AN1306

THERMAL DISTORTION IN VIDEO AMPLIFIERS

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ABSTRACT

Thermal distortion is a problem in many high resolution video amplifiers. Thermal distortion occurs when there are instantaneous power changes in the transistor stages. If the problem goes uncompensated, it leads to a visual effect known as smearing. This Application Note will discuss what smearing is, what causes thermal distortion, how to measure it and how to compensate the problem.

WHAT IS SMEARING?

Smearing is best explained by using an example. Smearing, or ghosting, is most noticeable when a black block is displayed on an all white background. Referring to Figure 1, both Sections a. and b. should be the same brightness. When there is a smearing problem, Section b. will be brighter than Section a. This problem is related to the droop of the video signal, and can be explained using Figure 2. Notice after the transition from black to white (from high voltage to low voltage), the video signal is below the specified white level. This signal shows up on the display as a section "brighter" than white. The signal does eventually settle to the white level; but until it does, the display will appear brighter than it should be.

WHAT CAUSES THERMAL DISTORTION?

The transistors of a video amplifier are often subject to large instantaneous power changes because of the large voltage swings, particularly on transitions from black to white. These power changes cause changes in the transistor's junction temperature. Due to the transistor's thermal time constant, which is the amount of time it takes something to heat up or cool down, the transistor can't change temperature fast enough. It is this thermal time constant and the fact that V_{BE} of a transistor changes with temperature, – 2 mV/°C, that causes thermal distortion.

Figure 3 shows a simple example that can be used to explain the thermal distortion concept. In the ideal case, where V_{BE} does not change with temperature, there is a power swing of 107 mW across the transistor. Using the 107 mW and a thermal resistance of 30°C/W, we can see how this power swing affects the output in the real case. (A change in power of 107 mW would create about the normal junction temperature T_E a change of ±1.6°C.) Notice on the plot of T_J, that the junction temperature does not change instantaneously. This is a result of the thermal time constant. Using – 2 mV/°C, we can calculate V_{BE}; from there we can calculate V_E, I_E, and V_O. This example clearly shows the distortion of the square wave.

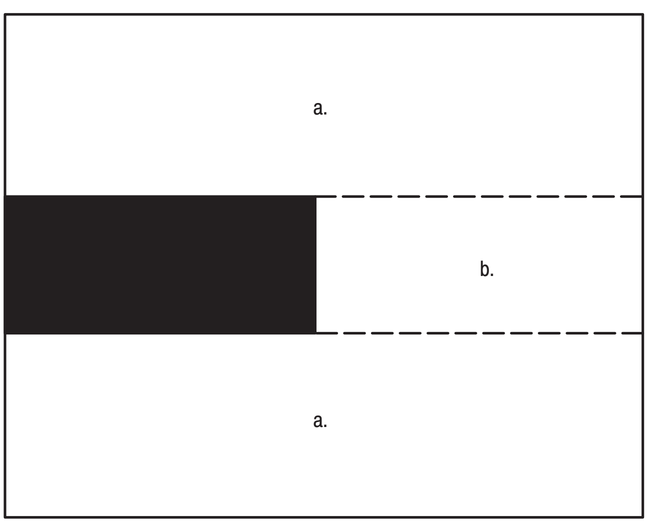


Figure 1.

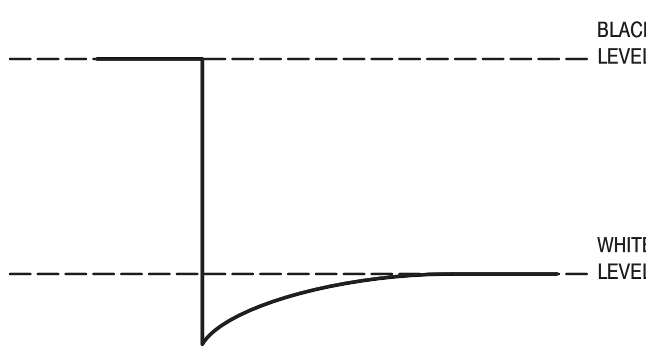


Figure 2.

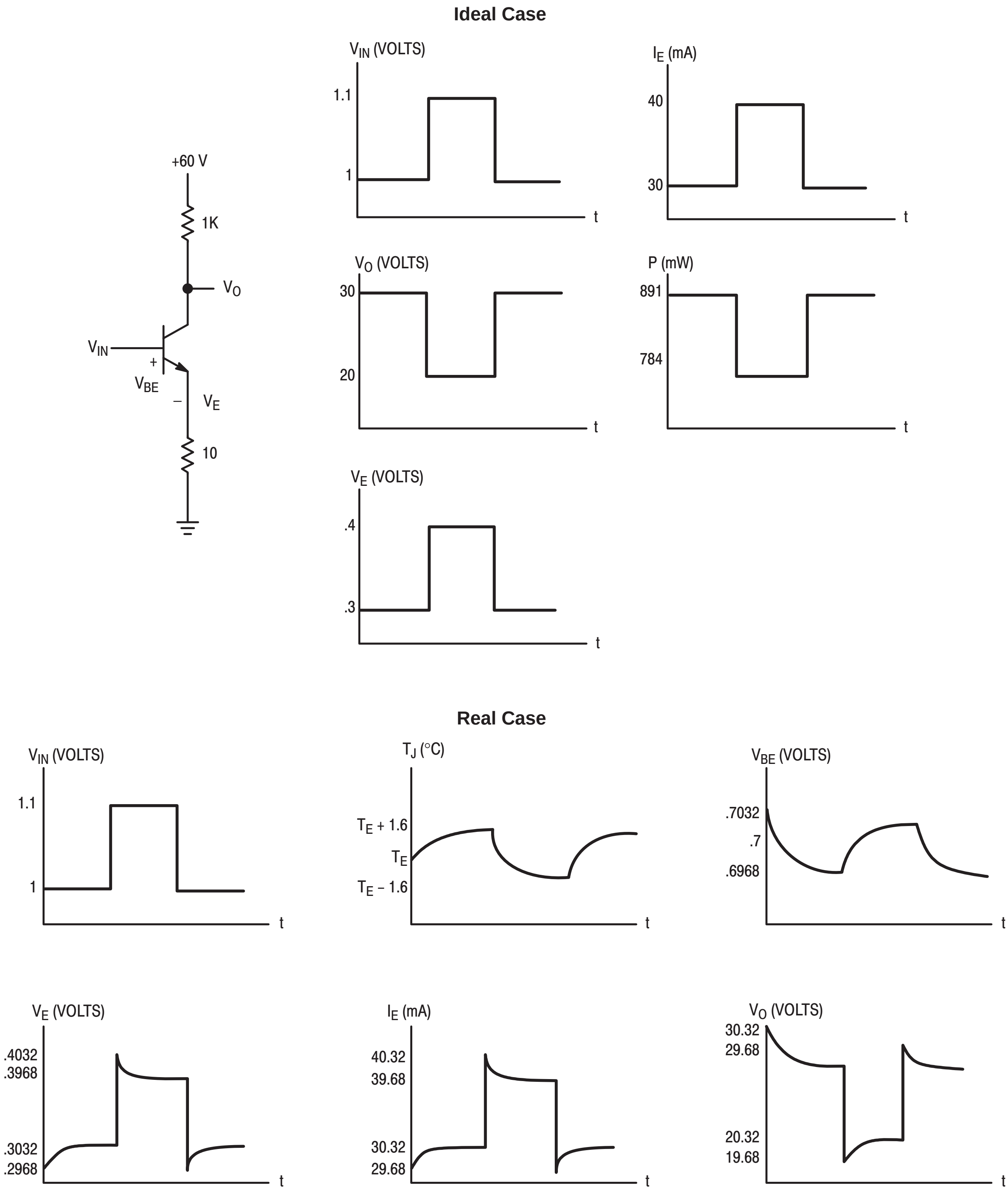

Ideal Case
+60 V
1K
V_O
V_{IN}
+
V_{BE}
−
V_E
10
V_{IN} (VOLTS)
1.1
1
t
I_E (mA)
40
30
t
V_O (VOLTS)
30
20
t
P (mW)
891
784
t
V_E (VOLTS)
.4
.3
t
Real Case
V_{IN} (VOLTS)
1.1
1
t
T_J (°C)
$T_E + 1.6$
T_E
$T_E - 1.6$
t
V_{BE} (VOLTS)
.7032
.7
.6968
t
V_E (VOLTS)
.4032
.3968
.3032
.2968
t
I_E (mA)
40.32
39.68
30.32
29.68
t
V_O (VOLTS)
30.32
29.68
20.32
19.68
t

Figure 3.

MEASURING THE DISTORTION

Making an accurate measurement of the distortion can be difficult. The oscilloscope must have enough vertical offset to enable the edge to be viewed with a reasonable scale. Often, flatness measurements in the 100 mV to 200 mV range must be measured on a 1 Volt/div scale. In this case, the accuracy is not good. Another issue that must be considered is scope performance at maximum offsets. When a scope is operating at a maximum offset, it may introduce some of its own distortion. Check with the manufacturer.

HOW TO COMPENSATE THE PROBLEM

There is no real standard on how small the distortion must be. Several years ago a 1% flatness was acceptable (400 mV for a 40 V swing). On today's high resolution displays, this is clearly unacceptable. A flatness of 200 mV for a 40 V swing will cause noticeable smearing problems. Some designers believe a 50 mV flatness is required, but anything less than 100 mV is generally acceptable. Flatness of 50 mV – 100 mV for a 40 V swing is very difficult to measure.

The effect of thermal distortion can be compensated. The Motorola CR2424 is used as an example to show some of the compensation techniques that can be utilized. The output waveform, when there is a distortion problem, appears as a signal with excessive mid and high frequency gain. The signal would be flat if this excessive gain were eliminated. One way of doing this is to use a series RC network as feedback from the output to the input. The CR2424 has an internal compensation network which noticeably improves the flatness. Unfortunately, this is only a first order compensation network and doesn't eliminate all problems. The flatness can be further improved by adding an external compensation network consisting of a 150 pF capacitor and a 200 kΩ resistor. Figure 4 shows the flatness of the CR2424 without the internal compensation network while Figure 5 shows the flatness with the internal network. Note the considerable improvement in the flatness of the output waveform when the complete CR2424, including its internal compensation network, is used.

Figure 6 shows the effect of an external compensation network. The improvement may seem small, but it can be seen on the CRT. Additional external compensation networks may be added to further improve the flatness. In oscilloscopes, where flatness is very important, as many as ten networks are used.

There is another flatness issue. The first 0.5 μs of the pulse is not flat. This can be seen in Figures 5 and 6. On the display, this problem shows up as a gray area right after the transition from black to white. This is a frequency response issue and can be corrected by adding an additional input peaking network. Figure 7 shows the circuit and a photo of the actual waveform.

When using the external compensation network techniques as previously described, there are several precautions that must be taken. The first precaution is that thermal distortion is dependent on signal swing. The distortion improves with smaller signal swings because the power changes are less. The 200 kΩ and 150 pF RC compensation network was optimized for a 40 V signal swing. For smaller signal swings, the compensation network tends to overcompensate causing the flatness to slope in the opposite direction, i.e., the smearing would appear darker than white instead of brighter than white. In this case, the CRT designer may want to adjust the compensation network (by changing the capacitor) to optimize the flatness at a different contrast level (voltage swing) on the display.

Another area of precaution is the 215 Ω input peaking resistor. Since the CR2424 is a feedback amplifier, the gain is determined by the input peaking resistor and the feedback network. The previously mentioned compensation networks were optimized for a 215 Ω input resistor. If the resistor was changed, the CR2424 would have a different gain and the compensation networks would no longer be optimized.

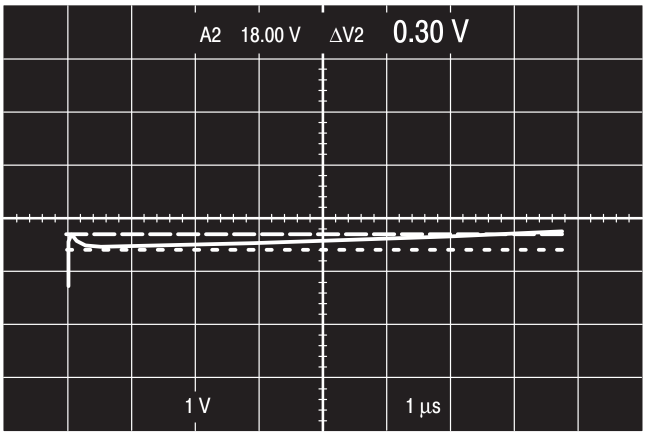


Figure 4. CR2424 Without Compensation

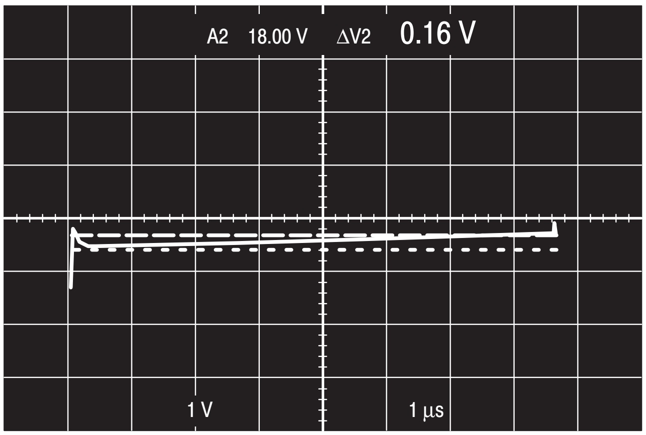
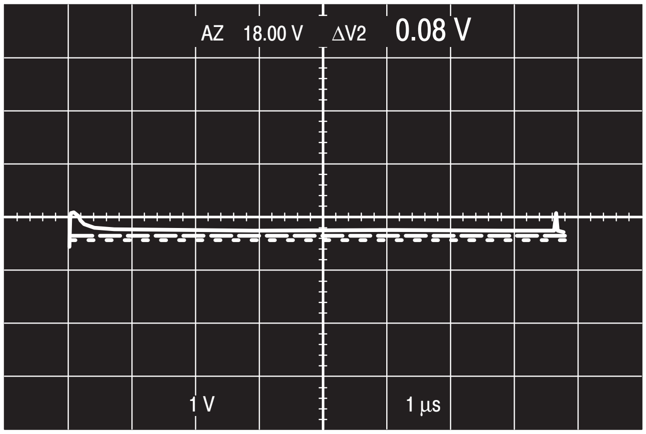


Figure 5. CR2424 With Internal Compensation



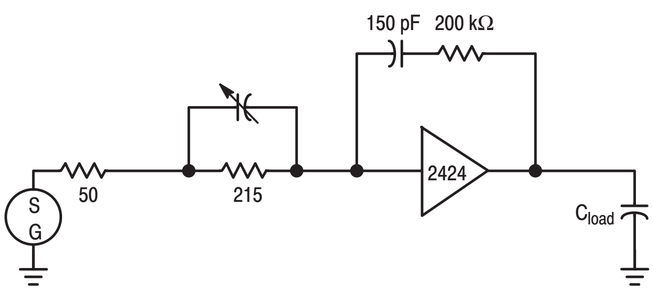
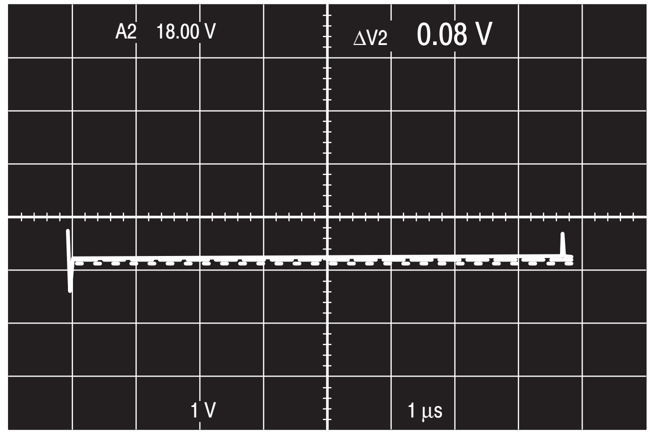


Figure 6. CR2424 With External Compensation



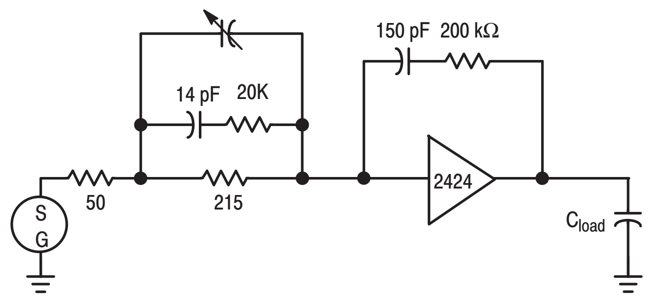


Figure 7. CR2424 With Modified Input Network

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