Communication Systems Design 2009

*Draft report:*

# MDDC30 Step-Down Regulator Testing

Minimal Network Element


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## Abstract

In this draft report we will present the MDDC30 step-down regulator circuit implementation, together with some tests we performed on it. The purpose of this circuit is to convert the voltage from the solar panels to the supercapacitors. After taking the measurements, we evaluate the results and draw some conclusions.

## 1. Step-Down Regulator

As stated in the “Measuring a Circuit Prototype for Balancing the Voltage between Supercapacitors” draft report [1], the step-down regulator is a necessary part of the overall power design. It is connected between the solar panels and the supercapacitor tank, including the balancing circuit. Its purpose is to take the high voltage of the solar panels (12 or 24 Volts) as input and convert it to the low voltage (5.4 Volts max, if supercapacitors are to be connected in pairs) that will charge the capacitors. Another important feature of the step-down circuit is that it regulates varying input voltages to a stable output value. This way we can adapt to the variations of the voltage from the solar panels at different times of a day.

*Figure 1: Photo of the step-down regulator circuit*

A commercial implementation of such a circuit is the MDDC30 (available at the MDfly ebay store [2]), shown in figure 1. It supports a range of voltages between 3 and 30 Volts as input and can provide voltages between 1.3 and 18 Volts as an output. The circuit is based on the LM2596-ADJ integrated circuit for converting the voltages, capable of driving a 3A load [3]. A potentiometer (the blue component in figure 1) is used to select the desired voltage of the output, which always has to be lower than the input. The cost of this implementation is 7.5 USD.

## 2. Tests on a single regulator

Important factor on deciding whether this step-down regulator is suitable for use in our system is the circuit's output voltage stability. To test this we supplied the circuit with different input voltage values (Vin) and measured its output voltage (Vout).

The input voltage was provided by a 70 W AC/DC power supply, which is capable of switching between various voltages in the range of 5-24 Volts. The nominal value, which is selected by inserting a small resistor, differs from the actual value that we measured. The difference is not great enough to influence our results though.

To select the output voltage we set Vin to the nominal 5 V and by measuring Vout with a multimeter, we adjusted the circuit's potentiometer so that we could measure 5 V on the output. This value was selected for its possibility of being used as a charging voltage for the supercapacitors. After that, we increased Vin and at each step we took a measurement of Vout.

In figure 2 we present the results of these measurements.

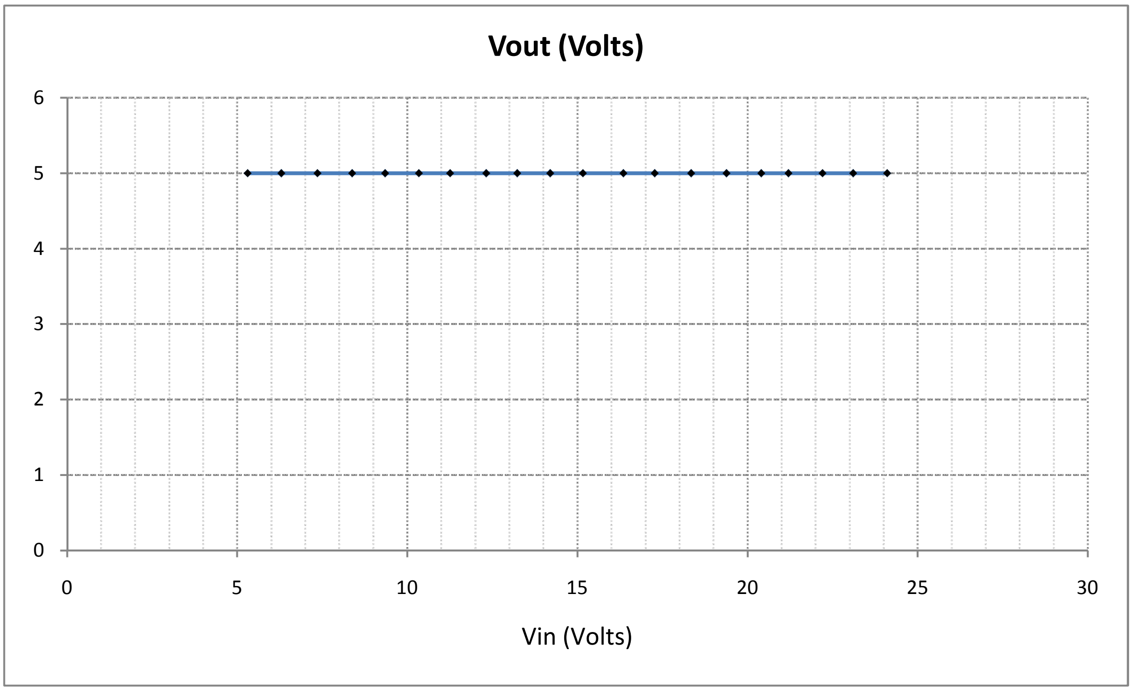


*Figure 2: Output voltage at different input voltages*

As we can see, the output voltage remains apparently steady at the range of input voltages we tested, although there might have been variations that were not noticed due to the accuracy limitations of the multimeter.

## 3. Tests on regulators connected in parallel

A step down regulator like this, given that its maximum output current is 3A, can provide a system with 15 Watts of power, when operating with a selected 5V output. It is therefore mandatory to connect more than one regulators in parallel in order to have sufficient energy for our system. We cannot say exactly how many at this point because we don't know the final power consumption of our router and also because it depends on the number of supercapacitors connected in series. The more supercapacitors connected in series we have, the less step down regulators we will need.

For now, we tested two step down regulators connected in parallel, as shown in the next figure.

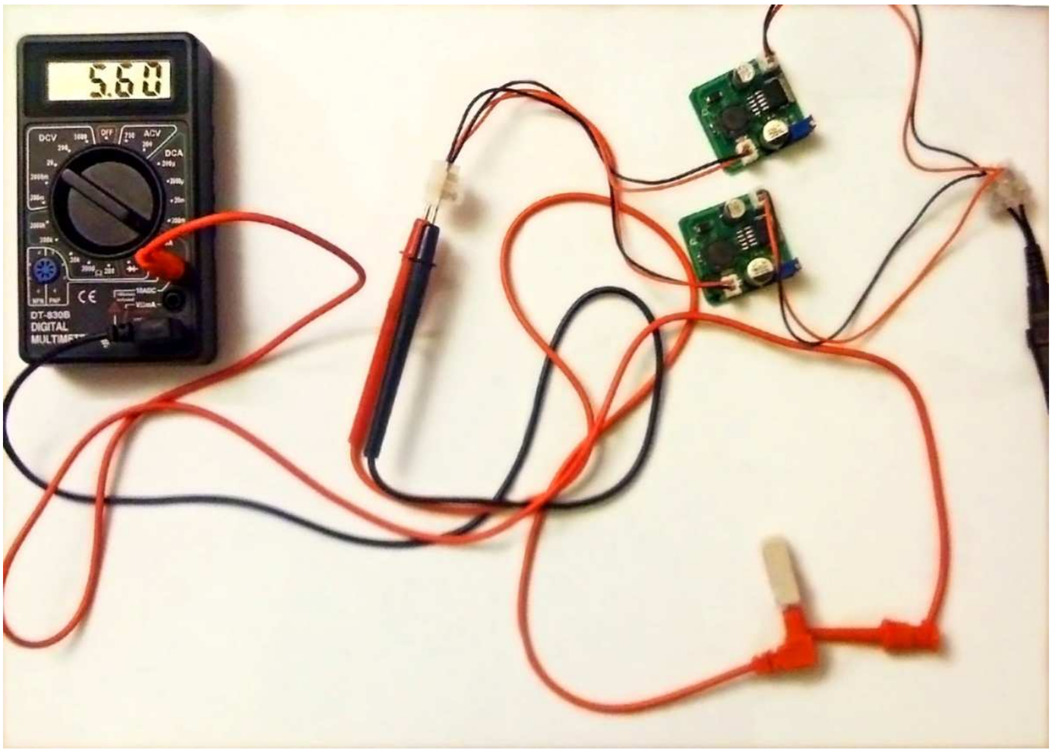


*Figure 3: Connected step down regulators, with a 0,22Ω resistor as load*

Additionally, when charging the supercapacitors, it is possible that we have current surges initially, that exceed by far the current calculated from the average power consumption of our system [4][5]. Thus it is important to know how our step down regulators perform under such circumstances.

With the setup shown above we tested the performance of the step down regulators under maximum load and we also tested their power efficiency.

To test how the step down regulators perform under maximum load, we connected them with a 0,22Ω resistor. The output voltage was adjusted to 5V on both circuits. The theoretically calculated current would be 22,7A, much higher than the 6A that the step down regulators can give when combined. We also performed the same test with each step down regulator separately.

Finally we tested the two connected regulators when connected with a Ubiquiti Bullet2, so as to see how they perform with a real device with a power demand much lower than the limit of the regulators. In this case the output voltage was adjusted at 6V (the minimum voltage a Bullet can work at is 5V).

In all tests the input voltage was 19V.Below we present the results of our test.

*Table 1: Measurements on step down regulator, with different loads and setups.*

| Load | Step down setup | | |
|---|---|---|---|
| **0,22Ω Resistor** | **In parallel** | | |
| | | In | Out |
| | V (Volts) | 18,7 | 4,67 |
| | I (A) | 2,01 | 5,64 |
| | P (W) | 37,587 | 26,3388 |
| | Efficiency | 70,07% | |
| | **Regulator 1** | | |
| | | In | Out |
| | V (Volts) | 18,9 | 2,84 |
| | I (A) | 1,25 | 3,97 |
| | P (W) | 23,625 | 11,2748 |
| | Efficiency | 47,72% | |
| | **Regulator 2** | | |
| | | In | Out |
| | V (Volts) | 18,87 | 3,04 |
| | I (A) | 1,57 | 4,32 |
| | P (W) | 29,6259 | 13,1328 |
| | Efficiency | 44,33% | |
| **Ubiquiti Bullet2** | **In parallel** | | |
| | | In | Out |
| | V (Volts) | 19,2 | 6 |
| | I (A) | 0,11 | 0,31 |
| | P (W) | 2,112 | 1,86 |
| | Efficiency | 88,07% | |

As we can see the current provided to the resistor was limited due to the step down regulators. Actually, in the case where both were connected in parallel, they were able to provide with quite steady current at about 5,6A. When we tested them separately they even went beyond their specification, with one reaching 4,32A. In this extreme case though the step down regulators couldn't keep this current for a long time and after a while both would fall to a much lower output current (down to 0,6A for regulator 1 and down to 3,3A for regulator 2), while also producing excessive amounts of heat.

In any case, the drawback was that we concurrently had voltage drop at the output and, as a result, the efficiency of the regulator was substantially deteriorated. Still we can say that for small periods of time we can tolerate with such bad efficiency.

On the other hand, when the regulators were connected with the Bullet and well within their limit, we observed that the output voltage was steady at the selected value and the efficiency was much better (88%).

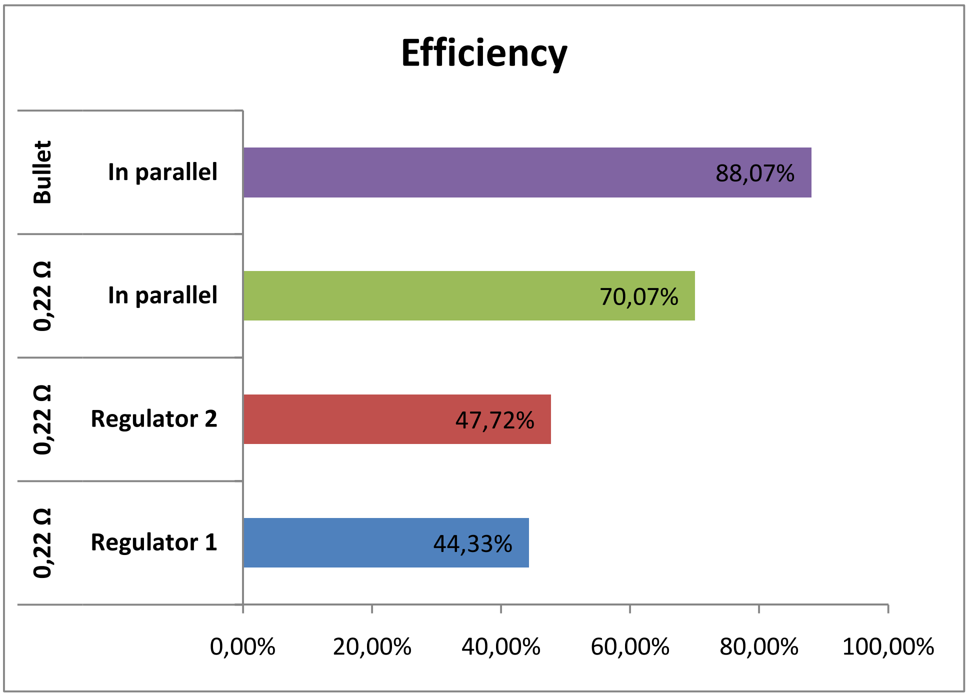


*Figure 4: Efficiency chart for different setups and loads.*

## 3. Conclusions

As shown above, the MDDC30 step-down regulator is capable of providing the supercapacitors with the desired voltage in a stable manner. Additionally its high efficiency and low cost make it a good choice for our energy system.

## References

[1] Draft Report: Measuring a Balancing Circuit Implementation (ver. 0.2 - 2009-10-13)

[2] MDDC30 circuit from MDFLY store at ebay.com

[3] LM2596 SIMPLE SWITCHER® Power Converter 150 kHz 3A Step-Down Voltage Regulator, National Semiconductor, www.national.com/ds/LM/**LM2596**.pdf

[4] Considerations when charging large supercapacitor banks, http://www.powerstream.com/supercap.htm

[5] Start-Up Current-Limiters for Supercapacitors in PDAs and Other Portable Devices (Rev 3.01), available at http://www.cap-xx.com/resources/app_notes/app_notes.htm