University of Washington

BEE331 Lab 1.1

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July 17, 2024

Characterising Diodes; I-V Curve

Design Objective

In this lab, we introduce ourselves to the diode, we characterise its function by the I-V curve.

Circuit Design Outline

With a resistor of an arbitrary impedance greater than 100Ω ($R \geq 100\Omega$), and the natural impedance of the Function Generator in series ($R_{TOT} = R_{FG} + R \geq 150\Omega$), the (1N4148 silicon) diode is set in series to forward-bias from the function generator. Set the function generator @ f=1kHz and $V_P = 5V$.

Figure 1: Series R + Diode

(a) LTSpice + Rudimentary Schematic Series RD (499Ω) Circuit

(b) LTSpice + Rudimentary Schematic Series RD (100Ω) Circuit

(c) Series RD Circuit 499Ω

(d) Series RD Circuit 100Ω

Descriptions of Measurements & Calculations

Analysis

- **i. Describe how you measured I_D and V_D?**

  At the node where R; ($R > 100\Omega$) and the Diode; (D) meet, we denote this junction as V_{out}. We attach our Multimetre's positive lead (Red) to V_{out}, and attached our ground lead to the opposing node of the Diode; (D) - which should be grounded.

- **ii. In this experiment how would you determine the value of $I_{D,max}$**

  $I_D = I_S(e^{\frac{V_D}{V_T}} - 1)$; reference Figure 1b.

- **iii. In the circuit, what limits I_D?**

  The characteristics of the I-V curve of a diode has current I_D exponentially rise towards a cut-off at the threshold, towards the C.V.D @ V_D.

- **iv. Explain why V_D does not change much while I_D can change a lot.**

  Given the equation of a Diode's characteristics of $I_D = I_S(e^{\frac{V_D}{V_T}} - 1)$. Putting the equation in reference to I_D is an exponential function, while V_D is a logarithmic function with a very slow rise time.

Figure 1: RD Circuit

(a) RD Circuit Measurement

(b) Sample Measurement

VT	0.025
Is	1.00E-09

ID	VD	Experiment 1.1 at 499 ohms V	Vd
0.05	0.000002	-5	-5
0.1	0.000005	-4.5	-4.5
0.15	0.000007	-4	-4
0.2	0.000010	-3.5	-3.5
0.25	0.000012	-3	-3
0.3	0.000015	-2.5	-2.5
0.35	0.000017	-2	-2
0.4	0.000020	-1.5	-1.5
0.45	0.000022	-1	-1
0.5	0.000025	-0.5	-0.5
0.55	0.000027	0	0
0.12	0.000006	0.2	0.1987
0.13	0.000006	0.4	0.3939
0.14	0.000007	0.6	0.5221
0.15	0.000007	0.8	0.5733
0.16	0.000008		

Summary & Conclusions

Revealed in Figure RD-Circuit 1A & 1B, the generated oscilloscope readings of the two periodic function match the characteristics of the transfer function found in 1b (RD Circuit). So the measurements do infact closely align.

Characterising Zener Diodes; I-V Curve

Design Objective

In this lab, we introduce ourselves to the *Zener* diode, we characterise its function by the I-V curve.

Circuit Design Outline

With a resistor of an arbitrary impedance greater than 100Ω ($R \geq 100\Omega$), and the natural impedance of the Function Generator in series ($R_{TOT} = R_{FG} + R \geq 150\Omega$), the (1N4732 or 1n5223) Zener diode is set in series set in reverse-polarity to procate reverse-breakdown from the diode; through the function generator. Set the function generator @ f=1kHz and $V_P = 5V$ (We'll be focusing on the negative portion of V_P).

Figure 2: Series R + Diode D_Z

(a) LTSpice + Rudimentary Schematic Series RD (499Ω) Circuit

(b) LTSpice + Rudimentary Schematic Series RD (10$k\Omega$) Circuit

(c) Series RD Circuit 499Ω

(d) Series RD Circuit 10$k\Omega$

Descriptions of Measurements & Calculations

Given the default theoretical calculation for a Diode in forward-bias: $I_D = I_S(e^{\frac{V_D}{V_T}} - 1)$; the dataset is similar in-nature - not exact because the characteristics of this diode differs - from section 1.1 of the lab.
The characteristic of a *Zener* Diode is its relationship to $-V_D$, as I_D enters **Reverse-Breakdown** @ $-V_{Z0}$; the point of breakdown.

Figure 2: RD_Z Circuit

(a) RD Circuit Measurement

(b) Sample Measurement

-1.00E-02	-0.00118672	-0.0056875
-1.00E-02	-0.00113594	-0.00564844
-1.00E-02	-0.00112969	-0.00552344
-9.99E-03	-0.00108516	-0.00557813
-9.99E-03	-0.00105469	-0.00552344
-9.99E-03	-0.00104062	-0.00542187
-9.99E-03	-0.00101172	-0.0054375
-9.99E-03	-0.00103359	-0.00510156

Summary & Conclusions

Revealed in Figure RD-Circuit 1A & 1B, the generated oscilloscope readings of the two periodic function match the characteristics of the transfer function found in 1b (RD_Z Circuit). So the measurements do infact closely align.

Discussion

- **i. Describe how you measured I_D and V_D?**

  At the node where R; ($R > 100\Omega$) and the Zener Diode; (D_Z) meet, we denote this junction as V_{out}. We attach our Multimetre's positive lead (Red) to V_{out}, and attached our ground lead to the opposing node of the Zener Diode; (D_Z) - which should be grounded.

- **ii. In this experiment how would you determine the value of $I_{D,max}$**

  Forward-Bias: $I_D = I_S(e^{\frac{V_D}{V_T}} - 1)$; reference Figure 1b.

  Reverse-Breakdown: The functioning range when $V_D < V_{D_{BR}}$; the output voltage of a reverse-breakdown Zener diode is $V_o = V_i - R_i * _i$ (the subscript of i meaning input of the function generator.)

- **iii. In the circuit, what limits I_D?**

  Forward-Bias: The characteristics of the I-V curve of a diode has current I_D exponentially rise towards a cut-off at the threshold, towards the C.V.D @ V_D.

  Reverse-Breakdown: Similarly to how the Forward-Bias meets an exponential curve towards its threshold; V_D, the Reverse-Breakdown meets and meets a sharp declination of V_o towards $-V_{D_{BR}}$.

- **iv. Explain why V_D does not change much while I_D can change a lot.**

  Given the equation of a Diode's characteristics of $I_D = I_S(e^{\frac{V_D}{V_T}} - 1)$. Putting the equation in reference to I_D is an exponential function, while V_D is a logarithmic function with a very slow rise time. This goes for both Forward-Bias and Reverse-Breakdown, only the output voltage nature changes.

Voltage Limiter Circuits; Standard & Zener Diode

Design Objective

In this lab, we introduce ourselves to two voltage-limiting circuits. One built with standard diodes and the other built with Zener diodes., we characterise its function by the I-V curve.

Circuit Design Outline

With a resistor of an arbitrary impedance greater than 100Ω ($R \geq 100\Omega$), and the natural impedance of the Function Generator in series ($R_{TOT} = R_{FG} + R \geq 150\Omega$), the designed High-Level Limiter Circuit is set in series to the resistor; through the function generator. Set the function generator @ f=200kHz and $V_P = 5V, 0.1V, 10V$ in High-Z impedance.

Figure 3: High-Level Limiter Circuit

(a) Rudimentary Generic Schematic of High-level Limiter Circuit

(b) LTSpice + Rudimentary Schematic Parallel Standard Diodes Circuit

(c) LTSpice + Rudimentary Schematic Series Opposing Zener Diodes Circuit

(d) Parallel Standard Diodes Circuit

(e) Series Opposing Zener Diodes Circuit

Descriptions of Measurements & Calculations

Given the default theoretical calculation for a Diode in forward-bias: $I_D = I_S(e^{\frac{V_D}{V_T}} - 1)$; the dataset is similar in-nature - not exact because the characteristics of this diode differs - from section 1.1 of the lab.
The characteristic of a *Zener* Diode is its relationship to $-V_D$, as I_D enters **Reverse-Breakdown** @ $-V_{Z0}$; the point of breakdown. Because of these characteristics, the Limiter-Circuits meet their respective "off" thresholds to logarithmically degrade the output voltage of V_o.

Figure 2: High-Limiter Circuit Scope

(a) Parallel RDD Circuit @ $0.1V_p$

(b) Parallel RDD Circuit @ $10V_p$

(c) Series Opposing-Polarity Zener Diode Circuit @ $0.1V_p$

(d) Series Opposing-Polarity Zener Diode Circuit @ $10V_p$

Summary & Conclusions

Revealed in Figure RDD-Circuit 0A & 0B, the generated oscilloscope readings of the two periodic function do in-fact dampen @ V_{in} (CH2) greatly to V_{out} (CH1). It is similary in the Series D_Z circuit.

Discussion

- **i. Describe how each limiter circuit limits the input voltage based on the output waveform you measured. How are the limiter circuits 1 and 2 different?**

  The first limiter circuit reduces peak voltage showing the behavior of the exponential diodes. This makes the output wave more square than the input wave because it is limiting the input before it can start curving back down. [Reference Above]

- **ii. What is the effect of setting the *Load Impedance to High Z* mode for the function generator?**

  Forward-Bias: $I_D = I_S(e^{\frac{V_D}{V_T}} - 1)$; reference Figure 1b.

  The instrument will display less attenuation when producing the signal; so in ley, less of a impeded signal.

- **iii. What settings did you use in the oscilloscope in order to suppress noises in the output signals??**

  Forward-Bias: The characteristics of the I-V curve of a diode has current I_D exponentially rise towards a cut-off at the threshold, towards the C.V.D @ V_D.

  High-Fine, Auto-range, 50% auto-trigger, AC-Coupling.

- **iv. For the limiter Circuit 1, can you make the output signal the same as the input signal by changing v_{peak}**

  You should be able to make the output signal the same by staying in the region where both diodes are in an "off" state. This will cause the circuit to not be limited by current through the diodes.

Full-Wave Bridge Rectifier Circuit

Design Objective

In this lab, we introduce ourselves to two voltage rectifying circuits: The Rectifier and Voltage Clamp. We demonstrated this two two applications across 3 circuits. We characterize its function in V_{out}.

Circuit Design Outline

[Guidelines do not ask for explanation on design. See Below.]

Figure 3: Bridge Rectifier Circuits

(a) LTSpice + Rudimentary Schematic Full-Wave Bridge Rectifier

(b) LTSpice + Rudimentary Schematic Full-Wave Bridge Rectifier with output filter

(c) LTSpice + Rudimentary Schematic Full-Wave Bridge Rectifier with output filter and Zener diode regulator as its output

Figure 4: Bridge Rectifier Circuits IRL

(a) Full-Wave Bridge Rectifier

(b) LTSpice + Rudimentary Schematic Full-Wave Bridge Rectifier with output filter and Zener diode regulator as its output

Descriptions of Measurements & Calculations

Given the default theoretical calculation for a Diode in forward-bias: $I_D = I_S(e^{\frac{V_D}{V_T}} - 1)$; the dataset is similar in-nature - not exact because the characteristics of this diode differs - from section 1.1 of the lab.
The characteristic of a *Zener* Diode is its relationship to $-V_D$, as I_D enters **Reverse-Breakdown** @ $-V_{Z0}$; the point of breakdown.
The utilisation of the Capacitors in the Bridge Circuit is to dissipate the voltage curve over a gentler duration. Because of these characteristics, the Bridge Circuit essentially dampens and *Rectifies* the entering voltage; V_{in} to V_o

Figure 5: Bridge Rectifier Circuits Scope

(a) Full-Wave Bridge Rectifier

(b) Full-Wave Bridge Rectifier with output filter

(c) Full-Wave Bridge Rectifier with output filter and Zener diode regulator as its output

Summary & Conclusions

Revealed in Figure RDD-Circuit 0A & 0B, the generated oscilloscope readings of the two periodic function do in-fact dampen @ V_{in} (CH2) greatly to V_{out} (CH1). It is similary in the Series D_Z circuit.

Discussion

- **i. Compare the measured versus simulated data and explain any differences.**

  The measured and simulated data find differences in components, breakdown region, ideal components; which differs in threshold ranges and dampening ranges, and a consistent AC signal that has no attenuation.

- **ii. What are the purposes of experiment 1.41, 1.42, and 1.43? You can explain this by comparing the output voltage waveforms.**

  The purpose of 1.4.1 is to limit the negative values of the AC waveform. The output voltage had no voltage under 0. The purpose of 1.4.2 is to have the circuit charge the capacitors at the turn-on voltage for the diodes then when the input is low enough the capacitor will discharge slowly creating a more linear signal.

- **Is it desirable to reduce the output ripple voltage? Why do you think that is?**

  Signal alignment; although, we would have to consider using a secondary signal system to propgate the missing values - we'd have a consistently voltage running at a timer rate scaling with total Impedances and Voltage output.

  It could also be desirable to reduce the output voltage of the ripple because the output voltage might be used for other components that need a certain voltage to operate. So, the ripple voltage can be changed to meet those needs.

- **At what load resistance does the regulated full-wave bridge rectifier come out of regulation?**

  $R_{Load} \geq 1k\Omega$

- **Explain how you would predict the minimum value of the load resistance for which the Zener diode still operates in the breakdown region.**

Deriving the theoretical calculation of the Zener Diode's breakdown range; $V_o = V_i - R_i *_i$ @ $D_{Z_{BR}}$, and considering $R_{Load} \geq (R_2 * \epsilon)$.

Addendum Pages

Figure 6: Jason Truong Addendum

(a) Lab Design Calculations

$$I_D = I_S(e^{qV_D / NkT} - 1)$$

Where,

I_D = Diode current in amps

I_S = Saturation current in amps (typically 1×10^{-12} amps)

e = Euler's constant (~ 2.718281828)

q = charge of election (1.6×10^{-19} coulombs)

V_D = Voltage applied across diode in volts

N = "Nonideality" or "Emission" coefficient (typically between 1 and 2)

k = Boltzmann's constant (1.38×10^{-23})

T = Junction Temperature in Kelvins

Bibliography

Cited:

- Lab 1 Manual
- Sedra, Adel, and Kenneth Smith. Microelectronic Circuits. S.L., Oxford Univ Press Us, 2019.
- "How Do You Calculate, a Silicon Junction Diode with N = 1 Has v = 0.7 v al I = 1 MA. What Is the Voltage Drop at I=0.1 MA and I=10 MA.?" Quora, 2024, appliedmathematics.quora.com/How-to-calculate-A-silicon-junction-diode-with-n-1-has-v-0-7-V-al-I-1-mA-What-is-the-voltage-drop-at-I-0-1-mA-an?top_ans=223007030. Accessed 15 July 2024.

(a) Look at her, she's perfect.