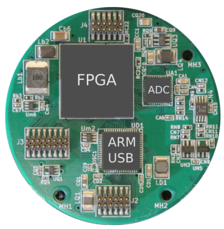
SiPM-3K-40MHz

BRIDGEPORT INSTRUMENTS, LLC **High speed MCA for SiPM**

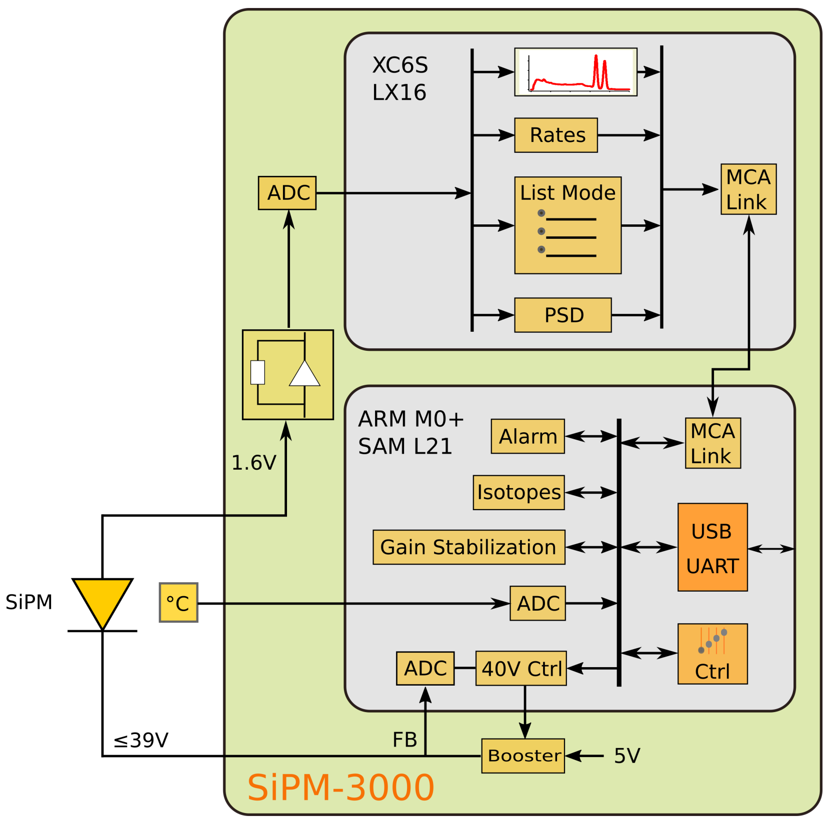


SiPM-3000 MCA with USB & GPIO.

The SiPM-3000 is a fast, high-performance MCA for SiPM with pulse shape discrimination capability and excellent pile up rejection. The MCA itself is implemented in an FPGA for loss-less two-bank histogram acquisition.

Control tasks are performed by an ARM M0+ processor. It operates the SiPM light sensor and exposes a USB interface. While the FPGA is acquiring data, the ARM processor performs programmable gain stabilization and custom analysis tasks.

Custom ARM software can provide alarming functions based on accurate statistical computations and convert the SiPM-3000 into a Portal Monitor Appliance that updates its alarm status 10 times per second.



MCA

- 4096 channels, 32-bit depth
- Hardware serves all scintillators
- Min. time between pulses: 0.25µs
- 2-bank histogram for loss-less data acquisition
- 500kcps throughput

Standard ARM functions

- Gain stabilization
- Support LED

Optional ARM functions

- Sample − Background
- Radiation Portal Monitor

Optional FPGA functions

- PSD with separate spectra (α/β, β/γ γ/n)
- Extended lengths, two-bank list mode

Customization

- Adjust SiPM voltage range
- Application-specific software
- Embedded software is safe against reverse engineering.

Ideal for portable systems:

- Low power consumption 5V@60mA=300mW
- USB or UART serial interface.

The SiPM-3000 is ideal for

- Scintillators with PSD capability
- High count-rate, high-precision spectroscopy

SiPM-3000 Summary

The SiPM-3000 combines the successful eMorpho FPGA-based MCA design with the ability to directly operate a SiPM-based radiation detector. The SiPM-3000 retains all the powerful capabilities of the eMorpho, including loss-less two-bank histogram acquisition and direct waveform sampling at 40MHz for on-the fly pulse shape discrimination.

While the FPGA is acquiring data, the ARM processor controls the SiPM, executes gain and performance stabilization. On top of that it has the resources to provide real-time data processing and exposes a USB interface.

The SiPM-3000 is ideal for high-precision loss-less spectroscopy combined with pulse shape discrimination (PSD). Applications are high-speed spectroscopy and Phoswich detectors.

Principle of operation
- I → V converter
- Continuous sampling by 12-bit ADC.
- FPGA tracks baseline, recognizes pulses
- Creates energy histogram with 4096 32-bit bins.

FPGA Functions
- Perform Histogram DAQ
- Measure count rates
- Perform PSD
- Acquire list mode data
- Acquire 1K sample oscilloscope traces
- Acquire auxiliary data; eg ROI-counts

ARM M0+ Functions
- Read Histogram & count rates from FPGA
- Control the 40V booster to power the SiPM.
- Read an external temperature sensor.
- Perform gain stabilization vs temperature.

Extended functionality
- Sample &mins; Background with computed contamination probability.
- Portal Monitor code updates alarms and background 10 times per second.
- Customer-specific

Conversion times
- Integration: Software-adjusted for the scintillator
- Adjustable dead time ≥ integration time
- Min. conversion time: 0.25µs

SiPM operating voltage
- Fixed positive polarity
- Standard: Up to 37.4V, effective

Server-side software
- MCA communicates via USB on Windows and Linux; x86/x64 & ARM processors, using libusb0.1
- MCA Data Server encapsulates device operation
- JSON command interface
- Client can be written in any programming language.
- Ethernet communication via robust transport layer using zeroMQ.

Client software
- wxMCA GUI for Windows and Linux
- Example clients in Python
- API in Python

Power supply
- Supply: 4.3V to 5.5V @ 60mA

Environmental
- Operational from -40°C to +60°C

Part numbers
- MCA: SiPM-3K-40M

Document no. sipm3k_flyer_u5.pdf

SiPM-3000 Standard and Optional Capabilities	
Capability	***Description***
Analog	Operate SiPM-arrays at up to 37V. Direct anode to amplifier coupling for highest signal fidelity and best pulse shape discrimination.
Gain stabilization	The SiPM-3000 can adjust the operating voltage and the digital gain independently as a function of temperature to ensure that both gain and trigger threshold remain constant over temperature. Such a look up table necessarily depends on the scintillator, and developers can program their own tables. A third lookup table can be used in conjunction with LED-based gain stabilization or for custom purposes.
Two-bank counter and histogram	The SiPM-3000 can count pulses in either of two active banks, one for samples to be measured and one for storing a background measurement. In dynamic environments, the two banks can be used to implement loss-less counting: One bank acquires data while the other bank can be read at leisure.
Net counts and histograms	Custom SiPM-3000 embedded software can report background-subtracted histograms and count rates.
High-speed DSP	In the SiPM-3000 the MCA is implemented in an FPGA and its input data stream is the digitized scintillator pulse waveform. As a result, the FPGA can apply pulse shape discrimination in real time. This supports various specialty applications at the highest possible speed and throughput. Examples are phoswiches and neutron/gamma detectors.
Analysis	Custom SiPM-3000 embedded software can report the probability that the measured sample count rate is compatible with the background count rate. Users can set an alarm threshold in terms of probability: Alarm if there is little chance ($<\varepsilon$) that the sample count rate is caused by the measured background.
Dynamic alarming	Custom SiPM-3000 embedded software and FPGA firmware can analyse and report count rates in time slices of 100ms, ie at a rate of 10/s. The device automatically tracks slowly changing backgrounds and will alarm on a passing source. Its digital output can be used to drive an audio or visual alarm.
Communication	The SiPM-3000 implements a USB-2.0 compatible USB 1.2 interface.

Gain stabilization

The SiPM-3000 can use a 20-point lookup table that describes the desired operating voltage and digital gain vs temperature behavior. The embedded processor applies this to counteract the SiPM vs temperature gain drift. Typically, the lookup table starts at lut_tmin=-30°C and increments in lut_dt=5°C steps up to 65°C. However, the developer can configure that to meet their requirements. And the developer can program a lookup table of their own choice into the non-volatile memory of the SiPM-3000.

The developer programming the lookup tables into the SiPM-3000 can set the lut_mode lock-bit to 1. That prevents a user from reading back a proprietary gain-stabilization lookup table.

Time-slice operation

There are dynamic situations, where a radioactive source can be measured only for a brief moment. Examples are a vehicle passing through a radiation portal monitor, or a person with a backpack detector walking past a stationary source.

The time-slice operation supports these cases. When equipped with the appropriate software and FPGA firmware, the SiPM tracks slow changes in the environmental background. An alarm is created when during a summation time (L) of typically 4 seconds, the accumulated counts are significantly more than what is expected from the background. The alarm threshold is defined as the probability that the measured counts (N) during a period L, could have been caused by the established background rate over the same period (B).A threshold of 1.0e-4 means that we alarm when $P(\text{Counts} \geq N|\text{BCK}) < 1.0\text{e-}4$.

For example, assume a summation time of 4 seconds and a background rate of 500cps for BCK=2000. Now assume that we count 2500cps in a particular 4s-period. The probability of the established background to cause 2224 counts or more in 4s is $P(\text{Counts} \geq 2224|\text{BCK}=2000) = 2.86\text{e-}7$. This smaller than the alarm threshold of 1.0e-4, and the embedded program will generate an alarm.

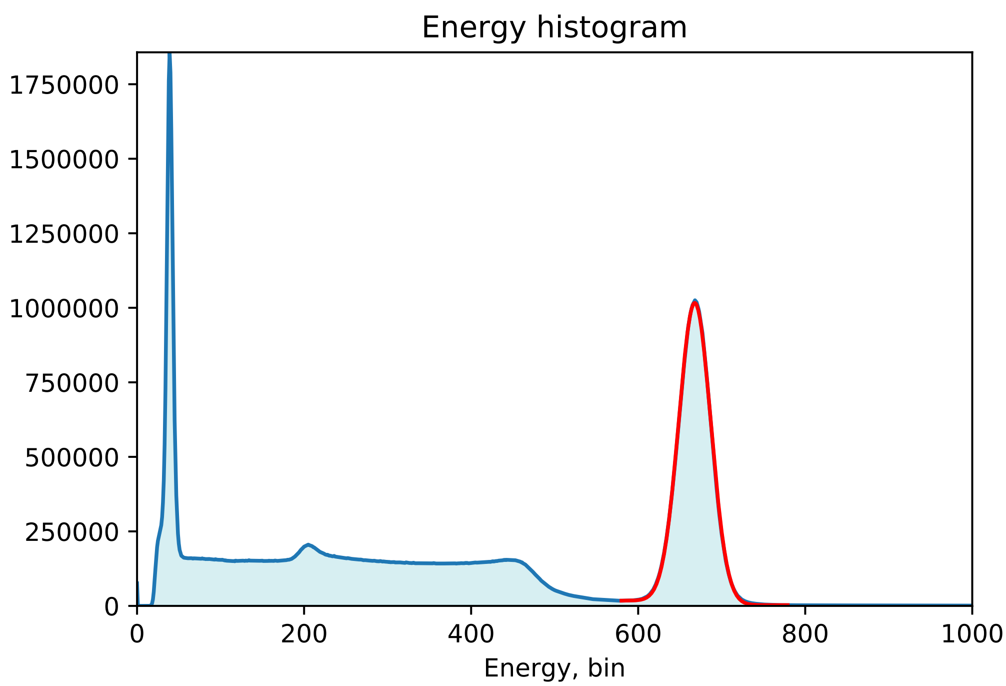
If the alarm condition is permanent, the software resets all the logic after a period of H time slices and starts counting again. It now will accept the suddenly higher level of radioactivity as the new normal background.

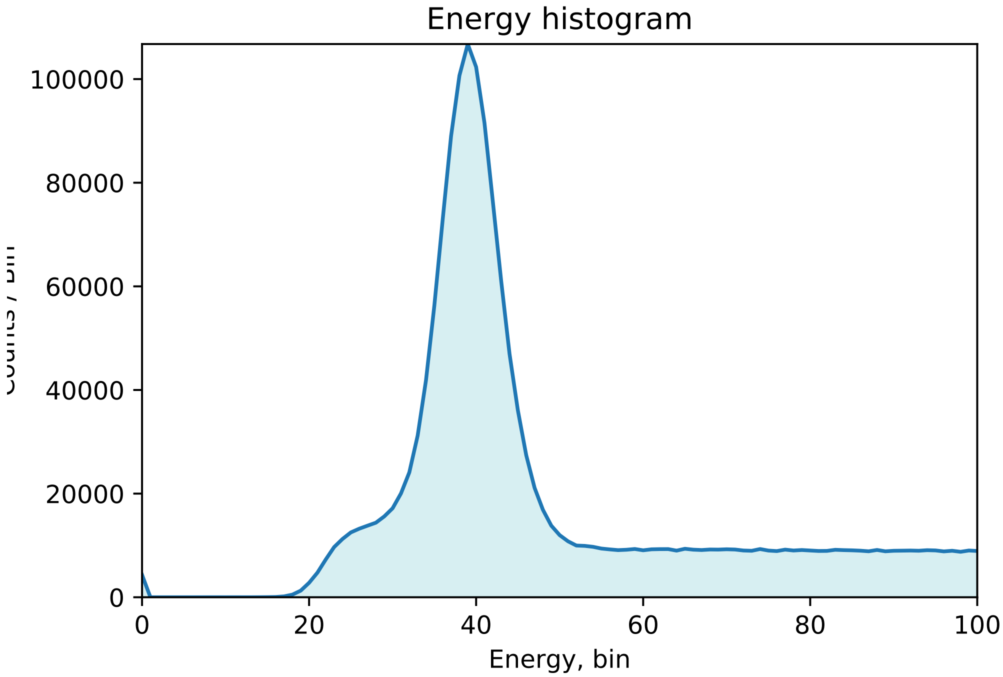
Finally, a 'wait' parameter tells the system to wait a number of time slices after turn-on or reset before being ready to alarm. This is necessary so that the background will be known with sufficient accuracy.

All told, the time-slice firmware provides an unprecedented, and highly configurable, but fully autonomous alarming system for portal monitors. This is ideal for very low-cost mass-produced pedestrian monitors, hand-held sweepers and similar applications.

SiPM-3000 Performance

MCA Performance





Cs-137 spectrum on a 50x50mm high-quality NaI(Tl) crystal, 2.4x2.4cm² Broadcom SiPM array. The energy resolution is 6.56%fwhm at 662keV. Gain and operating voltage were adjusted for a maximum measurable energy of 3.2MeV. Notice in the bottom panel that the spectrum cleanly extends to below 22keV.