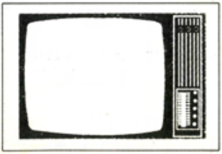
extending the TV-scope

As explained last month, a normal TV set can be used as an oscilloscope. A simple converter for this purpose was described in detail: the 'TV scope - basic version'. In an introductory article it was explained that this basic version could be extended, thereby eliminating its two major weaknesses: limited usefulness at high frequencies and lack of triggering facilities. Before discussing the details of the extension circuits, a fuller explanation of the underlying principles is in order.



The basic version of the TV scope, described last month, can be used to display low-frequency signals on the screen of a domestic TV receiver. This is achieved by sampling the input signal and using each sample to determine the position of a white spot on one line of the final picture. Sync pulses are added to complete the video signal, and an (optional) VHF/UHF modulator is included. The exact details of the circuits were described last month; for the discussion of the extension circuits it is sufficient to consider the basic version as a 'black box' with a low-frequency input and a video (or VHF/UHF) output. The only important technical details for the present are the sampling rate (TV line frequency, i.e. approximately 15 kHz), the fixed timebase frequency (TV frame frequency, i.e. 50 Hz, corresponding to 20 ms) and the lack of triggering facilities.

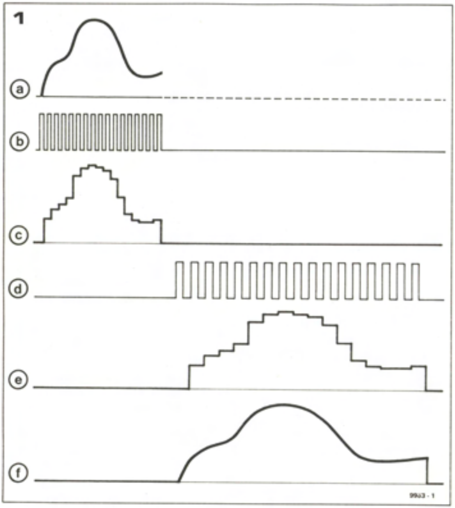
To extend the capabilities of the TV scope, the first priority is to get away from the fixed timebase frequency. Basically, what is required is a timebase expander, that is, a circuit that will 'slow down' a signal to any desired 'speed'. The signal goes in at one end, at high frequency, and comes out at the other with its frequency reduced to a manageable value. In a way, a tape recorder with several tape speeds is equivalent to a timebase expander. If a signal is recorded at, say, 15"/s and then played back at 7½"/s, the frequency of the output signal will be half that of the original. This corresponds to 'timebase expansion'.

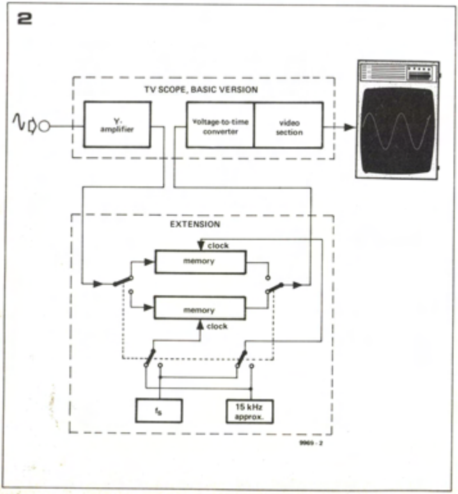
Timebase expansion can also be achieved by purely electronic means. In the extended version of the TV scope, the (by now familiar) bucket-brigade memory is used. The principle is simple: feed the signal into a bucket-brigade memory using a suitable (input) clock frequency and then retrieve it from the memory using a lower clock frequency. Figure 1 illustrates this. The original signal is shown at 'a'. It is assumed that the frequency is too high for the basic version of the TV scope to handle comfortably, so timebase expansion is required: the signal must be 'stretched' along the time axis. To this end, it is first read into the bucket-brigade memory. As explained in last month's article 'Analogue reverberation unit', this process involves sampling the input signal. In figure 1, the (sampling) clock pulses are shown at 'b' and the sampled signal, as stored in the memory, is signal 'c'. The latter signal consists of a succession of discrete voltages, and these can now be read out of memory using a lower clock rate (signal 'd'). The output signal ('e') is a similar succession of discrete steps, with one major difference: the steps are longer. Suitable filtering of this signal results in the final output signal 'f'. As can be seen, this signal has the same 'shape' as the original signal ('a'), but it has been 'stretched' over a longer period of time.

This figure illustrates the function of the extension circuit for the TV scope. Relatively high-frequency signals are read into a bucket-brigade memory, using a suitably high clock frequency, and then read out using a low clock frequency. The two clock frequencies are chosen such that the 'stretched' output signal can be clearly displayed on the basic version of the TV scope, in spite of its fixed 20 ms timebase.

A block diagram for the extended version of the TV scope was included last month in the introductory article, and it is repeated here (figure 2). The operating principle should, by now, be fairly clear. As explained earlier, two bucket-brigade memories are used (per channel). These are used alternately: as one is storing the input signal, the contents of the other are being read out and displayed on the screen. This additional complication is necessary if the display is to remain uninterrupted: if only one memory were available, the different clock frequency during the read-in cycle would make the display useless during that period.

A slight simplification of this block diagram is possible: the selector switch at the input to the two memories can be omitted. When a memory is being used as 'display memory', i.e. when it is being





read out, any new signal entered into it will remain unused – it will be lost during the following read-in cycle.

In the more detailed block diagram shown in figure 3, this input selector switch is omitted. Figure 3 is the 'final' block diagram of the extended version of the TV scope. The shaded portions are the extension circuits, which will be described in greater detail next month; the remainder is the basic version of the TV scope, as described last month. Some of the sections are shown in dotted lines, and these are only required for the two-channel version of the TV scope – i.e. if two signals are to be displayed on the screen simultaneously. If a single-channel version is sufficient, these portions may be omitted.

The basic structure should be fairly clear by now. Y_A is the input amplifier for (one channel of) the TV scope; the circuit details were discussed last month. The output signal u_{ya} is fed direct to the inputs of two analogue shift registers (bucket brigade memories), A1 and A2. At any given moment, one of these shift registers operates as 'input memory' and the other as 'display memory'. The 'input memory' samples and stores the input signal, u_{ya} (as noted earlier, the same signal is also stored in the 'display memory', but it is lost during the next read-in cycle). The clock frequency for the read-in cycle – i.e. the sampling frequency – determines the ultimate 'timebase expansion'.

Figure 1. The basic principle of 'timebase expansion'. The original signal, 'a', is sampled ('b' and 'c'), slowed down ('d' and 'e') and retrieved ('f'). The result is a 'stretched' replica of the original input.

Figure 2. A simple block diagram of the extended version of the TV scope.

Figure 3. A more detailed block diagram. The portions shown shaded-in are the extension circuits, the remainder is the basic version of the TV scope as described last month. This diagram shows the complete two-channel version; the sections shown in dotted lines are not required for a single-channel TV scope.

This signal is generated by the 'input timebase' – the latter being basically equivalent to the timebase in a normal oscilloscope: the input clock frequency determines the time scale along the X-axis in the final display. The phrase 'input timebase' is used to distinguish this circuit from the existing timebase in the basic version of the TV scope (the circuit that provides the clock- and sync pulses required for the actual display).
As the input signal is being sampled and stored in the input memory, the information stored in the other memory during the previous cycle is displayed on the screen. To this end, the display memory receives its clock signal, u_{line}, from the (output) timebase. The frequency of this clock signal can be either equal to or half of the fixed sampling rate of the basic version of the TV – approximately 15 kHz or 7.5 kHz. The output from the display memory, selected by S_a, is fed to a low-pass filter in order to retrieve the original waveshape (see figure 1, e and f). This signal is then processed by the circuits already described in the basic version of the TV scope and displayed on the screen of the television receiver. When the display cycle is completed, the electronic switches S_a, S_c, S_d (and S_b) are operated; the input memory becomes display memory and vice versa.
Obviously, the circuits for the second channel (shown in dotted lines in figure 3) operate in exactly the same way.

Control signals

Even if the basic principle of the TV scope may by now seem fairly straightforward, getting it to work reliably in practice is another matter and some fairly intricate control circuitry is required. Two different clock signals are required for the memories: 256 pulses at the desired sampling frequency during the input cycle, followed by 256 pulses at TV line frequency (or half that) during the display cycle. Moreover, the two clock pulse trains (Ø1 and Ø2) must be fed to the memories at the correct point in the input and display cycles.

Since the memories are used alternately as input and display memory, and since the changeover occurs at the end of each cycle as determined by the u_{reset} pulses from the (output) timebase, the two clock signals must obviously be linked in some way to the u_{reset} pulses. This is illustrated in figure 4. As can be seen, a further signal u_m is generated, which changes state at every u_{reset} pulse. This signal determines which of the memories is to operate as input memory and which is to operate as display memory: it controls the electronic switches $S_a \dots S_d$ in figure 3. The beginning of each display cycle is determined by the signal u_x. This signal goes 'high' shortly after each reset pulse, the delay between u_{reset} and u_x determining the position of the actual display along the time-axis ('X-position'). The beginning of the input clock pulse train is determined in a similar way by pulses generated by the trigger circuit, so that a stable picture can be obtained.
Each pulse train, both for Ø1 and for Ø2, consists of 256 pulses. The frequency of the output clock pulses is normally equal to TV line frequency; the input clock frequency is higher, and is determined by the desired time scale in the final display. The frequency of the u_{reset} pulses corresponds to TV frame frequency (50 Hz).
All the electronics involved in the memory circuits, including the control circuits that produce the signals shown in figure 4, are mounted on a single printed circuit board – the 'memory board'. This board can be linked into the basic version of the TV scope described last month, resulting in the 'extended version'.

Controls and facilities

The various facilities offered by the extended version of the TV scope can be assessed from the front panel controls. The prototype front panel is shown in figure 5. Most of the controls are direct equivalents of their counterparts on a 'normal' oscilloscope:
The on/off switch, labelled 'power', requires little explanation. Above it, there are two 'intensity' controls. 'Signal intensity' sets the brightness for the displayed signal; 'grid intensity' does the same for the calibration graticule.

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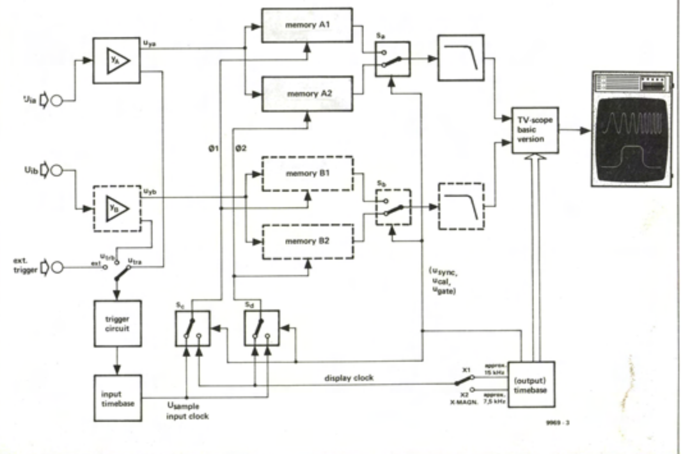

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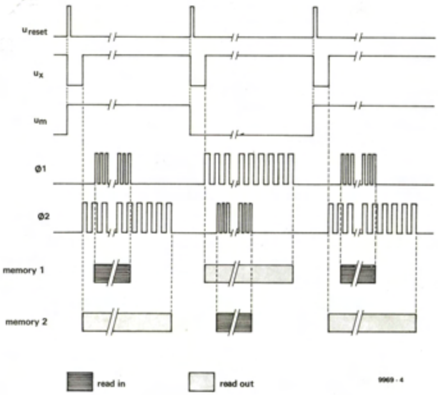

Two time-base controls set the scale of the X-axis in the display. A multi-position switch ('time/div') is used to select a basic period-per-division between 40 μs and 2 ms; fine control of this setting is provided by a potentiometer. A two-way switch, 'x-magnitude', is also included. With this switch in position 'x 1' and with the fine control turned fully clockwise ('cal'), the time per division corresponds to the value selected by the main time/div switch. When the 'x-magnitude' switch is set in position 'x 2', the signal being displayed is 'stretched' along the X-axis: the time per division is halved. The potentiometer marked 'x pos' (X position) sets the position of the displayed signal along the X-axis.

The switch 'trigger/free run' is also common to most 'scopes. In the 'trigger' position, the display is synchronised to an incoming signal. Exactly which incoming signal is used for this is selected by the switch marked 'trigger source': channel A or channel B ('Y_a' or 'Y_b', respectively), or an external trigger source connected to the socket below the trigger controls. This external trigger input is either AC- or DC-coupled, depending on the setting of the switch beside the input socket. The signal level at which triggering occurs is set by the 'trigger level' control; the fact that the TV scope is actually being triggered is signified by a green LED, 'trig'd'.

Figure 4. Some of the control signals required for the memory section. Ø1 is the clock signal for memory A1 (and B1 in a two-channel version); Ø2 is the clock for A2 (and B2). Each clock pulse train consists of 256 pulses. The input clock frequency is higher than the display clock, in order to obtain the necessary timebase expansion.

Figure 5. The (prototype) front panel for the extended version of the TV scope gives a good idea of the facilities offered.

Two signals can be displayed simultaneously on the TV scope: Y_a and Y_b. In some cases it will be useful to display them as two distinctly separate signals, side-by-side on the screen; at other times, it is more useful to have them overlapping so that minor differences can be evaluated – for instance, when comparing the input and output of an amplifier which is being driven to the verge of clipping. On the TV scope, the position of the two signals on the screen can be continuously varied between completely separate and exactly overlapping, by means of the control marked 'trace distance'. In essence, this control is a kind of synchronised Y-position control that affects both channels to an equal amount but in opposite directions.

The sensitivity of the TV scope is set by the controls marked 'volts/div'. On both input sections, the upper control is a multi-position switch and the lower is a fine control potentiometer. A switch next to the input socket offers a choice between AC and DC coupling. The Y-position control, as one would expect, sets the position of the trace along the Y-axis.

The circuit details, constructional hints and calibration procedure will be explained in detail next month. ◾

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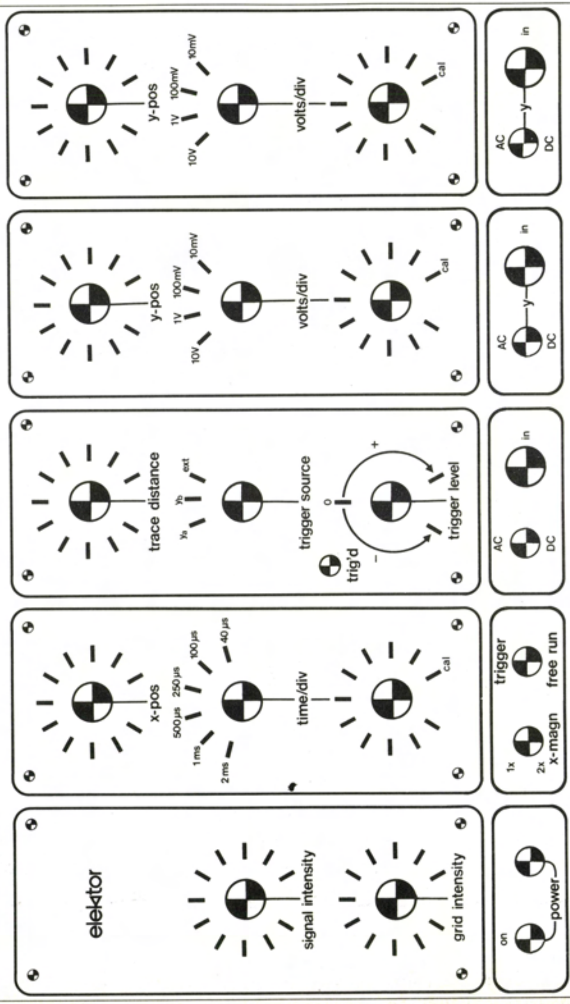
y-pos
10V
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AC
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10V
1V
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volts/div
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y
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trace distance
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trigger source
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trigger level
AC
DC
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1 ms
2 ms
500 μs
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100 μs
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time/div
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2x
x-magn
trigger
free run
elektor
signal intensity
grid intensity
on
power