A High-Performance Homebrew Transceiver: Part 5

A full-featured radio has many circuits associated with operator controls. This logic board uses a simple, direct method to execute those controls. This segment also covers the PTOs, frequency counter, power supply and some construction details.

By Mark Mandelkern, K5AM

Part 1 gave a general description of this transceiver, built for serious DX work and contest operating.[1] Parts 2 through 4 covered the main signal boards.[2, 3, 4] This article gives circuit details for the logic board, PTOs, frequency counter and power supply. It concludes the series describing the 40-MHz main panel. Subsequent articles will describe the three front-end panels for HF, 50 MHz and 144 MHz and will include performance measurements.

Logic Board

The K5AM homebrew transceiver was designed on a no-compromise basis with regard to performance and operating features. The result is that numerous circuits require operator adjustment and many of them interact. A general description of the logic board was given in Part 1. The board is shown here in Fig 1. The rather large circuit diagram need not be given here in its entirety; it will suffice to specify all the logical relations and to give examples of the methods used.

Requirements

Here are some transceiver features that require control by the logic board:

1. Instant, one-button PTO switching.
2. Six modes—a mode switch with only six leads.
3. Relay-switched crystal filters.
4. One-button second-PTO monitoring.
5. PTO B frequency spotting while listening to PTO A's frequency.
6. CW offset panel control with an audio monitor to hear the amount of offset.
7. Full break-in (QSK) at 50 WPM.
8. **TUNE** switch; pulse tuning or steady carrier.
9. Dual receive.
10. Secondary band selection.

In addition to the control circuitry for the features listed above, the logic board contains the T/R, R/T, PTT, key-line, standby, QSK, semi-QSK and automatic keyer circuits.

TTL Control: Is It Obsolete?

The motivation for using TTL to control this radio was discussed in Part 1 (pages 22-23). TTL stands for "transistor-transistor logic." This refers to a series of low-cost logic ICs

[1]Notes appear on page 00.

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that became available in 1972. The TTL system allows very simple and direct generation of the logic functions required to control radio circuits. The effectiveness of this system is shown by its continued use over three decades.

Modern alternatives to TTL exist. The currently very popular "PIC" system is a compact solution to control problems. However, TTL and other discrete-logic systems have not been completely superseded by PIC or other microprocessor systems—only supplemented. PICs operate with the same voltage levels as TTL, so the systems may be used in conjunction. PICs were not available in 1990 when this logic board was built. Even now, however, PICs may not be the preferred method for controlling a radio of this sort. Along with their many advantages, PICs have some disadvantages compared to TTL: PICs are more difficult to use, take longer to design, require facility in a programming language and require special equipment to physically install the program. In addition, to use PICs efficiently requires expertise in proper software-design processes.

This discussion assumes a single ham building a single radio. For mass production and team-designed equipment, or for a widely distributed amateur project with circuit boards, parts kits and preprogrammed devices, the situation is very different. The investment of time and money in a PIC controller is justified by the savings in production. In contrast, for one ham working alone in a garage workshop, using a PIC for a medium-sized project may be too involved.[5]

Along with the original 7400-series TTL, there are also many high-speed and low-power spin-offs. Thus for high-frequency and battery-operated devices, the 7400 series is indeed obsolete. For control of a line-powered radio in a home ham shack running usual amateur power levels, however, a few milliamperes won't matter, so the plain 7400 series is a good choice. The higher currents and lower impedances of this original series result in less susceptibility to RFI than some faster and low-power systems.

In summary, TTL is still a reasonable choice for controlling a homebrew transceiver, especially for someone who does not want to put down the soldering iron long enough to take a comprehensive course in programming.

Using TTL

Information on TTL and Boolean algebra can be found in various places.[6, 7] However, no extended study program is required. It is not necessary to understand much of what is inside the logic chips in order to use them, just as one need not explore the innards of a Pentium chip in order to send e-mail. Only the *function* of each chip need be known. Only four different types of TTL gates are used here and one type of data selector. If an inverter may be thought of as a 1-input **NAND** gate, then the four gate types used are all **NAND** gates: 1-input, 2-input, 3-input and 4-input. They are the 7404, 7400, 7410 and 7420, respec-tively. The data selector is discussed below. The func-tion and pin-outs for each of these ICs is given in the data book.[8]

Including some **OR** gates or other types could simplify some parts of the circuit. We must consider the trade-off, though, between achieving circuit simplicity and employing a small number of different gate types. Too many different gate types in a circuit design may result in some TTL pack-ages being 75% unused. This is especially true for this board, since it is built in eight small, self-contained sections.

It *is* necessary to acquire a working knowledge of the logical connectives: **AND**, **OR** and **NOT**; these are denoted in the formulas used here by •, + and ¯ (overline read as "bar"). DeMorgan's Theorem is needed to manipulate the expressions —it is just common sense. For a discussion of logical rules, notation and calculations see Chapter 7 of recent *ARRL Handbooks* (Note 6).

Input Lines

The behavior of logic circuits may be contemplated in terms of inputs and outputs. The *inputs* are the settings of all the various panel controls, plus the PTT and key lines. The *outputs* are the control lines leading to all the circuits in the radio. The inputs may be whatever the operator chooses; the outputs depend on the inputs. Thus, the inputs may be thought of as independent variables and the outputs as dependent variables. This enables us to think of the logic circuits as functions—in this case, Boolean functions. Boolean algebra is used to calculate the outputs as functions of the inputs. All the rules for Boolean calculations are in the referent of Note 6. In this design, *intermediate logic lines* are specified; interface circuits convert these lines to output lines.

Some notational conventions are used here to make the formulas easier to read. Capital Latin letters are used for TTL lines. The letters are chosen as mnemonics. For clarity, a letter alone indicates a high logic state, or an *enabled* function. The panel switches, however, are *grounded-to-operate* (that is, active low). For example, dual-receive is enabled by a switch that grounds a TTL line. Thus the line to the panel is labeled $\overline{D}$, so that dual receive is enabled when line $\overline{D}$ is low. An inverter on the logic board generates line D, which is high when dual receive is enabled. All TTL inputs are listed, in enabled form, in Table 1. In

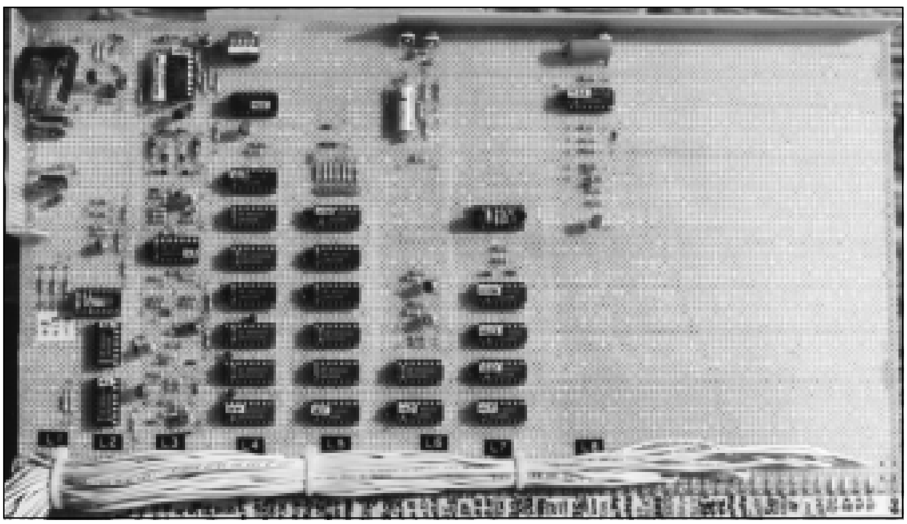


Fig 1—Top view of the logic board in the K5AM homebrew transceiver. The DIP test switch is at the top toward the left. At top center are the pulse-tuning adjustments for on/off timing. Toward the right, under the protective edging, is the QSK-delay adjustment. It keeps the transceiver in the transmit mode during the decay (break) portion of each CW element. This adjustment ensures that the CW element will not be chopped and that this delay is not excessive, so the receive circuits may recover quickly. This transceiver "hears" breaking stations while transmitting at 50 WPM.

Table 1

Logic-board output lines: This table lists TTL lines actuated by front-panel controls. The lines are denoted in *enabled* form (see text). There is no designation for the center position A/B of the PTO switch for split operation. No contact is made here—the split-operation command is deduced by the logic board. Thus, only two wires are sufficient for selecting three PTO modes.

A	PTO A; transceive
B	PTO B; transceive
D	Dual receive
M	Monitor frequency B
N	Noise blanker
S	Spot PTO B
PT	From PTT line
CWW	CW; 2-kHz bandwidth
CWN	CW; 200-Hz bandwidth
USB	Upper Sideband
LSB	Lower Sideband
AM	Carrier with two sidebands
FM	NBFM
SO	Spot CW offset
TD	Tune, pulse
TK	Tune, steady carrier

Table 2

Logic-board output lines: These lines lead to all parts of the radio, controlling all the circuits. Table 1 in Part 2 lists the Greek-letter prefixes that indicate the functionality of each type of line. For example, a m line enables a circuit when at ground level and disables it when at –15 V. This table indicates the circuits controlled by each line.

βR	Counter (readout)
βN	Noise blanker
βM	AM/FM relay and circuits
βX	Transmit relays and circuits
µPD	Product detector gate
βAM	AM detector gate
βFM	FM detector gate
βCR	Carrier gate for CW and Tune
βSB	Sideband selection, LSB/USB
βST	Sidetone oscillator
βSSB	Transmit SSB circuits
µA	PTO A
µB	PTO B
µD	Dual receive
µMO	Master oscillator
µOO	Offset oscillator
µSO	Spot CW offset
µIA	LO injection buffer for PTO A
µIB	LO injection buffer for PTO B
T/R	–15 V receive, 0 transmit
R/T	0 receive, –15 V transmit
XMIT	Transmit order to front-end panel

Table 3

Intermediate TTL lines: These lines operate in the logical realm between the input and output lines. They are formed as Boolean functions of the inputs and applied to the interface circuits to generate the outputs.

P	PTO A
Q	PTO B
R	Counter readout; PTO B
J	Receiver-mixer LO injection; PTO A only
K	Receiver-mixer LO injection; PTO B only
L	Receiver-mixer LO injection; dual receive
X	Transmit
T	Tune, pulse or steady
OP	Operate
KL	Key-line control
CW	CW, either bandwidth
PD	Product detector
CR	Carrier
ST	Sidetone
NB	Noise blanker
MO	Master oscillator
OO	Offset oscillator
SSB	LSB/USB, transmit

Table 4

Boolean Functions: These determine the operation of all circuits in the radio.

$$\mathrm{CR} = (\mathrm{CW} + \mathrm{T}) \bullet \mathrm{X}$$

$$\mathrm{CW} = \mathrm{CWW} + \mathrm{CWN}$$

$$\mathrm{J} = \mathrm{P} \bullet \overline{\mathrm{L}}$$

$$\mathrm{K} = \overline{\mathrm{P}} \bullet \overline{\mathrm{L}}$$

$$\mathrm{KL} = \mathrm{TK} + \left(\mathrm{X} \bullet \overline{\mathrm{CW}} \bullet \overline{\mathrm{TD}}\right)$$

$$\mathrm{L} = \overline{\mathrm{X}} \bullet \mathrm{D} \bullet \overline{\mathrm{M}} \bullet \overline{\mathrm{B}}$$

$$\mathrm{MO} = \overline{(\mathrm{CW} + \mathrm{T})} + \overline{\mathrm{X}}$$

$$\mathrm{NB} = \mathrm{N} \bullet \overline{\mathrm{X}}$$

$$\mathrm{OO} = \overline{\mathrm{MO}} + \left(\mathrm{SO} \bullet \overline{\mathrm{X}}\right)$$

$$\mathrm{P} = \left(\mathrm{A} \bullet \overline{\mathrm{M}}\right) + (\mathrm{A} \bullet \mathrm{X}) + \left(\overline{\mathrm{A}} \bullet \overline{\mathrm{B}} \bullet \overline{\mathrm{M}} \bullet \overline{\mathrm{X}}\right)$$

$$\mathrm{PD} = \overline{(\mathrm{AM} + \mathrm{FM} + \mathrm{SO})}$$

$$\mathrm{Q} = \overline{\mathrm{P}} + \left(\overline{\mathrm{X}} \bullet (\mathrm{S} + \mathrm{D})\right)$$

$$\mathrm{R} = \overline{\mathrm{P}} + \left(\overline{\mathrm{X}} \bullet \mathrm{S}\right)$$

$$\mathrm{SSB} = \left(\mathrm{LSB} + \mathrm{USB}\right) \bullet \mathrm{X} \bullet \overline{\mathrm{T}}$$

$$\mathrm{ST} = \mathrm{CW} \bullet \overline{\mathrm{T}}$$

$$\mathrm{T} = \mathrm{TD} + \mathrm{TK}$$

$$\mathrm{X} = \left(\mathrm{PT} + \mathrm{T}\right) \bullet \mathrm{OP}$$

the discussion, we will refer only to the lines representing enabled functions, without reference to the panel lines and the inverters. Using two hex-inverter TTL packages avoids having to work with all the input lines in reversed logic. The PTT and key lines are *external* inputs, labeled αPT and αKL, respectively. The Greek-letter prefix conventions, also used in previous series segments, are listed in Table 1 of Part 2. The logic board outputs also use Greek-letter prefixes. They are listed in Table 2 here.

Intermediate Logic Lines

Generation of these signals is the central function of the logic board. Various inputs, corresponding to operator controls, are combined to form logic lines that represent command signals for the circuits. At the intermediate point, they are still TTL-level signals; additional interfacing circuits produce the actual output lines. The TTL designations of the intermediate logic lines are given in Table 3. The circuit decisions involve Boolean functions; these are listed in Table 4.

For example, the function $NB = N \bullet \overline{X}$ (NB equals N **AND** not X) enables (high state) the noise blanker when the blanker control knob is pulled out, sending input line N high, but only when receiving. This limitation is necessary because the tunable noise-channel LO could cause a spurious output if allowed to run while transmitting. An interface circuit converts line NB to the output line βN.

As another example, pulling the dual-receive knob out sends input line D high. This turns on both PTOs—but not while transmitting! Thus the transmit line X must be combined with D. When transmitting, the PTO switch position must also be considered. When receiving, pressing the **MON** button must momentarily terminate the dual-receive function, enabling only PTO B. During split-frequency operation, the **SPOT B** switch turns on PTO B while receiving with PTO A; PTO B reads on the counter. The result is that the intermediate line Q, enabling PTO B, depends ultimately on six input lines.

Generating Boolean Functions

Only a few examples will be shown here. These may suggest ideas for using TTL on any small control problem that might arise. In Fig 2, the simple intermediate TTL lines CW and SSB are obtained with only a few gates. Somewhat more complicated are the intermediate lines CR, MO, and OO. Their circuit is shown in Fig 3. For Boolean functions with even more variables, data selectors are used. These are discussed below.

Output Lines

The intermediate logic lines must be converted to control signals that can be used by the circuits in the radio. Some of the circuits simply require a supply voltage to be turned on or off at the right times. Some circuits use dual-gate VHF MOSFETs, which require a positive voltage at the control gate to activate them, or a negative voltage to turn them off. There are also relays to control. The logical relation between an intermediate line and an output signal is simple and direct. For example, intermediate TTL line Q is high when PTO B is enabled and low otherwise. Output control line µB, derived from Q, is accordingly either 0 or –15 V. PTO B will run with 0 V on the control line, while –15 V applies cutoff bias to the oscillator and buffers.

Op amps are used to convert intermediate TTL lines to control signals. Two basic types are used here: ordinary op amps and comparators (which is, strictly speaking, not really an op amp). A regular op amp, such as LM324N, will generate a β-type control line, switching from about +15 V to –15 V. In practice, with ±15 V dc rails, only about ±13 to ±14 V is obtained. This is taken into account in the design of the circuits controlled and of the diode switches, although the full voltages are used in the discussions.

A comparator, such as the LM339N

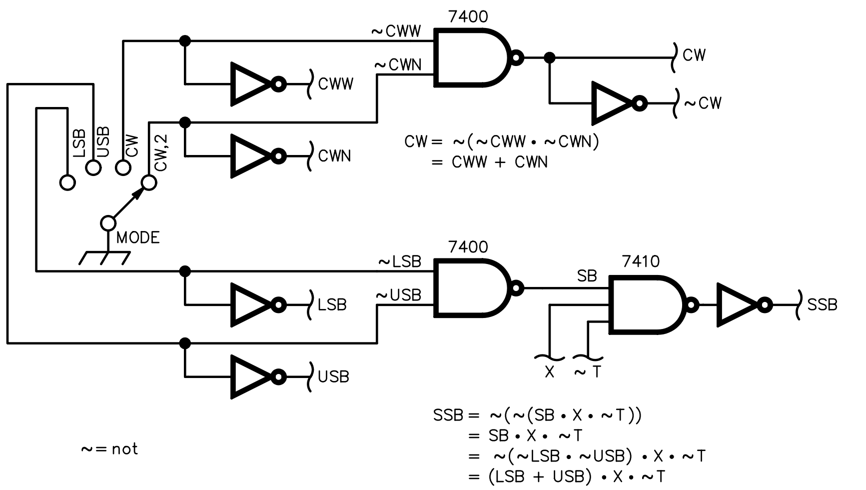


Fig 2—Intermediate TTL lines. This circuit generates the lines, CW and SSB, that control the transmit CW and SSB circuits. When using the TUNE function in SSB mode, the transmit SSB circuits are disabled. This avoids noise on the carrier while tuning. The calculations given here show how DeMorgan's Theorem and the other logic laws are used to design the circuits. The labels shown on the MODE switch are panel labels, not TTL designations. Not shown are the 2.2-kΩ pull-up resistors from the +5 V dc rail to each panel input line.

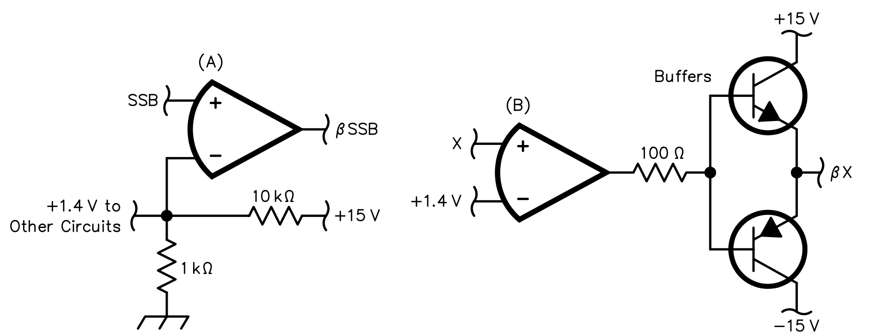


Fig 4—Interface circuits for obtaining control lines. In (A), the TTL line SSB is interfaced to obtain control line βSSB, used for controlling transmit SSB circuits. The circuit in (B) derives the control line βX from the TTL line X. Because line βX drives a number of circuits, the required current drain exceeds the capacity of the op amp, which has a maximum output of about 20 mA. With the buffer transistors added to the circuit as shown, we can draw well over 200 mA from line βX.

The schematics in this article use the following conventions: Except as noted, the op amps are LM324Ns, powered from the ±15 V dc rails. The transistors are small-signal types, such as 2N4401 (NPN) or 2N4403 (PNP); the diodes are small-signal silicon switching types such as 1N4148. Resistors are 1/4-W, carbon-film units. Trimmer potentiometers are one-turn miniature parts, such as Bourns 3386 (Digi-Key #3386F-nnn, see Note 22). Capacitors labeled "s.m." are silver micas, with values given in pF. Values of RF chokes (RFC) are given in µH. The 100-nF monolithic ceramic bypass capacitors at the power terminals of each TTL and op-amp package and 10-nF disc ceramic bypass capacitors at each board terminal are not shown. Unmarked coupling and bypass capacitors are 10-nF disc ceramics. Potentiometers labeled in all capital letters are front-panel controls; others are circuit-board trimmers for internal adjustments.

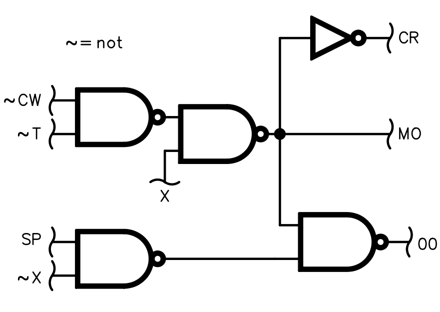


Fig 3—Intermediate TTL lines. This circuit generates the lines CR, MO and OO, for controlling the carrier, the master oscillator and the offset oscillator, respectively.

used here, has an open-collector output. With ±15 V dc rails, it provides either a –15 V output or an open circuit. This is useful for generating a µ-type control line. In later designs, however, only a regular op amp is used. This simplifies things, as a µ-type line can be generated from a β-type line merely with the addition of a diode. Thus, only the generation of β-type lines will be shown here.

One valuable characteristic of an op amp is its ability to supply moderate output current while drawing virtually no current from the inputs. Fig 4 shows the way TTL lines are converted to β-type control lines. Although we use 0 and 1 as logic symbols, the TTL circuits do not use 0 and 1 V for **FALSE** and **TRUE**, they use roughly 0 and 5 V. These voltages are only nominal; typical values might be 0.5 and 3.5 V. The exact range of permitted values is given in TTL reference books. A good intermediate value is 1.4 V. A voltage divider establishes this with only two resistors, and the reference voltage thus obtained is used throughout the logic board. We apply 1.4 V to the inverting input of the op amp and the TTL line to the noninverting input. When the TTL line shifts from about 0 V to about 4 V, the op-amp output shifts (nominally) from –15 V to +15 V. For example, if we apply the TTL line X (transmit), we obtain the output control line βX, which shifts from –15 V in receive to +15 V in transmit. One use of this βX line is to control MOSFETs in the transmitter section of the radio, with a voltage divider in the MOSFET circuit to obtain ±4 V for the control gate.

PTT and T/R Circuits

The STBY/OPER function is incorporated into the PTT circuit. Several output lines are provided for the transmit/receive function: T/R, R/T, XMIT and βX. This extra bit of circuitry simplifies design of other circuits throughout the radio. A PTT circuit is shown in Fig 5.[9]

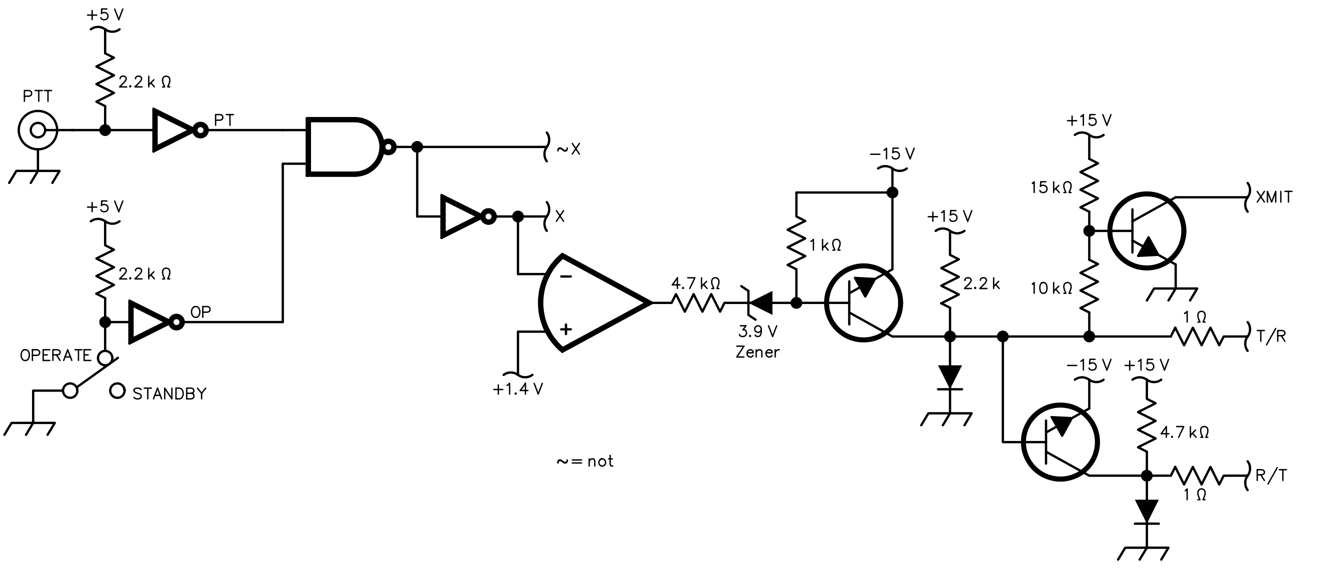


Fig 5—PTT and standby circuit schematic (see Note 9). In this circuit, the external PTT line, usually operated by a foot switch, is transformed into the TTL line X, for transmit. The STBY/OPER switch on the front panel enables the circuit. The output line XMIT conveys a transmit order to the selected front-end panel.

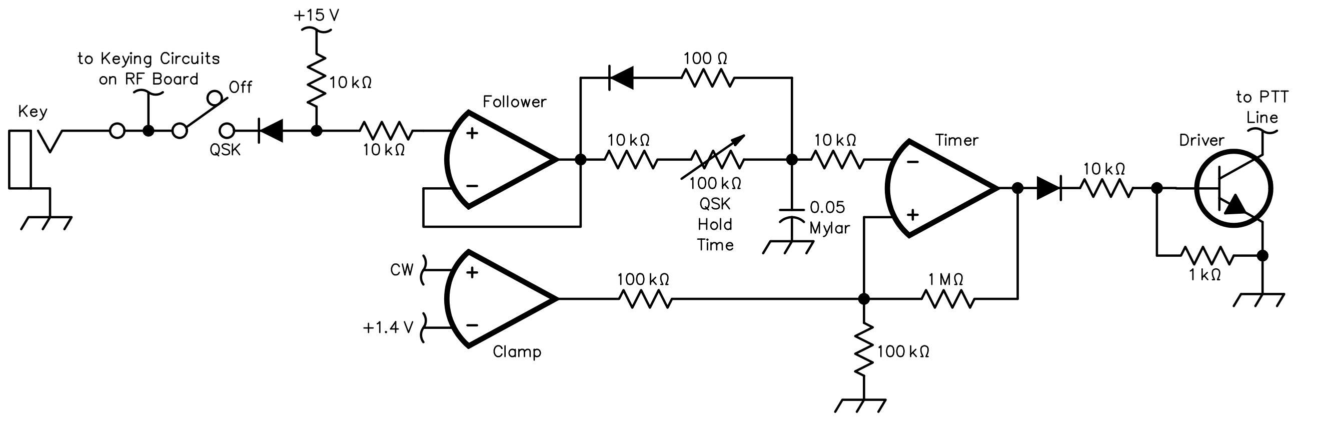


Fig 6—CW break-in (QSK) circuit (see Note 9). The timing adjustment is set for a PTT hold-in delay of about 4 ms after the end of each code element. This prevents any chopping of the decaying CW waveform. Other methods that introduce delay into the keying circuit may distort the CW waveform and cause excessive delay that degrades the QSK performance. This radio can hear breaking stations while sending at 50 WPM.

Key Line and Break-in Circuits

The interface of an external input line with internal circuits becomes critical for the keying line, since timing is important. We must have circuit isolation, otherwise capacity on the key line or from an external keyer might alter the timing and distort the keying waveform. A keying circuit is shown in Fig 6 (see Note 9). The keying waveform is developed at the 40-MHz buffers on the RF board, as shown in Fig 9 of Part 3. A Curtis 8044 keyer IC is included. It is valuable in case the external memory keyer fails.

There are two CW break-in modes. *Full break-in* (QSK) requires full receiver recovery between CW elements. This radio can hear breaking stations while sending at 50 WPM. *Semi-break-in* (SQSK) is a misnomer: It only implies an automatic PTT function. Stations cannot actually break in. SQSK is useful with an amplifier that lacks full break-in capability.

The QSK delay is set using a scope to eliminate chopping of the decay (break) portion of the CW waveform, while monitoring with a receiver to check for key clicks. Too much delay will inhibit quick receiver recovery and limit the ability of the radio to hear breaking stations between dits.

The keying section of the logic board includes the pulse-tuning circuit. The advantages of pulse tuning and of the circuit details were described in a previous article.[10] To reiterate: The chief ad-vantage is greatly reduced anode dissipation in the kilowatt-amplifier tubes. The circuit has on/off timing adjustments, so the pulse width and duty cycle may be adjusted. Settings for 13-ms on and 27-ms off provide a 33% duty cycle with a pulse rate cor-responding to shortened CW dits at 60 WPM.

PTO Control

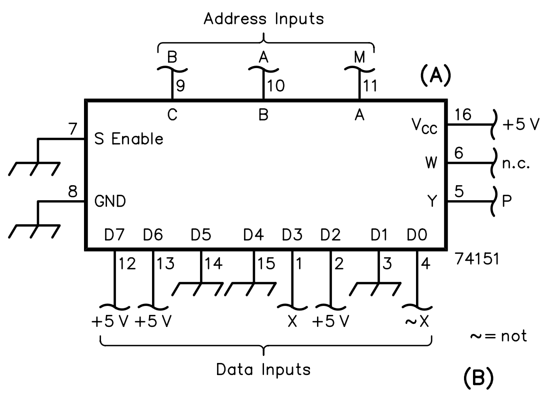
For the utmost in operating flexibility, PTO control is of special importance. This radio has two PTOs and dual-receive capability. In addition, it provides instant, one-button monitoring of the second frequency for split-frequency DX operations. This feature is useful because dual receive is not feasible with extremely weak, barely readable DX signals. There is also provision for spotting the transmit frequency while receiving, as for 40-meter DX SSB work. In any given situation, the logic board must make several decisions. Which PTOs should run? Which PTO should deter-mine the receiver's mixer injection? Which PTO should be displayed?

Data Selectors

Simple gates are used for most of the intermediate TTL functions. For the more-complicated functions, such as PTO control, 74151 *data selectors* are used as Boolean function generators. Complicated Boolean functions would require a large number of simple gates; a single data selector can often do the same job. The term *data selector* refers to the primary use of the device: to choose among several data inputs as determined by the address inputs. Here we employ its secondary use: as a *Boolean-function generator*. We may think of the selected data as the desired result, based on the operator's orders as applied to the address inputs. Three 74151 data selectors are used here to control PTO A, PTO B and counter display selection. Each 74151 is a 16-pin DIP device with three address inputs and eight data inputs.

The Boolean functions for the PTOs must have inputs involving manual PTO selection, dual receive, monitoring of the second PTO, spotting a frequency on the second PTO and the transmit/receive condition. As an example, the circuit for TTL line P, which determines power to PTO A, is shown in Fig 7. We have four variables, A, B, M and X, corresponding to the panel switches for **PTO A**, **PTO B**, **MON** and the transmit condition, respectively. Since the data selector has only three address inputs, a fourth input is effected by using the data inputs. These four variables together result in $2^4 = 16$ logic states. The desired output for each of these states is selected by configuring the appropriate data-input pin.

The three address inputs result in eight possible states, represented by numbers in binary form: 000_2 to 111_2, or 0_{10} to 7_{10}. For each of these states, output signal Y at pin 5 is determined by the level of the corresponding data-input pin. The data input pins are labeled D0 through D7. To generate P, the address inputs are M, A and B; these correspond to the **MON**, **PTO A** and **PTO B** switches. Note that three different labeling systems are employed! The circuit lines are M, A and B; the



(B)

Panel Switch	Address Input Lines			Input State		X	P	Data Input Line	Pin Number	Selected Connection
	B	A	M	Binary	Base 10					
A/B	0	0	0	000	Zero	0 1	1 0	D0	4	~X
	0	0	1	001	One		0	D1	3	⏚
A	0	1	0	010	Two		1	D2	2	+5
	0	1	1	011	Three	0 1	0 1	D3	1	X
B	1	0	0	100	Four		0	D4	15	⏚
	1	0	1	101	Five		0	D5	14	⏚

Fig 7—Data-selector logic diagram. The schematic at (A) shows the data selector used to generate the line P, which determines when PTO A runs. The 74151 data selector is used as a Boolean function generator. This method is simpler than using a large number of separate gates. The truth table for this Boolean function is shown at (B). The table is incomplete; there are no entries for the input states 110_2 and 111_2. These states occur when the operator throws the PTO switch in both directions at once!

chip manufacturer denotes the address inputs at the chip by A, B and C; the socket pins are numbered 11, 10 and 9. There is also a fourth variable in the Boolean function—namely X—and thus there are 16 possible input states. By applying X or $\overline{X}$ as data input when needed, we effectively obtain a 16-input device.

For example, in the state $\overline{B} \bullet A \bullet M$, we are in PTO-A mode while monitoring the B frequency. This state is represented by the binary number 011_2, or three; the corresponding data input terminal is labeled D3. Should PTO A run? If we are receiving, the answer is "no," because we are listening to the B frequency. However, "PTO A transceive" is selected on the panel, so when we begin transmitting, we should revert to PTO A, and the answer is "yes." We introduce this fourth variable by applying the transmit line X at data input terminal D3 (pin 5). Thus, during the input state 011_2, the output line, P, will follow the transmit line, X, as required. In this way, the eight-input data selector, which is a Boolean function generator for only three variables, handles four variables. Using the *enable* signal (pin 7), application of the 74151 may be extended even further in some cases.

Each of the 16 possible states determined by the four input variables is handled similarly. The first three variables determine eight states. For each of these states, the desired output is obtained by connecting one of four lines to the corresponding data input pin: +5 V dc, ground, X, or $\overline{X}$.

Note the absence of an input line for split operation. When the panel switch is in the center, A/B, position, both A and B lines are low; the logic board easily infers the split order from this situation. Thus at the data selector for line P, split operation is ordered in either of the address-input states 000_2 or 001_2: zero or one.

Mode-Switching Circuits

The use of logic circuits for mode switching yields many advantages, as discussed in Part 1, pp 22-23. A portion of the mode-switching circuit is shown in Fig 8. This circuit enables the sharp (200-Hz) CW filter when requested by the mode switch. Most of the power-supply load is on the +15 V dc rail, so certain circuits are run from the –15 V dc rail in an effort to distribute the load more evenly. The special sharp CW-filter preamplifier and the CWN relays present good opportunities for this. The special –15CWN line is at once a control line and a power source. The buffer circuit used to obtain more current for the βX control line in Fig 4 drops the available op-amp output voltage by an additional V_{be}, and so is not appropriate here. The circuit used for –15CWN, shown in Fig 8, provides nearly the full –15 V.

Secondary Band Selection

This radio has a special band-switching feature. Although quite meager compared to the many memories and flexibility of a computer controlled radio, it is very useful in many situations. The panel switch labeled **BAND** controls a line leading to the external front-end switch box, which has switches for choosing a primary and secondary band. The **BAND** switch on the main transceiver panel has the following functions: In the center position, no secondary band is selected; in the up position, whenever the radio switches to PTO B the secondary front-end panel is selected; in the down position, the secondary front-end is selected in all PTO modes.

The **BAND** switch has many uses. For example, one can be busy working an HF contest and set the thing up so that one touch of the **MON** button checks the 50.110-MHz DX calling frequency. Or, you can be working 6-meter DX and set

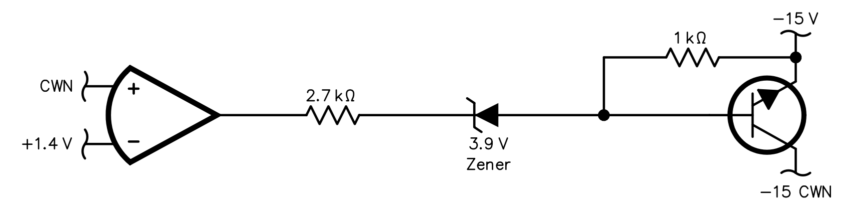


Fig 8—Circuit for controlling the sharp (200-Hz) CW filter. A simple NPN switch is used to provide current for the special sharp-CW preamplifier and the crystal-filter relays.

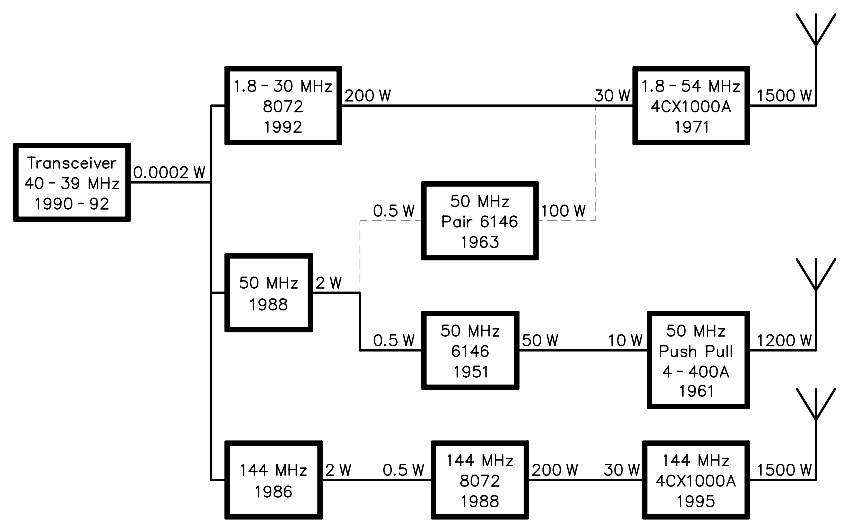


Fig 9—K5AM homebrew station layout. This shows how the main transceiver panel and the three front-end panels fit into the station. To obtain very high dynamic range and minimize spurious responses, the station uses only two mixing conversions on each band from 1.8 to 144 MHz.

To obtain the cleanest signal possible, the station uses class-A transistor stages up to 2 W, and then only tubes—class-AB_1 tetrodes. The diagram indicates the power (in watts) available from each unit and the power required by the next. The resulting headroom yields the best IMD performance. Gain is controlled at the milliwatt level in each front-end. To prevent splatter, ALC runs from each driver and each high-power amplifier back to the corresponding front-end panel, with ALC metering at the transceiver. There are no diodes in the signal path at any point in the station.

The 8072 is a conduction-cooled tetrode—identical to the well-known 8122 except that the 8072, with no air-cooling fins, clamps to a heat sink. The neutralized 8072 driver amplifier for 2 meters has 26 dB gain. The Eimac 4-400A bottles used in push-pull on 6 meters are the originals—only 39 years old and still running at full output!

up so that switching to PTO B immediately puts you on 28.885, the 6-meter DX liaison frequency. With some 6-meter DX openings lasting only 10 seconds, every second counts!

Rear-Panel Connections

Years of trouble with phono plugs and jacks led me to look for a better way to connect the radio to the rest of the station. Hams commonly use BNC connectors only for RF. Where reliability is important, however, it is common to use BNCs for control lines also. For contest work, I also want the highest level of reliability. Thus, I use BNCs for all rear-panel jacks that would normally use phono jacks.[11] All control connections at the rear panel are filtered—mostly with pi-sections using a 1-mH RFC and two 10-nF disc ceramic capacitors.

To facilitate interconnections at the operating bench, a dual-connector system is employed. In addition to the BNC and key jacks, a seven-pin DIN connector connects the PTT line, key line, keyer dit/dah lines and transmit control line to the separate front-end panels with one quick push. It also connects the ALC-meter lines from the front-end panels back to the main transceiver panel. This cable leads to a station-hub switch box on the operating bench that selects the front-end panel: HF, 50 MHz or 144 MHz. Each of the three panels also connects to the station hub with a single control cable and a coaxial cable for 40 MHz. Pulling the radio for a quick trip to the workbench to add a new feature (between contests) is an easy task. There is also a DIN jack on the radio for connecting a front-end panel directly to the radio, so the radio can be used independently of the hub or tested with one front-end panel at the workbench.[12]

Each front-end panel has a similar dual-connection arrangement. All this redundancy in connections required only a few extra hours of work, repaid many times since in convenience. The transceiver and front-end panels fit into the complete station layout as shown in Fig 9.

DIP Test Switch

Many test and alignment procedures require certain oscillators to be turned off. For example, sweep alignment of a filter following a mixer is impossible with the LO running and reacting with the sweep generator. For convenience, a four-gang DIP test switch is installed on the board. It can defeat MO, OO, PTO A or PTO B. The switch is positioned at the top of the board so it is easily reached with the logic board in place.[13]

Logic Board Construction

The board itself is shown in Fig 1; its general method of construction was described in Part 1. Rather than copper circuit board, the logic board is constructed on perf board. Wiring on the board is done mostly with wire-wrap, with some point-to-point hand wiring. The board's bottom surface is shown in Fig 10. A long copper strip along the edge with 59 terminals provides a common ground and a return for bypass capacitors on all the input and output lines.

Permeability-Tuned Oscillators

In a traditional homebrew radio, the VFOs may be the most difficult problem (leaving aside modern digital methods). The VFOs are most demanding of perfection. For the ham more comfortable with soldering irons and transistors than lathes or bearings, the mechanical demands may cause the most headaches; I sidestepped the mechanical obstacles. Although I built the circuit, filter and shielded box, these details are trivial compared to the powdered-iron tuning slug, coil, precision-rolled left-hand-drive screw, bearings, tuning rail, anti-backlash mechanism and the solid frame. All these mechanical parts were stolen from a junked Signal/One CX7.[14] Even after this grand larceny, there is still much work to be done for mechanical overhaul and adjustment of these old PTOs.[15] One shudders to think what it would cost to manufacture such a precision PTO mechanism today.

PTO Circuit

The PTO schematic is shown in Fig 11. The circuit is very similar to that used in the Signal/One, except that the Signal/One included no RIT. The circuit may also be used for a variable-capacitor-tuned VFO. The capacitor's reduction-gear tuning mechanism will be arranged by the individual builder. Because a frequency counter is used, the difficult problem of dial calibration is eliminated and linear tuning is not essential.

This PTO tunes about 25 kHz per revolution—no problem for old-timers, although faster than modern tastes would demand. There are several possible ways to reduce the tuning rate. One is to rewind the coil with a coarser pitch at the low end for the CW segments.[16] Another is to rewind the coil to reduce the range to 500 kHz, adding extra 10-meter segments to the HF front-end panel as needed.

The Case for RIT

An RIT function is essential in most operating situations. Arguments against it—while logically perfect—apply only to a perfect world. If every operator tuned his radio perfectly, RIT would not be necessary. While RIT is the solution for the listening operator, ironically it is RIT itself that often causes any mistuning by the offending

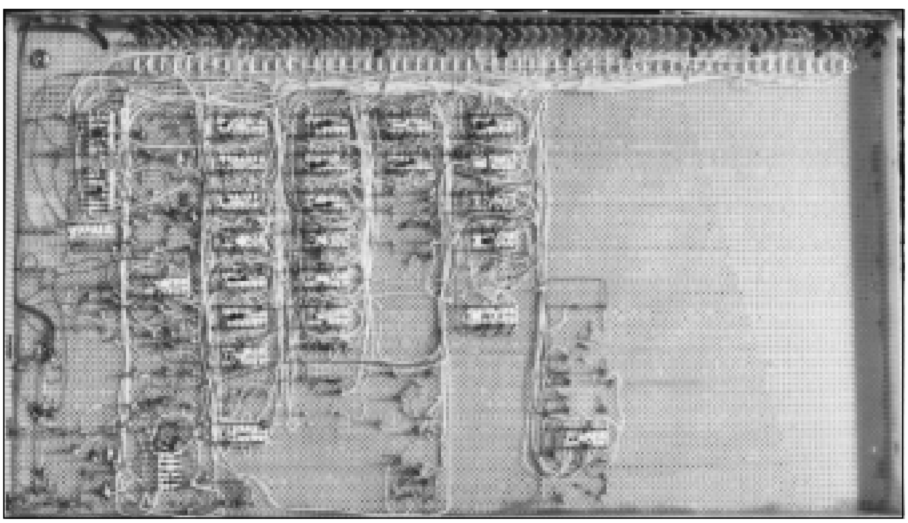


Fig 10—Bottom view of the logic board. Wire-wrap construction is used for the TTL and op-amp circuits and point-to-point wiring for the circuits with discrete components. To minimize connector troubles, the board is hard-wired to the radio. A 12-inch-long bundle of wires allows the board to be easily lifted and serviced.

transmit-ting operator. The problem is a general lack of awareness of the relation between the CQ-calling station and the replying station; that is, the requirement that the replying station tune with the RIT *off*. New operators might be advised simply: "Don't use the RIT until you acquire more experience."

In any event, a contest operator must have RIT to hear the offenders. There are also other valid uses for RIT. During a CW QSO, one might wish to change the received pitch to improve readability in QRN or avoid QRM. RIT is especially useful for moon-bounce work. After acquiring an EME signal and making the first call, I pull out the RIT knob. This fixes my transmit frequency while allowing me to adjust tuning as desired at a slower rate. The RIT is also used to adjust for Doppler shift. As always, the rule is: Never change the transmit frequency after a QSO has begun, or even after a first call.

RIT Circuit

The RIT system uses a simple transistor switch. Let's say the RIT is on. While receiving, the T/R line is at –15 V and keeps the transistor cut off, so the *Xmit-Set* trimmer has no effect; the varactor diode bias is varied by the RIT panel control. When transmitting, the T/R line is near ground; there is very little voltage at the RIT control, and it has no effect. Now, the transistor is turned on, so the *Xmit-Set* trimmer determines the varactor diode bias, setting the PTO frequency to the center of the RIT range. When the RIT is switched off, the transistor is always on, so the frequency is centered.

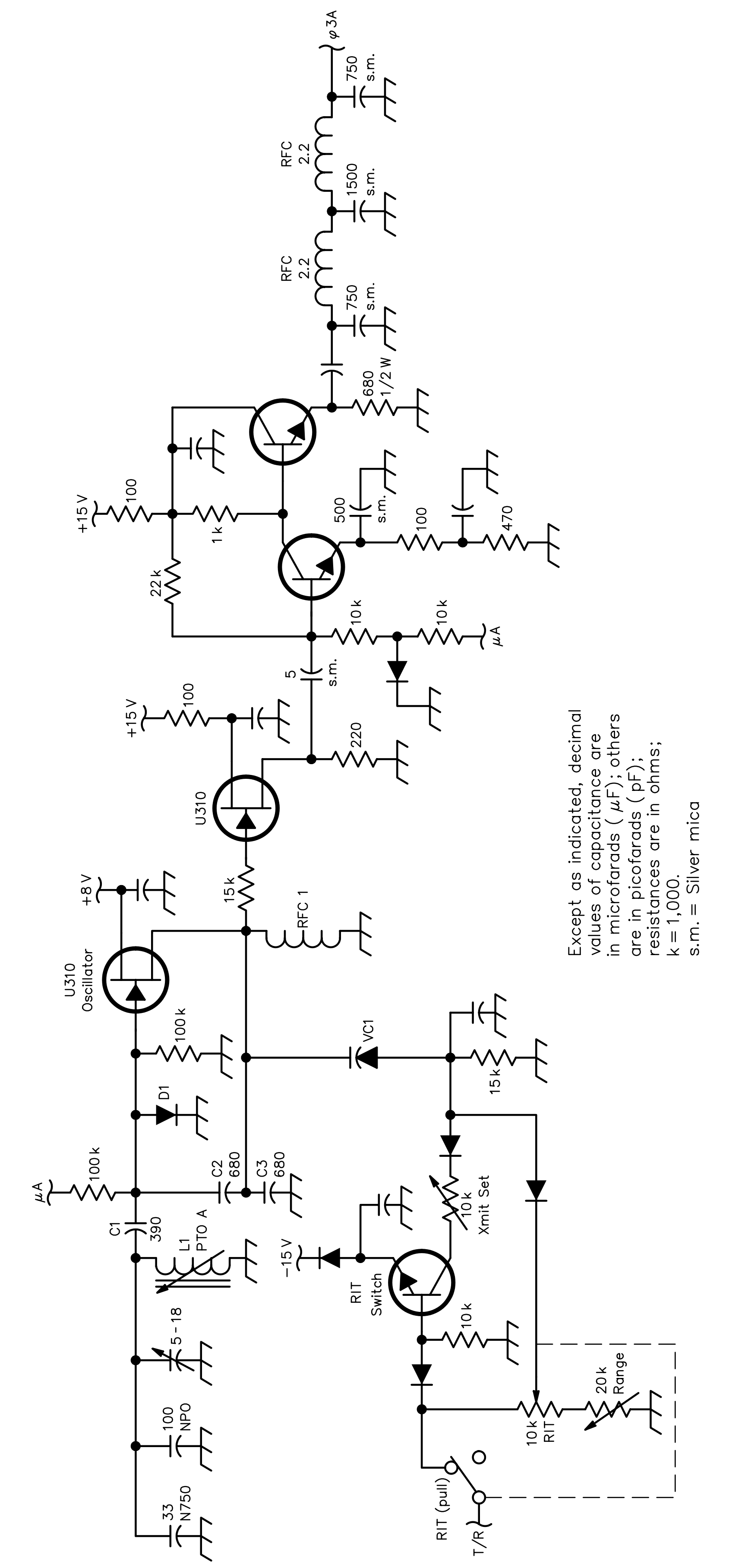
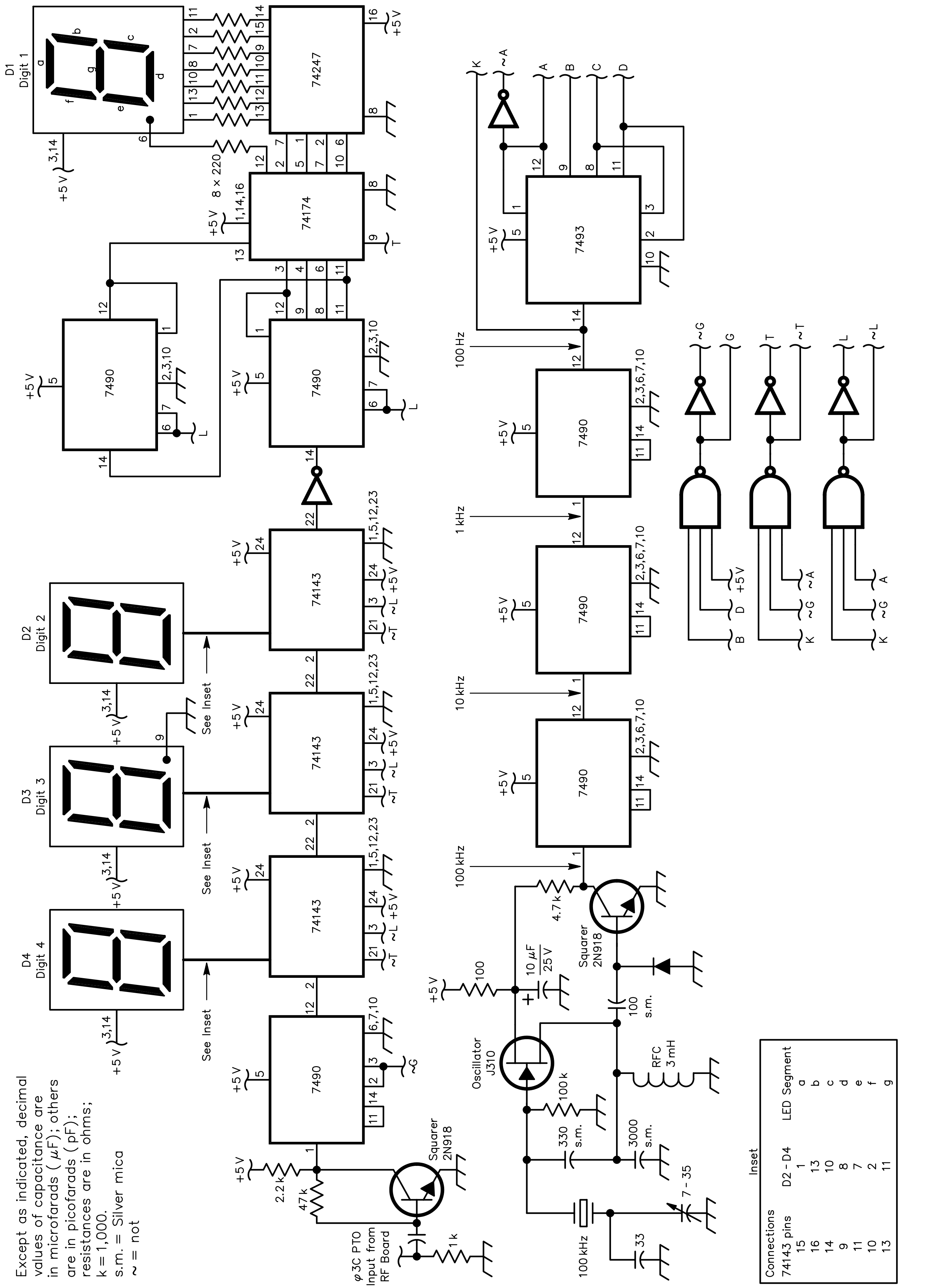


Fig 11—PTO schematic diagram. The 78L08 regulator that powers the oscillator is not shown.
C1—Temperature-stable monolithic ceramic capacitor, type C0G, 390 pF; Panasonic #ECU-S1H391JCA, Digi-Key #P4932 (see Note 22). From 0 to 60°C, these capacitors have a tolerance range of 0.1%.
C2-C3—Temperature-stable monolithic ceramic capacitor, type C0G, 680 pF; Panasonic #ECU-S1H681JCB, Digi-Key #P4935 (see Note 22 and comment for C1).
D1—Hot-carrier diode, HP-2800. A small-signal germanium diode, such as type 1N270, may also be used.
L1—Permeability-tuned oscillator coil, salvaged from a Signal-One CX7.
RFC 1—RF choke, 100 mH. A 1-mH choke is often seen in this sort of oscillator circuit; that is larger than needed and may cause pick-up of AC hum.
VC1—Varactor diode, nominal 33 pF. Motorola type MV2109, NTE type 614 (see Note 21).


Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k = 1,000. s.m. = Silver mica ~ = not
D1 Digit 1
D2 Digit 2
D3 Digit 3
D4 Digit 4
8 × 220
74247
74174
7490
74143
7493
See Inset
φ3C PTO Input from RF Board
Squarer 2N918
Oscillator J310
RFC 3 mH
100 kHz
10 kHz
1 kHz
100 Hz
Inset
Connections
74143 pins | D2 - D4 | LED Segment
15 | 1 | a
16 | 13 | b
14 | 10 | c
9 | 8 | d
11 | 7 | e
10 | 2 | f
13 | 11 | g

RIT Adjustment

The *Range-Set* trimmer is adjusted to obtain a range of ±1 kHz, which is most convenient. Varactor diodes of the same type may vary greatly in characteristics. If the RIT control does not yield equal shift in both directions from center, resistors are selected and installed between the arm and either side of the control to center the curve. The range obtained may also vary, hence requiring adjustment of the 15-kΩ resistor. Thus, the RIT circuits are individually fine-tuned.

PTO Construction

The original Signal/One PTO cover design has several drawbacks. The cover is held by only two screws and does not fit tightly, which results in an RF-leaky enclosure. Connections to the PTO circuit are made through plain insulated terminals, not feed-through capacitors, resulting in further leakage. For these reasons, new PTO enclosures were fabricated using copper-clad circuit board. Feed-through bypass capacitors are used. All the usual CX7 spurs caused by PTO leakage are eliminated. Building the HF front-end in a separate enclosure is also a major factor in this result.

Frequency Counter

The main transceiver panel covers 40-39 MHz, driving three front-end panels for HF, 50 MHz and 144 MHz. An external switch box with push buttons chooses one of these three. The HF panel (200 W) covers the ham bands up to 30 MHz in 10 1-MHz bands. The 50-54 MHz panel (2 W) has four 1-MHz bands. It was built during solar cycle 22, when ZLs and VKs still used the 51 and 52 MHz segments. The 144 MHz panel (2 W), used only for CW/SSB DX and for moonbounce, covers only 144-145 MHz. The frequency counter on the main panel counts only kilohertz. The operator must read the band from the switch box and the band switches on the front-end panels—an archaic method, although not a problem for experienced operators. The transceiver and front-end panels fit into the complete station layout as shown in Fig 9.

Counter Circuit

The counter is that section of the radio that is closest to a direct copy of an established circuit. With only slight changes, I combined circuits from several versions of Signal/One counters and from an independent supplier.[17] The design is straightforward; its circuit is shown in Fig 12. The chief advantage of this circuit is the absence of multiplexing, which can cause noise problems. The counter reads a PTO frequency directly, displaying only the kilohertz digits. Since the PTO range is 3.1 to 4.1 MHz (as explained in Part 1, p 20), the counter is configured to start at 090000_{10}. The resulting count, over 100-ms intervals, is 400000_{10} to 500000_{10}. Leading and trailing digits are not displayed. The PTO covers 1 MHz, with about 50 kHz over-range coverage at each end. The normally displayed readings are from 000.0 to 999.9. Beyond that, an overflow dot lights on the left of the display, warning the operator. With the band switch on 7 MHz, for example, a reading of 005.0 means 7005.0 kHz. However, a reading of .005.0 means 8005.0 kHz. Use caution!

The counter has three main sections. The portion from the crystal oscillator to the 7493 generates a 100-Hz clock, line K, with a period of 10 ms. The second section, consisting of the 7493 and associated TTL gates, divides the clock by 12; this yields a total counter period of 120 ms and

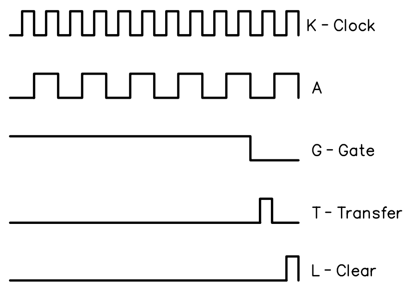


Fig 13—Timing chart for the frequency counter. Each horizontal division represents 5 ms. The vertical scales indicate the high or low states of each line. After the total span of 120 ms, the circuit is reset by the 7473, configured for a count of 12. The gate line, G, limits the actual counting interval to 100 ms; B and D are high when the 7473 reaches a binary count of 1010, or 10 counts of the 10 ms clock, K. Line A is used to divide the remaining 20 ms into two intervals, for T and L. The three-input gate for the transfer line, T, is wired so that T is high only during the 5 ms during which K is high, while G and A are low. The clear line, L, is obtained similarly.

Fig 12—Frequency counter schematic diagram (opposite). Commonly available TTL ICs are used. The simple gates are all included in one 7404 hex-inverter package and one 7410 triple three-input NAND gate package. Type 74143 is a combined BCD counter, storage latch, decoder and seven-segment output driver. It does not have a "start at nine" feature; this complicates the circuit by requiring several other ICs to drive the first digit.

D1-D4—LED panel read-out, seven-segment, common anode; HP type 7661, or 7660 for left-hand decimal point at the first digit for the over-range indicator. Panasonic types LN514OA and LN514GA (orange and green) are available at Digi-Key, #P327 and #P329 (also available in red and amber; see Note 22). The Panasonic LEDs are not available with left-hand decimal point. The over-range indicator may be placed to the right of the fourth digit.

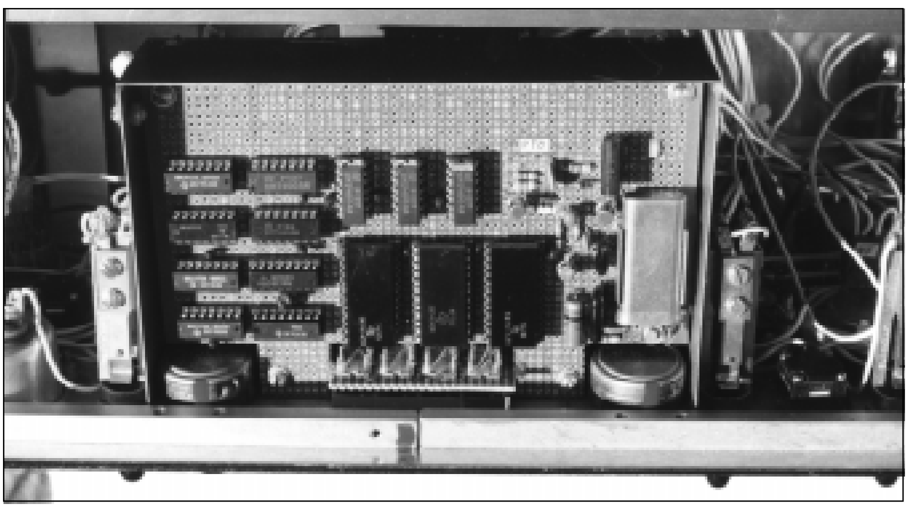


Fig 14—Top view of the frequency counter. The socketed DIP ICs are wire-wrapped; discrete components are hand wired point-to-point. The LED readout sub-board is also wire-wrapped and is cemented at right angles into the cutout on the main counter board.

produces the various control lines. The 7493 is a divide-by-16 binary counter; strapping the C and D output lines to the reset pins reduces it to a divide-by-12 counter. A count of 12 has binary output 1100_2; ie, C and D are high. The gate line, G, determines the total counting time of 100 ms. The remaining 20 ms of the total counter period are for the transfer (line T) and clear (line L) functions. A timing chart is shown in Fig 13.

The third portion of the counter, from the PTO input to the display digits, performs the actual counting. The more complicated circuit for the first digit implements the start-at-nine and over-range functions.

Powering the Counter

The LED drivers in the counter can become quite hot. The TTL ICs are specified for operation at 4.75 to 5.25 V. I found, however, that this counter would operate perfectly at voltages down to 3.5 V dc. An LM317 adjustable regulator, with input from the 7808 primary regulator, supplies the counter power. Tests were run over many months while work continued on other portions of the radio. A setting of 3.9 V has powered the counter adequately for 10 years, with greatly reduced IC temperatures and a much longer expected life. The LEDs also benefit from this technique, giving a softer, yet sharper display.

Counter Construction

The counter is seen in Fig 14. It is built on plain perfboard using wire-wrap construction. Four LED digits are used for the display: three in yellow for kilohertz and a green one for tenths of kilohertz. An escutcheon, seen in Fig 3 of Part 1, covers the ragged edges of the panel cutout; it was recycled from a CX7.

Power Supply

Design considerations and a general description of the power supply were given in Part 1, pp 23-24. The circuit uses standard IC regulators; the schematic need not be given here.[18] Four small transformers are used. A heat sink, spaced away from the rear panel, holds the four primary regulators: two 7818s, a 7918 and a 7808—all have TO-3 cases. Each of the four main boards employs TO-220 secondary regulators as needed: 7815, 7915 or 7805. One adjustable LM317 is used for the counter, as mentioned above. This double regulation avoids all transient problems. In addition, the IF board has a second 7815 regulator that powers only the AGC detector. This keeps AGC noise out of other circuits. In some radios, what sounds like an AGC click from inadequate AGC attack response is only noise conducted by a common power supply.

Cabinet Construction

Packaging for a full-featured radio can be a problem. The many circuits require considerable space. Modern mass-production methods are not available. A homebrew radio is more like a prototype; simple methods are required. Space must be provided for innumerable circuit modifications in the eternal quest for perfection.

The method used to build the main boards was described in Part 1 and is shown in the photos accompanying previous segments. The four main boards are secured inside the cabinet using pins. There are no removable screws or nuts to deal with. Each board has two small holes on the bottom wall and sits on pins fashioned from nylon screws attached to the cabinet bottom.

The IF board is pinned firmly in place by captive thumbscrews secured to the cabinet sides, which enter holes in the sidewalls of the board. This makes board removal very quick and easy. The plan was the same for the three other main boards. Because wire-harness overload developed during construction, however, the other boards had to be shortened; they have side pins only on the right. (I omit gruesome details, including the need to saw off the left end of the RF board after it was built and installed.) A removable top bracket with four nylon pins (not shown) secures the other boards using the IF board as an anchor. The four holes in the top walls may be seen in Fig 5 of Part 1.

Table 5 lists materials needed to assemble the cabinet. The LMB Omni Chassis series provides numerous prepunched holes for fastening and results in an excellently shielded enclosure. The cabinet's bottom plate is permanently attached—all work is done from the top of the radio. The cabinet itself has no front; this avoids the troublesome problem of drilling and mounting controls on a double wall. The front panel, for a standard 19-inch rack, has a plain, unpainted rear surface. This ensures good bonding and shielding. A ridge of square aluminum is permanently fastened to the rear of the panel, positioned to fit inside the cabinet. The bar is fastened to the panel with twelve permanent screws threaded into the bar from the front of the panel. These permanent front screws may be seen in Fig 3 of Part 1. Part of the bar may be seen here in Fig 14, and an outline of the bar is shown in Fig 15. The panel is released quickly and easily by removing hidden screws that thread into the bar from the sides, top and bottom of the cabinet. This method avoids the need to remove screws from the front of the panel and so prevents marring or scratching of the paint. All panel-mounted controls and assemblies swing down with the panel; there are no knobs to be removed or shafts to be disconnected. Similarly, the rear panel is easily lowered.

The best size for the main boards is 7.5×15×2 inches. Details were given in Part 1. The front panel is 8¾ inches high. The next standard size, 10½ inches, would allow space for another row of knobs along the top of the panel—and still more special features!

To avoid wire-harness overload, wiring between boards is best done with #24 stranded wire with thin (10-mil) insulation. Irradiated hook-up wire has insulation that will not melt from

Table 5

Material list for Cabinet Construction: The components used are intended for constructing a 4×17×17-inch chassis. Two sets of components are used, bolted together to form a cabinet 8×17×17-inches. LMB stock numbers are listed (see Note 23). The sides are 40-mil (1 mil = 0.001 inch) aluminum; the covers are 63-mil; the front panel is 125-mil. The cabinet is perfectly rigid when fully assembled. Because the bottom cover is permanently attached and all work is done from the top, the slight flexibility with the top cover off causes no trouble.

3	S417	Chassis sides (pair); 4×17 inches
2	C1717	Top and bottom covers; 17×17 inches
1	875	Front panel; 8¾×19 inches (Specify black, texture finish)

the heat of a soldering iron. Alpha 7054 irradiated #24 hook-up wire is available as Mouser #602-7054-100-01.[19] Coaxial-cable interconnections were discussed in Part 2, p 5.

There are several advantages to building the front-end sections on separate panels. First, the main transceiver panel—which boasts an output power of 200 mW—is made to generate a minimal amount of heat. This reduces drift problems to a negligible level. The CX7 powdered-iron sliding PTO cores used in this radio have a poor temperature characteristic, making compensation over the entire 1-MHz range impossible.[20] Keeping the main transceiver cabinet cool circumvents this problem. Second, the cabinet needs no vent holes and is completely dust-proof.

Front-Panel Layout

This radio was designed and built with the firm belief that it would never be published. The inside photos show neglect for appearance, putting a whole new dimension on the term "ugly construction." Eight years of modifications have not improved it!

A front panel is different: The operator will confront the panel for years to come and that is all most visitors to the shack will see. Every builder wants the front panel of his project to look special. Arrangement of controls is a serious matter, especially for contest work or all-night DXing. The goal is to promote convenient and efficient operating and, at the same time, a pleasing appearance.

An old Mac 512 computer with the *MacDraw* program was used to layout the panel, although any drawing program that produces full-size output could be used. Two panel versions, with and without center-lines, were kept on a floppy; this was easily managed by keeping the lines in an overlay file. A first-draft plain version was printed. Then all the knobs were set on top of the printout and the array studied for balance and general appearance. Changes were made, a new copy printed and the knobs again put in place. This process was repeated every evening for 30

Fig 15—Original template for the front panel. Drawn on a Mac 512 computer, the template is placed over the aluminum panel and each hole is center-punched right through the paper. A few of the panel functions and labels have been changed since the panel was punched.

days. The final panel template is shown in Fig 15. A photo of the panel is shown in Fig 3 of Part 1. Fig 4 of Part 1 shows the control labels clearly, but it is not drawn to scale; the Mac computer printed the template exactly to scale. The printout was taped in place over an aluminum panel and each hole was center-punched through the paper. Many of the other panels in the shack have at least one hole drilled in the wrong place. This transceiver panel, drilled using the template, is the exception.

Performance

It would be well for any construction article to present performance measurements right at the start. With apologies, detailed measurements for this radio must be postponed to a subsequent article, in which complete test set-up details will also be included. Measurements with the available equipment indicate performance at or above the level of factory radios recently reviewed, and eight years of operating have confirmed the results. Nonetheless, more test equipment must be acquired and techniques must be refined before specific measurements can be submitted for scrutiny by *QEX* readers. Unforeseen circumstances have caused delays.

Some articles present proof of performance by listing a few DX stations. This may not be convincing. On the other hand, mere bench measurements are no substitute for actual operating under severe conditions. The discrepancy between lab techniques and actual ham-band conditions is one problem.

The 20-kHz-separation IMD test is a case in point. Try to find a clear 20-kHz segment on the 20-meter band during a DX contest or Sweepstakes! While published reports of factory radios often indicate IMD performance only for 20-kHz spacing, there are expanded reports available that clearly show a deterioration of performance as the spacing is decreased Preliminary IMD tests indicate that the homebrew radio has the same excellent dynamic range at 3-kHz spacing as for 20-kHz. This is because the radio does not rely on a first-IF filter to shield the second mixer. See the discus-sions on "Tuning the First IF" and "Receiver Gain Distribution" in Part 1, pp 18-19. On-the-air tests can and must supplement lab measurements, with respect to actual band conditions, operating features and convenience.

Results

The following statements concern-ing on-the-air tests are not given in lieu of precise measurements to be presented later, but only in reply to some inquires.

During the eight years this homebrew radio has been in use, about 40 contest certificates have been received for events from 160 to 2 meters. Most of these are minor section awards; there is only one top-10 plaque on the wall.

However, a contest is a radio to severe test, for a radio, not only for a big-gun, but also for a little-pistol.

DX work also subjects equipment to severe tests. With no Beverage antenna, the radio (with an amplifier) has worked 110 countries on top band (1.8 MHz). With only a single Yagi on the horizon for moon-rise/moon-set (and again an amplifier), seven countries have been worked on moonbounce (144 MHz). All the ham frequencies in between have also been used extensively with excellent results.

Summary

This article concludes a series that describes the 40-MHz main panel of the K5AM homebrew transceiver. Although the radio was completed eight years ago and has been in constant use since, modifications and improvements are still in progress. Any suggestions are most welcome! Subsequent articles will describe the three front-end panels for HF, 50 MHz and 144 MHz.

Notes

[1] M. Mandelkern, K5AM, "A High-Performance Homebrew Transceiver: Part 1," *QEX*, Mar/Apr 1999, pp 16-24.

[2] M. Mandelkern, K5AM, "A High-Performance Homebrew Transceiver: Part 2," *QEX*, Sept/Oct 1999, pp 3-8.

[3] M. Mandelkern, K5AM, "A High-Performance Homebrew Transceiver: Part 3," *QEX*, Nov/Dec 1999, pp 41-51.

[4] M. Mandelkern, K5AM, "A High-Performance Homebrew Transceiver: Part 4," *QEX*, Jan/Feb 2000; pp 47-56.

[5] Thanks to Bill Carver, W7AAZ, for help with this discussion of TTL and PIC methods.

[6] R. Dean Straw, N6BV, Ed., *The ARRL Handbook for Radio Amateurs* (Newington: ARRL, 1999, Order #1832). ARRL publications are available from your local ARRL dealer or directly from the ARRL. Mail orders to Pub Sales Dept, ARRL, 225 Main St, Newington, CT 06111-1494. You can call us toll-free at tel 888-277-5289; fax your order to 860-594-0303; or send e-mail to **pubsales@arrl.org**. Check out the full ARRL publications line at **http://www.arrl .org/catalog**.

[7] D. Lancaster, *TTL Cookbook* (Indianapolis: Howard W. Sams & Co, 1974).

[8] D. DeMaw, W1FB, *The ARRL Electronics Data Book* (Newington: ARRL, 1988, Order #2197).

[9] By some historical accident, this station uses negative external control lines for PTT and key lines. Former Signal/One owners will understand. The circuits shown in Figs 5 and 6 are modified and untested circuits that are suggested for use with the positive external lines more commonly used.

[10] M. Mandelkern, K5AM, "Design Notes for 'A Luxury Linear' Amplifier," *QEX*, Nov 1996, pp 13-20.

[11] Thanks to Dan Hunt, K5WXN, for this suggestion.

[12] One of the most useful items of workbench test equipment is an old CX7, used as a test receiver or a test transmitter. With its bi-directional 40-MHz jack, it also serves as a front end for testing the basic transceiver or as an IF for testing a front-end panel. Added panel switches permit switching off the PA and the first LO as needed for various tests. All CX7 rear-panel connections are brought out to a test panel (on a shelf above the workbench) for quick connection to any device under test.

[13] The four switches disable the oscillators by applying –15 V to the lines µMO, µOO, µA, and µB.

[14] These radios can indeed be repaired and used. I have six in perfect working condition, including two converted to 50 MHz for mountaintop contesting. However, CX7s from early production runs lack some improvements in construction that are found in later runs, so when they are found at flea markets it is best to consider them as "parts radios" (ie, for salvaging valuable components). Anyone who wishes to restore a CX7—an enjoyable and instructive "boat-anchor" project—is better off starting with a later version. The best are those with Florida labels and serial numbers in the 800s and 900s.

[15] Thanks to Paul Kollar, W8CXS, for 25 years of advice on repairing CX7s and especially for detailed instructions for overhaul of the PTO mechanism.

[16] Coil adjusting has been tried in a different context and found feasible. In one of the CX7s converted to cover 50-51 MHz, shifting only two turns gained 150 kHz at the upper end, enough to cover the ZL segment near 51.110 MHz during solar cycle 22.

[17] Dick Cunningham, KØHHP (SK), produced LED counters to replace the Nixie counters in the CX7. This was not only a fine improvement that eliminated the flickering Nixies, but helped keep many CX7s on the air, since nearly all the original Nixie counter boards were defective.

[18] Each regulator requires input and output bypassing. Minimum requirements vary with the type of regulator and even with the manufacturer. To avoid consulting the data books every time a regulator is needed, I keep a stock of inexpensive surplus 2.2-µF tantalum electrolytics (a size sufficient for any type regulator) on hand. Two of these are installed directly at each regulator. Also, a 1-Ω, $^1/_4$-W (or a higher wattage where needed) series resistor is installed at the input and output of each regulator. A DMM set to the millivolt range and connected across the shunt will read-out in milliamperes directly. This helps to monitor current drain and locate defects. The resistors also serve as fuses in case of shorts.

This note affords a chance to insert a bit of voltage-regulator trivia. This concerns the LM317, used to power the counter in this radio. There are several misconceptions involved in use of the LM317 as commonly seen in published schematics. Most often one sees a 240-Ω resistor used to establish the minimum load current and the bias current for the control terminal. This value is seen in the data books and is apparently simply copied without further thought (see Note 24). However, there is nothing special about this particular value, which is not a common 10% value normally stocked by hams. It is never good to specify unusual components when common types will suffice. The data sheet specifies a minimum current for proper operation; with the 1.25-V reference voltage maintained between the output and control terminals and a specified 5-mA minimum load current, this works out to 250 Ω. The next lower 5% value of 240 Ω (available for factory design) is shown in the data books. In a ham workshop, the next lower 10% value of 220 Ω may be used. Of course, the required resistance at the control terminal must be calculated using the bias current obtained and chosen to provide the desired output voltage. Nonetheless, 220 Ω would still be wrong! The second common misinterpretation of the data sheets stems from the fact that the application diagrams are shown using the military or industrial versions of the regulator, the LM117 or LM217. The LM117/LM217 does have a 5-mA minimum load-current specification. This version is seldom seen at ham suppliers, and it would cost too much even if located. A careful reading of the specification sheet shows that the commercial/consumer version, the LM317, has a minimum load current of 10 mA. Thus the resistor should be a maximum of 125 Ω; either 120 Ω or 100 Ω could be used. All this is really trivia, of course; the circuit usually draws more than the required minimum. But an LM317 with a 240-Ω resistor in a schematic for a weekend ham project needn't send readers rushing out to look for a precise component

[19]Mouser Electronics, 2401 Hwy 287 N, Mansfield, TX 76063; tel 800-346-6873, fax 817-483-0931; **sales@mouser.com**; **www.mouser.com**.

[20]Thanks to Harold Johnson, W4ZCB, for information on the construction of the Signal/One PTOs.

[21]Hosfelt Electronics, 2700 Sunset Blvd, Steubenville, OH 43952; tel 800-524-6464, fax 800-524-5414; **hosfelt@clover.net**; **http://www.hosfelt.com/**

[22]Digi-Key Corp, 701 Brooks Ave S, PO Box 677, Thief River Falls, MN 56701-0677; tel 800-344-4539 (800-DIGI-KEY), fax 218-681-3380; **http://www.digikey.com/**

[23]LMB Heeger, Inc, 6400 Fleet St, Commerce, CA 90040; tel 213-728-5108, fax 213-728-4740; **www.lmbheeger.com**. Ask for a catalog and information on direct ordering with free shipping.

[24]For example, pp 10-10 to 10-17 in *1982 Voltage Regulator Handbook*, 1981, National Semiconductor Corp, 2900 Semiconductor Dr, Santa Clara, PO Box 58090, CA 95051; tel 408-721-5000; **www.national.com**.