Heathkit of the Month:
by Bob Eckweiler, AF6C

Heathkit

Heathkit VC-3 Voltage Calibrator.

Figure 1: Heathkit VC-3 Voltage Calibrator

Introduction:

The August 2013 Heathkit of the Month (#51) covered the IG-4505 Deluxe Oscilloscope Calibrator. It also briefly covered the VC-3 Voltage Calibrator using information gleaned from catalogs. To my surprise Bill - K6WHP recently presented me with a VC-3 complete with manual. One look at the unusual schematic and I knew it deserved an article all its own.

The VC-3 (Figure 1), third in the Heathkit line of oscilloscope voltage calibrators that were first introduced in 1952, appeared in late 1956. Figure 2 shows an ad for the Heathkit VC-3 from the 1958 catalog. It remained in production through 1962 at a price of $12.50. In those days the oscilloscope was the most prolific of Heathkit's products. From the O-1 oscilloscope (Heathkit's first electronic kit) introduced in September of 1947 through the end of 1956 Heathkit sold 14 different models, the O-1 through O-11, the OL-1, the OM-1 and OM-2. All had 5" CRTs except the OL-1 (3"), and all had AC coupled amplifiers and multivibrator sweep circuits. DC coupling and triggered sweep were on the horizon for Heathkit, but not yet incorporated. The first Heathkit oscilloscope featuring these improvements came in the fall of 1958, the OP-1 Professional Oscilloscope Kit. It sold for $179.95, about 2-1/2 times more than their previous top-of-the line Heathkit oscilloscope.

The Heathkit VC-3:

Prior to the OP-1, most of the hobby-grade oscilloscopes on the market had at best a 1 volt peak-to-peak test point that one could use to approximate the voltage of a wave form. Since the gains were mostly uncalibrated and the attenuator steps a full decade apart, measuring voltage was difficult without a way to compare it with a known signal. The VC-3 provides the ability to make that comparison easily.

The VC-3 puts out a rather impressive approximate 1 kc square wave that has an accu-

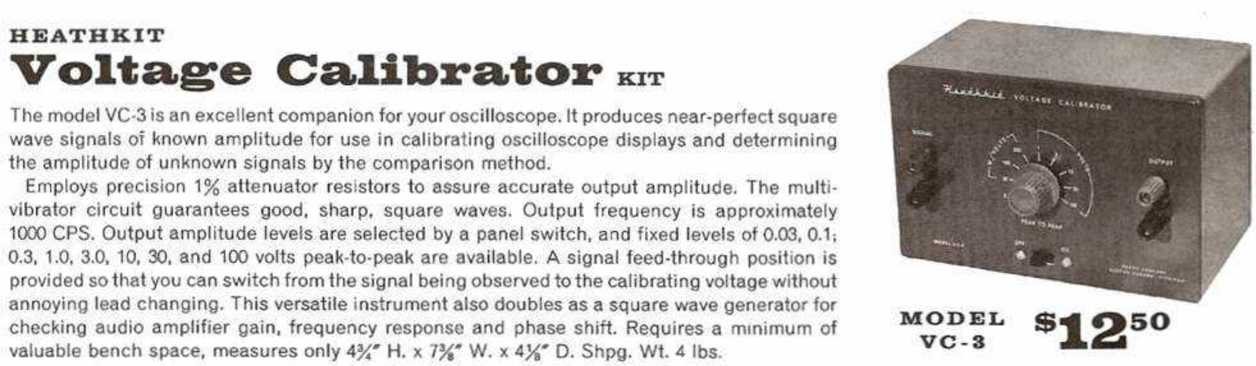

Figure 2: Heathkit VC-3 ad from the main 1958 Catalog

rate peak-to-peak voltage that can be set to one of eight ranges: 30mV, 100mV, 300mV, 1.0V, 3.0V, 10V, 30V and 100V. Being a square wave with flat tops and bottoms the calibration can be more easily set than when using a sine wave. The VC-3 also has an input to accept the signal under test and an output that connects to the oscilloscope input, so the user can switch between the signal being observed and the calibration signal with the turn of a switch.

The layout of the Heathkit VC-3 front panel is straightforward with only two switches and two dual binding posts. On the left is a pair of five-way binding posts marked **SIGNAL**, the upper one being colored red and the lower one black. On the right is a similar set of binding posts marked **OUTPUT**. Dead-center on the front panel is a nine-position rotary switch. The switch positions are marked in clockwise order: **SIG**[nal], **30**, **100**, **300**, **1**, **3**, **10**, **30**, **100**. The second through fourth positions are bracketed with the nomenclature **M/VOLTS**, and the last five positions are bracketed **VOLTS**. **PEAK TO PEAK** is marked below the switch. Below the rotary switch is the power switch – a slide switch marked **OFF ON**. Other nomenclature on the front panel are: ***Heathkit* VOLTAGE CALIBRATOR** across the top, **MODEL VC-3** at left bottom and **HEATH COMPANY BENTON HARBOR, MICHIGAN** on two lines at right bottom.

The VC-3 is housed in a 4–3/4 H x 7–3/8 W x 4–1/8 D gray cabinet and a dark gray front panel with white nomenclature. The cabinet (part# 90-39) is the same as used in many other Heathkit models of the time including the AM-2 SWR bridge and the QF-1 Q-Multiplier.

Heathkit VC-3 Operation:

Operation is simple. Connect the VC-3 OUTPUT posts to the vertical input of the oscilloscope. Connect the signal to be viewed to the INPUT posts of the VC-3. Place the PEAK TO PEAK rotary switch in the SIG position and adjust the scope to view the signal as desired. Next, switch the PEAK TO PEAK switch slowly clockwise until the square wave vertical amplitude covers a reasonable amount of the screen's vertical real estate and adjust the scope's vertical gain a small amount as needed to have the square wave cover a number of vertical divisions on the scope graticule. You can then easily calculate the vertical volts/division at the current vertical gain setting. Now return the PEAK TO PEAK switch to SIG, adjust the vertical position as needed, but don't touch the vertical gain. Since you now know how many volts each division is, you can measure the signal's peak-to-peak amplitude.

VC-3 Limitations:

There is one caution Heathkit mentions in the manual about using the VC-3. It involves using the VC-3 inline with signals having sharp rise-times or high frequencies over 100 kilocycles. If you are measuring such signals then the signal should be applied directly to the scope and not through the VC-3. The necessitates swapping the signal and VC-3 at the scope terminals as needed to make a voltage measurement. The reason is simple, the signal path through the VC-3 involves wiring that adds about 35 μμf (pF in today's lingo) of shunt capacitance to the signal and this will cause attenuation of higher frequency components of complex waveforms. Still, having to swap leads at the scope vertical

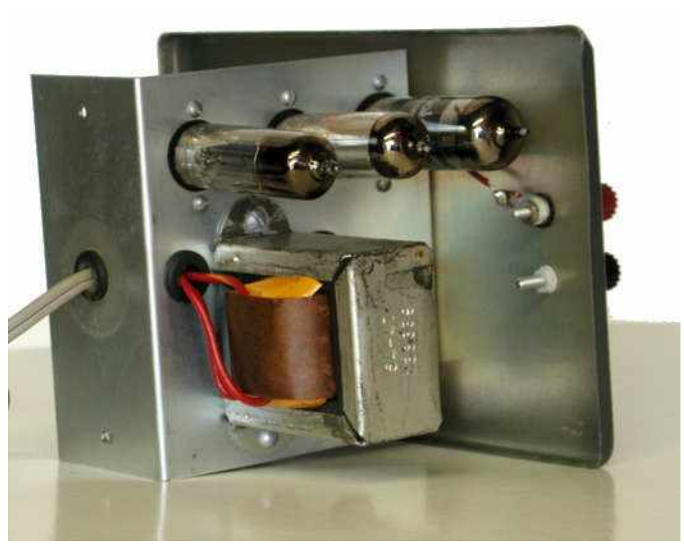

Figure 3: VC-3 inside left, showing the vertical chassis, transformer and three tubes (L to R) 6X4, 0A2 & 6AW8.

input is a small price to pay for being able to make reasonable voltage measurements on an otherwise uncalibrated piece of test equipment. For audio and low frequency measurements the oscilloscope can be left permanently connected through the VC-3.

VC-3 Circuit Description:

The schematic diagram of the VC-3 is shown in Figure 6. Probably what catches the eye first is that the tubes are drawn upside down! In fact looking a little closer the whole power supply is wired to produce a negative voltage. The VC-3 contains three tubes, a 6X4 dual diode rectifier, an 0A2 VR (voltage regulator) tube and a dual-section 6AW8 triode - pentode tube. The first two tubes function in the power supply while the third, dual-section, tube functions as a 1 kilocycle, symmetrical, free-running, square wave multivibrator. Output from the multivibrator goes through a switched precision voltage divider to produce proper calibrated voltage. Each of these three sections will be discussed separately.

<u>The VC-3 Power Supply Circuit</u>**:**

The power supply is transformer based, providing 6.3 VAC filament voltage to two of the tubes and 400 VCT to the plates of the 6X4 rectifier, producing about 230 VDC relative to the center-tap of the transformer. The DC is filtered by a 20 uF electrolytic capacitor. The negative side of the 230 volts goes to the the cathode of the 0A2 "cold-cathode" VR tube, and the positive side goes to the plate of the 0A2 VR tube through a dropping resistance of 3.4 KΩ (composed of two 6.8 KΩ 2-watt resistors in parallel). "Cold-cathode" refers to the fact the tube has no filament. Instead the tube contains an inert gas mixture that conducts at a given voltage (150 volts nominal for the 0A2); as it conducts it draws more or less current through the 3.4KΩ resistance keeping the voltage at the anode constant with respect to the cathode. A jumper between pins is used to disconnect the circuit should the tube be removed, preventing higher and possibly damaging voltages appearing.

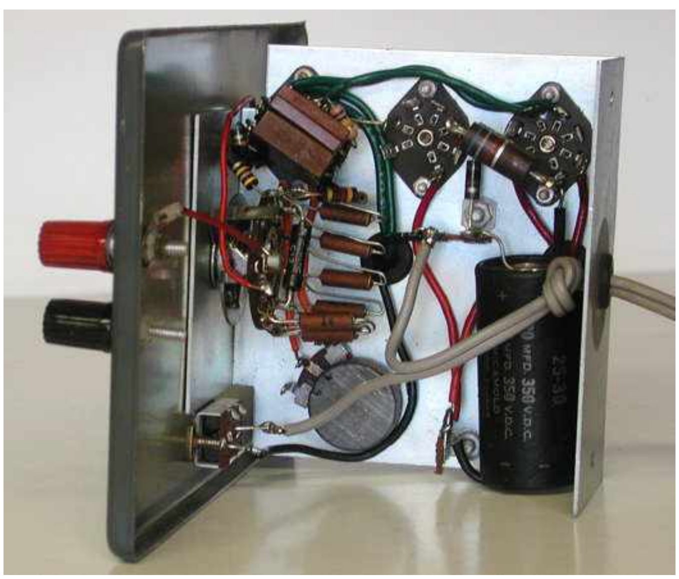

Figure 4: VC-3 inside right; the dual electrolytic capacitor is lower right, cal. pot lower center and rotary switch with precision resistors center towards left.

Placing a large capacitance across a VR tube often leads to instability, and the 20 µF electrolytic is 200 times higher than the recommended maximum capacitance, so a 100 Ω resistor is placed between the two for isolation. At first it was baffling as to why the resistor and capacitor are where they are. A simple C-R-C filter before the 3.4 KΩ dropping resistance would be a better choice - as the 100 Ω resistor reduces the regulation of the VR tube. Opening the unit revealed the answer - cost. The two 20 µF electrolytic capacitors are in the same package and share a common negative terminal. Hence the circuit was designed to fit this criteria. Using two separate capacitors would add significantly to the price of a kit that sold for $12.50, especially since the capacitor used was one common in many kits and bought in large quantities, likely at a good price break.

The output of the power supply is across the second 20 µF capacitor. The positive side is grounded and the negative side is passed through the jumper in the VR tube and on to the cathodes of the dual section multivibrator tube. Notice that neither side of the filament winding is grounded; instead one side is connected to the negative side of the power supply. This is done so the voltage between the cathode and filament will not exceed the filament to cathode maximum rating of 100 VDC.

The VC-3 Multivibrator Circuit:
The two 6AW8 tube sections are wired as a free running multivibrator. The triode section acting as one half the multivibrator and the pentode section as the other. The pentode section is wired as a triode with the screen-grid acting as the multivibrator plate with the actual plate isolated as in an electron-coupled oscillator. This isolation significantly reduces the influence of plate load changes on the frequency and waveform of the multivibrator. The frequency and duty cycle of the multivibrator are determined by the 470 KΩ and 4.7 KΩ plate resistors and the 0.0013 and 0.003 µF mica coupling capacitors. These values were selected for a nominal frequency of 1,000 cps and 50% duty factor. They vary significantly from each other due to the characteristics of the different tube sections.

VC-3 Output Switching Circuit:
The plate load of the pentode section of the 6AW8 is provided by a 20 KΩ precision voltage divider in series with an internal 10 KΩ variable calibration resistor. The positive side of the power supply is at ground potential, so one of the output terminals may be also. This is the reason that the power supply was designed with the positive side connected to ground.

Switch Position	Resistor	Resistor Sum	Voltage
1	n/a	n/a	(SIG)
2	6 Ω	6 Ω	0.03 V
3	14 Ω	20 Ω	0.1 V
4	40 Ω	60 Ω	0.3 V
5	140 Ω	200 Ω	1.0 V
6	400 Ω	600 Ω	3.0 V
7	1.4 KΩ	2.0 KΩ	10 V
8	4.0 KΩ	6.0 KΩ	30 V
9	14 KΩ	20 KΩ	100V

- Column Two is the values of the resistor chain. If you sum them all they add up to 20.0 KΩ
- Column Three is the sum of the resistors up to and including the switch position of the row.
- Column Four is the output voltage determined by: ((value in column 3) / 20 KΩ) * 100 V.

Table I - VC-3 Precision Voltage Divider Output Chain

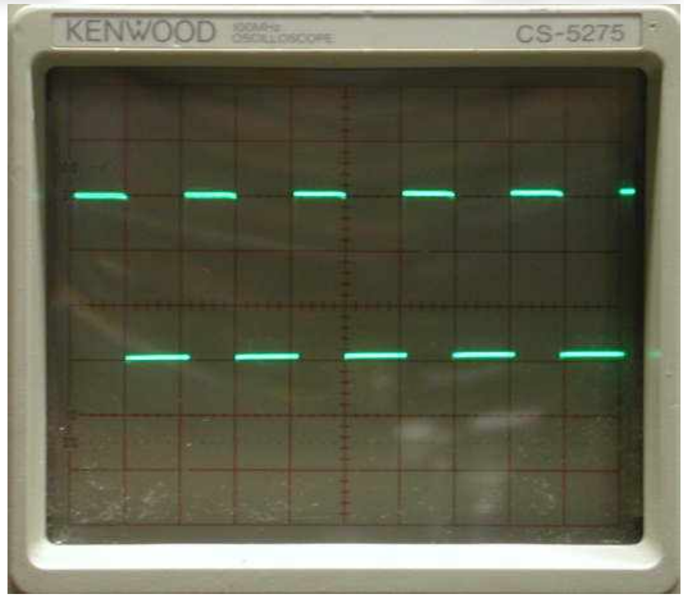

Figure 5: Modern oscilloscope screen showing the VC-3 output set to 3 V. (1 v/div Vert., 500 µS/div Horiz.)

The actual voltage at the plate (pin 9) of the pentode section varies from zero when the tube is cut off to approximately 135 volts negative when the tube is conducting. The calibration resistor connected between the voltage-divider chain and the plate is adjusted so the top of the chain is at -100 VDC when the tube is conducting. The resistor chain is composed of eight 1% precision resistors that sum to 20.0 KΩ. The resistor values and corresponding output voltages are given in Table I.

One obvious idiosyncrasy of the output signal is that it is a negative going square wave. This, however, should make no difference for AC coupled oscilloscope amplifiers, and eliminates capacitive coupling within the VC-3 that would only distort the waveform and introduce inaccuracies.

Since the impedance of the precision voltage divider is low compared to the one-megohm impedance of most Heathkit scopes of the day, negligible attenuation occurs. When the switch is in the SIG position, plate voltage is removed from the 6AW8 preventing calibrator noise on the output.

Summary:

Perusing the manual, the kit appears easy to assemble. The actual step-by-step instructions go from the bottom of page 6 to about an inch onto page 12, and two of those pages are full-page pictorials. Also included on those pages are seven figures and a detail drawing.

Looking at this manual, earlier manuals and more recent manuals it is evident the manuals, for which Heathkit is so well known, have evolved substantially over the years. This might make a good topic for a future Heathkit article.

Next month is the dreaded April issue. I have a few ideas but have not chosen one. Between now and then I'll be supporting the Baker-to-Vegas race and completing some family responsibilities that are time critical, (oh and taxes too.)

I've gotten numerous requests to write on the HW-12 & 12A series. If anyone has a PDF copy of the HW-12A, 22, 22A 32 or 32A manual please contact me and I'll try cover the series in a future Heathkit article; I have a copy of the HW-12 (non-A) manual.

I'd like to especially thank Bill - K6WHP for providing the VC-3 for this article, with a manual no less!

73, from AF6C

This article originally appeared in the March 2015 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.

Thanks - AF6C

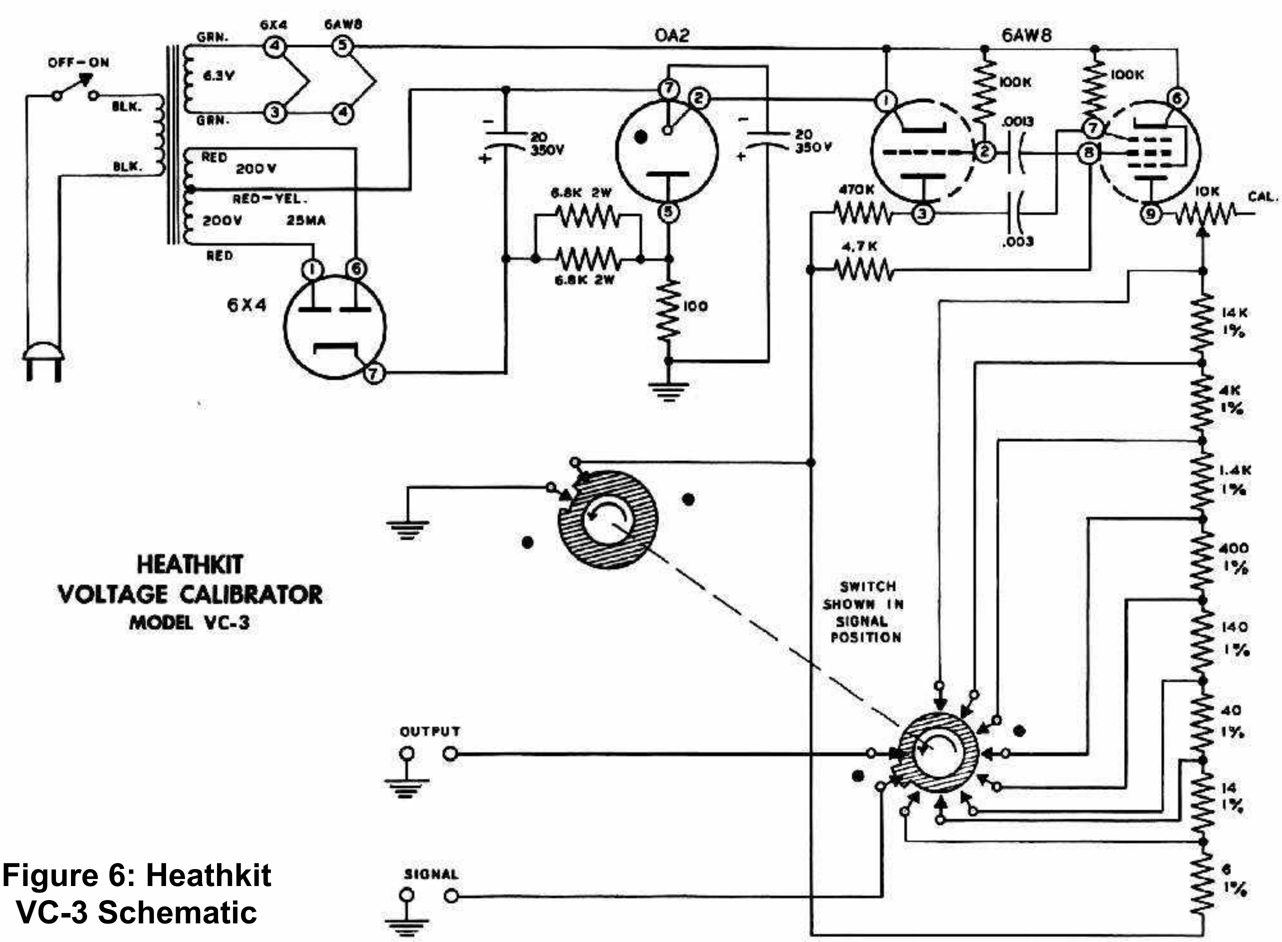

Figure 6: Heathkit VC-3 Schematic

