D-a converter forms programable gain control

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A monolithic multiplying digital-to-analog converter can be used with an operational amplifier to produce a simple digitally controlled amplifier. Logic voltages applied at the 10 input terminals of a converter such as the Analog Devices AD7520 control the gain. These voltages can provide 2^{10} discrete levels of amplification for an analog signal applied to the operational amplifier. The integrated circuit can handle analog signals up to ±10 volts, and the digital input levels are compatible with transistor-transistor logic and complementary-MOS.

A BCD-to-decimal decoder drives the d-a converter in the circuit of Fig. 1, giving gains as high as 60 decibels in 10 6-dB steps. The circuit requires only a few components because the multiplying converter IC contains the C-MOS switches and precision-resistor ladder network that set the gain of the amplifier.

The 741 op amp is connected as a conventional inverting amplifier, with an input resistor and a feedback resistor. As shown in Fig. 2, these resistors are elements of the d-a converter, and its control inputs determine the amount of resistance in the feedback loop.

Current from the output of the op amp that enters terminal 15 (V_{REF}) of the converter sees a resistance of R. This current, I_{REF}, divides in half at every node of a ladder network made up of resistors R and 2R. Part of this current goes to ground, and the remainder goes to the inverting input terminal of the op amp (virtual ground). In Fig. 2, since only the second control bit is high, I_F, the current fed back, is $I_{REF}/4$.

The input signal to the amplifier circuit is applied to terminal 16 of the AD7520 (the terminal marked $R_{FEEDBACK}$) because the internal resistor at this terminal matches the others in the converter. The input signal also sees a resistance of R and delivers a current equal to I_F. The gain of the amplifier circuit is

$$e_o/e_i = -I_{REF}R/I_FR = -I_{REF}/I_F$$

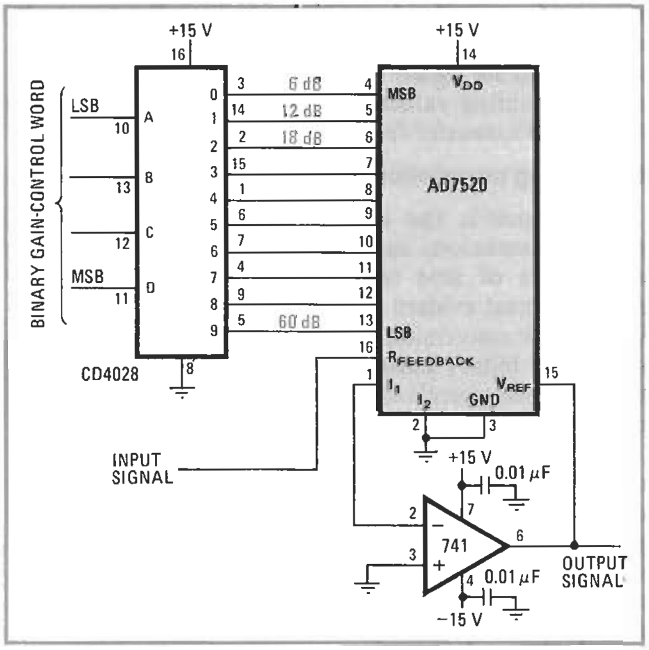
For the example in Fig. 2, where I_F is $I_{REF}/4$, the gain is -4, or 12 dB.

The input word in Fig. 1 causes only one of the AD7520's control inputs to go high. The voltage gain of the amplifier can be written as (-2^{n+1}). Expressed in decibels,

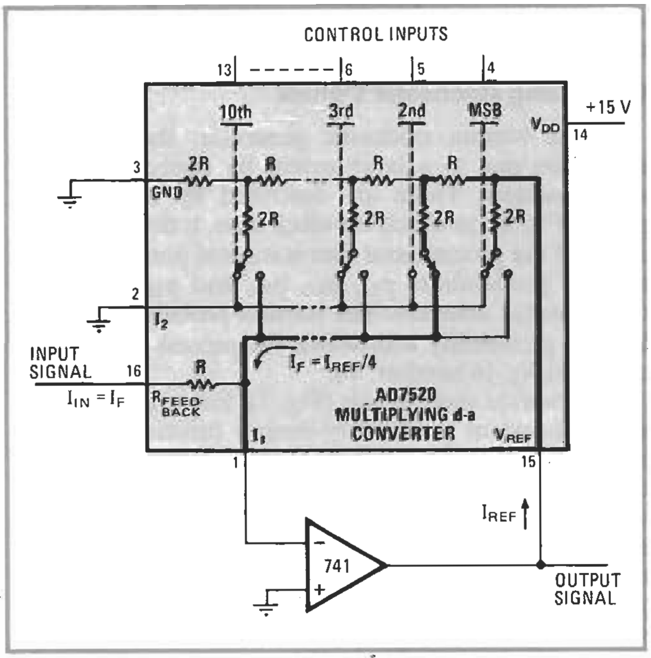
$$G = 6(n+1)\ dB$$

where n = 0, 1, . . . 9 is the value of the input word.

External resistors may be added in series or parallel at the amplifier's input to change the over-all gain or to allow input summing. Any standard op amp may be used, but fast op amps should be compensated carefully because many are unstable in low-gain configurations. □



1. Programable gain. Amplifier has gain of 6(n + 1) dB, where n is decimal value of binary-input word. Component count for circuit is low because the switches and resistors that control gain are all in AD7520 IC. Voltage levels for input logic are compatible with TTL and C-MOS, and analog input signal can be as large as ±10 V.



2. Resistors. Ladder network in AD7520 multiplying d-a converter provides feedback path for op amp. Current I_{REF} divides in half at every node of ladder, and switches set by control inputs determine current I_F that gets back to op amp's input terminal. Circuit gain is I_{REF}/I_F; for configuration shown, gain is -4, or 12 dB.