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EEL3111C

Tuesday P.10-11

Lab 2-Write Up

Introduction

The goal of this lab is to introduce the circuit design software, LTSpice, along with simple circuit ideal and real component design. By LTSpice simulations and analysis, we can confirm the actual resistor values and the resulting voltages of the R-2R ladder and the Resistor ladder. By applying the concept of LTSpice variables, such as spice directive, we were able to simulate real Monte Carlo resistors.

Discussion

2.5.1 Equivalent Resistance

In this portion of the lab, the equivalent resistance for an R-2R ladders was taken when it had 470 ohms resistors then again when it had 500 ohms resistors. The equivalent resistance was calculated by taking the voltage at Vout (1 V) and dividing it by the current passing through it.

Req470=489.73 ohms

Req500=500 ohms

The results demonstrate that one can accurately obtain the equivalent resistance through the function V/I=R at one node rather than calculating it through all the resistors since the resistance of an R-2R ladder is always R, regardless of the number of bits in the ladder. In a standard resistor ladder the resistors in the legs series are equal to R while the resistors in the parallel steps are equal to 2R, therefore equivalent resistance of the resistor ladder is expected to be the resistance of a leg added with a step divided by 3. For instances with 470 ohms resistors, (470 ohms+1000 ohms)/3=490 ohms which closely matches the calculated equivalent resistance by using the function V/I=R at Vout being at 489.73 ohms. Similarly, the calculated value of 500 ohms is equivalent to expected value stated in the lab. As the resistors varied, the effect on the resistor ladder is that of a corresponding change where increasing the resistance of the resistors will ultimately increase the equivalent resistance and vice versa.

2.5.2 Monte Carlo with Different Tolerances

Based on the resistor ladder on 2.4.3, the node voltages ranges (A-D) were recorded at different resistance tolerances.

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| Table 1: Voltages at Nodes | | | | | |
| Tolerance (%) | A (V) | B (V) | C (V) | D (mV) | Percent Error (%) |
| 5% (Prelab) | 4.446-4.356 | 3.24-3.04 | 1.96-1.76 | 648-549 | 0% Base |
| 1% | 4.412-4.399 | 3.156-3.116 | 1.884-1.844 | 606-588 | 0.765% |
| 0.1% | 4.4052-4.4026 | 3.1364-3.1324 | 1.8672-1.8632 | 597.4-595.6 | 0.918% |
| 0.05% | 4.4044-4.4030 | 3.1356-3.1336 | 1.8664-1.8644 | 596.97-595.98 | 0.936% |
| 0.01% | 4.40364-4.40346 | 3.13472-3.13432 | 1.86568-1.86524 | 596.54-596.36 | 0.953% |
| 0.005% | 4.40362-4.40346 | 3.13462-3.13442 | 1.86558-1.86536 | 596.493-596.403 | 0.954% |

Table 1: Result of running a DC operating point simulation to generate the node voltages at nodes A, B, C, and D with Monte Carlo function. Percent error is based on the prelab tolerance node A result (5%). Design based on Figure 2.5.2.

The expected result is that as the resistor tolerance decreases then the voltage range becomes more accurate to a single value. Base on table 1, the voltage ranges decreases and obtains more decimals values as the resistor tolerance decreases thus becoming a more defined lower value. From the percent error, which is based on the prelab value obtained with a 5% tolerance, it is seen that the error grows larger as the tolerance grows smaller. This means that the initial voltage range from the 5% tolerance resistor is too broad and that the actual voltage range is originally a lower range thus the smaller measured range means a greater difference for the error. It can also be seen that the voltage range different also reduces as in the resistor with a 5% resistance tolerance had a voltage different of 0.9 V at node A while the resistor with a 1% resistance tolerance had a voltage different of 0.013 V at node A, thus the results are becoming more exact.

2.5.3 Resistor Costs

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| Table 2: Resistor Costs | | |
| Resistor Tolerance (%) | Max Price ($) | Min Price ($) |
| 5% | 19 | 0.02601 |
| 1% | 8.05 | 0.1 |
| 0.1% | 4.84 | 0.56 |
| 0.05% | 2.57 | 0.9802 |
| 0.01% | 50.14 | 5.18 |
| 0.005% | 72.36 | 26.79 |

Table 2: The maximum and minimum cost for through hole resistors with the tolerances given.

As seen in table 2, cost of resistors with a tighter tolerance tend to have a higher minimum price. The minimum price of a resistor with 5% tolerance is approximately $0.02601 whereas the resistor with a one thousandth tighter tolerance, 0.005%, cost almost one thousandth times greater being at $26.79. As for the maximum price, there tend to be similar behavior with the cost of resistors with a tighter tolerance having a higher minimum price but only at the extreme values, 0.01% and 0.005%. Outside of that circumstance, the resistor maximum price tends to be based on how common the resistor is as the most commons resistors, 0.1% and 0.05%, tend to have a lower maximum price than that of a resistor with a 5% tolerance.

Conclusion

In conclusion, with the use of LTSpice, I was able to analyze and identify several features of the circuit designs that would have been difficult without such a software. The equivalent resistance properties of an R-2R ladders where the result of one bit of the ladder is comparable to the rest of the bits in the ladder, thus the entire ladder. Also, having a tighter tolerance on resistors provides more precise and smaller voltage ranges at a higher cost of expense.