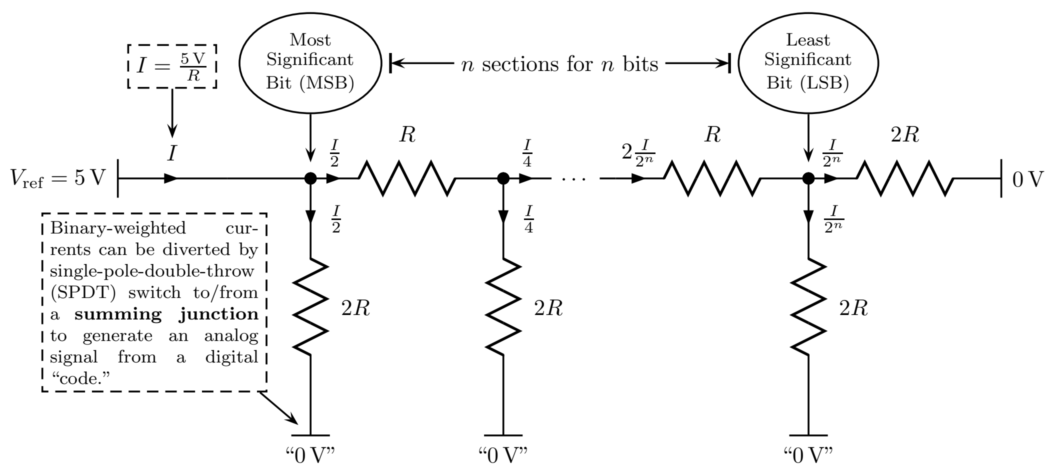
ECE 209: *Circuits and Electronics Laboratory*

Notes for Lab 7 (Digital-to-Analog (D/A) Application)

1. Digital-to-analog converter (DAC) — "1 least significant bit (LSB)" $\triangleq$ *Smallest output **step** possible*

   - Now, signals are generated by a computer as *codes* separated by intervals of time.
   - To use those signals in the physical world, need to convert those abstract codes to voltages.
   - When codes are in binary, each bit can *electronically* control a switch (e.g., a *transistor*); those switches turn on and off currents into **summing junction** formed by operational amplifier.
     - Amplifier **gain** changes output *scale* — "clicking" heard in function generators (50 Ω output?).
     - Modern DAC's use more complicated schemes. "1-bit DAC" technologies *pulse* modulate.
       - *Switches* (as opposed to analog amp.) burn negligible power (wall switches vs. dimmers).
       - Increase "number of bits" by increasing samples per second (no extra hardware).
       - So adjusting intensity in **time** can be very efficient and very cheap to implement.
       - Example: Digital lights only need to *quickly* turn red/green/blue on/off independently.
   - The standard summing amplifier uses weighted resistances to generate different currents.
     - In the configuration shown in the book, every new code causes current from V_{ref} to change.
       - Rapidly changing current can cause noise to spread to far regions of a circuit.
       - To fix, change pre-resistor SPST to post-resistor SPDT between ground & virtual ground.
     - More importantly, *integrated circuit* resistance *matching* is easy, but *ratio matching* is difficult.
       - Greatly affects *linearity* of the DAC (see INL/DNL nonlinearity specifications).
   - Clever R-$2R$ ladder solves both problems
     - Equivalent resistance into each ladder "wrung" is R (i.e., (new wrung)‖ladder $= 2R \| (R+R)$).
     - Regardless of number of bits and switch state, current into ladder is a fairly steady V_{ref}/R.
     - Each new section halves previous current. Last wrung of n-bit DAC carries $V_{\text{ref}}/R \times 2^{-n}$.



2. Introduce and complete the *Digital-to-Analog (D/A) Application* lab.

   - Resistor color codes: Black, Brown, ROYGBV, Gray, White correspond to **digits** 0–9
     - $\overset{1}{\text{Brn}}$-$\overset{0}{\text{Blk}}$-$\overset{2}{\text{Red}}$: 1 kΩ, $\overset{1}{\text{Brn}}$-$\overset{2}{\text{Red}}$-$\overset{2}{\text{Red}}$: 1.2 kΩ, $\overset{2}{\text{Red}}$-$\overset{2}{\text{Red}}$-$\overset{2}{\text{Red}}$: 2.2 kΩ, $\overset{1}{\text{Brn}}$-$\overset{0}{\text{Blk}}$-$\overset{3}{\text{Orange}}$: 10 kΩ
     - Also try parallel or series combinations (note: only R_F/R_0 and R_F/R **ratios** matter)
       - A resistance R is equal to $2R$ in parallel with $2R$ (e.g., 5 kΩ = 10 kΩ‖10 kΩ).
   - Mimic switches by **manually** connecting and disconnecting wires (don't open-circuit R-$2R$!).
   - For V_{ref}, use **sine wave** @ 5 V_{RMS} & 1 kHz; set DVM for $\text{V}_{\text{RMS,AC}}$ (expect **positive** values).