EE 505

Laboratory Experiment 2 Spring 2023

Statistical Characterization of Matching-Critical Circuits

In the previous laboratory experiment we investigated some properties of a R-2R network. For convenience in laboratory measurements, we used discrete resistors in an implementation. And to keep the number of measurements manageable, a 4-bit version of this network was investigated but emphasis was on characterizing the ENOB from an INL viewpoint. As was stated previously, the ENOB in primarily determined by the matching characteristics of the MSB portion of this network and if additional bits of resolution were added, the ENOB would not change much. With the low coast resistors used in the implementation, most measured an ENOB of around 10 bits.

A very simple calibration procedure was then implemented that involved simply interchanging in an algorithmic way a small number of resistors. Most observed an improvement of between 0.2LSB and 1 LSB though it is possible this interchange could degrade performance.

In this experiment additional statistical characteristics of this network will be considered. We will intentionally keep the number of physical bits at 4 to reduce computation time requirements but the results would be about the same if a larger number of bits of physical resolution were used. Though the R-2R is one of several different DAC structures that are used, and some are preferable to the R-2R in many applications. The concepts discussed in this experiment will be similar to that observed in other structures. The performance metric of interest will still be the INL-based ENOB.

We will consider only the series R-2R network shown in Fig. 1. In this experiment it will be assumed the witches are ideal. For notational convenience, the resistors are designated at $R_1 \ldots R_{13}$. Assume the resistors have a Gaussian distribution with a nominal value of 10K and a standard deviation of 300Ω.

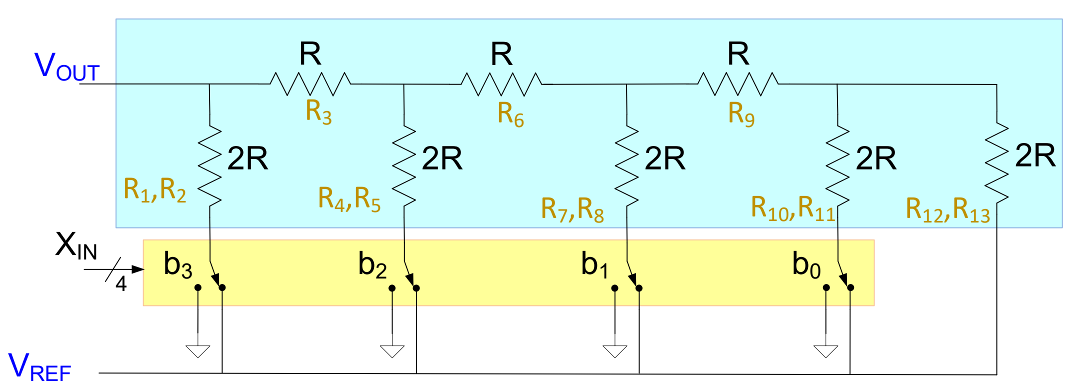

Fig. 1   Series R-2R Network

Probabilitiy Density Function (PDF)

Obtain an estimate of the PDF of the INL-ENOB for this R-2R network. It likely will need to be via a Monte Carlo Simulation.

Yield

If the parts are to be tested, what will be the yield if they must meet a 10 Bit specification?

Calibration

We will consider an alternate rearrangement calibration. For this calibration, with each R-2R DAC that you randomly generate, rearrange the resistors R_1 …R_6 to minimize the INL (or equivalently to maximize the ENOB) for that structure. With this re-arrangement, how does the PDF change and how does the yield change? Be quantitative.

Confidence

Likely in the previous pars of this experiment you picked a number of simulations to run to draw conclusions. Likely each of you used a different number of simulations. What you have obtained is an estimate of the statistics you were investigating and this estimate will improve as the number of samples increase. Unfortunately the simulation time also increases if the number of simulations increases. Authors are often silent on how confident they are with Monte Carlo simulations and often either simply state that Monte Carlo simulations have been done or give the number of simulations. But what you are actually doing when running these Monte Carlo simulations is hypothesis testing. For the yield calculations you did before calculations, rigorously quantify how confident you are in the yield you are predicting.

Calibration Revisted (extra credit)

In the previous experiment and in this experiment, two simple re-arrangement calibration procedures were discussed. Both should improve yield and the one discussed today is guaranteed to improve performance of every sample in the population. Can you identify another simple rearrangement calibration approach that gives better calibrated performance than either of the two that have been considered? Though rearrangement is probably not widely used for calibration, it may offer some practical benefits in some applications.