ASEN 3300, Fall 2023: Lab 5 Report Submission

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4. Experiment (25 pts)

4.1. Zener diode operation (6 pts)

a. Record your responses to 4.1.a in the table below:

V_{IN}:	1 V	2 V	3 V	4 V	5 V
V_{diode}:	0.99 V	2.09 V	3.01 V	4.03 V	5.02 V

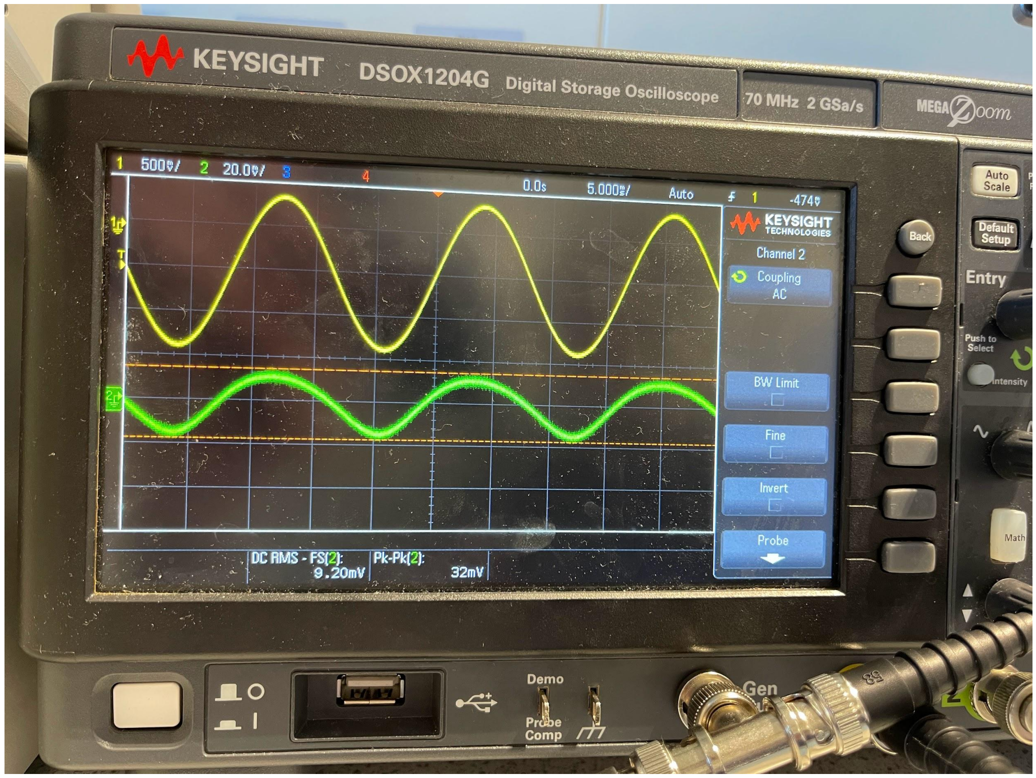
V_{IN}:	6 V	7 V	8 V	9 V	10 V
V_{diode}:	5.43 V	5.50 V	5.53 V	5.55 V	5.56 V

b. Record your response to 4.1.b below:

$I_{reverse} = I_{bias} = 0.147$ mA

c. Record your responses to 4.1.c below:

	10 kOhm	3.3 kOhm	330 Ohm
VDC across R_{LOAD}:	5.41 V	5.40 V	4.17 V
V_{RL}(P-P) AC ripple peak-to-peak voltage:	36 mV	44 mV	1.07 V



4.2. DC-DC converter (9 pts)

b. Record your responses to 4.2.b below:

Pin 1:	+V_in
Pin 2:	-V_in
Pin 4:	-V_out
Pin 5:	0 V
Pin 6:	+V_out

c. Record your responses to 4.2.c below:

V4-5:	-23.9 V
V5-6:	23.7 V
V4-6:	46.5 V
V4-GND:	2.12 mV
V6-GND:	3.04 mV

d. Record your response to 4.2.d below:

It makes sense why we don't see the expected value due to the fact that there is no load installed.

e. Record your responses to 4.2.e below:

V4-5:	-14.89 V
V5-6:	15.39 V
V4-6:	-30.3 V
V4-GND	-15.1 V
V6-GND	15.0 V

f. Record your responses to 4.2.f below:

DC Voltage (mean Component):	15.2 V
$AC_{pk\text{-}pk}$ Ripple Voltage:	126.25 mV
Measured Switching Frequency:	94.6 kHz

g. Record your responses to 4.2.g below:

	R_{LOAD} = 1 kΩ	R_{LOAD} = 3 kΩ
Power supply current:	150.9 mA	79.5 mA
Load current:	-15.5 mA	-4.72 mA

4.3. Linear power regulation with off-the-shelf components (6 pts)

b. Record your responses to 4.3.b below:

R1:	330 Ohm
R2:	1 K Ohm
Output Voltage with no load:	4.99 V

c. Record your responses to 4.3.c below:

	DC Voltage (mean component)	$AC_{pk\text{-}pk}$ Ripple Voltage
R_L = 10 kΩ	4.97 V	11.5 mV
R_L = 3.3 kΩ	4.97 V	13.1 mV
R_L = 330 Ω	4.97 V	10.4 mV

d. Record your response to 4.3.d below:

Minimum Required V_{IN} :	6.5 V

e. Record your responses to 4.3.e below:

	R_{LOAD} = 330 Ω	R_{LOAD} = 10 kΩ
$I_{powerSupply}$:	18.9 mA	4.4 mA
I_{LOAD} :	14.9 mA	.51 mA
V_{LOAD}	4.97 V	4.97 V

4.4. Power switching using transistors (4 pts)

a. Record your responses to 4.4.a below:

Whenever the connection from V_in is removed, the LED turns off. Whenever the connection to ground is broken, the LED turns off as well.

b. Record your response to 4.4.b below:

I_{R2} (current through resistor at the base of MOSFET) :	I = 5.09 mA

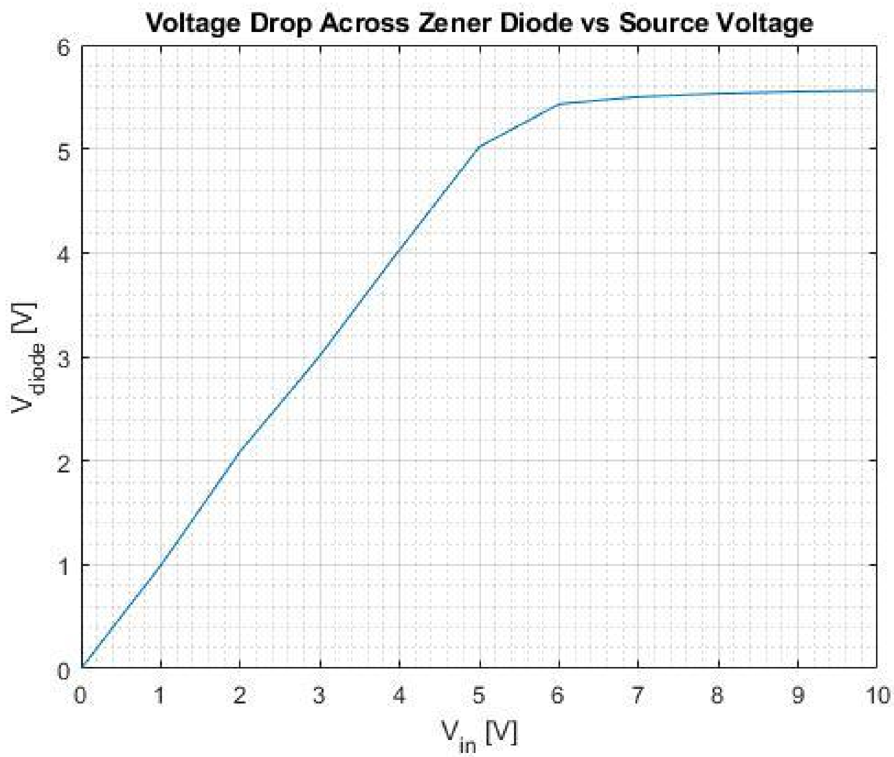
c. Record your responses to 4.4.c below:

We can see the LED blinking up to 76 Hz. When the duty cycle is 1%, the blinking is slower and super dim. As the duty cycle increases, the brightness and frequency of the blinking of the LED increase.

5. Analysis (25 pts)

5.1. Zener diode operation (7 pts)

a. Record your responses to 5.1.a below:



As the voltage from the DMM is increased from 0-10 V, the Zener Diode voltage drop is also increasing up until ~5.6 V, which is to be expected since the Zener Diode has a breakdown voltage of 5.6 V for ~5-89 mA of current.

b. Record your response to 5.1.b below:

In 4.1c, we see that with a 10kΩ resistor, there is a VDC of 5.41 V and a V_{RL}(P-P) of 36 mV. For a 1kΩ resistor, there is a VDC of 5.40 V and a V_{RL}(P-P) of 44 mV. For a 330Ω resistor, there is a VDC of 4.17 V and a V_{RL}(P-P) of 1.07 V. For higher resistor values, the VDC is closer to what we expect (5.6 V since it is in parallel with the Zener Diode), while with low resistor value, the VDC is decently far from what is expected. This same trend is seen with V_{RL}(P-P). V_{RL}(P-P) should be relatively small since the Zener Diode is holding a constant voltage despite the AC (with an input V_{RL}(P-P) of 2 V) + DC signal being applied. It is essentially trying to turn that AC signal into a constant DC signal. The R_{DYN}/R ratio for a 10kΩ resistor is 0.018, for a 1kΩ resistor it is 0.022, and for a 330Ω resistor, it is 0.535. This indicates that with our current limiting resistor, low load resistor values are not effective. When the load resistor is a higher value, the current drawn to the resistor is much lower than that of the Zener Diode.

c. Record your response to 5.1.c below:

The Z_z value from the datasheet is 11Ω at 20 mA. With a load resistor of 330Ω, R_{DYN} is 176.55Ω, for a 1kΩ load resistor, R_{DYN} is 7.26Ω, and for a 10kΩ load resistor, R_{DYN} is 5.94Ω. We see that there is some difference in R_{DYN} as compared to the datasheet, however the datasheet value is at 20 mA. The values calculated are around the expected range (with the exception of a load resistor of 330Ω) since R_{DYN} is on the order of a few ohms. When the load resistor is 330Ω, it is not the expected value due to the fact that the load resistor and current limiting resistor are the same values.

5.2. DC-DC converter (5 pts)

a. Record your response to 5.2.a below:

For section 4.2c, V4-5 is -23.9 V and V5-6 is 23.7 V. Since pin 5 is 0 V, pin 4 is -V_out, and pin 6 is +V_out, it makes sense that V4-5 is the same magnitude, but opposite sign of V5-6 and that V4-6 has double the magnitude (46.5 V). The same trend is seen is 4.2e.

b. Record your response to 5.2.b below:

Load resistors are to simulate the presence of a real load in the circuit while also meeting the load requirements. They also help stabilize the output voltage of the DC-DC converter. They are necessary as they are a useful tool for testing and gaining measurements. Some DC-DC converters also have required R loads to operate correctly. And finally, ensure the converter operates in the correct voltage range that will not damage the hardware.

c. Record your response to 5.2.c below:

Our output voltage was 15.2 V while the AC ripple voltage (voltage spikes) was only 0.126 V. With the low ripple voltage, we can see the DC-DC converter doing its job in trying to keep the voltage constant.

d. Record your response to 5.2.d below:

The circuit efficiency for the 1k ohm load resistor is 62.46 %. This was found by using the equation P_out/P_in. And the circuit efficiency for the 3k ohm load resistor was 36.04 % using the same equation. It is expected for the circuit efficiency to go down as the R_load increases. This is because the efficiency is highest when it matches its optimal load resistance. And the farther you move away from that optimal resistance, the lower your efficiency will be.

5.3. Linear Power Regulation (8 pts)

a. Record your response to 5.3.a below:

We measured the output voltage to be 4.99 V. In the prelab, we calculated the output voltage to be 5 V. Because of this, we selected R1 to be 330 ohms and R2 to be 1000 kiloohms. We were just about able to settle this with our measured output voltage only being slightly under the desired 5 V.

b. Record your response to 5.3.b below:

When using the zener diode, as the load resistance gets lower, the AC ripple voltage gets higher. This shows that the zener diode works better with a higher load resistance. With the linear regulator, the ripple voltage is relatively consistent based on the load resistor value. This shows that this may work better for a wider range of load resistance values. The output is improved on each step by first going through the capacitor, then through the linear regulator, and then back through another capacitor. Each time, the voltage will get smoother and smoother, ultimately making the results better.

c. Record your response to 5.3.c below:

For this part of the experiment, our Vin - Vout is around 4 V. Our measurement turned out to be slightly more than the expected value of 3 V for Vin - Vout. We settled on measuring a Vout output of 4.97 V with a 9 V Vin. This settles the minimum difference between Vin and Vout for the LM317.

d. Record your response to 5.3.d below:

For Rload = 330 ohms:
Pin = 170.1 mW
Pout = 74.05 m W
Efficiency = 43.5%

For Rload = 10 kilo ohm
Pin =39.6
Pout = 2.535
Efficiency = 6.40%

The efficiency is much better for the lower load resistor value.

5.4. Power switching using transistors (5 pts)

a. Record your response to 5.4.a below:

Obviously, if the system has no input voltage, there will be no current running through the LED, so it won't turn on. This is why when we remove the connection from Vin, the LED turns off. The reason that the LED turns off when it is disconnected from ground is because if there is no potential difference across the LED, there will be no current. With ground, we create a 5 V potential difference.

b. Record your response to 5.4.b below:

- A MOSFET has a very high input impedance at the gate, meaning that very little input current is required to control the current flow between source and drain
- Some fast switching MOSFETs can intake high frequency waves in order to switch on and off very fast.
- A bipolar transistor requires a constant current flow to remain on, while the MOSFET doesn't need a current at the gate to stay on.

Ultimately, a MOSFET is generally faster and more efficient than the bipolar transistors.

c. Record your response to 5.4.c below

Vin minimum is a specific minimum voltage value that is required to determine whether the MOSFET is in its on or off state. If you supply a Vin smaller than this minimum, the MOSFET will not enter its “on state”. This will result in no current flowing between the drain and source.

d. Record your response to 5.4.d below:

The frequency that we stop noticing the LED flicker is around 76 Hz. This relates to frames per second (fps) of a movie and refresh rate of a monitor due to the fact that at a certain fps and refresh rate, our eyes can longer tell that individual images are being displayed in sequence. This gives us the illusion of a video being played, when in reality it is just a series of pictures being displayed at a high frequency. This is the same for when we noticed the LED stops blinking; in reality it is still blinking at an extremely high rate.