Class #13: Open (semi-constrained) Design – Nodal Voltages

Purpose: The objective of this experiment is to apply previously learned concepts to design circuits with specific output voltages

Background: Before doing this experiment, students should be able to
- Analyze simple circuits consisting of combinations of resistors
- Measure the voltage at a node in a circuit using a Voltmeter
- Build simple circuits consisting of combinations of resistors
- Apply series and parallel resistance characteristics to simplify circuit analysis.
- Use voltage divider concepts to find the voltage across a resistor(s) and at a node
- Apply KCL to a circuit to generate a linearly independent system of equations
- Perform matrix mathematics

Learning Outcomes: Students will be able to
- Build and circuits based on a set of design restrictions
- Verify their circuit design using circuit analysis

Equipment Required:

- M1K Board (with Alice software) or Analog Discovery (with Waveforms Software)
- Voltmeter (Alice)
- Meter-Source (Alice)
- Parts Kit
- LTspice
- Pencil

Helpful links for this experiment can be found on the course website under Class #14

Pre-Lab

Required Reading: Before beginning the lab, at least one team member must read over and be generally acquainted with this document.

Background

In many design problems, we can find there is tremendous flexibility. Often there will be more variables than constraints, leaving many choices to the designer. For example, in the circuit shown in Figure 1, if the only constraint is that the voltage at A must 2V, then an infinite number of circuits are possible. There are three design choices to make, the voltage of V1 and the resistance values of the two resistors R1 and R2. We do recognize some additional design restrictions, for example, we know that the voltage source must be greater than 2V since the voltage divider always results in a 'step down' in voltage. Additional, once we pick a source voltage, we know the voltage divider expression determines a relationship between R1 and R2, $V_A = \dfrac{R2}{R2 + R1} V1$. For example, we could pick V1 = 4V, leading to the relationship R1 = R2. There are still an infinite number of possibilities, even though the source voltage has been chosen. Some practical considerations now emerge. Picking resistors that are too small can be problematic since we have verified that voltage sources have an internal resistance that we tend to neglect. If we chose resistance values, R1 = R2 = 1Ω, simulation results would give us VA = 2V, however, experimental results would likely produce a very different result. Another practical consideration with resistors is choosing a resistor value that is easy to locate (i.e. in our parts kit). Choosing R1 = R2 = 6kΩ would require using other resistors in series and parallel to obtain that value.

In our design process, we may wind up with a resistor value that is not a standard or readily available. That is fine, but let that be a single resistor value where we need to design a small resistor network (parallel and series) to implement that single value.

As you approach the design problems on the following page, you might
1) Layout a basic circuit that meets the provided restrictions
2) Assign voltage values that you feel will be sufficient to meet the goals
3) Assign values to some (not all) of the resistor values based on what is available in your parts kit.
4) Apply circuit analysis to any remaining resistors, determining a value that meets the requirements

(Note you can approach from another direction by assigning resistors values first and then choosing voltage source values that meet the requirements.)
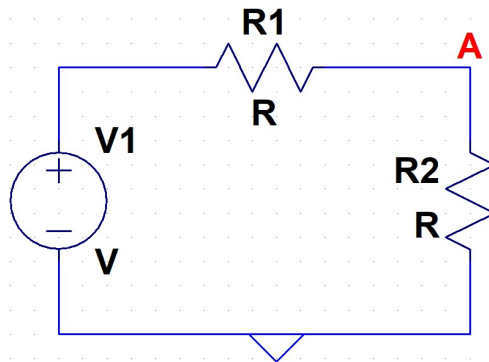

Figure 1: Voltage Divider

Part A – Design Challenges

- Include a schematic of each circuit design in your report
- Include LTspice simulation results verifying your design for each challenge
- Implement your circuit design on the protoboard and note how the measured results compare to the design criteria

Design Challenge 1:

Design a circuit with a node that has 2V (not the source node). Your circuit should consist of one voltage source and three equivalent resistors*. The resistors cannot be in series. Two of the resistors may be in parallel.

Design Challenge 2:

Design a circuit with a node that has 2V (not the source node). Your circuit should consist of two voltage sources and three equivalent resistors*. None of the resistors should be in parallel or series. The voltage sources should have a difference of at least 1V.

Design Challenge 3:

Design a circuit with one node at 2V and one node at 3V (neither are source nodes). Your circuit should consist of two voltage sources and resistors as needed. None of the resistors should be in parallel or series. The voltage sources should have a difference of at least 1V. Experiment demonstration required for this design challenge. Details provided in the experiment 12 template.

*equivalent resistors – resistor values that can be (but don't have to be) constructed by using resistors in parallel and/or series configurations available in the parts kit