Use your TV as a large screen oscilloscope

with this simple TV CRO adaptor

Here is a low cost instrument that will interest beginners and enthusiasts alike. It is a plug-in adaptor that converts any TV into a useful low frequency oscilloscope. Using only a few ICs it can display signals from 10Hz up to 300kHz with a sensitivity of 100mV rms for full-screen deflection.

by RON DE JONG

For anyone interested in electronics an oscilloscope is probably the single most useful instrument around. It measures everything from signal voltages to waveforms and frequency in one go. The bad news is that even a modest CRO is expensive and the cost of parts for an oscilloscope also make a project unattractive. For this reason we decided to produce a low cost TV/CRO adaptor. This is simply an adaptor which converts any TV into a low frequency, large screen oscilloscope.

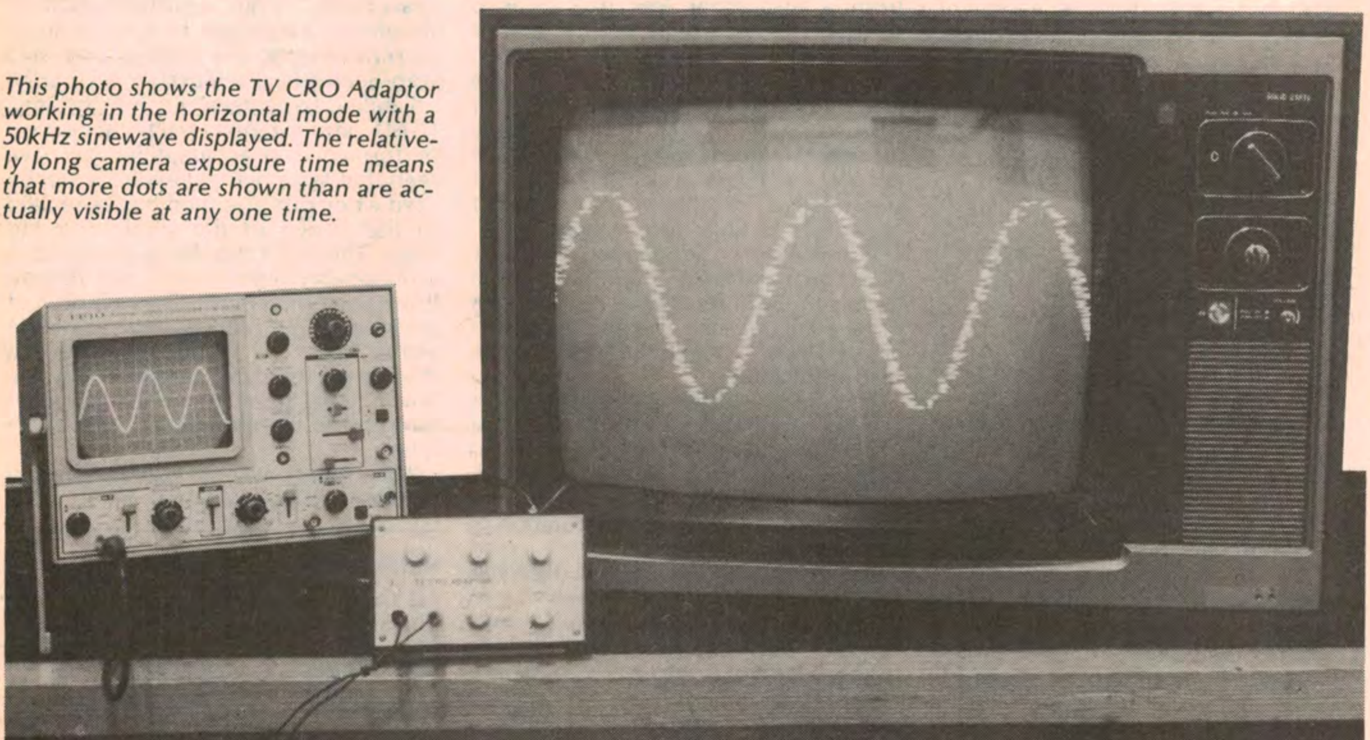
The idea is not new. In fact, we first produced such an adaptor back in March 1963 and circuits along similar lines have been published in other magazines. This design is completely new and has a frequency response up to 300kHz, which far exceeds the limit of a few hundred hertz for other designs. It also connects directly to the aerial inputs of the TV, making it easy to install. Alternatively, for an even better display, it has a composite video output for direct connection to the TV video input stages.

While it cannot compete with a conventional CRO with a bandwidth of several megahertz it does give a good display at the lower frequencies and it will be very useful in such applications as hifi and audio. For example square waves can be fed into an amplifier or a tape deck and the output displayed to check for frequency response, distortion, tape dropout and wow and flutter. The large size of the screen means that the adaptor could also be used as a dramatic display for large audiences or as a monitor for stereo systems.

As you might expect the adaptor works quite differently from a conventional CRO. Rather than deflecting the electron beam in response to the input signal the adaptor merely relies on the normal deflection system of the TV and, in effect, turns on the beam when it is in the correct position on the screen.

Now in a normal television set the whole screen is scanned 50 times a second. Each scan is called a field and

This photo shows the TV CRO Adaptor working in the horizontal mode with a 50kHz sinewave displayed. The relatively long camera exposure time means that more dots are shown than are actually visible at any one time.



consists of 312.5 horizontal lines, so the field frequency is (50 x 312.5) 15,625Hz. To keep the circuitry of the adaptor simple either of these two frequencies must be used as the timebase for the display. We have used both and the result is that two distinct display modes are available; the vertical mode and the horizontal mode.

These two display modes can be seen from the accompanying photographs. In the vertical mode the signal is displayed sweeping from top to bottom and in the horizontal mode the sweep is from left to right as in a conventional CRO. The reason for having the two modes is that the vertical mode is best used to display low frequency signals, while the horizontal sweep mode, is better for displaying higher frequency signals.

The situation is clarified in Fig. 1 and Fig. 2 which illustrate the vertical and horizontal modes respectively. Looking at the vertical mode first, a complete cycle of a 50Hz sine wave signal is shown superimposed on a sequence of lines representing the path of the electron beam across the television screen. The small dots where the two cross over are the points or dots which actually appear on the screen.

The adaptor generates these dots by sampling the input signal during each line scan. This sampled voltage is compared to a sawtooth voltage which increases linearly from the start of each line. When the sawtooth voltage equals the sampled voltage a brief video pulse is generated. This means that the higher the input voltage at the instant of a particular line scan the later the pulse will occur and the further to the right of the screen the dot will appear. This occurs for each line scan so that at the end of a field a complete picture of the waveform is built up.

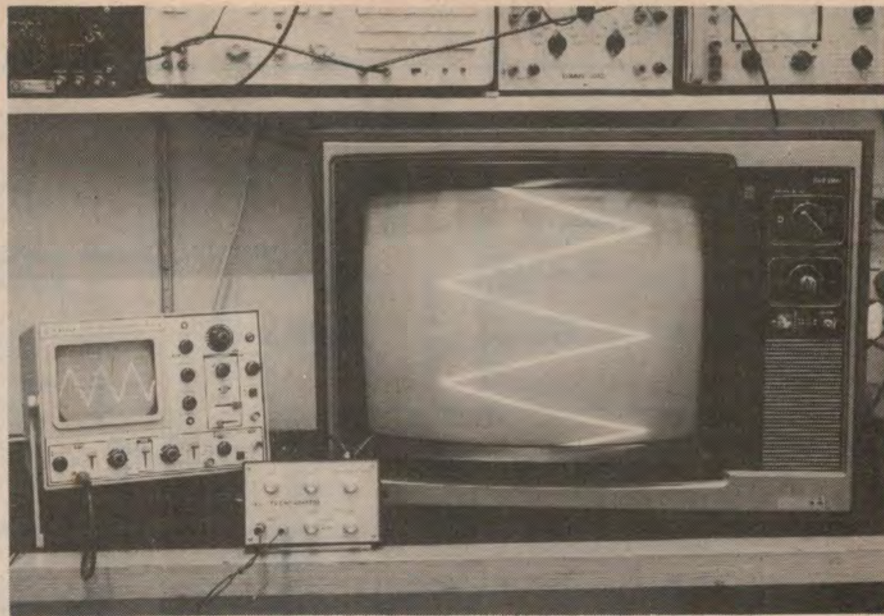
Video signals generated by the adaptor in the vertical mode can be seen in Fig. 1, line for line as they appear on the screen. Each line is 1/15,625s or 64us long and starts with a negative sync pulse 5us long, while the video pulses corresponding to the white areas on the screen are high.

The operation of the adaptor in the horizontal mode is shown in Fig. 2 which shows a sine wave signal as it would be displayed in the horizontal mode.

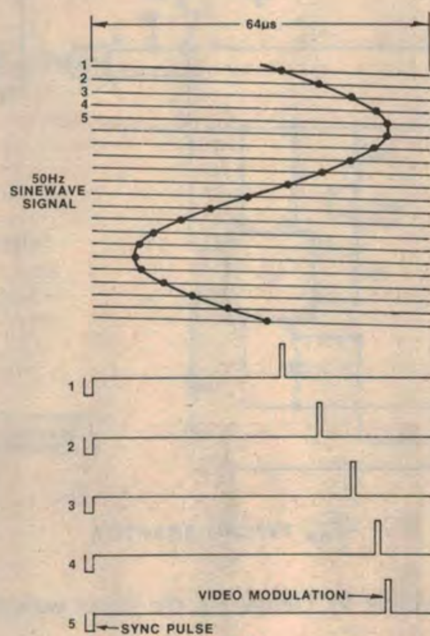
Fig. 3 shows the general operation of the adaptor, as described above. A timebase signal, from the vertical or horizontal oscillators, is compared with the input signal in a comparator which produces pulses whenever the two waveforms coincide. These video pulses are then mixed with the timebase sync pulses to produce a composite output.

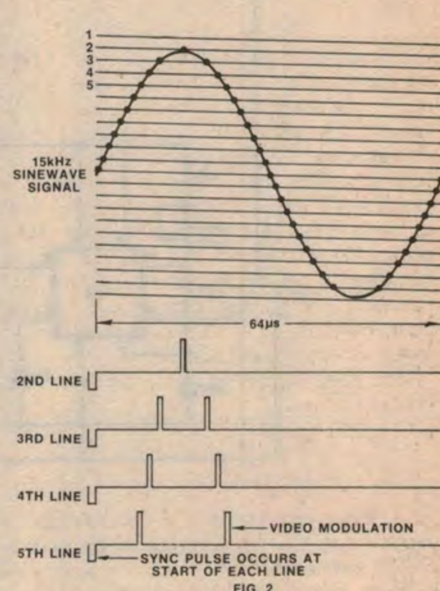
It should be noted at this point that in both the horizontal and vertical modes we assumed in our description that the input signal was locked either to the line or field frequencies resulting in a static display. For most cases, though, the input will not be locked and the display will appear to shift up or down in the vertical mode, while in the horizontal mode it would appear to "tear". This may not be important in the vertical mode but some sort of synchronism is clearly necessary in the horizontal mode.

This is provided by the sync circuit shown in the block diagram of Fig. 4. Firstly a zero crossing detector is used to generate a brief pulse at the start of each cycle of the input waveform. This signal is checked against the line sync pulses so if a new cycle starts just at the



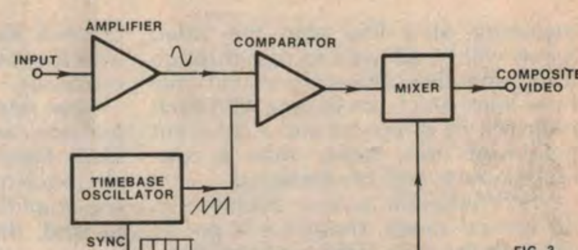
The TV CRO Adaptor working in the vertical mode, this time with a 150Hz triangle wave displayed. This mode is best used to display low frequency signals.

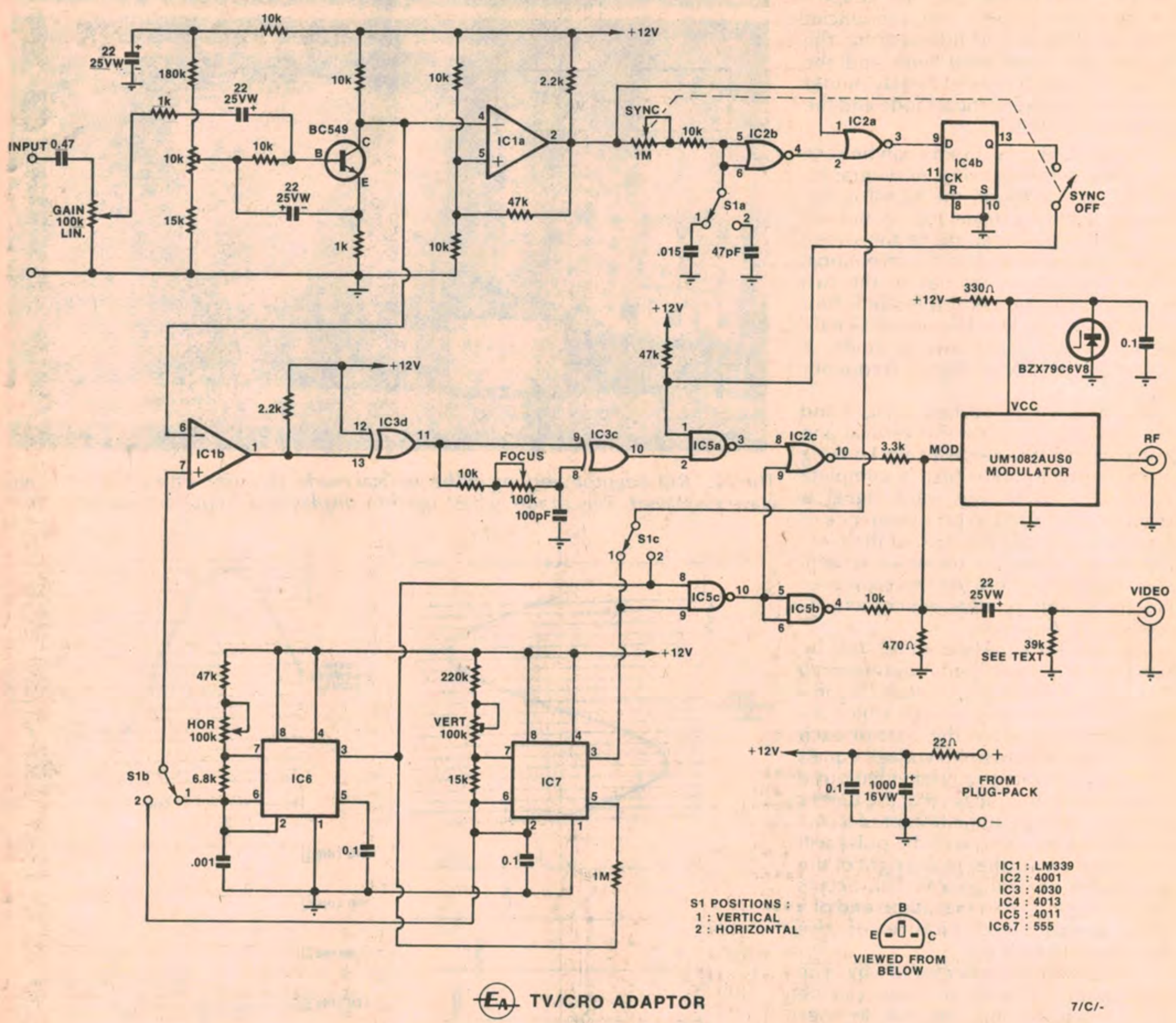




Figs. 1 & 2 illustrate how the adaptor works in the vertical and horizontal modes respectively.

Fig. 3: general operation of the TV CRO Adaptor. The input signal is compared with a timebase signal and mixed with the timebase sync pulses to produce a composite output.





The circuit works as a "sampling" oscilloscope by comparing the input waveform with the horizontal or vertical timebase.

beginning of a line scan the video signals will be allowed to pass through during that line. This ensures that only those lines which are in sync with each other will be displayed and a coherent picture of dots, rather than a continuous trace, will be displayed.

Synchronisation is also available in the vertical mode, though it is not as useful. In this case, if the waveform is to appear stationary the input signal must start from the same place at the beginning of each field. The sync circuit checks the signal from the zero crossing detector against the field sync pulse and if a cycle of the input waveform has just started then the video will be enabled for the rest of the field. In practice the result is a strobing effect with the waveform flashing up only occasionally.

Now refer to the circuit diagram to see how we have implemented these ideas. Input to the adaptor is via a simple bootstrapped transistor amplifier. The amplifier provides a gain of about 10 and the bootstrapping capacitor between emitter of Q1 and the wiper of the 10k trimpot provides an input impedance for the stage of around 100k. Together with 100k gain control, the input impedance is better than 50k. The 10k trimpot sets the quiescent output voltage of the stage and effectively acts as a shift control, moving the oscillograph either up and down or sideways depending on the display mode.

IC1b is the comparator shown in Fig. 3. It is fed with the amplified input signal and the sawtooth waveform obtained via switch S1b which selects either the vertical or horizontal sawtooth waveforms, depending on the mode. When the input signal exceeds the sawtooth waveform the output of the comparator will be low; if it is less than the sawtooth the output will be high. The important point to note though, is that at the instant the two voltages are equal the output of the comparator will swing either high or low.

This transition at the output of the

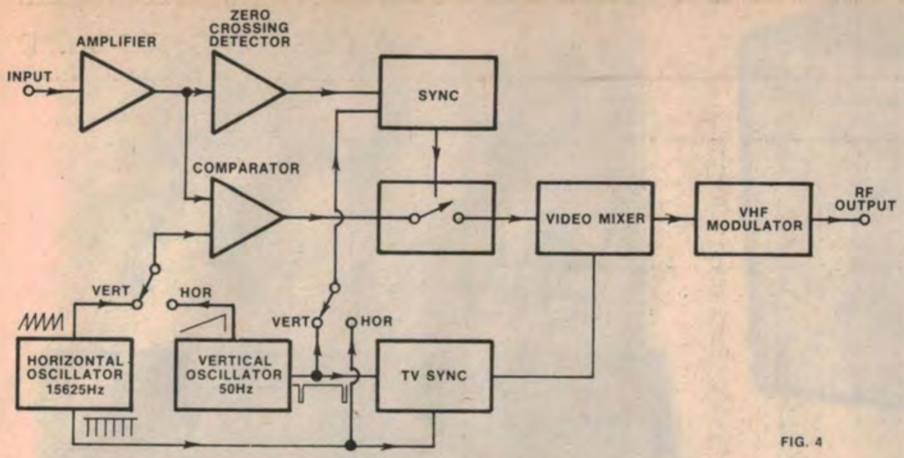
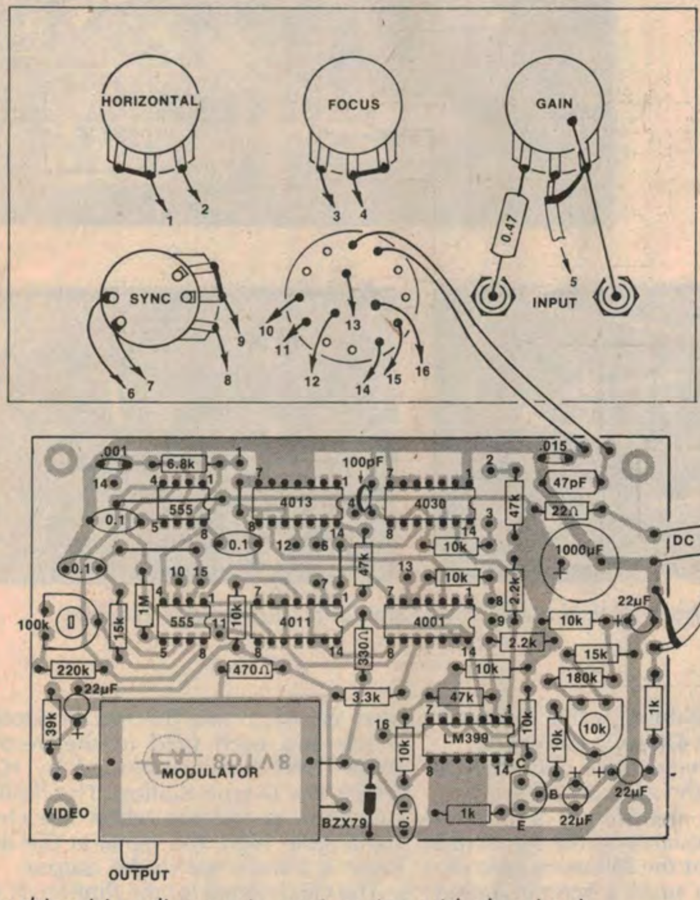


Fig. 4: block diagram of the final TV CRO Adaptor circuit.

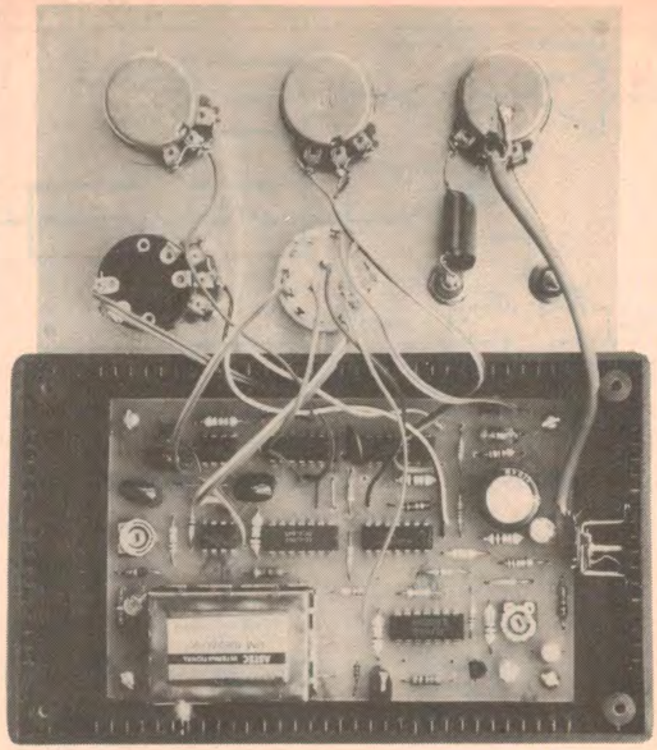


Follow this wiring diagram in conjunction with the circuit.

comparator must now be converted to a brief positive pulse which is the video signal, or the spot which appears on the screen. This is accomplished with IC3d and IC3c which are both exclusive-OR gates. IC3d buffers the output of the comparator and then drives one input of IC3c directly, and the other via a simple RC delay circuit consisting of a 100k potentiometer, a 10k resistor and 100pF capacitor.

When the output of the comparator changes state, the signal at one input of IC3c will be slightly delayed so for the period of the delay the two inputs will be different. The output of an XOR (exclusive-OR) gate is high only while its two inputs are different, hence a brief positive pulse will be generated by IC3c and the width of the pulse or the length of the dot on the screen is equal to the delay. This is controlled by the 100k potentiometer and for lack of a better name we have called it a "focus" control.

Referring back to the block diagram, Fig. 4, the video signal now passes to gate IC5a which is controlled by the sync circuit. Pin 2 of IC5a is the video input while pin 1 is the sync input. If pin 1 is high the video signal will simply be inverted by IC5a but if it is low the output of IC5a will always be high, effectively blocking the video signal. The



ABOVE & RIGHT: the completed prototype. The unit may be powered either from a 9V battery or from a plugpack power supply.

PARTS LIST

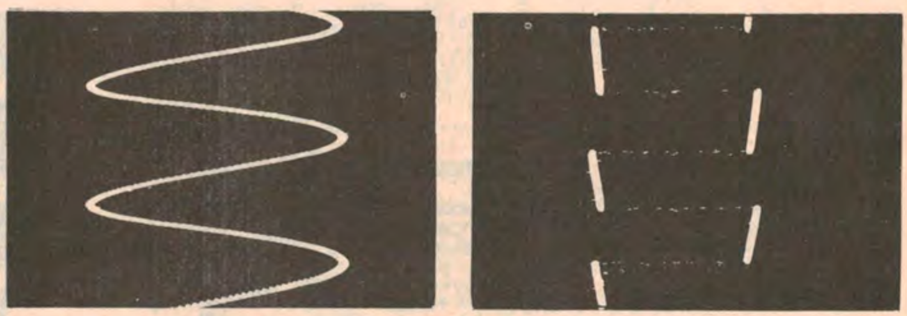
1 plastic utility box, 150 x 90 x 50mm (D x H x W)
1 Scotchcal front panel
1 PC board, 80TV8, 122mm x 77mm
1 UM1082AUS0 TV modulator
1 9 volt DC plug pack
1 2.1mm battery adapter socket
3 100k (linear) rotary potentiometers
1 1M (log) switch potentiometer
1 3-pole 2-position rotary switch
1 black binding post
1 red binding post
1 10k miniature horizontal trimpot
1 100k miniature horizontal trimpot
½-metre rainbow cable
4 15mm board supports

SEMICONDUCTORS
1 LM339 IC
1 4011 CMOS IC
1 4001 CMOS IC
1 4030 CMOS IC
1 4013 CMOS IC
2 555 ICs
1 BC549 transistor
1 BZX79-C6V8 zener diode

CAPACITORS
1 1000uF/16VW PC electrolytic
4 22uF/25VW electrolytics
1 0.47uF greencap (metallised polyester)
4 0.1uF greencap
1 0.015uF greencap
1 .001uF greencap
1 100pF ceramic or polystyrene
1 47pF ceramic or polystyrene

RESISTORS (all ¼ watt 5%)
1 x 1M, 1 x 220k, 1 x 180k, 3 x 47k, 1 x 39k, 2 x 15k, 8 x 10k, 1 x 6.8k, 1 x 3.3k, 2 x 2.2k, 2 x 1k, 1 x 330 ohm, 1 x 22 ohm.

NOTE: Ratings are those used on the prototype. Components with higher ratings may generally be used providing they are physicially compatible.



These photos show vertical mode 150Hz sine and square wave displays.

sync signal is disabled by the "sync off" switch and the 47k pull-up resistor.

The sync circuit consists of IC2b, IC2a and IC4b plus the zero crossing detector IC1a. The detector is a Schmitt trigger which squares up the signal to a level suitable for the following sync circuits. We have used a Schmitt rather than a common amplifier configuration because it results in a much cleaner signal, which is important as far as the sync is concerned.

Output from the detector is then fed to a delay circuit similar to that used in the video circuit. The period of the delay is set by the RC circuit consisting of a 1M potentiometer, 10k resistor and two capacitors which are selected via switch S1a. IC2b buffers and inverts this delayed signal which is then fed along with the signal to IC2a which is a NOR gate. The output of this gate is a brief positive pulse whenever a new cycle of the input waveform starts.

The purpose of the sync circuit, as we have already discussed, is to check that this "trigger" signal is present at the start of each line in the horizontal mode and each field in the vertical mode. This is accomplished by IC4b which is a D-type flipflop. The flipflop functions as follows: when the clock signal goes high, the signal at the data input is transferred to the output.

The clock signal for the flipflop, IC4b, is either the horizontal or vertical sync pulse depending on the display mode, while the data input is the signal from IC2a. If a cycle of the input waveform has just started the IC2a signal will be high for a time given by the 1M sync potentiometer and if a line scan begins during this time the flipflop will transfer the IC2a signal to its output. The video signals will then be "enabled" for the remainder of the line via IC5a.

If the signal from IC2a is long then more cycles of the input will be accepted so the display will be less fragmented. Unfortunately this also causes the display to be less coherent so there is a definite tradeoff. To get the signal lengths in the "ballpark" the mode switch S1a selects different

Direct video to your TV set

Some constructors may wish to use a direct video connection for an improvement in picture quality, although note that all our photographs were taken using the modulator output. One other advantage of a direct video connection is that there is less chance of interference to other TV sets in the vicinity.

The easiest approach is to connect the video output from the adaptor to the input of the video amplifier in the TV set; ie, immediately after the video detector. If you have access to the circuit diagram of the set you should be able to find the appropriate spot in the circuit without any trouble. Ideally, the circuit will also show the shape and amplitude of the composite sync/video waveform which is normally present at the input to the video amplifier stage.

For example, in a small valve portable TV set we modified for this purpose, the composite sync/video waveform is normally 2 volts peak-to-peak with positive video and negative sync. This is in the right ballpark for the adaptor, which has a composite sync/video amplitude of 1.6 volts peak-to-peak. All that we did was to connect the video from the adaptor to the grid of the video amplifier valve.

Much the same approach applies to solid state sets. Find the video detector and check the video waveform. Provided its polarity is correct and the amplitude is in the ballpark, you can feed the adaptor video signal into the base of the following video amplifier stage as before.

The TV set tuner is set to an unused channel. This means that no video modulation is present from within the set. The video signal will swamp the noise to produce a sharp display.

The polarity of the electrolytic coupling capacitor must be correct and it must have low leakage to avoid upsetting the bias of the following stage.

By suitably adjusting the brightness and contrast controls, a bright and steady display is obtained. The 39k resistor on the video output of the adaptor may not provide suitable bias for some TVs so the actual value is a matter of experimentation. On some sets you may have to remove the 39k resistor altogether.

All the foregoing assumes that you have a set with earthed chassis and transformer isolation from the mains supply. If not, you will just have to use an RF modulator.

Some other sets which have a separate sync detector will not be suitable for the above method of video connection. In these cases it may be possible to connect the sync and video from the adaptor separately, rather than use the composite waveform.

It is possible that the polarity of the video waveform within your set is reversed to that from the adaptor. This will result in poor or incorrect picture sync and a negative (ie, reversed) picture. The solution in this case is to build a single-stage common-emitter amplifier which will provide the necessary waveform polarity reversal.

Finally, if you propose to use an old set for which no circuit diagram is available, it is usually possible to identify the video amplifier relatively quickly. Just take note of the single wire from the picture tube socket which is the video output. Trace this back to the appropriate valve. From there it should be easy to identify the grid. This can be done by measuring voltages — the grid will usually be a few volts negative with respect to chassis.

The same approach would apply to solid state black and white TV sets. The video output transistor can be found by tracing the video output lead to the picture tube, back to its source. From there it's a matter of identifying the base of the transistor and then feeding the signal in as before.

delays, longer for the vertical mode and shorter for the horizontal mode.

So far we have discussed the video and sync circuits but not the horizontal and vertical oscillators. Both oscillators, IC6 and IC7, are 555 astable multivibrators, which are identical except for different frequency determining components. The sawtooth waveform is generated at pins 2 and 6 where the timing capacitor is alternately charged via the pull-up resistors and discharged via pin 7. The sawtooth waveforms are slightly non-linear because of the simple RC circuit used but this has only a minor affect on the performance. The output at pin 3 is used to derive the sync pulses for the video signal.

If the video display is to remain stable the vertical and horizontal oscillators must be in synchronism. This is achieved by connecting the output from pin 3 of the horizontal oscillator, IC6, to the control voltage pin of the vertical oscillator, IC7, via a 1M resistor. The two sync signals are then mixed together by NAND gate IC5c. The combined sync is used to blank the video signals during sync pulses to prevent any interference.

Video and sync pulses are finally mixed together by the resistive divider comprised of 3.3k, 10k and 470 ohm resistors. This gives a composite video output of about 1.6V p-p.

As well as being fed to an output socket, the composite video output is fed to the input of a commercial VHF TV modulator, the Astec type UM1082AUS, made in Malaysia and imported by Dick Smith Electronics. This is housed in a small metal box and is aligned to Australian TV channel 0. Output impedance of the modulator is 75 ohms unbalanced which makes it suitable for connection to the antenna coax socket on most colour TV receivers.

Power for the TV CRO Adaptor is derived from a plugpack power supply capable of delivering 9 to 12 volts DC at up to 100mA or more. The output of the plugpack is fed through a filter consisting of a 22-ohm resistor and 100uF capacitor. The VHF modulator is run from a zener diode regulator network, at 6.8 volts. Note that the unit may also be run from a single 9V battery. Current consumption is about 10 milliamps.

CONSTRUCTION

We constructed our adaptor in a plastic utility box measuring 150 x 90 x 50mm. All the circuitry, except for switches and components, is mounted on a printed circuit board (PCB) measuring 122 x 77mm and coded 80tv8.

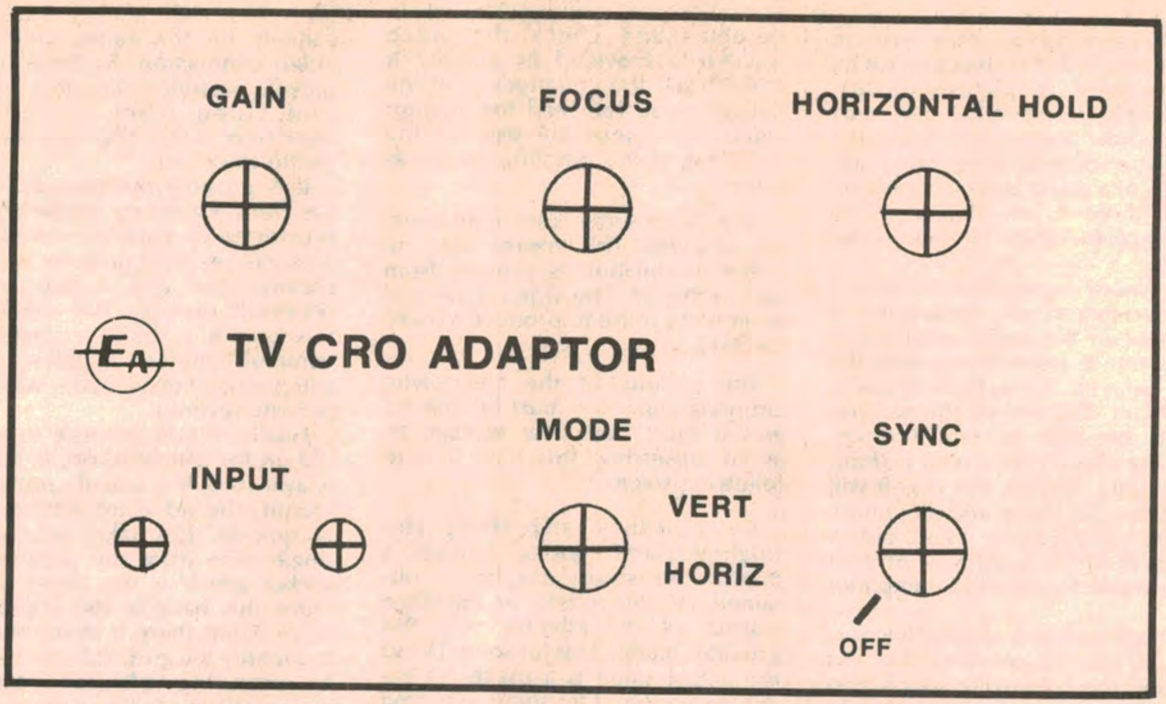
We suggest mounting the links and small components on the PCB first, leaving the CMOS ICs and modulator till last.

Take the usual precautions when soldering the CMOS ICs: avoid handling the pins; use a soldering iron with

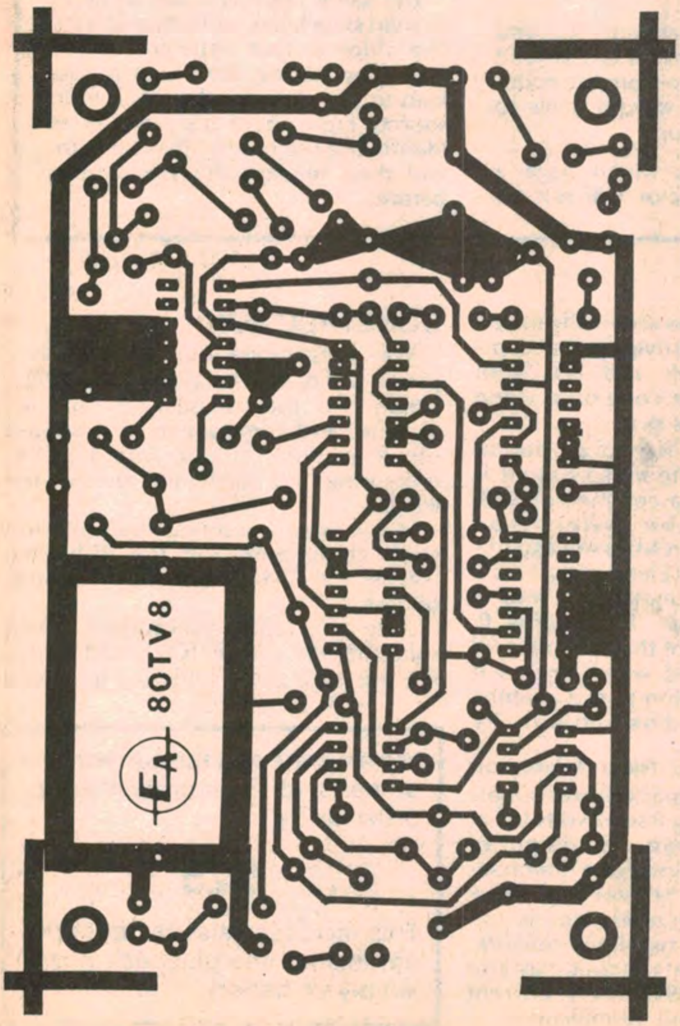
We estimate that the current cost of parts for this project is approximately

$25

This includes sales tax but does not include the plugpack power supply or battery.



Here are actual size artwork for the front panel and the PC board.



the barrel connected to one of the supply rails on the PCB; and solder the supply pins first. This allows the internal protection circuitry of the CMOS ICs to prevent damage from static charges.

The last step in assembly of the PCB is to solder the modulator in place.

Drill the front panel of the utility box using the front panel artwork, featured in this article, to obtain drilling centres. The artwork can also be used to produce an adhesive Scotchcal panel. Alternatively, you can obtain a finished Scotchcal panel from Radio Despatch Service, 869 George Street, Sydney or from Rod Irving Electronics, 499 High Street, Northcote, Melbourne.

The front panel input sockets are connected to the PC board via shielded audio cable to prevent signal pick-up from the oscillators. Note also that the aluminium front panel must be connected into circuit by soldering a link from the shield connection on the 100k gain potentiometer to the back of the potentiometer. Use the wiring diagram to complete connections of the switches, potentiometers and sockets.

The adaptor can now be "fired up". Connect the output of the modulator to the TV via a 75 ohm coaxial cable using an RCA plug at the adaptor end and a Belling Lee coax plug at the other end. Use a 75 to 300 ohm balun if a B/W TV without the necessary 75 ohm input is used. Switch the TV channel selector to channel 0 and with the adaptor in the vertical mode and sync off adjust the horizontal hold on the adaptor for a stable picture.

With a suitable input signal applied a display should now appear. It only remains to practice using the various controls such as sync and focus to obtain the best displays.

Just one final note about using the adaptor: When using the unit in the vertical mode, you may be tempted to turn your TV on its side for a more convenient viewing angle. For many TV sets this is permissible but the smaller portable valve sets do not have generous ventilation and may overheat when turned on their sides.

Well now, we are sure that many readers will agree that this adaptor is a good way of putting that old B&W set into use. Why not go ahead and put it together?