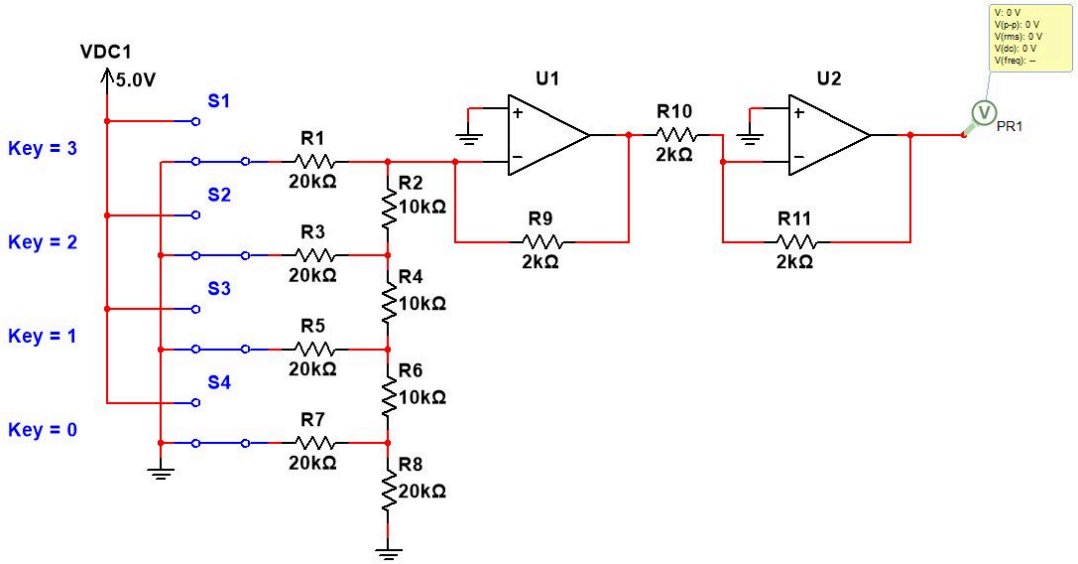
In the previous century, someone came up with a circuit that uses just two resistor values: a resistor, R, and twice that resistance, 2R. Here's a 4-bit DAC using what is called the R-2R Ladder at its input.



Using Multisim, build this circuit. Be really careful about the resistor values -- notice that R8 is 20 kΩ, and that R9 - R11 are all 2 kΩ.

Run your circuit, and fill in the following table of selected values. Make sure you record your answers in millivolts.

Binary Input	Output Voltage, mV
0000	0
0001	62.5
0100	250
1000	500
1111	937

You should have seen that the values range from 0 to 937.5 mV. Using the "range" related formula, determine the step size

62.5 mV/step

The problem is predicting this step size without actually building the circuit and testing it. For this, we'll try another approach. Notice that, for any of the samples you took, you can get the step size by dividing the output by the binary input. That's because, for example, there are four steps between 0 and step 4. To prove this, divide your output for step 4 by 4 to get the step size:

62.5 mV/step

So, what we need to do is find an easily-analyzed input value, determine its output, and divide by that number of steps. Look back at the circuit: The easiest input combination to analyze is 1000, or eight. Here's why.

Notice that there's a virtual ground at the inverting input, because the non-inverting input is grounded.

If all the lower bits are grounded, no current will come to the summing point, because they will all be at zero potential.

Therefore, if the most significant bit is HIGH, it will be the only input contributing anything to the output signal.

So, let's use circuit analysis to predict the theoretical step size for this R-2R ladder DAC.

What is the gain of the first amplifier for just the MSB? -0.1

What is the gain of the second amplifier? -1

So, for the MSB, what is the overall gain? 0.1

Multiply the HIGH input voltage for the MSB by this gain to determine the expected output for 1000. 500 mV

Now, divide by the number of steps between 0000 and 1000 to get the step size. 62.5 mV/step

That's it! Extending what we just did, we should be able to predict the output voltage for any input by multiplying the step size by the binary input value. Fill in the following table of selected values.

Binary Input	Predicted Output, mV
0011	187.5
0101	312.5
0111	437.5
1010	625
1101	812.5