Analog Electronic Circuits Lab

Lab Report: Experiment-3 – Full Wave Rectifiers
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The objective of this lab is to study and analyze **Full Wave Rectifiers (FWR)** using:

1. A **center-tap transformer** and two diodes.
2. A **bridge rectifier** using four diodes.

Additionally, the experiment involves **Transformer characterization** and frequency response analysis.

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1. Transformer Characterization

Procedure & Observations

1. **Input Signal:** A sine wave of **12Vpp, 1kHz** was applied using the function generator.
2. By using Center-tap terminal as common ground and Connect **Channel 1 of the DSO** to **VA** terminal, Connect **Channel 2 of the DSO** to **VB** terminal
3. **Measurement:** VA and VB were observed on **DSO (Digital Storage Oscilloscope)**.
4. **Phase & Amplitude Difference:**
    - The amplitude and phase difference between **VA** and **VB** were recorded.
    - **VA – VB =** 800mV and **Phase = 180° .**
    - The turns ratio N_1:N_2 was estimated based on VS = VA - VB.
    - **VP=** 12**V**pp/2 = 6V and **Vs=VA – VB .**
    - **VP/VS**=6000mV/800mV=**7.5=N1:N2 .**

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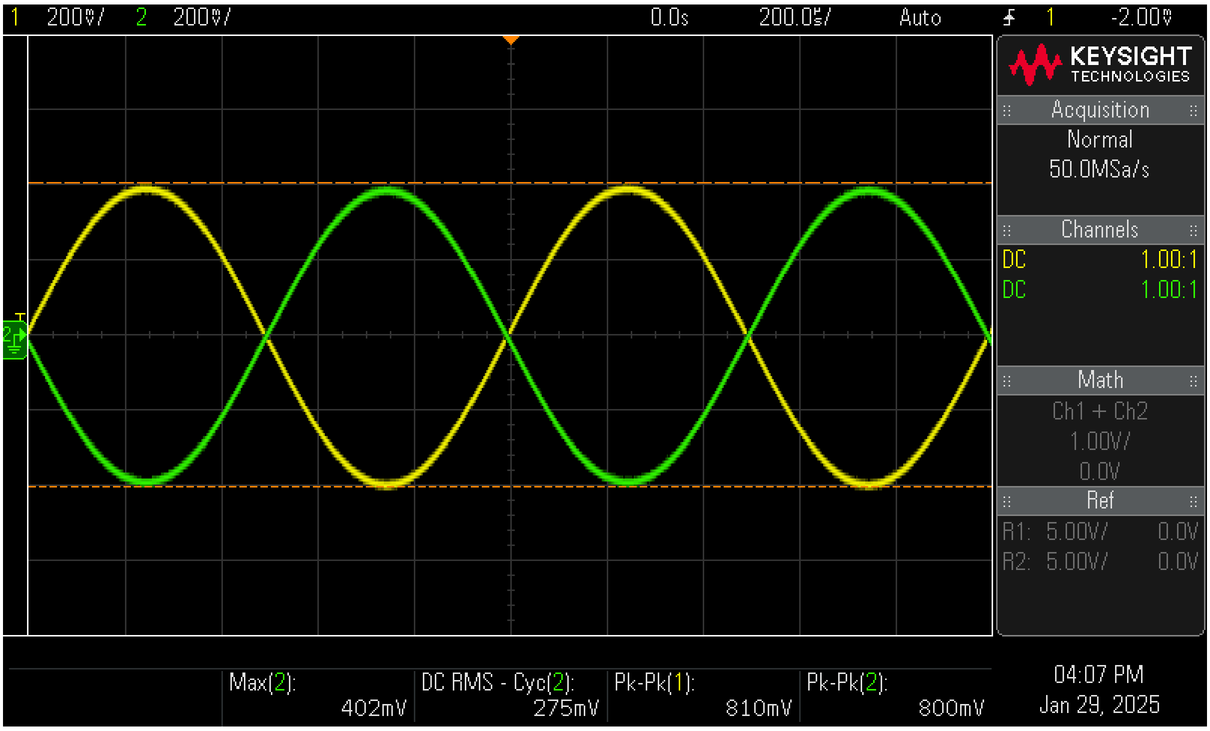

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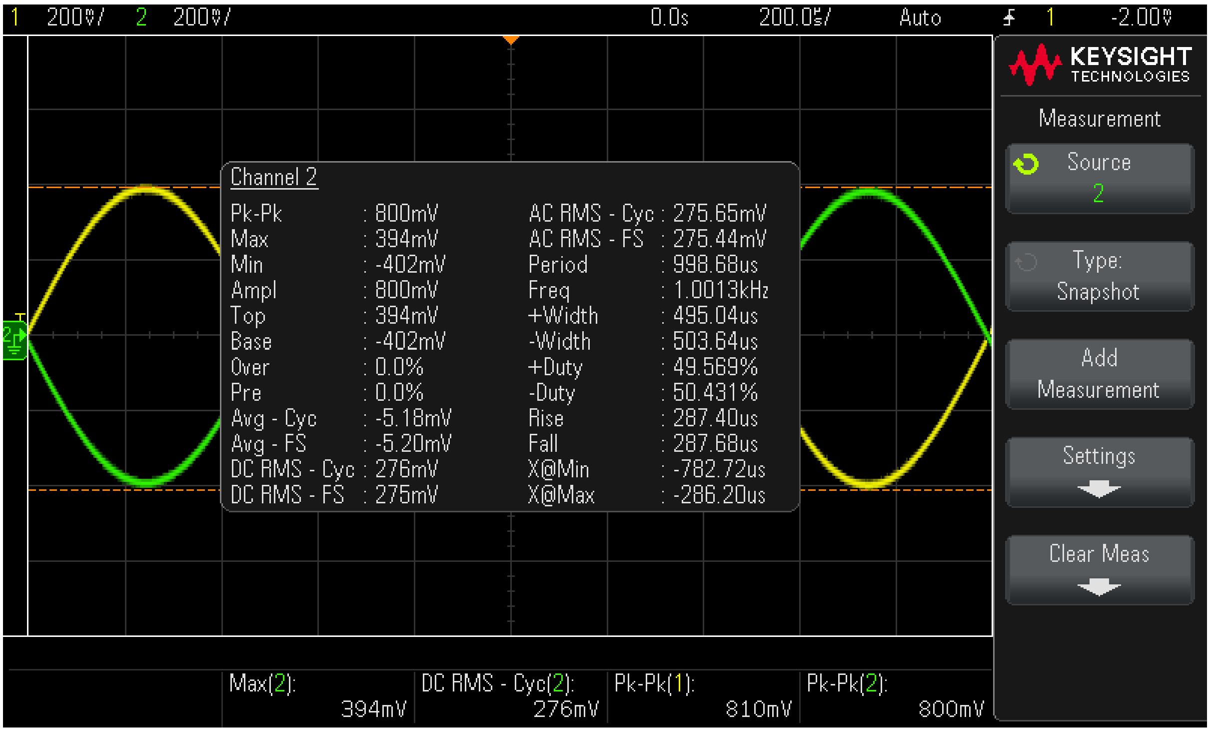
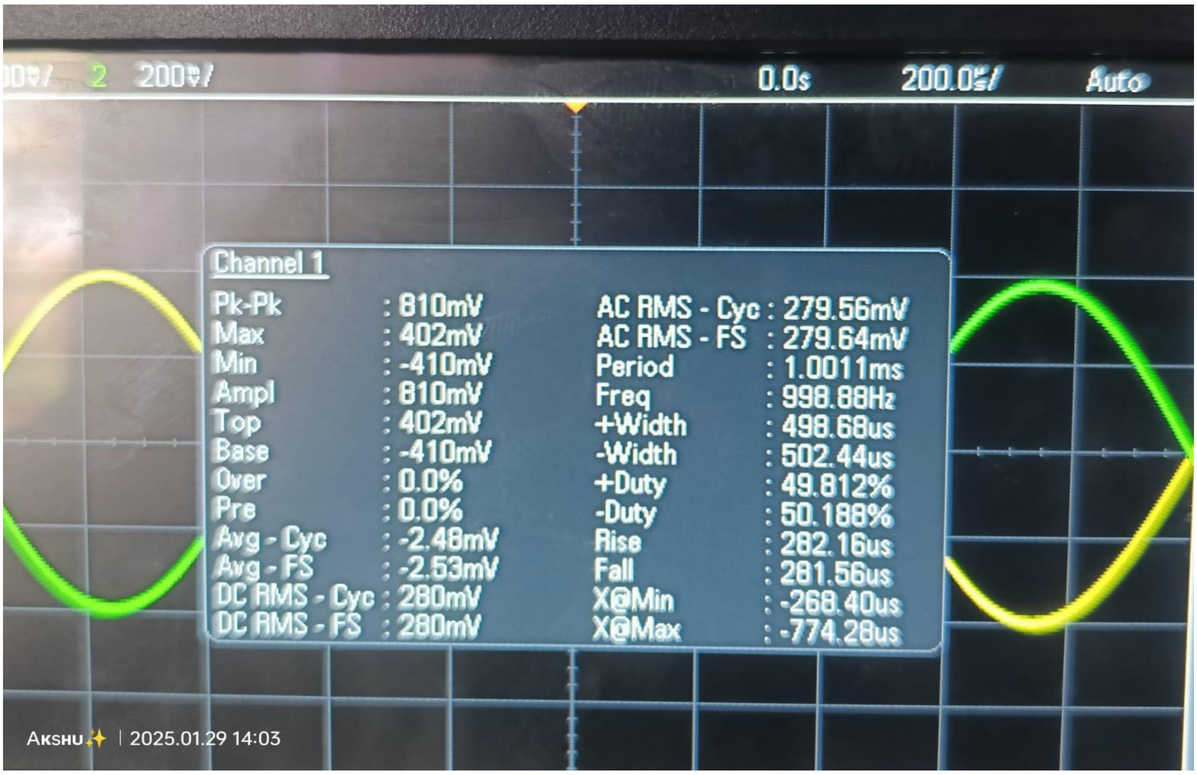
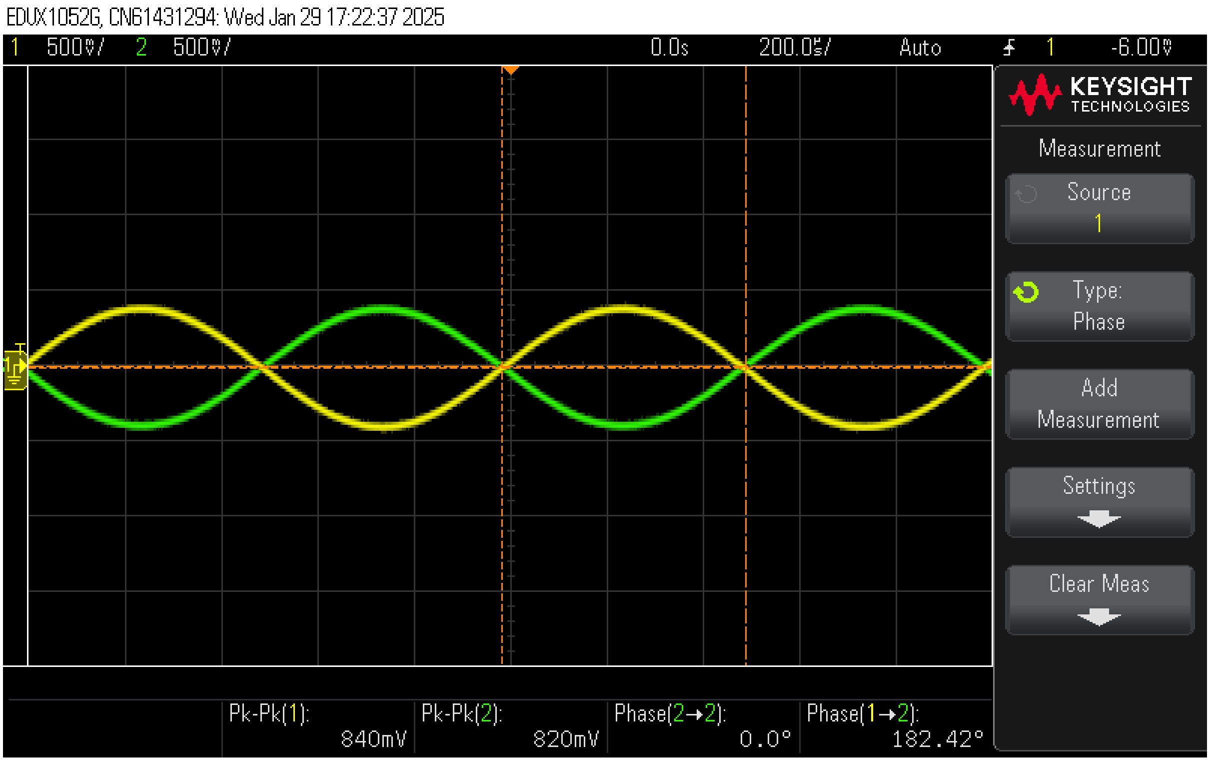
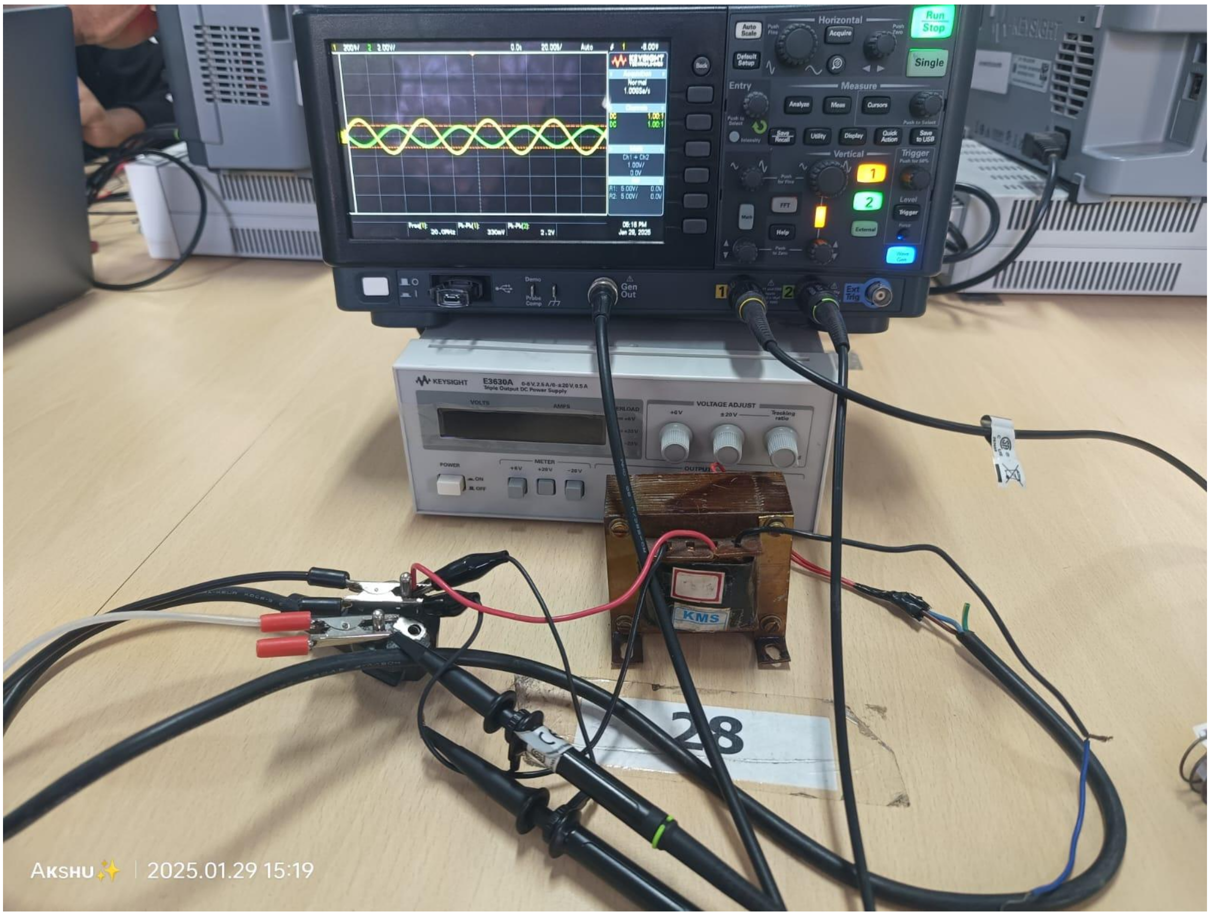






5. **Frequency Response Analysis:**
   - The experiment was repeated for **10 kHz, 50 kHz, 100 kHz, 1 MHz, 5 MHz, 10 MHz, and 20 MHz**.
   - The amplitude of **VA** was recorded at each frequency and presented in the table below:

Frequency (Hz)	Amplitude (VA) in mV	Amplitude (V_{in}) in V
10 kHz	405	12.1
50 kHz	405	12
100 kHz	415	12
1 MHz	480	11.8
5 MHz	160	7
10 MHz	600	4.4
20 MHz	160	2.1



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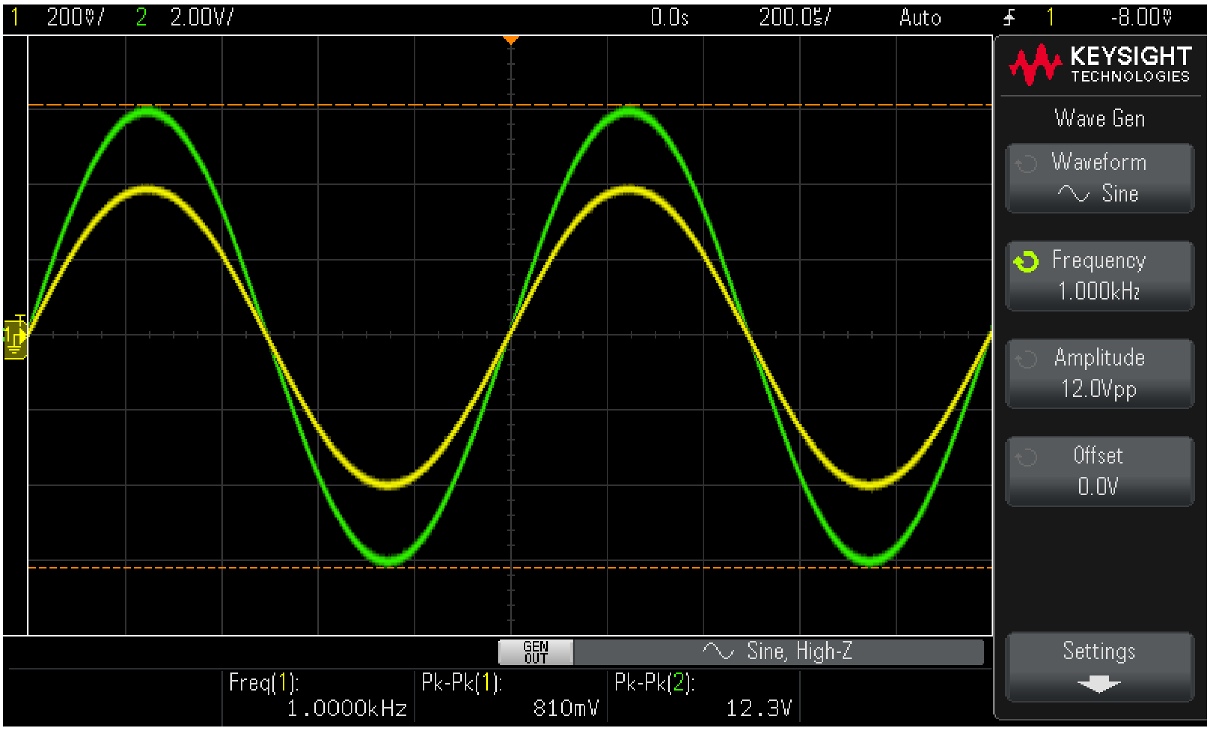

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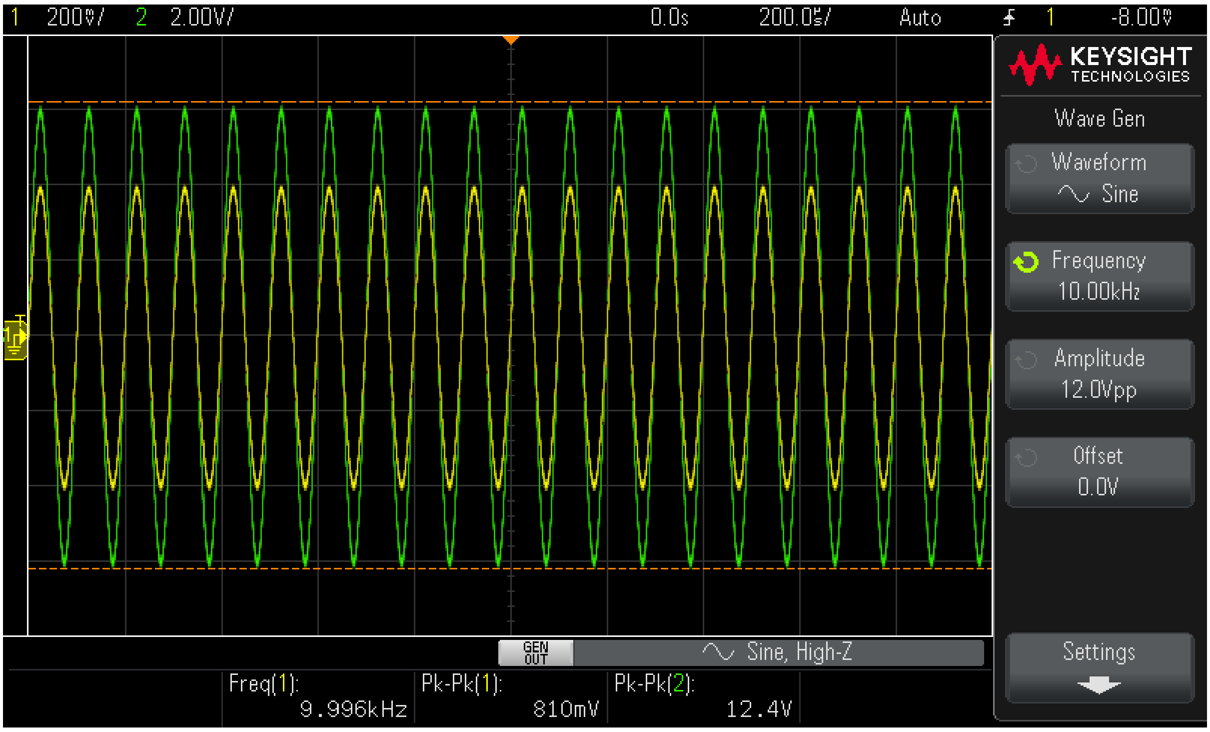

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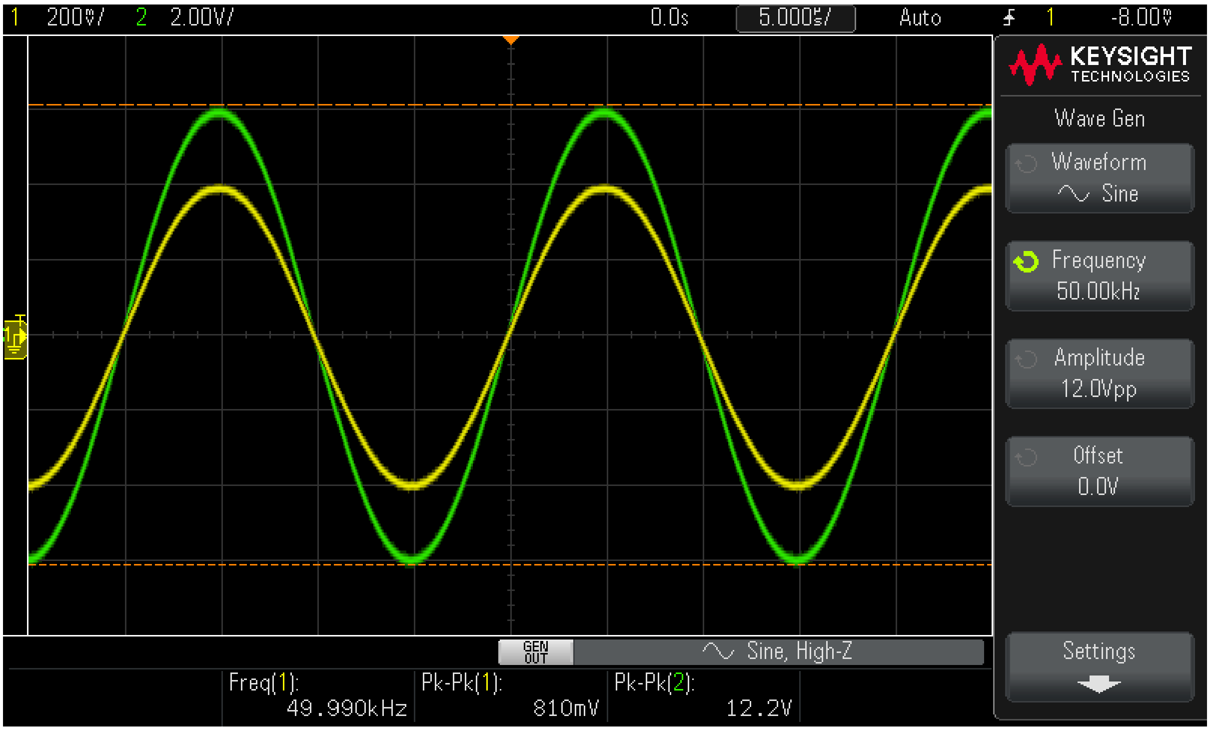

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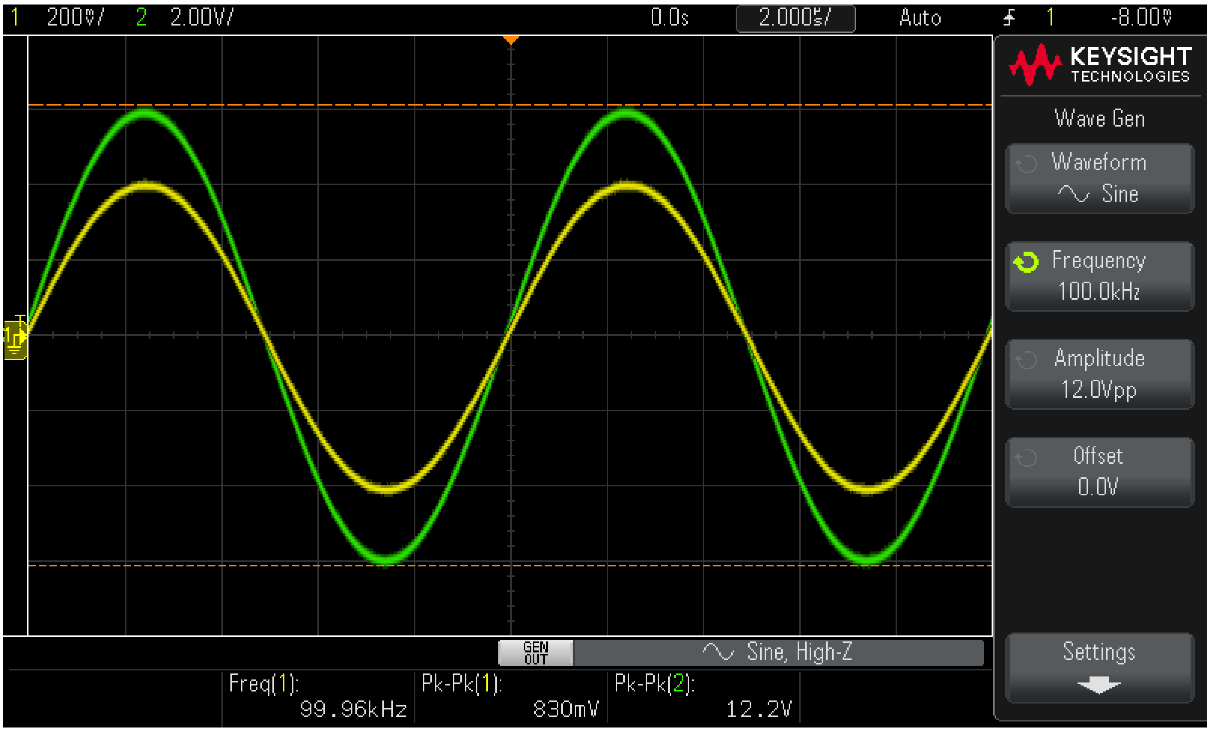

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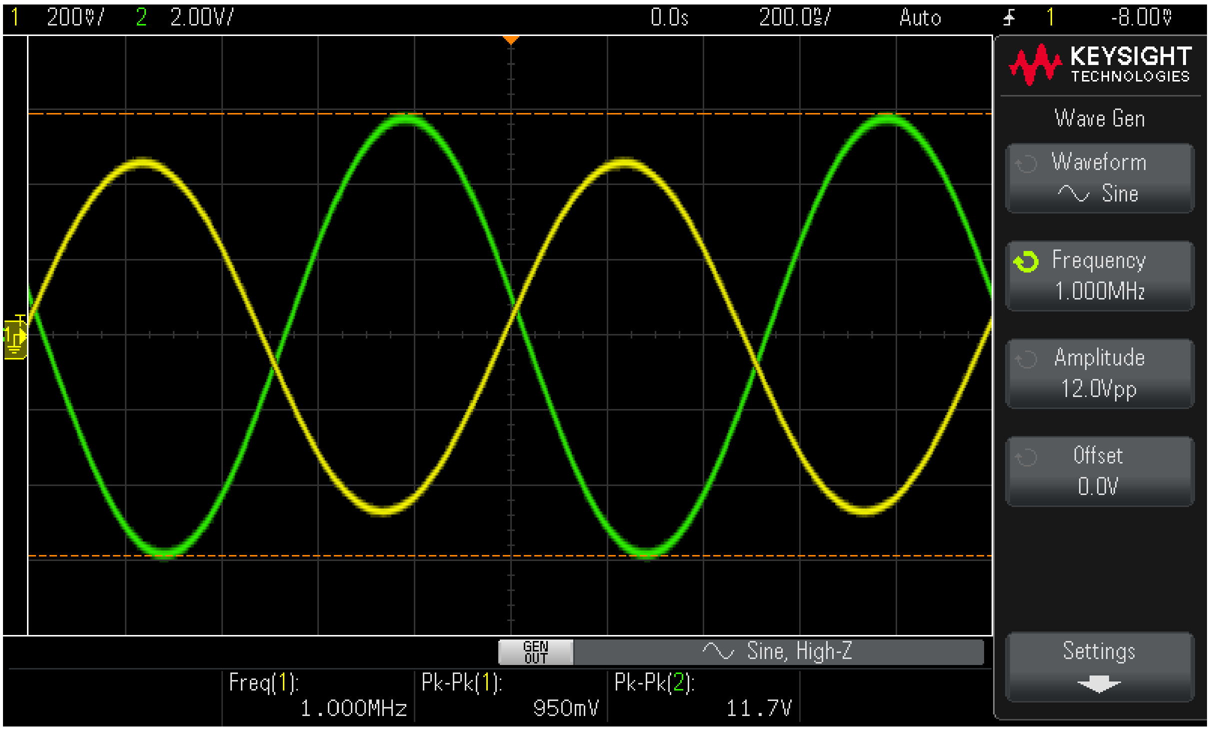

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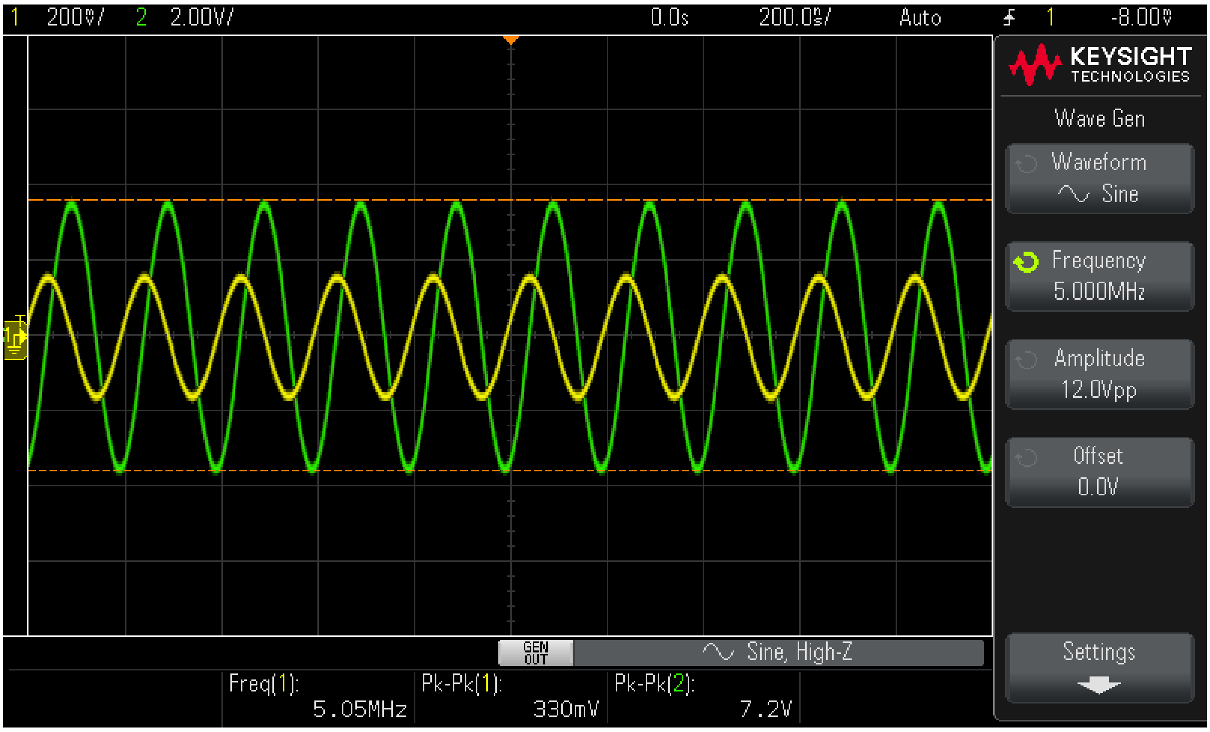

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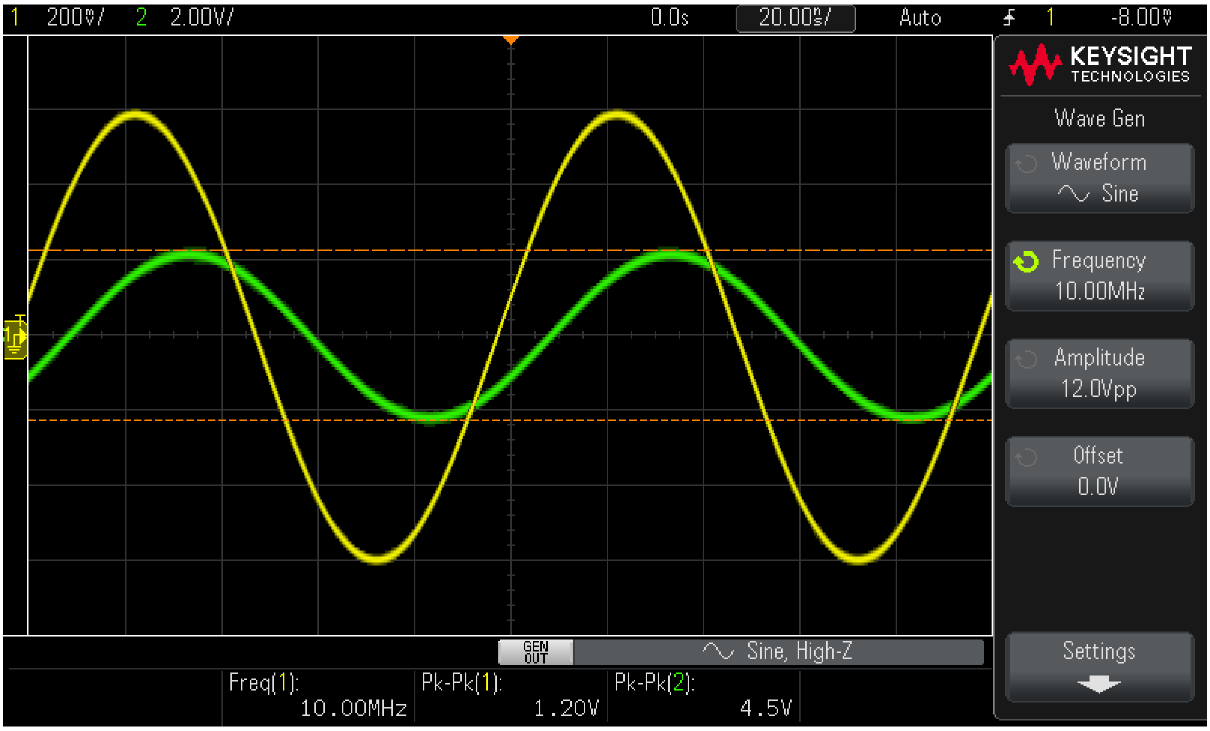

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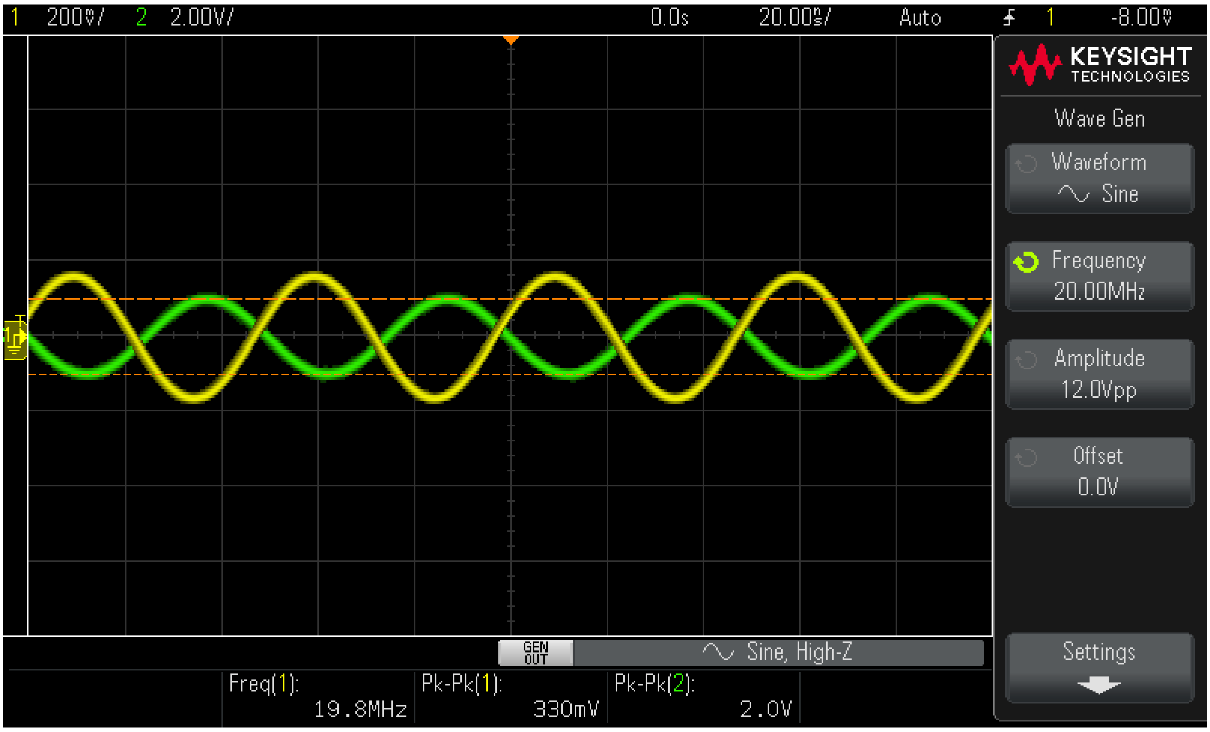

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Lab-3 / class-4 (104)

$V_A = 405\,mV$ (Yellow) (K letter T) channel-1

$V_B = -400\,mV$ (green) (~~black on~~ T) S (letter)

$V_A - V_B = 800\,mV$ (Amplitude)

ϕ difference $= \pi^c\,(180^\circ)\ (179^\circ - 182^\circ)$

$V_p = 12V_{pp}/2 = 6V$

$$\frac{V_p}{V_s} = \frac{6000\,mV}{800\,mV} = 7.5$$

S.No	f	V_A (channel-1)	Vin
1	10KHZ	405mV	12.2
	50KHZ	405mV	12.2
2.	100KHZ	415mV	12.2
3.	1MHZ	480 mV	11.8
4.	10MHZ	0.6V	4.4V 7V
5.	5MHZ	0.16V	
6.	20MHZ	0.16V	2.1V

6. **Effect of Frequency on input , output and several factors :**

- The magnitude of VA_AA initially increased, followed by a sudden drop and a slight increase.
- The probe wire may be acting as a low-pass filter, allowing only low-frequency inputs to pass while attenuating high-frequency signals.
- Every cable has a specific impedance, which affects the flow of alternating current.
- At higher frequencies, the impedance of the cable increases, leading to signal attenuation and a reduction in amplitude.
- The limited bandwidth of the input cable contributes to the reduction in amplitude with increasing frequency.
- The bandwidth of a cable is the range of frequencies that can pass through it with minimal attenuation. If the bandwidth is limited, attenuation at higher frequencies occurs, reducing the signal amplitude.
- As the input voltage frequency increases, a gradual decrease in peak voltage (Vp_pp) is observed, with a sudden drop at certain points.
- Several factors contribute to the lower-than-expected output of a step-down transformer when a high-frequency signal is applied:

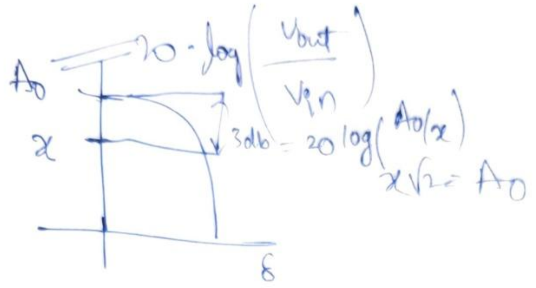
- Impedance Mismatch: If there is a mismatch between the transformer and the load, the signal may be reflected back to the source, reducing amplitude.
- Core Saturation: A high-frequency signal may saturate the transformer core, reducing its ability to step down voltage and leading to a drop in output voltage.
- Resonance Effects: The transformer may resonate at a specific frequency, causing a noticeable reduction in output voltage at that frequency.
- A reduction in amplitude was observed as frequency increased.
- Possible reason: Parasitic capacitance and limited bandwidth of the transformer.
- At higher frequencies, **eddy currents** increase in the transformer core, causing **power losses, heating, and additional resistance**, which lead to a **drop in output voltage and efficiency**.

7. **Bandwidth Measurement:**

   - **-3 dB bandwidth** was determined using the DSO by noting the frequency at which the amplitude dropped to **70.7% of its maximum value**.
   - **Plots** of **input (VP) and output (VA, VB)** were attached for reference.

   Explanation and Conclusion:

   The -3 dB bandwidth of the cable was determined by measuring the output amplitude (VA) at different frequencies. The initial input signal from the function generator was 12 Vpp at 1 kHz, with VA recorded. As the frequency increased from 10 kHz to 20 MHz, the amplitude of VA decreased, and the phase difference between the input and output signals was noted. Initially, at 1 kHz, the phase difference was minimal (close to 0°), but as the frequency increased, the phase difference reached 45° at the -3 dB point, indicating significant phase shift due to the cable's frequency response. The -3 dB point was identified when VA dropped to 70.7% of its initial value, which corresponds to the -3 dB bandwidth of the cable. This was approximately 4.4 MHz. The reduction in amplitude and the phase shift are due to parasitic effects like capacitance and resistance within the cable, limiting the transmission of high-frequency signals. The input-output voltage plots and phase shifts, with the -3 dB point clearly marked, are attached.



$3dB = 20\log A_0 - 20\log x$

$A_0 = 1$ as it passes all values

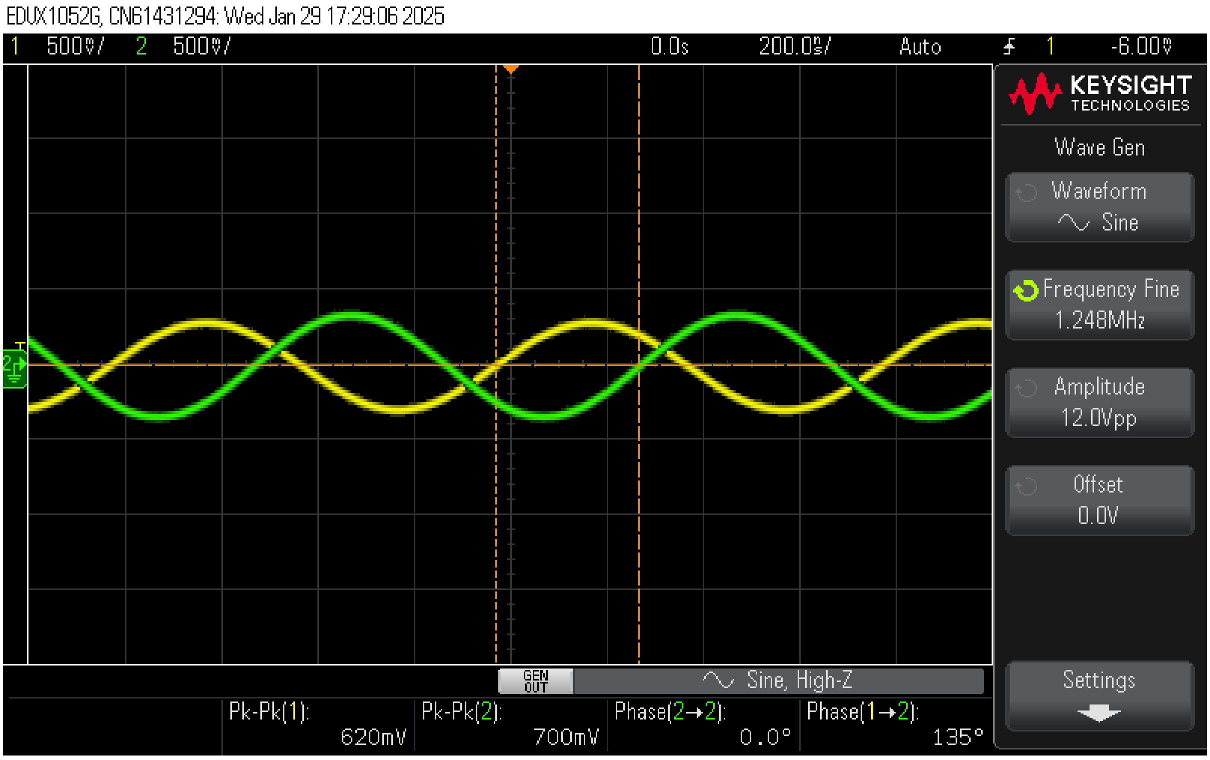
$20\log(A_0/x) = 3$

$A_0 = x \cdot 10^{3/20} \cong \sqrt{2}$

$A_0 = x\sqrt{2}$

$x = \frac{A_0}{\sqrt{2}} = \frac{1}{\sqrt{2}}$

=> -3 dB observed at where amplitude goes to $\frac{1}{\sqrt{2}}$ times of Amplitude $\frac{12}{\sqrt{2}} = 6\sqrt{2} = 8.484$



The output voltages is around vin/√2 that is 7.8 around 8.2 . Thus, the probe wire's -3dB band width is 4.4MHz.

2. Full Wave Rectifier using Center-Tap Transformer

Circuit Setup

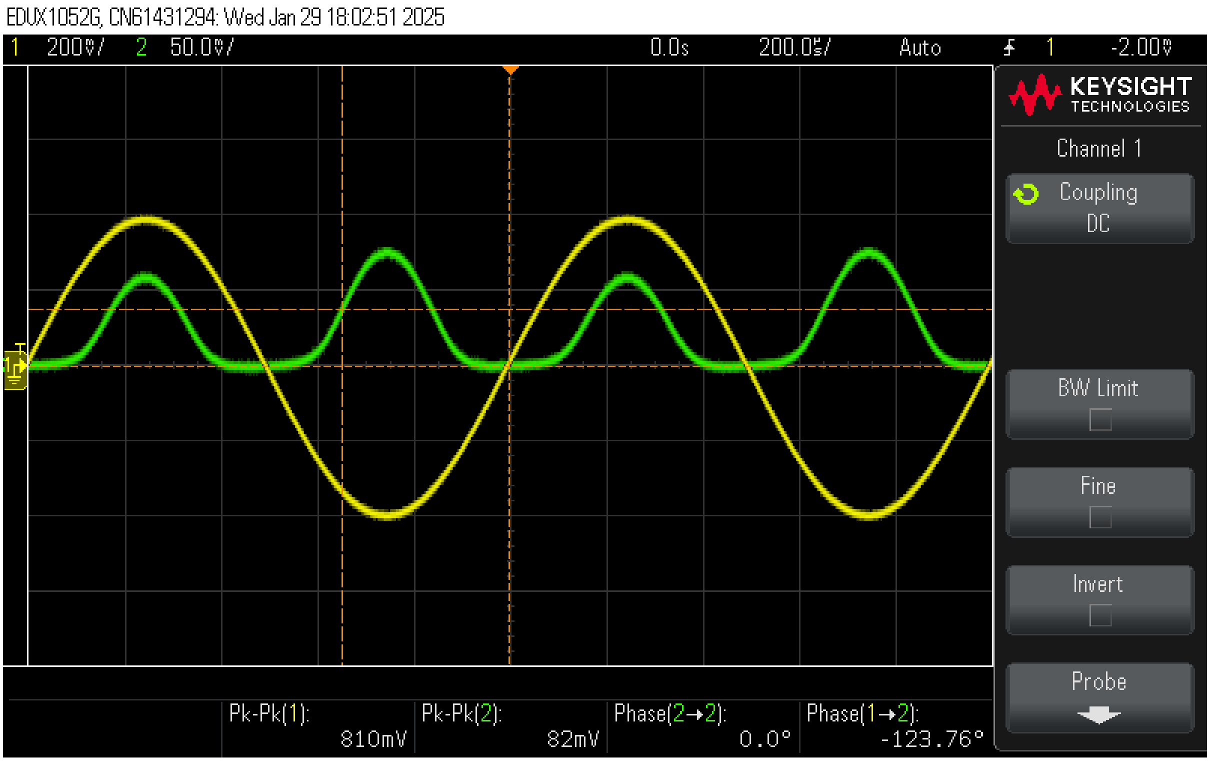
- The circuit was built using a **center-tap transformer, two diodes (D1, D2), and a load resistor (RL = 50 kΩ)**.
- The function generator provided **12Vpp at 1kHz**.

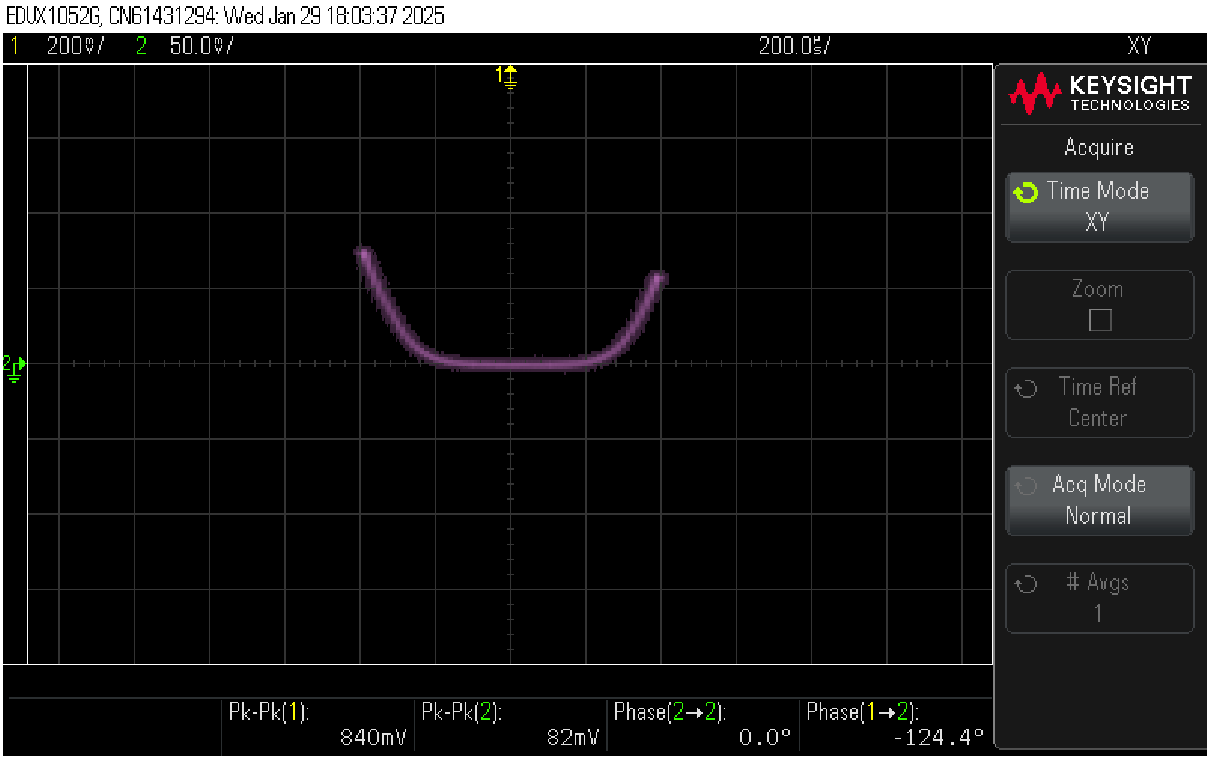
Observations

1. **Waveform Analysis:**
   - **VS1** and **Vout** were plotted using the **DSO**.
   - The output showed **full-wave rectification**, confirming the expected behavior.
2. **Current Calculation:**
   - **Peak current through RL** was calculated as: $\mathbf{I_L}$=Vout/R
   - $\mathbf{I_L = 82mV/50k\Omega = 1.64\ \mu A}$
3. **Voltage Drop & Hypothesis Verification:**
   - A **significant reduction in Vout amplitude** was observed.
   - Possible reason: **Diodes not fully turning ON due to insufficient forward current.**
   - This was verified using diode characterization, ensuring the forward bias current was within expected limits.
   - The full-wave rectifier (FWR) implemented using a center-tap transformer showed expected full-wave rectification behavior, but the output voltage amplitude was lower than anticipated. Upon investigating the issue, it was determined that the forward bias current through the diodes was insufficient, preventing them from fully turning on. Diode characterization data confirmed that the voltage across the diode was close to the expected forward voltage drop, around 699 mV, consistent with the 1N4007 diode's typical V_cut-in.

However, the observed diode voltage of approximately 7V was much higher than expected, indicating that the diodes were not conducting properly during the rectification process. This could be attributed to the diodes' inability to switch on fully, possibly due to a higher threshold voltage or inadequate forward current.

To address this issue, the next steps would involve measuring the forward bias current more precisely using a multimeter in ammeter mode, with the diode connected in series with a power supply. If the forward current is indeed too low, using diodes with a lower threshold voltage or higher current ratings could resolve the issue and improve the rectification efficiency.





3. Bridge Rectifier for Full Wave Rectification

Circuit Setup

- The circuit was built using **four diodes (D1, D2, D3, D4), a transformer, and RL = 50 kΩ**.
- 2 of **1 kΩ resistors** between the terminals A and B with VA and VB respectively
- The function generator provided **12Vpp at 1kHz**.

Observations

1. **Waveform Analysis:**
   - **VS1** and **Vout** were plotted.
   - Full-wave rectification was observed.
2. **Peak Current Calculation:**
   - Same calculation as in Section 3.
   - **I_L = 72mV/50kΩ = 1.44 μA**
3. **Voltage Drop Analysis:**
   - Compared to the center-tap rectifier, the bridge rectifier exhibited **higher efficiency** as it utilized both halves of the AC cycle more effectively.

  - And also voltage drop is almost same but slight change due to Vout varied by changing of channel in transformer.

4. Wall Supply Experiment:

- The function generator was replaced with the wall supply.
- The secondary side voltage of the transformer was plotted.
- Vout with the wall supply was measured and found to be higher compared to the function generator case.
- The output from the wall supply was less attenuated than the equivalent output from the DSO wave generator input.
- The forward bias voltage across the diodes rose in concert with the input voltage, increasing the diode current value.
- For the same resistance value, this resulted in a higher output voltage, leading to a less "turned off" output signal.

Explanation:

- The higher voltage at the secondary side of the transformer from the wall supply allows the diodes to conduct fully in forward bias, improving the rectification efficiency.
- As the input voltage increases, the forward bias voltage across the diodes also increases, which causes a larger current to flow through the diodes.
- This results in a higher output voltage, meaning the output is less attenuated and more consistent, enhancing the overall rectification performance.

Conclusion:

In this experiment, replacing the function generator with the wall supply provided a higher secondary voltage, which allowed the diodes to conduct fully in forward bias. This improved rectification efficiency and resulted in a higher output voltage. As the input voltage increased, the forward bias voltage across the diodes rose, leading to increased current flow through the diodes and a larger output voltage. Consequently, the output signal became less attenuated, highlighting the importance of using a higher input voltage for optimizing the performance of the bridge rectifier.

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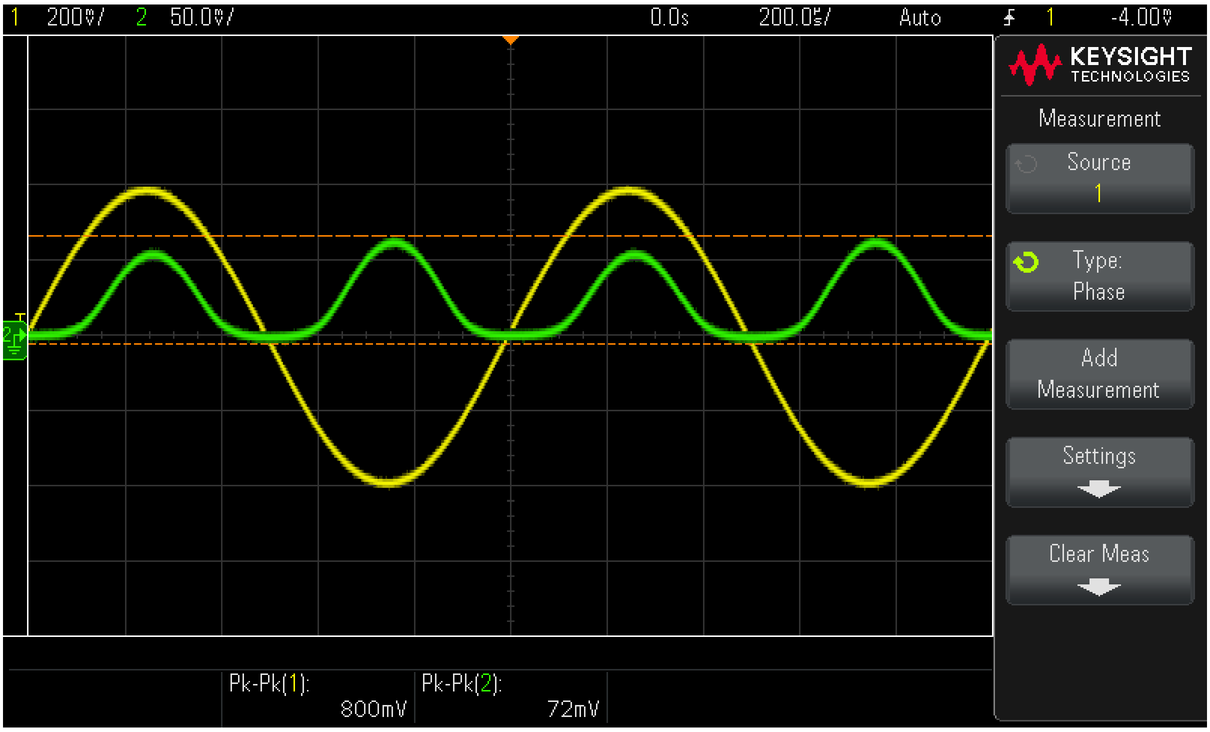

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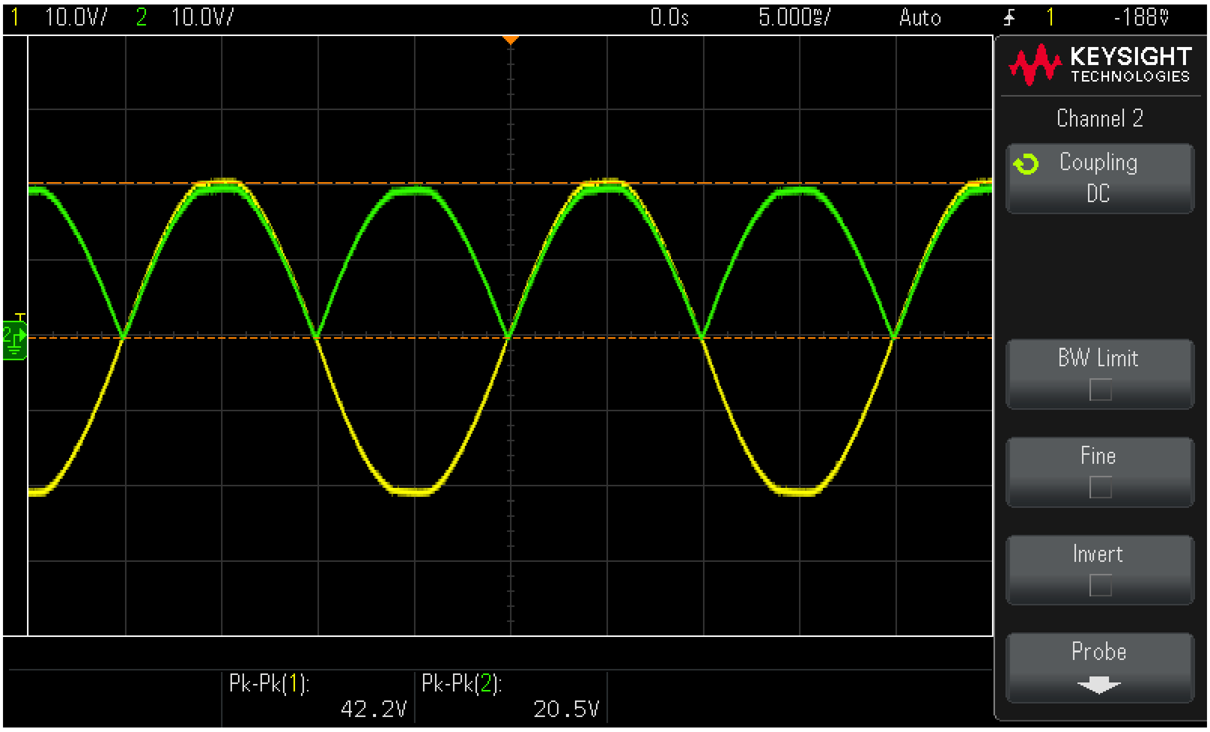

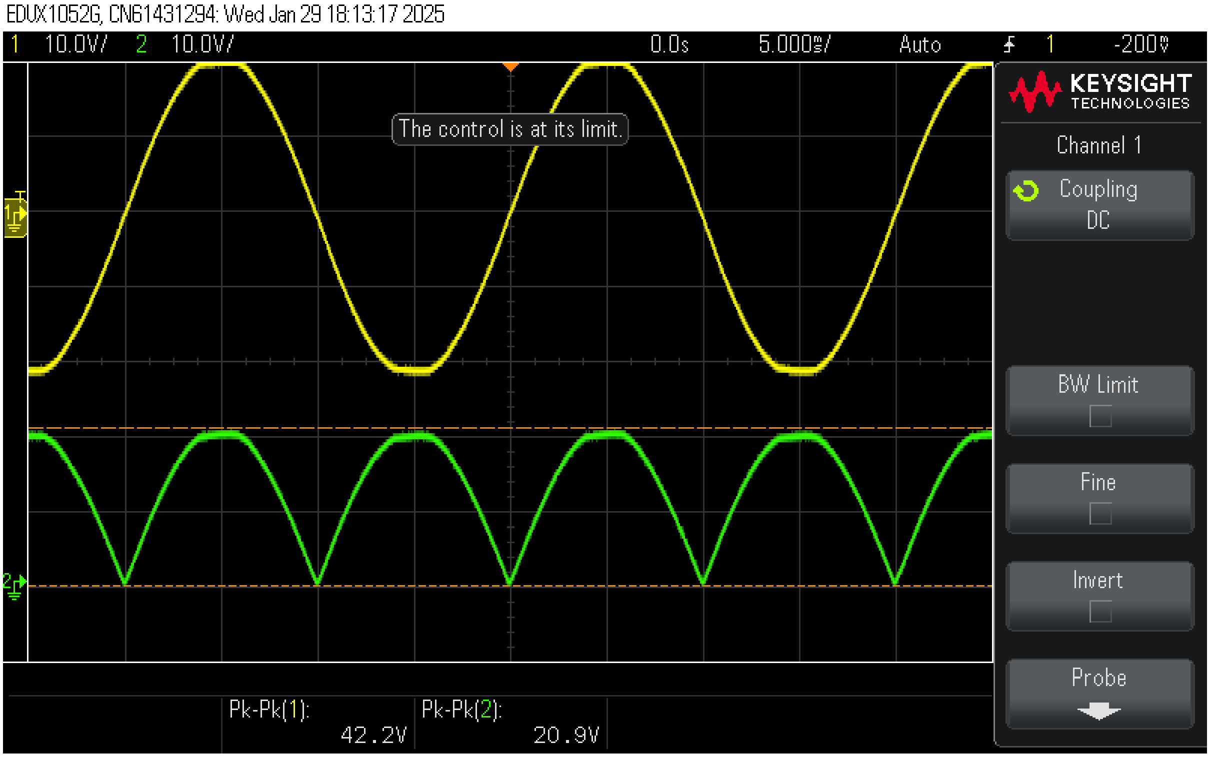

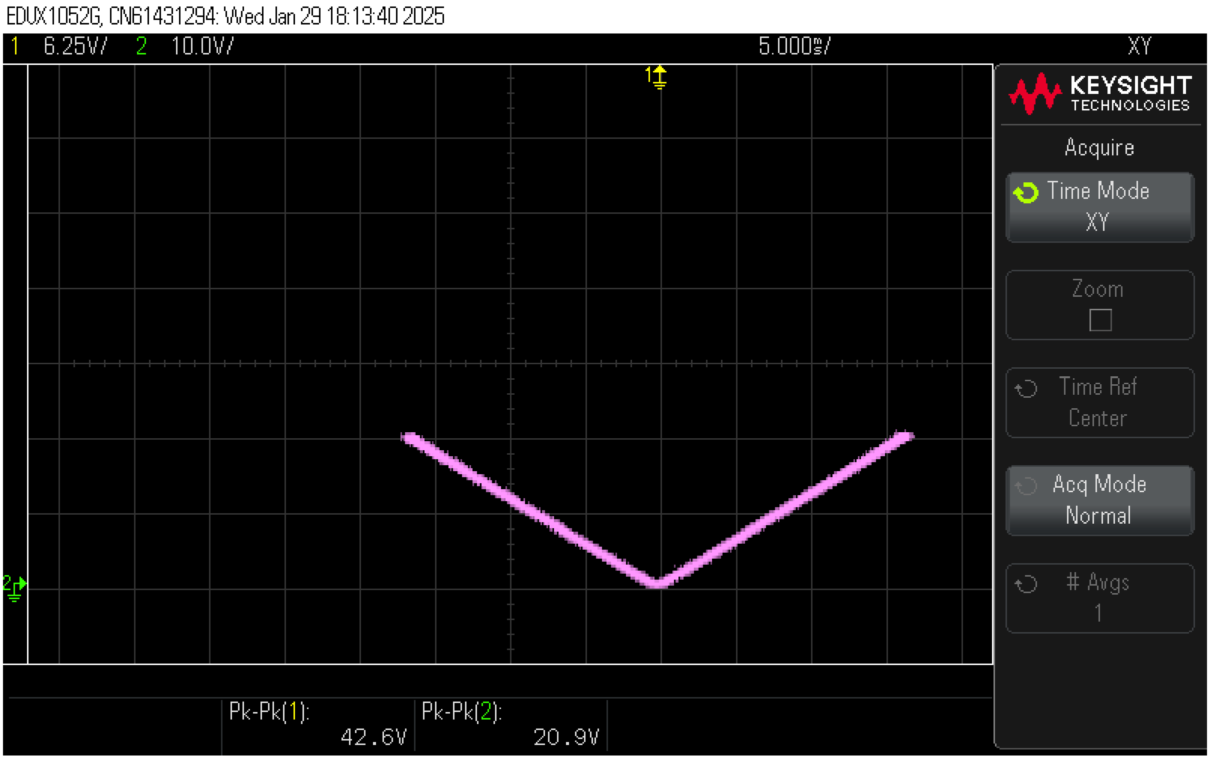

5. Conclusion

- The **full-wave rectifier (FWR) using a center-tap transformer** and the **bridge rectifier** were successfully implemented and analyzed.

- The **bridge rectifier** was found to be more efficient in utilizing both halves of the AC waveform.
- The **transformer bandwidth** was measured, and its **frequency response** was studied.
- The experiment demonstrated the effect of **forward bias current in diodes** and how **higher secondary voltage improves conduction**.