MX•COM, INC. MiXed Signal ICs

APPLICATION NOTE

MX029

Dual Digitally Controlled Amplifier

1. Introduction

The MX029 is a single-chip LSI circuit comprised of two individual, digitally controlled gain sections. Control of each gain section is accomplished through the serial interface. Each section has 48 distinct gain steps (+/-48dB of range in 2dB steps) plus MUTE. As shown in Figure 1 both gain stages have switchable inputs. This switching allows for selection of three different input signals on one channel and two on the other channel. One of the channels also has output switching. These features make it very easy to use the MX029 as a summing amplifier.

The MX029 can also be used as a digital to analog converter(DAC). For this application we take advantage of the 48 distinct gain settings. With a single DC input voltage the variable gain of the amplifier can be used to generate an analog output signal. This application note describes both applications, the MX029 as a summing amplifier and DAC.

Whenever the MX029 is used in any application the input signal should be as noise free as possible. Cutting off the serial clock when it is not being used will reduce noise. With high gain settings a very small amount of noise is amplified and becomes a problem.

When serial loading the MX029 make sure that the serial clock, serial data and LOAD/LATCH timing is correct. This seems to be a common problem for users, especially the timing of the LOAD/LATCH line. Use a storage scope to check your timing.

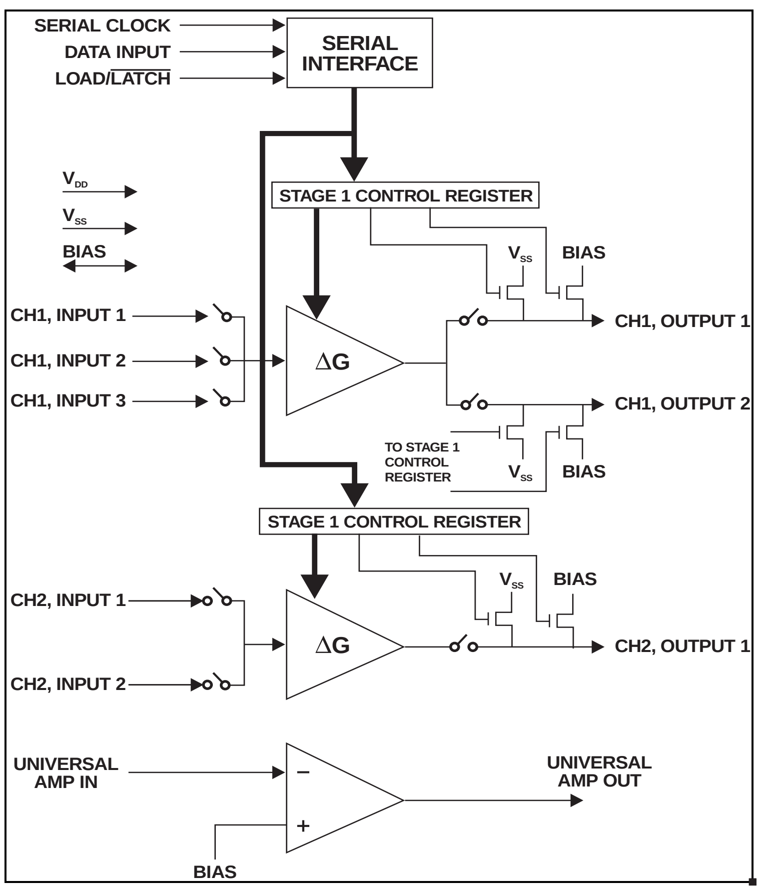

Figure 1: Device Block Diagram.

2. The MX029 as a Summing Amplifier

The MX029 can be used as a summing amplifier. Using channel one you can sum up to three different signals. With channel two you can sum two signals. As seen in Figure 2 very few external components are needed for the MX029 to be used as a summing amplifier.

The MX029 has an internal resistor that creates a voltage divider with R_{IN}. The configuration and value of this internal resistor is different in gain and attenuation mode, see Figure 2 and Figure 3. In gain mode the internal resistor is approximately 200KΩ and in attenuation mode the internal resistance is approximately 100KΩ. With a larger value of R_{IN} there will be more of a drop across R_{IN}. On the other hand, if the value of R_{IN} is too small the input source may not be able to drive R_{IN} due to source loading. Recommended values for R_{IN} are 10kΩ to 20kΩ. The equation used to calculate the signal level at the input of the MX029 for a two input summing amplifier is:

$$V_{IN029} = \frac{V_{IN1}(R_{IN2}R_L)}{R_{IN1}(R_{IN2}+R_L)+R_{IN2}R_L} + \frac{V_{IN2}(R_{IN1}R_L)}{R_{IN2}(R_{IN1}+R_L)+R_{IN1}R_L}$$

Where R_L is approximately 200KΩ in gain mode and 100KΩ in attenuation mode.

For a three input summing amplifier use the following equation :

$$V_{IN029} = \frac{V_{IN1}(R'//R_L)}{R_{IN1}+(R'//R_L)} + \frac{V_{IN2}(R''//R_L)}{R_{IN2}+(R''//R_L)} + \frac{V_{IN3}(R'''//R_L)}{R_{IN3}+(R'''//R_L)}$$

Where R' is the parallel combination of R_{IN2} and R_{IN3} (R_{IN2}// R_{IN3}) and R'' = R_{IN1}//R_{IN3} and R''' = R_{IN1}//R_{IN2} and R_L is approximately 200KΩ in gain mode and 100KΩ in attenuation mode.

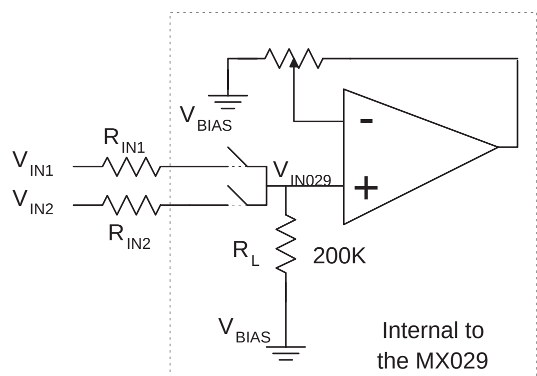

Figure 2: Gain Mode Configuration.

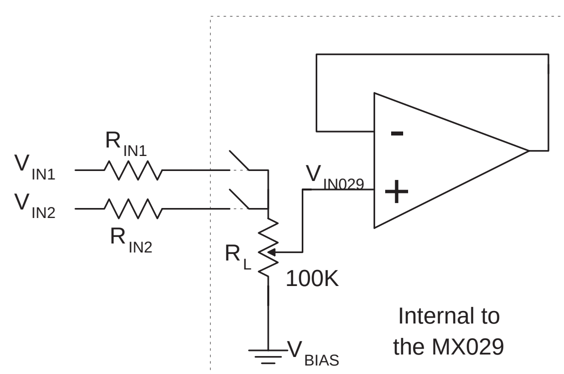

Figure 3: Attenuation Mode Configuration.

3. The MX029 as a digital to analog converter

The MX029 can be used as a digital to analog converter. The input should be DC coupled not AC coupled. If the part is AC coupled it will not function as a DAC.

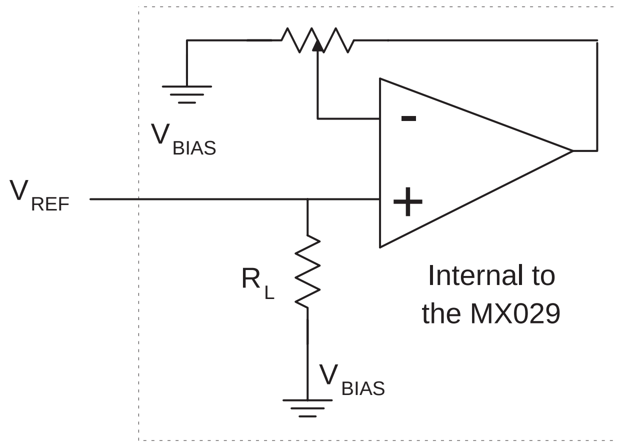

Figure 4: Using the MX029 as a DAC.

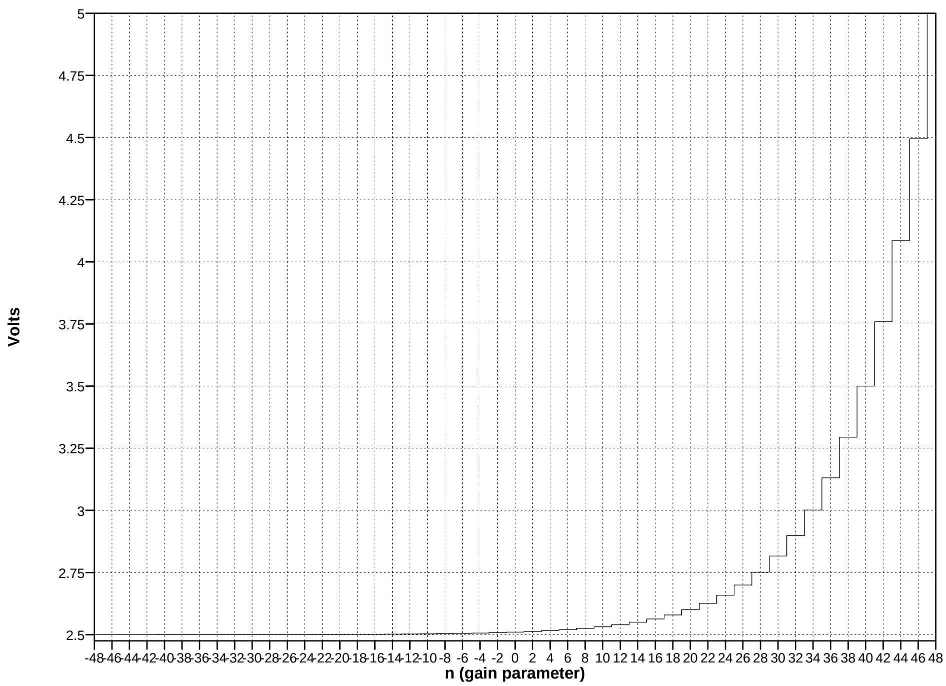

Figure 5: Volts vs. Gain Setting with V_{REF} at 2.51V.

When using the MX029 as a DAC there will be one input voltage(V_{REF}). To generate the output signal this input voltage is stepped up or down using the gain settings of the MX029. Each gain setting corresponds to a step on the output signal, see Figure 5. The minimum duration of each step(sample time) is approximately 8µs (giving a maximum sample rate of 125KHz). This is the time required to load and latch the 14 bits of serial data. This 125kHz sample rate can only be realized with negative gain settings. With gain settings 0dB to +30dB the amplifier's bandwidth will be the limiting factor and the maximum sample rate is approximately 20kHz. With gain settings above +30dB the maximum sample rate will be considerably less.

The analog GND of the MX029 is at $V_{DD}/2$ (V_{BIAS}). With a 5 volt power supply this voltage is 2.5 volts. With V_{BIAS} at $V_{DD}/2$ a sign bit is needed to get output levels above and below V_{BIAS}, see Figure 6. When in gain (attenuation) mode the difference of V_{BIAS} and the reference voltage(V_{REF}) will be amplified (attenuated).

$$V_{OUT} = (V_{REF} - V_{BIAS})10^{\frac{n}{20}} + V_{BIAS}$$

Where n is the gain setting -48 to +48. For n = 0, $V_{OUT} = V_{REF}$, for n < 0, V_{OUT} is between V_{REF} and V_{BIAS}, and for n > 1, V_{OUT} is between V_{REF} and a supply rail.

For example if V_{REF} is 2.4 volts and V_{BIAS} is 2.5 volts, with a gain setting of +24dB the output signal will $(2.4 - 2.5)10^{1.2} + 2.5V = 0.915$ volts.

To calculate the gain of each 2dB step use the following formula:

$$Gain = 10^{\frac{n}{20}}$$

Where n is the gain setting -48 to +48.

Figure 7 is an example of an output signal generated by changing the gain settings where the full dynamic range of the MX029 is used. To generate the output signal above V_{BIAS}, V_{REF} needs to be approximately 10 millivolts above V_{BIAS}. And to generate the output signal below V_{BIAS}, V_{REF} needs to be approximately 10 millivolts below V_{BIAS}. When using input levels 10 millivolts above or below V_{BIAS}, the input referred offset voltage of the amplifier must be compensated for by adjusting V_{REF} accordingly. An input referred offset voltage of 10 millivolts is not uncommon for an MX029. For this reason it is not very practical to use values of V_{REF} that are so close to V_{BIAS}. In this application the higher and lower gain settings will typically not be used. It is important to recognize that above V_{BIAS} the range is approximately 2.5 volts to 4.7 volts and below V_{BIAS} it is approximately 0.3 volts to 2.5 volts. With a sign bit the range is approximately 4.4 volts.

$$n_{MAX} = 20\log\frac{2.2V}{|V_{REF} - V_{BIAS}|}$$

Where n_{MAX} is the maximum gain setting with a particular V_{REF}.

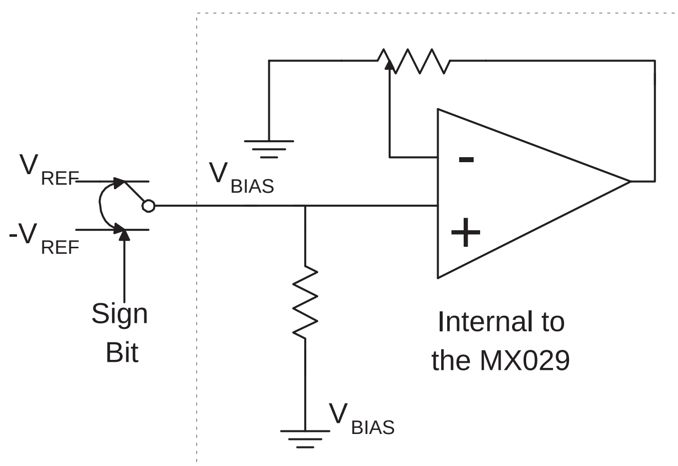

Figure 6: Using two V_{REF}s to generate an output that goes above and below V_{BIAS}.

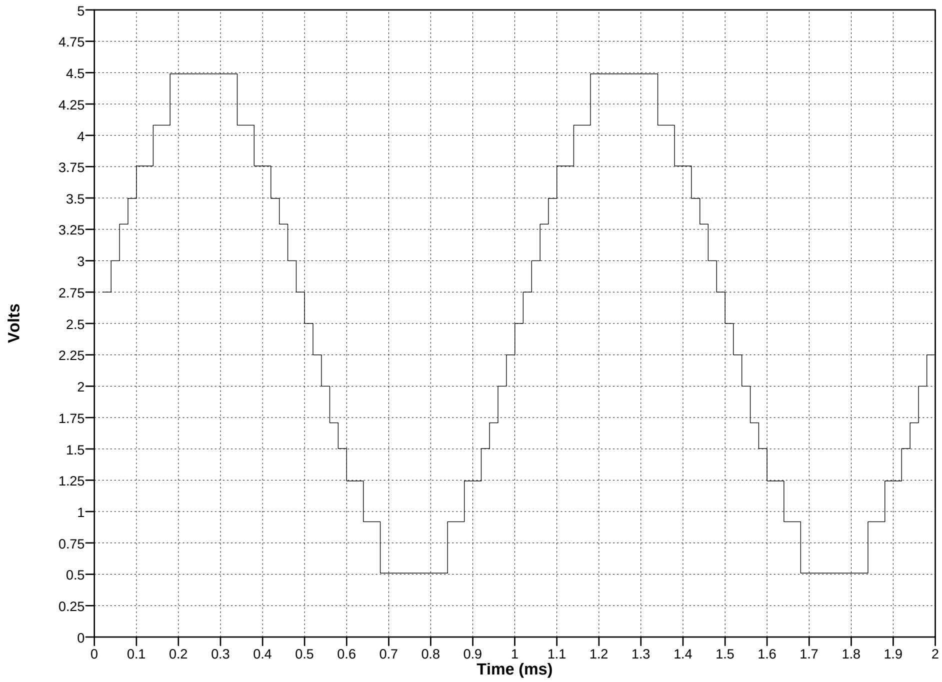

Figure 7: Example Output Signal.

Figure 7 is just one example of an output signal. There are many different output signals that can be generated. Before you start programming the MX029 take some time to think about what input signal level is necessary above or below V_{BIAS} to obtain the output signal that you desire.