

Heathkit of the Month #41:
by Bob Eckweiler, AF6C

Heathkit

Heathkit OL-1
"3-inch" Oscilloscope.

Introduction:

The first electronic kit Heathkit announced was the O-1 Oscilloscope. It came out in July of 1947. It was followed by in rapid succession by updated models, each featuring improvements, until in September of 1954 Heathkit came out with the O-10. These were all oscilloscopes that used 5-inch CRTs. However, about a month before the O-10 came out Heathkit announced its first oscilloscope with a smaller 3-inch CRT - the Heathkit OL-1.

By today's standards the OL-1 is not a great instrument, it lacks a few features that even the PACO S-50 o'scope I built in the late 50's had. Yet it was an instrument that one could use and that performed the basics very well. Viewing wave forms on a scope was not something many people outside of a well equipped electronics laboratory could do until Heathkit made the CRT oscilloscope an inexpensive and readily available piece of test equipment.

The Heathkit OL-1 was introduced in August of 1954. It remained in production for two years. This was the first Heathkit scope to use a 3-inch CRT, and the only one to use the 3GP1. The smaller CRT allows the OL-1 to be much more compact than the 5-inch CRT scopes. There was one in our science lab in high school.

I am aware of only five general purpose 3" CRT scopes they manufactured: Three were AC coupled; the OL-1 [1954 - 56], the IO-21 [1961-72] and the IO-17 [1968 - 73] - and two were DC coupled; the IO-10 [1960 - 70], and the EUW-25 [1965 - 70] The EUW-25 was part of the Malmstadt-Enke Instrumentation Lab by Heath.



Figure 1: Heathkit OL-1

The Heathkit OL-1:

The Heathkit OL-1 sold from August 1954 through August 1956. The cost was \$29.50, ten dollars less than the 5" O-1 sold for in 1947 and forty dollars less than the concurrent 5" O-10. Size-wise the OL-1 measures 9-1/2" H x 6-1/2" W x 11-3/4" D and weighs 11 lbs. By comparison the larger O-10 measures 8-5/8" H x 14-1/8" H X 16" D and weighs 20-1/2 lbs.

The front panel of the OL1 contains the CRT screen, eight control potentiometers, one 6-position rotary switch, and six binding post terminals; they are outlined in Table 1. The rear of the OL-1 contains two banana jacks, a DPDT slide switch and the entrance for the power cord (See Table 2). The jacks and switch allow for direct coupling to the vertical plates of the CRT (through high voltage isolation capacitors) for monitoring high frequency RF, such as RF from an amateur transmitter.

The vertical and horizontal amplifiers are identical and are specified for a frequency response

The Front Panel can be divided into two areas.
The Top Area consists of five items in three rows (Left to right and top to bottom):

INTEN[sity] - potentiometer. (no markings)
(Power sw. on pot. full CCW: **AC OFF**)

FOCUS - potentiometer (no markings)

3" CRT screen (centered)

VERTICAL CENTERING - potentiometer
(no markings)

HORIZONTAL CENTERING - potentiometer
(no markings)

The Bottom Area consists of eleven items in five rows (Left to right and top to bottom):

FREQ[ueency] VERNIER - potentiometer
(marked 0 - 100 in steps of 20)

VERT[ical] GAIN - potentiometer
(marked 0 - 100 in steps of 20)

HOR[izontal] GAIN - potentiometer
(marked 0 - 100 in steps of 20)

SYNC AMPLITUDE pot
(marked INT 10 - 0 - 10 EXT in steps of 2)

HOR[izontal] SELECTOR rotary sw. (6 pos)
(**HOR INPUT, 60 CY, 15 - 180, 180 - 1800, 1800 - 12KC, 12 KC - 100 KC**)

VERT[ical] INPUT - Binding Post - red
HOR[izontal] INPUT - Binding Post - red

G[rou]ND - Binding Post - black
(under vert. input post)

EXT[ernal] SYNC - Binding Post - red

60 CY[cle] TEST - Binding Post - red

G[rou]ND - Binding Post - black
(directly under horiz. input post)

Table 1 - The Front Panel

of ± 3 dB from 2 cps to 200 kc (± 6 dB from 1 cps to 400 kc) The input impedance for each amplifier is 10 M Ω shunted by 20 μ F. Due to the placement of the vertical and horizontal deflection plates within the CRT itself, there is a slight difference in sensitivity: 250 mV @ 1 kc input gives a deflection of 1" peak-to-peak ver-

The Rear Chassis consists of four items in one row (Left to right):

Power Cord - grommet passing line cord
VERT[ical] input selector DPDT slide-switch
(**INT[ernal] EXT[ernal]**)

Vertical direct input - two banana jacks (red) unmarked, mounted vertically

Table 2 - The Rear Panel

tically while 300 mV is required horizontally. The horizontal amplifier can also be driven by a built-in sweep oscillator. The saw-tooth oscillator operates from 20 cps to 100 kc. in four ranges selected by the **HOR. SELECTOR** switch. It can be synced to the vertical signal either from an external input or from the amplified vertical signal. The **SYNC. AMPLITUDE** potentiometer controls both INT and EXT sync. Two additional positions on the horizontal selector switch are for horizontal input and a 60 cps sine-wave sweep.

The 3GP1 CRT is a 3" round green phosphor medium persistence type. The CRT mounts near the top center of the front panel and is mounted in a metal ring. A felt lining sits between the glass of the CRT and the ring. Total acceleration voltage is on the order of 1,120 volts. The trace can be positioned on the CRT screen using the **VERTICAL CENTERING** and **HORIZONTAL CENTERING** controls. Two other controls adjust the **INTensity** and **FOCUS**. The **AC OFF** switch operates when the intensity pot is fully counterclockwise. The CRT astigmatism is fixed and no adjustment element is provided. Heathkit switched to the 3RP1 that allowed astigmatism adjustment on later 3-inch oscilloscopes.

The OL-1 utilizes eight tubes including five dual-triodes two rectifiers and the CRT. The vacuum tube lineup is shown in table 3.

The sync amplitude control is a center-zero potentiometer At center no signal is applied to the sync input of the sweep oscillator. Moving coun-

terclockwise from center increases the internal sync generated signal and moving clockwise from center increases any external signal applied to the sync input binding post.

OL-1 Circuit Description:

The OL-1 circuitry can be broken down into 5 areas: the power supplies, the CRT circuitry, the sweep oscillator and identical vertical and horizontal amplifiers. Figure 7 shows the schematic.

Power Supplies:

The power supply transformer has three filament windings, one being a 0.625 volt 0.3 A tap for the 1V2 HV rectifier tube. This winding is off the top of the 870 volt HV winding. The other two are independent 6.3 volt windings. One winding is highly insulated and designed to handle the high negative voltage on the CRT cathode that is tied internally to the CRT filament. A second 6.3 V winding supplies voltage to the remaining tube filaments and has one side grounded. The high voltage winding is multi-tapped with a 720 volt CT winding (360 - 0 - 360) for the low voltage supply and a 510 volt winding off one of the 360 volt winding ends. The aforementioned 0.625 filament winding is at the high end of this the HV winding.

The low voltage power supply is a full wave rectifier. It produces four, separately filtered, outputs on the order of 380, 240, 240 and 210 VDC. Rectification is done by a 6X4 7-pin miniature dual diode, and filtering is by a quad 20 µf 450V can capacitor. Three of the supplies have voltage dropping resistors as part of a pi filter.

The high voltage supply produces a negative 915 volts after being rectified by V6 a 1V2 HV diode tube, and filtered by a simple RC pi-network made up of two 0.1µF HV capacitors and a 47K resistor.

The CRT Circuit:

A voltage divider between the HV and ground made up of four resistors, two of them control

pots, provides most of the voltage to control the CRT electron stream. The first resistor in the divider is the intensity control (50 KΩ). It varies the voltage on the control grid between -915 and -880 volts. The cathode is connected to the low end of this control which effectively varies the voltage between the CRT's control grid and cathode from -35V to 0V. It is imperative for the health of the CRT that the grid never becomes positive with respect to the cathode, and this circuit assures that won't happen. A fixed 150KΩ resistor followed by the 250 KΩ focus control and fixed 470 KΩ 1W resistor to ground complete the CRT voltage divider. The voltage on the focus grid varies between around -620 volts.

Extra acceleration for the electron stream is developed by the third grid. It sits at a fixed potential of +240V provided by the B+ supply.

The beam deflection plates are all near 270V with the beam at center. These voltages are varied by the two push-pull deflection amplifiers yet to be discussed, drawing a trace on the screen.

Sweep Oscillator:

The sweep oscillator produces a saw tooth waveform as shown in Figure 2. For best performance the slowly rising slope should be as linear (straight) as possible and the falling

Heathkit OL-1 3" Oscilloscope Tube Lineup:

V1a*	12AU7	Input Buffer - Vertical
V1b*	12AU7	Vertical Amplifier
V2*	12AU7	Vertical Push-Pull Driver
V3*	12AX7	Multivibrator Sweep Oscillator
V4a*	12AU7	Input Buffer - Horizontal
V4b*	12AU7	Horizontal Amplifier
V5*	12AU7	Horizontal Push-Pull Driver
V6	6X4	Low Voltage Rectifier
V7	1V2	High Voltage Rectifier
V8	3GP1	3" Cathode Ray Tube

* These tubes mount on the circuit board.

Table 3 - Vacuum Tube Functions

slope should be steep. This waveform draws the trace horizontally across the screen. Any vertical signal applied while the trace is sweeping across the screen, moves the trace up and down along the horizontal path.

If the vertical signal is at a different level at the start of each sweep then the image will jump all over the place; therefore a way to sync the sweep oscillator to the vertical amplifier is provided. A bit of the signal is sampled from the cathode of the vertical driver tube (V2) and coupled to the sweep oscillator. If the sync signal is large enough, and the frequency of the sweep oscillator is adjusted so that the vertical is close to a multiple of its frequency, the sweep oscillator will sync and the trace will remain steady on the screen.

The sweep oscillator uses both triode sections of V3, a 12AX7 as a free-running multivibrator circuit. The frequency is determined by an RC network in the cathode of one of the triodes. Only a small part of the full RC curve is traversed with each sweep (around 1 to 2 volts) insuring good linearity. Sync is applied to the cathode of the triode that doesn't have the RC network. This sync, if close to a multiple of the frequency of the free-running multivibrator, will force the multivibrator to synchronize. The OL-1 sweep circuit has no blanking circuit. The

trace is moved horizontally across the screen left to right during the sweep and rapidly back to the left before the next sweep begins. This results in a light retrace line like the one shown in Figure 3. Many scopes blank the CRT during the retrace to eliminate the retrace line. The later Heathkit 3-inch scopes all incorporated blanking.

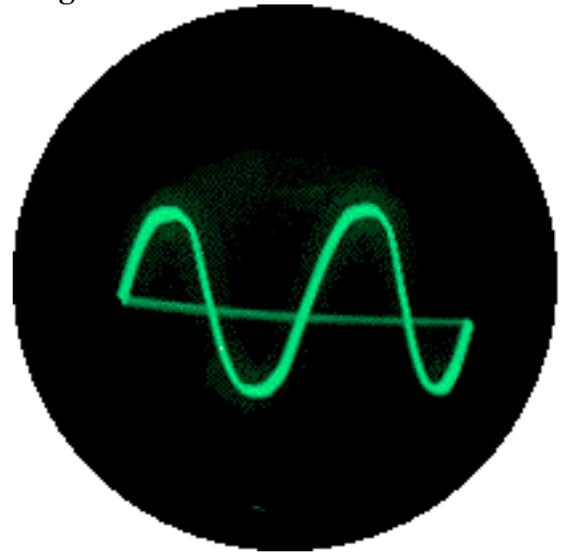


Figure 3: Two Cycles of a Sine Wave showing the Retrace Line

Vertical and Horizontal Circuitry:

The vertical (and horizontal) amplifier chains are identical; each is made up of two 12AU7 dual triodes. However, while the vertical signal only comes from the vertical input terminals, the horizontal input can be selected from three sources: the horizontal input terminals, the internal sweep oscillator or a 60 cycle test signal that is derived off the filament voltage. The selection is made with the horizontal selector rotary switch.

The input signal is coupled to V1A (V4A) [horizontal chain is shown in parentheses] a buffer stage that, using feedback from the cathode circuit to the grid bias, develops the high 10MΩ input impedance. The output is coupled from the buffer's cathode through a blocking capacitor, and the gain control potentiometer to the grid of a conventional amplifier V1B (V4B). The output of the amplifier is AC coupled to the deflection amplifier V2 (V5). The deflection am-

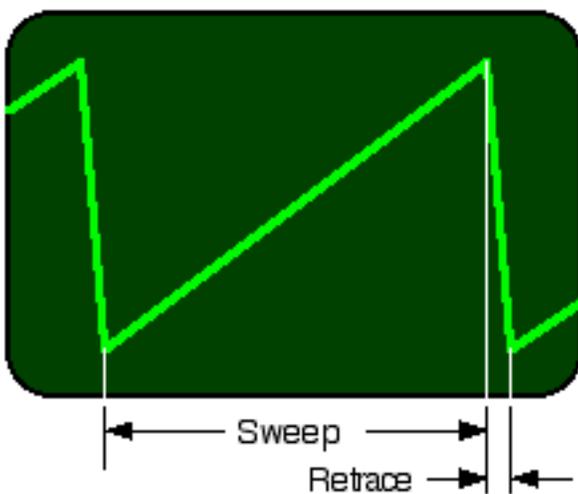


Figure 2: Sweep waveform

plifier is a fixed gain differential amplifier coupled by a common grid resistor. As the signal varies in one direction one plate becomes less positive and the other becomes more positive and vice versa. The plates are connected directly to the CRT deflection plates causing the beam to deflect. A small DC voltage controlled by a centering control differentially adjusts the bias on the differential amplifier allowing the trace to be statically positioned on the screen independent of the input signal.

Construction utilizes a printed circuit board that holds the vertical, horizontal and sweep circuitry (V-1 through V5). Heathkit stopped production of the OL-1 after two years. It was a popular model and can still be found used. However Heath didn't produce another 3-inch scope for about four years.

Heathkit IO-21 "3-inch" Oscilloscope:

The IO-21 came out in late 1961. It is similar in a lot of ways to its predecessor the OL-1. In some ways it is more advanced and in some ways it is not. Obviously missing from the front panel are the Intensity and Focus controls. The focus adjustment is internal and the intensity is fixed. The circuits are similar to the older scope but with a lot of small changes. Blanking has been added to hide the retrace line. There is no external sync input nor is there a sync level control. The front panel has only the CRT screen, the vertical and horizontal inputs and six controls - vertical and horizontal amplitude and position, **HOR/FREQ. SELECTOR** and the sweep frequency vernier.

The IO-21 has nearly the same electrical specifications as the OL-1. It measures 9-1/2"H x 6-1/2"W x 10" D. The IO-21 first appeared in the Christmas 1961 Gift Catalog, (80/01) selling for \$49.95. In 1969 the price had increased to \$61.95. Notice the "NEW" tag in the figure 5 ad.

The IO-21 uses a different CRT than the OL-1 - a 3RP1. This CRT features a grid to adjust the astigmatism (roundness) of the dot and is about an inch shorter than the 3GP1. Both the focus and astigmatism controls are located in-

ternally on the bracket that holds the neck of the CRT. The 3RP1 and 3RP1A became a favorite of Heathkit. It is used in the remaining 3-inch oscilloscopes as well as the HO-10 and SB-610 station monitors and the vector-scopes used for TV servicing. The HO-13 and SB-620 pan-adaptors use the 3RP7 CRT which is identical except for a higher persistence yellow phosphor screen.

Heathkit IO-17 "3-inch 5 mc" Oscilloscope:

Servicing color televisions requires a scope with a much higher vertical frequency response. Vertical amplifiers that top out at 200 or even 400 kc lack usability servicing the color circuitry; instead, a response of 5 mc is needed to properly service a color television.



Figure 4 Heathkit IO-17 "3" 5 mc Scope

Heathkit produced 5" oscilloscopes with a 5 mc frequency response since the O-10 in the mid-fifties. However most of these scopes didn't have a true 5 MHz bandwidth which is commonly measured at the -3dB point. The IO-17 was a 3" CRT scope with a vertical amplifier rated from 5 cps to 5 mc at ± 3 dB.

The horizontal amplifier and sweep circuits follow closely the circuits of the previous models with a few improvements and the addition of a

Sensational Values in Heathkit® Oscilloscopes

YOU WON'T FIND A FINER SCOPE AT THIS PRICE ANYWHERE!...



IO-21
\$49.95

Heathkit GENERAL PURPOSE 3" OSCILLOSCOPE

The brand new IO-21 oscilloscope is compact, lightweight, and surprisingly versatile in performance . . . fills hundreds of daily requirements. The exceptionally clean, open circuit layout makes assembly easy, trouble-free. Circuit design features identical vertical and horizontal amplifiers with a frequency response of ± 2 db from 2 cps to 200 kc. Sensitivity is .25 volts RMS/inch peak-to-peak deflection at 1 kc. Provision is made for direct connection to the vertical deflection plates of the cathode ray tube . . . ideal for high level R.F. monitoring. The Heath twin-triode sweep generator employed in this scope functions reliably from 20 to 100,000 cps in four switch-selected ranges. Automatic sync and retrace blanking. Provision for line sweep and internal or external sweep. Other features include a 3RP1 CR tube with special alloy neck shield to minimize the effects of ambient electrical fields that might cause trace distortion; focus and astigmatism controls to assure a sharp, fine trace and a husky power transformer. Power supply is fused for protection. An unbeatable scope value! 14 lbs.

- ✦ Push-pull vertical and horizontal amplifiers
- ✦ Wide range sweep generator 20 to 100,000 CPS
- ✦ Automatic sync—retrace blanking
- ✦ Neat, open circuit layout for easy assembly

SPECIFICATIONS: (Vertical and horizontal amplifiers identical): Frequency response: 2 db, 2 cps to 200 kc. Sensitivity: .25 volts RMS/inch P-P deflection at 1 kc. Input impedance: 10 megohms shunted by 20 uuf. Sweep generator: Range: 200-100,000 cps. Automatic sync, retrace blanking. Power requirements: 105-125 volts AC, 50-60 cycle, 40 watts. Dimensions: 9 1/2" H x 6 1/2" W x 10" D.

Kit IO-21 . . . no money dn., \$5 mo. **\$49.95**

"Space Saver" 3" DC OSCILLOSCOPE . . . small, compact, easy to carry . . .

ideal for use where extremely low sweep rates are desired

This attractive and versatile 3" DC scope fills a multitude of applications in industrial, medical and general service fields. Features identical AC or DC coupled vertical and horizontal amplifiers with a bandwidth of DC to 200 kc. Less than 5° phase shift between channels make it ideal for computer "read out" or for voltage, frequency and phase shift measurements. The recurrent sweep generator covers 5 cps to 50 kc in four overlapping ranges and lower sweep rates may be obtained by connecting additional capacity across the external binding posts provided. Other features include; switch-selection of internal or external sync, 3RP1 CR tube, special alloy CR tube shield to minimize trace distortion, astigmatism control for sharp trace, and voltage regulated power supply. 14 lbs.

Kit IO-10 . . . no money dn., \$8 mo. **\$79.95**

SPECIFICATIONS—(Vertical and horizontal channels identical): Bandwidth: DC to 200 kc (2db point). Sensitivity: 0.1 V (peak-to-peak) per 1/2" (un-calibrated). Attenuator: 3-position, compensated type. Gain control: Continuously variable. Input impedance: 3.6 megohms shunted by 35 mmf. Coupling: Either AC or DC, switch-selected. Relative phase shift between channels: Less than 5°. Sweep generator (recurrent type): Linear saw-tooth produced by multivibrator type generator covering 5 cps to 50 kc in four overlapping ranges. "External capacity" binding post for lower sweep rates. Sync provision: Either internal or external, switch-selected. Power requirements: 105-125 V 50-60 cycle AC at 100 watts max. Dimensions: 7 1/2" H x 4 1/2" W x 11" D

IO-10 **\$79.95**

- ✦ Identical vertical and horizontal DC or AC coupled amplifiers
- ✦ DC to 200 kc bandwidth—less than 5° phase shift between channels
- ✦ External capacity binding post for lower sweep rates
- ✦ Small compact size—measures only 7 5/8" h x 4 5/8" w x 11"d.



Figure 5: Ad for IO-21 & IO-10 Oscilloscopes from Heathkit's Christmas Gift Catalog #80/01

sync signal buffer stage and a blanking amplifier. No external sync input is provided.

Heathkit IO-10 "3-inch" DC Oscilloscope:

Neither the OL-1, IO-21 nor IO-17 can operate below a few cps. Better oscilloscopes can respond to DC voltages. The IO-10 is one of two 3-inch Heathkit scopes that is DC rated. Of course if you are measuring a small AC signal with a large DC component this can be a problem. Hence DC scopes let you choose between DC and AC coupling. DC amplification requires added circuit stability so these scopes are a lot more complex and cost more. Each amplifier has a DC balance control accessible via a hole in the cabinet or even on the front panel that needs occasional adjustment.

The IO-10 was manufactured from 1960 into the early seventies. In late 1961 it sold for \$79.95. (See Figure 5) and in mid 1969 it sold for \$99.95. To fully cover the circuitry would be beyond the scope of this article. Perhaps it will be featured in the future? Some major features of the IO-10 are:

- a. The power supply includes regulated +150 and -75 volt supplies for the DC amplifiers.
- b. Inputs include a three-section compensated step attenuator X1 - X10 - X100 for AC and DC.
- c. CRT is mu-metal shielded to protect from external magnetic interference.
- d. Concentric controls are utilized to reduce front panel clutter.

The IO-10 has identical vertical and horizontal amplifiers specified from DC to 200 kc. The sweep circuit covers 20 cps to 50 kc in four ranges and has provisions for adding an external capacitor to slow the sweep even further. External as well as internal sync is provided, and the CRT is blanked during retrace.

Heath EUW-25 “3-inch” DC Oscilloscope:

The EUW-25 scope came fully assembled. It was part of the **Malmstadt-Enke Instrumentation Lab** (Also designated the **Heath Science Series**) designed for education and small laboratories. Electrically the EUW-25 is very close to the IO-10; however the physical design is quite different (See figure 6). The scope also has features that make it more useful in its educational and lab role. These include:

1. Switches to short the vertical and horizontal inputs to aid trace position and balancing.
2. Vertical and horizontal beam control adjustments for setting trace centering.
3. Front panel screwdriver adjustment of vertical and horizontal DC balance.
4. Front panel screwdriver adjustment of sweep position balance.



Figure 6: Heath EUW-25 “3-inch DC Scope

5. External AC coupled vertical and horizontal inputs for directly applying signals to the CRT deflection plates.
6. External Z-axis input on the rear panel to allow intensity modulation.

One interesting tidbit with the EUW-25 involves the first stage of the vertical and horizontal amplifiers. The IO-10 uses a dual triode 6BS8 tube with one section serving each amplifier; however, the EUW-25 uses two separate single 6AB4 triode tubes, one for each amplifier. Whether this is for signal isolation, better DC stability or due to the wider chassis layout is an interesting point for discussion.

Conclusion:

These smaller 3-inch scopes provide some portability and size advantages that are lacking in the larger scopes. Many electronic enthusiasts probably started with one of these scopes.

I remember when Ken - W6HHC first got his Apple][computer. Before obtaining a disk drive, he was loading programs by cassette tape. His old IO-21 scope allowed him to set the level to make the loading from cassette tape quite reliable. His chess program, often loaded, was a challenge!

On the last page I've written a short Sidebar on the basic Oscilloscope. There is also a short request for information any readers have on the really old O1 - O7 Oscilloscopes that might help me cover them sometime in the future.

A special thank you goes to John Roberts - W6JOR for providing me the OL-1 manual.

73, from AF6C



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

Thanks - AF6C

This article originally appeared in the July 2012 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.

SIDEBAR:**The Basic Oscilloscope:**

The heart of a cathode ray oscilloscope is the cathode ray tube - CRT. The tube has a cathode that emits an electron stream that is accelerated and hits a phosphorescent screen producing a dot of light. Multiple grids control the stream of electrons and the focus and astigmatism of the dot; a final accelerating grid speeds up the electrons. Two sets of deflection electrodes can bend the electron stream and cause it to move position on the screen when differential voltages are applied to them.

One set deflection electrodes are connected to a "vertical" amplifier. This amplifier determines the vertical position of the dot. There is a position control that sets the static position with no signal applied and a gain control that sets the amplitude of the applied signal. Thus an AC signal applied to the vertical amplifier will draw a vertical line on the screen of the CRT. The line's amplitude is proportional to the gain of the amplifier and the peak-to-peak voltage of the signal.

The second set of deflection electrodes is connected to a "horizontal" amplifier, often similar to the vertical amplifier. A signal to the horizontal amplifier will move the dot in a horizontal direction. Independent of the horizontal input, the horizontal circuitry also contains a sweep circuit that can be used to move the dot across the screen from left to right at a constant rate, bringing it quickly back to the left edge of the screen before starting the next sweep. There is usually an adjustable sync circuit that couples the vertical signal to the sweep oscillator trigger so that the waveform displayed on the screen remains constant. The sync circuit also normally has the capability of syncing off an external sync input.

The pattern shown on the screen of the CRT is representative of the waveform of the signal applied to the vertical amplifier. As an example

if a 60 Hz signal is applied to the vertical input, the sweep is adjusted to 30 sweeps per second and the sync is adjusted for a steady image you would see two complete 60 Hz sine waves displayed on the screen of the CRT.

Of course modern CRT oscilloscopes have many additional features. First is increased bandwidth; scopes capable of reproducing waveforms up to a few hundred kHz were adequate for audio and even black-and-white TV servicing. Color TV requires a bandwidth around 5 MHz and modern scopes have bandwidths up to hundreds of MHz. Another feature is DC coupling where the vertical and horizontal amplifiers respond to DC inputs. Calibrated amplifiers with step attenuators that allow voltage measurements is another feature. Other modern features include triggered sweep, delayed sweep, and multiple vertical channels just to cover a few.

Today there are digital oscilloscopes that digitize the incoming signal and display it on a color LCD screen with very high bandwidth and a lot of features only a computer can easily provide. These units can be made compact since the large and often long CRT is no longer needed, just as LCD TVs are thinner than their CRT predecessors.

Request:

I would like to cover the original Heathkit Oscilloscopes from the O1 through the O11 in a future column. These were the kits that gave Heathkit a leg up in dominating the electronic kit business.

If you have one of these units and would be willing to send me some digital photos it would help me tremendously. Also if you have manuals I'd like to ask you some questions that I might have while working on the article. Schematics would also be nice to have so I can compare circuitry updates. I have schematics for the O-2, the O-7 the O-9, the O-10 and the O-11. If anyone can fill me in with others I'd appreciate it. GIFs JPGs or PDFs are fine. - [de AF6C](#)