ANALOG DEVICES

AN-364 APPLICATION NOTE

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Enhancing the Performance of the AD7111A and AD7112 LOGDACs

by Albert O'Grady

The AD7111A and AD7112 LOGDACs (LOGDAC®) are monolithic multiplying D/A converters featuring a wide dynamic range. Both DACs can attenuate an analog input signal over the range 0 dB to 88.5 dB in 0.375 dB steps. The degree of attenuation is determined by an 8-bit word applied to the on-board decode logic. This word is decoded into a 17-bit word before being applied to a 17-bit DAC. The fine step resolution over the entire dynamic range is achieved by the use of this 17-bit DAC. The AD7112 is a dual version of the AD7111A. Both parts offer fast interface timing and are easily interfaced to a standard 8-bit microprocessor bus via an 8-bit port and standard microprocessor control lines.

EXTENDING THE ACCURACY RANGE OF THE AD7112

The high attenuation levels of the AD7111A and AD7112 are specified with less accuracy than the low attenuation levels. Accuracy is relative to the 0 dB level. The most accurate range on these DACs is specified at ±0.17 dB in 0.375 dB steps from 0 dB to 36 dB attenuation and is guaranteed monotonic to 54 dB attenuation. A popular requirement is to extend the accuracy versus the attenuation range for these DACs. The most accurate range of the AD7112 can be easily extended from 36 dB to 72 dB in 0.375 dB steps by cascading the two DACs. Figure 1 shows a typical circuit configuration for the implementation of this scheme. The advantage of this circuit is that it is implemented using a dual op amp and the AD7112. No other precision external components are required. Both DACs in the AD7112 are easily controlled from a standard 8-bit microprocessor bus using standard microprocessor control lines. It is recommended when using this configuration that the total attenuation required be divided equally between DAC A and DAC B; this reduces crossover distortion caused by switching in and out large attenuation levels if one DAC is used as a fixed attenuator.

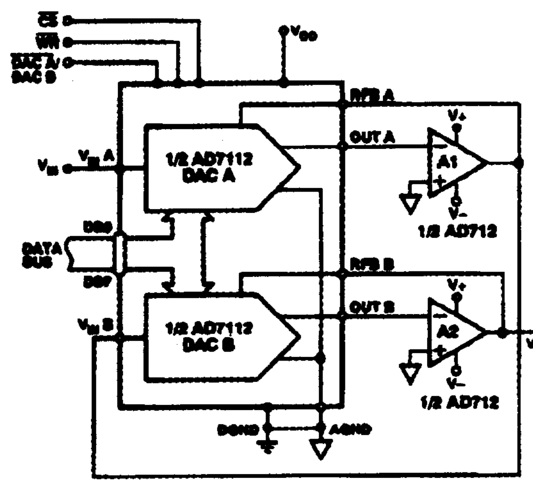

Figure 1. Extending Accuracy Range of AD7112

In dc applications, errors occur due to the output amplifiers' input bias currents and input offset voltages. Amplifier input bias current results in a dc offset at the output due to the current flowing through the feedback resistor of the DAC. The output amplifier is operated with a fixed feedback resistor, but the AD7112 output impedance varies with the programmed attenuation level. This has the effect of varying the noise gain of the amplifier thus creating a varying error due to input offset voltage. To minimize these effects, amplifiers with low input bias currents and offset voltages are recommended for dc applications. In ac applications, the dynamic performance of the AD7112 will depend on the gain phase characteristics of the output amplifier, together with good printed circuit board layout and decoupling components. If high speed amplifiers are used, it is recommended that a compensation capacitor be connected between the RFB and the input to the amplifier to compensate for phase lag introduced by the output capacitance of the DAC.

RANGE EXTENSION USING THE AD7111A

To extend the most accurate range on the AD7111A, it is necessary to use a precision attenuator or programmable gain amplifier in series with the LOGDAC to provide a fixed amount of the total attenuation required. At low levels of system attenuation, the precision attenuator is switched out of the circuit and contributes 0 dB of attenuation to the signal path and all attenuation is controlled by the LOGDAC. At some user defined input code, the precision attenuator switches in an attenuation equal to that defined by the input code, while the code for the LOGDAC is reset so as to give 0 dB attenuation.

Figure 2 shows a block diagram, based on the AD7111A, of how such a system may be implemented. In this configuration the high accuracy range is extended by 36 dB to give a range of 0 dB to 72 dB. The accuracy range has been extended by an amount equal to that introduced by the precision attenuator, assuming that the attenuator introduces no error.

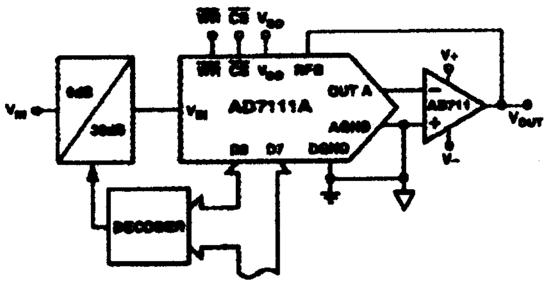

Figure 2. Extending Accuracy Range of AD7111A

With input codes 00H to 05FH, the fixed attenuator is out of the circuit and all attenuation is provided by the LOGDAC. When the code 080H appears on the data bus, the 36 dB fixed attenuator is switched into the circuit and the input code to the AD7111A is reset so as to provide 0 dB attenuation.

Figure 3 illustrates a circuit that implements the switched attenuator. The switches are shown for logic 0 on the control input which gives 0 dB attenuation. The control inputs to the AD7512 are driven from the same control signal, thus both switches are driven simultaneously. The components consist of 0.1% standard value resistors plus an AD7512DI single-pole double-throw switch. A 1 kΩ potentiometer is incorporated to precisely adjust the attenuation to 36 dB. The decoder block shown in Figure 2 determines the code at which the fixed attenuator is switched in or out of the circuit. This decoder can be implemented in software or hardware.

The accuracy of any step for input codes 00H to 05FH is ±A(0) ± 0.17 dB where *A(0)* is the gain error introduced by the precision attenuator relative to V_{IN} when the attenuator is set to 0 dB. For input codes 080H to 0BFH the step accuracy is ±A(36) ± 0.17 dB where *A(36)* is the

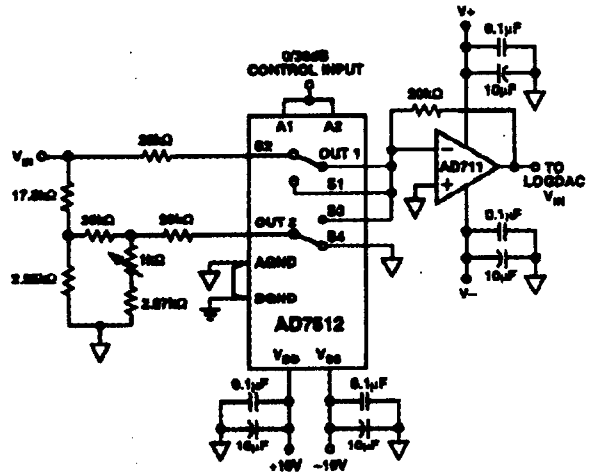

Figure 3. Fixed Attenuator

gain error in dB introduced by the precision attenuator relative to V_{IN} when set so as to provide 36 dB attenuation to the input signal and the ±0.17 dB is the AD7111A accuracy specification. To maintain monotonic operation at the change-over point, the attenuator step accuracy should be better than one-half the step size being used. The potentiometer in the attenuator circuit can be used to calibrate the attenuator accuracy.

ADDING FIXED GAIN TO LOGDAC OUTPUT

LOGDACs provide a minimum attenuation of 0 dB; however, by adding some external resistors it is possible to add a fixed gain to the output amplifier. Figure 4 shows a circuit to provide a fixed 20 dB gain at the output.

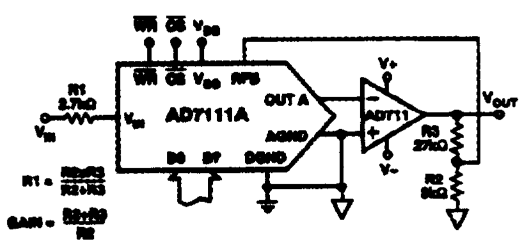

Figure 4. 20 dB Fixed Gain Circuit

Using three resistors is the recommended way (Ref 1) to add gain to the standard configuration. The transfer function for this circuit is as follows:

$$V_{OUT} = -V_{IN} \times 10\ exp - (0.375 \times N/20) \times (R2 + R3)/R2$$

V_{OUT} is independent of R_{FB}, the feedback resistor due to the inclusion of R1. All resistors should have matched temperature coefficients to minimize drift. This circuit provides attenuation in 0.375 dB steps over the range +20 dB to −16 dB with an accuracy of ±0.17 dB and in 0.75 dB steps over the range +20 dB to −28 dB with an accuracy of ±0.35 dB. The same arrangement is also applicable to the AD7112.

ADDING FIXED ATTENUATION TO LOGDAC OUTPUT

Fixed attenuation can be added to the output of a LOGDAC circuit in a similar manner to the gain described previously. Figure 5 shows how to implement this function. The transfer function for the circuit is as follows:

$$V_{OUT} = -V_{IN} \times 10 \exp - (0.375 \times N/20) \times R3/(R2 + R3)$$

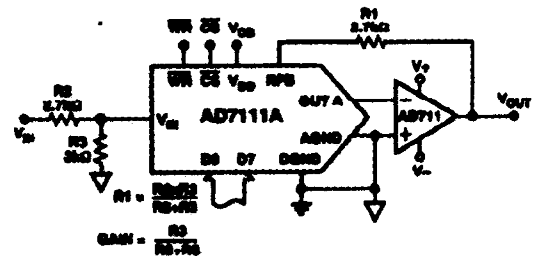

Figure 5. 20 dB Fixed Attenuation Circuit

The addition of R1 in the feedback loop of the amplifier makes the output independent of the feedback resistor R_{FB}. Again all resistors should have matched temperature coefficients to minimize drift.

This circuit provides attenuation in 0.375 dB steps from −20 dB to −56 dB with an accuracy of ±0.17 dB and in 0.75 dB steps from −20 dB to −68 dB with an accuracy of ±0.35 dB.

INCREASING STEP RESOLUTION OF A LOGDAC

The AD7111A and AD7112 provide attenuation in step sizes of 0.375 dB over a range of 0 dB to 88.5 dB. This is achieved in 239 steps for input codes 00H to 0EFH; for input codes greater than 0EFH full muting of the output occurs. The circuit of Figure 6 shows a method of increasing the step resolution of the AD7111A by switching in and out a resistor in the feedback loop of the amplifier.

With the switch open:

$$V_{OUT} = V_{OUT1} = -V_{IN} \times 10 \exp - (0.375 \times N/20)$$

where 0.375 is the step size (resolution) in dB and N is the input code in decimal.

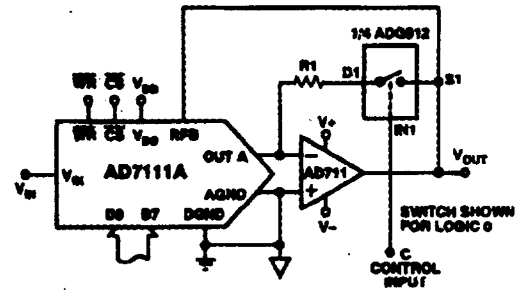

Figure 6. Increasing Step Resolution of the AD7111A

With the switch closed:

$$V_{OUT} = V_{OUT2} = -V_{IN} \times 10 \exp - (0.375 \times N/20) \times R1/(R1 + R_{FB}) - V_{OUT1} \times R1/(R1 + R_{FB})$$

For a step resolution of 0.1875 dB

$$20 \log V_{OUT2}/V_{OUT1} = -0.1875 \text{ dB}$$

$$V_{OUT2}/V_{OUT1} = 0.9786 = R1/(R1 + R_{FB})$$

$$R1 = 45.8265.R_{FB}$$

The control input which controls the switch operation can be considered as the LSB of the input control word. For any value of V_{OUT}, changing the control input from low to high automatically lowers V_{OUT} by 0.1875 dB. The overall equation for the circuit of Figure 6 is as follows:

$$V_{OUT} = -V_{IN} \, 10 \exp - \left(\frac{0.375N}{20} + C \times \frac{0.375}{40} \right)$$

where N is the input code to the DAC in decimal and C is either a 1 or 0 depending on the control input to the ADG512 switch.

This circuit may be prone to drift errors due to mismatch between R1 and R_{FB}.

Finer step resolution can be achieved by using banked switches and resistors.

COMBINED LINEAR/NONLINEAR DACS FOR FINE/COARSE ADJUST

It is possible to combine a LOGDAC with a Linear DAC to provide a fine/coarse adjust function. For an n-bit linear converter there are 2^n possible input codes giving 2^n-1 possible attenuation levels. These levels are linearly related to the input voltage; each level is separated by a constant percentage of input full scale since 1 LSB = $FS/2^n$.

Therefore, one half of the steps in a linear coded DAC cover a 6 dB attenuation range (0 dB to 6 dB), and one quarter of the codes cover another 6 dB attenuation (6 dB to 12 dB). Therefore, with increasing attenuation, the step size in dB terms is also increasing. The maximum attenuation in dB achievable with an n-bit linear converter is 20 log ($1/2^n$), i.e., for an 8-bit converter this amounts to 48 dB attenuation. The circuit of Figure 7 shows the combination of a linear and nonlinear DAC to provide fine and course attenuation. The AD7111A provides the coarse adjust with step sizes of 0.375 dB, 0.75 dB, 1.5 dB, etc. The AD7524 8-bit linear DAC can be used to provide the fine adjust. The AD7524 provides 128 steps in its 0 dB to 6 dB attenuation range with step sizes of less than or equal to 0.06 dB. Both DACs are programmable through an 8-bit microprocessor port with standard microprocessor control lines. This system is easily expandable to a dual channel system using the AD7528 dual linear digital-to-analog converter and the AD7112 LOGDAC.

REFERENCES

1. "Input Resistor Stabilizes MDACs Gain," by P. Brokaw, *EDN*, January 7, 1981, pages 210–211.

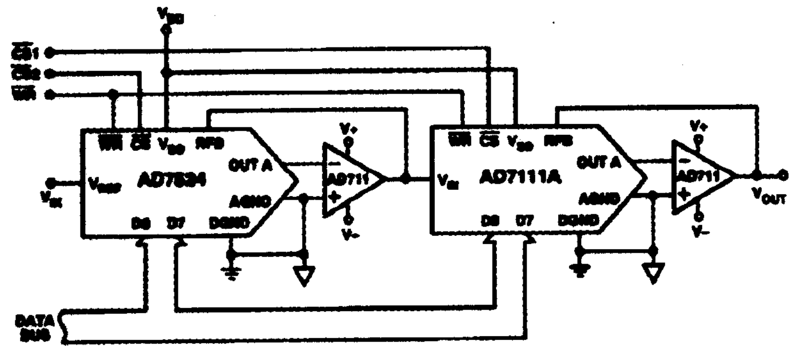

Figure 7. Combined Linear/Nonlinear DACs for Fine/Coarse Adjust

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