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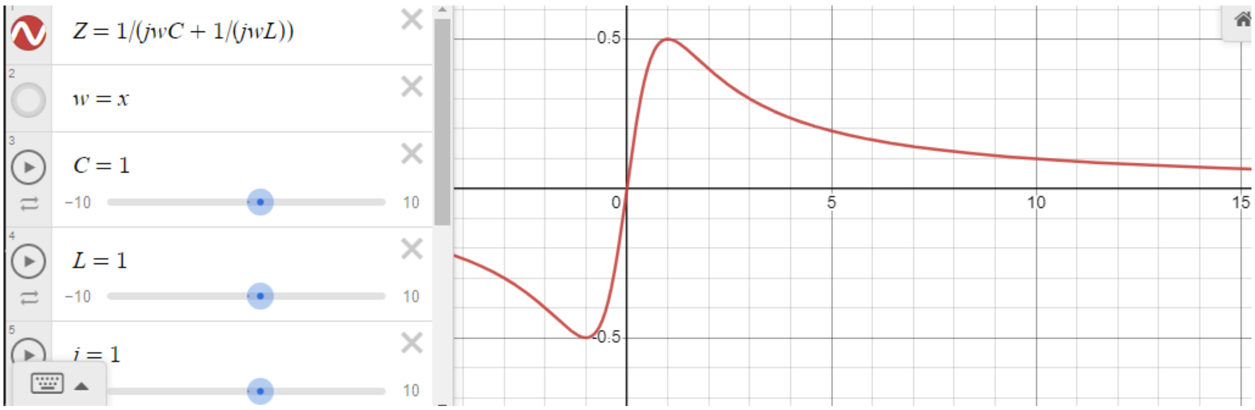
Intro to Electronics HW3

1) Consider an op amp circuit as shown in the figure below. The non-inverting input terminal is connected to ground. The feedback impedance is a capacitor C parallel to an inductor L .
    a) Calculate and sketch the impedance of the feedback impedance as a function of angular frequency ω.

Z=(ZC^-1+ZL^-1)^-1
ZC=1/jwC
ZL=jwL
Z=1/(jwC+1/(jwL))



    b) What is the resonance angular frequency (ω 0) of the feedback circuit?

1/sqrt(LC)

    c) Calculate the transfer function | H (ω) | = | V out / V 1 |. Sketch the transfer function.

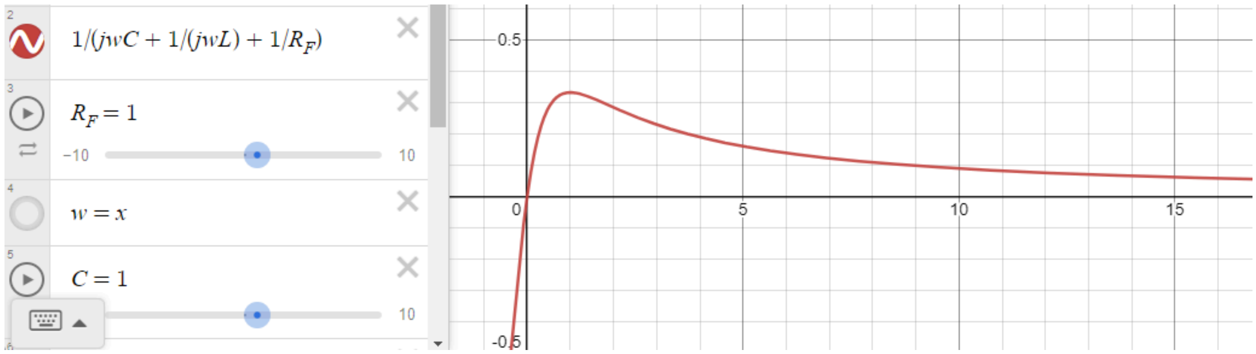
Vout=V1*RF/Rin=V1 * 1/(jwC+1/(jwL)) / R1
H(w)=1/(jwC+1/(jwL)) / R1

    d) Next, a resistor R F is added in parallel to the L and C . Draw the feedback circuit. Calculate the impedance.

ZF=(ZC^-1+ZL^-1+RF^-1)^-1 = 1/(jwC+1/(jwL)+1/RF)

    e) What is the feedback impedance at the resonance frequency ω 0 ? Sketch the impedance of the feedback impedance as a function of ω.

ZF=1/(j(1/sqrt(LC))C+1/(j(1/sqrt(LC))L)+1/RF)



f) Assume that R 1 = R F . What is the amplification of the amplifier at the resonance frequency?

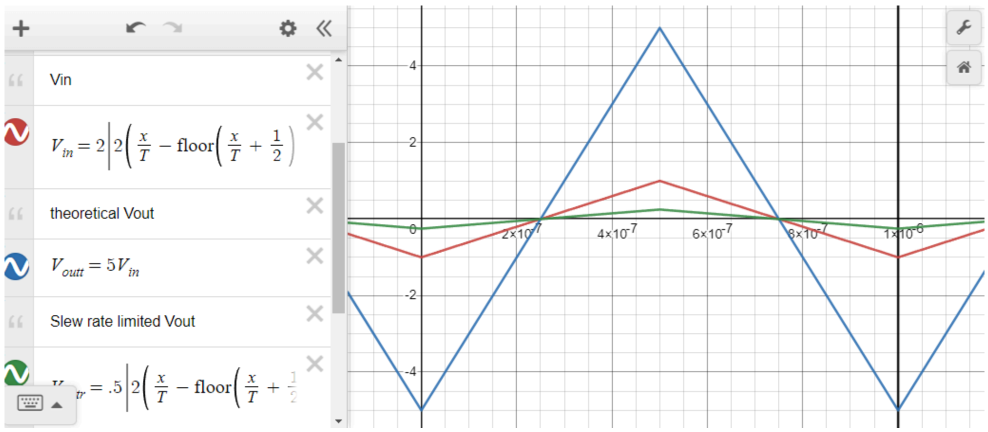
A = Rf/Rin = (1/(j(1/sqrt(LC))C+1/(j(1/sqrt(LC))L)+1/RF))/RF

2) An Op Amp has an open-circuit voltage gain of A VOC (that can be adjusted by the feedback resistor) and a slew rate of SR = 1 V/μs.

   a) Define the slew rate in your own words. Does the slew-rate limitation apply to the Op Amp's input or output voltage?

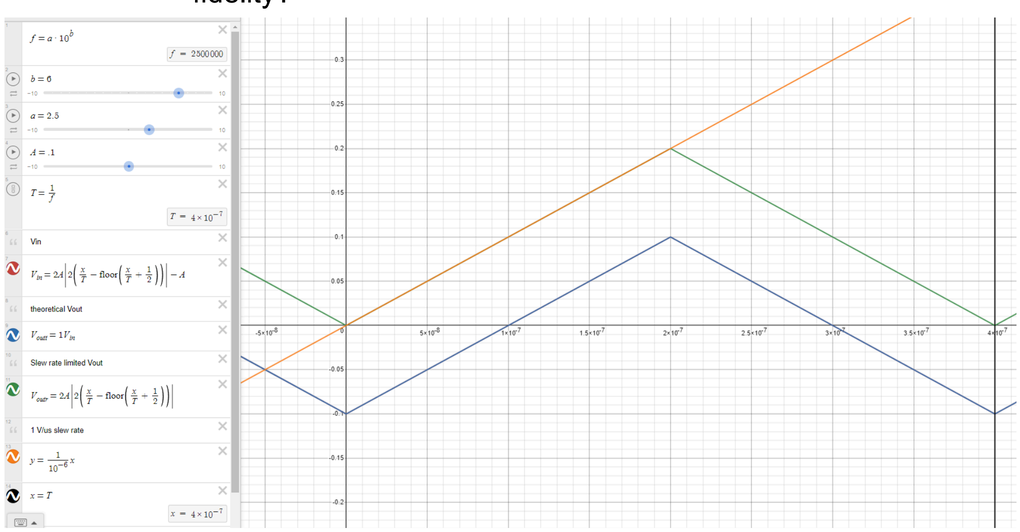
Slew rate is due to the switching speed limitations of an op amp's transistors. This leads to the output voltage not being able to change as instantaneously as the input, but only being able to change at a given rate.

   b) A triangular wave with period 1 μs and amplitude of 1 V is applied to the input of an Op Amp with an open-circuit voltage amplification of A VOC = 5. Sketch the input waveform. Sketch the output waveform of the Op Amp. Is the output signal distorted?



The op amp is limited by its slew rate. While it should theoretically change it's output 5 times faster than it's input, it can only change a quarter as fast, limiting it's amplitude to a quarter of the input, a twentieth of what it should be.

   c) For an Op Amp with A VOC = 1, can you determine the maximum frequency of an input triangular wave with amplitude 100 mV that can be amplified with high fidelity?



1 V/us = 10^6 V/s
.1V * 1 = .1V (amplitude)
.1 V / 10^6 V/s = 10^-7s (per gain of 0.1V, 1/4 period)
10^-7s * 4 = 4*10^-7s (per period)
1/(4*10^-7 s)=2.5*10^6 Hz (frequency)
2.5MHz

d) For an Op Amp with A VOC = 10, can you determine the maximum frequency of an input triangular wave with amplitude 100 mV that can be amplified with high fidelity?

1 V/us = 10^6 V/s
.1V * 10 = 1V (amplitude)
1 V / 10^6 V/s = 10^-6s (per gain of 1V, 1/4 period)
10^-6s * 4 = 4*10^-6s (per period)
1/(4*10^-6 s)=2.5*10^5 Hz (frequency)
250kHz

e) For an Op Amp with A VOC = 100, can you determine the maximum frequency of an input triangular wave with amplitude 100 mV that can be amplified with high fidelity?

1 V/us = 10^6 V/s
.1V * 100 = 10V (amplitude)
10 V / 10^6 V/s = 10^-5s (per gain of 10V, 1/4 period)
10^-5s * 4 = 4*10^-5s (per period)
1/(4*10^-5 s)=2.5*10^4 Hz (frequency)
25kHz

f) Assume that the bandwidth of an Op Amp is the maximum frequency at which a signal is amplified with high fidelity. What is the mathematical product of (Op Amp gain) × (Op Amp bandwidth) for the previous 3 questions? Is the mathematical product a constant?

1 * 2.5MHz = 2.5MHz
10 * 250kHz = 2.5MHz
100 * 25kHz = 2.5MHz

g) Is the constancy of the gain-bandwidth product a direct consequence of the finite slew rate of an Op Amp?

Yes, if you need to amplify a signal twice as much, you need twice as much time to do so, you can only have half the frequency. Therefore, twice the amplitude times half the frequency will be a constant.

3) Are the statements True or False ? Justify your answer with one or two sentences.

   a) A forward biased diode converts to heat the power of $V f \times I$, where $V f$ is the forward voltage and I is the diode current.

True, P=IV, I is current flowing through the diode, and Vf is the voltage across the diode.

   b) A reverse-biased pn-junction diode generally consumes no or very little power.

True, P=IV, so even with negative voltage, as long as you don't reach break down, there will be extremely little current and extremely little power. This can mathematically be explained by the exponential decay of current outweighing the linear increase in negative voltage.