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IMPROVING THE DRAKE TR-7

Reversible modifications enhance performance

Very few amateurs will disagree that today's HF ham gear has come a long way from what it was 10 or 20 years ago. Today's microprocessor-controlled radios offer an incredible number of features in small packages. All this technology has its price, however, as radios have become progressively more expensive, difficult to repair, and contain an increasing amount of surface-mount and proprietary components. At the same time we are offered this "high-tech" equipment, there is a growing interest in the simpler, less "option-intense" HF radios of the past.

The R.L. Drake Company, which held a commanding position in the amateur market in the 60s and 70s, was a trendsetter for the industry. The American-made TR-7, unveiled to the amateur community in 1978, is an excellent example of technological innovation. The TR-7 was one of the first amateur transceivers to offer continuous receiver coverage from 10 kHz to 30 MHz, and continuous transmit coverage from 1.5 to 30 MHz. Drake's use of up-conversion to an IF of 48 MHz and their continuous-duty, 150-watt output solid-state PA were also firsts. The TR-7 definitely established the trend towards the equipment we have today.

However, the TR-7 was not without its problems. Among these was the fact that, while the radio did offer continuous receive coverage down to 10 kHz, sensitivity below 1.5 MHz was poor. For the dyed-in-the-wool CW operator, the radio didn't offer full break-in (QSK) operation and the receive signal-to-noise (S/N) ratio was poor on weak CW signals. Finally, many amateurs found the noise from the PA cooling fan annoying.

Yet, with a few revisions, these problems in the TR-7 can be corrected. The four modifications I designed provide the following features:

- Full receive coverage from 10 kHz to 30 MHz with no reduction in sensitivity across the entire range.
- Smooth, quiet, full break-in (QSK) CW operation at full output power.
- A major improvement in the S/N ratio of weak CW signals.
- A reduction in cooling fan noise, because the fan operates only when it is needed.

One of my primary goals in designing modifications is that they are reversible. Nothing bothers me more than extra holes in front panels, cutouts in chassis, cut PC board traces, etc. All four modifications described in this article are 100 percent reversible and don't require the drilling of any holes. The radio can be returned to its stock configuration at any time, should this ever become necessary.

Theory of the design deficiencies

Receiver

The receiver in the TR-7 was state-of-the-art when it was designed in 1978. Sensitivity, selectivity, and stability are all very good. However, since the TR-7 was primarily designed for use as an HF transceiver, certain compromises were made in its design.

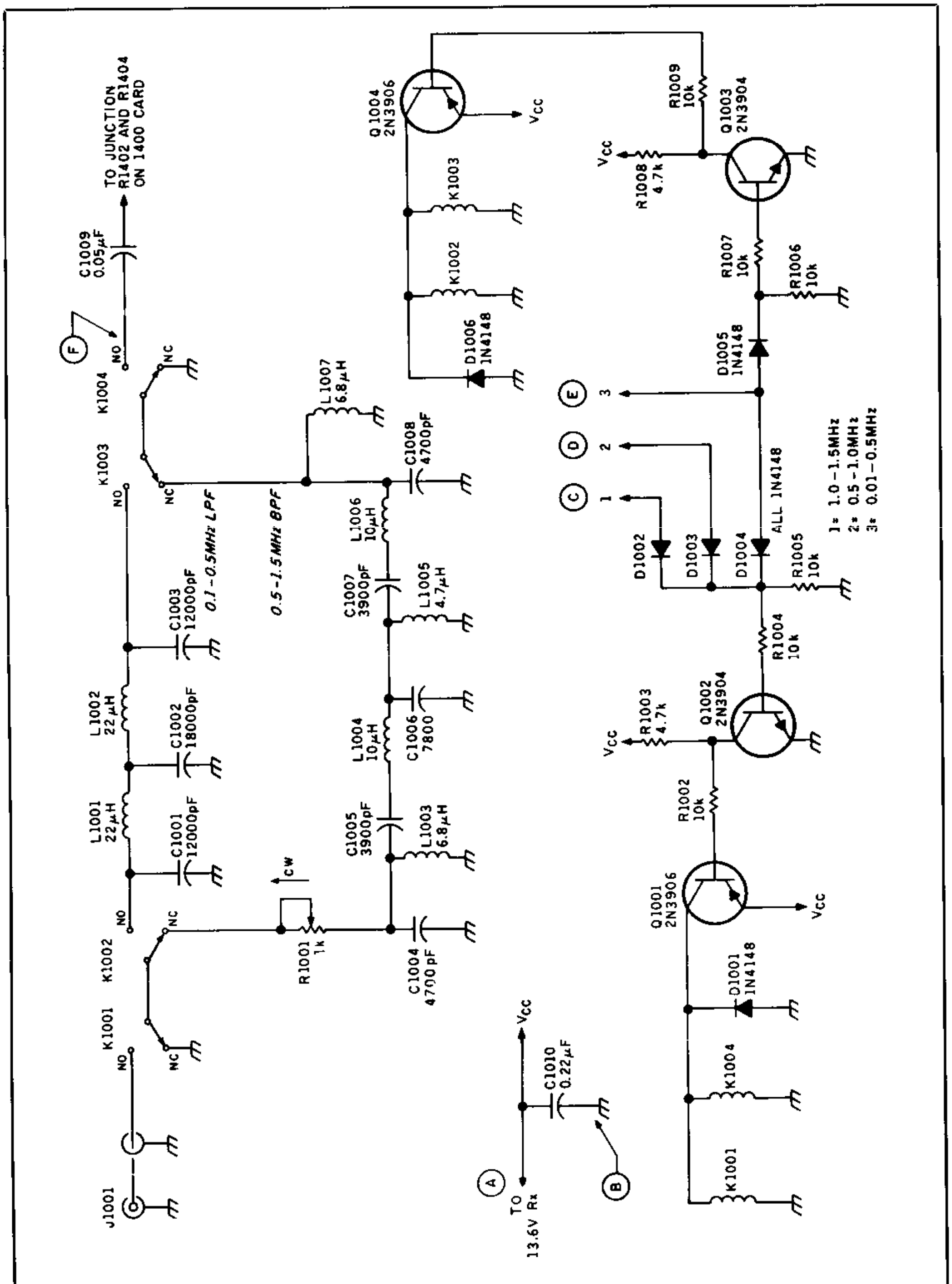

Figure 1. Front-end filter.

One problem is the poor sensitivity below 1.5 MHz. Drake advertised the radio as being capable (with the addition of the AUX-7 module) of receiving continuously from 0.01 to 30 MHz, with reduced performance below 1.5 MHz. However, TR-7 owners with AUX-7s learned that the receiver sensitivity below 1.5 MHz was far worse than the advertising implied. They were further disappointed to learn that the antenna input (marked VLF antenna on the schematic) was inconveniently located on the accessory connector.

The poor performance results from the

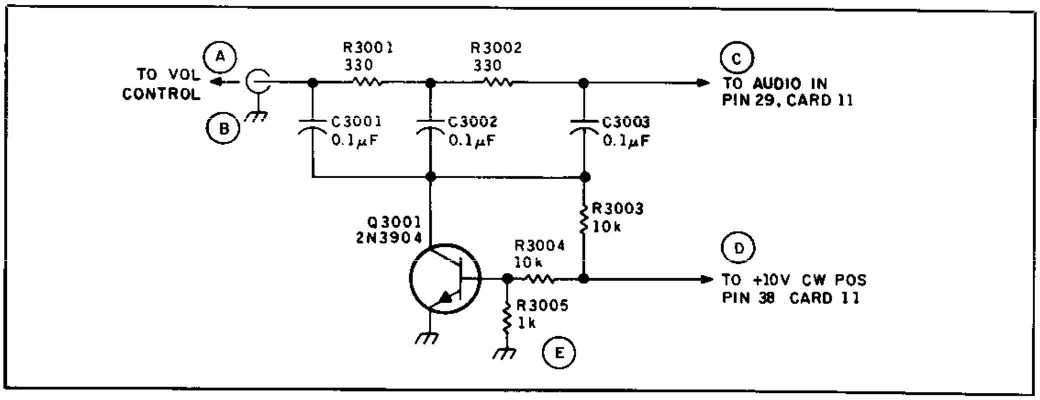

Figure 2. Audio filter circuit.

lack of any low-pass filtering below 1.5 MHz. Instead, Drake inserted a 20-dB fixed attenuator in series with the antenna to protect the mixer against overload in the 0.01 to 1.5-MHz range.

Another minor problem with the receiver is the annoying high-frequency noise present in the audio, which is especially noticeable when operating with narrow CW filters.

Transmitter

The transmitter in the TR-7 is excellent. The transmitted audio is clean, and the PA easily develops a solid 150-watt output across the entire 1.8 to 30-MHz range. Its main drawback is the lack of full break-in (QSK) CW.

The TR-7 manual states that with the CW delay control set fully counter-clockwise, the radio operates in the QSK mode up to about 20 WPM. Those who have tried this have been greatly disappointed. The chatter of the frame-type T/R relay is irritating, and the rapid transition between transmit and receive creates annoying thumps and pops in the speaker.

One other problem with the transmitter is that the original Drake FA-7 fan used to cool the PA operated whenever the set was on, whether it was needed or not. In addition, because it is an AC-powered fan, it wouldn't work at all when the TR-7 was used as a mobile or portable station.

Circuit description

Receiver front end

The installation of one low-pass and one band-pass filter in the front end solves the problem of poor performance below 1.5 MHz. I used a Chebyshev low-pass filter for the 0.01 to 0.5 MHz range and a Chebyshev bandpass filter for the 0.5 to 1.5-MHz range.[1] The bandpass filter used in the 0.5 to 1.5 MHz range protects the mixer from strong shortwave broadcast signals as well as strong VLF signals, like Loran-C. The AUX PROGRAM switch selects the appropriate 500-kHz frequency range and front-end filter (see **Figure 1**). The circuit is very straightforward, using relays for filter/antenna switching instead of diodes. I used relays to avoid the IMD products diode switches can introduce under strong signal conditions (such as those prevalent in the broadcast band).

Two relays on the front-end filter card select the appropriate filter. The normally closed contacts of relays K1002 and K1003 select the 0.5 to 1.5-MHz bandpass filter when the AUX PROGRAM switch is in position 1 or 2. Variable resistor R1001 adjusts the insertion loss of the 0.5 to 1.5-MHz bandpass filter to minimize broadcast-band intermodulation products. Transistor Q1003 is a driver for transistor Q1004, which actuates relays K1002 and K1003 when the AUX PROGRAM switch is placed in position 3. This enables the selection of the 0.01 to 0.5-MHz low-pass filter.[2]

Because the VLF/LF/MF antenna(s) may be left connected to the set at all times, transmitting with the TR-7 above 1.5 MHz could induce enough voltage in the low-frequency antenna to damage the filter or the mixer. Two additional relays on the front-end card prevent this type of damage. The normally closed contacts of relay K1001 disconnect the low-frequency antenna from the filter input, and the normally closed contacts of relay K1004 disconnect the mixer from the filter output.

Whenever the AUX PROGRAM switch is in one of the three positions associated with the 0.01 to 1.5-MHz range, a logic high is applied to the diode OR gate comprised of D1002-D1004. A logic high from this OR gate turns on Q1002, which turns on Q1001 and actuates relays K1001 and K1004. With K1001 and K1004 actuated, the appropriate

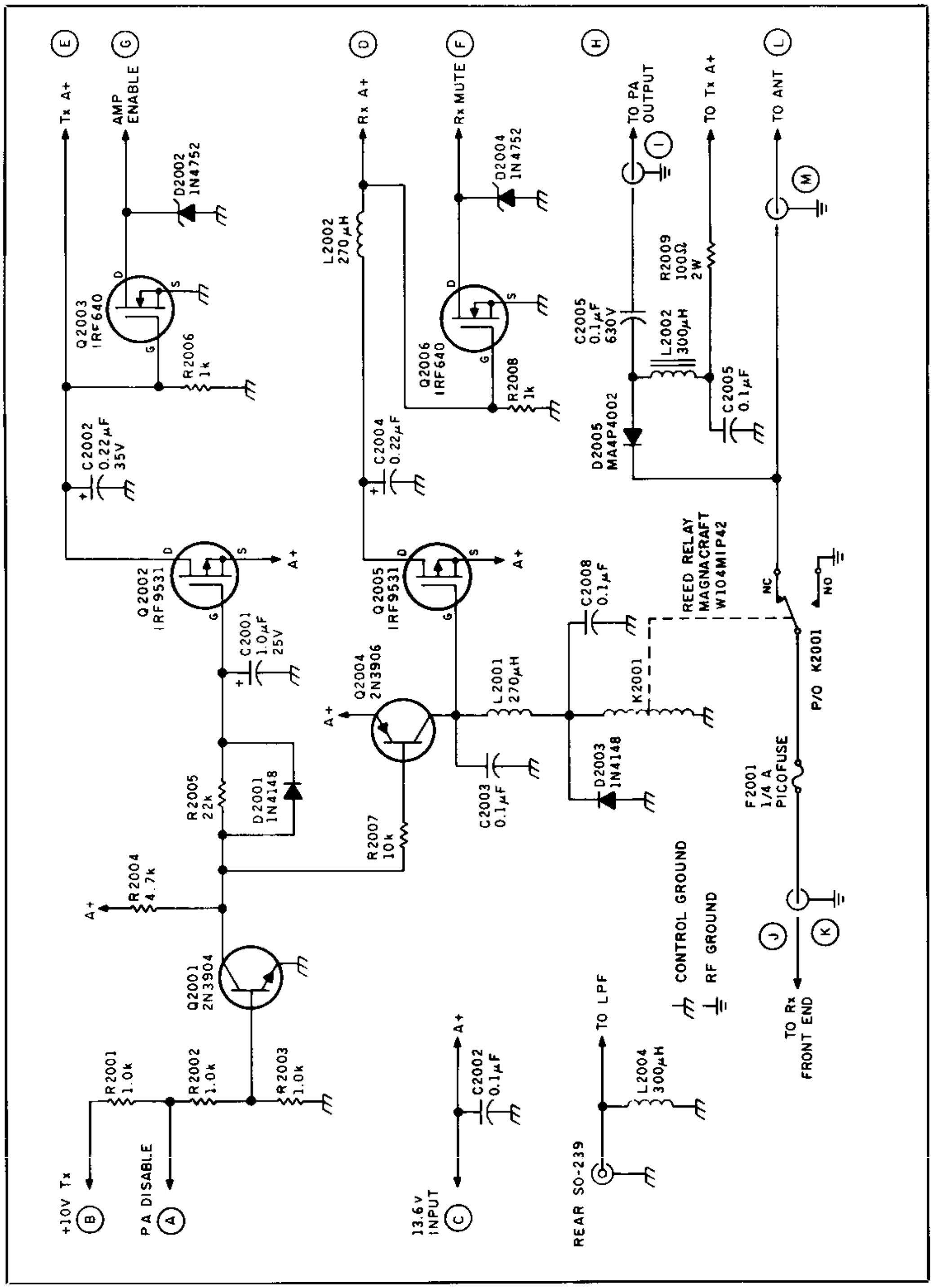

Figure 3. QSK card schematic.

front-end filter is placed in the low-frequency antenna circuit. The OR logic allows the use of this front end in TR-7s where a portion of the AUX-7 card is currently used for WARC bands, MARS frequencies, etc. Therefore, the three low-frequency ranges can be associated with any three positions on the AUX PROGRAM switch.

The inconvenient location of the low-frequency antenna connection on the accessory receptacle makes its relocation desirable. Fortunately, Drake made an unused phono jack available on the rear panel. You can substitute a BNC connector in place of this phono jack for use with the low-frequency antenna.

CW audio filter

The audio filter circuit is quite simple, yet it's very effective in reducing high-frequency noise when using narrow CW filters. The circuit is comprised of a simple RC filter[3] with a cutoff frequency of approximately 1500 Hz, and a simple transistor switch (see **Figure 2**). The filter is inserted into the high-impedance audio path from the AF GAIN control to the input of the audio amplifier.

When the MODE switch is in any position other than CW, transistor Q3001 is turned off, allowing the common for capacitors C3001-3003 to float at approximately 10 k above ground, disabling the low-pass filter. Resistors R3001 and 3002 are of such a low value compared to the input impedance of the amplifier that they introduce no discernable loss. Q3001 is turned on whenever pin 38 on the second IF/Audio card goes to + 10 volts when the MODE switch is in CW. This grounds the common for the RC filter, placing it into the circuit. Resistors R3004 and 3005 form a 10:1 voltage divider for the base of Q3001 to prevent it from turning on with the residual voltage (approximately 1 volt) present on pin 38 when the MODE switch is in any position other than CW.

Transmitter QSK

Modifying the radio to operate QSK was a bit of a challenge, due to Drake's use of a 4PDT relay for T/R switching. The functions of the T/R relay contacts are:

1) Switching A + from transmit to receive.
2) Switching the antenna from the receiver to the transmitter.
3) Protecting the mixers in the internal and external receivers.
4) Providing control for a linear amplifier.
5) Providing a means to mute an external receiver.

By emulating all of the functions of the T/R relay, the modified TR-7 can function in exactly the same transceive configuration as a stock unit.

My QSK circuit employs a high-power PIN diode, a reed relay, and several power MOSFET switching components (see **Figure 3**). Power MOSFETS are the easiest way to switch voltage quickly and quietly as required by QSK operation. Their speed and very low "on" resistance make them a perfect replacement for a mechanical relay. Both Q2002 and Q2005 replace the original RX/TX A + switching contacts. I used P-channel power MOSFETS for A + switching and N-channel devices to emulate the relay contact closures to ground for external control. The N-channel MOSFETS in this circuit were selected for their low "on" resistance (0.18 ohms).

The circuitry on the base of the transistor Q2001 exactly duplicates the existing TR-7 relay-driver circuit.[4] Every time the unit enters the transmit mode, + 10 volts is applied to R2001. Provided the PA Inhibit line isn't low, transistor Q2001 is turned on. When Q2001 turns on, its collector goes low, turning on Q2002 through an RC timing circuit comprised of R2005 and C2001. This delay circuit allows the receiver protection relay to switch prior to the generation of output power from the transmitter.

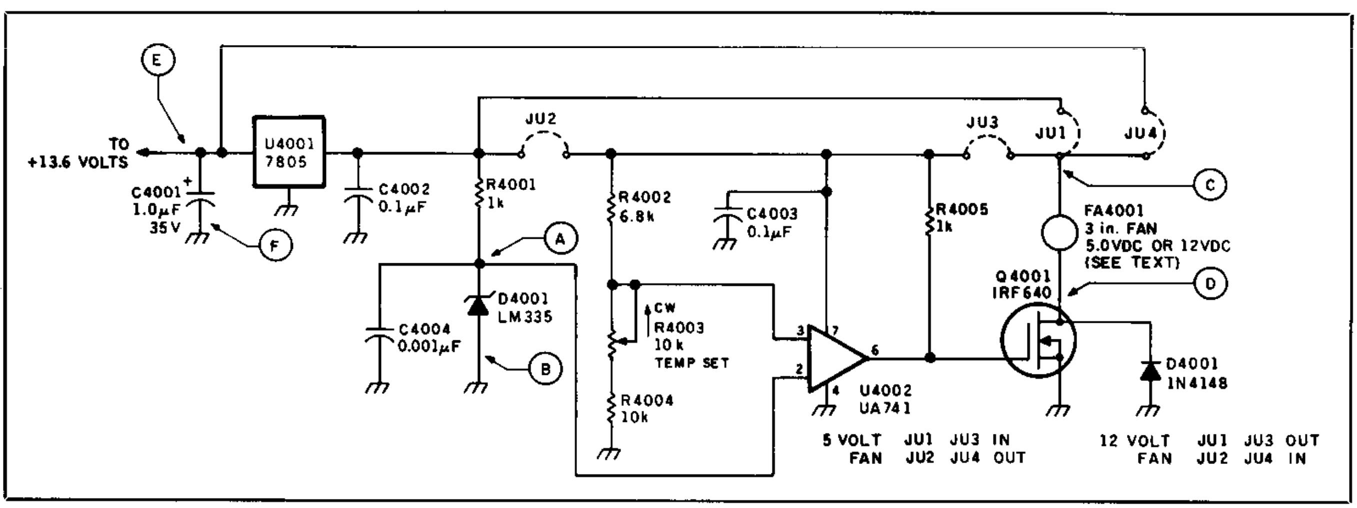

Figure 4. Fan control circuit.

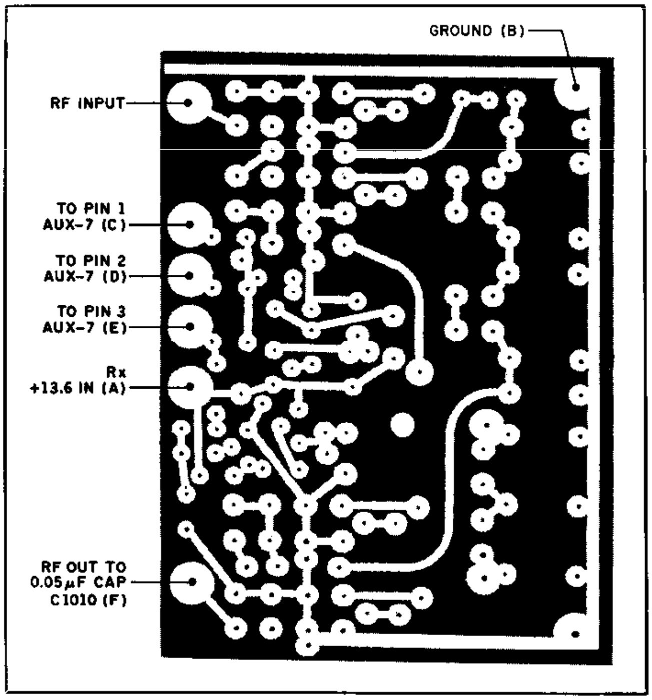

Figure 5. Front-end card foil layout.

When the collector of Q2001 goes low, Q2004 turns on, pulling the gate of Q2005 high and turning off A+ to the receiver. Q2004 also actuates reed relay K2001, grounding the receiver input. The gate for MOSFET Q2003 is tied across the TX A+ line. When the TX A+ line is high, Q2003 turns on, which supplies a ground to control an external linear amplifier. Zener diode D2002 clamps the drain of Q2003 to ground, protecting it from high drain-source voltages.[5]

Transmit/receive antenna switching is accomplished through the use of a high-power PIN diode and a reed relay. Both internal and external receiver front ends are protected by shorting them to ground through relay K2001. I used a reed relay for receiver protection because the broadband design and space limitations of the TR-7 preclude the installation of the necessary quarter-wave transformer for a shunt PIN switching diode.

The high-power PIN diode, D2005, is a low "on" resistance, long carrier-life device made by Microwave Associates (M/A-

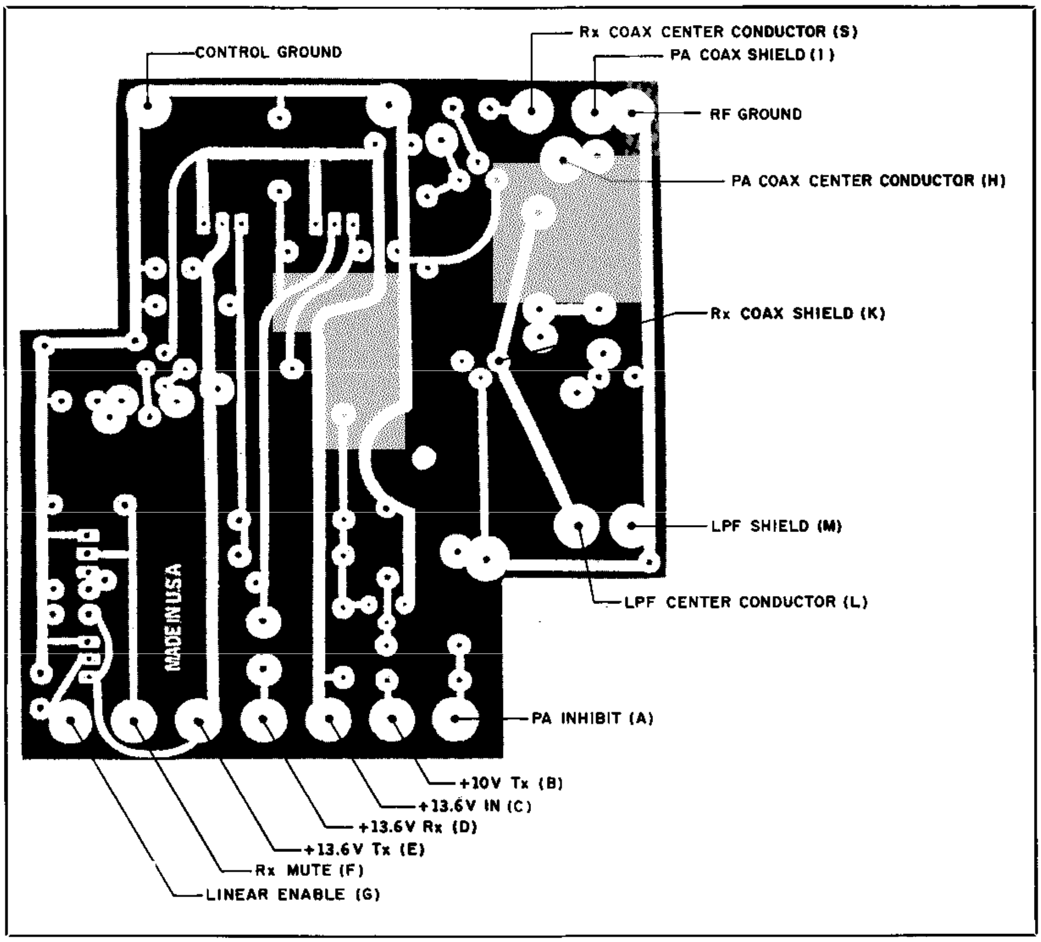

Figure 6. QSK card foil layout.

COM). It provides a high degree of isolation between the PA and the antenna circuit except when forward biased. Capacitor C2005 provides DC isolation for the forward bias voltage injected through RFC L2003. Resistor R2009 limits the forward bias current in D2005 to 135 mA. A second RFC is tied across the antenna jack, providing a low resistance DC ground return for D2005.[6]

During receive, transistor Q2001 is turned off. The collector of Q2001 goes high, turning off Q2002. Diode D2001 speeds up the turn off of Q2002 by bypassing R2005 during receive. With Q2001 turned off, Q2004 turns off, turning on MOSFET Q2005. This turns on A+ to the receiver. At the same time, K2001 is no longer actuated, connecting the antenna low-pass filter to the input of the receiver. When the RX A+ line is high, MOSFET Q2006 turns on, which in turn supplies a ground to the RX Mute line, enabling an external receiver. Zener diode D2004 acts as a voltage "clamp" to protect Q2006 from high drain-source voltages.

One final modification speeds up the transfer time from transmit back to receive. A stock TR-7 with the CW DELAY control fully counter-clockwise switches from transmit to receive in about 50 ms. Changing R310 on the TX Exciter card from 47 k to 22 k shortens this transition time to about 25 ms.

I made no modifications to the receiver AGC time constants. In the FAST AGC position in the CW mode, the AGC time constant is only 40 ms. This should be fast enough for most break-in operation.

Fan control circuit

The fan control circuit is comprised of a temperature-sensitive zener diode and a simple op-amp voltage comparator (see **Figure 4**). The output voltage from zener diode D4001 varies at a constant 10 mV/degree Kelvin. At 25 degrees Celsius, the voltage from D4001 is approximately 3 volts.[7] Resistors R4002 through 4004 serve as a variable voltage divider, with a range from approximately 3.0 to 3.7 volts. This voltage range corresponds to a temperature range of approximately 25 to 97 degrees Celsius. Voltage from the temperature sensor and the voltage divider are fed into pins 2 and 3 (respectively) of the UA741 op amp. Whenever the voltage on pin 2 (from the sensor) goes above the voltage present on pin 3, pin 6 of U4002 goes high, turning on power MOSFET Q4001 and turning on the cooling fan. I used a 5-volt fan in this application as they are readily available at very reasonable prices on the surplus market. However, if you can't find a 5-volt fan, a simple wiring change lets you substitute a 12-volt fan. A DC fan will operate during mobile or portable operation—a feature that wasn't possible with the stock FA-7.

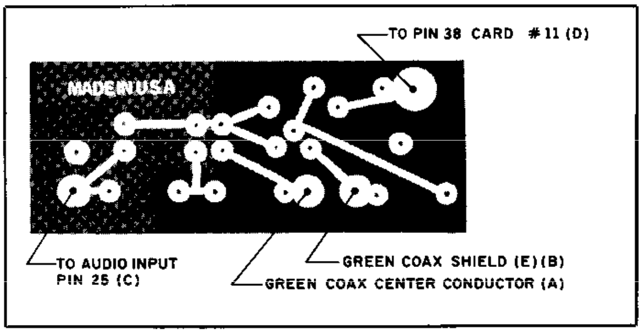

Figure 7. Audio filter foil layout.

Construction notes

Before you start, choose the modifications you wish to make. *Each of the modifications are independent, so I highly recommend that you put them in and test them one at a time.*

I've made every effort to be as thorough as possible in my construction and installation procedures, but I couldn't cover every aspect of this project. Be careful, take your time, and remember that you install these modifications at your own risk.

If you decide to make any of the modifications described here, you must construct the appropriate circuit boards shown in **Figures 5, 6, 7,** and **8**, and **Photos A, B, C,** and **D**. You may use the printed circuit board artwork from this article, or create

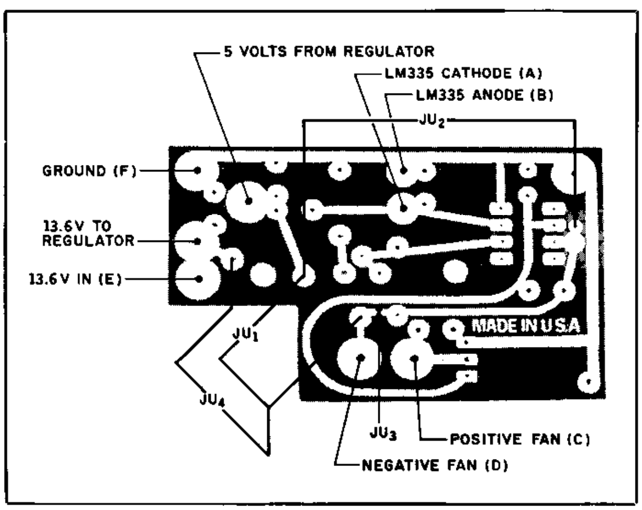

Figure 8. Fan control foil layout.

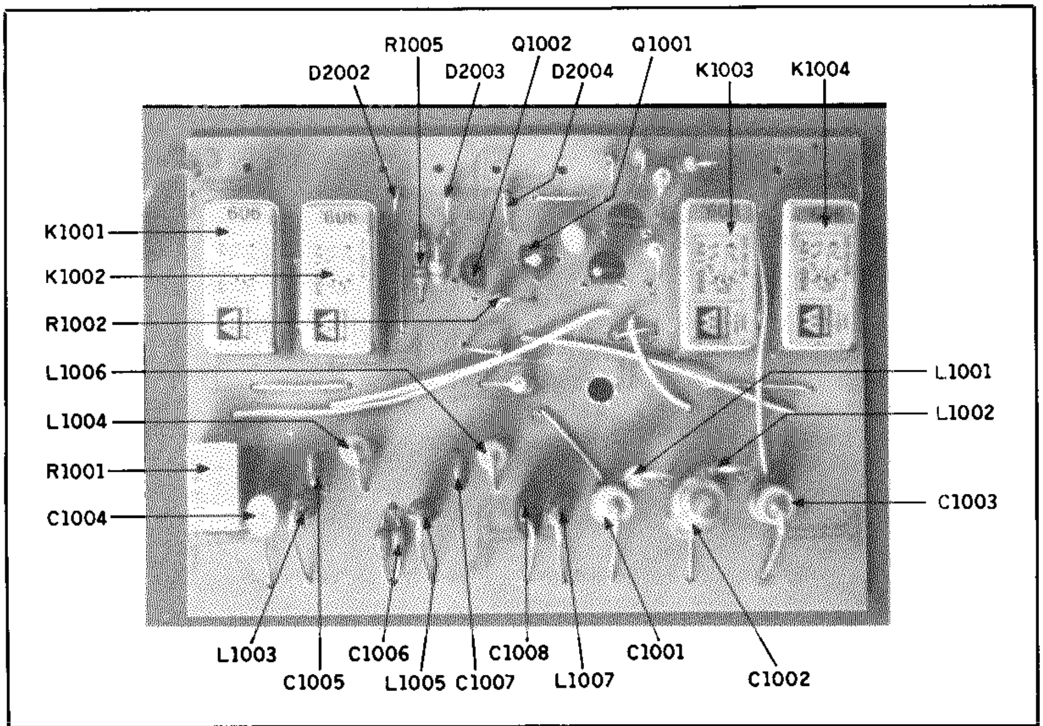

Photo A. Front-end card layout.

your own. I made all of my boards using the direct-etch method. If you decide to use this method as well, try to place all components exactly as they are shown on the artwork. Space is tight in the TR-7, so the board sizes and layouts are rather critical. This is especially true for the front-end and QSK cards, because the bandswitch passes over the center of each. If you must make parts substitutions, do so with some care; poor performance, inadequate space, or damage to the radio may result.

Make sure that your ground for the receiver coax duplicates the grounds shown in **Photos** E and F. It's important to keep the RF ground separate from the control ground on the QSK card. Ground the board to the chassis only to the two points mentioned in the text. Because of the power levels involved, ground loops may cause parasitic oscillations and/or receiver damage if you don't heed this advice. If you design your own QSK card layout, I strongly recommend that you test the circuit with a spectrum analyzer.

Don't attempt to use a higher permeability core with fewer turns for L2003 and L2004. At the power levels present in the TR-7, a higher permeability core may get so hot that the PA will shut down due to a high VSWR condition.

Finally, don't forget the heat sink for D2005. I used a 3/16-inch hex, 3/8-inch long, 4-40 standoff to secure the mounting stud for D2005. When mounted on this stud, the specified heat sink is sufficient to permit key-down operation at full output power for a minimum of ten minutes at a time. RFC L2003 is secured to the circuit board with a small wire tie through the board, and L2004 is secured to the ground strap for the LPF in the right rear corner of the LPF compartment (as viewed from the rear).

In order to have receive coverage below 1.5 MHz, you must have the DR-7 digital display and the AUX-7 card with the low-frequency PROM installed in your TR-7. If you don't have the AUX-7, or your AUX-7 doesn't have the low-frequency PROM, you must install the programming diodes described in the Drake service bulletin "RTM/RRM7 Replacement." These diodes are simple to install, and can be used to add low-frequency coverage to any TR-7, whether it has the AUX-7 or not. The RTM/RRM7 bulletin is available by sending an SASE with a note requesting the same to:

R.L. Drake Company
P.O. Box 3006
Miamisburg, Ohio 45342
Attn: Bill Frost

Install the diode modification as de-

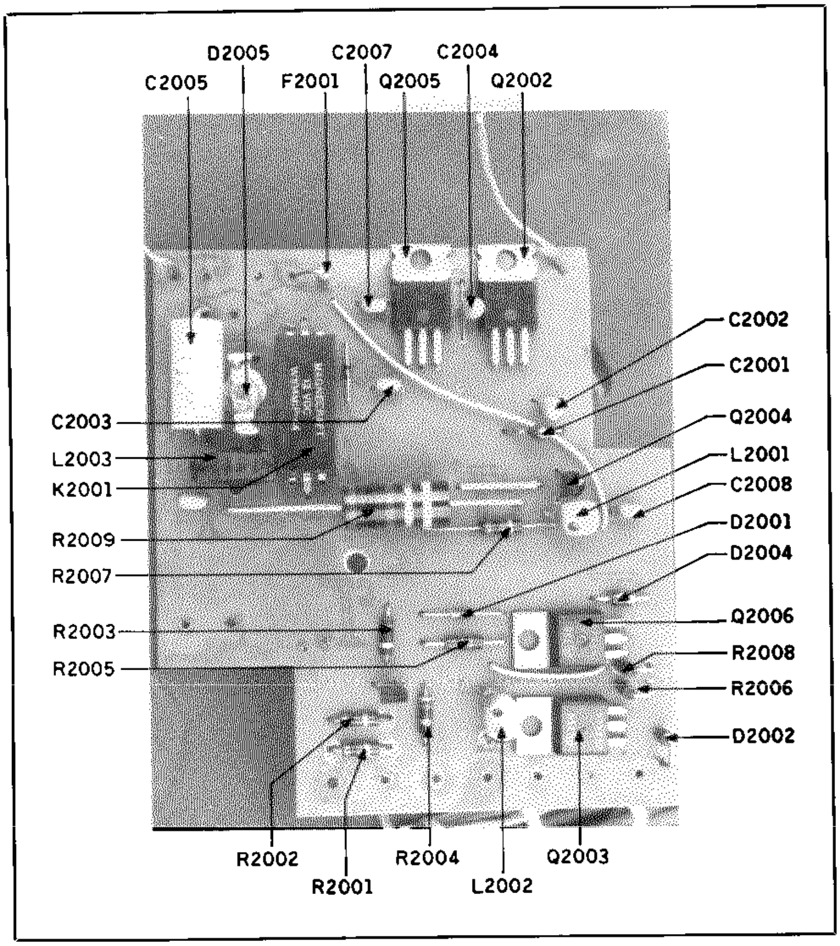

Photo B. QSK card layout.

scribed by Drake and test its operation according to their procedure. You are now ready to install the front-end card.

Installing the new front-end card

Begin by disconnecting the violet coaxial cable from the front low-pass filter switch card (Drake assembly #1400).[8] This coax is in the upper right-hand corner of the 1400 card as viewed from the front. Pull the coax up and out of the way; you'll need it for the new front-end card. Next, cut five, 12-inch long pieces of hookup wire of the following colors: red, black, yellow, blue, and white. Refer to **Figure 1**, and connect the five wires as follows:

1) Solder the red wire to point A.
2) Solder the black wire to point B.
3) Solder the yellow wire to point C.
4) Solder the blue wire to point D.
5) Solder the white wire to point E.
6) Solder one end of a 0.05-μF/100-volt mylar capacitor to point F.

The front-end card mounts inside the TR-7 high-pass filter assembly (see **Photo F**). To install the front-end card, remove the bandswitch knob, then remove the two screws holding the bandswitch detent unit onto the back of the radio. Mark the top side of the detent unit so you'll know how to reassemble the switch. With the detent loose, carefully pull the bandswitch rod out of the radio. Set it aside, along with its hardware and knob, for later reassembly. Next, unsolder the hot and ground wire from the speaker. Remove the four flat-head screws that retain the speaker and carefully remove it from the radio.

Mount the front-end card using a single 1/4-inch hex, 1/2-inch long brass standoff with no more than 1/4 inch of 4-40 thread. Screw the standoff into the short bushing pressed into the shield between the high-pass filter assembly and the main circuit area. Using an internal-tooth lockwasher,

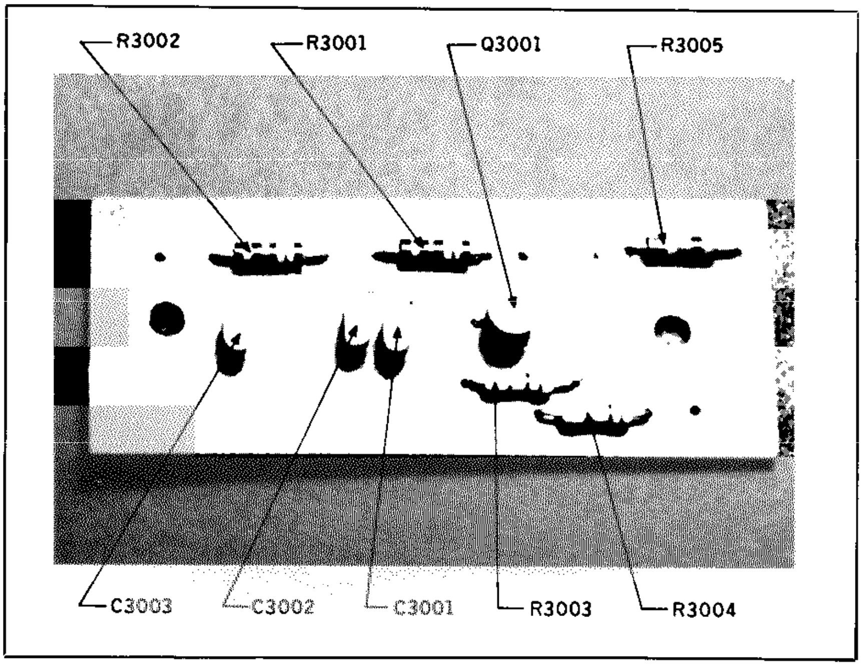

Photo C. Audio card layout.

tighten the standoff into the chassis bushing. After you have set the board in place, you can tighten the retaining screw easily using a screwdriver fed through one of the holes for the speaker grille. With the board mounted, feed the green, blue, and yellow wires between the 1400 card and the chassis. These will be connected to the appropriate points under the chassis in the next step. Leave the red A+ wire above the chassis.

Connect the violet coax that you disconnected from the 1400 card to the input of the new front-end card, with its shield to the ground foil on the 1400 card. Next, solder the free lead of the 0.05-μF capacitor on the front-end card to the junction of R1402 and R1404 on the 1400 card.[4] Solder the ground wire to the ground foil on the 1400 card, then connect the red A+ wire to the receiver A+ line on the 1500 card.[4] After you've made the A+ connection, turn the radio upside down with the front panel facing you. Connect the yellow lead to pin 1 of the AUX-7 card. This is the first card slot from the front of the radio. To find pin 1, count from the far right pin with the radio upside down and the front facing you. Connect the green wire to pin 2 and the blue wire to pin 3 of the AUX-7 card slot—again counting from the far right. Dress the wires into the existing harness with wire ties and turn the radio over.

Carefully reinstall the bandswitch rod into the TR-7. Make sure that you have the rod oriented according to the marks you made prior to its removal. *Be very careful when installing the rod to ensure that all switch wafers are lined up. Never force the rod should it become stuck during reinstallation.* Once you've inserted the rod through all wafers of the switch, reinstall the detent hardware and the bandswitch knob. Reinstall the speaker and reconnect its wires.

Finally, you may want to change the low-frequency antenna connection point on the rear panel. In its stock configuration, the low-frequency antenna was brought out on pin 7 of the ACCESSORY connector. Drake provided a spare phono connector on the rear panel that can be used for this antenna connection. Personally, I detest phono connectors, so I replaced it with a BNC connector (see **Photo G**). This is optional; if you feel that the phono jack will suffice, use it. If you prefer the BNC, you must enlarge the hole.

First, remove the four screws that hold the rear subpanel to the chassis. Gently pull this subpanel away from the radio as far as the leads will allow. If you are going to use a BNC connector, remove the unused phono jack immediately below the EXT RCVR jack. *Using extreme care, ream or drill this hole out to 3/8 inch.* Mount a BNC connector and grounding lug in this new hole. Next, using a narrow soldering iron with a small chisel tip, remove the violet coaxial cable from pin 7 of the ACCESSORY connector, and remove the shield from the

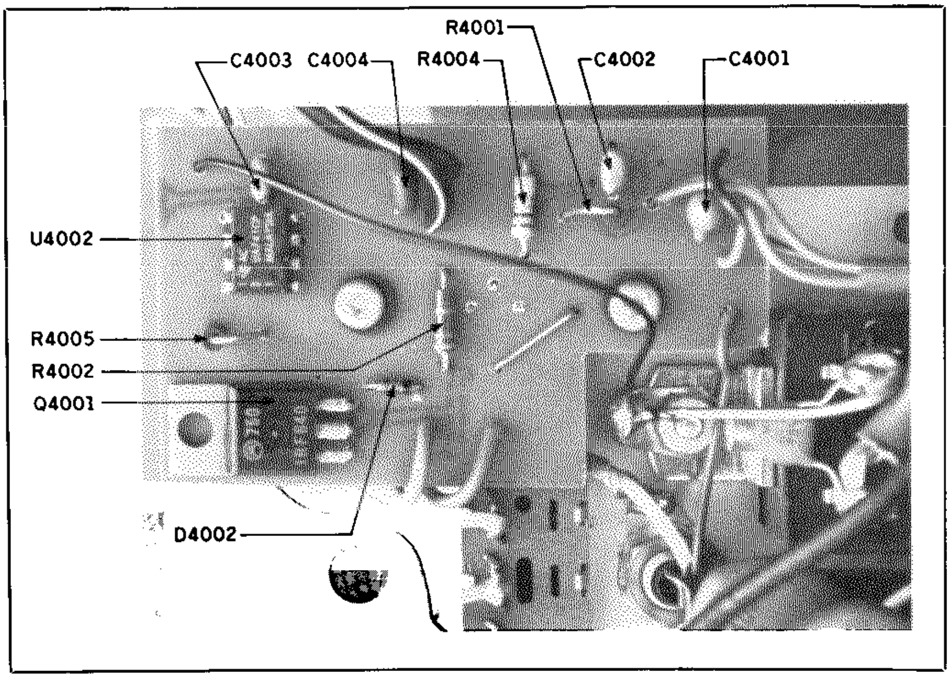

Photo D. Fan control layout.

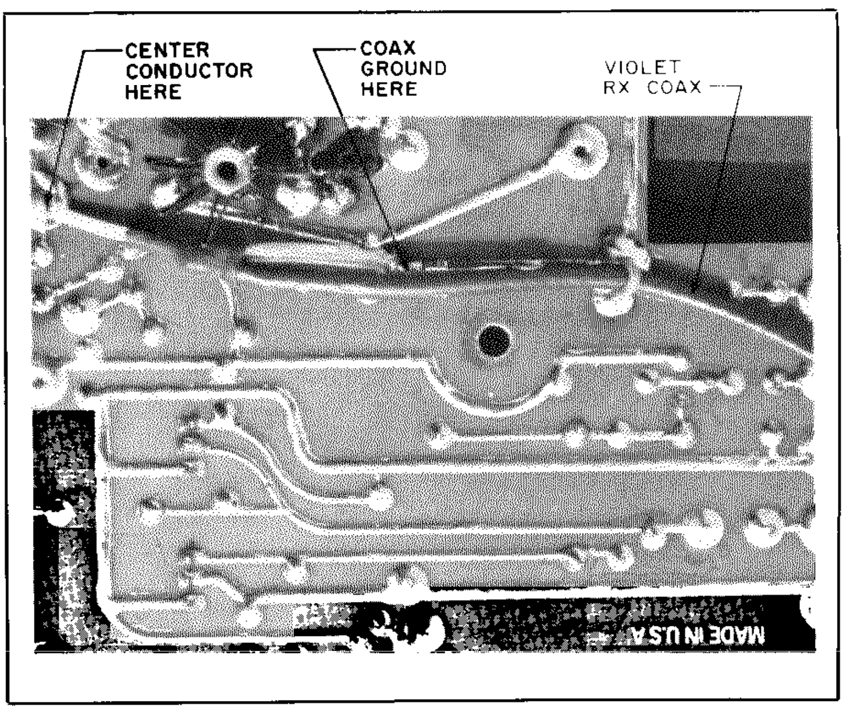

Photo E. QSK card RX coax grounding.

ground lug. Solder the center conductor of this violet coax to the center pin of the BNC connector, and solder the shield to the ground lug. Replace the subpanel, taking care not to pinch any of the wires that lead to it. The front-end card installation is now complete.

Front-end card testing

Note: Do not apply power to the set until instructed to do so, or damage may result.

Carefully inspect the wiring to the front-end card for melted insulation or loose wire strands. Turn the radio upside down and

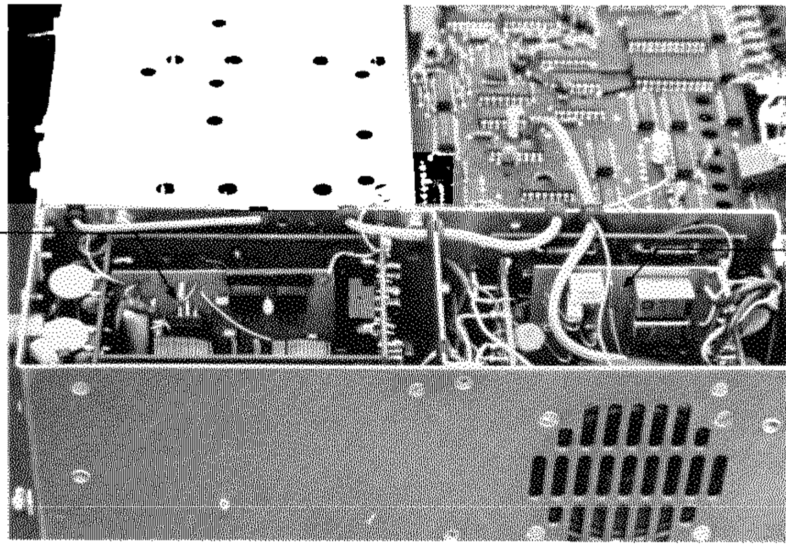

Photo F. QSK card and front-end card location.

shake out any remaining wire or drill fragments.

Preset the front-panel controls as shown in Table 1.

Connect an HF antenna to the rear-panel SO-239 connector. Then connect the power supply, and turn the radio on. The radio will power up on 7.500 MHz, and control functions should be normal. Tune around the 40-meter amateur band and make sure that HF operation of the radio is unaffected.

Place the AUX PROGRAM switch into position 1. Set the bandswitch to 1.5 MHz and set the tuning dial to 500. The display should read 1.500 MHz. Connect a low-frequency antenna to the BNC connector on the rear panel. When tuning down from 1.5 MHz, you should hear numerous broadcast signals. Next, select position 2 on the AUX PROGRAM switch. Tuning from 0.5 to 1.0 MHz, you should again hear numerous broadcast stations. Finally, select position 3 on the AUX PROGRAM switch. Relays K1002 and K1003 should now actuate, and if your antenna is efficient below 0.5 MHz, you should hear numerous aircraft beacons and similar low-frequency stations.

Control	Setting
RF GAIN	Full clockwise
AF GAIN	Full counter-clockwise
MIC GAIN	Full counter-clockwise
CARRIER	Full counter-clockwise
MODE	LSB
AUX PROGRAM	NORM
PBT	OFF
RIT	OFF
CAL	OFF
NB	OFF
PTT/VOX	PTT
REF/FWD	FWD
RCT	OFF
BAND	7 MHz
TUNING	500

Table 1. Front-panel control settings.

In the event any of the bands don't work, recheck your wiring to the AUX-7 card slot. Pins 1, 2, and 3 on the AUX-7 card slot go high whenever positions 1, 2, or 3 are selected on the AUX PROGRAM switch. Whenever any of the three low-frequency positions on the AUX PROGRAM switch are selected, relays K1001 and K1004 should be actuated. Relays K1002 and K1003 should be actuated only when the AUX PROGRAM switch is in position 3.

Operation

Operation of the front-end card is quite simple. To receive in the 10 kHz to 1.5 MHz range, simply select the appropriate 500-kHz band with the AUX PROGRAM switch. You can set the main bandswitch to any band except 21 or 28.5 MHz. The low-frequency antenna can remain connected to the set at all times, if you so desire.

QSK card installation

Installation of the QSK card is slightly more difficult than the front-end card, as it requires the removal of the low-pass filter switch board (Drake Assy #1900).

To begin the QSK card installation, turn the radio around so the back is facing you. Remove the hold-down wire on T/R relay K1901, remove it from its socket, and set it aside. Remove the bandswitch knob, and mark the top side of the bandswitch detent unit on the rear panel for reassembly later. Slowly remove the bandswitch rod from the high and low-pass filter assemblies and set it aside along with the knob and hardware.

Unsolder the three ground braids to the LPF assembly, and gently pull the front end of the LPF unit up so the wires on the 1900 card are accessible.[9] Using a soldering iron with a long, narrow tip, remove the following wires from the 1900 card *in the order listed*:

1) Grey coax at upper left of card.
2) Black coax at upper left of card.
3) Violet coax at upper left of card.
4) Pink wire with ferrite bead in upper right of card.
5) Tan wire in upper right of card.
6) Blue wire in upper right of card.
7) Red wire in upper right of card.
8) White wire in upper right of card.
9) Both orange wires in upper right of card.
10) Green wire in upper left of card.

After removing these wires, carefully pull the wire harness down through the bottom of the radio. This will bring all of the wires listed above (except 1, 4, and 5) into a position where you can connect them to the new QSK card. *Use care when performing this step; it is very easy to get one of these wires caught on the 1900 card switch wafer.* Cut the wire ties that held these wires in a bundle behind the 1900 card. Wires 4 and 5 are too short to be pulled down under the chassis. Instead, remove them from their connection points on the rear high-pass filter switch card (Drake Assy #1500) *making a note of the position of each wire.* Be careful not to lose the ferrite bead off the pink wire. Cut a 12-inch piece of both pink and tan hookup wire, and connect each to the appropriate locations on the 1500 card.[4] Make sure you don't forget to put the ferrite bead on the pink wire. Bundle these two wires together and feed them under the chassis through the LPF compartment. Carefully reinstall the LPF assembly in its compartment and resolder the three ground wires to their connection points.

The QSK card mounts on a standoff inside the low-pass filter assembly (see **Photo F**). The ideal hardware for this is a 1/4-inch hex, 3/4-inch long brass standoff with no more than 1/4 inch of 4-40 thread. Thread the standoff (along with an internal-tooth lockwasher) into the bushing pressed into the side wall of the LPF compartment.

You must solder three coaxial cables to the QSK card prior to its installation. These three cables are the ones that you disconnected earlier from the 1900 card (see **Figure 3**). Connect the center conductor of the black coax to point H on the QSK card, with the shield connected to point I. Disconnect the short grey coax from the 1900 card, this will be reconnected later. Solder the center conductor of this coax to point L and the shield to M. Finally, connect the center conductor of the violet coax to point J and the shield to point K. *Make sure the shield on the violet coax is grounded exactly as shown in* **Photo E**, *or ground loops may occur.*

The most difficult part of the QSK card installation is positioning the card and securing it to the standoff installed previously. Because there isn't any easy way to get a screwdriver into the LPF compartment, I recommend using a 4-40 bolt with a 3/16-inch hex head. You can tighten this type of bolt with a pair of long-nose pliers without too much difficulty. To install the card, carefully slide it into place, making sure you are on the proper side of the small bolts holding in the rear LPF switch wafer. Also make sure you don't damage the piston trimmer capacitor on the rear LPF card with the heat sink stud for D2005.

Install the center hold-down bolt as described above. Reinstall the bandswitch rod, taking care to align the detent unit with the mark made previously. *Never force the bandswitch rod when installing it. The switch wafers are easily damaged by excessive force.* Reinstall the detent-unit hardware and the bandswitch knob. Turn the radio upside down with the rear panel toward you, and connect the following wires to the QSK card (see **Figure 2**):

1) Connect the two orange wires to point A.
2) Connect the white wire to point B.
3) Connect the green wire to point C.

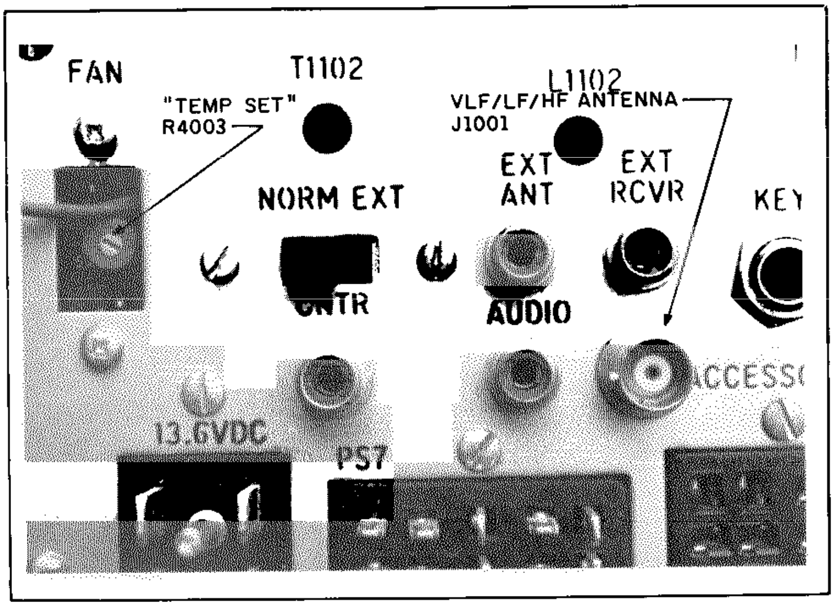

Photo G. Rear panel layout.

4) Connect the tan wire to point D.
5) Connect the pink wire to point E.
6) Connect the blue wire to point F.
7) Connect the red wire to point G.

Finally, turn the radio rightside up and attach a ground lug to the screw near L701 on the RF compartment cover. Next, run a 1/8-inch ground braid from the control ground on the QSK card to ground on the 1900 card. From this same ground point on the 1900 card, run another 1/8 inch ground braid to the solder lug just installed. Likewise, run a 1/8 inch ground braid from the QSK card RF ground to the LPF ground lug in the left rear corner of the LPF compartment (as viewed from the rear, see **Photo F**). Bundle the tan and pink wires together and dress them against the chassis. *Do not bundle the tan and pink wires with the other wiring to the QSK card or spurious emissions may result.* Bundle the orange, white, red, green and blue wires into the main chassis cable harness. Install the heat sink for diode D2005, taking care that it doesn't touch the inductors on the LPF card behind it. Finally, install a 300-uH toroidal choke from the center pin of the rear panel SO-239 antenna connector to ground.

To finish up the QSK modification, you need to change the value of resistor R310 on the Transmit Exciter board to speed up the minimum transmit-receive switching time and add an RF bypass capacitor to the ALC card. To change R310, remove the DR-7 digital display board (refer to the Drake service manual for specifics).[10] Then remove the shield from the VCO compartment (this is necessary to prevent damage to C307). Remove the Transmit Exciter card (the second card forward from the front of the VCO cage) and locate R310 (see **Photo H**).[11] Replace the original 47-k, 1/4-watt resistor with a 22-k, 1/4-watt device. Reinstall the Transmit Exciter card, taking care to line up the pins correctly. Then reinstall the VCO shield and the DR-7. Turn the radio over and remove the rear screw from the ALC (1600) card. Install a ground lug under this screw and solder the negative lead of a 0.1 uF, 35 volt tantalum capacitor to this lug. Solder the positive lead of this capacitor to the lug on the ALC card where the white and violet wires meet (+10 volts transmit). This completes the installation of the QSK card.

QSK card testing

Note: Do not apply power to the set until instructed to do so, or damage may result.

Carefully inspect the wiring to the QSK card for melted insulation or stray wire strands. Turn the radio upside down and shake loose any wire fragments. Once you've done this, preset the controls according to the settings in **Table 1**. Connect the power supply and a 50-ohm, 150-watt dummy load to the radio. Turn on the set, and ensure that the operation of the unit appears normal. The frequency display should show 7.500 MHz, and the unit should be in the receive mode. *Turn the radio off im-*

mediately if there are any unusual indications at this point.

Connect a key to the key jack on the rear panel. Place the MODE switch in the CW position. Connect a voltmeter to the tan wire on the 1500 card. You should measure about 13 volts during receive. Move the voltmeter to the pink wire on the 1500 card and depress the key; you should see about 13 volts during transmit. If either of these two voltages are very low or missing, refer to "QSK card troubleshooting" at the end of this section.

If all tests look good up to this point, hold down the key and slowly turn the CARRIER control clockwise until the internal wattmeter indicates 50 watts output power. Make sure the neon surge protector on the rear panel (above an RF choke near the key jack) is not illuminated. With the CW DELAY control fully counter-clockwise, release the key. The radio should revert to receive instantaneously. Turn the CW DELAY to mid-position, and briefly depress the key. The radio should switch into transmit, hang in this mode for a second, and switch back. If an external wattmeter is available, connect it between the TR-7 and the dummy load. With 50 watts output showing on the front-panel meter, you should read about 50 watts into the dummy load. Advance the CARRIER control until the front panel wattmeter reads 150 watts and the ALC light is on. Hold the radio keyed for two minutes. With the radio unkeyed, check for overheating of any of the components on the QSK card.

If all is well up to this point, you are ready to check the operation of the second set of MOSFET switches. Connect an ohmmeter from pin 11 on the ACCESSORY connector to chassis ground. With the TR-7 in the receive mode you should see a short; in transmit the circuit should be open. Move the ohmmeter from pin 11 of the ACCESSORY jack to pin 9 of the PS-7 jack. Here you should see an open circuit during receive and a short to ground during transmit. If the radio passes all of the tests listed above, the QSK card is working properly.

Operation

To use the TR-7 in the QSK mode, simply turn the CW DELAY control fully counterclockwise. If you wish to operate semi break-in, advance the CW DELAY control clockwise until you achieve the most comfortable "hang time" from transmit to receive. When using the TR-7 into an antenna of unknown impedance, always reduce out-

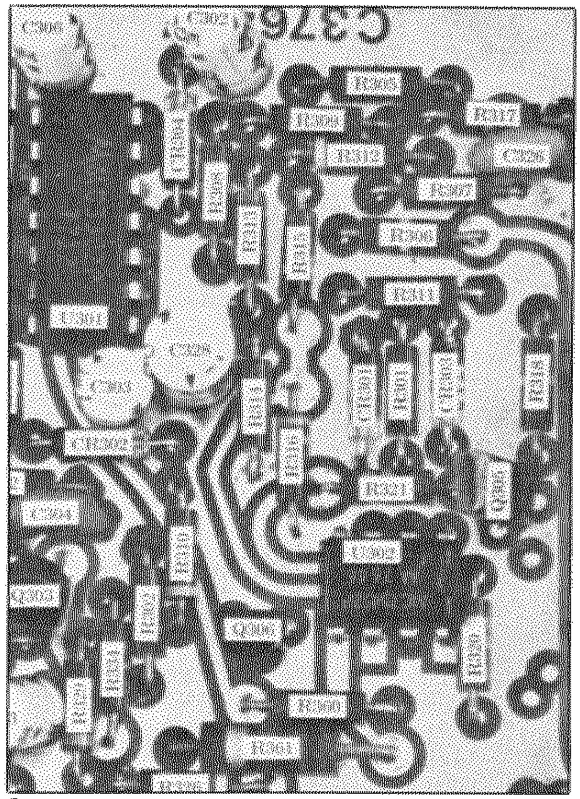

Photo H. Transmit Exciter board.

put power with the CARRIER control. The PIN diode and PA were designed to handle high VSWR conditions, but it's always best to reduce the stress on these components. As a final note, the PIN diode circuitry and heat sink were designed for continuous key-down operation, like RTTY. If you operate in these 100 percent duty-cycle modes, you must have a low VSWR to the radio and a cooling fan for the PA.

QSK card troubleshooting

If the QSK card doesn't function properly, check the status of the PA Inhibit line. If it's low, all transmit functions will be inhibited. A PA Inhibit signal is generated when the synthesizer becomes unlocked or the external VFO (if used) is in the SPOT mode. If the status of the PA Inhibit line is correct, recheck all wiring, making sure that the tan and pink wires aren't reversed. Also check transistors Q2002 and 2005 to ensure that they are neither shorted nor open.

Audio filter installation

The audio filter card is very simple to install. It mounts with two 1/2-inch long,

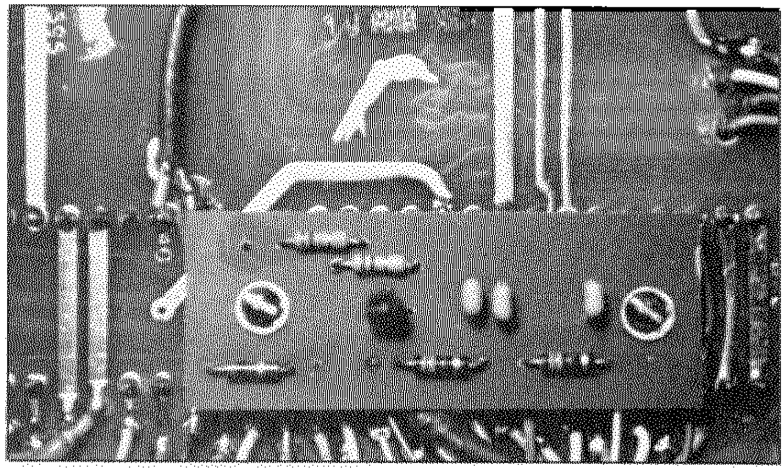

Photo I. Mounting the audio filter card.

4-40 bolts and two 1/4-long nylon standards (see **Photo I**). To install the card, turn the radio upside down with the rear panel facing you. Remove the two 4-40 screws in the right rear corner of the parent board. These screws are near pins 24 and 36 on the second IF/Audio board (card #11) at the extreme rear of the TR-7. Unsolder the green shielded cable from pin 29 of card 11, and unsolder the shield from ground. Cut two short pieces (approximately 2.5 inches) of red, black, and white hookup wire and solder them as follows (see **Figure 2**):

1) White wire to point C.
2) Red wire to point D.
3) Black wire to point E.

With this completed, you're ready to wire the audio filter card. Follow these steps:

1) Solder the white wire to pin 29 of card 11.
2) Solder the black wire to the ground adjacent to pin 29.
3) Solder the red wire to pin 38 of card 11.
4) Solder the center conductor of the green audio cable to point A on the audio filter card.
5) Solder the shield from the green audio cable to point B on the audio filter card.

The audio filter card installation is now complete.

Audio filter card testing

It's simple to test the audio filter card. Turn the TR-7 on and select LSB on the MODE switch. Check the voltage on the collector of Q3001; it should read approximately 0.95 volts. Select the CW position on the MODE switch; the collector voltage should drop to 0.05 volts. Select a narrow CW filter and advance the AF GAIN control. Listen to the noise in the speaker when in the CW position versus LSB. If all is working properly, you'll notice a substantial reduction in high frequency "hiss" when in the CW mode.

If the card fails to function properly, check all wiring, and make sure you didn't short the center conductor of the audio cable to the shield. Also make sure you didn't miscount the pins on the second IF/Audio card.

Fan control card installation

The fan control card is very easy to install. It fits in place of the 117 volt AC plug on the rear apron of the TR-7. To install it, turn the radio around so the rear panel is facing you. *With the power supply disconnected,* remove the four 4-40 bolts holding the center panel of the rear apron to the main chassis. *Carefully* fold the center panel down so it's almost horizontal. Remove the two 4-40 bolts holding the fan power plug to the panel. Cut the wires from this plug at the PS-7 control connector. Remove the fan plug; it is no longer needed.

Next, remove the second IF/Audio card from the radio. Remove the FA-7 fan. Mount a 7805 regulator IC to the chassis wall behind the PA. There's a hole immediately below the two coaxial-cable cutouts along the top of this wall that's in the perfect location for this IC (see **Photo J**). Make sure you apply a thin coating of silicon grease to the back of the 7805 prior to mounting it. The temperature sensor IC mounts within the center of the PA heat sink. I soldered the LM335 to the end of a short piece of #18 speaker "zip-cord." I in-

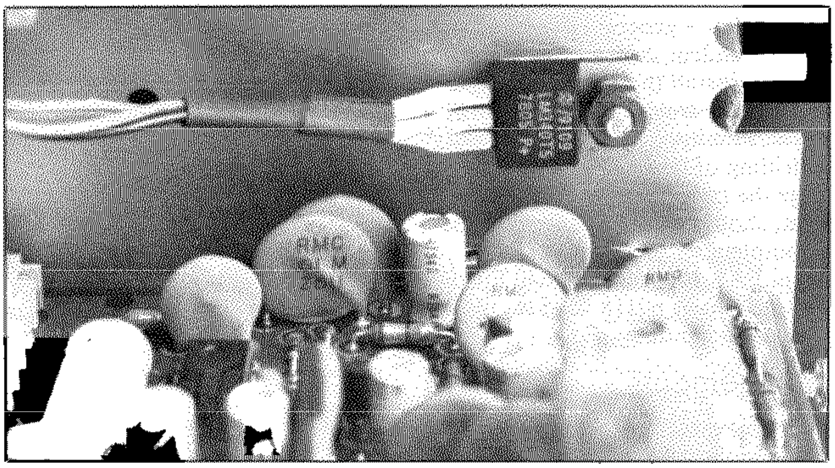

Photo J. 7805 mounting location.

sulated the connections with heat shrink and placed the IC in the center of the heat sink. It isn't necessary to mount this sensor; the temperature rise of the air in the heat sink is quite sufficient. Thread the sensor wires through an appropriately sized grommet and insert this grommet into the unused cutout above the 7805 regulator. Install the new 3-inch, 5-volts DC fan in place of the FA-7. *These fans can be very dangerous; its very easy to accidently get a finger caught in the blades. I strongly recommend the addition of a fan guard.* Thread the wires from the fan through the rectangular fan plug cutout. You are now ready to wire the control card.

Begin wiring by connecting the temperature sensor IC to the card (see **Figure 4**). Solder the lead from the cathode of the LM335 to point A and the anode of the LM335 to point B. Next, solder the positive fan lead to point C and the negative fan lead to point D. Finally, cut an 8-inch piece of red hookup wire, and connect it to point E, and a 3-inch piece of black hookup wire to point F.

Mount the fan control card to the center rear panel using two 3/16-inch hex, 3/8-inch long 4-40 standoffs. These standoffs supply sufficient clearance to mount the circuit board in place of the fan plug. When the card is in place, the fan temperature control will be in the center of the rectangular fan plug cutout (see **Photo G**). After mounting the card, solder the black wire to the ground connection for the four-pin connector, and solder the red wire to pin 9 of the ACCESSORY connector. Carefully replace the center panel and reinstall the four bolts that secure it to the chassis. Installation of the fan control card is now complete.

Testing the fan control card

Before applying power to the TR-7, turn the Temp. Set pot R4003 fully clockwise. This prevents the fan from coming on unless the ambient temperature at the sensor is above 97 degrees Celsius. Turn on the TR-7, and measure the voltage to pin 7 of U4002. This voltage should be 5.0 volts. Next, measure the voltage at pin 2 of U4002. The voltage at this point will vary with temperature, however it should be approximately 3 volts at 25 degrees Celsius. If all checks out up to this point, slowly rotate R4003 (Temp. Set) counterclockwise. If the ambient temperature is above 25 degrees Celsius, the fan will come on at some point in the rotation of this control. To set the pot to correspond to a specific temperature, calculate the LM335 voltage using the following formula:

$V = 10(273.18 + T)$, where T = Temperature in degrees Celsius and V = Voltage in millivolts.

For example, it you wanted the fan to come on at 50 degrees Celsuis, $V = 10(273.18 + 50)$ $V = 3230$ millivolts. R4003 would then be adjusted so pin 3 of U4002 measures 3.23 volts.

In the event the circuit doesn't work, check the voltage from R4003 to make sure it's within the ambient temperature range of the sensor D4001. In this circuit, whenever the voltage on pin 2 of U4002 goes above the voltage on pin 3, pin 6 of U4002 should go high.

Conclusion

These modifications make the TR-7 an excellent performer, both as a "CWbuff's" radio and as a general-coverage receiver. The independent design of the modifications lets you install them as you see fit. Wherever possible, I tried to use readily available parts. Finally, my design doesn't require the drilling of any holes—allowing you to change the radio back to its stock configuration, should this be required in the future. (A complete set of pc boards is available from FAR Circuits, 18N640 Field Court, Dundee, Illinois 60118 for $16, plus $3.50 shipping and handling. Ed.)

Acknowledgements

I would like to express my sincere appreciation to the people at M/A-COM for their help in the design of the PIN diode portion of the QSK card. I would also like to thank Bill Frost with the R.L. Drake Company for his assistance with documentation.

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5. International Rectifier, *Semiconductor Handbook*, 1981/82, pages A-8 through A-18.
6. M/A-COM (Gerald Hiller), *Design with PIN Diodes*, pages 1-18.
7. National Semiconductor, *Linear Data Handbook #2*, 1988, pages 6-21 through 6-23.
8. R.L. Drake Co., *TR-7 Service Manual*, 1980, page 2-89.
9. R.L. Drake Co., *TR-7 Service Manual*, 1980, page 2-102.
10. R.L. Drake Co., *TR-7 Service Manual*, 1980, pages 4-4 and 4-5.
11, R.L. Drake Co., *TR-7 Service Manual*, 1980, page 2-18.

Front-End Card Parts List

Part	Manufacturer	Description
C1001, 1003	(1)	12000 pF, 100 volts DC polyester capacitor
C1002	(1)	18000 pF, 100 volts DC polyester capacitor
C1004, 1008	(1)	4700 pF, 100 volts DC polyester capacitor
C1005, 1007	(1)	3900 pF, 100 volts DC polyester capacitor
C1006	(1)	7800 pF, 100 volts DC polyester capacitor
C1009	(1)	0.05 μF, 100 volts DC mylar capacitor
C1010	(1)	0.22 μF, 25 volts DC tantalum
D1001-D1006	(2)	1N4841 switching diode
K1001-K1004	(3)	subminature SPDT relay (Aromat RSD-12)
L1001, 1002	(5)	22 μH inductor
L1003, 1007	(5)	6.8 μH inductor
L1004, 1006	(5)	10 μH inductor
L1005	(5)	4.7 μH inductor
Q1001, 1004	(2)	2N3906 transistor
Q1002, 1003	(2)	2N3904 transistor
R1001	(6)	1 k potentiometer (Bourns 3386S-1-102)
R1002, 1004		
R1005, 1006		
R1007, 1009	(4)	10 k, 1/4 watt carbon-film resistor
R1003, 1008	(4)	4.7 k, 1/4 watt carbon-film resistor

QSK Card Parts List

Part	Manufacturer	Description
C2001	(1)	1.0 μF, 25 volts DC tantalum capacitor
C2002, 2004	(1)	0.22 μF, 25 volts DC tantalum capacitor
C2003, 2006		
C2007, 2008	(1)	0.1 μF, 100 volts DC monolithic capacitor
C2005	(1)	0.1 μF, 630 volts DC mylar capacitor
D2001, 2003	(2)	1N4148 switching diode
D2002, 2004	(2)	1N4752 33 volt, 1 watt zener diode
D2005	(7)	High-power PIN diode; M/A-COM MA4P4002D
F2001	(8)	1/4 A subminiature fuse
K2001	(9)	SPDT reed relay; Magnecraft W104MIP-42
L2001,2002	(5)	270 μH inductor
L2003, 2004	(10)	300 μH toroid; 70 turns #30 on Amidon T-50-61 core

Part	Manufacturer	Description
Q2001	(2)	2N3904 transistor
Q2002, 2005	(11)	IRF-9531 P-channel power MOSFET
Q2003, 2006	(2)	IRF-640 N-channel power MOSFET
Q2004	(2)	2N3906 transistor
R2001, 2002		
R2003, 2006		
R2008	(4)	1 k, 1/4 watt carbon-film resistor
R2004	(4)	4.7 k, 1/4 watt carbon-film resistor
R2005	(4)	22 k, 1/4 watt carbon-film resistor
R2007	(4)	10 k, 1/4 watt carbon-film resistor
R2009	(4)	100 ohm, 2 watt carbon resistor
Miscellaneous	(14)	heat sink, EG&G Wakefield 201CB

Audio Filter Parts List

Part	Manufacturer	Description
C3001, 3002		
C3003	(1)	0.1 μF, 100 volts DC monolithic capacitor
Q3001	(2)	2N3904 transistor
R3001, 3002	(4)	330 ohm, 1/4 watt carbon-film resistor
R3003, 3004	(4)	10 k, 1/4 watt carbon-film resistor
R3005	(4)	1 k, 1/4 watt carbon-film resistor

Fan Control Parts List

Part	Manufacturer	Description
C4001	(1)	1.0 μF, 25 volts DC tantalum capacitor
C4002, 4003	(1)	0.1 μF, 100 volts DC monolithic capacitor
C4004	(1)	0.001 μF, 100 volts DC disk ceramic capacitor
D4001	(12)	LM335 temperature-sensitive zener diode
D4002	(2)	1N4148 switching diode
FA4001	(13)	3 inch, 5 volts DC fan (Papst 8105G, see text)
Q4001	(2)	IRF-640 power MOSFET
R4001, 4005	(4)	1 k, 1/4 watt carbon-film resistor
R4002	(4)	6.8 k, 1/4 watt carbon-film resistor
R4003	(6)	10 k, 5 turn potentiometer (Bourns 3339P-1-103)
R4004	(4)	10 k, 1/4 watt carbon-film resistor
U4001	(12)	7805 regulator IC
U4002	(15)	UA741 operational amplifier IC

Manufacturers Listing

(1) Mallory Capacitor Co., P.O. Box 1284, Indianapolis, Indiana 46206.
(2) Motorola Inc., Semiconductor Products Sector, 3102 N. 56th Street, Phoenix, Arizona 85018.
(3) Aromat Corp., 629 Central Avenue, New Providence, New Jersey 07974
(4) Allen-Bradley Co. Inc., 1201 S. 2 Street, Milwaukee, Wisconsin 53204
(5) Sprague-Goodman Electronics Inc., 134 Fulton Avenue, Garden City Park, New York 11040
(6) Bourns, 1200 Columbia Avenue, Riverside, California 92507
(7) M/A-COM Inc., 43 South Avenue, Burlington, Massachusetts 01803
(8) Littlefuse-Tracor, 800 E. Northwest Highway, Des Plaines, Illinois 60016
(9) Magnecraft Electric Co., 1910 Techny Road, Northbrook, Illinois 60062-5376
(10) Amidon Associates, P.O. Box 956, Torrance, California 90508.
(11) International Rectifier, 348 Kansas Street, El Segundo, California 90245.
(12) National Semiconductor, 333 Western Avenue South, Portland, Maine 04016
(13) Pabst/Pamotor.
(14) EG&G Wakefield, 60 Audubon Road, Wakefield, Massachusetts 01880
(15) Fairchild Semiconductors; see National Semiconductor.

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