Diode

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CO-526-B - Electronics Lab

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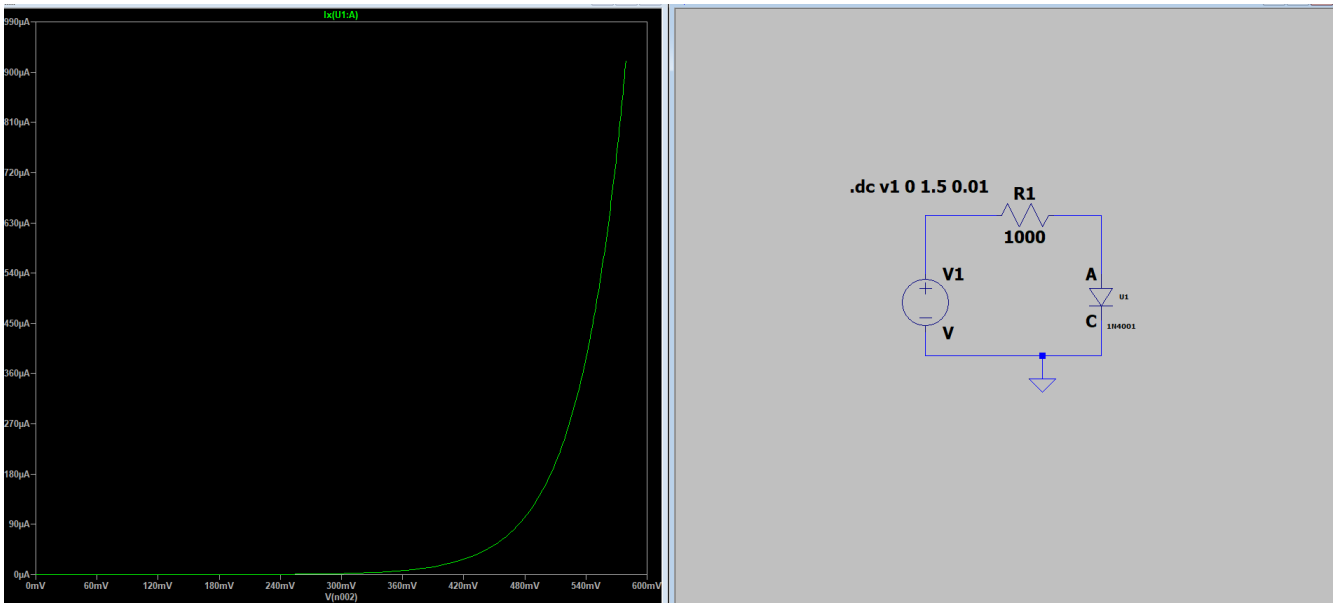
1 Introduction - Prelab

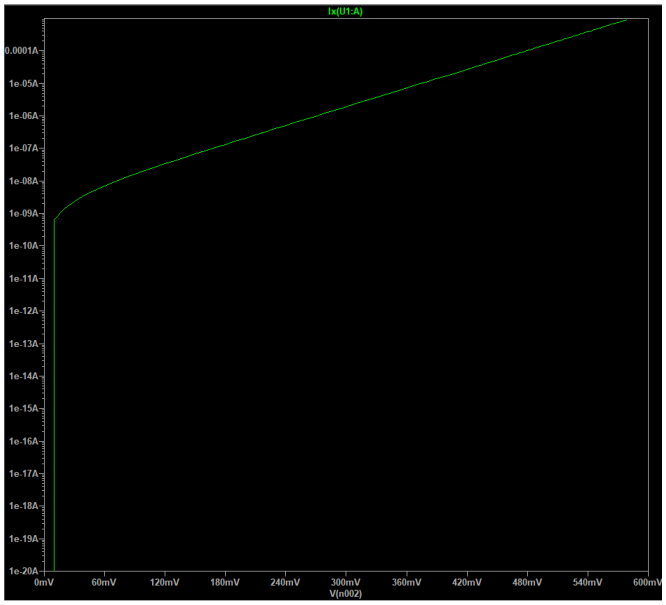
1.1 Current/ Voltage characteristics of a diode

1. Diode characteristic over a DC sweep analysis ($I_f = f(V_f)$).

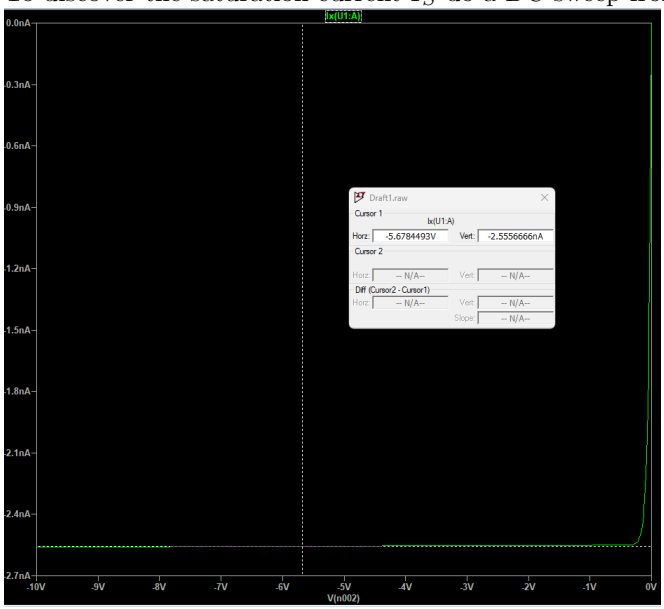


X axis: voltage over diode in respect to the ground, Y axis: current through the diode.

2. Same plot on a logarithmic scale:



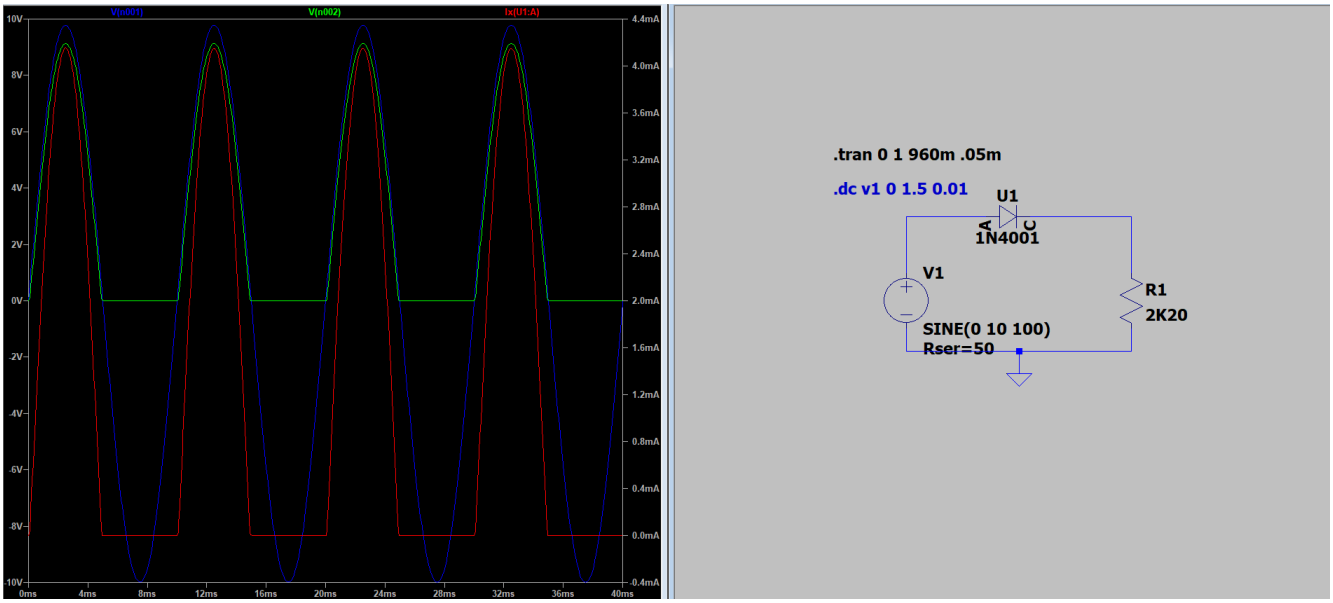
3. To discover the saturation current I_S do a DC sweep from -10 volts to 0.



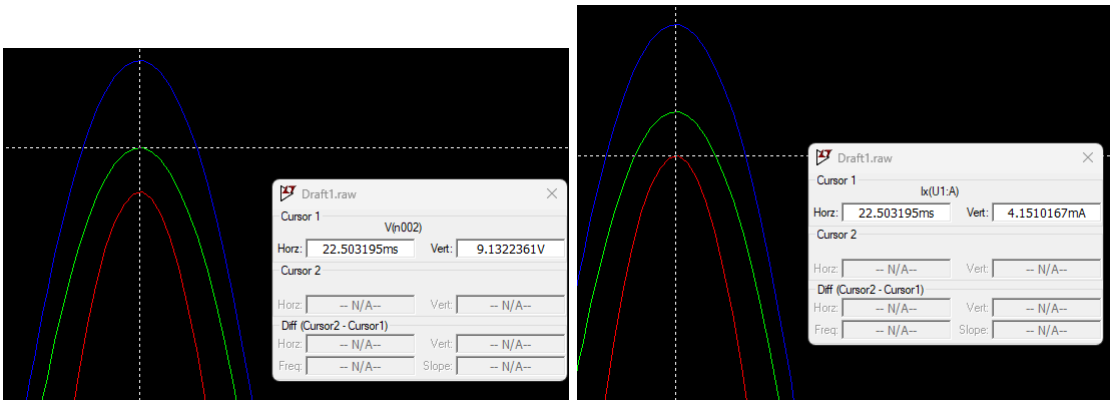
From the plot: I_S= -2.55nA.
Using the provided V_T= 26mV and the equation $I = I_S\ e^{(\frac{V}{nV_T})}$ (from the first plot V=500mV, I=160mA)
$n = \frac{V}{V_T ln(\frac{I}{I_S})} = 1.07$

1.2 Halfwave rectifier

1. Circuit without C1

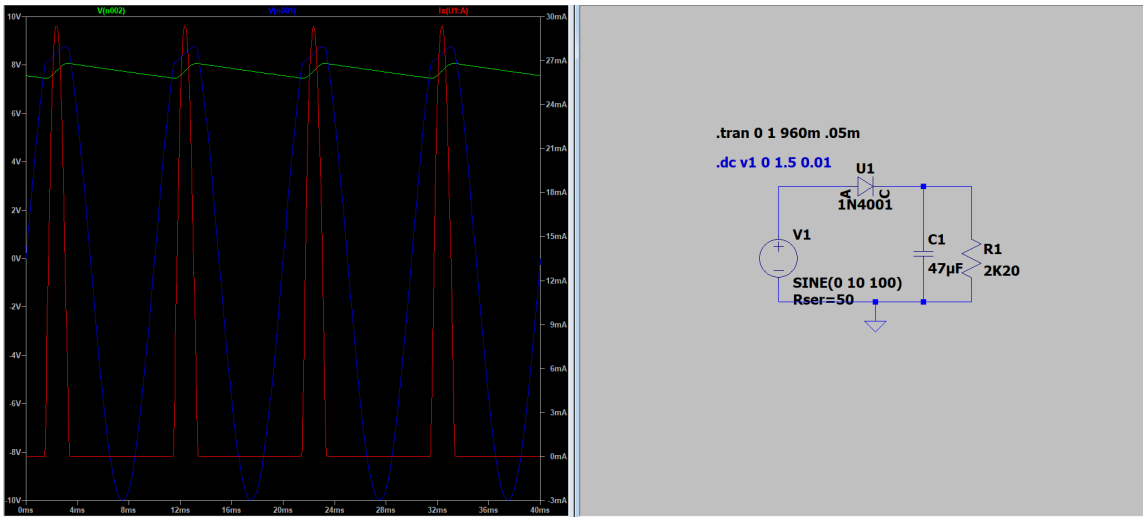


Blue line: V_{in}, green line: V_L, red line: I_D

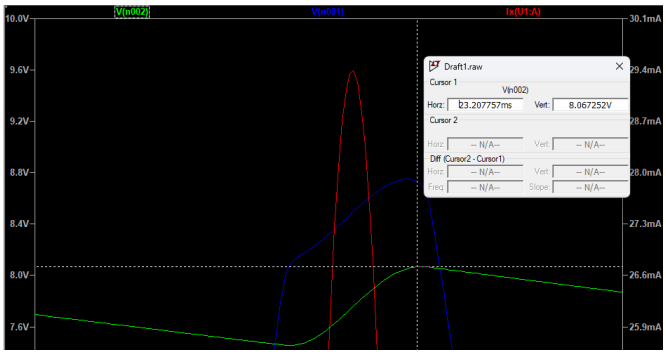


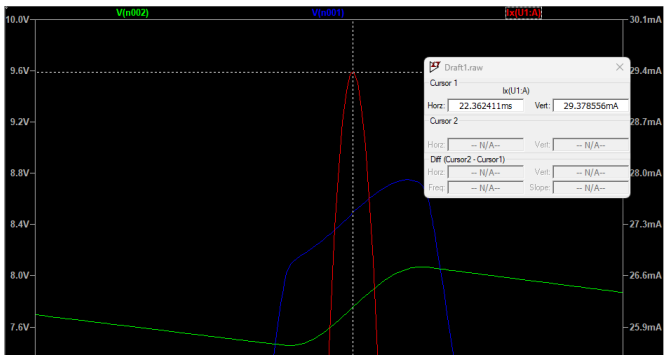
From the cursors: Peak R_V: 9.13V, peak I_D: 4.15mA.

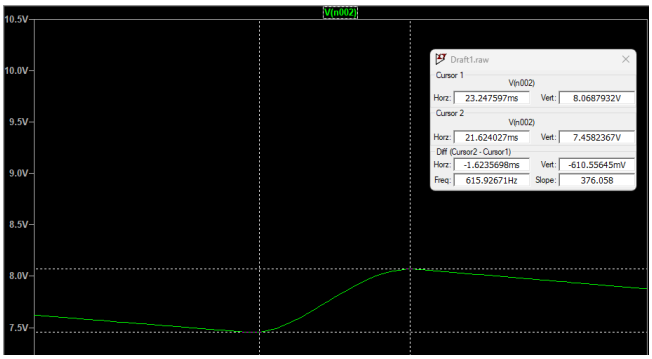
2. HWR with C1



Blue line: V_{in}, green line: V_L, red line: I_D





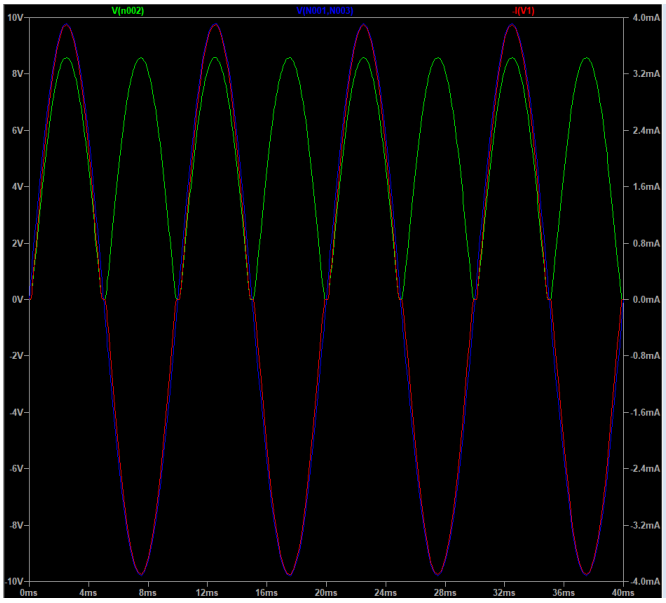


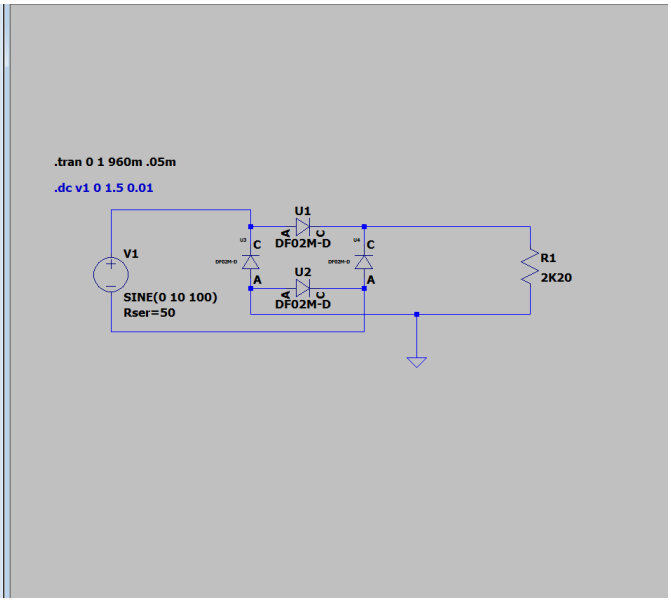
From the cursors: Peak R_V: 8.07V, peak I_D: 29.4mA, ripple on V_L: 610mVpp

Using the formula: $V_r = \frac{V_p}{fCR_L}(1 - \sqrt[4]{\frac{R_i}{R_L}})$
$V_r = 582\text{mV}$.

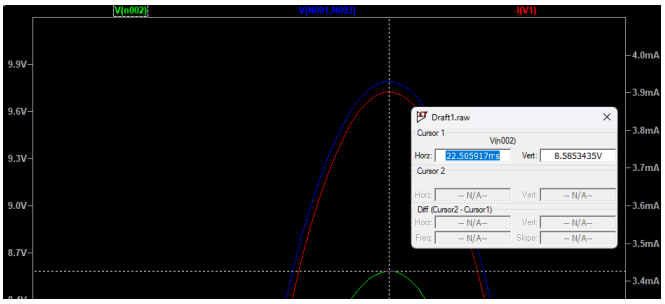
1.3 Fullwave rectifier

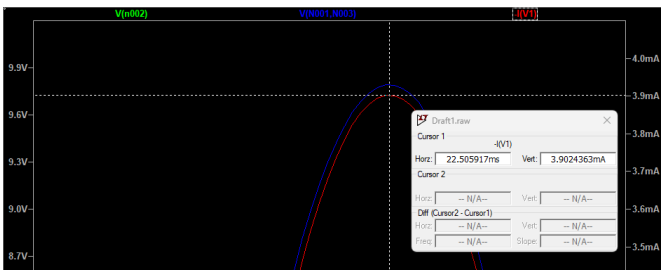
1. Circuit without C1





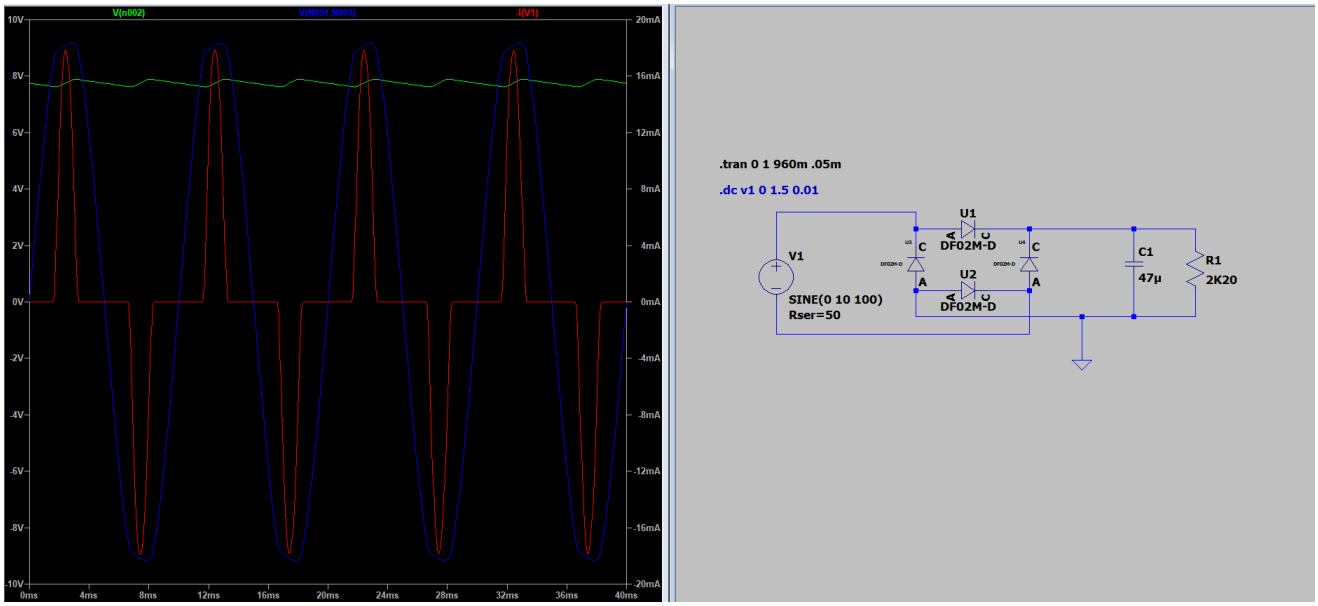
Blue line: V_{in}, green line: V_L, red line: I_D



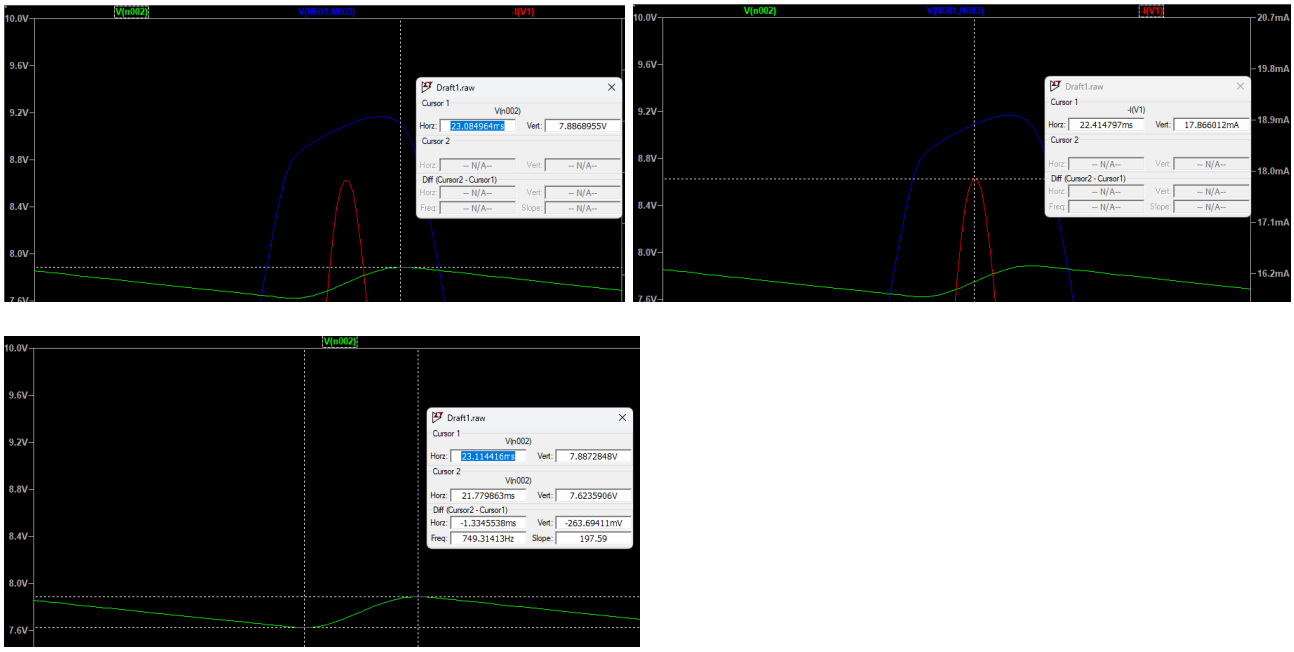


From the cursors: Peak R_V: 8.59V, peak I_D: 3.90mA.

2. FWR with C1



Blue line: V_{in}, green line: V_L, red line: I_D



From the cursors: Peak R_V: 7.89V, peak I_D: 17.87mA, ripple on V_L: 263mVpp

Theoretical ripple (half of HWR ripple): 291mV.

1.4 Rectifier

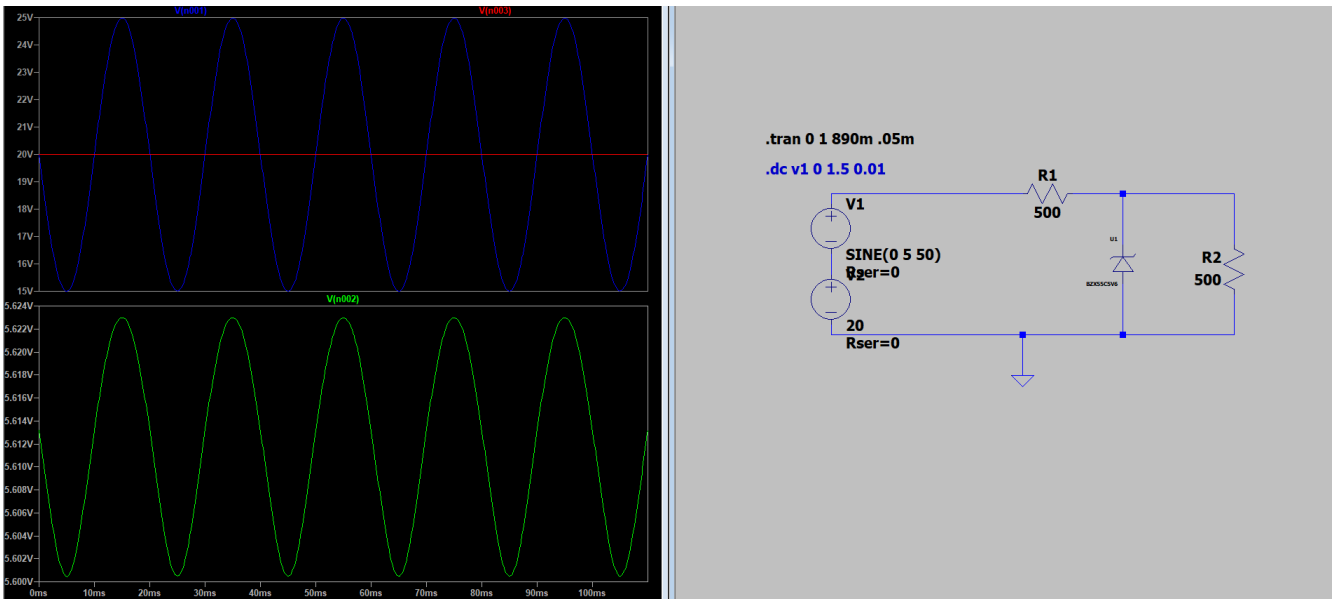
1. The peak load voltages without a capacitor are 9.13V and 8.59V. The voltage over the load it's smaller then the input sine amplitude because of the diode voltage drop, which is doubled in the full wave rectifier since the current passes through two diodes in series before reaching the resistor.

2. In both the HWR and FWR, I_D takes the shape of a sinusoid when there's no capacitor and follows the input voltage, delayed by the time it takes to reach VD_ON. When a capacitor is added to the circuit the current sinusoid is shrunk from the sides, that happens because it takes longer to reach VD_ON since the capacitor is providing a positive voltage to the diode cathode while discharging and after being charged.

3. The RC ratio influences the ripple, the bigger C and/or R is, the smaller the ripple will be, therefore a lighter load (higher resistance) and/or a bigger capacitor will provide a higher quality DC output.

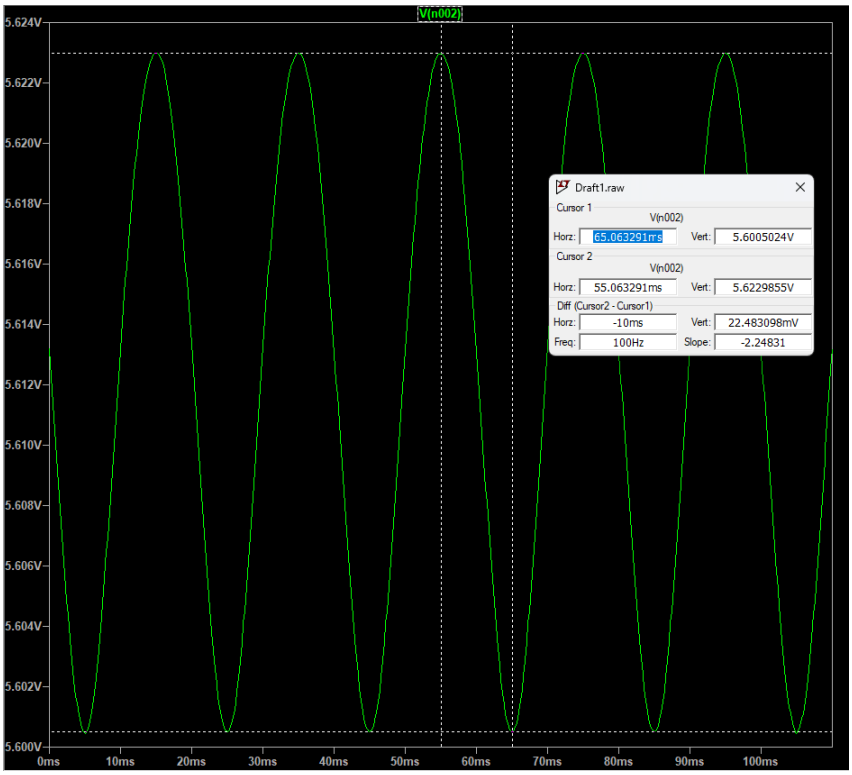
1.5 Zener diode

1. Transient analysis



Top pane: V_{in} (AC and DC), battom pane:V_L

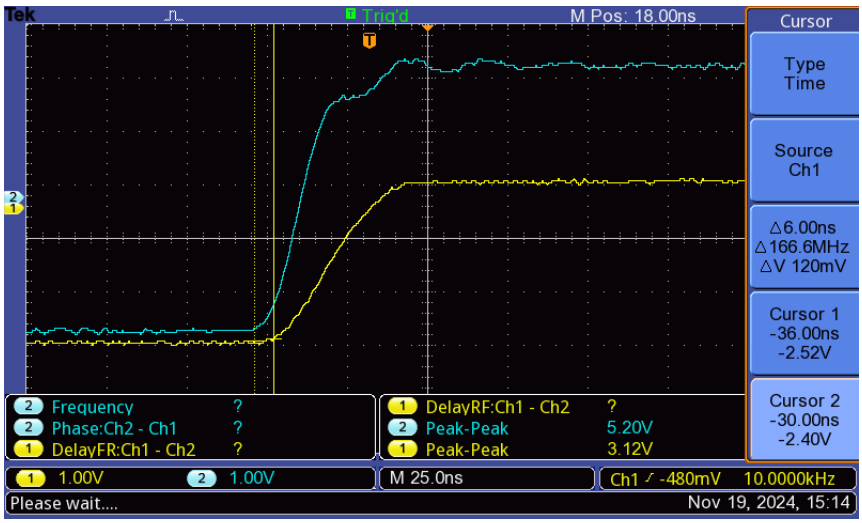
2. The circuit acts as a voltage regulator and maintains a constant voltage lower than both AC and DC sources. The regulated voltage is not perfectly constant but it's a sinewave with a small ripple of 22.5mVpp (see cursor below).



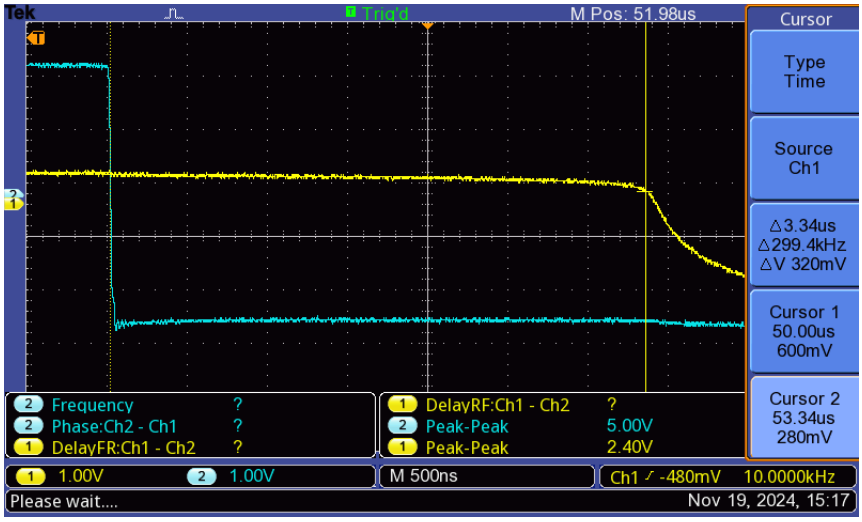
2 Experimental Set-up and Results

2.1 Diode Switching Characteristic

1. Diode 1N4001

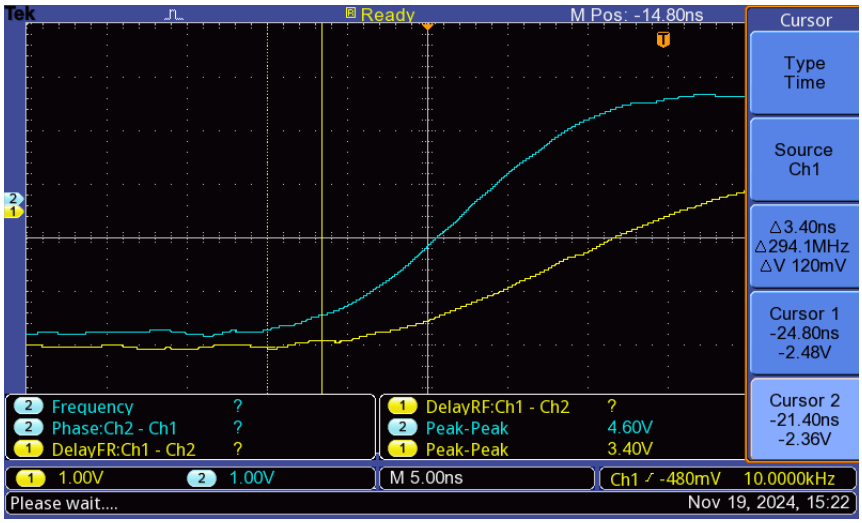


Measured t_d: 6ns.



Measured t_s: 3.34μs.

2. Signal diode 1N4148



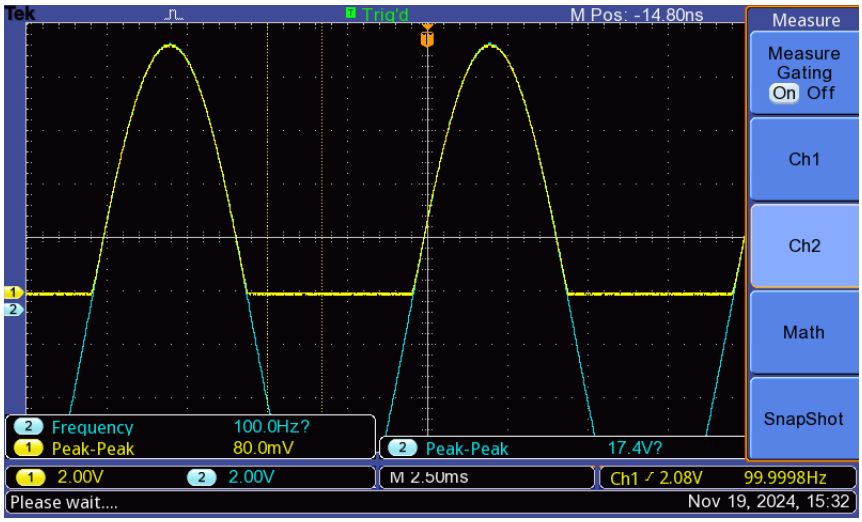
Measured t_d: 3.4ns.

Measured t_s: 0.01μs.

2.2 Rectifier

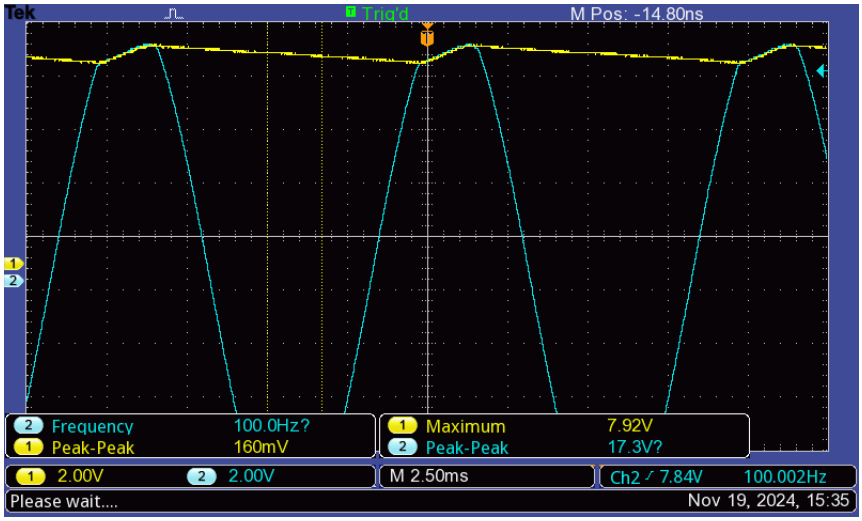
1. Half-wave rectifier

   (a) HWR without C1



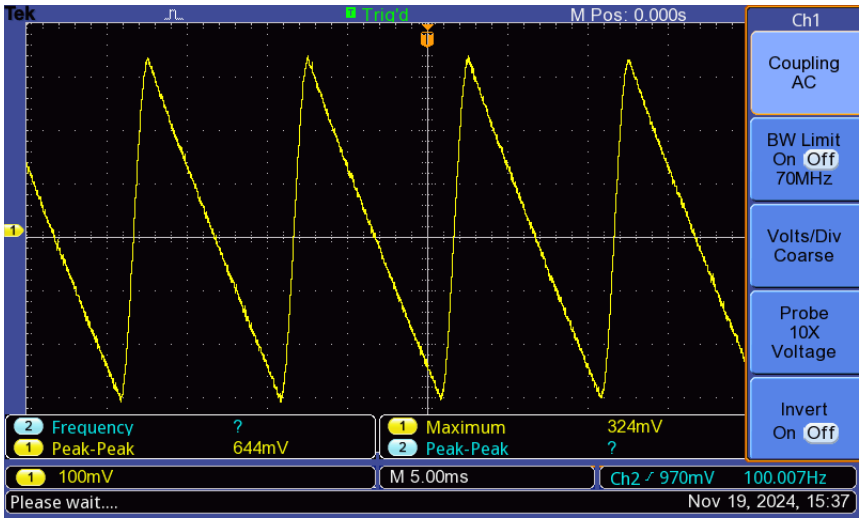
Since the peak to peak voltage of V_{in} is 17.4V its peak voltage is 8.7V, which is the same as V_L peak, since it takes only the top part of the sinewave

(b) HWR with C1



The peak voltage of V_{in} is the same as without C1, V_L peak voltage is 7.92V.

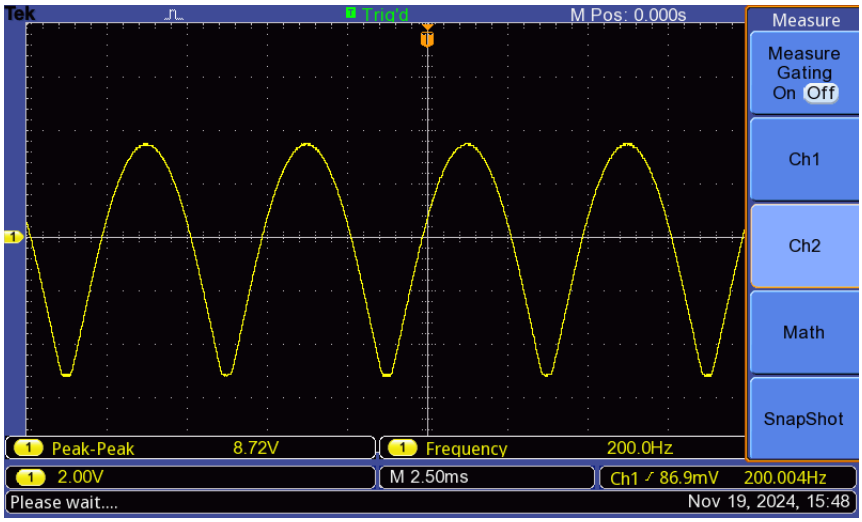
(c) Ripple voltage measurement



The peak to peak voltage of the V_L ripple is 644mV.

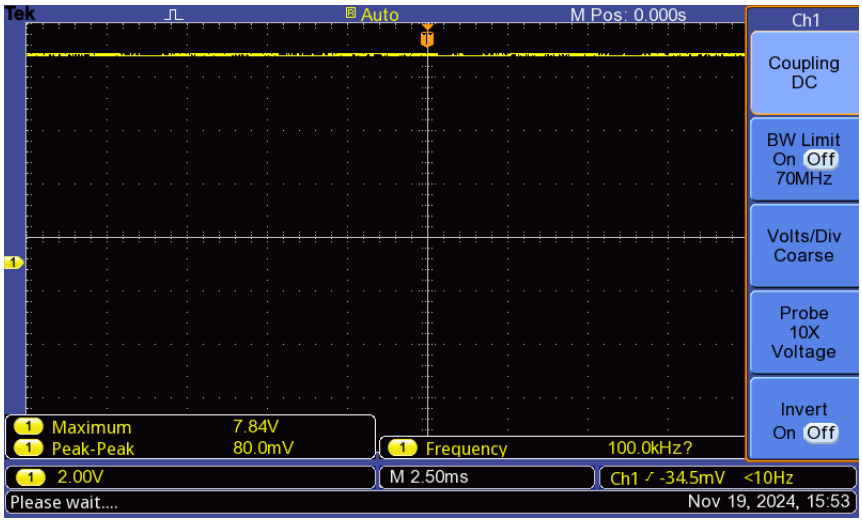
2. Full-wave rectifier

(a) HWR without C1



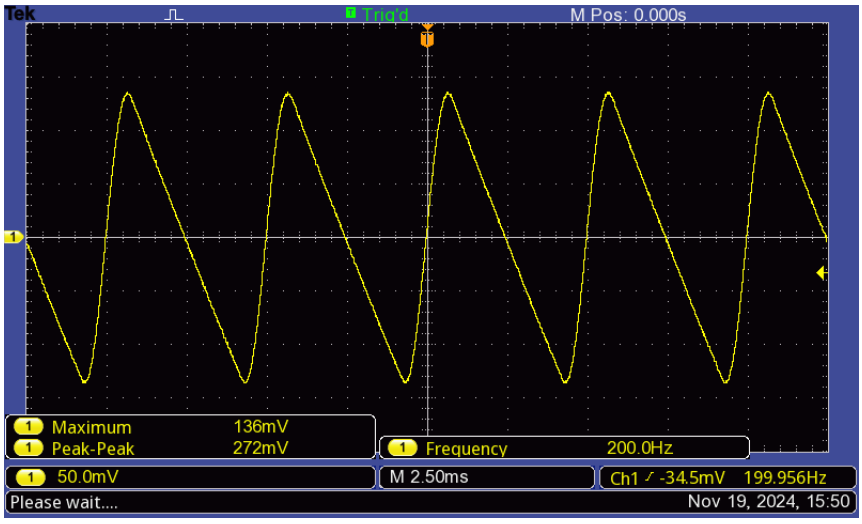
Since V_L has an halh sinusoid shape, the peak voltage is the same as peak to peak, so peak of V_L is 8.72V.

(b) HWR with C1



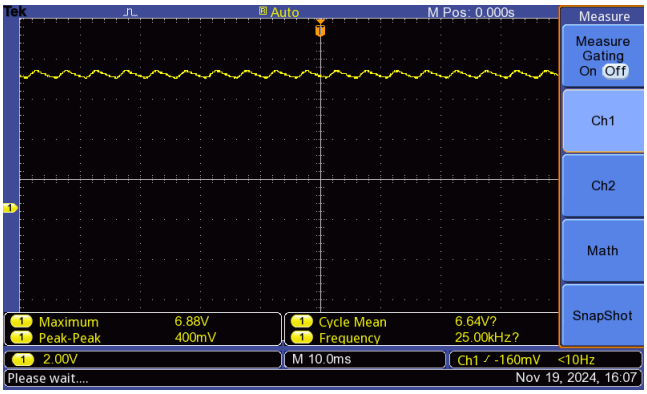
Using C1, the peak V_L is 7.84V.

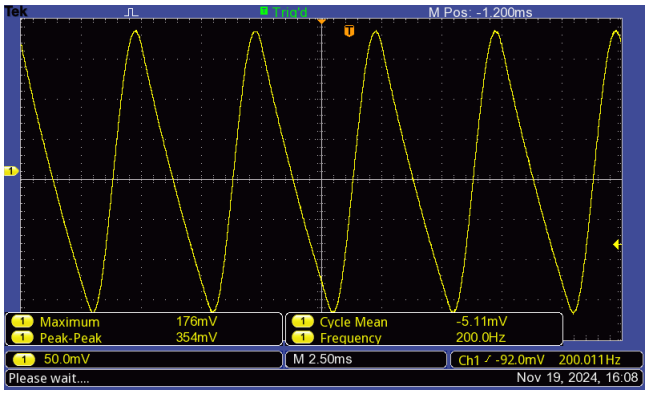
(c) Ripple voltage measurement



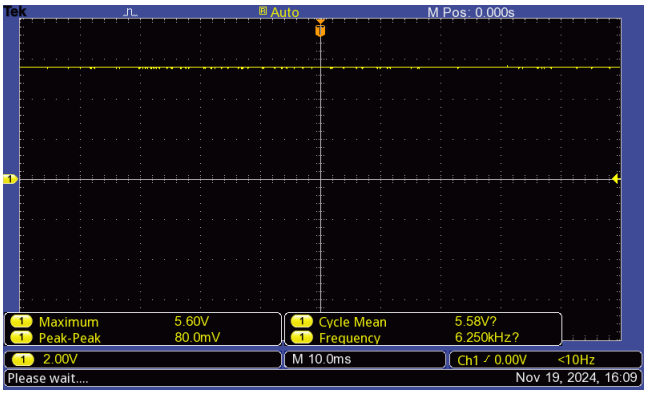
The peak to peak ripple voltage on top of V_L is 272mV.

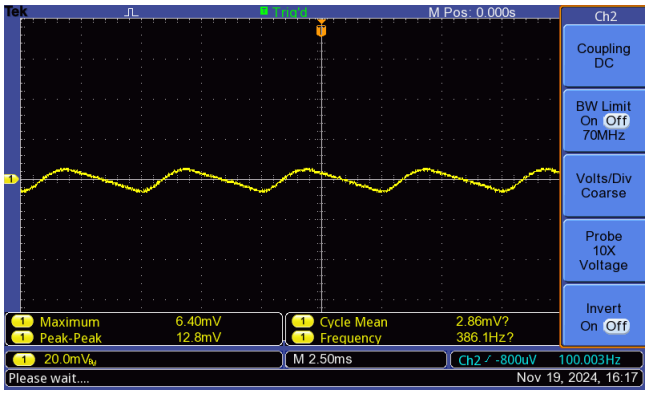
2.3 Zener diode





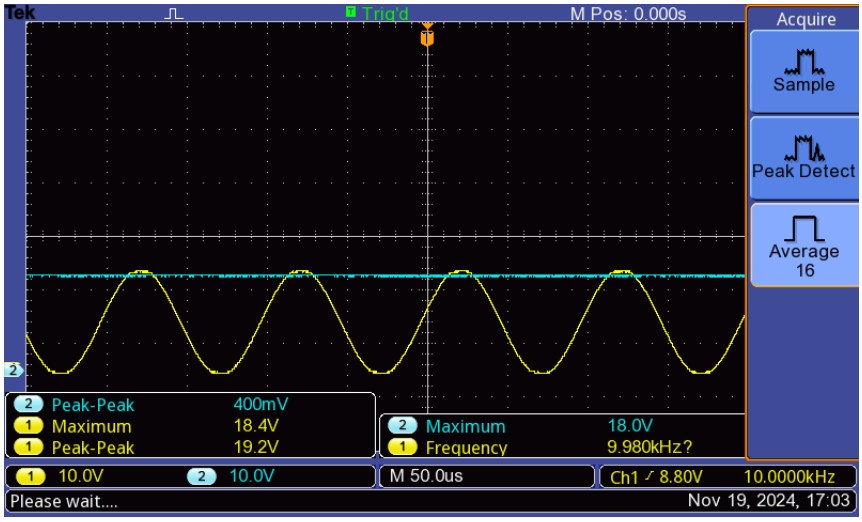
The DC voltage at C1 is 6.88V and the peak to peak ripple voltage is 354mV.



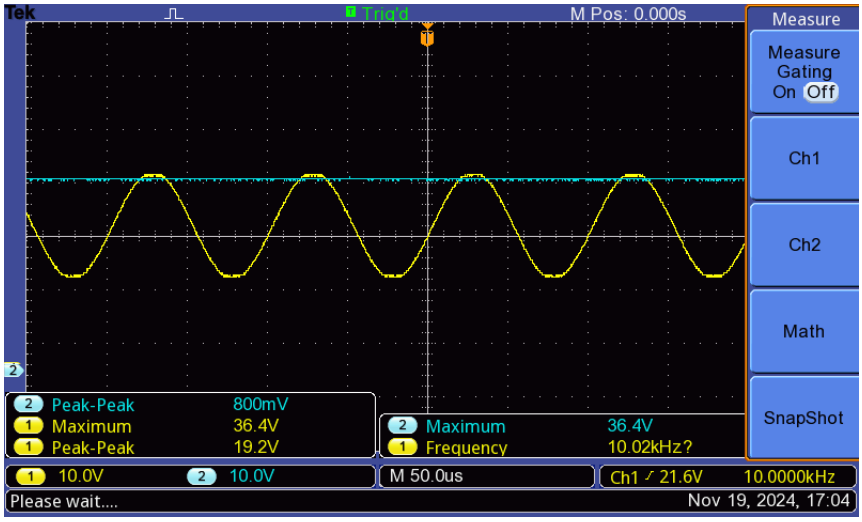


The DC voltage at the load resistor is 5.60V and the peak to peak ripple voltage is 12.8mV.

2.4 Voltage multiplier

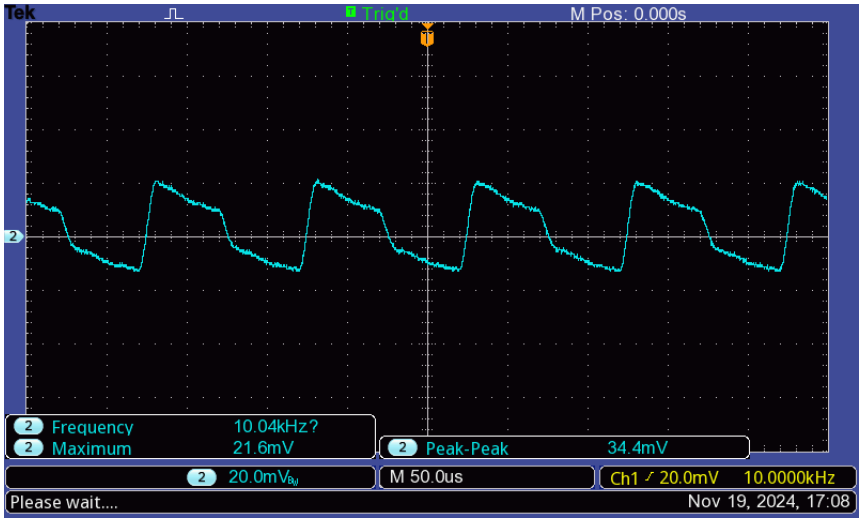
1. 

   At point A the peak to peak voltage is 19.2V and max 18.4V(channel 1), at point C the max voltage is 18.0V (channel 2).

2. 

   At point B the peak to peak voltage is 19.2V and max 36.4V(channel 1) , at point U_{out} the peak voltage is 36.4V, the voltages have the same shape as the two previous points but shifted up in max value.

3. Ripple voltage measurement



   The peak to peak ripple voltage at U_{out} is 34.4mV.

4. The measured voltages at points C and U_{out} are respectively 17.75V and 35.495V.

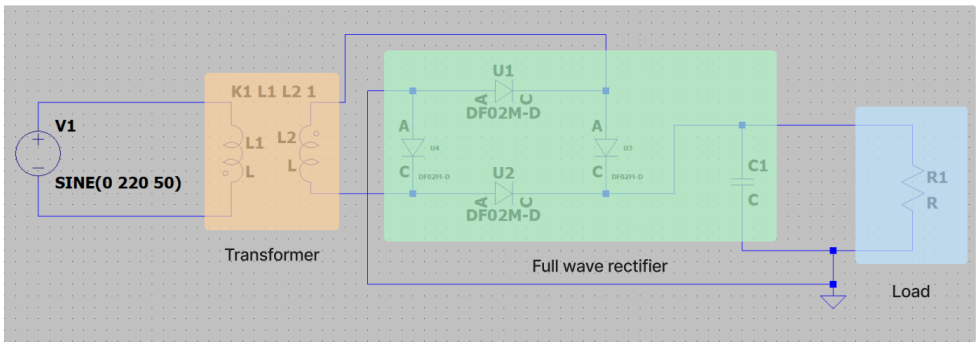
3 Evaluation

3.1 Diode Switching Characteristic

1. The signal diode 1N4148 is much faster in switching off compared to the 1N4001 diode, the latter probably has a larger depletion region and is probably designed to handle more power than the former.

2. The signal diode 1N4148 is best used in signal handling operations where the currents handled are minimal but high time precision is required, the 1N4001 diode is best use in less time sensitive scenarios like a rectifier circuit where higher currents must be handled.

3.2 Rectifier

1. 

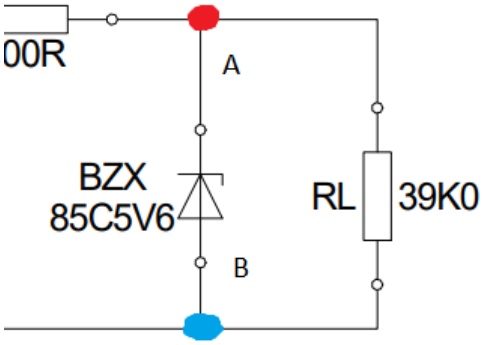
   To have a DC power supply we need two main components:

   (a) Transformer: used to decrease the voltage from the power line to a more manageable value with limited power loss.

   (b) Full wave rectifier: used to convert from AC to DC, the use of a capacitor is needed to limit the ripple as much as possible, in this way the DC output is of a high quality.

2. Simulated peak to peak ripple voltages: HWR: 610mV, FWR: 263mV. Calculated peak to peak ripple voltages: HWR: 582mV, FWR: 291mV. Measured peak to peak ripple voltages: HWR: 644mV, FWR: 272mV.
   The measured ripple voltages are consistently around 4% higher than the simulated voltages. While the calculated HWR ripple is smaller then both the simulated and measured voltage, the calculated FWR ripple is highter then both the simulated and measured ripples.

3.3 Zener diode

1. 

   Since the voltage over R_L is the same but reversed voltage over the zener diode (since the component is placed in the opposite direction compared to R_L), it has a voltage -5.60V, by looking at the component datasheet the current (flowing from point A to point B) is 5mA.

3.4 Voltage Multiplier

1. The voltage multiplier circuit is made of rectifier circuits and positive clamper circuits

2. The function of the rectifier component is ton convert the positive part of the AC signal to DC, the function of the clamper component is to add a DC signal to an AC one, to increase the RMS voltage.

3. The multiplication factor between the input amplitude and the output voltage is 2, the theoretical output voltage should be 40V but the measured one is 36.4V, this is due to the voltage loss in the non ideal diodes.

4. Each element has to be selected for the max voltage the component is subjected to, which is the max voltage present in the circuit "step" where the component is inserted.

5. By reducing the input frequency the voltage at U_{out} will decrease and the ripple will increase by a factor of around 100.