

# ECE 209: *Circuits and Electronics Laboratory*

## Notes for Lab 1 (Introduction to Instrumentation)

### 1. General lab report guidelines.

- Web site's section on [lab report writing resources](#) discusses good report structure and tone.
  - 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. See [web site](#) for details.
    - \* 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 (web site's [course policies](#) has details) and number pages.

### 2. Briefly discuss RMS (“root-mean-square”).

- RMS: The *DC amplitude* that has the *same average power dissipation* on a linear resistor.
- Mechanical engineers use  $g_{\text{RMS}}$  to describe power transmitted by *oscillations* (e.g., shaker table).

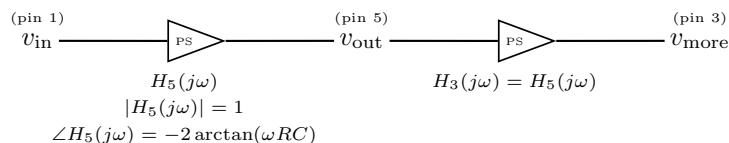
### 3. Discuss the need for a $\times 10$ probe.

- 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.
- $V_{\text{base}}$  and  $V_{\text{top}}$  are filtered versions of  $V_{\text{min}}$  and  $V_{\text{max}}$ . They show the most “prevalent” “steady-state” values rather than just an incidental extremes (e.g., they ignore overshoot transients).

5. Discuss 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. Discuss 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 V signal generates 4 V at the output of the function generator.
  - The input impedance 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. Introduce and complete 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  $90^\circ$  and  $180^\circ$  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**,

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

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

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

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

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

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

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