Fig. 10-27 – The heat sinks are mounted on an aluminum panel. When installing a power supply of this type, be sure to keep the heet sink fins in a vertical position to provide best air circulation. All of the filter capacitors are mounted in a row across the front of the chassis. RFC1 is located next to the transformer. Two sockets are mounted on the chassis side wall to accept an interconnecting cable from the transceiver. To the left of these sockets is the bias voltage adjustment control, R3. This model of the power supply was built by W8HS and assistanca was given by W8DDO, W9IWJ (of Delco Radio Corp.), and Jim Osborne (of Osborne Transformer Co.).

The supply oscillates at about 1000 Hz and audible noise is low. The main power to the supply is applied through K1B. K1A can be connected in parallel with the filament supply in the transceiver.

Hash filtering is provided by RFC1 and its associated bypass capacitors in the primary lead. Transient suppression is assured by CR13, CR16 and CR17. Bleeder resistors are used on each supply leg to provide a constant minimum load for the circuit. The supply can be operated without being connected to its load without fear of damaging the diodes or transistors, although this is not considered good practice. Input and output connectors for interconnection to the battery and the transceiver can be selected to meet the needs of the particular installation.

Construction

This circuit requires that the transistors be insulated from the heat sink. Suitable insulators are included with the devices. Silicone grease should be used to help conduct the heat away from the transistors.

No attempt has been made to make the supply small. It is built on a 12 X 6 X 3-inch chassis which allows plenty of room for the heavy conductors. The capacitors are mounted in a row along one side

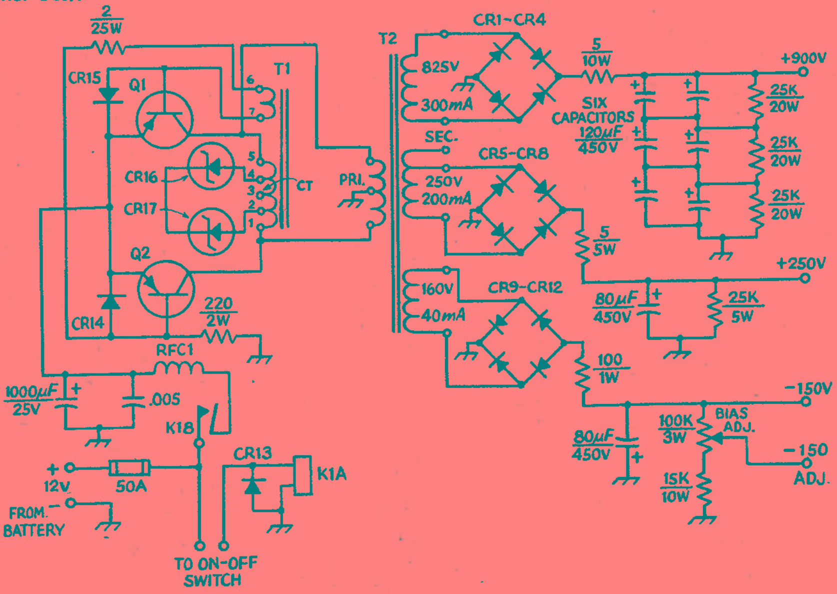

Fig. 10-28 – Circuit diagram of the mobile power supply. Polarized capacitors are electrolytic, others are paper or mica. Resistances are in ohms. Component designations not listed below are for text referenca.

CR1-CR13, incl. – 1000-PRV, 1.5-A silicon diode (Mallory MR 2.5 A or equiv.).

CR14, CR15 – 50-PRV, 3-A silicon diode (G.E. A15F).

CR16, CR17 – 18-volt, 1-watt, Zener diode (Motorola 1N4746).

K1 – Spst contactor relay, 60-A, 12-volt dc coil (Potter and Brumfield MB3D).

Q1, Q2 – Delco 2N1523 transistor (substitutions not recommended). Delco insulator kits (No. 7274633) are required. The heat sinks are Delco part No. 7281366.

R3 – 100,000-ohm, 3-watt, linear-taper control.

RFC1 – 20 turns, No. 10 enam. wire on a 1/4-inch dowel.

T1 – Feedback transformer, 1000-Hz (Osborne 6784).

T2 – Hipersil transformer, 1000-Hz (Osborne 21555).

of the chassis. The heat sinks, shown in the photograph, are mounted on a 1/8-inch-thick aluminum back plate.

The leads from the battery to the relay, and from the relay to the transistors and T1, should be No. 6 or No. 8 conductors. All ground leads should be connected to one point on the chassis. The wiring layout is uncritical and no other special precautions are necessary.

Operation

The power supply should be mounted as close to the battery terminals as possible to minimize voltage drop. If the supply is trunk mounted, 1/4-inch conductors should be used to connect it to the battery. A 300-volt tap is available on the secondary of T2. If the transciever requires more than 250 volts for proper operation, this tap can be used.

DC-TO-AC INVERTERS

It is possible to convert the automotive battery voltage from 12-volt dc to 117-volt ac, 60 Hz, by using an inverter. The principle of operation is substantially the same as for dc-to-dc converters, but larger transformers are needed to handle the lower switching rate. The primary circuit is the same as for the dc converters, but the secondary voltage is not rectified. Square-wave output is obtained, though some commercial inverters are available with sine-wave output. The latter is recommended for operating motor-driven equipment. The square-wave types introduce some buzz into the equipment they power, but a brute-force line filter can be used to knock down some of the harmonic energy from the square-wave output. Inverters are useful for powering soldering irons, light bulbs during portable/emergency operations, and to power small ac-operated transceivers. They are commercially available at power levels up to 500 watts or more, but the larger the unit the greater the demand on the car battery.

Fig. 10-29 — Top view of the dc-to-ac inverter. The transistors and their heat sink are at the right. Two ac outlets are used, offering greater convenience than would be possible with a single receptacle. A neon lamp lights when the unit is operation.

A HOME-MADE 175-WATT INVERTER

The unit shown here provides 60-Hz output, square wave, and has taps for 110, 117 or 125-volts. Because of the square-wave output, some hash noise may appear in the output of transmitters or receivers that are operated from the supply. If so, some form of filtering may be necessary at the output of the inverter.[1]

Construction

The inverter is built on a homemade base which measures 8 X 6 X 2 inches. A Bud CU-3009-A Minibox can be used as a chassis. Rubber feet are attached to the bottom cover of the Minibox to help prevent the assembly from scratching the automobile's finish if it is to be placed on the hood or trunk.

A large heat sink is used for cooling Q1 and Q2. The unit shown here is 4 inches long, 3 inches wide, and 2 inches high. It was manufactured by Delco Radio (part number 7281366). Any heat sink of similar dimensions will work satisfactorily. Because the circuit is operated in a common-collector configuration, the transistors need not be insulated from the heat sink, nor is it necessary to insulate the heat sink from the chassis. Silicone grease is used between the transistors and the heat sink, and between the heat sink and the chassis. This contributes to efficient heat transfer between the transistors and the thermal hardware.

All leads carrying primary current should be of large circular-mil size in order to prevent a voltage drop in that part of the circuit. Parallel sections of ac zip cord are used in this model. They are used between the input terminal block and the fuse holder, between the fuse holder and the toggle switch, and between the switch and the primary leads of T1. A dpst toggle switch is used at S1 to permit both sections to be used in parallel, increasing the current-handling capacity.

Two ac outlets are located on the top-front of the chassis so that more than one piece of equipment can be plugged in at the same time.

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[1] A brute-force line filter is often helpful in reducing this type of hash. Commercial units of this kind are available from most wholesale houses (J. W. Miller Co., No. 7818). A homemade filter might consist of two scramble-wound inductors containing 10 feet (each) of No. 12 enameled copper wire. A coil would be placed in each leg of the ac output. Four 0.1-μF 600-volt paper capacitors would be needed. They would be connected between the ends of each coil and ground. Such a filter could be built on the inverter chassis, or contained in its own case, outboard fashion.

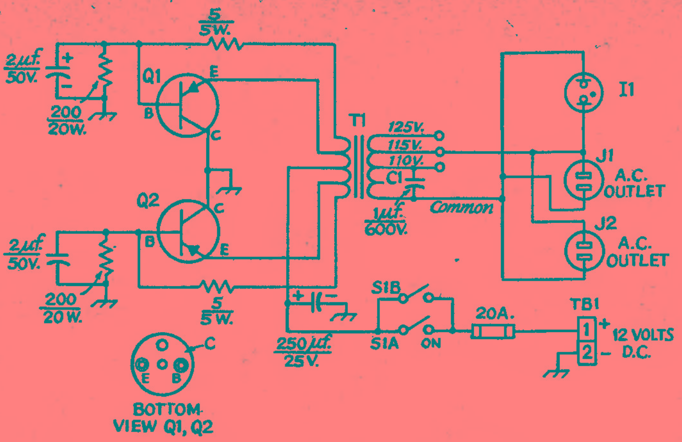


Fig. 10-30 — Schematic diagram of the inverter. Capacitance is in μF. Polarized capacitors ara electrolytic. Resistance is in ohms.
C1 — 1-μF 600-volt capacitor (paper type only).
DS1 — Neon panel-lamp assembly with built-in dropping resistor.
J1, J2 — Standard female-type ac outlet socket.
Q1, Q2 — High-wattage power transistor. 2N278 used here. (2N678, 2N1146, 2N173 suitable.)
S1 — Dpdt toggle switch with sections in parallel.
T1 — Inverter transformer, 12 volts dc to 117 volts ac (Triad TY-75A).
T81 — Two-terminal connector (Millen 37302 suitable).

Operation

In using the inverter, it is wise to have some kind of a load connected across the output of the unit when it is turned on. Without a secondary load, voltage peaks can occur and cause the destruction of the switching transistors, Q1 and Q2. The best procedure is to attach the equipment to the inverter's outlet receptacle, turn the equipment on, then activate the inverter by turning it on with S1. In turning the system off, this process should be reversed – turning the inverter off first, then the equipment.

Motor-operated equipment such as tape recorders and record players will not function satisfactorily from this inverter and should not be used with it. Also, make certain that the equipment which is to be operated from the inverter does not draw more than 100 watts if continuous-duty operation is planned. The inverter should safely handle intermittent loads of up to 175 watts.

For maximum efficiency, the inverter should be connected directly to the car-battery terminals by means of large-diameter conductors. The shorter the conductor length, the less voltage drop there will be in the line.

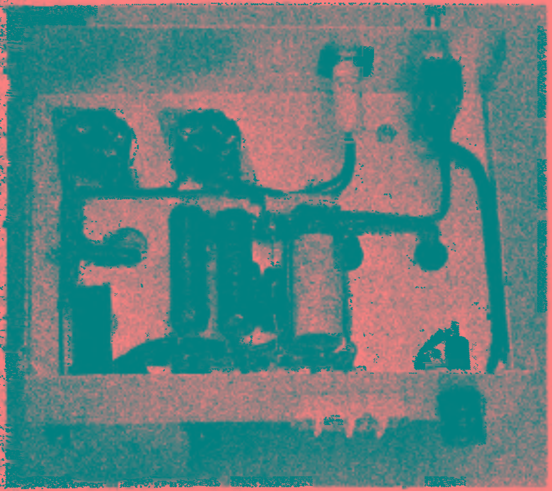


Fig. 10-31 — A look at the underside of the chassis. The resistors and capacitors ara mounted between insulated terminal strips. Ac zip cord, paralleled, is used for the heavy-duty primary wiring.

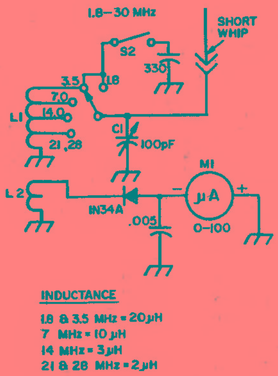


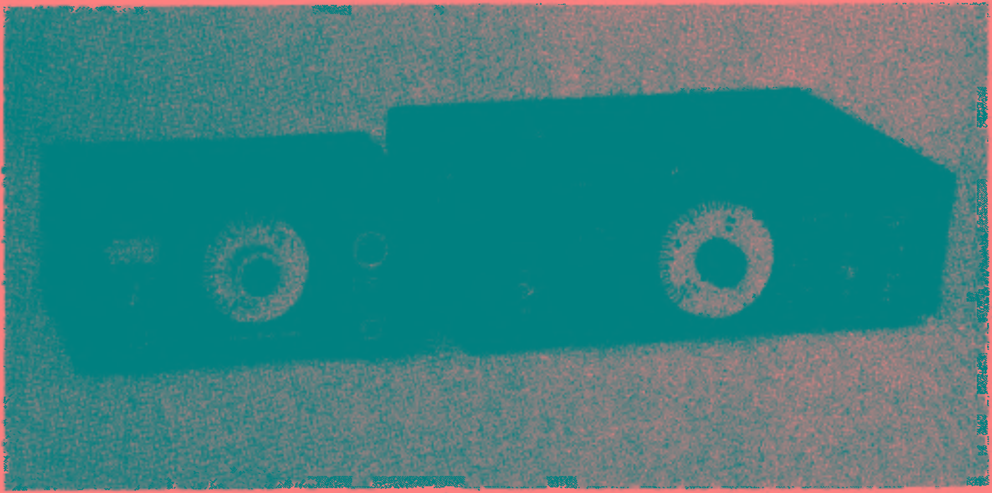
Fig. 10-32 — A band-switched field-strength meter for tuning up the hf-band mobile antenna. It should be assembled in a metal box. In use, it should be placed several feet from the antenna under test. C1 is tuned for a peak meter reading at the opereting frequency. It can be detuned for varying the sensitivity.

A BAND-SWITCHING FIELD-STRENGTH METER

The circuit of Fig. 10-32 can be used for tuning the mobile antenna system to resonance. It covers a range from 1.8 to 30 MHz. A single toroidal inductor is used in the tuned circuit. The coil is tapped to provide band switching by means of S1. C1 is tuned for a peak meter reading at the transmitter's output frequency. The unit should be housed in a metal utility box. A banana jack can be used for attaching the short whip antenna.

An Amidon Associates E-core, No. T-68-2, is wound with 50 turns of No. 26 enamel wire. It is tapped 10 turns from ground for 15- and 10-meter use, 18 turns from ground for 20 meters, and 36 turns above ground for 40 meters. The entire 50 turns are used for 80 and 160 meters. S2 adds a 330-pF capacitor for 160-meter operation. S1 can be a single wafer, single-pole, 5-position rotary switch of phenolic or ceramic insulation. S2 can be a spst slide switch. C1 is a Hammarlund HF-100 capacitor, or equivalent. (Amidon cores can be obtained from Amidon Associates, 12033 Otsego St., N. Hollywood, CA 91607.)

A DIRECT-CONVERSION KILOGRAM FOR 20 AND 40 METERS



When portability, low current drain, and simplicity are required in a receiver, it is hard to beat the technique of direct conversion. The unit described here covers the cw portion of both 20 and 40 meters. As total power consumption is on the order of 0.6 watt, battery operation is practical. Packaged in an aluminum box only 6 × 7 × 3 inches (HWD), the receiver weighs in at about one kilogram (2.2 pounds) and fits easily inside a suitcase. The receiver is designed to be compatible with the low-power solid-state transmitter described in Chapter 6.

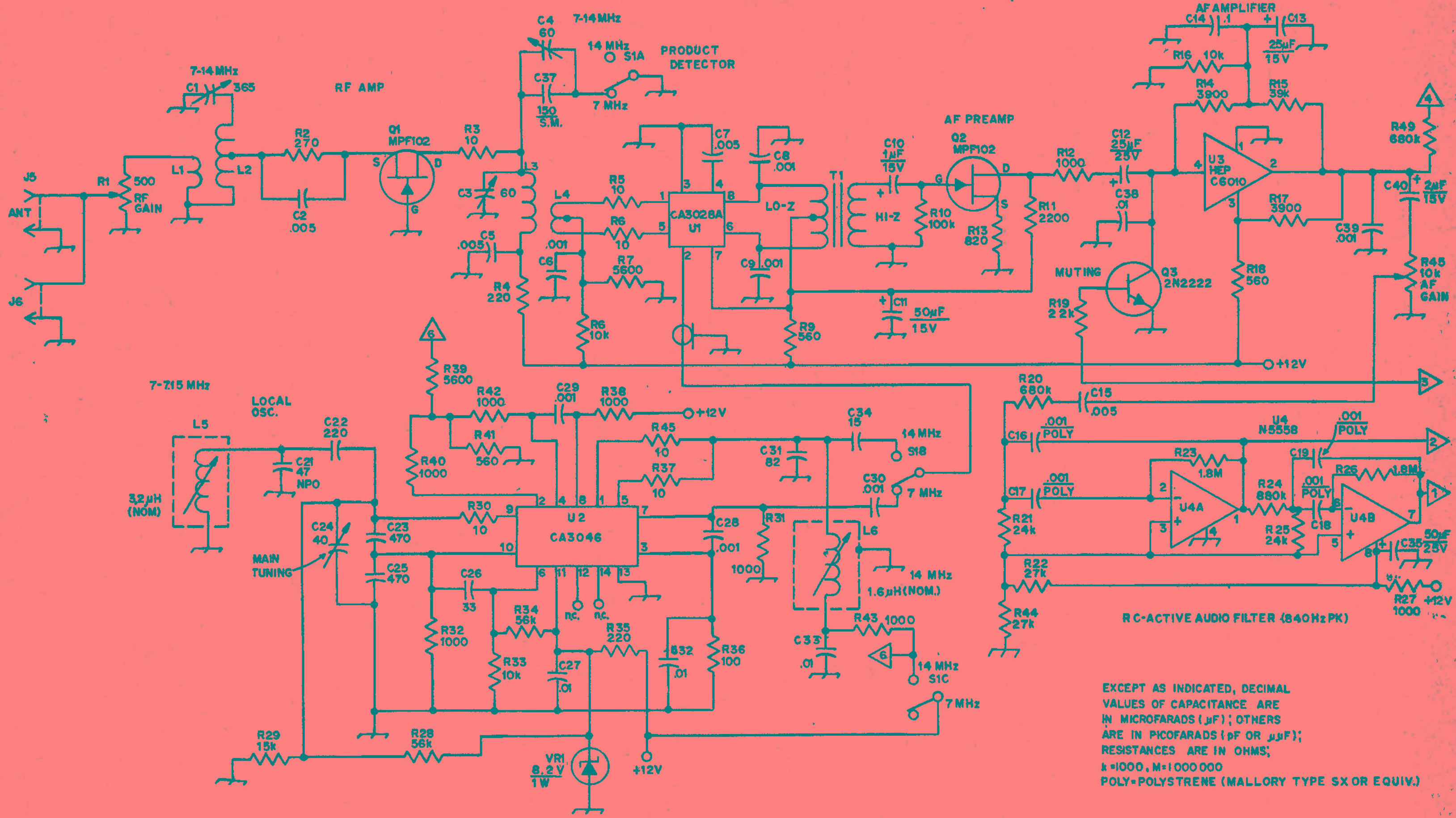
Circuit Overview

This approach to direct conversion uses an FET as a fixed-tuned rf amplifier, switchable between 20 and 40 meters. An IC transistor array serves as the heart of a band-switched local oscillator. A differential amplifier IC functions as a product detector. The audio channel uses an FET to establish a low noise figure, followed by a high-gain wide-band IC amplifier. Audio selectivity is achieved through the use of a two-stage active filter. A signal strength indication is obtained through the use of an audio-derived S-meter circuit.

Circuit Description

Q1 operates as a grounded-gate rf amplifier. C1, a front-panel mounted broadcast type variable capacitor, peaks the input of the stage for 40- or 20-meter reception. The output of the stage is tuned to 20 meters by L3-C3. One pole of S1 switches additional capacitance in parallel with C3 for 40-meter operation. L4 couples rf energy to the input of the product detector, U1. Local-oscillator injection is applied to pin 2 of U1, the base of the internal constant-current source transistor. The local oscillator is built around a CA3046 IC transistor array, and is identical to the VFO used in the companion transmitter described in Chapter 6.

The CA3046 contains three independent NPN



EXCEPT AS INDICATED, DECIMAL
VALUES OF CAPACITANCE ARE
IN MICROFARADS (µF); OTHERS
ARE IN PICOFARADS (pF OR µµF);
RESISTANCES ARE IN OHMS;
k=1000, M=1000000
POLY=POLYSTRENE (MALLORY TYPE SX OR EQUIV.)

silicon transistors plus one differentially connected transistor pair, and is available in a 14 pin dual inline package. The RCA CA3045 is directly interchangeable with the CA3046, and they are available surplus very inexpensively. The ICs have identical pin connections and electrical characteristics, and the only difference between the two is that the CA3046 is packaged in a ceramic case, while the CA3045 is packaged in a plastic case.

In this application, one transistor is used in a Colpitts VFO circuit operating at 7 MHz, one transistor is used as a phase splitter, and the differential pair is used as a push-push doubler to produce output at 14 MHz. One transistor is unused. The 7-MHz output is taken from the emitter of the phase splitter. The devices in the

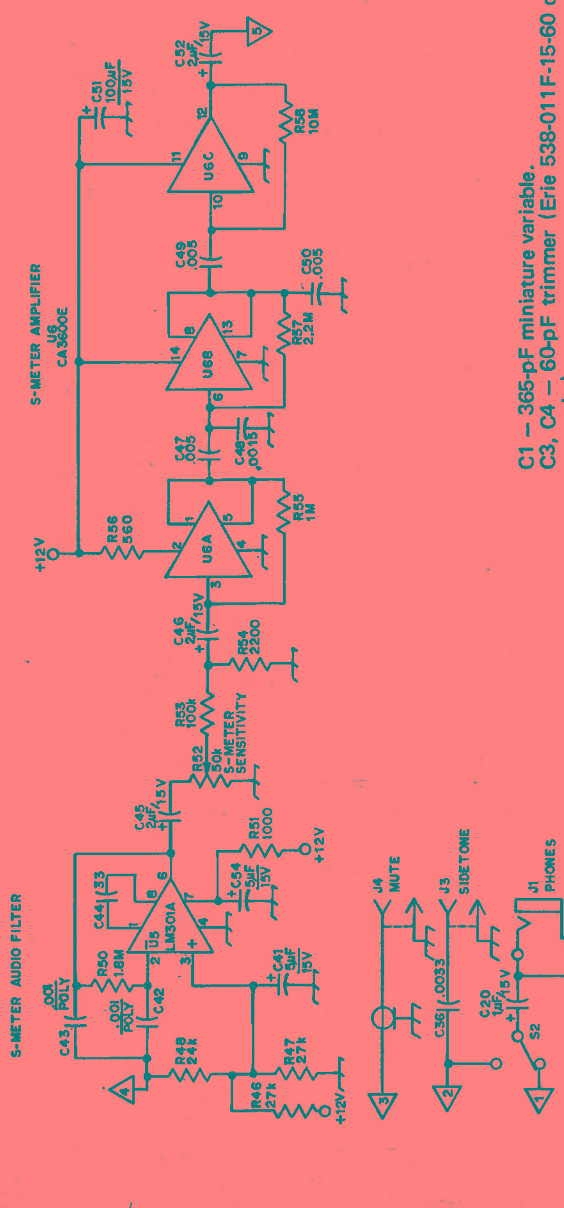


Fig. 1 — Schematic diagram of the diract-conversion receiver. Numbered perts in this diagram which are not listed below are so numbered for circuit-board identification and text discussion. Fixed-value resistors may be 1/2- or 1/4-watt composition. Polarized capacitors are electrolytic. Fixed-value cepacitors are disk ceramic, unless otherwise indicated.

C1 — 365-pF miniature variable.
C3, C4 — 60-pF trimmer (Erie 538-011 F-15-60 or equiv.).
C16, C17, C18, C19, C42, C43 — 1000-pF polystyrene.
C21 — 47-pF NPO.
C24 — three-section, 20-pF-per-section variable, two sections used (J.W. Miller 1460 or similar).
CR1 — Silicon diode.
J1 — Phone jack.
J2 — Miniature phone jack.
J3, J4, J6 — Phono jack.
J5 — SO-239 connector.
L1 — 2 turns small diameter hookup wire over L2.
L2 — 18 turns No. 22 enam. wound on Amidon T50-6 core (tep 4 turns above ground).
L3 — 25 turns No. 24 enam. wound on T50-6 core.
L4 — 6 turns small diameter hookup wire, center tepped, over L3.
L5 — 3.0-7.0 μH shielded variable inductor (J.W. Miller 9051 or equiv.).
L6 — 1.5-3.0 μH shielded variable inductor. (J.W. Miller 9050 or equiv.).
M1 — 100 microamperes full scale.
Q1, Q2 — MPF-102.
Q3 — 2N2222 or equiv.
S1 — 4pdt slide switch (Radio Shack 275-405).
S2 — spdt toggle switch.
T1 — Miniature interstage transformer, 2000-ohm ct to 10,000 ohms (Radio Shack 273-1378).
U1 — CA3028A.
U2 — CA3046 or CA3045.
U3 — HEP C6010 or MFC 4010A.
U4 — Dual 741 op amp (Radio Shack 276-038 or equiv.).
U5 — LM301A op amp.
U6 — CA3600E.
VR1 — 8.2-volt, 1-watt Zener diode.

Fig. 2 — Inside view of the receiver. Most of the components are mounted on e 4- × 6-inch printed-circuit board. The rf amplifier and product detector components are grouped together at the upper left corner of the board, while the audio channel occupies the left foreground. The VFO main-tuning capacitor, C24, is centered in the cabinet, and is positioned directly over the VFO. The S-meter amplifier circuitry is visible at the right.

CA3046 have a rated F_T of 550 MHz. R30, R37, and R45 are used to prevent vhf parasitic oscillations from occurring. S1B may be used to select either 40- or 20-meter output from the local oscillator, and S1C applies 12 volts dc to the frequency doubler portion of the oscillator for 20-meter operation. With the component values shown, the receiver covers 7.0 to 7.15 MHz and 14.0 to 14.3 MHz. A miniature interstage transformer, T1, is used to couple the output of the product detector to the audio channel. Q2 functions as a moderate-gain, low-noise audio preamplifier, which is followed by the integrated high-gain amplifier U3. Q3 has been included to allow for muting of the receiver during transmitting periods by the application of 12 volts dc to R19 (in series with the base of Q3) by means of a contact on the transmitter's T-R relay. This biases Q3 into conduction and effectively breaks the circuit path between Q2 and U3. A miniature pot is used at R45, which serves as the af gain control. The setting of R45 determines the input level to U4A-U4B. A small part of the output of U3 (taken off before the af gain control) is used to drive the S-meter circuitry. Audio selectivity for the receiver is provided by two cascaded active filter sections consisting of a dual 741 op amp, U4A-U4B, plus associated passive components. With the values shown in the schematic each individual filter section will have a peak response at 840 Hz and a bandwidth of 375 Hz (measured at 6 dB below peak response). When two sections are cascaded, a narrower filter with a bandwidth of 200 Hz results. It is advantageous to match the peak frequency response of each filter section closely by hand picking component values[1] to achieve optimum filter performance. Provision is made for using either a broad or a narrow response by using S2 to switch the headphones to either the output of U4A or U4B, respectively. The active filter drives a pair of high-impedance headphones directly. Provision for monitoring the transmitter sidetone is included by introducing the tone into the audio channel beyond the muting transistor, Q3. The audio-derived S-meter circuit uses a single-stage audio filter, followed by a meter amplifier. The filter is similar to one section of the audio channel filter and is necessary to assure that the meter indication is a function of the signal being monitored and not the result of extraneous signals at the output of U3. Thus, the S-meter reading does not vary with the setting of the af gain control, and does not operate while the sidetone is being monitored. The output of the S-meter filter drives a three-section integrated-circuit amplifier, U6. The rectified amplifier output drives a 100 micorampere full-scale meter for the signal strength indication. Pc mounted pots are used at R52 and R60 for S-meter adjustment (sensitivity and zero).

Construction

Construction of the receiver is greatly simplified by the use of an etched printed-circuit board for mounting most of the parts. A template is available from ARRL for 50 cents and an s.a.s.e. The entire receiver fits on a 4- × 6-inch board. If no S-meter is desired, it is a simple matter to adjust the layout to fit on a 4- × 4-1/2-inch board leaving out U5, U6, and their associated components. A

Fig. 3 — Front view of the direct-conversion receiver. The cabinet is homemade from two U-shaped pieces of .040-inch thick sheet aluminum. The front panel is painted battleship gray, and white "press-on" labels mark the function of the controls.

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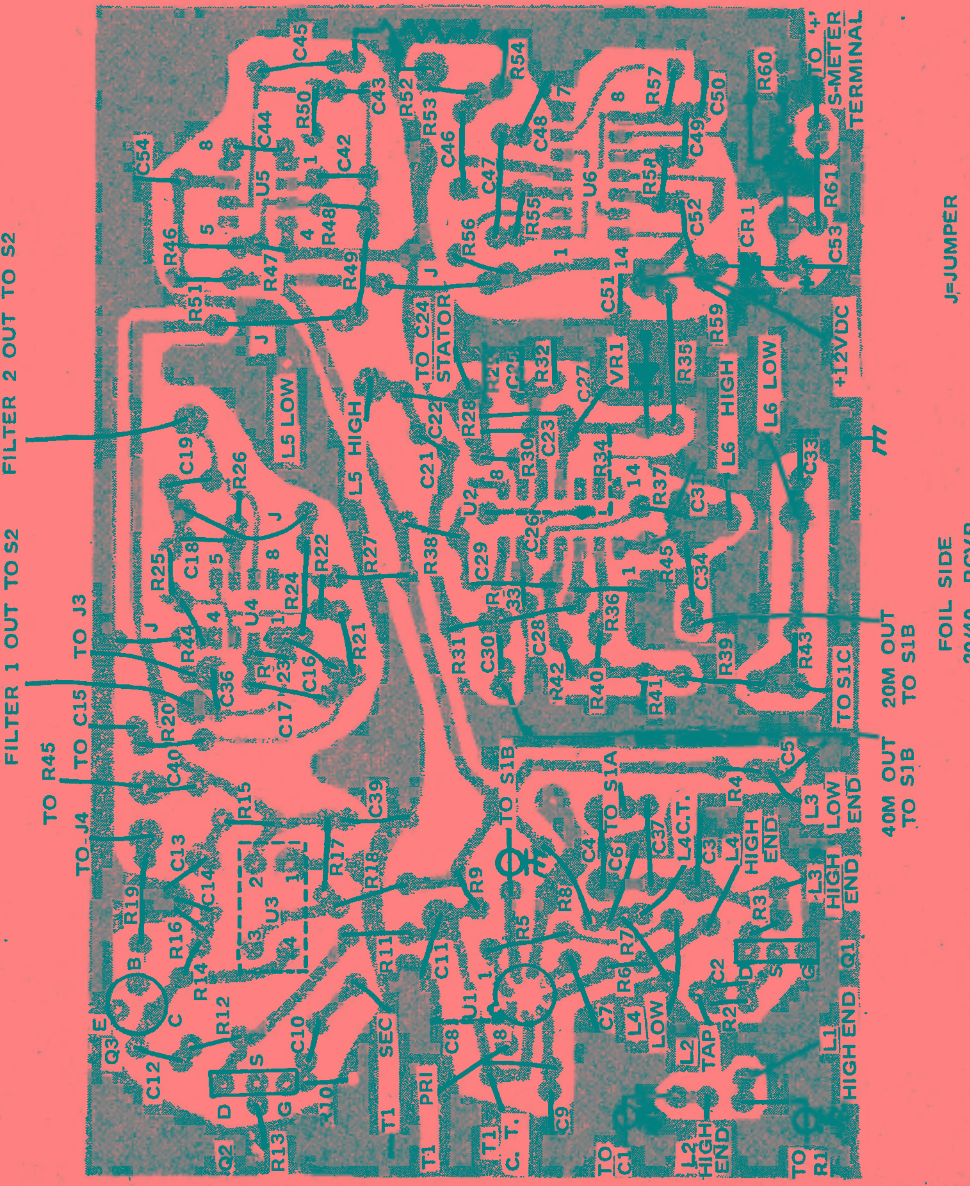
[1] Components plus a circuit board for the audio filter may be obtained from MFJ Enterprises, P.O. Box 494, Mississippi State, MS 39762

photo-etch process was used to produce the original board although it may be duplicated by other methods as long as sufficient care is taken in the vicinity of the IC pins and other high-density areas of the pattern to avoid the appearance of unwanted foil bridges. The prototype receiver was built on double-sided G-10 glass epoxy board, 1/16-inch thick. The circuit pattern is etched on the bottom of the board while the top is left as a continuous ground plane broken only where component leads project through the board. The ground plane is an aid to stability and interstage isolation. An easy technique for removing the ground plane around the component leads (after the bottom of the board has been drilled) is to use a large diameter drill (1/4-inch is satisfactory) and make a shallow hole in the top side of the board at every lead location. This may be done by hand, or very carefully with a drill press. The prototype receiver board was silver plated before component assembly, a step which while not required, makes soldering easier, and improves the appearance of the final product. Part of the key to building a compact receiver is the use of parts which are physically small. The use of small 50-volt disk ceramic capacitors can go a long way toward increasing packing density. Using miniature low-voltage electrolytic capacitors, toroidal inductors,

Fig. 4 — Parts placement and board layout for the receiver. R34, C8 and C26 are mounted on the foil side.



and 1/4-watt instead of 1/2-watt resistors where applicable will make construction much easier for the builder of portable equipment.

The placement of the front- and rear-panel-mounted parts is determined as much by symmetry as by the criterion of short leads. In the author's receiver, the S-meter, controls for af and rf gain, the band switch, input trimmer capacitor, selectivity switch, and the main tuning knob are located on the front panel. The rear panel includes banana jacks for the 12-volt dc input, phono jacks for sidetone and muting inputs from the transmitter, and a phone jack for headphones. For operating convenience, an SO-239 coax receptacle and a female phono jack wired in parallel were used as antenna connectors. The VFO tuning capacitor, C24, is mounted on an aluminum bracket from the front panel to achieve mechanical stability. The capacitor drive is a modified imported vernier dial. The original escutcheon, calibrated 0-100, was replaced with a homemade plastic dial. Fifty- and 25-kHz markers on the dial are made with thin black tape of the type usually used for printed-circuit artwork. The homemade U-shaped cabinet is spray painted with battleship gray enamel and white pressure-sensitive labels were added to identify the controls. The top cover is painted flat black. Professional-looking front-panel knobs complete the mechanical assembly.

Initial Adjustment

The local oscillator should be checked first for proper operation on 40 meters. With C24 almost fully meshed, L5 may be adjusted with a nonmetallic tool to set the output frequency to 7.000 MHz. A drop of melted wax will be sufficient to hold the slug in place. The frequency doubler portion of the local oscillator should be checked with an oscilloscope. L6 may be adjusted to provide the cleanest 14-MHz waveform. A signal generator and an oscilloscope may be used to verify that the audio channel is functioning. Assuming that parts tolerances were adhered to closely, the audio filter width and center frequency in both the broad and narrow positions should be comparable to the results mentioned above. With the aid of a signal generator or a weak on-the-air signal, the front-end response should be peaked first on 20 meters by adjusting C1 and C3, and then on 40 meters by adjusting C1 and C4. In actual operation, C1 is a front-panel control, and is tuned to the frequency band of interest. After C3 and C4 are set, it should not be necessary to repeak them. If the product detector is working correctly it should be possible to hook a pair of headphones to J1 or J2 and make these adjustments by ear. The S-meter zero and sensitivity controls can be adjusted according to operator preference.

A PORTABLE TRANSCEIVER FOR 144 MHz

Here's a vhf transceiver that's truly portable, is easy to build, and is capable of spanning many miles when used with a good antenna. It can be operated from its internal 12-volt flashlight-cell pack, from the cigar lighter of any 12-volt negative-ground car, or from an ac-operated 12-volt dc pack. The transmitter and the two-stage FET superregenerative receiver are assembled on etched circuit boards to simplify construction. The audio section is a prewired "import" – also on a circuit board. (From *QST*, August 1968.)

Receiver-Section Circuit

Two FETs are used in the simple receiver circuit of Fig. 3. A JFET (junction field-effect transistor), Q4, operates as a common-gate rf amplifier and offers a fair amount of detector isolation while providing a few decibels of gain. Its output is coupled to the detector, Q5, through C19, which is a "gimmick" capacitor. The latter consists of three turns of insulated hookup wire wrapped around the ground end of L8. The opposite end of the wire is soldered to the drain end of L7. A junction-type FET is used at Q4 to make it less subject to rf burnout than would be the case if an IGFET (insulated-gate FET) were used.

An IGFET is used as the detector, Q5. Since it is isolated from the antenna circuit there is little chance of its being harmed by strong rf fields.

Quench-frequency voltage is provided by R14 and C26 in the source lead of Q5. Feedback for the detector is between gate and source, making it

Fig. 1 — The 2-meter transceiver is housed in a legal-bond box. A homemade dial-calibration chart for the receiver is pasted on the inside of the lid. Two plastic cable clamps serve as holders for the two-section 1/4-wavelength whip antenna (inside lid) when the unit is not in use. The antenna is held together at the center by a homemade 1/4-inch diameter threaded coupling.

Fig. 2 — Top-chassis layout of the transceiver. The receiver section is at the left. Controls for regeneration and modulation are in the foreground near the center of the chassis. The audio module is at the lower right, and the transmitter board is near the panel, directly under the loudspeaker. The home-made heat sinks are visible at the left end of the audio board.

necessary to keep the source above rf ground by means of RFC4.

Af output from the detector is taken from the drain through a quench-frequency filter consisting of C24, C25, RFC5 and C27. The filter prevents the quench voltage from reaching the audio amplifier. L9 isolates the af signal from the B-plus line, and R15 varies the drain-supply voltage to control superregeneration. R16 is the af gain control.

A word of caution at this point: When soldering the IGFET, Q5, into the circuit, be sure to connect a clip lead between the tip of the soldering iron and a good earth ground. This will help prevent damage to the gate of the 3N128 should static charges be present. Also, *do not handle* the leads of Q5. The leads should be removed from their shorting collar by means of a non-plastic or nonmetallic tool. A wooden toothpick is recommended for this, and for spreading the leads apart. Once Q5 is soldered in place, it should be quite safe from static-charge damage.

Transmitter Circuit

Referring again to Fig. 3, the transmitter section starts out with a Colpitts oscillator, Q1, which uses 72-MHz overtone crystals. C1 and the internal base-emitter capacitance of Q1 control the feedback. RFC1 keeps the emitter above rf ground. Bandpass coupling is used between Q1 and Q2 to reduce harmonics in the driving signal to Q2. A capacitive divider, C5 and C6, is used to match the collector of Q1 to the low base impedance of Q2. The high value of capacitance between the base of Q2 (C6) and ground helps to further reduce harmonic energy in that part of the circuit. Both Q1 and Q2 are low-cost Motorola transistors designed for amplifier or oscillator use at frequencies up to 500 MHz. They have a beta spread of 20 to 200, and have a collector-dissipation rating of 500 milliwatts. Other transistors can be substituted provided they have similar specifications. Resistors R5 and R6 establish Class A bias for Q2, making it easier to drive with the low output of Q1.

An RCA 2N3512 is used in the power amplifier, Q3. It was selected because of its low cost ($1.08) and high maximum dissipation rating of 4 watts. It is designed for high-speed switching applications and has an f_T of 375 MHz. Its h_{FE} rating is approximately 10. The low h_{FE} makes it easier to stabilize than would be the case if a high-beta transistor were used. Other transistors can also be used at Q3; a 40290, an HEP-75, and a 2N3553 were tried and performed as well as the 2N3512, but are more costly. To assure good heat dissipation at Q3, a heat sink is clipped to the transistor body. A Wakefield Engineering NF205 costs 27 cents and is ideal.

A capacitive divider, C10 and C11, matches the output of Q2 to the base of Q3. C10 tunes L3 to resonance. Forward bias is used on the base of Q3 to establish Class AB conditions. This provided greater output from Q3 than resulted with Class-C operation, as is usually the case when the driver stage has low output. The collector tank of Q3 is a combination *L* and pi network. The *L* network, C12 and L4, matches the load to the collector. The pi network is used for harmonic reduction, a necessary provision when clean output is desired from transistorized transmitters. C12 tunes the PA tank to resonance; C15 serves as a loading control.

In order to assure suitable stability, the power leads of the stages are decoupled by means of C3, C9 and C14 in combination with R4, R8 and R11. The three resistors also serve as current-limiting devices to protect Q1, Q2 and Q3.

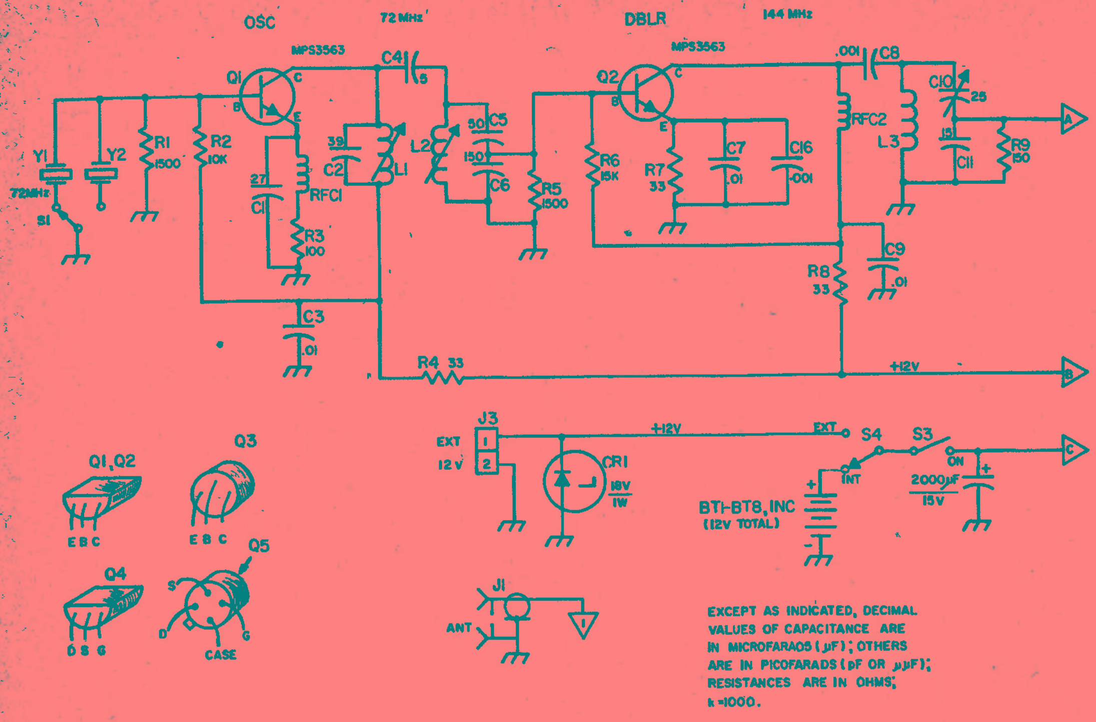


Fig. 3 — Schematic of the 2-meter transceiver. Fixed-value capacitors are disk ceramic axcept those with polarity marking, which ara electrolytic. Resistors are 1/2-watt composition. Component numbering is for identification of parts on the circuit-board templates. Significant parts are listed below in the usual manner.

AR1 — 200-milliwatt audio module (Round Hill Associates Model AA-100*).

BT1-BT8, incl. — Eight 1.5-volt size-D flashlight cells, series-connected and mounted inside box by means of four Keystone No. 176 dual-bettery clips.

C10, C12 — 5- to 25-pF ceramic trimmer (Erie 822-CN or equiv). (Midget 3- to 30-pF mica trimmer also suitable.)

C15 — 8- to 50-pF ceramic trimmer (Eria 822-AN or equiv). (Midget 8- to 60-pF mica trimmer also suiteble.)

C19 — Gimmick-type capacitor. See text.

C20 — 15-pF subminiature variable (E. F. Johnson 160-107).

C22 — 5-pF min. variable (Hammarlund MAPC-15B, all but one rotor and one stator plate removed).

CR1 — 18-volt 1-watt Zener diode (used for trensient protection during mobile operation).

J1 — SO-239 coax fitting (chassis mount).

J2, J3 — Two-terminal single-contact audio connector (Amphenol 75PC1M or similar).

L1, L2 — 3 turns No. 22 enam. wire spaced to occupy 1/2 inch on 1/4-inch dia ceramic slug-tuned form (J. W. Millar 4500-4*).

L3 — 4 turns No. 20 bare wire, 1/2 inch long, 5/16 inch ID.

L4 — 6 turns No. 20 bare wire, 1/2 inch long 5/16 inch ID.

L5 — Same as L3.

L6 — 8 turns No. 20 bare wire, 1 inch long, 5/16 inch ID. Tap 5 turns from source lead of Q4.

L7 — 5 turns No. 22 enam. wire, close-wound on 1/4-inch dia ceramic slug-tuned form (J. W. Miller 45005).

L8 — 4 turns No. 10 bare copper wire, 1 inch long, 3/8-inch ID. (The tap shown is not a physical one; see text discussion of C19.)

L9 — Totel primary winding of 500-ohm ct transistor output transformer. The 8-ohm secondary winding not used. (Argonne AR-164 or similar.)

R15-R17, incl. — 100,000-ohm audio-taper carbon control.

RFC1 — Miniature 50-µH choke (Millen 34300-50*).

RFC2-RFC4, incl. — Miniature 2.7-µH rf choke (Millen 34300-2.7).

RFC5 — Subminiature 10-mH rf choke (J. W. Miller 73F102AF).

S1, S4 — Spdt slide switch.

S2 — 4-pole 2-position phenolic single-section rotary wafer switch. (Mallory 3142J.)

S3 — Spst slide switch.

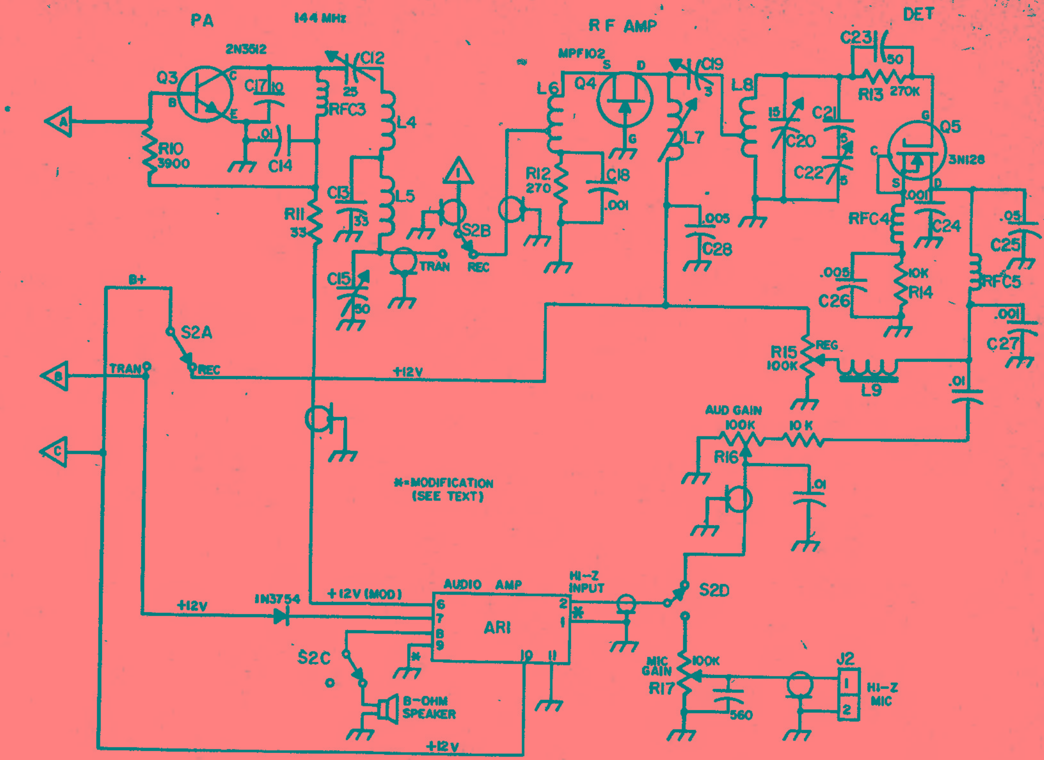
Y1, Y2 — 72-MHz overtone crystal (International Crystal Co. in HC-6/U holder*).

* Round Hill Assoc., Inc., 434 Sixth Ave., NY, NY 10011.

* J. W. Miller Co., 19070 Reyes Ave., Compton, CA 90221.

* International Crystal Co., 10 N. Lee St., Oklahoma City, OK 73102.

* James Millen Mfg. Co., 150 Exchange St., Malden, MA 02148.



The Audio Section

The audio channel, AR1, can be purchased for approximately $8.00. It has a 200-milliwatt output rating at 9 volts, but by increasing the operating voltage to 12, and adding heat sinks to the two output transistors, slightly more than 300 milliwatts of output are available. This was done in the circuit of Fig. 10

AR1 has two input impedances – 50 ohms and 100,000 ohms. Two output impedances are available, providing a 500-ohm transformer winding for modulator service, and an 8-ohm winding for driving a loudspeaker. The high-impedance input connects to the microphone gain control, R17, during transmit, and is switched to the receiver gain control, R16, during receive. The 50-ohm tap is not used.

Because the module is designed for a positive-ground bus (pnp transistors are used), it is necessary to "float" the entire assembly above chassis ground to prevent short-circuiting the

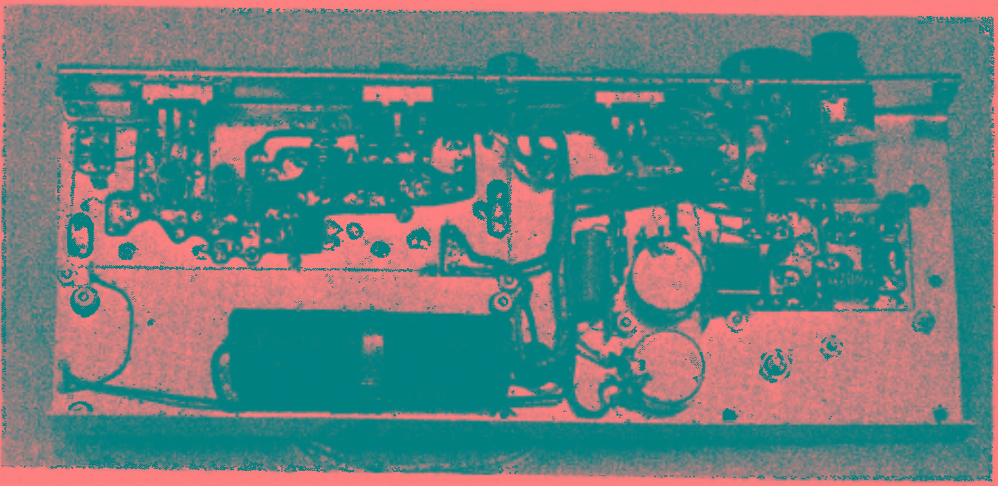


Fig. 4 – Bottom view of the chassis. The receiver board is at the right. The transmitter board is at the upper left. A 2000-μF 15-volt electrolytic is mounted near the rear lip of the chassis.

Fig. 5 – Details of the homemade heat sinks for AR1.

power supply. Information on the mounting techniques and some modifications to the board are given later.

Building the Transceiver

The packaging of this circuit can be up to the builder. In this instance a standard legal-bond box was chosen. It measures 5 X 6 X 11 1/2 inches.

The chassis and panel are made from 16-gauge aluminum sheeting. An aluminum cookie tin from a hardware store can be the source of the panel and chassis stock. Many are made of heavy-gauge material and are large enough to assure that there will be excess stock. The chassis measures 11 1/4 X 4 X 1 inch. The panel is 11 1/4 inches by 4 3/4 inches. After the panel holes are drilled, a coating of zinc chromate should be sprayed on it. Then, after thorough drying, a coat of spray-can enamel or lacquer can be added for the final touch. The zinc chromate helps the finish coat of paint adhere to the aluminum sheeting.

The receiver and transmitter are built on etched circuit boards, but point-to-point wiring could be used if done neatly and with short connections. Etched-circuit templates are available from the ARRL if desired.[1] They are to scale and show where the various parts are mounted.

AR1 is insulated from the main chassis to prevent short-circuiting the power supply. It has a plus-ground bus; the rest of the transceiver circuit uses a negative ground. A piece of cardboard is mounted between the circuit board and the chassis to prevent accidental contact between AR1 and the chassis. AR1 is bolted to the chassis at four points. The four mounting holes in the main chassis contain small rubber grommets, each serving as an insulator. Terminals 1 and 9 of the audio board are common to its plus-ground bus. These terminals must be disconnected from the ground bus by removing the thin copper connecting strip which joins the circuits. A pocket knife works nicely for this job; the copper can then be peeled off.

To operate AR1 at 12 volts it is necessary to add heat sinks to the two transistors nearest the output transformer. The sinks can be fashioned from pieces of thin brass, copper, or aluminum. They are 1 1/2 inches long and each is formed by warping the stock around a drill bit which is slightly smaller in diameter than the body of the transistor.

All interconnecting rf leads are made with subminiature coax cable, RG-174/U (Belden 8216). Shielded audio cable should be used for all af wiring which is more than a couple of inches in length. A bargain-house import is used for the receiver tuning dial. No slippage was noted with the 2-inch-diameter model used here. The next smaller model is not recommended because it will not handle the torque of the tuning capacitor.

A 2 1/2-inch-diameter loudspeaker is used. Its protective grille can be made from perforated aluminum.

Two 3-inch-long brass angle brackets, each with 3/4-inch sides, are used as mounts for the panel-chassis assembly inside the box. Two 6-32 nuts are soldered to the bottom side of each bracket, directly under No. 10 access holes. Four 6-32 X 3/8-inch screws hold the transceiver in place. The brackets are attached to the sides of the box with 4-40 hardware.

Tune-Up and Use

The receiver should be tested first. With an antenna connected to J1, apply operating voltage and adjust R15 until a rushing noise is heard in the speaker. Do not advance R15 beyond this point as the sensitivity of the receiver will decrease. Next, tune in a weak signal from another ham station (or

Fig. 6 – Eight size D cells are series connected to provide 12 volts. They are mounted in Keystone holders on the back wall of the bond box. The 1/4-inch diameter hole in the front of the cabinet (upper right of photo) permits final calibration of the raceiver (C20) after the installation is completed. The hole is opposite the shaft of C20.

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[1] Scale circuit-board templates and parts placement guide are available from ARRL for 25 cents and an s.a.s.e. Ready-made boards are often available commercially. For a list of suppliers, send ARRL an s.a.s.e.

from a signal generator) and tune L7 for a peak response. Chances are that when the peak is reached, the detector will stop oscillating. If this happens, advance R15 until the hiss returns. If it does not, detune L7 slightly until a compromise is reached (L7 usually loads the detector somewhat when it is tuned to the operating frequency). Alternatively, a 1000-ohm swamping resistor can be connected across L7 to reduce its effect on the detector. Trimmer C20 is used to set the tuning range of C22. The turns of L8 can be spread or compressed for additional frequency adjustment. The receiver should tune the entire 4-MHz of the 2-meter band, or nearly so.

A No. 49 pilot lamp makes a suitable dummy load for visual tune-up of the transmitter, though somewhat reactive at 144 MHz. First, determine that the oscillator, Q1, is operating by coupling a wavemeter (or grid-dip meter in the diode-detector position) to L1 and look for an indication of output. Adjust the slug in L1 for maximum output, then turn the transmitter on and off a few times to make sure the crystal always kicks in. If not, detune L1 slightly toward the high-frequency side of resonance until the oscillator does start each time. Next, peak L2, C10, C12 and C15 for maximum indication on the bulb. There will be some interaction between the circuits, so the foregoing steps should be repeated a few times to assure maximum output. Final adjustments should be made with the antenna connected, and with an SWR indicator in the line.[2]

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[2] A highly sensitive SWR indicator is needed at this power level. One of the Monimatch indicators with a 4-inch or longer line (air-dielectric element type) can provide full-scale readings if a 100-μA meter is installed. Alternatively, see *QST* August, 1967 for a low-power bridge. Also, see the "Monimatch Mark II," *QST*, February, 1957.

A SOLID STATE RECEIVER FOR PORTABLE USE

This design is based on the series Learning to Work With Semiconductors in April through September *QST*, 1974. The model shown here uses printed-circuit construction and slight alteration of components in the rf and mixer stages. Converters for the higher bands are also featured.

Circuitry

Toroids are used at the inputs of both the rf and mixer stages of the main receiver. Alignment and tracking problems are eliminated by winding an equal number of turns on L2 and L3 and using a dual capacitor (variable) with the same maximum capacitance in each section. The Miller unit specified here has sections of 170 pF and 365 pF. Plates must be removed from the 365 pF section to bring it down to 170 pF. Actually any dual capacitor above 100 pF will suffice as long as each section has approximately the same value. Be sure leads to C1A and C1B are kept short and at right angles to each other to prevent unwanted coupling. If instability becomes a problem, the gain of Q1 should be reduced by lowering the bias voltage on gate 2.

In the original design, a single-gate FET was used for the mixer. Unfortunately, pulling of the VFO on strong signals was experienced. A dual-gate MOSFET is used here; isolation between gates 1 and 2 is 40 dB.

The output of the mixer is fed to a Miller crystal filter/i-f transformer. At the cost of reduced selectivity, the yellow core i-f transformer used for the BFO circuit could be directly substituted.

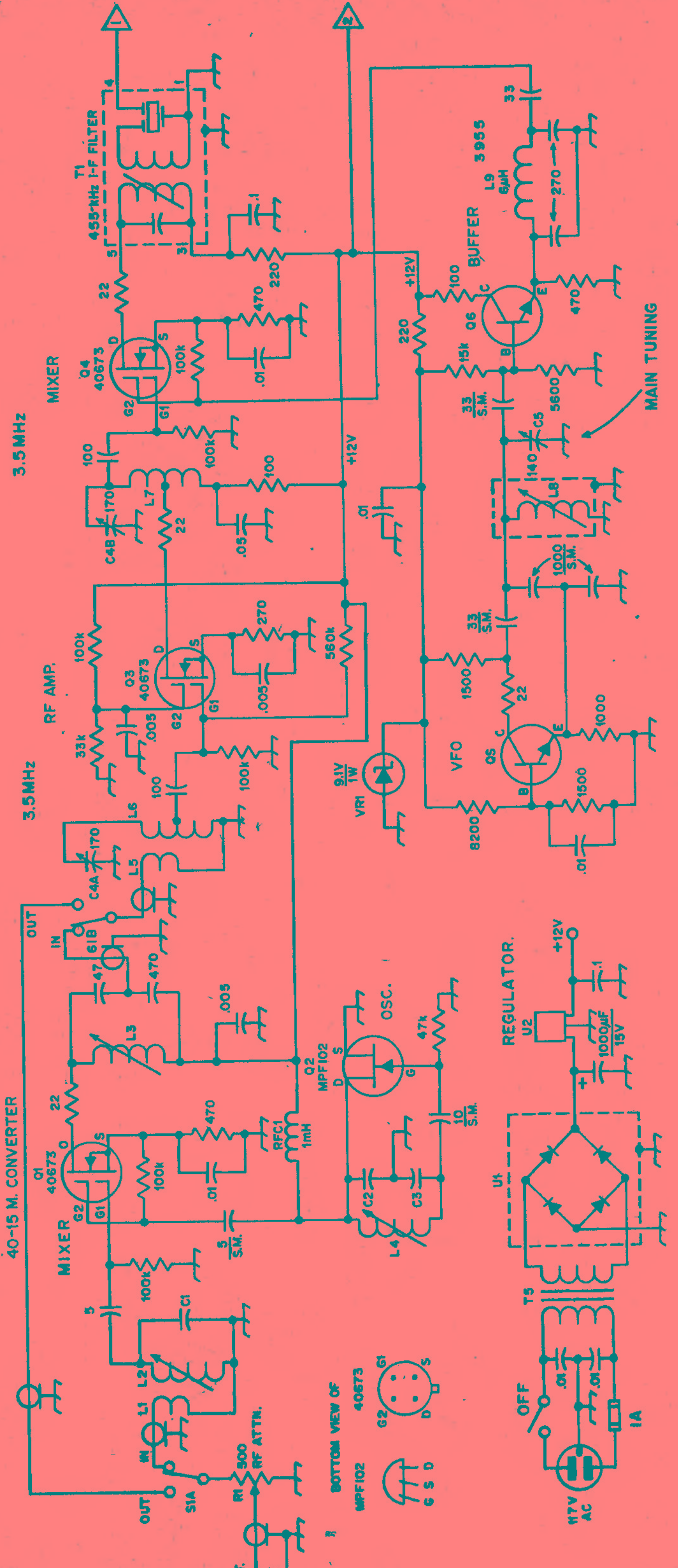
The VFO should tune from 3950 kHz to 4455 kHz which corresponds to a receive frequency of 3500 kHz to 4000 kHz with an i-f of 455 kHz. To assure undistorted output from the VFO, the dc collector voltage should be one half of the supply voltage (6 volts). Some adjustment of the 8200-ohm resistor at the base of Q4 may be required.

The BFO circuit was selected because it lends itself to an inexpensive i-f transformer for the tuning coil. Be sure to wire the coil as shown here (exactly the opposite as done in the *QST* version), otherwise the windings will be out of phase and the unit will not oscillate. The coupling capacitor in the output of the BFO should not be larger than 68 pF. In some cases this value may have to be reduced to provide stable operation.

The audio amplifier is capable of a voltage gain of 100 which should easily drive a high-impedance headset. The 100-μF capacitor and 100-ohm resistor in the B+ line form a decoupling network to prevent audio feedback to the detector (motorboating and howl).

Converter Section

The converter circuit for covering the higher amateur bands is simple yet effective. The oscillator coil (L5) should be adjusted to the frequency specified in the Table (listening for the note on a general-coverage receiver). The input and output coils are adjusted for maximum gain on a signal heard at the middle of the band. On 40 meters receiver tuning is backwards. On the dial, 7 MHz will read 4 MHz and 7.5 MHz will read 3.5 MHz. The other bands will tune normally (the lower end is at 3.5 MHz).


T1 455-kHz I-F FILTER
MIXER
Q4 40673
3.5 MHz
RF AMP.
Q3 40673
3.5 MHz
40-15 M. CONVERTER
MIXER
Q1 40673
Q2 MPF102
OSC.
RFC1 1mH
VFO
Q5
BUFFER
Q6
L9 6µH
3955
MAIN TUNING
C5
L8
L7
L6
L5
L4
L3
L2
L1
C1
C2
C3
C4A
C4B
S1A
S1B
IN
OUT
J1 ANT.
R1 500 RF ATTN.
VR1 9.1V 1W
+12V
REGULATOR
U2
U1
T5
117V AC
OFF
1A
1000µF 15V
BOTTOM VIEW OF
MPF102
40673
G S D
G2 G1 D S
33 S.M.
1000 S.M.
10 S.M.
5 S.M.
560k
100k
33k
15k
47k
5600
8200
1500
220
470
270
100
22
.005
.01
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.1
140
170
47

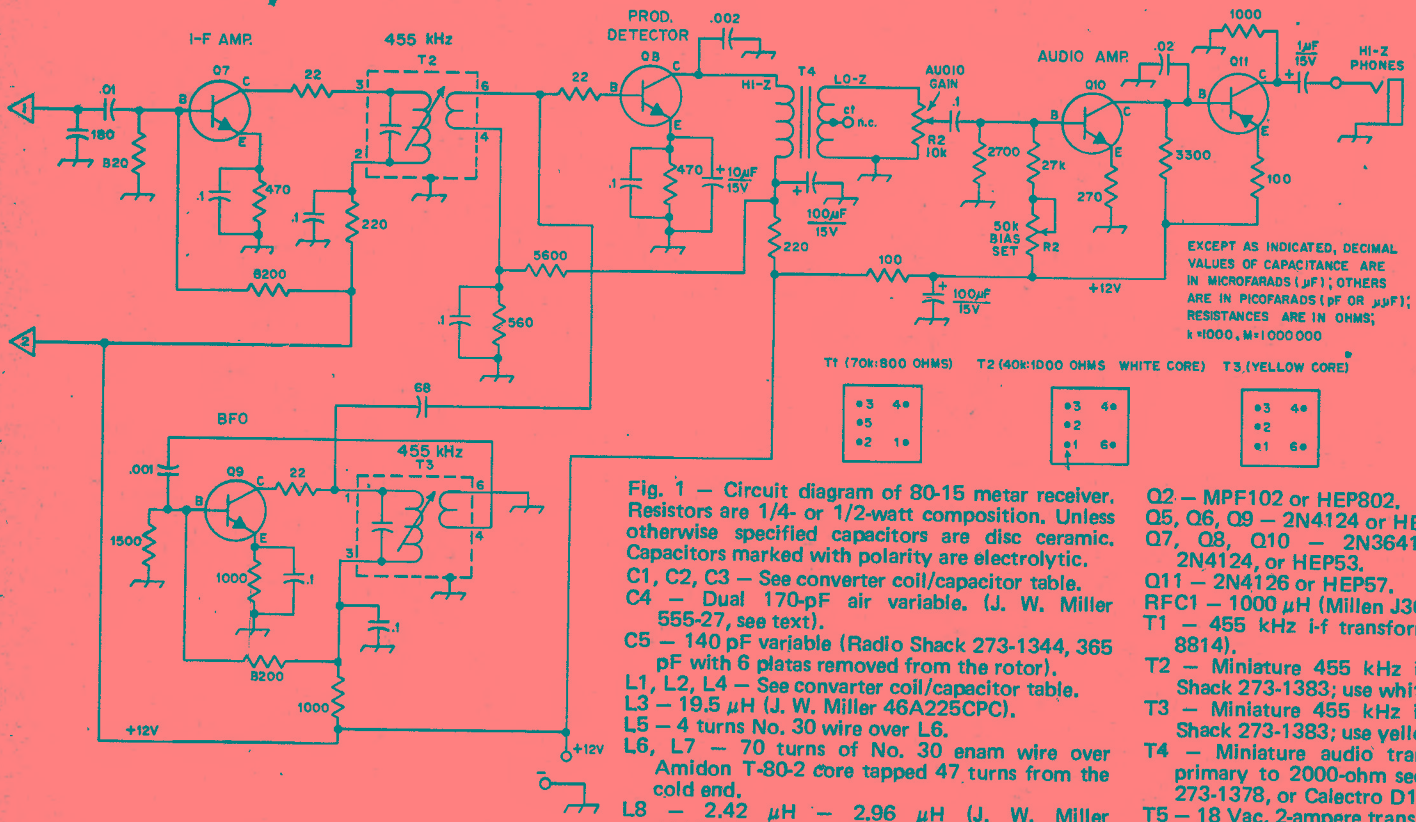


Fig. 1 — Circuit diagram of 80-15 meter receiver. Resistors are 1/4- or 1/2-watt composition. Unless otherwise specified capacitors are disc ceramic. Capacitors marked with polarity are electrolytic.

C1, C2, C3 — See converter coil/capacitor table.
C4 — Dual 170-pF air variable. (J. W. Miller 555-27, see text).
C5 — 140 pF variable (Radio Shack 273-1344, 365 pF with 6 plates removed from the rotor).
L1, L2, L4 — See converter coil/capacitor table.
L3 — 19.5 µH (J. W. Miller 46A225CPC).
L5 — 4 turns No. 30 wire over L6.
L6, L7 — 70 turns of No. 30 enam wire over Amidon T-80-2 core tapped 47 turns from the cold end.
L8 — 2.42 µH – 2.96 µH (J. W. Miller 46A276CPC).
L9 — 6 µH; 48 turns No. 30 enam. wire close-wound on 1/4-inch dia. form. Wooden or polystyrene rod suitable for form.
Q1, Q3, Q4 — 40673 RCA dual-gate MOSFET.
Q2 — MPF102 or HEP802.
Q5, Q6, Q9 — 2N4124 or HEP53.
Q7, Q8, Q10 — 2N3641, HEP736, 2N2222, 2N4124, or HEP53.
Q11 — 2N4126 or HEP57.
RFC1 — 1000 µH (Millen J302-1000).
T1 — 455 kHz i-f transformer/filter (J.W. Miller 8814).
T2 — Miniature 455 kHz i-f transformer (Radio Shack 273-1383; use white core).
T3 — Miniature 455 kHz i-f transformer (Radio Shack 273-1383; use yellow core).
T4 — Miniature audio transformer 10,000-ohm primary to 2000-ohm secondary (Radio Shack 273-1378, or Calectro D1-711).
T5 — 18 Vac, 2-ampere transformer (Poly Paks).
U1 — 50 PRV rectifier bridge.
U2 — Voltage regulator (National Semiconductor LM3407-12 or Motorola MC7812CP).

Top view of the basic receiver. The power supply is shown at the lower right. One of the converter boards is mounted at the top left.

Construction

Five circuit boards are used allowing the builder to test each one separately if desired. This method also permits the builder to easily modify or redo a portion of the circuit. The VFO board is enclosed on all four sides by soldering pc material to its edges. The entire assembly is then fastened to the main chassis with spade bolts. The tuning dial consists of an inexpensive vernier drive with the 9-100 faceplate removed. It is replaced by a plastic dial which has 25-kHz increments.

Alignment and Use

Fully mesh the VFO capacitor plates and tune L4 until a note is heard at 3950 kHz on *another* receiver. This sets the VFO 455 kHz *above* the receiver tuned frequency. Then connect an antenna and tune the i-f and BFO coils for maximum noise in the headphones. Do likewise with the audio bias adjustment. Tune in a signal and peak the preselector control on the front panel. The BFO coil in conjunction with the main tuning dial should be set for best reception of ssb or cw signals. The rf attenuator control should be used to reduce the receiver gain to prevent distortion and overloading by very strong signals.

Converter Coil and Capacitor Table

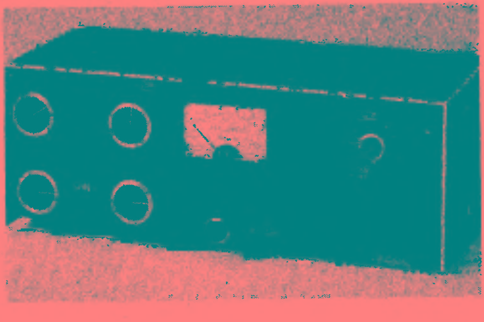
Band	*L1*	*L2*	*C1*	*L4*	*C2*	*C3*	*Oscillator Frequency*
40 Meters	7 turns over 12	13.2 µH-16.5 µH Miller 46A155 CPC	25 pF	2.42 µH-2.96 µH Miller 46A276CPC	220 pF	150 pF	11 MHz
20 Meters	3 turns over L2	6.1 µH-7.5 µH Miller 46A686CPC	15 pF	2.42 µH-2.96 µH Miller 46A276CPC	220 pF	150 pF	10.5 MHz
15 Meters	3 turns over L2	3.5 µH-4.27 µH Miller 46A396CPC	10 pF	1.42 µH-1.58 µH Miller 46A156CPC	100 pF	100 pF	7.5 MHz

A TRANSMATCH FOR QRP RIGS

This equipment permits matching low-power (five watts) transmitters to a wide range of impedances encountered when using random-length, single-wire antennas of the type common to portable and emergency operation. The unit will also match the transmitter to any coax line regardless of the mismatch reflected from the antenna to the feed end of the line.

Construction

The use of separate capacitors at C1 and C2, Fig. 1, requires slightly more manipulation during tune-up than would be the case with ganged capacitors, but once ball-park settings are found



Exterior view of the QRP Transmatch. The cabinet is homemade from solid sheet and perforated aluminum stock. The two controls at the far left are 365-pF variables, es is the one at the lower left of the Simpson meter. At the upper left of the meter is the varieble-inductence control. Directly under the meter is the meter-sensitivity potentiometer. The bridge function switch is visible at the upper right of the panel. Kurz-Kasch aluminum knobs are used on the controls.

Interior view of the Transmatch. The three variabla capacitors are grouped at the right. Note that two of them are mounted on insulating board. Just to the right of the meter one can see the inductance switch on which three toroids and one air-wound coil are mounted. The resistance bridge and function switch are located at the far left of the chassis.

for each operating band it is a simple matter to log them for future use. C2 and C3 must be mounted so that their rotor and stator sections are above chassis ground. This is accomplished easily by assembling them on a small piece of phenolic insulating board and using insulating shaft couplers (Allied Electronics No. 920-0120).

Three small toroidal inductors and one air-wound coil comprise the variable-inductor leg of the circuit, L1-L4, inclusive, and S2. With the constants specified for the circuit of Fig. 1 the tuner will give good performance from 80 through 10 meters. S2 is a low-cost imported component.

M1 can be any 1-mA instrument. A Simpson No. 2121 is shown in the photos, but may be a trifle too dear in terms of cost for those wishing to do the job at minimum investment. Many imported meters (Radio Shack No. 22-018 for one) can be purchased at a fraction of the cost common to high-quality American made instruments.

S1, in the unit pictured, is a double-pole, four-position, two-section ceramic wafer switch of the subminiature species. A piece of double-clad pc board is visible between the wafer sections. It was added to function as an rf shield between the two sections of S1, thereby helping to isolate the input and output ports of the resistance bridge. Any shorting-type double-pole, three-position switch should be suitable, ceramic or phenolic insulation. S1 and S2 are the shorting variety, thus preventing momentary no-load conditions from being seen by the transmitter. The package dimensions are 7-1/2 × 2-3/4 × 2-3/4 inches (18 × 6-1/2 × 6-1/2 cm). A cover was made from a section of surplus perforated-aluminum stock. Solid aluminum stock would be just as good. In fact, the entire enclosure could be constructed from galvanized furnace ducting, often available in scrap sizes from furnace repair shops. Rf shielding is not imperative when building housings for Transmatches.

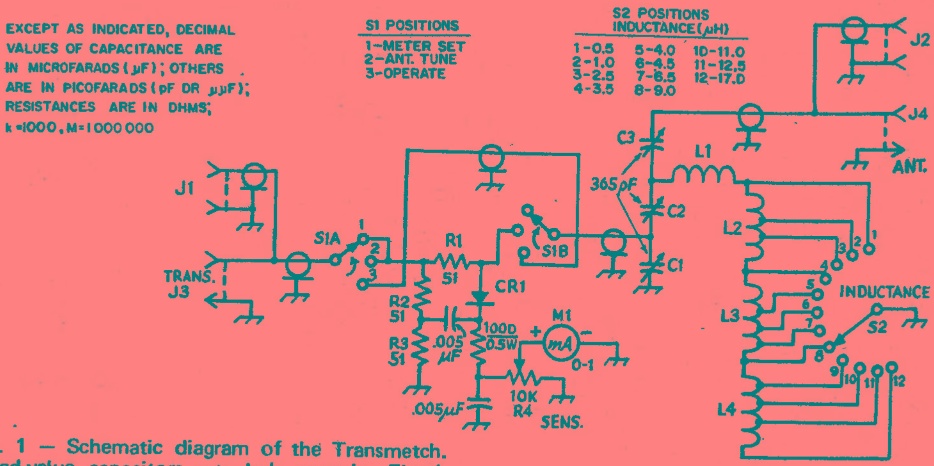


Fig. 1 — Schematic diagram of the Transmetch. Fixed-value capacitors are desk ceramic. Fixed-value resistors are composition types.

C1-C3, incl. — Miniature 365-pF variable (Archer/Radio Shack No. 272-1341 or equiv.).

CR1 — High-speed silicon diode, 1N914 or equiv.

J1, J2 — Phono connector, single-hole chassis mount.

J3, J4 — SO-239 style coax connector.

L1 — 15 turns No. 24 enam. wire, close-wound on 1/4-inch ID form. Remove form after winding.

L2 — 28 turns No. 24 enam. wire on Amidon T-50-6 toroid core. Tap 7 turns from eech end.

L3 — 27 turns No. 24 enam. wire on Amidon T-50-2 toroid cora. Tap at 5, 10 and 15 turns from L2 and.

L4 — 26 turns No. 24 enam. wire on Amidon T-68-2 toroid core. Tap at 6, 12 and 18 turns from L3 and.

M1 — 0- to 1-mA dc meter, 1-1/2 inches square. See text.

R1-R3, incl. — 51-ohm, 2-watt, 5-percent tolerance.

R4 — Miniature 10,000-ohm control, audio or linear taper suitable.

S1 — Two-pole, three-position, shorting-type rotary wafer switch. See text.

S2 — Single-pole, 12-position, rotary wafer switch, shorting type (Radio Shack No. 277-1385 or Calectro No. E-2-162).

Code Transmission

Keying a transmitter properly involves much more than merely turning it on and off with a fast manually operated switch (the key). If the output is permitted to go from zero to full instantaneously (zero "rise" time), side frequencies, or key clicks, will be generated for many kilohertz either side of the transmitter frequency, at the instant the key is closed. Similarly, if the output drops from full to zero instantaneously (zero "decay" time), side frequencies will be generated at the instant of opening the key. The amplitude of the side-frequency energy decreases with the frequency separation from the transmitter frequency. To avoid key clicks and thus to comply with the FCC regulations covering spurious radiations, the transmitter output must be "shaped" to provide finite rise and decay times for the envelope. The longer the rise and decay times, the less will be the side-frequency energy and extent.

Since the FCC regulations require that ". . . the frequency of the emitted wave shall be as constant as the state of the art permits," there should be no appreciable change in the transmitter frequency while energy is being radiated. A *slow* change in frequency is called a frequency drift; it is usually the result of thermal effects on the oscillator. A *fast* frequency change, observable during each *dit* or *dah* of the transmission, is called a chirp. Chirp is usually caused by a nonconstant load on the oscillator or by dc voltage changes on the oscillator during the keying cycle. Chirp may or may not be accompanied by drift.

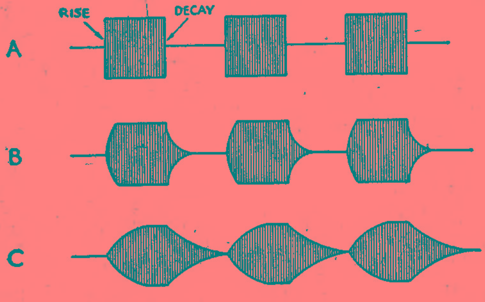


Fig. 11-1 — Typical oscilloscope displays of a code transmitter. The rectangular-shaped dots or dashes (A) have serious key clicks extending many kHz either side of the transmitter frequency. Using proper shaping circuits increases the rise and decay times to give signals with the envelope form of B. This signal would have practically no key clicks. Carrying the shaping process too far, as in C, results in a signal that is too "soft" and is not quite as easy to copy as B.

Oscilloscope displays of this type are obtained by coupling the transmitter rf to the vertical plates and using a slow sweep speed synchronized to the dot speed of an automatic key.

If the transmitter output is not reduced to zero when the key is up, a backwave (sometimes called a "spacing wave") will be radiated. A backwave is objectionable to the receiving operator if it is readily apparent; it makes the signal slightly harder to copy. However, a slight backwave, 40 dB or more below the key-down signal, will be discernible only when the signal-to-noise ratio is quite high. Some operators listening in the shack to their own signals and hearing a backwave think that the backwave can be heard on the air. It isn't necessarily so, and the best way to check is with an amateur a mile or so away. If he doesn't find the backwave objectionable on the S9+ signal, you can be sure that it won't be when the signal is weaker.

When any circuit carrying dc or ac is closed or opened, the small or large spark (depending upon the voltage and current) generates rf during the instant of make or break. This rf click covers a frequency range of many megahertz. When a transmitter is keyed, the spark at the key (and relay, if one is used) causes a click in the receiver. *This click has no effect on the transmitted signal.* Since it occurs at the same time that a click (if any) appears on the transmitter output, it must be eliminated if one is to listen critically to his own signal within the shack. A small rf filter is required at the contacts of the key (and relay); typical circuits and values are shown in Fig. 11-2. To check the effectiveness of the rf filter, listen on a band lower in frequency than the one the transmitter is tuned to, with a short receiving antenna and the receiver gain backed off.

What Transmitter Stage To Key

A satisfactory code signal, free from chirp and key clicks, can be amplified by a *linear* amplifier without affecting the keying characteristics in any way. If, however, the satisfactory signal is amplified by one or more nonlinear stages (e.g., a Class C multiplier or amplifier), the signal envelope will be modified. The rise and decay times will be decreased, possibly introducing significant key clicks that were not present on the signal before amplification. It is possible to compensate for the effect by using longer-than-normal rise and decay times in the excitation and letting the amplifier(s) modify the signal to an acceptable one.

Many two-, three- and even four-stage VFO-controlled transmitters are incapable of chirp-free output-amplifier keying because keying the output stage has an effect on the oscillator frequency and "pulls" it. Keying the amplifier presents a variable load to its driver stage, which in turn is felt as a variable load on the previous stage, and so on back

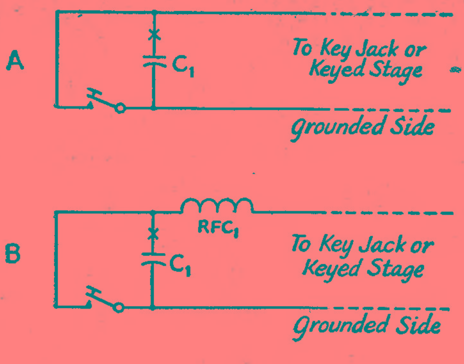


Fig. 11-2 — Typical filter circuits to apply at the key (and relay, if used) to minimize rf clicks. The simplest circuit (A) is a small capacitor mounted at the key. If this proves insufficient, an rf choke can be added to the ungrounded lead (B). The value of C1 is .001 to .01 μF; RFC1 can be 0.5 to 2.5 mH, with a current-carrying ability sufficient for the current in the keyed circuit. In difficult cases another small capacitor may be required on the other side of the rf choke. In all cases the rf filter should be mounted right at the key or relay terminals; sometimes the filter can be concealed under the key. When cathode or center-tap keying is used, the resistance of the rf choke or chokes will add cathode bias to the keyed stage, and in this case a high-current low-resistance choke may be required, or compensating reduction of the grid-leak bias (if it is used) may be needed. Shielded wire or coaxial cable makes a good keying lead.

A visible spark on "make" can often be reduced by the addition of a small (10 to 100 ohms) resistor in series with C1 (inserted at point "x"). Too high a value of resistance reduces the arc-suppressing effect on "break."

to the oscillator. Chances of pulling are especially high when the oscillator is on the same frequency as the keyed output stage, but frequency multiplication is no guarantee against pulling. Another source of reaction is the variation in oscillator supply voltage under keying conditions, but this can usually be handled by stabilizing the oscillator supply with a VR tube. If the objective is a completely chirp-free transmitter, the first step is to make sure that keying the amplifier stage (or stages) has no effect on the frequency. This can be checked by listening on the oscillator frequency while the amplifier stage is keyed. Listen for chirp on either side of zero beat, to eliminate the possibility of a chirpy receiver (caused by line-voltage changes or BFO pulling).

An amplifier can be keyed by any method that reduces the output to zero. Neutralized stages can be keyed in the cathode circuit, although where powers over 50 or 75 watts are involved it is often desirable to use a keying relay or vacuum tube keyer, to minimize the chances for electrical shock. Tube keying drops the supply voltages and adds cathode bias, points to be considered where maximum output is required. Blocked-grid keying is applicable to many neutralized stages, but it presents problems in high-powered amplifiers and requires a source of negative voltage. Output stages that aren't neutralized, such as many of the tetrodes and pentodes in widespread use, will usually leak a little and show some backwave regardless of how they are keyed. In a case like this it may be necessary to key two stages to eliminate backwave. They can be keyed in the cathodes, with blocked-grid keying, or in the screens. When screen keying is used, it is not always sufficient to reduce the screen voltage to zero; it may have to be taken to some negative value to bring the key-up plate current to zero, unless fixed negative control-grid bias is used. It should be apparent that where two stages are keyed, keying the earlier stage must have no effect on the oscillator frequency if completely chirp-free output is the goal.

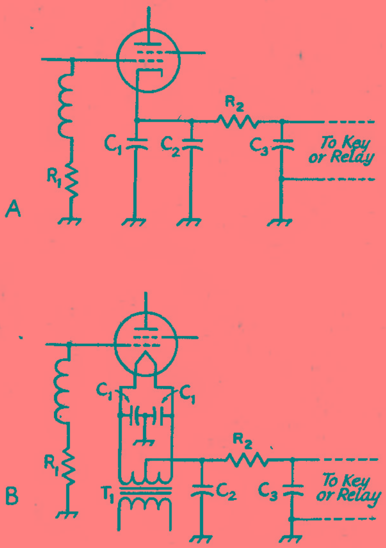


Fig. 11-3 — The besic cathode (A) and center-tap (B) keying circuits. In either case C1 is the rf return to ground, shunted by a larger capacitor, C2, for shaping. Voltage ratings at least equal to the cutoff voltage of the tube are required. T1 is the normal filament transformer. C1 and C3 can be about .01 μF.

The shaping of the signal is controlled by the values of R2 and C2. Increased capacitance at C2 will make the signal softer on break; increased resistance at R2 will make the signal softer on make.

Values at C2 will range from 0.5 to 10 μF, depending upon the tube type and operating conditions. The value of R2 will also vary with tube type and conditions, and may range from a few to one hundred ohms. When tetrodes or pentodes are keyed in this manner, a smaller value can sometimes be used at C2 if the screen-voltage supply is fixed and not obteined from the plate supply through a dropping resistor. If the resistor decreases the output (by adding too much cathode bias) the value of R1 should be reduced.

Oscillators keyed in the cathode can't be softened on break indefinitely by increasing the value of C2 because the grid-circuit time constant enters into the action.

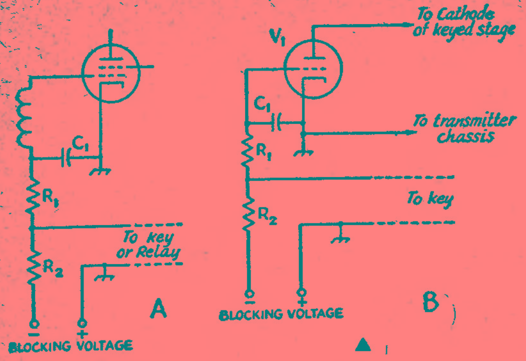


Fig. 11-4 — The basic circuit for blocked-grid keying is shown at A. R1 is the normal grid leak, and the blocking voltage must be at least several times the normel grid bias. The click on meke can be reduced by making C1 larger, and the click on break can be reduced by meking R2 larger. Usually the value of R2 will be 5 to 20 times the resistance of R1. The power supply current requirement depends upon the value of R2, since closing the key circuit places R2 across the blocking voltage supply.

An allied circuit is the vacuum-tube keyer of B. The tube V1 is connacted in the cathode circuit of the stage to be keyed. The values of C1, R1 and R2 determine the keying envelope in the same way that they do for blocked-grid keying. Values to start with might be 0.47 megohm for R1, 4.7 megohms for R2 and .0047 μF for C1.

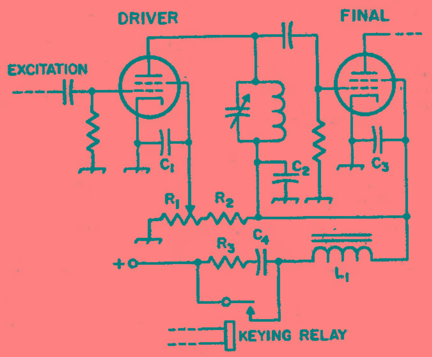
The blocking voltage supply must deliver saveral hundred volts, but the current drain is very low. A 6Y6 or other low plate-resistance tube is suitable for V1. To increase the current-carrying ability of a tube keyer, several tubes can be connected in parallel.

A vacuum-tube keyer adds cathode bias and drops the supply voltages to the keyed stage and will reduce the output of the stage. In oscillator keying it may be impossible to use a VT keyer without changing the oscillator dc grid return from ground to cathode.

Fig. 11-5 — When the driver-stage plate voltage is roughly the same as the screen voltage of a tetrode final amplifier, combined screen and driver keying is an excellent system. The envelope shaping is determined by the velues of L1, C4, and R3, although the rf bypass capacitors C1, C2 and C3 also have a slight effect. R1 serves as an excitation control for the final amplifier, by controlling tha screen voltage of the driver stage. If a triode driver is used, its plate voltage can be varied for excitation control.

The inductor L1 will not be too critical, and the secondary of a spare filament transformer can be used if a low-inductance choke is not available. The valuas of C4 and R3 will depend upon the inductance and the voltage and current levels, but good starting values are 0.1 μF and 50 ohms.

To minimize the possibility of electrical shock, it is recommended that a keying relay be used in this circuit, since both sides of the circuit are "hot." As in any transmitter, the signal will be chirp-free only if keying the driver stage has no effect on the oscillator frequency. (The Sigma 41FZ-35-ACS-SIL 6-volt ac relay is well-suited for keying applications.) ▼



Shaping of the keying is obtained in several ways. Vacuum-tube keyers, blocked-grid and cathode-keyed systems get suitable shaping with proper choice of resistor and capacitor values, while screen-grid keying can be shaped by using inductors or resistors and capacitors. Sample circuits are shown in Figs. 11-3, 11-4, and 11-5, together with instructions for their adjustment. There is no "best" adjustment, since this is a matter of personal preference and what you want your signal to sound like. Most operators seem to like the make to be heavier than the break. All of the circuits shown here are capable of a wide range of adjustment.

If the negative supply in a grid-block keyed stage fails, the tube will draw excessive key-up current. To protect against tube damage in this eventuality, an overload relay can be used or, more simply, a fast-acting fuse can be included in the cathode circuit.

OSCILLATOR KEYING

One may wonder why oscillator keying hasn't been mentioned earlier, since it is widely used. A sad fact of life is that excellent oscillator keying is infinitely more difficult to obtain than is excellent amplifier keying. If the objective is no detectable chirp, it is probably *impossible* to obtain with oscillator keying, particularly on the higher frequencies. The reasons are simple. Any keyed-oscillator transmitter requires shaping at the oscillator, which involves changing the operating conditions of the oscillator over a significant period of time. The output of the oscillator doesn't rise to full value immediately so the drive on the following stage is changing, which in turn may reflect a variable load on the oscillator. No oscillator has been devised that has no change in frequency over its entire operating voltage range and with a changing load. Furthermore, the shaping of the keyed-oscillator envelope usually has to be exaggerated, because the following stages will tend to sharpen up the keying and introduce clicks unless they are operated as linear amplifiers.

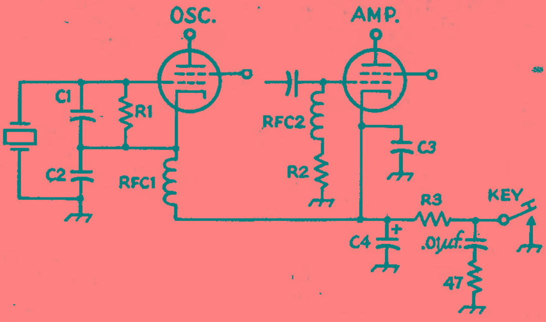


Fig. 11-6 — Simple differential-keying circuit for a crystal-controlled oscillator and power-amplifier transmitter.

Most simple crystal-controlled transmitters, commercial or home-built, return the oscillator grid-leak resistor, R1, to chassis, and "cathode keying" is used on the oscillator and amplifier stages. By returning the oscillator grid leak to the cathode, as shown here, negative power-supply-lead keying is used on the oscillator. A good crystal oscillator will operate with only 5 to 10 volts applied to it.

Using the above circuit, the signal is controlled by the shaping circuit, C4-R3. Increasing the value of R3 will make the signal "softer" on make; increasing the capacitance of C4 will make the signal softer on make and break. The oscillator will continue to operate after the amplifier has cut off, until the charge in C4 falls below the minimum operating voltage for the oscillator.

The .01-μF capacitor and 47-ohm resistor reduce the spark at the key contacts and minimize "key clicks" heard in the receiver and other nearby receivers. They *do not* control the key clicks associated with the signal miles away; these clicks are reduced by increasing the values of R3 and C4.

Since the oscillator may hold in between dots and dashes, a back wave may be present if the amplifier stage is not neutralized.

C1, C2 — Normal oscillator capacitors.
C3 — Amplifier rf cathode bypass capacitor.
C4 — Shaping capacitor, typically 1 to 10 μF, 250 volts, electrolytic
R1 — Oscillator grid leak; return to cathode instead of chassis ground.
R2 — Normal amplifier grid leak; no change.
R3 — Typically 47 to 100 ohms.
RFC1, RFC2 — As in transmitter, no change.

Break-in Keying

The usual argument for oscillator keying is that it permits break-in operation (see subsequent sections, also Chapter 23). If break-in operation is not contemplated and as near perfect keying as possible is the objective, then keying an amplifier or two by the methods outlined earlier is the solution. For operating convenience, an automatic transmitter "turner-onner" (see Campbell, *QST* Aug., 1956), which will turn on the power supplies and switch antenna relays and receiver muting devices, can be used. The station switches over to the complete "transmit" condition where the first dot is sent, and it holds in for a length of time dependent upon the setting of the delay. It is equivalent to voice-operated phone of the type commonly used by ssb stations. It does not permit hearing the other station whenever the key is up, as does full break-in.

Full break-in with excellent keying is not easy to come by, but it is easier than many amateurs think. Many use oscillator keying and put up with a second-best signal.

Differential Keying

The principle behind "differential" keying is to turn the oscillator on fast before a keyed amplifier stage can pass any signal and turn off the oscillator fast after the keyed amplifier stage has cut off. A number of circuits have been devised for accomplishing the action. The simplest, which should be applied *only* to a transmitter using a voltage-stable (crystal-controlled) oscillator is shown in Fig. 11-6. Many "simple" and kitted Novice transmitters can be modified to use this system, which approaches the performance of the "turner-onner" mentioned above insofar as the transmitter performance is concerned. With separate transmitting and receiving antennas, the performance is comparable.

A simple differential-keying circuit that can be applied to any grid-block keyed amplifier or tube-keyed stage by the addition of a triode and a VR tube is shown in Fig. 11-7. Using this keying

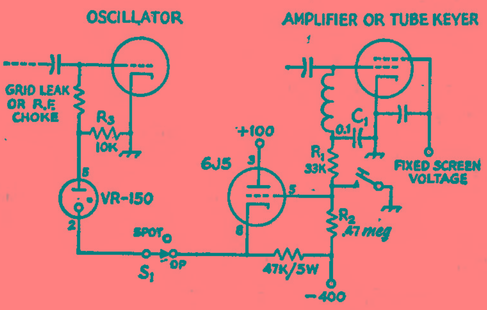


Fig. 11-7 — When satisfactory blocked-grid or tube keying of an amplifier stage has been obtained, this VR-tube break-in circuit can be applied to the transmitter to furnish differential keying. The constants shown here are suitable for blocked-grid keying of a 6146 amplifier; with a tube keyer the 6J5 and VR tube circuitry would be the same.

With the key up, sufficient current flows through R3 to give a voltage that will cut off the oscillator tube. When the key is closed, the cathode voltage of the 6J5 becomes close to ground potential, extinguishing the VR tube and permitting the oscillator to operate. Too much shunt capacity on the leads to the VR tube and too large a value of grid capacitance in the oscillator may slow down this action, and best performance will be obtained when the oscillator (turned on and off this way) sounds "clicky." The output envelope shaping is obtained in the amplifier, and it can be made softer by increasing the value of C1. If the keyed amplifier is a tetrode or pentode, the screen voltage should be obtained from a fixed voltage source or stiff voltage divider, not from the plate supply through a dropping resistor.

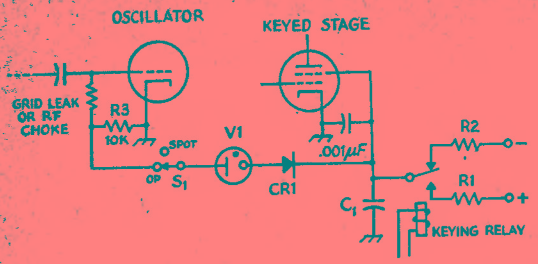


Fig. 11-8 – VR-tube differential keying in an amplifier screen circuit.

With key up and current flowing through V1 and CR1, the oscillator is cut off by the drop through R3. The keyed stage draws no current because its screen grid is negative. C1 is charged negatively to the value of the – source. When the relay is energized, C1 chargas through R1 to a + value. Before reaching zero (on its way +) there is insufficient voltaga to maintain ionization in V1, and the current is broken in R3, turning on the oscillator stage. As the screen voltage goes positive, the VR tube cennot reignite because the diode, CR1, will not conduct in that direction. The oscillator and keyed staga remain on as long as the relay is closed. When the relay opens, the voltage across C1 must be sufficiently negative for V1 to ionize before any bleeder current will pass through R3. By this time the screen of the keyed staga is so far negative that the tube has stopped conducting. (See Fig. 11-5 for suitable relay.)

system for break-in, the keying will be chirp-free if it is chirp-free with the VR tube removed from its socket to permit the oscillator to run all of the time. If the transmitter can't pass this test, it indicates that more isolation is required between keyed stage and oscillator.

Another VR-tube differential-keying circuit, useful when the screen-grid circuit of an amplifier is keyed, is shown in Fig. 11-8. The normal screen keying circuit is made up of the shaping capacitor C1, the keying relay (to remove dangerous voltages from the key), and the resistors R1 and R2. The + supply should be 50 to 100 volts higher than the normal screen voltage, and the – voltage should be sufficient to ignite the VR tube, V1, through the drop in R2 and R3. Current through R2 will be determined by the voltage required to cut off the oscillator; if 10 volts will do it the current will be 1 mA. For a desirable keying characteristic, R2 will usually have a higher value than R1. Increasing the value of C1 will soften both "make" and "break."

The tube used at V1 will depend upon the available negative supply voltage. If it is between 120 and 150, a 0A3/VR75 is recommended. Above this a 0C3/VR105 can be used. The diode, CR1, can be any unit operated within its ratings. A type 1N4005, for example, may be used with screen voltages under 600 and with far greater bleeder currents than are normally encountered – up to 1 ampere.

Clicks in Later Stages

It was mentioned earlier that key clicks can be generated in amplifier stages following the keyed stage or stages. This can be a puzzling problem to an operator who has spent considerable time adjusting the keying in his exciter unit for clickless keying, only to find that the clicks are bad when the amplifier unit is added. There are two possible causes for the clicks: low-frequency parasitic oscillations and amplifier "clipping."

Under some conditions an amplifier will be momentarily triggered into low-frequency parasitic oscillations, and clicks will be generated when the amplifier is driven by a keyed exciter. If these clicks are the result of low-frequency parasitic oscillations, they will be found in "groups" of clicks occurring at 50- to 150-kHz intervals either side of the transmitter frequency. Of course low-frequency parasitic oscillations can be generated in a keyed stage, and the operator should listen carefully to make sure that the output of the exciter is clean before he blames a later amplifier. Low-frequency parasitic oscillations are usually caused by poor choice in rf choke values, and the use of more inductance in the plate choke than in the grid choke for the same stage is recommended.

When the clicks introduced by the addition of an amplifier stage are found only near the transmitter frequency, amplifier "clipping" is indicated. It is quite common when fixed bias is used on the amplifier and the bias is well past the "cut-off" value. The effect can usually be minimized by using a combination of fixed and grid-leak bias for the amplifier stage. The fixed bias should be sufficient to hold the key-up plate current only to a low level and not to zero.

A linear amplifier (Class AB1, AB2 or B) will amplify the excitation without adding any clicks, and if clicks show up a low-frequency parasitic oscillation is probably the reason.

KEYING SPEEDS

In radio telegraphy the basic code element is the dot, or unit pulse. The time duration of a dot and a space is that of two unit pulses. A dash is three unit pulses long. The space between letters is three unit pulses; the space between words or groups is seven unit pulses. A speed of one baud is one pulse per second.

Assuming that a speed key is adjusted to give the proper dot, space and dash values mentioned above, the code speed can be found from

$$\text{Speed (wpm)} = \frac{\text{dots/min.}}{25} = 2.4 \times \text{dots/sec.}$$

E.g.: A properly adjusted electronic key gives a string of dots that count to 10 dots per second. Speed = 2.4 X 10 = 24 wpm.

Many modern electronic keyers use a clock or pulse-generator circuit which feeds a flip-flop dot generator. For these keyers the code speed may be determined directly from the clock frequency

$$\text{Speed (wpm)} = 1.2 \times \text{clock frequency (Hz)}.$$

For a quick and simple means of determining the code speed, send a continuous string of dashes and count the number of dashes which occur in a 5-second period. This number, to a close approximation, is the code speed in words per minute.

BREAK-IN OPERATION

Smooth cw break-in operation involves protecting the receiver from permanent damage by the transmitter power and assuring that the receiver will "recover" fast enough to be sensitive between dots and dashes, or at least between letters and words.

Separate Antennas

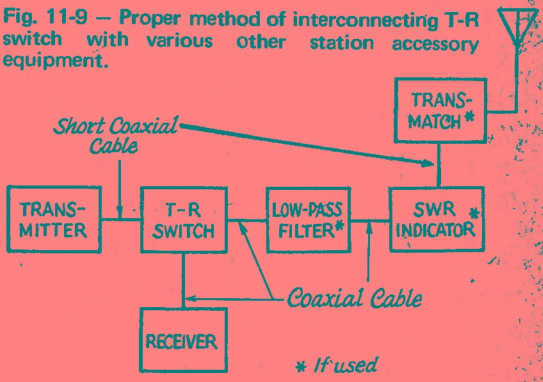
Few of the available antenna transfer relays are fast enough to follow keying, so the simplest break-in system is the use of a separate receiving antenna. If the transmitter power is low (25 or 50 watts) and the isolation between transmitting and receiving antennas is good, this method can be satisfactory. Best isolation is obtained by mounting the antennas as far apart as possible and at right angles to each other. Feed-line pickup should be minimized, through the use of coaxial cable or 300-ohm Twin-Lead. If the receiver recovers fast enough but the transmitter clicks are bothersome (they may be caused by the receiver overload and so exist only in the receiver) their effect on the operator can be minimized through the use of input and output limiters (see Chapter 8).

ELECTRONIC TRANSMIT-RECEIVE SWITCHES

When powers above 25 or 50 watts are used, where two antennas are not available, or when it is desired to use the same antenna for transmitting and receiving (a "must" when directional antennas are used), special treatment is required for quiet break-in operation on the transmitter frequency. A means must be provided for limiting the power that reaches the receiver input. This can be either a direct short-circuit, or may be a limiting device like an electronic switch used in the antenna feed line. The word "switch" is a misnomer in this case; the transmitter is connected directly to the antenna at all times. The receiver is connected to the antenna through the T-R switch, which functions to protect the receiver's input from transmitted power. In such a setup, all the operator need do is key the transmitter, and all the switching functions are taken care of by the T-R switch.

With the use of a T-R switch some steps should be taken to prevent receiver blocking. Turn off the agc or avc, decrease the rf gain setting, and advance the audio gain control. Use the rf gain control for obtaining the desired listening level. A little experimenting with the controls will provide the receiver settings best suited to individual operating preferences. A range of settings can usually be found, just on the threshold of receiver blocking, where comfortable levels of received signals are heard, and where, without adjusting the controls, the receiver can be used as a monitor during transmission. Usually no modification to the receiver is required, but if annoying clicks and thumps or excess volume occur at all settings of the receiver controls during transmission, their effect can be reduced with output audio limiting (see Chapter 8).

Fig. 11-9 — Proper method of interconnecting T-R switch with various other station accessory equipment.



TVI and T-R Switches

T-R switches generate harmonics of the transmitted signal because of rectification of the energy reaching the input of the switch. These harmonics can cause TVI if steps are not taken to prevent it. Any T-R switch should be very well shielded, and should be connected with as short as possible a cable length to the transmitter. In addition, a low-pass filter may be required in the transmission line between the T-R switch and the antenna. Fig. 11-9 shows the proper method of interconnecting the various station accessory equipment.

Reduction of Receiver Gain During Transmission

For absolutely smooth break-in operation with no clicks or thumps, means must be provided for momentarily reducing the gain through the receiver. The system shown in Fig. 11-10 permits quiet break-in operation of high-powered stations. It may require a simple operation on the receiver, although many commercial receivers already provide the connection and require no internal modification. The circuit is for use with a T-R switch and a single antenna. R1 is the regular receiver rf and i-f gain control. The ground lead is run to chassis ground through R2. A wire from the junction runs to the keying relay, K1. When the key is up, the ground side of R1 is connected to ground through the relay arm, and the receiver is in its normal operating condition. When the key is closed the relay closes, which breaks the ground connection from R1 and applies additional bias to the tubes in the receiver. This bias is controlled by R2. When the relay closes, it also closes the circuit to the transmitter keying circuit. A simple rf filter at the key suppresses the local clicks caused by the

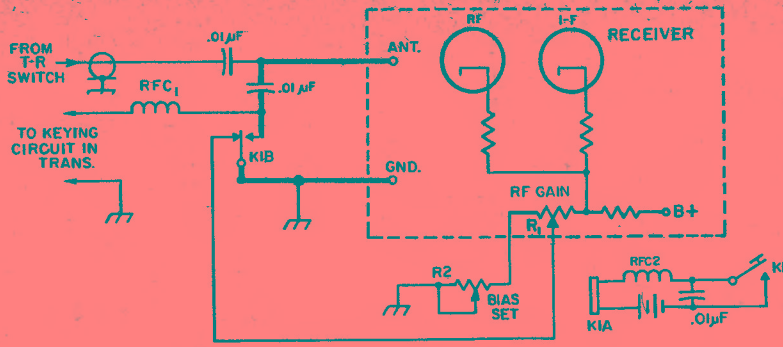


Fig. 11-10 – circuit for smooth break-in operation, using an electronic T-R switch. The leads shown as heavy lines should be kept as short as possible, to minimize direct transmitter pickup.

K1 – Spdt keying relay (Sigma 41FZ-10000-ACS-SIL or equiv.). Although battery and dc relay era shown, any suiteble ac or dc relay and power source can be used.

R1 – Receiver manual gain control.

R2 – 5000- or 10,000-ohm wire-wound potentiometer.

RFC1, RFC2 – 1- to 2 1/2-mH rf choke, current rating adequate for application.

relay current. This circuit is superior to any working on the agc line of the receiver because the cathode circuit(s) have shorter time constants than the agc circuits and will recover faster. A similar circuit may be used in the emitters or source leads of transistorized receivers.

TESTING AND MONITORING OF KEYING

In general, there are two common methods for monitoring one's "fist" and signal. The first type involves the use of an audio oscillator that is keyed simultaneously with the transmitter.

The second method is one that permits receiving the signal through one's receiver, and this generally requires that the receiver be tuned to the transmitter (not always convenient unless working on the same frequency) and that some method be provided for preventing overloading of the receiver, so that a good replica of the transmitted signal will be received. Except where quite low power is used, this usually involves a relay for simultaneously shorting the receiver input terminals and reducing the receiver gain.

An alternative is to use an rf-powered audio oscillator. This follows the keying very closely (but tells nothing about the quality – chirps or clicks – of the signal).

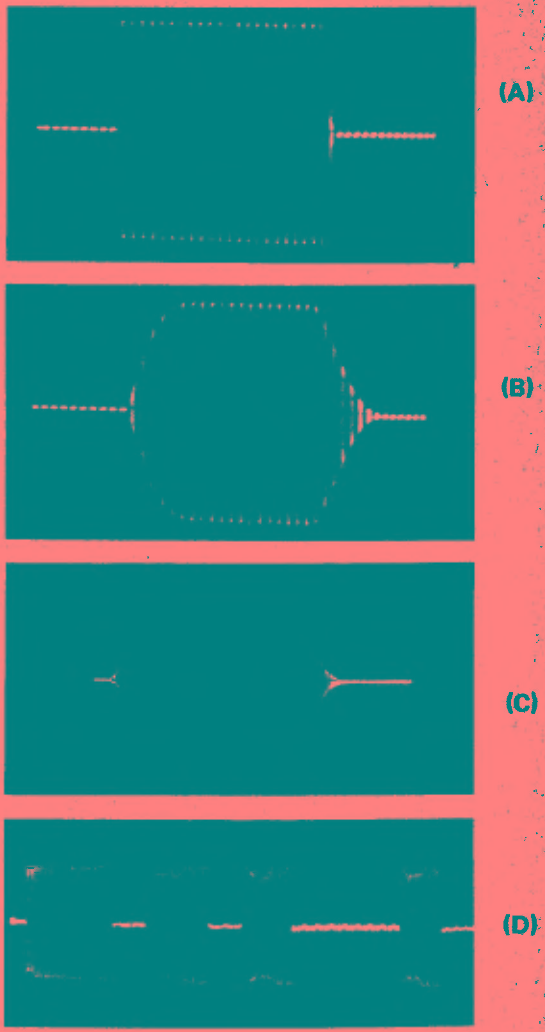
The easiest way to find out what your keyed signal sounds like on the air is to trade stations with a near-by ham friend some evening for a short QSO. If he is a half mile or so away, that's fine, but any distance where the signals are still S9 will be satisfactory.

After you have found out how to work his rig, make contact and then have him send slow dashes, with dash spacing (the letter "T" at about 5 wpm). With minimum selectivity, cut the rf gain back just enough to avoid receiver overloading (the condition where you get crisp signals instead of mushy ones) and tune slowly from out of beat-note range on one side of the signal through to zero and out the other side. Knowing the tempo of the dashes, you can readily identify any clicks in the vicinity as yours or someone else's. A good signal will have a thump on "make" that is perceptible only where you can also hear the beat note, and the click on "break" should be practically negligible at any point. If your signal is like that, it will sound good, provided there are no chirps. Then have your friend run off a string of fast dots with the bug – if they are easy to copy, your signal has no "tails" worth worrying about and is a good one for any speed up to the limit of manual keying. Make one check with the selectivity in, to see that the clicks off the signal frequency are negligible even at high signal level.

If you don't have any friends with whom to trade stations, you can still check your keying, although you have to be a little more careful. The transmitter output should be fed into a shielded dummy load. Ordinary incandescent lamps are unsatisfactory as lamp resistance varies too much with current. The thermal lag may cause the results to be misleading.

The first step is to get rid of the rf click at the key. This requires an rf filter (mentioned earlier). With no clicks from a spark at the key, disconnect the antenna from your receiver and short the antenna terminals with a short piece of wire. Tune in your own signal and reduce the rf gain to the point where your receiver doesn't overload. Detune any antenna trimmer the receiver may have. If you can't avoid overload with the rf gain-control range, pull out the rf amplifier tube and try again. If you still can't avoid overload, listen to the second harmonic as a last resort. An overloaded receiver can generate clicks.

Describing the volume level at which you should set your receiver for these "shack" tests is a little difficult. The rf filter should be effective with



These photos show cw signals as observed on an oscilloscope. At A is a dot generated at a 46-baud rate with no intentional shaping, while at B the shaping circuits have been adjusted for approximately 5-ms rise and decay times. Vertical lines are from a 1-kHz signal applied to the Z or intensity axis for timing. Shown at C is a shaped signal with the intensity modulation of the pattern removed. For each of these photos, sampled rf from the transmitter was fed directly to the deflection plates of the oscilloscope.

At D may be seen a received signal having essentially no shaping. The spike at the leading edge is typical of poor power-supply regulation, as is also the immediately following dip and rise in amplitude. The clicks were quite pronounced. This pattern is typical of many observed signals, although not by any means a worst case. The signal was taken from the receiver's i-f amplifier (before detection) using a hand-operated sweep circuit to reduce the sweep time to the order of one second. (Photos from *QST* for October and November 1966.)

the receiver running wide open and with an antenna connected. When you turn on the transmitter and take the steps mentioned to reduce the signal in the receiver, run the audio up and the rf down to the point where you can just hear a little "rushing" sound with the BFO off and the receiver tuned to the signal. This is with the selectivity in. At this level, a properly adjusted keying circuit will show no clicks off the rushing-sound range. With the BFO on and the same gain setting, there should be no clicks outside the beat-note range. When observing clicks, make the slow-dash and dot tests outlined previously.

Now you know how your signal sounds on the air, with one possible exception. If keying your transmitter makes the lights blink, you may not be able to tell too accurately about the chirp on your signal. However, if you are satisfied with the absence of chirp when tuning *either side of zero beat*, it is safe to assume that your receiver isn't chirping with the light flicker and that the observed signal is a true representation. No chirp either side of zero beat is fine. Don't try to make these tests without first getting rid of the rf click at the key, because clicks can mask a chirp.

The least satisfactory way to check your keying is to ask another ham on the air how your keying sounds. It is the least satisfactory because most hams are reluctant to be highly critical of another amateur's signal. In a great many cases they don't actually know what to look for or how to describe any aberrations they may observe.

A MEMORY FOR THE DELUXE KEYER

The system described below permits storage of up to 200 letters of text organized in one, two, three, or four messages. A digital display provides an indication of the message being sent or loaded (No. 1, 2, 3, or 4) and the message bit being addressed (0 to 512). Any number of pauses may be programmed into a message to allow manual insertion of changeable text (such as RST or

Fig. 1 — A look at the inside of the Accu-Memory. The power supply components may be seen at the left, and the three "stacked" circuit boards to their right. The fourth circuit board, containing the readout, is mounted behind the sloping portion of the front panel. The board at the bottom of the "stack" is that of the original Accu-Keyer.

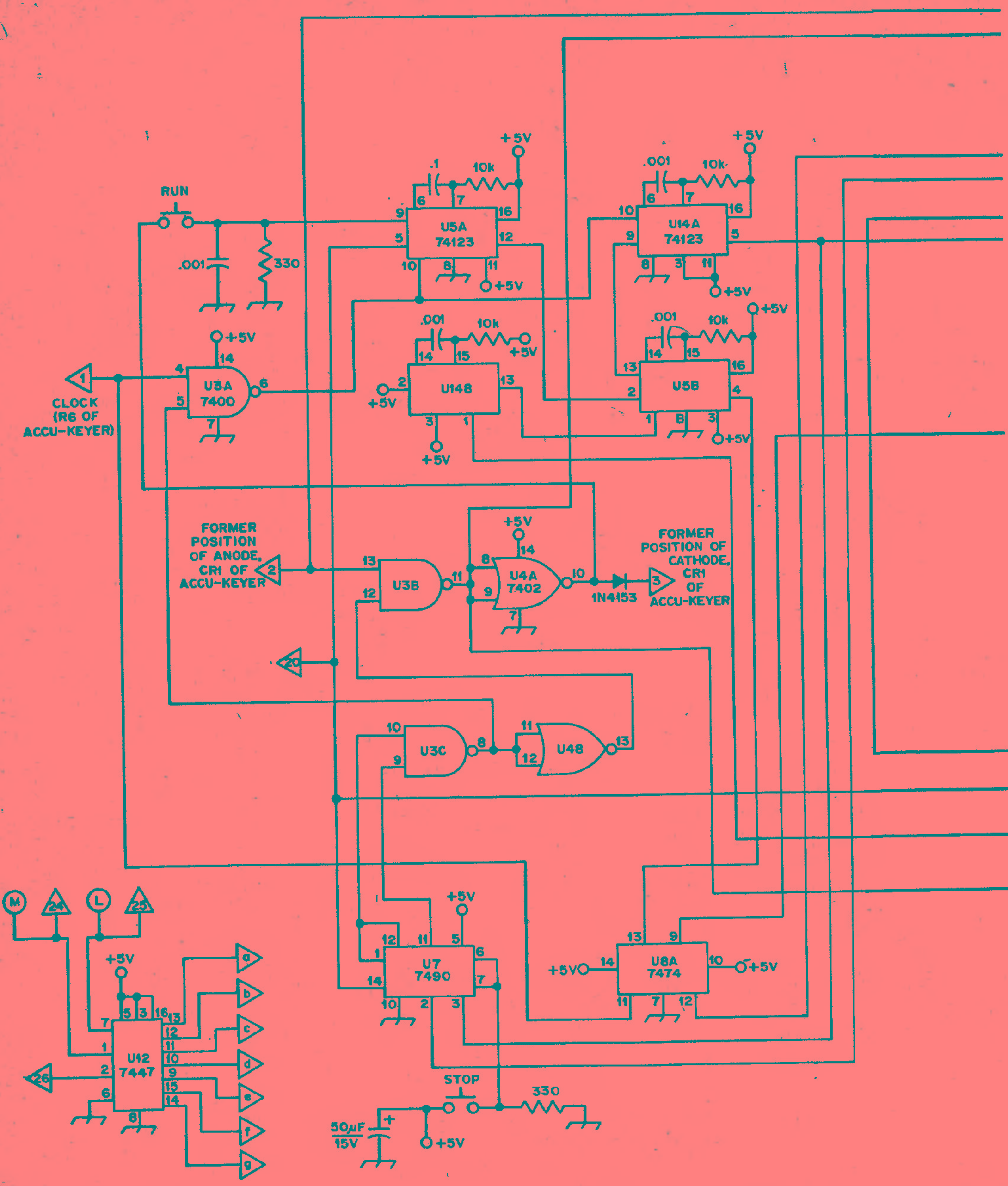
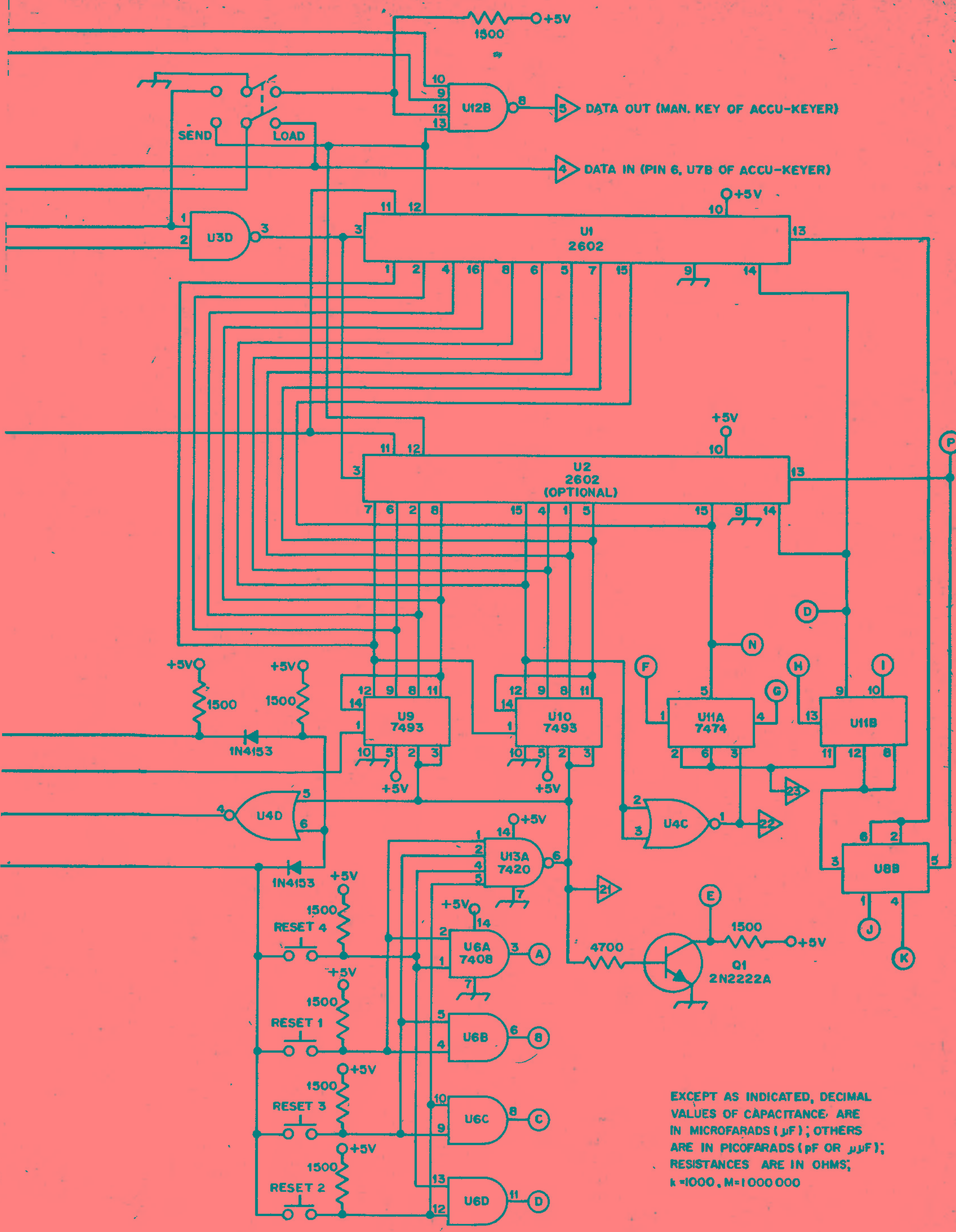


Fig. 2 — Diagram of memory circuitry of the Accu-Memory. See Table II for list of parts. Numbers and letters in triangles identify inter-connections to other parts of the Accu-Memory, as listed in Table I. Letters in circles indicate terminals for jumpars to be wired for either one or two RAM ICs. This wiring information is also listed in Table I.

contest serial number). After manual insertion a touch of the RUN button allows the remainder of the programmed message to continue. The message being sent may be aborted by pressing the STOP button (the "I didn't mean to press the button!" button). Unlike some programmable keyers, the use of a free-running (asynchronous) clock in the load mode has been avoided, greatly simplifying the loading process. All features of the original Accu-Keyer have been retained. The dot and dash memories of the Accu-Keyer and its automatic character-space feature are used to good advantage in the Accu-Memory.

In addition to the Accu-Keyer board, three printed circuit boards make up the Accu-Memory: a memory board, a display board, and a display-



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF); OTHERS ARE IN PICOFARADS (pF OR μμF); RESISTANCES ARE IN OHMS; k=1000, M=1000 000

driver board. The power supply provides 5 volts at 0.8 ampere to power all the circuitry.

The Accu-Memory has been "battle tested" in contests and has been found to be very effective in reducing operator fatigue. It is of use whenever there is a requirement for repeatedly sending the same cw sequences such as in contests, DX pileups, and net-control operations. Experience has shown that the digital displays are far more useful than originally anticipated.

Construction

As shown in Fig. 1, the Accu-Memory is constructed in an aluminum box made by cutting and bending sheet aluminum. The front-panel dimensions are deliberately made small because

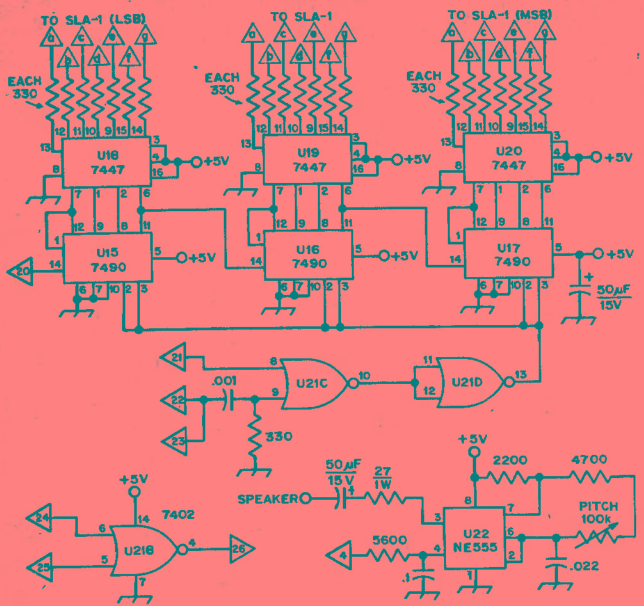


Fig. 3 — Diagram of driver and display. See Table II for list of parts. Numbers inside triangles identify interconnections to other parts of the Accu-Memory, as listed in Table I.

depth in most ham shacks is more abundant than frontal-area space. This method also gives a neat, streamlined appearance. The overall outside dimensions are 4-¼ × 3-½ × 10-½ with the length dimension measured across the bottom plate, less knobs and heat sink. The heat sink for the LM309 is attached to the rear panel,[1] along with the key jack, the output jack, and a fuse holder (Safety First!). Power supply components are located on the bottom plate near the rear. Two terminal strips are used to mount the power supply diodes and filter capacitor. All the other electronic parts are mounted on four printed-circuit cards.

The push buttons are sold by Solid State Systems (see footnote [1]). One word of caution: do not increase the value of the filter capacitor in the power supply. It has been chosen for minimum dissipation by the LM309 regulator.

Fig. 2 is a schematic diagram of the circuitry on the driver and display board. Wires that interconnect the boards are shown as numbers or lower case letters in triangles on the figures. Selectable jumpers allow the use of one or two RAM IC's. The jumper points are shown as capital letters in circles. Table I is a list of interconnecting wires. Table II gives a parts list for each board. Fig. 4 is a diagram of the power supply.

To send, place the LOAD/SEND switch in the SEND position and press the proper message button. The STOP button will halt sending, but the message can be continued from the halted point if the RUN button is depressed.

If it is desired to use the insert feature, load the first part of the message as described above. Then after the memory stops advancing, press the RUN button once, wait until the count stops, and then load the second half of the message. In the SEND mode the memory will send the first part, stop and allow insertion of manual input such as signal reports, and then, when the RUN button is depressed, continue with the second half. This procedure may be repeated as many times as necessary.

The readout indicates the message number and the location within the message starting at 000 and continuing through either 256 or 512, depending on whether one or two memories are installed. A decimal point lights when the keyer is sending either manually or automatically.

Helpful Advice

After a lot of correspondence with amateurs who built the Accu-Keyer, it is apparent that some do not know that there is a difference between a 7400, a 74H00, a 74L00, and a 74C00. These are all members of a family of quad two-input gates that are different internally and are not interchangeable (in almost all cases) with each other. Some IC distributors tend to be haphazard about which type they send.

As with the Accu-Keyer, ready-made boards are available for the memory through Garrett.[2] A business-size self-addressed stamped envelope is mandatory to reduce addressing time to a minimum. If any problems develop or changes occur in the circuit, a data sheet showing corrections will be included with the boards.

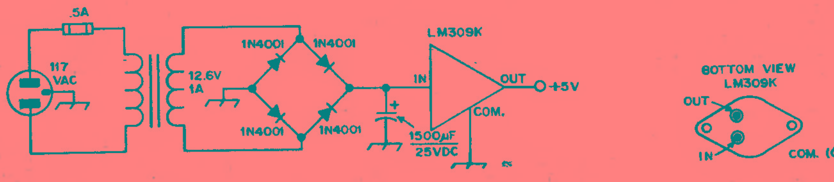


Fig. 4 — Power supply for Accu-Memory and

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[1] The hest sink for the LM-309 is available from Solid State Systems, Inc., Box 773, Columbia, MO 65201.

[2] As a service to those who wish to avail themselves, ready-made circuit boards may be obtained through James Garrett, WB4VVF, 126 W. Buchanon Ave., Orlando, FL 32809. All boards are glass epoxy and drilled. At the time of this printing, the Accu-Keyer board is $3.50. The memory, readout, and readout-driver boards are $12 as a set. The memory board, if ordered alone, is $6.

TABLE I – INTERCONNECTIONS

WIRE NUMBER	FUNCTION	
Keyer-to-memory interconnections.		
1	Clock – connect to R6	
2	Anode CR1	
3	Cathode CR1 (Remove CR1 in keyer and connect as shown.)	
4	Data in (Connect to U7B in keyer and tone oscillator on driver board.)	
5	Data out (Connect to manual key input, U7 pin 5 in keyer.)	
Memory-to-control switches		
6	Send 1	Dpdt switch
7	Send 2	
8	Load 1	
9	Load 2	
10	Common 1	
11	Common 2	
Memory to readout		
12	Insert	Push buttons
13	Insert return	
14	Reset 1	
15	Reset 2	
16	Reset 3	
17	Reset 4	
18	Reset common	
19	Stop	
a, b, c, d, e, f, g	Quadrant readout	
Memory to driver		
20	Readout count	
21	Readout reset	
22	Readout quadrant reset (use with one 2601)	
23	Readout quadrant reset (use with two 2602s)	
24	NOR 1	
25	NOR 2	
26	NOR out	
Driver to readout		
27-33 (a-g, LSB)	Least-significant digit	
34-40 (a-g, CSB)	Center-significant digit	
41-47 (a-g, MSB)	Most-significant digit	
48-49	Pitch control (short if no control desired)	
50	Speaker	

Memory interconnections

For one memory IC connect: A to H, B to G, C to I, D to F, J to ground, K to + 5 V, L to N, and M to O.

For two memory ICs connect: A to J, B to I, C to K, D to H, E to F, G to + 5 V, L to O, and M to P.

Connect DP (decimal point) on readout board to wire 13.

TABLE II – Accu-Memory Parts List

	Memory Board	
2	7474 ICs	U8, U11
2	7493 ICs	U9, U10
1	7408 IC	U6
2	74123 ICs	U5, U14
1	7400 IC	U3
1	7490 IC	U7
1	7402 IC	U4
1	7420 IC	U13
1	7447 IC	U12 (optional)
2	2102 or 2602 ICs	U1, U2 (U2 optional)
1	2N2222A transistor	
3	1N4148 silicon diodes or equivalent	
8	1500-Ω ¼-W resistors	
4	10-kΩ ¼-W resistors	
2	330-Ω resistors	
1	4700-Ω resistor	
4	.001-µF disk ceramic capacitors	
4	.1-µF disk ceramic capacitors	
1	50-µF 15-V electrolytic capacitor	
	Driver Board	
3	7490 ICs	
3	7447 ICs	
1	7402 IC	
1	NE555 IC	
22	330-Ω resistors	
1	5600-Ω resistors	
1	2200-Ω resistor	
1	4700-Ω resistor (33kΩ with no pitch control)	
1	27-Ω resistor	
1	.001-µF disk ceramic capacitor	
1	.022-µF disk ceramic capacitor	
2	.1 µF disk ceramic capacitors	
2	50-µF 15-V electrolytic capacitors	
	Readout Board	
4	SL A-1 readouts	
6	Push buttons (see text)	
8	330-Ω resistors	

DELUXE ALL-SOLID-STATE KEYER

The Accu-Keyer is a modern keying device with deluxe features available on only the most expensive of commercially available instruments, but it may be built for less than $25.

The basic circuit uses seven TTL integrated circuits which may be purchased at "bargain" suppliers for less than $3. Optional features which may be incorporated at the builder's discretion are a stiffly regulated power supply, a keying monitor, and provisions for solid-state keying of cathode-keyed transmitters.

The Accu-Keyer was designed with these features in mind:

1) Self-completing dots and dashes
2) Dot and dash memories
3) Iambic operation
4) Dot and dash insertion
5) Automatic character space (with switching provided to defeat this feature)
6) 5-50 wpm speed range
7) Low cost

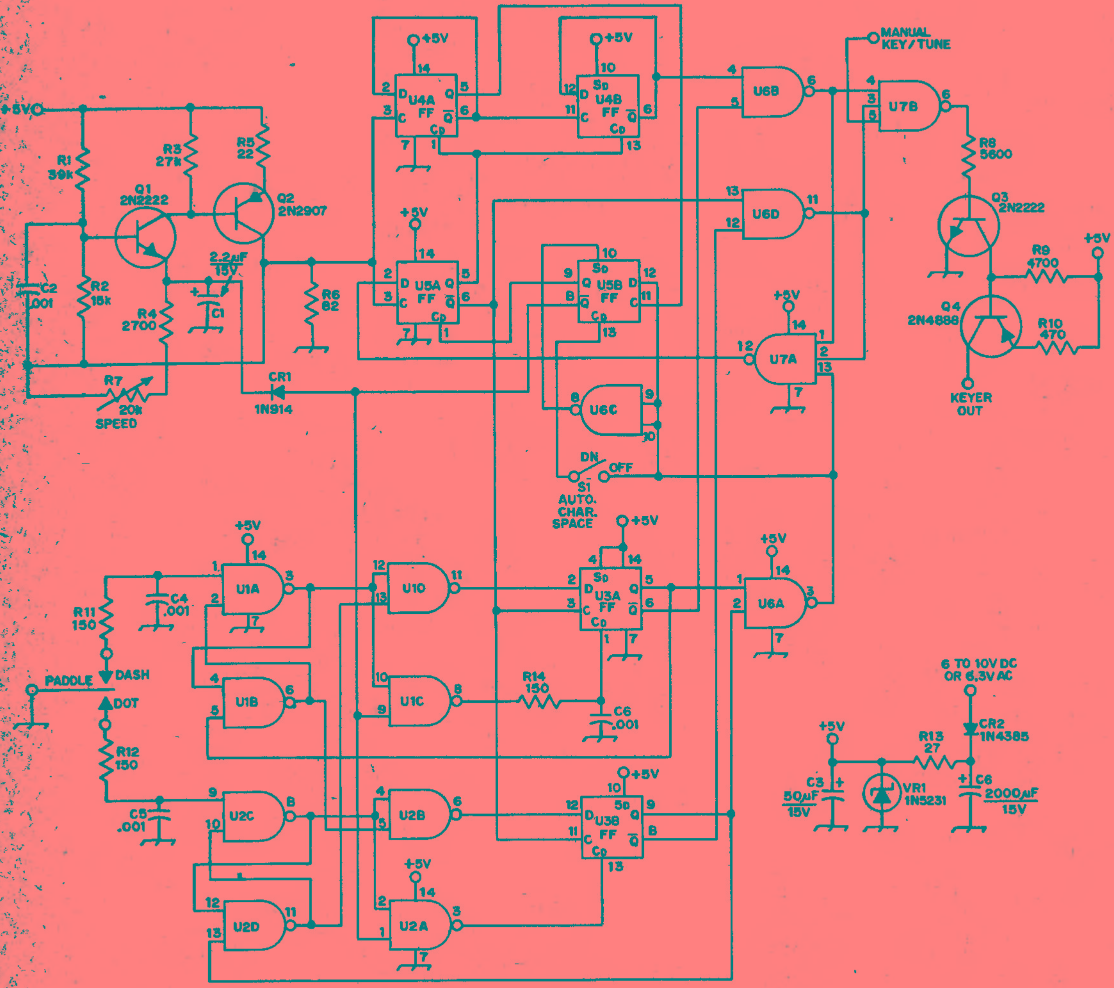
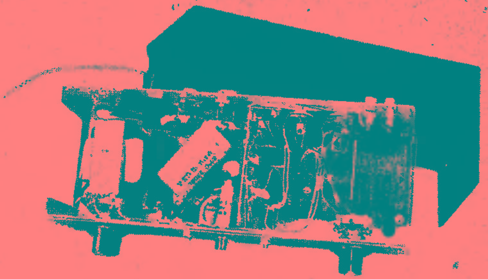


Fig. 2 — Schematic diagram of the Accu-Keyer. Resistances are in ohms; k = 1000. All capacitances are in microfarads. All resistors may be 1/4 watt except R13, which should have a 2-W rating. Capacitors with polarity indicated are electrolytic; all others are disk ceramic. Parts not listed below are for text reference and circuit-board identification.

CR1 — Small-signal silicon diode.
CR2 — Rectifier diode, 1/2 A or greater.
Q1, Q3 — Silicon npn, 250-mW, high-speed switching or rf-amplifier transistor.
Q2 — Silicon pnp, 250-mW, high-speed switching or rf-amplifier transistor.
Q4 — Silicon pnp, 250-mW, high-voltage af-amplifier transistor.
R7 — Reverse-log-taper control; Mallory U-28 suitable.
S1 — Spst toggle.
U1, U2, U6 — Quad 2-input NAND gate, type 7400.*
U3, U4, U5 — Dual type *D* flip-flop, type 7474.*
U7 — Triple 3-input NAND gate, type 7410.*
VR1 — 5.1-V, 0.5-W Zener diode.

* All ICs are dual-in-line package, 14 pin. Note: All ICs are available from various manufactuerers or as surplus. Motorola part numbers are prefixed by *MC* and suffixed by *P*. Texas Instruments parts have an *SN* prefix and *N* suffix. Signetics ICs have an *N* prefix and an *A* suffix. For example, Motorola's MC7400P is equivalent to Texas Instruments' SN7400N orSignetics' N7400A.

A peek inside the Accu-Keyer shows compact construction in this deluxe version built by W1RML. The ac-operated power supply components are located at the left, and the basic keyer board at the right. The keying monitor is constructed on a separate vertically mounted circuit board positioned near the center of the enclosure. The pitch control is mounted inside the keyer on this circuit board, as it is not adjusted frequently. The speaker is mounted over a "grille" formed by drilling many holes at the bottom of the enclosure, and is nearly hidden by the filter capacitor in this view. On the rear panel, in TO-3 style cases, are the 5-volt regulator IC and the cathode keying transistor.



The Circuit

The schematic diagram of the Accu-Keyer is shown in Fig. 2. The voltage applied to CR2 for powering the keyer may be either 8 to 10 volts dc or 6.3 volts ac, such as from the filament supply of a transmitter or receiver. If dc is applied, C6 is not required. If ac is applied to CR2, VR1 functions more to protect the ICs from overvoltage by limiting the amplitude of the ripple than it does for voltage regulation. If a well-filtered and regulated supply is desired, the circuit of Fig. 3A may be used in place of CR2, R13, and VR1 and associated capacitors. Constructed with the components shown, that supply will handle the keyer requirements with power to spare.

Should a keying monitor be desired, the diagram of Fig. 3B may be used to construct a circuit which will afford plenty of volume and a stable, pleasing tone. The circuit is a modified version of the code-practice oscillator appearing in Chapter 1. Equipped with such a monitor, the Accu-Keyer becomes ideal for conducting code practice sessions for small and medium-sized groups.

Fig. 3C shows a circuit which may be used for cathode-keyed or solid-state "QRP" transmitters. The Delco keying transistor will safely handle two amperes of current and a collector-to-emitter potential of 800 V, and yet its cost is less than that of a new mercury-wetted relay. The use of a transistor offers advantages over both vacuum-tube keying and relay keying of cathode-keyed rigs; the voltage drop across the transistor when saturated introduces negligible grid-cathode bias to the keyed stage, and the keying is softened somewhat over relay keying because the transistor cannot go from cutoff to saturation (or vice versa) instantaneously. For QRP transmitters, Q6 may be a 300- or 500-mW silicon npn transistor, such as a 2N2222 or 2N4123.

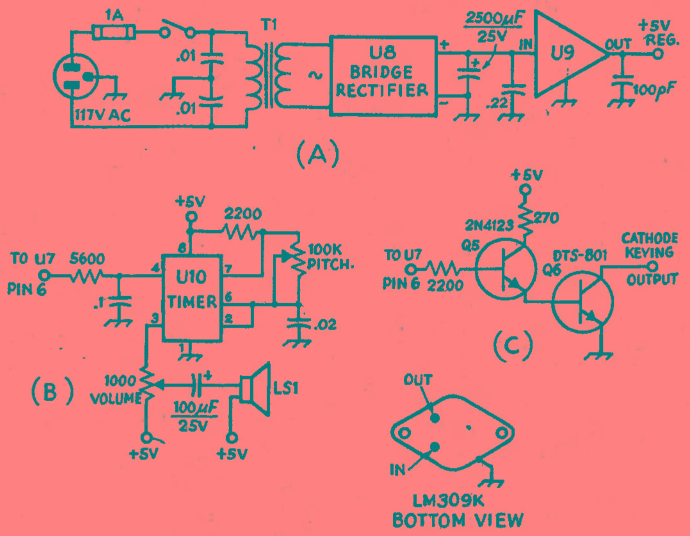


Fig. 3 — At A, optional ac-operated power supply circuit for the Accu-Keyer; At B, an optional monitor, and at C a circuit for cathode keying.

LS1 — Miniature speaker, 4-, 8- or 16-ohm impedance.

Q6 — High-voltage high-current silicon npn power transistor (Delco DTS-801, -802, or -804 or equiv.).

T1 — Surplus filament transformer, 12.6-V 1-A secondary rating.

U8 — Full-wave rectifier bridge, 1-A 50-V (Motorola 920-2, HEP 175, or equiv.). Four rectifier diodes in a bridge arrangement may be used instead.

U9 — Voltage-regulator IC, 5-volt (National Semiconductor LM309K or equiv.).

U10 — Signetics NE555 timer IC.

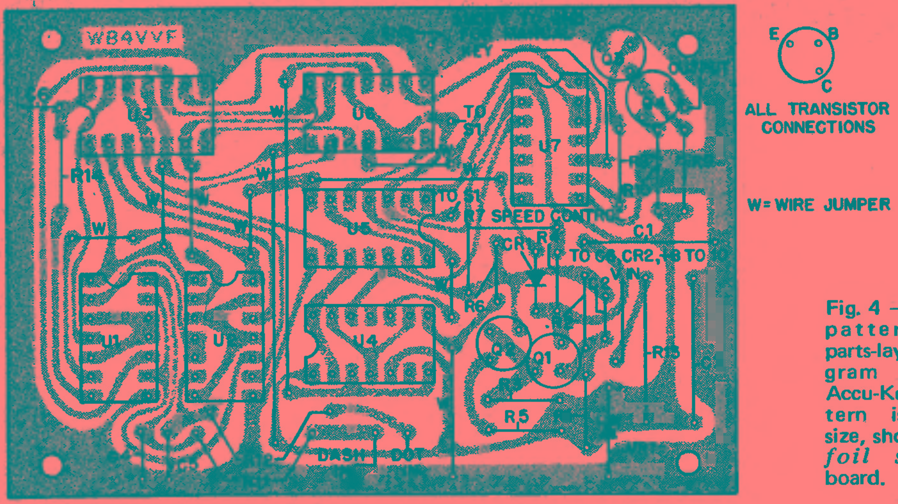


Fig. 4 — Etching pattern and parts-layout diagram for the Accu-Keyer. Pattern is actual size, shown from *foil side* of board.

Construction and Operation

A ready-made circuit board is available for the basic circuit of the Accu-Keyer. [1] Fig. 4 is an actual-size board layout and parts-placement guide. If the builder elects to use none of the optional circuit features of Fig. 3, the complete keyer may be built into a 3 × 2 × 5-inch Minibox. The board pattern in Fig. 4 contains all parts of Fig. 2 except the controls, the filter capacitor, and the rectifier in the power supply.

It is essential that all leads to the keyer be shielded from rf. RG-174/U coax may be used. A .01-μF bypass capacitor is provided on the power input to remove rf. As shown on the diagram, the inputs from the paddle are filtered by 150-ohm resistors bypassed by .001-μF capacitors. In stubborn cases it may be necessary to bypass the paddle contacts at the paddle itself.

Substitution of transistors for Q1 and Q2 may require changing the value of R5 to make the first clock pulse the same length as the rest. Both should be transistors with a beta of at least 60. Q3 is noncritical, and any good silicon transistor should work. Q4 should be capable of withstanding the transmistter key-up voltage. Any pnp silicon device having a reasonable beta and meeting this requirement should work. The value of C1 may be juggled to change the range of the speed control. The value specified gives a range of approximately 5 to 50 wpm.

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[1] A glass-epoxy board, pre-drilled, is available for $3.50 from James M. Garrett, WB4VVF, 126 W. Buchanon, Orlando, FL 32809.

A SINGLE-IC ELECTRONIC KEYER

Electronic keyers, depending on the features they offer, can be quite simple or they can be rather complex. This is a simple digital electronic keyer which uses only a single integrated circuit and a single transistor, yet it makes the sending of perfect code a rather easy task. The dots and dashes are self-completing, and code may be sent at any speed between 10 and 40 wpm with adjustment of the speed control. A weighting control is provided, too, a desirable feature to compensate for variations in wave shaping and time sequencing in different transmitter circuits. Keying is done with a high-voltage transistor, connected for use with grid-block-keyed transmitters or transmitters with equivalent solid-state circuits.

The keyer can be built for approximately $12. By using batteries to power the circuit, the cost of

The single-IC keyer is contained in a 2-1/8 × 3 × 5-1/4-inch metal box. The power switch is mounted on the ratio or weighting control. Jacks for the paddle and output keying, located on the rear of the box, are not visible in this view.

Because there are relatively few components in the keyer, there is ample room even with the batteries mounted inside the box. Although an etched circuit board was used in this keyer built by W1RML, perforated board and point-to-point wiring may be used in construction.

a power transformer is eliminated. The IC is available for approximately $2 at industrial electronic supply houses.

The method of construction is shown in the photographs. An etched circuit board was used for this version, but perforated board and point-to-point wiring work just as well if one uses care in making connections to the IC. The builder may find it desirable to use a socket for the IC, rather than to attempt to solder directly to the IC pins. The controls, jacks, and holders for the batteries are mounted directly on the metal box. The IC and the transistor, along with their associated components, are mounted on the circuit board.

The power switch, S1, must be of a double-pole type, to provide complete electrical isolation of the negative terminals of the two battery supplies with power off. Leaving these terminals connected together and ungrounding the common connection with a single-pole switch is not satisfactory, as current will still flow from the batteries. In the keyer shown in the photographs, S1 is located on the rear of the weight control. When the keyer is energized, the response is almost instantaneous, as there is nothing which must warm up before operation can commence.

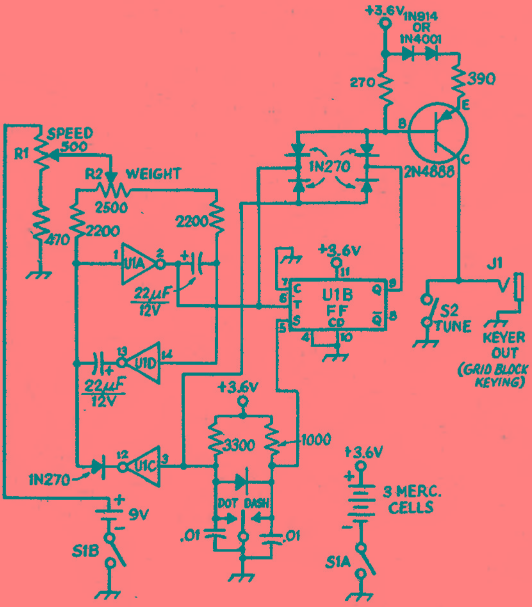

Fig. 1 — Schematic diagram of the single-IC keyer; circuit courtesy of W9HFM. Resistances are in ohms; k = 1000. All fixed resistors are 1/2-watt 10-percent tolerance.

Q1 — Silicon pnp, 300-mW, 150-V af-amplifier transistor.

R1, R2 — Linear taper.

S1 — Dpst. (Type shown in photograph is Mallory US27, mounted on rear of R2, which is Mallory type U6.)

S2 — Spst toggle.

U1 — Multifunction RTL IC, 1 *J-K* flip-flop, 1 inverter, 2 buffers (Motorola MC787P or HEP-C2503P or equiv.).

The speed range of the keyer is determined by the values of the two electrolytic capacitors, shown as 22 µF in the schematic diagram. If the builder desires to change the range, these values may be changed, always keeping the two equal. Smaller values will provide for an increase in the range.

To avoid the possibility of rf entering the keying enclosure, the key line should be shielded, with the shield conductor providing the ground return. Small-diameter coax such as RG-58/U or RG-59/U, or the smaller RG-174/U, is ideal for this purpose. The paddle line may be a twisted pair with shield, and the shield should provide the ground or common connection at the paddle itself. The two .01-µF bypass capacitors shown for the paddle leads should be installed where the wires from the paddle enter the keyer enclosure.

Bibliography

Source material and more extended discussions of topics covered in this chapter can be found in the references given below. In addition, a detailed bibilography of electronic keyer information is available upon request from ARRL Hq. Please enclose a stamped self-addressed business-size envelope.

Garrett, "The WB4VVF Accu-Keyer," *QST*, Aug., 1973.

Grammer, "Oscilloscope Setups for Transmitter Testing," *QST*, October, 1964; "V.F.O. Stability – Recap and Postscript," *QST*, Sept. and Oct., 1966; "Why Key Clicks?" *QST* Oct., 1966; "Low-Level Blocked-Grid Keying," *QST*, Nov., 1966.

McCoy, "Clicks and Chirps – Let's Clean 'Em Up!" *QST* Sept., 1967; "An R.F.-Actuated C.W. Monitor," *QST*, Nov., 1968; "Simplified Antenna Switching," *QST*, April, 1971.

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"A Relay Driver for Use with Solid-State Keyers," Gimmicks and Gadgets, *QST*, Oct., 1971. Also Feedback, *QST* for April, 1972.

Chapter 12

Amplitude Modulation and Double-Sideband Phone

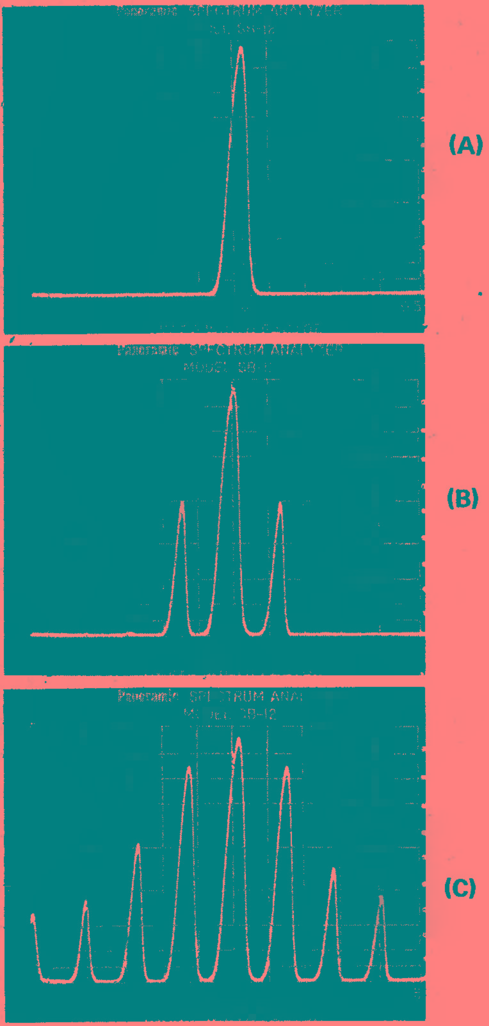

Fig. 12-1 — Spectrum-analyzer display of the rf output of an a-m transmitter. Frequency is presented on the horizontal axis (7-kHz total display width) versus relative amplitude of the signal component on the vertical axis. Shown at A is the unmodulated carrier, which occupies but a single frequency. At B the carrier is 20-percent modulated with a 1000-Hz tone. Each sideband may be seen to be at a level approximately 20 dB below the carrier. The signal bandwidth in this case is twice the modulating frequency, or 2 kHz. Shown at C is the widened channel bandwidth resulting from splatter caused by overmodulation. New frequencies, audio harmonics of the 1000-Hz modulating tone, extend for several kilohertz either side of the carrier.

As described in the chapter on circuit fundamentals, the process of modulation sets up groups of frequencies called **sidebands**, which appear symmetrically above and below the frequency of the unmodulated signal or carrier. If the instantaneous values of the amplitudes of all these separate frequencies are added together, the result is called the **modulation envelope.** In **amplitude modulation (a-m)** the modulation envelope follows the amplitude variations of the signal that is used to modulate the wave.

For example, modulation by a 1000-Hz tone will result in a modulation envelope that varies in amplitude at a 1000-Hz rate. The actual rf signal that produces such an envelope consists of three frequencies – the carrier, a side frequency 1000 Hz higher, and a side frequency 1000 Hz lower than the carrier. See Fig. 12-1. These three frequencies easily can be separated by a receiver having high selectivity. In order to reproduce the original modulation the receiver must have enough bandwidth to accept the carrier and the sidebands simultaneously. This is because an a-m detector responds to the modulation envelope rather than to the individual signal components, and the envelope will be distorted in the receiver unless all the frequency components in the signal go through without change in their amplitudes.

In the simple case of tone modulation the two side frequencies and the carrier are constant in amplitude – it is only the envelope amplitude that varies at the modulation rate. With more complex modulation such as voice or music the amplitudes and frequencies of the side frequencies vary from instant to instant. The amplitude of the modulation envelope varies from instant to instant in the same way as the complex audio-frequency signal causing the modulation. Even in this case the *carrier* amplitude is constant if the transmitter is properly modulated.

A-M Sidebands and Channel Width

Speech can be electrically reproduced, with high intelligibility, in a band of frequencies lying between approximately 100 and 3000 Hz. When these frequencies are combined with a radio-frequency carrier, the sidebands occupy the frequency spectrum from about 3000 Hz below the carrier frequency to 3000 Hz above – a total band or channel of about 6 kHz.

Actual speech frequencies extend up to 10,000 Hz or more, so it is possible to occupy a 20-kHz channel if no provision is made for reducing its width. For communication purposes such a channel width represents a waste of valuable spectrum space, since a 6-kHz channel is fully adequate for intelligibility. Occupying more than the minimum channel creates unnecessary interference.

THE MODULATION ENVELOPE

In Fig. 12-2 the drawing at A shows the unmodulated rf signal, assumed to be a sine wave of the desired radio frequency. The graph can be taken to represent either voltage or current.

In B, the signal is assumed to be modulated by the audio frequency shown in the small drawing above. This frequency is much lower than the carrier frequency, a necessary condition for good modulation. When the modulating voltage is "positive," (above its axis) the envelope amplitude is increased *above* its unmodulated amplitude; when the modulating voltage is "negative," the envelope amplitude is *decreased.* Thus the envelope grows larger and smaller with the polarity and amplitude of the modulating voltage.

The drawing at C shows what happens with stronger modulation. The envelope amplitude is doubled at the instant the modulating voltage reaches its positive peak. On the negative peak of the modulating voltage the envelope amplitude just reaches zero.

Percentage of Modulation

When a modulated signal is detected in a receiver, the detector output follows the modulation envelope. The stronger the modulation, therefore, the greater is the useful receiver output. Obviously, it is desirable to make the modulation as strong or "heavy" as possible. A wave modulated as in Fig. 12-2C would produce more useful audio output than the one shown at B.

The "depth" of the modulation is expressed as a percentage of the unmodulated carrier amplitude. In either B or C, Fig. 12-2, X represents the unmodulated carrier amplitude, Y is the maximum envelope amplitude on the modulation uppeak, and Z is the minimum envelope amplitude on the modulation downpeak.

In a properly operating modulation system the modulation envelope is an accurate reproduction of the modulating wave, as can be seen in Fig. 12-2 at B and C by comparing one side of the outline with the shape of the modulating wave. (The lower outline duplicates the upper, but simply appears upside down in the drawing.)

The percentage of modulation is

$$\%\,\text{Mod.} = \frac{Y-X}{X} \times 100 \text{ (upward modulation), or}$$

$$\%\,\text{Mod.} = \frac{X-Z}{X} \times 100 \text{ (downward modulation)}$$

If the two percentages differ, the larger of the two is customarily specified. If the wave shape of the modulation is such that its peak positive and negative amplitudes are equal, then the modulation percentage will be the same both up and down, and is

$$\%\,\text{Mod.} = \frac{Y-Z}{Y+Z} \times 100.$$

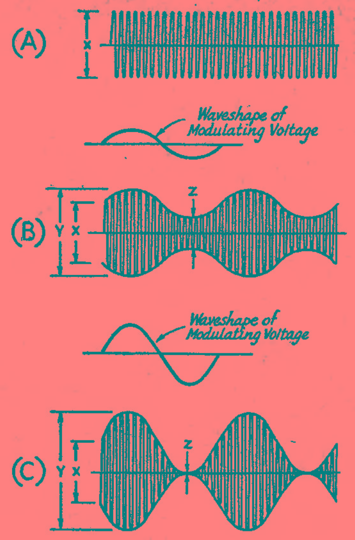

Fig. 12-2 — Graphical representation of (A) rf output unmodulated, (B) modulated 50 percent, (C) modulated 100 percent. The modulation envelope is shown by the thin outline on the modulated wave.

Power in Modulated Wave

The amplitude values shown in Fig. 12-2 correspond to current and voltage, so the drawings may be taken to represent instantaneous values of either. The power in the wave varies as the *square* of either the current or voltage, so at the peak of the modulation upswing the instantaneous power in the envelope of Fig. 12-2C is four times the unmodulated carrier power (because the current and voltage both are doubled). At the peak of the downswing the power is zero, since the amplitude is zero. These statements are true of 100-percent modulation no matter what the wave form of the modulation. The instantaneous envelope power in the modulated signal is proportional to the square of its envelope amplitude at every instant. This fact is highly important in the operation of every method of amplitude modulation.

It is convenient, and customary, to describe the operation of modulation systems in terms of sine-wave modulation. Although this wave shape is seldom actually used in practice (voice wave shapes depart very considerably from the sine form) it lends itself to simple calculations and its use as a standard permits comparison between systems on a common basis. With sine-wave modulation the *average* power in the modulated signal over any number of full cycles of the modulation frequency is found to be 1-1/2 times the power in the unmodulated carrier. In other words, the power output increases 50 percent with 100-percent modulation by a sine wave.

This relationship is very useful in the design of modulation systems and modulators, because any such system that is capable of increasing the *average* power output by 50 percent with sine-wave