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Design of Buck DC-DC Converter Space Application

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Abstract: ***The buck converter is a power electronic device which converts the higher level of input voltage to lower level of output voltage. For space applications, several tests were performed on direct current (DC) to (DC) converters to evaluate potential performance and reliability issues in space use of DC to DC converters and to determine if the use of electromagnetic interference (EMI) filters mitigates concerns observed during tests. Test findings reported here include those done up until January–June 2022. Tests performed include efficiency, regulation, load regulation, power consumption with inhibit on, load transient response, synchronization, and turn-on tests. Some of the test results presented here span the thermal range -20°C to 55°C. Lower range was extended to -40°C in some tested converters.***
Keywords: Buck converter, Satellite, Line regulation, Load regulation, Stress analysis, Electromagnetic interference

I. INTRODUCTION

A. *What is a Satellite?*

A satellite is an object that moves around a larger object. Earth is a satellite because it moves around the sun. The moon is a satellite because it moves around Earth. Earth and the moon are called "natural" satellites.
But usually when someone says "satellite," they are talking about a "man-made" satellite. Man-madesatellites are machines made by people. These machines are launched into space and orbit Earth or another body in space.

B. *Buck Converter*

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while drawing less average current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor usedfor synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). It is called a buck converter because the voltage across the inductor “bucks” or opposes the supply voltage. Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power asheat, but do not step up output current.

C. *Why is a buck converter needed in satellite*?

The main components of a satellite consist of the communications system, which includes theantennas and transponders that receive and retransmit signals, the power system, which includes the solar panels that provide power, and the propulsion system, which includes the rockets that propel the satellite. The propulsion system intern consists different parts like relay coils latch valves, thrusters, motors which requires lower levels of DC supply. So, for this reason Buck converter is used as auxiliarypower supply to power all these parts. And this helps in proper propulsion and proper launching & properworking of the satellite

II. OBJECTIVES AND MOTIVATION

1) Many applications require various power rails to supply power to different devices within a system.
2) Some rails may need to be very tightly regulated offering maximum peak to peak variation to meet their respective load in satellite.
3) Some rails on the other hand can power loads that are more robust to variations on the input supplyand therefore, do not require such tight regulation
4) For these requirements instead of having various supplies, a single buck converter can be used.
5) Higher voltages power converters in Satellite can be used as an auxiliary supply for relay coil, latch valves, motors, thrusters, etc.

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III. SYSTEM COMPONENTS

A. Power MOSFET (2N7269)

Environment A buck converter generates a pulsating ripple current with high di/dt at the input. Without input capacitors, ripple current is supplied by the upper power source. Printed circuit board (PCB) resistance and inductance causes high-voltage ripple that disrupts electronic devices. The circulating ripple current results in increased conducted and radiated EMI. Input capacitors provide a short bypass path for ripple current and stabilize bus voltage during a transient event. Among the different types of capacitors, the multilayer ceramic capacitor (MLCC) is particularly good regarding allowable ripple current. A starting point is to select the key ceramic capacitors to meet the requirements for ripple voltage and current.

This technology has over a decade of proven performance and reliability in satellite applications. These devices have been characterized for both Total Dose and Single Event Effects



Power MOSFET

B. Capacitor (120 Micro Farad)

Electromagnetic interference can cause serious problems to the manufacturers and the industralists. The combination of low Rdson and low gate charge reduces the power losses in switching applications such to DC converters and motor control. These devices retain all the well-established advantages of MOSFETs such as voltage control, fast switching, ease of paralleling and temperature stability of electrical parameters.

Single Event Effect (SEE) Hardened Low RDS (on) Low Total Gate Charge Proton Tolerant Simple Drive Requirements Ease of Paralleling Hermetically Sealed Ceramic Eyelets Light Weight.



Electrolytic Capacitor

C. Inductor

The 'buck' DC-DC converter is employed to step voltages down without isolation and utilizes an inductor as an energy storage element. An inductor is a passive electronic component that stores energy in the form of a magnetic field. The inductance is directly proportional to the number of turns in the coil. Inductance also depends on the radius of the coil and on the type of core material around which the coil is wound. The inductance value for buck converter can be calculated by using formula given below:

L= [Vin(max) - Vout] x [Vout + VD] / [Vin(max) + VD] x Iout x 0.3 x fsw]



Inductor

D. Shottky Diode (16YQ150C)

The Schottky diode (named after the German physicist Walter H. Schottky), also knownas Schottky barrier diode or hot-carrier diode, is a semiconductor diode formed by the junction ofa semiconductor with a metal. It has a low forward voltage drop and a very fast switching action.

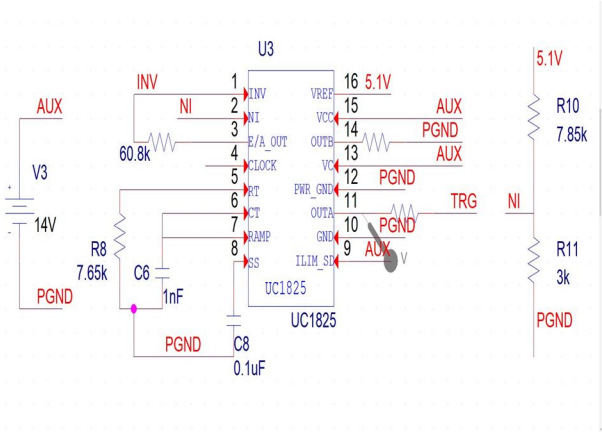
Buck converter comes under the family of switched mode power supply, The diode used must havelow recovery time for higher switching speed and low forward voltage drop to reduce power loss. As the schottky diode satisfies this requirement we use schottky diode. (16YQ150C).



Schottky diode

E. UC 1825A High Speed PWM Controller

The UC1825A family of PWM control ICs is optimized for high frequency switched mode powersupply applications. Particular care was given to minimizing propagation delays through the comparatorsand logic circuitry while maximizing bandwidth and slew rate of the error amplifier. This controller is designed for use in either current-mode or voltage mode systems with the capability for input voltage feed-forward.



UC High Speed PWM Module

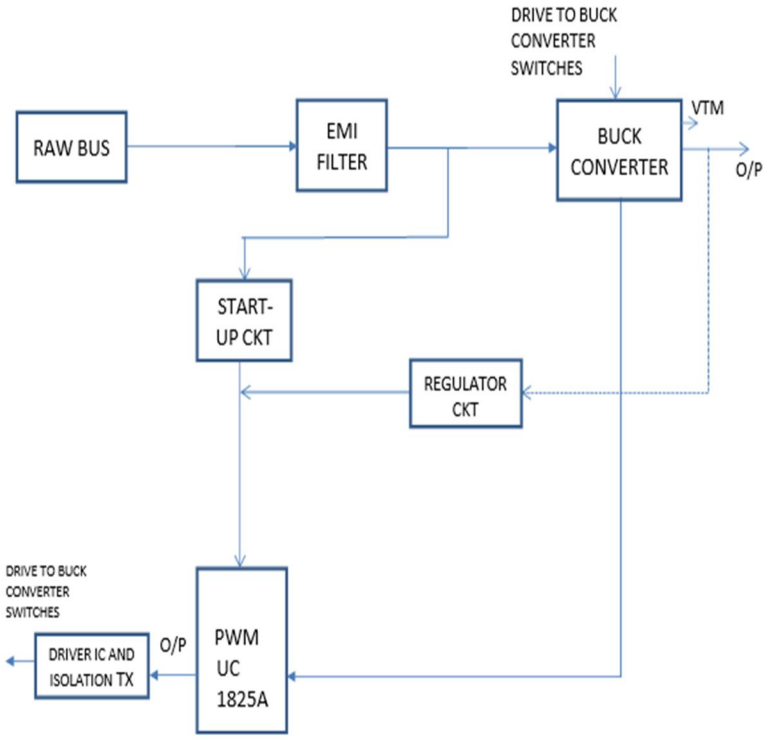
IV. PROPOSED METHODOLOGY

The development of a Buck converter system based on voltage controlled involves:

1) Buck converters for space applications.
2) Design of controller circuit and testing.
3) Design of converter circuit and testing.
4) Design of whole converter circuit and testing.
5) Simulation of circuit using Saber software.
6) Tracing the output and their relevance to our application as per requirement
7) Building the model of the converter and testing and performance analysis.

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V. PROPOSED MODEL



Block diagram

Our buck converter model is mainly designed to step down the voltage levels from 55v-70v input to 28v-40v output.
The complete block diagram consists of various sub circuits like.,

1) *Startup Circuit:* It is mainly used to turn on the converter by increasing the operating current from 0 up to the operating point that is 1A.
2) *Driver Circuit:* It is a component used to control another circuit or a component. It is basically a switching circuit which consists of switching elements like diode to turn on or turn off the complementary circuit.
3) *PWM Controller Circuit:* It consists of IC like PWM (1825A) which is used to obtain required voltage levels at the output ranging from 28v-40v by using pulse width modulation technique. Here PWM is used to control the switching frequency of the mosfet.

VI. RESULTS AND PERFORMANCE ANALYSIS

Various software (saberRD) and hardware tests we performed on the converter circuit like line regulation test, load regulation test, stress analysis, EMI/EMC test, stress analysis, hot and cold test by connecting single pole double throw switch along with the sequential driver in order to check the performance of the converter under all these conditions.
The converter was able to pass all these tests successfully by giving out the following results:

1) It was able to give constant 40v output during line and load regulation checks.
2) It was able to withstand and give required voltage while test in -20 degree and 65 degrees Celsius
3) The EMI/EMC analysis and stress analysis within range of 100db.

VII. CONCLUSION

1) A Buck converter system helps to replace the other different power supplies used in satellites which causes mal functioning.
2) A voltage-controlled mode Buck converter is used to provide voltage regulation for the CubeSat payloads.
3) Buck converter helps to meet the different kinds of loads that are within the satellite by providing different voltage levels.
4) These buck converters can be used as auxiliary supply for relay coil, motors, thrusters, latch valves, etc.

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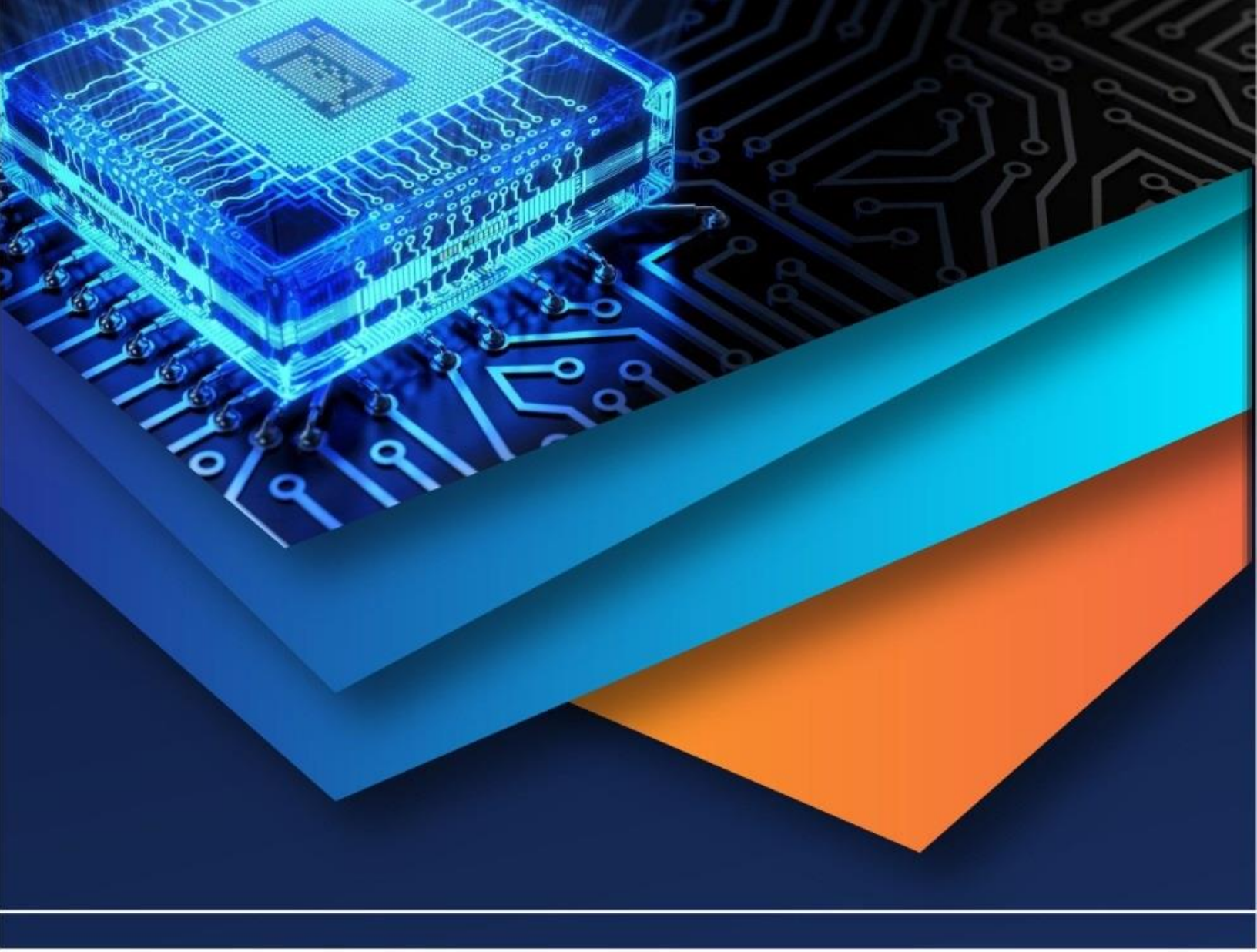
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