Create A 250-MHz Bandwidth Digital Potentiometer For Video Level Control

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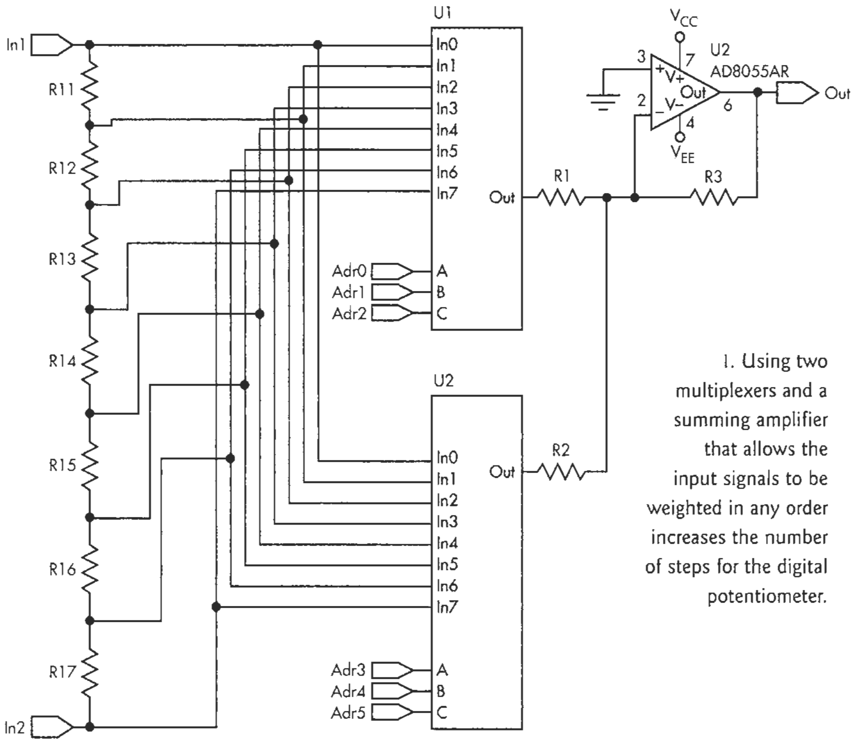
A circuit used to control the level of a video signal should have a 3-dB cutoff frequency of greater than 5 MHz for a television application or 100 MHz for a monitor application. CMOS-based digital potentiometers typically cannot be used as video devices because their frequency responses barely exceed 1 MHz. For such applications, a good choice would be a variable-gain amplifier (VGA) with analog or digital gain control. VGAs are offered as standard, off-the-shelf components by various component manufacturers

However, as the frequency range of VGAs improves, other parameters degrade. For instance, it's difficult to design high-frequency devices with low dc offsets and tight gain characteristics. In video applications, spreads in the gain and high dc offsets require additional effort to regenerate the black level or white balancing.

But a suitable video level-control circuit can be based on a digital potentiometer. In its basic form, a digital potentiometer includes an n-step resistor ladder connected to the n inputs of a multiplexer that chooses one of the ladder's points to connect to the output. Analog multiplexers for video applications have 16 inputs at most. Combining them with a 15-step resistor ladder will result in a 4-bit digital potentiometer, which is a poor solution for video applications.

A simple way to get more steps for the potentiometer is to use two multiplexers instead of one and to combine their output signals with a summing amplifier *(Fig. 1)*. The summing amplifier allows the input signals to be weighted in any order. For example, with two eight-input multiplexers and a weighting of 1:8 in the summing, a 64-step (6-bit) potentiometer is possible. This is a noticeable improvement but still too coarse for some applications.

To add more steps, use a video switch matrix like the AD8111 (16 inputs, eight outputs) or AD8175 (16 inputs, nine outputs). They have a 1-dB frequency response from dc to 250 MHz and a dc offset of 5 mV. These devices can be considered as eight (or nine) 16-to-1 multiplexers with parallel wired inputs. Every input is buffered and can be switched through to any output.



1. Using two multiplexers and a summing amplifier that allows the input signals to be weighted in any order increases the number of steps for the digital potentiometer.

A resistive attenuator connected to the inputs generates different levels of the video signal. These levels can be applied on random outputs of the matrix. An operational amplifier used as a summing device mixes them with the related weight and produces the desired gain or attenuation on the video signal at the output.

Combining the different attenuation levels on the inputs with the different weighted outputs of the matrix produces plenty of combinations for the signal level at the output of the summing amplifier $S = I^W$, where S is the number of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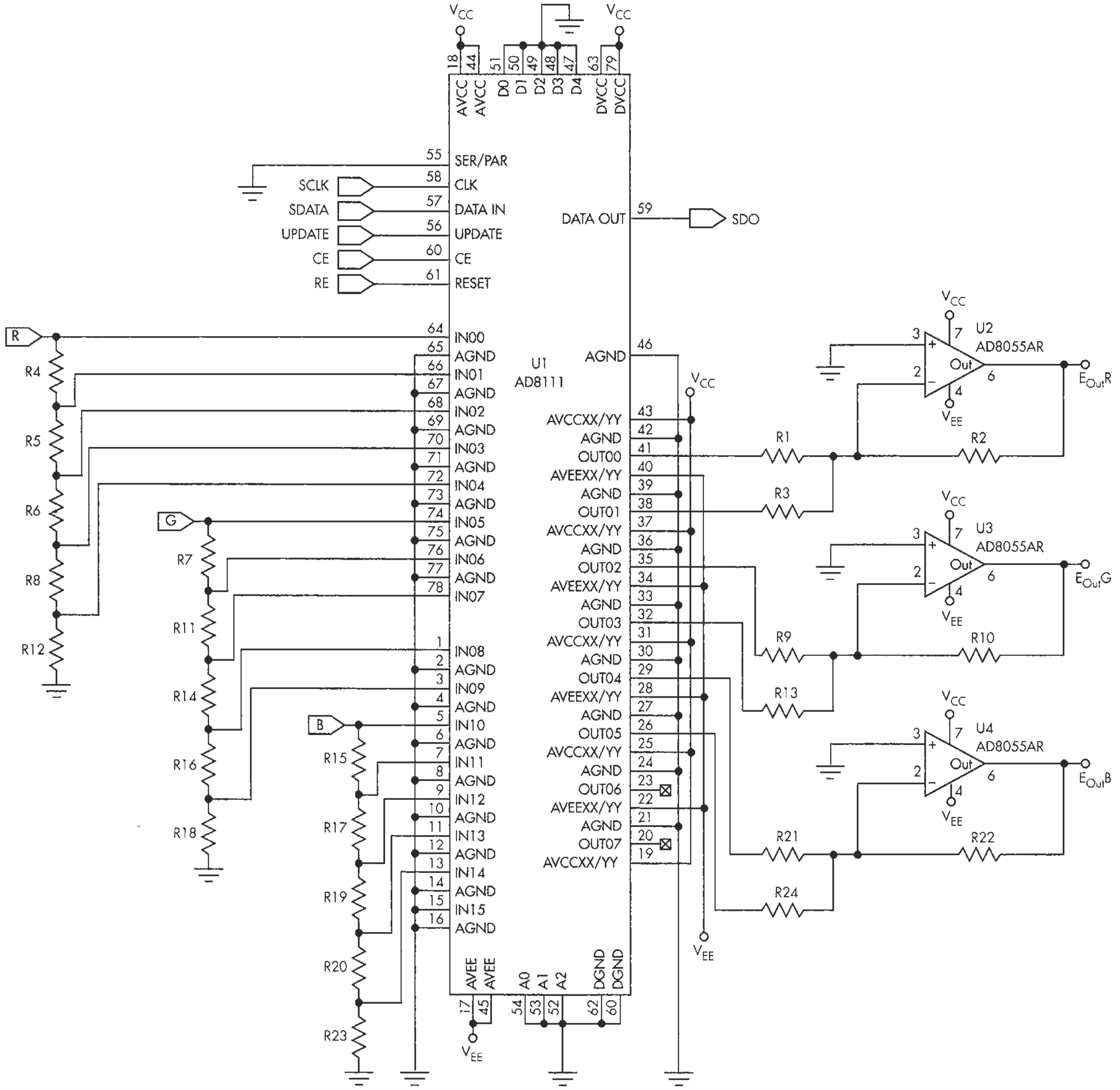
steps, I is the number of inputs connected to the resistive attenuator, and W is the number of the used outputs.

For example, the AD8111 (16 inputs, eight outputs) allows you to mix 16 levels in eight weights, resulting in a 16^8-step (2^{32}-step) potentiometer—an accuracy that's beyond current needs. But video signals are often split into their red, green, and blue (RGB) components, which need to be attenuated separately. This would require three independent potentiometers. Therefore, by using the same matrix for each of them, five levels of every color could be mixed in two weights. The result is a triple 25-step potentiometer (*Fig. 2*). With the AD8175, which has an additional output, three weights are possible, allowing 125 steps per color.

All of these calculations are based on the assumption that the ladder of the resistive attenuator consists of equal-valued resistors, and the mixer ratio equals the number of used inputs. Hence,

$$\frac{R1}{R3}=\frac{R9}{R13}=\frac{R21}{R24}=I$$

where I is the number of the used inputs.



2. With a video switch matrix like the AD8111, which has 16 inputs and eight outputs, the circuit has enough steps for video applications, as well as sufficient bandwidth.