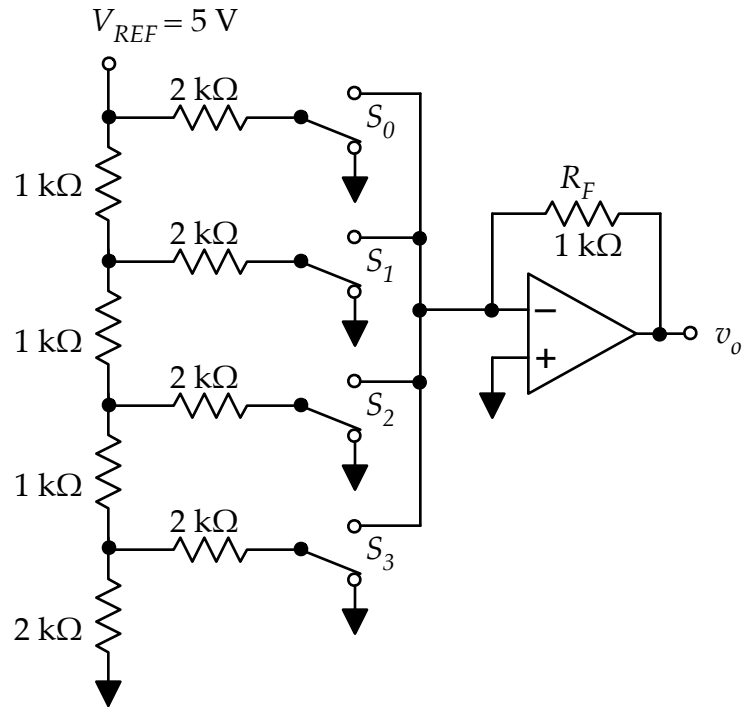


The circuit at right is a 4-bit digital-to-analog converter circuit that uses a configuration known as an  $R$ - $2R$  ladder. The switches are controlled by the bits of a digital input. For example, when bit 0 is low (logical 0), switch  $S_0$  connects to ground and when bit 0 is high (logical 1), the switch connects to the inverting input of the op amp.

You can assume that the op amp is ideal.



Calculate the output voltage for each of the 16 possible switch configurations.

(Yikes! Actually, you probably don't need to do 16 separate circuit calculations. Do a few different combinations and you will likely see a pattern develop. Also, note that when the switch is in the low state, it is *not just dangling* – it connects the corresponding  $2\text{-k}\Omega$  resistor to ground, meaning that the resistor will be in parallel with a lot of other stuff. But the resistor combinations reduce down in a rather clever way.)