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Low power High Voltage supply circuit for Photo Multiplier tubes in the Km3Net experiment

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The described system is developed in the framework of a deep-sea submerged Very Large Volume neutrino Telescope where photons are detected by a large number of Photo Multiplier Tubes [2]. These PMTs are placed in optical modules (OM). A basic Cockcroft-Walton (CW) voltage multiplier circuit design is used to generate multiple voltages to drive the dynodes of the photomultiplier tube. To achieve a long lifetime and a high reliability the dissipation in the OM must be kept to the minimum. The design is also constrained by size restrictions, load current, voltage range, and the maximum allowable ripple in the output voltage. A surface mount PMT-base PCB prototype is designed and successfully tested. The system draws less than 1.5 mA of supply current at a voltage of 3.3 V with a HV output up to -1200 Vdc, a factor 10 less than the commercially available state of the art.

Summary

The purpose of the PMT is conversion of photons from Cherenkov radiation. The Cherenkov light emitted by secondary charged particles (muons) created via a neutrino interaction in or near an optically transparent medium, such as water or ice is used to detect neutrinos. Cherenkov light is detected at the single-photon level, where a precise measurement of place and time of arrival of the photons associated to a secondary muon track is used to reconstruct the neutrino direction and energy. This basic principle is adopted for the KM3NeT neutrino telescope [1]; the target material will be the water in the deep Mediterranean Sea.
The neutrino telescope is composed of a number of vertical structures (the “Detection Units”: DUs), which are anchored to the sea bed and kept vertical by one or several buoys at their tops. Each DU carries photo-sensors and further devices for calibration. The basic photo-sensor unit is an “Optical Module (OM)” housing with several Photo Multiplier Tube (PMT’s), their high-voltage bases and their interfaces to a nanosecond precision data acquisition system. The KM3NeT research infrastructure [2] will be designed to survive at least a decade in the deep sea, under high pressure and in an aggressive salt water environment. The specification for the high-voltage bases is specified in the table below:

Supply voltage 800 < 1400 V
Gain 5x106
Gain slope(vs supp.Volt. log/log) 6.8
Voltage cathode-D1 150 < 500 V
Consecutive dynode, <300 V
Anode and D10 40 < 300 V
Table 1, Main parameters of the PMT-base

One of the major demands for the PMT electronics is providing a stable high voltage for all the dynodes. The described system uses a Cockcroft Walton multiplier [3] for the high voltage stack driven by a fly back converter. With care full selection of all the components the dissipation will be as low as 5mW while commercial solutions offer 50mW.

Ripple dynode to gnd 150 mVpp
dV/dt < 75mV/µs
Inter dynode ripple « 5 mVpp
Repetition rate power switching 2–10 kHz
Voltage input 2.5-4 V
Load < 4.5 mW
Voltage output 800-1200 V
Stab. factor 0.95% output at 38% input
3.3V on to stable cathode 6 s
Power during switch on < 50 mW
RFI radiation 150 kHz-2 MHz,-20 dB @ 200 mV/m
Table 2; specifications achieved with working prototype

Other applications of this design could be in apparatus demanding HV sources like handheld (& other) radiation measurement equipment, medical imaging equipment, medical scan equipments etc.

References
[1] http://www.km3net.org
[2] http://www.km3net.org/CDR/CDR-KM3NeT.pdf
[3] Cockcroft-Walton Voltage multipliers http://www.techlib.com/files/voltmult.pdf

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