Requirement Specifications

1. The DPS shall not suffer damage at temps down to -40°C.

2. The DPS shall maintain voltage output specifications over temperature range of 0-70°C.

3. The DPS shall have a power efficiency of >60% with 20 mA current load on either of the two outputs.

4. The DPS shall have a 5 V output with a voltage range of 4.77 V to 5.23 V and a current load capacity of 1.2 mA – 12mA.

5. The DPS shall have a 12 V output with a voltage range of 11.74 V to 12.27 V and a current load capacity of 2.8 mA – 20 mA.

6. The DPS shall operate with a single voltage input from 0 to 30 V. The input voltage must not be within +/- 10% of either of the output voltages (5 V and 12 V) to provide the limitation for the voltage and current capabilities of both output channels.

7. The DPS shall maintain voltage output specifications with an input voltage +/-20% from nominal.

8. The DPS shall have flying leads for the connection to the battery.

9. The DPS shall have test pins for the output voltages.

10. The DPS shall have a mass of no more than 25 g including PCB and components (without leads).

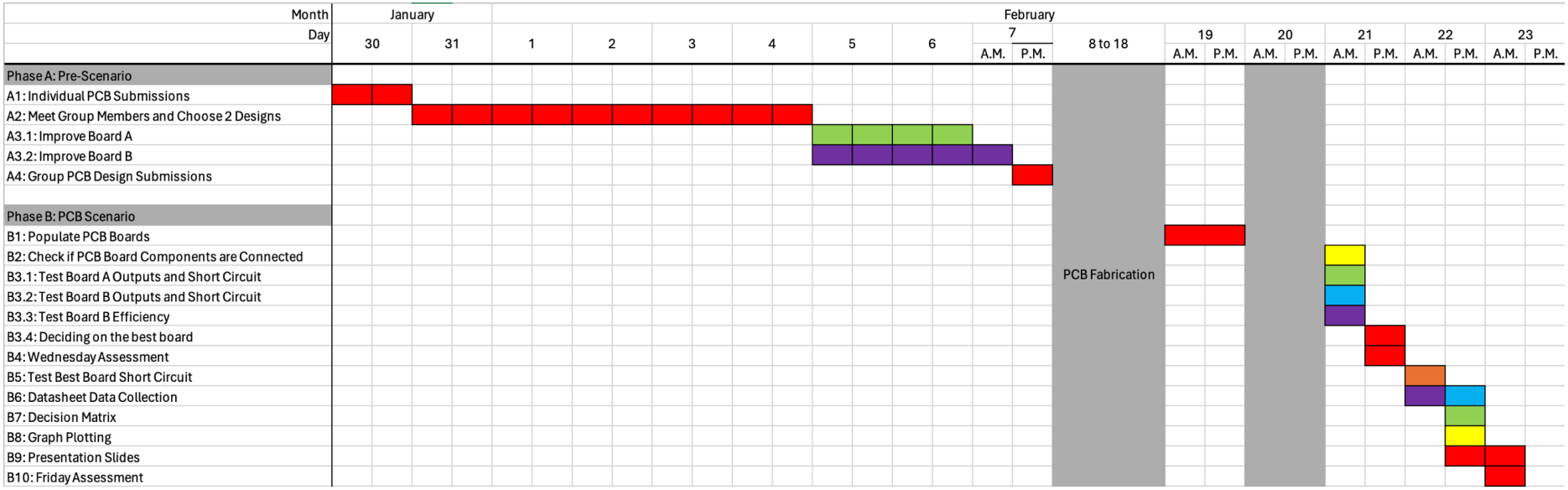
11. The DPS shall generate maximum 30 mA output current under a short circuit condition on either output.

Reference

1. Output Ripple Measurement Methods for DC-DC Converters, Richtek Technology Corporation
2. How to Measure Ripple for Better Design Outcomes, Texas Instruments Incorporated
3. Generating and Testing Power Ripples, https://www.monolithicpower.com/en/generating-and-testing-power-ripples
4. Understanding, Measuring, and Reducing Output Voltage Ripple, - Simple Switchers Wiki - SIMPLE SWITCHER®, TI E2E Community

Gantt Chart

Key:	
	All
	Bingji
	Nathan
	Shenhe
	Bing
	Chizou



Decision Matrix

Individual Circuit Designs

Requirement	Weight	Design A	Design B	Design C	Design D	Design E
The input voltage should not be within +/- 10% of 5V or 12V	5	5	5	5	5	5
The DPS shall maintain voltage output specifications with an input voltage +/-20% from nominal.	8	7	7	6	6	2
Track to track separation should be a minimum of 0.4mm	3	3	3	3	3	3
Track / Via / Pad to Board edge separation: No tracks within 2 mm of edge.	3	3	3	3	3	3
Track Width: Minimum 0.4 mm	3	3	2	3	3	2
Copper Pour Spacing: 1 mm	3	3	3	3	2	2
the DPS should have a power efficiency of >60% with a 20mA current load on either of the outputs	8	8	8	5	4	2
The DPS should have a 5V output with +/-0.5V with a 20mA current load	10	10	10	10	10	4
The DPS should have a 12V output with +/-1V with a 20mA current load	10	10	10	9	9	4
The DPS shall generate a maximum 30mA under short-circuit conditions	7	7	7	6	3	1
Sum		430	427	381	349	174

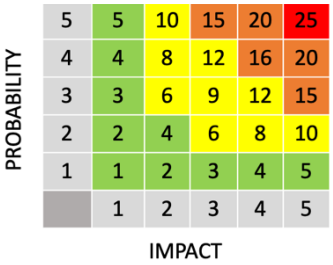
Design A and B are chosen for fabrication.

PCB Boards

Requirement	Weight	Board A1	Board A2	Board A3	Board B1	Board B2	Board B3
The input voltage should not be within +/- 10% of 5V or 12V	5	5	5	5	5	5	5
The DPS shall maintain voltage output specifications with an input voltage +/-20% from nominal	8	0	0	0	4	7	0
the DPS should have a power efficiency of >60% with a 20mA current load on either of the outputs	8	0	0	0	6	6	0
The DPS should have a 5V output with +/-0.5V with a 20mA current load	10	0	0	0	10	10	0
The DPS should have a 12V output with +/-1V with a 20mA current load	10	0	0	0	8	10	0
The DPS shall generate a maximum 30mA under short-circuit conditions	7	7	7	0	7	7	0
The DPS shall have a mass of no more than 25g	1	1	1	1	1	1	1
Sum		75	75	26	335	**379**	26

Board B2 is chosen for demonstration.

RISK REGISTER



Risk Description	Impact Description	Impact Level	Probability Level	Priority Level	Mitigation Notes	Owner
Brief Summary of the risk	What will happen if the risk is not mitigated or eliminated	Rate 1 (LOW) to 5 (HIGH)	Rate 1 (LOW) to 5 (HIGH)	Impact x Probability	What can be done to lower or eliminate the impact or probability	Who's responsible?
Incorrect Open Circuit output	Wrong voltage outputs does not meet requirements	5	3	15	Double-check circuit on Diptrace with all group members	Nathan and Bingji (Designers of circuits)
Collection of data is incorrect	Inaccurate data on datasheet	3	4	12	Repeat experiments and either get an average, or eliminate anomalies	Nathan and Bing
Overheating PCB	PCB is broken an unusable	5	2	10	Do continuity checks on PCB and check for broken traces before connecting to power supply	Board A: Bingji, Shenhe Board B: Nathan, Bing and Chizou
Components falling off PCB	Circuit will not be connected, and outputs will be incorrect	2	4	8	Makes sure enough solder paste is on pads and components are placed properly onto pads	Whoever populated the specific PCB Board
Broken tracks on PCB	Circuit will not be connected	2	4	8	Make the track widths wider on Diptrace	Nathan and Bingji (Designers of circuits)
Incorrect Placement of Components on PCB	Incorrect Voltage Outputs	3	2	6	Layout the components on a draft before placing it on the real PCB	Whoever populated the specific PCB Board
PCB is not printed on time	PCB testing is delayed	4	1	4	N/A	Lab Technicians
Broken testing equipment	PCB testing is delayed	2	1	2	N/A	Lab Technicians

Verification Test Plan

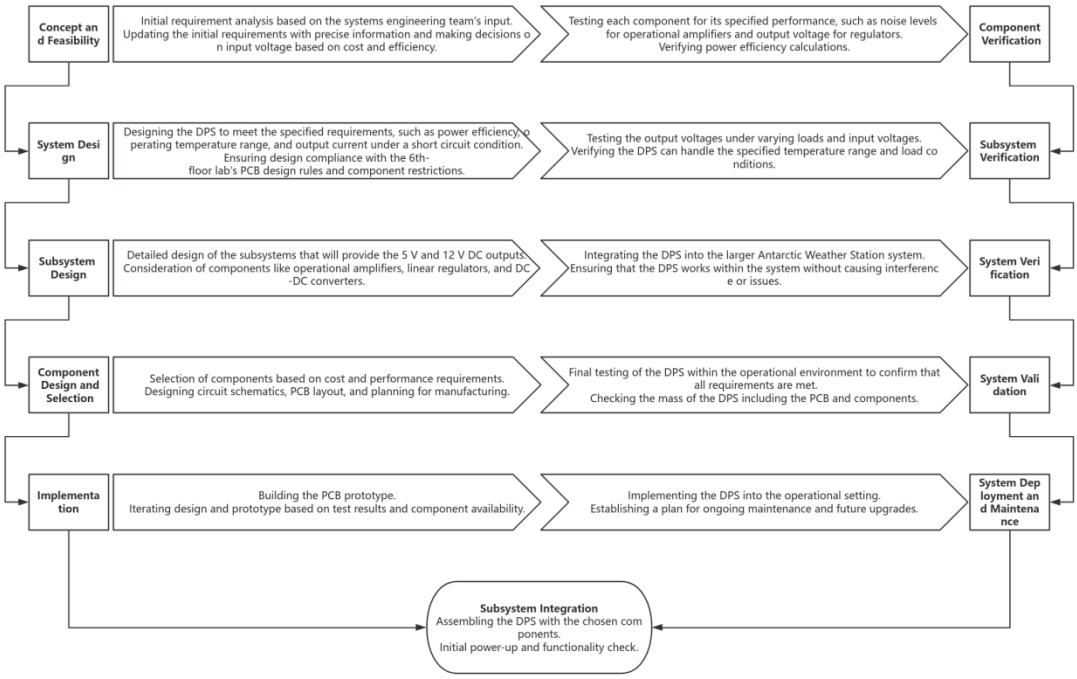
Requirements	Method	Verification Procedure
The DPS shall not suffer damage at temps down to -40°C	I	For all the different components used in the PCB design, check whether each of the component can survive at temperatures below -40 °C by checking each component's datasheets
The DPS shall maintain voltage output specifications over temperature range of 0-70°C.	A	As we do not have the equipment to test the board's temperature requirement, we can use Multisim to do a temperature sweep simulation. Using this tool, we can see the variation of the output voltage in relation to temperature.
The DPS shall have a power efficiency of >60% with 20 mA current load on either of the two outputs	T	Connect the one or both outputs of the DPS to a 20 mA current load and supply the DPS with a voltage using the power supply. Use the multimeter and multimeter probes to measure the output voltage. Record the input current and voltage shown on the power supply. Calculate the efficiency using the equation output power/input power.
The DPS shall have a 5 V output with a voltage range of 4.77 V to 5.23 V and a current load capacity of 1.2 mA – 12mA.	T	Supply the DPS with the chosen input voltage. Connect the 5V output directly to the oscilloscope. When the oscilloscope is turned on, record the voltage ripple using the measure function of the oscillisope.
The DPS shall have a 12 V output with a voltage range of 11.74 V to 12.27 V and a current load capacity of 2.8 mA – 20 mA.	T	Supply the DPS with the chosen input voltage. Connect the 12V output directly to the oscilloscope. When the oscilloscope is turned on, record the voltage ripple using the measure function of the oscillisope.
The DPS shall operate with a single voltage input from 0 to 30 V. The input voltage must not be within +/- 10% of either of the output voltages (5 V and 12 V).	T	Check the input voltage. Supply the DPS with the chosen input voltage and use a multimeter and multimeter probe to measure the voltage output of 5V and 12V.
The DPS shall maintain voltage output specifications with an input voltage +/-20% from nominal.	T	Connect the power supply to the input of the DPS. Adjust the input voltage +/-20% from the nominal and measure the output voltage using the multimeter and probes. Plot a graph of the output voltage vs input voltage.
The DPS shall have flying leads for the connection to the battery.	I	Inspect the board physically
The DPS shall have test pins for the output voltages.	T	Power the PCB board. Use a probe connected to a multimeter on the test pin a check whether the desired voltage is shown on the multimeter.
The DPS shall have a mass of no more than 25 g including PCB and components	T	Weigh the board on a weighing scale.
The DPS shall generate maximum 30 mA output current under a short circuit condition on either output.	T	Connect the output of the DPS in series with a multimeter which is connected to ground. Power the DPS and record the current reading on the multimeter.

Inspection (I) - visual examination of drawings, data, or the item itself without the use of special laboratory procedures or equipment.
Analysis (A) - evaluation of design or data by analytical techniques and may involve calculation or simulation.
Demonstration (D) - operation, adjustment, or reconfiguration.
Test (T) - formal test or measurement.

Verification Matrix

Requirement	Requirement Document	Method	Verification Plan Document	Responsible/organization person	Verification Result Document
The DPS shall not suffer damage at temps down to -40°C	Requirement Specifications	I	Verification Test Plan	Shen He	Verification Results
The DPS shall maintain voltage output specifications over temperature range of 0-70°C.		A		Bingji	
The DPS shall have a power efficiency of >60% with 20 mA current load on either of the two outputs		T		Nathan	
The DPS shall have a 5 V output with a voltage range of 4.77 V to 5.23 V and a current load capacity of 1.2 mA – 12mA.		T		Bing	
The DPS shall have a 12 V output with a voltage range of 11.74 V to 12.27 V and a current load capacity of 2.8 mA – 20 mA.		T		Bingji	
The DPS shall operate with a single voltage input from 0 to 30 V. The input voltage must not be within +/- 10% of either of the output voltages (5 V and 12 V).		T		Shen He, Bingji	
The DPS shall maintain voltage output specifications with an input voltage +/-20% from nominal.		T		Nathan, Bing	
The DPS shall have flying leads for the connection to the battery.		I		Chi Zou	
The DPS shall have test pins for the output voltages.		T		Nathan	
The DPS shall have a mass of no more than 25 g including PCB and components		T		Bingji	
The DPS shall generate maximum 30 mA output current under a short circuit condition on either output.		T		Chi Zou	

V-curve



Validation and feedback to the systems engineering team on the most suitable input voltage. Documenting the design process, verification results, and decisions made for future reference. Preparing for the two deadlines: individual submission of PCB layout and group submission of the best PCB designs.

Verification Results

The DPS shall not suffer damage at temps down to -40°C:

Check minimum temperatures of all components:

Resistors:

https://www.farnell.com/datasheets/2861419.pdf

Capacitors:

https://www.vishay.com/docs/45006/vjx8r.pdf

https://4donline.ihs.com/images/VipMasterIC/IC/KEME/KEME-S-A0018898346/KEME-S-A0018902173-1.pdf?hkey=6D3A4C79FDBF58556ACFDE234799DDF0

Capacitors:

https://docs.rs-online.com/7e5b/0900766b81662b7e.pdf

Diodes:

https://www.farnell.com/datasheets/2861346.pdf

Transistors:

https://assets.nexperia.com/documents/data-sheet/BC807W_SER.pdf

ICs:

https://www.ti.com/lit/ds/symlink/mc33063a.pdf?ts=1709855513830&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FMC33063A%252Fpart-details%252FMC33063AD

Header Pins:

https://cdn.harwin.com/pdfs/M20-877.pdf

The DPS shall maintain voltage output specifications over temperature range of 0-70°C.

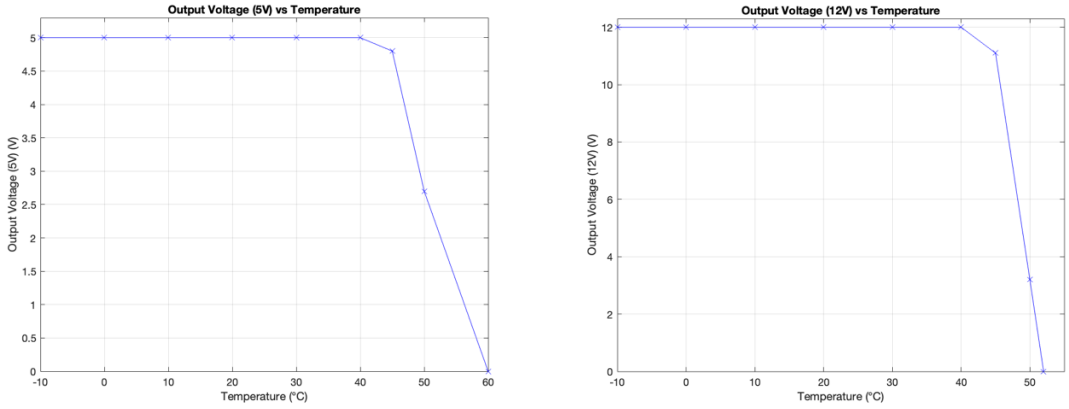


Figure 1: Output Voltage vs Temperature for 5V (Left) and 12V (Right)

The DPS shall have a power efficiency of >60% with 20 mA current load on either of the two outputs

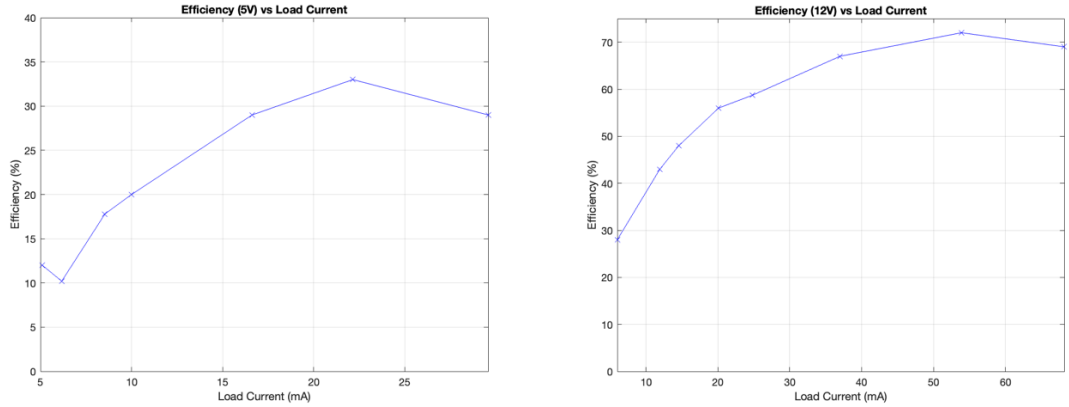


Figure 2: Efficiency vs Load Current for 5V (Left) and 12V (Right)

When both are operating, the efficiency of the DPS is 63%

The DPS shall have a 5 V output with a voltage range of 4.77 V to 5.23 V and a current load capacity of 1.2 mA – 12mA.

Figure 3: Ripple Voltage of 5V

The DPS shall have a 12 V output with a voltage range of 11.74 V to 12.27 V and a current load capacity of 2.8 mA – 20 mA.

Figure 4: Ripple Voltage of 12V

The DPS shall operate with a single voltage input from 0 to 30 V. The input voltage must not be within +/- 10% of either of the output voltages (5 V and 12 V).

Input Voltage : 18V

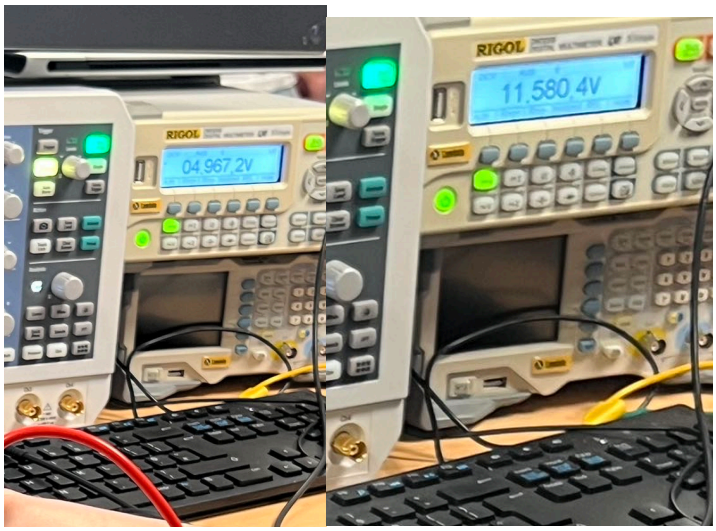


Figure 5: Multimeter photos of outputs of 5V (Left) and 12V (Right)

The DPS shall maintain voltage output specifications with an input voltage +/-20% from nominal.

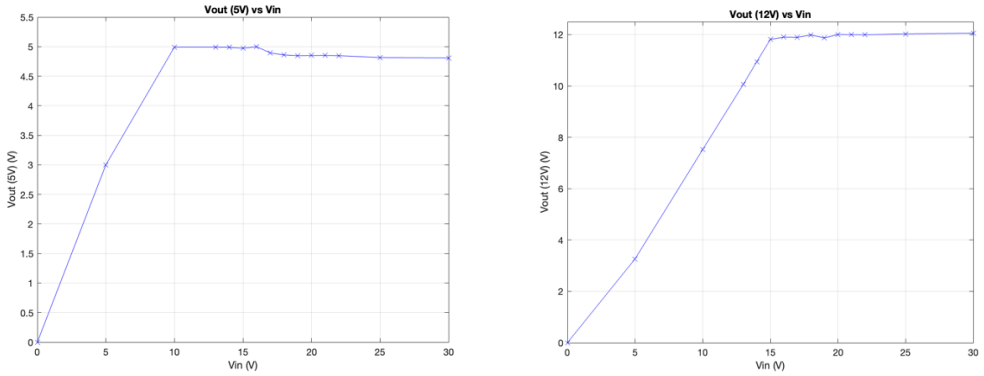


Figure 6: Vout vs Vin for 5V (Left) and 12 V (Right)

The DPS shall have test pins for the output voltages.

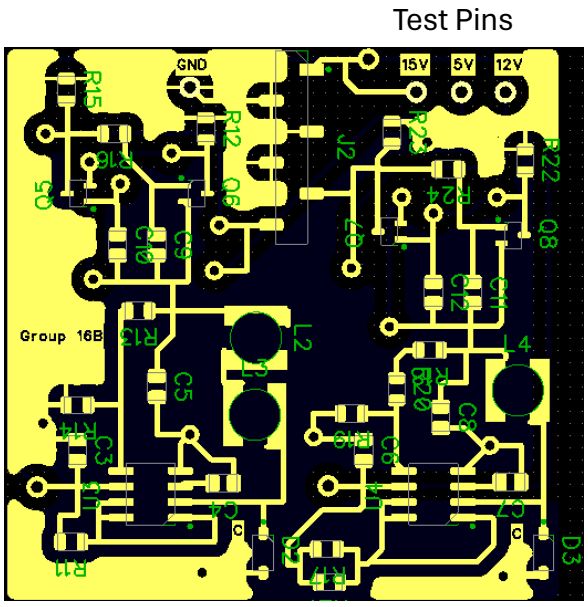


Figure 7: PCB Board showing test pins

The DPS shall have a mass of no more than 25 g including PCB and components

After weighing the board, the mass of the board is 6g

The DPS shall generate maximum 30 mA output current under a short circuit condition on either output.

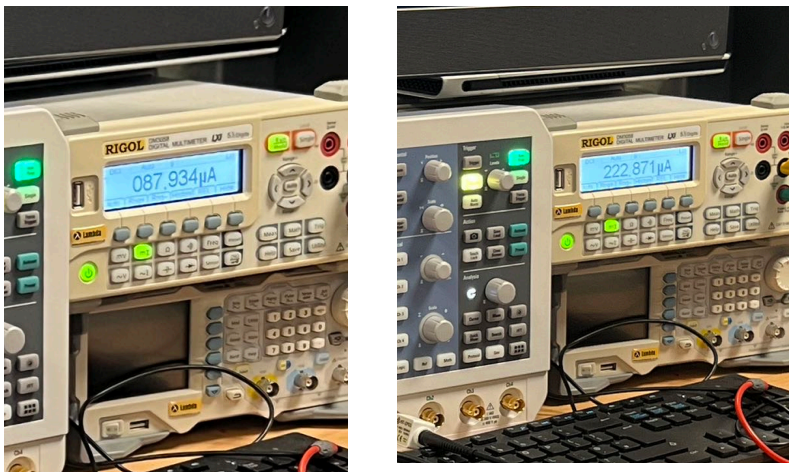


Figure 8: Multimeter reading showing short-circuit current of 5V (Left) and 12V (Right)

Manufacturing Test Plan

1.Introduction

The purpose of this Manufacturing Test Plan is to outline the strategy for ensuring that all PCB boards produced meet the basic functionality requirements and key specifications before shipment. This plan will not cover all details of the verification plan but will focus on essential functions and performance criteria. Based on the production requirement of 200 PCB boards, we will select 5 of them for the following test.

2. Test Scope

A series of tests will be carried out on the 5 selected PCB boards, and the operation performance of each PCB board under different test environments will be recorded.

3. Test Procedures

- **Temperature Test**
    - Heat and cool each board in a controlled environment.

  (The temperature must be controlled between 0 and 70 degrees Celsius.)
    - Measure the 5V and 12V outputs respectively at specified temperature intervals to verify voltage stability and performance.
- **Safety Test**
    - Short circuit the PCB output in a controlled setup.
    - Measure the current output record safety features like current limiters or fuses operate correctly.
- **Efficiency Test**
    - Connect a 20mA load to the output.
    - Measure the input and output power of the circuit and use the values to calculate the efficiency.
    - Efficiency should ideally be over 60%.
- **Weight Verification**
    - Weigh each board after assembling the requirement is below 25 grams.
    - Boards that exceed the weight requirement will do additional inspection to determine the cause of discrepancy.

4. Test Equipment

- Temperature-controlled chamber for thermal testing.
- Power supply, oscilloscope and multimeter for voltage and current measurement.
- Precision scale for weight verification.

5. Acceptance Criteria

- PCBs must maintain 5V and 12V outputs within ±5% of the rated voltage across the tested temperature range.
- Current during short circuit conditions must not exceed the maximum rated value.
- The weight of the PCB should be below 25g

6. Documentation

- Test results will be recorded with the serial number of each board.
- A test report will be generated, including a decision matrix showing how closely each board meet the required specifications and any deviations from expected results.

Costing

Bill of Materials						
Details of Every Part					Price (£)	
Components:	**Value:**	**Tolerance:**	**Quantity:**	**Supplier:**	**Unit Price:**	**Total Price:**
Resistors:	10 Ω	5 %	3	MULTICOMP PRO	0.05	0.15
	910 Ω	5 %	1	MULTICOMP PRO	0.01	0.01
	1 KΩ	5 %	1	MULTICOMP PRO	0.01	0.01
	1.5 KΩ	5 %	1	MULTICOMP PRO	0.01	0.01
	3 KΩ	5 %	1	MULTICOMP PRO	0.01	0.01
	5.1 KΩ	5 %	4	MULTICOMP PRO	0.01	0.04
	12 KΩ	5 %	1	MULTICOMP PRO	0.01	0.01
	51 KΩ	5 %	2	MULTICOMP PRO	0.02	0.04
Capacitors:	100 pF	5 %	4	VISHAY	0.13	0.52
	330 pF	5 %	2	VISHAY	0.15	0.30
	1 µF	10 %	2	KEMET	0.08	0.16
	10 µF	10 %	2	KEMET	0.16	0.32
Inductor:	330 µH	20 %	3	BOURNS	0.33	0.99
Diode:	1N5819HW		2	MULTICOMP PRO	0.21	0.42
Transistors:	BC807-40W		4	NEXPERIA	0.10	0.40
ICs:	MC33063AD		2	TEXAS INSTRUMENTS	2.51	5.02
Header Pin (6 Contacts):			1	HARWIN	0.39	0.39
PCB (50 × 50 mm)			1	Fairfield (7 Days)	0.96	0.96
Sum (VAT Included):					**11.71**	

Recurring Cost				
Part of Costs & Details			Cost (£)	
Events	**Time**	**Responsible Staff**	**Wage (£) (VAT Included)**	**Total**
Populating & Soldering (3 hours in total)	0.015 h	Technician	20/h	0.30
Testing (12 hours in total)	0.06 h	Technician	20/h	1.20
Packaging (3 hours in total)	0.015 h	Technician	20/h	0.30
Bill of Materials:			11.71	
Sum:			**13.51**	

Spare Materials (10 DPS Circuits)						
Details of Every Part					Price (£)	
Components:	**Value:**	**Tolerance:**	**Quantity:**	**Supplier:**	**Unit Price:**	**Total Price:**
Resistors:	10 Ω	5 %	30	MULTICOMP PRO	0.05	1.50
	910 Ω	5 %	10	MULTICOMP PRO	0.01	0.10
	1 KΩ	5 %	10	MULTICOMP PRO	0.01	0.10
	1.5 KΩ	5 %	10	MULTICOMP PRO	0.01	0.10
	3 KΩ	5 %	10	MULTICOMP PRO	0.01	0.10
	5.1 KΩ	5 %	40	MULTICOMP PRO	0.01	0.40
	12 KΩ	5 %	10	MULTICOMP PRO	0.01	0.10
	51 KΩ	5 %	20	MULTICOMP PRO	0.02	0.40
Capacitors:	100 pF	5 %	40	VISHAY	0.13	5.20
	330 pF	5 %	20	VISHAY	0.15	3.00
	1 µF	10 %	20	KEMET	0.08	1.60
	10 µF	10 %	20	KEMET	0.16	3.20
Inductor:	330 µH	20 %	30	BOURNS	0.33	9.90
Diode:	1N5819HW		20	MULTICOMP PRO	0.21	4.20
Transistors:	BC807-40W		40	NEXPERIA	0.10	4.00
ICs:	MC33063AD		20	TEXAS INSTRUMENTS	2.51	50.2
Header Pin (6 Contacts):			10	HARWIN	0.39	3.90
PCB (50×50 mm)			10	Fairfield (7 Days)	0.96	9.60
Sum (VAT Included):					**117.12**	

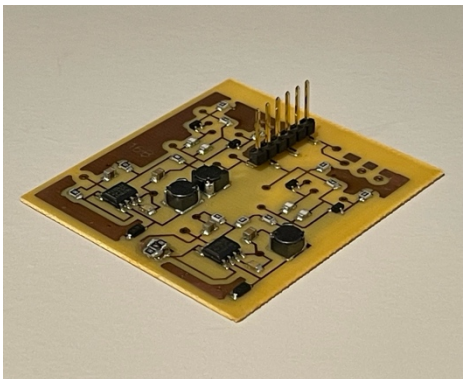
Non-Recurring Cost							
Engineering Salaries				**Equipment**		**Spare Materials**	**Shipping**
	Design	**Verification**	**Customer Support**	**Type**	**Cost (£)**		
Responsible Staff	**Design Engineer**	**Design Engineer**	**Technician**	**Reflow Oven**	1332.00	**10 DPS Circuits**	**UPS Economy (1 Day)**
				Soldering Station	17.70		
Wage (£) (VAT Included)	40/h	40/h	20/h	**Power Supply**	68.58		
				Multimeter	151.18		
Working hours	40 h	8 h	0.75 h	**Oscilloscope**	202.02		
				Jumper Wires	3.72		
Cost (£)	1600	320	15	1775.2		117.12	7.99
Sum:	**3835.31**						

Cost of a single DPS Board	
Part of Costs	**Cost (£)**
Recurring Cost	13.51
Non-Recurring Cost	3835.31
Cost per Board ($\text{Recurring Cost} + \frac{\text{Non-recurring Cost}}{\text{Number of Units Produced}}$)	32.69
Cost (200 Boards)	6537.31

Reference:

1. Farnell UK, https://uk.farnell.com/.
2. TECBRIDGE CIRCUITS, http://www.tecbridgecircuits.co.uk/priceform.php.

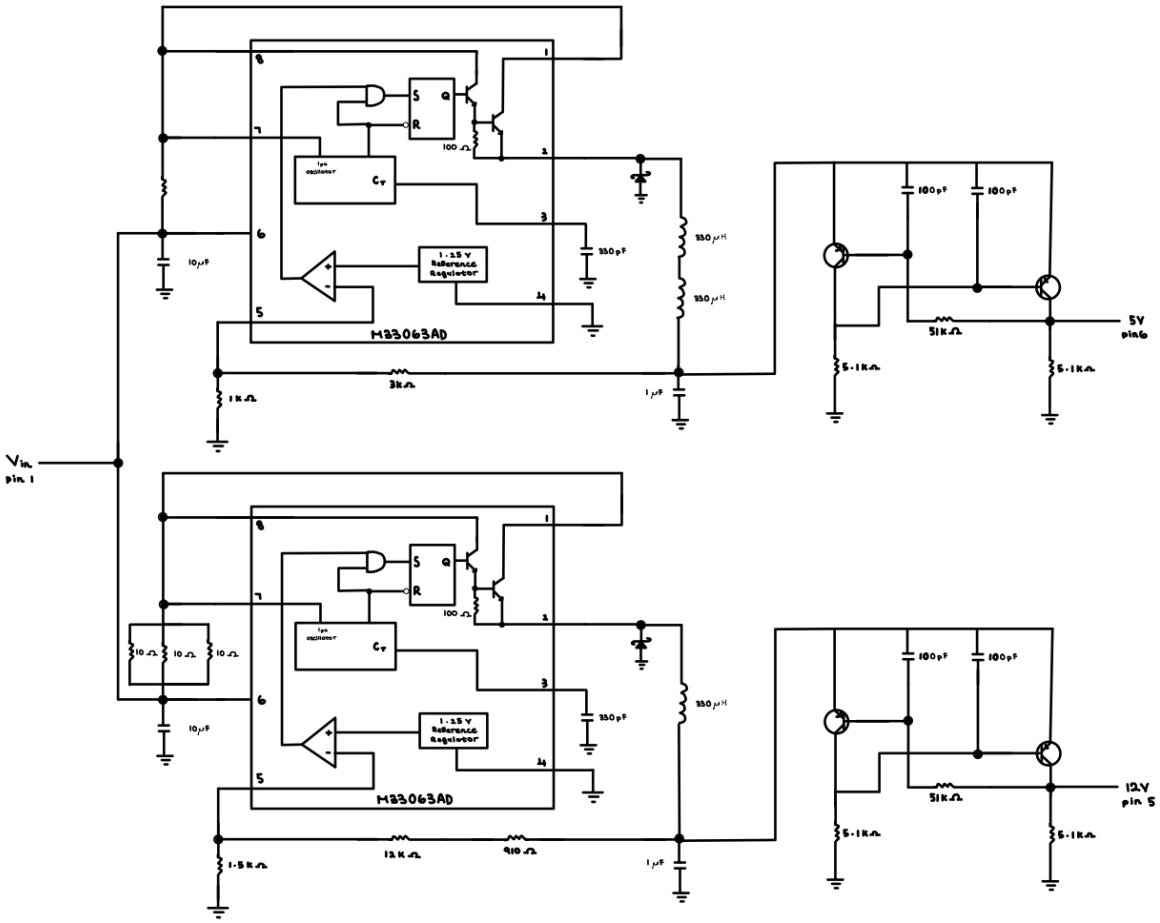
FEATURES



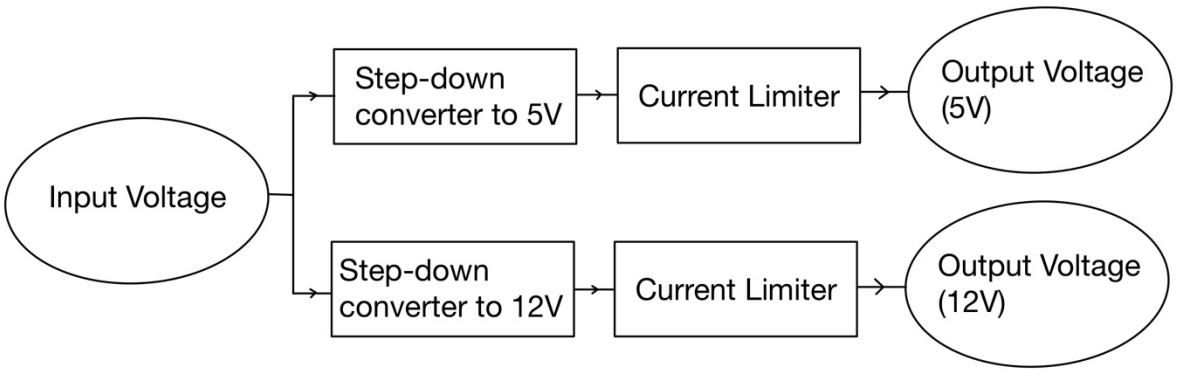
- **Input Voltages from 15 - 30V**
- **Outputs a constant voltage of 5V and 12V**
- **Steps down voltages using DC-DC Converter**
- **Maintains Voltage output from -40°C - 45°C**
- **Does not suffer damages at temperature below -40°C**
- **Current limiters to reduce short-circuit current**

The digital power supply is a circuit which provides a constant voltage of 5V and 12V. It contains DC-DC converters stepping down the voltage, followed by current limiter circuits which limits the short-circuit current. This digital power supply is built to survive cold weathers, surviving temperatures up to -40°C while having power efficiency of 63%.

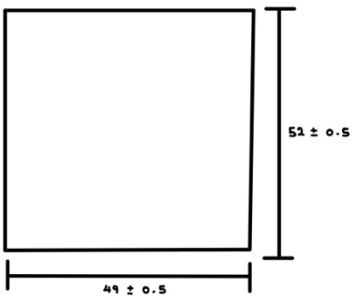
Circuit Diagram



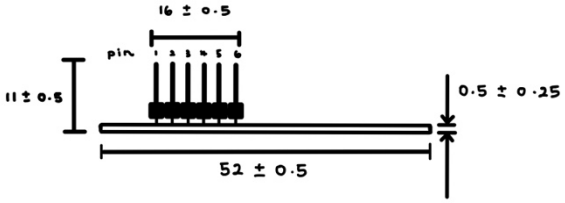
Flow Chart



Dimensions and Pinout



Top View



Side View

Pins:

1 – Input Voltage

2 – GND

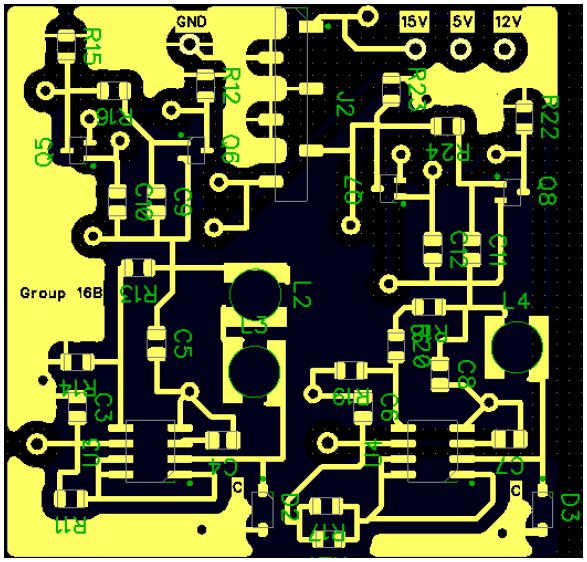
3 – GND

4 – GND

5 – 12V Output

6 – 5V Output

PCB Layout



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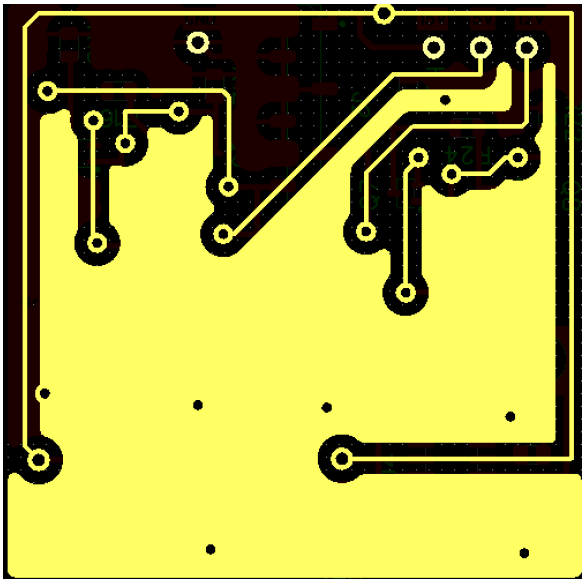

Bottom Layer

Mass..... 6g

Absolute Maximum Ratings over operating free-air temperature range (unless otherwise noted)

Operating Temperature ..... -40°C - 45°C

Maximum Input Voltage ..... 30 V

Maximum Output Voltage (5V) ..... 5.23 V

Maximum Output Voltage (12V) ..... 12.27 V

Maximum Output Current (5V) ..... 24 mA

Maximum Output Current (12V) ..... 48 mA

Storage Temperature ..... -40°C - 51°C

Recommended Operating Conditions

	MIN	MAX	UNIT
Input Voltage, V_{in}	15	22	V
Output Voltage, V_{out} (5V)	4.85	4.99	V
Output Voltage, V_{out} (12V)	11.81	11.99	V
Output Current, I_{out} (5V)		20	mA
Output Current, I_{out} (12V)		20	mA
Operating free-air temperature, T_A	0	40	°C

Electrical Characteristics

PARAMETERS	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Ripple (5V)	V_{in} = 16 V, T_A = 26°C		218		mV_{pp}
Ripple (12V)	V_{in} = 16 V, T_A = 26°C		322		mV_{pp}
Short- Circuit Current (5V)	V_{in} = 16 V, T_A = 26°C		88.0		µA
Short- Circuit Current (12V)	V_{in} = 16 V, T_A = 26°C		224.1		µA
Efficiency (5V)	V_{in} = 15V to 25V, T_A = 26°C	25	30	33	%
Efficiency (12V)	V_{in} = 15V to 25V, T_A = 26°C	47	54	57	%
Efficiency (5V and 12V)	V_{in} = 15V to 25V, T_A = 26°C	50	59	53	%
Input Impedance	V_{in} = 16 V, T_A = 26°C		0.53		MΩ
Output Impedance (5V)	V_{in} = 16 V, T_A = 26°C		4.54		kΩ
Output Impedance (12V)	V_{in} = 16 V, T_A = 26°C		4.53		kΩ

Typical Characteristics

*tests are done under $T_A = 26°C$

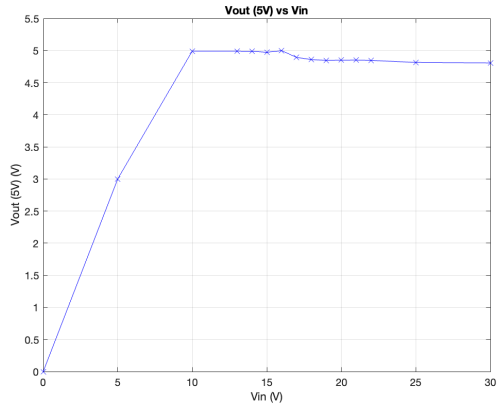

Figure 1: Output Voltage (5V) vs Input Voltage

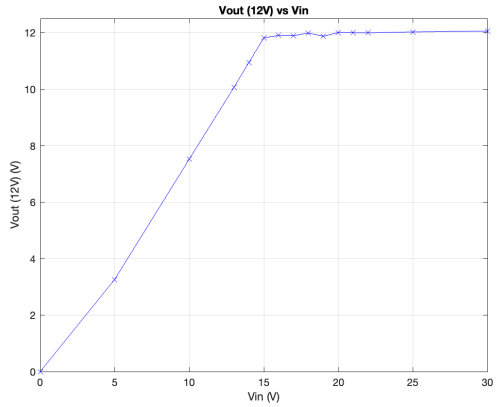

Figure 2: Output Voltage (12V) vs Input Voltage

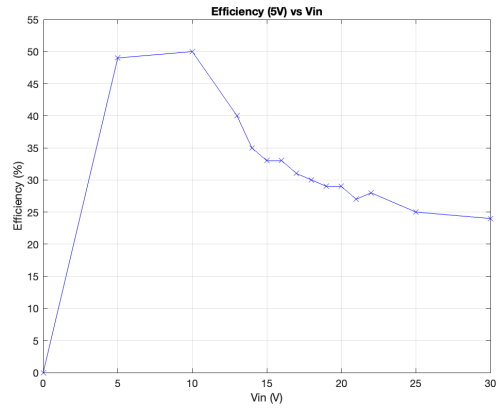

Figure 3: Efficiency (5V) vs Input Voltage

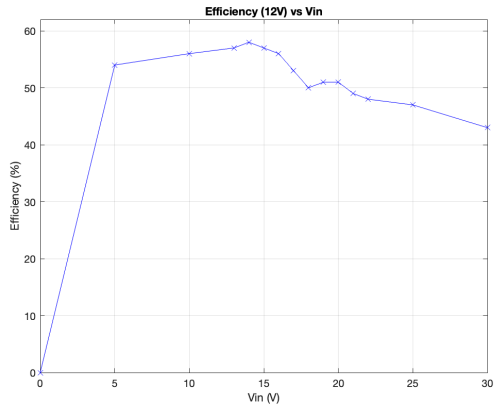

Figure 4: Efficiency (12V) vs Input Voltage

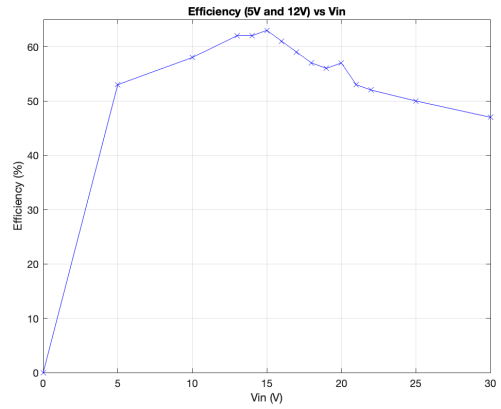

Figure 5: Efficiency (5V and 12V) vs Input Voltage

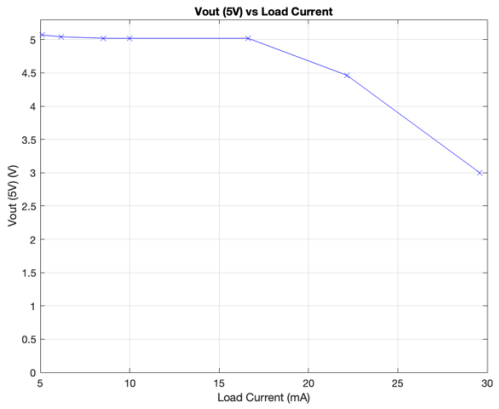

Figure 6: Output Voltage (5V) vs Load Current

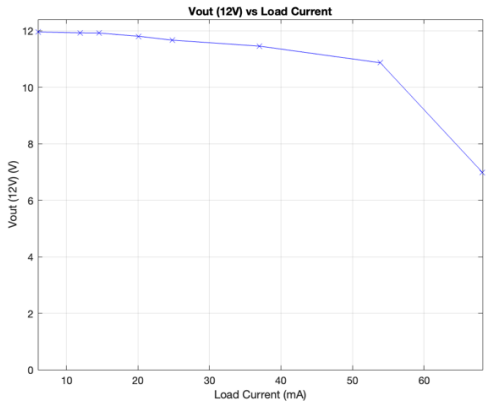

Figure 7: Output Voltage (12V) vs Load Current

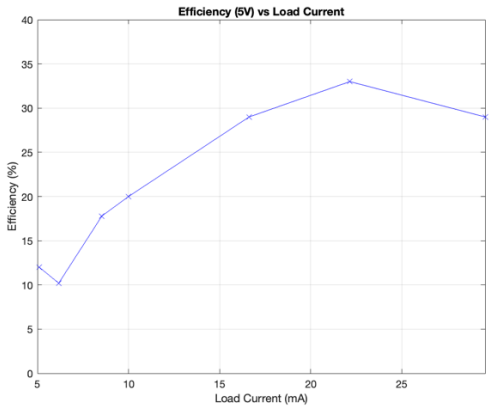

Figure 8: Efficiency (5V) vs Load Current

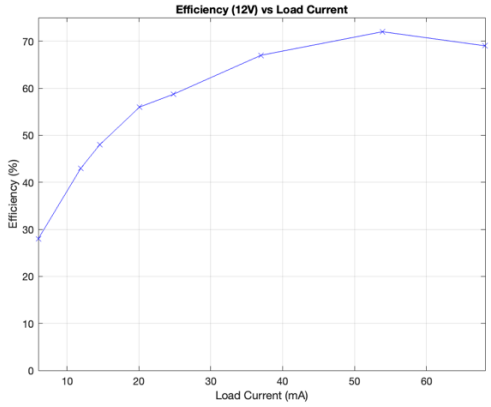

Figure 9: Efficiency (12V) vs Load Current

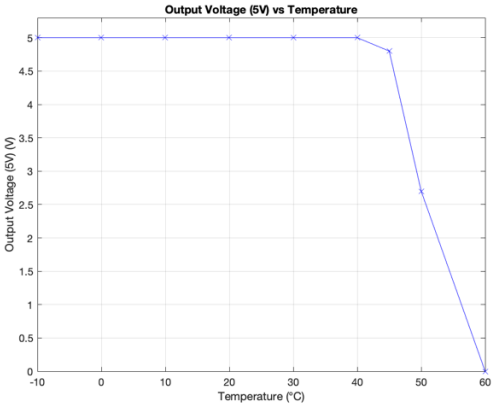

Figure 10: Output Voltage (5V) vs Temperature

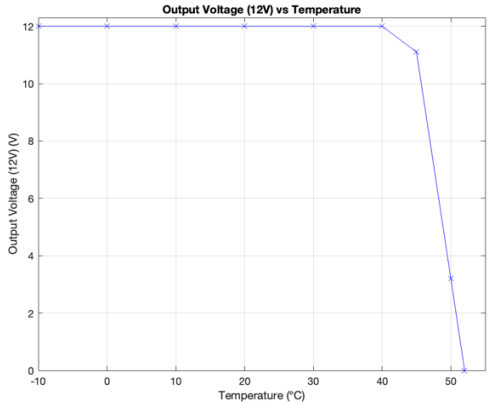

Figure 11: Output Voltage (12V) vs Temperature

Parts List:

Components:	Value:	Tolerance:	Quantity:	Supplier:
Resistors:	10 Ω	5 %	3	MULTICOMP PRO
	910 Ω		1	
	1 kΩ		1	
	1.5 kΩ		1	
	3 kΩ		1	
	5.1 kΩ		4	
	12 kΩ		1	
	51 kΩ		2	
Capacitors:	100 pF	5 %	4	VISHAY
	330 pF		2	
	1µF	10 %	2	KEMET
	10 µF		2	
Inductors:	330 µH	20 %	3	BOURNS

Diode:	1N5819HW	2	MULTICOMP PRO
Transistors:	BC807 – 40W	4	NEXPERIA
ICs:	MC33063AD	2	TEXAS INSTRUMENT
Header Pins (6 Contacts):		1	HARWIN
PCB (50 mm x 50 mm)		1	Fairfield (7 Days)