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application notes

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The Auxiliary Video Facility of the 1480-Series of Waveform Monitors.

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The AUXILIARY VIDEO facility of the 1480-Series of Waveform Monitors is a novel and imaginative feature, whose inclusion indicates the care taken during the planning of these instruments to ensure the greatest flexibility of use, combined with ease of operation and a degree of protection against obsolescence.

Its primary function is to make possible a wide range of signal processing facilities in a side chain, which can be switched in or out without impairing the normal use of the instrument. As can be seen from the schematic diagram (Figure 1), the AUX VIDEO path is functionally an alternative to the built-in range of networks available by the use of the RESPONSE control, but with the advantage of being isolated from the normal signal path by means of buffer amplifiers. It is provided with precision 75Ω input and output terminations, and an overall gain of 1.5 dB. This means that 75Ω passive networks can be inserted without fear of reflection effects, and that gain is available to compensate for their basic loss. The calibration will then be correct whichever path is in use.

The advantages of this facility are illustrated by the following examples.

Noise Reduction by Band Limitation

It is not always realised that the random noise associated with a video signal often possesses a bandwidth extending surprisingly far above the nominal upper limit of the video band. This comes about because the video signal spectrum is limited by aperture and other effects, whereas the equipment handling it is commonly made to have a wide bandwidth to minimise distortion.

In such instances, it follows that the signal-to-noise ratio can be improved at the cost of only a small signal impairment by limiting the bandwidth to its nominal value by means of a delay-compensated lowpass filter of suitable design. This is especially effective with signals which have been transmitted over long microwave links where the noise spectrum tends to rise with increasing frequency, and the greater part of the noise power lies at the higher frequencies.

An example of this is given in the photographs of Figures 2a and 2b, where the spectrum of the random noise was quasi-triangular. In Figure 2a it is not really possible to be sure how much distortion exists at the base of the 2T pulse, whereas in Figure 2b where the signal has previously been passed through an FL4/557 lowpass filter of BBC design connected between AUX VIDEO OUT and AUX VIDEO IN, it is clear that one would proceed with a measurement with much more confidence. The improvement is even greater subjectively than appears from the photographs.

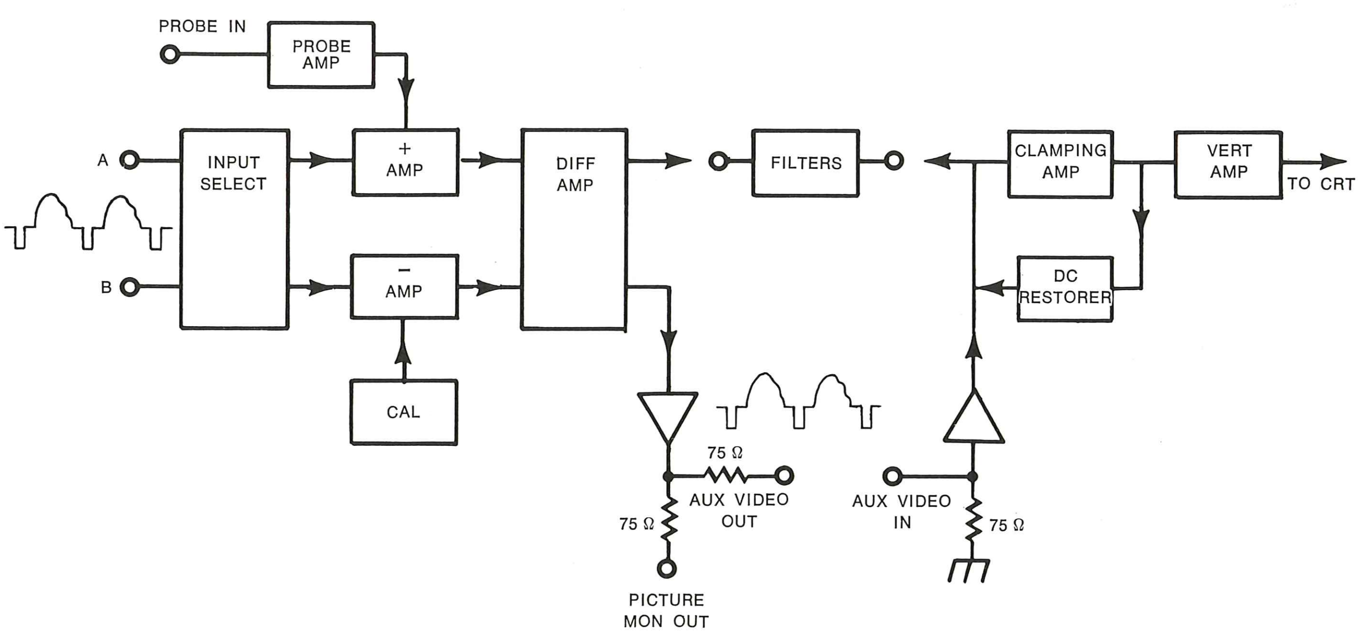


Figure 1. *Block Schematic of Auxiliary Video Facility.*

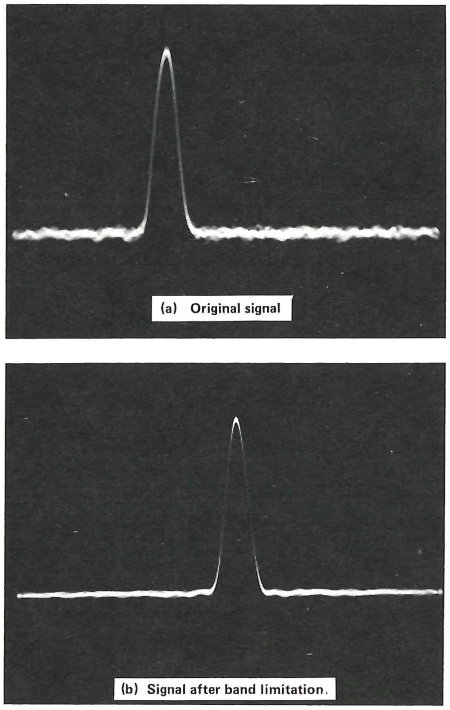


Figure 2. *Improvement in Signal-To-Noise Ratio by Band Limitation.*

The advantages of connecting the filter in the AUX VIDEO path are that it may be left in place as long as desired, ready to be called up at the turn of a switch, and that the distortion likely to be caused by connecting this type of filter between long coaxial cable lengths in a loop-through circuit is eliminated by the good 75Ω terminations provided by the AUX VIDEO path. Moreover, lowpass filters of this type have a considerable time delay, in this instance 500 ns, as can be seen by comparing Figures 2a and 2b. Any possibility of timing errors from such a delay in one signal path only is completely avoided by inserting the filter in the AUX VIDEO circuit.

Most usually, the basic loss of the filter is less than the 1.5 dB gain provided in the AUX VIDEO channel. It is then preferable to insert an attenuator pad of the correct value in series with the filter so as to make the AUX VIDEO gain unity while at the same time preserving the 75Ω circuit impedance. This will ensure that the calibration of the waveform monitor remains the same in both conditions of use. Details of suitable types of pad are given in Appendix I.

Insertion of Measuring Equipment

Video measuring equipment whose output requires a waveform monitor display can be inserted in series with the AUX VIDEO path whenever desired without breaking the input video feed. A case in point is described in some detail in Application Note #12, Part 4, where a TEKTRONIX 1478 Calibrated Chrominance Level Corrector is employed for the measurement of chrominance-luminance gain and delay inequalities. With this kind of connection it becomes possible to make measurements freely under in-service conditions with no fear that the use of the equipment will modify the video signal and become obvious to the viewer. For the same reason, the measuring equipment may be removed or interchanged without any effect on the video feed.

It is also possible to make use of the VIDEO OUT facility to drive another instrument simultaneously from the same signal. For instance, a vectorscope can be added when required without disturbing the normal utilisation of the waveform monitor.

Operational Networks

Tektronix has incorporated into the 1480-Series the widest practicable range of operational networks, that is chrominance and luminance separating filters, and so on. However, it is obviously not possible to anticipate all user requirements, and in fact it may well happen that these needs will change with time. The AUX VIDEO path provides the ability to add or to modify networks as the situation demands, thus ensuring a great deal of flexibility and a degree of protection against obsolescence.

Equaliser Design

Coaxial cable possesses a loss characteristic giving a steadily increasing attenuation with frequency, so in order to maintain the distortion at an acceptably low level it is necessary to equalise long cable runs. It will be shown that the AUX VIDEO facility can be utilised as a very simple and efficient means of designing these networks.

There are two approaches to video equaliser design. In the first, one measures the response to be equalised and then calculates the element values of the network best fitting the inverse of this response over the video band. In the second, advantage is taken of the fact that highly standardised TV test waveforms are now readily available, to obtain the equaliser values directly by inserting in series with the cable a variable network which is then adjusted until the output waveform is judged to have a sufficiently low degree of distortion. This latter method is very fast and economical, since the result is obtained immediately and without computation. It also has the great advantage that the effect of any small residual errors in the fit of the equaliser is automatically minimised, a benefit which could only be achieved by the first method with the aid of a complicated computer program.

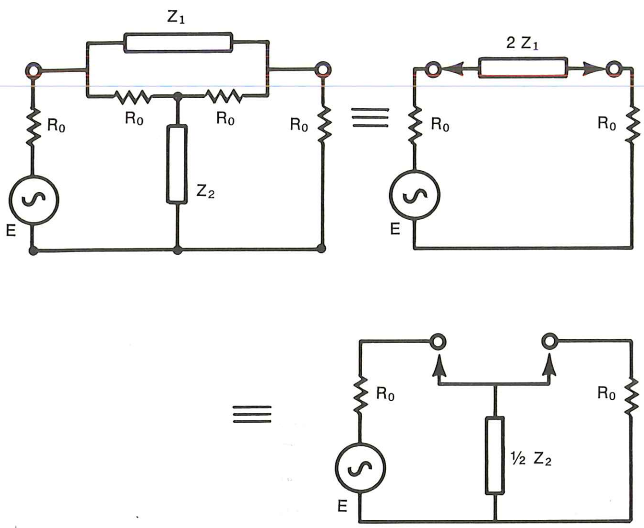
Principle of Variable Corrector

In general one would like to employ constant-resistance networks for equalization purposes since these may be inserted into a circuit of the same impedance without mismatch, and one is sure of obtaining the planned overall response. Unfortunately, even in their simplest forms they are quite complicated networks to make variable since in every instance a pair of arms has to be changed simultaneously so as to maintain the constant-resistance property.

However, there is an extremely useful, and largely neglected, simple relationship between the arms of a constant-resistance equaliser and the two-terminal network which, when inserted between a pair of equal resistances, gives the same insertion-loss characteristic.[1] This should be clear from the diagram (Figure 3).

Now the AUX VIDEO circuit in the 1480-Series provides just the requisite condition for the use of a two-terminal network as an equaliser, that is a pair of output and input impedances which are pure 75Ω resistances. It therefore becomes possible to construct a two-terminal network from variable resistors, capacitors and inductors which is capable of providing a very large range of loss characteristics when inserted in the AUX VIDEO path. Any one of these can then be converted immediately into the corresponding constant-resistance equaliser by a simple numerical process.

It might be mentioned that this is a very practical and efficient procedure which has been used professionally, in the U.K. for example, for the routine equalisation of coaxial cable circuits, and special equipment has been designed for the purpose.



$Z_1 Z_2 = R_0^2$

$$\text{Insertion loss} = 1 + \frac{Z_1}{R_0} = 1 + \frac{R_0}{Z_2}$$

Figure 3. *Equivalence between Constant-Resistance Equaliser and 2-Terminal Networks in Series and Shunt Insertion.*

Illustration of Design Procedure

Great care is taken with the 1480-Series to make sure that the gain is exactly the same in both the luminance and chrominance regions. However, when the monitor is installed the actual point at which the video signal is switched to its input is often physically separated from the input connector by an appreciable length of coaxial cable. It follows that the waveform monitor will have in effect a chrominance-luminance gain inequality which may be completely overlooked, and all chrominance amplitude measurements will be in error by that amount.

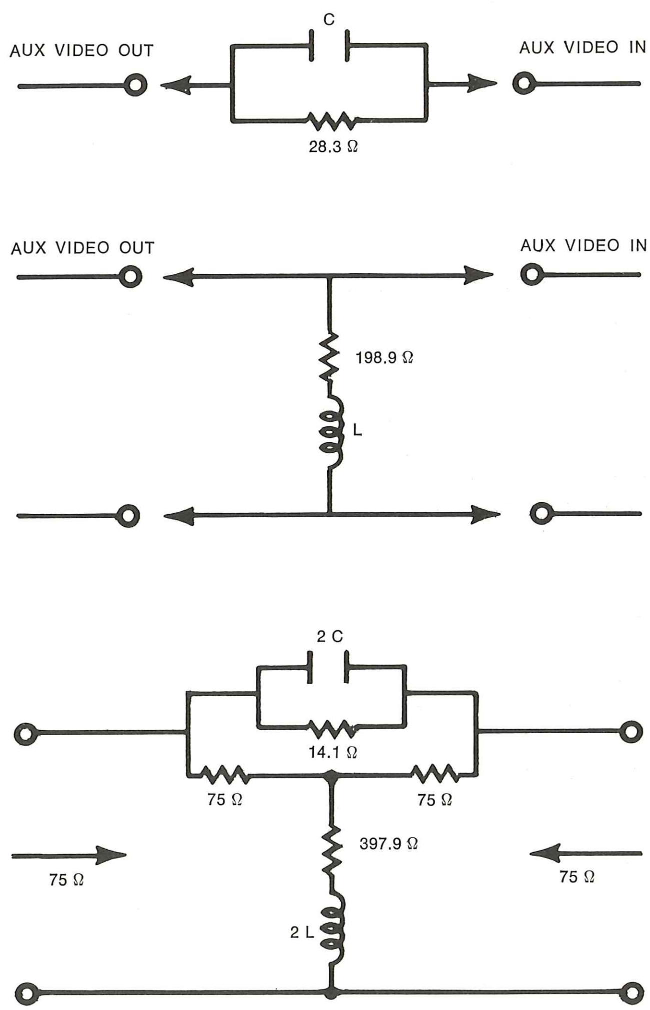
For instance, a typical high-quality flexible coaxial cable such as RG 59/U has a loss at 4.43 MHz of about 0.75 dB per 100 feet. Now as a result of the constraints of bay wiring it is very easy to have 20 feet or more of such cable between the waveform monitor input connector and a switching matrix, say in round numbers a chrominance-luminance gain inequality of 0.2 dB at the least. This is a significant error which should not be tolerated. The answer is to insert a simple constant-resistance equaliser in series with the input video feed.

The design procedure is as follows. The simplest equalisr configuration likely to give the required characteristic will always be chosen first. In this instance it will consist of a resistor and a capacitor in parallel for the series arm, as in Figure 4.

The next step is to select a value for the basic loss, that is the loss at zero frequency, which must obviously always be somewhat larger than the required subcarrier boost. For the sake of example this will be taken to be 1.5 dB, which is given in series insertion by a resistance of 28.3Ω. In most cases it is found easier to switch capacitors than inductors, so the series insertion form is preferred. This resistor is then connected between AUX VIDEO OUT and AUX VIDEO IN, and arrangements made to switch capacitors across it as required. The values for various subcarrier boosts are shown in Table I, for both 3.58 MHz and 4.43 MHz.

A video test signal generator providing a good sine-squared pulse and bar signal, such as the TEKTRONIX 148 for example, is then connected to the point where the video signal is normally applied, and a suitable display of the chrominance pulse (20T, 12.5T or 10T) obtained on the waveform monitor. Initially, with a resistor alone in the series arm, the baseline of the pulse will appear concave, but as the capacitance is increased from zero, this decreases until a point is reached where the baseline is as flat as in the input pulse. Multiplying this critical value by two gives the series arm capacitance of the constant-resistance equaliser.

The element values for the final equaliser can be calculated or taken from Table I. With these small values of correction its construction presents no real difficulties. The required capacitance can be synthesised by connecting values in parallel, and the inductance value can often be found to a sufficient accuracy in a series of commercial miniature wire-ended chokes.



$L = 75^2 C$

Figure 4. *Conversion of 2-Terminal Networks to the Equivalent Constant-Resistance Equaliser.*

The final step is to connect the equaliser in series with the waveform monitor and to readjust the gain to normal, since there will now be a loss of 1.5 dB in the circuit. This will present no problem if the monitor is used with a 75Ω termination since the loss can be made good simply by recalibrating the instrument with the preset variable gain control on the front panel, but with a loop-through connection it will become necessary to insert an amplifier. In this case, where video gain amplifiers are available to standard values such as 3 dB or 6 dB it will be most convenient to choose this value as the basic equaliser loss.

Table I

Values of 2C and 2L as a Function of Subcarrier Boost

Boost(dB)	3.58 MHz 2C(nF)	3.58 MHz 2L(μH)	4.43 MHz 2C(nF)	4.43 MHz 2L(μH)
0.1	0.91	5.1	0.74	4.2
0.2	1.34	7.6	1.08	6.1
0.3	1.71	9.6	1.38	7.8
0.4	2.06	11.6	1.67	9.4
0.5	2.42	13.6	1.96	11.0
0.6	2.79	15.7	2.26	12.7
0.7	3.20	18.0	2.59	14.6
0.8	3.67	20.6	2.96	16.7
0.9	4.20	23.6	3.39	19.1
1.0	4.85	27.3	3.92	22.1

Longer cable lengths can be equalised by exactly the same procedure, with the exception that the very simple configuration employed above will have to be replaced by a more complex structure. The one recommended does not in fact follow the desired law of attenuation particularly well, but where the loss at subcarrier frequency is no more than, say, 1 dB, the errors are negligibly small and any greater complexity of the equaliser arm is not justified by any improvement in performance. Details of networks suitable for cable equalisation in general can be found in suitable texts[1,2].

Impedance Transformation

The AUX VIDEO connector provides an output with a 75Ω source impedance and the same polarity as the output for any of the inputs to the waveform monitor. In particular, it may be used in conjunction with the X 10 probe as an impedance transformer between a very high and a 75Ω impedance. This is invaluable when one wishes to drive another instrument with a 75Ω input impedance, from a probe, for instance a TEKTRONIX vectorscope.

Conclusions

The examples given above are typical of the uses to which the AUX VIDEO facility can be put, and clearly demonstrate the potential it possesses for increasing the field of utilisation of the 1480-Series of Waveform Monitors. It is hoped they will suggest further ideas for employing this facility in the solution of operational and other problems.

References

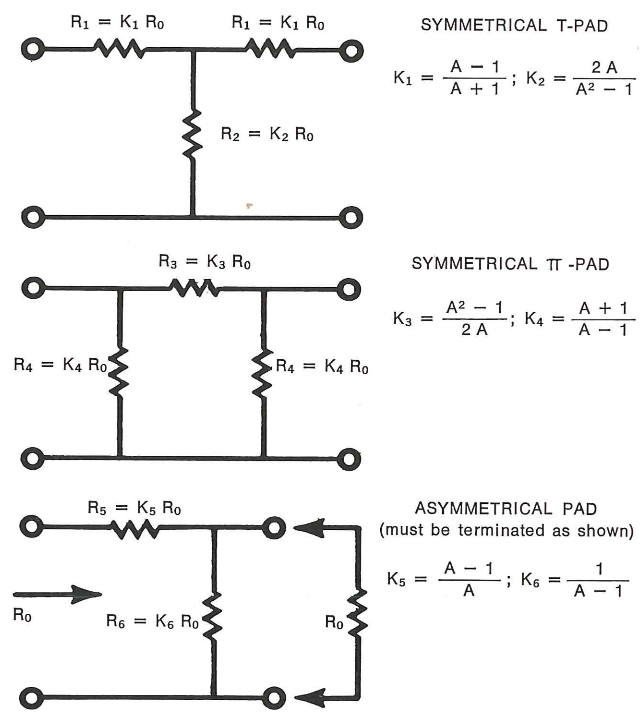
1: Bode: Network Analysis and Feedback Amplifier Design, D. Van Nostrand 1945.

2: Landee, Davis and Albrecht: Electronic Designer's Handbook, McGraw Hill, 1952.

Appendix 1

Resistance Values for 75Ω Attenuator Pads

dB Loss.	R_1 (Ω)	R_2 (Ω)	R_3 (Ω)	R_4 (Ω)	R_5 (Ω)	R_6 (Ω)
0.1	0.43	6.51k	0.86	13.0k	0.86	6.48k
0.2	0.86	3.26k	1.73	6.51k	1.71	3.22k
0.3	1.30	2.17k	2.59	4.34k	2.55	2.13k
0.4	1.73	1.63k	3.46	3.26k	3.38	1.59k
0.5	2.16	1.30k	4.32	2.61k	4.20	1.27k
0.6	2.59	1.08k	5.18	2.17k	5.01	1.05k
0.7	3.02	929	6.05	1.86k	5.81	894
0.8	3.45	813	6.92	1.63k	6.60	777
0.9	3.88	722	7.79	1.45k	7.38	687
1.0	4.31	650	8.65	1.30k	8.16	615
1.1	4.74	591	9.52	1.19k	8.92	556
1.2	5.17	541	10.39	1.09k	9.68	506
1.3	5.60	499	11.27	1.00k	10.46	465
1.4	6.03	463	12.14	932	11.16	429
1.5	6.46	432	13.02	871	11.90	398



A = INSERTION VOLTAGE RATIO = ANTILOG 0.05 (dB LOSS).

Figure 5. *Design of Attenuator Pads.*

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