Summary

Features

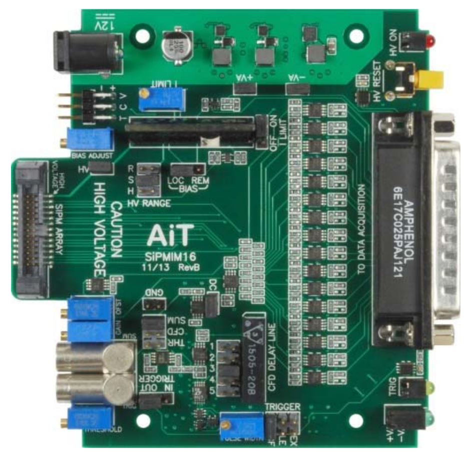
- Connects one ABL series 16-channel SiPM base
- Connects one AB4 series 4-channel SiPM base through a cable adapter
- Wideband DC-coupled signal path
- Buffers 16 SiPM signals for an external ADC
- Sums 16 SiPM signals with gain & offset adjustment
- Internal constant-fraction discriminator
- SiPM array bias is provided by a precision variable HV power supply with over-current shutdown, voltage monitor, and current monitor

Standard accessories

- 3 ft. 26-conductor micro-pitch cable assembly
- 1 ft. DB25F ribbon cable assembly
- 12V, 1A desktop power supply

Enclosure Front

Enclosure Back



Circuit Board

Local controls

- SiPM bias voltage
- Analog sum gain & offset; DC or AC coupling
- Discriminator threshold
- HV power supply over-current fault reset

Local output signals

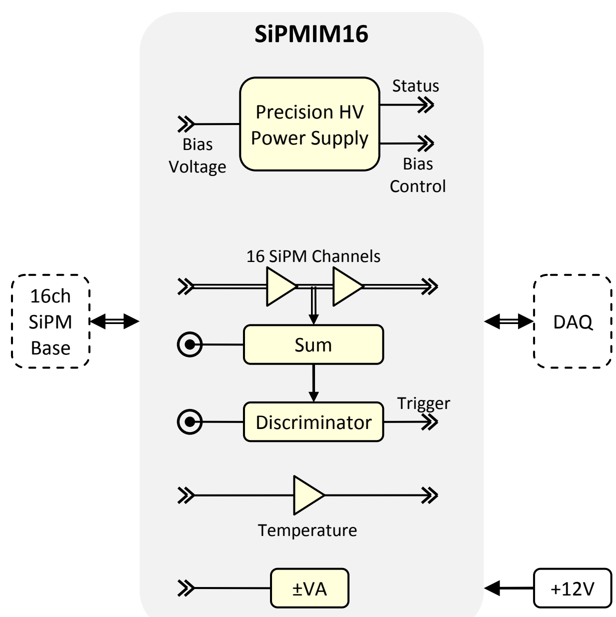
- Bias voltage, bias current, SiPM temperature
- Analog sum / CFD zero-crossing / threshold
- TTL trigger input / output

I/O Port signals for an external DAQ

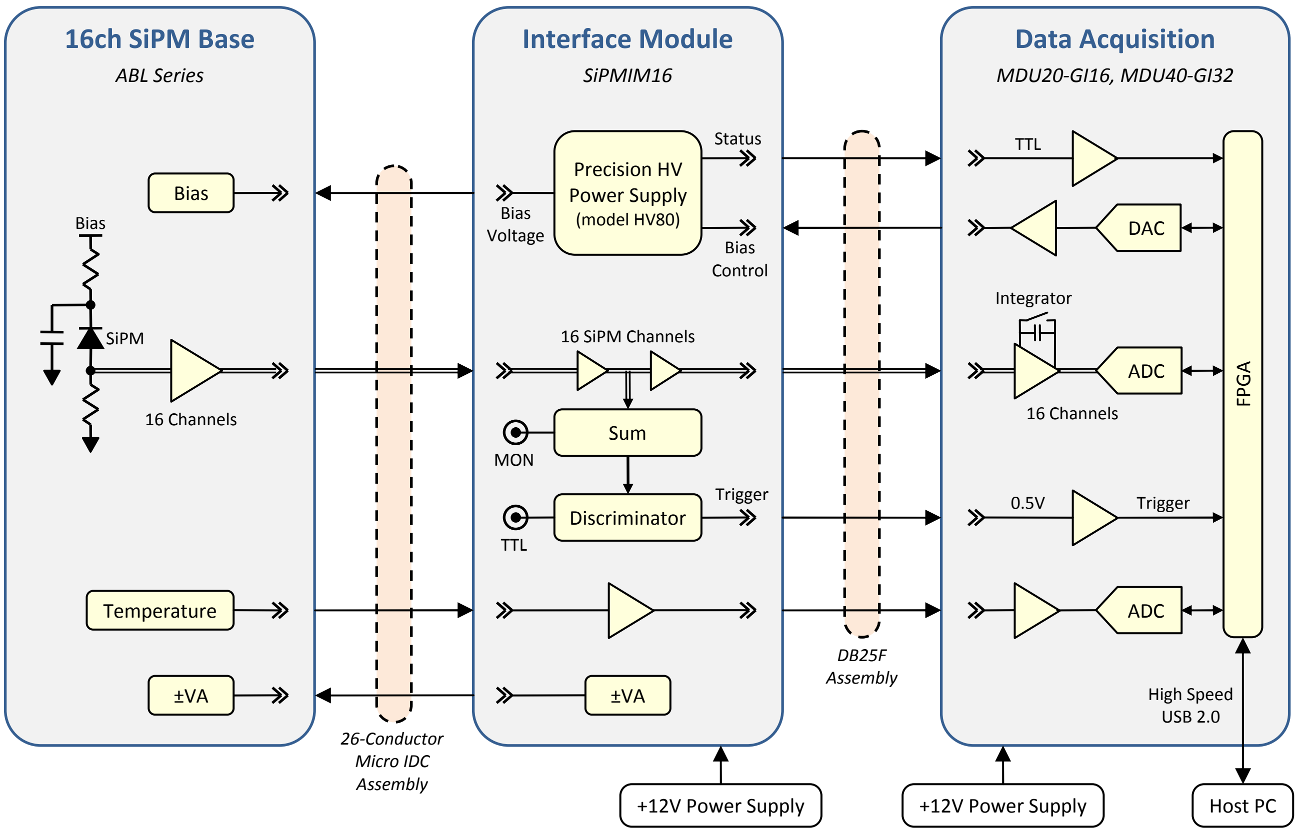
- 16 buffered SiPM signals
- SiPM Base temperature
- Bias voltage control and HV status
- Trigger

SiPM Base signals

- 16 SiPM signals
- SiPM bias voltage
- Amplifier power
- Base temperature



ABL Series 16-Channel SiPM Readout System



Summary

A 16-channel SiPM array readout system consists of an ABL series 16-channel SiPM Base, a SiPMIM16 ("IM16") Interface Module, and a 16/32-channel simultaneous sampling USB gated integrator model MDU20-GI16 or MDU40-GI32.

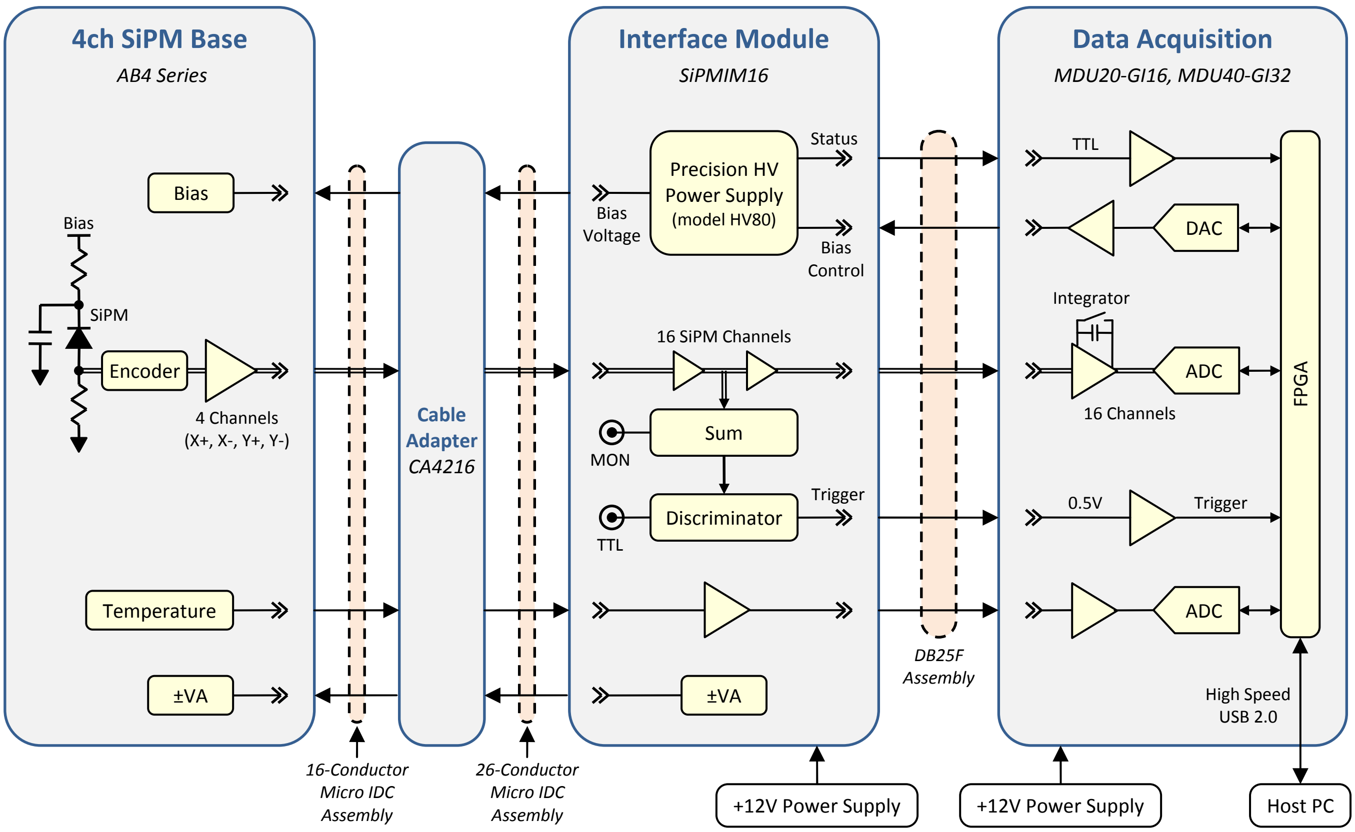
SiPM Base and Interface Module

The ABL Base connects to the IM16 through a micro-pitch ribbon cable that permits versatile placement of the Base. The IM16 powers the Base, buffers SiPM signals, and forms a trigger from the discriminated analog sum of all SiPM signals.

MDU20-GI16 and MDU40-GI32

The MDU20-GI16 has 16 simultaneous gated integrators followed by 16 simultaneous sampling ADCs. Each integrator is preceded by a 100ns analog delay to compensate for trigger latency. A 16-bit DAC controls SiPM bias and a 16-bit ADC monitors SiPM temperature. The IM16 connects to the MDU20-GI16 through a DB25F cable assembly. The MDU40-GI32 is a dual version of the MDU20-GI16 capable of controlling two IM16s.

AB4 Series 4-Channel SiPM Readout System



Summary

A 4-channel SiPM array readout system consists of an AB4 series 4-channel SiPM Base, a SiPMIM16 ("IM16") Interface Module, and a 16/32-channel simultaneous sampling USB gated integrator model MDU20-GI16 or MDU40-GI32. A cable adapter is required to connect the AB4 to the IM16.

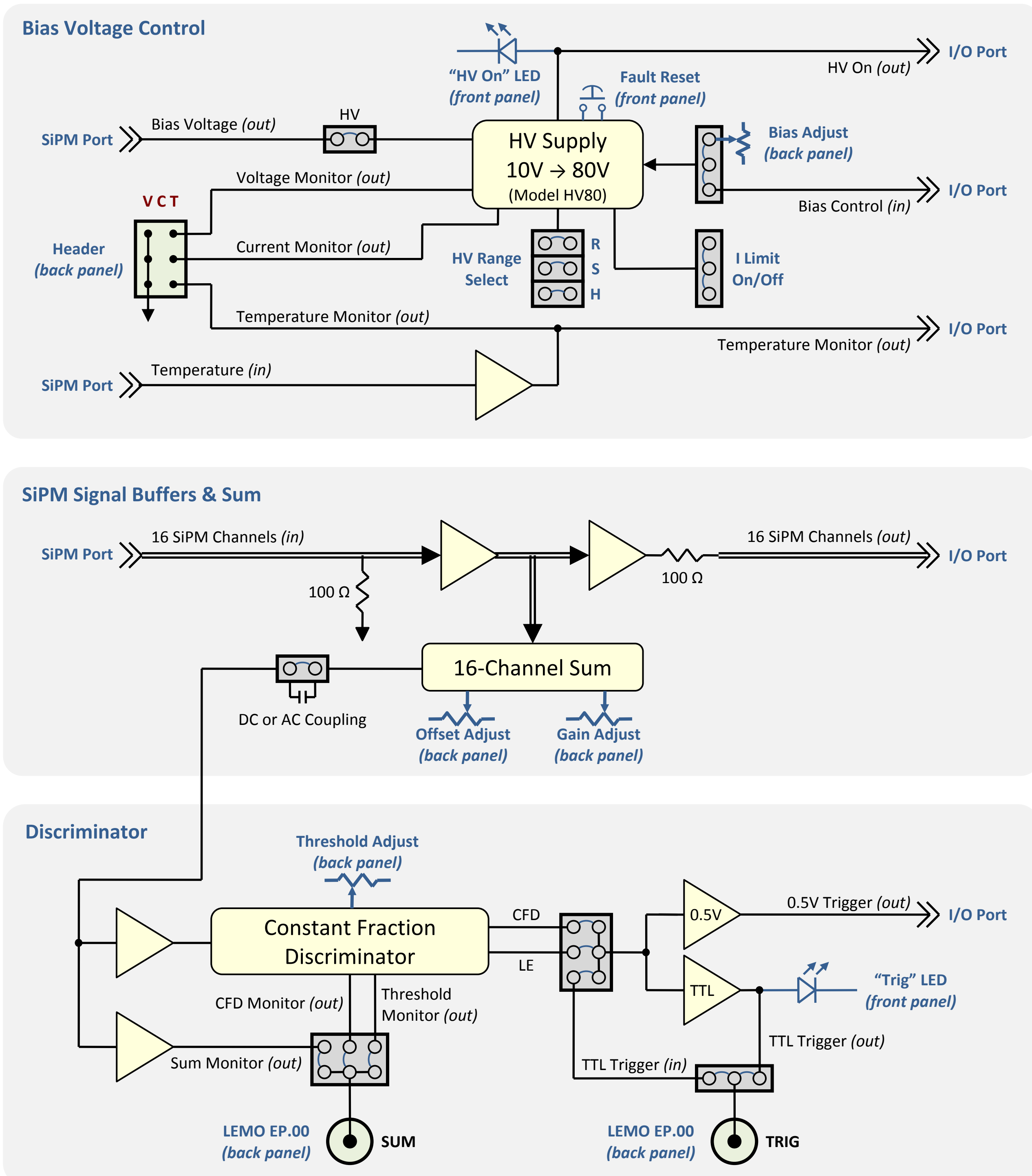
SiPM Base and Interface Module

The AB4 Base connects to the IM16 through a micro-pitch ribbon cable that permits versatile placement of the Base. The IM16 powers the Base, buffers SiPM signals, and forms a trigger from the discriminated analog sum of all SiPM signals.

MDU20-GI16 and MDU40-GI32

The MDU20-GI16 has 16 simultaneous gated integrators followed by 16 simultaneous sampling ADCs. Each integrator is preceded by a 100ns analog delay to compensate for trigger latency. A 16-bit DAC controls SiPM bias and a 16-bit ADC monitors SiPM temperature. The IM16 connects to the MDU20-GI16 through a DB25F cable assembly. The MDU40-GI32 is a dual version of the MDU20-GI16 capable of controlling two IM16s.

Architecture



(out) = output from the SiPMIM16, *(in)* = input to the SiPMIM16

= Jumper (select only one position per block)

Specifications

SiPM Signal Buffers	
Rise time	< 3 ns
Bandwidth (in → out)	120 MHz
Gain (in → out)	0.25 (100Ω source, 50Ω load)
Input voltage	±3V max., 100Ω input impedance
Output voltage	±1V max. (100Ω load), 50mA max., 100Ω output impedance
SiPM Signal Sum	
Rise time	< 4 ns
Bandwidth	80 MHz at min. gain, 50 MHz at max. gain
Gain adjust	0.25 → 2.5 *(25-turn potentiometer)*
Input offset adjust	±650mV, with in → sum gain = 1 *(25-turn potentiometer)*
Coupling	DC or AC; *(jumper selectable)*
AC-coupling time constant	10 µs
Output voltage	±1V max. (50Ω load), 50mA max., 50Ω output impedance
Trigger	
Options	Constant fraction discriminator, leading-edge discriminator, external 5V TTL, none; *(jumper selectable)*
I/O Port trigger output level	0.5V
External trigger input level	5V TTL, 100Ω input impedance
External trigger output level	5V TTL, 24mA
Constant Fraction Discriminator	
Timing resolution	100 ps min.
Threshold	0V → -1V
Fraction	40%
Output pulse width	20 ns
Analog delay	5-tap, 4 ns per tap, 12 ns nominal; *(jumper selectable)*
Leading-edge discriminator	Time-over-threshold output from CFD circuit; *(jumper selectable)*
Threshold & CFD monitors	Shared with sum monitor; *(jumper selectable)*
Gain	1
Bandwidth	100 MHz
Output voltage	±1V max. (50Ω load), 50mA max., 50Ω output impedance
Temperature Monitor	
Input voltage	+3V max., 1 MΩ input impedance
Output voltage	+3V max., 20mA max., 50Ω output impedance
Gain	1
Bias Power Supply	
Output voltage	10V → 80V, 2mA max. 4mA max. with over-current fault disabled (see **warnings**)
Load regulation	< 0.01%
Setpoint linearity	< 0.01%
Initial accuracy	< 0.05%, trimmable
Local bias control	*(25-turn potentiometer, jumper selectable range)*
High range	64V → 80V

Low range	28V → 33V
Remote bias control	0V → 2.5V control = 0V → 80V bias 1 MΩ input impedance
Voltage monitor	0V → 2.5V output = 0V → 80V bias 20mA max., 50Ω output impedance
Current monitor	0V → 2V output = 0mA → 2mA bias current, 10% min. accuracy 20mA max., 50Ω output impedance
Output over-current fault	>2mA output current disables HV power supply until reset
Fault reset	Resets HV power supply fault latch and momentarily bypasses the over-current fault circuit to enable the HV power supply
Over-current fault disable (*I Limit* Jumper = OFF)	Placing the *I Limit* jumper in the OFF position will disable the over-current fault circuit. It may be necessary to disable the over-current fault circuit if >2mA bias current is required. Please note the **warnings** about disabling the over-current fault circuit.
Fault bypass time	1 second typ.
Local reset	Front-panel pushbutton
Remote reset	Remote bias control transition from 0V to >0.5V
WARNING	Disabling the over-current fault circuit or repeating HV reset during a persistent fault condition may damage system components. Identify and remove the cause of the fault, restart the HV power supply at a safe voltage, then slowly restore normal bias voltage.

Base Amplifier Voltage	±2.8V, 200mA max. with VA = ±3.3V ±4.5V, 200mA max. with VA = ±5.0V
Power Supply Requirements	+12V DC, 170mA typ. (Iq, no signal, no load, HV on) with VA =±3.3V

LEDs

V+	Green	= Positive amplifier voltage on
V-	Green	= Negative amplifier voltage on
TRIG	Yellow	= Trigger
HV ON	Red	= HV power supply enabled

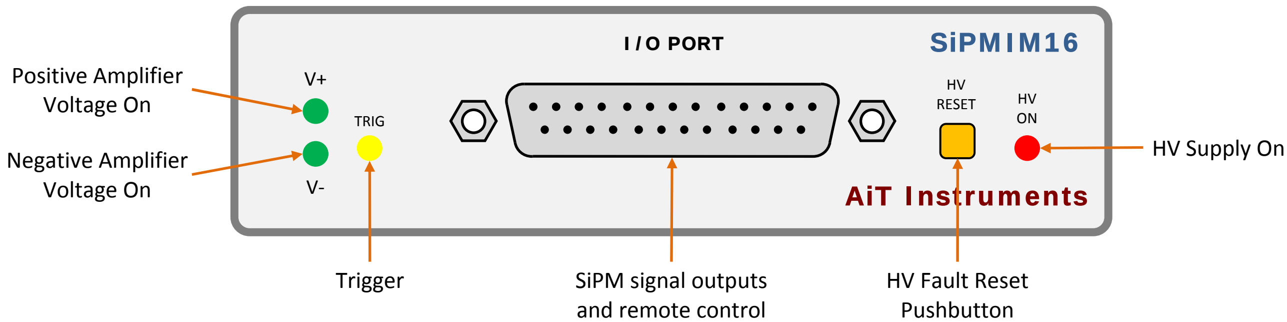
HV Reset Pushbutton	Resets a HV power supply fault

Mechanical

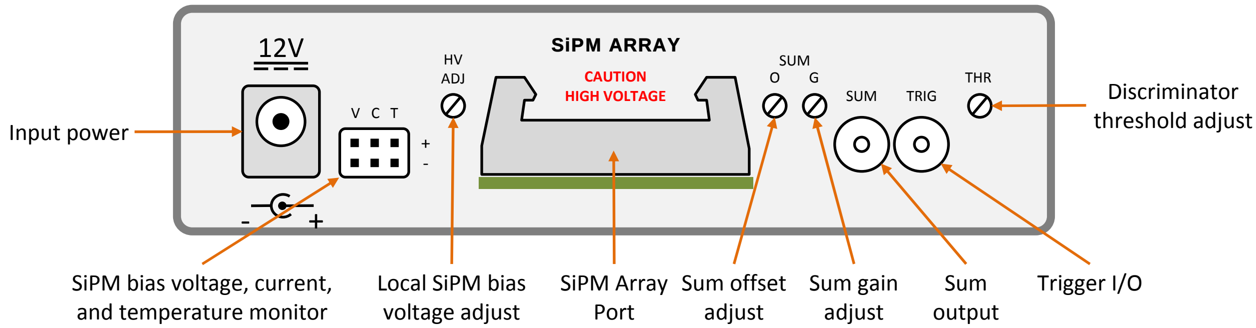
PCB overall dimensions	3.725” x 3.940”
PCB mounting holes, 4 each	0.12” diameter, accepts #4 hardware Do not exceed 0.25” dia. mounting hardware
Enclosure dimensions	4.18” (W), 3.40”(L), 1.15”(H)
Enclosure material	Aluminum
Connectors	
SiPM ARRAY	26-pin, 2-row latch-eject header, 0.050” pin pitch Mating assembly = Samtec FFSD-13-D-XX.XX-01-N (XX.XX = length in inches)
SUM, TRIG	Lemo EP.00 coaxial receptacle
VCT	6-pin, 2-row header, 0.1” pitch
I/O PORT	25 pin male D-sub
12V	Circular barrel power jack, 2.1mm ID, 5.5mm OD, center positive

Enclosure Front & Back Panels

Front Panel

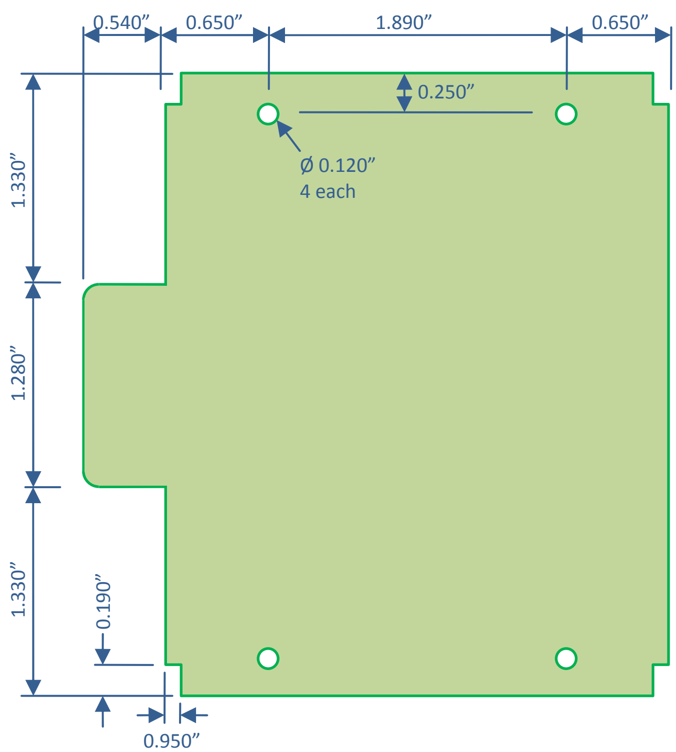


Back Panel

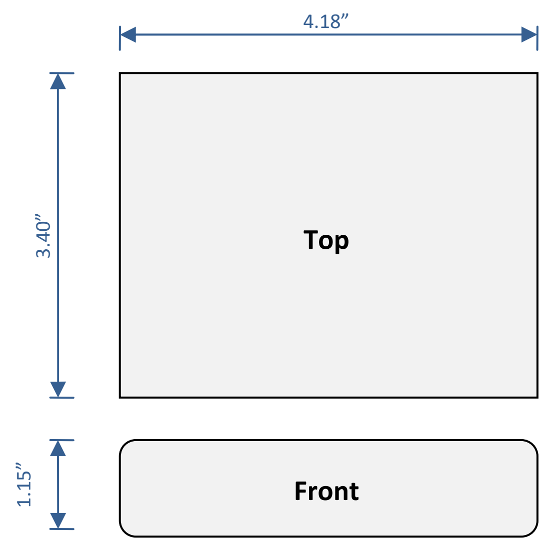


Mechanical

Circuit Board



Enclosure



4X4 SiPM Array Channel Map

Top, facing array

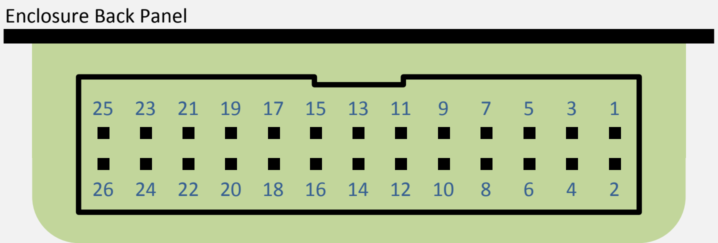
A1	B1	C1	D1
A2	B2	C2	D2
A3	B3	C3	D3
A4	B4	C4	D4

Bottom (bond area)

Connectors

SiPM Array Port

26-pin 0.050" latch-eject header

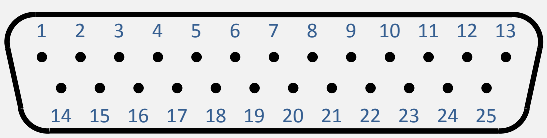


PCB Top View

Pin	Function	Pin	Function
1	D4	2	Temp
3	D1	4	GND
5	D2	6	D3
7	C4	8	GND
9	C1	10	C3
11	C2	12	-VA
13	B4	14	GND
15	B1	16	+VA
17	B2	18	B3
19	A4	20	GND
21	A1	22	A3
23	A2	24	GND
25	+Bias	26	GND

I/O Port

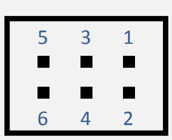
25-pin male D-sub



Pin	Function	Pin	Function
1	A1	14	B1
2	C1	15	D1
3	GND	16	A2
4	B2	17	C2
5	D2	18	GND
6	A3	19	B3
7	C3	20	D3
8	GND	21	A4
9	B4	22	C4
10	D4	23	GND
11	Bias Control	24	Temp
12	HV Status	25	Trigger
13	GND		

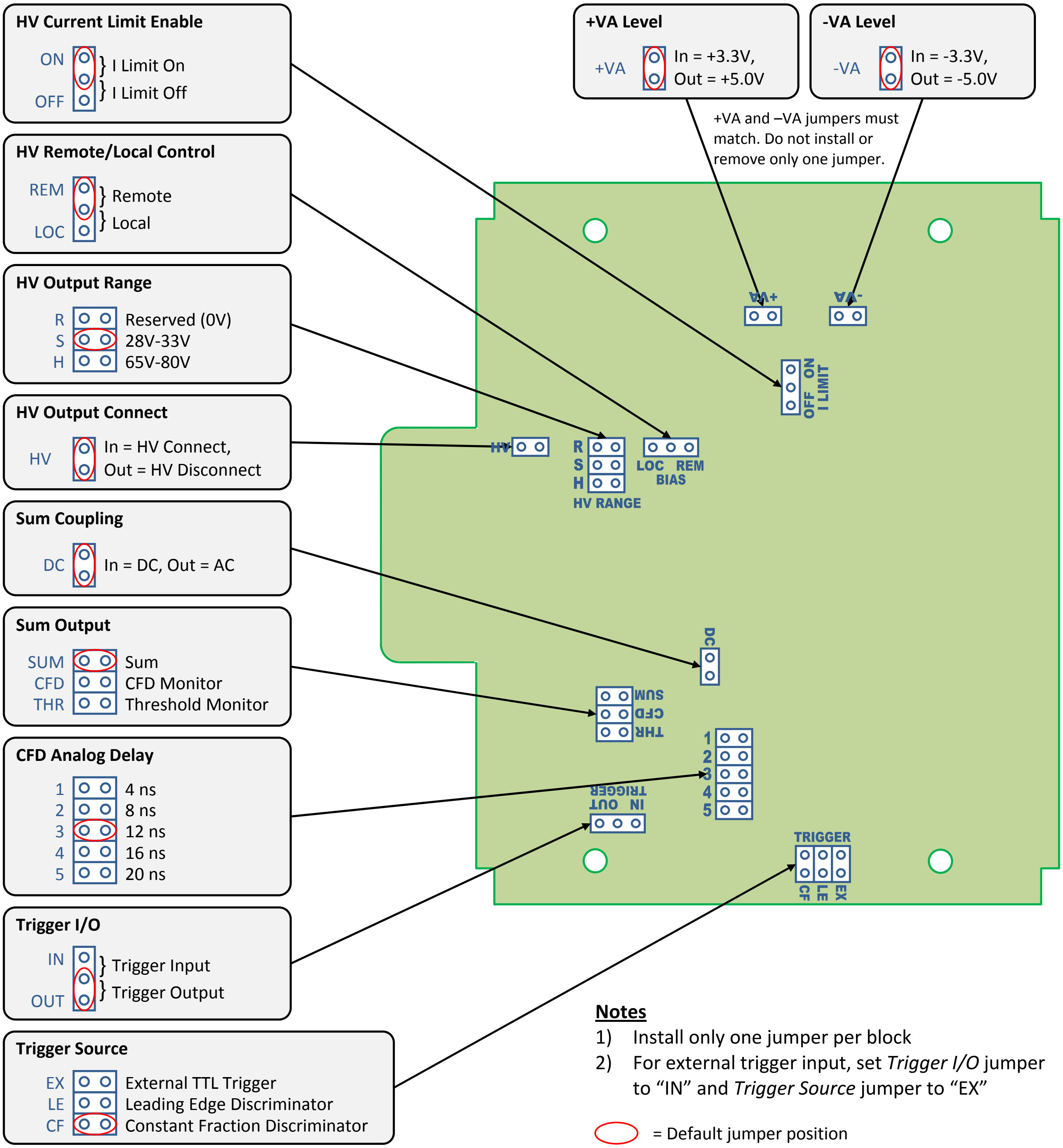
VCT Monitor

6-pin header



Pin	Function	Pin	Function
1	Temperature	2	GND
3	Bias Current	4	GND
5	Bias Voltage	6	GND

Jumpers



Notes

1) Install only one jumper per block
2) For external trigger input, set *Trigger I/O* jumper to "IN" and *Trigger Source* jumper to "EX"

= Default jumper position

Operation

Summary

Routine operating parameters can be adjusted through back-panel potentiometers. Occasional settings are configured by on-board jumpers, requiring enclosure disassembly. SiPM bias voltage control, HV status, SiPM temperature, and trigger are available on the I/O Port for remote operation.

When the IM16 is installed in a new application, a one-time manual setup is typically needed to adjust most IM16 settings. After the initial setup, normal operation may require few small adjustments.

Typical Setup for initial use

1. Disconnect power
2. Set jumpers as follows
    a. CFD Analog Delay = 12 ns
    b. Sum Output = SUM
    c. Trigger I/O = OUT
    d. Trigger Source = CFD
    e. Sum Coupling = DC (if AC coupling is used then sum offset calibration is not needed)
    f. HV Remote/Local Control = set as appropriate
    g. HV Range = set as appropriate
    h. HV Output Connect = Connected
    i. HV Current Limit = ON
    j. +VA = +3.3V
    k. –VA = -3.3V
3. Set potentiometers as follows
    a. HV ADJ = fully counterclockwise (lowest bias voltage)
    b. SUM Gain = 12.5 turns clockwise (medium gain)
    c. THR = fully counterclockwise (lowest threshold)

    Note: Do not adjust *Pulse Width* and *Current Limit* potentiometers
4. Connect cables
    a. Connect a Base using the micro IDC cable
    b. Connect *SUM* and *TRIG* outputs to two DC-coupled oscilloscope channels with 50 Ω input termination, and configure the oscilloscope to trigger on *TRIG*
    c. Connect a voltmeter to the *Bias Voltage Monitor*
5. Place the Base, with SiPM attached, in a low-light application capable of producing optical pulses
6. Begin operation
    a. Power the IM16
    b. Press *HV RESET* to enable the HV power supply if needed
    c. Allow the system to stabilize for at least 15 minutes
    d. *TRIG* may be noisy because of the low threshold
7. Set bias voltage

   a. Increase HV control voltage to the SiPM operating voltage (turn *HV ADJ* clockwise if using local bias control)
   b. If the bias voltage or optical signal level is too high then an over-current condition may disable the HV power supply. If this occurs then lower the bias voltage, press *HV RESET*, and slowly restore the normal bias voltage. Avoid restarting HV at high bias voltages.
8. Calibrate offset
   a. This adjustment is not necessary if the sum is AC coupled
   b. Adjust *SUM Offset* until the sum baseline is near zero (< 10 mV) as seen on the oscilloscope
   c. A valid trigger is not needed for this adjustment (use oscilloscope auto-trigger)
9. Set gain
   a. With SiPM signals present, adjust *SUM Gain* to the desired level
   b. A 50% full-scale gain setting, approx. 12.5/25 turns, is a typical starting reference
   c. For high gain, the sum offset may require re-adjustment
10. Set threshold
   a. With SiPM signals present, turn *THR* clockwise until the threshold is above the noise

Typical Setup for Normal Operation

1. Connect the Base with the IM16 power off
2. Optionally connect an oscilloscope to SUM and TRIG
3. Power the IM16
4. Press *HV RESET* to clear a possible over-current fault resulting from power-up inrush current
5. With SiPM signals present, adjust *HV ADJ*, *SUM Offset*, and *SUM Gain* as needed

Remote Operation

1. Set the *LOC/REM BIAS* jumper to *REM*
2. If the HV is off then cycle the remote bias control voltage to zero then above 0.5V to clear the fault
3. If the remote bias control voltage is greater than 0.5V then it will not be possible to reset the HV power supply using the *HV RESET* pushbutton. This condition is independent of the *LOC/REM BIAS* jumper.

±VA Amplifier Voltage Setting

The amplifier voltage provided to the SiPMIM16 and to the base is normally ±3.3V. If the SiPM signal amplitudes are saturating then increasing the amplifier voltage will prevent saturation in many cases. The amplifier voltage can be increased by removing the +VA and –VA jumpers. These jumpers must match. Do not install or remove only one jumper. Please note that a higher amplifier voltage will increase power consumption and heating.

External Discriminator Operation

1. Set the *SUM Output* jumper to SUM
2. Adjust *SUM Offset* and *SUM Gain* as needed

3. Connect the *SUM* output to an external discriminator
4. If the external discriminator will trigger an ADC connected to the I/O Port then the TRIG must be configured as a TTL trigger input:
    a. Set the *TRIGGER I/O* jumper to IN
    b. Set the *TRIGGER Source* jumper to EX
    c. Connect the external trigger TTL output to the TRIG connector

SiPM Bias Current Limit

The HV power supply will automatically disable if the output current exceeds its current limit. The over-current circuit is designed to protect only the HV power supply from damaging load currents. It is not designed to protect other equipment or personnel.

An over-current fault may occur during normal operation due to high SiPM bias current, high load capacitance, or high optical signal levels. While the protection circuit may offer incidental protection to the SiPM in some cases, it is not designed to prevent damage to the SiPM.

A fault reset clears an over-current fault latch and momentarily bypasses the protection circuit. Repeating HV resets during a persistent fault condition may damage system components. Identify and remove the cause of the fault, restart the HV power supply at a safe voltage, then slowly restore normal bias voltage.

Placing the I Limit jumper in the OFF position will disable the over-current fault circuit. It may be necessary to disable the over-current fault circuit if >2mA bias current is required. Please note the warnings about disabling the over-current fault circuit.

CFD Analog Delay Selection

The CFD circuit has a jumper selectable 5-tap analog delay line. The recommended delay for most applications is 12ns. A different analog delay can be selected by changing the position of CFD delay jumper to one of five taps. If the desired delay setting is unavailable then the socketed SIP delay line may be replaced with a different delay. Increasing the delay will increase trigger latency.

Leading-Edge Discriminator

The leading edge discriminator is part of the CFD circuit. It may be used as a trigger but its timing and noise performance may be inferior to the CFD. The discriminator output pulse is time-over-threshold with no pulse width control.

Sum DC/AC Coupling

Installing the *Sum Coupling* jumper will select DC coupling of the sum signal. DC coupling requires adjusting the sum offset to zero for correct operation of the internal CFD. DC coupling is typically recommended for high pulse rate applications.

Removing the *Sum Coupling* jumper will select AC coupling of the sum signal. AC coupling does not require DC offset adjustment. The RC time constant will produce an offset shift during high-rate operation.

Sum Offset Sensitivity to SiPM Bias Voltage

If the sum is DC coupled then changes in bias voltage may require offset adjustment to maintain the sum baseline near zero for proper discriminator operation. Small bias voltage changes typically do not require offset adjustment. Offset adjustment is not required if the sum is AC coupled.

System Assembly Guidelines

SiPM Cable Assembly

The SiPM micro-pitch cable assembly must be inserted firmly into the latch/eject header until the latches lock around the connector. Correct orientation results in the cable exiting directly away from the Interface Module without interference, and the red index conductor is located on the right side of the connector, facing back of the unit.

DB25F Cable Assembly

A flat ribbon cable assembly is recommended. Use the shortest cable necessary.

High Voltage

This device must be used only by personnel trained and qualified in safe handling, installation, and operation of high voltage equipment. The optional enclosure does not protect against high voltage exposure.

During operation, high voltage will normally be present in the following components:

- Interface Module circuit board
- SiPM Port signal connector pins
- Exposed base of the SiPM Port signal connector
- SiPM signal cable
- SiPM Base

Enclosure & PCB Mounting

This device is intended to be incorporated into another system or product. The circuit board may be mounted using standard #4 hardware. Mounting hardware should not exceed 0.25” diameter contact area with the circuit board. Allow for adequate ventilation space around the circuit board.

The optional enclosure is provided to simplify bench testing and permits mounting into 19” rack panels. Unassembled enclosure components may have sharp edges. Observe appropriate handling precautions.

Safety Information

WARNING – High Voltage

- High voltage may be present during operation
- High voltage stored on capacitors may be present after power is removed
- Improper handling may result in personnel injury or equipment damage

This high-voltage device must be used only by personnel trained and qualified in safe handling, installation, and operation of high-voltage equipment.

CAUTION – Electrostatic Discharge (ESD) Sensitivity

The circuit board can be damaged by electrostatic discharge. Observe precautions for handling electrostatic sensitive devices. Handle only at static-safe workstations.

High-Gain Photodetectors

High-gain photodetectors such as silicon photomultipliers may conduct damaging currents if exposed to high optical signal levels while the bias voltage is applied, or if the bias voltage exceeds the recommended operating range. These devices must be operated only in low-light conditions, and only within the manufacturer's recommended bias voltage range.

Handling and Disassembly

This product may be provided with or without a protective enclosure. Disassembled enclosure components and circuit boards may contain sharp edges. Take appropriate safety precautions while assembling or disassembling the enclosure and handling disassembled components.

Indoor Use Only

Do not operate this product in a wet/damp environment. Do not operate in an explosive atmosphere.