

D/A Converter Generates Hyperbolic Functions

Measurement and control systems frequently require fine resolution around a setpoint with wide dynamic ranging capability. This can be satisfied by systems designs which use a high resolution, strictly linear approach; but this is costly and often unnecessary. Nonlinear function fitting using multiplying digital-to-analog converters (DAC's) offers a desirable alternative by being both simpler and more cost-effective. This application note describes how extended range hyperbolic functions of the type A/X or $-A/X$ (where "A" indicates an analog constant, while "X" represents a decimally-expressed digital divisor) are easily generated by just two lowcost I.C.'s; an operational amplifier and a multiplying DAC. Circuit configurations are provided for each polarity output along with dynamic performance photographs and general design guidelines for either binary or BCD-coded divisors.

THEORY OF OPERATION (A/X)

Figure 1a shows the A/X function circuit which uses a two-digit BCD-coded DAC, the DAC-20EX, and a decompensated, wide-bandwidth op-amp, the OP-17. A constant current, I_{constant} , equal to the value of one least significant bit (LSB), flows into the DAC output terminal, I_O . Simultaneous adjustment of the scale factor and output amplifier offset voltage is enabled by a multi-turn, low tempco potentiometer, R_5 , which adjusts current $-I_R$ producing voltage $-V_R$ across R_2 . The LSB value (scale factor) equals $-V_R/R_1$.

Zener diode, D_2 , provides a stable reference voltage source. Because feedback for the op amp is through the DAC, capacitors C_1 and C_2 are added to provide proper phase compensation. Reference resistor R_3 is determined by the scale factor and the maximum current allowed into the DAC reference input V_{R+} . Bias

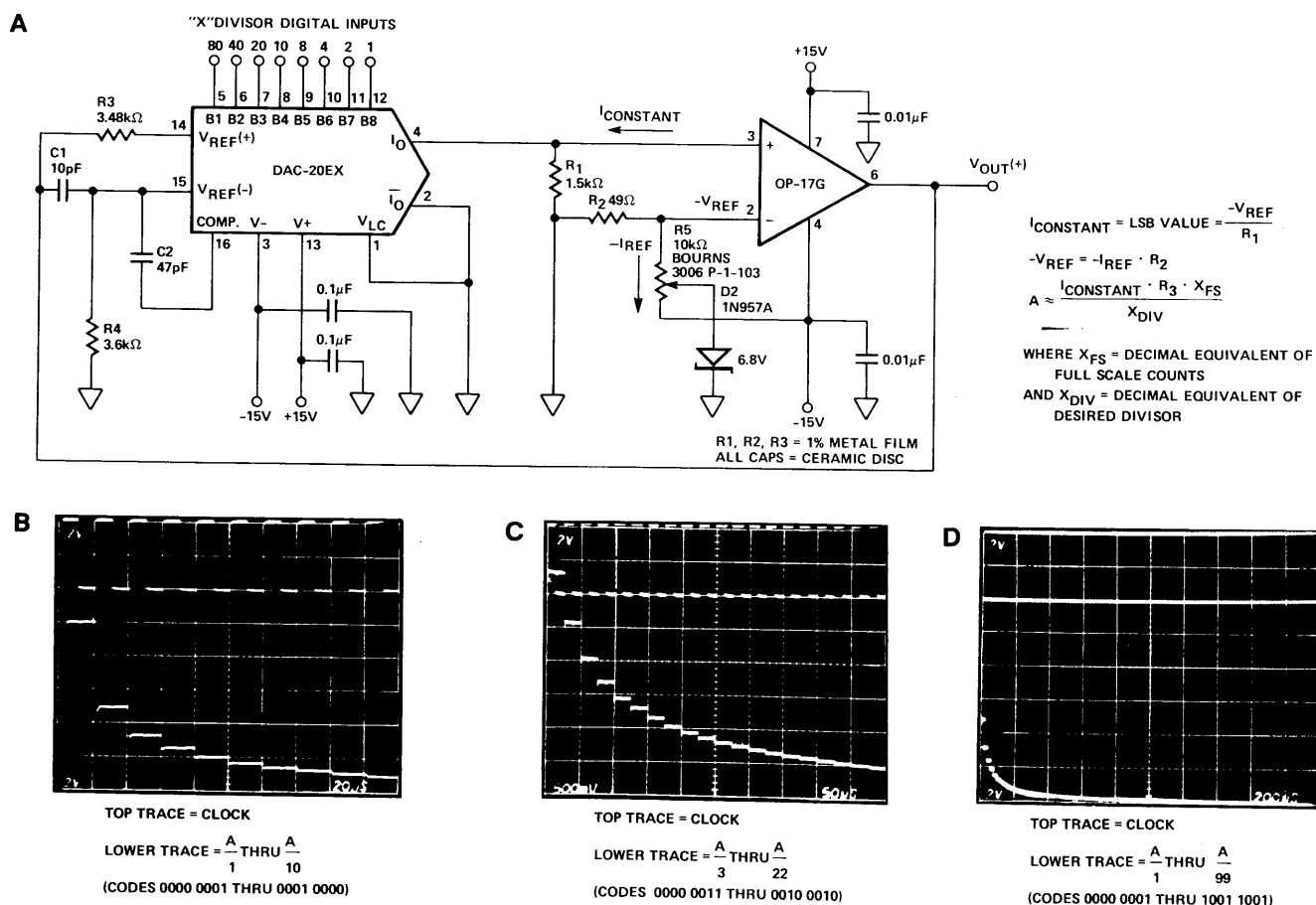


Figure 1. A/X Function Generator

current compensation for the DAC reference amplifier is accomplished by R4.

Figures 1b, 1c, and 1d show dynamic performance of circuit 1a when the digital inputs are swept by an external BCD up-counter with codes of 0000 0001 through 1001 1001 (division by zero is not allowed).

THEORY OF OPERATION ($-A/X$)

The circuit configuration for the $-A/X$ function is shown in Figure 2a. It is quite similar to that of Figure 1a with both the DAC reference amplifier and output amplifier terminals reversed. Capacitors C1 and C2 provide phase compensation. Figures 2b, 2c, and 2d show dynamic performance of circuit 2a.

DESIGN CONSIDERATIONS

1. Circuit speed and settling time are dictated by output op amp slew rate, scale factor, and compensation. Use of slower amplifiers considerably increases the illustrated set-

ting times. Effective slew rate of circuit 1a is $3V/\mu s$, while circuit 2a slews $0.6V/\mu s$.

2. Layout and breadboarding of high gain, wide-bandwidth devices necessitates considerable care with a ground plane with single point grounding being highly desirable. Decoupling capacitors located close to the devices' supply inputs are essential.
3. Accuracy of the circuit is within 1% over the $0^\circ C$ to $+70^\circ C$ temperature range with 1% metal film resistors R1, R2 and R3. DAC linearity becomes an important factor as the divisor decreases; for this reason 1/4 LSB linear DACs are recommended.
4. Binary coding may be accomplished by substituting an 8-bit binary-coded DAC-08EX for the two-digit BCD-coded DAC-20EX. In addition to adjusting circuit values however, a higher performance op amp such as the OP-17F is desirable because the output amplifier's input offset voltage drift becomes a more significant error source for overall scale factor stability over temperature. This is due to the increased resolution of the binary coding.

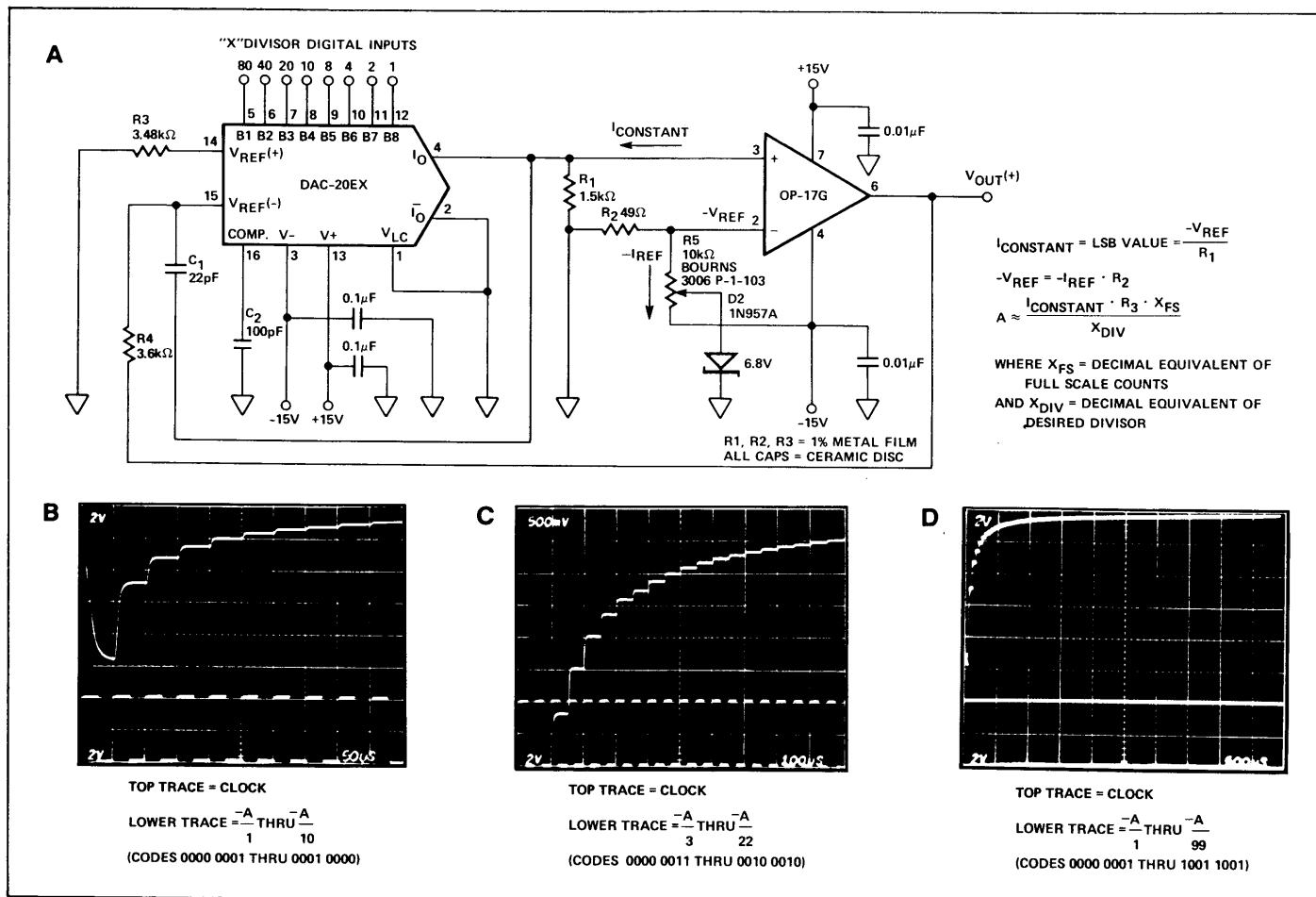


Figure 2. $-A/X$ Function Generator