Some Notes on Aperture Correction

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Abstract: **-- Many video systems use aperture (edge enhancement) correction to improve picture quality. This paper takes an analytical approach to look at the affect on image performance. Also taken into consideration are circuit requirements.**

INTRODUCTION

Aperture correction is the commonly used term to describe a circuit which performs edge enhancement in video amplifiers. Basically, using delay lines the circuit creates a pre-shoot and an post-shoot for every edge transition. Figure 1 shows the circuit diagram. The input signal passes through two delay lines. The center signal is the main signal, the outer two are both ahead and delayed in time. These three signals are summed in the proportions shown to create an edge correction signal. This signal is approximately the second derivative of the input signal. It only has an output during transistions. The correction signal is then summed with the main signal to add to the edge transition as shown in Figure 2.

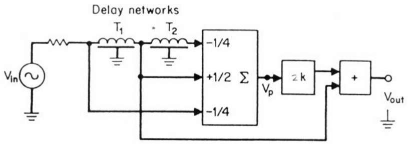

Figure 1.

The input signal is a soft step function (using a sinewave from $-\pi/2$ to $+\pi/2$ as the step). The correction signal is the bottom trace. It has a value of zero except during transitions. This signal is then multiplied by a gain factor (usually called sharpness) and added to the original signal. The result is the top trace. The resulting waveform has a shorter risetime with both pre- and post- peaking.

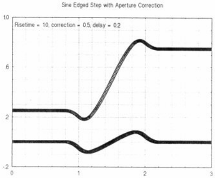

Figure 2.

MODELING AND SIMULATION

This circuit was implemented by writing a C program. The program's input is a data file consiting of time and value data points; basically a piece-wise-linear approximation of an input signal. The data files were either created by another C program or obtained from SPICE. The aperture correction program reads in the data file and performs a numerical representation of the circuit in Figure 1.

The program has an adjustable correction gain and delay. The delay line time can be optimized for any given signal. There are two possible optimizations. If a delay time of 1/2 pixel time is used, then there won't be any overlap from the boosted edges. This is the delay used for this analysis. A delay time of 1 pixel can be used, but the boosted edges now can overlap further increasing the signal. Any greater than this and the overlapping cancels out, thereby reducing the boost. For video signals, the latter delay is given as

$$delay = \frac{1}{2f_{max}}.$$

Figure 3 shows an example of the programs output. The input was a sinewave with a mimum at zero and a maximum at 1.0. That is, a sinewave with an amplitude of 1Vpp and an offset of 0.5V. The program computed the correction signal, bottom trace, multiplied it by the gain factor (adjustable) and output the resulting electronic signal. In a CRT display, however, we are interested in the electron beam intensity, not the cathode waveform. The current will not go negative. To model this the output signal is truncated at zero. This waveform is the top trace.

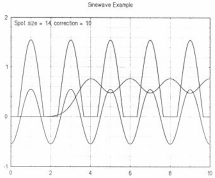

Figure 3.

Now we need to see the resulting affect on the screen. This is done by convolving in time the output signal with a representation of the electron beam spot distribution function. For this analysis it is assumed that the distribution is gaussian. For simplicity of the mathematics, the spot width will be made independent of intensity (which is not exactly reality). Another program was written to perform a numerical convolution. The resulting output waveform represents the light distribution on the face of the CRT. This is the middle trace in Figure 3. From this data, we can calculate modulation using

$$M = \frac{L_{max} - L_{min}}{L_{max} + L_{min}} \times 100\%.$$

This is done for the full frequency range of interest to generate an MTF curve. An example is shown in Figure 4.

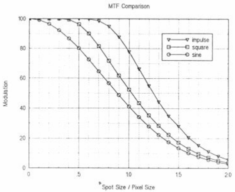

Figure 4.

SINE WAVES

Video systems and broadcast TV can be best modeled using sinewaves. Digital scan converters and doublers may apply more to the next section. Using an input sinewave of full amplitude (black to white) the MTF was calculated and is shown in Figure 5. It can be seen that there is improvement with increased correction gain.

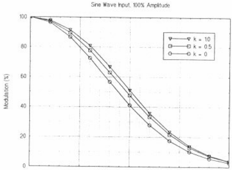

Figure 5.

A much greater improvement can be seen in the small signal response. Using an input signal of 0.5Vpp with a 0.5V offset, we get a greatly improved modulation transfer function. This data is plotted in Figure 6. With the high value of correction gain of 2.0, the resulting MTF is dramatically better than a non-corrected response. This has peaking in the lower end which results in visible aberrations in the picture. This is not desireable. A correction gain value of about 1.5 would give the best response. This improvement cannot be understated. The increase in MTFA from k=0 to k=1.0 is 38%! This basically translates in to a picture that is 38% sharper. This is improved even more with k=1.5.

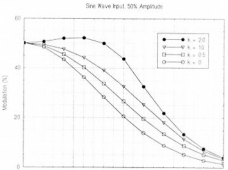

Figure 6.

SQUARE WAVES

This section will look at the effect of aperture correction on square waves. This is the type of waveform in computer and graphics displays. The edges are usually rounded by bandwidth limitations, but we will ignore that and focus on the ideal case.

An MTF plot was made for differing values of sharpness (gain factor k). This plot is shown in Figure 7. This case is for a square wave from black to white. A full 100% step. The MTF does not seem to change much as the sharpness is increased. In fact, the MTF decreases. This is explained by the fact that the beam current does not go negative. Hence, with increased enhancement the average value of output also increases. It does not stay at 50%. This increase in the black level effectively reduces the modulation. This also explains why the improvement for 100% sinewaves is not that dramatic.

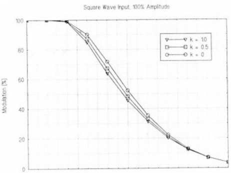

Figure 7.

The same is done for a smaller step size. The small signal case is simulated using a 0.5Vpp square wave with a 0.5V offset. The results are shown in Figure 8. This time the MTF improves with increased k. There is little difference, however, between k=0.5 and k=1.0.

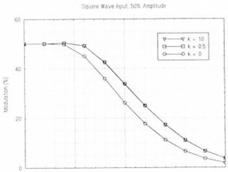

Figure 8.

ELECTRONIC CONSIDERATIONS

All of this improvement does not come without a price. To achieve a value of k=1.5 using sinewaves, the amplifier will need a headroom of +5dB. This is almost double the video swing. It is already difficult to achieve decent bandwidth at regular output voltage swings, but to double it could be expensive.

Another problem is the use of delay lines. To get long enough delays to work with most signals, the only reasonable choice is LC delay lines. Use of coaxial cables is not wise because of the lengths required. The problem with LC delay lines is that their risetime is approximately equal to their delay time. Since the main signal goes through a delay line, bandwidth is effectively reduced. This is not really a problem for sinewaves.

RESULTS

This analysis of aperture correction gives us several results:

- Does not work well for square waves.
- Large signal sinewaves do not improve that much.
- Small signal sinewaves improve dramatically.
- Optimum gain factor is about 1.5.
- Need +5dB headroom for sinewaves.
- Improvement in mid level detail can be greatly enhanced, but little affect on large signal transitions.

Even if the longer delay time is used we will probably get similar results.

This leads us to draw some conclusions about possible implementations. Aperture correction is best used on sinewave video signals only. For small signal transistions, a gain factor of about 1.5 should be used with a gain factor of zero for large signal transistions. This will eliminate the need for so much headroom in the amplifier without any loss of performance. To accomplish this a new circuit must be developed which gives a dynamically variable gain correction. For example, if the gain factor was based on

$$k = 1 - |(input - 0.5)|$$

a good compromise would be achieved. Implementing such a circuit may not be simple nor cost effective.