Final Practice Exam

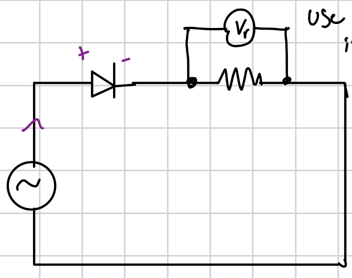
2 Diodes

1. Build a circuit using a silicon diode and a resistor in series. Drive the circuit with a sinusoidal source voltage with a peak-to-peak voltage of 3 V, and measure the voltage drop across the resistor using an oscilloscope. Choose a trigger setting.

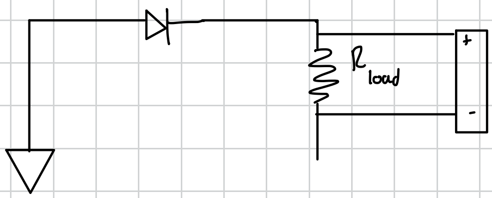
2. Draw the circuit diagram. Did you use a ground isolation unit? Why or why not?

3. Inspect the trace on the scope carefully and explain what you see. Does the general shape of the signal make sense? What about the the maximum and minimum values?

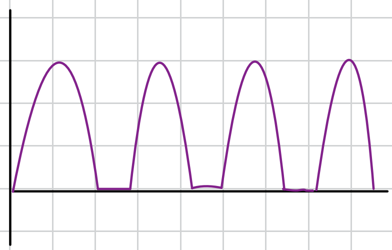
4. Consider the following rectifier circuit driven by a sinusoidal source voltage.



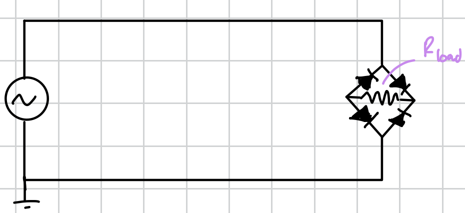
2. We use the ground isolation unit to avoid introducing ground where we do not need it, creating a short circuit. the resistor is not connected to ground so we use the ground isolation unit to avoid grounding it.



this is a half wave rectifier circuit so the voltage across the resistor looks like a wave that does not dip - only peaks above 0



a full wave rectifier circuit looks like



4. Consider the following rectifier circuit driven by a sinusoidal source voltage.

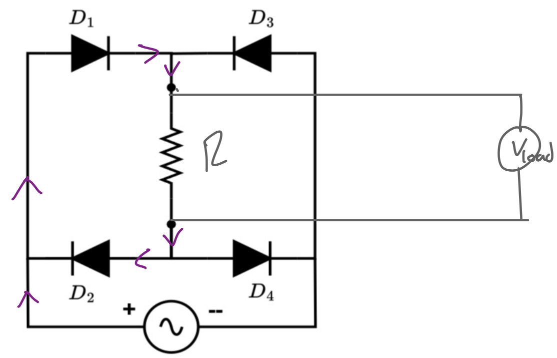


Fig. 1: Rectifier circuit

(a) What kind of rectifier circuit is this?

(b) Copy the circuit in your paper-notebook, then draw the path of the current for the positive half cycle.

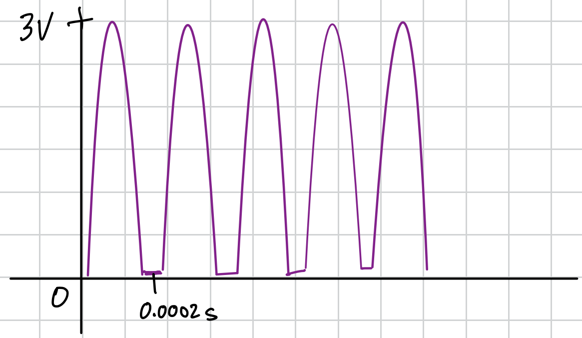
(c) State where and how you would connect the oscilloscope to observe the rectified signal.

(d) Using proper units and scales on both axes, draw the trace you would see on the scope. Assume that the source voltage has a frequency of 5 kHz and has a peak-to-peak amplitude of 6 V. Do not build the circuit.

a) this is a full wave rectifier circuit

c) connect the oscilloscope across the load resistor to observe the rectified signal

d)



period of the wave $= T = \frac{1}{f}$

$T = \frac{1}{5\times10^{3}\ Hz} = 0.0002\ s$

Peak of rectified wave is $\frac{1}{2}$ of P-P input voltage

3 LR circuit:

In your parts box find two resistors with resistance of approximately 10 $k\Omega$ and an inductor with inductance $L = 100$ mH.

1. How would you connect these elements so that your circuit has a characteristic time constant of 20 μs?
2. Measure the values of the resistance and the inductance, calculate the expected time constant τ with the parts you have, and propagate uncertainties to determine the uncertainty in the expected value of τ.
3. Draw your circuit that shows the resistor combination and the inductor in series with a square wave source. Build the circuit and drive it with a positive square wave between 0 V and 5 V. Set up your scope to measure the voltages across the resistors and across the inductor. Think about whether you need to use a ground isolation unit. Display these traces together with the source voltage on your scope.
4. Transfer the traces to the computer and analyze the data to extract the time constant, τ, of your circuit using a linear fit.
5. You must also determine the uncertainty in τ and evaluate the goodness of your fit. To simplify data acquisition, you may consider that the uncertainty for all voltage values is 3%. State your reduced χ^2 value and the P-value for your comparison between data and fit.
6. Quantitatively compare your calculated and measured values of tau. Do your calculation on paper, and use the notebook only to compute numerical values.

τ of an RL in Series

$$\tau = \frac{L}{R}$$

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_{total} = \left(\frac{1}{10000} + \frac{1}{10{,}000}\right)^{-1} = \frac{10000}{2}$$

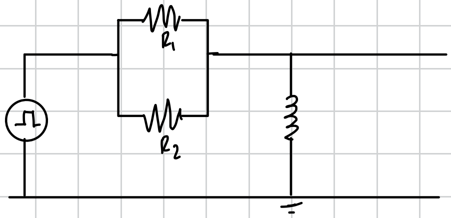
$$20\times10^{-6} = \frac{100\times10^{-3}}{\frac{10000}{2}}$$

1. the Resistors would be in parallel so they add like $R_{total} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}$

2. $\tau = \frac{L}{R_{total}}$ $\qquad \sigma_{R_{total}} = \sqrt{\left(-\frac{1}{R_1^2}\right)^2 \sigma_{R_2}^2 + \left(-\frac{1}{R_2^2}\sigma_{R_1}\right)^2}$

$$\sigma_\tau = \sqrt{\left(\frac{1}{R_{total}}\sigma_L\right)^2 + \left(\frac{-L}{R_{total}^2}\sigma_{R_{tot}}\right)^2}$$

3.



yes, we should use the ground isolation unit to measure voltage across the resistor and inductor so we don't introduce ground

4. τ is $\frac{1}{\text{Slope}}$ of linear fit

6. Quantitatively Compare measured and calculated τ value

$$\Delta = \text{theory} - \text{measure}$$

$$\sigma_\Delta = \sqrt{\sigma_{theory}^2 + \sigma_{measure}^2}$$

to be consistent $\frac{\Delta}{\sigma_\Delta} \le 2$

4 RC filters

Draw two circuits: a high pass and a low pass RC filter, each driven by a square wave source.

(a) Explain why one is called a high pass and the other a low pass filter.

(b) Suppose $R = 3\,k\Omega$ and $C = 40$ nF. Calculate the characteristic time constant, τ, and the cut-off frequency f_0 of each circuit. ✓

(c) Draw the frequency response of each circuit and mark any relevant values on the voltage axis and on the frequency axis. ✓

(d) You want to measure the voltages across the resistor and the capacitor. How would you connect the oscilloscope to each circuit? Draw the corresponding connections on each circuit diagram and explain why you chose to connect the way you did.

(e) Choose one of the filters. Suppose you are driving it at the cutoff frequency f_0 with a sinusoidal source that has a peak to peak voltage of 1 V. Draw the voltage across the resistor that you expect to see on the oscilloscope. Mark any relevant values on the axes.

(f) Build the circuit you chose, and display the trace of the voltage across R on the scope. Take the time to compare this display with your prediction. Tune the function generator first above and then below the cut-off frequency. Each time compare the amplitude of the signal to the one you measured at f_0. Compare your observation with the frequency response you drew in (c) above. Does it make sense?

(g) Imagine you changed out the square wave generator for a simple switch and a battery. Redraw your circuit diagram. What would the voltage across the resistor look like just after the switch was closed? What would it look like a long time after the switch was closed? What about for the capacitor? Mark any relevant values on the axes.

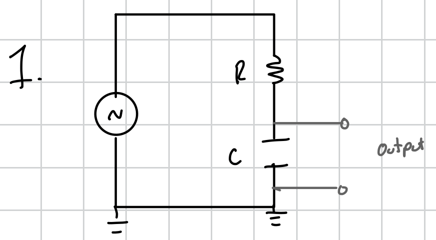
(h) Imagine further you changed out the capacitor for an inductor, and repeat the analysis above: what would the voltage across the resistor look like just after the switch was closed? What would it look like a long time after the switch was closed? What about for the inductor? Mark any relevant values on the axes.

DC current instead of AC

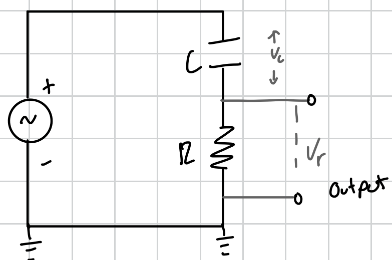
2. τ for RC $=$ RC

$f_0 = \frac{1}{2\pi RC} = \frac{1}{2\pi\tau}$

1.



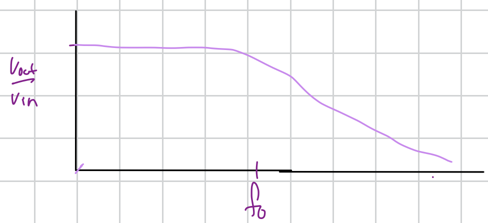
Low Pass

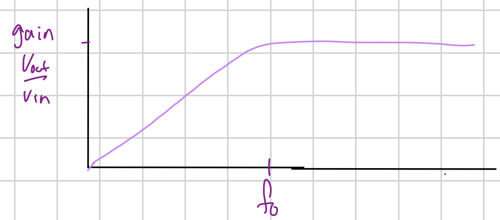


High Pass

high frequencies go through the Capacitor to ground so they get filtered out

Capacitor lets the high frequency pass and the lower frequency go through the resistor to ground





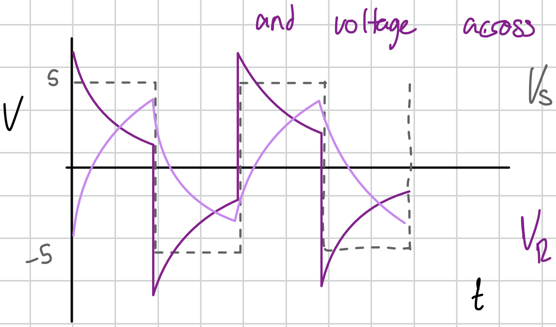
What happens to V_R as we drive close to f_0

as we drive Close to f_0 the reactance of the capacitor decreases So more current goes to the capacitor and voltage across the resistor decreases

What happens to V_R as $f \to f_0$?

if $\omega = 0$ $V_c = V_0$

$V_R = \frac{\omega t}{\sqrt{1+\omega^2 t^2}} V_0$



the Square wave will cause the capacitor to discharge and recharge repeatedly

What happens if we use a switch

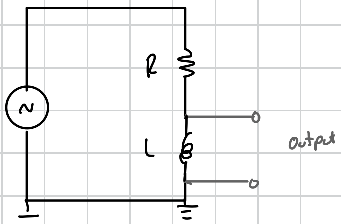
after switch is closed no charge on the capacitor

So the initial capacitor voltage = battery voltage and $V_R = 0$

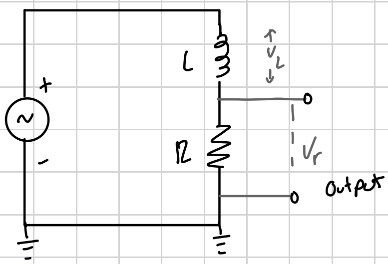
then after a long time, no voltage on capacitor

right after switch is closed, no charge on capacitor so voltage across resistor is max. Voltage across the capacitor is low

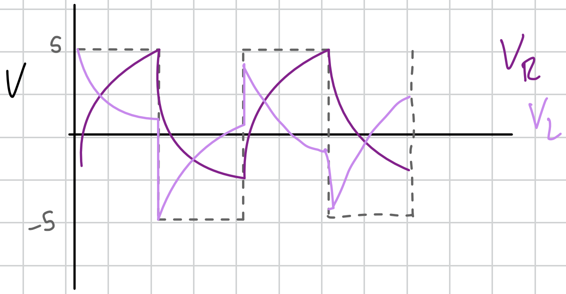
Replace C w/ L

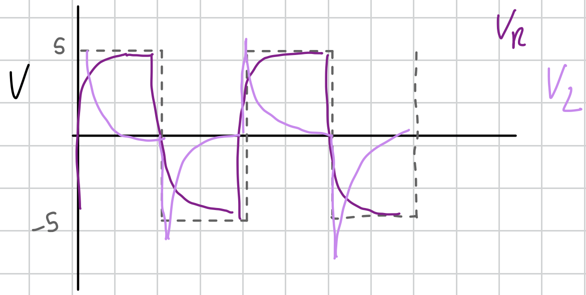


High Pass



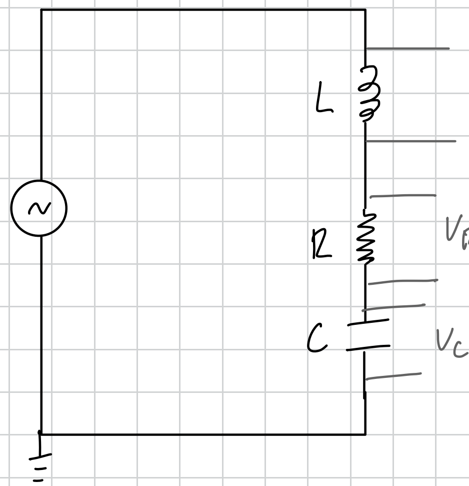
Low Pass





5 LRC circuit

1. Choose a resistor, an inductor and a capacitor from your parts box and measure their resistance, inductance and capacitance, respectively.
2. Use these values to predict the resonance frequency and the quality factor of your circuit. Be sure to propagate uncertainties as needed. Don't forget about the 50Ω in the source, as well as the internal resistance of the inductor.
3. Draw the circuit diagram for an RLC circuit using these parts and a sine wave generator.
4. Imagine you drove the system at resonance. Sketch a plot of what you expect the voltage across the resistor, inductor, and capacitor to look like. Pay attention to the relative magnitudes and phases.
5. Now, build your RLC circuit with these elements using the function generator as your source. Choose a sine-wave as source, and set the peak-to-peak voltage of your source to 1 V. Measure the voltages across all three circuit elements and display them together with your source voltage on the screen of the oscilloscope.
6. Tune the frequency of the source signal to resonance. In your notebook, comment on the relative phase shifts between the four signals displayed. Do they agree with your prediction above?
7. Determine the quality factor of the circuit from the traces displayed.
8. Compare the measured quality factor with the predicted one. Do they agree? You must give a quantitative answer.
9. Review the resonance curve that you measured in Lab 7 (voltages vs frequency) and explain why the curves for V_C and V_L are asymmetric. Be sure to understand how the capacitor and the inductor behave below and above resonance.



$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}} \qquad Q = \frac{1}{\omega_0 RC} = \frac{\omega_0 L}{R}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

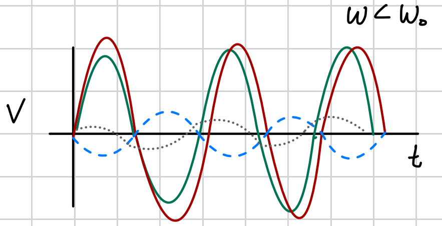
$\varphi_R = \varphi$ in phase w/ source

$\varphi_L = \varphi + \frac{\pi}{2}$ leads

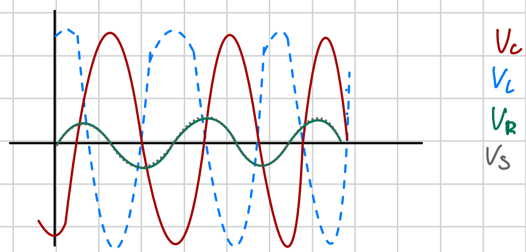
$\varphi_C = \varphi - \frac{\pi}{2}$ lags

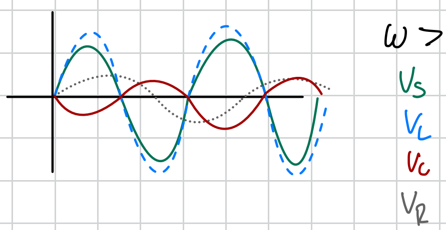
at reasonance

$\omega < \omega_0$



V_C is high at lower freq
V_L is lowr at low freq





$\omega > \omega_0$

Source and voltage perfectly in phase
V_C and V_L same amplitud π phase shift

at reasonance $V = \frac{I}{R}$

amplitude of the capacitor is lowered above reasonance
amplitude of inductor is higher

6 Transistor

Consider the following circuit:

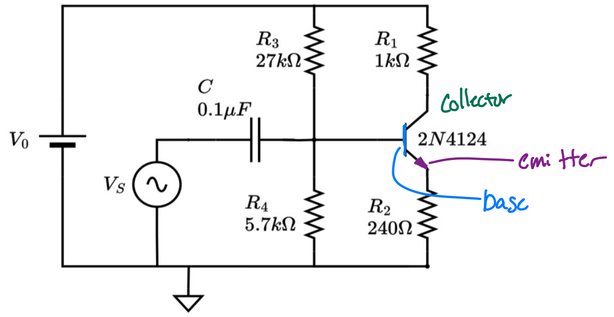
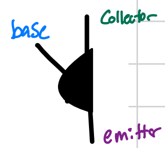
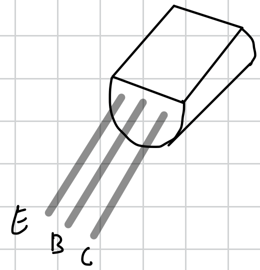


Fig. 2: A common emitter amplifier system.





1. Copy the circuit diagram in your notebook and mark base, emitter and collector with B, E and C, respectively.
2. What is the voltage drop across base-emitter?
3. What is the gain of this circuit (this is a *signed* number)?
4. What assumption is made about the base current?
5. Where in this circuit would you pick off the signal to measure (or use) the amplified source signal?

Voltage drop across the base-emitter is 0.7 V for a Silicon transistor

$$\text{gain} = \frac{V_{out} \text{ of base}}{V_{in} \text{ through emit}} =$$