
EE/CprE/SE 492 WEEKLY REPORT 04

9/29/2020 – 10/12/2020

Group number: 08

Project title: High Resolution Digitally Trimmable Resistor

Client &/Advisor: Prof. Randy Geiger

Team Members/Role: Clark Reimers - Test Engineer, Pierce Nablo - Design Engineer, Alek Benson - Information Manager, Oluwatosin Oyekan - Meeting Lead

❖ Weekly Summary

During the past 2 weeks our group has been working on drafting new designs, optimizing current designs, and incorporating a binary weighted structure into our designs. We have been focusing on comparing the temperature coefficients of both resistance and voltage of the resistor ratios. We managed to switch many designs to the new standardizations, and are trying to work with 2-bit binary weighted structures to get the designs to a more realistic configuration. We also have been facing the issue of a new potential design, the voltage divider structure, that has another issue of a large total resistance value. The required amount of resistance, or size of the device, would be too large to achieve the desired results. We are working on comparing this design fairly, and are working on reducing the total resistance value of the design to more accurately compare it.

❖ Past week accomplishments

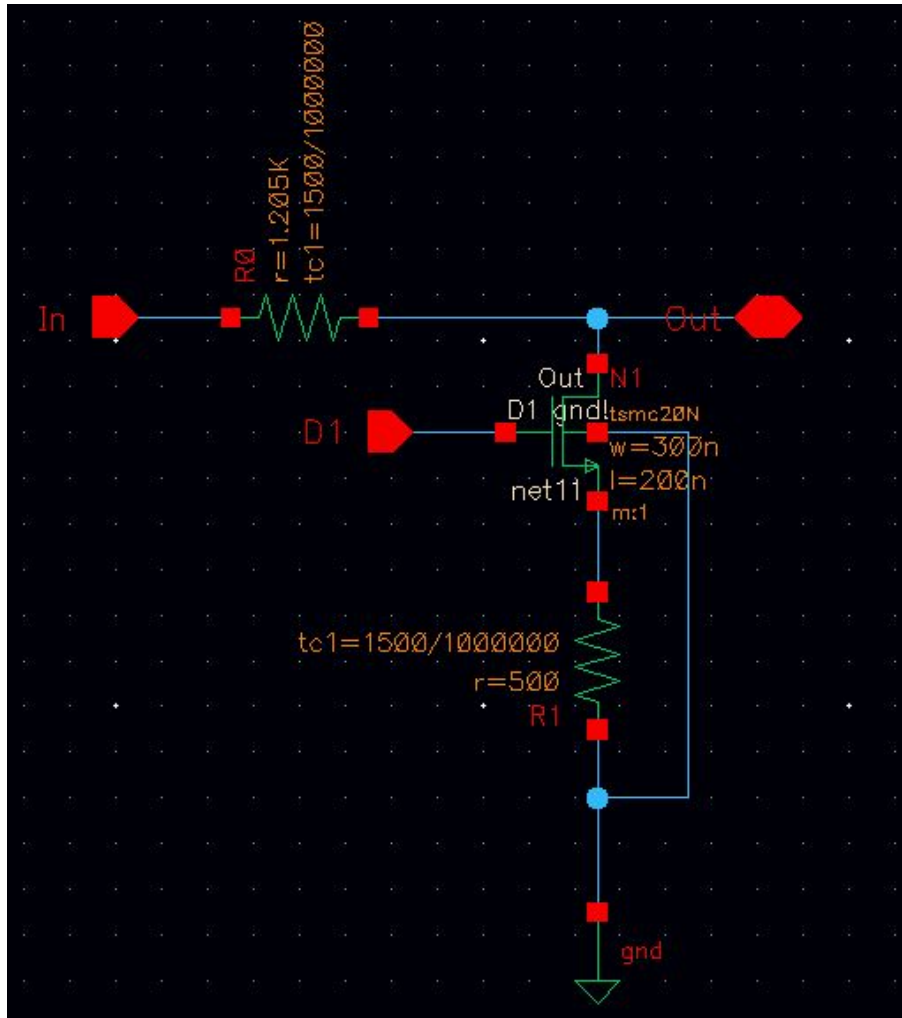
Clark Reimers:

- Reviewed the voltage divider structure that I discarded last time
 - Discovered that it may actually be a good circuit
 - Expanded to 2 bit architecture
 - Modified to be binary weighted
 - Optimized
 - Reduced area of design
 - Modified to 1% trim
- Continued work on T-branch
 - Tried to optimize
 - Decent TCV
 - Not good enough
 - Discarded
- Finished working on the Matrix structure we developed in semester 1
 - Decent TCV.
 - Not good enough

■ Discarded

- Started looking into other ways to reduce TCV
- Updated website

Voltage Divider:

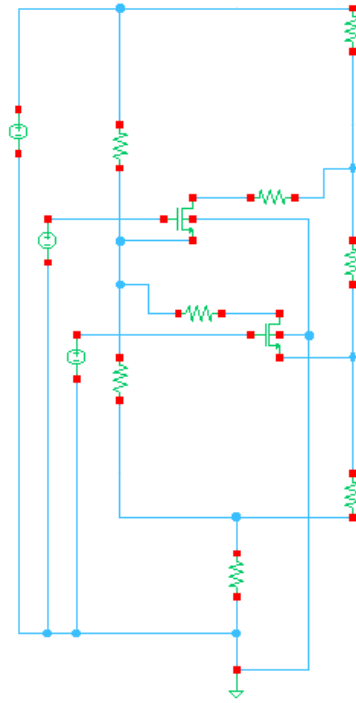


VD all bits on									
Temp	Vdd	Vout	Current	R	TCV	TCR			
27	1	3.31E-01	3.31E-05	20,200.17	2.40E-04	1,500.00	7.94E-11	2.40E-04	
28	1	0.3311239927	3.31E-05	20,230.47					
VD 1 bit on									
Temp	Vdd	Vout	Current	R	TCV	TCR			
27	1	0.3322263763	3.32E-05	20,099.96	-9.11E-03	1,500.01	-3.03E-09	-9.11E-03	
28	1	0.3322263733	3.32E-05	20,130.11					
VD other bit on									
Temp	Vdd	Vout	Current	R	TCV	TCR			
27	1	0.3322263443	3.32E-05	20,099.96	-9.39E-04	1,500.00	-3.12E-10	-9.39E-04	
28	1	0.332226344	3.32E-05	20,130.11					
VD bits off									
Temp	Vdd	Vout	Current	R	TCV	TCR			
27	1	0.3333333141	3.33E-05	20,000.00	-2.25E-03	1,500.00	-7.50E-10	-2.25E-03	
28	1	0.3333333134	3.33E-05	20,030.00					

Pierce Nablo:

- Simulated the Resistor Truss to dial in a binary trim to 1%
- I ran into issues with getting the binary trim to be usable; this issue will be shown in the data below.
- I made a new excel sheet to calculate the switch sizes
- Worked on PIRM presentation

Resistor Truss Design



switch config	Temp	Vout	Iout	R	TCR	TCV	Trim
off	27	0.5001250939	5.00E-05	9,997.50	2004.008216	-0.000199950	0
off	28	0.5001250938	4.99E-05	10,017.53			
switch config	Temp	Vout	Iout	R	TCR	TCV	Trim
off, on	27	0.500945482	5.01E-05	9,961.17	1999.998595	0.001397358	36.33
off, on	28	0.5009454827	5.00E-05	9,981.09			
switch config	Temp	Vout	Iout	R	TCR	TCV	Trim
On, off	27	0.5016811644	5.02E-05	9,926.67	1996.002555	0.005381904	70.83
On, off	28	0.5016811671	5.01E-05	9,946.48			
switch config	Temp	Vout	Iout	R	TCR	TCV	Trim
On, on	27	0.5027975325	5.03E-05	9,884.74	1992.023207	0.008552150	112.76
On, on	28	5.03E-01	5.02E-05	9,904.43			

Data above shows the first attempt to get a binary trim on the truss structure.

Form Uniqueness					Parameters																			
Truss Design with 10K, 9K2K9K sides. Switch and trim resistor used for trimming.					Vdd =	1.00 V				UCox(n)	0.000350				V(n)	0.5 V								
					Res Total =	10,000.00 Ohms				Vg1	5 V				Vg2	5 V								
					Load Res =	10,000.00 Ohms																		
Run	Resistor Configuration					Simulate				Calculate		Performance			Total Trim Res		Equivalent Switch Resistance. (all gates on)							
	Level	Left Res (Ohms)	Switch size W (n)	Trim Res L (n)	Right Res (Ohms)	State	Temp	V	I	Resistance	Trim	TCR	TCV	% Trim	Switch Res	Total	Width (n)	Vs (v)	Length (n)					
1	1				9,000	OFF OFF	27.00	0.499999999990	0.000050000000	10,000.00	0.00	2004.0080	0.0000	0.00%										
	2	10,000	30,000	200	4,100	OFF OFF	28.00	0.499999999990	0.000049900000	10,020.04					4.76	4,104.76	300	0.751237	1615.716853					
	3				2,000	ON OFF	27.00	0.500443565800	0.000050000000	9,991.13	8.87	-0.0050	0.0050	0.09%										
	4	10,000	30,000	200	4,100	ON OFF	28.00	0.500443568830	0.000050000000	9,991.13					4.76	4,104.76	300	0.730814	1624.519166					
	5				9,000	OFF ON	27.00	0.500443568430	0.000050000000	9,991.13	8.87	-0.0048	0.0048	0.09%										
	6					OFF ON	28.00	0.500443566700	0.000050000000	9,991.13														
	7					ON ON	27.00	0.502474299600	0.000050200000	9,910.87	89.13	-0.0762	0.0754	0.89%										
	8					ON ON	28.00	0.502474337500	0.000050200000	9,910.87														
2	1				9,000	OFF OFF	27.00	0.499999999990	0.000050000000	10,000.00	0.00	2004.0080	0.0000	0.00%										
	2	10,000	30,000	200	2,050	OFF OFF	28.00	0.499999999990	0.000049900000	10,020.04					4.76	2,054.76	300	0.755833	867.8946382					
	3				2,000	ON OFF	27.00	0.500519128900	0.000050100000	9,969.68	30.32	1999.9932	0.0068	0.30%										
	4	10,000	30,000	200	6,150	ON OFF	28.00	0.500519132300	0.000050000000	9,989.62					4.76	6,154.76	300	0.726936	2438.34261					
	5				9,000	OFF ON	27.00	0.500387249800	0.000050000000	9,992.25	7.74	-0.0036	0.0036	0.08%										
	6					OFF ON	28.00	0.500387251600	0.000050000000	9,992.25														
	7					ON ON	27.00	0.502566622000	0.000050300000	9,889.33	110.67	1991.9491	0.0818	1.11%										
	8					ON ON	28.00	0.502566663100	0.000050200000	9,809.03														
3	1				9,000	OFF OFF	27.00	0.499999999990	0.000050000000	10,000.00	0.00	2004.0080	0.0000	0.00%										
	2	10,000	30,000	200	6,150	OFF OFF	28.00	0.499999999990	0.000049900000	10,020.04					4.76	6,154.76	300	0.746733	2425.548799					
	3				2,000	ON OFF	27.00	0.500387250900	0.000050000000	9,992.25	7.75	-0.0038	0.0038	0.08%										
	4	10,000	30,000	200	2,050	ON OFF	28.00	0.500387252600	0.000050000000	9,992.25					4.76	2,054.76	300	0.735127	812.2713497					
	5				9,000	OFF ON	27.00	0.500519128900	0.000050100000	9,969.68	30.32	1999.9932	0.0068	0.30%										
	6					OFF ON	28.00	0.500519130200	0.000050000000	9,989.62														
	7					ON ON	27.00	0.502566617900	0.000050300000	9,889.33	110.67	1991.9491	0.0818	1.11%										
	8					ON ON	28.00	0.502566659000	0.000050200000	9,809.03														

The data above shows a modified resistor arrangement in order to get the trim resistor size down to a reasonable size. I am having trouble though with the binary trim sizing though.

Alek Benson:

- Optimized ladder structure to improve overall size and trimming performance.
- Worked on switching ladder over to binary weighted trimming.
- Worked on drafting new designs with modifications to voltage divider and ladder structures.

Simulate		Calculate		Performance				
State	Temp	V	I	Resistance	Trim	TCR	TCV	% Trim
OFF OFF	27.00	0.49999999996	0.00005000000	10,000.00	0.00	1500.0000	0.0000	0.00%
OFF OFF	28.00	0.49999999995	0.00004992511	10,015.00				
ON OFF	27.00	0.50031543396	0.00005003154	9,987.39	12.61	1500.4813	-0.2401	0.13%
ON OFF	28.00	0.50031531381	0.00004995660	10,002.38				
OFF ON	27.00	0.50093906453	0.00005009391	9,962.51	37.49	1506.8693	-3.4231	0.37%
OFF ON	28.00	0.50093734978	0.00005001871	9,977.52				
ON ON	27.00	0.50096512151	0.00005009651	9,961.47	38.53	1506.9005	-3.4384	0.39%
ON ON	28.00	0.50096339898	0.00005002131	9,976.48				
OFF OFF	27.00	0.49999999996	0.00005000000	10,000.00	0.00	1500.0000	0.0000	0.00%
OFF OFF	28.00	0.49999999995	0.00004992511	10,015.00				
ON OFF	27.00	0.50085048695	0.00005008505	9,966.04	33.96	1502.1674	-1.0803	0.34%
ON OFF	28.00	0.50084994591	0.00005000998	9,981.01				
OFF ON	27.00	0.50242772187	0.00005024277	9,903.36	96.64	1500.2210	-0.1098	0.97%
OFF ON	28.00	0.50242766671	0.00005016752	9,918.22				
ON ON	27.00	0.50252778869	0.00005025278	9,899.40	100.60	1500.2089	-0.1038	1.01%
ON ON	28.00	0.50252773655	0.00005017751	9,914.25				

- Worked on trying to optimize each bit into many different trimming amounts.

Oluwatosin Oyekan:

- Simulated the truss design but my results weren't up to par
- Brainstormed on some new circuit designs we can use, currently thinking on mixing two of our already existing designs together
- Listened to my other team members solution on their simulations to fix my results

◆ Pending issues

Clark Reimers:

- Need to change resistor ratios of voltage divider to an R2R.

Pierce Nablo:

- I am starting to have VPN issues into the ISU network for accessing the linux machines. I have requested access to 2046 lab room in order to work on senior design on campus.

Alek Benson:

- No Issues

Oluwatosin Oyenekan:

- No Issues

❖ **Individual contributions**

<u>Name</u>	<u>Hours 9/29 - 10/5</u>	<u>Hours 10/6 - 9/12</u>	<u>Hours cumulative</u>
Clark Reimers	8	6	56
Pierce Nablo	7	7	57
Alek Benson	6	8	57
Oluwatosin Oyenekan	6	6	51

❖ **Plans for the upcoming week**

Clark Reimers: Continue work on optimizing the voltage divider area and TCV. Start expanding it to further resolution, if I can make the optimizations. Brainstorm some new designs to look into as well.

Alek Benson: The plan for the upcoming week is to continue to work on binary weighted structures. Also, I will try to make modifications to the ladder structure and compare to the other structures.

Oluwatosin Oyenekan: My Plan for this coming week is to design a hybrid simulation on our other design and simulate it and compare the results with that of our previous designs

Pierce Nablo: I plan on tackling the binary weighted trim issue in the coming week. I believe the issue is coming from the resistor sizing on the current driving sides.

❖ **Summary of weekly advisor meeting**

During the past advisor meetings, our team has discussed some different potential designs and created drafts to show to Dr. Geiger. We spent time simulating the designs and discussing the data and documentation of our findings about different structures. We also spent time reworking some designs to better address sizing issues and reworking designs to incorporate a binary weighted trim. Dr. Geiger is happy with the work done with these reworking ideas, and the advisor meetings have gone well.