SIMPLE PIECEWISE LINEAR COMPRESSION CIRCUIT

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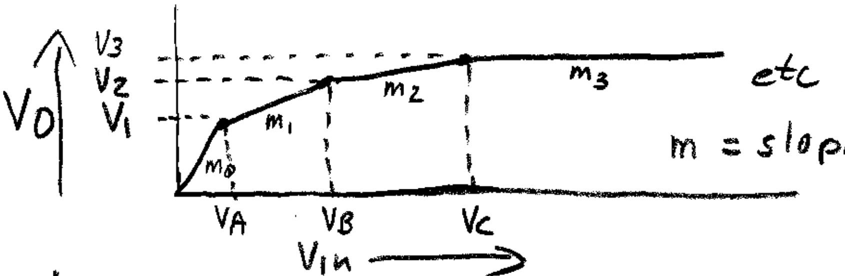

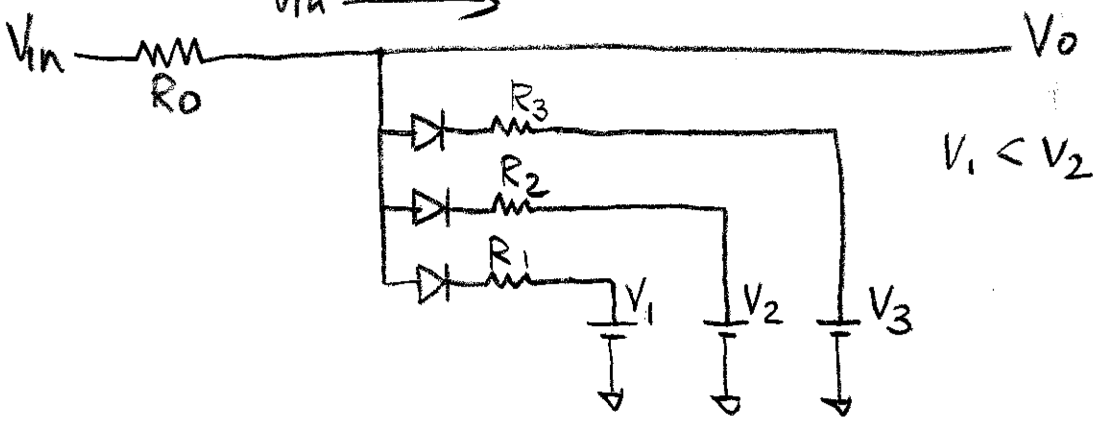

$V_1 < V_2 < V_3$

Analysis: (FIND V_A, V_B, + V_C)

We will assume ideal diodes for simplicity of illustration. A good diode model is 0.56 V in series with 33 ohms.

$$
\left.\begin{aligned}
m_0 &= 1\\
V_A &= 0 + \frac{(V_1 - 0)}{m_1} = V_1\\
m_1 &= R_1/(R_0 + R_1)\\
V_B &= V_A + \frac{(V_2 - V_1)}{m_1}\\
m_2 &= R_1\|R_2/(R_0 + R_1\|R_2)\\
V_C &= V_B + \frac{(V_3 - V_2)}{m_2}\\
m_3 &= R_1\|R_2\|R_3/(R_0 + R_1\|R_2\|R_3)
\end{aligned}\right\}\ \text{Analytic Equations}
$$

The diode voltage adds to V_1, V_2, V_3 and the diode resistance adds to R_1, R_2, R_3

For any input voltage, V_{in}, V_o can be found by first determining the voltage range, $V_A \to V_B$, $V_B \to V_C$, etc. that brackets the input voltage. Then interpolate between the corresponding V_1, V_2, V_3, etc. For example, if V_{in} is between V_A and V_B then $V_O = \left(\frac{V_{in} - V_A}{V_B - V_A}\right) * (V_2 - V_1) + V_1$

Design:

The pairs of voltages, (V_A, V_1), (V_B, V_2), (V_C, V_3), etc have been determined by some means for a good fit to a desired function. The problem is to determine the required resistors. The basic procedure is to pick a value for R_o and then use ratios to calculate R_1, R_2, R_3, etc. We reverse the analytic equations.

$$m_1 = \frac{V_2 - V_1}{V_B - V_A} = \frac{R_1}{R_o + R_1} = \frac{(R_1/R_o)}{1 + (R_1/R_o)}$$

R_1 is only unknown

$$\frac{R_1}{R_o} = \frac{m_1}{1 - m_1} \qquad \boxed{R_1 = R_o\left(\frac{m_1}{1 - m_1}\right)}$$

$$m_2 = \frac{V_3 - V_2}{V_C - V_A} = \frac{R_1 \| R_2}{R_o + R_1 \| R_2} = \frac{R_1 \| R_2 / R_o}{1 + \frac{R_1 \| R_2}{R_o}}$$

R_2 is only unknown

$$\frac{R_1 \| R_2}{R_o} = \frac{m_2}{1 - m_2} \qquad \boxed{R_1 \| R_2 = R_o\left(\frac{m_2}{1 - m_2}\right)} \qquad \boxed{R_2 = \frac{1}{\frac{1}{(R_1 \| R_2)} - \frac{1}{R_1}}}$$

$$m_3 = \frac{V_4 - V_3}{V_D - V_C} = \frac{R_1 \| R_2 \| R_3}{R_0 + R_1 \| R_2 \| R_3} = \frac{\left(R_1 \| R_2 \| R_3 / R_0\right)}{1 + \left(\frac{R_1 \| R_2 \| R_3}{R_0}\right)}$$

R_3 is only unknown

$$\frac{R_1 \| R_2 \| R_3}{R_0} = \frac{m_3}{1 - m_3}$$

$$R_1 \| R_2 \| R_3 = R_0 \left(\frac{m_3}{1 - m_3}\right)$$

$$R_3 = \frac{1}{\frac{1}{R_1 \| R_2 \| R_3} - \frac{1}{R_1 \| R_2}}$$

Already known from earlier calculations

This same pattern continues for as many segments as exist

SIMPLE PIECEWISE LINEAR EXPANSION CIRCUIT

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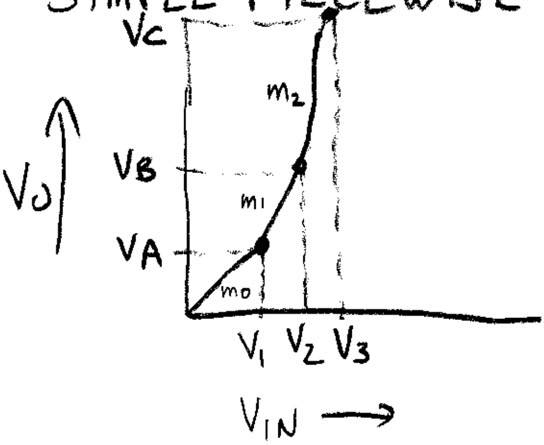

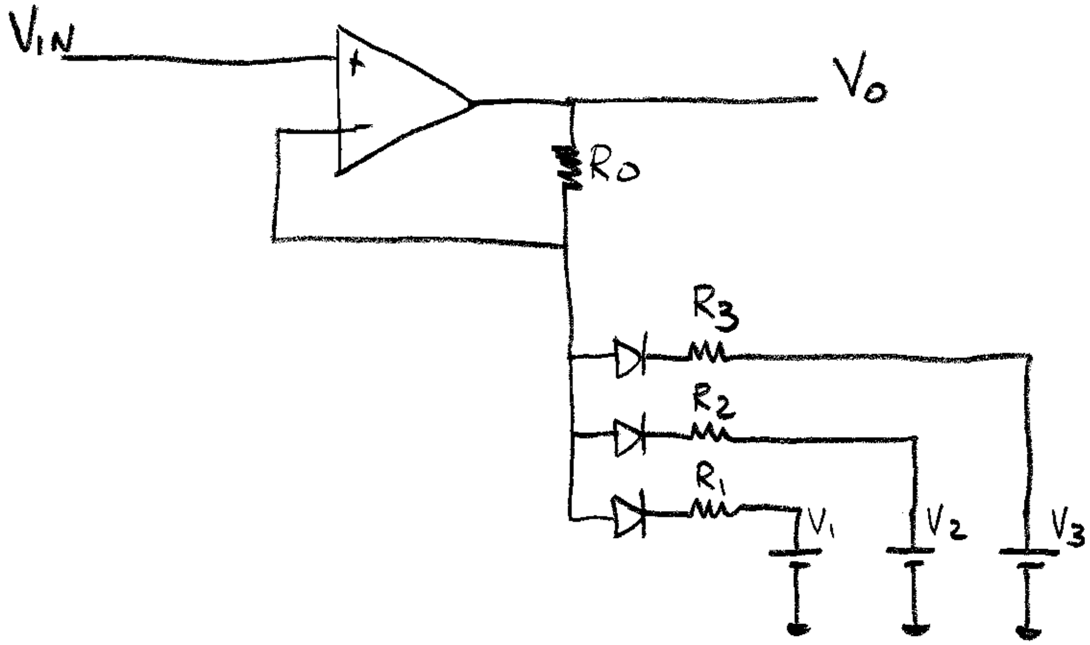

$V_1 < V_2 < V_3$

Analysis (Find V_A, V_B, + V_C)

$$m_0 = 1$$

$$V_A = 0 + (V_1 - 0)m_0 = V_1$$

$$m_1 = 1 + \frac{R_0}{R_1}$$

$$V_B = V_A + (V_2 - V_1)m_1$$

$$m_2 = 1 + R_0/R_1 \| R_2$$

$$V_C = V_B + (V_3 - V_2)m_2$$

$$m_3 = 1 + R_0/R_1 \| R_2 \| R_3$$

Analytic Equations

For any input voltage, V_{IN}, V_o can be found by first determining the voltage range, $V_1 \rightarrow V_2$, $V_2 \longrightarrow V_3$, etc. that brackets the input voltage. Then interpolate between the corresponding V_A, V_B, V_C, etc. For example, if V_{in} is between V_1 and V_2 then $V_o = \left(\frac{V_{in} - V_1}{V_2 - V_1}\right) * (V_B - V_A) + V_A$.

Design:

The pairs of voltages, (V_1, V_A), (V_2, V_B), (V_3, V_C), etc. have been determined by some means for a good fit to a desired function. The problem is to determine the required resistors. The basic procedure is to pick a value for R_o and then use ratios to calculate R_1, R_2, R_3, etc. We reverse the analytic equations.

$$m_1 = \frac{V_B - V_A}{V_2 - V_1} = 1 + \frac{R_o}{R_1}$$ R_1 is only unknown

$$\frac{R_o}{R_1} = m_1 - 1$$

$$\boxed{R_1 = \frac{R_o}{m_1 - 1}}$$

$$m_2 = \frac{V_C - V_B}{V_3 - V_2} = 1 + \frac{R_o}{R_1 \| R_2}$$ R_2 is only unknown

$$\frac{R_o}{R_1 \| R_2} = m_2 - 1$$

$$R_1 \| R_2 = \frac{R_o}{m_2 - 1}$$

$$R_2 = \frac{1}{\frac{1}{R_1 \| R_2} - \frac{1}{R_1}}$$

already known

$$m_3 = \frac{V_D - V_C}{V_4 - V_3} = 1 + \frac{R_o}{R_1 \| R_2 \| R_3}$$

$$\frac{R_o}{R_1 \| R_2 \| R_3} = m_3 - 1$$

$$R_1 \| R_2 \| R_3 = \frac{R_o}{m_3 - 1}$$

$$R_3 = \frac{1}{\frac{1}{R_1 \| R_2 \| R_3} - \frac{1}{R_1 \| R_2}}$$

already known

This same pattern continues for as many segments as exist

Homework for Non-linear Circuits

1. Compression:

Design a three segment non-linear circuit to implement the following table. Use the circuit in the notes on compression. Let $R_3 = 10k$

V_{in}	V_o	
0	0	First segment (0 to 1.0)
1.0	1.0	2nd segment (1.0 to 3.0)
3.0	2.0	3rd segment (3.0 to 10.0)
10.0	5.0	

Find:
V_1, V_2
R_1, R_2

2 Expansion

Design a three segment non-linear circuit to implement the following table. Use the circuit in the notes on expansion. Let $R_3 = 10k$

V_{in}	V_o	
0	0	1st segment (0 to 2.0)
2.0	2.0	2nd segment (2.0 to 3.0)
3.0	4.0	3rd segment (3.0 to 4.0)
4.0	10.0	

Find:
V_1, V_2
R_1, R_2

Hint: Develop a design method for each of these. You will need it on the final!