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by Matthew Perry

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1. Executive Summary

This assignment shows the development of a successful design of a power supply. Working towards a specification stated by a customer, their needs were met through implementing suitable components through research and testing. The values of these components were firstly calculated using design techniques and tested. In summary, this created a safe, reliable, and suitable system.

2. Planning and reflection

This assignment will be carried out methodically. The student will aim to achieve the customers' requirements for the power supply while identifying key specifications such as voltage output, current capacity, size constraints and thermal considerations.

Research will be carried out to explore best practices and design choices that can impact the power supplies final characteristics such as efficiency, thermal and cost.

Theoretical calculations will be carried out to design the power supply and simulated for testing. From the simulations, results will be recorded and analysed. An evaluation on the design will be conducted and a conclusion will be drawn on the highlights of what was completed.

After completion of this assignment, it has shown that a successful design has been achieved and proved through testing. Analysing the design showed how each component effects the design and the final specification. This signified the importance for the student to research and select suitable components to implement within the design.

This will influence the students life long learning by carrying out research on components and design techniques while working to a specification within electronic design.

3. Methodology

3.1 Technical Specification

Discussing the technical requirements that need to be met and any further information with the customer produced the following specification table. This table has compiled the information needed to design a power supply that suits their needs.

For context, the power supply will be used to power flow meters that require the desired voltage and a programmable logic controller.

Design Specification				
Electrical Characteristics		Physical Considerations		
Requirement	Value	Characteristic	Context	Result
Input Voltage	230VAC	Weight	How will they want this power supply mounted & if it is in an enclosure where will that enclosure be installed?	The power supply will be DIN Rail mounted inside a control cabinet.
DC Operating Voltage	24.9V DC	Size	Is there a physical constraint on how big the power supply can be.	With the power supply being used inside a control panel it should follow the typical size specification of H130mm, W33mm, D125mm (Figure 7).
DC Current	2A	Cooling	Is any cooling required/provided?	Extractor fan on control panel.
DC Power Rating	25.8W	Environment	Where will the system be operating to identify any adverse conditions.	The system will be operating in a clean room with expected average room temperatures of (18-20 Degrees).
Power Dissipation	48.8W	/	/	/

Table 1; Design Specification

3.2 Ethics

Although the system will be specifically designed for this application, it is important to consider ethics within the design. Ethics in Engineering relate to the moral values, issues and decisions involved in engineering practices (Baura, 2006). Following the rules of conduct stated by the IET the student will act with integrity with whom their work is connected and towards other members while safeguarding public interest relating to health, safety, and the environment (IET, 2019).

Sustainability

Sustainability can benefit the environmental issue when designing a new product. It will be important to carry out the following.

- Use resources effectively – The student will use non-renewable resources sparingly while selecting components.
- Eliminating excess waste – The student will utilise digital tools such as simulation methods (Multisim) to prevent waste created by physical prototype. Additionally, schematics and some theoretically calculated will be drawn digitally reducing paper waste.
- Considering material alternatives – If possible, greener materials will be selected for the design.
- Product life cycle – Following design procedures will ensure a functioning product and with the inclusion of quality components should extend the life cycle of the product.
- Efficiency – Considering thermal qualities could lead to less energy being used.

(Melgarejo, 2022)

Safety

Considering the safety of the design, the system itself should be enclosed to prevent electrical shock to users/engineers that could encounter the system. Fail safe protection such as short circuit protection should be implemented in the design in case a fault occurs in the future.

Intellectual Property

The design of the system will be carried out by the student without infringing on existing patents or intellectual property rights. Lastly, the documents and simulations will be appropriately stored to prevent un-authorized use that could lead to changes to the design or duplication.

Codes of Practice

While carrying out the design, relevant codes of practices will be followed. An example of the codes of practice that will be used are shown below.

Codes of Practice	
<u>Codes of Practice</u>	<u>Where could this be applicable?</u>
BS 7671 IET Wiring Regulations	That the wiring of the system follows the national standard.
IEEE Standards	Considering the ethics statement that was published, additionally concerns about how the design will be carried out.
Waste Electrical and Electronic Equipment (WEEE) Directive	Considering that the components selected can be recycled and are not hazardous to the environment.
Electrical Equipment (Safety) Regulations 2016	Fail safe methods such as short circuit protection should be implemented, and the design should be tested (simulated) before being delivered to the customer.

Table 2; Codes of Practice

3.3 Power Supply Operation

A power supply can be defined as a device that converts the output from an AC supply to a steady DC output. Firstly, an AC voltage may be stepped down or up from the supply and then rectified to provide a pulsating DC and then filtered to eliminate ripple which leads to a smooth voltage. Then the voltage is regulated to produce a constant output level even if there are variations in the AC line voltage or load

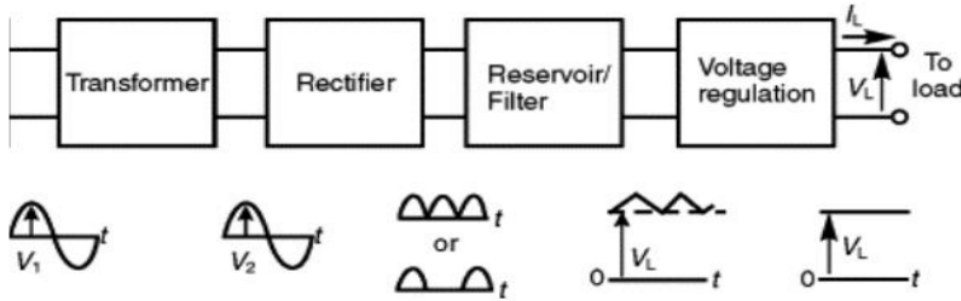


Figure 1; Power Supply Configuration

(Creecraft & Gergely, 2002)

3.4 Voltage Regulator

A voltage regulator converts the incoming power to the desired type (AC-DC or DC-AC) and desired voltage/current specifications. It does this while maintaining a constant output voltage regardless of changes of input voltage, load current or temperature. It also converts the incoming power to the desired type (AC-DC or DC-AC) (DigiKey, 2020).

Following the technical specification:

- $V_{out} = 24.9V$ DC
- Output Current = 2A
- $C_{ref} = 0.1\mu F$; for low noise operation.
- $R1 + R2 = 60K \Omega$

The following calculations to be completed to design the voltage regulator circuit.

Implementing $R2$ in series with the output to limit the current in the event of a short circuit.

$$R2 = \frac{V_{ref}}{V_{out}} * (R1 + R2) \therefore \frac{7}{24.9} (60k) = 1687.47 \Omega$$

Using E24 resistor = 1690 Ω

Adding a series resistor to limit the current that goes through the Zener diode.

$$R1 = (R1 + R2) - R2 \therefore 60K - 16K = 44K \Omega$$

Using E24 resistor = 43K Ω

Implementing RSC to monitor the current.

The 0.6V is used from the internal circuit on the data sheet and overcomes BE junctions between 2 and 3.

$$RSC = \frac{0.6}{ISC} \therefore \frac{0.6}{2} = 0.3\Omega$$

Using E24 resistor = 0.33 Ω

R3 will be used between the base and emitter of the transistor to set the current limit.

$$R3 = \frac{R1 * R2}{R1 + R2} \therefore \frac{43 * 16}{43 + 16} = 11.66K\Omega$$

Using E12 resistor = 11.5K Ω

3.5 Filter Capacitor & Transformer Rectifier Ratings

The capacitor can be implemented to help reduce noise such as ripple and interference signal & the full wave rectifier will be used to convert both half cycles from the transformer and convert them to direct current.

Using the base values determined in the voltage regulator design:

- V_C (DC) = 24.9.V DC
- V_{ripple} = Selecting 3V initially
- I_o = 2A
- f = 60Hz
- $V_m = V_C + \frac{1}{2}(V_C) = 24.9 + \frac{1}{2}(24.9) = 37.35V$

The ripple factor is defined as the ratio of the RMS value of an alternating current component in the rectified output to the average value of rectified output.

The ripple factor can be calculated as:

$$rf = \frac{3}{2 * \sqrt{2} * 24.9} = 0.0425 * 100 = 4.259\%$$

At $rf = 4\%$, $\omega CRL = 10$ determined by using the full wave parameter characteristics shown in Figure 9.

$$RL = \frac{VC}{IO} = \frac{24.9}{2} = 12.45\Omega$$

$$C = \frac{\omega CRL}{2\pi f * RL} = \frac{10}{2\pi(60) * 12.45} = 2.13\mu F$$

Maximum expected voltage:

$$2 * V_m = 2 * 37.35 = 74.7V$$

3.6 Rectifier Requirements

The rectifier shown in Figure 11 operates by current flowing from the top of the secondary to through the D1/D2 junction. D2 specifically offers a forward bias path so current flows through D2 to the junction with D4 and the load. D4 has a reverse bias path and then the current must flow down through the load. From ground, current continues to D1/D3 junction. Because D1's cathode is tied to the high side of the secondary the potential is higher than the anode side which means it is reverse bias. Lastly the current flows down D3. In summary, the rectifier D2 & D3 are forward bias whereas D1 and D4 are reverse bias (Fiore, 2020).

Calculating as a percentage VC/VM as a percentage:

$$\frac{VC}{Vm} \times 100 = \frac{24.9}{37.35} \times 100 = 60\%$$

Then using the graph shown in Figure 8 shows that RS/RL is 20%.

Average forward current per diode:

$$IF (avg) = \frac{Io}{2} = \frac{2}{2} = 1A$$

RMS & Peak

$$RS = 0.2 * RL = 0.2 * 12.45 = 2.49 \text{ or } RS = 0.2 \frac{VC}{Io} = 0.2 \frac{24.9}{2} = 2.49$$

$$\% \frac{RS}{nRL} = \frac{2.49}{2 * 12.45} = 0.1$$

$$n\omega CRL = 2 * 10 = 20$$

Using the following Schade graph:

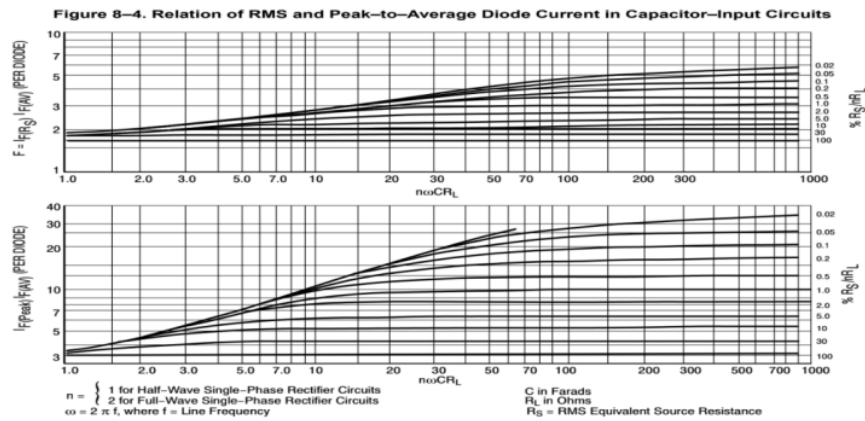


Figure 2; Schade Graph RMS and Peak to Average Diode Current

$I_F(\text{RMS}) = 3$ & $I_F(\text{peak}) = 16.6$

PIV = V_M is 37.35V therefore, $\text{PIV} = 2 \times 37.35 = 74.7\text{V}$

$$I_{\text{Surge}} = \frac{V_m}{R_s + ESR} = \frac{37.35}{2.49} = 15A$$

ESR is the minimum equivalent series resistance of the filter capacitor from the data sheet. Due to the value of R_S being so large compared to what ESR would be, it has been omitted from the equation.

3.7 Transformer

A transformer will be used to step down the incoming voltage to a secondary voltage to be rectified.

Secondary leg RMS voltage

where, $n = 1$ for half-wave and $n = 2$ for full-wave bridge

$$V_S = \frac{\{V_m + (n)1.0\}}{\sqrt{2}} = \frac{\{37.25 + (2)1.0\}}{\sqrt{2}} = 27.82V$$

Secondary resistance should be 2.66 Ohms.

Secondary RMS current

$$\sqrt{2} I_{rms} = \sqrt{2} \times 2 = 2.82A$$

Transformer VA rating

$$VA \text{ Rating} = V_{secondary} \times I_{rms} \times \sqrt{2}$$

$$VA \text{ Rating} = 27.82 \times 2.82 \times \sqrt{2} = 110.948VA$$

Turns ratio will be the ratio required to reduce the input supply voltage down to the required secondary voltage:

$$\text{Turns Ratio} = \frac{V_{Supply}}{V_{Secondary}} = \frac{325.26}{27.82} = 11.6 : 1$$

3.8 Heatsink

A heat sink may be implemented in the design to enhance heat dissipation if required to maintain a safe temperature. Firstly, it will be determined if a heat sink is required for the regulator that should be operating at 20 degrees ambient temperature.

Compiling the following values:

$$PD = V_{in} \times I = 24.9 \times 2 = 49.8W$$

$$T_A \text{ (Ambient Air Temperature } ^\circ\text{C)} = 20^\circ\text{C}$$

$$T_J \text{ (Junction Temperature } ^\circ\text{C)} = 200^\circ\text{C}$$

$$\theta_{JA} \text{ (Thermal resistance from junction to ambient air)} = 100$$

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

$$T_J = 20 + (49.8 \times 100) = 5000^\circ\text{C}$$

Since T_J is larger than the maximum junction temperature stated on the data sheet of 200°C a heat sink must be implemented.

Using the 2N3055 with a TO-204 case, relevant characteristics from the manufacturers data sheet shown Figure 9 for the value of θ_{JC} & Table 4 for the value of θ_{CS} .

Compiling the following values:

$$\theta_{JC} \text{ (Junction to case thermal resistance)} = 1.5 ^\circ\text{C/W}$$

$$\theta_{CS} \text{ (Case to heatsink thermal resistance)} = 1.6 ^\circ\text{C/W (Insulator with heatsink compound)}$$

Calculating the heatsink to ambient thermal resistance (θ_{SA}):

$$\theta_{SA} = \frac{T_J - T_A}{PD} - \theta_{JC} - \theta_{CS}$$
$$\theta_{SA} = \frac{200 - 20}{49.8} - 1.5 - 1.6 = 0.514 \Omega$$

4. Results

4.1 Voltage Regulator

Creating a simulation of the voltage regulator circuit on Multisim Shown in Figure 3, the values of R1, R2 and VCC were altered to obtain the desired output voltage. Table 3 shows the variation and results that occurred.

Voltage Regulator for 24.9V						
VCC	240V	48V	48V	28V	28V	26.6V
R1	44K	44K	88K	44K	22K	44k
R2	1687	1687	3.3K	1687	3.3K	1.6k
Output	187	46.2	46.3	26.3	26.3	24.9
Error	162.1	21.3	21.4	1.4	1.4	0
Result	Not Suitable	Not Suitable	Not Suitable	Not Suitable	Not Suitable	Suitable

Table 3; Simulation Voltage Regulator Design

Figure 3 shows the configuration with the chosen VCC and resistor values.

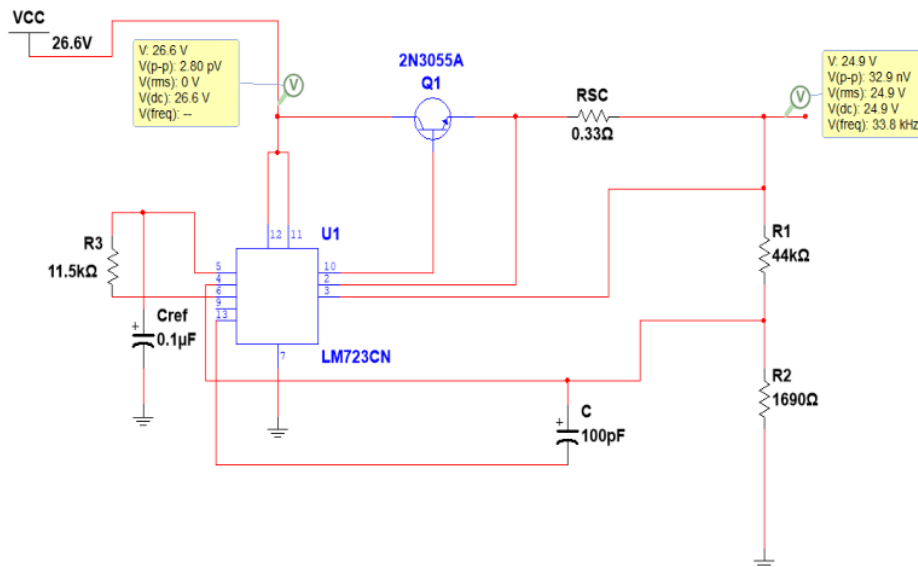


Figure 3; Method; Voltage Regulator NPN Boost Configuration

This shows that the values within this configuration create the desired output.

4.3 Rectifier

An oscilloscope was used to measure the voltage and analyse the waveforms before and after being rectified. In summary, the voltage is lower after being rectified and is utilising the top half of the wave.

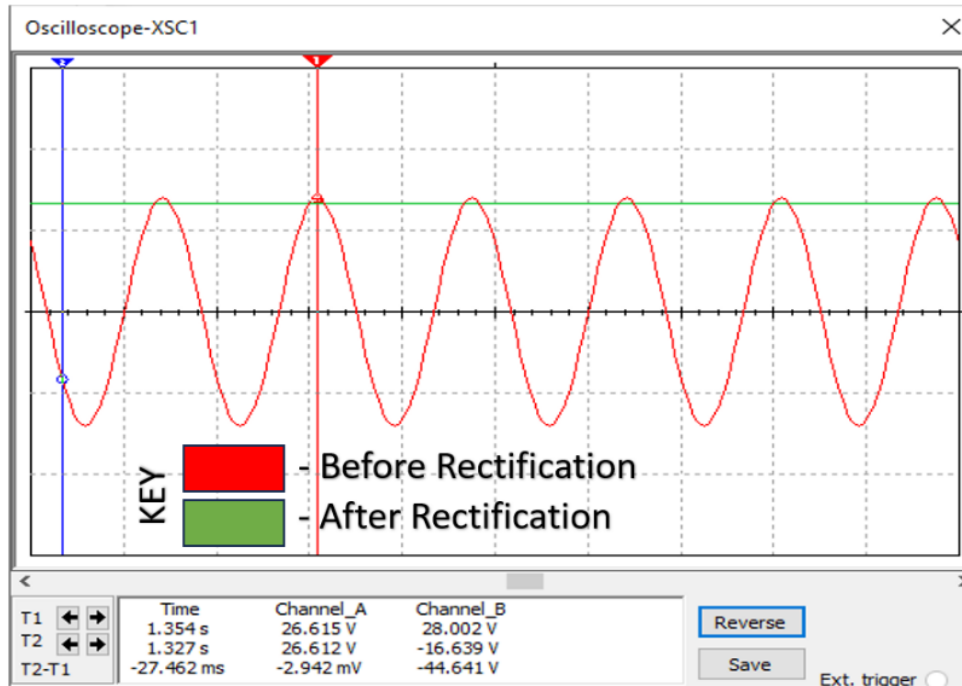


Figure 4; Before and After Rectifier

Results gathered from the test were compiled into the table below.

I/O Voltage Rectification		
	Voltage	Wave
Incoming	28V	Positive and Negative (AC)
Outgoing	26.6V	Positive Half (DC)
Error	1.4V	/

Table 5; IO Voltage Rectification

4.4 Transformer

The voltage was tested with on Multisim using an oscilloscope, testing the primary and secondary side. The scale of both inputs was matched to fit both waveforms on the y-axis.

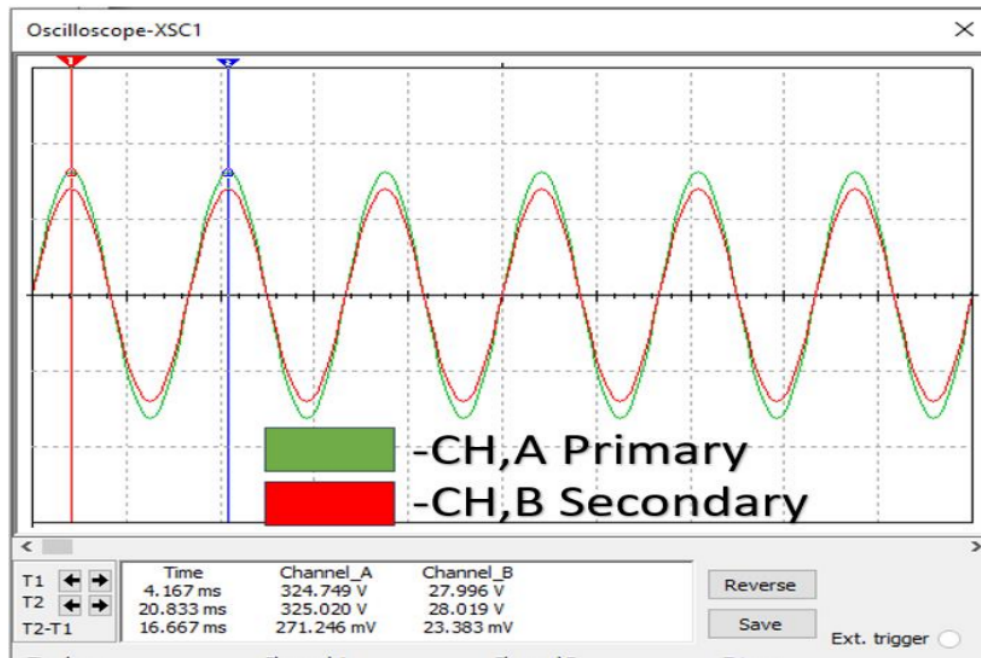


Figure 5; Before and After Step Down Transformer

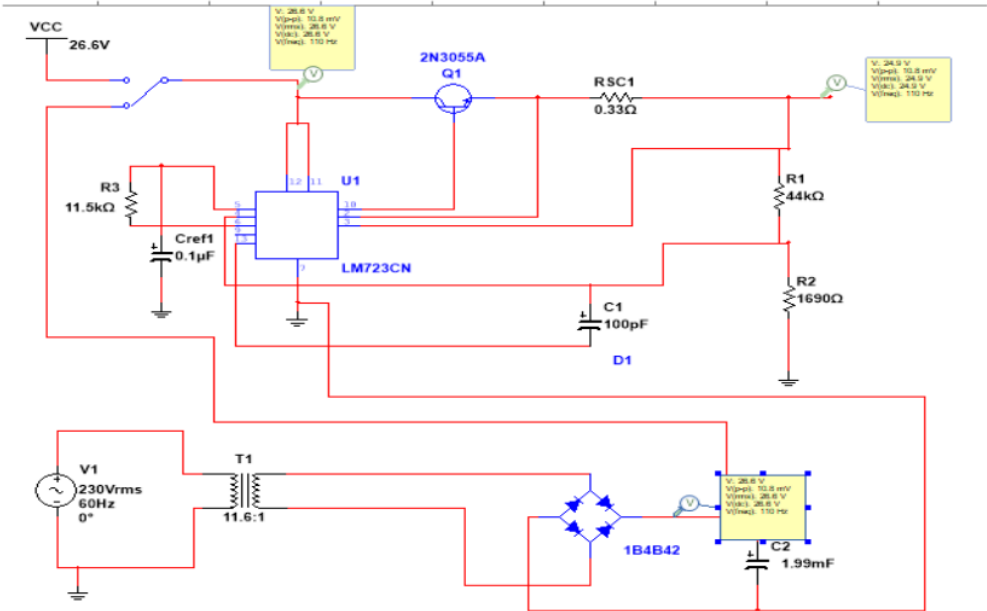
The results were compiled and can be shown in the table below.

Transformer Test			
Characteristic	Calculated	Recorded	Error
Primary Voltage	325.26V	325V	0.26V
Secondary Voltage	27.82V	28V	0.18V

Table 6;Transformer Test

4.5 Final Circuit

The final circuit was compiled, and an interactive simulation was carried out. From this, voltage probes were used to record the voltages within the circuit.



Final Circuit Test			
Characteristic	Specification	Recorded	Error
Incoming	230V	230VRMS	0
Outgoing	24.9V	24.9V	0

Table 7; Final Circuit Test

5. Analysis

5.1 Regulator

Analysing the table shown in Table 3, it can be shown that altering R1 & R2 had little effect on the output voltage. Using common values of VCC, it can be shown that decreasing the input voltage then decreased the output voltage. The regulator has an input voltage range of 9.5 to 40V, so while trialling alternative R1/R2 and VCC values, a voltage closer to the desired output was chosen. By using a value of 26.6V VCC and the calculated R1/R2 values could be used to obtain 24.9V.

5.2 Filter Capacitor

Comparing the two circuits created for testing, one implementing a smoothing capacitor, and another without it can be shown that the capacitor smooths the incoming voltage significantly. Comparing the waveforms it can be seen the circuit with the filter, there is constant voltage and without shows the pulses with gaps. These pulses can reduce the voltage regulation and the voltage level.

The value of the capacitor was varied to see the effects. It was shown that using a lower farad value reduced the stabilising time however by doing this it can lead to insufficient energy storage, increased ripple, and increased stress on the capacitor. Using a greater value increased the stabilising time while reducing the output voltage. Overall, changing the value of the capacitor made the circuit unstable.

In summary, the capacitor improves voltage regulation by ensuring the output voltage remains constant even when load conditions or input voltages vary. The capacitor rating was selected as the calculated value to ensure the voltage regulation was efficient.

5.3 Rectifier

Testing the incoming and outgoing voltages/wave forms shows that the rectifier worked as intended. The AC positive and negative cycles contributed to the DC output where only the positive cycle was used. Recording the incoming and outgoing voltages it showed the voltage drop due to the diodes within the rectifier which can range from 0.5 to 0.8V for most silicone diodes (Mazur, 2010).

Where $(V_f) = 0.7V$

$$\text{Voltage Drop } (V_d) = 2 \times V_f$$

$$\text{Voltage Drop } (V_d) = 2 \times 0.7 = 1.4V$$

$$\text{Incoming } V - V_d = \text{Output } V$$

$$28 - 1.4 = 26.6V$$

5.4 Transformer

The transformer testing showed that the component specifications met the desired output, while calculating the turns ratio it was important to consider the VRMS value. 230VRMS corresponds to the peak voltage of 325V as shown:

$$230 \times \sqrt{2} = 325V$$

5.5 Heatsink

Different methods of mounting and packaging types such as dry mounting and different cases were calculated. By trailing the other methods, often the Case to heatsink thermal resistance was lower which created the ambient thermal resistance to be higher. An example of this is shown below where CS=0.5 seen in is Table 9 which is a dry metal-on-metal T0-204 package.

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

$$\theta_{SA} = \frac{200 - 20}{49.8} - 1.5 - 0.5 = 1.61\Omega$$

Ambient Resistance Comparison Varying θ_{CS}			
Type	θ_{CS} (Case to heatsink thermal resistance)	θ_{SA} (Ambient thermal resistance)	Selected?
T0-204 Metal-to-Metal Dry	0.5 Ω	1.61 Ω	YES
T0-220 Using an Insulator with Heatsink Compound	1.6 Ω	0.5 Ω	NO

Table 8; Ambient Resistance Comparison Varying θ_{CS}

By implementing the heatsink, it can prevent electronic failure due to thermal issues. Due to the system being located inside a control panel, this means the temperature may fluctuate and rise causing the devices life cycle to be reduced (Advanced Energy, 2020). While trailing the different values of CS, a lower value of ambient thermal resistance is generally better. Thermal resistance measures how well a material or component conducts heat, and lower thermal resistance means better heat conduction.

6. Evaluation

6.1 Voltage regulator

The R1/R2 resistance values having little effect on the output could be due to voltage reference tolerance or limitations with the components selected. A trimmer pot could have been implemented in the voltage regulator for R2 in because the voltage regulator can vary by 5 percent either way.

The calculated resistor values were accurate to what was required, however in real world applications those values aren't obtainable. Instead, preferred values are chosen and purchased due to availability from manufacturers. In the student's design E24 rated resistors were selected to complement the standard values of other electronic components such as the capacitors. The E24 rated resistors have a tolerance as low as one percent, which makes them precise, however in the design if a current limiting resistor was used it should be rounded up to prevent overloading.

Cref was selected as $0.1\mu\text{F}$ for low noise operation due to the NPN boost configuration. This value is effective in filtering out high frequency noise such as fast transients or switching noise that can then be shunted to ground by the capacitor. However, it can be seen studying the regulator in Figure 15 Cref is used between pins 5 and 6 which will help stabilize the reference voltage within the control or feedback loop of the boost converter.

6.2 Filter Capacitor

It was ensured that the filter capacitor had a higher voltage rating higher than the expected DC voltage and to handle the ripple current. If this was not considered it could have led to failure, leakage, swelling or rupture of the capacitor itself.

6.3 Rectifier

The full bridge rectifier was suitable and offered good voltage regulation while utilising both half waves of the AC voltage making it efficient.

6.4 Heatsink

The heatsinks would have to be tested once a practical design is created. The tests could consist of using a thermal sensor or thermocouple to measure the temperature of the heatsink. Additionally, carrying out no load tests, underload and maximum load and recording temperatures of the components to ensure they are not overheating.

6.5 Recommendations

During the design, considerations for electromagnetic interference should be carried out. Due to the system being in a control panel, it may be close to other electronic systems. By not considering this factor it could lead to malfunctions or disruptions to other equipment.

An LED indicator would be a good inclusion during the design, this could make engineers or operators aware that the system is energised for safety and working correctly.

Safety techniques such as inrush current limiting could be implemented to prevent overloading components. A surge could happen when a sudden charging of capacitors or energising inductors when switching the system on. Common methods that could be implemented are NTC thermistors or thermally activated switches.

7. Conclusion

In conclusion, the design and testing of the power supply has been comprehensive and informative. It showed where each component had a vital role in ensuring the overall functionality and stability of the system. Discussions with the customer to determine requirements allowed a specification table to be drawn to be used as a foundational guide for the design.

The regulator design showed the importance of adjusting VCC and selecting suitable R1/R2 values within the regulators input voltage range to obtain the specified voltage of 24.9V.

Testing the rectifier confirmed its efficiency in converting AC to DC while still utilising both halves of the AC waveform. The voltage drop was highlighted due to the diodes which resulted in a final output voltage of 26.6V.

Including the smoothing capacitor showed that it significantly improved the voltage by reducing the ripple voltage while considering energy storage and stabilizing time.

The transformer testing ensured that the design met the desired output considering VRMS values for accurate turn ratio calculations.

Throughout the testing and design stages, variations were made to see how this would impact the circuit regarding output voltage, current, and frequency. Once these changes were analysed, the appropriate value of components were selected and justified.

Evaluating the design identified key considerations such as voltage reference tolerance and appropriate resistor values within the regulator. Appropriate voltage rating for the filter capacitor and suitability of the full bridge rectifier. It was noted that testing the heatsinks under various conditions in a practical application was emphasised to prevent electronic failure to do thermal conditions.

The recommendations for a future design included considerations for electromagnetic interference, an LED indicator for operational awareness and further safety measures for inrush current limiting.

Finally, this design has had an integrated approach ensures that the designed power supply system is not only successful with meeting the customer's needs but also aligns with responsible engineering practices, meeting the needs of the user while upholding ethical and sustainable standards.

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9. Appendices

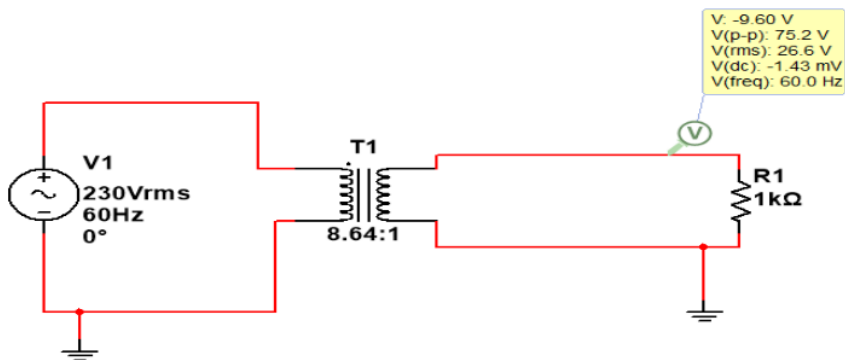


Figure 6; Basic Transformer

DIN Rail Power Supplies

Product Description

From RS Pro a range of high-performance power supplies in a compact 35mm DIN rail mounting package for convenience and space saving. These DIN rail mount power supplies are available with a range of power ratings from 15W to 240W and accept single-phase AC input for conversion into a single DC output of either 12V, 15V, 24V or 48V DC.

General Specifications

Type	Switch Mode
AC or DC Input Voltage	230VAC
AC or DC Output Voltage	24VDC
Number of Outputs	1
Special Features	Compact Size, Cooling by Free Air Convection, LED Indicator for DC Low, LED Indicator for DC Power On, 3-Years Warranty, 100% Full Load Burn-In Test
Mounting Type	DIN Rail, Vertical Mount
Short Circuit Protection	Yes
Over Voltage Protection	Yes
Indication of Output Voltage	LED, continuous green light
Applications	Sensors, Transmitters/receivers, Analyzers, PLCs, Motors, Actuators, Solenoids, Relays

Electrical Specifications

RS Stock#	Input Voltage	Output Voltage	Output Current	Output Wattage	Efficiency (Typ)
136-8312	100VAC-240VAC	+ 12VDC	5A	60W	84%
136-8314	100VAC-240VAC	+ 15VDC	4.6A	70W	84%
136-8315	100VAC-240VAC	+ 24VDC	3A	70W	86%
136-8316	100VAC-240VAC	+ 48VDC	1.5A	70W	86%

DIN Rail Power Supplies

Mechanical

Marking

Marking	No.	Assignment
1	1	DC+ Output Terminal
2	2	DC+ Output Terminal
3	3	DC+ Output Terminal
4	4	DC+ Output Terminal
5	5	AC/L1 Input Terminal
6	6	AC/L2 Input Terminal
7	7	AC Grounding Terminal
8	8	DC Output voltage adjustment trimmer
9	9	DC Output On indicator LED (Green)
10	10	DC Output Low indicator LED (Red)

Figure 7; Competitor Power Supply

(RS Components, 2024)

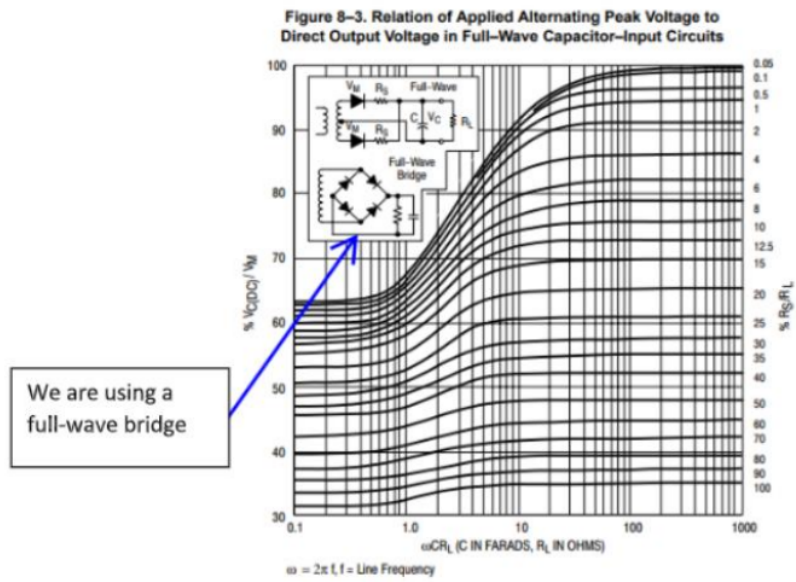


Figure 8; Schade Curve Applied Alternating Peak Voltage to Direct Output Voltage

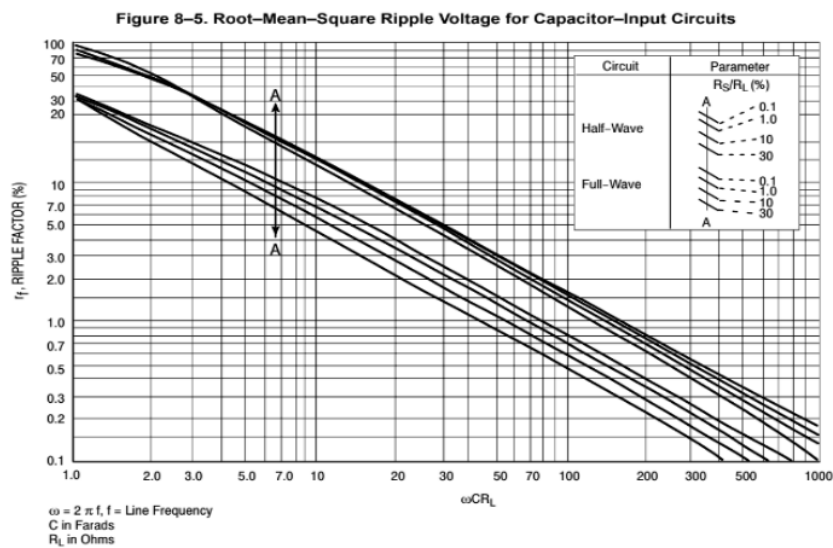


Figure 9; Voltage for Capacitor-Input Circuits

Table 4. Electrical characteristics for LM723 (refer to the test circuits, $T_A = 25^\circ\text{C}$, unless otherwise specified.)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$\Delta V_O/\Delta V_I$	Line regulation	$V_I = 12$ to 15 V		0.01	0.1	%
		$V_I = 12$ to 40 V		0.02	0.2	
		$V_I = 12$ to 15 V , $T_A = -55$ to 125°C			0.3	
$\Delta V_O/V_O$	Load regulation	$I_O = 1$ to 50 mA		0.03	0.15	%
		$I_O = 1$ to 10 mA , $T_A = -55$ to 125°C			0.6	
V_{REF}	Reference voltage	$I_{REF} = 160\text{ }\mu\text{A}$	6.95	7.15	7.35	V
SVR	Supply voltage rejection	$f = 100\text{ Hz}$ to 10 kHz	$C_{REF} = 0$	74		dB
			$C_{REF} = 5\text{ }\mu\text{F}$	86		
$\Delta V_O/\Delta T$	Output voltage drift				150	ppm/ $^\circ\text{C}$
I_{SC}	Output current limit	$R_{SC} = 10\Omega$, $V_O = 0\text{ V}$		65		mA
V_I	Input voltage range		9.5		40	V
V_O	Output voltage range		2		37	V
V_O/V_I			3		38	V
I_Q	Quiescent current	$V_I = 30\text{ V}$, $I_O = 0\text{ mA}$		2.3	5	mA
K_{SH}	Long term stability			0.1		%/1000 hrs
eN	Output noise voltage	$BW = 100\text{ Hz}$ to 10 kHz	$C_{REF} = 0$	20		μV
			$C_{REF} = 5\text{ }\mu\text{F}$	2.5		

LM723

Maximum ratings

3 Maximum ratings

Table 2. Absolute maximum ratings

Symbol	Parameter	Value		Unit
		LM723	LM723C	
V_I	DC input voltage	40	40	V
ΔV_{IO}	Dropout voltage	40	40	V
I_O	Output current	150	150	mA
I_{REF}	Current from V_{REF}	15	25	mA
T_{OP}	Operating Temperature	-55 to 125	0 to 70	$^\circ\text{C}$
T_{STG}	Storage Temperature	-65 to 150	-65 to 150	$^\circ\text{C}$
T_J	Junction Temperature	150	125	$^\circ\text{C}$

Table 3. Thermal data

Symbol	Parameter	DIP14	Unit
$R_{\theta JA}$	Thermal resistance junction-ambient Max	200	$^\circ\text{C/W}$

Figure 10; LM723 Data Sheet

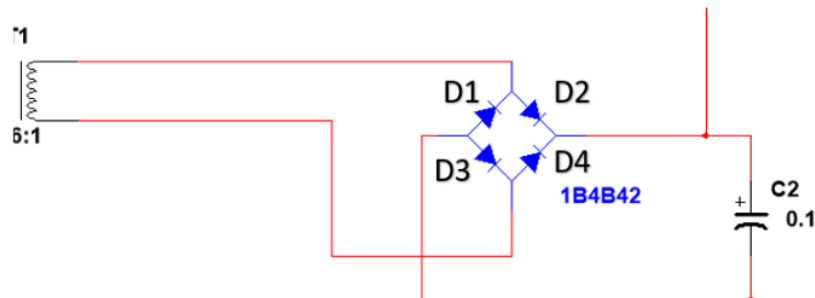


Figure 11; Rectifier Operation

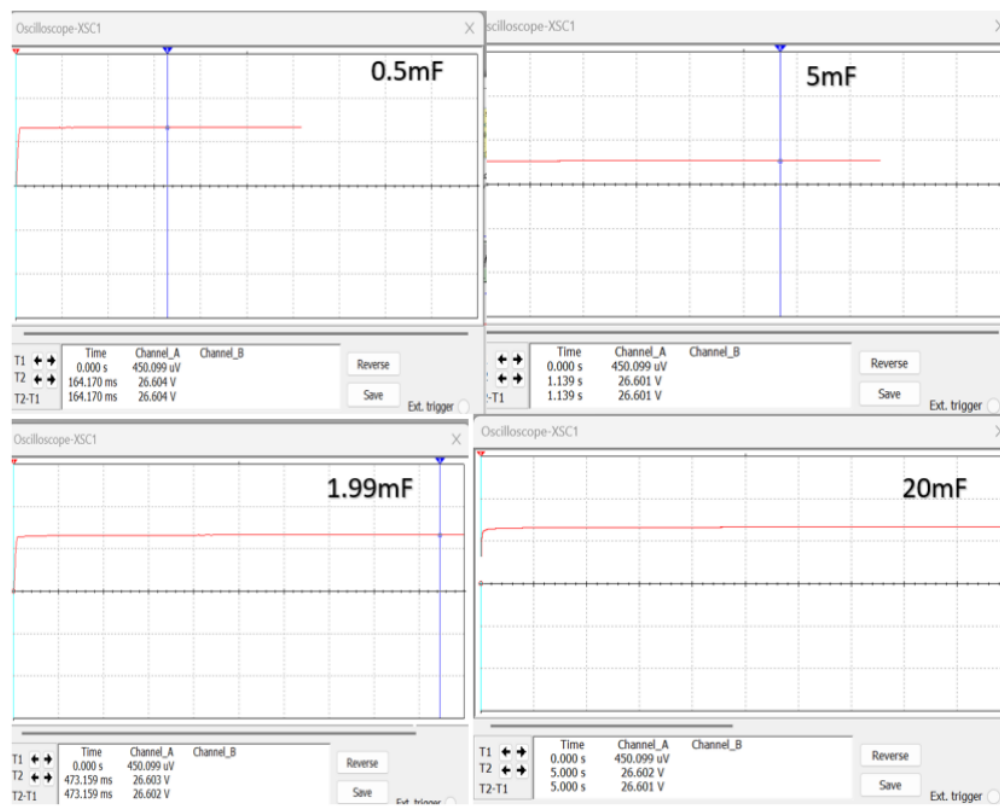


Figure 12; Filter Capacitor Variation Transient

Table 15-1. θ_{CS} For Various Packages & Mounting Arrangements

Case	θ_{CS}			
	Metal-to-Metal*		Using an Insulator*	
	Dry	With Heatsink Compound	With Heatsink Compound	Type
TO-204	0.5°C/W	0.1°C/W	0.36°C/W 0.28°C/W	3 mil MICA Anodized Aluminum
TO-220	1.2°C/W	1.0°C/W	1.6°C/W	2 mil MICA

*Typical values; heatsink surface should be free of oxidation, paint, and anodization

Table 9; Case-to-heatsink thermal resistance

Absolute maximum rating

2N3055, MJ2955

1 Absolute maximum rating

Table 2. Absolute maximum rating

Symbol	Parameter	Value		Unit
		NPN	2N3055	
		PNP	MJ2955	
V_{CBO}	Collector-base voltage ($I_E = 0$)		100	V
V_{CER}	Collector-emitter voltage ($R_{BE} = 100 \Omega$)		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	°C
T_J	Max. operating junction temperature		200	°C

Table 3. Thermal data

Symbol	Parameter	Value	Unit
$R_{thj-case}$	Thermal resistance junction-case max	1.5	°C/W

Note: For PNP type voltage and current values are negative

Figure 13; 2N3055 Data Sheet

Features

- For Use With:
Universal
Rectangular Alu
- Mounting: PCB
Mount
- Thermal Resistance
0.83°C/W

RS PRO Heatsinks

RS Stock No.: 903-3087



General Specifications

For Use With	Universal Rectangular Alu
Material	Aluminium
Mounting	PCB Mount
Application	High Power Semiconductor Device, Optoelectronic Device
Finish	Anodized
Notes	• Thermal Resistance is calculated based on a distributed heat load and vertically mounted fins anodised heatsink with a 60°C temperature. • Under general operating conditions the thermal mounting arrangement of the device is not know and therefore the figures should be used as a guide to selection. • We recommend that the effectiveness of any heatsink is tested in the specific operating environment in which it will be subjected.

Mechanical Specifications

Length	100mm
Width	100mm
Height	15mm
Dimension	100 x 100 x 15mm

Electrical Specifications

Thermal Resistance	0.83°C/W
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Figure 14; Heatsink, Universal Rectangular Alu, 0.5°C/W, 150 x 66 x 40mm, PCB Mount

Connection Diagram

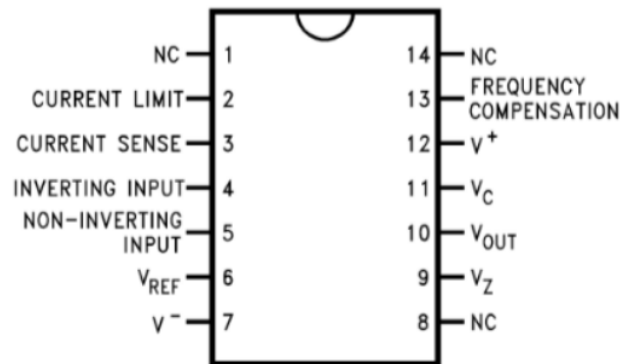


**Figure 1. Top View
CDIP Package or PDIP Package
See Package J or NFF0014A**

Figure 15; Voltage Regulator Connection Diagram

FINAL GRADE

GENERAL COMMENTS

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GRADING FORM: CSG-RUBIC

MATTHEW PERRY

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RESEARCH-INFORMED LITERATURE



There was evidence of extensive further reading and research from credible and reliable sources. Your interpretation and understanding of the additional research was very good and

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demonstrated a deep underlying appreciation of the subject. Your references were consistently applied and appropriate to the task and your reference list was of an appropriate length for this assignment.

KNOWLEDGE AND UNDERSTANDING



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.

24

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.

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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 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.

25

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.

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