BY DAVID L. MATTIS

DIGITAL FREQUENCY READOUT FOR SHORTWAVE RECEIVERS

Programmable counters provide direct display of received frequency to 30 MHz.

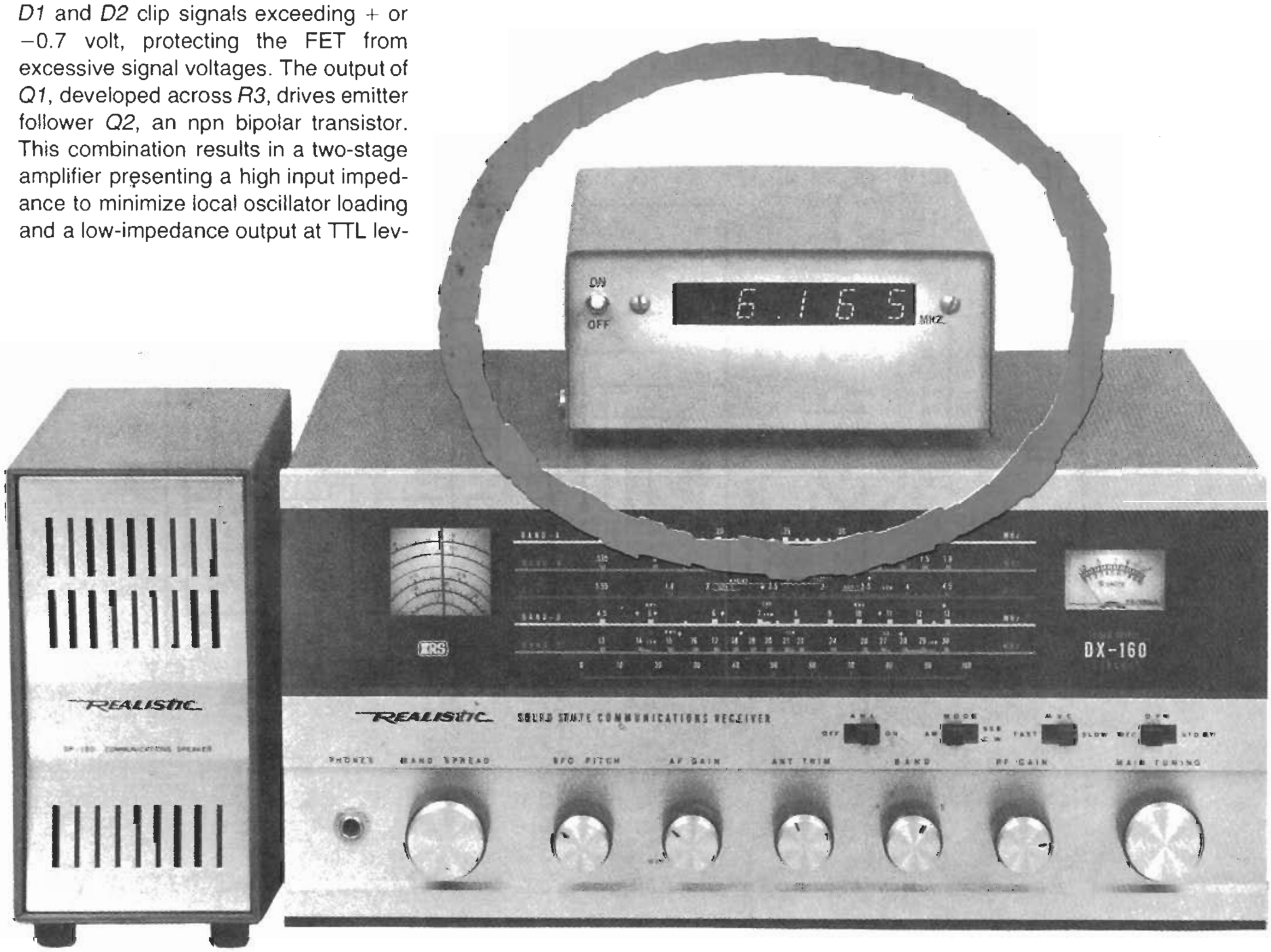
ALTHOUGH "beginner's" shortwave receivers provide an inexpensive entry to a fascinating hobby, they do have limitations. A major one is poor dial calibration, which makes monitoring and QSL procedures difficult.

Fortunately, external circuitry can compensate for this limitation. The digital frequency display project presented here will allow the user to determine a transmitter's frequency to the nearest kilohertz on a bright, stable LED display. It accepts an input signal from the receiver's local oscillator, converts the signal to a TTL-compatible form which is then counted. Programmable counters are pre-loaded to compensate for the receiver i-f, thus allowing direct readout of the received frequency. The project will work with most single- and multiple-conversion receivers from the longwave broadcast band through 10 meters (30 MHz). Total project cost is about $110.

About the Circuit. The schematic diagram of the digital frequency readout is shown in Fig. 1. An input signal from the receiver's local oscillator is coupled through *C1* and *R1* and applied to the gate of *Q1*, an n-channel FET. Diodes *D1* and *D2* clip signals exceeding + or −0.7 volt, protecting the FET from excessive signal voltages. The output of *Q1*, developed across *R3*, drives emitter follower *Q2*, an npn bipolar transistor. This combination results in a two-stage amplifier presenting a high input impedance to minimize local oscillator loading and a low-impedance output at TTL levels. Ferrite beads *L1* and *L2*, together with disc capacitor *C3*, are used for r-f decoupling on the +5-volt line.

A two-stage Schmitt trigger composed of NAND gates *IC1A* and *IC1B* converts the amplified local oscillator signal into a square wave, which is then gated by *IC1C*. The gating interval (10 milliseconds) is provided by a crystal controlled time base and divide chain. A 4-MHz square wave generated by *IC19* is first divided by 4 by the flip-flops in *IC2*. The 1-MHz output of the second flip-flop is further divided by two dual decade counters (*IC3* and *IC4*) to yield a 100-Hz reference signal. The second decade counter in *IC4* is wired as a bi-quinary counter to provide a symmetrical square-wave output signal. This counter also supplies three control signals to *IC5*, which generates the latch and preset control pulses at the end of each counting (gate) interval which govern the counting and display IC's.

For a 10-ms counting interval, a 50-Hz gating signal is required. It is obtained by dividing the symmetrical 100-Hz output of *IC4* by two. This is performed by *IC6*, a JK flip-flop. The 50-Hz square



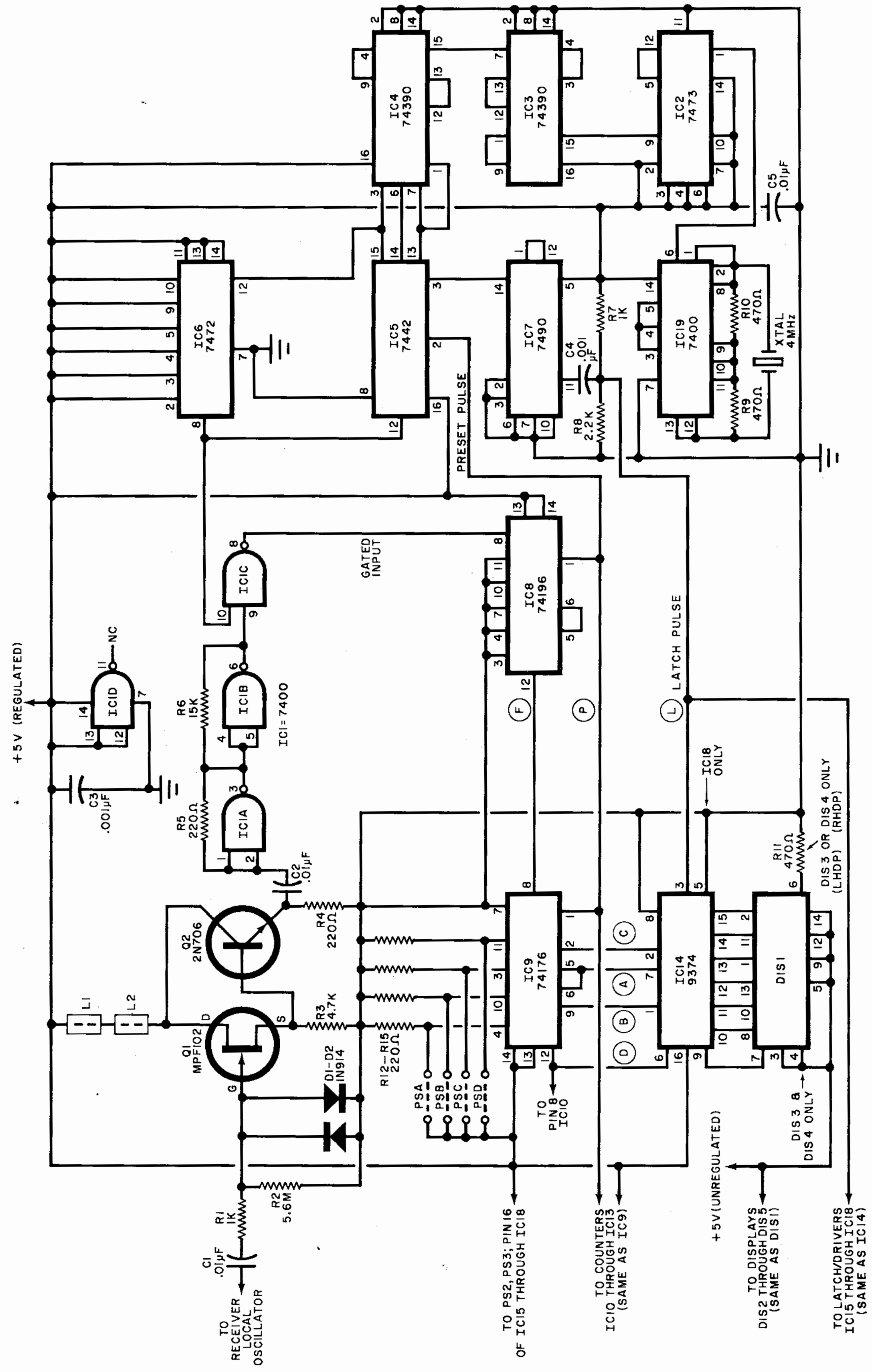


Fig. 1. Schematic diagram. For simplicity, only one decade of display is shown.

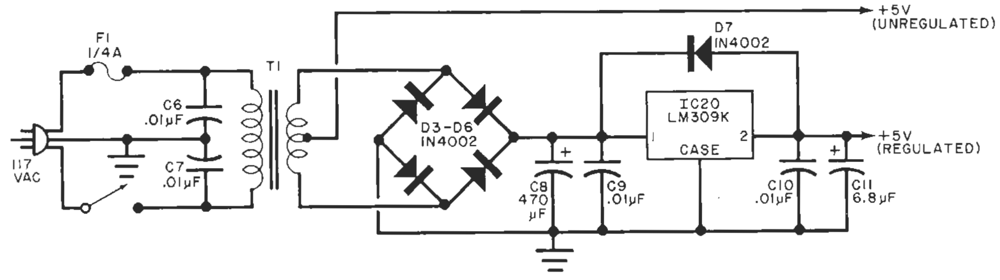


Fig. 2. Schematic diagram of the power supply.

wave is applied to both *IC5* and to one input of NAND gate *IC1C*. When the gate signal is high (for 10 ms), *IC1C* passes an inverted version of the squared local oscillator signal to counters *IC8* through *IC13*. During the 10-ms "low" period, *IC5* produces the latch and preset control pulses.

Even though the counters resolve the local oscillator frequency to the nearest 0.1 kHz during the 10-ms gate interval, the received frequency is displayed only to the nearest kilohertz. The use of the undisplayed 0.1-kHz counter (*IC8*) eliminates the bothersome "bobble" in the least significant digit in other frequency readouts, thus providing a steady frequency display. A 1-kHz bobble occurs only when the counter is at the borderline between two frequencies—for example, 6.1649 and 6.1650 MHz.

Counter *IC8* is specified as a 74196 programmable counter IC, but *IC9* through *IC13* are specified as 74176 IC's. The 74196 is used to insure reliable performance to 30 MHz. However, a hand-picked 74176 which can function up to 30 MHz can be used in place of the costlier 74196. The preset feature of these IC's permits the display of the received signal's frequency, even though the counters are working with the local oscillator frequency, which is actually higher or lower by the intermediate frequency of the receiver. Counters *IC9* through *IC13* can be pre-loaded with any value determined by programming jumpers or switches at points *PSA* through *PSD*. The counters are loaded with this number at the reception of the preset pulse prior to the initiation of each counting interval.

At the end of every tenth counting cycle, a latch pulse appears at the output (pin 11) of *IC7*. It is then differentiated by *C4*, *R8*, and *R7* and applied to latch/decoders *IC14* through *IC18*. When this happens, the binary information accumulated in the programmable counters is transferred, stored, and decoded for display on seven-segment LED readouts *DIS1* through *DIS5*. The latch pulse is generated by *IC5*. Although preset pulses are produced after each counting interval, only one in every ten counts is transferred to the 9374 latch/decoders (*IC14* through *IC18*). This is so because *IC7* divides the input signal from *IC5* to produce a latch pulse with a frequency of 10 Hz.

As a result, the display flickers noticeably when the frequency is changing. Also, blurring and readout of spurious eight's—common problems with seven-segment displays—do not occur during a shift in frequency. Rather, the 10-Hz latch rate permits the display to track each frequency change with legible readout values.

The project's power supply (Fig. 2) is

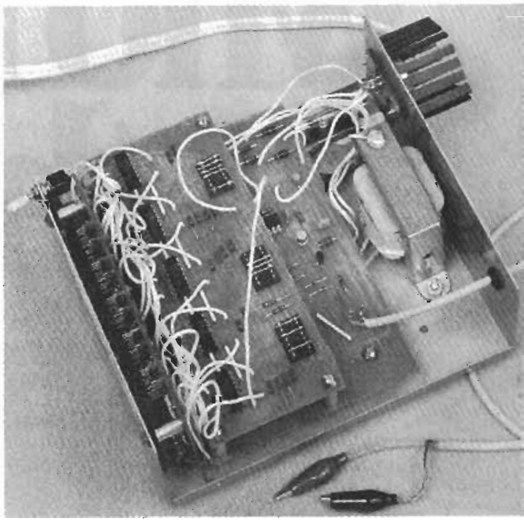


Fig. 3. Photo of prototype.

PARTS LIST

C1,C6,C7,C9—0.01-μF, 1000-volt disc ceramic capacitor
C2,C5,C10—0.01-μF, disc ceramic capacitor
C3,C4—0.001-μF disc ceramic capacitor
C8—470-μF, 25-volt electolytic capacitor
C11—6.8-μF, 25-volt tantalum capacitor
D1,D2—1N914 switching diode
D3 through D7—1N4002 rectifier
DIS1 through DIS5—MAN-1 or MAN-64 common anode seven-segment LED display
F1—¼-ampere, 250-volt, 3-AG slow-blow fuse.
IC1,IC19—7400 quad 2-input NAND gate
IC2—7473 dual JK master-slave flip-flop
IC3,IC4—74390 dual 4-bit decade counter (Texas Instruments)
IC5—7442 BCD-to-decimal decoder
IC6—7472 JK master-slave flip-flop
IC7—7490 decade counter
IC8—74196 45-MHz presettable decade counter (see text)
IC9 through IC13—74176 25-MHz presettable decade counter
IC14 through IC18—F9374PC latch/7-segment decoder/driver (Fairchild)
IC20—LM309K 5-volt regulator
L1,L2—Ferrite bead (⅛" × ⅛" or 3.2 × 3.2 mm)
Q1—MPF102 n-channel JFET
Q2—2N706 npn transistor
The following resistors are ¼-watt, 5% tolerance:
R1,R7—1000 ohms
R2—5.6 megohms
R3—4700 ohms
R4,R5,R12 through R29—220 ohms
R6—15,000 ohms
R8—2200 ohms
R9 through R11—470 ohms
S1—SPST miniature toggle switch
PS1 through PS3—DIP switches (see text)
T1—12.6-volt, 1.2-ampere center-tapped transformer
XTAL—4-MHz, 0.0025% tolerance crystal
Misc.—Suitable enclosure (7¼" × 6¼" × 2¾" or 18.4 × 15.9 × 7 cm suggested); red Plexiglas bezel (5¼" × 1" or 13.3 × 2.5 cm); transistor sockets; IC sockets or Molex Soldercons; heat sink compound; TO-3 heat sink (1¼" or 3.2-cm fins); metal spacers; machine hardware; line cord; coaxial cable; rubber grommets; hookup wire; solder; fuseholder; etc.

Note: The following are available from Mattis Electronics, Box 162, Morton Grove, IL 60053. Set of three etched, drilled and plated pc boards (No. SW-1), $18.95; 4-MHz precision crystal (No. SW-2), $9.95; Five F9374PC latch/decoder/driver IC's (No. SW-3), $15.95; Kit of parts including three pc boards, crystal, IC's, discrete semiconductors and pc board components (No. SW-4), $74.95; Complete kit of parts including enclosure and power-supply components (No. SW-5), $109.95. All prices include shipping charges within the USA. Illinois residents add 5% sales tax.

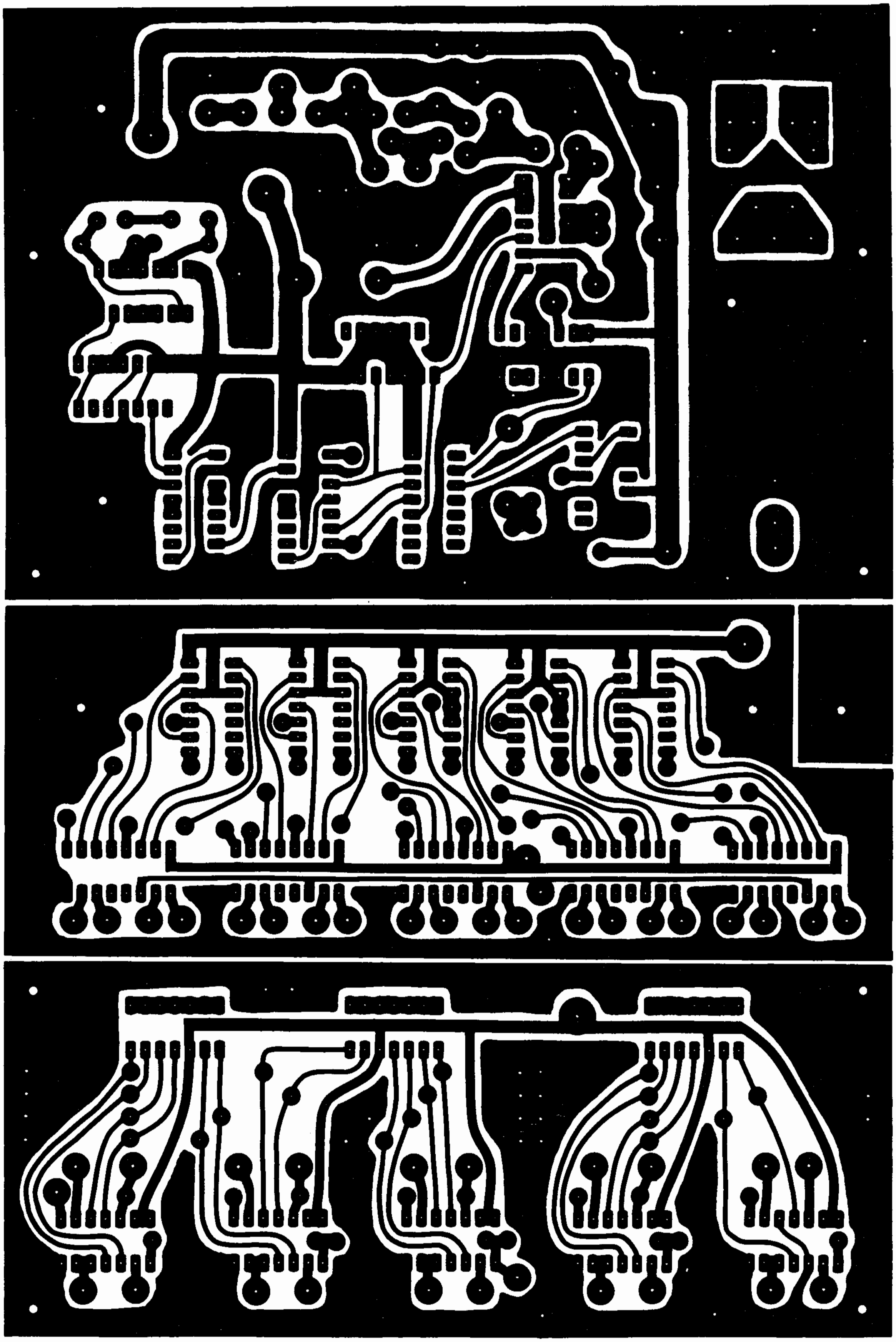


Fig. 4. Etching and drilling guides for main (top), display (center), and counter (bottom) pc boards.

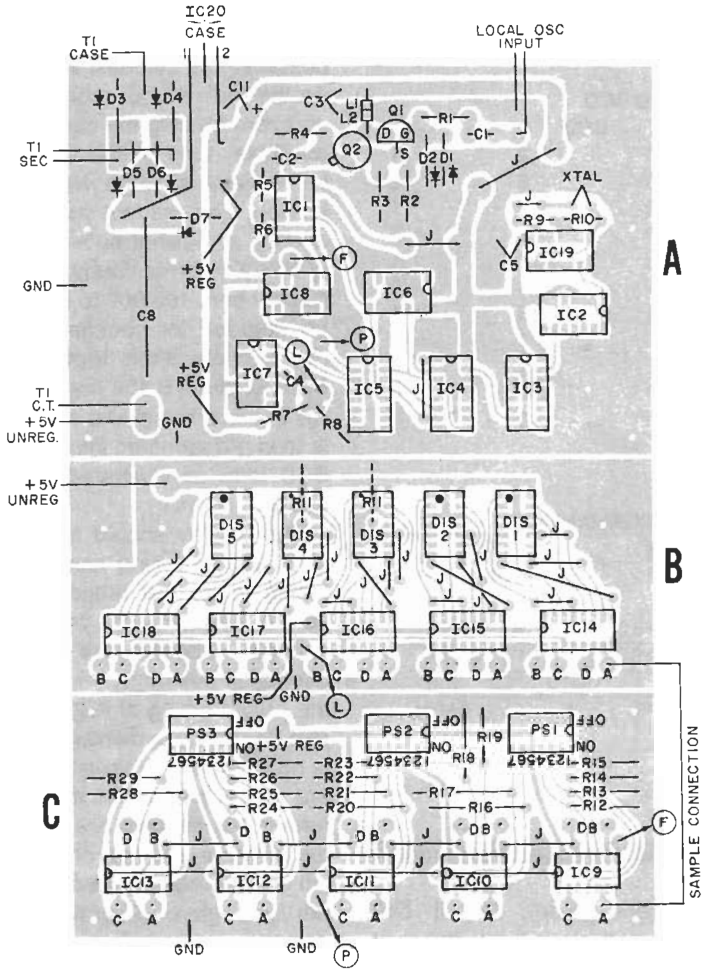


Fig. 5. Parts placement guides for main (top), display (center), and counter (bottom) pc boards.

a combination full-wave and bridge rectifier using a single 12.6-volt, center-tapped transformer. Two dc outputs are provided. The bridge rectifier (*D3* through *D6*) delivers pulsating dc to *C8* which acts as a filter. The filtered dc (+16 volts) is then applied to *IC20*, an LM309K voltage regulator, which is protected against transients by *D7*, *C9* and *C10*. A well-regulated +5-volt dc output is thus provided for the TTL IC's and the input circuit.

Another +5-volt dc source is derived from the center tap of *T1*, *D3* and *D4*. The three components form a full-wave rectifier, but its output is unfiltered and unregulated. This output is used to power the seven-segment readouts (*DIS1* through *DIS5*). The unfiltered, pulsating dc has a ripple frequency of 120 Hz, which is great enough to prevent display flicker and results in a display brightness comparable to that obtained with a steady dc source. Removing the display current demand from the regulated supply substantially reduces the amount of heat generated in the power transformer and voltage regulator IC, but causes no adverse effects. Display segment current limiting is performed internally by the 9374 IC's which also contain internal latch memories. No external current limiting resistors or bistable latch IC's are required, as is often the case with other decoder/driver chips.

Construction. The project should be assembled using printed circuit boards and IC sockets or Molex Soldercons. Transistor sockets (standard and TO-3) are also recommended for *Q1*, *Q2*, and *IC20*. The author used three pc boards in his prototype (Fig. 3). The boards can be interconnected with short lengths of No. 20 stranded hookup wire. Suitable etching and drilling guides are shown in Figs. 4 and 5 (A, B, and C) for the Main, Display, and Counter boards, respectively. Use the minimum amount of heat necessary for good solder connections. Be sure to observe polarities and pin basings of discrete semiconductors, IC's, and electrolytic capacitors.

Figure 3 shows how the boards and power supply components were mounted in the project enclosure. The Counter and Main pc boards were secured to the bottom of the cabinet using ¾-inch (1.9 cm) threaded metal spacers, while the Display board was mounted behind a bezel on the front of the case using ½-inch (1.3-cm) threaded metal spacers. Voltage regulator *IC20* must be properly heat sinked and mounted on the exterior of the enclosure's rear panel. Use heat sink compound to insure proper heat transfer, and be sure to connect a length of hookup wire between the regulator socket's center ground bus and the Main pc board's ground. Also, make sure that *IC20's* mounting screws are in firm contact with the IC's case and the TO-3 socket's ground bus. The author also recommends grounding the power transformer's case.

Because TTL IC's are high-current switching devices, the steep edges of their output waveforms contain large amounts of r-f energy. Unless certain precautions are taken, this r-f will produce high noise levels at the receiver output. First, a metal case must be used—but it must also be perforated or vented to allow heat to dissipate. Second, both the project's and receiver's enclosures must be tied to a good earth ground. Third, both sides of the ac power line must be bypassed with 0.01-μF disc ceramic capacitors (*C6* and *C7*).

Checkout and Use. A typical receiver's local oscillator is shown schematically in Fig. 6. Whether the receiver uses a FET, tube, or transistor oscillator, the point where the local oscillator signal must be tapped off is the same—at the capacitor coupling the output of the oscillator to the mixer. The author suggests that the signal be sampled on the local oscillator side of the coupling capacitor. For the following three popular SW receivers, the appropriate points are: Realistic DX-160, junction of *C12* and *R32* (drain of *Q8*); Lafayette HA-600A, junction of *C6* and *R21*; Heathkit GR-78, junction of *C308*, *R203*, and *R204*. (Note: if you are using a tube-type receiver, *beware of high voltage!*) The connection should be made with small-diameter coaxial cable such as RG-58-U. You might find it desirable to mount an RCA phono jack on the back of receiver and bring the coax from the local oscillator output to this point. Then you can interconnect the display and receiver with a short coaxial jumper terminated with an RCA phono plug. Alternatively, you can terminate one end of the jumper with small alligator clips, as

TABLE A
CONVERTING DECIMAL NUMBERS TO BCD

Number	BCD 8	4	2	1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

TABLE B
COUNTER BOARD PROGRAMMING ASSIGNMENTS

<table>
<tr><th>Programming section</th><th colspan="2">PS3</th><th colspan="2">PS2</th><th>PS1</th></tr>
<tr><td>Programming input number</td><td colspan="2">7654321</td><td colspan="2">7654321</td><td>7654321</td></tr>
<tr><td>BCD designation</td><td colspan="2">81-8241</td><td colspan="2">8241-82</td><td>41-8241</td></tr>
<tr><td>Actual programming*</td><td colspan="2">1111001</td><td colspan="2">0011100</td><td>1010010</td></tr>
<tr><td>Counter controlled</td><td>IC13</td><td>IC12</td><td>IC11</td><td>IC10</td><td>IC9</td></tr>
<tr><td>Frequency displayed (receiver off)</td><td>9</td><td>9</td><td>.5</td><td>4</td><td>4 MHz</td></tr>
</table>

*0 = no jumper or open switch (OFF),
1 = jumper or closed switch (ON).

was done with the prototype (Fig. 3). The clip would then be attached to the proper tie point within the receiver.

The counters will be programmed with DIP switches (seven spst switches mounted in a DIP) or with wire jumpers on the counter board. If you are using DIP switches, make sure that all switches are in the OFF position. If wire jumpers are to be used, do not install any of them yet.

Turn the power switch (*S1*) on. The display should read 0.000 with the second zero to the left of the decimal point blanked off. Insert No. 22 solid jumpers across the IC sockets at the number 5 positions of *PS1* and *PS3* and at the number 3 position of *PS2* (see component placement guide). Or, if DIP switches are used, close the switches at these positions. Then momentarily insert a jumper across the other IC socket positions and verify that the corresponding counter responds according to Table B. For DIP switches, this is accomplished by turning the remaining switches on and off. As voltage is applied to each programming input, the BCD value of that input will be displayed on the corresponding LED readout.

After completing the checkout procedure turn the power off and connect the hot and ground sides of the coaxial jumper to receiver's local oscillator output and chassis, respectively. Turn on the receiver and tune it to WWV or WWVH at 5 MHz. Tune the receiver to the station's carrier as accurately as possible. You can best do this by turning on the bfo—if your receiver has one—and zero beating the carrier. If no bfo is available, tune in the carrier for maximum signal strength. Now turn the project on. The readout will display a frequency somewhat above or below that of WWV's carrier. Subtract the number display from 105.000 to obtain the number needed for counter programming. For example, if the display reads 5.456 MHz, subtract 5.456 from 105.000. You will obtain a remainder of 99.544, which is then programmed into the counters in BCD form as illustrated in TABLES A and B.

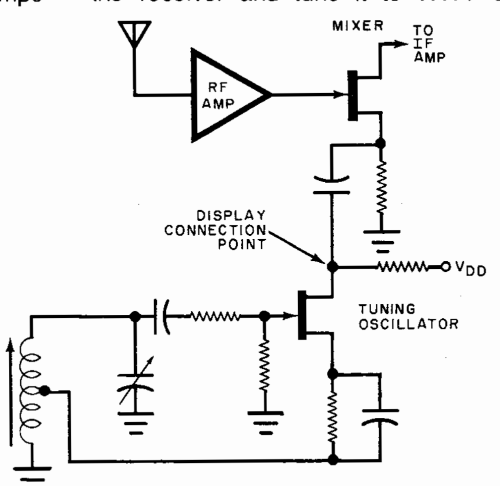


Fig. 6. Typical local oscillator circuit

The display should now read 5.000 MHz. Programming can be verified by tuning in an AM broadcast station of known frequency for maximum signal strength. Observe the displayed frequency. If it is off by 1 kHz or so, adjust the programming of *IC9* so that the correct frequency is displayed. The project is now properly programmed for receivers with a fixed i-f for all bands and no further adjustments are needed. When the receiver is turned off but the project left on, the readout will display the number you have programmed into the counters.

Some multiple conversion receivers, such as the Heath GR-78, will require different programming for different bands. Thumbwheel switches with BCD outputs can be mounted on the front panel and used in place of jumpers or DIP switches. This will greatly speed programming.

The project is *not* suitable for use with those multiple conversion receivers having second (lower) i-f's with variable frequency (local) oscillators operating *below* the first i-f. In such a case, the tunable oscillator's output frequency is highest when the receiver is tuned to the lowest frequency within a given band. Conversely, the oscillator's output frequency is lowest when the receiver is tuned to the highest frequency within the band. However, receivers using this type of i-f generally have dial mechanisms with wide bandspread and frequency readout to the nearest one or five kilohertz. Therefore, they do not need the kind of improvement this project can provide.

For inexpensive SW receivers, however, this project is an enormous asset. Not only will it greatly enhance the user's enjoyment of shortwave listening, it will also make station tuning and logging a "breeze." ◇

TUNE YOUR RECEIVER BY THE NUMBERS!

Add a 4-digit display and locate stations quickly and accurately

BY GARY McCLELLAN

A DIGITAL frequency display on a radio is a special nicety. If you own an AM/FM or FM-only receiver that has the old-fashioned analog dial, here is how you can add an LED digital display that will make it easier to tell what frequency you're on and will also help you locate any station.

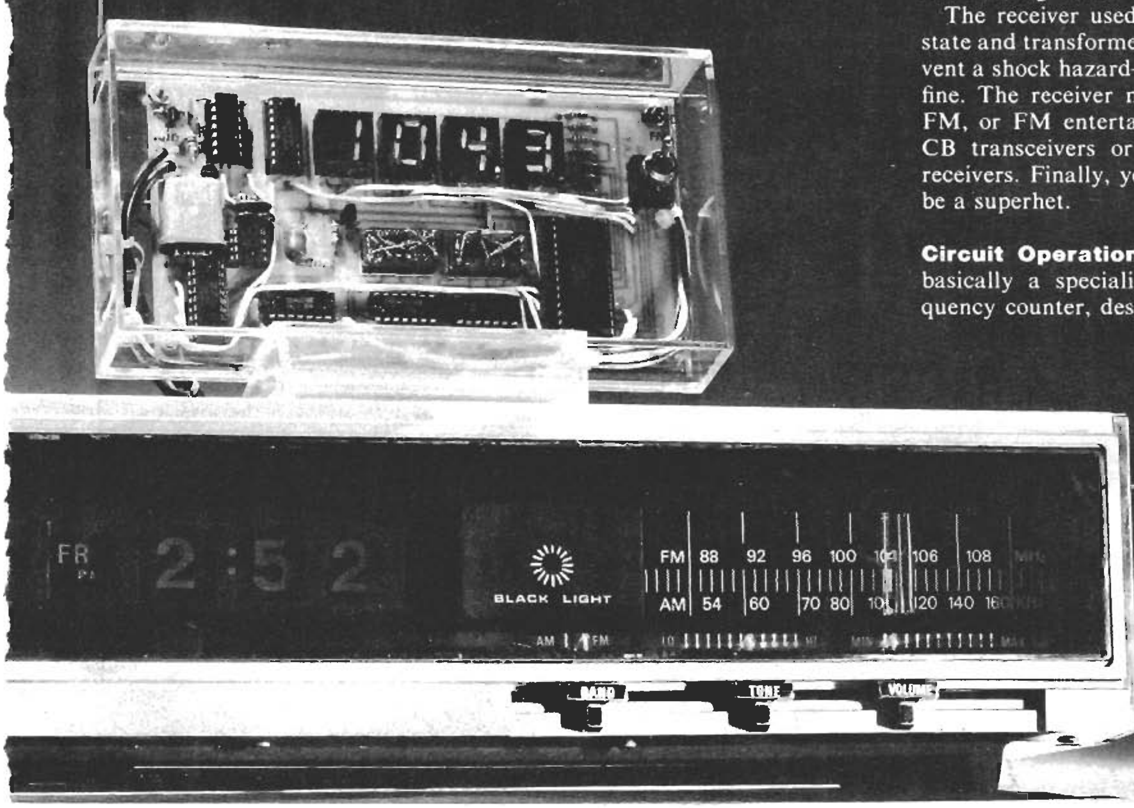
The display indicates AM frequencies to the nearest 1 kHz and FM frequencies to the nearest 100 kHz. Also, the project can be used at long-wave frequencies.

Besides superior resolution as compared to a dial, the display project offers a display update of ten readings a second, fast enough to "follow" the tuning knob. Also, it is adaptable to a wide range of receivers having different intermediate frequencies. Two simple PROMs, made out of a few diodes, program the project to suit the circuit.

Only three connections to the receiver itself are required (AM local oscillator, FM local oscillator, and ground). It is suggested that you obtain the schematic of your receiver as this will make installation much easier. In addition, a tiny module is installed inside the receiver for FM signal processing. The display itself is separate from the receiver to allow for convenient positioning. If desired, the display can be built inside the receiver, as it is small enough to replace most tuning dials.

The receiver used should be solid-state and transformer-powered to prevent a shock hazard—battery sets are fine. The receiver must be an AM/FM, or FM entertainment type—no CB transceivers or communications receivers. Finally, your receiver must be a superhet.

Circuit Operation. The project is basically a specialized type of frequency counter, designed to measure



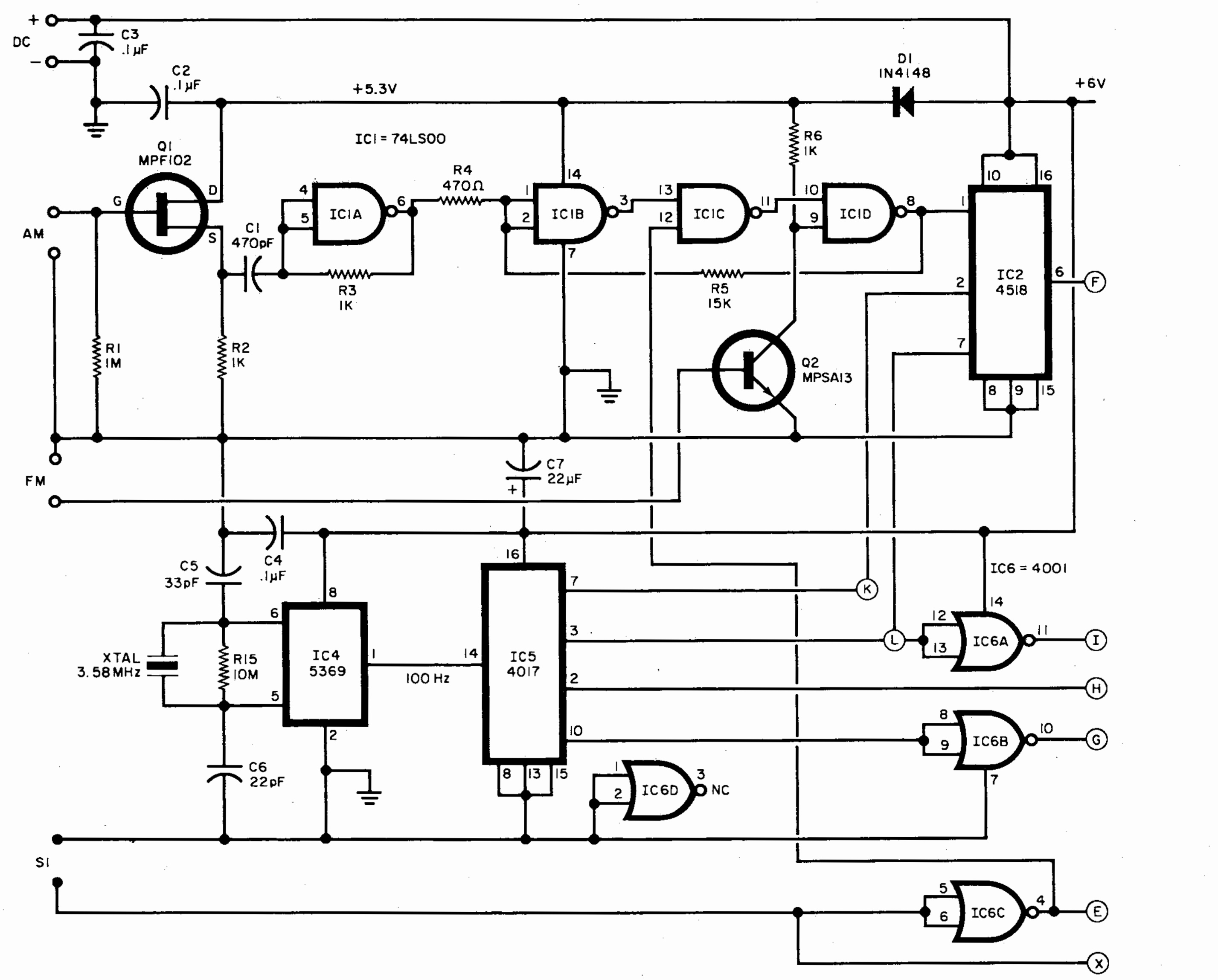


Fig. 1. The schematic for the digital display circuit, shown on these two pages, can be divided into three functional sections: AM input, time base, and programmable counter.

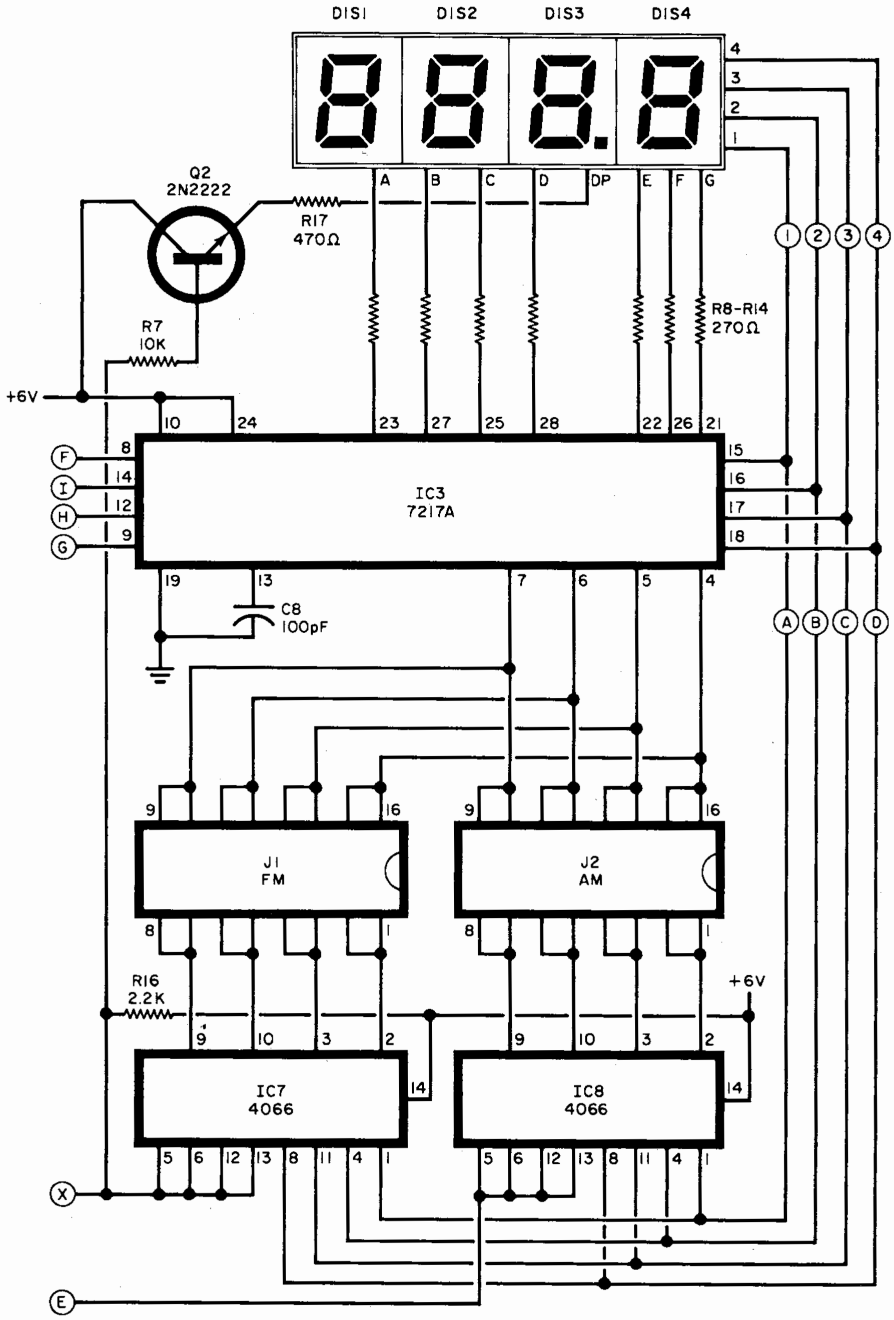
the receiver's local oscillators, and subtract the i-f to display the actual (not local oscillator) frequency to which the receiver is tuned. CMOS logic is used for low current drain.

The schematic, shown in Fig. 1, can be broken down into three sections; AM input, time base, and programmable counter. Each section will be described in detail.

Signals from the AM local oscillator appear at the gate of *Q1*, a FET source follower. This stage has no gain, but simply insures that the input will have a high impedance to reduce loading of the local oscillator. The output of *Q1* drives *IC1A*, a TTL gate wired as an amplifier, to boost the sensitivity. The output of *IC1A* drives *IC1B* and *IC1C*, which converts the local oscillator sine-wave signal into a square wave, suitable for driving digital circuitry. Gate *IC1D* allows either the AM or FM signal to pass to the remainder of the counter.

The FM signal, converted to a square wave, comes from an external board and drives *Q2*, which passes the signal on to *IC1D*. The output of *IC1D* drives *IC2*, a divide-by-10 counter. This counter scales the input frequency by 10 to drive the slower counter circuit that follows. The one-count error inherent in other frequency counters is also reduced by *IC2* because it is reset (via pin 7) with the remainder of the circuitry. This produces a stable display—one where the last digit isn't constantly changing. The AM input circuit has a sensitivity of 40 mV at 2 MHz, at least four times more than required in most applications.

The time-base circuitry consists of *IC4*, *IC5*, and *IC6*. The 3.58-MHz color-TV crystal generates the stable timing frequency while *IC4*, a CMOS time base designed for this type of application, provides the necessary oscillator for the crystal and divides its frequency down to 100 Hz. The 100-Hz signal drives decade counter *IC5*. This device has 10 decoded outputs and each output is high for 10 ms (the period of 100 Hz). Pin 3 goes high first to reset counters *IC2* and *IC3* to zero. Then pin 2 goes high to force



PARTS LIST
(Display Board)

C1—470-pF disc capacitor
C2,C3,C4—0.1-µF, 16-V disc capacitor
C5—33-pF disc capacitor
C6—22-pF disc capacitor
C7—22-µF, 16-V electrolytic
C8—100-pf disc capacitor
D1—1N4148 diode
DIS1 through DIS4—FND-503 common-cathode LED display (Radio Shack 276-1647)
IC1—74LS00 TTL quad NAND gate
IC2—CD4518 decade counter
IC3—Intersil ICM7217A programmable counter
IC4—National MM5369 EST/N timebase
IC5—CD4017 decade counter
IC6—CD4001 quad NOR gate
IC7,IC8—CD4066 switch
J1,J2—16-pin IC socket
Q1—MPF102 JFET transistor
Q1—MPSA13 Darlington transistor
R1—1-MΩ, ¼-W, 5% resistor
R2,R3,R6—1-kΩ, ¼-W, 5% resistor
R4,R17—470-Ω, ¼-W, 5% resistor
R5—15-kΩ, ¼-W, 5% resistor
R7—10-kΩ, ¼-W, 5% resistor
R8 through R14—270-Ω, ¼-W, 5% resistor
R15—10-MΩ, ¼-W, 5% resistor
R16—2.2-kΩ, ¼-W, 5% resistor
XTAL—3.579-MHz crystal
Misc.—IC sockets, Molex Soldercons, wire, solder, etc.

Note: The following is available from Technico Services, Box 20 HC, Orangehurst, Fullerton, CA 92633: set of two pc boards (for display and prescaler), #DISP-1, for $12.00. Outside US, add $3.00 for shipping and handling. California residents, add sales tax.

counter *IC3* to load a preset value (the i-f we want to subtract). After that, pin 7 goes high. When this signal occurs, a gate inside *IC2* is enabled, allowing the signal from the receiver local oscillator (via *IC1*) to be counted. Finally, pin 10 goes high to update the display, showing the correct frequency.

The gates of *IC6* are wired as inverters, and interface the time base to the different parts of the circuit. One section, *IC6C*, is important in that it provides AM/FM display switching. When the *S1* terminals are open, the FM frequency is displayed because the input to *IC6C* is high due to *R16*. This, in turn, enables *IC7*, a quad electronic spst switch, connecting the FM diode PROM in *J1* to the counter. Simultaneously, *Q3* is turned on, causing the decimal point in the display to glow. Since the output of *IC6C* is low, this disables *IC1C* so that any signal from the AM local oscillator won't trigger the counter. When the *S1* terminals are shorted, the project displays AM frequency. The output of *IC6C* is high, enabling *IC1C* so that AM signals can get through. And finally, *IC8* is enabled, connecting the AM diode PROM in *J2* to the counter.

Programmable counter *IC3* is set to a value determined by the *J1* or *J2* plug-ins. It counts frequency from this point and displays the result on four seven-segment displays (*DIS1* through *DIS4*). Since the operation of the reset, count, and latch functions of *IC3* were described in the time-base section, all that's left is the programming circuitry. This is the job of *IC7*, *IC8*, *J1*, and *J2*. Transmission gates *IC7* and *IC8* each contain four switches, and making the four enable lines (pins 5,6,12,13) high turns them on. Because of *IC6C*, either *IC7* or *IC8* will be on at a given time. For example, when *IC7* is on, the lines from *J1* (FM) are connected to the output of *IC3*, enabling *IC3* to program itself to whatever data is on *J1*. In this project, the *J1*, *J2* plug-ins use a few diodes to program the counter. Conversely, when *IC8* is on, *IC7* is off. Then *J2* is connected to the counter.

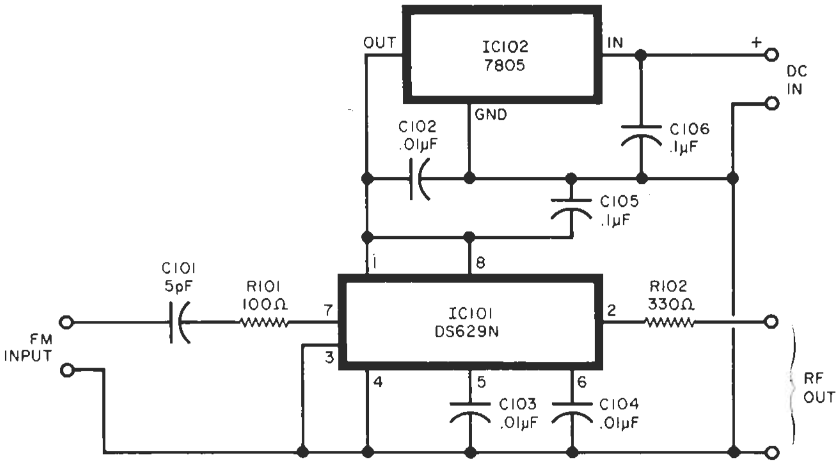
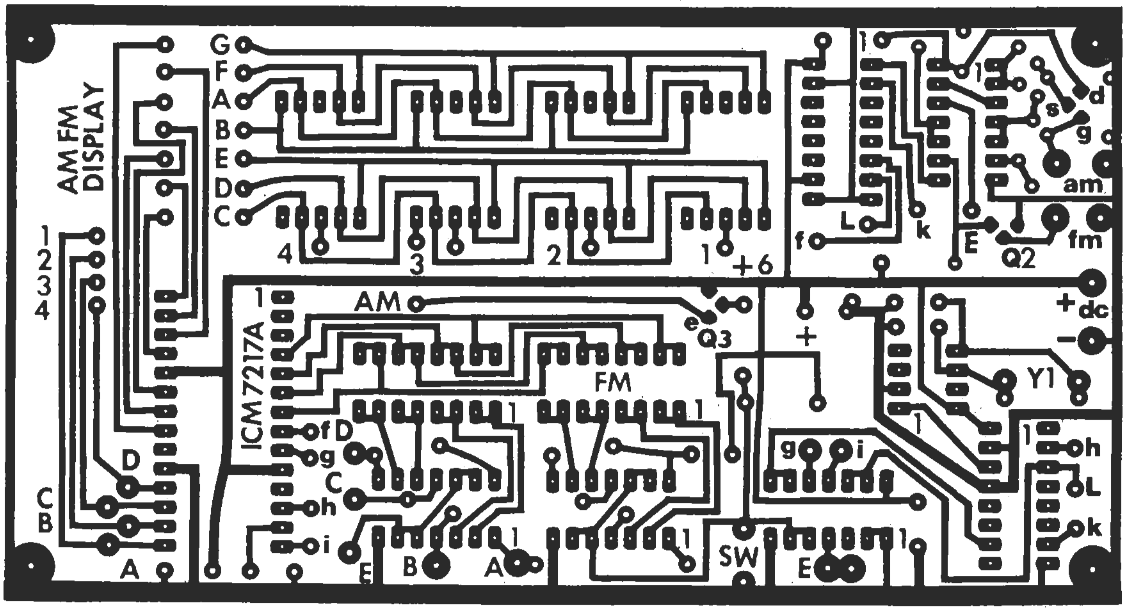


Fig. 2. The FM prescaler circuit is installed inside the receiver and connected to the FM local oscillator.

PARTS LIST
(Prescaler)

C101—5-pF disc capacitor
C102,C103,C104—0.01-µF, 50-V disc capacitor
C104,C106—0.1-µF, 16-V disc capacitor
IC101—National DS8629N VHF prescaler
IC102—7804, 5-volt regulator
R101—100-Ω, ¼-W, 5% resistor
R102—330-Ω, ¼-W, 5% resistor
Misc. IC socket, cable, wire, solder, etc.
Note: See Display Board Parts List for ordering information on pc board.



The FM prescaler board (Fig. 2) is installed inside the receiver and connected to the FM local oscillator. Otherwise, the long cables required to bring out the FM local-oscillator signal would detune the oscillator, making the FM section inoperative.

This board contains vhf prescaler *IC101*, especially designed for this type of application. It features a built-in preamplifier, and a divide-by-100 counter. Input sensitivity is about 25 mV at 100 MHz, or about five times more gain than is required. This insures good performance with almost any FM receiver, including battery types with low-level oscillator outputs. The output of the prescaler board drives the FM input on the display board. The signal is in the 1-MHz range, and is at TTL level. Voltage

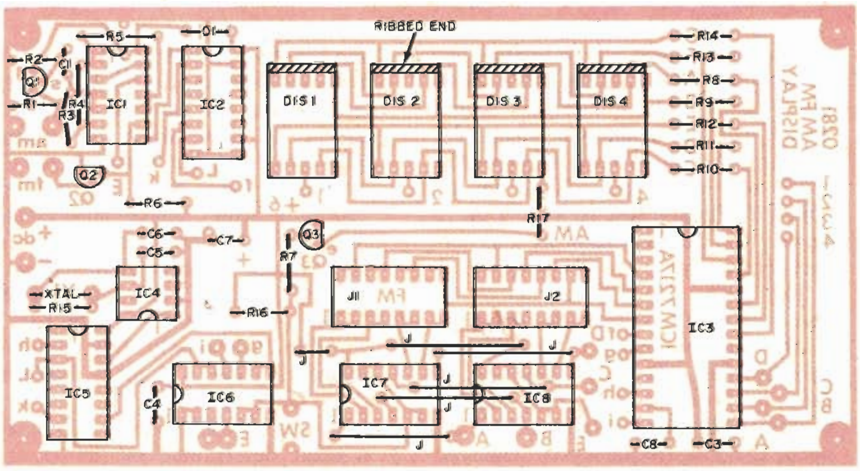


Fig. 3. Foil pattern (top) and component layout (bottom) for the display board. Note the bare-wire jumpers which must be installed before the components.

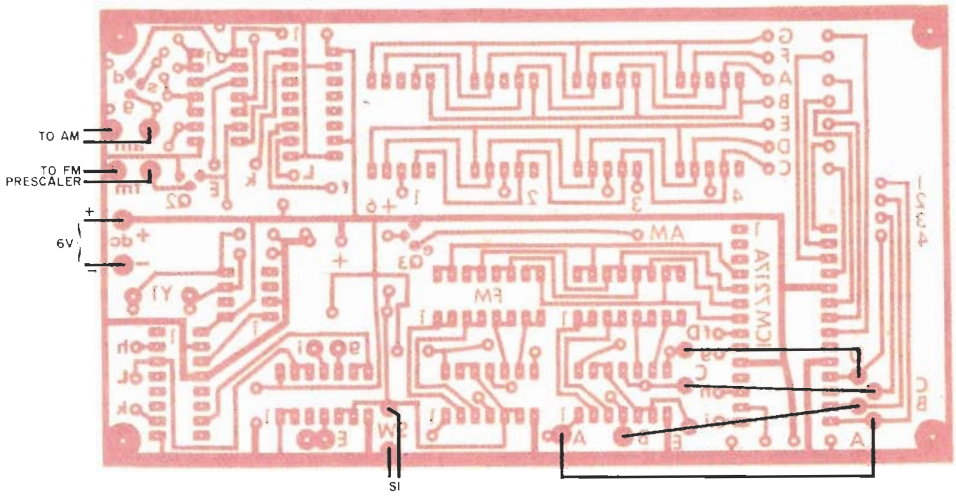
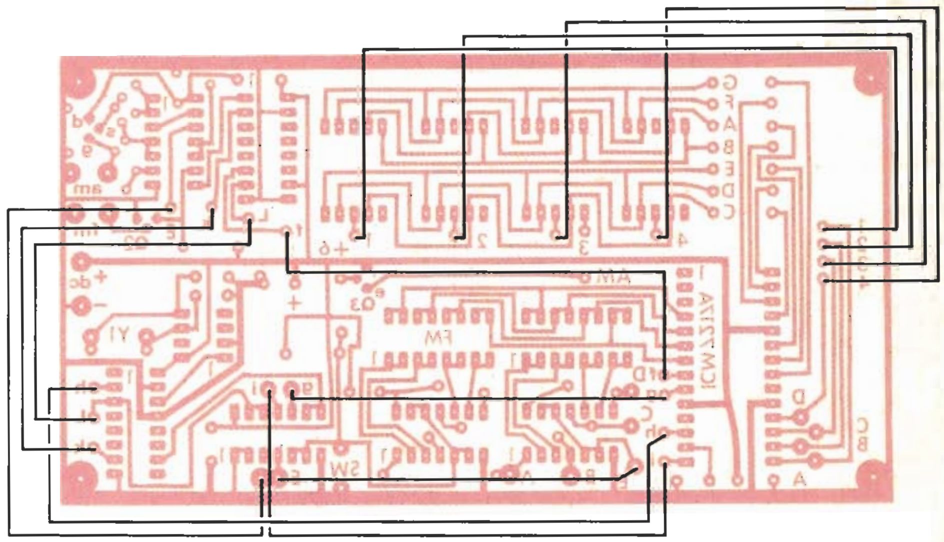


Fig. 4. At left and below are additional jumpers of insulated wire to be installed on the display board. Use RG-174 coaxial cable to make the connections off the board.



regulator *IC102* ensures that there is a low-impedance 5-volt power source available, and keeps r-f noise off the power leads.

Construction. The foil pattern and component installation for the main board are shown in Fig. 3.

Install the sockets for all the ICs and *J1* and *J2*. Molex Soldercons may be used for the four LED displays. Install the jumpers as shown in Fig. 3 using bare wire as required. Make sure that these jumpers are flush against the pc board. Then install the remainder of the components. Carefully install sockets for *IC7* and *IC8* making sure that no shorts are made to the jumpers on the board. Then install insulated jumpers as shown in Fig. 4. Upon completion of all wiring, and after it has been checked, install the ICs. Use lengths of RG-174 coaxial cable for the connections off the board shown in Fig. 4.

The foil pattern and component installation for the FM prescaler board are shown in Fig. 5. Use a socket for *IC101*. Use the shortest possible lead length when installing the capacitors on the board, and *do not* use Mylar capacitors in this application.

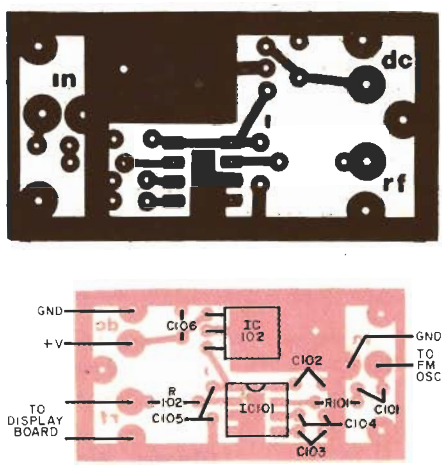


Fig. 5. Foil pattern and component layout for the prescaler board.

Installation. The necessary connections to the receiver are shown in Fig. 6. Figure 6A shows the circuit to use when the receiver has a single-stage converter approach; Fig. 6B shows use with a conventional local oscillator; while Fig. 6C illustrates the connections for a typical AM converter. In the FM mode, mount the prescaler as close to the FM converter/oscillator as possible to reduce detuning due to long leads.

Start the installation by removing the receiver power plug. Carefully remove the top and bottom covers to gain access to the r-f circuitry. In some cases it may be necessary to remove a shield to get at the r-f circuit. Using the schematic, locate the

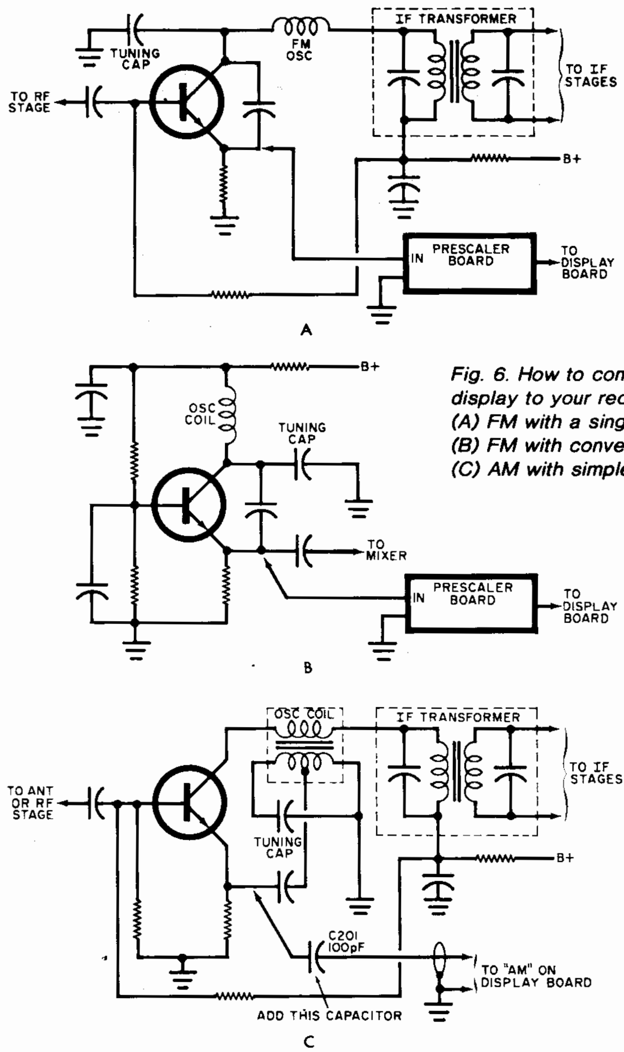


Fig. 6. How to connect the digital display to your receiver: (A) FM with a single-stage converter; (B) FM with conventional local oscillator; (C) AM with simple converter.

antenna input connections and trace the circuitry towards the i-f section to locate the local oscillator. In many cases, this will be identified on the schematic. Note that in some sets a "converter" may be used instead—this circuit serves as both a mixer and the local oscillator.

Once you have located the AM/FM local oscillators, or converters, use the appropriate circuit of Fig. 6 to make the connections. Start with the FM connections by referring to the diagram that is closest to your circuit. Chances are, either the converter of Fig. 6A, or the grounded-base oscillator of Fig. 6B will match your circuit. Note that in both cases, the prescaler board connects to the emitter lead of the transistors. The emitter lead is chosen because it is the lowest impedance point in the circuit and connecting elsewhere may excessively load the converter/oscillator and stop oscillation. For the AM connection, simply make the connection to the emitter of the converter transistor as shown in Fig. 1C. Capacitor *C201* has been included to decouple any dc component, and reduce circuit loading to the bare minimum.

The FM prescaler board must be positioned very close (within two inches) to the FM local oscillator. Also, the board must be securely mounted to the chassis or receiver circuit board. The ground lead of the prescaler connects to the ground on the tuning capacitor, and the signal lead is soldered directly to the emitter of the converter transistor. Your particular installation may be different, depending upon how much space you have available. Study the layout of your receiver carefully, and you will probably find several ways to install the prescaler. One more tip if you plan to mount the prescaler on the main circuit board: use heat sparingly on any i-f transformers you use for mountings, as the plastic elements inside these transformers can melt, and change the alignment. Quickly tin the transformer case, and allow it to cool. Then sweat solder the prescaler board in place. To connect the AM cable, connect one end of *C201*, a 100-pF disc capacitor, to the emitter lead of the AM converter transistor. Then cut a 3-foot length of RG-174 coax cable, and prepare both ends. Connect the shield to ground near *C201*, and connect the other end of the capacitor to the center conductor of the coax cable.

To finish up the receiver, route the wires and cables through a hole, such as a vent, in the rear panel, then cut the cables the same length. Prepare the ends, and install a male connector on them. Any of the low-cost Molex connectors should work fine, and the choice of connector is up to you. The receiver top and bottom covers may now be reinstalled.

If you have a power supply that can provide 9-volts dc unregulated at 100 mA, and 6-volts dc regulated at 50 mA, use it. Otherwise, build the simple power supply shown in Fig. 7. A few words about the parts, and construction. The 9-volt dc supply is a calculator type charger plug, al-

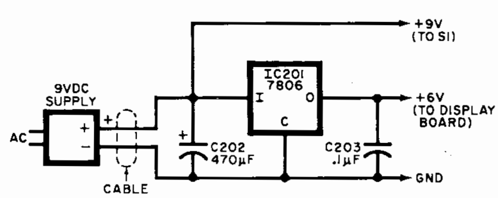


Fig. 7. Schematic of a simple power supply suitable for the digital display circuit.

PARTS LIST
(Power Supply and Final Assembly)

C201—100-pF disc capacitor
C202—470-µF, 16-V electolytic
C203—0.1-µF disc capacitor
IC201—7806 voltage regulator (6V, 1A)
S1—Dpdt miniature toggle switch

Misc.—Cabinet for display board, 9-volt charger plug (500 mA) (Jim-Pak DC-900), DIP headers, fourteen IN4148 diodes, 4-pin cable connector set, perf board, coax cable, wire, solder, etc.

though a separate transformer and full-wave rectifier may be used.

The display board can be installed in a cabinet, or if desired, inside the receiver. However, it is suggested that a separate metal cabinet be used. If a plastic case is used, keep it at least a foot away from the receiver. Regardless of the case you choose, mount the display board on the rear of the case using spacers and 4-40 hardware. Then drill holes in the rear, adjacent to the board for the power and signal leads. Turn to the front of the case, and cut out a rectangular hole for the displays. If desired, a commercial bezel, such as from Radio Shack may be used for a better appearance. After that, finish up the case by drilling a hole for the AM/FM switch, *S1*.

To connect the leads (including power) to the display board, route the cables through one of the holes in the rear of the case, then connect them to the appropriate pins of the connector. Add a third lead to carry +9 volts to switch *S1*. Refer to Fig. 8 for the final wiring details. Finishing touches like bundling wires and cables from the receiver using cable ties, labelling the case using press-on letters, etc., may be added to the project.

Programming. The diode-encoded PROMs for *J1* and *J2* are required. These PROMs are necessary to subtract the i-f from the display to produce the correct tuning frequency of the receiver.

If the display is powered up without the PROMs installed, only the decimal point may be lit. Turn on the receiver, and tune in an FM station between 106 and 108 MHz. Do this carefully, as careful tuning insures maximum accuracy from the project. Set *S1* to FM and note that the display indicates between 116.0 and 118.7 indicating the local oscillator frequency. Determine the frequency of the FM station and determine the required displacement (i-f) as display frequency minus station frequency. Subtract the i-f frequency from 1000.0 (maximum display count) to determine the PROM "number."

For technical reasons, this form of addition must be used to program the display. For example, for an i-f of 10.7 MHz, the PROM number would be "989.3." Record this number. The next step is to program the PROM with the number just determined. This is done using diodes and the following BCD truth table.

Number	"1"	"2"	"4"	"8"
1	X	-	-	-
2	-	X	-	-
3	X	X	-	-
4	-	-	X	-
5	X	-	X	-
6	-	X	X	-
7	X	X	X	-
8	-	-	-	X
9	X	-	-	X
0	-	-	-	-

This table is slightly different from the traditional BCD truth table. In place of a logic 1, an X representing a diode has been used. What this means is that, if you want to display a 1, you'll wire a diode from the BCD 1 pin to the desired digit as shown in Fig. 9A. The same holds true for any other numbers to be programmed. The table shows what diodes are required, and where they connect. In all cases, the diode banded end points toward the desired digit. Study the top view of the *J1*/*J2* pinouts as shown in Fig. 9A. Note that each function shares two adjacent pins, this makes connecting many diodes easier. Also note the digit numbers along the bottom of the sockets. These numbers correspond to the LED digits on the board, with 4 being the lefthand digit, and 1 the righthand.

Start the wiring by programming digit #4. Using our example of 989.3, this would be the first 9. Referring to the table, a BCD 9 equals diodes from 1 and 8. Two diodes are connected from pins 10 (BCD 1) and 16 (BCD 8) to pin 1 of the DIP header (digit 4). At this point, check your work by plugging the header into *J1* on the display board. With the receiver turned off, set *S1* to FM and note a display of 900.0 Repeat the process for digit 2 (this would be the 8 of our example of 989.3). Look up 8 in the table, and connect the diode between pins 16 (BCD 8) and 3 (digit 3).

Check your work by plugging the PROM into *J1* on the display board. You should get a display of 980.00. Continue with digits 2 and 1 in the same manner. When you are done, try the PROM in the display board, and you should be rewarded with the PROM number you calculated. In all probability, the finished PROM will look like the one of Fig. 9B. This is the

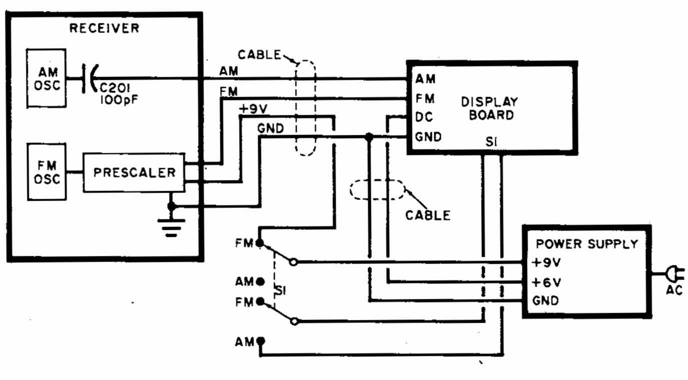


Fig. 8. Connecting the digital display and power supply to the receiver. Note the coaxial cables. Switch S1 can be mounted in any convenient location.

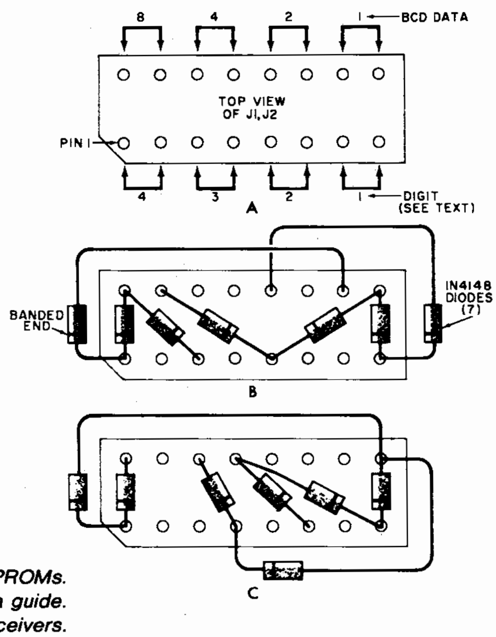


Fig. 9. How to program the diode-encoded PROMs. Use the truth table in the text as a guide. Diagram (B) is for FM; (C) is for AM receivers.

one for 989.3, or a 10.7-MHz i-f. If you get confused about the programming, just build this PROM as shown. It will work with most FM receivers, and be accurate within a few hundred kHz. This completes the FM PROM programming, and the project is ready for use with your FM receiver.

If your receiver has an AM band, continue with the AM PROM programming. It works exactly the same as the FM programming, and the steps are identical. The only differences are the frequencies and the PROM number. This is because of the different frequency coverage, and the i-f, which is usually 455 kHz in AM receivers.

Let's go through the AM PROM programming procedure, starting with the exact i-f. For best accuracy, tune in an AM station as close to the high end of the band as you can. Also, select a fairly weak station, because the tuning is more critical, and that leads to better accuracy. Jot down the frequency displayed by the project with *S1* set to AM. Determine the frequency the station is broadcasting on by looking it up in the newspaper, or waiting for station identification. Jot this value down, and then subtract it from the display frequency to determine the exact i-f.

Convert the i-f to PROM number by subtracting it from 10000. If, for example, your receiver has a 455-kHz i-f, the PROM number works out to 9545. Record the calculated number.

Use the table above to connect the diodes. Start by wiring digit 4, as you did with the FM PROM. Note that the banded ends of the diodes all point toward the digits. Check your work by plugging the PROM into *J2* on the display board. Remember to power down the receiver for the check, otherwise the local oscillator signal will confuse you. Continue with the other digits in order. When they are all done, check the PROM by plugging it into *J2*; you should get a display of the PROM number you calculated. If the programming confuses you, simply build the PROM shown in Fig. 9C. It is for a 455-kHz i-f, and accuracy will be good enough for most applications.

Only a few additional tips on the display's use are in order. Remember to set *S1* to suit the band (AM or FM) you are listening to, otherwise you will get a display of only the PROM number. Second, the FM prescaler may cause a slight detuning of the FM section. In that case, touch up the FM oscillator trimmer to bring the receiver dial back into calibration. ◇