Station Setup and Accessory Projects

22

Although many hams never try to build a major project, such as a transmitter, receiver or amplifier, they do have to assemble the various components into a working station. There are many benefits to be derived from assembling a safe, comfortable, easy-to-operate collection of radio gear, whether the shack is at home, in the car or in a field. This chapter, written by Wally Blackburn, AA8DX, covers the many aspects of setting up an efficient station.

This chapter will detail some of the "how tos" of setting up a station for fixed, mobile and portable operation. Such topics as station location, finding adequate power sources, station layout and cable routing are covered, along with some of the practical aspects of antenna erection and maintenance.

Regardless of the type of installation you are attempting, good planning greatly increases your chances of success. Take the time to think the project all the way through, consider alternatives, and make rough measurements and sketches during your planning and along the way. You will save headaches and time by avoiding "shortcuts." What might seem to save time now may come back to haunt you with extra work when you could be enjoying your shack.

One of the first considerations should be to determine what type of operating you intend to do. While you do not want to strictly limit your options later, you need to consider what you want to do, how much you have to spend and what room you have to work with. There is a big difference between a casual operating position and a "big gun" contest station, for example.

Fixed Stations

SELECTING A LOCATION

Selecting the right location for your station is the first and perhaps the most important step in assembling a safe, comfortable, convenient station. The exact location will depend on the type of home you have and how much space can be devoted to your station. Fortunate amateurs will have a spare room to devote to housing the station; some may even have a separate building for their exclusive use. Most must make do with a spot in the cellar or attic, or a corner of the living room is pressed into service.

Examine the possibilities from several angles. A station should be comfortable; odds are good that you'll be spending a lot of time there over the years. Some unfinished basements are damp and drafty—not an ideal environment for several hours of leisurely hamming. Attics have their drawbacks, too; they can be stifling during warmer months. If possible, locate your station away from the heavy traffic areas of your home. Operation of your station should not interfere with family life. A night of chasing DX on 80 m may be exciting to you, but the other members of your household may not share your enthusiasm.

Keep in mind that you must connect your station to the outside world. The location you choose should be convenient to a good power source and an adequate ground. If you use a computer and modem, you may need access to a telephone jack. There should be a fairly direct route to the outside for running antenna feed lines, rotator control cables and the like.

Although most homes will not have an "ideal" space meeting all requirements, the right location for you will be obvious after you scout around. The amateurs whose stations are depicted in **Figs 22.1** through **22.3** all found the right spot for them. Weigh the trade-offs and decide which features you can do without and which are necessary for your style of operation. If possible pick an area large enough for future expansion.

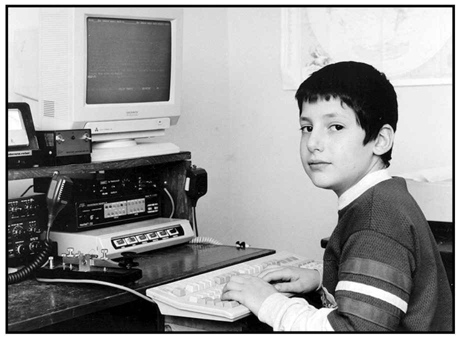


Fig 22.1—Danny, KD4HQV, appreciates the simplicity that his operating position affords. ***(Photo courtesy Conard Murray, WS4S)***

THE STATION GROUND

Grounding is an important factor in overall station safety, as detailed in the **Safety** chapter. An effective ground system is

Fig 22.2—VE6AFO's QSL card reveals an impressive array of gear. Although many hams would appreciate having this much space to devote to a station, most of us must make do with less.

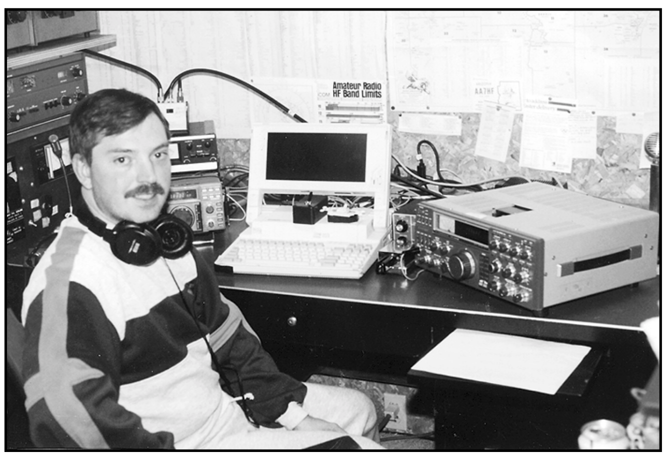


Fig 22.3—Scott, KA9FOX, operated this well laid-out station, W9UP, during a recent contest. ***(Photo courtesy N0BSH)***

necessary for every amateur station. The mission of the ground system is twofold. First, it reduces the possibility of electrical shock if something in a piece of equipment should fail and the chassis or cabinet becomes "hot." If connected to a properly grounded outlet, a three-wire electrical system grounds the chassis. Much amateur equipment still uses the ungrounded two-wire system, however. A ground system to prevent shock hazards is generally referred to as *dc ground*.

The second job the ground system must perform is to provide a low-impedance path to ground for any stray RF current inside the station. Stray RF can cause equipment to malfunction and contributes to RFI problems. This low-impedance path is usually called *RF ground*. In most stations, dc ground and RF ground are provided by the same system.

Ground Noise

Noise in ground systems can affect our sensitive radio equipment. It is usually related to one of three problems:

1) Insufficient ground conductor size
2) Loose ground connections
3) Ground loops

These matters are treated in precise scientific research equipment and certain industrial instruments by attention to certain rules. The ground conductor should be at least as large as the largest conductor in the primary power circuit. Ground conductors should provide a solid connection to both ground and to the equipment being grounded. Liberal use of lock washers and star washers is highly recommended. A loose ground connection is a tremendous source of noise, particularly in a sensitive receiving system.

Ground loops should be avoided at all costs. A short discussion of what a ground loop is and how to avoid them may lead you down the proper path. A ground loop is formed when more than one ground current is flowing in a single conductor. This commonly occurs when grounds are "daisy-chained" (series linked). The correct way to ground equipment is to bring all ground conductors out radially from a common point to either a good driven earth ground or a cold-water system. If one or more earth grounds are used, they should be bonded back to the service entrance panel. Details appear in the **Safety** chapter.

Ground noise can affect transmitted and received signals. With the low audio levels required to drive amateur transmitters, and the ever-increasing sensitivity of our receivers, correct grounding is critical.

STATION POWER

Amateur Radio stations generally require a 120-V ac power source. The 120-V ac is then converted to the proper ac or dc levels required for the station equipment. Power supply theory is covered in the **Power Supplies** chapter, and safety issues are covered in the **Safety** chapter. If your station is located in a room with electrical outlets, you're in luck. If your station is located in the basement, an attic or another area without a convenient 120-V source, you will have to run a line to your operating position.

Surge Protection

Typically, the ac power lines provide an adequate, well-regulated source of electrical power for most uses. At the same time, these lines are fraught with frequent power surges that, while harmless to most household equipment, may cause damage to more sensitive devices such as computers or test equipment. A common method of protecting these devices is through the use of surge protectors. More information on these and lightning protection is in the **Safety** chapter.

STATION LAYOUT

Station layout is largely a matter of personal taste and needs. It will depend mostly on the amount of space available, the equipment involved and the types of operating to be done. With these factors in mind, some basic design considerations apply to all stations.

The Operating Table

The operating table may be an office or computer desk, a kitchen table or a custom-made bench. What you use will depend on space, materials at hand and cost. The two most important considerations are height and size of the top. Most commercial desks are about 29 inches above the floor. This is a comfortable height for most adults. Heights much lower or higher than this may cause an awkward operating position.

The dimensions of the top are an important consideration. A deep (36 inches or more) top will allow plenty of room for equipment interconnections along the back, equipment about midway and room for writing toward the front. The length of the top will depend on the amount of equipment being used. An office or computer desk makes a good operating table. These are often about 36 inches deep and 60 inches wide. Drawers can be used for storage of logbooks, headphones, writing materials, and so on. Desks specifically designed for computer use often have built-in shelves that can be used for equipment stacking. Desks of this type are available ready-to-assemble at most discount and home improvement stores. The low price and adaptable design of these desks make them an attractive option for an operating position. An example is shown in **Fig 22.4.**

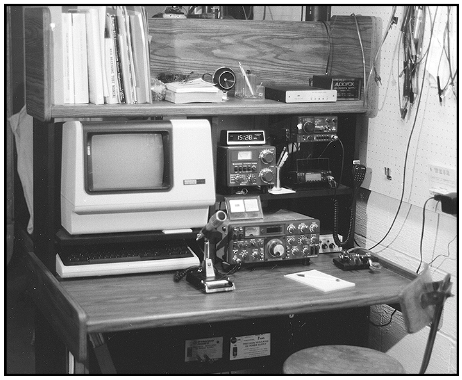


Fig 22.4—The basement makes a good location if it is dry. A ready-to-assemble computer desk makes an ideal operating table at a reasonable price. This setup belongs to WK8H. *(Photo courtesy AA8DX)*

Stacking Equipment

No matter how large your operating table is, some vertical stacking of equipment may be necessary to allow you to reach everything from your chair. Stacking pieces of equipment directly on top of one another is not a good idea because most amateur equipment needs air flow around it for cooling. A shelf like that shown in **Fig 22.5** can improve equipment layout in many situations. Dimensions of the shelf can be adjusted to fit the size of your operating table.

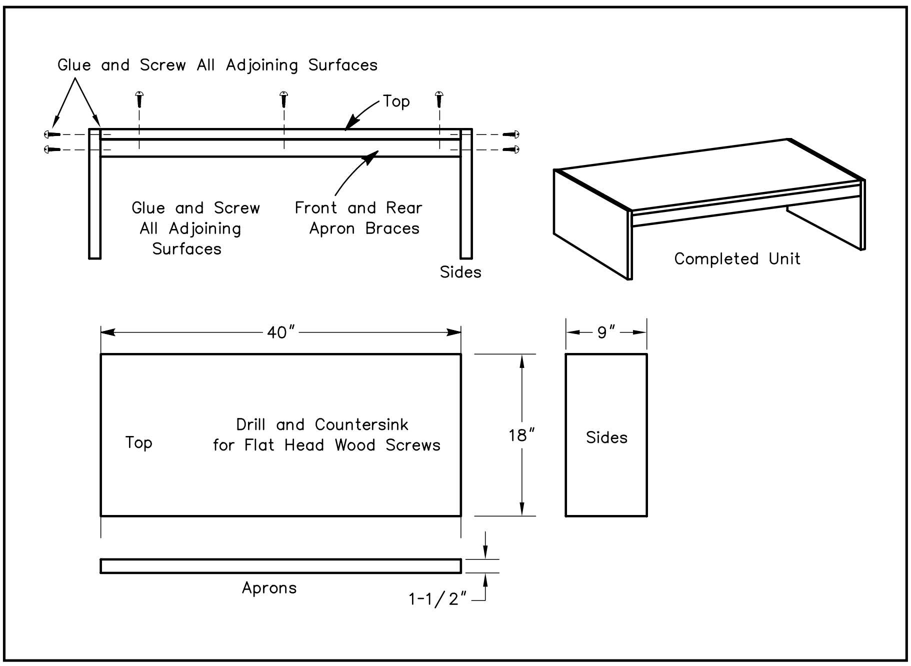


Fig 22.5—A simple but strong equipment shelf can be built from readily available materials. Use $^3/_4$-inch plywood along with glue and screws for the joints for adequate strength.

Arranging the Equipment

When you have acquired the operating table and shelving for your station, the next task is arranging the equipment in a convenient, orderly manner. The first step is to provide power outlets and a good ground as described in a previous section. Be conservative in estimating the number of power outlets for your installation; radio equipment has a habit of multiplying with time, so plan for the future at the outset.

Fig 22.6 illustrates a sample station layout. The rear of the operating table is spaced about 1 1/2 ft from the wall to allow easy access to the rear of the equipment. This installation incorporates two separate operating positions, one for HF and one for VHF. When the operator is seated at the HF operating position, the keyer and transceiver controls are within easy reach. The keyer, keyer paddle and transceiver are the most-often adjusted pieces of equipment in the station. The speaker is positioned right in front of the operator for the best possible reception. Accessory equipment not often adjusted, including the amplifier, antenna switch and rotator control box, is located on the shelf above the transceiver. The SWR/power meter and clock, often consulted but rarely touched, are located where the operator can view them without head movement. All HF-related equipment can be reached without moving the chair.

This layout assumes that the operator is right-handed. The keyer paddle is operated with the right hand, and the keyer speed and transceiver controls are operated with the left hand. This setup allows the operator to write or send with the right hand without having to cross hands to adjust the controls. If the operator is left-handed, some repositioning of equipment is necessary, but the idea is the same. For best results during CW operation, the paddle should be weighted to keep it from "walking" across the table. It should be oriented such that the operator's entire arm from wrist to elbow rests on the table top to prevent fatigue.

Some operators prefer to place the station transceiver on the shelf to leave the table top clear for

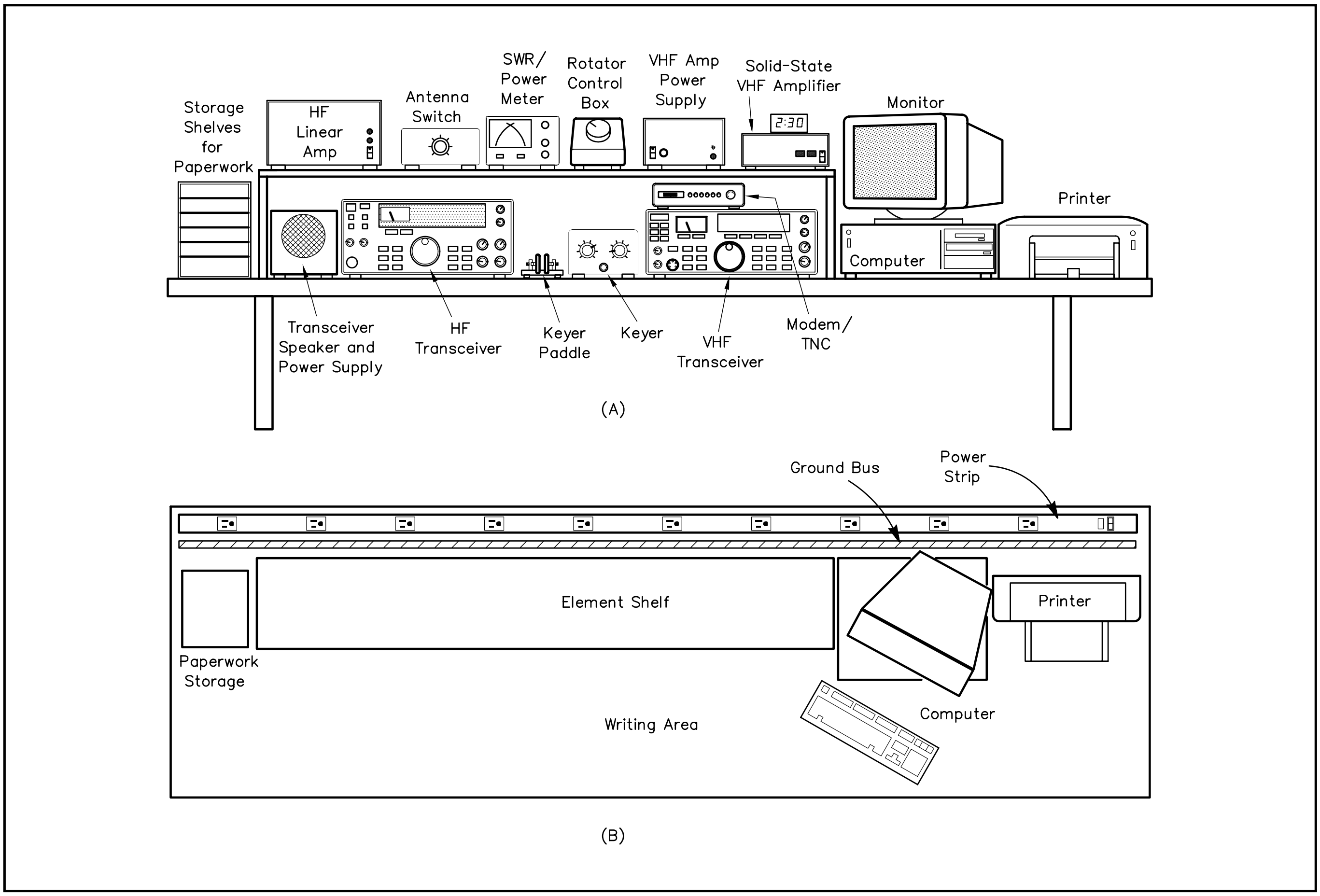


Fig 22.6—Example station layout as seen from the front (A) and the top (B). The equipment is spaced far enough apart that air circulates on all sides of each cabinet.

writing. This arrangement leads to fatigue from having an unsupported arm in the air most of the time. If you rest your elbows on the table top, they will quickly become sore. If you rarely operate for prolonged periods, however, you may not be inconvenienced by having the transceiver on the shelf. The real secret to having a clear table top for logging, and so on, is to make the operating table deep enough that your entire arm from elbow to wrist rests on the table with the front panels of the equipment at your fingertips. This leaves plenty of room for paperwork, even with a microphone and keyer paddle on the table.

The VHF operating position in this station is similar to the HF position. The amplifier and power supply are located on the shelf. The station triband beam and VHF beam are on the same tower, so the rotator control box is located where it can be seen and reached from both operating positions. This operator is active on packet radio on a local VHF repeater, so the computer, printer, terminal node controller and modem are all clustered within easy reach of the VHF transceiver.

This sample layout is intended to give you ideas for designing your own station. Study the photos of station layouts presented here, in other chapters of this *Handbook* and in *QST*. Visit the shacks of amateur friends to view their ideas. Station layout is always changing as you acquire new gear, dispose of old gear, change operating habits and interests or become active on different bands. Configure the station to suit your interests, and keep thinking of ways to refine the layout. **Figs 22.7** and **22.8** show station arrangements tailored for specific purposes.

Equipment that is adjusted frequently sits on the table top, while equipment requiring infrequent adjustment is perched on a shelf. All equipment is positioned so the operator does not have to move the chair to reach anything at the operating position.

Aids for Hams with Disabilities

A station used by an amateur with physical disabilities or sensory impairments may require adapted equipment or particular layout considerations. The station may be highly customized to meet the operator's needs or just require a bit of "tweaking."

The myriad of individual needs makes describing all of the possible adaptive methods impractical. Each situation must be approached individually, with consideration to the operator's particular needs.

However, many types of situations have already been encountered and worked through by others, eliminating the need to start from scratch in every case.

An excellent resource is the Courage Handi-Ham System. The Courage Handi-Ham System, a part of the Courage Center, provides a number of services to hams (and aspiring hams) with disabilities. These include study materials, equipment loans, adapted equipment, a newsletter and much more. Information needed to reach the Courage Handi-Hams is in the **References** chapter.

INTERCONNECTING YOUR EQUIPMENT

Once you have your equipment and get it arranged, you will have to interconnect it all. No matter how simple the station, you will at least have antenna, power and microphone or key connections. Equipment such as amplifiers, computers, TNCs and so on add complexity. By keeping your equipment interconnections well organized and of high quality, you will avoid problems later on.

Fig 22.7—It was back to basics for Elias, K4IX, during a recent Field Day.

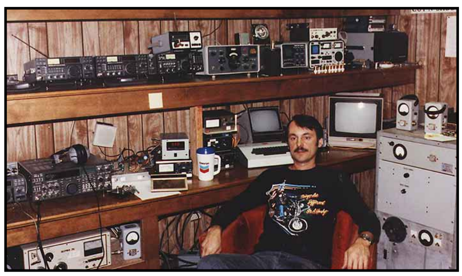


Fig 22.8—Richard, WB5DGR, uses a homebrew 1.5-kW amplifier to seek EME contacts from this nicely laid out station.

Often, ready-made cables will be available. But in many cases you will have to make your own cables. A big advantage of making your own cables is that you can customize the length. This allows more flexibility in arranging your equipment and avoids unsightly extra cable all over the place. Many manufacturers supply connectors with their equipment along with pinout information in the manual. This allows you to make the necessary cables in the lengths you need for your particular installation.

Always use high quality wire, cables and connectors in your shack. Take your time and make good mechanical and electrical connections on your cable ends. Sloppy cables are often a source of trouble. Often the problems they cause are intermittent and difficult to track down. You can bet that they will crop up right in the middle of a contest or during a rare DX QSO! Even worse, a poor quality connection could cause RFI or even create a fire hazard. A cable with a poor mechanical connection could come loose and short a power supply to ground or apply a voltage where it should not be. Wire and cables should have good quality insulation that is rated high enough to prevent shock hazards.

Interconnections should be neatly bundled and labeled. Wire ties, masking tape or paper labels with string work well. See **Fig 22.9**. Whatever method you use, proper labeling makes disconnecting and reconnecting equipment much easier. **Fig 22.10** illustrates the number of potential interconnections in a modern, full-featured transceiver.

Wire and Cable

The type of wire or cable to use depends on the job at hand. The wire must be of sufficient size to carry the necessary current. Use the tables in the **Component Data** chapter to find this information. Never use underrated wire; it will be a fire hazard. Be sure to check the insulation too. For high-voltage applications, the insulation must be rated at least a bit higher than the intended voltage. A good rule of thumb is to use a rating at least twice what is needed.

Use good quality coaxial cable of sufficient size for connecting transmitters, transceivers, antenna switches, antenna tuners and so on. RG-58 might be fine for a short patch between your transceiver and SWR bridge, but is too small to use between your legal-limit amplifier and Transmatch.

Hookup wire may be stranded or solid. Generally, stranded is a better choice since it is less prone to break under repeated flexing. Many applications require shielded wire to reduce the chances of RF getting into the equipment. RG-174 is a good choice for control, audio and some low-power applications. Shielded microphone or computer cable can be used where more conductors are necessary. For more information, see the **Transmission Lines** chapter.

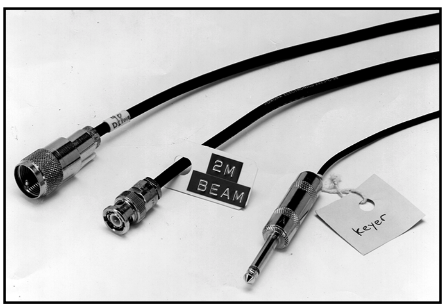


Fig 22.9—Labels on the cables make it much easier to rearrange things in the station. Labeling ideas include masking tape, cardboard labels attached with string and labels attached to fasteners found on plastic bags (such as bread bags).

Fig 22.10—The back of this Ten-Tec Omni VI HF transceiver shows some of the many types of connectors encountered in the amateur station. Note that this variety is found on a single piece of equipment. *(Photo courtesy AA8DX)*

Connectors

While the number of different types of connectors is mind-boggling, many manufacturers of amateur equipment use a few standard types. If you are involved in any group activities such as public service or emergency-preparedness work, check to see what kinds of connectors others in the group use and standardize connectors wherever possible. Assume connectors are not waterproof, unless you specifically buy one clearly marked for outdoor use (and assemble it correctly).

Audio, Power and Control Connectors

The simplest form of connector is found on terminal blocks. Although it is possible to strip the insulation from wire and wrap it around the screw, this method is not ideal. The wire tends to "squirm" out from under the screw when tightening, allowing strands to hang free, possibly shorting to other screws.

Terminal lugs, such as those in **Fig 22.11**, solve the problem. These lugs may be crimped (with the proper tool), soldered or both. Terminal lugs are available in different sizes. Use the appropriate size for your wire to get the best results.

Some common multipin connectors are shown in **Fig 22.12**. The connector in Fig 22.12A is often referred to as a "Cinch-Jones connector." It is frequently used for connections to power supplies from various types of equipment. Supplying from two to eight conductors, these connectors are keyed so that they go together only one way. They offer good mechanical and electrical connections, and the pins are large enough to handle high current. If your cable is too small for the strain relief fitting, build up the outer jacket with a few layers of electrical tape until the strain relief clamps securely. The strain relief will keep your wires from breaking away under flexing or from a sudden tug on the cable.

The plug in Fig 22.12B is usually called a "molex" connector. This plug consists of an insulated outer shell that houses the individual male or female "fingers." Each finger is individually soldered or crimped onto a conductor of the cable and inserted in the shell, locking into place. These connectors are used on many brands of amateur gear for power and accessory connections.

Fig 22.12C shows a DIN connector. Commonly having five to eight pins, these connectors are a European standard that have found favor with amateur equipment manufacturers around the world. They are generally used for accessory connections. A smaller version, the Miniature DIN, is becoming popular. It is most often used in portable gear but can be found on some full-size equipment as well.

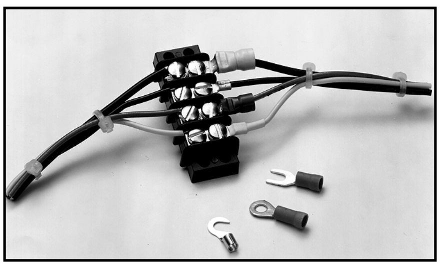
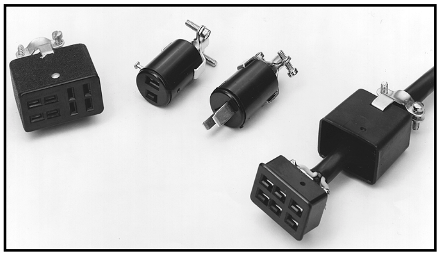
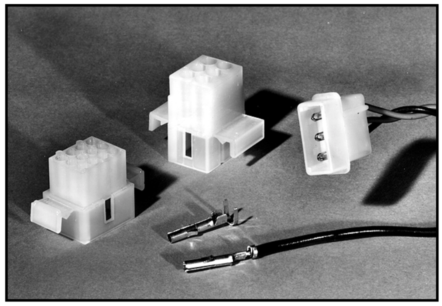


Fig 22.11—The wires on one side of this terminal block have connectors; the others do not. The connectors make it possible to secure different wire sizes to the strip and also make it much easier to change things around.



(A)



(B)

(C)

Fig 22.12—The plugs shown at A are often used to connect equipment to remote power supplies. The multipin connectors at B are used for control, signal and power lines. The DIN plug at C offers shielding and is often used for connecting accessories to transceivers.

Various types of phone plugs are shown in **Fig 22.14**. The 1/4-inch (largest) is usually used on amateur equipment for headphone and Morse key connections. They are available with plastic and metal bodies. The metal is usually a better choice because it provides shielding and is more durable.

Fig 22.14 also shows the 1/8-inch phone plug. These plugs, sometimes called miniature phone plugs, are used for earphone, external speaker, key and control lines. There is also a subminiature (3/32-inch) phone plug that is not common on amateur gear.

The phono, or RCA, plug shown in **Fig 22.15** is popular among amateurs. It is used for everything from amplifier relay-control lines, to low-voltage power lines, to low-level RF lines, to antenna lines. Several styles are available, but the best choice is the shielded type with the screw-on metal body. As with the phone plugs, the metal bodies provide shielding and are very durable.

Nowhere is there more variation than among microphone connectors. Manufacturers seem to go out of their way to use incompatible connectors! The most popular types of physical connectors are the four- and eight-pin microphone connectors shown in **Fig 22.16**. The simplest connectors provide three connections: audio, ground and push-to-talk (PTT). More complex connectors allow for such things as control lines from the microphone for frequency changes or power to the microphone for a preamplifier. When connecting a microphone to your rig, especially an aftermarket one, consult the manual. Follow the manufacturer's recommendations for best results.

If the same microphone will be used for multiple rigs with incompatible connectors, one or more adapters will be necessary. Adapters can be made with short pieces of cable and the necessary connectors at each end.

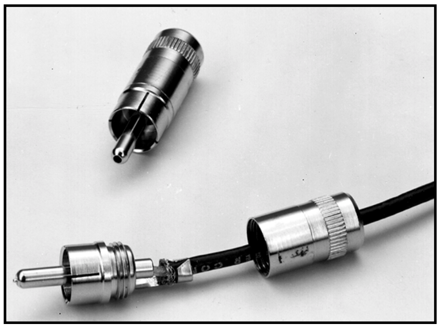


Fig 22.15—Phono plugs have countless uses around the shack. They are small and shielded; the type with the metal body is easy to grip. Be careful not to use too much heat when soldering the ground (outer) conductor—you may melt the insulation.

RF Connectors

There are many different types of RF connectors for coaxial cable, but the three most common for amateur use are the *UHF*, *Type N* and *BNC* families. The type of connector used for a specific job depends on the size of the cable, the frequency of operation and the power levels involved.

The so-called UHF connector is found on most HF and some VHF equipment. It is the only connector many hams will ever see on coaxial cable. PL-259 is another name for the UHF male, and the female is also known as the SO-239. These connectors are rated for full legal amateur power at HF. They are poor for UHF work because they do not present a constant impedance, so the UHF label is a misnomer. PL-259 connectors are designed to fit RG-8 and RG-11 size cable

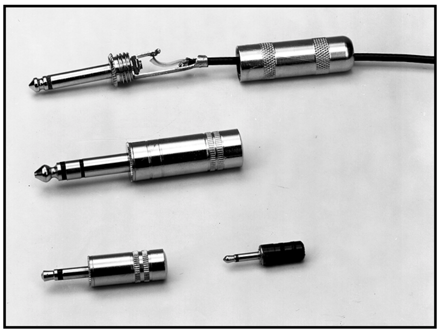


Fig 22.14—The phone-plug family. The 1/4-inch type is often used for head-phone and key connections on amateur equipment. The three-circuit version is used with stereo headphones. The mini phone plug is commonly used for connecting external speakers to receivers and transceivers. A subminiphone plug is shown in the foreground for comparison. The shielded style with metal barrel is more durable than the plastic style.

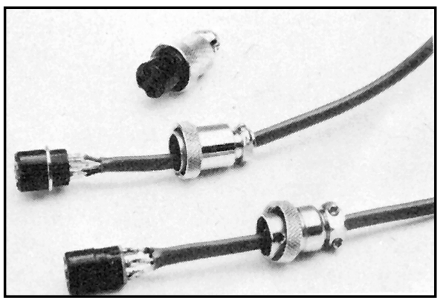


Fig 22.16—The four-pin mike connector is common on modern transmitters and receivers. More elaborate rigs use the eight-pin type. The extra conductors may be used for switches to remotely control the frequency or to power a preamplifier built into the mike case.

(0.405-inch OD). Adapters are available for use with smaller RG-58, RG-59 and RG-8X size cable. UHF connectors are not weatherproof.

Fig 22.17 shows how to install the solder type of PL-259 on RG-8 cable. Proper preparation of the cable end is the key to success. Follow these simple steps. Measure back about $^3/_4$-inch from the cable end and slightly score the outer jacket around its circumference. With a sharp knife, cut through the outer jacket, through the braid, and through the dielectric, right down to the center conductor. Be careful not to score the center conductor. Cutting through all outer layers at once keeps the braid from separating. Pull the severed outer jacket, braid and dielectric off the end of the cable as one piece. Inspect the area around the cut, looking for any strands of braid hanging loose and snip them off. There won't be any if your knife was sharp enough. Next, score the outer jacket about $^5/_{16}$-inch back from the first cut. Cut through the jacket lightly; do not score the braid. This step takes practice. If you score the braid, start again. Remove the outer jacket.

Tin the exposed braid and center conductor, but apply the solder sparingly and avoid melting the dielectric. Slide the coupling ring onto the cable. Screw the connector body onto the cable. If you prepared the cable to the right dimensions, the center conductor will protrude through the center pin, the braid will show through the solder holes, and the body will actually thread onto the outer cable jacket.

Solder the braid through the solder holes. Solder through all four holes; poor connection to the braid is the most common form of PL-259 failure. A good connection between connector and braid is just as important as that between the center conductor and connector. Use a large soldering iron for this job. With practice, you'll learn how much heat to use. If you use too little heat, the solder will bead up, not really flowing onto the connector body. If you use too much heat, the dielectric will melt, letting the braid and center conductor touch. Most PL-259s are nickel plated, but silver-plated connectors are much easier to solder and only slightly more expensive.

Solder the center conductor to the center pin. The solder should flow on the inside, not the outside, of the center pin. If you wait until the connector body cools off from soldering the braid, you'll have less trouble with the dielectric melting. Trim the center conductor to be even with the end of the center pin. Use a small file to round the end, removing any solder that built up on the outer surface of the center pin.

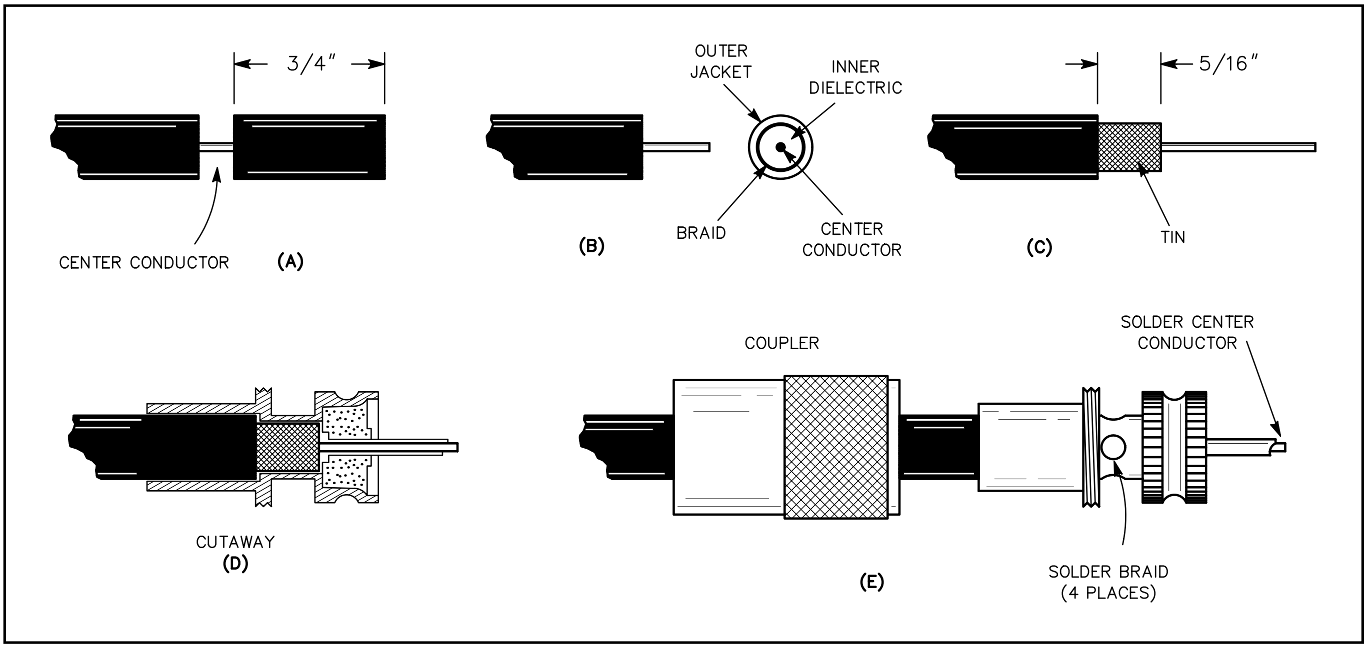


Fig 22.17—The PL-259, or UHF, connector is almost universal for amateur HF work and is popular for equipment operating in the VHF range. Steps A through E are described in detail in the text.

Use a sharp knife, very fine sandpaper or steel wool to remove any solder flux from the outer surface of the center pin. Screw the coupling ring onto the body, and you're finished.

Fig 22.18 shows two options available if you want to use RG-58 or RG-59 size cable with PL-259 connectors. The crimp-on connectors manufactured specially for the smaller cable work very well if installed correctly. The alternative method involves using adapters for the smaller cable with standard RG-8 size PL-259s. Prepare the cable as shown. Once the braid is prepared, screw the adapter into the PL-259 shell and finish the job as you would a PL-259 on RG-8 cable.

The BNC connectors illustrated in **Fig 22.19** are popular for low power levels at VHF and UHF. They accept RG-58 and RG-59 cable, and are available for cable mounting in both male and female versions. Several different styles are available, so be sure to use the dimensions for the type you have. Follow the installation instructions carefully. If you prepare the cable to the wrong dimensions, the center pin will not seat properly with connectors of the opposite gender. Sharp scissors are a big help for trimming the braid evenly.

The Type N connector, illustrated in **Fig 22.20**, is a must for high-power VHF and UHF operation. N connectors are available in male and female versions for cable mounting and are designed for RG-8

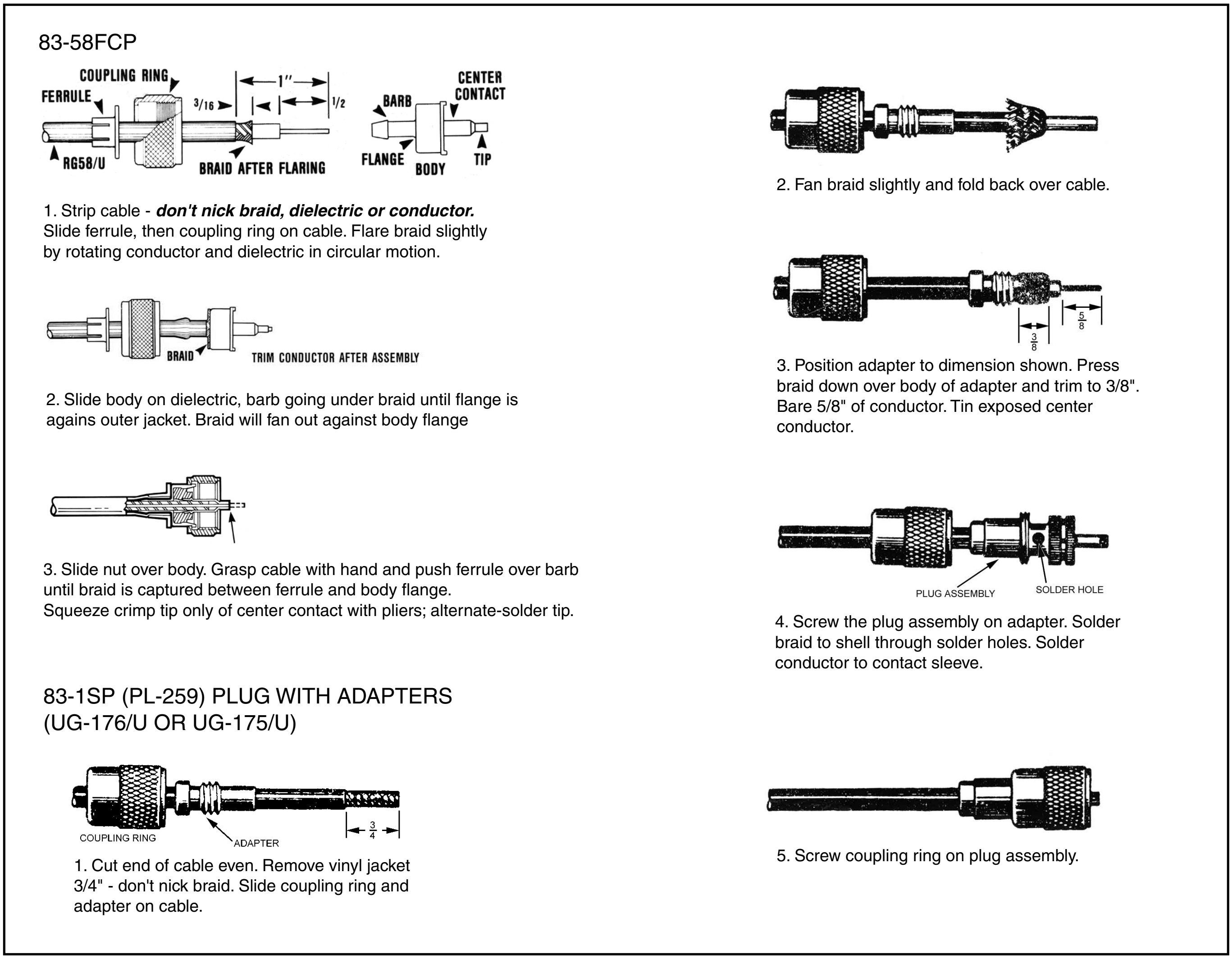
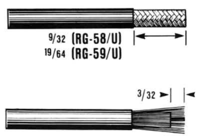


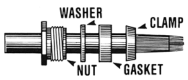
Fig 22.18—Crimp-on connectors and adapters for use with standard PL-259 connectors are popular for connecting to RG-58 and RG-59 type cable. *(Courtesy Amphenol Electronic Components, RF Division, Bunker Ramo Corp)*

BNC CONNECTORS

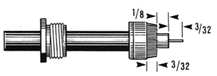
Standard Clamp



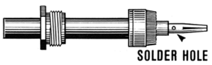
1. Cut cable even. Strip jacket. Fray braid and strip dielectric. ***Don't nick braid or center conductor.*** Tin center conductor.



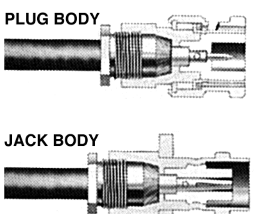
2. Taper braid. Slide nut, washer, gasket and clamp over braid. Clamp inner shoulder should fit squarely against end of jacket.



3. With clamp in place, comb out braid, fold back smooth as shown. Trim center conductor.

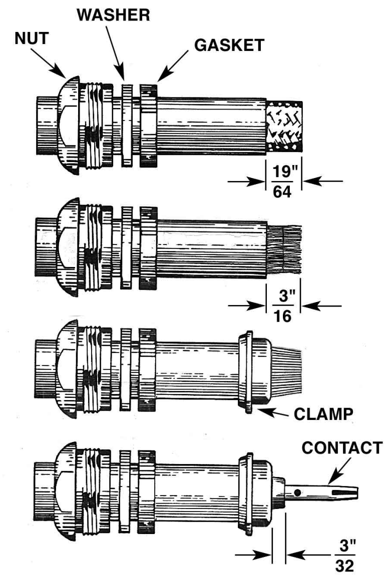


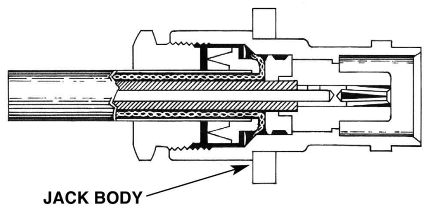
4. Solder contact on conductor through solder hole. Contact should butt against dielectric. Remove excess solder from outside of contact. Avoid excess heat to prevent swollen dielectric which would interfere with connector body.

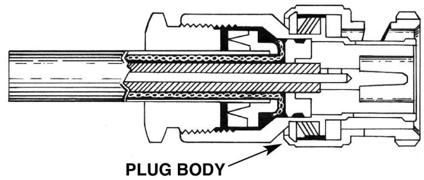


5. Push assembly into body. Screw nut into body with wrench until tight. ***Don't rotate body on cable to tighten.***

Improved Clamp

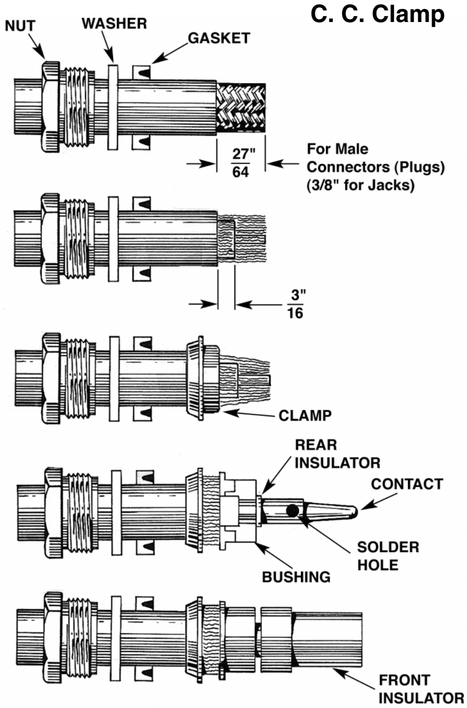


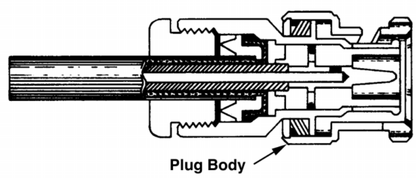




Follow 1, 2, 3 and 4 in BNC connectors (standard clamp) exceptas noted. Strip cable as shown. Slide gasket on cable *with groove facing clamp.* Slide clamp *with sharp edge facing gasket.* Clamp *should* cut gasket to seal properly.

C. C. Clamp





1. Follow steps 1, 2, and 3 as outlined for the standard-clamp BNC connector.

2. Slide on bushing, rear insulator and contact. The parts must butt securely against each other, as shown.

3. Solder the center conductor to the contact. Remove flux and excess solder.

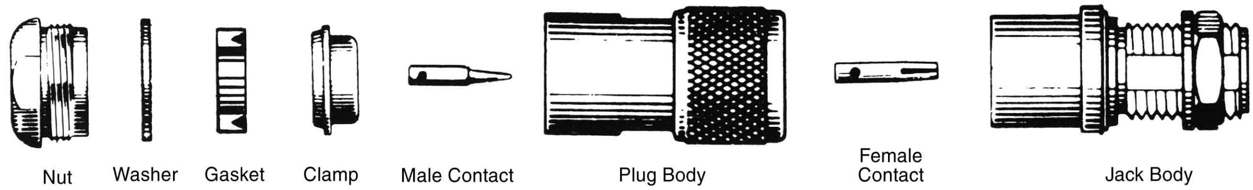
4. Slide the front insulator over the contact, making sure it butts against the contact shoulder.

5. Insert the prepared cable end into the connector body and tighten the nut. Make sure the sharp edge of the clamp seats properly in the gasket.

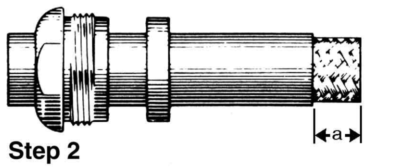
Fig 22.19—BNC connectors are common on VHF and UHF equipment at low power levels. ***(Courtesy Amphenol Electronic Components, RF Division, Bunker Ramo Corp)***

Type N assembly instructions

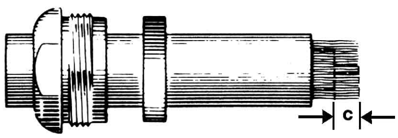
CLAMP TYPES



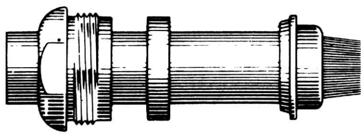
Step 1



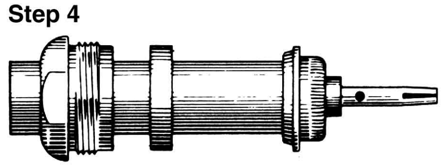
Step 2



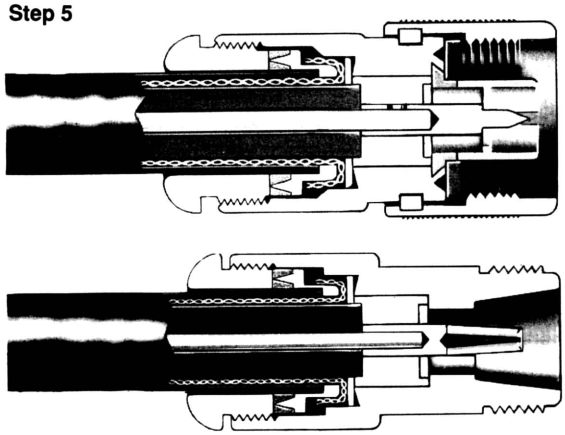
Step 3



Step 4



Step 5



Amphenol Number	Connector Type	Cable RG-/U	Strip Dims., inches (mm)	
			a	c
82-61	N Plug	8, 9, 144, 165, 213, 214, 216, 225	0.359(9.1)	0.234(6.0)
82-62	N Panel Jack	8, 9, 87A, 144, 165, 213, 214, 216, 225	0.312(7.9)	0.187(4.7)
82-63	N Jack		0.281(7.1)	0.156(4.0)
82-67	N Bulkhead Jack			
82-202	N Plug	8, 9, 144, 165, 213, 214, 216, 225	0.359(9.1)	0.234(6.0)
82-202-1006	N Plug	Belden 9913	0.359(9.1)	0.234(6.0)
82-835	N Angle Plug	8, 9, 87A, 144, 165, 213, 214, 216, 225	0.281(7.1)	0.156(4.0)
18750	N Angle Plug	58, 141, 142	0.484(12.3)	0.234(5.9)
34025	N Plug		0.390(9.9)	0.203(5.2)
34525	N Plug	59, 62, 71, 140, 210	0.410(10.4)	0.230(5.8)
35025	N Jack	58, 141, 142	0.375(9.5)	0.187(4.7)
36500	N Jack	59, 62, 71, 140, 210	0.484(12.3)	0.200(5.1)

Step 1 Place nut and gasket, with "V" groove toward clamp, over cable and cut off jacket to dim. a.

Step 2 Comb out braid and fold out. Cut off cable dielectric to dim. c as shown.

Step 3 Pull braid wires forward and taper toward center conductor. Place clamp over braid and push back against cable jacket.

Step 4 Fold back braid wires as shown, trim braid to proper length and form over clamp as shown. Solder contact to center conductor.

Step 5 Insert cable and parts into connector body. Make sure sharp edge of clamp seats properly in gasket. Tighten nut.

Fig 22.20—Type N connectors are a must for high-power VHF and UHF operation. ***(Courtesy Amphenol Electronic Components, RF Microwave Operations)***

size cable. Unlike UHF connectors, they are designed to maintain a constant impedance at cable joints. Like BNC connectors, it is important to prepare the cable to the right dimensions. The center pin must be positioned correctly to mate with the center pin of connectors of the opposite gender. Use the right dimensions for the connector style you have.

Computer Connectors

As if the array of connectors related to amateur gear were not enough, the prevalence of the computer in the shack has brought with it another set of connectors to consider. Most connections between computers and their peripherals are made with some form of multiconductor cable. Examples include shielded, unshielded and ribbon cable. Common connectors used are the 9- and 25-pin D-Subminiature connector, the DIN and Miniature DIN and the 36-pin Amphenol connector. Various edge-card connectors are used internally (and sometimes externally) on many computers. **Fig 22.21** shows a variety of computer connectors.

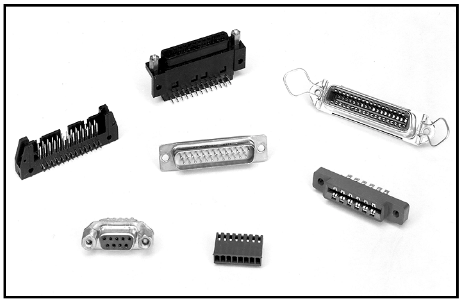


Fig 22.21—Various computer connectors.

EIA-232 Serial Connections

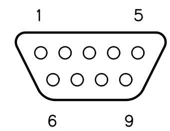
The serial port on a computer is arguably the most used, and often most troublesome, connector encountered by the amateur. The serial port is used to connect modems, TNCs, computer mice and some printers to the computer. As the name implies, the data is transmitted serially.

The EIA-232-D (commonly referred to as RS-232) standard defines a system used to send data over relatively long distances. It is commonly used to send data anywhere from a few feet to 50 feet or more. The standard specifies the physical connection and signal lines. The serial ports on most computers comply with the EIA-232-D standard only to the degree necessary to operate with common peripherals. **Fig 22.22** shows the two most common connectors used for computer serial ports. A 9-pin connector can be adapted to a 25-pin by connecting like signals. Earth ground is not provided in the 9-pin version.

Equipment connected via EIA-232-D is usually classified in one of two ways: DTE (data terminal equipment) or DCE (data communication equipment). Terminals and computers are examples of DTE, while modems and TNCs are DCE.

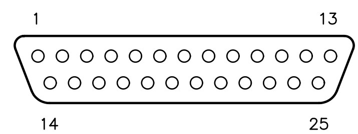
The binary data is represented by specific voltage levels on the signal line. The EIA-232-D standard specifies that a binary one is represented by a voltage ranging from –3 to –25 V. A binary zero ranges from 3 to 25 V. ±12 V is a common level in many types of equipment, but anything within the specified ranges is just as valid.

The RTS (request to send), CTS (clear to send), DTR (data terminal ready) and DSR (data set ready) lines are used for handshaking signals. These signals are used to coordinate the communication between the DTE and DCE. The RTS and DTR line are used by the DTE to indicate to the DCE that it is ready to receive data from the DCE. The DCE uses the CTS/DSR lines to signal the DTE as to



Pin	Direction	Description
1	I	Data Carrier Detect (DCD)
2	I	Receive Data (RX)
3	O	Transmit Data (TX)
4	O	Data Terminal Ready (DTR)
5	GND	Signal Ground (GND)
6	I	Data Set Ready (DSR)
7	O	Request To Send (RTS)
8	I	Clear To Send (CTS)
9	I	Ring Indicator (RI)

(A)



Pin	Direction	Description
1	GND	Earth Ground
2	O	Transmit Data (TX)
3	I	Receive Data (RX)
4	O	Request To Send (RTS)
5	I	Clear To Send (CTS)
6	I	Data Set Ready (DSR)
7	GND	Signal Ground (GND)
8	I	Data Carrier Detect (DCD)
20	O	Data Terminal Ready (DTR)
22	I	Ring Indicator (RI)

(B)

Fig 22.22—The two most common implementations of EIA-232-D serial connections on personal computers use 9- and 25-pin connectors.

whether or not it is ready to accept data. DCD (data carrier detect) is also sometimes used by the DCE to signal the DTE that an active carrier is present on the communication line. A +12-V signal represents an active handshaking signal. The equipment "drops" the line to –12 V when it is unable to receive data.

You may notice that the name "ready to send" is sort of a misnomer for the DTE since it actually uses it to signal that it is ready to receive. This is a leftover from when communication was mostly one-way—DTE to DCE. Note also that the signal names really only make sense from the DTE point of view. For example, pin 2 is called TD on both sides, even though the DCE is receiving data on that pin. This is another example of this one-way terminology.

It would be much too simple if all serial devices implemented all of the EIA-232-D specifications. Some equipment ignores some or all of the handshaking signals. Other equipment expects handshaking signals to be used as specified. Connecting these two types of equipment together will result in a frustrating situation. One side will blindly send data while the other side blindly ignores all data sent to it!

Fig 22.23 shows the different possible ways to connect equipment. Fig 22.23A shows how to connect a "normal" DTE/DCE combination. This assumes both sides correctly implement all of the handshaking signals. If one or both sides ignore handshaking signals, the connections shown in Fig 22.23B will be necessary. In this scheme, each side is sending the handshaking signals to itself. This little bit of deceit will almost always work, but handshaking signals that are present will be ineffective.

Null Modem Connections

Some equipment does not fall completely in the DTE or DCE category. Some serial printers, for example, act as DCE while others act as DTE. Whenever a DTE/DTE or DCE/DCE connection is needed a special connection, known as a *null modem* connection, must be made. An example might be connecting two computers together so they can transmit data back and forth. A null modem connection simply crosses the signal and handshaking lines. **Fig 22.24** shows a normal null modem connection (A) and one for equipment that ignores handshaking (B).

Parallel Connections

Another common computer port is the parallel port. The most popular use for the parallel port by far is for printer connections. As the name implies, data is sent in a parallel fashion. There are eight data lines accompanied by a number of control and handshaking lines. A parallel printer connection typically uses a 25-pin D-Subminiature connector at the computer end and a 36-pin Amphenol connector (often called an Epson connector) on the printer.

Connecting Computers to Amateur Equipment

Most modern transceivers provide a serial connection that allows external control of the rig, typically with a computer. Commands sent over

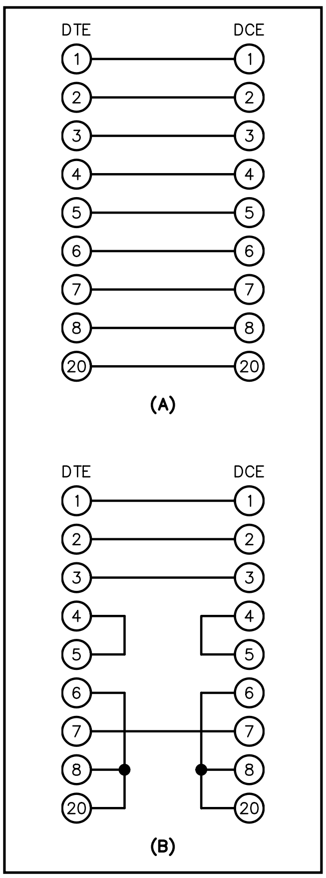


Fig 22.23—EIA-232-D serial connections for normal DTE/DCE (A) and those that ignore handshaking (B).

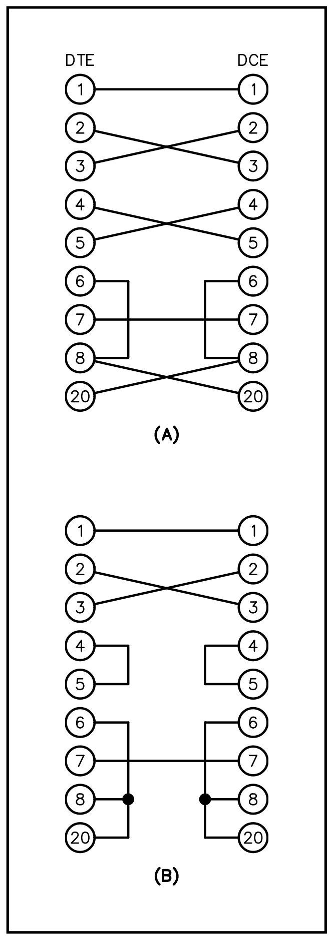


Fig 22.24—EIA-232-D null modem serial connection.

this serial control line can cause the rig to change frequency, mode and other parameters. Logging and contest software running on the computer often takes advantage of this capability.

The serial port of most radios operates with the TTL signal levels of 0 V for a binary 0 and 5 V for a binary 1. This is incompatible with the ±12 V of the serial port on the computer. For this reason, level shifting is required to connect the radio to the computer.

A couple of level shifter projects appear in the projects section at the end of this chapter. One of these two examples will work in most rig control situations, although some minor modifications may be necessary. Use the manual and technical documentation to find out what signals your radio requires and choose the circuit that fits the bill. The important factors to note are whether handshaking is implemented and what polarity the radio expects for the signals. In some cases, a 5-V level represents a logic 1 (active high) and in others a logic 0 (active low).

CSMA/CD Bus

Some equipment, notably ICOM rigs with the CI-V interface and recent Ten-Tec gear, use a CSMA/CD (carrier-sense multiple access/collision detect) bus that can interconnect a number of radios and computers simultaneously. This bus basically consists of a single wire, on which the devices transmit and receive data, and a ground wire. **Fig 22.25** illustrates the CSMA/CD scheme.

Each device connected to the bus has its own unique digital address. A radio comes from the manufacturer with a default address that can be changed if desired, usually by setting dip switches inside the radio. Information is sent on the bus in the form of packets that include the control data and the address of the device (radio or computer) for which they are intended. A device receives every packet but only acts on the data when its address is embedded in the packet.

A device listens to the bus before transmitting to make sure it is idle. A problem occurs when both devices transmit on the bus at the same time: They both listen, hear nothing and start to send. When this happens, the packets garble each other. This is known as a collision. That is where the CSMA/CD bus collision-detection feature comes in: The devices detect the collision and each sender waits a random amount of time before resending. The sender waiting the shorter random time will get to send first.

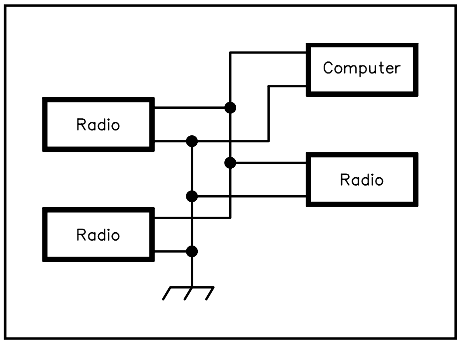


Fig 22.25—The basic two-wire bus system that ICOM and some Ten-Tec radios share among several radios and computers. In its simplest form, the network would include only one radio and one computer.

Computer/TNC Connections

TNCs (terminal node controllers) also connect to the computer (or terminal) via the serial port. A TNC typically implements handshaking signals. Therefore, a connector like the one in Fig 22.23A will be necessary. Connectors at the TNC end vary with manufacturer. The documentation included with the TNC will provide details for hooking the TNC to the computer.

DOCUMENTING YOUR STATION

An often neglected but very important part of putting together your station is properly documenting your work. Ideally, you should diagram your entire station from the ac power lines to the antenna on paper and keep the information in a special notebook with sections for the various facets of your installation. Having the station well documented is an invaluable aid when tracking down a problem or planning a modification. Rather than having to search your memory for information on what you did a long time ago, you'll have the facts on hand.

Besides recording the interconnections and hardware around your station, you should also keep track of the performance of your equipment. Each time you install a new antenna, measure the SWR at different points in the band and make a table or plot a curve. Later, if you suspect a problem, you'll be able to look in your records and compare your SWR with the original performance.

In your shack, you can measure the power output from your transmitter(s) and amplifier(s) on each band. These measurements will be helpful if you later suspect you have a problem. If you have access to a signal generator, you can measure receiver performance for future reference.

INTERFACING HIGH-VOLTAGE EQUIPMENT TO SOLID-STATE ACCESSORIES

Many amateurs use a variety of equipment manufactured or home brewed over a considerable time period. For example, a ham might be keying a '60s-era tube rig with a recently built microcontroller-based electronic keyer. Many hams have modern solid-state radios connected to high-power vacuum-tube amplifiers.

Often, there is more involved in connecting HV (high-voltage) vacuum-tube gear to solid-state accessories than a cable and the appropriate connectors. The solid-state switching devices used in some equipment will be destroyed if used to switch the HV load of vacuum tube gear. The polarity involved is important too. Even if the voltage is low enough, a key-line might bias a solid-state device in such a way as to cause it to fail. What is needed is another form of level converter.

MOSFET Level Converters

While relays can often be rigged to interface the equipment, their noise, slow speed and external power requirement make them an unattractive solution in some cases. An alternative is to use power MOSFETs. Capable of handling substantial voltages and currents, power MOSFETs have become common design items. This has made them inexpensive and readily available.

Nearly all control signals use a common ground as one side of the control line. This leads to one of four basic level-conversion scenarios when equipment is interconnected:

1) A positive line must be actuated by a negative-only control switch.

2) A negative line must be actuated by a positive-only control switch.

3) A positive line must be actuated by a positive-only control switch.

4) A negative line must be actuated by a negative-only control switch.

In cases 3 and 4 the polarity is not the problem. These situations become important when the control-switching device is incapable of handling the required open-circuit voltage or closed-circuit current.

Case 1 can be handled by the circuit in **Fig 22.26A**. This circuit is ideal for interfacing

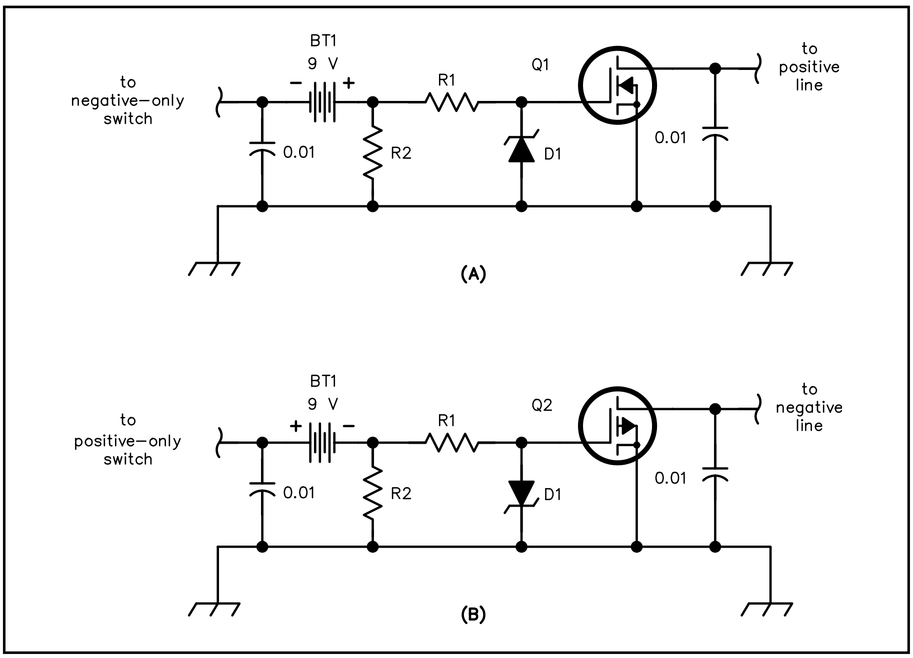


Fig 22.26—Level-shifter circuits for opposite input and output polarities. At A, from a negative-only switch to a positive line; B, from a positive-only switch to a negative line.

BT—9-V transistor-radio battery.
D1—15-V, 1-W Zener diode (1N4744 or equiv).
Q1—IRF620.
Q2—IRF220 (see text).
R1—100 W, 10%, 1/4 W.
R2—10 kW, 10%, 1/4 W.

keyers designed for grid-block keying to positive CW key lines. A circuit suitable for case 2 is shown in **Fig 22.26B**. This circuit is simply the mirror image of that in Fig 22.26A with respect to circuit polarity. Here, a P-channel device is used to actuate the negative line from a positive-only control switch.

Cases 3 and 4 require the addition of an inverter, as shown in **Fig 22.27**. The inverter provides the logic reversal needed to drive the gate of the MOSFET high, activating the control line, when the control switch shorts the input to ground.

Almost any power MOSFET can be used in the level converters, provided the voltage and current ratings are sufficient to handle the signal levels to be switched. A wide variety of suitable devices is available from most large mail-order supply houses.

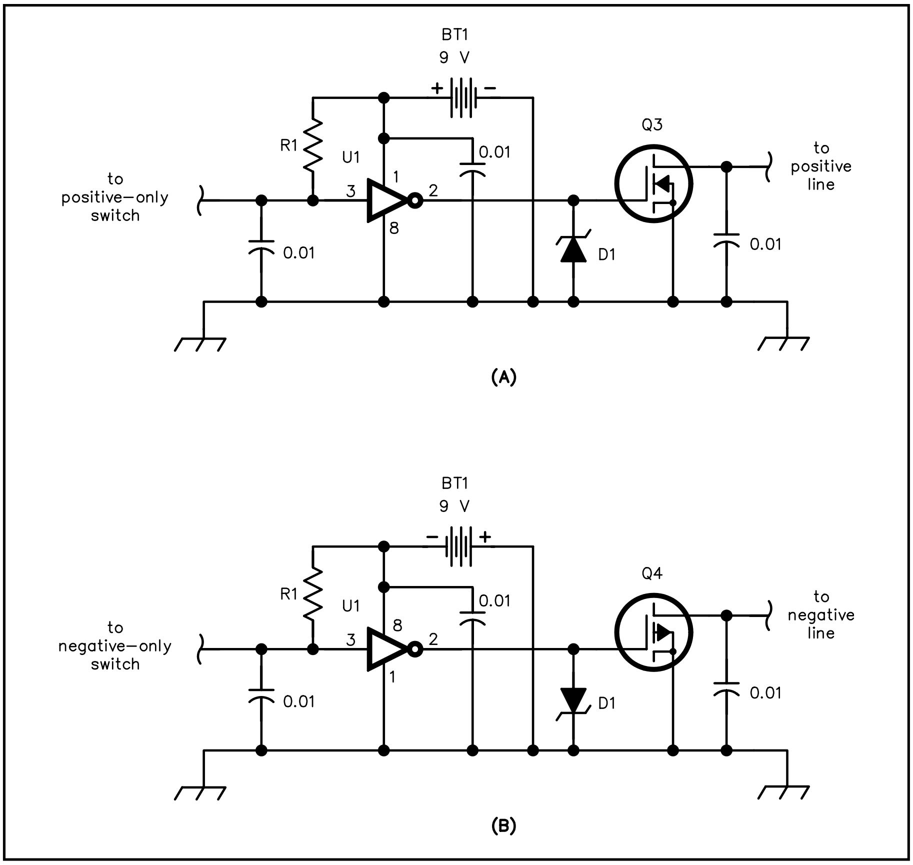


Fig 22.27—Circuits for same-polarity level shifters. At A, for positive-only switches and lines; B, for negative-only switches and lines.

BT1—9-V transistor-radio battery.
D1—15-V, 1-W Zener diode (1N4744 or equiv).
Q3—IRF620.
Q4—IRF220 (see text).
R1—10 kΩ, 10%, 1/4 W.
U1—CD4049 CMOS inverting hex buffer, one section used (unused sections not shown; pins 5, 7, 9, 11 and 14 tied to ground).

Mobile and Portable Installations

Time and again, radio amateurs have been pressed into service in times of need. New developments outside of Amateur Radio (cellular phones, for example) often bring with them predictions that amateurs will no longer be needed to provide emergency communications. Just as often, a disaster proves beyond doubt the falseness of that exclamation. When the call for emergency communication is voiced by government and disaster relief organizations, mobile and portable equipment is pressed into service where needed. In addition to the occasional emergency or disaster type of communications, mobile and portable operation under normal conditions can challenge and reward the amateur operator.

Most mobile operation today is carried out by means of narrow-band repeaters. Major repeater frequencies reside in the 146 and 440-MHz bands. As these bands become increasingly congested, the 222 and 1240-MHz bands are being used for this reliable service mode as well. Many amateurs also enjoy mobile and portable HF operation because of the challenge and possibilities of worldwide communication.

MOBILE STATIONS

Installation and setup of mobile equipment can be considerably more challenging than for a fixed station. Tight quarters, limited placement options and harsher environments require innovation and attention to detail for a successful installation. The equipment should be placed so that operation will not interfere with driving. Driving safely is always the primary consideration; operating radio equipment is secondary. See **Fig 22.28** for one neat solution. If your vehicle has an airbag, be sure it can deploy unimpeded.

Mobile operation is not confined to lower power levels than in fixed stations. Many modern VHF FM transceivers are capable of 25 to 50 W of output. Compact HF rigs usually have outputs in the 100-W range and run directly from the 13.6-V supply.

If a piece of equipment will draw more than a few amps, it is best to run a heavy cable directly to the battery. Few circuits in an automobile electrical system can safely carry the more than 20 A required for a 100-W HF transceiver. Check the table in the **Component Data** chapter to verify the current handling capabilities of various gauges of wire and cable. Adequate and well-placed fuses are necessary to prevent fire hazards. For maximum safety, fuse both the hot and ground lines near the battery. Automobile fires are costly and dangerous.

The limited space available makes antennas for mobile operation quite different than those for fixed stations. This is especially true for HF antennas. The **Antennas** chapter contains information for building and using mobile antennas.

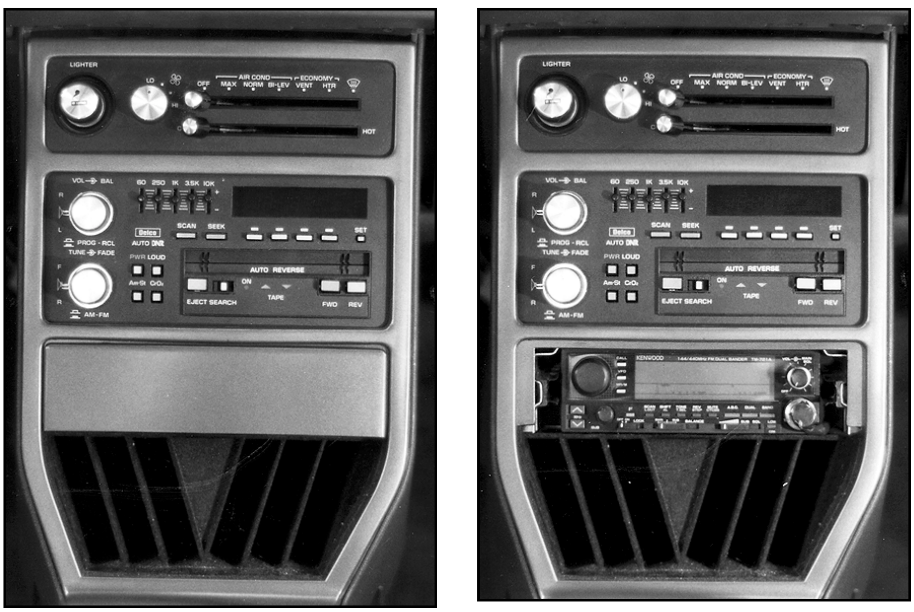


Fig 22.28—N8KDY removed the ashtray for his mobile installation. The old faceplate for the ashtray is used as a cover for the rig when not in use. This may help reduce the temptation for would-be thieves. *(Photo courtesy AA8DX)*

Interference

In the past, interference in mobile installations almost always concerned interference to the radio equipment. Examples include ignition noise and charging-system noise. Modern automobiles—packed with arrays of sensors and one or more on-board computers—have made interference a two-way street. The original type of interference (to the radio) has also increased with the proliferation of these devices. An entire chapter in the *ARRL RFI Book* is devoted to ways to prevent and cure this problem.

The Sounds of Amateur Radio — **Automobile ignition noise as received with an SSB detector**

The Sounds of Amateur Radio — **Automobile ignition noise as received with an AM detector.**

The Sounds of Amateur Radio — **Automobile ignition noise as received with an FM detector.**

PORTABLE STATIONS

Many amateurs experience the joys of portable operation once each year in the annual emergency exercise known as Field Day. Setting up an effective portable station requires organization, planning and some experience. For example, some knowledge of propagation is essential to picking the right band or bands for the intended communications link(s). Portable operation is difficult enough without dragging along excess equipment and antennas that will never be used.

Some problems encountered in portable operation that are not normally experienced in fixed-station operation include finding an appropriate power source and erecting an effective antenna. The equipment used should be as compact and lightweight as possible. A good portable setup is simple. Although you may bring gobs of gear to Field Day and set it up the day before, during a real emergency speed is of the essence. The less equipment to set up, the faster it will be operational.

Portable AC Power Sources

There are two popular sources of ac power for use in the field. One is referred to as a dc-to-ac converter, or more commonly, an *inverter*. The ac output of an inverter is a square wave. Therefore, some types of equipment cannot be operated from the inverter. Certain types of motors are among those devices that require a sine-wave output. **Fig 22.34** shows a typical commercial inverter. This model delivers 120 V of ac at 175 W continuous power rating. It requires 6 or 12 V dc input.

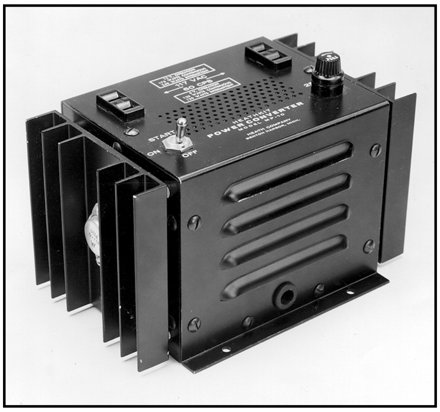


Fig 22.34—Photograph of a commercial dc-to-ac inverter that operates from 6 to 12 V dc and delivers 120 V ac (square wave) at 175 W.

Besides having a square-wave output, inverters have some other traits that make them less than desirable for field use. Commonly available models do not provide a great deal of power. The 175-W model shown in Fig 22.34 could barely power a few light bulbs, let alone a number of transceivers. Higher-power models are available but are quite expensive. Another problem is that the batteries supplying the inverter with primary power are discharged as power is drawn from the inverter.

Popularity and a number of competing manufacturers have caused gasoline generators to come down considerably in price. For a reliable, adequate source of ac (with sine-wave output), the gasoline-engine-driven generator is the best choice. (While still referred to as generators, practically all modern units actually use alternators to generate ac power.) Generators have become smaller and lighter as manufacturers have used aluminum and other lightweight materials in their construction. **Fig 22.35** shows the type of generator often used during Field Day.

Generators in the 3 to 5-kW range are easily handled by two people and can provide power for a relatively large multioperator field site. Most generators provide 12 V dc output in addition to 120/240 V ac.

Generator Maintenance

Proper maintenance is necessary to obtain rated output and a decent service life from a gasoline generator. A number of simple measures will prolong the life of the equipment and help maintain reliability.

It is a good idea to log the dates the unit is used and the operating time in hours. Many generators have hour-meters to make this simple. Include dates of maintenance and the type of service performed. The manufacturer's manual should be the primary source of maintenance information and the final word on operating procedures and safety. The manual should be thoroughly covered by all persons who will operate and maintain the unit.

Particular attention should be paid to fuel quality and lubricating oil. A typical gasoline generator is often used at or near its rated capacity. The engine driving the alternator is under a heavy load that varies with the operation of connected electrical equipment. For these reasons, the demands on the lubricating oil are usually greater than for most gasoline-engine powered equipment such as lawn mowers, tractors and even automobiles. Only the grades and types of oil specified in the manual should be used. The oil should be changed at the specified intervals usually given as a number of operating hours.

Fuel should be clean, fresh and of good quality. Many problems with gasoline generators are caused by fuel problems. Examples include dirt or water in the fuel and old, stale fuel. Gasoline stored for any length of time changes as the more volatile components evaporate. This leaves excess amounts of varnish-like substances that will clog carburetor passages. If the generator will be stored for a long period, it is a good idea to run it until all of the fuel is burned. Another option is the use of fuel stabilizers added to the gasoline before storage.

Spark plugs should be changed as specified. Faulty spark plugs are a common cause of ignition problems. A couple of spare spark plugs should always be kept with the unit, along with tools needed to change them. Always use the type of spark plug recommended by the manufacturer.

Fig 22.35—Modern gasoline engine-powered generators offer considerable ac power output in a relatively compact and lightweight package.

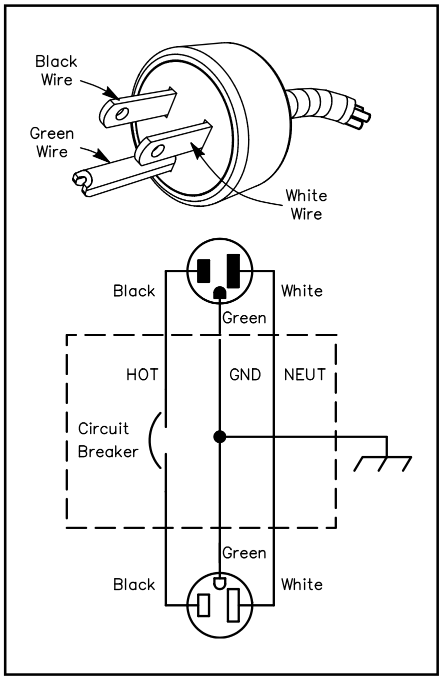


Fig 22.36—A simple accessory that provides overload protection for generators that do not have such provisions built in.

Generator Ground

A proper ground for the generator is absolutely necessary for both safety reasons and to ensure proper operation of equipment powered from the unit. Most generators are supplied with a three-wire outlet, and the ground should connect to the plug as shown in **Fig 22.36**. Some generators require that the frame be grounded also. An adequate pipe or rod should be driven into the ground near the generator and connected to the provided clamp or lug. If no connection is provided, a clamp can be used to connect the ground lead to the frame of the generator. As always, follow the manufacturer's recommendations.

Portable Antennas

An effective antenna system is essential to all types of operation. Effective portable antennas, however, are more difficult to devise than their fixed-station counterparts. A portable antenna must be light, compact and easy to assemble. It is also important to remember that the portable antenna may be erected at a variety of sites, not all of which will offer ready-made supports. Strive for the best antenna system possible because operations in the field are often restricted to low power by power supply and equipment considerations. Some antennas suitable for portable operation are described in the **Antennas** chapter.

Antenna Supports

While some amateurs have access to a truck or trailer with a portable tower, most are limited to what nature supplies, along with simple push-up masts. Select a portable site that is as high and clear as possible. Elevation is especially important if your operation involves VHF. Trees, buildings, flagpoles, telephone poles and the like can be pressed into service to support wire antennas. Drooping dipoles are often chosen over horizontal dipoles because they require only one support.

An aluminum extension ladder makes an effective antenna support, as shown in **Fig 22.38**. In this installation, a mast, rotator and beam are attached to the top of the second ladder section with the ladder near the ground. The ladder is then pushed vertical and the lower set of guy wires attached to the guy anchors. When the first set of guy wires is secured, the ladder may be extended and the top guy wires attached to the anchors. Do not attempt to climb a guyed ladder.

Figs 22.39 and **22.40** illustrate two methods for mounting portable antennas de-

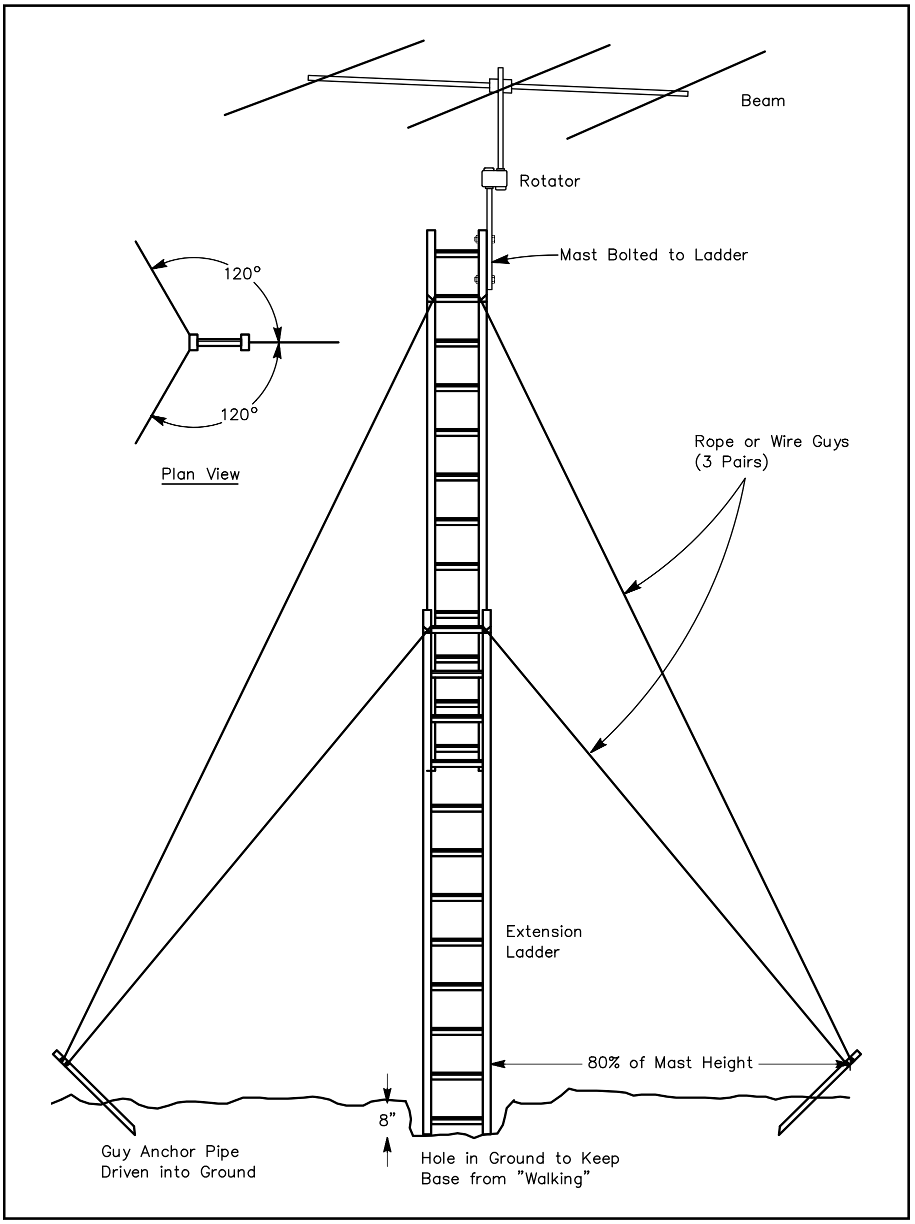


Fig 22.38—An aluminum extension ladder makes a simple but sturdy portable antenna support. Attach the antenna and feed lines to the top ladder section while it is nested and laying on the ground. Push the ladder vertical, attach the bottom guys and extend the ladder. Attach the top guys. Do not attempt to climb this type of antenna support.

(A)

(B)

Fig 22.39—The portable tower mounting system by WA7LYI. At A, a truck is "parked" on the homemade base plate to weigh it down. At B, the antennas, mast and rotator are mounted before the tower is pushed up. Do not attempt to climb a temporary tower installation.

scribed by Terry Wilkinson, WA7LYI. Although the antennas shown are used for VHF work, the same principles can be applied to small HF beams as well.

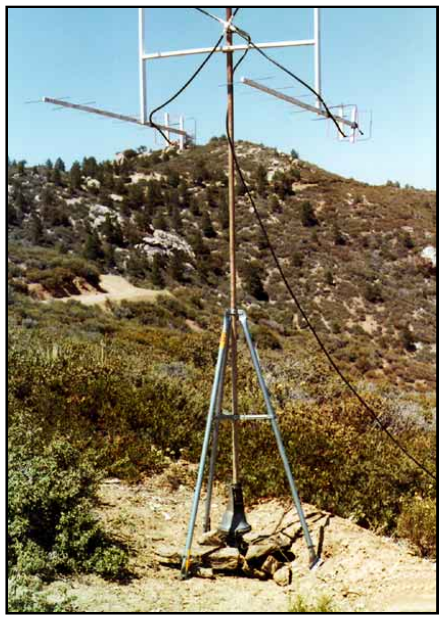
In Fig 22.39, a 3-ft section of Rohn 25 tower is welded to a pair of large hinges, which in turn are welded to a steel plate measuring approximately 18×30 inches. One of the rear wheels of a pickup truck is "parked" on the plate, ensuring that it will not move. In Fig 22.39, quad array antennas for 144 and 222 MHz are mounted on a Rohn 25 top section, complete with rotator and feed lines. The tower is then pushed up into place using the hinges, and guy ropes anchored to heavy-duty stakes driven into the ground complete the installation. This method of portable tower installation offers an exceptionally easy-to-erect, yet sturdy, antenna support. Towers installed in this manner may be 30 or 40 ft high; the limiting factor is the number of "pushers" and "rope pullers" needed to get into the air. A portable station located in the bed of the pickup truck completes the installation.

The second method of mounting portable beams described by WA7LYI is shown in Fig 22.40. This support is intended for use with small or medium-sized VHF and UHF arrays. It is available from any dealer selling television antennas; tripods of this type are usually mounted on the roof of a house. Open the tripod to its full size and drive a pipe into the ground at each leg. Use ahose clamp or small U-bolt to anchor each leg to its pipe.

The rotator mount is made from a 6-inch-long section of $1^1/_2$-inch-diameter pipe welded to the center of an "X" made from two 2-ft-

(A)

(B)



(C)

Fig 22.40—The portable mast and tripod by WA7LYI. At A, the tripod is clamped to stakes driven into the ground. The rotator is attached to a homemade pipe mount. At B, rocks piled on the rotator must keep the rotator from twisting and add weight to stabilize the mast. At C, a 10-ft mast is inserted into the tripod/rotator base assembly. Four 432-MHz Quagis are mounted at the top.

long pieces of concrete reinforcing rod (rebar). The rotator clamps onto the pipe, and the whole assembly is placed in the center of the tripod. Large rocks placed on the rebar hold the rotator in place, and the antennas are mounted on a 10 or 15-ft mast section. This system is easy to make and set up.

Tips for Portable Antennas

Any of the antennas described in the **Antennas** chapter or available from commercial manufacturers may be used for portable operation. Generally, though, big or heavy antennas should be passed over in favor of smaller arrays. The couple of decibels of gain a 5-element, 20-m beam may have over a 3-element version is insignificant compared to the mechanical considerations. Stick with arrays of reasonable size that are easily assembled.

Wire antennas should be cut to size and tuned prior to their use in the field. Be careful when coiling these antennas for transport, or you may end up with a tangled mess when you need an antenna in a hurry. The coaxial cable should be attached to the center insulator with a connector for speed in assembly. Use RG-58 for the low bands and RG-8X for higher-band antennas. Although these cables exhibit higher loss than standard RG-8, they are far more compact and weigh much less for a given length.

Beam antennas should be assembled and tested before taking them afield. Break the beam into as few pieces as necessary for transportation and mark each joint for speed in reassembly. Hex nuts can be replaced with wing nuts to reduce the number of tools necessary.

Ground Rod Installation

A large sledgehammer, a small step ladder and a lot of elbow grease. That's the usual formula for driving in an 8-foot ground rod. Michael Goins, WB5YKX, reports success using fluid hydraulics to ease the task in very dense clay soil.

He suggests digging a small hole, about a foot deep, just enough to hold a few gallons of water. When the hole is complete, pour water into the hole, and then push the ground rod in as far as it will go. Next, pull it out completely. Some of the water will run into the smaller hole made by the ground rod.

Repeat the process, allowing water to run into the small hole each time you remove the rod. Continue pushing and removing until the rod is sunk as far as you want. About 6 inches of rod above the ground is usually enough to allow convenient connection of bonding clamps.

THE TiCK-2—A TINY CMOS KEYER 2

TiCK-2 stands for "Tiny CMOS Keyer 2." It is based on an 8-pin DIP microcontroller from Microchip Corporation, the PIC 12C509. This IC is a perfect candidate for all sorts of Amateur Radio applications because of its small size and high performance capabilities. This project was described fully in Oct 1997 *QST* by Gary M. Diana, Sr, N2JGU, and Bradley S. Mitchell, WB8YGG. The keyer has the following features:

- One memory message—a single memory message, capable of at least playing back "CQ CQ DE *callsign callsign* K"
- Mode A and B iambic keying
- Low current requirement—to support portable use.
- Low parts count—consistent with a goal for small physical size.
- Simple interfaces—this includes the rig and user interfaces. The user interface must be simple; ie, the operator shouldn't need a manual. The rig interface should be simple as well: paddles in, key line out.
- Sidetone—supply an audible sidetone for user-feedback functions and to support transceivers that do not have a built-in sidetone.
- Paddle select—allow the operator to swap the dot and dash paddles without having to rewire the keyer (or flip the paddles upside down!).
- Manual keying—permit interfacing a straight key (or external keyer) to the TiCK.

DESIGN

The PIC 12C509 has two pages of 512 bytes of program read-only memory (ROM) and 41 bytes of random-access memory (RAM). This means that all the keyer *functions* have to fit within the ROM. The keyer *settings* such as speed, paddle selection, iambic mode and sidetone enable are stored in RAM. The RAM in this microcontroller is *volatile*, that is, the values stored in memory are lost if the power to the chip is cycled off, then on—but there's not much of a need to do that because of the low power requirements for the chip.

A 12C509 has eight pins. Two pins are needed for the dc input and ground connections. The IC requires a clock signal. Several clock-source options are available; you can use: a crystal, RC (resistor and capacitor) circuit, resonator, or the IC's internal oscillator. The authors chose the internal 4-MHz oscillator to reduce the external parts count. Two I/O lines are used for the paddle input. One output feeds the key line, another output is required for the audio feedback (sidetone) and a third I/O line is assigned to a pushbutton.

USER INTERFACE

Using the two paddles and a pushbutton, you can access all of the TiCK's functions. Certain user-interface functions need to be more easily accessible than others; a prioritized list of functions (from most to least accessible) is presented in **Table 22.1**.

The TiCK employs a *single button interface* (SBI). This simplifies the TiCK PC board, minimizes the part count and makes for ease of use. Most other electronic keyers have multibutton user interfaces, which, if used infrequently, make it difficult to remember the commands. Here, a single button push takes you through the functions, one at a time, at a comfortable pace (based on the current speed of the keyer). Once the code for the desired function is heard, you simply let up on the button. The TiCK then executes the appropriate function, and/or waits for the appropriate input, either from the paddles or the pushbutton itself, depending on the function in question. Once the function is complete, the TiCK goes back into keyer mode, ready to send code through the key line.

The TiCK-2 IC generates a sidetone signal that can be connected to a piezoelectric element or fed to the audio chain of a transceiver. The latter option is rig-specific, but can be handled by more experienced builders.

Table 22.1
TiCK-2 User Interface Description

Action	*TiCK-1 and 2 Response*	*Function*
Press pushbutton	S (dit-dit-dit)	Speed adjust: Press dit to decrease, dah to increase speed.
Hold pushbutton down	M (dah-dah)	Memory playback: Plays the message from memory, using the key line and sidetone (if enabled).
Hold pushbutton down	T (dah)	Tune: To unkey rig, press either paddle or pushbutton.
Hold pushbutton down	A (dit-dah)	ADMIN mode: Allows access to various TiCK-2 IC setup parameters.
Hold pushbutton down	I (dit-dit)	Input mode: Allows message entry. Press pushbutton when input is complete.
Hold pushbutton down	P (dit-dah-dah-dit)	Paddle select: Press paddle desired to designate as dit paddle.
Hold pushbutton down	A (dit-dah)	Audio select: Press dit to enable sidetone, dah to disable. Default: enabled.
Hold pushbutton down	SK (dit-dit-dit dah-dit-dah)	Straight key select: Pressing either paddle toggles the TiCK to/from straight key/keyer mode. Default: keyer mode.
Hold pushbutton down	M (dah-dah)	Mode select: Pressing the dit paddle puts the TiCK into iambic mode A; dah selects iambic mode B (the default).
Hold pushbutton down	K (dah-dit-dah)	Keyer mode: If pushbutton is released, the keyer returns to normal operation.
Hold pushbutton down	S (dit-dit-dit)	Cycle repeats with Speed adjust.

THE TiCK LIKES TO SLEEP

To meet the low-current requirement, the authors took advantage of the 12C509's ability to *sleep*. In sleep mode, the processor shuts down and waits for input from either of the two paddles. While sleeping, the TiCK-2 consumes just a few microamperes. The TiCK-2 doesn't wait long to go to sleep either: As soon as there is no input from the paddles, it's snoozing! This feature should be especially attractive to amateurs who want to use the TiCK-2 in a portable station.

ASSEMBLING THE TiCK

The TiCK-2's PC board size (1 × 1.2 inches) supports its use as an embedded and stand-alone keyer. The PC board has two dc input ports, one at J2 for 7 to 25 V and another (J4, AUXILIARY) for 2.5 to 5.5 V. The input at J2 is routed to an on-board 5 V regulator (U2), while the AUXILIARY input feeds the TiCK-2 directly. When making the dc connections, observe proper polarity: There is no built-in reverse-voltage protection at either dc input port.

The voltage regulator's bias current is quite high and will drain a 9 V battery quickly, even though the TiCK itself draws very little current. For this reason, the "most QRP way" to go may be to power the chip via the AUXILIARY power input and omit U2, C1 and C2.

When using the AUXILIARY dc input port, or if *both* dc inputs are used, connect a diode between the power source and the AUXILIARY power input pin, attaching the diode anode to the power source and the cathode to the AUXILIARY power input pin. This provides IC and battery protection and can also be used to deliver battery backup for your keyer settings.

SIDETONE

A piezo audio transducer can be wired directly to the TiCK-2's audio output: pads and board space

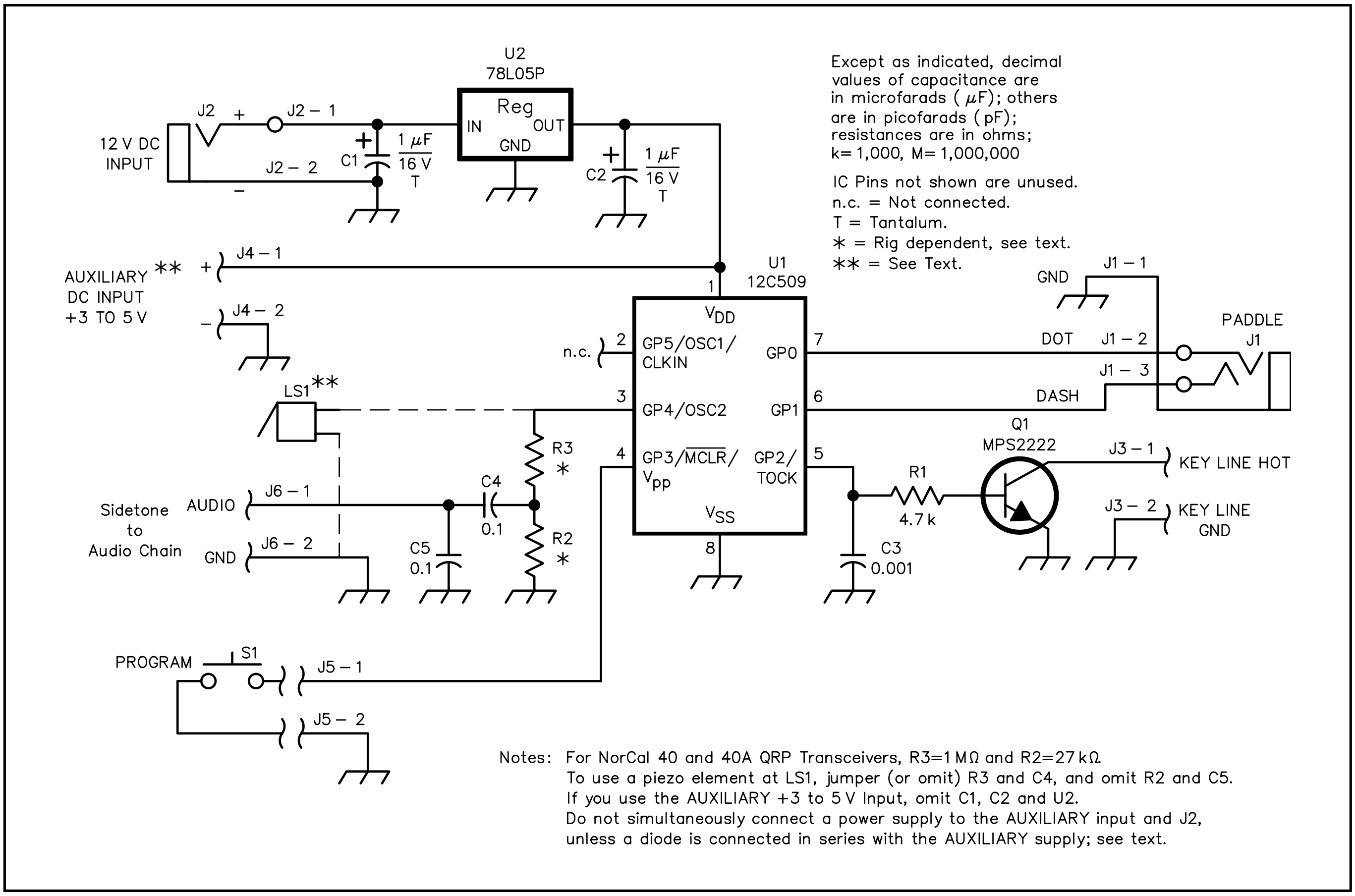
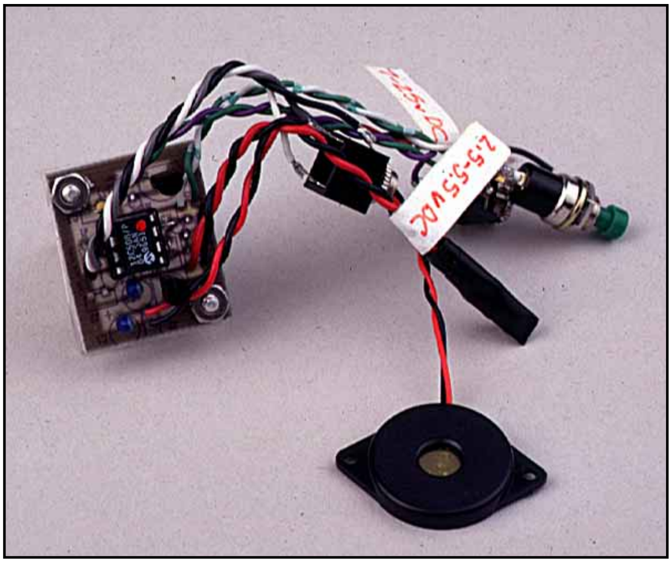


Fig 22.42—Schematic of the TiCK-2 keyer. Equivalent parts can be substituted. Unless otherwise specified, resistors are 1/4 W, 5%-tolerance carbon-composition or film units. The PIC12C509 IC must be programmed before use; see Note in the parts list for U1. RS part numbers in parentheses are RadioShack; M = Mouser (Mouser Electronics, see the Address List in the References chapter).

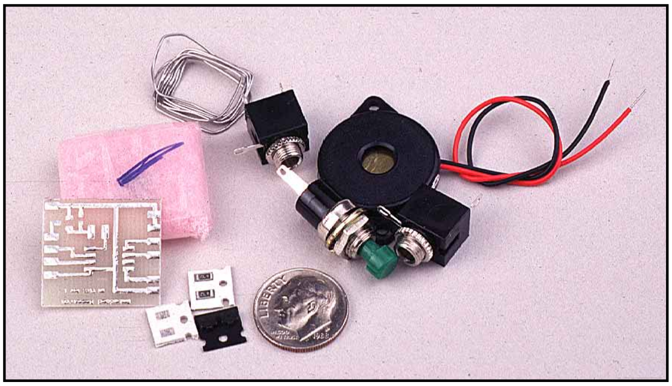
C1, C2—1 µF, 16 V tantalum (RS 272-1434; M 581-1.0K35V).
J1—3-circuit jack (RS 274-249; M 161-3402).
J2—2-circuit jack (RS 274-251) or coaxial (RS 274-1563 or 274-1576).
J3—2-circuit jack (RS 274-251; M16PJ135).
LS1—Optional piezo element (RS 273-064).
Q1—MPS2222A, 2N2222, PN2222, NPN (RS 276-2709; M 333-PN2222).
S1—Normally open pushbutton (RS 275-1571; M 10PA011).
U1—Programmed PIC 12C509, available from Embedded Research. (See the Address List in the References chapter.) The TiCK-2 chip/data sheet, $10; TiCK-2 programmed IC, PC board and manual, $15; TiCK-2 programmed IC, PC-board, parts and manual, $21. All prices are postpaid within the continental US. Canadian residents please add $5; all others add $6 for shipping. New York state residents please add 8% sales tax. The DIP and SOIC (surface-mount) chips and kits are the same price. Please specify which one you prefer when ordering. Note: Components *not* included with the SMD version kit are the voltage regulator and voltage divider components for the audio output. Source code is not available.
U2—5 V, 100 mA regulator (RS 276-1770; M 333-ML78L05A).
Misc: PC board, 8-pin DIP socket, hardware, wire (use stranded #22 to #28, Teflon insulated for heat/solder resistance).

are available for voltage-divider components. This eliminates the need to interface the TiCK-2 with a transceiver's audio chain. Use a piezo *element*, not a piezo *buzzer*. A piezo *buzzer* contains an internal oscillator and requires only a dc voltage to generate the sound, whereas a piezo *element* requires an external oscillator signal (available at pin 3 of U1).

If you choose to embed the keyer in a rig and want to hear the keyer's sidetone instead of the rig's sidetone, you may choose to add R2, R3, C4 and C5. Typically R3 should be 1 MΩ to limit current. R2's value is dictated by the amount of drive required. A value of 27 kΩ is a good start. C4 and C5 values of 0.1 µF work quite well. C4 and C5 soften the square wave and capacitively couple J6-1 to the square-wave output of pin 3. Decreasing the value of R2 decreases the amount of drive voltage, especially below 5 kΩ. Use a 20 kΩ to 30 kΩ trimmer potentiometer at R2 when experimenting.



(A)



(B)

Fig 22.43—At A, photo of DIP version, and at B, SMD version of the TiCK-2.

IN USE

To avoid RF pickup, keep all leads to and from the TiCK as short as possible. The authors tested the TiCK in a variety of RF environments and found it to be relatively immune to RF. Make sure your radio gear is well grounded and avoid situations that cause an RF-hot shack.

The TiCK keys low-voltage positive lines, common in today's solid-state rigs. Don't try to directly key a tube rig because you will likely—at a minimum—ruin output transistor Q1.

To use the TiCK as a code-practice oscillator, connect a piezo element to the audio output at pin 3. If more volume is needed, use an audio amplifier, such as RadioShack's 277-1008.

The higher the power-supply voltage (within the specified limits), the greater the piezo element's volume. Use 5 V (as opposed to 3 V) if more volume is desired. Also, try experimenting with the location of the piezo element to determine the proper mounting for maximum volume.

JUST WHEN YOU THOUGHT IT WAS SMALL ENOUGH...

In addition to the DIP version of the TiCK-2, there is also a surface-mount version of the keyer. This uses a 12C509 IC, which resides in a medium-size SOIC package measuring roughly 5 × 5 mm! This is approximately *two-thirds* the size of the DIP version of the IC. (For simplicity, the surface-mount keyer does not include the regulator circuitry.)

The surface-mount version of the TiCK PC board has no provisions for standoffs, but it can easily be mounted in an enclosure (or on the back of a battery!) using double-stick foam tape. The authors used this method to put the surface-mount TiCK into some really tiny enclosures. To assist the builder, the pads on the TiCK board are larger than necessary.

VINTAGE RADIO T/R ADAPTER

This T/R Adapter provides automatic transmit/receive switching for many vintage transmitters and receivers. It provides time-sequenced antenna transfer, receiver muting and transmitter keying in semi and full break-in CW modes or with push-to-talk systems in AM or SSB.

General Description

The vintage radio adapter consists of two assemblies, the control unit and a remotely located antenna relay. The control unit accepts key, keyer or push-to-talk input and produces time-sequenced outputs to transfer the antenna between receiver and transmitter, mute the receiver and key either cathode keyed or grid block keyed transmitters. The antenna relay is remotely mounted to aid in running coaxial cable and to minimize relay noise. The antenna relay is rated to handle over 100 W. If high power is contemplated, an antenna relay with a higher power rating is needed. A complete circuit board kit is available, making the unit very easy to duplicate. If you choose to build the unit from scratch, a template package that includes the PC board layout and part placement diagram is available from ARRL HQ.[1]

How it Works

The control circuit of the adapter is based on the C1V keyer/controller chip from Radio Adventures Corp. See **Fig 22.44A**. In this circuit, the controller features of the chip are used to provide the sequencing outputs to various circuits. By adding a few components, the keyer functions of the C1V can be utilized if desired.

When the KEY input line is pulled low by a key, bug, keyer or push-to-talk switch, the C1V controller chip immediately raises the ANT signal pin, pin 9, and SEMI signal, pin 3, switching the antenna from receiver to transmitter and muting the receiver. About 5.5 ms later the C1V raises the TX signal pin, pin 10, keying the transmitter. The delay provides time for the relays to transfer and for the receiver to quiet.

When the KEY line is released, the C1V controller delays 5.5 ms and then lowers the TX signal, pin 10, unkeying the transmitter. This 5.5-ms delay compensates for the 5.5-ms transmit delay at the start of the keying sequence, hence preserving the keying waveform. 5.5 ms after lowering the TX pin, the C1V controller lowers the ANT pin, pin 9, switching the antenna back to the receiver and unmuting the receiver. This delay allows time for the transmitter power to decay before switching the antenna, preventing "hot" switching the antenna relay. This process provides full break-in keying up to about 40 WPM. See **Fig 22.45A**.

Although ANT signal, pin 9, follows the keying, SEMI, pin 3, delays on release of the key. The amount of delay is determined by the setting of the DELAY potentiometer, R1. The delay can be varied from about 10 ms to about 1.5 seconds. If KEY line is again lowered before the delay is completed, the delay timer is reset and the full delay time is available after KEY is released. The output of SEMI, pin 3, provides semi break-in timing for use in situations where QSK is not desired.

Level shifter transistor Q1 can be connected to either ANT or SEMI as desired. Q1 drives relay amplifier Q3, which in turn energizes relay K1 and the remote antenna relay (see Fig 22.44B).

Level shifter transistor Q2 drives Q4, which provides drive for the HEXFET transistor used for cathode (positive) keying and the high voltage PNP transistor used for grid block (negative) keying.

The HEXFET power transistor selected for the cathode keying output will key currents beyond 500 mA and open circuit voltages of beyond 200 V. These ratings should be adequate for most cathode-keyed rigs.

The PNP transistor is rated at over 200 V and 10 mA. If your application requires higher voltage or current, a transistor with adequate ratings must be substituted and emitter resistor R11 must be reduced in value to provide sufficient current. The value of the

[1]See Chapter 30, **References**, for template.

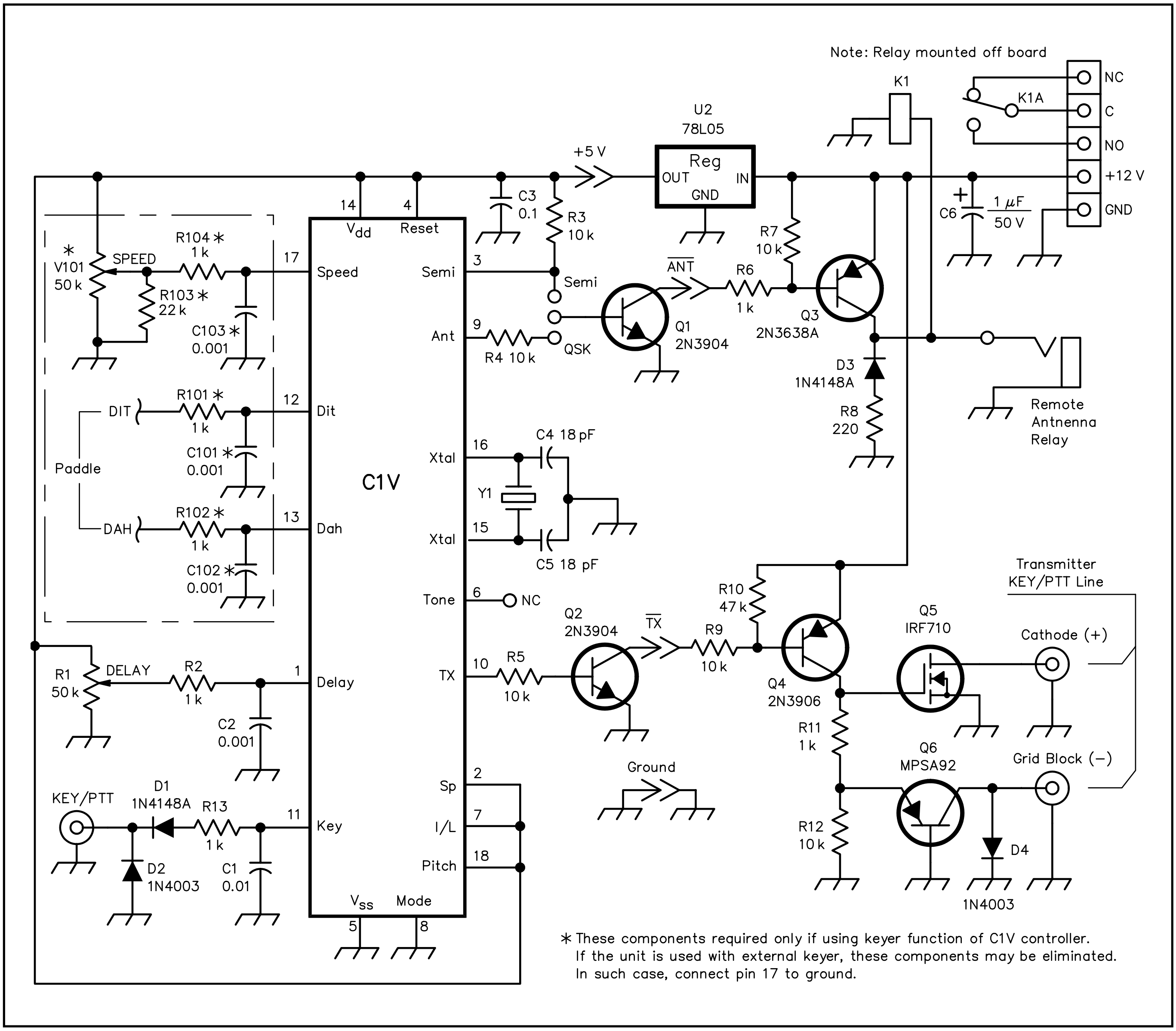


Fig 22.44A—Schematic diagram of the T/R switch. The circuit within the dashed lines is optional—it is used with the keyer function of the C1V controller. If an external keyer is used, this circuit can be eliminated; in this case, connect pin 17 to ground.

C1—0.01-µF, 50-V disc capacitor (Mouser CD50Z6-103M).
C2—0.001-µF, 50-V disc capacitor (Mouser CD50P6-102M).
C3—0.1-µF disc capacitor (Mouser CD100U5-104M).
C4, C5—18-pF, 100-V, 10% NP0 disc capacitor (Mouser 100N2-018J).
C6—1-µF, 50-V, vertical electrolytic (Mouser XRL50V1.0).
D1, D3—1N4148A switching diode.
D2, D4—1N4003 power diode.
K1—SPDT relay, 2 A, 12-V dc coil (Radio Adventures BAS111DC12).
Q1, Q2—2N3904 NPN, TO-92.
Q3—2N3638A PNP, TO-92.
Q4—2N3906 PNP, TO-92.
Q5—IRF710 HEXFET, TO-220.
Q6—PNP, TO-92 (MPSA92).
R1—50-kΩ potentiometer, linear taper (Mouser 31CN405).
R2, R6, R11, R13—1 kΩ, 1/4-W, 5% carbon film.
R3, R4, R5, R7, R9, R12—10-kΩ, 1/4-W, 5% carbon film.
R8—220-Ω, 1/4-W, 5% carbon film.
R10—47 kΩ, 1/4-W, 5% carbon film.
U1—C1V keyer/controller chip (Radio Adventures).
U2—78L05 5-V voltage regulator TO-92 (Mouser NJM78L05A).
Y1—2.0-MHz resonator (supplied with C1V).
Misc—Vintage Radio Adapter PC board (Radio Adventures 090-0112).

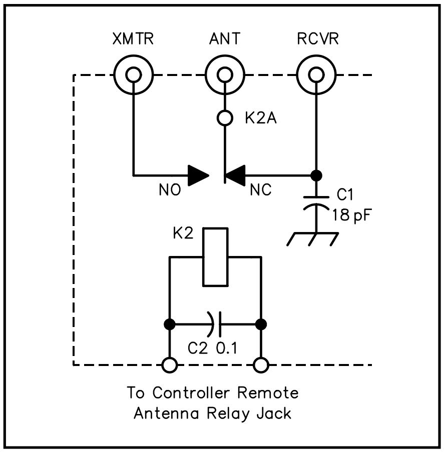


Fig 22.44B—The remote antenna relay schematic diagram.
C1—18-pF disc ceramic, #100N2-018J
C2—0.1-µF disc ceramic, #CD100U5-104M.
K2—SPDT relay, 2 A, 12 V dc coil.
Misc:
Bud Econobox, $1^{1}/_{16} \times 3^{5}/_{8} \times 1^{1}/_{2}$, #CU-123.
SO-239 coaxial connectors.

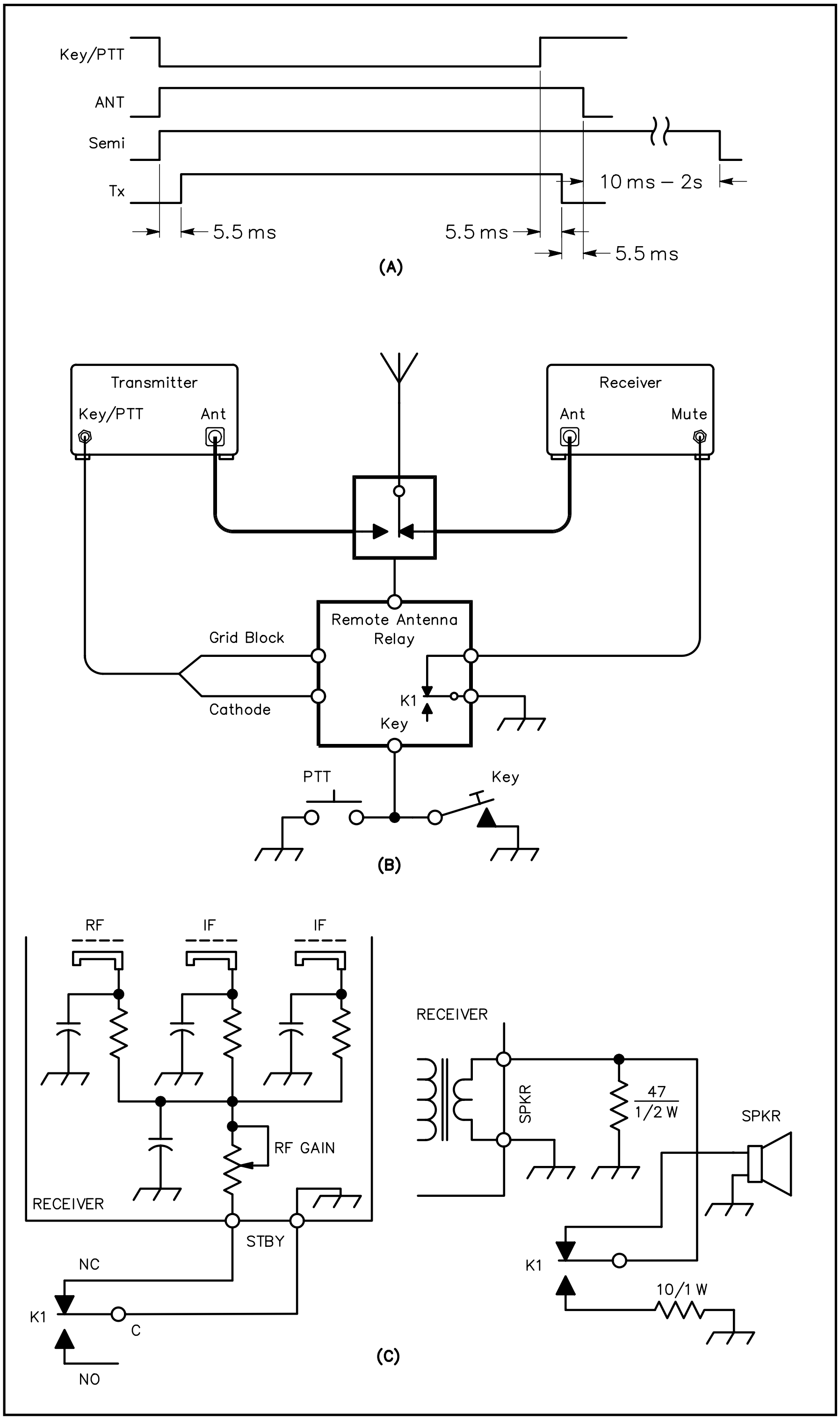


Fig 22.45—(A) Timing diagram of the C1V keyer/controller chip. The text explains how the control circuit works. (B) Block diagram showing how the antenna switch can connect to a vintage station. (C) Sample receiver mute circuits. Left: The receiver can be muted in the cathode or RF gain circuit. Right: If you prefer, the mute relay can also be connected to the speaker circuit.

resistor can be found with the following formula: R11 = 10/I. For example, to switch 20 mA, R11 = 10/0.02 = 500 Ω, a 470-Ω resistor would be used.

Construction

Construction is straightforward if the circuit board kit is used. If you choose to hand wire your unit on perf board or lay out your own circuit board, layout is not critical. The finished boards can be mounted in an enclosure of your choice. It is convenient to mount the antenna relay in its own enclosure to reduce the possibility of RF getting into the logic circuits and to make routing of coaxial cables more direct. Note that the relays are mounted on small carrier PC boards and are suspended by their leads only. This method of mounting greatly reduces relay noise that occurs when the relays are mounted on the main PC board.

Installation

Power requirements for the adapter are 12 V dc at approximately 120 mA. Antenna connections are straightforward and need no further discussion. Select either the cathode or grid block output for connection to your transmitter as appropriate. See **Fig 22.45B**.

There are a couple of options for muting the receiver. **Fig 22.45C** (left) shows a typical circuit for muting the receiver in the cathode or RF gain circuit. Many receivers bring the mute terminals to the rear apron. In some cases it may be necessary to go inside the receiver to bring out the cathode circuit.

If your receiver does not provide mute terminals and/or you do not want to mute in the cathode circuit, you can connect the mute relay K1 into the speaker circuit as shown in Fig 22.45C (right). The resistors ensure that the speaker terminals of the receiver are always terminated by a load close to 8 Ω, preventing possible damage to the receiver if the resistors were not used.

Note: Some receivers, especially those built in the '30s and '40s, put the receiver into a standby condition by opening the center tap of the power transformer high-voltage winding. *Do not* attempt to mute your receiver by this method. Use cathode or speaker muting instead.

For AM or SSB systems, connect the receiver as discussed, choose the QSK connection for level shifter transistor Q1 and connect the microphone PTT switch to the key/PTT input.

QUICK AND EASY CW WITH YOUR PC

A couple of chips and a few hours work will yield this CW only terminal for a PC. Designed by Ralph Taggart, WB8DQT, the software transforms a computer into a Morse machine that's a full-function CW keyboard *and* a receive display terminal.

The circuit works with IBM-compatible PCs and uses the printer port to communicate with the computer. Parts cost is generally less than $50, and a printed-circuit board is available to make construction easier.

Circuit Description

Each stage of the circuit in **Fig 22.46A** is labeled with its function. Ferrite beads are used to keep RF from entering the unit. K1 provides isolation, so any transmitter may be keyed without worrying about polarity. Fig 22.46B shows the power and computer interconnections for the circuit board.

Power Supply Options

Three voltage sources are required (+12 V, +5 V and –9 V) at relatively low current. The simplest approach is to use a wall-mount power transformer/supply (200 mA minimum) to provide the +12 V. A 7805 voltage regulator chip (U6) produces +5 V from the +12 V bus for the 74LS TTL ICs. Since the –9 V current requirements are very low, a 9 V alkaline transistor battery was used in WB8DQT's unit. This battery is switched in and out using one set of contacts on the POWER switch and will last a long time—unless you forget to turn the unit off between operating sessions!

The Computer Connection

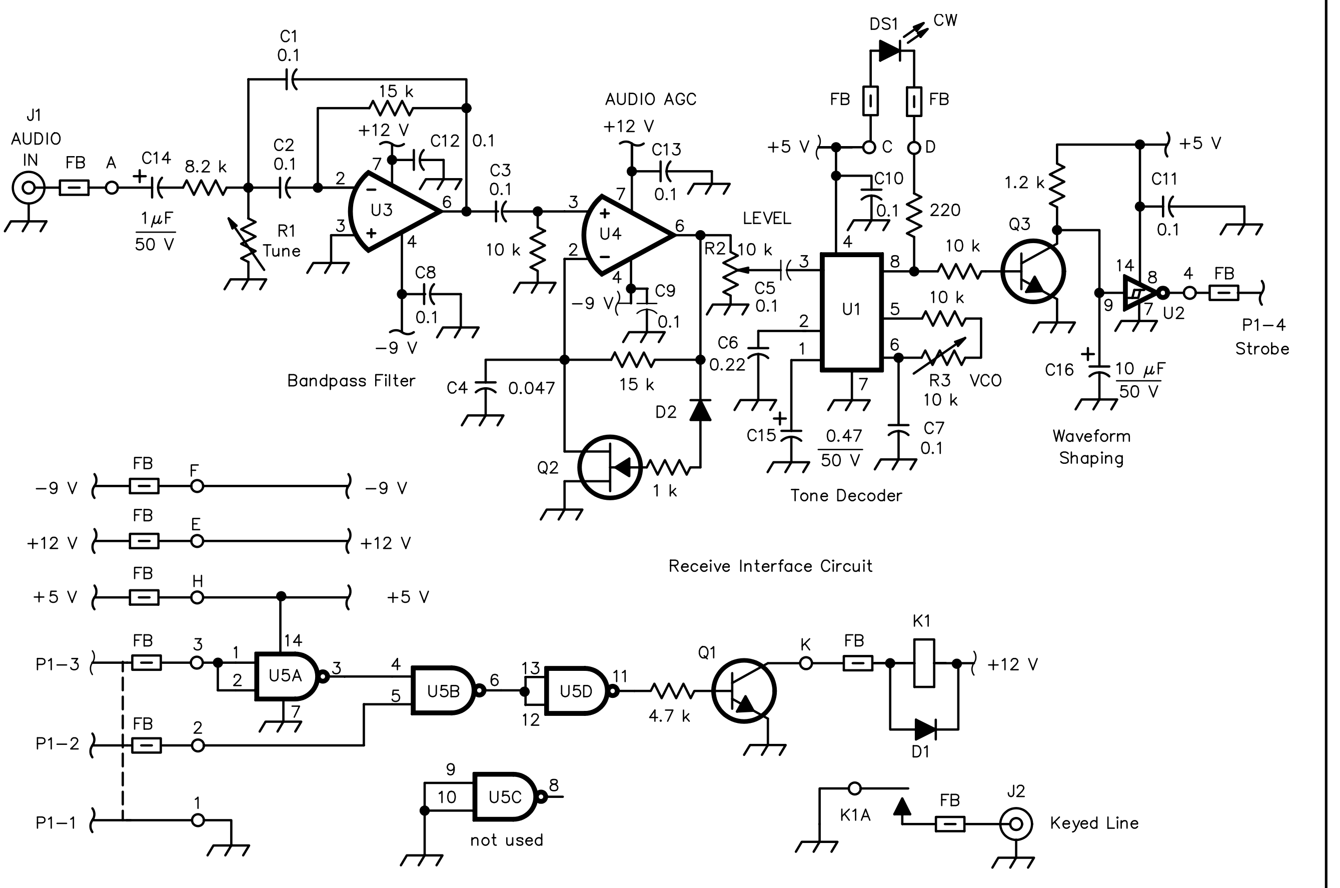
The circuit connects to the PC parallel printer port, which is usually a DB-25F (female) connector on the rear of the computer. A standard cable with a mating DB-25M (male) connector on one end and

Fig 22.46—Schematic of the CW interface. All fixed value resistors are 1/4 W, 5%-tolerance carbon film. Capacitance values are in microfarads (µF). RS indicates RadioShack part numbers. IC sections not shown are not used.

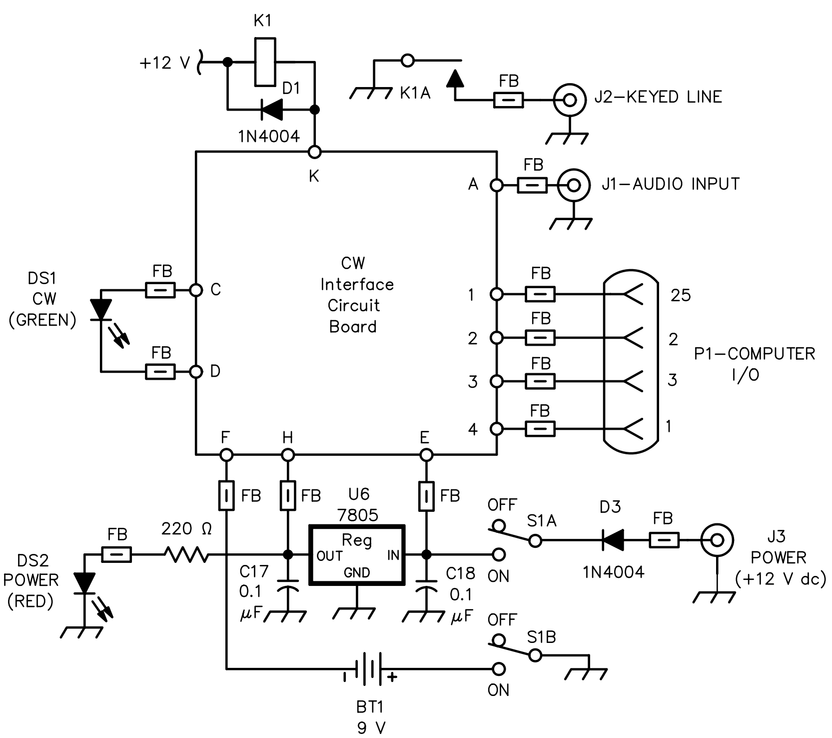
C1-C3, C5, C7-C13—0.1 µF monolithic or disc ceramic, 50 V.
C4—0.047 µF Polypropylene (dipped Mylar), 50 V.
C6—0.22 µF Polypropylene (dipped Mylar), 50 V.
C14—1 µF Tantalum or electrolytic, 50 V.
C15—0.47 µF Tantalum or electrolytic, 50 V.
C16—10 µF Tantalum or electrolytic, 50 V.
D1, D3—1N4004.
D2—1N270 germanium.
DS1—Green panel-mount LED.
DS2—Red panel-mount LED.
FB—Ferrite beads (11 total).
K1—12 V dc SPST reed relay (RS-275-233).
J1, J2—RCA phono jacks.
P1—4-pin microphone jack (RS-274-002).
Q1, Q3—2N4401.
Q2—MPF102.
R1—1 kΩ.
R2, R3—10 kΩ.
U1—NE567CN PLL tone decoder (8 pin).
U2—74LS14N hex Schmitt trigger (14 pin).
U3, U4—LM741CN op amp (8 pin).
U5—74LS00N quad NAND gate (14 pin).
4-pin microphone plug (RS-274-001).
4-pin microphone socket (chassis mount).
DB-25M Connector (RS-276-1547).
DB-25 Shell (RS-276-1549).
Coaxial power connector (RS-274-1563).
8-pin DIP IC sockets.
14-pin DIP IC sockets.
DPDT miniature toggle switch.

J3 is a panel-mounting coaxial power jack to match your wall-mount/transformer power supply. BT1 is a 9-V alkaline battery. See text. C17 and C18 are 0.1 µF, 50 V monolithic or disc ceramic bypass capacitors. The +5 V regulator chip should be mounted to the grounded wall of the cabinet. Off-board components are duplicated in section B of this drawing (J1, J2, P1, the CW LED indicator, and K1). The CW and POWER indicators are panel-mounting LED indicators (red for POWER and green for CW). FB indicates optional ferrite beads used to prevent RF interference with the interface circuits.

[Schematic on next page.]



Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k=1,000, M=1,000,000. Labeled circles (A–K, 1–4) indicate PC board connections.



DB-25F on the other end could be used. This cable is available at any computer store, but it would require a DB-25M to be mounted on your project box.

Unfortunately, DB-25 connectors need an odd-shaped mounting hole, which is difficult to make with standard shop tools. Since only four conductors are needed (ground, printer data bits 0 and 1, and the strobe data bit), it's easier to make a cable. Use a 4-pin microphone connector at one end and a DB-25M at the other end. Wire the cable as follows:

Function	*Microphone Plug*	*DB-25M Connector*
Ground	1	25
Printer data 0	2	2
Printer data 1	3	3
Printer strobe	4	1

Drill a $^5/_8$-inch round hole on the rear apron of the project enclosure for the mating chassis-mount 4-pin microphone socket.

Keying Options

For equipment with a positive, low-voltage keying line, point K on the board can be connected directly to the keying jack. In this case, omit K1 and its 1N4004 diode. For a wider range of transmitting equipment, use the keying relay. Mount it anywhere in the cabinet using a dab of silicone adhesive or a piece of double-sided foam mounting tape.

Construction

The simplest way to construct this circuit is on a single PC board. The PC-board pattern and parts overlay are available from the ARRL.[1] Make a PC board, or use the overlay to wire the circuit using perf-board. An etched and drilled PC board, with a silk-screened parts layout, is available from FAR Circuits.[2]

Any cabinet or enclosure that can accommodate the circuit board can be used. The POWER switch and POWER and CW LED indicators are the only front-panel items. J2 (KEYED LINE), J1 (AUDIO IN), J3 (+12 V DC POWER) and P1 (COMPUTER) are on the rear apron of the enclosure.

Alignment

There are three alignment adjustments, all of which are for the receive mode. Start by loading (and running) the software and turning the unit on. Switch the receiver to a dummy antenna to eliminate any interfering signals, and tune the receiver to a strong signal from a frequency calibrator or any other stable signal source. Carefully adjust the receiver for peak audio output. You may need a Y connector so the receiver can feed the interface and a speaker.

Connect a pair of headphones to the junction of the 0.1-µF capacitor and 10-kΩ resistor at pin 3 of U4. Adjust the Tune (R1) control on the PC board for the loudest signal. The filter is sharp, so make the adjustment carefully.

Set the PC board Level pot (R2) to midrange and adjust the VCO pot (R3) until the CW LED (DS1) comes on. Decrease the Level setting slightly (adjust the control in a counterclockwise direction) and readjust the VCO pot, if required, to cause the CW LED to light. Continue to reduce the Level setting in small steps, each time readjusting the VCO setting, until you reach the point where operation of the CW indicator becomes erratic.

[1] See Chapter 30, **References**, for information on ordering template packages.

[2] A circuit board is available for $5 (plus $1.50) from FAR Circuits (see the Address List in the **References** chapter).

Now turn the Level control back (clockwise) to just past the point where the LED comes on with no sign of erratic operation. The Level threshold setting is critical for best operation of the receive demodulator. If the control is advanced too far, the LED will trigger on background noise and copy will be difficult. If you reduce the setting too far, the interface will trigger erratically, even with a clean beat note. If you have a reasonably good CW receiver (CW bandwidth crystal filters and/or good audio filtering), you can back down the Level control until the LED stops flickering on all but the strongest noise pulses, but where it will still key reliably on a properly tuned CW signal.

Software Installation

The software for this project is available from *ARRLWeb* (see page viii). The distribution files include *MORSE.EXE*, a sample set-up file (CW.DAT), a sample logging file (LOG.DAT), the HELP text file (CWHELP.DAT) and the program Quick-BASIC source code (MORSE.BAS). To run the program log into the directory holding these files and type *MORSE <CR>*. The symbol <CR> stands for *Return* or *Enter*, depending on your keyboard.

The program menu permits you to enter or change the following items:

SPEED—Select a transmitting speed from 5 to 60 WPM. The program autocalibrates to your computer clock speed, and transmitting speeds are accurate to within 1%. On receive, the system automatically tracks the speed of the station you are copying up to 50 or 60 WPM.

YOUR CALL—You can enter your call sign so you never have to type it in routine exchanges. The call can be changed at any time if you want to use the program for contests, special events, or any other situation where you will be using another call.

OTHER CALL—If you enter the call of the station you are working (or would like to work), you can send all standard call exchanges at the beginning and end of a transmission with a single keystroke.

CQ OPTIONS—Select one of two CQ formats. The "standard" format is a 3x3 call using your call sign. The program also lets you store a custom CQ format, which is useful for contests.

MESSAGE BUFFERS—There are two message buffers. Either can be used for transmitting.

SIDETONE—Select on or off and a frequency of 400 to 1200 Hz.

WEIGHTING—Variable from 0.50 through 1.50.

DEFAULT SETUP—All the information discussed up to this point can be saved into a default disk file (CW.DAT). These choices will then be selected whenever you boot the program. Any setup can be saved at anytime.

LOGGING—The program supports a range of logging functions. It even includes the ability to check the log and let you know if you have worked that station before. If you have fully implemented the logging options, it will tell you the operator's name and QTH.

HELP FILES—If you forget how to use a function or are using the program for the first time, you can call up on-screen HELP files that explain every function.

AN EXPANDABLE HEADPHONE MIXER

From time to time, active amateurs find themselves wanting to listen to two or more rigs simultaneously with one set of headphones. For example, a DXer might want to comb the bands looking for new ones while keeping an ear on the local 2-m DX repeater. Or, a contester might want to work 20 m in the morning while keeping another receiver tuned to 15 m waiting for that band to open. There are a number of possible uses for a headphone mixer in the ham shack.

The mixer shown in **Figs 22.47** and **22.48** will allow simultaneous monitoring of up to three rigs. Level controls for each channel allow the audio in one channel to be prominent, while the others are kept in the background. Although this project was built for operation with three different rigs, the builder may vary the number of input sections to suit particular station requirements. This mixer was built in the ARRL Lab by Mark Wilson, K1RO.

CIRCUIT DETAILS

The heart of the mixer is an LM386 low-power audio amplifier IC. This 8-pin device is capable of up to 400-mW output at 8 W—more than enough for headphone listening. The LM386 will operate from 4- to 12-V dc, so almost any station power supply, or even a battery, will power it.

As shown in Fig 22.48, the input circuitry for each channel consists of an 8.2-Ω resistor (R1-R3) to provide proper termination for the audio stage of each transceiver, a 5000-Ω level control (R4-R6) and a 5600-Ω resistor (R7-R9) for isolation between channels. C1 sets the gain of the LM386 to 46 dB. With pins 1 and 8 open, the gain would be 26 dB. Feedback resistor R10 was chosen experimentally for minimum amplifier total harmonic distortion (THD). C2 and R11 form a "snubber" to prevent high-frequency oscillation, adding to amplifier stability. None of the parts values are particularly critical, except R1-R3, which should be as close to 8 Ω as possible.

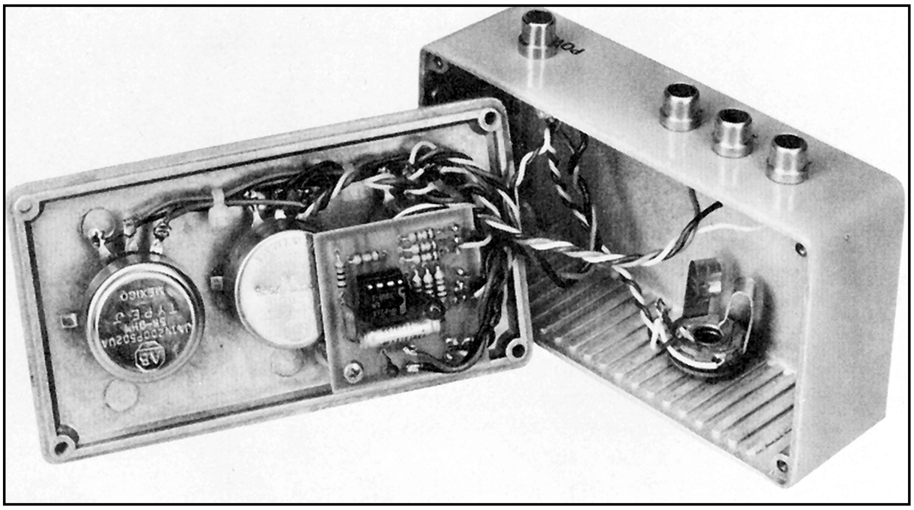


Fig 22.47—The 3-channel headphone mixer is built on a small PC board. Lead length was kept to a minimum to aid stability.

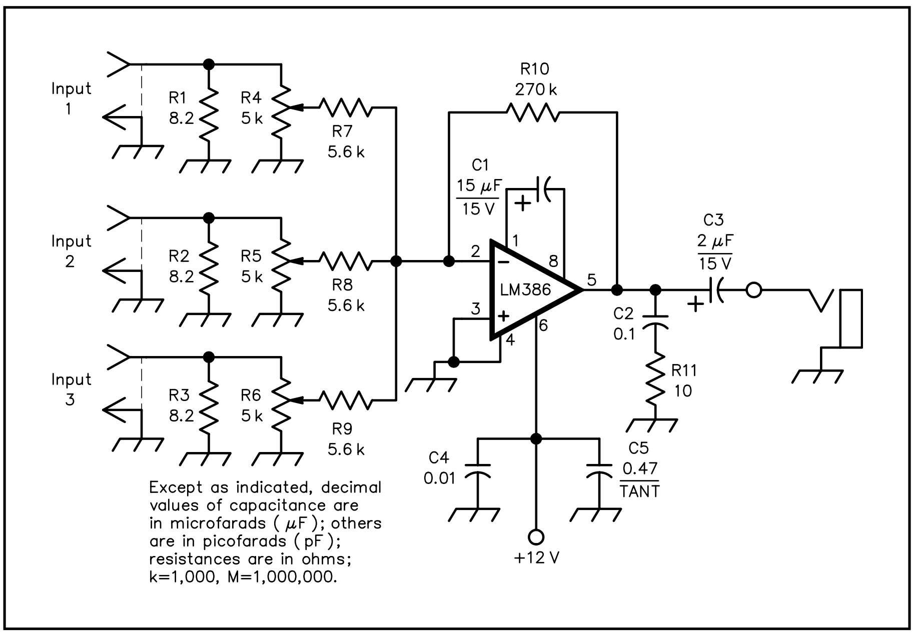


Fig 22.48—Schematic diagram of the LM386 headphone mixer. All resistors are $^{1}/_{4}$ W. Capacitors are disc ceramic unless noted.

CONSTRUCTION

Most of the components are arranged on a small PC board.[1] Perfboard will work fine also, but some attention to detail is necessary because of the high gain of the LM386. Liberal use of ground connections, short lead lengths and a bypass capacitor on the power-supply line all add to amplifier stability.

The mixer was built in a small diecast box. Tantalum capacitors and $^1/_4$-W resistors were used to keep size to a minimum. The ’386 IC is available from RadioShack (cat. no. 276-1731). A 0.01-µF capacitor and a ferrite bead on the power lead help keep RF out of the circuit. In addition, shielded cable is highly recommended for all connections to the mixer. The output jack is wired to accept stereo headphones.

Output power is about 250 mW at 5% THD into an 8-Ω load. The output waveform faithfully reproduces the input waveform, and no signs of oscillation or instability are apparent.

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[1] See Chapter 30, **References**, for template.

A VACUUM MANIPULATOR FOR CHIP COMPONENTS

Many builders could benefit from a simple machine to manipulate tiny chip components. This vacuum handler, designed and built by Dave Reynolds, KE7QF, accurately places those parts on your circuit board and holds them in place as you solder. You supply the vacuum — by sucking on a piece of plastic tubing such as that used with aquarium pumps. Other vacuum sources are also available. You might try a long piece of line connected to the vacuum system on your car. An old refrigerator compressor motor (with the refrigerant safely disposed) can also be used as a simple vacuum pump.

A common automotive universal joint serves as the swing bearing. It's strong, precise and inexpensive; a miracle of mechanical evolution. All the materials needed to build the manipulator are common items, but its performance is first class, and it definitely looks cool on the workbench. **Table 22.2** lists most of the necessary parts and materials.

The 12 inch square base was cut from pre-finished shelf material, and it is elevated by pieces of $^3/_4 \times 1^1/_2$ inch wood scrap cut to length for each side. The base is not critical; it only needs to be solid and level.

Build your manipulator with the arm extending inward from your off-dominant side. I'm right-handed so the open side of my manipulator is on the right. My soldering iron is on the right for the same reason. My unit includes a soldering iron holder made from a discarded speaker grill. That's it at the upper right of the lead photo. A $^3/_4$ inch trash hole in front of the iron has a small removable container below.

My probe is made from a ball pen refill with the ball carefully ground off, then emptied by prying out the plug and wick, and running water through backwards under pressure. Soaking the refill in a test tube of acetone helped loosen up the mess, but I warn you, mess is a key word. The stainless pen part looks really neat, but unless you're ready to challenge the messy aspects, you might want to use small diameter aluminum tubing.

The probe needs to be solid, non-solderable, and the right size. That means about 0.040 or 0.050 inch across the opening. Spin the probe in a drill and smooth the end where you ground off the ball. It has to make a good vacuum seal with the parts you want to pick up.

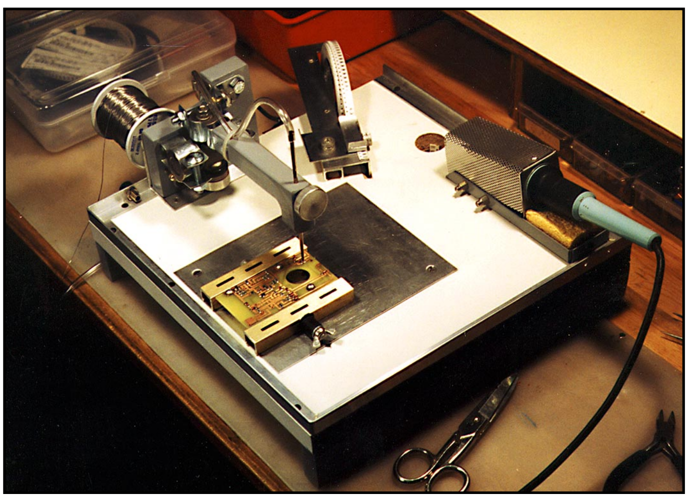
The arm and also the swing-bearing backboard were cut from $^3/_4$ inch wood, shaped, finished and painted. You could use pine, poplar or just about any wood you happen to have.

I never need more than about four inches of working radius for my boards, so the arm is about 5 inches long. See the lead photo for a view of the arm, with the pen refill installed through the head. Carefully drill vertically through the wooden probe head. I drilled a second hole in the end of the head, then threaded a thumb screw from a mobile speaker mount into the head to secure the probe. Any small bolt will do the job.

The new universal joints cost $6.95 each. I chose one for a 1970s Datsun; GMB part number 1052. Any joint will work, but I chose this one for the grease fitting hole in the center of one end

Table 22.2
Parts List

Item	*Cost*
One slotted shelf bracket	$2.00
Two auto universal joints	15.00
A pre-finished shelf board	5.00
Three conduit hangers	.90
One ball pen refill	1.00
$1^1/_2 \times 1^1/_2$ inch aluminum angle	3.00
Bolts, wood scraps, sheet metal	Scrounged
Total — a very reasonable	$26.90



cap. A $2^1/_2$ inch long #10 bolt goes through the grease fitting hole, through the body of the cross piece and out through the second end cap. The bolt is tightened just enough to ensure slack-free swing of the arm. See **Fig 22.49**. Originally I had planned to drill the other bolt hole in the opposite end cap. After ruining several bits trying to drill this hole, I bought another $6.95 joint just to get a second bearing cap with the grease fitting hole in its center. Those caps are hardened and extremely difficult to drill. I recommend you buy two of the joints on your first trip to the auto parts store. Universal joints for some other vehicles also have the grease fitting centered in one end cap. Ask your friendly auto parts dealer for help identifying a suitable universal joint.

The right and left bearings of the U-joint are clamped to the backboard, and they provide the up and down swing of the arm. The bearings at the top and bottom provide the side to side swing. The bearing holders shown in the photos are called #0 electrical conduit hangers; they're usually used to secure $^1/_2$ inch electrical conduit to a wall. I formed the curves a little closer to the 0.984 inch diameter of the bearing cap by squeezing on them with a vise while the bearing cap was in place.

Stretched across the bottom bearing is my state-of-the-art "elastomeric excursion biasing means" (EEBM)—a rubber band. This pulls back on the lower bearing, resulting in a slight downward tension on the vacuum tip. Holding down on the tiny parts keeps them in place and prevents "tombstoning."

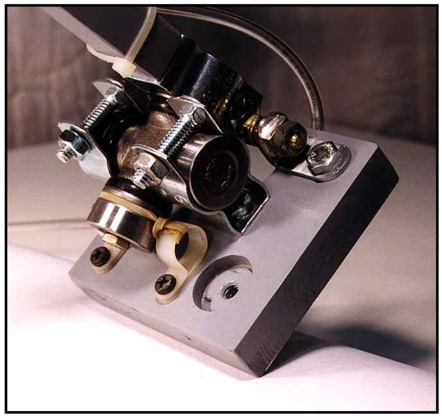
The backboard, bearing and probe arm are a subassembly, as shown in Fig 22.49. A small angle bracket and adjustment bolt is mounted at the top right of the backboard. The top bearing clamp contacts this bolt as a "rear limit." In use, you hold the probe at this rear-limit, and position the circuit board so the probe is exactly over where you want the part. Then, when you return with the part, it ends up precisely where you want it, ready to solder.

The backboard assembly is secured to the base with a thumb screw through a slotted hole in a piece of angle aluminum on the base. You need about $^3/_8$ inch side adjustment to recenter the probe for different tape widths. (I later found that by removing the swing bearing and arm, the base became an excellent ESD controlled working area for other projects.)

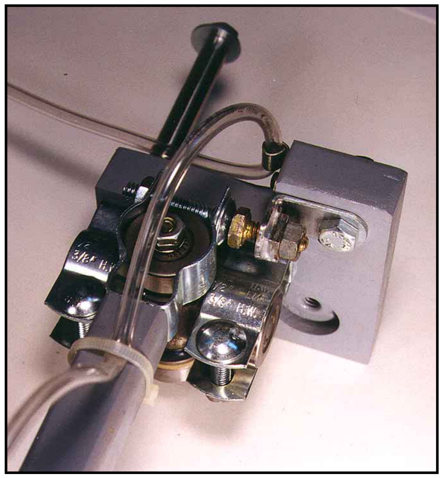
At the rear of the backboard, a long bolt with washers serves as a solder roll holder. It reduces clutter and helps you concentrate on assembly. See Fig 22.49B.

Much of the precision is determined where the part is picked up. It needs to be in correct angular position and the probe needs to center on it. The arm should swing over to the pickup point in a wide arc of less than 90º. Mine goes about 70º.

If your parts are not confined in tape, you can devise a part holder that's moveable instead of adjusting the backboard. I did that for a while. SM parts like to bounce and slide off the work surface, always into a hiding place. Just try finding a SOT-23 transistor in a rug! That's one reason why I added the metal rail around the edge of the machine. The rail is grounded to help with ESD control.



(A)



(B)

Fig 22.49 — A shows the swing bearing assembly with tensioner, backstop adjustment, and thumbscrew captive nut. B shows a view of the swing bearing, with good detail of the backstop adjustment, the double-nutted bolt through the universal joint body and the hose routing. The cutout section of the back board allows clearance for the mounting bolt as the assembly swings around to pick up components.

BUILDING A TAPE FEEDER

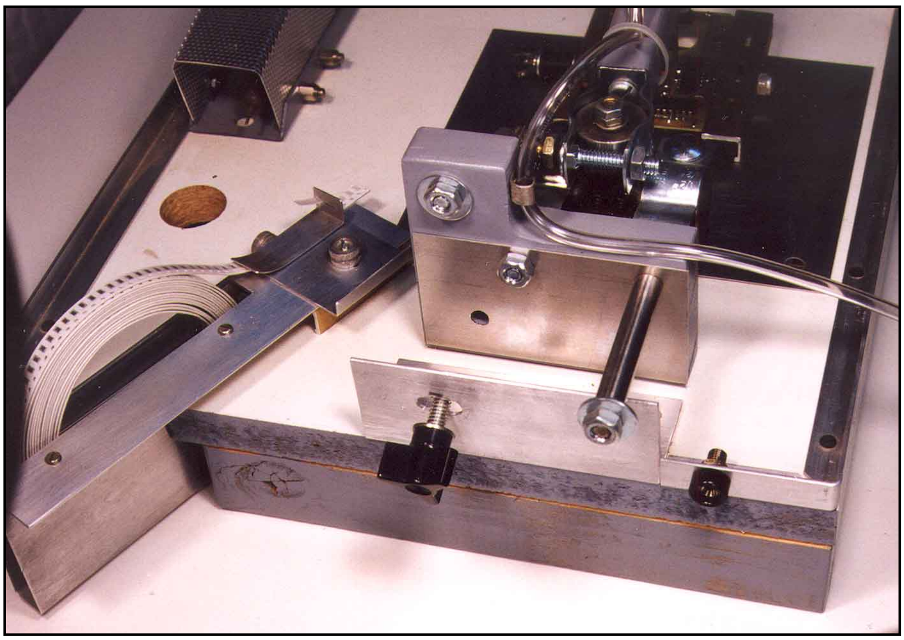
I still lost parts, so I built the aluminum magazine shown in **Fig 22.50** to feed taped parts accurately. I purchased inexpensive *cut tape* rolls of a few hundred of the component values that I always seem to design around. When I encounter a part I don't have on tape, I slide a length of old tape into the magazine, and it positions the odd part.

The magazine only needs to stabilize about a 4 inch by $^1/_2$ inch wide roll of parts tape. No center axle is required. Tapes for big or small parts differ, so you want to make the feed-out guides adjustable for different widths and different thicknesses. See the photos of Fig 22.50 for details. Tapes that you may plan to control will be on the order of 0.040 × 0.300 inches up to perhaps 0.080 × 0.500 for SOT223 parts.

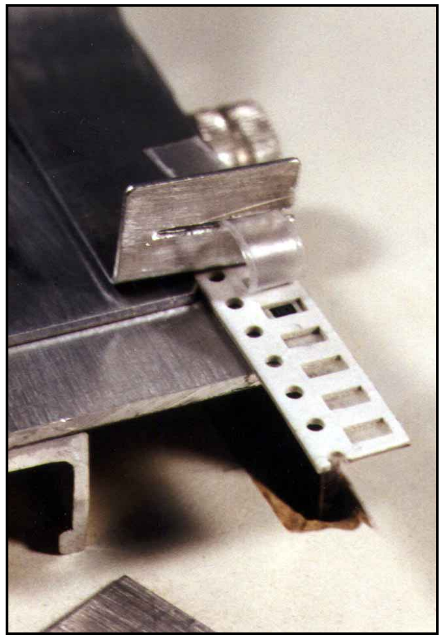
The magazine slides into a slot cut in the floor of the fixture, and a bolt holds it securely in place. The same bolt secures the tape's side adjustment plate. Parts should be picked up at the same elevation as the circuit board, so the height of the board holder is the height you need for the pick up area. I used a spacer made from the same shelf hanger that provided the circuit board holder, to be described later.

The side adjuster needs to be about 0.040 inch thick and adjustable to keep the tape confined to a straight line of movement. Both adjustments should be firm, but not tight. In use, the tape is advanced by hand, and excess tape and cover is snipped off as required.

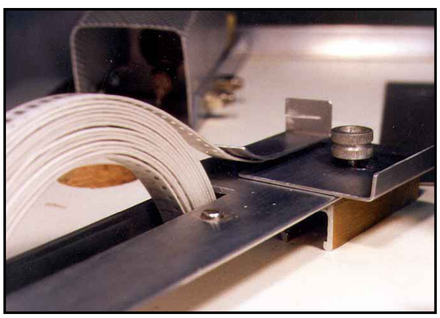
The sheet metal guide that holds down on the tape includes a section bent upward at the front, with a narrow horizontal slot. The slot is for the tape's paper cover to be peeled back and put through, out of the way. That solves a nuisance problem. The cutoffs are pushed into the trash hole.



(A)



(B)



(C)

Fig 22.50 — A shows the backboard subassembly detached from the mounting bracket and adjustment slot, with the parts-tape holder magazine feeding parts tape into guides. B shows a close-up view of the tape holder. C shows the tape exiting the magazine guides. Note the adjustment nuts at the top and right side, and the "peeling guide" for the tape cover.

AN ELECTROSTATIC-DISCHARGE-PROTECTED WORK SURFACE

A square sheet-metal assembly floor is placed where the work is done. The straight edges give visual reference of whether or not the board, and consequently the part, is positioned squarely. All metal parts are electrically connected on the bottom of the base, and a banana jack on the rail is provided to connect to the workbench electrostatic ground system. If you open and install all static sensitive parts in this environment, you shouldn't have ESD problems.

Observe standard safety practices, including a resistor (usually 1 MΩ) in the ground circuit to protect you from serious electrical shock in the case of unintended contact with line voltage. It hurts; I've been there. It's a good idea to measure the ac voltages between "line neutral" points on your bench and earth ground. I once found 60 V at 80 mA!

The circuit board holder is made from two small lengths of metal shelf hanger material which has a U type section of about $^5/_8$ inch wide by $^1/_2$ inch high. It is adjusted by a wing nut on a 10-24 through bolt, and a short piece of rubber hose provides spring tension to hold the board firmly by its edges. **Fig 22.51** shows the board holder. It does not fasten to the assembly floor. You move the board and holder to position the appropriate mounting location under the probe tip. You need a board holder like this to allow for parts and connections on the bottom side. It also bleeds off electrical charges, so any substitute material should be metal.

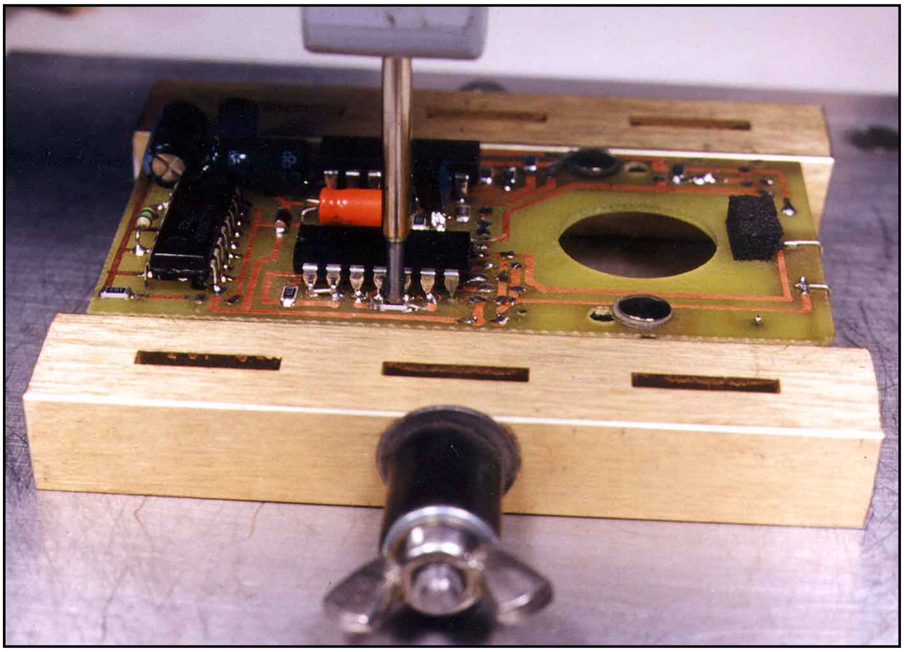
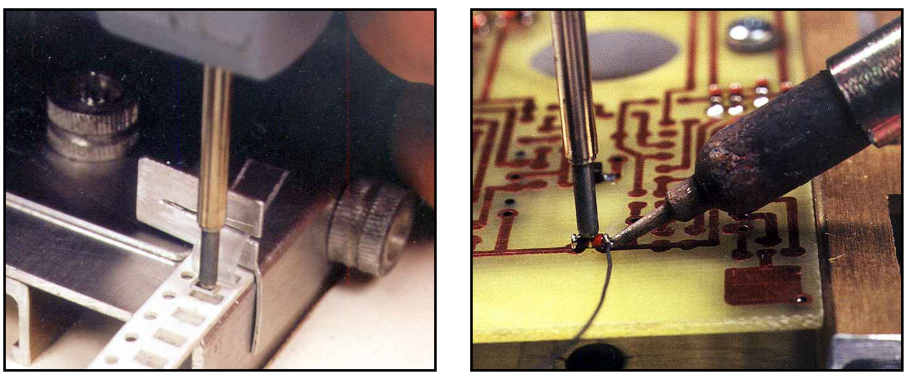


Fig 22.51 — This photo shows the construction details for the board holder. Notice that SM and conventional parts share board space on this project.

USING THE VACUUM HANDLER

After you have built all the pieces, using the vacuum handler is a simple process. First, swing the arm over the work area until the top clamp hits the rear limit screw. Now position the circuit board (and holder) so the exact part location is under the probe tip. Now swing the arm over to the tape holder and let it down to the component. Suck on the end of the plastic tubing like you were drinking through a straw (or turn on your vacuum source) to pick up the part. See **Fig 22.52A**.



(A) (B)

Fig 22.52 — A shows the vacuum handler lifting a component off the tape package. B shows a DO-35 diode, ready to solder onto the home made board. Two quick dabs of solder and the job is done.

Swing the arm back over the work until it hits the stop and lower the component into position. The rubber band and the weight of the arm will hold everything in position while you solder. See Fig 22.52B. Solder both sides, and you're done. Position the board for the next component and go pick it up.

MISCELLANEOUS RAMBLINGS

Surface mount implies no leads through drilled holes. While many SM parts are plentiful and inexpensive, others, like inductors and large capacitors, can be difficult to obtain. I use a combination of chip parts and conventional parts with the leads formed for soldering to the surface. Conventional ICs with leads bent inward make excellent SM parts.

I made a fixture to form the pins evenly by using a couple of elevated sheet metal edges to confine the "dead bug" legs. Large washers space the sheet metal to the appropriate height. The holes through the sheet metal are a bit large, to allow some adjustment when clamping the IC to the fixture. A form made from a 0.3 inch wide piece of 0.060 inch thick circuit board material is placed between the legs, and the appropriate legs are bent flat inward. Then the form is removed and the ends of the bent legs are bent the rest of the way down to the body. This results in "knees" that contact the pads for soldering. Pins are left straight when they need to go through a hole for contact on the other side of the circuit board. Ground this fixture for working with CMOS. **Fig 22.53** shows the details of this fixture and its use.

Chip resistors and capacitors come in size numbers such as 2512, 1210, 1206, 0805, 0603, or 0402. A 1206 size may be considered as 0.12 inches long and 0.06 inches wide. Applying tenths of an inch as above, the tiny 0402 is about 0.040 × 0.020. I wouldn't recommend the tiny ones for beginners. I like the 1206 because it gives good size reduction and works out well on a $^{1}/_{10}$ inch grid.

An hour spent installing surface mount components will convert you. It's faster, cheaper, and parts are widely available — more available than many of the parts we loved in the "good old days." Probably ten thousand resistors fit in the space of an 813. You could shrink your cluttered workshop into a briefcase. There are no leads to cut or form. Lots less holes to drill. Industry likes it and you will too.

If this article encourages you to begin designing circuits and boards to enter surface mount, bear in mind that a computer isn't necessary. Use your brain. Draw your *proven circuit* on both sides of quadrille paper with a pencil. Erase and rearrange as required; it becomes an interesting puzzle and it's rewarding at the end.

I found a deal on some 0.015 inch diameter 63-37 solder at a hamfest, and it's much easier than the 0.032 inch diameter solder that I started with. My soldering iron is a good quality unit, without bells or whistles. It has a 0.060 inch chisel tip and it's rated at 25 W. I use a grounded frame isolation transformer and stay clear of the house "ground neutral."

Some suppliers insist on selling reels of ten thousand pieces, but they are *not* your only source. Others now sell single parts at about the same price as through-hole parts. A tape roll of a hundred resistors for several dollars is reasonable for a serious builder. Most designers tend to use just a few values, and

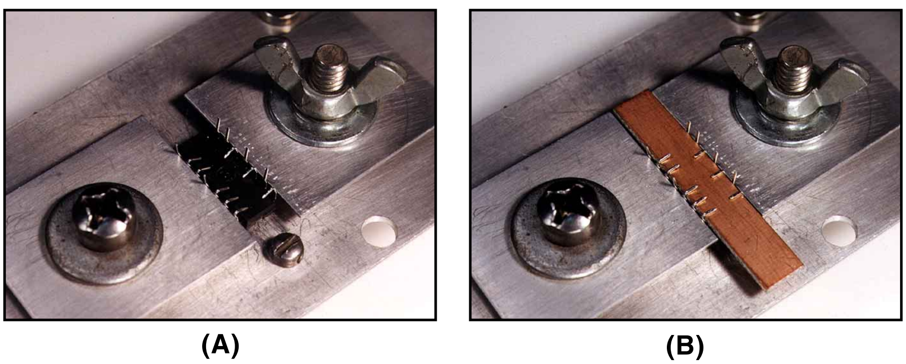


Fig 22.53 — A shows the pin former in action. Selected pins are bent flat onto the 0.060 × 0.3 inch center guide. The grounding jack is just visible in the upper right corner. B shows the ends of the pins bent down after the center guide was removed. Several pins were left straight for contrast here.

good coverage of the common ones probably needn't exceed ten or so different values.

Then there's scrounging. SM parts are easily removed, and there's a huge supply of discarded phones, audio, computer boards and on and on. Leads don't get shortened, and many recovered parts are better than anything you can buy. You learn about design practice, and that can be applied to your projects.

So build a fixture something like this and you'll have more fun than those guys who are just sitting around saying "Nope, ya just can't build stuff no more." They speak for themselves.

Some sources of catalogs that include SM parts (this is not a complete listing) are DC Electronics, Digi-Key, Jameco, Mouser and Tech America. See the **References** chapter for contact information.

AUDIO BREAK-OUT BOX

Two integrated circuits and a small PC board are all you need to solve the problem of feeding one receiver into several add-ons, such as a TNC, a PC interface or a speaker. Ben Spencer, G4YNM, described this project in March 1995 *QST*. It takes the audio output from a receiver and applies it to the inputs of four identical, independent, low-level AF amplifiers and one high-level (1-W output) AF amplifier.

Each low-level output channel can provide up to 20 dB of gain that's independently adjustable. You can apply audio to each of your accessories at a selected level without changing the level to the other accessories. In addition you can set the level to the speaker independently. Turn the speaker volume up to tune in the signal, and then turn the speaker volume down once tuning is finished and the mode is operating.

Circuit Description

Four identical low-level channels, each feeding an amplifier (U1A, B, C and D), are shown in **Fig 22.56**. Using the top channel as an example, C1 connects the input jack J1 to the noninverting input of U1A. R3 and R4 set U1A's voltage gain. R4 is the gain control, and when set fully clockwise (maximum resistance), the amplifier's gain is 10 (20 dB). At a counterclockwise (minimum resistance) setting, the amplifier's gain is 1 (0 dB).

The lower cut-off frequency (set by C2 and R3) is 16 Hz. The upper cut-off frequency of each channel is well beyond the audio frequency range. Each channel's output is dc isolated from its load; for example, U1A's output is dc isolated by C3.

R17 is the volume control for AF power amplifier U2 This stage will drive a low-impedance load such as a loudspeaker (4 to 16 Ω) at a level up to 1 W.

Construction

A single-sided PC board is available,[1] but the unit will work equally well built on perf-board. A template available from the ARRL[2] includes a PC board layout and a parts layout. This parts layout also can be used as a guide for construction on perf-board. The PC board directly accepts vertical and horizontal-mount single-turn potentiometers, but you can run wires from the mounting holes to front-panel-mount potentiometers. Since the project uses high-gain audio circuits, enclose it in a metal box. Place the input and output jacks on the rear panel to keep the interconnecting leads out of the way.

Checkout

After rechecking your wiring and soldering, connect the circuit to a 12-V power supply. The current drawn should be less than 50 mA when no audio is applied. Connect J1 to the AF output of your receiver and a speaker to J6. Adjust R17, VOLUME, for a comfortable listening level. Next check the operation of the low-power outputs by connecting J2, J3, J4 and J5 to a small earplug. Vary the four gain controls to check their operation. Each gain control can now be set to provide the audio level needed for each add-on.

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[1] PC boards are available for $6, plus $1.50 shipping, from FAR Circuits (see the Address List in the **References** chapter).

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[2] See Chapter 30, **References**, for template.

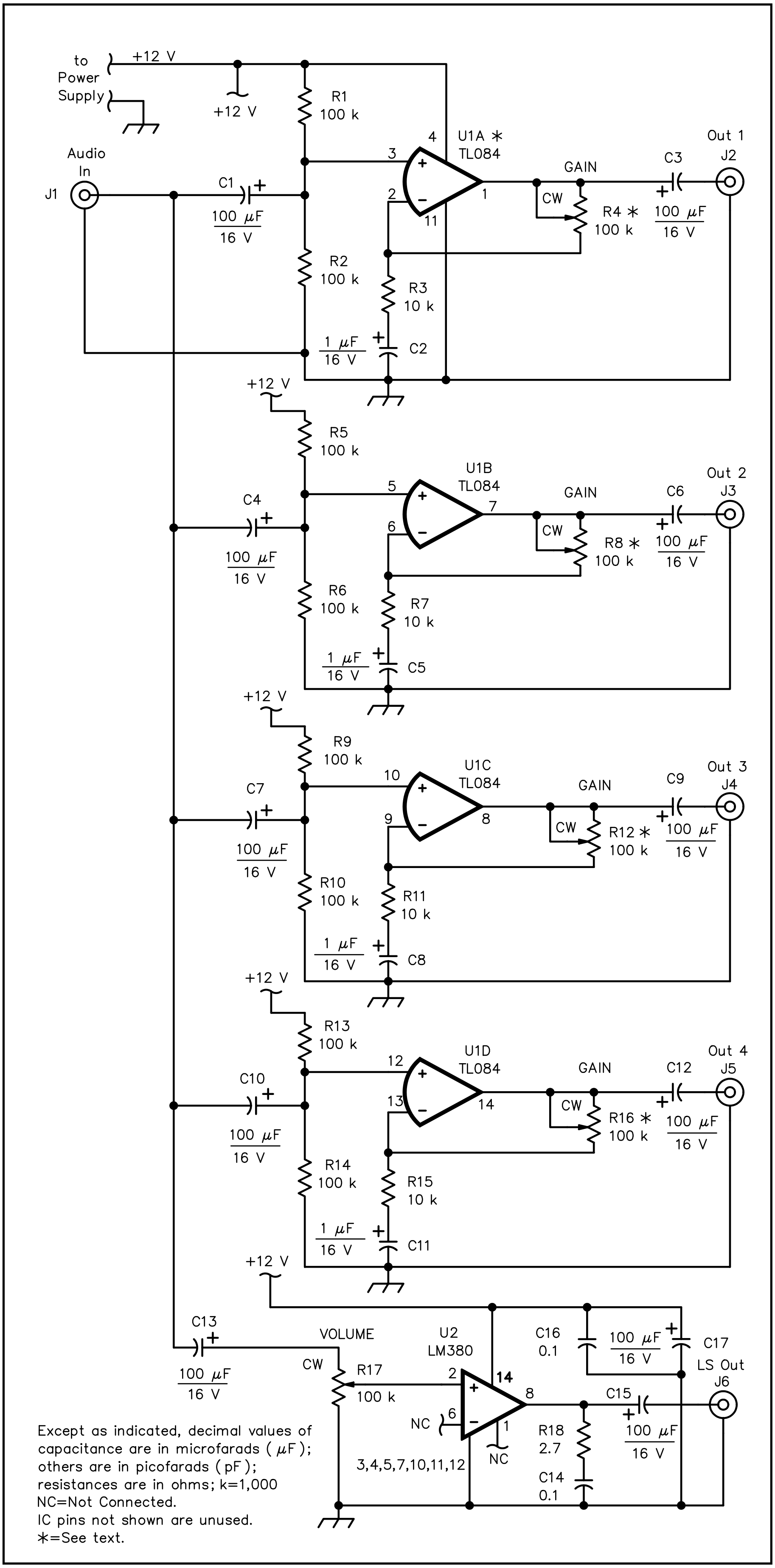


Fig 22.56—This audio break-out box requires less than 500-mA from a 12-VDC supply. All resistors are 1/4-W, 5%-tolerance carbon-composition or film units unless otherwise specified. RS numbers in parentheses are RadioShack stock numbers.

C1, C3, C4, C6, C7, C9, C10, C12, C13, C15, C17—100 µF, 16-V radial electrolytic or tantalum (RS 272-1028).

C2, C5, C8, C11—1 µF, 16-V radial electrolytic or tantalum (RS 272-1434).

C14, C16—0.1 µF, 50 V disc ceramic (RS 272-135).

R1, R2, R5, R6, R9, R10, R13, R14—100 kΩ.

R3, R7, R11, R15—10 kΩ.

R4, R8, R12, R16, R17—100-kΩ log or audio taper, panel-mount potentiometer (RS 271-1722) or PC-board vertical-mount trimmer potentiometer; see text.

R18—2.7 Ω, 1/2 W.

U1—TL084, TL074, or LM324 quad op amp (RS 276-1711).

U2—LM380N 2-W audio power amplifier. The LM380 is available in several packages. Be sure to use the 14-pin DIP if you are going to build this project on the PC board from FAR or from the ARRL template.

Misc: Single-sided PC board (see Note 1), enclosure, knobs, IC sockets, input and output connectors of choice, hook-up wire.

AN SWR DETECTOR AUDIO ADAPTER

This SWR detector audio adapter is designed specifically for blind or vision-impaired amateurs, but anyone can use it. The basic circuit can be adapted to any application where you want to use an audio tone rather than a meter to give an indication of the value of a dc voltage.

Usually a meter (or meters) is used to display SWR by measuring the feed line forward and reflected voltages. This adapter generates two tones with frequencies that are proportional to these voltages. The tones are fed to a pair of stereo headphones (the miniature types are ideal) so one ear hears the forward-voltage tone and the other ear hears the reflected-voltage tone. Ben Spencer, G4YNM, described this system in the July 1994 *QST*. He connected the forward voltage tone to his left earphone and reverse voltage tone to his right earphone. Thus, tuning up a transmitter is simply a matter of tuning for the highest pitched tone in the left ear, and the lowest pitched tone in the right ear.

The PC board can be installed in existing SWR detectors, and the forward and reflected voltages obtained by tapping into the lines that currently connect the voltage sensors to the existing meters or meter selector switch.

Circuit Description

The audio-adapter circuit is shown in **Fig 22.57**. Each half of the adapter circuit operates identically. Most SWR detectors consist of two RF voltage sensors, one for forward voltage and one for reverse. These voltages are diode-rectified. The resulting dc voltages are fed to meters that indicate relative forward and reflected power. With this circuit, the forward and reflected voltages are applied to the audio adapter board and drive voltage-controlled oscillators (VCOs).

The forward dc voltage from the SWR detector is routed to R1, buffered by U1B, fed to SENSITIVITY control R5A and applied to VCO U2B. As the voltage on pin 1 of U2B increases, so does the frequency of the tone output at U2B pin 10.

Adjusting the Sensitivity control sets the range of audio tones produced by the audio adapter. This signal is fed via VOLUME control R6A to the audio amplifier (U3A) to drive the left headphone. Zener diode Dl limits the maximum input voltage, partly to protect U1B, but also to limit the upper VCO frequency to about 3 kHz.

Without any dc input, each VCO runs at a low frequency (approximately 380 Hz) to tell you the unit is operating. Increased voltage on the transmission line— even from a low-power transmitter— is sufficient to cause the tone frequency to increase noticeably. As the voltage decreases, so does the frequency of the tone.

Construction

A single-sided PC board and template package are available.[1,2] The PC board is small enough to fit inside most existing SWR detectors and the circuit can be battery operated if required. Mount a stereo headphone jack on the SWR detector's front panel to accept the headphone plug.

R6A and R6B are parts of a dual-section, panel-mount potentiometer. R5A and R5B are PC-board mounted trimmer potentiometers. For those who want a panel-mounted SENSITIVITY control, a dual-gang potentiometer can be substituted for R5A and R5B.

Testing and Calibration

Once the unit is installed in an SWR detector, connect a 5-V power supply to the audio adapter board. When power is applied. you should hear two identical low frequency tones in the headphones. Adjust the VOLUME controls to provide a comfortable listening level.

1 PC boards are available for $2.50, plus $1.50 shipping, from FAR Circuits (see the address list in the **References** chapter).

2 See Chapter 30, **References**, for template.

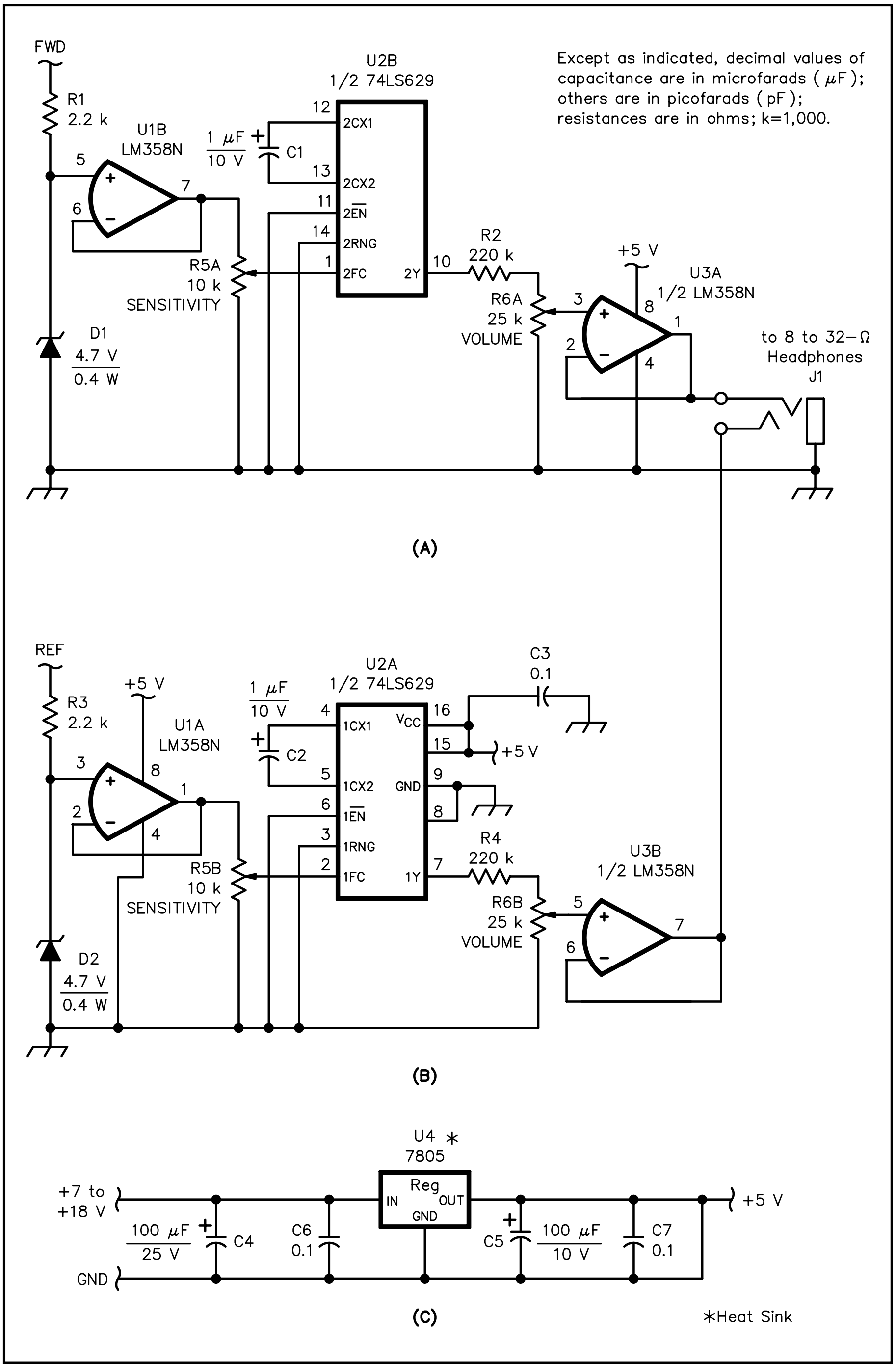


Fig 22.57—Schematic of the SWR detector audio-adapter circuit. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units. All capacitors are disc ceramic unless otherwise stated. The circuits of A and B are identical, each driving one earphone of an 8- to 32-Ω stereo headset. At A, the forward-voltage circuit; at B, the reflected-voltage circuit. A voltage regulator that provides 5-V dc is shown at C.

R5A, R5B—10-kΩ horizontal-mount trimmer potentiometer; optionally, a 25-kΩ dual-gang, panel-mount potentiometer can be used.

R6—25-kΩ dual-gang, panel-mount potentiometer.

U1, U3—LM358N dual op amp (available from Jameco. See the Address List in the References chapter) or substitute an NTE928M (available from Hosfelt Electronics).

U2—74LS629 dual VCO (available from Jameco) or a NTE74LS629 (available from Hosfelt Electronics).

Misc: PC board, stereo headphone jack, 8 to 32-Ω stereo headphones, mounting hardware.

Next, connect your transmitter to a dummy load via the SWR detector. When you key your transmitter, the tone in the left earpiece should increase in frequency quite dramatically, representing increasing forward power. Theoretically, with a matched line and load, there should be no reflected voltage and therefore, the right-headphone tone shouldn't change. In all probability, however, the tone frequency will increase, but only slightly.

If you use an antenna tuner for matching your antenna system, you'll hear the two tones change frequency according to the degree of mismatch. The best match is indicated by the forward headphone tone reaching its maximum frequency while the reflected (right) headphone tone frequency decreases to its minimum.

PC VOLTMETER AND SWR BRIDGE

Personal computers are very good at doing arithmetic. To use this capability around the shack, the first thing to do is convert whatever you want to measure (voltage, power, SWR) to numbers. Next you have to find a way to put these numbers into your computer. Paul Danzer, N1II, took a single chip A/D (analog to digital converter) and built this unit to connect to a computer printer port. Construction and testing is just a few evenings' work. The software to run the chip is included with the *Handbook* companion software, available for downloading from *ARRLWeb* (see page vii).

Circuit Description

The circuit consists of a single-chip A/D converter, U2, and a DB-25 male plug (**Fig 22.58**). Pins 2 and 3 are identical voltage inputs, with a range from 0 to slightly less than the supply voltage V_{CC} (+5 V). R1, R2, C3 and C4 provide some input isolation and RF bypass. There are four signal leads on U2—DO is the converted data from the A/D out to the computer, DI and CS are control signals from the computer and CLK is a computer generated clock signal sent to pin 7 of U2.

The +5 V supply is obtained from a +12 V source and regulator U1. One favorite accident, common in many ham shacks, is to connect power supply leads backwards. Diode D1 prevents any damage from this action. Current drain is usually less than 20 mA, so any 5-V regulator may be used for U1. The power supply ground, circuit ground and computer ground are all tied together.

In this form the circuit gives two identical dc voltmeters. To extend the range, a 2:1 divider, using 50-kΩ resistors, is shown. Resistor accuracy is not important, since the circuit is calibrated in the accompanying software.

The breadboard circuit, built

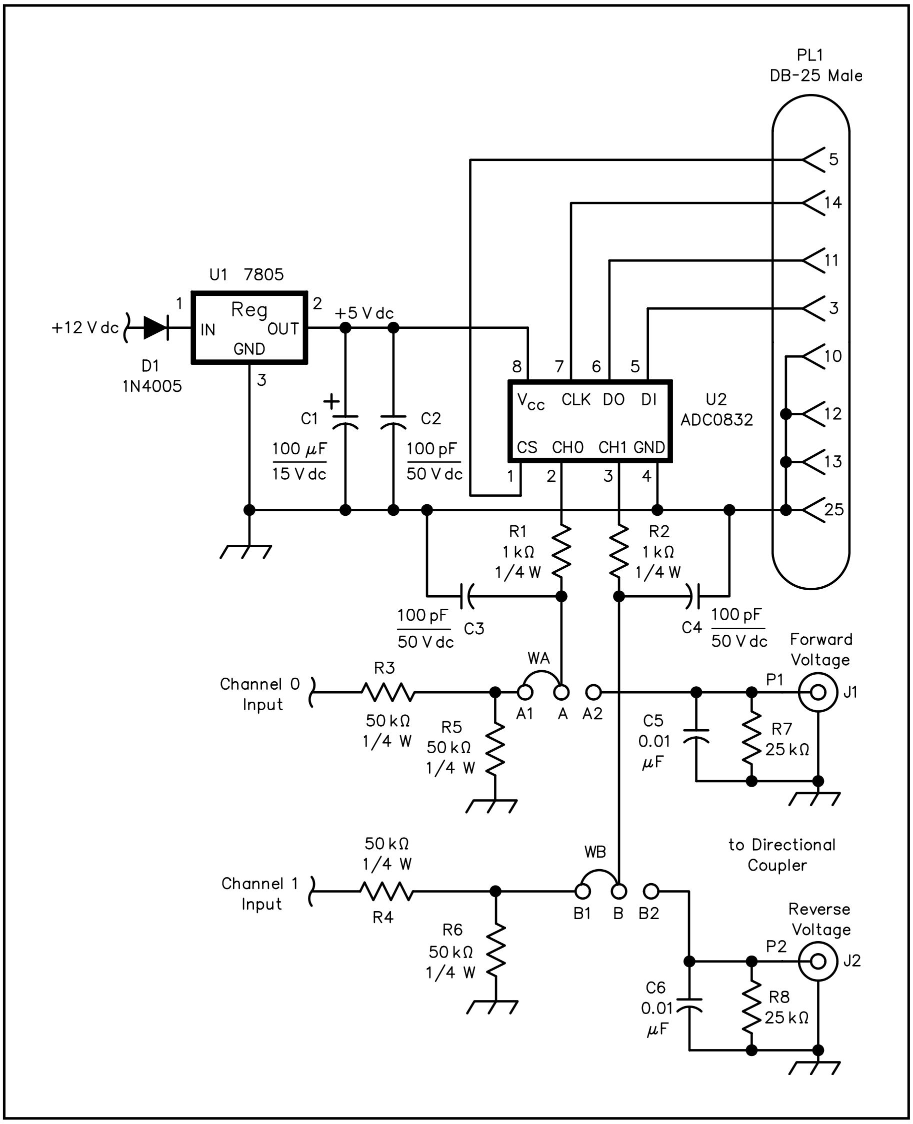


Fig 22.58—Only two chips are used to provide a dual-channel voltmeter. PL1 is connected through a standard 25-pin cable to a computer printer port. U2 requires an 8-pin IC socket. All resistors are 1/4 W. You can use the A/D as an SWR display by connecting it to a sensor such as the one used in the Tandem Match described in this chapter (see text). A few more resistors are all that are needed to change the voltmeter scale. The 50 kΩ resistors form 2:1 voltage dividers, extending the voltmeter scale (on both channels) to almost 10-V dc.

on a universal PC board (RadioShack 276-150), is shown in **Fig 22.59**. The voltage regulator is on the top left and the converter chip, U2, in an 8-pin socket. Power is brought in through a MOLEX plug. Signal input and ground are on the wire stubs. Two strips of soft aluminum, bent into L-shapes, hold the male DB-25 connector (RadioShack 276-1547) to the PC board.

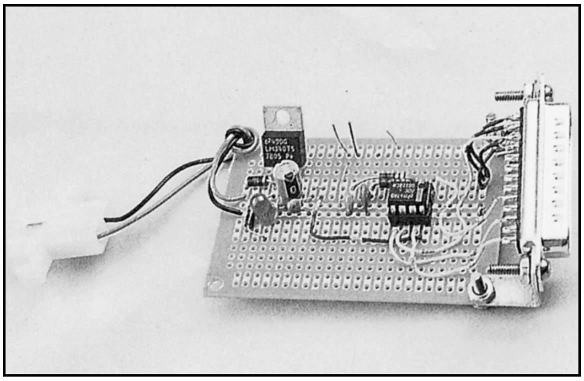


Fig 22.59—Construction of this model took only one evening. No special tools are required. All parts except U2 are available from most suppliers as well as RadioShack. The A/D converter chip can be purchased from any National Semiconductor dealer such as Digi-Key. See the Address List in the References chapter.

Use It As An SWR Bridge

Most analog SWR measuring devices use a meter, which has a nonlinear scale calibration. An SWR of 3:1 is usually close to center scale, and values above this are rarely printed. To use the PC voltmeter as an SWR bridge indicator, move jumpers WA and WB from the A1 and B1 positions to the A2 and B2 positions. Disconnect the cathodes (banded end) of the diode detectors in your SWR bridge and connect them to J1 and J2.

The current that flows out of these diodes, and into J1 and J2, goes through the 25 kΩ resistors R7 and R8, to provide voltages of less than 5 V. These voltages are proportional to the forward and reverse voltages developed in the directional coupler. The software in the PC takes the sum and difference of these forward and reverse voltages, and calculates the SWR.

Software

The software, including a voltmeter function and an SWR function, is written in GW-BASIC and saved as an ASCII file. Therefore you can read it on any word processor, but if you modify it make sure you resave it as an ASCII file. It can be imported into QBasic and most other BASIC dialects.

It was written to be understandable rather than to be most efficient. Each line of basic code has a comment or explanation. It can be modified for most computers. The printer port used is LPT1, which is at a hex address of 378, 379 and 37A. If you wish to use LPT2 (printer port 2) try changing these addresses to 278, 279 and 27A.

Gary Sutcliffe, W9XT, wrote a small BASIC program to help you find the addresses of your printer ports. Run FINDLPT.BAS, which is included with the *Handbook* companion software, available for downloading from the ARRL Internet site (see page vii).

The CONV.BAS program was written to run on computers as slow as 4.7-MHz PC/XTs. If you get erratic results with a much faster computer, set line 1020 (CD=1) to a higher value to increase the width of the computer generated clock pulses.

The CONV.BAS program operates by first reading the value of voltage at point A into the computer, followed by the voltage at point B. It then prints on the screen these two values, and computes their sum and difference to derive the SWR. If you use the project as a voltmeter, simply ignore the SWR reading on the screen or suppress it by deleting lines 2150, 2160 and 2170. If the two voltages are very close to each other (within 1 mV) the program declares a bad reading for SWR.

Calibration

Lines 120 and 130 in the program independently set the calibration for the two voltage inputs. To calibrate a channel, apply a known voltage to the input point A. Read the value on the PC screen. Now multiply the constant in line 120 by the correct value and divide the result by the value you previously saw on the screen. Repeat the procedure for input point B and line 130.

THE TANDEM MATCH—AN ACCURATE DIRECTIONAL WATTMETER

Most SWR meters are not very accurate at low power levels because the detector diodes do not respond to low voltage in a linear fashion. This design uses a compensating circuit to cancel diode nonlinearity. It also provides peak detection for SSB operation and direct SWR readout that does not vary with power level. **Fig 22.65** is a photo of the completed project. The following information is condensed from an article by John Grebenkemper, KI6WX, in January 1987 *QST*. Some modifications by KI6WX were detailed in the "Technical Correspondence" column of July 1993 *QST*. A PC Board is available from FAR Circuits.[1]

CIRCUIT DESCRIPTION

A directional coupler consists of an input port, an output port and a coupled port. Ideally, a portion of the power flowing from the input to the output appears at the coupled port, but *none* of the power flowing from the output to the input appears at the coupled port.

The coupler used in the Tandem Match consists of a pair of toroidal transformers connected in tandem. The configuration was patented by Carl G. Sontheimer and Raymond E. Fredrick (US Patent no. 3,426,298, issued February 4, 1969). It has been described by Perras, Spaudling (see Bibliography) and others. With coupling factors of 20 dB greater, this coupler is suitable to sample both forward and reflected power.

The configuration used in the Tandem Match works well over the frequency range of 1.8 to 54 MHz, with a nominal coupling factor of 30 dB. Over this range, insertion loss is less than 0.1 dB. The coupling factor is flat to within ±0.1 dB from 1.8 to 30 MHz, and increases to only ±0.3 dB at 50 MHz. Directivity exceeds 35 dB from 1.8 to 30 MHz and exceeds 26 dB at 50 MHz.

The low-frequency limit of this directional coupler is determined by the inductance of the transformer secondary windings. The inductive reactance should be greater than 150 Ω (three times the line characteristic impedance) to reduce insertion loss. The high-frequency limit of this directional coupler is determined by the length of the transformer windings. When the winding length approaches a significant fraction of a wavelength, coupler performance deteriorates.

The coupler described here may overheat at 1500 W on 160 m (because of the high circulating current in the secondary of T2). The problem could be corrected by using a larger core or one with greater permeability. A larger core would require longer windings; that option would decrease the high-frequency limit.

Most amateur directional wattmeters use a germanium-diode detector to minimize the forward voltage drop. Detector voltage drop is still significant, however, and an uncompensated diode detector does not respond to small signals in a linear fashion. Many directional wattmeters compensate for diode nonlinearity by adjusting the meter scale.

The effect of underestimating detected power worsens at low power levels. Under these conditions, the ratio of the forward power to the reflected power is overestimated because the reflected power is always less than the forward power. This results in an instrument that underestimates SWR, particularly as power is reduced. A directional wattmeter can be checked for this effect by measuring SWR at several power levels. The SWR should be independent of power level.

The Tandem Match uses a feedback circuit to compensate for

[1] A PC board is available from FAR Circuits. See the Address List in the **References** chapter. PC board template packages are also available from FAR Circuits.

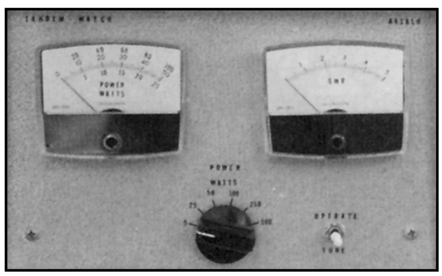


Fig 22.65—The Tandem Match uses a pair of meters to display net forward power and true SWR simultaneously.

diode nonlinearity. Transmission-line SWR is displayed on a linear scale. Since the displayed SWR is not affected by changes in transmitter power, a matching network can be simply adjusted to minimize SWR. Transmatch adjustment requires only a few watts.

Table 22.4
Performance Specifications for the Tandem Match

Power range:	1.5 to 1500 W
Frequency range:	1.8 to 54 MHz
Power accuracy:	Better than ±10% (±0.4 dB)
SWR accuracy:	Better than ±5%
Minimum SWR:	Less than 1.05:1
Power display:	Linear, suitable for use with either analog or digital meters
SWR display:	Linear, suitable for use with either analog or digital meters
Calibration:	Requires only an accurate voltmeter

CONSTRUCTION

The schematic diagram for the Tandem Match is shown in **Fig 22.70**. The circuit is designed to operate from batteries and draws very little power. Much of the circuitry is of high impedance, so take care to isolate it from RF fields. House the circuit in a metal case. Most problems in the prototype were caused by stray RF in the op-amp circuitry.

The schematic shows two construction options. Connect jumpers W1, W2 and W3 to use the circuit as it was originally designed (with two 9-V batteries and TLC27L4 or TLC27M4 op amps). By omitting these jumpers, any quad FET-input op amps can be used instead of the TLC27x4s. Possible substitutes include the TL064, TL074, TL084, LF347 and LF444. In that case you should also omit the 9-V batteries and the automatic turn-on circuitry of Q1, Q2 and Q3 (everything to the left of the jumpers on the top row of the diagram). Now you will have to connect an external + 15 V supply between the + V line and chassis ground and a –15 V supply to the – V line.

The FAR Circuits Tandem Match circuit board is double sided, but does not have plated-through holes. The component side is mainly the chassis and circuit ground planes, although there are a few signal traces. You will have to install "jumper posts" in a few locations, and solder them to both sides of the board to connect these traces. Carefully follow the schematic diagram and parts-placement diagram supplied with the board to identify these "posts." Check the board carefully to ensure that none of the ground traces pass too close to a circuit lead. You may have to scrape a bit of foil away from a few places around the component holes. This is easy with an X-ACTO knife.

The trimmer pots must be square multiturn units with top adjustment screws for use with the FAR Circuits board. Mount the ferrite beads so they don't touch any board trace; the beads have sufficient leakage to cause problems in the high impedance parts of the circuit. Before mounting the SO-239 connectors to the circuit board, enlarge the center location holes to $^5/_8$ inch diameter to accept the connector body. The components connected to the SO-239 are soldered directly between the center pin and the board traces. See Fig 22.72.

DIRECTIONAL COUPLER

The directional coupler is constructed in its own small ($2^3/_4 \times 2^3/_4 \times 2^1/_4$-inch) aluminum box (see **Fig 22.71**). Two pairs of SO-239 connectors are mounted on opposite sides of the box. A piece of PC board is run diagonally across the box to improve coupler directivity. The pieces of RG-8X coaxial cable pass through holes in the PC board. (Note: Some brands of "mini 8" cable have extremely low breakdown voltage ratings and are unsuitable to carry even 100 W when the SWR exceeds 1:1. See "High-Power Operation" for details of a coupler made with RG-8 cable.)

Begin by constructing T1 and T2, which are identical except for their end connections. (Refer to Fig 22.71.) The primary for each transformer is the center conductor of a length of RG-8X coaxial cable. Cut two cable lengths sufficient for mounting as shown in the figure. Strip the cable jacket, braid and dielectric as shown. The cable braid is used as a Faraday shield between the transformer windings, so it is

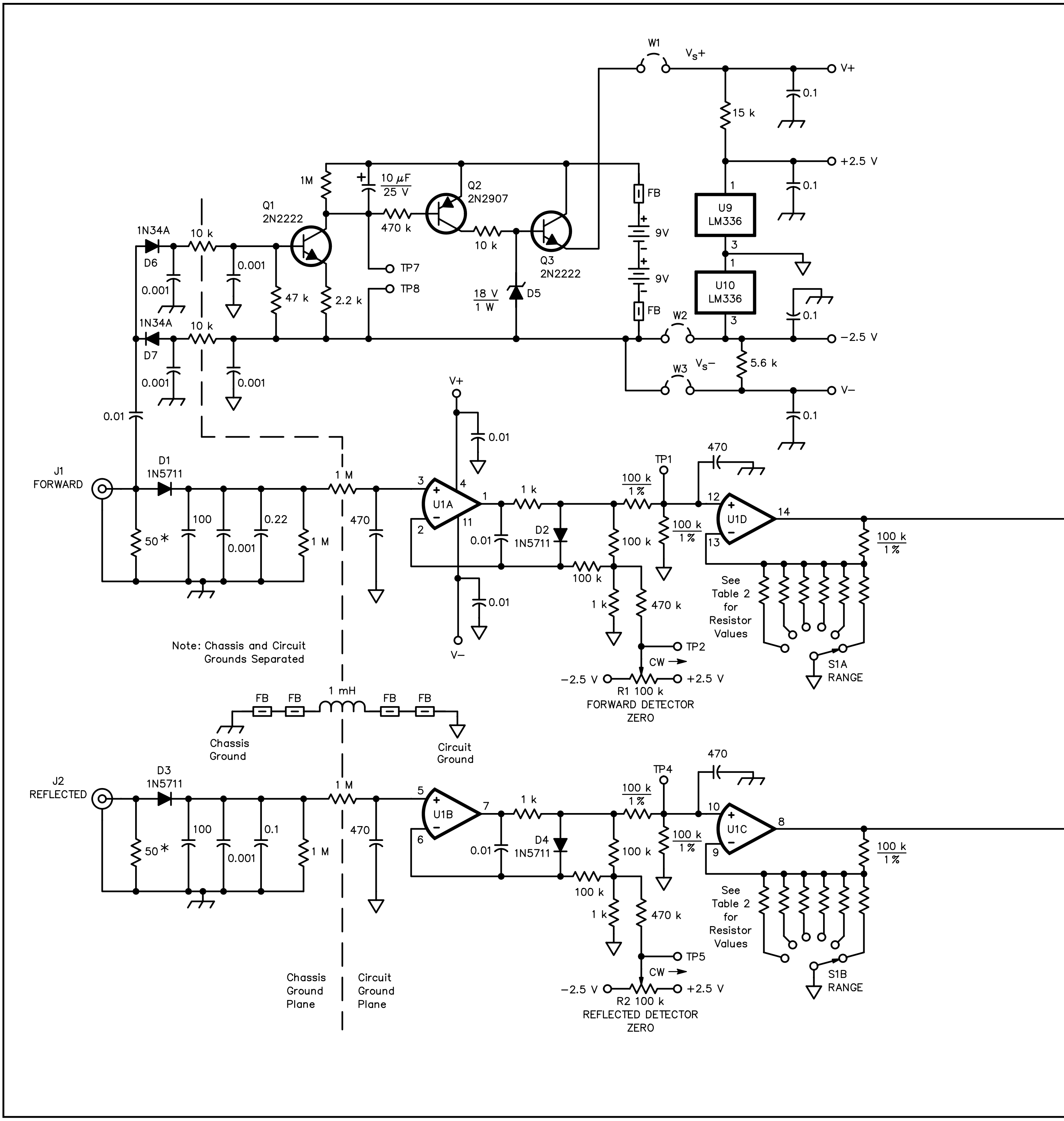
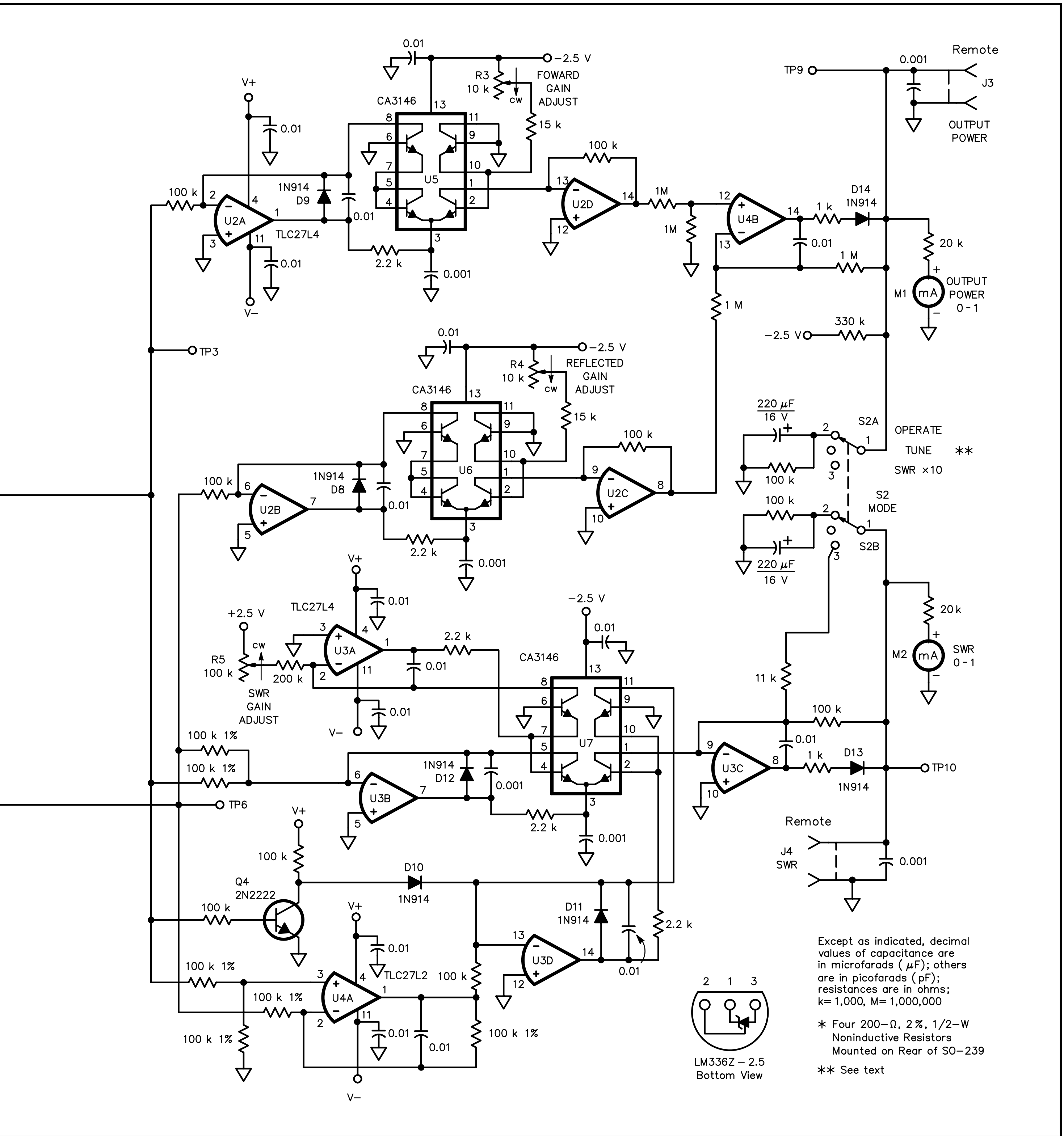


Fig 22.70—Schematic diagram of the Tandem Match directional wattmeter. Parts identified as RS are from RadioShack. Contact information for parts suppliers appears in the References chapter.

D1-D4—1N5711
D6, D7—1N34A or 1N271
D8-D14—1N914.
FB—Ferrite bead, Amidon FB-73-101 or equiv.
J1, J2—SO-239 connector.
J3, J4—Open-circuit jack.
M1, M2—1 mA panel meter.
Q1, Q3, Q4—2N2222 metal case only.
Q2—2N2907 metal case or equiv.
R1, R2, R5—100-kΩ, 10-turn cermet Trimpot.
R3, R4—10-kΩ, 10-turn, cermet Trimpot.
U1-U3—TLC27M4 op amp
U4—TLC27L2 or TLC27M2.
U5-U7—CA3146.
U9, U10—LM336.



Remote
J3
OUTPUT POWER
TP9
R3 10 k
FOWARD GAIN ADJUST
CA3146
U5
U2A
TLC27L4
1N914 D9
U2D
U4B
D14 1N914
M1
OUTPUT POWER 0 - 1
TP3
R4 10 k
REFLECTED GAIN ADJUST
U6
U2B
1N914 D8
U2C
220 µF 16 V
S2A
OPERATE
TUNE
**
SWR ×10
S2 MODE
S2B
TLC27L4
U3A
R5 100 k
SWR GAIN ADJUST
U7
M2
SWR 0 - 1
U3B
1N914 D12
U3C
D13 1N914
TP10
TP6
Q4 2N2222
D10 1N914
D11 1N914
U3D
Remote
J4 SWR
U4A
TLC27L2
LM336Z – 2.5 Bottom View
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k= 1,000, M= 1,000,000
* Four 200–Ω, 2%, 1/2–W Noninductive Resistors Mounted on Rear of SO–239
** See text

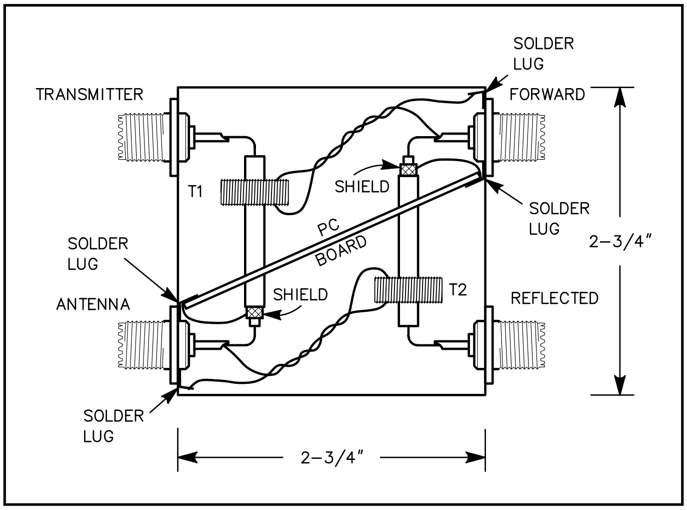


Fig 22.71 —Construction details for the directional coupler. A metal case is required.

only grounded at one end. *Important—connect the braid only at one end or the directional-coupler circuit will not work properly!* Wind two transformer secondaries, each 31 turns of #24 enameled wire on a T-50-3 iron-powder core. Slip each core over one of the prepared cable pieces (including both the shield and the outer insulation). Mount and connect the transformers as shown in Fig 22.71, with the wires running through separate holes in the copper-clad PC board.

The directional coupler can be mounted separately from the rest of the circuitry if desired. If so, use two coaxial cables to carry the forward- and reflected-power signals from the directional coupler to the detector inputs. Be aware, however, that any losses in the cables will affect power readings.

This directional coupler has not been used at power levels in excess of 100 W. For more information about using Tandem Match at high power levels, see "High-Power Operation."

DETECTOR AND SIGNAL-PROCESSING CIRCUITS

The detector and signal-processing circuits were constructed on a perforated, copper-clad circuit board. These circuits use two separate grounds—*it is extremely important to isolate the grounds as shown in the circuit diagram*. Failure to do so may result in faulty circuit operation. Separate grounds prevent RF currents on the cable shield from affecting the op-amp circuitry.

The directional coupler requires good 50-Ω loads. They are constructed on the back of the female UHF chassis connectors where the cables from the directional coupler enter the wattmeter housing. Each load consists of four 200-Ω resistors connected from the center conductor of the UHF connector to the four holes on the mounting flange, as shown in **Fig 22.72**. The detector diode is then mounted from the center conductor of the connector to the 100-pF and 1000-pF bypass capacitors, which are located next to the connector. The response of this load and detector combination measures flat to beyond 500 MHz.

Schottky-barrier diodes (type 1N5711) were used in this design because they were readily available. Any RF-detector diode with a low forward voltage drop (less than 300 mV) and reverse breakdown voltage greater than 30 V could be used. (Germanium diodes could be used in this circuit, but performance will suffer. If germanium diodes are used, reduce the values of the detector-diode and feedback-diode load resistors by a factor of 10.)

The rest of the circuit layout is not critical, but keep the lead lengths of 0.001- and 0.01-µF bypass capacitors short. The capacitors provide additional bypass paths for the op-amp circuitry.

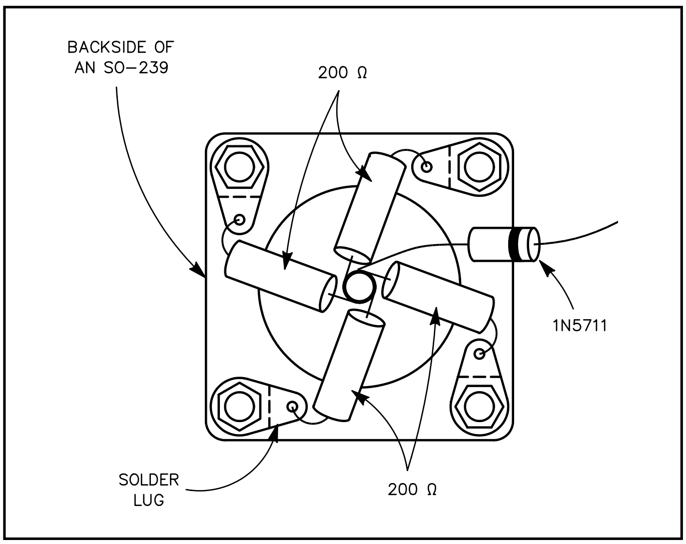


Fig 22.72—The parallel load resistors mounted on an SO-239 connector. Four 200-Ω resistors are mounted in parallel to provide a 50-Ω detector load.

D6 and D7 form a voltage doubler to detect the presence of a carrier. When the forward power exceeds 1.5 W, Q3 switches on and stays on until about 10 seconds after the carrier drops. (A connection from TP7 to TP9 forces the unit on, even with no carrier present.) The regulated references of +2.5 V and –2.5 V generated by the LM334 and LM336 are critical. Zener-diode substitutes would significantly degrade performance.

The four op amps in U1 compensate for nonlinearity of the detector diodes. D1-D2 and D3-D4 are the matched diode pairs discussed above. A RANGE switch selects the meter range. (A six-position switch was used here because it was handy.) The resistor values for the RANGE switch are shown in **Table 22.5**. Full-scale input power gives an output at U1C or U1D of 7.07 V. The forward- and reflected-power detectors are zeroed with R1 and R2.

The forward- and reflected-detector voltages are squared by U2, U5 and U6 so that the output voltages are proportional to forward and reflected power. The gain constants are adjusted using R3 and R4 so that an input of 7.07 V to the squaring circuit gives an output of 5 V. The difference between these two voltages is used by U4B to yield an output that is proportional to the power delivered to the transmission line. This voltage is peak detected (by an RC circuit connected to the OPERATE position of the MODE switch) to indicate and hold the maximum power measurement during CW or SSB transmissions.

SWR is computed from the forward and reflected voltages by U3, U4 and U7. When no carrier is present, Q4 forces the SWR reading to be zero (that is, when the forward power is less than 2% of the full-scale setting of the RANGE switch). The SWR computation circuit gain is adjusted by R5. The output is peak detected in the OPERATE mode to steady the SWR reading during CW or SSB transmissions.

Transistor arrays (U5, U6 and U7) are used for the log and antilog circuits to guarantee that the transistors will be well matched. Discrete transistors may be used, but accuracy may suffer.

A three-position toggle switch selects the three operating modes. In the OPERATE mode, the power and SWR outputs are peak detected and held for a few seconds to allow meter reading during actual transmissions. In the TUNE mode, the meters display instantaneous output power and SWR.

A digital voltmeter is used to obtain more precise readings than are possible with analog meters. The output power range is 0 to 5 V (0 V = 0 W and 5 V = full scale). SWR output varies from 1 V (SWR = 1:1) to 5 V (SWR = 5:1). Voltages above 5 V are unreliable because of voltage limiting in some of the op amp circuits.

Table 22.5
Range-Switch Resistor Values

Full-Scale Power Level (W)	*Range Resistor (1% Precision) (kΩ)*
1	2.32
2	3.24
3	4.02
5	5.23
10	7.68
15	9.53
20	11.0
25	12.7
30	15.0
50	18.7
100	28.7
150	37.4
200	46.4
250	54.9
300	63.4
500	100.0
1000	237.0
1500	649.0
2000	open

CALIBRATION

The directional wattmeter can be calibrated with an accurate voltmeter. All calibration is done with dc voltages. The directional-coupler and detector circuits are inherently accurate if correctly built. To calibrate the wattmeter, use the following procedure:

1) Set the MODE switch to TUNE and the RANGE switch to 100 W or less.
2) Jumper TP7 to TP8. This turns the unit on.
3) Jumper TP1 to TP2. Adjust R1 for 0 V at TP3.
4) Jumper TP4 to TP5. Adjust R2 for 0 V at TP6.
5) Adjust R1 for 7.07 V at TP3.
6) Adjust R3 for 5.00 V at TP9, or a full-scale reading on M1.
7) Adjust R2 for 7.07 V at TP6.
8) Adjust R4 for 0 V at TP9, or a zero reading on M1.
9) Adjust R2 for 4.71 V at TP6.
10) Adjust R5 for 5.00 V at TP10, or a full-scale reading on M2.

11) Set the RANGE switch to its most sensitive scale.
12) Remove jumpers from TP1 to TP2 and TP4 to TP5.
13) Adjust R1 for 0 V at TP3.
14) Adjust R2 for 0 V at TP6.
15) Remove jumper from TP7 to TP8.

This completes the calibration procedure. This procedure has been found to equal calibration with expensive laboratory equipment. The directional wattmeter should now be ready for use.

ACCURACY

Performance of the Tandem Match has been compared to other well-known directional couplers and laboratory test equipment, and it equals any amateur directional wattmeter tested. Power measurement accuracy of the Tandem Match compares well to a Hewlett-Packard HP-436A power meter. The HP meter has a specified measurement error of less than ±0.05 dB. The Tandem Match tracked the 436A within ±0.5 dB from 10 mW to 100 W and within ±0.1 dB from 1 W to 100 W. The unit was not tested above 1200 W because a transmitter with a higher power rating was not available.

SWR performance was equally good when compared to the SWR calculated from measurements made with 436A and a calibrated directional coupler. The Tandem Match tracked the calculated SWR within ±5% for SWR values from 1:1 to 5:1. SWR measurements were made at 8 W and 100 W.

OPERATION

Connect the Tandem Match in the 50-Ω line between the transmitter and the antenna matching network (or antenna if no matching network is used). Set the RANGE switch to a range greater than the transmitter output rating and the MODE switch to TUNE. When the transmitter is keyed, the Tandem Match automatically switches on and indicates both power delivered to the antenna and SWR on the transmission line. When no carrier is present, the output power and SWR meters indicate zero.

The OPERATE mode includes RC circuitry to momentarily hold the peak-power and SWR readings during CW or SSB transmissions. The peak detectors are not ideal, so there could be about 10% variation from the actual power peaks and the SWR reading. The SWR×10 mode increases the maximum readable SWR to 50:1. This range should be sufficient to cover any SWR value that occurs in amateur use. (A 50-ft open stub of RG-8 yields a measured SWR of only 43:1, or less, at 2.4 MHz because of cable loss. Higher frequencies and longer cables exhibit a smaller maximum SWR.)

It is easy to use the Tandem Match to adjust an antenna-matching network. Adjust the transmitter for minimum output power (at least 1.5 W). With the carrier on and the MODE switch set to TUNE or SWR×10, adjust the matching network for minimum SWR. Once minimum SWR is obtained, set the transmitter to the proper operating mode and output power. Place the Tandem Match in the OPERATE mode.

PARTS

Few parts suppliers carry all the components needed for these couplers. Each may stock different parts. Good sources include Digi-Key, Surplus Sales of Nebraska, Newark Electronics and Anchor Electronics. See the Address List in the **References** Chapter.

HIGH-POWER OPERATION

This material was condensed from a letter by Frank Van Zant, KL7IBA, that appears in July 1989 *QST* (pp 42-43). In April 1988, Zack Lau, W1VT, described a directional-coupler circuit (based on the same principle as Grebenkemper's circuit) for a QRP transceiver (see the bibliography at the end of this chapter). The main advantage of Lau's circuit is very low parts count.

Grebenkemper uses complex log-antilog amplifiers to provide good measurement accuracy. This application gets away from complex circuitry, but retains reasonable measurement accuracy over the 1 to 1500-W range. It also forfeits the SWR-computation feature.

Lau's coupler uses ferrite toroids. It works great at low power levels, but the ferrite toroids heat excessively with high power, causing erratic meter readings and the potential for burned parts.

The Revised Design

Powdered-iron toroids are used for the transformers in this version of Lau's basic circuit. The number of turns on the secondaries was increased to compensate for the lower permeability of powdered iron.

Two meters display reflected and forward power (see **Fig 22.73**). The germanium detector diodes (D1 and D2—1N34) provide fairly accurate meter readings particularly if the meter is calibrated (using R3, R4 and R5) to place the normal transmitter output at midscale. If the winding sense of the transformers is reversed, the meters are transposed (the forward-power meter becomes the reflected-power meter, and vice versa).

Construction

Fig 22.74 shows the physical layout of this coupler. The pickup unit is mounted in a $3^1/_2 \times 3^1/_2 \times 4$-inch box. The meters, PC-mount potentiometers and HIGH/LOW power switch are mounted in a separate

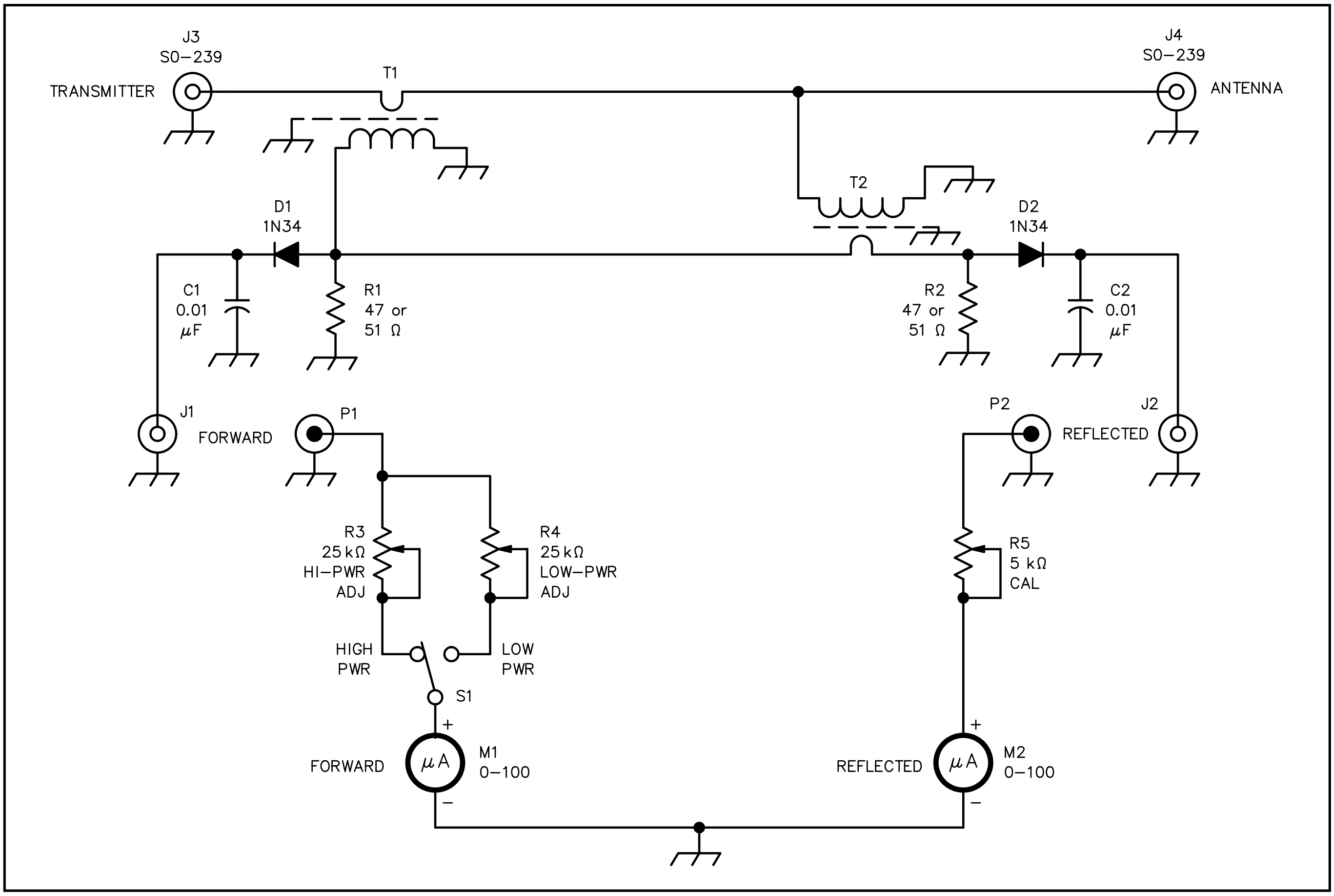


Fig 22.73—Schematic diagram of the high-power directional coupler. D1 and D2 are germanium diodes (1N34 or equiv). R1 and R2 are 47- or 51-Ω $^1/_2$-W resistors. C1 and C2 have 500-V ratings. The secondary windings of T1 and T2 each consist of 40 turns of #26 to 30 enameled wire on T-68-2 powdered-iron toroid cores. If the coupler is built into an existing antenna tuner, the primary of T1 can be part of the tuner coaxial output line. The remotely located meters (M1 and M2) are connected to the coupler box at J1 and J2 via P1 and P2.

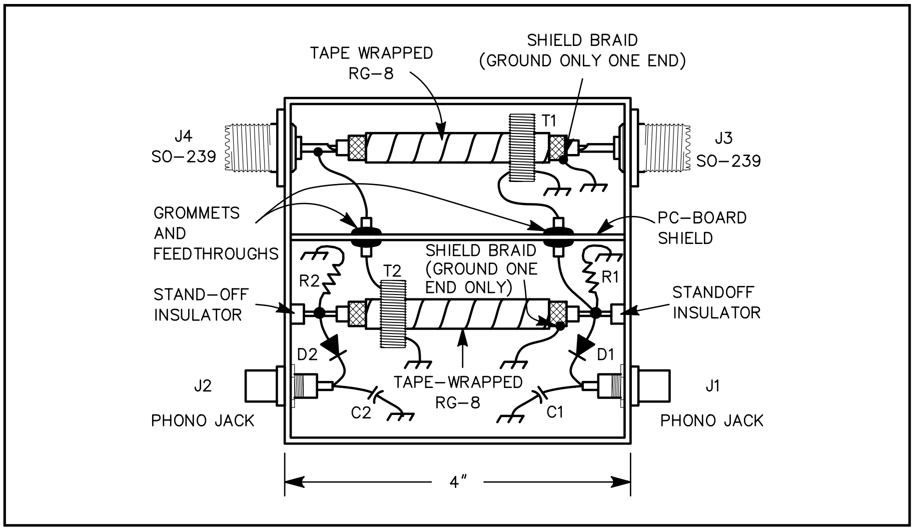


Fig 22.74—Directional-coupler construction details. Grommets or standoff insulators can be used to route the secondary windings of T1 and T2 through the PC-board shield. A $3^1/_2 \times 3^1/_2 \times$ 4-inch metal box serves as the enclosure.

box or a compartment in an antenna tuner.

The primary windings of T1 and T2 are constructed much as Grebenkemper described, but use RG-8 with its jacket removed so that the core and secondary winding may fit over the cable. The braid is wrapped with fiberglass tape to insulate it from the secondary winding. An excellent alternative to fiberglass tape—with even higher RF voltage-breakdown characteristics—is ordinary plumber's Teflon pipe tape, available at most hardware stores.

The transformer secondaries are wound on T-68-2 powdered-iron toroid cores. They are 40 turns of #26 to 30 enameled wire spread evenly around each core. By using #26 to 30 wire on the cores, the cores slip over the tape-wrapped RG-8 lines. With #26 wire on the toroids, a single layer of tape (slightly more with Teflon tape) over the braid provides an extremely snug fit for the core. Use care when fitting the cores onto the RG-8 assemblies. After the toroids are mounted on the RG-8 sections, coat the assembly with General Cement Corp Polystyrene Q Dope, or use a spot or two of RTV sealant to hold the windings in place and fix the transformers on the RG-8 primary windings.

Mount a PC-board shield in the center of the box. between T1 and T2, to minimize coupling between transformers. Suspend T1 between SO-239 connectors and T2 between two standoff insulators. The detector circuits (C1, C2, D1, D2, R1 and R2) are mounted inside the coupler box as shown.

Calibration, Tune up and Operation

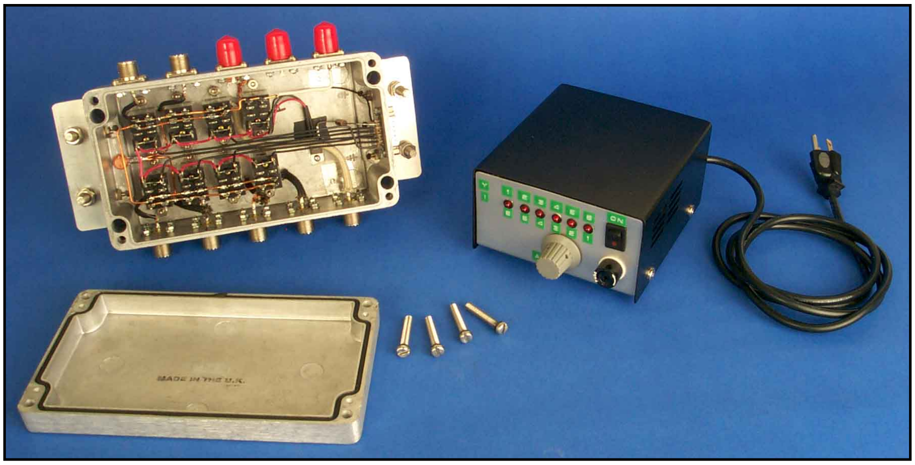
The coupler has excellent directivity. Calibrate the meters for various power levels with an RF ammeter and a 50-Ω dummy load. Calculate I^2R for each power level, and mark the meter faces accordingly. Use R3, R4 and R5 to adjust the meter readings within the ranges. Diode nonlinearities are thus taken into account, and Grebenkemper's signal-processing circuits are not needed for relatively accurate power readings.

Start the tune-up process using about 10 W, adjust the antenna tuner for minimum reflected power, and increase power while adjusting the tuner to minimize reflected power.

This circuit has been built into several antenna tuners with good success. The bridge worked well at 1.5-kW output on 1.8 MHz. It also worked fine from 3.5 to 30 MHz with 1.2- and 1.5-kW output. The antenna is easily tuned for a 1:1 SWR using the null indication provided.

Amplifier settings for a matched antenna, as indicated with the wattmeter, closely agreed with those for a 50-Ω dummy load. Checks with a Palomar noise bridge and a Heath Antenna Scope also verified these findings. This circuit should handle more than 1.5 kW, *as long as the SWR on the feed line through the wattmeter is kept at or near 1:1*. (On one occasion high power was applied while the antenna tuner was not coupled to a load. Naturally the SWR was extremely high, and the output transformer secondary winding opened like a fuse. This resulted from the excessively high voltage across the secondary. The damage was easily and quickly repaired.)

AN EXTERNAL AUTOMATIC ANTENNA SWITCH FOR USE WITH YAESU OR ICOM RADIOS



This antenna-switching-control project involves a combination of ideas from several earlier published articles.[1, 2, 3] This system was designed to mount the antenna relay box outside the shack, such as on a tower. With this arrangement, only a single antenna feed line needs to be brought into the shack. The lead photo shows the control unit and relay box, designed and built by Joe Carcia, NJ1Q. As the W1AW chief operator, Joe has plans for the switch at W1AW. Either an ICOM or Yaesu HF radio will automatically select the proper antenna. In addition, a manual switch can override the ICOM automatic selection. That feature also provides a way to use the antenna with other radios. The antenna switch is not a two-radio switch, though. It will only work with one radio at a time.

Many builders may want to use only the ICOM or only the Yaesu portion of the interface circuitry, depending on the brand of radio they own. The project is a "hacker's dream." It can be built in a variety of forms, with the only limitations being the builder's imagination.

CIRCUIT DESCRIPTION

Fig 22.75 is a block diagram of the complete system. An ICOM or Yaesu HF radio connects to the appropriate decoder via the accessory connector on the back of the radio. Some other modern rigs have an accessory connector used for automatic bandswitching of amplifiers, tuners and other equipment. For example, Ten-Tec radios apply a 10 to 14-V dc signal to pins on the DB-25 interface connector for the various bands. Other radios use particular voltages on one of the accessory-connector pins to indicate the selected band. Check the owner's manual of your radio for specific information, or contact the manufacturer's service department for more details. You may be able to adapt the ideas presented in this project for use with other radios.

A single length of coax and a multiconductor control cable run from the rig and decoder/control box to the remotely located switch unit. The remote relay box is equipped with SO-239 connectors for the input as well as the output to each antenna. You can use any type of connectors, though.

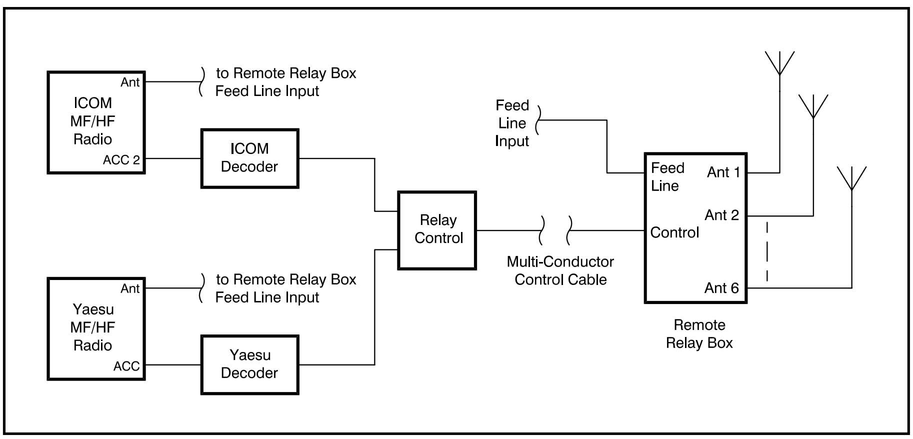


Fig 22.75 — Block diagram of the remotely controlled automatic antenna switch.

ICOM radios use an 8-V reference and a voltage divider system to provide a stepped band-data output voltage.

Table 22.6 shows the output voltage at the accessory socket when the radio is switched to the various bands. Notice that seven voltage steps can be used to select different antennas. The ICOM accessory connector pin assignments needed for this project are:

Pin 1 +8 V reference
Pin 2 Ground
Pin 4 Band signal voltage
Pin 7 +12 (13.8) V supply

Yaesu radios provide the band information as binary coded decimal (BCD) data on four lines. Nine different BCD values allow you to select a different antenna for each of the MF/HF bands. Table 22.6 also shows the BCD data from Yaesu radios for the various bands. The Yaesu 8-pin DIN accessory connector pin assignments needed for this project are:

Pin 1 +12 (13.8) V supply
Pin 3 Ground
Pin 4 Band Data A
Pin 5 Band Data B
Pin 6 Band Data C
Pin 7 Band Data D

Table 22.6
ICOM Accessory Connector Output Voltages By Band

Band (MHz)	*Output Voltage*
1.8	7 – 8.0
3.5	6 – 6.5
7	5 – 5.5
14	4 – 4.5
18, 21	3 – 3.5
24, 28	2 – 2.5
10	0 – 1.2

Note: The voltage step between bands is not constant, but close to 1.0 V, and the 10-MHz band is not in sequence with the others.

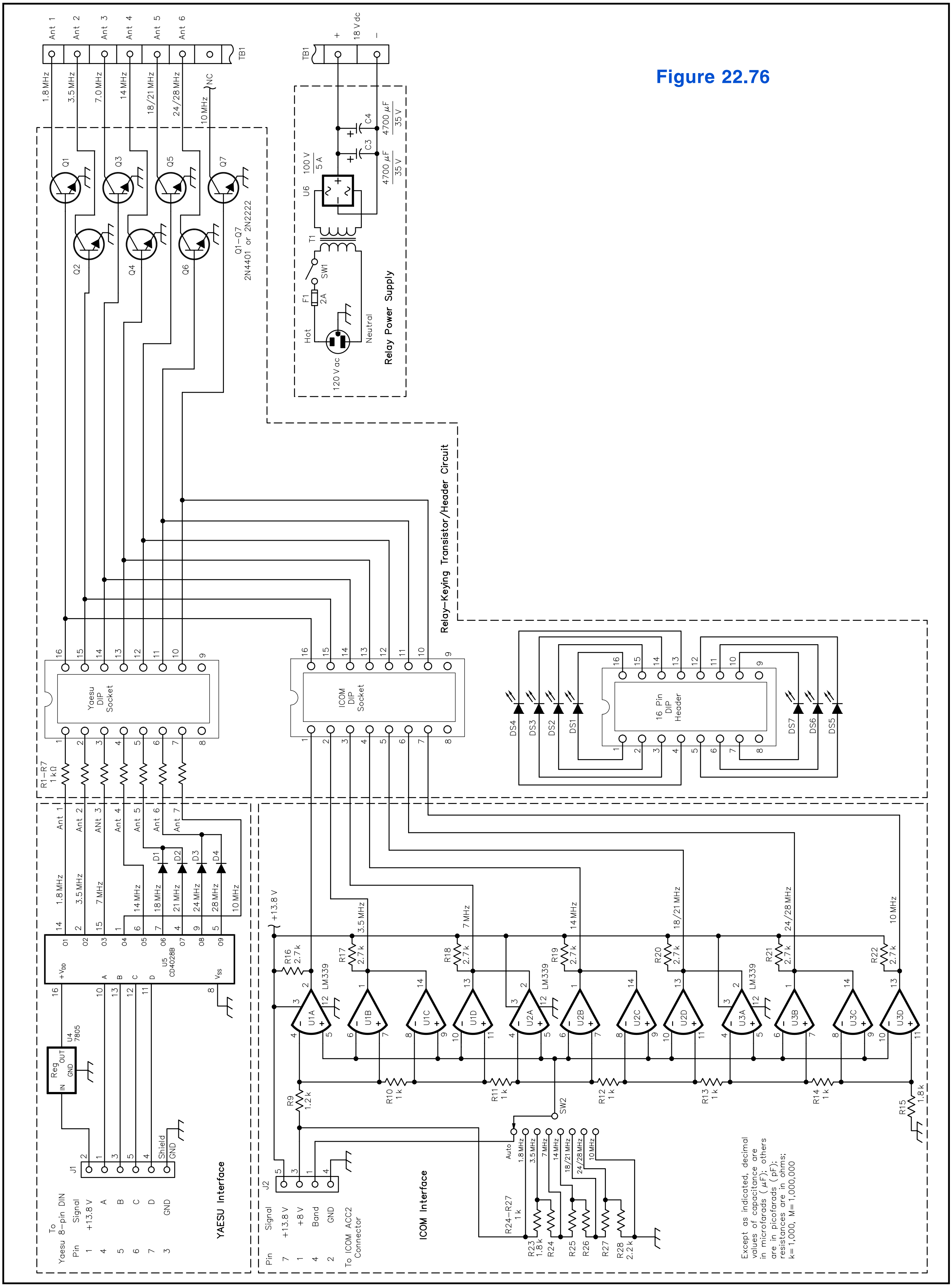
Fig 22.76 is the schematic diagram for the control box. We will discuss each part of the control circuit later in this description. First, let's turn our attention to the external antenna box.

EXTERNAL ANTENNA BOX

Only the number of control lines going out to the relay box limits the number of antennas this relay box will switch. The unit shown in the lead photo has ten SO-239 connectors, to switch the common feed line to any of nine antennas. Many hams will use an eight-conductor rotator cable (such as *Belden 9405*) to the relay box. Using eight wires, we can control seven relays (six for antennas and one to ground the

Fig. 22.76 — This schematic diagram shows the circuitry inside the main control box. The circuit is divided into four main sections: The *ICOM interface circuit*, the *Yaesu interface circuit*, the *Relay-keying transistor/header board* and the *Relay power supply*. Most of the components are available from RadioShack. Resistors are 1/4 W, 5% tolerance carbon-composition. The rotary switch allows manual antenna selection, which would be useful for rigs other than ICOM or Yaesu. A stable 8-V reference source must be made available to use the manual switch with non-ICOM rigs. The DIP sockets are used by the LED header to select the appropriate interface circuit for the radio being used. Note that only the Yaesu interface selector socket has resistors in line. Use flexible, stranded wire for the LED header and LEDs. This part of the circuit can be hard wired if only one type of rig will be used.

C1 — 10 µF, 16 V electrolytic
C2 — 0.1 µF, 50 V
C3, C4 — 4700 µF, 35 V
D1-D4 — 1N4001
DS1-DS7 — Red LED
F1 — 2A fuse
J1, J2 — Five-pin DIN socket (panel mount)
Q1-Q7 — 2N4401 or 2N2222
R1-R7 — 1 kΩ, 1/2 W
R9—1.2 kΩ
R10-R14 — 1 kΩ
R15, R23 — 1.8 kΩ
R16-R22, R28 — 2.7 kΩ
R24-R27 — 1 kΩ
SW1 — SPST, 250 V, 15 A
SW2 — 1 pole, 8 position rotary
T1 — 12.6 V ac C.T. 2A (or equivalent)
TB1 — 8 position terminal barrier strip
U1-U3 — LM339 comparator
U4 — LM7805 +5 V regulator
U5 — CD4028B (or equivalent) BCD decoder
U6 — 100 V, 5 A (or better) bridge rectifier
16 pin DIP sockets
16 pin DIP header



Relay Power Supply
Relay–Keying Transistor/Header Circuit
YAESU Interface
ICOM Interface
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k=1,000, M=1,000,000

Figure 22.76

feed line for lightning protection) with the relay coil B+ supply, as well as a ground lead. The lead photo shows eight relays, and I plan to add two additional relays so I can select between all nine antennas when I install the unit at W1AW. The box contains a 12 V dc voltage regulator (LM7812 or equivalent), which I bolted to the aluminum box. I used an insulating spacer (TO-220 mounting hardware) between the back of the regulator and the box, and applied a layer of heat-sink compound on both sides of the insulating wafer. There is also a connector for power and control lines. I used a DB-15 connector because I plan to add more relays and control lines later, so I can switch between 9 antennas. A DB-9 connector would be suitable for use with the eight-conductor control cable, or you may wish to use a weatherproof connector. **Fig 22.77** shows the relay box schematic diagram.

Since the box will be located outside, I used a weatherproof metal box—a *Hammond Manufacturing*, type 1590Z150, watertight aluminum box. It's about $8^1/_2 \times 4^3/_4 \times 3^1/_8$ inches. This is a rather hefty box, meant to be exposed to years of various weather conditions. You can, however, use almost anything.

The coax connectors are mounted so each particular antenna connector is close to the relay, without too much crowding. I used flange-mount SO-239s (although the single hole type will also work). For added weather protection (and conductivity), I applied Penetrox® to the connector flange mount, including the threads of the mounting screws. On the power/control line connector, I used Coax Seal®.

I attached aluminum angle stock on either side of the box to mount it on a tower leg. The

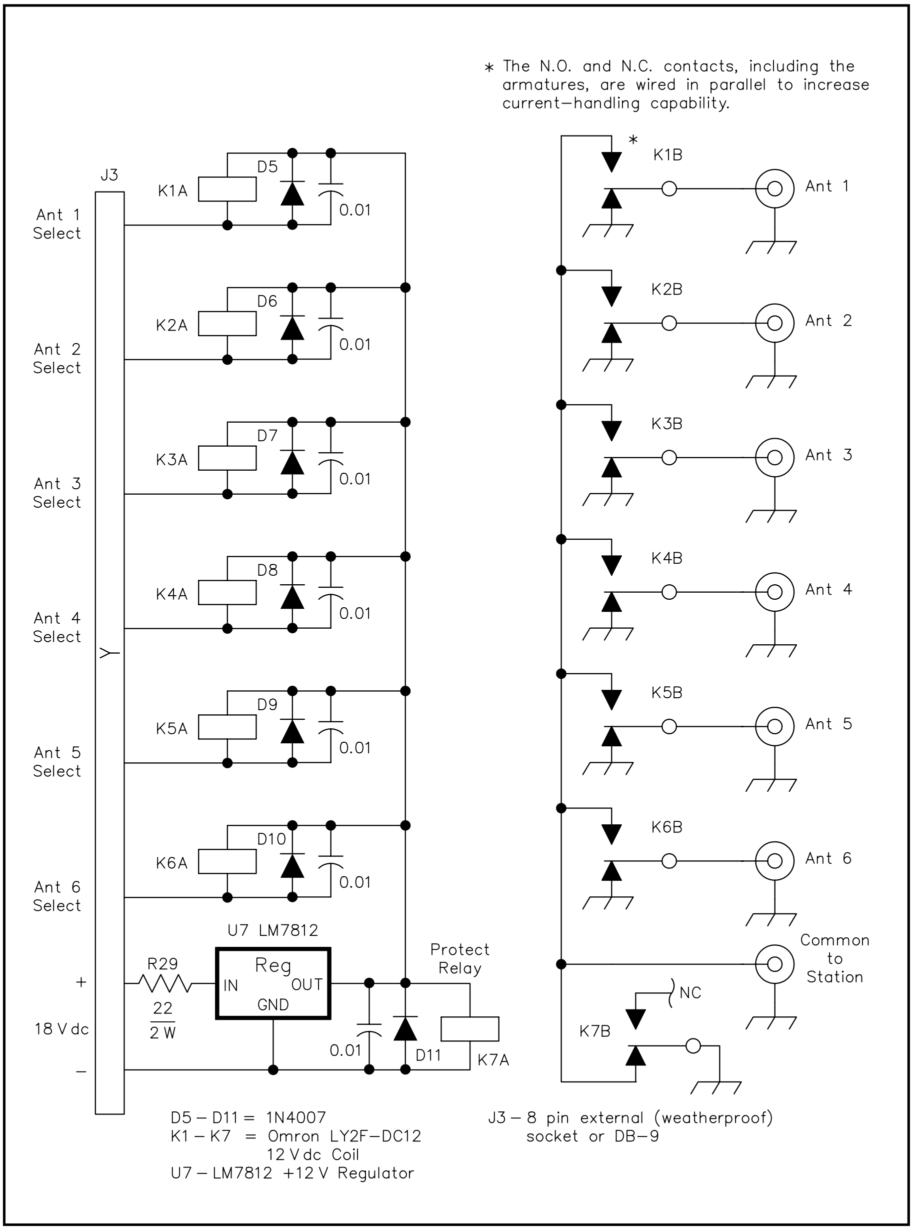


Fig 22.77 — The schematic diagram for the external antenna relay box. All relays are DPDT, 250 V ac, 15 A contacts. R29 is used to limit the regulator current. Mount the regulator using TO-220 mounting hardware, with heatsink compound. With the exception of the normally closed and normallly open contacts, all wiring is #22 solid copper wire.

D5-D11 — 1N4007
J3 — 8 pin external weatherproof connector (or DB-9 with appropriate weather sealant).
K1-K7 — Omron LY2F-DC12 with 12 V coil (Allied Electronics Stock number 821-2019)
U7 — LM7812 +12 V regulator

U-bolts should be of the proper size to fit the tower leg. They should also be galvanized or made of stainless steel.

ANTENNA RELAYS

One of the more difficult parts of this project was the modification of the relays (DPDT Omron LY2F-DC12). To improve isolation, the moveable contacts (armature) are wired in parallel and the connecting wire is routed through a hole in the relay case.

Remove the relay from its plastic case. Unsolder and remove the small wires from the armatures. Carefully solder a jumper across the armature lugs. I used #20 solid copper. Then solder a piece of very flexible wire (such as braid from RG-58 cable) to either armature lug. Obviously, the location of the wire depends on which side you wish to connect the SO-239. You will also need to make a hole in the plastic case that is large enough to accommodate the armature wire without placing any strain on the free movement of the armature. I slipped a length of insulating tubing over this wire to prevent it from shorting to the aluminum box.

The normally open and normally closed contacts are also wired in parallel. This can be done on the lugs themselves. For this, I used no. 12 solid copper wire.

I mounted the relays in the aluminum box, oriented so they could be wired together without difficulty. (See **Photo A.**) With the exception of the wire used for the relay coils (no. 22 solid wire), I used no. 12 solid copper wire for the rest of the connections.

To eliminate the possibility of spikes or "back emf," a 1N4007 diode is soldered across the coil contacts of each relay. In addition, 0.01-µF capacitors across the diodes will reduce the possibility of stray RF causing problems with the relay operation.

Since the cable run from the shack to the tower can be quite long, consideration has to be given to the voltage drop that may occur. The relays require 12 V dc. As such, I installed a 12 V dc regulator in the box, and fed it with 18 V dc (at 2 amps) from the control box. If the cable run is not that long, however, you could just use a 12-V supply.

One of the relays is used for lightning protection. When not in use, the relay grounds the line coming in from the shack. When the control box is activated, it applies power to this relay, thus removing the ground on the station feed line. All the antenna lines are grounded through the normally closed relay contacts. They remain grounded until the relay receives power from the control box.

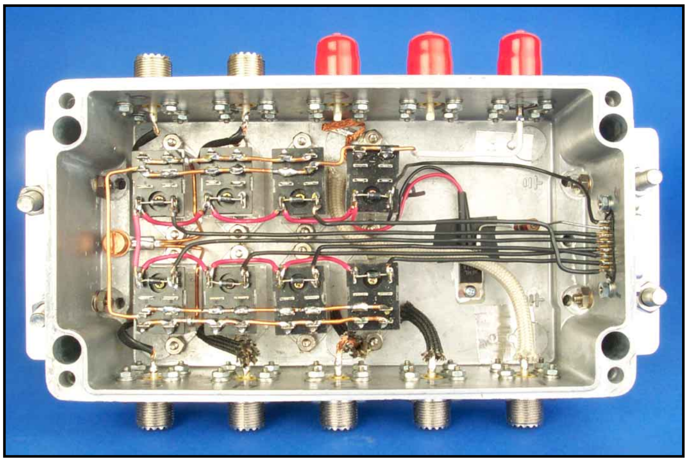


Photo A — This photo shows the external relay box. The LM7812 regulator is mounted to the bottom of the box. The relay normally open and normally closed contacts are wired in parallel using #12 solid copper. Joe Carcia plans to install two additional relays to use this project at W1AW, so he included the extra flange-mount SO-239 connectors when he was drilling holes in the box. Unused SO-239s can be capped off.

CONTROL BOX

This is the heart of the system. The 18 V dc power supply for the relays is located in this box, in addition to the Yaesu and ICOM decoder circuits and the relay-control circuitry. All connections to the relay box are made via an 8-position terminal barrier strip mounted on the back of the control box.

The front of the box has LEDs that indicate the selected antenna. A rotary switch can be used for manual antenna selection. The power switch and fuse are also located on the front panel.

The wiring schemes on the Yaesu and ICOM

ACC sockets are so different, I opted to have a 5-pin DIN connector for each rig on the control box. Since there is only one set of LEDs, I used an 8-pin DIP header to select the appropriate control circuit for each radio. See **Photo B**.

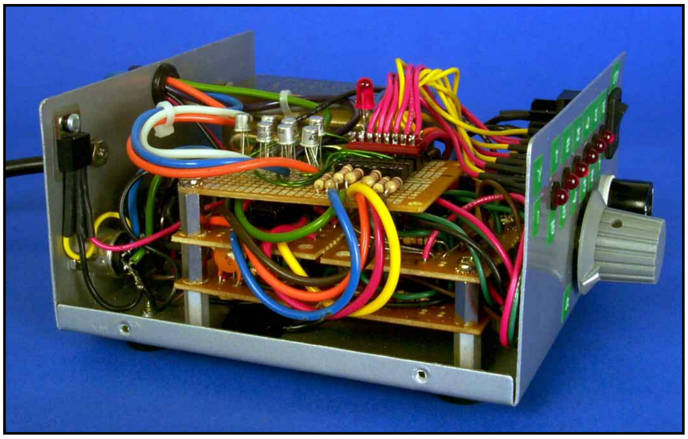


Photo B — This photo shows the inside of the control box. A RadioShack aluminum enclosure holds all of the components. The ICOM interface is built on a two-section RadioShack Universal Project Board (276-159B) and another single section of the same board. The bottom board in the enclosure as well as the right half of the middle section hold the ICOM circuit. The Yaesu interface is built on another section of the Universal Project Board, and is on the left side of the middle section. The top circuit board is a RadioShack Universal Project Board (276-150), which holds the DIP sockets and relay-selection transistors. The circuit boards use point-to-point wiring. All high voltage leads are insulated. The LEDs are mounted in holders on the front panel. The 7805 5-V regulator is mounted on the back panel using TO-220 mounting hardware, with heatsink compound.

ICOM CIRCUITRY

This circuit originally appeared in April 1993 *QST*.[2] I've modified the circuit slightly to fit my application. The original circuit allowed for switching between seven antennas (from 160 to 10 meters). The Band Data signal from the ICOM radios goes to a string of LM339 comparators. Resistors R9 through R15 divide the 8-V reference signal from the rig to provide midpoint references between the band signal levels. The LM339 comparators decide which band the radio is on. A single comparator selects the 1.8 or 10 MHz band because those bands are at opposite ends of the range. The other bands each use two comparators. One determines if the band signal is above the band level and the other determines if it is below the band level. If the signal is between those two levels, the appropriate LED and relay-selection transistor switch is turned on.

I used point-to-point wiring on RadioShack Universal Project Boards to build the various circuit sections. The ICOM interface uses both sections of a 276-159B project board shown at the bottom of the stack in Photo B for U1 and U2. Another section of project board holds U3, located on the right side of the middle section.

The ICOM circuit allows for manual antenna selection. The 8-V reference is normally taken directly from the ICOM ACC socket. If this circuit is to be used with other equipment, then a regulated 8-V source should be provided.

YAESU CIRCUITRY

The neat thing about Yaesu band data is that it's in a binary format. This means you can use a simple BCD decoder for band switching. The BCD output ranges from 1 to 9. In essence, you can switch between 9 antennas (or bands). Since the relay box switches just six antennas, I incorporated steering diodes (D1 through D4 in Fig 22.76) so I can use one antenna connection for multiple bands. In this regard, I opted to use one antenna connection for 17 and 15 meters, and another connection for 12 and 10 meters because the ICOM band data combines those bands. I did not include the control line or relay for a 30 meter antenna with this version of the project.

Yaesu Band Data Voltage Output (BCD)

Band	*A (1)*	*B (2)*	*C (4)*	*D (8)*	*(BCD Equiv.)*
1.8	5V	0V	0V	0V	1
3.5	0V	5V	0V	0V	2
7.0	5V	5V	0V	0V	3
10.1	0V	0V	5V	0V	4
14	5V	0V	5V	0V	5
18.068	0V	5V	5V	0V	6
21	5V	5V	5V	0V	7
24.89	0V	0V	0V	5V	8
28	5V	0V	0V	5V	9

One section of the RadioShack 276-159B project board holds the Yaesu interface circuit. That board is shown on the left side of the middle layer of the stack shown in Photo B.

DIP SOCKETS AND HEADER

A RadioShack Universal Project Board, 276-150 holds the DIP sockets along with the relay keying transistors. This board is shown as the top layer in Photo B. The Yaesu socket has 1-kΩ resistors wired in series with each input pin. The other header connects directly to the ICOM circuitry.

The DIP header is used to switch the keying transistors between the ICOM and Yaesu circuitry. The LEDs are used to indicate antenna number. Use stranded wire (for its flexibility) when connecting to the LEDs.

RELAY KEYING TRANSISTORS

Both circuits use the same transistor-keying scheme, so I only needed one set of transistors. Each transistor collector connects to the terminal barrier strip. The emitters are grounded, and the bases are wired in parallel to the two 16-pin DIP sockets. The band data turns on one of the transistors, effectively grounding that relay-control lead. Current flows through the selected relay coil, switching that relay to the normally open position and connecting the station feed line to the proper antenna.

POWER SUPPLY

The power supply is used strictly for the relays. Other power requirements are taken from the rig used. There is room here for variations on the power supply theme. In this case, I used a 12.6 V, center-tapped, 2 A power transformer. I feed the output to a bridge rectifier, and two 4700 µF, 35-V electrolytics. (I happened to have these parts on hand.)

NOTES

[1] "An Antenna Switching System for Multi-Two and Single-Multi Contesting," by Tony Brock-Fisher, K1KP, January 1995 *NCJ*.

[2] "A Remotely Controlled Antenna Switch," by Nigel Thompson, April 1993 *QST*.

[3] "NA Logging Program© Section 11"

A TRIO OF TRANSCEIVER/COMPUTER INTERFACES

Virtually all modern Amateur Radio transceivers (and many general-coverage receivers) have provisions for external computer control. Most hams take advantage of this feature using software specifically developed for control, or primarily intended for some other purpose (such as contest logging), with rig control as a secondary function.

Unfortunately, the serial port on most radios cannot be directly connected to the serial port on most computers. The problem is that most radios use TTL signal levels while most computers use RS-232-D.

The interfaces described here simply convert the TTL levels used by the radio to the RS-232-D levels used by the computer, and vice versa. Interfaces of this type are often referred to as level shifters. Two basic designs, one having a couple of variations, cover the popular brands of radios. This article, by Wally Blackburn, AA8DX, first appeared in February 1993 *QST*.

TYPE ONE: ICOM CI-V

The simplest interface is the one used for the ICOM CI-V system. This interface works with newer ICOM and Ten-Tec rigs. **Fig 22.79** shows the two-wire bus system used in these radios.

This arrangement uses a CSMA/CD (carrier-sense multiple access/collision detect) bus. This refers to a bus that a number of stations share to transmit and receive data. In effect, the bus is a single wire and common ground that interconnect a number of radios and computers.

The single wire is used for transmitting and receiving data. Each device has its own unique digital address. Information is transferred on the bus in the form of packets that include the data and the address of the intended receiving device.

The schematic for the ICOM/Ten-Tec interface is shown in **Fig 22.80**. It is also the Yaesu interface. The only difference is that the transmit data (TxD) and receive data (RxD) are jumpered together for the ICOM/Ten-Tec version.

The signal lines are active-high TTL. This means that a logical one is represented by a binary one (+5 V). To shift this to RS-232-D it must converted to –12 V while a binary zero (0 V) must be converted to +12 V. In the other direction, the opposites are needed: –12 V to +5 V and +12 V to 0 V.

U1 is used as a buffer to meet the interface specifications of the radio's circuitry and provide some isolation. U2 is a 5-V-powered RS-232-D transceiver chip that translates between TTL and RS-232-D levels. This chip uses charge pumps to obtain ±10 V from a single +5-V supply. This device is used in all three interfaces.

A DB25 female (DB25F) is typically used at the computer end. Refer to the discussion of RS-232-D earlier in the chapter for 9-pin connector information. The interface connects to the radio via a $^1/_8$-inch phone plug. The sleeve is ground and the tip is the bus connection.

It is worth noting that the ICOM and Ten-Tec radios use identical basic command sets (although the Ten-Tec includes additional commands). Thus, driver software is compatible. The manufacturers are to be commended for working toward standardizing these interfaces somewhat. This allows Ten-Tec radios to be used with all popular software that supports the ICOM CI-V interface. When configuring the software, simply indicate that an ICOM radio (such as the IC-735) is connected.

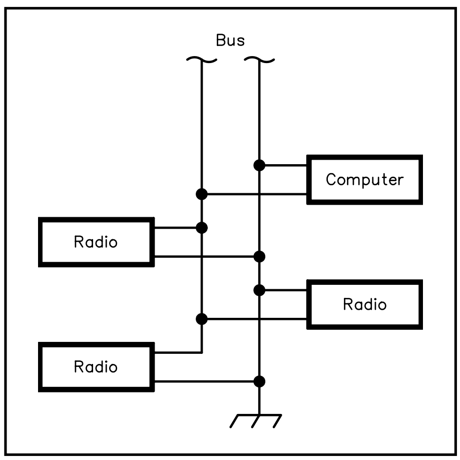


Fig 22.79—The basic two-wire bus system that ICOM and newer Ten-Tec radios share among several radios and computers. In its simplest form, the bus would include only one radio and one computer.

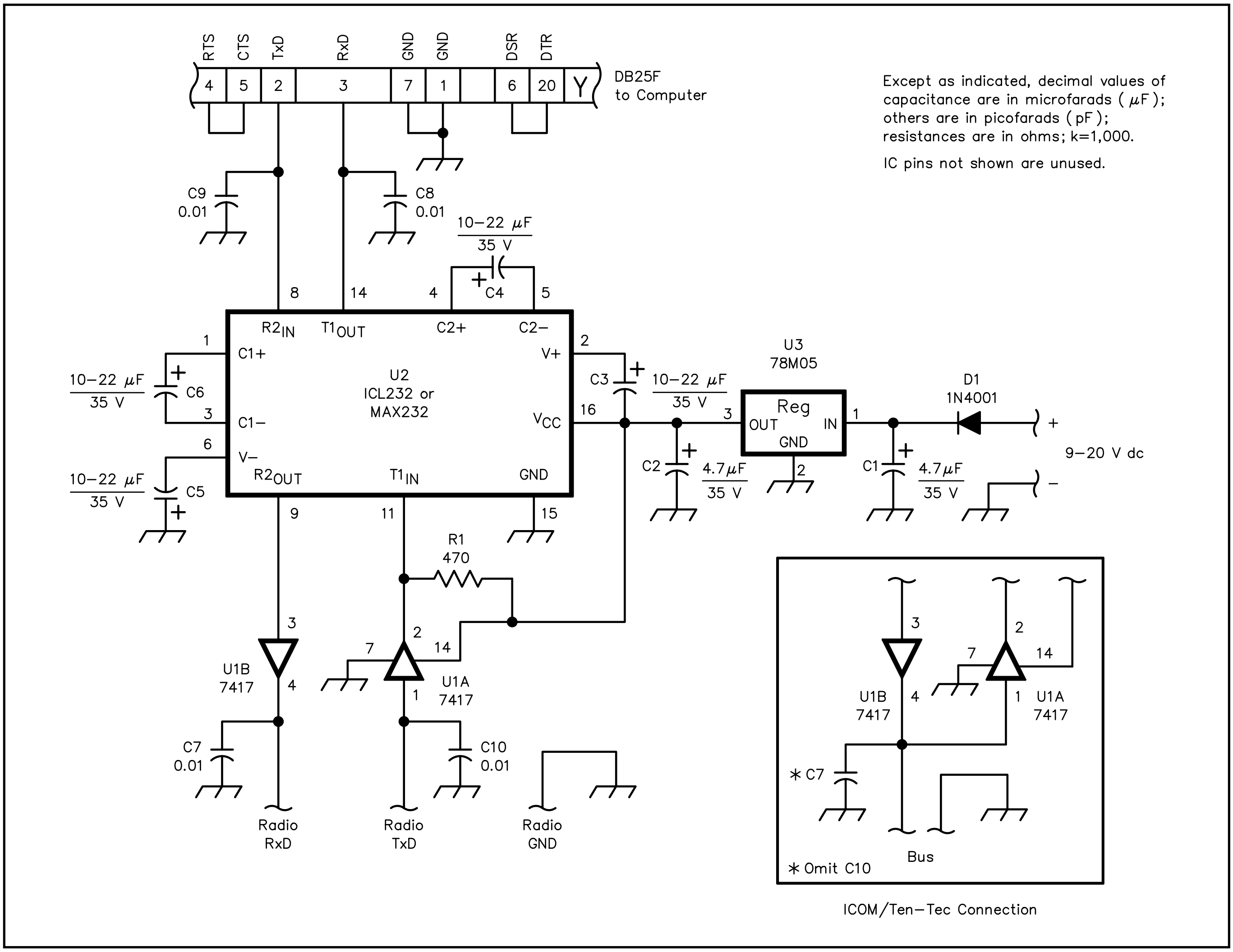


Fig 22.80—ICOM/Ten-Tec/Yaesu interface schematic. The insert shows the ICOM/Ten-Tec bus connection, which simply involves tying two pins together and eliminating a bypass capacitor.

C7-C10—0.01-µF ceramic disc.
U1—7417 hex buffer/driver.
U2—Harris ICL232 or Maxim MAX232.

TYPE TWO: YAESU INTERFACE

The interface used for Yaesu rigs is identical to the one described for the ICOM/Ten-Tec, except that RxD and TxD are not jumpered together. Refer to Fig 22.80. This arrangement uses only the RxD and TxD lines; no flow control is used.

The same computer connector is used, but the radio connector varies with model. Refer to the manual for your particular rig to determine the connector type and pin arrangement.

TYPE THREE: KENWOOD

The interface setup used with Kenwood radios is different in two ways from the previous two: Request-to-Send (RTS) and Clear-to-Send (CTS) handshaking is implemented and the polarity is reversed on the data lines. The signals used on the Kenwood system are active-low. This means that 0 V represents a logic one and +5 V represents a logic zero. This characteristic makes it easy to fully isolate the radio and the computer since a signal line only has to be grounded to assert it. Optoisolators can be used to simply switch the line to ground.

The schematic in **Fig 22.81** shows the Kenwood interface circuit. Note the different grounds for the computer and the radio. This, in conjunction with a separate power supply for the interface, provides excellent isolation.

The radio connector is a 6-pin DIN plug. The manual for the rig details this connector and the pin assignments.

Some of the earlier Kenwood radios require additional parts before their serial connection can be used. The TS-440S and R-5000 require installation of a chipset and some others, such as the TS-940S require an internal circuit board.

CONSTRUCTION AND TESTING

The interfaces can be built using a PC board, breadboarding, or point-to-point wiring. PC boards and MAX232 ICs are available from FAR Circuits. See the address list in the **References** chapter. The PC board template is available in the **References** chapter.

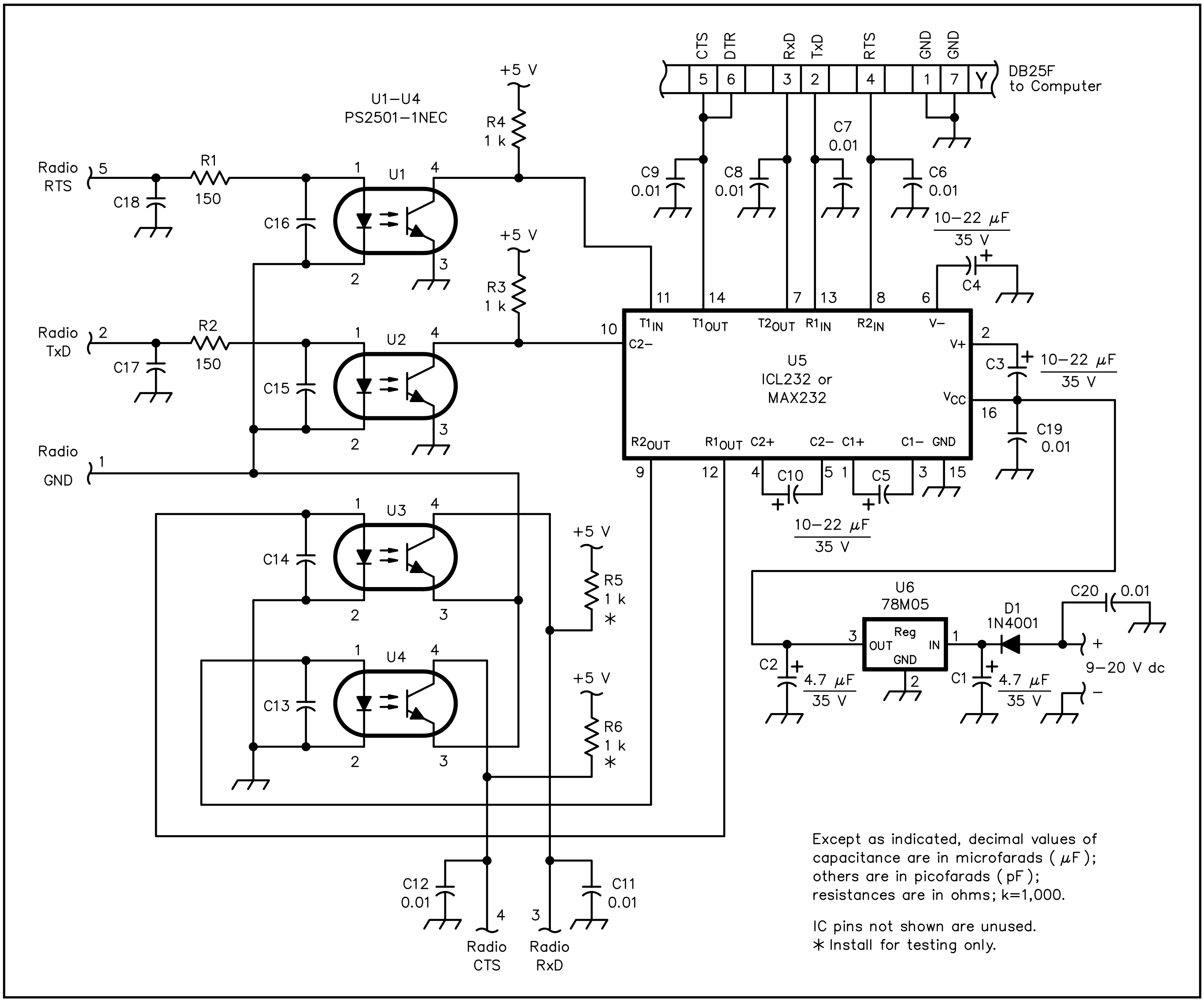


Fig 22.81—Kenwood interface schematic.

C6-C9, C11, C12, C17, C18—0.01-µF ceramic disc.
C13-C16, C19-C21—0.01 µF ceramic disc.
U1-U4—PS2501-1NEC (available from Digi-Key).
U5—Harris ICL232 or Maxim MAX232.

It is a good idea to enclose the interface in a metal case and ground it well. Use of a separate power supply is also a good idea. You may be tempted to take 13.8 V from your radio—and it works well in many cases: but you sacrifice some isolation and may have noise problems. Since these interfaces draw only 10 to 20 mA, a wall transformer is an easy option.

The interface can be tested using the data in **Tables 22.7, 8** and **9**. Remember, all you are doing is shifting voltage levels. You will need a 5-V supply, a 9-V battery and a voltmeter. Simply supply the voltages as described in the corresponding table for your interface and check for the correct voltage on the other side. When an input of –9 V is called for, simply connect the positive terminal of the battery to ground.

During normal operation, the input signals to the radio float to 5 V because of pullup resistors inside the radio. These include RxD on the Yaesu interface, the bus on the ICOM/Ten-Tec version, and RxD and CTS on the Kenwood interface. To simulate this during testing, these lines must be tied to a 5-V supply through 1-kΩ resistors. Connecting these to the supply without current-limiting resistors will damage the interface circuitry. R5 and R6 in the Kenwood schematic illustrate this. They are not shown (but are still needed) in the ICOM/Ten-Tec/Yaesu schematic. Also, be sure to note the separate grounds on the Kenwood interface during testing.

Another subject worth discussing is the radio's communication configuration. The serial ports of both the radio and the computer must be set to the same baud rate, parity, and number of start and stop bits. Check your radio's documentation and configure your software or use the PC-DOS/MS-DOS MODE command as described in the computer manual.

Table 22.7
Kenwood Interface Testing

Apply	*Result*
GND to Radio-5	–8 to –12 V at PC-5
+5 V to Radio-5	+8 to +12 V at PC-5
+9 V to PC-4	+5 V at Radio-4
–9 V to PC-4	0 V at Radio-4
GND to Radio-2	–8 to –12 at PC-3
+5 V to Radio-2	+8 to +12 V at PC-3
+9 V to PC-2	+5 V to Radio-3
–9 V to PC-2	0 V at Radio-3

Table 22.8
ICOM/Ten-Tec Interface Testing

Apply	*Result*
GND to Bus	+8 to +12 V at PC-3
+5 V to Bus	–8 to –12 V at PC-3
–9 V to PC-2	+5 V on Bus
+9 V to PC-2	0 V on Bus

Table 22.9
Yaesu Interface Testing

Apply	*Result*
GND to Radio TxD	+8 to +12 V at PC-3
+5 V to Radio TxD	–8 to –12 V at PC-3
+9 V to PC-2	0 V at Radio RxD
–9 V to PC-2	+5 V at Radio RxD

A COMPUTER-CONTROLLED TWO-RADIO SWITCHBOX

This versatile computer-controlled two-radio switchbox was designed by Dean Straw, N6BV, who made it primarily for contest operations using one of the popular computer logging programs, such as *CT*, *NA* or *TR*. The switchbox was built into two boxes, a main unit and a hard-wired remote head. **Fig 22.82** shows the back of the main unit, and **Fig 22.83** shows the small wired-remote head. The remote head is compact enough to place almost anywhere on a crowded operating desk. Besides toggle switches, it uses red and green LED annunciators to tell the operator exactly what is happening.

RadioShack components were used throughout the project as much as possible so that parts availability should not be a hurdle for potential builders. The overall cost using all-new parts was about $160.

OVERVIEW OF FEATURES

The switchbox controls both transmitting and receiving functions for either phone or CW modes. (Data modes that connect through the transceiver's microphone input or that use direct FSK could also be controlled through the switchbox, using additional external switching.) This particular switchbox was built to work with two ICOM IC-765 HF transceivers, but you can easily wire the microphone, PTT, headphone and CW key-line connections to match your own radios.

Receiving Features

For this discussion, assume that Radio A is located to the left in front of the operator and Radio B is to the right. Assume also that the two radios are connected to separate antennas (and perhaps linear amplifiers), and that interaction and overload between the two radios has been minimized by good engineering. In other words, Radio B can receive effectively on one frequency band, even while Radio A is transmitting full power on another band—and vice versa. Here we'll assume that you are using stereo headphones. You can select:

1. Radio A in both ears (monaural)—for both transmit and receive, in the RX A switch position.

2. Radio B in both ears (monaural)—for both transmit and receive, in the RX B switch position.

3. Radio A in the left ear; Radio B in the right ear—for both transmit and receive, in the STEREO switch position.

4. Radio A in both ears in receive; Radio B in both ears while Radio A is transmitting, toggling automatically while in the AUTO TX switch position.

5. Radio B in both ears in receive; Radio A in both ears while Radio B is transmitting, toggling automatically while in the AUTO TX switch position.

6. Green LEDs on the remote head give instant indication of the source(s) of audio in the stereo headphones.

The AUTO TX facility in 4 and 5 above allows you to call CQ on one radio, while devoting full attention to listening to the second radio. You could, for example, look for new multipliers in a contest or to check whether another band is open or not. Late in a contest, you can easily become mesmerized listening to your own voice from a voice recorder calling CQ, or listening to the computer au-

Fig 22.82—A view of the rear panel of the main box of the Two-Radio Switchbox.

Fig 22.83—The remote head for the Two-Radio Switchbox.

tomatically calling CQ on CW. The AUTO TX facility forces you to pay attention to the second radio—but this function can be switched off, if you like, from the remote head. If you choose the STEREO receiving mode, the AUTO TX function is automatically disabled, since it would make it pretty confusing to have the right and left audio sources shift automatically.

Another useful feature in STEREO is a BLEND control on the main box. This allows you to shift the apparent position of the right-hand receive audio somewhere between full-right and near the middle of your spatial hearing range. Some operators claim that this helps cut down on fatigue during long operating sessions when using stereo reception.

There is a second stereo headphone jack on the main box, with a switch labelled FOLLOW A or B ONLY. A second operator can either monitor what the first operator is doing (perhaps for training or coordination during a contest), or else the second operator can pay full attention to the second receiver.

Each audio channel incorporates an LM-386 IC audio amplifier that provides more-than-adequate power to drive any types of headphones, regardless of their impedance. Separate level controls for each LM-386 equalize audio levels. These amplifiers are very useful for radios that have marginal or inadequate internal stereo headphone amplifiers. Each input is shunted by a 10-Ω resistor to provide a proper load for the radio driving it.

The switchbox also has a separate SIDETONE input jack for audio from an external keyer. This connects to the B channel so that you can still hear sidetone when you have selected AUTO TX (with Radio A as transmitter) and use the paddle instead of the computer to send CW, perhaps to send a fill for a missed report.

The wiring bundles going to each radio are set up to accommodate external DSP filters, something that can bring a high-quality older transceiver up to "modern" status, comparable to the newer radios with all their DSP bells and whistles.

Transmitting Features

1. The microphone "hot" line, the microphone "cold" line, the CW key line and the PTT line are all switched between Radio A and Radio B. Both microphone "hot" and "cold" leads are switched to reduce the possibility of ground-loop induced 60-Hz hum on your transmitted signal.
2. In the TX A switch position on the remote head, Radio A is selected manually, or the computer program can control transmitter selection through one of its parallel ports. Placing the switch in position TX B overrides computer control and selects Radio B manually.
3. A manual T/R CONTROL switch, S5, on the main box can disable automatic computer control of the transmitter selection. While the *TR* program allows this function to be set by software control, *CT* doesn't have this ability, so S5 was added.
4. An external paddle may be connected to J10 to send CW, using the *TR* computer program as a keyer.
5. Two sets of paralleled, diode-isolated RCA phono jacks (J3 through J6) are mounted on the main box. You can connect the AMPLIFIER RELAY control lines from each transceiver to both the switchbox and two external amplifiers without needing Y-connectors. By the way, only one radio can transmit at a time with this switchbox. This keeps you completely legal in any single-operator or multi-single contest category.
6. An RCA phono connector J9 is available for an external foot-switch input to the *TR* program.
7. A K1KP-style RadioShack voice-keyer module is built into the main box. The voice keyer can be controlled either by an external computer or from the front panel of the remote head.
8. A separate EXT KEYER RCA phono connector J13 mounts on the main box. This parallels the LPT CW keyer output from the computer program.
9. Red LEDs on the remote head indicate which transmitter is active while it is transmitting.

THE SCHEMATIC

Fig 22.84A shows the schematic of the PCB used in the two-radio switchbox, and Fig 22.84B shows the interconnection diagram from the PCB to the other components in the main box and the remote head. Switching relays K1 and K2 are the heart of the receive-audio circuitry. K1A selects audio from either Receiver A or B (buffered by the LM-386 audio ampliers U1 and U2) and applies it to the left-ear terminal of headphone output jack J11. Relay K2B normally connects the right-ear terminal of J11 in parallel with the left-ear terminal, for monaural operation. In the STEREO mode, K2B puts the output from Receiver B into the right ear. Note that S3A on the remote head disables K1 when STEREO mode is selected, so that Receiver A output remains in the left ear, with Receiver B output in the right ear.

Relay contacts K1B are used to turn on the Green receive LEDs in the control head to indicate whether audio is coming from Receiver A alone, B alone, or both A and B together in stereo. Many contest operators have trained themselves to listen to two radios simultaneously in STEREO mode. But many of us are only endowed with a single brain, and we get easily distracted in stereo! Thus the AUTO CQ feature was added to the switchbox.

In this mode, when S4 in the control head is set to AUTO TX and S3 is set to MONO, closure to ground on the AMPLIFIER RELAY line by either transceiver will toggle between the audio outputs from Receiver A and B automatically. When the radio stops transmitting, the receive audio will toggle back. Both AMPLIFIER RELAY control lines are isolated from each other by summing diodes.

Just so you won't be surprised, both the *CT* and *TR* software programs energize "Radio 2" as what we call "Radio A," and "Radio 1" as "Radio B." This is slightly non-intuitive but it seems to be a function of the default state of the computer parallel port. The operator, however, quickly becomes accustomed to this and toggles between the radios, while watching the computer screen to see which frequency band is active.

The author borrowed most of the transmitting selection circuitry from an N6TR design. (N6TR is the creator of the *TR* program.) Transistor Q7 was added to control the K1KP-style voice keyer from the computer program's F1 function key when in phone mode.

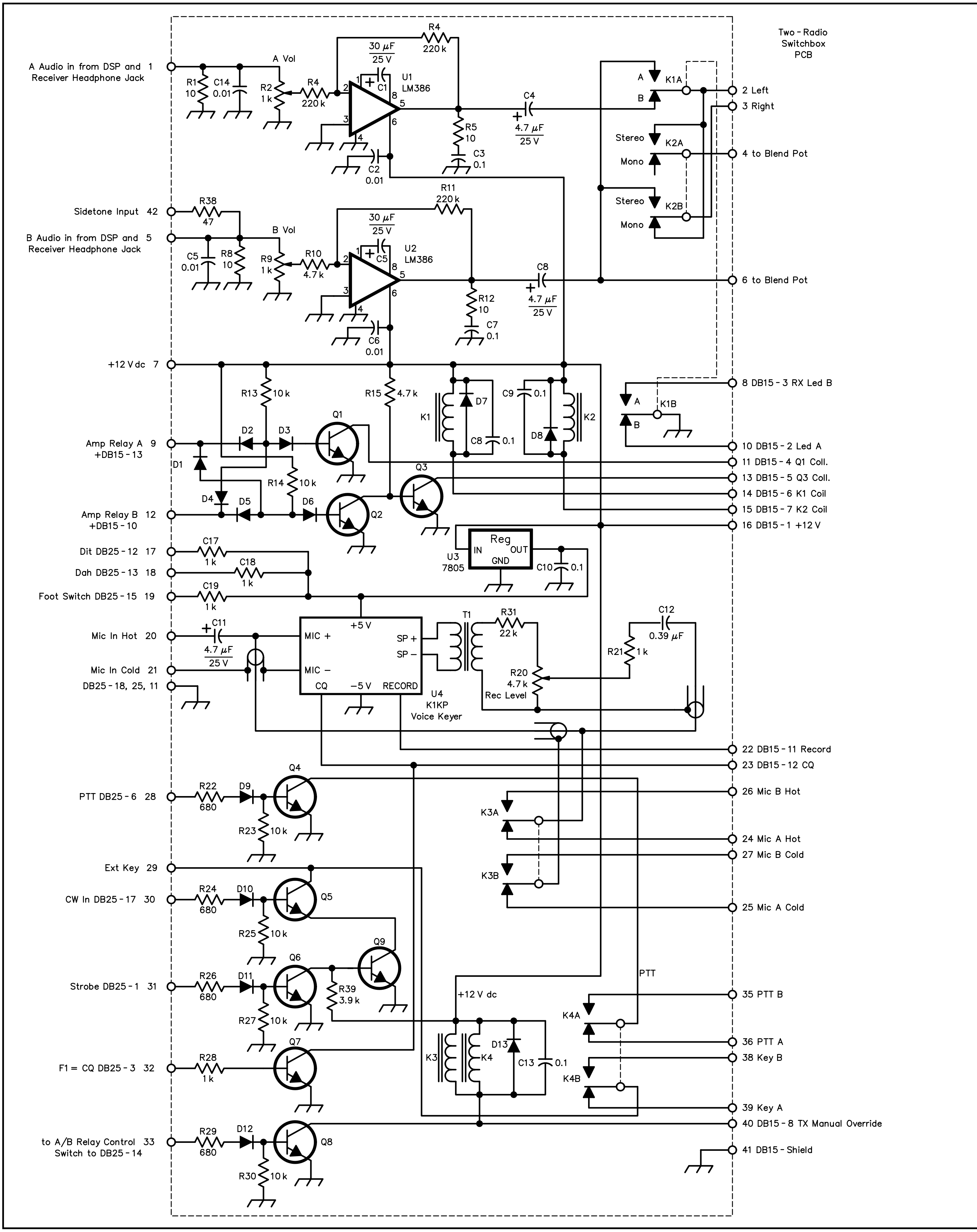
CONSTRUCTION

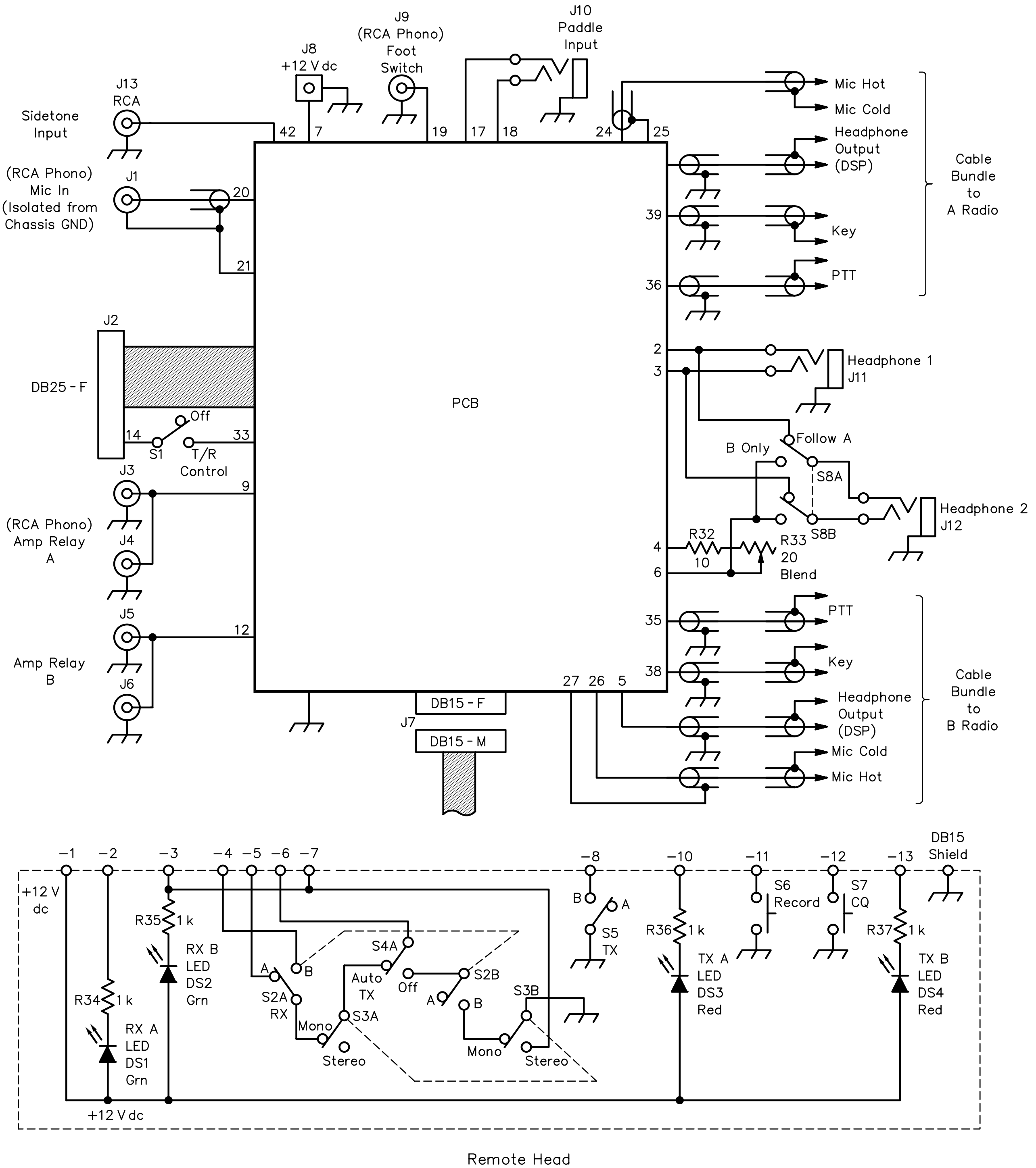
Fig 22.85 shows a view of the inside of the completed main unit box. The author chose to use a standard Bud LMB 6 × 4 × 3$^{1}/_{2}$-inch aluminum box, but things got pretty crowded as you can see. You will probably want to use a bigger box—and you will probably choose to use smaller cables in the bundles going to each transceiver. N6BV taped together three standard "zip cords" for the key-line, PTT and receiver audio cables, plus a shielded cable for the microphone line. This bundle was definitely overkill

Fig 22.84—At A, schematic diagram for the PCB. At B, the interconnection diagram for the Two-Radio Switchbox. Resistors are $^{1}/_{4}$ W. Capacitors are disk ceramic. Capacitors marked with polarity are electrolytic.

D1-D13—General-purpose silicon switching diodes, such as 1N4148 or 1N914 (RS 276-1620).
DS1, DS2—Green LED (RS 276-069A).
DS3, DS4—Red LED (RS 276-068A).
J1—Insulated RCA phono jack for microphone input.
J3-6, J6, J9, J13—Chassis-mounting, grounded RCA phono jack (RS 274-346).
J10-12—$^{1}/_{4}$-inch stereo phone jack (RS 274-312B).
J8—DC power jack (RS 274-1565A).
K1-K4—DPDT 12-V PC-mount relay (RS 275-49A).
Q1-Q9—General-purpose NPN switching transistor, 2N2222 or 2N3904 style (RS 276-1617).
R2, R9—1 kΩ PCB potentiometer (RS 271-280).
R21—4.7 kΩ PCB potentiometer (RS 271-281).
S1-S8—Flat lever switch, DPDT (RS-275-636B).
S6, S7—Momentary contact SPST (RS 275-1556A).
U1, U2—LM386 audio amplifier (RS 276-1731).
U3—7805 5-V regulator (RS 271-281).
U4—Voice record/playback module (RS 276-1326). Remove R5 and R6 from PCB.

[Schematic diagram on next page.]


Two - Radio Switchbox PCB
A Audio in from DSP and Receiver Headphone Jack 1
A Vol
U1 LM386
C4 4.7 µF 25 V
2 Left
3 Right
4 to Blend Pot
Sidetone Input 42
B Audio in from DSP and Receiver Headphone Jack 5
B Vol
U2 LM386
6 to Blend Pot
+12 Vdc 7
8 DB15 - 3 RX Led B
Amp Relay A 9 +DB15 - 13
10 DB15 - 2 Led A
11 DB15 - 4 Q1 Coll.
13 DB15 - 5 Q3 Coll.
14 DB15 - 6 K1 Coil
15 DB15 - 7 K2 Coil
Amp Relay B 12 +DB15 - 10
16 DB15 - 1 +12 V
Dit DB25 - 12 17
Dah DB25 - 13 18
Foot Switch DB25 - 15 19
U3 7805
Mic In Hot 20
Mic In Cold 21
DB25 - 18, 25, 11
U4 K1KP Voice Keyer
Rec Level
22 DB15 - 11 Record
23 DB15 - 12 CQ
PTT DB25 - 6 28
26 Mic B Hot
24 Mic A Hot
27 Mic B Cold
Ext Key 29
CW In DB25 - 17 30
25 Mic A Cold
Strobe DB25 - 1 31
35 PTT B
36 PTT A
38 Key B
F1 = CQ DB25 - 3 32
39 Key A
40 DB15 - 8 TX Manual Override
to A/B Relay Control 33 Switch to DB25 - 14
41 DB15 - Shield


J10
Paddle
Input
J9
(RCA Phono)
Foot
Switch
J8
+12 V dc
J13
RCA
Sidetone
Input
(RCA Phono)
Mic In
(Isolated from
Chassis GND)
J1
J2
DB25 - F
Off
S1
T/R
Control
J3
(RCA Phono)
Amp Relay
A
J4
J5
Amp Relay
B
J6
PCB
DB15 - F
J7
DB15 - M
Mic Hot
Mic Cold
Headphone
Output
(DSP)
Key
PTT
Cable
Bundle
to
A Radio
Headphone 1
J11
Follow A
B Only
S8A
S8B
Headphone 2
J12
R32
10
R33
20
Blend
PTT
Key
Headphone
Output
(DSP)
Mic Cold
Mic Hot
Cable
Bundle
to
B Radio
DB15
Shield
+12 V
dc
R35
1 k
RX B
LED
DS2
Grn
R34
1 k
RX A
LED
DS1
Grn
S4A
Auto
TX
Off
S2A
RX
S3A
Mono
Stereo
S2B
S3B
Mono
Stereo
S5
TX
R36
1 k
TX A
LED
DS3
Red
S6
Record
S7
CQ
R37
1 k
TX B
LED
DS4
Red
+12 V dc
Remote Head

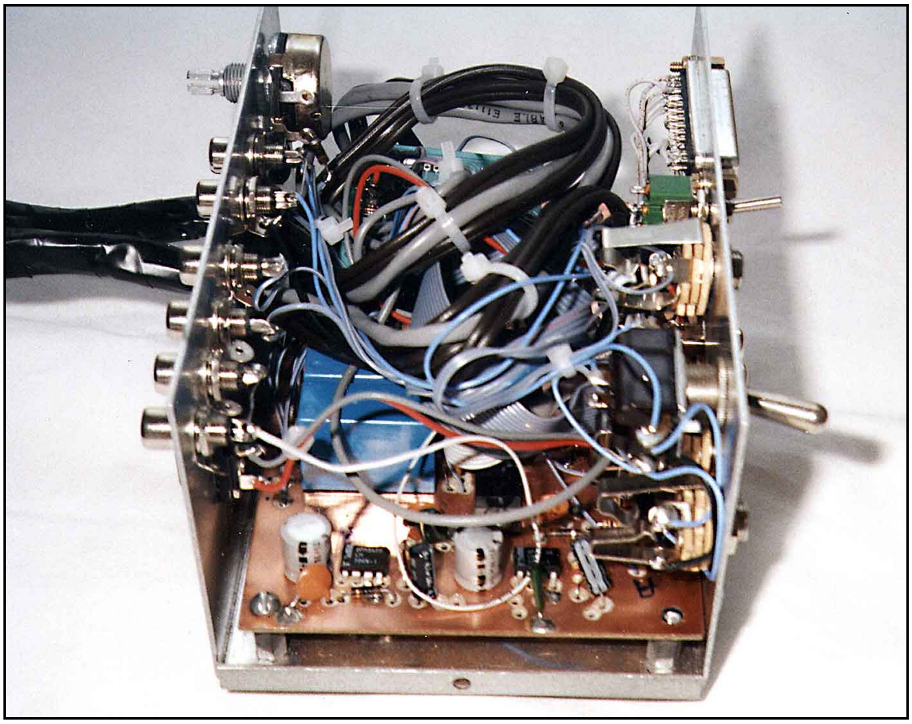


Fig 22.85—Inside the main box. With service loops for the cable bundles going to the two radios, the inside of the main box is cramped and a larger box would be a good idea!

in terms of current-handling capacity and made the service loops inside the main box quite bulky. Smaller-gauge "speaker wire" would have been far easier to handle.

Most of the switchbox circuitry was built on a single-sided copper PCB using "wired-traces construction" (also called the "Lazy PC Board" technique), described in the **Circuit Construction** chapter. A large-diameter drill was used to ream out the copper around holes where the ground plane was supposed to be removed. The RadioShack 273-1326 voice-keyer board was stuck to the tops of relays K3 and K4 using double-sided sticky tape.

A 25-pin DB25F connector was mounted on the main box for J2 and an inexpensive 6-foot long 25-conductor DB25M-to-DM25M cable (bought at a local computer store) went to the computer's parallel port. Much of the point-to-point wiring to the DB25 and DB15 connectors used ribbon wires from a scavenged surplus computer.

The remote-control head required a total of 12 wires from the main box, and a 15-pin DB15M connector J7 was used so that an inexpensive commercial VGA computer DB15F cable could be used. The connector at one end was cut off the 6-foot long cable, which was then hard-wired into the remote head. Tie wraps were used to provide mechanical strain reliefs for cables entering into the main box and into the remote head.

The author created labels using a word processing program in 12-point Times Roman typeface. These were laser printed onto a thin mylar sheet used for creating overhead transparency films. Clear nail polish ("Hard As Nails") was brushed lightly over the labels on the mylar sheet to protect them from wear. After the polish had dried, the labels were cut out using a paper cutter and they were then stuck onto the boxes using more clear nail polish as glue.

OPERATION

The switchbox and remote head can be operated entirely manually, with no connection to a computer, if you like. However, it is a lot more fun when you can control each radio from the computer keyboard, especially if you've interfaced the radio to read and write the frequency to the transceivers! Then you can "point-and-shoot" from packet DX spots or you can type in a desired frequency and press the [Enter] key to tune your radio.

You must set up your computer program to control the two-radio switchbox through a parallel (LPT) port. If you control your radios' frequencies, you will do that through serial ports. Follow the directions for your software carefully. In general, you've got to get everything *exactly right* in order for all functions to work properly, particularly the frequency and mode controls for your radio. Connect the switchbox to a source of +12 V dc that can source about 1 A. The ICOM radios have a jack on the back that will provide this.

With the control head switches set to TX A, MONO and TX AUTO OFF, toggle between Radio 2 and Radio 1. In the *CT* program press ALT-, (press the ALT key and the comma key together) or in *TR* press ALT-R to toggle between transmitter A and B. You should hear relays changing in the switchbox and when you go into transmit the red Transmit LEDs on the remote head will light for the appropriate transmitter.

Now, switch between the RX A and the RX B positions. The green receiver RX A and RX B LEDs on the control head should alternately light. Try the STEREO switch to see both green LEDs light up. Switch back to MONO and then switch the TX AUTO switch on and key the transmitter. The RX A and RX B LEDs should toggle as you key and unkey the transmitter.

Adjust the receiver front-panel volume controls for normal audio levels, probably with the front-panel headphone plugs from the switchbox pulled out so that the speakers in the radios are enabled. Then plug both headphones into the radios and adjust the 1 kΩ level pots on the PCB so that the levels are equal for Radio A and Radio B when the switch is changed between RX A and RX B positions on the remote head. Now, check out STEREO headphone operation and adjust the BLEND pot for the spacial placement you prefer.

Now, put one of the radios into SSB mode, after connecting the RF output to a dummy load so you don't interfere with anyone on the air. Speak into the microphone while holding down the RECORD button on the remote head and record a message into the voice keyer module. Now, press the Voice CQ button and adjust the 5-kΩ level pot on the PCB to equalize the level between the microphone and the voice keyer.

You should now be all set to enjoy computer-controlled two-radio operation!

TR TIME-DELAY GENERATOR

If you've ever blown up your new GaAsFET preamp or hard-to-find coaxial relay, or are just plain worried about it, this transmit/receive (TR) time-delay generator is for you. This little circuit makes it simple to put some reliability into your present station or to get that new VHF or UHF transverter on the air fast, safe and simple. Its primary application is for VHF/UHF transverter, amplifier and antenna switching, but it can be used in any amplifier-antenna scheme. An enable signal to the TR generator will produce sequential output commands to receive relay, a TR relay, an amplifier and a transverter—automatically. All you do is sit back and work DX! This project was designed and built by Chip Angle, N6CA.

WHY SEQUENCE?

Several problems may arise in stations using transverters, extra power amplifiers and external antenna-mounted TR relays. The block diagram of a typical station is shown in **Fig 22.87**. When the HF exciter is switched into transmit by the PTT or VOX line, it immediately puts out a ground (or in some cases a positive voltage) command for relay control, and an RF signal.

If voltage is applied to the transverter, amplifier and antenna relays simultaneously, RF can be applied as the relay contacts bounce. In most cases, RF will be applied before a relay can make full closure. This can easily arc contacts on dc and RF relays and cause permanent damage. In addition, if the TR relay is not fully closed before RF from the power amplifier is applied, excessive RF may leak into the receive side of the relay. The likely result—preamplifier failure!

Fig 22.88 is a block diagram of a station with a remote-mounted preamp and antenna relays. The TR time-delay generator supplies commands, one after another, going into transmit and going back to receive from transmit, to turn on all station relays in the right order, eliminating the problems just described.

CIRCUIT DETAILS

Here's how it works. See the schematic diagram in **Fig 22.89**. Assume we're in receive and are going to transmit. A ground command to Q2 (or a positive voltage command to Q1) turns Q2 off. This allows C1 to charge through R1 plus 1.5 kΩ. This rising voltage is applied to all positive (+) inputs of U1, a quad comparator. The ladder network on all negative (–) inputs of U1 sets the threshold point of each comparator at a successively higher level. As C1 charges up, each comparator, starting with U1A, will sequentially change output states.

The comparator outputs are fed into U2, a quad exclusive-OR gate. This was included in the design to allow "state pro-

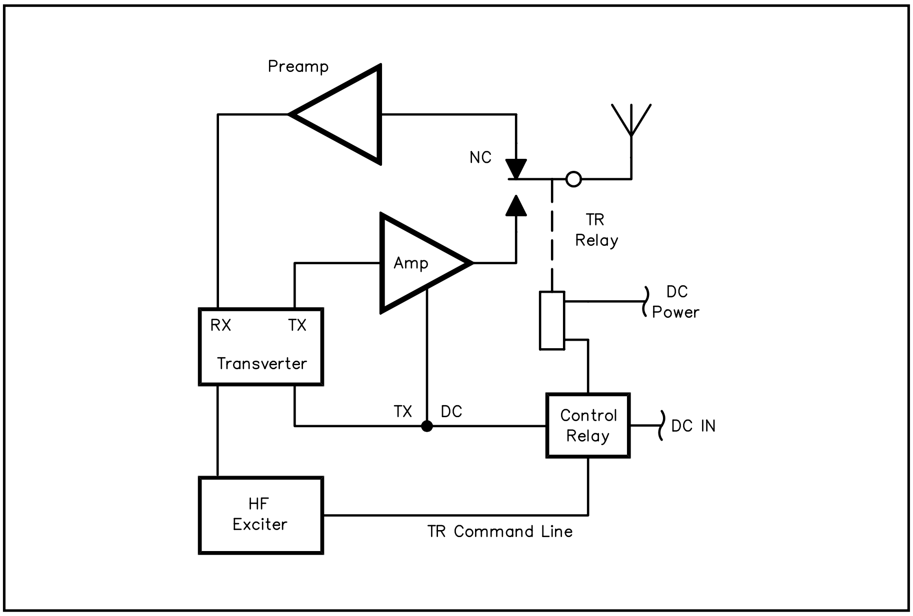


Fig 22.87—A typical VHF or UHF station arrangement with transverter, preamp and power amp. As shown, most TR relays change at the same time.

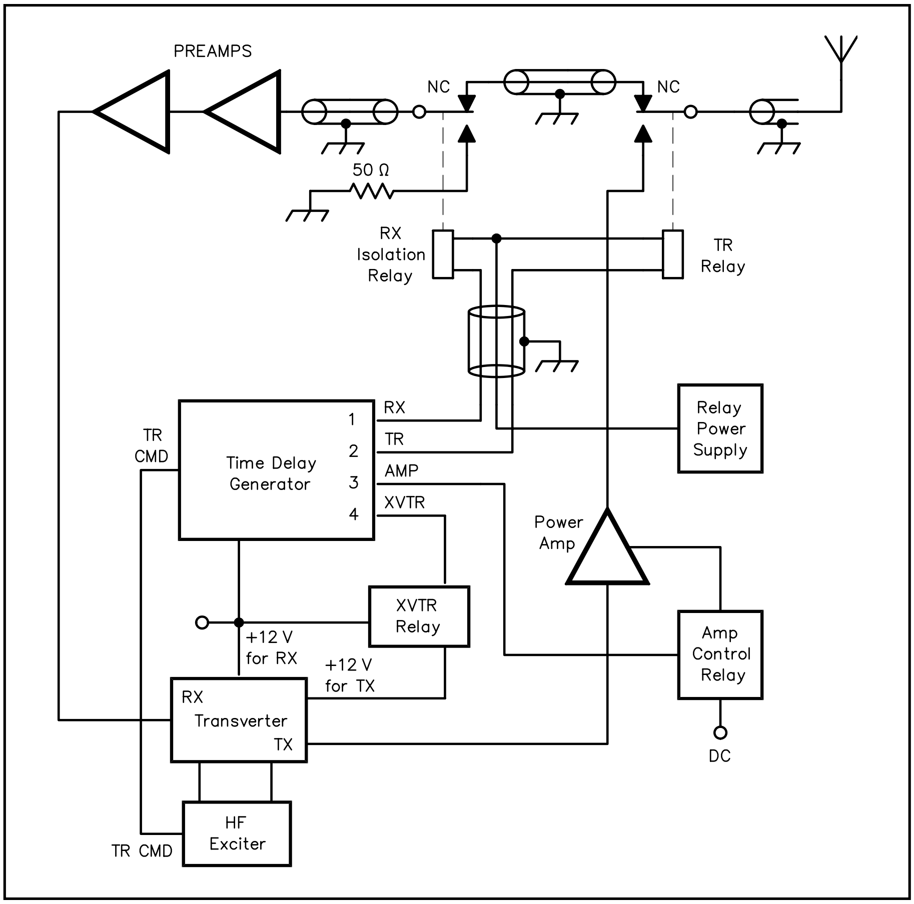


Fig 22.88—Block diagram of the VHF/UHF station with a remote-mounted preamp and antenna relays. The TR time-delay generator makes sure that everything switches in the right order.

gramming" of the various relays throughout the system. Because of the wide variety of available relays, primarily coaxial, you may be stuck with a relay that's exactly what you need—except its contacts are open when it's energized. To use this relay, you merely invert the output state of the delay generator by using a jumper between the appropriate OR-gate input and ground. Now, the relay will be "on" during receive and "off" during transmit. This might seem kind of strange; however, high-quality coaxial relays are hard to come by and if "backwards" relays are all you have, you'd better use them.

The outputs of U2 drive transistors Q3-Q6, which are "on" in the receive mode. Drive from the OR gates turns these transistors "off." This causes the collectors of Q3-Q6 to go high, allowing the base-to-emitter junctions of Q7-Q10 to be forward-biased through the LEDs to turn on the relays in sequential order. The LEDs serve as built-in indicators to check performance and sequencing of the generator. This is convenient if any state changes are made.

When the output transistors (Q7-Q10) are turned on, they pull the return side of the relay coils to ground. These output transistors were selected because of their high beta, a very low saturation voltage (V_{CE}) and low cost. They can switch (and have been tested at) 35 V at 600 mA for many days of continuous operation. If substitutions are planned, test one of the new transistors with the relays you plan to use to be sure that the transistor will be able to power the relay for long periods.

To go from transmit to receive, the sequencing order is reversed. This gives additional protection to the various system components. C1 discharges through R1 and Q2 to ground.

Fig 22.90 shows the relative states and duration of the four output commands when enabled. With the values specified for R1 and C1, there will be intervals of 30 to 50 milliseconds between the four output commands. Exact timing will vary because of component tolerances. Most likely everything will be okay with the values shown, but it's a good idea to check the timing with an oscilloscope just to be sure. Minor changes to the value of R1 may be necessary.

Most relays, especially coaxial, will require about 10 ms to change states and stop bouncing. The 30-ms delay will give adequate time for all closures to occur.

CONSTRUCTION AND HOOKUP

One of the more popular antenna changeover schemes uses two coaxial relays: one for actual TR switching and one for receiver/preamplifier protection. See Fig 22.88.

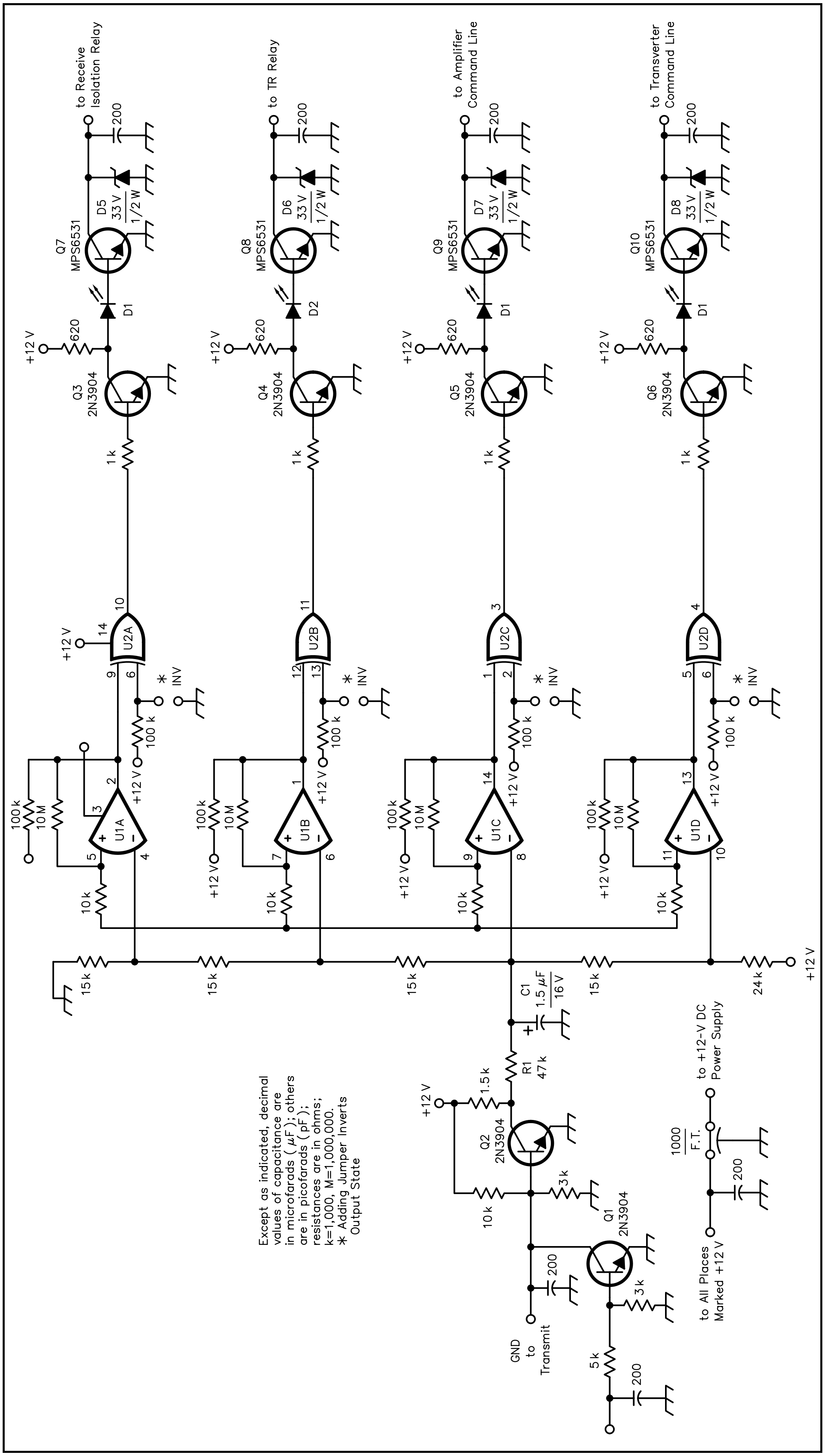


Fig 22.89—Schematic diagram of the TR time-delay generator. Resistors are $^1/_4$ W. Capacitors are disc ceramic. Capacitors marked with polarity are electrolytic.

D1-D4—Red LED (MV55, HP 5082-4482 or equiv.)

D5-D8—33-V, 500-mW Zener diode (1N973A or equiv.)

C1—1.5-μF, 16-V or greater, axial-lead electrolytic capacitor. See text.

Q1-Q6—General purpose NPN transistor (2N3904 or equiv.)

Q7-Q10—Low-power NPN amplifier transistor, MPS6531 or equiv. Must be able to switch up to 35 V at 600 mA continuously. See text.

R1—47-kΩ, $^1/_4$-W resistor. This resistor sets the TR delay time constant and may have to be varied slightly to achieve the desired delay. See text.

U1—Quad comparator, LM339 or equiv.

U2—Quad, 2-input exclusive or gate (74C86N, CD4030A or equiv.)

Many RF relays have very poor isolation especially at VHF and UHF frequencies. Some of the more popular surplus relays have only 40-dB isolation at 144 MHz or higher. If you are running high power, say 1000 W (+60 dBm) at the relay, the receive side of the relay will see +20 dBm (100 mW) when the station is transmitting. This power level is enough to inflict fatal damage on your favorite preamplifier.

Adding a second relay, called the RX isolation relay here, terminates the preamp in a 50-Ω load during transmission and increases the isolation significantly. Also, in the event of TR relay failure, this extra relay will protect the receive preamplifier.

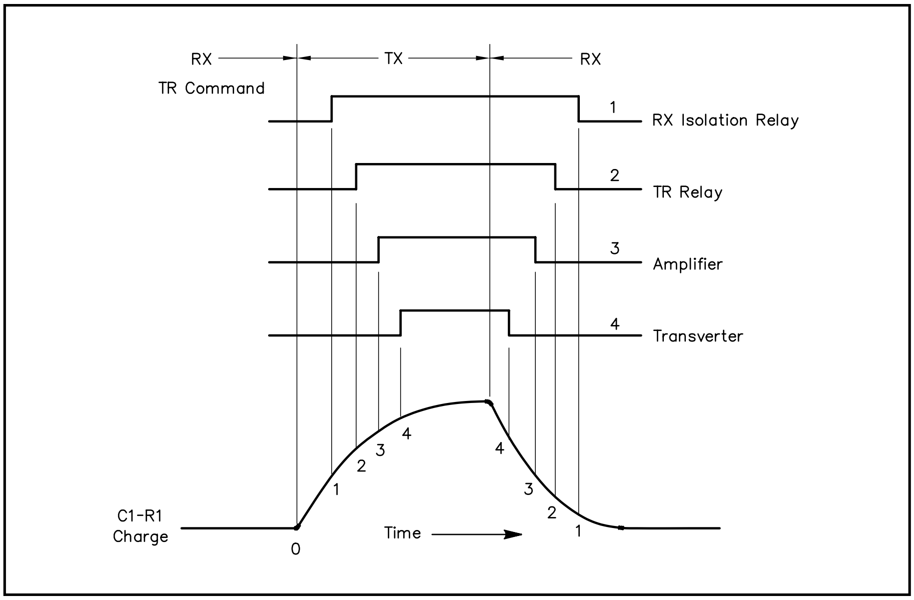


Fig 22.90—The relative states and durations of the four output commands when enabled. This diagram shows the sequence of events when going from receive to transmit and back to receive. The TR delay generator allows about 30 to 50 ms for each relay to close before activating the next one in line.

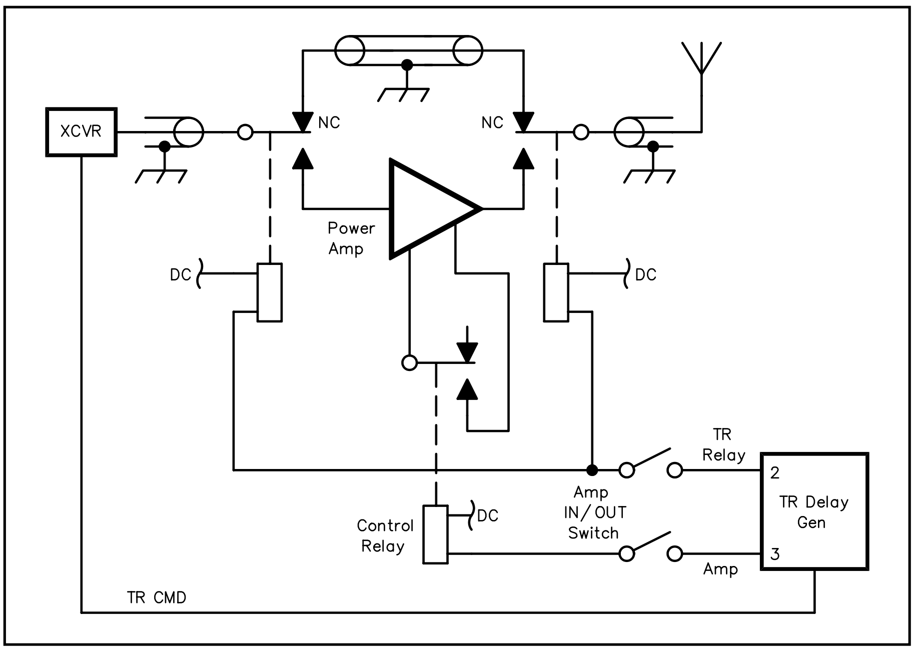


Fig 22.91—The TR time-delay generator can also be used to sequence the relays in an HF power amplifier.

As shown in Fig 22.88, both relays can be controlled with three wires. This scheme provides maximum protection for the receiver. If high-quality relays are used and verified to be in working order, relay losses can be kept well below 0.1 dB, even at 1296 MHz. The three-conductor cable to the remote relays should be shielded to eliminate transients or other interference.

By reversing the RX-TX state of the TR relays (that is, connecting the transmitter Hardline and 50-Ω preamp termination to the normally open relay ports instead of the normally closed side), receiver protection can be provided. When the station is not in use and the system is turned off, the receive preamplifier will be terminated in 50 Ω instead of being connected to the antenna. The relays must be energized to receive. This might seem a little backward; however, if you are having static-charge-induced preamplifier failures, this may solve your problem.

Most coaxial relays aren't designed to be energized continuously. Therefore, adequate heat sinking of coaxial relays must be considered. A pair of Transco Y relays can be energized for several hours when mounted to an aluminum plate 12 inches square and 1/4 inch thick. Thermal paste will give better heat transfer to the plate. For long-winded operators, it is a good idea to heat sink the relays even when they are energized only in transmit.

Fig 22.91 shows typical HF power amplifier interconnections. In this application, amplifier in/out and sequencing are all provided. The amplifier will always have an antenna connected to its output before drive is applied.

Many TR changeover schemes are possible depending on system requirements. Most are easily satisfied with this TR delay generator.

The TR delay generator is built on a $2^1/_2 \times 3^1/_4$-inch PC board.[1] See **Fig 22.92**. Connections to the rest of the system are made through feedthrough capacitors. Do not use feedthrough capacitors larger than 2000 pF because peak current through the output switching transistors may be excessive.

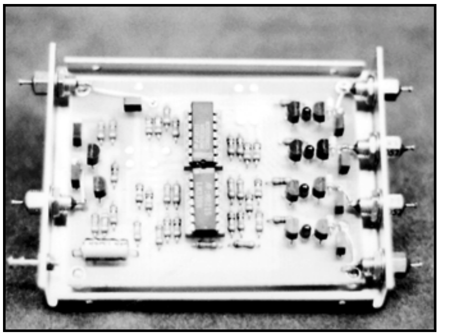


Fig 22.92—The completed time-delay generator fits in a small aluminum box.

[1] See Chapter 30, **References**, for template.

A SIMPLE 10-MINUTE ID TIMER

This project was originally described in "Hints and Kinks" in the November 1993 issue of *QST* by John Conklin, WD0O. It is an update to an earlier WD0O design for which parts are no longer available.

This simple and effective timer can be built in an evening and uses inexpensive and easily obtained parts. Its timing cycle is independent of supply voltage and resets automatically upon power-up, as well as at the end of each cycle.

CONSTRUCTION AND ADJUSTMENT

Assembly is straightforward and parts layout is not critical. The circuit of **Fig 22.94** can be built on a small piece of perfboard and housed in an inexpensive enclosure. To calibrate the time, set R1, TIME ADJ, at midpoint initially, and then adjust it by trial and error to achieve a 10-minute timing cycle. The buzzer will sound for about 1 second at the end of each cycle.

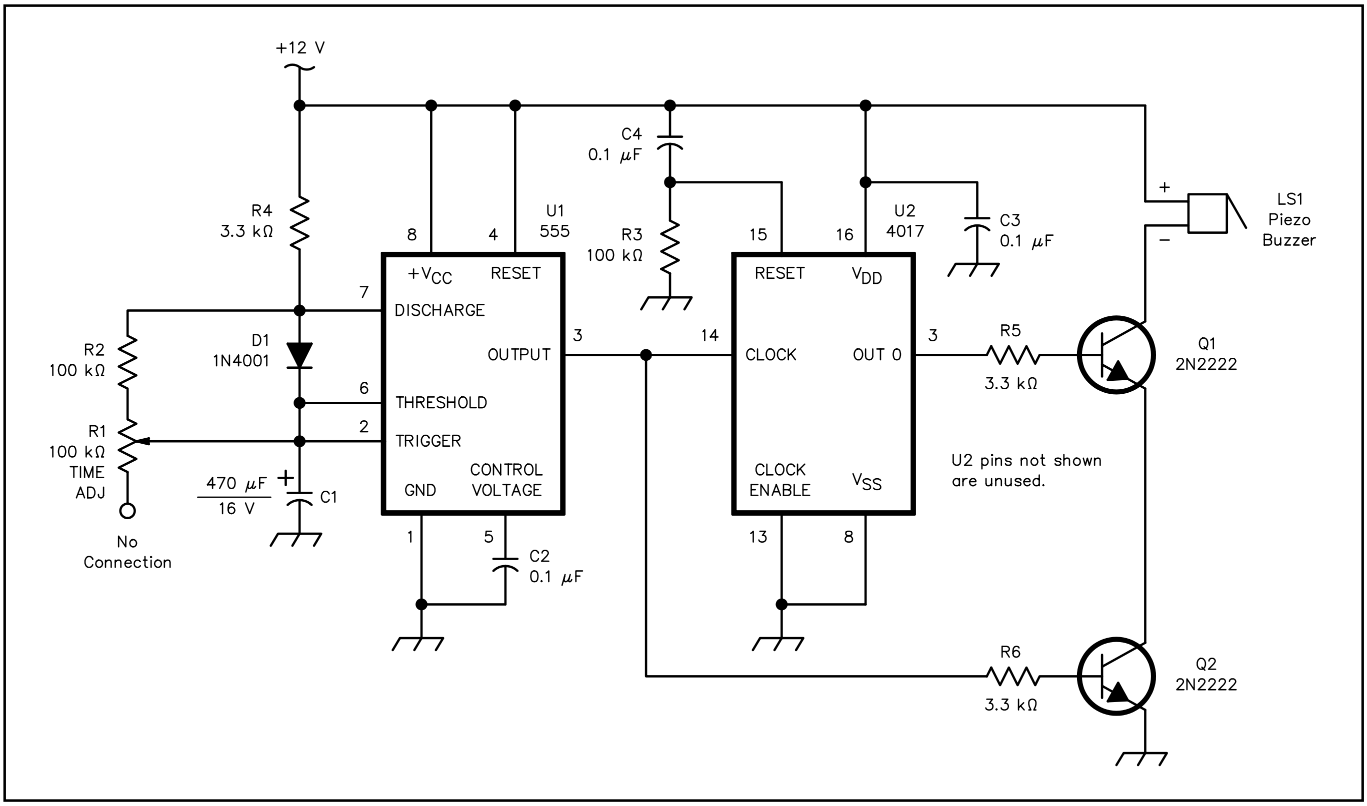


Fig 22.94—The new and improved 10-minute reminder uses easy-to-get components. Part numbers in parentheses are RadioShack; equivalent parts can be substituted. Resistors are 1/4-W, 5% or 10% tolerance units.

C1—470-µF electrolytic, 16 V or more (272-957).
C2, C3, C4—0.1 µF, 16 V or more (272-109).
D1—1N4001, 50 PIV, 1 A (276-1101).
LS1—12-V piezo buzzer (273-074).
Q1, Q2—2N2222 or MPS2222A (276-2009).
R1—100-kΩ trimmer potentiometer (271-284).
R2, R3—100 kΩ (271-1347).
R4, R5, R6—3.3 kΩ (271-1328).
U1—555 timer IC (276-1723).
U2—4017 decade counter IC (276-2417).

HIGH-POWER ARRL ANTENNA TUNER FOR BALANCED OR UNBALANCED LINES

Only rarely does a transmission line connect at one end to a real-world antenna that has an impedance of exactly 50 Ω. An antenna tuner is often used to transform whatever impedance results at the input to the transmission line to the 50 Ω needed by a modern transceiver. Generally, only when a transceiver is working into the load for which it was designed can it deliver its rated power, at its rated level of distortion. Many transceivers have built-in antenna tuners capable of handling a modest range of impedance mismatches. Most are rated for SWRs up to 3:1 on an unbalanced coax line. Such a built-in tuner will probably work fine when you use the transceiver by itself. Thus, if your transceiver has a built-in antenna tuner and if you use coax-fed antennas, you probably don't need an external antenna tuner.

REASONS FOR USING AN ANTENNA TUNER

If you use a linear amplifier, however, you may find that it can't load some coax-fed antennas with even moderate SWRs, particularly on 160 or 80 meters. This is usually due to a loading capacitor that is marginal in capability. Some amplifiers even have protective circuits that prevent you from using the amplifier when the SWR is higher than about 2:1. For this situation you may well need a high-power antenna tuner. Bear in mind that although an antenna tuner will bring the SWR down to 1:1 at the amplifier—that is, it presents a 50-Ω load to the amplifier—it will not change the actual SWR condition on the transmission line going to the antenna itself. Fortunately, most amateur HF coax-fed antennas are operated close to resonance and any additional loss on the line due to SWR is not a big problem. If you wish to operate a single-wire antenna on multiple frequency bands, an antenna tuner also will be needed. As an example, if you choose a 130-foot long dipole for this task, fed in the center with 450-Ω ladder line, the feed-point impedance of this antenna over the 1.8 to 29.7-MHz range will vary drastically! Further, the antenna and the feed line are both balanced, requiring a balanced type of antenna tuner. What you need is a balanced antenna tuner that can handle a very wide range of impedances, all without arcing or overheating internally.

DESIGN PHILOSOPHY BEHIND THE ARRL HIGH-POWER TUNER

Dean Straw, N6BV, designed this antenna tuner with three objectives in mind: First, it would operate over a wide range of loads, at full legal power. Second, it would be a high efficiency design, with minimal losses, including losses in the balun. This leads to the third objective: Include a balun operating within its design impedances. Often, a balun is added to the output of a tuner. If it is designed as a 4:1 unit, it expects to see 200 Ω on its output. Connect it to ladder line and let it see a 1000-Ω load, and spectacular arcing can occur even at moderate (100 W) power levels.

For that reason this unit was designed with the balun on the input of the tuner. This antenna tuner is designed to handle full legal power from 160 to 10 meters, matching a wide range of either balanced or unbalanced impedances. The network configuration is a high-pass T-network, with two series variable capacitors and a variable shunt inductor. See **Fig 22.95** for the schematic of the tuner. Note that the schematic is drawn in a somewhat unusual fashion. This is done to emphasize that the common connection of the series input and output capacitors and the shunt inductor is actually the subchassis used to mount these components away from the tuner's cabinet. The subchassis is insulated from the main cabinet using four heavy-duty 2-inch steatite cones.

While a T-network type of tuner can be very lossy if care isn't taken, it is very flexible in the range of impedances it can match. Special attention has been paid to minimize power loss in this tuner—particularly for low-impedance loads on the lower-frequency amateur bands. Preventing arcing or excessive power dissipation for low-impedance loads on 160 meters represents the most challenging conditions for an antenna tuner designer! To see the computed range of impedances it can handle, look

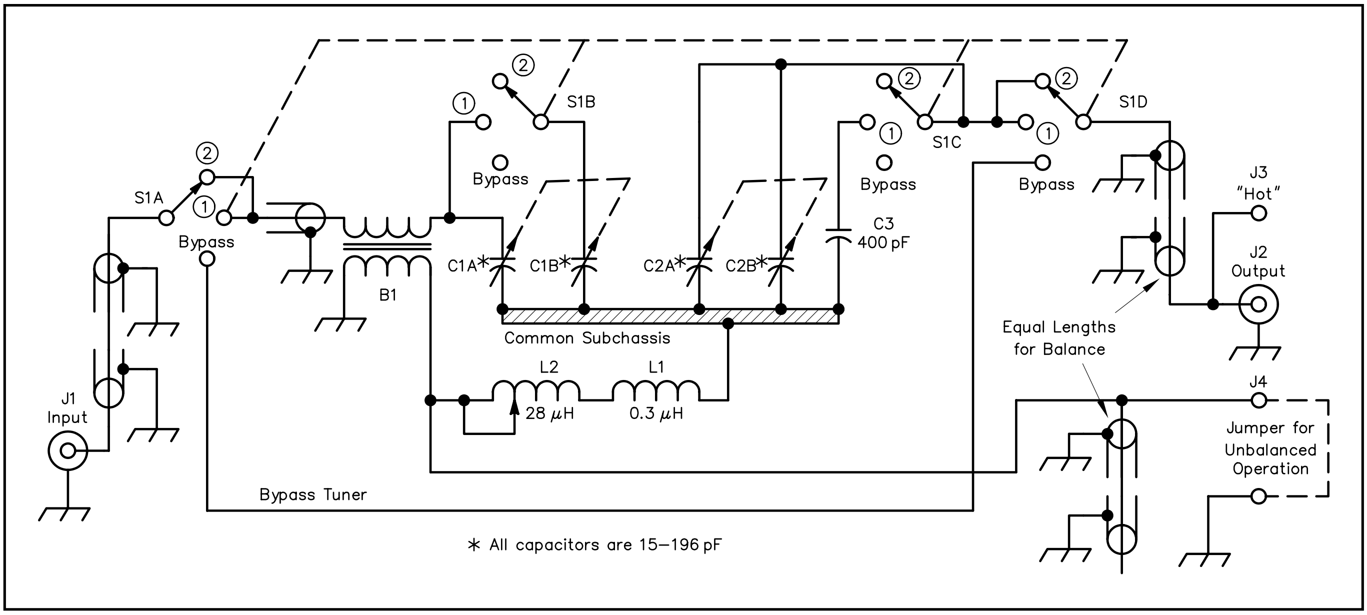


Fig 22.95—Schematic diagram of the ARRL Antenna Tuner.

B1—Balun, 12 turns bifilar wound #10 Formvar wire side-by-side on 2.4-inch OD Type 43 core.

C1, C2—15-196 pF transmitting variable with voltage rating of 3000 V peak, such as the E. F. Johnson 154-507-1.

C3—Home-made 400 pF capacitor; more than 10 kV voltage breakdown. Made from plate glass from a "5 × 7-inch" picture frame, sandwiched in between a 4 × 6-inch, 0.030-inch thick aluminum plate and the electrically floating subchassis that also forms the common connection between C1, C2 and L1.

L1—Fixed inductor, approximately 0.3 µH, 4 turns of 1/4-inch copper tubing formed on 1-inch OD tubing.

L2—Rotary inductor, 28 µH inductance, Cardwell E. F. Johnson 229-203, with steatite coil form.

S1—HV switch, Radio Switch Corp R862E033000.

over the tables in the ASCII file called TUNER.SUM available from *ARRLWeb* (see page vii). The tables were created using the program AAT, included with the 18th Edition of *The ARRL Antenna Book*. They show the percentage of power lost for 253 individual impedances, for each amateur band from 1.8 to 29.7 MHz. Where a match cannot be achieved a blank is shown; where the capability is limited due to voltage breakdown of one of the components a "V" is placed. Where the minimum capacitance of a tuning capacitor is too large for a match, a "C–" is placed. Where an "L+" appears, there is insufficient inductance available to match that impedance. A "P" indicates that the power loss at that impedance exceeds 20%. For example, assume that the load at 1.8 MHz is $12.5 + j\,0\ \Omega$. For this example, the output capacitor C3 in this example is set by the program to 750 pF. This dictates the values for the other two components. At 1.8 MHz, for typical values of component unloaded Q (200 for the coil), 7.9% of the power delivered to the input of the network is lost as heat. For 1500 W at the input, the loss in the network is thus 119 W. Of this, 98 W ends up in the inductor, which must be able to handle this without melting or detuning. The T-network must be used judiciously, lest it burn itself up or arc over internally!

One of the techniques used to minimize power lost in this tuner is the use of a relatively large output capacitor. (The output variable capacitor has a maximum capacitance of approximately 400 pF, including an estimated 20 pF of stray capacitance.) An additional 400 pF of fixed capacitor can be switched across the output variable capacitor. At 750 pF output capacitance, enough heat is generated at 1500 W input to make the inductor uncomfortably warm to the touch after 30 seconds of full-power key-down operation, but not enough to destroy the coil for a 12.5-Ω load.

For a variable capacitor used in a T-network tuner, there is a trade-off between the range of minimum to maximum capacitance and the voltage rating. This tuner uses two identical Cardwell-Johnson dual-section 154-507-1 air-variable capacitors, rated at 3000 V. Each section of the capacitor ranges from 15 to 196 pF, with an estimated 10 pF of stray capacitance associated with each section. Both sections are wired in parallel for the output capacitor, while they are switched in or out using switch S1B for the input capacitor. This strategy allows the minimum capacitance of the input capacitor to be smaller to match high-impedance loads at the higher frequencies.

The roller inductor is a high-quality Cardwell 229-203-1 unit, with a steatite body to enable it to dissipate heat without damage. The roller inductor is augmented with a series 0.3 µH coil made of four turns of $^1/_4$-inch copper tubing formed on a 1-inch OD form (which is then removed). This fixed coil can dissipate more heat when low values of inductance are needed for low-impedance loads at high frequencies. Both variable capacitors and the roller inductor use ceramic-insulated shaft couplers, since all components are "hot" electrically. Each shaft goes through a grounded bushing at the front panel to make sure none of the knobs is hot.

The balun allowing operation with balanced loads is placed at the input of this antenna coupler, rather than at the output where it is commonly placed in other designs. Putting the balun at the input stresses the balun less, since it is operating into its design resistance of 50 Ω, once the network is tuned. For unbalanced (coax) operation, the common point at the bottom of the roller inductor is grounded at the feedthrough insulator at the rear of the cabinet. In the prototype antenna tuner, the balun was wound using 12 turns of #10 formvar insulated wire, wound side-by-side in bifilar fashion on a 2.4-inch OD core of type 43 material. After 60 seconds of key-down operation at 1500 W on 29.7 MHz, the wire becomes warm to the touch, although the core itself remains cool. We estimated that 25 W was being dissipated in the balun.

Alternatively, if you don't intend to use the tuner for balanced lines, you can delete the balun altogether. A piece of RG-213 coax is used to connect the output coaxial socket (in parallel with the "hot" insulated feedthrough insulator) to S1D common. This adds approximately 15 pF fixed capacity to ground. An equal length of RG-213 is used at the "cold" feed-through insulator so that the circuit remains balanced to ground when used with balanced transmission lines. When the cold terminal is jumpered to ground for unbalanced loads (that is, using the coax connector), the extra length of RG-213 is shorted out and is thus out of the circuit.

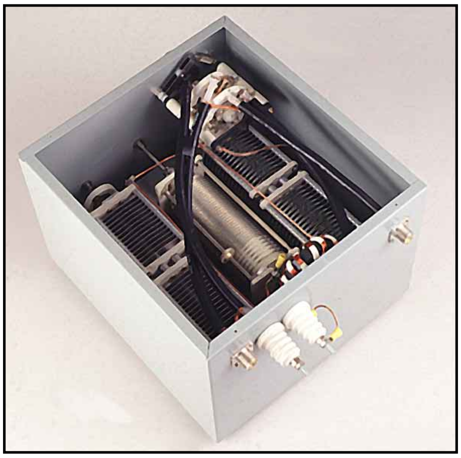


Fig 22.96—Interior view of the ARRL Antenna Tuner. The balun is mounted near the input coaxial connector. The two feedthrough insulators for balanced-line operation are located near the output coaxial unbalanced connector. The Radioswitch Corporation high-voltage switch is mounted to the front panel. Ceramic-insulated shaft couplers through ground $^1/_4$-inch panel bushings couple the variable components to the knobs.

CONSTRUCTION

The prototype antenna tuner was mounted in a Hammond model 14151 heavy-duty, painted steel cabinet. This is an exceptionally well-constructed cabinet that does not flex or jump around on the operating table when the roller inductor shaft is rotated vigorously. The electrical components inside were spaced well away from the steel cabinet to keep losses down, especially in the variable inductor. There is also lots of clearance between components and the chassis itself to prevent arcing and stray capacity to ground. See **Figs 22.96** and 22.97 showing the layout inside the cabinet of the prototype tuner. Fig 22.98 shows a view of the front panel. The turns-counter dial for the roller inductor was bought from Surplus Sales of Nebraska.

The 400 pF fixed capacitor is constructed using low-cost plate glass from a 5 × 7-inch picture frame, together with an approxi-

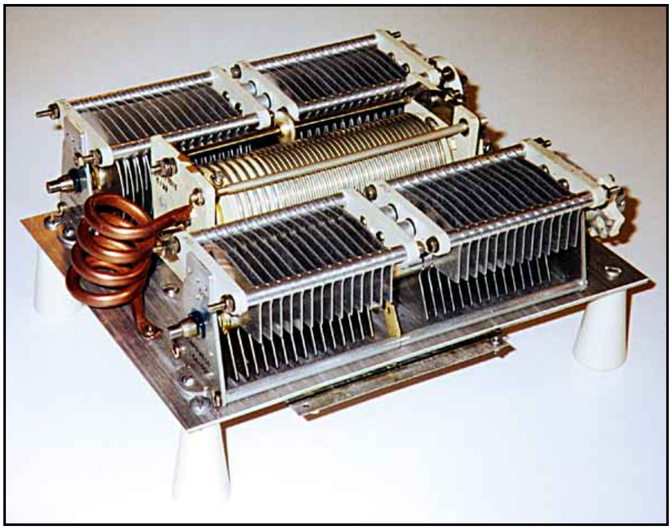


Fig 22.97—The subchassis, showing the four white insulators used to isolate the subchassis from the cabinet. The homemade 400-pF fixed capacitor C3 is epoxied to the bottom of the subchassis, sandwiching a piece of plate glass as the dielectric between the subchassis and a flat piece of aluminum.

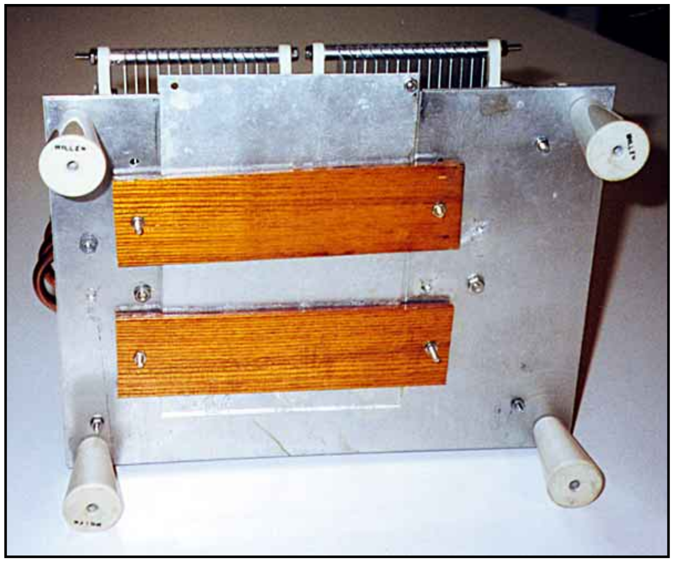


Fig 22.99—Bottom view of subchassis, showing the two strips of wood ensuring mechanical stability of the C3 capacitor assembly.

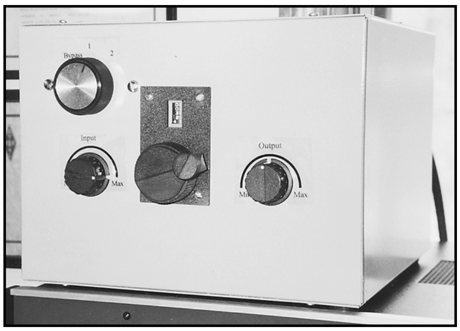


Fig 22.98—Front panel view of the ARRL Antenna Tuner. The high-quality turns counter dial is from Surplus Sales of Nebraska.

mately 4 × 6-inch flat piece of sheet aluminum that is 0.030-inch thick. The tuner's $10\frac{1}{2} \times 8$-inch subchassis forms the other plate of this homebrew capacitor. For mechanical rigidity, the subchassis uses two $\frac{1}{16}$-inch thick aluminum plates. The $\frac{1}{16}$-inch thick glass is epoxied to the bottom of the subchassis. The 4 × 6-inch aluminum sheet forming the second plate of the 400-pF fixed capacitor is in turn epoxied to the glass to make a stable, high-voltage, high-current fixed capacitor. Two strips of wood are screwed down over the assembly underneath the subchassis to make sure the capacitor stays in place. The estimated breakdown voltage is 12,000 V. See **Fig 22.99** for a bottom view of the subchassis.

Note: The dielectric constant of the glass in a cheap ($2 at Walmart) picture frame varies. The final dimensions of the aluminum sheet secured to the glass with one-hour epoxy was varied by sliding it in and out until 400 pF was reached, while the epoxy was still wet, using an Autek RF-1 as a capacitance meter. Don't let epoxy slop over the edges—this can arc and burn.

S1 is bolted directly to the front of the cabinet. S1 is a special high-voltage RF switch from Radio Switch Corporation, with four poles and three positions. It is not inexpensive, but we wanted to have no weak points in the prototype unit. A more frugal ham might want to substitute two more common surplus DPDT switches for S1. One would bypass the tuner when the operator desires to do that. The other would switch the additional 400 pF fixed capacitor across variable C3 and also parallel both sections of C1 together for the lower frequencies. Both switches would have to be capable of handling high RF voltages, of course.

OPERATION

The ARRL Antenna Tuner shown here is designed to handle the output from transmitters that operate up to 1.5 kW. An external SWR indicator is used between the transmitter and the antenna tuner to show when a matched condition is attained. Most often the SWR meter built into the transceiver is used to tune the tuner and then the amplifier is switched on. The builder may want to integrate an SWR meter in the tuner circuit between J1 and the arm of S1A. Never "hot switch" an antenna tuner, as this can damage both transmitter and tuner. For initial setting below 10 MHz, set S1 to position 2 and C1 at midrange, C2 at full mesh. With a few watts of RF, adjust the roller inductor for a decrease in reflected power. Then adjust C1 and L2 alternately for the lowest possible SWR, also adjusting C2 if necessary. If a satisfactory SWR cannot be achieved, try S1 at position 3 and repeat the steps above. Finally, increase the transmitter power to maximum and touch up the tuner's controls if necessary. When tuning, keep your transmissions brief and identify your station.

For operation above 10 MHz, again initially use S1 set to position 2, and if SWR cannot be lowered properly, try S1 set to position 3. This will probably be necessary for 24 or 28-MHz operation. In general, you want to set C2 for as much capacitance as possible, especially on the lower frequencies. This will result in the least amount of loss through the antenna tuner. The first position of S1 permits switched-through operation direct to the antenna when the antenna tuner is not needed.

FURTHER COMMENTS ABOUT THE ARRL ANTENNA TUNER

Surplus coils and capacitors are suitable for use in this circuit. L2 should have at least 25 µH of inductance and be constructed with a steatite body. There are roller inductors on the market made with Delrin plastic bodies but these are very prone to melting under stress and should be avoided. The tuning capacitors need to have 200 pF or more of capacitance per section at a breakdown voltage of at least 3000 V. You could save some money by using a single-section variable capacitor for the output capacitor, rather than the dual-section unit we used. It should have a maximum capacitance of 400 pF and a voltage rating of 3000 V.

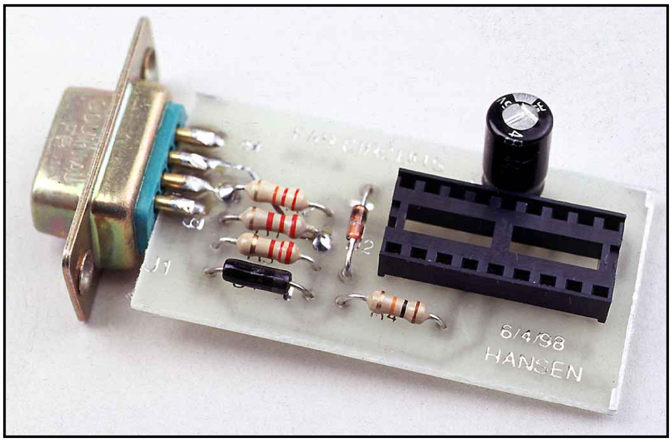
Measured insertion loss for this antenna tuner is low. The worst-case load tested was four 50-Ω dummy loads in parallel to make a 12.5-Ω load at 1.8 MHz. Running 1500 W keydown for 30 seconds heated the variable inductor enough so that you wouldn't want to keep your hand on it for long. None of the other components became hot in this test.

At higher frequencies (and into a 50-Ω load at 1.8 MHz), the coil was only warm to the touch at 1500 W keydown for 30 seconds. The #10 balun wire, as mentioned previously, was the warmest component in the antenna tuner for frequencies above 14 MHz, although it was far from catastrophic.

REFERENCES

1. Frank Witt, "How to Evaluate Your Antenna Tuner—*Parts 1 and 2*," *QST*, April and May 1995, pp 30-34 and pp 33-37, respectively.
2. Frank Witt, "Baluns in the Real (and Complex) World," *The ARRL Antenna Compendium, Vol 5* (Newington, ARRL: 1996), pp 171-181.
3. "*QST* Compares: Four High-Power Antenna Tuners," *QST*, Mar 1997, pp 73-77.
4. *The ARRL Antenna Book*, 18th Edition (Newington, ARRL: 1997). See Chapters 25 and 26.

USING PIC MICROCONTROLLERS IN AMATEUR RADIO PROJECTS



This article by John A. Hansen, W2FS first appeared in October 1998 *QST*. It is an introduction to using one of the simplest and cheapest microprocessors, Microchip Technology's Peripheral Interface Controllers—PICs—in Amateur Radio applications. It provides you with the necessary background to begin using PIC chips and give you some pointers on where to learn more about them. Most importantly, it will describe how to build a circuit that allows *you* to program PIC chips yourself—at a cost of less than $5! The next time you want to build a project that includes a PIC chip, if the source code is available, you'll be able to *program your own chip* instead of paying someone to do it for you!

WHAT EMBEDDED MICROCONTROLLERS DO

An embedded microcontroller is a tiny computer that receives data, makes calculations or decisions based on that data and then acts in response. It interacts with the rest of the world through pins that can be configured as inputs *and* outputs. Configuring a pin as an *input* means that the microcontroller can *read* the pin to determine whether the voltage on it is high or low. When a pin is *high*, it means that 5 V is applied to it. When the pin is *low*, it means the pin is at ground potential. When a pin is configured as an *output*, it means that the microcontroller itself can make the pin high (+5 V) or low (0 V).

The microcontroller acts on a set of instructions (a *program*) that determine how the microcontroller converts these input signals into output signals. The range of functions that these microcontrollers can perform is incredible! That's especially true when you consider that the chip's behavior is limited solely to finding out whether input pins are high or low, then setting output pins either high or low in response!

Microcontroller inputs might be pushbuttons (or arrays of buttons in a keypad), sensors of various types such as temperature, pressure, or acceleration (fed through an analog-to-digital converter — ADC), or a serial or parallel data stream from any device capable of generating serial or parallel data (DTMF decoders, radio computer ports, PCs, etc). As long as the information can be presented to the microcontroller as a high or low signal on one or more input pins, the controller can recognize the information and perform predefined functions in response.

By using transistor switches or relays, the microcontroller outputs can switch external devices on and off, generate sounds, or send serial or parallel data to control other devices. Text or data from the microcontroller can be displayed on an LCD panel, or sent to a speech synthesis chip to be read aloud. Microcontroller projects in *QST* include a repeater controller[1], a CW Ider[2] and a remote base controller.[3] Each of these projects would have been *vastly* more complex, less capable and much more expensive if embedded microcontrollers had not been available. And think of it: We have only begun to scratch the surface of things that can be done with these ICs!

THE MICROCHIP PIC

Microchip Technology's series of PIC microcontrollers are

[1] Jeff Otterson, N1KDO, Peter Gailunas, KA1OKQ, Richard Cox, N1LTL, "Build a $60 Talking Repeater Controller," *QST*, Feb 1997, pp 37-40.

[2] Bob Anding, AA5OY, "A PIC of an IDer," *QST*, Jan 1998, pp 36-38.

[3] John Hansen, W2FS, "An Inexpensive, Remote-Base Station Controller Using the Basic Stamp," *QST*, May 1998, pp 33-37.

among the most widely used by experimenters.[4] They are quite cheap and relatively easy to use. Microchip makes an assortment of these processors that hold differing program sizes and amounts of data. Some of these ICs include such features as on-board ADCs, serial ports, large numbers of input or output pins and multiple timers. To program these chips, you need a special programmer. To erase *most* of them, you need an ultraviolet eraser. In addition to the cost of the eraser (about $50), erasing one of these PICs takes about four minutes. So, if you are debugging a program by running it, checking how it functions and then making changes, getting to the finished project can be painfully slow.

Fortunately, Microchip has developed one series of chips that is *electrically* programmable and erasable. These chips can be programmed and erased over and over again—electrically. Not only does this make the process of programming and reprogramming easier, it also saves the time and expense of a UV eraser.

One common version of these electrically programmable and erasable products was Microchip's 16C84. It has been largely superseded by their 16F84. In the 'F84, Microchip replaced the 16C84's EEPROM with flash memory. Operationally, both ICs are quite similar.[5] The 16F84 is nearly pin and code compatible with the 'C84, and has more room for data. In single quantities, the 16F84 costs about $6. If you buy 25 of them at a time, you can cut that cost by a third. Because of its ease of use, the 16F84 is an ideal chip to use when learning about PIC microcontrollers.

A ROAD MAP TO THE 16F84

Fig 22.100 shows a very simple circuit for experimenting with the 16F84 PIC: an LED and a piezo speaker. The PIC's pins labeled RB0-RB7 and RA0-RA4 are general input/output pins that the IC's program can specify as receiv-

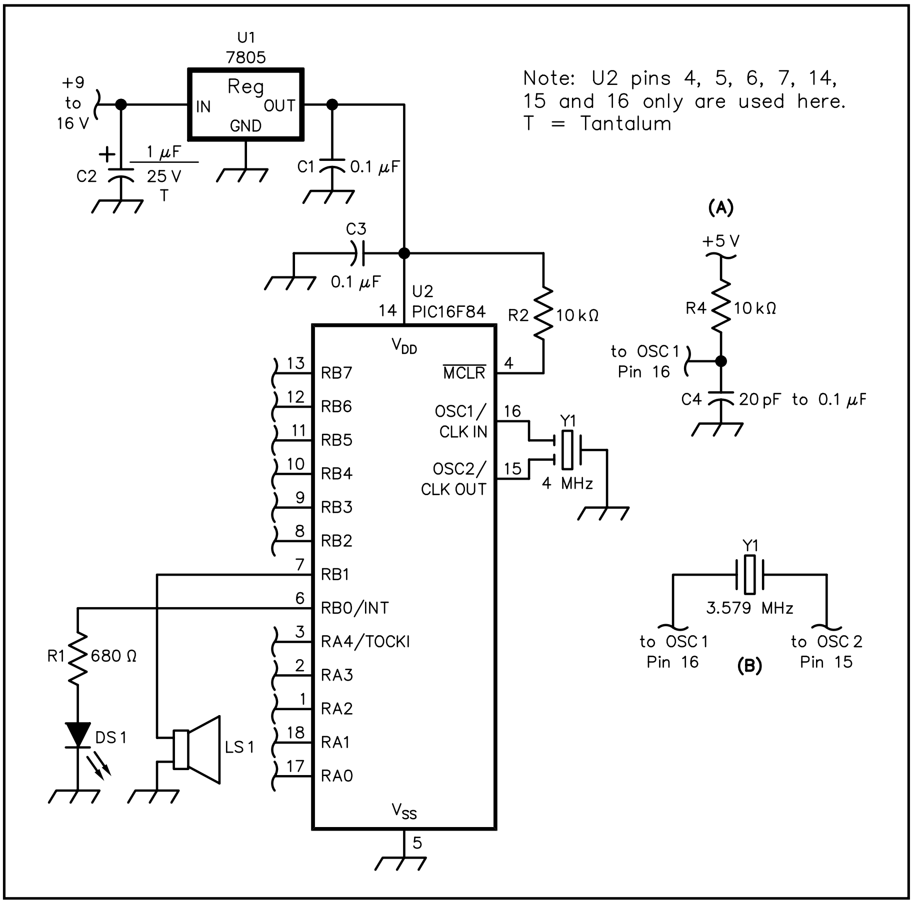


Fig 22.100 — Schematic of the PIC sound-experimentation circuit. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition or film units; equivalent parts can be substituted. RS part numbers in parentheses are RadioShack; DK numbers are Digi-Key.

C2—1 µF, 25 V tantalum (DK P2059; RS 272-1434)
LS1 — Piezo speaker element (RS 273-091)
U1 — 7805 12 V, 1 A positive regulator (DK NJM7805FA; RS 276-1770)
U2 — PIC16F84 microcontroller (see PIC Resources sidebar)
Y1 — 4 MHz resonator (DK PX400) or 3.579 MHz crystal (DK CTX049, HC-49 holder)

[4] Microchip Technology. See References chapter Address List for contact information.

[5] Because these chips are so similar, any project you find that uses a 16C84 (such as the Talking Repeater Controller; see Note 1) can be built with a 16F84.

ing or sending signals. In this simple circuit, we use only two outputs: RB0 and RB1. Through RB0, we can make the PIC light an LED. RB1 has been hooked to a small piezo speaker to allow experimentation with sound. The piezo speaker is an excellent choice for this application because it can be hooked directly to the output pin of the PIC to provide a fairly loud sound.

The rest of the parts in this circuit are needed in every PIC circuit to make it work. Positive 5 V is always applied to the V_{DD} pin and ground to the V_{SS} pin. Fig 22.100 shows how to use a 7805 voltage regulator to convert a 9 to 16 V supply to 5 V. An easy alternative is to buy a battery holder that holds four AA cells and use them to power the circuit. Although four AA cells deliver 6 V rather than 5 V, the PIC will handle that voltage level without difficulty.

The PIC needs a clock source connected to pins **OSC1** and **OSC2**. We have a number of clock options. The simplest is an RC timing circuit (see insert A of Fig 22.100), but its clock rate is slow and it does not provide a high-stability timing source. If you simply want to light an LED, the RC circuit is fine, but it is inappropriate for tasks that require more accurate timing (such as serial data communication). You can also use an external oscillator, but this is a more expensive solution than is really necessary. A crystal can be connected between the **OSC1** and **OSC2** (see insert B of Fig 22.100). Microchip recommends including small-value capacitors on both crystal leads, but most users have found this to be unnecessary. TV colorburst crystals (3.5795 MHz) are readily available, inexpensive and work well in this application.

The cheapest way to provide a stable clock, however, is to use a ceramic resonator (shown connected to U2 in Fig 22.100). These resonators are extremely small parts (smaller than crystals) and generally cost less than $1 each. (Make sure you get resonators with integrated capacitors.) To use a resonator, simply hook its outside pins to the PIC's **OSC1** and **OSC2** pins and the resonator's middle pin to ground.

Finally, you need to apply 5 V dc to the PIC's **MCLR** pin. You could connect 5 V dc directly to this pin, but it's better to apply it through a 10 kΩ current-limiting resistor; then you can restart the PIC's program by simply shorting U2 pins 4 and 5. If you try this without the resistor, you'll create a short circuit across your power supply. You will find that 10 kΩ resistors are extremely common in PIC circuits. They are used to limit current. When you apply 5 V to a 10 kΩ resistor, there is a current of 0.5 mA (E/R = 5/10000 = 0.0005). This is sufficient current for the chip to detect the signal, offers minimal power supply drain and will not damage the PIC. If you are going to do extensive work with PICs, buy 10 kΩ resistors in bulk. Because the PIC is a CMOS device, it is a good idea to tie each *unused* input pin to +5 V through a 10 kΩ resistor in your final design. For experimentation purposes, this isn't necessary.

I'll get to the programming of the PIC later on. (First, we need a programmer for the PIC.) When it comes time to build the circuit of Fig 22.100, I suggest you do so using a solderless breadboard (RadioShack and other suppliers have them.) This will provide you with a test bed for experiments and trial designs for your circuits. You will be able to build a circuit with any combination of inputs and outputs you would like. Once you have finalized your design, you can transfer it to a protoboard or a PC board.

PROGRAMMING HARDWARE

Before you can use a PIC, you must program it for the task you want it to accomplish. In some instances, the program might be written for you. Authors of many *QST* projects that use PICs (and other micros) make the source code available. So, even if you have no interest in writing your own PIC programs, it may be useful to have a PIC programmer to burn chips using code written by others. There are a number of commercially made PIC programmers available, some of which cost more than $150.

For those who like to roll their own, **Fig 22.101** shows an incredibly simple PIC 16C84/16F84 programming circuit. It is based on a design by Ludwig Catta, with a few changes made to ensure that all parts can be purchased at RadioShack. The device is powered directly from your computer's serial port, so no other power supply is required. If all the parts are purchased new, this programmer still costs

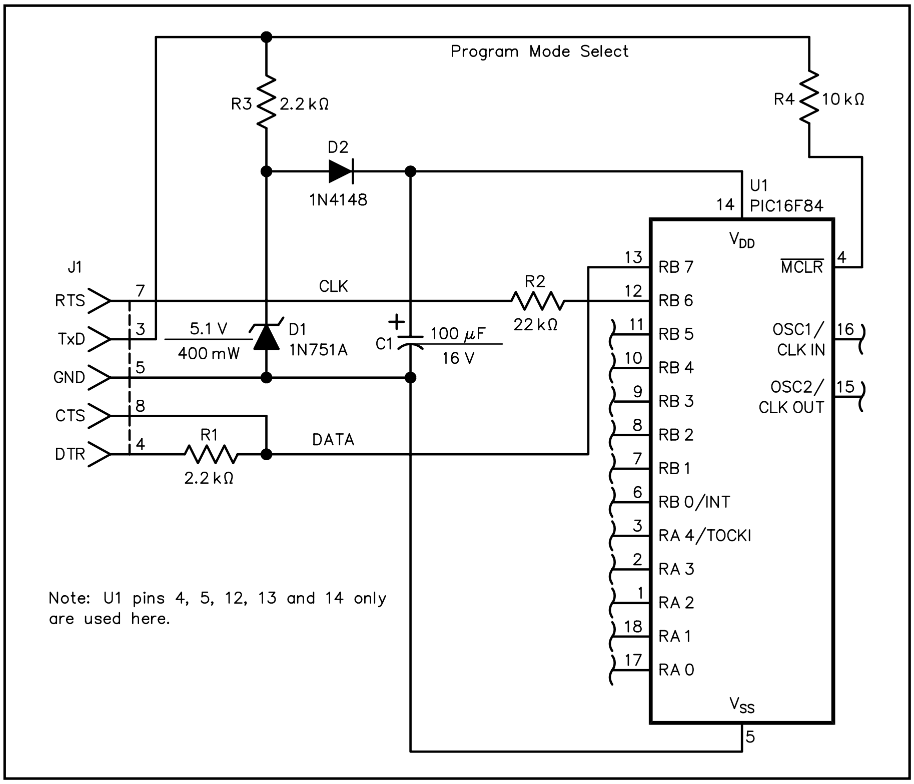


Fig 22.101 — The simple PIC programmer schematic. Unless otherwise specified, resistors are $^{1}/_{4}$ W, 5% tolerance carbon-composition or film units. Equivalent parts can be substituted. RS part numbers in parentheses are RadioShack; DK numbers are Digi-Key.

C1 — 100 µF, 16 V electrolytic (DK P1119)
D1 — 5.1 V, 400 mW Zener diode (DK 1N5231BDICT; RS 276-565)
D2 — 1N4148 or 1N914 (DK 1N4148DICT; RS 276-1122)
J1 — D89
U1 — PIC16F84 microcontroller (see PIC Resources sidebar)

less than $5 to build. You will need a socket to hold the PIC while it is being programmed. You can use a standard 18 pin DIP socket if you're simply burning a single chip based on someone else's program code. If you're planning to use the programmer to do your own development work (requiring frequent insertion and extraction of the PIC), however, buy a zero-insertion-force (ZIF) socket to minimize the wear and tear on the chips.

SOFTWARE NEEDED TO USE THE PROGRAMMER

The code (program) that is eventually loaded into the PIC consists of a series of hexadecimal numbers collectively called *machine language*. Generally speaking, it's extremely difficult to actually write programs in machine language, so virtually all designers use an intermediate step: They write the software in *assembler* or a *high-level language* (such as *BASIC* or *C*). They then use an *assembler* or *compiler* to convert the code to the machine language that the PIC can understand. You can usually determine which type of code is in a file by the file name's extension:

- HEX—machine language files that can be loaded directly into the PIC
- ASM—files written in assembler. They must be converted into HEX before they can be loaded into the PIC.
- C, H—files written in *C*. They must be compiled before they can be used. Depending on the compiler used, they might be converted into .ASM files, or directly to HEX.
- BAS—files written in *BASIC*. They must be compiled before they can be used.

For *BASIC* and *C* files, you cannot use just any compiler to convert them into HEX files. You must use a compiler *specifically designed* to generate instructions that can be read by the PIC.

The most popular tool used to convert assembly language files to HEX files is available from Microchip itself. Called *MPASM*, it is easy to use—best of all, it is *free*! You can obtain *MPASM* from Microchip's Web site.[6] You can write the assembly language instructions using any editor that handles plain ASCII text (such as *Windows Notepad* or the DOS *Edit* program), then use *MPASM* to compile the code into a HEX file.

You also need software to load the HEX file into the PIC. The

[6] Microchip Technology, http://www.microchip.com. At that site, you will also find a free program called *MPLAB*. It is a complete development environment including an editor, a simulator and an assembler.

best program I've found for doing this is called *PIX*.[7] It supposedly is a DOS program, but the author had trouble getting it to run when his computer was booted in MS-DOS! *PIX* runs fine when he runs it in a DOS box within *Windows*, however (that's a switch!). To get *PIX* to work with the programmer of Fig 22.101, first edit the *PIX.CFG* file that comes with the program. Find the two lines that say:

Port=LPT1

and

Programmer = Shaer

Place a semicolon at the start of each line. Then find the line that says:

;Programmer=Ludi

and remove the semicolon. Next, add a line that says:

Port=COM*x*

where *x* is the number of the serial port to which your programmer is connected.

It is important to use a *short* serial cable to connect your programmer to your computer. In building the programmer in Fig 22.101, I simply glued a female DB-9 connector onto the programmer itself and then plugged the programmer directly into the serial port on my computer. In any case, do not use a cable longer than about a foot. See **Fig 22.102**. FAR Circuits makes PC boards for the programmer and the other projects in this article. See the Address List in the **References** chapter.

When you run the program with the simple PIC programmer hooked up to your serial port, you will probably see a dialog box that says, **MODEM DETECTED** or **No/Bad Hardware**. **Not True Continue**. Highlight the answer **YES** and press **ENTER**. The program will then start. This program allows you to read and write code to PICs and erase PICs. It will even disassemble the HEX code to show you the assembly language instructions. Pressing function key **F3** allows you to load your HEX file into the *PIX* program. When you press the **F9** key, the program loads into the PIC.

In summary, you use an ASCII text editor to write your assembly language instructions and save the file with an ASM extension. Then, use *MPASM* to assemble the ASM file into a HEX file. Finally, use *PIX* to load the HEX file into your PIC. To test your program, simply plug the programmed PIC into the completed target circuit and apply power. It should automatically begin executing its program.

BUILDING YOUR FIRST PROGRAM

Learning to write assembly-language programs for the PIC is no trivial matter. This section is not a tutorial in assembler, but will give you a sense of what it is like.[8]

The circuit of **Fig 22.103** can be used to construct a simple code-practice oscillator (CPO). Sure, there are simpler ways to build a CPO than using a computer-on-a-chip, but this application does provide a good introduction to programming PICs. Furthermore, you can build this project using only two resistors,

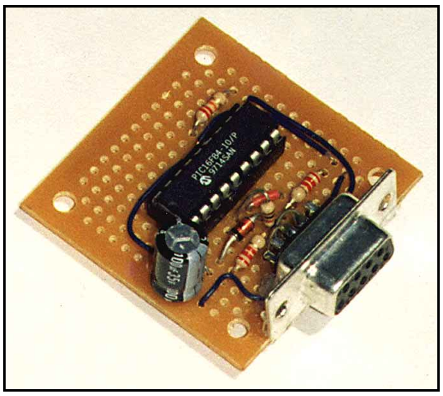


Fig 22.102 — Here's the home-made PIC programmer. The DB9 connector is glued to the perf board for direct connection to the PC Com port. *Photo by John Martinson, WB2WXN.*

[7] Available at **http://home5.swipnet.se/~w-53783/**.

[8] For a good beginner's tutorial in assembler for the PIC, see David Benson, *Easy PIC'n: A Beginner's Guide to using PIC 16/17 Microcontrollers*, (Kelseyville, California: Square 1 Electronics, 1996).

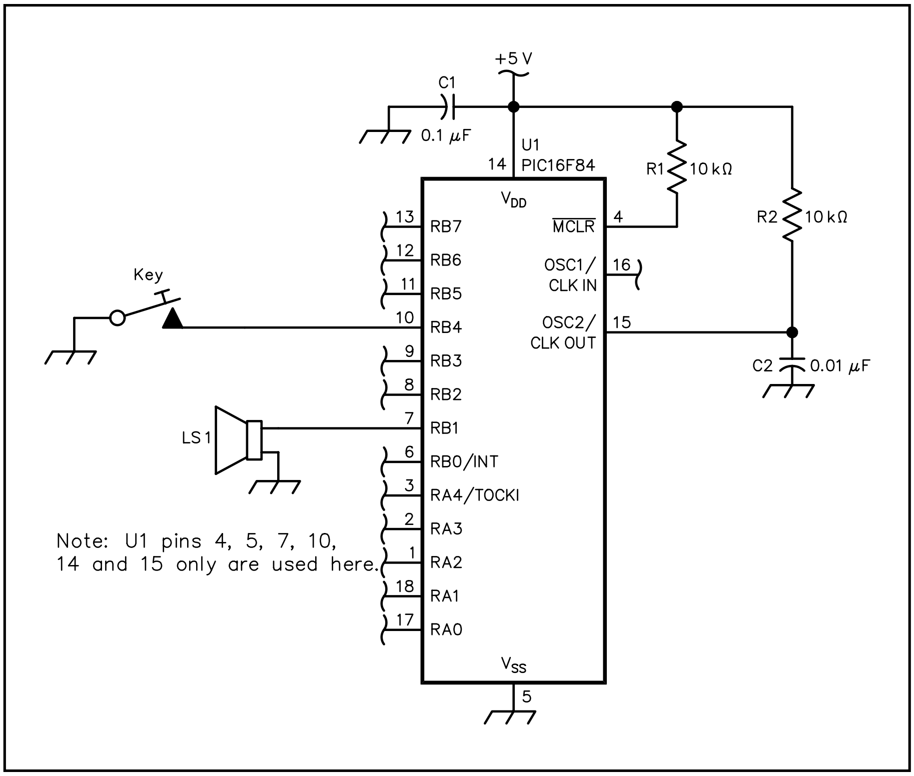


Fig 22.103 — Code-practice oscillator schematic using a PIC microcontroller. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition or film units. Equivalent parts can be substituted.

LS1 — Piezo speaker element (RS 273-091)

U1 — PIC16F84 microcontroller (see PIC Resources sidebar)

two capacitors, the 16F84 PIC and a piezo speaker, making this just about as inexpensive a way to build a CPO as the more traditional methods. The CPO circuit uses an RC timing circuit for the clock. The key is connected between pin RB4 and ground. The speed at which the processor runs can be altered by changing the value of C2. Any capacitance value between 220 pF to 0.01 µF will work, with lower capacitance values resulting in a higher-pitched oscillator.

Using your text editor, enter the code given in **Table 22.10** and name the saved file CPO.ASM. Enter the code in three columns as shown. You don't need to have the exact spacing shown between columns, but you do need to have your code in three columns. Note the two underscores preceding the word "config." In Table 22.10, they appear as one long underline.

Table 22.10

An Assembly-Language Program to Create a Code Practice Oscillator (CPO.ASM)

```
        list      p=16F84
        __config  0x3FF3
portb   equ       0x06
        org       0x000
        movlw     0x00
        option
        movlw     0xFD
        tris      portb
start   btfsc      portb,4
        goto      start
        bsf       portb,1
        bcf       portb,1
        goto      start
        end
```

The first line of code tells the assembler which PIC is being used. In the second line, the internal configuration of the clock and the timers is set up. Here we specify that we are using an RC circuit for the clock. If we wanted to use a colorburst crystal or a ceramic resonator, we would have specified 0x3FF1.

The third line makes the code easier to read. The internal location for the Port B I/O lines (RB0 through RB7) is 0x06. This line of code specifies that we will call this location "portb" instead. The "org" instruction in the next line says where the program should start; in this case at the first instruction entered in the chip (at location 0).

The next two lines enable internal pull-up resistors on all of the Port B pins that are used as inputs. This means that 5 V is applied to each of these pins through a current-limiting resistor. This happens inside the chip and requires no external components. As a result, each of the input lines sees a 5 V signal, unless you short the pin to ground. This is the mechanism used for keying the CPO. When you key the CPO, it momentarily connects pin RB4 to ground. The program detects that this pin is low, and generates a tone as long as the pin is grounded.

The next two lines determine which of the PIC's pins will be inputs, and which will be outputs.[9] The PIC assumes the pins are inputs, unless it is specifically told to make them outputs. In this case, the value FD (11111101 in binary) changes RB1 to an output. The next line is labeled "start" so that the program can loop back up to this line when it needs to. Once it gets to this point, all the program does is repeatedly execute the remaining lines of the program (except the end statement). This forms what is called an *infinite loop* because the program just continues doing this until you shut off the power to the microprocessor. In most programming environments infinite loops are avoided at all costs — they are often the things that cause computers to "hang" when they occur unintentionally. With PICs, however, infinite loops are very common. They are used whenever you want the PIC to continue running the same program over and over again until the power is shut off.

The line labeled "start" says that if pin four on Port B (RB4) is low (grounded), skip the next line of code. That next line just sends the program back to "start." Thus, if pin RB4 is high (+5 V), the program continues to alternate between these two lines of code until pin RB4 is grounded. When pin RB4 is grounded, the instruction to go back to "start" is skipped. The next two lines of code

[9] Microchip considers the *option* and *tris* instructions outdated. However, they will work in most applications. Because the alternative methods for configuring the I/O pins and pull-up resistors are somewhat more complicated, in the interest of simplicity, the first approach is selected for this project.

PIC Resources

Books

Benson, David, *Easy PIC'n: A Beginner's Guide to using PIC 16/17 Microcontrollers* (Kelseyville, California: Square 1 Electronics, 1996). It's a good introduction to PIC chips and assembly programming.

Benson, David, *PIC'n Up the Pace: PIC 16/17 Microcontroller Applications Guide* (Kelseyville, California: Square 1 Electronics, 1997). Essential reading if you are serious about learning assembler. If you plan to use a *C* or *BASIC* compiler, you need not have this book.

Predko, Myke, *Programming and Customizing the PIC Microcontroller* (New York, McGraw-Hill, 1998). Somewhat more advanced, this book contains a good discussion of the PIC architecture and lots of projects.

Peatman, John B., *Design With PIC Microcontrollers* (New York: Prentice Hall, 1997). This is a well written college-level text on PIC microcontrollers.

Compilers

PCM, a *C* compiler available from Custom Computer Services, Inc. See the **References** chapter for contact information. Price, $99.

Hi-Tech's PIC *C* compiler. Although this compiler is too expensive for most of us ($850), a working demo is available for free that will compile small projects. HI-Tech Software, LLC. See the **References** chapter for contact information.

PicBasic Compiler, a *BASIC* compiler available from microEngineering Labs, Inc. See the **References** chapter for contact information. Price: $99.95.

PIC Chips and Other Parts

Digi-Key Corporation. See the **References** chapter for contact information. Digi-Key also stocks ceramic resonators and ZIF sockets.

JDR Microdevices. See the **References** chapter for contact information.

[Author's note: This is not an exhaustive list of resources. There is a wide range of resources available for PICs including complete development environments that sell for over $2000. I have focused here only on those resources that are within the budget of a typical amateur.—*John Hansen, W2FS*] take pin RB1 high (bsf) and low (bcf) again. Then the program goes back up to "start." The effect of this is that if pin RB4 is grounded, the program causes pin RB1 to alternate between 5 V and ground at the same rate that the microprocessor clock is running. This produces a rectangular wave (not quite square) at about 700 Hz. Because we are using an RC circuit to clock the chip, it runs at a relatively low frequency. If we had used a 4 MHz crystal instead (which runs the microprocessor clock at 1 MHz), it would have been necessary to insert additional delay instructions to slow down the rate at which pin RB1 alternates between high and low. A CPO that runs at 1 MHz is not very useful! You won't hear it!

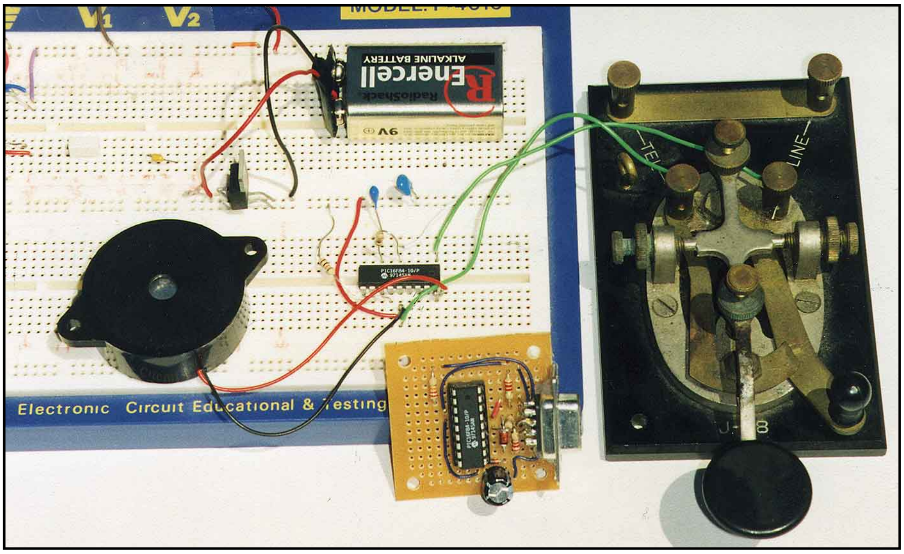


Fig 22.104 — CPO on a breadboard—keyed by one of the famous J-38s. A perfboard version of the Ludwig Catta (Ludi) PIC programmer is in the foreground. *Photo by John Martinson, WB2WXN*

That's all there is to it. After you have saved the CPO.ASM file, use *MPASM* to compile it into a HEX file using the command: **MPASM CPO**

If any errors are reported during the compiling process, it means you have mistyped something. By viewing the *CPO. ERR* file, you can find out which lines contain the errors. After the program assembles without error, use *PIX* to load the HEX file into your 16F84 PIC.

When you get this project running, try changing the code to lower the tone. Or, try having the PIC light an LED (as in Fig 22.100) *and* generate a tone. Each time you change the program, you need to rerun *MPASM* to reassemble the code and reload it into the chip with *PIX*. By experimenting with variations of this basic circuit, you can better understand how assembly-language instructions work.

ISN'T THERE AN EASIER WAY?

Of course, there is an easier way to do this. You can use a high-level language such as *C* or *BASIC* to write your program. For that, however, you need a compiler that converts your *BASIC* or *C* code into assembler or machine language. The cheapest of these compilers costs about $100. There are indications that some share-ware compilers are beginning to come into the market, however. I've had very good luck with the Custom Computer Services, Inc compiler called *PCM*. It costs just under $100, and has built-in routines to make serial communication particularly easy. If you are going to do a lot of work with PICs, spending the money on a compiler may be worth considering

CREATING A PIC-BASED IDER

Table 22.11 contains the assembly-language code that makes a 16F84 PIC generate Morse code. The code is designed to work with the circuit of Fig 22.100, using a ceramic resonator or a 3.5795-MHz colorburst crystal. Audio output is obtained at pin RB1. The program is designed to be easy to modify to insert your choice of call sign, Morse code speed and transmit interval. To change the Morse code speed, alter the lines labeled "dahlen" and "ditlen." To change the ID interval, change the number between the apostrophes in the line labeled "loop." Change the lines that start with the label "top" to change the call sign (or other text) that is to be transmitted by the chip. Follow the pattern shown in the

Table 22.11

An Assembly Language Program for a PIC Morse Code Generator

```
         list      p=16f84
         radix     hex
         __config  0x3FF1
dahlen   equ       d'99'      ; <==controls code speed..increase
ditlen   equ       d'33'      ;<==(though not over 255) for
         org       0x000      ;slower code, decrease for
         MOVLW     00         ;faster code. Make sure the
         MOVWF     0A.        ;top number is three times ;the bottom
         GOTO      start
         NOP
         NOP
time     MOVF      10,W
         BTFSC     03,2
         GOTO      endtime
uptop    MOVLW     01
         MOVWF     0D
upagn    CLRF      0C
doagn    DECFSZ    0C,F
         GOTO      doagn
         DECFSZ    0D,F
         GOTO      upagn
         MOVLW     4A
         MOVWF     0C
upone    DECFSZ    0C,F
         GOTO      upone
         DECFSZ    10,F
         GOTO      uptop
endtime  RETLW     00

dah      MOVLW     01         ;subroutine to do a dah
         MOVWF     0E
agn3dah  MOVLW     dahlen
         SUBWF     0E,W
         BTFSC     03,0
         GOTO      enddah
         BSF       06,1       ;turn on pin B1
         MOVLW     01
         MOVWF     10
         CALL      time       ;wait 1 millisecond
         BCF       06,1       ;turn off pin B1
         MOVLW     01
         MOVWF     10
         CALL      time       ;wait 1 millisecond
         MOVF      0E,W
         INCF      0E,F
         GOTO      agn3dah    ;loop up to do it again.
enddah   MOVLW     3C         ;add a small delay
         MOVWF     10
         CALL      time
         RETLW     00

dit      MOVLW     01         ;subroutine to do a dit
         MOVWF     0E
agn3dit  MOVLW     ditlen
         SUBWF     0E,W
         BTFSC     03,0
         GOTO      enddit
         BSF       06,1       ;turn on pin B1
```

Continued on next page.

Table 22.11

An Assembly Language Program for a PIC Morse Code Generator

Continued from previous page.

```
            MOVLW   01
            MOVWF   10
            CALL    time        ;wait 1 millisecond
            BCF     06,1        ;turn off pin B1
            MOVLW   01
            MOVWF   10
            CALL    time        ;wait 1 millisecond
            MOVF    0E,W
            INCF    0E,F
            GOTO    agn3dit     ;loop up and do it again.
enddit      MOVLW   3C          ;add a small delay
            MOVWF   10
            CALL    time
            RETLW   00

lspace              0xB4        ;subroutine to make a
            MOVLW               ;letter space
            MOVWF   10
            CALL    time
            RETLW   00

start       CLRF    04          ;MAIN PROGRAM
                                ;STARTS HERE
            MOVLW   0xFD
            TRIS    6

top         CALL    dit         ;modify this code to
                                ;xmit the
            CALL    dah         ;CW you want to send
            CALL    dah
            CALL    lspace      ;lspace is a pause for
                                ;the space between
            CALL    dit         ;letters. Include it after
                                ;each letter.
            CALL    dit         ;As it appears here, the
                                ;IDer will
            CALL    dah         ;transmit W2FS
            CALL    dah
            CALL    dah
            CALL    lspace
            CALL    dit
            CALL    dit
            CALL    dah
            CALL    dit
            CALL    lspace
            CALL    dit
            CALL    dit
            CALL    dit

            MOVLW   01
            MOVWF   0E
                                ;this code programs the
                                ;delay between IDs.
loop        MOVLW   d'150'      ;<= 4 × this number =
                                ;number of seconds
```

Continued on next page.

Table 22.11

An Assembly Language Program for a PIC Morse Code Generator

Continued from previous page.

```
          SUBWF    0E,W       ;between IDs when
                              ;using a 4 MHz resonator.
          BTFSC    03,0
          GOTO     bottom
          MOVLW    10
          MOVWF    0F
again     MOVLW    0xFA
          MOVWF    10
          CALL     time
          DECFSZ   0F,F
          GOTO     again
          MOVF     0E,W
          INCF     0E,F
          GOTO     loop
bottom    GOTO     top
          END
```

program and make sure you put an "lspace" after the end of each letter. If you plan to transmit text other than just a call sign, you can do this by adding extra "lspace" instructions to create longer delays between the words. When altering this code, be sure to keep the label "top" on the same line as the first code element to be sent.

If you type in the program yourself, you may leave out the comments on each line by dropping the semicolon and the text that follows it. Blank lines can either be left in or deleted as you prefer. Alternatively, you can download this file from the ARRL's FTP site and edit it. The program may look long, but it only uses about 10% of the program capacity of a 16F84.

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