better frequency stability for the Drake TR7

Adding a circuit board improves performance without affecting appearance

Although the TR7 has a rather stable VFO, it can still be improved. With this modification, its stability becomes comparable to that of synthesized frequency generators; consequently, it becomes more useful in the following ways:

- If you're operating on AMTOR, retuning is not necessary.
- Your operating frequency is stable within a second or so after switch-on, even in a cold shack.
- The frequency setting remains stable for an indefinite length of time, making the rig usable for remotely controlled installations such as AMTOR repeaters.

Improved frequency stability is achieved by means of a Digital Automatic Frequency Control (DAFC) circuit. A frequency counter with a crystal-controlled reference measures the frequency to be stabilized. If the count is above or below a defined fixed value, a dc voltage controlling a varicap within the VFO is altered so as to counteract any frequency deviation. The divider ratios used in this design produce a series of stable frequencies which are separated from each other by 30.5 Hz. Actually, the frequency slowly varies about the *nearest* 30.5-Hz point. This is because the output is either too low or too high, but never exactly on. That's why the control voltage continues to hunt.

These fluctuations are generally not noticed when operating in CW, SSB, AMTOR, or RTTY. If you connect a frequency counter, you can see that the VFO frequency excursions amount to not more than ± 10 Hz. PA0KSB has designed a circuit that can be incorporated into existing VFOs; he describes the theory behind this kind of frequency control in detail in reference 1.

The present circuit provides VFO frequency control by applying the correcting voltage to the RIT-line. This also enables a possibly connected external VFO to be frequency controlled when switched on.

The reference frequency used is the TR7's 500-kHz signal drived from the 40-MHz main crystal reference, thereby eliminating the need for a separate crystal oscillator. PA0KSB's circuit uses a pointer instrument to indicate the tuning voltage and an UP/DOWN switch for manual control of this voltage.

I wanted to find a way to avoid drilling holes into the front panel of the transceiver for additional switches and a meter. The TR7 already has UP/DOWN keys; when you depress the STORE key, the UP/DOWN keys are assigned to the DAFC circuit for as long as the STORE key is held down. The rest of the time the UP/DOWN keys perform their usual functions. This means that the initial function of the STORE key can no longer be used — a sacrifice which is more than justified by the advantages of the DAFC circuit. But I couldn't find a way to have the S-meter indicate the DAFC control voltage; instead I adopted an idea proposed by K6EHV.[2] Two lamps indicating the upper and the lower limit of the control voltage are sufficient to display this information. The FIXED lamp (the *upper* one) indicates that the control voltage has exceeded its upper limit. The SET BAND lamp (the *lower* one) shows that the control voltage has gone below its lower limit. Besides being DAFC indicators, both lamps still serve their traditional purpose; in normal operation the control voltage does not reach either limit, so the double use of the lamps presents no problem.

circuit description

The circuit for this modification is shown in fig. 1.

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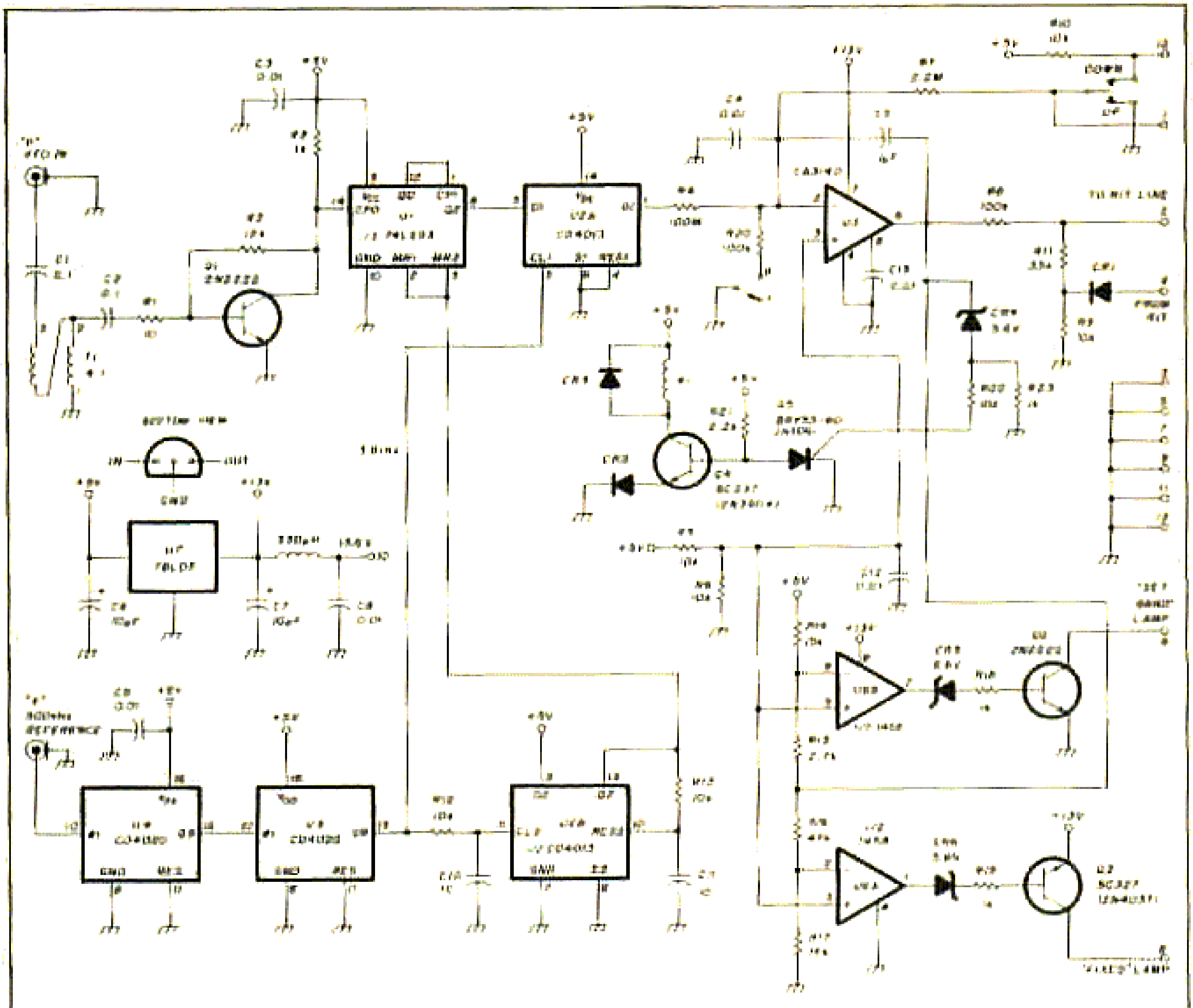


fig. 1 TR7 frequency correction schematic diagram.

The VFO signal enters the DAFC circuit at terminal P. A broadband autotransformer, T1, steps down the signal to match it to the low impedance input of Q1, where it is amplified to TTL level to enable it to drive the frequency counter chip U1. U1 divides the VFO frequency by 8. After each counting period, the count (1 bit) is stored in U2A and the counter is reset to zero. The binary counters U4 and U5 divide the 500-kHz reference by 2^{17}, thus establishing the counting period of 262 ms. A short time (determined by R12, C10) after the rising edge of the counter clock, U2B generates the reset pulse for the counter. The reset pulse width is given by R13, C11. The integrator U3 transforms the 1-bit count result into a slowly rising and falling dc voltage which is used to control the VFO frequency. The integrator time constant is established by R4 and C5. This control voltage and the former RIT voltage entering the circuit at terminal 4 are combined via R8 and R11. The resulting dc voltage is put onto the RIT line at terminal 2 for the VFO in use (internal or external). CR1 and R9 reduce the original RIT voltage so that the combined voltage looks like the former RIT voltage when RIT and DAFC voltages are at mid-range. The integrator output voltage, and with it the VFO frequency, can be raised or lowered manually by applying either +5 volts or 0 volts via R7 to the integrator input.

The circuit associated with thyristor Q5 ensures that the integrator output voltage starts at mid-range at power-up. After switch-on, Q4 conducts, thereby pulling the integrator input down via R20 and the relay contact to ground. U3's output voltage rises at a rate determined by R20 and C5. As soon as it reaches approximately 6 volts, SCR Q5 fires and cuts off the relay driver Q4, which releases the integrator input by floating R20. This mechanism is not repeatable because Q5 remains on (i.e., conducting) via R21 until the power is turned off.

The two op amps of U6 are used as comparators. The upper comparator drives Q2 into saturation when the integrator output voltage drops below the lower limit of about 2 volts. Q2 turns on the SET BAND lamp. The lower op amp drives Q3 and with it the FIXED lamp when the output voltage rises above the upper limit of about 10.5 volts.

construction

Component layout is not critical. I have built several versions of this circuit mostly using Veroboard. Follow sound rf construction techniques in the area of T1, Q1, and U1: provide a low impedance common ground, keep leads short, and pay attention to shielding. The components used are easy to obtain and low in cost. Impedance transformer T1 is wound on a ferrite toroid core (Philips Part No. 4322 020 97170) with an OD of approximately 0.37 inch and an ID of approximately 0.22 inch. There is no reason why other suitable types — for example, an Amidon FT37-63 or FT37-67 — could not be used.

The winding consists of ten turns of a twisted transmission line you can make yourself. Stretch out a 23.6-inch length of enameled copper wire with a diameter of about 0.016 inch (AWG 26) to smooth out any bends, then cut it in half. Using a hand drill, twist the two pieces to obtain about five turns per inch. Wind ten turns of this transmission line on the toroidal core, taking care that the windings are equally spaced on the circumference. Then connect one end of one wire with the opposite end of the other wire. This connection is the low impedance port (2) of the transformer. The other two ends form the high impedance input (3) and the ground end (1), respectively. They may be interchanged without any effect because the transformer is symmetrical.

The relay may be replaced by a 12-volt type, in which case it has to be connected to the 13.6-volt bus. The capacitor at C5 should be a polystyrene or similar type. Electrolytic or tantalum capacitors would exhibit too much leakage at this point of extremely high resistance. To keep the height of the pc board low, we used three 0.33-μF capacitors instead of one 1-μF capacitor. The voltage divider chain for the comparators (R14, R15, R16, R17) should be selected to be within 2 percent of nominal value to define the range limits of the control voltage accurately.

initial tests

The completed circuit board should be tested before it's incorporated into the transceiver. The following hints assume that there are no leads and signals connected, except for the 13.6-volt supply and those mentioned. When removing and replacing ICs, be sure to disconnect the power supply first.

power supply

Remove all ICs except regulator U7. Verify that there is + 5 volts at the regulator output. Check whether there is 2.5 volts at pins 3 and 5 of U6. The current drain from the 13.6-volt supply should be around 10 mA. Insert all ICs. The current drain should now be around 30 mA.

integrator

Remove U2. After power is connected, the relay should actuate momentarily and drop out immediately. The output voltage at pin 6 of U3 should be in the vicinity of 6 volts. Connect terminal No. 1 of the board to ground (corresponding to a depressed UP switch). The output voltage of U3 should rise within a few seconds to 11 volts. Connect terminal 1 with terminal 12, (corresponding to a closed DOWN circuit). The output voltage of U3 should decrease within a few seconds to about 0.1 volts.

comparators

The following maneuvers are performed by manipulating the UP and DOWN contacts as described above. Lower the integrator output voltage, starting from 6 volts. When the 2-volt level is crossed, output pin 7 of U6 should jump from 2 volts to about 12 volts.

Raise the integrator output voltage, starting from 6 volts. When the 10.5-volt level is crossed, output pin 1 of U6 should jump from 12 volts to about 2 volts.

time base

Remove U2. Apply the 500-kHz signal to terminal X. (You may use either the 500-kHz signal from the TR7 or a signal from another source. In any case, it should be a square wave of 4 to 5 V_{pp}.) At pin 13 of U5 there should be a square wave of 3.81 Hz.

frequency counter

Remove U2, grounding pins 2 and 3 of U1. Connect the VFO signal (from the main board of the TR7) to terminal P. At pin 8 of U1, you should now detect a square wave measuring one-eighth of the VFO frequency. You can verify this by connecting the DAFC terminal P to the VFO line of the main board; doing this should cause just a minor drop of the VFO (PTO) voltage in the TR7.

installation

The DAFC circuit board is mounted to the lower side of the main board as shown in **fig. 2**. Insert a sheet of flexible pressure-resistant insulating material between the two soldered sides. The circuit board and

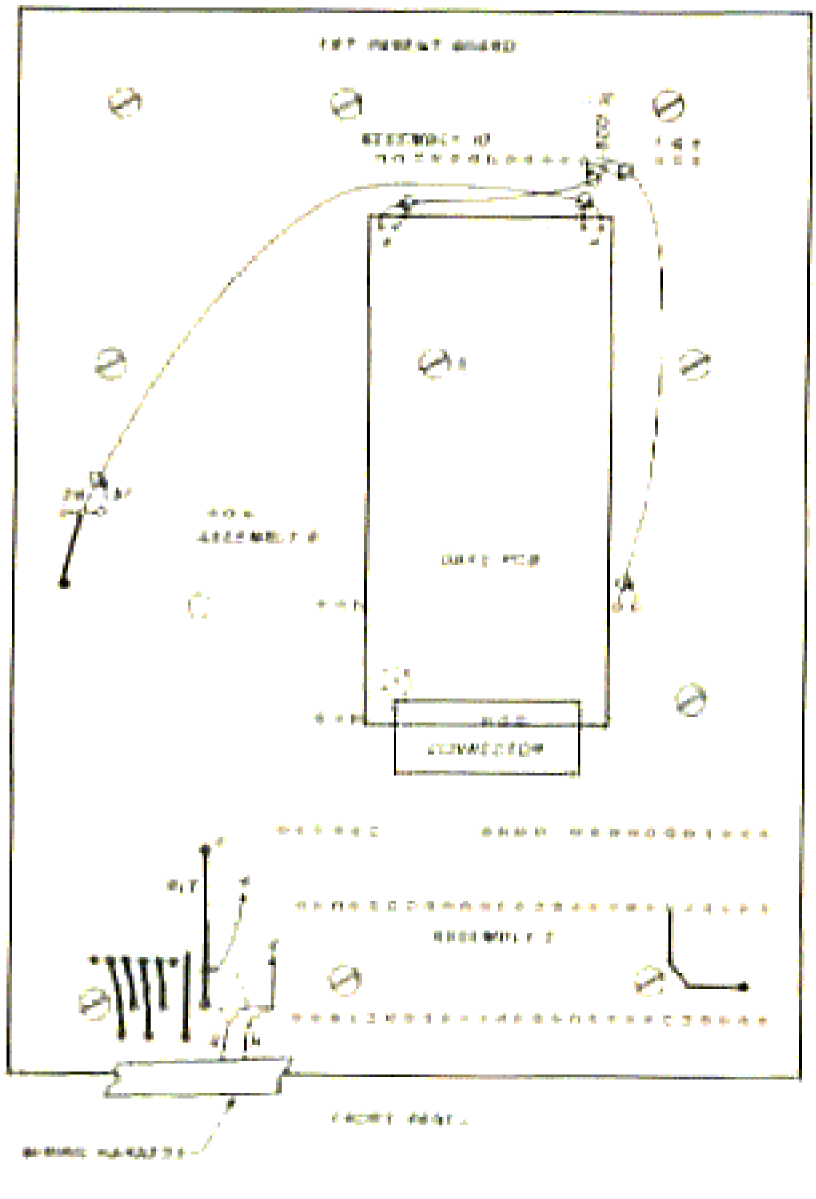


fig. 2. Positioning of the DAFC PCB on the TR7 main board and arrangement of the different connecting points.

the insulating sheet are fixed to the main board by means of a screw (S in **fig. 2**) and two insulating spacers, each about 0.08 inch thick. To be on the safe side, insulate the bottom cover of the TR7 with insulating tape or sheet. The connection of the board to the TR7 is via a 13-pin connector and two small-diameter coaxial cables. (See **photo B.**)

switch wiring

Label all applicable wires before modifying (see **fig. 3**). After identifying wires A through F, unsolder all connections from the three switches and remove the spring hook from the STORE switch so that it can no longer lock when depressed. The new wiring of the switches is shown in **fig. 4 and fig. 5**. Wire F of the former STORE function is no longer used. Insulate its dead end and bend it into a safe place. The two wires from D2a and S2m are dressed together with the wire from the FIXED RCV switch towards the bottom side of the main board. The various connections to the DAFC board are shown in the figures, with their respective connector numbers circled.

Parts list for digital AFC:

C1,C2	0.1 μF
C3,C4,C8,C9, C12,C13	0.01 μF
C5	1 μF (or three 0.33 μF)
C6,C7	10 μF 16 V
C10,C11	10 pF
CR1,CR2,CR3	1N4148
CR4,CR5,CR6	5.6-volt Zener 1N708A or 1N4626
K1	Reed relay
L1	330 μH ferrite choke
Q1,Q2	2N2222
Q3	BC327 or 2N4037
Q4	BC237 or 2N3904
Q5	BRY55-60 2N5061
R1	10 ohms
R2	12 k
R3,R18,R19	1 k
R4	100 megohms
R5,R6,R9,R10, R12,R13,R22	10 k
R7	2.2 megohms
R8,R20	100 k
R11	33 k
R14,R17	15 k
R16	51 k
R21	2.2 k
U1	74LS93
U2	CD4013BE
U3	CA3140
U4,U5	CD4020BE
U6	CA1458
U7	LM78L05

connections on the main board

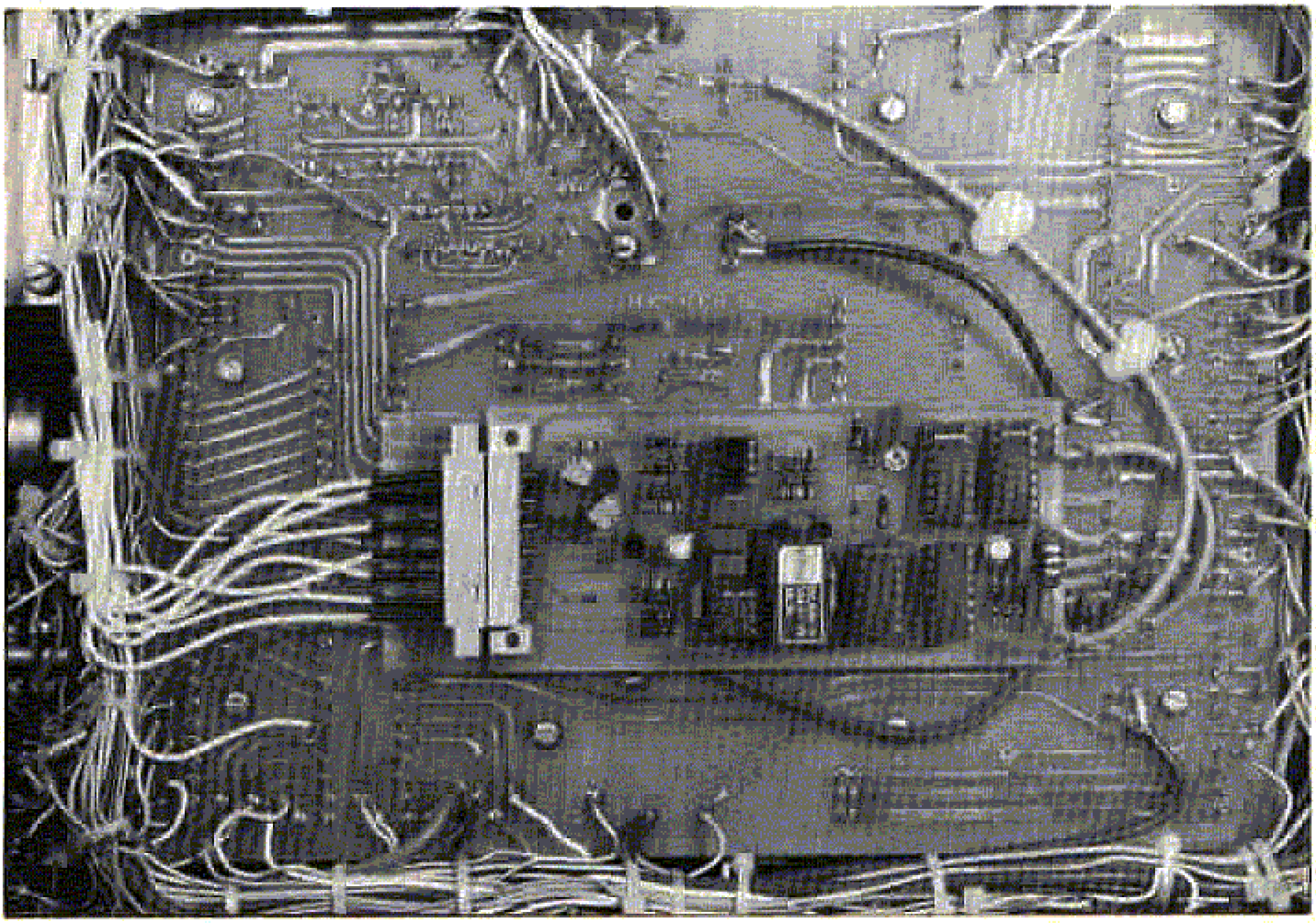
Figure 2 shows the bottom side of the TR7 main board. The connecting points which are used to install the DAFC board are labeled with assembly and pin numbers according to the TR7 service manual. The power supply board is not part of the main board; it is located to the left of the main board between the PA radiator and the rf and a-f gain controls. The 13.6-volt supply voltage is picked up from pin 9 (counted from the left) of the power supply board. The RIT control voltage is available on the conductor labeled RIT in **fig. 2**. In the original wiring the RIT voltage is run from this conductor to the internal and external VFOs with one wire each.

Two wires (labeled G and H) have to be removed from the RIT conductor and connected instead to the DAFC connector, pin 2. The RIT conductor is connected to DAFC connector, pin 4. This completes the installation. It might now be necessary to realign the RIT control center setting according to the service manual (section 3.16).

To gain confidence in this modification, zero-beat a strong a-m broadcast station. Switch on the passband tuning at its center position to allow for maximum response at the carrier center frequency. Try the best zero-beat setting you can obtain; it will be somewhere between 0 and 15 Hz. Don't worry if you hear a rather unsteady beat note. The fluctuations are in the order of a few Hz — less than you will ever notice in one of the stability-sensitive operating modes. If you leave the rig untouched and check in after hours or even days, the beat note will still be moving back and forth, but will be near the same 30.5 Hz point — and by the same few Hz!

operation

This DAFC circuit controls any undesirable frequency excursions under 2 kHz. If the drift exceeds this range, one of the two lamps — either FIXED (upper limit) or SET BAND (lower limit) — will light to announce that the DAFC cannot compensate for any further drift. It is obvious that with the inherent stability of the TR7 VFO, this condition is not very likely to occur. Holding down STORE momentarily DOWN



Closeup shows new board placement and wiring in the TR7.

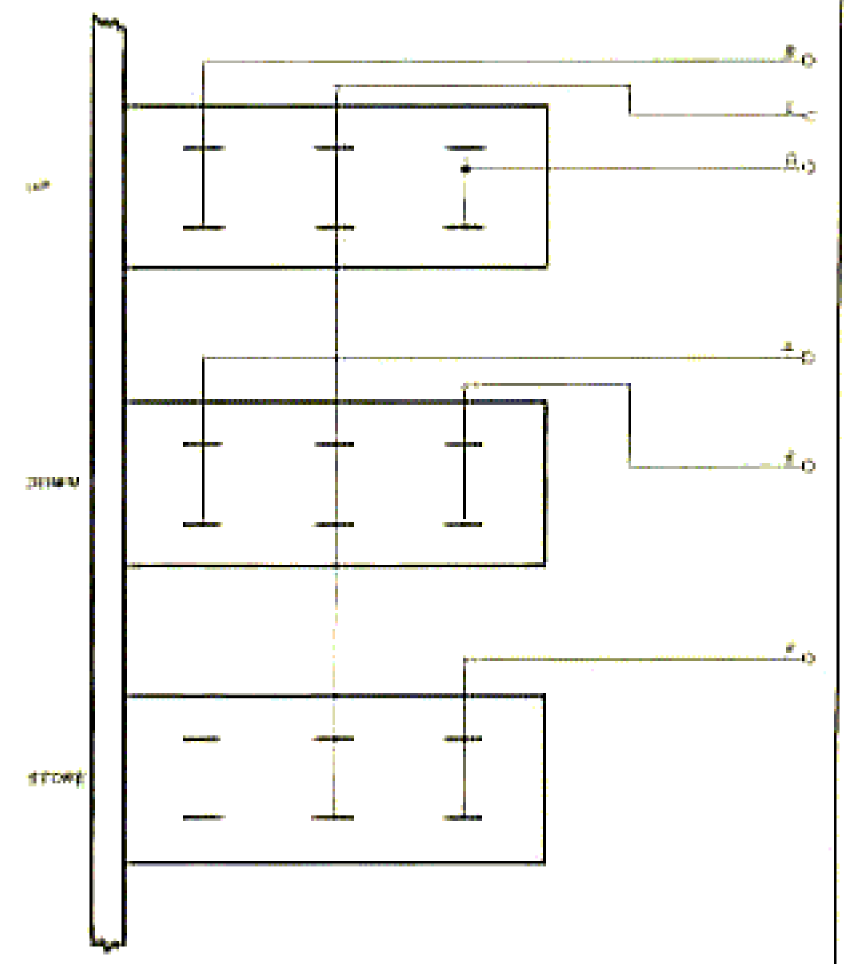


fig. 3. Original wiring of the UP, DOWN, and STORE keys.

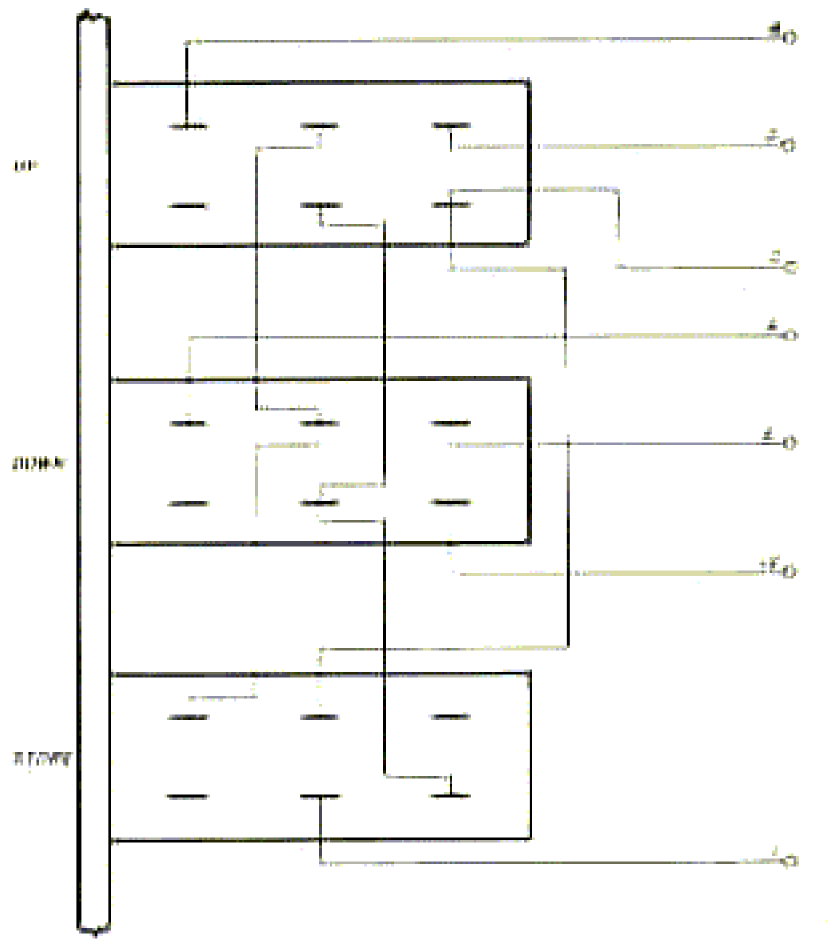


fig. 4. Modified wiring of the UP, DOWN, and STORE keys.

or UP, as is appropriate, brings the DAFC voltage back into its operating range. (UP and DOWN can also be used as a fine tuning, but I think the main tuning knob does a better job.) After several months of operation with more than one modified TR7, the range limits were never reached. It is therefore left to the reader to decide whether to build the circuit with or without the comparator stage and with or without making the connections to the lamps and switches. Tuning behavior and the traditional functions of the UP and DOWN keys are not impaired at all by the DAFC.

limitations

When operating with RIT switched on, you have to take into account that after an RX/TX/RX transition it is not necessarily true that the frequency will be on the same 30.5-Hz spot as it was before. The DAFC has no means of remembering previous voltage/fre-

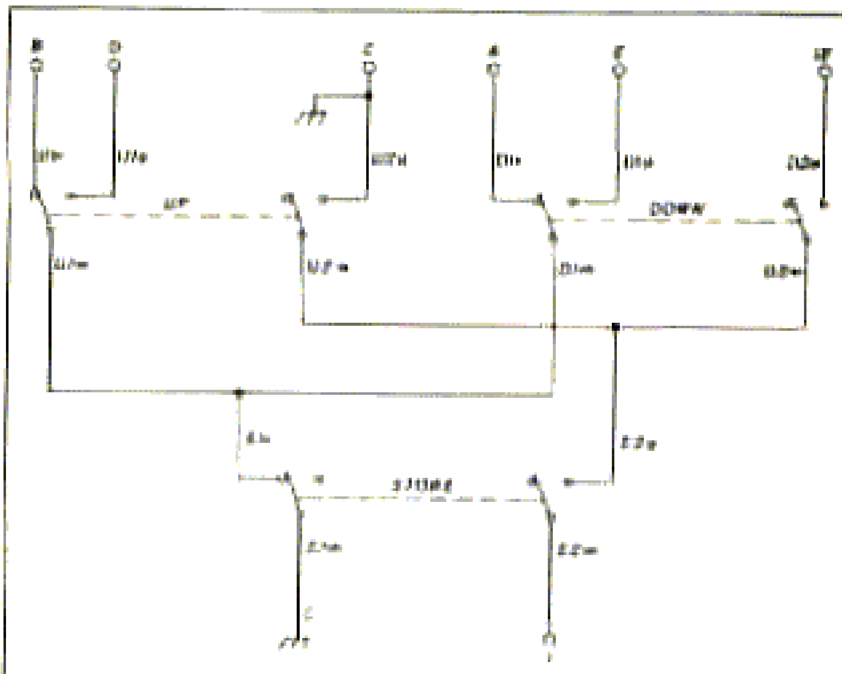


fig. 5. Modified circuit of the UP, DOWN, and STORE keys.

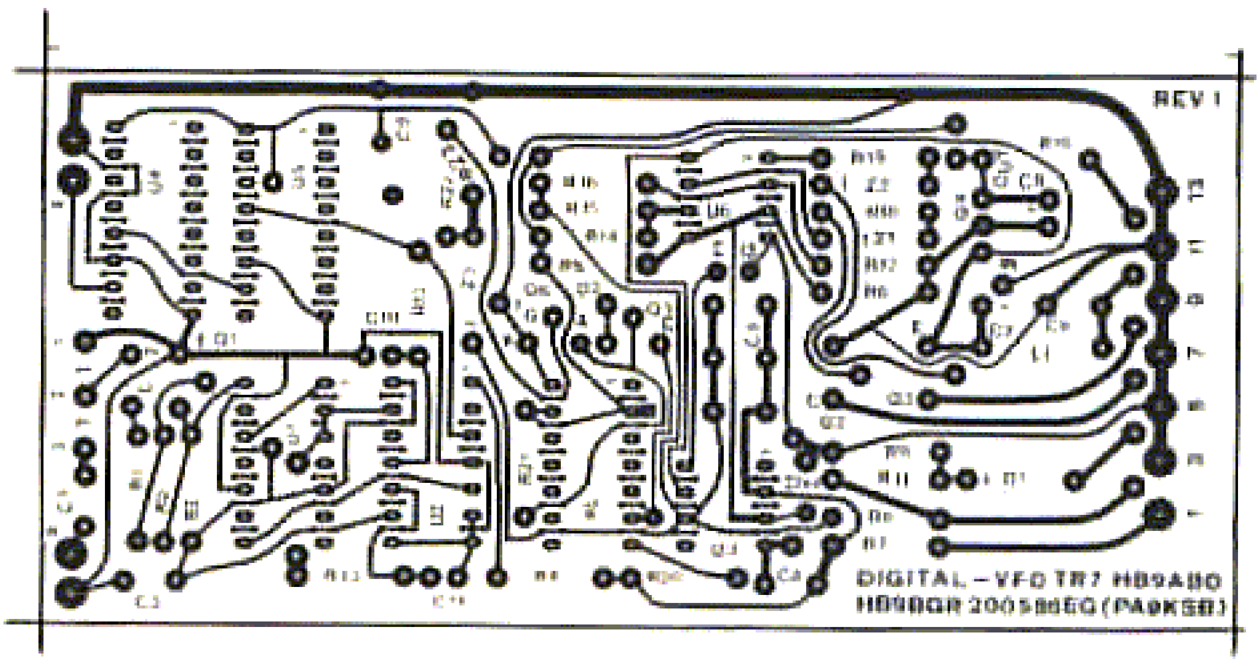
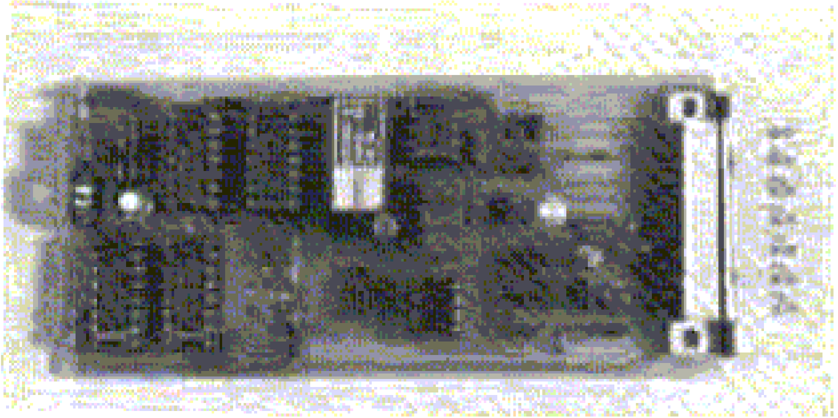


fig. 6. TR7 frequency correcting circuit pc board (foil side).

Table 1. Interconnections between the board and the transceiver. (See figs. 2 and 5.)

designation on DAFC board	connector pin number	Destination within TR7
VFO (PTO) signal (P)		assembly No. 06, pin 38
braid (coax VFO)		assembly No. 06, pin 37
500 kHz reference (X)		assembly No. 10, pin 10
braid – 500 kHz		assembly No. 10, pin 11
13.6-volt supply	10	assembly No. 21, pin 9 (power supply board)
RIT voltage from RIT circuitry	4	conductor labeled RIT
RIT output voltage	2	to wires G and H
+5 volts via R10	12	DOWN switch lug D2a
integrator input via R7	1	STORE switch lug S2m
SET BAND lamp	6	assembly No. 02, pin 6
FIXED lamp	8	FIXED RCV key
ground	3, 5, 7, 9, 11, 13	ground solder lug near assembly No. 21



Frequency correcting circuit improves TR7 stability

quency conditions once the controlling voltage has been changed externally. (That's what happens when RIT is in operation.)

After the power is turned on, you might occasionally hear a short chirp. This is caused by the control voltage being driven into mid-range. Because there are spurious responses at 21266.7 and 28050.0 kHz due to harmonics of the VFO frequency generated by the nonlinear amplifier at Q1, it is important to use good shielding at that stage.

conclusion

Working with the modified TR7 is very rewarding: no longer is there any need to warm up before a sked. Just switch your rig on and tune in. Should a frequency difference arise during a QSO, you can be confident that it's caused by the other station's equipment!

Although this modification isn't difficult, it's a good idea to review references 1 and 2 as well as the TR7 service manual. Doing so will help you understand what you're doing at every step along the way.

Materials for this project can be obtained from HB9BGR (Charlie Egli, HB9BGR, Rümelbachstrasse 9, CH-8153 Rumlang, Switzerland). A list of available items, with prices (U.S. currency, air mail delivery included), follows.

Printed circuit board, undrilled	$12.00
Drilled circuit board	$15.00
Kit with all components and undrilled PCB	$61.00
Kit with all components and drilled PCB	$64.00
Assembled and tested unit	$92.00

For those who wish to etch their own full-size printed circuit board, artwork is provided in **fig. 6**. Follow the foil side labels and detail shown in the photos for parts placement.

references

1. "Drift Correction Circuit for Free Running Oscillators," Klaas Spaargaren, PA0KSB, *ham radio*, December 1977.
2. "AFC Circuit for VFOs," by Reed Easton, K6EHV, *ham radio*, June, 1979.