IV. Lab 4: Diode Circuits

A. Introduction

1. Oscilloscope Probe

An *oscilloscope probe* is a device that is used to connect your oscilloscope to measurement points in a circuit. In this lab, each of your Tektronix TBS1052C oscilloscopes came with a passive 10x Tektronix TPP0100 oscilloscope probe. A picture of this probe in use is shown in Figure IV-1. The probe has a clip at its tip that you connect to the point in the circuit that you want to measure. It also has a clip off to the side that you connect to the circuit ground. The other end of the probe has a BNC connector that you connect to the oscilloscope. The oscilloscope will then display the voltage at the probe tip relative to the circuit ground.

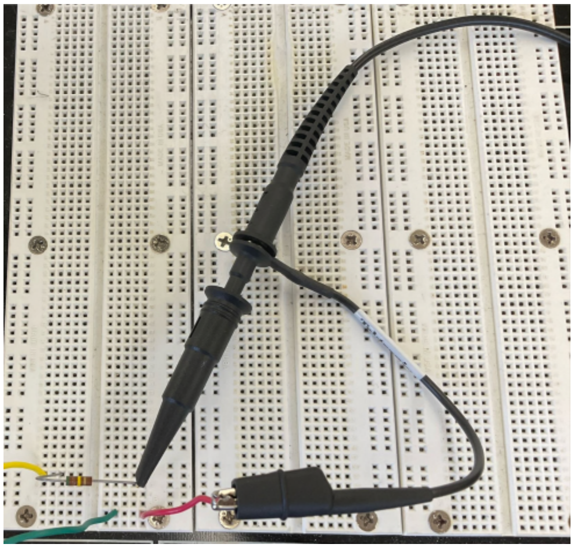


Figure IV-1. Oscilloscope probe connected to a circuit.

A 10x passive oscilloscope probe attenuates the voltage into the scope by a factor of 10. In order to still read the correct voltage, you need to set “Probe Setup” to 10x. This internally corrects for the factor of 10 reduction by the probe so that the scope correctly displays the voltage at the probe tip.

Reasons why you might want to use an oscilloscope probe:

- The clips that come with the probe make it convenient to attach to your circuit.
- A 10x probe increases the input impedance of the oscilloscope measurement by about a factor of 10. This can reduce the loading of your circuit by the oscilloscope impedance, which could improve the accuracy of your measurement.

Reasons why you might not want to use an oscilloscope probe:

- You are measuring an instrument with a BNC connection at its output, so the clip lead on the probe makes it much less convenient to make a connection.

- When you use a 10x scope probe, you lose a factor of 10 in the smallest volts per division you can see, which can make the oscilloscope less sensitive. If you are looking at very small signals, it might be better not to use the probe.
- If you are struggling with an *RC* time constant due to a capacitance *C* in your circuit and the oscilloscope resistive impedance *R*, an oscilloscope probe could make that time constant ten times longer, which you might not want.

For a detailed analysis of how the oscilloscope probe works, please refer to the HW2 solutions for problem 1 and problem 2.

2. Diodes

In this lab, you'll build a number of circuits using *diodes*. A diode is a semiconductor component that has the nonlinear current *vs.* voltage relation (*IV* curve) shown in Figure IV-2(b). You'll be using two different diode types. The first type is the 1N4007 pn junction diode. This is one of the most common and widely used diodes. The other type is the 1N4736A Zener diode. Specification sheets for both of these diodes are reproduced in section B.4 below.

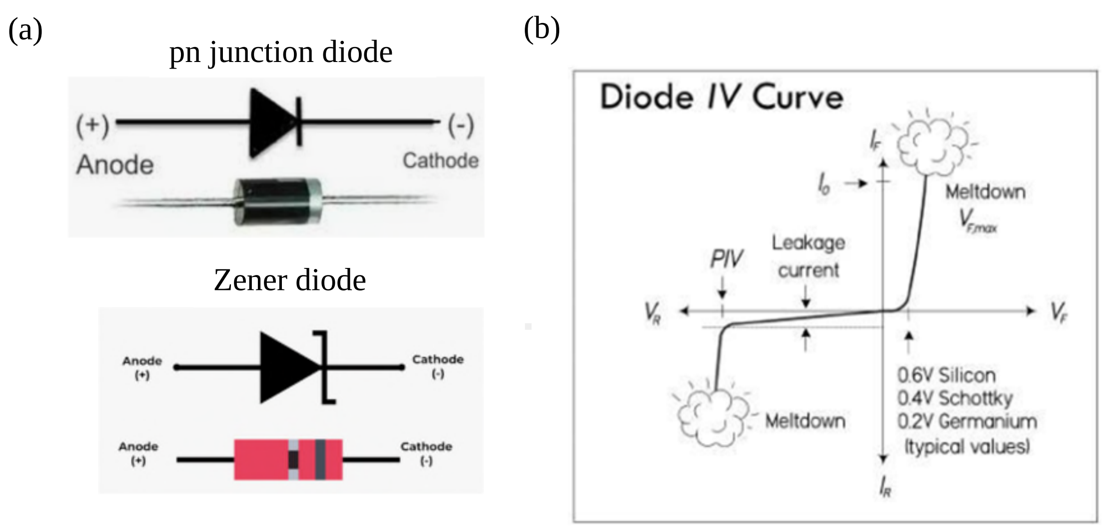


Figure IV-2 (a) Symbol for and identification of anode and cathode for a pn junction diode and for a Zener diode. (b) Diode *IV* curve. Figure is from PEFI.

The symbols for the pn junction diode and the Zener diode are given in Figure IV-2(a). Each diode has an anode and a cathode, with the arrow in the symbol pointing from anode to cathode. The voltage *V* is defined as the voltage on the anode minus the voltage on the cathode. The current *I* is defined to be positive if it flows in the direction of the arrow, from anode to cathode. On a physical diode, the end with the band on it is always the cathode. The only way to be sure what diode type you have is to read the part number written on it and look up its specification sheet. We have a lighted magnifier in the lab for this purpose if the lettering is too small to make out.

To a first approximation, the diode freely conducts current in the direction of the arrow and blocks the current in the reverse direction. In detail the behavior is a little different. For one thing, the current doesn't suddenly switch on for even a very small positive voltage. Instead, the current increases exponentially with voltage. For a silicon diode, it takes about 0.6 V of voltage drop for the current to turn on, where we take “on” to mean that the current reaches about 1 mA. A much higher current would take a higher voltage, although not that much higher due to the exponential dependence.

Any given diode has a “breakdown voltage”. This is a negative voltage beyond which the diode no longer blocks the reverse current. pn junction diodes have a specified peak-inverse-voltage (PIV) or peak-reverse-voltage (PRV). This is guaranteed to be smaller than the breakdown voltage. As long as the negative voltage applied to the diode is smaller than the PIV or PRV, the diode will block any reverse current except for a very small leakage current.

One thing to be aware of when using diodes is that their impedance is quite low when they are conducting. Thus, if you have a power supply that can deliver several amps of current and you put that supply across the diode at a voltage setting well above 0.6 V, the diode will draw the full current available from the supply and might blow up. A similar comment applies to negative voltages larger than the PIV. That is the meaning of the “meltdown” symbols in Figure IV-2(b). So you need to limit either the applied voltage or available current to the diode to keep it from blowing up.

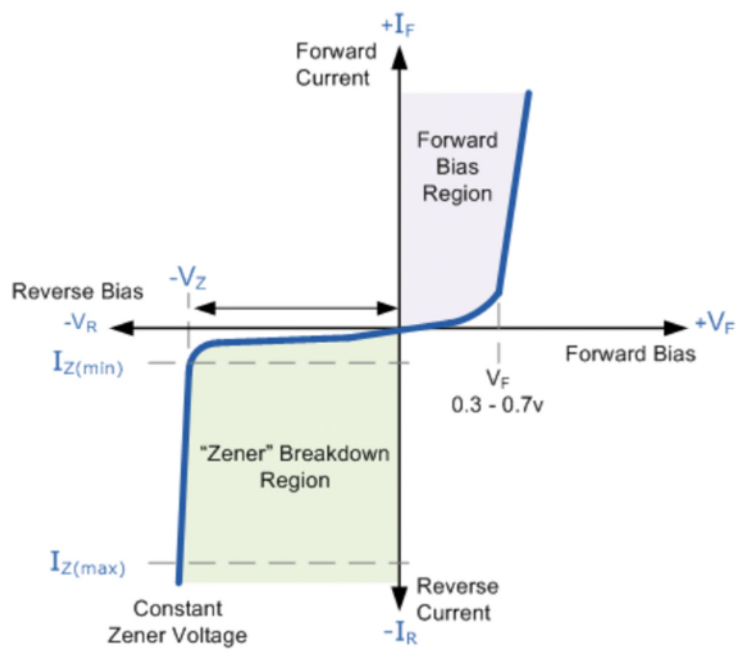


Figure IV-3. Allowed operating region in the *IV* diagram for a Zener diode.

A *Zener diode* differs from a normal pn-junction diode in that its reverse breakdown voltage meets reasonably tight tolerances and that it is *designed* to be used in the reverse-breakdown mode. It will have some specified maximum reverse current $I_{Z(\mathrm{max})}$. This means that the Zener diode can be used anywhere along the curve shown in Figure IV-3. Each Zener diode will generally have a specified minimum reverse current $I_{Z(\mathrm{min})}$ or test current $I_{Z(\mathrm{test})}$. The *Zener voltage* $-V_Z$ is the voltage at which this current $I_{Z(\mathrm{min})}$ or $I_{Z(\mathrm{test})}$ is reached. Above this current, the slope of the current *vs.* voltage line is generally pretty steep, which means that the voltage across the Zener diode will generally be pretty stable even if the current varies somewhat. This makes Zener diodes suitable for their primary application as voltage regulators.

B. Procedure

1. Oscilloscope probe

a) <u>Compensation capacitor</u>

Take your oscilloscope probe and connect it to the oscilloscope CH1. Connect the tip of the scope probe to the terminal marked "Probe Comp" in the lower right corner. Connect the ground clip to the ground terminal just below that. Since you are using a scope probe, set the CH1 Probe Setup to 10x. The Probe Comp terminal outputs a square wave. Adjust the scope controls until you can clearly see several cycles of this square wave.

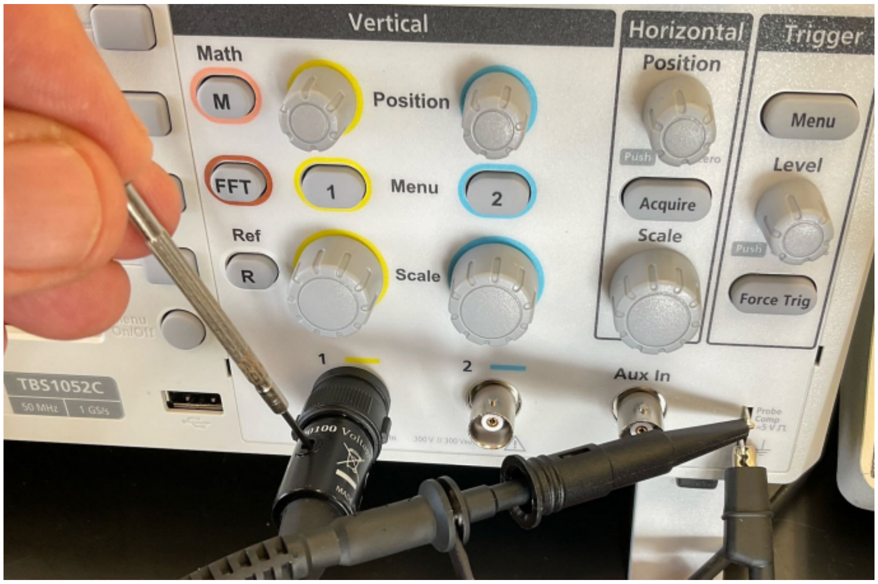


Figure IV-4. Adjusting the compensation capacitor on an oscilloscope probe.

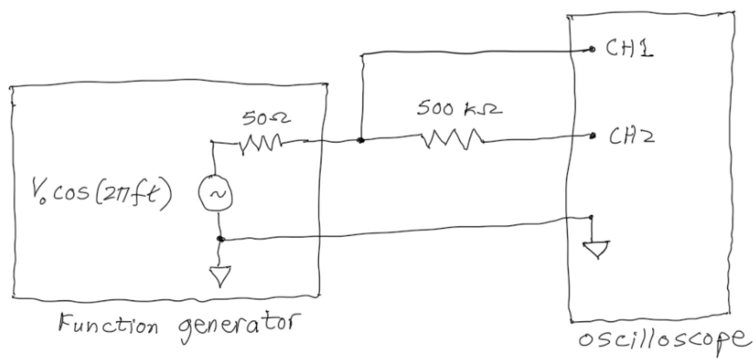
Next, find the small screw adjustment near the probe BNC connector, as illustrated in Figure IV-4. We have a number of precision screwdriver sets. Only the smallest flat-head screwdriver in these sets (1.4 mm) will work to turn the screw. Using this screwdriver, turn the screw in both directions and watch what happens to your waveform. When you turn the screw, you are adjusting the compensation capacitor in the probe. The capacitor is adjusted properly when you have an accurate square wave.

For your report: Include images of your scope display when the capacitor is properly adjusted, when it is displaced to one side of proper adjustment, and when it is displaced to the other side of proper adjustment. Explain why the changes to the square wave are happening. (You may want to refer to HW2, solutions to problem 1 and problem 2.

When you are finished with this part, be sure to leave the capacitor adjustment in the position that gives you the most accurate square wave.

b) <u>Reduction of oscilloscope load on a signal with a 10x probe.</u>

(a)



(b)

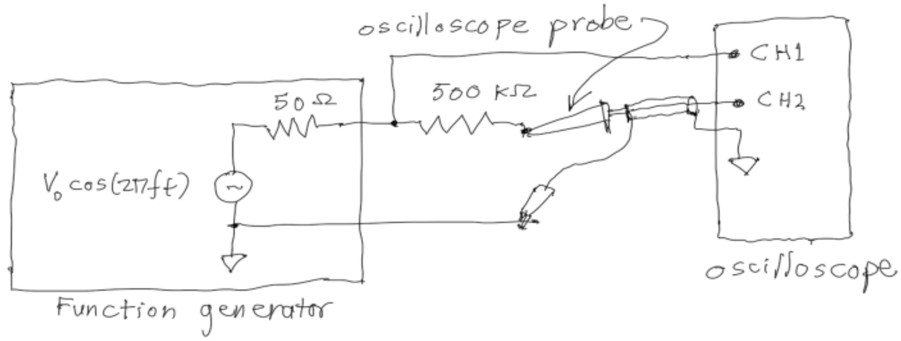


Figure IV-5. Measurement of a high impedance signal source with (a) direct connection to an oscilloscope input channel, (b) an oscilloscope probe.

Direct oscilloscope connection.

Set up the circuit shown in Figure IV-5(a). You will probably want to connect a BNC cable to the oscilloscope CH2 input and use a clip lead adapter at the other end to connect to the $500\ \text{k}\Omega$ resistor and the circuit ground. It may make things easier to set both channels to AC coupling. Don't forget that the Probe Setup should be 1x in both channels. In this circuit, the 50 Ohm resistor represents the internal output impedance of one of the BK precision function generators. You measure the direct output of this generator on the oscilloscope CH1. CH2 measures the signal on the side of the $500\ \text{k}\Omega$ resistor that is opposite the signal generator. In this way, we simulate a signal source with $500\ \text{k}\Omega$ output impedance.

Vary the frequency of the function generator and compare how the true signal out of the generator (CH1) compares to the signal measured by the oscilloscope with the $500\ \text{k}\Omega$ source impedance (CH2).

For your report: Describe qualitatively how the signal recorded in CH2 compares to the true output of the function generator in CH1 for different frequencies. Determine the amplitude ratio of the two signals and the phase shift between them for a frequency f = 3 kHz. Include a copy of your oscilloscope display for this measurement. How close do these numbers come to the ones calculated for this situation in HW 2? (Note that the actual capacitance and resistance values may be a little different than assumed in HW 2.)

Connection with an oscilloscope probe.

Next, set up the circuit shown in Figure IV-5(b). You will basically replace your BNC cable and clip leads with the oscilloscope probe. Don't forget to set "Probe Set-up" to 10X in channel 2. Again, vary the frequency of the function generator and compare how the true signal out of the generator (CH1) compares to the signal measured by the oscilloscope with the $500\ \text{k}\Omega$ source impedance (CH2).

For your report: Describe qualitatively how the signal recorded in CH2 compares to the true output of the function generator in CH1 for different frequencies. Also, determine the amplitude ratio of the two signals and the phase shift between them for a frequency f = 3 kHz. Include a copy of your oscilloscope display for this measurement. How close do these numbers come to the one calculated for this situation in HW 2? (Note that the actual capacitance and resistance values may be a little different than assumed in HW 2.) Comment on the extent to which the oscilloscope loading effects are reduced by the scope probe compared to the direct connection.

Comment on oscilloscope probe use.

From this point forward in this laboratory course, consider the advantages and disadvantages of direct oscilloscope connections *vs.* an oscilloscope probe connection for each measurement. *Feel free to use either type of connection depending on which seems better.*

2. Diode Circuits

a) <u>Multimeter diode test</u>

Get a 1N4007 diode from the parts bins. Your BK Precision 388B digital multimeter (DMM) has a diode test function. Use this function to test your diode. To do this, you'll probably want to use a dual banana-to-BNC adapter, a BNC cable, and a BNC to clip lead adapter. When you use these, don't forget to make sure that the tabbed side of the banana-to-BNC adapter goes into the COM input of your DMM. When you do this, the center BNC wire (red clip) is connected to the $\text{V}\Omega$ input and the outer conductor (black clip) is connected to the COM input.

Put the DMM into diode test mode by rotating the dial to point at the diode symbol. When you do this, the DMM is set to drive a current of 0.5 to 1 mA from the $\text{V}\Omega$ terminal to the common terminal. It will then display the voltage needed to drive that current. However it has a maximum voltage output of about 3 V. This is called the open circuit voltage. So, if the device under test cannot carry a 1 mA current the DMM will just display the open circuit voltage. But if the device under test can carry the 0.5 to 1 mA current, it will display the voltage needed to drive that current.

Test your diode with an orientation such that the DMM drives current from anode to cathode. What voltage is displayed? Then reverse the connection of the diode. What voltage is displayed now? You will know your diode is good if the voltage for the anode-to-cathode direction matches the expected diode drop, and the voltage for the reverse connection matches the open circuit voltage.

For your report: give your measured voltage for both the forward and reverse connection of the diode, and comment on whether your diode tests good.

b) Half-wave rectifier

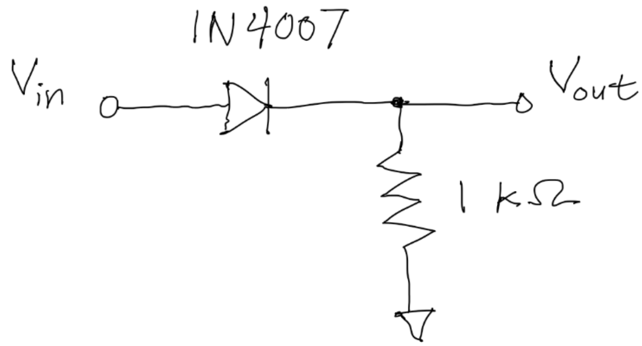


Figure IV-6. Half-wave rectifier

Build the *half-wave rectifier circuit* shown in Figure IV-6. Apply a 4 Volt amplitude, 1 kHz frequency sine wave with no offset to V_{in}. (Note that your oscilloscope will show the amplitude as 8 Volts, since it defines “amplitude” as the difference between the highest and lowest voltage of the waveform. This is twice the normal definition of amplitude in physics.) Set up your oscilloscope to display V_{in} on channel 1 and V_{out} on channel 2. You should make sure that both the channel 1 and channel 2 inputs are set for DC coupling. Set the oscilloscope up to measure the CH1 amplitude, frequency, max, and min, and the CH2 max and min.

For your report: Include a copy of the oscilloscope screen displaying V_{in} and V_{out} along with your measurements. Explain as much as you can about the waveforms that you observe. Be sure to explain why V2(max) and V2(min) take the values that they do.

~~c) Full-wave rectifier.~~ *This part is removed from the procedure due to circuit properties not matching description below. See section B.3 below an explanation.*

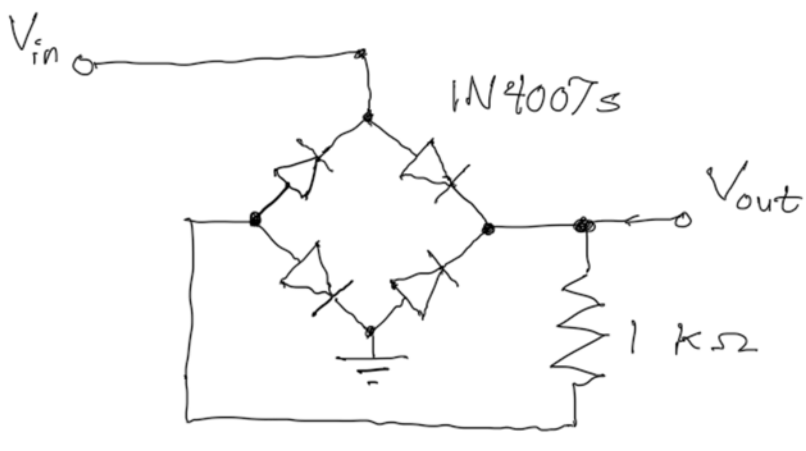


Figure IV-7. Full wave rectifier

Build the *full-wave rectifier* circuit shown in Figure IV-7. Apply a 4 Volt amplitude, 1 kHz frequency sine wave with no offset to V_{in} Set up your oscilloscope to display V_{in} on channel 1 and V_{out} on channel 2. Set the oscilloscope up to measure the CH1 amplitude, frequency, max, and min, and the CH2 max and min.

For your report: Include a copy of the oscilloscope screen displaying V_{in} and V_{out} along with your measurements. Explain as much as you can about the waveforms that you observe. Be sure to explain why V2(max) and V2(min) take the values that they do.

~~d) Filtered full-wave rectifier~~ *This part is removed from the procedure due to circuit properties not matching description below. See section B.3 below for an explanation.*

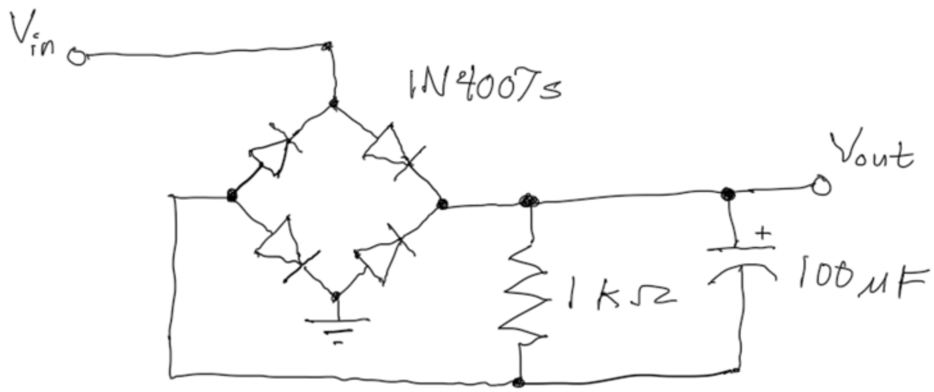


Figure IV-8. Filtered full-wave rectifier

Build the filtered full-wave rectifier circuit shown in Figure IV-8. Be sure to insert the electrolytic capacitor with the correct polarity. (For a capacitor with the leads coming from both ends, the positive lead is on the side with the indent. For a capacitor with both leads coming from the same end, the negative lead is the one next to the light-colored stripe down the side of the capacitor. The arrow on this stripe points to the negative lead.) Apply a 4 Volt amplitude, 1 kHz frequency sine wave with no offset to V_{in}. Set up your oscilloscope to display V_{in} on channel 1 and V_{out} on channel 2. Set the oscilloscope up to measure the CH1 amplitude, frequency, max, and min, and the CH2 max and min.

For your report: Include a copy of the oscilloscope screen displaying V_{in} and V_{out} along with your measurements. What effect did adding the capacitor have on the output? What is the residual voltage variation in the output $\Delta V = V2(\max) - V2(\min)$? Does this match the formula for ΔV given in lecture?

e) Diode clamp

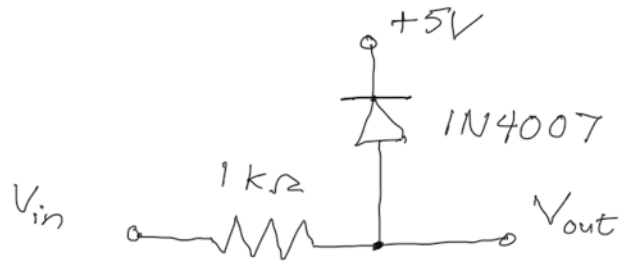


Figure IV-9. Diode clamp circuit

Build the diode clamp circuit shown in Figure IV-9. (For the PB-503 protoboards, you should be able to get your +5V source from the +5V supply in the upper right. The +5 V supply isn't working properly on the PB-505A protoboards. If you are using one of these, you should get your +5V supply either from the variable positive supply in the upper right, or from one of the TTi EL302R power supplies.)

Apply a 10 Volt amplitude, 1 kHz frequency sine wave with no offset to V_{in}. Set up your oscilloscope to display V_{in} on channel 1 and V_{out} on channel 2. Set the oscilloscope up to measure the CH1 amplitude frequency, max, and min, and the CH2 max and min.

For your report: Include a copy of the oscilloscope screen displaying V_{in} and V_{out} along with your measurements. What does this circuit do? Explain as much as you can about the observed waveforms. Be sure to explain your observed value of the clamp voltage.

f) Zener diode *IV* curve

Take one of our TTi EL302R power supplies to your bench. Do not connect the diode yet. Plug it in and turn it on. In the lower right there is an "on" button and light. This determines whether the supply is outputting voltage or not. Make sure the button is out and the "on" light is unlit. Turn the three knobs and watch what happens. You will see that you can change a voltage value and a current value. These are the *setpoints* for the voltage and current. What happens is that when you push the on button, the supply will deliver either the setpoint voltage or the setpoint current. Which one of these depends on which is more limiting to the output. For example suppose you have the supply set to 10 Volts and 1 Amp. When you turn on the supply, if it only takes 0.6 Amps to get the voltage up to 10 Volts, the supply will put out 10 Volts and 0.6 Amps. But if it would take only 5 Volts to get to 1 Amp, the supply will put out 5 Volts and 1 Amp. It won't put out more than 5 Volts because that would require the current to be larger than the setpoint. Once the on button is pressed in, the meters read the *actual* voltage and current being delivered by the supply.

With the "on" button still out, change the setpoint voltage to 1 Volt and the setpoint current to 0.12 Amps. This will limit the current that the supply can put out to 0.12 Amps, which is low enough that you won't blow up your diode. Do not change the current setting after this point, in order to protect your diode.

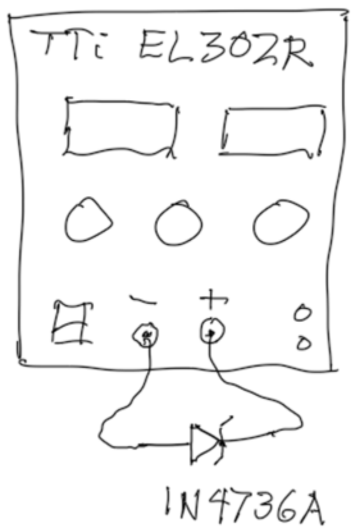


Figure IV-10. Arrangement to measure the *IV* curve of the 1N4736A Zener diode

Next, connect a 1N4736A Zener diode to your supply as shown in Figure IV-10. Note that the supply is set-up to provide a *reverse* voltage to the diode. Now, push the “on” button in so that the supply begins to output voltage. Vary the voltage and see what happens. (*Again, leave the current setting untouched*.) You should be able to observe the characteristic Zener *IV* behavior for negative voltage: no conduction up to some voltage, followed by a very quick rise in current as the Zener voltage is reached and then surpassed.

For your report: Make a table and a graph of the Zener diode current *vs.* reverse voltage. Don’t take evenly spaced voltage values. Instead, take most of your data in the voltage range where the Zener current rises rapidly from 1 mA to 120 mA. It may help to use the fine control on the voltage. How steep is this curve? If you had an application where the current pulled through the Zener diode varied between 50 mA and 100 mA, how stable would the voltage across it be?

3. Explanation for the behavior of four diode circuit in parts 2c and 2d.

An LTSpice simulation of the usual circuit for the full-wave rectifier is shown in Figure IV-11. The circuit is driven by a sine wave with 4 Volt amplitude and 1 kHz frequency. Vout1 shows the expected output for a full wave rectifier. Vout2 is equal to zero since it is connected to the circuit ground. The 2.7 Volt height of the rectified signal is approximately equal to the 4 Volt amplitude of the drive minus the approximately 1.2 Volt drop of the two diodes in the conduction pathway.

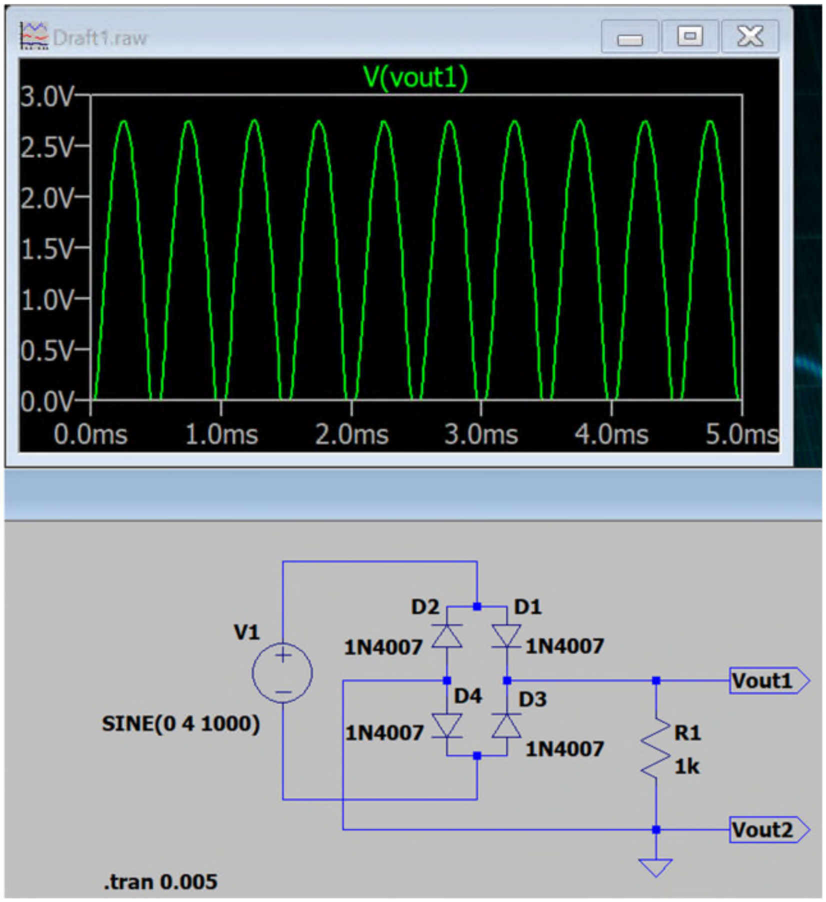


Figure IV-11. LT Spice simulation of the a full-wave rectifier.

The circuit of part 2c differs in the placement of the circuit ground. In this case the circuit ground is on one side of the voltage source. Everything else about the circuit is the same. An LTSpice simulation of this circuit is shown in Figure IV-12. It can be seen that the signal at Vout1 now looks like that of a half-wave rectifier, not a full wave rectifier. However the voltage at Vout2 is no longer zero. It now shows the signal of a half-wave rectifier in the negative direction. If we measure the voltage across the resistor (Vout1 – Vout2), we see that it is exactly the same as it was in the normal full-wave rectifier. The difference between the two circuits is that when we ground one side of the resistor, the full-wave rectified output appears directly at Vout1. But when we ground one side of the input voltage source, the full-wave rectified output appears only in the difference between Vout1 and Vout2.

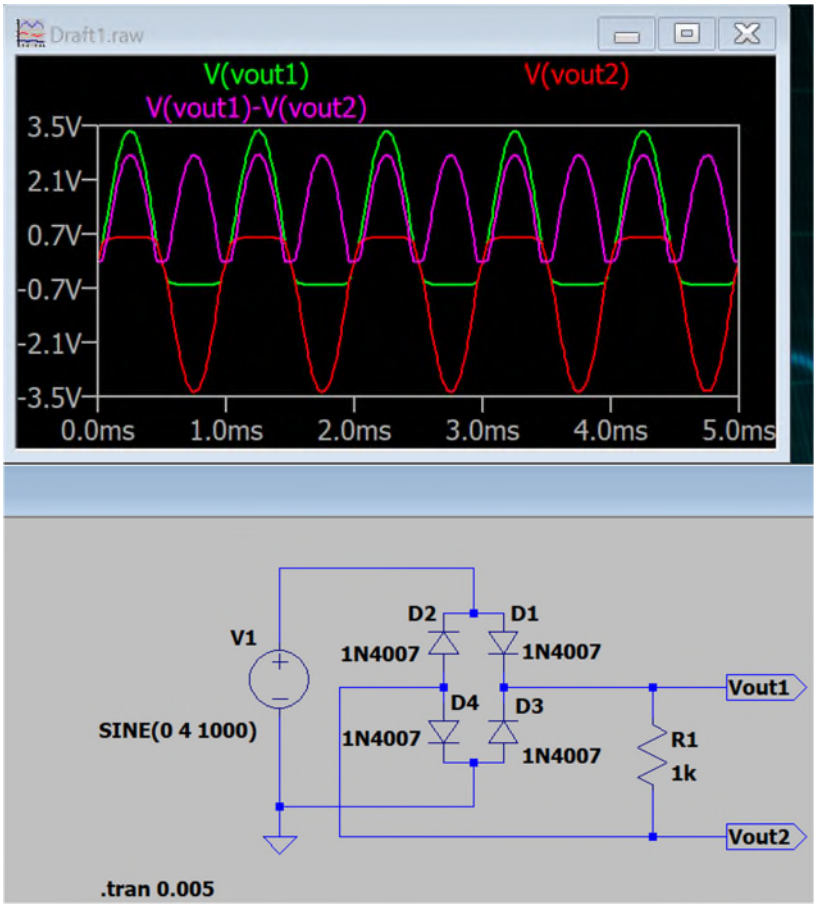


Figure IV-12. LTSpice simulation of the circuit of part 2c.

You might wonder whey we didn't just ground one side of the resistor as in Figure IV-11 in the experiment. The reason is that we couldn't because the function generator signal source had already connected one side of its output to ground. We can't then add a different ground to the circuit, for instance on one side of the resistor. If we did that, then the two ground connections would effectively short circuit D4, taking it out of the circuit completely. We would no longer have a full-wave rectifier circuit in that case.

In the usual application in a power supply, the sine wave voltage source is provided by the secondary winding of a transformer. This is electrically just coils of insulated wire. An AC voltage is generated by induction in the transformer, but there is no connection to the wire to establish a DC ground. So in that case we're free to ground one side of R1 as in Figure IV-11.

4. Specification sheets

VISHAY.

1N4001, 1N4002, 1N4003, 1N4004, 1N4005, 1N4006, 1N4007

www.vishay.com

Vishay General Semiconductor

General Purpose Plastic Rectifier

DO-41 (DO-204AL)

FEATURES

- Low forward voltage drop
- Low leakage current
- High forward surge capability
- Solder dip 275 °C max. 10 s, per JESD 22-B106
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

RoHS COMPLIANT

PRIMARY CHARACTERISTICS	
$I_{F(AV)}$	1.0 A
V_{RRM}	50 V, 100 V, 200 V, 400 V, 600 V, 800 V, 1000 V
I_{FSM} (8.3 ms sine-wave)	30 A
I_{FSM} (square wave t_p = 1 ms)	45 A
V_F	1.1 V
I_R	5.0 μA
T_J max.	150 °C
Package	DO-41 (DO-204AL)
Circuit configuration	Single

TYPICAL APPLICATIONS

For use in general purpose rectification of power supplies, inverters, converters, and freewheeling diodes application.

MECHANICAL DATA

Case: DO-41 (DO-204AL), molded epoxy body
Molding compound meets UL 94 V-0 flammability rating
Base P/N-E3 - RoHS-compliant, commercial grade

Terminals: matte tin plated leads, solderable per J-STD-002 and JESD 22-B102
E3 suffix meets JESD 201 class 1A whisker test

Polarity: color band denotes cathode end

MAXIMUM RATINGS (T_A = 25 °C unless otherwise noted)

PARAMETER	SYMBOL	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	UNIT
Maximum repetitive peak reverse voltage	V_{RRM}	50	100	200	400	600	800	1000	V
Maximum RMS voltage	V_{RMS}	35	70	140	280	420	560	700	V
Maximum DC blocking voltage	V_{DC}	50	100	200	400	600	800	1000	V
Maximum average forward rectified current 0.375" (9.5 mm) lead length at T_A = 75 °C	$I_{F(AV)}$	1.0							A
Peak forward surge current 8.3 ms single half sine-wave superimposed on rated load	I_{FSM}	30							A
Non-repetitive peak forward surge current square waveform T_A = 25 °C (fig. 3), t_p = 1 ms	I_{FSM}	45							A
t_p = 2 ms		35							
t_p = 5 ms		30							
Maximum full load reverse current, full cycle average 0.375" (9.5 mm) lead length T_L = 75 °C	$I_{R(AV)}$	30							μA
Rating for fusing (t < 8.3 ms)	I^2t [(1)]	3.7							A^2s
Operating junction and storage temperature range	T_J, T_{STG}	-50 to +150							°C

Note

(1) For device using on bridge rectifier application

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ELECTRICAL CHARACTERISTICS (T_A = 25 °C unless otherwise noted)											
PARAMETER	**TEST CONDITIONS**		**SYMBOL**	**1N4001**	**1N4002**	**1N4003**	**1N4004**	**1N4005**	**1N4006**	**1N4007**	**UNIT**
Maximum instantaneous forward voltage	1.0 A		V_F	1.1							V
Maximum DC reverse current at rated DC blocking voltage		T_A = 25 °C	I_R	5.0							μA
		T_A = 125 °C		50							
Typical junction capacitance	4.0 V, 1 MHz		C_J	15							pF

THERMAL CHARACTERISTICS (T_A = 25 °C unless otherwise noted)									
PARAMETER	**SYMBOL**	**1N4001**	**1N4002**	**1N4003**	**1N4004**	**1N4005**	**1N4006**	**1N4007**	**UNIT**
Typical thermal resistance	$R_{\theta JA}$ (1)	50							°C/W
	$R_{\theta JL}$ (1)	25							

Note

(1) Thermal resistance from junction to ambient at 0.375" (9.5 mm) lead length, PCB mounted

ORDERING INFORMATION (Example)				
PREFERRED P/N	**UNIT WEIGHT (g)**	**PREFERRED PACKAGE CODE**	**BASE QUANTITY**	**DELIVERY MODE**
1N4004-E3/54	0.33	54	5500	13" diameter paper tape and reel
1N4004-E3/73	0.33	73	3000	Ammo pack packaging

RATINGS AND CHARACTERISTICS CURVES (T_A = 25 °C unless otherwise noted)

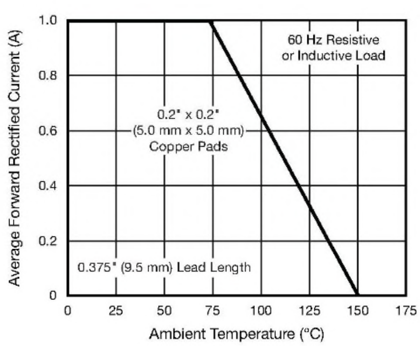

Fig. 1 - Forward Current Derating Curve

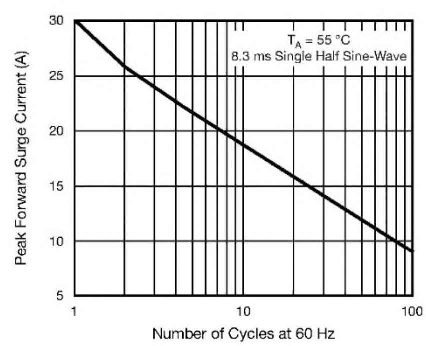

Fig. 2 - Maximum Non-repetitive Peak Forward Surge Current

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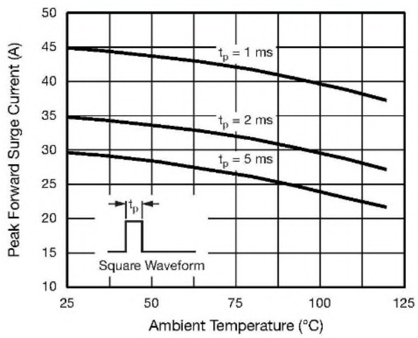

Fig. 3 - Non-Repetitive Peak Forward Surge Current

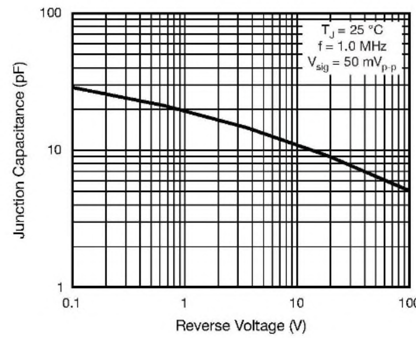

Fig. 6 - Typical Junction Capacitance

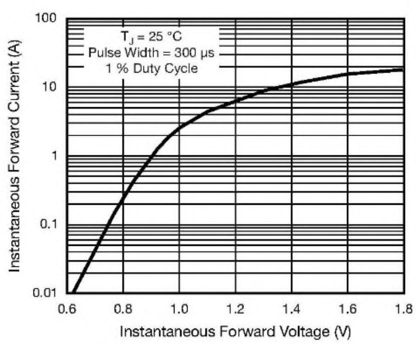

Fig. 4 - Typical Instantaneous Forward Characteristics

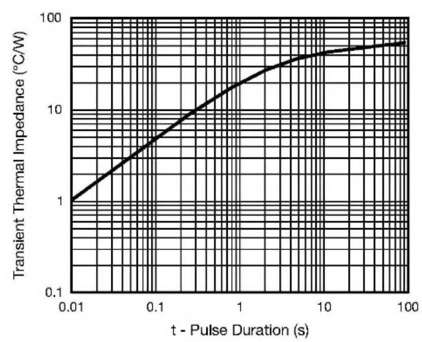

Fig. 7 - Typical Transient Thermal Impedance

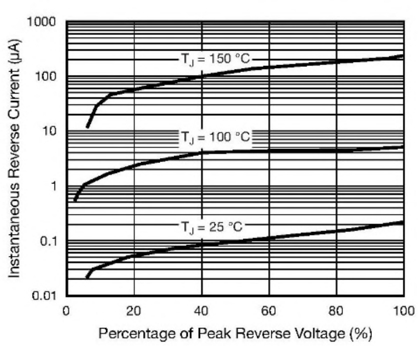

Fig. 5 - Typical Reverse Characteristics

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DATA SHEET
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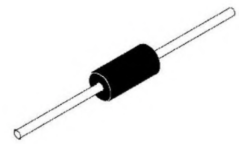
Zener Diodes
1N4728A - 1N4758A



AXIAL LEAD
CASE 017AH

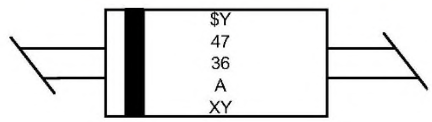
ABSOLUTE MAXIMUM RATINGS (Note 1)
T_a = 25°C unless otherwise noted

Symbol	Parameter	Value	Unit
P_D	Power Dissipation @ TL ≤ 50°C, Lead Length = 3/8″	1.0	W
	Derate above 50°C	6.67	mW/°C
T_J, T_{STG}	Operating and Storage Temperature Range	−65 to +200	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. These ratings are limiting values above which the serviceability of the diode may be impaired.

MARKING DIAGRAM



$Y = Logo
4736A = Specific Device Code
XY = Date Code

ORDERING INFORMATION

See detailed ordering and shipping information on page 3 of this data sheet.

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ELECTRICAL CHARACTERISTICS T_a = 25°C unless otherwise noted

Device	V_Z (V) @ I_Z (Note 2) Min.	Typ.	Max.	Test Current I_Z (mA)	Max. Zener Impedance Z_Z @ I_Z (Ω)	Z_{ZK} @ I_{ZK} (Ω)	I_{ZK} (mA)	Leakage Current I_R (μA)	V_R (V)	Non−Repetitive Peak Reverse Current I_{ZSM} (mA) (Note 3)
1N4728A	3.135	3.3	3.465	76	10	400	1	100	1	1380
1N4732A	4.465	4.7	4.935	53	8	500	1	10	1	970
1N4733A	4.845	5.1	5.355	49	7	550	1	10	1	890
1N4734A	5.32	5.6	5.88	45	5	600	1	10	2	810
1N4735A	5.89	6.2	6.51	41	2	700	1	10	3	730
1N4736A	6.46	6.8	7.14	37	3.5	700	1	10	4	660
1N4737A	7.125	7.5	7.875	34	4	700	0.5	10	5	605
1N4738A	7.79	8.2	8.61	31	4.5	700	0.5	10	6	550
1N4739A	8.645	9.1	9.555	28	5	700	0.5	10	7	500
1N4740A	9.5	10	10.5	25	7	700	0.25	10	7.6	454
1N4741A	10.45	11	11.55	23	8	700	0.25	5	8.4	414
1N4742A	11.4	12	12.6	21	9	700	0.25	5	9.1	380
1N4743A	12.35	13	13.65	19	10	700	0.25	5	9.9	344
1N4744A	14.25	15	15.75	17	14	700	0.25	5	11.4	304
1N4745A	15.2	16	16.8	15.5	16	700	0.25	5	12.2	285
1N4746A	17.1	18	18.9	14	20	750	0.25	5	13.7	250
1N4747A	19	20	21	12.5	22	750	0.25	5	15.2	225
1N4748A	20.9	22	23.1	11.5	23	750	0.25	5	16.7	205
1N4749A	22.8	24	25.2	10.5	25	750	0.25	5	18.2	190
1N4750A	25.65	27	28.35	9.5	35	750	0.25	5	20.6	170
1N4751A	28.5	30	31.5	8.5	40	1000	0.25	5	22.8	150
1N4752A	31.35	33	34.65	7.5	45	1000	0.25	5	25.1	135
1N4753A	34.2	36	37.8	7	50	1000	0.25	5	27.4	125
1N4754A	37.05	39	40.95	6.5	60	1000	0.25	5	29.7	115
1N4755A	40.85	43	45.15	6	70	1500	0.25	5	32.7	110
1N4756A	44.65	47	49.35	5.5	80	1500	0.25	5	35.8	95
1N4757A	48.45	51	53.55	5	95	1500	0.25	5	38.8	90
1N4758A	53.2	56	58.8	4.5	110	2000	0.25	5	42.6	80

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

NOTES:
2. Zener Voltage (V_Z).
   The zener voltage is measured with the device junction in the thermal equilibrium at the lead temperature (T_L) at 30°C ±1°C and 3/8″ lead length.
3. 2 Square wave Reverse Surge at 8.3 ms soak time.

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