DESIGN OF INTEGRATED MULTISTAGE DC-DC CONVRTER

Sachin Davangere[1], Sandeep B V[2]

[1]*MTECH, Dept of Electrical and Electronics, KVGCE, Karnataka, India*
[2]*Asst. Prof, Dept of Electrical and Electronics, KVGCE, Karnataka, India*

Abstract

Due to the functionality increase of modern battery powered portable devices, the battery life is an important issue. To extend the battery life, an efficient voltage regulator (VR) is required. In this paper discusses the employment of two-stage architecture on the design of point-of-load (POL) Dc- Dc converters. At first, the paper discusses the benefits of an integrated two-stage step-down converter with example to clarify the benefits of the design over one-stage approach. The results of two-stage converter are to be compared with the one-stage approach in addition to size and cost reduction. Then, the benefits of replacing boost converters by integrated two-stage step-up converters are discussed followed by a design example for two-stage step-up converter. The circuits are to be simulated and compared with the help of MATLAB/SIMULINK.

Keywords: *voltage regulator (VR), point-of-load (POL), MATLAB/SIMULINK*

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1. INTRODUCTION

Most recent researches and efforts in the design of integrated DC-DC converters are concentrated on realizing high efficiency with a significant reduction on the solution size. However, combining high efficiency with small size is not compliant with applications that have wide input/output ratio. The increased demand for multifunctional portable devices that are battery powered by a single battery pack puts more stress over the design of DC-DC converters. Note books are good examples to be considered. They are powered by a combination of small battery cells that give a nominal voltage source of 12V. Notebooks do a variety of functions which require a large number of chips. Each chip requires its own supply voltage that ranges between 0.75V and 3.3V in most cases.

Power Management ICs (PMICs) are required to manage the battery voltage and produce the required voltage for each chip. Current trend in PMICs design is to produce the required supply voltages directly from the battery. However, the limitations of achieving high efficiency are facing PMICs especially for high-current large input/output ratio applications (12V to 0.75V for notebooks microprocessor as an example).Two-stage architecture was proposed to solve the abovementioned efficiency limitations in single-stage buck converters. However, the proposed solution was discussed and implemented discretely. This make the improvement in efficiency is possible, but the PCB area allocated for the solution is increased. Increasing the input and output range of DC-DC converters in general has a direct reverse impact on the size and the cost of the converter in addition to the well known impact on converter efficiency.

This paper discusses the drawbacks of operating wide input/output range single-stage DC-DC converters and the solutions being discussed and proposed by researchers in the past. Then, the paper shows the benefits of employing two stage architecture on the design of integrated DC-DC converter. The idea is discussed for step-down and step-up DC-DC converters. The benefits are manifested by two examples. The first converter is two-stage step-down converter that is intended to replace the one-stage buck converter. The second converter is two-stage step-up converter that is intended to replace the one-stage boost converter. The benefits of integrating two-stage converter are discussed from the efficiency, size, cost, and stability point of views.

2. PRINCIPLE AND OPERATION

2.1 Open Loop Two Stage Buck Converter

The switched capacitor voltage divider (SCVD) topology is shown in figure below. When the switches S1 and S2 are turned on the output capacitor will be charged. When the switches S3 and S4 are turned on the output capacitor will be discharged. The duty cycle is fixed to 50% thus its output voltage will be affected by input voltage, load current and internal resistance of the converter.

The operation of the circuit can be divided into two phases. During the first phase, S1 and S2 are ON which connects the flying capacitor CF in series with the input voltage and the capacitor Co. This phase is called the charging phase and during this phase, the two capacitors charge from the input source. At the second phase, S3 and S4 are ON which connects the flying capacitor CF in parallel with the output capacitor Co. This phase is called the discharging phase and the load is supplied by the required current through this phase.

To allow the integration of the SCVD circuit, the switches S1, S2, S3, and S4 in Figure are implemented using CMOS technology. Figure shows the SCVD after implementing the switches in CMOS technology. Only S4 has a path to ground. This means that we can implement it as NMOS power switch with its body and source terminals connected to ground. The switches S1, S2 and S3 have no path to the ground which means that we cannot implement them as NMOS transistors without facing the body-effect problem. Same procedure will be applied to the second stage also.

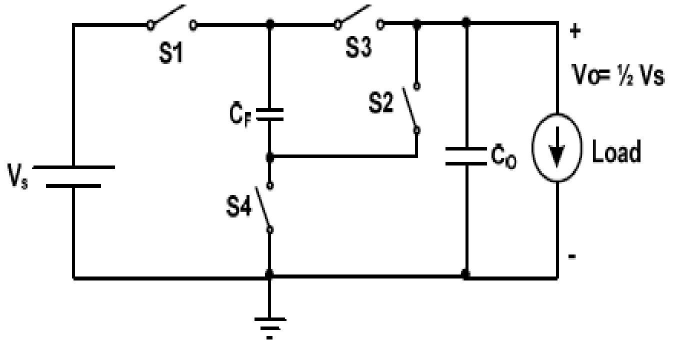

Fig -1: Conventional SC voltage divider.

2.2 Closed Loop Two Stage Buck Converter

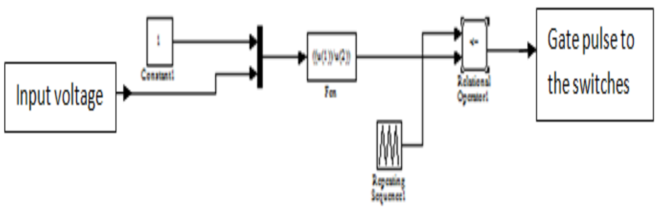

Fig -2: Feed back control loop

Constant block: The Constant block generates a real or complex constant value. The block generates scalar, vector, or matrix output, depending on the dimensionality of the Constant value parameter. The output of the block has the same dimensions and elements as the Constant value parameter.

Function block: The function block applies the specified mathematical expression to its input. It is using as a arithmetic operator.

Relational Operator block: compares two inputs using the Relational operator parameter that you specify. The first input corresponds to the top input port and the second input to the bottom input port. <= TRUE if the first input is less than or equal to the second input.

The working principle of the closed loop buck converter is same as the open loop circuit instead of giving pulse generator control feedback is used for giving pulse.

2.3 Open Loop Two Stage Boost Converter

The charge pump dc-dc converter is the power converter that consists of switches and energy transfer capacitor in the power stage. The charge pump doubler circuit is shown in below.

During the first phase of operation, the flying capacitor C1 is connected to input voltage and allowed to charge to Vin. During this phase, the output capacitor supplies the load by current. At the second phase, the flying capacitor C1 is flipped and connected in series with the input source. During this second phase, the output capacitor is allowed to charge by the voltage summation of the input source and flying capacitor C1.

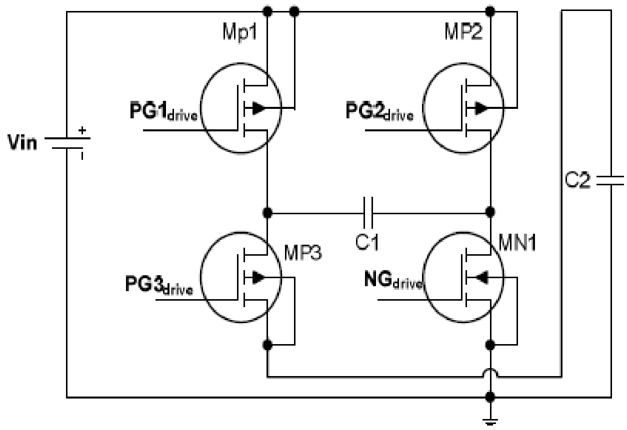

Fig3: Charge pump doubler circute

The output of the charge pump doubler is fed to the boost converter as an input to the boost converter. The below mentioned figure represents the boost converter. It works under the operating principle, the sudden variations in input current was resist by the inductor in the input circuit. When switch is OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures a constant output voltage $V_o(t) = V_o$(constant).

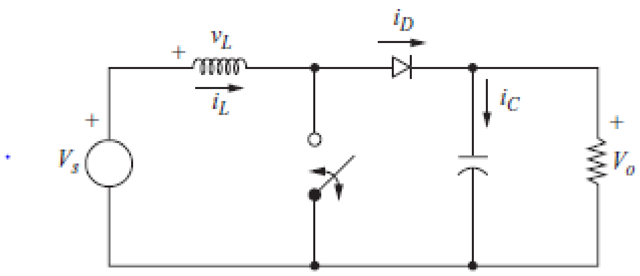

Fig-4:.Boost convrter

2.4 Closed Loop Two Stage Boost Converter

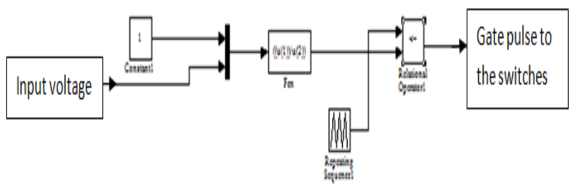

Fig5: Feed back control loop

Constant block: The Constant block generates a real or complex constant value. The block generates scalar, vector, or matrix output, depending on the dimensionality of the Constant value parameter. The output of the block has the same dimensions and elements as the Constant value parameter.

Function block: The function block applies the specified mathematical expression to its input. It is using as a arithmetic operator.

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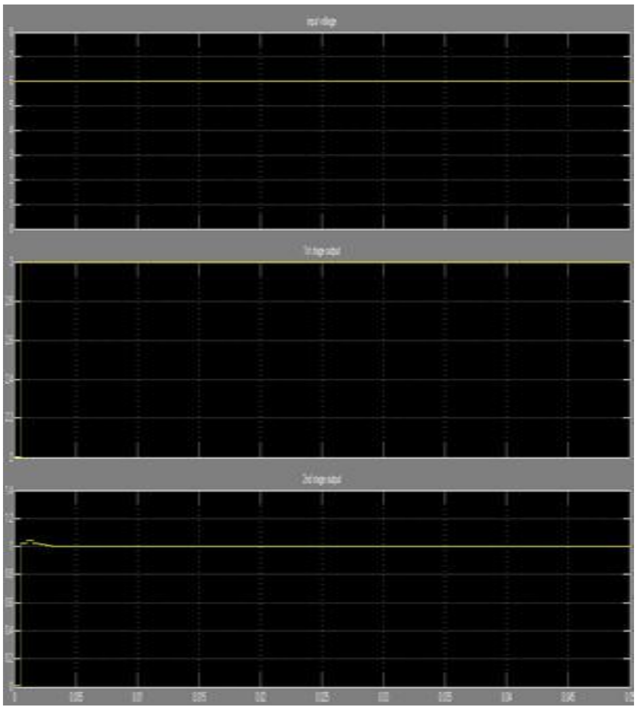
The working principle of the closed loop buck converter is same as the open loop circuit instead of giving pulse generator control feedback is used for giving pulse.

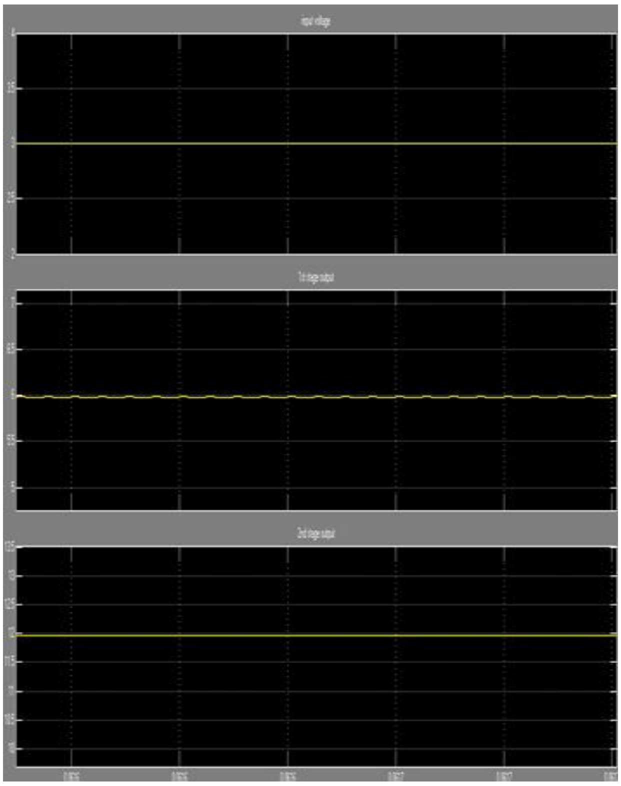
3. SIMULATED RESULT

The simulation is carried out using MATLAB/SIMULINK. The result is presented here.

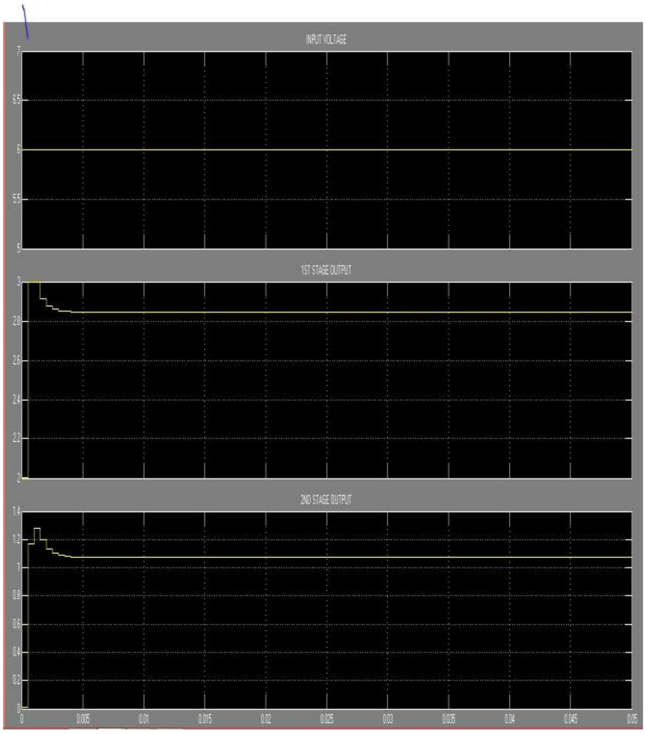
3.1 Open Loop Buck Converter



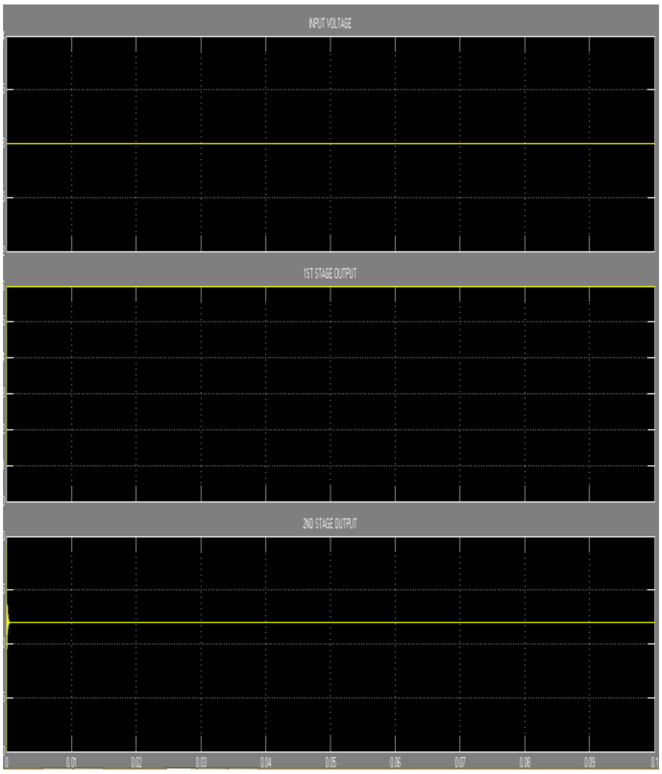
3.2 Open Loop Boost Converter



3.3 Closed Loop Buck Converter



3.4 Closed Loop Boost Convrter



4. CONCLUSION

This paper discussed the impacts of wide input/output voltages on DC-DC converters. The effect of applying two - stage architecture on the design of DC-Dc converters has been investigated by two design examples. The first example is applied for step-down DC-DC converter where the idea showed that two-stage buck converter provides high efficiency in comparison to one-stage buck converter. Add to this, the possibility of integrating the two-stage on a single chip has been increased due to the use of low-power switches. The same is true for two-stage boost converters where the efficiency was improved and the system stability has been improved significantly due to reducing the duty cycle.

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BIOGRAPHIES

Sachin davangere was born in Davangere, karanataka, in 1990. He received the eng. degree in electrical and electronics engineering from the Technical University of VTU KARANATAKA, in 2012. Pursuing Mtech post graduation in computer application in industrial drives from the technical university of VTU.

Asst Prof, Sandeep B.V. was born in madekeri, karanataka, in 1987. He received the eng. degree in electrical engineering from the Technical University of VTU, karanataka, in 2010. In 2013, he received the Mtech degree in energy system engineering from the technical University of VTU.