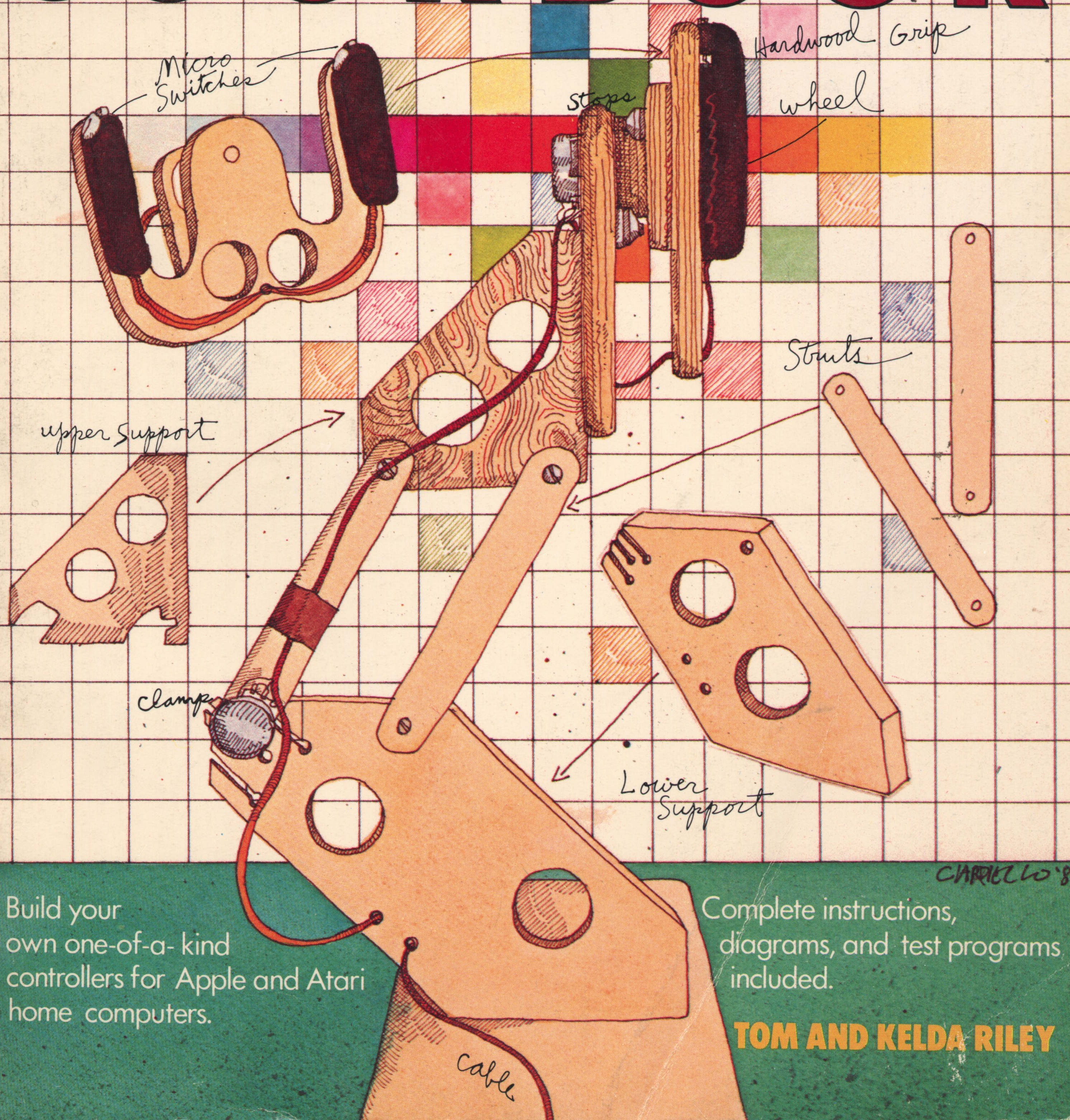
THE COMPUTER CONTROLLER COOKBOOK



Build your own one-of-a- kind controllers for Apple and Atari home computers.

Complete instructions, diagrams, and test programs included.

TOM AND KELDA RILEY

THE COMPUTER CONTROLLER COOKBOOK

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The Computer Controller Cookbook

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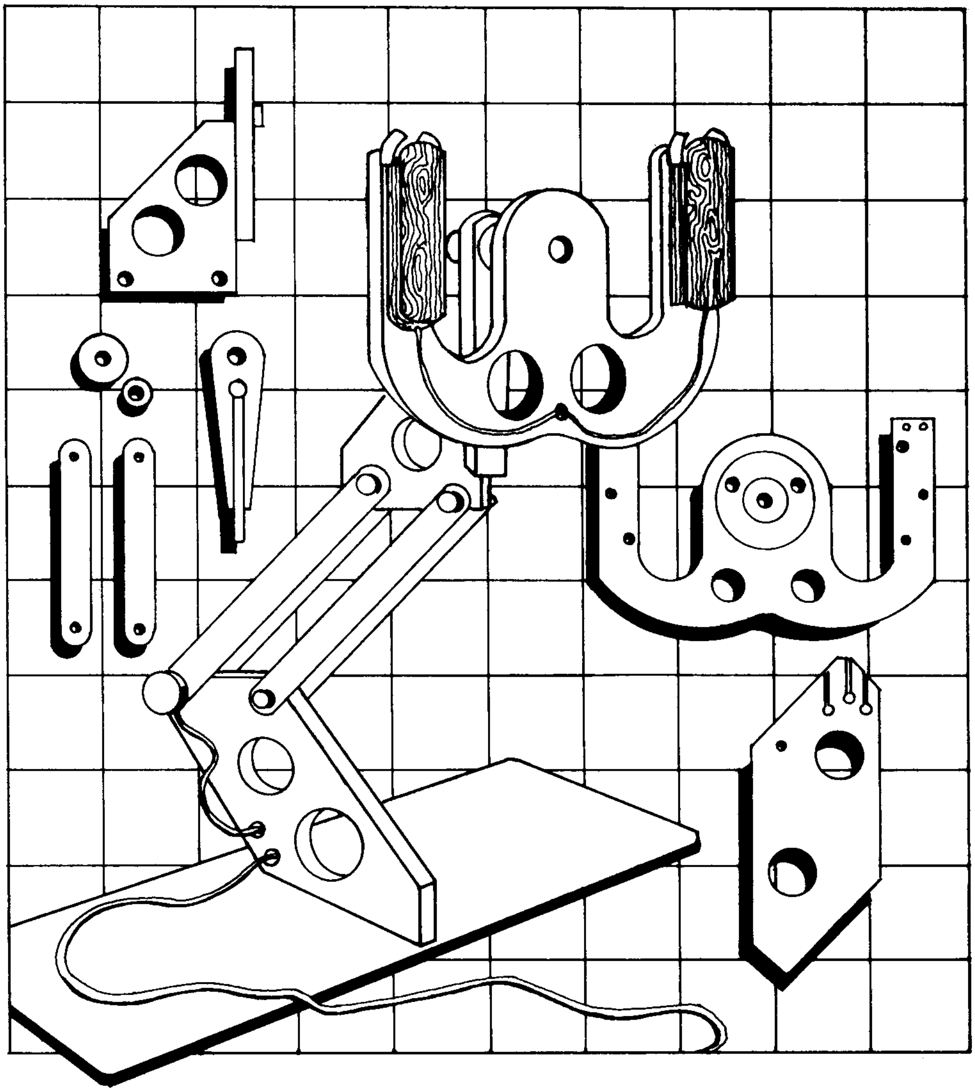


Introduction

The idea of building computer hardware yourself may seem a little scary at first. After all, personal computers are now as powerful and sophisticated as the biggest computers of only a few years ago. How can a novice presume to build something to be attached to such a valuable and complicated machine?

Unfortunately, while books, classes, and tutorials on how to use software packages are everywhere, instructions on how to use, build, or repair hardware are not. Most people's experience with hardware is limited to reading instructions on how to hook up cables or stick connectors in the right slots. This book is designed to teach you to build mechanical and electronic controllers for your personal computer. By "controllers" we mean all those devices—including joysticks, paddles, and custom circuits—used to regulate a computer's activities.

Constructing the simple and clearly explained projects in this book can serve as an excellent introduction to the hardware side of computer technology. We believe that you will gain tremendous confidence in your ability to use computers when you realize that the magical box on your desk is a collection of physical parts that do understandable things in the real world.

WHY STUDY HARDWARE?

Experience with electronic hardware is important in any field that uses computers and other electronic instruments. A career in traditionally academic disciplines like physics, astronomy, experimental psychology, or medicine can be advanced by the ability to assemble or repair electronic or computer-controlled instruments. All too often someone with no experience with soldering has to make cables or circuits for expensive experimental instruments and then be judged on how well the equipment operates.

Even if your experience with electronic equipment is limited to plugging it in, it is important to be familiar with the principles and techniques of electronics. You may not always be able to depend on others to do your hardware work for you. If you use electronic equipment in your profession, you should be competent at working with it.

The ability to read and work with schematics (the graphic representations of electronic circuits) is a good example of the kind of skill we're talking about. You can't learn to read schematics by simply unfolding the schematic at the back of your computer's reference manual and reading through it. You have to start with simple circuits (and simple schematics), like those for the game controllers in this book. As your schematic-reading ability develops you'll be amazed at how much information you'll be able to get from a dog-eared second-generation photocopy of a schematic with text written in French (or Greek).

You may have noticed that the controller projects have a number of features in common with the new discipline of robotics. Both depend on the construction of mechanical devices and the interconnection of these devices with computers. At present, the cost of experimenting with even the simplest robots is too high for the average person. Working on controller projects like the Airplane Wheel and the Super Stick will give you a good introduction to the basic electronic and mechanical skills required for robotics at a modest cost.

WHO CAN USE THIS BOOK?

A good beginner's hardware project should be useful, easy to build and test, inexpensive, and carefully explained. We've included everything you need to complete the controllers: detailed drawings, parts lists, step-by-step instructions, information on where to get parts (and how much you can expect to pay), and programs to test the finished projects.

We've included a chapter on construction and an electronics tutorial (including an introduction to soldering techniques) to help those who have little or no workshop experience.

You don't need an elaborate home workshop to build these controllers. If you can use hand tools and common power tools, you should be able to tackle the necessary wood, plastic, and metal work. In the few cases where more elaborate tools are necessary (for example, one version of the Super Stick calls for metal machining tools), the special requirements are clearly noted.

Completing these projects doesn't require extensive knowledge of electronics, either. If you have put together any kind of electronics kit and can do elementary soldering, you should have no trouble with the circuits.

Parents may want to help their children build these controllers. Most kids are enthusiastic about using these controllers, but would probably need some assistance in constructing them. Here's your chance to work with your child on a project you'll both find challenging and enjoyable. Some of the projects would make great gifts for younger children.

These designs are also excellent projects for students in high school or adult education shop classes. They are challenging, but not too difficult for a student with proper supervision, instruction, and access to the right tools. It seems fairly evident that today's students would be much more interested in building a Race Car Steering Wheel than a spice rack.

REQUIREMENTS FOR USING THIS BOOK

All of the projects have been built, tested, and used as controllers for our Apple II Plus computer. Fortunately, the game controller circuits for most home computers are similar, and these designs can be adapted to most home computers that have a game port. We've given many suggestions for how to do this in the individual chapters, and a special section of the Electronics Tutorial, "Adapting the Controllers to Different Computers," goes into the subject in more detail. Specific instructions are given for the Atari, Commodore VIC-20, IBM Personal Computer, and Radio Shack systems. Chapter 9, "Converters: Between Apple and Atari," concentrates on conversions between the two machines we've had the most experience with. Because these machines use two of the most frequently encountered designs for game controllers, this chapter provides an excellent example of machine-to-machine adaptations.

We've also included six programs (written in Applesoft Basic) that you can use to test the completed controllers. All but two of the programs can easily be converted into the version of Basic available for different machines. The Drawing program contains graphics handling functions, and the Digitizer contains disk handling instructions, that are specific to the Apple computer.

HOW TO USE THIS BOOK

This workbook is designed to teach you basic electronic and mechanical skills by giving you step-by-step instructions. The best way to use this book is to build the projects, not just read about them.

A good way to start, though, is by reading through the "Construction Notes" and the "Electronics Tutorial" (chapters 13 and 14). These two chapters explain the basic design of the controller electronics, and the methods we'll use to construct the different projects. Read these sections carefully—making sure that you understand them. The information they contain can be critical when you're knee-deep in a project.

Pay special attention to these instructions regarding safety. Make sure that what you're doing or the way you're doing it can't injure you or your machine. This is especially true for the projects that use AC power. If you don't know what you're doing, or if you're unwilling to follow the simple guidelines we've provided, stay away from these projects.

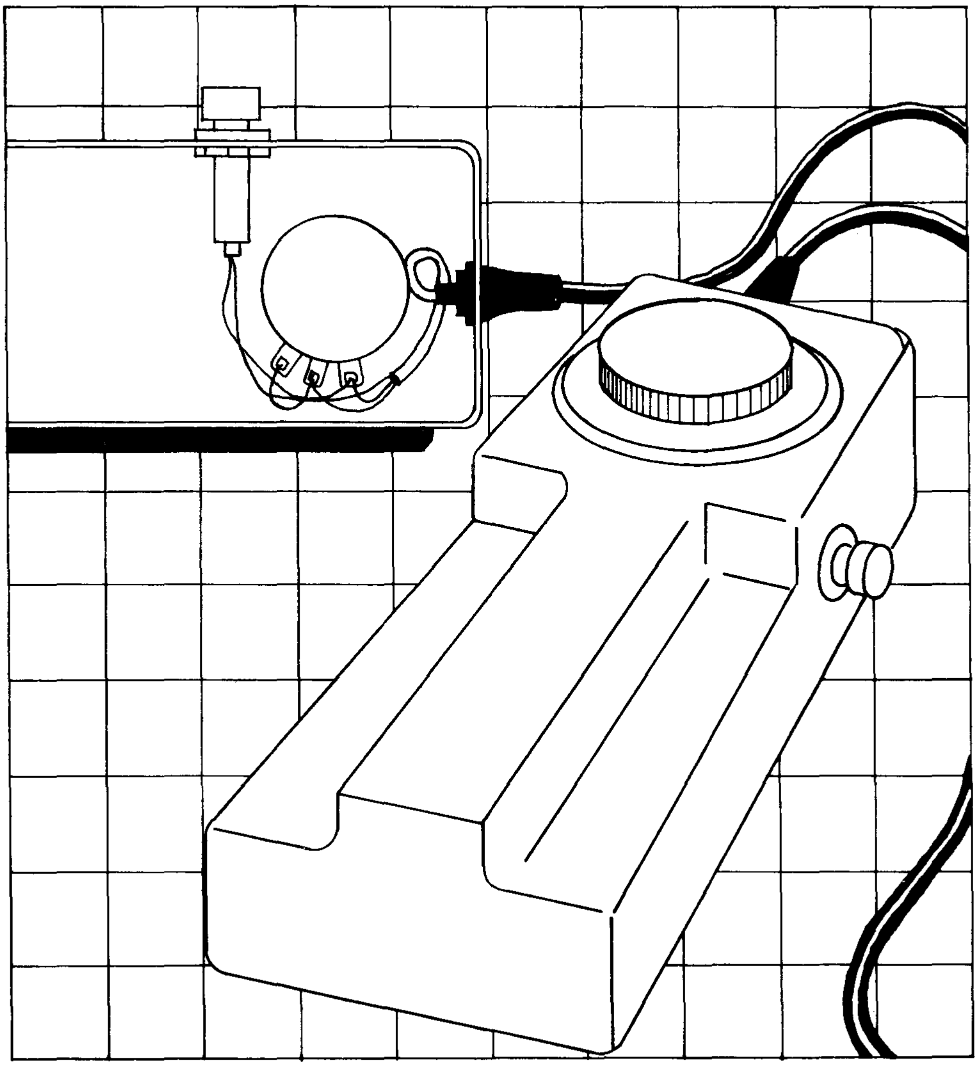
Just about everyone's got a few paddles or joysticks around that don't work quite as well as they used to. Turn to chapter 1, "Rebuilding Paddles and Joysticks," and give your controllers a tune-up. Working with familiar commercial hardware is a good introduction to the skills and tools you'll need to carry out the more complicated projects that follow.

If you run into problems with the rebuilding, go back and reread the chapters on construction and electronics. Try to figure out what you did wrong, or what you didn't understand. If you still feel unclear or unsure about what you're trying to do, it may be time to try other books or magazines, friends with electronics or mechanical experience, or a home computer user's group for further instructions or explanations.

When you feel ready to progress to a more difficult project, look through the book and pick the project that really catches your eye—and plunge right in! Maybe you've always wanted to be able to play Star Invaders while eating a cheeseburger—the Foot Pedals make it possible! Or maybe you're intrigued by controllers that can work from across the room—try building the Sound Pushbutton. You goal is to learn how to build your own hardware to control your "personal" computer, so it makes sense to choose projects that appeal to you personally.

Not every project you build will be a smashing success—every learning process involves at least a few mistakes. As you gain experience in the necessary construction skills, your projects will become more and more impressive—and you will become more and more confident in your ability to get the most enjoyment out of your "magic box."

Tom Riley
Kelda Riley



1 Rebuilding Paddles and Joysticks

The easiest way to learn how to build controllers for your home computer is by rebuilding a commercial paddle or joystick. This is a useful training exercise and, in many cases, a necessary project because commercial paddles, which may cost up to $60, are not built very substantially, and they often don't stand up to the rigorous workouts they get.

Commercial paddles can fail for several reasons: wires can be broken inside the cables, connectors can be bent or crushed, the potentiometer wipers can fail to make contact, or the pushbuttons can break mechanically. Virtually all of these failures are due to the breakage of weak parts that any competent designer would have realized were inadequate for their intended use. This chapter will concentrate on teaching you to fix this kind of controller failure. Fortunately, most of these breakdowns are easily diagnosed and repaired. Doing so will provide a good lesson in basic electronics.

TYPES OF CONTROLS

We have an Apple II Plus Computer; most of the controls in this book were designed and tested for that machine. We will attempt, however, to point out the changes in the designs that are necessary to adapt them for other computers whenever we have the appropriate information. Most home computers have similar electronic circuits for their game controls.

Controls come in two general types: digital and analog. A digital control (like the Atari paddle) consists of a group of pushbuttons. An analog control, made up of potentiometers that can be adjusted uniformly over a range, is much more versatile.

Most of the projects in this book will feature analog controls, but we will throw in a couple of projects for digital controllers just for good measure. The various digital paddles are almost identical, but there are two distinct types of analog controls. They differ in the cost of their components and in their electrical wiring, and we will point out these differences.

A WIZARD FOUND THESE PADDLES AND RESURRECTED THEM

Strange as it may seem, it is cheaper, and the final product is better, if you rebuild paddles rather than buy new ones. Let's see what it would take to reconstruct a beat-up pair of Apple paddles and end up with units that are better than the originals. Let's assume that there are broken wires in the cables, that the plug has a missing pin, and that one of the pushbuttons and both of the potentiometers are broken.

The heart of the paddle is the potentiometer (pot), the electrical component that is located beneath the knob and controls the adjustment range. (See the Electronics Tutorial in Chapter 14 for more complete explanations of the different electronic components used in the projects.) The maximum resistance of the pot is measured in ohms. The Apple, unfortunately, uses a paddle pot with a value of 150K ohms (K indicates thousands).

Pots of this value are often hard to locate. Other computer manufacturers use much more common values, like 100K ohms and 1 meg-ohm, for their paddle pots. In order to rebuild the paddles you will need to buy two new pots. (The information in the section on correction capacitors demonstrates that it is possible, though somewhat complicated, to use lower values for the paddle pot.)

You can obtain decent pots from mail-order electronics houses or from local electronics supply stores that sell to the public (look for ads for the latter in your local Yellow Pages). Radio Shack pots are of such poor manufacture that we cannot recommend them. Pots advertised as Mil Spec (built to military specification) are usually excellent, but the 150K value is rare.

A good pot will be completely sealed, will feel very smooth mechanically, and will be linear, i.e. a graph of how far the knob is turned versus the resulting change in resistance will be a straight line. Most good pots will have quarter-inch round stems. If you want to use the knobs from the Apple paddle, you will have to file the shaft flat on one side.

The next item on our agenda is the paddle pushbutton, often referred to as the FIRE button. A good pushbutton should make a click that can be heard and felt. The button should be about 3/8-inch in diameter so that using it doesn't tire your finger. A good quality pushbutton switch will cost up to $3. Many of the better ones are slightly larger than the factory originals, so you may have to enlarge or move the hole.

Since the index finger can control the FIRE button faster and more precisely than the thumb, you may want to move the switch to the back of the paddle where it can be pressed with the index finger when the paddle is held in either hand.

The cable is also a critical component of the paddle. The wires can be small, but the cable must be mechanically sound and quite flexible. This project requires two cables (3-wire, 3-conductor), each about five feet long. We have found that telephone modular cable with four fine, multistranded wires is good for building paddles. You can purchase satisfactory telephone cable from Radio Shack. You can also weave several individual wires into a cable with a Boy Scout rope-making machine or pull #26 wires inside aquarium tubing. Both of these procedures have worked for us in various projects.

Replacing the plug is another important part of rebuilding the paddle. On the Apple, the plug is a standard DIP (Dual Inline Package) plug. It can easily be made from a device called a header, or component carrier, at a cost of about $1.25. A header looks something like a standard chip, but has a row of tiny forks to which the individual wires are soldered. Whenever you are soldering on this device, plug it into a loose socket so that the pins will be held straight and will not loosen in the plastic.

MECHANICAL REBUILDING

You will note in figure 1-1 that several mechanical changes were made to the paddle case. First, the new pots were mounted and, if necessary, filed flat to accept the knob. The new switches were mounted in the original holes; you can relocate them if you want to. Paper labels clearly identifying the paddle number were put on the front of the case and covered with transparent tape. A line was drawn on the knob with a felt-tip marker to indicate the amount of turn.

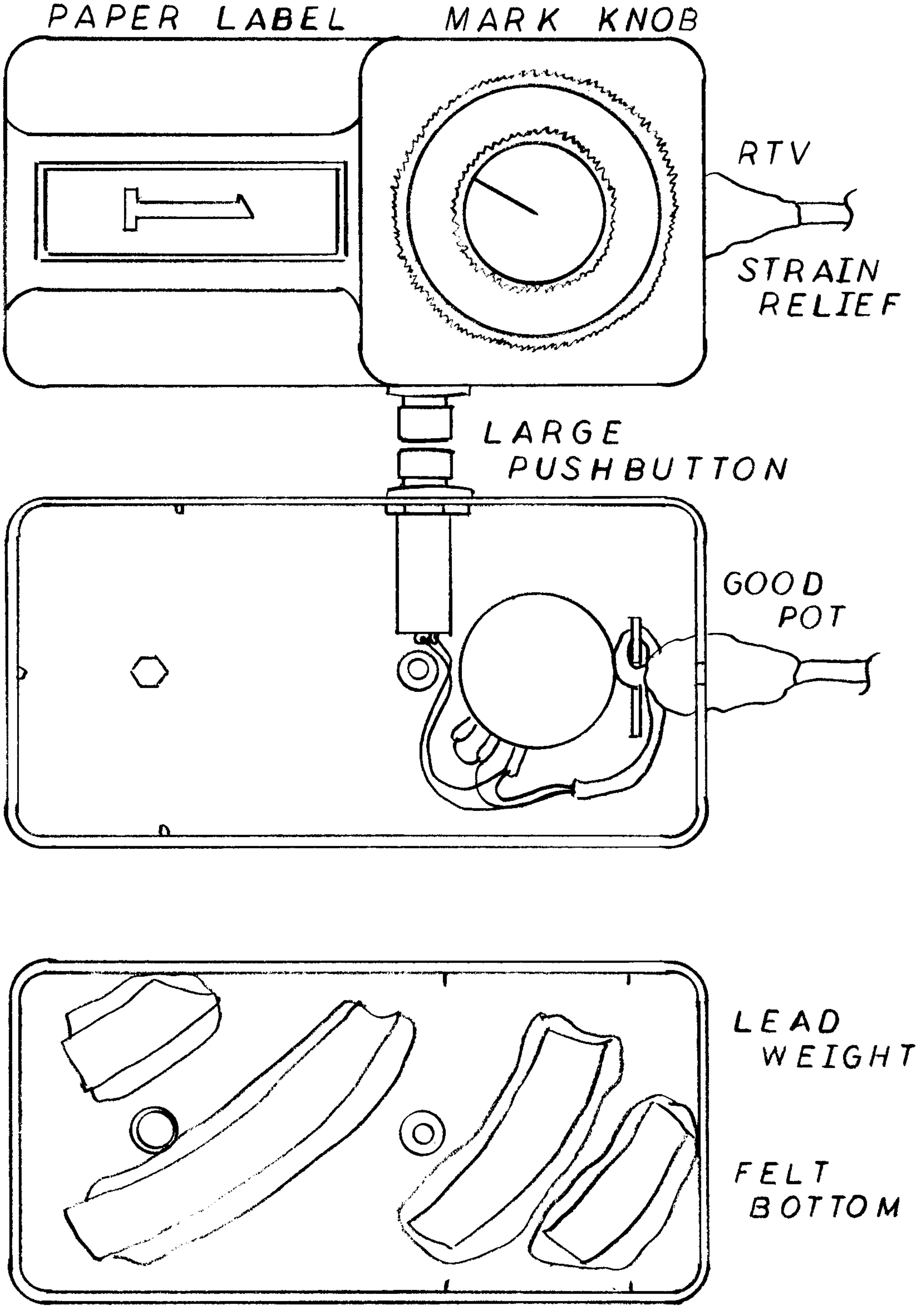
To give the paddle a solid feel, weights were glued into the bottom half of the case. We used lead wheel weights that had fallen off automobile wheels; they were scavenged on bicycling trips. Fishing weights would also serve the purpose. Such weights can be installed with either epoxy or silicone sealant. We covered the bottom of the paddle with felt, attaching it with rubber cement, to further improve the feel and insure that the paddle will not scratch furniture. In addition, it may be necessary to enlarge the notch for the cable, particularly if you use telephone cable.

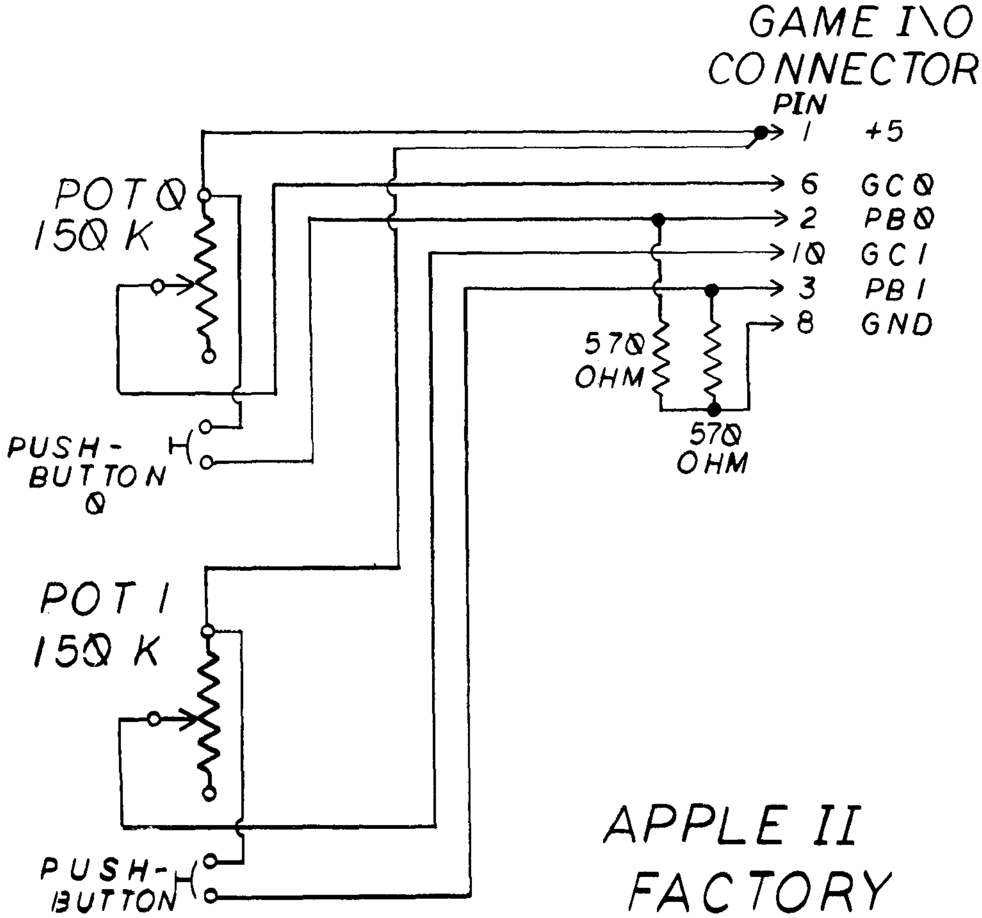
ELECTRICAL WIRING

Figure 1-2 shows the standard schematic for an Apple paddle. You may want to refer to page 100 of the *Apple II Reference Manual* for

REBUILT PADDLES

FIG. 1-1





APPLE II
FACTORY
GAME
CONTROLLER
SCHEMATIC
FIG. 1-2

more details. Note that two resistors from the original paddle, with a value of 570 ohms each, are mounted in the game connector. You may use resistors of any value from 570 to 1000 ohms, rated at 1/4 watt and 5% tolerance.

You should do the soldering with a small pencil-type iron of from 25 to 42 watts and resin-core soldering. The use of acid-core solder on electronic equipment will destroy it forever and always—no resurrection is possible.

CHECK AND DOUBLE CHECK

The professional procedure for making up a circuit from the schematic requires two photocopies of the schematic drawing and a colored pencil. As you solder the connection, neatly color in each connector and wire on the first copy of the schematic. When everything is colored in, you are finished.

The second copy is used for the test. When your work is complete, take the fresh copy of the drawing and, with a multimeter, carefully check each line for continuity, coloring it in on the drawing. You will often find that you have missed soldering a wire or two in the circuit.

SOLDERING

You may want to unbolt the potentiometer and the pushbutton to make soldering easier. Cut the cables to length and very carefully strip back the outer insulation. Be especially careful not to nick the wires. A small pair of wire strippers, the type that look like pliers and have an adjustment bolt, are best for this job.

If you use telephone modular cable, you will find that you have four wires, one more than is necessary. The best use for this extra wire is to double up and use two wires for the line from pin 1 (the +5 volt power supply), which goes to one side of the pot and one side of the switch. This will reduce the chance of the pushbutton affecting the pot reading.

You will note that figure 1-1 also shows a jumper between the unused leg of the pot and the center terminal. This is considered good electronic practice and helps performance somewhat when the pot begins to wear. If the pushbutton has three terminals, be sure to use the pair marked C (common) and N.O. (normally open).

To attach the header, strip back the insulation from the cable and expose the wires, trim them neatly to the length required, and tin about 1/8-inch of bare wire on each with solder. Plug the header into an empty socket and locate the mark for pin 1. The cables usually are fed in from the pin 8 end to make them easy to plug into the Apple. Now you can fit the wires into the tiny forks, holding them with a pair of long-nose pliers, and solder them in place.

Clip off the excess wire with a small pair of diagonal cutters. Place the two pull-down resistors into the header, shortening and bending their leads to fit the forks precisely. Hold the wires with long-nose pliers, not your fingers, while you are soldering.

If you have a multimeter, you can now check out your work without the risk of plugging it into the computer. Put it on a low ohms scale and measure for continuity between the pins on the connector and the appropriate points indicated in figure 1-2. In addition, measure from pin 1, the +5 supply, to pin 8, the ground, to insure that impedance is greater than 50 ohms, and that it remains greater than 50 ohms for all settings of the pot and all pushbutton combinations. It is a good idea to have a friend check your work for you. In any case, checking it three times usually insures correctness.

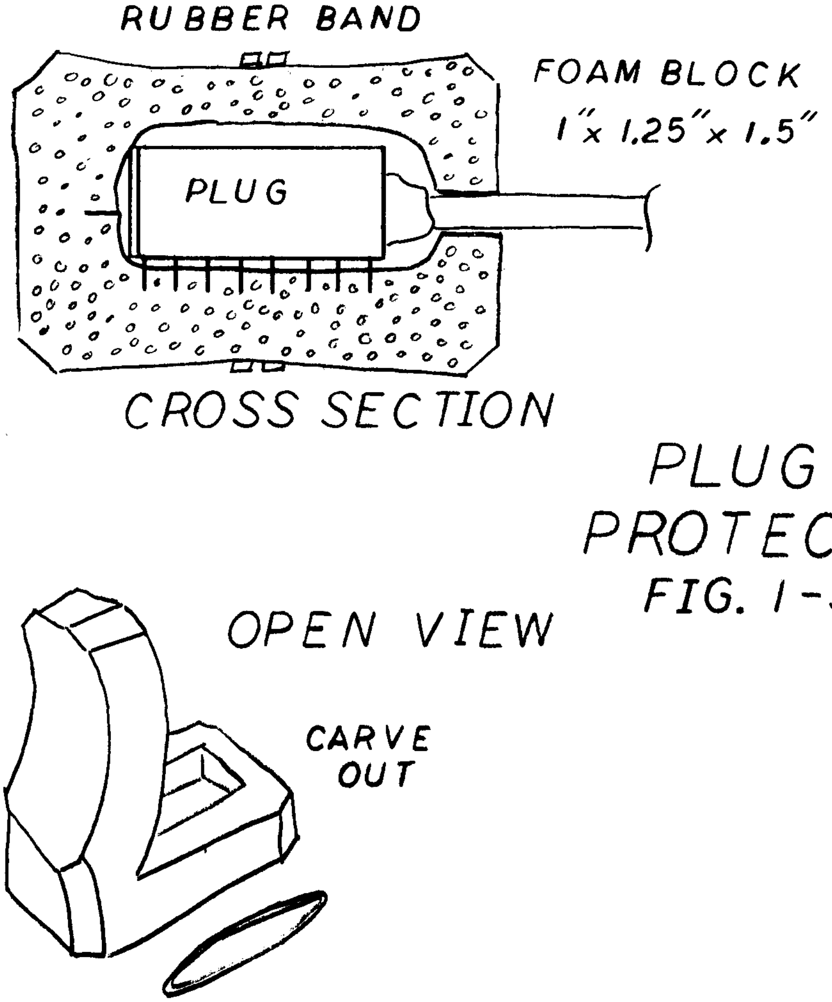
THE SMOKE TEST

Turn off your computer. Never attach or remove anything from a computer with the power on. Check again for your #1 pin, properly plug it into the paddle connector, and turn the computer back on. If the computer behaves irregularly, *turn it off immediately*, unplug the paddle, and recheck all your work. An example of irregular behavior: if the disk routine starts up over and over again, it indicates a short to the +5 pin.

If nothing untoward happens, you can run the Controller Checkout program in chapter 15 to check out the functions of the paddle and pushbuttons. If all is well, turn off your computer and remove the paddle connector.

FINISHING UP THE JOB

Your next task is to install the bottoms on the paddles and build up a strain relief for the cables out of silicone sealant. This material, used for bathroom caulking, is available at most hardware stores. The clear sealant is best for electronics work since it is the least messy. (This material is quite irritating if it gets on your skin or in your eyes, so be careful using it.) You may have to apply two coats of sealant to get a neat result. Allow each coat to dry overnight.



PLUG PROTECTOR
FIG. 1-3

A FINAL TOUCH

One of the most common problems with Apple paddles is bent pins in the connector. This isn't a failure in the design; computer users simply leave them lying around unprotected. Figure 1-3 shows a protective foam block for the connector that should be used whenever the paddle isn't attached to the computer. The best material for this is the stiff but flexible white foam that is used to pack delicate electronic equipment. This foam is easily worked with a pair of scissors. A rubber band holds the foam block in place. A loose socket can also be used to protect the pins.

JOYSTICKS

Most of the procedures we use in reconstructing a paddle can also be used for fixing a joystick. You can obviously replace the connector and the cable. In this case, the cable will require more conductors: four conductors if there is one pushbutton, five if there are two, and six if correction capacitors are required. A double run of the modular telephone cable with stranded wires works much better than the commonly used ribbon cable. There is usually plenty of room in the joystick case to install new pushbuttons; it is just a matter of matching holes.

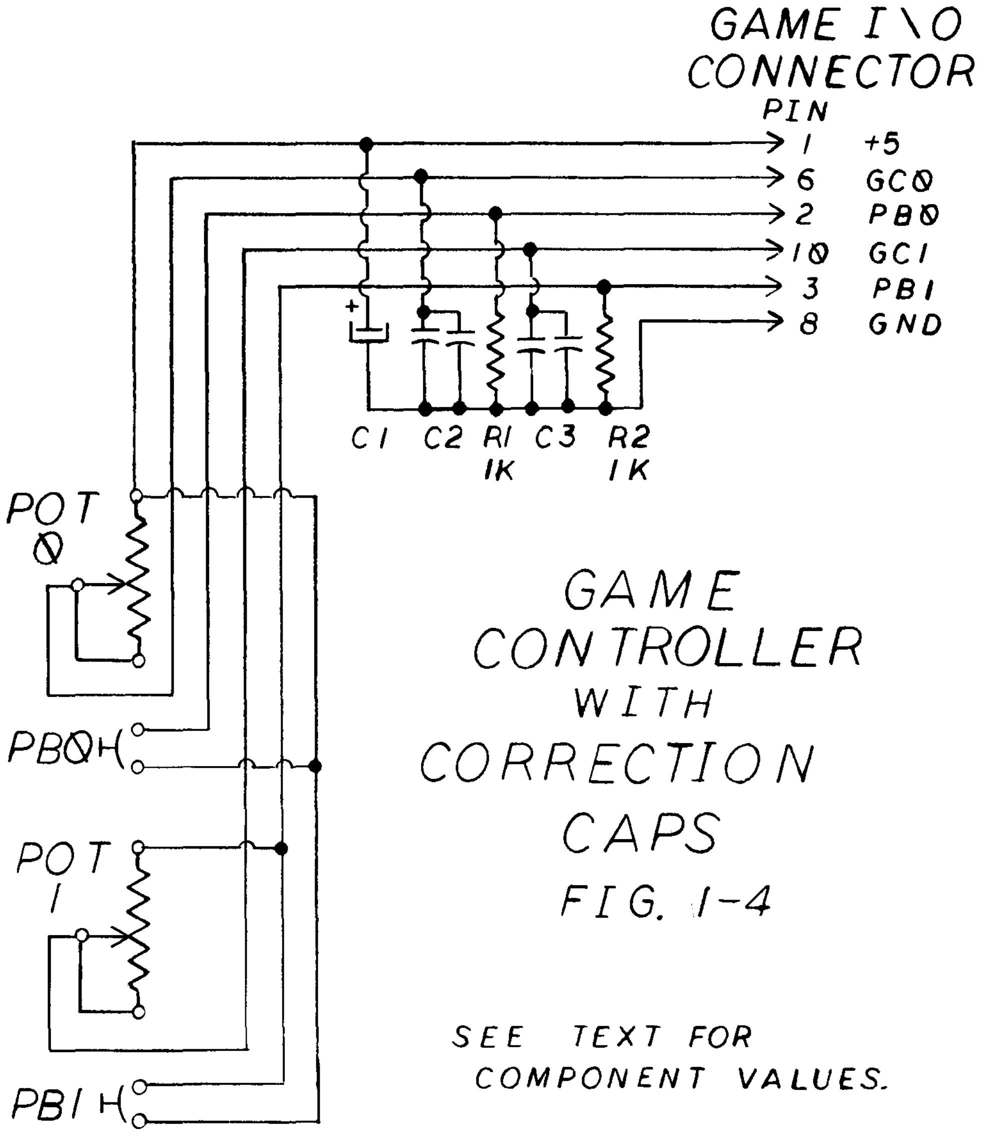
The joystick element containing the two pots and the mechanical linkage is more difficult to replace. It is almost impossible to find replacements for just the pots, and the commonly available replacements for the entire element are not very good. You may also have to use pot values other than those originally intended and add correction caps (see the explanation of correction caps below). Joystick elements with centering springs and tabs are usually better made than those without.

One of the special problems that occurs with joysticks is failure to zero. When this occurs, a pot will read a small positive number—instead of zero—even though the pot is in its extreme low position. Failure to zero is usually caused by poor mechanical construction of the joystick element. There is a procedure to correct this problem, described in the section on Zeroing Joystick Elements below, but it is difficult to complete successfully.

Be sure to provide proper strain relief for the cable where it exits from the box. The wires of ribbon cables often break at this point.

CORRECTION CAPACITORS

One of the most common ways in which home computers read input from paddles uses a timer circuit. You can tell if this is the procedure used by your computer by counting the wires from the paddle pot back to the computer. If there are two wires (the +5 and pot wires), then the pot is wired as a variable resistor and is used in a timer. If there are three wires (the +5, ground, and pot wires), then the pot is used as a variable voltage device, or true potentiometer. The Apple, the Commodore



GAME
CONTROLLER
WITH
CORRECTION
CAPS
FIG. 1-4

SEE TEXT FOR
COMPONENT VALUES.

VIC-20, and many other computers use the timing circuit. Some Radio Shack models use true potentiometers.

The timing circuit can be adjusted for pot values lower than the original values. This adjustment can be made by adding small capacitors within the paddle and thus requires no modification of the host computer. Figure 1-4 shows how the correction caps can be added to a standard controller circuit.

The Correction Cap Calculation program in chapter 15 will assist you in calculating the correction cap values for the Apple II. The program works by taking the maximum value of the pot and multipying it by the value of a small cap inside the computer to form a constant. You then divide that constant by the new maximum pot value and subtract the original cap value. This gives you the correction cap value required.

For the Apple the original maximum pot value is 150K ohms. The original cap is a .022 microfarad. If you have a different computer you can probably get the maximum pot value by opening a paddle and either reading the value off the pot or measuring it with a multimeter. You can usually find the cap on your computer's schematic by tracing the wires from the paddle port back into the machine. These values can then be placed in line 18 of the program.

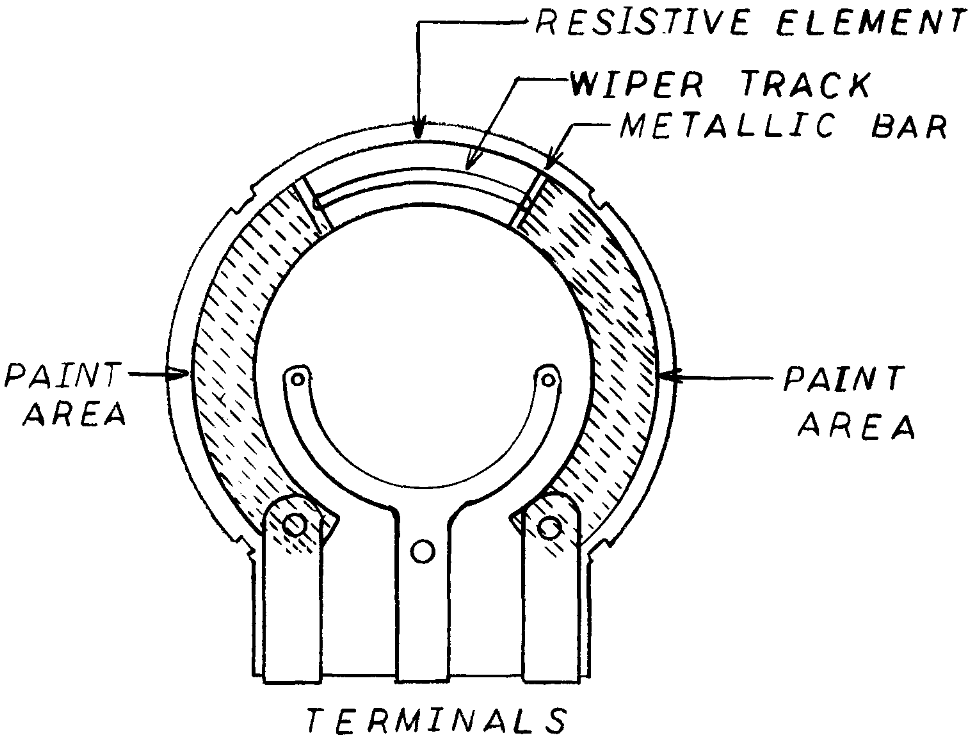
The correction caps are soldered from the game control pin to the ground. If they are put inside the paddle, you must bring a ground wire out to the paddle. Alternatively, they can be mounted on a small printed circuit board a few inches down the cable from the connector and encased in packing foam.

It is difficult to obtain the exact values desired, so you are probably just as well off to buy an inexpensive selection of caps and use trial and error.

To test your work, run the Controller Checkout program again. If the reading reaches 255 before the pot is turned to its maximum, the cap is too big. If the reading never reaches 255, the correction cap is too small. Several small caps in parallel may be needed to get the correct value. The Correction Cap Calculation program contains the limitations of this procedure.

ZEROING JOYSTICK ELEMENTS

A common failure of joysticks, particularly cheap ones, is not to go to zero. This can be corrected, but the procedure is tricky, and it is possible to ruin the joystick element. If you decide to attempt the correction, first unsolder and disassemble the joystick element and remove the potentiometer. The metal back must then be removed from the pot by straightening the small metal tabs. Do it carefully, because



ZEROING JOYSTICK ELEMENTS
FIG. 1-5

these tabs will not bend many times before they break. In removing the back be careful not to lose any of the internal parts.

Now the pot element should look like figure 1-5. Note that there is a small active area of resistive element in the middle and two large inactive areas on either side. The problem is that the inactive areas have too much resistance to read as zero. Look closely at the limits of the wiper track, which leaves a mark in the active area.

The trick is to reduce the resistance of the inactive areas. This can be done by painting over them with sterling silver pigmented paint, available at electronics stores, or with a homemade paint made from clear nail polish and lock graphite. Needless to say, the expensive silver paint is better.

Carefully wipe clean the inactive areas. Make up a mixture of nail polish and graphite into a paste on a smooth surface, then paint the inactive area of the pot element, covering the terminal end and continuing until you just touch the end of the wiper track. Be very careful that the paint goes nowhere else, particularly not where it might touch the metal case or the metal feelers for the central terminal. It may take two coats for complete coverage. Allow the paint to dry thoroughly.

Now reassemble the pot and the joystick element. Resolder the wires according to the schematic. Run the checkout program. If correction caps were used you may have to adjust their values.

Parts List
Rebuilding Game Paddles and Joysticks

Number Required	Description of Part	Suggested Supplier	Total Cost
2	Pots, 150K, short shaft, JA1N0565I54UA	Newark	$8.00
2	Pushbuttons, #275-609	R.S.	1.90
12 ft.	Telephone cable, #278-366	R.S.	1.80
1	16-pin header plug	Jameco	.70
2	Resistors, 1K, 1/4 watt, 5%	R.S.	.20
Misc.	Silicone sealant, weights, labels	Local	1.40
		Approximate Cost	$14.00

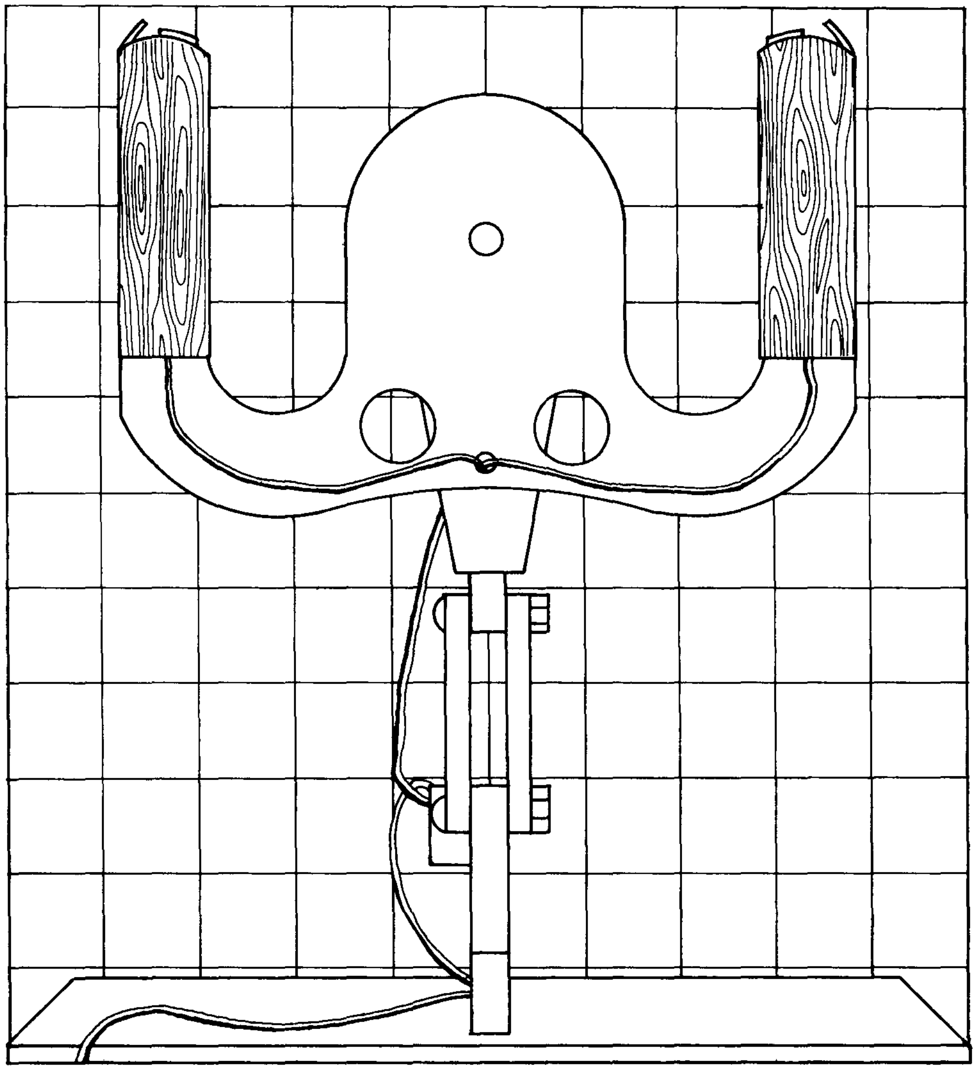
Suppliers:

Newark Electronics
See Yellow Pages or call main office (312) 638-4411 for local sales office address.
Minimum order $25.00

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

R.S.—Radio Shack
See Yellow Pages

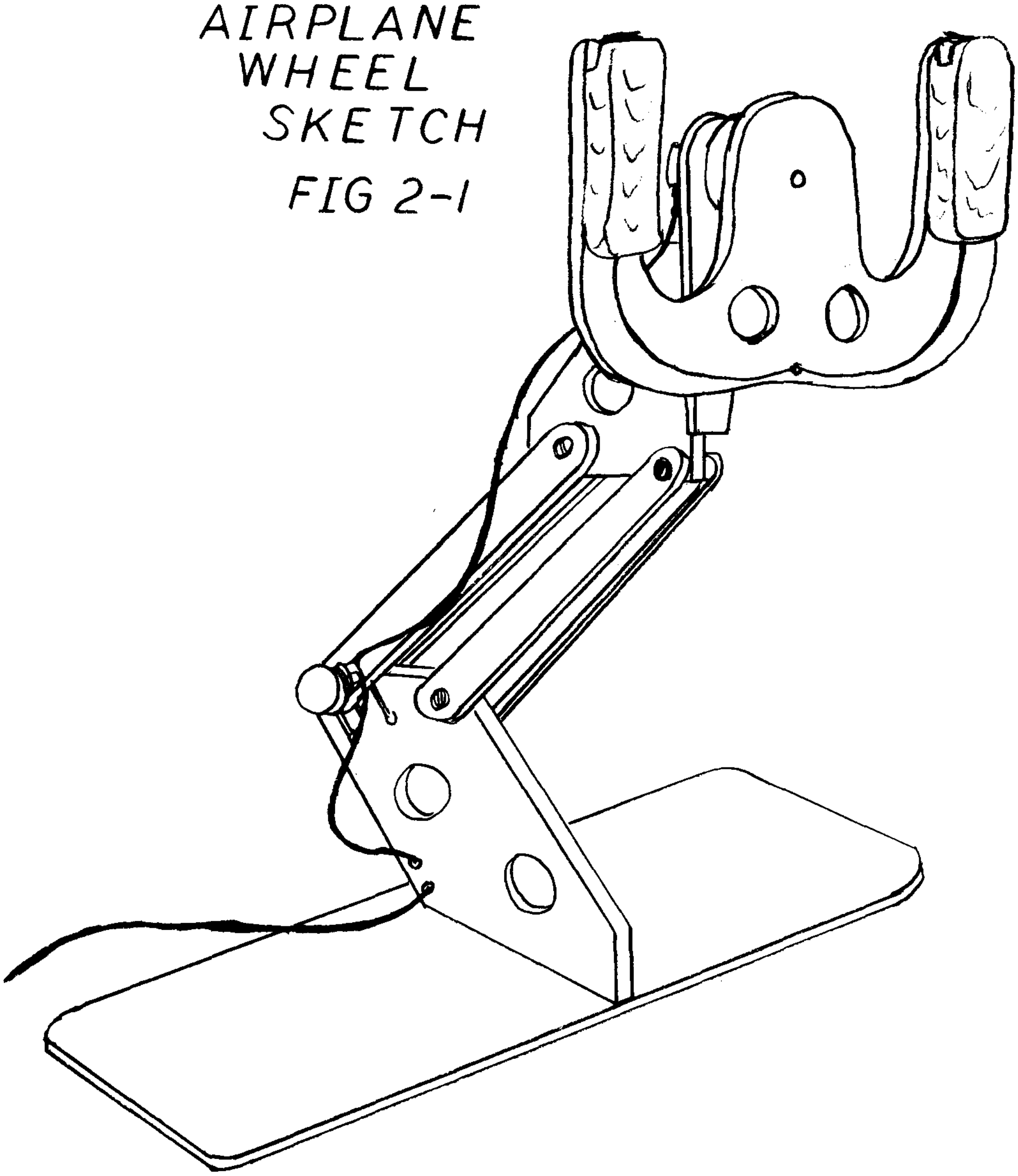
All other parts were purchased at a local hardware store.



2 Airplane Wheel

The first chapter in this book of homebuilt controls for personal computers explained the rebuilding of existing paddles and joysticks to improve their electrical performance, beef them up mechanically, and give them a better feel. In this chapter we will tell you how to build a new type of control, one which can't be purchased at any price. We call it an airplane wheel; a pilot might refer to it as a control yoke.

AIRPLANE WHEEL SKETCH FIG 2-1



This control has two pushbuttons and provides two analog inputs. The first is the degree of turn of the wheel, and the second is the position of the wheel forward and back. By using these two inputs the airplane wheel control closely imitates the actual controls of a small aircraft.

There are several airplane flight simulator programs and related games on the market, but they depend on input from the computer keyboard or from standard game paddles or joysticks. Unfortunately, no one flies an airplane by punching keys on a typewriter, and that isn't the way you learn to fly either.

USING THE CONTROL

To use this control you sit in a chair in front of your computer with the leg board of the control under your legs and the central wheel support between them. Thus seated, you can turn the wheel, push it forward and back, press the pushbuttons, reach the keyboard, and see the screen—all without changing position. All you have to do is plug in the control, run your flight simulator program using the paddle rather than the keyboard mode, and take off. The wiring shown in the drawings is consistent with the *A2-FS1 Flight Simulator* program from Sublogic.

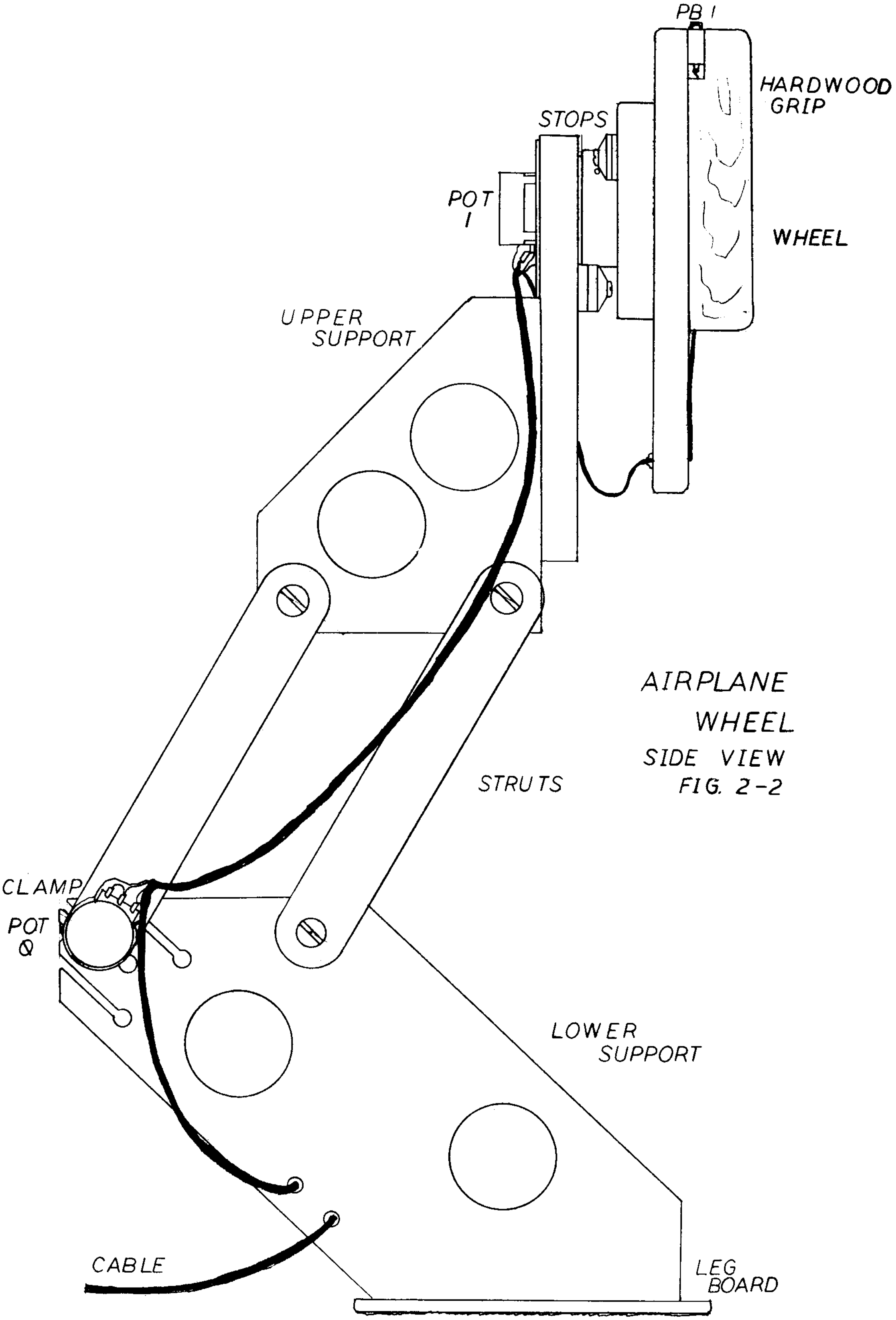
THE DRAWINGS

Before you get excited and start building this device, let's look briefly at the drawings. Figure 2-1 is a sketch of the completed prototype indicating the leg board, lower support and struts, the wheel itself, and the hardwood grips. Note that two microswitches are mounted in the grips, pot 1 is mounted in the wheel axis, and pot 0 is mounted on the lower back strut.

Figure 2-2 is a side view that gives much more detail on the assembly of the unit. Figures 2-3 and 2-4 show details of the component parts. Figure 2-5 is the electrical schematic, which will be explained in a separate section.

CONSTRUCTION MATERIALS

The airplane wheel is constructed primarily of plywood and sheet metal. It can be built entirely with hand tools, but the use of a table or radial arm saw will soeed up the work. It is therefore helpful if you



AIRPLANE WHEEL SIDE VIEW FIG. 2-2

have access to a home workshop or a local high school woodshop.

The best material to use in constructing the control is 1/2-inch hardwood plywood. We made the prototype out of the maple plywood door of a discarded kitchen cabinet. Regular fir plywood can be used, but the unit will not finish up as nicely. Plexiglass scrap, 3/8-inch or 1/2-inch thick, would make a striking unit; plexiglass can be worked with wood tools if you proceed carefully. Many plastic suppliers will sell scrap by the pound at reasonable prices. Solid hardwood would also produce a good-looking unit, but it would be necessary to use a power plane to cut the hardwood down to the 1/2-inch thickness required.

The small parts needed to build the control include plastic washers cut from coffee can lids and bushings cut from 1/4-inch (internal diameter) brass tubing. The latter can be purchased at a hobby shop. A scrap of sheet metal, plexiglass, or Formica will be necessary for mounting pot 1. The required nuts, bolts, flat washers, and wood screws are given in the parts list at the end of the chapter.

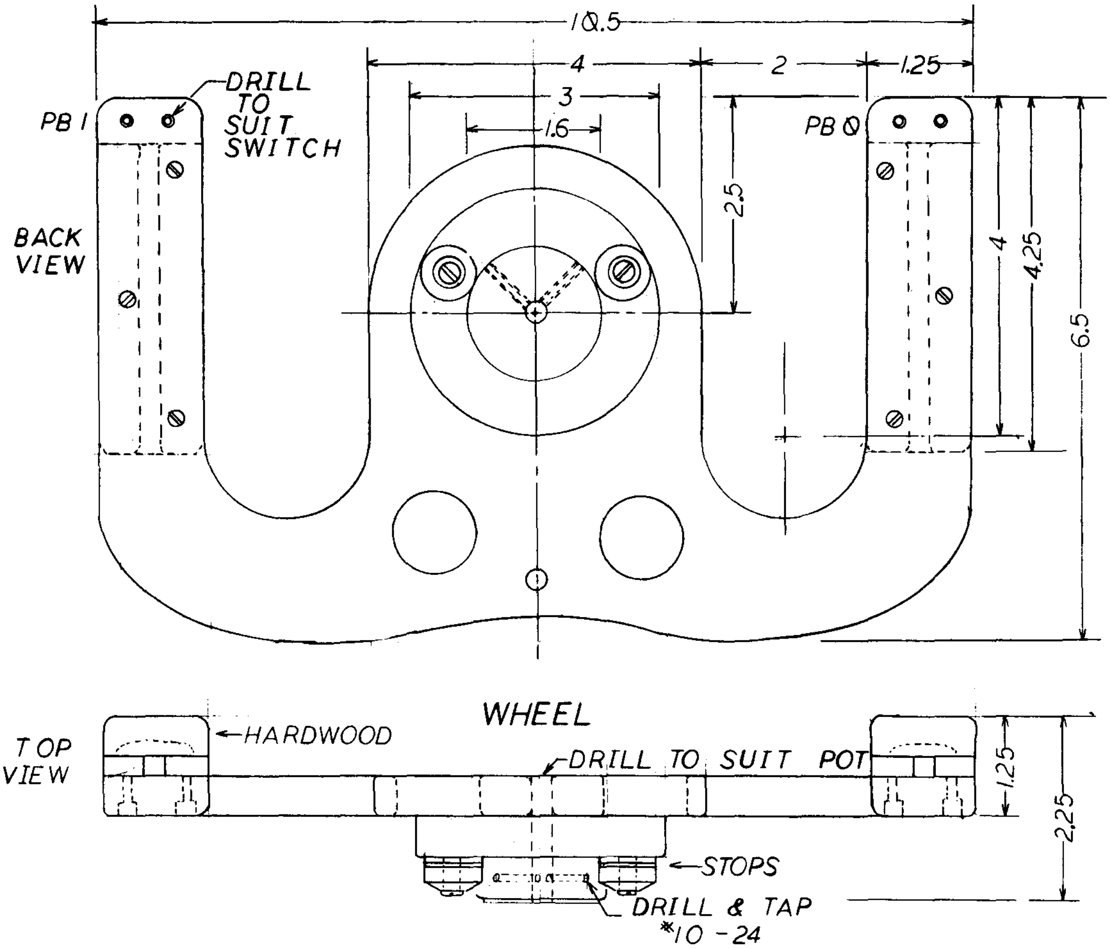
CONSTRUCTION STEPS

Assemble all the materials and parts you will need for the project. Then start work by cutting out all the wood, metal, and plastic parts. The large holes in the upper and lower supports are included simply for decoration, to give the control a lighter, less massive look. They were cut out with a hole saw and a power drill, but can be omitted if this tool isn't readily available.

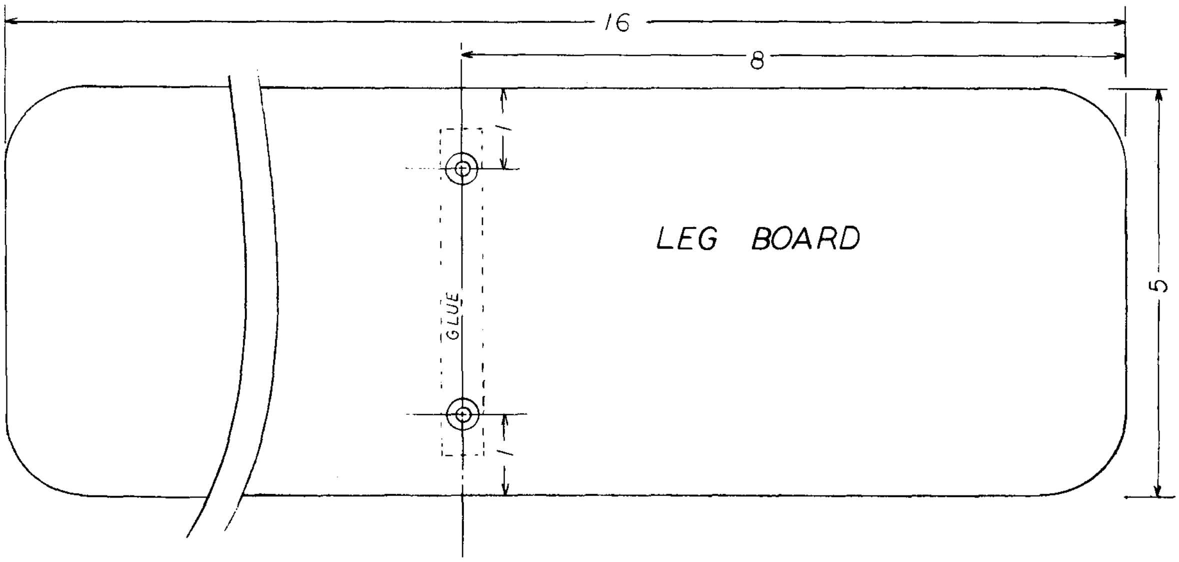
The physical size of pots from different manufacturers varies somewhat, so if you begin the woodwork before you have the pots, just drill 3/16-inch pilot holes for both the mounting hole and the shaft. When you obtain the pots you can drill out the holes for an exact fit.

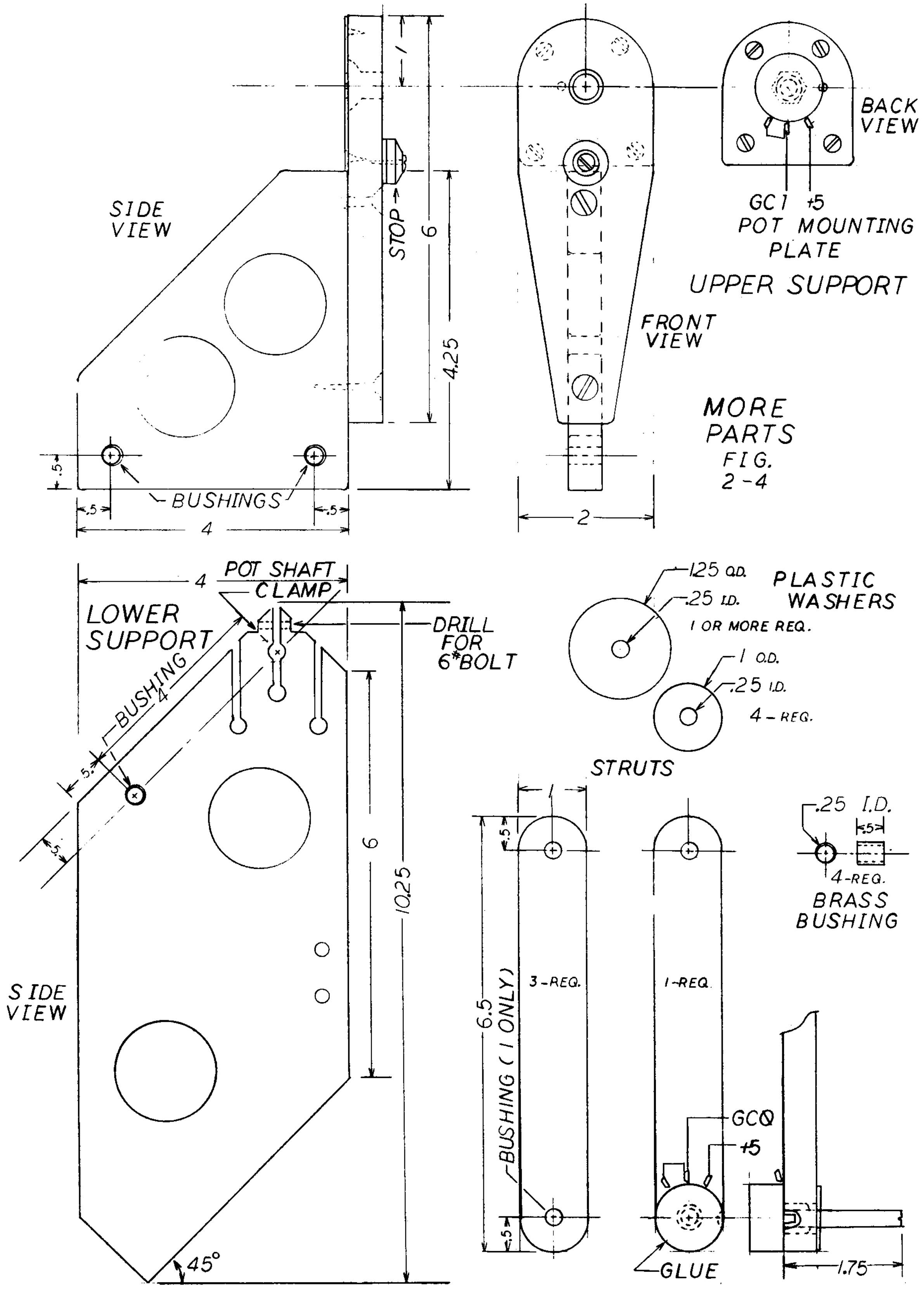
Potentiometers are designed to be mounted through thin metal. To mount them on wood that is too thick for the pot bushing, first mount the pot on a 1/16 to 1/4-inch piece of stiff material—aluminum or steel sheet metal, plexiglass, or Formica. Then screw this piece securely to the wood. This is the method used for mounting pot 1 (see figure 2-4). Pot 0 is shown mounted directly in the wood, but it could also be mounted in the manner just described.

When drilling sheet metal, never hold the work with your hand; the metal will spin and cut your fingers. Hold the sheet metal with vise


10.5
4
2
1.25
3
1.6
DRILL TO SUIT SWITCH
PB 1
PB 0
BACK VIEW
2.5
4
4.25
6.5
WHEEL
TOP VIEW
HARDWOOD
DRILL TO SUIT POT
1.25
2.25
STOPS
DRILL & TAP *10 -24

PARTS
FIG. 2-3


16
8
1
GLUE
1
LEG BOARD
5



MORE PARTS
FIG. 2-4

grip pliers or in a bench vise. With any of these materials, start with a pilot hole of about 1/8-inch in order to locate exactly the center of the hole, and back up the drilled piece with scrap wood to prevent breakout damage.

Observe that the wheel is attached to pot 1 by set screws tapped into the wood ("tapping" is the cutting of screw threads on the inside of a hole). Drilling and tapping is usually done in metal, not wood, but we have found that hardwoods like oak and maple work satisfactorily if the tap has coarse threads like the #10-24 shown in figure 2-3. No lubricant is required for tapping in wood. Two Allen set screws at least 1/2-inch long should be installed at right angles to each other. The tapping is most easily accomplished before the steering wheel parts are assembled.

Inside the potentiometer is a small metal tab that stops the pot from turning a complete 360 degrees. (Most pots turn through 300 degrees.) This internal tab is fairly weak, so stronger stops must be built to keep it from being accidentally broken in vigorous play. Figures 2-2, 2-3, and 2-4 show one stop screwed onto the top support and two screwed onto the wheel. These stops can be made from faucet washers or small rubber feet attached with roundhead screws. You may have to insert flat washers under them if they don't touch each other. These stops will be precisely located during final assembly.

Both of the pots have 2-inch shafts. These long-shafted pots are sometimes difficult to obtain. If you can't find them locally, you can order them by mail. The ones for the prototype were ordered from Newark Electronics. The minimum order is $25, so you may want to go in with some other people on an order. Delivery time is four to six weeks.

Two microswitches are mounted in the wooden grips for use as pushbuttons. They are shown in figure 2-2 mounted at the top of the grips; here, they are pressed with the thumbs. If you prefer, they could be pointed away from the user or to the inside of the wheel and pressed with the index finger. The switches and the #2 mounting bolts were bought at Radio Shack, but suitable switches can be purchased from many mail-order houses. The Radio Shack switches (Cat. No. 275-016) have a small metal lever that is attached with a rather weak hinge. Reinforcing this hinge with a matchhead-size dab of silicone sealant helps to strengthen it.

The microswitches are mounted on the plywood wheel and covered by the hardwood grips, which also have a hidden groove for the switch wires. The grips on the prototype were cut from scrap walnut, so they are particularly attractive.

The plastic washers are inserted wherever two wood parts would otherwise rub against each other. They are cut with scissors from polyethylene coffee can lids; the central holes can be cut with a hand paper punch. These washers provide smooth turning while relieving the strain on the pot shafts.

The three bushings on the supports are installed where wood moves against the bolt threads. These bushings on the prototype were cut from model shop tubing with a small triangular file. There is also a bushing in the one strut which goes over the shaft of pot 0. Flat metal washers are also used wherever bolt heads and nuts come in contact with the wood.

The lower support has built into it a clamp for the shaft of pot 0. The pot itself is mounted on the end of one strut and moves with that strut. The pot is fitted to the strut and held with silicone sealer. In constructing the clamp, a pattern of holes is cut into the support to let the clamp close down on the shaft when the #6 nut and bolt and flat washer are tightened. We strengthened the wood around the clamp by coating it with epoxy, and later redrilled the holes.

SUB-ASSEMBLY OF WOOD PARTS

After you have cut out all wood parts and given them a preliminary sanding, you can begin assembling them. The lower support is attached to the leg board with two #8 x 1-inch flathead wood screws and wood glue. Counter-sink the screws flush with the wood surface. Assemble the top wheel support in the same way. We prefer to use Elmer's Carpenter's Wood Glue, but any good quality wood glue will do. Keep a damp cloth handy to wipe off excess glue.

Next, assemble the wheel hub with wood glue by putting a 1/4-inch bolt with flat washers through the central hole in each piece. Tighten the bolt to clamp the three pieces together. The hand grips have to be custom-fitted to the wheel and holes for #4 screws drilled through the plywood wheel, but the grips are not glued on. For the microswitches, drill mounting holes through the plywood, not the grips.

FINISHING THE WOOD

If you have done a good job on the woodwork, it is worth doing the same high quality work on the finish. Prepare the wood by rounding all corners with a fine rasp, and sand all surfaces. An orbital sander is best for this job: start with #80 sandpaper, then do a light sanding with #120 paper to finish up. The plywood parts can be stained if you want a dark finish, or they can be painted with an oil-base enamel in a color you like.

Now you are ready to apply a satin-finish polyurethane varnish, using two or three coats over a stain or one coat over enamel. The polyurethane will give the enamel a rich look and keep it from leaving marks on the furniture or the floor.

FINAL ASSEMBLY

Pot 1 should now be installed through its mounting plate. Be sure to make a small hole for its spin prevention tab. Screw the mounting plate to the top wheel support. The four brass bushings are installed in the following locations: two in the top support, one in the front hole of the bottom support, and one in a back strut. If the bushings fit tightly you will not need to glue them. Pot 0 is glued on one of the struts. The hole in the strut should be drilled out to a snug fit on the pot bushing (not on the smaller shaft). Then cut a notch for the tab and glue the pot to the strut with epoxy or silicone sealant.

Next attach the struts to the two supports, using two flat washers, two plastic washers, and a nut for each pair. When you are certain you have the unit assembled correctly, lock on the nut with Loctite thread sealant, Super Glue, or fingernail polish. The bolts should be tight, but the struts must move freely when moderate force is applied. You can also install the clamp bolt in the lower support at this time, but do not clamp the pot shaft until the final adjustments are made.

You can lubricate the bushings and flat washers with a tiny amount of petroleum jelly or candle wax. We think the wax gives a better feel to the movement of the finished device.

Now press the wheel onto the pot shaft. You may have to chase the hole with a drill bit to clear out excess glue and finish. The big plastic washer goes between the wheel and the support. If the pot shaft sticks out of the front of the wheel, you can either cut off the shaft or install additional large washers. The wheel stop on the top support can be installed at this point, but the two stops on the wheel itself must be left off until final adjustments are made.

ELECTRICAL COMPONENTS

Electrically, this unit is just an overgrown joystick with two pots and two pushbuttons. The wiring schematic (figure 2-5) is for the Apple II, but you can build an airplane wheel for any computer that can handle a two-pot joystick and at least one pushbutton. To do it, you must use the correct pot values, find the right plug, and make changes (mostly pin numbers) in the electrical wiring to fit your machine. Your task is simply to search out this information concerning a standard joystick for your system and copy the electrical connections, and use it to adapt our schematics for your own use.

In the prototype, the pot 1 value is 150K ohms, an unusual value but standard for Apple paddles. Pot 1 should be long-shafted, completely enclosed, and of good mechanical construction. The parts list at the end of the chapter gives a suggested manufacturer's part number and supplier. If the pot does not have a screwdriver slot across the end of the shaft, you will have to cut one with a hacksaw, since the shaft must be turned with respect to the wheel during final adjustment.

Pot 0 is a bit different. This pot does not turn through its full range. (As noted earlier, a normal pot will turn through 300 degrees from one stop to the other.) The struts that move pot 0 will permit only about 170 degrees of turn. If you desire a full reading you must use a larger pot, one that will go from 0 ohms to 150K ohms over a turn of 170 degrees. You also have to choose a value for the pot that will let you purchase the actual item.

For the Apple II, a value of 250K ohms works very well. Other computers will require a value about one and one-half times that of the standard pot. For an Atari which uses 1 meg-ohm pots, you will need a 1.5 meg-ohm pot which must also be long-shafted and mechanically sound.

The pushbuttons in the prototype are microswitches that have a metal lever on top. We purchased them at Radio Shack. There are three

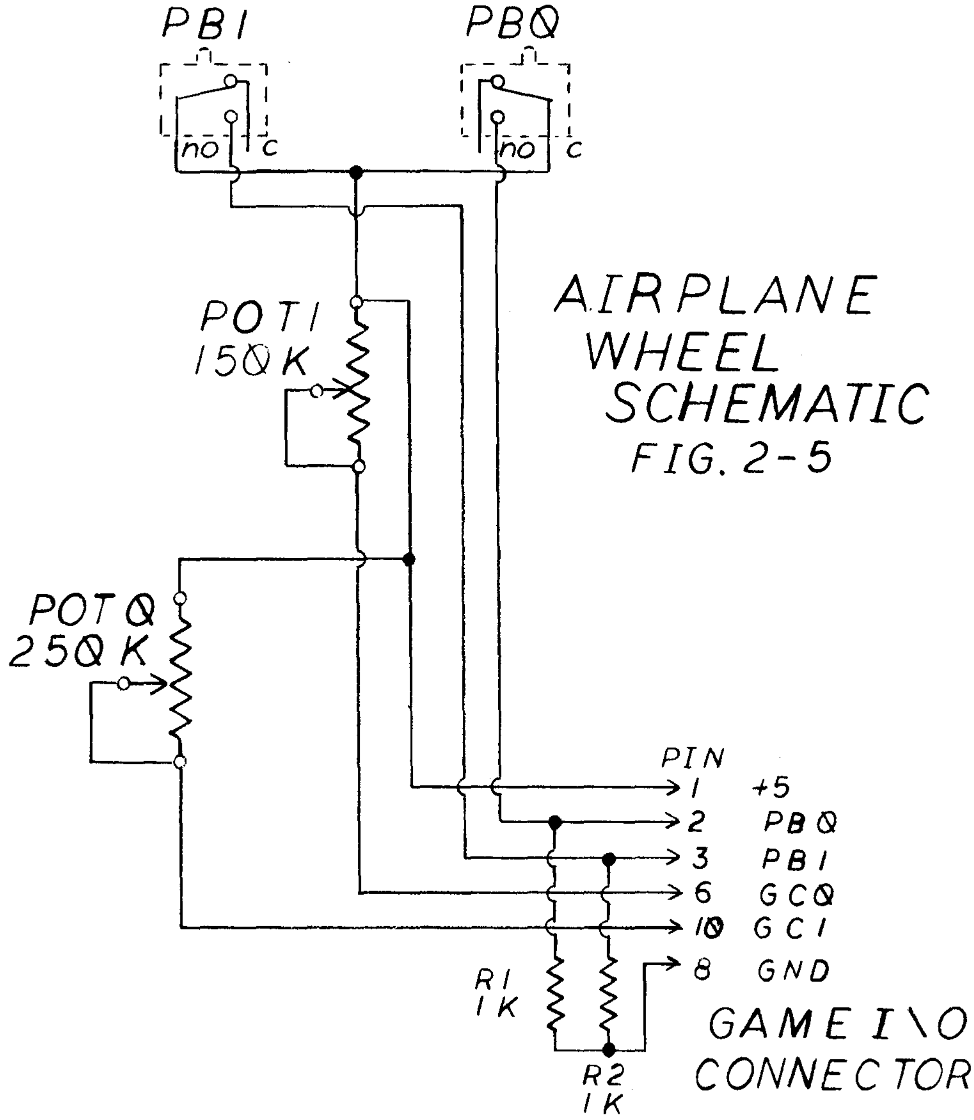


FIG. 2-5

terminals on the bottom of each switch, labeled C, N.O., and N.C. We used the one marked C (common) and the one marked N.O. (normally open). You can use any type of normally open, momentary-contact switch that will fit neatly on the wheel.

The plug for the Apple II is a 16-pin DIP header, sometimes called a component carrier. When you solder this device, be sure to plug it into an unattached 16-pin socket so that the heat doesn't loosen and misalign the pins. The #1 pin of the plug is marked by a cut-off corner; the wires normally trail out the end near pin #8.

Figure 2-5 shows two 1K ohm pull-down resistors from the pushbutton pins #2 and #3 to ground. If you are very careful, you can mount these resistors inside the header itself.

The schematic also shows correction caps, which are necessary only if the pots you are using have too low a resistance value (see the discussion of correction caps in chapter 1). If you use correction caps, they can be mounted on a small piece of printed circuit board about one foot up the cable. The electrical noise prevention cap shown in figure 2-5 is optional, but could be mounted beside the correction caps.

To determine the number of conductors required for the cable, count the +5 supply, the two pot wires, and the two pushbutton wires: you will need five conductors. If you weren't able to find exactly the pot size you need and are using correction caps, you will also need a ground wire.

We don't like working with the flat ribbon cables that are used in many commercial joysticks, having repaired too many broken wires in them. Radio Shack sells a good 4-wire telephone cable (Cat. No. 278-366) that works well in constructing controls if you are careful not to overheat it while soldering. If you have the correct pot values and choose to use only one pushbutton, you could get by with only four wires and run a single cable. If you need more than four wires, you should use two runs of cable and double up the +5 wire.

SOLDERING PROCEDURES

To do the soldering in this project you need a small soldering iron (about 25 watts), resin-core solder, wire strippers, and a small pair of long-nose pliers. Figures 2-2 and 2-4 show which terminals of the pots to use for the various wires and where to route the cable. Start wiring at the pushbuttons and work back to the plug. You will need a three-conductor loop of cable to extend from the wheel to the back of the top support. It must be long enough to allow rotation of the wheel through 300 degrees. You can work out the correct length and location of the anchors by trial and error.

Before you wire the unit, make two photocopies of figure 2-5. Then, as you run each wire and make each solder joint, trace it in on one of the copies with a colored pencil. After you have finished the wiring, it is a good idea to have another person go over the unit, checking out the wires with a colored pencil on the second photocopy to make certain that you haven't omitted any connections.

If you have a multimeter you should also check the resistance from pin #1 (+5 supply) to pin #8 (ground). You should always get a reading of at least 50 ohms on any control, and the reading ought to be much greater. Watch this reading while pushing the buttons and turning the pots. It must always be high.

ALIGNMENT

Aligning the control requires a simple program that repeatedly shows the reading of pots 0 and 1 and the condition, open or closed, of pushbuttons 0 and 1. You can use the Controller Checkout program from chapter 15. Or you can write your own program. Be sure to put a slight delay between the two paddle readings. Check out the program on a standard joystick or paddle before testing your new controller.

Now turn off the computer and plug in the new unit, making certain that the #1 pin in the plug is in the correct hole. Turn on the computer. If it doesn't start up *exactly as usual,* turn it off at once and recheck your work. Now load your check program and place the airplane wheel in position under your legs.

We will start the adjustments with pot 1. Turn the airplane wheel slowly and check that the pot reading goes from 0 to 255. Now center the wheel and, using a standard screwdriver, turn the pot shaft inside the wheel until the reading is 127 with the wheel centered. Press the wheel firmly on the shaft and tighten the set screws.

To locate the two stops on the wheel (the single stop is already mounted on the top support), turn the wheel until you feel one of the stops inside the pot. Now back off this stop just a little and check that the reading on the screen hasn't changed. Hold the stop in place and mark its center with a sharp point, like an awl. Repeat the procedure on the other side for the third stop. You may have to remove the wheel to install the stops properly, then replace and center it again.

To adjust pot 0, pull the wheel as far forward as you can, leaving the clamping bolt loose. Adjust the pot with a standard screwdriver until the reading on the screen just reaches 0. The forward motion must be stopped by contact of the wood parts, not by the tab inside the pot. Now lock the clamp by tightening the clamp bolt. Pushing the wheel back should now bring the reading all the way up to 255, and a reading of 127 should be at a center position that is comfortable to hold. Press the pushbuttons to make sure they work.

Now load your favorite flight simulator program or space game and take off.

FINISHING TOUCHES

To give the unit a finished appearance and make it last longer, you may want to do the following:

- To keep the cable out of your way and prevent it from being pulled loose, you can tie it to the wood parts.
- Use silicone sealant to cover the exposed electrical connections and the back of the plug. This is called "potting."
- The ends of the wire loop between the top support and the wheel should be mechanically secured. You can tie one end to the pot with dental floss and silicone sealant. Likewise, secure the other end to the wheel with the same materials and a small screw.
- Glue felt on one or both sides of the leg board with contact cement to give a nice finishing touch to the controller.
- You can personalize the finished unit by placing a paper cutout or a hand-drawn emblem in the center of of the wheel. This should be done after final pot adjustments are complete. Our prototype is adorned with a tiger's head (easily recognizable from an ad for a popular printer).

The drawings show the prototype exactly as built. You almost certainly will want to make some improvements of your own, particularly if you build more than one unit. As mentioned earlier, the clamp and mount for pot 0 could be strengthened with some sheet metal parts and set screws.

The wheel axis of the prototype is parallel to the leg board and floor. A pilot who tested the unit suggested angling this axis down a little in back to be more like the steering wheel of a light plane. This could be done by adjusting the angles of the lower support.

The unit shown in the drawings is about right for most average-size adults. You could extend the lower support as much as four inches if the controller were to be used primarily by a taller individual, or shorten it by two inches for children.

Parts List
Airplane Wheel

Number Required	Description of Part	Suggested Supplier	Total Cost
1	Pot, .15 meg, 2″ shaft, JA1N200P154UA	Newark	$4.00
1	Pot, .25 meg, 2″ shaft, JA2N200P254UA (pots manufactured by Allen-Bradley)	Newark	4.00
2	Submini lever switches, #275-016	R.S.	2.80
4	Bolts and nuts, #2 x 5/8″	R.S.	2.00
20 feet	Telephone cable, 4-conductor, #278-366	R.S.	2.40
1	16-pin DIP header	Jameco	.70
1	16-pin DIP socket	Jameco	.70
2	Resistors, 1K ohm, 1/4 watt, 5%	R.S.	.20
2 feet	Hardwood plywood, 1″ x 2″		4.00
1 foot	Masonite, 1/8″ tempered		2.00
2 feet	Hardwood, 1 x 2	Scrap	
1	Bolt and nut, #6 x 3/4″		.20
3	Bolts, 1/4 x 20 x 2″		1.50
3	Nuts, 1/4 x 20		.30
8	Flat washers, 1/4		.30
3	Rubber feet with screws		1.70
4	Flathead screws, #8 x 1″		.25
2	Set screws, #10-24 x 1/2″		.50
4	Flathead screws, #6 x 1/2″		.25
6	Flathead screws, #4 x 3/4″		.50
1	Brass tube, 1/4″ I.D.	Hobby shop	.60
2	Coffee can lids, polyethylene	Scrap	
1	Sheet metal plate, 2″ x 2″	Scrap	
2 feet	Cotton felt		1.00
1 ounce	Silicone sealant		1.20
1 pint	Polyurethane varnish		2.00
1 pint	Stain or enamel for finishing		2.00
Misc.	Sandpaper, electrical tape, glue, etc.		.90
		Approximate Cost	$36.00

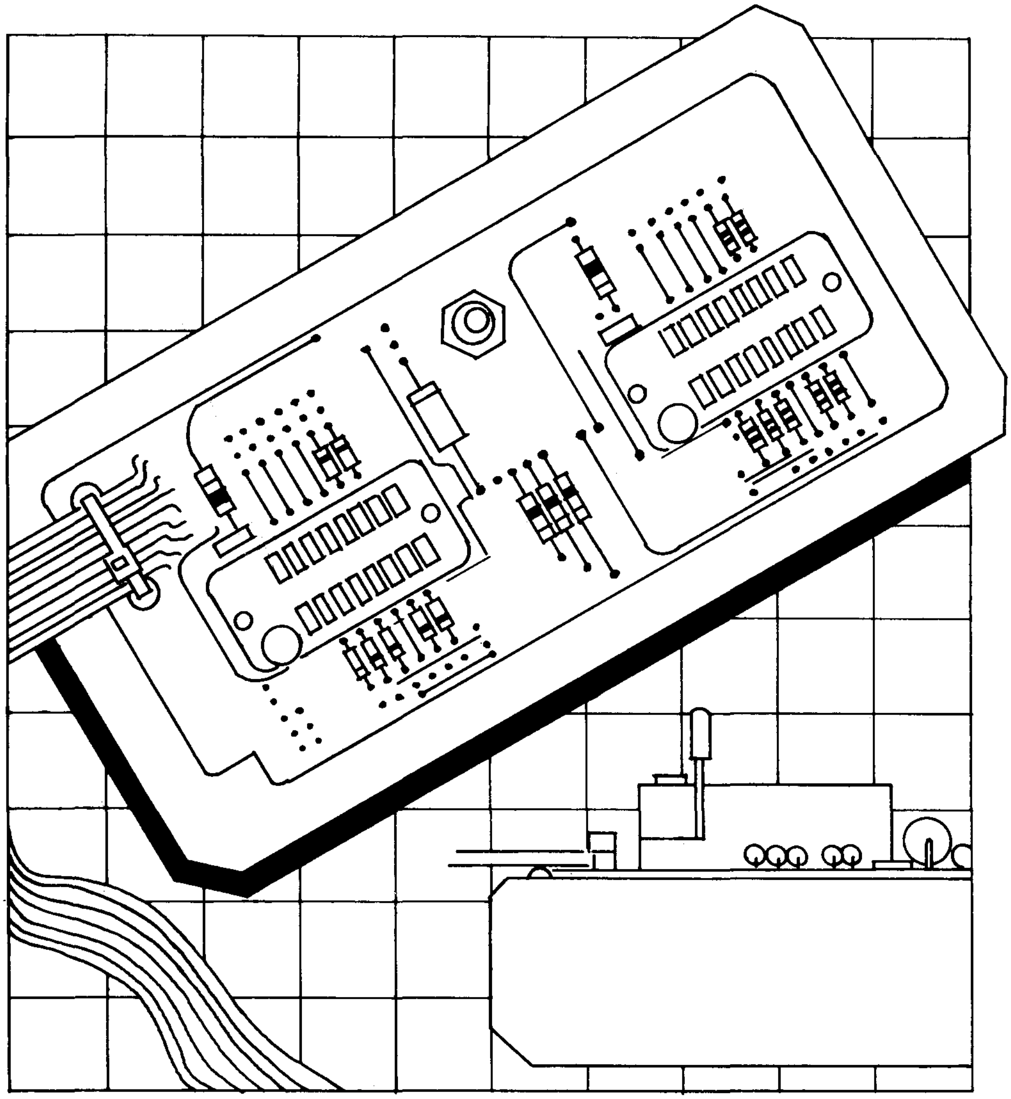
Suppliers:

Newark Electronics
See Yellow Pages or call main office (312) 638-4411 for local sales office address.
Minimum order $25.00

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

R.S.—Radio Shack
See Yellow Pages

All other parts were purchased at a local hardware store.



3 Multiple Socket Extensions

In this chapter we will show you how to build multiple socket extensions for Apple computers. These devices provide a number of convenient functions for the computer user: they bring the paddle socket out of the case to a position beside the keyboard, they permit switching between paddles without interrupting the program currently running and, with appropriate software, they will let you use two standard joysticks at once.

Socket extensions are available commercially, of course, but no single unit will have all the features of the socket extension we will describe. Besides, you can construct a home built unit for about half the cost of a commercial one. A multiple socket extension is an excellent first project for learning to work on computer hardware, since the device is simple and easy to construct. The materials to build it are easy to obtain, and only a small multimeter is required for testing the finished unit. What more could you want?

Figures 3-1 through 3-5 give you the details of units that were built for the Apple II. We will discuss what might be done to construct multiple socket extensions for other computers later in the chapter.

TYPES OF MULTIPLE SOCKETS

There are two types of multiple socket extensions. Those which permit the choice of one of two or more paddles will be referred to as *selection units.* Those which permit two standard paddle sets or joysticks to be used at the same time will be called *two person units.*

We will also describe special features for each type of unit, including click action power switches, isolation diodes that prevent paddles from affecting each other's readings, and zip (zero insertion pressure) sockets. These special features will let you customize the unit to your exact needs.

A WORD OF CAUTION

Good practice for working on electronic equipment requires that the power to the unit be turned off before any plug is installed or removed. The power switches on these multiple sockets are intended to allow you to select among paddles already plugged into the sockets. Plugging in a paddle when the power switch is off but the computer is turned on violates good practice, although it is preferable to plugging the paddle into a live socket. *Remember:* turn off the main power supply to your computer before plugging in or unplugging a paddle from any of these socket extensions.

TOOLS REQUIRED

The construction of a socket extension is primarily a precise and somewhat tedious soldering job. Soldering is the keystone of all hardware skills and one that can only be learned through practice. It is definitely a skill worth mastering.

For this project you need a small pencil soldering iron of about 25 watts and a stand to hold it, a sponge to clean the tip of the iron, desoldering braid to remove solder bridges, and fine resin-core solder. Other tools you should have on hand include a pair of small diagonal cutters, long-nose pliers (for bending fine wires), an X-acto or other small-bladed knife, and wire strippers. The plier-type wire strippers with an adjustment bolt work well but must be adjusted and tested on each new wire size.

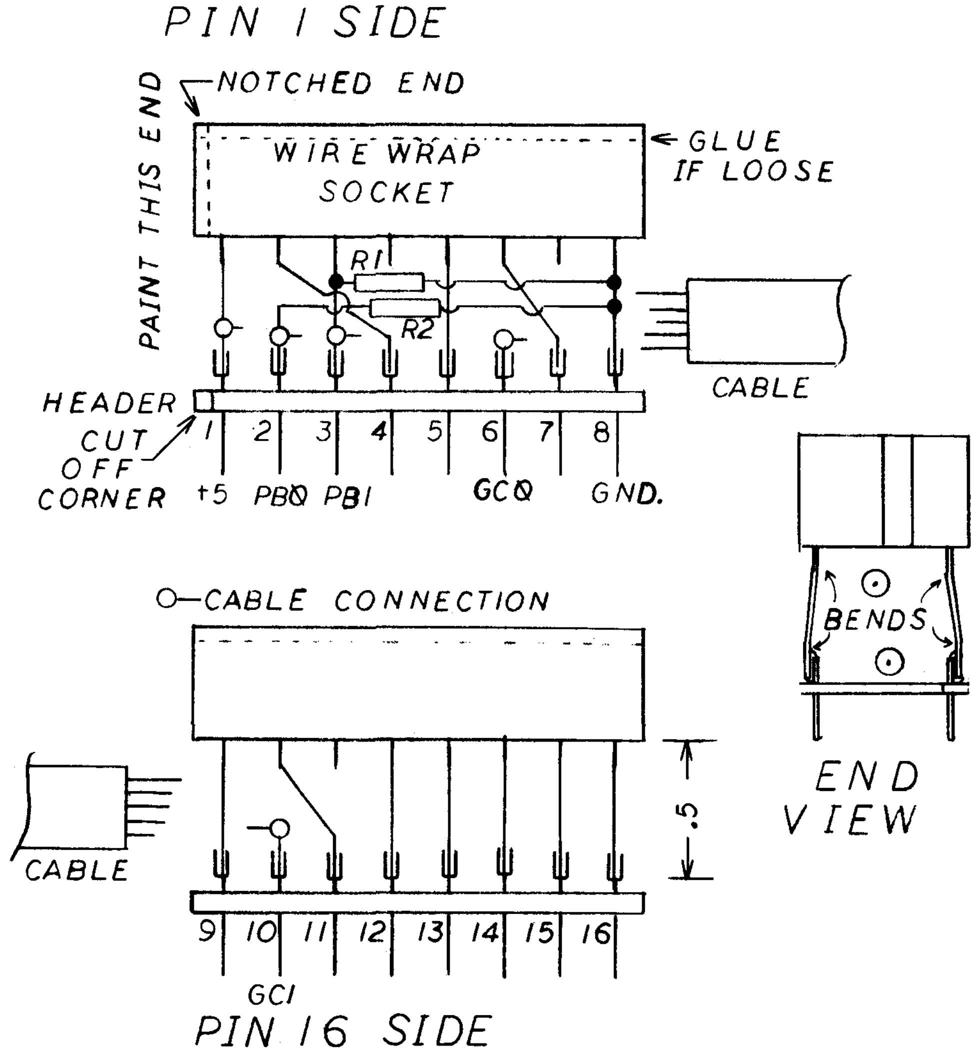
THE STACKED PLUG UNIT

The plugs on Apple paddles are easily damaged and therefore have to be replaced in many cases. It is helpful to replace the paddle plug with a stacked plug and socket, thus providing an extra socket of the two-person type. For this replacement you will need a 16-pin wire wrap socket and a 16-pin DIP header. The construction details are given in figure 3-1. The socket will ride on top of the header, providing not only a new socket but also a handle for the plug.

First trim off the socket pins to an even 1/2-inch and bend them out slightly. (You might cut the #2 pin 1/16-inch longer.) Then straighten the pin ends as shown in the end view of figure 3-1; this allows the wire-wrap pins to slip over the spades of the header. Double check to be sure that the pin 1 end of the header, marked with a cut off corner, is matched to the pin 1 end of the socket, marked with a notch or cut off corner.

Plug the header into another unattached socket so that its pins will not misalign when heated. Solder pins 1, 8, 9, and 16. Then solder pins 3, 5, 12, 13, 14, and 15. Cut off pins 4, 7, and 11 about 1/8-inch down from the socket. Using long-nose pliers, bend pin 6 over to fit into spade 7 and bend pin 10 over to reach spade 4.

Now for the tricky part: pin 2 must be bent around behind pin 3 to reach spade 4, but without touching pin 3. If this gives you trouble, try cutting off the #2 pin 1/8 inch from the socket and soldering a 3/4-inch piece of insulated #22 solid wire between the pin 2 stub and spade 4.



APPLE STACKED PLUG
FIG. 3-1

If the old paddle plug that you are replacing with the stacked unit needs pull-down resistors for its pushbuttons, these can be installed between the socket pins. We used two 1/4 watt, 1K ohm, 5% tolerance resistors. They share pin 8 for ground; one resistor goes to spade 2 and the other to pin 3. Trim the wires carefully, bend them neatly around the pins, and then solder.

The cable should be stripped of its outer cover for 3/4-inch and the wire trimmed. Since the cable normally enters from the pin 8 end, the +5 wire will be longest and the ground wire shortest. Strip the wire back 3/16-inch, twist the strands, bend them into a small hook, and tin the wire. Your wire stripper must be set so that none of the fine wires are cut. Try several adjustments on a scrap of the same wire until you have it set correctly. One at a time, press each wire into the correct fork or close the hook around the pin shaft, and solder it.

The pin 1 end should be marked with light-colored fingernail polish, model enamel, or white typing correction fluid covered with clear fingernail polish. Sometimes the plastic top of the socket comes loose and has to be glued back on with Super Glue or clear nail polish.

TESTING THE STACKED PLUG UNIT

If you have a multimeter you should check your wiring for continuity and to insure against shorts. Pin 1 to pin 8 must measure in excess of 50 ohms, and the measurement is usually much greater.

If you have difficulty inserting a plug into the new socket the first time you try it, stick a medium sewing needle into each of the holes in the socket to realign the internal parts with the holes. If you plug the control with this stacked socket into the Apple and then plug a standard set of paddles or a joystick into the new socket, pot 0 of the second joystick acts as pot 2, and its pot 1 acts as pot 3. Similarly, its pushbutton 0 acts as pushbutton 2, but its pushbutton 1 remains pushbutton 1 and is shared with the original paddle (the Apple II has only three pushbuttons). Incidentally, if you have made the shift key modification for upper/lower case, it will hold pushbutton 2 closed unless the shift key is pressed. This will interfere with the use of the pushbutton on the second joystick plugged into the stacked plug.

You now have all the hardware you need to play two-person competitive games with full joystick control. There is not much software available that has this feature, but you can dream, or even write your own.

THE SELECTION SWITCH

Now let's look at the construction of a multiple socket that can be placed beside the Apple to let you choose between two paddles with the flick of a switch. Figure 3-2 is a sketch of this unit showing the component layout. The terminations of the main cable wires and two side cables are not shown because they would hide the components. These cables will be discussed later. This multiple socket extension has all the most popular features, including zip sockets, a click switch, and isolation diodes. If you don't need all of these features and want to leave one or more of them off, the cost of the parts will be reduced.

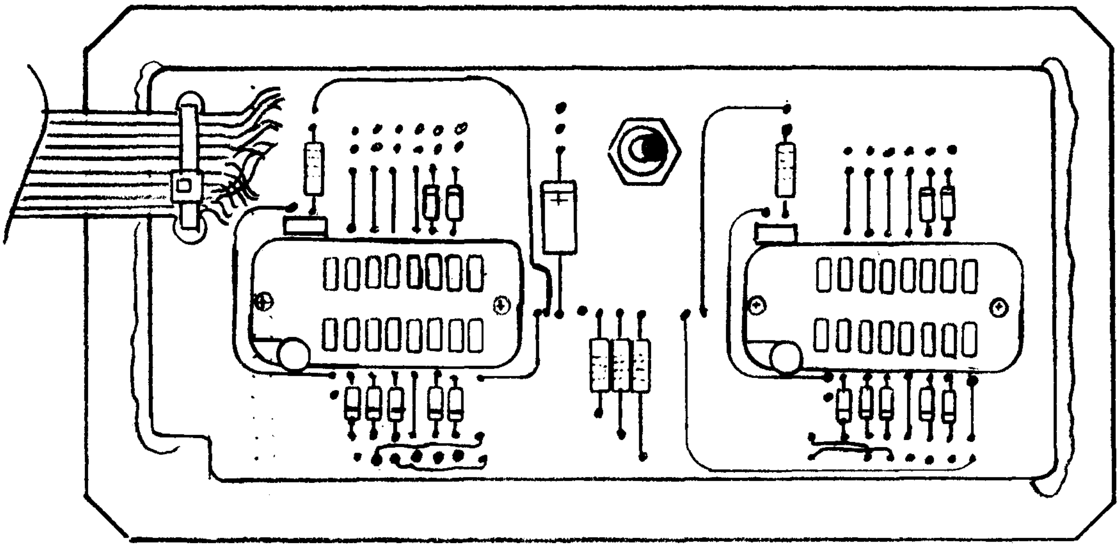
The zip plugs used for this unit cost about $6.20 each (see the parts list at the end of the chapter), compared to $1.00 for a good standard socket. The zip plugs are larger and have a small lever on the side that locks and unlocks the socket. If you have only one set of paddles and a joystick and want to switch back and forth between them, you probably won't want to pay extra for zip plugs, so buy standard, gold-plated sockets.

We prefer a switch that clicks and makes positive contact to the simple slide switches commonly used on commercial extension sockets. A click switch, however, extends below the circuit board, requiring the foam block shown in figure 3-1 for a base.

Figure 3-3 is the schematic for the selection socket. It is basically very simple: 13 pins of the plug are connected to their counterparts on each socket. The +5 supply (pin 1) is filtered with a capacitor and switched between the two sockets. The isolation diodes are the only complication.

Each socket has seven 1N914 or equivalent general purpose silicon diodes. On the pushbutton lines, they prevent the pull-down resistors of the plugged in paddles from being in parallel. This would waste +5 current and, if more than four paddles were plugged in at one time, might overload the +5 supply. The use of these diodes makes necessary the three 10K pull-down resistors (R3, R4, and R5) on this board.

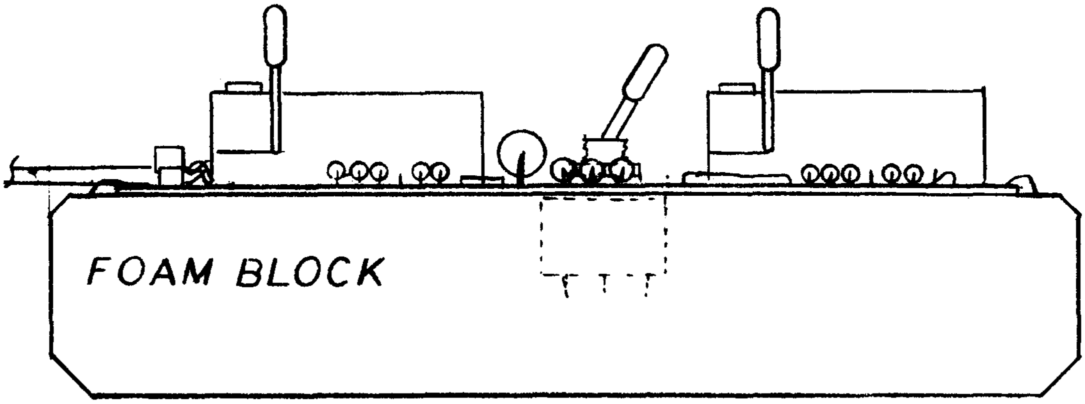
The four diodes on the game control inputs prevent the pots in the unused paddles from affecting the readings of the one in use. These diodes are a must if correction caps are used on a controller in that socket. Since they have an effect on the paddle readings, some devices, such as the sketch pad in the next chapter, will have to have their calibrations checked when used in sockets with diodes.



TOP VIEW

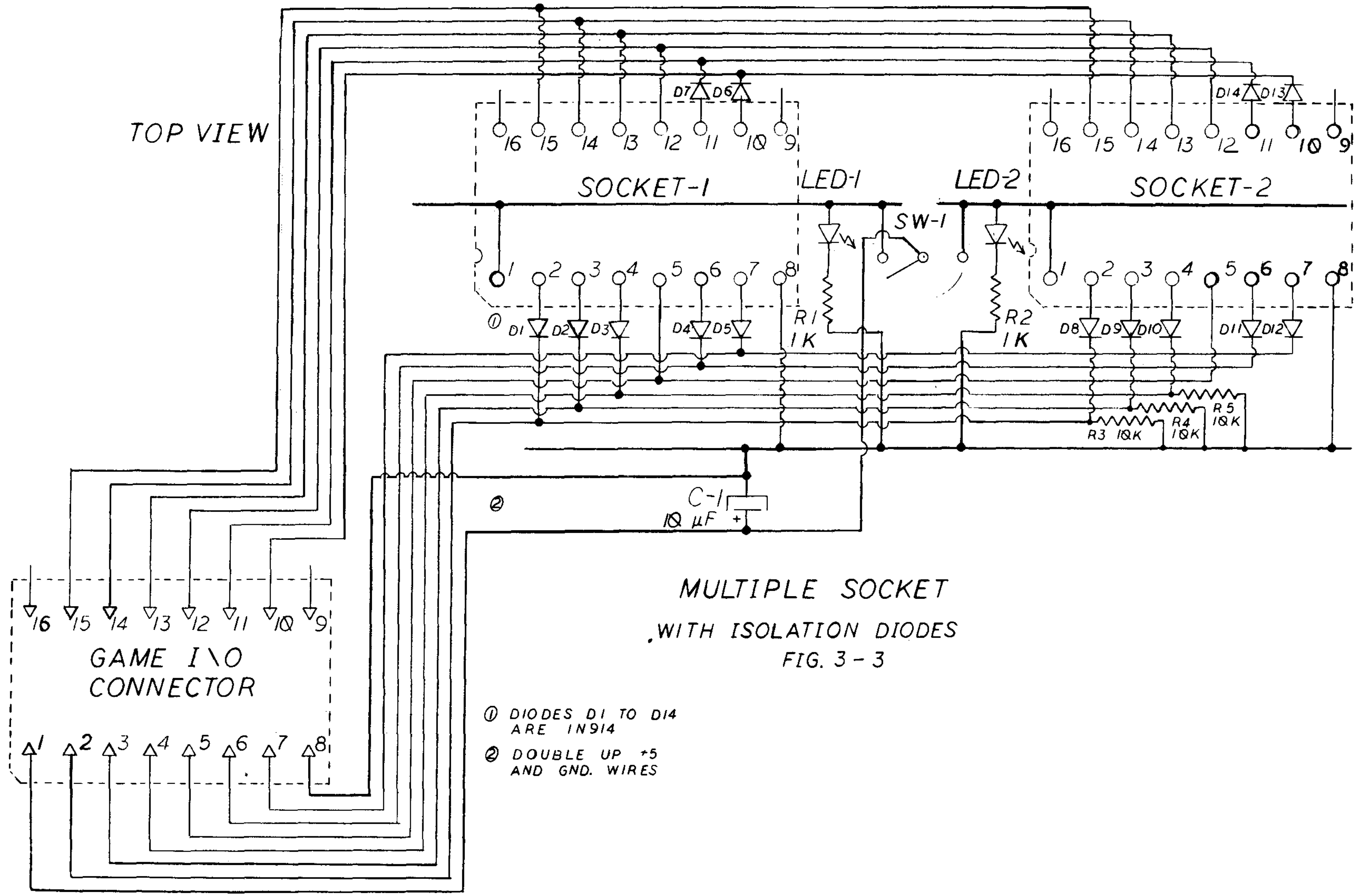
SIDE CABLES NOT SHOWN

SIDE VIEW



MULTIPLE SOCKET WITH
ISOLATION DIODES

FIG. 3-2



MULTIPLE SOCKET
WITH ISOLATION DIODES
FIG. 3 - 3

THE CIRCUIT BOARD FOR THE SELECTION SWITCH

Figure 3-4 shows the bottom of half of a Radio Shack printed circuit board (Cat.No. 276-154A Experimental), with modifications to suit this device. The board was cut in half by scoring both sides with an X-acto knife and breaking it over the edge of a table. Each half will make a two-socket unit. Drill a hole in the board to suit the switch you choose and 2 holes for a wire tie to secure the main cable.

The existing copper lanes then have to be cut in 24 places, as shown by the dashed lines in figure 3-4. This is done by making two cuts, 1/32 of an inch apart, with an X-acto knife and removing the copper sliver between the cuts. Some skill and practice, as well as a sharp knife blade, are required for this step.

Smooth the edges of the board and the drilled holes with a fine file. Clean the copper lanes by rubbing them vigorously with a pink eraser. This last step, a standard electronics practice, is vital.

The sockets are installed first. Figure 3-4 shows the pin locations from the bottom: both #1 pins go toward the cable end. The socket pins and all wires should be bent over flat for 1/16 of an inch before soldering, since this circuit board does not have the metal-lined holes (often called "plated-through") that a more expensive board would.

The 1N914 diodes can now be installed on pins 2, 3, 4, 6, 7, 10, and 11 of each socket. The end with the black band is the cathode, or positive terminal, and must point away from the socket. Bend the wires over flat, solder them, and cut off the excess. In eighteen places shown in figure 3-4, the wires must be bent across an open space to make a bridge from one small copper pad to another. Use the wires cut off of the diodes to make striaght wire jumpers the same length as the diodes for pins 5, 12, 13, 14, and 15 on both sockets. This step will make it easier to install the cables.

One of the long copper traces that runs through the socket is used for the ground bus. The negative lead of the capacitor and one end of each pull-down resistor (R3, R4, R5) go to the ground bus. In addition, a wire from pin 8 of each socket must be run to this bus, as shown in figure 3-2.

The single-pole double-throw switch requires three insulated wires on the underside of the board. The first wire runs from the plus wire of the cap to the center common of the switch, and the other two wires run from pin 1 of each socket to the opposite switch terminal.

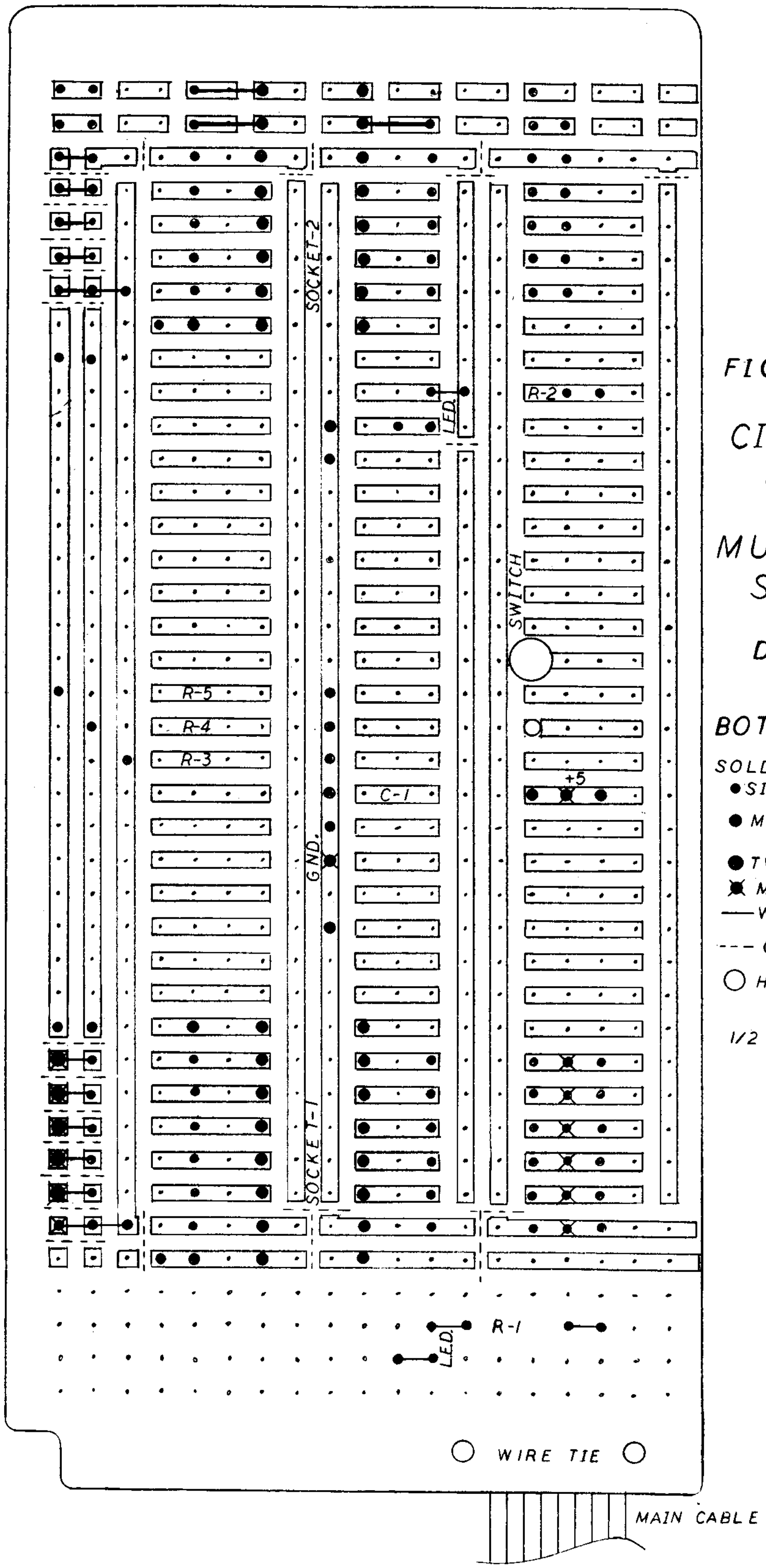


FIG. 3-4

CIRCUIT BOARD FOR MULTIPLE SOCKET WITH DIODES

BOTTOM VIEW

SOLDER JOINTS

- SINGLE WIRE
- MAJOR PART
- TWO WIRES
- MAIN CABLE

—— WIRE BRIDGE

- - - CUT TRACE

○ HOLES

1/2 RADIO SHACK
CAT NO 276-154A

The LEDs (light emitting diodes) used for the prototype are small and rectangular, one red, one green. They are slightly more expensive than round LEDs, but that is the only difference. Purchase round ones of any color, if you prefer them. Install the LEDs beside the socket and even with its top. From the positive terminal, run a wire around to pin 1 of each socket. Then install the current-limiting resistors R1 and R2 on a wire run to the ground bus for each. The LED for socket 1 is in an area where there are no copper pads, so loop one wire around the other one before you solder them.

On the pin 1 side (see figure 3-4), three bus lanes are used for the pull-down resistors of the pushbuttons. Short insulated jumper wires are needed to run between pins 3 and 4 and these buses on each end, as shown in figure 3-2. Both #2 pins are jumped to a bus below the board. As detailed in figure 3-5, two of these jumper wires go into holes through which cable wires must also be inserted, so you must wait until the second wire is ready before you solder them both. There are a total of five such double-wire holes, and it is somewhat tricky to install and solder the wires. When using a general-purpose circuit board, you will run into a few difficulties like this as a matter of course.

CABLES FOR THE SELECTION SWITCH

The two side cables noted previously must now be made up and installed. (They were omitted from figure 3-2 for the sake of clarity; their locations are shown on figure 3-5.) The one on the pin 1 side has three conductors for pins 5, 6, and 7. The one on the pin 16 side has six conductors for pins 10, 11, 12, 13, 14, and 15. You can use two pieces of ribbon cable or individual wires for these cables.

The main cable requires 14 conductors. You can use a DIP jumper cable; these come with DIP plugs on each end. Cut off one plug and fan out the wires. Be certain to check the jumper for continuity end to end and for each wire, since DIP jumpers sometimes have open pins.

We prefer to use 16-wire ribbon cable (cut from 20-wire ribbon) and double up the wires on pins 1 and 8. This improves the electrical characteristics of the unit and lets you add the stacked plug/socket described earlier. The pull-down resistors R3, R4, and R5 need not be put inside the plug since they are on the board, but careful soldering is required to place 16 wires in so small a space.

Separate two inches of ribbon on the board end of the cable into individual wires and trim them to the required length. The longest wire is the double ground that runs to the central bus. The +5 wires that run to the plus end of the cap are only a bit shorter. The rest of the wires connect along each side of socket 1. Each wire is trimmed, stripped, twisted, tinned, inserted into its hole, and then soldered.

People with small hands have a definite advantage in doing this type of electronic work. You will find that a stand or clamp to hold the board is a great help.

The cables should be laid down neatly and secured with a wire wrap. A 1-inch thick block of white plastic foam, stiff but flexible, from a shipping box makes an excellent base for the unit. Cut out a hole for the switch and secure the board in place with a small amount of silicone sealant. If you are concerned about the exposed wires you could cover the top with a sheet of plastic with three holes cut into it.

TESTING THE SELECTION SWITCH

To test the selection unit, measure the resistance from pin 1 to pin 8 of each socket. The reading should be infinite at all switch positions. Inspect the solder side of the circuit board, looking for bridges between copper lanes and cold solder joints that have an excess of dark resin. To double check your work, ask a friend to check conductance wire-by-wire, with the multimeter on a low ohms setting, and color in a second photocopy of the schematic.

When you are satisfied that the circuit tests out correctly, plug in the selection socket and turn on your computer. (We assume that you first turned your computer off if it was already on.) If the computer does not start up in a completely normal fashion, turn it off at once and recheck your work. If the computer starts up correctly, try the switch and watch the LEDs. Next, turn off the computer and plug a trusted paddle into your new socket extension. Start up the computer again and run the Controller Checkout program from chapter 15.

If there are any bugs in the unit, they will quickly become apparent. Turn off the computer and carefully check the solder joints associated with any feature that didn't work properly. Most problems are visible on close inspection. Also, remember to test the stacked plug that is now inside the computer case.

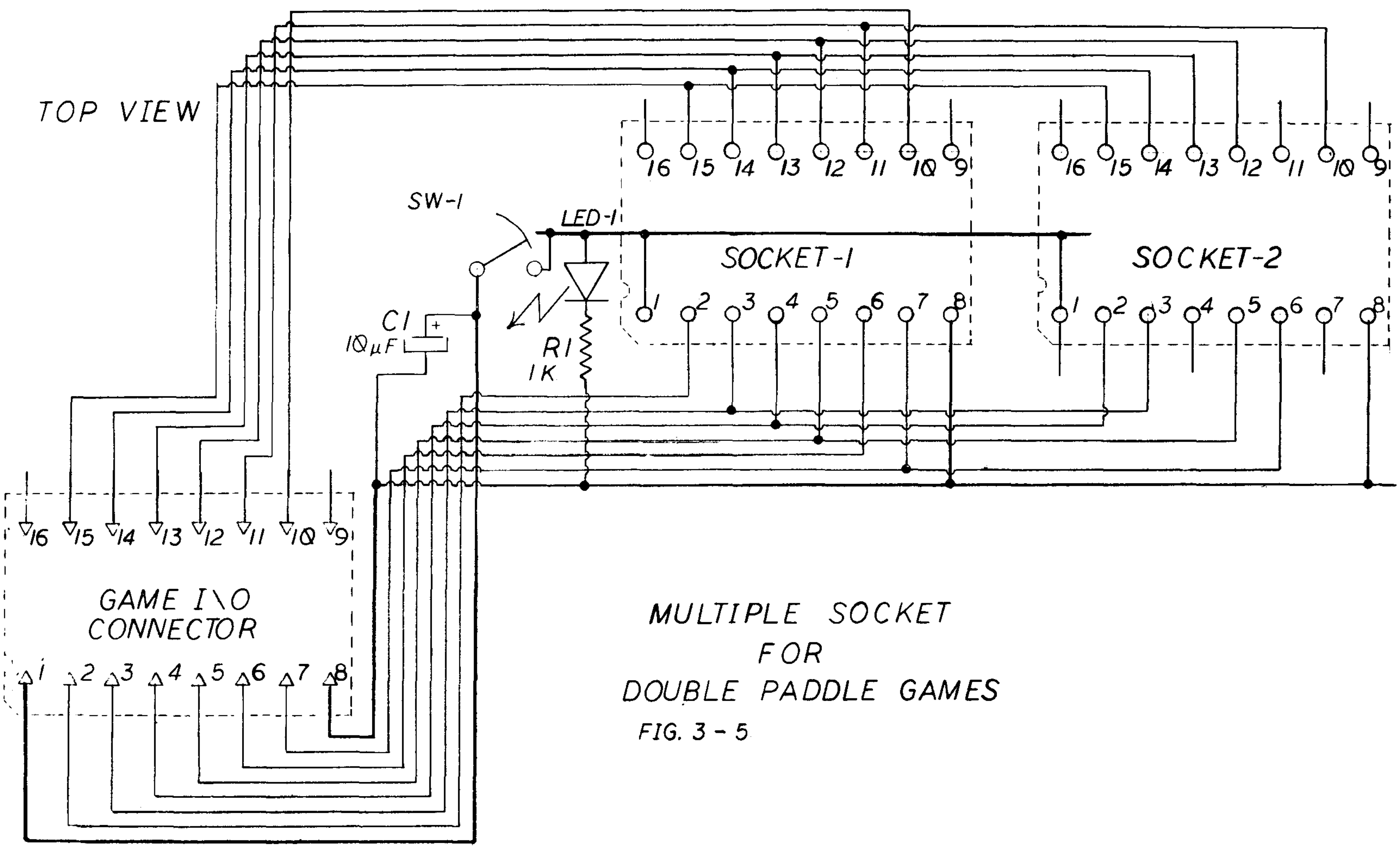
CONSTRUCTION OF OTHER TYPES OF EXTENSIONS

Figure 3-5 is the circuit schematic for a two-person game multiple socket board. This unit has an ON/OFF switch for both sockets and does not need isolation diodes. Pins 2 and 4, 6 and 7, and 10 and 11 are cross wired. Like the stacked plug, this circuit gives you the two-person game feature, but makes it available outside the Apple case.

Alternatively, you could make up a four-socket board that included both schematics (figures 3-4 and 3-5), with a three-position rotary switch in the center. The rotary switch would direct power to sockets 1, 2, or 3, while the fourth socket on the board would be attached to socket 3 as shown in figure 3-5. Seven isolation diodes would be required for socket 3 (none for socket 4), but the connection to socket 4 would be located between the diodes and the sockets. But why stop at four sockets? There is no particular limit except the size of the circuit board.

The owners of computers other than the Apple will find it beneficial to bring the game ports out of the case and add a choice switch. The type of plug is different for each computer, and of course the pin numbers will change. In many systems, all the plugs and sockets would be on short cables, with the switch, diodes and resistors on a circuit board in the center. It will take some work to find the correct pin out information and to locate a supplier for the connectors. Some systems may use pull-up resistors, connected to the +5 rather than the ground, instead of the Apple pull-down resistors. Other systems may not need resistors at all.

There is one other type of multiple control worth mentioning. The multiplexing control, for which the computer chooses the active control, is not used for games. When the control input is a measurement (for example, of temperature or light level) and you must log the measurements from more than four sensors



MULTIPLE SOCKET
FOR
DOUBLE PADDLE GAMES
FIG. 3 - 5

automatically, you would use a multiplexing control. In this way you could monitor a solar hot water system or a science project. This type of multiple socket is quite similar to the units we have just described but requires a few additional integrated circuits.

IN CONCLUSION

The multiple socket extension is one of the most popular additions to the Apple and other personal computers. The home built version not only costs less than a commercial unit but has more features and is an excellent beginning project in computer hardware.

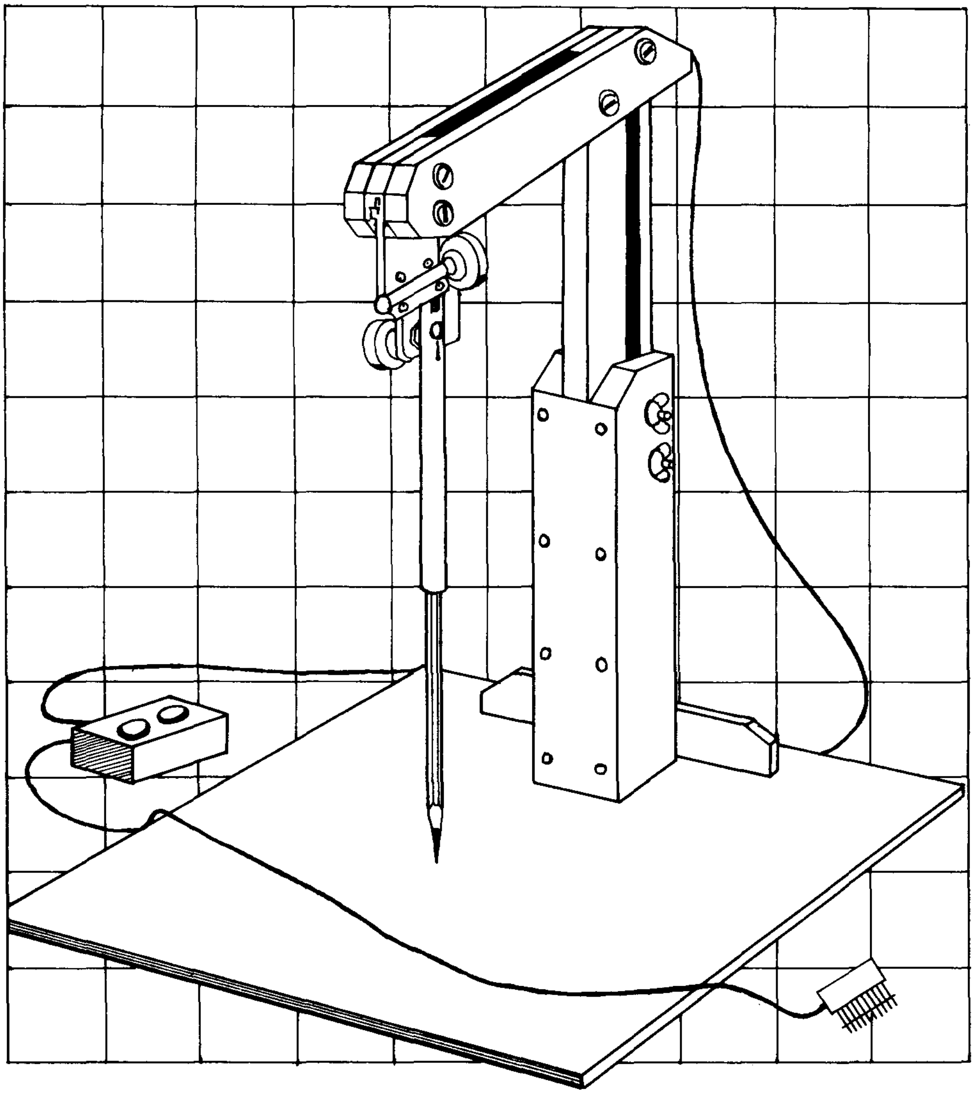
Parts List
Multiple Socket Extensions

Number Required	Description of Part	Suggested Supplier	Total Cost
1	Experimental Bread Board, #276-154A	R.S.	$3.70
2	16-pin ZIP DIP sockets, #216-3340	Jameco	12.40
2	16-pin W.W. sockets, gold plated	Jameco	1.40
1	16-pin header plug	Jameco	.70
2 ft.	Ribbon cable, 20-conductor	R.S.	.40
14	1N914 (or1N4148) diodes	Jameco	1.00
1	Capacitor, 10 uf, 15 volt	R.S.	.40
3	Resistors, 10K ohm, 1/4 watt, 5%	R.S.	.40
2	Resistors, 1K ohm, 1/4 watt, 5%	R.S.	.40
2	Light Emitting Diodes	R.S.	1.50
Misc.	Silicone sealant, solder, etc.		1.10
		Approximate Cost	$26.00

Suppliers:

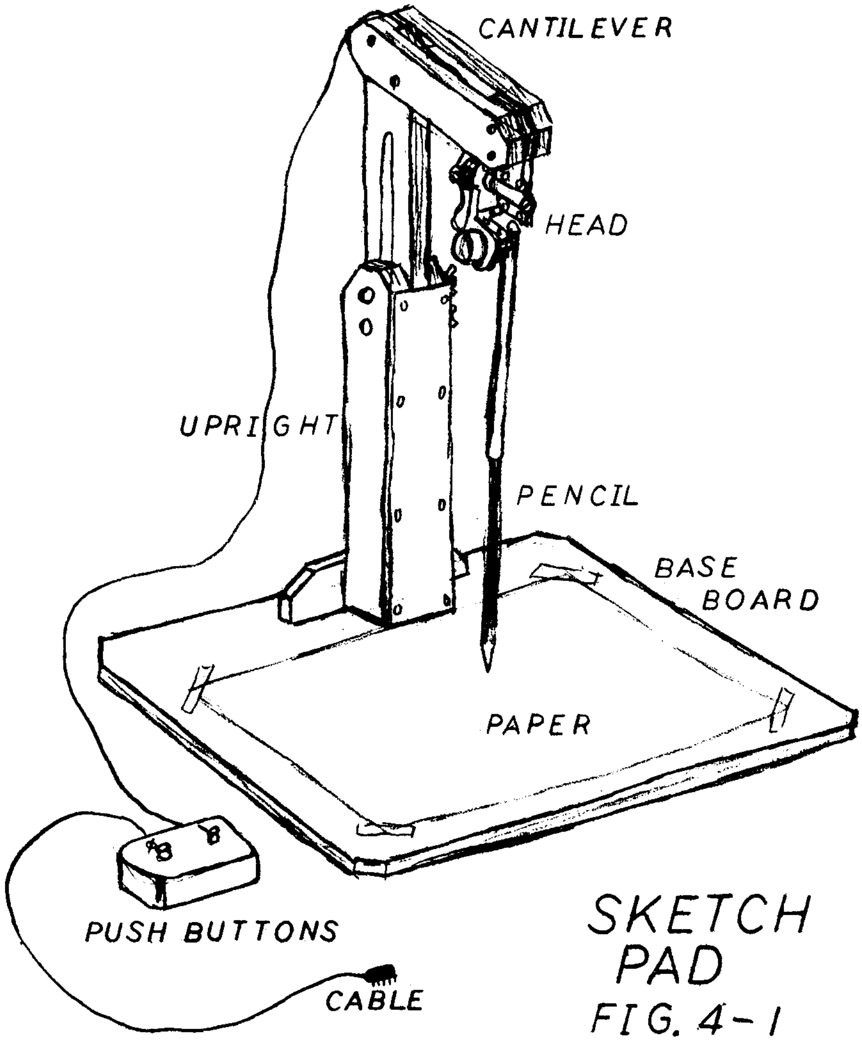
Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

R.S.—Radio Shack
See Yellow Pages



4 Sketch Pad

The capacity of the Apple and other home computers to produce complex graphics gives us an exciting new artistic medium, but it is often difficult to use. There are several commercial software packages that simplify entering images into the computer, but the lack of suitable drawing instruments limits their use. Graphics paddles and graphics tablets are currently on the market, but the cost of this hardware is prohibitive for many would-be computer artists.



SKETCH
PAD
FIG. 4-1

If you are interested in experimenting with computer graphics but can't spend much money on hardware, consider building this versatile sketch pad, which will let you draw directly into the high resolution graphics screen. We will show you how to construct the sketch pad for a total cost of about $30.

FEATURES OF THE DEVICE

The sketch pad has a drawing surface slightly larger than a standard sheet of paper (8-1/2 x 11 inches). You can attach drawings and photographs to the pad and trace them into the hi-res screen, or you can use a blank sheet of paper and simultaneously draw on the paper and the screen. You can also use the sketch pad to read graphs, strip charts, and business charts directly into the computer.

Figure 4-1 is a drawing of the finished device. Features to note are the baseboard, the upright post which can be adjusted to change scale, the head with its two potentiometers, the cantilever, the pencil holder, and the cable with a box for the pushbuttons.

The unit is constructed of plywood and sheet metal and can easily be made in a home workshop or shop class. It could be built completely with hand tools, but the use of a table or radial arm saw speeds up the job. The wiring is extremely simple, so the electronics work shouldn't intimidate an interested builder. All in all, this is a good beginner's project.

We have included three programs in Applesoft Basic (see chapter 15) to give you a start in using the sketch pad. A Linearity Test program shows how well this sketch pad or a similar commercial graphics unit is working. The Drawing program, lets you draw directly onto the hi-res graphics screen in three different modes, store pictures on disk, and then retrieve them. The Digitizer is a program that lets you measure points on data sheets and enter them into your computer for data analysis, a process called "digitizing the data." The sketch pad will digitize quickly and with reasonable accuracy, and this program will store and retrieve the data from disk as well. We will examine all of these programs in detail later in the chapter.

PRECISION AND LINEARITY

Simple game controllers can be rather sloppy devices, since accuracy is often sacrificed for speed and feel. But in constructing a sketch pad, you want all the precision you can get.

Two parameters are important in obtaining that precision. First is the theoretical precision of the electronic circuits, whether they are 8 bit, 10 bit, or greater. Second is the uniformity or linearity of the mechanical to electrical converters, in this case the potentiometers. These considerations arise whenever you are continuously changing quantities (analog) to numbers (digital) or vice versa.

The paddle input on the Apple II and most other home computers is a timer circuit which converts a resistance value into a number between 0 and 255. This is an inexpensive and stable 8 bit analog to digital (A to D) converter. It is also an extremely slow one. The best possible precision it can have is one part in 256, or about 0.57%. This sounds pretty good; old style panel meters had an accuracy of about 5% at best.

The problem with even 0.5% precision is that errors creep in because of aging components and temperature changes, so that the theoretical precision is rarely achieved. And, if you have to measure several numbers and use them in mathematical equations, the inaccuracies tend to add up. Expensive computer systems usually have 10 or 12 bit A to D converters. (The most accurate converter we have seen was a 24 bit system in an astronomical observatory.) The more precision you try for, the more difficult it is to calibrate and stablize the system so that you can approach its theoretical limit.

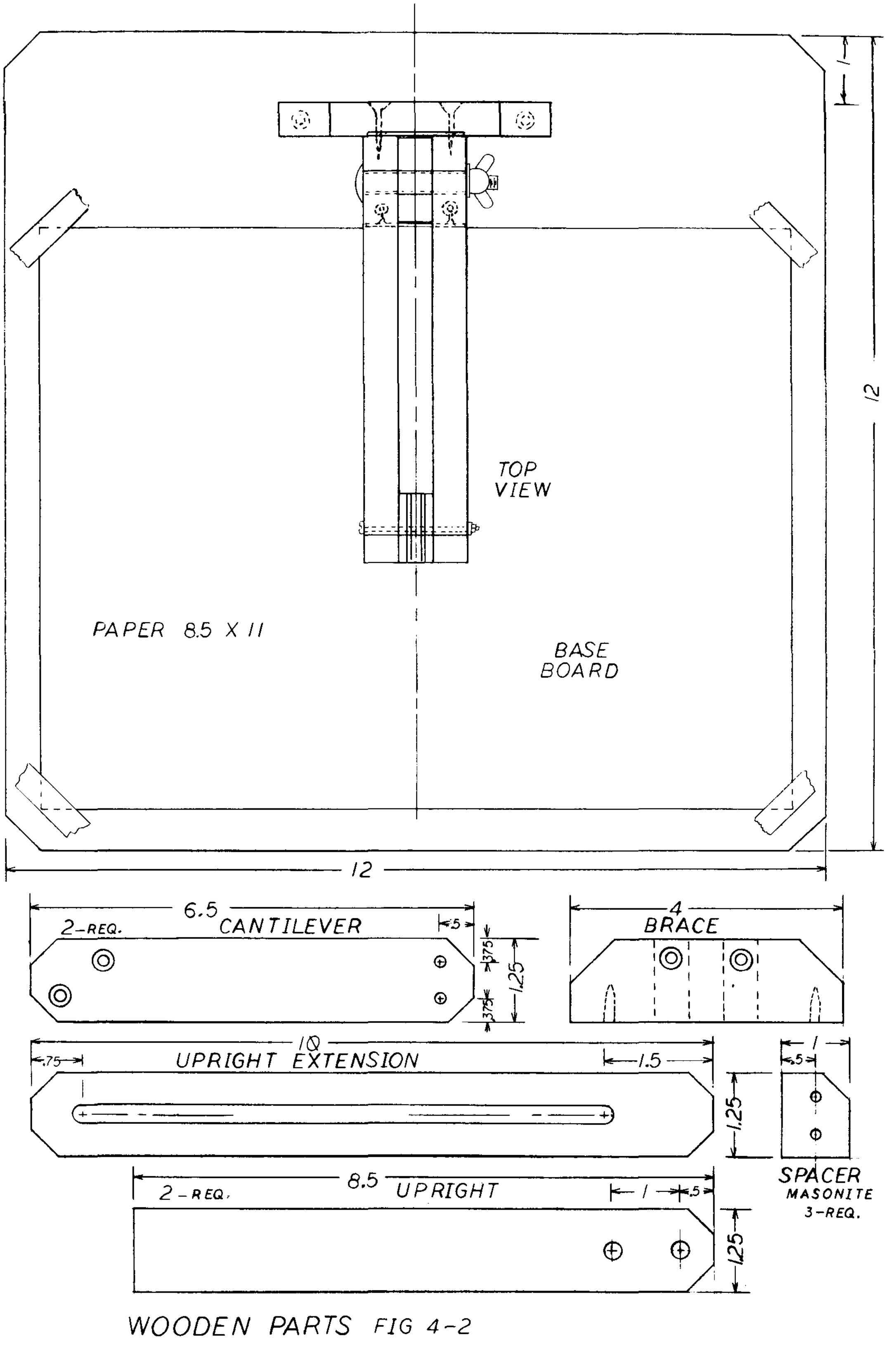
The second problem is linearity. For the sketch pad, linearity defines how straight a line it will draw. The electronic timer circuit has strikingly good linearity, but the potentiometers do not. If we draw a graph of the resistance of a pot versus the degree of turn of the pot shaft, we should get a straight line. But if the manufacturing processes for the resistive element in the pot are not extremely uniform, the measured reading will vary from the ideal straight line. If you use cheap, non-linear pots in the sketch pad, the lines you draw with it will be bent. Your drawings will look like the reflections in a funhouse mirror.

There is not much you can do to increase the precision of the Apple's 8 bit digitizer, at least not cheaply. But eight bits is almost enough for Apple graphics, anyway. The resolution of the hi-res screen is 280 by 192 picture elements, and the two paddles resolve 256 by 256. This is more than enough precision vertically, and we are only short by 8% horizontally.

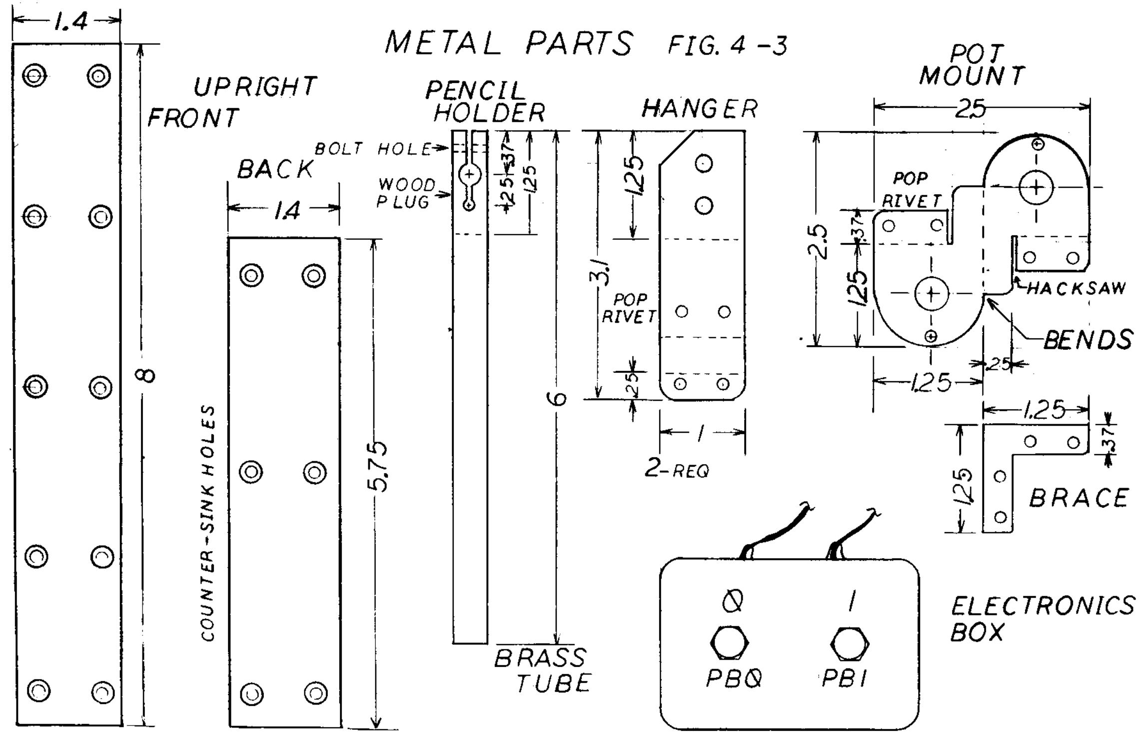
CONSTRUCTION

Figure 4-2 gives a top view of the baseboard and details of other wooden parts. The first step in constructing the sketch pad is to gather all the materials and cut out the parts.

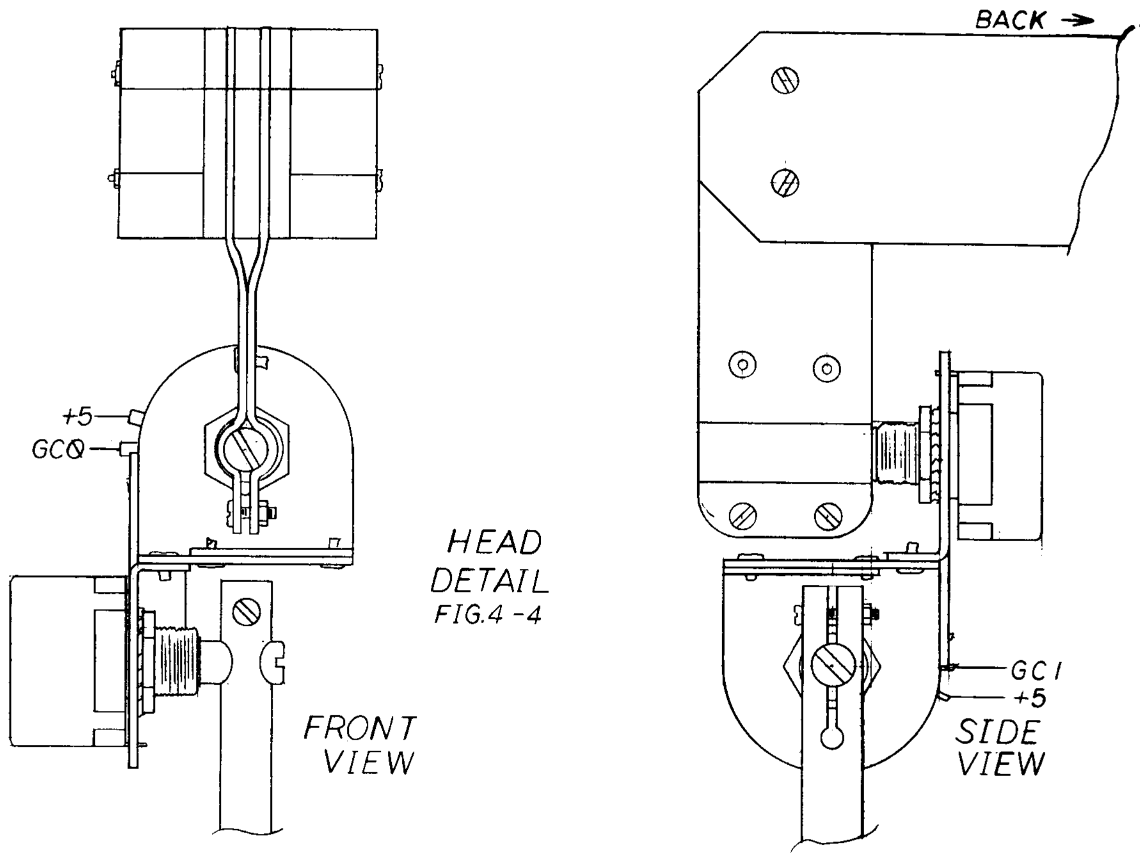
The prototype was made from 1/2-inch hardwood plywood (part of a salvaged kitchen cabinet), but standard fir plywood would work as



WOODEN PARTS FIG 4-2



METAL PARTS FIG. 4-3



HEAD
DETAIL
FIG. 4-4

well. The drawing surface of the baseboard must be sanded smooth. The wooden parts of the uprights and cantilever were cut from the same plywood and also had to be well-sanded, particularly along the edges. Most of the holes shown in figure 4-1 are for #8 x 1-inch wood screws. They were drilled with a Screw Mate drill, which produces exactly the right shape hole and counter-sink.

Most of the metal parts (see figure 4-3) were cut from a 1/16-inch thick piece of aluminum scrap. Galvanized steel about 1/32-inch thick would also give good results. You must be able to work the material with hand shears, but it can't be so flimsy that the parts are easily bent. When you are drilling sheet metal, you should hold it with vise grip pliers or in a bench vise to keep it from spinning and cutting your hand. The front and back of the upright have countersunk holes for #6 flathead wood screws. File all edges and corners smooth as soon as you cut or drill them.

The parts for the head, which holds the two pots, are somewhat complicated; figure 4-4 shows them in detail. It helps if you have your pots in hand so you can trial-fit them. If your first attempt doesn't look right, make another.

Cut out the two metal pieces that form the hanger (as shown in figure 4-3), then drill only the two central pop rivet holes. Pop rivet the pieces together. Now open up the bottom parts of the hanger and bend them around a 1/4-inch bolt to form the pot shaft clamp. Bend back the bottom tabs so that they don't quite touch. With the bolt still in place (it substitutes for the pot shaft), drill the clamp bolt holes for the bottom shaft. Drill the top bolt holes. Then, using this metal piece as a pattern, drill the matching holes in the cantilever parts and the masonite spacers.

Cut out the pot mount piece and brace, file the edges smooth, and drill the holes for the pots. You will need a hacksaw for the two small cuts. Use the pots to mark the positions of the spin prevention tab holes. Now bend the pot mount to look like the one in figure 4-4. For the prototype, the metal was bent in a bench vise with custom-made oak jaw faces. Fit the brace in position and clamp it with vice grip pliers in order to drill the pop rivet holes. Install each pop rivet after its hole is drilled, working from the outside to the inside.

The holder for the drawing instrument is made from brass tubing available at your local hobby shop. You may want to make several different size holders for pencils, pens, and a plain wooden pointer or stylus. Be sure to take the instruments to the hobby shop with you for trial fittings. Cut the brass tubing with a small triangular file. If the fit is a little loose you can insert a 3/8-inch wide strip of heavy polyethylene sheet (a garbage bag is a good source) inside the tube. You may have to cut the erasers off the pencils.

Next, cut a 1-1/4 inch wood plug from 3/8-inch maple dowel to fit inside the top of the tube and glue it in place with epoxy. After the glue has completely set (preferably overnight), drill the pot shaft hole, the bolt hole, and the saw cleft stop hole. Make the saw cleft with a hacksaw and file all edges smooth.

Put together the wood parts with wood screws and carpenter's glue and then fit and mount the metal parts. Install the clamping bolts, but leave them loose; the upright extension should slip smoothly into the upright. You may have to sand and rasp the extension some more to get a smooth adjustment.

When everything fits, take off the metal parts and fine sand the wood. All wood parts should be finished with two or three coats of satin-finish polyurethane varnish. When the varnish is thoroughly dry, reassemble the entire device.

To prevent the sketch pad from scratching your furniture, you can glue cotton felt to the bottom of the baseboard with contact cement. To make a better surface to work on than the finished wood, attach a heavy piece of drawing paper to the unit with drafting tape.

ELECTRICAL COMPONENTS

The utility of the sketch pad is dependent on good potentiometers: the pots must be as linear as possible. We have had good luck with the pots that meet military specifications (Mil Spec) described in the parts list, but even with these you should consider buying a few extras so that you can choose the ones that draw the straightest lines. The pots listed have short shafts; they are just long enough for the homemade clamps. If you have a choice, get long-shafted pots and saw off the shafts as needed.

The pots do not travel through their full turning of 300 degrees, so you will need pots with values much greater than the standard values of your computer. The 1 meg-ohm pots listed work well for the Apple II, which normally uses 150K pots.

If you can't find good pots with the higher values, or if you find some especially good pots at a surplus store, you can use correction capacitors, as described in chapter 1. Correction caps can easily be mounted in the pushbutton box, and you are much more likely to obtain straight lines if you use them.

The pushbuttons, which should be at least 3/8-inch in diameter, are mounted in a small plastic box. Your fingers will tire quickly if the buttons are smaller than this. The correction caps, pull-down resistors (R1 and R2), and the filter cap (C1) are mounted on a small piece of printed circuit board that is placed in this box.

WIRING

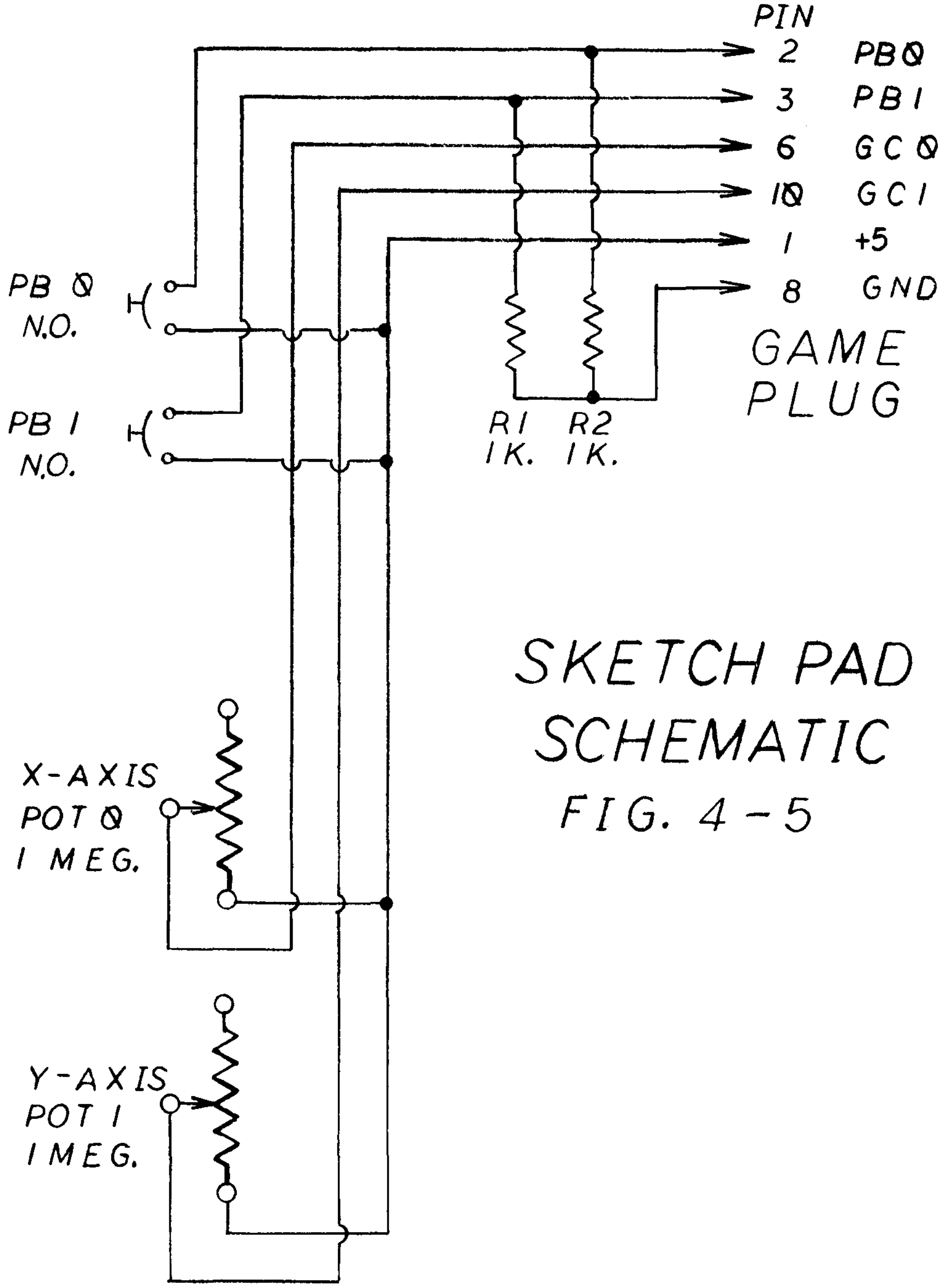
For the electronics work on this project you will need a small pencil soldering iron of 25 to 40 watts and fine resin-core solder. The necessary hand tools are long-nose pliers, diagonal cutters, and wire strippers.

The cable from the pots to the pushbutton box must be very flexible and have at least three conductors. Using four-conductor telephone cable with the +5 wire doubled up worked well for the prototype. The cable should be about 30 inches in length—long enough to loop to the top of the upright and then run to the pushbutton box. Figure 4-4 shows the pot terminals to which you will solder the wires.

The run from the pushbutton box to the plug requires six conductors. Two lengths of telephone cable will work nicely. Ribbon cable can also be used for this run if that is what you have on hand. If you have extra wires, double up the +5 supply and ground. The length of this cable will depend on how far away from the computer you want to place the sketch pad for general use.

The plug is a standard 16-pin DIP header. You can mount resistors R1 and R2 on it if you like. Be very careful to identify pin 1 by its marked corner. The cable usually enters the header from the pin 8 end.

The best way to check your wiring is to make two photocopies of figure 4-5. On the first copy, color in each wire, component, and solder joint as you progress. Go over your work again and color in the second copy as a final check. This is standard practice in electronics.



SKETCH PAD SCHEMATIC

FIG. 4-5

TESTING AND ALIGNMENT

If you have a multimeter, check the resistance from pin 1 to ground pin 8. It should be at least 50 ohms (normally, it will be much higher) even when you press the buttons and turn the pots. Shut down your computer, plug in the sketch pad, and turn the computer on again. If your computer does not start up in the normal way, turn it off at once and recheck your work. Then run the Controller Checkout program from chapter 15.

To adjust the pots, tape a blank piece of paper on the board and mark the spot in the center where the pencil is exactly straight up and down. With a program running that shows the pot readings, and with the clamping bolts loose, turn the pot shafts within the clamps until both readings are 128 when the pencil is on the mark.

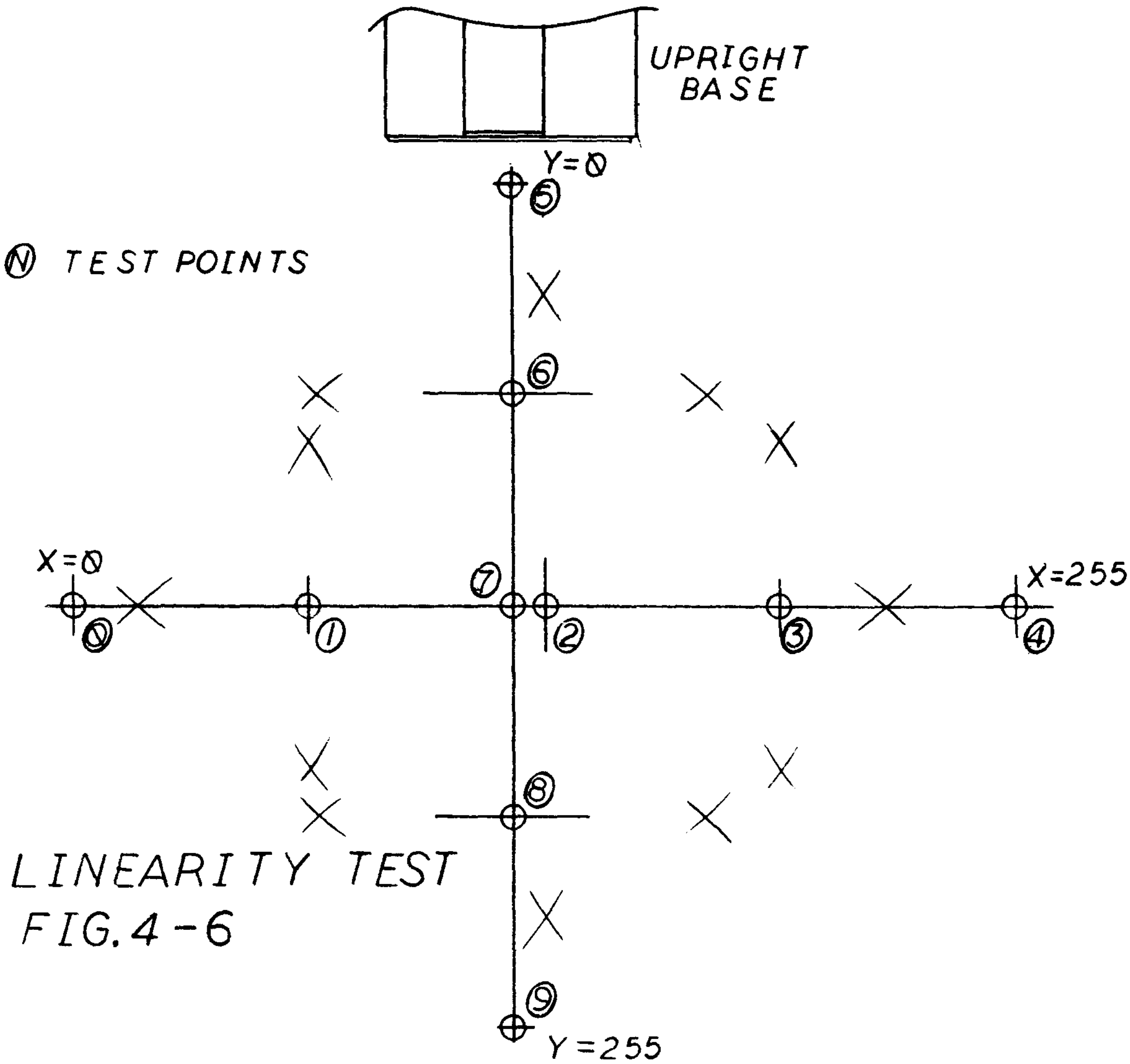
Now tighten all three clamping bolts. Move the pencil around the paper and make marks at the 0 and 255 points in each direction . The reading in the top left-hand corner should be 0,0, just as the top left-hand corner of the hi-res graphics screen is 0,0. If one or both axes are backwards, you can reverse them by moving the +5 wire to the other outside pot terminal and resetting the 128,128 point.

Try moving the upright up and down to change scale. Mark the 0 and 255 limits for different upright heights to learn the range of sizes available for drawings. You should be able to adjust from about 6 x 8 inches down to 3 x 4 inches. If 0 and 255 fall off the baseboard, you will need the correction caps as discussed earlier.

LINEARITY TEST

The Linearity Test program (see chapter 15) provides a test of the linearity of your pots and the accuracy of the sketch pad as a whole. To make this test you will need paper, a compass, and a straight edge. Tape the paper to the board and run the program.

As shown in figure 4-6, draw a line front to back down the center of the paper. Mark the points on this line where Y, as shown on the screen, becomes 0 and where it reaches 255. Using the compass, bisect this line (the required arcs are shown in figure 4-6). Draw the bisecting line completely across the paper. Bisect each half of the first line with short cross marks. Mark the points on this line 5, 6, 7, 8, and 9, as shown in figure 4-6.



LINEARITY TEST
FIG. 4-6

Mark the 0 and 255 points on the X axis line and bisect the line between these points. The central point #2 may or may not fall exactly on the Y axis. Bisect each half of the Y line and mark points 0 to 4.

Now for the linearity test. Carefully place the pencil on point 0 and press the 0 button, then do the same for points 1, 2, 3, and 4 in turn. Move to points 5 through 9 and at each press pushbutton 1. The screen will now show the correct reading for each point, the value actually read, the error, and the error as a percentage of full scale. The lowest repeatable score could have as low as 0.5% as the worst error percentage. Sketch pads with error rates below 4% will generally produce good drawings. Run and test several times to see how good you are at hitting the same points. Pots with large error values will draw distorted pictures, but the distortions may lead to interesting effects.

After testing the unit as described, you may want to cover the exposed wires on the pots and the DIP header with several coats of fingernail polish or with silicone sealant. Gluing cotton felt to the bottom of the pushbutton box will keep it from scratching the desktop. Be sure to mark pushbuttons 0 and 1 clearly.

THE DRAWING PROGRAM

Now that the device (and perhaps its builder) have been thoroughly checked out, we can begin to draw with the sketch pad. The Drawing program listed in chapter 15 is a fairly detailed sketching program. It lets you draw pictures in three different modes, save your work on disk, and retrieve it. The program is menu-driven and includes instructions.

First tape a clean piece of paper onto the board. To run the program, select item #1 on the menu to clear the hi-res screen. Next enter item #4, Drawing Continuous Points, and read the instructions. Press RETURN. As you move the pencil, dots will appear on the screen. The 0 pushbutton will show the values X, Y, and HCOLOR. Pressing numbers 1 through 7 on the keyboard will change HCOLOR to the number pressed. The ESCAPE key will bring you back to the main menu.

Again, press 1 to clear the screen; now select item 5, Drawing by Continuous Lines. The rules are similar to those for selection 4, but we think the resulting drawings look better. You might trace a plastic circle template to see how distorted the circles are on the hi-res screen. Tracing the same shape several times will give you some idea of how accurately you can copy drawings. Press ESCAPE to return to the main menu.

The third drawing mode is 6 on the menu, Drawing by Reference Point Lines. Both pushbuttons are used here. Pushbutton 0 does just what it did before. Pushbutton 1 has a new function: it fixes the stylus location as a reference point, which will be shown as a small blinking cursor on the screen. To draw in this mode, think of your picture as a series of straight lines. Move the stylus to one end of a line and press button 1. Find the other end of the line and press 1 again. A line will appear on the screen between the reference points. This drawing mode is least affected by the non-linearity of the pots.

You can use all three modes in one picture: draw straight lines with the reference point mode, draw curves with the continuous line mode, and fill in areas with the continuous point mode. To erase, simply change HCOLOR to 0 or 4 (black) and retrace the line. You can shift between the modes without erasing the screen.

Main menu selections 2 and 3 place and retrieve the entire hi-res screen on the disk (this requires 34 disk sectors). Practice saving and retrieving a simple practice sketch before spending a lot time on a drawing. You don't want to risk losing a masterpiece by making a simple mistake.

THE DIGITIZING PROGRAM

The digitizing program (see chapter 15) assumes that you have a stack of up to 41 graphs or charts, each with up to 15 data points, and that you need to transfer this information into the computer. You must first name the disk file. If you want to add to an existing file, answer that the file is not new—the program will get the file off the disk.

Adjust the height of the sketch pad upright so that the stylus will just cover the entire area where points are found on any of the graphs. If all your graphs are the same size, make a reference corner by taping strips of cardboard to the sketch pad base. This will make it easy to place each graph in the same location.

Write down the values of X = 0, X = 255, Y = 0, and Y = 255 on the axes of the graphs. These readings will be needed in the next step. Press pushbutton 0 to continue.

Enter the units of the X axis (centimeters, days, whatever), then the graph axis value for X = 0 and the graph axis value when X = 255. Do the same for the Y axis. Since the 0,0 point is in the upper lefthand corner, the value for Y = 0 is usually larger than the value for Y = 255.

Now you are ready to transcribe data. Place sheet 0 on the baseboard, move the stylus to the first point, and press pushbutton 0. The screen will show the X reading, the Y reading, the X axis value in the X units of the graph, and the Y axis value in the Y units. Continue moving the stylus and pressing pushbutton 0 to enter up to 15 data points.

Pressing pushbutton 1 at any time will bring up a question asking if a new sheet is desired. A YES answer brings up a new sheet, a NO answer sends you to the disk storage routine.

This digitizing program is intended as an example to get you started. You will probably want to add correction features and restructure the data files to suit your data reduction programs. The number of sheets and points is limited by the size of your computer's memory.

SUMMING UP

The sketch pad is an inexpensive, easy-to-build device that can be used for computer art work and data entry. Its major limitation is the imprecise linearity of inexpensive pots. (Commercial units, however, also have difficulty achieving good linearity.) The programs included here let you check the quality of the sketch pad and help you get started with drawing and data entry.

Parts List
Sketch Pad

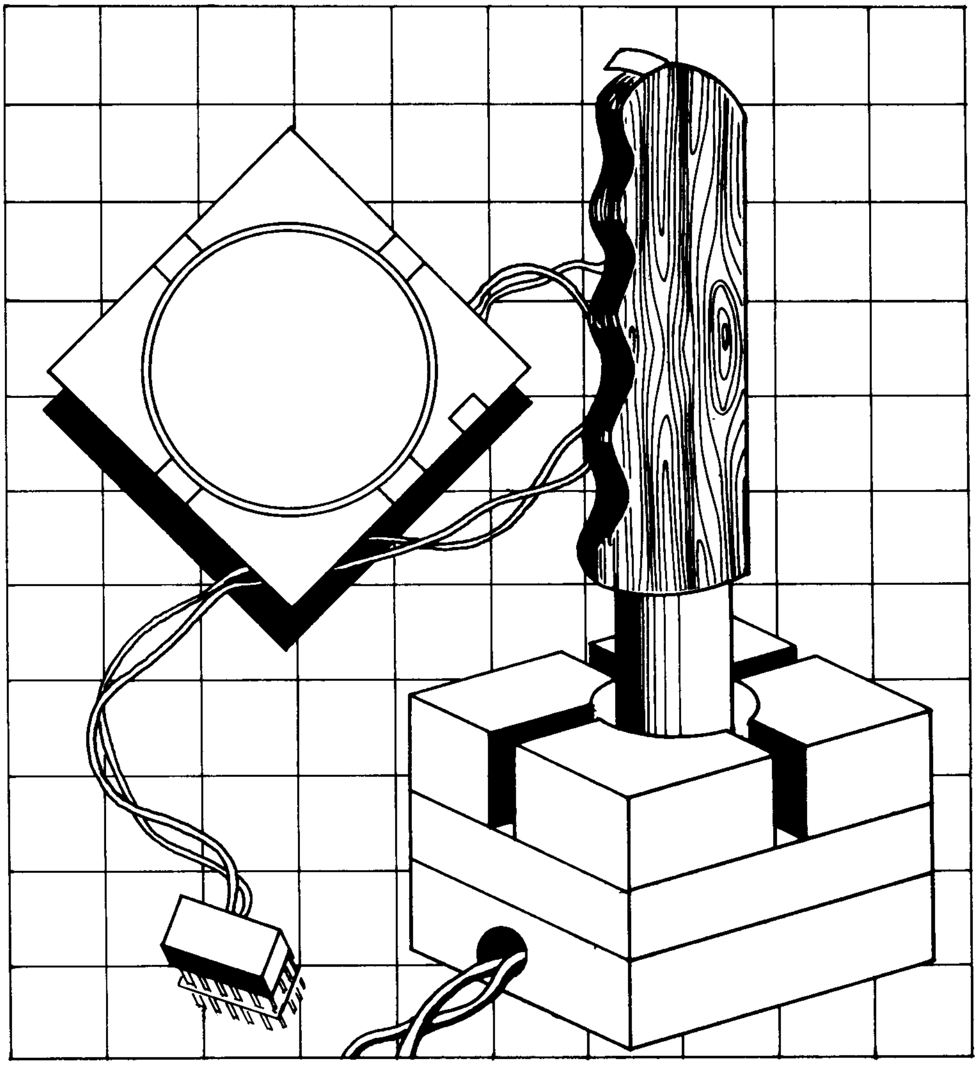
Number Required	Description of Part	Suggested Supplier	Total Cost
3	Linear taper pot, 1 meg, mil spec, CMU1052	Jameco	$9.00
1	16-pin DIP header	Jameco	.70
2	Pushbuttons, #275-609	R.S.	1.90
1	Box, #270-230	R.S.	1.90
12 feet	Telephone cable, #278-365	R.S.	3.00
2	Resistors, 1K, 1/4 watt	R.S.	.40
2 sq.ft.	Plywood, 1/2″ hardwood preferred		4.00
1 sq.ft.	Sheet metal, aluminum or steel		1.00
2	Bolts, 1/4 x 2″		.60
2	Wing nuts, 1/4″		.30
2	Flat washers, 1/4″		.10
16	Flathead wood screws, #6 x 1/2″		.60
10	Flathead wood screws, #8 x 1″		.60
3	Bolts with lockwashers and nuts, #6 x 1/2″		.40
2	Bolts with nuts, #8 x 1-3/4″		.30
6	Pop rivets, 1/8″ x 3/16″		.40
1	Brass tube (to fit pencil)	Hobby shop	.60
Misc.	Cotton felt, sandpaper, varnish, etc.		2.50
		Approximate Cost	$28.00

Suppliers:

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

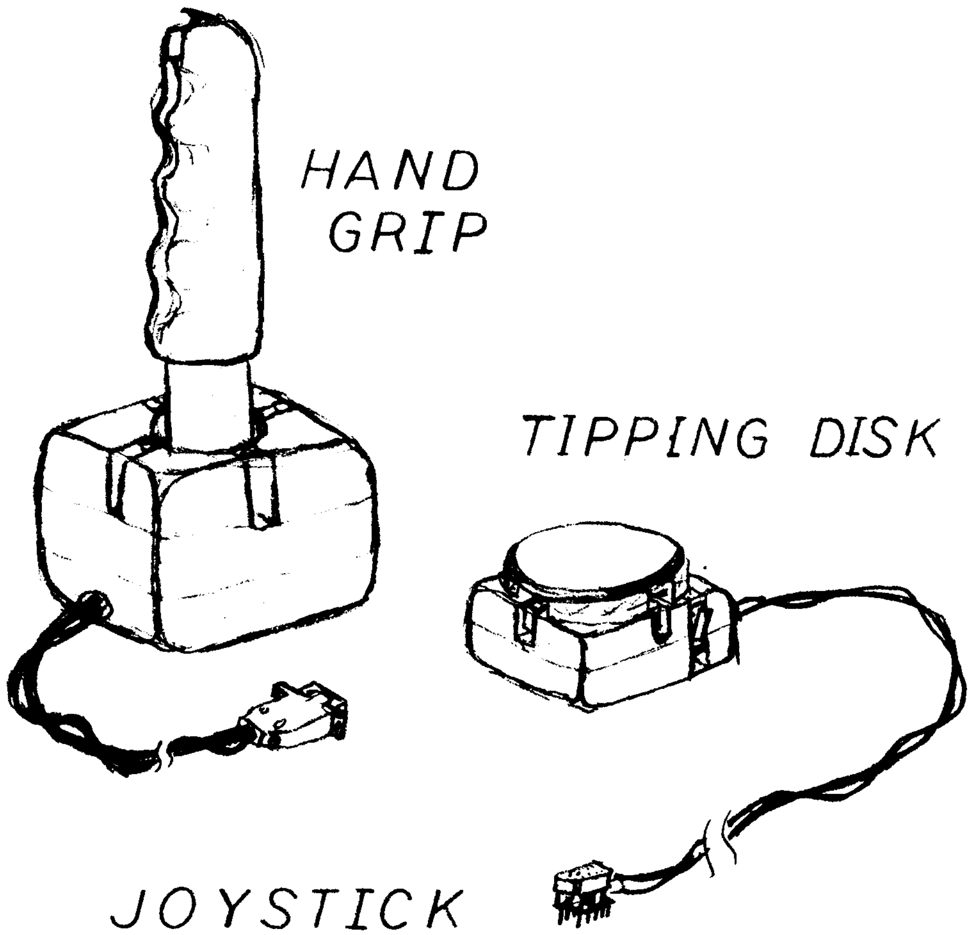
R.S.—Radio Shack
See Yellow Pages

All other parts were purchased at a local hardware store.



5 Homebuilt Atari Joysticks

In this chapter we are going to look at some homebuilt joysticks for the Atari and Atari-compatible systems. We will describe two different designs for Atari joysticks: one is similar to the commercial unit, but the other is a new type of joystick that can be customized for individual hand fit and high-speed action. We will also include the electronic circuit needed to wire these Atari joysticks for use on an Apple computer.



JOYSTICK
SKETCHES
FIG. 5-1

THE ELECTRONICS OF THE ATARI JOYSTICK

The Atari joystick is simply a collection of five normally-open, momentary-contact switches. These five switches allow the computer to detect a movement in eight directions and to read the input from a FIRE button. The four switches which control direction are paired so that only one switch of each pair can be pressed at a time. One pair controls up or down on the screen, the other pair controls left or right.

These switches are paired by mechanical linkages rather than by electrical circuits. The fifth switch, the FIRE pushbutton, is mechanically independent of the others, but all share one common electrical conductor.

This construction is completely different from that of Apple-type joysticks, which feature two lever-controlled variable resistors. The Apple joysticks are analog input devices, having many values over their range, while the Atari type are digital, with only a few discrete input commands.

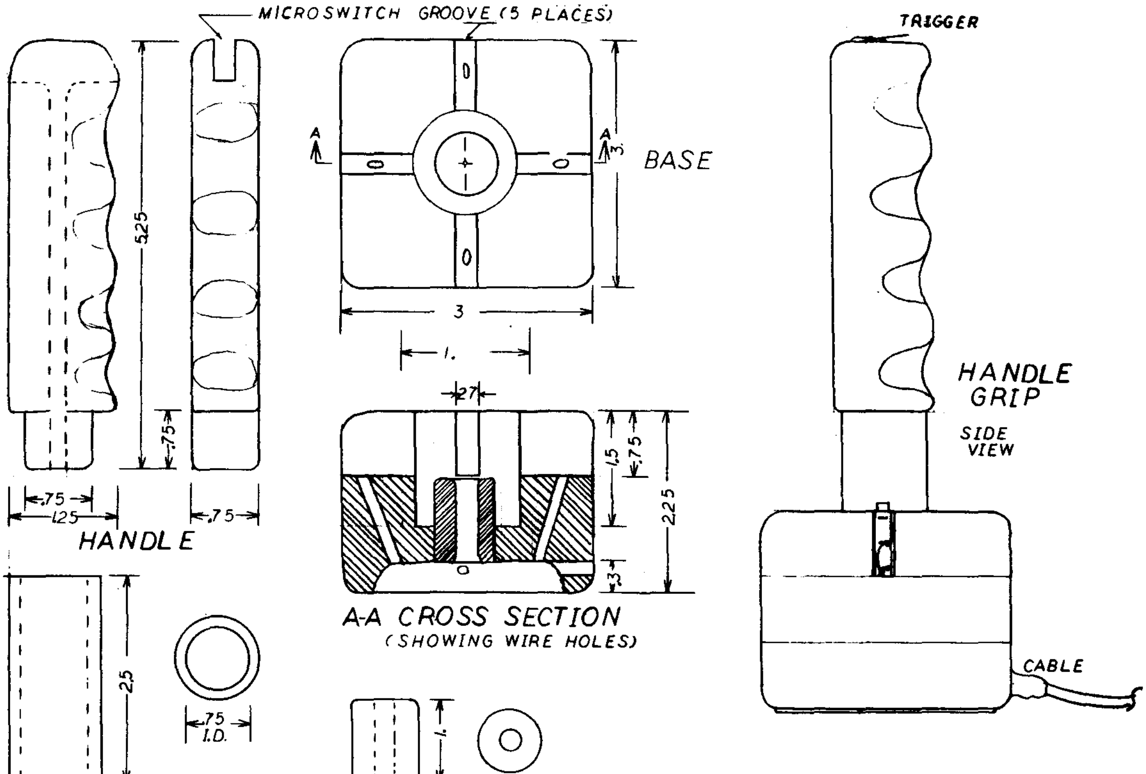
In an Atari-type joystick you need precise control so that you can give an exact command every time, good feel so that your hands don't tire, and, above all, speed. Another helpful feature, but one that most commercial joysticks for the Atari lack, is tactile feedback, which means that there is a definite sound and feel when electrical contact is made. The joystick should also have good mechanical strength to insure long life, since it will see heavy use.

Most commercial units for the Atari do not meet the above requirements. They are often awkward to hold, particularly for lefthanders; it is difficult to tell when contact is made, and handle movement is limited and rubbery. We think you can obtain a far superior joystick if you build your own. Constructing an Atari-type joystick may seem to be a somewhat mundane exercise, but working out the details of precise, rapid hand movement makes this task an excellent lesson in man/machine interface.

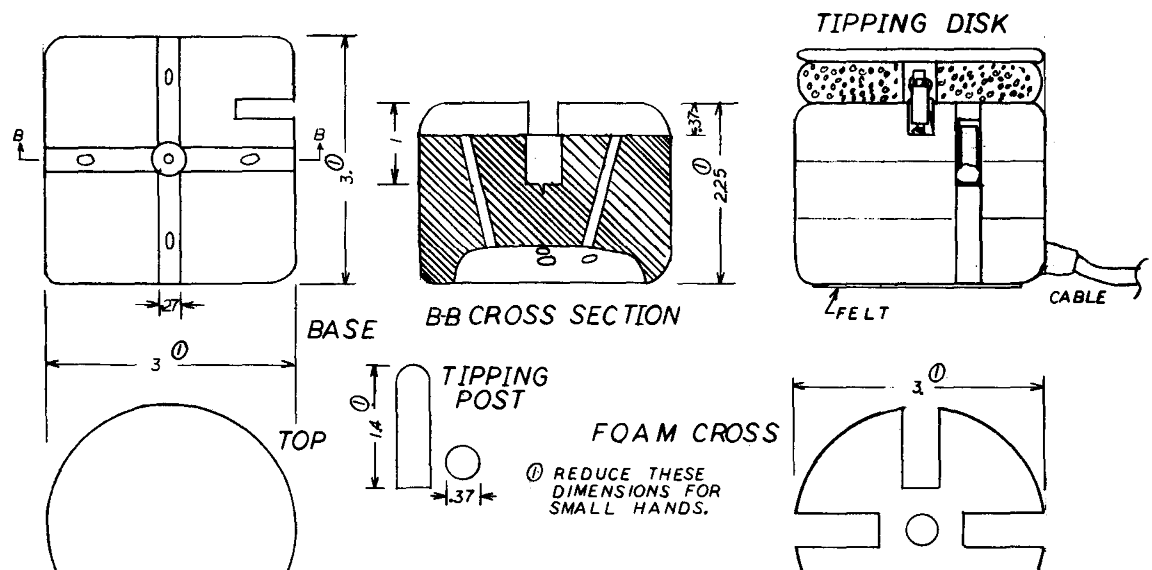
FEATURES OF TWO HOMEBUILT UNITS

Figure 5-1 shows sketches of two joysticks for the Atari. Each unit is constructed from a block of hardwood in which the switches and wiring are embedded. The hand grip joystick, like the standard unit, is used by holding the block in one hand and the grip in the other. The FIRE button on top of the handle will feel natural to most players. The weight of the homebuilt unit improves the feel, and the switches click to give you tactile feedback.

To operate the tipping disk unit, you hold the block in one hand and work the FIRE button with the index finger of that hand. (Your index finger can press a button more quickly than your thumb.) With



ATARI JOYSTICK
FIG. 5-2



TIPPING DISK
JOYSTICK
FIG. 5-3

the finger tips or palm of your other hand you press the disk to direct the movement. With the tipping disk joystick, the player controls the computer with hand movements that are quite different from those of the conventional units.

CONSTRUCTION OF THE HAND GRIP JOYSTICK

Figure 5-2 presents a side view of the component parts of the hand grip unit. The base is a hardwood block that you make by gluing three 3/4-inch thick boards together. We used oak for all the wooden parts of the prototypes, but any attractive wood free from cracks and large knots will do as well. You could use clear pine, but the finished unit will not be as strong or good looking.

Cut the microswitch grooves with a dado blade in a table or radial arm saw (or use a router or handsaw). Since it is somewhat difficult to cut grooves in this small a block with a power saw, you might want to start with three 14 by 3-inch boards. Apply carpenter's glue and clamp them together. Drill the large holes and cut the microswitch grooves for four blocks into the one large piece. This accomplished, you can then saw the large piece into four blocks. This is easier than trying to work with a small block and scarcely increases your cost. If you want to make only one joystick, choose the best of the blocks and discard the others.

Cut out the large central hole with a hole saw in an electric drill or with a large adjustable auger bit in a brace. It is easiest to do this before the grooves are cut.

The rubber hose shown in figure 5-2 serves as a flexible joint. It is the type used for automobile heaters and was purchased at an auto supply store. Other types of hose might be used if they are springy and not too stiff. Size the wood plug and the base for the hand grip for a snug fit in the hose.

The hand grip was cut from a single piece of 3/4-inch thick lumber. With a wood rasp, contour the front of the grip to fit the fingers of your hand. The microswitch groove was cut with a small handsaw and a 1/4-inch wood chisel. If you prefer, you can move this switch to the front of the grip so that you can operate it with your index finger rather than your thumb. The hole down the middle for the fire button wires was drilled with a 1/4-inch paddle drill.

Drill the hole for the wood plug and then carve out part of the bottom of the block to make a cavity in which to place the wire connectors. Glue the plug in place. For the wire of each microswitch drill a 3/16-inch hole; drill a slightly larger hole for the main cable. All of these holes lead to the bottom cavity.

Rasp off the outside corners of the block. (The amount of rounding off you choose to do is one aspect of customizing your unit.) Sand all surfaces smooth, taking special care with the hand grip. The best finish for the wood parts is two coats of polyurethane varnish.

CONSTRUCTION OF THE TIPPING DISK JOYSTICK

The construction of the tipping disk is much the same as that of the hand grip unit. If anything, the tipping disk is easier to build. Figure 5-3 shows details of the parts. Cut out the three pieces of hardwood and glue them together. As noted before, it is easier to make several blocks at once and cut them apart later. Drill the 3/8-inch central hole and cut the microswitch grooves, following the instructions for the hand grip unit.

The groove for the FIRE button is on the side of the block; in figure 5-3 it is shown for right-handed players. The right or left hand orientation of the unit is set when you cut this groove and the hole for the main cable. To properly locate the groove, hold the partially finished block in your hand and find the most comfortable place for your index finger.

Drill the holes for the wires and the main cable and chisel out the bottom compartment as before. Round off all outside corners until the unit rests comfortably in your hand and sand all surfaces smooth.

The tipping disk itself is made of masonite or other thin material. It can be any diameter that suits you, either larger or smaller than the base block. Cut it out with a coping saw, and round off and smooth the edges. The disk and the block should be finished with polyurethane varnish before you begin wiring the unit.

The tipping post is a short piece of 3/8-inch dowel, one end of which is rounded. The exact height of the post and shape of the rounded top affect the feel of the finished joystick, so it is one of the key elements for personalizing the unit. Do not glue this piece into the block until you have tried the action and then shaped the end to get the response you want.

The springy foam cross that fits beneath the disk was cut with household scissors from 1/2-inch thick polyurethane shipping material. The thickness and shape of this foam piece is another important element in personalizing the unit.

ADJUSTING THE SIZE OF THE JOYSTICKS

The dimensions given for both these joysticks will produce a unit that fits an adult's hands. Smaller hands will need a smaller block. You can reduce the 3-inch square dimensions of the block to as small as 2-1/4-inches for the tipping disk and to 2-1/2-inches for the hand grip unit. The smaller blocks are somewhat harder to wire. If you cut a wood block large enough to make three or four units, you can cut them down to the exact size you need. (Remember the woodworker's lament, "I've cut it off twice already, and it's still too short.")

ELECTRICAL COMPONENTS

The key electrical parts of these units are the switches. They are, in fact, almost the only electrical parts. Radio Shack submini lever switches were used for the prototypes. Discount mail order houses like PolyPaks (see chapter 14 for their address) have similar switches for about half the price. Look for those described as "Leaf" microswitches. The size of these switches and their terminals varies, so it is best to have them in hand before cutting the microswitch grooves in the wood block. Since the hinges on the Radio Shack switches (and probably most others) are a bit weak, they were strengthened with a matchhead-size dab of silicone sealant.

The cable for each unit requires six conductors. We used two runs of 4-conductor telephone cable with stranded wires, but you could use any small, flexible 6-conductor cable.

The plug for the homebuilt Atari joystick is a DE9S socket from Jameco Electronics; it is a first cousin to the RS232 socket used on many peripherals. The hand-wired version of this socket requires a separate plastic hood. The two plastic tabs on the hood stick out too far and must be filed down. The two clamping screws included with the hood aren't needed for this project.

Distinguishing plugs from sockets on computer equipment can be confusing. A connector is a plug if the small metal parts that conduct the electricity are metal prongs. It is a socket if these small parts are receivers for the prongs (note the letter "S" for socket in DE9S). Either type of connector may be mounted on a cable or in the electrical device itself. Be careful not to order the wrong type.

ELECTRICAL WIRING

Figure 5-4 is the electrical schematic for any Atari-type joystick. Each of the five microswitches is wired as a normally-open, momentary-contact switch. All of their common terminals (a small "c" will identify them) are connected together and wired to pin 8. Each switch has its own wire on the normally open (n.o.) terminal.

To install the switches, solder two 3-inch pigtails of insulated wire to each switch. Telephone cable wire is excellent for this purpose. Use one color of wire for all the common terminals and five different colors for the normally open terminals. Poke the wire through the holes. Position the switches with their hinges toward the center on the disk unit and down on the hand grip unit. The switches on the hand grip unit should just touch the rubber hose in its central position.

The switches were wedged into place in the grooves with flat slivers of wood from a popsicle stick and fixed in place with silicone sealant. Apply only a small amount of sealant and let it set for a few hours. (If necessary, you can add more when you have completely checked out the joystick.)

Now turn the block over. Trim the wires short, but leave enough length to make the solder joints. Bring the main cable into the cavity and strip and tin all wires. Group all the common wires together, twist them, and solder the joint. Solder each of the five other 2-wire joints, wrap each joint with a small piece of electrical tape, and press them all into the cavity.

Strip and tin all the wires on the socket end of the cable. Pass the cable through the hood and solder each terminal. It is easier to solder the socket if you clamp it upright in front of you in a small vise.

CHECKING THE CIRCUITS

You can use a multimeter set on a low ohms scale to check the wiring. Place one lead on socket terminal 8 and with the other lead move in turn to terminals 1, 2, 3, 4, and 6. On each terminal, press all the switches to be certain that the correct switch, and only the correct switch, shows continuity when pressed. Examine the socket solder joints for solder bridges and cold joints covered with dark resin. Make any necessary repairs. Don't assemble the connector until you are entirely satisfied with your work.

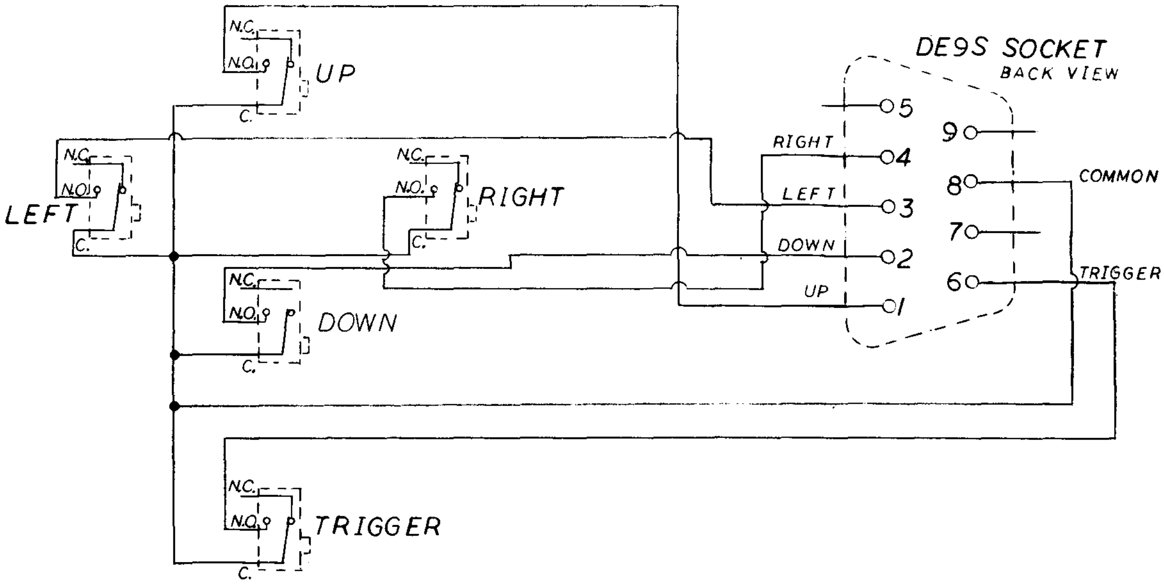
TEST RUN

Turn off your Atari. Plug in your new joystick and turn the system on again. If it doesn't start up in the normal way, turn it off immediately and recheck your work. Then run your favorite game to try out the unit. If you get crazy responses, you have probably wired some of the switches to the wrong connector pins.

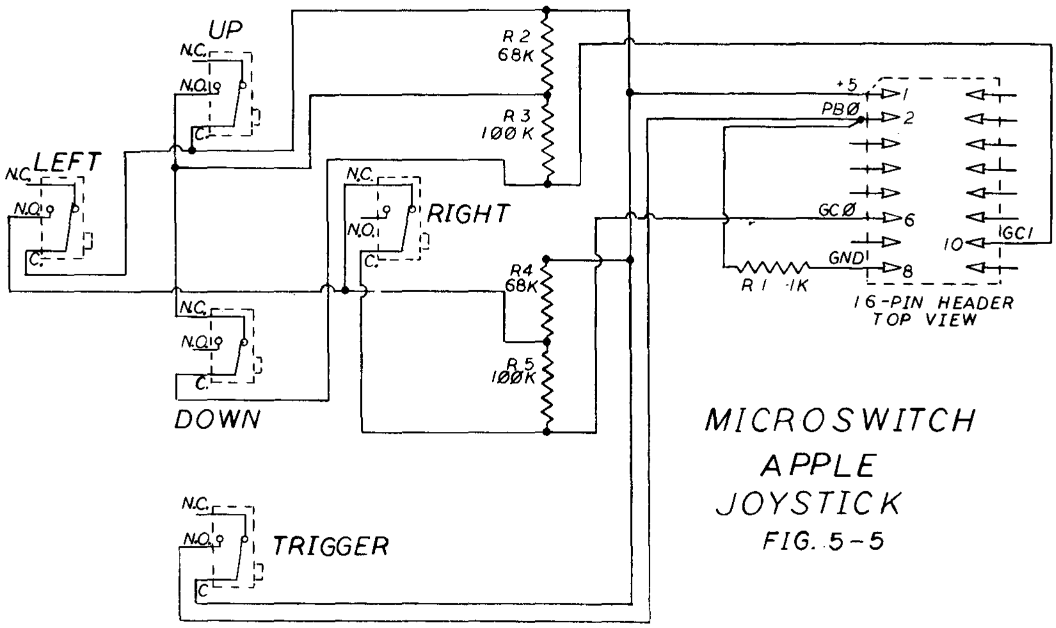
FINISHING UP

When the switches work correctly you can put the finishing touches on the new joystick. The hand grip unit could probably use more silicone sealant on the switches and on the main cable where it comes out of the block. In addition, you can fill the bottom cavity with sealant, cover it with a piece of plastic, and clamp or weight it to a flat surface. After the sealant has set overnight, peel off the plastic, trim any excess sealant, and glue cotton felt to the bottom with contact cement.

The tipping disk unit deserves some personalizing touches. First secure the switches, main cable, and cavity as above. Then try out different combinations of thickness of the foam cross and height of the tipping post and shape of its top until you get a response you like. You can even do without the post altogether, or you can eliminate the foam by gluing the disk to the post with silicone sealant. Use whatever combination feels good and improves your speed. When you get the combination you like, glue the foam to the block and the tipping disk with contact cement.



MICROSWITCH ATARI JOYSTICK
FIG. 5 - 4



MICROSWITCH
APPLE
JOYSTICK
FIG. 5-5

ATARI JOYSTICK CIRCUIT FOR THE APPLE

If you own an Apple computer you may want to make an Atari-type joystick for playing games that require only limited directions. *Snoogle* and many other arcade games are more enjoyable when played with Atari-type paddles than with Apple paddles because the former have faster response. The resistance values of the two potentiometers in such a paddle, however, are limited to "full on," "average," and "full off."

The construction of this joystick for an Apple is almost the same as it is for the Atari systems, except that you will have to make the bottom cavity slightly larger. Figure 5-5 gives you the schematic for wiring the unit. Note that two of the switches (down and right) use the normally closed terminal. The resistors R2, R3, R4, and R5 can be placed on a postage stamp size piece of printed circuit board and hidden in the cavity in the block. Resistor R1 can be placed in the header plug so that only a 4-wire cable will be needed.

This circuit works by mimicking a pot, using two resistors and two switches. If you don't press a switch, the game control inputs see the 68K resistors and read approximately 128. If you press the left (UP) switch, the game controls see zero resistance and read 0. If you press the right (DOWN) switch, the controls see 168K (68K plus 100K) and read full scale, 255.

Resistors R3 and R4 are not absolutely necessary, since the game controls read full scale when open, but it is easier to understand the circuit if they are shown. The stacked plug and socket described in chapter 3 works very well with the Apple-adapted joystick.

SUMMING UP

You can build joysticks for the Atari in a home or school workshop. The materials will cost you less than the purchase of a commercial joystick, and the great advantage is that you can personalize your joystick for the exact feel and action you want.

Parts List
Homebuilt Atari Joysticks

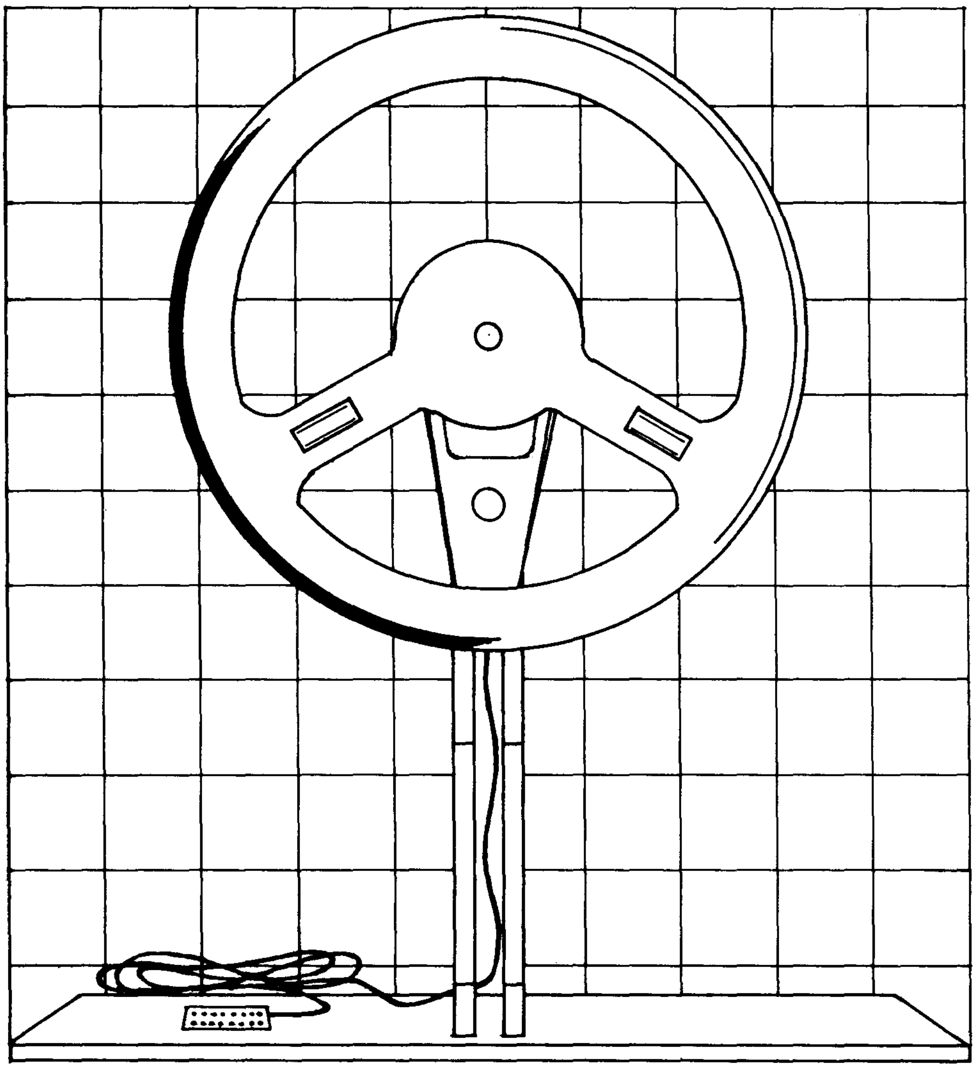
Number Required	Description of Part	Suggested Supplier	Total Cost
5	Lever switch, #275-016	R.S.	$7.00
10 feet	Telephone cable, #278-366	R.S.	1.20
1	Socket, 9-contact, DE9S (D-submin. connectors series)	Jameco	2.00
1	Hood, DE-9H (D-submin. hoods)	Jameco	1.20
1 sq.ft.	Hardwood	Local	2.50
Misc.	Silicone sealant, finish, etc.	Local	1.10
		Approximate Cost	$15.00

Suppliers:

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

R.S.—Radio Shack
See Yellow Pages

All other parts were purchased at a local hardware store.



6 Race Car Steering Wheel

There are several auto racing programs on the market, but playing them with a standard joystick or paddle doesn't give you the sensation of driving a real machine over a race course. In this chapter we will build a steering wheel that closely simulates the controls of an automobile. This analog input device has a single potentiometer that is turned by the steering wheel and a push button that serves as the accelerator or horn. A special plug/socket lets two of these units operate at the same time, thus opening up the possibility of two-person competitive racing programs. With this controller and appropriate software, game players can learn valuable driving skills like recovery from skids and automatic reactions to traffic hazards. This steering wheel puts you in the driver's seat.

The steering wheel prototypes were tested on an Apple II Plus computer using the *International Grand Prix* program (Riverbank Software, Inc., P.O. Box 128, Denton, Maryland 21629). The unit will work on any program that uses one paddle and one pushbutton. The design can easily be adapted for other computers by duplicating the pot value, wiring, and connector of the standard paddle for that machine.

This controller is similar to the airplane steering wheel described in chapter 2, but its design is even simpler. In fact, this is one of the most straightforward projects in the series: the parts are easy to find, construction is mostly woodworking, and the wiring requires minimal familiarity with electronics. Take some care with this project and you will be proud of the result.

CONSTRUCTION OF THE WHEEL SUPPORT

Figure 6-1 is a sketch of the finished unit. A detailed side view is given in Figure 6-2. The key parts are the leg board, the lower and upper supports, the pot mount, the three stops, and the wheel itself with hub and switches.

Figure 6-3 gives you details of the construction. The pot is shown mounted on the upper support so that you can see which electrical terminals are used and the location of the cables. A detailed cross-section of a microswitch mount is also shown. The two microswitches are wired as a single pushbutton.

Most of the parts are 1/2-inch plywood. Scraps of birch plywood were used for the wheels of the prototypes, but common fir plywood would look almost as good. The plywood was too thick to make a comfortable leg board, so 1/8-inch tempered masonite was substituted. The wheel hub was cut from a scrap of hardwood (oak or

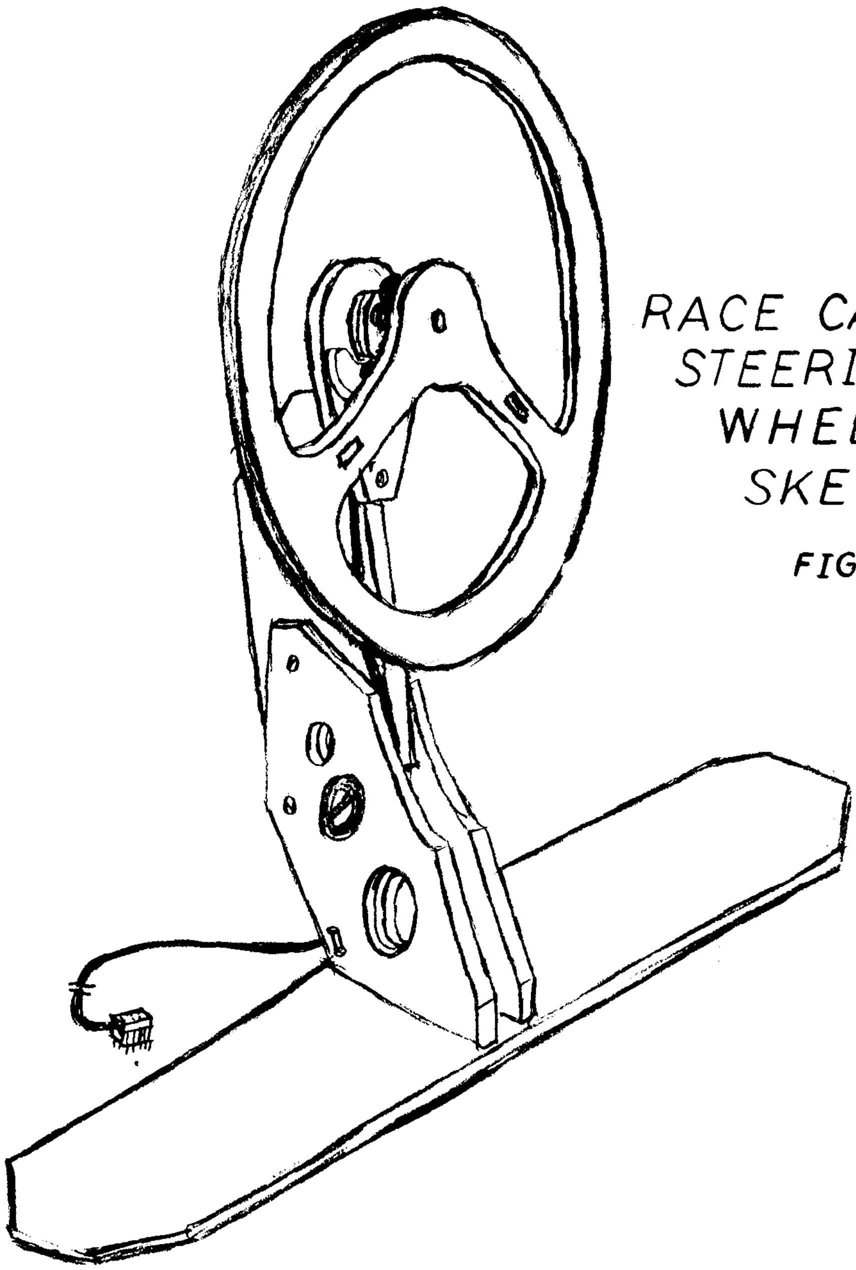
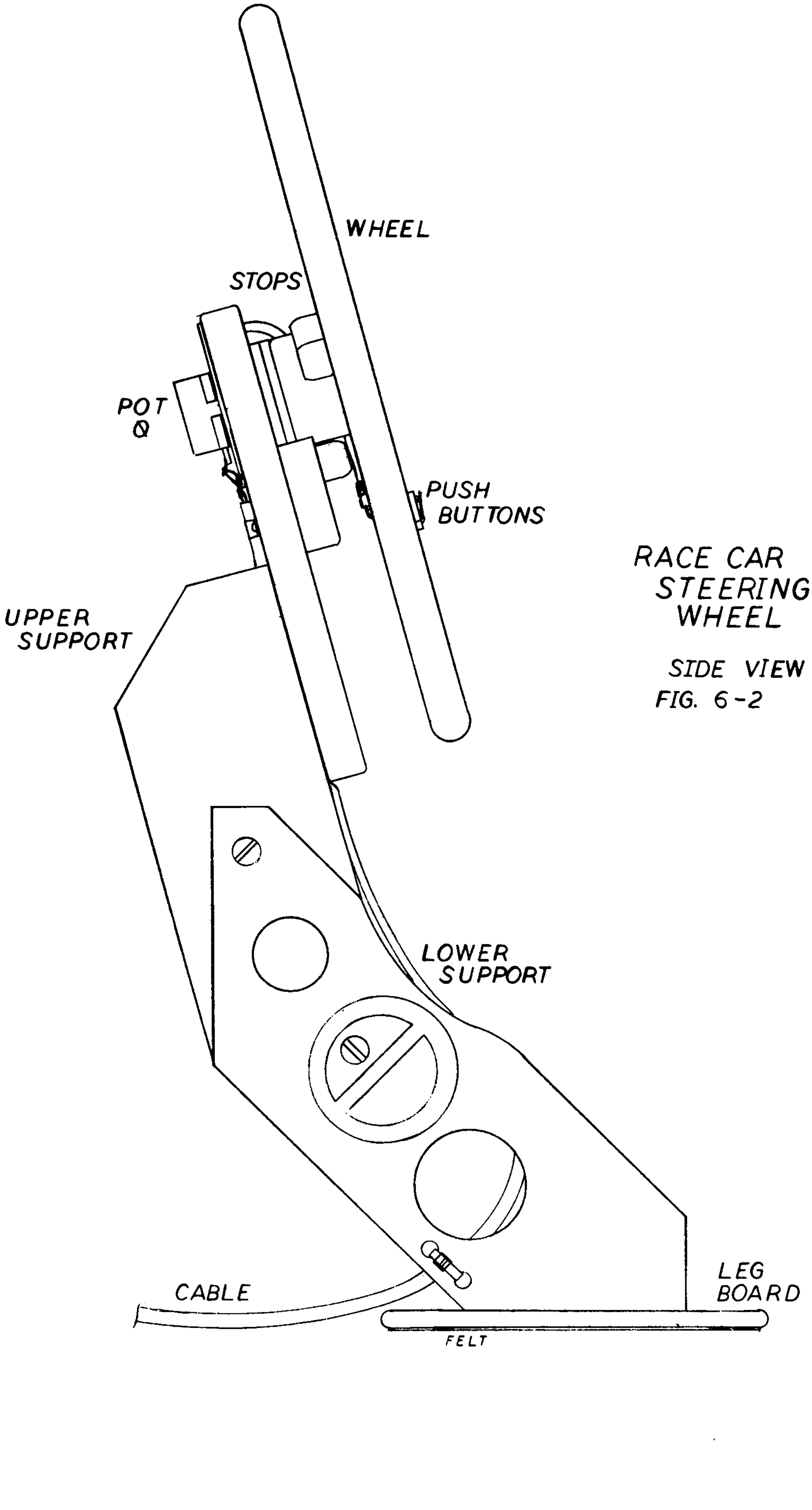


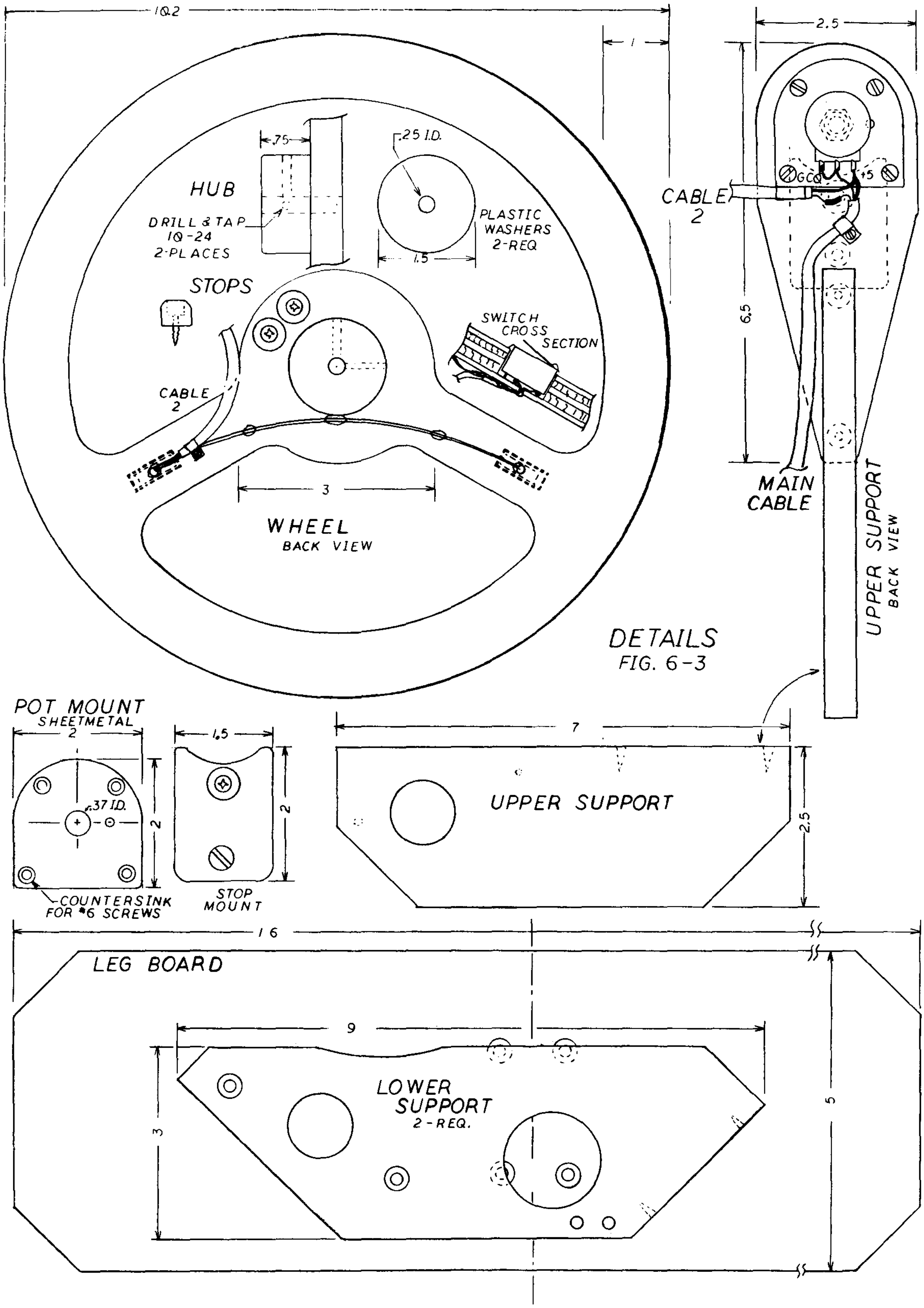
FIG. 6-1

maple is preferred) since hardwood will drill and tap better than softwood. Mount the pot on a scrap of sheet metal that is stiff but that can be cut with sheet metal shears.



RACE CAR
STEERING
WHEEL

SIDE VIEW
FIG. 6-2


10.2
1
.75
HUB
DRILL & TAP
10-24
2-PLACES
.25 I.D.
PLASTIC
WASHERS
2-REQ
1.5
STOPS
SWITCH
CROSS
SECTION
CABLE
2
3
WHEEL
BACK VIEW
2.5
CABLE
2
6.5
MAIN
CABLE
UPPER SUPPORT
BACK VIEW
DETAILS
FIG. 6-3
POT MOUNT
SHEETMETAL
2
.37 I.D.
2
COUNTERSINK
FOR #6 SCREWS
1.5
2
STOP
MOUNT
7
UPPER SUPPORT
2.5
16
LEG BOARD
9
LOWER
SUPPORT
2-REQ.
3
5

Cut the two lower supports from two 3 x 9-inch pieces of 1/2-inch fir plywood. This will produce a medium-size steering wheel. If the unit will be used primarily by adults, you may want to add two to four inches to the length of the supports. The extra length is especially desirable if you use the wheel while holding a small child in your lap. Children like to play with this controller even when they are too young to understand what the program is all about. A pair of wheels, one with the longer supports, works well for parent/child games.

The holes in the supports are merely for decoration. The large one was cut with a hole saw in a drill and the small one with a 1-inch paddle bit. Center the two lower support pieces one-half inch apart on the leg board and attach them with four 1-inch x #8 flathead wood screws and carpenter's glue.

The upper support is fashioned from three plywood pieces and the sheet metal plate on which the pot is mounted. Put the two larger pieces together with two wood screws and glue. Cut out the sheet metal plate, then drill, counter-sink, and fit it to the pot mount. Hold the metal with vise grip pliers while drilling, or the sheet will spin and cut your fingers. Size the central hole (usually 3/8-inch) to fit the pot. The small hole is for the spin prevention tab on the pot. The four corner holes are for 1/2-inch x #6 flathead screws. Don't install the small stop mounting block until you complete and trial fit the wheel.

CONSTRUCTION OF THE WHEEL

The wheel itself can be any size that suits your needs. The 10 and 1/4-inch diameter of the prototypes was determined by the size of the material on hand. For wheels much larger than this the size of the upper support will have to be increased. Draw the wheel on plywood with a compass and straight edge and cut it out with a saber saw or coping saw.

The hardwood disk for the hub was cut out with a power drill hole saw. Drill and tap the two holes before attaching the hub to the wheel. No lubrication is used for tapping in wood, but you should remove and clean the tap several times during the process. Attach the hub to the wheel with carpenter's glue and clamp it with a 1/4-inch bolt and flat washers through the center hole until the glue dries.

For the prototypes we purchased Radio Shack #275-016 lever switches. Cut a rectangular cavity for them in the wheel spokes with a small wood chisel or X-acto knife. This cavity should stop one ply short of coming through the plywood. Then drill a small hole the rest of the way through for the wire.

FINISHING AND ASSEMBLY

Sand all wooden parts and remove sharp corners with a fine wood rasp. Fill any holes in the edges of the plywood with wood putty or with wood splinters and glue. Smooth the edges of the sheet metal pot mount with a fine file.

Now slip the top support between the two bottom supports and secure it with wood screws and glue. Make certain that the screws, which come in from opposite sides, miss each other. The angle of the finished wheel is set by this step. Figure 6-2 shows the approximate angle, but you can suit yourself since this adjustment is a major factor in personalizing the unit.

Install the pot mount with the pot in place. Place several of the washers shown in figure 6-3 on the pot shaft. At least one washer should be polyethylene plastic (cut, for example, from a coffee can lid). The rest of the washers can be masonite, wood, or plastic, cut out with a hole saw. It is easier to add washers than to cut off a pot shaft; about 1/4-inch thickness of washers will be enough to take up the extra pot shaft length.

Drill out the central hole in the hub to remove glue and then fit the hub onto the shaft. Curve the top of the stop mount with a rasp to loosely fit the curve of the hub. You can put a thin piece of cardboard between the hub and the stop mount while marking its position. Then, with the wheel removed, attach the stop mount with a single screw and carpenter's glue.

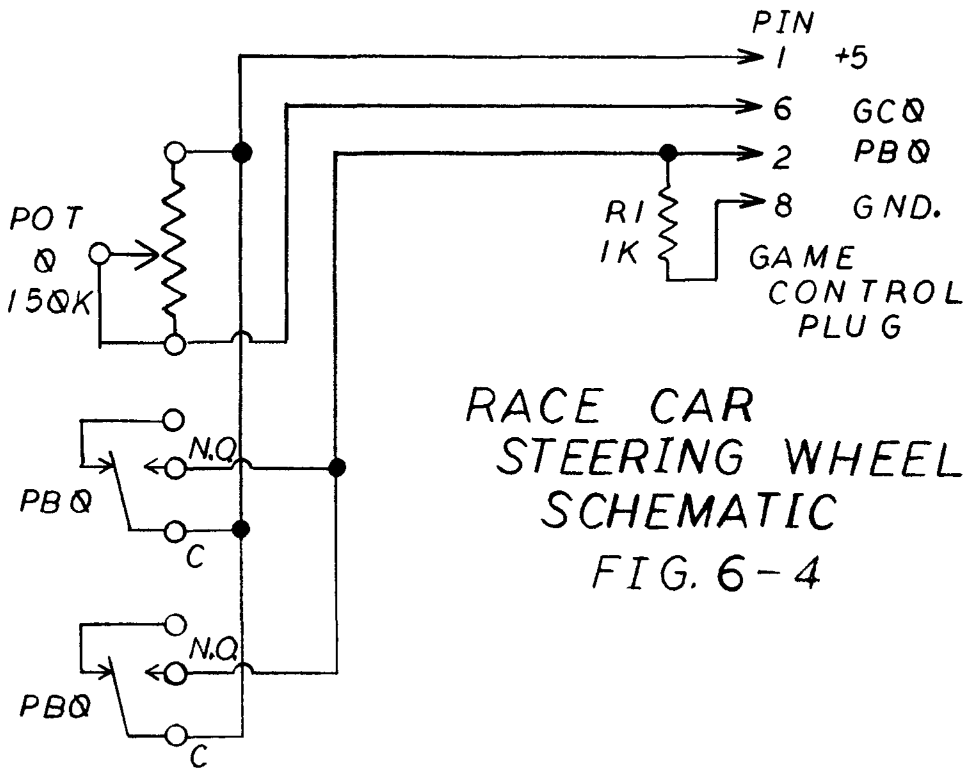
Now remove the wheel and pot mounting plate and sand all wood parts. The wheel will look best if stained and varnished. The other wood parts should get two coats of a bright colored enamel. Finish up with a coat of satin-finish polyurethane varnish over all the wood parts. A coat of varnish not only improves the appearance of the device but also keeps the enamel from leaving marks on furniture and floors.

ELECTRICAL WIRING

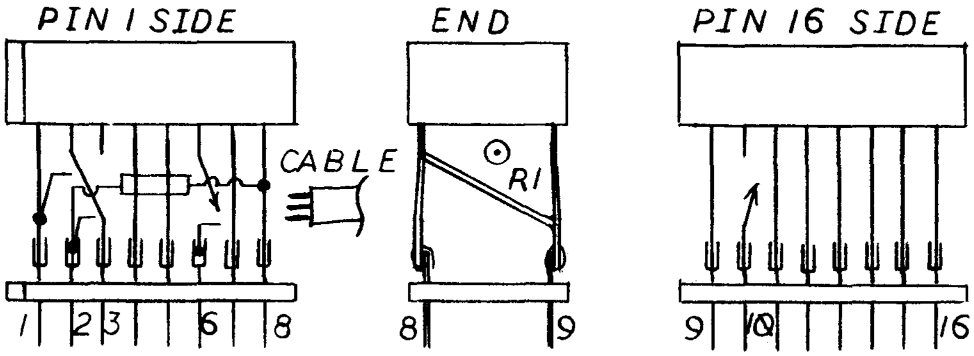
For the electrical work you will need a pencil soldering iron of from 25 to 42 watts with a fine point, a damp sponge for cleaning the tip of the iron, wire strippers, a pair of small long-nose pliers, and small-diameter resin-core solder. Even if you are a beginner you shouldn't have much trouble with the electronic work involved in this project. Use the proper tools and be careful with the soldering.

Make two photocopies of the schematic (figure 6-4). On the first copy, color in each wire and solder joint as soon as you complete it. When you finish your work, color in the second copy while checking each connection.

Buy long-shafted pots of good mechanical construction. They should have a screw driver slot on the end; otherwise you will have to cut the slot with a hacksaw. Figure 6-3, the back view of the upper support, shows the terminals to which you will be soldering the cable wires.



RACE CAR STEERING WHEEL SCHEMATIC
FIG. 6-4



SPECIAL PLUG/SOCKET
FOR FIRST UNIT
FIG. 6-5

For the switches: use any small momentary-contact, single pole single throw, normally-open switch that can easily be mounted on the wheel spoke. The hinge on the Radio Shack lever switch is somewhat weak so it was reinforced with a matchhead size dab of silicone sealant. The two switches are connected together by a pair of small wires and either of them will act as pushbutton 0.

As you can see in figure 6-4, only a 3-conductor cable is required for a unit. We used 4-conductor telephone cable and doubled up the +5 supply wire. The cable can be secured to the lower support with a plastic wire tie passed through the two small holes shown in the lower support.

The cable from the pot to the wheel can be secured by forming a small flag, or tab, on the side of the cable with electrical tape. Wrap several layers of tape around the cable, leaving the 1/4-inch flag off to one side. On the pot mount end secure the flag under the mounting plate; on the wheel end use a small flathead screw and washer to secure the flag. Figure 6-3 shows each end of this cable so that you can route it correctly. The cable is about 11 inches long and makes a loop behind the wheel. We used a piece of the 4-conductor telephone cable, although only two small conductors are needed. You will work out the exact length and placement of the cable after the stops are installed.

The plug/socket shown in figure 6-5 is similar but not identical to the one for two-person games described in chapter 3, "Multiple Socket Extensions." With this plug/socket a second single-pot paddle can be plugged into the back of the first race car wheel and the second unit will function as GC1 and PB1. You will be able to use two steering wheels for competitive racing games as soon as someone out there writes the software.

The plug/socket is a standard wire-wrap socket on which all pins except 6, 3, and 10 are cut to 1/2-inch. Cut pin 6 to about 5/8-inch and cut pins 3 and 10 to 1/8-inch. Then bend out the pins slightly and straighten them to fit over the spades of a 16-pin DIP header. Plug the header into a loose socket before soldering and double check to be certain that both #1 pins are on the same end. Pin 6 must be bent across to reach spade 10 on the header and pin 2 bent to reach spade 3. Install the pull-down resistor R1 between the socket pins. The cable usually enters from the pin 8 end. If you have difficulty inserting a plug into the socket after the soldering, stick a sewing needle into each hole in turn to realign the socket parts.

If you decide to make a second steering wheel you will want to use a standard plug/socket on it so that foot pedals can be used with the wheels. Foot pedal controllers are discussed in chapter 8.

FINAL ADJUSTMENTS

Now mount the single stop on the upper support. For all three stops you can use small rubber feet or faucet washers held on with panhead screws. Reinstall the wheel with the washers on the pot shaft, leaving the set screws loose. The best set screws are the Allen type, but those with standard screwdriver slots will work.

At this point install the main cable and plug but leave the cable that runs to the switches disconnected. Check your work visually against the schematic (figure 6-4). If you have a multimeter, check the resistance between pin 1 and pin 8. This must measure at least 50 ohms on any controller and should be completely open (infinite) on this unit.

Turn off your computer, plug in the new controller, and turn the computer back on. If start up is not completely normal, turn it off immediately and recheck all your work on the steering wheel. When the system starts up properly, run the Controller Checkout program from chapter 15.

You need to see the readings of GC0 and PB0 continuously so that you can adjust your unit for full scale and zero. Try turning the wheel left and right to determine if you can get readings over the full range from 0 to 255. Center the wheel and adjust the pot shaft inside the wheel with a screwdriver until you obtain a reading of 128. Then press the wheel firmly onto the shaft and tighten the set screws.

Turn the wheel gently clockwise until you feel the internal stop. Back off until the reading just becomes 255 and place the second stop on the wheel snugly beside the first stop, which is mounted on the upper support. Mark the center of the second stop with a sharp point. Follow the same procedure counter-clockwise for 0 and mark the third stop. Turn off the computer and unplug the steering wheel. Remove the wheel from the pot shaft and install the two stops on it.

The wheel can now be reinstalled and centered on 128. The readings should cover the full range from 0 to 255, but when you turn the wheel you should hit the external stops before you reach the weaker stops inside the pot.

Install the pushbutton cable by first attaching it to the upper support. Then experiment with various lengths of cable while turning the wheel. This cable should make a single loop behind the wheel to keep it out of your way while you are playing. When you have determined the correct length and direction for the cable, install a tape flag and screw it onto the wheel near the hole for the switch wire.

As noted in figure 6-4, both switches are wired in parallel so that each of them can function as PB0. This lets you use either hand to press the pushbutton. The cable wires are attached to the common and normally open terminals. You can secure the pair of wires between the two switches to the back of the wheel with silicone sealant.

FINISHING TOUCHES

You may want to cover exposed electrical connections with silicone sealant (clear sealant is the least messy to work with). You can cover the bottom of the leg board with cotton felt, gluing it on with contact cement. A decal or paper cutout glued to the center of the wheel looks sporty. Be sure to draw a number on the sides of the lower support with a felt tip marker. We used 0 for the first wheel and 1 for the second. Numbering the units will help you keep track of which is which when you play a game, and besides, all racing machines have a number. Test your unit one more time with the Controller Checkout program and then run your favorite racing game.

Parts List
Race Car Steering Wheel

Number Required	Description of Part	Suggested Supplier	Total Cost
1	Pot, .15 meg, JA1N200P154UA	Newark	$4.00
2	Submini lever switch, #275-016	R.S.	2.80
10 ft.	Telephone cable, #278-366	R.S.	1.10
1	16-pin DIP header	Jameco	.70
1	16-pin wire wrap socket	Jameco	.70
3 sq. ft.	Plywood, fir, 1/2″		2.00
1 sq. ft.	Tempered masonite, 1/8″		1.00
11	Flathead wood screws, 1″ x #8		1.00
4	Flathead wood screws, 1/2″ x #6		.50
4	Panhead wood screws, 1/2″ x #6		.50
3	Rubber feet, small		.70
Misc.	Paint, varnish, glue		2.00
		Approximate Cost	$16.00

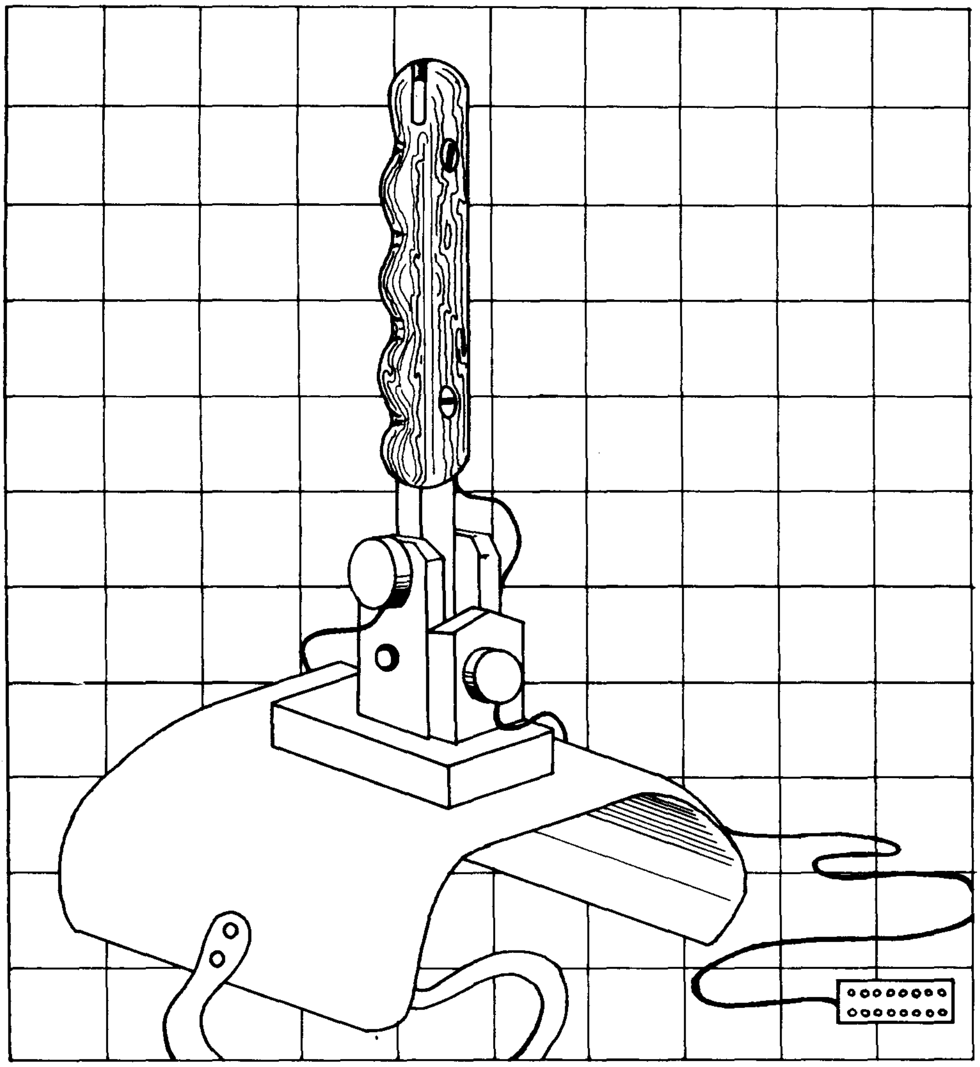
Suppliers:

Newark Electronics
See Yellow Pages or call
main office (312) 638-4411
for local sales office address.
Minimum order $25.00

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

R.S.—Radio Shack
See Yellow Pages

All other parts were purchased at a local hardware store.



7 Super Stick

Commercial analog joysticks for the Apple and other home computers are powerful tools for directing a cursor and playing games, but for the most part they are flimsy units. They don't give the player the sensation of handling actual machine controls. Super Stick, by contrast, is a much larger device, about the size of the control stick for a high-performance aircraft. Super Stick is not quite as fast in response as the lightweight commercial units, but it has the robust feel of a controller for a real machine.

This chapter gives you construction details for two different versions of Super Stick. The machined version is the most challenging construction project in the book, and the finished device is the most elegant. It is the only design we've included that requires metal machining tools for its construction. It makes an exciting project for an experienced hobbyist or a student in an advanced metal shop class. The second version, made from sheet metal and wood, is not quite as elegant, but it can be built in the home workshop. The materials for either unit are not difficult to obtain. You should read through the instructions and decide which would be more appropriate, keeping in mind your needs and the tools you have available.

CONSTRUCTION OF THE MACHINED SUPER STICK

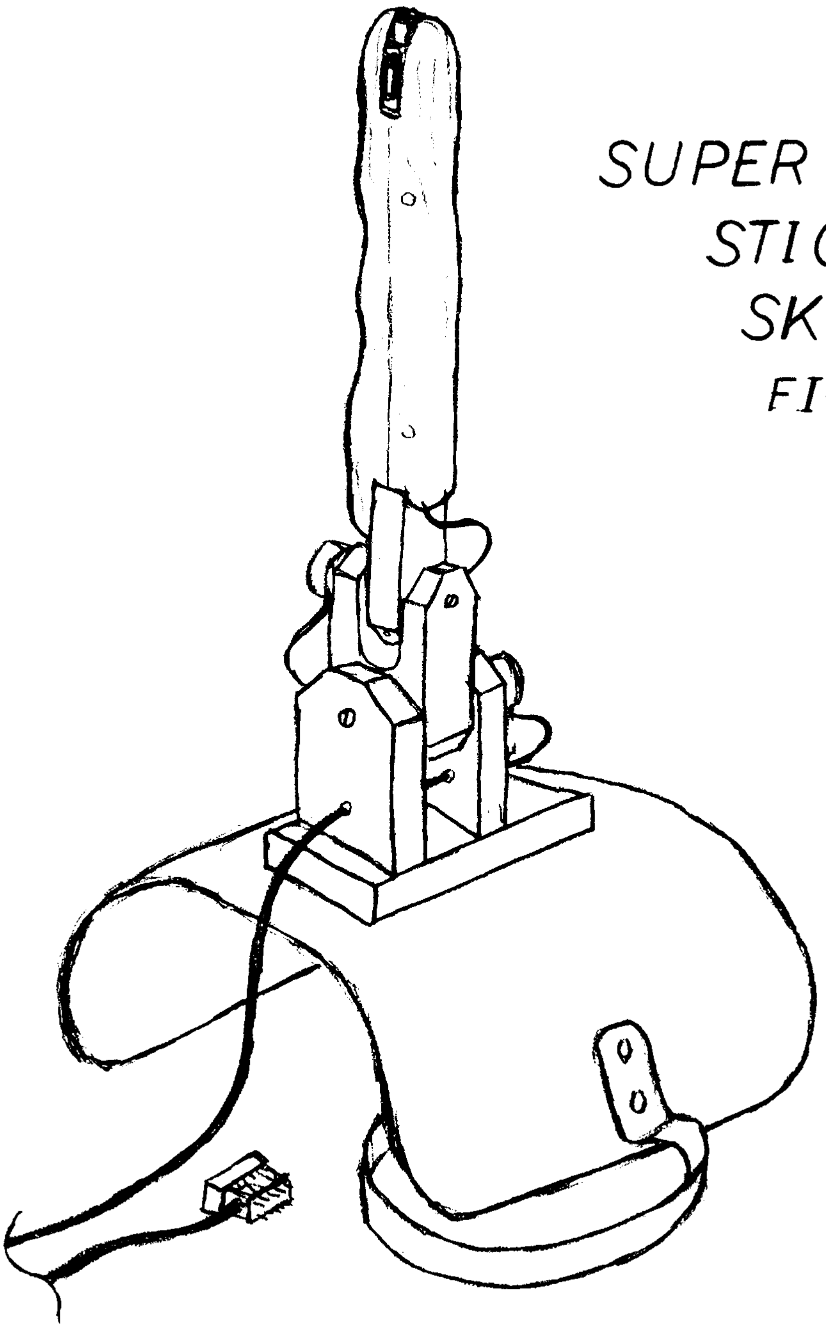
Figure 7-1 is a sketch of the machined version. The hardwood handle contains two pushbuttons and is supported by a double-articulated wrist that serves as the mount for the two potentiometers. The upper structure is supported by a machined base and a sheet metal saddle that straps to the leg.

Figure 7-2, in front and side views, gives many more details of the completed device. It shows the location of the pots and pushbuttons, as well as details of the pot wiring.

Figure 7-3 provides details of the component parts. The handle grip is fashioned from two pieces of 6 x 1-1/4-inch hardwood. Walnut is particularly attractive, but true mahogany also makes a striking handle. Alternatively, you could use clear pine and paint the handle jet black, to get a high-tech look.

Cut out the wood blanks with a radial arm or table saw and then contour them into shape with wood rasps and sandpaper. Countersink three flathead screws (1/2-inch x #4) into the wood to hold the two halves of the grip together. Then drill the holes for the bolts (1/2-inch x #2) to mount the pushbuttons and the shaft clamp for the top potentiometer.

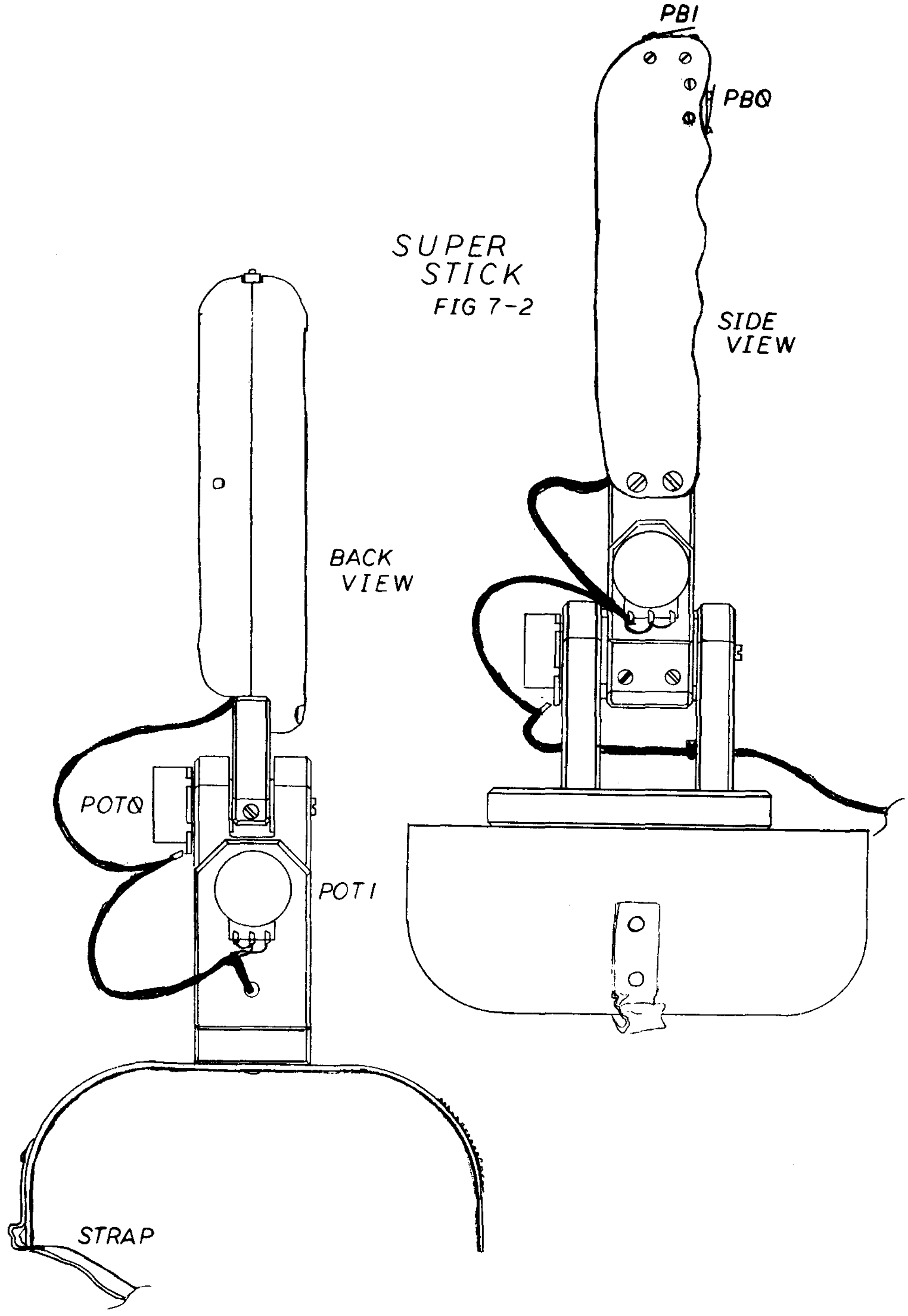
The machining attachment for a small metal lathe was used to work the aluminum for the top clamp, wrist, and two base uprights. You can use any material that can be machined, including aluminum, brass, steel, or plastic. By starting with stock a little thicker than 1/2-



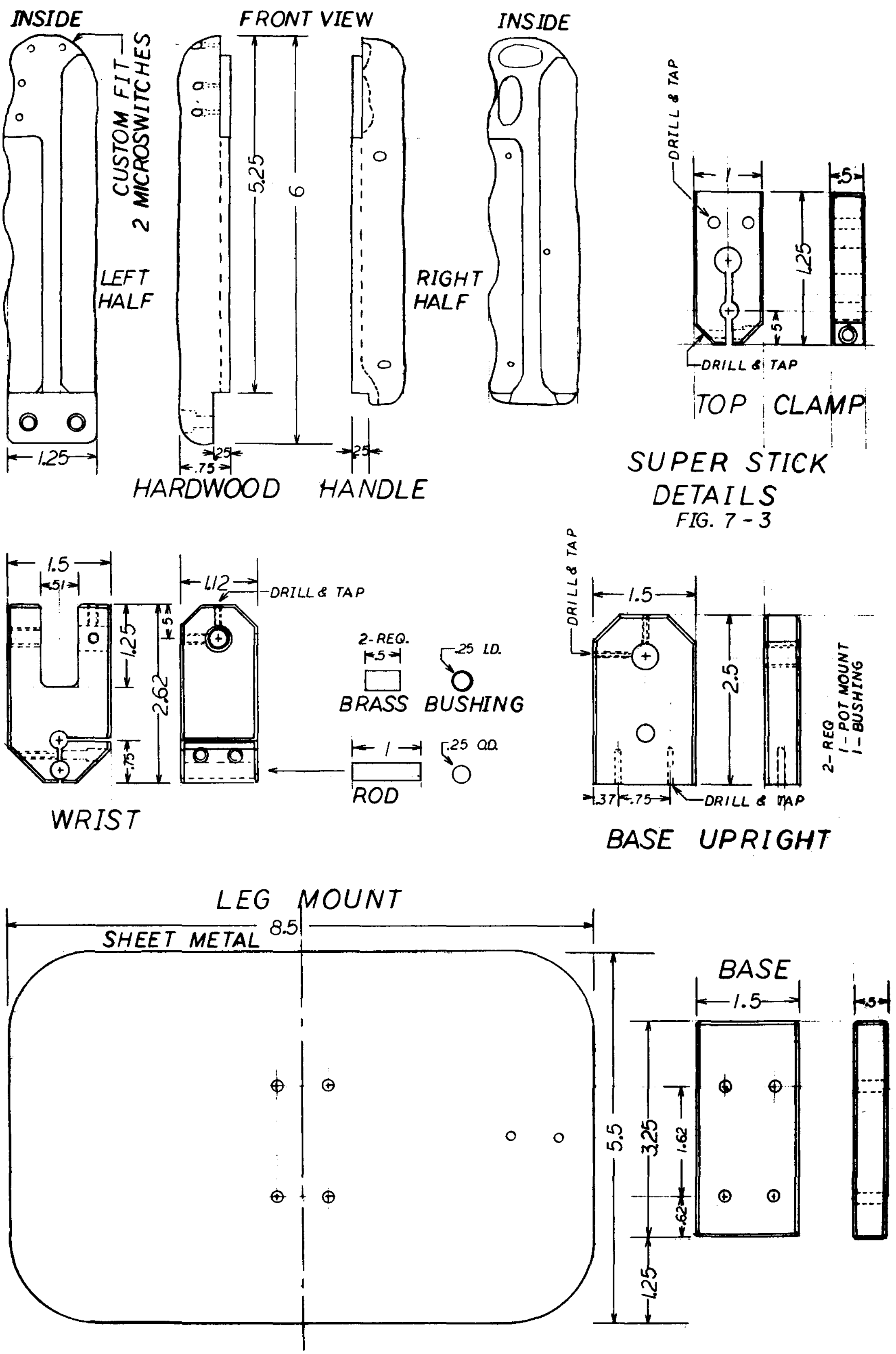
SUPER STICK SKETCH FIG. 7-1

inch, we were able to take a slight amount off all the surfaces, thus leaving them with a decorative pattern of machining marks.

First rough out the pieces with a band saw and machine them to slightly larger than finished dimensions. Then drill all the holes and



SUPER
STICK
FIG 7-2



SUPER STICK DETAILS
FIG. 7-3

tap the threads that are shown in figure 7-3. Choose the tap size that is appropriate for available bolts and set screws. Caphead screws set in counter-sunk holes are best for the top clamp and wrist, while panhead bolts are best for the leg mount and base.

When you complete the rough work, go back over all surfaces with a small milling tool on a final shallow pass. This will bring the pieces down to exact dimensions and leave the characteristic markings. On the prototype, all edges were beveled off with a power-belt bench sander. You could also use a fine file for this step.

The brass bushings were cut from 1/4-inch (internal diameter) hobby shop tubing, but commercial brass bushings with thicker walls would be easier to machine. You could even machine these bushings from brass stock on a lathe. The bushings should not spin, so remember to secure them in place with thread sealant.

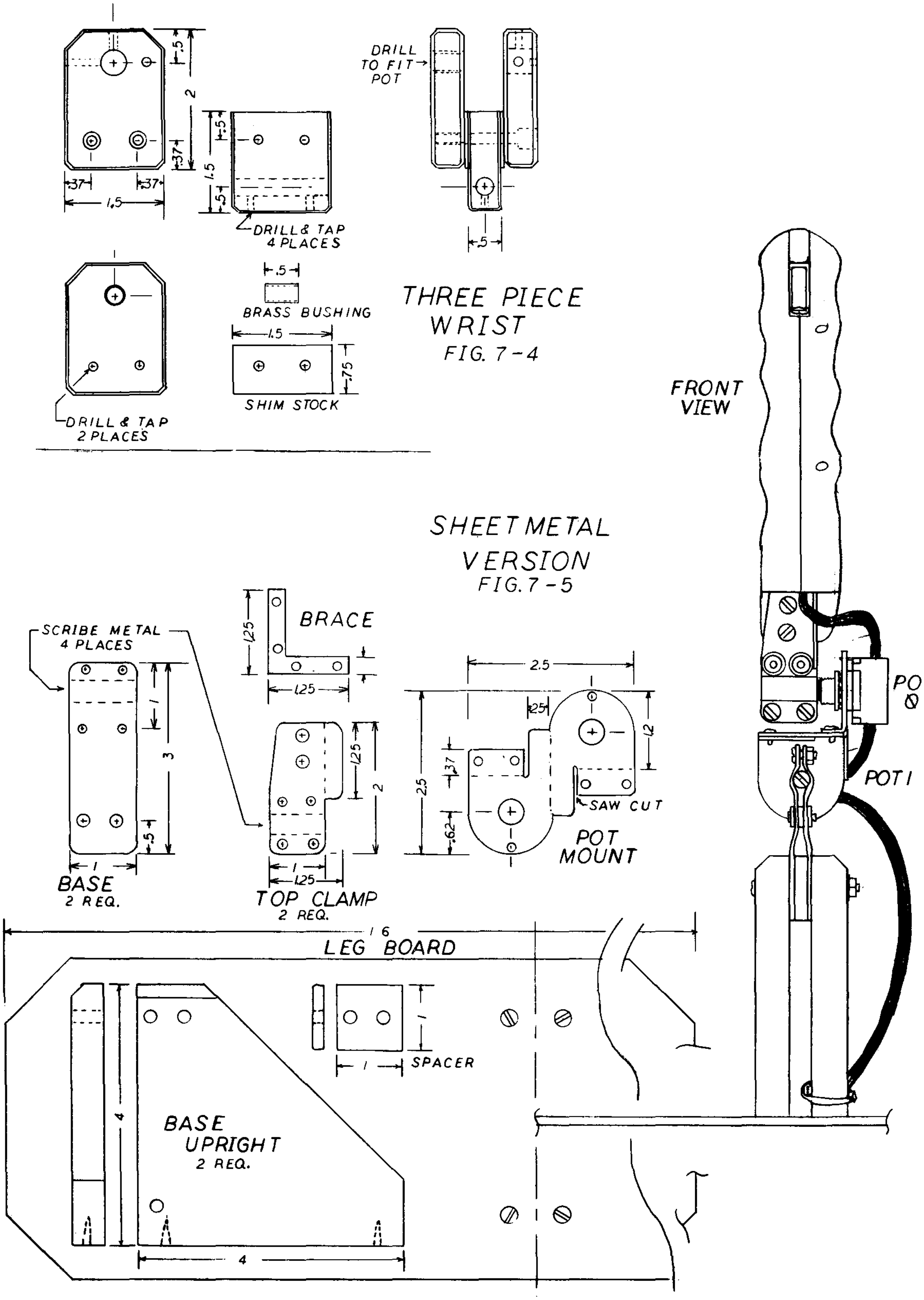
Since you may have difficulty obtaining the thicker block needed for the one-piece wrist, figure 7-4 shows an alternate construction of the wrist using three pieces of 1/2-inch stock. To insure that the top clamp piece will move easily between the two uprights, two pieces of shim stock are required for construction.

The pots will be needed during machining to measure the exact size of their mounting bushings and shafts. Different manufacturers vary the sizes slightly. If you do not have the pot when you do the machining, leave 3/16-inch pilot holes for the time being. Trim the pot shafts to the correct length and saw screwdriver slots in their ends.

The leg mount for the prototype was cut from 1/16-inch aluminum sheet and then drilled, using the base as the pattern. Pass panhead screws up through the leg mount and base and screw them into the two base uprights. The leg mount was finished with an orbital sander to remove all tool marks and give a matte finish. You could use a small cup wire brush in a drill press to obtain the swirled finish found on the cowling of the Spirit of St. Louis.

When assembling the pot mounts, don't overtighten the set screws and clamps, since this can crush the pots and make them hard to turn. Put some sealant like Loctite on the bolt threads to insure that they don't loosen.

The wood handle requires fine sanding, staining, and finishing with two coats of polyurethane varnish. After you attach the leg mount to the base and uprights, bend it to fit your leg. Cover the inside of the leg mount with cotton felt. Attach a cloth or leather strap to the leg mount with swat rivets from a leather supply store. Sew a piece of Velcro to the free end of the strap and glue the Velcro mate to the leg mount with epoxy.



THREE PIECE WRIST
FIG. 7-4

SHEET METAL VERSION
FIG. 7-5

CONSTRUCTION OF THE SHEET METAL VERSION

Since not everyone has access to a machine shop, we decided to include a home workshop version of the Super Stick that can be constructed from sheet metal and wood. No unusual tools are necessary for the project. The result, shown in figure 7-5, is a solid, attractive device with good, fast action.

The construction of the sheet metal Super Stick is similar to that of the Sketch Pad (see chapter 4). For the metal work, only a drill, sheet metal shears, file, and pop rivet gun are necessary. Either hand or power saws can be used for the wood work.

The metal should be stiff, but thin enough to cut with hand shears; aluminum or galvanized steel will do nicely. Cut out the six metal pieces, then round and smooth all edges with a file. Make the two cuts for the pot mount with a hacksaw.

Hold the metal pieces with vise grips or in a bench vise while drilling them. To start each hole, strike a point with a center punch, then drill a pilot hole of about 1/8-inch. Don't drill the pop rivet holes in the pot mount until you are ready to install the rivets. The two holes in the pot mount for the spin prevention tabs must be custom fitted to the pots you choose.

You can make the bends in the sheet metal with a sheetmetal brake, a vise, or vise grip pliers. Only one of the top clamps needs to have the large side tabs shown in figure 7-5. The only bends that are difficult to form are those for the pot shaft clamps in the base and for the top clamp. Pop rivet the pieces together, then bend open the two pieces and form the clamp around a 1/4-inch bolt. Using washers on the pop rivets keeps the sheet metal from bending in the wrong places. The two sheet metal ends of the clamp should be about 1/8-inch apart with the shaft installed.

Don't worry if you fail in your first attempt to make the sheet metal parts. Sheet metal is cheap, so discard the piece and start over. Bend the pot mount in the direction shown in the front view (figure 7-5). Clamp the predrilled brace in place with vise grips and drill the first pop rivet hole. Install the rivet, then drill the holes and install the other three rivets in turn.

Now cut off the pot shafts and saw screwdriver slots into their ends. Apply Loctite to the pot mounting threads after you complete the final adjustments.

The handle grips on the prototype were cut from hardwood scrap with a radial arm saw and then shaped with wood rasps and sandpaper. The bottom of the handle at the lower end where the top clamp is attached is a little different than that of the machined version. The notch on the sheet metal unit cuts both pieces, but the top clamp is screwed to only one piece of the handle. You can make the inside wire groove and switch cutouts with a saw or wood chisels.

The leg board and spacer are cut from tempered masonite. You can make the base upright from any available wood or plywood. The base should be held together with screws and glue, but the handle is held together with counter-sunk screws only, since you have to open it up again to wire the switches. Sand all wood parts and finish them with two coats of polyurethane varnish.

ELECTRICAL WIRING

The wiring for this project is not difficult since Super Stick is simply a two-pot joystick with one or two pushbuttons. The pots should be mechanically superior and long shafted. You will have to cut the shafts to length and add screwdriver slots, as noted previously. The pots in these units do not travel through their full 300 degree turn. You can use pots with values larger than standard for your computer, or you can work with easier-to-obtain pots with values of 100K and add correction caps as described in chapter 1. (The standard pot value for the Apple is 150K; for this prototype we used 250K pots.) You can mount the correction caps on a small piece of PCB in the cable about a foot from the plug and encase them in foam packing material.

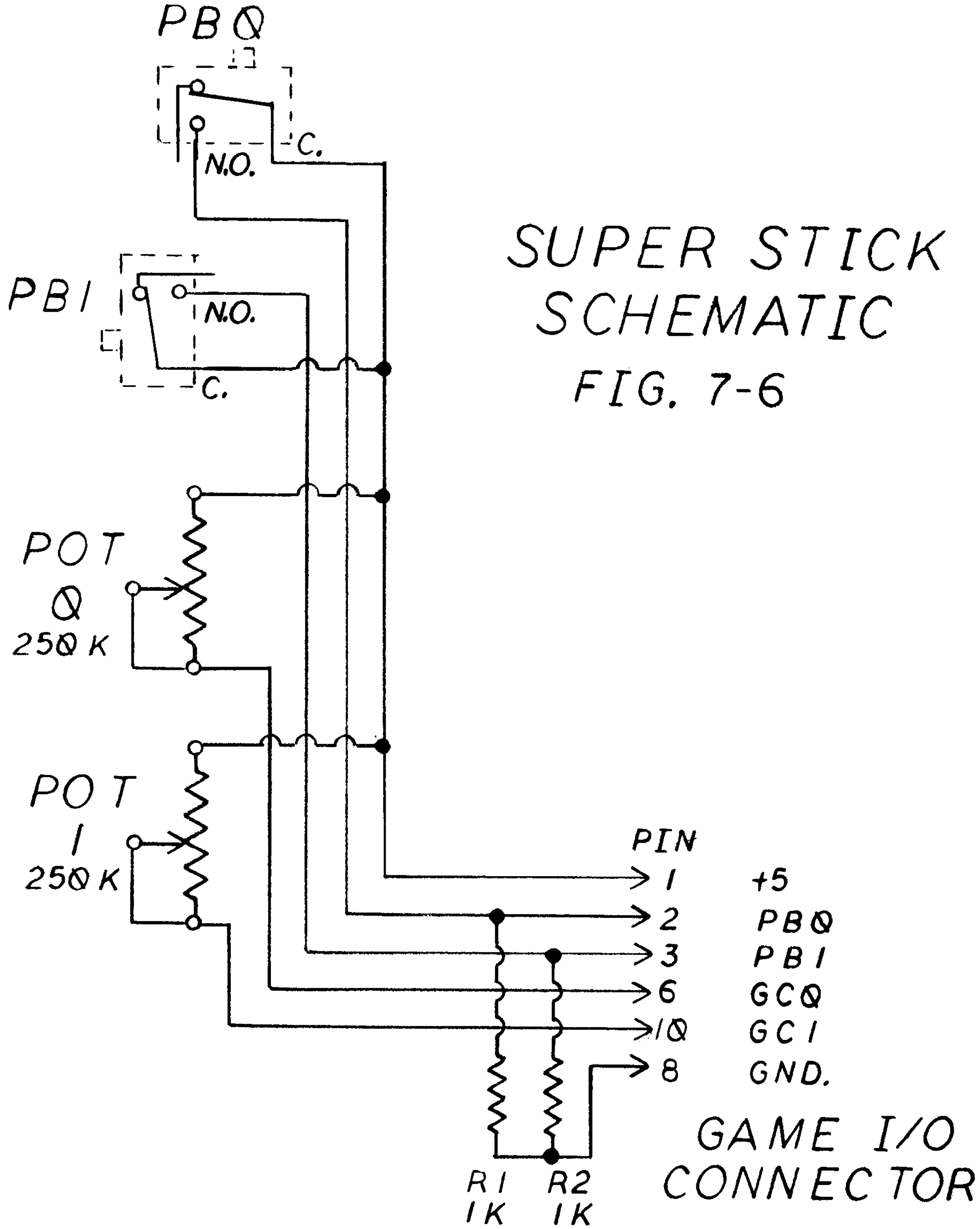
For pushbuttons you can purchase any normally-open, momentary-contact switches that can be mounted easily on the handle. We used subminiature lever switches mounted with #2 nuts and bolts. The switches and bolts came from Radio Shack.

If you choose to install only one switch you will need only four wires in the cable. The telephone cable noted in the parts list is adequate. For two switches a 5-wire cable is necessary, and this is harder to find. You can substitute two runs of the 4-wire telephone cable, which gives you extra wires to double up the +5 and ground if you use correction caps.

The best plug for Super Stick is the plug/socket described in chapter 3. The pull-down resistors R1 and R2 (figure 7-6) can be

SUPER STICK SCHEMATIC

FIG. 7-6



mounted inside the plug. If you look carefully at the pots in figure 7-2 you can see which outside terminal is connected to the center terminal with a loop of wire, as indicated in the schematic (figure 7-6).

TESTING AND ALIGNMENT

When you are through with the wiring, check your work against figure 7-6. Then turn off the computer, plug in your new joystick, and turn on the computer again. If startup does not proceed exactly as usual, turn the computer off immediately and recheck your work.

Now run the Controller Checkout program and check the pushbuttons and pot readings. Adjust the pots by loosening the clamping bolts and turning the shafts with a screwdriver until you get readings of 128 for both GC0 and GC1 with the handle straight up. Then retighten the bolts and move the stick all around. You should be able to get full range readings (0 to 255) in both axes.

If either axis works backwards to the way you intended, trade the wires on the outside terminals of that pot and realign the unit. Now you are ready to run one of your favorite games to test the action of your new Super Stick. We think you will find game playing a lot more exciting with a solid controller to grasp.

FINISHING UP

You can lock all the clamp bolts with Loctite or nail polish. The cables should be securely tied to the pot terminals with dental floss; coat the terminals with silicone sealant. A dab of sealant on the pushbutton hinges will help to strengthen them. Secure the cable to the base with a plastic wire tie.

The leg mount and strap cannot easily be adjusted down to fit a child's leg. If you prefer, you can mount the machined Super Stick on a leg board like the one the sheet metal version is mounted on.

Parts List
Super Stick

Number Required	Description of Part	Suggested Supplier	Total Cost
2	Pots, .25 meg, JA1N200P254UA	Newark	$4.00
2	Submini lever switch, #275-016	R.S.	2.80
1	16-pin DIP header	Jameco	.70
1	16-pin wire wrap socket	Jameco	.70
14 ft.	Telephone cable, #278-366	R.S.	1.50
2	Resistors, 1K, 1/4 watt	R.S.	.20
4 lbs.	Aluminum machine stock	Shop	5.00
1/2 sq.ft.	Hardwood	Shop	1.00
1 sq.ft.	Sheet metal, aluminum	Shop	.50
Misc.	Bolts, felt, glue	Local	2.40
		Approximate Cost	**$20.00**

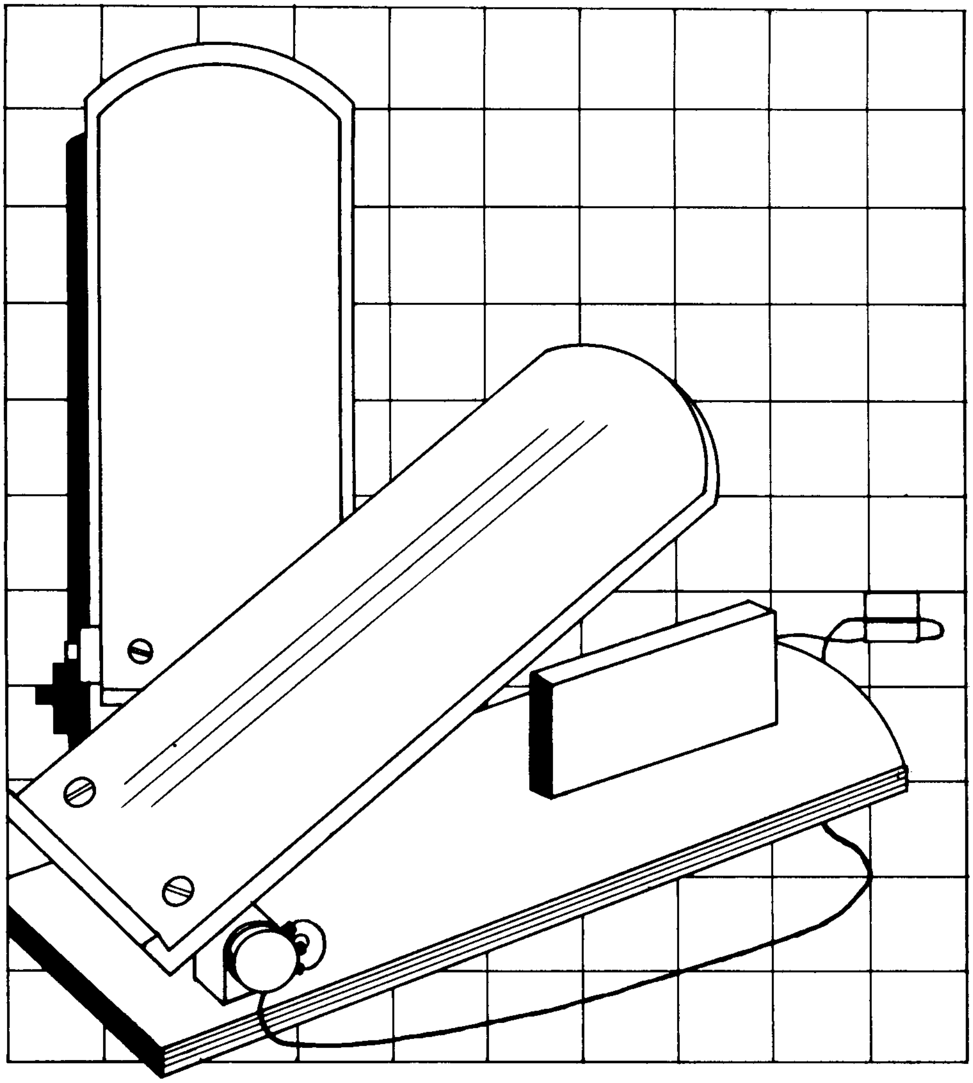
Suppliers:

Newark Electronics
See Yellow Pages or call main office (312) 638-4411 for local sales office address.
Minimum order $25.00

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

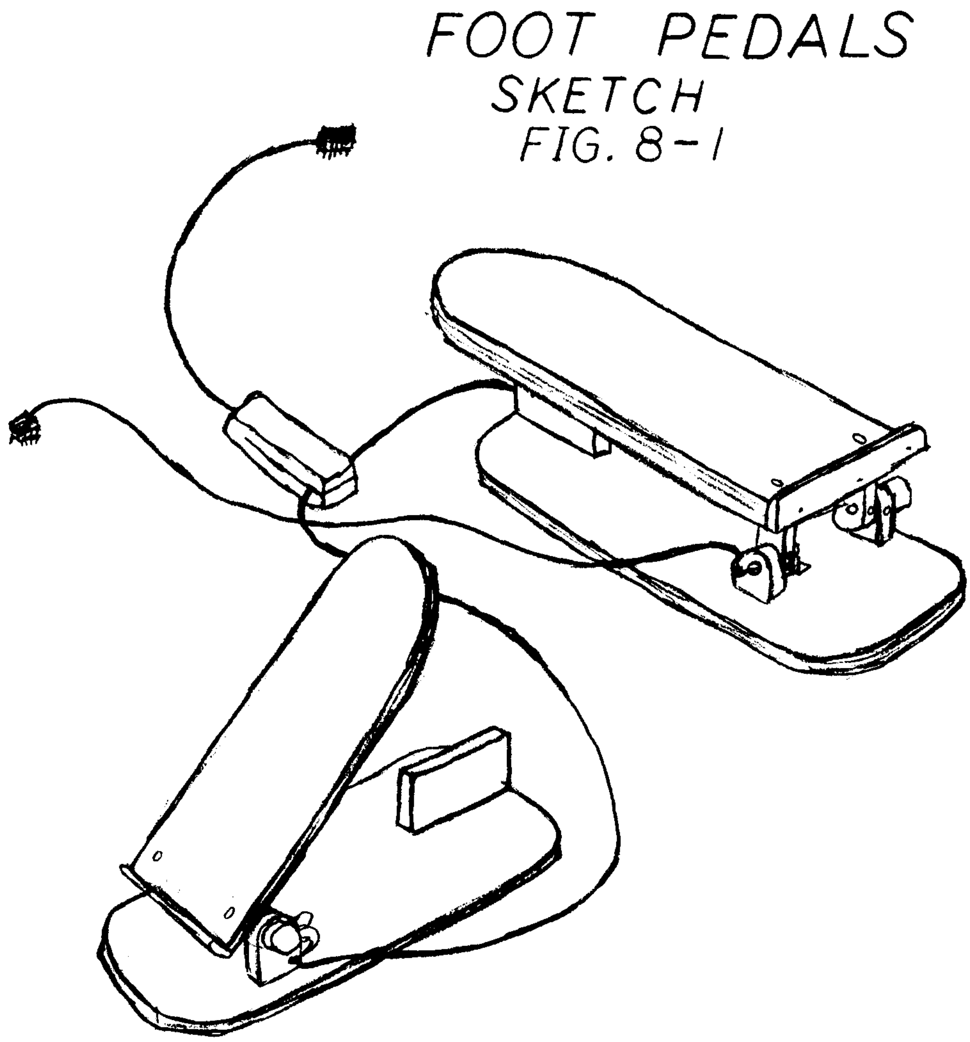
Shop—These items were obtained through the shop in which the work was done.

All other parts were purchased at a local hardware store.



8 Foot Pedals

To get realistic action from the airplane or race car steering wheels (see chapters 2 and 6) you need to use foot pedals with them. But the need for foot pedals goes beyond making games more enjoyable. Several of the most important aspects of flying and driving involve the coordination of hand and foot movements. You can't use the power of the computer to learn to fly or drive until you can practice these essential coordination skills.



These skills are critical in dangerous situations, such as landing a light plane in strong crosswinds or recovering from a skid on an icy bridge. With the steering wheels, foot pedals, and appropriate software, you can practice vital responses in a simulated but realistic environment. You can learn to anticipate and prevent accidents and gain the confidence you need to pass licensing tests.

At present there are no commercial programs that use both steering wheel game controls and foot pedals. As this kind of hardware becomes available, commercial programs will certainly be modified to take advantage of this new feature. Meanwhile, you can write your own. If you can come up with even a modest program incorporating foot pedals you could undoubtedly get it published as an article in a magazine. The steering wheel/foot pedal combinations add such realism to flight and traffic simulations that we are certain software development will proceed at a rapid pace.

The program we used to test the foot pedal prototypes was *International Grand Prix* by Richard Orban, from Riverbank Software, Inc. This program uses one paddle for the race car steering wheel and one pushbutton for the accelerator/brake. When this program is used with the race car steering wheel (chapter 6), the wheel controls the steering and the horn button controls acceleration and braking. This is a vast improvement over a conventional paddle in terms of feel and realistic action, but we all know that you don't brake an automobile by honking the horn.

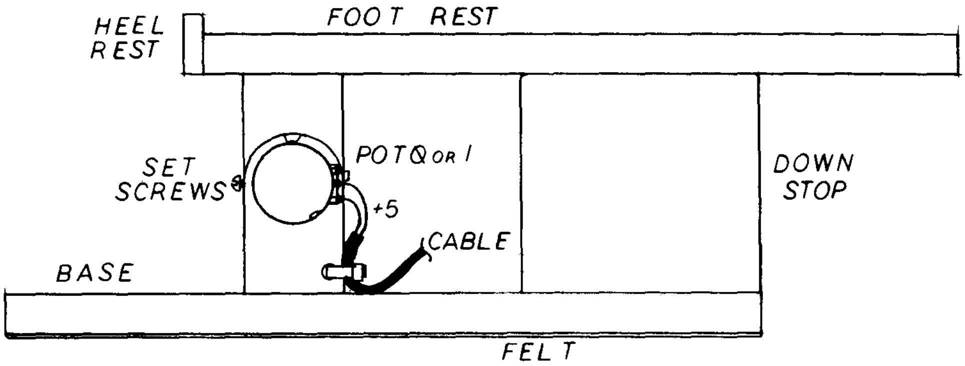
The prototype foot pedals were originally designed with two pots and no pushbuttons. To use a foot pedal with the *International Grand Prix* program we added a simple microswitch and a second cable and plug (see figure 8-1). Now the car accelerates when you move the foot pedal forward and brakes when you move it back. This is one step closer to real driving.

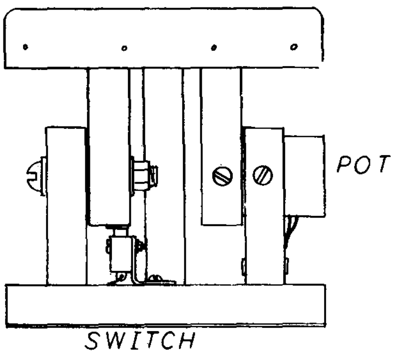
CONSTRUCTION

This is the easiest project to build in the entire book. It is a good exercise for the home or school woodshop, and the materials are inexpensive and readily obtainable. All the wood parts are 1/2-inch fir plywood except the heel rest, which is hardwood scrap. You can complete this project using only hand tools, but a table or radial arm saw will speed your work.

Figure 8-2 shows side and back views of a completed foot pedal. The left and right units are identical, so remember to make enough parts for two units. Figure 8-3 gives you details of the separate parts and a top view of both the base and the foot rest.

The eight pivot supports (figure 8-3) require careful attention. Two are simple pieces of plywood with 1/4-inch holes and a thumbtack at one end. The holes in two more supports are lined with brass bushings (1/4-inch ID). Another two supports have a 1/4-inch hole for the pot shaft and a drilled and tapped hole for a set screw. The last two supports are drilled out for the pot mounting bushing (usually 3/8-inch), tapped for a set screw, and notched for the spin prevention tab on the pot.

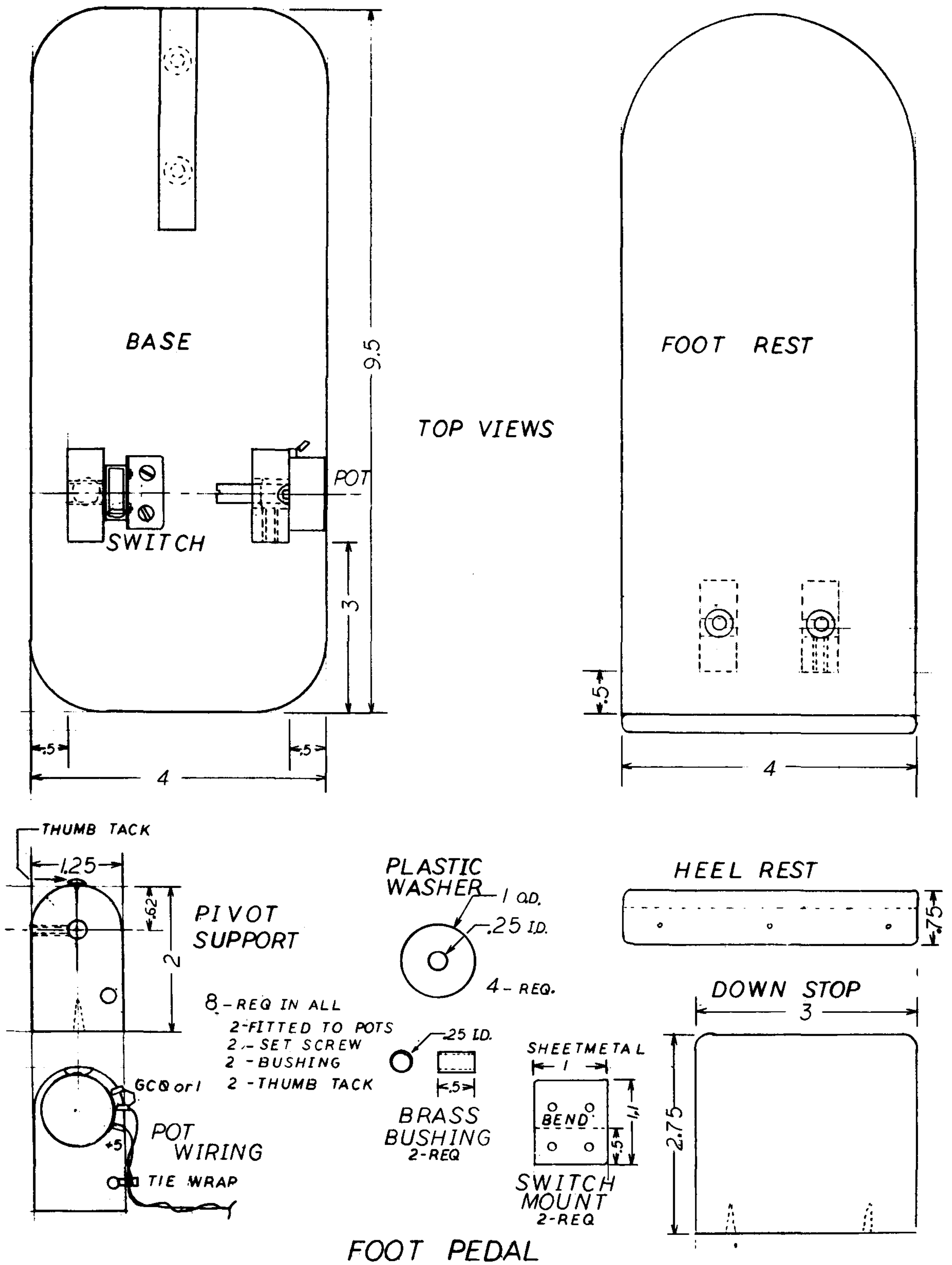




FOOT PEDAL SIDE AND BACK VIEWS
FIG. 8-2

After cutting out the plywood and hardwood pieces, round the corners and edges with a rasp or saber saw and sand all parts smooth. A Screw Mate drill bit is ideal for drilling the screw holes. Assemble the bases with 1-inch x #8 flathead screws and carpenter's glue. Then assemble the pots, upper pivot supports, and bolts. Attach the foot board to the upper pivot supports with the same size screws. Now take the entire unit apart and finish all wood parts with a bright-colored oil-based enamel.

If you are installing the switch feature that lets the foot pedal act as one pushbutton for the *International Grand Prix* program, you will need a small sheet metal switch mount (see figure 8-2). Using hand shears, cut this out of galvanized steel, aluminum, or brass. Drill the top two holes in the metal to suit the switch and the bottom two for 1/2-inch x #6 panhead screws. For the prototypes we used a submini lever switch. The switch and the small mounting nuts and bolts were purchased at Radio Shack. Hold the sheet metal with vise grip pliers or in a bench vise while drilling so that it won't spin and cut your fingers.



FOOT PEDAL DETAILS

FIG. 8 - 3

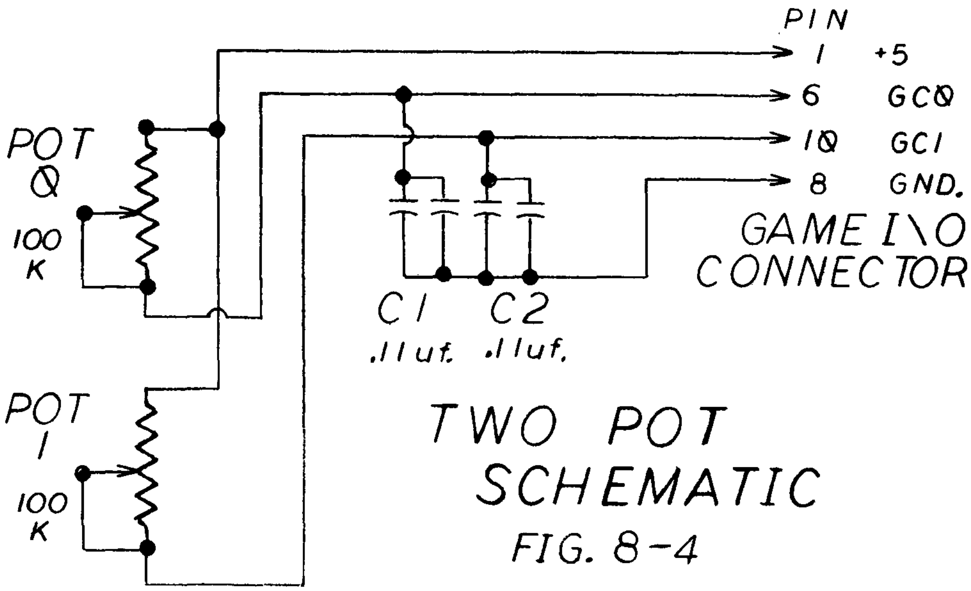
It is best to make the mount a little short, then move it up into position by shimming under it with thin cardboard, wood, metal, or plastic. The thumbtack shown in figure 8-2 should throw the switch when your foot is in a comfortable position, in the middle of the pedal's range of movement.

The 1/4-inch bolts that form half the turning axis must have flat washers where the bolthead and nut touch the wood, and a plastic washer between the two wood parts. After final assembly, lock the nut by applying Loctite, Super Glue, or fingernail polish to the threads.

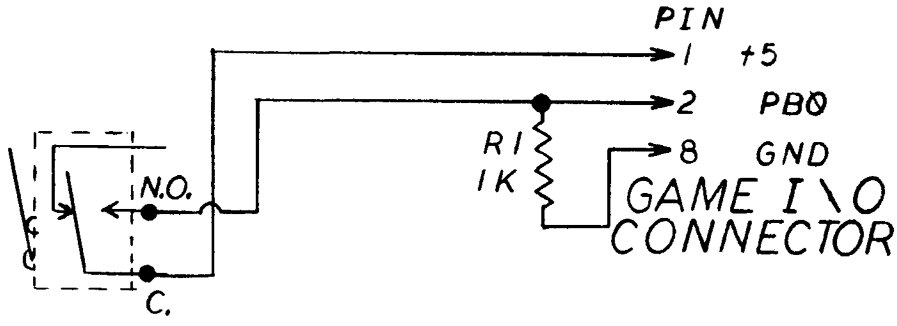
ELECTRICAL WIRING

The foot pedal prototypes were wired for two separate game control arrangements. One arrangement has two foot pedals, each with one pot and no push button. The second arrangement has a single pushbutton on one foot pedal and was designed especially for playing *International Grand Prix.*

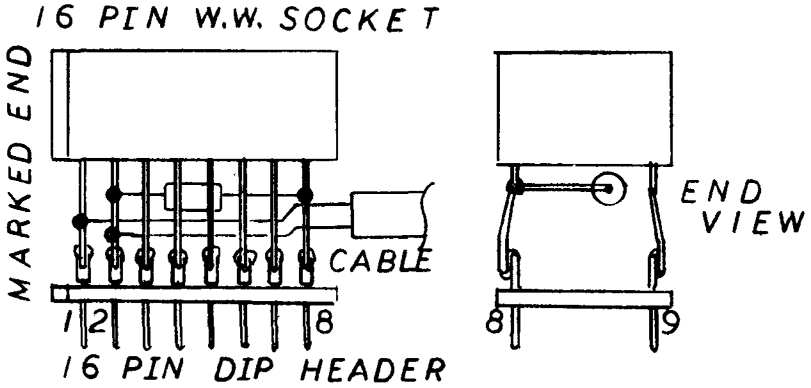
Figure 8-4 is the schematic for the two-pedal version. The pots have short shafts (7/8-inch) and are mechanically rugged. They do not turn through a full 300 degrees, so their maximum values must be



TWO POT SCHEMATIC
FIG. 8-4



ONE-SWITCH
SCHEMATIC
FIG. 8-5



SIMPLE SOCKET/PLUG
FIG. 8-6

about four times the normal paddle pot values. If you use lower value pots, correction capacitors C1 and C2 will be needed. For the prototypes, 100K pots and correction caps were used. These caps were placed on a small piece of printed circuit board and encased in a foam block at the place where the cables from the two pedals come together (see figure 8-1). If you use correction caps you will have to run the

Correction Cap Calculation program from the software chapter to work out their values.

The circuit for the single-pedal version is shown in figure 8-5. The common and normally-open terminals of the switch are utilized. The pull-down resistor R1 is placed in the plug/socket (figure 8-6). Note that all the pins on the socket pass straight through; no pins are cut or bent. This circuit simply adds an additional pushbutton 0 to whatever paddle is plugged into its socket.

If you make up two foot pedals and add the switch circuit (figure 8-5) with its separate plug/socket to the foot pedal with pot 1, you will be ready to play any existing games and the future software that will use all the foot pedal pots. While you are waiting for the new software, you can plug the two-pedal version into the plug/socket of the switch version and play your favorite single-paddle games with your feet.

FINISHING UP

You don't want the foot pedals to slide under your feet, so the bottoms should be covered with something that grips the floor. If you will be placing them on wood or linoleum, cut and fit some pieces from an old inner tube on them. Cotton felt will grip a rug; for thicker carpets try incising shallow saw cuts across the width of the bottom. Extra weight helps, so you can add extra thicknesses of plywood to the baseboard or simply make the baseboard out of 3/4-inch stock.

Perhaps you want the units to spring back to the open position when there's no pressure on them. You could do this by attaching rubber bands from the heel rest to the middle of the base, or by placing a urethane foam block under the middle of the footrest. There are probably many other different ways to spring-load these foot pedals. Use your imagination and experience to come up with a solution that suits your needs.

Parts List
Foot Pedals

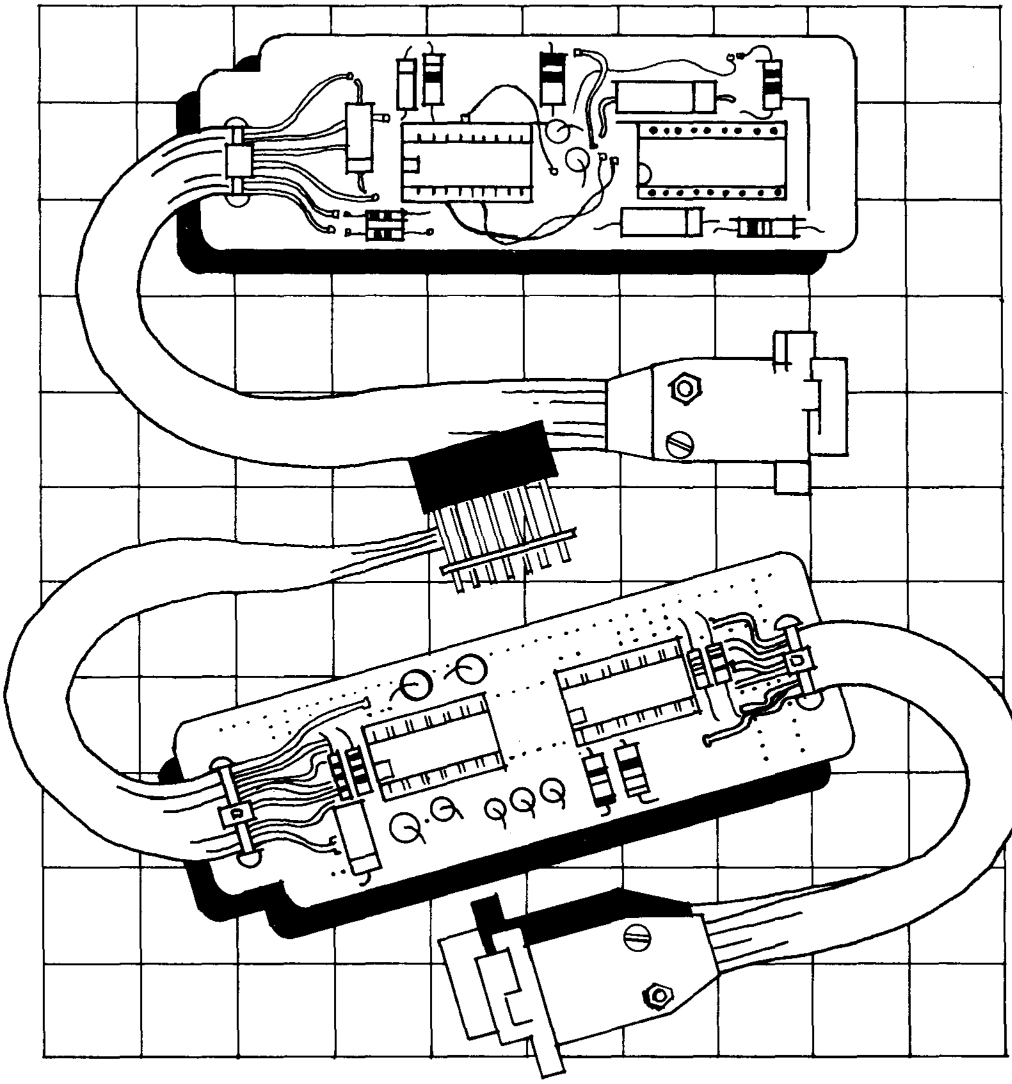
Number Required	Description of Part	Suggested Supplier	Total Cost
2	Pots, 100K, short shaft	Jameco	$6.00
1	Submini lever switch, #275-016	R.S.	1.30
15 ft.	Telephone cable, #278-373	R.S.	1.70
2	16-pin DIP headers	Jameco	1.40
2	16-pin sockets, wire wrap	Jameco	1.40
1	Resistor, 1K, 1/4 watt	R.S.	.10
2 sq.ft.	Plywood, 1/2″ fir	Local	2.00
2	Bolts, 1/4″ x 1-1/2″	Local	1.00
4	Flat washers, 1/4″	Local	.20
2	Nuts, 1/4″	Local	.10
1 inch	Brass tubing, 1/4″ I.D.	Hobby shop	.20
6	Flathead screws, 1″ x #8	Local	.50
4	Set screws, 1/2″ x #10 x 24	Local	.50
Misc.	Nails, sandpaper, finish	Local	2.10
		Approximate Cost	$19.00

Suppliers:

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

R.S.—Radio Shack
See Yellow Pages

All other parts were purchased at a local hardware store.



9 Converters: Between Apple and Atari

If you or your friends have Atari game systems and an Apple computer, you might want to use your favorite Atari joystick to play games on the Apple. Or maybe you want to play games on your Atari using an Apple joystick. With the two converters described in this chapter you can have both these options.

There are some limitations, however. The Atari-type joysticks have a digital output, so you can use them on the Apple for only the simplest games, like *Snoogle,* for which the joystick directs the movement of a character. For the many arcade games that require only digital input, Atari joysticks are much faster than conventional Apple joysticks.

We will cover the construction of two small circuit boards that function as converters: the first one, an Atari-to-Apple converter, plugs into an Apple computer. You plug your Atari joystick into this converter to play fast-action arcade games on the Apple. The second converter plugs into an Atari system so that you can plug an Apple joystick into it. Now you can play Atari games with your Apple controllers.

The Atari-to-Apple converter will greatly increase your speed in playing arcade games on the Apple, especially if it is used with homebuilt Atari paddles like the Tipping Disk (see chapter 5). Consequently, we expect that there will be greater interest in this first type of converter. The second converter, the Apple-to-Atari, is included because there is educational value in making up the circuit. But even more important, newly developed flight simulator or race car games for Atari-type systems will greatly benefit from being played with the steering wheel and foot pedal designs given in this book. Then your Apple-to-Atari converter will provide an exciting new realism when you play these games.

Both of these boards are good beginning electronics projects. Each has one or two integrated circuits, a few components, and some cables and plugs. Each is easily assembled on a small piece of general purpose printed circuit board. The parts are inexpensive and easy to obtain.

CHARACTERISTICS OF APPLE AND ATARI JOYSTICKS

The Apple joystick and the Atari joystick are two completely different devices. The Apple joystick has two lever-controlled pots and a pushbutton, while the Atari joystick is a collection of five pushbuttons, four of which are mechanically connected in two pairs. The Atari-to-Apple converter must make pushbutton closures look like changing pot values. The Apple-to-Atari converter must make changing pot values look like switch closures. In addition, there are two other differences between these joysticks that may cause some confusion when you build these converters.

First, the Apple joystick has its common connection (one side of each pot and each pushbutton) connected to the +5 volt supply line. The common connection for the Atari joystick (one side of each switch) is normally connected to the ground wire. The easiest way to design each of these connectors was to make the common connection of the type required by the host computer. This means that pin 8 of the Atari connector, which normally would be connected to ground, is connected to the +5 volt supply (pin 1) of the Apple game plug on the Atari-to-Apple converter.

The second difference is that the connector on the end of an Apple joystick cable has pins on it, so it is defined as a plug. The connector on the end of the Atari joystick cable has holes in it, so technically it is a socket. We have used the correct terms in the hope that you will order the correct parts. If you get confused, blame Atari, since they have installed a socket where you normally expect to find a plug.

CONSTRUCTION

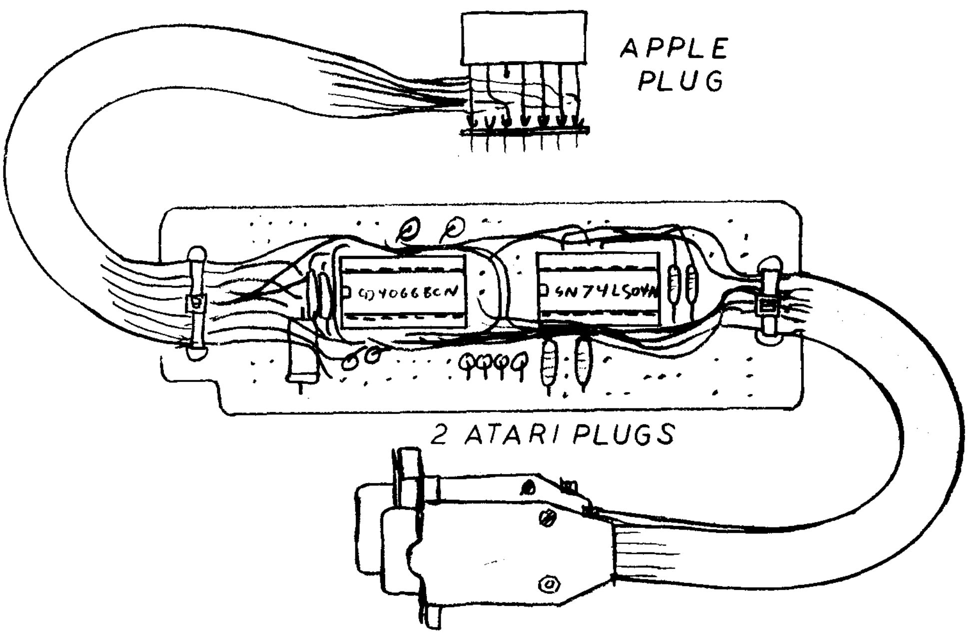
Each circuit is made up from one-third of a printed circuit board (Radio Shack #276-154). You can mount the board in a small plastic box like a cassette tape holder or inside a block of flexible packing foam. To cut the circuit board, score it deeply with an X-acto knife and break it over the edge of a table. Drill the holes for the wire ties with the end of the knife and file all the circuit board edges smooth. Mounted on the board are several resistors and capacitors and sockets for the chips. Both boards draw the small amount of power they need from the host computer.

Most of the connectors for both converters are mounted on short pieces of cable. The Apple-to-Atari converter does have one socket for the Apple joystick; this socket is mounted directly on the board rather than on a cable.

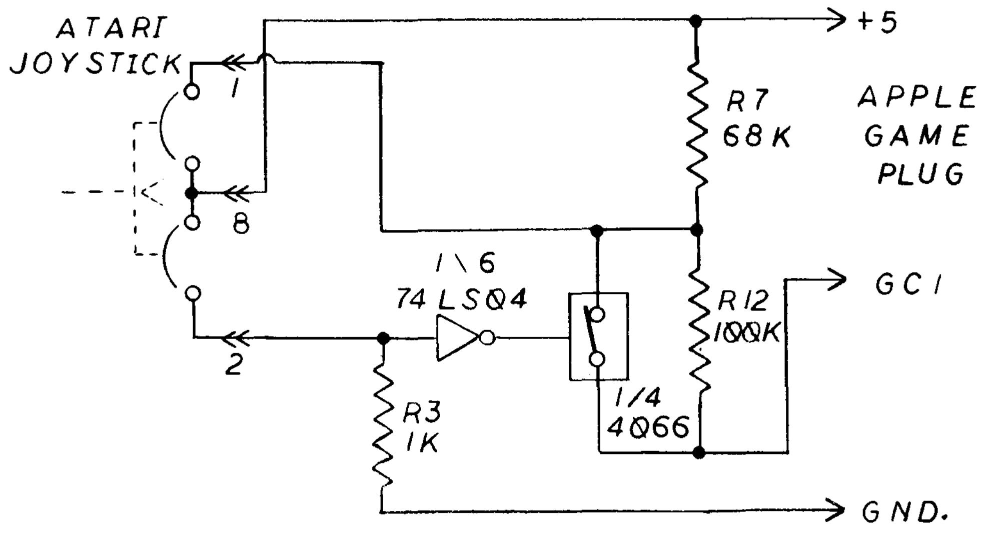
THE ATARI TO APPLE CONVERTER: CIRCUIT THEORY

Figure 9-1 is a sketch of the Atari-to-Apple Converter without an enclosing box. Since this simple circuit can handle two joysticks, giving you the option of playing two-person games, the sketch shows plugs for two Atari joysticks. If you won't be playing such games you can install only one connector and save a little money. The circuit requires two chips, one capacitor, and fourteen resistors.

Figure 9-2 is a simplified schematic of the circuit that will help you understand how the card works. As noted, two chips are used. The 74LS04, a digital chip, has six inverters. If the input to an inverter is high (+5 volts) then its output goes low (nearly 0 volts), and vice versa. The second chip, the 4066, is a special purpose CMOS chip. It acts like four small single-pole, single-throw relays. If one of its control lines is



SKETCH - ATARI TO APPLE CONVERTER
FIG. 9-1



ATARI TO APPLE SIMPLIFIED SCHEMATIC
FIG. 9-2

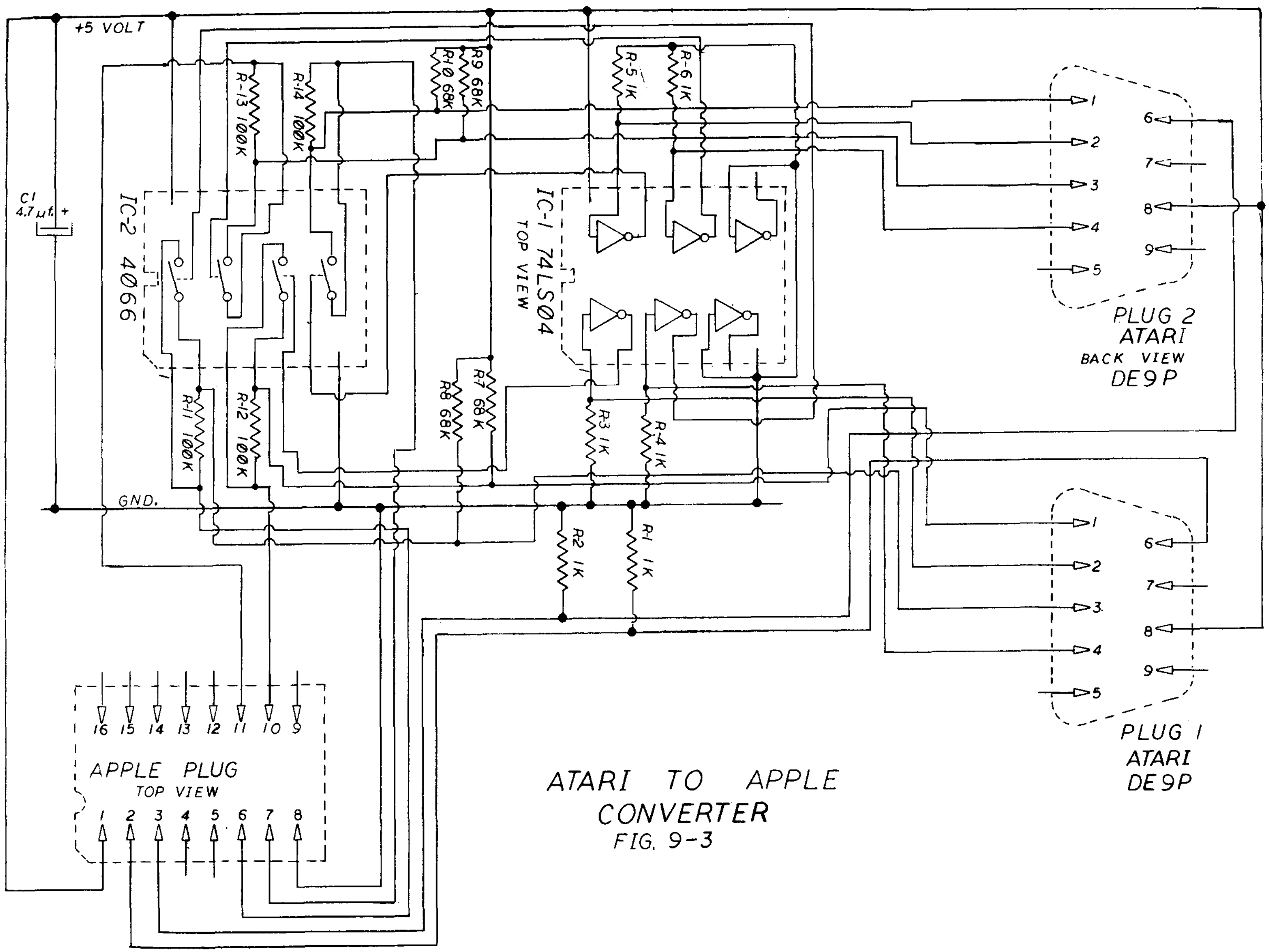
brought high (+5 to +15 volts), then one of the relays closes and conducts electricity. If the control line is low (0 volts), then the relay is open and does not conduct.

The Atari joystick has two internal normally-open switches that correspond to the directions up and down. For the Apple to read these two switch closures they must be converted to pot readings between 0 and 150K.

Depending on the position of the Atari joystick, the game control circuit may read 68K (R7), 0, or 168K (R7 + R12). These resistive values are read as 128, 0, and 255 by the Apple, and the program interprets them as center, up, and down.

With the handle in the center position, R7 is in the circuit but R12 is bypassed by one section of the 4066, so the reading is 128. If the handle is pushed up, the switch in the joystick bypasses R7 and the reading is 0. If the handle is pushed down, the section of the 4066 opens and the reading is 255.

The inverter in the 74LS04 and the pull-down resistor R3 make the section of the 4066 operate the opposite of the down switch in the joystick: when the down switch is open the 4066 section is closed and vice versa.



ATARI TO APPLE
CONVERTER
FIG. 9-3

This circuit is repeated for the left and right switches. Since there are four switches in the 4066 chip and six inverters in the 47LS04 chip, you can control two joysticks with just these two chips simply by adding a few more resistors and a second connector.

THE ATARI-TO-APPLE CONVERTER: WIRING

Figure 9-3 is the complete schematic of the Atari-to-Apple converter. Once again, follow the procedures outlined in chapter 14 for checking your wiring by coloring in two copies of the schematic. The Apple plug is a 16-pin DIP header and is shown as it appears from the top. The Atari connectors are shown from the back as they will appear when you solder them.

A word of caution: the 4066 is a CMOS chip and these are easily damaged by static electricity. Leave the 4066 in its protective package until you have completed the circuit and thoroughly checked it out. It is imperative that you use a socket on the board for this chip.

We used #24 solid wire from a scrap of telephone cable for jumpers on the board. Ribbon cable was used for the cables to the connectors. The cable for the Apple plug requires eight conductors, but we doubled up the +5 supply and ground, so ten conductors were installed. Two 6-wire runs of cable were used for the Atari sockets.

Double check your work before applying power to the circuit. Color in the second copy of the schematic, using an ohms meter to trace the wires. When everything checks out, plug the two chips into their sockets on the board, making sure the #1 pins are in the correct places, and install the plastic hoods on the Atari connectors. The hoods have small plastic tabs that may have to be filed down. They also come with mounting bolts, which aren't needed for this project.

To test the converter, turn off your computer, plug in the new unit (without a joystick attached to it), and turn the computer back on. If the computer does not start up exactly as usual, turn it off immediately and recheck all your work. When the circuit checks out, turn off your computer, plug in an Atari joystick, and turn on the computer again. Now run the Controller Checkout program from the software section and check out the game paddle reading of your new adapter and joystick combination.

THE APPLE-TO-ATARI CONVERTER

Figure 9-4 is a sketch of the Apple-to-Atari converter. If an Apple-style joystick or set of paddles is plugged into the empty socket on this board and the Atari socket is plugged into an Atari game port, the Apple joystick will perform like an Atari joystick.

The mechanical construction of this converter is quite similar to the one just described. It is built on one-third of a general-purpose circuit board and has one chip, twelve components, a cable and socket to connect to the Atari, and a simple DIP socket for the Apple joystick.

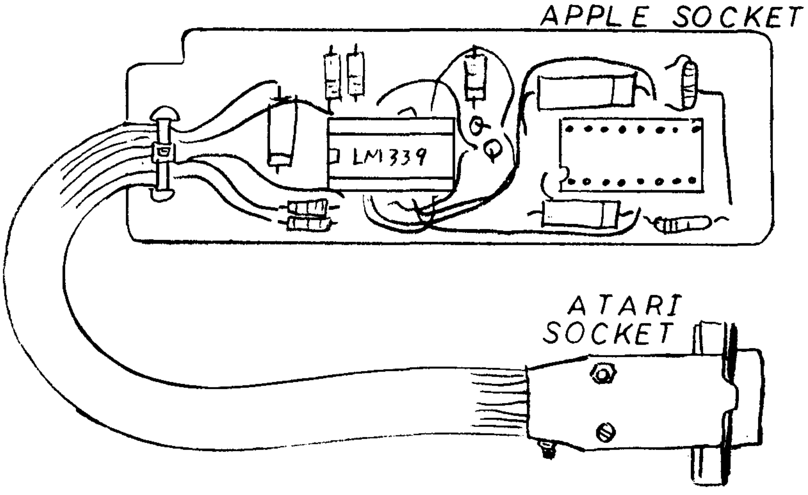
Figure 9-5, the simplified schematic, shows that this converter works on completely different principles than the first one. The pot in the Apple joystick is used in a resistive bridge with R1 so that the voltage on pin 1 varies with the pot setting. Capacitor C3 reduces electrical noise.

The LM339 chip contains four voltage comparators, each with two inputs and one output. They compare the voltage on one of their inputs with a reference voltage on the other input. They produce a digital output to indicate whether or not the input voltage is greater than the reference. The pull-up resistors R4 and R5 make the outputs look like the switch closures of a standard Atari joystick.

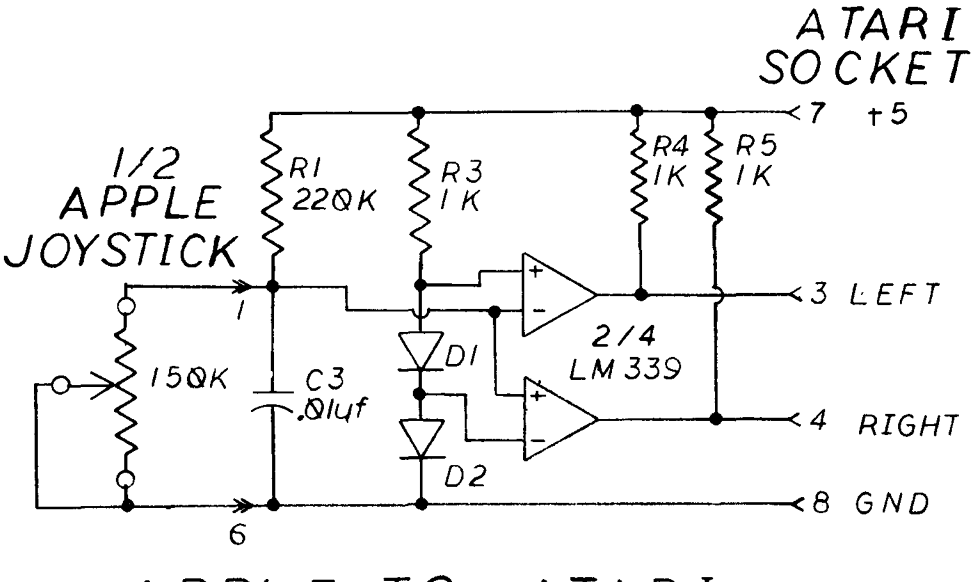
The diodes D1 and D2, along with resistor R3, provide two reference voltages (0.7 volts and 1.4 volts) for the comparators. Here we are using a property of a real diode, its forward conductance voltage drop, which a theoretically ideal diode would not have. If we passed a small current through an ideal diode there would be no voltage drop. If we pass a current through a real silicon diode, however, there is a drop of about 0.7 volts, and this drop changes very little with fluctuations in temperature and current.

Two comparators in the LM339 compare the voltage from pot 1 with our two reference voltages and put out the correct digital signals for the joystick position: left, right, or center. A similar circuit checks pot 0 for the signals for up, down, or center.

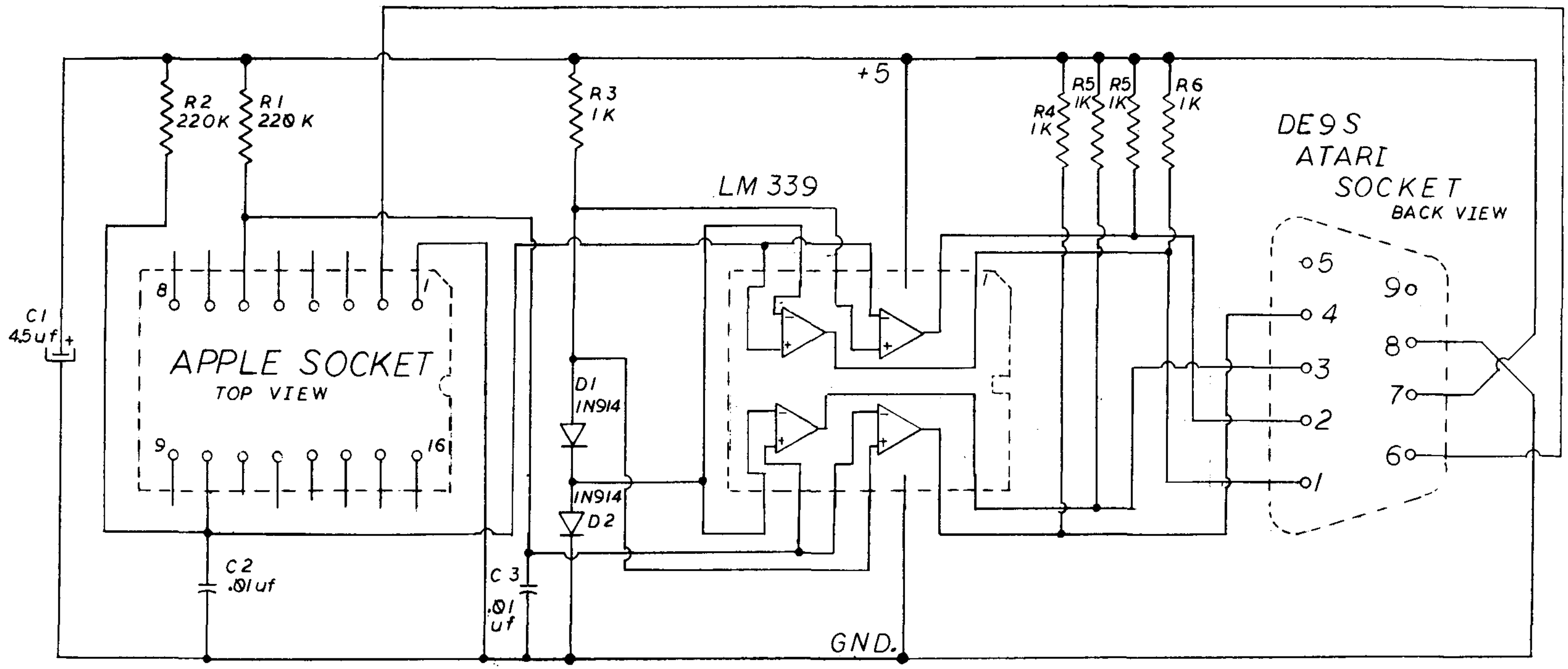
You will have to adjust the circuit to use this converter with joysticks that have correction caps. The resistive bridge circuit measures resistance only, so if the pot is not 150K, resistors R1 and R2 will have to be changed. The correct value is about one and a half times the value of the joystick pot.



SKETCH - APPLE TO ATARI CONVERTER
FIG 9-4



APPLE TO ATARI SIMPLIFIED SCHEMATIC
FIG. 9-5



APPLE TO ATARI
CONVERTER
FIG. 9-6

Figure 9-6 is a detailed schematic for wiring the converter. Be sure you lay out the #1 pins on the chip and socket in the correct direction. The plus lead of capacitor C1 must go to the +5 supply. On the LM339, the pins used for the +5 and ground are not those commonly used for digital chips (the 74LS series), so double check them before applying power.

Double check your wiring, do not plug any electronic device into a live socket, and be quick to turn off the Atari if everything doesn't look absolutely right.

FINISHING UP

As mentioned earlier, the circuit boards should be mounted in small boxes to prevent the wires from shorting. You could use cassette tape boxes, cutting out holes for the cables with a coping saw and small files. Alternatively, you could encase the circuit in a foam block, as was described for the Multiple Socket Extension (see chapter 3). Or you could purchase a small electronics box, fit the circuit board into the box before mounting the components, and drill and file out holes for the cables. Depending on the box you use, you may have to cut the PCB and arrange the components differently from those of the prototype.

From the standpoint of their electronics, these two converters are the most sophisticated projects in this book. A little care in their construction, however, will give you an excellent lesson in electronics and a device that will greatly increase your enjoyment of your other controllers.

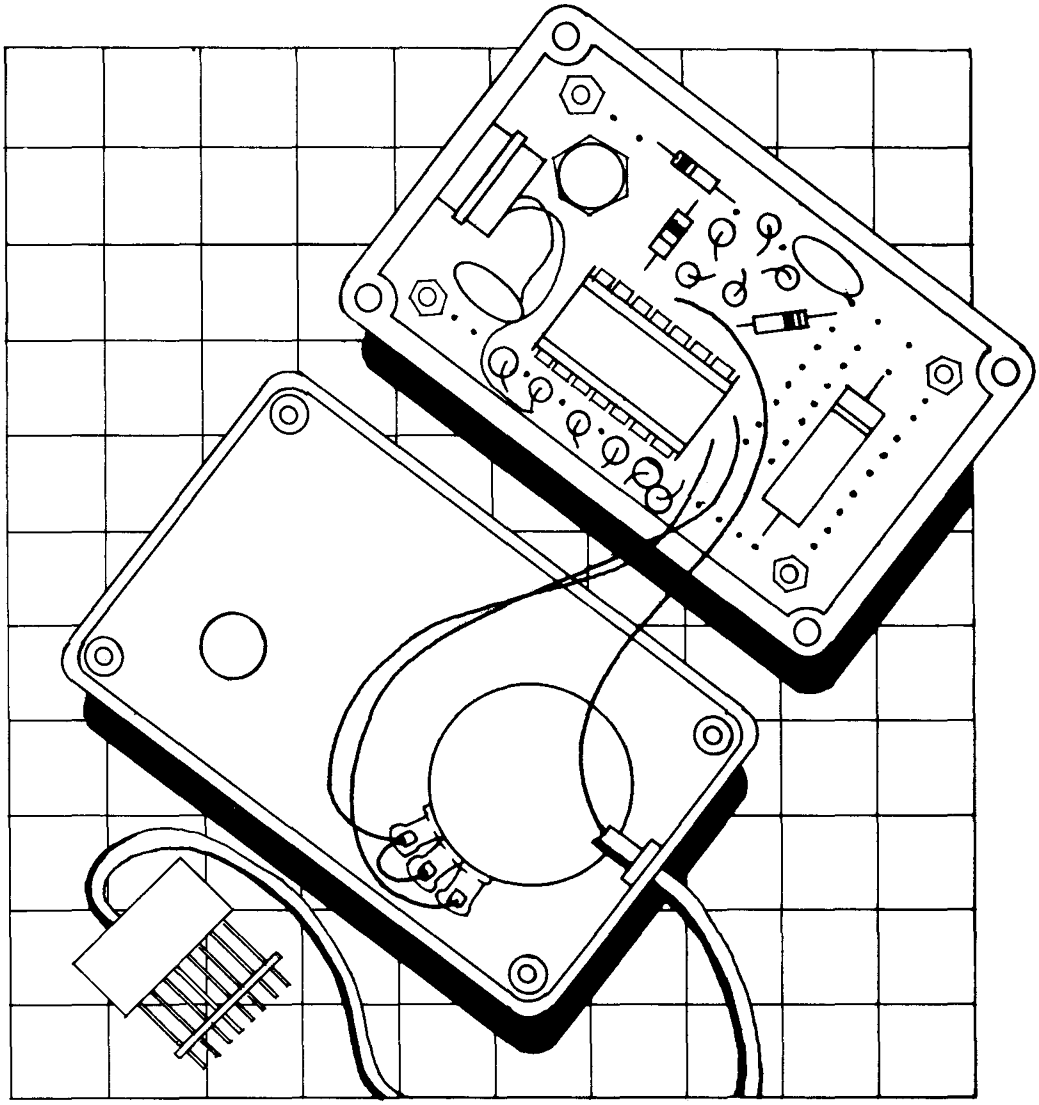
Parts List
Atari to Apple Converter

Number Required	Description of Part	Suggested Supplier	Total Cost
1	74LS04 hex inverter chip	Jameco	$ .30
1	CD4066 quad bilateral switch chip	Jameco	.40
2	IC sockets, 14-pin, gold	Jameco	.90
1	Header plug, 16-pin	Jameco	.70
2	DE9S sockets, 9-contact	Jameco	2.80
2	DE-9H D-subminiature hoods	Jameco	2.40
1	Capacitor, 4.7 microfarad, tantalum	Jameco	.45
4	Resistors, 100K, 1/4 watt, 5%	Jameco	.30
4	Resistors, 68K, 1/4 watt, 5%	Jameco	.30
6	Resistors, 1K, 1/4 watt, 5%	Jameco	.40
1	Printed circuit board #276-154	R.S.	2.00
3 ft.	Ribbon cable, 16-conductor, #171-16	Jameco	1.80
Misc.	Box, silicone sealant	Local	1.25
		Approximate Cost	**$15.00**

Parts List
Apple to Atari Converter

Number Required	Description of Part	Suggested Supplier	Total Cost
1	LM339 quad comparator	Jameco	$ .70
1	IC socket, 14-pin	Jameco	.40
1	IC socket, 16-pin, gold	Jameco	.50
1	DE9S socket, 9-contact	Jameco	1.95
1	DE-9H hood	Jameco	1.20
1	Printed circuit board, #276-154	R.S.	2.00
2	1N914 diodes	R.S.	.20
1	Capacitor, 4.7 microfarad, tantalum	Jameco	.45
2	Capacitor, .01 microfarad, disc	Jameco	.20
5	Resistors, 1K, 1/4 watt, 5%	R.S.	.40
2	Resistors, 220K, 1/4 watt, 5%	R.S.	.20
2 ft.	Telephone cable, #278-366	R.S.	.30
Misc.	Box, silicone sealant	Local	.50
		Approximate Cost	**$ 9.00**

Suppliers: Jameco Electronics, 1355 Shoreway Road, Belmont, CA 94002
R.S.—Radio Shack, See Yellow Pages



10 Sound Pushbutton

A lot of arcade game players will instinctively shout commands at the screen when the action gets exciting. There are so many times when it would be more fun to control game movements by vocal commands than by pushing buttons. This device, the sound pushbutton, lets you do just that, since making a sound will have the same effect as pressing a paddle button. A potentiometer provides sensitivity control with a wide range of adjustment, so low-level background noise will not set the device off. The construction is simple and the materials are inexpensive and easy to obtain.

CONSTRUCTION

The sound pushbutton is encased in a small plastic box. The device consists of a microphone element, a pot, and a circuit board with one chip, three capacitors, one LED, and 14 resistors. It is connected to the computer with a 3-wire cable and a simple plug/socket.

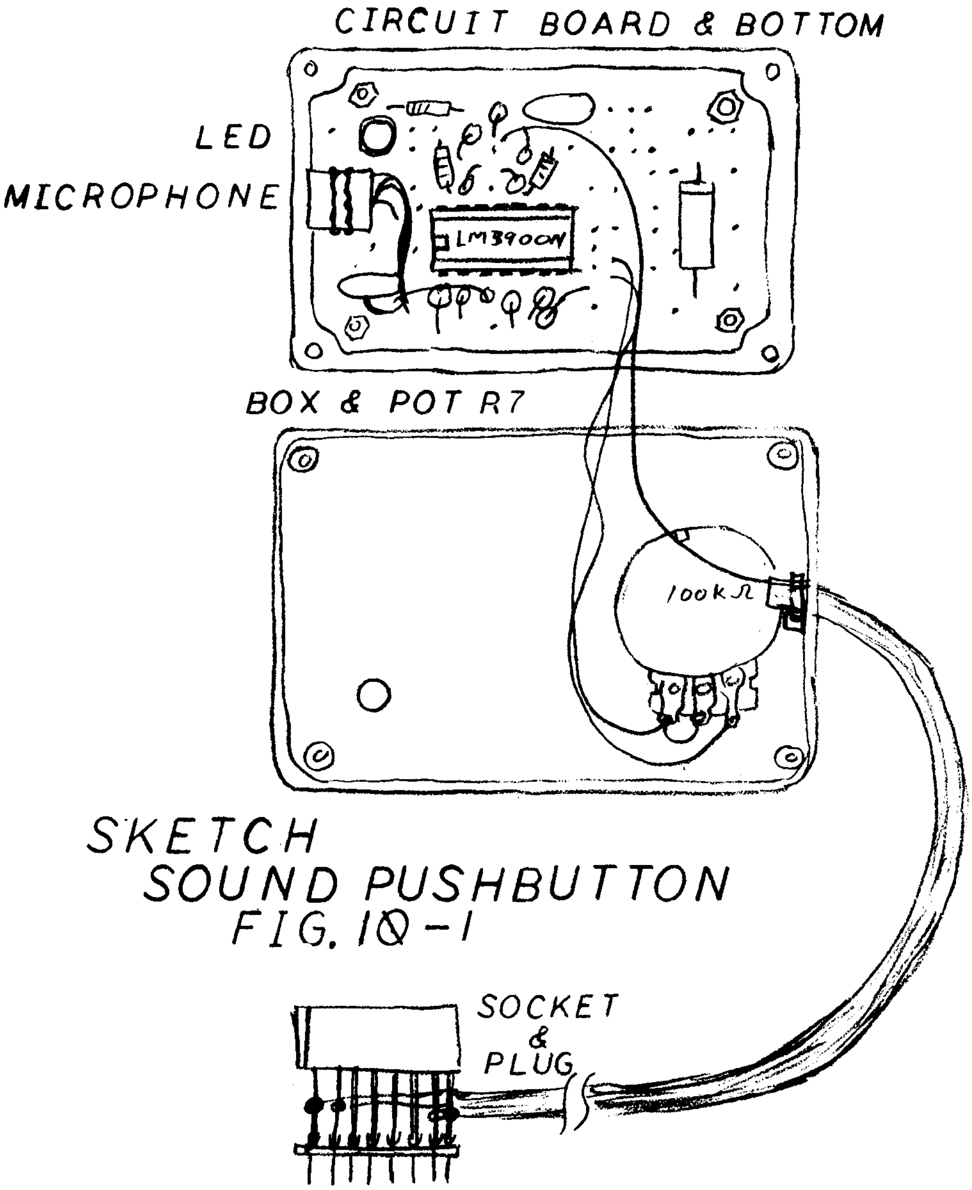
To begin, cut a piece of circuit board to fit inside the box. Cut the board by scoring both sides deeply with an X-acto knife and breaking it over the edge of a table. File off the corners of the board so that it doesn't hit the screw posts in the box. Mount the board on the bottom of the box with four small bolts. You will need spacers or extra nuts to raise the board off the metal bottom of the box.

Next position the microphone on the center of one end of the circuit board. Mount the element by looping wire over it and soldering the wire to the board. Carefully determine where the microphone will be located near the end of the plastic box and drill a 1/4-inch hole to let sound inside to reach the element.

The sensitivity pot is mounted through the top of the box on the end away from the microphone. You may have to add a 3/8-inch flat washer to mount the pot on the thin plastic. Now drill a hole for the cable in the end of the box just beneath the pot. Mount the LED on long leads so that its base is about 1/4-inch above the circuit board. Find the spot on the box just above the LED and drill a 3/16-inch hole so that it can be seen. As a finishing touch, you might want to add rubber feet to the bottom of the box so it will not scratch your desktop.

ELECTRONIC OPERATION

Figure 10-2 is an explanatory schematic which shows the appearance of the sound signal at five points along the circuit path to the computer. The key to this circuit is the LM3900 chip, a quad



SKETCH
SOUND PUSHBUTTON
FIG. 10-1

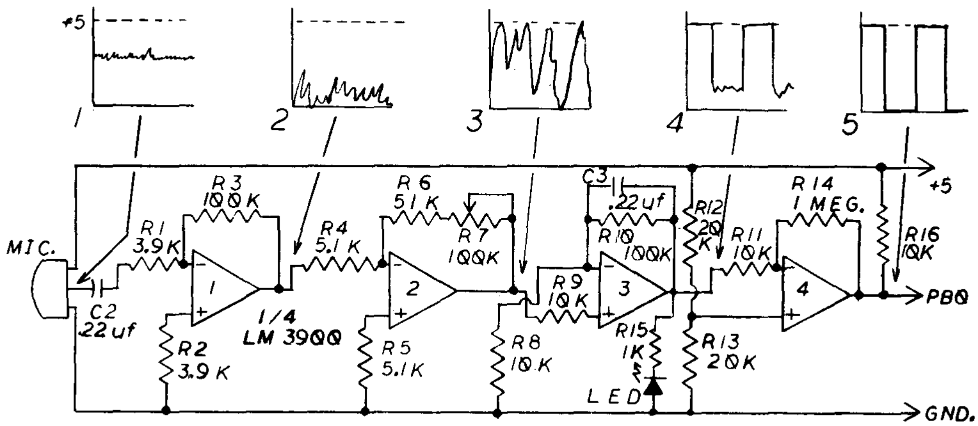
operational amplifier that operates on +5 volts.

Operational amplifiers (op-amps) are basic and popular building blocks for analog circuits. The standard op-amp has two analog inputs (one plus, one minus) and a single analog output. It takes the difference between the incoming signals and multiplies the difference by an enormous amount (the gain) to produce the output. The gain may be as much as 100,000 to 1. To achieve control over such large gains, a set of input and feedback resistors is used with the op-amp.

In the first section of the circuit (figure 10-2), resistor R3 is the feedback resistor and R1 and R2 are the input resistors. The gain of this stage is R3 divided by R1 (100K divided by 3.9K = 26). The small signal coming from the microphone, shown in the first waveform drawing, is multiplied by 26 to become the second waveform. Resistor R2 adds a zero voltage to the input from the microphone, helping to prevent oscillations and improve temperature stability.

Most op-amps use plus and minus power supplies to provide a full range of possible outputs. The LM3900 uses only the +5 supply, so its output is limited to the range of 0 to 5 volts. When you are designing a circuit with the LM3900 you have to make certain that your intended output will fall in this range.

In the first stage of the circuit the input from the microphone is amplified. The second stage provides additional gain, and this gain is controlled by the sensitivity pot. This stage uses the LM3900's limited



EXPLANATORY SCHEMATIC
SOUND PUSHBUTTON
FIG. 10-2

output range to amplify half the waveform so that weak signals will be close to 0 volts and strong signals will be amplified to +5 volts.

The third stage of the circuit provides additional gain and filters out the high frequency portion of the signal with capacitor C3. This filtering makes the signal more like the steady pushing of a button and eliminates bounce and electrical noise. The LED is also driven by this stage.

The last stage compares the signal with half of the +5 volts provided by the voltage divider (resistors R12 and R13). The output of this stage is then either 0 or +5 and is therefore a proper digital signal.

WIRING THE CIRCUIT

Remove the circuit board from the box and add a 14-pin DIP socket to the components (the microphone and LED) already on it. Now add the wires, resistors, and capacitors, marking off each on a copy of figure 10-3 as they are installed.

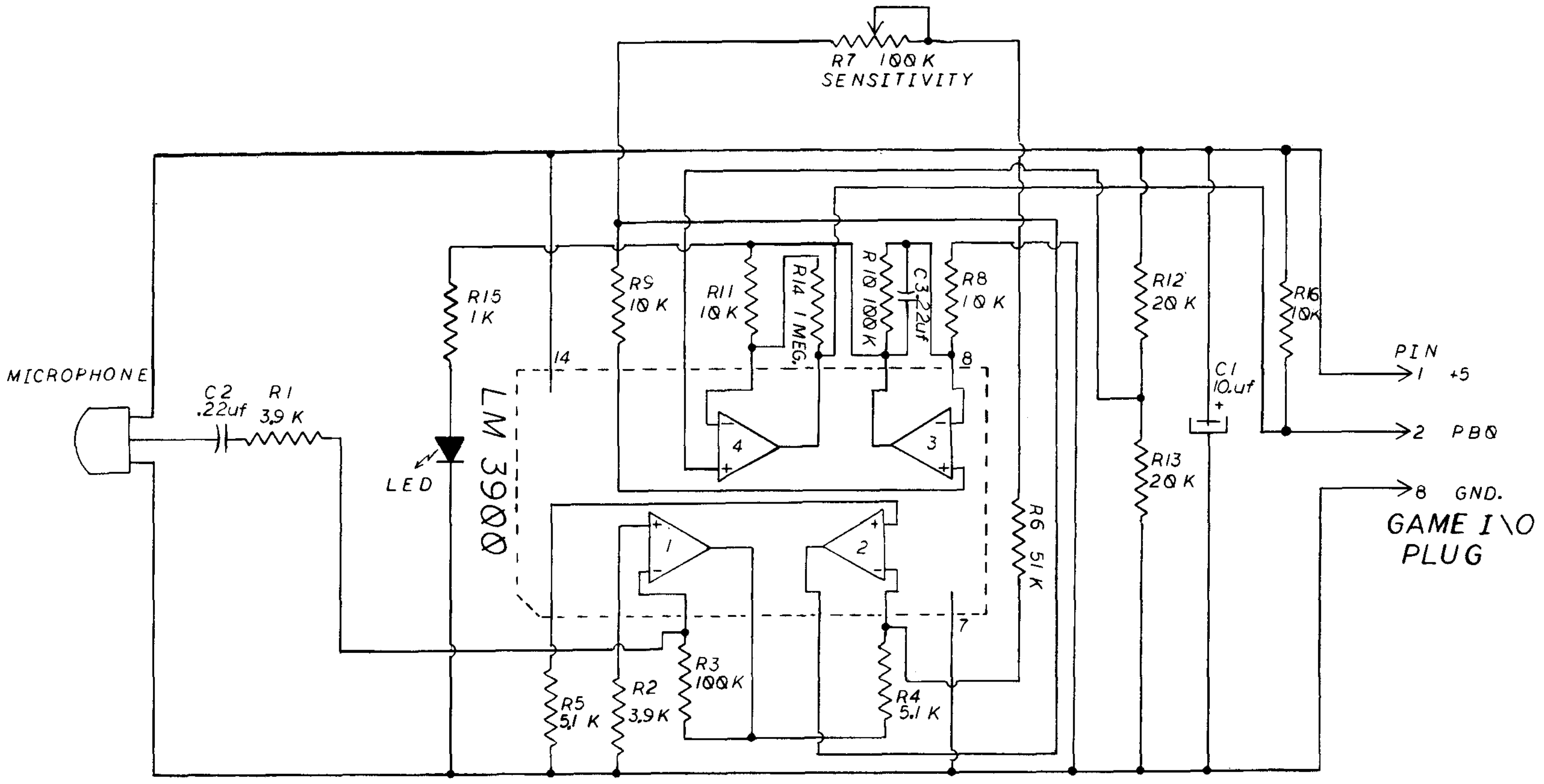
Since there is no mechanical strain on this device, the pot you buy does not have to be an expensive one. If you purchase the pot given in the parts list, you will have to shorten the shaft and add a knob. The cable requires only three wires. Telephone cable with four wires works well for this unit and gives you an extra wire to double up the ground.

The best plug for this unit is a simple plug/socket similar to the more complex one described in chapter 3. For this one, do not bend or cut short any of the socket pins. You will almost always be using the sound pushbutton with another controller, and you want all the controller functions to pass through the plug/socket.

TESTING

When you have finished the wiring, examine your work closely for solder bridges and shorted wires. Plug the LM3900 into the socket in the board and check to make certain there is at least 50 ohms between pin 1 and pin 8 of the plug. We got a reading of 1.3K when we tested the prototype. Mount the circuit board on the bottom and close the box.

Turn off your computer. Plug the new sound pushbutton into the game I/O connector and turn it on again. If the computer doesn't start



SCHEMATIC SOUND PUSHBUTTON

FIG. 10-3

up exactly as usual, shut it down immediately and recheck all your work on the new unit.

Now run the Controller Checkout program from the software chapter and watch the screen to determine if the 0 pushbutton responds to sounds. Try various settings of the sensitivity control while making sounds of differing volume.

Turn the computer off, plug a controller you know is in good working order into the back of the sound pushbutton plug, and rerun the Controller Checkout program. Test all the functions of the sound pushbutton and the controller. Now you can try it out with your favorite games. Instead of wearing out your fingers, you can yell at the screen and get a response.

OTHER COMPUTERS

The output of the sound pushbutton is very close to a standard digital signal and should be acceptable to any computer system that has at least one pushbutton input and that can provide a small amount of +5 voltage. You will, of course, need a different plug, and the plug pins may have different numbers than the ones shown for the Apple. See the section on other computers in the Electronics Tutorial for more information on how to adapt this controller to other computers.

Parts List
Sound Pushbutton

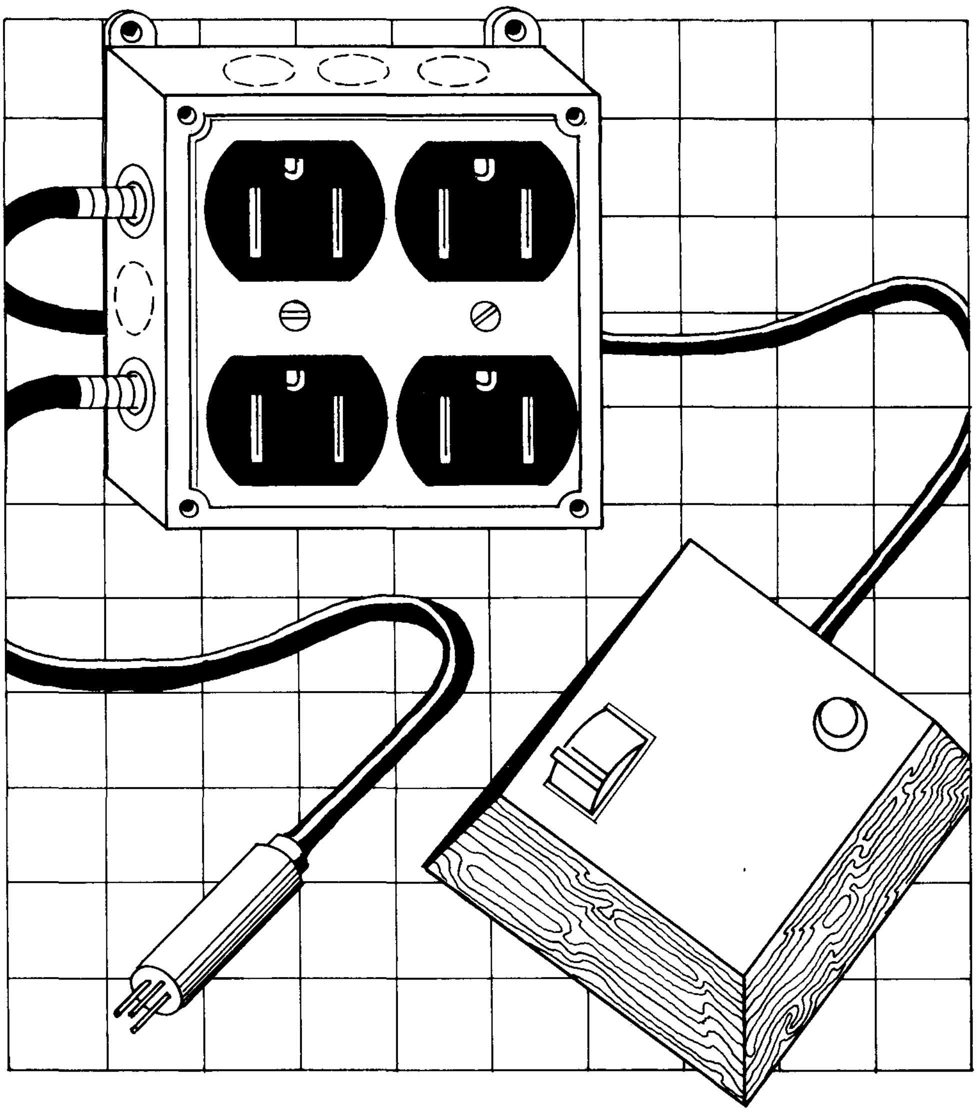
Number Required	Description of Part	Suggested Supplier	Total Cost
1	Experimental box, #270-230	R.S.	$1.60
1	Pot, 100K, #271-1722	R.S.	1.10
1/2	Printed circuit board, #276-154	R.S.	2.00
1	LED, round, any color	R.S.	.40
1	Microphone element, #270-092	R.S.	3.00
1	Quad op amp, LM3900	Jameco	.60
1	14-pin DIP socket	Jameco	.40
1	16-pin DIP socket, wire wrap	Jameco	.70
1	16-pin DIP header	Jameco	.70
2 ft.	Telephone cable, #278-366	R.S.	.30
1	Cap, 10 microfarads at 10 volts	Jameco	.20
2	Caps, .2 microfarads at 10 volts	Jameco	.30
2	Resistors, 3.9K, 1/4 watt	Jameco	.20
2	Resistors, 100K, 1/4 watt	Jameco	.20
2	Resistors. 5.1K, 1/4 watt	Jameco	.20
1	Resistor, 51K, 1/4 watt	Jameco	.10
3	Resistors, 10K, 1/4 watt	Jameco	.30
2	Resistors, 20K, 1/4 watt	Jameco	.20
1	Resistor, 1 Meg, 1/4 watt	Jameco	.10
1	Resistor, 1K, 1/4 watt	Jameco	.10
Misc.	Bolts, spacers, felt	Local	.60
		Approximate Cost	**$14.00**

Suppliers:

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

R.S.—Radio Shack
See Yellow Pages

All other parts were purchased at a local hardware store.



11 Desk Switched Outlet Box

On the Apple and most other home computers the ON/OFF switch is not conveniently located and frequently wears out. This switch usually causes more problems than any other single piece of hardware in the system. The switch itself is difficult to replace because it is built into the power supply box. It would also be handy to automatically turn on other devices like the monitor and the printer at the same time that the computer is switched on. There are commercial switched outlets that serve this purpose, but they are priced much too high ($30-$50) in relation to the materials they contain. Besides, the switches in these units are usually located beside the outlets and thus are no easier to reach than the original Apple switch.

This chapter covers the construction of a desk switched outlet box in which the ON/OFF switch is placed in an attractive box beside the computer and the outlets are in back of and below the desk. Special add-on features, including a power-on light, a voltage spike suppressor, and an electromagnetic interference filter are also outlined. You can install only those features that you decide you need.

The materials for this project are readily available. Most can be found at any hardware store that has a home electric department and the rest can be found at Radio Shack. A few simple household tools including a screwdriver, long-nose pliers, and a soldering iron are required. Construction involves primarily the assembly of ready-made parts.

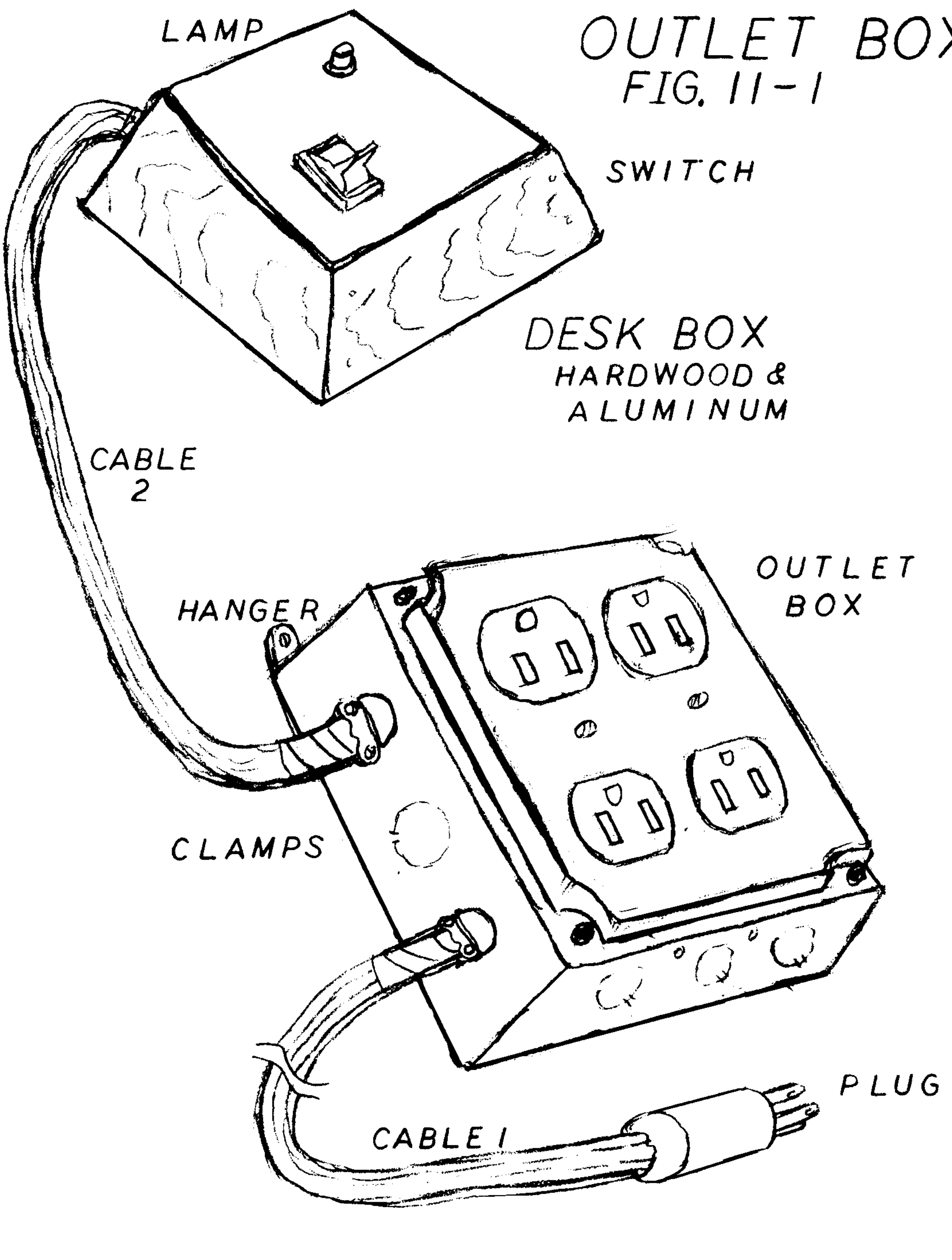
CONSTRUCTION OF THE OUTLET BOX

The outlet box is a standard 4-inch square conduit box with a front plate for two duplex outlets, a cover (if the front plate does not include one), and two cable clamps. If you want to include some of the special features you will need a larger box. Local electrical supply houses usually carry larger multiple conduit boxes or single outlet boxes that bolt together side by side to house any number of outlets.

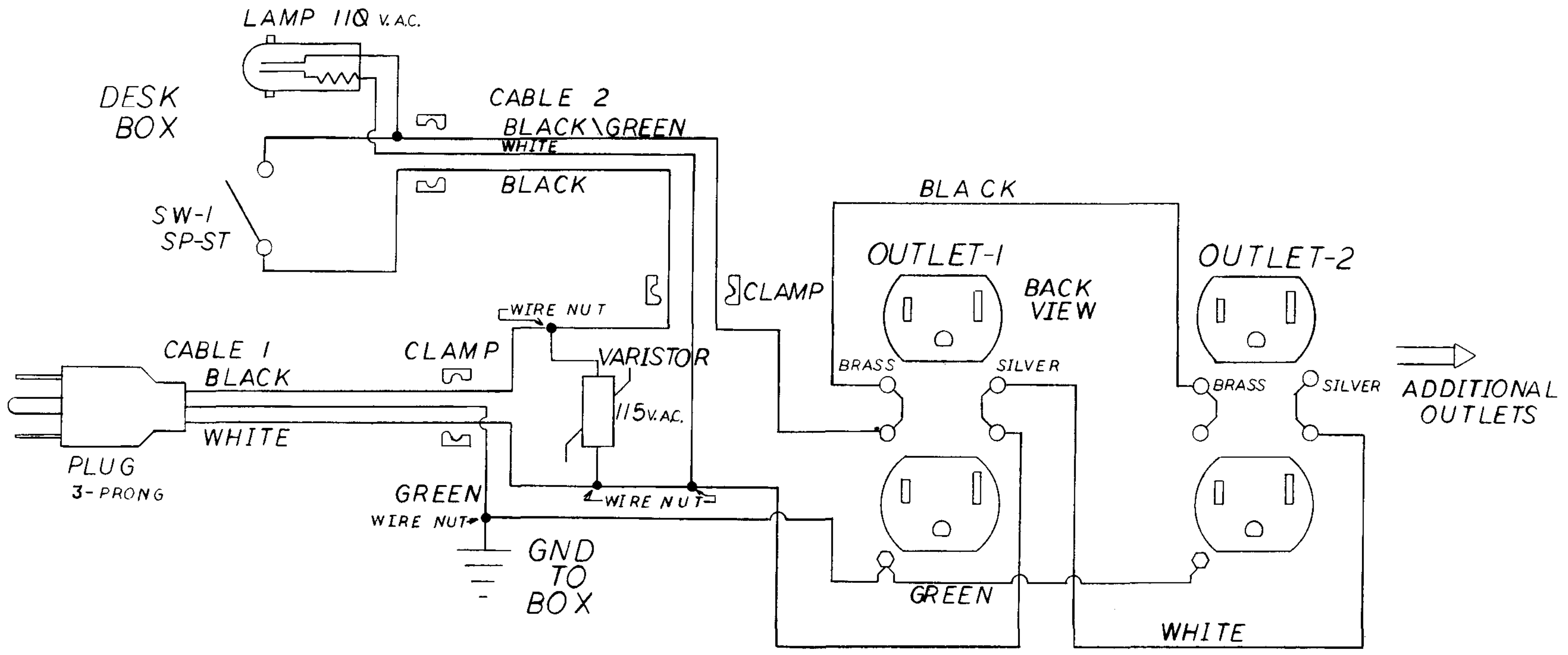
We pop riveted a small sheet metal tab to the back of the box so that we could hang it under the desk with two panhead screws. If you plan to place the box on the back of your desk you can attach plastic feet or cover the bottom with felt.

To install the cable clamps, knock out two of the metal slugs, place the clamps through the hole, and tighten the nut inside the box. The clamping screws should face the front of the box. A bit of Loctite or Super Glue on the nut threads will secure the nut.

The box for the ON/OFF switch should be decorative. You can, of course, use any metal or plastic box, but most electronic and electrical boxes look out of place on a desk. Our prototype switch box



DESK SWITCHED
OUTLET BOX
FIG. 11-1



DESK SWITCHED
OUTLET BOX
FIG. 11-2

has sloping hardwood sides and a sheet metal top and bottom, as shown in figure 11-1. Making the sloping sides is a good exercise in the use of a radial arm or table saw. If you don't have a shop manual that demonstrates how to set the angles you will have to do some trial and error work on scrap wood. The corners are held together with wood glue and finishing nails driven into predrilled holes. After the four sides were glued together, the top was sloped and the bottom flattened with hand tools. You will have to file out a notch in the back for the cable. Sand the hardwood pieces and finish them with polyurethane varnish.

Cut the top and bottom plates from aluminum or steel. Drill and file the top to fit the switch and the lamp. Drill and counter-sink holes in the bottom plate for six #6 flathead screws. Attach the top to the box with silicone sealant or epoxy so that no screws will show. Finish the top plate with an orbital sander to a uniform matte finish and then varnish the entire box.

ELECTRICAL ASSEMBLY

For the electrical work you will need wire strippers, long-nose pliers, wire cutters, and a medium-size standard screwdriver. This project requires a soldering iron of about 50 watts to tin the wires and solder the connections on the switch and lamp. A 50 watt iron is larger than the size called for in the other controller projects, but it is a standard iron used for many household jobs.

The electrical wiring is shown in figure 11-2. Note that wire colors are indicated. These colors are an important part of the National Electrical Code and must be followed scrupulously. The Electronics Tutorial in chapter 14 contains a detailed explanation of the correct procedures for wiring this unit and other AC appliances. You should review the section on AC Codes and Wiring Practices before starting this project. As before, coloring in two photocopies of the wiring diagram (figure 11-2) is the best way to keep track of and check your work.

The easiest way to obtain the cable is to purchase an extension cord long enough to make both cables. A 12-foot cord is usually sufficient. Cut off the outlet end and about four feet of cable to make cable #2. Number 14 3-conductor cable is best for almost all home and office computer systems.

You will have to join several wires together in four places, as shown in figure 11-2. This is most easily done with wire nuts; yellow ones are the correct size for this project if you use #14 wire. The proper installation of wire nuts is covered in the discussion of AC Codes in the Electronics Tutorial.

The varistor shown in figure 11-2 removes voltage spikes from the incoming line. It has two bare solid-wire leads. You should cover all but the last 1/2-inch of each of these leads with insulation stripped from scrap wire to insure that the leads don't touch the metal box.

You can attach green wire pigtails about six inches long to the green screws on the two outlets. Attach another pigtail to the box with either a green screw or a green metal clip. You can group these pigtails and the green wires from cable #1 together with a yellow wire nut.

Make the connections between the outlets with scrap wire of the correct color and size. Alternatively, you can purchase a short piece of 3-wire #12 Rolex cable (used for the wiring in houses) and remove the outer cover to provide three separate wires of the correct size and insulation color.

Choose a switch that looks good on the desk box. A simple ON/OFF switch, single-pole single-throw (SPST), with 10-amp current capacity will be suitable for all but the largest computer systems. If the switch you purchase has more sections (double-pole single-throw or double-pole double-throw), you can parallel the SPST sections to increase the current capacity. Some of the better switches have a 110-volt AC light built into the switch.

TESTING

When you have completed all the connections and checked your work, screw the box together and tighten the cable clamps. Plug the unit into a 3-wire house outlet *with nothing plugged into the new outlet box.* If the circuit breaker doesn't blow, throw the desk switch. The lamp on the switch box should turn on and off with the switch. If it stays lighted all the time, it is connected to the wrong side of the switch.

Now plug a light load like a reading lamp into the outlet box and try the switch again. If you encounter any problem (a blown circuit breaker or a switch that works backwards), unplug the unit, recheck all the wiring, and make corrections. When the unit works properly with a household lamp you can plug your computer into the outlet.

FINISHING TOUCHES

There are several other features you may want to add to your unit. If you are concerned about lightning strikes or other severe electrical surges, you can add two additional varistors. One should be installed from the black wire to the green and the other from the white wire to the green wire beside the first varistor.

If electrical interference is affecting your television set or your neighbor's when your computer is on, you might add an EMI filter like Radio Shack's #273-100. This will prevent electrical noise from leaving the computer by way of the AC line. Since most such noise is radiated directly into the air, this probably won't help your television reception much. If you add the filter you will also need a larger box.

If you decide you want a fuse and fuse holder you will, again, need a slightly larger outlet box. Alternatively, small pushbutton-style circuit breakers can be purchased through large mail-order electronics houses. A rating of 10 amps at 110 volts would be suitable for most personal computer systems.

If unauthorized people have been using your system or turning off the computer when you have intentionally left it on to run a long program you may want to add a key switch to the desk box. Mount the key switch (for example, Radio Shack #49-523) in the switch box either in series (lock OFF) or parallel (lock ON) with the main switch. Since the key switch usually has a lower amp rating, use the main switch routinely and key only when you need the lock feature.

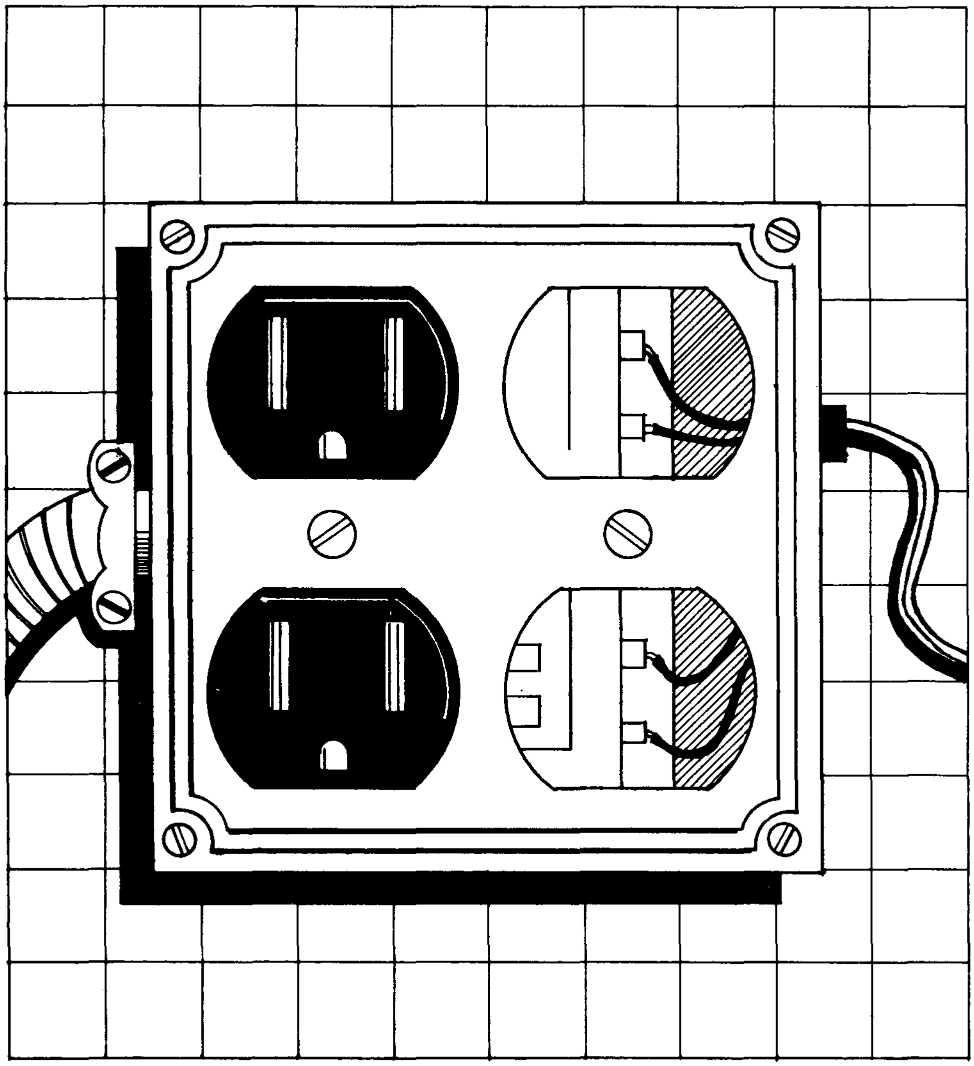
We are confident that you will use the Desk Switched Outlet Box more than any other device in this series of designs. We have built at least a half dozen of them. They make great gifts for anyone who uses a computer, either at home or at work.

Parts List
Desk Switched Outlet Box

Number Required	Description of Part	Suggested Supplier	Total Cost
1	Outlet box, 4" square	Local	$2.00
2	Outlets, 3-wire duplex	Local	2.00
1	Box cover	Local	.50
1	Extension cord, 12-ft., 3 - #12 wires	Local	4.00
1	Lamp, 110 volt AC, #272-708	R.S.	2.00
1	Varistor, #276-570	R.S.	1.10
1	Switch, #275-641	R.S.	2.00
2	Cable clamps	Local	.50
3	Wire nuts, yellow	Local	.50
1	Ground clip, green	Local	.25
1	Box, ornamental		4.00
Misc.	Glue, finish, feet, etc.	Local	1.15
		Approximate Cost	$21.00

Suppliers: R.S.—Radio Shack
See Yellow Pages

All other parts were purchased at a local hardware store.



12 AC Outlet Controller

The control of household devices that run on alternating current (AC) is one of the most often discussed applications for the home computer. Most people assume that this type of control requires complicated electronic circuits. In fact, it is not difficult to design or build a computer controlled AC outlet and, thanks to the availability of solid state relays, it is only moderately expensive to add this capability to your home computer. These relays use solid state components, usually triacs, to control normal AC current with a low-power digital signal. The Computer Controlled AC Outlet is little more than a normal outlet box with the addition of a solid state relay and two cables connecting it to the computer and the AC power supply.

The Apple has four annunciator outputs that can directly drive these relays. Other computers, like the Commodore VIC-20, have pushbutton inputs that can be converted to digital outputs by setting soft switches in the computer's memory. Solid state relays will work well with these systems, too.

THE AC RELAY

The input of a 5-volt solid state relay requires little current and can be driven by outputs rated at 1 TTL (transistor-transistor logic), which is approximately 5 milliamps at 5 volts. The 74LS chips referred to in these projects are TTL chips. By comparison, a single LED requires about 20 milliamps for normal light levels and may overload annunciator outputs.

The output of a solid state relay is rated by the maximum current (measured in amps) it can carry and the maximum RMS AC voltage it can control. Inexpensive relays are usually rated between 4 and 10 amps of 110 volts AC. More expensive ones (up to 40 amps of 440 volts) can be purchased for controlling higher-powered equipment.

Solid state relays handle only alternating current. They can turn on direct current but they can't turn it off. These relays have no internal moving parts or contacts to wear out. They should last for many years if they aren't cooked to death by extensive overheating or shorted out by a voltage spike.

The current ratings given in manufacturers' data sheets are for resistive loads, like incandescent lamps or resistance heaters. To use the relays on inductive loads (e.g., motors and heavy transformer devices), you must purchase relays that have about twice the rating of the device's normal operating current. To protect the relay from voltage spikes, particularly those caused by suddenly turning off an inductive load, you must add a varistor, as shown in figure 12-2.

To protect the relay from overheating, make certain that its metal bottom is in good thermal contact with a metal heat sink. If the relay is mounted in a heavy metal box and the back of the box is exposed to free air, a small relay will be cooled adequately. For higher powered and multiple relays you may have to install an aluminum heat sink in the back of the box and space the relays an inch or more apart. Use a heat conductive compound like Radio Shack #276-1372 on the metal backs of the relays to improve heat transfer. Since the relay backs are insulated from the AC, you don't need a layer of electrical insulation between the relay and the box.

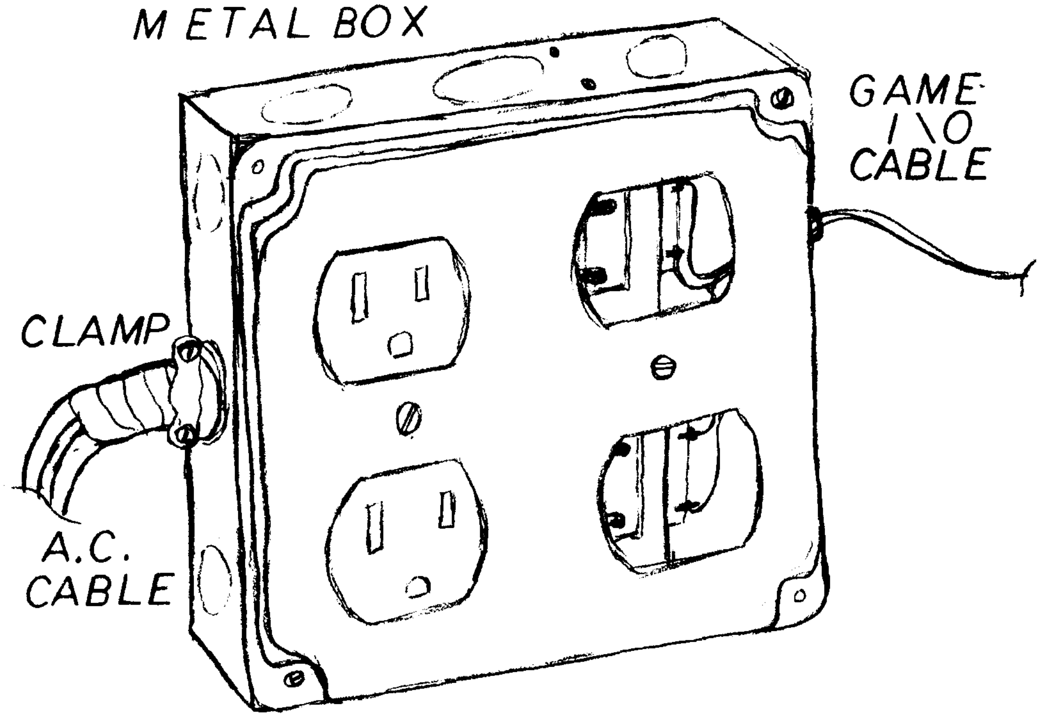
Good news: There has been a recent breakthrough in the manufacture of solid state relays. The new technology, called S^3X, lets the relays function with fewer parts than the present design. The new units exhibit markedly better performance with inductive loads and will generally run cooler. These relays should be available soon, and perhaps we'll be able to purchase the old style units at cheaper prices from the surplus houses.

MECHANICAL CONSTRUCTION

The solid state relays for the prototype conduit box were purchased from PolyPaks (see the parts list for their address). They are smaller than most other solid state relays and have solder terminals instead of the usual screw terminals. You may be able to get them from PolyPaks or from another surplus electronics company. If not, the standard commercial relays are a stock item at Newark and other large houses. If you can't obtain the small relays, you will need a box larger than the 4-inch square indicated in the parts list.

The prototype box has a cover for two duplex outlets and two cable clamps. One or even two of the smallest AC relays can be mounted in this box, taking the place of one of the outlets.

To be absolutely certain that the AC wires will not make contact with the wires running to the computer, you should fashion a sheet metal partition to divide the relays into two sections. First make a cardboard pattern and then cut the partition out with tin snips. Attach the partition to the box with bolts or pop rivets. You can also make a sheet metal hanger for the back of the box, or devise some other mounting arrangement. You should also cover two of the outlet holes with a piece of sheet metal.



CONTROLLED
A.C. OUTLET
FIG. 12-1

For larger or more powerful systems (more than two outlets or more than 10 amps total) you will need a bigger electrical box. Called NEMA boxes (National Electrical Manufacturers Association), these can be either #4 (vented) or #12 (sealed). For extremely high-powered systems (4 kilowatt or greater) you will have to cut the back out of the box and replace it with a large aluminum heat sink. You could make your own box out of sheet metal or other non-flammable material. On a large system the loads should probably be cabled directly to the relays without the use of sockets and plugs.

The cable that runs from the box to the computer will be too small for normal electrical cable clamps. You can use a strain relief (Radio Shack #278-1636) instead, or enclose the cable in tape and heat shrinkable tubing.

ELECTRICAL WIRING

The wiring in this project is similar to that of the Desk Switched Outlet Box in chapter 11. Once again, it is necessary to follow the electrical code guidelines, so review them before starting to wire this unit (see the section on AC codes in the Electronics Tutorial).

Figure 12-2 is the schematic for a two-relay system. The power cable is a 3-wire #14 extension cord with the outlet end cut off. If you are using two relays on the same outlet you must separate the two sockets electrically. Break off the small metal bridge between the two brass screws on the black wire side only. For currents of up to 10 amps, #14 wire will be adequate. For high-current systems you will need #12 or larger wire.

The two varistors shown in figure 12-2 provide protection from voltage spikes. These are necessary to control inductive loads like motors or flourescent lights.

The current in the control lines to the computer is so inconsequential that extremely small wire in this cable will meet the electrical requirements. You will, however, need a cable that is strong enough to withstand a reasonable amount of wear. If you have extra wires in the cable it is a good idea to double up the ground wire.

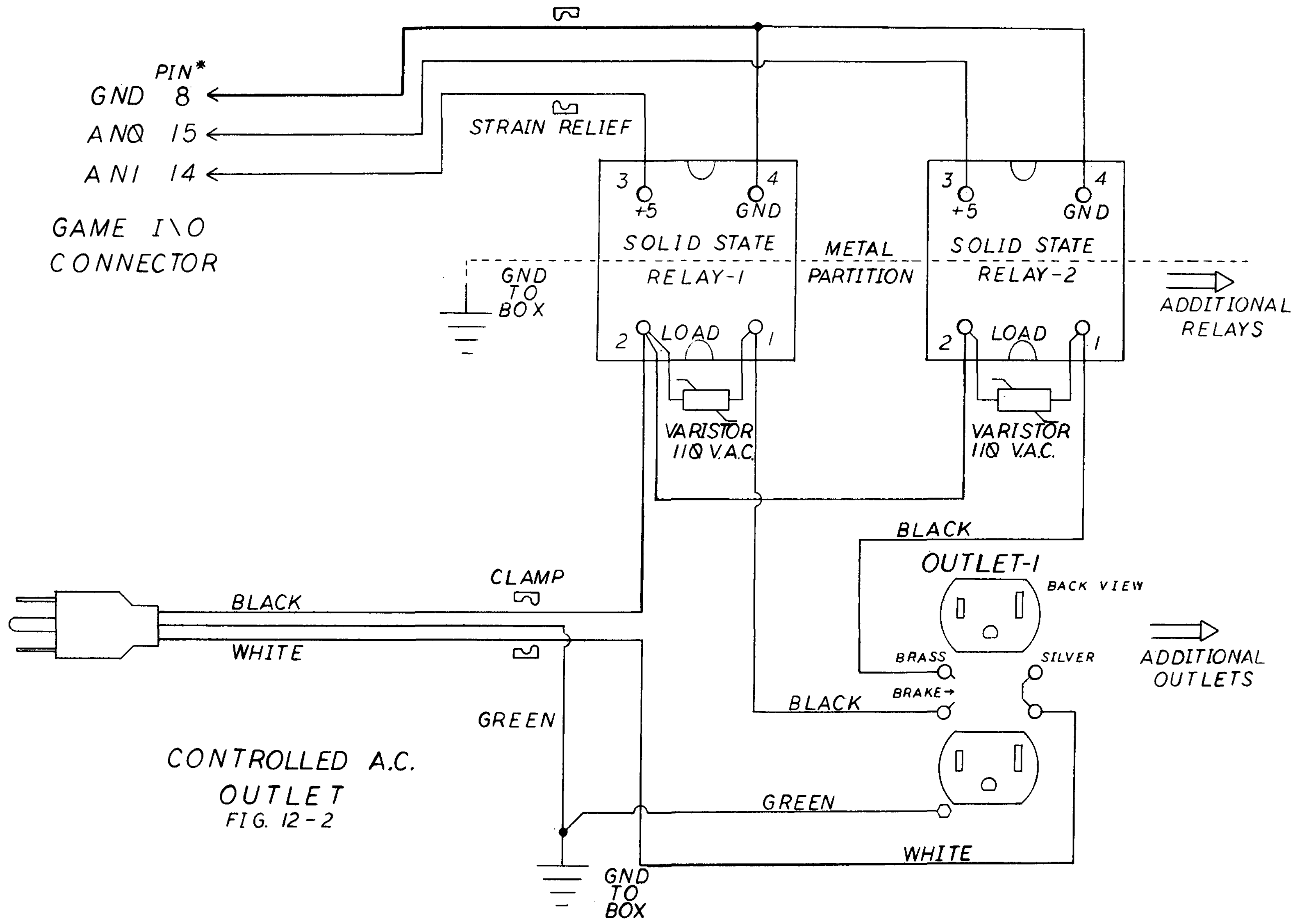
The best plug for the AC outlet box is a stacked plug similar to the one described in chapter 3. All the pins of this one, however, should pass straight through, with no tricky crossovers. A stacked plug lets you plug in the AC outlet box and still use conventional controllers, providing they do not require the annunciator outputs.

The outlet box must only be used with 3-prong grounded systems. You must clip or screw the green wire of the power cord to the metal box and connect the green screws on the outlets to the box with green wires.

If you like, you can add a fuse and fuse holder or circuit breaker for each circuit. As noted for other special features, this may necessitate using a larger box.

TESTING

Check your wiring using the procedures we have described for coloring in two copies of the schematic. After you have finished the connections, assemble the box and tighten the cable clamps. Before



CONTROLLED A.C.
OUTLET
FIG. 12-2

testing the unit on your computer, you should plug it into a household outlet. With a multimeter, measure the AC voltage between each of the computer connector leads and the metal box to be sure that no AC is read on any of the pins. Plug an incandescent lamp into the AC outlet box; the lamp should not come on.

Now unplug the outlet box from the wall. Make sure your computer is turned off. Install the plug into the computer's game control socket, plug the outlet box into house current, and turn on the computer. If the computer doesn't start up in a completely normal fashion, turn it off immediately, unplug everything, and recheck all your work.

Run the Annunciator Checkout program in the software chapter. A lamp plugged into this controlled socket should turn on and off as the checkout program runs.

How large an AC control system could an Apple handle? Each of the four annunciator outputs could control a relay, and the relays are available with ratings up to 40 amps at 440 volts. If you want to get serious, however, you will have to add a simple multiplexing card (four 74LS chips). The four annunciator inputs and the strobe line could then drive 32 relays, for a total of 560 kilowatts. That should be enough power to provide the mind-boggling light show for a "Who" concert.

Parts List
AC Outlet Controller

Number Required	Description of Part	Suggested Supplier	Total Cost
1	Outlet box	Local	$2.00
1	Cover for box	Local	1.50
2	Cable clamps	Local	.50
1	Duplex outlet	Local	1.00
2	Solid state relays	Poly	20.00
1	Extension cord,12 ft., 3-#12 wires	Local	4.50
15 ft.	Telephone cable, #278-366	R.S.	1.70
1	16-pin DIP header	Jameco	.70
1	16-pin socket, wire wrap	Jameco	.70
1/4 oz.	Heat sink compound, #276-1372	R.S.	.50
Misc.	Bolts, feet, etc.	Local	.90
		Approximate Cost	$34.00

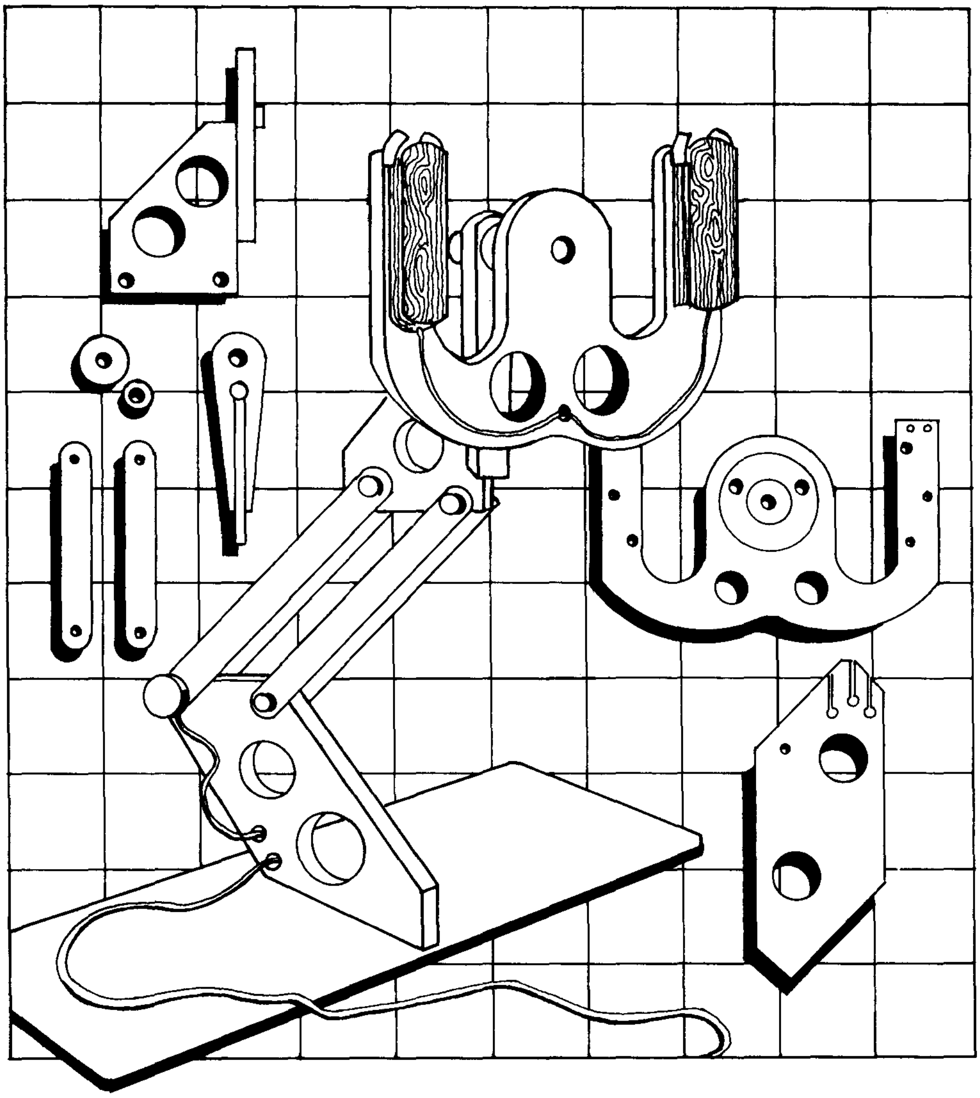
Suppliers:

Jameco Electronics
1355 Shoreway Road
Belmont, CA 94002
Minimum order $10.00

PolyPaks, Inc.
16-18 Del Carmine Street
Wakefield, MA 01880

R.S.—Radio Shack
See Yellow Pages

All other parts were purchased at a local hardware store.



13 Construction Notes

In building these controllers you can choose from a variety of materials and make a great many modifications to suit your requirements. We have put together prototypes of all the designs; when we made more than one prototype the units were never exactly alike. We used scrap materials extensively and often adjusted the plans to take advantage of available materials. If you can't find a specified part or material, substitute something else that you *can* find.

READING THE DRAWINGS

The illustrations in this book are not the kind of mechanical drawings that a professional machine designer would produce. They were done as illustrations of how the projects were put together and could not be sent to a machine shop for professional fabrication. They do include all the necessary information and dimensions, and the text gives you the steps to follow for constructing the units.

Where they are omitted, the dimensions are not critical and you should adjust them for available materials or for your physical size. (Do not attempt to make up a limerick here—a classic already exists.) For items like pot mounts you should first purchase the specified part and then adjust the dimensions of the mounting holes to fit that part.

Don't be afraid to adjust the dimensions of the device to suit your needs and materials. The worst that can happen is that you have to build a second or third unit before you get exactly what you want. Your early attempts will sometimes make nice gifts for your friends (of various dimensions). The entire process is an important experience in working out man/machine interactions.

TOOLS FOR CONTROLLER CONSTRUCTION

You can build all the controllers in this manual with common hand tools. Many of them are even easier to construct if you have access to a radial arm or table saw. As noted in the introduction, most of these designs make excellent projects for school wood, metal, or electronics shops. The following tools are best for constructing the units:

(1) A radial arm or table saw with a plywood blade
(2) A 3/8-inch variable speed drill with twist drills, screwmate drills, and a counter-sink
(3) Vise grip pliers (one of the all-time great tools)
(4) Drill and taps for common bolt sizes (#8-32 and #6-32)
(5) Pop rivet gun and small pop rivets
(6) Bench vise with wooden jaw inserts
(7) Orbital sander and sand paper
(8) Miscellaneous hand tools: screwdrivers, hacksaw, sheet metal shears, etc.

The following tools are not required, but if they are available you can do more advanced work on some of the projects:

(9) A drill press or holder for the electric drill
(10) Mandrel and hole saws for the drill
(11) A metal lathe with milling attachment

If a particular tool is not available there is almost always some way around the the problem. The text makes many suggestions for alternatives you can try.

MATERIALS

Many of the materials for these controllers were salvaged or scrap. The parts list for each project gives the materials actually used for the prototypes, but don't be afraid to experiment with alternatives. Here are some suggestions on what to use and where to get it.

Lumber. The hardwood lumber for many of the prototypes was scrap from furniture projects. Clear softwood is also suitable, except for those parts that must have holes drilled and tapped into the wood. Just remember that the hardwoods can be finished more attractively than the softwoods.

Plywood. We salvaged much of the hardwood plywood for the prototypes from a pair of old kitchen cabinet doors. Many hardware stores sell small pieces of hardwood plywood. Maple is probably the best for these projects since it is extremely hard and doesn't splinter easily. Common fir plywood can be substituted and will look just fine if carefully finished.

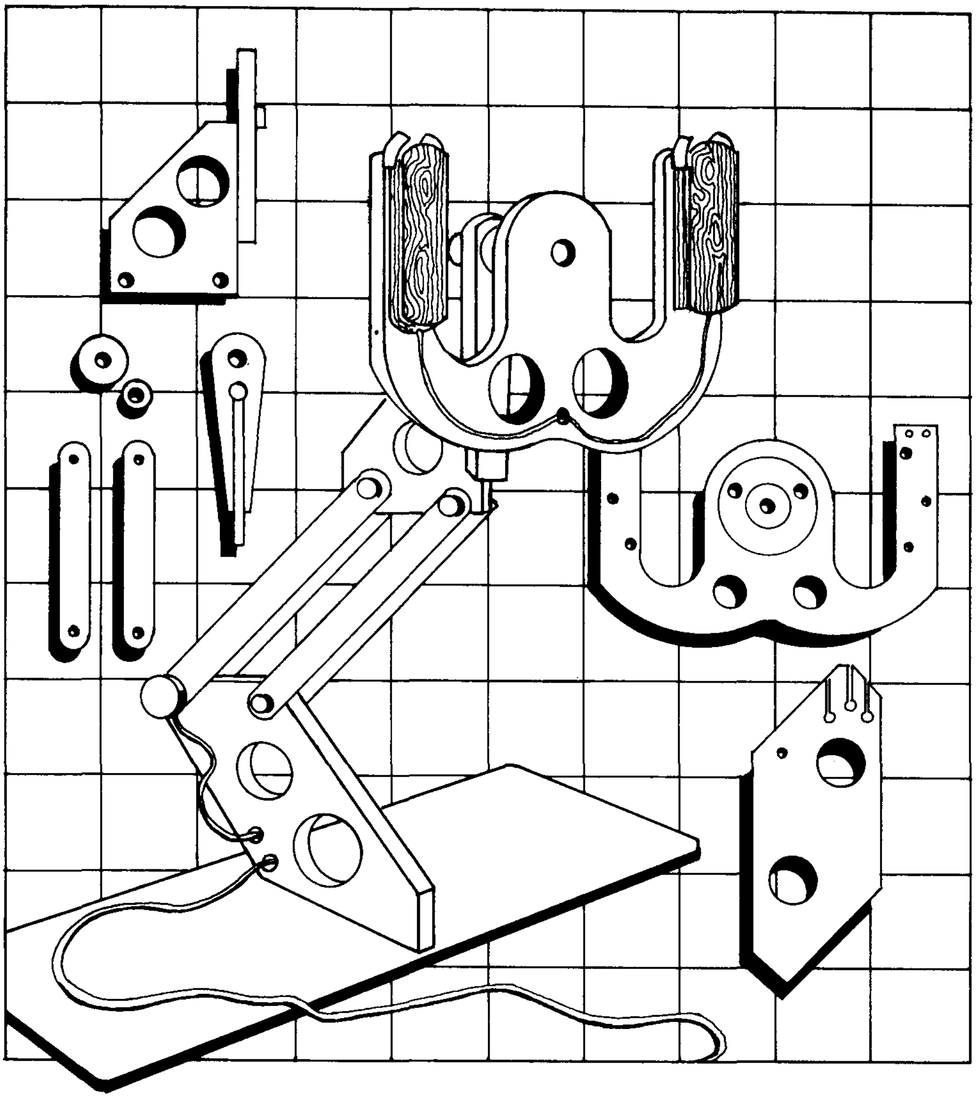
Plastic. In constructing many of these devices you could replace plywood and metal parts with plexiglass with striking results. You can often purchase scrap plexiglass in pieces large and thick enough for the units from local suppliers of industrial plastics. The scrap, sold by the pound, is about as expensive as hardwood plywood. You can successfully work plexiglass with woodworking tools once you are accustomed to its peculiarities. Sand the sawcut edges with increasingly fine sandpaper until the saw marks are completely removed. Then you can polish the edges with Crest toothpaste or a polishing compound from the plastics supplier.

Many of the projects specify plastic washers cut from coffee can lids. This plastic is polyethylene; it has a soapy feel and serves as a lubricant between wood parts. You can cut it with household scissors.

Metals. The one controller prototype that requires machining, the Super Stick, was made from machinist's aluminum. The machined parts could also be cut from brass, steel, stainless steel, or machinable plastic, depending on available scrap and the desired final appearance. The sheet metal we used was either 1/16-inch soft aluminum from an old cookie sheet or galvanized steel scrap from heavy heating ductwork. The sheet metal must be stiff enough to hold its shape but light enough to be worked with sheet metal shears.

Glues. Wood parts were glued with Elmer's Carpenter's Wood Glue, a tan liquid, and felt pieces were attached with Elmer's Cabinetmaker's Contact Cement. The latter can be cleaned up with water, a nice feature for the home craftsman. No lockwashers were used: all bolts were secured with thread sealant on final assembly. The bolt threads must be oil-free for this to work properly. You can substitute Super Glue or fingernail polish for the sealant.

Wherever rubbery adhesion was needed, we used G. E. Silicone Glue and Sealant. Also known as RTV (room temperature vulcanizing), this was used to form strain reliefs for cables and for insulation over electrical connections. Don't use an excessive amount of RTV in any application since it can ooze out and look very sloppy. Clear sealant is the least messy to work with. You should also note that this material contains an acid catalyst and can cause eye and skin irritation if handled carelessly.



14 The Electronics Tutorial

This chapter will help those of you with a limited background in electronics get started on the controller projects. We trust that more experienced hands will also find many suggestions that will speed up their work.

If you follow the guidelines in these sections and the specific details in the project chapters, you should produce creditable results in your electronics construction. You will benefit most from the tutorial if you read through the chapter and then refer back to specific sections as you work on a project. The following topics are included:

1. Electronic Components
2. Where to Buy Electronic Components
3. Reading Schematics
4. Controller Electronics
5. Adapting the Controllers to Different Computers
6. Tools Required for the Electronics Work
7. How to Solder
8. AC Codes and Wiring Practices
9. Safety Precautions
10. References

ELECTRONIC COMPONENTS

The following electronic components are used in constructing the projects in this book. They are also the ones found in most beginning electronics projects and, in fact, make up the majority of all electronics equipment.

Resistors. These colorful two-wire devices resist the flow of electrical current. A current flow through a resistor results in voltage across it (Ohm's law):

Voltage = Resistance x Current

$$V = R \times I$$

This equation is used more often than any other equation in electronics. If you know any two of the variables, you can calculate the third.

Resistors are measured in ohms or thousands of ohms (K-ohms). Most resistors are banded, using a standard color code that gives their value in two digits (first and second bands), a multiplier (third band),

and a tolerance (fourth band). The colors and corresponding digits are:

Resistor Values

Digit	Color (Bands 1 and 2)	Color (Band 3)	Multiplier
0	Black	Black	1
1	Brown	Brown	10
2	Red	Red	100
3	Orange	Orange	1,000
4	Yellow	Yellow	10,000
5	Green	Green	100,000
6	Blue	Blue	1,000,000
7	Violet	Violet	10,000,000
8	Gray	Gray	
9	White	White	

Tolerance (Band 4, if present)

No band	±20%	
Silver	±10%	
Gold	±5%	(now standard)

Examples of resistor values as indicated by their colored bands are:

330 ohm 5%	Orange, Orange, Brown, Gold
1K ohm 10%	Brown, Black, Red, Silver
50K ohm 5%	Green, Black, Orange, Gold

Resistors are also rated by the power they will dissipate without burning up. Power is defined as voltage times current and is measured in watts. All the resistors we will be using in these projects are 1/4 watt.

$$\text{Power} = \text{Voltage} \times \text{Current}$$

$$P = V \times I$$

Potentiometers. These devices, commonly referred to as pots, are resistors with a sliding contact. They were originally used in a voltage divider circuit called a potentiometer circuit, which is where the name comes from. They can also be employed as variable resistors, which is how they are used in most of the controller circuits. A true potentiometer has at least one wire on each of its three terminals. Pots employed as variable resistors use only two terminals and often have the unused terminal wired to the center terminal.

Like all resistors, pots are measured in ohms, K-ohms, or meg-ohms (millions of ohms). In operation, most pots make nearly one complete turn (usually about 300 degrees). Other pots, in order of frequency of use, turn one, ten, twenty, five, or three times. It is also possible for a pot to slide in a straight line. The knobs on most electronic devices turn potentiometers.

In choosing pots for electronic devices, mechanical considerations are usually more important than electrical ones: How good is the bearing? How long is the shaft? Is the shaft round or flattened?

The primary electrical property we look for is linearity. That is, a graph of the amount of turn of the pot shaft versus the resistance should be a straight line. The description of the Sketch Pad project (chapter 4) goes into linearity in more detail since it is critical for good sketching. Generally, the more expensive the pot, the better the linearity.

Some of the best available pots are rated "Military Specification" (Mil Spec or Mil No.). These pots have excellent mechanical construction and good linearity, so look for this rating in the electronics catalogs.

The value of the potentiometers in the standard Apple paddle, 150K ohms or .15 meg-ohms, is an uncommon one. Pots of this value are sometimes hard to find. Chapter 1, "Rebuilding Paddles and Joysticks," gives a procedure for using pots with values like 250K, which are easier to find. The Atari and the Commodore VIC-20 computers use the much more common value of 1 meg-ohm.

Capacitors. These components, often called caps, store an electrical charge. Caps always contain two electrical conductors with an insulator between them. They are measured in farads: if a cap is 1 farad, then a current of 1 amp flowing into it for 1 second will charge it to 1 volt. A 1-farad cap would be about the size of a bathtub. The caps we will be working with are measured in microfarads (one-millionth of a farad) and are small enough to fit on a printed circuit board. When designing circuits you must avoid using very large value caps since they are just too big physically. We will use capacitors to smooth out DC voltage, to pass AC while blocking DC, and paired with a resistor in a timing circuit.

For large values (1 to 10 microfarads) we will generally be using a type called electrolytic caps. They must have one lead (marked with a dot or a + sign) attached to a more positive DC voltage than the other lead. Electrolytic caps do not last as long as most other electronic components, so we will avoid using them whenever possible. But electrolytic caps made with the metal tantalum are smaller and longer lived. Although more expensive, they are usually worth the extra cost.

Wires and Cables. The wires used for digital electronics are much smaller than those used in household wiring. Sizes #22 - #30 are most often employed in electronics work. Lamps and power tools use #12 or #14. The bigger the number, the smaller the wire; even numbers denote copper wire. As far as the electrical requirements of these controllers are concerned, you could use wire that is hair-fine (#42). You would have difficulty working with it, however, since it breaks so easily. On the other hand, wires that are too thick will not fit into the solder lugs on digital electronic parts and circuit boards.

There are only two conductors in these projects that might work better with larger wires. They are the +5 volt power supply line and the ground wire. If these wires are too small, the controller functions might lose independence, in which case pressing a pushbutton would cause a pot reading to change. Fortunately, doubling up these wires works as well as using larger-size wire, and it is much easier to obtain cables with a few extra wires than cables with a few wires of a different size.

Flat ribbon cable is often used for commercial controllers, but we don't like it because it has no protective cover. The wires on the outer edge of the ribbon break too easily. We used 4-wire telephone cable, inexpensive and readily available, for most of the controller prototypes. The insulation on this cable, however, can be damaged if it is overheated during soldering.

We have also made serviceable cables by pulling plastic insulated wire through plastic tubing (e.g., plastic aquarium tubing). We have also used a homemade rope-making machine to braid cables, with good results.

Circuit Board. In many of these projects you have to mount electronic components on a board and attach wires. You can do this job in a professional way by utilizing printed circuit boards (PCB) that come with pre-drilled holes in a regular pattern and copper lanes on one side. All the components and wires are placed on the top side, which is bare, and all the soldering is done on the bottom side, which has rows of copper lanes. The two sides of a circuit board are commonly referred to as the component side and the solder side. One panel of PCB (Radio Shack #276-154) is big enough to make two or three controller circuits.

You can cut a board by scoring it deeply with an X-acto knife and steel straight edge and then breaking it over the edge of a table. You can also spin the knife to enlarge the holes for mounting bolts and switches. The copper lanes must be cleaned with a pink pencil eraser before you start to solder.

For the prototypes the circuits were wired by soldering short jumper wires between the pre-formed copper pads on the standard boards. This is called point-to-point electrical wiring and is the best procedure to follow for these small circuit boards. For larger projects you can use a procedure called wire wrapping, in which fine wires are wrapped around metal posts with special tools. Wire wrapping is used extensively to build prototyes of digital circuits that have more than three chips.

If you were making large numbers of a circuit board you would use photographic techniques to produce custom-printed boards specifically for that circuit. This more complex and expensive procedure would eliminate most of the hand wiring involved in point-to-point wiring and wire wrapping.

Integrated Circuits. These components, the key to digital electronics, are referred to as chips. On a tiny chip of silicon, transistors, diodes, and resistors are arranged in a circuit. The circuits we will use, called DIP (Dual Inline Packages) chips, are encased in black rectangular boxes with silver wires projecting out of the sides, like the legs of a caterpillar.

We will use three types of chips in these projects. The first, transistor-transistor logic (TTL) chips, have numbers that begin with 74 or 74LS. TTLs, the most common type of digital chip, operate on +5 volts only. They are cheap and easy to find, medium fast, and provide a wide range of functions.

We will also use a few chips called CMOS (complementary metal oxide semiconductor). They can operate on 3 to 15 volts and consume an amazingly small amount of electrical power. CMOS chips also provide a wide variety of functions and are used extensively in battery-powered equipment. They cost more than TTLs and can easily be ruined by static electricity during installation. Leave CMOS chips in their protective packages until just before inserting them into their sockets.

The third type we will use, the analog chip, handles continuously changing (analog) signals and is used in amplifiers and voltage level sensors. A piece of digital equipment usually requires at least a few analog chips. They are quite similar to the TTLs but may require voltages other than +5 volts (often ± 10 or ± 15 volts).

WHERE TO BUY ELECTRONIC COMPONENTS

Radio Shack stores are definitely the handiest to shop at of all electronics suppliers. The quality of most of their components is acceptable. Their potentiometers, however, are of poor quality and we cannot recommend them. The selection is often limited: an outlet will stock only a few of each catalog item and will often be sold out of the part you need. Radio Shack prices are somewhat high, but this is to be expected from a convenience store. Radio Shack reference books are quite good. Many professionals look down on this chain, but they have so often provided a part that kept one of our projects moving at a critical time that we are grateful that the stores are almost everywhere.

Discount mail-order houses handle lots of surplus and seconds and their prices are low. Sometimes you get a real buy; sometimes you get junk. These companies periodically mail out fliers and run ads in electronics and computer magazines. They usually require a minimum order of about $10. We have ordered several items from PolyPaks Inc. (16-18 Del Carmine St., Wakefield, MA 01880) with good results.

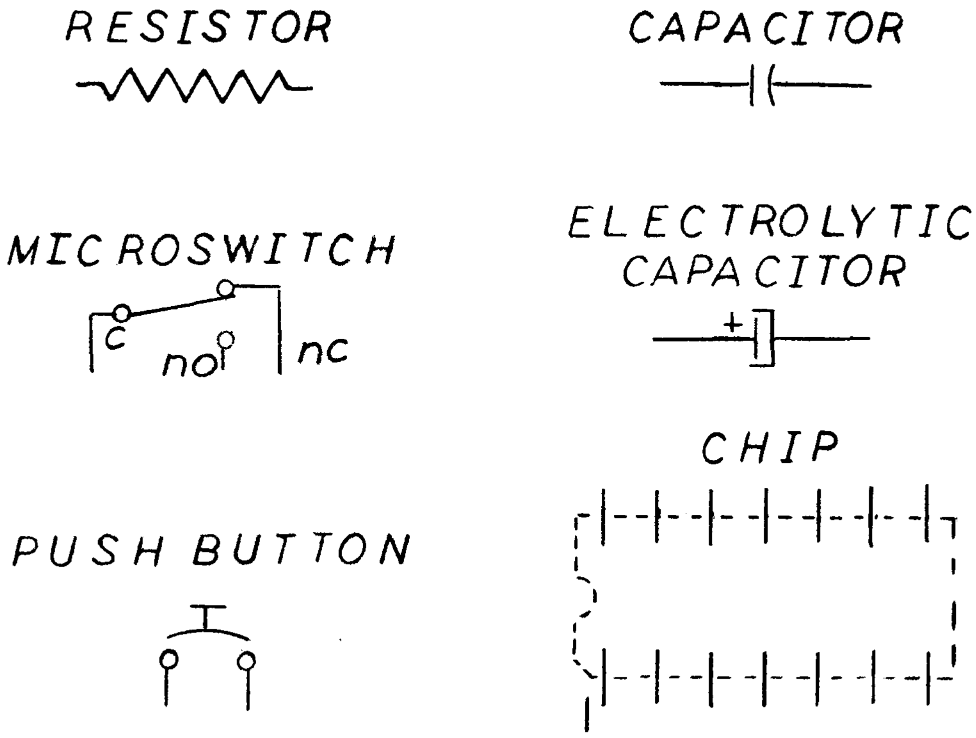
Small mail-order houses have a limited selection of good quality components and usually put out a catalog that will be sent to you for a price. These houses are listed in the pages of electronics and computer magazines. We have been particularly pleased with Jameco Electronics (1355 Shoreway Road, Belmont, CA 94002). The minimum order is only $10, and their turnaround time is remarkably fast.

Local over-the-counter stores for the most part sell wholesale to electronic repairmen and commercial customers, but some stores will sell retail for cash. Look in the Yellow Pages under "Electronic Equipment and Supplies—Dealers." Telephone first to find out if they sell to the public and what hours they are open, but don't try to order by phone. The counter people often have encyclopedic knowledge of where to get obscure parts, but they must give preference to their large customers. It is best to go to the counter in person and patiently wait your turn. If the part you need is fairly common or used frequently by repairmen, ham radio operators, or serious electronic hackers, then the store will have it.

Big catalog stores have an enormous stock of components and put out large catalogs. They cater to commercial accounts but will usually accept a minimum order of about $25. To buy from them you must first locate the local sales representative, either by going to the Yellow Pages or by contacting the firm's central office. The local rep will send you a copy of the catalog and, when you are ready to order, will use a computer to make certain the items you want are in stock. An order will generally take two to three weeks, but if an item is out of stock there may be a delay of six to eight weeks. Work with the sales rep and the catalog to find substitutes for out-of-stock items. We have ordered parts from Newark Electronics (500 N. Pulaski Road, Chicago, IL 60624) and Allied Electronics (401 E. 8th St., Fort Worth, TX 76102). Both of these firms have offices nationwide.

READING SCHEMATICS

Most information about the wiring of electronic devices is presented in stylized drawings called schematics. Schematics are not difficult to comprehend once you are familiar with a few basic symbols.



The solid lines on the schematic represent electrical conductors like wires and printed circuit lanes. If there is a dot where two solid lines meet or cross the conductors are connected. If there is a small loop or no dot the conductors do not connect.

All the component terminals which are continuously connected by solid lines will be at the same voltage; together these are called a node. In making up the circuit you do not have to make the joint exactly where the dot appears on the schematic. The solder joints can be made at any convenient location as long as the terminals shown as one node are connected in the final wiring.

The wiggly lines represent **resistors** and are labeled R1, R2, and so on. A wiggly line with an arrow pointing at it is a **potentiometer.** The arrow represents the wiper arm of the pot and is usually, but not always, the middle terminal.

Switches are shown as dots with a swing line that looks like a door. Terminals for switches are labeled n.o. (normally open), n.c. (normally closed), and c (common). For the most part we use single-pole, double-throw switches, with one each of these three kinds of terminals. With a single-pole double-throw switch, a single wire can be switched between two terminals. The small microswitches used for triggers and pushbuttons in many of the projects are single-pole, double-throw. They make an audible click when pressed, a good feature in a controller.

We also use a pushbutton switch with only two terminals. This is a normally-open momentary-contact switch and usually appears on the schematics as two circles with a curved bar almost touching them. Pushbuttons with tops at least 3/8-inch in diameter are the least tiring to press, and those that make a click are preferable.

Capacitors show up on schematics in two styles. Both are represented by two parallel lines. For non-electrolytic caps, one of the lines is slightly curved. In the symbol for electrolytic caps, one of the lines has two extensions and looks like a three-sided box reaching out to enclose the other line. The positive lead is marked with a plus sign.

Chips are shown in this book as dashed lines that form boxes around special symbols. In order to understand how chips are related to their representations on the schematic, it is important to know how the pins are numbered. This is more difficult than you might suspect, and mistaking pin numbers is probably the most frequent cause of burned-up chips.

Place the chip with its legs pointing down on your worktable, with the notched end away from you. You should be able to see the manufacturer's insignia and read the part number indicating the type of chip, like the 74LS04. That number may begin or end with extra numbers which indicate ratings, for example, the military temperature range. Chips often have a date code that can, unfortunately, be mistaken for the part number. Pin 1 is on the left side closest to the notch and is sometimes marked with a dot or circle. The pin numbering continues down the left side, across the bottom, and up the right side of the chip. For these projects we will be using DIP chips with either 14 or 16 pins.

The best way to mount chips is to buy chip sockets for them. Make all solder connections to the sockets and then plug in the chips as the last step in constructing the circuit. Pin 1 of a socket is often marked by a cut-off corner.

The **game connector** for the Apple is a 16-pin DIP header (sometimes called a component carrier) that plugs directly into a standard chip socket. A **DIP header** looks similar to a chip but has small forked lugs to which wires can be soldered. Other home computers use different types of connectors. Information about them can be found in the operating manual for the machine or by examining a standard set of paddles for the system.

Reading schematics is a fundamental requirement for learning about computer hardware. With practice you will soon be able to read them and turn the various symbols into functioning electronic circuits.

A Note on How to Check Your Work

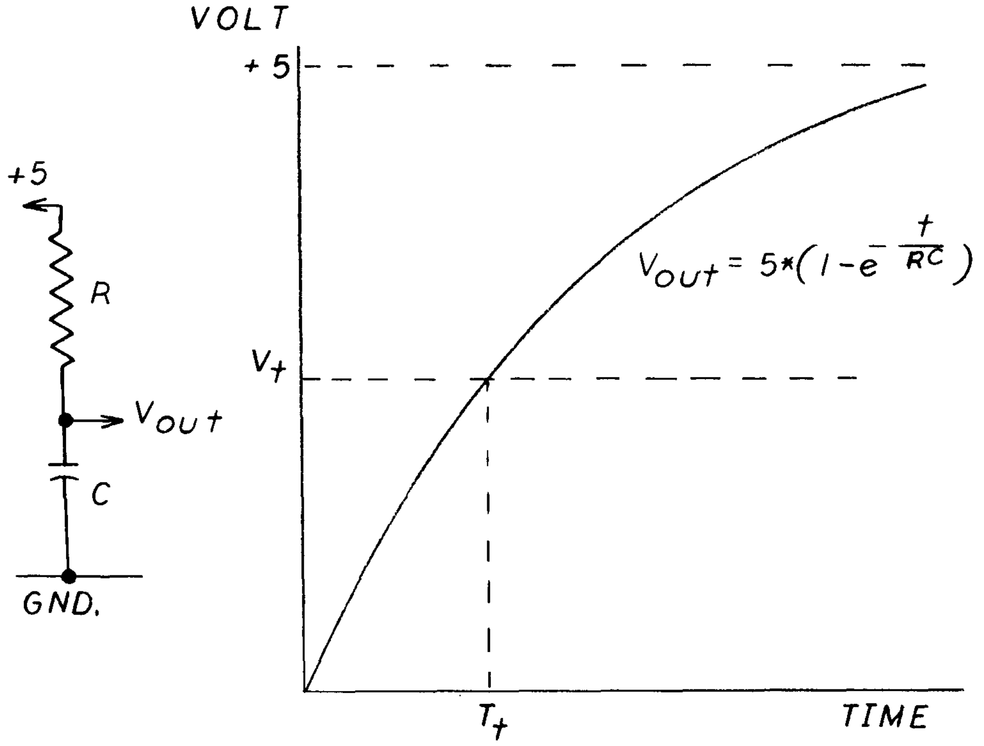
The best way to check your wiring on electronics projects is to make two photcopies of the schematic before you start. As you add a wire to the circuit, draw over the appropriate line on the first copy with a colored pencil. Color in each wire, joint, and component as you add it to the device. When everything is colored in you know you have finished the circuit.

Color in the second copy, point by point, as you check over your work, either visually or with a multimeter. Many professionals use this method of coloring in two schematics to check their work. To provide an even better check, you can ask someone else to color in the second copy as *they* check the circuit.

CONTROLLER ELECTRONICS

The electronic circuits in home computer game controllers are not difficult to understand. They have several digital inputs (pushbuttons), some digital outputs (annunciators), and a few analog inputs (game controls). The circuits don't change much from one make to another. Even though these circuits are very simple, they can be adapted to perform a great many tasks. The projects in this book are only a sample of their many applications.

The digital inputs expect inputs of either 0 or +5 volts. Their input resistance is several thousand ohms, so they don't draw much current. Less than 4 milliamps is required to turn them on; this is referred to as 1 standard TTL input. Since these inputs should not be floating (an input that is not connected to either the +5 supply or



TIMER CHART
FIG. 14-1

ground is described as "floating"), a pull-up or pull-down resistor is used in the circuits. The Apple uses pull-down resistors connected from the input to ground, while the Atari uses pull-up resistors connected from the input to the +5. For the controller prototypes we used 1K ohm resistors for either application. Digital inputs in controllers may be driven by either switches or TTL chips.

The annunciators are usually rated to drive 1 TTL input. Annunciators can supply no more than 5 milliamps of current. This is not enough for an LED, which needs 20 milliamps. Therefore an inverter or other chip must be placed in the circuit before an annunciator can power an LED or even a large number of TTL inputs.

Two types of analog inputs are used on home computers: the true analog-to-digital converter and the timer. Some Radio Shack computers and all expensive data logging systems used in industry use true A-to-D converters. In these, a continuously changing (analog) voltage is converted to a series of numbers (digital). When a pot is used as an input device for these circuits it must be wired to provide a varying voltage. To do this, it must be wired in a true potentiometer circuit, which requires three wires (+5, ground, and signal). You can tell that a pot is connected for this kind of circuit if you see that three separate wires are attached to it.

The timer type of analog input uses a circuit based on a popular chip, the 555 timer. This timer is controlled by both a capacitor inside the computer and by the game control pot wired as a variable resistor (two wires). When a reading is called for, the computer starts the timer and begins to count from 0 to 255. The number it has reached when the timer goes off (see below) is the reading.

Drawing 14-1 shows how the timer is controlled. When the timer is started, the capacitor is discharged and then allowed to recharge through the resistor in the controller. The resistance of the controller is dependent on the setting of the mechanical knob. The lower the resistance, the faster the capacitor can charge, so less time is available for the computer to count. When the amount of resistance in the controller is high (i.e. the controller is at its highest setting) the capacitor will charge to the trigger reference voltage more slowly, allowing the timer's counter to reach a higher value before the timer is tripped. When the trigger reference voltage (about 1.7 volts) set in the design of the timer is reached, the timer is tripped and sets a flag so that the computer will stop counting. This length of time is controlled by the product of the capacitance times the resistance of the controller. Chapter 1 gives you more information on this kind of circuit in the discussion of correction capacitors.

ADAPTING THE CONTROLLERS TO DIFFERENT COMPUTERS

The circuits for the game paddle inputs of most home computers are quite similar. They differ mainly in the connectors used and the value of the pots. In this section we'd like to discuss the basic similarities and differences in game controller design, and give you some hints on how to adapt the projects described in this book for different home computers.

Apple II

All the designs in this book were tested on the Apple II Plus, which uses a 16-pin DIP plug for its connector. This plug fits a standard IC socket, but it isn't very strong and is often damaged. The new Apple II/e adds a 9-pin D connector to the back of the console, but we think most people will continue to employ extension sockets and standard DIP connectors. The 9-pin D connector is the same socket used by Atari, but the sockets for the two machines are not pin compatible.

The Apple II uses 150K ohm pots and a timer circuit. As noted previously, 150K ohms is a non-standard pot value and is sometimes difficult to find. Pull-down resistors are used on the pushbutton inputs. These are connected from the input (pins 2, 3, or 4) to the ground (pin 8). The factory paddles have 570-ohm resistors hidden in their connectors, but we prefer to substitute 1K resistors since this value is easier to obtain, saves a little power, and is adequate for pushbutton inputs.

Atari Systems

You shouldn't have any trouble adapting the controller designs to Atari systems. They use a 9-pin D connector that is strong and readily available. The D connectors that you can wire yourself have plastic cases or hoods that may be too large for the Atari sockets. You can file away some of the plastic for a good fit. The plug pinout is shown in figure 14-2, which shows the game control schematic for the Atari and Commodore VIC-20 computers.

The value of Atari paddle pots is 1 meg-ohm, a size that is easy to find, but quite large. Such large value pots tend to wear out sooner than those of lower values. The pots have two wires, indicating that this is a timer circuit.

To use the Correction Cap Calculation in the software chapter, change line 18 to read: 18 RMX = 1000 : CI = .001 : NM$ = "ATARI". The pushbuttons have pull-up resistors going to the +5 supply, but the circuit seems to work just fine without them. We generally used 1K resistors for pull-ups when working with Atari computers.

The Commodore VIC-20

The Commodore VIC-20 has an attractive game input circuit custom-made for this system. You can readily adapt this circuit to the controller projects. The VIC-20, however, has only two analog inputs so you can't use two standard joysticks at the same time or the foot pedals along with the airplane wheel.

Commodore, like Atari, utilizes a 9-pin D connector. The pinouts for the two systems are identical (as shown in figure 14-2). The system uses the pots in timer circuits. You can use the Correction Cap Calculation by changing line 18 to read: 18 RMX = 1000 : CI = .001 : NM$ = "VIC-20".

The pots are 1 meg-ohm and are wired as variable resistors for a timer circuit. The internal capacitors are .001 microfarads. The pushbutton inputs, which can also be made to act as outputs, or annunciators, do not seem to need resistors. We generally add 1K pull-ups anyway, since it is considered good electronics practice.

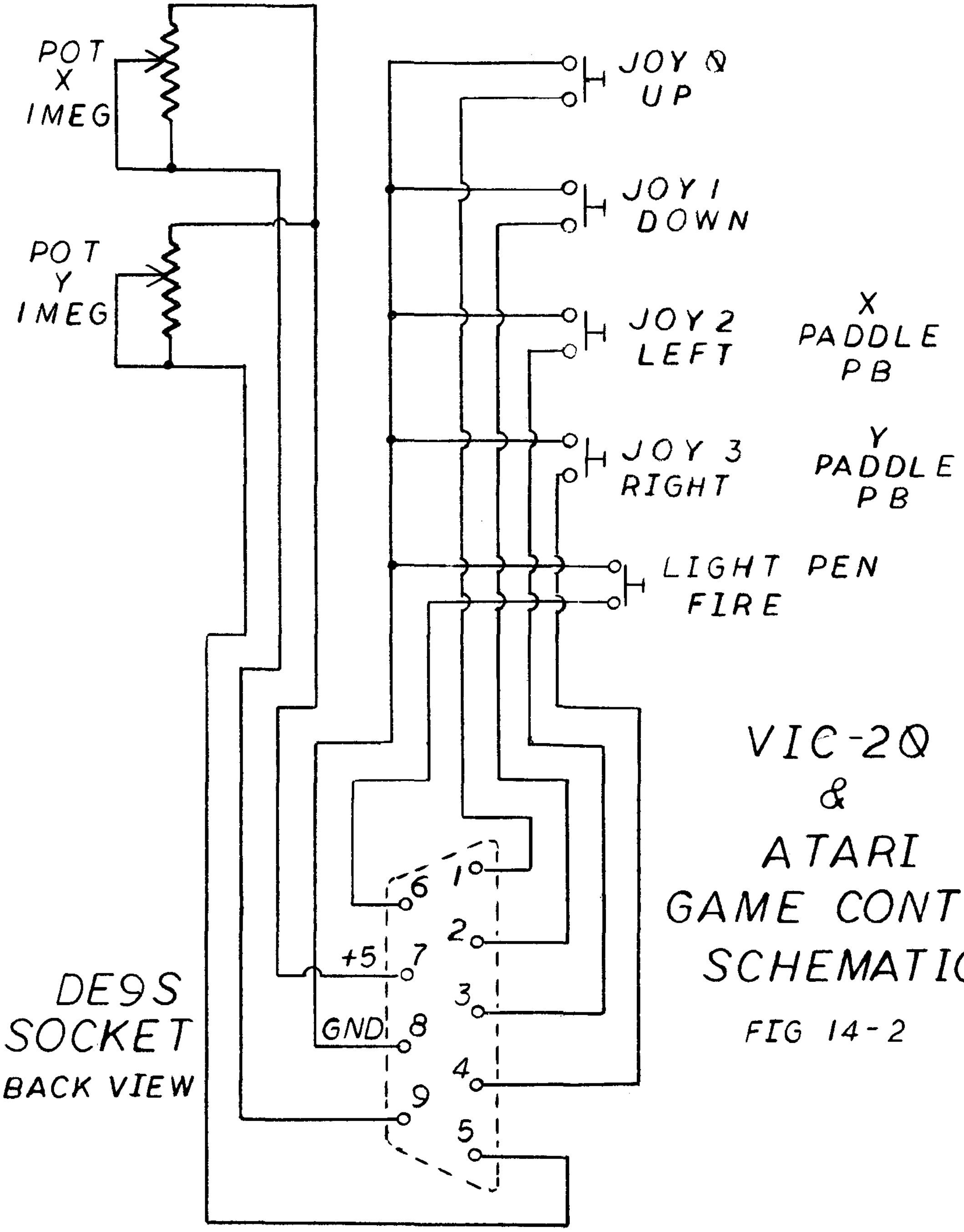
IBM Personal Computer

The IBM Personal Computer does not come with a game connector, but you can purchase a game control adapter card that fits into one of the computer's card slots. With this card the computer can read up to four pots and four pushbuttons. All the projects are easily adapted for use with this card, except the controlled AC outlet (chapter 12). The controlled outlet requires an annunciator output, which is not provided by the IBM card.

Figure 14-3 shows the schematic for two joysticks for the IBM PC. The joysticks have timer-type potentiometer circuits and use 100K pots. The pushbuttons connect from the pushbutton lines to ground and require no pull-up or pull-down resistors.

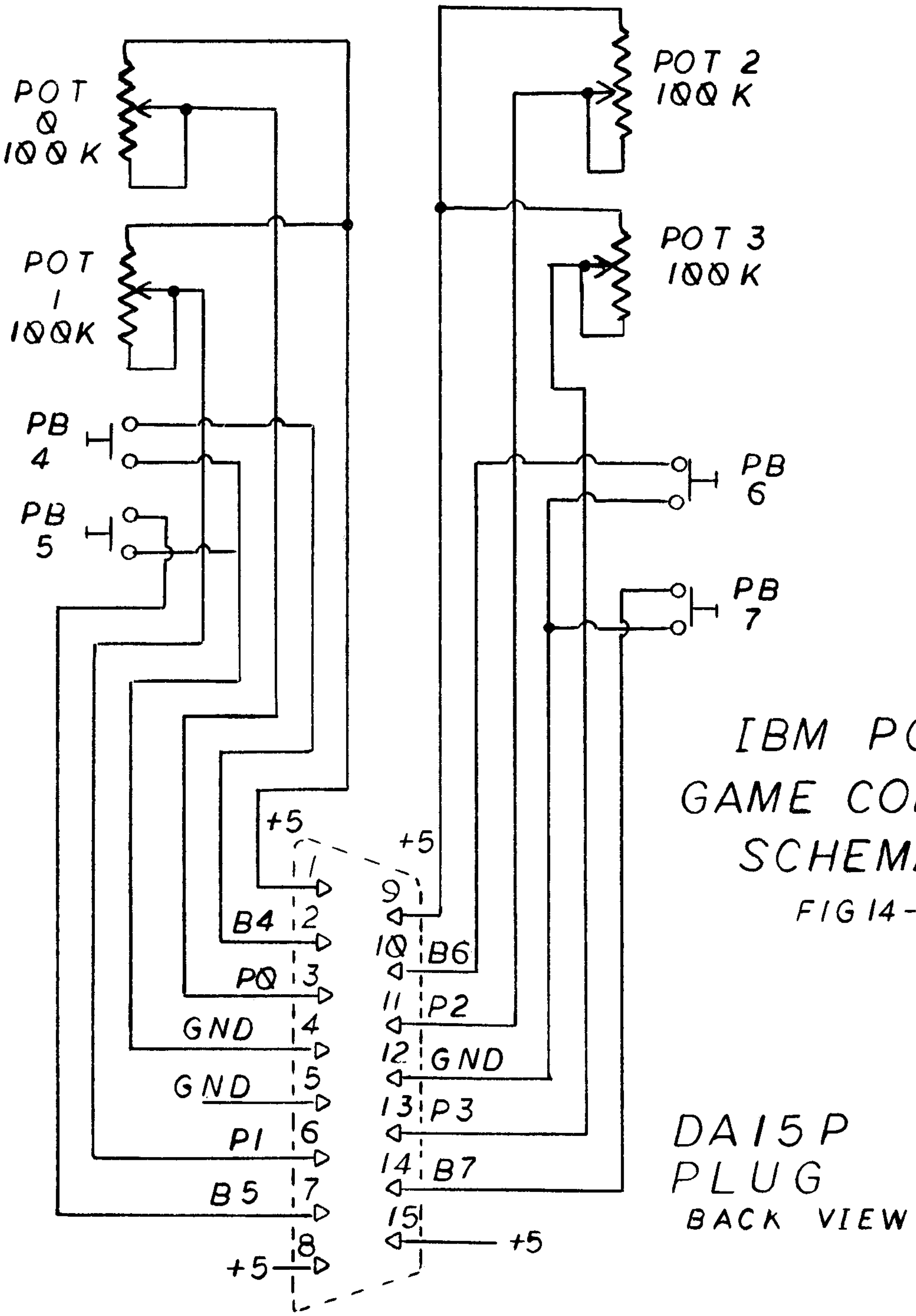
The IBM uses a 15-pin D connector, usually available from the same sources as the 9-pin connector used by Atari and the 25-pin (RS-232C) connectors in the D connector series. Note (on figure 14-3) that the +5 volt supply and the ground are available on several pins. You can use any of the pins indicated on the drawing.

The Correction Cap Calculation should allow you to use lower values for the pot. You will have to change line 18 in the listing to read: 18 RMX = 100 : CI = .011 : NM$ = "IBM PC". This line gives the



VIC-20
&
ATARI
GAME CONTROL
SCHEMATIC

FIG 14-2



IBM PC
GAME CONTROL
SCHEMATIC
FIG 14-3

maximum pot value as 100K, the internal cap size as .011 microfarads, and the computer's name.

Instructions for reading the game inputs are given in detail in the documents that come with the game control adapter card. No changes in these instructions are needed for the IBM PC to read the controllers in this book.

Radio Shack Models

Some Radio Shack computers come with a game controller; others can take an add-on device to accept the game controller. You can adapt most of these projects to any Radio Shack model that can handle their standard game paddle.

Radio Shack paddles use the DIN (Deutsche Industrie-Norm) connector. It originated in Europe and comes in several pin configurations. Make certain the connector you buy not only has the right number of pins but also has them in the correct pattern.

The 100K pots are wired as voltage dividers or true potentiometers. The true potentiometer circuit will accept a wide range of maximum pot values, but since correction caps work with timer circuits only, they cannot be used to control pot values here. This creates a problem with controllers like the Airplane Wheel and Super Stick in which the pots do not travel through their entire range. For these controllers we recommend that you start with a pot of about 250K and use the painting procedure described in chapter 1 under the heading "Zeroing Joystick Elements" to reduce the resistance of the unwanted portions of the pot to zero. Complete the mechanical construction and remove the back of the pot by straightening the two metal tabs. Then mark the limits of travel for the pot wiper and paint the pot element with conductive paint from the marks to the terminals.

Other Computers

In general, if a home computer can handle a pair of paddles with a total of two pots and two pushbuttons, most of the controllers in this book can be adapted for that computer.

The user manual or perhaps a reference book will give you the information you need concerning the game connector and its pin assignments. You may have to take apart the factory paddles to learn the standard pot value. You can then work out the paddle circuit with an ohm meter. Look for the standard components and circuit designs we've described above. Draw your own schematic after finding out which pins are connected to which pot and switch terminals. Look out for pull-up or pull-down resistors that may be hidden in the connector or embedded in plastic parts.

For each new computer model that appears on the market, a magazine article will quickly follow that evaluates its paddles and joysticks and usually explains the paddle connection. If the system in question has been around for awhile, look through back issues of *Creative Computing* and other magazines that regularly review computer equipment. You might even ask the person who sold you the computer where to find out this kind of information.

TOOLS REQUIRED FOR THE ELECTRONICS WORK

You will need the tools we discuss here for the electronics work in the controller projects. These tools are also often extremely useful for carrying out other household tasks. You may already have several of them on hand.

Soldering Iron. Most of these projects require a small pencil soldering iron of 25 to 42 watts with a 1/8-inch chisel point. Larger irons are likely to damage the components, the circuit board, or the insulation on the wiring. Different models, even if they have the same wattage, may deliver different amounts of heat to the joint. If you do much electronics work you will probably end up with two or more irons so that you have just the right one available for a particular job.

You will find these soldering aids indispensable: a roll of solder wick (Radio Shack #64-2040) to correct your mistakes, a piece of wet sponge to clean the tip, and a stand for the iron. Good soldering is the most important skill in electronics and will be covered in detail in the next section.

Long-nose Pliers. A small pair (5-inch) is best for electronics work. Don't use them for jobs like bending coat hangers or you will ruin them.

Diagonal Cutters. You will need diagonal cutters, called dikes, to cut off wires close to the circuit board. Again, a 5-inch pair is best for this work. Don't use these to cut coat hangers either.

Wire Strippers. A pair that looks like wire cutters and is adjusted by a bolt through the handle is most suitable for these projects. You will have to change the adjustment for each wire size and test the strippers on scrap wire after each adjustment to make sure that you don't cut any fine copper wires. It takes practice to use wire strippers without damaging the wire, but developing this skill is crucial for wiring the projects correctly.

Multimeter. Although not absolutely required for these projects, an inexpensive multimeter is extremely useful for checking your wiring before plugging a new unit into your computer. An analog multimeter with a half-dozen resistance and DC voltage ranges will serve nicely. Any Radio Shack multimeter on sale, sometimes for as little as $10, is a good buy. The more expensive digital meters are difficult to use. A less expensive meter will serve you better for these projects.

HOW TO SOLDER

Soldering is the most basic and critical skill in electronics. Many components will be destroyed if they are not soldered well, and since it is almost impossible to turn a poor soldering job into a good one, it is important to do the job right the first time. Fortunately, it isn't hard to learn to solder correctly. If you follow the suggestions below and put in even a modest amount of time in practice, you should have no problem mastering the technique.

Use the correct iron for the job. For electronics work use a pencil iron of 25 to 42 watts with a 1/8-inch chisel tip. A larger iron can lift the copper lanes off the circuit board, melt wire insulation, and damage components. The transformer-type pistol-grip irons used for household repairs have too large a point and too much power for electronics work. Only one of the projects, the Desk Switched Outlet Box, uses an iron this large.

Buy small-diameter resin-core solder. One acid-core solder joint will destroy an entire electronic device. Acid-core solder is used to work sheet metal and usually comes in large diameters. If you have any doubt about the type of core, don't use the solder. The solder for these projects should be a 50/50 tin/lead alloy about .032-inch in diameter.

Keep the tip of the iron clean. Rub the tip frequently over a damp sponge to remove excess solder and resin. You will find it helpful to keep the sponge in a jar lid on your workbench.

Make good mechanical connections before applying solder. Twist multi-strand wire tightly—loose strands will cause shorts. Wrap wire around posts with the long-nose pliers. Push wires through the printed circuit board and bend them slightly on the bottom side. When you are ready to solder, take your hands off the work. All the wires to be soldered should stay in place. You can't hold a wire in place with your finger and start soldering; the result is a bad joint and a burned finger.

Heat the joint, not the solder. Cover the clean tip of the iron sparingly with solder (this is called tinning the tip), and then place the tip on the joint. When the joint begins to heat, touch the solder to the joint, not to the iron. The solder should melt and then flow as a liquid over the joint. When the joint is uniformly covered, remove the solder and then the iron. Let the joint cool for a few seconds before you touch the wires.

Inspect the joint. The joint should be covered with a smooth coat of solder. You shouldn't see any untinned copper wires or dark buildup of excess resin. The solder must clearly have been a liquid that flowed and then cooled. Also look for fine strands of wire or bridges of solder between the joint just finished and its neighbors. These can usually be removed with dikes, solder wick, and soldering iron.

There are two types of bad joints: those that got too hot during soldering and those that never got hot enough. The hot joint is characterized by insulation that pulls back from the wire, copper lanes that lift off the board, a discolored printed circuit board, and sometimes even damaged components.

A cold joint may have lumps of solder that didn't flow, dark patches of resin, or places where copper wires show through the solder. A cold joint can be caused by an iron that is too small for the job, an improperly cleaned and tinned tip, poor thermal contact between the tip and the joint, or simply because you didn't leave the iron on the joint long enough.

Take safety precautions. A poorly handled soldering iron can burn your fingers and your desk or worktable. It could even start a fire. It is important that you buy or make a weighted stand for your iron and then use it to hold the iron. Always unplug the iron when you leave the room, even if you plan to be gone for only a short time. Make this a habit so when you leave your house you won't have to wonder, "Did I unplug the soldering iron?"

Craftsmanship. Soldering is an important skill. Every time you start a new job try to do it better than the last one. This is a key attitude for developing good skills in any field.

AC CODES AND WIRING PRACTICES

It is surprising how many otherwise competent electronic technicians don't know or don't understand the importance of following National Electrical Code guidelines when working on AC devices. We will summarize the parts of the code that are necessary for constructing these projects (see *The National Electrical Code Handbook,* produced by the National Fire Protection Association, Quincy, Massachusetts). This information is critical not just for working on controllers but for all household electronics work, from rewiring a lamp to installing an outlet in a room.

Color Codes

The key to wiring AC devices correctly is to follow the color code for wires and terminals. Green wires and wires without insulation are the safety ground and are connected to all metal boxes, conduits, and frames. Their screw terminals are green; sometimes they have green clips instead of screw terminals. Proper installation of green wires minimizes the hazards of electrical shock and fire while reducing electrical noise. The safety ground wires should be the same size as the other colored wires in a circuit. The green line must never be switched, fused, or run through a circuit breaker. It carries current only in the case of a fault in the circuit. In Europe the safety ground wire is yellow with green stripes.

The white wire is the power return. It carries current back from the load, but is close to ground voltage except when a fault occurs. The screw color for the white wire is silver. If all the wires in a cable are the same color (as is the case in plastic lamp cord), the correct wire to use for the power return will always be marked. The mark is usually a series of ridges along the outside of the wire or, more rarely, a colored thread wrapped around the copper conductor. On AC outlets and plugs the white wire goes to the wider prong (the indication that it is the marked prong). Like the green wire, the white wire is never switched, fused, or run through a circuit breaker.

The power wire can be any color except white or green; it cannot be a bare wire. The most common colors for the power wire are black, red, and blue. The screw terminals are brass colored. Since these wires carry power to the electrical device, they are the only wires you can switch, fuse, or run through a circuit breaker.

When you are running a wire to a switch that is separated from the main device, you will sometimes need a cable with two power wires but you won't need the white or green wires. In chapter 11 (the Desk Switched Outlet Box), cable 2 from the outlet box to the switch box (figure 11-2) requires two power wires and a white wire. The AC code lets you paint both exposed ends of a wire the color you need, so you don't have to buy special cable, e.g., one with a green and two black wires. You will find that felt tip marking pens work well for painting wires a dark color. White electrical tape is wrapped around dark wires to color them white. If you paint a wire you must be careful to mark it in every place where you remove the covering, even in intermediate boxes. Painting a wire is an important safety step since it clearly indicates the arrangement of the circuit, particularly to those who might have to repair it at a later date.

Wire Size

The larger the number, the smaller the size of the wire. Even numbers indicate that the wire is copper. Most electronic devices are wired with #12, #14, or #16 wires for AC power. Solid #12 wire is now standard for long runs and for house wiring and is also used for high-current loads like heaters, hot plates, and air conditioners. If you plan to plug several medium-power electronic devices into the Desk Switched Outlet and run the cord more than 15 feet, you might go to the extra expense of using #12 wire. For most medium-power microcomputer and home electric systems, #14 wire is adequate, and #16 wire will suffice for systems with loads of 100 watts or less.

Placing wires in screw terminals looks easy, but it is often done incorrectly. To attach a wire to a screw terminal, twist the stranded wire tightly together and form it into a hook. Place the hook around the screw in a clockwise direction. This is important: you will twist the wire more tightly as you tighten the screw if the wire is wound clockwise. If you put the hook on backwards, you will loosen it as you tighten the screw. Close the hook with long-nose pliers and then tighten the screw. When you have finished the wiring, go back over all the screw terminals to be sure they are tight.

Wire Nuts

Wire nuts are small plastic and metal devices for connecting several wires together. To properly install them, group all the wires together in a bundle between your thumb and index finger. Cut them off evenly and strip their insulation back 1/2-inch from the end for solid wires and 3/4-inch for stranded wires. If any of the wires are stranded, you will need to twist all the stripped wires together into a bundle using long-nose pliers. If all the wires are solid, as is usual for house wiring, leave them straight.

Now twist the wire nut on with your fingers as tightly as you can. Rock the nut back and forth with one finger looped around the bundle of wires. If the nut has grabbed all the wires, they will move back and forth as a group. If you can feel any wire moving independently of the group, take off the nut, even out the bundle, and try again. If you stripped the wires properly, all the bare copper should be hidden from view inside the nut.

SAFETY PRECAUTIONS

Please be careful when building the projects in this book. You can learn from minor mistakes, but serious ones have no redeeming virtues. Avoid the big mistakes that can cause injuries or damage valuable equipment.

Don't burn down your house. Use your soldering stand and unplug your iron every time you leave the room. Use only outlets that have proper fuses or circuit breakers and don't plug too many devices into one outlet.

Keep stray electrical power out of your computer. Carefully check devices that use alternating current (like the monitor and the controlled AC outlet) to insure that stray AC cannot find its way into the computer. If you are working on a controller with an AC cord, give this device an extra check with the multimeter before connecting it to your computer.

Avoid electrical shocks. Follow all codes for AC devices. Unplug the AC cords before opening the case of an electrical or electronic device. Don't work on power equipement while you are alone. Always have another person nearby who can cut off the power or go for help in an emergency.

Don't plug any device into live equipment. This rule refers to both connectors and printed circuit boards. In most instances, nothing untoward will happen if you plug a paddle into your computer when it is already on, but you could create a spark that in turn could destroy an electronic component. It is bad practice, so don't take the chance.

Don't short the computer power supply to ground. Depending on the computer, a short to ground may blow out a fuse, and could conceivably damage the power supply. Check and recheck the +5 wires on all newly-built devices with a multimeter before plugging them in. On the Apple, the +5 supply (pin 1) must read at least 50 ohms to ground (pin 8), and usually measures much more. The Apple's power supply can provide only 100 milliamps at +5 volts to the game control socket. By Ohm's law a resistance of 50 ohms will draw the entire 100 milliamps, so this value is the lowest resistance allowed. Other computers will have similar limiting current values which must be observed. This information is usually given in the reference manual for a computer, in the section on the game controller connector.

If you turn on your computer with a new controller plugged in and it doesn't start up in its normal fashion, the +5 may be shorted. Turn the computer off immediately and recheck all your work. A chip plugged in backwards is often the cause of this kind of short.

Use common sense. Proceed carefully and check your work. Don't work on equipment when you are ill or overtired or taking drugs of any kind. The whole point is to do the job right the first time.

REFERENCES

The references below will be useful for understanding the electronics in the controller projects as well as for a general study of the subject:

Engineer's Notebook II: Integrated Circuit Applications, Forrest M. Mims III, Radio Shack Cat. No. 276-5002, $2.49. This softbound volume is perfect for beginners and of great value for professionals. It gives you schematics for hundreds of circuits that you can actually get the parts for. We have a $50 reference book that isn't as good as this one. An essential tool and an incredible buy for the price.

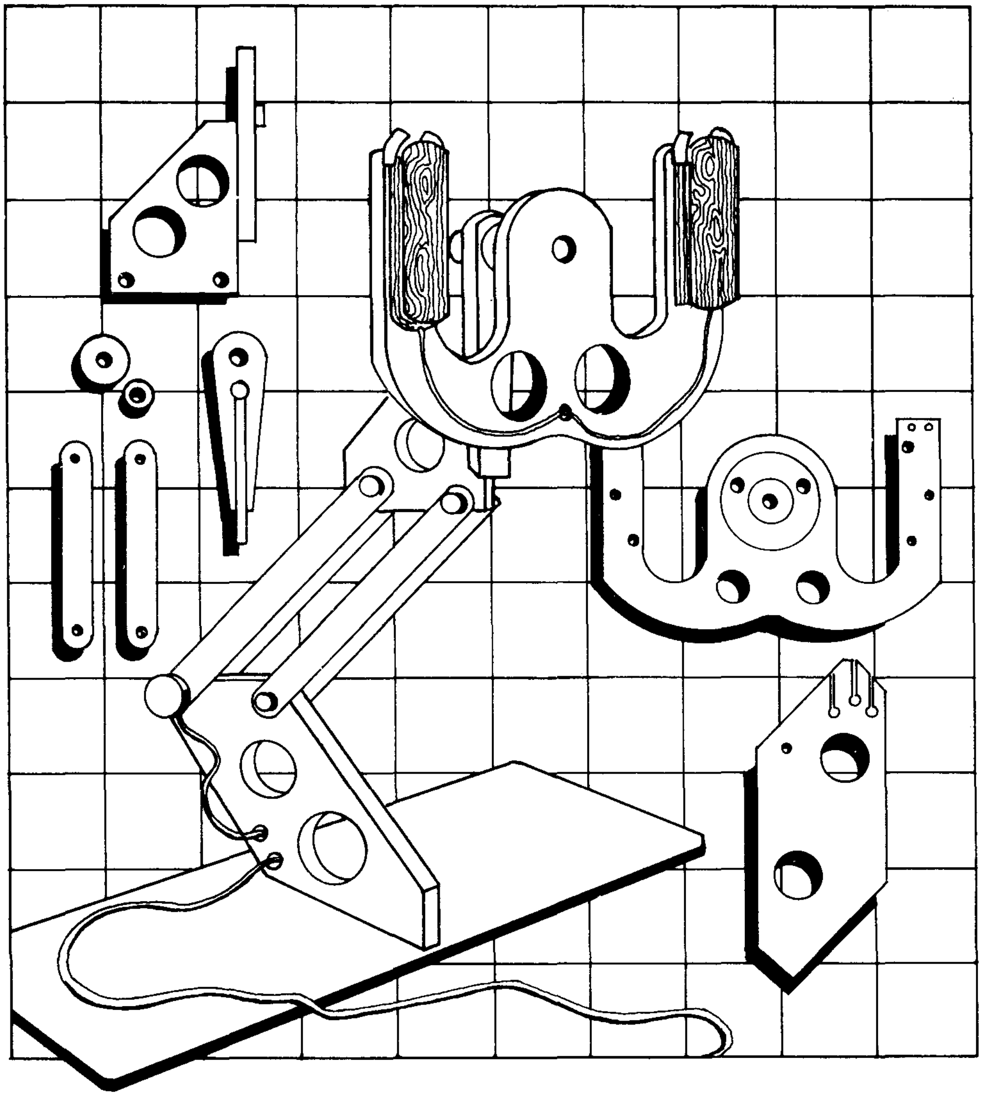
Semiconductor Reference Guide, Radio Shack Cat. No. 276-4006, $3.49. This softbound guide isn't as helpful as *Engineer's Notebook II,* but it does contain good information on available components. Since much of the material is in the form of measured parameters (voltages, timings, etc.), a beginner may find this guide difficult to use at first. You will soon learn to pick out the specific information you need.

Radio Shack/Texas Instruments Learning Center books on various topics in electronics. These books, sold at Radio Shack, are generally well written and reasonably priced. Several of the volumes cover microprocessors and digital equipment. They tend, however, to stress the achievements of Texas Instruments and overlook everyone else's.

The National Electrical Code Handbook, edited by Joseph A. Ross, published by the National Fire Protection Association, Quincy, Massachusetts, provides excellent guidelines for electricians or electronic technicians working with AC devices. This book is a critical reference tool for using your computer to control AC power, as well as for any household electrical work.

Computers & Electronics (formerly *Popular Electronics*) and other amateur electronics magazines. These magazines often feature lots of articles on how to build items of dubious utility from parts that aren't available. They do contain excellent learning projects, however, and the ads in the back are helpful in ordering parts from electronics suppliers.

Creative Computing and other computer magazines. These magazines focus on home computers, but stress software and reviews of commercial hardware. The articles on how to build hardware for the computer are usually too advanced for the beginner. After completing several of the projects in this book, however, you will be able to move up and take on these more complex and challenging circuits.



15 Software

These six programs in Applesoft Basic will help you construct, test, and use your homebuilt controllers. The six listings are:

- Controller Checkout
- Correction Cap Calculation
- Linearity Test
- Drawing Program
- Digitizer
- Annunciator Checkout

All but the Drawing and Digitizer programs can easily be converted into any other version of Basic with only a few changes. The Drawing Program contains many graphics handling functions for the Apple, and the Digitizer has several disk handling instructions. These listings will require a little more work to adapt them to other computers.

The use of each of the programs is detailed in the project chapter in which it is first required. The materials in this chapter are therefore limited to the organization of the program, any unusual features, and the major variables. This information should help you understand the listings and make modifications in them to suit your needs.

CONTROLLER CHECKOUT

With this program you can check out all the pushbuttons and game control pots on the controllers you build. You will also need it to make mechanical adjustments. The listing is introduced in chapter 1 and referred to in almost all subsequent chapters.

Step by Step Through the Listing

The program sets constants (line 280), clears the screen (line 300), and displays a screen format giving the pushbutton and game control numbers (lines 40 to 190). The pushbuttons are read (lines 210 to 230) and the values are displayed in a cleared space on the screen (lines 237 to 239).

The game control pots are then read (lines 250 to 265). Note the delays between readings (lines 252, 257, 262). The space to display this information is cleared and the values are entered (lines 270 to 280). Next the pushbuttons are checked to see if any have been pressed and the appropriate word, OPEN or CLOSED, is displayed (lines 290 to 325). The process is repeated in an endless loop (line 330).

Using the Program

When you are confident you have wired your new controller correctly, plug it in, turn on the computer, and run this program. If the computer doesn't start up in the normal way, turn it off immediately and recheck all your work on the controller.

When everything is in order, run the checkout program. Try moving the pots and pressing the pushbuttons to see if they function properly. If the new device requires mechanical adjustment, you can do this while reading the game control values from the screen.

Variables

Variable	Line	Description
OP$	25	A string saying OPEN
CL$	25	A string saying CLOSED
BL$	25	Blank spaces to remove words

Variable	Line	Description
P0	210	The reading of pushbutton 0
P1	220	The reading of pushbutton 1
P2	230	The reading of pushbutton 2
G0	250	The reading of game control 0
G1	255	The reading of game control 1
G2	260	The reading of game control 2
G3	265	The reading of game control 3

```
10  REM  **********************
12  REM  *
14  REM  * CONTROLLER CHECKOUT
16  REM  *
18  REM  * TOM RILEY COPYRIGHT 83

20  REM  *
22  REM  **********************
24  REM
25 OP$ = "OPEN  ":CL$ = "CLOSED":
     BL$ = "       "
30  TEXT : HOME
34  REM
35  REM  ** DISPLAY FORMAT
40  VTAB 2: HTAB 6
50  PRINT "CONTROLLER CHECKOUT -
     APPLE II"
60  VTAB 6
70  PRINT "   THIS PROGRAM TESTS
     CONTROLLER"
80  PRINT "PUSHBUTTONS AND POTS."

90  PRINT
100  VTAB 10: HTAB 8: PRINT "PB0
     IS "
110  VTAB 12: HTAB 8: PRINT "PB1
     IS "
120  VTAB 14: HTAB 8: PRINT "PB2
     IS "
140  VTAB 17: HTAB 14: PRINT "PDL
     (0) = "
150  VTAB 18: HTAB 14: PRINT "PDL
     (1) = "
160  VTAB 19: HTAB 14: PRINT "PDL
     (2) =  "
170  VTAB 20: HTAB 14: PRINT "PDL
     (3) = "
190  FOR I = 10 TO 14 STEP 2: VTAB
     I: HTAB 15: PRINT OP$: NEXT

198  REM
200  REM  ** READ PUSHBUTTONS
210 P0 =  PEEK ( - 16287)
220 P1 =  PEEK ( - 16286)
230 P2 =  PEEK ( - 16285)
237  VTAB 10: HTAB 25: PRINT BL$;
     : HTAB 25: PRINT P0
238  VTAB 12: HTAB 25: PRINT BL$;
     : HTAB 25: PRINT P1
239  VTAB 14: HTAB 25: PRINT BL$;
     : HTAB 25: PRINT P2
240  REM
245  REM  ** READ CONTROLLER POTS
250 G0 =  PDL (0)
252  FOR I = 1 TO 10: NEXT I: REM
      DELAY REQUIRED
255 G1 =  PDL (1)
257  FOR I = 1 TO 10: NEXT I
260 G2 =  PDL (2)
262  FOR I = 1 TO 10: NEXT I
265 G3 =  PDL (3)
270  FOR I = 17 TO 20: VTAB I: HTAB
     23: PRINT BL$: NEXT I
280  VTAB 17: HTAB 23: PRINT G0: VTAB
     18: HTAB 23: PRINT G1: VTAB
     19: HTAB 23: PRINT G2: VTAB
     20: HTAB 23: PRINT G3
285  REM  * PUSHBUTTON OPEN OR CL
     OSED
290  IF P0 > 127 OR P1 > 127 OR P
     2 > 127 THEN  GOTO 300
294  FOR I = 10 TO 14 STEP 2: VTAB
     I: HTAB 15: PRINT OP$: NEXT

296  GOTO 210
300  IF P0 > 127 THEN  VTAB 10: HTAB
     15: PRINT CL$
305  IF P0 < 128 THEN  VTAB 10: HTAB
     15: PRINT OP$
310  IF P1 > 127 THEN  VTAB 12: HTAB
     15: PRINT CL$
315  IF P1 < 128 THEN  VTAB 12: HTAB
     15: PRINT OP$
320  IF P2 > 127 THEN  VTAB 14: HTAB
     15: PRINT CL$
325  IF P2 < 128 THEN  VTAB 14: HTAB
     15: PRINT OP$
330  GOTO 210
999  END
```

CORRECTION CAP CALCULATION

This program calculates the value of the correction caps needed when you choose a potentiometer with a lower maximum value than the standard paddle pots for the computer. This approach works only for computers that have timer game control circuits, like Apple, Atari, and the Commodore VIC-20.

The use of this program is described in detail in chapter 1. The program will be needed whenever you build a controller requiring correction caps.

Step by Step Through the Listing

The internal capacitor value and the maximum paddle value for a computer are set (line 18). This is the only line that will have to be changed to use this program for computers other than the Apple. The constant for the system is then calculated (line 19).

Information about the program is displayed (lines 35 to 160), and you are given the choice of automatic or manual operation (line 164). For automatic mode, you must plug the completed controller without correction caps into the game I/O connection and set the pots to their maximum values before you run the program.

If you choose manual operation, execution continues with a request for the maximum pot value of the new device in K-ohms (lines 170 to 175). A check is then made for too large or too small a pot value (lines 180 to 190). The correction cap is calculated (lines 200, 205) and displayed (line 210). Execution is then returned to the automatic/manual question (line 164).

If the pot value you provide is too high, correction caps don't work. The use of an alternative correction resistor is suggested (lines 320 to 340). The resistor is then calculated (lines 350, 357) and displayed (line 360). Execution is again returned to the automatic/manual question (line 164).

If you choose automatic mode, instructions are given (lines 1000 to 1095). The controller pots are each read, the correction cap values calculated, and the values displayed in turn (lines 1110 to 1148). The keyboard is then checked to see if any key has been pressed (line 1160). If so, the program is ended (line 1170).

Variables

Variable	Line	Description
RMX	18	Maximum value of pot for this computer
CI	18	Value of cap inside the computer in microfarads
NM$	18	Name of computer
K	19	Constant for the computer system
MA$	164	Choice between manual or automatic modes
R	175	Maximum value of pot in new controller
C	200	Value of correction cap in microfarads
RC	350	Value of correction resistor in K-ohms
P0	1110	Reading for game control 0
C0	1115	Correction cap for game control 0
P1	1120	Reading for game control 1
C1	1125	Correction cap for game control 1
P2	1130	Reading for game control 2
C2	1135	Correction cap for game control 2
P3	1140	Reading for game control 3
C3	1145	Correction cap for game control 3
Q	1170	Check for keyboard key being pressed

```
1  REM  ************************
2  REM  *
3  REM  * CORECTION CAP
4  REM  *   CALCULATION
5  REM  *
6  REM  * TOM RILEY COPYRIGHT 83
7  REM  *
8  REM  *************************

9  REM
17  REM   POT & CAP VALUE FOR APP
    LE II
18 RMX = 150:CI = .022:NM$ = "APP
    LE II"
19 K = RMX * CI
20  TEXT : HOME
30  VTAB 2: HTAB 5
34  REM
35  REM  *** INFORMATION
40  PRINT "CAPACITOR ADJUSTMENT C
    ALCULATION"
45  VTAB 4: PRINT "              FOR
     ";NM$
50  VTAB 6
60  PRINT "FOR A CONTROLLER TO BE
     CORRECTLY READ,"
70  PRINT "A TIMER IT CONTROLS MU
    ST WORK PROPERLY."
80  PRINT "THE TIMER IS CONTROLLE
    D BY A CAPACITOR"
90  PRINT "AND THE POT IN THE CON
    TROLLER WIRED AS"
100  PRINT "A VARIABLE RESISTOR."

110  PRINT
120  PRINT "    THE PRODUCT OF TH
     E CAPACITOR AND"
130  PRINT "THE MAXIMUM RESISTANC
     E MUST REMAIN THE"
140  PRINT "SAME.  CORRECTION CAP
     S MAY BE ADDED"
150  PRINT "INSIDE THE CONTROLLER
```

```
     IF POT VALUE"
155  PRINT "IS TOO LOW."
16Ø  PRINT
161  REM
162  REM  ** CHOOSE MANUAL OR AUT
     OMATIC
164  INPUT "MANUAL OR AUTOMATIC ?
      (M OR A) ";MA$
166  IF MA$ = "A" THEN  GOTO 1ØØØ
167  PRINT
168  REM
169  REM  *** MANUAL CALCULATION
17Ø  HTAB 6: PRINT "MAX. POT. RES
     . >          K-OHMS";
175  HTAB 22: INPUT " ";R
177 L =  PEEK (37): VTAB L: HTAB
     29: PRINT "K-OHMS"
18Ø  IF R > RMX THEN  GOTO 3ØØ
19Ø  IF R = Ø OR R < Ø THEN  PRINT
     "POT VALUE MUST BE GREATER T
     HAN Ø": GOTO 16Ø
2ØØ C = K / R - CI
2Ø5 C =  INT (C * 1ØØØØ + .5) / 1
     ØØØØ
2Ø7  PRINT
21Ø  PRINT "CORRECTION CAP IS ";C
     ;" MICROFARADS"
22Ø  GOTO 16Ø
3ØØ  REM  ** HIGH POT VALUE CALCU
     LATION
31Ø  PRINT
32Ø  PRINT "CAP CORRECTION DOES N
     OT WORK ABOVE ";RMX;" K"
33Ø  PRINT "A CORRECTION RESISTOR
      FROM +5 TO WIPER"
34Ø  PRINT "MAY HELP BUT THE RESU
     LT IS NOT LINEAR."
35Ø RC = (R * RMX) / (R - RMX)
355 RC =  INT (RC * 1Ø) / 1Ø
357  PRINT
36Ø  PRINT "      CORRECTION RESIS
     TOR IS ";RC;" K-OHM"
37Ø  GOTO 16Ø
999  END
1ØØØ  REM  *** AUTOMATIC MODE
1Ø1Ø  HOME
1Ø2Ø  PRINT "     AUTOMATIC MODE"
1Ø3Ø  PRINT : PRINT
1Ø4Ø  PRINT "   TURN ALL PADDLE P
     OTS TO THEIR HIGHEST"
1Ø45  PRINT "VALUES."
1Ø5Ø  PRINT
1Ø6Ø  PRINT "   THE CAP VALUE SHO
     WN WILL MAKE THESE"
1Ø7Ø  PRINT "SETTINGS READ 255."
1Ø8Ø  PRINT
1Ø9Ø  PRINT "PRESS ANY KEY TO QUI
     T."
1Ø95  PRINT : PRINT
1Ø99  REM
11ØØ  REM   **  READ POTS AND CAL
     CULATE COR. CAP.
11Ø5  VTAB 14
111Ø PØ =  PDL (Ø)
1112  IF PØ = Ø THEN PØ = 1
1115 CØ = (CI * 255) / PØ - CI
1117 CØ =  INT (CØ * 1ØØØ + .5) /
     1ØØØ
1118  PRINT "GCØ READING ";PØ;"
     COR.CAP ";CØ;"     "
1119  PRINT
112Ø P1 =  PDL (1)
1122  IF P1 = Ø THEN P1 = 1
1125 C1 = (CI * 255) / P1 - CI
1127 C1 =  INT (C1 * 1ØØØ + .5) /
     1ØØØ
1128  PRINT "GC1 READING "P1;"  C
     OR.CAP ";C1;"      "
1129  PRINT
113Ø P2 =  PDL (2)
1132  IF P2 = Ø THEN P2 = 1
1135 C2 = (CI * 255) / P2 - CI
1137 C2 =  INT (C2 * 1ØØØ + .5) /
     1ØØØ
1138  PRINT "GC2 READING ";P2;"
     COR.CAP ";C2;"      "
1139  PRINT
114Ø P3 =  PDL (3)
1142  IF P3 = Ø THEN P3 = 1
1145 C3 = (CI * 255) / P3 - CI
1147 C3 =  INT (C3 * 1ØØØ + .5) /
     1ØØØ
1148  PRINT "GC3 READING ";P3;"
     COR.CAP ";C3;"      "
116Ø Q =  PEEK ( - 16384): POKE  -
     16368,Ø
117Ø  IF Q > 127 THEN  GOTO 9999
1175  REM  ** ENDLESS LOOP
118Ø  GOTO 11ØØ
9999  END
```

LINEARITY TEST

The Linearity Test checks the linearity of graphic input devices that use the game control inputs. Linearity is the ability of an input device to transform a mechanical input (the turning of a paddle) into an electronic input accurately. The use of this program is described in detail in chapter 5 on the Sketch Pad. Linearity is essential to sketch pad performance as well as to many other forms of data entry.

Step by Step Through the Listing

Initial values for constants are set (lines 30 to 70). The display format is produced (lines 100 to 298). The subroutine (lines 1000 to 1090) for the game control input reading is then called up (in line 310). The value of the 0 game control input is read and displayed (lines 1010, 1020). The 0 pushbutton is read and checked to see if RETURN is needed (lines 1027, 1028). Game control #1 input is read and displayed (lines 1030, 1040). Pushbutton #1 is read and checked to see if RETURN is needed (lines 1070, 1080). The subroutine is then repeated (line 1090).

The errors and precentage error of full scale are calculated and rounded off to two decimal places (lines 312, 314). A check is then made to determine which pushbutton was pressed, and the values are displayed (lines 330, 340). The axes are checked to see if they are complete (lines 342, 344) and the flashing cursors are moved (lines 355, 365). There is a slight pause (line 370) and execution is sent either to a new test question (line 380) or returned (line 390) to the subroutine.

Variables

Variable	Line	Description
X(5)	30	A vector of the correct values in the X axis
Y(5)	30	A vector of the correct values in the Y axis
NX	70	Number of the X point being read (0 to 5)
NY	70	Number of the Y point being read (0 to 5)

Variable	Line	Description
XE	312	Error in X axis reading
PX	312	Percentage error in X axis reading
YE	314	Error in Y axis reading
PY	314	Percentage error in Y axis reading
PT$	330	String telling if point is on X or Y axis
YN$	420	String answering YES/NO questions
X	1010	Reading of game control 0
P0B	1027	Reading of pushbutton 0
Y	1030	Reading of game control 1

```
10Ø  REM  ***********************
12   REM  *
14   REM  *  LINEARITY TEST
16   REM  *
18   REM  * TOM RILEY COPYRIGHT 83
2Ø   REM  *
22   REM  ***********************
24   REM
3Ø   DIM X(5),Y(5)
5Ø   FOR N = Ø TO 4
55 X(N) = 255 * N / 4:Y(N) = X(N)
6Ø   NEXT N
7Ø NX = Ø:NY = Ø
9Ø   HOME
1ØØ  REM  ** HEADINGS
11Ø  PRINT "          LINEARITY TES
     T"
12Ø  PRINT
125  PRINT "            CORRECT  REA
     D  ERROR     %"
13Ø  PRINT " X - AXIS"
132  PRINT
135  PRINT "POINT Ø = ";X(Ø)
14Ø  PRINT "POINT 1 = ";X(1)
15Ø  PRINT "POINT 2 = ";X(2)
16Ø  PRINT "POINT 3 = ";X(3)
17Ø  PRINT "POINT 4 = ";X(4)
18Ø  PRINT
19Ø  PRINT " Y - AXIS"
195  PRINT
2ØØ  PRINT "POINT 5 = ";Y(Ø)
21Ø  PRINT "POINT 6 = ";Y(1)
22Ø  PRINT "POINT 7 = ";Y(2)
23Ø  PRINT "POINT 8 = ";Y(3)
24Ø  PRINT "POINT 9 = ";Y(4)
26Ø  PRINT
27Ø  PRINT "PRESENT POSITION"
28Ø  PRINT
29Ø  PRINT "      X =          Y
     ="
295  FLASH : VTAB 6: HTAB 18: PRINT
     " "
298  VTAB 14: HTAB 18: PRINT " ":
     NORMAL
3ØØ  REM  READ PADDLES
31Ø  GOSUB 1ØØØ
312 XE =  INT ((X - X(NX)) * 1ØØ)
     / 1ØØ:PX =  INT (XE / .255)
     / 1Ø
314 YE =  INT ((Y - Y(NY)) * 1ØØ)
     / 1ØØ:PY =  INT (YE / .255)
     / 1Ø
32Ø  REM  ** NOTE TEST POINTS
33Ø  IF PT$ = "X" THEN  VTAB (6 +
     NX): HTAB 18: PRINT X;: HTAB
     25: PRINT XE;: HTAB 33: PRINT
     PX:NX = NX + 1
34Ø  IF PT$ = "Y" THEN  VTAB (14 +
     NY): HTAB 18: PRINT Y;: HTAB
     25: PRINT YE;: HTAB 33: PRINT
     PY:NY = NY + 1
342  IF NX > 5 THEN NX = 5
344  IF NY > 5 THEN NX = 5
355  FLASH : VTAB (6 + NX): HTAB
     18: PRINT " ": NORMAL
365  FLASH : VTAB (14 + NY): HTAB
     18: PRINT " ": NORMAL
37Ø  FOR N = 1 TO 5ØØ: NEXT N
38Ø  IF NY = 5 AND NX = 5 THEN  GOTO
     4ØØ
39Ø  GOTO 3ØØ
4ØØ  REM  ** TEST AGAIN ?
41Ø  VTAB 2Ø
42Ø  INPUT "NEW TEST ? ( Y OR N )
     ";YN$
43Ø  IF YN$ = "Y" THEN  GOTO 7Ø
999  END
```

continued . . .

```
1000  REM  ** READ PADDLES SUBROU
     TINE
1010 X =  PDL (0)
1020  VTAB 22: HTAB 10: PRINT "
     ";
1025  HTAB 10: PRINT X
1027 P0B =  PEEK ( - 16287)
1028  IF P0B > 127 AND NX < 5 THEN
     PT$ = "X": RETURN
1030 Y =  PDL (1)
1040  VTAB 22: HTAB 25: PRINT "
     ";
1045  HTAB 25: PRINT Y
1070 P1B =  PEEK ( - 16286)
1080  IF P1B > 127 AND NY < 5 THEN
     PT$ = "Y": RETURN
1090  GOTO 1010
9999  END
```

DRAWING PROGRAM

Using this program you can draw directly into the hi-res screen with any paddle, joystick, or controller. It was written for the Sketch Pad controller and is described in detail in chapter 4.

Sections

This program uses a Main Menu to direct execution to any of six subroutines:

1	Clears High Res Screen	(lines 130 to 135)
2	Gets Drawing From Disk	(lines 2000 to 2130)
3	Puts Drawing on Disk	(lines 3000 to 3190)
4	Draws Continuous Points	(lines 4000 to 4155)
5	Draws Continuous Lines	(lines 5000 to 5210)
6	Draws Reference Point Lines	(lines 6000 to 6410)

There is also a Main Menu subroutine (lines 8000 to 8130) and an Introduction (lines 9000 to 9195). The program enters the graphics mode by poke commands (lines 5210, 6280) so that the screen is not erased when you are switching from one drawing to another. The many REM statements should help you follow the flow of the program.

In each of the three drawing programs, information is displayed (lines 4000 to 4150) and then graphics are set (line 4210). The game control inputs 0 and 1 are read (lines 4320, 4330) and plotted (line 4340). The keyboard is checked to see if a return to the main menu is called for (line 4350). Pushbutton 0 is then checked to see if HCOLOR needs changing (line 4400) and the subroutine is repeated. The other two drawing routines are almost identical.

Variables

Variable	Line	Description
C1	70	Picture elements in the Y axis
C2	70	Maximum game control reading
C3	70	Picture elements in the X axis

Variable	Line	Description
C	80	Current value of HCOLOR
YN$	90	Answer to YES/NO questions
D$	90	Control D
A	130	Main Menu selection number
DN$	2110	File name of drawing
X	4320	Current value of game control 0
Y	4330	Current value of game control 1
B0	4350	Reading of pushbutton 0
K	4350	Reading of key that has been pressed
B1	6320	Reading of pushbutton 1
X1	6360	Last reference value of X
Y1	6360	Last reference value of Y

```
10  REM  ***********************
11  REM  *
12  REM  *   DRAWING PROGRAM
14  REM  *        FOR
16  REM  *    THE HOME-BUILT
18  REM  *     SKETCH PAD
20  REM  *
22  REM  * TOM RILEY COPYRIGHT 83

24  REM  *
26  REM  ***********************

30  REM
50  TEXT : HOME
70 C1 = 191:C2 = 255:C3 = 279
80 C = 3: HCOLOR= C
90 YN$ = "":D$ =  CHR$ (4)
100  REM  *** MAIN MENU
110  GOSUB 9000: REM  INTRODUCTIO
     N
120  GOSUB 8000: REM   MAIN MENU
125 YN$ = ""
130  IF A = 1 THEN  VTAB 22: INPUT
     " ARE YOU SURE ? (Y/N) ";YN$

135  IF YN$ = "Y" THEN  HGR : TEXT

140  IF A = 2 THEN  GOSUB 2000
150  IF A = 3 THEN  GOSUB 3000
160  IF A = 4 THEN  GOSUB 4000
170  IF A = 5 THEN  GOSUB 5000
180  IF A = 6 THEN  GOSUB 6000
190  IF A = 7 THEN  HOME : END
200  GOTO 120
2000  REM  ** GET A DRAWING FROM
      DISK
2010  HOME :D$ =  CHR$ (4)
2020  HTAB 7: PRINT "GETTING A DR
      AWING FROM DISK"
2030  VTAB 7: PRINT "    GETTING
     A DRAWING WILL DESTROY"
2040  INPUT "THE DRAWING NOW IN M
     EMORY.  OK ? (Y/N) ";YN$
2060  IF  LEFT$ (YN$,1) = "N" THEN
      RETURN
2070  PRINT
2080  INPUT "    CATALOG ? (Y/N)
     ";YN$
2090  IF  LEFT$ (YN$,1) = "Y" THEN
      PRINT D$;"CATALOG"
2100  PRINT
2110  INPUT "DRAWING NAME ? ";DN$

2120  PRINT D$;"BLOAD ";DN$
2130  RETURN
2999  END

3000  REM  *** SAVE DRAWING ON DI
      SK
3010  HOME
3020  HTAB 7: PRINT "SAVE A DRAWI
      NG ON DISK"
3040  VTAB 4: INPUT "    CATALOG
      ? (Y/N) ";YN$
3050  IF YN$ = "Y" THEN  PRINT D$
      ;"CATALOG"
3060  PRINT
3070  INPUT "DRAWING NAME ? ";DN$

3080  PRINT
3090  INPUT "    IS THERE A DRAWI
      NG OF THAT NAME ON  THIS DIS
      K ? (Y/N) ";YN$
3100  IF YN$ = "Y" THEN  PRINT D$
      ;"DELETE ";DN$
3110  PRINT D$;"BSAVE ";DN$;",A$2
      000,L$2000 "
3190  RETURN
3999  END
4000  REM  *** CONTINUOUS POINT D
```

```
     RAWING
4010  TEXT : HOME
4020  HTAB 5: PRINT "DRAWING BY C
     ONTINUOUS POINTS"
4030  VTAB 5: PRINT "   THE POINT
      THE STYLUS IS ON WILL"
4040  PRINT "BE DRAWN REPEATEDLY.
     "
4045  PRINT
4050  PRINT "    THE ZERO (0) BUT
     TON WILL SHOW THE "
4060  PRINT "'X' AND 'Y' COØRDINA
     TES AND HCOLOR."
4075  PRINT
4080  PRINT "    THE NUMBERS 0 TO
      7 WILL SELECT"
4090  PRINT "HCOLOR."
4095  PRINT
4100  PRINT "   THE ORIGIN IS THE
      UPPER LEFT CORNER."
4110  PRINT "FROM LEFT TO RIGHT I
     S X = 0 TO 279."
4120  PRINT "FROM TOP TO BOTTOM I
     S Y = 0 TO 191."
4125  PRINT
4140  PRINT "   PRESS 'ESC' TO RE
     TURN TO MAIN MENU."
4150  VTAB 23: INPUT "  ( PRESS R
     ETURN )  ";YN$
4155  HOME
4200  REM   *** SETTING GRAPHICS

4210  POKE  - 16297,0: POKE  - 16
     300,0: POKE  - 16302,0: POKE
      - 16304,0
4300  REM  *** WATCHING PADDLE
4320 X =  INT ( PDL (0) * C3 / C2
     )
4330 Y =  INT ( PDL (1) * C1 / C2
     )
4340  HPLOT X,Y
4350 B0 =  PEEK ( - 16287):K =  PEEK
     ( - 16384): POKE  - 16368,0
4360  IF B0 > 127 OR K > 127 THEN
     4390
4370  GOTO 4320
4390  HOME
4400  IF B0 > 127 THEN  POKE  - 1
     6301,0: VTAB 22: PRINT "  X
     = ";X;"  Y = ";Y;"  HCOLOR =
      ";C: FOR I = 0 TO 1000: NEXT
     I: POKE  - 16302,0: GOTO 432
     0
4410  IF K = 155 THEN  RETURN
4420  GOSUB 4500
4430  GOTO 4320
4500  REM  *** CHECK HCOLOR
4510  IF K = 177 THEN C = 1: HCOLOR=
     C
4520  IF K = 178 THEN C = 2: HCOLOR=
     C
4530  IF K = 179 THEN C = 3: HCOLOR=
     C
4540  IF K = 180 THEN C = 4: HCOLOR=
     C
4550  IF K = 181 THEN C = 5: HCOLOR=
     C
4560  IF K = 182 THEN C = 6: HCOLOR=
     C
4570  IF K = 183 THEN C = 7: HCOLOR=
     C
4580  IF K = 176 THEN C = 0: HCOLOR=
     C
4999  RETURN
5000  REM   *** CONTINUOUS LINE D
     RAWING
5010  TEXT : HOME
5015  PRINT
5020  HTAB 7: PRINT "DRAWING BY C
     ONTINUOUS POINTS"
5030  VTAB 5: PRINT "    THE POIN
     T THE STYLUS IS ON WILL"
5040  PRINT "BE USED AS THE END P
     OINT OF A LINE"
5050  PRINT "DRAWN FROM THE LAST
     LINE'S END POINT."
5060  PRINT
5070  PRINT "    THE ZERO (0) BUT
     TON WILL DISPLAY"
5080  PRINT "'X' AND 'Y' COORDINA
     TES AND THE HCOLOR."
5090  PRINT
5100  PRINT "    PRESSING A NUMBE
     R 0 THROUGH 7 WILL"
5110  PRINT "CHANGE HCOLOR TO THA
     T NUMBER."
5120  PRINT
5130  PRINT "    PRESSING THE 'ES
     C' KEY WILL RETURN"
5140  PRINT "YOU TO THE MAIN MENU
     ."
5190  VTAB 23: INPUT "  ( PRESS R
     ETURN TO CONTINUE )  ";YN$
5195  HOME
5200  REM   *** SETTING GRAPHICS
5210  POKE  - 16297,0: POKE  - 16
     300,0: POKE  - 16302,0: POKE
      - 16304,0
5300  REM   *** WATCHING PADDLE

5310  REM  *** X POT 0 , Y POT 1

5320 X =  INT ( PDL (0) * C3 / C2
     )
5330 Y =  INT ( PDL (1) * C1 / C2
     )
5340 X1 = X:Y1 = Y
5350 X =  INT ( PDL (0) * C3 / C2
```

```
     )
5360 Y =  INT ( PDL (1) * C1 / C2
     )
5370  HPLOT X,Y TO X1,Y1
5380 X1 = X:Y1 = Y
5390 BØ =  PEEK ( - 16287):K =  PEEK
     ( - 16384): POKE  - 16368,Ø
5400  IF BØ > 127 OR K > 127 THEN
     5420
5410  GOTO 5350
5420  IF BØ > 127 THEN  POKE  - 1
     6301,Ø: VTAB 22: PRINT "  X
     = ";X;"  Y = ";Y;"  HCOLOR =
      ";C;"         ": FOR I = Ø TO
     1000: NEXT I: POKE  - 16302,
     Ø: GOTO 5350
5430  IF K = 155 THEN  RETURN
5440  GOSUB 4500
5510  GOTO 5350
5999  END
6000  REM  *** REFERENCE POINT LI
     NES
6010  TEXT : HOME
6030  HTAB 7: PRINT "DRAWING BY R
     EFERENCE POINTS"
6040  VTAB 3: PRINT "    THE STYL
     US AND PADDLE BUTTONS"
6050  PRINT "ARE USED TO FIND REF
     ERENCE POINTS AND"
6060  PRINT "THEN DRAW LINES BETW
     EEN THEM."
6070  PRINT
6080  PRINT "    THE ZERO (Ø) BUT
     TON DISPLAYS "
6090  PRINT "THE 'X' AND 'Y' COOR
     DINATES AND HCOLOR."
6100  PRINT
6110  PRINT "    THE ONE (1) BUTT
     ON WILL FIX THE"
6120  PRINT "STYLUS LOCATION AS A
      REFERENCE POINT."
6130  PRINT "WHEN A SECOND REFERE
     NCE POINT IS CHOSEN"
6140  PRINT "A LINE IS DRAWN BETW
     EEN THEM."
6150  PRINT
6160  PRINT "    PRESSING KEY 'C'
      CLEARS THE"
6170  PRINT "REFERENCE POINTS."
6180  PRINT
6190  PRINT "    PRESSING A NUMBE
     R BETWEEN Ø AND 7"
6200  PRINT "SELECTS HCOLOR."
6210  PRINT
6230  PRINT "    PRESSING 'ESC' R
     ETURNS YOU TO"
6240  PRINT "THE MAIN MENU."
6250  VTAB 23: INPUT "       ( PRE
     SS RETURN )  ";YN$
6260  HOME
6270  REM  *** SETTING GRAPHICS
6280  POKE  - 16297,Ø: POKE  - 16
     300,Ø: POKE  - 16302,Ø: POKE
      - 16304,Ø
6290  HOME
6300  REM  ** WATCHING PADDLES
6305 DD = Ø
6310 X =  INT ( PDL (Ø) * C3 / C2
     )
6315 Y =  INT ( PDL (1) * C1 / C2
     )
6320 BØ =  PEEK ( - 16287):B1 =  PEEK
     ( - 16286):K =  PEEK ( - 163
     84): POKE  - 16368,Ø
6330  IF BØ > 127 OR B1 > 127 OR
     K > 127 THEN 6350
6340  GOTO 6310
6350  IF BØ > 127 THEN  POKE  - 1
     6301,Ø: VTAB 22: PRINT "  X
     = ";X;"  Y = ";Y;"  HCOLOR =
      ";C;"      ": FOR I = Ø TO 1
     000: NEXT I: POKE  - 16302,Ø
     : GOTO 6310
6360  IF B1 > 127 AND DD = Ø THEN
     X1 = X:Y1 = Y:DD = 1: HPLOT
     X,Y: VTAB 23: PRINT "  REF P
     OINT 1 SELECTED": FOR I = Ø TO
     500: NEXT I: GOTO 6380
6370  IF B1 > 127 AND DD = 1 THEN
      HPLOT X1,Y1 TO X,Y:DD = Ø: FOR
     I = Ø TO 500: NEXT I: HOME
6380  IF K = 155 THEN  RETURN
6390  GOSUB 4500
6400  IF K = 195 THEN DD = Ø: HOME
     : HCOLOR= Ø: HPLOT X1,Y1: HCOLOR=
     C
6410  GOTO 6310
6999  END
8000  REM   *** MAIN MENU
8010  TEXT : HOME
8020  HTAB 14: PRINT "MAIN MENU"
8030  VTAB 5
8040  HTAB 8: PRINT "(1) CLEAR HI
     -RES SCREEN"
8045  PRINT
8050  HTAB 8: PRINT "(2) GET DRAW
     ING FROM DISK"
8055  PRINT
8060  HTAB 8: PRINT "(3) PUT DRAW
     ING ON DISK"
8065  PRINT
8070  HTAB 8: PRINT "(4) DRAW CON
     TINUOUS POINTS"
8075  PRINT
8080  HTAB 8: PRINT "(5) DRAW CON
     TINUOUS LINES"
8085  PRINT
8090  HTAB 8: PRINT "(6) DRAW REF
```

```
     ERENCE POINT LINES"
8095  PRINT
8100  HTAB 8: PRINT "(7) QUIT "
8110  VTAB 22: INPUT "  CHOOSE A
     NUMBER :  ";A
8120  IF A < 0 OR A > 7 THEN  GOTO
     8110
8130  RETURN
8999  END
9000  REM  ***    INTRODUCTION
9010  VTAB 1: HTAB 10: PRINT "SKE
     TCHING PROGRAM"
9020  HTAB 16: PRINT "FOR"
9030  HTAB 8: PRINT "HOME-BUILT S
     KETCH PAD"
9040  VTAB 5: PRINT "    THIS PRO
     GRAM WAS PREPARED FOR USE"
9050  PRINT "WITH THE HOME-BUILT
     SKETCH PAD."
9060  PRINT "IT MAY BE USED WITH
     EITHER THE SKETCH"
9070  PRINT "PAD OR ANY DOUBLE PO
     T PADDLE."
9080  PRINT
9090  PRINT "    THE MAIN MENU WI
     LL LET YOU CHOOSE"
9100  PRINT "TO DRAW IN SEVERAL D
     IFFERENT WAYS OR"
9110  PRINT "MOVE DRAWINGS ON OR
     OFF THE DISK."
9120  PRINT
9130  PRINT "    WITH A LITTLE PR
     ACTICE YOU WILL"
9140  PRINT "SOON CHOOSE WHICH WA
     Y YOU LIKE BEST."
9190  VTAB 23: INPUT " ( PRESS TH
     E RETURN KEY TO CONTINUE ) "
     ;YN$
9195  RETURN
9999  END
```

DIGITIZING

With this program you can enter data from charts and graphs directly into your computer with the Sketch Pad. The use of the program is explained in detail in chapter 4, along with the information on building the Sketch Pad.

Step by Step Through the Listing

An array is first dimensioned to hold the data in memory (line 30). The input is limited to 41 pages with 16 data points per page, but these limits may be changed depending on available memory. The disk file name is requested (lines 100 to 150): if the file is old the disk is read (lines 200 to 285) and an End of File marker is sought (line 285).

An adjustment procedure is run (lines 300 to 400) for moving the height of the upright and locating the correct position for the charts on the drawing board. The game control inputs are read and displayed (lines 400 to 490) to aid in these adjustments.

The units and limits for each axis are entered (lines 500 to 690) and scaling constants calculated (lines 660 to 690). Data taking is then begun (lines 800 to 1260), information is given (lines 810 to 830), and the format is displayed (lines 870 to 930). The game control inputs are again read and displayed (lines 1000 to 1058). If pushbutton 0 has been pressed, the data point is recorded and the index increased by 1 (line 1060). There is a short delay (line 1065). If pushbutton 1 has been pressed, execution is directed to the new sheet section (lines 1200 to 1260). If not, execution is directed back to read a new point (line 1100).

The new sheet section zeros all unused points on the current sheet (lines 1205 to 1208) and adjusts the indexes (lines 1210, 1220). If another sheet is requested (line 1250), execution returns to data taking (line 1260). If no new sheet is requested, the file-to-disk storage function is entered automatically (lines 1300 to 1520). If you want to know the structure of the disk file, it can most readily be seen from the disk storage routine (lines 1420 to 1510). The disk file structure can be adjusted to suit your needs.

Variables

Variable	Line	Description
PT%	30	An integer array of the data point readings
D$	50	Control D
PTN	60	The number of the point
SN	60	The number of the sheet
F$	140	The name of the disk file for the data
YN$	160	The answer to YES/NO questions
Q$	180	A second YES/NO answer
UX$	232	Units of the X axis
UY$	232	Units of the Y axis
X0V	234	Value of the 0 point on the X axis
XMV	234	Value of the 255 point on the X axis
Y0V	234	Value of the 0 point on the Y axis
YMV	234	Value of the 255 point on the Y axis
EOF$	270	End of File marker
X	410	Reading of game control 0
P0B	440	Reading of pushbutton 0
Y	460	Reading of game control 1
AX	660	Conversion ratio for X axis
AY	680	Conversion ratio for Y axis
XV	1020	Current value of X
YV	1055	Current value of Y

```
10  REM  ***********************
12  REM  *
14  REM  * DIGITIZER
16  REM  *
18  REM  * TOM RILEY COPYRRIGHT 8
    3
20  REM  *
22  REM  ***********************
24  REM
30  DIM PT%(4Ø,2,15)
35  REM  ** LIMITS: 41 PAGES WITH
     16 DATA POINTS PER PAGE
5Ø D$ =  CHR$ (4)
6Ø PTN = 1:SN = Ø
1ØØ  REM  *** NAME OF FILE
11Ø  HOME
12Ø  PRINT "    DIGITIZING WITH SK
     ETCH PAD"
13Ø  PRINT : PRINT
14Ø  INPUT "NAME OF FILE ? ";F$
15Ø  PRINT
16Ø  INPUT "IS THIS A NEW FILE ?
     (Y OR N) ";YN$
17Ø  PRINT
175  IF YN$ = "Y" THEN  GOTO 3ØØ
18Ø  INPUT "IS DISK WITH THIS FIL
     E IN THE DRIVE ? ";Q$
185  PRINT
19Ø  IF Q$ = "N" THEN  PRINT "PUT
      THE CORRECT DISK INTO THE D
     RIVE.": GOTO 17Ø
2ØØ  REM  ** READING FILE FROM DI
     SK
21Ø  PRINT D$;"OPEN ";F$
22Ø  PRINT D$;"READ ";F$
23Ø  INPUT SN
232  INPUT UX$: INPUT UY$
234  INPUT XØV,XMV,YØV,YMV
```

```
235  FOR R = Ø TO SN
240  FOR S = Ø TO 1
245  FOR T = Ø TO 15
250  INPUT PT%(R,S,T)
260  NEXT : NEXT : NEXT
270  INPUT EOF$
280  PRINT D$;"CLOSE ";F$
285  IF EOF$ <  > "EOF" THEN  PRINT
     "FILE READING ERROR ": END
300  REM  *** ADJUST SKETCH PAD
310  HOME
320  PRINT "   ADJUST SKETCH PAD"

330  PRINT : PRINT
340  PRINT "       USE THE X AND Y
     READINGS BELOW"
350  PRINT "TO ADJUST THE LOCATIO
     N OF THE SHEET"
360  PRINT "AND THE HEIGHT OF THE
      UPRIGHT."
370  PRINT
380  PRINT "       PRESS PBØ TO CON
     TINUE."
390  VTAB 16: PRINT "      X =
         Y ="
400  REM  * READ PADDLES
410 X =  PDL (Ø)
420  VTAB 16: HTAB 1Ø: PRINT "
     ";
430  HTAB 1Ø: PRINT X
440 PØB =  PEEK ( - 16287)
450  IF PØB > 127 THEN  GOTO 5ØØ
460 Y =  PDL (1)
470  VTAB 16: HTAB 2Ø: PRINT "
     ";
480  HTAB 2Ø: PRINT Y
490  GOTO 41Ø
500  REM  ** SCALE INFORMATION
510  HOME
520  PRINT "SCALING INFORMATION "

530  PRINT
540  INPUT "UNITS OF X AXIS ? ";U
     X$
550  PRINT
560  INPUT "VALUE FOR X=Ø ? ";XØV

570  INPUT "VALUE FOR X MAX. ? ";
     XMV
580  IF XØV = XMV THEN  GOTO 55Ø
590  PRINT
600  INPUT "UNITS FOR Y AXIS ? ";
     UY$
610  PRINT
620  INPUT "VALUE FOR Y=Ø ? ";YØV

630  INPUT "VALUE FOR Y MAX. ? ";
     YMV
640  IF YØV = YMV THEN  GOTO 61Ø
650  PRINT
660 AX = (XMV - XØV) / 255
670 AX =  INT (AX * 1ØØØ) / 1ØØØ
680 AY = (YMV - YØV) / 255
690 AY =  INT (AY * 1ØØØ) / 1ØØØ
800  REM  *** TAKE DATA
810  HOME
820  PRINT "PRESS PBØ TO TAKE DAT
     A"
830  PRINT "PRESS PB1 TO START NE
     W SHEET"
870  PRINT
875  PRINT "SHEET NUMBER =  ";SN
877  PRINT
880  PRINT "            X     Y";
885  HTAB 2Ø: PRINT "X-";UX$;: HTAB
     3Ø: PRINT "Y-";UY$
890  PRINT
900  FOR N = 1 TO 15
910  PRINT " PT ";N;" =  Ø"
920  NEXT N
930  VTAB 24: PRINT "      X =
      Y =     ";
1000  REM   * READ PADDLES
1010 X =  PDL (Ø)
1020 XV = AX * X + XØV
1025 XV =  INT (XV * 1ØØØ) / 1ØØØ

1030 PØB =  PEEK ( - 16287)
1040 P1B =  PEEK ( - 16286)
1045  VTAB 24: HTAB 1Ø: PRINT "
      ";
1047  HTAB 1Ø: PRINT X;
1050 Y =  PDL (1)
1055 YV = AY * Y + YØV
1056 YV =  INT (YV * 1ØØØ) / 1ØØØ

1057  HTAB 2Ø: PRINT "    ";
1058  HTAB 2Ø: PRINT Y;
1060  IF PØB > 127 THEN PT%(SN,Ø,
     PTN) = X:PT%(SN,1,PTN) = Y: VTAB
     (7 + PTN): HTAB 1Ø: PRINT X;
     : HTAB 14: PRINT Y;: HTAB 2Ø
     : PRINT XV;: HTAB 3Ø: PRINT
     YV:PTN = PTN + 1
1065  FOR N = 1 TO 2ØØ: NEXT
1070  IF P1B > 127 OR PTN > 15 THEN
      GOTO 12ØØ
1100  GOTO 1ØØØ
1200  REM  ** NEW SHEET
1203  IF PTN >  = 15 THEN  GOTO 1
     21Ø
1205  FOR N = PTN TO 15
1207 PT%(SN,Ø,N) = Ø:PT%(SN,1,N) =
     Ø
1208  NEXT
1210 SN = SN + 1
1220 PTN = 1
1240  PRINT " ": VTAB 23
```

```
1250  INPUT "ANOTHER SHEET ? (Y O
    R N) ";YN$
1260  IF YN$ = "Y" GOTO 8ØØ
1300  REM  ** SAVE FILE TO DISK
1310  HOME
1320  PRINT "    SAVE FILE TO DIS
    K"
1330  PRINT
1340  INPUT "IS STORAGE DISK IN T
    HE DRIVE ? ";YN$
1350  PRINT
1360  IF YN$ = "N" THEN  PRINT "P
    LACE THE STORAGE DISK IN THE
     DRIVE.": GOTO 133Ø
1370  PRINT
1380  INPUT "IS THIS A NEW FILE O
    N THIS DISK ? ";YN$
1390  PRINT
14ØØ  IF YN$ = "N" THEN  PRINT D$
    ;"DELETE ";F$
141Ø  PRINT
142Ø  PRINT D$;"OPEN ";F$
143Ø  PRINT D$;"WRITE ";F$
144Ø  PRINT SN
1444  PRINT UX$: PRINT UY$
1446  PRINT XØV: PRINT XMV: PRINT
    YØV: PRINT YMV
145Ø  FOR R = Ø TO SN
146Ø  FOR S = Ø TO 1
147Ø  FOR T = Ø TO 15
148Ø  PRINT PT%(R,S,T)
149Ø  NEXT : NEXT : NEXT
15ØØ  PRINT "EOF"
151Ø  PRINT D$;"CLOSE ";F$
152Ø  GOTO 6Ø
9999  END
```

ANNUNCIATOR TEST

With the Annunciator Test program you can test new controllers that use the Apple's four annunciator outputs (pins 13, 14, 15, 16) or the strobe (pin 5). One such device is the Computer Controlled AC Outlet, described in chapter 12. The test program turns these outputs on and off at a slow, steady pace and shows their status on the screen. You can then compare the output of your new controller with the status of the computer's output.

Step by Step Through the Listing

Execution is first directed (line 15) to the start up subroutine (lines 500 to 590), which displays the format on the screen. Each annunciator in turn is switched off, with a pause between each step (lines 20 to 85). They are turned on again in sequence, and the keyboard bell is sounded (lines 100 to 170) to indicate that a sequence is complete.

The strobe is pulsed and a count kept of the total number of pulses (lines 180 to 190). The entire process is then repeated in an endless loop (line 200).

Variables

Variable	Line	Description
Z	180	Dummy variable for pulsing strobe
SC	185	Count of total strobe pulses
BEL$	515	Control G, which rings bell

```
1  REM  ************************
2  REM  *
3  REM  * ANNUNCIATOR CHECKOUT
4  REM  *
5  REM  * TOM RILEY COPYRIGHT 83
6  REM  *
7  REM  ************************
8  REM
15  GOSUB 500
20  POKE  - 16296,1
25  VTAB 8: HTAB 18: PRINT "OFF"
30  GOSUB 1000
40  POKE  - 16294,1
45  VTAB 10: HTAB 18: PRINT "OFF"

50  GOSUB 1000
60  POKE  - 16292,1
65  VTAB 12: HTAB 18: PRINT "OFF"

70  GOSUB 1000
80  POKE  - 16290,1
85  VTAB 14: HTAB 18: PRINT "OFF"

90  GOSUB 1000
100  POKE  - 16295,0
105  VTAB 8: HTAB 18: PRINT "ON "
  ;BEL$
110  GOSUB 1000
120  POKE  - 16293,0
125  VTAB 10: HTAB 18: PRINT "ON
  ";BEL$
130  GOSUB 1000
140  POKE  - 16291,0
145  VTAB 12: HTAB 18: PRINT "ON
  ";BEL$
150  GOSUB 1000
160  POKE  - 16289,0
165  VTAB 14: HTAB 18: PRINT "ON
  ";BEL$
170  GOSUB 1000
180 Z =  PEEK ( - 16320)
185 SC = SC + 1
190  VTAB 16: HTAB 21: PRINT SC
200  GOTO 20
500  REM  *** START UP
510  TEXT : HOME
515 SC = 0:BEL$ =  CHR$ (7): REM
   CONTROL G - BELL
520  VTAB 4: HTAB 8: PRINT "ANNUN
  CIATIOR TEST"
530  VTAB 8: HTAB 10: PRINT "AN0
  IS "
540  VTAB 10: HTAB 10: PRINT "AN1
  IS "
550  VTAB 12: HTAB 10: PRINT "AN2
  IS "
560  VTAB 14: HTAB 10: PRINT "AN3
  IS "
570  VTAB 16: HTAB 5: PRINT "STRO
  BE COUNT IS "
590  RETURN
1000  REM  *** DELAY
1010  FOR I = 1 TO 400
1020  NEXT I
1030  RETURN
9999  END
```

Computers/Apple and Atari

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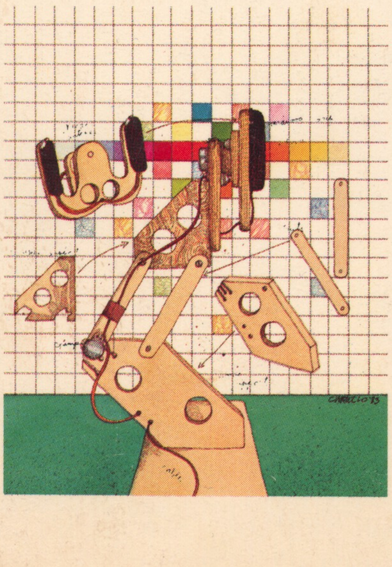

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