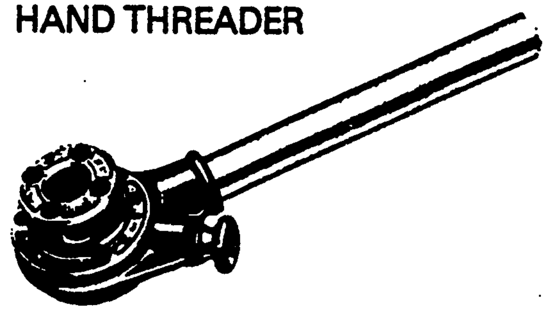


Figure 1-74 Used to thread rigid conduit pipe at a variety of locations on the job site. (Courtesy of The Ridge Tool Company)

POWER THREADER WITH STAND

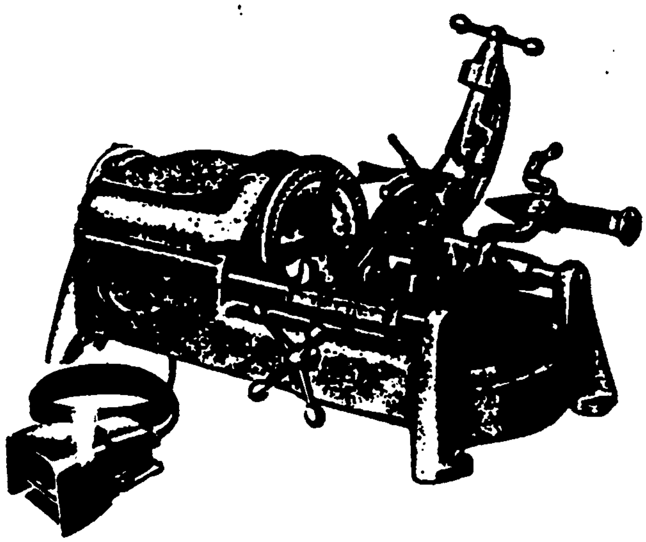


Figure 1-75 Used to thread rigid conduit pipe at a more centralized location. (Courtesy of The Ridge Tool Company)

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POWER WIRE PULLER

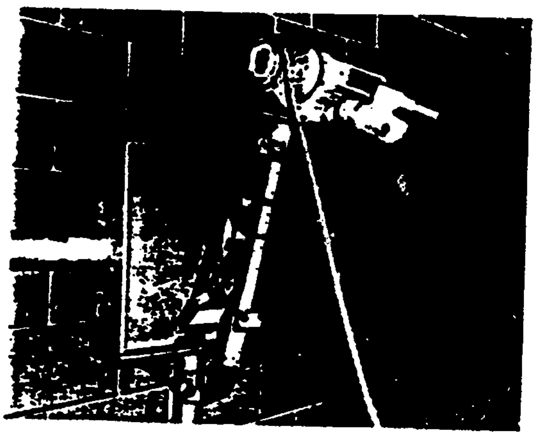


Figure 1-64 Used to pull larger cables and wires into place. (Greenlee Tool Division, Ex-Cell-O Corporation).

REAMING TOOL

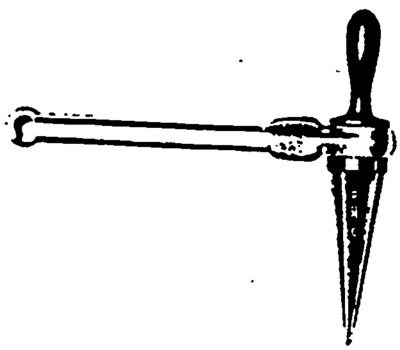


Figure 1-65 Used to deburr or remove rough edges from inside cut conduit. (Courtesy of The Ridge Tool Company)

HEAVY DUTY HAMMER DRILL

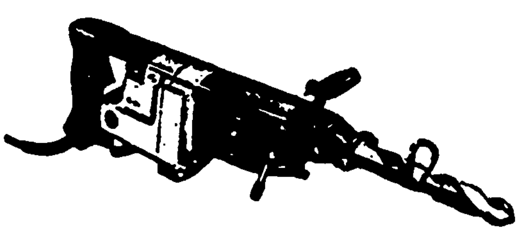


Figure 1-66 Because of the hammer action of the drill, it is ideal for drilling concrete when fasteners are being installed. (Milwaukee Electric Tool Corporation)

ADJUSTABLE WRENCH

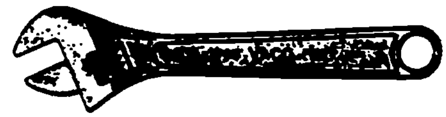


Figure 1-67 Tightens positive sized items such as hex head lag screws, bolts, and larger size conduit couplings. (Vaco Products Company)

CHAIN PIPE WRENCH

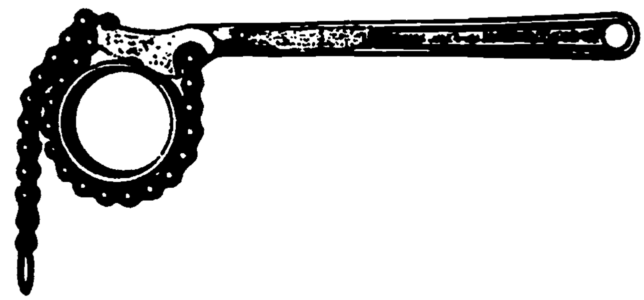


Figure 1-68 Used to tighten and loosen larger pipes and conduit. (Courtesy of The Ridge Tool Company)

HEX KEY WRENCH SET

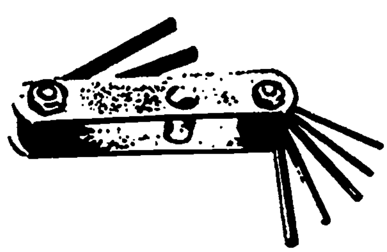


Figure 1-69 Used for tightening positive sized hex head bolts. (Vaco Products Company)

TIE-RAP GUN

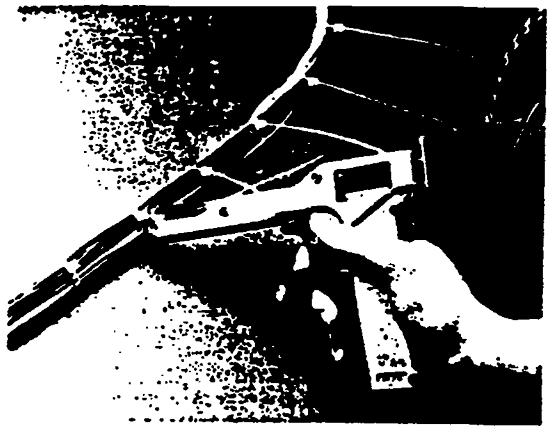


Figure 1-81 Used to firmly secure wires in wire runs and harnesses. (Dennison)

WIRE LUBRICANT

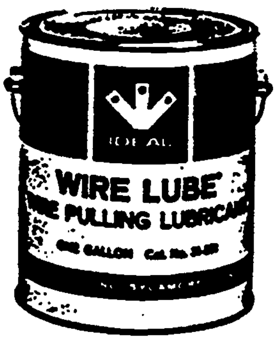


Figure 1-82 When applied to outside of electrical wires, it allows them to be pulled more easily through conduit. (Ideal Industries, Inc.)

ELECTRICIAN'S TAPE

Figure 1-83 Used to provide insulation to electrical connections once repairs or installation have been made. (3M Corporation)

SAFETY GLASSES

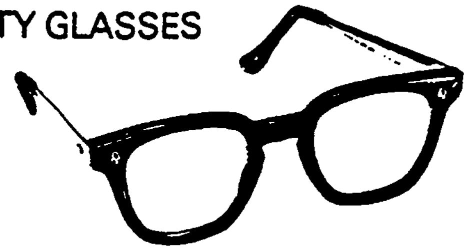


Figure 1-84 Provide eye protection from flying objects and debris. Required on all construction sites. (Fendall Company)

SAFETY HARD HAT

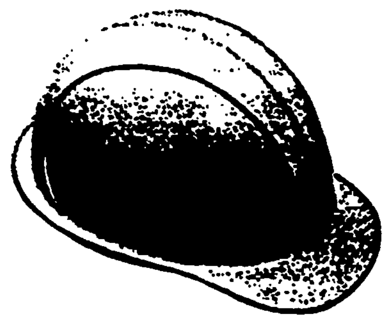


Figure 1-85 Usually made of high density polyethylene to protect against impact, chemicals, and high voltage. Required on all construction sites. (Klein Tools, Inc.)

LOCK-OUT TAG

Figure 1-86 Used in conjunction with padlock to warn others that equipment is shut down for repair and that someone is working on it. (General Electric)

PADLOCK

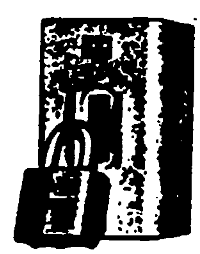


Figure 1-87 Used to provide lock-out protection for electrical equipment. May also be used on a tool box. (Cutler Hammer)

HYDRAULIC PUNCH SET

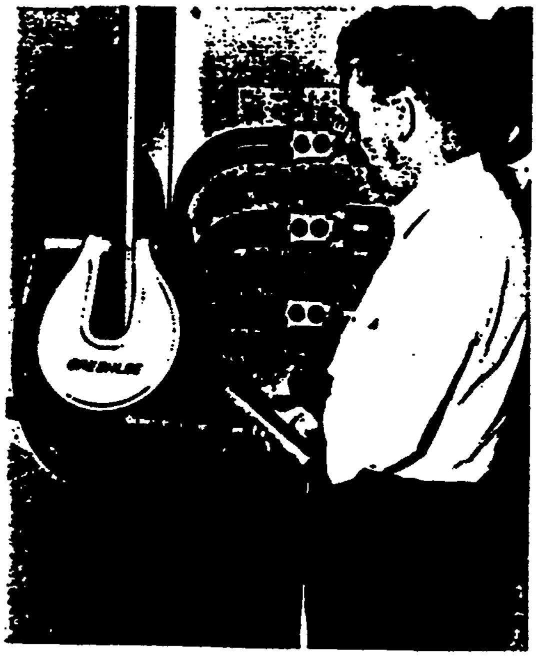


Figure 1-76 Used to punch holes in metal enclosures and cabinets through use of hydraulic cylinder. (Greenlee Tool Division, Ex-Cell-O Corporation)

KNOCK OUT PUNCH

Figure 1-77 Used to punch holes in metal enclosures and cabinets through the use of wrenches or sockets. (Greenlee Tool Division, Ex-Cell-O Corporation)

TAP AND DIE SET

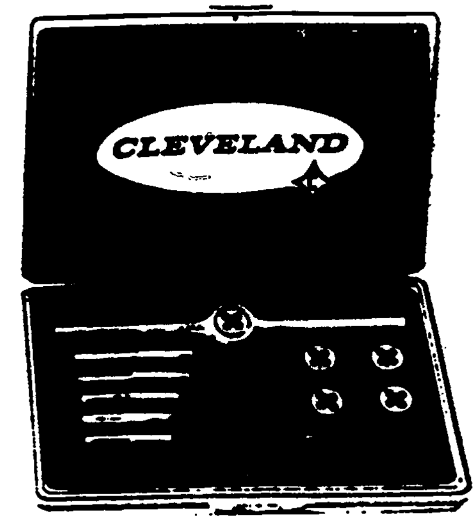


Figure 1-78 Used to provide threading for control panel mounting, bolts, nuts, and steel rod. (The Cleveland Twist Drill Company)

POWER STUD GUN

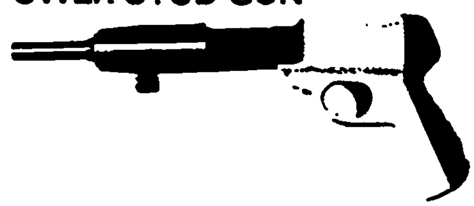


Figure 1-79 Used to firmly secure fasteners in concrete. Extreme care must be exercised when using this device. In certain cases one must be licensed to use it. (DESA Industries)

WIRE MARKERS

Figure 1-80 Used to properly mark and identify wires and matching terminal ends. (Ideal Industries, Inc.)

OSCILLOSCOPE

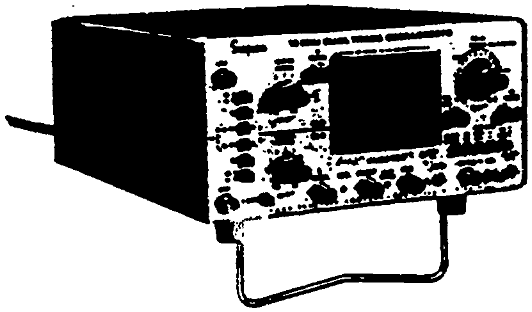


Figure 1-94 Used to troubleshoot and verify outputs and inputs of electronic devices. Used with transducers, it may be used in vibration analysis. (Courtesy of Simpson Electric Company, Elgin, Illinois)

DIGITAL LOGIC PROBE

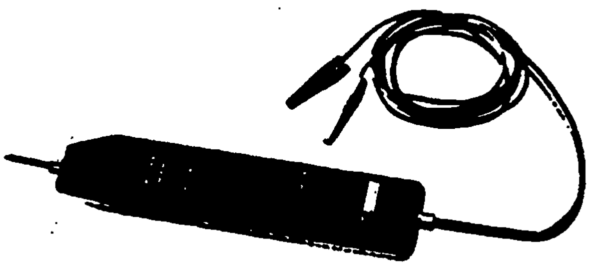


Figure 1-95 Used to troubleshoot and verify outputs and inputs of digital logic circuits. (B & K Dynascan Corporation)

DIGITAL HAND TACHOMETER

Figure 1-96 Used to record the rotational speed of motors in revolutions per minute. (James G. Biddle Company)

VOLTAGE TESTER

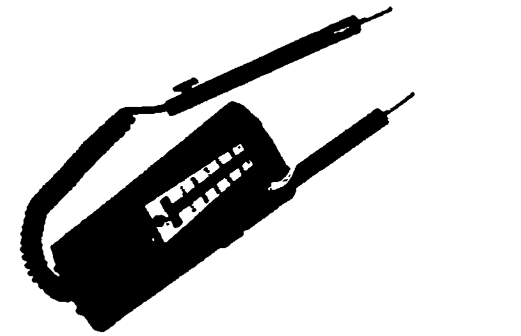


Figure 1-97 Used to measure AC/DC voltages up to 600 volts. (Amprobe Instrument, Division of Core Industries, Inc.)

GROUNDED CIRCUIT TESTER

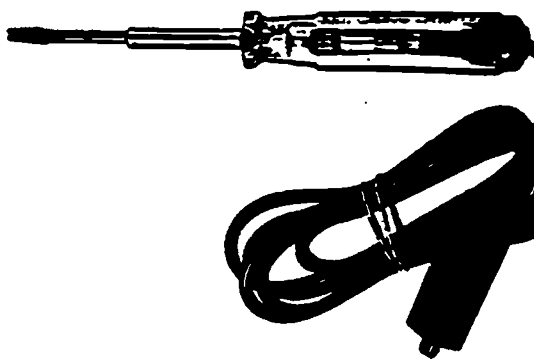


Figure 1-98 Provides method of testing for ground in AC or DC circuits from 100 to 500 volts. (Vaco Products Company)

CONTINUITY TESTER

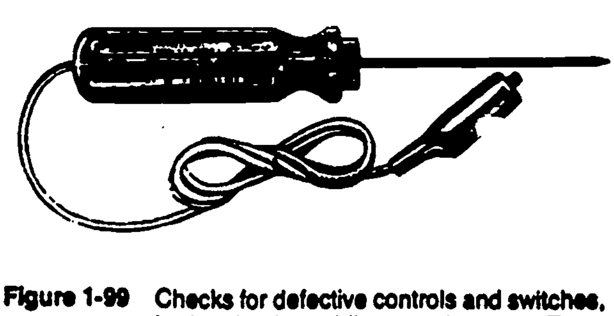


Figure 1-99 Checks for defective controls and switches, broken leads and lines, and motors. Tests for continuity of circuit with power off. (Vaco Products Company)

FUSE PULLER

Figure 1-88 Safely removes cartridge type fuses. (Ideal Industries, Inc.)

FLASHLIGHT

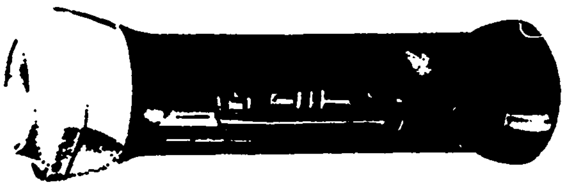


Figure 1-89 Used for emergency lighting and inspection. (Union Carbide Corporation).

POLAROID CAMERA

Figure 1-90 When making circuit changes, especially in conduit, use instant photographs as a means of evaluating changes without returning to the job site. (Polaroid Corporation)

POLARIZED RECEPTACLE TESTER

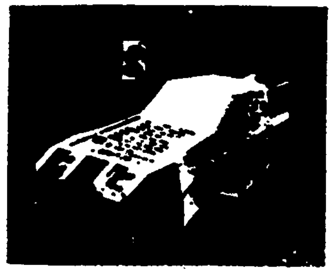


Figure 1-91 Used to verify grounding and proper installation of three-wire outlets. (Ideal Industries, Inc.)

INDUSTRIAL VOM WITH CLAMP-ON AMMETER

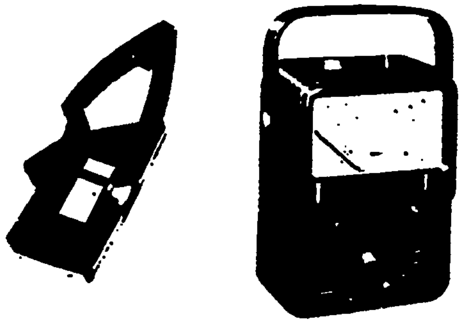


Figure 1-92 Used to measure voltage, current, and resistance. Clamp-on ammeter attachment allows AC/DC current to be measured without breaking circuit. (Courtesy of Simpson Electric Company, Elgin, Illinois)

DIGITAL AC/DC AMMETER

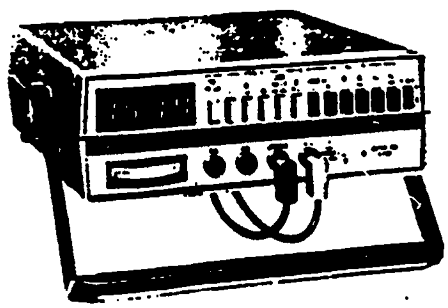


Figure 1-93 Used to measure high values of AC/DC current. (Courtesy of Simpson Electric Company, Elgin, Illinois)

TEST LEAD SET

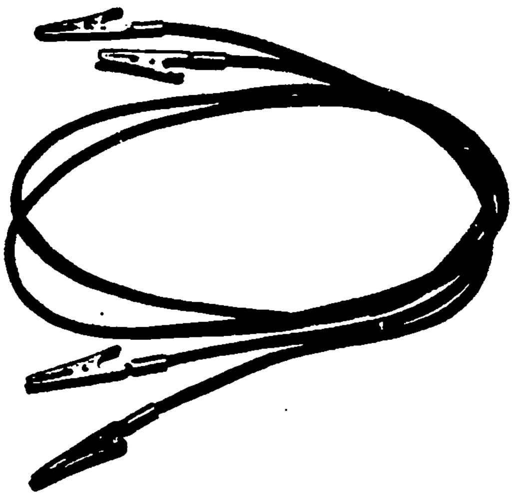


Figure 1-100 Used with test equipment and control circuits in isolation problems. (Vaco Products Company)

MEGOHMMETER

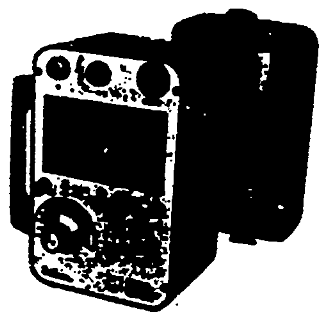


Figure 1-101 Used for testing the insulation properties of motors, transformers, cables, generators, and other related equipment. (Associated Research, Inc.)

STRIP CHART RECORDER

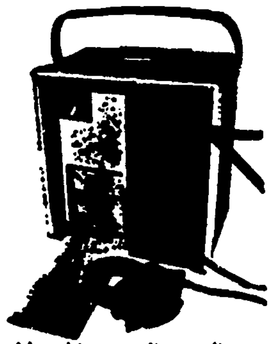


Figure 1-102 Used to monitor voltage and current variations over extended periods of time. (Amprobe Instrument, Division of Core Industries, Inc.)

OHMMETER (VIBROGROUND)

Figure 1-103 Used for testing of resistance of man-made grounds and solid resistivity for corrosion control. (Associated Research, Inc.)

PHASE SEQUENCE INDICATOR

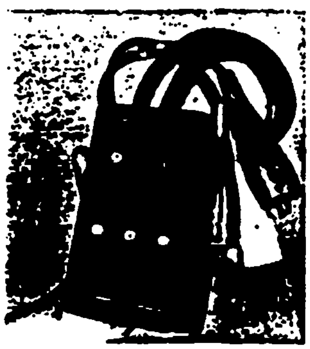


Figure 1-104 Used to determine proper phasing of three-phase systems. (Associated Research, Inc.)

DEVELOPING ELECTRICAL/MECHANICAL APTITUDES

SOLDERING---DESOLDERING

1. When touching the work with the iron, try to contact the part of the greater mass with the flat (larger) part of the tip while trying to touch the part of the smaller mass with the side or edge (smaller part).

2. Immediately on tool-to-work contact, create a fast heat bridge by placing the core solder in the gap. This will melt the flux and then some solder, which will permit localized wetting for rapid heat flow.

3. Once the core solder starts melting, draw it around the joint in the direction of flow.

4. Remove solder first after sufficient metal has been added to the joint.

5. Next, remove the iron, but only after the solder has reached the desired contour as dictated by surface tension.

6. Allow the solder to freeze without vibration to avoid disturbed joints.

7. Always place the heat (soldering-iron tip) on the side opposite insulation and heat-sensitive components.

8. Do not melt the solder on top of the soldering iron and carry it to the work (puddling).

9. Do not place the soldering iron on top of core solder or interpose core solder between the work and tip; flux will spit and not run onto the connection.

10. Do not pull or push on solder joint for inspection.

GLOSSARY

ACID FLUX - Does an excellent job of cleaning metals to remove surface oxidation; but it is highly corrosive. Never use it for electrical or electronic soldering.

ALLOY - A mixture of two or more different elements, where at least one is a metal. Solder is an alloy of tin and lead.

EUTECTIC COMPOSITION - This is the tin-lead alloy that has the lowest possible melting temperature (361°F.), also called "eutectic solder." It also has no plastic state and, therefore, goes directly from the liquid state to the solid state. This means that it cools and hardens very rapidly. Eutectic solder has a 63-37 tin-lead ratio. 60/40 solder is used in electronics most commonly because it comes very close to this eutectic state.

FLUX - A substance that is used to remove the surface oxide from a metal piece before it is soldered. Most of the solder used in electronics has flux built right into it. Always use rosin-core solder for any kind of electronic or electrical work.

FLUX-COATED BRAID - A very effective means of removing solder from a connection. Place the braid over the connection, heat it with the iron, and the solder will be drawn up into it as water is drawn into a sponge.

IRON-CLAD TIPS - Soldering iron tips are made out of copper, but they are often plated with a coating of iron to reduce the effects of oxidation and to help keep it clean. Many of these tips also have a gold or silver plating. These are also called "plated tips."

MELTING POINT - The particular temperature at which a given tin-lead alloy (solder) melts. The 60/40 solder that is used most commonly in electronic and electrical work has a melting point of 370°F.

OXIDATION, OXIDE - Most metals, when exposed to the air, have an insulating layer of oxide form on their surface. This oxide prevents solder from adhering to the metal. It is removed from the metal surfaces by the flux. You should also minimize oxidation on soldering tips by covering them at regular intervals with a coating of solder.

PLASTIC STATE - A semi-liquid state in which the solder can be molded or moved to some degree, but is not liquid enough to actually run or flow.

ROSIN CORE SOLDER - The most common type of solder used in electronics, usually described as "60/40 rosin core solder." The rosin flux is noncorrosive. Therefore, if any should remain on the outside of the connection after the solder has hardened, it will not do any harm.

SOLDER - A tin/lead alloy that melts at a very low temperature, making it ideal for the joining together of other metals. Melted solder is flowed over the other metals; and when it cools, it produces an excellent electrical connection that is also strong physically.

SOLDER BRIDGE - An accidental solder connection between two close-together lugs or pins, or between close-together foils on a circuit board. Avoid solder bridges around close-together work by using an iron with a small tip and thin solder. To eliminate a solder bridge, use any of the unsoldering methods; or hold the solder bridge above the iron so that, when it is heated, the solder will flow down onto the tip of the iron.

TINNING THE TIP - The process of applying a layer of solder to the tip of a soldering iron. This layer of solder minimizes the formation of oxide on the tip. The oxide layer would greatly reduce the amount of heat that could be transferred to the connection.

TIP - The part of the soldering iron that comes in contact with the connection. Usually it is a copper rod that is pointed or chisel-shaped at one end. Many tips are iron-clad, and have a gold or silver plating to reduce the effects of oxidation, to extend its life, and to improve heat transfer. Soldering iron tips are usually replaceable.

WETTING - In any properly made connection, the molecules of solder mix with those on the surface of the metal being soldered. This is called "wetting." The solder actually imbeds itself into the surface of the metal.

SOLDERING SAFETY

Soldering is a safe process if the hazards associated with soldering are recognized and normal safety precautions are observed. The possible sources of danger to personnel and property are from heat, fire, electricity, fumes, and chemicals.

Since soldering is a process which requires heat, the risk of receiving painful and dangerous burns is always present. Burns can be received from the primary source of heat, from explosions caused by flames, and from handling soldered metals before they have cooled sufficiently. Burns are a personnel problem and can be avoided by thorough training.

Closely associated with the dangers of heat is the fire hazard. Fires can cause extensive property damage and are frequently the cause of loss of life or injury to personnel. The equipment used for general purpose soldering presents a definite fire hazard at all times. Fire can result from the careless handling of flame-heating devices or from their use in the vicinity of inflammable fumes and liquids. Fire hazards can be greatly reduced by observing simple safety precautions.

Volatile fumes are a hazard both to personnel and property; however, the danger can be decreased during soldering operations if adequate ventilation is provided. Fumes from gasoline and alcohol present as explosion hazard since they can be ignited by an open flame or by a spark. Combustible gas mixtures such as oxygen and acetylene, present the same kind of danger. Other fumes may be injurious to the health of operating personnel. For example, fumes from heated fluxes and from degreasing liquids can cause skin and lung irritations.

Since electrical soldering equipment is so widely used, an electrical hazard to personnel and property often exists. Electrical defects in soldering equipment and associated supply circuits can cause fires and explosions under certain conditions. This hazard can be minimized by the use of equipment in good condition. As with all electrical equipment, the danger of electrical shock to operating personnel is present.

Chemicals which may present a health hazard are used extensively in soldering fluxes and degreasing solutions. Noncorrosive fluxes present few problems but the alkalies and acids used in corrosive fluxes may cause skin irritations and burns. Danger to the eyes also exist since many of the chemicals are in liquid solutions, and splashing or spattering may occur. The hazard presented by chemicals is slight if the proper safety precautions are observed.

Many precautions are common to all types of soldering. They must be observed to prevent personnel injuries and damage to property.

1. To avoid painful burns, do not handle hot metals. In addition, completed soldering assemblies may be dropped and damaged by handling them when they are hot.

2. Select the proper working area for soldering. Choose a well-ventilated location, away from all fire hazards.

3. Mechanically hold large work pieces securely while they are being soldered. Severe injuries and burns may be received because of a falling work piece.

4. Wear the proper clothing and protective devices when you are soldering.

5. Maintain a clean working area to prevent fires. Remove combustible materials from the floor and from the surrounding areas.

6. Keep firefighting devices and first-aid supplies near the soldering area. All equipment should be checked at regular intervals.

7. Always use an authorized iron holder.

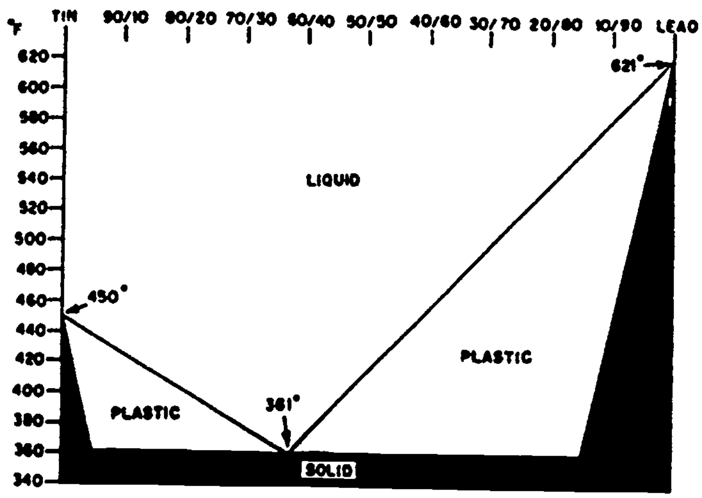
SOLDERING: A FINE ART

Solder is one of the oldest, simplest, and most useful of all the metals in use as a fusible alloy. Soldering, because of its very simplicity and ease of application, has come to be regarded as something which can be taken for granted. This is not the case. Engineers and technicians have found that many failures attributed to electrical components were actually the fault of poorly soldered connections. Because of the importance of high quality standards in the field of electronics today, soldering has become a fine art, far from the simple task it was years ago.

Before we cover the actual process of soldering, I think we should discuss the very nature of solder.

Ordinary solder is a fusible alloy of tin and lead. When tin and lead are alloyed, the percentage of tin and lead is expressed as a ratio, with tin as the first number. For example, 60/40 means the solder is 60 percent tin and 40 percent lead. There are many classes of solder available that have many uses. They can be grouped as follows: Flux core type, solid wire, and bar solder.

The composition of commercial solder covers the entire range of tin-lead ratios. Their characteristics are shown in figure 1. Note that pure tin becomes a liquid at 450 degrees F, and pure lead becomes a liquid at 621 degrees F. When the two metals are alloyed, new liquefaction points are created, depending upon the tin-lead ratio.



Referring to figure 1 again, we can see that with the correct ratio of tin and lead, we can create an alloy with a low melting point of 361 degrees F. The alloy is a mixture of 63 percent tin and 37 percent lead and is known as the eutectic composition, or eutectic solder.

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With the exception of the eutectic alloy [63 percent tin and 37 percent lead], all solders in the tin-lead series are ratios which do not melt sharply at any one temperature. The different ratios pass through an intermediate range of plasticity before going into the liquid range. This intermediate range of plasticity also takes place in cooling from liquid to the solid state.

A working knowledge of the plastic range of solders is very helpful in selecting the type of solder needed for a specific job. For example, in plumbing a wiping solder of 50 percent tin or less is acceptable, due to the long time in the intermediate range of plasticity. In electronics however, many components are heat sensitive and cannot with stand high temperatures for any length of time. In this case, higher tin alloys, which have a shorter range of plasticity are used.

Figure 1 shows that a tin-lead ratio of 60/40 meets the needs when soldering electrical components. A low melting point coupled with a short time in the plastic range reduces the time an temperature at the connection. A 60/40 solder is primarily used in conventional circuits and terminals where the melting point and flexibility of this solder can be tolerated. The flexibility of 60/40 solder is not as desirable when working on printed circuit boards as when working on conventional circuits. The delicate nature of metal foil wiring and the increased heat sensitivity of miniaturized parts require a solder with the lowest melting point possible. Looking at figure 1, we can see that the alloy with the lowest possible melting point is 63 percent tin and 37 percent lead, or eutectic solder. This composition will meet the needs of minimum time and heat on the solder joint.

The eutectic composition [63/37] with its negligible plastic range and sharp and distinct melting point make this composition the preferred solder on printed circuit boards. If 63/37 solder cannot be obtained, a tin-lead ratio of 60/40 is sufficiently close to the eutectic composition to be generally acceptable.

Now that we have covered the properties of solder, I think the next item we should discuss is soldering flux. I don't think it is necessary to talk of the makeup of flux, but we should have an understanding of the reason for using it.

When exposed to the atmosphere, common metals acquire a thin nonmetallic film known as oxide. The longer the exposure, the thicker this film becomes. Oxide film form an effective insulating barrier. As ,long as this nonmetallic barrier is present,metals cannot make actual metal to metal contact. As a result, soldering action cannot properly take place.

The purpose of the soldering flux is to remove this nonmetallic oxide film from the surface of metals and keep it removed during the soldering process. The flux has a melting point lower than the solder. As the flux melts, it exerts a chemical action which loosens the oxides on the metal surface. The loosened oxides, wetted by the flux, coagulate and are suspended in the flux body. The solder then melts, floating the lighter flux and impurities suspended in it, to the outer surface and edges of the molten solder. Most of the flux is burned away during the soldering process, leaving only a small amount of residue when cool.

Note that flux copes only with metal oxides; it does not remove paint, shellac, sulfides, gross forms of dirt, or other inert matter from the surface of metals.

Soldering fluxes may be conveniently divided into three general groups:

1. The chloride or acid type.
2. The organic type.
3. The rosin or resin type.

You will be using the rosin or resin type solder flux. The flux from this type of solder is noncorrosive and electrically nonconductive. The electrical resistance of a cubic inch of rosin has the staggering value of 3,300 trillion ohms.

The noncorrosiveness of rosin flux pertains only to the residue of the flux; rosin flux corrodes hot metal while the flux is in the hot liquid state because of the chemical action needed to remove the oxide.

When cooled to the solid state, rosin reverts to a completely inert and inactive form. Consequently, it is ideal for use on electronic equipment.

Let's talk about the actual soldering process. To someone not familiar with soldering, the process might look as though the solder simply sticks the metals together like glue. What actually happens is really very different.

Soldering is the process of joining two or more metals by the application of heat and a low melting alloy. The alloy flows between and around the metals to be joined. Upon cooling, it actually solidifies and bonds the metals together. In its molten state, solder secures metals by means of a metal solvent or intermetallic solution action.

The solvent or solution action may be illustrated as follows: ordinary table salt has to be heated to 1,488 degrees F before it melts. However, when a little water is added, it melts easily without any heat. The action of molten solder on a metal such as copper may be compared to the action of water on salt.

This solvent or intermetallic solution action chemically dissolves part of the metal surfaces to be joined. The solvent action occurs at temperatures well below the melting of the metals being soldered.

The solvent property of molten solder is a fundamental property of soft solder. This soft solder property is different from that of brazing alloys, whose action involves the formation of a fusion alloy with the metal that is being joined and from welding alloys whose action involves actual fusion of the metals being joined.

A solder joint is chemical in character rather than purely physical because the attachment is formed in part by chemical action rather than by mere physical adhesion. Therefore, the properties of a solder joint are different from those of the original solder.

The complete metallic continuity of a soldered connection insures a permanent and constant electrically conductive medium.

We have talked about the properties of solder, the role of flux in soldering, and the actual process that takes place during the act of soldering. Now is the time to discuss how solder is actually applied.

Solder may be applied in a number of ways; but for now, we will only be concerned with one of them, the conductive-type soldering iron. The three basic elements of a soldering iron are the heating unit, the heater block, [which acts as a heat reservoir], and the tip [for transferring heat to the work].

In a basic iron, the input voltage is fixed so the tip temperature depends on the capacity of the heating unit, and the mass of the tip and block. There are many irons on the market which incorporate different methods of controlling the temperature of the tip. The arguments for and against controlling tip temperature are many but that is not the real problem. The biggest problem in soldering is controlling the heat cycle of the work. How fast, how long, and how hot are the main considerations.

Several other things have to be considered also. One factor is relative thermal mass. If we use a small tip on a large mass, the temperature rise of the mass will be slow. By using a large tip on a small mass, the temperature will rise very quickly, even though the temperature of the tip is the same. Each joint to be soldered, whether it is a wire, a terminal, or a circuit board, has its own particular thermal mass. Each one has to be considered when selecting the correct soldering iron.

Another important factor is the surface condition of the joint to be soldered. One of the most important points to remember in soldering is that you cannot solder on a dirty surface. Always make sure the work to be soldered is free from grease or oil films and other oxides. The work should be wiped clean with a solvent such as trichoethane or isopropyl alcohol. The remaining oxides can be removed with a fine abrasive.

One more thing to consider is thermal linkage or the area of contact between the tip and the work. The contact or linkage area is very small, but it can be increased greatly by creating a solder bridge. This is done by applying a small amount of solder between the tip of the iron and the work piece. this will be explained to you in more detail during the lab session.

Just one more thing before we start our lab session. Because of the many factors involved, soldering may sound quite complex to you. Believe me, it really isn't. All it takes is a little practice and a few important points to remember. One general rule is, "get in and out as fast as you can". Usually this means one to two seconds dwell time on the joint to be soldered. Never try to "spread" the solder like butter. All you end up doing is overheating the work and getting a cold solder joint.

Remember, when you perform any kind of work, you become part of it. As you take action on the work piece, it reacts to what you do. By sensing the change, you can react and modify your actions to accomplish the final result. This will become apparent as we enter the lab sessions. I could talk or write forever about the fine art of soldering, but until you actually get a soldering iron in your hand, it is still all theory. LEARN BY DOING!!!!!!!

We are all going to make mistakes, but the important thing is that we learn from them. Well, enough talking for now; let's get to the fun portion of the course. If there are any questions, feel free to ask the instructor about them.

SOLDERING TERMINALS

There are many different types of terminals. Some of the most common are; turret, cup, bifurcated, and hook or pierced terminals. Before discussing them individually, there are a few important points to remember that are common to all soldered terminals.

When soldering wire to terminals, an insulation gap must exist. This is the space between the terminal and the insulation of the wire. This gap provides an inspection area to determine whether there is damage to the wire at the joint. It also provides an area to determine if wicking has taken place. The insulation gap should be no closer to the terminal than one wire diameter size [including insulation] and no further than two wire diameters. These dimensions are the same for all wire sizes. Before soldering wire to a terminal, the wire should always be tinned and formed. A pair of round-nosed pliers is used to form the wire. The actual wrap of the wire depends on the job specs. It may be one-half turn [180 degrees], or it may be as much as one full wrap [360 degrees]. The recommended wrap is three-fourths wrap [270 degrees]. This ensures against the wire moving while soldering and for its easy removal, if necessary. When one wire is used, it should be placed flat against the base of the terminal. In this way, any mechanical stress will be placed on the board, not the terminal. When two or more wires are used, they should come in from the same direction and wrapped in the same direction. They are placed so the insulation of the wires are in contact with each other. One should be on top of the other with a small space between the bare portions of the wire.

SOLDERING PROCEDURES

TURRET TERMINALS: The soldering iron is applied to the point of maximum thermal mass, usually near the midpoint of the wire wrap. A solder bridge is then made between the iron and the work to be soldered. Solder is applied opposite the solder bridge until it flows evenly around the terminal. The iron is then removed in a upper motion.

CUP TERMINALS: A cup type terminal is nothing more than a hollow cylinder. The lead is inserted and the soldered without any mechanical connection. The "trick" to soldering this type of terminal is using the right amount of solder. It shouldn't spill over the top and down the sides. The recommended procedure for determining the right amount of solder is a "solder preform". This is made by twisting a short piece of solder together. Insert it into the cup and cut it off flush with the top of the terminal. The soldering iron is then held against the side of the terminal until the solder melts.

The wire is then inserted fully into the cup, and the iron tip removed. Make sure the wire is stationary until the solder cools. When soldering cup terminals inside a connector, one has to be very careful. There may be so little space around the cups that heat from the iron may damage adjacent wires. In a case like this, a resistance soldering tool can be very useful. The tool has a pair of electrodes that grip the cup and allows current to flow through the cup. This creates enough heat for solder to melt. The tips can be positioned around the cup when they are cold so no damage is done to surrounding areas.

BIFURCATED TERMINALS: Wire may enter these terminals several different ways: from the top, bottom, or side. The most common, or side entry, is used when one or more wires are terminated. The wrap may be 90 or 180 degrees. The 180 degree wrap is usually used on small diameter wire. When the wire is entering from the top, it is usually bent into a double thickness, using the wire as a filler conductor. From the bottom, the wire is bent over 90 degrees where it emerges and trimmed so it doesn't extend beyond the diameter of the terminal. The side entry is usually the same as the bottom: a 90 degree angle, formed, then trimmed.The soldering procedure is as follows: apply iron to the point of maximum thermal mass; make a solder bridge to increase thermal linkage; apply solder to the opposite side of the terminal; as the solder begins to flow, remove iron in an upward motion. During soldering, the hole of the terminal is not filled to the bottom with solder, but it should be bridged over. Again, remember the insulation gap.

HOOKED AND PIERCED TERMINALS: Hook terminals are found on a variety of components, the most common being hermetically sealed relays. The wrap on these terminals should be at least 90 degrees. When there are two wires going to the terminal, they should enter from opposite sides. Wire ends should not extend beyond the entry point of the opposite wire. This allows insulation sleeving to cover the connection. The soldering procedure is the same as other terminals, with one exception. This type of connection uses the least amount of solder than the others. The solder should be removed just before the tip so you don't leave an excessive amount of solder on the terminal. The pierced terminal is very similar to the hook terminal. The only difference being the pierce has a hole instead of an open hook. Wire may enter either side or from the top of the terminal. The wrap is 90 degrees, and the solder procedure is the same. The hole does not have to be filled with solder, but there should be a good solder connection between the wire and the contact surfaces of the terminals.

DESOLDERING

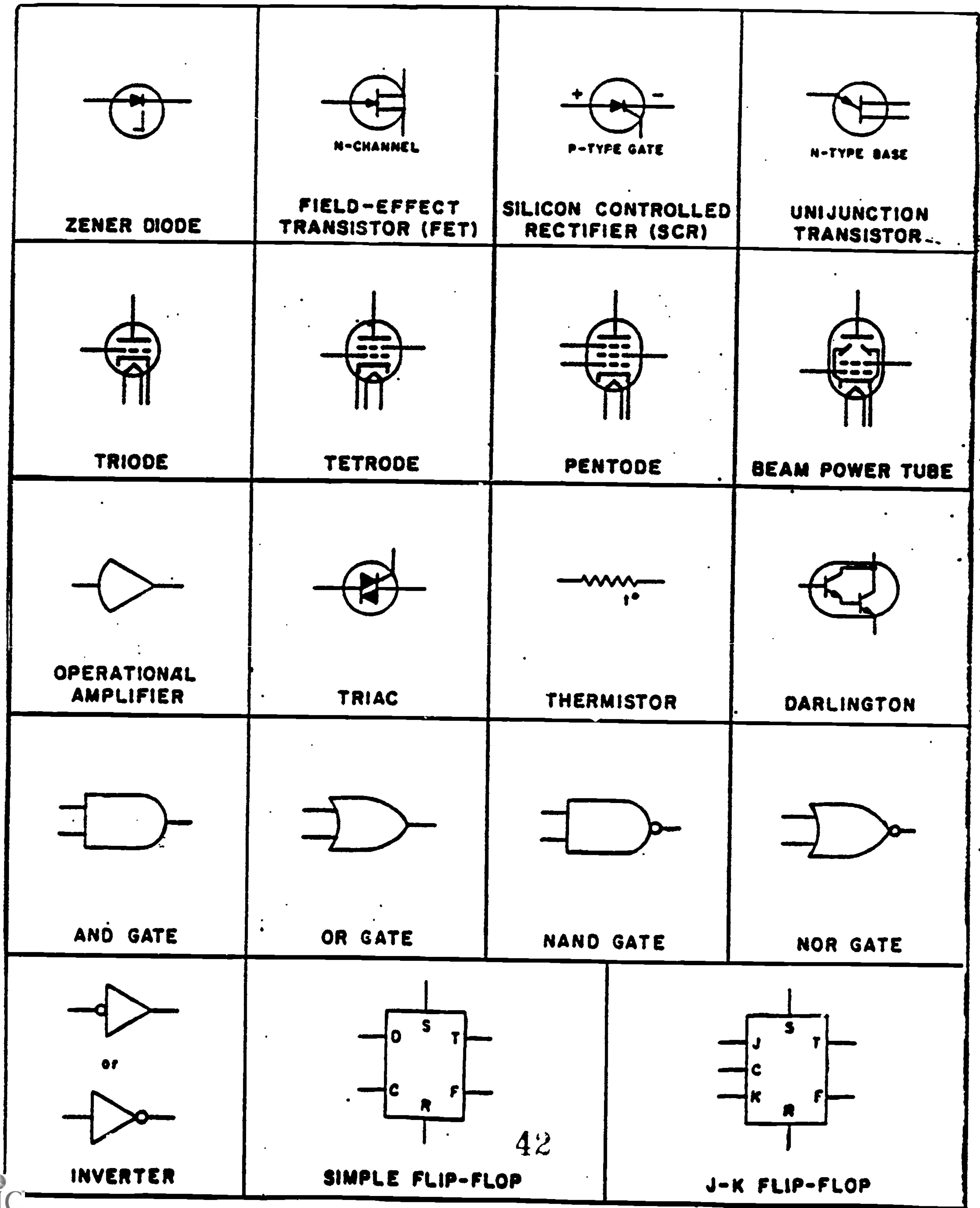
There are many desoldering aids on the market today. The two most common are "solder wick" and the "solder sucker". The solder wick is nothing more than braided copper that draws the solder from the component lead when it is heated sufficiently. It is placed between the work to be desoldered and the soldering iron tip.

The "solder sucker" works on the vacuum principle. As the solder is heated, a vacuum device is used to lift the solder away. There are many different types and makes on the market, from a hand-held squeeze bulb to an automatic desoldering station complete with its own vacuum pump and heated hollow tip. I could talk all day about the procedure for desoldering, but it would not mean a thing. You have to get the feel of doing it. This is one operation that practice REALLY makes perfect. You will know what I'm talking about when you try it!!!

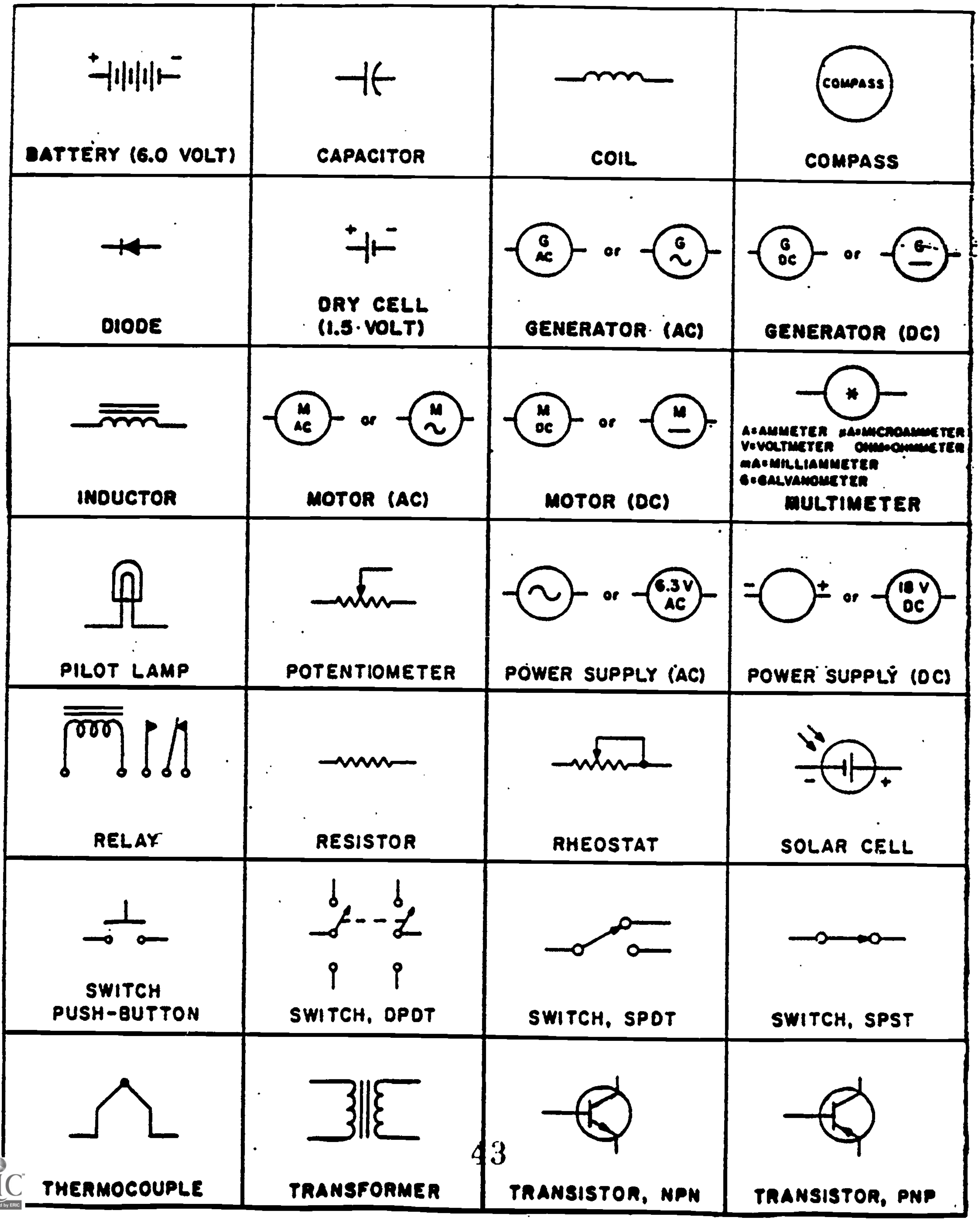
DEVELOPING ELECTRICAL/MECHANICAL APTITUDES

ELECTRONIC COMPONENTS and D.C. CIRCUITS

SCHEMATIC SYMBOLS

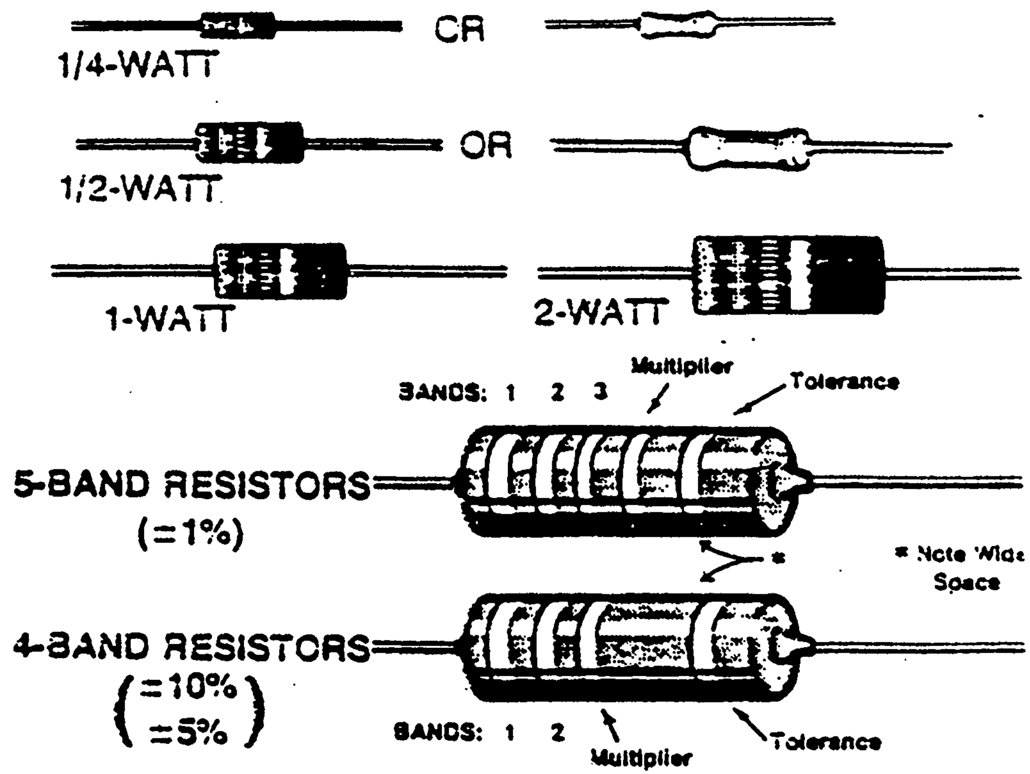


SCHEMATIC SYMBOLS



?...'S

Resistors are identified in Parts Lists and steps by their resistance value in Ω (ohms), kΩ (kilohms), or MΩ (megohms). They are usually identified by a color code and four or five color bands, where each color represents a number. These colors (except for the last band, which indicates a resistor's "tolerance") will be given in the steps in their proper order. Therefore, the following color code is given for information only. NOTE: Occasionally, a "precision" or "power" resistor may have the value stamped on it.



Band 1 1st Digit		Band 2 2nd Digit		Band 3 (if used) 3rd Digit		Multiplier		Resistance Tolerance	
Color	Digit	Color	Digit	Color	Digit	Color	Multiplier	Color	Tolerance
Black	0	Black	0	Black	0	Black	1	Silver	±10%
Brown	1	Brown	1	Brown	1	Brown	10	Gold	± 5%
Red	2	Red	2	Red	2	Red	100	Brown	± 1%
Orange	3	Orange	3	Orange	3	Orange	1,000		
Yellow	4	Yellow	4	Yellow	4	Yellow	10,000		
Green	5	Green	5	Green	5	Green	100,000		
Blue	6	Blue	6	Blue	6	Blue	1,000,000		
Violet	7	Violet	7	Violet	7	Silver	0.01		
Gray	8	Gray	8	Gray	8	Gold	0.1		
White	9	White	9	White	9				

Reading the Resistor Color Code

0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Gray
9	White

Tolerance

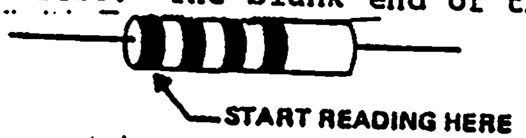
Gold	5%
Silver	10%
No band	20%

Fractional Multipliers

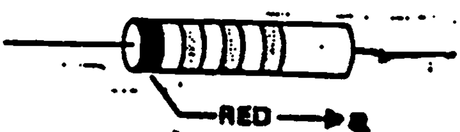
Gold	x	.1
Silver	x	.01

The resistor color code is a very important part of electronics. You must learn the code and how to apply it to a resistor. You will experience little difficulty with the code if you follow these steps:

. Turn the resistor so that the band closest to the end of the resistor body is to your left. The blank end of the resistor body is to your right.

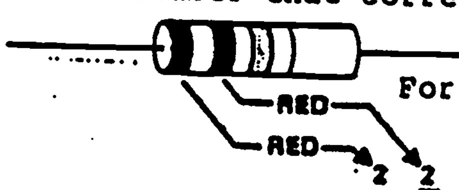


The first band indicates a number. Look up the number on the color code chart that corresponds to the color of the band and write it down.



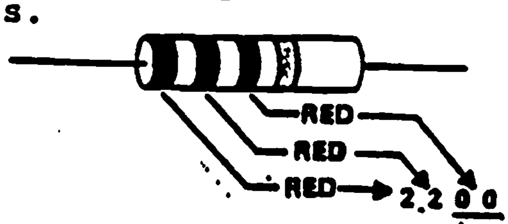
For example: If the first band is red, the first digit is 2.

The second band also indicates a number. Go to the chart again and write down the number that corresponds with the color of the second band.



For example: If the second band is red, 2 is the number.

The third band of the resistor is the multiplier band. This simply tells you how many zeros to write after the first two digits. If, as in this case, the band is also red, you should write two zeros after the first two digits.



The third band is silver or gold, a "fractional multiplier" is indicated. A gold band indicates that the first two digits of the resistor's value should be multiplied by .1. A silver band tells you to multiply the first two digits by .01. Remember, these fractional multipliers are to be used only when the third band is gold or silver.

The fourth band is called the "tolerance" band. This band indicates the range of values the resistor may have and still be considered "good". If this resistor has a silver tolerance band, according to the chart this means that the resistor's value is supposed to be within plus or minus 10% of its indicated value. The indicated value of the resistor is 2200 ohms. In order to find what 10% of 2200 is, you must multiply 2200 by .1 (you get point one by moving the decimal point two places to the left like this....10% = .10 (You may remember how to do this by remembering that the two zeros in the percent sign stand for the two places you must shift when converting from a percentage to a decimal fraction.) Now, to find the actual ohmic value of 10%, you multiply 2200 by .1

```
 2200
 x .1
 ----
220.0
```

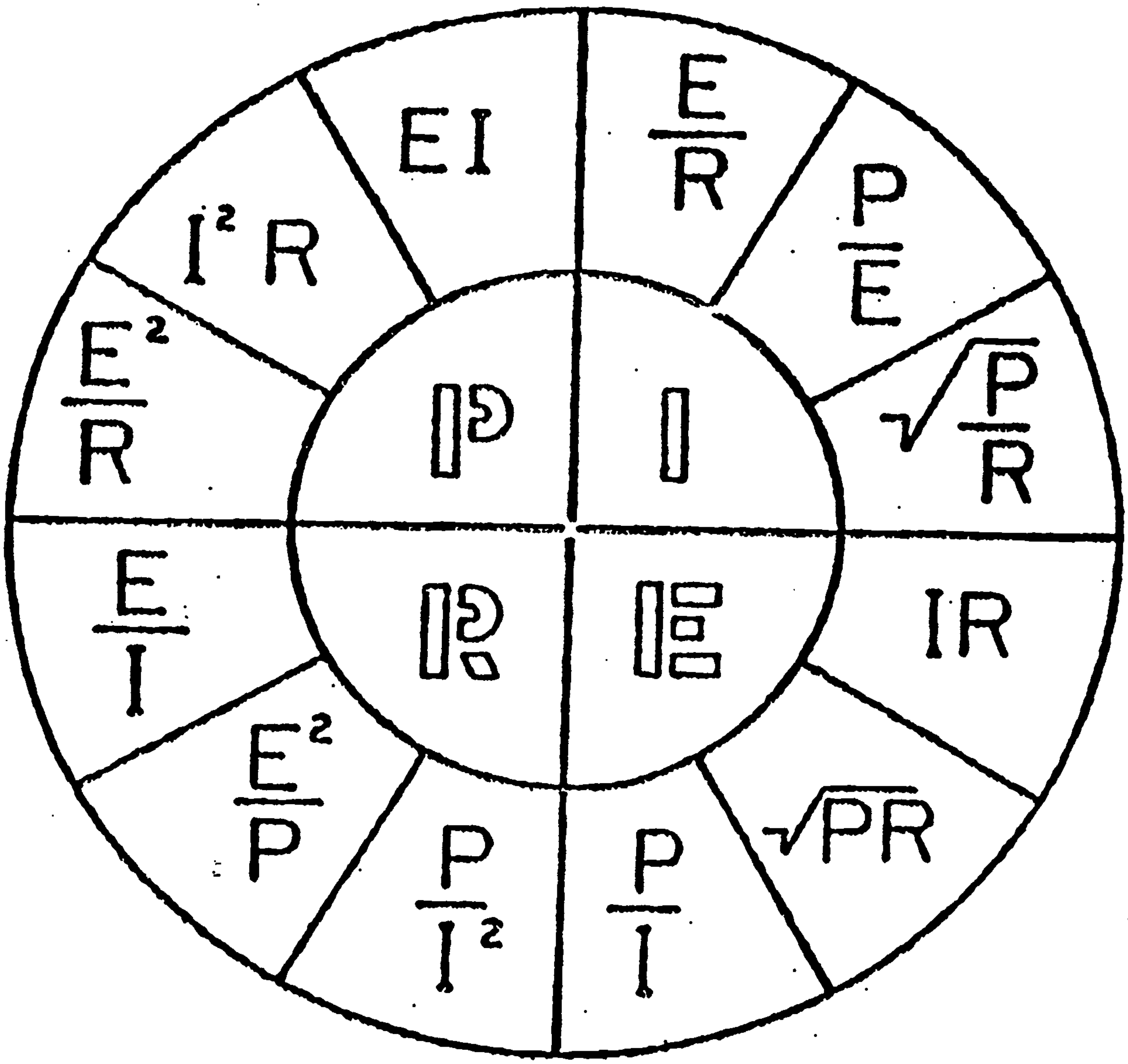
Since there is only one decimal place in the numbers to be multiplied, the decimal point in the answer is shifted one place, giving you 220 ohms.

To find the actual ohmic range of the resistor, you must add 220 ohms to 2200 ohms, and subtract 220 ohms from 2200 ohms.

```
  2200 ohms                 2200 ohms
+ 220 ohms                 - 220 ohms
----------                 ----------
  2420 ohms                 1980 ohms
```

This 2200 ohm resistor is within tolerance if its value is between 1980 and 2420 ohms.

HANDOUT
OHM'S/WATTS LAW WHEEL



Lab/Worksheet

HANDOUT
OHM'S/WATTS LAW AND ENERGY

INTRODUCTION

VOLTAGE is the electrical pressure developed by the source or the potential difference developed across a load.

CURRENT is the flow of electrons through an electrical circuit, according to electron theory.

RESISTANCE is the electrical opposition to current flow.

POWER is the energy dissipated in an electrical/electronic circuit or by a component.

Using the Ohm's/Watts Law Wheel as reference, determine the unknowns asked for. Do your work on scratch paper and keep it with the lab assignment.

1. E = 100 V, I = 2 amps., R = ____________

P = ____________

2. E = 50 V, R = 1 K ohms, I = ____________

P = ____________

3. I = .5 amps., R = 50 ohms, E = ____________

P = ____________

4. P = 10 W, I = 2 amps., E = ____________

R = ____________

5. E = 100 V, I = .5 amps., P = ____________

R = ____________

6. P = 500 W, E = 250 V, I = ____________

R = ____________

7. P = 100W, I = 2 amps., R = ____________

E = ____________

8. E = 10 V, P = 10 W, R = ____________

I = ____________

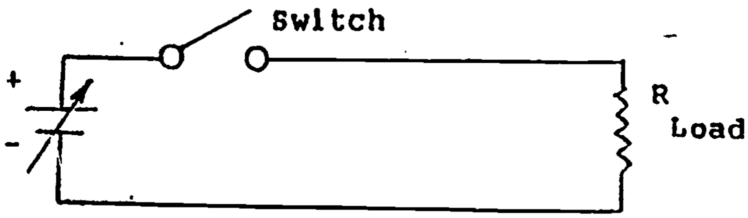


Figure 5-1: Experimental circuit to verify Ohm's/Watts Law.

Zero the ohmmeter and connect it across the load resistor as indicated in Figure 5-2.

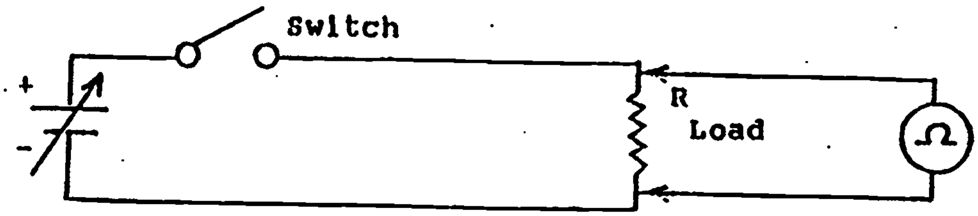


Figure 5-2: Resistance measurement connection.

Connect the voltmeter across the load resistor as indicated in Figure 5-3. NOTE: Set the voltmeter to a range that can handle the amount of voltage that will be applied to the circuit.

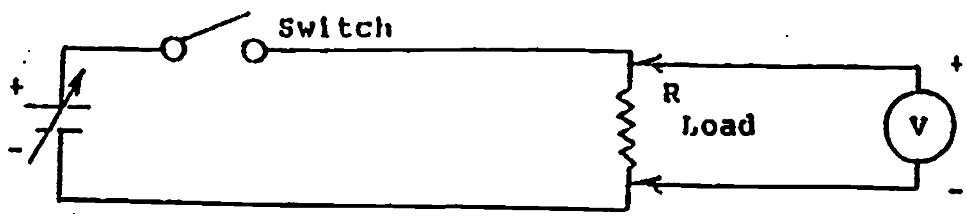


Figure 5-3: Voltage measurement connection.

With the voltage supply still set, open the switch and connect the ammeter as indicated in Figure 5-4 to measure the current through the load resistor. Make sure the ammeter is set on a high enough range to measure the DC current.

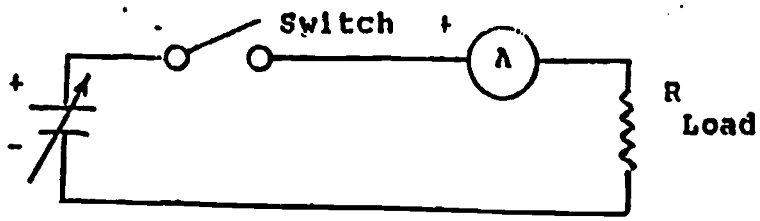


Figure 5-4: Current measurement connection.

ACTIVITY 4-2
A LAB EXPERIMENT: LAMP SWITCHING CIRCUIT

Purpose

The following activity will provide experience in using switches and fuses. It also provides experience in building circuits from diagrams.

Materials

- [1] 6-V dry battery or power supply
- [1] no. 47 lamp
- [1] 0.5-A fuse, 32 V (or greater)
- [1] VOM
- [1] lamp holder for no. 47 lamp
- [2] SPDT toggle switches (1-A, 125-V ac rating)
- [1] fuse holder

Procedure

1. Using an ohmmeter, check for continuity between the center terminal and the outside terminals of one of the toggle switches. Change the switch to its other position and again check for continuity. Now check for continuity between the two outside terminals with the switch in one position and then the other. Which terminal of the switch is the pole?
2. Construct the circuit shown in Fig. 4-1.
   a. Throw S_1 back and forth while observing the lamp. Does the lamp turn off and on?
   b. Throw S_2 back and forth. Does the lamp turn off and on?
   c. Can S_1 control the lamp with S_2 in either position?
3. While the lamp is on, remove F_1 from its holder. Removal of the fuse gives the same effect as a blown fuse. Now measure the voltage across the terminals of the fuse holder. Reinsert F_1 and again measure the voltage across its terminals. Can a voltmeter be used to indicate the condition of a fuse in a circuit? How?
4. Turn the lamp off with S_2. Now measure the voltage between the center terminal and the outside terminals of S_2. Next measure the voltage between the center terminal and the outside terminal of S_1. Can a voltmeter indicate whether a switch is open?

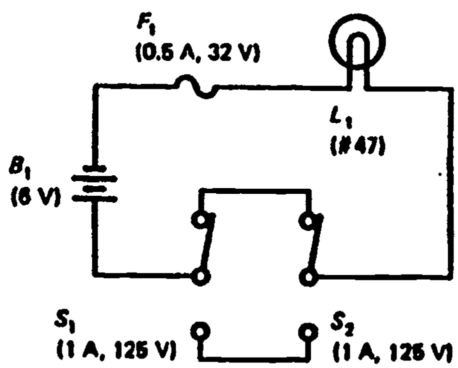
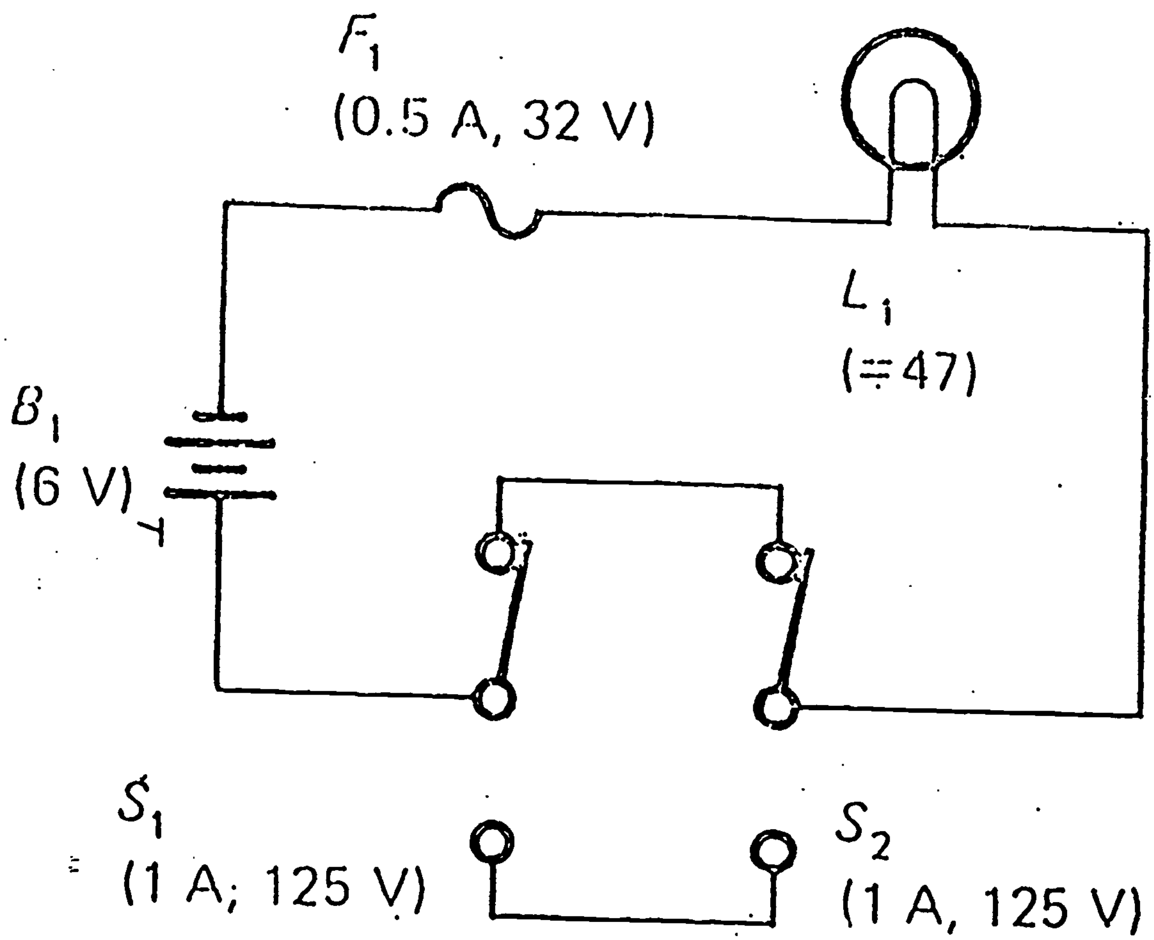


Figure 4-1. Lamp switching circuit.


F_1
(0.5 A, 32 V)
L_1
(≑47)
B_1
(6 V)
S_1
(1 A; 125 V)
S_2
(1 A, 125 V)

DEVELOPING ELECTRICAL/MECHANICAL APTITUDES

INTRODUCTION to ALTERNATING CURRENT AND VOLTAGE

A.C. GLOSSARY

Alternating current (ac) Current that reverses direction in response to a change in source vo age polarity.

Average value The average of a sine wave over one half-cycle. It is 0.637 times the peak valu

Baseline The normal level of a pulse waveform. The voltage level in the absence of a pulse.

CRT Cathode-ray tube.

Cycle One repetition of a periodic waveform.

Degree The unit of angular measure corresponding to 1/360 of a complete revolution.

Duty cycle A characteristic of a pulse waveform that indicates the percentage of time that pulse is present during a cycle. The ratio of pulse width to period.

Effective value A measure of the heating effect of a sine wave. Also known as the rms (ro mean square) value.

Falling edge The negative-going transition of a pulse.

Fall time The time interval required for a pulse to change from 90% to 10% of its full amp tude.

Frequency A measure of the rate of change of a periodic function. The number of cycl completed in 1 s. The unit of frequency is the hertz.

Generator An energy source that produces electrical signals.

Harmonics The frequencies contained in a composite waveform, which are integer multiples the repetition frequency (fundamental).

Hertz (Hz) The unit of frequency. One hertz equals one cycle per second.

Hypotenuse The longest side of a right triangle.

Input The voltage, current, or power applied to an electrical circuit to produce a desired resul

Instantaneous value The voltage or current value of a waveform at a given instant in time.

Lag A condition of the phase or time relationship of waveforms in which one waveform behind the other in phase or time.

Lead A condition of the phase or time relationship of waveforms in which one waveform i ahead of the other in phase or time. Also, a wire or cable connection to a device o instrument.

Leading edge The first step or transition of a pulse.

Magnitude The value of a quantity, such as the number of volts of voltage or the number o amperes of current.

Oscillator An electronic circuit that produces a time-varying signal without an external inpu signal using positive feedback.

Oscilloscope A measurement instrument that displays signal waveforms on a screen.

Peak value The voltage or current value of a waveform at its maximum positive or negative points.

Peak-to-peak value The voltage or current value of a waveform measured from its minimum to its maximum points.

Period The time interval of one complete cycle of a periodic waveform.

Periodic Characterized by a repetition at fixed time intervals.

Phase The relative displacement of a time-varying waveform in terms of its occurrence with respect to a reference.

Phasor A representation of a sine wave in terms of both magnitude and phase angle.

Pulse A type of waveform that consists of two equal and opposite steps in voltage or current separated by a time interval.

Pulse width The time interval between the opposite steps of an ideal pulse. For a nonideal pulse, the time between the 50% points on the leading and trailing edges.

Radian A unit of angular measurement. There are 2π rads in one complete revolution. One radian equals 57.3°.

Ramp A type of waveform characterized by a linear increase or decrease in voltage or current.

Right angle A 90° angle.

Rise time The time interval required for a pulse to change from 10% to 90% of its amplitude.

Rising edge The positive-going transition of a pulse.

Root mean square (rms) The value of a sine wave that indicates its heating effect, also known as the effective value. It is equal to 0.707 times the peak value.

Sawtooth A type of electrical waveform composed of ramps. A special case of a triangular wave.

Trailing edge The second step or transition of a pulse.

Triangular wave A type of electrical waveform that consists of two ramps.

Trigger The activating unit of some electronic devices or instruments.

Waveform The pattern of variations of a voltage or current showing how the quantity changes with time.

A.C. FORMULAS

$V_{rms} \cong 0.707V_p$ Root-mean-square voltage (sine wave)

$I_{rms} \cong 0.707I_p$ Root-mean-square current (sine wave)

$V_p \cong 1.414V_{rms}$ Peak voltage (sine wave)

$I_p \cong 1.414I_{rms}$ Peak current (sine wave)

$V_{pp} = 2.828V_{rms}$ Peak-to-peak voltage (sine wave)

$I_{pp} = 2.828I_{rms}$ Peak-to-peak current (sine wave)

$V_{avg} \cong 0.637V_p$ Average voltage (sine wave)

$I_{avg} \cong 0.637I_p$ Average current (sine wave)

$f = \text{number of pole pairs} \times (\text{rev/s})$ Frequency

$$\text{rad} = \left(\frac{\pi \text{ rad}}{180°}\right) \times \text{degrees}$$

$$\text{degrees} = \left(\frac{180°}{\pi \text{ rad}}\right) \times \text{rad}$$

$y = A \sin \theta$ General equation for a sine wave

$y = A \sin(\theta - \phi)$ Lagging sine wave

$y = A \sin(\theta + \phi)$ Leading sine wave

$$\text{Percent duty cycle} = \left(\frac{t_w}{T}\right)100\%$$

$V_{avg} = \text{baseline} + (\text{duty cycle})(\text{amplitude})$ Average value of pulse waveform

$f = \dfrac{1}{T}$ Frequency

$T = \dfrac{1}{f}$ Period

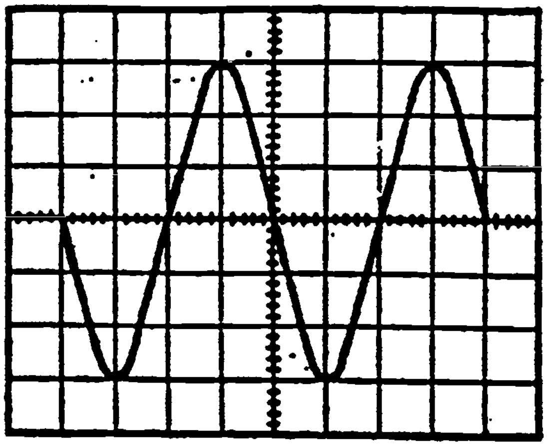
$V_{pp} = 2V_p$ Peak-to-peak voltage (sine wave)

$I_{pp} = 2I_p$ Peak-to-peak current (sine wave)

WAVEFORM ANALYSIS WORKSHEET

Given the following waveform display, analyze the sine wave for the unknowns asked for using the given information as reference.

V/Div = 5.0 T/Div = 20 ms/Div



Solve for the following: Voltage Peak = ____________________

Voltage Peak-to-Peak = ____________________

Voltage RMS = ____________________

Period in seconds = ____________________

Frequency in Hertz = ____________________

Using the waveform displayed in Question 1 as reference, determine the following: V/Div and T/Div, if the frequency of the display is 250 KHz and the RMS voltage is 21.21 volts.

V/Div = ____________________

T/Div = ____________________

Given the following information for a sine wave solve for the unknown asked for.

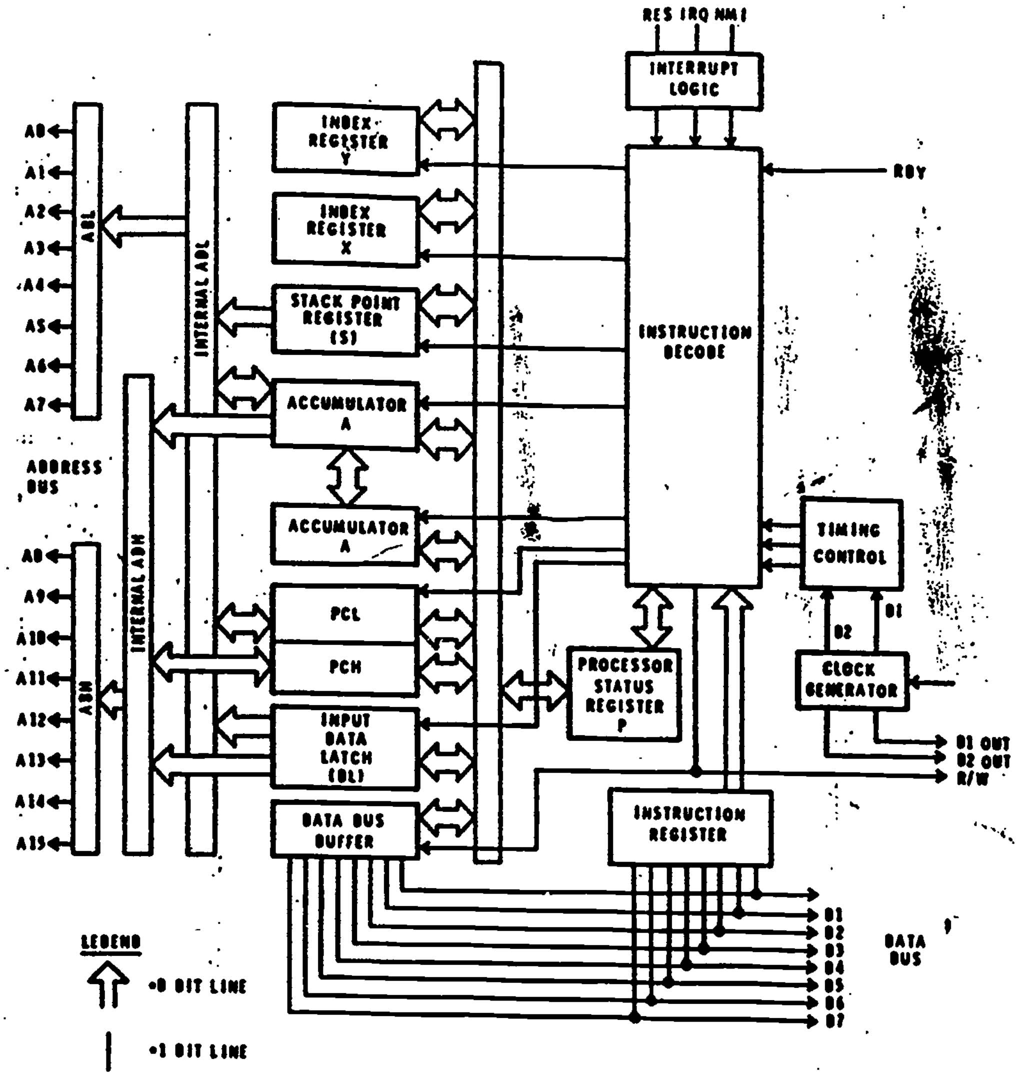
A. If T = 0.015 seconds then Frequency = ____________________

B. If F = 30 Hz then Time = ____________________

C. If Peak Voltage = 150 V then RMS Voltage = ____________________

D. If RMS Voltage = 115 V then Peak-to-Peak Voltage = ____________________

DEVELOPING ELECTRICAL/MECHANICAL APTITUDES



INTRODUCTION to DIGITAL ELECTRONICS

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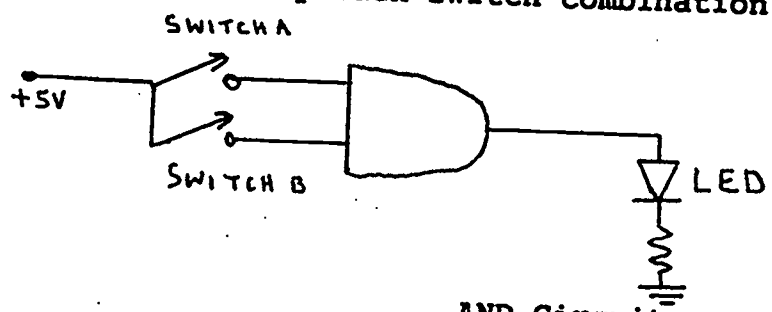
Lab Exercise 2

Using Logic Gates to Implement Digital Decision Making.

Set up the circuit below. This is a simple AND gate. Fill in the truth table as you try each switch combination.

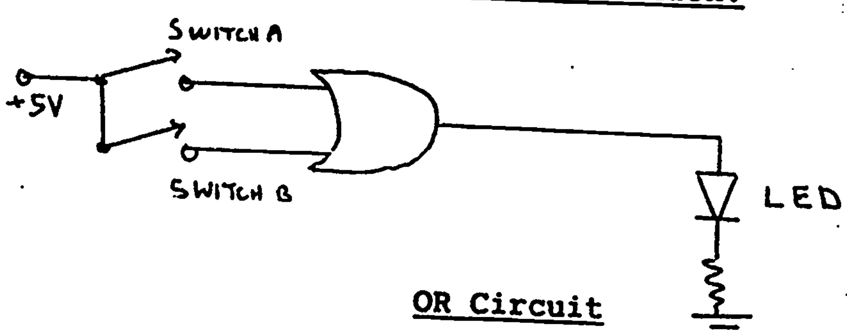


AND Circuit

Truth Table for an AND Circuit

Switch A	Switch B	L.E.D.

Set up the circuit below. This is a simple OR gate. Fill in the truth table as you try each switch combination.



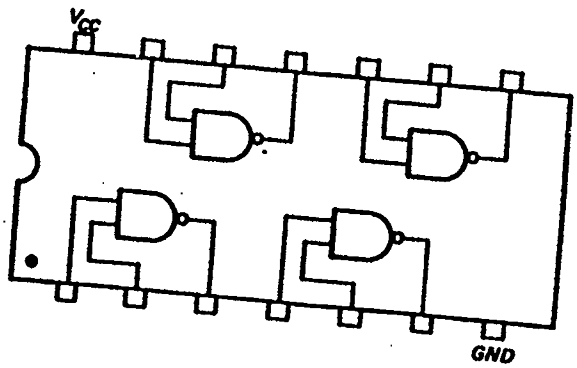
OR Circuit

Truth Table for an OR Circuit

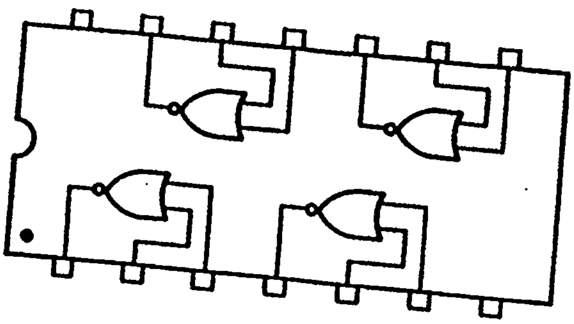
Switch A	Switch B	L.E.D.

Appendix A: Pin Configurations

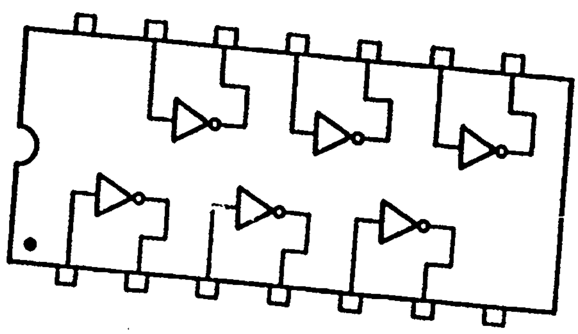
The following appendix supplies the pin configurations for the popular 7400 series and MC1400 series integrated circuit (IC) chips. Other families are equally adaptable to all experiments in the manual. The requirement in all cases is to familiarize yourself with the pin layouts of the chips you are using, as well as all the specifications concerning your particular IC family. Pin 14 or 16, depending on the IC size, is connected to V_{CC}, and pin 7 or 8 is connected to ground, except where noted (see 7400 as an example).



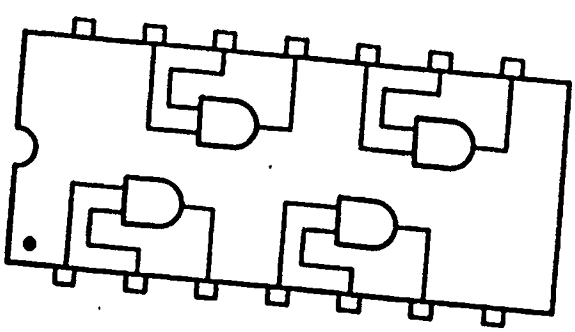
7400/74C00
Quad two-input NAND



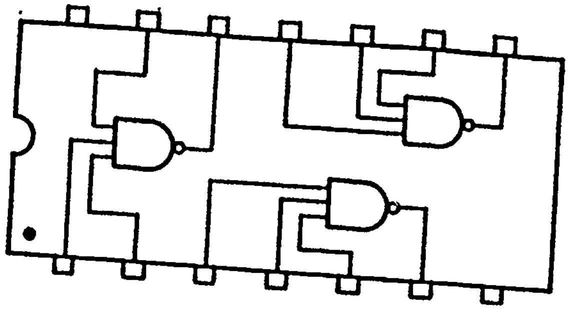
7402/74C02
Quad two-input NOR



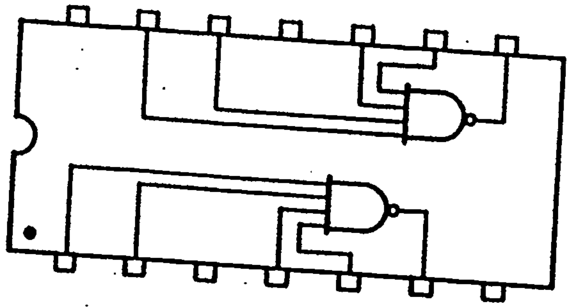
7404/74C04/MC14069
Hex inverter



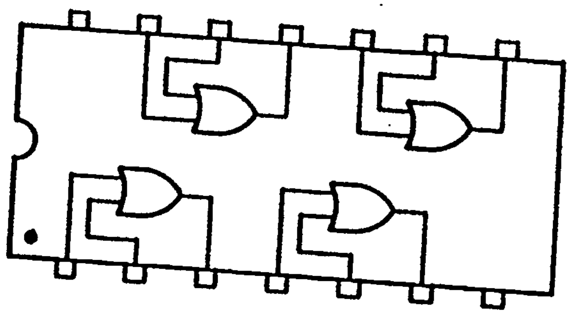
7408/74C08
Quad two-input AND



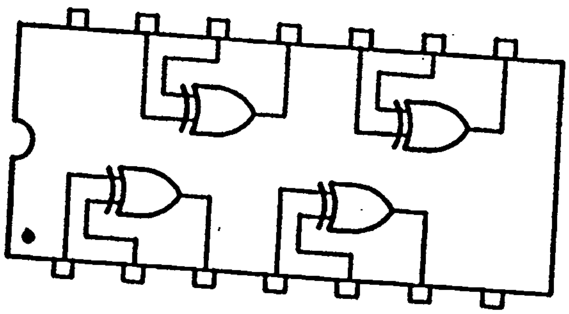
7410/74C10
Three-input NAND



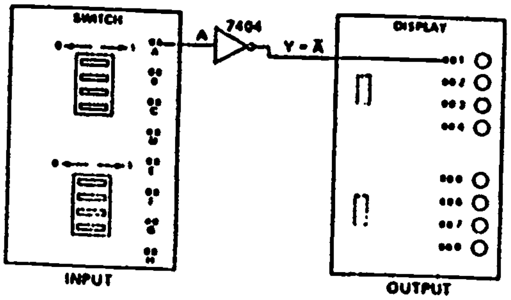
7420/74C20
Four-input NAND



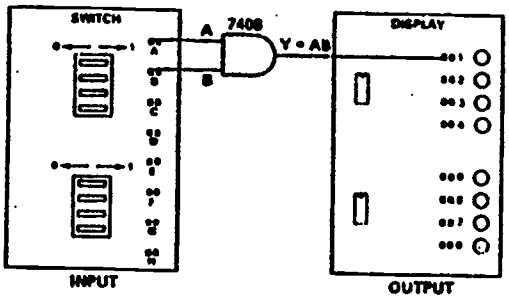
7432/74C32
Two-input OR



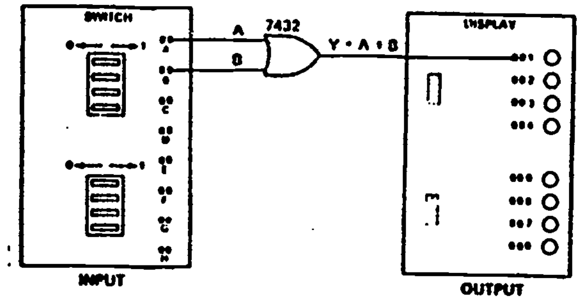
7486 (TTL)
Two-input EXCLUSIVE-OR



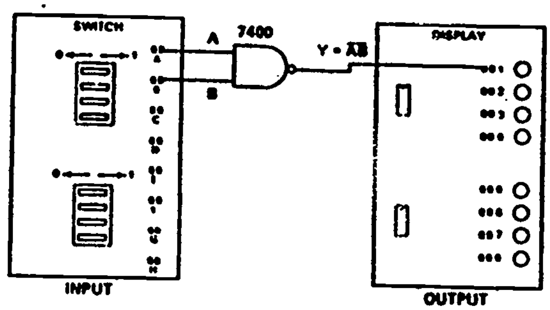
INPUT	OUTPUT
A	Y
0	
1	



INPUTS		OUTPUT
A	B	Y=AB
0	0	
0	1	
1	0	
1	1	



INPUTS		OUTPUT
A	B	Y=A+B
0	0	
0	1	
1	0	
1	1	



INPUTS		OUTPUT
A	B	$Y=\overline{AB}$
0	0	
0	1	
1	0	
1	1	