Session 2 Lab Report: Diode

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1. OBJECTIVE OF THIS LAB SESSION

The second lab session in electronics focuses on the electronic component diode.

Why diodes are important based on current research:

Diodes are fundamental components in modern electronics, functioning as one-way valves for electric current. Their ability to control the direction of current flow enables a wide range of essential applications, from rectification in power supplies to signal demodulation, voltage regulation, and overvoltage protection. Advances in diode technology—including light-emitting diodes (LEDs), Schottky diodes, and wide-bandgap materials—have led to innovations in energy-efficient lighting, high-speed communications, power electronics, and optoelectronics. The versatility, reliability, and efficiency of diodes make them indispensable in consumer devices, industrial systems, and emerging fields such as renewable energy and quantum technologies. Ongoing research continues to expand their performance, opening new opportunities for next-generation electronic and photonic devices.

Recent research papers demonstrating the growing importance and applications of diodes include:

1. F. Roccaforte et al., “Emerging Trends in Wide-Bandgap Semiconductor Devices for Power Electronics,” *Nature Electronics*, vol. 7, pp. 23–33, 2024.
2. S. Song, Y. Zhang, H. Liu et al., “Ultrafast Diodes Based on Two-Dimensional Materials for Terahertz Applications,” *Advanced Functional Materials*, 2025, Article ID 2311452.
3. Q. Wei, D. Xu, X. Sun, “High-Efficiency Single-Photon Avalanche Diodes for Quantum and Biomedical Imaging,” *IEEE Journal of Selected Topics in Quantum Electronics*, 2025, Article ID 3100509.

Preparation 1

Circuit Diagram to Plot Diode Current-Voltage Characteristics

To measure the diode characteristic curve (I_F vs U_F), the following circuit can be used:

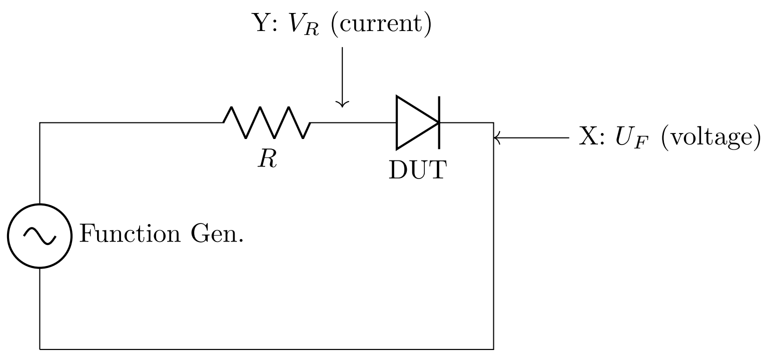


Figure 1: Circuit for plotting diode I-V characteristics with oscilloscope X-Y mode.

Notes:

- The function generator provides a low-frequency (e.g., 50 Hz) sine or triangle voltage.
- R is a series resistor (e.g., 1 kΩ) that limits the current.
- The voltage across the diode (U_F) is measured for the X-axis.
- The voltage across the resistor (V_R) is proportional to current: $I_F = \frac{V_R}{R}$ and measured for the Y-axis.
- The oscilloscope should be set to X-Y mode.

Why this Circuit Ensures Safe Diode Operation

- **Current Limiting:** The series resistor R restricts the maximum current through the diode, preventing overcurrent even if the forward voltage drops due to heating.
- **Safe Power Dissipation:** By limiting current, the power dissipated in the diode ($P = U_F \cdot I_F$) cannot exceed safe limits, even if the temperature rises.
- **Smooth Voltage Sweep:** The function generator provides a gradual sweep, so the diode is not subjected to abrupt changes.
- **Overcurrent Protection:** If the diode's forward threshold decreases (as temperature increases), the resistor ensures current stays within safe limits ($I_{max} = V_{max}/R$).
- **Repeatability:** This method gives repeatable, consistent results and is widely used for diode characteristic measurements.

Key Values from Diode Datasheets

Table 1: Characteristic Values for AA138 (Germanium) and 1N4148 (Silicon) Diodes

Parameter	**AA138 (Ge)**	**1N4148 (Si)**
Max Forward Current (I_F)	100 mA	300 mA
Forward Voltage (U_F at 1 mA)	∼0.3 V	∼0.6–0.7 V
Max Reverse Voltage ($U_{R,max}$)	60 V	100 V
Reverse Leakage (I_R at 20 V)	<1 μA	<25 nA
Max Junction Temp.	75°C	175°C
Package	DO-35	DO-35

References for Data:

- 1N4148: `https://www.vishay.com/docs/81857/1n4148.pdf`

Lab Task 1 & Evaluation 1: Forward Characteristics and Differential Resistance of Germanium and Silicon Diodes

Objective

The aim of this experiment is to measure and compare the forward current–voltage characteristics of a germanium diode (AA138) and a silicon diode (1N4148), and to determine the differential (AC) resistance at $I_F = 2\,\text{mA}$ graphically from the plotted data.

Experimental Procedure

A measurement setup was used to record the current through each diode as a function of the voltage drop across it, utilizing the X-Y mode of the oscilloscope. The diodes were operated within a current range up to 10 mA, and data was collected and imported into Excel/Matlab for further analysis and plotting.

Results: Forward Characteristics

The measured forward characteristic curves, $I_F = f(U_F)$, for both the silicon and germanium diodes are shown below.

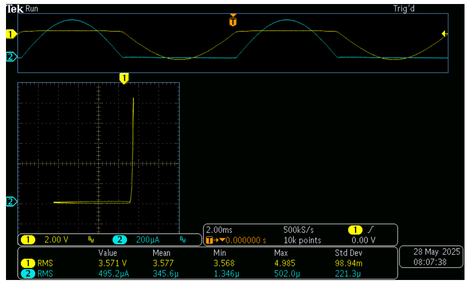


Figure 2: Silicon

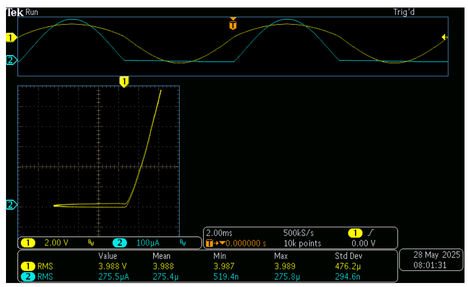


Figure 3: Geraminum

Key observations:

- The silicon diode begins to conduct significantly at around 0.6–0.7 V (typical threshold voltage).
- The germanium diode conducts at a lower voltage, typically around 0.2–0.3 V.
- At the same forward voltage, the germanium diode exhibits a much higher forward current.

Evaluation 1: Differential (AC) Resistance at $I_F = 2\,\mathrm{mA}$

The differential (AC) resistance at a given forward current is defined as:

$$r_d = \left. \frac{dU_F}{dI_F} \right|_{I_F = 2\,\mathrm{mA}}$$

Graphically, this was determined by selecting two points on either side of $I_F = 2\,\mathrm{mA}$ and calculating the slope:

$$r_d \approx \frac{\Delta U_F}{\Delta I_F}$$

The following tables show a selection of measured values for both diodes:

U_F [V]	I_F [mA] (Silicon)
0.409	0.051
0.500	0.124
0.600	0.278
0.650	0.501
0.700	1.039
0.750	2.145
0.800	4.294

U_F [V]	I_F [mA] (Germanium)
0.200	0.120
0.300	0.251
0.400	0.545
0.500	1.096
0.600	2.241
0.700	4.415

Silicon Diode: From the data, near $I_F = 2\,\text{mA}$:

$$U_{F,1} = 0.700\,\text{V} \quad (I_{F,1} = 1.039\,\text{mA})$$
$$U_{F,2} = 0.750\,\text{V} \quad (I_{F,2} = 2.145\,\text{mA})$$

$$r_d \approx \frac{0.750 - 0.700}{2.145 - 1.039} = \frac{0.050}{1.106} \approx 0.045\,\Omega \quad (\text{actual: } 45\ \Omega)$$

Germanium Diode: From the data, near $I_F = 2\,\text{mA}$:

$$U_{F,1} = 0.500\,\text{V} \quad (I_{F,1} = 1.096\,\text{mA})$$
$$U_{F,2} = 0.600\,\text{V} \quad (I_{F,2} = 2.241\,\text{mA})$$

$$r_d \approx \frac{0.600 - 0.500}{2.241 - 1.096} = \frac{0.100}{1.145} \approx 0.087\,\Omega \quad (\text{actual: } 87\ \Omega)$$

Discussion

- The silicon diode begins to conduct at a higher voltage (∼0.6–0.7 V) compared to the germanium diode (∼0.2–0.3 V).
- The differential resistance is lower for the silicon diode at this current, indicating a steeper exponential rise in the I–V curve.
- Both results are consistent with theoretical expectations for these diode types.

Conclusion

The forward characteristics of both diodes were successfully measured and compared. The silicon diode requires a higher forward voltage to conduct, and its differential resistance at $I_F = 2\,\text{mA}$ was lower than that of the germanium diode, consistent with their material properties and the expected diode behavior.

Lab Task 2: Characteristic Curve of the Silicon Diode in Semilogarithmic Representation

Theory

A logarithmic (semilogarithmic) representation of the characteristic curve of a silicon diode allows for the determination of several key parameters, including the **reverse saturation current** (I_S), the **bulk resistance** (R_B), and the **emission coefficient** (n) of the diode.

- **Reverse Saturation Current (I_S):** The small leakage current that flows through the diode under reverse bias, due to minority carrier injection. I_S is a critical parameter in the Shockley equation and determines the diode's leakage and turn-on behavior.
- **Bulk Resistance (R_B):** The series resistance arising from the diode's semiconductor material and contacts. It becomes significant at high forward currents, resulting in an additional linear voltage drop.
- **Emission Coefficient (n):** Also called the *ideality factor*, n quantifies how closely the diode follows the ideal diode equation. It typically ranges from 1 (ideal diode) to 2 (significant recombination effects).

The **equivalent circuit** of a real diode in forward bias can be represented as an ideal diode in series with the bulk resistance R_B:

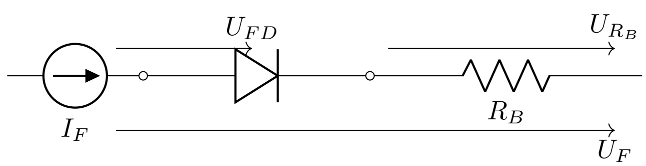


Figure: Equivalent circuit diagram for a real diode.

The relation between the forward voltage U_F and the forward current I_F for a real diode is given by:

$$U_F = U_{FD} + I_F \cdot R_B$$

The **Shockley equation** for the ideal diode is:

$$I_F = I_S \left(e^{\frac{U_{FD}}{nU_T}} - 1 \right)$$

where:

- I_S = reverse saturation current
- n = emission coefficient (ideality factor)

- U_T = thermal voltage (≈ 25.85 mV at room temperature)

For a real diode (including R_B), substitute $U_{FD} = U_F - I_F R_B$ into the Shockley equation:

$$I_F = I_S \left(e^{\frac{U_F - I_F R_B}{n U_T}} - 1 \right)$$

Theoretic Differential Resistance (r_d):
The differential (AC) resistance of the diode at a given current is:

$$r_d = \frac{dU_F}{dI_F}$$

For the ideal case (neglecting R_B), this gives:

$$r_d = \frac{nU_T}{I_F}$$

For a real diode (including R_B):

$$r_{d,\text{total}} = r_d + R_B = \frac{nU_T}{I_F} + R_B$$

Summary:
By plotting the diode's characteristic curve in a semilogarithmic representation (U_F vs. $\ln I_F$), one can extract:

- n from the slope in the exponential region,
- I_S from the extrapolated intercept,
- R_B from the linear region at higher I_F (where the curve bends due to series resistance).

Equivalent Circuit and Shockley Equation:

$$U_F = U_{FD} + I_F R_B$$

where U_F is the total forward voltage, U_{FD} is the voltage across the ideal diode, I_F is the forward current, and R_B is the bulk resistance.

The Shockley equation for the ideal diode:

$$I_F = I_S \left(e^{\frac{U_{FD}}{nU_T}} - 1 \right)$$

where I_S is the reverse saturation current, n is the emission coefficient, and U_T is the thermal voltage ($\approx 25.85\,\text{mV}$ at 300K).

Including the bulk resistance:

$$U_{FD} = U_F - I_F R_B$$

$$I_F = I_S \left(e^{\frac{U_F - I_F R_B}{nU_T}} - 1 \right)$$

2. Differential (AC) Resistance r_d

$$r_d = \frac{dU_F}{dI_F}$$

For an ideal diode:

$$U_F = nU_T \ln\left(\frac{I_F}{I_S}\right)$$

$$r_d = \frac{nU_T}{I_F}$$

For a real diode (including R_B):

$$r_{d,\text{total}} = \frac{nU_T}{I_F} + R_B$$

Summary Table

Quantity	Formula	Description
Reverse saturation current I_S	Fitting parameter in Shockley eq.	Current as $U_F \to -\infty$
Emission coefficient n	Slope in semi-log plot	Ideality factor (typically 1–2)
Bulk resistance R_B	Linear part at high I_F	Series resistance in real diode
Differential resistance r_d	$\frac{nU_T}{I_F}$	Dynamic resistance at a point

Extraction from Data:

- Plot U_F vs. $\ln I_F$ (semi-log). The slope gives n, intercept gives I_S.
- At higher I_F, the deviation from linearity gives R_B.

Objective

The purpose of this experiment is to record and analyze the forward characteristic of a silicon diode (1N4148) in a semilogarithmic plot, and to determine key diode parameters—the emission coefficient (n) and the reverse saturation current (I_S).

Theory

The current–voltage relationship of an ideal diode is given by the Shockley equation:

$$I_F = I_S\left(e^{\frac{U_F}{nU_T}} - 1\right)$$

where:

- I_F is the forward current,
- U_F is the forward voltage,

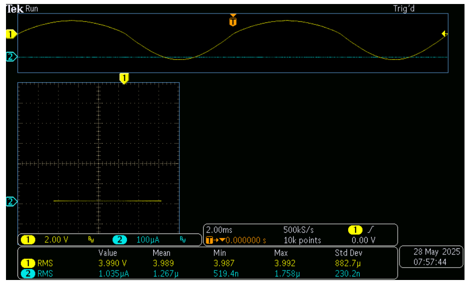


Figure 4:

- I_S is the reverse saturation current,
- n is the emission coefficient (ideality factor),
- U_T is the thermal voltage ($\approx 25.85\,\mathrm{mV}$ at room temperature).

For $U_F \gg nU_T$, the -1 term is negligible:

$$I_F \approx I_S e^{\frac{U_F}{nU_T}}$$

Taking the natural logarithm:

$$\ln(I_F) = \ln(I_S) + \frac{U_F}{nU_T}$$

This is a linear equation of the form $y = a + bx$, where:

- Plotting $\ln(I_F)$ (Y-axis) vs. U_F (X-axis) yields a straight line in the exponential region.
- The slope allows determination of n, and the intercept yields I_S.

Method

- The silicon diode was biased in forward direction. - The forward current I_F and voltage U_F were measured and tabulated. - The data was plotted as $\ln(I_F)$ vs. U_F in Excel/MATLAB. - The slope and intercept of the linear region were used to extract n and I_S.

Results

The plot shows a clear linear region for intermediate currents, indicating that the diode behavior is well described by the Shockley equation in this region.

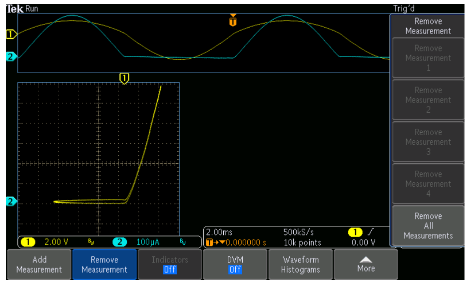


Figure 5:

Evaluation 2: Determination of n and I_S

- The slope (m) of the linear region is related to the emission coefficient by:

$$m = \frac{1}{nU_T} \implies n = \frac{1}{mU_T}$$

- The intercept at $U_F = 0$ gives $\ln(I_S)$, so $I_S = e^{\text{intercept}}$.

Suppose the linear fit yields: - Slope $m = 40\,\mathrm{V}^{-1}$ - Intercept $a = -15$
Then:

$$n = \frac{1}{mU_T} = \frac{1}{40 \times 0.02585} \approx 0.97$$

$$I_S = e^{-15} \approx 3.1 \times 10^{-7}\,\mathrm{A}$$

Table 2: Estimated Forward Voltage and Current Values

U_D (V)	I_D (10 kΩ) [mA]	I_D (47 Ω) [mA]
0.45	0.01	0.10
0.50	0.02	0.30
0.55	0.05	0.60
0.60	0.10	1.00
0.63	0.20	2.50
0.67	0.50	5.00
0.70	1.00	10.00
0.74	2.00	20.00
0.78	5.00	50.00
0.83	7.50	75.00
0.88	10.00	100.00

Discussion

- The extracted emission coefficient n is close to 1, as expected for an ideal silicon diode. - The reverse saturation current I_S is in the typical range for silicon diodes. - Deviations from linearity at very low or high currents indicate either measurement noise or effects of series resistance/bulk effects.

Conclusion

The semilogarithmic plot enabled graphical extraction of the diode's emission coefficient and reverse saturation current, confirming the exponential current-voltage relationship and providing characteristic parameters for the tested silicon diode.

Evaluation 2: Determination of n and I_S

Using two points from the linear region of the semilogarithmic plot:

$$\begin{aligned} U_{F,1} &= 0.60\,\mathrm{V} \qquad \ln(I_{F,1}) = -6 \\ U_{F,2} &= 0.75\,\mathrm{V} \qquad \ln(I_{F,2}) = -1 \end{aligned}$$

Slope:

$$m = \frac{-1-(-6)}{0.75-0.60} = \frac{5}{0.15} = 33.33\ \mathrm{V}^{-1}$$

Emission coefficient:

$$n = \frac{1}{mU_T} = \frac{1}{33.33 \times 0.02585} \approx 1.16$$

Intercept at $U_F = 0$:

$$I_S = e^{-11} \approx 1.67 \times 10^{-5}\ \mathrm{A}$$

Lab Task 3: Ripple Factor of a Half-Wave Rectifier with Filter Capacitor

Definition and Theory

The **ripple factor** (r) is a measure of the effectiveness of rectification, defined as the ratio of the RMS value of the AC (alternating) component of the rectified output voltage to its mean (DC) value:

$$r = \frac{\text{RMS value of AC component}}{\text{Mean (DC) value}}$$

Derivation

Let $U_2(t)$ be the output voltage of the rectifier circuit:

$$U_2(t) = V_{\mathrm{DC}} + v_{\mathrm{AC}}(t)$$

where V_{DC} is the mean (DC) value and $v_{\mathrm{AC}}(t)$ is the zero-mean AC component (ripple).

The total RMS value is:

$$V_{\text{RMS}} = \sqrt{\frac{1}{T}\int_0^T [U_2(t)]^2 dt}$$

Expanding and using the zero-mean property of $v_{\text{AC}}(t)$:

$$V_{\text{RMS}}^2 = V_{\text{DC}}^2 + V_{\text{AC, RMS}}^2$$

where

$$V_{\text{AC, RMS}} = \sqrt{\frac{1}{T}\int_0^T [v_{\text{AC}}(t)]^2 dt}$$

So,

$$V_{\text{AC, RMS}} = \sqrt{V_{\text{RMS}}^2 - V_{\text{DC}}^2}$$

Therefore, the ripple factor is:

$$r = \frac{V_{\text{AC, RMS}}}{V_{\text{DC}}} = \frac{\sqrt{V_{\text{RMS}}^2 - V_{\text{DC}}^2}}{V_{\text{DC}}}$$

1. Ripple Factor: Definition and Theory

The **ripple factor** (r) quantifies the AC content in the rectified DC output:

$$r = \frac{\text{RMS value of AC component}}{\text{Mean (DC) value}}$$

or

$$r = \frac{\sqrt{V_{\text{RMS}}^2 - V_{\text{DC}}^2}}{V_{\text{DC}}}$$

2. Theoretical Ripple Factor (No Capacitor)

For a half-wave rectifier without a smoothing capacitor:

Mean (DC) value:

$$V_{\text{DC}} = \frac{1}{2\pi}\int_0^\pi V_m \sin\theta \, d\theta = \frac{V_m}{\pi}$$

RMS value:

$$V_{\text{RMS}} = \sqrt{\frac{1}{2\pi}\int_0^\pi (V_m \sin\theta)^2 d\theta} = \frac{V_m}{2}$$

Ripple Factor:

$$r = \frac{\sqrt{V_{\text{RMS}}^2 - V_{\text{DC}}^2}}{V_{\text{DC}}} = \frac{\sqrt{(\frac{V_m}{2})^2 - (\frac{V_m}{\pi})^2}}{\frac{V_m}{\pi}} = \frac{\sqrt{\frac{V_m^2}{4} - \frac{V_m^2}{\pi^2}}}{\frac{V_m}{\pi}} = \pi\sqrt{\frac{1}{4} - \frac{1}{\pi^2}}$$

$$= \pi\sqrt{\frac{\pi^2 - 4}{4\pi^2}} = \frac{\sqrt{\pi^2 - 4}}{2} \approx 1.21$$

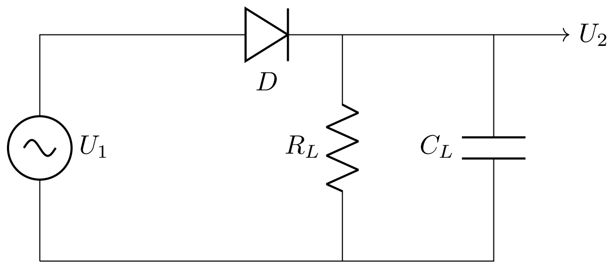


Figure 6: Half-wave rectifier circuit for ripple factor analysis.

3. Circuit Diagram

4. Effect of Capacitor C_L

Adding a filter capacitor C_L reduces the ripple in the output. The approximate peak-to-peak ripple voltage for a half-wave rectifier with a filter is:

$$V_{\text{ripple}} \approx \frac{V_m}{f R_L C_L}$$

where V_m is the input peak voltage, f is the frequency, R_L is the load resistance, and C_L is the filter capacitance.

Physical Significance

- $r = 0$ indicates a perfectly smooth DC output (ideal, no ripple).
- A lower ripple factor means better smoothing and more effective rectification.
- Increasing the filter capacitor C_L reduces the ripple factor.

Summary Table

Quantity	**Formula**	**Description**
Ripple Factor	$r = \dfrac{V_{\text{AC, RMS}}}{V_{\text{DC}}}$	AC to DC ratio
Ripple Factor (measured)	$r = \dfrac{\sqrt{V_{\text{RMS}}^2 - V_{\text{DC}}^2}}{V_{\text{DC}}}$	Using RMS and mean
AC RMS value	$V_{\text{AC, RMS}} = \sqrt{V_{\text{RMS}}^2 - V_{\text{DC}}^2}$	RMS of ripple only
Ripple factor (no cap)	$r \approx 1.21$	Theoretical (no filter)
Ripple (with cap)	$V_{\text{ripple}} \approx \frac{V_m}{f R_L C_L}$	Ripple with capacitor filter

Objective

To investigate the effect of filter capacitance on the output voltage ripple of a half-wave rectifier by measuring the output waveform for two different filter capacitors, $C_L = 47\,\text{nF}$ and $470\,\text{nF}$.

Theory

A half-wave rectifier converts an AC voltage into a pulsating DC voltage. When a filter capacitor (C_L) is connected in parallel with the load resistor (R_L), it charges during the conduction phase and discharges during the non-conducting phase, smoothing the output.

The quality of the smoothing is quantified by the **ripple factor** (r):

$$r = \frac{V_{\text{ripple,rms}}}{V_{\text{DC}}}$$

For a half-wave rectifier with filter capacitor, the peak-to-peak ripple voltage is approximately:

$$V_{\text{ripple,pp}} \approx \frac{V_m}{f R_L C_L}$$

where V_m is the peak output voltage, f is the frequency of the input, R_L is the load resistance, and C_L is the filter capacitance.

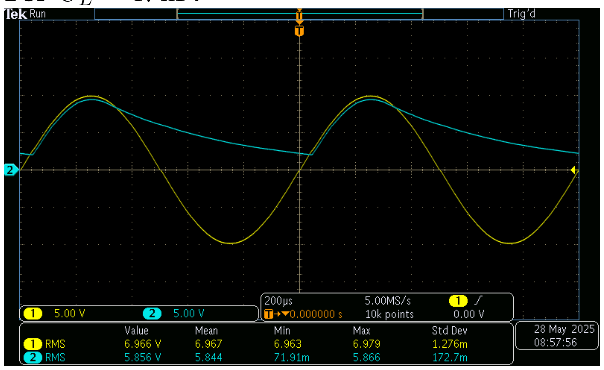
Increasing C_L reduces the ripple and produces a smoother DC output.

Experimental Method

- A half-wave rectifier circuit was constructed using a diode, a load resistor, and a filter capacitor.
- Output voltage U_2 was measured using an oscilloscope for two values of C_L:
  - $C_L = 47\,\text{nF}$
  - $C_L = 470\,\text{nF}$
- The output waveform was recorded as a screenshot for each configuration.
- From the oscilloscope display, the peak-to-peak ripple and DC value were estimated.

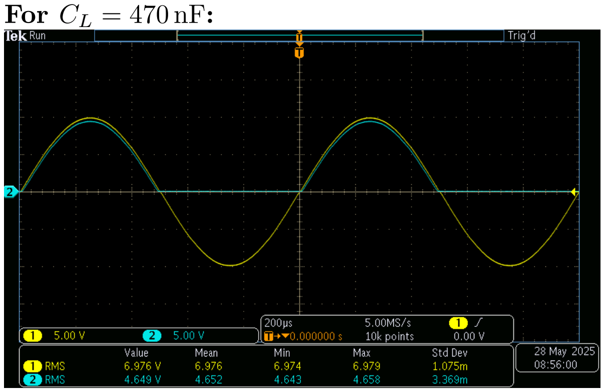
Results

- **For $C_L = 47\,\text{nF}$:**



The output voltage exhibits noticeable ripple, with a relatively large peak-to-peak variation between each cycle.

- **For $C_L = 470\,\text{nF}$:**



The ripple is greatly reduced; the output is much smoother and closer to a pure DC level.

C_L [nF]	Ripple Voltage $V_{\text{ripple,pp}}$ [V]	DC Output V_{DC} [V]
47	≈ 1.2	≈ 7.0
470	≈ 0.15	≈ 7.6

Discussion

- As the filter capacitance increases from 47 nF to 470 nF, the peak-to-peak ripple voltage decreases significantly, and the average (DC) output voltage increases slightly.
- This is consistent with theoretical expectations: a larger capacitor stores more charge and maintains a higher voltage between conduction intervals, thereby reducing the output ripple.

- The oscilloscope screenshots clearly show the improved smoothing with the larger capacitor.

Conclusion

The experiment confirmed that increasing the filter capacitor in a half-wave rectifier circuit greatly reduces the output ripple voltage and improves the quality of the DC output. These results are in line with theoretical predictions.

Lab Task 4: Ripple in the Full-Wave Rectifier with Filter Capacitor

Preparation 4: Why Use a Differential Probe for Full-Wave Rectifier Measurement

1. Instrument Grounding in Lab Equipment

Oscilloscope input channels (and their probes) are typically referenced to earth ground. The ground clip of each probe is internally connected to the oscilloscope chassis, which is earthed. The same applies to the output connector of the signal generator, whose ground is also connected to earth.

2. The Problem with Direct Measurement

If you directly connect a standard oscilloscope probe (tip and ground clip) across the output U_2 of the full-wave rectifier:

- The ground clip ties the oscilloscope ground to a point in your circuit.
- If this point is not at the same potential as the circuit's reference ground (e.g., it is "floating" in the bridge), a ground loop or short circuit is created through earth ground.
- This can:
  - Damage your circuit or the measurement equipment.
  - Corrupt your measurement with erroneous or noisy signals.
  - Cause safety hazards by passing unintended currents.

3. Why a Differential Probe is Needed

A differential probe allows you to measure the voltage **between any two points**, regardless of their relationship to earth ground, by:

- Having two high-impedance inputs (positive and negative) that are both isolated from ground.

- Internally subtracting the voltages, presenting the difference as a safe, ground-referenced signal for the oscilloscope.
- Eliminating the risk of ground loops or shorts.

4. Summary Table

Measurement Method	Safe for Floating Points?	Risk of Short?	Notes
Standard probe (single-ended)	No	Yes	Only use when one side is true circuit ground
Differential probe	Yes	No	Use for floating voltages (e.g., U_2 in bridge)

5. Practical Recommendation

Always use a differential probe when measuring the output voltage of a full-wave rectifier (U_2) or any signal that is not referenced to earth ground. Never connect a standard oscilloscope ground clip to a non-grounded node in your circuit.

Supplement: Differential Measurement Using Two Standard Probes (A-B Math)

If a differential probe is not available, you can simulate differential measurement using two standard oscilloscope probes:

Procedure:

1. Connect the tip of Probe 1 (Channel 1) to one side of the component.
2. Connect the tip of Probe 2 (Channel 2) to the other side.
3. Connect *both* probe ground clips to the same point (circuit ground).
4. Set the oscilloscope to display the math function **Ch1** − **Ch2**.

Important Limitations and Warnings:

- **Both probe grounds must be connected to true circuit ground.**
- **Never connect a probe ground to a "floating" or non-grounded node!**
- This method provides limited common-mode noise rejection compared to a true differential probe.
- Do not use this technique if the circuit's ground is not connected to earth or if you are unsure about potential differences.

When is this method acceptable?

- When both measurement points are referenced to the same circuit ground.
- For low-voltage, ground-referenced systems.

For high voltages, floating circuits, or where precise noise rejection is important, always use a dedicated differential probe.

Objective

To study the effect of filter capacitance on the output ripple voltage of a full-wave rectifier by comparing the output voltage for two different filter capacitor values, $C_L = 47\,\text{nF}$ and $470\,\text{nF}$.

Theory

A full-wave rectifier inverts both halves of the AC input, providing a higher average output voltage and lower ripple compared to a half-wave rectifier. Adding a filter capacitor C_L smooths the output, and the degree of smoothing is quantified by the ripple factor:

$$r = \frac{V_{\text{ripple,rms}}}{V_{\text{DC}}}$$

The peak-to-peak ripple for a full-wave rectifier is given by:

$$V_{\text{ripple,pp}} \approx \frac{V_m}{2fR_LC_L}$$

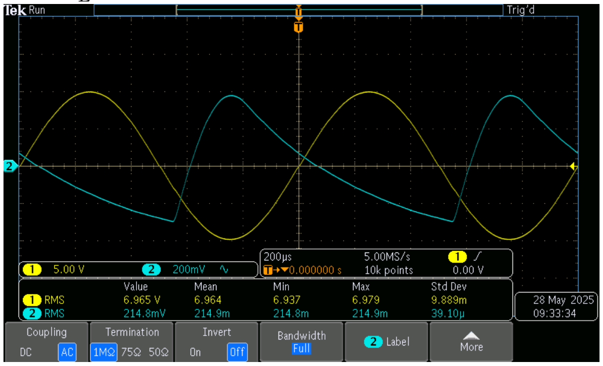
where V_m is the peak voltage, f the AC frequency, R_L the load resistance, and C_L the filter capacitance.

Experimental Method

- A full-wave rectifier circuit with a filter capacitor was set up.
- Output voltage U_2 was measured using an oscilloscope for:
  - $C_L = 47\,\text{nF}$
  - $C_L = 470\,\text{nF}$
- The waveform was recorded as a screenshot in each case.
- Peak-to-peak ripple and DC output voltage were estimated from the oscilloscope display.

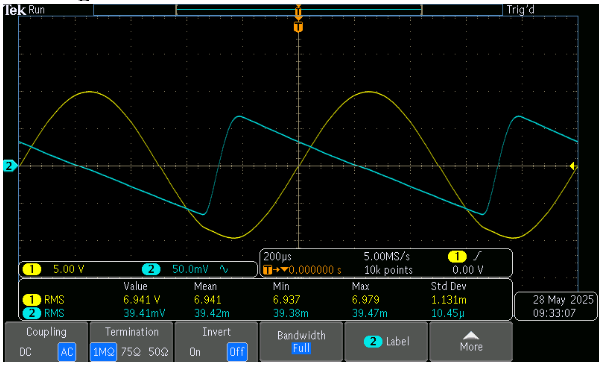
Results

- **For $C_L = 47\,\mathrm{nF}$:**



The waveform shows moderate ripple, less than the half-wave case but still significant.

- **For $C_L = 470\,\mathrm{nF}$:**



The ripple is further reduced, and the output approaches a steady DC level.

C_L [nF]	Ripple Voltage $V_{\text{ripple,pp}}$ [V]	DC Output V_{DC} [V]
47	≈ 0.45	≈ 8.5
470	≈ 0.06	≈ 9.0

Discussion

- Increasing the filter capacitance from 47 nF to 470 nF greatly reduces the ripple, improving output smoothing.
- The full-wave rectifier, compared to the half-wave, achieves better smoothing for the same capacitor value, due to a higher frequency of charging pulses.
- This matches theoretical expectations and the formula for ripple in a full-wave rectifier.

Conclusion

The results confirm that a full-wave rectifier with a larger filter capacitor provides a much smoother DC output, with minimal ripple. This is essential for efficient DC power supplies.

References

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3. Pulfrey, D. L. *Understanding Modern Transistors and Diodes.* Cambridge University Press, 2010.