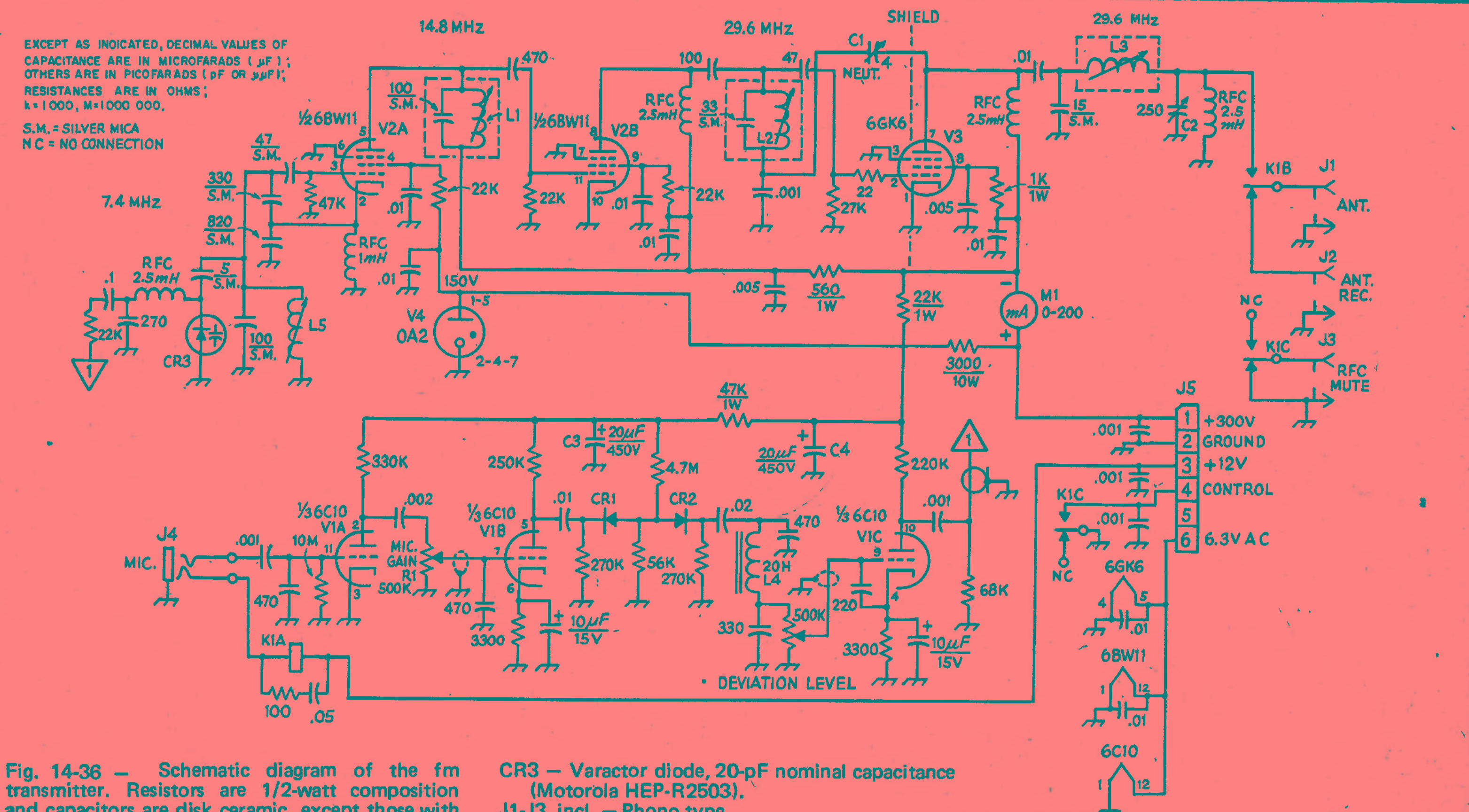

Fig. 14-36 — Schematic diagram of the fm transmitter. Resistors are 1/2-watt composition and capacitors are disk ceramic, except those with polarity marked which are electrolytic.

C1 — Miniature air variable (Johnson 189-501-5 or similar).

C2 — Mica-insulated padder (J. W. Miller 160-E or similar).

C3, C4 — Tubular electrolytic.

CR1, CR2 — 1N67A or similar germanium diode.

CR3 — Varactor diode, 20-pF nominal capacitance (Motorola HEP-R2503).

J1-J3, incl. — Phono type.

J4 — 3-circuit microphone jack.

K1 — 3 pdt relay, 3-A contacts, 12-volt coil (Potter and Brumfield KHP17D11).

L1, L5 — 1-1.87-μH slug-tuned coil (J. W. Miller 42A156CBI).

L2 — Approx. 0.9 μH slug-tuned coil, J. W. Miller 42A156CBI with 5 turns removed.

L3 — 1.35-2.75-μH slug-tuned coil (J. W. Miller 42A226CBI).

L4 — 20-H filter choke, 15 mA (Stancor C-1515 or similar).

M1 — Milliammeter (Simpson 06171).

R1 — Audio-taper composition control.

R2 — Linear-taper composition control.

Fig. 14-37 — Bottom view of the transmitter. The audio components are grouped on the right-hand side of the chassis, while the exciter section runs from top to bottom along the left-hand chassis wall. All external connections are brought out to the rear-deck jacks, with the exception of the microphone connector which is located on the front panel.

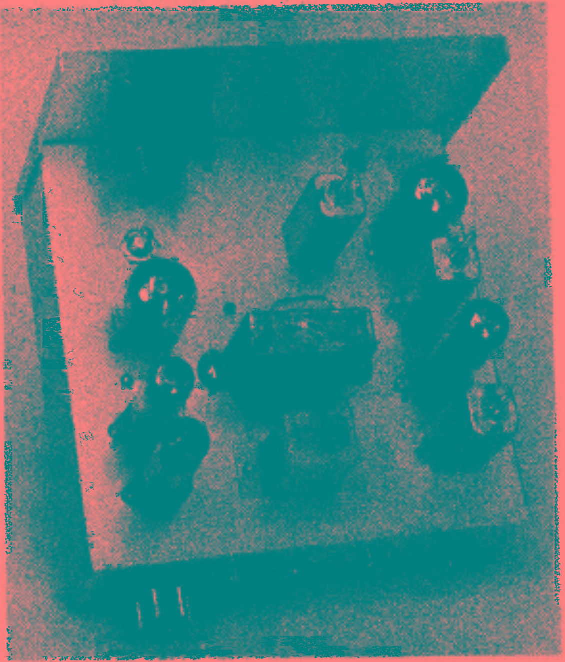

Fig. 14-38 — Either a single 0A2 or two 0A3 VR tubes may be used to regulate the screen voltage for the oscillator. In this model two regulators are used, the two tubes located at the lower-right side of the chassis. The control just below the meter is the DEVIATION adjustment.

running about 9-watts input power. A pi-section network couples the final amplifier to the antenna. Send-receive switching is accomplished by K1, which is activated by a PTT switch on the microphone.

Construction Details

The transmitter is built on a 7 X 7 X 2-inch chassis (Bud AC-405), using a 7 X 5-inch front panel. The plate-current meter, M1, is a useful tune-up accessory, but it may be replaced by a test jack in the interest of economy. After the initial adjustments have been accomplished, the rig will seldom need "touching up." The inexperienced builder should follow the general layout shown in the photographs. All tuned circuits except the oscillator are housed in shielded cans (J. W. Miller S-32). A shield isolating the input and output pins of the V3 socket is a good idea. Long audio leads should be run through shielded cable to prevent hum and rf pickup.

Tuning

The fm transmitter may be operated from an ac or mobile power supply. Suitable designs are given in Chapter 5. After checking the wiring for a second time for errors, apply filament power and allow the tubes to warm up. Then key K1 on, and check to see that the 0A2 (or two 0A3s) voltage-regulator tube is operating properly. Check the screen-voltage lead for the oscillator to see that it supplies 150 volts.

Use a 40-meter receiver to monitor the oscillator signal. With no audio applied, the oscillator should produce a clean carrier. Adjust L5 until the frequency of the oscillator is close to 7.4 MHz. A wavemeter, coupled to L1 and L2, should be employed to tune up the oscillator and doubler tank circuits, respectively. Insure that these tuned circuits are in fact resonated at the frequencies indicated on the diagram. Mistuning can result in spurious signals being radiated outside the amateur bands. Then, adjust L3 and C2 for maximum output power to a 50-ohm dummy load. An rf power bridge or Monimatch can be used to check the output level.

Erratic plate current readings usually indicate instability in the PA stage. If such a problem develops, disconnect the screen-voltage lead of the 6GK6. Couple a wavemeter to L3 and adjust the neutralizing capacitor, C1, for minimum rf energy at L3. Then, reconnect the screen lead.

With a test audio signal applied, the MIC. GAIN control should be advanced until clipping action starts (monitor the output of the clipper stage on an oscilloscope). Then, set the DEVIATION control for the desired amount of fm. Note: *FCC* *regulations require that the deviation of an amateur fm transmitter be held to 2.5 kHz or less below 29 MHz.* Above 29 MHz larger amounts of deviation may be employed; 5 and 15 kHz are the current standards for the operation around 29.6 MHz. Methods of setting deviation are discussed earlier in this chapter. With the microphone connected, the MIC. GAIN control should be advanced until about 10 dB of speech clipping is produced, when speaking in a normal voice.

A TONE-BURST GENERATOR FOR REPEATER ACCESS

This circuit was designed in an effort to side step some of the problems of tone-burst generators, such as instability, temperature effects, difficulty of adjustment, or hard-to-find components. Cost was also a consideration; the unit can be duplicated with all new parts (excluding the pc board) for $10 or less. Stability is such that drift is less than one hertz after an hour of operation. Potentiometers allow ease of adjustment to the desired frequencies of operation. The design is centered around a Signetics NE566V phase locked loop IC[1]. The tone frequencies are determined by C1 and R1 plus R2 through R7. The capacitance remains constant and the resistance is changed to set the various tones.

The formula

$$f = \frac{1}{3 \cdot R1 \cdot C1}$$

is used to calculate the frequency of oscillation.

[1] *Phase-Locked Loops Applications,* Signetics Corporation, 811 East Arques Ave., Sunnyvale, CA 94086.

The total resistance needed is approximately 28 kΩ for 1800 Hz and 20 kΩ for 2400 Hz. Since the overall resistance, between the extremes, is only 8 kΩ, potentiometers of 10-kΩ value were used to adjust the frequency and a 50-kΩ unit was used to set the range. Shunting C1 with Q1 causes the tone to cease. The values of C2 and R8 determine the burst duration.

In operation Q1 has +12 V applied to the base and is in full conduction, shunting C1. When the PTT line is grounded, Q1 will cut off and allow the PLL to oscillate. C2 will begin charging through R8 and again force Q1 into conduction, shunting C1, and stopping the oscillation. The .05 µF capacitor and the 1-MΩ resistor provide isolation and a high impedance to the audio line.

Construction

Since the NE566V is a voltage-controlled oscillator, it is very sensitive to voltage changes and a Zener-diode regulated supply is a necessity. The HEP724 (Q1) must be removed from the circuit in

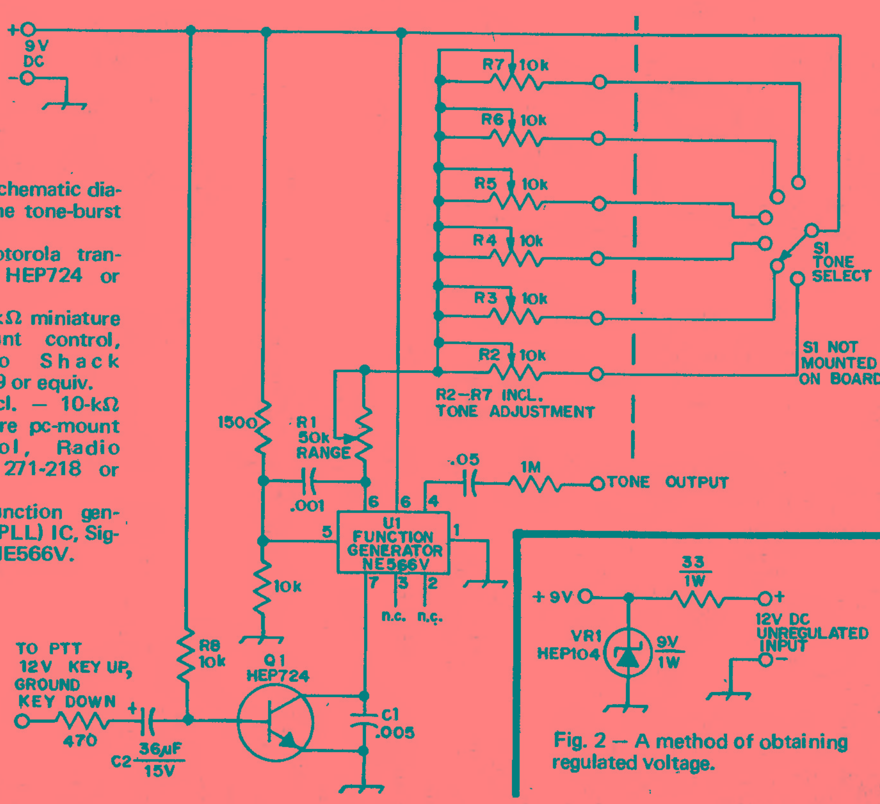

Fig. 1 — Schematic diagram of the tone-burst generator.
Q1 — Motorola transistor, HEP724 or equiv.
R1 — 50 kΩ miniature pc-mount control, Radio Shack 271-219 or equiv.
R2-R7, incl. — 10-kΩ miniature pc-mount control, Radio Shack 271-218 or equiv.
U1 — Function generator (PLL) IC, Signetics NE566V.

Fig. 2 — A method of obtaining regulated voltage.

Top view of the circuit board built by Glenn Dickson, WB5BAF. The unit was originally described in April, *QST*, 1974.

order to adjust the tones; therefore, a socket should be used for this transistor.

The circuit is constructed on a pc board measuring 1-1/4 × 2-7/8 inches (32 × 73 mm). A single-pole, 6-position switch is used to select the desired tone. Don't forget to provide an ON-OFF switch. Some people get upset if you are using tone-burst and the repeater doesn't require it.

Adjustment

Remove Q1 from the circuit. This will allow the oscillator to run continuously. Connect a counter to the junction of the .05μF capacitor and the 1-MΩ resistor.

Set R2 through R7 to minimum resistance, then adjust R1 for 2500 Hz. Set the selector switch to position 1 and adjust the corresponding control for the desired frequency. Repeat this with the rest of the potentiometers.

After setting all of the controls replace Q1 and check the burst duration. Using a value of 35 μF for C2 will give a burst duration of 0.4 second. If a different duration is desired change the value of C2. Do not change the value of R8.

A TONE BEEP KEYER FOR REPEATERS

This simple telemetry[1] circuit was designed for the WR6ABN repeater. Earlier uses of tones and tone bursts reminded users to allow time for breaking stations, and to indicate that the time-out timer had been reset. This latter indication was by means of transmitting two tones simultaneously.

This system is designed to inhibit one of the two tones, selectively, and allow either the high or low tone to indicate the position of the user's carrier in the receiver passband.

The sensors were adjusted to trip the relays at 1 kHz above or below the center frequency; this appears to be a practical value for narrow-band receivers. Thus, the "on-channel" slot is 2-kHz wide, centered about the receiver input frequency.

This system makes use of such nonexotic equipment as relays to perform the switching. Those readers who are well versed in solid-state logic systems will find it easy to apply the principles to their favorite machine.

Technical Description

The 741 op amp is set for a dc gain of 1000. The ac gain of the circuit is very low, as set by the 1 μF bypass capacitor across the 1-MΩ resistor in the feedback loop, and the 1 μF across the 50-kΩ control in the input circuit. The output of the 741 feeds two transistors and a zero-center meter.

The steering diodes, CR1 and CR2, allow the op amp to drive Q1 or Q2 into conduction and to charge C1 or C2 to the value of the op-amp output voltage. R1 and R2 allow capacitors C1 and C2 to charge above the base voltage of the transistors and to cause them to conduct for about 5 seconds after the drive voltage from the op amp is removed. This delay acts as a memory, so the delayed tone beep can indicate the frequency readout after the carrier of the user station goes off.

Note that the poor ac frequency response of the op-amp means that the input to it must remain for approximately 3 seconds in order for it to load C1 or C2 for the readout. This delay was intentional for two reasons: (1) to prevent noise or fluctuating signals from giving false readings, and (2) to prevent unscrupulous users from abusing the device by keying up several short bursts.

The input to the op amp is shorted to ground when a carrier is not present. This prevents noise from loading up the sensor prior to a reading. It also allows the adjustment of the dc offset control, R5. The calibrate potentiometer, R6, is adjusted to a point where signals 1 kHz above or below the center frequency of the receiver will just trip relays K4 or K5. (Note that the receiver should be adjusted so that the discriminator voltage is zero with no signal.) This adjustment of R6 to ±1 kHz determines the slot width. The center frequency is determined by the usual crystal-oscillator adjustments in the receiver.

K1 can be the normal COR or a separate relay keyed by the COR. This relay keys both the input to the op amp and the delay relay, K2. Because of the discharge time of C3, K2 will have a delayed release. When K2 releases, it keys K3 for a short period as determined by C4 and R8. The values needed for C3, C4, R7 and R8 will vary, depending upon the characteristics of K2 and K3.

[1] "Telemetering. Measurement with the aid of intermediate means that permit the measurement to be interpreted at a distance from the primary detector." — *IEEE Standard Dictionary of Electrical and Electronics Terms, 1972.*

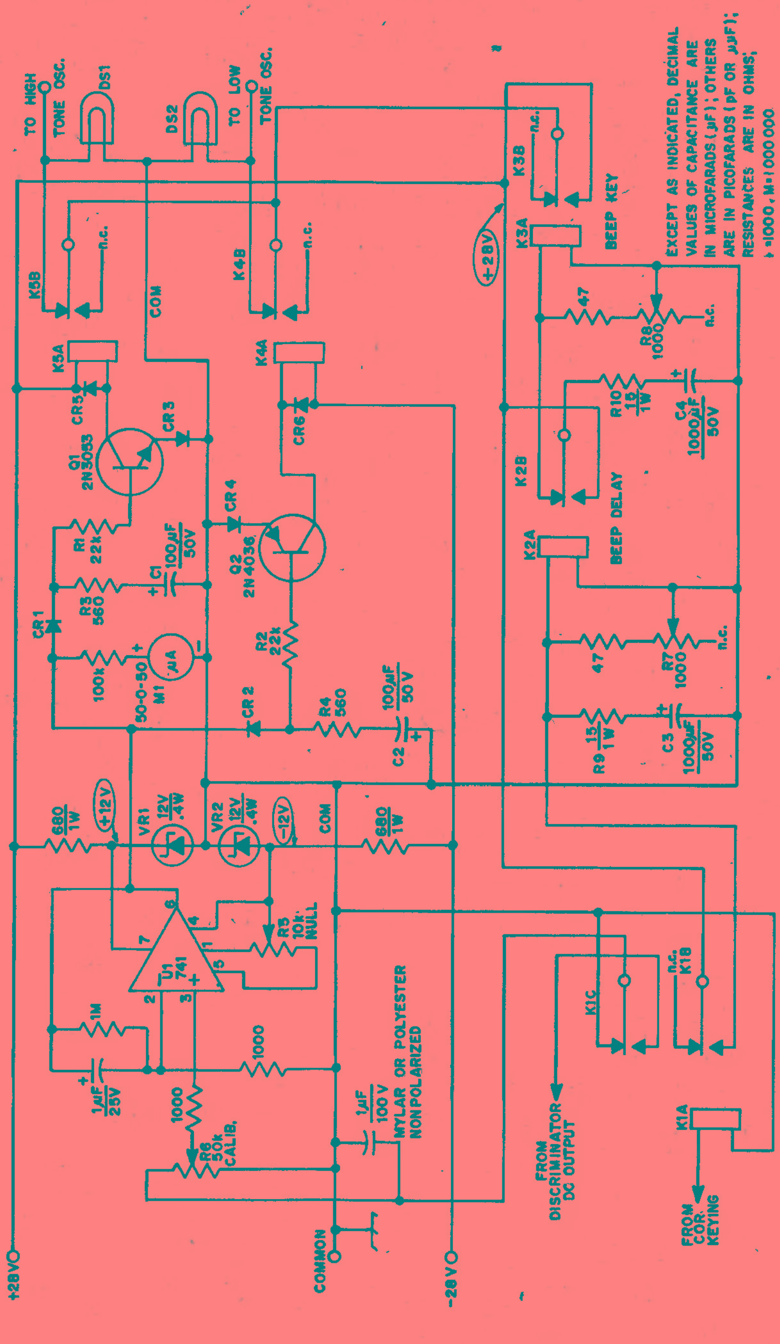

Fig. 1 — The schematic diagram of the tone-beep keyer. A dual 28-V supply is used in this system, but there should be no difficulty in revising values to make use of lower voltages. The charging current of C1 through C4 is limited to a sefe value by means of the series resistor in each case. If the meter is omitted, tip jacks should be provided to aid in adjusting the circuit.

CR1-CR6, incl. — Silicon diodes, 1N2069 or equiv.

DS1, DS2 — 28-V pilot lamps. Lower-voltage units or LEDs with suitable dropping resistors may be used.

K1 — Dpdt relay. Coil voltage and current must be compatible with voltages available from receiver COR circuitry.

K2-K5, incl. — Spdt relays, 450- to 700-ohm coil for 24 V dc. Allied Control T154-2C or equiv.

U1 — Operational amplifier IC. Fairchild µA741 (U5B7741312), Signetics µA741T or µA741CV, Motorola MC1741G or MC1741P1 or equiv.

Operational Notes

1) K2 establishes length of delay between end of carrier and keying of tone beep.

2) K3 establishes length of tone beep.

3) K4 or K5 select the desired tone to be keyed.

4) Adjust R5, NULL control, for zero dc volts at the output of the 741 with K1 deenergized.

5) The trip point of K4 or K5 is adjusted by means of R6, the CALIBRATE control. It should be adjusted while monitoring a carrier set to the desired frequency offset value.

This unit was built by W6MEP and described originally in *QST* for May, 1974.

IMPROVING FM RECEIVER PERFORMANCE

Many older fm receivers, and some new models, do not have sufficient sensitivity or limiting capability. Also, the transceivers designed for the mobile telephone service do not have a squelch or audio power-amplifier circuit. Suitable accessory units can be easily constructed to improve the performance of a rig deficient in any of these areas.

A simple preamplifier, such as shown in Fig. 14-45 for 146 MHz and in Fig. 14-47 for 440 MHz, may be added to a receiver to increase its sensitivity and to improve limiting (as the overall gain before the limiter will be increased by 10-15 dB). The 2-meter version uses a dual-gate MOSFET while the 440-MHz unit employs two JFETs in a grounded-gate circuit. Both amplifiers are adjusted by peaking all tuned circuits for maximum limiter current while receiving a weak signal.

A receiver will have a poor limiting characteristic if the gain before the limiter circuit is insufficient, or if the limiter itself is of poor design. The circuit of Fig. 14-48 can be added to a receiver to replace an existing limiter stage. The new limiter uses an RCA CA3011 integrated circuit. Care must be used in the installation and layout of this high-gain IC to insure stability. The CA3011 will provide a "hard" limiting characteristic with about 100 mV of signal input.

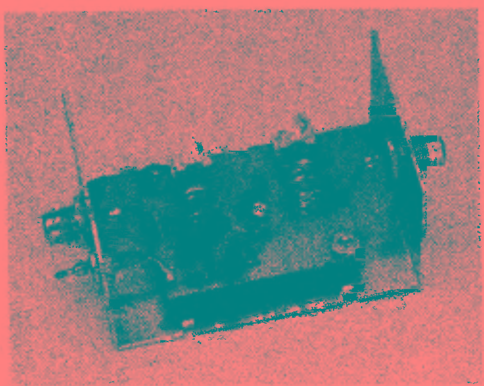

Fig. 14-44 — The 2-meter preamp. may be mounted in a small Minibox or connected directly inside an fm receiver.

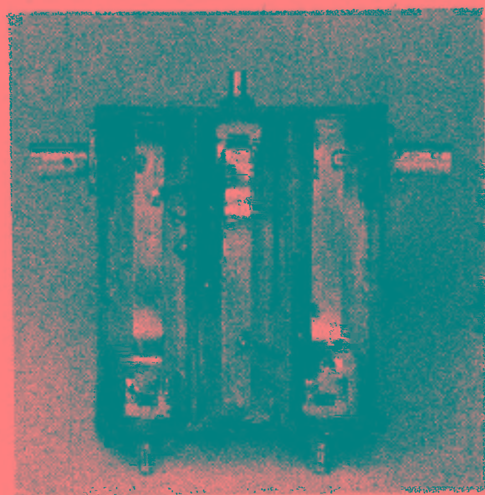

Fig. 14-46 — The 440-MHz preamplifier is constructed in e 3 X 3 1/2 X 1-inch box made of double-sided circuit board. All abutting edges are soldered to complete the enclosure. Two 3 X 15/16-inch shields separate the tuned lines.

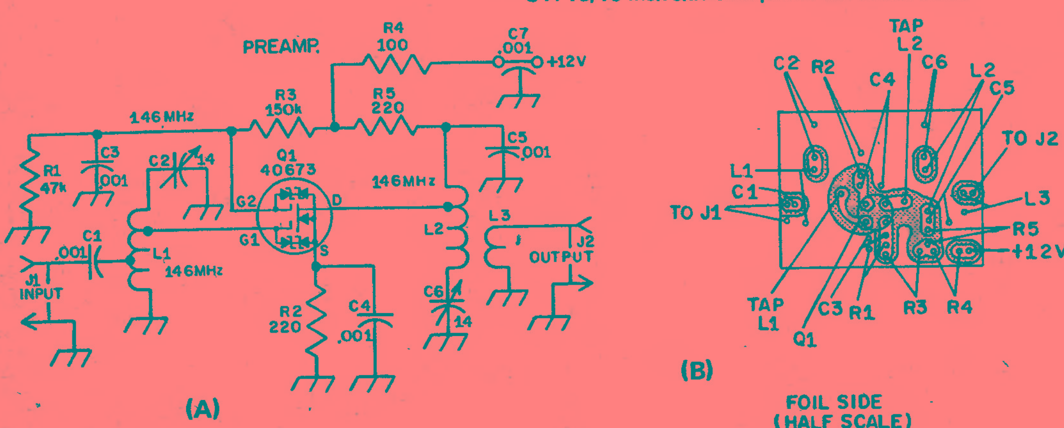

Fig. 14-45 — Circuit diagram (A) and pc-board layout (B) for the 2-meter preamplifier. Resistors are 1/4-watt composition and capacitors are disk ceramic unless otherwise noted. Componants not listed below are given designators for circuit-board location purposes.

C2, C6 — Air variable (Johnson 189-506-5).

J1, J2 — Phono type, panel mount

L1 — 5 turns, No. 16, 5/16 inch dia, 1/2 inch long. Tapped at 2 turns for the antenna connection, and 4 turns for G1.

L2 — 4 turns, No. 16, 5/16 inch dia, 3/8 inch long. Tapped at 2 turns.

L3 — 1 turn, plastic-covered hookup wire, 5/16 inch dia, placed between two turns of L2.

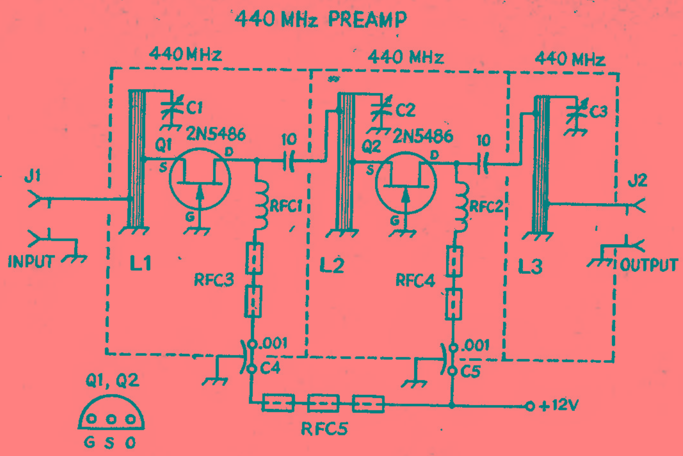

Fig. 14-47 — Schematic diagram of the uhf preamplifier. Capacitors are disk ceramic unless otherwise noted.

C1-C3, incl. — 1.4 to 9.2-pF miniature variable (Johnson 189-0563-001).

C4, C5 — Feedthrough type.

J1, J2 — BNC type, chassis mount.

L1-L3, incl. — 2 5/8 X 1/4-inch strip of brass, soldered to the enclosure on one end and to the capacitor at the other. Input and output taps (on L1 and L3) are 1/2-inch up from the ground end. Drain taps for Q1 and Q2 on L2 and L3, respectively, are made just below C2 and C3.

RFC1, RFC2 — 420-MHz choke (Miller 4584).

RFC3, RFC4 — Two ferrite beads on a short piece of No. 20 hookup wire. (Beads are available from Amidon Associates, 12033 Otsego St., N. Hollywood, CA 91607.)

RFC5 — Three ferrite beads on No. 20 hookup wire.

Q1, Q2 — Motorola JFET.

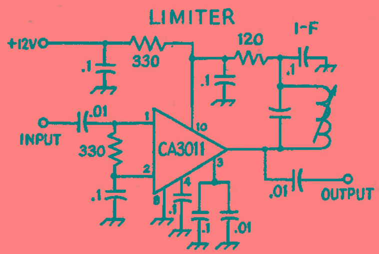

Fig. 14-48 — Diagram of a limiter which may be added between the last i-f stage and the detector of a receiver.

FM Bibliography

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A SOLID-STATE FM TRANSMITTER FOR 146 MHz

In an effort to shrink the dimensions of the solid-state fm transmitter treated earlier in *QST*, and in the 1972 *ARRL Handbook*, it became necessary to eliminate one stage of the rf section, and to reduce the size of the speech amplifier and clipper. The product of that effort is shown schematically in Fig. 1.

A slightly different electrical approach was taken, wherein the oscillator was called upon to deliver a fair amount of power. The increased output from Q1 permitted the deletion of a driver stage ahead of the PA. The change made it necessary to pay particular attention to the design of all networks between stages, providing adequate selectivity to assure suppression of unwanted output frequencies. The criterion was met, as evidenced by a spectral display of the output energy. The MK-II version is as clean as was the MK-I model.

A logical approach to reducing the area occupied by the speech amplifier and clipper was the employment of a transistor-array IC as opposed to the use of discrete components. The latter technique was used in the MK-I example.

Circuit Highlights

Generally, the circuit of Fig. 1 follows the classic sonobuoy format given in RCA's *Power Circuits, DC to Microwaves.*[1] Some of the circuit changes made are radical; others are subtle. The

[1] Recommended for amateur libraries. Order from local radio store, or write RCA Electronic Components, Harrison, NJ 07029. Price: $2.

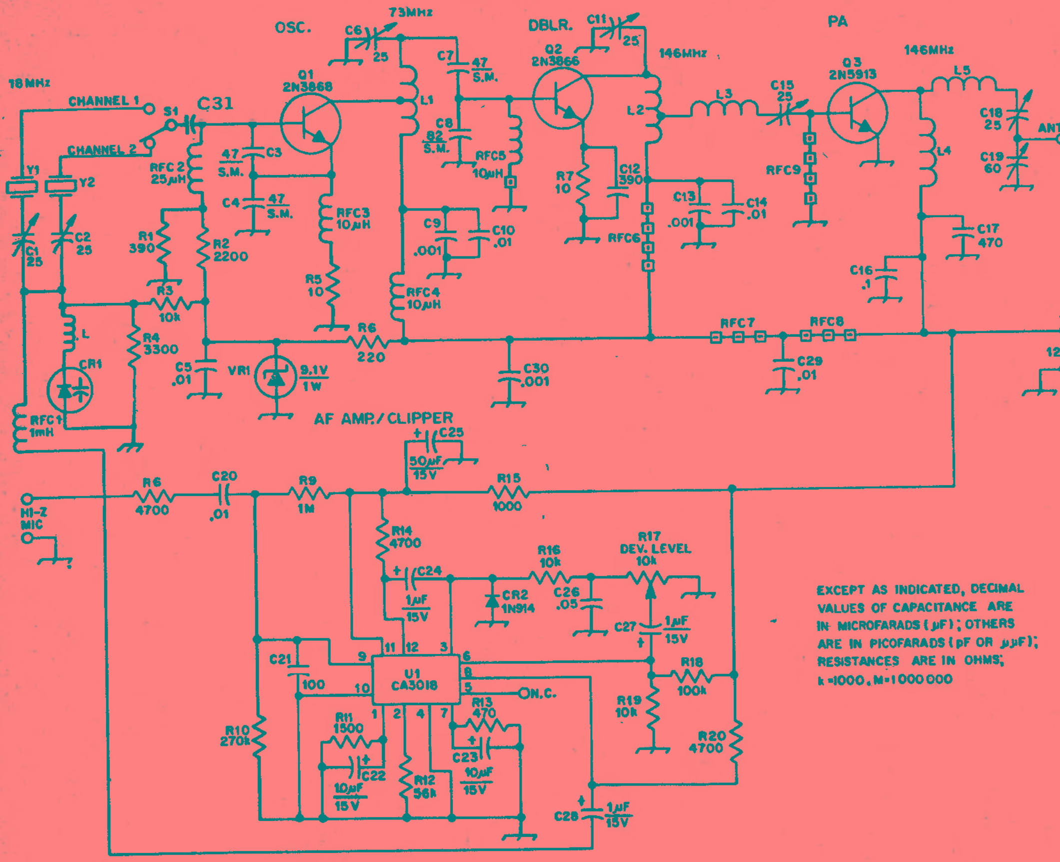


Fig. 1 — Schematic diagram of the 2-meter fm transmitter. Fixed-value capacitors are disk ceramic unless otherwise marked. Polarized capacitors are electrolytic. Fixed-value resistors are 1/2-watt composition. Numbered components not appearing in parts list are so numbered for pc-board layout purposes only. Use crown type heat sink on Q1, larger style on Q2 and Q3.

C1, C2, C6, C11, C15, C18 — 7- to 25-pF miniature ceramic trimmer (Erie 538-002B-7-25 or equiv. Avail. new from Newark Electronics. Avail. surplus from Reliance Merchandising Co., Phila. PA).
C19 — 15- to 60-pF miniature ceramic trimmer (Erie 538-002F-15-60 or equiv.).
C31 — 100-pF silver mica.
CR1 — Voltage-variable capecitor (Varicap) diode.
CR2 — High-speed silicon switching diode.
L — 1 to 2 μH inductor. 20 turns No. 30 enam. close-wound on 100,000 ohm, 1-watt resistor.
L1 — 5 turns No. 16 tinned bus wire, 1/4-inch ID × 5/8 inch long. Tap at 1-1/2 turns from 12-volt end.
L2 — 3 turns No. 16 tinned bus wire, 1/4-inch ID × 3/8 inch long. Tap at 1/2 turn from C13 end.
L3 — 4 turns No. 22 enam. wire, close-wound, 1/4-inch ID.
L4 — 25 turns No. 28 enam. wire, close-wound on body of 100,000-ohm, 1-watt resistor. Use resistor pigtails as anchor points for ends of winding.
L5 — 5 turns No. 16 tinned bus wire, 5/16 ID × 1/2 inch long.
Q1-Q3, incl.— RCA transistor.
R17 — 10,000-ohm pc-board carbon control linear taper (Mallory MTC 14L1 or equiv.).
RFC1 — 1-mH miniature rf choke (Millen J300-25).
RFC3, RFC4 — 10-μH miniature rf choke (Millen J300-10).
RFC5 — 10-μH miniature rf choke (Millen J300-10) with one Amidon ferrite bead over ground-end pigtail.
RFC6, RFC9 — 4 Amidon ferrite beads on 1/2-inch length of No. 24 wire (Amidon Associates, 12033 Otsego St., No. Hollywood, CA 91607).
RFC7, RFC8 — Same as RFC6 but with three beads on 3/8-inch length of wire.
S1 — Spdt slide or rotary switch.
U1 — RCA integrated circuit.
VR1 — 9.1 volt, 1-watt Zener diode.
Y1, Y2 — 18-MHz crystal (International Crystal Co. ground for 20-pF load capacitance. HC-25/U holder. Use International FM-2 pc-board crystal socket). High accuracy .002 percent temperature-tolerance crystal recommended.

boiled-down version is based on amateur-band performance criteria and the more commonly available supply voltage of 12. Emphasis has been placed on good frequency stability, narrow-band deviation (up to 6 kHz), and relative freedom from spurious output.

Low-cost transistors are used at Q1 and Q2. A ballasted transistor (mismatch protected) is used at Q3 to prevent burnout resulting from temporary open- or short-circuit conditions in the antenna system. The current OEM price (single lot) for the 2N5913 is $3.63. Over-the-counter prices will be slightly higher, but it is recommended that the builder use the '5913 if he wishes to have the circuit perform as specified here. Substitutes for any of the devices used in the circuit should be employed only by those who are experienced in semiconductor work. The wrong choice can lead to dismal results with the circuit – instability, low output, or destruction of one or more of the transistors.

Ferrite beads are used generously in the circuit, for decoupling of the dc bus and as rf chokes.[2] The beads provide low-Q impedances and are superior to solenoid-wound inductors in preventing circuit instability caused by tuned-base-tuned-collector conditions. A further aid to stability is provided through the use of high and low values of capacitance (combined) in various parts of the circuit. This standard technique helps to assure stability at hf and vhf, and is necessary because of the high f_T of the transistors used.[3]

Transistor sockets should not be used at Q1, Q2 or Q3. The additional lead lengths resulting from the use of sockets could lead to instability problems. Those wishing to use a socket at U1 may do so by redesigning the pc board to allow a socket to be installed (bringing the twelve holes for the IC closer together). Alternatively, one might employ an IC socket which has fairly long lugs, bending the lugs outward to mate with the holes in the pc-board.

Speech Amplifier

U1 consists of four bipolar transistors on a common substrate. Two of the transistors are connected for use as a Darlington pair. The remaining two are separate from one another. In the circuit of Fig. 1 the Darlington pair serves as a preamplifier for a high-impedance crystal, ceramic, or dynamic microphone. One of the separate transistors is used as a diode in the clipper circuit (an outboard silicon diode is used to clip the opposite side of the af sine wave), and the remaining transistor amplifies the clipped audio after it is filtered by an *R-C* network. Deviation is set by adjustment of a pc-board potentiometer, R17.

The processed audio is fed to CR1, the varactor diode modulator. Some reverse bias is used on CR1 to assure greater linearity of modulation (3 volts dc taken from the junction of R3 and R4). As the audio voltage is impressed across CR1, the junction capacitance of the diode shifts above the steady-state value which exists when no af voltage is present. The change in capacitance shifts the crystal frequency above and below its nominal value to provide fm.

Construction

There are no special instructions provided the builder follows the template pattern offered.[4] However, it is worth mentioning that the *QST*

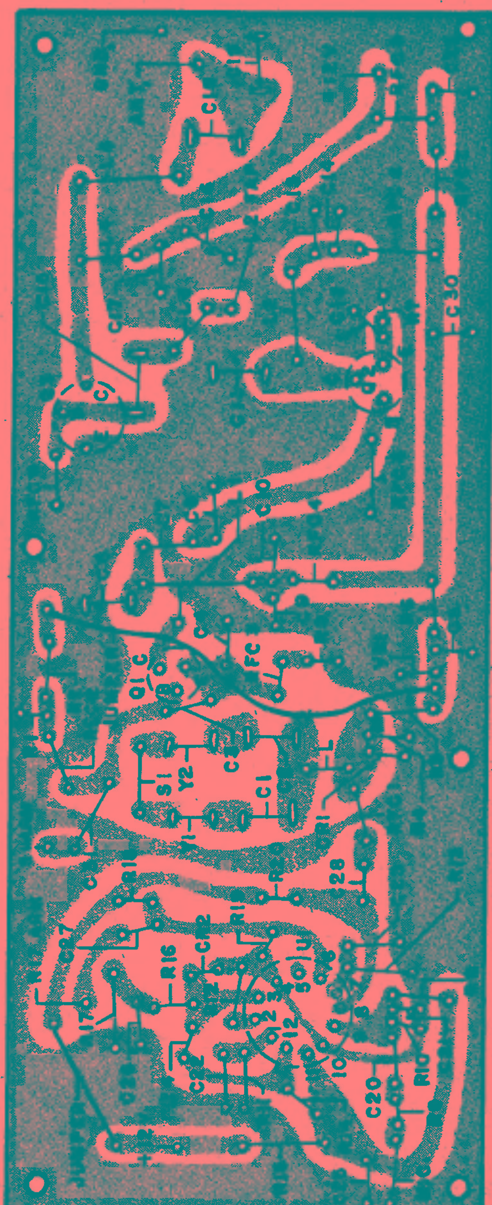


Fig. 2 – Template and parts layout for the transmitter drawn to full scale. Foil-side view.

[2] See parts list for ordering information.

[3] The higher the f_T (upper-frequency rating) of a transistor, the greater will be its gain capability at lower frequencies, thus giving rise to unwanted hf or lf oscillations.

model was built on glass-epoxy circuit board. Those attempting to use phenolic or other types of pc board may encounter difficulty in obtaining proper circuit performance. The dielectric properties of the various board materials are different, thereby causing different values of capacitance to exist between pc-board foil strips. The condition can cause instability, unwanted coupling, and tuned circuits that will not hit resonance. Some builders of the MK-I transmitter learned this the hard way!

Transistors Q2 and Q3 require fairly hefty heat sinks if good efficiency and longevity of the devices is to be realized. Homemade sinks are shown in the photo. Each consists of a piece of 1/16-inch thick aluminum (brass or copper is ok) formed over a drill bit slightly smaller in diameter than a TO-5 transistor case. The aluminum can be crimped in a bench vise until it fits snugly around the drill body. Silicone grease should be used to coat the transistor bodies prior to installation of the heat sinks. The height of the sinks is 1 inch. The ID is approximately 1/4 inch.

Lead lengths of the wires going from the pc board to S1 should be kept short – preferably less than 1-1/2 inches long. Coaxial cable (50-ohm impedance) should be used between the antenna terminals on the pc board and the antenna connector. The shield braid must be grounded at each end of the cable. Similarly, shielded cable should be employed between the microphone jack and the audio-input terminals on the pc board.

Checkout and Use

Initial checkout should be undertaken at reduced supply voltage. Apply a voltage of between 6 and 12, making certain that a dummy load of approximately 50 ohms is connected to the output of Q3. A 56-ohm 2-watt resistor or a No. 47 pilot lamp will suffice. Using a wavemeter tuned to 73 MHz, adjust the collector tank of Q1 for a peak reading on the wavemeter. Next, set the wavemeter for operation at 146 MHz and adjust the collector tuned circuit of Q2 for maximum meter indication. The tank circuit of Q3 should be adjusted for maximum power output as observed on an rf wattmeter or Monimatch-type SWR indicator. A rough check can be made by using a No. 47 lamp as a load, adjusting for maximum bulb brilliancy. The next step is to raise the supply voltage to 12 and repeat the tweaking procedure outlined above. If all stages are functioning normally, a No. 47 lamp should illuminate to slightly more than normal brilliance. Power output into a 50-ohm load should be between 1-1/2 and 2 watts Current drain will be between 200 and 250 mA, speech amplifier included.

Adjustment of the transmitter frequency and deviation can best be done while using a vhf frequency counter and deviation meter. Alternatively, one can put the transmitter in service and ask one of the other fm operators in the area to observe his receiver's discriminator meter while you adjust your crystal trimmer for a zero reading. Deviation can be set reasonably close to the desired amount by comparing your modulation against that of other local stations, having a third operator report the comparisons.

This transmitter is well suited as a companion unit to the fm receiver described in Chapter 3, and in *QST*.[5] The two units can be packaged to form a trans-receiver for portable, mobile, or fixed-station use. The transmitter can be used to drive a high-power solid-state 2-meter amplifier, described later in this chapter, if one wishes to put on a pair of "boots."[6]

[5] DeMaw, "A Single-Conversion 2-Meter FM Receiver," *QST*, August, 1972.

[6] Hejhall, "Some 2-Meter Solid-State RF Power-Amplifier Circuits," *QST*, May, 1972, p. 40.

[7] Write: Spectrum Research Laboratory, Box 5824, Tucson, AZ 85703.

2-METER SOLID-STATE RF POWER-AMPLIFIERS

The majority of the commercially made 2-meter fm transceivers available today have rf power-output levels of 1 to 15 watts. There are many occasions when an fm operator would like to have a little more power to be able to work over greater distances. Described here are two amplifiers, one for 25 watts and another for 50 watts output for the 2-meter band. Both amplifiers use a single transistor and operate directly from a 13.6-volt vehicular electrical system.

Circuit Description

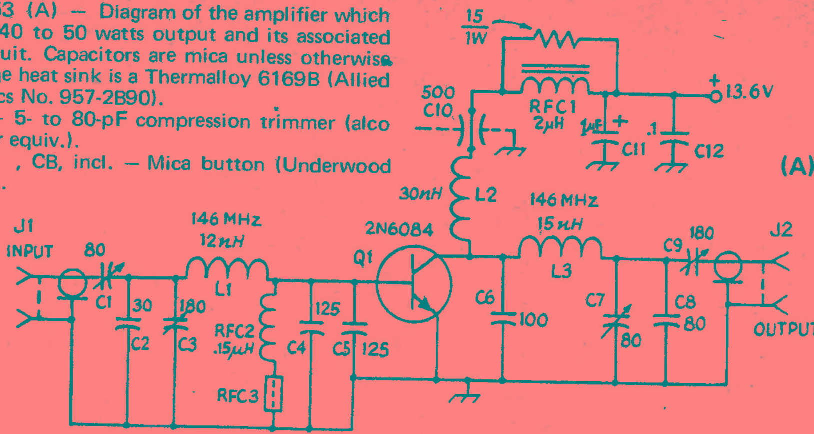
The amplifier circuit shown in Fig. 14-53 utilizes a single 2N6084 transistor operated in a Class-C, zero-bias configuration. This mode of operation has the advantages of high collector efficiency at full output and zero dc current drain when no rf driving signal is applied. The reader should note that zero-bias operation yields an amplifier that is not a "linear." It is designed for

Fig. 14-52 – An end view of the breadboard version of the 50-watt 2-meter amplifier. The input circuit is at the lower right, and the output network is at the upper left.

Fig. 14-53 (A) — Diagram of the amplifier which provides 40 to 50 watts output and its associated COR circuit. Capacitors are mica unless otherwise noted. The heat sink is a Thermalloy 6169B (Allied Electronics No. 957-2B90).

C1, C7 — 5- to 80-pF compression trimmer (alco 462 or equiv.).

C2, C4-C , CB, incl. — Mica button (Underwood J-101).



C3, C9 — 9- to 180-pF compression trimmer (Arco 463 or equiv.).

C10 — Feedthrough type.

C11 — Tantalum.

C12, C15, C16 — Ceramic disk.

C13, C14 — 39-pF mica (Elmenco 6ED390J03 or equiv.).

CR1 — 100-PRV or more, 500-mA or more silicon diode (Motorola 1N4001 or equiv.).

CR2,CR3 — High-speed, low capacitance 100-PRV silicon diode (Motorola MSD7000 dual package used here).

J1,J2 — Coaxial connector, panel mount.

K1 — 4pdt open-frame relay, 12-V contacts (Comar CRD-1603-4S35 or equiv., Sigma 67R4-12D also suitable), modified as described below.

L1 — 12 nH, No. 10 tinned wire, 1 1/4-inch long straight conductor.

L2 — 30 nH, 1 3/4 turns, No. 10 tinned wire, 3/8 inch ID, 3/4 inch long.

L3 — 15 nH, No. 14 tinned wire, 3/4-inch long straight conductor.

L4 — 2 turns of No. 18 tinned wire 1/4-inch ID, 0.2 inch long (approximately 44 nH).

Q1 — Motorola silicon power transistor.

Q2 — Npn silicon Darlington transistor, h_{FE} of 5000 or more (Motorola MPS-A13 or equiv.).

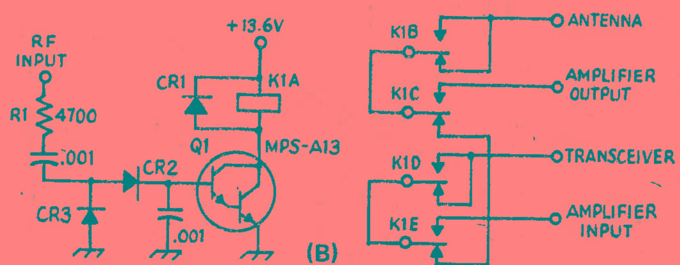
R1 — 15 ohm, 1-watt composition.

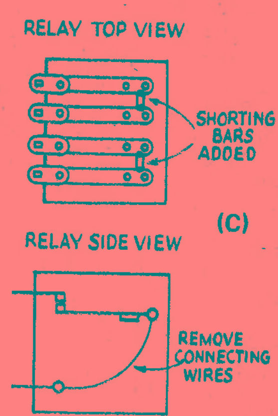
R2 — 4700 ohm 1/2-watt composition

RFC1 — 17 turns, No. 16 enam. wire wound on Amidon T-80-2 toroid core.

RFC2 — Molded rf choke (J. W. Miller 9250-15).

RFC3 — Ferrite bead (Ferroxcube 56-590-65/3B or equiv.).





(B) COR circuit. Capacitors are disk ceramic.

The COR relay is modified by removing the connecting wires from all four wiper arms and adding two shorting bars, as shown. Only the stationary-contact connections are used.

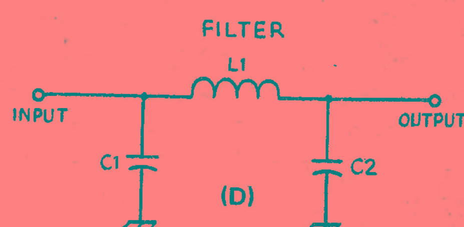
CR1 — 100-PRV or more, 500-mA or more silicon diode (Motorola 1N4001 or equiv.).

CR2, CR3 — High-speed, low-capacitance 100-PRV silicon diode (Motorola MSD7000 dual package used here).

K1 — 4pdt open-frame relay, 12-V contacts (Comar CRD-1603-4S35 or equiv., Sigma 67R4-12D also suitable), modified as described below.

Q2 — Npn silicon Darlington transistor, h_{FE} of 5000 or more (Motorola MPS-A13 or equiv.).

(C) The COR relay is modified by removing the connecting wires from all four wiper arms and adding two shorting bars, as shown. Only the stationary-contact connections are used.



(D) Pi-section output filter, C1 and C2 are 39-pF mica capacitors (Elmenco 6ED390J03 or equiv.), and L1 consists of 2 turns of No. 18 tinned wire, 1/4 inch ID, 0.2 inch long (approximately 44 nH).

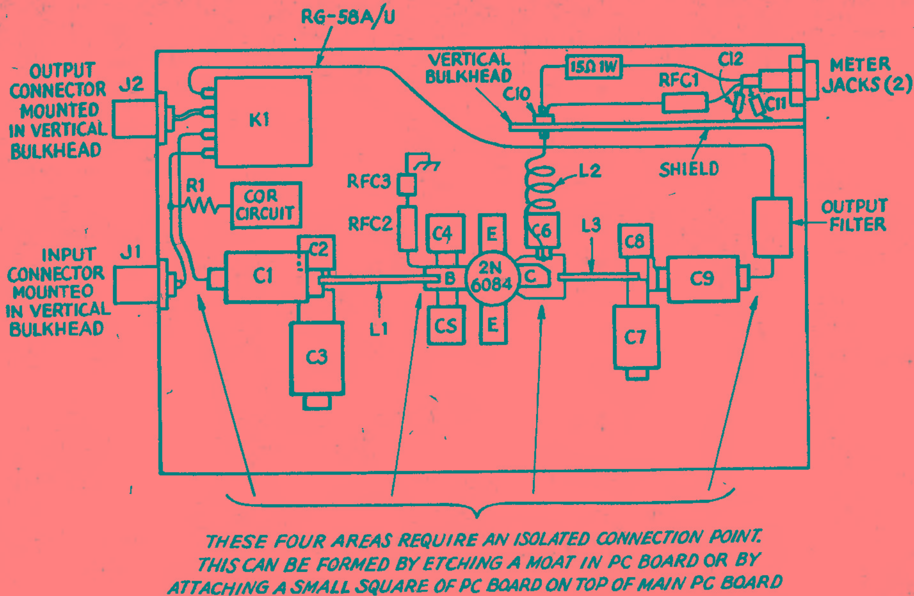


Fig. 14-54 — Parts-layout diagram for the 50-watt amplifier (not to scale). A 4 × 6-inch pc board is used as the base.

fm (or cw— operation only, and would produce objectional distortion and splatter if used to amplify either a-m or ssb signals.

The amplifier operates directly from an automobile electrical system, so no additional power supply is required for mobile operation. The input and output-tuned circuits are designed to match the impedances of the transistor to a 50-ohm driving source and to a 50-ohm antenna system, respectively. Since both the input and output impedances of the transistor are extremely low (in the 1- to 5-ohm region), the matching networks employed are somewhat different than those used with tubes. The networks chosen for the amplifier are optimized for low-impedance matching, and they perform their tasks efficiently. The network designs for this amplifier were done with the aid of a computer.

The elaborate decoupling network used in the collector dc feed is for the purpose of assuring amplifier stability with a wide variety of loads and tuning conditions. The 2N6084 transistor is conservatively rated at 40 watts output (approximately 60 watts dc input). The amplifier can readily be driven to power output levels considerably higher than 40 watts, but it is recommended that it be kept below 50 watts output. If your transmitter or transceiver has greater than 10 watts output, an attenuator should be used at the amplifier input to keep the output from the amplifier below 50 watts.

Construction Details

Construction of the amplifier is straightforward. The usual precautions that must be observed when building a solid-state final amplifier are followed. These precautions include proper mechanical mounting of the transistor, emitter grounding, heat sinking, and decoupling of the supply-voltage leads. Most of the components used are conventional items which are readily available, with two exceptions. The fixed mica capacitors, Underwood type J-101, are a special mica unit designed for high-frequency applications. The core for RFC1 and the rf bead used for RFC3 are available from Elna Ferrite Labs, Inc., 9 Pine Grove St., Woodstock, NY 12498.

The amplifier is constructed on a pc board which is bolted to a heat sink. A few islands can be etched on the board for tie points, at the builder's discretion; a complex foil pattern is not required. In the amplifier shown in the photo, islands were etched only for input and output tie points. Circuit-board islands may also be etched for the transistor base and collector leads. However, an interesting alternative method was used in the author's breadboard amplifier. The base and collector islands were formed by attaching small pieces of pc board to the top of the main board. This procedure added a few tenths of a pF of capacitance at the connection points, so if you choose to etch islands directly on the main board you may want to increase the value of C6 slightly. (The values of C4 and C5 are not critical.)

A word about the care of a stud-mount rf power transistor: Two of the most important mounting precautions are (1) to assure that there is no upward pressure (in the direction of the ceramic cap) applied to the leads, and (2) that the nut on the mounting stud is not over-tightened. The way to accomplish item 1 is to install the nuts *first* and solder the leads to the circuit later. For item 1, the recommended stud torque is 6 inch-pounds. For those who don't have a torque wrench in the

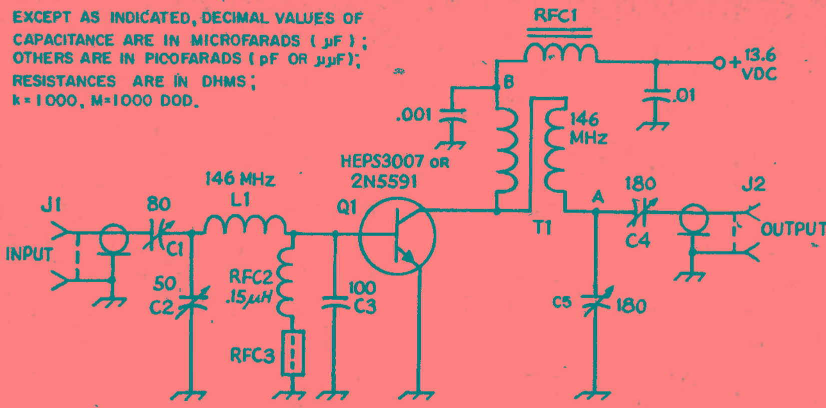


Fig. 14-55 — Circuit diagram of the 25-watt amplifier. Capacitors are disk ceramic unless otherwise noted.
C1 — 5- to 80-pF compression trimmer (Arco 462 or equiv.).
C2 — 2- to 50-pF compression trimmer (Arco 461 or equiv.).
C3 — Button mica (Underwood J-101).
C4, C5 — 9- to 180-]-pF compression trimmer (Arco 463 or equiv.).
J1, J2 — Coaxial connactor, panel mount.
L1 — 1-inch length of No. 14 tinned wire.
Q1 — Motorola silicon power transistor (2N5591 or HEP S3007 for 25 W output, 2N5590 or HEP S3006 for 10 W output).
RFC1 — Ferroxcube VK200-19/4B ferrite choke.
RFC2 — Molded rf choke (J. W. Miller 9250-15).
RFC3 — Ferrite beed (Ferroxcube 56-590-65/3B or equiv.).
T1 — See Fig. 14-56.

shack, remember that it is better to under tighten than to over tighten the mounting nut.

The transistor stud is mounted through a hole drilled in the heat sink. A thermal compound, such as Dow Corning 340 heat-sink grease, should be used to decrease the thermal resistance from transistor case to heat sink. See the excellent article by White in *QST* for April, 1971, for details of heat-sink design.

Series impedance in the emitter circuit can drastically reduce the gain of the amplifier. Both transistor emitter leads should be grounded as close to the transistor body as is practical.

The wiring for the dc voltage feeder to the collector should have extremely low dc resistance. Even a drop of one volt can significantly reduce the power output of the amplifier. A good goal is less than 0.5 volt drop from the car battery to the transistor collector. With operating currents of several amperes, a total dc resistance of only a fraction of an ohm is needed. A standard commercially made heat sink is used for the 50-watt amplifier, and it is adequate for amateur communications. Forced-air cooling across the heat sink should be used for any appliation requiring long-term key-down operation at 40 watts or more of output.

Tune-Up Procedure

Generally, the best way to tune a transistor final is for maximum rf power output. If this approach results in exceeding the power ratings of the transistor, then the power output should be reduced by reducing the drive-level, not by detuning the final. In the case of an outboard PA stage, such as described here, both the input and output networks can be tuned for maximum rf output, if the driving source has an output impedance of approximately 50 ohms. However, a better procedure consists of tuning the output tank circuit for maximum rf output and tuning the input circuit for minimum SWR as measured between the exciter and the final amplifier. This tune-up procedure has the added advantage of assuring that the amplifier presents a 50-ohm load to the exciter. A dc ammeter to check collector current is a useful tune-up aid. Since tuning is for peak output, a Monimatch-type SWR bridge is adequate for the job. Also, the wattmeter described in Chapter 22 would be an excellent choice. The best tuning procedure is to monitor simultaneously both output power (absolute or relative) and the SWR between the exciter and amplifier.

First, apply dc voltage with no rf drive. No collector current should flow. Then apply a low level of rf drive – perhaps 25 percent or less of the rated 10 watts maximum drive – and tune the input network for maximum indicated collector current. The networks may not tune to resonance at this low drive level, but you should at least get an indication of proper operation by smooth tuning and lack of any erratic behavior in the collector-current reading. Gradually increase the drive, retuning as you go, until the rated 7-10 watts input and 40 to 50 watts output are obtained. As power input is increased, use the recommended tuning procedure of maximum output from the output tank and minimum input SWR for the input circuit.

There is danger of low-frequency oscillations with most transistor amplifiers. A scope of 5-MHz or more bandwidth connected to the dc feeder at point A makes an excellent indicator of any low-frequency oscillation. It is possible to have

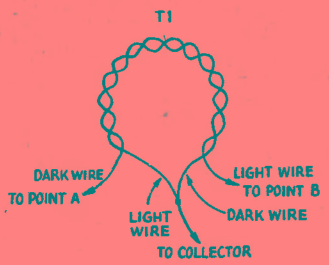


Fig. 14-56 — Transmission-line output transformer consisting of 2 4-inch long conductors, No. 20 enam. wire, twisted to 16 crests per inch, using an electric drill. The conductors should be color coded, one with one color and one with a second color. Form the twisted pair into a 1/2-inch dia circle. Unwind the leads so that only the portion of the pair forming the circle remains twisted. Connect the leads of each color as shown.

signal output on all hf and vhf amateur bands and all TV channels, simultaneously, when a bad case of parasitic oscillation occurs. For those who may have access to one, the best indicator of parasitic oscillation is a wide-band spectrum analyzer.

An Additional Design

For those who own a low-power fm transceiver, an intermediate amplifier stage or a final amplifier providing 10 to 25 watts may be desired. The circuit of Fig. 14-55 is suitable for the 2N5591 or HEP S3007 transistors (25 watts), and the 2N5590 or HEP 3006 transistors (10 watts). An unusual feature of this circuit is the use of a transmission-line transformer in the output network. The construction and tune-up procedures for the amplifiers of Fig. 14-55 is similar to that described earlier for the 50-watt amplifier.

Accessories

When an amplifier stage is used with an fm transceiver, a method of automatic transmit/receive switching is needed. A simple carrier-operated relay (COR), such as shown in Fig. 14-16 can be employed for the amplifiers described in this article. The level of input rf required to operate the COR is determined by the value of R1. One to two watts of 2-meter energy will operate K1 when a 4700-ohm resistor is employed. The rf signal is rectified by two high-speed switching diodes; the dc output from the rectifier is applied to Q1, a Darlington-connected transistor pair. When sufficient current is developed in the base circuit, Q1 will turn on, activating K1. A transient-suppression diode is included across the relay coil to prevent voltage-spike damage to Q1.

The switching circuits needed to take the amplifier in and out of the circuit- are somewhat complex. The cost of four coaxial relays would be prohibitive. But, an open-frame relay can cause sufficient loss at 146 MHz to severely degrade the sensitivity of the associated receiver. To get around this problem the author modified an inexpensive relay. The long leads to the wiper arms were removed and discarded. Two shorting bars were added, as shown in the drawing. External connections were made only to the stationary contacts. Received signal loss through the modified relay measured 0.4 dB — an insignificant amount.

Second-harmonic output from the 50-watt amplifier measured 34 dB down from the level of the 146-MHz energy. Thus, the computer-design output network compares favorably with the pi-section tank circuits often used in hf transmitters. To assure that harmonic energy didn't cause a problem to other services, a simple pi-section output filter was added. This filter is designed for 50-ohm input and output impedances; it can be used with any two-meter amplifier. The insertion loss of the filter at 146 MHz is 0.2 dB, while it provides 46 dB attenuation at 292 MHz and 25 dB at 438 MHz.

Appendix A

1) Amidon toriod cores are available from Amidon Associates, 12033 Otsego Street, No. Hollywood, CA 91607.

2) Ferroxcube components can be purchased from Elna Ferrite Laboratories, Inc., 9 Pine Grove Street, Woodstock, NY 12498.

3) J. W. Miller chokes are available from distributors, or directly from J. W. Miller, 19070 Reyes Ave., Compton, CA 90224.

4) Underwood mica capacitors must be ordered directly from the manufacturer, Underwood Electric and Manufacturing Company, Inc., P. O. Box 188, Maywood, IL 60153. Price for the J-101 units specified in this article is approximately $1.20 each (specify the value — in pF — desired).

5) A circuit board for the 50-watt amplifier will be available from Spectrum Research Labs, P. O. Box 5824, Tucson, AZ 85703.

2-METER FM RECEIVER

An fm purist is not likely to settle for second-rate receiver performance in this day of vhf-band saturation. A satisfactory fm receiver must be able to separate the various repeater output frequencies without being affected by IMD and overload problems. The sensitivity must be good, and so should the limiting characteristics. Few low-cost designs satisfy the foregoing criteria. The circuit of Fig. 14-58 represents a practical compromise between cost and circuit complexity, yet provides performance which is comparable to that of many commercial fm receivers in use by amateurs.

The single-conversion solid-state fm receiver described here is intended as a mate for the transmitter shown in Fig. 14-50. This design centers around a multifunction IC, the CA3089E. Circuit simplicity, good performance, and low cost are the keynotes in this project.

Circuit Highlights

A JFET was chosen for rf amplifier Q1, Fig. 14-58. Neutralization is unnecessary provided the gate and drain elements are tapped down on their

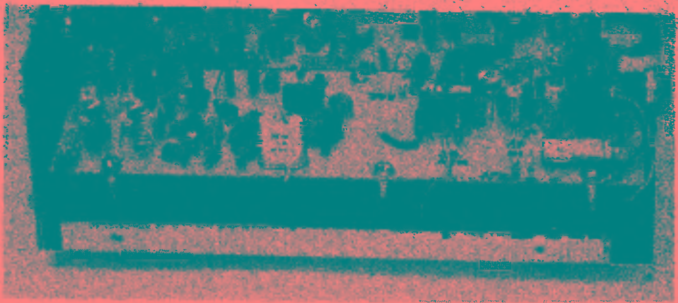


Fig. 14-57 — This photo shows the final breadboard version of the fm receiver. Some of the bypass capacitors are located on the foil side of the pc board in this example. The template and parts-layout sheet provides for topside mounting of the capacitors. The differences between the receiver shown here and the final model are quite minor.

respective tuned circuits. For simplicity's sake only two tuned circuits are used ahead of the mixer, which uses a dual-gate MOSFET. The combination of FETs Q1 and Q2 assures low IMD and provides good immunity to overloading. Output from the mixer is supplied to FL1. This is a four-pole 10.7-MHz i-f filter which is fed from a 900-ohm tap point on tuned circuit C9-C10-L3.

The oscillator/multiplier stage, Q3, is a carbon copy of that used by Pearce-Simpson in their Gladding 25 fm transceiver. It is one of the simplest circuits one can use, yet it performs well. Injection to the mixer is supplied at 157 MHz (10.7-MHz i-f plus the frequency of the received signal). The oscillator crystal frequency is one half the injection frequency – 78 MHz in this example. No netting trimmers are necessary if crystals for the Gladding circuit are ordered and used. Frequency doubling from 78 MHz is accomplished in the collector circuit of Q3.

I-f amplifier U1 is a CA3028A wired for cascode operation. FL1 connects to input terminal 2 through a .01-μF blocking capacitor. Terminating resistor R7 is selected for the characteristic impedance of the filter used. The KVG filter has a 910-ohm bilateral impedance, so if precise matching is desired one can use a 910-ohm unit at R7. Output from U1 is fed to multifunction chirp U2, across R11.

Audio output from U2 is amplified by Q4 before being routed to U3, a transformerless 1-watt output IC. Though the MC1454 is designed to work into a 16-ohm speaker, good results can be had when using an 8-ohm speaker.

Construction

How the receiver is packaged can best be decided by the builder. Two choices are offered: dividing the board in two parts and stacking one section above the other on standoff posts. If this is done it will be necessary to cut the board midway between U1 and U2. If compactness is not necessary the constructor can follow a one-piece assembly format, keeping the board its 8 × 2-11/16-inch size.

Those who desire additional crystal positions can make the board slightly longer. This will provide room for more crystal sockets, but will require that a switch with more positions be used for S1.

It is recommended that transistor and IC sockets be avoided except at Q4 and U3. Short leads between the bodies of the devices and the pc board must be maintained to prevent unstable operation. The use of sockets will cause instability unless low-profile receptacles are used. Similarly, the pigtails on the bypass capacitors should be kept as short as possible in all parts of the rf circuit.

The wiring which connects the audio and squelch controls to the circuit board should be of the shielded variety. If the board is cut into two sections, as mentioned earlier, use shielded cable between U1 and U2, routing the i-f signal from pin 6 of U1 to pin 1 of U2. *Don't leave out C16.*

The leads from S1 to the crystal sockets must be kept as short as possible – less than 1-1/2 inches each. As a further aid to circuit stability mount the pc board on a metal cabinet wall or chassis by means of four or six metal standoff posts. This technique is beneficial in preventing rf ground loops.

Checkout and Alignment

It should be stressed that there is no simple way to align an fm receiver. A stable signal generator will be required, preferably one with fm capability. Initial alignment cannot be properly effected by using off-the-air fm signals. A weak-signal source can be built by using the modulator and crystal oscillator stage of the low power transmitter described in Fig. 14-50. Whatever method is used, make certain that the test signal is no farther off frequency than 200 Hz from the desired frequency of reception. Ideally, the signal source should be *exactly* on the chosen input frequency of the receiver.

Connect the signal generator to J1. Attach a meter across J2 and J3. Make certain that a speaker is hooked to the output of U3. Assuming that an ohmmeter check shows no shorted or open circuits in the completed assembly, connect a 12-volt dc supply to the receiver. With the squelch turned off (maximum hiss noise) adjust C2, C4, and C44 for an upward deflection of the relative-signal-strength meter (at J2 and J3). Next, adjust C10 for maximum meter reading. Repeat these steps two more times. All tuning adjustments should provide fairly sharp peaks when the circuits are tuned to resonance.

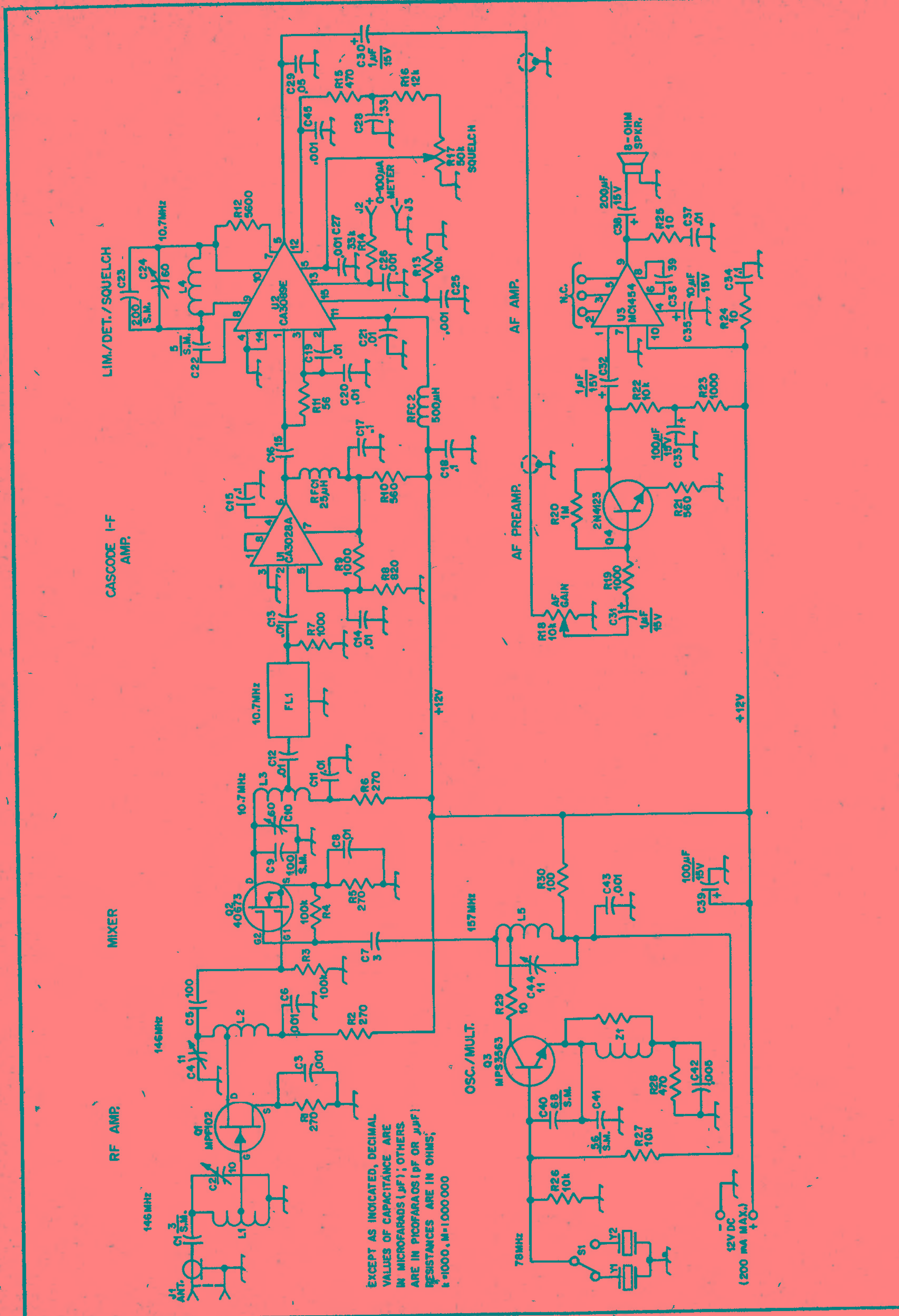

RF AMP.
MIXER
CASCODE I-F AMP.
LIM./DET./SQUELCH
AF PREAMP.
AF AMP.
OSC./MULT.
146 MHz
10.7 MHz
157 MHz
78 MHz
+12V
J1 ANT.
12V DC (200 mA MAX.)
8-OHM SPKR.
0-100μA METER
R17 50k SQUELCH
R18 10k AF GAIN
EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF); OTHERS ARE IN PICOFARADS (pF OR μμF); RESISTANCES ARE IN OHMS; k = 1000, M = 1000 000

Fig. 14-58 – Schematic diagram of the fm receiver. Fixed-value capacitors are disk ceramic unless otherwise noted. Polarized capacitors are electrolytic. Fixed-value resistors are 1/2-watt composition types. Numbered components not in parts list are identified for pc-board layout purposes only. A tamplate and parts layout diagram are available from ARRL Hq. for $0.50. A circuit board is available from Spectrum Research Labs., Box 5824, Tucson, AZ 85703.

C1 – 3-pF silver mica. For precise matching substitute a 10-pF trimmer for the fixed-value capacitor.
C2, C4, C44 – 11-pF pc-mount miniature air variable. (E.F. Johnson 187-0106-005, avail. from Newark Electronics).
C10, C24 – Subminiature ceramic trimmer, 15 to 60 pF (Eria 538-011F-15-60, available from Newark Electronics, or surplus from Reliance Merchandising, 2223 Arch St., Phila., PA 19103).
FL1 – See text and footnotes.
J1 – Coax receptacle of builder's choice.
J2, J3 – Binding posts of pin jacks.
L1 – 5 turns No. 18 tinned bus wire, 1/4-inch ID × 1/2-inch long. Tap gata of Q1 at 2-1/2 turns from hi-*Z* end.
L2 – 4 turns tap at 1 turn from the top (high-impedance) end.
L3 – 16 turns No. 22 enam. wire to occupy entire circumference of Amidon T-50-2 toroid core. Tap at 6 turns from hi-*Z* end for FL1.
L4 – 1-μH high-*Q* inductor, unloaded *Q* 150 or greater. 18 turns No. 24 enam. wire to occupy entire circumference of Amidon T-37-2 toroid core (Amidon Assoc., 12033 Otsego St., N. Hollywood, CA 91607).
L5 – 5 turns No. 18 tinned bus wire, 1/4-inch ID × 1/2 inch long. Tap collector via R29 at 1 turn from hi-*Z* end.
Q1, Q3, Q4 – Motorola Transistor.
Q2 – RCA MOSFET
R17 – 50,000-ohm linear-taper carbon control.
R18 – 10,000-ohm audio-taper carbon control.
RFC1 – 25-μH choke (Millen J300-25 or equivalent).
RFC2 – 500-μH choke (Millen J300-500 or equivalent).
S1 – Spdt minieture slide or wafer switch, non-shorting.
U1, U2 – RCA integrated circuit.
U3 – Motorola intagrated circuits.
Y1, Y2 – International Crystal Co. receiving crystal ground to Pearce-Simpson Gladding 25 specs. Nylon crystal sockets available from International Crystal Co.
Z1 – Rf choke consisting of 8 turns No. 24 enam. wire, close-wound on body of 1000-ohm 1/2-watt carbon resistor. Solder coil leads to resistor pigtails.

A frequency-modulated signal will be required for on-the-nose adjustment of the detector (L4 and C24). C24 should be adjusted slowly until the point is found where best audio quality occurs. Audio recovery will be the lowest at this point, creating the illusion of reduced receiver sensitivity. If no fm signal is available for this part of the alignment, tune the detector for minimum hiss noise as heard in the speaker. After the detector is aligned, readjust C10 for best audio quality of a received fm signal. It may be necessary to go back and forth between C10 and C24, carefully tweaking each capacitor for the best received-signal audio quality. The detector should be adjusted while a strong signal (100 μV or greater) is being supplied at J1.

Adjustment of the squelch control should provide complete muting of the hiss noise (no signal present) as approximately midrange in its rotation. If the audio channel is functioning properly one should find that plenty of volume occurs at less than a midrange setting of R18.

Performance

In two models built, both identical to the circuit of Fig. 14-58, sensitivity checked out at roughly 0.8 μV for 20 dB of quieting. This sensitivity figure is by no means spectacular, but is quite ample for work in the primary signal contour of any repeater. The addition of a dual-gate MOSFET preamplifier ahead of Q1 resulted in a sensitivity of 0.25 μV for 20 dB of quieting. The barefoot receiver requires approximately 0.5 μV of input signal to open the squelch. A more elaborate circuit would have provided greater sensitivity, but at increased cost and greater circuit complexity.

Hard limiting occurs at signal input levels in excess of 10 μV, with 3 dB of limiting exhibited at 1 μV. Addition of an outboard preamplifier will greatly improve the limiting characteristics, and this would benefit those who are dealing primarily with weak signals.

A KVG XM 107S04 i-f filter (FL1)[1] is used in the circuit of Fig. 14-58. However, any 10.7-MHz filter with suitable handwidth characteristics for amateur fm reception can be substituted for the unit specified. During the development period a Piezo Technology Comline filter was used at FL1.[2] The model tried was a PTI 2194F, which sells for $10 per unit in single lots. Club groups may wish to take advantage of the 5 to 9 price break . . $5.95 each. The PTI 2194F gave performance similar to that of the KVG unit.

Each brand of filter has its own characteristic impedance, so if substitutions are made it will be necessary to change the tap position on L3 to assure a proper match between Q2 and FL1. Similarly, the ohmic value of R7 will have to be changed.

1 A product review describing the filter's characteristics was given in *QST* for June., 1972, p. 56. The filter sells for $15.95 and can be ordered from Spectrum International, Box 87, Topsfield, MA 01983. A drilled printed circuit board is available for $5 from: D.L. McClaren, W8URX, 19721 Maplewood Avenue, Cleveland, OH 44135.

2 Piezo Technology Inc., Box 7877, Orlando, FL 32804.

Specialized Communications Systems

The field of specialized amateur communications systems includes radioteletype, amateur television, amateur facsimile, phone patching, and space and satellite communications. Radio control of models is not a "communications" system in the amateur (two-way) sense. The specialized hobby of radio control does have a large following, but "citizen-band" provisions for frequency allocations and operator registrations divorce it from the strictly ham-radio field (unless one wishes to avoid the QRM).

By far the greatest activity in the specialized fields is to be found in radioteletype (RTTY). Operation using frequency-shift keying techniques is permitted on all amateur bands except 160 meters.

Activity in amateur TV (ATV) can be found primarily in a number of population centers around the country. Most of the work is based on converted entertainment receivers and manufacturer's-surplus camera tubes (vidicons). ATV is permitted on the amateur bands above 420 MHz, and this and the broadband nature of the transmissions precludes extensive DX work.

Slow-scan TV (SSTV) is a narrow-band system that is permitted in any of the phone bands except 160 meters. It is a completely electronic system, however; no photographic techniques are required. Pictures are transmitted in 8 seconds or less.

Amateur facsimile operation, under present U.S. regulations, is permitted only above 50.1 MHz. Operation in the 6- and 2-meter bands is restricted to the use of shifting audio tones with an amplitude-modulated carrier (A4 emission), so operation through an fm repeater on these bands is prohibited. Facsimile operation is undertaken primarily by groups in heavily populated areas.

Amateur satellites – called *Oscars* for Orbiting Satellites Carrying Amateur Radio – offer another way of extending the range of vhf and uhf stations. Satellites can also operate in the hf region to provide communication during times of poor ionospheric conditions.

Phone patches permit third parties to communicate via amateur radio, through an interconnection between the amateur's station equipment and his telephone line. With voice operation in use, phone patching may be conducted in any amateur voice band between domestic stations, or between stations of any two countries permitting third-party communications.

RADIOTELETYPE (RTTY)

Radioteletype (abbreviated RTTY) is a form of telegraphic communication employing typewriter-like machines for (1) generating a coded set of electrical impulses when a typewriter key corresponding to the desired letter or symbol is pressed, and (2) converting a received set of such impulses into the corresponding printed character. The message to be sent is typed out in much the same way that it would be written on a typewriter, but the printing is done at the distant receiving point. The teletypewriter at the sending point may also print the same material.

The teleprinter machines used for RTTY are far too complex mechanically for home construction, and if purchased new would be highly expensive. However, used teletypewriters in good mechanical condition are available at quite reasonable prices. These are machines retired from commercial service but capable of entirely satisfactory operation in amateur work. They may be obtained from several sources on condition that they will be used purely for amateur purposes and will not be resold for commercial use.

Some dealers and amateurs around the country make it known by advertising that they handle parts or may be a source for machines and accessory equipment. *QST*'s Ham-Ads and other publications often show good buys in equipment as amateurs move about, obtain newer equipment, or change interests.

Periodic publications are available which are devoted exclusively to amateur RTTY. Such publications carry timely technical articles and operating information, as well as classified ads.

The Teletype Corp. Model 28ASR teleprinter is used by many amateurs. In addition to the keyboard and page printer, this model contains facilities for making and sending perforated tapes.

Over the years *QST* has carried a number of articles on all aspects of RTTY, including a detailed series by Hoff in 1965 and 1966. For a list of surplus-equipment dealers, information on publishers of RTTY periodicals, and a bibliography of all articles on RTTY which have appeared in *QST*, write to RTTY T.I.S., ARRL Headquarters, 225 Main Street, Newington, CT 06111. U.S. residents should enclose a stamped business-size envelope bearing a return address with their request.

Types of Machines

There are two general types of machines, the **page printer** and the **tape printer.** The former prints on a paper roll about the same width as a business letterhead. The latter prints on paper tape, usually gummed on the reverse side so it may be cut to letter-size width and pasted on a sheet of paper in a series of lines. The page printer is the more common type in the equipment available to amateurs.

The operating speed of most machines is such that characters are sent at the rate of either 60, 67, 75 or 100 wpm depending on the gearing ratio of a particular machine. Current FCC regulations allow amateurs the use of any of these four speeds. Interchangeable gears permit most machines to operate at these speeds. Ordinary teletypewriters are of the start-stop variety, in which the pulse-forming mechanism (motor driven) is at rest until a typewriter key is depressed. At this time it begins operating, forms the proper pulse sequence, and then comes to rest again before the next key is depressed to form the succeeding character. The receiving mechanism operates in similar fashion, being set into operation by the first pulse of the sequence from the transmitter. Thus, although the actual transmission speed cannot exceed about 60 wpm (or whatever maximum speed the machine is geared for), it can be considerably slower, depending on the typing speed of the operator.

It is also possible to transmit by using perforated tape. This has the advantage that the complete message may be typed out in advance of actual transmission, at any convenient speed; when transmitted, however, it is sent at the machine's normal maximum speed. A special tape reader, called a **transmitter-distributor,** and tape perforator are required for this process. A **reperforator** is a device that may be connected to the conventional teletypewriter for punching tape when the machine is operated in the regular way. It may thus be used either for an original message or for "taping" an incoming message for later retransmission.

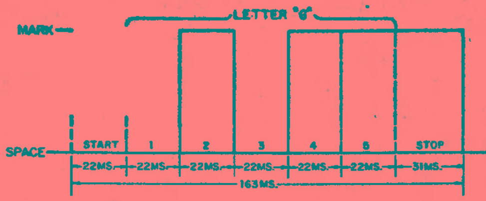


Fig. 15A-1 — Pulse sequence in the teleprinter code. Each character begins with a start pulse, always a "space," and ends with a "stop" pulse, always a "mark." The distribution of marks and spaces in the five elemants between stert and stop determines the particular character transmitted.

Teleprinter Code

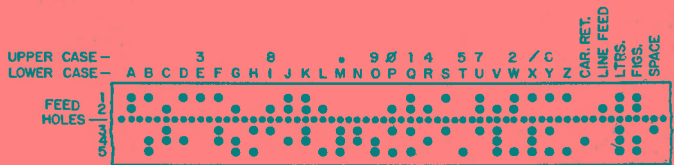
In the special code used for teleprinter operation, every character has five "elements" sent in sequence. Each element has two possible states, either "mark" or "space," which are indicated by different types of electrical impulses (i.e., mark might be indicated by a negative voltage and space by a positive voltage). At 60 wpm each element occupies a time of 22 milliseconds. In addition, there is an intial "start" element (space), also 22 ms long, to set the sending and receiving mechanisms in operation, and a terminal "stop" element (mark) 31 ms long, to end the operation and ready the machine for the next character. This sequence is illustrated in Fig. 15A-1, which shows the letter G with its start and stop elements.

At maximum machine speed, it takes 163 ms to send each character. This is the equivalent of 368 operations per minute. At 75 wpm with this same code, 460 operations per minute result, and 600 for 100 wpm. The letter code as it appears on perforated tape is shown in Fig. 15A-2, where the black dots indicate marking pulses. Figures and arbitrary signs – punctuation, etc. – use the same set of code impulses as the alphabet, and are selected by shifting the carriage as in the case of an ordinary typewriter. The carriage shift is accomplished by transmitting either the "LTRS" or "FIGS" code symbol as required. There is also a "carriage return" code character to bring the carriage back to the starting position after the end of the line is reached on a page printer, and a "line feed" character to advance the page to the next line after a line is completed.

Additional System Requirements

To be used in radio communication, the pulses (dc) generated by the teletypewriter must be utilized in some way to key a radio transmitter so they may be sent in proper sequence and usable form to a distant point. At the receiving end the incoming signal must be converted into dc pulses suitable for operating the printer. These functions,

Fig. 15A-2 — Teleprinter letter code as it appears on perforated tape; start and stop elements do not appear. Elemants are numbered from top to bottom; dots indicete marking pulses. Numerals, punctuation, and other arbitrary symbols are secured by carriage shift. There are no lower-case letters on a teletypewriter using this 5-unit code.



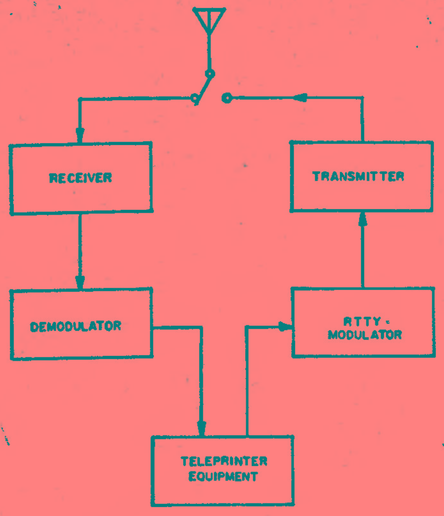


Fig. 15A-3 — Block diagram showing the basic equipment required for amateur RTTY operation.

shown in block form in Fig. 15A-3, are performed by electronic units known respectively as the frequency-shift keyer or RTTY modulator and receiving converter or RTTY demodulator.

The radio transmitter and receiver are quite conventional in design. Practically all the special features needed can be incorporated in the keyer and converter, so that most ordinary amateur equipment is suitable for RTTY with little or no modification.

Transmission Methods

It is quite possible to transmit teleprinter signals by ordinary "on-off" or "make-break" keying such as is used in regular hand-keyed cw transmission. In practice, however, frequency-shift keying is preferred because it gives definite pulses on both mark and space, which is an advantage in printer operation. Also, since fsk can be received by methods similar to those used for fm reception, there is considerable discrimination against noise, both natural and manmade, distributed uniformly across the receiver's passband, when the received signal is not too weak. Both factors make for increased reliability in printer operation.

Frequency-Shift Keying

On the vhf bands where A2 transmission is permitted, audio frequency-shift keying (afsk) is generally used. In this case the rf carrier is transmitted continuously, the pulses being transmitted by frequency-shifted tone modulation. The audio frequencies used have been more-or-less standardized at 2125 and 2975 Hz, the shift being 850 Hz. (These frequencies are the 5th and 7th harmonics, respectively, of 425 Hz, which is half the shift frequency, and thus are convenient for calibration and alignment purposes.) With afsk, the lower audio frequency is customarily used for mark and the higher for space.

Below 50 MHz, F1 or fsk emission must be used. The carrier is on continuously, but its frequency is shifted to represent marks and spaces. General practice with fsk is to use a frequency shift of 850 Hz, although FCC regulations permit the use of any value of frequency shift up to 900 Hz. The smaller values of shift have been shown to have a signal-to-noise-ratio advantage, and 170-Hz shift is currently being used by a number of amateurs. The nominal transmitter frequency is the mark condition and the frequency is shifted 850 Hz (or whatever shift may have been chosen) lower for the space signal.

RTTY with SSB Transmitters

A number of amateurs operating RTTY in the hf bands, below 30 MHz, are using audio tones fed into the microphone input of an ssb transmitter. With properly designed and constructed equipment which is correctly adjusted, this provides a satisfactory method of obtaining F1 emission. The user should make certain, however, that audio distortion, carrier, and unwanted sidebands are not present to the degree of causing interference in receiving equipment of good engineering design. The user should also make certain that *the equipment is capable of withstanding the higher-than-normal average power involved.* The RTTY signal is transmitted with a 100-percent duty cycle, i.e., the average-to-peak power ratio is 1, while ordinary speech waveforms generally have duty cycles in the order of 25 percent or less. Many ssb transmitters, such as those using sweep-tube final amplifiers, are designed only for low-duty-cycle use. Power-supply components, such as the plate-voltage transformer, may also be rated for light-duty use only. As a general rule when using ssb equipment for RTTY operation, the dc input power to the final PA stage should be no more than twice the plate dissipation rating of the PA tube or tubes.

FREQUENCY-SHIFT KEYERS

The keyboard contacts of the teletypewriter actuate a direct-current circuit that operates the printer magnets. In the "resting" condition the contacts are closed (mark). In operation the contacts open for "space." Because of the presence of dc voltage across the open keyboard contacts in such an arrangement, they cannot normally be used directly to frequency-shift-key another circuit. Isolation in the form of a keying relay or electronic switching is ordinarily used.

Saturated-Diode Keying

Perhaps the simplest satisfactory circuit for frequency-shift keying a VFO is the one shown in Fig. 1. This uses a diode to switch a capacitor in and out of the circuit, and is intended for use in a transmitter which heterodynes the VFO signal to the operating frequency. Because of the small number of parts required for the modification, they can often be mounted on a small homemade subchassis, which in turn is mounted alongside the VFO tube. Connection to the VFO circuit can be made by removing the tube from its socket,

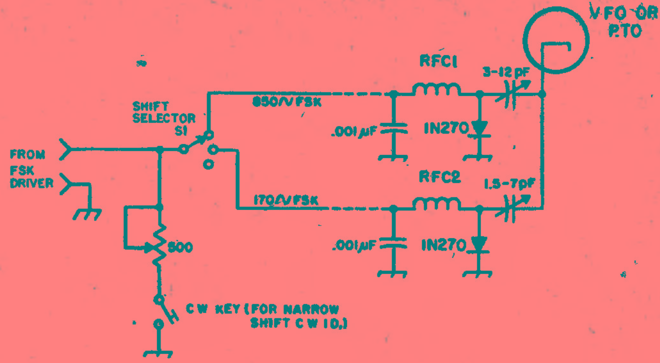


Fig. 1 — Frequency-shift keyer using seturated diodes

RFC1, RFC2 — 2.5 mH (National R-100 or equiv.).
S — Spdt rotary, toggle, or slide.

wrapping the connecting lead around the tube's cathode pin, and reinserting the tube in its socket. The variable capacitors are adjusted for the desired shifts. Once set, the shifts will remain constant for all bands of operation. With this circuit the VFO frequency will be lower on space when the fsk driver of the RTTY demodulator shown later is used. If VFO "sideband inversion" takes place in a mixer stage of the transmitter, it will be necessary to key from the afsk driver output of the demodulator to send a signal which is "right side up."

Be sure to use an NP0 type miniature ceramic trimmer for best stability. Use only an rf choke wound on a ceramic form. Ferrite or iron-core types are not suitable because of excessive internal capacitance, so the National type R-100 is recommended. Use only the 1N270 diode specified. This diode is a special high-conductance computer type which provides maximum circuit *Q*, avoiding variations in oscillator output level.

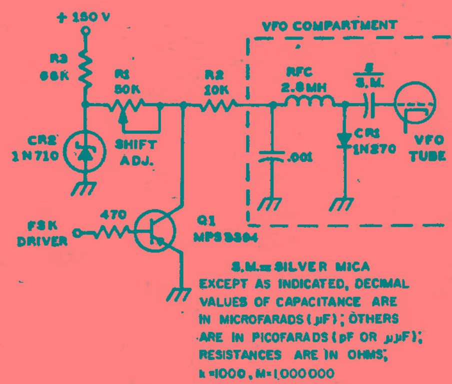


Fig. 2 — "Shift-pot" frequency-shift keyer circuit. The shift-adjustment control may be remoted from the VFO circuit.
CR2 — Zener, 6.5-V 400 mW (1N710 or equiv.).
R1 — Linear-taper control, low wattage.
Q1 — Audio transistor, npn silicon (Motorola MPS3394 or equiv.).

"Shift-Pot" Keying Circuit

The circuit of Fig. 2 may be used with transmitters having a VFO followed by frequency-multiplying stages. The amount of frequency multiplication in such transmitters changes from one amateur band to another, and to maintain a constant transmitted frequency shift readjustment is necessary during band changes. In this circuit the natural VFO frequency is used for mark, and for space the frequency is lowered somewhat depending on the current flowing through CR1. R1 adjusts this current, and therefore controls the amount of frequency shift. As shown, the circuit may be keyed by the fsk driver stage of the RTTY demodulator shown later. If a keying relay is used, Q1 may be omitted and the keying contacts (closed on mark, open on space) connected directly from the junction of R1 and R2 to ground.

Leads inside the VFO compartment should be kept as short as possible. Lead length to the remainder of the circuit is not critical, but to avoid inducing rf or 60-Hz hum into the circuit, shielded wiring should be used for runs longer than a few inches. Positive voltages other than 150 may be used for the bias supply; the value and wattage of R3 should be chosen to supply a current of 2 mA or more to the 6.5-V Zener diode.

AN RTTY DEMODULATOR

Fig. 1 on page 462 shows the diagram of a solid-state demodulator which can be built for approximately $60. Using surplus 88-mH toroidal inductors,[1] the discriminator filters operate with audio tones of 2125 and 2295 Hz for copying 170-Hz shift, which is used almost exclusively on the amateur bands these days.

The demodulator is intended to be operated from a 500-ohm source. If only a 4- or 8-ohm speaker output is available at the receiver, a small line to voice-coil transformer should be used between the receiver and the demodulator to provide the proper impedance match. An integrated-circuit operational amplifier, having very high-gain capability, is used for the limiter. The discriminator filters and detectors convert the shifting audio tones into dc pulses which are amplified in the slicer section. The keyer transistor,

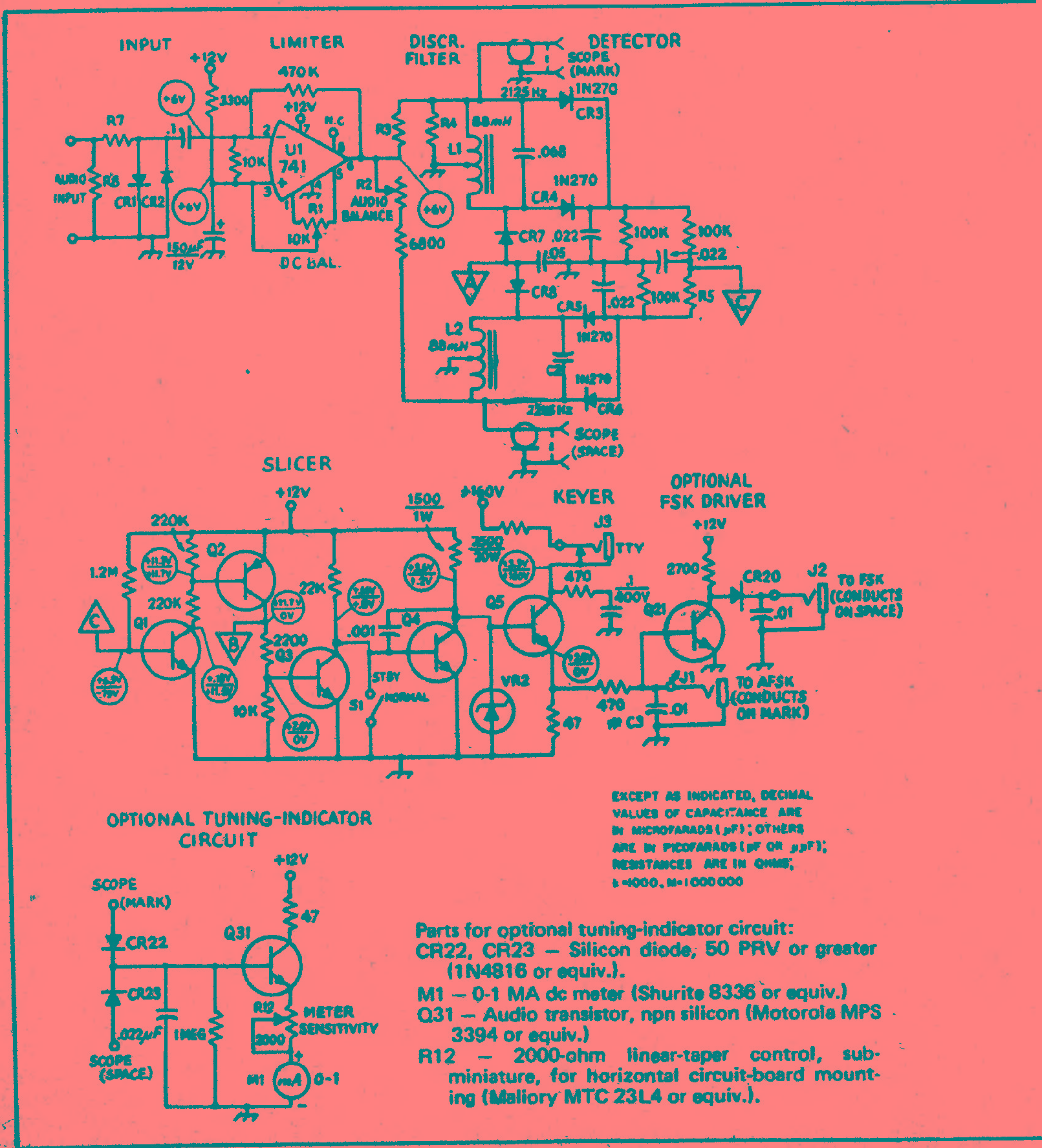
[1] See *QST* Ham-Ads for suppliers of 88-mH toroids.

Q5, controls the printer selector magnets, which should be wired for 60-mA operation. The teleprinter keyboard is to be connected in series with the printer magnets, both being connected to the demodulator via J3. Typing at the keyboard will then produce local copy on the printer and will also produce voltages at J1 and J2 for frequency-shift keying a transmitter or an audio oscillator.

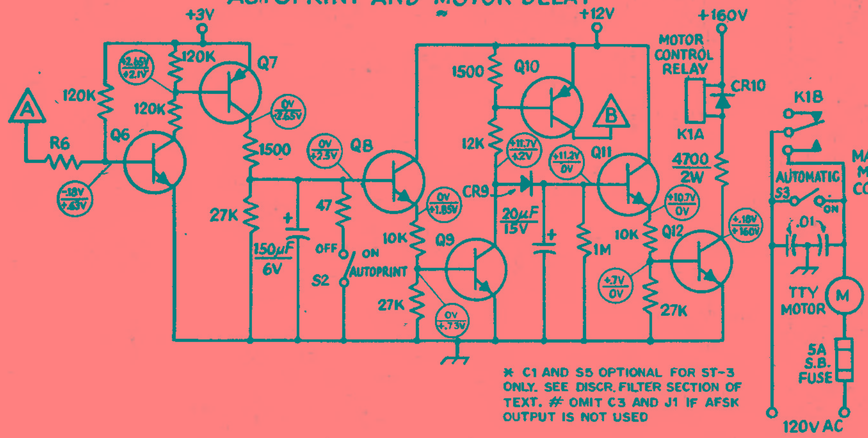
The autoprint and motor-delay section provides optional features which are not necessary for basic operation. This section provides a simulated mark signal at the keyer when no RTTY signal is being received, preventing cw signals and random noise from printing "garble" at the printer. The motor-control circuit energizes the teleprinter motor in the presence of an RTTY signal, but turns off the motor should there be no RTTY signal present for approximately 30 seconds.

Adjustments

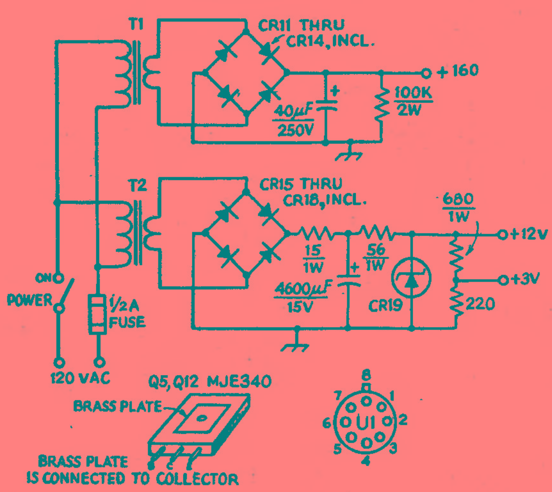
With a VTVM, measure the +12-V supply potential. Ground the audio input to the demodulator, and connect the VTVM to pin 3 of the IC. Adjust R1 through its total range, and note that the voltage changes from approximately 1.6 V at either extreme to about +6 V at the center setting of R1. Perform a coarse adjustment of R1 by setting it for a peak meter reading, approximately +6 V. Now move the VTVM lead to pin 6 of the IC. Slowly adjust R1 in either direction, and note that adjustment of just a *small fraction* of a



AUTOPRINT AND MOTOR DELAY



POWER SUPPLY



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 = 1 000 000

C1 — Optional
C2 — .033 μF, paper or Mylar, 75- or 100-volt rating.
C3 — .01 μF Mylar or disk, 600 volt. Omit if af keying output is not used.
CR1, CR2, CR7, CR8, CR9, CR15-CR18, incl., CR20 — Silicon diode, 50 PRV or greater (1N4816 or equiv.)
CR3-CR6, incl. — Garmanium diode, type 1N270.
CR10-CR14, incl. — Silicon rectifier, 400 PRV or greater (1N4004 or equiv.).
CR19 — Zener diode, 12-V, 1-W (Sarkes-Tarzian VR-12 or equiv.).
CR21 — Zener diode, 4.3-V, 400-mW (1N4731 or equiv.).
J1, J2 — Phone jacks. Omit J1 if af keying output is not used.
J3 — Phone jack, single circuit, shorting.
K1 — 110-V dc relay, dpdt contacts with 10-A minimum rating (Potter and Brumfield type KA11DG or equiv.).
L1, L2 — 88 mH toroid.
Q1, Q6, Q8, Q9, Q11, Q21 — Audio transistor, npn silicon (Motorola MPS3394 or equiv.).
Q2, Q7, Q10 — Audio transistor, pnp silicon (Motorola MPS3702 or equiv.).
Q3, Q4 — Ganeral-purpose transistor, npn silicon (Motorola MPS2926 or equiv.).
Q5, Q12 — Audio transistor, npn silicon, 300-V collector-emitter rating (Motorola MJE340 or equiv.).
R1, R2 — 10,000-ohm linear taper control, subminiature, for horizontal circuit-board mounting (Mallory MTC-14L4 or equiv.).
R3 — 5600 ohms.
R4 — 18,000 ohms.
R5 — 82,000 ohms.
R6 — 0.1 megohm.
R7 — 1000 ohms.
RB — 560 ohms.
S1-S5, incl. — Spst toggla. S5 optional.
T1 — Power; primary 120 V; secondary 125 V (Chicago-Stancor PA-8421 or Triad N51-X or equiv.).
T2 — Power; primary 120 V; secondary 12 V, 350 mA (Chicago-Stancor P8391 or equiv.).
U1 — Integrated-circuit operationel amplifier, μA741, TO-5 package.

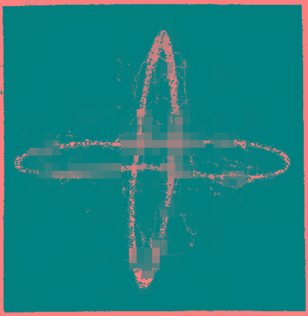
Fig. 1 — The ST-4 RTTY demodulator (by Hoff — from *QST*, April 1970). Unlass otherwise indicated, resistors are 1/4-watt 10-percent tolerance. Capacitors with polarity indicated are electrolytic. Dc operating voltages ara indicated in the limiter, slicer, keyer, and autoprint and motor deley circuits. All voltages are measured with respect to chassis ground with a VTVM. In the slicer and keyer stages, voltage values above the line should appear with a mark tone present at the damodulator input, while values below the line appear with a spaca tone present. In the autoprint and motor dalay circuit, voltage values above the line occur with a mark or space tone present while those values below the line are present with only receiver noise applied at the demodulator input.

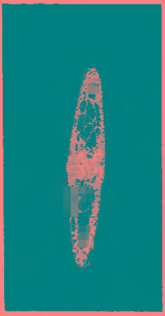
The RTTY demodulator may be constructed on a large circuit board which is mounted inside a standard aluminum chassis, as shown here. A decorative self-adhesive paper provides the grained-wood appearance. The meter is optional and provides a tuning indication for use in the hf amateur bands.

turn causes the voltage to swing from approximately +1 V to +11 V. Carefully perform a fine adjustment of R1 by setting it for a voltmeter reading of half the supply voltage, approximately +6 V. Next, again measure the voltage at pin 3. If the potential is approximately +6 V, R1 is properly set. If the potential is in the range of +2 V or less, R1 is misadjusted, and the procedure thus far should be repeated.

Next connect the VTVM to point A. With a mark-tone input, adjust the tone frequency for a maximum reading around −2.5 volts. Then change the tone for maximum reading on the space frequency. Adjust R2 until the voltages are equal.

With afsk at vhf, audio tones modulating the carrier are fed from the receiver to the RTTY demodulator. At hf, the BFO must be energized and the signal tuned as if it were a lower sideband signal for the proper pitches. If the tuning-indicator meter is used, the hf signal should be tuned for an unflickering indication. A VTVM connected at point A of Fig. 1 will give the same type of indication. An oscilloscope may be connected to the points indicated in the filter section and used for a tuning indicator, as shown in the accompanying photographs.





Oscilloscope prasentetions of the type obtained with the scope mark and scope space connections in the filter section ara made. For these displays the mark fraquency is displayed on the horizontel axis and the space fraquency on the verticel axis. The signals appear as ellipses because some of the mark signal appears in the space channel and vice versa. Although only one frequency is present at a given instant, the persistence of the scope screen permits simultaneous observation of both frequencies. The photo at the left shows a received signal during normal reception, while the photo at the right shows a signal during unusual conditions of selective fading, where the mark frequency is momentarily absent.

AMATEUR TELEVISION (ATV)

Television is not exactly new to amateur radio. Enterprising amateurs have been playing with this branch of the electronics art for a matter of 45 years or more. Files of *QST* dating back to the '20s offer proof that there was amateur television before many of our present-day amateurs were born. The methods used then bore little resemblance to the techniques employed today, but hams were sending and receiving pictures (or trying to) two generations ago.

An actual 440-MHz TV pictura transmitted with the equipment shown in Fig. 15B-2.

QST carried many articles on television from 1925 on, and there was plenty of interest. But the work was being done by the motor-driven scanning disk method, and it was doomed to failure. Though many dollars and man-hours were spent on the problem, nobody succeeded in developing mechanical systems that were completely practical. As early as 1928, a *QST* author was pointing out the possibilities of electronic television, using the then rare-and-expensive cathode-ray tube. The days of the scanning disk were numbered.

But predicting the coming of electronic television and bringing it about were two quite different matters. Though it had become fashionable, by 1931, to say that "Television is just around the corner," the cathode-ray tube was a laboratory curiosity, and it was to remain so for some years to come, as far as most amateurs were concerned. Not until 1937 was the subject of

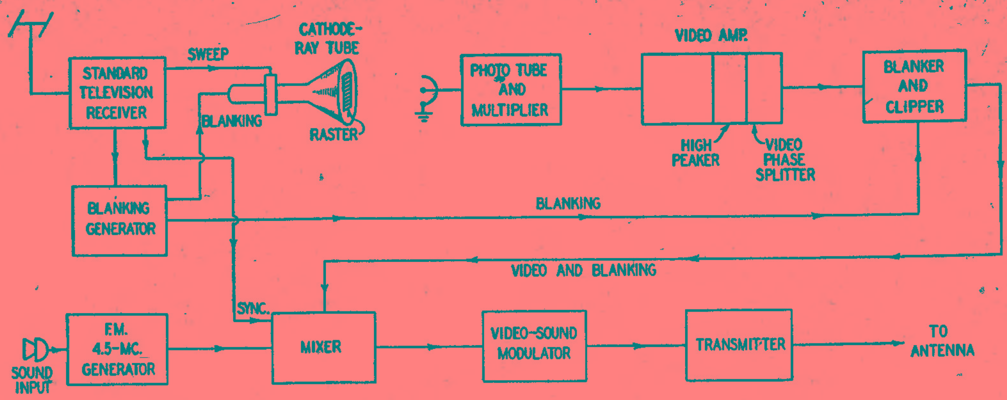


Fig. 15B-1 — Block diagram of the television system used by W2BK, formerly W2LNP. (From *QST*, June, 1950.)

television to appear again in *QST*. By then the problems involved in electronic television were gradually being solved. Usable components were beginning to appear, and television experimental work loomed as a possible field for the more advanced amateur. For more than two years almost every issue of *QST* carried something on television, but it was mostly concerned with the receiving end. The generation of a television picture for transmission was still considered to be beyond the radio amateur, until moderately priced iconoscope tubes were introduced for amateur use in 1940. Television transmitter and camera design were treated extensively in *QST* for 1940.

The highly involved and expensive process required in getting on the air for actual television communication was just too much for most amateurs, and progress in amateur television slowed to a standstill until well into the postwar period. At that time, availability of most of the needed components on the surplus market gave amateur television the push that it had always needed, and the period since 1948 has seen more amateur TV activity than existed in all previous years combined. By 1960, color-TV signals were being transmitted by amateurs.

From several cities in this country has come news of activity in amateur television. Much of the effort has been concerned with transmitting. The trend in this country has been to use transmitting systems that would tie in with those employed in commercial services, so that ordinary home television receivers could be used for amateur work by the addition of a simple converter. In this country amateur TV is limited to the frequencies from 420 MHz up, because of the bandwidth involved.

A Novel Way to Get Started

The cost and complexity of TV gear has so far left most amateurs convinced that television is not for them, but ways have been found to cut corners. There have been several ideas developed for bringing the transmission of television nearer to the abilities of the average experienced ham. One such simplified system was developed by J. R. Popkin-Clurman, W2LNP, later to become W2BK. This system simplifies matters for the ham who would like to transmit transparencies (film negatives or positives, movies, diagrams, visual messages) without going into the complexities of camera design and construction. It also lets a local TV station and a standard TV receiver do some of the work, as shown in block-diagram form in Fig. 15B-1. A standard TV receiver is tuned to a local station and the lead from the receiver video amplifier to the cathode-ray tube is disconnected and the output of the amplifier is fed to a blanking generator. The output of the blanking generator is applied to the receiver cathode-ray tube, the raster of which is used as a light source.

In the simplest form of picture transmission, a transparency is placed directly on the face of the cathode-ray tube, which for this purpose can be almost any type, including those with P-7 phosphor. Light from the raster, passing through the transparency, is picked up by a photo tube and multiplier and fed to a video-amplifier unit that includes a high-frequency peaker and possibly a video phase inverter. The latter is used only if it is desired to transmit negatives in positive form. After passing through a clipper and blanking inserter and a mixer, the signal is ready for the modulator and transmitter. Sound and video are

Fig. 15B-2 — The transmitting portion of a complete ATV station. The video system utilizes a modified RCA TV Eye closed-circuit camera and control unit, shown at the left. The 440-MHz TV signal comes out the BNC connector at the end of the mixer-amplifier chassis. The power supply and bias battery are also visible in the photograph. (From *QST*, November, 1962)

transmitted on the same channel, first by frequency modulating a 4.5-MHz oscillator. The 420-MHz transmitter is modulated simultaneously with this signal and the video, by means of the video-sound modulator.

The signal thus transmitted has all the characteristics of a commercial video transmission, and may be received on any standard home television receiver equipped with a 420-MHz converter. In the absence of a local TV station it is merely necessary to derive the sync and blanking from the receiver's own sweep circuits. In this case the picture will have only 262 lines, noninterlaced. It retains the same horizontal resolution, but the vertical resolution is reduced. In this type of operation it is desirable to sync the vertical to the 60-Hz power supply, to reduce hum effects.

The photo tube may be a 931-A multiplier type, available as surplus. The output of the photo tube is fed into a series of video amplifiers, one of which is a high-frequency peaker. This is necessary to compensate for the build-up and decay times of the cathode-ray tube's phosphor screen.

The rf section of the transmitter is crystal-controlled. The receiver has a crystal mixer and a 6J6 oscillator, followed by a cascode amplifier working into a home television receiver. The channel used for the i-f should be one that is not in use locally, and should be in the low-TV band for best results.

The system may be adapted for transmission of movies. A film-projector light source is removed, and the photo tube installed in its place. A 60-Hz synchronous motor is used to drive the film sprocket and the film is run at 30 frames per second instead of 16 or 24. It is necessary to blank the raster during the film pull-down time. Pictures of live subjects may also be transmitted by projecting the light from the raster on the subject and collecting the reflected light with a condensing-lens system for the photo tube. Considerably greater light is needed than for transparencies, and a 5TP4 or a 5WP15 projection cathode-ray tube, with its associated high voltage, is suitable.

Adapting Closed-Circuit TV Systems

By adapting closed-circuit TV systems, a number of amateurs have been able to get a picture on the air without having to struggle with cut-and-try methods, not to mention the mechanical problems of camera construction. A manufactured TV camera and control unit are used, along with home-built rf sections necessary for the ATV station. Such a system is not restricted to sending slides or stills. It is capable of transmitting a moving picture of professional quality. Such a station is shown in Fig. 15B-2.

Many closed-circuit TV cameras provide a picture signal on any regular TV channel from 2 to 6, inclusive. In a typical system, the camera contains a vidicon camera tube, a three-stage video amplifier, a video output stage, a 55- to 85-MHz tunable oscillator, and a modulator stage that combines the rf, video, and sync signals from a control unit. The control unit contains the horizontal and vertical deflection circuits for the vidicon tube, a protective circuit that prevents damage to the vidicon in the event of a sweep-circuit failure, a blanking and vertical sync stage, and the power supply. For use in an ATV station, most amateurs choose to modify the camera oscillator circuit to provide crystal-controlled operation on a locally unused low TV channel. In this way, a regular TV receiver can be used as a monitor. The video-modulated rf signal from the camera is fed through amplifier and mixer stages to derive the transmitted video signal. For reception, a converter is used ahead of a regular TV receiver.

SLOW-SCAN TELEVISION (SSTV)

Because of the required bandwidth, amateur TV transmissions in this country are limited to the frequencies above 420 MHz. With essentially line-of-sight propagation of signals at these frequencies, it has always been necessary for an amateur wishing to engage in ATV to interest another local amateur in this mode, or for him to work into a local group which may already be active if he did not wish to transmit pictures merely for his own amusement. For this reason, ATV has had little to offer to the amateur who lives in a sparsely populated area, perhaps hundreds of miles from any large city. Slow-scan TV, on the other hand, offers a great deal. By using voice-channel bandwidths, SSTV transmissions may be used in any amateur band except 160 meters. The amateur in the sparsely populated area can exchange pictures with the fellows in the big city, the next state, or even with fellows in other countries.

Fig. 51C-1 — A typical slow-scan TV picture.

Work in the area of SSTV was pioneered by a group of amateurs headed by Copthorne Macdonald, W4ZII (later to become in succession, WA2BCW, WAØNLQ, WA2FLJ, and W1GNQ). The first of Macdonald's several articles on the subject appeared in *QST* in 1958. Early on-the-air tests took place in the then-available 11-meter shared band, the only hf amateur band where "facsimile" transmissions were permitted. The video information was transmitted as amplitude modulation of a 2000-Hz subcarrier tone, which in turn was fed into the speech-amplifier circuits of a conventional transmitter.

The loss to U.S. amateurs of the 27-MHz band in September 1958 did much to dampen the enthusiasm of would-be slow scanners. However, special temporary authorizations were granted by the FCC to a few amateurs for the purpose of making experimental SSTV transmissions, first on 10 meters, and later on 20 meters. Tests by WA2BCW and others in 1959 and 1960 indicated that signal fading and interfering transmissions from other stations caused considerable degrading of pictures received from subcarrier a-m (scam) transmissions. This led to experiments with subcarrier fm (scfm) transmissions, and the superiority of this technique for average propagation conditions was immediately recognized. The resulting standards proposed by Macdonald in January 1961 have since been adapted and are in use today (see Table I). In the scfm system, the frequency of the audio tone conveys the video information, with 1500 Hz representing black and 2300 Hz representing white. Intermediate shades of gray are transmitted with intermediate-frequency tones. Tones of 1200 Hz (ultrablack) are used to transmit vertical and horizontal sync pulses. The success of experiments in the mid '60s on 20 meters with scfm, and especially the fact that SSTV occupies a normal voice-channel bandwidth with no side-frequency products to cause interference on adjacent channels, led to changes in the FCC rules.

SSTV Emissions

Since August 1968, narrow-band A5 and F5 emissions (SSTV) have been permitted in the Advanced and Extra Class portions of 75, 40, 20 and 15 meters, in all but the cw-only portions of 10, 6, and 2 meters, and the entire amateur range above 220 MHz. The regulations permit the transmission of independent sidebands, with picture information contained in one sideband and voice in the other. Few amateurs today are equipped for this type of operation, however. The usual practice is to intersperse picture transmissions with voice transmissions on single sideband.

A stipulation in the U.S. regulations limits the bandwidth of A5 or F5 emissions below 50 MHz; they must not exceed that of an A3 single-sideband emission, approximately 3000 Hz. This precludes the use of an a-m transmitter with the standard SSTV subcarrier tones. Most amateurs operating in the hf bands feed the video information as a varying-frequency tone into the microphone input of an ssb transmitter, and with carrier suppression, F5 emission results. A seldom-used but quite feasible alternative is to frequency modulate an rf oscillator with video signals from the camera.

Because of the narrow bandwidth used, tape recordings of SSTV video signals can be made with an ordinary *audio* tape recorder running at 3 3/4 inches per second. Nearly every slow scanner preserves some of his on-the-air contacts on tape, and most prepare an interesting program to be transmitted. A good number of amateurs begin making two-way picture transmissions while equipped with nothing more than a receiving monitor and a tape recorder, in addition to ordinary station equipment. In lieu of a camera, they enlist the aid of a friend having the proper equipment to prepare a taped program which is sent during transmissions. Because of the slow frame rate with SSTV (one picture every 7 or 8 seconds), live pictures of anything except still subjects are impractical. Viewing a series of SSTV frames has frequently been compared to viewing a series of projected photographic slides.

Experiments are currently being made with the transmission of color pictures by SSTV. Various techniques are being used, but in essence the process involves the sending of three separate frames of the same picture, with a red, a blue, and

The SSTV Viewing Adapter with the top cover removed. The adapter may be constructed on Vectorbord, as shown. The transformer near the rear (left) is in the power supply circuit; the one near the front is in the video detector stage. On the front panel are the power switch and indicator, the manual vertical-sweep push button, and vertical sync control. Phono jacks on the rear panel are for connections to the oscilloscope and receiver. Two banana jacks are used for the CRT connections. (Originally described in *QST* for June, 1970, by W7ABW and W7FEN.)

TABLE I

Amateur Slow-Scan Standards

	60-Hz Areas	*50-Hz Areas*
Sweep Rates:		
Horizontal	15 Hz (60 Hz/4)	16 2/3 Hz (50 Hz/3)
Vertical	8 sec.	7.2 sec.
No. of Scanning Lines	120	120
Aspect Ratio	1:1	1:1
Direction of Scan:		
Horizontal	Left to Right	Left to Right
Vertical	Top to Bottom	Top to Bottom
Sync Pulse Duration:		
Horizontal	5 millisec.	5 millisec.
Vertical	30 millisec.	30 millisec.
Subcarrier Freq.:		
Sync	1200 Hz	1200 Hz
Black	1500 Hz	1500 Hz
White	2300 Hz	2300 Hz
Req. Trans. Bandwidth	1.0 to 2.5 kHz	1.0 to 2.5 kHz

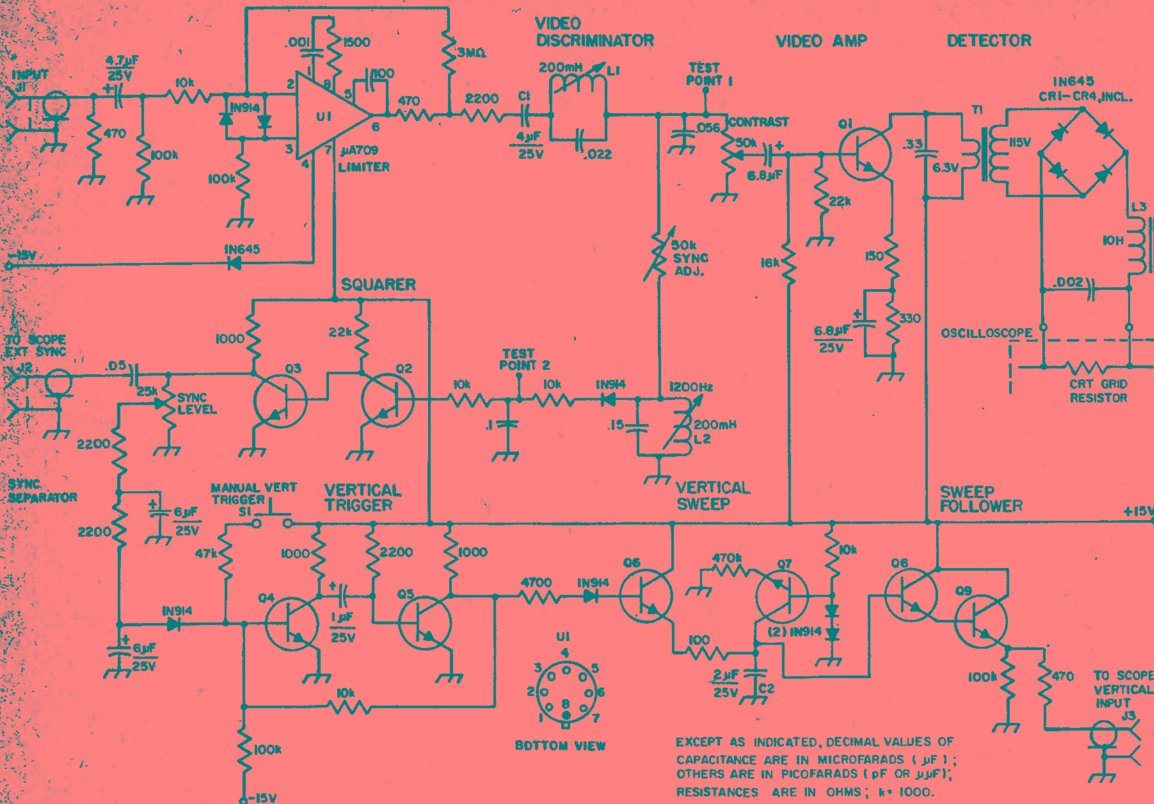


Fig. 1 — Schematic diagram of the slow-scan adapter. Capacitors with polarity indicated are electrolytic, others are caramic or paper, excapt as indicated. Variable resistors are composition controls, linear taper. Resistors are 1/2-watt.

C1 — 4-μF, 25-volt, nonpolarized tantalum.
C2 — 2-μF, 25-volt, Mylar.
J1-J3, incl. — Phono jack.
L1, L2 — Variable inductor, approx. 200 mH (Miller 6330, UTC HVC-6, or Stancor WC-14).
L3 — 10-H, low-current choke, 3000-volt insulation from ground (Burstein-Applebea 1BA959).
Q1-Q9, incl. — 2N718, 2N697, 2N2222, or 2N3641-3.
T1 — 6.3-volt, low current, 3000-volt insulation.
U1 — Operational amplifier (Fairchild μA709, Texas Instruments SN6715 or Motorola SC4070G).

a green filter successively placed in front of the camera lens for each of the three frames. At the receiving end of the circuit, corresponding filters are used and each frame is photographed on color film. After a tricolor exposure is made, the photograph is developed and printed in the normal manner. The use of Polaroid camera equipment with color film is popular in this work because it affords on-the-spot processing. Color reproduction by this technique can be quite good.

SLOW-SCAN TV VIEWING ADAPTER FOR OSCILLOSCOPES

The slow-scan TV adapter shown in Figs. 1-4, incl., permits the ham with an oscilloscope to view slow-scan TV with a minimum of investment and effort. The adapter has been used successfully with several oscilloscopes, including the Tektronix 514, Dumont 304, Heathkit IO-18, Heathkit IO-10, and a Navy surplus scope, OS-8B.

The oscilloscope's horizontal scan must be able to synchronize from an external trigger at 15 Hz. The scope should have a dc vertical input that will accept 10 volts. If the scope does not have a dc input, the vertical deflection amplifier may be able to be driven directly. The circuit shown in Fig. 3 was used with the Heath IO-18. This arrangement should be adaptable to other scopes not having a dc input, but R1 and R2 would have to be scaled to provide proper centering.

Most oscilloscopes have cathode-ray tubes with a P1 phosphor. The P1 phosphor is of short persistence, which is not suitable for slow-scan TV. Therefore, the P1 tube should be replaced with a P7-phosphor tube which has the long persistence required. The last two characters of the CRT type usually indicate the phosphor, and most types are available in several different phosphors. The Heath IO-18 uses a 5UP1 which was replaced with a 5UP7 at a cost of less than $15.00.[1] If a direct substitute cannot be found, it may be possible to find a

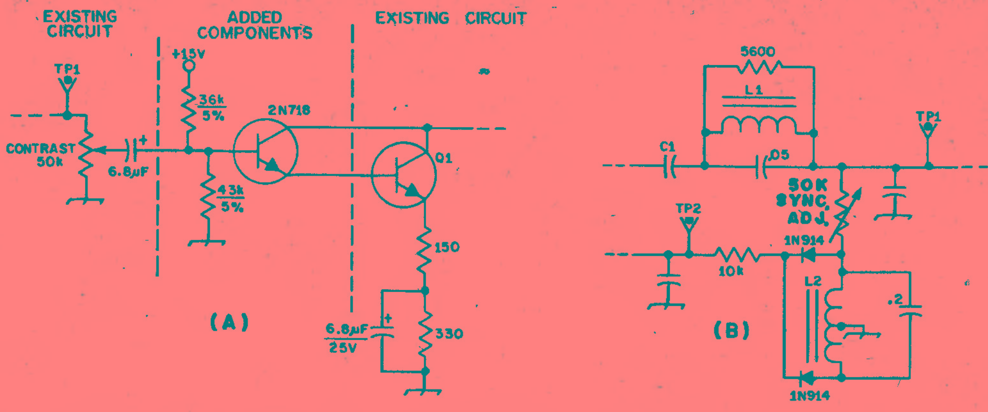


Fig. 2 — At A, a circuit which may be added to increase the contrast of the SSTV adapter, and at B, an alternative circuit using surplus 88-mH toroidal inductors for L1 and L2. If the circuit of A is used, the 18,000- and 22,000-ohm resistors shown connected to the base of Q1 in Fig. 1 are unnecessary.

surplus CRT of another type which will function. The Dumont 304 used a 5ABP1 CRT, which was replaced with a 5CP7. This CRT was obtained on the surplus market for less than $5.00.[2] If the purchase of a new oscilloscope is anticipated, a P7-phosphor cathode-ray tube should be requested.

Adapter Circuit Design

The schematic diagram of the slow-scan TV converter is shown in Fig. 1. The slow-scan signal from the audio output of a communications receiver, tape recorder, or other source is fed into the input of an integrated-circuit operational amplifier having a gain of 300. Therefore, a 0.1-volt ac peak-to-peak signal causes the amplifier to limit at the supply voltages, and the limited output will be approximately 28 volts ac peak-to-peak. The limited signal is then fed to a series video discriminator. The output of the video discriminator is fed to Q1, a video amplifier with a 6.3-volt ac filament transformer as a collector load. The transformer is used to provide voltage step-up. A transformer with 3000-volt insulation from ground is used, as the CRT grid circuit has a 1400-volt potential which must be insulated from ground. The video is then full-wave rectified and fed to a 1000-Hz filter. The output video dc is then connected across the scope CRT's series grid resistor to modulate the CRT intensity.

The output of the video discriminator is also fed to a 1200-Hz sync discriminator. This circuit passes only the 1200-Hz sync pulses. The 1200-Hz sync pulses are then rectified, filtered and fed to a two-stage amplifier, Q2 and Q3. The output of this squarer provides 15-volt sync pulses.

A 5-volt sawtooth voltage is required for vertical sweep on the oscilloscope. This voltage should have a very fast rise time and a linear decay. A sync separator circuit is used to separate the 30-ms vertical pulses from the 5-ms horizontal pulses. The vertical pulses are fed into the vertical trigger, a one-shot multivibrator. Provision is made for manually triggering the vertical sweep with a front-panel push button, S1, in case a vertical sync pulse is missed. The multivibrator triggers a transistor switch, Q6, that instantaneously charges C2 every time a vertical sync pulse is received. This capacitor is discharged at a linear rate through Q7. The base of Q7 is biased by two diodes at 1.2 volts. Thus, the current through the 0.47-megohm emitter resistor is held at a constant value, giving a linear voltage discharge across C2. This sawtooth voltage is sampled by a Darlington transistor follower, Q8 and Q9, whose output will sweep from 10 to 5 volts dc when receiving slow-scan TV. The value of 5 volts was chosen so that when a signal is not present, the dot on the scope CRT will be off the screen.

If the capability for high contrast is desired, the video signal level may be increased by adding a 2N718 transistor ahead of Q1, as shown in Fig. 2A. For those who wish to use 88-mH toroids in place of the variable inductors, L1 and L2, the circuit of Fig. 2B may be used.

Construction

The layout is relatively noncritical with the exception of the 6-volt ac filament transformer which will have high voltage on the secondary, so necessary precautions must be taken. It should be mounted away from the power transformer to minimize hum pickup. High-voltage wire is used to bring the CRT grid connection into the unit. Sockets were used for the IC amplifier and transistors; however, the components can be soldered directly into the circuit. The vertical-scan output lead should be shielded. Several types of transistors may be used; the circuit was designed for devices with a minimum beta of 50. A variety of integrated operational amplifiers may be used; however, the 709 was chosen because of its low cost and availability.

Scope Modification

The potential between the CRT's control grid and the cathode varies the intensity. The control

[1] Available from Barry Electronics, 512 Broadway, New York, NY 10012.
[2] Catalog SC2799P7, Fair Radio Sales, P. O. Box 1105, Lima, OH 45802.

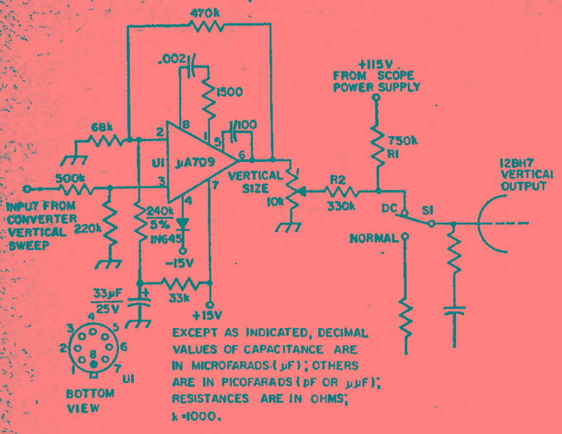


Fig. 3 — Amplifier circuit to provide a dc vertical input for ac-only oscilloscopes. Capacitors are ceramic, and resistors are 1/2-watt. The switch, S1, may be any convenient type. The operational amplifier, U1, is a Fairchild μA709. R1 and R2 should be adjusted in value to give proper centering, if necessary.

grid usually has an isolation resistor in series with the negative voltage lead. Video from the converter is connected across this resistor to vary the intensity of the CRT. This resistor should be at least 100 kΩ. If it is not this large in the existing scope circuit, it should be changed. This will have no effect on the scope's operation, since this control grid draws no current. There is usually ample room on most scopes to install two additional insulated jacks on the terminal board that has the direct deflection-plate connections.

Adjustment

1) Connect the scope's vertical input to test point 1.

2) Connect a 2350-Hz signal to the input and adjust the video discriminator coil L1 for minimum indication on the scope. This is usually with the slug fully inserted.

3) Connect the scope to test point 2. Change the input to 1200 Hz and peak the sync discriminator coil L2 for maximum indication on the scope. Connect a dc voltmeter between the collector of Q3 (sync level) and ground. With a 1300-Hz tone fed to the input of the adapter, adjust the 50,000 ohm sync adjust control to the point where the dc voltmeter just reads +15 volts.

4) Make the connections from the adpater to the oscilloscope's external sync, vertical input, and the CRT grid.

5) Connect the adapter's input to the receiver or tape recorder.

6) Set the contrast control at midposition and the sync control to maximum.

7) Adjust the scope's sweep to 15 Hz for trigger lock.

8) Adjust the size of the raster with the scope horizontal and vertical size controls until a square raster is obtained.

9) Adjust the adapter contrast and the scope intensity controls until a clear picture is obtained. If the picture is negative, the connections to the CRT grid should be reversed.

10) When a picture is obtained, the sync level should be adjusted to a point just before sync is lost. This will eliminate false triggering when copying weak signals and, if a vertical sync pulse is missed, the manual trigger can be used.

The finished adapter can be finally tested in several ways:

1) Tune to one of the SSTV frequencies listed below and look for a station transmitting SSTV. Tune the signal as you normally would for ssb. It is a good idea to tape-record a few pictures off the air — they then can be played back as often as necessary while adjusting the adapter.

2) Send a blank recording tape (with return postage) to any amateur who is equipped with an SSTV flying-spot scanner or camera. All amateurs in this field are happy to make a tape to get a newcomer going.

3) Listen to the SSTV frequencies. You may find a nearby amateur is on the air with SSTV. You can take your adapter to his shack to try it directly on a picture generator.

The slow-scan TV adapter has given good pictures on the scopes tried. A hood should be provided around the CRT face for direct viewing. Scopes with CRT tubes that have an accelerator will provide a brighter scan. The Heath IO-18 scope uses a CRT without the accelerator, and the brightness was noticeably less than others tried.

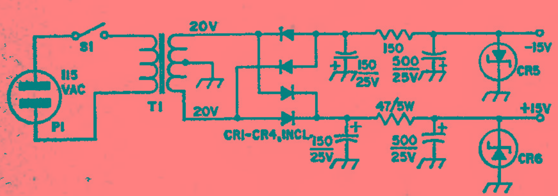


Fig. 4 — Power supply for the adapter. Capacitors are electrolytic. Resistors are 1/2-watt unless otherwise specified.
CR1-CR4, incl. — Silicon type, 200 PRV or greater (Motorola 1N4002, 1N4004 or 1N4007).
CR5, CR6 — 15-volt, 1-watt Zener (Centralab R4128-4, Unitriode Uz715).
P1 — Fused line plug.
S1 — Toggle.
T1 — 40-volt ct, 100 mA (Triad F90X).

> At the present time, most SSTV operation takes place on 20 meters, on or above 14,230 kHz. Local nets operate on 3845 kHz. Other hf calling and working frequencies are 7171, 21,340, and 28,680 kHz. (In the U.S., SSTV emissions are authorized in the Advanced and Extra Class portions of all hf phone bands.) Stations from all continents are to be found on SSTV. The DX capability of SSTV is being demonstrated daily by picture exchanges between the U.S. and Canada and foraign amateurs.

FACSIMILE

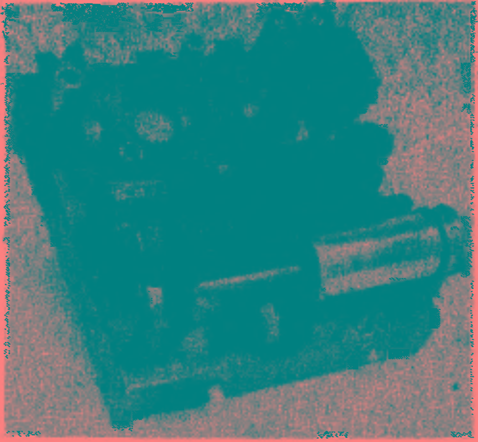
Facsimile (FAX) is an electronic or electromechanical process by which graphic information is transmitted by wire or by radio to a distant receiving point, where it is recorded in a permanent printed form. Common uses of FAX include the transmission of maps, schematic diagrams, drawings, photographs, and other fixed images. At the present time, amplitude modulated facsimile (A4) is permitted in the U.S. on six meters between 50.1 and 54.0 MHz, on two meters between 144.1 and 148.0 MHz, and on all amateur frequencies above 220 MHz. Frequency modulated facsimile (F4) is permitted on all amateur frequencies above 220 MHz.

FAX TRANSMISSION

The most common method of converting written or printed images into the electrical signals used for modulating a transmitter involves photoelectric scanning. The material to be transmitted is wrapped around a cylinder or drum which is rotated about its longitudinal axis, while a tiny spot of light is projected on the surface of the material. The reflected light from the subject copy is focused on a photoconductive tube or photomultiplier. The amplified output of the phototube is an electrical analog of the varying light intensities reflected from the information being scanned. Each rotation of the drum provides one scanning line. As the drum turns, it is slowly moved laterally by a lead screw, causing slight separation of adjacent scanning lines. In this manner, the scanning beam strikes the subject copy in the form of a helix.

The band of frequencies that the output of the phototube occupies is called the baseband. The baseband ordinarily consists of varying dc levels (which represent the range of densities from white to black on the copy) and frequencies in the low audio and subaudio range (which arise from the rapid transitions between the various densities encountered by the scanning beam). On some systems, maximum output is interpreted as white, minimum output is interpreted as black, and intermediate values represent shades of grey. Other systems use the opposite scheme. The baseband signal may be used to vary the frequency of a voltage-controlled oscillator, in order to generate an fm subcarrier (not unlike an SSTV subcarrier) in which the highest frequency represents white, the lowest frequency represents black, and intermediate frequencies represent grey (or vice-versa). Alternatively, the baseband signal may be used to vary the amplitude of a constant-frequency subcarrier.

Another method sometimes used is to interrupt the reflected light from the subject copy by placing a chopper wheel between the light source and the phototube. If the light is interrupted 2400 times per second, the output of the phototube is an amplitude modulated 2400-Hz subcarrier. This system is used in the Western Union Telefax transceivers described later in this chapter.



The Telefax transceiver with cover removed. The shaft along which the drum traverses is visible at the left of the drum. The photo-optic assembly may be seen on the right-hand side of the chassis, just behind the drum.

RECEIVING FAX

Most FAX receiving systems available to the amateur operate on an electromechanical basis. Received a-m subcarrier signals may be demodulated with a diode or other envelope detector. Fm signals are first passed through a limiter to remove amplitude variations, and then through a discriminator and detector. The output from the detector in either case is a varying dc signal corresponding to the lightness and darkness variation in the subject material. There are several methods currently used to transfer the varying dc signal into a printed record of the original copy. Some of the more common processes include the use of electrolytic paper, electrothermal paper, and photosensitive paper.

The action of electrolytic paper is based on the change of color that results from the passage of an electric current through an iron stylus and paper treated with a special electrolyte. A sheet of paper is wrapped around a metal drum on the receiving machine, and the amplified signal voltage is applied between the pointed stylus and the drum. The variation in current caused by the signal voltage appears as variations in the darkness of the paper. The drum rotates, and simultaneously either the drum or the stylus moves laterally, in order to separate the adjacent lines. A drum and stylus are used with electrothermal paper, which has a coating that breaks down chemically when an electric current passes through it, and changes color according to the strength of the current. A lamp replaces the stylus when photosensitive paper is being used. The demodulated signal voltage is used to modulate the intensity of the light source, which exposes the paper. The paper is usually wrapped around a rotating cylinder (as in the previous cases). After exposure, the paper must be processed in a darkroom. Many modern facsimile recorders use a "flat paper" process whereby it is not necessary to place the sensitive recording material around a cylinder. Instead, the paper is continuously drawn from a roll across a flat "writing surface," and an electrode moves across this surface in synchronism with the drum revolution speed at the transmitter.

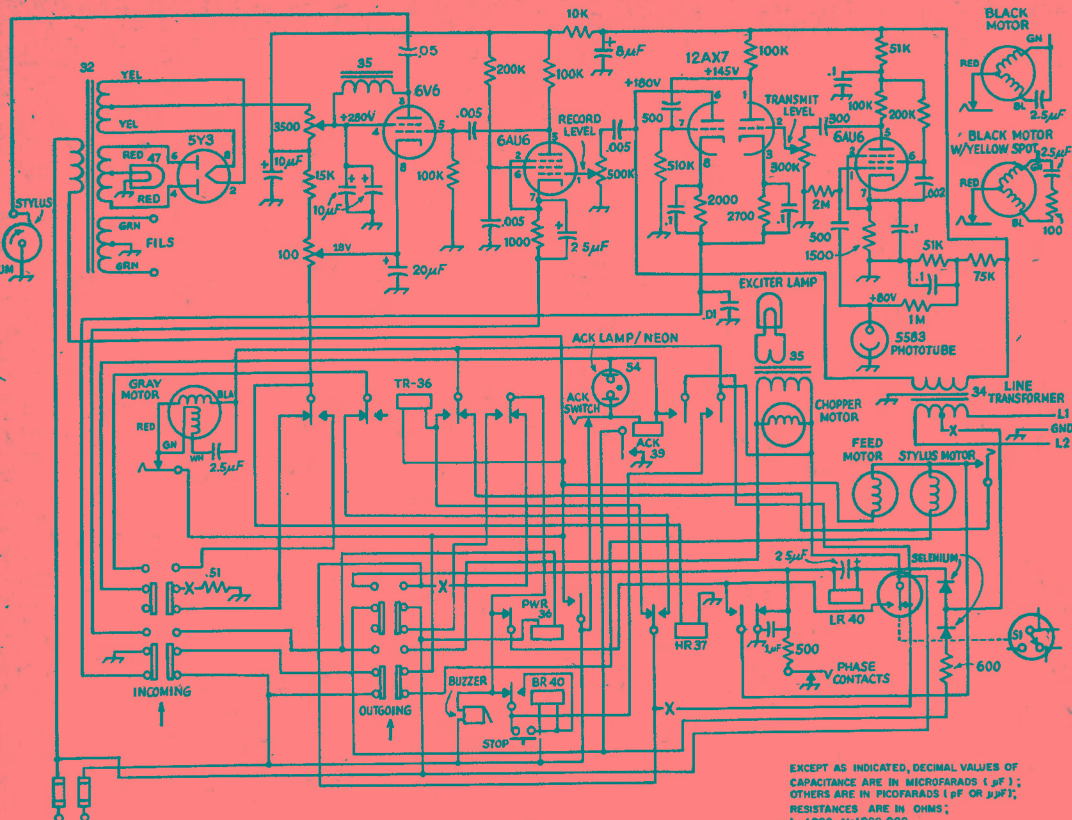


Fig. 1 — Schematic diagram of the modified Telefax transceiver.

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. X = OPENED CONNECTION

Synchronization

It is important that the speeds of the FAX transmitter drum and FAX receiver drum be as close to identical as possible. Failure to match the speeds will result in diagonal tearing or skewing of the received copy. In practice, synchronous motors locked to the frequency of the 60-Hz ac line are used to drive both the drum and the lead screw on a machine.

Phasing

While synchronization ensures that the received FAX picture is spatially consistant with the subject copy being transmitted, it is also important that the start of each scan line coincide with the edge of the paper on the receiving end. If this is not done, the possibility exists (in fact it is probable) that the received image will run off the edge of the paper. Thus, it is necessary for the transmitting machine to send a series of phasing pulses prior to sending the actual picture.

CONVERSION OF TELEFAX TRANSCEIVERS TO AMATEUR SERVICE

Conversion of a telefax transceiver is easy to do. First, remove the cover and check the tubes in a tube tester. Check to see if you have a stylus. If necessary, replace the stylus with carbon-steel wire only. A wire brush is a common source of stylus wire.

Remove the exciter lamp, clean its opening, and set it aside in a safe place. These lamps are hard to obtain. Carefully remove the lamp telescope, then remove the lenses, and clean them. Be sure to replace the lenses in the same direction as they came out. Replace the telescope and exciter lamp. Plug in the 117-V line cord and push the white OUTGOING button to turn on the lamp. Focus the light spot on the drum by moving the telescope back and forth.

Remove the photo-tube telescope and clean both lenses, then reassemble. Turn on the lamp and focus the telescope image on the pinhole at the back of the telescope tube assembly. Put a paper with typed letters on the cylinder. Focus the edge of a letter on the pin hole. This is very important if you are to send sharp pictures.

Remove the bottom plate and solder a .01-μF disk capacitor from the junction of the 2000-ohm and 2700-ohm resistors in the cathode circuits of the 12AX7 tube to ground. This keeps rf out of the video amplifier. Clip one of the leads of the 51-ohm 2-watt resistor on the INCOMING pushbutton switch. The other two leads can also be clipped and the switch can be used to switch the line between your mic and the receiver's audio output.

Clip the wire coming from relay LR, the normally closed contact, and going to relay HR, the moving contact. Clip the wire on the rear of the OUTGOING push button, the normally open contact. Run a wire from this contact to the moving contact of relay HR just made available. See Fig. 1. These changes assure proper operation of the transmit-receive relay.

Remove the ACKNOWLEDGE push button, solder the leads together, and insulate them with spaghetti or tape. In the push-button hole, mount a spdt toggle switch. Disconnect the leads going to the contacts of relay LR (line relay). Run three wires from the spot switch to the three leads at relay LR, replacing the relay function with the switch. Now, when you close the switch, the carriage mechanism for the drum will feed. If your transmitter is keyed with a push-to-talk switch, you may use a dpdt switch, with the second pole to key the PTT line. This will key the transmitter automatically at the start of the scan.

Carefully remove the line transformer and remount it on the rear apron of the chassis in a vertical position behind relay LR. In the original position, the "gray motor" on the chassis above the line transformer will induce hum into the video signal. Solder the shield leads at the old line-transformer location, red to red and black to black. Run two shielded leads from the secondary of the line transformer through the nearby hole in the rear apron and to the LINE terminal strip. Hook a shielded lead to the LINE terminals of the line transformer for connection to your rig's mic jack and speaker leads.

It may be necessary to replace the stylus shielded lead. The old rubber-insulated shield may have become very leaky. Also it's a good idea to replace the lead from the 6V6 tube to the plate choke.

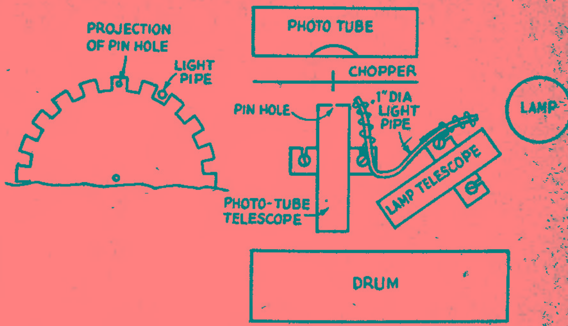


Fig. 2 — Addition of a fiber-optics light pipe for transmission of positive pictures.

Positive Pictures

Fig. 2 shows a modification for sending positive pictures. Mount a short piece of fiber-optics light pipe between the exciter lamp and the chopper wheel. The light pipe is easily held in place by wrapping it with No. 14 wire, placing the wire under the two telescope screws, as shown in Fig. 2. Carefully position the light pipe so it shines through a slot in the chopper wheel when the pin-hole light is cut off by the chopper. Connect an oscilloscope or ac voltmeter to the LINE leads and move the light pipe nearer to or farther from the exciter lamp until the scope or meter shows a null. Fig. 3 shows an experimentally derived circuit which will send sync pulses when in the OUTGOING mode before picture scanning begins. This circuit also receives sync pulses before scan begins to synchronize the drum angle.

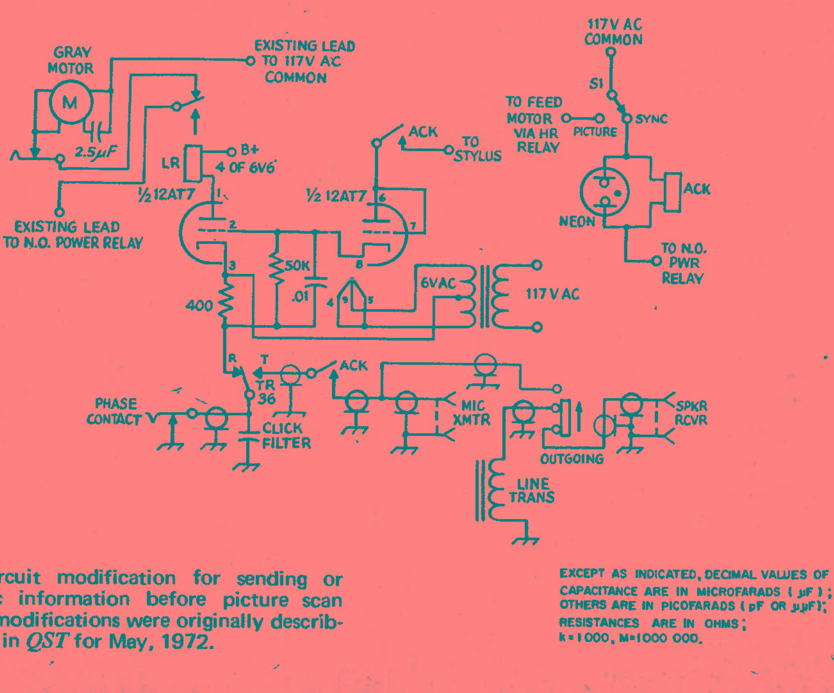


Fig. 3 — Circuit modification for sending or receiving sync information before picture scan begins. These modifications were originally described by W7QCV in *QST* for May, 1972.

SPACE COMMUNICATIONS

The use of vhf and uhf frequencies for intermediate and long distance communications has become possible through space communications techniques. There are basically two types of systems: passive and active. A passive system uses a celestial object such as the moon or an artificial reflecting satellite to return signals to earth. An active system consists of a space vehicle carrying an electronic repeater.

THE MOON AS A PASSIVE REFLECTOR

Communication by reflecting signals off the lunar surface has drawn the interest of an increasing number of amateurs in recent years, despite the considerable challenge such work represents. The requirements for earth-moon-earth (EME) communication are fairly well known. Overcoming the extremely high path loss of the EME circuit calls for close to the maximum transmitter power output obtainable with one kilowatt input, the best possible receiver, and very large high-gain antennas. The highest practical receiver selectivity is helpful, and visual signal-readout is often employed.

These requirements contribute their own problems. Narrow bandwidth demands exceptional frequency stability and calibration accuracy in both transmitter and receiver. High antenna gain means narrow beamwidth, in a system where a slowly moving target that is often invisible must be hit. And even when all demanding conditions are satisfied, the best one can expect is a signal barely distinguishable in the noise.

But the rewards are considerable, for the EME circuit provides vhf and uhf communications potential for any two points on earth where the moon is above the horizon. A surprising number of amateurs have accepted this supreme challenge, and before the end of 1970, all amateur bands from 144 to 2300 MHz had been employed successfully for lunar communications.

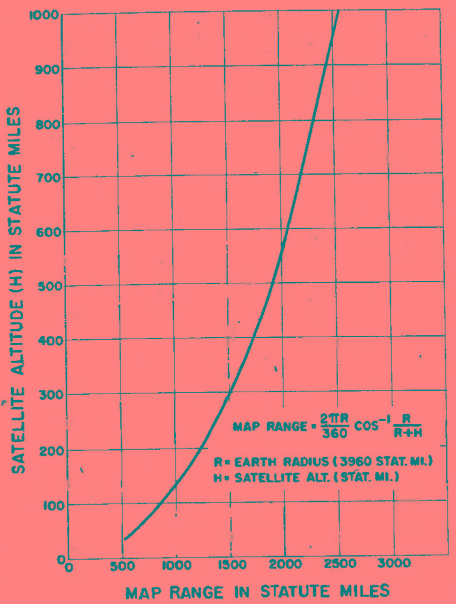


Fig. 15E-1 — Satellite altitude above earth versus ground station map range (statute miles).

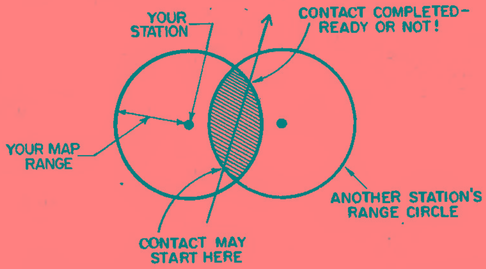


Fig. 15E-2 — Satellite passes through the range of two stations, enabling contact.

SATELLITES

Exciting communications possibilities are afforded through the use of amateur satellites. They function much in the same way as terrestrial repeaters, to relay signals over greater distances than normally feasible. (See chapter 14.) With satellites, the area is usually international in scope. Thus, DX communication on frequencies unable to support ionospheric propagation is possible.

Three amateur communications satellites have been orbited to date. Oscar 3, used in early 1965, was a 144-MHz in-band repeater; Oscar 4, launched in late 1965, repeated 144-MHz signals in the 420-MHz band; Oscar 6, launched in October, 1972, is a long-lifetime translator, repeating 144-MHz signals in the 28-MHz band. Oscars 1, 2, and 5 were beacon satellites for scientific and training purposes.

Current amateur plans for satellite systems involve the use of the 28-, 144-, and 420-MHz bands. Crossband repeaters are favored. Thus, expected combinations might be: 144 uplink, 28 downlink; 420 uplink, 144 downlink; or 144 uplink, 420 downlink. There is a trend toward designing amateur satellites with higher system gains (i.e., higher sensitivity and greater output). The objective is to permit the use of these satellites by average-sized amateur ground stations. Future satellite lifetimes of one year or more can be expected. Effort will be made for successive satellites to utilize similar frequency combinations to alleviate the need for equipment changes in ground stations.

A principal factor in determining how far one can communicate via a particular satellite is the orbit. Higher altitude orbits put the satellite within line-of-sight of greater areas of the earth. Fig. 15E-1 can be used to determine your map range for a satellite according to its altitude. For example, a satellite at 910 miles would give a map range of 2450 miles. For illustration, draw on a map a circle centered on your location with a radius equal to the map range. Each time the satellite is directly over any point