iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** V **Month of publication:** May 2015

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

A Booster and PWM Based Power Amplifier for Reaction Wheel

Rosemary Jose[1], Ramna Radhakrishnan[2]

[1]*Student, M.Tech Power Electronics, Department of Electrical and Electronics Engineering, KMEA Engineering College, Ernakulam, Kerala, India*

[2]*Assistant Professor, Department of Electrical and Electronics Engineering, KMEA Engineering College, Ernakulam, Kerala, India*

***Abstract*— Reaction wheel is an inertial actuator in a spacecraft attitude control system and is used to generate suitable attitude control torques for correcting spacecraft attitude deviation or adjusting to an assigned attitude. As back emf increases with speed, we have to provide high voltage as input to the motor. The boost converter is the best choice to boost up the voltage received from the solar panel to a required level. Also a PWM based power amplifier is essential to energize the coils of the reaction wheel. This paper gives the design of a boost converter with variable input voltage in the range from 28V to 40V and which is capable of boosting up the voltage to 50V with 2A as output current. This output voltage will be the input to PWM based power amplifier.**

***Keywords*—Boost converter, Reaction wheel(RW), Pulse Width Modulation(PWM), PWM based power amplifier,H bridge.**

I. INTRODUCTION

Flywheel is an inertial actuator in a spacecraft attitude control system and is used to generate suitable attitude control torques for correcting spacecraft attitude deviation or adjusting to an assigned attitude. Flywheels used as inertial actuators can be divided into reaction flywheels and momentum flywheels, and generate attitude torque by changing their rotor's speed to keep the spacecraft stable or change its attitude through momentum exchange with spacecraft. There are two types of reaction wheels. They are ball bearing reaction wheels and magnetically suspended reaction wheel.

In Ball Bearing reaction wheel, ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls.

Magnetic bearing reaction wheels can offer distinctive advantages like virtually zero wear and extremely low friction losses. They do not suffer from stiction-friction effects common with mechanical ball bearing reaction wheels, making the deep space missions efficient with long hibernation periods, long lifetime requirements and wide operational temperature ranges. Furthermore, they are highly suitable for antenna fine pointing purposes on geostationary satellite missions where conventional bearing wheels may limit the satellite lifetime. The speed rage of reaction wheels is about 3500 to 7000 Rpm. In high torque reaction wheels, as back emf is always proportional to speed, it produces high back emf so we have to give high voltage as input to the motor. For this DC-DC converters are used. DC-DC converters are operated in BUCK, BOOST and BUCK-BOOST at different voltage conversion ratios. Boost converters are used to obtain higher output voltage in comparison with the input DC voltage. These converters, when operated under open loop condition, it exhibits poor voltage regulation and unsatisfactory dynamic response, and hence, this converter is generally provided with closed loop control for output voltage regulation. The mode of operation of the converter varies from ON to OFF state of the power switch and traditionally small signal linearization techniques have largely been employed for controller design. Many control strategies have been proposed switch ON and OFF (duty cycle).The purpose of the work is to develop a boost converter that is able to boost up a variable DC voltages to a constant DC voltage with desired output voltage value. This boost converter output is given to the power amplifier. After the conversion of the low voltage DC power to a high voltage DC source, the second step is to convert the high DC source to an AC waveform using pulse width modulation. As the circuit converts DC signal to required AC source it is also called as inverter. Using the PWM based power amplifier, the coils of the reaction wheel is energized.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

II. BOOST CONVERTER

A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power (P=VI) must be conserved, the output current is lower than the source current.

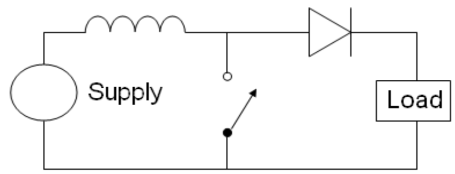

Fig 1.Boost Converter

A. Design of boost converter

Minimum input voltage,Vin(min)=28

Maximum input voltage,Vin(max)=40

Required output voltage, Vout= 50V

Switching frequency,f= 20KHz

Output current Io=2A

Ripple current (ΔI)=10% of Io=.2A

Minimum duty cycle required,

$$D\min = 1 - \frac{Vin(\max)}{Vout} = \frac{Vout - Vin(\max)}{Vout} = 16\% \qquad (1)$$

Minimum duty cycle required,

$$D\max = 1 - \frac{Vin(\min)}{Vout} = \frac{Vout - Vin(\min)}{Vout} = 44\% \qquad (2)$$

Input inductance,

$$L = \frac{Vin(\min)(Vout - Vin(\min))}{\Delta I * f * Vout} = \frac{Vin(\min) D\max}{\Delta I * f} \qquad (3)$$

$$= \frac{28 * .44}{.2 * 20 * 10^3} = 3.08 \mu H$$

Output capacitance,

$$C = \frac{Io * D\max}{f * \Delta Vout} \qquad (4)$$

A ripple voltage of 500mV is assumed.

Therefore $C = \frac{2 * .44}{20 * 10^3 . * 500} = 88 \mu F$

Equivalent series resistance required to limit the ripple voltage to $\Delta Vout$,(ESR) is given by

$$ESR = \frac{\Delta Vout}{\frac{Io}{1 - D\max} + \frac{\Delta I}{2}} = 136 milliohm \qquad (5)$$

B. Closed loop boost converter

The boost operation in closed loop gives us constant 50 V output voltages for any input voltage in the range 28V to 40V.

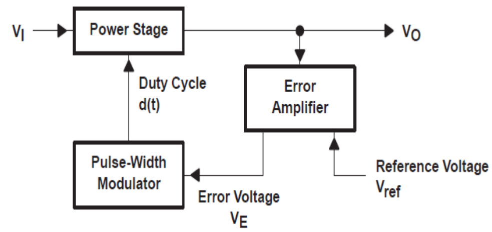

Fig 2.Closed loop control

A suitable error amplifier must be used in order to compare the output voltage with a reference voltage. The output of the error amplifier is given to the PWM modulator in order to set the required duty cycle. The PWM modulator output serves as the gate pulse for MOSFET.

III. PWM BASED POWER AMPLIFIER

After the conversion of the low voltage DC power to a high voltage DC source, the second step is to convert the high DC source to an AC waveform using pulse width modulation. As the circuit converts DC signal to required AC source it is also called as inverter. Of the different DC-AC inverters on the market today there are essentially two different forms of AC output generated ie modified sine wave, and pure sine wave. A modified sine wave can be seen as more of a square wave than a sine wave; it passes the high DC voltage for specified amounts of time so that the average power and rms voltage are the same as if it were a sine wave. These types of inverters are much cheaper than pure sine wave inverters and therefore are attractive alternatives. Pure sine wave inverters, on the other hand, produce a sine wave output identical to the power coming out of an electrical outlet. These devices are able to run more sensitive devices.

In electronic power converters and motors, PWM is used extensively as a means of powering alternating current (AC) devices with an available direct current (DC) source or for advanced DC/AC conversion. Variation of duty cycle in the PWM signal to provide a DC voltage across the load in a specific pattern will appear to the load as an AC signal, or can control the speed of motors that would otherwise run only at full speed or off. This is further explained in this section. The pattern at which the duty cycle of a PWM signal varies can be created through simple analog components, a digital microcontroller, or specific PWM integrated circuits. Analog PWM control requires the generation of both reference and carrier signals that feed into a comparator which creates output signals based on the difference between the signals.

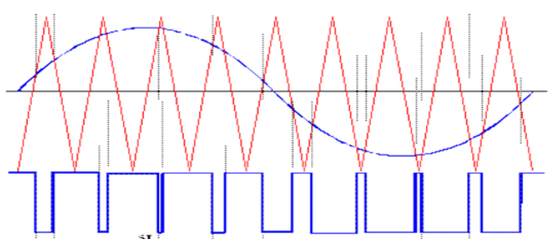

Fig.3 Pulse Width Modulation

The reference signal is sinusoidal and at the frequency of the desired output signal, while the carrier signal is often either a saw tooth or triangular wave at a frequency significantly greater than the reference. When the carrier signal exceeds the reference, the comparator output signal is at one state, and when the reference is at a higher voltage, the output is at its second state. An H Bridge Configuration is used to energize the coils. An H Bridge or full bridge converter is a switching configuration composed of four switches in an arrangement that resembles an H. By controlling different switches in the bridge, a positive, negative, or zero potential voltage can be placed across a load. When this load is a motor, these states correspond to forward, reverse, and off.

International Journal for Research in Applied Science & Engineering
Technology (IJRASET)

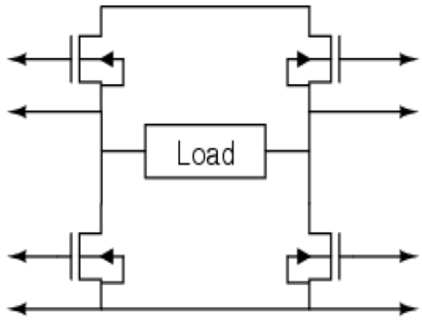

Fig4.HBridge Configuration using N Channel MOSFETs

Figure 4 shows the H Bridge circuit consists of four switches corresponding to high side left, high side right, low side left, and low side right. There are four possible switch positions that can be used to obtain voltages across the load.

The switches used to implement an H Bridge can be mechanical or built from solid state transistors. Selection of the proper switches varies greatly. The use of P Channel MOSFETs on the high side and N Channel MOSFETs on the low side is easier, but using all N Channel MOSFETs and a FET driver, lower "on" resistance can be obtained resulting in reduced power loss. The use of all N Channel MOSFETs requires a driver, since in order to turn on a high side N Channel MOSFET, there must be a voltage higher than the switching voltage. This difficulty is often overcome by driver circuits capable of charging an external capacitor to create additional potential.

IV. SIMULATION RESULTS

The simulation results of boost converter and Pwm based power amplifier using Orcad-Pspice.

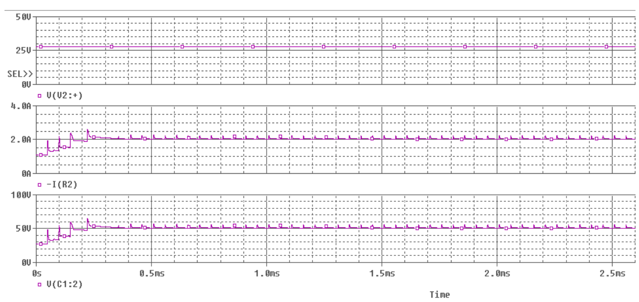

Fig.5 Output of boost converter

Fig .5 shows the simulation result of boost converter for 28V input. The first graph in fig.5 shows the input 28V, the second graph is the output current 2A. And the third graph is the output of boost converter i.e. 50V.

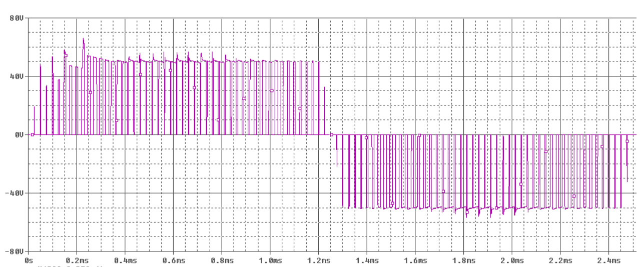

Fig.6. PWM power amplifier output

Fig.6 shows the output observed across the load of PWM based power amplifier .It also gives 50V output. In order to get the pure sine wave output, a filter must be used.

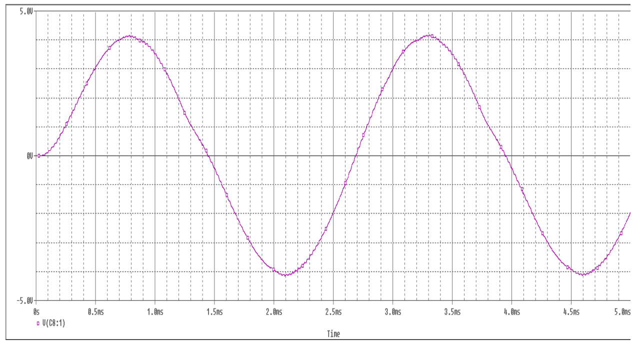

Fig. 7 Filtered output

The output is measured using suitable opamp and filtered out to produce pure sine wave output.

V. CONCLUSION

Reaction wheels are used in spacecrafts for precise attitude control. Reaction wheels run at high speed in order to change the orientation of the satellite. The voltage obtained from the solar panel to run the motor will not be always meet the requirement. That is as back emf increases, we have to supply much voltage to run the the high torque reaction wheel. So in order to provide a constant high output voltage, a boost converter and to energize coils of reaction wheel, PWM based power amplifier should be required. A boost converter is designed with input voltage in the range 28V to 40V using Orcad-Pspice. The simulation results of boost converter and PWM based power amplifier are obtained.

REFERENCES

[1] Pallav Dutta, Sankar Narayan Mahato "Design of Mathematical Model and Performance Analysis of BLBLDC Motor" International Conference on Control, Instrumentation, Energy & Communication 2014.

[2] Pallav Dutta, Sankar Narayan Mahato "Design of Mathematical Model and Performance Analysis of BLBLDC Motor" International Conference on Control, Instrumentation, Energy & Communication 2014.

[3] T.R.Haridas, M.H.Ravichandran, P.V.Unnikrishnan, C.C.Joseph, Robert Devasahayam "Magnetic bearing for reaction wheels in space applications" Proceedings of WTC2005 Tribology Congress III Washington Hilton, D.C., USA, September 2012.

[4] Jaouad Tanouti, Mohammed Setti, Abdelhak Aziz and El Mamoun Aziz. "Application of feedback-feedforward loop digital control to a PWM dc-dc boost converter used for solar photovoltaic systems" Proceedings of Conference,IEEE on Renewable and Sustainable Energy, 2014 .

[5] Jaouad Tanouti, Mohammed Setti, Abdelhak Aziz and El Mamoun Aziz. "Application of feedback-feedforward loop digital control to a PWM dc-dc boost converter used for solar photovoltaic systems" Proceedings of Conference,IEEE on Renewable and Sustainable Energy, 2014.

[6] Khalid H Mohamed, Taib B. Ibrahim and Nordin B. Saad "Boost Converter Design with Stable Output Voltage for Wave Energy Conversion System", International Journal of Information Technology and Electrical Engineering, Volume 2, Issue 1 February 2013

[7] Zhu Changsheng, Mao Zhiwei "A PWM Based Switching Power Amplifier for Active Magnetic Bearings" In proceedings of the Eighth International Conference, IEEE on Electrical Machines and Systems, 2005, Volume 2

[8] Guangzhong Cao and Chong-won Lee "Development of PWM Power Amdifier for Active Magnetic Bearings" Proceedings of the 5th World Congress on Intelligent Control and Automation, June 15-19, 2004, Hangzhou, P.R. China

[9] G. Seshagiri Rao, S. Raghu, N. Rajasekaran, "Design of Feedback Controller for Boost Converter Using Optimization Technique", International Journal of Power Electronics and Drive System (IJPEDS) Vol. 3, No. 1, March 2013, pp. 117-128.