C-Series SiPM Sensors

Silicon Photomultipliers (SiPM), Low-Noise, Blue-Sensitive

ON Semiconductor®

www.onsemi.com

The C−Series low-light sensors from ON Semiconductor feature an industry-leading low dark-count rate combined with a high PDE. For ultrafast timing applications, C-Series sensors have a fast output that can have a rise time of 300 ps and a pulse width of 600 ps. The C−Series is available in different sensor sizes (1 mm, 3 mm and 6 mm) and packaged in a 4-side tileable surface mount (SMT) package that is compatible with industry standard, lead-free, reflow soldering processes.

The C−Series Silicon Photomultipliers (SiPM) form a range of high gain, single-photon sensitive, UV-to-visible light sensors. They have performance characteristics similar to a conventional PMT, while benefiting from the practical advantages of solid-state technology: low operating voltage, excellent temperature stability, robustness, compactness, output uniformity, and low cost. For advice on the usage of these sensors please refer to the Biasing and Readout Application Note.

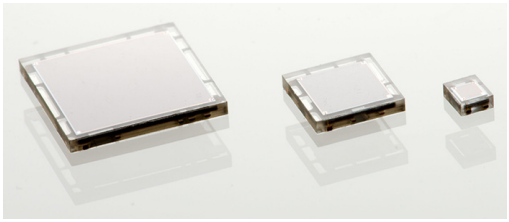


Figure 1. C−Series Sensors

ORDERING INFORMATION

See detailed ordering and shipping information on page 15 of this data sheet.

Table 1. PERFORMANCE PARAMETERS

Sensor Size	Microcell Size	Parameter (Note 1)	Overvoltage	Min.	Typ.	Max.	Units
1 mm	10μ, 20μ, 35μ	Breakdown Voltage (Vbr) (Note 3)		24.2		24.7	V
3 mm	20μ, 35μ, 50μ						
6 mm	35μ						
1 mm	10μ, 20μ, 35μ	Recommended overvoltage Range (Voltage above Vbr) (Note 2)		1.0		5.0	V
3 mm	20μ, 35μ, 50μ						
6 mm	35μ						
1 mm	10μ, 20μ, 35μ	Spectral Range (Note 4)		300		950	nm
3 mm	20μ, 35μ, 50μ						
6 mm	35μ						
1 mm	10μ, 20μ, 35μ	Peak Wavelength (λp)			420		nm
3 mm	20μ, 35μ, 50μ						
6 mm	35μ						

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Table 1. PERFORMANCE PARAMETERS (continued)

Sensor Size	Microcell Size	Parameter (Note 1)	Overvoltage	Min.	Typ.	Max.	Units
1 mm	10μ	PDE (Note 5) at λp	Vbr + 2.5 V		14		%
	20μ				24		%
	35μ				31		%
1 mm	10μ		Vbr + 5.0 V		18		%
	20μ				31		%
	35μ				41		%
3 mm	20μ		Vbr + 2.5 V		24		%
	35μ				31		%
	50μ				35		%
3 mm	20μ		Vbr + 5.0 V		31		%
	35μ				41		%
	50μ				47		%
6 mm	35μ		Vbr + 2.5 V		31		%
6 mm	35μ		Vbr + 5.0 V		41		%
1 mm	10μ	Gain (anode to cathode readout)	Vbr + 2.5 V		2×10^5		
	20μ				1×10^6		
	35μ				3×10^6		
3 mm	20μ				1×10^6		
	35μ				3×10^6		
	50μ				6×10^6		
6 mm	35μ				3×10^6		
1 mm	10μ	Dark Current (Note 6)	Vbr + 2.5 V		1	3	nA
	20μ				5	16	nA
	35μ				15	49	nA
3 mm	20μ				50	142	nA
	35μ				154	443	nA
	50μ				319	914	nA
6 mm	35μ				618	1750	nA

Table 1. PERFORMANCE PARAMETERS (continued)

Sensor Size	Microcell Size	Parameter (Note 1)	Overvoltage	Min.	Typ.	Max.	Units
1 mm	10μ	Dark Count Rate	Vbr + 2.5 V		30	96	kHz
	20μ				30	96	kHz
	35μ				30	96	kHz
3 mm	20μ				300	860	kHz
	35μ				300	860	kHz
	50μ				300	860	kHz
6 mm	35μ				1200	3400	kHz
1 mm	10μ, 20μ, 35μ	Rise Time − Fast Output (Note 7)			0.3		ns
3 mm	20μ, 35μ, 50μ				0.6		ns
6 mm	35μ				1.0		ns
1 mm	10μ, 20μ, 35μ	Signal Pulse Width − Fast Output (FWHM)			0.6		ns
3 mm	20μ, 35μ, 50μ				1.5		ns
6 mm	35μ				3.2		ns
1 mm	10μ	Microcell recharge time constant (Note 8)			5		ns
	20μ				23		ns
	35μ				82		ns
3 mm	20μ				23		ns
	35μ				82		ns
	50μ				159		ns
6 mm	35μ				95		ns
1 mm	10μ	Capacitance (Note 9) (anode−cathode)	Vbr + 2.5 V		50		pF
	20μ				90		pF
	35μ				100		pF
3 mm	20μ				770		pF
	35μ				850		pF
	50μ				920		pF
6 mm	35μ				3400		pF
1 mm	10μ	Capacitance (Note 9) (fast terminal to cathode)	Vbr + 2.5 V		1		pF
	20μ				1		pF
	35μ				1		pF

Table 1. PERFORMANCE PARAMETERS (continued)

Sensor Size	Microcell Size	Parameter (Note 1)	Overvoltage	Min.	Typ.	Max.	Units
3 mm	20μ	Capacitance (Note 9) (fast terminal to cathode)	Vbr + 2.5 V		20		pF
	35μ				12		pF
	50μ				7		pF
6 mm	35μ				48		pF
1 mm	10μ, 20μ, 35μ	Temperature dependence of Vbr			21.5		mV/°C
3 mm	20μ, 35μ, 50μ						
6 mm	35μ						
1 mm	10μ, 20μ, 35μ	Temperature dependence of Gain (Note 10)			−0.8		%/°C
3 mm	20μ, 35μ, 50μ						
6 mm	35μ						
1 mm	10μ	Crosstalk	Vbr + 2.5 V		0.6		%
	20μ				3		%
	35μ				7		%
3 mm	20μ				3		%
	35μ				7		%
	50μ				10		%
6 mm	35μ				7		%
1 mm	10μ	Afterpulsing	Vbr + 2.5 V		0.2		%
	20μ				0.2		%
	35μ				0.2		%
3 mm	20μ				0.2		%
	35μ				0.2		%
	50μ				0.6		%
6 mm	35μ				0.2		%

1. All measurements made at 2.5 V overvoltage and 21°C unless otherwise stated.
2. Please consult the maximum current levels on page 6 when selecting the overvoltage to apply.
3. The breakdown voltage (Vbr) is defined as the value of the voltage intercept of a straight line fit to a plot of $\sqrt{I}$ vs V, where I is the current and V is the bias voltage.
4. The range where PDE > 1% at Vbr + 5.0 V.
5. Note that the PDE does not contain contributions from afterpulsing or crosstalk.
6. Dark current derived from dark count data as $DC \times M \times q \times (1 + CT)$, where DC is dark count, M is gain, q is the charge of an electron, and CT is cross talk.
7. Measured as time to go from 10% to 90% of the peak amplitude.
8. RC charging time constant of the microcell (τ)
9. Internal capacitance of the sensor. Typically add 2−3 pF for sensor in package. Listed by unique microcell size for each part version.
10. Quoted as the percentage change per degree C from the measured value at 21°C.

GENERAL PARAMETERS

Table 2. GENERAL PARAMETERS

	1 mm	3 mm	6 mm
	10010, 10020, 10035	**30020, 30035, 30050**	**60035**
Active area	1×1 mm^2	3×3 mm^2	6×6 mm^2
No. of microcells	10010: 2880 10020: 1296 10035: 504	30020: 10998 30035: 4774 30050: 2668	60035: 18980
Microcell fill factor	10010: 28% 10020: 48% 10035: 64%	30020: 48% 30035: 64% 30050: 72%	60035: 64%

Table 3. PACKAGE PARAMETERS

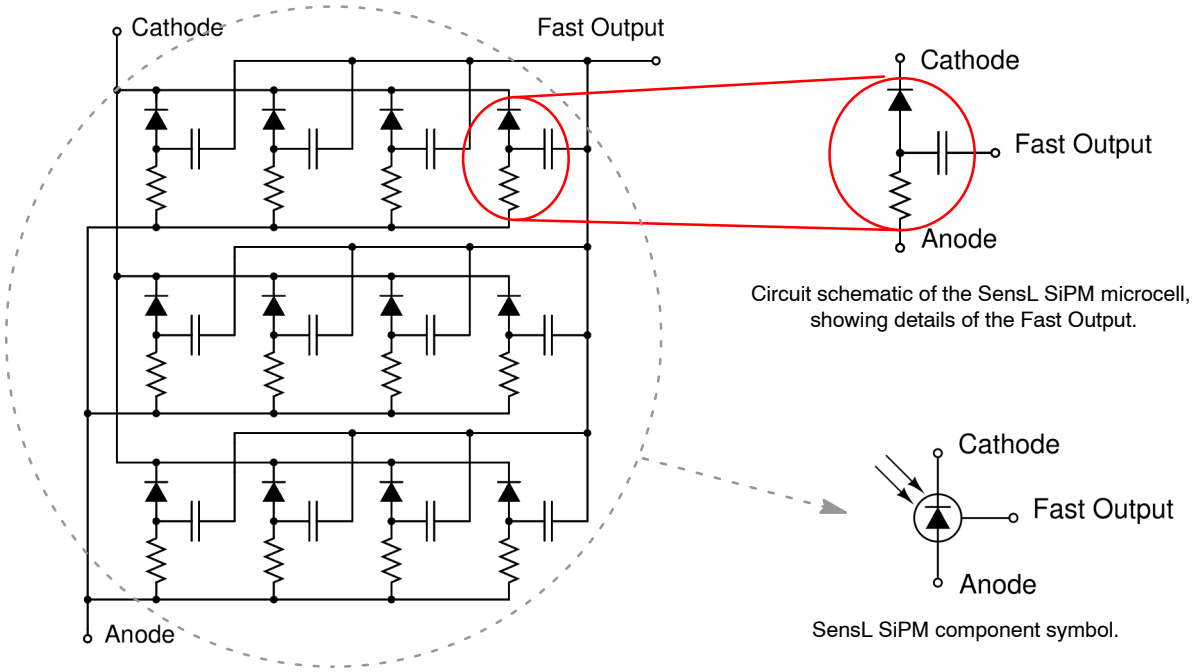
	1 mm	3 mm	6 mm
	10010, 10020, 10035	**30020, 30035, 30050**	**60035**
Package dimensions	1.5×1.8 mm^2	4×4 mm^2	7×7 mm^2
Recommended operating temperature range	−40°C to +85°C		
Maximum storage temperature	+105°C		
Soldering conditions	Lead−free, reflow soldering process compatible (MSL 3 for tape & reel quantities; MSL 4 for tape only qty.) See the SMT Handling Tech Note for more details.		
Encapsulant type	Clear transfer molding compound		
Encapsulant refractive Index	1.59 @ 420 nm		

Table 4. MAXIMUM CURRENT LEVELS FOR EACH SENSOR SIZE

1 mm	3 mm	6 mm
10010, 10020, 10035	**30020, 30035, 30050**	**60035**
6 mA	15 mA	20 mA

CIRCUIT SCHEMATICS

An SiPM is formed of a large number (hundreds or thousands) of microcells. Each microcell is an avalanche photodiode with its own quench resistor and a capacitively coupled fast output. These microcells are arranged in a close-packed array with all of the like terminals (e.g. all of the anodes) summed together. The array of microcells can thus be considered as a single photodiode sensor with three terminals: anode, cathode and fast output.



Simplified circuit schematic of the SensL® SiPM showing only a 12 microcell example. Typically, SiPM sensors have hundreds or thousands of microcells.

Circuit schematic of the SensL SiPM microcell, showing details of the Fast Output.

SensL SiPM component symbol.

Figure 2. Circuit Schematic

PERFORMANCE

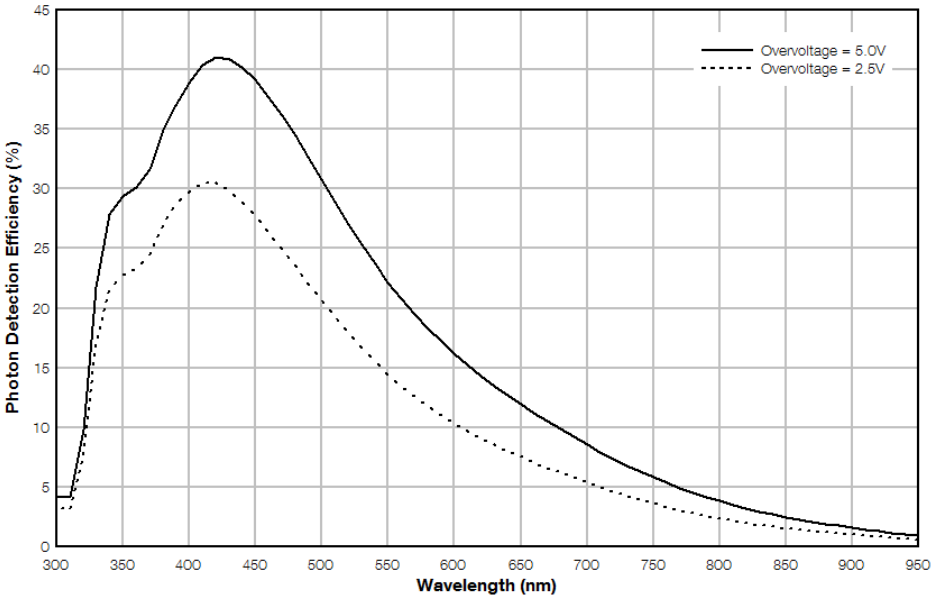


Figure 3. PDE versus Wavelength
(MicroFC−30035−SMT)

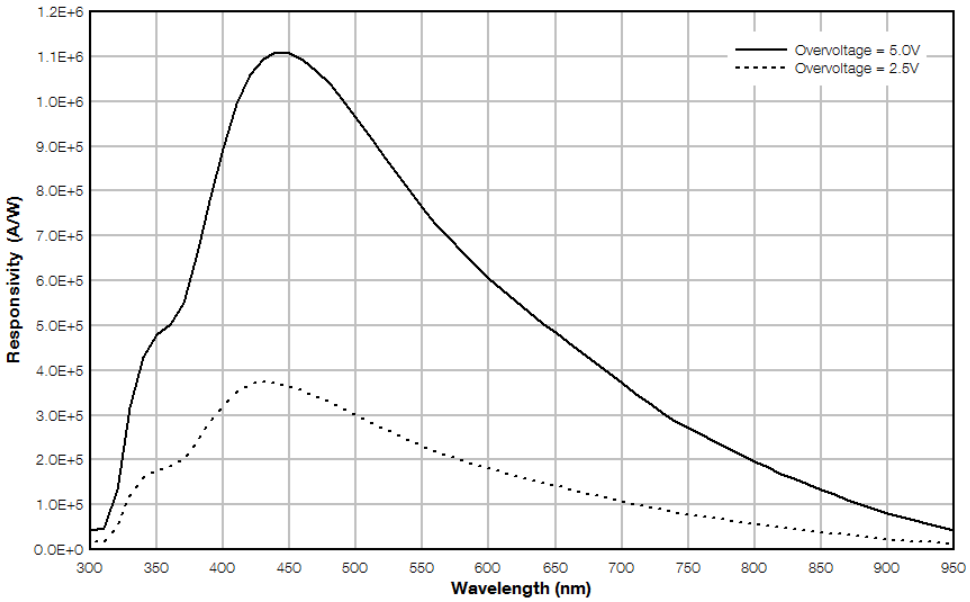


Figure 4. Responsivity versus Wavelength
(MicroFC−30035−SMT)

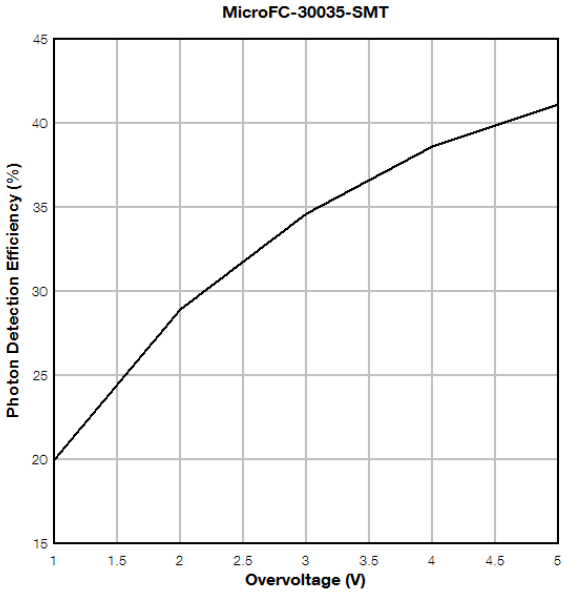


Figure 5. PDE at 420 nm versus Voltage

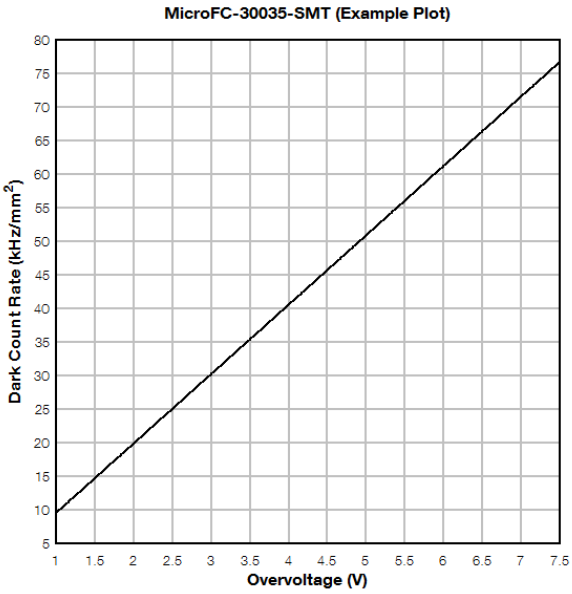


Figure 6. Dark Count Rate versus Overvoltage

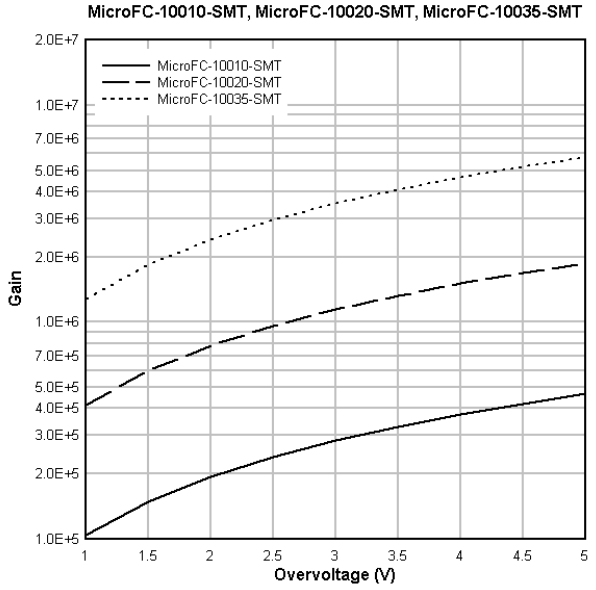


Figure 7. Gain versus Overvoltage

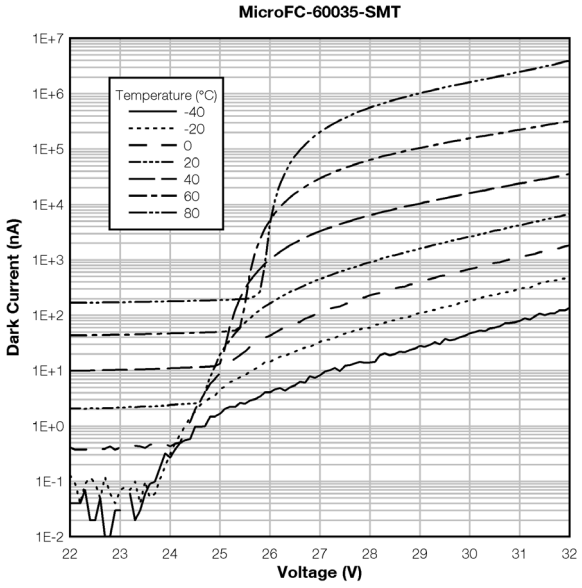


Figure 8. Dark Current versus Voltage and Temperature

EVALUATION BOARD OPTIONS

SMA Biasing Board (MicroFC−SMA−XXXXX)

The MicroFC−SMA is a printed circuit board (PCB) that can facilitate the evaluation of the C−Series SMT sensors. The board has three female SMA connectors for connecting the bias voltage, the standard output from the anode and the fast output signal. The output signals can be connected directly to a 50 Ω-terminated oscilloscope for viewing. The biasing and output signal tracks are laid out in such a way as to preserve the fast timing characteristics of the sensor.

The MicroFC−SMA is recommended for users who require a plug-and-play set-up to quickly evaluate C−Series SMT sensors with optimum timing performance. The board also allows the standard output from the anode-cathode readout to be observed at the same time as the fast output. The outputs can be connected directly to the oscilloscope or measurement device, but external preamplification may be required to boost the signal. The table below lists the SMA board connections. The SMA board electrical schematics are available to download in the SMT Board Reference Design document.

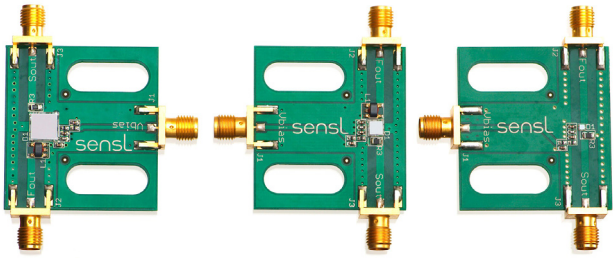


Figure 9. SMA Biasing Board

MicroFC−SMA−XXXXX	
Output	**Function**
Vbias	Positive bias input (cathode)
Fout	Fast output
Sout	Standard output (anode)

Pin Adapter (MicroFC−SMTPA−XXXXX)

The SMT Pin Adapter board (SMTPA) is a small PCB board that houses the SMT sensor and has through-hole pins to allow for use with standard sockets or probe clips. This product is useful for those needing a quick way to evaluate the C−Series SMT sensors without the need for specialist surface-mount soldering. While this is a ‘quick fix’ suitable for many evaluations, it should be noted that the timing performance from this board will not be optimized and if the best possible timing performance is required, the MicroFC−SMA−XXXXX is recommended. The pin-out information is shown in the table below. The SMTPA board electrical schematics are shown in Figure 12 and are available to download in the SMT Board Reference Design document.



Figure 10. Pin Adapter

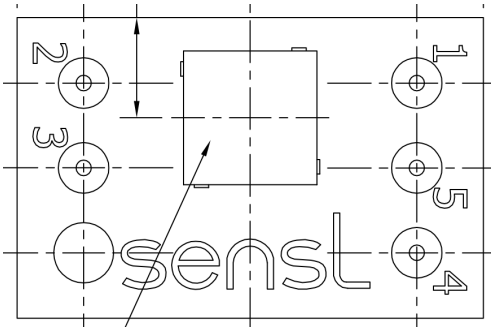


Figure 11. MicroFC−SMTPA−XXXXX

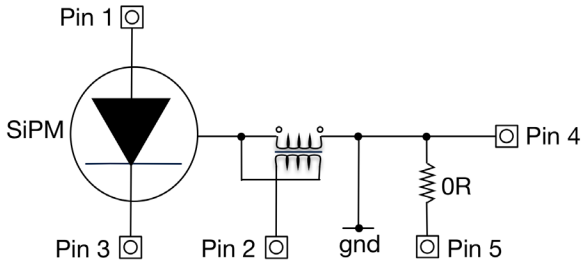


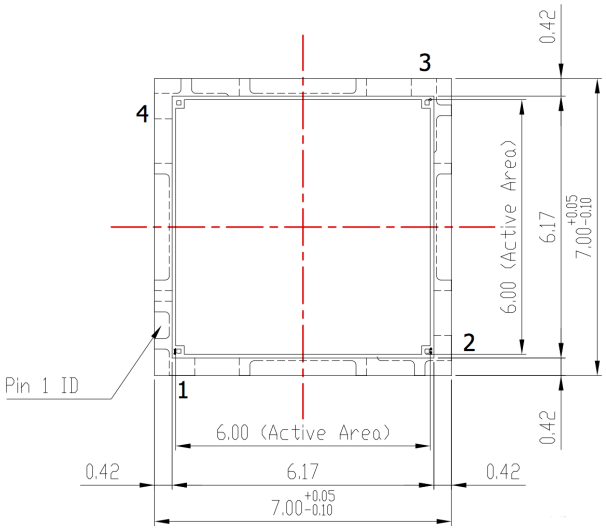
Figure 12. SMTPA Board Circuit Schematic

MicroFC−SMTPA−XXXXX	
Pin No.	**Connection**
1	Anode
2	Fast output
3	Cathode
4	Ground
5	No connect

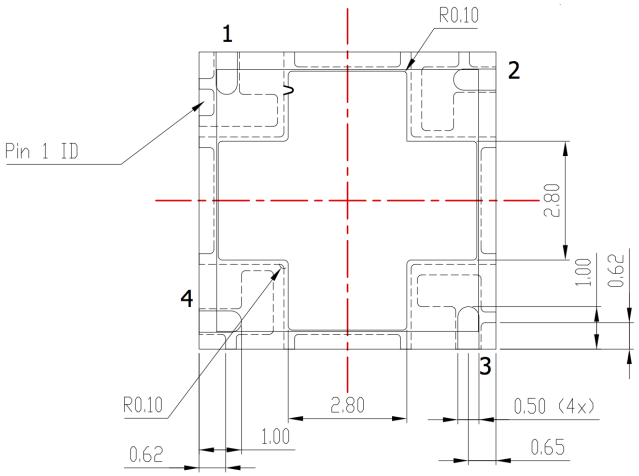
PACKAGE DIMENSIONS

(All Dimensions in mm)

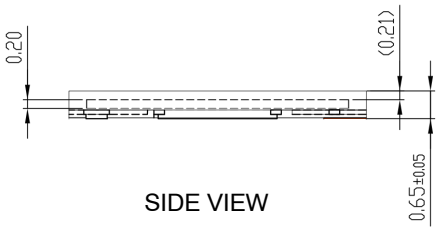
MicroFC−60035−SMT



TOP VIEW



BOTTOM VIEW



SIDE VIEW

Pin Assignments	
Pin #	MicroFC−60035−SMT
1	Anode
2	Fast Output
3	Cathode
4, 5	No Connect*

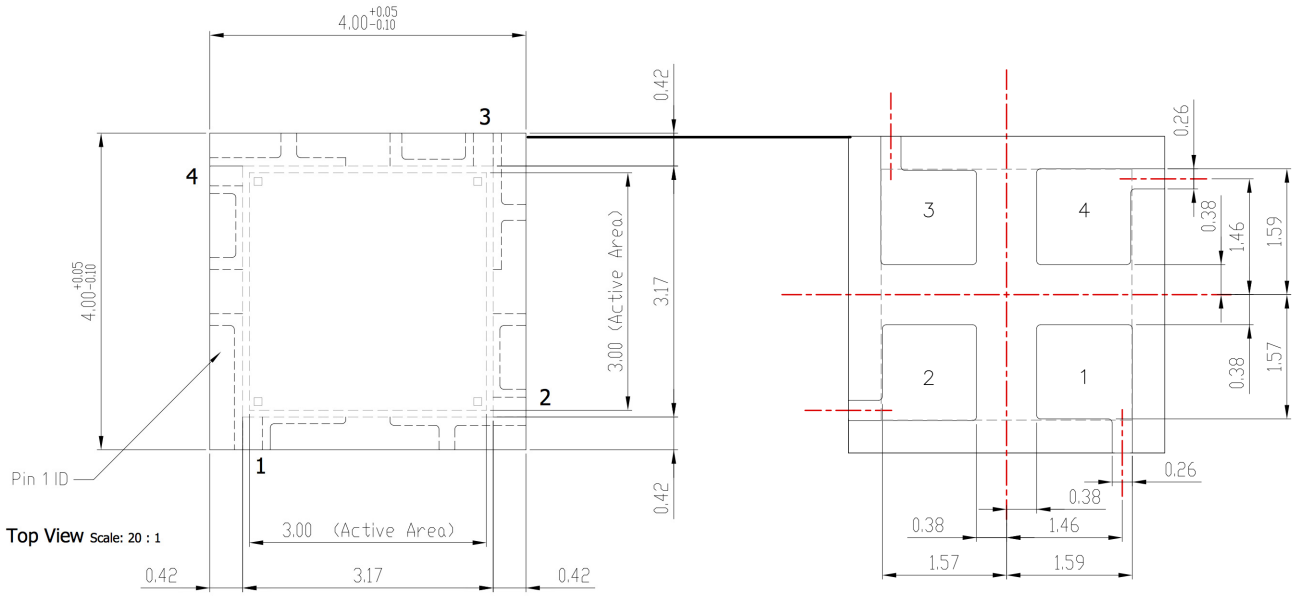
*The ‘No Connect’ pin 4 should be soldered to the PCB. This pin can be connected to ground but it can also be left floating without affecting the dark noise. It is recommended that the Pin 5 paddle is NOT soldered to the PCB and is left floating to achieve optimal soldering on pins 1 to 4. Please note the full advice in the CAD file.

The complete MicroFC−60035−SMT CAD file, including solder footprint and tape and reel drawing, is available to download here.

PACKAGE DIMENSIONS

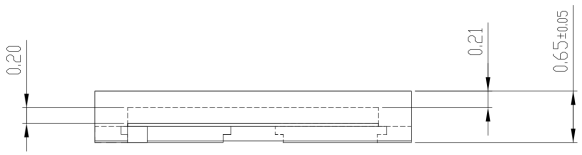
(All Dimensions in mm)

MicroFC−30035−SMT



TOP VIEW

BOTTOM VIEW



SIDE VIEW

Pin Assignments	
Pin #	MicroFC−300XX−SMT
1	Anode
2	Fast Output
3	Cathode
4	No Connect*

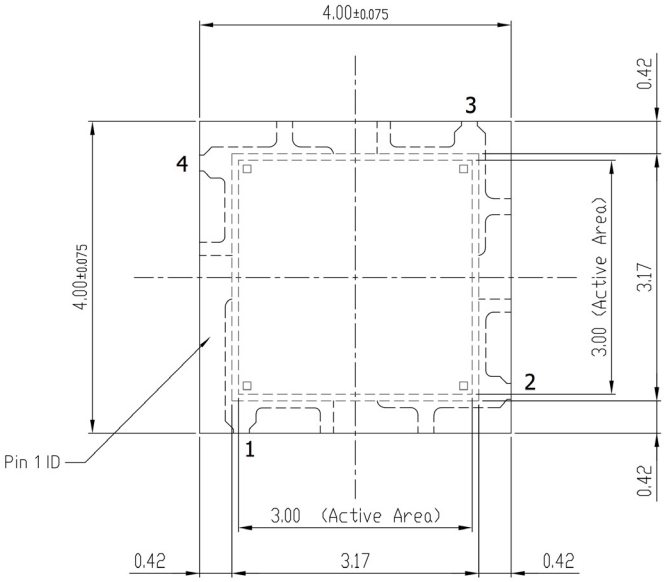
*The ‘No Connect’ pin 4 should be soldered to the PCB. It can be connected to ground but it can also be left floating without affecting the dark noise.

The complete MicroFC−30035−SMT CAD file, including solder footprint and tape and reel drawing, is available to download here.

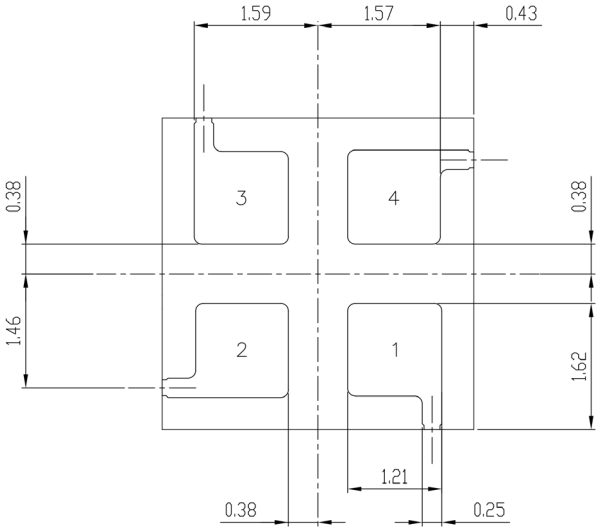
PACKAGE DIMENSIONS

(All Dimensions in mm)

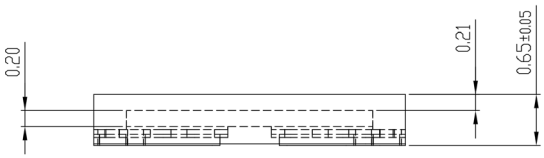
MicroFC−30020−SMT & MicroFC−30050−SMT



TOP VIEW



BOTTOM VIEW



SIDE VIEW

Pin Assignments	
Pin #	MicroFC−300XX−SMT
1	Anode
2	Fast Output
3	Cathode
4	No Connect*

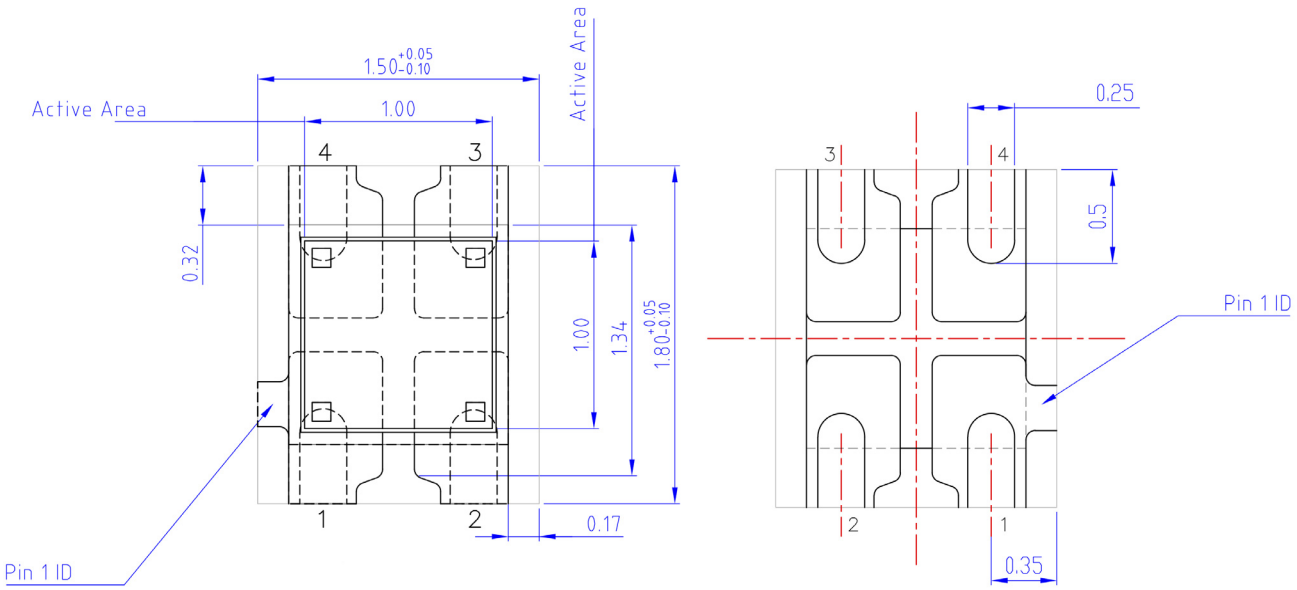
*The ‘No Connect’ pin 4 should be soldered to the PCB. It can be connected to ground but it can also be left floating without affecting the dark noise.

The complete MicroFC−300XX−SMT CAD and solder footprint file is available to download here.

PACKAGE DIMENSIONS

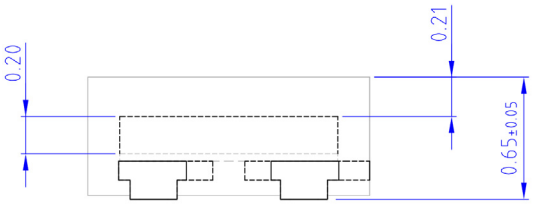
(All Dimensions in mm)

MicroFC−10010−SMT, MicroFC−10020−SMT & MicroFC−10035−SMT



TOP VIEW

BOTTOM VIEW



SIDE VIEW

Pin Assignments	
Pin #	MicroFC−100XX−SMT
1	Anode
2	Fast Output
3	Cathode
4	No Connect*

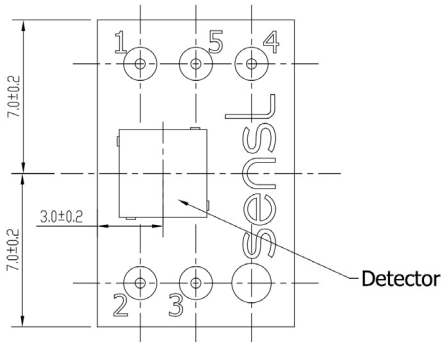
*The ‘No Connect’ pin 4 should be soldered to the PCB. It can be connected to ground but it can also be left floating without affecting the dark noise.

The complete MicroFC−100XX−SMT CAD and solder footprint file is available to download here.

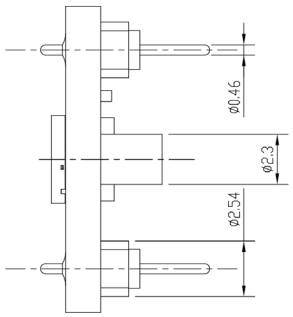
PACKAGE DIMENSIONS

(All Dimensions in mm)

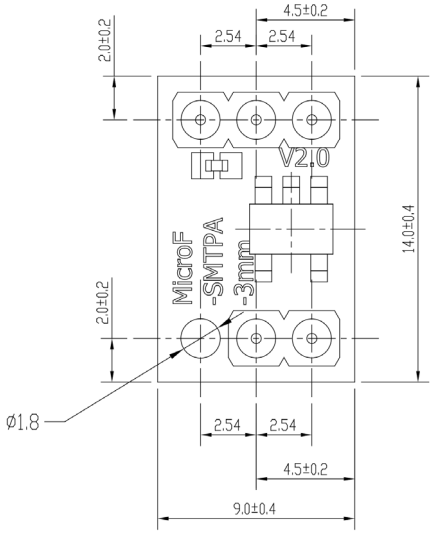
MicroFC−SMTPA Board



TOP VIEW



SIDE VIEW

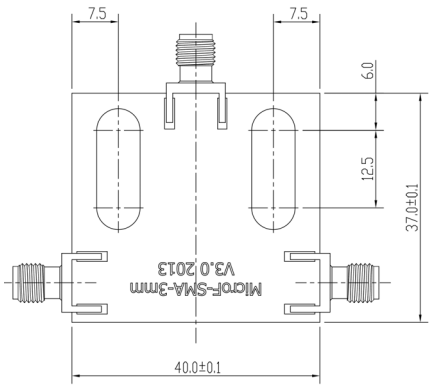


BOTTOM VIEW

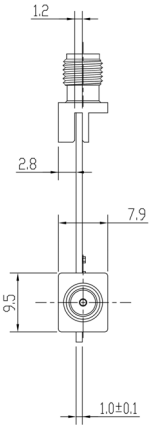
The complete SMTPA board CAD files are available to download:
1 mm – MicroFC−SMTPA−100XX
3 mm – MicroFC−SMTPA−300XX
6 mm – MicroFC−SMTPA−60035

The electrical schematics for the SMTPA board is available in the SMT Board Reference Design document.

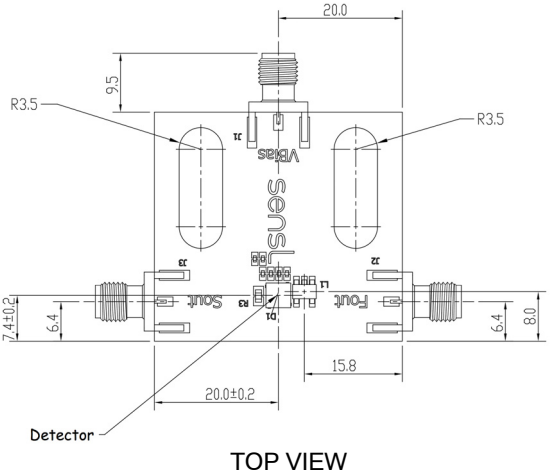
MicroFC−SMA Board



BOTTOM VIEW



SIDE VIEW



TOP VIEW

The complete SMA board CAD files are available to download:
1 mm – MicroFC−SMA−100XX
3 mm – MicroFC−SMA−300XX
6 mm – MicroFC−SMA−60035

The electrical schematics for the SMA board is available in the SMT Board Reference Design document.

USEFUL LINKS

- Introduction to Silicon Photomultipliers Application Note − If you are new to SiPM, this document explains their operation and main performance parameters.
- Biasing and Readout Application Note − This document gives detailed information on how to bias the sensor for both standard and fast configurations, and amplifying and reading out the signal.
- How to Evaluate and Compare Silicon Photomultipliers Application Note − Information on what to consider when selecting an SiPM.
- Handling and Soldering Guide − This document gives information on safe handling of the sensors and soldering to PCB.
- ON Semiconductor Website − for more information on all of ON Semiconductor's products as well as application information.
- CAD file library − ON Semiconductor CAD files include solder footprints and tape and reel information.
- 3D drawing library − 3D files for ON Semiconductor products can be downloaded as SolidWorks, STEP and Inventor files.

ORDERING INFORMATION

Table 5. ORDERING INFORMATION

Product Code (Note 11)	**Microcell Size (Total Number)**	**Sensor Active Area**	**Package Type**	**Delivery Options** (Note 12)
10000 Series				
MicroFC−10010−SMT	10 μm (2880 microcells)	1 mm × 1 mm	4-side tileable, surface mount package (SMT)	TR1, TR
MicroFC−SMA−10010			SMT sensor mounted onto a PCB with SMA connectors for bias and output.	PK
MicroFC−SMTPA−10010			SMT sensor mounted onto a pin adapter board.	PK
MicroFC−10020−SMT	20 μm (1296 microcells)		4-side tileable, surface mount package (SMT)	TR1, TR
MicroFC−SMA−10020			SMT sensor mounted onto a PCB with SMA connectors for bias and output.	PK
MicroFC−SMTPA−10020			SMT sensor mounted onto a pin adapter board.	PK
MicroFC−10035−SMT	35 μm (576 microcells)		4-side tileable, surface mount package (SMT)	TR1, TR
MicroFC−SMA−10035			SMT sensor mounted onto a PCB with SMA connectors for bias and output.	PK
MicroFC−SMTPA−10035			SMT sensor mounted onto a pin adapter board.	PK

Table 5. ORDERING INFORMATION (continued)

Product Code (Note 11)	Microcell Size (Total Number)	Sensor Active Area	Package Type	Delivery Options (Note 12)
30000 Series				
MicroFC−30020−SMT	20 μm (10998 microcells)	3 mm × 3 mm	4-side tileable, surface mount package (SMT)	TR1, TR
MicroFC−SMA−30020			SMT sensor mounted onto a PCB with SMA connectors for bias and output.	PK
MicroFC−SMTPA−30020			SMT sensor mounted onto a pin adapter board	PK
MicroFC−30035−SMT	35 μm (4774 microcells)		4-side tileable, surface mount package (SMT)	TR1, TR
MicroFC−SMA−30035			SMT sensor mounted onto a PCB with SMA connectors for bias and output.	PK
MicroFC−SMTPA−30035			SMT sensor mounted onto a pin adapter board	PK
MicroFC−30050−SMT	50 μm (2668 microcells)		4-side tileable, surface mount package (SMT)	TR1, TR
MicroFC−SMA−30050			SMT sensor mounted onto a PCB with SMA connectors for bias and output.	PK
MicroFC−SMTPA−30050			SMT sensor mounted onto a pin adapter board	PK
60000 Series				
MicroFC−60035−SMT	35 μm (18980 microcells)	6mm × 6mm	4-side tileable, surface mount package (SMT)	TR1, TR
MicroFC−SMA−60035			SMT sensor mounted onto a PCB with SMA connectors for bias and output.	PK
MicroFC−SMTPA−60035			SMT sensor mounted onto a pin adapter board	PK

11. All Devices are Pb−Free and are RoHS Compliant.
12. The two−letter delivery option code should be appended to the order number, e.g.) to receive MicroFC−60035−SMT on tape and reel, use MicroFC−60035−SMT−TR. The codes are as follows:
    PK = ESD Package
    TR1 = Tape
    TR = Tape and Reel

    There is a minimum order quantity (MOQ) of 3000 for the tape and reel (TR) option. The TR option is only available in multiples of the MOQ.

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