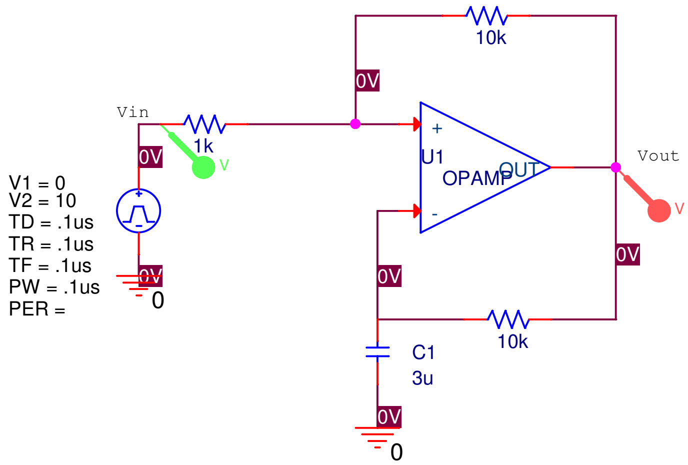

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Xi Kun Zou

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Date: Wednesday, May 10, 2017
Sheet 1 of 1

XiKun Zou

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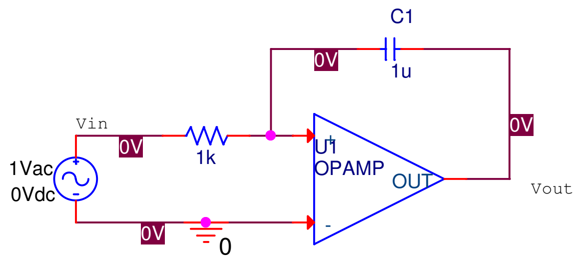

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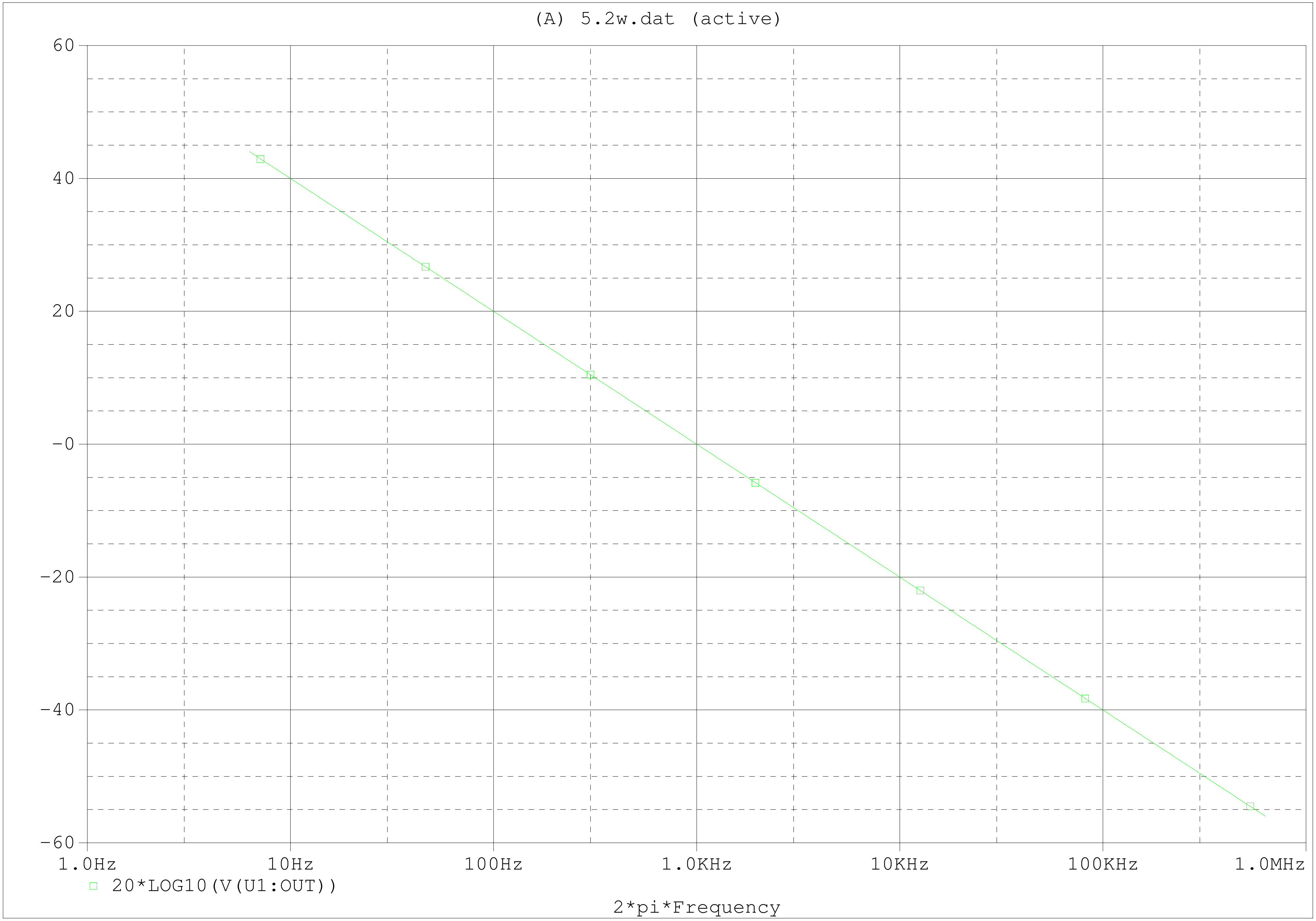

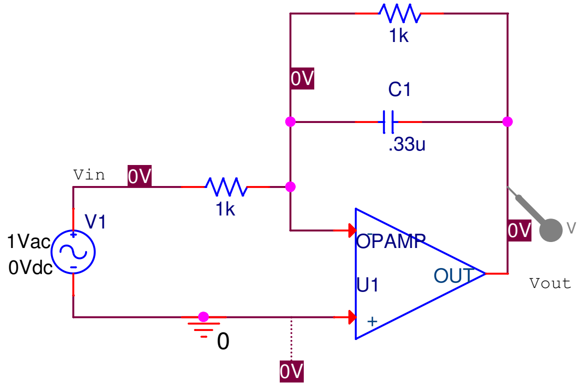

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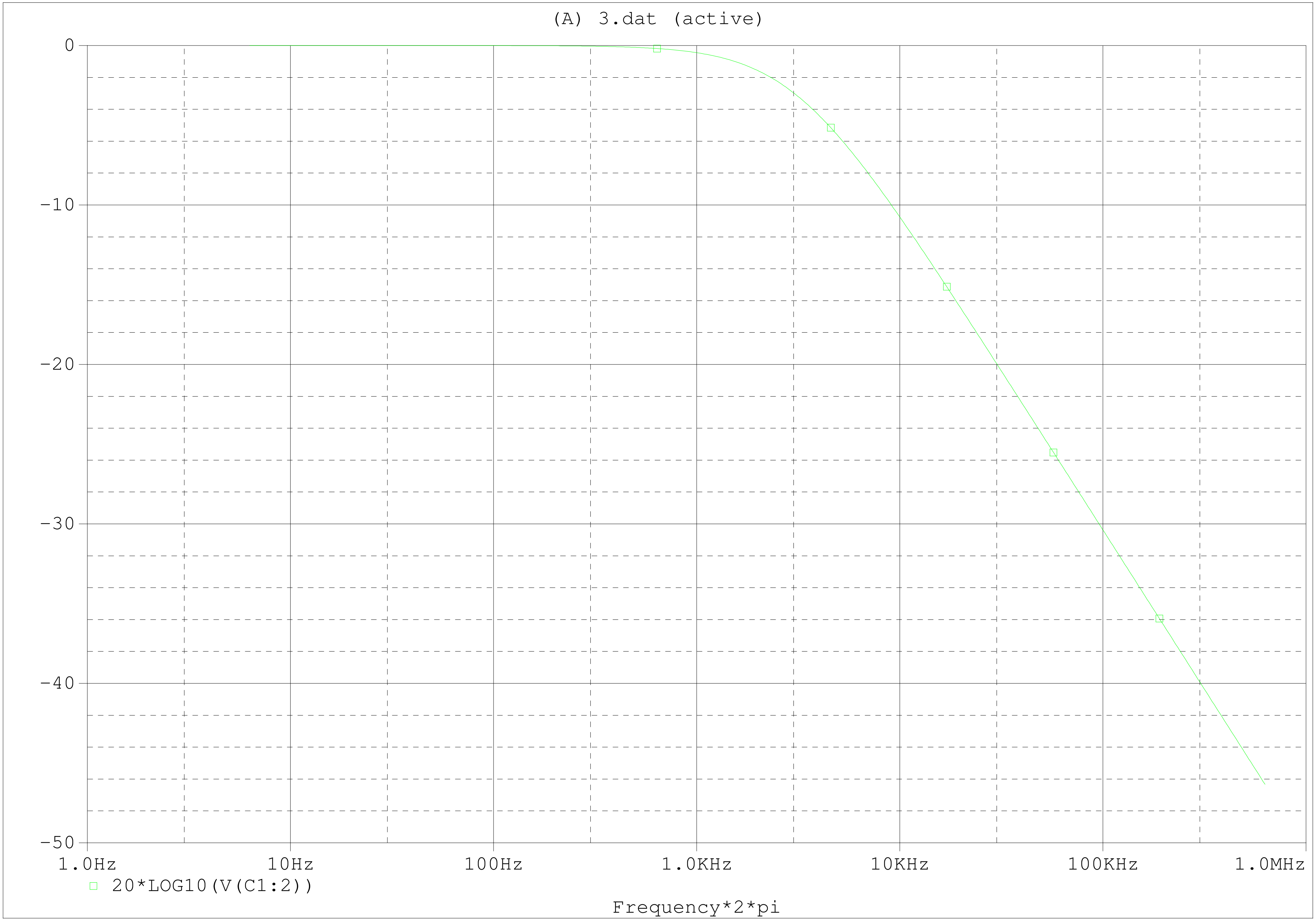

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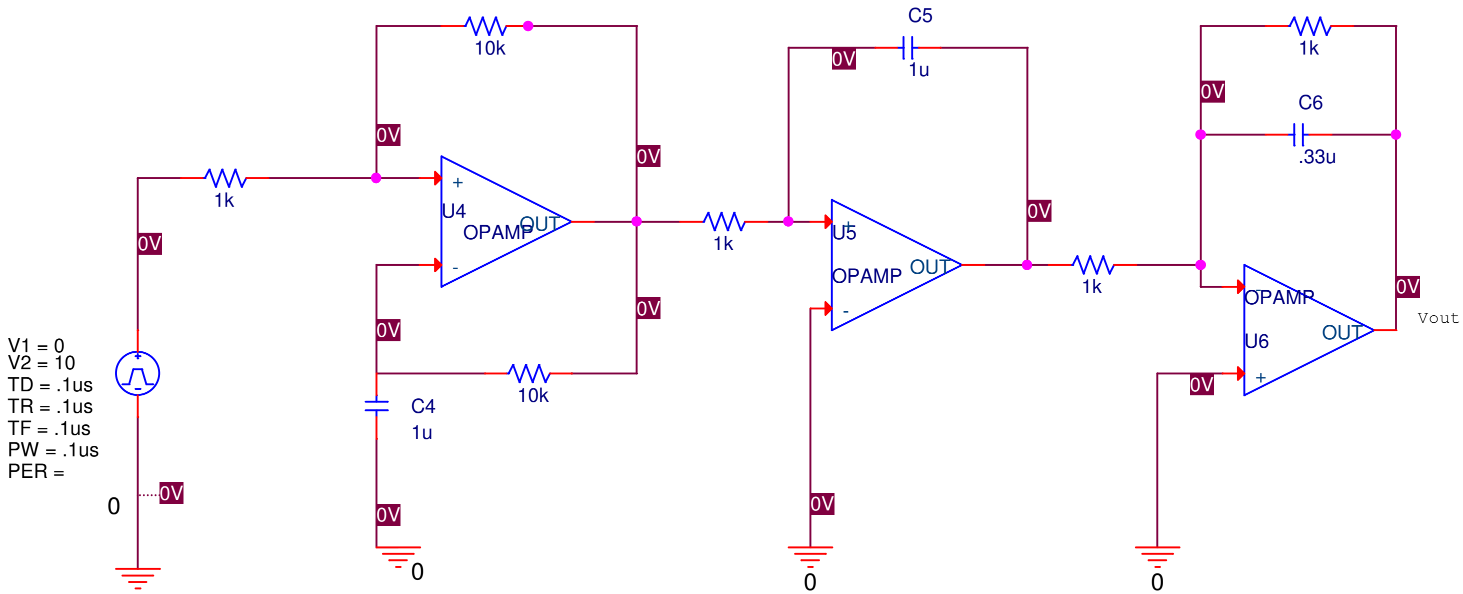

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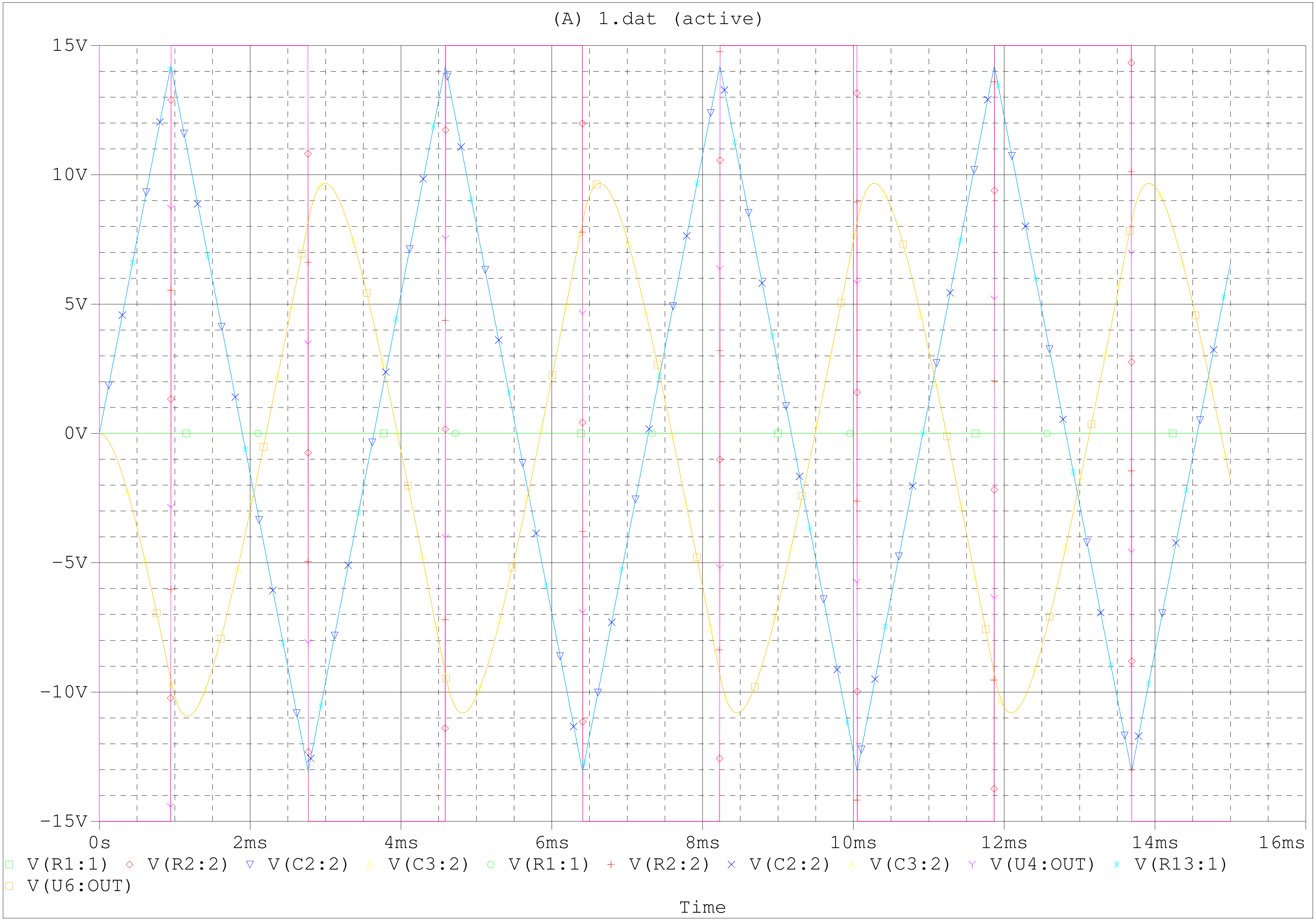

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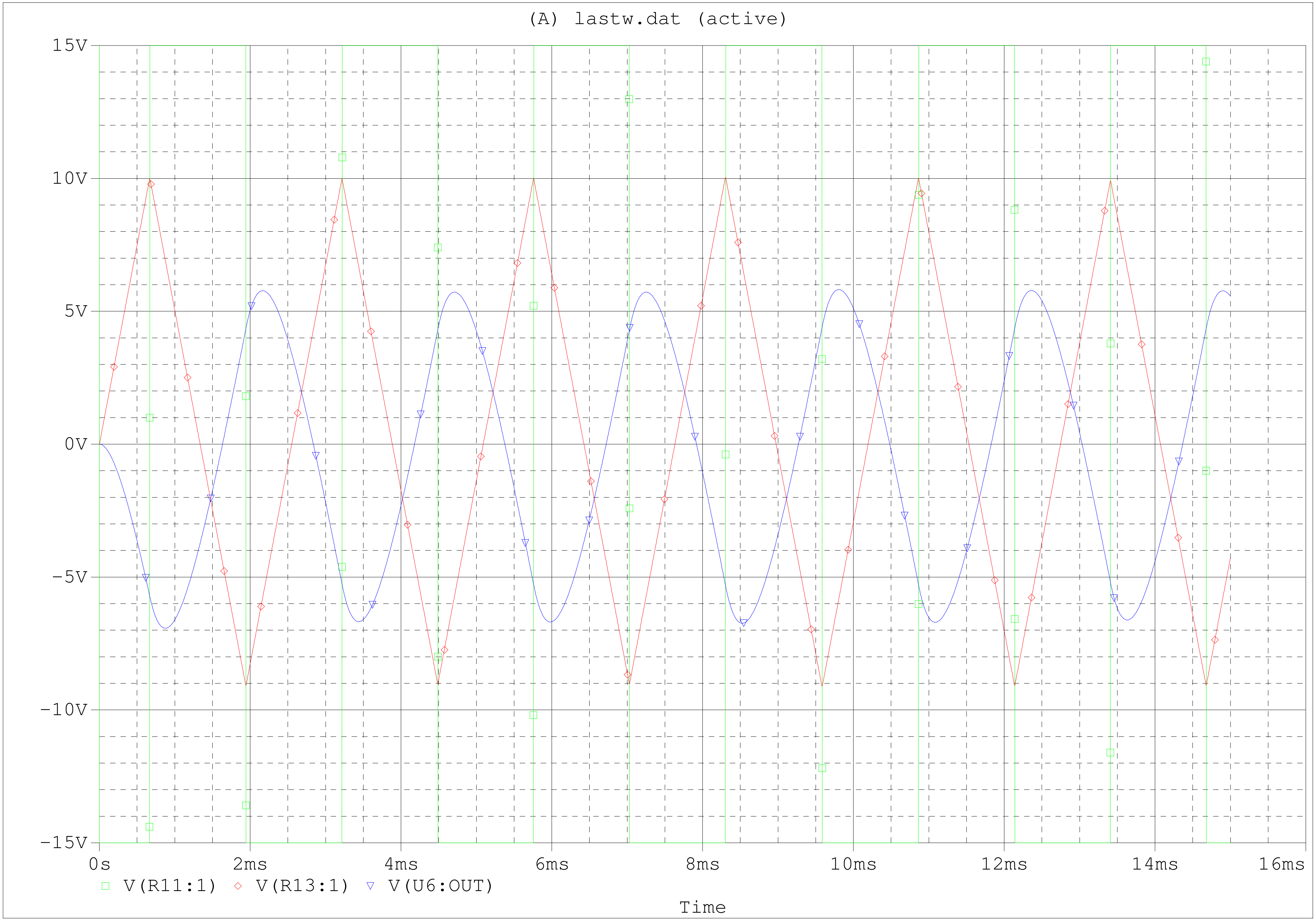
(A) lastw.dat (active)
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10V
5V
0V
-5V
-10V
-15V
0s
2ms
4ms
6ms
8ms
10ms
12ms
14ms
16ms
V(R11:1)
V(R13:1)
V(U6:OUT)
Time

ECE 212 Spring 2017
Circuit Analysis II

M / Th / F
Group A / B

Names: Xi Kun Zou

Lab 5: Building a Function Generator

Objectives

In this lab exercise you will build a function generator capable of generating square, triangle, and sine waves. The frequency and amplitude of these waves will be controlled through potentiometers. There will be some frequency analysis to aid in the understanding of Laplace transforms, Bode plots, and Fourier series. Finally, the function generator will be connected to the stereo amplifier constructed during Lab 3 in order to monitor to the generated waveforms through a speaker.

Pre-Lab Instructions (10pts)

Part One: Square Wave Generator

1. Simulate the unstable multivibrator shown in Figure 1. The voltage source in the diagram is the PSpice part "VPULSE," a voltage pulse needed to start the circuit oscillating. Note that when you actually build the circuit in lab, noise in the circuit will be enough to start oscillations. To view the output, set up a transient response with a runtime of about 15ms and a maximum step size ("step ceiling" in PSpice 9.1) of 5μs.

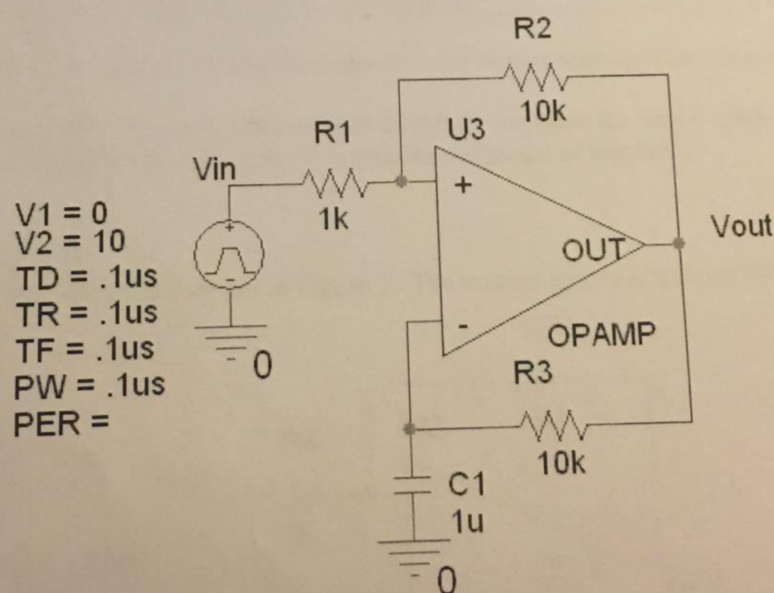


Figure 1: Unstable Multivibrator

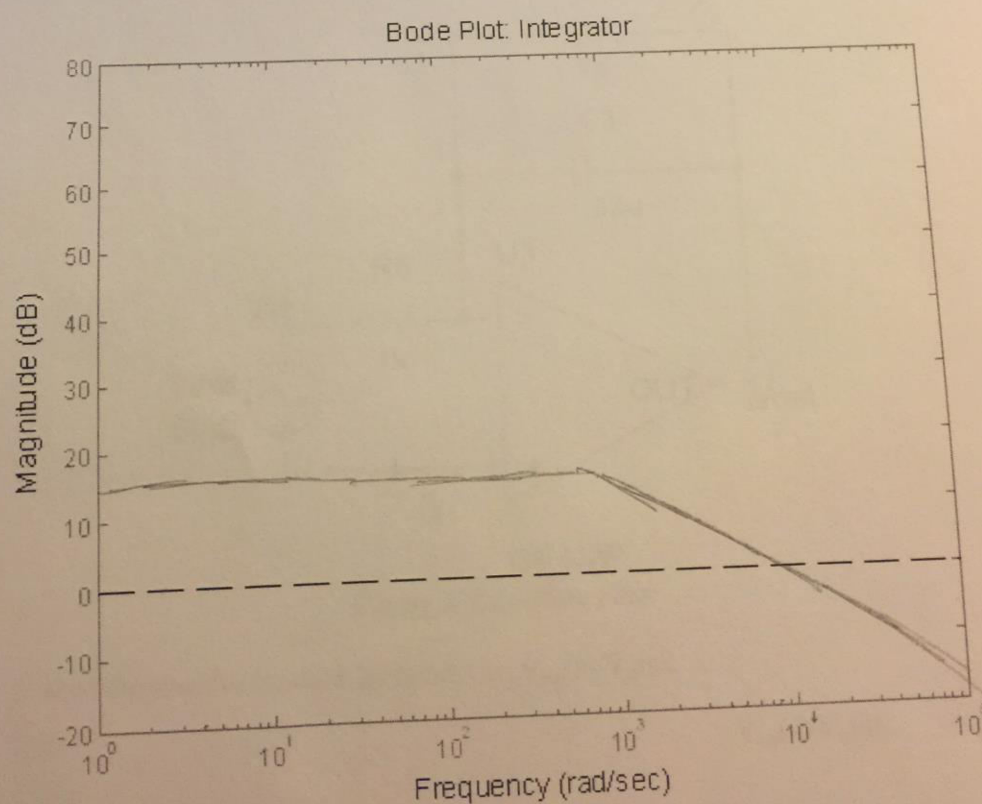
2. Find the transfer function by hand, i.e., $\mathbf{V}_{out}(\mathbf{s})/\mathbf{V}_{in}(\mathbf{s})$. Later in the lab, the input of the integrator is going to be the output of the square-wave generator, either +15V or –15V, DC. For the sake of analysis, we can say that $v_{in}(t) = -15u(t)$ or $v_{in}(t) = 15u(t)$, depending on if the square-wave is at its minimum or maximum value.

If we take the input as $-15u(t)$, what will the output of the integrator be in both the frequency and time domains (hint: the integral of a constant)? What will the output be in both the frequency and time domains if the input is $+15u(t)$?

$V_{out} = -\int_0^t \frac{V_{in}}{R_4 C}\,dt$

$\mathbf{V}_{out}(\mathbf{s})/\mathbf{V}_{in}(\mathbf{s})$	$-1000/s$
$\mathbf{V}_{out}(\mathbf{s})$ $(v_{in}(t) = -15u(t))$	$15000/s^2$
$v_{out}(t)$ $(v_{in}(t) = -15u(t))$	$15000t$
$\mathbf{V}_{out}(\mathbf{s})$ $(v_{in}(t) = +15u(t))$	$-15000/s^2$
$v_{out}(t)$ $(v_{in}(t) = +15u(t))$	$-15000t$

3. Sketch the asymptotic Bode plot of the transfer function of the integrator:



4. In PSpice, make a Bode plot of the transfer function by conducting an AC sweep on the input voltage. In the simulation profile for AC Sweep, set the start frequency to 1Hz, the end frequency to 100,000Hz, and the points per decade to 100. The sweep type should be logarithmic ("decade" in PSpice 9.1). Add a voltage marker to the output of the integrator. On the plot of the output voltage, change the trace to "20*LOG10(V(U2:OUT))" to get the gain in decibels (U2:OUT is the output node of the op-amp, which may be labeled differently in your circuit). Change the x-axis from Hz to rad/s by first selecting "Axis Setting" from the Plot menu, then clicking "Axis Variable" and changing "Frequency" to "2*pi*Frequency."

Print out the Bode plot. (**NOTE: your name must appear in the filename of all circuit and waveform printouts!**)

How much does the gain (value plotted on the y-axis) change per decade (a factor of 10, e.g., between 100rad/s and 1000rad/s)?

dB/decade -20 dB/decade

Part Three: Low-Pass Filter

1. Simulate the circuit shown in Figure 3.

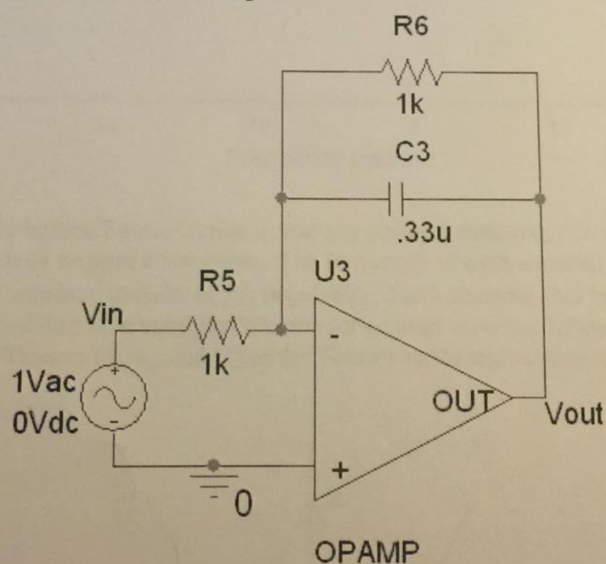
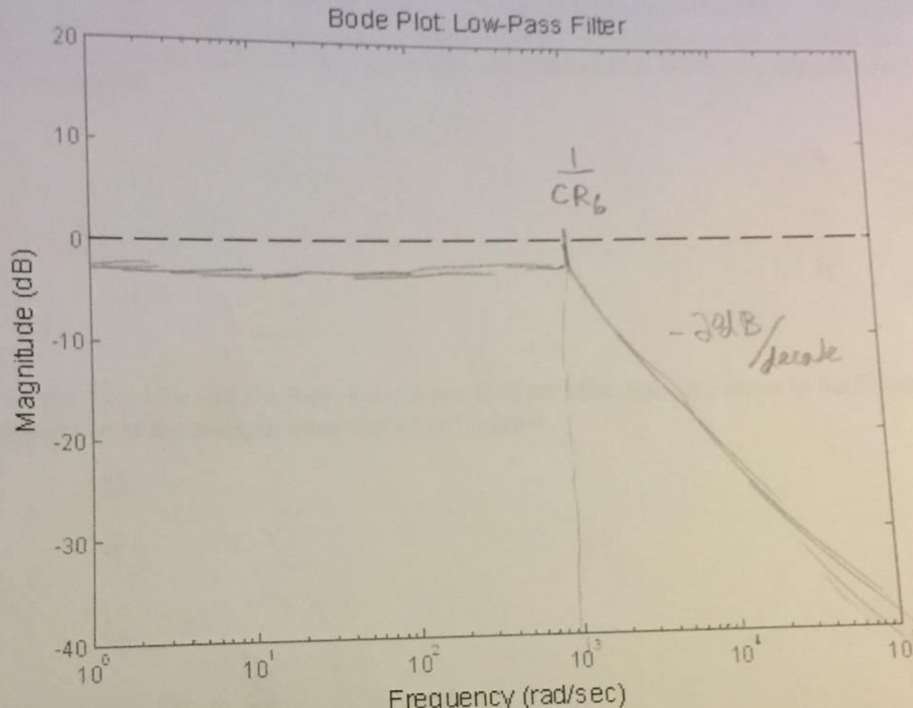


Figure 3: Low-Pass Filter

2. Find the transfer function by hand, i.e., $\mathbf{V}_{out}(\mathbf{s})/\mathbf{V}_{in}(\mathbf{s})$.

$\mathbf{V}_{out}(\mathbf{s})/\mathbf{V}_{in}(\mathbf{s})$ $-\frac{R6}{R5} = -1$

3. Sketch the asymptotic Bode Plot of the transfer function of the low-pass filter:



4. The theory behind Fourier series is that any periodic function, $f(t)$, with period T, can be written as the sum of weighted sinusoids. The frequency of each sinusoid is a positive integer multiple of ω_0, the frequency in rad/s of $f(t)$ ($\omega_0=2\pi/T$). Each sinusoid also has a coefficient multiplying it, determining how strongly that sine (or cosine) wave contributes to the function $f(t)$. Derive the coefficients (a_0, a_n, and b_n) of the Fourier series representation of the following signal:

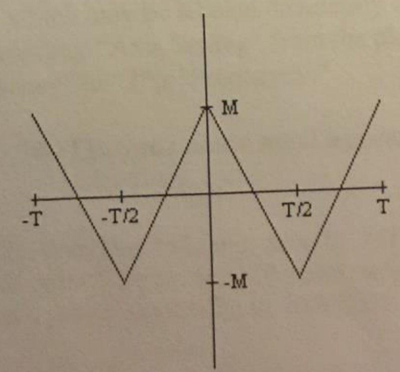


Figure 4: Triangle-Wave Input (to the Low-Pass Filter)

This calculation will need to be done on a separate page. Here is a hint to aid you in finding the coefficients: Is this function even or odd? For even functions, $b_n = 0$, meaning the function is comprised entirely of cosine waves. For odd functions, $a_n = 0$, meaning the function is comprised entirely of sine waves. If the function is even, it is recommended to double the integral over half the period to find a_n. If it is odd, use you can also double the integral over half the period to find b_n.

Even

a_0 $\underline{M}$

a_n $\frac{2M}{n\pi}\sin\left(\frac{n\pi}{2}\right)$

b_n $\underline{0}$

5. For M = 15V and T = 3ms, write down the first three non-zero terms in the Fourier series expansion of the triangle wave shown in Figure 4.

$a_1 =$

$a_3 =$

$a_0 = M$

$f(t) =$ 15 , 9.5493 , −3.1831

6. Make a Bode plot of the transfer function by conducting an AC sweep on the input voltage. In the simulation profile for AC Sweep, set the start frequency to 1Hz, the end frequency to 100,000Hz and the points per decade to 100. The sweep type should be logarithmic ("decade" in 9.1). Add a voltage marker to the output of the circuit. On the plot of the output voltage, change the trace to "20*LOG10(V(U3:OUT))" to get the gain in decibels (U3:OUT is the output node of the op-amp, which may be labeled differently in your circuit). Change the x-axis from Hz to rad/s by first selecting "Axis Setting" from the plot menu, then clicking "Axis Variable" and changing "Frequency" to "2*pi*Frequency."

Print out the Bode plot. (**NOTE: your name must appear in the filename of all circuit and waveform printouts!**)

At what frequency (rad/s) does the Bode plot drop by 3dB from its constant value? This frequency is known as the "3dB point." After the 3dB point, what is the rolloff (i.e., how much does the gain decrease per decade, say from 10kHz to 100kHz)?

3dB point (rad/s) $\underline{1\text{KHz}}$

Rolloff (dB/decade) $\underline{-20\text{dB/dec}}$

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Part 3 . 4

Even

$$a_0 = 2\frac{1}{T}\int_0^{T/2} f(t)\,dt$$

$$= \frac{M4}{T}\int_0^{T/4} dt$$

$$= \frac{4M}{T}\left(T/4\right) = M$$

$$a_n = \frac{4}{T}\int_0^{T/4} f(t)\cos(n\omega_0 t)\,dt$$

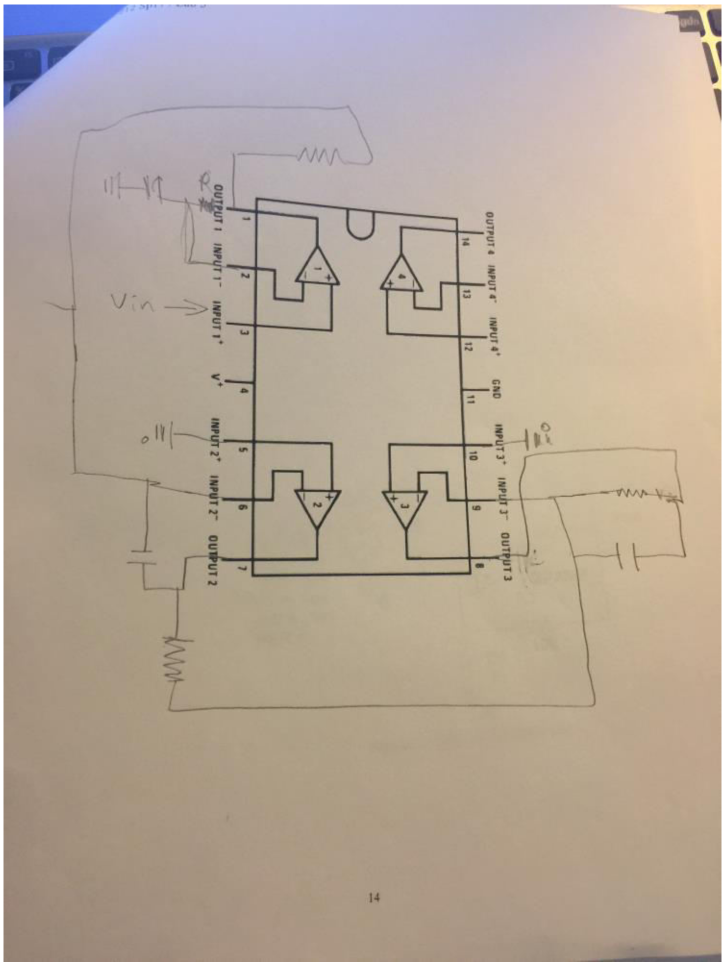
$$= \frac{M4}{T}\int_0^{T/4} \cos(n\omega_0 t)\,dt$$

$$= \frac{2M}{n\pi}\left(\sin\left(\frac{n\pi}{2}\right) - 0\right)$$

$$= \frac{2M}{n\pi}\sin\left(\frac{n\pi}{2}\right)$$

$$b_n = 0$$

3. This function generator is a combination of an unstable multi-vibrator, an integrator op-amp and a low pass filter op-amp. The op-amp multi-vibrator works as an analogue comparator. It compares the voltages on its two inputs and gives a positive or negative output depending on the input, which generates rectangular output wave forms. Then the output becomes the input of the integrator op-amp which generates output that can respond to changes in the input voltage over time. When the input is triangular the output waveform is sinusoidal. At last the output becomes the input of the low pass filter op-amp.



5.

Base on the Equation T= $2R_3C_1 \ln((1+b)/(1-b))$

As R_3 decreases, T becomes smaller as well due to proportionality.

And since T is period and frequency is 1/T, Thus as R3 decreases, Frequency increases. Since the total output does not change, the amplitude of the resulting wave must decreases.