High Resolution Digitally Trimmable Resistor

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Intended Users and Uses:

Intended users: Circuit designers or researchers.

Intended uses: Trimmable resistors are used when final adjustments of circuits are required. They can also be used in initial adjustments into next stages.

Problem:

The goal of this project is to solve the need to incrementally adjust a voltage for input to a circuit device such as an amplifier. This requires very fine adjustment increments while maintaining precision under various temperature ranges. There is also a need to be able to integrate this on an IC in order to be small and modular.

Solution:

This requires a high resolution solution that will require a digitally controlled resistor structure. This design will be re-trimmable and capable of trimming at small increments up to a total of 1%. This design will be optimized to reduce the total resistance size as well as the temperature dependencies of the device.

Design Requirements:

Functional requirements

- Temperature dependencies should be minimized. A TCV of 0 is ideal
- Equivalent resistance can be trimmed to ±1%
- Binary weighted structure. First bit sets 1/2% trim, second sets 1/4% trim, third sets 1/8% trim, and fourth sets 1/16% trim

Non-functional requirements

- Area of design should be comparable to current market solutions

Operating environment

- Not intended for rugged, wet, or extreme environments

Design approach

Research methods of trimmable resistors

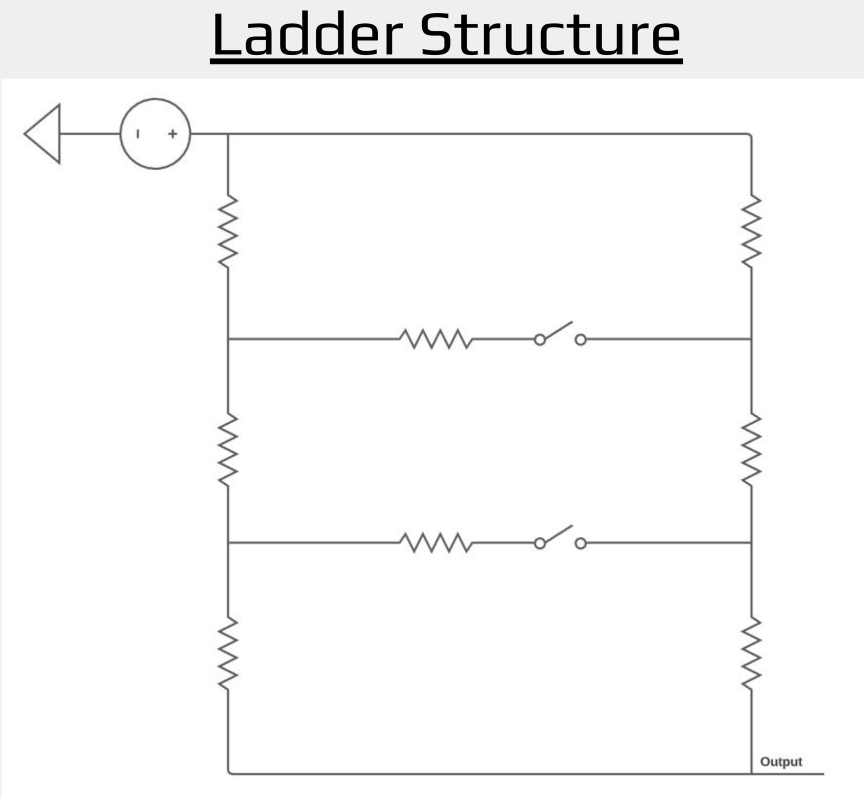
- Research ways to minimize TCV
- Research how to get high resolution binary trim

Brainstorm design schematics to simulate

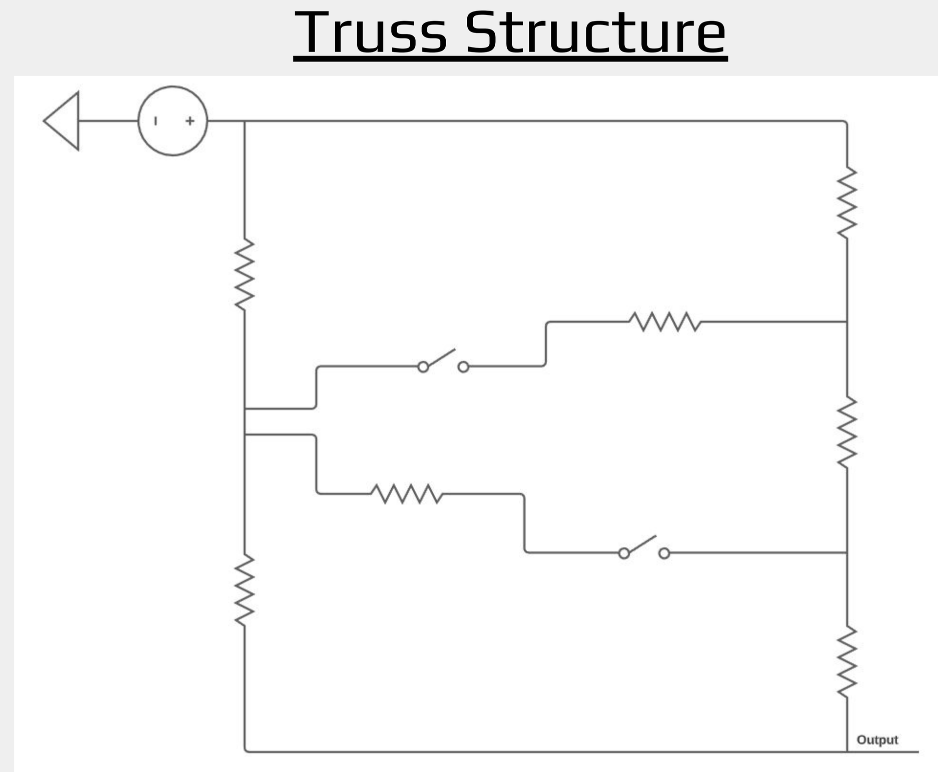
- Compare to reference design (Area, TCR, TCV)
- Make improvements where possible
- Come up with new ideas as needed and improve until goals are met

Designs:

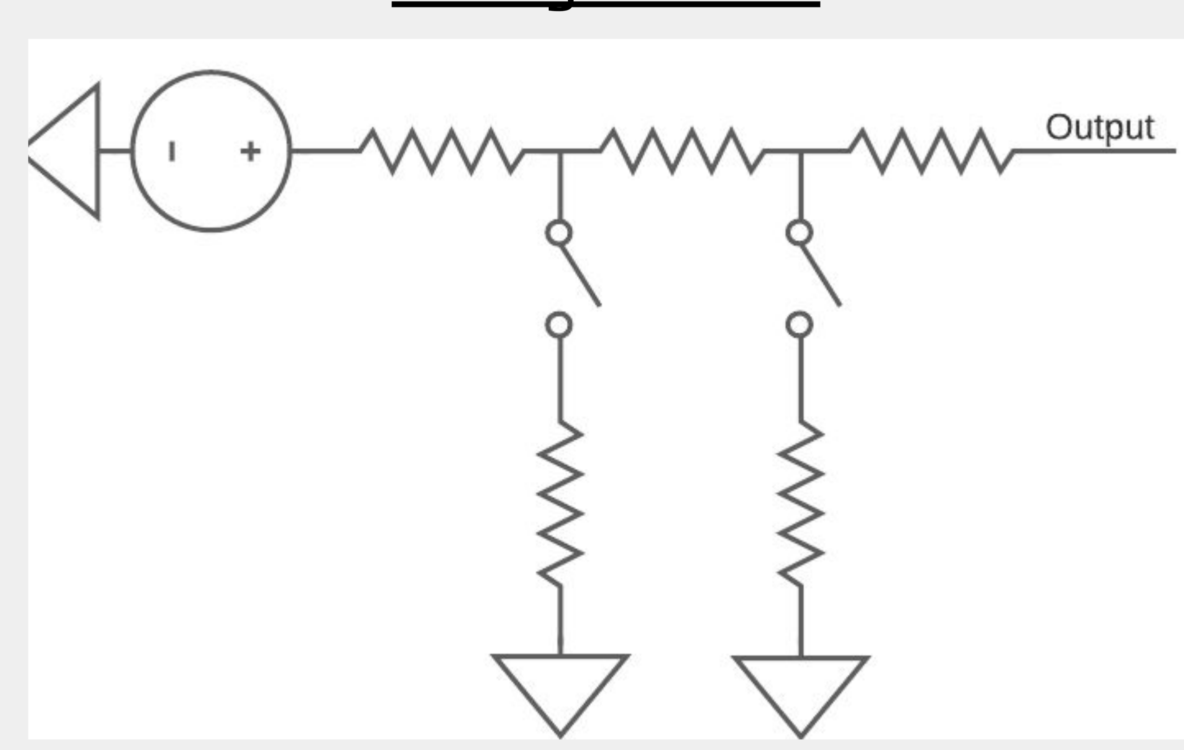
Ladder Structure



Truss Structure



Voltage Divider

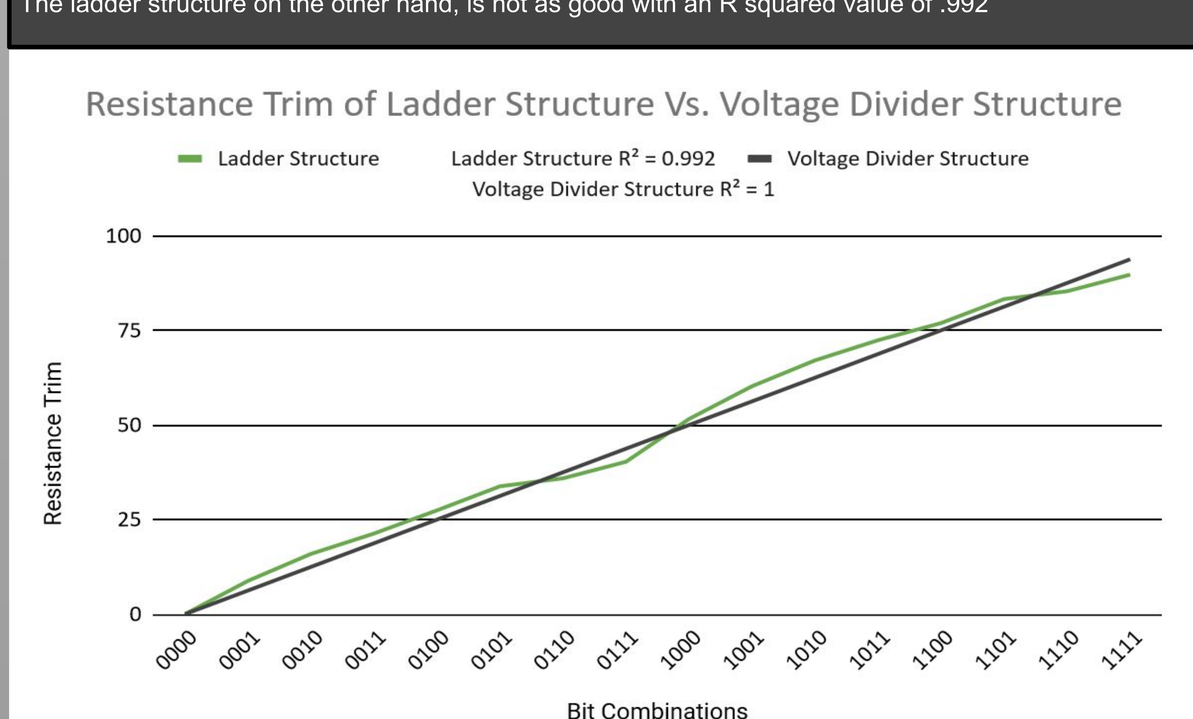


Testing Environment:

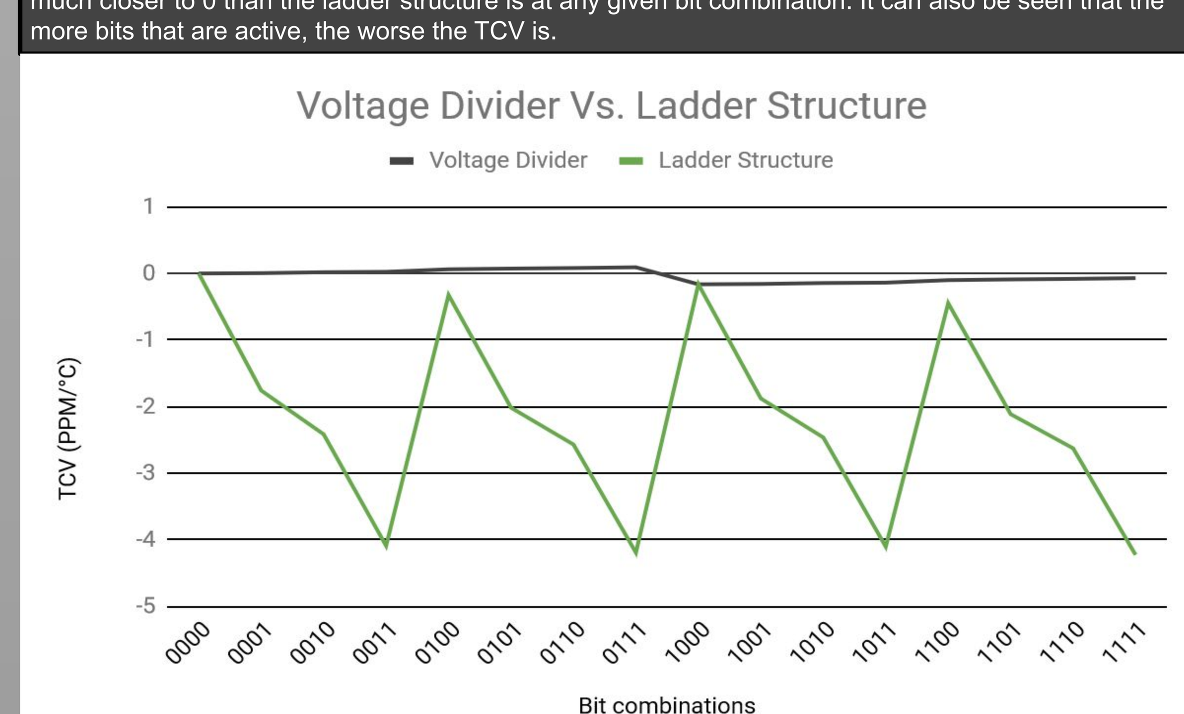
Spectre
ADE-L DC Temperature Sweep
ADE-L Parametric Analysis

MATLAB
Ladder Structure Trimming Calculator
Voltage Divider Trimming Calculator

This graph indicates that the voltage divider is perfectly binary weighted (within a certain resolution). The ladder structure on the other hand, is not as good with an R squared value of .992



The ideal TCV value for a design is 0. In this graph, it is observable that the voltage divider structure is much closer to 0 than the ladder structure is at any given bit combination. It can also be seen that the more bits that are active, the worse the TCV is.



Comparisons

- TCV is the percent change in voltage with respect to (w.r.t) changes in temperature (measured in PPM/°C)
  - Voltage divider is better w.r.t TCV
- Voltage divider is better w.r.t area
- Voltage divider is easier to implement
- Voltage divider has higher resolution
- Ladder structure will likely be better in area as we expand beyond 4 bits

Technical Details of Voltage Divider:

- 10 kOhm Trimmable Resistor
- TSMC 180nm process
- 4-bit Binary Weighted Structure
- 300n x 200n size n-mos
- 1500 ppm/°C p+ poly resistors
- 36.5 kOhm Total Resistor Area
- Total Trim TCV: -.069921784

Software Modules:

- Cadence Virtuoso and Spectre - Simulation
- Matlab - Simulation and Calculation
- Excel - Data Management
- Google - Collaboration Tools

Technical Details of Ladder Structure:

- 10 kOhm Trimmable Resistor
- TSMC 180nm process
- 4-bit Binary Weighted Structure
- 300n x 200n size n-mos
- 1500 ppm/°C p+ poly resistors
- 40 kOhm Total Resistor Area
- Total Trim TCV: -4.226142607