

# Electronic Design

*by* Carl Jones

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**Module:** SGEE6000 – Electronic Design

**Assignment:** Regulated Power Supplies

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## Executive summary

This assignment provides an insight in to the design procedures for meeting specification set by customers. As part of the assignment research into how there are lots of directive and codes of practice set out to produce harmonized between us and Europe and how such a small electronic design is governed by such large regulations?

Methods of analysis included research using credible sources, practical simulation, and research into materials data sheets. Design of the power supply following specification required and carrying out calculation to select the correct components.

Conclusion made and recommendation for the assignment cover how theoretical design alone doesn't always give the required outcome and that the use of software like multisim allows tweaking of component values to achieve the best results.

*ES should cover each section  
and is effectively the entire  
report in brief*

## 1. Specification for Design.

A power supply unit to power a field instrument required designing. The power supply will be mounted outdoors and on rotation machinery.

Customer specification given as below.

Input voltage = 110V AC +/- 18%

Input current = 2 Amps

Input frequency = 50 Hz

Output Voltage = 24 vdc

Output current = 500mA

As the power supply is to be mounted outdoors, weather condition will play a part in the design.

Extreme weather means the PSU will need to be able to work in efficiently in hot or cold conditions

Nominal operation temperature between -20 °C + 60

Considerations in how the PSU will be kept cool from overheating and be kept warm enough so that condensation does not occur.

The enclosure of the PSU needs to be of rating IP67 to protect from heavy rain and wet conditions.

Vibration from the machine rotating needs to be considered, this requires a test to be carried out to determine mechanical weakness or degradation.

To meet the required environmental design BS EN 60068-2 will be used which covers testing of electronic equipment to withstand condition such as extreme weather hot/cold and operational environments.

The full design must comply with British and European standards and directives to enable a CE mark to be issued.

Directives applied to this design are

**The low voltage Directive (LVD)** – Ensures that electrical equipment provides a high level of protection within certain voltage limits.

**Electromagnetic Compatibility (EMC) Directive** - Ensures that Electrical and Electronic equipment do not cause electromagnetic disturbance by generating or being affected. EMC directive limits the emissions that can be caused by equipment.

**RoHS Directive** – Restriction of Hazardous Substances which can be used in Electrical and Electronic equipment.

There are a lot more directives and standards which make up a compliant design for a safe sustainable power supply meeting all the required needs of the customer.

The design of the power supply requires all sections of figure 1 to be considered and designed to create the working power supply.

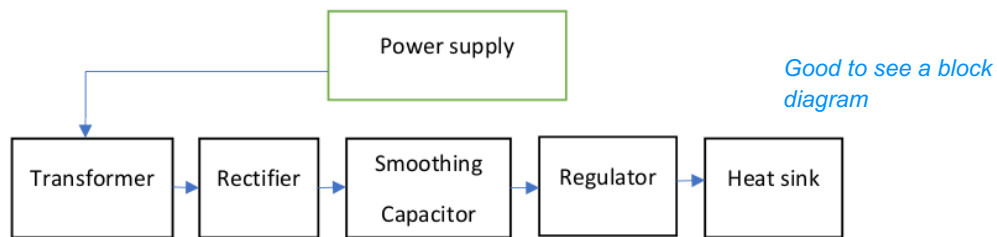


Figure 1- part of psu to design

## 2. Design of the regulator.

Regulator performance requirements.

Output voltage  $V_o = 24\text{ V} \pm 0.1\text{V}$

Output current  $I_o = 500\text{mA}$

Load regulation  $\leq 0.1\%$  for  $I_o = 10\text{mA}$  to  $500\text{mA}$

Line regulation  $\leq 0.1\%$

Output Ripple  $\leq 2.0\text{ mVpp}$

Max Ambient temperature.  $T_A \leq +60^\circ\text{C}$

Supply will have common Load to a negative supply.

With the list of requirements produce research into available regulator chips was carried out.

### **LM317M – 3 terminal adjustable regulator.**

This regulator is an adjustable 3 terminal positive voltage regulator, the device has a feedback relative to the output voltage instead of Ground. Regulator diagram figure 2

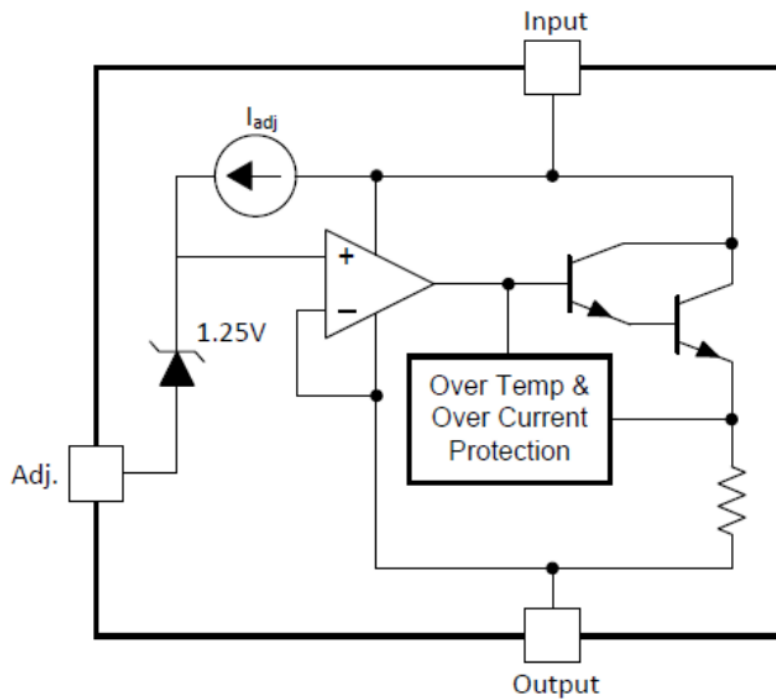


Figure 2 – LM317M regulator (Instruments, 2014)

Features:

Adjustable output = 1.25V to 37 V

Output current =  $\leq 500\text{mA}$

Internal Short circuit current limiting

Thermal Overload protection

LM317 has no ground terminal so it is a floating regulator. Due to this the LM317 does not satisfy the design requirements.

**MC1723C voltage regulator.**

Features.

Output voltage  $V_o = 2\text{Vdc to } 37\text{Vdc}$

Current output  $I_o = 150\text{mAdc}$

Line regulation = 0.01%

Load Regulation = 0.03%

Adjustable short circuit protection.

TA = 0°C to +70 °C

From analysing the regulators specification from the manufactures data sheet, MC1723C was the most suitable regulator to meet required performance requirements. From the feature output current is noticed to only be 150 mAdc, with the use of external pass transistors the output capacity can be increased to +5Adc.

With the MC1723C being the preferred chip all the components required to make the circuit figure 2, needed to be calculated using values from the design spec and from the regulator data sheet.

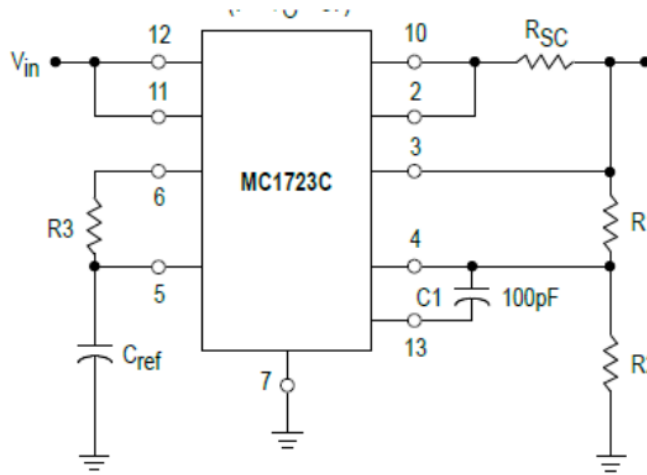


Figure 3 – MC 1723C regulator (motorola, 2015)

Components to be determined were Cref, R1, R2, R3 and Rsc.

Cref is the output noise voltage, for low noise operation the value selected was 0.1μf

R1 + R2 was chosen between 10KΩ to 100KΩ value selected for initial design was 40KΩ

R2 was calculated with the following formulae.

$$R2 = \frac{7.0}{V_o} (R1 + R2)$$

Value 7.0 is Vref from data sheet.

Vo = 24V

$$R1 + R2 = 40K\Omega$$

$$R2 = \frac{7.0}{24} (40) = 11.66 K\Omega$$

R2 was rounded up to 12K $\Omega$  *preferred values*

$$R1 = 40k\Omega - 12K\Omega = 28K\Omega$$

Short circuit current limit Rsc was calculated

$$R_{sc} = \frac{V_{sense}}{I_{sc}}$$

V sense is the fixed value from the base transfer voltage of the transistor.

$$V_{sense} = 0.6V$$

Isc is the specified design current = 500mA

$$R_{sc} = \frac{0.6}{500 \times 10^{-3}} = 1.2\Omega$$

$$R3 = \frac{R1 \times R2}{R1 + R2} = \frac{336K}{40K} = 8.4K\Omega$$

The input voltage to the MC1723 regulator needed to be calculated to give an output of 24v, to do this the data sheet had to be used to find out the minimum and maximum value of voltage also the differential for the input- output voltage.

From the data sheet

$$\text{Input min} = 9.5V$$

$$\text{Input Max} = 40V$$

$$\text{Input-output differential voltage} = 3.0V$$

$$\text{Voltage required was } V_{in} = V_o + 3 = 24 + 3 = 27V$$

As the required output current needed a transistor and Rsc, these created volt-drop on the circuit.

To overcome this the transistor base emitter voltage is added to the calculation.

$$V_{in} = V_o + 2\phi + 3, \text{ where } \phi = V_{BEon} = 0.6V$$

$$V_{in} = 24 + 1.2 + 3 = 28.2V$$

So required input voltage to regulator to generate specified 24V output is 28.2V.

28.2V satisfies the required voltages for MC1723C as it is between the min and max.

### 3. Design of the input stage.

The power supply consists of three more circuits

Input transformer.

Rectifier.

Smoothing capacitor.

Each of which could be work out from values obtained from the regulator circuit.

The required full load average dc output voltage of the Capacitor input filter =  $V_c(dc) = 28.2Vdc$

The maximum no load peak to peak ripple voltage =  $V_{ripple} = 3V_{pp}$

Maximum no load output voltage =  $V_m = 42.3V$

Full load filter output current =  $I_o = 500mA$

Input frequency =  $f = 50Hz$ .

To size the smoothing capacitors to sufficient reduce ripple attenuation before the regulator, the following equation was used.

$$rf = \frac{V_{ripple}}{2\sqrt{2}V_c(dc)} \times 100$$

$$rf = \frac{3}{2\sqrt{2}28.2} \times 100 = 3.76\%$$

Filter capacitor

$$C = \frac{\omega CRL}{2\pi f \left( \frac{V_c(dc)}{I_o} \right)}$$

Using the standard schade graph figure 3 to find  $R_s/RL\%$

**Figure 8-3. Relation of Applied Alternating Peak Voltage to Direct Output Voltage in Full-Wave Capacitor-Input Circuits**

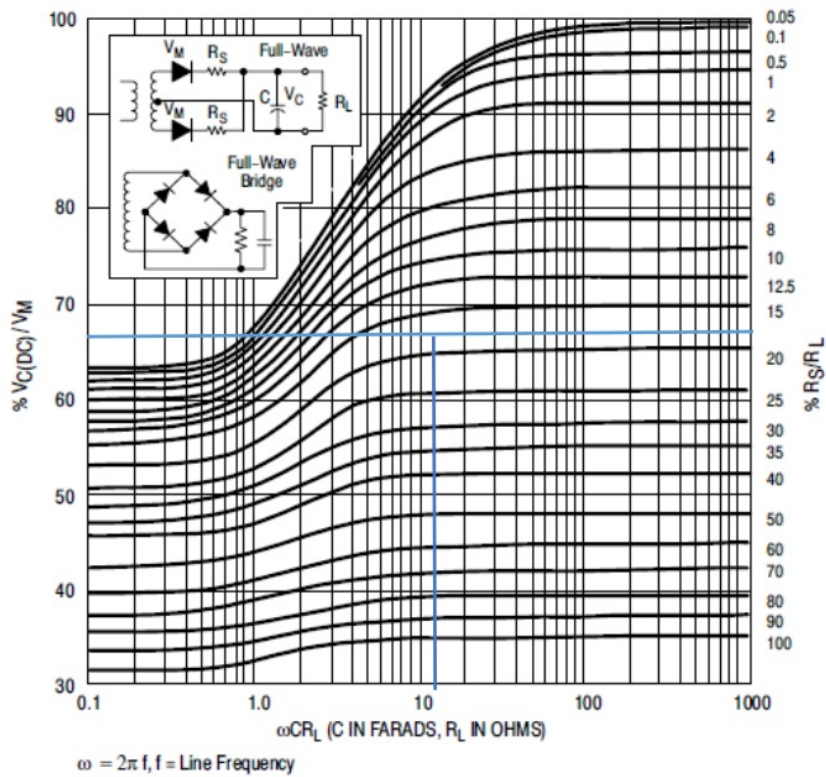


Figure 4- Schade graph 1

$$\frac{V_c(dc)}{V_m} \times 100 = \frac{28.2}{42.3} \times 100 = 66.7\%$$

From drawing a straight line across on the graph for the 66.7 % on  $V_c(DC)/V_m$  axis  $R_s/R_L$  could be recorded to the nearest number.

$$R_s/R_L = 15\%$$

Calculate  $R_L$

$$R_L = \frac{V_c}{I_o} = \frac{28.2}{500^{-3}} = 56.2\Omega$$

Calculate  $R_s$

$$R_s = 0.15 \times 56.2 = 8.46\Omega$$

From Schade graph figure 3  $\omega CR_L = 18$

Calculate the smoothing capacitor

$$C = \frac{18}{2\pi f \left(\frac{28.2}{0.5}\right)} = 0.1\mu f$$

*Seems a little low, would expect 2000uf at least*

Capacitor max voltage =  $2 \times V_m = 85$  volts round up to 100V.

Capacitor specification for design = 0.1μf, max voltage 100V

Capacitor selection is MCCC100V104KY5P - CERAMIC CAPACITOR 0.1UF, 100V form multcomp pro, its RoSH compliant and specification needs are met, also economical to buy



*Figure 5- smoothing capacitor*

The full wave rectifier requirements were then calculated

Average current for full wave rectification =  $I_o/2$

$$I_f(avg) = \frac{0.5}{2} = 200mA$$

From Schade graph Figure 4, the current rating for RMS and Peak could be determined.

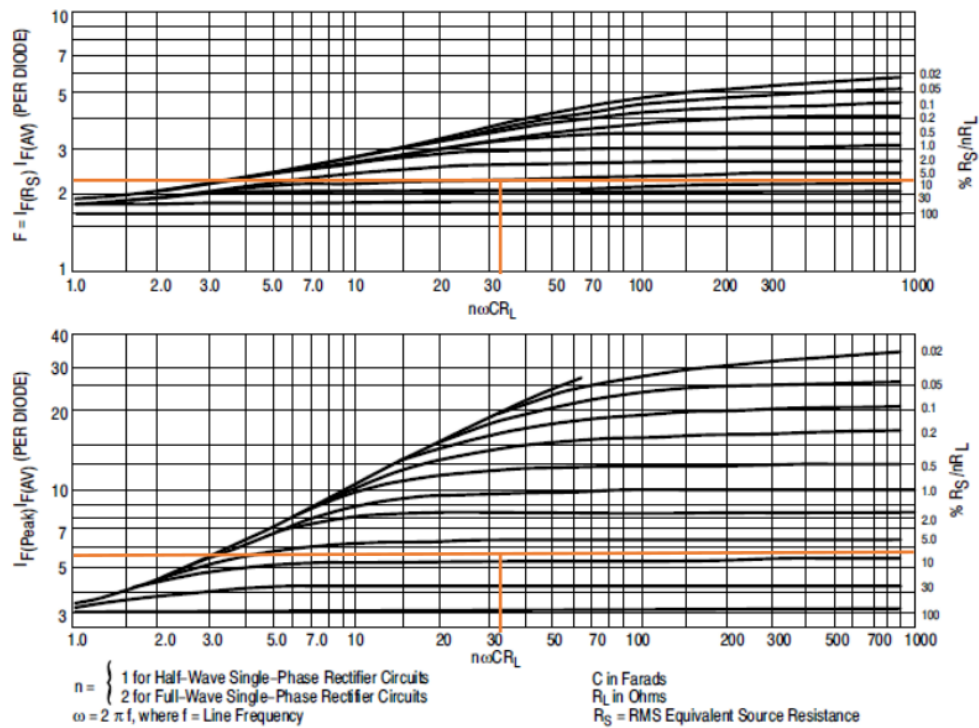


Figure 6- Schade graph 2

$R_S/nR_L$  from the figure 4, where  $n = 2$  for full wave

$$\frac{R_S}{nR_L} = \frac{8.46}{2 \times 56.2} \times 100 = 7.5\%$$

Drawing a straight line on the graphs figure 4,  $I_f(\text{RMS})$  and  $I_f(\text{peak})$  were recorded.

$$I_f(\text{RMS}) = 2.2 \text{ A}$$

$$I_f(\text{Peak}) = 5.6 \times I_f(\text{avg}) \times 0.5 = 1.4 \text{ A}$$

Surge current protection is required due to protect the diodes from high currents caused by the capacitor.

$$I_{\text{surge}} = \frac{V_m}{R_S} = \frac{42.3}{8.46} = 5 \text{ A}$$

### Input transformer selection

Requirements for the supply were 110v

Secondary Coil RMS voltage of the transformer

$$V_s = \frac{V_m + (n) \times 1}{\sqrt{2}} = \frac{42.3 + 2}{\sqrt{2}} = 31.3 \text{ vac}$$

Transformer turns ratio

$$\frac{V_{in}}{V_s} = \frac{110}{31.3} = 3.5 = 3:1 \text{ ratio step down}$$

Resistance of the secondary windings was found from Schade graph figure 3.

$$R_s = 8.46 \Omega$$

Transformer VA rating

$$2 \times V_s \times I_f(\text{rms}) = 2 \times 31.3 \times 2.2 = 137 \text{ VA}$$

#### 4. Thermal management system

Requirements for the power supply were to be installed outside which meant hot weather condition and the fact the PSU will be built in to an IP rated enclosure would mean a heat sink would be required for cooling as there would be no natural air flow.

T<sub>a</sub> (ambient temp specified) = +60°C

T<sub>J</sub> = 200° C (from data sheet 2N3055)

Heatsink formulae

$$T_J = T_A + P_D \theta_{JA}$$

$$P_D = V_{in} \times I_{sc}$$

$$P_D = 28.2 \times 0.5 = 55$$

Solve  $\theta_{sa}$

$$\theta_{SA} = (T_J - T_A / P_D) - (\theta_{JC} + \theta_{CS}) = ((200 - 60) / 14.1) - (1.52 + 0.1) = 8.31^\circ \text{CW}$$

## 5. Build and simulate.

Using Multisim a prototype of the circuit was created. Components used were all that had been specified in each section of the design process. Figure 7 is the circuit

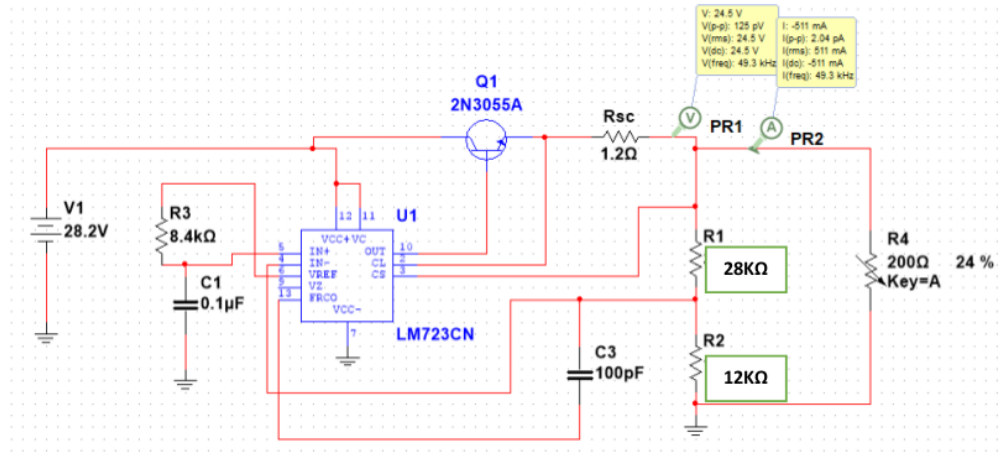


Figure 7 – design layout of regulator

All the resistor were setup to the design calculated values. R4 was put on the circuit as a variable load. To analysis the output of the regulator R4 was set to 0Ω and then incremented every 3Ω while recording the output current and Voltage. Figure 6 test results.

| load resistor 200 ohms | Load V | Load I |
|------------------------|--------|--------|
| 0                      | 0      | 511    |
| 3                      | 1.34   | 511    |
| 6                      | 2.95   | 511    |
| 9                      | 3.75   | 511    |
| 12                     | 5.81   | 511    |
| 15                     | 7.13   | 511    |
| 18                     | 8.93   | 511    |
| 21                     | 10.1   | 511    |
| 24                     | 12.4   | 511    |
| 27                     | 13.8   | 511    |
| 30                     | 15.6   | 511    |
| 33                     | 17.2   | 511    |
| 36                     | 19.9   | 511    |
| 39                     | 21.6   | 511    |
| 42                     | 21.6   | 511    |

|    |      |     |
|----|------|-----|
| 45 | 21.4 | 506 |
| 48 | 21.1 | 504 |
| 51 | 21.1 | 498 |
| 54 | 19.8 | 482 |
| 57 | 19.7 | 468 |
| 60 | 19.6 | 447 |

Figure 8 – recorded values for current and voltage

Voltage and current loaded and values recorded for  $R1 = 28K\Omega + R2 = 12K\Omega$

As seen from the analysis of result the circuit did not generate the required output voltage to current rating of 24V at 500mA. As the load resistance increased the output reached a the point of decay where rated current crosses the voltage Figure 7

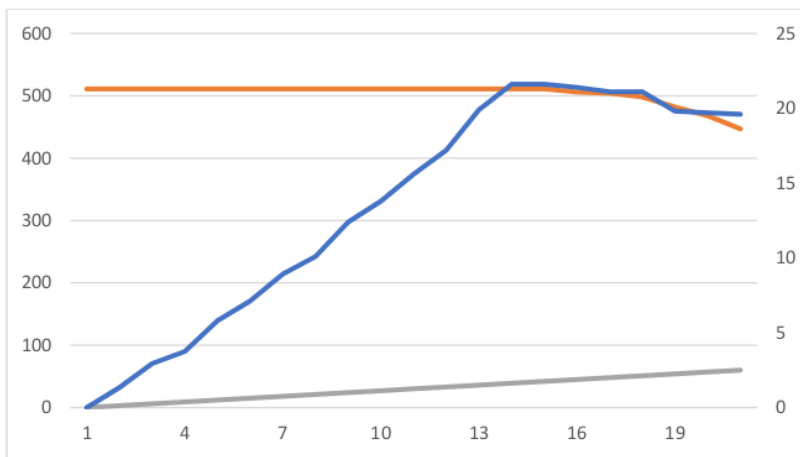


Figure 9- Graph of results test 1

As the specified output voltage was not reached  $R1 + R2$  were adjusted

$R1 = 30K\Omega + R2 = 10K\Omega$ , the values of both resistors must always add up to  $40K\Omega$

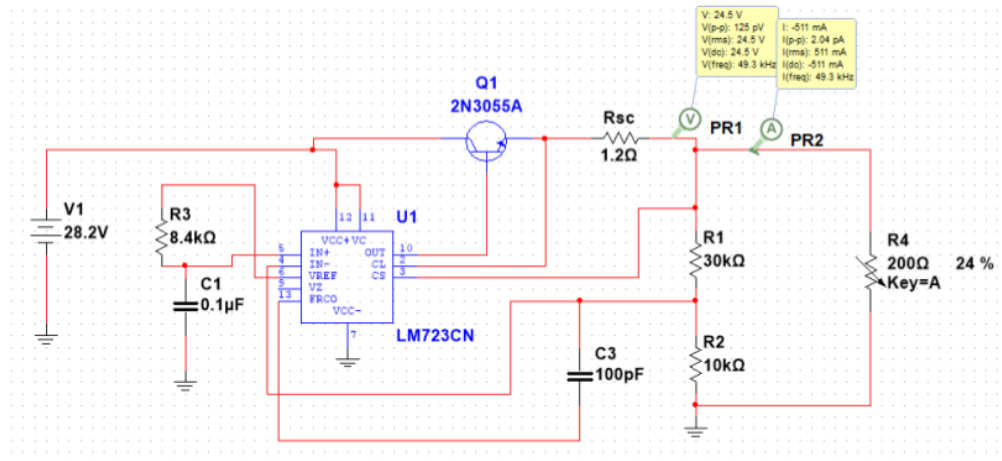


Figure 10 – circuit with resistors R1 + R2 changed

Simulation was then run again and results recoded.

| Load Resistor 200 ohms | Load V | Load I |
|------------------------|--------|--------|
| 0                      | 0      | 511    |
| 3                      | 1.54   | 511    |
| 6                      | 3.08   | 511    |
| 9                      | 4.61   | 511    |
| 12                     | 6.15   | 511    |
| 15                     | 7.68   | 511    |
| 18                     | 9.22   | 511    |
| 21                     | 10.8   | 511    |
| 24                     | 12.3   | 511    |
| 27                     | 13.8   | 511    |
| 30                     | 15.4   | 511    |
| 33                     | 16.9   | 511    |
| 36                     | 18.4   | 511    |
| 39                     | 19.9   | 511    |
| 42                     | 21.5   | 511    |
| 45                     | 23     | 511    |
| 48                     | 24.5   | 511    |
| 51                     | 25.2   | 495    |
| 54                     | 25.3   | 469    |
| 57                     | 25.4   | 445    |
| 60                     | 25.4   | 423    |

Figure 11 – simulation results after modified R1+ R2

From Analysis of the results in figure 8 by changing the resistor values created the correct voltage range for the regulator output which met the required specification. It showed that even though the

values had been calculated using all the required values for manufactures data sheets for the selected components, still needed to be tweaked through the aid of simulation test software.

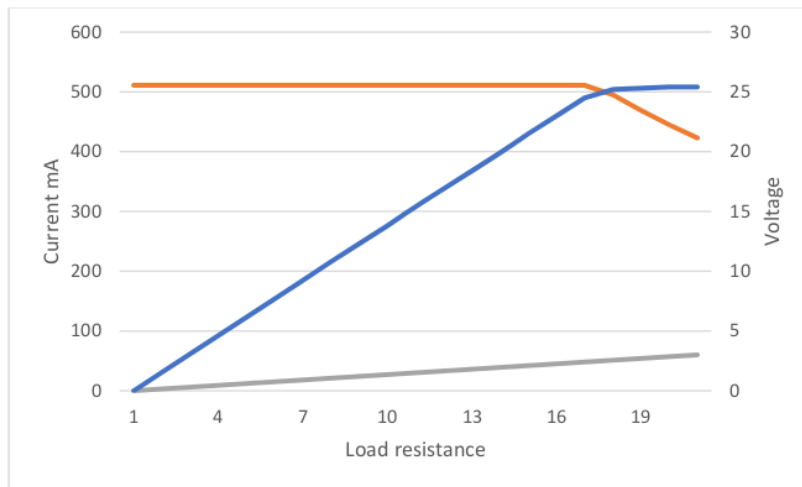
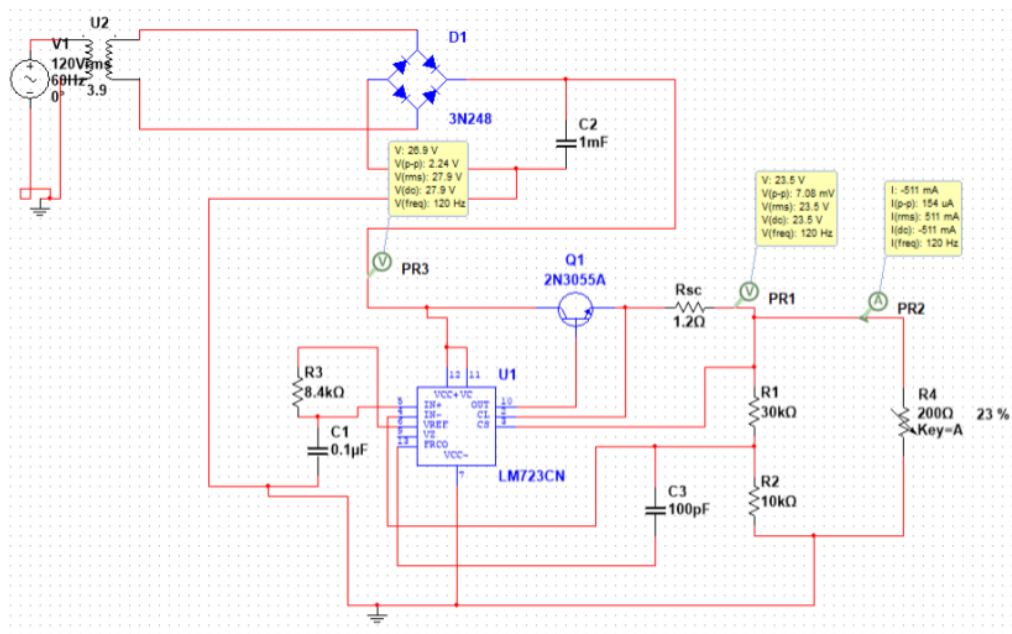


Figure 12 – graph of voltage current output

Figure 12 shows as the load resistance increased the output voltage increased, output current stayed steady at 511mA until the cross over point where the load resistance got too large and the regulator started to fail.

Using the Multisim software the full circuit was built using the specified components and values. Figure 13 is the complete circuit with transformer, rectifier and smoothing capacitor.



## Conclusions and recommendations

To conclude this assignment, the brief was covered and successfully proved the design stages of a power supply. The specification required for the power supply were achieved by calculation, simulation and with the aid of component research which supplied data sheets to compare and verify correct components were used.

Design of the regulator showed that even though components are selected off theoretical values through the aid of calculation, this can still lead to an incorrect outcome. Simulation software like Multisim proved its usefulness in design as building and simulating proved adjustments to components was required.

Research in to what is required during the design stages to meet demands set out by customers and not just for the physical selection of components, but ethical, environmental, sustainability, all the directive set out for harmonization for equipment for use throughout Europe. Health and safety aspects also directives on use of harmful materials. My outcome from the research is that a lot of work needs to go in to the design before any components are even research so that everything is proven and in place to gain a CE mark.

Recommendation for the assignment are that there wasn't enough time to maybe build with the use of Multisim a couple of different design showing and proving the variety of components available and how connecting up multiple components can achieve similar outcomes. Maybe the use of other software would have proved more reliable as multisim seemed to be limited and didn't allow full function of the design. My simulation proved the full circuit worked for a couple of minutes but then crashed.

Literature on the components and trying to source different types proved to be a little bit difficult but achievable sources of information was obtained from manufactures web sites and component data sheets.

Overall this was a good assignment, gave an insight in to the design industry and how meeting specifications for Electrical and Electronic equipment can be achieved.

## Citation List

Instruments, T. (2014, 3). *www.ti.com*. Retrieved from [www.ti.com/lit/ds/symlink/lm317m.pdf](http://www.ti.com/lit/ds/symlink/lm317m.pdf)

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Thomas, S. (n.d.). Retrieved from <https://www.fictiv.com/hwg/design/heat-sink-design-guide>





# Electronic Design

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## GRADEMARK REPORT

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FINAL GRADE

GENERAL COMMENTS

79/100

**Instructor**

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**Text Comment.** ES should cover each section and is effectively the entire report in brief

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**Text Comment.** Good to see a block diagram

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**Text Comment.** preferred values

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**Text Comment.** Seems a little low, would expect 2000uf at least

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**CARL  
JONES**

**79**

### RESEARCH-INFORMED LITERATURE

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The research was intend to be finding appropriate real components that meet both the electrical and environmental spec

**3**

### KNOWLEDGE AND UNDERSTANDING

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The knowledge and understanding of the subject



demonstrated by this assignment was generally excellent. There were very 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 highly competent critical understanding of the main concepts and expanded your knowledge well beyond that contained in the course notes.

**25**

## ANALYSIS



Your analysis of the task was excellent, both in class and as shown in this assignment. You have demonstrated highly competent analytical skills and your approach to the task was highly logical. You carried out a detailed evaluation of the results and included an excellent conclusion relating your practical results to accepted theory. You have demonstrated a capacity for independent thought and your interpretation of the quantitative and qualitative data was excellent with sound judgements based on wholly valid arguments.

**25**

## PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally excellent. You used both the basic and advanced features of the resources appropriately when designing the circuit and you used appropriate advanced options for testing and evaluating the circuit performance. You managed to design an effective circuit that functioned well within the

**17**

specification and achieved this by rarely asking for assistance thus demonstrating some advanced problem solving skills. Your results were comprehensive and allowed for a detailed conclusion to be written.

## SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was written in a professional and confident style, however you still need to be more efficient with your word count. The report was very well presented, with excellent diagrams in appropriate places, good sentence/paragraph structure and clear calculations.

**9**