EE105: Voltage Supply Lab

Lab5

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Abstract:

The purpose of this lab is to model and design a constant voltage supply and apply it to a load.

Section 1 Pre-lab:

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Figure 1 shows a circuit for implementation of a constant voltage supply. The input u is the common outlet voltage $u(t) = 120\sin(2\pi 60t)$. The circuit involves a transformer with $N = 10$ and a diode. The diode current and voltage are related by the nonlinear function in Table 1.

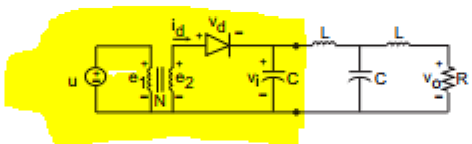


Figure 1: Voltage supply circuit.

```
function [id]=diode(vd)
A = 0.001;
if vd > 0.7
    Rd = 0.01;
    id = A + (vd - 0.7)/Rd;
else
    Rd = 1000;
    id = A + (vd - 0.7)/Rd;
end.
```

Table 1: Diode Model.

Procedure:

For the circuit in *Figure 1*, we are to construct a bond graph and a state space model, which is shown in *Figure 1a* below.

Results:

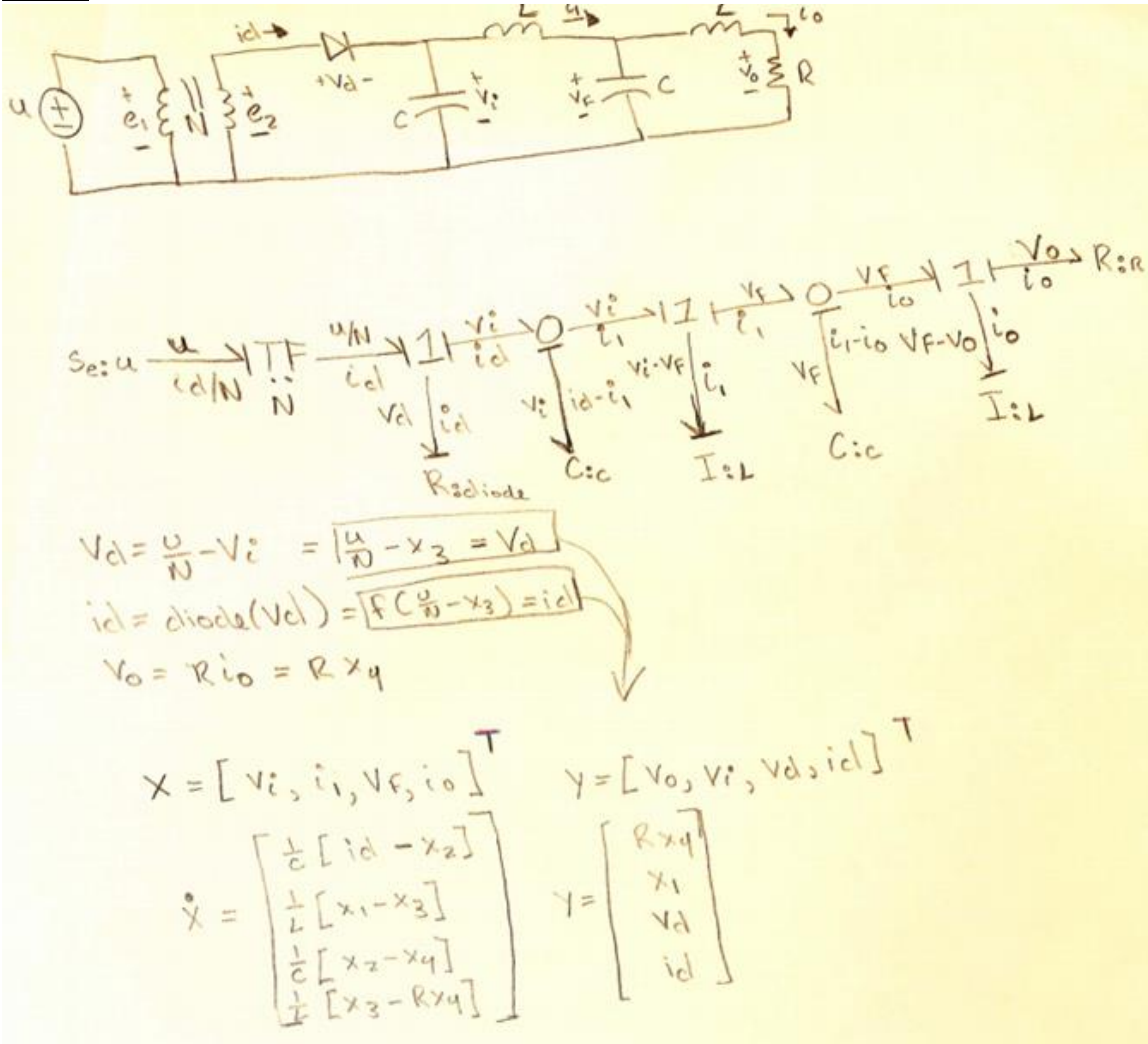


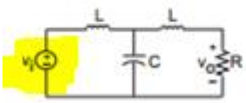
Figure 1a: State Space Model for Figure 1

Section 2 Lab:

Section 2.1 Find L :

Procedure:
For this section, we were required to find the Inductance value, L, for the system in *Figure 2* that would result in a gain of .1 at a frequency of 60 Hz. We know R, C, and s. for each value of L you can compute H. Then plot |H| versus L to choose the value of L that meets the criteria.

$C = 100\mu$ Farads.
$R = 1000$ Ohms.



The transfer function from input to output is

$$\frac{V_o(s)}{V_i(s)} = H(s) = \frac{R}{L^2Cs^3 + RLCs^2 + 2Ls + R}.$$

Figure 2: Filter for voltage supply.

Code:

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```
%Lab5 Part 1
R = 1000; %Ohms
C = 100E-6; %Farads
L = [.5:.01:1.0]; %Henrys
w = 2*pi*60; %Rad/sec
s = w*1i;

%Polyval: y = polyval(p,x)
Num = [0 0 R];
Den = [(C*s^3) (R*C*s^2 + 2*s) (R)];
m = abs(polyval(Num,L)./polyval(Den,L));
%Plot m vs L
plot(L,m);
xlabel('L,Henry');
ylabel('|H(jw)|');
title('|H(jw)| v. L');
grid on;
```

Figure 3: Matlab Code to Find L

Results:

Running the code from *Figure 3*, we obtain the plots show below in *Figure 4*

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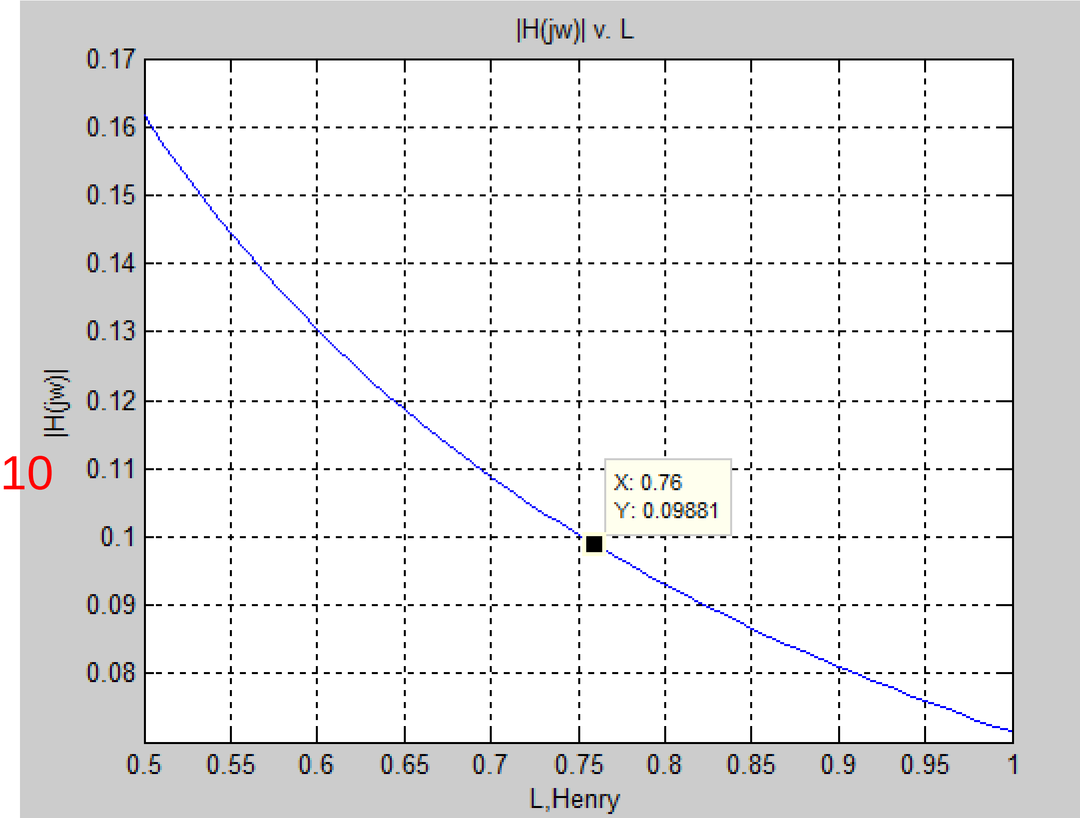

Figure 4: Plot showing |H(jw)| for different L values.

By using the MATLAB trace function, we can obtain a value of L that satisfies our desired condition. In this case that value will be L = .76 H, as seen in *Figure 4*.

Section 2.2: Implementing the System

Procedure:

For this section we were asked to implement the system from the Pre-lab in Simulink. This required us to design a Simulink simulation (Figure 5) that implements our State Space Model of the circuit shown in Figure 1 (Figure 6). We are then asked to analyze the results and draw conclusion about the purpose of this circuit.

Code/Block Diagrams:

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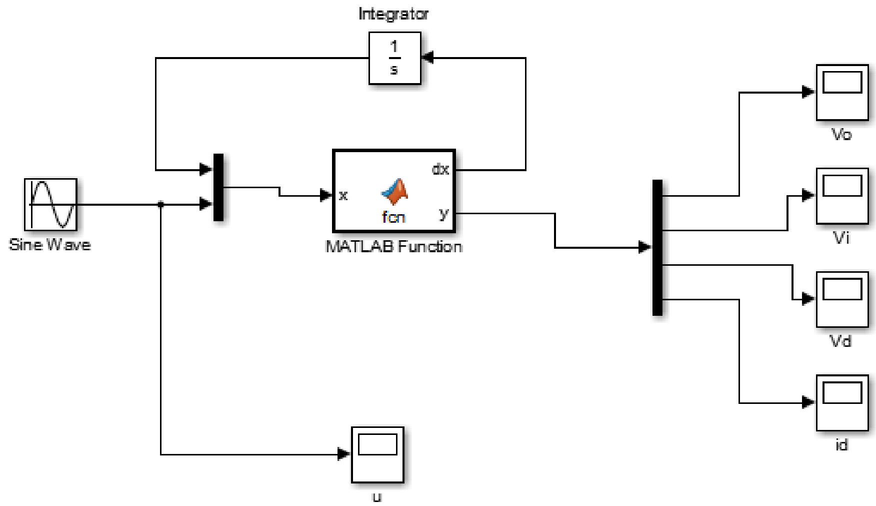

Figure 5: Simulink Simulation to model Figure 1

Table 1 implemented in Matlab

```
function [id]=diode(vd)
A = 0.001;
if vd > 0.7
Rd = 0.01;
id = A + (vd - 0.7)/Rd;
else
Rd = 1000;
id = A + (vd - 0.7)/Rd;
end
```

Figure 1a State Space Equation Implmentation

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```
function [dx, y] = fcn(x)
%#codegen
    R = 1000; %Ohms
    L = .76; %Farads
    C = 100E-6; %Henrys
    N = 10; %Turns
    vd = 0;
    id = 0;


%Assign function inputs to S.S.Vector
x1 = x(1); %x1 = vi
x2 = x(2); %x2 = i1
x3 = x(3); %x3 = vf
x4 = x(4); %x4 = io
u  = x(5); %u = sin(wt)

vd =(u/N)-x1; %vd = u/N - vi
id = diode(vd); %id = funct(vd)

%Assign Output Equtions
y1 = R*x4; %v0 = Rx4
y2 = x1; %vi = x1
y3 = vd; %vd = u/N-x1
y4 = id; %id = funct(vd)

%Assign dx vector to function output
dx1 = (1/C)*(id-x2); %dx1 = (1/C)(id-i1)
dx2 = (1/L)*(x1-x3); %dx2 = (1/L)(x1-x3)
dx3 = (1/C)*(x2-x4); %dx3 = (1/C)(x2-x4)
dx4 = (1/L)*(x3-R*x4); %dx4 = (1/L)(x3-Rx4)

dx = [dx1; dx2; dx3; dx4];
%Assign Output equition to function output
y = [y1; y2; y3; y4];
```

Figure 6: Code to Implement State Space Model in MATLAB Function Block

Results:

By implementing the block diagram showed in Figure 5, the different scope outputs to the graph are shown below.

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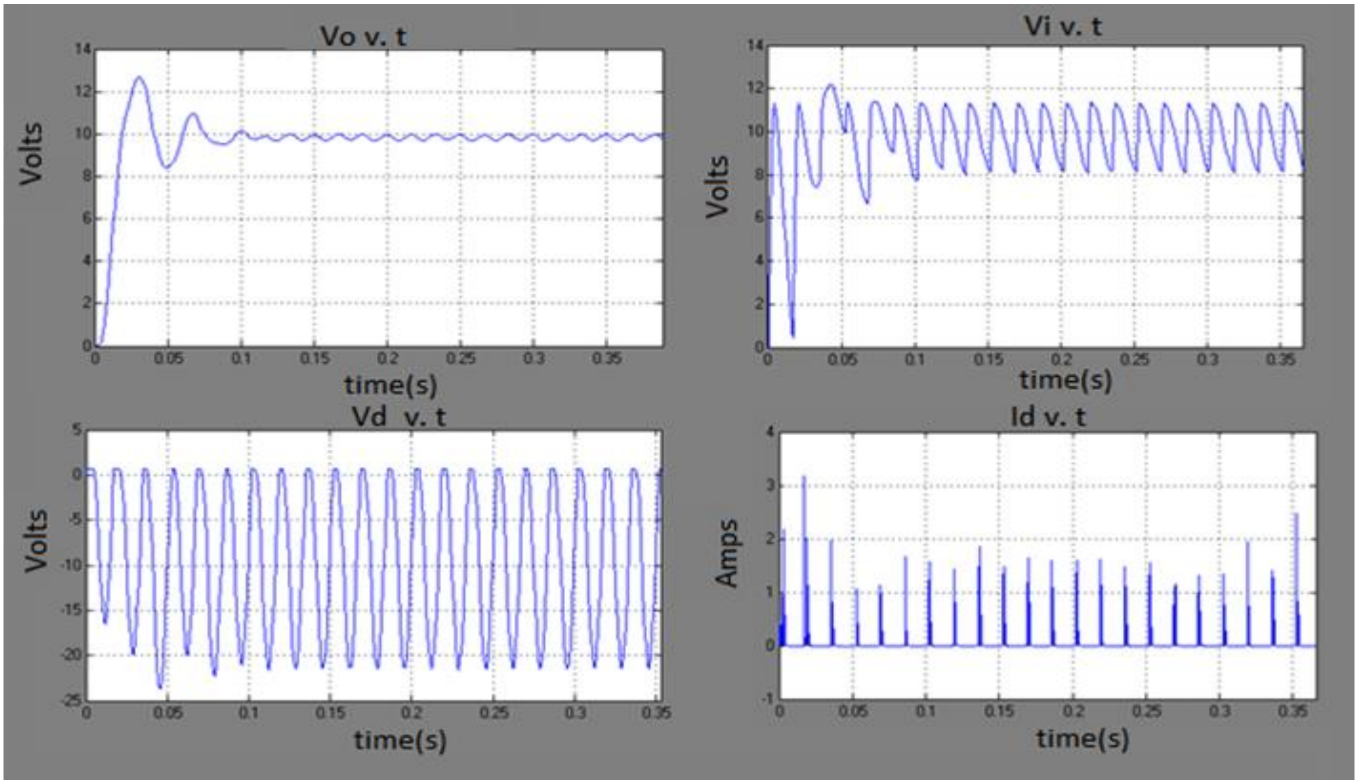

Figure 7a: Scope Outputs for Figure 5

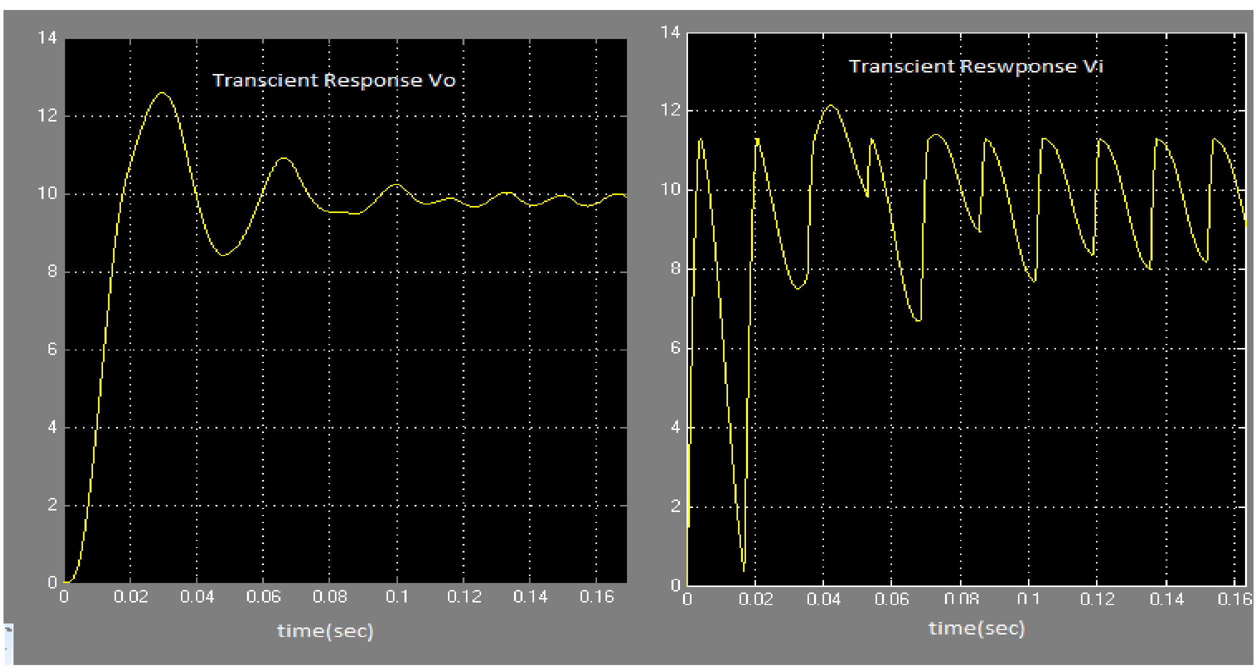

Figure 7b: Zoomed Transient Response of Vo and Vi

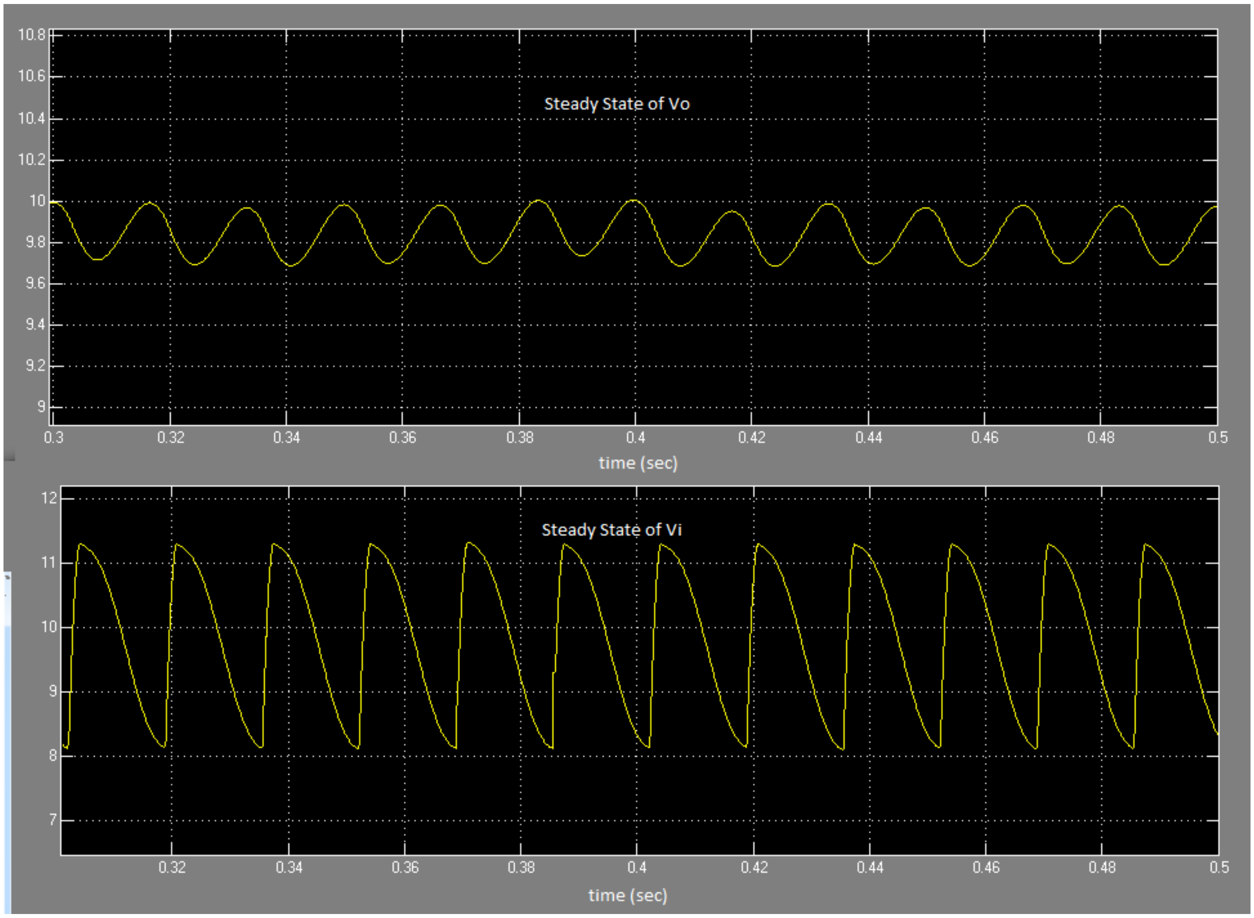

Figure 7c: Zoomed in Steady State Response of Vo and Vi

We can see from *Figure 7a, Figure 7b* and *Figure 7c* the time-varying results of the waveform. We can observe:

- the diode ensures that the current through it is only positive;
- the capacitor charges during the first cycle, has a transient that decays away within 0.1 second, then maintains a steady-state oscillation of 3.2 volts (peak-to-peak);
- the output voltage across the resistor Vo is .3 volts (peak-to-peak).

Therefore, the sequence of energy storage devices (capacitors and inductors) have done their job of reducing the voltage oscillation by a factor of 10.6, which exceeds the spec of 10%. Success!

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Now we consider the circuit in *Figure 1* as having two subsystems, with the highlighted portion on the left acting as one system and the other half of the system acting as another subsystem. The system that is highlighted serves as a positive voltage source that is stepped down from that of the 120 V input. We can see this in the Vi plot in Figure 7c. *Figure 2* shows how thinking about this subsystem as a voltage source *Vi,* can greatly simplify the system.

The subsystem on the right is there to provide a steady and stable output voltage. This can be seen by observing the Figure 7b and Figure 7c graphs. We can see the voltage is now oscillating very little and is supplying an almost constant 10 Volts when compared to the initial input.

The purpose of the diode is to only allow current to flow in one direction, which only happens when the voltage is greater than 0.7 V. The transformer steps down the voltage, while the inductors and capacitors store energy to stabilize the current through the resistive load. Together, we have created a stable DC Source out of 120 V AC input. To further and dramatically stabilize the voltage, a solid state voltage regulator could be used in place of the LCL sequence of energy storage elements.

Section 2.3 Varying R:

Procedure:
For this section we were asked observe the behavior of output voltage as we vary the resistance of the load.

Results:
By varying the resistance of our R value, the output oscillations vary as well. The corresponding Voltage Percent Variation changes can be seen in the table below.

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Resistance, Ω	Calculation	Percentage Variance of v_o
100	(6.77V-6.48V)/6.625V*100%	4.377%
200	(8.20V-7.85V)/8.025V*100%	4.361%
300	(8.83V-8.48V)/8.655V*100%	4.044%
400	(9.20V-8.86V)/9.03V*100%	3.765%
500	(9.45V-9.12V)/9.285V*100%	3.554%
600	(9.62V-9.31V)/9.465V*100%	3.275%
700	(9.74V-9.44V)/9.59V*100%	3.128%
800	(9.85V-9.56V)/9.705V*100%	2.988%
900	(9.9V-9.63V)/9.765V*100%	2.765%
1000	(9.98V-9.71V)/9.845V*100%	2.743%

Table 2: Percent Variation

By looking at both Figure 8 and *Table 2*, we can see that as the resistance of the load increases the percent variation of the output voltage also increase. So the bigger the load, the less variance we have in the output voltage.

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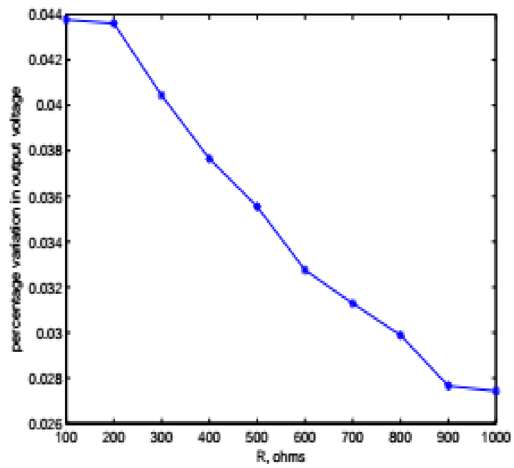

Figure 8: Percent Variation v. Resistance

The reason for the increase in variation with decreasing resistance is that smaller resistance, the current is larger, during each half cycle when the diode is preventing negative current, the load current is being supplied by discharging the capacitors, which lowers their voltage. During the other half cycle the capacitors recharge. The higher current yields a larger peak-to-peak swing.

Conclusion: +10

The purpose of this lab was to model, simulate, and understand a half-wave Voltage Supply. This allowed us to choose parameters and observe the effects of these parameters on the system as a whole. This also allowed us how to deal with non-linear systems in Matlab.