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AN-137
APPLICATION NOTE

# A Digitally Programmable Gain and Attenuation Amplifier Design

by James Wong

By adding two resistors to the output amplifier feedback loop of a current output D/A converter, you can get gain control in addition to attenuation control. Figure 1 shows a complete digitally programmable amplifier that is capable of producing gain as well as attenuation in the range of 1/64 to 64. The circuit derives its range by using a 12-bit CMOS D/A converter.

The design is based on the fact that the transfer function from the input to the output of the D/A converter is purely voltage attenuation. Connecting the two resistors $R_1$ and $R_2$ in a "T" configuration inside the feedback loop of the output amplifier produces a voltage gain from the resistor junction to the output. If $R_1$ is much smaller than $R_{FB}$ (in this case $R_{FB}$ is 11kΩ), then the gain produced is approximately equal to $1 + R_2/R_1$, or 64. The result is a programmable gain amplifier that has a transfer function of:

$$A_V = -\left(\frac{D}{4096}\right)(64),$$

where D represents the binary weighted digital code of the D/A converter.

Of course, the added gain of the T-network does increase the noise gain of the circuit. Be sure to choose a low noise amplifier to begin with.

By using a low noise, high-frequency op amp such as the OP-61, besides keeping noise level down, it gives the circuit a wide bandwidth performance even at high-gain settings.

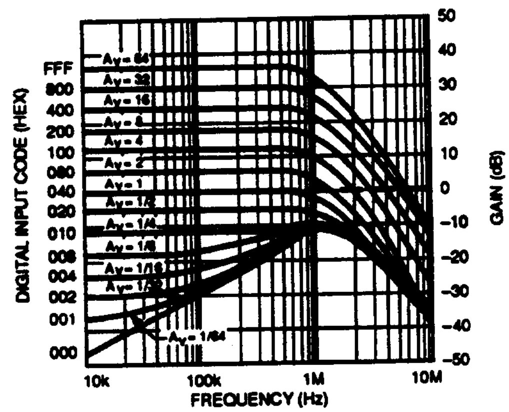


**FIGURE 2:** *Gain vs. Frequency Response for the Twelve Binary Gain Settings*

Figure 2 shows the frequency response of the programmable gain circuit at various gain settings. At high gains, the amplifier has 1MHz bandwidth. At gains below 1/4, the D/A converter's stray capacitance feedthrough limits the amplifier bandwidth, while still achieving 20kHz.

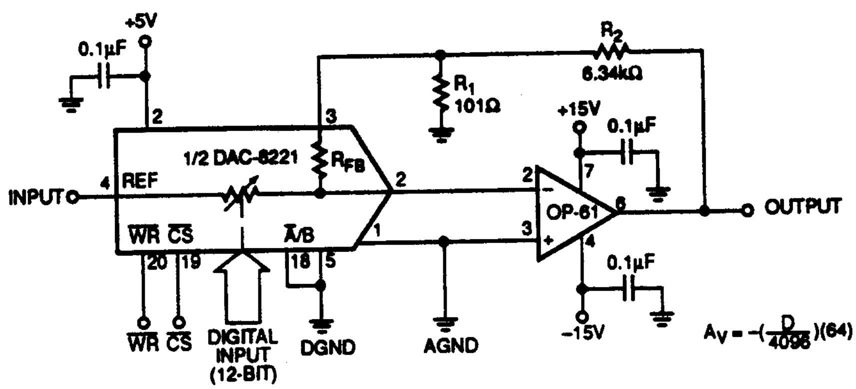


**FIGURE 1:** *Two Resistors $R_1$ and $R_2$ Add a Gain of 64 to the D/A Converter, Resulting in a Simple Digitally Programmable Gain Amplifier*