ECE 209: *Circuits and Electronics Laboratory*

Course Packet Errata

As of the Autumn 2008 edition of the ECE 209 course packet, the following errors should be corrected.

Resistor Color Codes

- In the ***Basic circuit elements*** section under the image of a resistor, the colors should be ordered by number (i.e., from 0–9). Then it would be clear that 2–7 are the **ROYGBV** colors of a rainbow.

Experiment 1: Introduction to Oscilloscope & Function Generator

- Under **1. Oscilloscope** in the **introductory material,**
  - In ***8) Measure the phase difference***, the expression for θ uses the **principal arcsine**, and so it is only valid for **quadrant I** phase angles between 0° and 90°. Often, θ will need to be manipulated to place the phase in the proper quadrant.

Quadrant	Positive Phase Difference	Negative Phase Difference
I	θ	$-360° + \theta$
II	$180° - \theta$	$-180° - \theta$
III	$180° + \theta$	$-180° + \theta$
IV	$360° - \theta$	$-\theta$

Because the filters in this class are **causal**, phase differences will usually be *negative* indicating that signals have been "delayed."

- Under **part 6** of the **exercises,**
  - Because these frequencies are all greater than 1.7 kHz, this circuit provides a phase shift from **quadrant III,** and so the expression for θ should be

$$\theta = \arcsin\left(\frac{\text{distance between two vertical intersections}}{\text{maximum vertical extension of ellipse}}\right) - 180°.$$

Experiment 4: Frequency Response of First Order Active Circuits

- In **1. Frequency Response of First Order Active Low Pass Filter** in the **intro. material,**
  - The Phase Response in Figure 2 has a deceiving vertical scale.
    - The highest value on the scale *should* be −180°.
    - The lowest value on the scale *should* be −270°.

  Technically, there is nothing wrong with the present scale. However, it may be confusing to associate *positive* phase shift with a *low-pass filter* that is described as adding *lag*. The source of the confusion is the extra 180° shift that accompanies the inverting configuration.

- In **2. Frequency Response of First Order Active High Pass Filter** in the **intro. material,**
  - Change R to R_1 in ϕ expression so that $\phi(\omega) = -90° - \arctan(R_1 C\omega)$.

- Under **part 2** of the **exercises**,
  - The **Calculated phase shift** in the last column of the data table should read

$$-180° + \arcsin\left(\frac{\text{intersection}}{V_{\text{opp}}}\right).$$

  Otherwise, phase shift will be −180° for low frequencies and −90° for high frequencies, which is incorrect for a high-pass filter. Figure 4 in the introductory material shows the correct curve.

Experiment 5: Step Response of Second Order Circuits

- Under **2. Frequency Response of Second Order Low Pass Filter** in the **intro. material,**
  - The expression for phase should be

$$\phi(\omega) = -\operatorname{arctan2}\left(2\xi\omega_0\omega,\, \omega_0^2 - \omega^2\right) \triangleq \begin{cases} -\arctan\left(\frac{2\xi\omega_0\omega}{\omega_0^2-\omega^2}\right) & \text{if } \omega < \omega_0, \\ -90^\circ & \text{if } \omega = \omega_0, \\ -180^\circ - \arctan\left(\frac{2\xi\omega_0\omega}{\omega_0^2-\omega^2}\right) & \text{if } \omega > \omega_0. \end{cases}$$

    That is, ϕ cannot be calculated without specifying the quadrant of the $H(j\omega)$ phasor. As ω increases, ϕ should swing smoothly from 0° to -180°, as shown in the phase response in Figure 2.
  - In the phase response in Figure 2, it should be noted that the steepness of the transition region depends on the damping ratio ξ. That is, as the damping ratio decreases, not only does the magnitude response get a higher peak, but the phase response gets **steeper.** In fact, for $\xi = 0$, the phase response is a negative step that switches from 0° to -180° at $\omega = \omega_0$.

Experiment 6: Non-Linear Circuit — Diode and Transistor Switch

- Under **2. Transistor Switch** in the **intro. material,**
  - The explanation refers to current I_b and nodes c and e, but it does not define these entities.
    * Current I_b flows through resistor R_1 into the **base** of the transistor.
    * Node c (i.e., transistor **collector**) is the positive (i.e., "+") side of output $V_{\text{out}}(t)$.
    * Node e (i.e., transistor **emitter**) is the negative (i.e., "−") side of output $V_{\text{out}}(t)$.
  - In the explanation, "$V0$" should be named V_{out} to match Figure 3.

Experiment 7: D/A Application

- Under **1. DAC using Summing Amplifier** in the **intro. material,**
  - The expression for *output voltage* is *wrong.* The R_0 and R_f variables should be swapped:

$$V_{\text{out}} = -I \cdot R_f = -\frac{R_f}{R_0} V_{\text{ref}} \left(8D_3 + 4D_2 + 2D_1 + D_0\right)$$

- In **both** of the **exercises**,
  - The V_{ref} signal would normally be a constant $5\,\mathrm{V_{DC}}$.
  - However, it is not trivial to generate a **third** DC voltage in *this* laboratory.
    * The DC supply provides the $15\,\mathrm{V_{DC}}$ and $-15\,\mathrm{V_{DC}}$ supply rails for the operational amplifier, and so the $5\,\mathrm{V_{DC}}$ reference would have to be derived from the $15\,\mathrm{V_{DC}}$ rail (e.g., using a voltage divider followed by a unity-gain buffer circuit).
  - For simplicity, let V_{ref} be a **sine wave** with $5\,\mathrm{V_{RMS}}$ amplitude and 1 kHz frequency.
    * Set digital voltmeter (DVM) to measure **AC RMS voltage *INSTEAD* of DC voltage.**
    * Note that **all measured voltages will be positive** even though we expect them to be negative. This effect is an artifact of using RMS rather than DC.
    * Function generator has $50\,\Omega$ output impedance (i.e., Thévenin equivalent resistance is $50\,\Omega$).
      · So for the current-summing DAC, you should measure **both** V_{out} and V_{ref} for each input.
      · As the current-summing DAC requires more current, V_{ref} will fall because of the voltage dropped across the $50\,\Omega$ output impedance.
      · In the R-$2R$ ladder, the current draw is the **same for every input,** and so the V_{ref} should also be steady (but not necessarily $5\,\mathrm{V_{RMS}}$) across all inputs.