High Voltage Power Supply Design for Photo Multiplier Tube

Anand Antony ee12b113@smail.iitm.ac.in
Nikunj Agrawal ae13b017@smail.iitm.ac.in

A) INTRODUCTION :

CubeSats are playing a vital role in the development of new compact technologies for small satellites and because of their promising potential, the CubeSats have been widely embraced by universities for conducting space research projects. IITMSAT is a student driven Nano-satellite embraced by IIT Madras leading to the development of Space-based Proton-Electron Energy Detector (SPEED). It is a payload that is being developed to be launched on-board IITMSAT. The scientific objective of the payload is to gather data on the variations in the charge particle flux below the inner Van Allen radiation belts. SPEED is designed to obtain energy spectra of high-energy protons and electrons, specifically designed to investigate correlations between variations in these spectra and seismic activity, solar flares and lightning storms. The SPEED electronics consists of Peak hold Detector, Charge-Sensitive Pre-Amplifier, TIVA microcontroller and Photo Multiplier Tubes. This paper describes the development of the high voltage power supply for the photo multiplier tubes (PMT) of SPEED. In SPEED, photo multiplier tubes operates at around 1000 V to 1300 V with very strict ripple requirements and requires very precise and controlled high voltage. Due to their high gain and extremely light sensitivity photomultipliers (PMTs) can easily be damaged by applying excessive light to the photocathode and thus exceeding the maximum output current. A novel compact and controllable high voltage power supply based on integrated DC-DC converters is developed which provides ultralow ripple of about 0.3% to 0.5% at an output of 1000 volts which is further reduced by the 5th order low – pass filter circuitry. Innovative automatic current protection circuitry is developed for protecting PMT from being damaged by saturation current. We are able to develop voltage monitoring and regulation system for high voltage with a voltage regulation of 0.1% .Voltage regulation is achieved by control software based on TIVA microcontroller based solution. A number of tests have been performed to provide very reliable and efficient high voltage power supply for PMT. This poster reflects upon the development of ultra-low noise and ripple power supply for the photo multiplier tube. The goal is to create a very reliable high voltage power supply for the photo multiplier tubes of SPEED and this poster reflects upon the development of the same.

B) OBJECTIVES :

- Design of a power supply that can provide 1500 Volts with the maximum output current of 300 µA
- Output Ripple of the high power supply should be less than 1 Volt
- The Voltage regulation and Voltage controllability should be less than 1Volt
- Need of Current Limiting Circuitry in order to prevent the damage to the PMT due to excessive current
- Input needs to be taken from variable DC supply of 6 – 18 Volts
- Circuit needs to sustain drastic variable temperature and should be functional in vacuum

C) CHALLENGES :

- Whole Power Electronics of High Voltage Power Supply needs to very compact
- Biggest challenge was to overcome strict constraints of Ripple Requirements
- We can trade off on lower current requirement.
- Designing High Voltage traces in PCB was challenging.

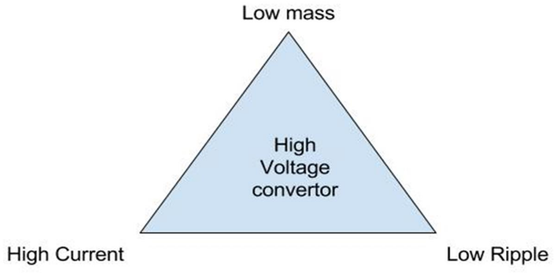

Fig 1 Design Constraints

D) DESIGN ARCHITECTURE :

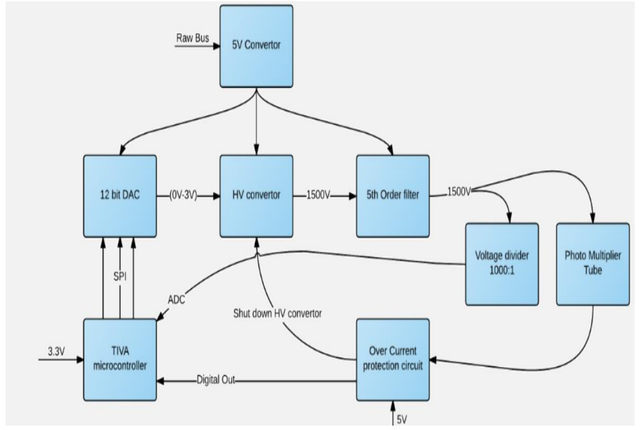

Fig 2 High Voltage Design Architecture

The High Voltage (HV) Convertor is 5 SAR 1500 from Pico electronics. The Output Voltage of the HV convertor is controllable by giving a variable linear reference Voltage. The variable reference Voltage is given by 12Bit SPI DAC LT2632. The HV convertor linearly varies its output voltage from 0V to 1500V for linear variation of input reference Voltage from 0V to 3V. This enables to control the HV convertor to set the output current with a precision of 0.5V.

The High Voltage Convertor produces 294 kHz ripple, and this was also seen in the PMT output, to suppress the Ripple we devised a low pass active 5th order filter from LT1062, and repurposed this filter for High Voltage application by using suitable High Voltage decoupling capacitors that decouple High Voltage DC to the AC ripple. This filters rolls of AC ripple from the DC High Voltage component. Before Addition of filter the output of PMT produces ripple of 294 KHz at 182.5mV peak to peak, after the addition of filter, the ripple voltage reduced to 26.4mV peak to peak.

Fig 3 High Voltage Output before implementing filter design
Scale : y axis -50 mV ; x axis -20 µs

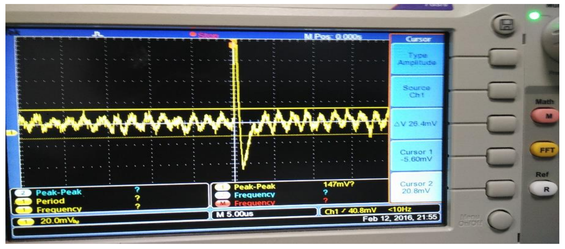

Fig 4 High Voltage Output after addition of filter design
Scale : y axis -20 mV ; x axis -5 µs

We also determined the Amplitude response to find out the maximum ripple Voltage the filter can filter out without allowing high frequency jitter. Since the Supply Voltage of the filter is given as 5V , the Amplitude response saturation peaked at around 4.5V.

The Series resistance due to the Active filter reduced the accuracy of the output Voltage. To improve the Output Voltage regulation and also to monitor the Output Voltage of High Voltage Convertor, we added a 20 MΩ Resistive voltage divider with divider ratio of 1000:1 by Caddock HVD5-A20M-050-05 .

The Over current Protection circuit was designed to Prevent the PMTs getting damaged to saturation currents. The saturation currents may happen mainly due to accidental exposure of PMT to light. The saturation current of the currently used PMT for payload is about 100uA. The Over current Protection circuit is designed to turn off HV convertor, in the event if the return current of PMT exceeds 100uA for 60 seconds. After that it restarts the HV convertor.

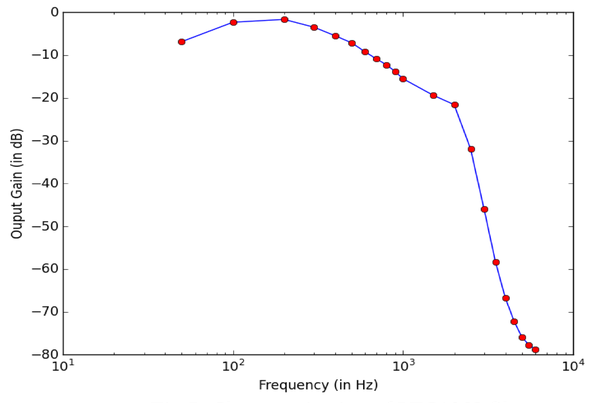

Fig 5 Characterisation of LTC1062 filter

ACKNOWLDGEMENTS :

Special Thanks to our Sponsors

- Dr Krishna Chivakula (Indo-MiM)
- Mr V. Shankar
- Mr, Srikanth Jadcherla
- Dr Sriram Jaisimha
- Mr D. Chandrashekar
- Batch of 1985 of IIT-Madras

Thanks to

- Central Electronics Centre, IIT-Madras for helping us in prototyping
- IIT-Madras for facilitating this Project