NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

VARIABLE DC POWER SUPPLY

Graduation Project
EE-400

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ABSTRACT

In our world electronic is developing and entering people life, so we can say that without electronic devices people life can be a nightmare. We can say these words because of electronic is always increasin people life Standard and prove lots of easiness

At the same time in practical circuits and circuit designs, power supply is the important device.

In this Project 0-15 V dc variable power supply design is target. In practical this device is designed and formed at the same time. The necessary tests are formed and this device is working excellent.

Because of this the theorical information is used and developed practical ability.

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INTRODUCTION

Virtually every piece of electronic equipment, e.g., computers and their peripherals, calculators, TV and hi-fi equipment,and instruments, is powered from a DC power source,be it a battery or a DC power supply. Most of this equipment requires not only DC voltage but voltage that is also well filtered and regulated. Since power supplies are so widely used in electronic equipment, these devices now comprise a worldwide segment of the electronics market in excess of $5 billion annually. There are three types of electronic power conversion devices in use today which are classified as follows according to their input and output :

1) the AC/DC power supply; 2) DC/DC converter; 3) the DC/AC inverter. Each has its own area of use but this paper will only deal with the first , which are the most commonly used. A power supply converting AC line voltage to DC power must perform the following functions at high efficiency and at low cost:

1. Rectification: Convert the incoming AC line voltage to DC voltage.
2. Voltage transformation: Supply the correct DC voltage level(s).
3. Filtering: Smooth the ripple of the rectified voltage.
4. Regulation: Control the output voltage level to a constant value irrespective of line, load and temperature changes.

5. Isolation: Separate electrically the output from the input voltage source.
6. Protection: Prevent damaging voltage surges from reaching the output; provide back-up power or shut down during a brown-out.

An *ideal power supply would be characterized by supplying* a *smooth output voltage regardless of variations in line voltage,* load current or ambient temperature at 100% conversion efficiency. compares a real power supply to this ideal one and further illustrates some power supply terms.

1. An Overview – Making It in Electronics

1.1 ELECTRONICS DESIGN AND FABRICATION IN THE SCHOOL LABORATORY

1.1.1 The Need for an Electronics Design and Fabrication Experience

In order to appreciate why, as future electronics technicians, need to have an electronics design and fabrication background, let's see how the familiar "learning by doing" concept fits nicely into the activities that lie ahead and examine the possibility of a new career path, that of fabrication technologist.

What Electronics Technicians Actually Do

Electronics technicians build, repair, test, modify, and install electronic devices and equipment. That is electronic fabrication. They are hands-on group. If electronic theory is overriding interest, perhaps should strive to be an engineer rather than a technician. A soldering iron, rather than a hand calculator, will be primary tool.

Fabrication technologist: A new Career Path?

Ordinarily, the electronics technician is expected to do it all: installation, maintenance, testing, trouble shooting, repair, and prototyping. Whether in medical, communications, industrial, computer, military, or consumer electronics, the technician deals with all aspects of the equipment, except perhaps its initial design. This is particularly true, for instance, with regard to troubleshooting and repair, two areas that are often seen as merging into one. Until recently, if finding the problem repair was just a simple follow up: grab some solder, a soldering iron , a couple of additional hand tools, and the repair was quick and easy. With just a little training almost anyone could do it!
Increasingly , this is no longer the case. In many situations, prototyping and repair have become so complex, sophisticated, and demanding of special skills that the typical generalist electronics technician cannot be expected to do them well, if at all. Rising to meet the challenge , fortunately, is the fabrication technologist, a skilled technician specializing in the prototyping, rework, and repair of electronic devices.

It is true in most cases, especially in small and medium-sized firms, that an electronics technician is still required to handle routine repairs and do an occasional prototype. But today's rapid trend toward microminiaturized components and multilayered circuit boards has created a host of specialized problems in repair, rework, and prototyping. The fabrication technologist is emerging to deal with this new reality.

Rework involves re-establishing a device's functional and physical characteristics without deviating from the original manufacturer's specifications.

Repair means re-establishing the functionality, quality, and reliability of an assembly that has failed or has been damaged. It may require deviations from the original manufacturer's specifications, however.

Prototyping, of course, involves the creation of a hand-assembled Project that will resemble as thoroughly as possible the final, mass-produced equipment.

While the skills necessary to produce a quality prototype differ somewhat from those required for circuit repair and rework, there is except, considerable commonality among the three areas. Circuit board fabrication, component assembly, sheet metal cutting and bending, the application of external finishes and rubon lettering-all these techniques are necessary for Project repair, rework, and prototyping.

1.2 THE ELECTRONIC DESIGN AND FABRICATION PROCESS

1.2.1 From thought to finished prototype: A five stage process

The five stages required to design and fabricate a working prototype Project: design; drawing; experimenting; prototyping; and testing, troubleshooting, and final documentation. What follows is a brief look at each stage, defining what the stage is and explaining why it is needed.

Design stage. The Project design is usually, but not always, done by the electronics engineer. The technician, however, is often intimately involved. At the very least, the technician is expected to spot errors and inconsistencies in design, particularly when they concern product packaging, testing, installation and maintenance.

At this stage, a two-step design process takes place. It involves producing a Concepts and Requirements Document and a set of three design drawings. One of these drawings, the circuit design sketch, is often difficult to read and incomplete in this beginning stage, especially with regard to component identification. This sketch must be finished and cleaned up, at a later time, before any serious work on the Project can begin.

Drawing stage. A group of ten drawings is required to explain graphically how the Project will be build. A working schematic, breadboard drawing, printed circuit board design layout and artwork, and fabrication and assembly drawings must be produced. Further more, a sheet metal layout, wiring diagram, and packaging illustration will be necessary. Although all of these drawings are eventually completed and become part of the Project Report, only the design drawing set and working schematic drawing will actually be done before proceeding to the experimenting stage.

Experimenting stage. This stage often referred to as the breadbroading stage, is essential in proving out the design; that is, to see if the circuit actually Works. Various quick and easy circuit assembly methods, the most popular of which involves the use of engineering solder less circuit board, have been developed specifically for use in the experimenting stage. With solder less circuit board, circuits can be assembled and altered in very little time, in many cases, without requiring any soldering at all. More permanent methods of circuit assembly involving cut-slash-and-hook, wire wrapping, and etchless printed circuit board are also extensively used. A breadboard drawing and experiment Results document are produced at this time.

Prototyping Stage. It is here that a permanent, working Project is actually built. Prototype devices are almost always made with printed circuit boards: circuits in which the interconnecting wires have been replaced by conductive strips etched onto an insulating board. The design and manufacture of printed circuit boards are a major part of the entire fabrication process. All of the remaining drawings are completed at this stage.

Testing, Troubleshooting, and Final documentation stage. Once the prototype is completed, it must be tested. Does it meet the design requirements? Does it work under adverse environmental conditions? Often extensive laboratory and field testing is needed to determine the answers. If the device does not work correctly, naturally it must be fixed. Troubleshooting becomes a very necessary part of this stage. The test Results and Summary and Recommendations Documents are now produced. Finally, all the documentation must come together. The Project Report, with its written and graphics documentation is assembled at this time.

These, then, are the five stages required to produce a working prototype Project and Project Report. Of course, there is, strictly speaking a sixth stage. It is the production stage, in which the Project is mass-produced. Because assemblers, rather than technicians, are usually involved here.

1.3 TOOLS OF THE TRADE: ON BOARD

The tools needed to design and fabricate an electronic Project fall into two broad categories: those used on the drawing board and those needed on the workbench. Tools for the drawing board re required to make schematic, wiring, sheet metal, and assembly drawings, along with printed circuit board design layouts and artwork. Tools used on the bench are essential for mechanical and electronic assembly.

The two environments, the board and the bench, should be kept as separate as possible. The general mess associated with the hand and power tools required to build a Project has no place in the drafting area, where the Project is designed and working drawings are made.

In this section we list each drafting tool needed and explain what it does. Discussion of their use, however, comes later, in chapters where the applicable drawing procedure is described.

1.3.1 The drafting Table

There are two types of drawing tables: the permanent table mounted on "all fours" and the portable drawing table, one that literally can go anywhere.

Sturdy and Smooth

When it comes to a "stay-in-one-place" drafting table, four legs are usually better than two. Simply put, such tables are more stable, less likely to wobble while trying to draw a straight line. A smooth surface to draw on is a must. This surface is ordinarily obtained in one of two ways: either by coating the table with a roll of Borco, a vinyl-like material especially formulated to provide a smooth drawing surface, or by using a drawing board. A drawing board is made of seasoned, straight-grained soft woods and is designed to be used with a T-square and triangles.

Although some drafters prefer to stand at their tables, most usually sit. Above all, the chair you choose should be comfortable. Chairs with an adjustable seat height and back support-the ideal choice-are available from many commercial sources.

Lighting should be chosen with great care. The key factor here is to provide direct, as well as indirect, illumination. Drafting lamps with articulated support arms are available. They can accommodate a 100-watt bulb, have an adjustable arm, and include a clamp so that they can be mounted on the edge of the drawing table.

Portable Drafting Tables

Various portable drafting tables are available that make drawing convenient and inexpensive for the part-time or on-the-go drafter. Many of these units consist of far more than a drafting table. A number of them contain a small drafting machine: an instrument that allows to quickly draw straight lines at designated lngts and angles. For the student primarily interested in electronics fabrication, the economy of the portable drafting table would be its main attraction. But before make a decision, read on. An even more preferable solution, the mini-drafting machine, may be answering.

1.3.2 Drafting Equipment

Here, both new and traditional drafting equipment are discussed, as well as printed circuit board design and artwork materials.

Equipment for Drawing Straight Lines

The Standard drafting machine is large and expensive, and its cost is rarely justified for the part-time electronics drafter. A much better way to go is to buy a traditional package of drafting tools consisting of a T-square, two triangles, protractor, scale, and drawing board-all that is necessary to draw straight lines at any particular length or angle.

However combine all of these features in a fascinating product known as a minidrafting machine that sells for less than 12 dollars. These machines, one of which is illustrated are made of durable plastic and contain two pairs of knurled rollers that contact the paper surface. No special table or paper is required. With just a few minutes practice, will be making pencilled or inked lines just like a Professional.

Pencils. Because they allow for the interchanging of leads, mechanical refill pencils are preferred over wood pencils. The lead itself comes in variety of grades: from very hard, which will draw a light line to extremely soft, which lay a dark line on the paper. Selected a 4H for drawing dimension and hidden lines; use a 2H or H for object lines.

Paper. For the ten-drawing set will be producing, graph paper with a 0.100 inch*0.100 inch cross-sectional grid is required. It is available in 8.5 inch*11 inch sheets of vellum or layout bond paper. The grid should be printed in nonreproducible blue. This means that the grid pattern will not reproduce when the drawing is copied.

Compass and Circle Guides. Compass and circle guides are used to draw circles and arcs. For the circles greater than 1.5 inches in diameter, the compass should be used. For small circles, rounds, or fillets the circle guide is ideal.

Drafting Templates. Templates save time and effort. One to aid in making schematic symbols, the other for creating printed circuit board design layouts. The latter should be chosen in the full, or 1 * scale.

Scale. Avoid the ones available at the local drugstore; quality is of the utmost importance here. A mechanical engineer's scale, graduated in 0.02 inch, is required. It doesn't really matter if it's triangular or flat, as long as it of good quality.

Printed Circuit Board Design Layout and Tape-up Equipment

In additional to the printed circuit layout template, to need colored pencils, an X-acto knife, acetate sheets, tape-up materials and possibly a light table

Colored Pencils. A set of colored pencils come in handy when producing the printed circuit board design layout. A half dozen different colors are all that is required.

X-Acto Knife. An X-acto knife holder accepts a variety of blade shapes. Because the blade will be used to cut layout tape or position stick on pads. Blades should be changed frequently, so purchase a package with at least five blades.

Acetate Sheets. These thin, clear, plastic like sheets as a bas a for printed circuit artwork. They are available in individual or packaged sheets and in an assortment of sizes.

Artwork Materials. Materials for artwork consist of the component mounting configurations and the rolls of opaque tape will be using to tape up printed circuit design layout.

Light Table. A light table is useful, but certainly not required. Printed circuit tape-up is easier when light shines up through the design layout, drawn on graph paper, through to the acetate sheet placed on top of it. A light table gives this advantage. If use one, be sure that the work surface is flooded with completely diffused, shadow-free light.

1.4 TOOLS OF THE TRADE: ON THE BENCH

1.4.1 The Bench: More Than the Kitchen Table

As with tools for the drawing board, tools for the workbench must be chosen for their quality. As a working technician be judged by the tools

Location and structure

Ideally, the workbench should be located in an area that will provide a minimum of distractions. Such a location will increase the likelihood that the bench will used only for its intended purpose, electronics fabrication.

The workbench area should remain relatively clean. The dirt and mess associated with normal mechanical assembly is incompatible with modern electronics fabrication. Electronic assembly is considered a "light industry" light clean.

In term of structure, the workbench must provide comfort to lessen fatigue. It should have a solid, non-metallic surface and be of such height that can rest elbows comfortably on the surface.

Adequate storage must also be provided. Shelves should be placed immediately in front of the work area to house test equipment. For storing electronic components and small hardware items modular plastic drawer are ideal. An alternate approach is to arrange a baker' dozen of boxes or drawers. Twelve of the boxes would contain the dozen basic electronic components used in electronics: resistors, capacitors, transistors and the like. The thirteenth box would be labelled "miscellaneous." Nothing should remain in this particular junk box too long.

1.4.2 Tools for the Workbench

Now it's time to take a look at the tools that go on the workbench. The discussion divides them into two broad categories: Those used for mechanical work and those required for electrical work. However, keep in mind that the distinction between the two is not always clear-cut. A needle nose pliers finds a function in both holding small pieces of hardware and bending wire.

Tools for mechanical work

What follows is a list of must have tools, those that are essential to the mechanical fabrication associated with Project building.

1. Drivers. There are two types of drivers: screwdrivers and nut drivers. The former are used to turn screws; the latter, to twist nuts.

Screwdrivers are either blade or Philips head. The blade type has a chisel-shaped head that mates with straight slotted screws. Philips screwdrivers are designed to fit screws with star-shaped holes in their head. Sets of each type are available in two packaging styles: one containing individual screwdrivers, the other having a handle into which any of several driver shafts can be inserted.

A set of inexpensive jeweller's screwdrivers also is useful in electronic assembly. They are necessary to turn the tiny setscrews holding shaft couplers and control knobs.

Nut drivers are almost as indispensable as screwdrivers. They too, come individually or as a set with driver shafts that plug into a common handle. Choose those with a hollow shaft. This type allows to keep a grip on the nut even through the screw on which the nut is mounted is protruding.

2. Pliers, Cutters, and Wire Strippers. Pliers are small pincers with long, jagged jaws. They are used for holding small objects or for bending and cutting wire. In electronics fabrication, two types are required: slip-joint pliers handle the bulk of heavy mechanical assembly; for holding wires in place during soldering and for acting as a heat sink, needle nose pliers are the logical choice.

Diagonal cutters, also called dykes, are used to cut wires or component leads. A diagonal cutter should be made of high quality tool steel, and its jaws should be well aligned. With a little practice, use diagonal cutters to strip wire. A better approach, however, is to purchase an inexpensive wire stripper, either the simple plier type or a compound unit that automatically adjusts to wire size, specifically designed to do the job. With such a tool, the possibility of nicking or gouging a wire is greatly reduced.

3. Wrenches. A wrench- a tool with adjustable jaw, lugs or sockets at one or both ends- is used for holding, twisting or turning a bolt or nut. One type of particular interest to us, is the Allen wrench, consisting of an L-shaped hexagonal bar of hardened steel either end of which fits the socket of a screw or bolt The Allen wrench is used to install or remove control knobs with small Allen setscrews. A complete set, with a dozen or more wrenches, sells for just a few dollars. No technician should be without one.

4. Metal-Working Tools. The more common metalworking tools needed by the electronics technician. A hacksaw for cutting metal, a centre punch for marking the center of holes to be drilled, a reamer to enlarge or shape a hole, a tin snip to cut sheet metal, and a set of files for forming or smoothing metal surfaces are all tools likely to be familiar to the electronics enthusiast. Two metalworking tools designed to punch and cut holes in sheet metal, however, may require an introduction.

A set of chassis punches makes cutting large holes in chassis for sockets, meters, panel lights, and so forth, a breeze. They make neat, clean holes.

Another handy chassis cutter is the nibbling tool, with it, bite-size chunks of metal are taken out of the chassis in the process of forming practically any shape hole of any required size. A nibbler can be purchased for less than 10 dollars. It is an excellent investment.

5. Drills and Drill Bits. Two type of drills need to be considered. The power hand drill is indispensable for general drilling in wood, plastic, and metal. Select one that has a variable speed control, a chunk capacity of ¼ inch or 3/8 inch, and either a grounded

three-conductor cord or a two –conductor cord with double-insulated plastic body. Drill bits, which actually do the cutting, should be of high-speed steel, not carbon steel, as high-speed steel bits have the superior cutting and wearing characteristics required in electronics fabrication. Buy a set that has bits ranging in size from 3/32 inch to 3/8 inch.

A drill particularly adaptable for printed circuit board work is the Dremel Moto Tool, a high-speed drill and grinder. This drill, which can be held comfortably in one hand, accepts drill bits ranging in size from #80 to #30. The Dremel Moto Tool can be converted into an excellent printed circuit board drill press by mounting it in one of the many drill stands designed specifically to accommodate it. A Dremel Moto Tool is essential for those wanting to manufacture their own printed circuit boards.

Tools for Electrical Work

Tools for use in electrical work are needed to secure connections between conductors. Because most connections are still made with solder, soldering and desoldering equipment is emphasized in this book. Nonetheless, wire-wrapping materials and solder less breadboards are also explored.

1. Soldering equipment. Soldering is the process of joining metal leads, wires and terminals by melting an alloy of tin and lead over them. To heat the connection a soldering iron is used. Soldering irons come in two basic configurations: guns and pencils. Guns are basically used to supply heat to large electrical connections and metal chassis. For general electronics fabrication, only a soldering pencil should be used.

Soldering irons have a wattage rating that measures how quickly they transfer heat. A 25- to 35-watt iron is a good choice, particularly for printed circuit board fabrication. It should have a well-insulated handle and, preferably, a grounded tip to protect static-sensitive components. Although controlled temperature and cordless soldering irons are also available, the former are quite expensive and the latter are used only rarely.

2. Desoldering Equipment. Unfortunately, what is often assembled sometimes must be disassembled. When it is necessary to desolder connections, special implements are required. The rubber suction bulb with a Teflon tip draws up molten solder that has been reheated with a soldering iron. A combination bulb and soldering iron is also available. The desoldering pump uses the action of a spring-loaded plunger to suck up, in one quick action, melted solder from a connection. Finally, there is the desoldering wick, a braided copper material that uses capillary action to pull up the hot solder. Any of these tools will do the job of removing solder from an electrical connection. Their selection is based both on the particular job to be done and on personal preference.

3. Wire-Wrapping Equipment. Wire wrapping is tightly wrapping the stripped ends of a thin wire around a square or rectangular terminal post. No soldering is involved in making the connection. Wire wrapping as a bread boarding method is discussed.

Specially wire wrap sockets are needed when connecting integrated circuits. The pins must be longer than those on the solder type socket and they must be square, not round or flat. Various terminal posts, designed specifically for wire wrapping, are also necessary. Component leads will be attached to the non-wire-wrapped side of the terminal post, usually by soldering.

Wire wrapping equipment is available from a number of sources. OK Machine and Tool Corporation and Vector Electronics Company, Inc., are the leading manufacturers.

4. Solder less Circuit Board. In the early stage of bread boarding when the circuit design may be undergoing frequent, changes, a quick and easy system of circuit assembly is required. Solder less circuit board provides that method. The board consists of a plastic block with arrays of holes spaced 0.10 inch apart. Electrical conductors interconnect adjacent rows or columns of holes. The board readily accepts IC pins and the leads of other electronic components. Thus the technician can build up a circuit with reliable connections without having to resort to soldering or wire wrapping.

Some solder less circuit boards are designed with interlocking ridges so that any number can be snapped together to expand the total bread boarding area.

Additional Tools for Modern Electronic Circuits

Before the advent of printed circuit technology, the tools required for electronics fabrication were basic and few. Today, a screwdriver, needle nose pliers, and soldering iron just are not enough.

2. Safety

Congratulations!
We will examine why practicing good safety is considered an essential job requirement. We will investigate how exposure to hazardous conditions affects various parts of the human body and how to minimize the risks arising from electrical shock, contact with toxic chemicals, and the misuse of hand and power tools. We will also analyze how by storing static electricity, can be the source of danger, destroying the projects around.

2.1 SAFETY: WHO CARES?

2.1.1 Safety as a Part of Job Description

Companies take safety very seriously. On the firm's entrance examination, someone are just as likely to be asked a question on the safe handling of etching solutions as one on Ohm' law. The reason is the bottom line: accidents cost money. Let's look at the economic and legal issues from the employer's standpoint. Then consider why should also be sharing this concern for a safe working environment.

Economic and legal Issues
As an electronics technician, will be required to perform such tasks as soldering, operating complex test equipment, building and repairing electronic devices, using hand and power tools, and possibly handling toxic and hazardous materials. In today's electronics environment, it is not uncommon to find printed circuit boards populated with dozens of sensitive integrated circuits, which together cost hundreds of dollars. In some sophisticated laboratories, oscilloscopes and related pieces of test equipment can cost as much as a new automobile.

But much more serious than damage to equipment is injury to people. The lost hours due to accidents are costing U.S. industry billons of dollars a year. Although accidents will happen, not try to be "accident prone."

2.1.2 Body Parts Susceptible to Damage

The human body is a fragile thin. It is easily cut, bruised, burned, irritated, shocked, and poisoned. External organs associated with our five senses and internal organs vital to our very lives are susceptible to injury in the school or workplace.

Covering Five Senses

Although bionics is the current rage, and electronics has contributed mightily to its development, most would agree that the real thing is still the best. To keep our eyes, ears, nose, throat, and skin safe from harm, we must first see how they can be hurt when exposed to hazardous conditions.

Injury to the eyes can cause permanent blindness. Small objects, such as clipped component leads and flying solder balls, can stab and burn sensitive parts of the eye. Furthermore, a splash of acid or the spray from a cleaning solvent can, at the very least, irritate; at the worst, it can destroy the entire eye. Even a bright flash of light from a xenon strobe tube, for example, can cause a serious accident. If only momentarily blinded, it may be enough to make susceptible to other forms of injury.

Loud sounds and high-pitched tones can be very irritating to the ears. In extreme cases they may cause temporary or even permanent hearing loss. It isn't just heavy metal rock bands that can produce such noises. They can be found right in the electronics laboratory.

Yet toxic fumes can be irritating to the membranes lining the nasal passages. More importantly, the nose is one entry leading to the lungs. Damage there can be very serious, as it may affect ability to breathe properly.

There is the skin, the outer layer designed to protect the entire body. Destruction of nerve endings as a result of electrical shock, burns from soldering irons and hot components, acid irritations, and, of course, common cuts, bruises, and abrasions can occur in an environment where safety is lax.

At The Heart of the Matter

Of all the internal organs, the heart is certainly the most vital. If it stop, even for only four to six minutes, death can result. Many factors can cause the heart to stop beating. Here, however, only the most relevant one electrocution or electrical shock is considered. Let's see just what electrical shock is and how it can destroy the heart.

Electrical shock is the passage of current through the human body, as it does anywhere else, when a complete circuit exists. A source of voltage and a conducting path are all that is required. Note, however, that the path for current flows must be complete. The reason is that although it has a place to come from it has no place to go (in this case, the battery's positive terminal).

The same is true when the human body is the conducting path. As illustrated in figure 2-2a, even through the person is touching the positive terminal of the voltage source, he is in no danger. As long as he is wearing insulated boots, current can find no path through him to the negative, or ground, terminal of the battery. However , if he completes the circuit by, for instance, touching the negative battery terminal with the *other hand current will indeed flow, as in Figure 2-2b. Just how much current depends* on a number of factors.

One way to increase current flow is to reduce circuit resistance. Body resistance may be quite high if skin moisture is low and there are no cuts or abrasions at the point of electrical contact. In such cases, little current will flow and only a mild shock may result. Nonetheless, if any these factors are reversed, resistance will be lowered and large amounts of current could result. If the path for current flow is through the chest, the heart can receive a lethal dose of current, an electrical shock. The heart will then most likely go into fibrillation and stop beating.

How much current is enough to kill? Although the amount varies widely and especially depends on the organs that current passes through, it is less than probably think. Figure 2-3 gives the effects of even mild doses of current. A mere 1 to 20 mA can cause a painful sensation; at 30 mA, breathing may stop; and 100 to 300 mA is enough to cause electrocution. Clearly, even small amounts of unwanted current through the body can be very dangerous to health.

2.2 WHERE THE DANGER LIES

It is time to look at where, in the school laboratory or workplace, the danger to safety lies. Problem areas and practical solutions will be identified. Although specific advice in the form of "do's and don't's" will be given, keep in mind that maintaining a safe working environment isn't complicated.

2.2.1 Electricity: The Tingle That Hurts

The problem is that there's both good news and bad news. The good news is that today's electronic devices, many of which are solid state and battery powered, are much safer than their predecessors of the vacuum tube era. Instead of circuits in amperes, we now have equipment operating on 5 to 12 volts dc and drawing currents of less than 50 to 100 mA. The bad news is that many systems even though employing solid-state circuitry, do not get their power directly from a battery but rather from the ac line. And any electronic project that is plugged into the wall outlet is a potential death trap.

The problem with ac is twofold. The ordinary wall outlet will supply up to 25 amperes of current, certainly enough under many conditions to kill someone. In addition, ac tends to "hang on." The victim can be prevented from releasing the source of voltage, thus increasing the damage to the body.

But circuit powered from the ac line are not the only problem. A serious shock can be had from many circuits, dc or ac, containing charged capacitors, faulty wiring, or shorted components. Treat every electronic circuit as potentially hazardous. Electricity, though not to be unduly feared, must certainly be respected.

The solution to being safe while working with electricity is to follow some basic "do's and don't's." Here are the more important ones:

The do's

Do work with one hand behind someone back while testing live circuits. In that way if you complete the path for current flow, at least it won't be through heart.

Do use an isolation transformer or Varian while working on ac-powered equipment. These devices isolate the powered equipment from the power source, adding a strong measure of safety.

Do make sure all capacitors are discharged before troubleshooting begins. Use an insulated screwdriver to short out capacitor leads.

Do use 3-conductor grounded line cords and polarized plugs with ac-operated equipment. Both items reduce the danger from short-circuited chassis.

Do keep fingers out of live chassis. Test all circuits with a voltmeter or specially designed test lamps.

The Don't's

Don't install or remove any electronic components while the circuit is connected to a power source. Following this procedure will protect as well as the component.

Don't over fuse. Using a fuse with a higher rating than is recommended only defeats the fuse's purpose.

Don't work with wet hands. As noted earlier, if body resistance goes down, current flow goes up. Even sweat can moisten the hands enough to cause excessive current flow.

Don't cut wires carrying electricity. Again, it isn't just the ac line cord that is lethal. Assume all wires carry enough current to harm.

Don't disconnect electrical devices from the wall outlet by pulling on the line cord; pull the plug handle.

2.2.2 Exposure to Toxic and Hazardous Chemicals

Let's examine the problems associated with potentially dangerous chemicals and how best to protect ourselves when working around various sprays and liquids.

With toxic and hazardous chemicals, should be concerned about inhaling vapours, swallowing liquids, acid burns on the skin, contact with the eyes, and the overall danger of fire and explosion. Chemicals such as etching solutions, spray paints, component cleaners, glues, photographic developing solutions, and general household solvents, all of which are likely to be found in the electronics laboratory, can cause health hazards if improperly used or stored. To minimize risks, here are some do's and don't's:

Do's

Do ready the labels on all the chemicals use. Pay particular attention to printed warnings.

Do work in well-ventilated areas. This is particularly important when using paint and chemical sprays.

Do wear eye protection when working around hazardous chemicals

Do wear rubber gloves when working with acid solutions. Be sure they are washed or thrown away when work is done.

Do hold printed circuit boards securely with tongs when placing them in or removing them from an acid solution.

Do immediately clean all tools that have come in contact with hazardous chemicals. This will prevent someone from inadvertently touching the toxic substances.

Don't's

Don't pour solvents, paints, or acids down the drain. In addition to being a health hazard, in many localities it is illegal.

Don't transfer chemical to unlabeled containers.

Don't inhale fumes from soldering paste. Such fumes can be harmful to lungs.

Don't leave any chemical in open containers where they can be splashed or spilled. Put all unused chemicals safely away, prefably in a locked metal cabinet.

Don't place any chemicals near sparks or open flames. Assume all chemicals are highly combustible.

2.2.3 Safety Hazards Caused by the Misuse of Hand Tools

In this section hand tool safety is discussed. For convenience hand tools are defined as those that are held in the hand and are not powered by electricity.

Hand tools can be more dangerous than power tools. Why? Because they are used more often and we tend to dismiss their risk. Do not be deceived. A spil of a hacksaw blade or the launching of a loose hammerhead can maim someone else for life. Whether it's a puncture from a file tang, a gash from a saw blade, or a slit from a knife, hand tools can do plenty of damage. To avoid the obvious dangers, consider this list of important do's and don't's:

The do's

Do keep hands free of dirt, grease, or oil when using hand tools.

Do keep hand tools sharp. A dull tool is more dangerous than a sharp one because with a dull tool tend to apply more pressure, increasing the likelihood of slippage.

Do cut away from someone body, not toward it.

Do secure all small pieces of work in vise or with appropriate clamps.

Do put sharp tools away when not in use. Leaving knives, awls, and punches lying around for someone to lean on is extremely dangerous.

The Don't's

Don' carry hand tools in pocket; they may injure someone else.

Don't use a file without a handle. An exposed file tang can easily puncture hand or wrist.

Don't toss any hand tools to a neighbour. Flying objects of any kind are never to be seen in the electronics laboratory.
Don't run hands over the edges of sheet metal. Such edges are sharp and can cause severe cuts.

2.2.4 Safety hazards caused by the Misuse of power Tools

Power tools are defined as those that use electricity, usually in the form of ac from the wall outlet. Let's look at the problems and solutions for this area, the do's and don't's.

Power tools can burn, cut, scrape, and even hit with flying objects. Because most of them plug directly into the wall outlet, they can also give a nasty electrical shock. Injuries from power tools occur by long hair or unsuitable clothing getting caught in a revolving machine, by small objects flying out of a drill press vise, by a hot soldering iron being left where someone can lean against it. To prevent such injures, practice the correct safety procedures as outlined by instructor, and follow these do's and don't's:

The do's

Do turn on and off all power tools. Do not allow others to do it.

Do make sure all objects being drilled or cut are securely fastened. Small objects and especially sheet metal, should be held in a vise, clamp, or suitable gripping tool such as pliers or vise grips.

Do see to it that all implements and adjusting tools are removed from the work area.

Do remove the chuck key from a drill press before turning on the machine. A flying chuck key is a frequent cause of injury in the laboratory.

Do ease up on the drill pressure as you break through the work. This will reduce the possibility of the material "grabbing."

Do grasp a soldering iron only by the handle. Don't reach for a falling soldering iron let it fall.

Do return a soldering iron to its holder. It should be in either one of two places: hand or in the holder.

Don't's

Don't ever leave power tools unattended. If the tool is on, stay with it until it is off and until all parts have stopped moving.

Don't wear clothing or accessories that can get tangled in revolving machine parts.

Don't distract others while they are using power tools. If distractions cause problems with hand tools, the same is doubly true for power equipment.

Don't stand in the direct "throw" of any machine. Don't line up with a revolving saw blade or spinning grinding wheel.

Don't remove guards or safety devices from power tools. They have been installed for a good reason; keep them in place.

Don't put face too close to moving machinery: Metal chips and oil spray can cause eye and skin injury.

Don't test a soldering iron with your hand. Assume all soldering irons are hot. Test them by attempting to melt a piece of solder.

Don't hand a soldering iron directly to another person. Instead, return it to its holder. The other person can take it from there.

2.2.5 Project safety

The static Electricity Monster

Static electricity is a stationary charge. As such, it is a potential (voltage) waiting to go somewhere. If that charge gets to a sensitive circuit, it could destroy the circuit. In the normal course of work, it possible to build up a static charge of more than 50000 volts. But today's solid-state circuits don't need anything like that kind of voltage to rende them useless. In some cases, less than a few volts of static electricity is all that it takes.

How the Static Charge is Created

The most common way of creating a static charge is through friction, where electrons are turn off one surface to accumulate on another. Any time objects are rubbed together, friction is created. And if the substances are of dissimilar materials, the accumulated charge can be considerable. If one or both of the elements is no conducting, the charges will leak off quickly and little danger exists. The solution, then, is either to keep charged insulating materials away from sensitive circuits or make sure the charge is bled away before it can do any damage.

Materials Susceptible to Damage

Any integrated circuit in the MOS (metal-oxide semiconductor) family can be easily destroyed by static discharge. In addition, many transistors are Subject to the same effect. If it is a solid state circuit assume the circuit is susceptible to damage from static electricity. This will not be true in all cases, but it is best to proceed as through it were. Following basic electrostatic discharge safety procedures for all circuits is not difficult. Get in the habit of doing it.

Projecting Circuits

One way to reduce the risk from static electricity is to keep the room's humidity high. With high humidity there is a greater conducting path, and thus an electrostatic build-up will leak away much easier.

The key to protecting circuits, however, is to try to bring everything around to a common potential. If there is no difference in charge, there is no voltage, and therefore no static build-up.

Be sure all MOS-type integrated circuits remain packaged in antistatic materials consist until used. These materials consists of specially coated plastic carriers, conductive foam, or aluminium foil. The ideal is to keep all pins of an IC shorted together and thus at the same potential. In that way no charge can build up between them.

When handling MOS components, avoid touching the pins. That will keep any charge might have accumulated off the component leads, which are, of course, connected to the solid-state material within the IC package.

Never install or remove integrated circuits while power is still applied to the circuit. The sudden voltage jolt that could result may damage them.

If possible, use an antistatic wrist strap. The strap brings to ground potential. Assuming components are there too, no charge can build up.

Use a soldering iron with a grounded tip. In that way no static charge will transfer to the sensitive components while they are being soldered in the circuit.

The ideal is to prevent a static build-up in the first place. If that is not possible, at least make sure that any such charge has a path to leak away. Doing that will ensure safe operation for projects.

2.2.6 Environmental Concerns

A moment ago we discussed exposure to toxic and hazardous chemicals. We saw how handling such materials can, if one is not vigilant, have a detrimental effect on those working in a laboratory or industrial setting. Broader issues of environmental concern have begun to surface, however, and will assume greater significance for the electronics industry and those employed in it, in the decades to come. In this concluding section, we need to see why the prototype electronics technician, should be interested in such matters and what role might be in workplace environmental protection.

Why should be concerned

First, the entire electronics industry is "going green," and for good reasons. Companies such as Intel, Tektronix, and 3M, to name but a few, are spending millions of dollars a year disposing of every day toxic waste-the chemicals and other substances used to manufacture semiconductors, printed circuit boards, and other products. In some cases, with certain solvents and metals, it costs more to dispose of them than to buy them. Ways have to be found to either reduce the demand for such materials or recycle them more efficiently. Every employee at an electronics firm, whether it is a large or small enterprise, has to be part of that solution. As an electronics design and fabrication technician involved in prototyping.

There is a second, and perhaps more relevant, reason why in particular will be involved with environmental issues, most notably those of waste disposal on the back end to how toxins are used up front. In other words, environmental concerns are becoming firmly entrenched in product design and production. For example, Texas Instruments was planning to make a device with a mercury switch. Even though safeguards had been incorporated to deal with the mercury, the firm decided to redo the design using steel balls instead. The point is that working with the design and fabrication of prototype projects, will need to involve with "green design," electronic products that are environmentally friendly from the start.

3. The Design Process an Ideal Is Born

3.1 ELECTRONICS DESIGN: PROBLEMS IN SEARCH OF SOLUTIONS

3.1.1 Design and Designers

Electronics can't solve all of our problems; and, as we know, it can create a few difficulties of its own. But in a great many cases, the electronic solution is the best solution. For the foreseeable future, countless new electronic products and services will need to be designed and produced. Let's take a look at the people who will be doing the creating.

The designer

Who designs or creates electronic products and services? Are they engineers, designers, technicians, or just plain tinkerers? Actually., any of the above. Someone don't have to be an electronics engineering to do design. Although it helps to have formal course work, anyone who creates something may qualify as a designer. Technicians, for example, are constantly modifying, improving on, and creating new projects. Because they, of all the electronics personnel, are closest to the actual working device, technicians are often in the best position to see what changes and improvements need to be made. And, given their electronics training and experience, they can usually come up with an actual design to solve the problem.

The key to electronics design is taking the system approach. This means knowing about electronic circuitry, the role of input and output transducers, and the fundamentals of good product packaging. It also means understanding and respecting the users' needs. We'll look at these and other design aspects more closely later in the chapter.

For now, it is enough to understand that being an electronics designer does not mean crossing some invisible barrier, some magic line that separates the hobbyist and technician from the college trained engineer. Given the right attitude and technical experience, anyone else, can do electronics design work.

3.1.2 The design Methodology

In addition to having the appropriate attitude and technical expertise, must familiarize with electronic design method methodologies. One such design method involves identifying problem and solution categories. As a result, often gain clearer insight into the overall design effort. Let's see what this means.

Identifying the Problem Category

Usually design problems can be put into one of three categories: (1) a need in search of a product or service; (2) a product or service in search of a need; or (3) improvement on an existing product. Obviously, the differences among these three categories are not that well defined. Nonetheless, an attempt at classifying each design project into one of these three categories is bound to help conceptualize the design problem.

In the first instance we often find ourselves saying, "We have this problem. Can electronics help us with the solution?" Illustrations of this type of thinking are endless.

Suppose are constantly "bugged" by mosquitoes at the company's annual picnic. From gallons of insecticide to gas-powered flyswatters. But what about an ultrasonic electronic oscillator that drives mosquitoes batty? Small battery powered units that actually claim to do just that are available at local sporting goods store. Or do constantly misplace the car keys, searching frantically for them on the mantle, between the couch pillows, or in jacket pocket? Well someone has come up with an electronic solution: a small circuit attached to the key chain that lets out a high-pitched audio tone when clap your hands. Now, retrieving lost keys is as easy as snapping fingers.

These, and the other examples mentioned earlier, have one thing in common: first there was a need or problem, and then came the solution.

It doesn't always work that way. Often we think of the product or service first and then look to see if there is a real need for it. And, if there is, does a product or service already exist to satisfy that need? What about a string of small dc lights that "dance" to the music? Such a colour organ can be designed and built easily. But has someone already done it? If not, and create such a product, would anyone buy it? How about an emergency strobe light that campers could carry into the outback? If lost, they could use it to signal search crews. Again, designing and building such a product isn't difficult. But is there a market for it? In these examples, first the product came quickly to mind; the need had yet to be determined.

Sometimes we just want to improve on what we already have. This could be as simple as adding an on-off indicator light to a power supply, or as complex as upgrading an analog tachometer to a digital version. The latter, of course, could be considered a brand-new product, not just an upgrade.

The idea behind identifying a problem category is simply to help formulate the design effort. Once the problem is clear, can move on to singling out the best type of solution.

Identifying the solution Category

Regardless of how the problem is categorized, one of three solution approaches is usually taken: (1) we see if the product or service already exists; (2) we see if we can modify an existing item that is close to what we want; or (3) if the first two methods don't work, we design a new product from scratch. Let's briefly examine each procedure.

Why waste time, money, and tremendous design effort if what want already exists? Why reinvent the wheel? It is, in part, the designer's responsibility to know what's out there and if a particular design is "common property," to be used freely by all. True, company may still find it more advantageous to design and make its own version of a particular item, but, at the very least, the option to choose what is already available should be there.

Perhaps what are looking for already exists, and only a slight modification is all that needed. Designers spend a greate deal of time poring over data sheets of circuit schematics that are very close to what they require. An extra stage of amplification, the addition of a variable speed control, slightly more filtering at the output make these kinds of small modifications and could have a custom-designed project that exactly meets needs.

3.2 ELECTRONIC DESIGN: THE SYSTEMS APPROACH

To do electronics design, must be able to recognize the complete electronic system and understand how it functions. We'll look at the systems approach first. In today's industrial environment also need to be familiar with the concept of Total Quality Management. We'll examine and role in it, next. It's then on to an exploration of the important two-step design process. We will also find out about some basic sketching techniques useful in the design stage.

3.2.1 The fundamentals of Electronics Design

Here we explore the fundamentals of electronics design by defining the term electronic system. Then we go on to discuss electronic components: their function, description, packaging styles, and selection and acquisition. In addition to providing insight into the design process, this procedure also allows us to review some important principles of electronics.

Electronic component Function

Electronic components can be classified as either active or passive. Active components control electrons by switching or regulating them; passive components help the active components carry out these functions.

A giant leap from the electrical to the electronic age occurred in 1906, with the invention of the first active component, the vacuum tube. Now, for the first time, electrons were all alone. These minute particles, travelling between the vacuum tube's cathode and plate, could be controlled by a tiny grid of wire with a negative charge placed on it. The result? Switching speeds in the hundreds of thousands per second and amplification on the order of a million or more.

By combining this first active component in various ways, the electronic computer was born, as was radio, television, and a host of other twentieth century electronic wonders. Clearly, the vacuum tube is one of the most important inventions of all time.

Amazing as it was, the vacuum tube had its shortcomings. It was relatively large, easily breakable, generally unreliable, hungry for power, and had a limited life expectancy. A more efficient replacement was needed.

In 1947, the transistor emerged from the laboratory, as a second-generation active component, to challenge the vacuum tube. The new transistor did everything its predecessor did, only better. It was smaller, highly reliable, consumed milliwatts instead of watts of power, and could be counted on to last at least as long as any other component in the circuit. In addition, once quantity production opened up, transistor costs plummeted to only pennies per unit, while the average vacuum tube still sold for more than two dollars.

But even with the transistor, improvements were called for. Using basic transistor technology, engineers at Fairchild developed a tiny component, no bigger than an infant's fingernail, that contained dozens of transistor elements. These transistors, along with various resistor and capacitors fabricated in the same way, were combined to form entire circuits on a single tiny sliver of silicon. The year was 1958, and the integrated circuit had arrived.

Today, integrated circuits containing hundreds of thousands of transistor elements are being mass-produced for just a few dollars. This third-generation active component has all the advantages of discrete transistors, plus the added benefit of much greater circuit density and, surprisingly, even lower power consumption.

We are not through yet. Although the microprocessor is a type of integrated circuit, many feel that this device, developed in 1972, is so radically different from its predecessors that it deserves its own identity as an active component. The microprocessor, of which there are now more in use than there are people on earth, is programmable. It is software that determines its function. This means that the same microprocessor can be used in a microwave oven, a videocassette recorder, an automobile cruise control, or a personal computer. What distinguishes one from the other is the program it is fed. This component, which is the heart of all computer-based systems, has revolutionized the design of electronic products and services. Now, the electronics designer must know about computer software as well as computer hardware.

The passive components resistors, capacitors, inductors, and transformers-help the active components manipulate electrical current. The resistor limits current flow drops voltage. It is probably the most abundant of all components; rarely does an electronic circuit not contain at least one resistor. The capacitor acts as a temporary battery to store an electrical charge. It is used in timing circuits, turners, and filters. The inductor, which stores electrical energy in a magnetic field, acts as a choke and a long with a capacitor, as a tuner. The transformer steps up or down incoming voltage. It is found in power supplies and as an energy-matching component in amplifiers and oscillators.

Electronic Component Description

Let's take a moment to examine more closely the most widely used active and passive electronic components.

Diodes. A diode is a two-element (cathode and anode) components that allows current to flow through it in one direction only. The Diode conducts current when forward-biased. It blocks current flow when reversed-biased. Thus, the diode acts as a one-way valve. It is used primarily for switching, through it also operates as a rectifier to change ac to dc.

Diodes are rated with regard to current and voltage handling ability. For example, a 1N4001 diode is rated at 1 ampere/50 volts. That is, it will carry up to 1 ampere while handling up to 50 volts. The question is, Could such a diode work in a circuit requiring only 500 mA at 25V? Yes it could.

Transistors. A transistor is a semiconductor component that can both switch and amplify. It consists of three terminals: Emitter, Base, and Collector. There are two configurations, NPN and PNP. There are also two broad types, classified according to current-handling ability: general-purpose and power transistors.

A transistor is operated as an amplifier or as a switch. As an amplifier, a small varying signal placed on the base causes a much larger varying signal to flow from collector to emitter. When a transistor is operated as a switch, it is either at cut-off (no collector-emitter current is allowed to flow) or saturation (maximum collector-emitter current flows).

The transistor as an amplifier finds extensive use in audio and radio frequency equipment. As a switch it is used to activate and deactivate a wide variety of circuit loads.

Silicon Controlled Rectifiers (SCRs). The SCR is a three-terminal solid-state latching switch. It conducts current from the cathode to the anode when the gate receives a positive voltage. Once the conduction takes place, it continues even when the control voltage to the gate is removed. The SCR ceases conducting only when the anode voltage is removed, reduced, or reversed. Thus, we have a latching switch, designed to operate primarily in a dc circuit.

For example, a 1-ampere/200-volt SCR conducts up to 1 ampere while handling up to 200 volts. Will such an SCR work in a circuit delivering 500 mA at 6 V? Yes of course.

SCRs are used extensively in burglar alarms, color organs, strobe lights, and industrial control applications where dc is involved anywhere, that is, where a solid-state latch is required.

Triacs. A triac is a back-to-back SCR. It functions as an electrically controlled switch for ac loads. Like an SCR, the triac is rated in terms of current and voltage handling ability. The former ranges from 1 to over 40 amperes; the latter, from 200 to 600 volts. Triacs are used to control high-current, high-voltage ac loads. In dc circuits we use the SCR; in ac circuits, where current and voltage tend to be higher, the triac is the choice.

Voltage Regulators. A voltage regulator is a circuit that holds an output voltage at a predetermined value regardless of normal input voltage changes or changes in load impedance. There are fixed and variable voltage regulators. The former have fixed output, such as 5.0, 6.0, 10.0, and 18.0 volts. The latter hold their output voltage steady within a predetermined range. For example, the LM317 is a 1.2-17 volt regulator. When set to any voltage within that range, it holds the output at the selected voltage.

Many voltage regulators come in a three-terminal package. They have only one input terminal, one output terminal, and one ground terminal. Such regulators are chosen primarily to satisfy the voltage and current requirements of the load. For example, the LM7805 is a fixed 5-volt/1-ampere voltage regulator. It holds the output voltage at 5 volts while the load draws up to 1 ampere. If the load exceeds 1 ampere, the voltage regulator automatically shut down. It resumes operation when the load requirement is reduced below 1 ampere.

Voltage regulators are a must for any dc power supply. Considering their simplicity and low cost, there is no reason why they shouldn't be designed into every power-supply project.

ORDERING INFORMATION

T_J	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 125°C	PowerFLEX™ (KTE)	Reel of 2000	LM317KTER	LM317
	SOT-223 (DCY)	Tube of 80	LM317DCY	L3
		Reel of 2500	LM317DCYR	
	TO-220 (KC)	Tube of 50	LM317KC	LM317
	TO-220, short shoulder (KCS)	Tube of 20	LM317KCS	

package thermal data

PACKAGE	BOARD	θ_{JC}	θ_{JA}	θ_{JP}‡
PowerFLEX™ (KTE)	High K, JESD 51-5	3°C/W	23°C/W	
SOT-223 (DCY)	High K, JESD 51-7	4°C/W	53°C/W	
TO-220 (KC/KCS)	High K, JESD 51-5	17°C/W	19°C/W	3°C/W

recommended operating conditions

		MIN	MAX	UNIT
$V_I - V_O$	Input-to-output voltage differential	3	37	V
I_O	Output current		1.5	A
T_J	Operating virtual junction temperature	0	125	°C

electrical characteristics over recommended ranges of operating virtual junction temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			MIN	TYP	MAX	UNIT
Line regulation‡	$V_I - V_O$ = 3 V to 40 V		T_J = 25°C		0.01	0.04	%/V
			T_J = 0°C to 125°C		0.02	0.07	
Load regulation	I_O = 10 mA to 1500 mA	C_{ADJ} = 10 μF§, T_J = 25°C	$V_O \le 5$ V			25	mV
			$V_O \ge 5$ V		0.1	0.5	$\%V_O$
		T_J = 0°C to 125°C	$V_O \le 5$ V		20	70	mV
			$V_O \ge 5$ V		0.3	1.5	$\%V_O$
Thermal regulation	20-ms pulse, T_J = 25°C				0.03	0.07	$\%V_O$/W
ADJUST terminal current					50	100	μA
Change in ADJUST terminal current	$V_I - V_O$ = 2.5 V to 40 V, $P_D \le 20$ W, I_O = 10 mA to 1500 mA				0.2	5	μA
Reference voltage	$V_I - V_O$ = 3 V to 40 V, $P_D \le 20$ W, I_O = 10 mA to 1500 mA			1.2	1.25	1.3	V
Output-voltage temperature stability	T_J = 0°C to 125°C				0.7		$\%V_O$
Minimum load current to maintain regulation	$V_I - V_O$ = 40 V				3.5	10	mA
Maximum output current	$V_I - V_O \le 15$ V, $P_D < P_{MAX}$ (see Note 1)			1.5	2.2		A
	$V_I - V_O \le 40$ V, $P_D < P_{MAX}$ (see Note 1), T_J = 25°C			0.15	0.4		
RMS output noise voltage (% of V_O)	f = 10 Hz to 10 kHz, T_J = 25°C				0.003		$\%V_O$
Ripple rejection	V_O = 10 V, f = 120 Hz		C_{ADJ} = 0 μF§		57		dB
			C_{ADJ} = 10 μF§	62	64		
Long-term stability	T_J = 25°C				0.3	1	%/1k Hrs

Resistors. A resistor is a passive electronic component that acts to oppose current flow and drop voltage. Note the color band, which we will discuss in a moment.

Resistors have two ratings. They have a resistance value, measured in ohms, and a heat-dissipation factor, measured in watts. The ohm is just a measurement of resistance, or opposition, to current flow. The more ohms, the more resistance. Standard carbon-composition resistors range in value from less than 1 ohm to over 100 million ohms.

A resistor's wattage rating is a measurement of how much heat it will get rid of. The larger its physical size, the greater its wattage rating. Common ratings are ¼, ½, 1, and 2 watts.

Carbon resistors use a color code to display their value in ohms. Four colored bands surround the resistor body. Each color is assigned a numeric value Black is 0; Brown, 1; red, 2; and so on. The first three bands give the value in ohms, the fourth band the tolerance in percent of nominal value. Furthermore, the first two bands represent numerals while the third band designates the number of zeros to be added to the numerical value.

Resistors find application in virtually every circuit. They are the most popular of all electronic components, active or passive.

Capacitors. A capacitor is a passive component that stores electricity. It consists of two metal plates separated by a dielectric, or insulator. There are two types of fixed capacitors: polarized and nonpolarized. The former have a positive and negative lead. Also known as electrolytic capacitors, polarized capacitors must be installed in a circuit in the correct direction. Nonpolarized capacitors can be installed in either direction.

Note that the positive lead of an electrolytic capacitor is identified by physical characteristics in one of two ways: In radial leads, the positive lead is the longer of the two. In axial leads, the positive lead emerges from the side where the cylinder indents.

Capacitor values are given in microfarads and Pico farads. Values up to 1 microfarad are nonpolarized; beyond 1 microfarad the capacitor is almost always polarized. Capacitors have a voltage rating, too. For example, 47 microfarad/50 volts. This capacitor should not be placed in a circuit where more than 50 volts would be impressed across its leads.

Capacitors are used as filters in power suplies, in tuning circuits for radios, and as part of resistance/capacitance (R/C) networks in timing circuits.

Inductors. An inductor, or coil, stores energy in a magnetic field. It consists of a coil of wire wound on an air or iron core. Inductors are nonpolarized, that is, they can be installed in either direction within the circuit. Indictor values are given in millihenries or microhenries. They have no voltage rating. Coils are used in motors, antennas, turners, relays, and solenoids.

Transformers. A transformer looks very much like a coil. That is because a transformer consists of two or more windings wrapped around a common core. It's really just two or more coils using the same core.

A transformer steps ac voltage up or down. Its primary coil receives the incoming voltage. Through magnetic induction, the voltage is induced into the secondary winding. If the secondary winding has more turns than the primary, the incoming voltage is stepped up. If the number of windings in the secondary coil is less than that of the primary, the incoming voltage is reduced.

Transformers are classified as power, audio, and radio frequency (RF). The former are the largest, the latter the smallest. Transformers are used in power supplies, audio and video equipment, and in general, to isolate one ac circuit from another.

Component Packaging Styles

If such components have polarity, the positive terminal is usually specified with a longer lead, or the body of the component has a polarity marking clearly shown.

Leads for active components, integrated circuits, and components in the transistor family are identified differently. They are determined according to a packaging style that usually goes with a specific lead configuration. Yet you can't always be sure that these configurations will match the particular components are working with. To play it safe, look up the packaging style and lead pattern in the data sheet for the appropriate component. This is the only way can be absolutely sure of lead placement.

Electronic Component Selection and Acquisition

As an electronics technician, particularly one involved in prototype design and fabrication, will be concerned with the selection and acquisition of electronic components, not just for the prototype, it's not simply enough to get the circuit up and running. Must do so with electronic components and hardware that will be readily available in large quantities and at reasonable prices. In other words, the prototype technician must look ahead to the final, mass-produced product in determining component selection and acquisition.

The first step in learning to make such decisions is to gain as much knowledge as possible about electronic components; what's available, from what vendors, delivery schedules, and, of course, pricing. When out in industry, two sources will be of primary help: (1) Company's purchasing agent; and (2) part catalogs such as the EEM.

3.2.2 Total Quality Management (TQM) and the Design process

TQM is one of the hottest buzzwords in corporate America today. It's an umbrella term for quality programs that have spread throughout U.S. industry in the past dozen years. It developed in response to the Japanese emphasis on superior-quality products.

Total Quality Management started with large companies but has spread to smaller ones, as the former have insisted that the latter, who often act as suppliers to their large kin, adopt quality programs of their own. Let's see just what TQM is and how it fits into electronic design and the systems approach.

The what and why of TQM

Total Quality Management represents as its name indicates, a company's total commitment to quality. TQM is essentially customer and employee-driven. What does this mean? First, there is an intense focus on customer satisfaction. Customers, however, are internal as well as external. An assembler may be the "customer" of a technician who builds a prototype, for instance, just as the person who buys the final, mass-produced product is the customer of everyone in the company.

Second, TQM involves a new work relationship based on trust and teamwork. The idea centers around the term empowerment, where management gives employees wide latitude in how they go about achieving the company's goals. By getting employees involved at all levels from design to shipping, companies hope that a shift will occur from catching and correcting defects at the end of the process, to monitoring the process itself so that defects do not occur. Such an approach, the essence of TQM, represents a real sea change for many U.S. companies.

The Electronics Technician's Role in TQM

Improving quality involves much more than beefing up the quality assurance (QA) department, increasing inspection and rejection at the back end-It's really about designing quality in at the front end. An electronics technician dealing with prototype design and fabrication, are going to be a key player in TQM implementation. And the emphasis on "player" is significant. TQM makes considerable use of concepts such as the team method and quality circles.

3.2.3 The Two-Step Design Process

The project design process involves two steps. We need to produce a Concepts and Requirements Document and a set of design drawing. The concepts and Requirements Document, in addition to stating the project concept, spells out just what is to be done, by whom, and when. The design drawings consist of a system diagram, circuit design sketch, and packaging plan. Let's examine both items in turn.

Concepts and Requirements Document

The concepts and Requirements Document doesn't have to be a lengthy thesis; one or two typewritten pages will do. Its purpose is to state clearly why the project should be undertaken, the basic design requirements, how those requirements are to be met, and who is to do exactly what and when. First, a goals declaration is made, followed by a list of objectives, a clarification of responsibility statement, and a short discussion of the theory of operation. Here's what we mean:

Project Goals. The goals declaration simply states what the project is, why it is needed, and why it is better to build it rather than obtain it commercially. For example, suppose want to solve the problem of break-ins in the electronics laboratory an illustration of a need in search of a product problem category. Conclude that by installing a burglar alarm system the incidences of theft will be reduced. The project, then, is a burglar alarm, and its purpose is to reduce break-ins. Also, because nothing is available commercially that will meet the company's particular needs, are proposing that the company build the burglar alarm.

Project Objectives. First, state the design requirements. For example, the system should be reliable, low in cost, safe to operate, have an entry delay, produce a loud siren sound when triggered, and protect all doors and windows. Next, specify how those particular requirements, or objectives, will be met. Here could say that reliability will be achieved by using solid-state components; low cost, by building the circuit on a PC board; safe operation, with the use of batteries; and so on. It's basically a question of stating specific design criteria and how they are to be met.

Project Responsibilities. It is very important, early on, to find out who is going to do what and set deadlines for the completion of the various tasks. Who will provide the design sketches? Who is going to make the complete drawing set? Who builds the prototype? Who tests and troubleshoots the project? And, of course, where does the responsibility for documentation lie? Adjustments can, and will, be made as the project progresses. But general commitments in terms of personnel and facilities need to be made now, in the Concept and Requirements Document.

Theory of Operation. A brief explanation of how the circuit works should be included. Although marketing personnel, and even some production people, may wish to skip this section, it is useful for all those involved in the design and prototyping phases.

After the Concepts and Requirements Document is accepted, it is signed off by the appropriate personnel and appears later as part of the Project Report. We'll look more closely at the Concepts and Requirements Document in the next section, where the Sample Project, the Variable Power Supply, is also examined.

3.2.4 Sketching Techniques

Sketching is an important skill that every technical person should develop. The ability to get thoughts down on paper quickly, in graphic form, for someone to evaluate is an important asset. Let's examine a few techniques that will help do just that.

Sketching System Diagrams
Just be sure to drawn a solid block for functional units that are part of the complete system and a broken block for functional units that are part of the system but not the

project will be building. Also, don't forget to include the lines, with arrows, that indicate signal flow between functional units.

Sketching Schematic Drawings

A schematic drawing consists of electronic component symbols with interconnecting conductors. These components are identified and their lead and pin numbers indicated.

A schematic sketch differs from a working schematic drawing primarily in two ways. One, the sketch is often incomplete in detail. Integrated circuit pin numbers are usually omitted, supply voltages are "understood," and even the identity of major components may be missing. The assumption, made by the sketcher is that someone else will look up this missing information when the working schematic is produced.

The second way in which the sketch differs from the working schematic is that, in the sketch, little, if any, attention is paid to such things as component layout, line work, and scaled lettering. The idea is to put down the basic circuit as quickly as possible.

Nonetheless, the schematic sketch is no excuse for sloppiness and unorganized work. The sketch must be understandable and correct. It is one thing to leave IC pin numbers off the sketch. To be looked up at a latter time, but quite another to put the wrong pin numbers on the drawing.

Keep this in mind when are called on to produce a quick schematic sketch. Because most likely will be sketching schematic from one that is already drawn in books or magazines, job will be fairly easy. Work in a logical progression, usually from left to right, and try not to forget any important details.

Sketching Pictorial Drawings

This often means drawing in isometric. In such an approach, objects are usually sketched by first developing an isometric cube and then "cutting the cube away" to get the final shape want.

Isometric means equal measure. In an isometric drawing, the three common planes showing height, width, and depth are drawn true length. On an isometric drawing, vertical lines remain vertical, but horizontal lines recede at 30-degree angles. Any nonisometric lines are drawn between isometric points.

Start with the basic cube, drawn in isometric, and then in successive steps hack away at it until the final shape emerges. As the drawing progresses, will probably need to erase unwanted guidelines. When the final shape has emerged, can darken the remaining object lines.

3.3 ELECTRONICS DESIGN: PRACTICAL PROJECTS

3.3.1 Designing the variable power supply

Here the concepts and Requirements Document and design drawings the two step design process for the Variable Power Supply are discussed.

Concepts and Requirements Documents for the Variable supply

The complete Concepts and Requirements Documents for the Variable Power Supply are presented. The project goals state what is to be built, why it is a desirable project, and in this case, what is to be gained by having electronics students build the device. In industry, of course, having engineers and technicians work on a project just to gain experience may not be a reasonable justification for proceeding. Nonetheless, it is important to realize that the experience factor, even in the industrial setting, is not to be discounted.

Project objectives require achieving optimum benefits with regard to cost, reliability, safety, appearance, and ease of use. How these objectives are to be realized is also stated, in general terms.

In industry, this would rarely be the case. Designers, technicians, and technical writers would be involved and tentative due dates assigned. But because this is also to be a complete learning experience, carry forward every phase of project design and construction.

Design Drawings for the Variable Power Supply

The power supply project itself is not a complete electronic system, only the circuit portion of it. A power supply converts alternating current (ac) into direct current (dc). It is an all-electronic device, taking one form of electricity at its input (ac) and supplying another form at its output (dc). In that sense it is similar to an amplifier, or any other electronic circuit, that "only" manipulates electrical current.

But the power supply is part of an electrical system, nonetheless. The input transducer is the generator at the power plant supplying ac to the wall outlet. The generator changes mechanical energy into electricity. The output transducer is the load connected to the dc output terminals of the power supply. Eventually, that load, be it a radio, television, computer, alarm, or whatever, will change electricity into another form of energy. Thus, there is indeed a complete electronic system.

This is a sketch that designers, technicians, and other technical personnel use to evaluate how the power supply works. In this instance, note that the drawing is quite complete. After all, the project is a simple one and the circuit design is not hard to arrive at.

It shows the proposed size and shape of the sheet metal enclosure, suggested finishing treatment, and the locations of the on-off switch, panel light, voltage terminal posts, variable voltage control potentiometer, and dial face. Remember, this is not a final drawing, merely a first proposal showing how the complete prototype might look.

Theory of Operation

As noted, a power supply converts ac to dc. All four active components require dc. Some of the circuits using these components get their dc from batteries. But most will plug into a wall outlet, which, of course, supplies ac. The devices employing these circuits, such as televisions or stereos, will have power supplies built in as just one more circuit. There is, however, a need for what is known as "bench power supplies": separate units designed for use in experimenting, testing, and troubleshooting dc-powered projects. The Variable Power Supply fits into this category.

Specifically, the Variable power Supply takes the 240 volts ac at its input and supplies 0 to 15 volts dc at the output. The supply is fully regulated, which means it will maintain the set voltage even though load current requirements may fluctuate. It also overload protected. In case of a short circuit across the output terminals, the supply will shut down, rather than burn out.

Along with the appropriate voltage waveforms at important points. The ac line cord couples, via switch S1, the 240 V ac to the primary of transformer steps down the 240 V ac to approximately 15.5 V ac. Diodes D1-D4 form a full-wave bridge to change the ac to pulsating direct current. The light emitting diode D5, along with its current limiting resistor R1, is used as a power "on" indicator. Capacitor c1 filters the pdc to smooth dc. Capacitor C2 provides high frequency by passing. The variable voltage regulator U1 sets its output voltage by a control loop consisting of resistor R2 and R3. By adjusting potentiometer R3, the output voltage can be varied over the 0 to 15 volt range. Finally, capacitor C3 acts to swamp any ringing effect developed by the control loop and thereby ensures stability of the voltage regulator's output.

4. Drawings

No doubt heard it a thousand times, which may make it a hit stale but certainly no less true.yes a picture? (Or drawing) realty is worth a thousand words. Maybe we could produce the required documentation for our project without any drawings at all Maybe. But the resulting Project Report would certainly be a greet deal thicker and much, much more difficult to write and read, In fact, it's hard to conceive of doing such a thing. The effort Required to put into words what can » easily be conveyed with special symbols and lines—well, one Shudders just to think of it- Drawings are not only desirable m explaining something like project design and fabrication they are essential For example ten drawings are required lo clanft[1] how a project works and how it is *to* be built Anything less would make describing in words, the project design and fabrication process far *too* burdensome-In this chapter we cover two major topics. First, explain the role or the drawing in communication a message or idea and introduce the ten-drawing set used throughout the book. Second, we zero in on the working schematic: the legible circuit design drawing that everyone can work from. We will find out how to read such a schematic and Then how to draw one

4.1 DRAWING: THE LANGUAGE OF ENGINEERING

In this section we find out the this is so, why the drawing is indispensable to technical communication We start out by examining drawings in general and then those necessary to complete the design and fabrication process.

4.1.1 When Words Are Not Enough

Let's explore the basic need for drawing then look at the three common types used in industry: mechanical architectural, and electronic.

Why Draw?

The ancient Egyptians spared themselves such mental anguish when (hey built the pyramids and other architectural wonders. They used draw-trigs sketched on papyrus to convey construction details.

Leonardo da Vinci was not only a superb artist but an excellent draftsman- He made detailed drawings of everything from a file-making device to a flying machine.

Today, the da Vinci's—drafters, that is—of the world are still hard at work. Many of them may use computer-aided design (CAD) to assist in the drafting process but in the end it is still a drawing that is produced If the classical Chinese thought a picture was worth a thousand words today's high-tech Engineers and technicians couldn't agree more.

From the Realistic to the Abstract

Whether it be in manufacturing, construction, or assembly, the appropriate drawings are designed to show how to make or build something. In manufacturing, mechanical *drawings based on* orthographic (right-angle) projection illustrate three dimensional objects on a two-dimensional surface (the drawing paper). *Although it takes special* training *to* read such drawings, they are, nevertheless, highly realistic, in that the objects as drawn look very much like the actual thing. Architectural drawings explain how a structure IS erected. These drawings are also fairly realistic, especially with regard to building elevations. Yet there is certainly an element of abstraction when symbols are used to represent everything from kitchen sinks to various types of concrete slabs.

Finally, there are electronic drawings. Illustrating the "electronics" of a project, these drawings are almost entirely abstract. A pictorial drawing of a capacitor or diode, for example, is rarely illustrated, and then only when absolutely necessary.

4.1.2 Electronic Fabrication Drawings

The design drawings we have seen already. The working schematic we will review momentarily. The breadboard drawing is a simple layout of components as they will appear in an experiment layout. The next four drawings are concerned with printed circuit boards. The first is a PC design layout; the second, an artwork drawing developed from the layout; the third, a fabrication drawing of the PC board itself; and the fourth, an assembly drawing to show how components are installed on the PC board. The sheet metal drawing is basically a two-dimensional layout of a metal chassis or an enclosure. The wiring diagram illuminates how off board components are connected. Finally the packaging drawing shows how the finished project will look.

The Ten Drawings: A Brief Explanation
Let's examine the purpose and characteristics of each drawing in more detail. As we do, take a moment to look at an example of each drawing.

1. Design Drawings. The three design drawings—the system (functional) diagram, circuit design sketch, and packaging plan—are preliminary drawings presented with the Concepts and Requirements Document. However, the circuit design sketch and packaging plan will be used to develop the more formal working schematic and final packaging drawing.

2. Working Schematic Drawing. The single most important drawing in the entire package, the working schematic illustrates in a precise and readable manner what the circuit consists of and how it is connected. It differs from the circuit design sketch in that the working schematic is clear and understandable enough for everyone to work from. The drawing is made up of component symbols and interconnecting lines.

3. Breadboard Drawing. This drawing shows the layout of components on a breadboard. It is usually drawn to scale on graph paper. Although not always necessary, when experimental layouts are complex, the inclusion of a breadboard drawing can save valuable experimenting time.

4. PC Board Design Layout Drawing. Drawn on 0.10 inch grid paper, often with colored pencils, this drawing shows a sketch of the component layout and trace patterns for the printed circuit board. Frequently drawn with the aid of a PC design layout template, the drawing may be produced at 1x or 2x scale.

5. PC Board Artwork. This drawing consists of the actual tape-up of the PC board design layout. Opaque (usually black) tape, donut pads, and various artwork component mounting configurations are pressed down on a clear acetate sheet that has been placed over the PC board design layout. It is from this artwork that a film negative will be produced to be used in etching the printed circuit boards.

6. PC Board Fabrication Drawing. Basically a standard mechanical drawing, this illustration shows haw the PC board is to be fabricated. All board dimensions, along

with hole sizes and quantities, are given. In addition, specification for PC board base material—copper-clad, solder coating, or silk screening (when applicable)—are provided on the drawing.

7. PC Assembly Drawing. Not unlike a mechanical assembly drawing, this type also shows where parts are placed and how they fit together. A template is used to lay out the electronic components over a screened image of the PC board traces. A parts list is included, often on the drawing itself.

8. Sheet Metal Drawing. The sheet metal drawing is a two-dimensional layout of the pattern required to produce a metal chassis or enclosure. Fold lines are indicated, as well as say holes, slots, and grooves a pictorial illustration is often included to show how the finished object looks when "folded together."

9. Wiring Diagram. This diagram shows how any "off-board" wiring and components are connected to each other and to the printed circuit board. In complex projects the wiring plan may be pictorial. In simple layouts it is strictly schematic, with wires shown as horizontal and vertical lines.

10. Final Packaging Drawing. This drawing shows how the final project will look from the outside. The Locations of all panel light, knobs, switches, and so on are shown and dimensioned if necessary. Any surface finishing treatment, such as paint or contact paper, is documented. Also, all appropriate lettering and other labeling are illustrated. Let's concentrate on the second, and most important of the drawings, the working schematic.

4.2 WORKING SCHEMATIC: THE CIRCUIT SCHEME

A schematic drawing, as noted earlier, shown what's connected to what—in other words. How electronic components are tied together we need to see how this is done. No electronics technician can get by within at least being able to read a schematic. Also, knowing how to draw one certainly wouldn't hurt. And because drawing a schematic is almost as easy to do as reading one, we'll show you how to do both.

4.2.1 Reading Schematic Drawings

Reading a schematic drawing involves knowing two things. You must recognize the schematic symbols for the components used, and must understand how interconnections are represented on the drawing. That's really all there is to it.

Component Schematic Drawings

1. A component that is variable, or adjustable, includes an arrow as an integral part of its symbol. For example, a potentiometer is a variable resistor. Note the arrow representing one of its three leads.

2. Arrows are also used to indicate the emitting or receiving of various forms of energy. If an arrow is pointing away from the symbol, the component gives off energy. Note the Light-emitting diode (LED). On the other hand, if the arrow points inward, toward the symbol, it means the component receives energy from an external source. The photocell (light -sensitive resistor) is a good illustration.

1. Sometimes component leads are identified with letter symbols. For example, the transistor symbols shown in Figure 4-1 have their emitter (E), base (B), and collector (C) leads noted.
Finally, note the schematic symbols for ground (Figure 4-2c). The symbol on the left is the most widely used and denotes earth or chassis ground. If more than one such symbol is present at various points in a schematic, there is a common connection, or return point, for the circuit.
The ground symbol to the right is for chassis ground only. If it is drawn connected to the ground line of a three-prong ac line cord (see schematic for the variable power supply), the chassis is then at earth ground potential. The connection adds a measure of safety should the chassis become "hot."

Connecting Schematic Symbols
On a schematic drawing, lines indicate wires or component leads. No connection is indicated by letting the lines cross. If a connection is intended, a dot is plated at the junction. The half-Loop to show no connection (Figure 4-2a) is no longer used-Notice, also (Figure 4-2b), that a connection dot is used only when three or more lines {wires or component leads) come together. It is not used when only two such wires (or leads) are connected

The Complete schematic
1. On the schematic drawing itself, each component is given its own letter-number reference designation to distinguish one from another. The letter identifies the class of component; the number, the sequence. For example, R5 indicates the fifth resistor in the circuit.

2. Generally, circuit signals flow from left to right, with inputs on the left and outputs on the right.
3- Generally, voltage potentials are shown with the highest voltage at the top of the sheet and the lowest at the bottom. When differential supplies are used, the positive bus is usually on the top of the schematic, ground (or common) in the middle, and the negative bus on the bottom.

4.2.2 To Read Is Not to Write

Just a there are those who can read better than they can write there are technicians who, while fully understanding a schematic, have some difficulty in drawing one. Yet, by using the proper tools and following correct procedures, practically anyone can produce a top-quality schematic drawing. Let's see how.

Drawing Procedures
In drawing schematics, problems arise most often when we target to include something. A biasing resistor was not inserted, a reference designation left off, or an IC pin number not indicated. To avoid these and similar mistakes, and to progress in a logical manner, it's best to Follow *a* step-by-step drawing procedure. Here, then, are ten steps to completing a schematic drawing (see Figure 4-3)

1. Border and Title Block. Draw a border and the paper at least ¼" From all outer edges. Then include a title block that provides for, at a minimum the name of the drawing, name of the drafter, approval signature date, scale, (if applicable), and drawing number. Make all lines wide and bold, hut not uneven and smudgy. If you have trouble making

your line work as even and sharp as it should be, consult the appropriate section of a good engineering drawing text.

2. Schematic Symbol. Draw the key (control) components first. Next draw the passive components, such as resistors and capacitors. Use the schematic template for both types.

3. Interconnections. Draw all interconnections with vertical or horizontal lines. Do not place a dot where lines cross but no connection is intended.

4. Connection Dots. Now "heavy up" all connection points (where three or more lines meet) with 1/16" to 1/8" dots. Such "dot holes" are usually op the schematic template.

FIGURE 4-1
Component schematic symbols

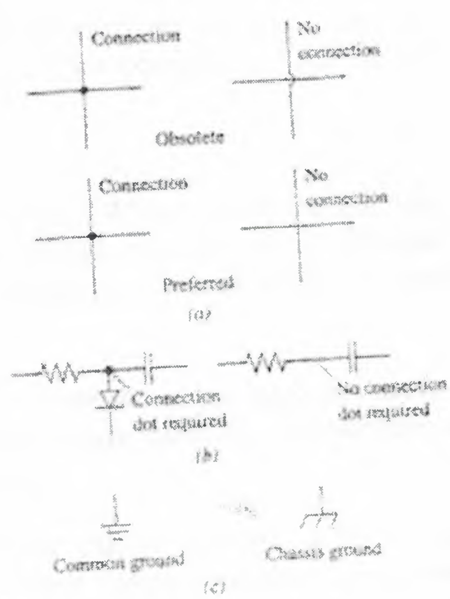

FIGURE 4-2
Connections on a schematic drawing

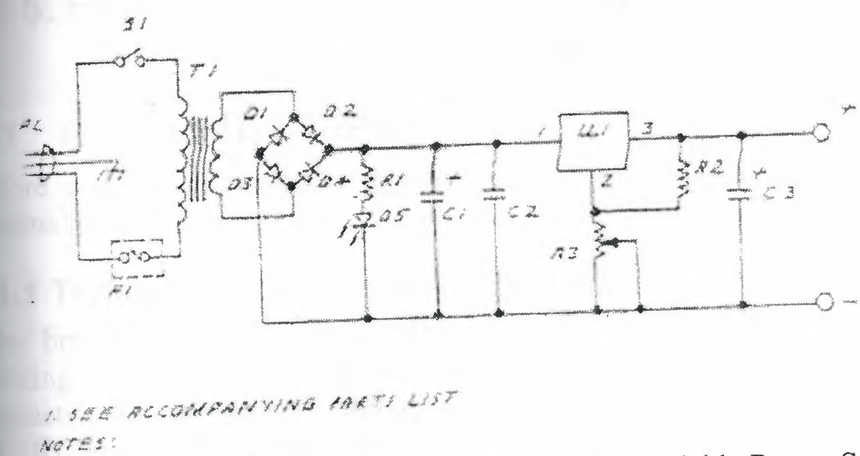

FIGURE 4-3 Working schematic. Variable Power Supply

5. Arrowheads it's time to put in all arrow-heads. They will be needed on energy-emitting and -receiving symbols, for example, LEDs and photodiodes, and on variable components, such as potentiometers and adjustable capacitors.

6. Reference Designation. Reference designations are very important and easy to mess up. Keep the letter-number combination on the same line. That is, don't put an R (the resistor) on one line and die 14 (the fourteenth resistor) on another. You should, however, place the resistance value, when shown (12 k for example), on a different line from the reference designation.

7- Pin Numbers and Lead Identifications.
This is another area where it's easy to forget something. When numbering the pins for ICs, voltage regulators and the like, make sure you include numbers. When designating component leads, such as the emitter, base, and collector of a transistor, is equally vigilant in including all identifications.

8. Drawing Notes. One way to start notes is from the bottom of the page and move up. The reason is obvious: may want to include additional notes later on. Another approach is to start from the upper right corner and move down.

9. Parts List. On very simple schematics, the parts list can be included on the drawing. With more complex circuits, heaver, a separate sheet listing electronic components, connectors, and all hardware items is required. In using a separate sheet, it is a good idea to begin the listing at the top of the sheet so that new parts can be added; it's easy to forget small items, such as a screw or heat sink.

10. Drawing Check. The only way to reduce
Mistakes and present as complete a drawing as possible is to check it over carefully.

5. Experimenting- Breadbroading to Prove Out the Design

5.1 *MAKING IT, STEP BY STEP*

Before clipping components together and powering up circuits, let's examine the reasons for bread-boarding and the skills necessary to do it.

5.1.1 Trying It Out Before Going All Out

Why breadboard? Why nut go all out, go for broke— now? After all, we have a working schematic, it looks good, and that means the project is sure to work. Call up production and tell them to tool up. Tell them to order the components and PC boards for 10,000 units. Why waste time? No need to experiment or build prototypes. Who knows where the competition may be? Have got to take a change.

But hold on a moment True, many a company has had just this kind of attitude. But notice the word"had" The surest route to catastrophic failure is to skip the bread boarding and prototyping stages and jump right into production. Every project, no matter how simple in design or concept, must be thoroughly analyzed and tested through the building of at least one breadboard and one prototype unit. Only then can consider mass production.

Proving out the Design

Electrons don't run around on the schematic drawing. A design may work in theory, but that simply isn't good enough. We need to see it work in practice. We need to prove *out* the design.

At this point we are not so much concerned with project layout and packaging hut with whether or not the circuit functions—that is, if the circuit design is valid. To determine that, need a quick and easy method of assembling the components into a functioning unit. Such a technique must allow us to change or substitute components quickly and easily. Minor and even major circuit modifications will often be required. We need to experiment with new designs; in other words, must breadboard.

Bread boarding is a circuit, assembly system that allows components and interconnections to be assembled and changed in their design stage easily. There are many bread boarding Systems to choose from, and shortly well be examining the six techniques must widely used. But first, let's see just what the differences are among breadbroading, prototyping, and production.

Bread boarding, Prototyping, Production; Where to Draw the Line

There is some disagreement as to where to draw the line between the bread boarding and prototyping stages. Is wire wrapping, for example, a bread-boarding or prototyping method? Actually, wire trapping is not only used in both of these stages but in the production stage as well. Solderless circuit board is definitely part of bread boarding, but many prototype projects also use it. To understand what methods work best at each stage, need to remember some definitions.

In bread boarding, it is essential to product easily temporary circuit using available parts. The prototype, although also easy to produce, must be rugged and capable of operating under severe conditions. The prototype should be suitable for complete evaluation of mechanical as well as electrical form, design, and performance. Approved parts must be used. In other words, the prototype must be completely representative of the final, mass produced equipment.

5.1.2 Breadbroad Documentation

At this stage a breadboard drawing and an Experiment Results Document are produced. The breadboard drawing is nothing more than a simple component layout to be used as a guide in assembling the breadboarded circuit The Experiment Results Document is a statement about what happened during the experimenting, or breadboarding, stage it can be as short as one paragraph or run into many pages of explanation.

5.2 *SOLDERING: THE TIE THAT BINDS*

For well over 50 years, using basically the same materials and essentially the same procedure, technicians have employed soldering as the "tie that binds" in electronic circuits. For a secure electrical and mechanical joint between components and wires, nothing has ever replaced it, or is likely to in the foreseeable future. As electronics technician will need to know how to solder and desolder, and how to do both well. At the production stage it is mandatory; it is a rare prototype project that does not contain at least a few solder joints, Furthermore, in many cases even breadboarding requires some soldering here and there.

In this section we begin by examining soldering characteristics. Also look at flux and its role in the soldering process. Next investigate the soldering iron, looking at basic Construction, various types, temperature characteristics, and soldering iron tips Then discuss the soldering process itself. Probe basic methods, the soldering printed circuit boards, point-to-point soldering, the characteristics of good and bad solder joints, and the need for and means of flux removal.

Finally, we examine desoldering equipment and techniques. Throughout, the discussion will be confined to hand soldering and desoldering. Explore "automatic" wave and dip soldering in Part 2 which deals with surface mount technology.

5.2.1 Solder: A Liquid Bond

Before we can learn to solder and desolder, must investigate solder itself: what it is and what it does. Than we need to examine the all-important role of flux in the soldering process.

Solder Characteristics

Solder i*s* an alloy (mixture) of tin and lead. The exact ratio of tin to lead determines its strength, hardness, and melting point. Solder can also be successfully alloyed with other metals such as copper, When the solder applied to copper melts, a thin film of copper is actually dissolved from the surface, forming an alloy that is part solder and part copper, with characteristics all its own. An intermetallic bond is formed between the parts. Thus, solder is not a glue, it does not stick component leads and copper traces together. It doesn't fuse them, as in welding, either. A new electrically conductive and mechanically strong material (alloy) is actually formed when the soldering process Lakes place.

Soldering Flux

Plain solder, that is, solder without any flux in its core, cannot adhere to metal surfaces. This is because such Surfaces are covered with oxide films. These films are created when oxygen combines with metal and forms an oxide layer. Rust is a good example.

Oxide films interfere with the solvent, or alloying, action that must take place for a good solder joint to form. The problem is that oxidation occurs rapidly when the temperature of metal is raised, as when applying the tip of a hot soldering iron to the joint to be soldered. The oxides formed must be removed immediately before soldering takes place.

Fluxes can dissolve oxides that have developed and prevent new ones from Forming when heat is applied, (They also lower surface tension and aid its wetting actions.) When rosin-core flux is used, oxides are brought to the surface while solder is molten. The left-over oxides and flux form a slag around the joint, which is later cleaned off with a suitable flux remover.

Fluxes used in soldering are almost always rosin based. Rosin is a mixture of organic acids Extracted from pine trees. At room temperature, these fluxes are noncorrosive. But as their temperature rises, they become "active," raising their corrosive Characteristics. It is this activity; however, that causes the deoxidizing action.

The corrosive nature of rosin-based solder is not a Problem, since its corrosive action takes place for only a short period of time as the solder joint is heated. When the joint is returned to room Temperature, Corrosion ceases. Nonetheless flux residue should he removed from a printed circuit board after soldering for at least three reason. One, the flux is sticky and may cause foreign particles to adhere to the board and create bridges and shorts. Two, with the flux removed, the printed circuit board is easier to inspect for defects. And, three, the board has a much better appearance when the flux is eliminated. Will look at how flux is removed shortly.

Flux, as have seen, is imbedded in solder (rosin-core solder). It is also available separately in paste or liquid form. The former is used when cleaning and tinning a soldering iron, the latter to add flux when needed in soldering and desoldering.

5.2.2 Soldering irons

Types of Soldering Irons

The conductive soldering iron is used to administer heat to the joint to be soldered. Solder is then applied to the heated connection (not to the iron), which melts the solder. In its simplest form, such an iron consists of a resistance heating unit (coil connected to the ac line), a heater block to act as a heat reservoir, and the metal soldering tip, which is a pipeline for heat flowing to the work.

There are two types of soldering irons that arc of particular interest to those in prototype work. The least-expensive all-around iron for electronic assembly is a 30-watt pencil-type with easily inter-changeable tips. Such an iron is easy to handle and, with proper care, can last many years. The iron should have a grounded tip to prevent electrostatic discharge (ESD), Prices range from under 10 dollars to over 50 dollars.

Soldering iron Temperature

Controlling and maintaining the tip temperature of soldering iron is important. Though not critical. A good iron will maintain its idle temperature with little variation. But when the soldering iron tip contacts the joint to be soldered, a myriad of factors act to cause temperature to vary. Relative thermal mass, determined by the mass of the metal to be heated, surface con*dition.* Oxides or contaminants covering the pads or leads, and thermal linkage, the area of contact between the metal tip and the work area, all play an important role, especially in production work. In prototype construction, however, where Soldering is done at a more leisurely pace, these factors are of less concern. Using a quality iron with a proper tip is the best way to ensure excellent heat transfer to the solder joint

Soldering Iron Tips
The purpose of the soldering iron core, must remember, is to transfer heat to the all-important tip. Let's see what these tips are made of, what different shapes are available, and how such tips should be maintained.

Tips may be either unplated copper or iron-plated (clad). While the former transfer the maximum amount of heat, they require frequent dressing and tinning since the tip will wear away with use as the solder dissolves some of the copper. Unplated copper tips are rarely used in prototype work.

Iron-plated tips demand only occasional surface cleaning and no traditional tinning, where the tip is filed clean before heating. With this type of tip, the entire surface is protected against scaling. Though iron-plated tips are more expensive than the unplated variety, their added coat is justified by lower maintenance. They are the choice for all prototype and moat production work.

The conical- and pyramid-style tips are used for general assembly and repair work.

Bevel designs allow for rapidly heat transfer and are used for soldering terminal pad connections on single-sided PC boards.

Chisel-style tips allow for large areas to be heated rapidly. They work well where point-to-point soldering is called for.

To some extent tip style is a matter of individual preference. The best approach is to maintain a variety of styles and experiment with each under varying soldering conditions.

Soldering iron tip maintenance is essential. A poorly maintained tip installed in the best soldering iron will render the entire tool useless. Here are some tips to follow in maintaining your soldering iron tips:

Make sure the tip is fully seated (Installed) into the heating element and tightly attached to the iron.

The tip should be removed daily to prevent an Oxidation scale from accumulating between the Heating element and the tip and set screw.

A plated tip should first be cleaned while cold with a line grade of steel wool until the surface id bright. The iron is then heated and solder applied as the tip warms up. This is known as surface tinning.

Before using the iron, wipe the tip lightly and quickly across a damp sponge to remove any oxides.

5.2.3 Soldering

Soldering- The Basic Procedure
To solder an electronic project, you will need, at a minimum, three basic items: a soldering iron, solder, and a damp sponge recall, the purpose of the iron is to heat the joint. It is the heat from the joint that melts the solder. To rid the iron of accumulated gook (contaminants), wipe it frequently on a damp sponge.

After cleaning the joint to be soldered of all dirt and grease, follow these four steps in completing any solder connection:

1. With the Iron, apply heat to the connection
2. Apply solder to the heated connection.

3. Remove the solder from the heated connection.
4. Remove the source of heat (the soldering iron).

Of the four steps, which should take a total of two to three seconds, the last one is perhaps the most critical In order to ensure a smooth, even wetting action of the solder, keep the iron on the joint a "long instant" after the solder has been removed. If the iron is taken away too quickly, the solder connection will not form well.

Soldering on Printed Circuit Boards
Soldering on a printed circuit board, particularly a single-sided board, requires special caution due to the heat sensitivity of the board pads and traces. Too much heat, applied with too much pressure, can quickly lift a pad or trace from the board laminate. To avoid this catastrophe, apply the iron tip with a light touch for no more than three seconds. The iron should rest on the pad rather than be pressed to it.

In soldering integrated circuits to a printed circuit board, a few specific steps are worth noting;

Heat damage to the component must be avoided. Try to complete the soldering of a given pin in no more than three seconds.

After inserting the IC, clinch two leads (pins) on opposite corners to hold the IC in place while soldering is completed.

When soldering the lead to the pad, touch the iron tip to one side of the joint while applying solder to the opposite side.

To avoid heat buildup when soldering a row of pins, alternate so that leads next lo each other are not soldered consecutively.

5.2.4 Desoldering

Regrettably, there comes a time when it is necessary *to* desolder, *not* just solder. When components fail, if have installed the wrong component, installed the right component but incorrectly, or when we just want to make changes or upgrades to a circuit desoldering is unavoidable. When it becomes necessary to do so, it is worth noting that the skills required in desoldering are every bit as demanding as those for soldering, especially when we are trying to save both the PC board and the electronic component. To remove electronic components from a circuit is not, however, the only reason desoldering is done. Desoldering is also required to eliminate potential shorts caused *by* solder balls, globs, bridges, and icicles. Furthermore, poor-quality connections resulting from fractured, overheated, or contaminated solder may necessitate desoldering. Even removing excess solder on script that prevents legible PC board identification is often dictated. Desoldering, as can see, is serious business. It demands our full study and attention.

Desoldering Braid
Desoldering braid is a loosely woven, flux impregnated, stranded braid of copper wire. A strip of the braid is placed over the solder joint and a soldering iron placed on top of the braid. The heat from the braid net only melts the solder but causes it to travel up the braid through capillary action. When a portion of the braid becomes clogged with solder, it is simply snipped off with diagonal cutters.

The techniques for removing solder from PC boards using desoldering braid are simple and straightforward. To begin with, always saturate the braid with liquid flux.

ther dip the braid in a jar of flux or brush the flux over the braid after you have laid it in place. To remove a solder bridge place the braid first on one trace and heat, then on the opposite trace and heat again.

5.3 PROJECT BREADBOARDING AND TROUBLESHOOTING

5.3.1 Breadboarding the Projects

The Variable Power Supply will be breadboarded using the solderless circuit board approach. However, any of the methods discussed could be used, although the wire-wrapping and the universal printed circuit board systems are not particularly applicable with these projects

Breadboarding the Variable Power Supply

Working from a breadboard drawing and a copy of the working schematic, start to build the circuit. The breadboard drawing takes only a few minutes to prepare. The tentative locations of all components are shown. Note how much alike the breadboard and schematic drawings are. This is a characteristic of breadboarding with solderless circuit board. Compare the breadboard drawing with a picture of the final layout and the value of a breadboard drawing quickly becomes apparent.

Regardless of the breadboarding method chosen, it is an excellent idea to trace over the schematic drawing with a colored pencil as you proceed in the actual project construction. As a component or wire is installed, color over the schematic symbol or line on a copy of the working schematic. This will allow seeing in an instant not only what have completed but what still have to do.

The following points are worth noting:

1. The transformer, line cord, and switch are not mounted directly on the solderless circuit board. Three wire nuts are used to connect these components: one to connect the line cord to one primary lead on T_1 another to connect the line cord to one end of S_1 and a third to connect the other end of S_1 to the remaining primary lend of T_1. Two wires have been soldered onto the terminals of S_1 to make the switch connections.
2. Diodes D1-D4 are arranged in a bridge, as shown in the schematic drawing.
3. One Lead of component D5, C1-C3, and R3 is con-netted to a common bus line, in this case the Negative bus.
4. Some soldering is required when wires have to be connected to components, such as switch S1 and potentiometer R3.
5. Tin the leads of all multistoried wires before inserting into solderless circuit board.

Before plugging in the project, place an ohm meter across the output terminals (+ and -). Adjust potentiometer R3 throughout its range, as do so. the meter should indicate approximately 390 to 5,000 ohms. If there is no variation in resistance, or the reading falls below 300 ohms, check for faulty wiring. Finally, double check diode polarity and that the transformer primary and secondary leads are not reserved.

If everything checks out, plug in the line cord and turn on switch S1. Does LED D5 light? If it does, with a voltmeter measure the output voltage across the negative and positive terminals while adjusting potentiometer R3. should get 0 to 15 V dc. If the LED does not light, or do not get the correct voltage output immediately unplug the project and read the section on troubleshooting.

5.3.2 Troubleshooting the Variable Power Supply

If the LED in the power supply does not light, it may be in backwards or it May he turned out. Check for both possibilities if the LED now lights, check the output voltage, as discussed earlier. If the LED still does not light, or the output voltage is incorrect, measure the voltages at the points indicated on the schematic and chart. Work forward, starting with points.

6. Prototyping- Project Packaging

6.1 CABINETS: THE DESIGN PHASE

The Buy/Make Decision
Numerous companies sell many types of ready-made chassis, enclosures, boxes, cabinets, and panels constructed of metal, plastic, or wood. The advantages of purchasing a completed box are obvious: A great deal of construction time is saved and the product is usually of high quality. Yet even with a purchased cabinet, some fabrication on part will most likely be required. Drilling holes and punching or cutting slots are often necessary. Performing these operations "in the fold"—that is, with the box already bent and formed—is not easy. This factor needs to be considered when deciding to buy or make.

Although buying a formed cabinet for the prototype project has its advantages. If want complete control over the design, fabrication, and finish of project housing, will need to make it. Furthermore, the learning experience and skills acquired in producing a box from scratch will be of great value to any prospective technician. And when future boss says, "even built the cabinet too." will know that you made the right buy/make decision.

Design Considerations
The overriding design consideration has to do with purpose. Specifically, what is the cabinet to be used for? A power supply? What? All subsequent design criteria stem from this one factor. With purpose or intent uppermost in mind, consider such element as materials, size and shape, ease of fabrication, safety of use, appearance, and cost. As examine each item in turn, note how interrelated each factor is, and how planning for one often requires thinking about all the others.

Materials. Most cabinets used to house prototype project are made of metal, either cold-rolled steel or, more commonly, aluminum. Plastic is used when electrical safety is of primary concern and wood when appearance is of chief importance. Both plastic and wood, however, are fairly difficult to work with. Unless other considerations dominate, aluminum sheet metal serves most purposes quite well.

Size *and Shape*. Size, of course, is determined primarily by the bulk of electronic circuitry. The cabinet-should be no larger than necessary to house and mount the electronics. Yet consideration must also he given to such factors as access to component parts, heat dissipation, and project handling.

In choosing the cabinet shape, thought must be given not only to appearance but to function and ease of repair and fabrication. Some of the more common cabinet styled one can either buy or make. It is important not to over design by creating a fancy-looking box. As with most design consideration, the simpler the better is the rule to follow.

Ease of Fabrication. The "keep it simple" philosophy is especially relevant to cabinet fabrication. In reference to sheet metal, the various cuts, holes, and bends can get out of hand if do not careful. In fact, too many bends may simply be impossible to achieve. The rule, again, is only what is necessary to accomplish the task.

Safety of Use. Two considerations are important here. We want the cabinet to protect the project and to protect us from the project. The box should be deigned and fabricated such that It can support the various circuit components and provide ventilation if necessary. In turn, if dangerous currents are present, we want the cabinet to prevent us, at least under normal circumstances from reaching them.

6.2 CABINETS: THE FABRICATION PROCESS

It is time to go into the shop and build a cabinet. First, will see how the sheet metal is cut and how holes are drilled, punched, or notched. Then will find out how the sheet metal is folded into place.

6.2.1 Working in the Flat: Making Holes

Making Round Holes: Drilling
We can make round holes in the sheet metal by drilling or punching them. Generally, holes up to ¼ inch in diameter are drilled; anything larger is punched.

The procedure for drilling a small hole in sheet metal is as follows:
1. Center punch all holes that require drilling. With the use of a center punch and hammer, make a small indentation at the center of the hole to be drilled. One Light tap of the hammer is all that is needed to make the mark. The purpose of this indentation is to provide a "home" for the drill bit—to prevent it from "walking" (moving off center) at the initial moment of drill and metal contact.
2. Back up the sheet metal with a piece of wood, at least 3/8 inch thick. Not only does this provide a solid surface for the drill bit to enter after it has penetrated the sheet metal but it also reduces the severity of any burrs that may form.
3. Fasten the sheet metal and wood backing securely to the drill press table, preferably with a C-clamp.
4. Drill the hole using appropriate drill speed and feed. Generally, the larger the hole, the slower the drill speed. Drill feed should always be at a slow, steady pace and extend at least a quarter-inch into the wood backing. If holes need to be enlarged slight, a tapered hand reamer can be used for that purpose.

All holes, when drilled, will form burrs on one or both sides of the sheet metal. These sharp, jagged protrusions must be removed. To remove them, use a toll designed specifically for this purpose, or a large drill bit wrapped with electrical tape to prevent cutting your hand A Dremel Moto-tool with a small grinding wheel also does an excellent job of deburring. If burrs still remain, they may need to be cleaned up with a round-nose file.

Making Pound Holes: Punching
For round holes larger than ¼ inch, good, clean (burr-free) holes can be cut with either a chassis punch or a multistation turret punch. Let's examine each tool.

The chassis punch comes in many sizes, from 3/8" to more than 2" in diameter. The chassis punch consists of three parts: *a* punch die, and draw screw. Explaining how the chassis punch is used will also describe how it works

1. A hole is drilled in the sheet metal large enough to accept the draw screw.
2. The top end of the chassis punch (known simply as the punch) is secured in a vise. It has two parallel flats that make it easy to grip between the jaws of the vise.
3. The sheet metal is positioned over the punch at the point where the hole is to be formed.
4. The die is positioned over the sheet metal in line with the punch.
5. The draw screw is inserted through the die, the sheet metal, and into the punch.

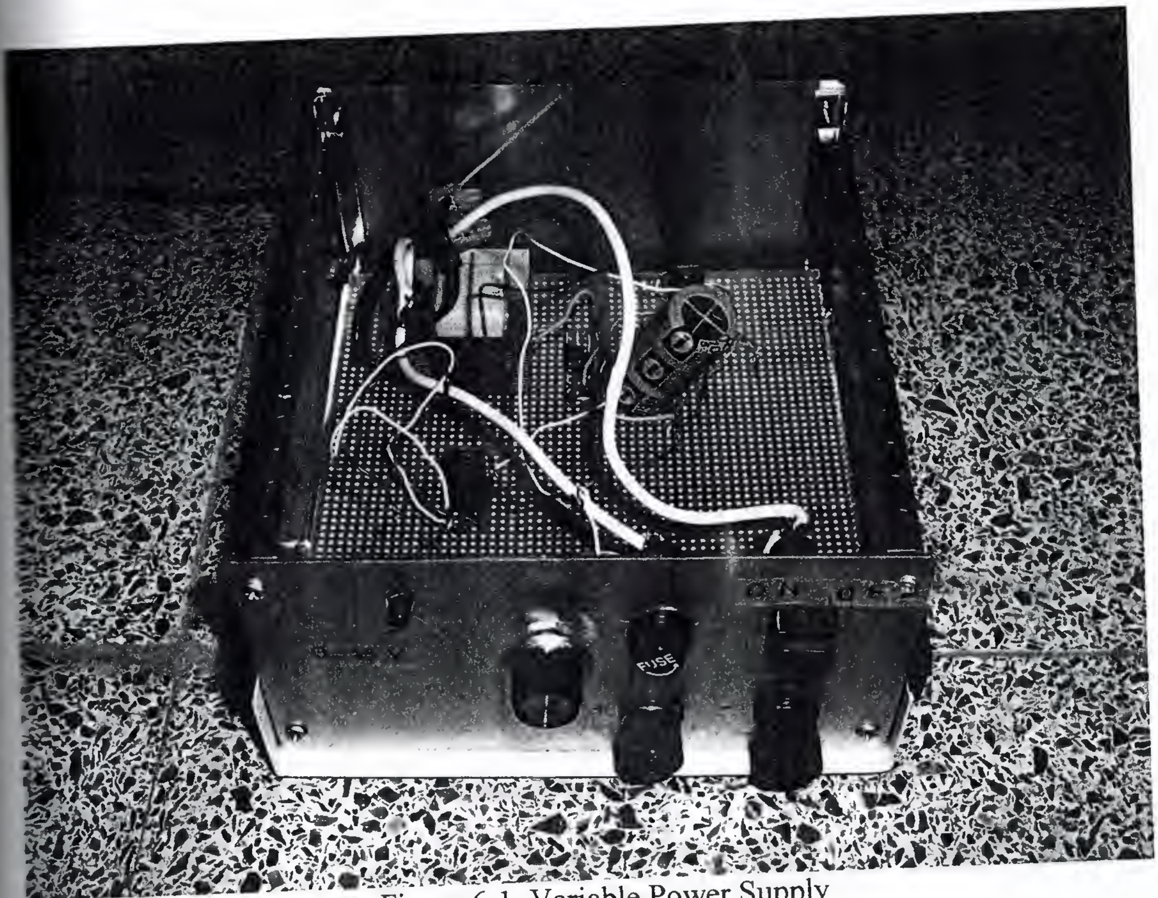

Figure 6-1 Variable Power Supply

6. The draw screw is tightened down with a wrench.

As the screw is turned, it draws the die and punch together when the sheet metal pops through, the screw is loosened and the die and punch separated. The sheet metal is then lifted off, and the blank punched piece of metal is extracted from the punch. The cutting action that results from this type of punching operation ordinarily produces a clean and burr-free hole.

The turret punch contains many different size die and punch combinations that can easily be swung into place for instant cutting. In addition to the advantage of having so many punches available at the swing of a turret, with this machine no predrilling of a draw screw holes of a draw turret punch. However, all holes produced with turret punch should still be center punched to allow the die to align correctly.
Note also that same large-diameter hole saws are on the market for use on aluminum.

And finally operational testing allowed us to determine the Variable Power Supply project was functioning Correctly. (Figure 6-1)

CONCLUSION

The traditional electronics course and how the lecture and lab approach to learning can be supplemented with an electronics fabrication experience were discussed. By examining just what it is electronics technicians do, an appreciation of the need for learning how to design, build, troubleshoot, and document a complete prototype project was gained.

The tools of the trade, both on the board and on the bench, were explored. Examined the drafting table, along with the materials that go with it. The basic equipment necessary to make schematic drawings was described, as well as what is needed to produce the design layout and artwork for printed circuit board fabrication. Finally, considered the workbench and its requirements in term of space, size, construction, and lighting and power needs. Concluded with an inventory of the tools required for mechanical and electronics fabrication.

Just why it is so important to care about safety. Then, after looking at what body parts are susceptible to harm, focused on where the danger lies. Examined the risks related to electrical shock, toxic and hazardous chemicals, the misuse of hand and power tools, the dangers of static electricity to projects, and industry-wide environmental concerns.

The fundamentals of electronic design and the two-step design process. Defined an electronic system as one that has three parts: input transducer, electronic circuit and output transducer. Those circuits are made up of active and passive electronic components. The former control electrons by switching or regulating them; the latter help the active and passive electronic components. Found out that circuits, too, can be classified as switching or regulating. When the circuits are coupled with input and output transducers, components that change one form of energy into another have a complete electronic system.

Look at design and designers, considering the types of electronic products and services created to solve particular needs and the kind of people who do the creating and what type of training they need.

The fundamentals of electronic design and the two-step design process. An electronic system as one that has three parts: input transducer, electronic circuit, and output transducer. That circuits are made up to active and passive electronic components. The former control electrons by switching or regulating them; the latter help the active components do their job. When the circuits are coupled with input and output transducers, components that change one form of energy into another.

The former states the project goals, objectives, and responsibilities, as well as describing the project theory of operation.

The cut-slash-and-hook method is still used when assembling high circuits, such as large power supplies. Solderless wiring terminals can do the same thing, only without the need to solder. We explored ways to assemble modern circuits using solderless circuit board and wire wrapping and looked at the universal printed circuit board as a way to enhance the wire-wrapping technique.

REFERENCES

[1] Ronald A. Reis, "Electronic Project Design and Fabrication", Third Edition, Prentice Hall, 1995

[2] Fakhreddin Mamedov,Özgür Cemal Özerdem, "Handbook EE 400", Neu, 2001

[3] http://www.web-ee.com/primers/files/AN-556.pdf

[4] http://focus.ti.com/lit/ds/symlink/lm317.pdf

[5] http://sosnick.uchicago.edu/LM317_Spec_Sheet.pdf

[6] http://services.eng.uts.edu.au/~venkat/pe_html/ch05s5/ch05s5p1.htm

[7] http://www.discovercircuits.com/P/pwr-variable.htm

[8] http://services.eng.uts.edu.au/~venkat/pe_html/ch01/ch01_p1.htm