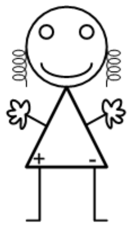
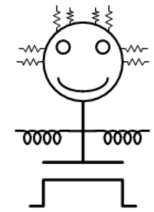


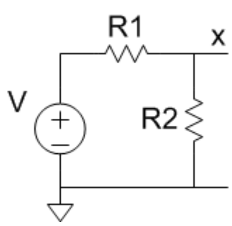
E84: Introduction to Electrical Engineering

Lab 3: Sensors

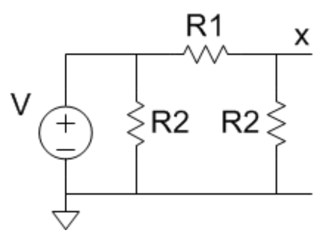


Warm-Up

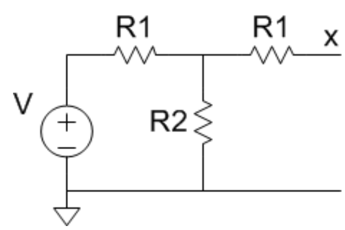
1) Supposed a potentiometer of resistance R is connected between GND and VDD, and the wiper position x is expressed in the range [0, 1], with 0 being at the bottom by the ground node and 1 being at the top near the VDD node. Develop a Thevenin equivalent circuit for the potentiometer as a function of x.
2) Compute the Thevenin and Norton equivalents for the following attentuators. viewed from node x



(a) L-attenuator

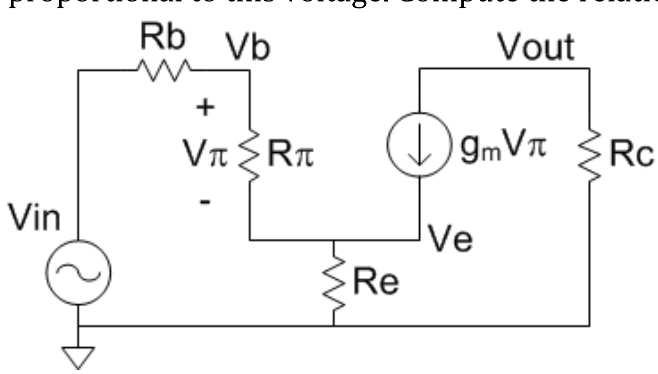


(b) Π-attenuator



(c) T-attentuator

3) The following circuit diagram is a small-signal model of a common emitter bipolar transistor amplifier with emitter degradation (you will derive such a model later this semester). Note that V_π is the voltage drop across resistor R_π, and that the voltage-dependent current source produces a current that is proportional to this voltage. Compute the relationship between Vin and Vout.



Lab

*** load cell on Wheatstone bridge? Later lab adds amplifier?

Solutions

Warm-Up

1) Using the voltage divider equation and parallel and series combinations, these can be solved by inspection:

(a) 1 V (b) 2 V (c) 3 V

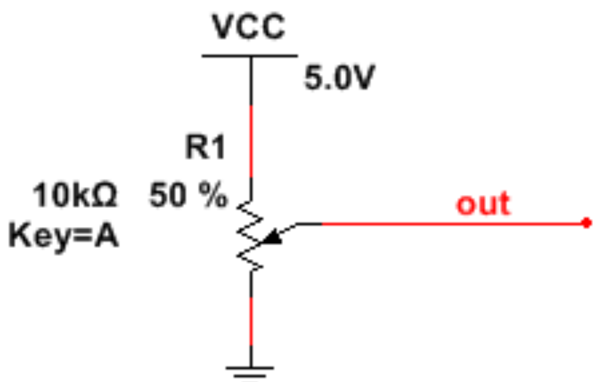
2) This circuit is called an R-2R ladder and functions as a 3-bit digital-to-analog converter. This can be done painfully by KCL or intuitively by recursively applying Thevenin equivalents.

$X = [R_L / (R + R_L)] (D_0 + 2D_1 + 4D_2)/8$

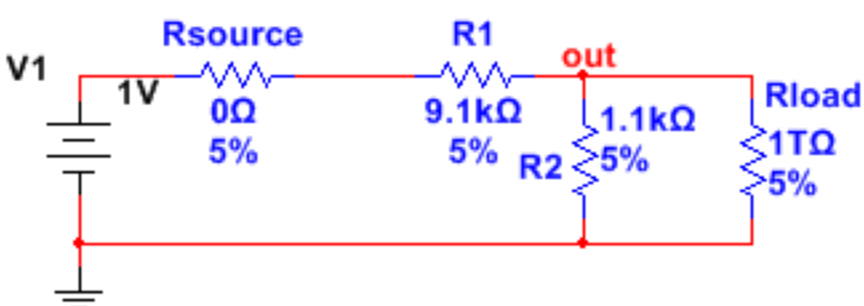
This circuit can be extended to N inputs by adding more stages of the R-2R ladder.

Lab

1) 10k Potentiometer



The output varies from 0 to 5 V as the knob is turned.



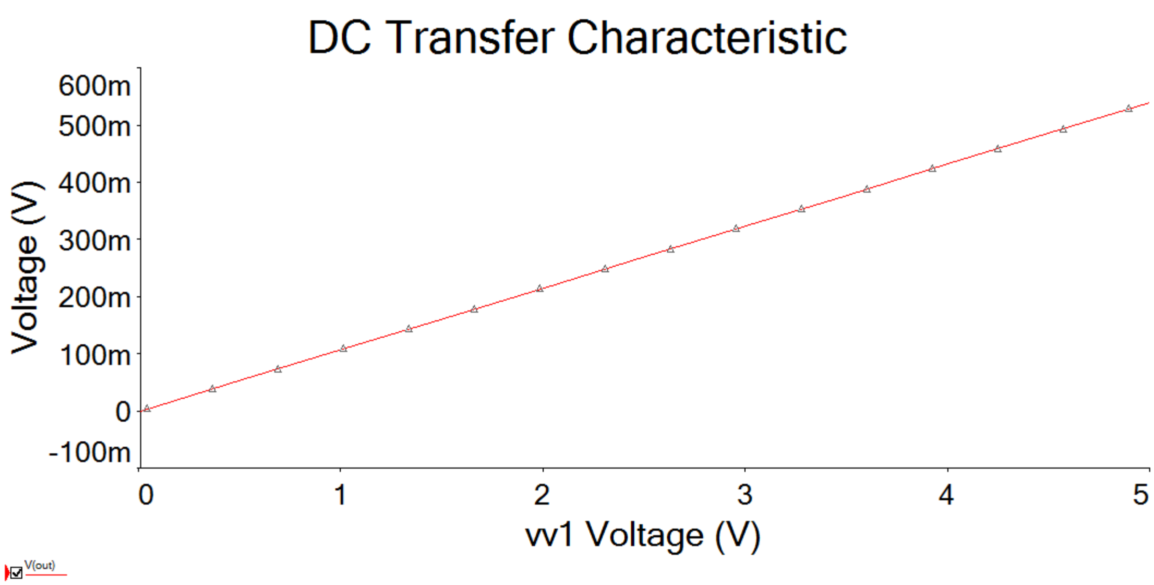
2)

Vout = Vin [(R2 || RL) / (R2 || RL + R1 + Rs)]

Choose R1 = 9.1k, R2 = 1.1k to achieve the following performance

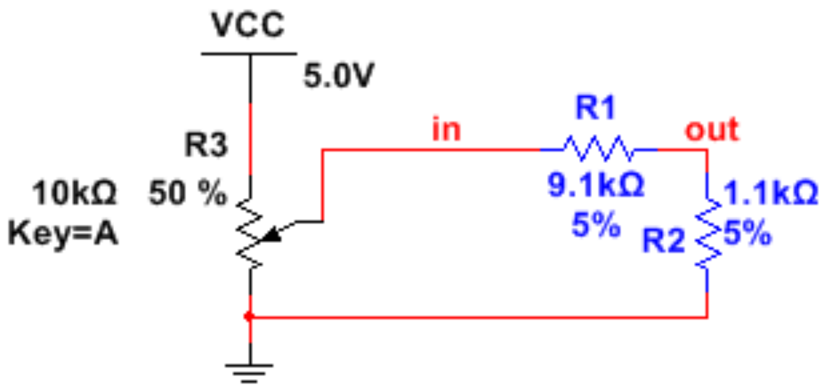
Case	**R1**	**R2**	**RL**	**Rs**	**Gain**
Unloaded	9.1k	1.1k	Infinity	0	0.108
Load impedance	9.1k	1.1k	10k	0	0.098
Source impedance	9.1k	1.1k	Infinity	1k	0.098
Both	9.1k	1.1k	10k	1k	0.089
Unloaded w/ variation	9.1k – 5%	1.1k + 5%	Infinity	0	1.18
Fully loaded w/ variation	9.1k + 5%	1.1k – 5%	10k	1k	0.082

The DC sweep with nominal values and no source or load impedance confirms the unloaded gain of 0.108.



3) The potentiometer has a Thevenin equivalent of 2.5 V in series with 5k.

When the source impedance is 5k and load impedance is infinite, the attenuator has a nominal gain of 0.0867. Hence, the output is 0.216 V rather than the nominal 0.25 V achieved by a perfect divide-by-10 attenuator. In other words, the attenuator loads the potentiometer and reduces the voltage.



Vin = 2.008 V; Vout = 0.216 V

Grading Rubric:

2	Complete, succinct, and coherent typed lab report
	WARM-UP
3	Warm-up Problem 1 (1 each)
4	Warm-up Problem 2 (2 for correct equation, 1 for application, 1 for extension to N bits)
	PART 1
1	Schematic for potentiometer circuit
1	Test results indicating potentiometer circuit operates
	PART 2
1	Multisim schematic for attenuator
2	Analysis of attenuator (including proof that attenuation is within spec across source and load impedance and component variation effects)
2	Simulation of attenuator (including component variation)
2	Test results showing attenuator works across loading
	PART 3
1	Measured attenuator output of about 0.18 V
2	Analysis or simulation agreeing with measurement and explanation of result (including noting that source impedance higher than attenuator was designed to accept so output is < 0.25 V)

Total: 19