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Development of a low-cost power supply with multiple self-adjustable outputs for the operation of silicon photo-multipliers

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Abstract
We present the design of a low-cost (~$400 USD) and high-precision power supply for silicon photomultipliers (SiPMs), widely used in particle detection and photon-counting applications. The system provides four independent output channels, each delivering a tunable bias voltage from 10-58 V with 10mV resolution and less than 1mV noise level. Each channel incorporates a PT100 temperature sensor (15 °C–40 °C range) enabling real-time thermal monitoring and automatic temperature-compensated voltage adjustment to stabilize SiPM gain. The device also supports individual voltage calibration and storage of optimal operating points. Integrated current limiting (100µA/channel) protects the sensors. This compact and versatile design offers a cost-effective alternative to commercial systems, with features tailored for research and development settings.

Keywords: low-cost power supply; multiple outputs; silicon photo-multipliers.

Desarrollo de una fuente de alimentación de bajo costo con múltiples salidas ajustables para la operación de fotomultiplicadores de silicio

Resumen
Presentamos el diseño de una fuente de alimentación de bajo coste (~400 USD) y alta precisión para fotomultiplicadores de silicio (SiPMs), ampliamente utilizados en aplicaciones de detección de partículas y conteo de fotones. El sistema ofrece cuatro canales de salida independientes, cada uno con un voltaje de polarización ajustable entre 10 V y 58 V, con una resolución de 10 mV y un nivel de ruido inferior a 1 mV. Cada canal incorpora un sensor de temperatura PT100 (rango de 15 °C a 40 °C), lo que permite el monitoreo térmico en tiempo real y el ajuste automático del voltaje compensado por temperatura para estabilizar la ganancia del SiPM. El dispositivo también permite la calibración individual del voltaje y el almacenamiento de los puntos óptimos de operación. Un limitador de corriente integrado (100 µA por canal) protege a los sensores. Este diseño compacto y versátil representa una alternativa económica a los sistemas comerciales, con prestaciones orientadas a entornos de investigación y desarrollo.

Palabras clave: fuente de alimentación de bajo costo; múltiples canales de salida; fotomultiplicadores de silicio.

1. Introduction

Silicon photomultipliers (SiPMs) have emerged as versatile solid-state photon detectors, replacing traditional photomultiplier tubes in various applications [1,2]. SiPMs offer advantages such as high sensitivity, compact size, mechanical robustness, and magnetic field insensitivity [2,3]. They are widely used in particle and nuclear physics experiments, medical imaging, and environmental science [1,2]. In positron emission tomography (PET), SiPMs present challenges in signal multiplexing and readout due to their large number of output channels [3]. To fully utilize the capabilities of these sensors, understanding their fundamental properties, including gain fluctuation, afterpulsing, and photon detection

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efficiency, is crucial [4]. Ongoing research focuses on improving SiPM performance in terms of spatial, energy, and timing resolutions for various applications, particularly in PET systems [3,4].

As with every electronic device, the power supply is a crucial component of a system of operating SiPMs [5-7] mainly because the output signal can be influenced by the amount of noise caused by it. Furthermore, the optimal gain of each SiPM might fluctuate if the bias voltage is not stable during operation [4]. A minimal set of considerations to take into account for the design of a power supply to be used in photon detection experiments must include (i) a stable bias voltage, with noise level under a certain threshold to avoid any signal contamination of the SiPM when excited; (ii) a limited operation current to prevent damage on the sensors; (iii) independent bias voltage supply for each SiPM in the array; (iv) a bias voltage compensation demanded by temperature variations in the SiPM operation. In spite of the fact of being produced in series, every SiPM has its own individual physical properties, which makes its performance unique and independent of the rest of sensors even when operating at the same bias voltage in the same environment. Thus, to achieve optimal performance of the entire system, each SiPM has to be supplied with a specific bias voltage, which needs to be fine-tuned.

Under these conditions, we propose and develop a power supply with specific physical features, allowing the adjustment of its parameters in each channel independently, according to the external temperature of operation of the SiPMs. The model consists of four of these sensors, supplied with bias voltages in the range of 10-57V with a resolution of 10mV and a limited current of 100µA, providing a maximum noise level of 1mV. The temperature in each channel is sensed by a PT100 resistive sensor in the range of 15°C to 40°C and the bias voltage is automatically compensated to achieve optimal operation. All the calibration parameters and the optimal operational voltage level are recorded independently for each channel. The schematic diagram of the developed power supply is shown in Fig. 1.

To present the design and test our development, the rest of the article is organized as follows: Section 2 presents the description of the hardware and Section 3 the graphical interface, including the PC interface and firmware. The calibration procedure and adjustment of the components is discussed in detail in Section 4. Designed tests and results are presented in Section 5 and a comparison of costs and specifications of similar power supplies in the market is discussed in Section 6. Conclusions and outlook are finally drawn in Section 7.

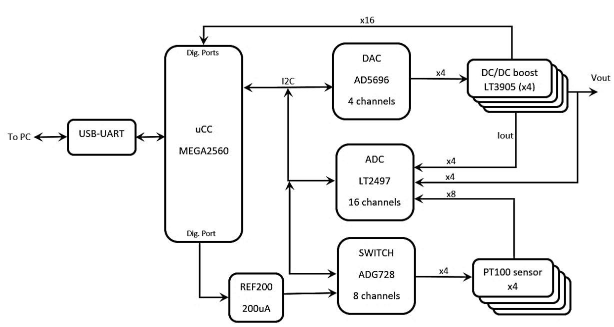

Figure 1. Schematic diagram of the proposed power supply.
Source: Self-designed.

2. Hardware

2.1 Boost-type switching power supply

The four output channels for the SiPMs are based upon the LT3905 integrated circuit, which acts as a boost-converter with the following specifications [8]: Bias voltage in the range from 2.7-12V; output voltage 2.5-65V; maximum output current of 3mA; digital pins for monitoring and control, including sensor loss detector (LOS), excess current consumption detector (ILIM) and enable/disable output voltage (EN/UVLO); analog pins for monitoring and control, including output voltage from 0-1.25V (CTRL) and supplied current monitor (MON). For the SiPMs protection, the chip is connected such that the output voltage does not exceed 58V with a maximum current consumption of 100µA. A sketch of the suggested connection of the LT3905 integrated circuit by the manufacturer is shown in Fig. 2. One can observe that through the CTRL pin, the output voltage is adjusted. LOS and ILIM pins are digital signals to detect low and excess current consumption, respectively and the output current of the APD pin can be measured in the MON pin. Furthermore, the EN/UVLO pin is used to control the activation/deactivation of the circuit to avoid damage on the SiPMs and the board itself, in case of failure.

2.2 Output voltage control for the SiPMs

To adjust the voltage of the pin CTRL off the LT3905, a digital/analog converter AD5696R is used, which exhibits the following specifications [9]: Bias voltage of 2.7-5.5V; 16-bits resolution; reference voltage 2.5V internal and 1V-2.5V external; gain of output voltage 1x and 2x; 4 output channels controlled independently; I2C communication. Through this circuit the output voltage level of each LT3905 is adjusted by varying the voltage in the CTRL pin from 0 to 1.25V according to

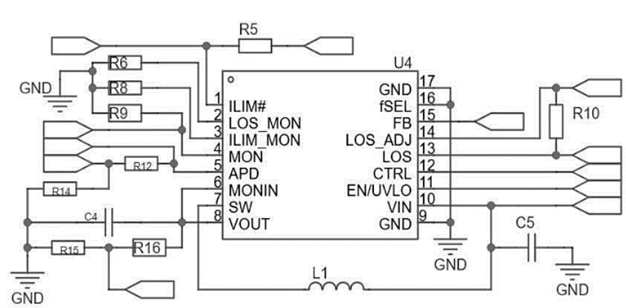

Figure 2. A typical connection diagram of the LT3905 integrated circuit according to the recommendation of the manufacturer [8].
Source: Self-designed.

$$V_{CTRL} = \frac{(DC) * 1.25}{2^{16}}, \qquad DC = 0 - 65535, \tag{1}$$

where DC stands for Digital Code. The maximum output voltage of the LT3905 is attained by a voltage divisor between the V_{out} and FB pins and does not exceed 58V, the upper limit for the SiPM optimal operation. The minimum measured value of the voltage, given the above configuration, on the other hand, was 2.5V, and altogether yield an output voltage of 2.5V when $V_{CTRL} = 0$, and $V_{out} = 58$V when $V_{CTRL} = 1.25$V. Such a linear relation can be expressed as

$$V_{out} = 2.5V + \frac{58-2,5}{1.25} V_{CRTL} = 2.5V + 44.4 V_{CTRL}, \tag{2}$$

or, upon integrating the value of the DAC,

$$V_{out} = 2.5V + \frac{44.4*DC*1.25V}{65536} = 2.5V + \frac{55.5*DC}{65536}. \tag{3}$$

Given that the manufacturer does not provide the sensitivity of the CTRL pin, these values were physically tested on the chip and yield a resolution of

$$\Delta V_{out} = \frac{55.5V}{65536} = 0.847 \frac{mV}{bit}, \tag{4}$$

which is satisfactory for our purposes.

2.3 Measurement of temperature, voltage and current of the SiPMs

For measuring temperature, output voltage, and current, the LTC2497 A/D converter is used, which features the following specifications [10]: Bias voltage of 2.7-5.5V; 16 channels in single-ended mode, 8 channels in differential mode, or a combination of both; 16-bit resolution; reference voltage of 0.1V to VCC; direct connection to differential sensors; I2C communication; maximum sampling rate of 100SPS. Due to the high flexibility of this converter, the channel allocation for the aforementioned signal measurements is 8 channels for differential measurements of PT100 sensors and 8 single-ended channels for output voltage and current measurements.

A typical connection diagram for this ADC is shown in Fig. 3.

As can be observed, this converter reads voltages differentially, simplifying the connection of PT100 sensors to measure the temperature of the SiPMs. The measurement methods for the three aforementioned variables are: For the output voltage, a voltage divider connected in parallel to the SiPM; for the output current, the resistor connected to the MON pin of the LT3905 generates a voltage of 1mV/µA, which is measured

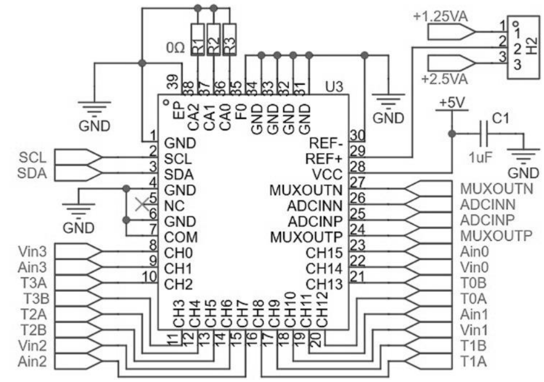

Figure 3. Connection diagram of the LTC2497 integrated circuit according to the recommendation of the manufacturer [10].
Source: Self-designed.

directly across this resistor; finally, for the PT100 sensor voltage, a 200µA current is driven through the sensor, creating a differential voltage across its terminals. The generated voltage (which depends on ambient temperature) is measured directly using two ADC channels. The implementation of this stage is currently under consideration given the need for experimental characterization of the SiPM response under controlled circumstances.

2.4 General control of the supply

All the previously mentioned components are controlled by an ATmega2560 microcontroller, which features the following specifications [11]: Operating voltage of 2.7-5.5V; 8-bit processor; I2C, SPI and UART communication interfaces, digital input/output ports with TTL levels of 2.7-5V and interrupt handling capability. This component manages communication between the converters for both output voltage adjustment and acquisition of voltage, current, and temperature signals from the four channels of the power supply. Communication with the control interface is established via the UART port using a USB-UART converter. Through this interface, the output voltage configurations for each channel are transmitted, while voltage, current, and temperature readings from each channel are received.

The implementation of the power supply is shown in Fig. 4, whereas a prototype of the metallic case to reduce electromagnetic interference is shown in Fig. 5.

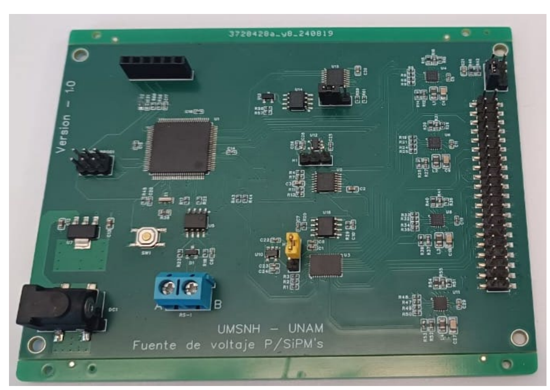

Figure 4. A photograph of the implementation of the power supply.
Source: Self-captured photograph.

Figure 5. A photograph of the prototype metallic case of the power supply.
Source: Self-captured photograph.

3. Graphical interface

3.1 User interface software

To control all functions of the power supply, a graphical user interface (GUI) was developed in the NetBeans integrated development environment (IDE), with the aim of ensuring portability across different operating systems. When the program is launched, the interface detects the COM ports assigned by the operating system. The user must select the one corresponding to the voltage source and press the "Connect" button. If the connection is successfully established, the system displays the message "Connected"; otherwise, shows "Unconnected".

The interface displays the current voltage, current, and temperature values for each channel enabled by the user. Once the channels are activated, the user can modify their values and choose whether to apply temperature correction. At the bottom, a table displays the channels, updating approximately every minute—the time required for the microcontroller to sample all channels and compute their averages. A sample screenshot of the interface is shown in Fig. 6.

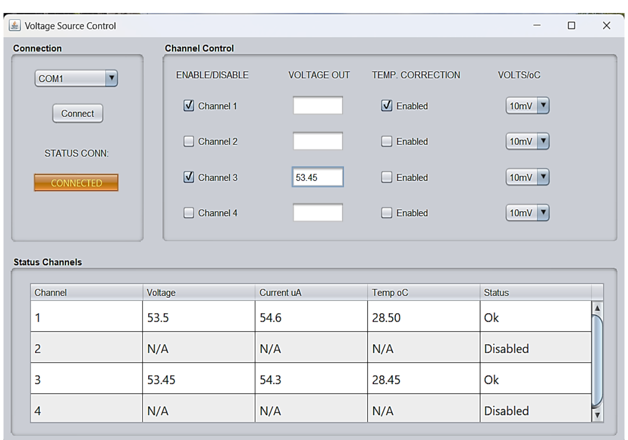

Figure 6. A screenshot of the control interface of the power supply.
Source: Self-shoot.

3.2 Microcontroller software implementation

The microcontroller firmware was developed in C language using a state-based architecture to optimize processor efficiency. This scheme manages the various peripherals employed, including the UART serial port, digital I/O ports, and I2C serial interface. For communication with the user interface, the UART serial port is used in conjunction with a USB-UART adapter. The system continuously polls this interface to check for user requests. If no request is pending, the firmware executes the following tasks: A/D conversion with one input channel sampled at a time (4 voltage channels, 4 current channels, and 4 temperature channels). To prevent excessive delays that could disrupt communication responsiveness, not all channels are converted simultaneously; Averaging the current readings with previous measurements for each channel; output voltage level of a channel is adjusted if enabled via the interface; digital pin monitoring for active signals on digital pins. If detected, it notifies the user and triggers the appropriate action; acquired data transmission to the user interface for display.

The firmware supports the following user commands: (i) Enable/disable a channel; (ii) adjust the output voltage level of a channel; (iii) enable/disable automatic temperature compensation; (iv) monitor voltage, current, and temperature readings per channel or collectively.

4. Calibration and adjustment of the power supply components

To ensure the required precision of the power supply, calibration of both the DAC and ADC conversion signals was performed using a KEITHLEY Model 6514 precision electrometer. This instrument was employed to measure the output voltage and current values using resistive charges of known values. Given that the electrometer and the power supply display a series RS-232 and USB interfaces, a PYTHON script was written to automatically assign an output voltage value which is compared against the measured value after a stabilization time interval of approximately 10s. These tests were performed 5 times each at a room temperature of 22ºC and then averaged, as shown in Figs. 7-11.

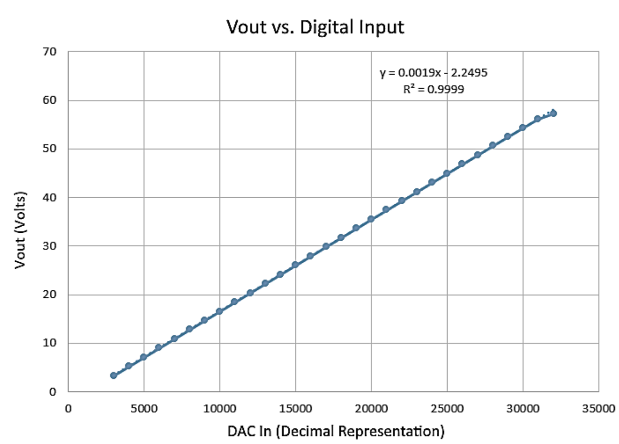

Figure 7. Output voltage as seen in the DAC.
Source: Self-generated.

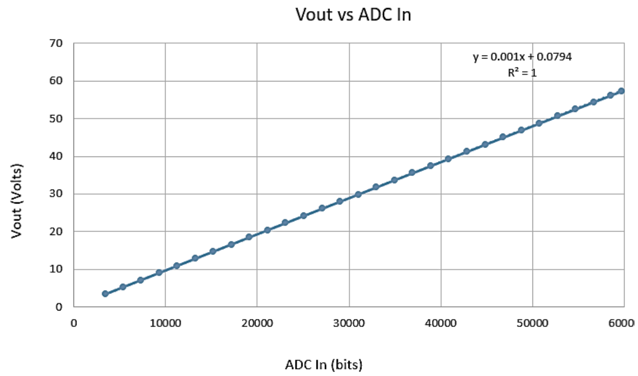

Figure 8. Relationship Between Input Voltage and ADC Output Code (Decimal Representation).
Source: Self-generated.

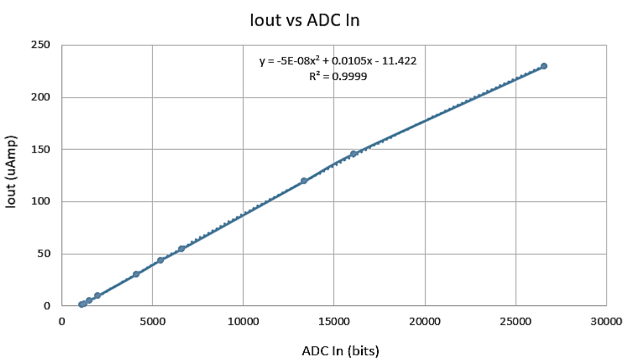

Figure 9. Output current in the ADC.
Source: Self-generated.

We observe a linear behavior which is corroborated with a linear regression. A similar trend can be observed in the ADC output expressed in decimal code, as shown in Fig. 8.

Finally, the output current in the ADC in bits is displayed in Fig. 9, which also describes linear behavior.

With this data, the microcontroller is programmed according to the linear fits obtained from linear regression to adjust the output voltage of the power supply, as well as to read the voltage and current delivered to the sensor, and

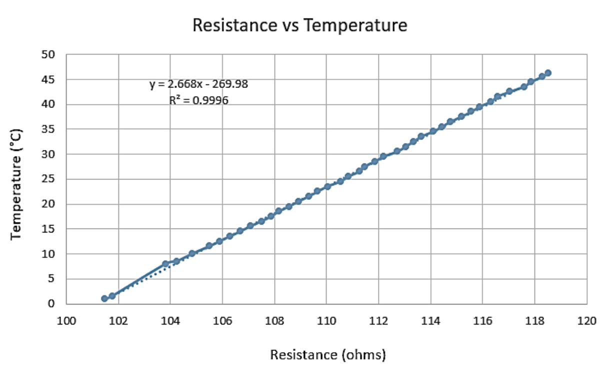

Figure 10. Resistance in the PT100 sensor as a function of temperature.
Source: Self-generated.

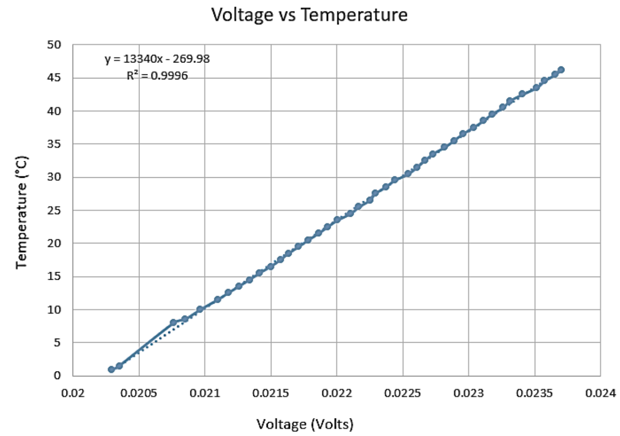

Figure 11. Voltage of the PT100 sensor as a function of temperature.
Source: Self-generated.

to perform necessary corrections for both temperature variations and component deviations. Voltage and current displayed consistent measured values and only measurements on temperature showed outliners, which were discarded.

For the calibration of the temperature sensor, a current of 200μA is injected in a PT100. This generates a potential difference across its terminals, which is measured with the KEITHLEY 6514 electrometer and the ADC converter. These measurements are depicted in Fig. 10.

When the current circulates through the PT100 sensor, the potential difference proportional to the resistance of this component is measured by the ADC, as shown in Fig. 11.

From the test, we obtain the following for the power supply:

- Output voltage: 2.5V-58V
- Resolution of the output voltage: 0.86mV/bit
- Maximum output current: 140μA
- Resolution of measured output voltage: 0.88mV/bit
- Resolution of temperature measurement: 0.0006 ºC/bit

Although these values are satisfactory for the initial needs, additional tests at different temperatures are required to warrant the precision of the results with different conditions.

5. Tests and results

5.1 Measurement of the noise level of the power supply in the load

For testing the power supply, a HAMAMATSU SiPM sensor Series 13 with a minimum operating voltage of 53V and a recommended overvoltage ±3V was connected in series with a 50-ohm resistor.

The power supply was connected to the sensor via shielded SMA cables. Using an SMA "T" connector, an oscilloscope was attached such that channel 1 monitors the supply voltage whereas channel 2 measures the voltage drop across the 50-ohm resistor. To analyze the noise level in the sensor, channel 2 was set to AC coupling, suppressing the DC component. Fig. 12 shows the two signals.

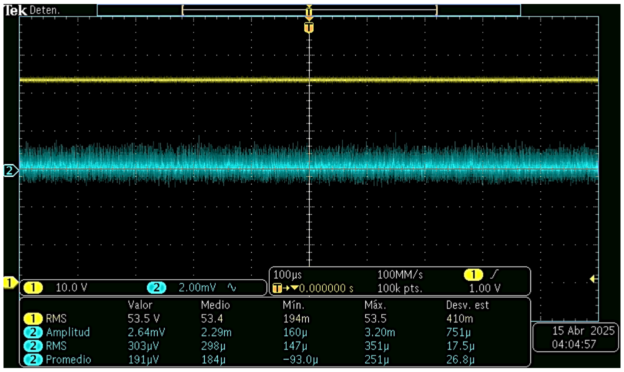

Figure 12. Output voltage of the power supply (yellow) and noise level in the load (blue).
Source: Self-generated.

As shown in the Fig. 12, the sensor bias voltage is set at 53.5V, while the output voltage across the load exhibits a noise signal below 0.3mVRMS, thereby meeting the design requirement.

Several tests were conducted to verify the proper operation of the power supply. One of such tests involved cosmic ray signal measurements, for a constant irradiation of the system. For this purpose, a plastic scintillator EJ232 with dimensions 20x20x5mm^3 coupled to the sensor is used. The experimental setup is housed in a light-tight plastic enclosure to prevent SiPM excitation from ambient light and is directly connected to an oscilloscope. A preliminary evaluation was conducted both with and without a preamplification stage, leading to the conclusion that, under the operating conditions of this experiment, preamplification is not required. The system was subsequently operated continuously at room temperature for approximately two weeks, during which about 2000 events were recorded. Each event was processed offline using dedicated software to determine the baseline voltage and the peak signal amplitude. The signal rise time was evaluated using a constant-fraction timing method by measuring the time interval required for each event to reach fixed fractions of its maximum amplitude (10%–75%). These time intervals were accumulated into a histogram and statistically analyzed, yielding a Gaussian distribution. From this analysis, a raw rise-time estimate of

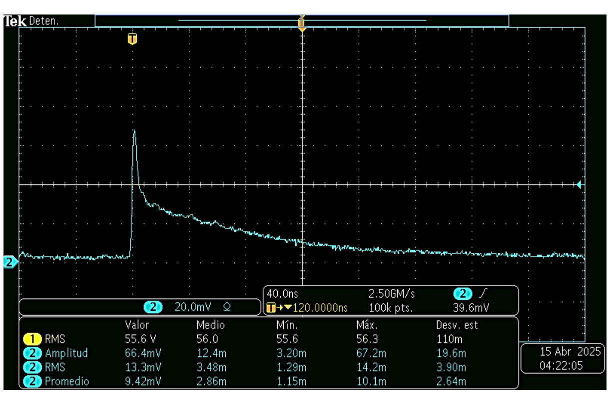

Figure 13. Output signal of the detection system excited by cosmic rays.
Source: Self-generated.

17 ns was obtained for the experimental setup. After applying a signal-to-noise ratio correction, the resulting time resolution was determined to be 49±5 ps. Fig. 13 shows a typical signal for the detection of a cosmic rays particle.

As can be observed, the sensor signal is highly stable with low noise levels, enabling reliable detection of cosmic ray particles generating peaks above 66.4mV. This performance ensures trustworthy readings while minimizing the risk of false positives that could potentially arise from power supply noise.

5.2 Stability test: Voltage vs Time

To monitor voltage variability as a function of the operating time of the power supply, we employ once more the KEITHLEY 6514 electrometer connected to a PC to record voltage values over an extended period (approximately 1.5 hours) at a selected operating voltage of 53.3V that corresponds to the threshold voltage for HAMAMATSU SiPM sensor operation. The measured values are shown in Fig. 14.

Analysis of the data reveals an average voltage of 53.299V with a standard deviation of 0.6mV, indicating excellent power supply voltage stability.

Based on these results, we conclude that the voltage supply meets all required specifications for reliably powering optical sensors. The final power supply specifications are as follows:

- Number of channels: 4
- Operating voltage range: 10 - 58V
- Maximum operating current per channel: 100µA
- Maximum noise level: 0.5mVRMS
- Output voltage adjustment resolution: 10mV
- Voltage measurement resolution: 0.88mV
- Power consumption: 2W (no load) / 4W (full load)

As for the traceability of the calibration when the power supply is used in different conditions, the system implements a reference voltage REF2025 with the following features:

- Output voltage: 1.25V and 2.5V
- Thermal drift: 8ppm/°C from -40°C to 125°C
- High initial precision: +/- 0.05%
- Follow up of output voltage over temperature: 7ppm/°C

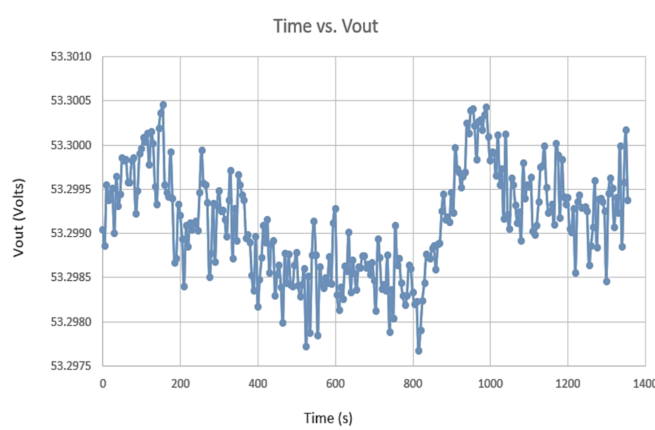

Figure 14. Variation of the sensor voltage in time. In total, 1400 readings were made, each every 10 seconds apart.
Source: Self-generated.

Due to the use of this reference, the ADC measurements would be less influenced by the variation of room temperature where the power supply operates. Nevertheless, tests should be conducted to determine whether the use of such a reference suffices or additional adjustments should be done due to the operation temperature.

6. Costs comparison

In this section we present a comparison of our proposal of power supply with available models.

CAEN N1418/N1419 Family – Modular/Desk. A high-voltage module designed to deliver precise and stable power to detectors used in nuclear and particle physics experiments. This system features up to four independent channels, each with individual voltage and current control, enabling flexible and safe configuration. It is particularly notable for its low ripple, overload and short-circuit protection, and local/remote monitoring capabilities, making it a reliable choice for laboratory environments requiring high electrical precision and stability.

Specifications:

- Type: Modular (N1418) or benchtop (N1419) unit
- Channels: 1 channel (N1419) / up to 4 channels (N1418)
- Voltage Range: 0-100 V (N1418) / 0-130 V (N1419)
- Maximum Current: ~1 mA per channel
- Control: Manual and remote (USB, Ethernet on select models)
- Protections: Overvoltage, overcurrent

Hamamatsu C11204-01 Series. A compact module specifically designed to provide bias voltage for SiPMs. It employs a digitally controlled DC-DC converter, generating an adjustable high-voltage output typically ranging from 30-90V, with high stability and low noise—critical features for ensuring optimal performance in photon detection applications. This power supply includes an I2C communication interface, enabling remote monitoring and control of key parameters such as output voltage, supplied current, and internal temperature, making it easily integrable into broader data acquisition or scientific instrumentation systems.

Specifications*:*

- Type: Dedicated SiPM bias voltage supply
- Channels: 1 channel
- Voltage Range: 20–90V
- Maximum Current: ~0.5 mA
- Fine Adjustment Resolution: steps of 1.8mV
- Interface: Serial (I2C)
- Compatibility: Exclusive to specific Hamamatsu sensors
- Estimated Price: ~$1,000 USD

CAEN DT5485. A compact and reliable model designed to deliver high-precision bias voltages for scientific applications, particularly in nuclear and particle physics experiments. This model stands out for its exceptional stability, low ripple noise, and multi-channel operation capability, enabling safe and efficient power delivery to sensitive detectors. Its modular design ensures seamless integration into larger instrumentation systems while providing precise control and real-time monitoring of electrical parameters.

Specifications:

- Type: Benchtop, high-precision
- Channels: 8 independent channels
- Voltage Range: 0–100V
- Resolution: 1 mV (voltage) / 1 nA (current)
- Control Interfaces: USB, Ethernet, CAEN Graphical User Interface (GUI)
- Compatibility: Optimized for laboratory setups with multi-SiPM configurations
- Estimated Price: ~$3,500–4,200 USD

Keithley 2400 Series. A precision instrument from the SourceMeter® family, designed to source voltage or current with high accuracy while simultaneously measuring electrical parameters including voltage, current, and resistance. Its operation is based on four-quadrant capability (both sourcing and sinking power), enabling use as either a power source or electronic load. This makes it ideal for characterizing semiconductor devices, electronic materials, and sensors. The instrument provides pico Ampere and microvolt measurement resolution and includes digital control interfaces (GPIB, RS-232, and USB) for seamless integration into automated test and laboratory systems. Due to its versatility, stability, and real-time measurement capabilities, the Keithley 2400 is widely used in advanced electronics research, development, and quality assurance applications.

Specifications:

- Type: Precision benchtop source/measure unit
- Channels: 1 channel (per unit)
- Voltage Range: Up to 200V
- Control: Touchscreen, GPIB, USB, LAN
- Compatibility: Optimized for I-V characterization
- ~$6,000–7,500 USD

Note: While costly, it is invaluable for laboratories requiring precise sourcing and measurement capabilities.

This proposal. The developed power supply features four independent output channels, each providing an adjustable bias voltage ranging from 10-57V with 15mV resolution. The high resolution enables precise operational voltage tuning, which is critical for optimizing SiPM performance. The system maintains a maximum noise level of 10mV and incorporates PT100 temperature sensors for all four channels, enabling real-time thermal monitoring within a 15-40°C range.

Specifications:

- Channels: 4 (independent)
- Voltage Range: 10-57V (per channel)
- Control: Graphical interface via PC (Windows/Linux/macOS)
- Interface: USB connectivity
- Compatibility: Supports any sensor within voltage range
- Resolution: 10mV (voltage)
- Maximum Current per Channel: 1mA

Table 1.
Comparative table of different power supplies for SiPM systems.
Source: Self-elaboration

Power Supply	CAEN	Hamma-matsu	CAEN	Keithley	This proposal
Model	A1418/ 1419	C11204-01	DT5485	2400	-------
Channels	1-4	1	8	1	4
Voltage	0-130V	20-90V	0-100V	±200V	10-57V
Remote Control	Yes	No	Yes	Yes	Yes
Cost (USD)	1200-3000	1000	3500-4200	6000-7500	350-400
Recommen-dations	Tests or basic research	Plug and play solutions	Multichannel system	Accurate characterization	Basic research

7. Conclusions and outlook

The power supply is a critical component in any electrical or electronic circuit, where its performance in load regulation, noise level, and voltage stability significantly impacts the overall functionality of powered devices and systems. Based on the experimental results obtained from the tested proposal, we conclude that the design meets the specified requirements while remaining a cost-effective solution for powering SiPM sensors as compared with other options available in the market, as summarized in Table 1. Due to the flexibility of the implemented components, the power supply can be adapted for other types of sensors, provided that the necessary hardware modifications are made. The current design supports loads of up to 2mA at voltages reaching 63V. Future work on the power supply design is focused on enhancing communication speed by optimizing component performance or switching to a more efficient communication protocol, increasing the sampling rate of the ADC converter for improved signal acquisition, expanding the channel capacity to accommodate a larger number of sensors; implementing modular channel design to allow individual channel replacement in case of failure, and integrating TCP/IP connectivity to enable networked control of multiple power supplies via a centralized web interface, thereby scaling the channel capacity of the full system. These advancements aim to improve versatility, reliability, and scalability, making the voltage source suitable for a broader range of applications in sensor-based systems.

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References

[1] Simon, F., Silicon photomultipliers in particle and nuclear physics, nuclear instruments and methods in physics research section a: Accelerators, Spectrometers, Detectors and Associated Equipment, 926, pp. 85-100, 2019. DOI: https://doi.org/10.1016/j.nima.2018.11.042.

[2] Stagliano, M., d'Errico, F., Abegão, L., and Chierici, A., Silicon photomultiplier current and prospective applications in biological and radiological photonics, International Journal of Science and Engineering 4(4), pp. 7-15, 2018. DOI: https://doi.org/10.53555/eijse.v4i4.143.

[3] Park, H., Yi, M., and Lee, J.S., Silicon photomultiplier signal readout and multiplexing techniques for positron emission tomography: a review. Biomed. Eng. Lett. 12, pp. 263-283, 2022. DOI: https://doi.org/10.1007/s13534-022-00234-y.

[4] Gundacker, S., and Heering, A., The silicon photomultiplier: fundamentals and applications of a modern solid-state photon detector Phys. Med. Biol. 65(7), pp. 1-31, 2020. DOI: https://doi.org/10.1088/1361-6560/ab7b2d.

[5] Schumacher, J., Auffenberg, J., Bretz, T., Hebbeker, T., Louis, D. and Zantis, F.P., Dedicated power supply system for silicon photomultipliers. Proceedings of Science, 236, art. 0605, 2016. DOI: https://doi.org/10.22323/1.236.0605.

[6] Javakhishvili, O.I., Keshelashvili, I., Mchedlishvili, D., Gagoshidze, M., Hahnraths, T., Kacharava, A., Metreveli, Z., Müller, F., Sefzick, T., Shergelashvili, D., Soltner, H., and Ströher, H., Development of a multi-channel power supply for silicon photomultipliers reading out inorganic scintillators, Nuclear Instruments and Methods in Physics Research Section a: Accelerators, Spectrometers, Detectors and Associated Equipment, 977, art. 164337, 2020. DOI: https://doi.org/10.1016/j.nima.2020.164337.

[7] Eigen, G., Cvach, J., Kvasnicka, J., Polak, I., Træet A. and Zalieckas, J., Gain stabilization of SiPMs with an adaptive power supply. Journal of Instrumentation 14, art. 5006, 2019. DOI: https://doi.org/10.1088/1748-0221/14/05/P05006.

[8] LT3905. Data sheet of the manufacturer, [online]. Available at: https://www.analog.com/media/en/technical-documentation/data-sheets/3905fa.pdf.

[9] AD5696. Data sheet of the manufacturer, [online]. Available at: https://www.analog.com/media/en/technical-documentation/data-sheets/ad5696_5694.pdf.

[10] LTC2497. Data sheet of the manufacturer, [online]. Available at: https://www.analog.com/media/en/technical-documentation/data-sheets/2497fb.pdf.

[11] ATMEL - MEGA2560. Data sheet of the manufacturer, [online]. Available at: https://ww1.microchip.com/downloads/aemDocuments/documents/OTH/ProductDocuments/DataSheets/ATmega640-1280-1281-2560-2561-Datasheet-DS40002211A.pdf.

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