EECS 100/43
Lab 6 – Frequency Response

1. Objective

In this lab, you will learn about the concept of gain-bandwidth product of an op-amp.

2. Equipment

a. Breadboard
b. Wire cutters
c. Wires
d. Oscilloscope
e. Function Generator
f. Power supply
g. AD827 op-amp **[NOTE: THIS DOES NOT HAVE THE SAME BEHAVIOUR AS THE LMC6482. SO PLEASE MAKE SURE TO GET THE CORRECT OP-AMP FROM YOUR TA].**
h. Various connectors for the power supply, function generator and oscilloscope.

3. Theory

a. Concept of Frequency Response

As you learned from class, **EVERY** electronics component does not behave the same at all frequencies. That is, their response differs according to the frequency of your input signal. In other words, **EVERY** electronics component has a **FREQUENCY RESPONSE.**

The algorithm you use to measure frequency response in lab is:

a. Input a sinusoid of a known amplitude, frequency and phase.
b. Measure the amplitude, frequency and phase difference at the output. Plot the gain versus frequency on one plot[1] and phase versus frequency on another plot.
c. Change the frequency to a higher value, go back to step (a).

If you have a linear system, then the sinusoidal output frequency is the same as the sinusoidal input frequency. In this lab, we will explore a very important frequency-response related property of op-amps: the gain-bandwidth product.

[1] If you plot gain in dB (linear scale) versus the frequency (log scale) you get the Bode magnitude plot.

b. Concept of Gain-Bandwidth product of an op-amp

Probably the most important feature of an op-amp is its **gain-bandwidth product and the fact that it is a constant[2].** You know the definition of gain: ratio of the output variable to the input variable. There is no universal agreed upon definition of bandwidth. **For this lab, we will define the bandwidth as the frequency at which the gain decreases by 3 dB.** You should now complete Prelab Task 1.

If the gain-bandwidth product of an op-amp is constant and is 5 MHz (gain is dimensionless), it means:

a. If the op-amp is wired up for unity gain (voltage-follower), the gain drops by 3 dB or the amplitude (in volts) decreases by a factor of $\frac{1}{\sqrt{2}}$ at a frequency of 5 MHz.

b. If you have the op-amp wired for a gain of 10, then the gain drops by 3 dB at a frequency of 0.5 MHz. Notice that the gain-bandwidth product is 10 * 0.5 MHz = 5 MHz.

c. If you have the op-amp wired for a gain of -20, then the gain drops by 3 dB at a frequency of 0.25 MHz. Notice that the magnitude of the gain is what matters for the gain-bandwidth product: |-20| x 0.25 MHz = 5 MHz.

Why is the gain-bandwidth product so important? Answer: it tells you for what frequency values your op-amp acts in gain-mode before the components inside the op-amp start functioning differently – your op-amp starts loosing gain. You can find the gain-bandwidth product of op-amps in datasheets: this is probably the most important factor (after power requirements) that you want to look at while selecting op-amps for your design. Ask yourself this question: what is the maximum operational frequency of your circuit? If this frequency is less than the bandwidth of the selected op-amp, then your op-amp is fine for the design.

[2] The fact that the gain-bandwidth product is constant is not a physical law, rather a consequence of the design. A mathematical explanation of this property is beyond the scope of this class. But it is interesting to note that not all op-amps have this property: current feedback op-amps don't have this property.

4. PRELAB NAME:________________________________/SECTION____

Please turn in **INDIVIDUAL COPIES** of the prelab. They are due **10 MINUTES** after start of lab, **NO EXCEPTIONS!**

a. TASK 1: You should start understanding the nomenclature of frequency response: the most important of which is the decibel. Read Appendix D from your textbook, it describes the decibel. Now in the function plot below (zoom in to view the signal), what is the bandwidth of the signal?

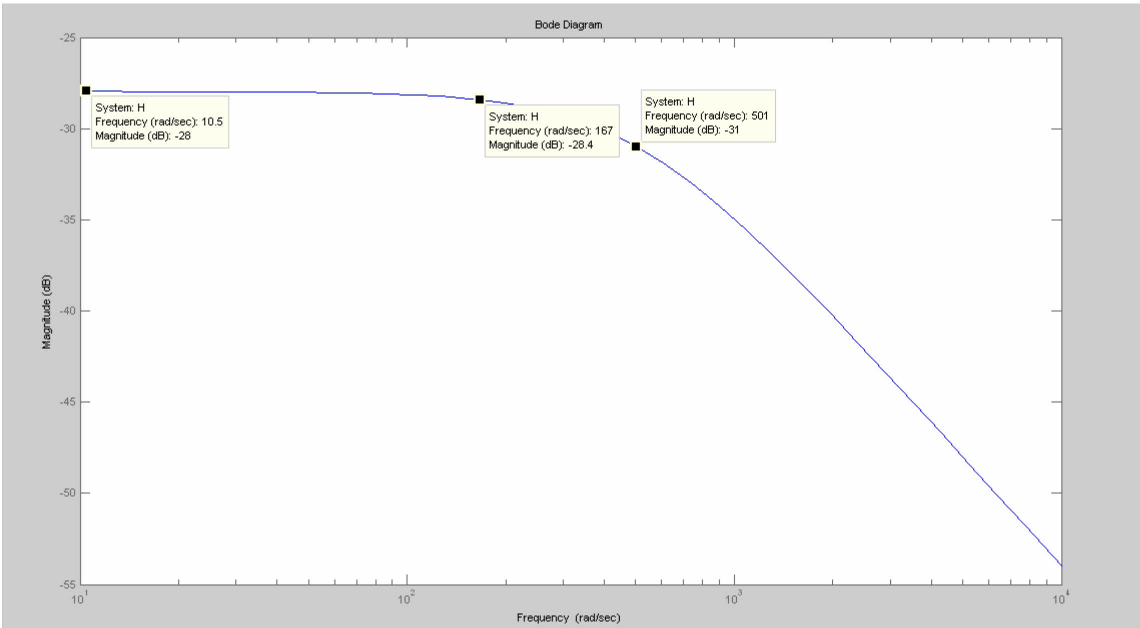

Figure 1. Bode magnitude plot of a complex-valued function. The bandwidth is defined as the frequency at which the signal gain drops by 3 dB

PRELAB COMPLETE: ________________________________ (TA CHECKOFF)

5. REPORT NAME(S):________________________________/SECTION____

a. TASK 1: Build the following AD827 circuits on the breadboard and power up the op-amp. **PLEASE BE VERY CAREFUL WHILE HANDLING THIS OP-AMP, DOUBLE CHECK POWER CONNECTIONS! IF IN DOUBT, ASK THE TA! WE DON'T HAVE A LOT OF THESE OP-AMPS, SO DON'T BLOW THEM UP!**

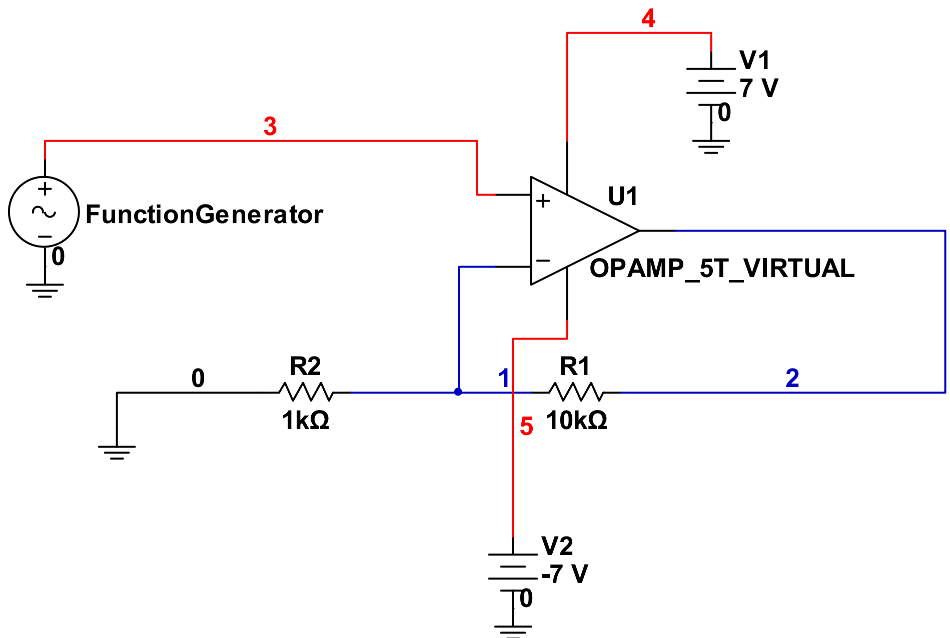

Figure 2. Non-inverting amplifier 1

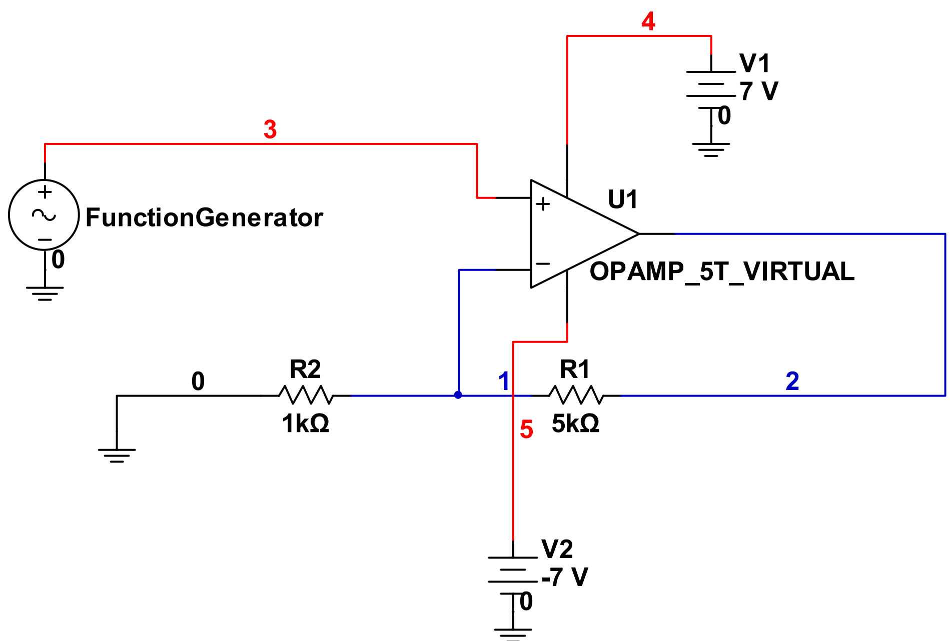

Figure 3. Non-inverting amplifier 2

For each circuit:

1. Compute the gain.
2. Use 1 Vpp sine wave (1 Vpp as measured on the scope) as input to your circuit and measure the bandwidth.
3. Determine the gain-bandwidth product

Circuit	Gain	Bandwidth	Gain-Bandwidth product
Non-inverting amplifier 1			
Non-inverting amplifier 2			

Table 1. Gain-Bandwidth product comparison.

TURN IN ONE REPORT PER GROUP AT THE END OF YOUR LAB SESSION. THERE IS NO TAKE HOME REPORT.

6. REVISION HISTORY

Date/Author	Revision Comments
Summer 2007/Bharathwaj Muthuswamy	Typed up source documentation, organized lab report, typed up solutions.