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.
   - \(\star\) 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).
     - \(\star\) 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 \(V_{\text{ref}}\) 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.
       - \(\star\) Greatly affects linearity of the DAC (see INL/DNL nonlinearity specifications).
   - Clever \(R-2R\) ladder solves both problems
     - Equivalent resistance into each ladder “wring” is \(R\) (i.e., (new wrung)\(\|\)ladder = \(2R\|\left((R+R)\right)\)).
     - Regardless of number of bits and switch state, current into ladder is a fairly steady \(V_{\text{ref}}/R\).
     - Each new section halves previous current. Last wrung of \(n\)-bit DAC carries \(V_{\text{ref}}/R \times 2^{-n}\).

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V_{\text{ref}} = 5 \text{ V}
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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
     - Brn-Blk-Red: 1 kΩ, Brn-Red-Red: 1.2 kΩ, Red-Red-Red: 2.2 kΩ, Brn-Blk-Orange: 10 kΩ
     - Also try parallel or series combinations (note: only \(R_F/R_0\) and \(R_F/R\) ratios matter)
       - \(\star\) 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 \(V_{\text{ref}}\) use sine wave \(\odot\) 5 V\(_{\text{RMS}}\) & 1 kHz; set DVM for \(V_{\text{RMS,AC}}\) (expect positive values).