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Title **DESIGN AND IMPLEMENTATION OF BUCK CONVERTER**

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DESIGN AND IMPLEMENTATION OF BUCK CONVERTER

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Abstract-Buck converters are step down DC-DC converters that are widely being used in different electronic devices like laptops, PDA's, cell phones and also electric vehicles to obtain different level of voltages. These converters are nothing but, high frequency switching devices operating on PWM principle. The need for more and more lighter and smaller electronic devices propels the need for reduced size of converters operating at higher load currents. With all these inadvertent conditions the switching frequency has jumped from KHz range to MHz range.The switching devices are made to turn on and turn off the entire load current at high di/dt , and also withstand high voltage stress across them.Due to these two effects there occurs increased power losses in these converters and reduces the efficiency significantly. The reduction in efficiency is
highly unacceptable as it leads to shorter battery life and de-rated device conditions. During the hardware implementation the Ton,Toff and operating frequency were found out and thoroughly tuned through the IC SG1524 circuit and various waveforms across load resistor and test points were noted down. These waveforms were found to be in precise proximity of the theoretically observed waveforms.

Index terms- Buck converter, PWM principle, IC SG1524

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1. INTRODUCTION

DC-DC converters are electronic devices that are used to change DC electrical power efficiently from one voltage level to another. The use of one or more switches for the purpose of power conversion can be regarded as a SMPS. A few applications of DC-DC converters are where 5V DC on a personal computer motherboard must be stepped down to 3V, 2V or less. In all of these applications, we want to change the DC energy from one voltage level to another, while wasting as little as possible in the process. In other words, we want to perform the conversion with the highest possible efficiency. DC-DC Converters are needed because unlike AC, DC can't simply be stepped up or down using a transformer. In many ways a DC-DC converter is the DC equivalent of a transformer. They essentially just change the input energy into a different impedance level.

SWITCHING MODE REGULATORS

DC converters can be used as switching-mode regulators to convert a dc voltage, normally unregulated to a regulated dc output voltage. The regulation is achieved by PWM at a fixed frequency and the switching device is normally BJT, MOSFET, or IGBT. The output of dc converters contains harmonics and the ripple content is normally reduced by an LC filter.

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Switching regulators are commercially available as integrated circuits. The designer can select the switching frequency by choosing the values of R and C of frequency oscillator. As a rule of thumb, to maximize efficiency, the minimum oscillator period should be about 100 times longer than the transistor switching time; for example, if a transistor has a switching time of 0.5µs, the oscillator period would be 50µs, which gives the maximum oscillator frequency of 20kHz. This limitation is due a switching loss in transistor. The transistor switching loss increases with the switching frequency and as a result the efficiency decreases. In addition, the core loss of inductors limits the high-frequency operation. Control voltage is obtained by comparing the output voltage with its desired value. The reference 7 voltage can be compared with a saw-tooth voltage to generate the PWM control signal for the dc converter. There are three basic topologies of switching regulators.

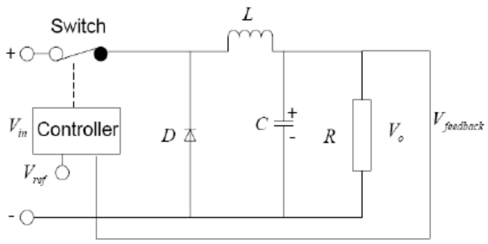

Fig 1.1

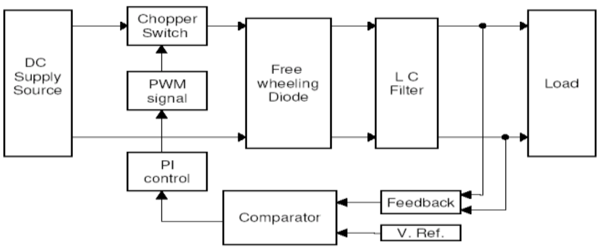

Fig1.2

2.MODES OF OPERATION

This circuit can operate in the following ways.

Mode 1

The first state corresponds to the case when the switch is ON. In this state, the current through the inductor rises, and the energy stored in it increases, during this state the inductor acquires energy.

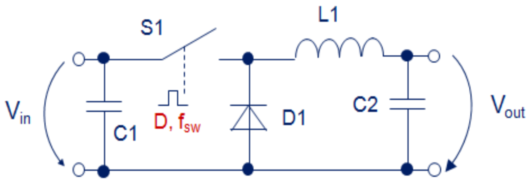

fig1.3

$$V_i = L_o \frac{di_L}{dt} + V_o = L_o \frac{\Delta I_L}{DT} + V_o$$

When the switch is closed, the diode is in the OFF state. The diode is there so there will always be a current source for the inductor.

Mode 2

The second state is when the switch is OFF and the diode is ON. In this state, the inductor current free-wheels through the diode and the inductor supplies energy to the RC network at the output. The energy in the inductor falls in this state.

$$0 = V_o + L_o \frac{di_L}{dt} = V_o - L_o \frac{\Delta I_L}{(1-D)T}$$

When the switch is open, the inductor discharges its energy. When all of its energy has discharged, the current falls to zero and tends to reverse, but the diode blocks conduction in the reverse direction. In the third state both the diode and the switch are OFF, in this state the capacitor discharges its energy and the inductor is at rest with no energy stored in it.

There cannot be a net change in flux in the inductor or it would saturate over a number of cycles. The increase in current while the switch is on must exactly equal the decrease in current while the switch is open.

$$\frac{V_i - V_o}{L_o} DT = \frac{V_o}{L_o}(1-D)T$$

$$\frac{V_i - V_o}{L_o} DT = \frac{V_o}{L_o}(1-D)T$$

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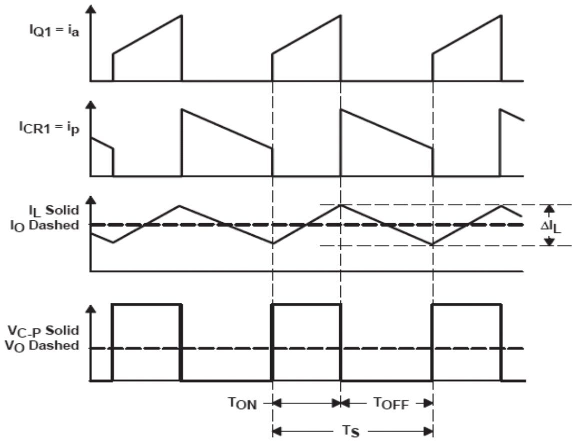

DESIGN PROCEDURE:

Period, T=1/fsw

DUTY CYCLE ,D=V0/Vin

D= Iin / Iout

Output current, I0=P/V0

Iin=D*Iou

CALCULATION OF INDUCTANCE:

T = Il*L*Vi/(V0(Vi-V0))

CALCULATION OF Cin AND Cout*:*

T=D/fsw

Fsw-switching frequency

Iripple=1/2*Iload

Cin= T/((Vripple/Iripple)-ESR)

Cout=V0(Vi-V0)/8*L*Vi*f^2*change in V0

2. COMPONENTS:

I. Advanced Regulating Pulse Width Modulator

DESCRIPTION

This monolithic integrated circuit contains all the control circuitry for a regulating power supply inverter or switching regulator. Included in a 16-pin dual-in-line package is the voltage reference, error amplifier, oscillator, pulse width modulator, pulse steering flip-flop, dual alternating output switches and current limiting and shut-down circuitry. This device can be used for switching regulators of either polarity, transformer coupled DC to DC converters, transformerless voltage doublers and polarity converters, as well as other power applications. The SG1524 is specified for operation over the full military ambient temperature range of -55°C to +125°C, the SG2524 for -25°C to +85°C, and the SG3524 is designed for commercial applications of 0°C to +70°C.

FEATURES

- 8V to 40V operation
- 5V reference
- Reference line and load regulation of 0.4%
- Reference temperature coefficient < ± 1%
- 100Hz to 300KHz oscillator range
- Excellent external sync capability
- Dual 50mA output transistors
- Current limit circuitry
- Complete PWM power control circuitry
- Single ended or push-pull outputs
- Total supply current less than 10mA

HIGH RELIABILITY FEATURES - SG1524

- Available to MIL-STD-883B and DESC SMD
- MIL-M-38510/12601BEA - JAN1524J
- Radiation data available
- LMI level "S" processing available

The UC1524, UC2524 and UC3524 incorporate on a single monolithic chip all the functions required for the construction of regulating power supplies, invertersor switching regulators.They can also be used as the control element for high-power-output applications. The UC1524 family was designed for witching regulators of either polarity, transformer-coupled dc-to-dc converters, transformerless voltage

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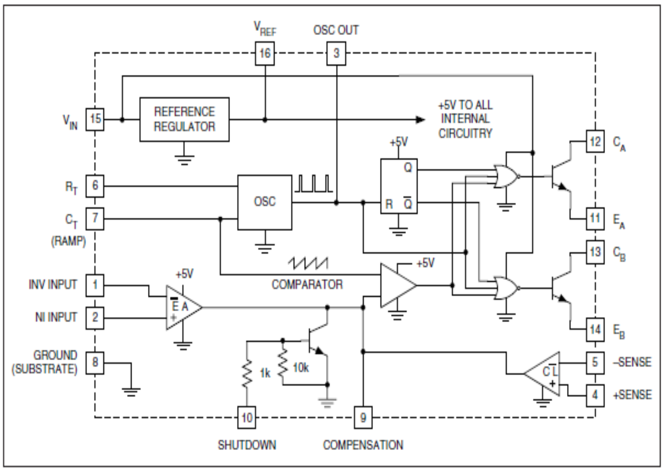
doublers and polarity converter applications employing fixed-frequency, pulse-width modulation techniques.

BLOCK DIAGRAM



APPLICATION NOTES

OSCILLATOR

The oscillator in the SG1524 uses an external resistor RT to establish a constant charging current into an external capacitor CT. While this uses more current than a series-connected RC, it provides a linear ramp voltage at CT which is used as a time dependent reference for the PWM comparator. The range of values for CT also has limits, as the discharge time of CT determines the pulse width of the oscillator output pulse. The pulse is used (among other things) as a blanking pulse to both outputs to insure that there is no possibility of having both outputs on simultaneously during transitions. This output dead time relationship is shown in Fig

Internal structure of ic 1524:

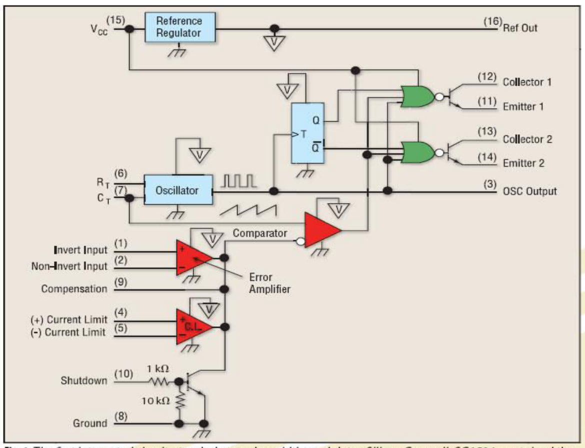
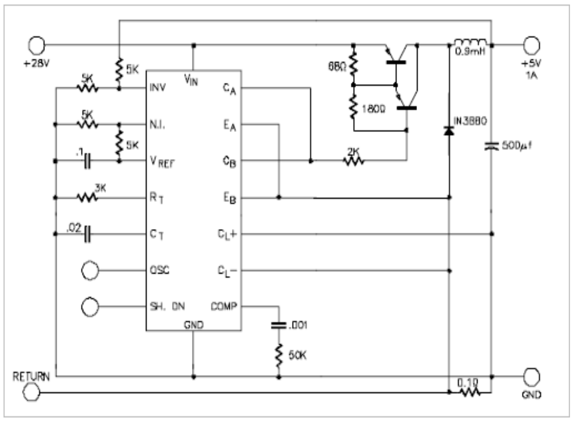


Fig. 1. The first integrated circuit, stand-alone pulse-width modulator, Silicon General's SG1524, contained the analog and digital circuitry to drive the input transistors of a switching regulator power supply.

FEEDBACK

Feedback and control circuitry can be carefully nested around these circuitsto regulate the energy transfer and maintain a constant output within normal operating conditions. Control by pulse-widthmodulation is necessary for regulating theoutput.

Pin diagram of IC SG1524



CURRENT LIMITING

The current limiting circuitry of the SG1524 is shown in Fig By matching the base-emitter voltages of Q1 and Q2, and assuming a negligible voltage drop across R1:

C.L. Threshold = VBE(Q1) + I1• R2 - VBE(Q2) = I1• R2

The most important of these is the limited common-mode voltage range: ±0.3 volts around ground. This requires sensing in the ground or return line of the power supply. Also precautions should be taken to not turn on the parasitic substrate diode of the integrated circuit, even under transient conditions. A Schottky clamp diode at Pin 5 may be required in some configurations to achieve this. A second factor to consider is that the response time is relatively slow. The current limit amplifier is internally compensated by R1, C1 ,and Q1, resulting in a roll-off pole at approximately 300 Hz. A third factor to consider is the bias current of the C.L. Sense pins.

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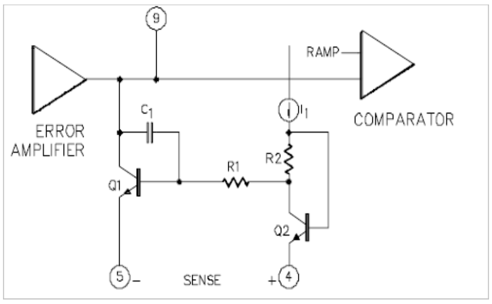
A constant current of approximately 150□A flows out of Pin 4, and a variable current with a range of 0-150□A flows out of Pin 5. As a result, the equivalent source impedance seen by the current sense pins should be less than 50 ohms to keep the threshold error less than 5%. Since the gain of this circuit is relatively low (42 dB), there is a transition region as the current limit amplifier takes over pulse width control from the error amplifier. For testing purposes, threshold is defined as the input voltage required to get 25% duty cycle (+2 volts at the error amplifier output) with the error amplifier signaling maximum duty cycle.

APPLICATION NOTE: If the current limit function is not used on the SG1524, the common-mode voltage range restriction requires both current sense pins to be grounded.



Power MOSFET

This N-Channel enhancement mode silicon gate power fieldeffect transistor is designed, tested and guaranteed towithstand a specified level of energy in the breakdownavalanche mode of operation. These MOSFETs aredesigned for applications such as switching regulators,switching converters, motor drivers, relay drivers, and driversfor high power bipolar switching transistors requiring highspeed and low gate drive power. They can be operateddirectly from integrated circuits

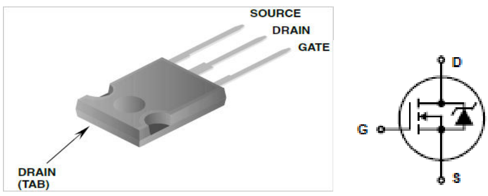
.In its crudest form a switch can be a toggle switch which switches between supply voltage and ground. But for all practical applications which we shall consider we will deal with transistors. Transistors chosen for use in switching power supplies must have fast switching times and should be able to withstand the voltage spikes produced by the inductor. The input on the gate of the transistor is normally a Pulse Width Modulated (PWM)signal which will determine the ON and OFF time. Sizing of the power switch is determined by the load current and off-state voltage capability.

Another new device likely to displace the BJT in many high power applications is the Insulated Gate Bipolar Transistor (IGBT). This device combines the low power drive characteristics of the MOSFET with the low conduction losses and high blocking voltage characteristics of the BJT. Therefore the device is highly suited to high power, high voltage applications.

Features

- 30A, 200V
- rds.(ON) = 0.085W
- Single Pulse Avalanche Energy Rated
- SOA is Power Dissipation Limited
- Nanosecond Switching Speeds
- Linear Transfer Characteristics
- High Input Impedance
- Related Literature

\- TB334 "Guidelines for Soldering Surface Mount
Components to PC Boards



II. OUTPUT CAPACITOR & INPUT CAPACITOR:

In switching power supply power stages, the function of output capacitance is to store energy. The energy is stored in the capacitor's electric field due to the voltage applied. The function of a capacitor is to attempt to maintain a constant

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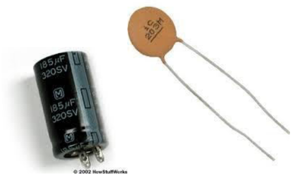
voltage. Electrolytic capacitor of value 100uF is used in the case of output capacitance. Electrolytic capacitor of value 2.33uF is used in the case of input capacitance.

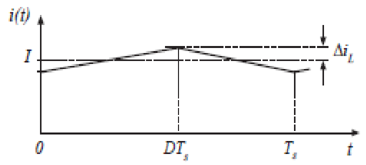


III. OUTPUT INDUCATNCE:

The function of the inductor is to limit the current slew rate (limit the current inrush) through the power switch when the circuit is ON. The current through the inductor cannot change suddenly. When the current through an inductor tends to fall, the inductor tends to maintain the current by acting as a source. This limits the otherwise high-peak current that would be limited by the switch resistance alone. The key advantage is when the inductor is used to drop voltage, it stores energy. Also the inductor controls the percent of the ripple and determines whether or not the circuit is operating in the continuous mode.

In switching power supply power stages, the function of inductors is to store energy. The energy is stored in their magnetic field due the current flowing. The function of an inductor is usually to attempt to maintain a constant current or sometimes to limit the rate of change of current flow.

IV. Inductor current waveform



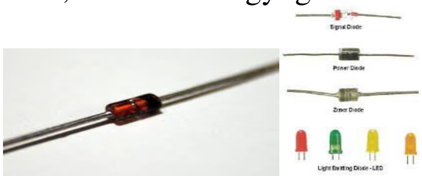
The given inductance value L must be obtained. The inductance is given by $L = n2/R\ g$

$= m0\ Ac\ n2/lg$

V. GENERAL DIODE AND ZENER DIODE:

The purpose of using Zener diode is to maintain 13V peak-peak output voltage at the collector output of the IC UC3524.This inturn given to the gate drive of MOSFET.

The function of freewheeling diode starts when the switch is in the off state.Due to the energy stored in the inductor the diode start conducting in the off state, so the energy gets dissipated in the load.

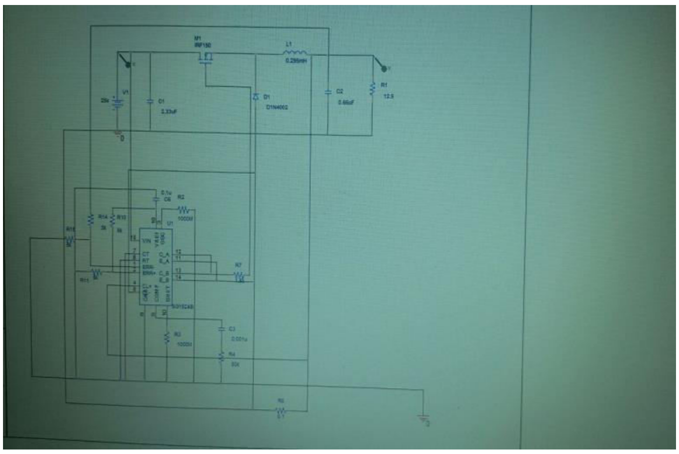


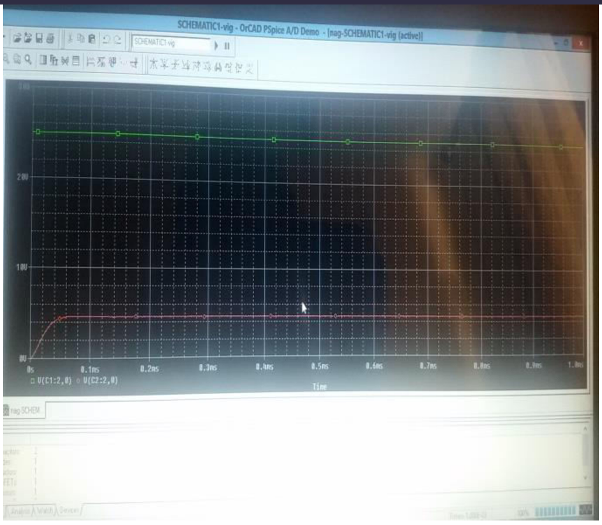
VI. SIMULATION:

CADENCE:

Cadence is a software package used to simulate the power electronic circuits.

The student version is available on the ORCAD website, this was downloaded and can be used for simulation of the circuits once design procedure is completed.





θJA is actually made up of at least two separate thermal resistances in series. One is the thermal resistance inside the device package, between the junction and its outside case, called θJC. The other is the resistance between the case and the ambient, θCA . Because θJC is under the control of the manufacturer, nothing can be done with it. It is typically low. Another stage can be introduced between the case and ambient. This is where the heat sink in θCA is now split into θCS and θSA, where θS is the thermal resistance of the interface compound used, and θSA is the thermal resistance of the heat sink.

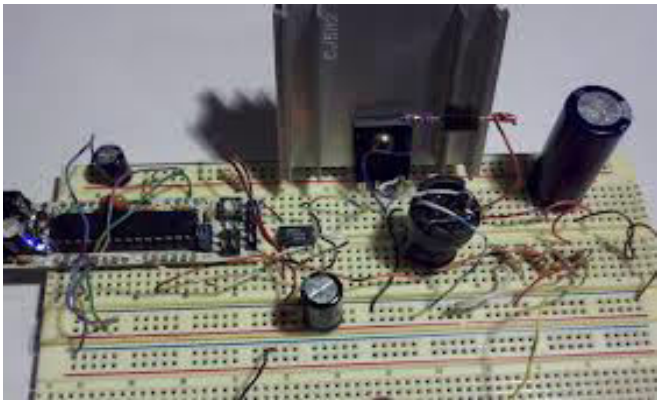
VII. HEAT SINK:

Power dissipation performance must be well understood prior to integrating devices on a printed-circuitboard (PCB) to ensure that any given device is operated within its defined temperature limits. When adevice is running, it consumes electrical energy that is transformed into heat. Most of the heat is typicallygenerated by switching devices like MOSFETs, ICs, etc. This application report discusses the thermaldissipation terminology and how to design a proper heatsink for a given dissipation limit.

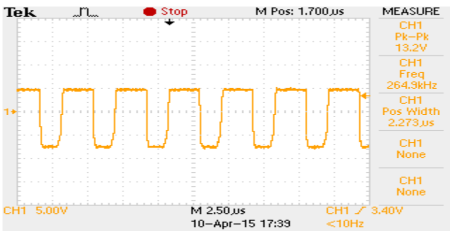
The following are the various important parameters in selecting a heat sink.

1. Thermal resistance θSA
2. Airflow
3. Volumetric resistance
4. Fin density
5. Fin spacing
6. Width
7. Length

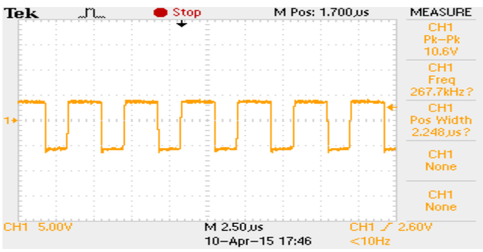
VIII. PRACTICAL CIRCUIT ON THE BREAD BOARD



GATE OUTPUT VOLTAGE:



SOURCE OUTPUT VOLTAGE:



OUTPUT VOLTAGE WAVEFORM:

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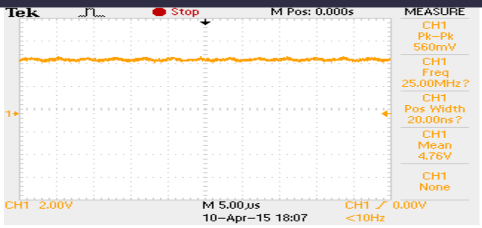
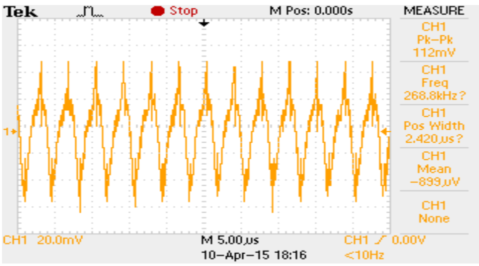


OUTPUT VOLTAGE RIPPLE WAVEFORM:



IX.APPLICATIONS OF STEP DOWN CONVERTER

DC to DC conversion is common in all large manufactured products. Two prime examples are computers and motor vehicles. Using a buck converter offers a much cheaper solution to supplying large systems comprised of smaller components. Rather than buying several power supplies to charge lower rated components, buck converters can be used to step down the voltage to safely supply all components demanding a power supply. Here are some common examples of where a buck converter is implemented:-Trucks generally run off a 24 V DC battery. Car radios are rated at 12 V, so a buck converter is used to step down the voltage to supply the radio. - Supply outlets in motor vehicles for personal electronics, generally rated at 5V or 9V- Computers, buck converters are used to step down the voltage to supply components such as the processor.-Regulating voltage in computers for CPU chips.

DC to DC conversion for electronic manufactured products is always in demand. It saves manufactures money and eliminates many design constraints, by allowing lower rated components to be used in larger systems.

a. Computer power supply

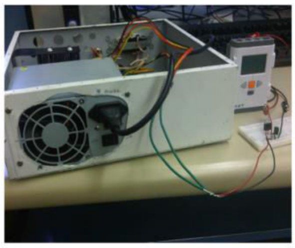


Figure 10: Power up LEGO NXT Brick using computer power supply as voltage source.

b. Speed control of brushless dc motor

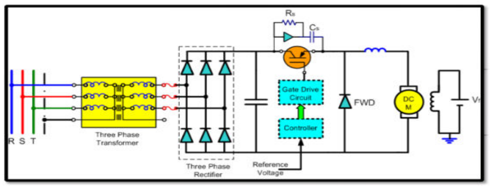
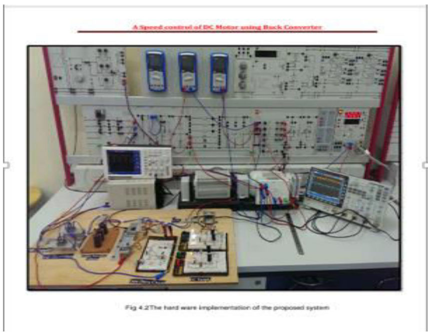


Fig.4.1 the circuit diagram



X. CONCLUSION:

1. In conclusion, the step-down (Buck) converter circuit had been successfully built using the SG1524 positive voltage regulator.

2. Based on the measurements that are performed, the step-down circuit was able to convert the higher DC input voltage (20V-30V) to 5V DC output voltage.

3. The SG1524 voltage regulator was also able to stabilize the resulting DC output voltage, as it was determined to have reasonably steady value.

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4. SG1524 Datasheet and Circuit Schematic Overview.

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