Eugenio Mejia   Oct 9, 2015

The multiplying DAC (MDAC) is the precision digital-to-analog converter (DAC) architecture with the strongest DC specifications. These specifications are important for applications that demand high DC accuracy, including calibration as well as test and measurement. MDACs tend to have the lowest integral non-linearity (INL), which enables high accuracy.

Another advantage is that most MDAC devices feature an unbuffered output. Wait… why wouldn't a DAC with an integrated buffer be better? Well, being unbuffered gives the MDAC its greatest strength. It allows system designer to select an output amplifier that satisfies the application's specifications instead of being confined to the specifications of an integrated solution.

So all you need to do is select a great amplifier and you are done? Sadly, it is not so simple. The MDAC has certain interactions with its output amplifier that can cause errors that are not readily apparent. In short, you need an amplifier with a low-input offset voltage (V_{OS}) and a low-input offset current (I_{OS}). Any other specification will depend on your particular application. Let's start by looking at the easy one: I_{OS}.

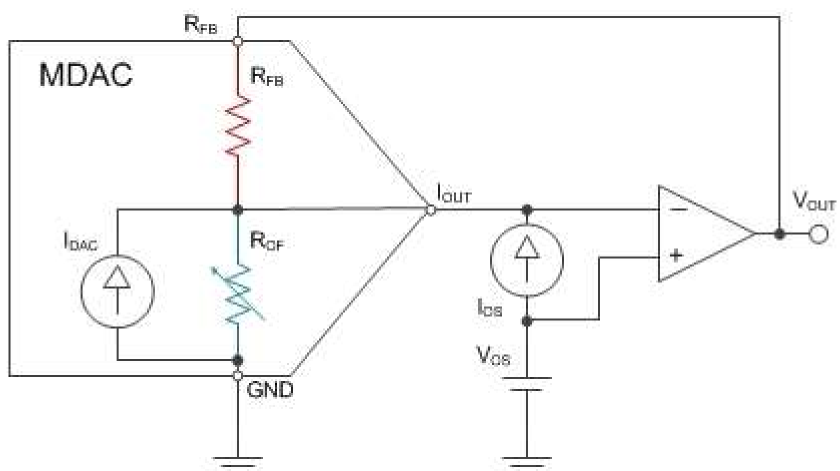

Figure 1: Simplified MDAC model

IOS causes an output offset error equal to R_{FB}* I_{OS} (as shown in Equation 1) due to superposition. This offset error does **not** change with code, so it is a constant error that you can easily calibrate if necessary. The IOS value in precision amplifiers is usually so small that the offset error contribution is negligible, but now at least you know that it's there if you have to use an amplifier with a larger IOS.

$$V_{OUT}\big|_{I_{OS}} = R_{FB} \cdot I_{OS} \quad (1)$$

$$V_{OUT}\big|_{V_{OS}} \approx 2.4 \cdot V_{OS} \quad (2)$$

- V_{OS} is a bit more difficult to explain. Looking at the simplified model of the MDAC in Figure 1, you can see that V_{OS} will observe a noninverting gain of $1+ R_{FB} / R_{OF}$. R_{FB} is a constant term that you can find in the data sheet of your DAC, while R_{OF} is a value that changes with the output code of the DAC.

This means that the effect of V_{OS} at the output will vary with code. The input offset error will be modulated by the DAC input code and will cause an output linearity error. To define exactly how large this error will be, I recommend taking a look at this ±10V Four-Quadrant Multiplying DAC TI Designs reference design. It explains in great detail how large this error can be, depending on your MDAC.

A simple rule to follow is to multiply V_{OS} times 2.4, regardless of the MDAC you're using, which is an overestimate of the linearity error introduced by the amplifier (see Equation 2). If your circuit design is complex enough that it requires the utmost precision, you may want to take a look at the reference design anyway, as it is a great source of information when designing with MDACs.

This is only the first part in our MDAC series. In the meantime, if you need a refresher on the different kinds of DAC output errors, take a look at this post by Kevin Duke, "DAC essentials: static specifications and linearity." He does a great job explaining how each of specification affects your desired output.

You can also learn more about MDACs in this video from my colleague Rahul Prakash. In the video, Rahul explains what an MDAC is and how it works. Toward the end, he even provides three tips to keep in mind when designing with an MDAC.

Are you designing with MDACs? Let us know how by posting a comment below.