Heathkit of the Month #83:
by Bob Eckweiler, AF6C

AMATEUR RADIO - SWL

Heathkit HG-10 / HG-10B Variable Frequency Oscillator (VFO)

Introduction:

Last October the Heathkit VF-1 VFO was covered (HotM #79). This VFO, originally built and styled for the AT-1 transmitter, also worked with the DX-20, DX-35 and DX-40 ham transmitters. In 1960 Heathkit replaced the DX-40 with the DX-60. Besides some technical changes, the DX-60's styling was modernized. With minor changes the VF-1 would work with the DX-60 though they clashed in appearance. VFOs were very popular at the time since novice class licensees were required to be crystal controlled ("rock-bound") until they upgraded to the general class license, at which time they could use a VFO to easily change the transmitter frequency. In 1972 the rules changed due mostly to technological advances and the crystal controlled requirement was dropped.

The popularity of the DX-60, and of VFOs in general, influenced Heathkit to design a completely new VFO for the DX-60. The result was the Heathkit HG-10 (Figure 1), and it was a marvel of springs, dial string and gears. The VF-1 sold for $19.95, but the HG-10 was released in 1961 with a price tag of $34.95. The HG-10 was produced for seven years before, in 1966, it was replaced with the HG-10B (Figure 2).

Here is a link to the index of Heathkit of the Month (HotM) articles:
http://www.w6ze.org/Heathkit/Heathkit_Index.html

Figure 1: Heathkit HG-10 VFO

The HG-10 VFO:

The HG-10 includes many changes over the older Heathkit VF-1 besides styling. The older VF-1 covers the 160-meter band as well as the (then) amateur 11-meter band. These

HG-10 / HG-10B FREQUENCIES

Band (M)	Band (mc)	VFO Freq. (mc)	×
Freq. Range 1:			
80	3.500 - 4.000	3.500 - 4.000	1
Freq. Range 2:			
40	7.000 - 7.425	7.000 - 7.425	1
20	14.000 - 14.850	7.000 - 7.425	2
15	21.000 - 22.275	7.000 - 7.425	3
10	28.000 - 29.700	7.000 - 7.425	4
Freq. Range 3:			
6	50.000 - 54.000	8.333 - 9.000	6
Freq. Range 4:			
2	144.000 - 148.000	8.000 - 8.222	18

Notes:
1. **×** is the multiplication factor that occurs in the transmitter.

Table I - HG-10(B) Band Operation

bands are both missing from the HG-10. Instead, the six and two-meter bands have been added. The older VF-1 has three individually calibrated frequency ranges while the HG-10 has four. These are shown in table I.

Frequency is read on a slide-rule dial. The tubular dial drum has a separate scale for each of the seven bands; the illuminated drum rotates with the band switch so only the scale for the band in use is visible. The HG-10 dial window is about 5-1/2” wide and the actual marked scale measures 4-5/8” (for 7.0 to 7.425 mc). Since 40-meters through 10 meters all use the same basic 7.000 - 7.425 frequency range, the length of the in-band portion of the scale is different for each band. The 10 meter band uses the full scale length, while 40-meters uses 70%, 20-meters 40% and 15-meters 35%. The other three bands, since they each have a custom frequency range, use 100% of the scale.

The VFO tuning uses a 28:1 vernier gear drive. The gears are anti-backlash. Though not complicated to build, due mostly to Heathkit’s ability to produce clear assembly manuals, when you were done you might feel like you could fix your car’s transmission. Specifications for the HG-10 are given in table II.

The B+ power requirements for the HG-10 are a little more complicated than the specifications make them out to be. If you connect the HG-10 to 108 VDC B+ voltage you will have a problem. The 0B2 voltage regulator tube regulates at 108 V and it is connected to the B+ input through a 10K resistor. That resistor is going to drop some voltage and the 0B2 will not fire and thus not regulate. The DX-60/(A)/(B) and HW-16 provide about 300 - 350 VDC to their rear connector where the HG-10 is designed to plug in. With the internal 10K resistor these voltages will fire the 0B2 and keep the voltage at 108 VDC while drawing around 19 to 25 MA from the host. The older DX-40 provides 600 VDC to the rear connector, but it has a 15K 10W resistor in series with the wire to the connector. To use the DX-40 with the 15K resistor (IN THE DX-40) should be replaced with a 10K 10W resistor. The 10K 10W resistor in the HG-10 also needs to remain. The HG-10(B) manual presents a table that specifies the resistor size you should use in place of the

HG-10 SPECIFICATIONS
(from Heathkit Ass’y Manual)

Output Frequencies: (kilocycles)	3500 - 4000, 7000 - 7425. 8333 - 9000, 8000 - 8222.
Calibrated Bands:	80-40-20-15-10-6-2 M
RF Output:	> 5 volts RMS (open ckt.)
Load Impedance:	> 50 KΩ
Tube Complement:	1/2 6CH8 Oscillator (P) 1/2 6CH8 Cath. Follower (T) 0B2 Voltage Regulator
Power Requirements:	6.3 V AC at 0.75A 108 V DC at 25 mA (See text)
Cabinet Size:	9-3/8” W x 6-1/2” H x 9-1/8” D
Net Weight:	9-1/2 lbs.

Table II - HG-10 / HG-10B Specifications

Figure 2: The Later Heathkit HG-10B VFO

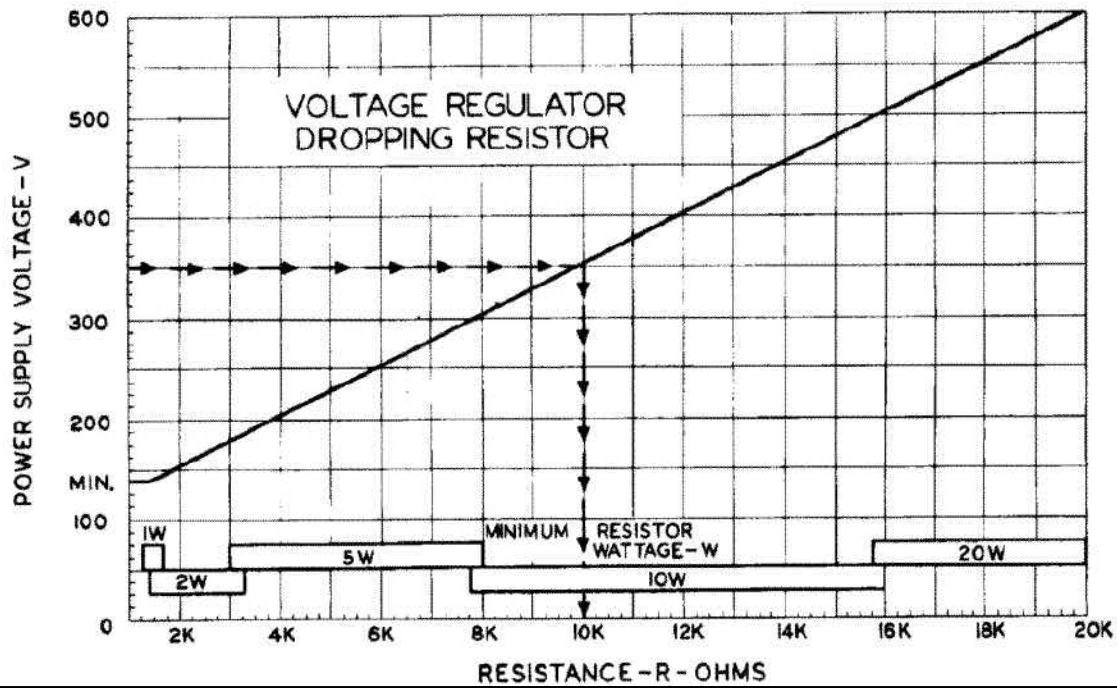


Figure 3: Chart from the HG-10 manual showing the proper dropping resistor R11 value for different B+ voltages.

10K 10W resistor in the HG-10 for other B+ voltages. This graph is shown in Figure 3.

The HG-10B VFO:

In late 1966 Heathkit update the HG-10 to the HG-10B. Why there was no HG-10A is a mystery. However, the HG-10B came out around the time the DX-60A was replaced with the DX-60B, so maybe Heathkit wanted people to think that the new VFO was designed as a match to the DX-60B. And, while it is true the HG-10B has at least one minor circuit modification, most of the changes were paint and styling changes to match the new DX-60B. Most obvious is the paint which went from smooth to textured, and the colors that changed slightly; both features that also changed in the upgrade to the DX-60B.

The HG-10B Controls:

The layout of the HG-10(B) controls is simple and straightforward. Table III lists the front panel controls and the rear panel connections.

The HG-10(B) circuit:

The HG-10 and HG-10B circuits are nearly identical. Any differences will be noted during this discussion. the HG-10 VFO may be broken down into the following parts: Power, oscillator, buffer and keying. Figure 9 shows the schematic of the original HG-10 VFO.

Power Supply:

Power is supplied from an external source, usually the transmitter, though any external supply above about 140 volts will work with the proper dropping resistor as discussed earlier. Regulation is provided by a 0B2 gas tube. The 0B2 requires a minimum of 133 VDC to assure the gas will ionize and begin to conduct. Once the gas fires the voltage across the tube will remain at a nominal voltage of 108 volts as long as the current through the tube remains between 5 and 30 ma. The actual voltage varies by tube and manufacturer, but is between 101 and 114 volts. Actual regulation is specified as 1 volt average and 4 volts maximum over the 5 to 30 ma current range. When the tube fires

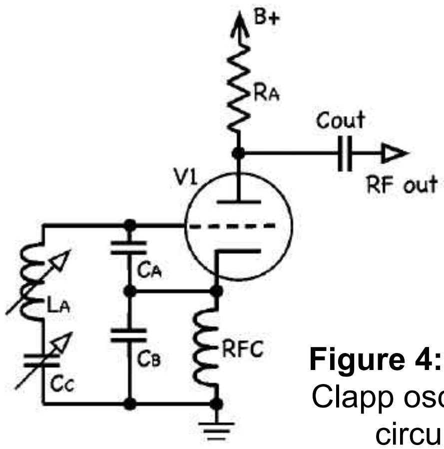


Figure 4: Basic Clapp oscillator circuit.

you can see a soft blue-violet glow within the tube. If you are having problems like the VFO changing frequency during keying, check that the tube continues to glow throughout the cycle; some change in intensity will occur.

Oscillator:

Like the older VF-1, the HB-10 uses a pentode tube in an electron coupled Clapp oscillator circuit. The Clapp oscillator is a variant of the Colpitts oscillator with an added capacitance in series with the coil C_C. This capacitance is usually made variable and adjusts the frequency. Figure 4 shows the basic circuit. C1 and C2 are often identical in value and made up of multiple capacitors in parallel. These capacitors have different temperature coefficients and are chosen to keep the oscillator from drifting over temperature variations. C3 is also often made up of multiple capacitors, trimmers for setting the oscillator calibration as well as fixed capacitors for padding and temperature compensation.

Variable capacitors C1 and C2 are the two-section main FREQUENCY control. Each sec-

HG-10 / HG - 10B
Controls and Connections

Top half of front panel (centered):

Slide-Rule Dial - (Only selected band's scale shows)
(Spacing: [minor tick], [mid tick], [major tick] - fig 5)

80 METERS:3.5, 3.6, 3.7, 3.8, 3.9, 4.0 (mc)
Spacing: 10 kc, 50 kc, 100 kc.

40 METERS:7.0, 7.1, 7.2, 7.3, 7.4 (mc)
Spacing: 10 kc, 50 kc, 100 kc.

20 METERS:14.0, 14.1, 14.2, …, 14.7, 14.8 (mc)
Spacing: 20 kc, (none), 100 kc.

15 METERS:21.0, 21.1, 21.2, …, 22.1, 22.2 (mc)
Spacing: 25 kc, 50 kc, 100 kc.

10 METERS:28.0, 28.5, 29.0, 29.5 (mc)
Spacing: 50 kc, 100 kc, 500 kc
(ticks continue to 29.7)

6 METERS: 50, 51, 52. 53, 54
Spacing: 100 kc, 500 kc, 1 mc.

2 METERS: 144, 145, 146, 147,148
Spacing: 100 kc, 500 kc, 1 mc.

Bottom half of front panel (L to R):

FUNCTION: (rotary switch - 3 position)
STand**BY**, **OP**e**R**ate, **SPOT**

FREQUENCY (dual 5 - 25 µµf variable capacitor)
28 : 1 geared vernier drive

BAND: (rotary switch - 7 position)
80, **40**, **20**, **15**, **10**, **6**, **2**

Rear panel skirt (L to R from rear):

RF OUTPUT (RCA Phono jack)

KEY (1/4" phone jack)

POWER (Cable with strain relief)
8-pin octal plug at far end of cable:
Pin 1: Ground (black)
Pin 2: Filament - 6.3 VAC (white)
Pin 4: B+ (red)
Pin 8: Key line (green)

Table III

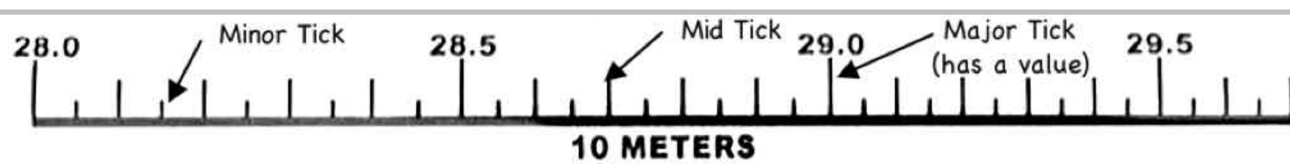


Figure 5: Typical slide rule scale (10-Meters selected) identifying tick mark types for Table III

tion has a capacitance of 5 to 25 µµf; C2 is in parallel with C1 when on the 80-meter band and not used on the other bands.

Table IV shows the frequency determining capacitors that make up the four different frequency ranges of the VFO. For frequency stability C11, C13, C17, C22 and C23 are N750 type that have a negative temperature coefficient of 750 parts per million (PPM) per degree Kelvin. This corrects drift from the rest of the capacitors that either have positive or no temperature drift (NPO).

Feedback for the oscillator is from the cathode of the pentode section of V1A. The RF choke (RFC2) prevents the RF from being bypassed to ground while R2 provides the DC path to ground when the VFO is operating.

In an electron coupled oscillator the screen provides voltage for the pentode and the RF signal passes through the grounded suppressor grid to the plate. This circuit tends to isolate the plate load from the oscillator, providing more stability. The plate is untuned and the RF is isolated from the B+ line by RFC1. Interestingly, RFC1 is the only component I've found that has changed value between the original HG-10 and the HG-10B. It was changed from 390 µH down to 28 µH. Why this was done may have been for cost reduction? However, in 1973 Heathkit released service bulletin HG-10B-1 which states:

> Hum On 40 Meters
>
> Replace RFC-1, 28uH [PN 45-18] with a 350 uH choke coil, [PN 45-82]. This change will be put into production soon.

Cathode Follower Buffer:

V1B, the triode section of the 6CH8, is a cathode follower. They have been covered many times in HotM articles. It should suffice to say it provides isolation by having a high input impedance and a low output impedance with a voltage gain of somewhat less than one. R3 through R6 set the tube's oper-

HG-10 / HG-10B
Frequency Determining Components:

On all bands:
C20 and C22[1] act as C_A
C21 and C23[1] act as C_B

When on 80 Meters (3500 - 4000 kc):
L3 acts as L_A
C1[5], C2[5], C7[6], C13[1] and C14 act as C_C
C19 also affects the frequency [2]

When on 40 thru 10 Meters (7000 - 7425 kc):
L2 acts as L_A
C1[5], C6[6], C11[1] and C12 act as C_C
C18 also affects the frequency [2]

When on 6 Meters (8333 - 9000 kc):
L1 acts as L_A
C1[5], C5[6], C9, and C10, act as C_C
C16 and C17[1] also affect the frequency [2]
C15 also affects the frequency [3]

When on 2-Meters (8000 - 8222 kc):
L1 acts as L_A
C1[5], C5[6], C9, C10, act as C_C
C16 and C17[1] also affect the frequency [2]
C3[6], C4[6], and C8 also affect the frequency [4]

Notes:
1. These capacitors have a negative temperature coefficient (N750) for temperature compensation.
2. This capacitor is not shown in Figure 4. It is across the series capacitors C_A and C_B.
3. This capacitor is in series with C_C reducing its overall capacitance.
4. These capacitors are in series and parallel with C1, the main tuning capacitor, reducing its overall tuning range.
5. C1 and C2 are the dual-section main tuning capacitor.
6. These capacitors are trimmers for calibration.

Table IV

ating parameters. The RF output is taken across R5 which sets the output impedance as R6 is bypassed to RF by C31.

Keying Circuits:

The DX-60 series and the HW-16 use grid-block keying, while the DX-40 uses cathode keying. The HG-10(B) is designed to work with either with some minor wiring changes. The oscillator tube V1A can be prevented from oscillating by R7, the large resistor in the cathode circuit. This resistor raises the cathode voltage enough to prevent oscillation; shorting it out will key on the oscillator. The oscillator can also be prevented from oscillating by applying a negative voltage across R9 to bias the tube off.

When using grid-block keying the keying should be done at the transmitter. A low current, fairly high negative voltage (usually a bit greater than 100 VDC) appears across the open key. This negative voltage is applied to the necessary stages of the transmitter to cut them off; thus no signal appears at the output of the transmitter. When the key is closed the negative voltage is shorted to ground and the stages operate normally.

This negative keying voltage appears on the HG-10(B) VFO keying line that comes in via the octal plug from pin-8. This voltage is connected through an NE-2 neon bulb which lights with the key up and drops the keying voltage by 75 to 90 volts. With the **FUNCTION** switch in the **OPR** mode this lower negative voltage appears across R22 and biases off the oscillator tube V1A. At the same time the FUNCTION switch shorts R7 to ground, bringing the oscillator cathode near ground; now the only reason the oscillator is not functioning is the negative voltage across R9. When the key is closed in the transmitter the negative voltage drops to zero, the neon bulb goes out, and the voltage across R9 drops, causing the oscillator to start, and output to appear at the **RF OUTPUT** jack.

The HG-10 may be converted to cathode keying by two simple changes in the HG-10B circuitry as shown in the schematic. First, move the green wire on terminal strip A from terminal 2 to terminal 3. And second, remove the wire between terminals 2 and 3 on the **KEY** phone jack. The green wire mentioned above is the keying lead from the octal plug.

When the preceding modifications are made to the HG-10(B) it can be used with cathode keying. The two key jacks are now in parallel and a key may be used in either. With the FUNCTION switch in the OPR position the key is connected across R7, the large cathode resistor that is keeping the oscillator biased off. When the key is closed R7 becomes shorted and the cathode voltage drops allowing the oscillator to start. Thus the oscillator is keyed along with the transmitter.

When the FUNCTION switch is in the **STBY** (standby) position the key jack and keying lead are open and the oscillator is biased off; when the FUNCTION switch is in the **SPOT** position the key jack and keying lead are open and a short appears across R7 causing the oscillator to operate independently of the transmitter keying. The oscillator can be heard in the receiver and the receiver or VFO may be adjusted to the other's frequency.

Mechanical Design:

It would be amiss to discuss the HG-10(B) without commenting on the mechanical layout. Like its predecessor the VF-1, the HG-10(B) has heavy ceramic coils, a double bearing tuning capacitor and rigid construction to improve stability, but is also has features that made up a part of Heathkit design in the early sixties ham products. Someone on the Heath design team must have been a mechanical engineer who loved gears and pulleys. Much of the ham gear of that period features a rotating drum that turns with the band-switch, showing only the current band to the user. They also feature a smooth geared drive for the tuning capacitor. This multi-gear tuning system mounts between the front panel and a sub-panel. Equipment of the day featuring such mechanical wonderment include the MR-1 (“Comanche” mobile receiver), MT-1 (“Cheyenne” mobile transmitter), RX-1 (“Mohawk” HF receiver), TX-1 (“Apache” HF transmitter), HR-20 (mobile SSB receiver), HX-20 (mobile SSB transmitter), and possibly others.

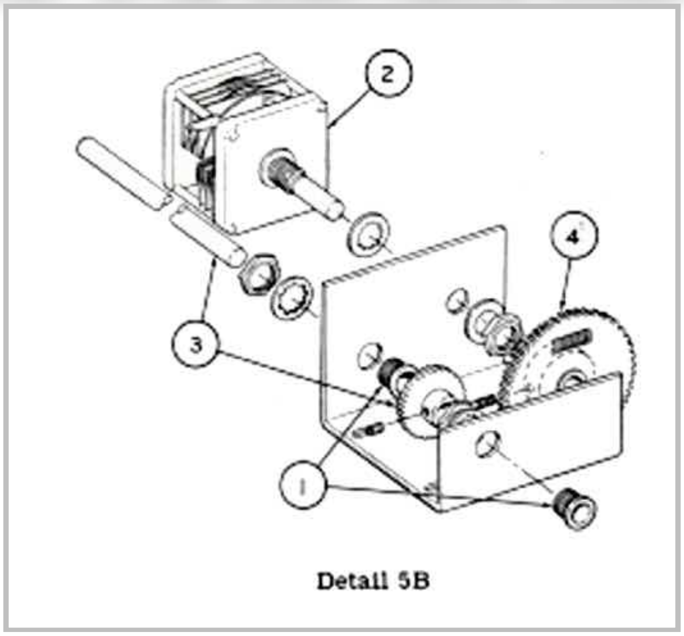


Figure 7: Drawing showing the HG-10 VFO capacitor. The long shaft #3 mates with the coupling #10 of figure 6.

Figures 6 and 7 show the mechanical layout of the HG-10(B) gear reduction for the FREQUENCY tuning capacitor. The sub-panel mounts behind the front panel with the gear mounting plate towards the front. The shaft (#9) protrudes out the front and holds the main tuning knob. The pulley (#16) drives the dial pointer across the slide-rule dial via dial-cord and a bunch of idler pulleys not shown in these drawings.

Figure 8 shows the drum assembly. The pulley on the band-switch (#29) connects to the pulley (#23) on the dial drum via dial-string, causing it to rotate to the correct dial scale as the band-switch is turned.

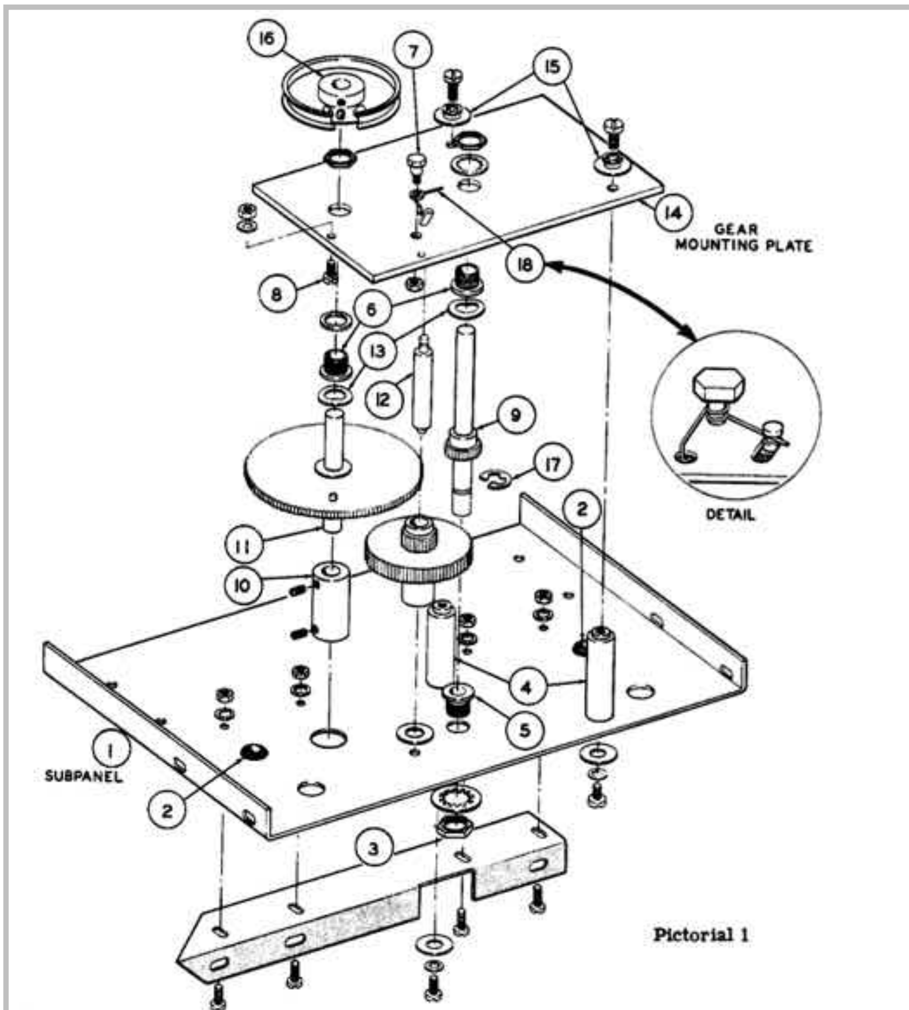


Figure 6: Drawing showing the HG-10 VFO sub panel with gear mounting plate and set of reduction gears. The geared shaft #9 protrudes through the front panel and holds the FREQUENCY knob.

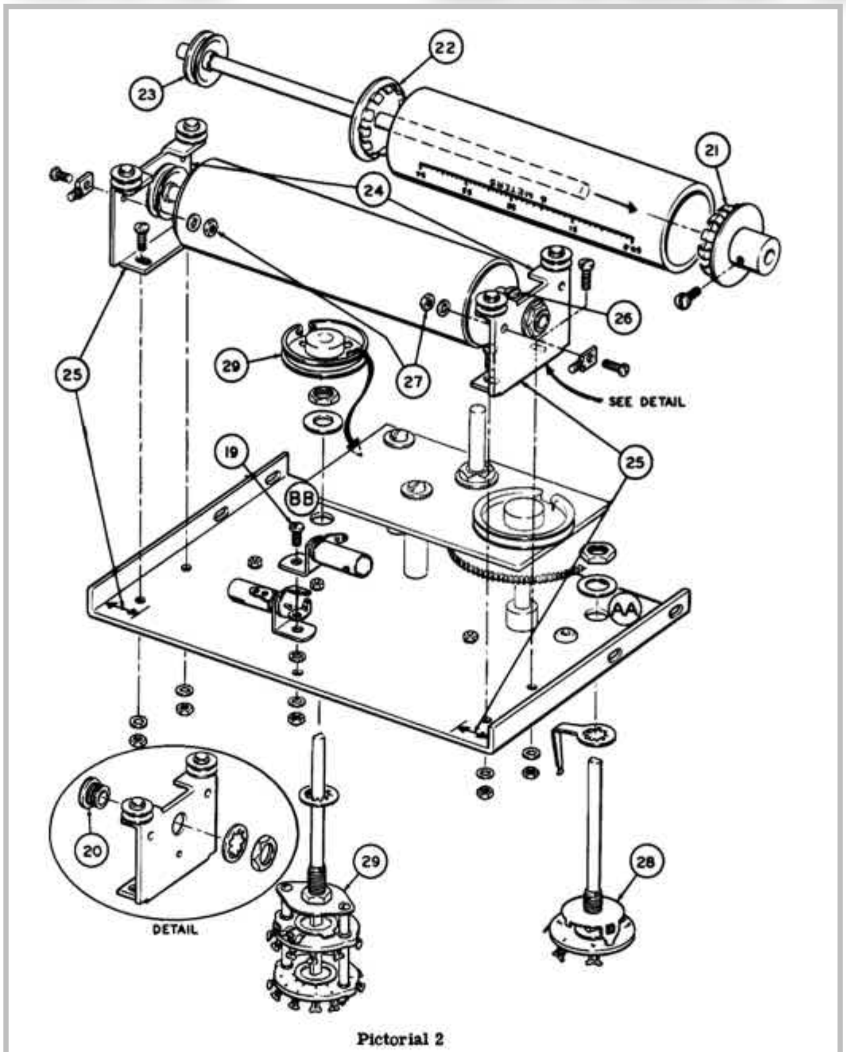


Figure 8: Dial drum assembly shown mounting to the front sub-panel of figure 6.

Proper alignment and lubrication is required to achieve the best dial results. A little extra time here pays off with smooth tuning.

Summary:

While the change from crystal to VFO operation for the novices occurred in 1972, a lot of novice rigs were in use and many were still being sold due to their low price compared with a transmitter with built-a in VFO. The more expensive radios used frequency synthesizers locked to a standard crystal providing frequency control as well as crystal stability. These radios were expensive and so VFOs continued to sell. It wasn't until older synthesized radios began to come up on the used market at reasonable prices that the need for an external VFO began to decline. The HG-10B continued in production until 1976, four years after the rules changed.

Many HG-10(B) VFOs are also used on VHF. The oscillator has the stability to operate AM, and CW on 6 and 2-meters, and reports can be found that claim they were useable on 1-3/4 and even 3/4-meters on AM, and CW.

General HotM Comments:

V-6 Voltmeter Restoration:

My V-6 voltmeter project is on hold while I wait for a part. Can you believe that a 0.01 µf 2KV axial lead capacitor would be hard to find? Mouser was out until just recently and so I have a few on the way along with some other parts for another Heathkit project. I was able to find a 200K 1% precision resistor that is part of the range attenuator. The original was open.

Why not a Link to the HotM Index?:

While looking over some old emails I came across correspondence from Dave, W6OVP (Dave provided me with a lot of very useful information for the HA-14 Compact KW Amplifier article for HotM #58). I don't remember seeing this before, but Dave commented:

> *Suggest you could maybe put a link at the bottom of EACH of your review pages to steer viewers* […] *back to the* 'Orange County Club Heathkit Articles' […] *link. Potential customers should not have to hunt for your products. :-! .*

Great idea Dave! Sorry it took me so long to implement it. Starting with this article, I will include the link to the Heathkit of the Month index on the first page of each article. From that index the articles can be accessed. Adding a link to previous articles may be difficult to do for reasons I may explain in a future article.

What's Up Next?:

With taxes due and the Baker to Vegas race looming I may not get time to do an article next month. However, I was talking with Chuck Penson (author of those great Heathkit books, and he suggested I write on the O-12 oscilloscope. I actually have one here that is in need of restoring. I thought I'd do even more and cover the whole 'O-#' oscilloscope line, (there are twelve of them altogether) spending more time on history and evolution and less on circuit description. I was thinking of doing it in three parts, the O-1 to O-4. the O-5 to O-8 and the O-9 to O-12. I was able to obtain from Chuck a schematic of the O-1, the first Heathkit. It's missing some information but is reasonably complete. Unfortunately, it is not a good enough reproduction for an article, but the circuit is simple so maybe I can redraw it if I can't find a better copy. I don't think the manual (it was really a schematic, parts list and some assembly notes, I've been told, is available for sale. The three parts won't appear consecutively; I'll try to write on another kit or two in-between sections.

73, from AF6C

This article originally appeared in the March 2018 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.

Remember, if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.

Be sure to update> Thanks - AF6C

A HEATHKIT Short

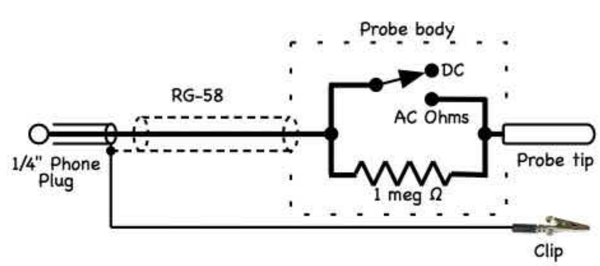
Heathkit VTVM Probes:

Over the years the probes that came with Heathkit VTVMs changed. In older units there were three connectors on the front panel, Two banana jacks (red and black) for AC and Ohms measurements with appropriate red and black test leads, and a phone jack for a shielded cable with a black probe holding a 1 meg Ω resistor that is in series with the lead, for DC voltage measurements.

With the release in 1961 of the IM-11, which replaced the V7-A, the three leads were combined into one that plugs into a phone jack. The plug-in test lead is a single shielded cable that goes to a new test probe. On that test probe is a switch that switches the 1 meg Ω resistor in for DC measurements and out for AC and Ohms measurements. A black test lead with an alligator clip comes out of the phone plug separately and provides the common lead.

Those probes get broken or lost, thus there are numerous articles on replacing them. Some suggest placing the switching of the 1 meg Ω resistor inside the VTVM. Don't do this. That resistor is located close to the test point to isolate the cable capacitance from the circuit under measurement. This capacitance can affect the circuit operation, even if you're measuring DC voltages.

73, from AF6C



A simple replacement probe for late VTVMs. Use a simple slide switch & Belden 8899-BLK for clip lead.

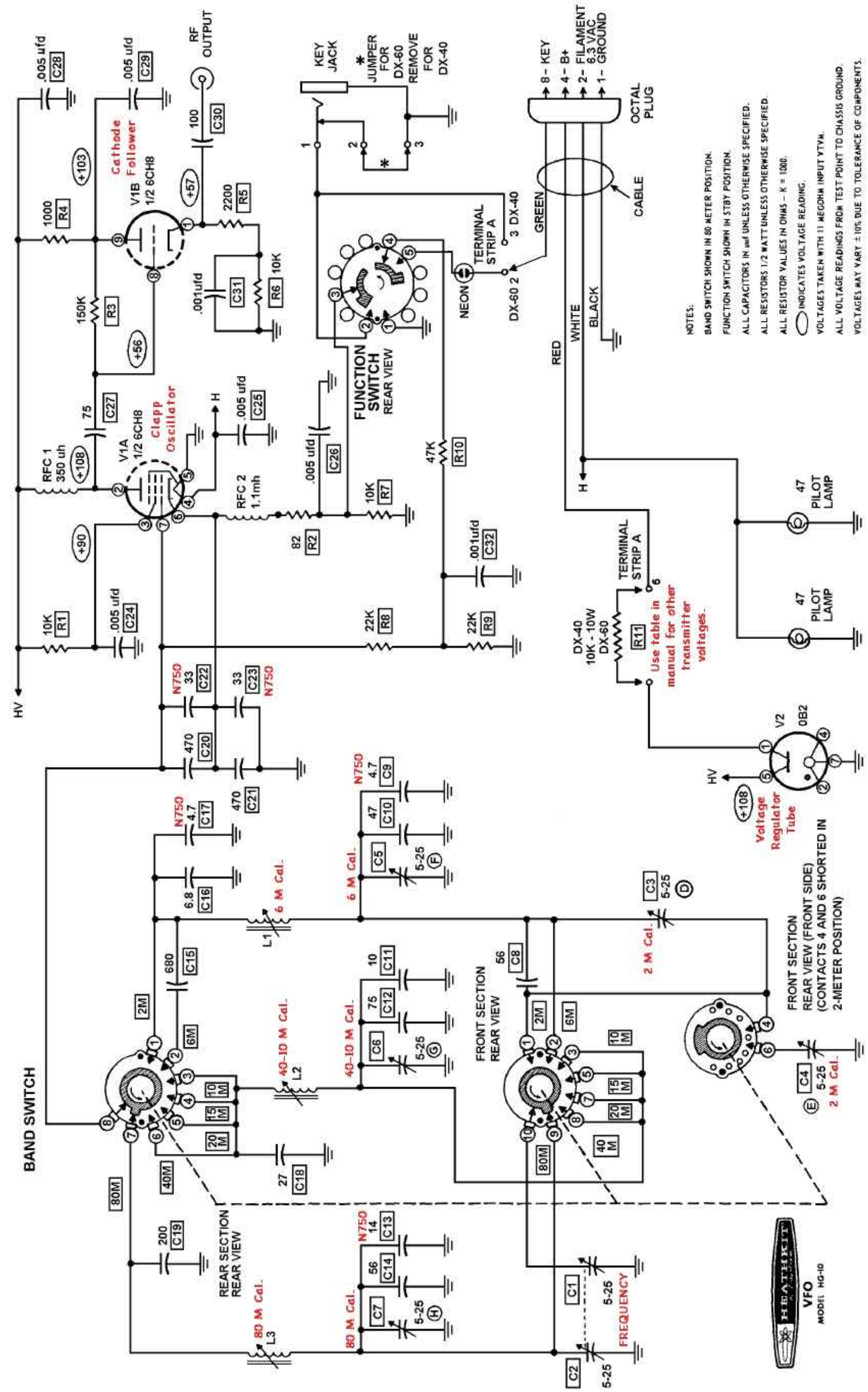


Figure 9: Heathkit HG-10 Schematic