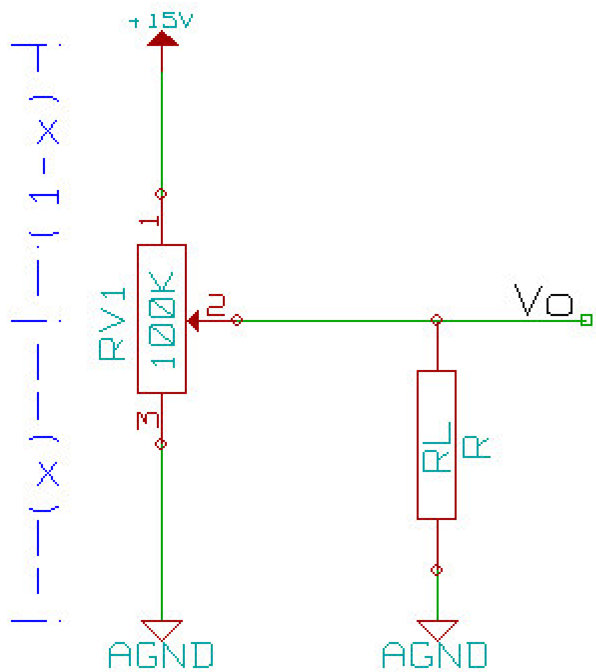
Potentiometer linearity - Ryan Williams

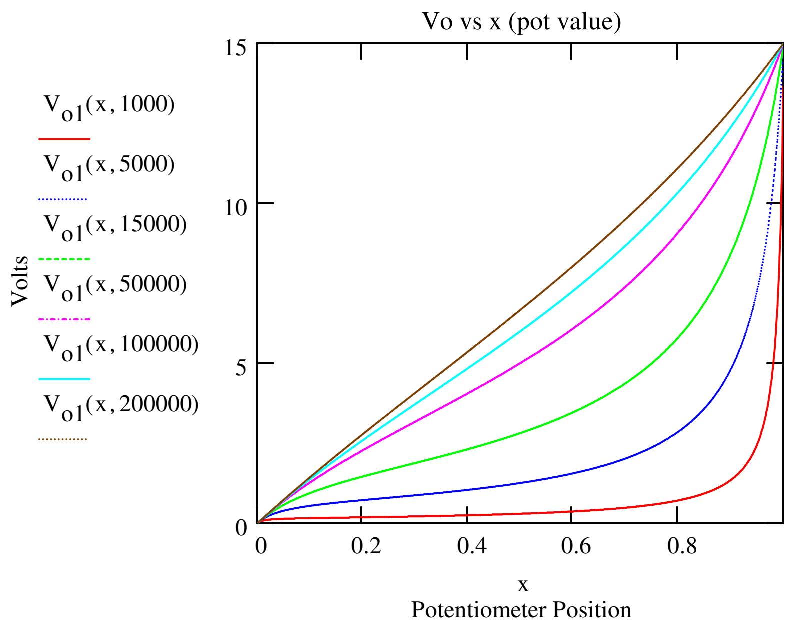


The circuit above shows a pot used to attenuate 15V for a control voltage. The resistor RL represents the load resistance and may also be an input resistor to an inverting opamp circuit. In an inverting opamp circuit the ground would be virtual ground (at the inverting input). The 15V could also be replaced by any voltage input to the circuit. I have given the pot position a value of x. x will be a number between 0 and 1. the resistance between pin 3 and the center tap (pin 2) is x multiplied by the pot resistance (100K). The resistance between pin 1 and the center tap is (1-x) multiplied by the pot resistance. The purpose of this analysis is to see the effect of the load resitor value on the linearity of the output voltage as the pot value x is moved from 0 to 1. The following equations show nodal analysis of the circuit.

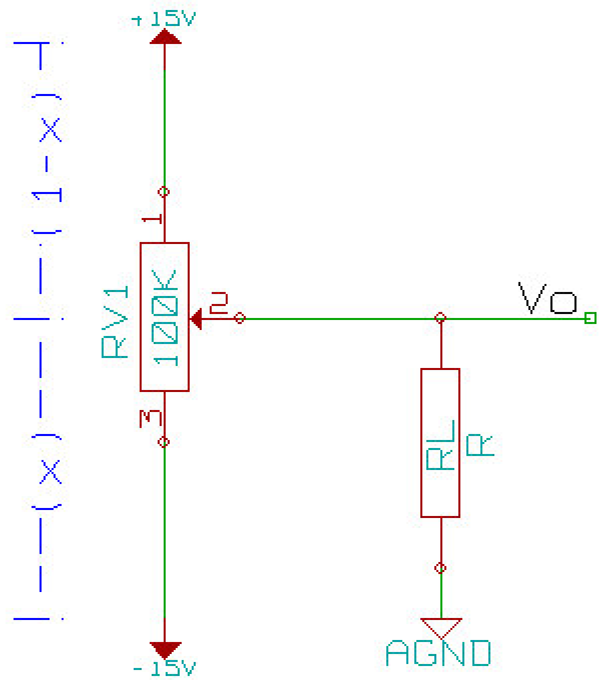
$$0 = \frac{15 - V_o}{(1-x)\cdot 100000} - \frac{V_o - 0}{x\cdot 100000} - \frac{V_o - 0}{R_L}$$

$$V_{o1}(x, R_L) := \frac{\dfrac{15}{(1-x)\cdot 100000}}{\dfrac{1}{(1-x)\cdot 100000} + \dfrac{1}{x\cdot 100000} + \dfrac{1}{R_L}}$$

I am using mathcad here so I can easily plot the equation without simplifing it any further. The plots below show Vo1 vs x for several different load resistors (RL).



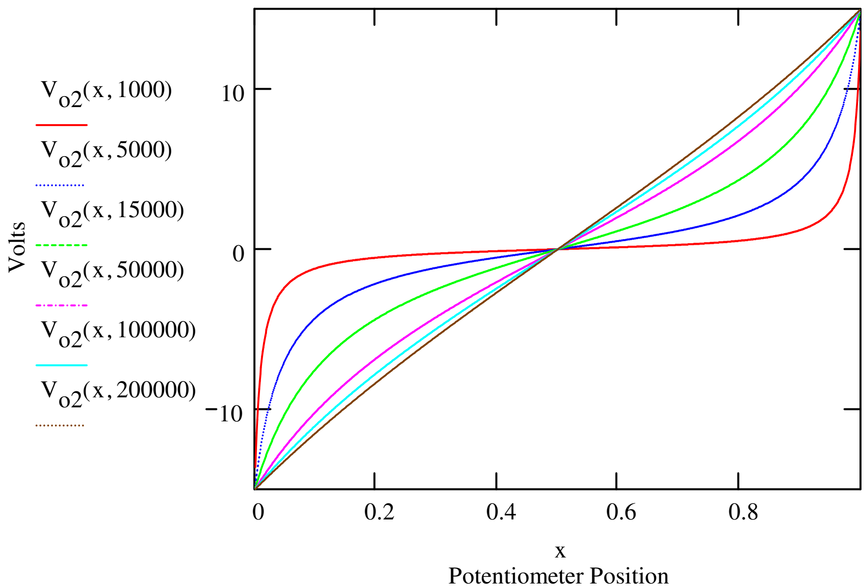
From the above plot we can see that the curve becomes more linear as the load resistance gets large with respect to the pot's resistance. I have stopped plotting at RL of 200K (2*pot_value) because the curve does not change much for larger load resistors. If a small load resistor is used then there will not be much control at the high end of the pot. This might be ok if you want to use a linear pot inplace of a log pot. Next we will look at using a pot to mix between two (non-zero) voltages.



$$0 = \frac{15 - V}{(1 - x)\cdot 100000} + \frac{-15 - V}{x\cdot 100000} - \frac{V}{R_L}$$

$$V_{o2}(x, R_L) := \frac{15\cdot\left[\dfrac{1}{(1 - x)\cdot 100000} - \dfrac{1}{(x)\cdot 100000}\right]}{\dfrac{1}{x\cdot 100000} + \dfrac{1}{(1 - x)\cdot 100000} + \dfrac{1}{R_L}}$$

For a pot used to mix between two voltage sources we have a similar situation but the curve looks different. The following plot shows +15V and -15V mixed using a 100K pot and several load resistor values.



$V_{o2}(x, 1000)$
$V_{o2}(x, 5000)$
$V_{o2}(x, 15000)$
$V_{o2}(x, 50000)$
$V_{o2}(x, 100000)$
$V_{o2}(x, 200000)$
Volts
10
0
−10
0
0.2
0.4
0.6
0.8
x
Potentiometer Position