

Building a DC-DC Step-Down (Buck) Converter Circuit Using Positive Voltage Regulator

Felix Adisaputra

November 19, 2010

Executive Summary

Voltage regulator is one type of electrical regulators that provides the ability to maintain the voltage at the constant level. It is also capable of stepping-up, stepping-down, and inverting the input voltage supply. Voltage regulator also utilizes the negative feedback control loop. Some designs of voltage regulator can isolate output voltage from the input. In this application note, the LM7809 3-Terminal 1A Positive Linear Voltage Regulator will be used for building a DC-DC step-down (buck) converter circuit.

Keywords: voltage regulator, positive voltage regulator, linear voltage regulator, DC-DC converter, step-down converter, buck converter.

Introduction

Voltage regulators are commonly found in the power supplies as they play a major role to stabilize the output DC voltages. The operation of the voltage regulators basically by comparing the actual output voltage with the internal fixed reference voltage and utilize the negative feedback control loop in order to increase accuracy and reduce the error.

The LM7809 is a positive voltage regulator that is made by Fairchild Semiconductor. It is a positive linear voltage regulator with three terminal pins. Unlike switching voltage regulator, positive linear voltage regulator only has the functionality of stepping-down (input voltage must be greater than the output voltage). This particular voltage regulator has limiting output current, short circuit and thermal shut down protection.

Figure 1 below is the block diagram of LM7809 that illustrates the implementation process of each element inside the voltage regulator.

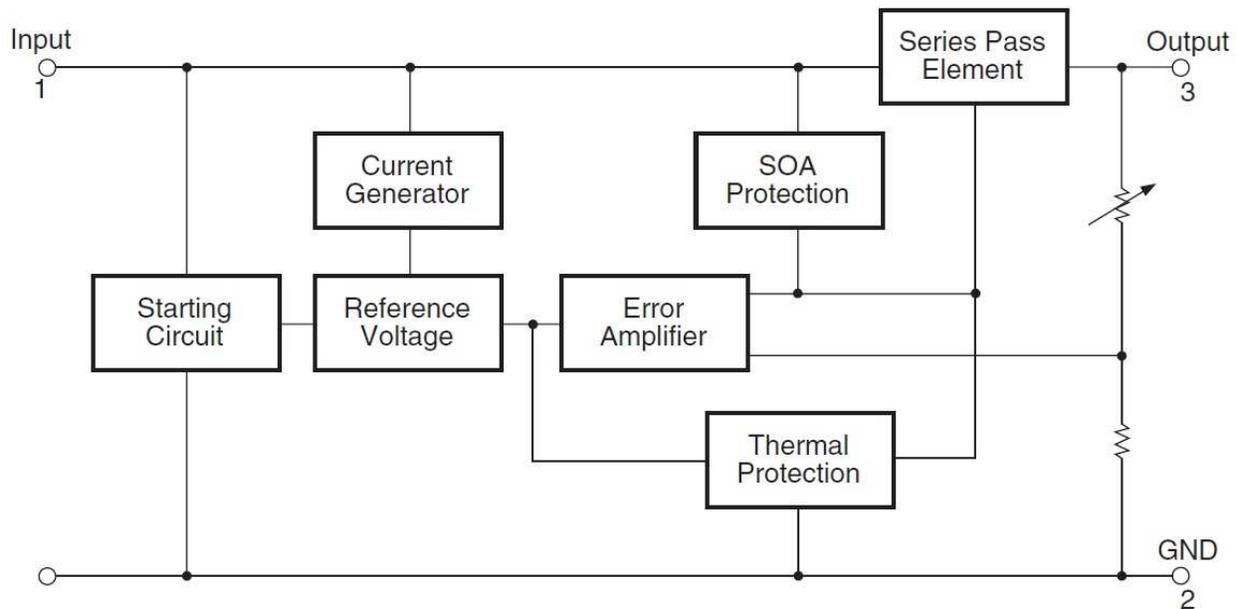


Figure 1: LM7809 Block Diagram.

This LM7809 voltage regulator typically is set to have 11V-17V input and will step it down to 9V output. The maximum output current that this voltage regulator can draw is 1A. However, under normal condition, the current that flows through the voltage regulator should not exceed 500mA.

Objectives

The primary objective is to build a simple circuit of DC-DC stepping-down (Buck) converter. With the LM7809 positive voltage regulator, it is expected to have about 11V-17V DC input stepping-down to 9V DC output. And the secondary objective is to be able to achieve output voltage that is stabilized at its level. This stabilization performance should be done by the voltage regulator.

Issues

The final circuit of the DC-DC step-down (Buck) converter would have additional electronic components other than the voltage regulator itself. Some components are capacitors with capacitance value that are not common. Also, it is expected to have some heat issue considering a very low tolerable current value that can flow through the voltage regulator.

Steps

Below is the picture of the LM7809 pins orientation and representation,

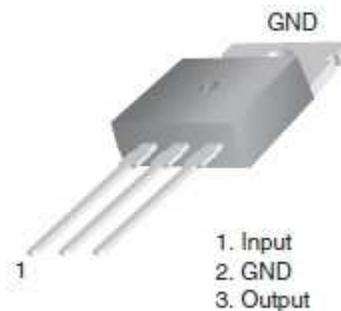


Figure 2: LM7809 pins orientation and representation.

The circuit for the DC-DC step-down (Buck) converter would have the LM7809 voltage regulator, two capacitors with capacitance value of $0.33\mu\text{F}$ and $0.1\mu\text{F}$. Figure 3 below shows the corresponding circuit,

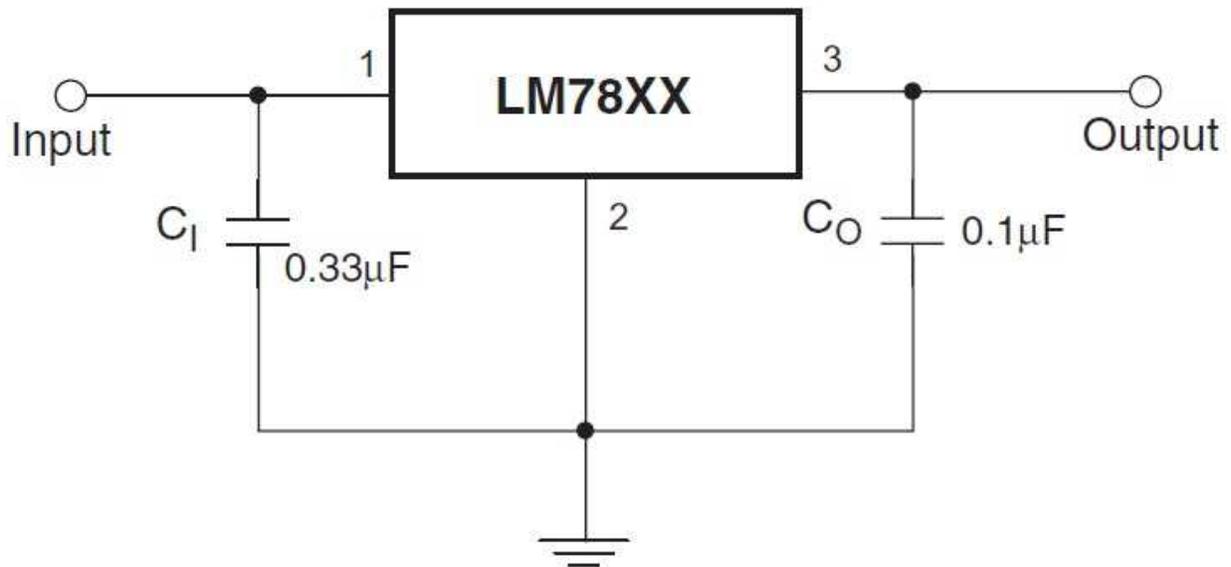


Figure 3: DC-DC step-down (Buck) converter circuit.

Step 1: The LM7809 voltage regulator is placed in the desired position on the circuit board.

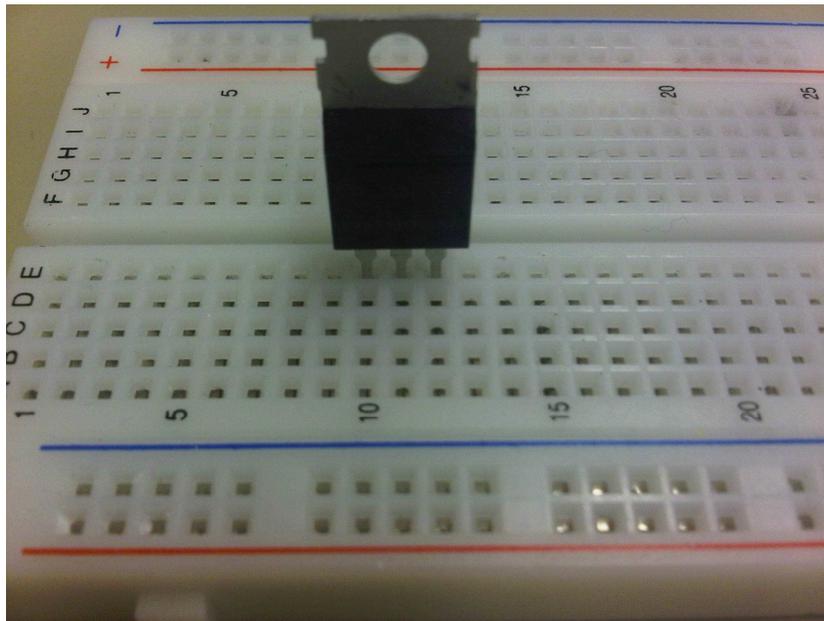


Figure 4: LM7809 is placed on the circuit board.

Step 2: Connects pin 1 of the LM7809 to the ground through 0.33 μ F capacitor.

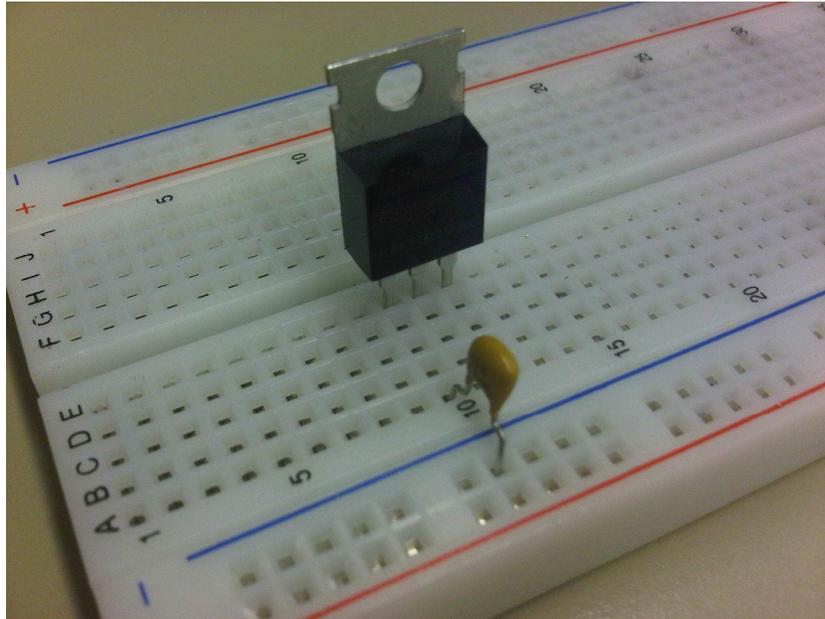


Figure 5: 0.33 μ F capacitor is added to the circuit.

Step 3: Pin 2 of LM7809 is connected directly to the ground with short wire.

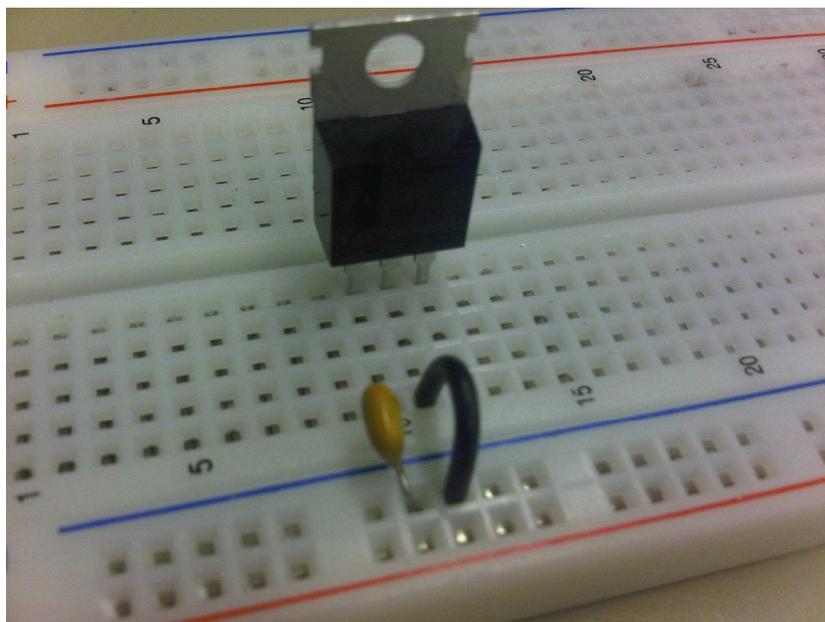


Figure 6: Connection between pin 2 of LM7809 and ground.

Step 4: Connect pin 3 of the LM7809 to the ground through 0.1 μ F capacitor.

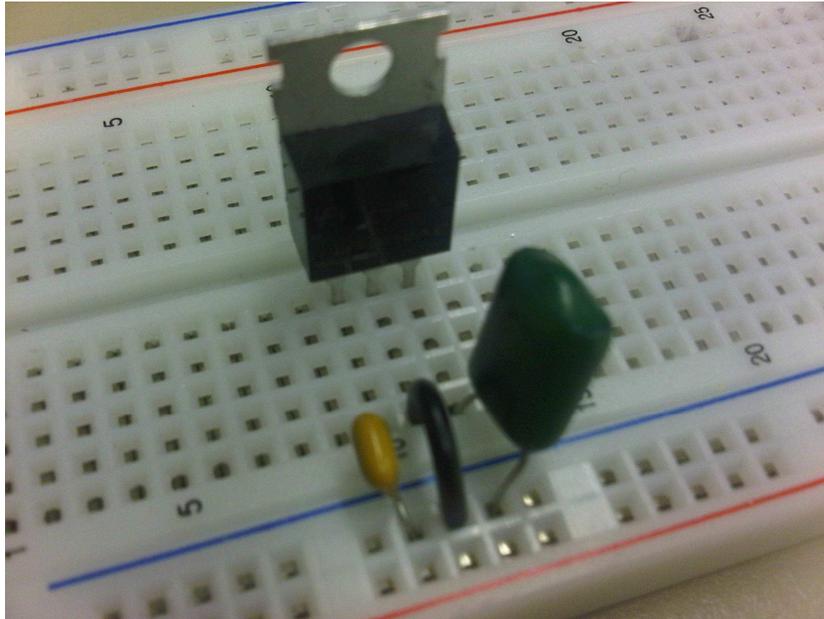


Figure 7: 0.1 μ F Capacitor is added to the circuit.

Step 5: The DC voltage source (11V-17V) is connected to the circuit on the input end.

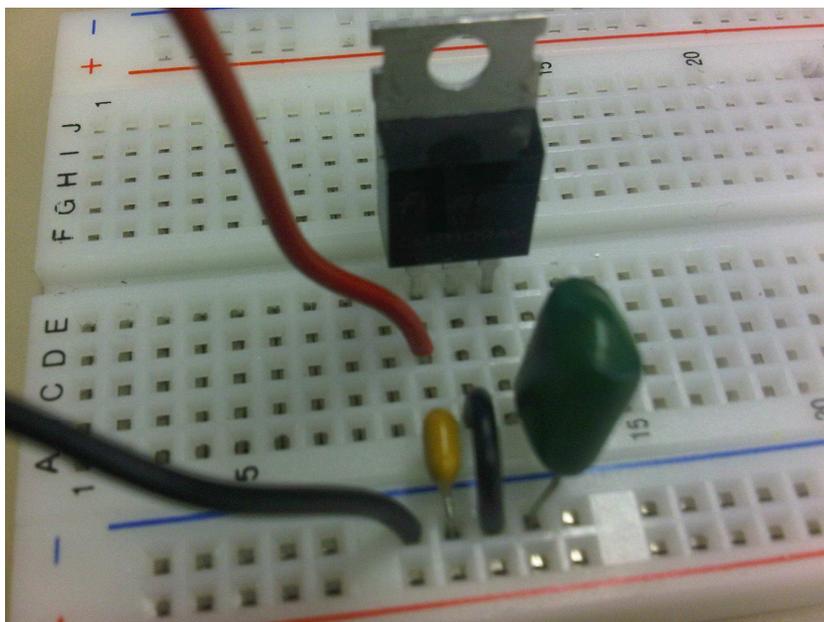


Figure 8: DC input voltage is supplied.

Step 6: The DC output voltage is ready to be connected to the load.

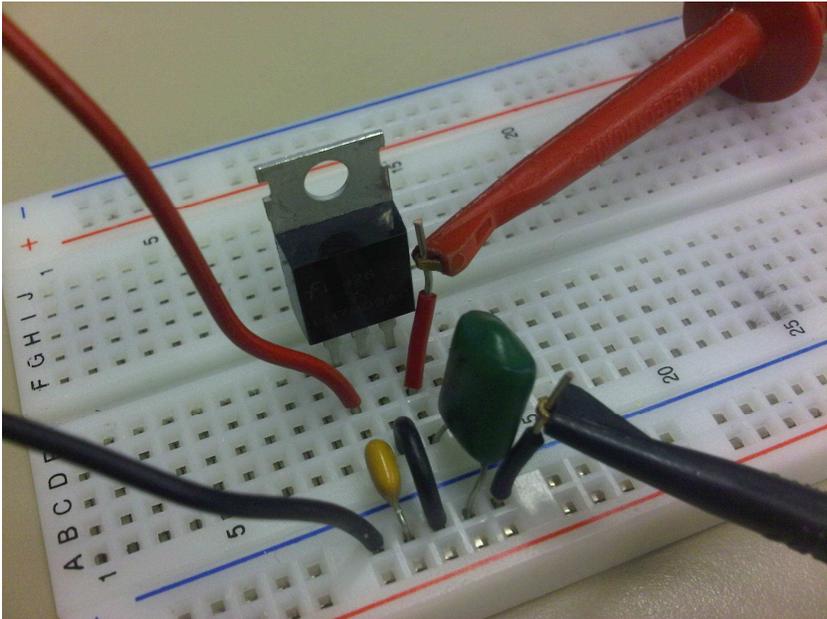


Figure 9: DC output voltage is connected to the load.

Examples

One application is demonstrated below, where a computer power supply is used as the voltage source to power up the LEGO NXT Brick. The computer power supply has 12V DC output and the LEGO NXT Brick requires 9V to fully operate. The LM7809 circuit is then applied to step-down the voltage from 12V to 9V. Figure 10 below shows the final set-up to obtain this application.

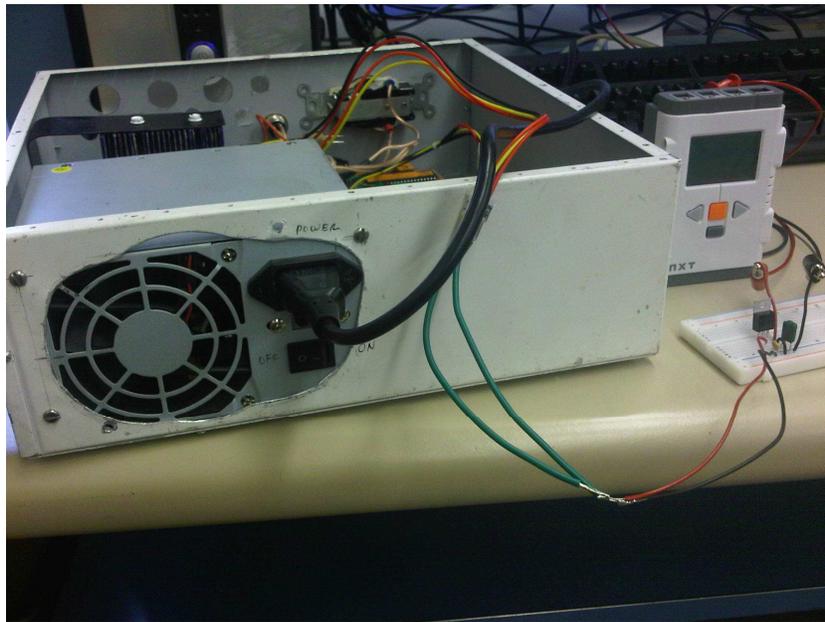


Figure 10: Power up LEGO NXT Brick using computer power supply as voltage source.

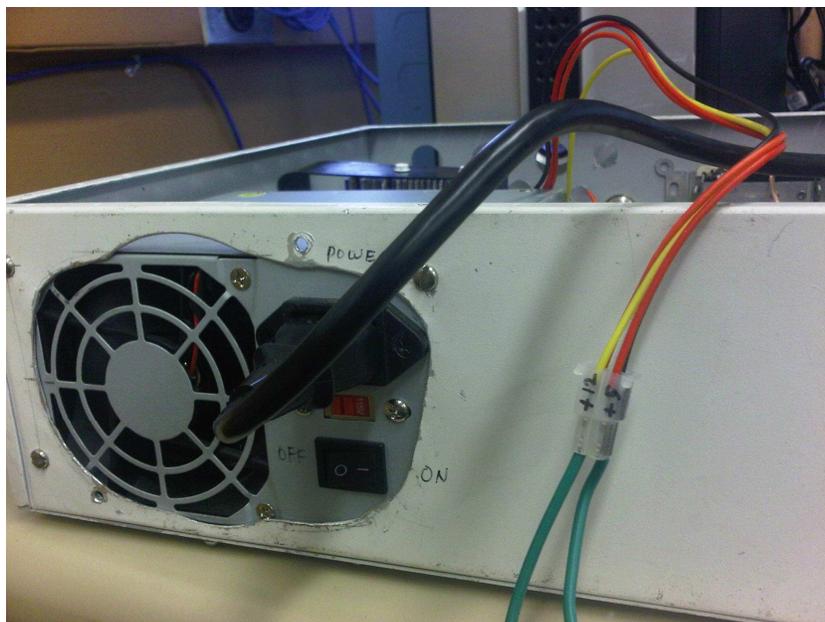


Figure 11: Power supply provides 12V DC and ground.

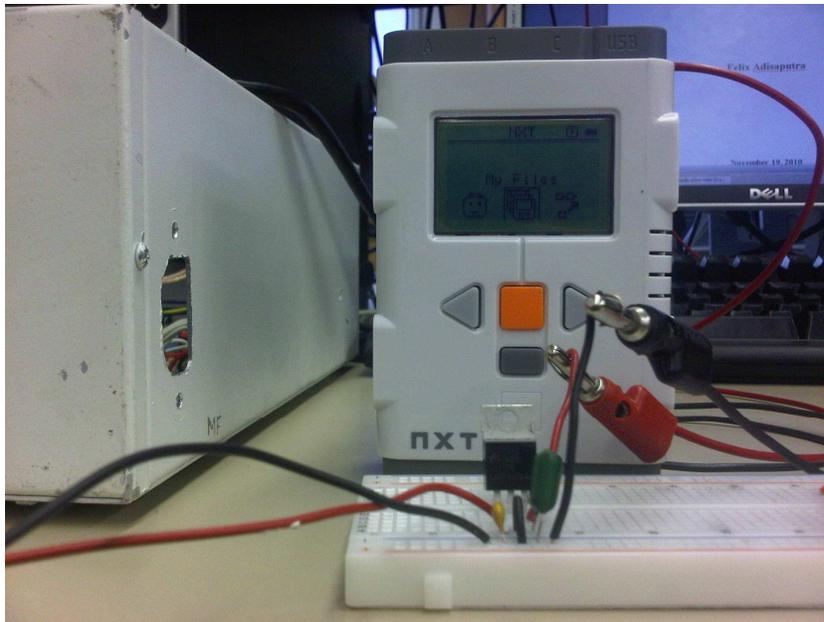


Figure 12: Closer look of the circuit to LEGO NXT Brick connection.

Hardware/Software Developed

There are only common electrical components are required for the hardware point-of-view. The LM7809 is one of the most important components in the step-down (Buck) converter circuit along with the $0.33\mu\text{F}$ and $0.1\mu\text{F}$ capacitors. Some wires are also required for the input, output, and ground connection. As for the software concern, there is no need for any software to be developed to achieve the outcome of the circuit. The LM7809 voltage regulator does not have the microcontroller element that needs to be programmed to perform the stepping-down voltage conversion.

Results

As results, the LM7809 step-down circuit has excellent precision for its output voltage. Some measurements have been done for the particular application that is described above, the output voltage of the LM7809 step-down circuit is 8.9642V DC, when it is supplied with 12V DC computer power supply. Compared to 9V, it is calculated to be 0.39% error. Furthermore, with appropriate measurement, the output voltage also found to be stabilized very well, as its output voltage value seemed fairly steady. For the output current of the corresponding circuit, it is measured to be 69.296mA.

Conclusions

In conclusion, the step-down (Buck) converter circuit had been successfully built using the LM7809 positive voltage regulator. Based on the measurements that are performed, the step-down circuit was able to convert the higher DC input voltage (11V-17V) to 9V DC output voltage. The LM7809 voltage regulator was also able to stabilize the resulting DC output voltage, as it was determined to have reasonably steady value.

Recommendations

Although the LM7809 voltage regulator performed the step-down converter circuit quite well, there is a potential problem that might occur in the long run. The case of the LM7809 voltage regulator was quite hot when it only draws 1/10 of its output current limitation. This heat issue could be a major problem if the voltage regulator is required to draw more power out of it.

Attaching an appropriate heatsink could be a suitable option to solve this heat problem. However, in the LM7809 datasheet, there is another explanation of how to build a high current voltage regulator.

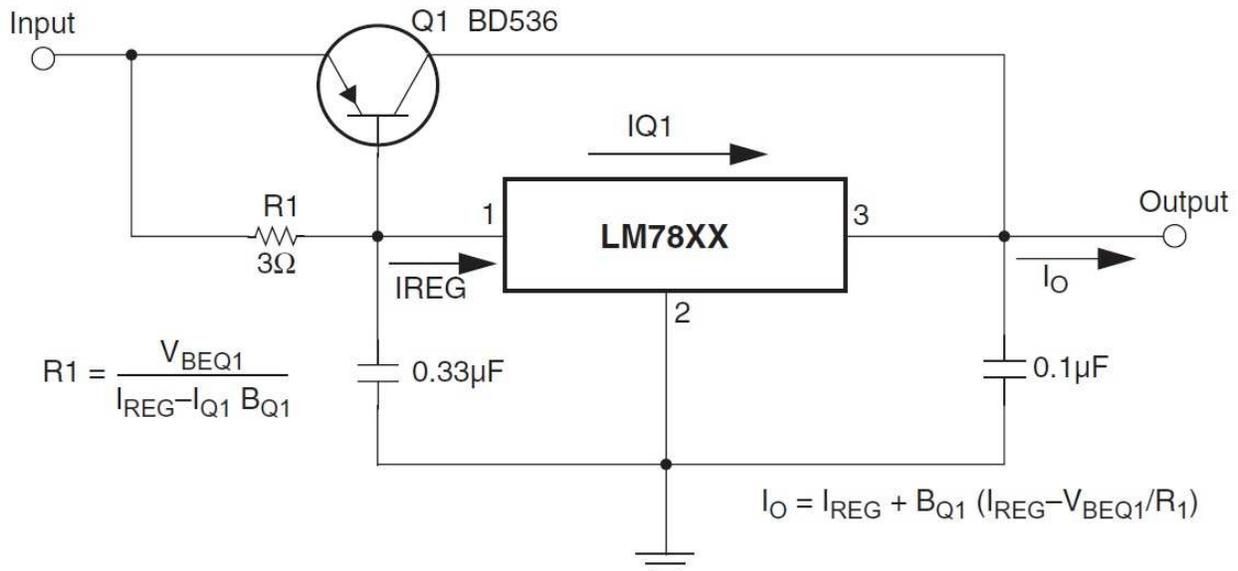


Figure 13: High Current Voltage Regulator Circuit

This high current voltage regulator circuit requires additional electrical components such as a power transistor and a resistor. The final circuit also seems to be more complicated.

References

LM7809 Positive Voltage Regulator Datasheet
<<http://www.fairchildsemi.com/ds/LM/LM7805.pdf>>

Gasperi and Hurbain, Extreme NXT, Extending the LEGO MINDSTROMS NXT to the Next Level. 2007.