Name:_____

One-Channel "Equalizer"

Component values:
$R_1 = 100 \text{ k}\Omega$ $P_1 = 100 \text{ k}\Omega$
$R_2 = 10 \text{ k}\Omega$ $C_1 = 5 \text{ nF}$
$R_3 = 10 \text{ k}\Omega$ $C_2 = 100 \text{ nF}$
$R_8 = 100 \text{ k}\Omega$
$V_{max} = +15 \text{ V}$ $V_{min} = -15 \text{ V}$

1. This is a "virtual lab": you will be using "CircuitMod" to perform all the "building" and measuring. Record your data, etc. in Excel. Submit only your Excel document (no paper, no CircuitMod file). You will be graded on the organization, clarity, and professionalism of your Excel document. Do columns have labels and units? Are calculations done in a reasonable place, or way off to the side? Do your choices of colors make things better or worse? Is it compact or spread out everywhere?

   In CircuitMod, use an AC source for V_{in}. Right-click it and choose "edit" to vary the properties (amplitude and frequency). V_{max} and V_{min} are used only when you right-click on the op-amps. To make measurements of the output, right-click on the wire connecting R_8 to V_{out}, and choose "View in Scope". Then right click on the scope trace itself (along the bottom), and choose only "Show voltage". Set your "simulation speed" slider to the max, so that as you make changes, the results are updated in the scope as soon as possible.

2. You'll see a slider on the right that is linked to the potentiometer! Adjust it to full "boost" (maximum V_{out}: read the scale on the bottom left). With V_{in} having an amplitude of one volt, adjust the frequency of the AC source until the amplitude of the output as shown in the scope is *maximum*. Record this center frequency f_0 and the associated amplitude V_{boost} in Table 1. Note that this in Hz, not rad/s. Repeat this measurement for $|V_{in}| = 2 \text{ V}$ and 3 V.

   Look out for a trap! There's something wrong with the given component values that prevents you from repeating this measurement for 3V! In CircuitMod, change the necessary value(s) (given in the box above) before recording any values for $|V_{in}| = 3 \text{ V}$.

3. Use your first f_0 (i.e., when $V_{in} = 1\text{V}$) to compute the column of frequencies shown in table 2, then measure the output amplitude at each f when the potentiometer is at full "boost". You don't need to repeat this for other input V_{in} amplitudes. If $r = V_{out}/V_{in}$…

4. Compute a new column for the normalized response in "boost" mode: $h(\omega) = \left(\dfrac{r(f) - 1}{r(f_0) - 1} \right)$.

Then $h_{LO} = h_{HI} = \dfrac{1}{\sqrt{2}}$. Use this formula to compute the amplitude $V_{LO} = V_{HI}$ at the edges of the bandwidth. Then adjust f for your circuit until the output reaches this amplitude. Record the corresponding $f_{LO} < f_0$ and $f_{HI} > f_0$. Determine the bandwidth (in Hz). Note: If you use the "apply" button in the CircuitMod dialog, changes are implemented without even leaving the dialog!

5. Repeat steps 2 through 4 with the potentiometer at full "cut" (minimum V_{out}). In this case, you're looking for the frequency that creates the *minimum* amplitude of the output! Surprisingly, the proper normalization $g(f)$ is the same as $h(f)$! Again, $g_{LO} = g_{HI} = \dfrac{1}{\sqrt{2}}$. Compute V_{LO} and V_{HI} at full "cut".

6. Your plots of h vs. f and g vs. f should include separate series to plot the vertical lines corresponding to f_0, f_{LO}, and f_{HI} (see dashed lines on figure…).

7. Write your discussion comments (see next page) in a reasonable place in Excel!
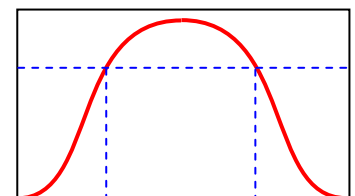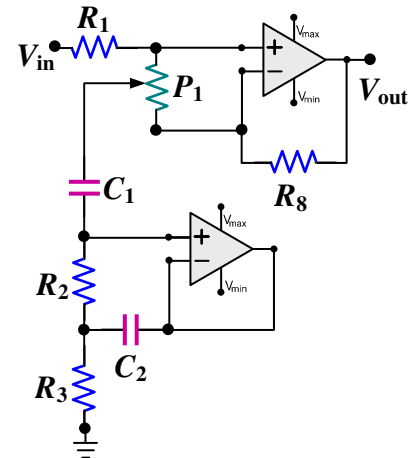
Table 1: Recorded Data Example

For V_{in}:	1 V	2 V	3 V
$f_{0 \text{ boost}}$ (Hz) measured			
V_{boost} at f_0 (V) measured			
$h_{LO} = h_{HI}$ (boost) computed	0.7071	0.7071	0.7071
$V_{LO} = V_{HI}$ (boost) computed			
$f_{LO \text{ boost}}$ (Hz) measured			
$f_{HI \text{ boost}}$ (Hz) measured			
BW_{boost} (Hz) computed			
$f_{0 \text{ cut}}$ (Hz) measured			
V_{cut} at f_0 (V) measured			
$g_{LO} = g_{HI}$ (cut) computed	0.7071	0.7071	0.7071
$V_{LO} = V_{HI}$ (cut) computed			
$f_{LO \text{ cut}}$ (Hz) measured			
$f_{HI \text{ cut}}$ (Hz) measured			
BW_{cut} (Hz) computed			

Table 2: Recorded Data for $V_{in} = 1$

	computed f (Hz)	measured $V_{\text{out:boost}}$	measured $V_{\text{out:cut}}$
$0.07 f_0$			
$0.15 f_0$			
$0.25 f_0$			
$0.40 f_0$			
$0.60 f_0$			
$0.75 f_0$			
$0.85 f_0$			
$0.93 f_0$			
$1.00 f_0$			
$1.10 f_0$			
$1.25 f_0$			
$1.66 f_0$			
$2.20 f_0$			
$3.75 f_0$			
$5.00 f_0$			
$10.00 f_0$			

Discussion:

- What is the maximum gain of this equalizer band?

- Discuss the "trap" that you discovered in step 2.

- What is the general algebraic relationship between the maximum "boost" (V_{boost} (f_0)) and the biggest "cut" (V_{cut} (f_0))? You'll need to look at your data from $V_{in} = 1$, 2, and 3 V to answer this question!

- You noticed that f_0 was independent of $|V_{in}|$, and independent of the degree of boosting or cutting. Discuss why you should have known this before doing any measurements. So, don't refer to the "invented" results h or g.

- The bandwidth was independent of $|V_{in}|$, but *did* depend on the degree of boost/cut. Discuss why that must be true. Again, don't refer to the "invented" results g or h.

- Plots: $h(f)$ and $g(f)$ for $V_{in} = 1$ V.