Heathkit of the Month:
by Bob Eckweiler, AF6C

Heathkit

ELECTRONIC TEST EQUIPMENT
Heathkit FMO-1
FM TEST OSCILLATOR

Figure 1: Heathkit FMO-1 FM Test Oscillator

Introduction:

When the switch-over to digital television occurred on June 12th 2009 a lot of Heathkit test equipment designed to service CRT televisions became obsolete. Included are various alignment generators, CRT rejuvenators, etc. They suddenly became of value only to collectors, owners of old TVs and those using one of the FCC mandated converter boxes with an old TV. However, the new large screen LCD TVs, that offer energy savings and higher resolution, quickly became popular and most of the older CRT TVs have found their way to the electronic recyclers.

Discussions about other uses for the obsolete Heathkit TV test instruments, without extensive modifications, were held on some of the Heathkit group sites without any useful ideas arising so far.

One piece of equipment that survived is the Heathkit FMO-1 FM Test Oscillator which is useful for aligning FM radios more than TVs.

The FMO-1 FM Test Oscillator:

The FMO-1 FM Test Oscillator (Figure 1) provides all the necessary audio, IF and RF signals needed to align a monaural FM tuner or radio that uses the almost universal 10.7 MHz IF frequency. This includes signals for alignment of discriminators, ratio detectors and other FM demodulators.

The FMO-1 was first offered in the fall of 1959. It appeared in the November issue of Electronics World and was marked “price to be announced” (See Figure 2). In the March 1960 Catalog supplement the price was listed at $34.95. The FMO-1 continued production into 1967. It is offered in the 1967 catalog (810/67A), and still at the original $34.95 price, but was not shown in the 1968 catalog. By that time most current FM tuners were stereo and Heathkit was offering the IG-112 FM Stereo Generator, which provides the features of the FMO-1 and the necessary signals to align the FM multiplex circuits in stereo FM tuners and radios as well.

Specifications for the FMO-1 are shown in Table I. Only the 10.0 and 10.7 oscillator signals are crystal controlled. All the other oscillator signals use inductors to determine frequency and do not have crystal accuracy.

Output Frequencies:	
R.F. Alignment:	90 mc(Switch selected)
	100 mc
	107 mc
Modulation:	400-cycle (Incidental FM)
I.F. & Detector Alignment:	10.7 mc sweep
Sweep (Variable):	200 kc to > 1 mc
Markers:	10.7 mc (crystal)
	100 kc submarkers
Modulation	400-cycle AM
Other:	10.0 mc (crystal)
	100 kc
	400-cycle audio
Tube Complement:	2 -6U8 dual section (Triode / Pentode)
Power requirements:	105 - 125 VAC 60~ 12 watts
Size (inches):	7-3/8 H x 4-3/4 W x 4-3/8 D
Net Weight:	5 lbs.

Table I: Heathkit FMO-1 Specifications

However both crystal oscillators are designed to be rich in harmonics so they may be used to calibrate the RF alignment oscillators in-situ.

The FMO-1 Operation:

The FMO-1 FM Test Oscillator actually consists of three separate oscillator circuits and an output amplifier.

The first oscillator circuit has four functions that are switch selected by a large knob on the front panel. The first function is a 10.7 mc. sweep oscillator, and the other three functions are fixed VHF oscillators at frequencies of 90, 100 and 107 mc., these are frequencies near the lower end, middle and upper end of the 88 to 108 mc FM broadcast band.

The second oscillator circuit has two frequencies that are also switch selected. In certain switch positions the first function acts as a 400 cycle audio oscillator that is used as a modulation signal for the RF oscillators when modulated RF is desired. The second function is as a 100 KC oscillator that is used as a marker with the sweep oscillator. When using the sweep oscillator the markers appear at 10.6 and 10.8 mc. (and, if the sweep width is set wide enough, also at 10.5 and 10.9 mc.)

The third oscillator circuit is a crystal controlled oscillator with two crystals that may be switch selected. These oscillators are designed to be rich in harmonics up through

Front panel controls are located in five rows:

Top row (Centered):
1. (Large knob unnamed) 5-position rotary switch
   OFF, 10.7 MC SWEEP, 90 MC 100 MC 107 MC

Second row (L to R):
1. **MODULATION** - 5-position rotary switch:
   OFF, 400~ MOD, 400~ OUT, 100 KC MOD, 100KC OUT
   LEVEL: - Potentiometer - no markings
   Control - concentric with switch:
2. **MARKER OSCILLATOR -** 3-position rotary switch:
   OFF, 10.0 MC, 10.7 MC
   LEVEL: - Potentiometer - no other pot markings
   Control - concentric with switch:

Third row (Centerd):
1. Neon pilot lamp - no markings

Fourth row: (L to R):
1. **SWEEP WIDTH** - Potentiometer w/switch
   A.C. OFF (Full CCW) no other pot markings.
2. **RF - AF** Output - two pos. slide switch
3. **OUTPUT** - Potentiometer
   MAX. (Full CW) no other pot markings.

Fifth row (Centered):
1. Amphenol Series 75 single button contact connector:
   75-PC1M (chassis receptacle)
   (Mates with 75-MC1F cable plug)
   Output (unmarked)

Table II: FMO-1 Front Panel Controls

New Test Equipment

HEATHKIT FMO-1

Price to be announced

AN INSTRUMENT LONG-AWAITED BY SERVICE TECHNICIANS EVERYWHERE!

HEATHKIT FM TEST OSCILLATOR KIT (FMO-1)

Here in one compact, easy-to-use instrument are provided all the test signals and sweep frequencies required for fast, easy alignment and troubleshooting of RF, IF and detector sections of FM tuners and receivers. An instrument unique in the test equipment field . . . being the only one of its type designed especially for FM service work.

SPECIFICATIONS—Output frequencies: for RF alignment, 90 mc (FM band low end), 100 mc (FM band middle range), 107 mc (FM band high end). **Modulation:** 400 cycle incidental FM. **IF and detector alignment:** 10.7 mc sweep. **Sweep width markers:** 30 kc to over 1 mc, variable, 10.7 mc (crystal), 100 kc sub-markers. **Modulation:** 400 cycle AM. **For other applications:** 10.0 mc (crystal) and harmonics, 100 kc, 400 cycle audio. **Controls:** main frequency selector, modulation switch/concentric level control, marker oscillator switch/concentric level control, sweep width—power switch, output control, AF-RF (source impedance) switch. **Power supply:** transformer, selenium rectifier. **Power requirements:** 105-125 V, 50/60 cycles, 12 watts. **Cabinet size:** 7⅞" H. x 4⅜" W. x 4⅝" D.

FIGURE 2: Heathkit FMO-1 Ad From November 1959 *Electronics World* Magazine

the FM broadcast band. The first crystal is at 10.7 mc. which is used as a precision marker for the center frequency of the sweep oscillator and is also used to calibrate the 107 mc oscillator. The second crystal is at 10.0 mc which provides a precision signal for calibration of the 90 and 100 mc. oscillators.

Fig. 3: 10.7 MC IF alignment scope pattern.

Calibration of the 10.7 mc. IF of a standard FM receiver by the FMO-1 requires use of the 10.7 mc. sweep oscillator and an oscilloscope (preferably one that has a line frequency sweep as most older Heathkit scopes do. This is because the sweep oscillator is driven at the line frequency). Depending on the detector circuit in the tuner or radio, the output the 10.7 sweep oscillator is injected into the last IF (ratio detector), or the IF stage before the limiter stage (discriminator detector). The scope is connected across the negative end of the load resistor (ratio detector), or grid resistor of limiter circuit (discriminator detector), The 10.7 mc. marker is added to the sweep oscillator and the IF transformer between the test oscillator and scope is adjusted for a symmetrical waveform of highest amplitude with the marker in the center of the peak (Figure 3 shows a typical waveform). The 100 kc. markers can the turned on to produce pips at 10.6 and 10.8 mc. for further symmetry adjustment. The 10.7 mc. marker signal level must be increased to beat with the 100 kc. signal to get the pips and this adds some distortion to the waveform. The level needs to be adjusted to the point where the pips are barely visible to decrease this distortion.

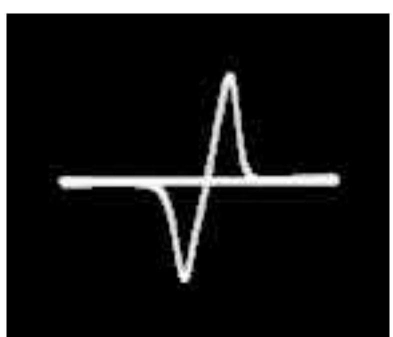

Fig. 4: FM Detector alignment waveform.

The FMO-1 test oscillator is then moved one stage backwards towards the antenna and the procedure is repeated. It is important to have the sweep and marker signals at as low a level as gives a good trace on the oscilloscope. This is continued until all the IF stages are aligned.

After aligning the IF, the detector stage is aligned. The 10.7 mc. sweep signal is applied to the first or preferably the second IF, which will give a cleaner trace. The scope is connected to the high end of the volume pot. The detector transformer primary is then adjusted for the largest length of the line crossing the baseline (see figure 4). Next, the 400 cps modulation is turned on which causes the baseline to “wiggle”. The detector transformer secondary is then adjusted to minimize this wiggle. The 100 kc. markers can again be turned on. They should appear symmetrically on the ’S’ shaped curve near the peaks.

Finally the RF section of the FM tuner or radio is calibrated. The scope is reconnected to the point used for IF alignment, and the FMO-1 output is connected to the antenna leads using a dummy antenna (a 150Ω resistor in series with each leg of the FMO-1 output cable). The FMO-1 oscillator is set to 107 mc. with 400 cps modulation, and the local oscillator trimmer on the unit being calibrated is adjusted until a clean sine wave appears on the scope. The RF amplifier trimmer is then adjusted for maximum level. The FMO-1 is then set to 90 mc. and the local oscillator slug is adjusted for a clean sine wave. The RF amplifier slug is then adjusted for maximum level. This procedure is repeated until no further adjustment is required to correct the frequency or increase the gain.

This simplified version of the alignment procedure gives a good overview. The Heathkit FMO-1 manual goes into a lot of added detail and should be consulted before attempting an alignment.

V1A 6U8 Triode:
10.7 MC Sweep Oscillator
Very High Frequency Oscillator (90, 100, 107 MC)

V1B 6U8 Pentode:
400 CPS Modulation Oscillator
100 KC Sub-marker Oscillator

V2A 6U8 Triode:
Cathode Follower Output Amplifier

V2B 6U8 Pentode:
Crystal Marker Oscillator (10.0 MC, 10.7 MC)

Table III: Heathkit FMO-1 Tube Functions

The FMO-1 FM Test Oscillator Circuitry:
FMO-1 consists of a series of oscillators. These are the Sweep Oscillator, the Very High Frequency (VHF) Oscillator, the 400 cps Modulation Oscillator, the 100 kc. Sub-Marker Oscillator. and Crystal Marker Oscillator. There is also a cathode follower output stage to provide a low and high impedance output signal (switch selected). This is all done with two 6U8 dual-section (triode and pentode) tubes. Table 3 shows the tube lineup and their functions. Two of the tube sections perform two oscillator functions, so not all signals are available at all times; however, the way they are arranged, there should be no reason to need to do so.

Simplified schematics of each circuit is presented as part of their discussion. These schematics are from the Heathkit manual with added notations. Note that none of the extensive switching is shown. The schematics represent the circuit as it is when selected. The full schematic may be found at:

http://www.w6ze.org/Heathkit/Sch/FMO-1-Sch.jpg

The 10.7 MC Sweep Oscillator (V1A):
A triode Hartley circuit is used for the sweep oscillator (see fig. 5A). Part of the capacitance for the resonant circuit is the diode.

The effective capacitance of a diode that is back-biased depends on the applied voltage. This voltage is derived from the filament supply and causes the oscillator frequency to change at a 60 cycle rate around the 10.7 mc. center frequency. During the negative half of the 60 cycle the voltage is coupled to the grid through C13 turning off the oscillator and effectively flat-lining the return trace. The level of the applied AC voltage determines the width of the sweep frequency and is adjustable by the **SWEEP WIDTH** control. R2 provides a DC return path for the diode bias voltage.

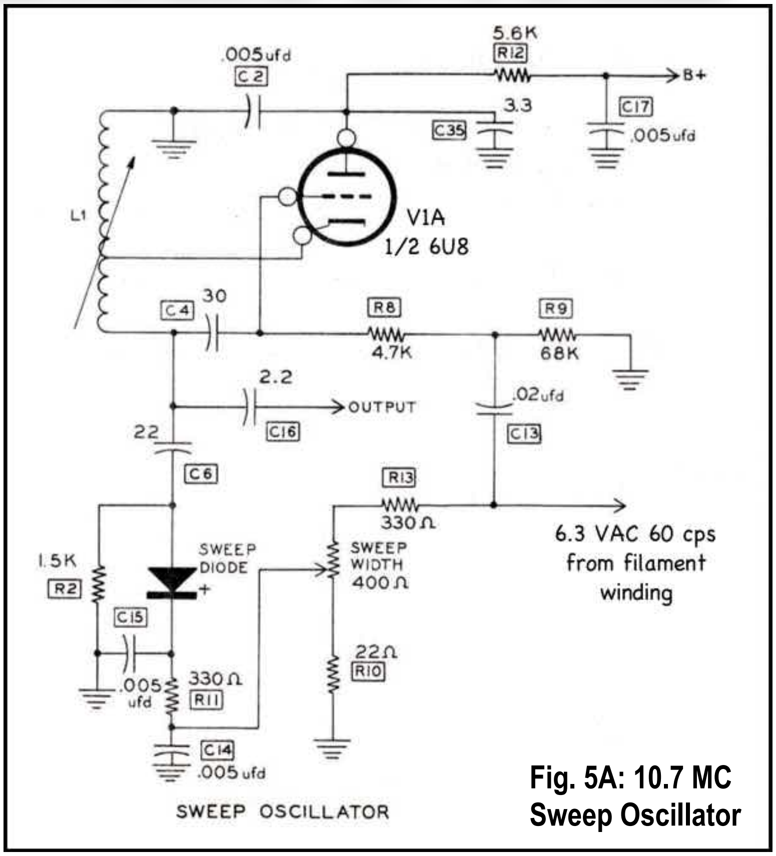

Fig. 5A: 10.7 MC Sweep Oscillator

<u>Very High Frequency (VHF) Oscillator</u> (V1A): The VHF oscillator uses the same tube section as the sweep oscillator, V1A. When one of the three VHF frequencies (90, 100, or 107 mc.) are selected, V1A operates as a Colpitts oscillator with either L2, L3 or L4 switched in depending on the desired frequency (see Fig. 5B).

This oscillator may be modulated if desired. The modulation signal is coupled to the plate of the tube. The resulting audio voltage causes the oscillator to vary slightly in frequency resulting in incidental FM modulation. Modulation at either 400 cps or 100 kc may be selected.

Many of the components of the sweep oscillator are also used in the VHF oscillator circuit. These include: R12, C2, C16, C17, and C35.

<u>400 CPS Modulation Oscillator</u> (V1B): An electron coupled Hartley oscillator produces a nominal 400-cycle audio signal used to modulate the sweep and HF oscillators (see .Fig. 5C). This oscillator uses the pentode section of V1 (the suppressor grid is not shown). A center tapped audio choke, which along with C22, form an LC circuit that determines the frequency. Feedback to sustain oscillation is from the screen grid, and the signal is taken from the plate; this "electron coupling" helps isolate the plate load from the oscillator, improving stability.

The 400 cps signal is available as an output as well as a modulation source, and can be used for troubleshooting the audio circuits of the device under test.

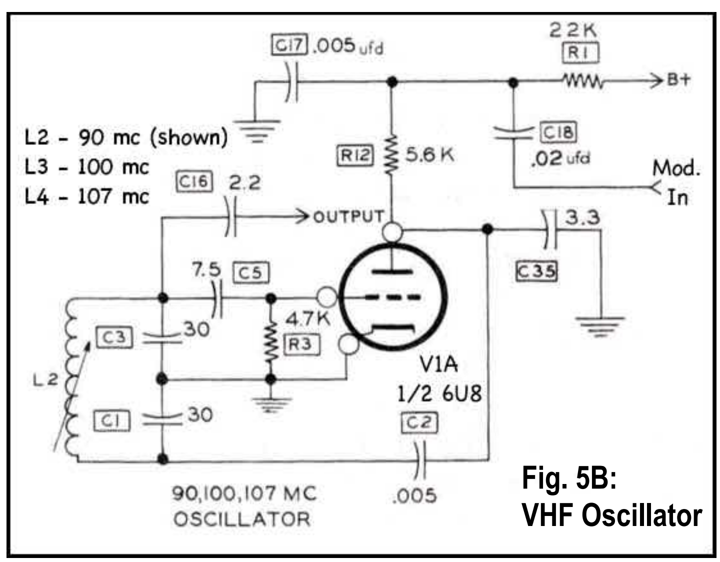

Fig. 5B: VHF Oscillator

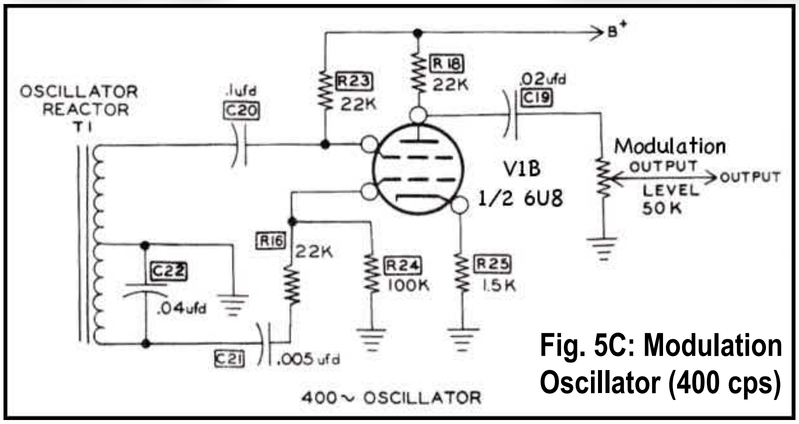

Fig. 5C: Modulation Oscillator (400 cps)

100 KC Sub-Marker Oscillator (V1B):
TThis oscillator utilizes the same pentode section of V1B as the 400 cps modulation oscillator. It too is an electron coupled Hartley oscillator, but uses L7 and C29 as the tank circuit to form a 100 kc oscillator in a circuit very similar to the previous oscillator (see Fig. 5D). Common components include: C19, R23 through R25, and the MODULATION LEVEL potentiometer. Since harmonic content is desirable for this oscillator, R16 is excluded, generating clipping and harmonics.

Crystal Marker Oscillator (V2B):
The pentode section of the second tube (V2B) is dedicated to the crystal marker oscillator (see Fig. 5E). An electron-coupled Pierce oscillator operates with either a 10.0 or 10.7 mc., switch-selected, crystal. The tube bias is set so the crystal will produce harmonics, as

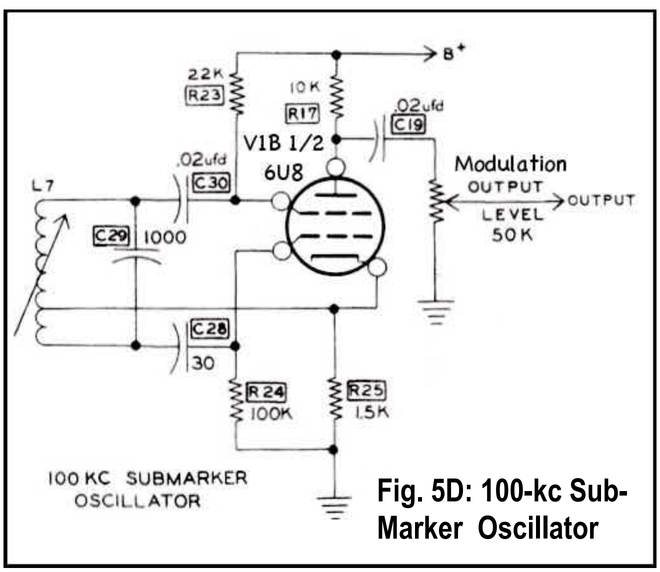

Fig. 5D: 100-kc Sub-Marker Oscillator

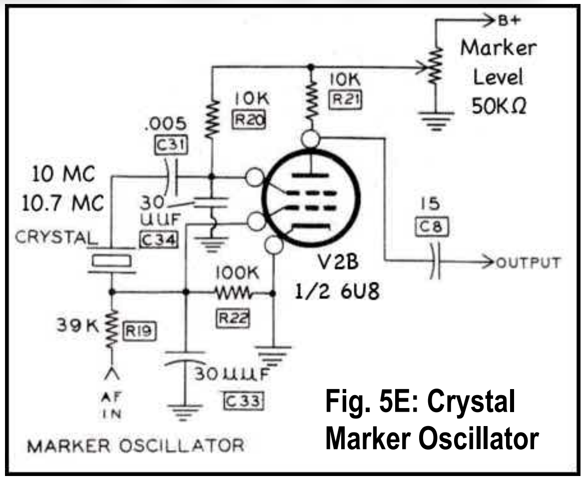

Fig. 5E: Crystal Marker Oscillator

this oscillator is also used to calibrate the 90, 100 and 107 mc. VHF oscillator frequencies.

The crystal marker oscillator can be modulated by either the 400 cps or 100 kc. modulation signal.

Output Circuit (V2A):
The output circuit (see Fig. 5F) is a cathode follower using the triode section of a 6U8 vacuum tube (V2A). Its input signal is either the VHF oscillator or the sweep oscillator. When using the sweep oscillator with the marker oscillator the latter signal is fed into the cathode of the follower. This prevents mixing of the two signals producing sum and difference frequencies. Instead the marker frequency appears as a pip on top of the sweep frequency marking where that frequency is located on the oscilloscope trace. When the 400 CPS modulation is output it is fed directly to the OUTPUT control, bypassing the cathode follower.

The **RF-AF** slide switch changes the output impedance of the FMO-1. In the RF position the output is a nominal 50 ohms. In the AF position the output is high impedance. During RF use the Hi-Z AF position may be used.

Power Supply:
The power supply (see Fig. 5G) uses a conventional transformer based half wave cir-

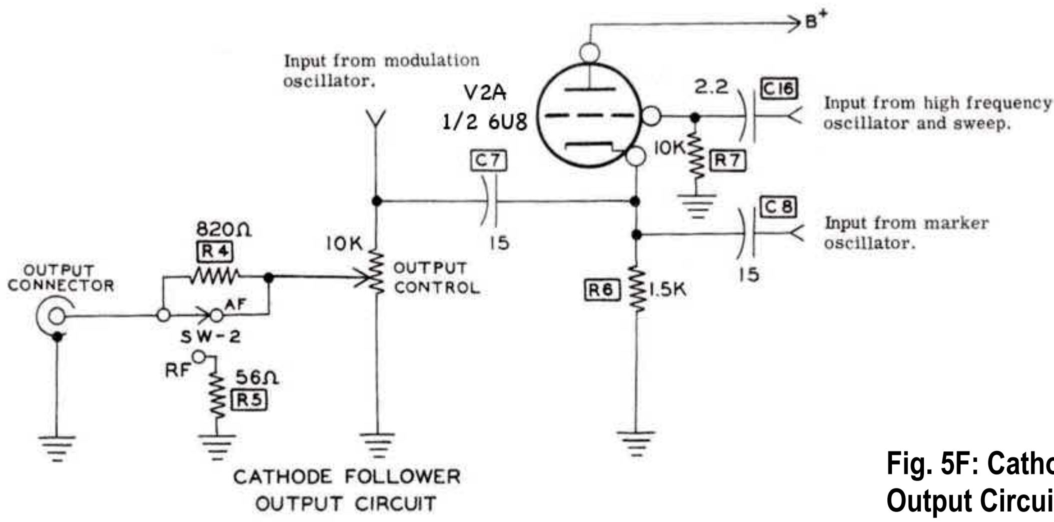

Fig. 5F: Cathode Follower Output Circuit

cuit. Plate B+ voltage rectification is by a low current sealed selenium rectifier. The supply provides a nominal 107 volts DC from a simple PI RC filter. An NE-2 neon bulb, driven by the B+ and current limited by R15, is used as a pilot light.

The transformer also supplies filament power to the two 6U8 tubes. The AC filament voltage is also used as the sweeping voltage and blanking signal or the 10.7 mc. sweep oscillator.

A dual PI LC filter, inline with the AC power where it enters the FMO-1, helps prevent RF from entering or leaving the FMO-1 via the power lines.

SUMMARY:

This unit was purchased used some years back. At that time it was used to align an FM-4 Heathkit tuner. Since then it has occasionally been used as an accurate 10.7 mc. signal source around the shack. Recently it was noted that the switching, which is quite extensive throughout the unit, was noisy. This FMO-1 now sits quietly awaiting a good cleaning, recapping and calibration. New capacitors to replace those that are over 50

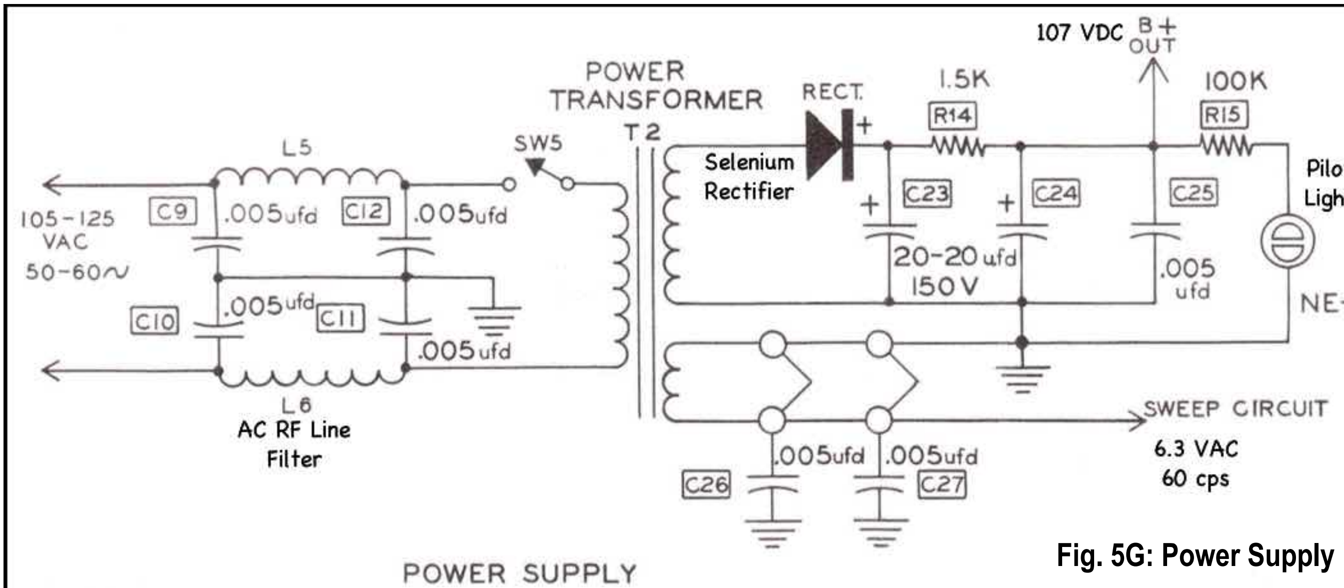

Fig. 5G: Power Supply

years old in the house, but due to low priority, the spare time to get to the job has not been found.

While good for broadband FM alignment, the sweep capability of the FMO-1 has not been tried for alignment of a narrowband FM communications device.

Other News:

Chuck Penson - WA7ZZE reports his latest book, ***Heathkit Hifi and Stereo Products*** has encountered a few publishing delays, but should be out in the next few months. I hope to write a review when it becomes available. Stay tuned.

Heathkit V-6 Restoration Project

At last October's OCARC radio auction I picked up a Heathkit V-6 VTVM. Upon opening it up I found serious corrosion where the battery had obviously leaked. I totally disassembled the kit, and finding the front panel and meter in good shape decided to do a complete rebuild. I was able to clean the damaged chassis parts and nickel-coat the damage. Right now I am awaiting the arrival of some parts before I start reassembling the VTVM. Sadly I didn't take photos of the original damage, but I still plan to do an article on the restoration of the V-6. Here's a shot of the chassis, as I started reassembly.

73, de AF6C

OUTPUT SIGNALS

Frequency	How Obtained	Use
400 cps audio	Direct switching	Testing audio circuits, Modulation signal[3]
100 kc.	Direct switching	Calibrating instruments, modulation signal, marker[3]
10.0 mc. (Xtal)	Direct switching	Calibrating instruments[1,2,3]
10.7 mc. (Xtal)	Direct switching	Calibrating instruments[1,2,3], center IF frequency, marker
10.7 mc. sweep	Direct switching	IF sweep alignment
90 mc.	Direct switching	Front-end alignment
96.3	10.7 mc. harmonic	Front-end alignment
100 mc.	Direct switching	Front-end alignment
107 mc.	Direct switching	Front-end alignment

The following may be modulated by 400 cps or 100 kc.:

10.0 mc. (AM)

10.7 mc. (AM)

90 mc. (AM plus incidental FM)

100 mc. (AM plus incidental FM)

107 mc. (AM plus incidental FM)

Notes:

1. Either crystal oscillator frequency may be used simultaneously with any other available frequency (the 400 cps and 100 kc. are modulating signals, rather than being mixed).
2. The output from the crystal (marker) oscillator may be mixed with the output from the VHF oscillator at the same time one of the two is being modulated with the 400 cps or 100 kc. signal.
3. The small red knobs control the output amplitude of the modulation and marker oscillators independently. The main **OUTPUT** control adjusts the level of all signals appearing at the output connector simultaneously.

Table IV: Summary of Output Signals & Modulation Capability
(Information for this Table came directly from page 45 of the Heathkit FMO-1 manual.)

Here is a link to the index of Heathkit of the Month (HotM) articles:

http://www.w6ze.org/Heathkit/Heathkit_Index.html