USING SUPER OP AMPS TO PUSH TECHNOLOGICAL FRONTIERS: AN ULTRAPURE OSCILLATOR

by Dale Eagar

The advent of high speed op amps allows the implementation of circuits that were impossible just a few years ago. This article describes a new topology that makes use of these new high speed circuits and makes astounding improvements in its performance. An oscillator using such op amps has distortion limits beyond our ability to measure.

An Ultralow Distortion, 10kHz Sine Wave Source for Calibration of 16-Bit or Higher A/D Converters

The path to low distortion in an amplifier or an oscillator begins with amplifiers with the lowest possible open-loop distortion and lots of excess open-loop gain in the frequency band of interest. The next step is closing the loop, thereby reducing open-loop distortion by an amount approximately equal to the loop gain. This is not easy, as certain stability criteria must be met by an amplifier that isn't an oscillator or by an oscillator that oscillates at a specified frequency.

The trick used in this circuit is to build an amplifier that has excessive gain where it is needed but no excess gain or phase shift where it isn't. In many applications the band from DC to 100kHz requires the above mentioned high gain; the gain should fall off when the open-loop gain falls through unity (around 5MHz). How this is done in the flesh (silicon) is shown here.

Circuit Operation and Circuit Evolution

A standard inverting amplifier topology, as shown in Figure 87, has a finite open-loop gain in the frequency band of interest (see Figure 88), with some open-loop harmonic distortion (about –60dB) and an open-loop output impedance of about 70Ω.

The amplifier shown in Figure 87 can achieve low distortion, but since the circuit has a limited loop gain, the curative effects of feedback can only be taken so far. The designer must also be careful to ensure that R_L is many times higher than the open-loop output impedance of U1.

Figure 89's circuit makes several improvements over the circuit of Figure 87. First, the open-loop gain of U1 is multiplied by $A_V(f)$, the gain of the composite amplifier stage A1. Second, the input impedance of A1 can be made very high, further improving both open-loop gain of U1 and the open-loop harmonic distortion of U1. Third, the output voltage swing of U1 is decreased, keeping its output circuitry in its lowest distortion area.

The composite circuit, A1, consists of three sections. The first section, as seen in Figure 90, has the gain/phase plot shown in Figure 92. Note the high gain at 10kHz (60dB) and the gain of 6dB at 5MHz, with only 17 degrees of phase contribution. In fact, this looks so nice that you might ask, "why not use two?" and thus reduce your distortion by an additional 60dB?

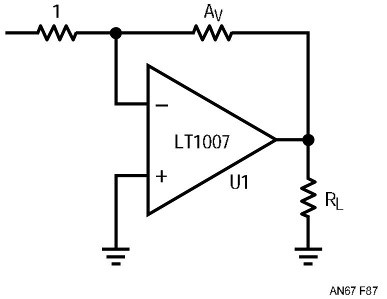

Figure 87. Conventional Inverting Op Amp Topology

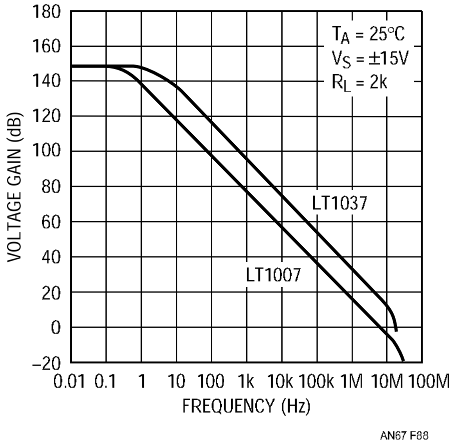

Figure 88. Voltage Gain vs Frequency

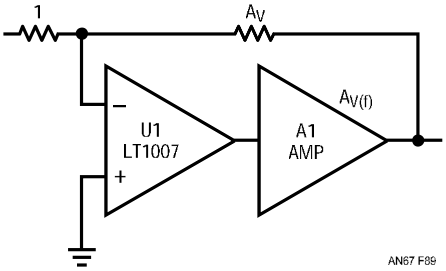

Figure 89. LT1007 Followed by Composite Amplifier A1

The second section, shown in Figure 91, has the gain/phase plot shown in Figure 93. Note that here the gain doesn't change significantly, but the phase is positive just where we want it (1MHz to 5MHz) to allow a very stable system to be built.

The third section, as you might guess, is the same as the first. In sum, the gain/phase plot of the composite amplifier A1 is shown in Figure 94. Note the gain, which is in

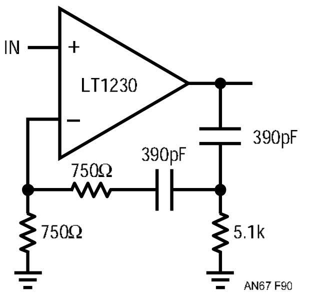

Figure 90. First Section of Composite Amplifier A1

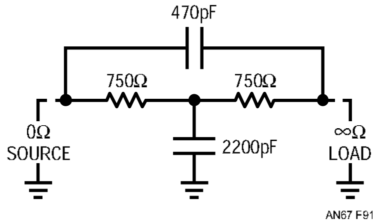

Figure 91. Second Section of Composite Amplifier A1

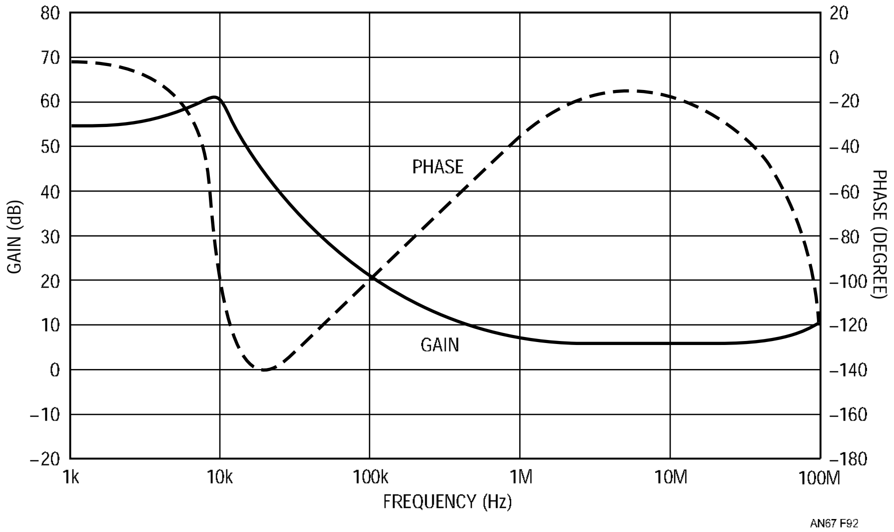

Figure 92. Gain/Phase Response of Circuit Shown in Figure 90

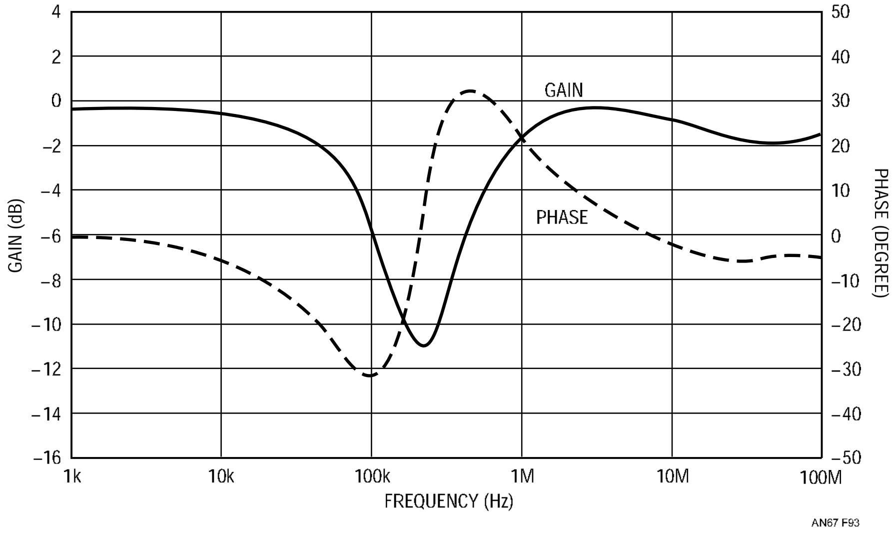

Figure 93. Gain/Phase Response of Circuit Shown in Figure 91

excess of 120db at 10kHz and the total phase contribution of about –20 degrees at 5MHz. The complete gain block is shown in Figure 95.

Super Gain Block Oscillator Circuitry

When A1, as described above is connected with U1, as shown in Figure 89, the resulting circuit is not only unity-gain stable but has open-loop gain of 180dB at 10kHz (yes, 1 billion). This means that the closed-loop harmonic distortion can easily be kept in the region of "parts per billion."

A Wien bridge oscillator with harmonic distortion in the parts per billion is shown in Figure 96. The super op amps S1 and S2 are the previously described composite amplifiers as shown in Figure 95. Note that the output is taken between the two outputs of S1 and S2. This topology gives the best signal-to-noise ratio, in addition to balancing the

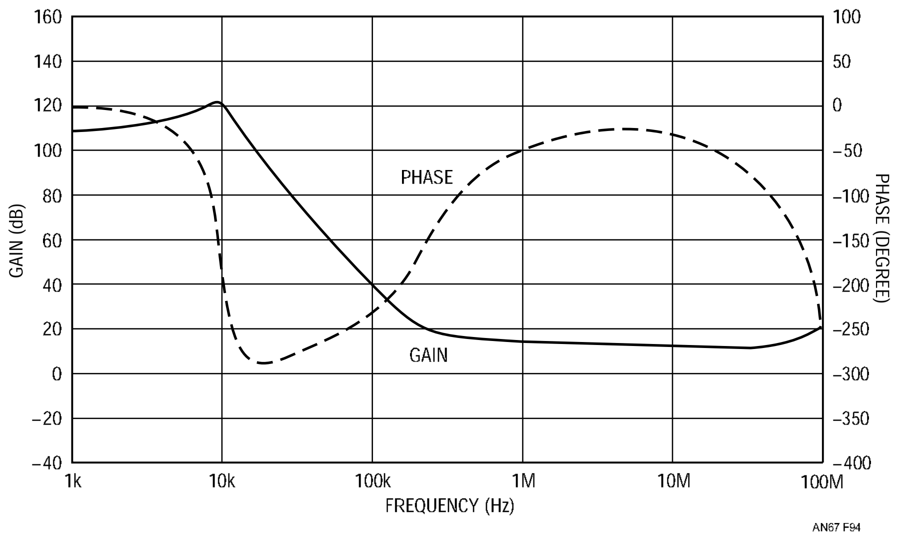

Figure 94. Gain/Phase Response of Composite Amplifier A1 (Shown in Figure 89)

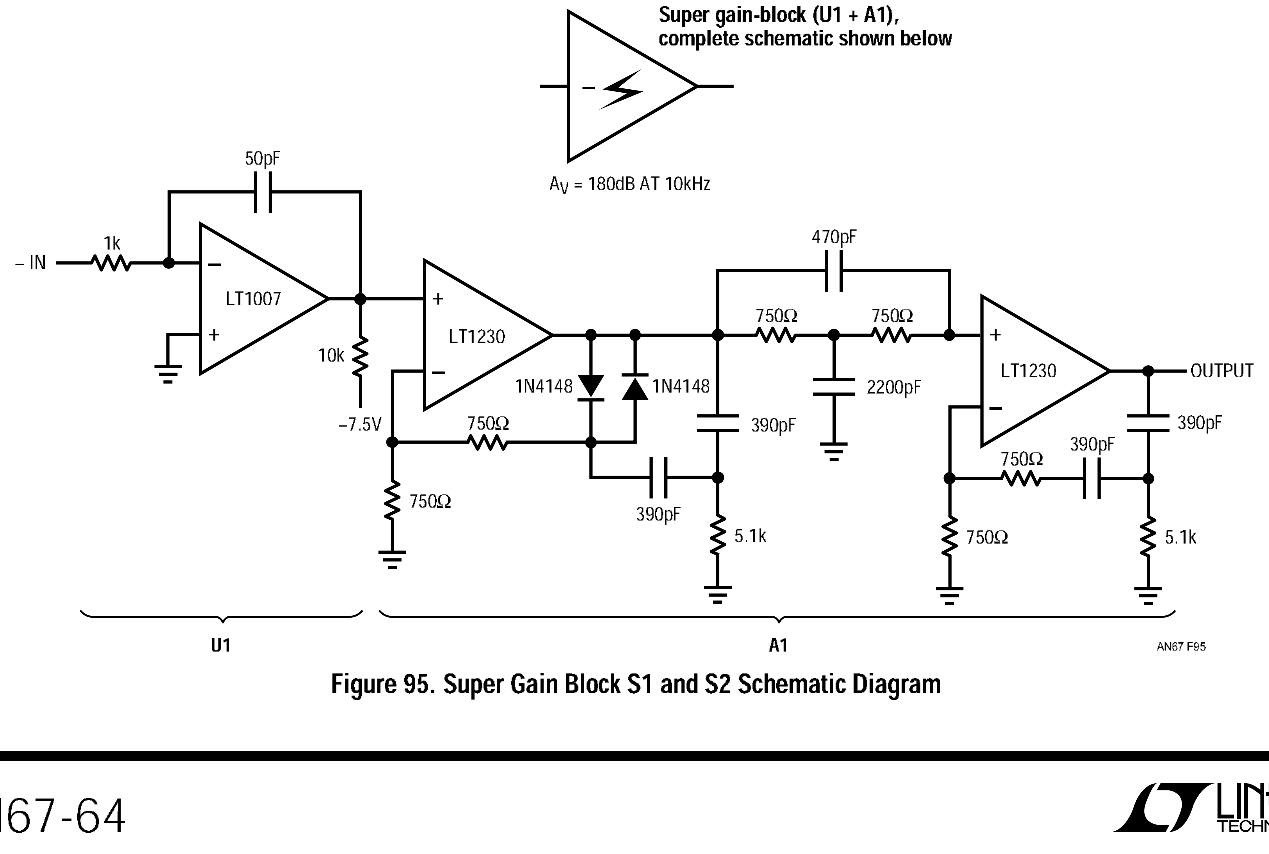

Figure 95. Super Gain Block S1 and S2 Schematic Diagram

power supply currents and their harmonics. Taking the output from one amplifier's output to ground is also valid.

To align the circuit, first center the output amplitude adjustment potentiometer. Next, adjust the gain trim for oscillation while also adjusting the output amplitude for $5V_{P-P}$ output (single ended). Next, adjust the gain trim to $1V_{P-P}$ at the output of the LT1228. Finally, connect a spectrum analyzer to the output of the LT1228 and adjust the second harmonic trim potentiometer for a null in the second harmonic of the oscillator frequency. The measurement of the harmonic distortion of this oscillator defies all of our resources, but appears to be well into the parts-per-billion range.

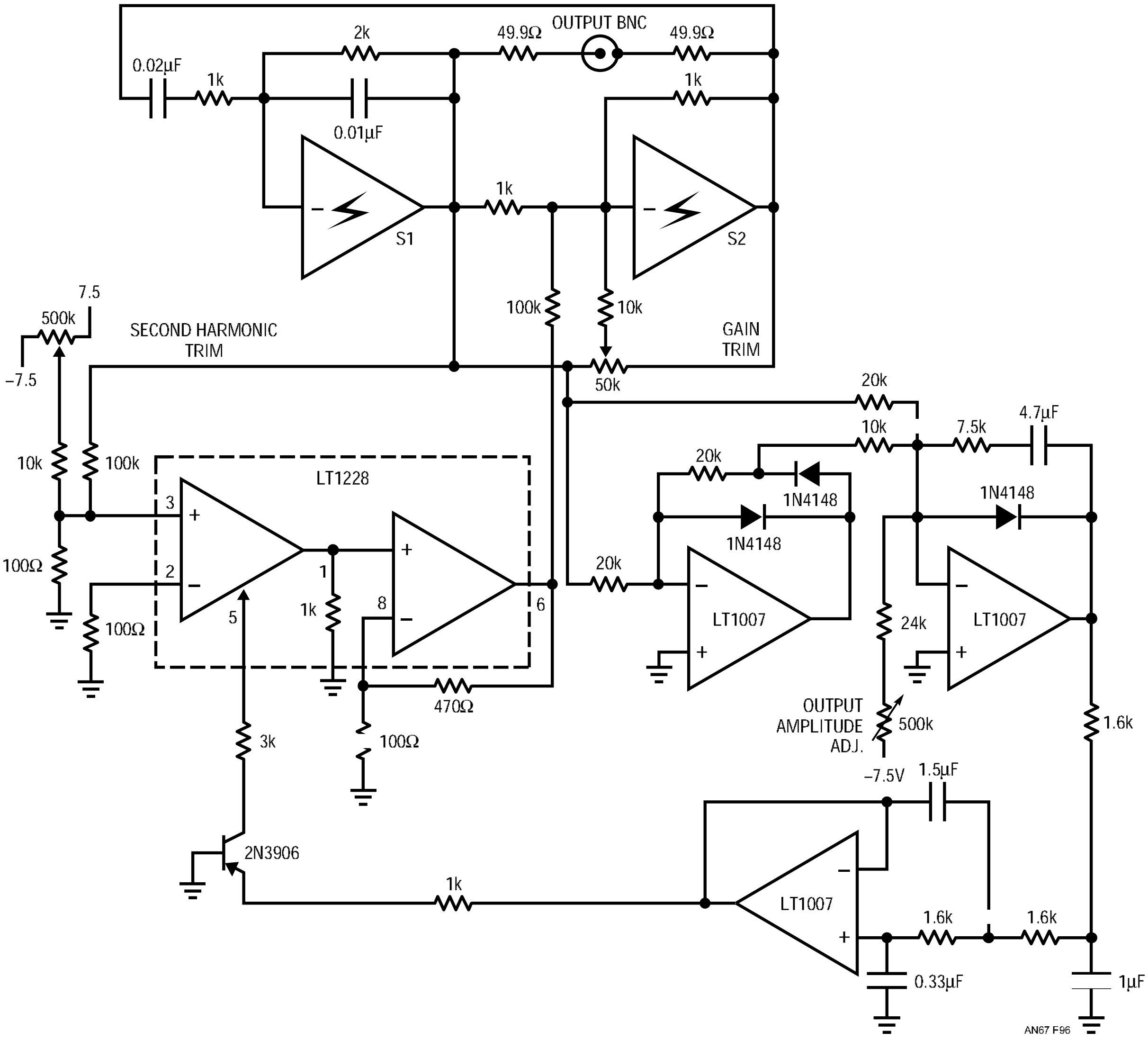

Figure 96. Schematic Diagram: Wien Bridge Oscillator with Distortion in the Parts-per-Billion Range

FAST VIDEO MUX USES LT1203/LT1205

by Frank Cox

To demonstrate the switching speed of the LT1203/LT1205, the RGB MUX of Figure 97 is used to switch the inputs of an RGB workstation with a 22ns pixel width. Figure 98a is a photo showing the workstation output and RGB MUX output. The slight rise time degradation at the RGB MUX output is due to the bandwidth of the LT1260 current feedback amplifier used to drive the 75Ω cable. In Figure 98b the LT1203 switches at the end of the first pixel to an input at zero and removes the following pixels.

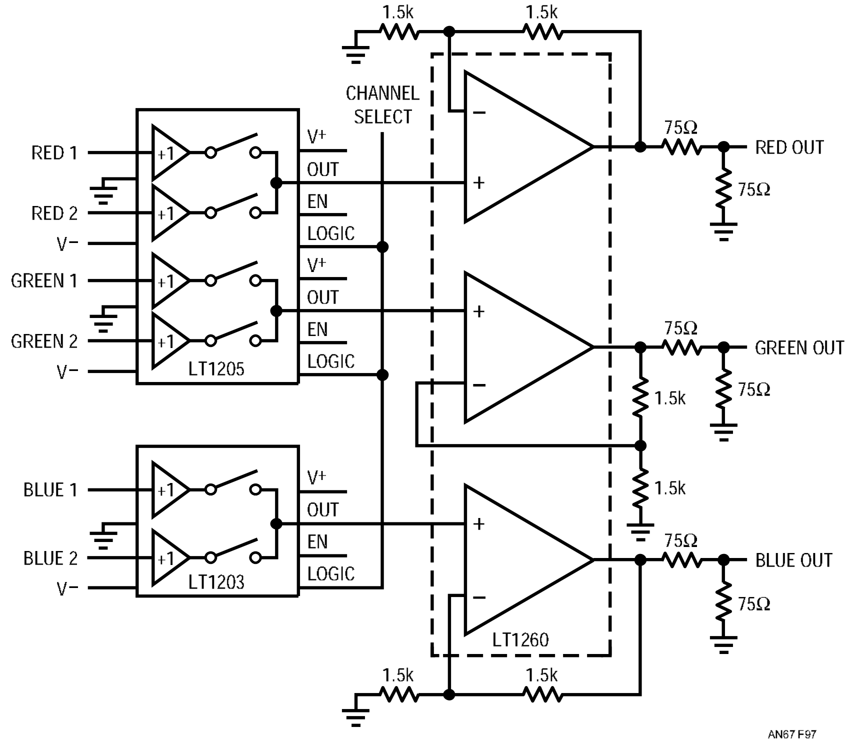

Figure 97. Fast RGB MUX

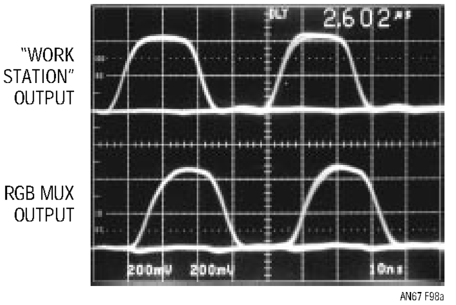

Figure 98a. Workstation and RGB MUX Output

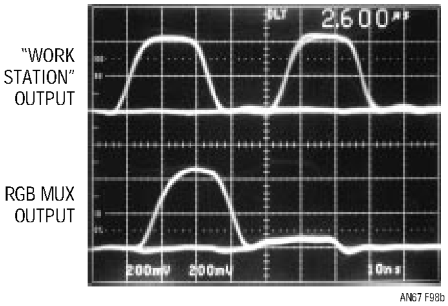

Figure 98b. RGB MUX Output Switched to Ground After One Pixel

USING A FAST ANALOG MULTIPLEXER TO SWITCH VIDEO SIGNALS FOR NTSC "PICTURE-IN-PICTURE" DISPLAYS

by Frank Cox

Introduction

The majority of production[1] video switching consists of selecting one video source out of many for signal routing or scene editing. For these purposes, the video signal is switched during the vertical interval in order to reduce visual switching transients. The image is blanked during this time, so if the horizontal and vertical synchronization and subcarrier lock are maintained, there will be no visible artifacts. Although vertical interval switching is adequate for most routing functions, there are times when it is desirable to switch two synchronous video signals during the active (visible) portion of the line to obtain picture-in-picture, key or overlay effects. Picture-in-picture or active video switching requires signal-to-signal transitions that are both clean and fast. A clean transition should have a minimum of preshoot, overshoot, ringing or other aberrations commonly lumped under the term "glitching."

Using the LT1204

A quality high speed multiplexer amplifier can be used with good results for active video switching. The important specifications for this application are small, controlled switching glitch, good switching speed, low distortion, good dynamic range, wide bandwidth, low path loss, low channel-to-channel crosstalk and good channel-to-channel offset matching. The LT1204 specifications match these requirements quite well, especially in the areas of bandwidth, distortion and channel-to-channel crosstalk (which is an outstanding 90dB at 10MHz). The LT1204 was evaluated for use in active video switching with the test setup shown in Figure 99. Figure 100 shows the video waveform of a switch between a 50% white level and a 0% white level about 30% into the active interval and back again at about 60% of the active interval. The switch artifact is brief and well controlled. Figure 101 is an expanded view of the same waveform. When viewed on a monitor, the switch artifact is just visible as a very fine

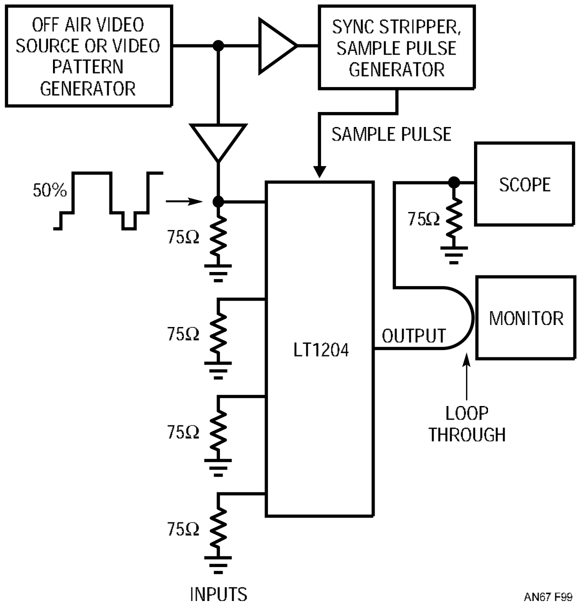

Figure 99. "Picture-in-Picture" Test Setup

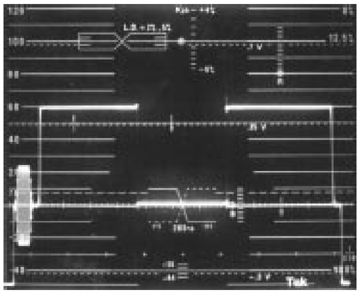

Figure 100. Video Waveform Switched from 50% White Level to 0% White Level and Back

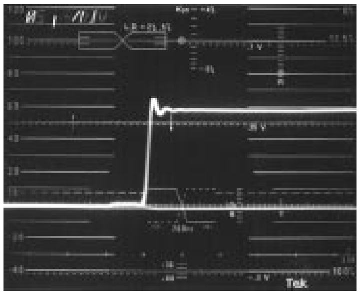

Figure 101. Expanded View of Rising Edge of LT1204 Switching from 0% to 50% (50ns Horizontal Division)