ANALOG DEVICES

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AN-299
APPLICATION NOTE

Simple Circuit Provides Ratiometric Reference Levels for AD782X Family of Half-Flash ADCs

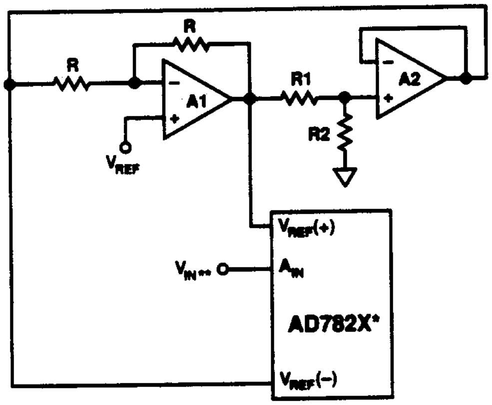
by John Wynne

The 8-bit AD782X family of high speed ADCs comprises of the following:

- –AD7820; Single Channel, Unipolar, 1.36 μs conversion time.
- –AD7821; Single Channel, Unipolar or Bipolar, 660 ns conversion time (improved version of AD7820).
- –AD7824; Four Channel, Unipolar, 2.5 μs conversion time per channel.
- –AD7828; Eight Channel, Unipolar, 2.5 μs conversion time per channel.

All of the converters run off of a single +5 V supply to convert positive input signals. Additionally the AD7821 can convert negative input signals if its V_{SS} pin is tied to –5 V. Refer to the individual data sheets for more complete information on the devices. This application note presents a circuit which can provide ratiometric reference voltages suitable for use with the AD782X family of half-flash ADCs.

The circuit in Figure 1 accepts a positive input reference voltage V_{REF} and, by implicit feedback, generates two additional reference voltages, $V_{REF}(+)$ and $V_{REF}(-)$, equally spaced above and below the original input reference level. The width of this window, determined by the ratio of R1 to R2, is a fixed percentage of the input reference voltage and remains a fixed percentage independent of the actual value of the reference level. Thus the window tracks the reference voltage. When used with ADCs such as the AD782X family, which have separate $V_{REF}(+)$ and $V_{REF}(-)$ inputs to impress a reference voltage across a resistor string, the circuit can generate programmable ratiometric reference levels to effectively increase the resolution of the ADC. With the added advantage of single supply operation the circuit can find uses in such applications as power supply monitoring, limit detection, head positioning servos' in disc drives, etc.



*ADDITIONAL CIRCUITRY OMITTED FOR CLARITY
**AD7820 & AD7821 – SINGLE CHANNEL,
AD7824 – FOUR CHANNEL, AD7828 – EIGHT CHANNEL

Figure 1. $V_{REF}(+)$, $V_{REF}(-)$ Generator with AD782X ADC

From Figure 1 the expressions for $V_{REF}(+)$ and $V_{REF}(-)$ are as follows:

$$V_{REF}(+) = 2\,V_{REF}\frac{1}{1+X} \qquad (1)$$

$$V_{REF}(-) = 2\,V_{REF}\frac{X}{1+X} \qquad (2)$$

$$= V_{REF}(+)\,X$$

$$\text{where: } X = \frac{R2}{R1+R2}$$

If a span voltage, V_{SPAN}, is defined as the difference between these levels then:

$$V_{SPAN} = V_{REF}(+) - V_{REF}(-)$$

$$= 2\,V_{REF}\frac{1-X}{1+X} \qquad (3)$$

For instance, with $X = 0$ $V_{SPAN} = 2\,V_{REF}$
with $X = 1/2$ $V_{SPAN} = 2/3\,V_{REF}$
with $X = 1$ $V_{SPAN} = 0$

There is thus a nonlinear relationship between X and V_{SPAN}. This is shown very graphically in Figure 2 where $V_{REF}(+)$ and $V_{REF}(-)$ are plotted versus the resistor divider ratio X. Note that as X approaches unity the generated voltages converge towards the reference voltage. Suggestions for making the ratio X digitally programmable are shown further in the text.

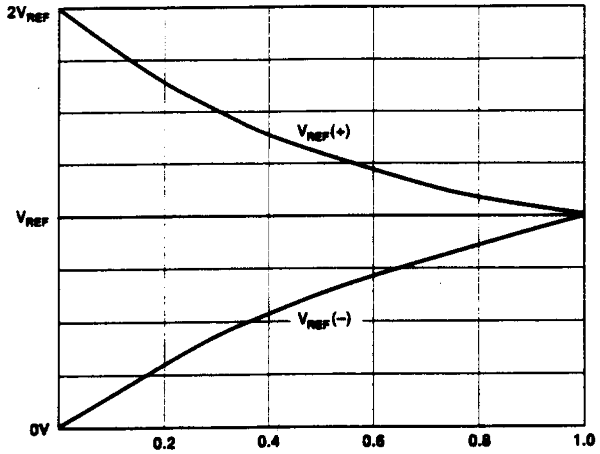


Figure 2. $V_{REF}(+)$, $V_{REF}(-)$ Voltages vs. Divider Ratio X

The plots indicate that the span voltage can vary from 2 V_{REF} to 0 V. In practice at either of these extremes, problems can arise. If used in a single-supply application, the op amp driving the bottom [$V_{REF}(-)$] of the ADC resistor string (e.g., A2 in Figure 1) will have difficulty in getting down to 0 V. Similarly, the op amp driving the top [$V_{REF}(+)$] of the ADC resistor string (e.g., A1 in Figure 1) might experience headroom problems if 2 V_{REF} approaches the op amp's V_{DD} level. At the other extreme the smallest usable span voltage is determined by the ADC. Typically the AD782X family, designed for a span voltage of 5 V, can convert with no missing codes down to a span voltage of 1 V.

Because of the transient currents which flow in the ADC resistor string during conversion it is necessary to decouple both $V_{REF}(+)$ and $V_{REF}(-)$ signals at the pins of the ADC. The op amps used for A1 and A2 should be considered for stability when driving capacitive loads of 0.1 µF or 0.2 µF.

dB or %

Dependent upon the application, the circuit can be viewed either as a means of increasing the effective resolution of the ADC or else as providing a voltage window (equal to full scale of the ADC) which can be placed around some input voltage to be monitored. For example, to increase the effective resolution of the converter from 8 bits to 10 bits in 6 dB steps (every 6 dB increase in dynamic range is equivalent to an extra bit of resolution), three different resistor divider ratios (X values) are required. Suitable values for X are found by choosing V_{REF} and V_{SPAN} and solving Equation 3 for X. Table I lists one possible set of values for X with their corresponding voltage levels computed for V_{REF} = [illegible].5 V.

X	$V_{REF}(+)$	$V_{REF}(-)$	V_{SPAN}	Effective Resolution
0.111	4.5 V	0.5 V	4.0 V	8 Bits
0.428	3.5 V	1.5 V	2.0 V	9 Bits
0.667	3.0 V	2.0 V	1.0 V	10 Bits

Table I. Possible Set of X Values to Increase ADC Dynamic Range in 6 dB Steps

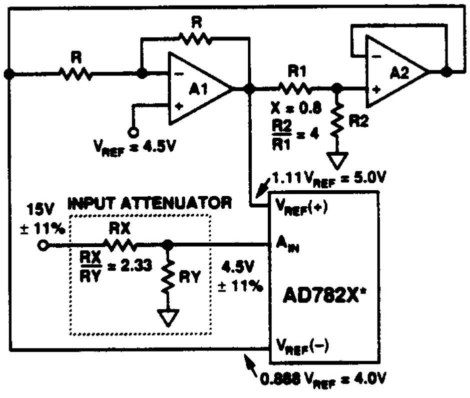
In applications such as power supply monitoring or when converting servo signals in HDD systems, it is probably more useful to talk about the span range as being a percentage of the input voltage. In terms of the span voltage;

$$V_{REF}(+) = V_{REF} + V_{SPAN}/2$$

$$V_{REF}(-) = V_{REF} - V_{SPAN}/2$$

If V_{REF} is chosen to be equal to the nominal analog input voltage (V_{IN}) to be monitored, then the ADC can measure voltages which extend above and below nominal V_{IN} by $V_{SPAN}/2$. For instance, with X = 0.5; $V_{REF}(+)$ = 1.33 V_{REF} and $V_{REF}(-)$ = 0.667 V_{REF}. The span voltage is 0.667 V_{REF}. With V_{REF} chosen to be equal to the nominal input voltage V_{IN}, the full-scale analog input range to the ADC is V_{IN} ± 0.33 V_{IN} or V_{IN} ± 33%. Similarly with X = 0.8, the full-scale range is V_{IN} ± 11%. Thus the ADC result can be directly interpreted as a measure of the percentage variation of the input voltage from its nominal value.

When monitoring voltages greater than +5 V, some initial signal conditioning (i.e., attenuation) will be necessary in order to avoid applying any input or reference voltage higher than +5 V to the ADC. Figure 3 shows a representative system to monitor a +15 V nominal supply having a tolerance of ±11%. It may be necessary to buffer the A_{IN} of the AD782X to avoid errors due to high source impedance. To measure tolerances tighter than



*ADDITIONAL CIRCUITRY OMITTED FOR CLARITY

Figure 3. Monitoring a +15 V ± 11% Supply

±11% the span voltage will drop below 1 V since $V_{REF}(+)$ is limited to +5 V maximum. To avoid this situation it will be necessary to amplify the small tolerance voltage to an acceptable level. One method of achieving this is shown in Figure 4.

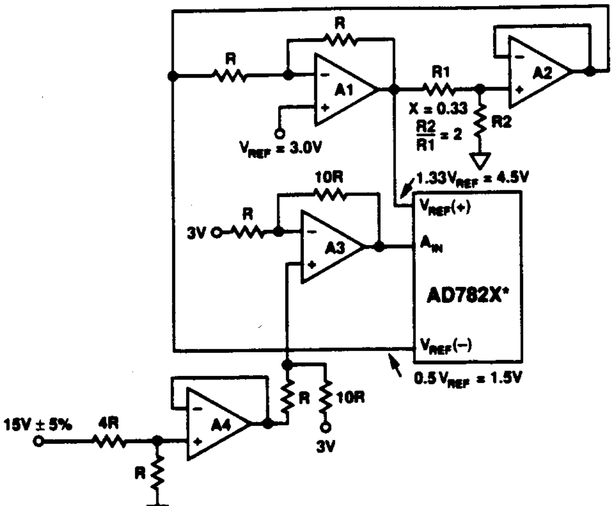


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Figure 4. Monitoring a +15 V ± 5% Supply

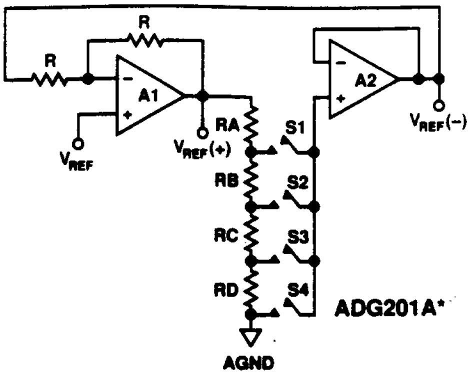
The circuits presented so far all deal with a positive V_{REF}. Can the circuits handle a negative V_{REF}? The answer is yes, but only one ADC in the AD782X family can directly convert negative voltages. This is the AD7821. By tying its V_{SS} pin to −5 V (V_{DD} remains at +5 V), the AD7821 can convert negative voltages down to −5 V. However its $V_{REF}(+)$ input must always be maintained more positive than its $V_{REF}(-)$ input. This necessitates a switchover of the $V_{REF}(+)$, $V_{REF}(-)$ connections when using a negative reference. For instance, in Figure 3, to monitor −15 V ±11%, the ADC must be the AD7821 with −5 V applied to its V_{SS} input; the 4.5 V reference now becomes −4.5 V, the output of A1 now drives the $V_{REF}(-)$ input of the ADC; and the A2 output now drives $V_{REF}(+)$. The op amps are now driven with bipolar supply voltages. All else remains the same.

Suggested Circuits to Provide Programmable Divider Ratios

In Figure 5 the divider ratio is dependent on whichever switch is closed, i.e., with S2 closed, divider ratio X is:

$$X = \frac{RC + RD}{RA + RB + RC + RD}$$

This circuit offers the advantage that the ON resistance of the switches does not play a part in determining the ratio X.



*ADDITIONAL CIRCUITRY OMITTED FOR CLARITY

Figure 5. Programmable Divider Ratio X with Discrete Resistors

Figure 6 shows how an 8-bit DAC, the AD7524, can be used to determine whatever divider ratio X is required with much finer resolution than is possible with discrete resistors alone. The gain of A2 is given as:

$$G = 1 + \frac{256}{N}$$

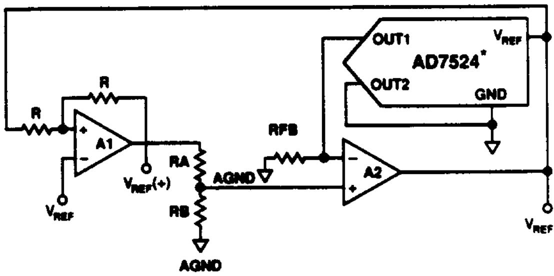
where:

N is the decimal equivalent of the 8-bit DAC code.

Of the possible 255 gain levels programmable with the DAC, 128 of them cover the gain range from 1 to 2, 64 cover gains from 2 to 4, etc. Thus very fine resolution of low gains is possible. However since the noninverting gain of A2 is always greater than unity, RA & RB provide some fixed attenuation before the programmable gain stage. The overall divider ratio is:

$$X = G\frac{RB}{RA + RB}$$

The requirement that X must be always be less than unity [i.e., $V_{REF}(+) > V_{REF}(-)$] places an upper limit on the usable programmable gain range.



*DIGITAL DATA INPUTS AND ADDITIONAL CIRCUITRY OMITTED FOR CLARITY

Figure 6. Programmable Divider Ratio X with 8-Bit CMOS DAC