Heathkit of the Month #85:
by Bob Eckweiler, AF6C

Heathkit

ELECTRONIC TEST EQUIPMENT

Heathkit 'O' Series Oscilloscopes Part I O-1 through O-4

Introduction:

The first electronic kit to carry the Heathkit brand was introduced in an ad in the July 1947 issue of ***Radio News***. This ad for an "Oscilloscope Kit" for $39.50 was just nine lines at the bottom of a full column ad (1/3 page) featuring 94 other electronic items. The "Oscilloscope Kit" was later designated the **O-1**[1] (See **figure 1**). A reproduction of the nine-line ad is shown in **figure 2**. The next two ads appear in the September and November 1947 issues with photos; the first, under the heading **HEATHKIT 5" OSCILLOSCOPE** (**Figure 3**) and the second alongside the parts that make up the scope (Figure 4).

A total of twelve versions of the 'O' series of scopes were released on an average yearly cycle until 1960. Heathkit kept the price constant until late 1951, but with the O-7 the kit's cost began to climb to the point, where in 1954, Heathkit began releasing four less expensive scopes, the 3" **OL-1** (HotM #41) and three less-expensive 5" scopes, the **OM-1**, **OM-2** and **OM-3**. These won't be covered as part of the **'O'** series; nor will two other scopes, the **OP-1** "Professional" and the **OR-1**

[1] Notes appear at the end of the article.

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

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

Figure 1: The First Heathkit: The O-1 Oscilloscope. (Handle appears to be from a later model scope)

"Research" scopes that feature DC coupling. The OP-1 sold for more than two-and-a-half times the cost of the **O-12**, and the OR-1 sold for just under twice the cost of the O-12.

The O-1 through O-4 Oscilloscope CRT:

The Cathode Ray Tube (CRT) commonly used in the O-1 through O-4 is the 5BP1[2]. The initial number for this CRT designation (and many others) is the screen diameter, (nominally 5") a one or more character identification (B here) and a P followed by a number is the phosphor used in the screen. P1 is probably the most common for oscilloscopes; when hit by electrons it produces a medium persistence green fluorescence.

Rumor has it that Heath Company purchased a boxcar full of 5BP1 CRTs as war

OSCILLOSCOPE KIT

Complete 5" Oscilloscope Kit includes punched and formed steel case, chassis, lettered panel, all tubes, oil filled condensers, cased scope transformer. frequency compensated amplifiers. 15 - 30,000 cycle sweep generator, every part supplied complete with diagram and instructions and excellent training course $39.50

Fig. 2: Text of the first (9-line) O-1 Ad. *Radio News* July 1947

surplus. And this got them started in manufacturing their first kit oscilloscope. Starting in June 1948 Heath warned about a possible CRT shortage in their flyer and in the subsequent *Radio News* ad; it stated *"Order one now while surplus tubes make this extremely low price possible"*. However, Heath evidently found more sources because the $39.50 price remained the same through the O-4 and beyond. Some of those surplus tubes evidently turned out to have the P4 phosphor, so for awhile Heath specified the CRT as either the 5BP1 or 5BP4 for the O-3 and O-4. P4 is a medium persistence white phosphor also used in early black and white TVs.

The early Heath surplus ads were selling a lot of metal oil-filled condensers [3], and bathtub condensers, as were many surplus houses. These normally expensive and high quality parts could be had for a song after the war. Their long life (at the price of size and weight) can be attested to today, as many of these are functioning as well today as in the forties. Heath used these condensers in their early model scopes, but started phasing them out starting with the O-4.

All of the scopes include a **60 CY. TEST** binding post. This is a connection to the 6.3 V rms. filament line through a current limiting 10KΩ resistor. It can be used to check scope calibration and operation.

The Heathkit Model O-1

Announced in July of 1947, and replaced with the O-2 in an ad in the February 1948 issue of ***RadioNews***, the O-1 is a behemoth of a scope weighing about 55 lb.[4]; it is likely the heaviest scope Heathkit ever made. The

Figure 3: First image of the Heathkit 5" Scope (O-1) from the Heath ad in the September 1947 issue of ***Radio News***. Also this ad is the first use of the name ***Heathkit*** !

Figure 4: November 1947 issue of ***Radio News***. shows the Heath 5" O'scope (O-1) along side a layout of the parts used.

large weight is due to the steel cabinet and chassis, and a large sealed war surplus power transformer that was only used in the O-1. It was replaced with smaller, lighter ones in the later o'scopes. The cabinet measures 15" H x 10" W x 17" D. The depth of this scope and, most others, is determined by the length of the CRT. Heathkit did make a few larger scopes; most notably the IO-14 with dimensions of 15" H x 10.5" W x 22" D. But the IO-14 weights 15 lb. less and has 20 more tubes than the O-1. Little documentation exists on the O-1; these early Heathkits didn't come with the famous manuals accompanying later kits. Instead they came with five individual sheets: schematic, parts, instruction, construction and an isometric drawing [5]. Only the schematic sheet is available to this author. It wasn't until the O-3 that Heathkit started a part number system, which was replaced not too many years later with the one that has been in use since. The O-1 parts carry R1, R2 … Rn and C1, C2 … Cn type designations, etc. Part values are not on the schematic but instead on a separate parts sheet. Some schematics available for the O-1 and O-2 scopes contain penciled in values for some of the components. These marks were probably done by the builder. Many of these are reasonable in value, but others seem questionable.

ABBREVIATIONS Used in Tables I-2 to I-4:

BLK.	Blanking	**HORIZ.**	Horizontal
CY.	Cycle	**INT.**	Internal / Intensity
DWN.	Down	**INTEN.**	Intensity
EXT.	External	**K**	x 1,000
FREQ.	Frequency	**M**	x 1,000 (really!)
GEN.	Generator	**SYN.**	Synchronization
GND.	Ground	**VERT.**	Vertical
HOR.	Horizontal		

TABLE I-1

Heathkit O-1 Specifications:

Very few specifications were given for the O-1 other than the sweep frequency range spanning 15 cps to 30K cps. Other specs can be

Heathkit O-1 Front Panel Layout

The left third (top-to-near bottom):

INTEN.	Potentiometer
scale is circular CW arrow.	
VERTICAL POSITIONING	Potentiometer
scale is circular CW arrow.	
SYN. INPUT	Binding post
VERT. INPUT	Binding post
(Vertical) **GAIN**	Potentiometer
100, **90**, **80** ,**70**, …, **10**, **0** (arbitrary scale)	

The center third (top-to-near bottom):

CRT Screen	five-inch diameter
SYN.	Potentiometer
0, **10**, **20** ,**30**, …, **90**, **100** (arbitrary scale)	
(Sweep) **FREQ.**	Rotary switch 7-pos.
HORIZ. INPUT, **15** - 60, **60** - 220, **220** - 900	
900 - 3K, **3K** - 10K, **10K** - **30K** (cps - coarse)	
(Sweep) **FINE FREQ.**	Potentiometer
0, **10**, **20** ,**30**, …, **90**, **100** (arbitrary scale)	

The right third (top-to-near bottom):

FOCUS	Potentiometer
scale is circular CW arrow	
HORIZONTAL POSITIONING	Potentiometer
scale is circular CW arrow.	
60 CY. TEST (6.3 volts)	Binding post
HORIZ. INPUT	Binding post
(Horizontal) **GAIN**	Potentiometer
100, **90**, **80** ,**70**, …, **10**, **0** (arbitrary scale)	

The full bottom row L to R):

GND	Binding post
INT. SYN. / **EXT.**	Toggle switch, SPDT
BLK. IN / **OUT**	Toggle switch, SPDT
Pilot lamp	Jeweled red Indicator
Power **ON** / **OFF**	Toggle switch, SPST
GND	Binding post

Note: Bold capital text represents actual front panel printing
See Table I-1 for abbreviations used here.

Table I-2

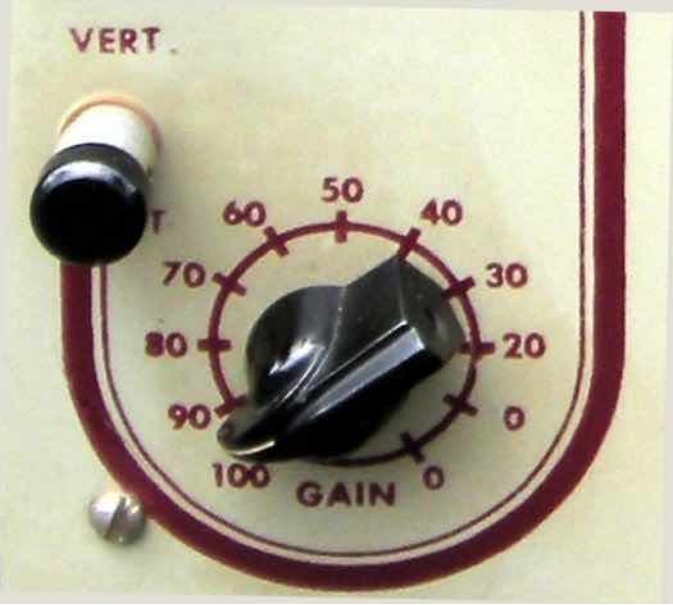


Figure 5: O-1 vertical gain control showing reversed scale. Horizontal control is identical.

gleaned from the front panel controls but one mostly has to assume they are close to the O-2 model which came out at the end of 1947. Table III, near the end of this article shows the published specifications of the O-1 through O-4 oscilloscopes.

The O-1 Front Panel:

The O-1 front panel came painted in the colors Heathkit would use until sometime in 1954, a cream-beige color and maroon red. There's plenty of room on the large front panel for the O-1 controls. Table I-2 shows the layout and nomenclature (in bold) of the controls and connections. At the top of the front panel is the word "Heathkit" in a script logo form [6], followed by the word "Oscilloscope" in a san-serif font. The six binding posts on the front panel are of the style that allows you to push in on the insulated black cap and then insert a wire or pin-plug into the hole. Releasing the black cap causes spring pressure to hold the wire or pin in place. These were probably obtained as war surplus. Similar style posts can be found on war surplus equipment, often as antenna connectors.

Of interest are the vertical and horizontal **GAIN** controls. They appear to work backwards from normal as shown by 100 at the full counterclockwise position and 0 at the full clockwise position; see **figure 5**. Subsequent scopes were numbered clockwise.

Also of interest is the coarse sweep FREQ. switch. It is a six position rotary switch on the original schematic, but a seven position switch on the o'scope photos available.

Heathkit O-1 Circuit Description:

A readable but poor copy of a Heathkit O-1 oscilloscope schematic was obtained [7]. It has been redrawn using a vector graphic program and appears at the end of this writeup. Component values hand-written on the original are included but should not be trusted.

The Heathkit O-1 uses five tubes plus the CRT. They are shown in Table II. Four of the tubes are standard vacuum tubes of the period, one is the CRT and the last is a thyratron gas tube. These same tubes, or equivalent substitutes, are also used in the O-2, O-3 and O-4.

The O-1 circuit can be divided into five areas: The B+ power supply; the HV power supply; the vertical amplifier, the horizontal amplifier and the sweep generator:

The B+ Power Supply:

The heart of the two power supplies is the transformer. This massive potted unit has 18 ceramic solder terminals and six secondary windings including four filament windings: one 5V winding for each 5Y3 rectifier; one 6.3V isolated winding for the CRT; and one 6.3V winding for the remaining tubes. There is also a center tapped winding for the B+ on the order of 600 to 700 VAC and a 575 volt winding between one side of the B+ winding and the HV filament winding for the high voltage [8].

The B+ winding is rectified in a full-wave configuration by one of the 5Y3 tubes and the output is filtered by a dual 5 µf surplus oil-filled condenser (C11 and C12) and an 6 henry choke CH1). B+ output is guessed to be around 300 to 350 volts DC. Current requirements are low for the B+ circuits, less than 50 ma.

The High Voltage Power Supply:

the 5BP1 CRT requires negative high voltage on the order to 1 to 2 KV. The O-1 HV power supply produces about –1,000 volts. One half of the 350 volt B+ winding is connected in series with a low current 575 volt winding. At the top of this winding is a well insulated 5V 2 ampere winding. The five volt winding supplies filament power to another 5Y3 rectifier tube. The two plates of this 5Y3 are wired together to make the tube a single diode rectifier. Output from the plates is filtered with an HV oil condenser. The two series winding produce about 925 volts rms. which should result in a DC voltage somewhere around –1000 volts to –1200 VDC. For this article an assumption of –1000 VDC will be made. The war surplus oil-filled filter condenser used is believed to be rated at 1000 V.

The choice of a 5Y3 rectifier is interesting. It has a peak inverse voltage rating of 1400 volts, yet with the plate held at –1000 VDC due to the charge on the filter condenser and the filament (cathode) at +1300 volts during the nonconducting peak part of the AC cycle, the PIV rating is over voltage by close to 900 volts! I have to assume Heath did a lot of experimenting before deciding on using this tube. HV rectifiers were expensive and this must have been a cost related decision. The 5Y3 continued to be used through the O-9 o'scope. With the O-10, the HV rectifier tube was changed to the 1V2 which has a PIV rating of over 6 KV. The 5Y3 tube must have worked well to have been used for so long, evidently without major problems.

A separate 6.3 volt filament winding for the CRT is necessary as the filament and cathode within the tube are in close proximity and could easily arc. To prevent this, the manufacturers internally connected one side of the filament and the CRT cathode together. Thus the filament is at a negative potential of around 1000 VDC and there is a separate (well insulated) filament winding for the CRT.

Output from the HV supply goes thru a chain of resistors, totaling about 1.2 megohms, to ground. the first resistor is the intensity control; the wiper goes to the CRT control grid and the low end of the pot goes to the CRT cathode. Thus, the grid is more negative than the cathode and the difference decreases as the pot is increase, lowering the bias on the grid and increasing the electrons striking the phosphorus screen. Next in the chain is a fixed resistor followed by the FOCUS pot; the wiper of this pot goes to the focus anode of the CRT, and the pot controls the focus voltage that causes the beam to converge at the screen. The low end of the FOCUS pot goes to ground through two more resistors. The junction of these resistors is around 120 volts negative and provides a negative voltage to one end of the positioning potentiometers.

The Vertical Amplifier:

The vertical amplifier consists of a single 6SJ7 pentode. A cathode resistor provides bias and negative feedback to improve linearity. Input

O-1 - O-4 Tube Lineup

#:	Tube #	Subst.	Type	Use
1	5Y3		Dual Diode	B+ Rectifier
2	5Y3		Dual Diode	HV Rectifier
3	6SJ7		Pentode	Vertical Amplifier
4	6SJ7		Pentode	Horizontal Amplifier
5	844	6Q5	Thyratron	Sweep Generator
6	5BP1	5BP4	CRT	Display

Table II

to the vertical amplifier is through a binding post; a corresponding ground post sits below it. The input is capacitively coupled to the grid of the 6SJ7 through the vertical gain potentiometer. Frequency compensation is by a peaking coil in series with the plate load resistor.

Screen voltage is obtained from a dropping resistor and a filter condenser to hold the screen voltage reasonably steady. The output of the RC network also supplies the horizontal amplifier's 6SJ7 tube. Screen voltage works out to be about 120 VDC with the values given.

The 5BP1 CRT has a nominal vertical plate sensitivity of 42 volts-per-inch of deflection. Thus, to get a vertical signal that fills the 5" vertical screen the voltage on the vertical deflection plates must be 210 volts peak-to-peak. This corresponds with an rms. AC voltage of just over 74 V rms. Assuming the plate load resistor is 100KΩ this works out to a current change of 2.1 ma. With a B+ voltage of 350 VDC the tube saturation current is 3.5 ma (ignoring cathode bias resistance). If the tube is biased at the center of the load line, the plate must swing from about 70 to 280 volts for five inches of deflection. Rough calculations give a gain of around 20 resulting in a maximum input sensitivity of 0.75 Vrms for a deflection of one-inch. This is close to the 0.65 V value given for the O-3 with its refined amplifier circuit.

The output of the vertical amplifier is coupled by a condenser to one of the vertical deflection plates so a negative changing plate voltage will result in upward deflection. The other vertical deflection plate is tied to ground. The **VERTICAL POSITION** potentiometer superimposes a DC bias between ±120 VDC on the vertical amplifier signal to set the trace vertical position. A separate output from the vertical amplifier is coupled through an isolation condenser to the INT./EXT. SYNc switch.

The Horizontal Amplifier:

The horizontal amplifier is identical to the vertical amplifier with two exceptions. There is no peaking coil to extend the frequency response and the trace positioning is done with the **HORIZONTAL POSITION** control. The horizontal deflection plates have lower volts-per-inch deflection and are slightly more sensitive.

The Sweep Circuit:

The heart of the O-1 sweep circuit is an 884 gas-filled thyratron triode. This tube normally does not conduct until the voltage between the plate and cathode reaches a "firing voltage". This voltage varies from around 25 to 300 volts depending on the negative bias on the grid; the more negative the grid, the higher the firing voltage. In the O-1 the grid bias is set to around 4.5 volts by R24 and R25. One of five timing condensers is selected by the **FREQ**uency switch and it appears between the cathode and plate of the thyratron. The timing condenser begins to charge from the B + supply through R27 and the **FINE FREQ**uency pot (R28).

In free running mode (no sync signal) the condenser continues to charge until it reaches about 35 volts at which time the thyratron fires and the timing condenser discharges rapidly. A small resistance (R23), in series with the plate, limits the discharge current to a safe value. Once the timing condenser is discharged the tube stops conducting and the condenser begins charging again. The voltage across the timing condenser is thus a sawtooth wave. Since the sawtooth voltage is only over about one tenth of the B+ voltage, the ramp up is quite linear, and since the discharge is rapid, the slope of the back edge of the sawtooth is almost vertical. This sawtooth sweep voltage is coupled to the horizontal amplifier to make the beam move across the

screen from left to right at a constant speed and then quickly back to the left.

When a sync signal is applied, either from an external source or the output of the vertical amplifier, the sweep will continue to work as before except that a positive going voltage, AC coupled to the grid of the thyratron through the **SYN**c pot will cause the thyratron to fire causing the trace to move rapidly to the left and start a new sweep. By adjusting the SYNc pot and the FINE FREQuency controls a cyclic event can be made to appear stationary on the face of the CRT. Once the thyratron has fired, sync signals will have no effect until the discharge of the timing condenser has finished and it is again charging.

To switch from horizontal sweep to an external horizontal input the FREQuency switch is moved to the **HORIZ. INPUT** position. This grounds the plate of the thyratron, stopping the sawtooth oscillations. Strangely, the horizontal input binding posts are connected to the sweep oscillator at all times. Thus any signal, or capacitance attached to the horizontal input terminals when in sweep mode can interfere with the timing. An isolation resistor (R3 - value unknown) provides some isolation to limit this problem. In subsequent scopes in the 'O' line the horizontal input is switched out entirely when not in use.

Blanking:

A switch on the front panel of the O-1 couples the top of the sweep condenser to the to grid 1 of the CRT through condenser. This has little effect when the timing condenser is charging, but the rapid discharge causes a negative pulse. This blanks (or dims) the CRT trace as it flies back from right to left due also to the discharge. This blanking may be turned off by the BLK switch on the front panel. Evidently it either didn't perform well or was not needed as blanking disappeared from the O - series scopes until the O-10.

The Heathkit O-2 Oscilloscope:

One only needs to see the O-2 oscilloscope next to the O-1 to know that there were major physical changes made. The O-2, which first appeared in the December - January (1947 / 1948) Heath flyer (See **figure 6**), and the in the Heath ad in the February 1948 issue of *Radio News*, is quite a bit smaller and less than half the weight of the O-1. Only the depth dimension remained the same at 17"- governed by the length of the CRT. Heathkit referred to this scope as the "New 1948 Heathkit 5 Inch Oscilloscope Kit". A slogan that never changed when the O-3 scope was released in mid 1948.

The front panel controls changed from the O-1. (See Table I-3 and Figure 7) The three controls down the center of the O-1 are now located in a triangular pattern in the center. Gone is the HORIZ. INPUT position on the sweep frequency switch, replaced by the **SWEEP GEN. / HOR. INPUT** toggle switch located among binding posts, a pilot light and other toggle switches in a double row across the bottom. The new style binding posts are screw type instead of push type. Also gone is the blanking switch of the O-1. The VERT. INPUT and HOR. INPUT binding posts, along with their associated GNDs, have been moved to the bottom two rows. The **INT. SYN / EXT. SYN, SWEEP GEN. / HOR. INPUT** and **ON / OFF** toggle switches are mounted horizontally instead of vertically.

Heathkit O-2 Circuit Changes:

The O-2 continues to use the parts identification scheme of the O-1. The power supplies utilize a lighter transformer; plate and HV winding voltages may have changed some, and a change to a single 2 μf filter condenser

The NEW 1948
HEATHKIT 5 INCH
OSCILLOSCOPE KIT

Features

- Frequency compensated vertical and horizontal amplifiers.
- Beautiful two color panel.
- Sweep circuit supplying 15 to 30,000 cycles.
- All controls on front panel.
- Ideal for television and radio trouble shooting.
- Convenient portable size—weighs only 26 pounds.
- Cabinet dimensions 8½" x 13" high by 17" deep.
- Provision for external synchronization.
- Test voltage post on front panel.
- Deflection sensitivity .65 volts per inch full gain.
- Frequency response plus or minus 20% from 50 cycles to 50 KC.
- Input impedance 1 megohm and 50 MMF.
- Tubes supplied: 2 6SJ7, 2 5Y3, 1 884, 1 5BP1.
- Operates from 110 volt 60 cycle AC.
- Power supply delivers 1100 volts negative, 350 volts positive, making 1450 volts available for the CR tube.
- All oil filled condensers used, assuring long life.

$39.50

Nothing ELSE TO BUY . . .

Figure 6: O-2 Ad from the Dec/Jan 1948/49 Heath Flyer introducing the New O-2 Scope.

for the HV results in a published 1,100 V CRT acceleration voltage. The ad also states: *"Power supply delivers 1100 volts negative, 350 volts positive, making 1450 volts available for the CR tube."* That voltage may be "available" but it is not used, the CRT acceleration anode remains connected to ground and not to the 350 volt B+.

The vertical and horizontal amplifiers have a few changes. Besides the loss of the peaking coil in the vertical amplifier, both now have 2 KΩ cathode resistors resulting in better operating gain (The O-1 is believed to use 820 Ω). The cathode resistors are bypassed by a 0.0068 µf condenser to boost higher frequency gain with a 3 db gain point at 12 kc. Vertical sensitivity is specified at 0.65 volts/inch and frequency response at 50 cps to 50 kc ±20% (+1.6 db to –1.9 db).

The third area of change is to the sweep generator. Instead of six sweep ranges there are now five, though they still cover the 15 cps to 30 kc sweep range, perhaps with less overlap. The other sweep generator change is that the horizontal input is totally switched out of the circuit when using sweep.

Heathkit O-2 Front Panel Layout

The top row (L to R):

INTEN.	Potentiometer
scale is circular CW arrow.	
CRT Screen	five-inch diameter
FOCUS	Potentiometer
scale is circular CW arrow	

The second row (L to R):

VERTICAL POSITION	Potentiometer
DWN. scale is circular CW arrow **UP**	
(Sweep) **FREQ. SELECTOR**	Rotary switch 6-pos.
15 - 60, **60** - 220, **220** - 900, **900** - 3K, **3K** - 10K, **10K** - **30K** (cps)	
HORIZONTAL POSITION	Potentiometer
LEFT scale is circular CW arrow **RIGHT**	

The third row (L to R):

(Vertical) **GAIN**	Potentiometer
SYNCRONIZING	Potentiometer
FREQ. VERNIER	Potentiometer
(Horizontal) **GAIN**	Potentiometer
(These four controls each have the same scale):	
0, **10**, **20** ,**30**, …, **90**, **100** (arbitrary scale)	

The fourth row L to R):

VERT. INPUT	Binding post
INT SYN / EXT SYN	Toggle switch, SPDT
Pilot lamp	Jeweled red Indicator
SWEEP GEN. / HOR. INPUT	Toggle switch, SPDT
HOR. INPUT	Binding post

The fifth row L to R):

GND.	Binding post
SYN. INPUT	Binding post
Power **ON** / **OFF**	Toggle switch, SPST
60 CY. TEST (6.3 volts)	Binding post
GND.	Binding post

Notes: Bold caps text represents actual front panel markings.
See Table I-1 for abbreviations used here.

Table I-3

Figure 7: The Heathkit O-2 Oscilloscope. Photo courtesy of Chuck Penson - WA7ZZE

The Heathkit O-3 Oscilloscope:

Heathkit released the O-3 oscilloscope and about the only clue it happened was that the top handle changed from a pull-drawer type to polished metal. This appears have been a good change. Note that the handle on the O-1 in figure 1 has been changed to the later style. Lifting 55 lb. with the original handle must have been painful. Careful observers will also note that the O-3 vertical and horizontal gain pots now have a switch at the fully counter-clockwise position. Fully CCW is marked as **PLATES** and the former 0 (zero) mark immediately clockwise says **AMP** (See **figure 8**). This added text can be seen on most ads that show the Heathkit front panel, which helps in detecting the O-3 model in an ad. Internally more changes happened.

Heathkit O-3 Circuit Changes:

Again the power transformer has been changed. Voltages appear the same, but the new transformer has wire leads instead of terminals used in the O-1 and O-2 transformers. The O-3 schematic [9] shows the color coding of these leads.

The most significant change is the ability to directly couple the vertical and horizontal inputs to the scope deflection plates. This allows the display of much higher frequencies, like transmitter RF, allowing the monitoring of modulation, etc. The change is the addition of a SPDT switch to the associated (V or H) gain control activated at the fully CCW (PLATES position). When activated the switch disconnects the amplifier and directly connects the input through the existing coupling condenser to the deflection plate. The centering controls, which are after the coupling condenser still allow control of the trace position.

Heathkit O-3 / O-4 Front Panel Layout

The top row: (Same as top row of O-2)

The second row (Same as 2nd row of O-2) except:

(Sweep) **FREQ. SELECTOR** Rotary switch 5-pos.
15 - 80, **80** - 180, **180** - 900,
800 - 6000, **6000** - **30M** (cps)

The third row (L to R):

(Vertical) **GAIN** Pot w/CCW switch
PLATES - (Vert. input switched directly to CRT)
AMP., **10**, **20**, …, **90**, **100** (arbitrary scale)

SYNCRONIZING Potentiometer

FREQ. VERNIER Potentiometer
(These two controls each have the same scale):
0, **10**, **20** ,**30**, …, **90**, **100** (arbitrary scale)

(Horizontal) **GAIN** Pot w/sw ccw position
PLATES - (Horiz. input switched directly to CRT)
AMP., **10**, **20**, …, **90**, **100** (arbitrary scale)

The fourth row (Same as 0-2 4th row of O-2):

The fifth row (Same as 5th row of O-2):

Notes: Bold caps text represents actual front panel markings.
See Table I-1 for abbreviations used here.

Table I-4

Another significant change is the addition of an intensity modulation input on the rear panel of the scope. This input is in the form of a red phone tip-jack just above the power cord exit. It allows modulating the intensity of the trace, and is directly coupled through a 0.01 µf condenser to grid one of the CRT.

The vertical and horizontal amplifiers had a slight change in the cathode resistor bypass condenser from 6800 µµf to 5000 µµf. This moves the 3 db gain point up to 19 kc.

During the production of the O-3 the three toggle switches (part # O46 for SPST & O53 for SPDT) on the front panel were replaced with less expensive slide switches (part # O94 for SPST & O95 for SPDT). This mandated a change in the front panel fabrication. The date on the parts sheet that has this change is 09/20/1948.

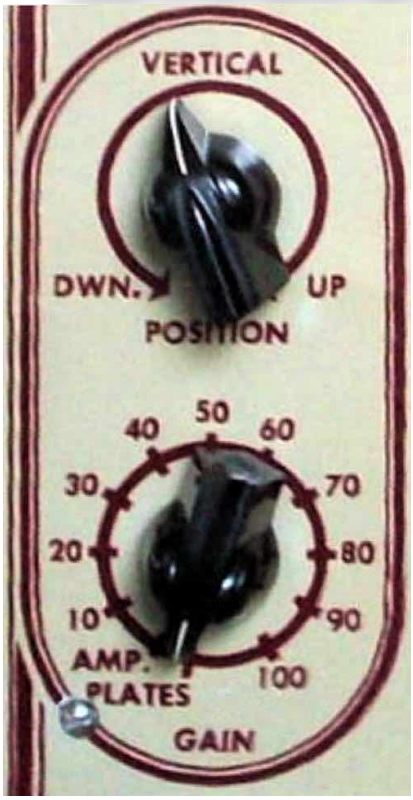


Figure 8: O-3 Plates Switch

The O-3 also sports a new parts numbering system to be discussed in a later paragraph.

The Heathkit O-4 Oscilloscope:

The change from the O-3 to the O-4 oscilloscope occurred without fanfare. It appears the new scope was introduced in the April 1949 Heathkit flyer (See **Figure 9**). There was no change to the scope's outward appearance other than the front panel showing O-4 instead of O-3, and one could have missed it entirely except for two things. First, in the same flyer, right below the scope ad, was an ad for a "Heathkit Scope R.C. Tube Shield" (This must have been a typo and should have read "…***C.R***. Tube Shield" See **figure 10**). This ad states the shield, which sold for $2.50 *"Fits all O-2, O-3,* ***and O-4*** *models"*. Thus it must be assumed the O-4 is being shown in the current ad. The second reason is that, for the first time, Heathkit mentions their current parts suppliers, including Mallory, Centralab, KenRad and Chicago Transformer Company, all big-time electronic component manufacturers. Much of the surplus must have dried up, but Heathkit was able to maintain quality and the $39.50 price. Surplus 5BP1 CRTs still were abundant.

The O-4 is electrically identical to the O-3 with the exception of numerous component changes. Up to this point Heathkit advertised the use of *"long-life oil-filled condensers"*. These were war surplus, and Heathkit was selling them as surplus by the truckload for the previous two years. However the dual 5 µf oil filled condenser (O73) in the B+ power supply and the two 8 µf tubular condensers (O50) in the B+ and amplifier screen circuits were replaced by a single triple section 20 µf can condenser (O96). The vertical and horizontal amplifier coupling condensers were changed from 0.5µf bathtub condensers (O61) to 0.25 µf tubular paper condensers (O97). Also, the two 0.25 µf oil bathtub condensers (O62) were replaced with 0.1µf tubular paper condensers (049); these condensers directly couple the inputs to the CRT deflection plates when their gain control is in the PLATE position. Finally, the intensity modulation input load resistor (O16) was increased to a higher wattage resistor (O18).

The O-4 is the last of the five-tube plus CRT scope line. In September 1949 the O-5 was released sporting seven tubes plus the CRT.

Figure 9: Ad for the new Heathkit 5" O-4 Oscilloscope from the April 1949 Heath Flyer

It is the first Heathkit scope to feature push-pull vertical and horizontal amplifiers. The O-5 through O-8 will be discussed in a future *Heathkit of the Month* article.

Early Heathkit Part Numbers:

As mentioned earlier, the O-1 and O-2 had no part numbering system other than a schematic identification (R1 for instance). R1 could be one value for the O-1 and a completely different value for the O-2.

The O-3 sported a new parts identification system. Parts are identified by one or two letters followed by a two or three digit number. The use of an additional suffix (such as L or R for left or right parts) is found on some part numbers. The leading letter(s) signifies the first kit the part was used in: A for audio amplifier, O for oscilloscope, V for

Figure 10: CRT Shield Offered in April 1949 Flyer

VTVM, etc. The number is sequential and starts at ten. This system was used through the O-6 and across the kit line. The system Heath would use for the rest of their existence was implemented in late 1951. It appears in the O-7 scope and the V-6 VTVM manuals.

A Gain Changer:

Heathkit often included letters and mods in their flyers. One of particular interest shows how to increase the gain of the vertical amplifier (at the cost of bandwidth). It is reprinted in **figure 11**.

Summary:

These initial kits played an important role in the growth of Heathkit as a company. Their consistent updating of products as well as dedication to keeping the kits at an affordable price helped this company to reach number one in the electronic kit business.

Finding information on these kits was not easy. I'm still hoping to acquire a parts list and perhaps construction notes for the O-1 and O-2. This article will be on the club's Heathkit website and updated when and if further information comes to the author.

Acknowledgements:

I have some people to thank for helping me with information for this article:

First is Chuck Penson - WA7ZZE, who provided many of the pictures, schematics and parts lists for the O-series scopes. Chuck is the author of three books on Heathkits including one that is due out this summer.

Second is Erich Brueschke - KC9ACE whose article ***The First Heathkit, the O-1 Oscilloscope, and the series from O-1 through O-12*** provided photos and insight into the O-1 and O-2 oscilloscopes. My attempts to contact Erich have been futile so far. See note 5 for the source of his article.

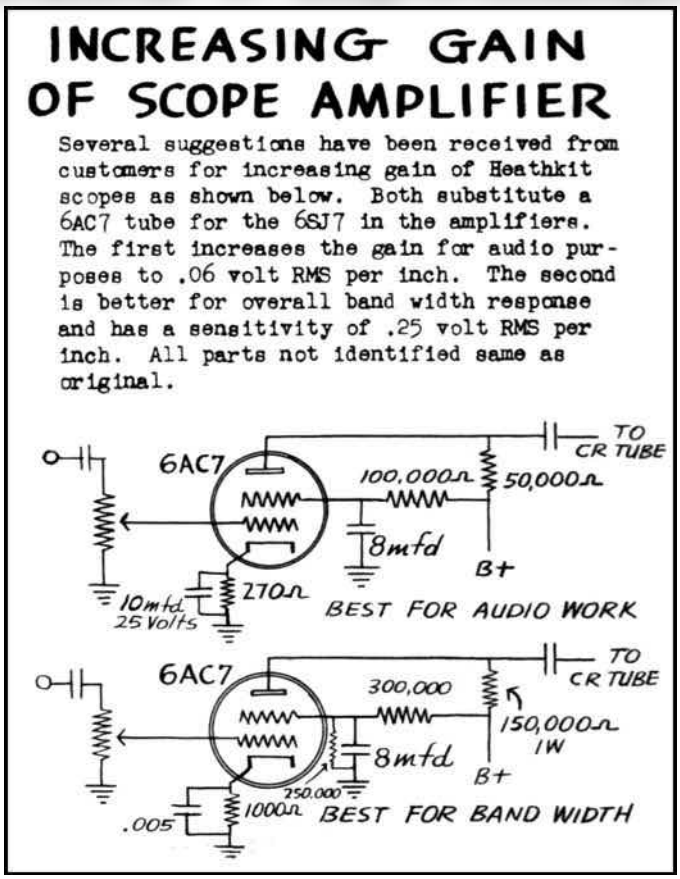


Figure 11: Gain modification suggestions from the June 1949 Heathkit Flyer.

Third is Keith Greenhalgh who has put some excellent photos of Heathkits on ***Flickr***. My attempts to contact him have also so far failed, but I do have a new email to try. However, his high resolution photos did let me look into the insides of the O-3 and O-4 scopes, and I was able to answer some of the questions I had concerning changes, updated parts and features. The photos he presents are of kits that he has restored impressively.

Coming Up:

Part II of the O series scope article, which is a few months off yet, will discuss the O-5 through O-8 oscilloscopes.

Next month I plan to discuss the V-6 VTVM I've been restoring. Power has been applied and it seems to be working nicely. The new tubes are burning in and the final calibration is all that is needed to complete the meter

Specification	O-1	O-2	O-3	O-4
Announced Date: Discontinued Date:	Announced July 1947 December 1947	January 1948 June 1948	July 1948 April 1949	April 1949 September 1949
Input Impedance	Not given	1 megohm and 50 µµf	1 megohm and 50 µµf	1 megohm and 50 µµf
Sensitivity (volts per inch)	Not given	0.65 volts/inch	0.65 volts/inch	0.65 volts/inch
Freq. Response V Amp.	Not given	50 cps to 50 kc ±20%	50 cps to 50 kc ±20%	50 cps to 50 kc ±20%
Freq. Response H Amp.	Not given	Assumed slightly less than vertical amplifier	Assumed slightly less than vertical amplifier	Assumed slightly less than vertical amplifier
Horizontal Sweep Range Range Switch Positions	15 cps to 30 kc 6 plus HORIZ. INPUT	15 cps to 30 kc 5	15 cps to 30 kc 5	15 cps to 30 kc 5
60-cycle Test Voltage Post	Yes	Yes	Yes	Yes
Electrostatic CRT Shield	No	Upgrade kit available in Spring of 1949	Upgrade kit available in Spring of 1949	Upgrade kit available in Spring of 1949
Direct Input to CRT Deflection Plates	No	No	Yes	Yes
Intensity (Z) Modulation Input	No	No	Yes	Yes
Size H" x W" x D"	15 x 10 x 17	13 x 8-1/2 x 17	13 x 8-1/2 x 17	13 x 8-1/2 x 17
Net. Weight (lb.)	55	26	26	Not given
Shipping Weight	Not given (freight)	35	35	24
Price US$	$39.50	$39.50	$39.50	$39.50

Table III Heathkit O-1 through O-4 Specifications

Notes:

1. The O-1 designation was never published and only surmised when the next scope officially received the O-2 designation on its front panel and schematic drawing.
2. The 5BP1 CRT and others are discussed in detail in ***Bob's TechTalk*** article #51 published in the May 2018 ***RF Newsletter***.
3. In keeping with the era of these kits ***condenser*** is being used in place of ***capacitor***.
4. Weight and dimension information are from ***Heathkit Test Equipment Products*** by Chuck Penson (WA7ZZE) as well as by emails with him.
5. Document information is from "**The First Heathkit, the O-1 Oscilloscope"** by Erich Brueschke, **AWA Review** Volume 26, 2013.
6. As shown in the Header to this article.
7. Obtained from Chuck Penson (WA7ZZE) and from Erich Brueschke's AWA article (see note 5).
8. Actual transformer voltages for the O-1 have not been published. These voltage are from a later transformer. However the voltages are believed to be reasonably close.
9. Schematics of the O-1 through O-4 will be posted at http://www.w6ze.org/Heathkit/Sch/o_scopes.html when and if they become available for posting.

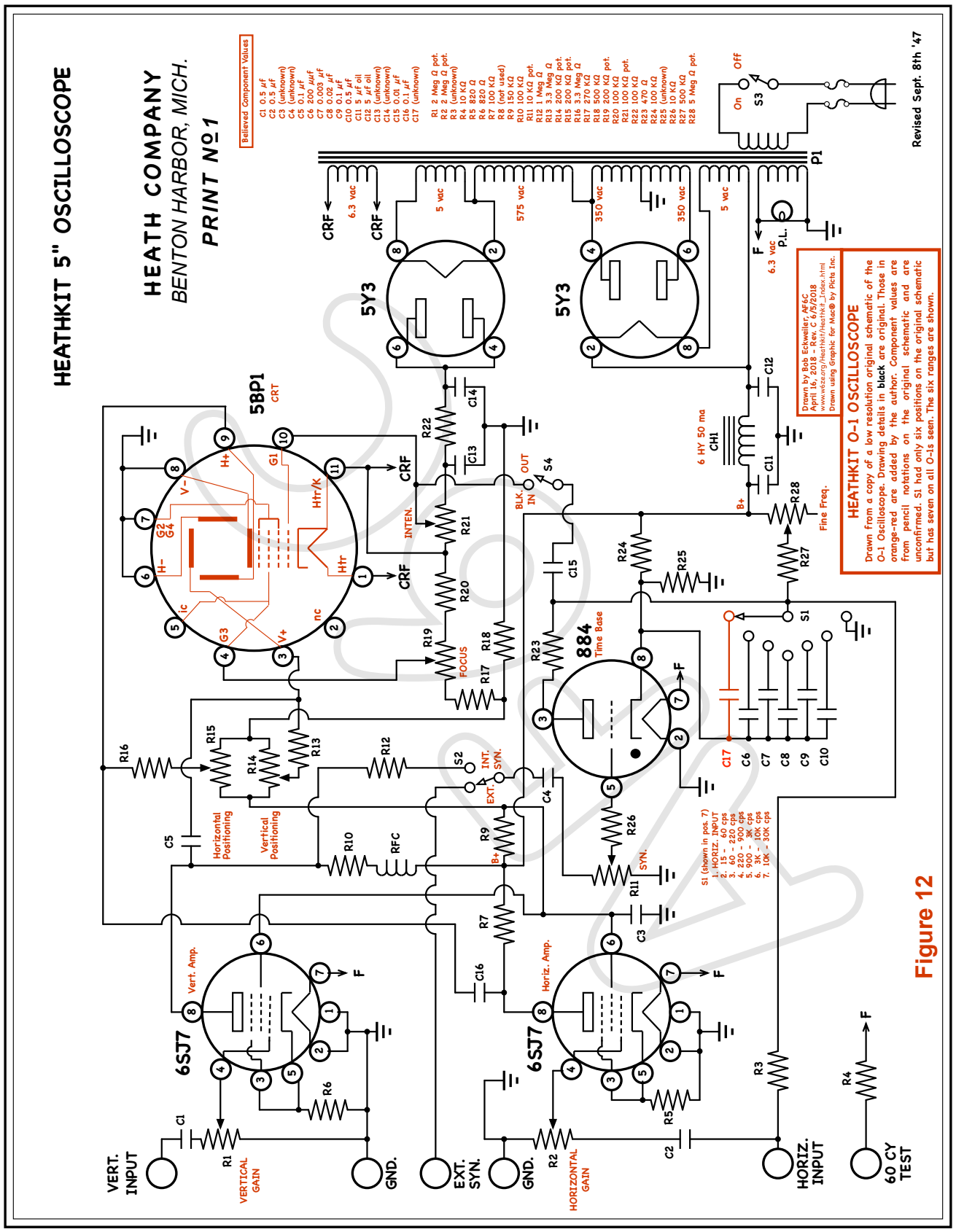
other than painting the cabinet and removing scratches from the meter face.

73, from AF6C

This article originally appeared in the June 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.

Thanks - AF6C


HEATHKIT 5" OSCILLOSCOPE
HEATH COMPANY
BENTON HARBOR, MICH.
PRINT Nº 1
Revised Sept. 8th '47
HEATHKIT O-1 OSCILLOSCOPE
Drawn from a copy of a low resolution original schematic of the O-1 Oscilloscope. Drawing details in black are original. Those in orange-red are added by the author. Component values are from pencil notations on the original schematic and are unconfirmed. S1 had only six positions on the original schematic but has seven on all O-1s seen. The six ranges are shown.
Drawn by Bob Eckweiler, AF6C
April 16, 2018 – Rev. C 6/5/2018
www.w6zze.org/HeathKit/HeathKit_Index.html
Drawn using Graphic for Mac® by Pieta Inc.
Believed Component Values
C1 0.5 µf
C2 0.5 µf
C3 (unknown)
C4 (unknown)
C5 0.1 µf
C6 200 µµf
C7 0.003 µf
C8 0.02 µf
C9 0.1 µf
C10 0.5 µf
C11 5 µf oil
C12 5 µf oil
C13 (unknown)
C14 (unknown)
C15 0.01 µf
C16 0.1 µf
C17 (unknown)
R1 2 Meg Ω pot.
R2 2 Meg Ω pot.
R3 (unknown)
R4 10 KΩ
R5 820 Ω
R6 820 Ω
R7 100 KΩ
R8 (not used)
R9 150 KΩ
R10 100 KΩ
R11 10 KΩ pot.
R12 1 Meg Ω
R13 3.3 Meg Ω
R14 200 KΩ pot.
R15 200 KΩ pot.
R16 3.3 Meg Ω
R17 270 KΩ
R18 500 KΩ
R19 200 KΩ pot.
R20 100 KΩ
R21 100 KΩ pot.
R22 100 Ω
R23 470 Ω
R24 100 KΩ
R25 (unknown)
R26 10 KΩ
R27 500 KΩ
R28 5 Meg Ω pot.
5BP1 CRT
5Y3
6SJ7
884 Time Base
Vert. Amp.
Horiz. Amp.
Horizontal Positioning
Vertical Positioning
INTEN.
FOCUS
Fine Freq.
BLK. IN
OUT
INT.
EXT.
SYN.
S1 (shown in pos. 7)
1. HORIZ. INPUT
2. 15 - 60 cps
3. 60 - 220 cps
4. 220 - 900 cps
5. 900 - 3K cps
6. 3K - 10K cps
7. 10K - 30K cps
6 HY 50 ma
CH1
P.L.
P1
S1
S2
S3
S4
VERT. INPUT
VERTICAL GAIN
HORIZONTAL GAIN
HORIZ. INPUT
60 CY TEST
EXT. SYN.
GND.
CRF
Figure 12