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Linearizing the z-axis of an oscilloscope display

CHRISTOPHER M. HARRIS and ISRAEL ABRAMOV
Brooklyn College, City University of New York
Brooklyn, New York

In most oscilloscopes, the luminance of the display is not proportional to the z-axis voltage. We describe a simple circuit for linearizing this relationship.

Stimuli are often displayed on oscilloscopes by modulating the intensity (z-axis) of the raster line. Unfortunately, the transfer function of the z-axis in many oscilloscopes is nonlinear and is usually positively accelerated in profile. Described here is a simple circuit to linearize display oscilloscopes (Tektronix 606 and 608) on which we present sinusoidal gratings of low harmonic distortion and high contrast.

The circuit is shown in Figure 1. The input signal, Z(in), is first attenuated by R1. Thereafter, the circuit is basically a four-segment attenuator. The upper arm of the divider consists of R2 in series with three resistors (R4, R6, R8) shunted by FET switches. The lower arm is made up of R9. When Z(in) is low, the gate voltages as determined by R3, R5, and R7 are greater than their corresponding source voltages and all FETs are on, so that the voltage division is at a minimum. However, as Z(in) increases, the source voltages also increase until the FETs turn off. This increases the resistance in the upper arm of the divider and therefore further attenuates Z(in). By presetting R3, R5, and R7, the three FET switches can be made to turn off at different voltage levels of Z(in), and thus provide a four-segment attenuator with increasing attenuation as Z(in) increases (negatively accelerated transfer function). This attenuator is most effective when switch 1 is allowed to turn off before switch 2, with switch 3 being the last to turn off. The transition from one segment to another is quite smooth, since these FET devices do not have a sharp on/off "knee." R10 provides an overall attenuation used to scale the four previous scale factors. R11 adds to Z(out) a constant offset voltage, which may be needed to turn the oscilloscope just on for zero input.

Adjusting the circuit requires some trial and error in the following procedure: (1) A raster is created on the oscilloscope exactly as is done when stimuli are presented to subjects; this is necessary because the voltage-to-luminance transfer depends partially on the dwell time of the spot at any location of the screen. (2) A region of the screen is monitored by a fast, linear photocell (e.g., United Detector Technology, PIN-10 in parallel with 100 ohms). (3) The oscilloscope's intensity control is set to zero. (4) Some slow sinusoid or ramp is used for Z(in). (5) Z(in) and the output of the photocell are used as x and y inputs to another oscilloscope; if the voltage-luminance transfer in the display oscilloscope is linear, the trace comparing these two signals will be a straight, diagonal line; if it is not straight, the appropriate resistors must be changed to produce a straight line. Although it is easier to make these adjustments if Z(in) is slow, it is essential to check the final settings using signals up to the fastest that will be used for stimulus displays.

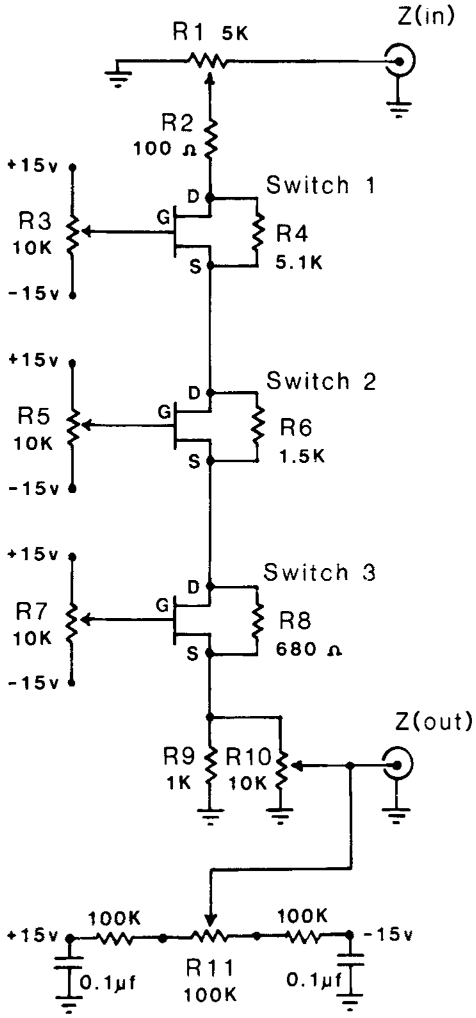

Figure 1. Circuit for linearizing the z-axis of an oscilloscope display. The three FET switches are all in one chip (D-MOS FET multiplexor. Signetics; SD5200N); G denotes gate, D is drain, and S is source. Note: It is essential for correct operation that the polarities of the FET switches be as shown. All variable resistors are 10-turn. The ciruit and the in and out connectors should all be shielded.

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