Selected PCB Justification

Group 29

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List of Contents

Circuit 1

Designed by Enxu Liu

1. Multisim schematics and outputs

The PCB receives an input voltage of 10V to give an output of 12V and an output of 5V. The circuit uses two UA723CD voltage regulator chips, along with a MC33063AD DC-DC converter. The short circuit protection harnesses the built-in protection of UA723CD chips along with a short-circuit protection resistance. The circuit schematics is shown in Figure 1.1 below.

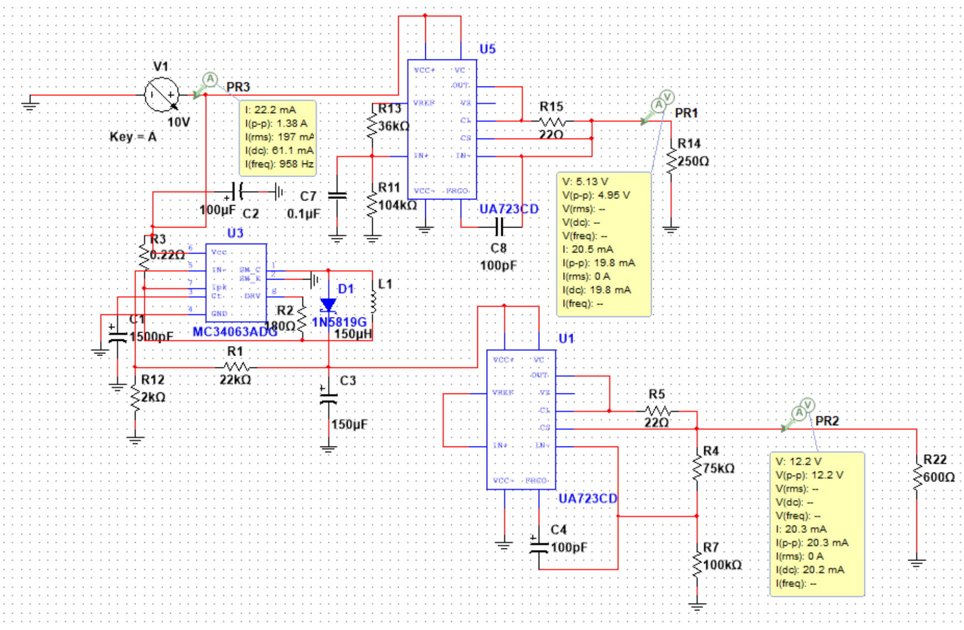

Figure 1.1: Circuit schematics of circuit 1

It can be seen that:

The 5V terminal outputs a 5.13V.
The 12V terminal outputs a 12.2V.
Output current for both terminals reach 20mA.

2. Power Efficiency

Efficiency of 5V terminal alone: 5.13*20.5/10*22.2=47.3%
Efficiency of 12V terminal alone:12.2*20.1/10*38=64.5%

Overall efficiency: $\frac{5.13*19.8+12.2*20.2}{10 *61.1} = 57.0\%$

3. Short circuit current:

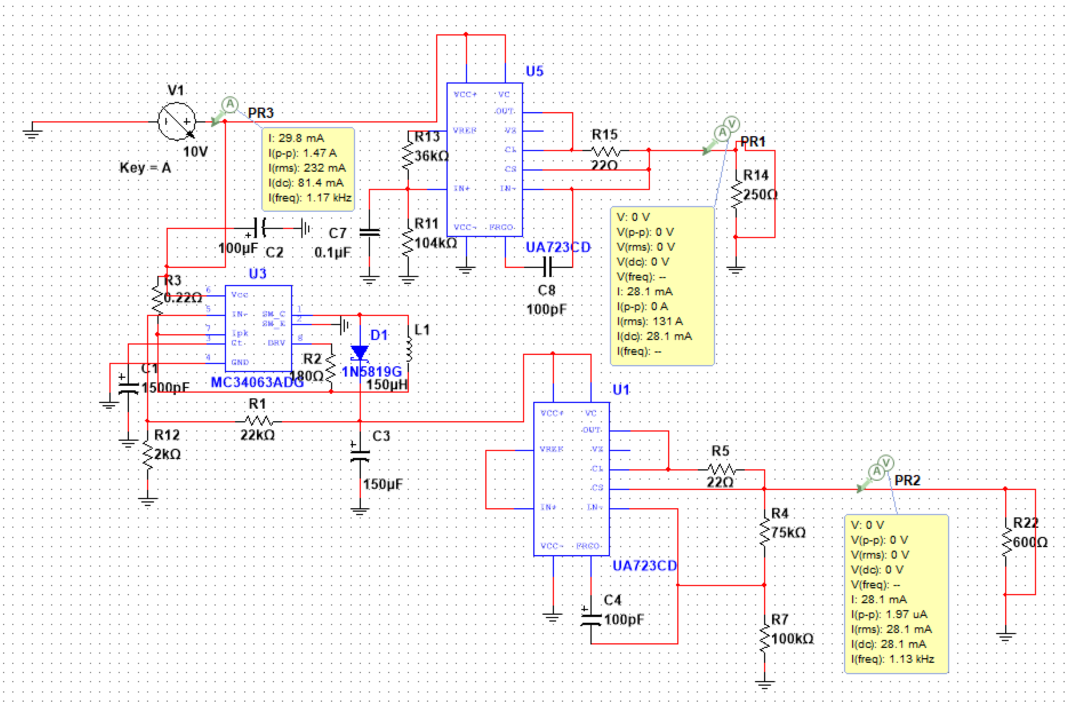

Figure 1.2: Short circuit testing for circuit 1

The short circuit current of 5V terminal:28.1mA
The short circuit current of 12V terminal:28.1mA

4. Input voltage range

The input voltage range is from 8 V to 10.8 V, with the nominal input voltage at 10 V.

5. PCB design

(a) (b)

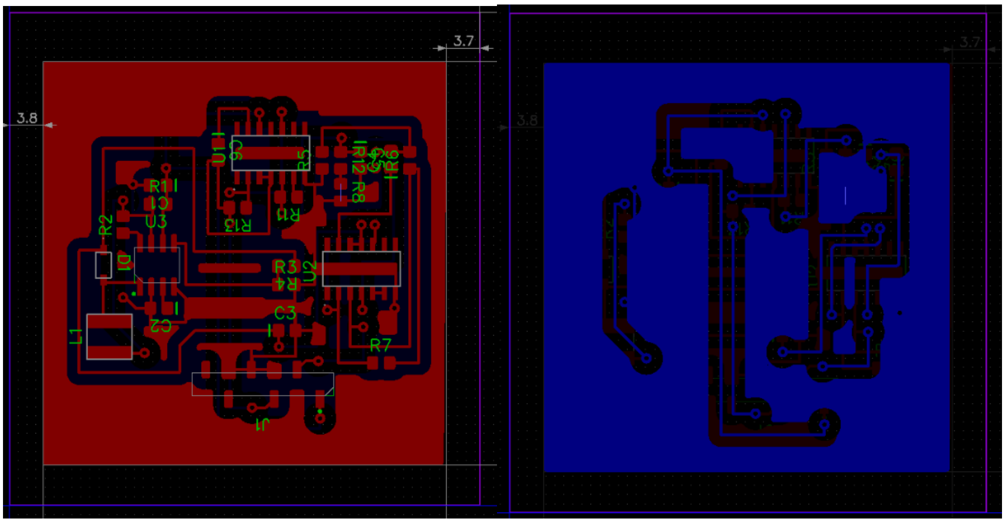

Figure 1.3: PCB Design of circuit 1 for (a) Top Side; (b) Bottom Side

6. Conclusion

Circuit 1 outputs steady voltages of 5V and 12V with short circuit protection achieved. However, its input voltage range is a bit small and its efficiency a bit lower than 60%.

Circuit 2 ----- Designed by Alex Jitaru

1. Multisim schematics and outputs

This design has an input voltage of 15 V to provide 12 V and 5 V on two outputs. Each branch utilizes a TL317 adjustable regulator to limit the output voltages to 5 and 12 V. At the start of each branch, a current limiter circuit is included to prevent the short circuit of 30 mA from being exceeded. Each current limiter consists of two NPN transistors (BC817-40W) and two resistors. The circuit schematics is shown in Figure 2.1 below.

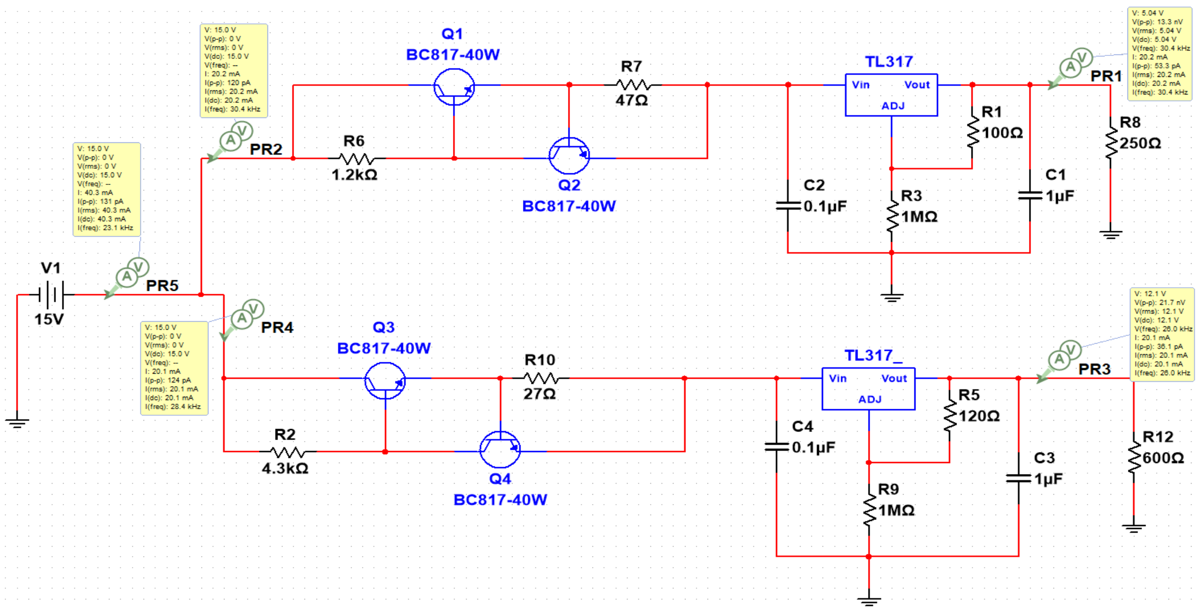

Figure 2.1: Circuit schematics of circuit 2

The outputs are 5.04 V and 20.2 mA for the 5 V branch and 12.1 V and 20.1 mA for the 12 V.

2. Power efficiency

5V branch efficiency: $\left(\frac{5.04 * 20.2}{15 * 20.2}\right) * 100 = 33.6\,\%$

12V branch efficiency: $\left(\frac{12.1 * 20.1}{15 * 20.1}\right) * 100 = 80.67\,\%$

Overall efficiency: $\frac{(5.04 * 20.2) + (12.1 * 20.1)}{15 * 40.3} * 100 = 57.07\,\%$

3. Short circuit current

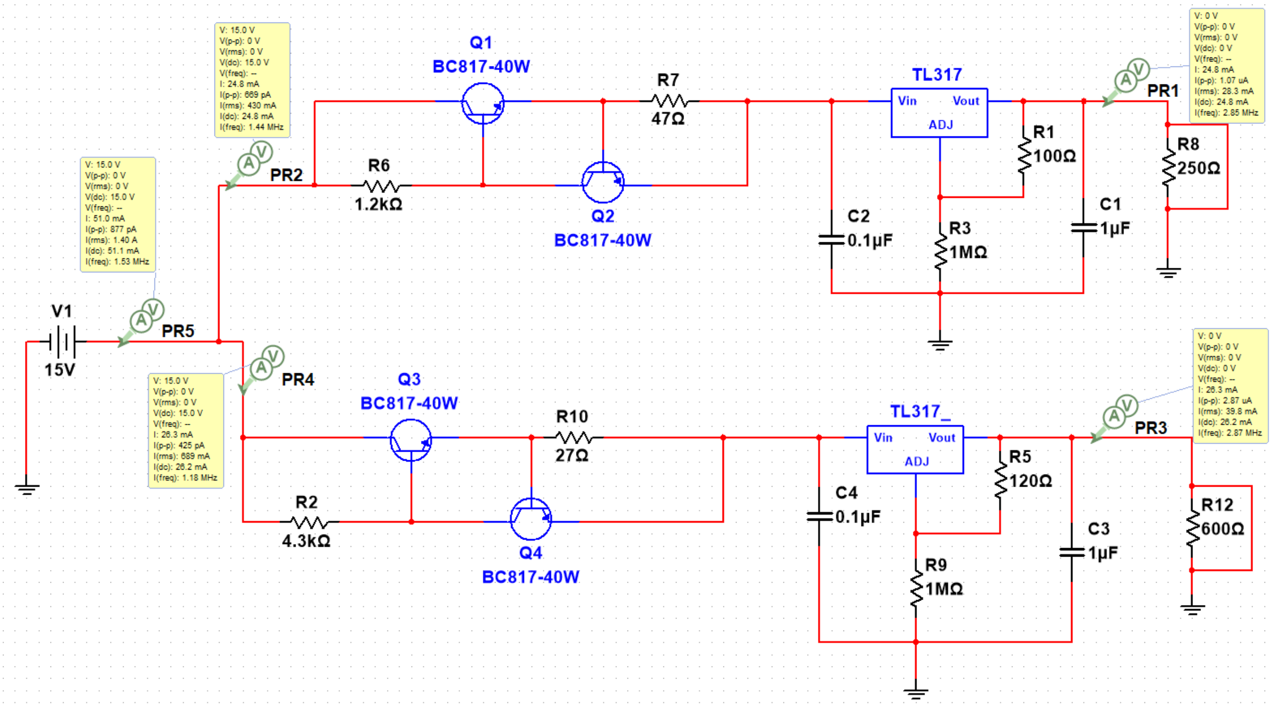

Figure 2.2: Short circuit testing for circuit 2

5V branch short-circuit current: 24.8 mA

12V branch short-circuit current: 26.3 mA

4. Input voltage range

The input voltage range is from 14.8 V to 15.8 V, with the nominal input voltage at 15 V.

5. PCB design

(a) (b)

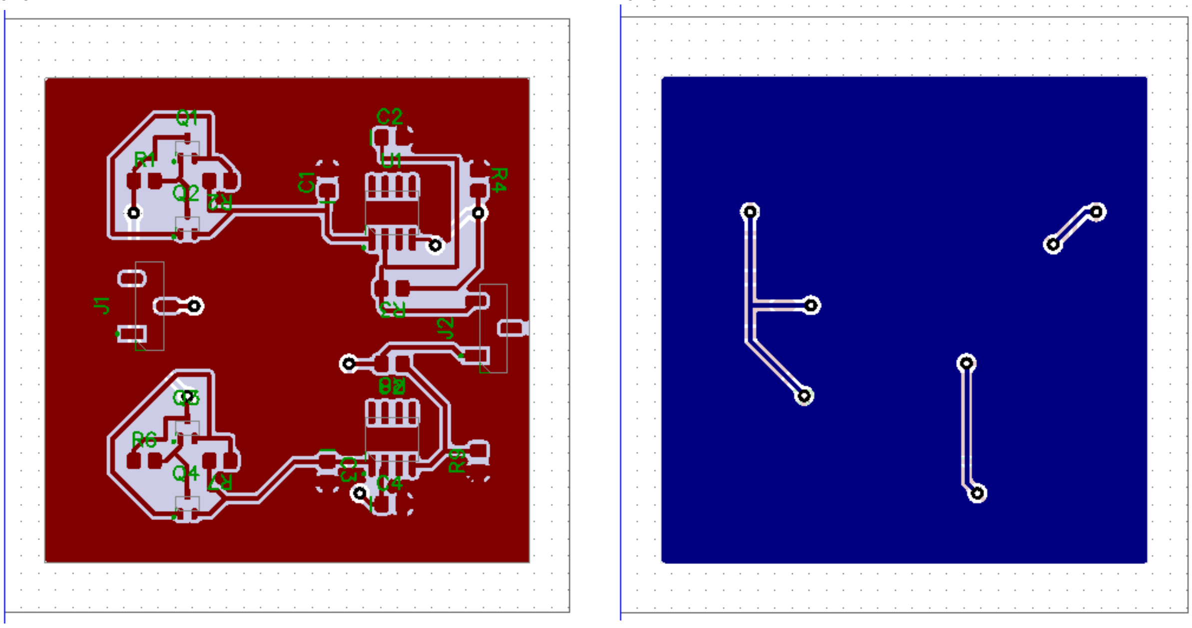

Figure 2.3: PCB Design of circuit 2 for (a) Top Side; (b) Bottom Side

6. Conclusion

Circuit 2 outputs steady voltages of 5V and 12V with short circuit protection achieved. However, its input voltage range is a bit small and its efficiency a bit lower than 60%.

Circuit 3

Designed by Tyler Hosein

1. Multisim circuit schematics and outputs

This power supply circuit was designed using the 12V voltage regulator IC (MC78M12CDTG) and the 5V voltage regulator IC (MC78M05CDTG), supplied by 14.5V simultaneously. To create short circuit protection, NPN BJT transistors (BC817-40W) and PNP BJT transistors (BC807 -40W) were used. The circuit schematics is shown in Figure 3.1 below.

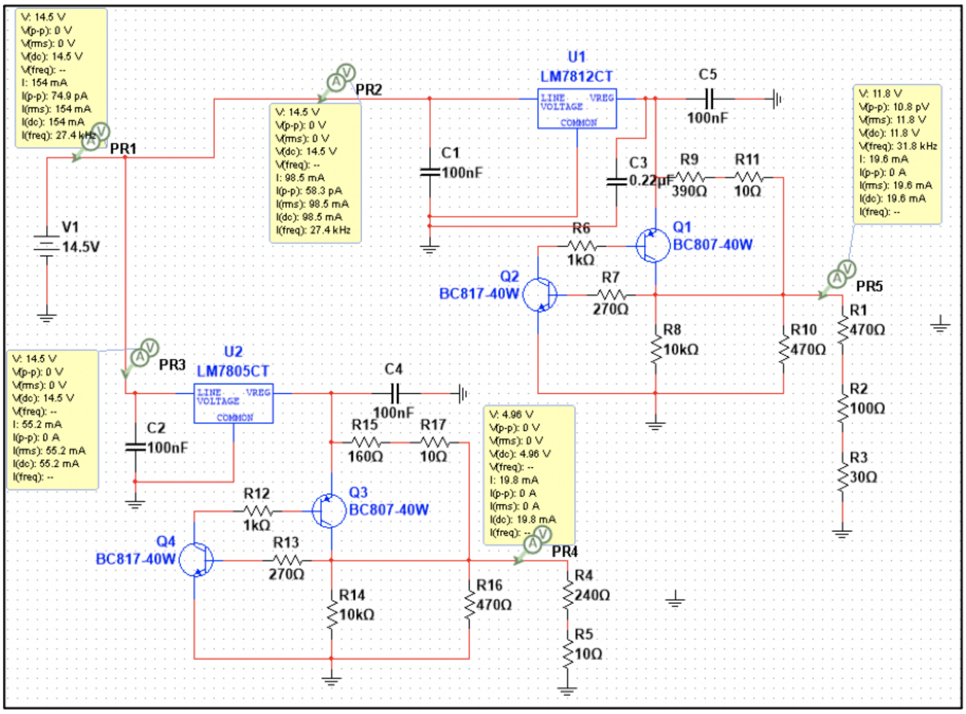

Figure 3.1: Circuit schematics of circuit 3

Figure 3.1 shows the required output voltages and currents at both the 12V and 5V outputs. As shown above:
Output at 12V = 11.8V, output current = 19.6mA
Output at 5V = 4.96V, output current = 19.8mA

2. Power efficiency

5V output alone:

Input power, $\mathrm{Pin} = \mathrm{Vin} * \mathrm{Iin} = 14.5 * 0.0552 = 0.8004\mathrm{W}$

Output power, $\mathrm{Pout\_5} = \mathrm{Vout} * \mathrm{Iout} = 4.96 * 0.0198 = 0.098208\mathrm{W}$

Efficiency = $\left(\frac{\mathrm{Pout}}{\mathrm{Pin}}\right) * 100 = \left(\frac{0.098208}{0.8004}\right) * 100 = 12.27\%$

12V output alone:

Input power, $\mathrm{Pin} = \mathrm{Vin} * \mathrm{Iin} = 14.5 * 0.0985 = 1.42825\mathrm{W}$

Output power, $\mathrm{Pout\_12} = \mathrm{Vout} * \mathrm{Iout} = 11.8 * 0.0196 = 0.23128\mathrm{W}$

Efficiency = $\left(\frac{\mathrm{Pout\_12}}{\mathrm{Pin}}\right) * 100 = \left(\frac{0.23128}{1.42825}\right) * 100 = 16.19\%$

Overall efficiency:

Overall input, $\mathrm{Pin\_ov} = 14.5 * 0.154 = 2.233\mathrm{W}$

Overall Efficiency = $\left(\frac{\mathrm{Pout\_12} + \mathrm{Pout\_5}}{Pin\_ov}\right) * 100 = \left(\frac{0.23128 + 0.098208}{2.233}\right) * 100 = 14.76\%$

From the above calculations, it can be seen that the efficiency of the circuit designed was well below the required value of >60% efficiency.

3. Short circuit outputs

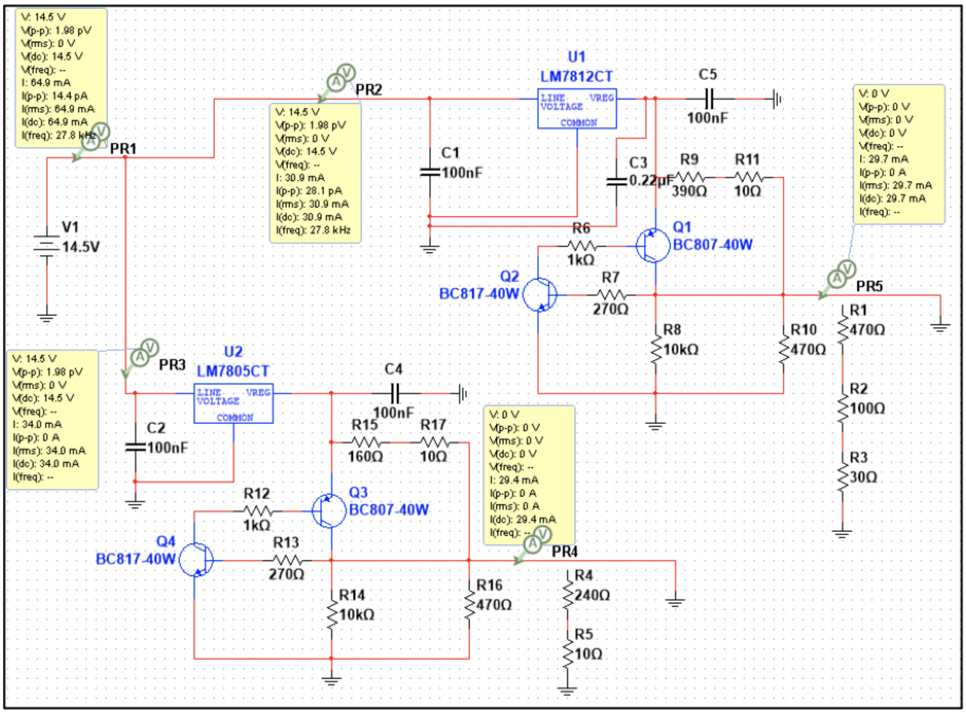

Figure 3.2: Short circuit testing for circuit 3

Figure 3.2 is showing short circuit current outputs at both 12V and 5V outputs when shorted.
As seen above:
Short circuit current at 12V output = 29.7mA
Short circuit current at 5V output = 29.4mA

4. Input voltage range

The input voltage range is from 13.2 V to 16.8 V, with the nominal input voltage at 14.5 V.

5. PCB Design:

(a) (b)

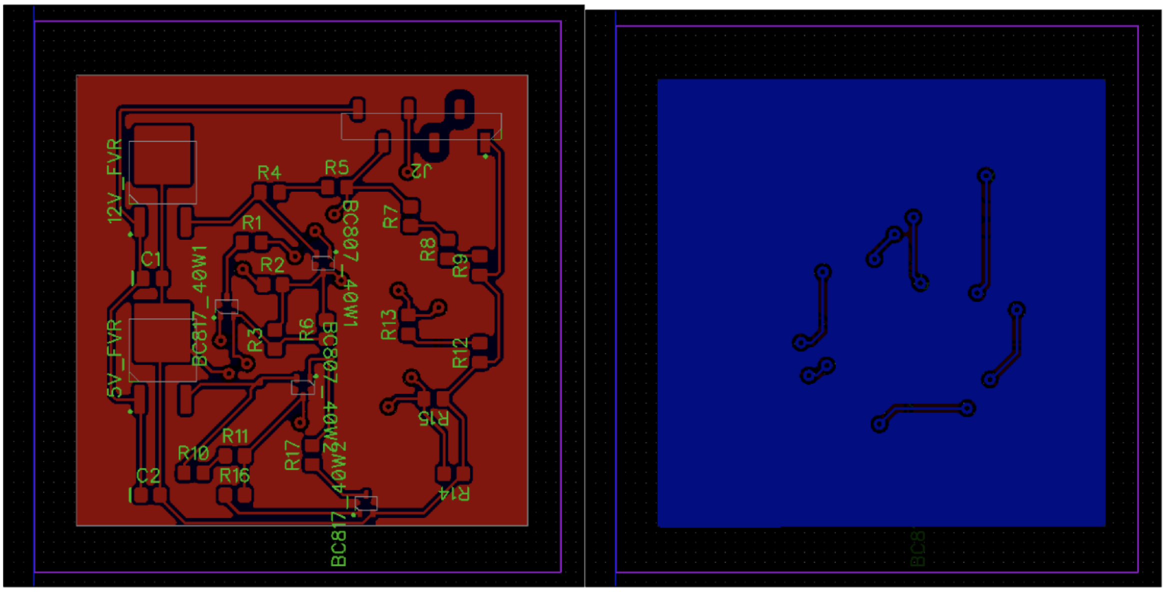

Figure 3.3: PCB Design of circuit 3 for (a) Top Side; (b) Bottom Side

6. Conclusion

Circuit 3 outputs steady voltages of 5V and 12V with short circuit protection achieved. However, its power efficiency is much less than 60%.

Circuit 4

Designed by Wenbo Chen

1. Multisim circuit schematics and outputs

This circuit use 3V as an input with two step-up DC-DC converters and two current limiters to control the short circuit currents. The circuit schematics is shown in Figure 4.1 below.

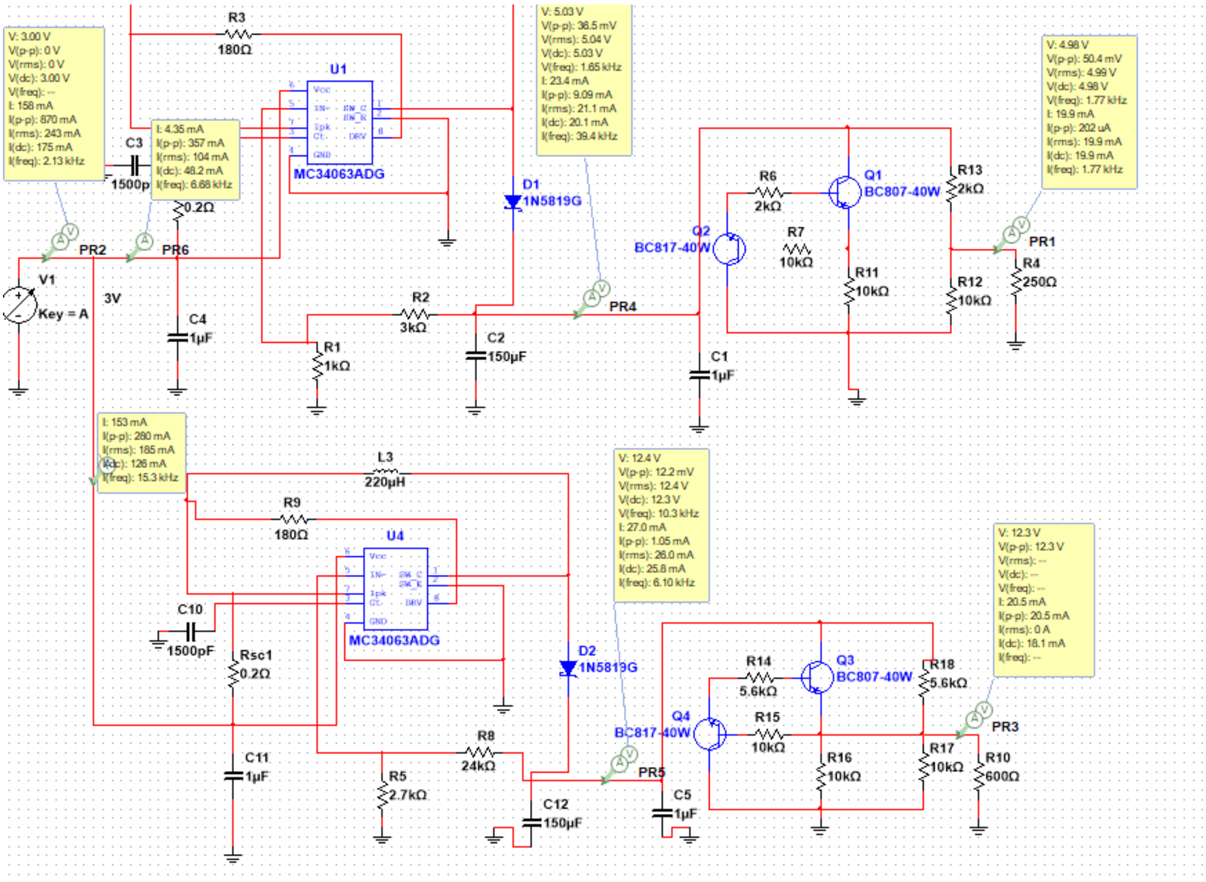

Figure 4.1: Circuit schematics of circuit 4

Input voltage: 3V
5V circuit output: 4.98V, 19.9mA
12V circuit output: 12.3V, 20.5mA

2. Power Efficiency

5V: 5V: 99.1mW/144.6mW=68.5%
12V: 264.5mW/387mW=68.3%
Overall: 363.6mW/531.6mW=68.4%

3. Short-circuit current

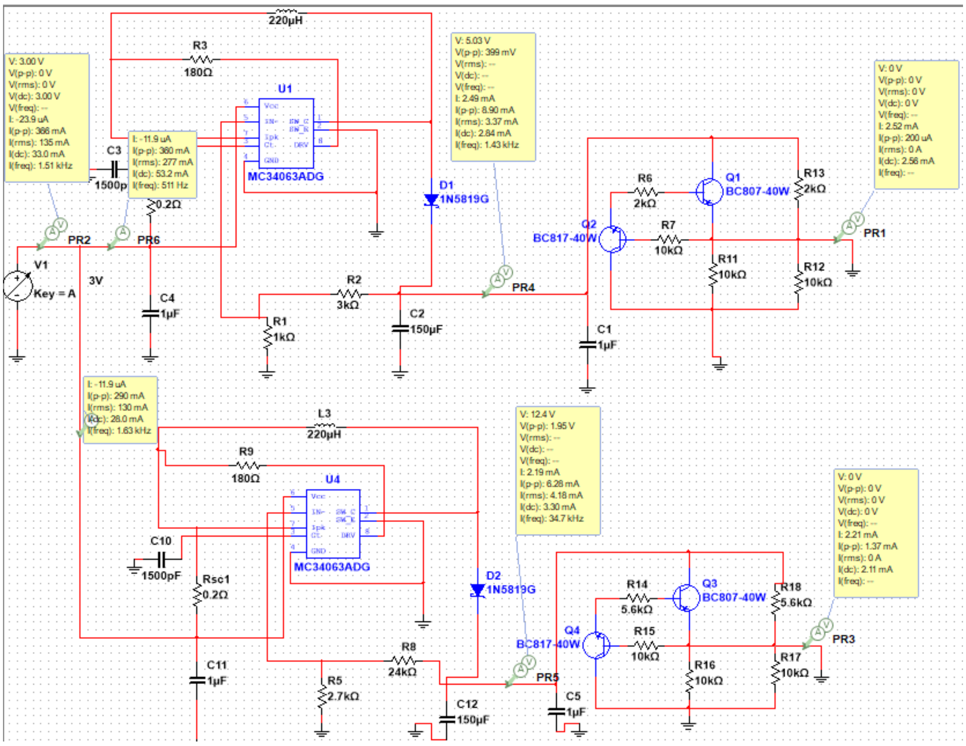

Figure 4.2: Short circuit testing for circuit 4

It can be seen that the short circuit current for 5V is 2.56mA and 12V is 2.11mA.

4. Input voltage range

The operating range of the input is from 3V to 4V (The input cannot be lower than 3V for the IC chip and higher than 4V due to the requirement specification)

5. PCB Design (1 of the 2 implementing)

(a) **(b)**

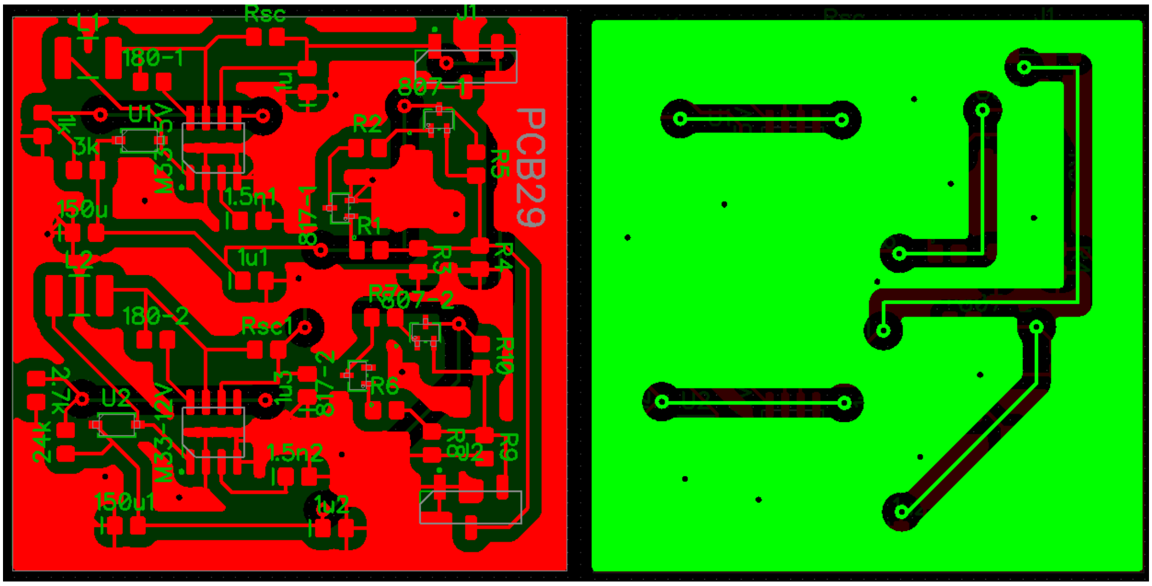

Figure 4.3: PCB Design of circuit 4 for (a) Top Side; (b) Bottom Side

6. Conclusion

Circuit 4 has a desirable efficiency of 68.4% with short circuit protection achieved. However, testing in real life shows that the DC-DC converter MC33063AD will make the voltage output fluctuate significantly. Also, this circuit has too many component therefore it is difficult to be manufactured.

Circuit 5

Designed by ChenChen Deng

1. Multisim circuit schematics and outputs:

This circuit use 7V as an input with one step-up DC-DC converter, one step-down DC-DC converter and two current limiters for the short circuit current control. The circuit schematics is shown in Figure 5.1 below.

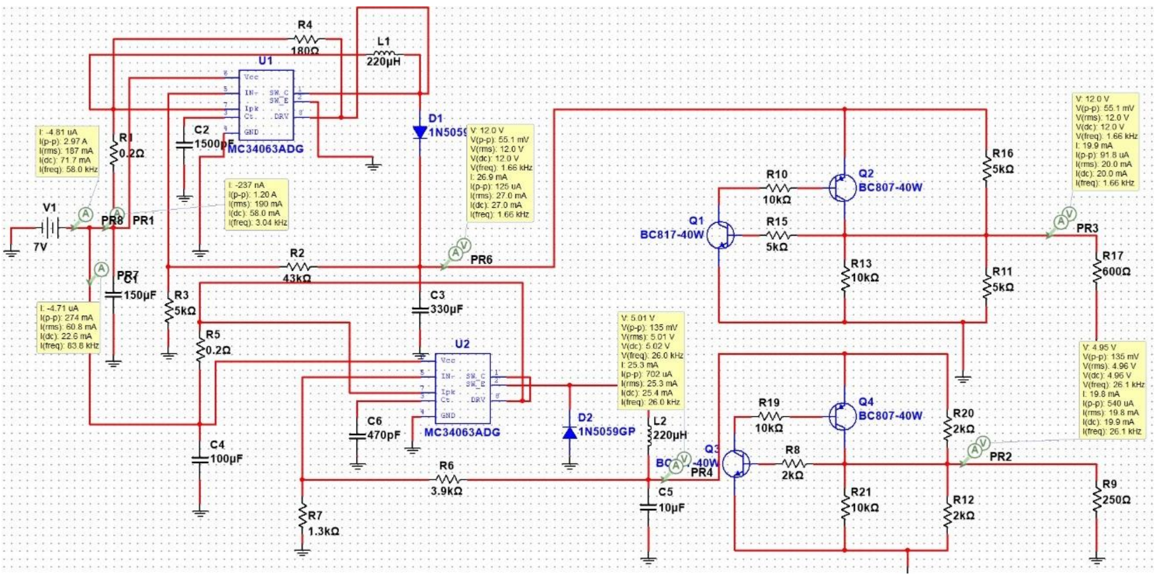

Figure 5.1: Circuit schematics of circuit 5

The input is 7V, output for 12V is 12V and output for 5V is 4.95V.

2. Power efficiency

For 5V: $\frac{4.95V \times 19.8mA}{7V \times 22.6mA} = 61.9\%$

For 12V: $\frac{12V \times 19.9mA}{7V \times 58mA} = 58.8\%$

Overall efficiency: $\frac{4.95V\times19.8mA+12V\times19.9mA}{7V\times80.6mA} = 59.7\%$

3. Short circuit current

Short circuit currents: N/A

4. Input voltage range

The input voltage range is from 6 V to 8.5 V, with the nominal input voltage at 7 V.

5. PCB Design

(a) **(b)**

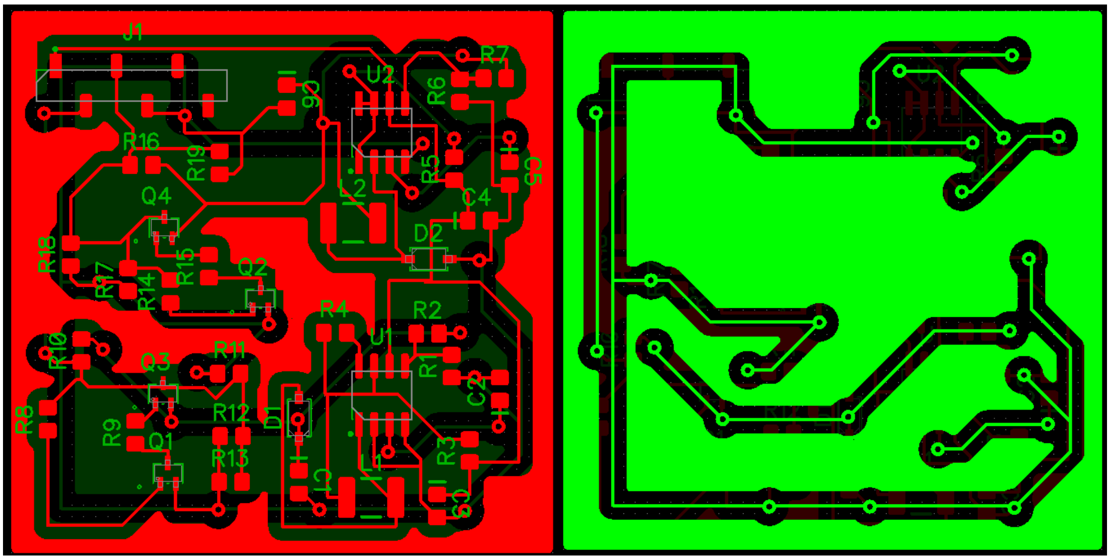

Figure 5.2: PCB Design of circuit 5 for (a) Top Side; (b) Bottom Side

6. Conclusion

Circuit 5 has a desirable efficiency at around 60%. However, the short circuit protection is not achieved. Also, testing in real life shows that the DC-DC converter MC330 will make the voltage output fluctuate significantly.

Circuit 6 (Final Chosen One)

Designed by Yanjun Zhou

1. Multisim circuit schematics and outputs

The circuit only uses two IC chips and both of them are UA723CD. The 5V branch is formed by the "Basic Low-Voltage Regulator" configuration of UA723CD and the 12V branch is formed by the "Basic High-Voltage Regulator" configuration of UA723CD. Both of the branches are supplied with an input voltage of 14V. The circuit schematics is shown in Figure 6.1 below.

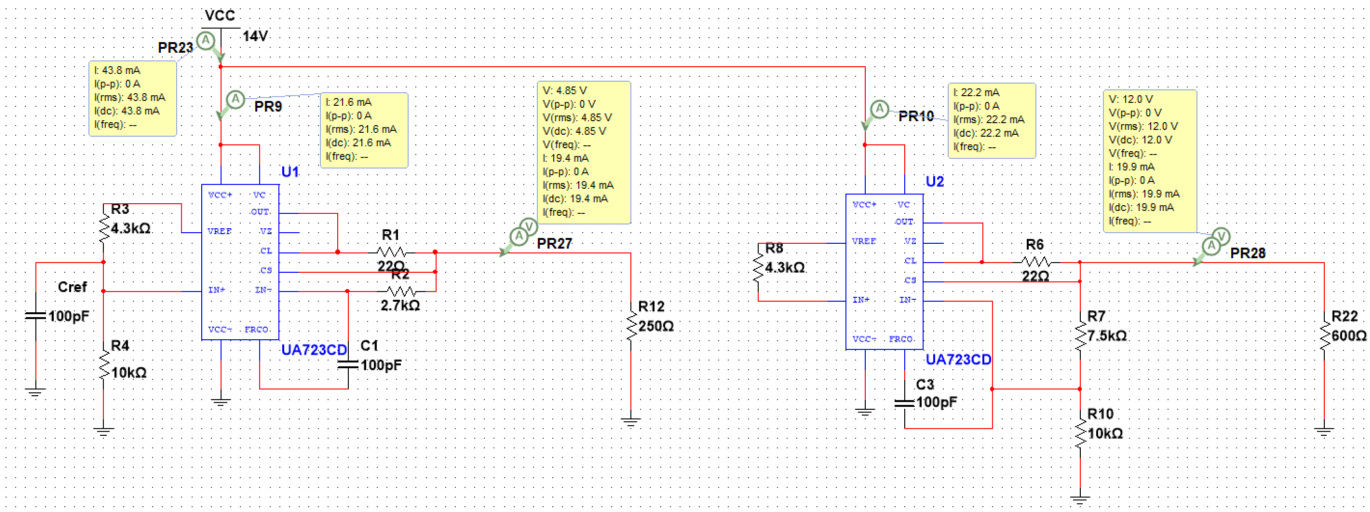

Figure 6.1: Circuit schematics of circuit 1

Input voltage: 14V, Input current: 43.8mA
5V circuit output: 4.85V, 19.4mA
(Note: Setting R3 = 3.9k will make output to 5V, but this is not the case in real life. In real life, the output will get closer to 5V when R3 = 4.3k. As a result, R3 is kept at 4.3k.)
12V circuit output: 12.0V, 19.9mA

2. Power Efficiency Calculation

5V branch:

$$\text{Input power} = \text{Vin} * \text{Iin} = 14\text{V} * 21.6\text{mA} = 302.4\text{mW}$$

$$\text{Output power} = \text{Vout} * \text{Iout} = 4.85\text{V} * 19.4\text{mA} = 94.09\text{mW}$$

$$\text{Efficiency} = \frac{94.09\text{mW}}{302.4\text{mW}} = 31.1\%$$

12V branch

$$\text{Input power} = \text{Vin} * \text{Iin} = 14\text{V} * 22.2\text{mA} = 310.8\text{mW}$$

$$\text{Output power} = \text{Vout} * \text{Iout} = 12.0\text{V} * 19.9\text{mA} = 238.8\text{mW}$$

$$\text{Efficiency} = \frac{238.8\text{mW}}{310.8\text{mW}} = 76.8\%$$

Overall

Overall input voltage = 14V
Overall input current = 43.8mA

$$\text{Overall Input power} = \text{Vin} * \text{Iin} = 14\text{V} * 43.8\text{mA} = 613.2\text{mW}$$

$$\text{Overall Output power} = \text{Pout\_5V} + \text{Pout\_12V} = 94.09\text{mW} + 238.8\text{mW}$$
$$= 332.89\text{mW}$$

$$\text{Overall Efficiency} = 332.89\text{mW} / 613.2\text{mW} = 54.3\%$$

3. Short circuit current

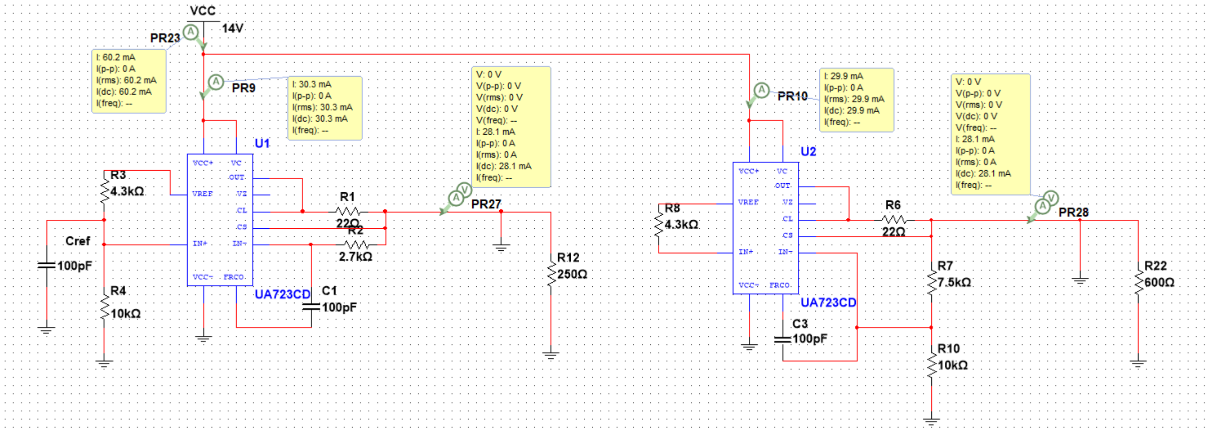

Figure 6.2: Short circuit testing for circuit 6

The short circuit currents are 28.1mA for both 5V and 12V circuit.

4. Input voltage range

The input voltage range is from 13.2 V to 16.8 V, with the nominal input voltage at 14 V.

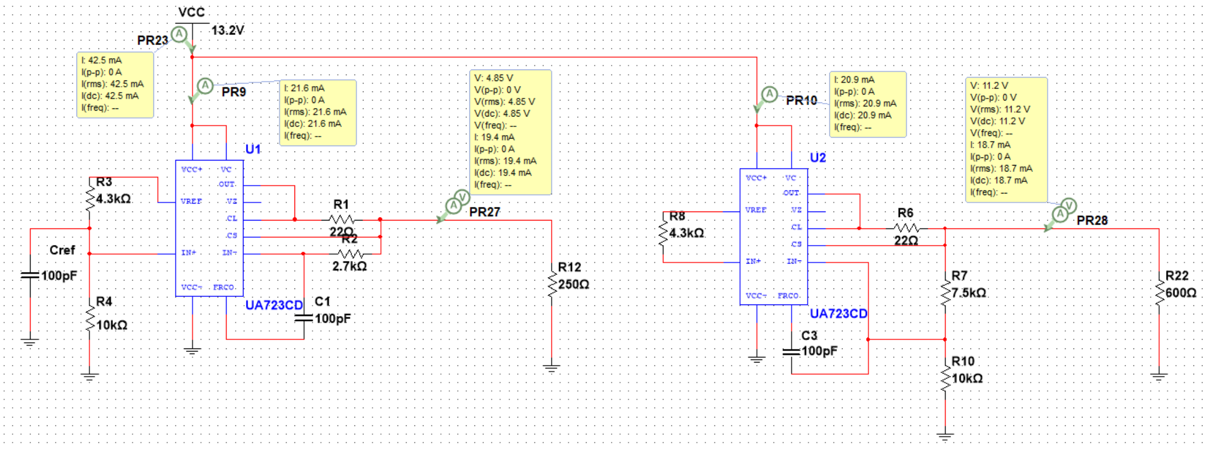

Figure 6.3: Operation of circuit 6 at 13.2V input

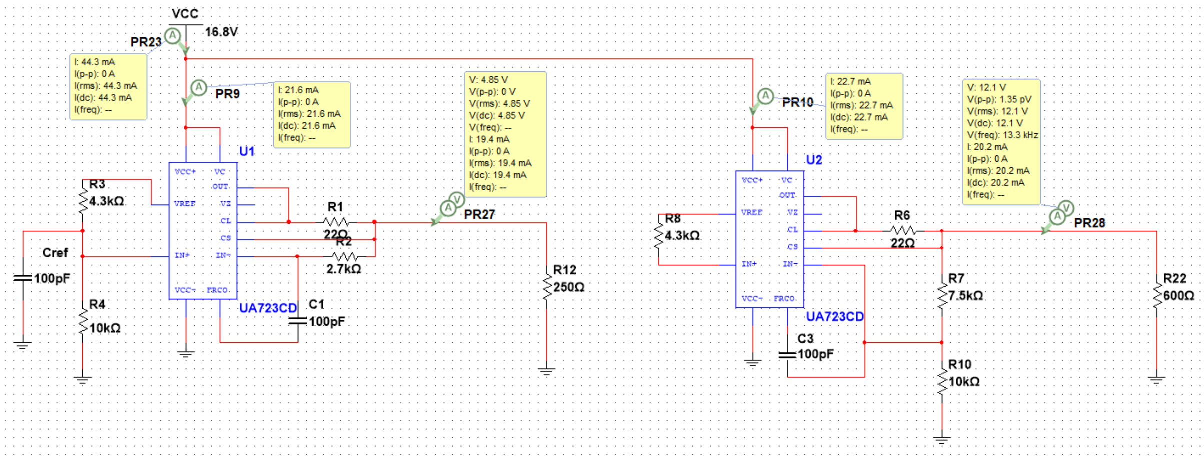

Figure 6.4: Operation of circuit 6 at 16.8V input

When input is 13.2V, the 12V circuit outputs 11.2V, which is the lowest acceptable output according to the specification.

The higher bound 16.8V is the higher bound in the specification document, which is 20% from nominal. When the input is 16.8V, the 12V circuit outputs 12.1V, which is lower than the highest acceptable output according to the specification.

5. PCB design

(a) **(b)**

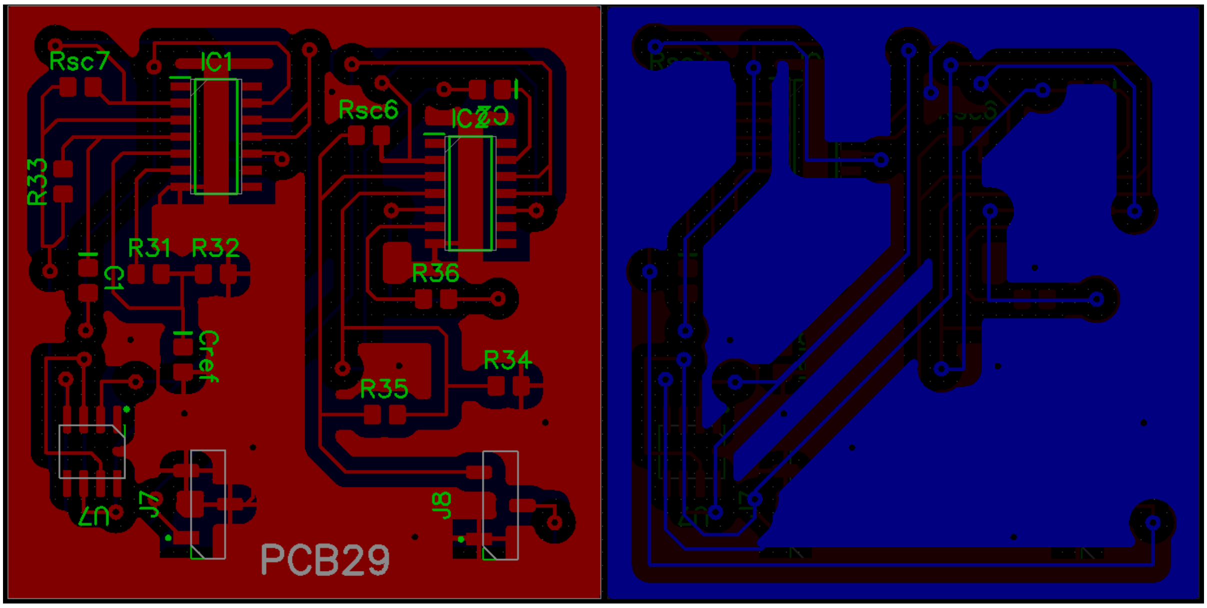

Figure 6.5: PCB Design of circuit 6 for (a) Top Side; (b) Bottom Side

6. Conclusion

Circuit 6 outputs steady voltages of 5V and 12V with short circuit protection achieved. It also accepts a wide range of input voltage. However, its efficiency a bit lower than 60%.

Justification of Choice

Summarization of drawbacks of all circuits
Circuit 1: (i) Small input voltage range; (ii) Efficiency a bit lower than 60%
Circuit 2: (i) Small input voltage range; (ii) Efficiency a bit lower than 60%
Circuit 3: (i) The efficiency is much lower than 60%
Circuit 4: (i)The DC-DC converter MC33063AD makes the voltage output fluctuate significantly in real life; (ii) Having too much components therefore difficult to manufacture.
Circuit 5: (i)Cannot perform short circuit protection. (ii)The DC-DC converter MC330 makes the output fluctuate significantly in real life.
Circuit 6: (i) Efficiency a bit lower than 60%

It can be seen that all circuits have some aspects that do not reach the requirements. Circuit 6 is chosen because it has the least number of drawbacks. The only problem it has is efficiency and everything else works fine. The efficiency is just a little bit below 60%, so this shouldn't be a big problem. Another advantage of circuit 6 is that it is easy to be manufactured, as the PCB layout is not very complicated.

Another reason that circuit 6 is chosen is that its simulation result on Multisim reflect reality better. The results shown above are all based on simulations on Multisim. However, some of the IC chips (e.g MC33063AD) used in other circuits cannot be found in Multisim, so alternative chips are used to replace them. Those alternatives may not have the same behaviour as the original one, which reduces the reliability of those designs. In other words, the operation of those circuits in real life might be very different to simulations. By contrast, circuit 6 only uses one type of IC chip called UA723CD and this type of chip can be found on Multisim. This means that the simulation of circuit 6 reflects the reality better, making this design more reliable than others.

Performance of Circuit 6 in Real Life

1. Actual Output

Voltage

Figure 7.1 Scope capture of voltage output at Vin=14V

Output voltage for the 5V supply: 5.004 V

Output voltage for the 12V supply: 11.997 V

Vp-p: still exists if the scope is not connected to anything. It is caused by noise inferences in the background not the circuit itself. (The voltage output of circuit itself is stable)

Current

Figure 7.2 Output current for 5V when RL=253Ω

Figure 7.3 Output current for 12V when RL=611Ω

Overall, it can be seen that the output current and voltage are all at expected value.

2. Power efficiency calculation

(a) **(b)**

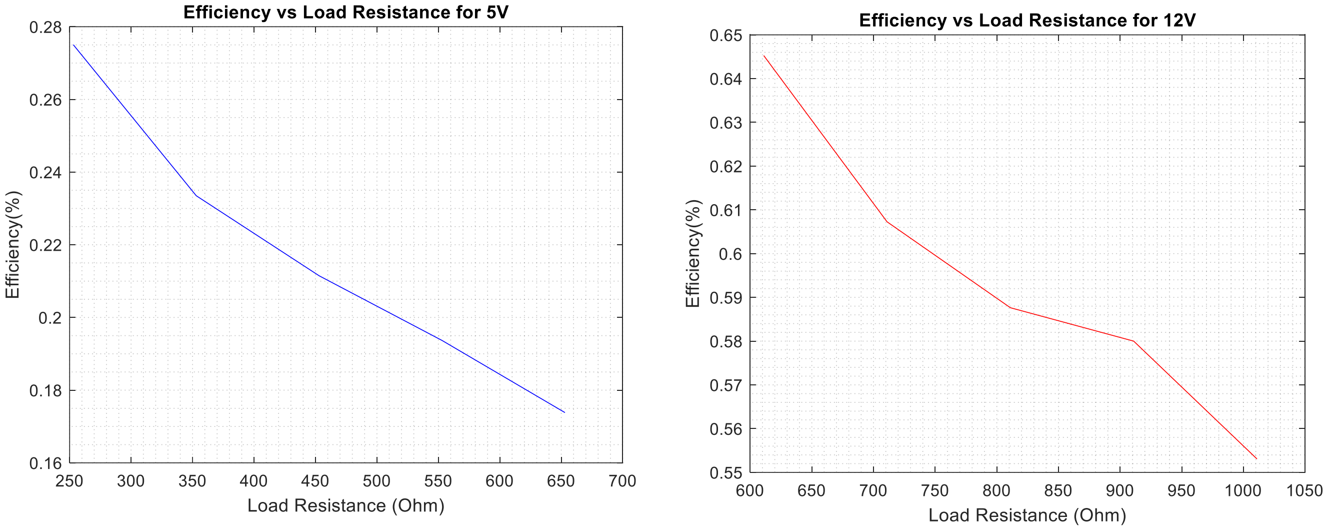

Figure 7.4 (a) Efficiency vs Load Resistance for 5V, (b) Efficiency vs Load Resistance for 12V

5V branch:

$$\text{Input power} = \text{Vin} * \text{Iin} = 14\text{V} * 26\text{mA} = 364\text{mW}$$

$$\text{Output power} = \text{Vout} * \text{Iout} = 5.052\text{V} * 19.730\text{mA} = 99.67\text{mW}$$

$$\text{Efficiency} = \frac{99.67\text{mW}}{364\text{mW}} = 27.4\%$$

12V branch

$$\text{Input power} = \text{Vin} * \text{Iin} = 14\text{V} * 26\text{mA} = 364\text{mW}$$

$$\text{Output power} = \text{Vout} * \text{Iout} = 12.0\text{V} * 19.9\text{mA} = 238.8\text{mW}$$

$$\text{Efficiency} = \frac{235.04\text{mW}}{364\text{mW}} = 64.6\%$$

Overall

Overall input voltage = 14V

Overall input current = 52mA

$$\text{Overall Input power} = \text{Vin} * \text{Iin} = 14\text{V} * 52\text{mA} = 728\text{mW}$$

$$\text{Overall Output power} = \text{Pout\_5V} + \text{Pout\_12V} = 99.67\text{mW} + 235.04\text{mW} = 334.71\text{mW}$$

$$\text{Overall Efficiency} = \frac{334.71\text{mW}}{728\text{mW}} = 46.0\%$$

Overall, it can be seen that the power efficiency is a bit lower than expected.

3. Input voltage range

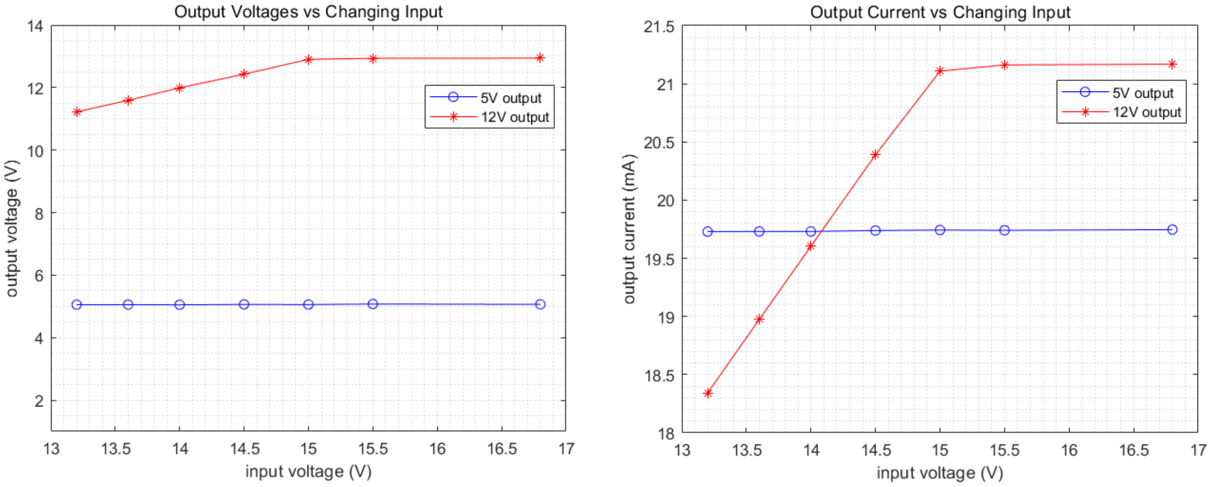

Figure 7.5 (a) Output Voltage vs Changing Input, (b) Output Current vs Changing Input

Output Voltage

5V branch: Stays at around 5V.

12V branch: The output voltage at 14V of input is 11.99V. It increases linearly from 11.2V to 12.8V from 13.2V-15V input, from 11.2V to 12.8V. Then it stays at around 12.8V, which is still acceptable according to specification.

Output Current

5V: Stays at around 19.73mA.

12V: The output current at 14V of input is 19.6mA. It increases linearly from 13.2V to 15V input, then stays at around 21.2mA. The output current is high because the output voltage is high (But still within the range). The output current can be reduced by increasing load resistance

Overall, it can be seen that input voltage range is still 13.2V to 16.8V as expected.

4. Short circuit current

Figure 7.6 Short circuit current for 5V branch

Figure 7.7 Short circuit current for 12V

Overall, it can be seen that the short circuit current is still below 30mA as expected.

Conclusion

Conclusively, circuit 6 is chosen because its only problem is with efficiency, and the efficiency is just slight lower than 60%. The real-life test results of circuit 6 agrees with simulation, except the efficiency is a bit lower than expected.