Programmable-Gain Amp Uses Arbitrary-Attenuation Step Ladder

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The R-2R ladder, a well known resistor topology, is often used to implement a current or voltage 6-dB step attenuator. By appropriately scaling the resistor values, this network also can be modified to provide any desired attenuation.

The modified resistor ladder uses three different resistor values *(see the figure)*. A short algebraic manipulation can show that:

Step attenuation (dB) = 20 log $[R3/(R1 + R3)]$

$R_{IN} = R1 + R3$

$R2 = R3\,(1 + R3/R1)$

If R1 = R3, then R2 = 2 × R1. In this case, the R-2R network provides a 6-dB step attenuation.

To determine the resistor values for a specific step attenuation and input resistance, use the formulas:

$K = 10^{[\text{step attenuation (dB)}/20]}$

(Note that the step attenuation (dB) value should be negative!)

$R1 = R_{IN}\,(1 - K)$

$R2 = R_{IN} \times K/(1 - K)$

$R3 = K \times R_{IN}$

For example, to implement a resistor ladder with a −1.5-dB step attenuation and 500-Ω input impedance:

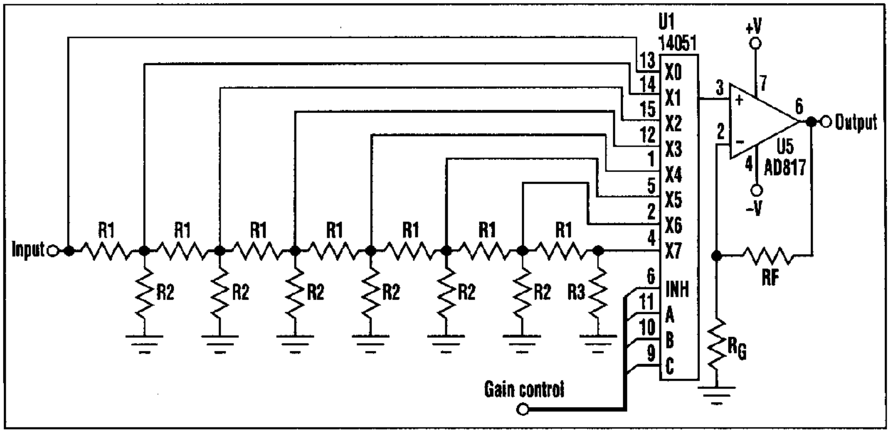
$K = 0.8414$

$R1 = 500\,(1 - 0.8414) = 79.3\ \Omega$

$R2 = 500 \times 0.8414/(1 - 0.8414) = 2653\ \Omega$

$R3 = 0.8414 \times 500 = 420.7\ \Omega$

There are a couple of interesting points to observe about the PGA circuit. A standard CMOS analog switch is used to connect the attenuated signal to the noninverting input of the op amp, which has a high input impedance. Since the current through the switch is negligible, low attenuation and distortion is achieved. A wide-bandwidth (video-bandwidth), low-distortion PGA is created through the use of very low-cost standard devices.



This wide-bandwidth, low-distortion programmable gain amplifier (PGA) is built using low-cost standard devices, eliminating the need for an expensive programmable-gain amp IC.