SIMPLIS does not allow the multiplication or division of two (or more) dynamically-varying waveforms.

B1 1 2 V=V(4,8)*V(5,3)*15m is not allowed with Simplis

Instead, you must resort to logarithmic expressions to perform these operations:

Decimal base

$$\log_{10}(a \cdot b) = \log_{10} a + \log_{10} b$$

$$10^{(\log_{10} a + \log_{10} b)} = a \cdot b$$

e base

$$\ln(a \cdot b) = \ln a + \ln b$$

$$e^{(\ln a + \ln b)} = a \cdot b$$

For a division:

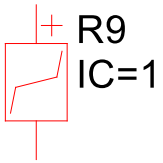
$$\log_{10}\left(\frac{a}{b}\right) = \log_{10} a - \log_{10} b$$

$$10^{(\log_{10} a - \log_{10} b)} = \frac{a}{b}$$

$$\ln\left(\frac{a}{b}\right) = \ln a - \ln b$$

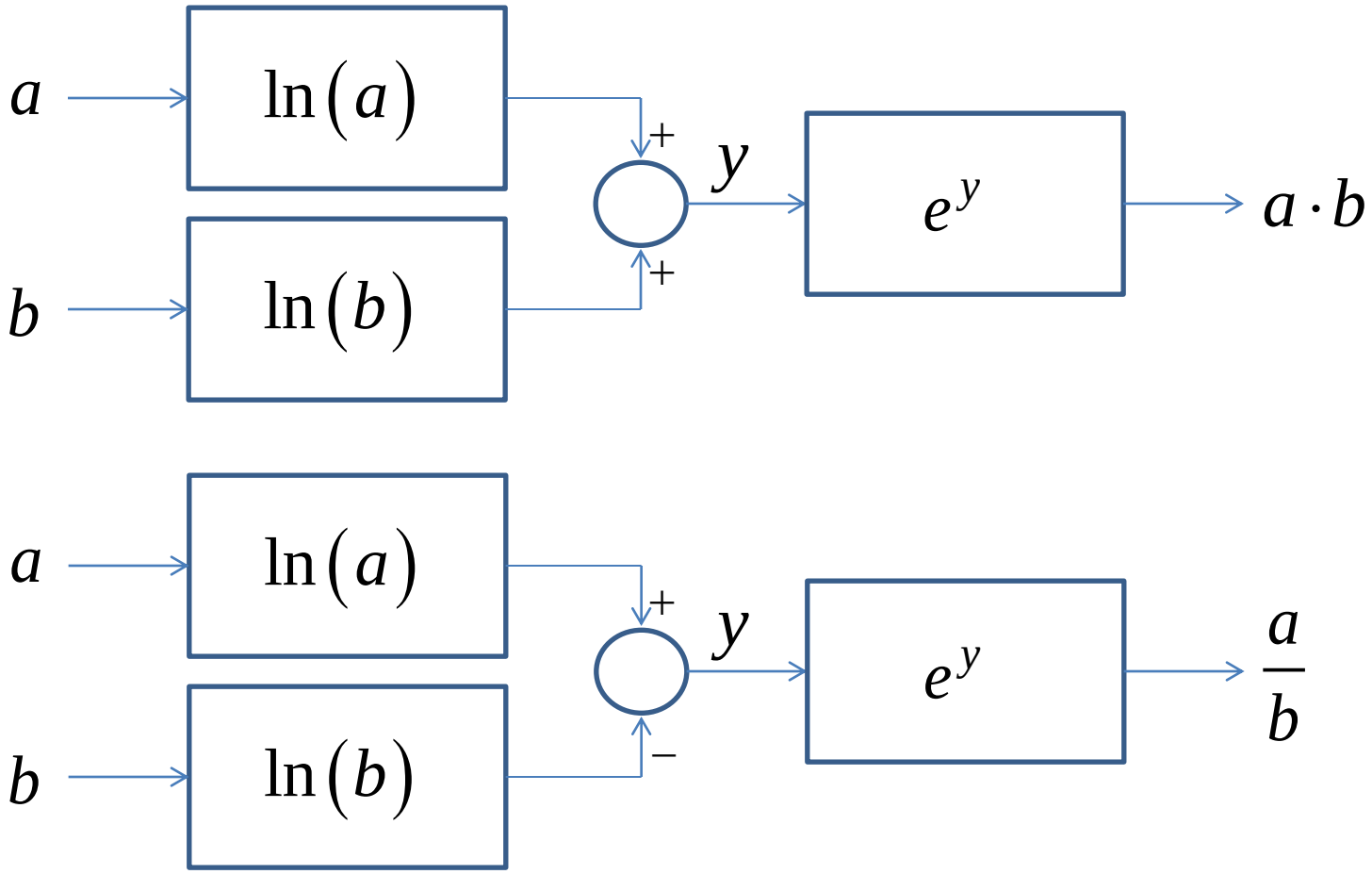
$$e^{(\ln a - \ln b)} = \frac{a}{b}$$

SIMPLIS offers a way to create functions in a piece-wise-linear way via a PWL component, the VPWL or IPWL resistor:

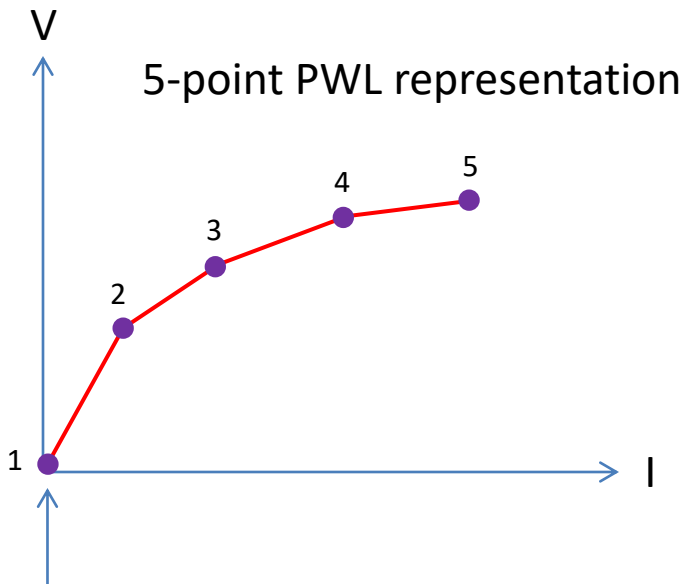


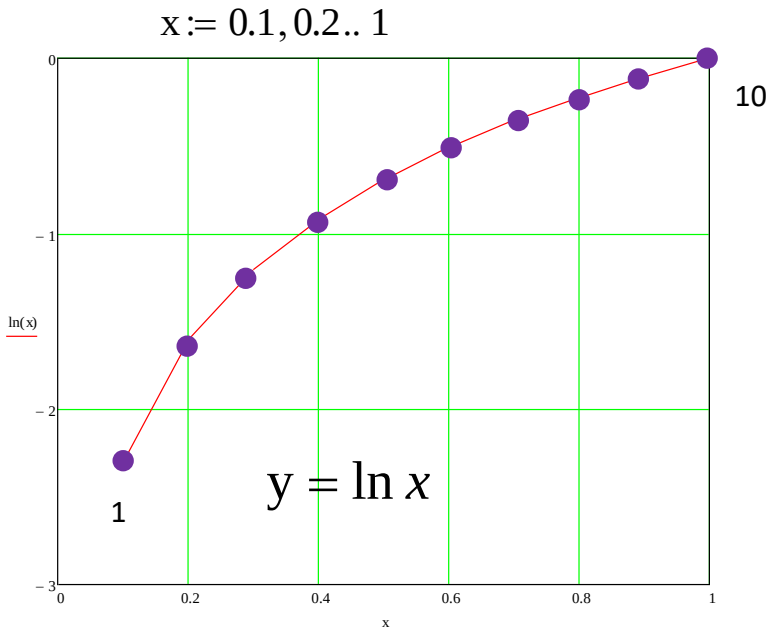
Christophe Basso
January 2018

You will have to take the logarithm of the considered variables and sum/subtract them before taking the exponential of the result.



You will have to know the range within which a and b vary but also the range within which y will vary. This is important to make sure the variation remains within the adopted data points.





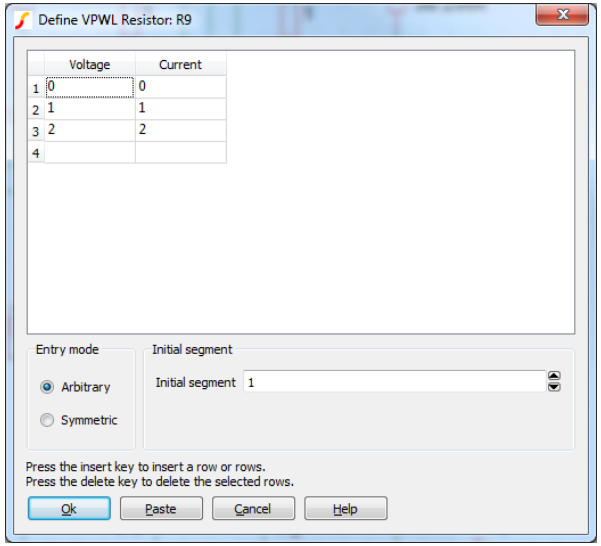
The best tool is actually Excel since the generated values will be copied/pasted into the selected SIMPLIS V or IPWL element

Input Output

	A	B	C	D	E	F	G
1		x	Ln(x)		x	exp(x)	
2		1.00E-01	-2.30259		-2.30259	0.1	
3		2.00E-01	-1.60944		-1.60944	0.2	
4		3.00E-01	-1.20397		-1.20397	0.3	
5		4.00E-01	-0.91629		-0.91629	0.4	
6		5.00E-01	-0.69315		-0.69315	0.5	
7		6.00E-01	-0.51083		-0.51083	0.6	
8		7.00E-01	-0.35667		-0.35667	0.7	
9		8.00E-01	-0.22314		-0.22314	0.8	
10		9.00E-01	-0.10536		-0.10536	0.9	
11		1.00E+00	-1.1E-16		-1.1E-16	1	
12							

The range is given by the input signals while the number of points depends on the expected precision in the calculation. Assuming a 0-1 V input range with crude variations in 150 or 200 mV steps. In this case, perhaps 10-20 points will suffice to map the input signal into the lookup table. If the input signal is going through small increments, increase the number of point with 10-20-mV steps.

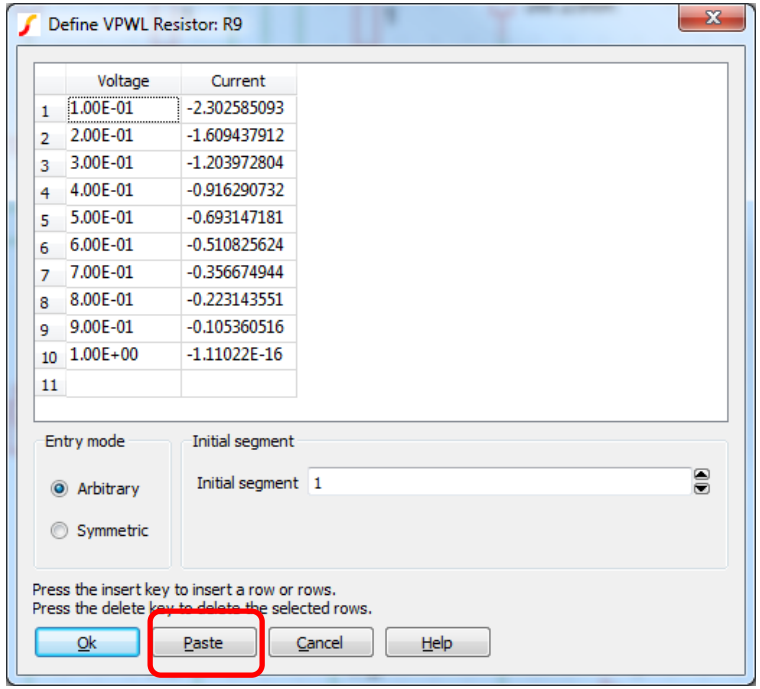
Double-click on the newly-placed VPWL element:



Select data in Excel - Copy

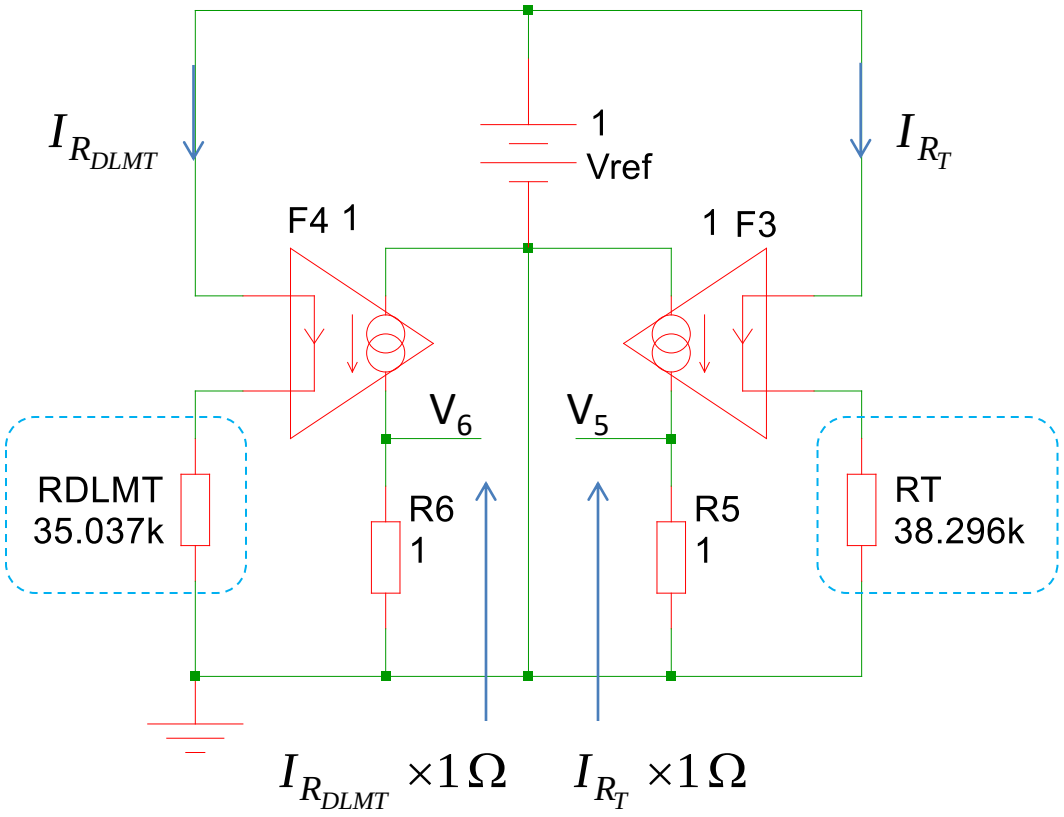
x	Ln(x)
1.00E-01	-2.30259
2.00E-01	-1.60944
3.00E-01	-1.20397
4.00E-01	-0.91629
5.00E-01	-0.69315
6.00E-01	-0.51083
7.00E-01	-0.35667
8.00E-01	-0.22314
9.00E-01	-0.10536
1.00E+00	-1.1E-16

Press Paste to paste the data into the array



You want to multiply two currents together:

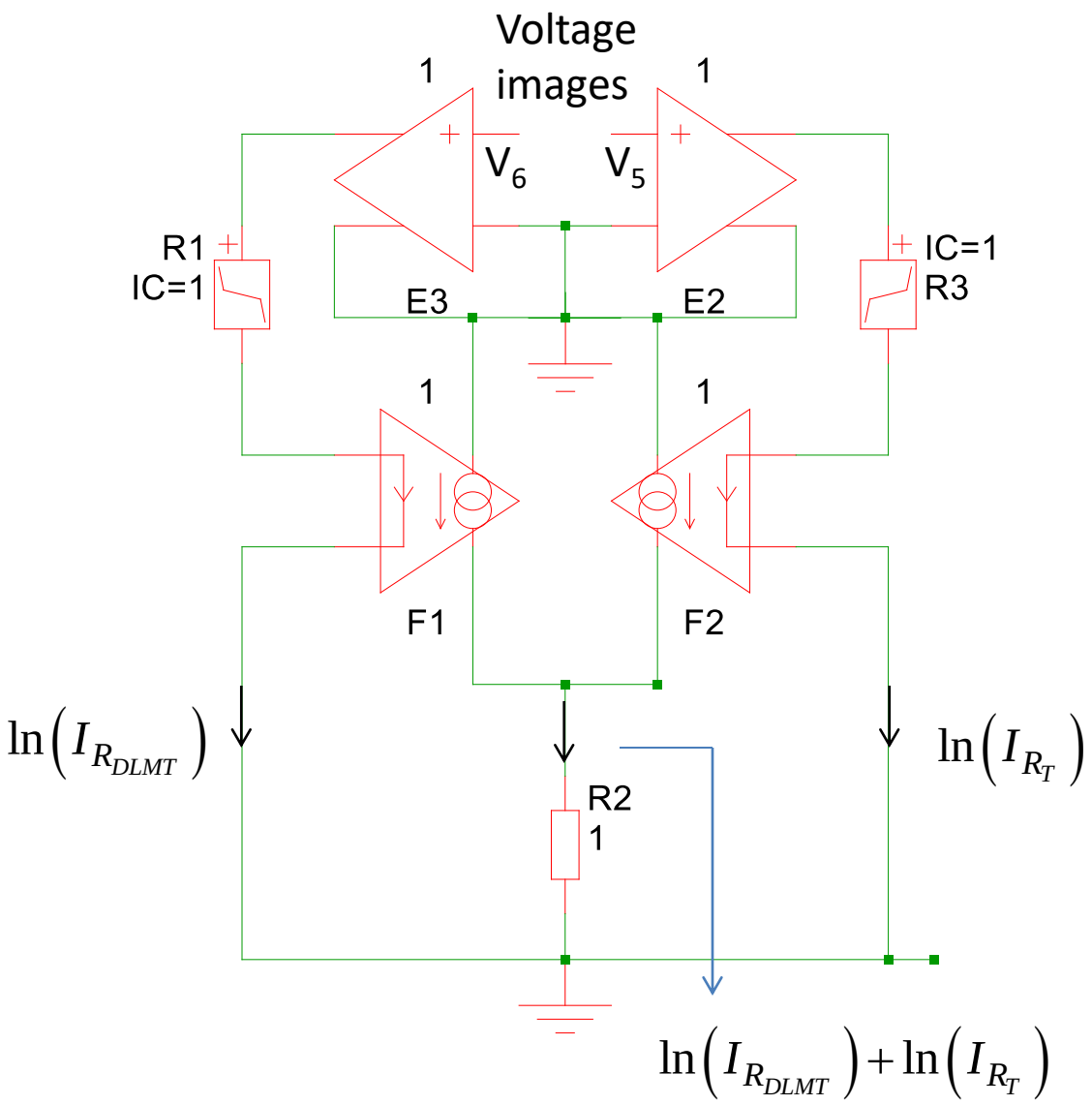
1. Mirror current variables via a F source and transform them into a voltage



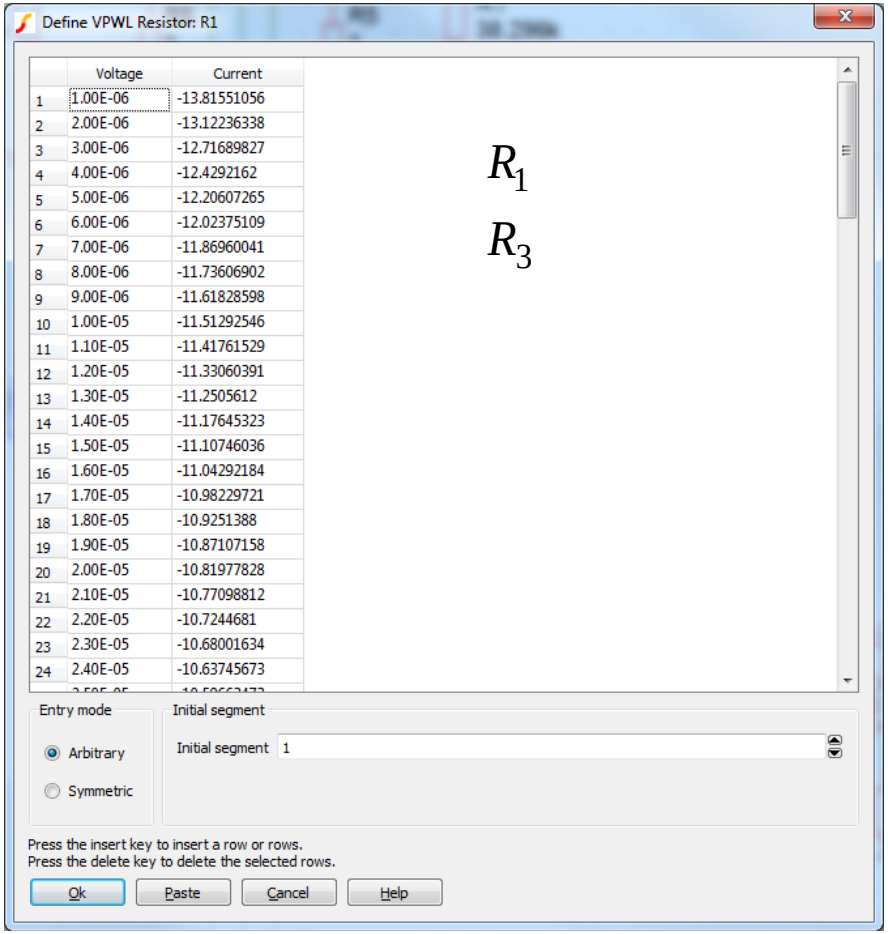
These resistors program the chip currents by absorbing current from the 1-V bias.

Voltage images of the currents circulating in RDLMT and RT

2. Take the natural logarithm of the buffered voltages

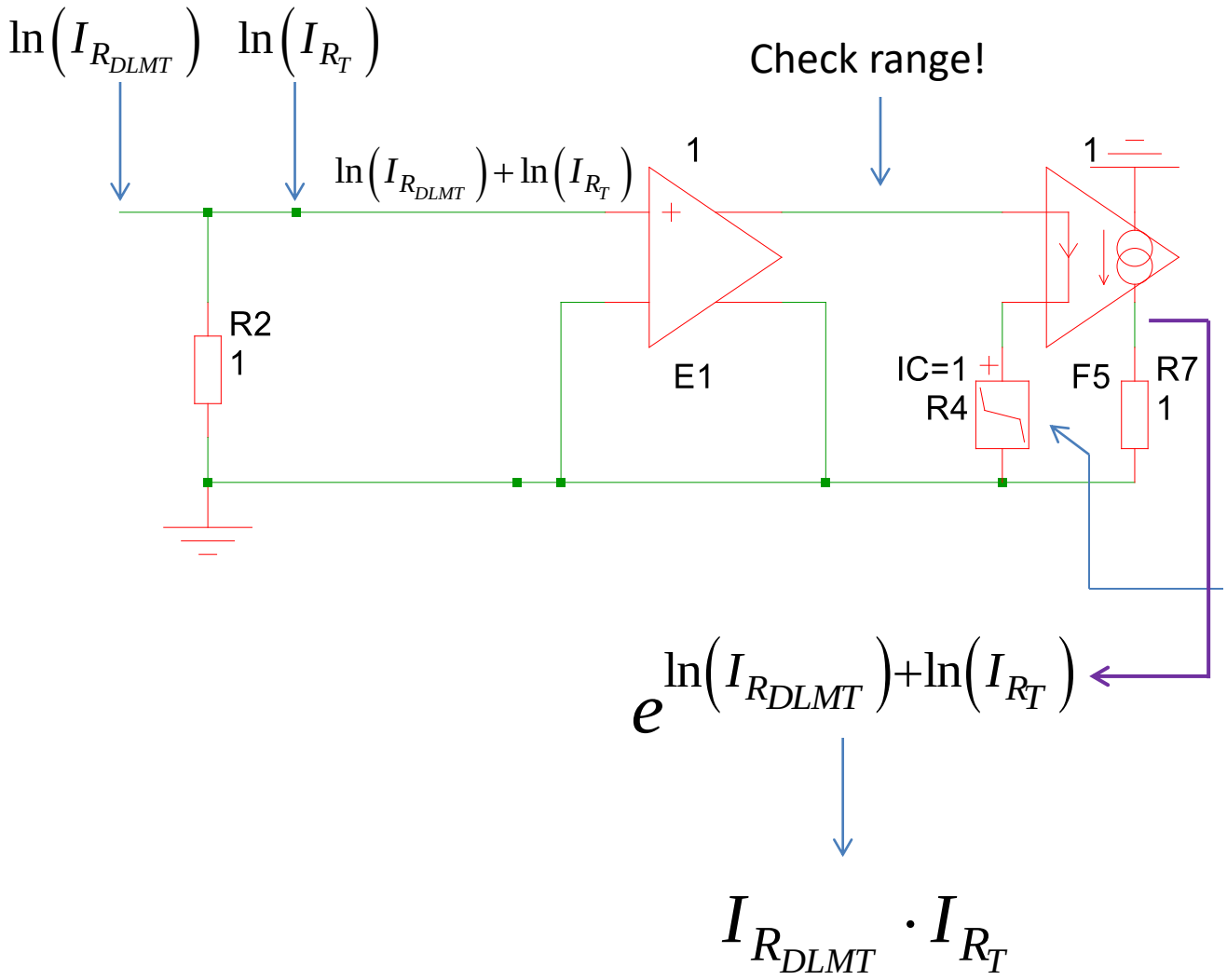


The biasing voltage for the resistances is 1 V. Typical values for the resistances range from 10 kΩ to 70 kΩ. As such, the current may vary from 100 µA down to 15 µA. I've built a VPWL following the below list: 1 µV to 100 µV by 1 µV steps (100 points).



You see in the right side the resulting current which ranges from -13.8 A to -9.2 A. Summing these values implies a total current representative of the two currents ranging from -30 A to -17.6 A.

Now that we have the sum of the natural logarithms, we need to take the exponential of the buffered result to obtain the wanted multiplication.



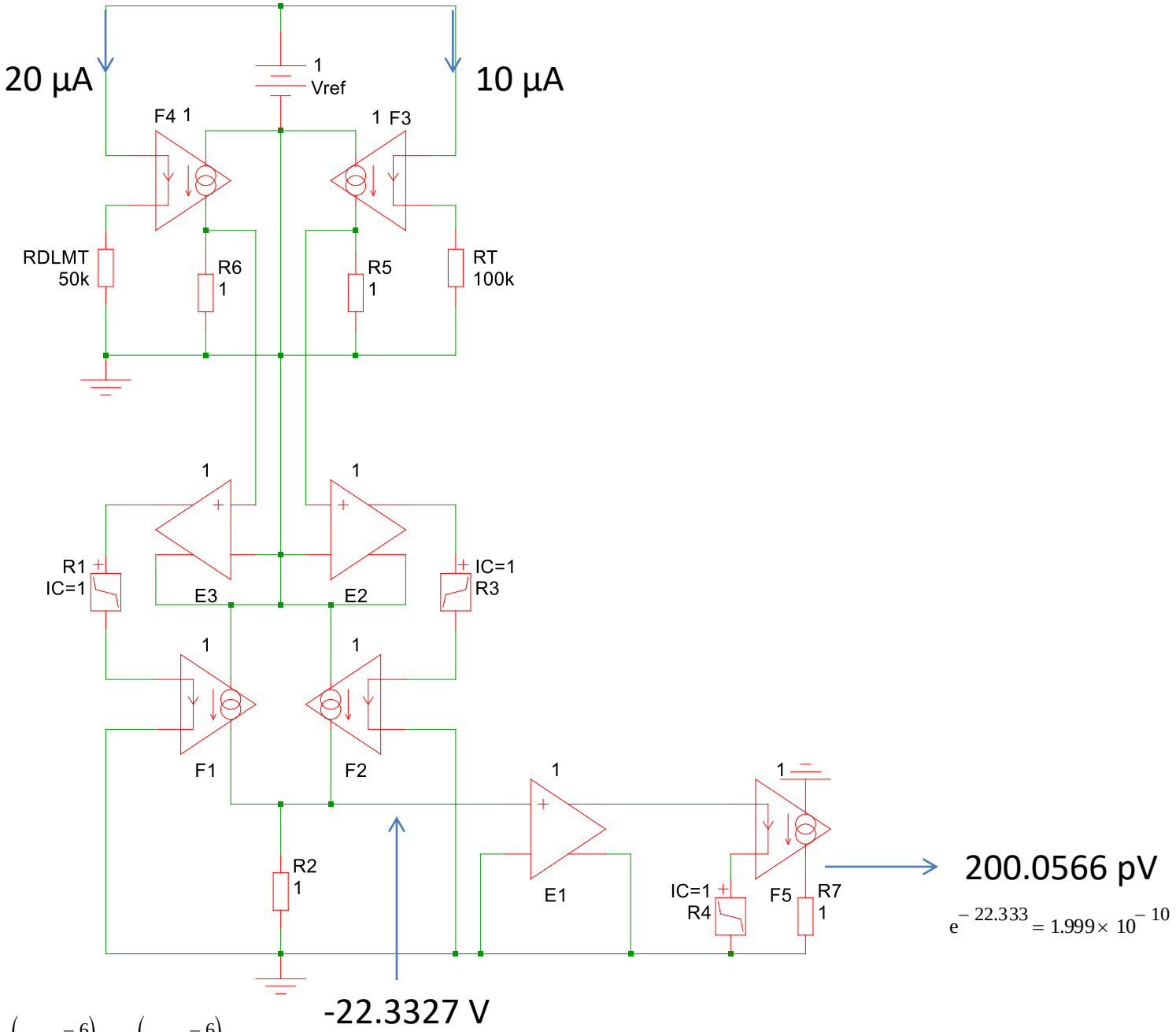
Define VPWL Resistor: R4

	Voltage	Current
1	-30	9.35762E-14
2	-29.95	9.8374E-14
3	-29.9	1.03418E-13
4	-29.85	1.0872E-13
5	-29.8	1.14294E-13
6	-29.75	1.20154E-13
7	-29.7	1.26315E-13
8	-29.65	1.32791E-13
9	-29.6	1.39599E-13
10	-29.55	1.46757E-13
11	-29.5	1.54281E-13
12	-29.45	1.62191E-13
13	-29.4	1.70507E-13
14	-29.35	1.79249E-13
15	-29.3	1.88439E-13
16	-29.25	1.98101E-13
17	-29.2	2.08258E-13
18	-29.15	2.18935E-13
19	-29.1	2.3016E-13
20	-29.05	2.41961E-13
21	-29	2.54367E-13
22	-28.95	2.67408E-13
23	-28.9	2.81119E-13
24	-28.85	2.95532E-13

Entry mode | Initial segment

Range is likely to be between -30 to -17 A, setting the VPWL limits.

-17.6

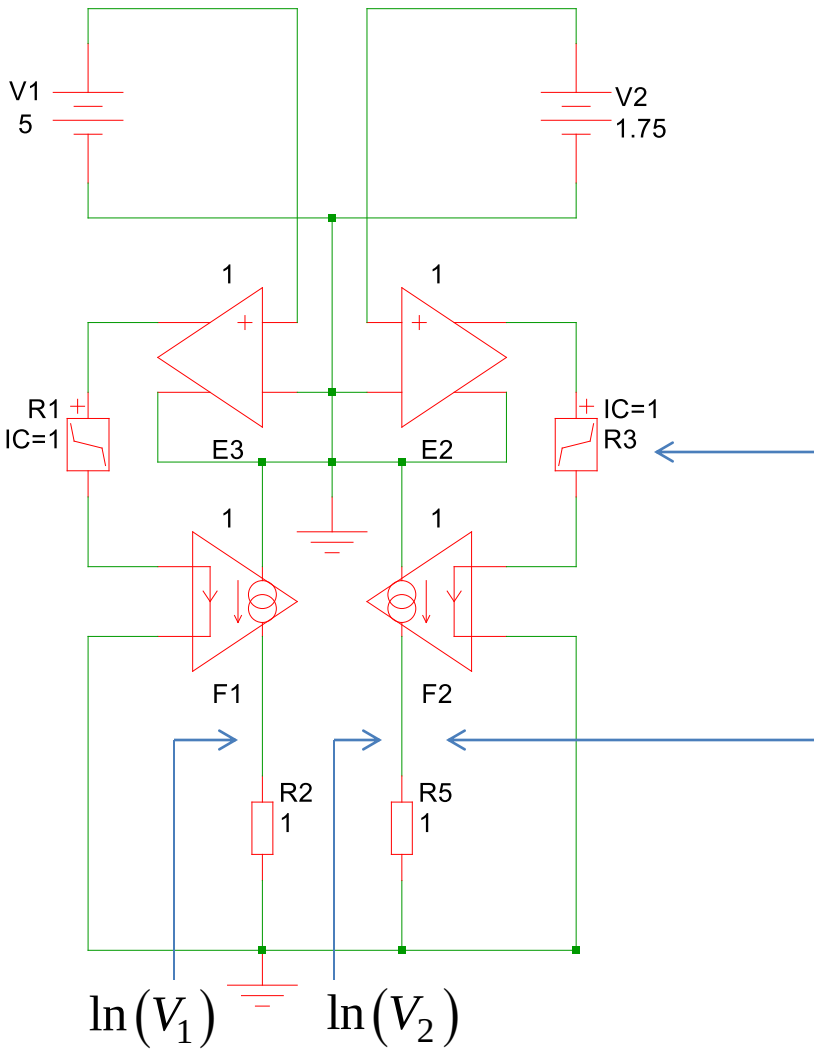


$$e^{-22.333} = 1.999 \times 10^{-10}$$

$$\ln\left(20 \cdot 10^{-6}\right) + \ln\left(10 \cdot 10^{-6}\right) = -22.333$$

For a division, you need to reverse the sign when summing both logarithmic currents. Assume you want to divide V_1 by V_2. Both voltages vary between 200 mV to 5 V in crude steps.

Ln function



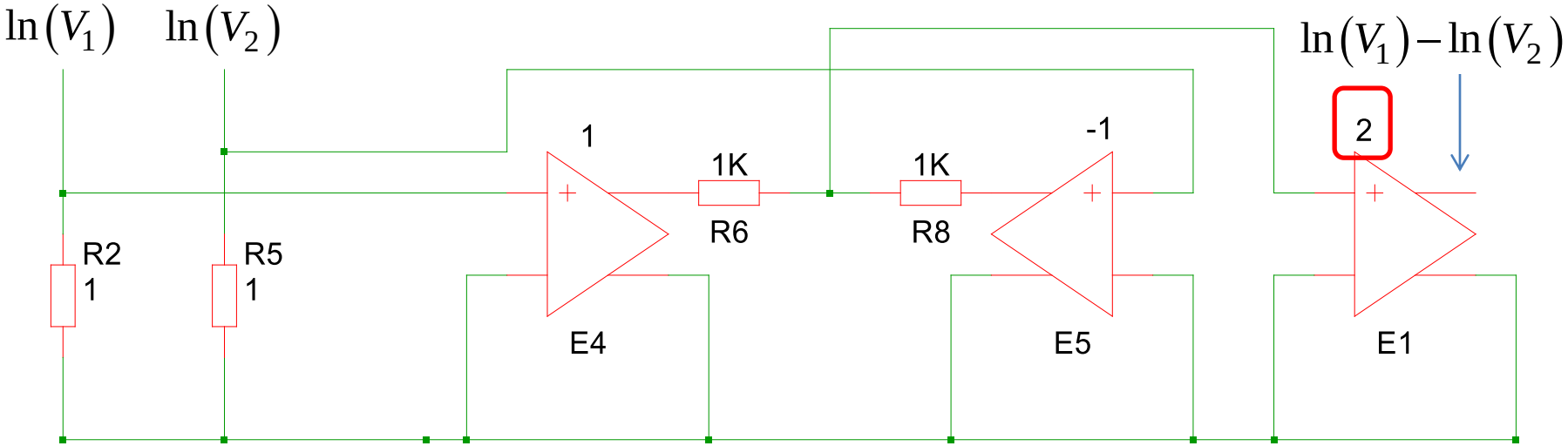
Define VPWL Resistor: R1

	Voltage	Current
1	2.00E-01	-1.609437912
2	8.00E-01	-0.223143551
3	1.40E+00	0.336472237
4	2.10E+00	0.741937345
5	2.60E+00	0.955511445
6	3.10E+00	1.131402111
7	3.60E+00	1.280933845
8	4.10E+00	1.410986974
9	4.60E+00	1.526056303
10	5.10E+00	1.62924054

Current (but voltage across the 1-Ω res) sets the range: -1.6 V to 1.7 V

Buffer the voltage inputs and transform into a currents flowing in the 1-Ω resistors

Then subtract the two voltage outputs. May ways to sum voltages, this one is one possibility.



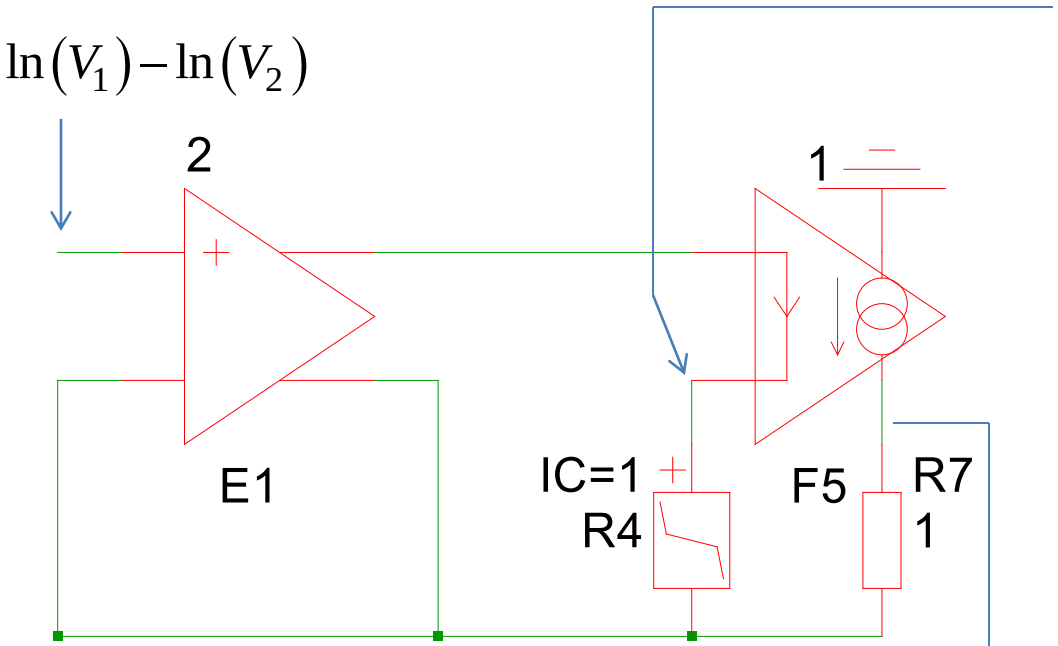
$$\ln(V_1)-\ln(V_2)$$

$$\ln(10m)-\ln(5)=-6$$

$$\ln(5)-\ln(0.01)=6$$

range will be between – 6 to 6 V

We will now calculate the exponential of the subtracted voltages



$$e^{\ln(V_1)-\ln(V_2)}$$

$$\frac{V_1}{V_2}$$

$$\frac{5}{1.75} \rightarrow 2.96$$

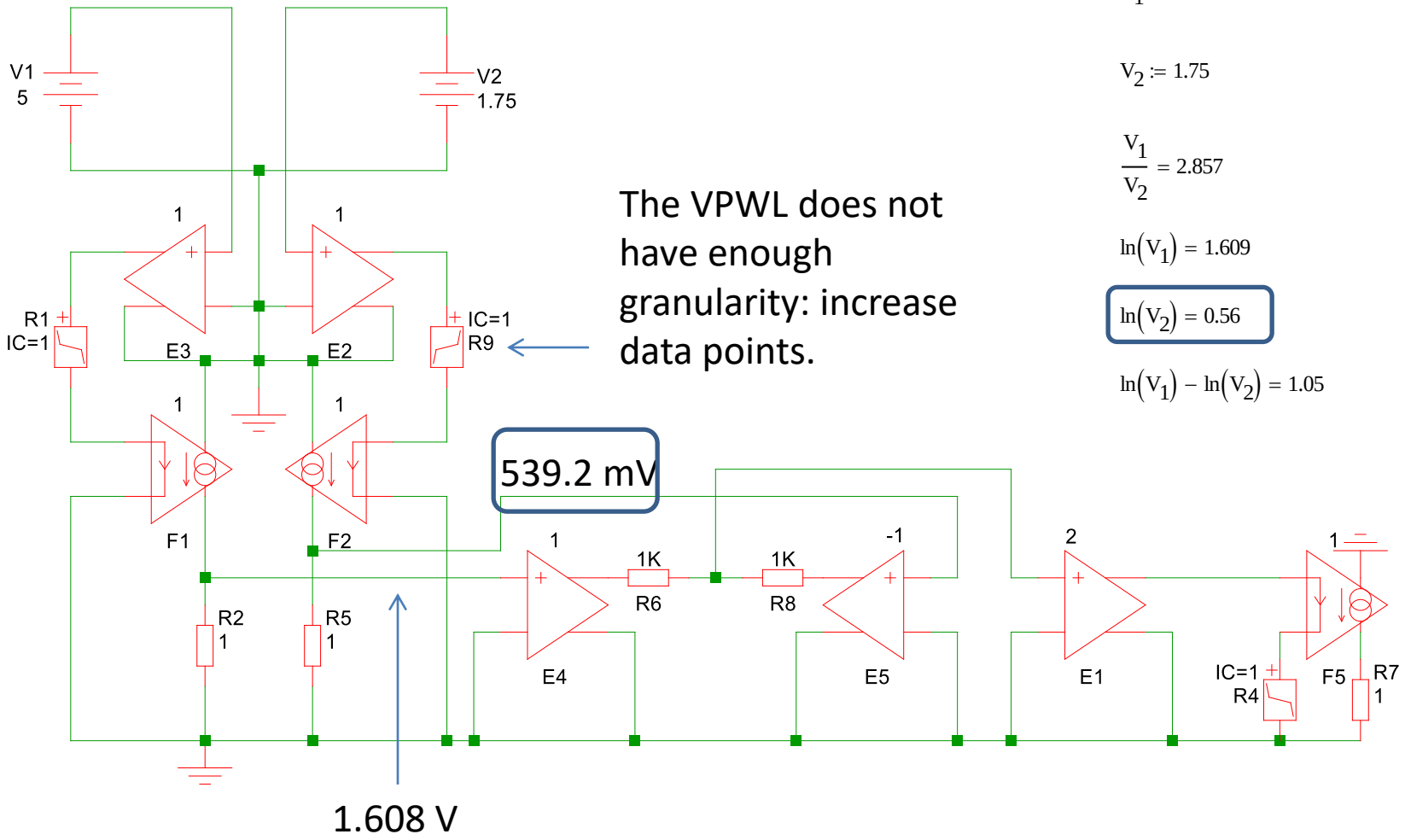
Some error remains

Define VPWL Resistor: R4

	Voltage	Current
1	-6	0.002478752
2	-5.5	0.004086771
3	-5	0.006737947
4	-4.5	0.011108997
5	-4	0.018315639
6	-3.5	0.030197383
7	-3	0.049787068
8	-2.5	0.082084999
9	-2	0.135335283
10	-1.5	0.22313016
11	-1	0.367879441
12	-0.5	0.60653066
13	0	1
14	0.5	1.648721271
15	1	2.718281828
16	1.5	4.48168907
17	2	7.389056099
18	2.5	12.18249396
19	3	20.08553692
20	3.5	33.11545196
21	4	54.59815003
22	4.5	90.0171313
23	5	148.4131591
24	5.5	244.6919323

Entry mode | Initial segment

Track the error on the intermediate calculation steps:



The VPWL does not have enough granularity: increase data points.

$V_1 := 5$

$V_2 := 1.75$

$\frac{V_1}{V_2} = 2.857$

$\ln(V_1) = 1.609$

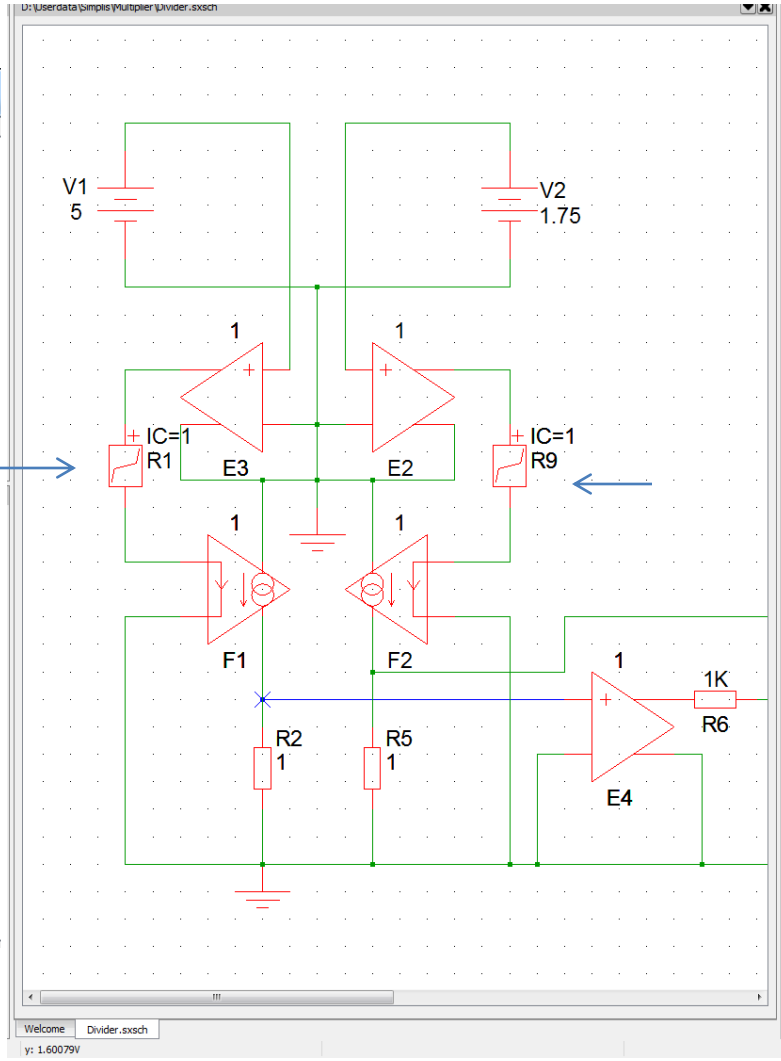
$\ln(V_2) = 0.56$

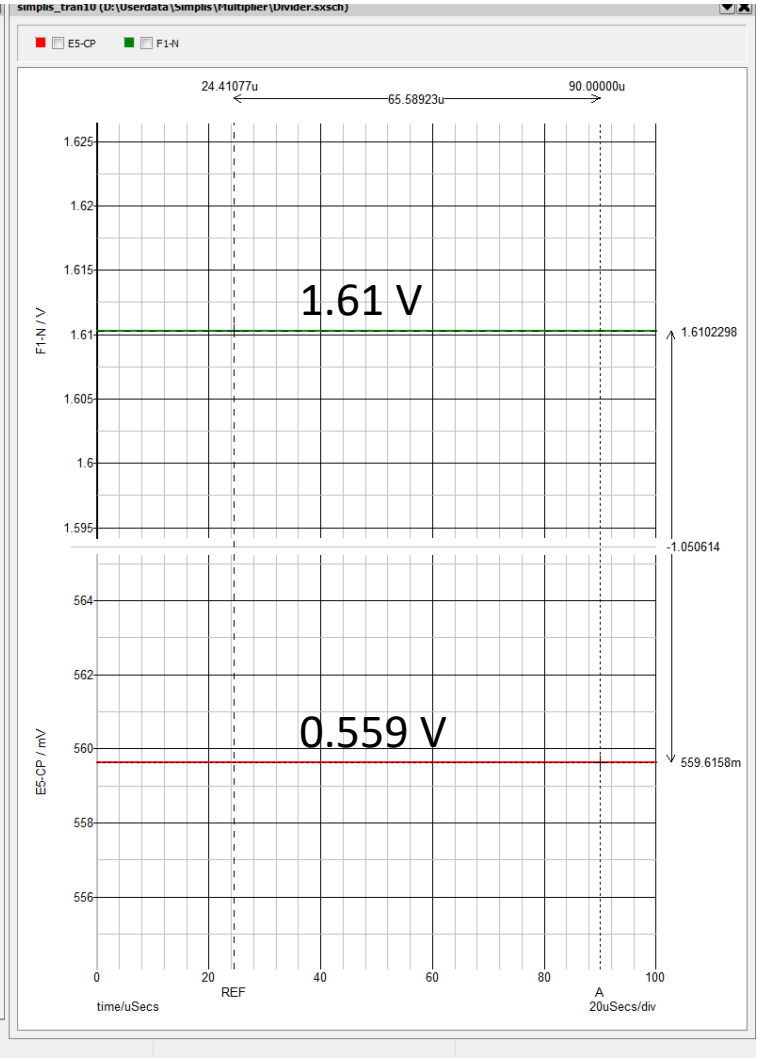
$\ln(V_1) - \ln(V_2) = 1.05$

Resolution is increased to 50 data points with 100-mV steps

Define VPWL Resistor: R9

	Voltage	Current
1	5.00E-02	-2.995732274
2	1.50E-01	-1.897119985
3	2.50E-01	-1.386294361
4	3.50E-01	-1.049822124
5	4.50E-01	-0.798507696
6	5.50E-01	-0.597837001
7	6.50E-01	-0.430782916
8	7.50E-01	-0.287682072
9	8.50E-01	-0.162518929
10	9.50E-01	-0.051293294
11	1.05E+00	0.048790164
12	1.15E+00	0.139761942
13	1.25E+00	0.223143551
14	1.35E+00	0.300104592
15	1.45E+00	0.371563556
16	1.55E+00	0.438254931
17	1.65E+00	0.500775288
18	1.75E+00	0.559615788
19	1.85E+00	0.615185639
20	1.95E+00	0.667829373
21	2.05E+00	0.717839793
22	2.15E+00	0.765467842
23	2.25E+00	0.810930216
24	2.35E+00	0.854415328

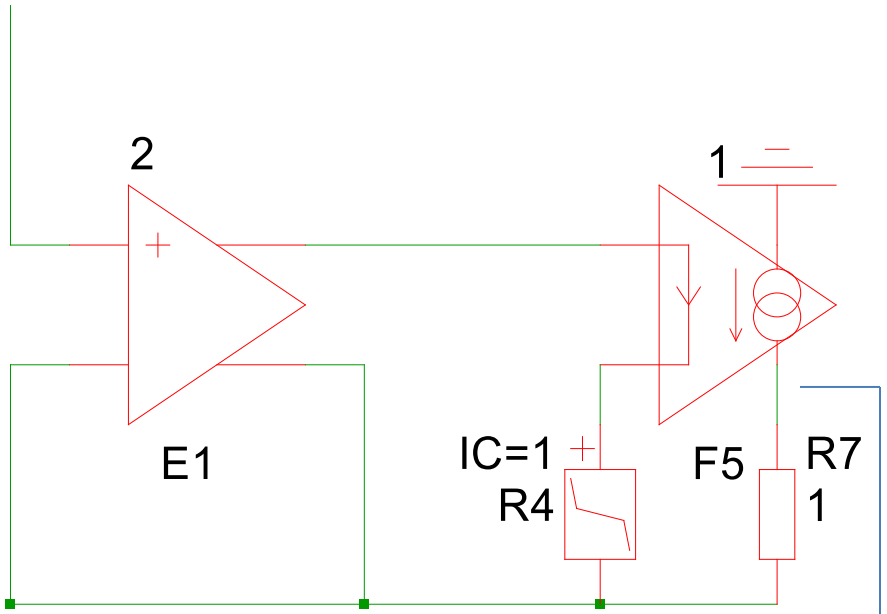




Increase the granularity for the last resistor to 120 data points

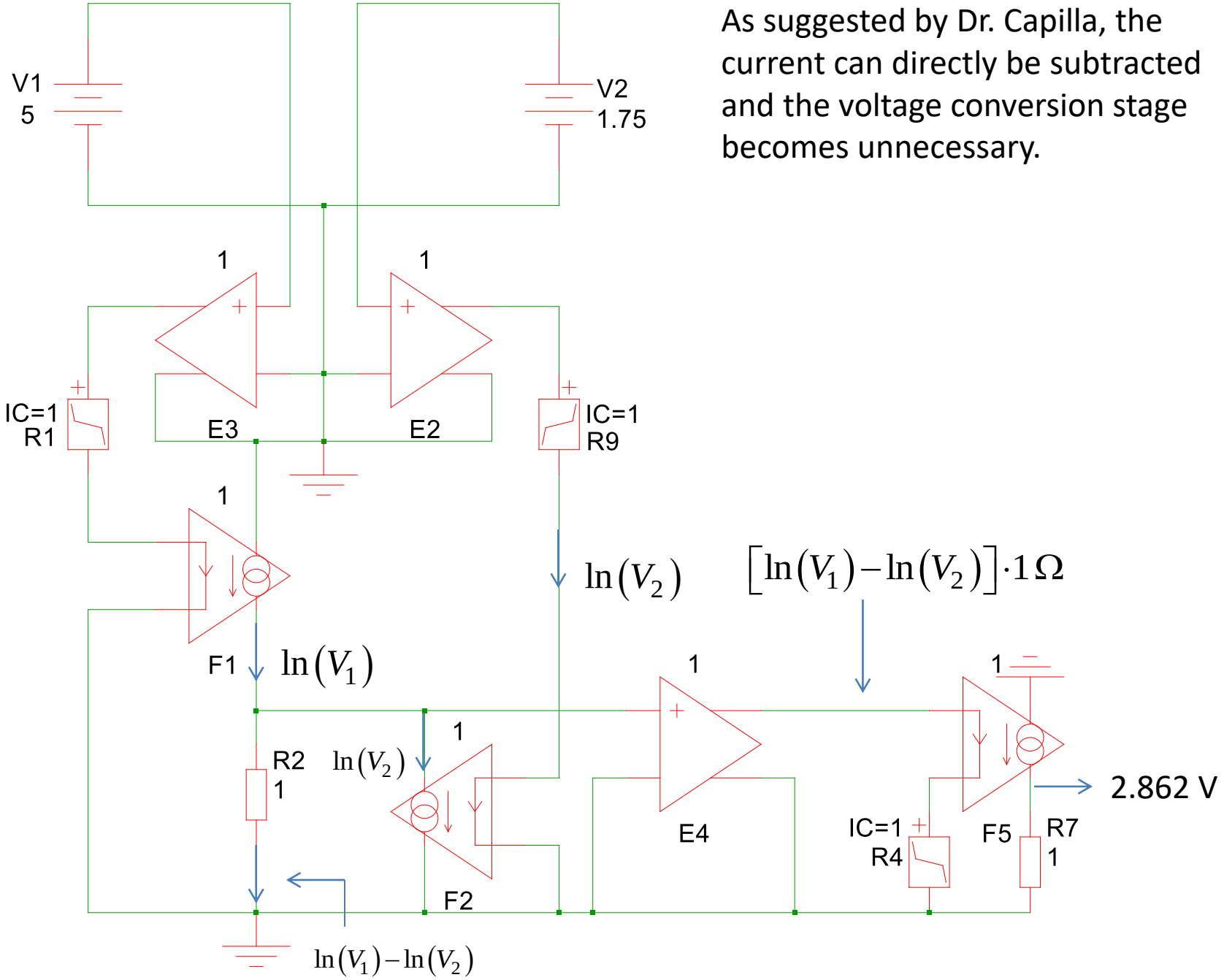
Define VPWL Resistor: R4

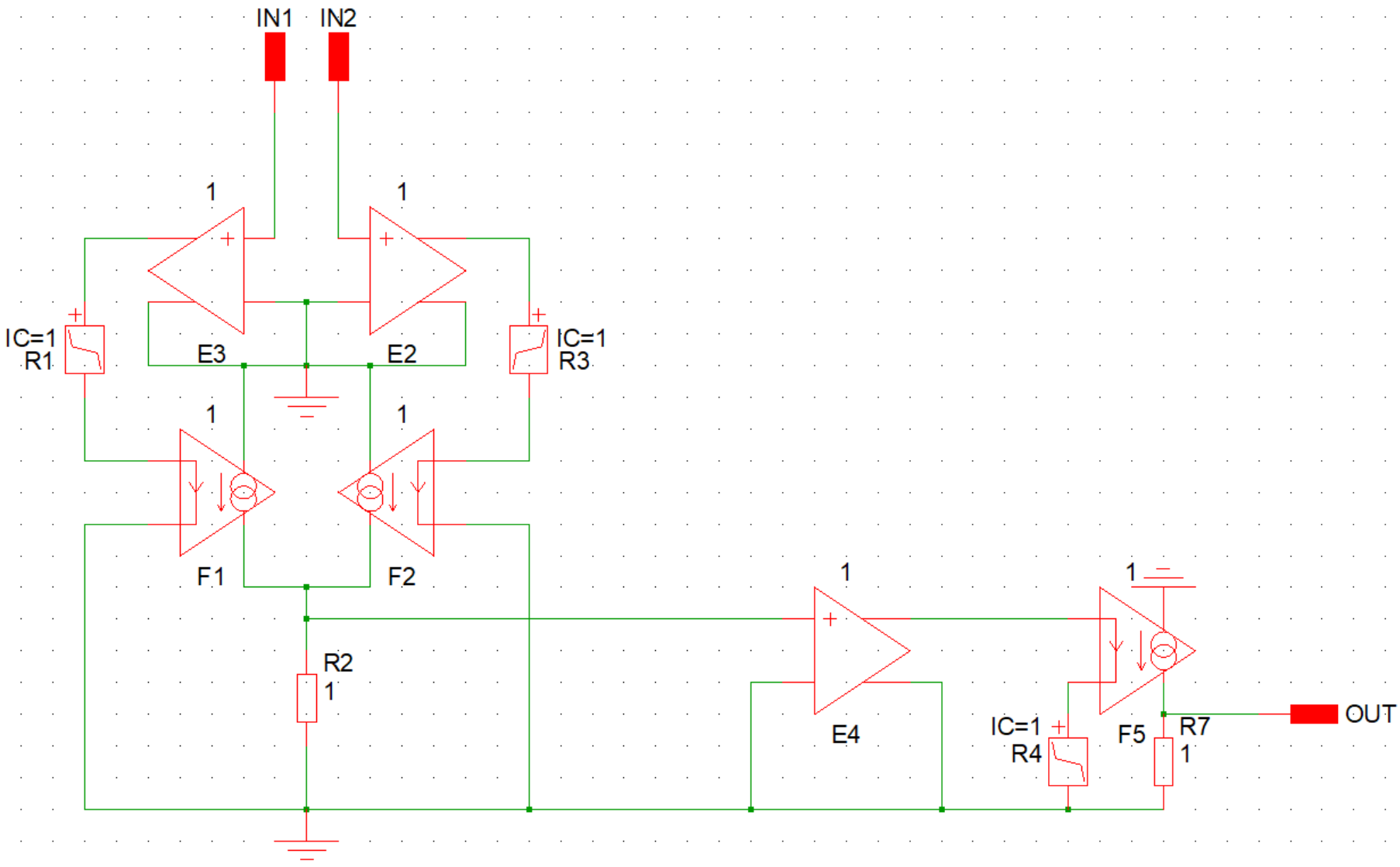
	Voltage	Current
1	-6	0.002478752
2	-5.9	0.002739445
3	-5.8	0.003027555
4	-5.7	0.003345965
5	-5.6	0.003697864
6	-5.5	0.004086771
7	-5.4	0.004516581
8	-5.3	0.004991594
9	-5.2	0.005516564
10	-5.1	0.006096747
11	-5	0.006737947
12	-4.9	0.007446583
13	-4.8	0.008229747
14	-4.7	0.009095277
15	-4.6	0.010051836
16	-4.5	0.011108997
17	-4.4	0.01227734
18	-4.3	0.013568559
19	-4.2	0.014995577
20	-4.1	0.016572675
21	-4	0.018315639
22	-3.9	0.020241911
23	-3.8	0.022370772
24	-3.7	0.024723526



$$\frac{5}{1.75} = 2.857 \qquad \frac{5}{1.75} \rightarrow 2.862$$

As suggested by Dr. Capilla, the current can directly be subtracted and the voltage conversion stage becomes unnecessary.





Final multiplier subcircuit

Math operations between dynamic signals in Simplis require the usage of log functions that are summed or subtracted. The result is then conveyed through an exponential expression to obtain the final result.

It is important to correctly assess the signal dynamics when configuring the VPWL resistors. Increasing the number of segments is better for precision but detrimental to simulation speed: some tradeoff is necessary here.