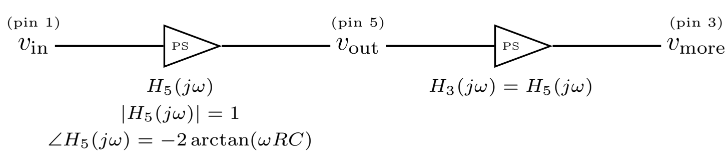
ECE 209: *Circuits and Electronics Laboratory*

Notes for Lab 1 (Introduction to Instrumentation)

1. General lab report guidelines:
    - The scientific method should be in the back of your mind always.
        - Experiments are used to **test our theories** (i.e., *hypotheses*) and inform us about future experiments (e.g., to explain differences from theoretical expectations).
        - Scientists study the natural world. Engineers study technology.
    - Your report should stand *on its own* in **paragraph form** (i.e., *NOT* a *list* of answers!).
        - Do **NOT** refer to anything related to the **classroom** (e.g., "students," "instructor," etc.).
        - Write as if you were submitting to a supervisor or journal.
        - *Publication* is the final step in the *cycle* of the scientific method.
    - When possible, *figures* and *tables* should be **in line** with the rest of your *typed* text.
        - *Number* tables and figures and refer to them *by number* (e.g., "Figure 2"; not "below").
            * Each figure should have a *descriptive caption.* Do **NOT** let captions float onto the next page (i.e., tie them to the figures rather than just typing them beneath).
            * All modern word processing packages can automatically number figures and tables. They can update references to them automatically too.
        - Hand-drawn figures (on *engineering graph paper*) can be submitted.
            * They can be photocopied or pasted into the report or attached at the end.
            * Like all figures, they should be numbered.
            * **Alternatively,** you can use a **digital photograph** (e.g., from your *camera phone*).
    - Include a cover page and number pages.
2. RMS ("root-mean-square"):
    - RMS: The *DC amplitude* that has the *same* ***average*** *power dissipation* on a linear resistor.
    - Mechanical engineers use g_{RMS} to describe power transmitted by *oscillations* (e.g., shaker table).
3. The need for a $\times 10$ probe:
    - Together, oscilloscope channel's parallel resistance and capacitance look like $1\,\text{M}\Omega$ to DC and $\sim 0\,\Omega$ to AC, and a standard "$\times 1$ probe" looks like $\sim 0\,\Omega$.
        - Large circuit impedances (e.g., capacitors or large resistors) can be *loaded* by the scope — picture a *tiny* capacitor discharging into the scope.
        - High-bandwidth signals (e.g., sharp edges) will be distorted by probe-scope "filter."
    - Together, the $\times 10$ probe's parallel resistance and capacitance looks like $9\times$ the oscilloscope impedance at *all* frequencies.
        - The resulting probe-scope divider has 0.1 gain *everywhere,* and so the **scope** multiplies $\times 10$.
        - The circuit is loaded *less* than before (for less loading, use an *active probe*).
4. Oscilloscope settings: AC & DC coupling, vernier (pronounced "VUR-nee-er") scales, base, and top.
    - DC coupling *short circuits* probe and channel.
    - AC coupling puts a high-pass filter with a very low corner between probe and channel.
    - Vernier option causes knob to move through finer steps.
    - V_{base} and V_{top} are filtered versions of V_{min} and V_{max}. They show the most "prevalent" "steady-state" values rather than just an incidental extremes (e.g., they ignore overshoot transients).

5. Lissajous (pronounced "LEE-suh-zhoo") figures:
   - Picture a harmonograph — a pendulum swings a pen on top of a moving canvas.
   - Originally used to find the frequency of a signal given another signal of known frequency.
   - In our laboratory, we can use them to measure phase shift.
   - Lissajous figures are *now* used for entertainment (e.g., laser light shows) more than measurement.
6. HIGH Z mode:
   - ECE 311/312: Matched termination prevents *reflections* that can distort high-frequency signals.
   - Function generators have a standard $50\,\Omega$ output impedance for use in high-frequency applications.
     - The function generators expect that the signal destination looks like $50\,\Omega$ to ground.
     - The resulting $50\,\Omega$-$50\,\Omega$ divider cuts signals in half.
     - So the function generator has to *double* signals internally. A desired $2\,\mathrm{V}$ signal generates $4\,\mathrm{V}$ at the output of the function generator.
   - The input imepdance of our circuits is *MUCH* higher than $50\,\Omega$.
     - So we need the function generator to *NOT* amplify the desired signal.
     - The function generator's HIGH Z setting restores the the "expected" behavior.
7. The *Introduction to Instrumentation* lab:
   - Probes and cables are in far cabinet.
     - Oscilloscope $\times 10$ probes have **color bands** — take **two** *different* colors back to your table.
       - **NEVER** connect the BNC end of a $\times 10$ ***oscilloscope*** probe to the *function generator!*
       - Also can use [Ref] button on *end of probe* to locate probe on screen.
       - Removable "hats" help to probe tiny points.
       - Remember to set *oscilloscope channel* for the $\times 10$ probe as appropriate.
     - The "$\times 1$ probes" are the BNC cables that are typically only used with the *function generator*.
   - Using AUTOSCALE frequently is a **very bad habit** — you should learn to adjust the horizontal (i.e., seconds/division) and the vertical (i.e., Volts/div) scales manually. The Vernier settings give you fine-grained control over the scales.
   - Remember to set HIGH Z mode on *function generator*.
   - **Phase-shifter circuits** are in cardboard box in the cabinet nearest to the door.
     - Use Lissajous figure handout to help decipher figures — make sure your angles are in the correct quadrant (hint: *probably* quadrant III — between 90° and 180° of phase *delay*).
     - Use phase-shifter circuit handout to compare measured and expected results — handout has formula for the expected phase shift for a given frequency.



So from **pin 1** to **pin 1**,

$$\left|\frac{V_{\text{in}}(j\omega)}{V_{\text{in}}(j\omega)}\right| = 1 \qquad \text{and} \qquad \angle\frac{V_{\text{in}}(j\omega)}{V_{\text{in}}(j\omega)} = 0^\circ,$$

and from **pin 1** to **pin 5**,

$$\left|\frac{V_{\text{out}}(j\omega)}{V_{\text{in}}(j\omega)}\right| = |H_5(j\omega)| = 1 \qquad \text{and} \qquad \angle\frac{V_{\text{out}}(j\omega)}{V_{\text{in}}(j\omega)} = \angle H_5(j\omega) = -2\arctan(\omega RC),$$

and from **pin 1** to **pin 3**,

$$\left|\frac{V_{\text{more}}(j\omega)}{V_{\text{in}}(j\omega)}\right| = |H_5(j\omega)H_3(j\omega)| = 1 \quad \text{and} \quad \angle\frac{V_{\text{more}}(j\omega)}{V_{\text{in}}(j\omega)} = \angle H_5(j\omega) + \angle H_3(j\omega) = -4\arctan(\omega RC)$$

where $R = 2\,\mathrm{k}\Omega$ and $C = 47\,\mathrm{nF}$. Because $1/(2\pi RC) \approx 1.7\,\mathrm{kHz}$, when $1.7\,\mathrm{kHz}$ is put on pin 1, we expect a -90° phase shift at pin 5 and a -180° phase shift (i.e., an inversion) at pin 3.

     - In report, make it clear that you understand the phase-shift-and-figure-shape relationship.