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by David Thomas

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Course: BSc (Hons) Electrical and Electronic Engineering
Module: SGEE6005 Electronic Design
Assignment: Regulated Power Supply Design
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- ① EXCELLENT RESEARCH WITH CITATIONS AND A CITATION LIST USING HARVARD.
- ② DESIGN WAS ACCURATE AND EXPLAINED IN DETAIL.
- ③ TESTING WAS COMPREHENSIVE AND DEMONSTRATED THAT THE CIRCUIT MET THE SPEC.
- ④ A GOOD STOPPING LIST OF APPROPRIATE COMPONENTS WAS PROVIDED.
- ⑤ EXCELLENT CONCLUSION.

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1. Executive Summary

The project aim was to provide an understanding of, and practical exposure to, electronic power supply design, highlighting the importance of establishing a detailed specification at an early stage in order to produce a design that meets customer requirements.

Following the generation of a suitable specification for a 12volt DC power supply to an automatic steam pressure reducing valve, the project began with the theoretical design. Additional challenges were presented by the nature of and proximity to the supplied device, requiring further environmental, health and safety and protection measure considerations. With the focal point being the final output, a 'Bottom-Up' design approach was used, starting from the regulator up, each component being selected based on its known behaviour and characteristics in order to meet the specification. A current boost circuit incorporating external pass transistors was added to increase the output current of the MC1723C regulator chip to achieve the required 1.0Amp, along with constant current limiting measures to protect from short circuiting or overload. As predicted with a 'Bottom-Up' approach, a number of adjustments were required to fine tune the design for optimal performance. Addition of a suitable capacitor and rectifier to the circuit was made, the Schade curve graph references alongside circuit reference values, used to calculate the required values. The final front end design element of the circuit was selection of a suitable transformer, rated higher than the design calculation of 31.99VA. All components selected had been certified against safety standards, were from reputable manufacturers and suppliers, and rated for operation in humid conditions at temperatures up to 35 °C i.e. suitable for the intended application. To ensure effective cooling of the transistor as a result of the significant heat generation with current boost, a heatsink with suitably rated thermal resistance was added to the overall design.

The design was tested using Multisim to compare the performance against the original specification, and proved the design theory with the regulator output meeting the specification required to power the automatic steam pressure reducing valve. Combining the back end of the circuit (the regulator) with the front-end design successfully generated the required output of 12VDC and 1.0A.

Following the above success, overall evaluation of the project design and execution was made to identify areas for further improvement. This included a review of project costings with the final design being 50% over-budget primarily as a result of higher than anticipated costs of the enclosure.

2. Researching Requirements & Compilation of the Specification

A specification detailing the requirements of the power supply is initially drafted to provide clear instruction on performance, construction and quality standards that must be met during the design. Although it may not be possible to establish or define all specifications at the initial design stage, it is essential to confirm certain requirements and parameters before the process commences (Tech Web, 2022). Part of this process requires consideration of the intended application, which in this instance involves a 12volt DC supply to an automatic steam pressure reducing valve.



Figure 1 - Automatic Steam Pressure Reducing Valve

For the automatic steam pressure reducing valve, as illustrated in the image above, the power supply is required to have a standard European nominal incoming 230-volt, 50Hz, AC supply. Consideration of the power requirements of the output must also be made to inform the current requirements. In this case in order to operate internal instrumentation that utilise current to drive transmission of data (4 to 20mA nominal), a 1-amp output is required for the application.

The specification extends beyond physical electrical design details to include Health and Safety standards/considerations, with the need for all design elements and components to be certified. Given the time and cost associated with testing to the required standards it would be desirable to ensure all chosen components are already certified. As such it is important that relevant safety standards are referenced in the specification. (Mammano, 2005) Protection measures for the power supply also need to be considered. The supply will therefore be connected to the enclosure via suitably sized and rated barrier gland, sealing each cable core in order to provide a variety of protection measures, and must be in accordance with the required IP rating. The supply will have local isolation and a suitably rated fused connection for required component protection (Schweber, 2020). Given the nature of the application, there are further considerations regarding design requirements that need to be included in the specification, as the power supply will be mounted in close vicinity to the steam valve on plant and as such will need to be able to withstand hot and humid conditions. Temperatures significantly higher than ambient are likely to be reached and, as it is not possible to use forced air cooling due to the nature of the installation, enclosure and heat generated from the components, a temperature rating of up to 35°C needs to be specified to prevent the occurrence of any critical failures as a result of component damage (Tech Web, 2022). The emission of steam from the valve during operation presents a risk of water ingress and potential corrosion to the power supply, and therefore a degree of ingress protection to seal the electrical enclosure is required. This should be provided in accordance with defined international standards, in this case IP65 rating would be appropriate providing a protection level equivalent to water being projected from a nozzle (Enclosure Company, 2022).

Taking into consideration the above, illustrated in the table is the summary specification and therefore design requirements of the power supply.

Specification Requirements	
V _{AC} Input	230V
V _{DC} Output	12v
Input frequency	50Hz
Ambient Temperature Rating	Up to 35°C
Ingress Protection	Minimum of IP65
Component cost	Less than £500.00

Table 1 - Design Requirements

EXCELLENT CONTEXT AND SPECIFICATION.

3. Design Method, Choices & Calculations

3.1. Regulator Circuit

The first stage of the design process involved design of the voltage regulator which is required to ensure the output voltages generated by the supply are in-line with that withstood by the electrical equipment i.e. as detailed in the design specification. A positive adjustable output IC regulator configuration (Scillc, 2002) was selected to produce the required 12VDC supply, with the Motorola MC1723C chip (positive or negative regulator) determined to be a suitable chip, featuring 0°C to $+70^{\circ}\text{C}$ temperature protection, which meets the specification requirements of needing to be compatible in temperatures up to 35°C . However, it only has the capability to deliver output currents up to 150mA_{dc} (see appendix 7.1 for chip datasheet). In order to provide a greater output current than that provided by the standard regular circuit configuration, a current boost circuit can be used which incorporates external pass transistors (Scillc, 2002). In this case the NPN current boost connection was selected to be able to deliver an output of several amperes, the limit of which is determined by the external pass transistor (Scillc, 2002). Illustrated in the image below is the representative diagram for the MC1723C chip.

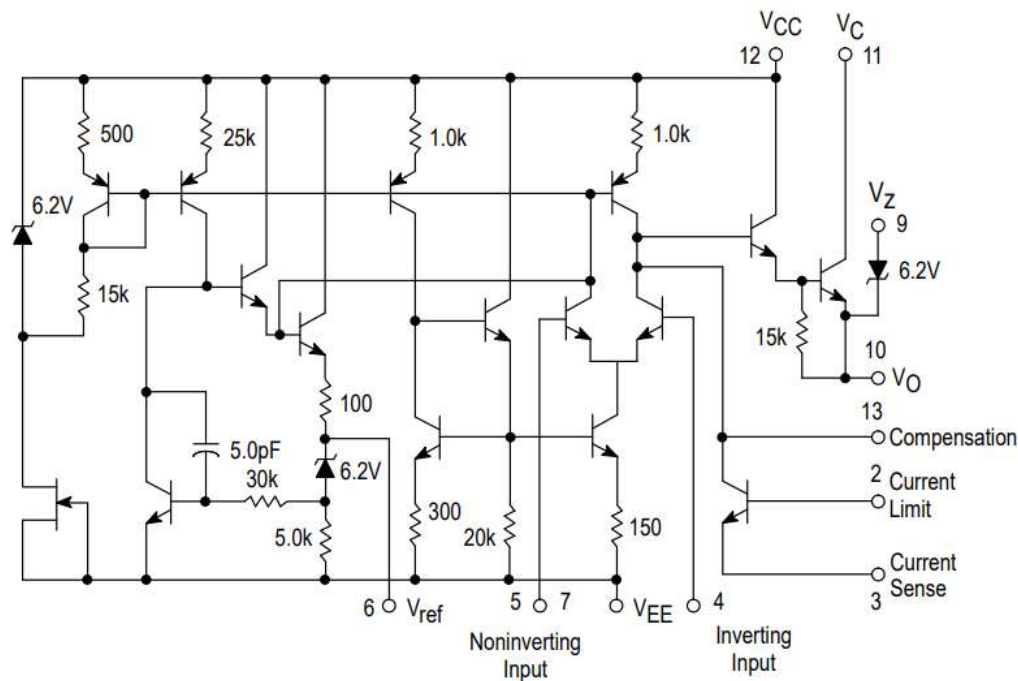


Figure 2 - MC1723C Representative chip

(Diode, 2020)

EXTRA INFO LIKE
THIS CAN GO IN THE
APPENDIX.

The VCC+ connection Pin 12, is connected to the 230VAC supply which is also connected to Pin 11. The VCC- connection Pin 7, is connected to ground. Constant current limiting is employed to protect the circuit (and power supply) from short circuiting or being subject to overload (Schweber, 2020). This feature examines the drop in voltage across R_{SC} , Pins 2 and 3, with an increase in output current resulting in a proportional increase in the former. Once the voltage drop is equivalent to the voltage of the base-emitter ON, the current remains static. In order to allow a higher current, the R_{SC} , needs to therefore be adjusted accordingly from the current value of 0.33Ω . To minimise low-frequency noise a low capacitance capacitor to block low frequency signals is placed across Pins 5 and 6 (Scillc, 2002). The output of the chip, Pins 4 and 10, is determined by the balanced values of $(R1+R2)$ behaving as a potentiometer.

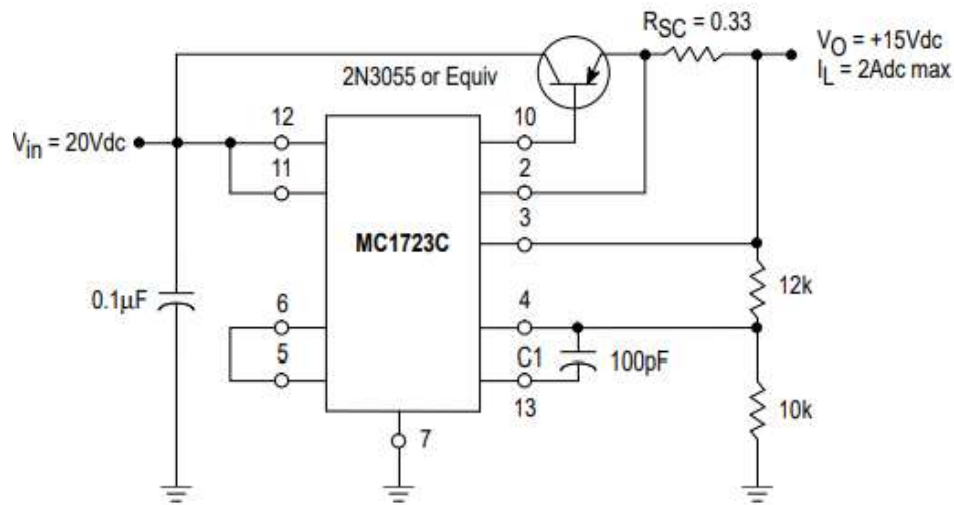


Figure 3 - MC1723C Chip NPN Current Boost Connection

(Diode, 2020)

Shown in the image above, is the MC1723C chip schematic for NPN current boost setup.

Another safety protection feature that could be included in the design of the power supply is voltage over-protection, ensuring the supply is switched off or output clamped if voltage is in excess of that defined to prevent component /circuit damage/failure. Many approaches can be used however the simplest is a crowbar circuit, where the connection exists between the regulator output and load, involving SCR, Zener diode, resistor and capacitor. Under normal operation there is no conduction through the diode, however excess voltage leads to conduction, eventually causing a short circuit and grounding of the output. The choice of Zener diode must provide a voltage higher than the output. (Sunpower Electronics, 2019)

Calculations for the regulator design component values were first calculated using the design requirements. The total sum of (R1+R2) is set to 30KΩ, whilst the value of V_{REF} is a set value of 7v, a characteristic of the chip. The base-emitter junction volt drop is divided by the current sensing.

$$R2 = \frac{V_{ref}}{V_{out}} (R1 + R2) = \frac{7.0}{12} (30,000) = 17,500\Omega \text{ or } 17.5K\Omega$$

Equation 1 - Regulator R2 Value

$$R1 = (R1 + R2) - R2 = 30,000 - 17,500 = 12,500\Omega \text{ or } 12.5K\Omega$$

Equation 2 - Regulator R1 Value

$$R_{SC} = \frac{0.6}{I_{cs}} = \frac{0.6}{1} = 0.6\Omega$$

Equation 3 - Regulator R_{SC} Value

$$V_{in} = \geq 12v + 2\phi + 3v = 12 + 1.2 + 3 = 16.2v$$

Equation 4 - Regulator Minimum Input Voltage

$$V_{in} = \leq 12v + 2\phi + 38v = 12 + 1.2 + 38 = 51.2v$$

Equation 5 - Regulator Maximum Input Voltage

The input minimum and maximum voltage is calculated by the required design output voltage, 2ϕ, which are volt losses to the transistors, as well as (V_{IN} – V_{OUT}) voltage differential values taken from the component datasheet (set at 3v minimum value and 38v maximum). C_{REF} is set at 0.1μF, which is required for minimising low-frequency noise to maintain the signal integrity. With the component values selected and calculated, the circuit was designed using Multisim and the datasheet configuration for the MC1723C Chip NPN Current Boost Connection. Component values were subsequently altered through trial and error to fine-tune the circuit in an attempt to optimise the performance.

Component	Selected/Calculated Values
VCC	20V
R1	12.5KΩ
R2	17.5KΩ
R _{SC}	0.6Ω
C _{REF}	0.1 μF

Table 2 - Regulator Component Values

Shown in the table above are the initial component values for the regulator circuit that were selected after using the above calculations. In the image below is the final design of the regulator circuit, which includes the final adjusted component values for achieving optimal performance.

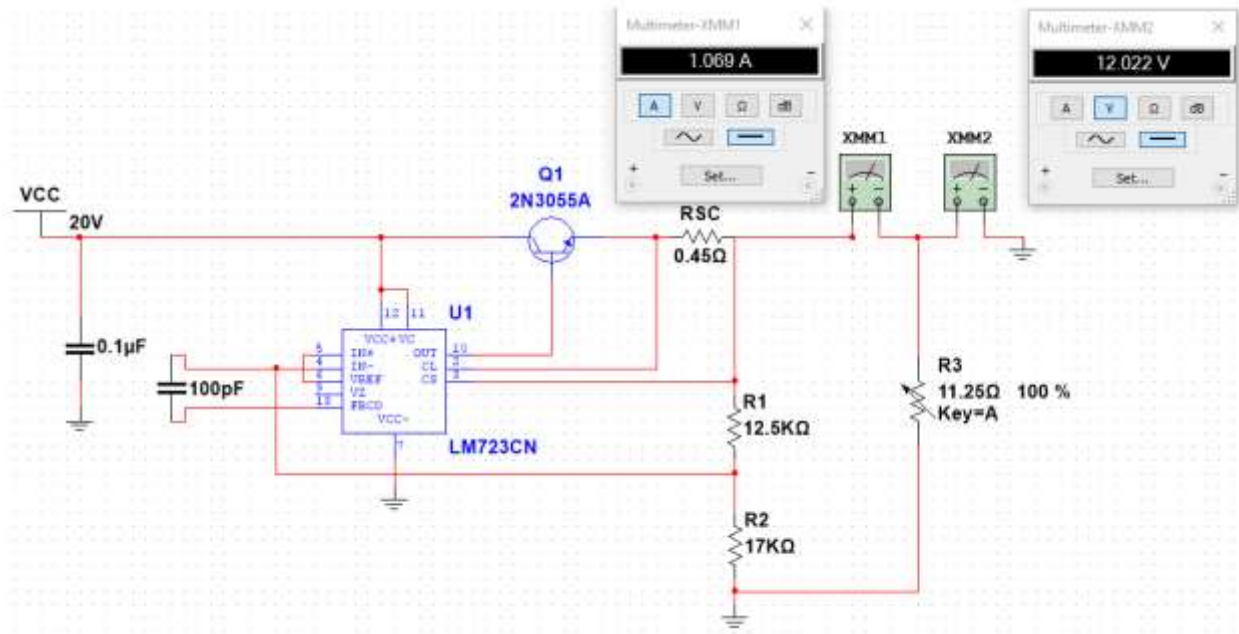


Figure 4 - MultiSim Regulator Circuit

3.2. Circuit Smoothing Capacitor Design

Parameter	Value
$V_C (V_{IN})$	20v
V ripple	3V
Frequency	50hz
$V_M (V_{IN} + (0.5 \times V_{IN}))$	30v
$I_O (I_{MAX})$	1A

Table 3 - Circuit Rectifying & Smoothing Values

The circuit values as shown in the table above, are required along with the use of the Schade curve graph references, as shown in appendix 7.2, to calculate capacitor and rectifier values for the design.

To calculate the value for Ripple Factor (r_F):

$$r_F = \frac{V \text{ Ripple (pp)}}{2\sqrt{2}V_C (DC)} \times 100\% = \frac{3}{2 \times \sqrt{2} \times 20} \times 100 = 5.303\%$$

Equation 6 - Circuit Rectifying & Smoothing Ripple Factor Value

Using the root-mean-square ripple voltage for capacitor-input circuit graph, (shown in appendix 7.2), a suitable value between the minimum and maximum values was selected, as shown in the table below.

ωCRL Min & Max Values	Selected ωCRL Value
$\omega CRL \text{ Min} = 8$	$\omega CRL = 10$
$\omega CRL \text{ Max} = 17$	

Table 4 - ωCRL Values from Schade Curve Graph

From the selected value of ωCRL , the smoothing capacitor can be calculated, where:

$$R_L = \frac{V_C}{I_O} = \frac{20}{1} = 20\Omega$$

Equation 7 - Smoothing Capacitor R_L Value

$$C = \frac{(\omega C R_L)}{2\pi f R_L} = \frac{10}{2\pi \times 50 \times \left(\frac{20}{1}\right)} = 1.59\text{mf or } 1591\mu\text{f}$$

Equation 8 - Smoothing Capacitor Value

Smoothing capacitors are electrolytic, and have a working voltage. For the capacitor, the working voltage is required to be double ($2 \times V_m$) the maximum expected voltage for safety, ($2 \times V_m = 2 \times 30 = 60V$). The selected capacitor is a 63VDC 1800 μF Electrolytic Capacitor, see below for details and appendix 7.2 for selected capacitor data sheet.

■ Specifications

Category temp. range	-55 to +105°C
Rated W.V. Range	6.3 to 100 V .DC
Nominal Cap. Range	1.0 to 15000 μF
Capacitance Tolerance	$\pm 20\%$ (120Hz/+20°C)

$I < 0.01 CV$ or $30 \mu A$

Figure 5 - Capacitor Datasheet Details

3.3. Bridge Rectifier

For the bridge rectifier stage of the design, the V_C/V_m is to be calculated as a percentage:

$$\frac{V_C}{V_m} 100\% = \frac{20}{30} \times 100 = 67\%$$

Equation 9 - Bridge Rectifier V_C/V_m Percentage Value

From the relationship of applied alternating peak voltage to direct output voltage in full-wave capacitor-input circuit's Schade Graph (see appendix 7.3) the $\%R_S/R_L$ is obtained. With the $\%R_S/R_L$ obtained, the rectifier requirements are able to be determined.

For full wave rectification, the average current is half the output current:

$$I_f(\text{avg}) = \frac{I_o}{2} = \frac{1}{2} = 0.5A$$

Equation 10 - Bridge Rectifier I_f Average Value

Root mean squared (RMS) and Peak repetitive rectifier current ratings can be determined from the relationship of RMS and Peak, to the average diode current in capacitor input circuit's Schade graph, see appendix 7.3, the $n\omega C R_L$ value is obtained.

From the relationship of RMS and Peak to average diode current in capacitor input circuit's Schade graph:

$$I_f(\text{rms}) = F \times I_f(\text{avg}) = 2 \times 0.5 = 1A$$

Equation 11 - Bridge Rectifier I_f RMS Value

$$I_f(\text{peak}) = F \times I_f(\text{avg}) = 5.2 \times 0.5 = 2.6A$$

Equation 12 - Bridge Rectifier I_f Peak Value

The rectifier peak inverse voltage rating (PIV rating) equals V_m for the full-wave bridge circuit. In addition, a minimum safety margin of 50% is advisable due to the possibility of line transients.

$$PIV = V_M = 30v \text{ double for safety margin} = 2 \times 30 = 60v$$

Equation 13 - Bridge Rectifier PIV Value

To calculate maximum surge current:

$$I_{\text{surge}} = \frac{V_m}{R_s + R_{SR}} = \frac{30}{4} = 7.5A$$

Equation 14 - Bridge Rectifier Surge Current Value

Calculated Bridge Rectifier Details	
PIV	60v
I Peak	2.6A
I Surge	7.5A
I average	5.2A

Table 5 - Calculated Bridge Rectifier Details

Using the bridge rectifier calculated values as illustrated in the table above, the selected bridge rectifier is the Multicomp Pro KBPC3502 suitable for PIV of 200v and surge current of 35A. See below for details and appendix 7.3 for selected full wave bridge rectifier data sheets.



Features

- Surge overload -240~500 Amperes peak
- Low forward voltage drop
- Electrically isolated base -2000 Volts
- Solderable 0.25" FAST ON terminals
- Materials used carries UL recognition

Mechanical Data

Mounting Position : Any
Reverse Voltage : 50 to 1000 Volts
Forward Current : 10/15/25/35/50 Ampere

Glass Passivated Bridge Rectifiers, 15A 50V	KBPC15005
Glass Passivated Bridge Rectifiers, 35A 200V	KBPC3502
Glass Passivated Bridge Rectifiers, 35A 1000V	KBPC3510

Figure 6 - Bridge Rectifier Datasheet Details

3.4. Transformer Design

The values of the supply transformer can now be calculated:

Secondary Voltage:

$$V_s = \frac{V_m + n(2:0)}{\sqrt{2}} = \frac{30 + 2}{\sqrt{2}} = 22.627v$$

Equation 15 - Transformer Secondary Voltage

Secondary Current:

$$I_o \times \sqrt{2} = 1 \times \sqrt{2} = 1.414A$$

Equation 16 - Transformer Secondary Current

Secondary Resistance:

$$RL \times 0.2 = 20 \times 0.2 = 4\Omega$$

Equation 17 - Transformer Secondary Resistance

VA Rating:

$$V_s \times I_s = 22.627 \times 1.414 = 31.99VA$$

Equation 18 - Transformer VA Rating

Turns Ratio:

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{230}{22.627} = 10.16v = 10:1$$

Equation 19 - Transformer Turns Ratio

Calculated Transformer Details	
VA Rating	32VA
V secondary	23v
I secondary	1.4A
Ω Secondary	4Ω

From the transformer calculated values as illustrated in the table above, a 230v to 24VAC din rail mounted transformer was chosen. See below and appendix 7.4 for full data sheet for the selected transformer.

Specifications	
Power:	24 – 75 VA
Frequency:	50/60 Hz
Primary:	230 VAC
Secondary:	12 VAC or 24 VAC
Isolation:	4 kV RMS
Temp. class:	E (120°) / ta 40°C
Protection class	IP20
Standards:	EN61558-2-6

Figure 7 - Transformer Datasheet Details

(RS Components, 2022)

Characteristic	Value
Primary Voltage	230v
Secondary Voltage	24v
Power Rating	35VA
Mounting Type	Din Rail
Maximum operating temperature	+130°C

Table 6 - Transformer Details

(RS Components, 2022)

The selected transformer is the 8055310 rated for 35VA, which is higher than the design calculation of 31.99VA. As the pressure reducing valve only requires 1A, the transformer rating is suitable. The transformer is suitable for working temperatures of +130°C, more than adequate for the maximum temperatures likely to be experienced of the installation.

3.5. Heatsink Design

As the 2N3055 NPN transistor (see appendix 7.5 for full transistor datasheet) chosen for the design requirement is being used to boost current, a large quantity of heat will be generated with the increasing current. To effectively cool the transistor to ensure performance longevity and reliability, a heatsink will be required, providing a large surface area to efficiently remove and dispel the heat into the surrounding environment. Heatsink performance depends on several factors relating to the concept of heat transfer, which are accounted for in the standard equation for heatsink (Lee, 1995) (see below):

$$\theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA}$$

Equation 20 - Standard Heatsink Equation

Characteristic	
J	Junction
C	Case
A	Atmosphere
S	Heatsink

Table 7 - Heatsink Equation Characteristics

In order to determine if a heatsink was required to ensure equipment is operated within its temperature rating, the equation below was used, incorporating the values of maximum ambient temperature (TA) and power dissipated (PD):

$$TA = \theta_{TJ} - (PD \times \theta_{JA}) = \theta_{TJ} = TA - (PD \times \theta_{JA})$$
$$= 35 + (16.8 \times 100) = 1715^{\circ}\text{C}$$

Equation 21 - Heatsink Requirement

$$\theta_{SA} = \frac{\theta_{TJ} - TA}{PD} - \theta_{JC} - \theta_{CS} = \theta_{SA} = \frac{100 - 35}{16.8} - 1.5 - 1.6 = 0.769^{\circ}\text{C/W}$$

Equation 22 - Heatsink Thermal Resistance

The calculations illustrated above support the use of a heatsink in the design. The heatsink will be required to have a thermal resistance below 0.769°C/W. The selected heatsink for the application, as shown below, and in full in appendix 7.5, features a thermal resistance of 0.75°C/W, less than the required specification of 0.769°C/W, when placed with an insulator and heatsink compound.

WKV Part Number	Description	Width	Height	Length	Thermal Resistance °C/w/3"
125520	9.75" Wide x 12" Flatback heatsink 16473 xx5384	9.75	2.28	12	0.75
	9.75" Wide x 36" Flatback heatsink				

Figure 8 - Heatsink Datasheet

(Wakefield-vette, 2021)

As the power supply will be placed within an IP68 rated enclosure, the junction with the inclusion of the heatsink and the installation ambient temperature will reach temperatures of 99.68°C, as illustrated in the calculations below. Given this is comfortably within the range specified in the 2N3055G data sheet, the heatsink inclusion will satisfy temperature rating requirements of the device.

$$\phi_{JA} = PD(\phi_{SA} + \phi_{JC} + \phi_{CS}) = 16.8 (0.75 + 1.5 + 1.6) = 64.68^{\circ}\text{C}$$

$$\phi_{JA} + \text{Ambient Temp} = 64.88 + 35 = 99.68^{\circ}\text{C}$$

Equation 23 - Junction Calculated Operating Temperature

T _{stg}	Storage temperature	-65 to 200	°C
T _J	Max. operating junction temperature	200	°C

Figure 9 - Transistor Junction Operating Temperature

(STMicroelectronics, 2013)

3.6. Design Choices

An additional consideration to the regulated power supply design, is also that of the enclosure for all the required components to be housed. As the installation is required to be within proximity to the automatic steam pressure reducing valve, the enclosure will have to be sufficiently rated to withstand the anticipated environmental conditions.

The selected enclosure chosen for the designed supply is the Slayson ASM404020, with the addition of the ASPI1212 back plate to suit enabling dedicated mounting of the required components, preventing any compromise of the IP68 ingress rating (sufficient protection against moisture steam and dust, as per design specification). The decision to make use of an enclosure made of stainless steel was made as, although not an initial design requirement, the environment is not suitable for plastic or glass reinforced plastic enclosures, and steel enclosures would likely eventually rust (see appendix 7.6 for enclosure data sheet)

Shown in the table below is a final list of all the components selected for the regulated power supply design. Although the selected components are not necessarily an exact match for the calculated component values, values stated in the components' data sheets (specifications) are compatible with the minimum or maximum permitted values as appropriate.

No	Component	Manufacturer	Component Details	Component Units	Component Cost
1	Transformer	RS Pro	8055310	1	£54.85
2	Bridge Rectifier	Multicomp Pro	KBPC3502	1	£8.51
3	Heatsink	Wakefield-Vette	125520	1	£60.62
4	NPN Chip	Motorola	MC1723C	1	£4.63
5	Transistor	ON Semiconductor	2N3055	1	£6.24
6	Capacitor	Panasonic	63VDC 1800 μ F	50	£110.85
7	Enclosure	Slayson	ASM404020	1	£495.54
8	Resistor 1 12.5K Ω	Ohmite	B20J12K5E	1	£5.42
9	Resistor 2	Arcol	MRA020717K4BTA015		£4.73
10	Resistor 3	Tyco Electronics	YR1B11K3CC	5	£2.04
11	Resistor Sensing Current	KOAglobal	MOSX3CT521RR47J	1	£0.32
Total Build Cost					£753.75

Table 8 - Component List & Costings

4. Testing, Results & Analysis

To begin the circuit build, as with the design stage, the regulator was first constructed and tested to ensure the specified output of the design was being met.

Building the circuit using the initial calculated values for the design components, resulted in the circuit output values not meeting the design specification. As a result, the circuit was the fine-tuned and through trial-and-error methods of testing, the correct components values were found that provided the desired voltage and current outputs. A summary of the calculated and tuned component values is shown in the table below.

Calculated Component Values		Circuit Tuned Component Values	
R1	12.5K Ω	R1	12.5K Ω
R2	17.5K Ω	R2	17K Ω
RSC	0.6 Ω	RSC	0.45 Ω

Table 9 - Regulator Component Value Comparison

Illustrated in the image below is the revised circuit with the component values for the desired design specifications.

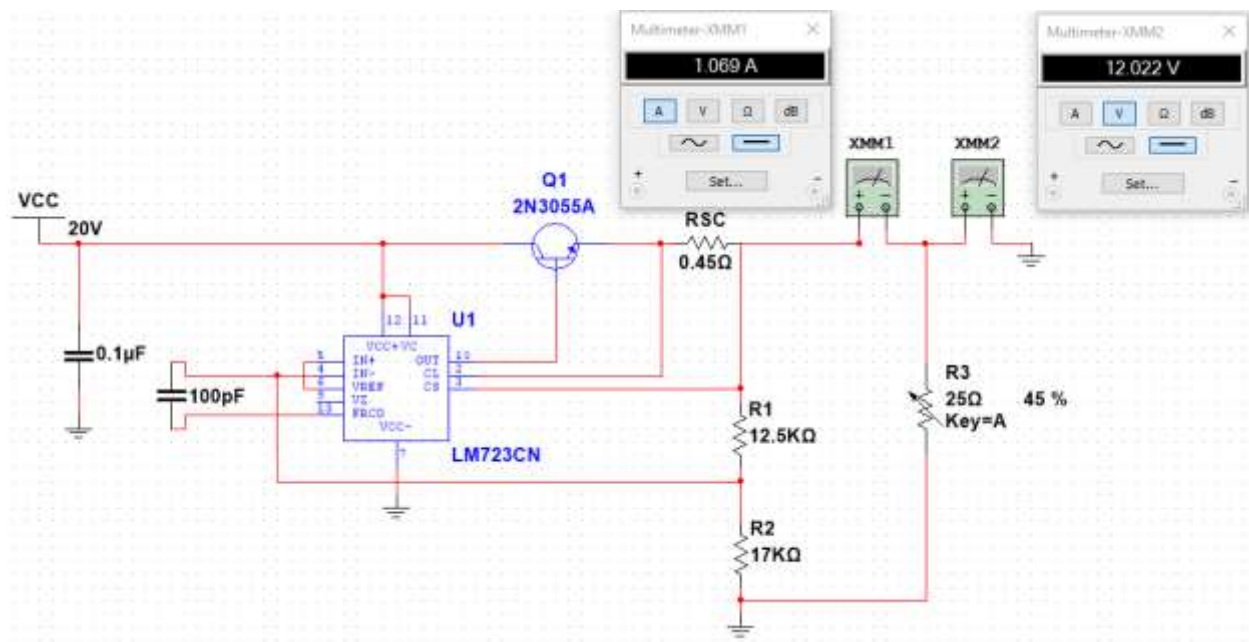


Figure 10 - Simulated Regulator Circuit

Once the simulation of the voltage regulator had been achieved, the load, R3, was varied in order to provide an assessment of the circuit performance. The load was varied to determine the working region of the regulator for the required output.

Shown in the graph below, as the voltage (blue trend line) rises to the required specification value of 12v, the current (red trend line) is at its maximum value of 1.357A. When the voltage reaches the required specified value of 12v, the R3 load resistance value is 8.75Ω. As the load value is increased, the current value decreases; when the load value reaches 11.25Ω, the current output is then 1.069A, while the voltage remains at 12v (see appendix 7.7 for circuit working region values). Between these points the regulator is within its optimum working region. As the load continues to increase, the relationship between resistance, current and voltage (Ohm's law) is demonstrated, with an increase in resistance, resulting in a steady decline of current while the voltage remains constant. The graph demonstrates that the simulation output has met the design specification, as the output values are as required to power the automatic steam pressure reducing valve.

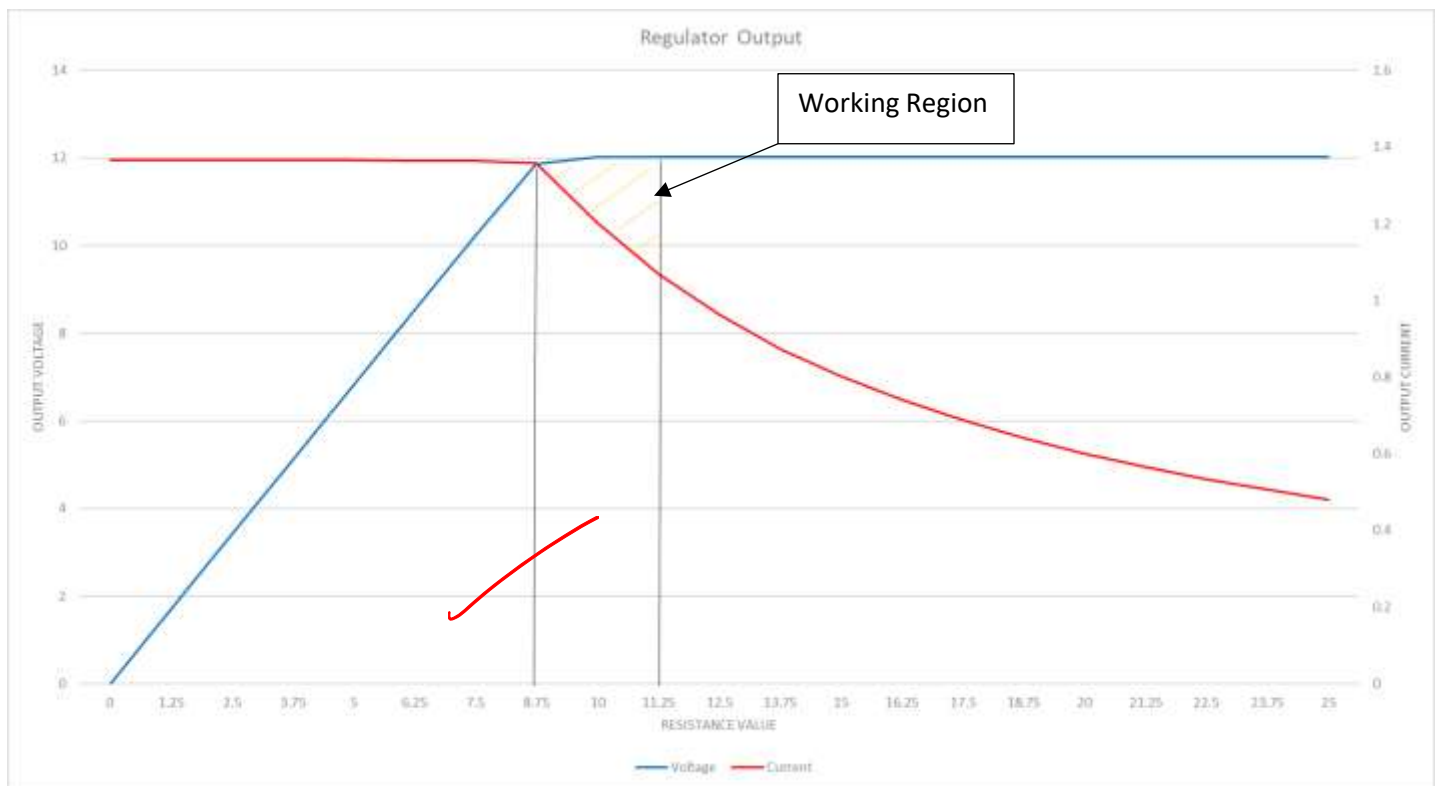


Figure 11 - R3 Minimum & Maximum Load Value for Design Working Region

Following the successful design and simulation of the regulator (back-end) circuit, the front-end was then simulated in MultiSim, using the design specified and calculated component values. As illustrated in the image below, a 10:1 turns ratio transformer is supplied by a simulated 230VAC power supply. The secondary of the transformer then supplies the bridge rectifier, which converts the AC voltage to a rippled DC voltage. The rippled DC voltage is then smoothed by the capacitor.

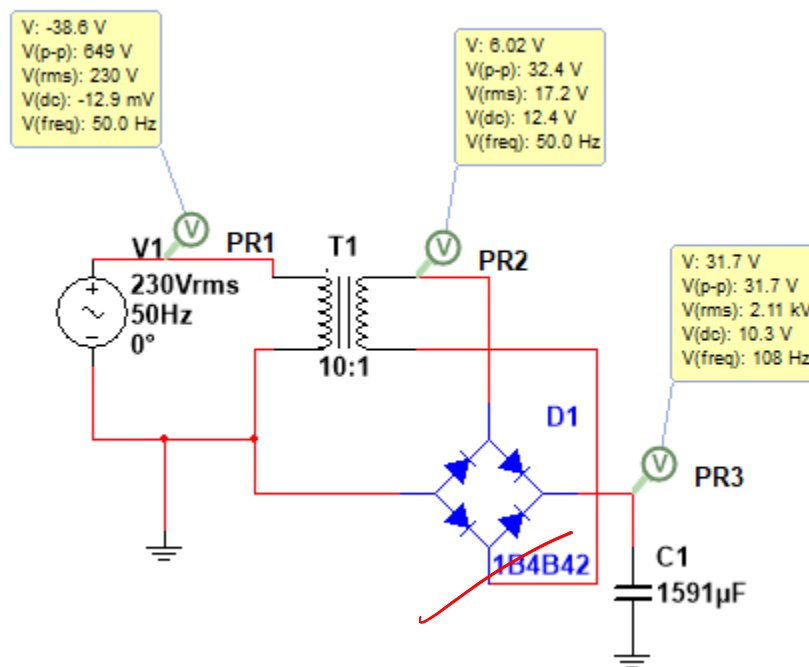


Figure 12 - Design Front End

On successfully simulating the circuit's front end, both the regulator and the front end were then combined, as illustrated in the image below, to simulate and evaluate the full circuit (see appendix 7.7 for larger illustration). The designed and simulated circuit successfully met the design specification. Providing the load of the power supply is kept at 11.25Ω (i.e. optimal operation range/working region, as shown in figure 11), the integrated circuit has a stable 12VDC output, and results in the desired output current of 1.0A by switching the NPN transistor. For lower resistance loads, the current will gradually increase to a maximum value of 1.357A, whilst the voltage will drop off. For higher resistance loads, the voltage will remain at a constant 12VDC, whilst the current will decrease.

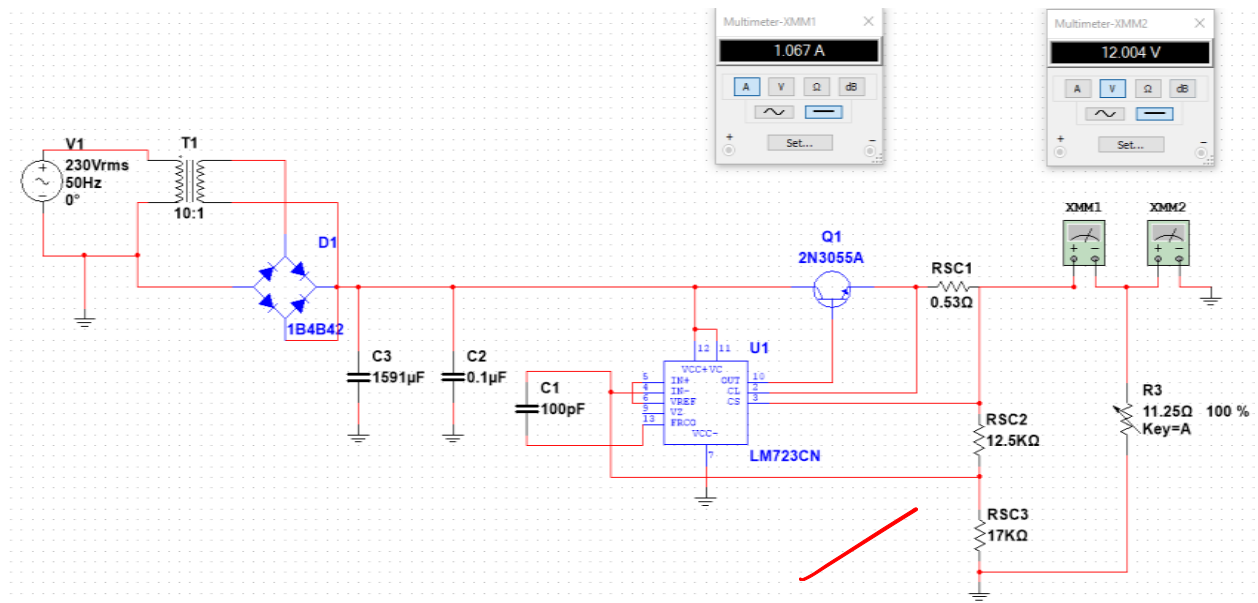


Figure 13 - Regulated Power Supply

5. Conclusions

The benefits of preparing a comprehensive specification when designing any electrical system are well understood. Time spent considering the intended use, performance and construction requirements, along with any quality and standards that must be met, often results in a timelier, and more satisfactory project delivery. In addition, it can help the project costing process.

This was successfully demonstrated in this project, with the initial specification requirements effectively used to inform the design of a power supply. Although a number of design methods can be employed which can influence the simulation process, given the focal point of the design in this instance was to achieve the desired output, a 'Bottom-Up' design process was used. Using this, beginning with the regulator, each component part of the system was individually chosen to meet the calculated requirements, based on established behaviour and data sheet information. However, one of the known disadvantages of using this process is that when combined, the overall performance is not often exactly as predicted, which became evident during the project, with trial and error adjustments being required to generate an optimal design and performance.

Although initial costings specified the project to be less than £500, the finished design of the power supply was significantly over budget by approximately 50%. This was primarily a result of the decision to use stainless steel, over steel, for the enclosure. Significant savings therefore could be made here if the customer deemed the cost overrun too high. However, given the nature of the equipment the power supply is feeding, consideration and discussion should be had over the long-term costs benefits of opting for the stainless steel, the initial outlay likely to outweigh the cost of early replacement of steel due to rusting. To improve the aesthetics and reduce overall costs further consideration could be given to the proposed location of the power supply as positioning it further away from the pressure reducing valve would reduce the temperature rating requirements, and therefore likely reduce the need for such a large heatsink, or possibly remove the need at all, and also the need for a stainless-steel enclosure.

Although considered in the design process, the final simulated circuit lacked the inclusion of a Zener diode for voltage over-protection and therefore the effectiveness of could not be tested. Including the diode in the circuit design would allow testing of Zener voltage regulator calculations by simulating over-voltage and operation of the protection mechanism.

Although potential improvements to the power supply circuit design could be made, overall the project was considered a success, demonstrating the ability to create and simulate a circuit design to meet a required specification.

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7. Appendix

7.1. Regulator Circuit

MC1723C

MAXIMUM RATINGS ($T_A = +25^\circ\text{C}$, unless otherwise noted.)

Rating	Symbol	Value	Unit
Pulse Voltage from V_{CC} to V_{EE} (50 ms)	$V_{I(p)}$	50	V_{pk}
Continuous Voltage from V_{CC} to V_{EE}	V_I	40	Vdc
Input–Output Voltage Differential	$V_I - V_O$	40	Vdc
Maximum Output Current	I_L	150	mA
Current from V_{ref}	I_{ref}	15	mA
Current from V_Z	I_Z	25	mA
Voltage Between Noninverting Input and V_{EE}	V_{ie}	8.0	Vdc
Differential Input Voltage	V_{id}	± 5.0	Vdc
Power Dissipation and Thermal Characteristics $T_A = +25^\circ\text{C}$ Derate above $T_A = +25^\circ\text{C}$ Thermal Resistance, Junction–to–Air	P_D $1/\theta_{JA}$ θ_{JA}	1.25 10 100	W mW/ $^\circ\text{C}$ $^\circ\text{C}/\text{W}$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to $+175$	$^\circ\text{C}$
Operating Ambient Temperature Range	T_A	0 to $+70$	$^\circ\text{C}$

ELECTRICAL CHARACTERISTICS ($T_A = +25^\circ\text{C}$, $V_{in} = 12\text{ Vdc}$, $V_O = 5.0\text{ Vdc}$, $I_L = 1.0\text{ mA}$, $R_{SC} = 0$, $C_1 = 100\text{ pF}$, $C_{ref} = 0$ and divider impedance as seen by the error amplifier $\leq 10\text{ k}\Omega$ connected as shown in Figure 2, unless otherwise noted.)

Characteristics	Symbol	Min	Typ	Max	Unit
Input Voltage Range	V_I	9.5	–	40	Vdc
Output Voltage Range	V_O	2.0	–	37	Vdc
Input–Output Voltage Differential	$V_I - V_O$	3.0	–	38	Vdc
Reference Voltage	V_{ref}	6.80	7.15	7.50	Vdc
Standby Current Drain ($I_L = 0$, $V_{in} = 30\text{ V}$)	I_{IB}	–	2.3	4.0	mA
Output Noise Voltage ($f = 100\text{ Hz}$ to 10 kHz) $C_{ref} = 0$ $C_{ref} = 5.0\text{ }\mu\text{F}$	V_n	– –	20 2.5	– –	$\mu\text{V(RMS)}$
Average Temperature Coefficient of Output Voltage ($T_{low} < T_A < T_{high}$)	TCV_O	–	0.003	0.015	$\%/^\circ\text{C}$
Line Regulation $(T_A = 25^\circ\text{C}) \begin{cases} 12\text{ V} < V_{in} < 15\text{ V} \\ 12\text{ V} < V_{in} < 40\text{ V} \end{cases}$ $(T_{low} < T_A < T_{high})$ $12\text{ V} < V_{in} < 15\text{ V}$	Reg_{line}	– – –	0.01 0.1 –	0.1 0.5 0.3	$\% V_O$
Load Regulation ($1.0\text{ mA} < I_L < 50\text{ mA}$) $T_A = 25^\circ\text{C}$ $T_{low} < T_A < T_{high}$	Reg_{load}	– –	0.03 –	0.2 0.6	$\% V_O$
Ripple Rejection ($f = 50\text{ Hz}$ to 10 kHz) $C_{ref} = 0$ $C_{ref} = 5.0\text{ }\mu\text{F}$	RR	– –	74 86	– –	dB
Short Circuit Current Limit ($R_{SC} = 10\text{ }\Omega$, $V_O = 0$)	I_{SC}	–	65	–	mA
Long Term Stability	$\Delta V_O/t$	–	0.1	–	$\%/1000\text{ Hr.}$

NOTE: T_{low} to $T_{high} = 0^\circ$ to $+70^\circ\text{C}$

Figure 14 - MC1723C Chip

(Diode, 2020)

7.2. Smoothing Capacitor Circuit

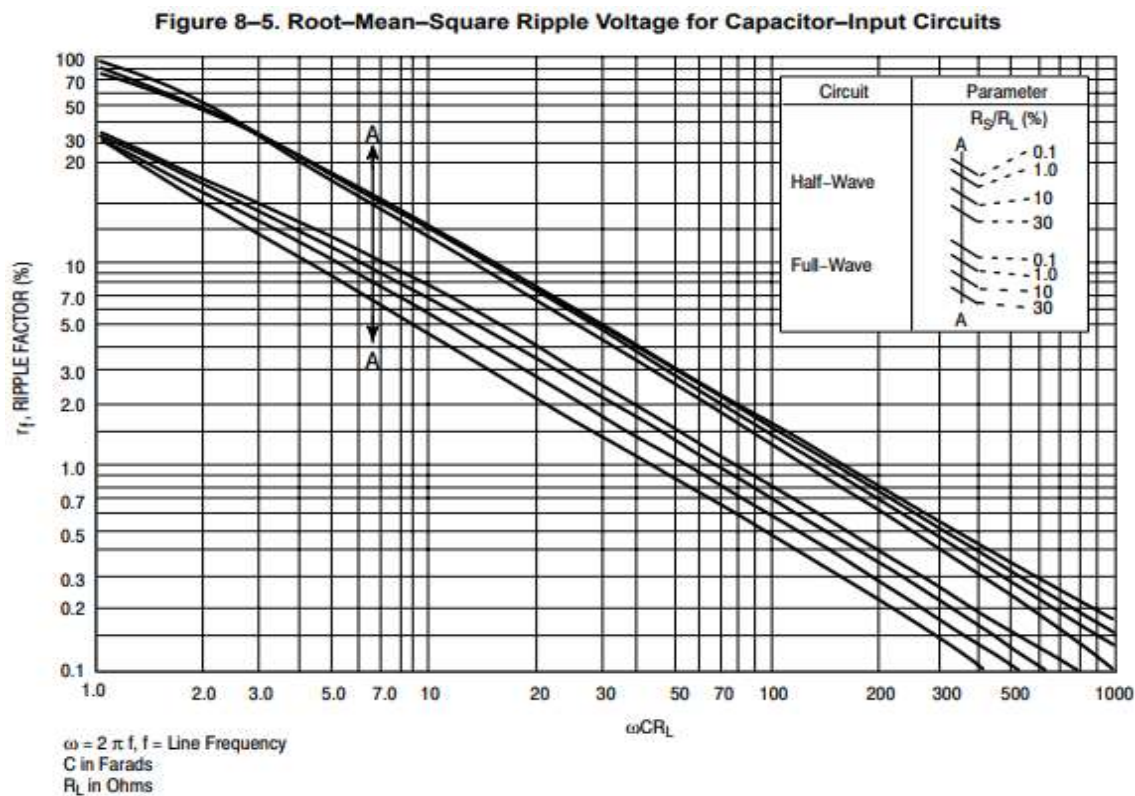


Figure 15 - Capacitor Schade Graph

(Sauriol, 2003)

■ Standard Products

W.V.	Cap. (±20%)	Case size		Specification			Lead Length				Part No.	Min. Packaging Qty	
		Dia.	Length	Ripple current (100kHz) (+105°C) (mA)	Imped- ance (100kHz) (+20°C) (Ω)	Endur- ance (hours)	Lead Dia.	Lead Space				Straight Leads	Taping
								Straight	Taping	Taping			
(V)	(μF)	(mm)	(mm)				(mm)	(mm)	(mm)	(mm)		(pcs)	(pcs)
63	1800	18	40	3205	0.025	5000	0.80	7.5			EEUFC1J182	50	
	5.6	5	11	80	4.10	1000	0.50	2.0	5.0	2.5	EEUFC2A5R6(1)	200	2000

Figure 16 - Smoothing Capacitor Datasheet

(RS Components, 2021)

Radial Lead Type

Series: FC Type : A

Country of Origin

Japan
Malaysia
China



- Features Endurance : 105°C 1000 h to 5000 h
Low impedance
RoHS directive compliant

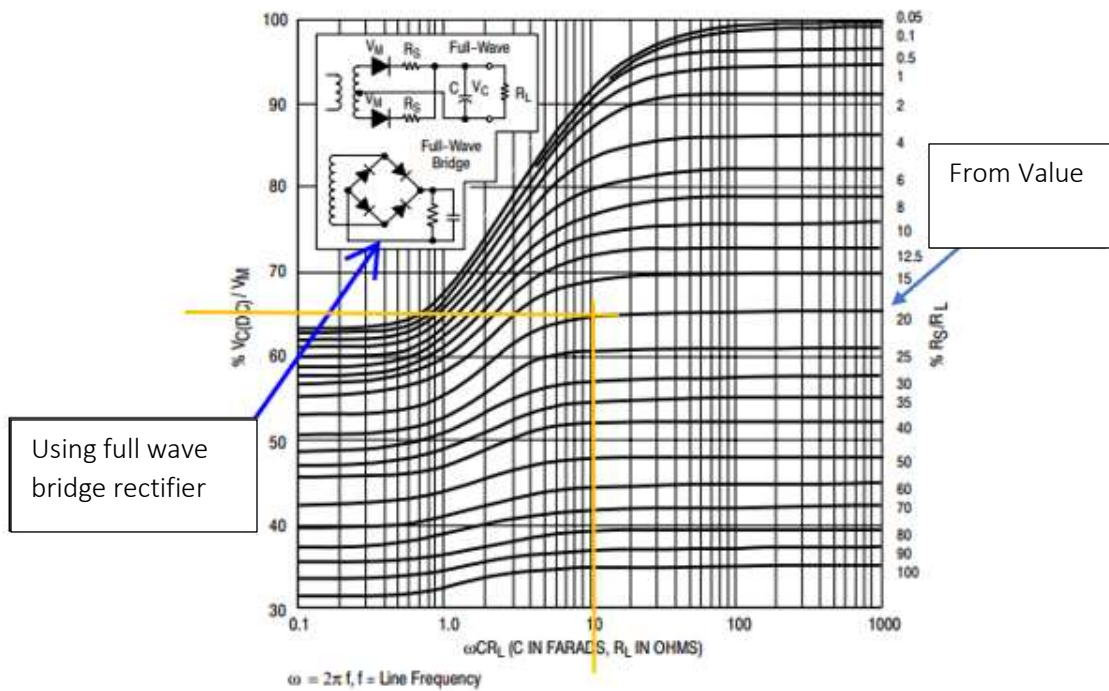
■ Specifications

Category temp. range	-55 to + 105°C																										
Rated W.V. Range	6.3 to 100 V .DC																										
Nominal Cap. Range	1.0 to 15000 μ F																										
Capacitance Tolerance	±20 % (120Hz/+20°C)																										
DC Leakage Current	I ≤ 0.01 CV or 3(μ A) after 2 minues application of rated working voltage at +20°C (Whichever is greater)																										
tan δ	<table><tr><td>W.V.(V)</td><td>6.3</td><td>10</td><td>16</td><td>25</td><td>35</td><td>50</td><td>63</td><td>100</td></tr><tr><td>tan δ</td><td>0.22</td><td>0.19</td><td>0.16</td><td>0.14</td><td>0.12</td><td>0.10</td><td>0.08</td><td>0.07</td></tr></table>									W.V.(V)	6.3	10	16	25	35	50	63	100	tan δ	0.22	0.19	0.16	0.14	0.12	0.10	0.08	0.07
	W.V.(V)	6.3	10	16	25	35	50	63	100																		
	tan δ	0.22	0.19	0.16	0.14	0.12	0.10	0.08	0.07																		
For capacitance value > 1000μF, add 0.02 per every 1000 μF.																											
Endurance	After following life test with DC voltage and +105±2°C ripple current value applied (The sum of DC and ripple peak voltage shall not exceed the rated working voltage), the capacitors shall meet the limits specified below. Duration : 1000 hours (φ4 to 6.3), 2000hours (φ8), 3000 hours (φ10), 5000 hours (φ12.5 to 18) Post test requirement at +20 °C																										
	Capacitance change		±20% of initial measured value																								
	tan δ		≤ 200 % of initial specified value																								
	DC leakage current		≤ initial specified value																								
Shelf Life	After storage for 1000 hours at +105±2 °C with no voltage applied and then being stabilized at +20 °C, capacitor shall meet the limits specified in Endurance. (With voltage treatment)																										

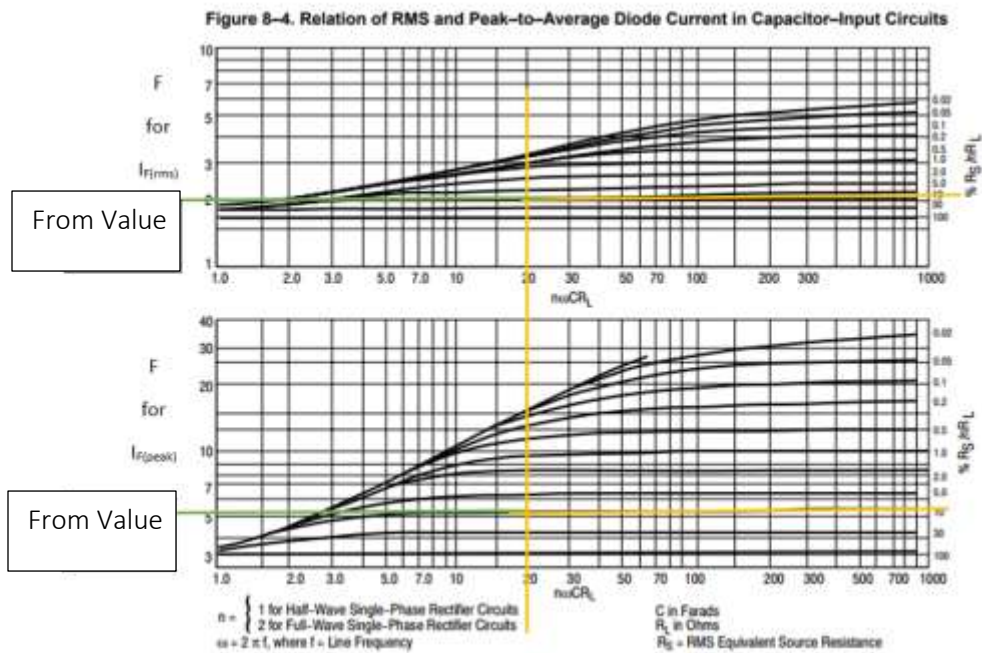
Figure 17 - Smoothing Capacitor Datasheet

(RS Components, 2021)

7.3. Bridge Rectifier Circuit



(Sauriol, 2003)



(Sauriol, 2003)



Features

- Surge overload -240~500 Amperes peak
- Low forward voltage drop
- Electrically isolated base -2000 Volts
- Solderable 0.25" FAST ON terminals
- Materials used carries UL recognition

Mechanical Data

Mounting Position : Any
 Reverse Voltage : 50 to 1000 Volts
 Forward Current : 10/15/25/35/50 Ampere

Maximum Ratings and Electrical Characteristics:

Rating at 25°C ambient temperature unless otherwise specified.

Single phase, half wave, 60Hz, resistive or inductive load.

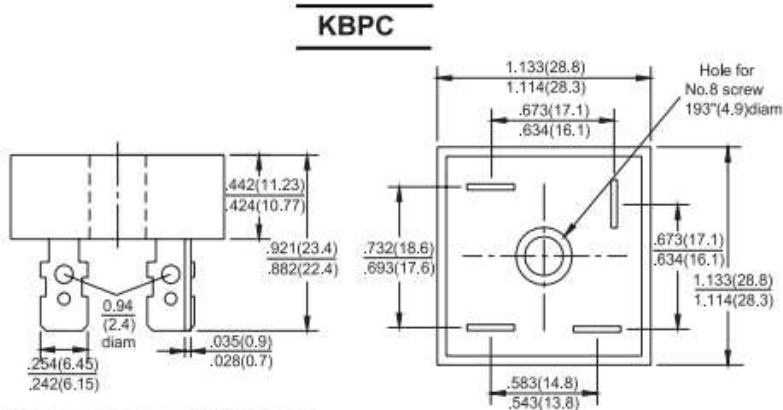
For capacitive load, derate current by 20%.

Part Number	Max. Recurrent Peak Reverse Voltage	Max. RMS Bridge Input Voltage	Max. Average Forward Rectified Output Current @T _c = 55°C	Peak Forward Surge Current 8.3ms Single Half Sine-Wave Super Imposed on Rated Load
	V _{RRM}	V _{RMS}	I _(AV)	I _{FSM}
KBPC3504	400	280	35	400
KBPC1508	800	560	15	300
KBPC15005	50	35	15	300
KBPC3502	200	140	35	400
KBPC3510	1000	700	35	400
KBPC1510	1000	700	15	300
KBPC1501	100	70	15	300
KBPC2504	400	280	25	400
KBPC5006	600	420	50	500
KBPC3506	600	420	35	400
KBPC5002	200	140	50	500
KBPC25005	50	35	25	400
KBPC3501	100	70	35	400
KBPC1506	600	420	15	300
KBPC5010	1000	700	50	500
KBPC50005	50	35	50	500
KBPC2502	200	140	25	400
KBPC1504	400	280	15	300
KBPC2508	800	560	25	400

Figure 20 - Bridge Rectifier Datasheet

(Multicomp Pro, 2019)

Dimensions:



Dimensions : Inches (Millimetres)

Part Number Table

Description	Part Number
Glass Passivated Bridge Rectifiers, 35A 400V	KBPC3504
Glass Passivated Bridge Rectifiers, 15A 800V	KBPC1508
Glass Passivated Bridge Rectifiers, 15A 50V	KBPC15005
Glass Passivated Bridge Rectifiers, 35A 200V	KBPC3502
Glass Passivated Bridge Rectifiers, 35A 1000V	KBPC3510
Glass Passivated Bridge Rectifiers, 15A 1000V	KBPC1510
Glass Passivated Bridge Rectifiers, 15A 100V	KBPC1501
Glass Passivated Bridge Rectifiers, 25A 400V	KBPC2504
Glass Passivated Bridge Rectifiers, 50A 600V	KBPC5006
Glass Passivated Bridge Rectifiers, 35A 600V	KBPC3506
Glass Passivated Bridge Rectifiers, 50A 200V	KBPC5002
Glass Passivated Bridge Rectifiers, 25A 50V	KBPC25005
Glass Passivated Bridge Rectifiers, 35A 100V	KBPC3501
Glass Passivated Bridge Rectifiers, 15A 600V	KBPC1506
Glass Passivated Bridge Rectifiers, 50A 1000V	KBPC5010
Glass Passivated Bridge Rectifiers, 50A 50V	KBPC50005
Glass Passivated Bridge Rectifiers, 25A 200V	KBPC2502
Glass Passivated Bridge Rectifiers, 15A 400V	KBPC1504
Glass Passivated Bridge Rectifiers, 25A 800V	KBPC2508

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Figure 21 - Bridge Rectifier Datasheet

(Multicomp Pro, 2019)

7.4. Circuit Transformer

Datasheet

M36 DIN Rail Series Transformers RS Pro

The class II single phase transformers with integrated screw terminals and DIN rail. TS35 mounts in modular enclosures are designed according to the following specifications.

- High quality safety isolating transformers designed for use in general applications.
- Standard primary winding 230VAC.
- Designed for continuous load.
- Detailed product specification on permanent label.
- High efficiency, low regulation design
- 100% electrical and flash tested
- Protected against short circuit and overload



Specifications

Power:	24 – 75 VA
Frequency:	50/60 Hz
Primary:	230 VAC
Secondary:	12 VAC or 24 VAC
Isolation:	4 kV RMS
Temp. class:	E (120°) / ta 40 °C
Protection class	IP20
Standards:	EN61558-2-6

CE 

Order Details:

RS Stock number	Power VA	Specification	No-load voltage	According to
8055308	24	M36 DIN Rail Series, 12V	14.4V	EN61558-2-6
8055317	24	M36 DIN Rail Series, 24V	28.8V	EN61558-2-6
8055310	35	M36 DIN Rail Series, 12V	13.8V	EN61558-2-6
8055314	35	M36 DIN Rail Series, 24V	27.6V	EN61558-2-6

Figure 22 - Transformer Datasheet

(RS Components, 2022)

7.5. Circuit Heat Sink

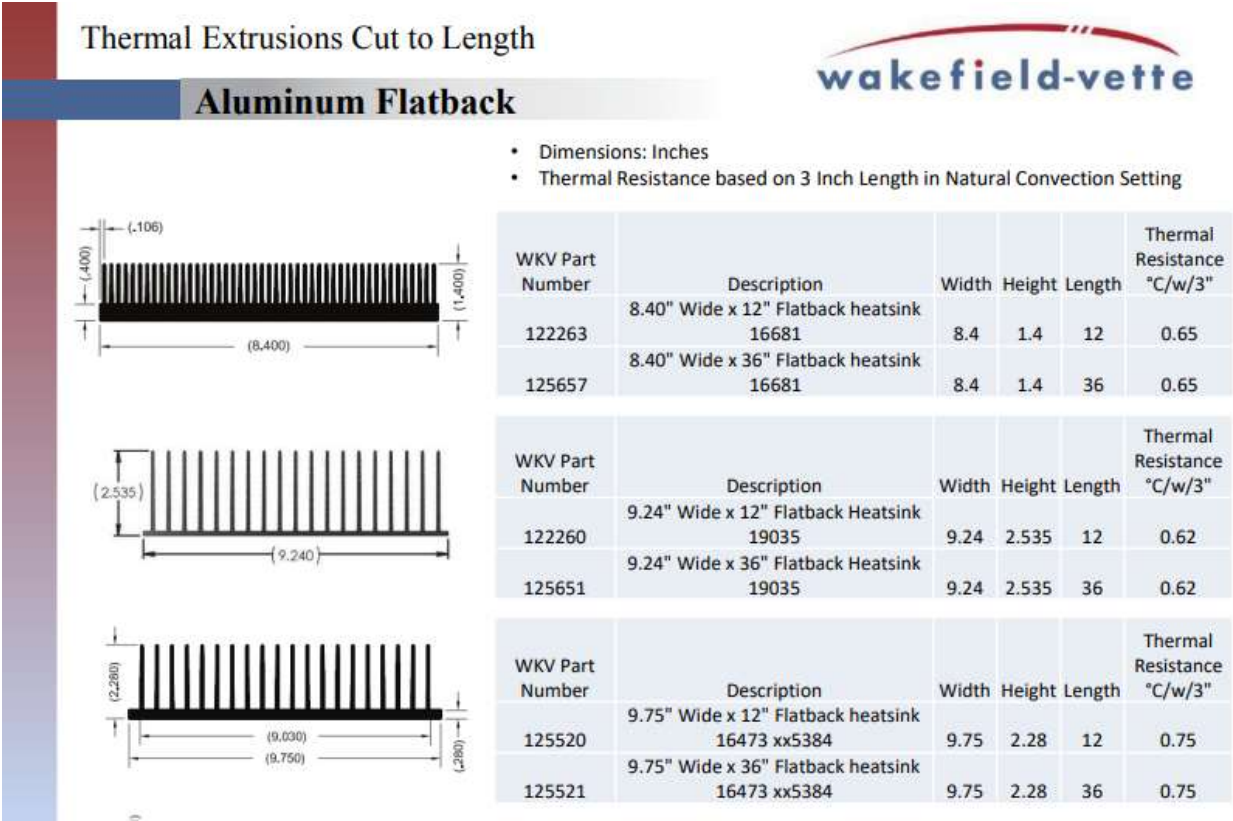


Figure 23 - Heatsink Datasheet

(Wakefield-vette, 2021)

Figure 24 - Transistor Thermal Datasheet

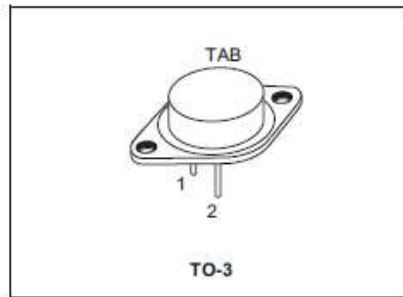
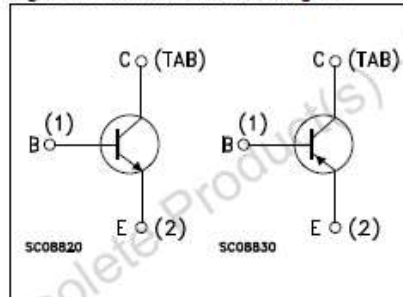


Figure 1. Internal schematic diagram



Features

- Low collector-emitter saturation voltage
- Complementary NPN - PNP transistors

Applications

- General purpose
- Audio amplifier

Description

The devices are manufactured in planar technology with "base island" layout and are suitable for audio, power linear and switching applications.

Table 1. Device summary

Order code	Marking	Package	Packaging
2N3055	2N3055	TO-3	Tray
MJ2955	MJ2955		

Table 2. Absolute maximum rating

Symbol	Parameter	Value		Unit
		NPN	2N3055	
		PNP	MJ2955	
V_{CB0}	Collector-base voltage ($I_E = 0$)		100	V
V_{CER}	Collector-emitter voltage ($R_{\theta E} = 100 \Omega$)		70	V
V_{CEO}	Collector-emitter voltage ($I_B = 0$)		60	V
V_{EBO}	Emitter-base voltage ($I_C = 0$)		7	V
I_C	Collector current		15	A
I_B	Base current		7	A
P_{TOT}	Total dissipation at $T_c \leq 25^\circ\text{C}$		115	W
T_{stg}	Storage temperature		-65 to 200	$^\circ\text{C}$
T_J	Max. operating junction temperature		200	$^\circ\text{C}$

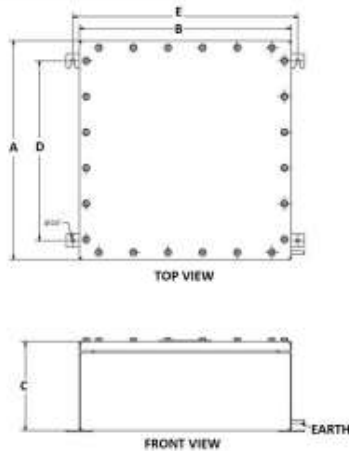
Table 3. Thermal data

Symbol	Parameter	Value	Unit
$R_{\theta j\text{-case}}$	Thermal resistance junction-case max	1.5	$^\circ\text{C/W}$

Figure 25 - Transistor Datasheet

(STMicroelectronics, 2013)

7.6. Design Choices



INDUSTRY STANDARDS

Meets NEMA Type 6P requirements

NEMA 4,4X,6P and IP68

APPLICATION

SLAYSON Submersible **Compact Series** offers NEMA 6P / IP68 protection against water and dust ingress at depths up to 15ft / 5m. Submersible Standard Enclosures are manufactured as standard from 14g Marine Grade 316 Stainless Steel, ensuring protection in harsh and corrosive environments.

MODIFICATION AND CUSTOMIZATION

SLAYSON excels at modifying and customizing all our products to meet your exact specifications. Contact our experienced Engineers about your project specific solution.

SPECIFICATIONS

- Submersible up to 15 ft / 5 m
- Manufactured from 14 gauge Type 316 Marine Grade Stainless Steel
- Seams continuously welded and dressed
- Single piece Neoprene gasket
- Minimum flange width to maximize internal capacity
- Mounting brackets on enclosure rear for direct wall mounting
- Grounding stud on body
- Mounting studs for optional internal mount plates
- #3 polish finish

ACCESSORIES

- Internal Mount/Back Plates
- External ground mounting stand
- Custom entry holes
- IP68 Stainless Steel cable glands / chord grips
- EMI / RFI Shielding Protection Available
- Hinged Lid
- Welded in place Bosses
- Variety of finishes

PART NUMBER	A Height: in (mm)	B Width: in (mm)	C Depth: in (mm)	D Mount Height: in (mm)	E Mount Width: in (mm)	BACK PLATE PART NUMBER	Height: in (mm)	Width: in (mm)	Gauge	Weight (lbs)
ASMI202008	20 (508)	20 (508)	08 (203.2)	16 (406.4)	22 (558.8)	ASPI1616	16 (406.4)	16 (406.4)	14	25
ASMI202006	20 (508)	20 (508)	06 (152.4)	16 (406.4)	22 (558.8)	ASPI1616	16 (406.4)	16 (406.4)	14	24
ASMI181808	18 (457.2)	18 (457.2)	08 (203.2)	14 (355.6)	20 (508)	ASPI1414	14 (355.6)	14 (355.6)	14	24
ASMI181806	18 (457.2)	18 (457.2)	06 (152.4)	14 (355.6)	20 (508)	ASPI1414	14 (355.6)	14 (355.6)	14	22
ASMI161608	16 (406.4)	16 (406.4)	08 (203.2)	12 (304.8)	18 (457.2)	ASPI1212	12 (304.8)	12 (304.8)	14	22
ASMI161606	16 (406.4)	16 (406.4)	06 (152.4)	12 (304.8)	18 (457.2)	ASPI1212	12 (304.8)	12 (304.8)	14	20
ASMI141408	14 (355.6)	14 (355.6)	08 (203.2)	10 (254)	16 (406.4)	ASPI1010	10 (254)	10 (254)	14	20
ASMI141406	14 (355.6)	14 (355.6)	06 (152.4)	10 (254)	16 (406.4)	ASPI1010	10 (254)	10 (254)	14	18
ASMI121208	12 (304.8)	12 (304.8)	08 (203.2)	08 (203.2)	14 (355.6)	ASPI0808	08 (203.2)	08 (203.2)	14	18

Figure 26 - Enclosure Datasheet

(Slayson, 2022)

200 Series

Brown Devil® Vitreous Enamel Power



Ohmite's Brown Devil® is a small, exceptionally durable power resistor. It features all-welded construction and rugged, flame resistant conformal lead free vitreous enamel coating to ensure successful performance under high temperatures.

The wirewound 200 Series has a hollow-core construction, which accommodates rigid mounting with brackets or thru bolts.

Mounting brackets not included with resistors.



FEATURES

- Rugged lead free vitreous enamel coating
- All-welded construction.
- Self supporting terminal mounting option.
- Higher power ratings.
- Flame-resistant lead free vitreous enamel coating.
- RoHS compliant product available. Add "E" suffix to part number to specify.

SERIES SPECIFICATIONS

Series	Wattage	Ohms	Lead Gauge	Max. Voltage*
B5	5.25	0.1-20K	20	187
B8	8.0	0.03-25K	18	250
B12	12.0	0.08-51K	18	625
B20	20.0	0.1-100K	18	750

Non-Inductive versions available. Insert "N" before tolerance code.

Example: B5NJ10RE

Also available in low cost Centohm or Silicone coating. Consult Ohmite.

* Maximum Voltage is based on Ohm's Law [$V=\sqrt{P \cdot R}$] as limited by the resistance value of specified product

CHARACTERISTICS

Coating	lead-free vitreous enamel
Core	Ceramic
Terminals	Tinned axial; RoHS solder composition is 96% Sn, 3.5% Ag, 0.5% Cu
Derating	Linearly from 100% @ +25°C to 0% @ +350°C
Tolerance	1Ω+: ±5% under 1Ω: ±10%
Power rating	Based on 25°C free air rating
Overload	10 times rated wattage for 5 seconds
Temperature coefficient	5Ω and under: ±400 ppm/°C Above 5Ω: ±260 ppm/°C
Max. amps	To calculate, use the formula $\sqrt{P/R}$

Figure 27 - Resistor R1 Datasheet

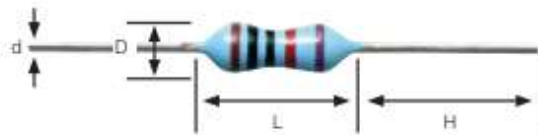
(Ohmite, Unknown)

Characteristics

Tolerance (Code):	$\pm 0.05\%$, $\pm 0.1\%$ (B), $\pm 0.25\%$ (C), $\pm 0.5\%$ (D), $\pm 1\%$ (F)
Operating temperature:	-55°C to $+155^{\circ}\text{C}$
Temperature coefficient:	$\pm 5\text{ppm}/^{\circ}\text{C}$, $\pm 10\text{ppm}/^{\circ}\text{C}$, $\pm 15\text{ppm}/^{\circ}\text{C}$, $\pm 25\text{ppm}/^{\circ}\text{C}$, $\pm 50\text{ppm}/^{\circ}\text{C}$, $\pm 100\text{ppm}/^{\circ}\text{C}$
Overload:	$\pm 0.25\%$ rated continuous working voltage $= \sqrt{(P \cdot R)} \cdot 2.5$ for 5 seconds
Endurance:	$\pm 0.2\%$, $70 \pm 2^{\circ}\text{C}$, rated continuous working voltage for 1000 hours with 1.5 hrs ON and 0.5 hrs OFF
Damp heat with load:	$\pm 0.3\%$, $40 \pm 2^{\circ}\text{C}$, 90 - 95% RH, rated continuous working voltage for 1000 hours with 1.5 hrs ON and 0.5 hrs OFF
Solderability:	90% min coverage, $245 \pm 5^{\circ}\text{C}$ for 3 seconds
Temperature coefficient:	by type, resistance value 25°C and 100°C
Pulse overload:	$\pm 0.75\%$, 4 times rated continuous working voltage $= \sqrt{(P \cdot R)}$ for 10,000 cycles with 1 second ON and 25 seconds OFF
Terminal strength:	Tensile $\geq 2.5\text{kg}$, direct load for 10 seconds in the direction of the terminal leads
Shelf life:	$\Delta R \pm 0.1\%$, 12 months at $25^{\circ}\text{C} \pm 3^{\circ}\text{C}$, 80% RH maximum

Dimensions (mm)

Type	L	D	H	d ± 0.03
MRA0104	$3.3 \pm 0.7/-0.2$	1.8 ± 0.3	29 ± 2.0	0.45
MRA0207	6.3 ± 0.5	2.3 ± 0.3	28 ± 2.0	0.55
MRA0309	9.0 ± 0.5	3.2 ± 0.5	26 ± 2.0	0.65
MRA0412	11.5 ± 1.0	4.5 ± 0.5	35 ± 2.0	0.78
MRA0516	15.5 ± 1.0	5.0 ± 0.5	32 ± 2.0	0.78

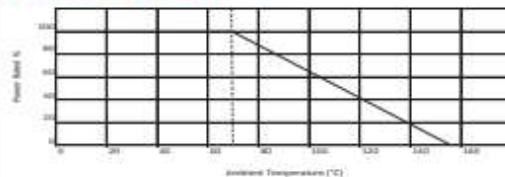


Ordering Procedure

Standard Resistor: Series, Resistance Value, Tolerance, TCR, Packaging (TA: Taped Ammo, TR: Taped Reel)

e.g.: MRA0104 10R B 15PPM TA

Derating Curve



ARCOL UK Limited,
Threemilestone Ind. Estate,
Truro, Cornwall, TR4 9LG, UK.
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F +44 (0) 1872 222002
E sales@arcolresistors.com

www.arcolresistors.com

The information contained herein does not form part of a contract and is subject to change without notice. ARCOL operate a policy of continual product development, therefore, specifications may change.

It is the responsibility of the customer to ensure that the component selected from our range is suitable for the intended application. If in doubt please ask ARCOL.

Figure 28 - Resistor R2 Datasheet

(Arcol, 2014)

Type R Series



The resistive element comprises a thin film of nickel-chrome alloy evaporated onto a high thermal conductivity ceramic element. Metal end caps are force fitted to the element prior to spiralling to value. Tinned copper lead wires are welded to the end caps and the components are then coated. One coat of phenolic resin is followed by three coats of epoxy resin. All resistors are tested for value and tolerance.

Key Features

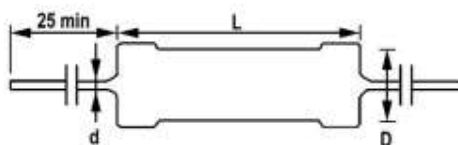
- Precision metal film resistors with tolerance to 0.1% and temperature coefficients to 15ppm.
- Metal film resistors have excellent stability under load and severe environmental conditions. They exhibit very low noise current and voltage coefficients. Precision metal film resistors are particularly suitable in all applications where long-term stability is important.

Type R Series

Characteristics - Electrical

	YR8	ER8	CR8	YR1	ER1	CR1	YR2	ER2	CR2
Rated Power @ 70 °C (W)	0.125			0.25			0.5		
Resistance Range (ohms) Min	51R1			10R			10R		
Max	511K			1M0			1M0		
Tolerance (%)				0.1	0.25	0.5			
Code Letter				B	C	D			
Temperature Coefficient (ppm/°C)	± 15	± 25	± 50	± 15	± 25	± 50	± 15	± 25	± 50
Selection Series				E96					
Limiting Element Voltage - Nominal (V)	200			250			350		
Maximum Overload Voltage (V)	400			500			700		
Operating Temperature Range (°C)				-65 to +155					
Dielectric Strength (V)				500					
Insulation Resistance Min Dry (Mohms)				10,000					
Voltage Coefficient Max (ppm/V)				5					

Dimensions



Style	L*	D	d nom
R8	3.3 ± 0.1	1.7 ± 0.2	0.45
R1	6.3 ± 0.3	2.3 ± 0.2	0.6
R2	9.5 ± 0.5	3.5 ± 0.5	0.6

* Length is measured in accordance with IEC 294

Derating Curve

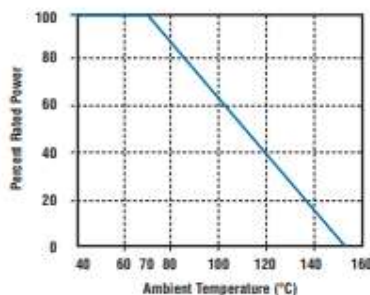


Figure 29 - Resistor R3 Datasheet

(Tyco Electronics , 2005)



Coating color : Lavender

Marking : Color code (0.5W, 1W)

Alphanumeric (2W, 3W, 5W)

Features

- Small size power type resistors.
- Flame retardant coating. (Equivalent to UL94 V-0)
- Automatic insertion is applicable.
- Various types of formings are available.
- High reliability.
- Products meet EU-RoHS requirements.
- Automatic mounting machine is applicable by surface mounted device style lead forming.

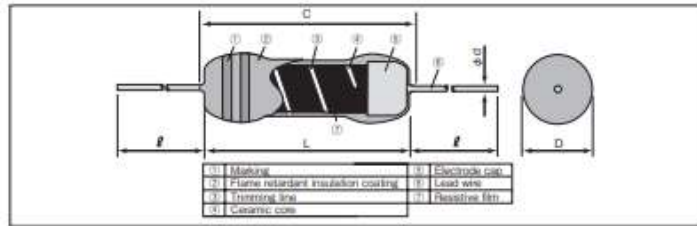
Reference Standards

IEC 60115-4

JIS C 5201-4

EIAJ RC-2138

Construction



Dimensions

Type	Dimensions: (mm)					Weight (g) (1000pcs)
	L	C Max.	D	d (Nominal) ^{*)}	g ^{*)}	
MOS(X) 1/2	6.2±0.5	7.1	2.5±0.5	0.6	24Min.	250
MOS(X) 1	9.0±1.0	11.1	3.0±0.5			350
MOS(X) 2	12.0±1.0	15.0	4.0±0.5			800
MOS(X) 3	15.5±1.0	18.0	6.0±1.0	0.8	30±3	1,400
MOS(X) 5	24.5±1.0	28.0	9.0±1.0		38±3	5,240

*) Lead length changes depending on taping and forming type. Example: 1C, 1CT52, 1CT526=0.6mm 1C8, 1CT528=0.8mm

Type Designation

Example

MOS	1	C	T52	A	103	J
Product Code	Power Rating	Terminal Surface Material	Taping & Forming	Packaging	Nominal Resistance	Resistance Tolerance
MOS: 小形酸化金属皮膜 固定抵抗器 MOSX: 小形金属皮膜 固定抵抗器	1/2: 0.5W 1: 1W 2: 2W 3: 3W 5: 5W	C: SnCu	See table below	A: AMMO R: REEL Nil: BOX T52-T56: Plastic enclosed (H forming)	F: 4 digits G, J: 3 digits	F: ±1% G: ±2% J: ±5%

Contact us when you have control request for environmental hazardous material other than the substance specified by EU-RoHS.

For further information on taping and forming, please refer to APPENDIX C on the back pages.

Taping & Forming Matrix

Type	Axial Taping				Stand-off Axial Taping			VT Radial Taping			GT Radial Taping			L Forming ^{*)}						U Forming		M Forming ^{*)}						N Forming ^{*)}			
	T26	T52	T521	T631	L52	L621	L631	VTP	VTE	VTF	GT	GT4	L10A	L125A	L15A	L20A	L25A	L30A	L35A	U	UCL	M10	M125	M15	M20	M26	M30	N145	N17	N20	
MOS 00 1/2C	○	○	—	—	—	—	—	○	○	—	○	○	—	—	—	—	—	—	—	—	—	○	—	—	—	—	—	—	—	—	—
MOS 00 1C	—	○	—	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MOS 00 2C	—	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MOS 00 3C	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MOS 00 5C	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

*) P166,167 Ref. Secondary Processed Products

Ratings

Type	Power Rating	Resistance Range (Ω)			T.C.R. (×10 ⁻⁶ /K)	Max. Working Voltage	Max. Overload Voltage	Dielectric Withstanding Voltage	Taping&Q'ty/AMMO pack (pcs)					
		F: ±1% (E4-E6) ^{*)}	G: ±2% (E24) ^{*)}	J: ±5% (E24)					T26A	T52A	T521A	T631A		
MOS1/2C	0.5W	10~47k	10~47k	10~47k	±300	$E=\sqrt{P \times R}$ (V)	600V	400V	2,000	2,000	—	—		
MOS1C	1W	10~68k	10~68k	10~100k				500V	—	2,000	—	—		
MOS2C	2W	10~100k	10~100k					350V	700V	700V	—	—	500	1,000
MOS3C	3W	—						500V	1000V	800V	—	—	—	—
MOS5C	5W							1.0~9.1	0.22~9.1	0.1~9.1	$E=\sqrt{P \times R}$ (V)	$E \times 2.5$ (V)	400V	2,000
MOSX1/2C	0.5W	500V	—	2,000		—	—							
MOSX1C	1W	700V	—	1,000		1,000	—						—	
MOSX2C	2W	—	800V	—		—	500						1,000	
MOSX3C	3W		—	—		—	—						—	
MOSX5C	5W		—	—		—	—	—						

Figure 30 - Resistor RSC Datasheet

(Koaglobal, 2021)

7.7. Testing, Results & Analysis

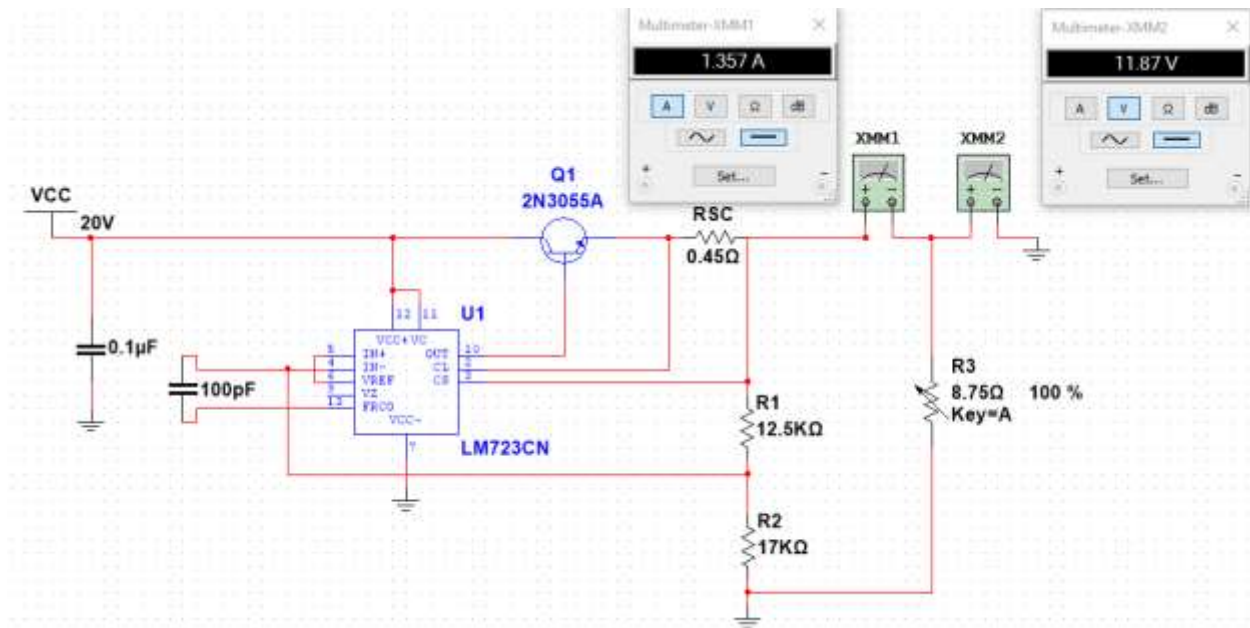


Figure 31 - R3 Minimum Load Value for Design Working Region

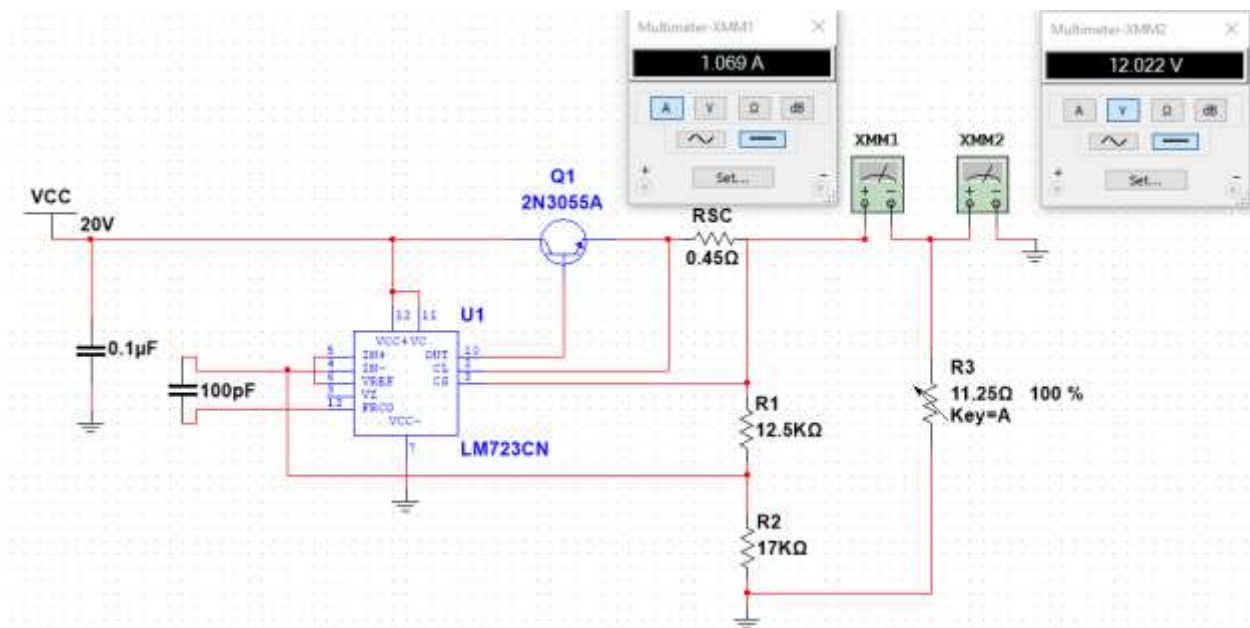


Figure 32 - R3 Maximum Load Value for Design Working Region

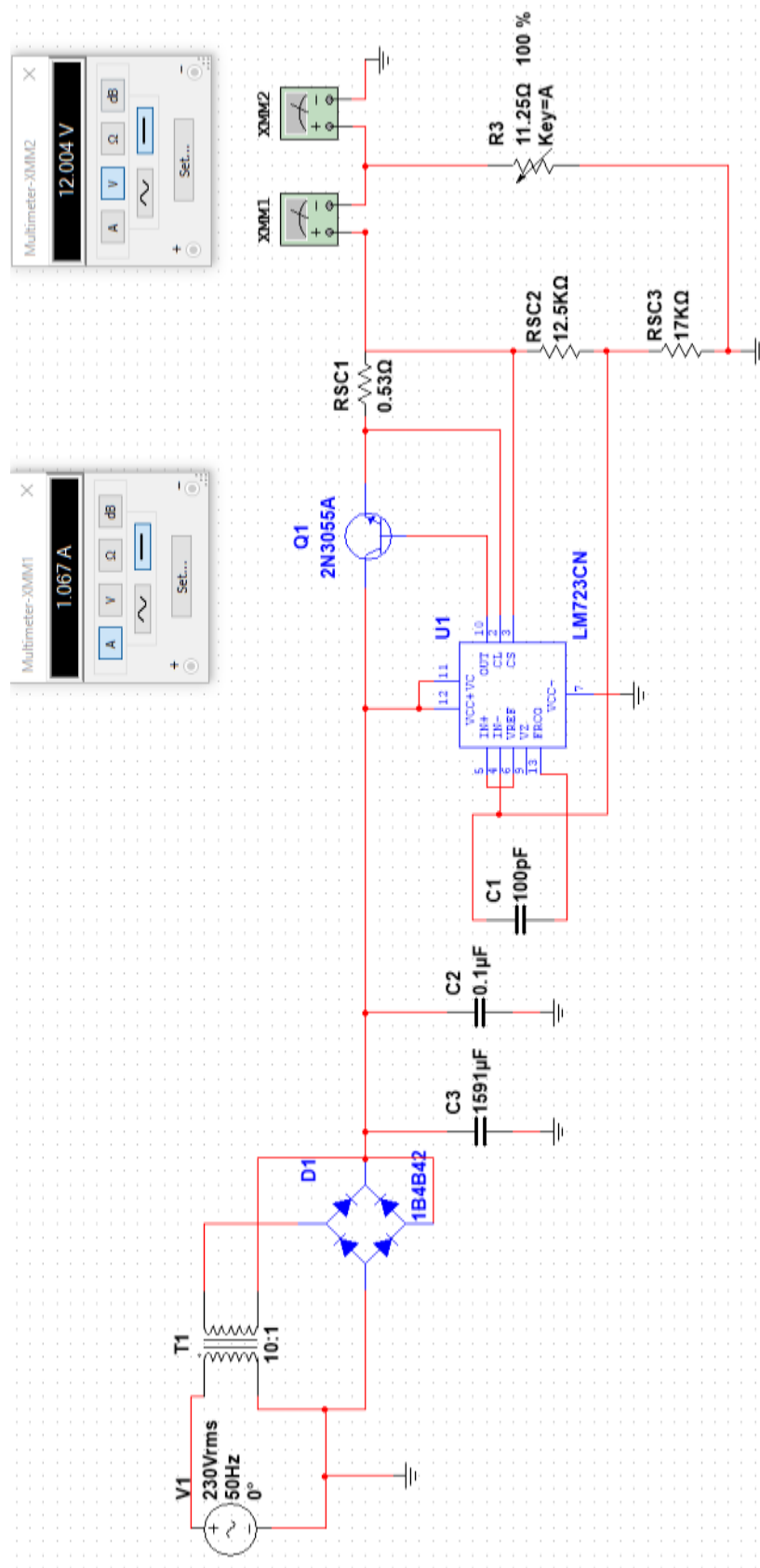


Figure 33 - Regulated Power Supply

FINAL GRADE

GENERAL COMMENTS

Instructor

82/100

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GRADING FORM: CSG-RUBIC

DAVID THOMAS**82****RESEARCH-INFORMED LITERATURE**

There was evidence of considerable further reading and research from highly credible and reliable sources. Your interpretation and understanding of the additional research was exceptional and demonstrated a deep underlying appreciation of the subject. Your references were consistently applied to a high level of competency and your reference list was extensive for this assignment.

8**KNOWLEDGE AND UNDERSTANDING**

The knowledge and understanding of the subject demonstrated by this assignment was exceptional. There were no gaps in your knowledge of the basic principles and the higher level concepts were extremely well explained. Your explanation of the design process and calculations was also excellent and you have demonstrated an exceptionally detailed knowledge and critical understanding of the main concepts and expanded your knowledge beyond that contained in the course notes.

25

ANALYSIS



Your analysis of the task was outstanding, 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 connecting ideas and providing logical and persuasive arguments. You have demonstrated a considerable capacity for independent thought and the ability to see beyond the question and your interpretation of the quantitative and qualitative data was exceptional with sound judgements based on wholly valid arguments.

24

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally exceptional. 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 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 attempted.

17

SKILLS FOR PROFESSIONAL PRAC.



In this assignment you have demonstrated skills in working individually and also collaboratively. Your written report was exceptionally well structured and written in a highly coherent and logical way. The report was presented in a professional manner using appropriate language and formatting, good diagrams in appropriate places, good sentence/paragraph structure and clear calculations.

8