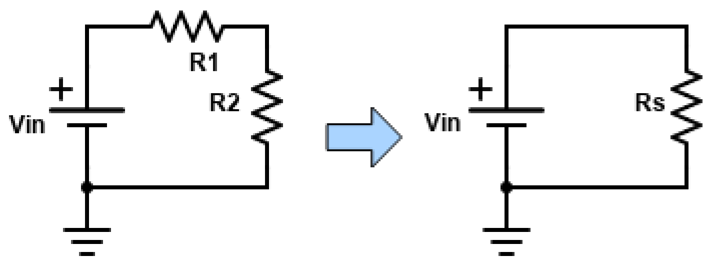
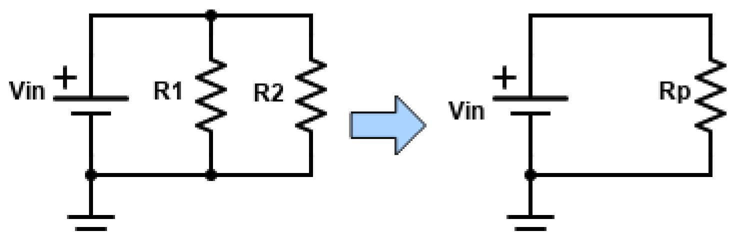
Series-Parallel Equivalent Resistance (circuits fall 2022)

The aim of this classtime workshop is to develop and explore expressions for series and parallel equivalent resistors. They pop up all the time in Circuits. We can often *simplify* circuits using the series or parallel equivalent resistance, leading to a quick and easy analysis.

1. **Series equivalent resistance**: How much total current flows in the series circuit? What is the total voltage drop across R1 and R2 in series. Therefore, write Rs, in terms of R1 and R2 such that the same amount of current flows in both circuits.



2. **Parallel equivalent resistance:** How much total current flows in the parallel circuit? (How much current does the battery have to supply?) How much current flows in R1 and R2, respectively? Therefore, write Rp, in terms of R1 and R2 such that the same amount of current flows in both circuits.



3. Assume Vin = 5V; R1 =1kΩ, R2 = 4kΩ. How much total current flows in the series and parallel circuits, respectively? What is the ratio of currents I_{R1}/I_{R2} for the series and parallel circuits above?. Given your results, does it hold true that *current flows through the path of least resistance*? Briefly justify.

4. How would the formulae for Rs and Rp generalize if we had *N* resistors in series or parallel, respectively?

5. Compute the equivalent resistance of the following resistor networks:

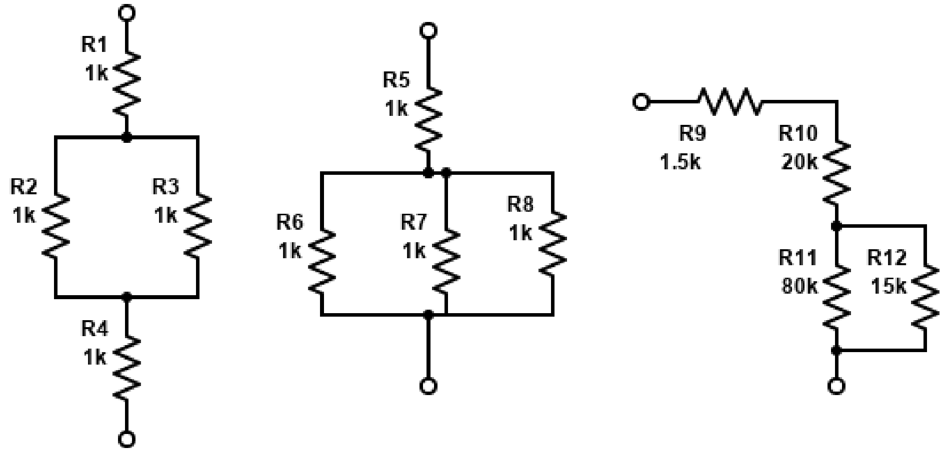


Figure 1. Three resistor networks for your consideration

6. Compute the output voltage Vout for the following circuits. (Recall voltage dividers and your results above!)

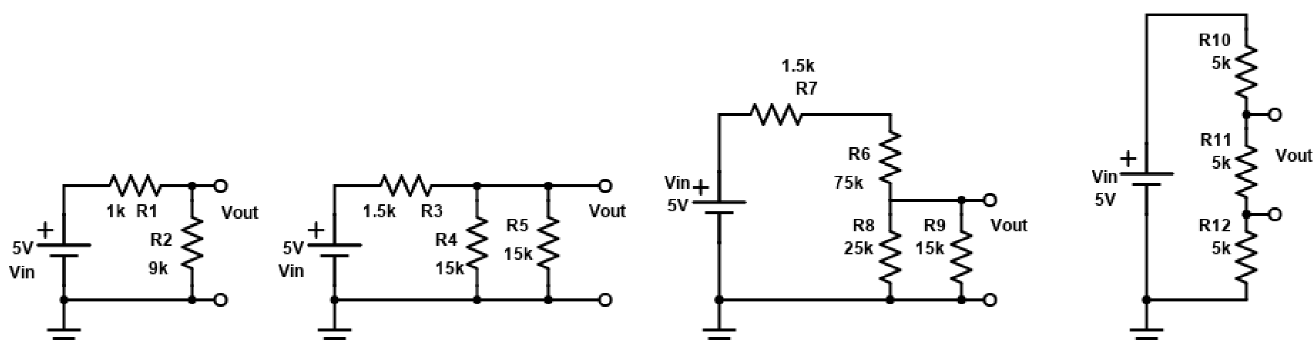


Figure 2. Four circuits for your consideration. Compute Vout in each case.

Audio Volume Knob Circuit

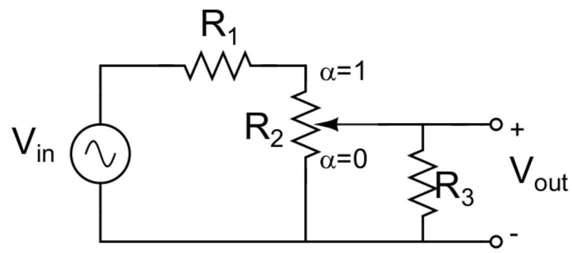


Figure 3. Audio volume knob control circuit. R1 = 1.5k, R3 = 15k, R2 = 100k pot.

1. Label the 3 contacts of the potentiometer R2 on the circuit diagram above (Figure 3).
2. Consider α as the parameter that describes the rotation of the knob. The position α = 0 means the wiper terminal is positioned at the very bottom limit; α = 1 means it is all the way at the top.
    a. What is the resistance of the 'top' and 'bottom' portions of the potentiometer for α = 0, 0.25, 0.5, 0.75, 1. It may be helpful to consider the following figure, which shows a potentiometer as two resistors R_{AW} ('top') part and R_{WB} ('bottom') part.

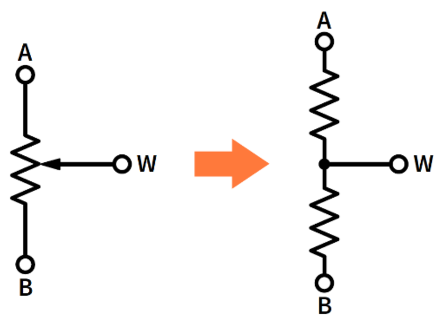


Figure 4. Potentiometer can be thought of as a 'top' and 'bottom' series resistors. Image credit: https://www.circuitbread.com/tutorials/basics-of-potentiometers

    b. Now, write an algebraic expression for the resistance of the 'bottom' part of the potentiometer R_{WB} (top node to wiper terminal) in terms of α and R2. Do the same for the 'top' part R_{AW}.

3. Transform the audio circuit into a voltage divider as indicated in Figure 5. What resistors are in series? In parallel? Write expressions for Rs and Rp in terms of R1, R2, R3, and α. (Hint: Again, it may be helpful to diagram the pot as 2 series resistors per Figure 2.)

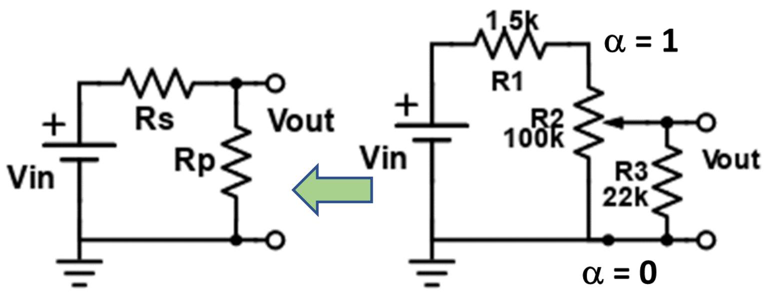


Figure 5. The audio circuit (right) can be analyzed as a voltage divider using series and parallel equivalent resistance. How very nice.

4. Complete items 1-3 in the [lab manual](#) (bottom of page 2).

5. Diagram how you will layout your circuit using the breadboard below. The figure on the right shows on very beautiful graphic illustrating the connection between the circuit schematic and the actual physical layout (aspirational!).

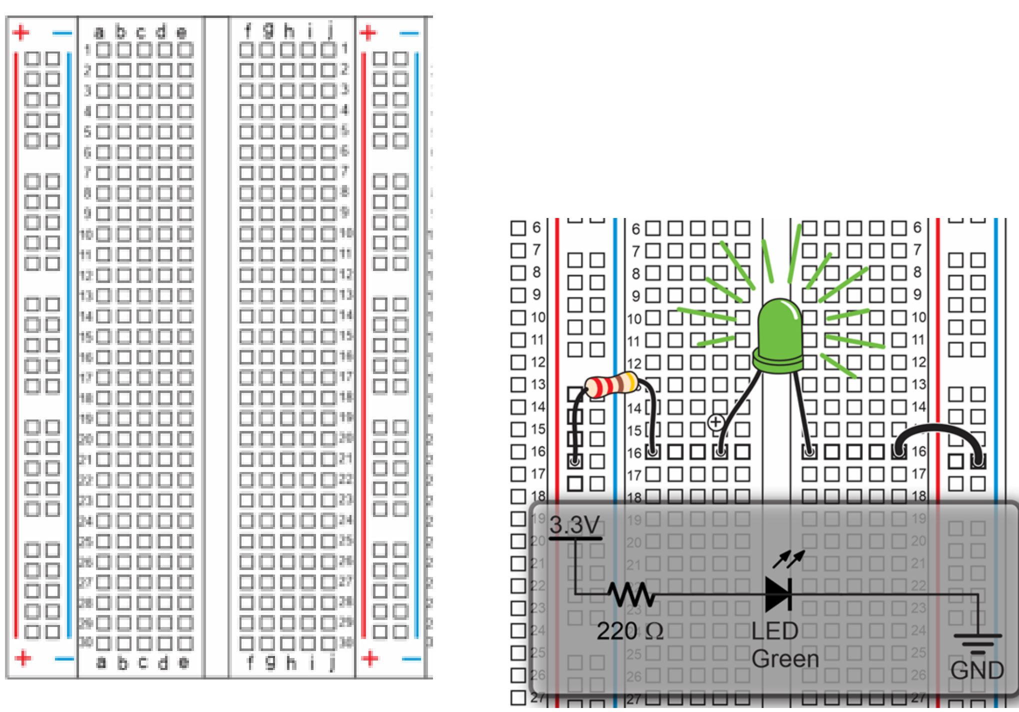


Figure 6. Left panel: diagram your circuit build. Right panel: gorgeous illustration connecting circuit schematic to actual build on the board. Image credit: https://learn.parallax.com/tutorials/language/python/breadboard-setup-and-testing-microbit/first-breadboard-circuit