A low-cost power supply for silicon photomultipliers

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The HYPATIA project[1)] will eventually comprise several hundred GAGG and $CeBr_3$ crystals with silicon photomultiplier (SiPM) readouts. Due to SiPM devices' gain dependence on temperature and bias voltage, they require power supplies with temperature compensation and high stability. Commercially available power supplies for large amounts of SiPMs are not readily available at an affordable price. To keep costs low for a large project like HYPATIA, we are developing our own power supplies.

A first prototype having 4 outputs on a single PCB provided a proof-of-principle. The photos of Fig. 1 show a second prototype device. This most recent version has a 16 channel modular design to allow quick replacement of units. A Raspberry Pi single-board computer controls temperature compensation and provides a user-friendly web-based interface as shown in Fig. 2.

The presently operational design comprises a large backplane with eighteen 64-wire PCIe sockets installed as card edge sockets. One PCIe socket accepts a power distribution module (left-most module in Fig. 1), there are sixteen sockets for SiPM power supply modules, and one socket for the Raspberry Pi support module (right-most module in Fig. 1). The power distribution module uses a stack of 5 W DC-DC voltage converters to produce ± 15 V and $+75$ V supply rails, a set of low-drop voltage regulators to produce ± 6 V, and a switch-mode voltage regulator to produce 5 V to power the Raspberry Pi. The Raspberry Pi module interfaces the general-purpose input/output lines of the Raspberry Pi into the backplane to connect with SiPM power supply modules, while also sporting a 16-channel bipolar digital-to-analog converter (AD5360) to produce the programming voltages for the SiPM power supply modules.

The SiPM power supply modules each have an ADA4700-1 low-cost high-voltage operational amplifier implemented as an inverting amplifier with gain of $g = -6$ to allow for up to 60 V output voltage. The -15 V and $+75$ V supplies form the supply rails to power the operational amplifiers. The bipolar 16-bit programming inputs result in the output have an LSB of 1.8 mV. To allow for temperature compensation of the SiPM gain, each module has an LTC2452 ultra-tiny 16-bit $\Delta\Sigma$ analog-to-digital (ADC) converter to sample the voltage from an analog voltage sensor attached to each SiPM module. The ADC has sufficient precision to register temperature changes of $\Delta T < 100$ mK.

A software package running the Raspberry Pi reads the temperatures every 16 ms. A one-minute rolling average temperature is calculated for each module and the SiPM bias voltage is adjusted to account for temperature changes each second. The prototype device has been extensively tested in offline and online conditions and found to provide performance meeting or exceeding commercially available solutions, at a small-scale production cost of less than ¥10,000 per channel.

A third prototype is currently being developed. This prototype will add continuous direct monitoring of the SiPM bias voltages as well as the SiPM bias currents.

Fig. 1. Second prototype device with 16 channels. (a) top view (b) front panel view.

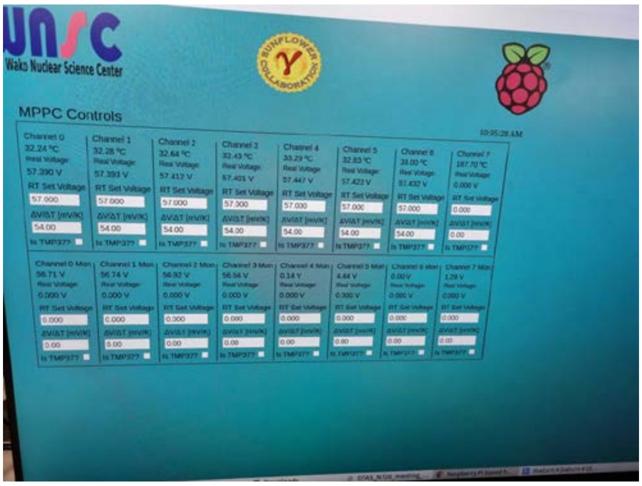

Fig. 2. Screenshot of the web interface used to provide simple control of the power supply.

References
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