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by Jack Rogers

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1. Executive Summary

In this assignment a wide range of research was carried out to find the correct and suitable requirements to build and test a regulated power supply. The wide range of research included looking at datasheets to find the right specifications, cost management, electrical and health & safety standards. Also, a step-by-step implementation on how to design the regulated power supply was created using equations and descriptive work. Finally, a testing stage was completed and an analysis and conclusion of this was done to determine if the power supply created was an effective option for its use.

2. Planning and reflection

The approach that will be taken to this assignment will be to time manage each step of the design process when creating the regulated power supply. For the design of the circuits of the power supply NI Multisim will be used. The equations will then be worked out and typed in the report by using the equation tool in Microsoft word. Also, for the planning of this the consideration of the ethical and environmental factors will be addressed. After Testing is complete research will be done to ensure the components are correct ones needed for the power supply.

3. Research (about the spec)

After completing the testing and design for the power supply the components that are be required will be researched below.

3.1 Components for Voltage Regulator

3.1.1 Resistors

After calculating the value for R1 the preferred resistor Value was 33k Ω . This Resistor can be shown below.

RS PRO 33k Ω Carbon Film Resistor 2W $\pm$ 5%

RS Stock No.: 707-8928 | Brand: [RS PRO](#)



Figure 1 - R1 33k Ω

(Ltd., 2024)

This resistor is a very suitable component for the power supply as it has a minimum operating temperature of -55°C and a maximum operating temperature of 155°C. Therefore, this resistor meets the specification.

After calculating the value for R2 the preferred resistor Value was 15k Ω . This Resistor can be shown below.

RS PRO 15k Ω Carbon Film Resistor 2W $\pm$ 5%

RS Stock No.: 707-8918 | Brand: [RS PRO](#)



Figure 2 - R2 15k Ω

This resistor is a very suitable component for the power supply as it has a minimum operating temperature of -55°C and a maximum operating temperature of 155°C. Therefore, this resistor meets the specification. (Components, 2024)

After calculating the value for RSC the preferred resistor Value was 0.15Ω, this Resistor can be shown below.

TT ELECTRONICS / WELWYN W22-0R15JI

Through Hole Resistor, 0.15 ohm, W22, 7 W, ± 5%, Axial Leaded, 200 V



Image is for illustrative purposes only. Please refer to product description.

Manufacturer: TT ELECTRONICS / WELWYN

Manufacturer Part No: W22-0R15JI

Manufacturer Standard Lead Time: 38 weeks

Order Code: 9504370

Your Part No:

Product Range: W22

Technical Datasheet: [W22-0R15JI Datasheet](#)

Figure 3 - RSC 0.15Ω

This resistor is a very suitable component for the power supply as it has a minimum operating temperature of -55°C and a maximum operating temperature of 350°C. Therefore, this resistor meets the specification. (Farnell, Through hole resistors, 2024)

3.2 Capacitor

After gathering the calculations and values for the capacitor in the power supply the image below shows the one that is needed.

DCM782U075EC2B



Images are for reference only
See Product Specifications

Mouser No: 598-DCM782U075EC2B

Mfr. No: DCM782U075EC2B

Mfr.: Cornell Dubilier - CDE

Customer No:

Description: Aluminium Electrolytic Capacitors - Screw Terminal 75V 7800uF Case 1.750 x 4.125in

Datasheet: [DCM782U075EC2B Datasheet \(PDF\)](#)

Figure 4 - Capacitor 7800uF

This capacitor has the correct values and has a minimum operating temperature of -40°C and a maximum operating temperature of 85°C. The resistor required for the specification is quite limited. Also, it is a large capacitor, but it will fit inside the power supply. Therefore, this capacitor meets the specification. (Mouser Electronics, 2024)

3.3 Rectifier

Below is the bridge rectifier that meets the specification. It has a 2A average current and a voltage peak of 200v. This rectifier is a through hole and can be soldered onto the circuit board. It also has a maximum operating temperature of 150 degrees and a min temperature of -40 degrees. (RSPRO, 2024)

Vishay Bridge Rectifier, 2A, 200V, 4-Pin

RS Stock No.: 395-2954 | Mfr. Part No.: VS-2KBP02 | Brand: [Vishay](#)

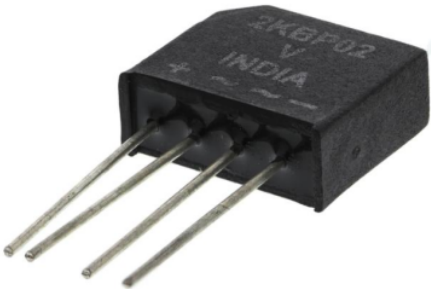


Figure 5 - Bridge Rectifier

3.4 Transformer

MYRRA 44306

PCB Transformer, EI 54 x 18.8, Encapsulated Safety Isolating, 230V, 24V, 16 VA, 50Hz ,



Figure 6 - Transformer



Manufacturer: _____

Manufacturer Part No: _____

Manufacturer Standard
Lead Time: _____

Order Code: _____

The suggested transformer to use is shown in the figure above. It has the correct step-down voltage and frequency. (FARNELL, 2024)

3.5 Heatsink

The heatsink that is required is shown below.

FISCHER ELEKTRONIK LA 6/100 12V

Fan / Force Cooled Heat Sink, Hollow Fin Aggregate, 0.2 °C/W, 74 mm, 62 mm, 100 mm, 56 m³/h, 41 dBA



 **FISCHER ELEKTRONIK**

Manufacturer:	FISCHER ELEKTRONIK
Manufacturer Part No:	LA 6/100 12V
Manufacturer Standard Lead Time:	13 weeks
Order Code:	1222505

Your Part No: ⓘ

Enter your part num

 Add to compare

Figure 7 - Heatsink Research

Because the thermal resistance is very low this will require a large heatsink for the power supply. This heatsink will be able to keep the power supply cool at operating temperature. This will help stop overheating in the circuit. (Farnell, Fan Cooled Heat Sink, 2024)

4. Methodology

4.1 Specification

Firstly, a specification table was made, this was created so that a future customer that would need a specific type of power supply would be able to see this and know if it was a suitable choice. The value from the component is shown in Table 1 below.

Table 1 - Specification

Attributes	Values
Output Current	4A
Output Voltage	24v
Power Dissipated	96W
Supply Required	240v
Frequency Input	50Hz
Height	90mm
Width	72mm
Suitable Location	In a Cold Environment

In terms of intellectual property there was no need to patent the component as the power supply design is a common method.

4.1.2 Health and Safety

This component will be based in a panel and therefore will have a good security as the panel can be locked off. This is very important for health and safety reasons as it will require a certain level of authority and training to have access to unlocking the lock off. To reduce the risk of electrocution the component will have an isolated cover built onto it so that the circuit board inside can't be easily touched. Also, to prevent overcurrent issues from happening a supply voltage will pass through the MCB and will then input the power supply.

4.1.3 Ethical

To support worker's rights most power supplies are created out of recyclable material as it is eco-friendly. This is then taken into consideration when a component of this sort is being purchased.

4.1.4 Codes of Practice

The BS7671 wiring regulation are for the connection and locking off part of the creation. This code is also linked to health and safety. An IP rating of 66 is given for the component. This means that if the panel was to get washed it can withstand a small amount of water.

4.2 Voltage Regulator

Firstly, creating a voltage regulator was the start of the designing process for the power supply. To do this the values that were given in the specification will be used to work out what voltage regulator is required. Below are the equations that were used to find this out:

$$C_{ref} = 0.1\mu f$$

$$R1 + R2 = 50k\Omega$$

In this case a 56k ohm resistor is the preferred value from the E12 Series of resistors. The preferred value for each resistor was then chosen and stated below.

Next was to pick a Vref figure between 6.8v and 7.5v, therefore 7.4v was chosen.

$$R2 = \frac{7.4V}{24V} (R1 + R2)$$

$$R2 = \frac{7.4V}{24V} (50k\Omega)$$

$$R2 = 15.5K\Omega \text{ (15k}\Omega \text{ preferred value)}$$

$$R1 = 50k - R2 = 50k - 15.5k = 34.5k\Omega \text{ (33k}\Omega \text{ preferred value)}$$

$$R3 = \frac{R1 R2}{R1 + R2} = \frac{34.5k \times 15.5k}{50k} = 10.7k\Omega \text{ (10k}\Omega \text{ preferred value)}$$

In the equation below the 0.6v comes from the initial circuit diagram on the datasheet as it overcomes the base emitter junction between pins 2+3.

$$R_{sc} = \frac{0.6}{I_{sc}} = \frac{0.6v}{4A} = 0.15\Omega$$

4.2.1 Table of results for Voltage Regulator

In the table below, the values that have been gathered from the results of the equation for the voltage regulator.

Table 2 - Table of Results for Voltage Regulator

Characteristics	Values
Vout	24vdc
Iout	4A
Cref	0.1uF
R1	33KΩ
R2	15KΩ
R3	10.7k Ω
RSC	0.15Ω
Vin	25.7v

4.2.2

After gathering the results a circuit can then be designed and built on the software Multisim.

This is shown in the figure below.

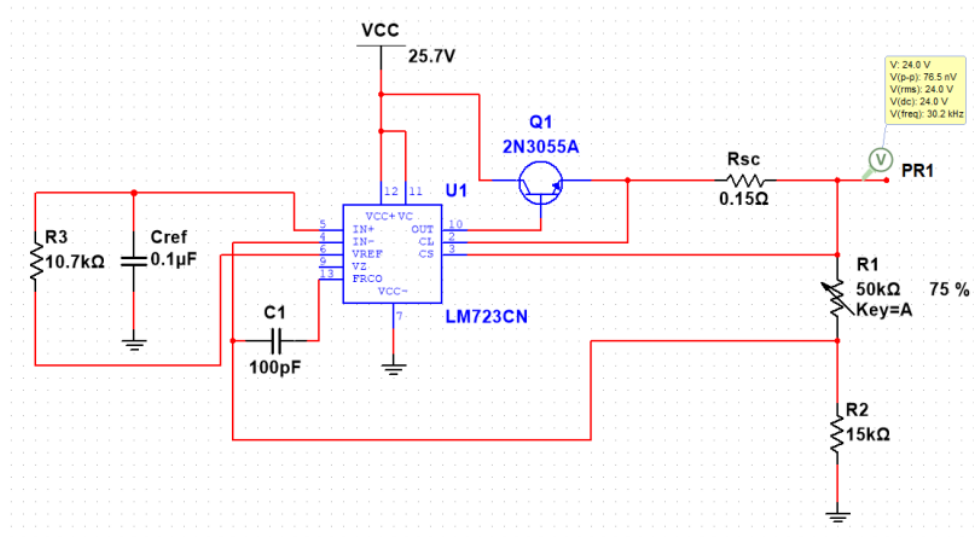


Figure 8 - Voltage Regulator Circuit

After designing the circuit the readings on Vout was higher than expected. In order then to fine tune the regulator a variable resistor was added into R1 as this helped get the output voltage to exactly 24v.

4.3 Capacitor Design

After completing the regulator, the capacitor was next to design and build. The purpose of the capacitor here is to create a smoothing effect and will help give out a steadier constant voltage output. The table below are the values are required for the calculations required to design the capacitor.

Table 3 - Capacitor Values

Characteristics	Values
Vc (Vin)	26v
Vm	39v
V ripple	3v
F	50Hz
Io	4A

Below are the equations that were completed, and the values found were then put in the table.

$$V_c = 26v$$

$$V_m = 26 + \frac{1}{2} \times 26 = 39v$$

$$I_o = 4A$$

$$f = 50Hz$$

$$rf = \frac{3}{2\sqrt{2} \times 26} \times 100 = 4\%$$

To find the value of ωCR_L the ripple factor will need to be used by looking at the full wave circuit graph shown below.

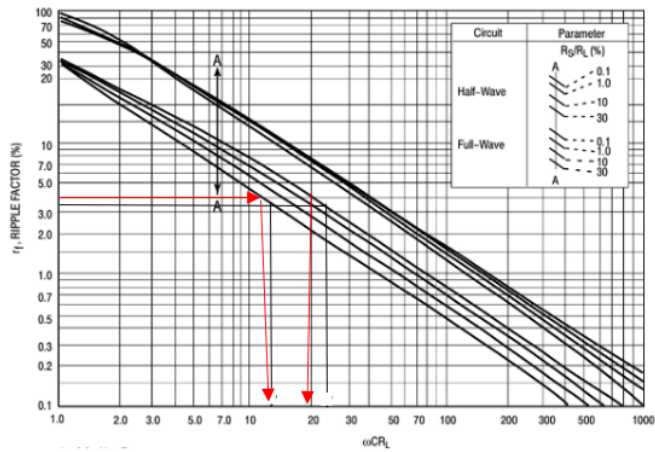


Figure 9 - Ripple Factor / ωCR_L Graph

By looking at the graph where the two points cross on the full wave inner and outer lines the ωCR_L is then decided between the two values. In this case $\omega CR_L = 16$. (Semiconductor, 2002)

Next was to work out the V_c/V_m .

$$\frac{V_c}{V_m} = 66\%$$

To find the R_S/R_L value the graph below will show this.

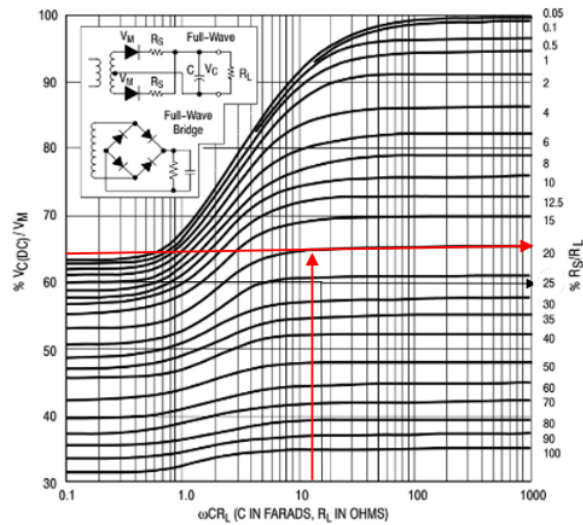


Figure 10 - V_C/V_M / ωCR_L Graph

From the graph above its clear to see that the points cross and reference to give us $\frac{R_S}{R_L} = 20\%$. (Semiconductor, 2002)

Next step was to work out R_L and R_S individually which can be shown in the equations below.

$$R_L = \frac{V_C}{I_O} = \frac{26}{4} = 6.5\Omega$$

$$R_S = 0.2 \times \frac{V_C}{I_O} = 0.2 \times \frac{26}{4} = 1.3\Omega$$

After these values were worked out the value of C can then be worked out. This is shown in the equation below.

$$C = \frac{\omega C R_L}{2\pi f \left(\frac{V_C}{I_O}\right)}$$

$$C = \frac{16}{2\pi \times 50 \left(\frac{26}{4}\right)} = 7835\mu F$$

Therefore, the filter capacitor preferred value is $C = 7800\mu F$.

4.4 Rectifier Design

In the circuit the voltage will have to be rectified from AC and then converted to DC. This is done by using a rectifier which will contain diodes to complete this task. The equations to work out the rectifier design will be shown below.

Firstly, the IF average was calculated below.

$$I_f (Avg) = \frac{I_O}{2} = \frac{4}{2} = 2$$

Next was to calculate the IF rms value.

$$I_f (Rms) = 2 \times I_f (Avg) = 2 \times 2 = 4$$

Then the calculations below were done.

$$\omega C R_L \text{ where } n = 2$$

$$\frac{R_S}{n R_L} = \frac{1.3}{2 \times 6.5} = 0.1 = 10\%$$

$$n C R_L = 2 \times 16 = 32$$

By looking at the graph below, this will show us where the IF avg can be found.

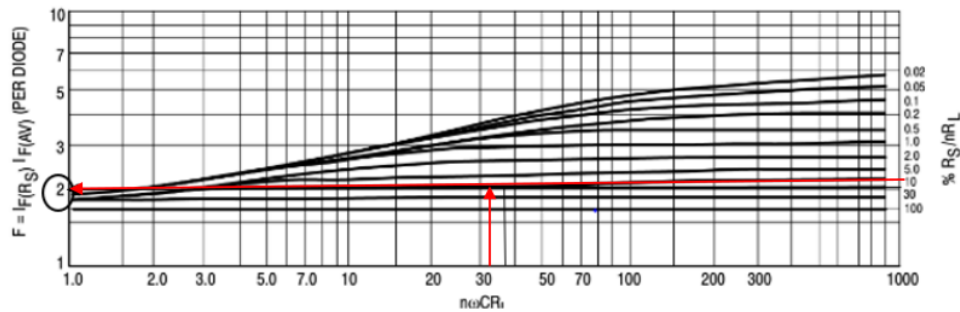


Figure 11 - IF Avg Graph

Next was to calculate the IF peak but first the value had to be gathered from the graph below using the previous figures. (Semiconductor, 2002)

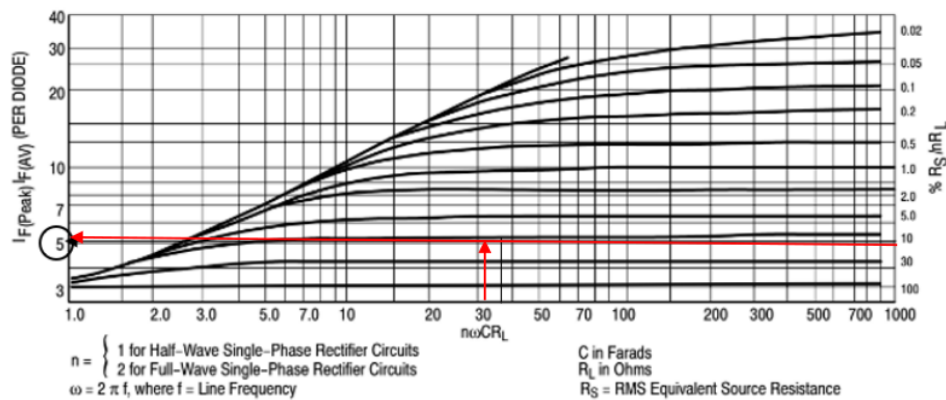


Figure 12 - IF peak graph

(Semiconductor, 2002)

After finding the point cross on the IF peak graph the calculations could then be done.

$$If(Peak) = 5.2 \times If(Avg) = 5.2 \times 2 = 10.4$$

Next was to work out the PIV rectifier rating which is shown in the calculation below.

$$PIV = (Vm \times 2) + \frac{Vm}{2} = (39 \times 2) + \frac{39}{2} = 97.5v$$

Then the I surge value was calculated to show the maximum current surge for the rectifier.

$$I_{surge} = \frac{Vm}{Rs} = \frac{39}{1.3} = 30A$$

In the table below are the values required to design the rectifier.

Table 4 - Rectifier Results Table

Characteristics	Values
IF avg	2A
IF rms	4A
IF peak	10.4A
PIV	97.5v
I surge	30A

4.5 Transformer Design

In the power supply a step-down transformer will be required as this will reduce the voltage that will enter the rectifier. Below are the calculations and design of how the transformer was created.

Firstly, the V_s value had to be calculated, this is shown below.

Where $n=2$ (for full wave as used prior).

$$V_s = \frac{V_m + n}{\sqrt{2}} = \frac{39 + 2}{\sqrt{2}} = 29v$$

Next the Secondary Current I_{rms} which is shown in the equation below.

$$\text{Secondary Current } (I_{rms}) = I_o \times \sqrt{2} = 4 \times \sqrt{2} = 5.7A$$

From this the VA rating could then be calculated.

$$VA = V_s \times I_{rms} \times \sqrt{2}$$

$$VA = 29 \times 5.7 \times \sqrt{2}$$

$$VA = 233.8v$$

From the following equations and figures the ratio of the transformer can be given.

$$\text{Transformer} = 10:1$$

Then a results table was made featuring the results from the transformer equations which is shown below.

Table 5 - Transformer Results

Characteristics	Values
VS	26v
Secondary Current I_{rms}	5.7A
VA	233.8v
Transformer Ratio	10:1

From gathering the results from the calculations of the transformer a circuit on Multisim was then created with the transformer and rectifier connected. This can be shown in the image below.

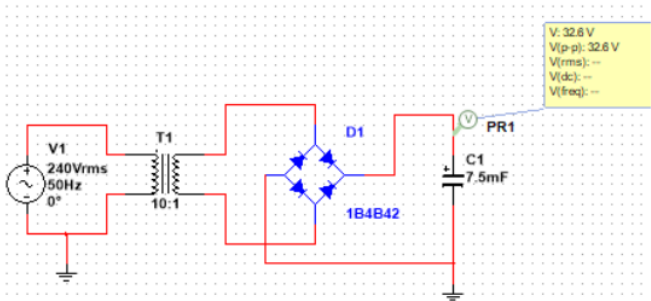


Figure 13 Transformer and Rectifier Circuit

4.6 Heatsink

Next was to design a heat sink as this will then carry the purpose of removing heat from the transistor as this will help to increase its lifespan, efficiency and help secure a safe working temperature.

The equations for the heat sink are shown below.

$$PD = Vo \times Io = 24 \times 4 = 96W$$

$$\phi_{SA} = \frac{T_J - T_A}{P_D} - \phi_{JC} - \phi_{CS}$$

$$\phi_{SA} = \frac{200 - 0}{96} - 1.5 - 0.36$$

$$\phi_{SA} = 0.223^{\circ} \text{ C/W}$$

These results were then put into a table of results which is shown below.

Table 6 - Heat Sink Results

Characteristics	Values
TJ (Max Working Temperature)	200°C
TA (Ambient Temperature)	0°C
PD (Power Dissipated)	96W
θJC (Junction to case thermal resistance)	1.5 C/W
θJA (Desired working temperature)	35°
θCS (Case to heatsink temperature)	0.36°
θSA (Heatsink to atmosphere)	0.223° C/W

Apart from the calculated results the figures above were gathered from the datasheet of the transistor.

After the heatsink had been calculated and designed the two circuits on Multisim were combined to give the completed power supply circuit. This can be shown in the image below.

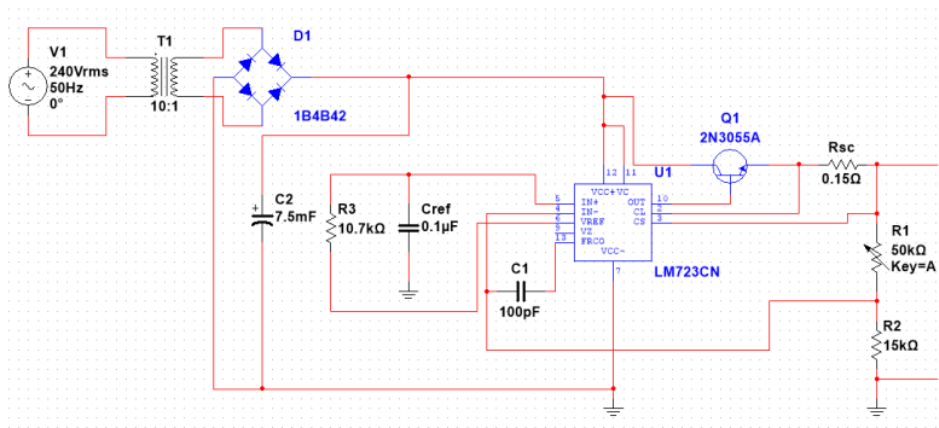


Figure 14 - Power Supply Circuit

4.7 Testing

After completing the design of the circuit, a series of tests was done on the power supply circuit. Although there isn't much testing that can be done on this, a load test can be done to see what characteristics get affected such as the current and voltage. By adding a resistor (R4) to the circuit and changing its value from 0 – 100ohm, a test table was made to see the rate of change in current and voltage. To gather the results into a table the readings were taken from the two probes 'PR1' and 'PR3' in the circuit below.

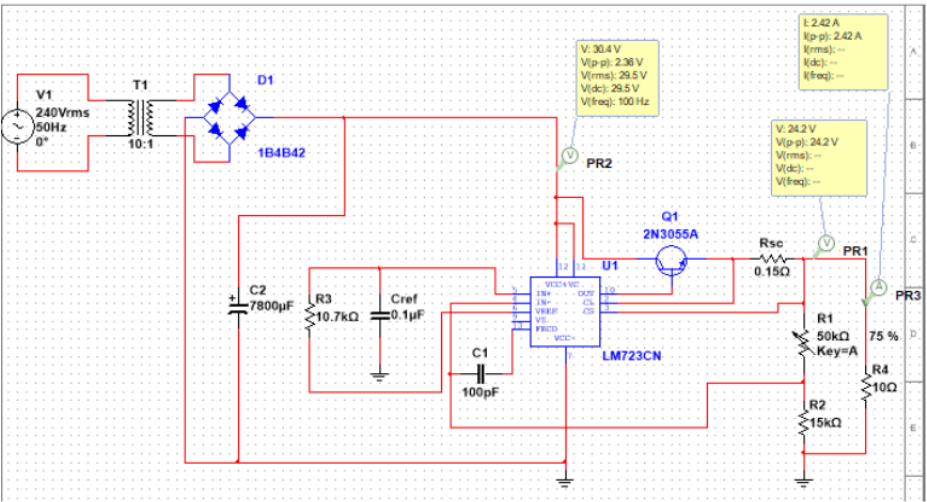


Figure 15 - Testing Circuit

Table 7 - Power Supply Test Results

Load Resistance (Ω)	Current (A)	Voltage (V)
0	4	0
2	4	8.19
4	4	16.4
5	4	20.4
6	3.99	24
8	3	24.2
10	2.42	24.2
20	1.21	24.2
50	0.484	24.2
100	0.242	24.2

A table of results was then created as shown in 'table 7' above. The tests that were completed on Multisim where the results were gathered from are shown in figures 17-26 in the appendix. By using the figures gathered in this table a graph of results was then created on Excel as shown below.

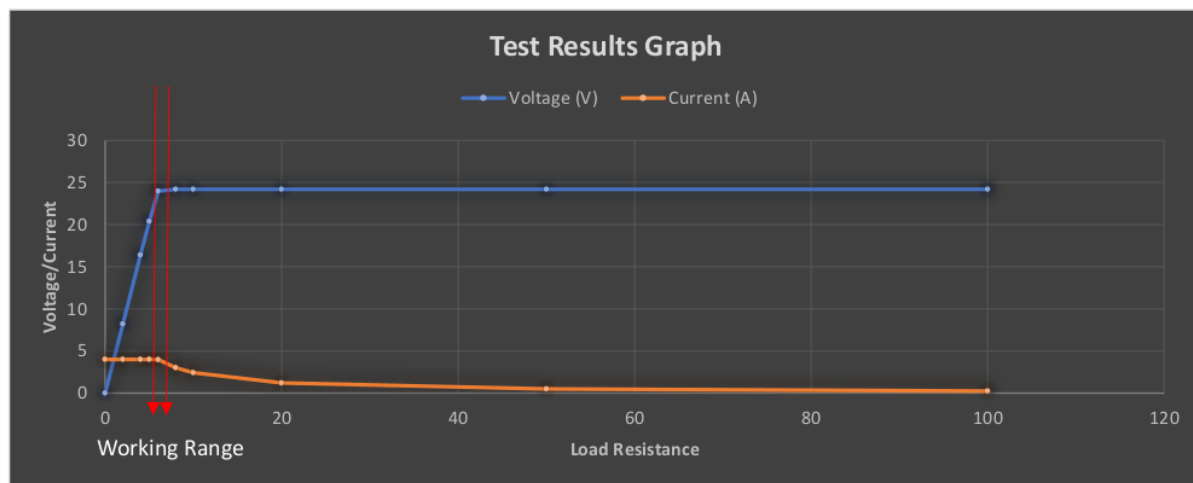


Figure 16 - Test Results Graph

These results were analysed and compared with one another.

5. Analysis

By looking at figure 16 in the testing the graph was analysed, and it was clear to see that when the load resistance would increase so would the voltage, but the current would then decrease, this is due to ohms law. In the graph the voltage did not exceed over 24v, the reason for this is because the voltage regulator.

After the 10 ohm point in the graph the voltage line is a transient response as it stays in a straight line. Also, by looking at the current this had decreased at a fast rate after 8-10 ohms. This means that there less of an optimal working range as this is also shown by the two red lines on the graph where the voltage and current are at their peak working values at around 6 ohms.

6. Evaluation

By looking at the analysed test results and all the design process it was clear to see that the power supply design met the correct specifications by giving an output voltage of 24v and an output current of 4A. As the correct outputs were given this meant that the design, calculations and building of the power supply was a success.

Although, during the testing it was noticed that there was a small optimal working range was present as the current drop of would increase highly after the 6-8 ohms mark in the load resistor. Obviously, this is not ideal as the load resistance is dependent on what would be connected to the output of the power supply.

One recommendation would be that for the power supply to have a greater optimal working range so that it will benefit a wider amount of load, then a larger margin of error on the power supply would be needed.

7. Conclusion

The purpose of this assignment was to design and build a power supply and give an understanding of how to do this and meet the customers' needs and specification. Firstly, the specification was gathered and what figures were needed, and these were then put into a table. From this table calculations could then be done to work out the different stages of the power supply such as the voltage regulator, capacitor, rectifier, transformer and heatsink.

After the calculations had been complete all the figures were then put into tables so that the customer would be able to gather the information easier. From the calculated figures research for what exact components will be required to order to build this power supply practically.

Next, by gathering the calculated figures and the specification values circuits could then be designed and built on Multisim. The circuit was built in sections and then combined to give the complete power supply circuit. Once, this was built a variable load resistor was adding to the circuit and then its load was changed to see the different characteristics in the current and voltage outputs. After testing the results were then put into a table and analysed so that the customer can see its full working range of the power supply.

The results in the table were then gathered and made into a graph so that it was clear to see the current drop off point and the peak voltage point.

Overall, this assignment was a success and has been implemented correctly with a wide range of knowledge and understanding about the electronic design and creating a working system gathered from it.

8. Citation list

References

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9. Appendix

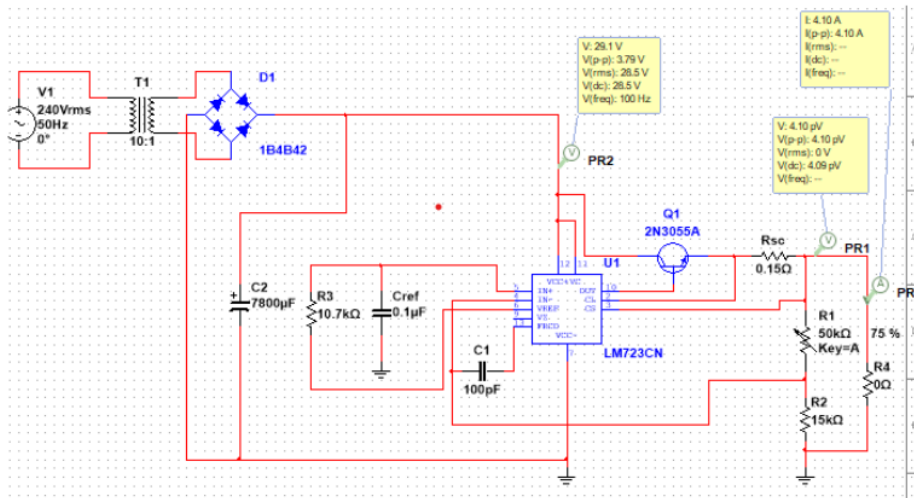


Figure 17 - Test at 0 Ohms

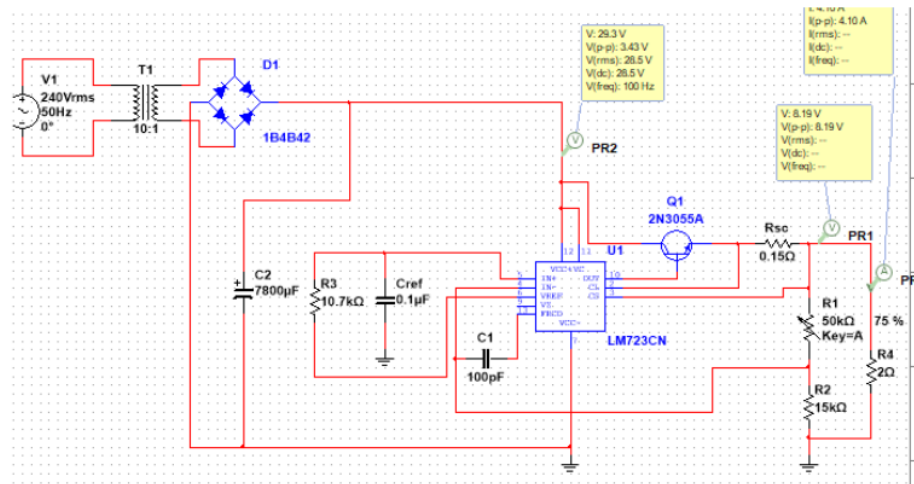


Figure 18 - Test at 2 Ohms

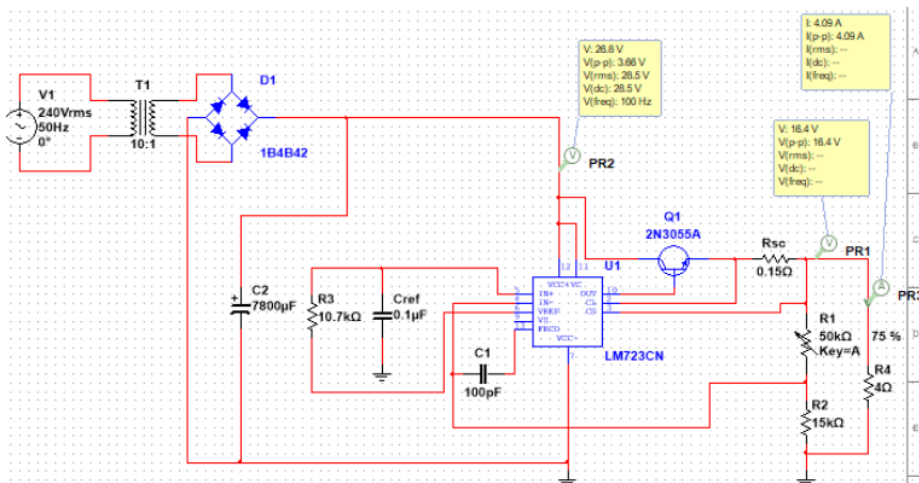


Figure 19 - Test at 4 Ohms

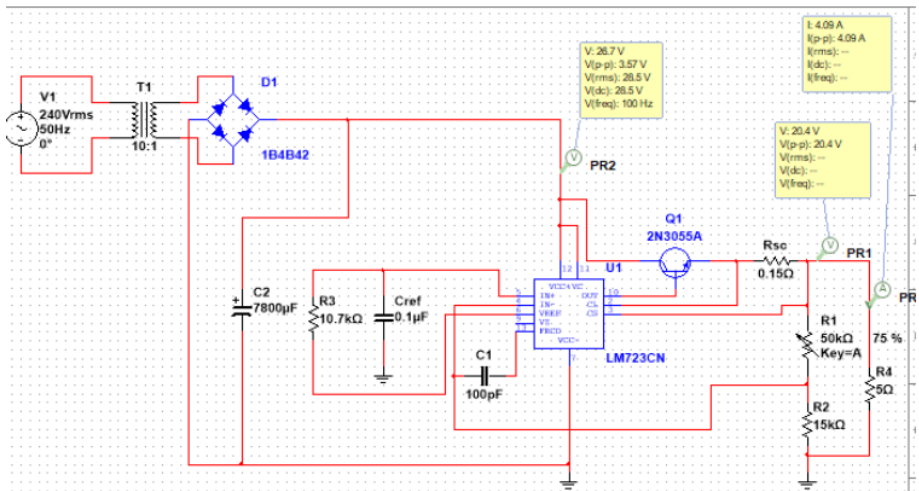


Figure 20 - Test at 5 Ohms

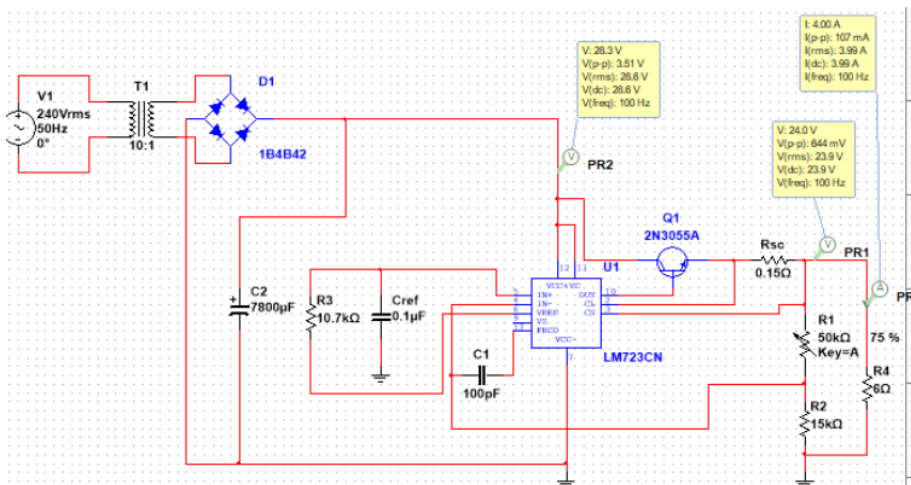


Figure 21 - Test at 6 Ohms

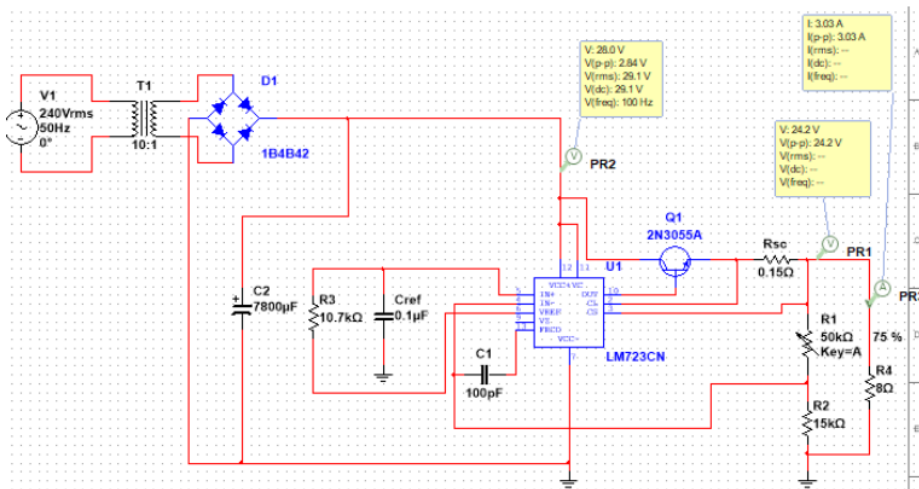


Figure 22 - Test at 8 Ohms

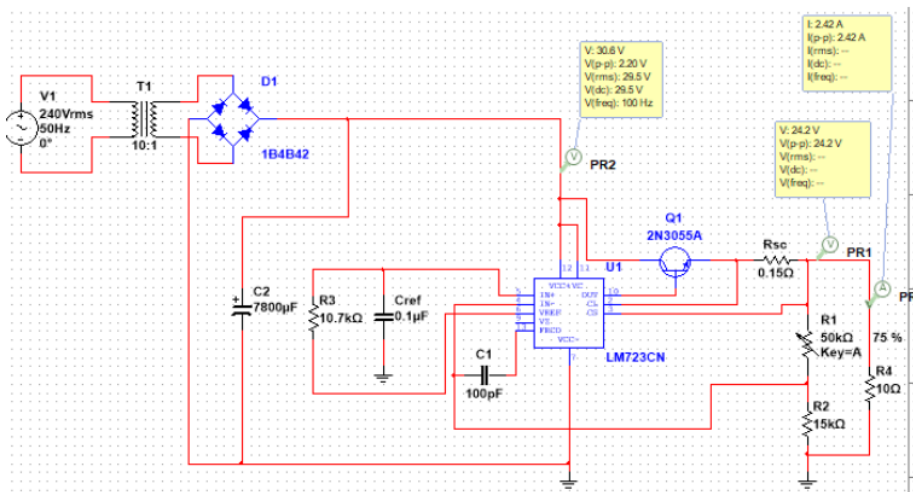


Figure 23 - Test at 10 Ohms

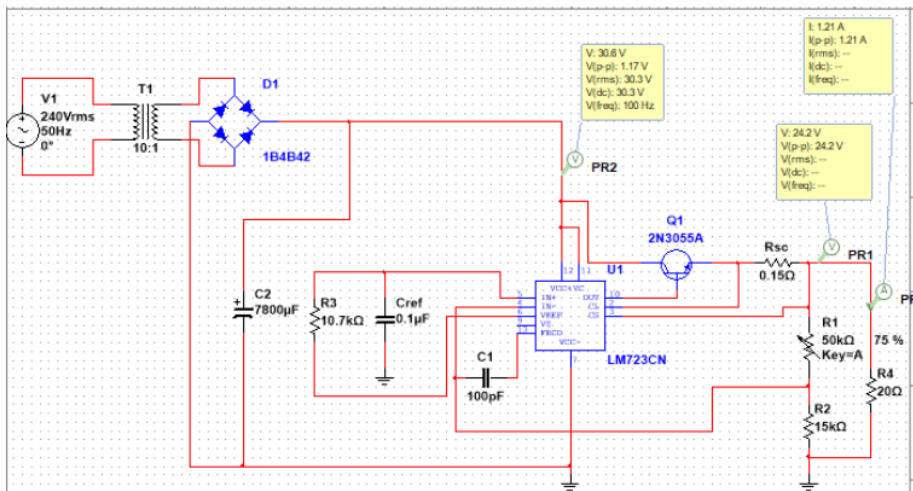


Figure 24 - Test at 20 Ohms

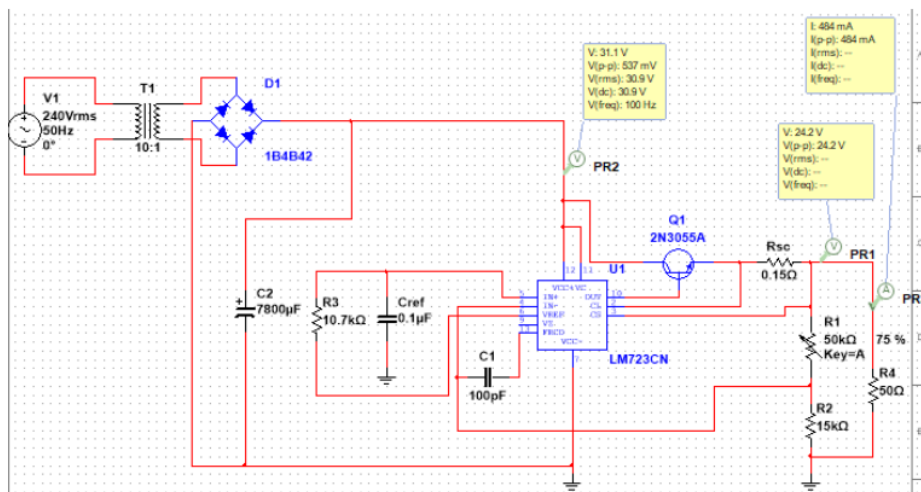


Figure 25 - Test at 50 Ohms

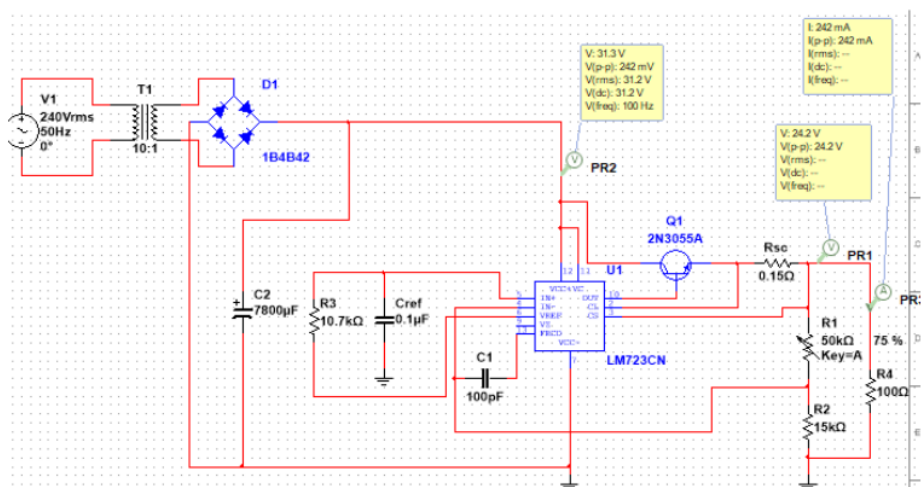


Figure 26 - Test at 100 Ohms

FINAL GRADE

GENERAL COMMENTS

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GRADING FORM: CSG-RUBIC

JACK ROGERS

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RESEARCH-INFORMED LITERATURE



There was very good evidence of further reading and research from credible and reliable sources. Your interpretation and understanding of the additional research was good and demonstrated a very good underlying appreciation of the subject. Your references were appropriate to the task and applied with few errors or inconsistencies. Your reference list was of an appropriate length for this assignment.

7

KNOWLEDGE AND UNDERSTANDING



The knowledge and understanding of the subject demonstrated by this assignment was generally very good. There were few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was demonstrated to a high degree. You have demonstrated a competent critical understanding of the main concepts and expanded your knowledge beyond that contained in the course notes.

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ANALYSIS



Your explanation of the design process was good and the conclusions showed that you can interpret quantitative and qualitative data, although this was often descriptive. You could have evaluated the results and specified whether they concurred with theory suggesting reasons for any discrepancies. You have however demonstrated good analytical skills and your approach to the task was logical. Arguments made in the conclusions were mostly valid and demonstrated a good understanding of the topic. Further work – in your conclusion, you should relate the results to the original specification and to accepted theory.

11

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally very good. You used the resources appropriately when designing the circuit and you used appropriate options for testing and evaluating the circuit performance. You managed to design an effective circuit that functioned within the specification and achieved this by only asking for assistance when appropriate thus demonstrating some advanced problem solving skills. Your results were comprehensive and allowed for a detailed conclusion to be attempted.

SKILLS FOR PROFESSIONAL PRAC.



Your written report was generally well written in a coherent and fluent manner that contained most of the required detail, although it lacked the depth of explanation required in places. Avoid the use of photographs and/or scans of hand-written notes and utilise the available word count more effectively. You need to be more selective with where you put diagrams and graphs, only put those essential for the explanation in the report, the rest can be referred to in the appendix.