Intermediate Project

Algorythm implemenation for Four-Switch Buck-boost Converter

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1 Abstract

DC-to-DC converter [1] is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. Device considered in the project is able to lower or boost input voltage and is bidirectional. This converter is capable of operating as a voltage source or current source.

2 Description

The aim of this project is implementation of a four-switch buck-boost converter [2] algorithm [3] with smooth transition between buck and boost modes. For this purpose the project of inverter evaluation board is used. Main task of algorithm is to regulate output voltage based on reference voltage. This project is a base for more advanced projects.

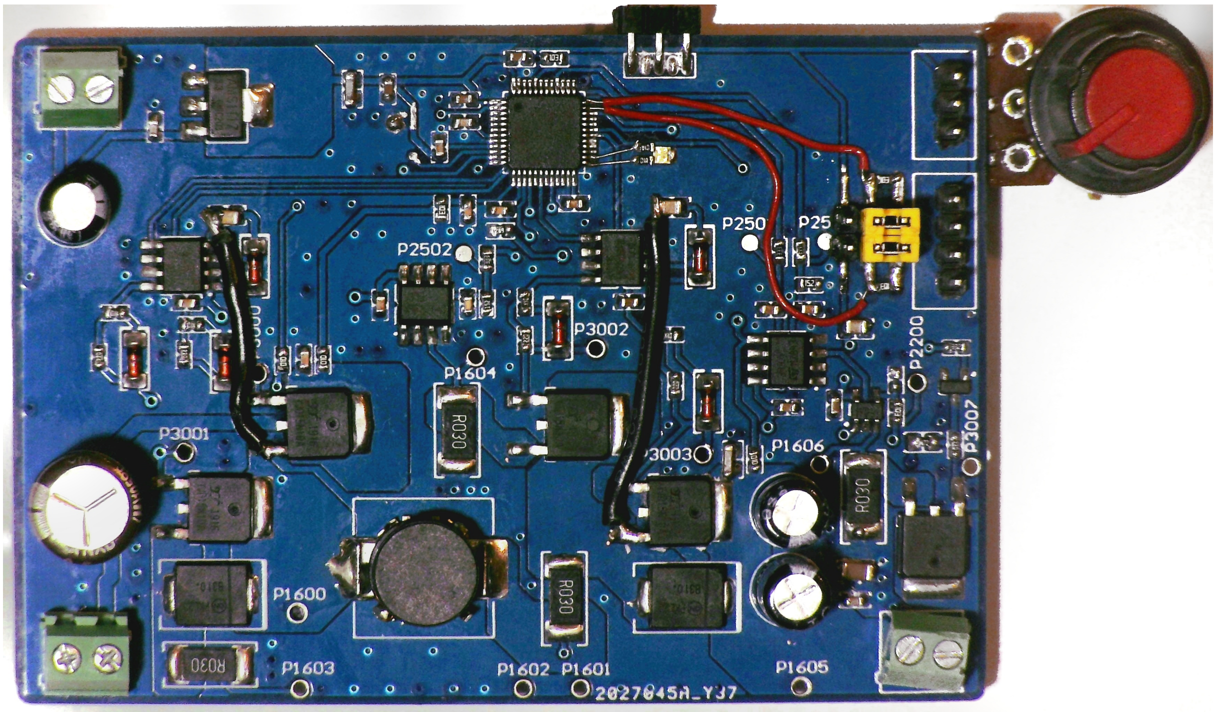

Figure 1: Evaluation inverter board

3 Tools

STM Cube IDE was used To program the microcontroller on board. Visualisation and debugging was made with the usage of STM Studio software. Electronics and algorithm simulations were conducted on LTSpice software.

4 Control of the device

Device can be controlled by potentiometer or external analog voltage source from 0 to 3.3V. For communication there are external UART connectors on board, but communication is not implemented in software. Direction of voltage conversion can be changed by changing down the yellow jumper. Undervoltage of input voltage is signalised by blue led and overvoltage is signalised by red led.

5 Algorithm implementation and simulation

Algorithm considered in this project is based on article **Modeling and Controlling Strategy of Four-Switch Buck-boost Convertor with Smooth Mode Transitions [3]**. Main advantage of this solution it is smooth transition between buck and boost mode. Algorithm used in this article is based on analogous components. For testing purposes of the algorithm LTSpice simulation was created. Electronic schematic is shown in the picture 2.

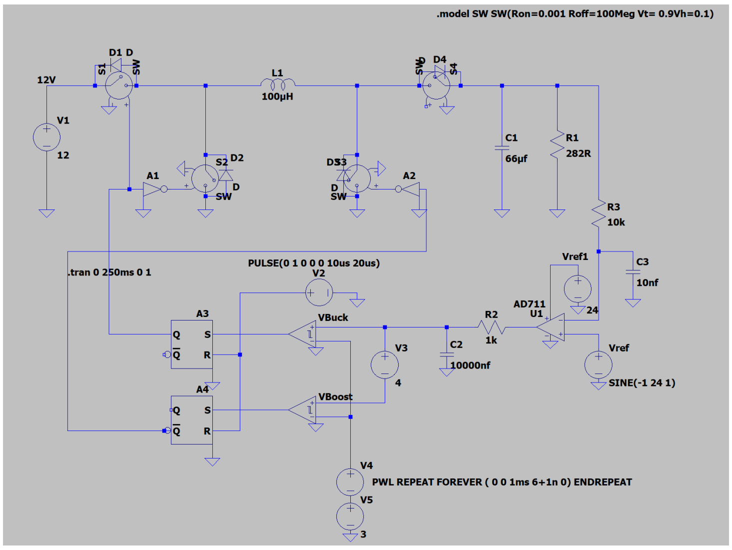

Figure 2: LTSpice simulation

Device in this project is based on a microcontroller. Analog parts from the article project were replaced by software algorithm implementation on microcontroller. Functional principle of operation was modified and adapted to work in a discrete environment. Principle of algorithm operation is shown on picture 3.

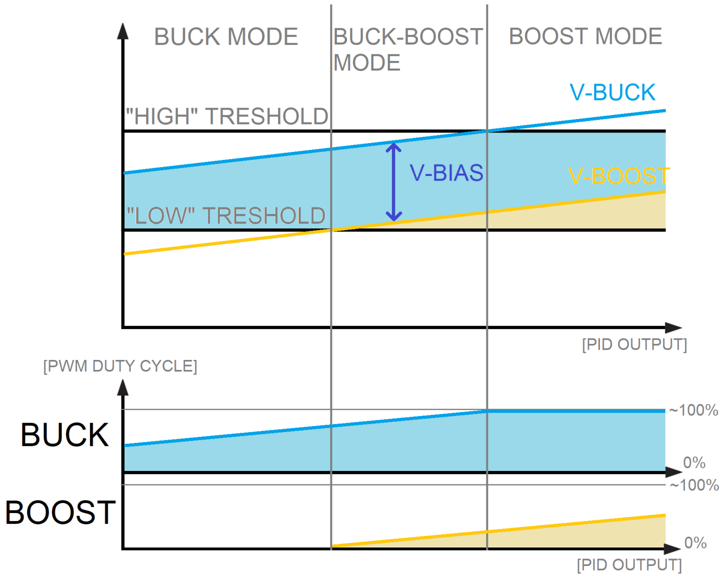

Figure 3: Diagram of implemented algorithm

Main task of the algorithm is to calculate the PWM duty cycle for transistors that are "responsible" for lowering and boosting voltage. Value for buck mode(V-BUCK) is directly an output of the PI controller. Input of PI controller is the difference signal(error) between desired voltage and output voltage of the converter. Value for boost mode(V-BOOST) is just a shifted buck mode value by constant(V-BIAS) value. To calculate PWM duty cycle for buck mode the position of this value between "low threshold" and "high threshold" is calculated. When buck value reaches or is higher than "high threshold" then duty cycle is maximal, when buck mode value is under or equal to "low threshold" then duty cycle is minimal. Identical operation is performed for PWM duty cycle for boost mode.

6 Testing

Tests are divided into two categories:

- Constant input voltage, altering reference voltage - In this test reference voltage is changing. Results show how the algorithm switches between buck and boost modes without unwanted rapid voltage rises. Results of the test are shown on picture 5. Crucial is that the green line (output voltage) and blue line (desired voltage) are close together. Another vital aspect is stability of the controller, when the above lines crosses the grey line(input voltage) .

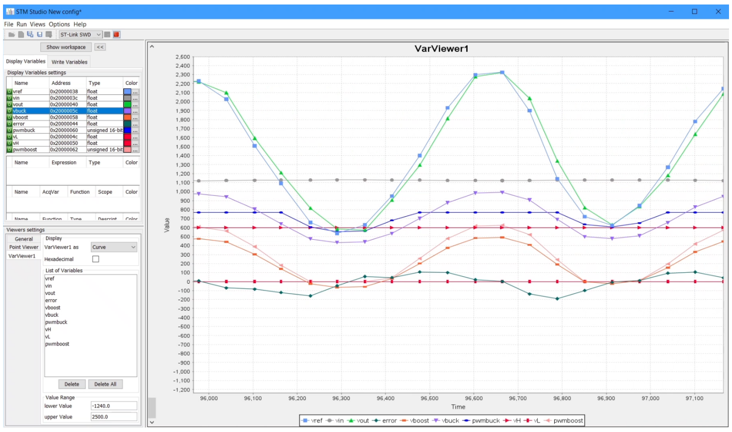

Figure 4: Constant input voltage, altering reference voltage

- Constant output voltage, altering input voltage - In this test input voltage (grey line) changes and controller should stabilise output voltage (blue line)

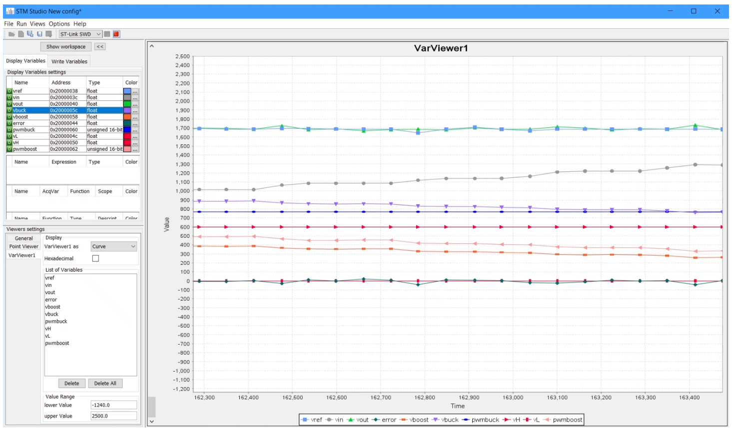

Figure 5: Constant input voltage, altering reference voltage

Tests was conducted under load 282Ω

7 Conclusion

Results of the tests show that the controller is stable and works quite reasonable in simple form. Visualisation inaccuracy in output voltage is determined by PI regulator settings, lack of compensation of ADC readings and sampling frequency of debugger.

References

[1] DC-to-DC converter.
https://en.wikipedia.org/wiki/DC-to-DC_converter.

[2] Texas Instruments. 4-Switch buck-boost bi-directional DC-DC converter. *https://www.ti.com/tool/PMP21529#design-products*.

[3] Wei-zhong Zhan, Hui-pin Lin, Yao Zhang, Ji-min Jin. Modeling and Controlling Strategy of Four-Switch Buck-boost Convertor with Smooth Mode Transitions. *https://www.benthamopen.com/FULLTEXT/TOEEJ-11-57*, August 2013.