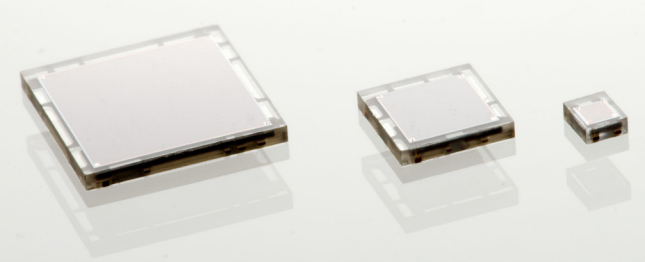
Low Noise, Blue-Sensitive Silicon Photomultipliers

SensL's C-Series low-light sensors feature an industry-leading low dark-count rate combined with a high PDE that is extended much further into the blue part of the spectrum using a high-volume, P-on-N silicon process. For ultrafast timing applications select C-Series sensors have a fast output that can have a rise time of 300ps and a pulse width of 600ps. The C-Series is available in different sensor sizes (1mm, 3mm and 6mm) and packaged in a variety of formats, including a 4-side tileable surface mount (SMT) package that is compatible with industry standard, lead-free, reflow soldering processes. C-Series sensors are pin-for-pin compatible with the B-Series.

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 more information on the SensL products, please refer to the website, www.sensl.com.



PERFORMANCE PARAMETERS

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

[1] *All measurements made at 2.5V 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 √I vs V, where I is the current and V is the overvoltage.*
[4] *The range where PDE >1% at Vbr + 5.0V.*

Sensor Size	Microcell Size	Parameter	Overvoltage	Min.	Typ.	Max.	Units
1mm	10µ	PDE [5] at λp	Vbr + 2.5V		14		%
	20µ				24		%
	35µ				31		%
	50µ				35		%
1mm	10µ		Vbr + 5.0V		18		%
	20µ				31		%
	35µ				41		%
	50µ				47		%
3mm	20µ		Vbr + 2.5V		24		%
	35µ				31		%
	50µ				35		%
3mm	20µ		Vbr + 5.0V		31		%
	35µ				41		%
	50µ				47		%
6mm	35µ		Vbr + 2.5V		31		%
6mm	35µ		Vbr + 5.0V		41		%
1mm	10µ	Gain (anode to cathode readout)	Vbr + 2.5V		$2x10^5$		
	20µ				$1x10^6$		
	35µ				$3x10^6$		
	50µ				$6x10^6$		
3mm	20µ				$1x10^6$		
	35µ				$3x10^6$		
	50µ				$6x10^6$		
6mm	35µ				$3x10^6$		
1mm	10µ	Dark Current [6]	Vbr + 2.5V		1	3	nA
	20µ				5	16	nA
	35µ				15	49	nA
	50µ				32	102	nA
3mm	20µ				50	142	nA
	35µ				154	443	nA
	50µ				319	914	nA
6mm	35µ				618	1750	nA
1mm	10µ	Dark Count Rate	Vbr + 2.5V		30	96	kHz
	20µ				30	96	kHz
	35µ				30	96	kHz
	50µ				30	96	kHz
3mm	20µ				300	860	kHz
	35µ				300	860	kHz
	50µ				300	860	kHz
6mm	35µ				1200	3400	kHz

[5] *Note that the PDE does not contain contributions from afterpulsing or crosstalk.*
[6] *Dark current derived from dark count data as DC*M*q*(1+CT), where DC is dark count, M is gain, q is the charge of an electron, and CT is cross talk.*

Sensor Size	Microcell Size	Parameter	Overvoltage	Min.	Typ.	Max.	Units
1mm	10µ, 20µ, 35µ, 50µ	Rise Time - Fast Output [7]			0.3		ns
3mm	20µ, 35µ, 50µ				0.6		ns
6mm	35µ				1.0		ns
1mm	10µ, 20µ, 35µ, 50µ	Signal Pulse Width - Fast Output (FWHM)			0.6		ns
3mm	20µ, 35µ, 50µ				1.5		ns
6mm	35µ				3.2		ns
1mm	10µ	Microcell recharge time constant [8]			5		ns
	20µ				23		ns
	35µ				82		ns
	50µ				159		ns
3mm	20µ				23		ns
	35µ				82		ns
	50µ				159		ns
6mm	35µ				95		ns
1mm	10µ	Capacitance [9] (anode-cathode)	Vbr + 2.5V		50		pF
	20µ				90		pF
	35µ				100		pF
	50µ				110		pF
3mm	20µ				770		pF
	35µ				850		pF
	50µ				920		pF
6mm	35µ				3400		pF
1mm	10µ	Capacitance [9] (fast terminal to cathode)	Vbr + 2.5V		1		pF
	20µ				1		pF
	35µ				1		pF
	50µ				1		pF
3mm	20µ				20		pF
	35µ				12		pF
	50µ				7		pF
6mm	35µ				48		pF
1mm	10µ, 20µ, 35µ, 50µ	Temperature dependence of Vbr			21.5		mV/°C
3mm	20µ, 35µ, 50µ						
6mm	35µ						
1mm	10µ, 20µ, 35µ, 50µ	Temperature dependence of Gain [10]			-0.8		%/°C
3mm	20µ, 35µ, 50µ						
6mm	35µ						

[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 2-3pF 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.

Sensor Size	Microcell Size	Parameter	Overvoltage	Min.	Typ.	Max.	Units
1mm	10µ	Crosstalk	Vbr + 2.5V		0.6		%
	20µ				3		%
	35µ				7		%
	50µ				10		%
3mm	20µ				3		%
	35µ				7		%
	50µ				10		%
6mm	35µ				7		%
1mm	10µ	Afterpulsing	Vbr + 2.5V		0.2		%
	20µ				0.2		%
	35µ				0.2		%
	50µ				0.6		%
3mm	20µ				0.2		%
	35µ				0.2		%
	50µ				0.6		%
6mm	35µ				0.2		%

GENERAL PARAMETERS

	1mm	3mm	6mm
	10010, 10020, 10035, 10050	30020, 30035, 30050	60035
Active area	1 x 1 mm^2	3 x 3 mm^2	6 x 6 mm^2
No. of microcells	10010: 2880 10020: 1296 10035: 504 10050: 282	30020: 10998 30035: 4774 30050: 2668	60035: 18980
Microcell fill factor	10010: 28% 10020: 48% 10035: 64% 10050: 72%	30020: 48% 30035: 64% 30050: 72%	60035: 64%

SMT Package Specifics			
	1mm	3mm	6mm
	10010, 10020, 10035, 10050	30020, 30035, 30050	60035
Package dimensions	1.5 x 1.8 mm^2	4 x 4 mm^2	7 x 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 @ 420nm		

X18 Package Specifics (1mm only)			
	1mm	3mm	6mm
	10010, 10020, 10035, 10050	30020, 30035, 30050	60035
Recommended operating temperature range	-40°C to +85°C		
Maximum storage temperature	+125°C		
Soldering conditions	Soldering iron, maximum of 260°C for no more than 10 sec. See the Soldering Tech Note for more details.		

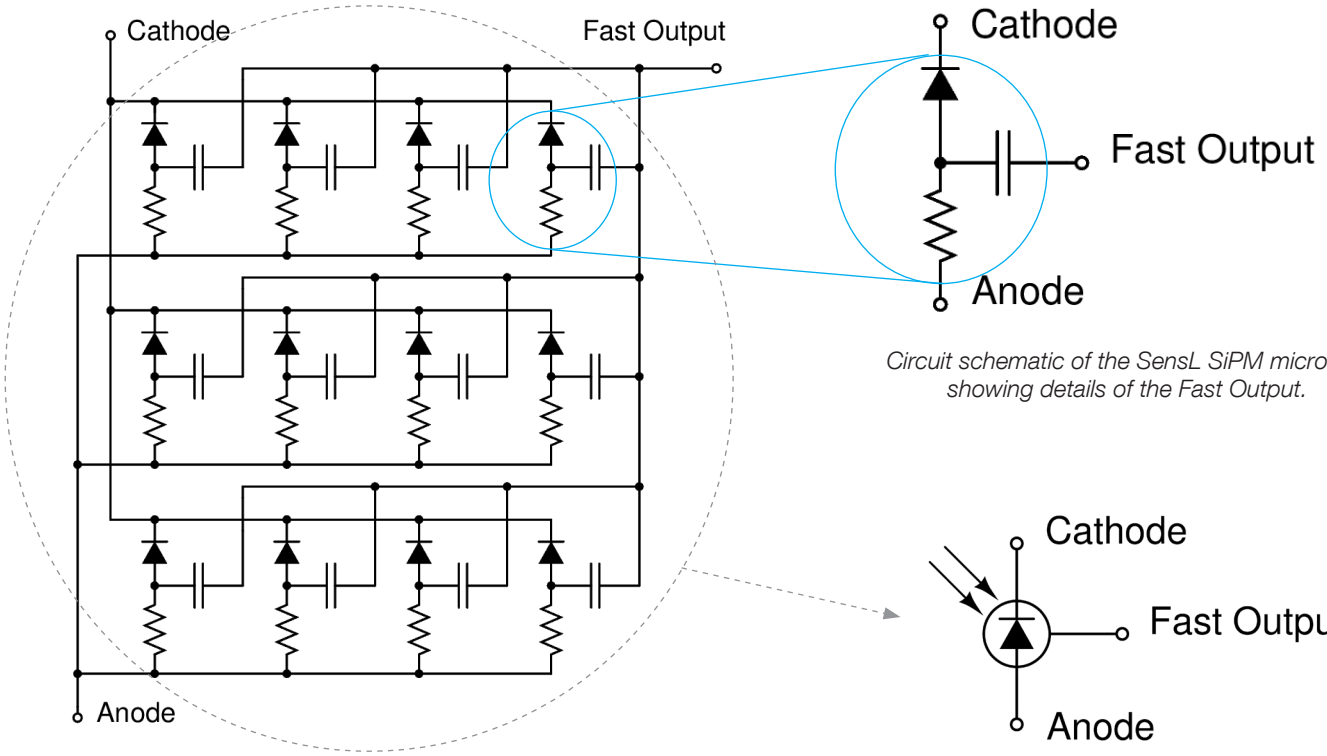
X13 Package Specifics			
	1mm	3mm	6mm
	10035	30035	60035
Recommended operating temperature range	0°C to +40°C		
Maximum storage temperature	+50°C		
Soldering conditions	Soldering iron, max. of 260°C for 5sec, 2mm from ceramic base. See the Soldering Tech Note for more details.		
Encapsulant material	Epoxy		

Maximum current levels for each sensor size and package type			
Package type	1mm 10010, 10020, 10035, 10050	3mm 30020, 30035,30050	6mm 60035
SMT	2mA (A1) * 6mA (C1) *	15mA	20mA
X18	4mA	-	-
X13	-	3mA	5mA

** A1 and C1 are package versions. Please consult this PCN for more information.*

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.

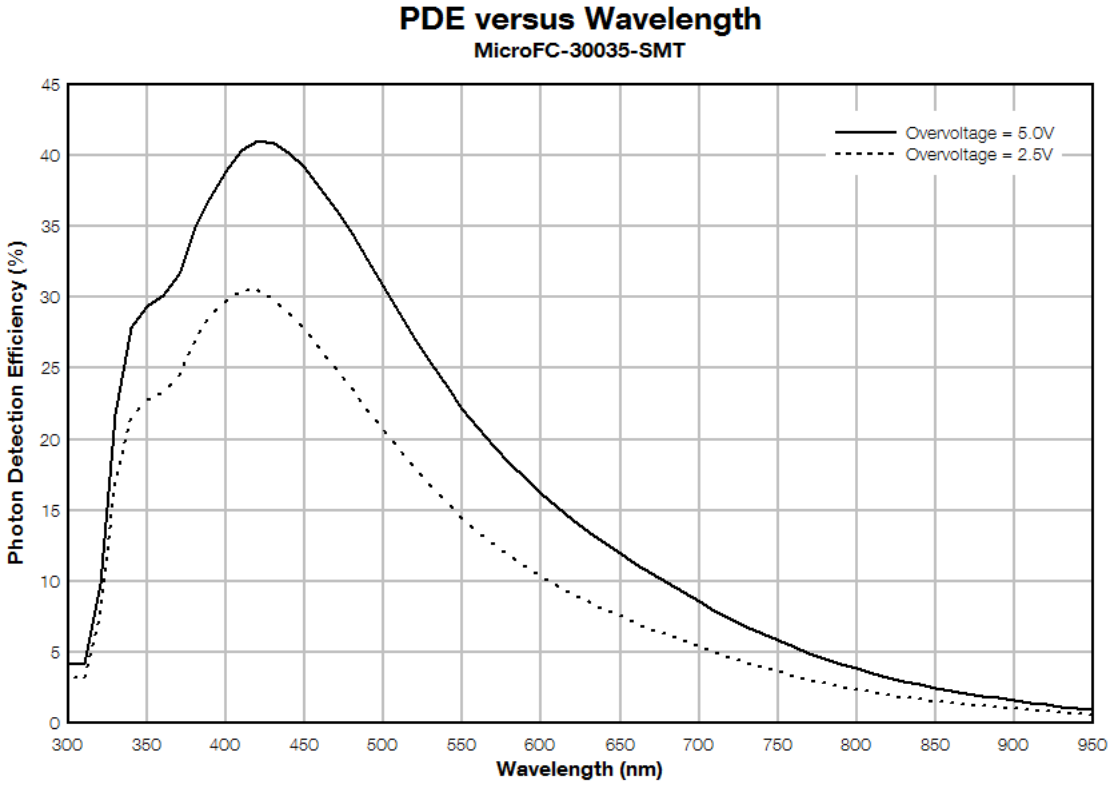


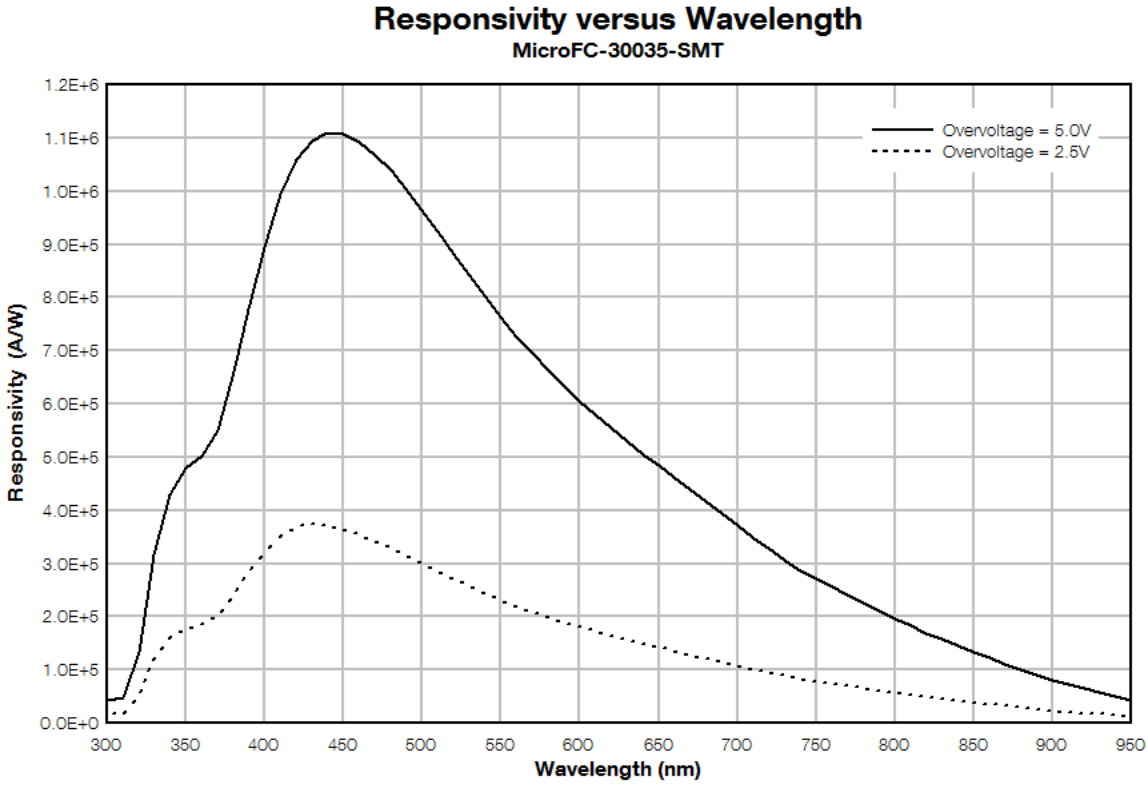
Simplified circuit schematic of the SensL SiPM showing only a 12 microcell example. Typically, SiPM sensors have hundreds or thousands of microcells.

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

SensL SiPM component symbol.

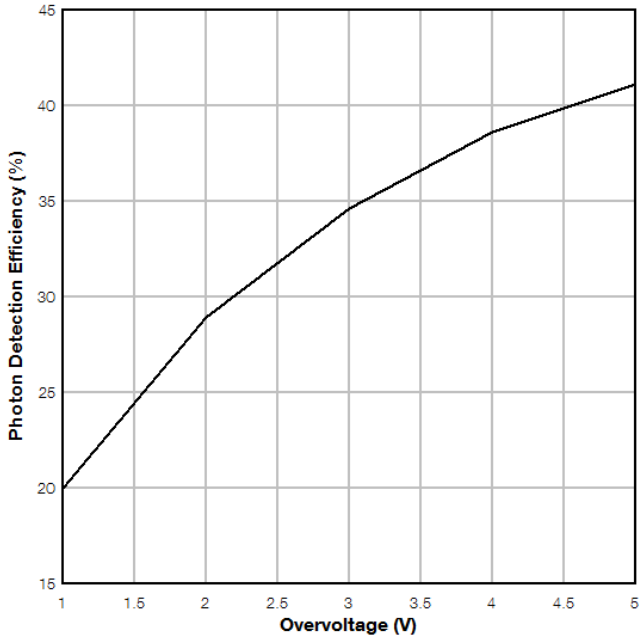
PERFORMANCE





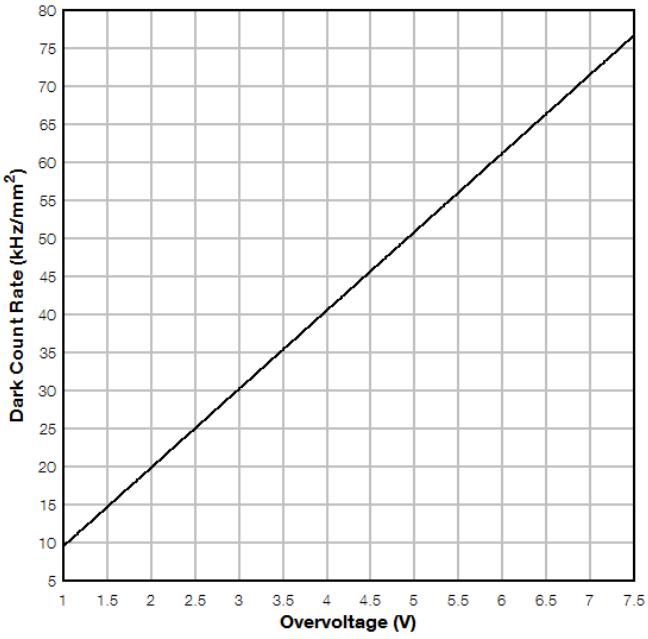
PDE at 420nm versus Voltage

MicroFC-30035-SMT



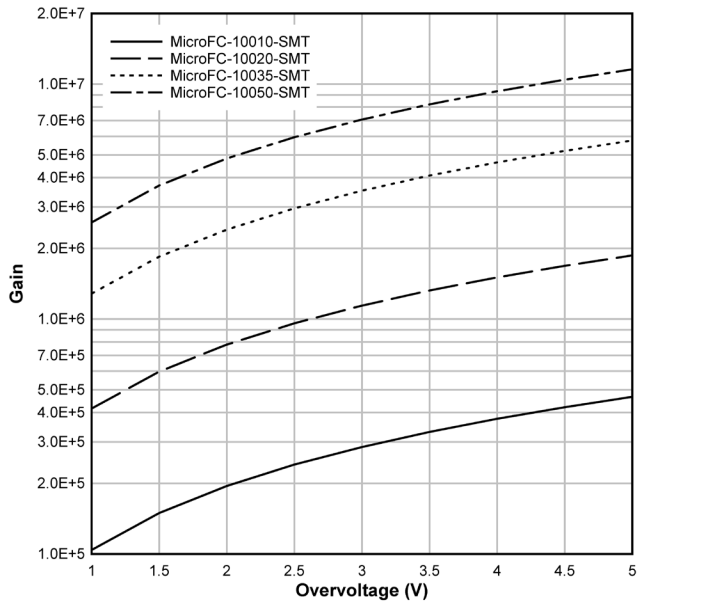
Dark Count Rate versus Overvoltage

MicroFC-30035-SMT (Example Plot)



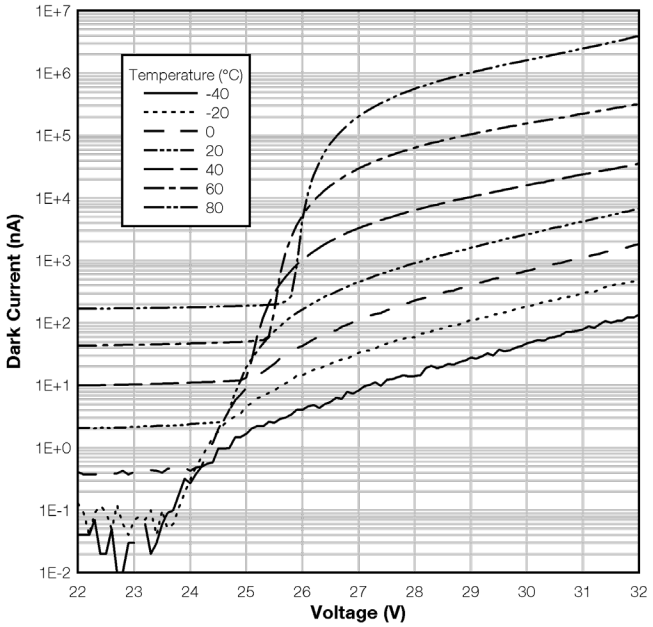
Gain versus Overvoltage

MicroFC-10010-SMT, MicroFC-10020-SMT, MicroFC-10035-SMT, MicroFC-10050-SMT



Dark Current versus Voltage and Temperature

MicroFC-60035-SMT

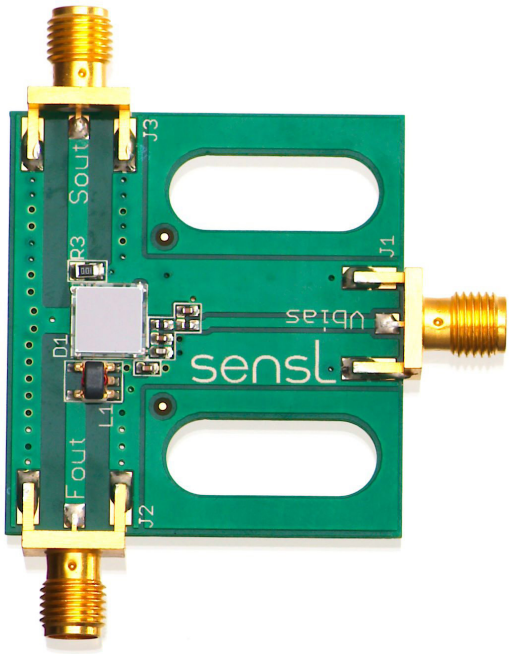


EVALUATION BOARD OPTIONS

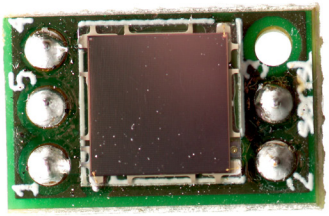
SMA BIASING BOARD (MicroFC-SMA-XXXXX)

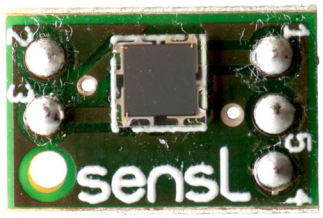
The MicroFC-SMA is a printed circuit board (PCB) that can facilitate the evaluation of the C-Series SMT sensors. The board has three female SMA connectors for connecting the bias voltage, the standard output from the anode and the fast output signal. The output signals can be connected directly to a 50Ω-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.

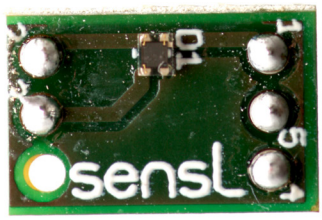
The MicroFC-SMA is recommended for users who require a plug-and-play set-up to quickly evaluate C-Series SMT sensors with optimum timing performance. The board also allows the standard output from the anode to be observed at the same time as the fast output. The outputs can be connected directly to the 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.



Output	Function
Vbias	positive bias input (cathode)
Fout	fast output
Sout	standard output (anode)

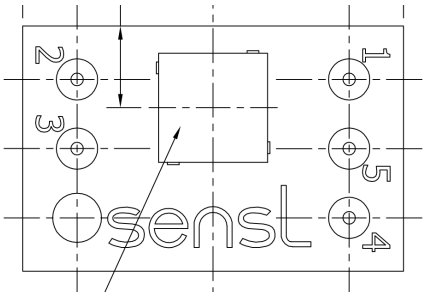






PIN ADAPTER (MicroFC-SMTPA-XXXXX)

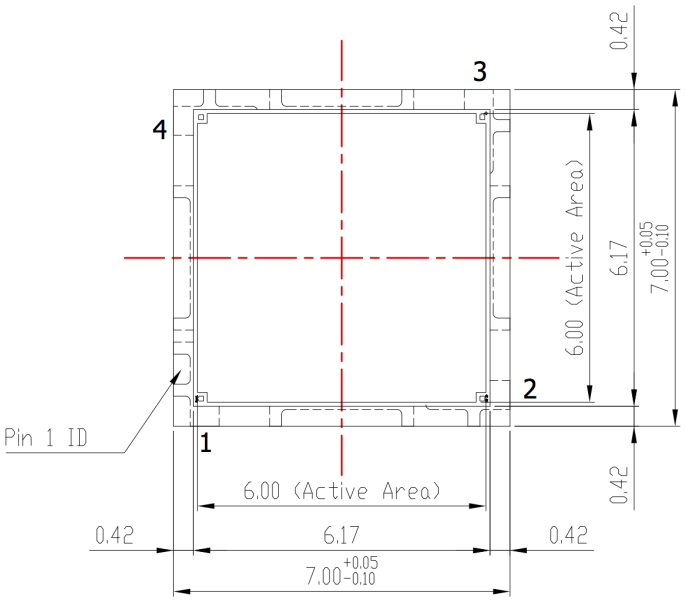
The SMT Pin Adapter board (SMTPA) is a small PCB board that houses the SMT sensor and has through-hole pins to allow for use with standard sockets or probe clips. This product is useful for those needing a quick way to evaluate the C-Series SMT sensors without the need for specialist surface-mount soldering. 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 and the C-Series User Manual contains information on biasing the sensor. The SMTPA board electrical schematics are available to download in the SMT Board Reference Design document.



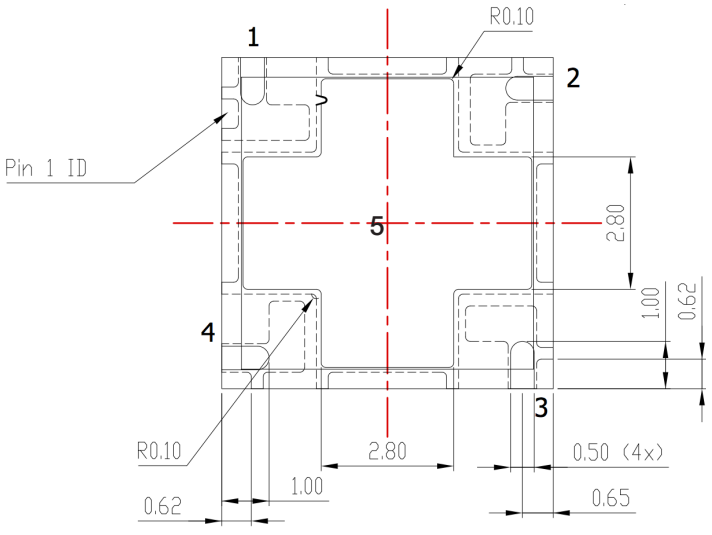
MicroFC-SMTPA-XXXXX	
Pin No.	Connection
1	anode
2	fast output
3	cathode
4	ground
5	no connect

PACKAGE DRAWINGS (All Dimensions in mm)

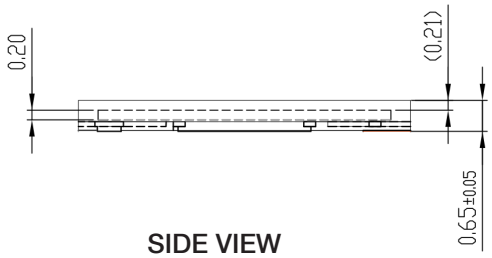
MicroFC-60035-SMT-C1 *



TOP VIEW



BOTTOM VIEW



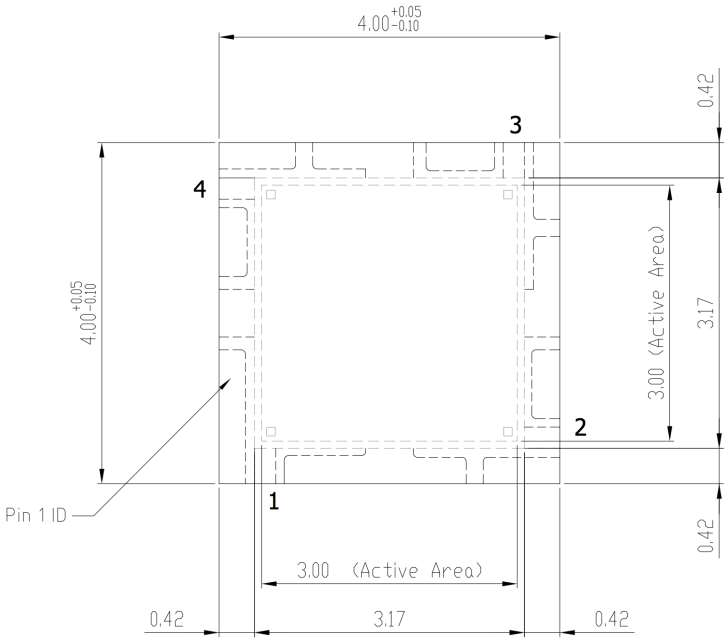
SIDE VIEW

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

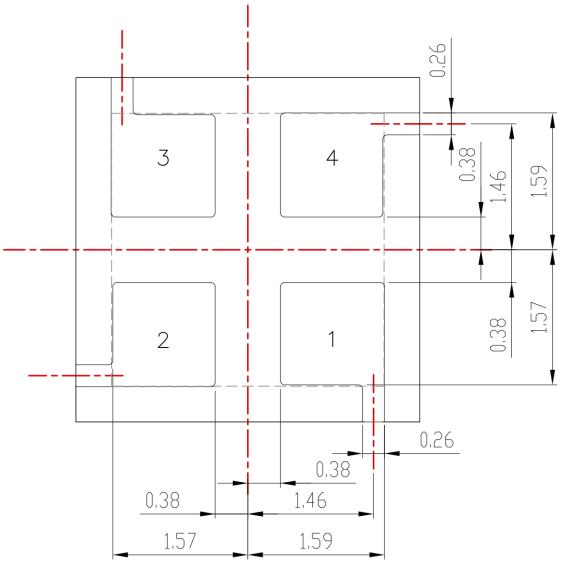
** Please consult the PCN concerning C-Series SMT parts.*
*** The 'No Connect' pin 4 should be soldered to the PCB. This pin can be connected to ground but it can also be left floating without affecting the dark noise. It is recommended that the Pin 5 paddle is NOT soldered to the PCB and is left floating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

The complete MicroFC-60035-SMT-C1 CAD file, including solder footprint and tape and reel drawing, is available to download here.

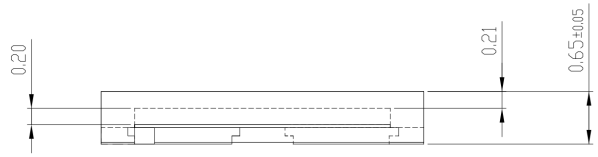
MicroFC-30035-SMT-C1 *



TOP VIEW



BOTTOM VIEW



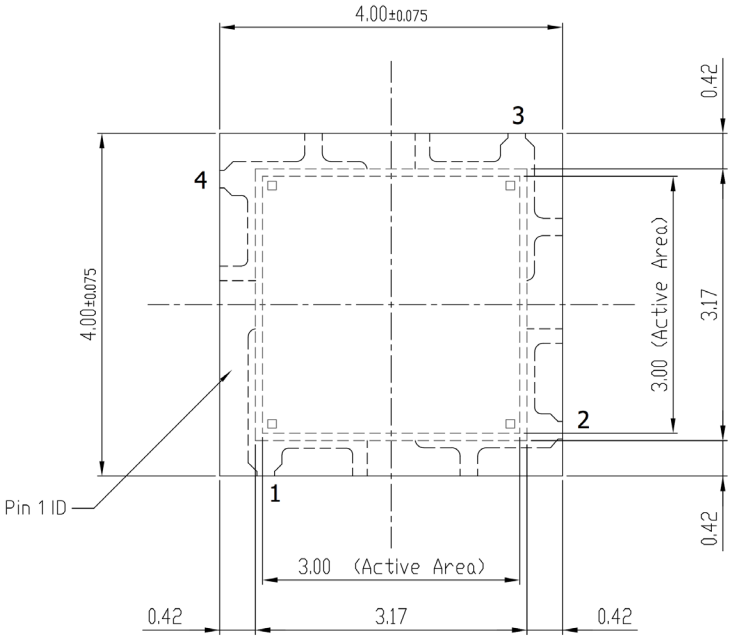
SIDE VIEW

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

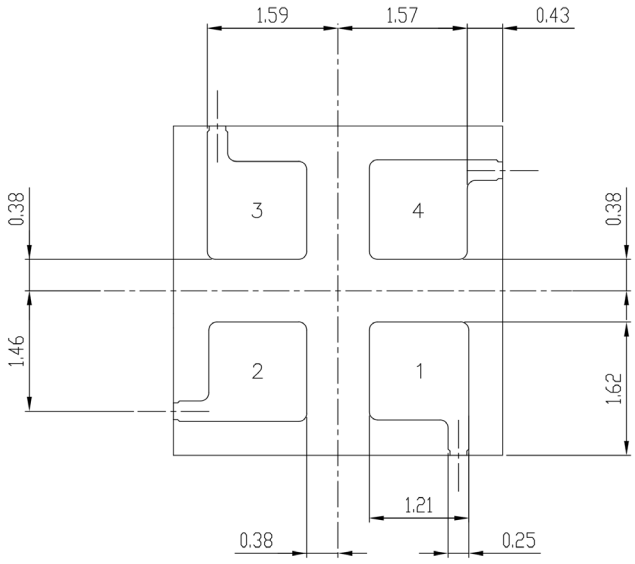
** Please consult the PCN concerning C-Series SMT parts.*
*** The 'No Connect' pin 4 should be soldered to the PCB. It can be connected to ground but it can also be left floating without affecting the dark noise.*

The complete MicroFC-300XX-SMT-C1 CAD file, including solder footprint and tape and reel drawing, is available to download here.

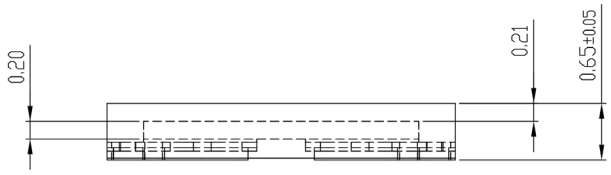
MicroFC-30020-SMT-A1 & MicroFC-30050-SMT-A1 *



TOP VIEW



BOTTOM VIEW



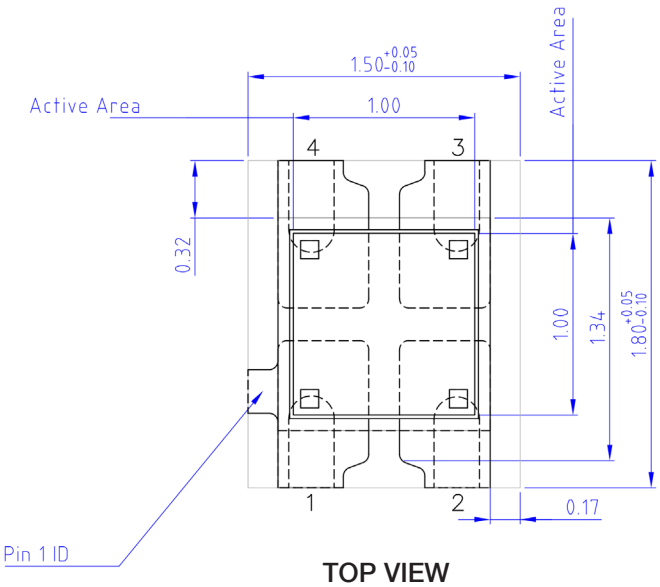
SIDE VIEW

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

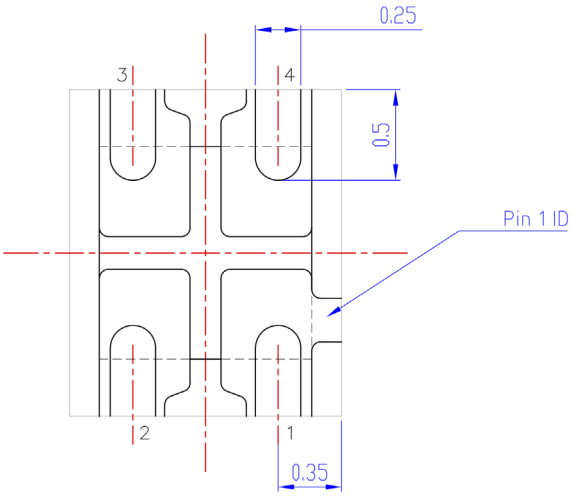
** The 'No Connect' pin 4 should be soldered to the PCB. It can be connected to ground but it can also be left floating without affecting the dark noise.*

The complete MicroFC-300XX-SMT-A1 CAD and solder footprint file is available to download here.

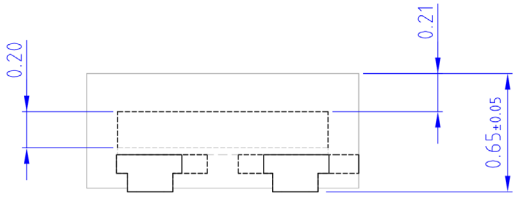
MicroFC-10010-SMT-C1, MicroFC-10020-SMT-C1 & MicroFC-10035-SMT-C1*



TOP VIEW



BOTTOM VIEW



SIDE VIEW

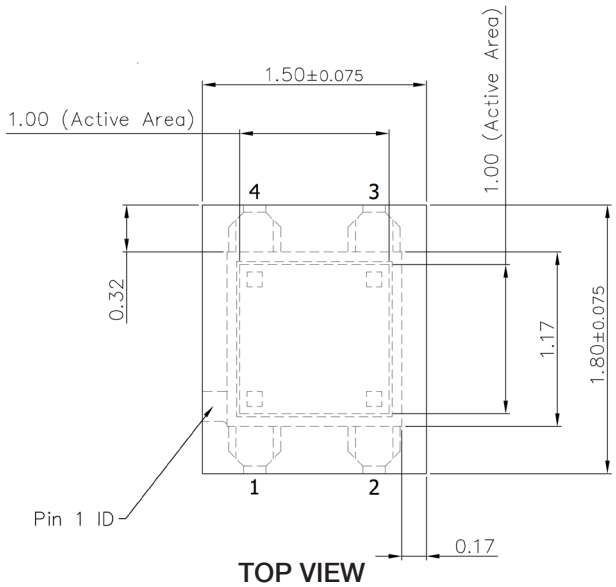
Pin Assignments	
Pin #	MicroFC-100XX-SMT
1	Anode
2	Fast Output
3	Cathode
4	No Connect *

** Please consult the PCN concerning C-Series SMT parts.*

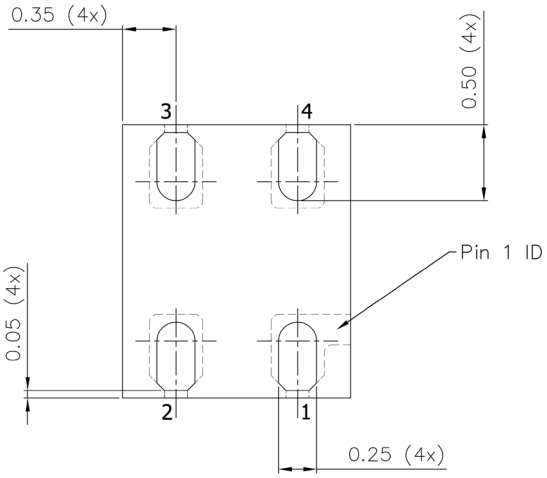
*** The 'No Connect' pin 4 should be soldered to the PCB. It can be connected to ground but it can also be left floating without affecting the dark noise.*

The complete MicroFC-100XX-SMT-C1 CAD and solder footprint file is available to download here.

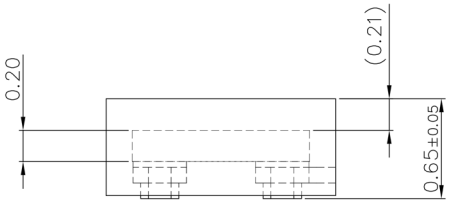
MicroFC-10050-SMT-A1



TOP VIEW



BOTTOM VIEW



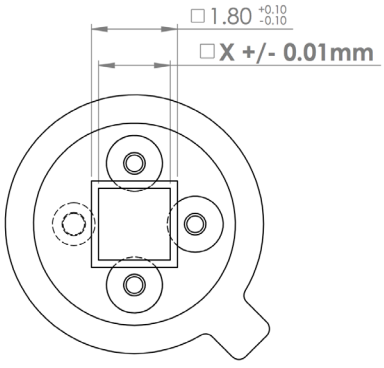
SIDE VIEW

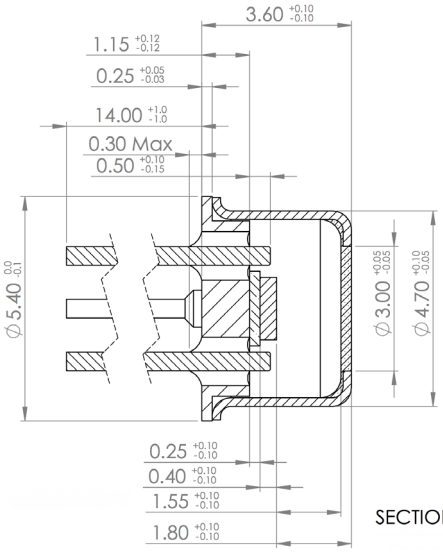
Pin Assignments	
Pin #	MicroFC-100XX-SMT
1	Anode
2	Fast Output
3	Cathode
4	No Connect *

** 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.*

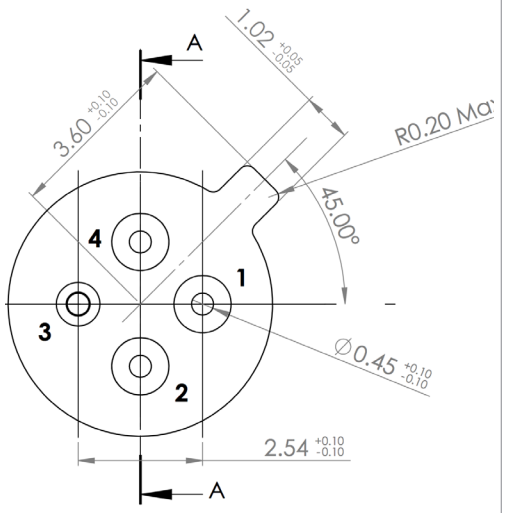
The complete MicroFC-100XX-SMT-A1 CAD and solder footprint file is available to download here.

MicroFC-100XX-X18



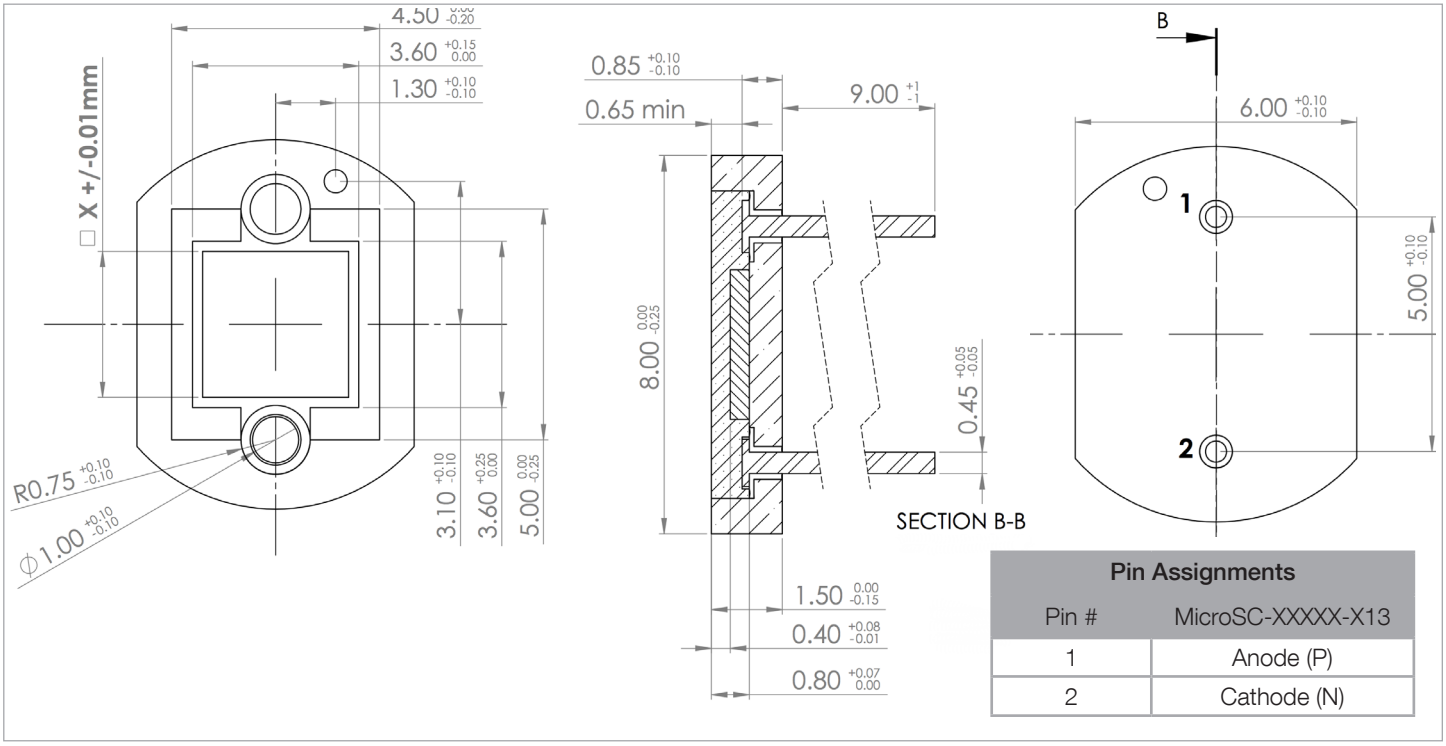


SECTION A-A



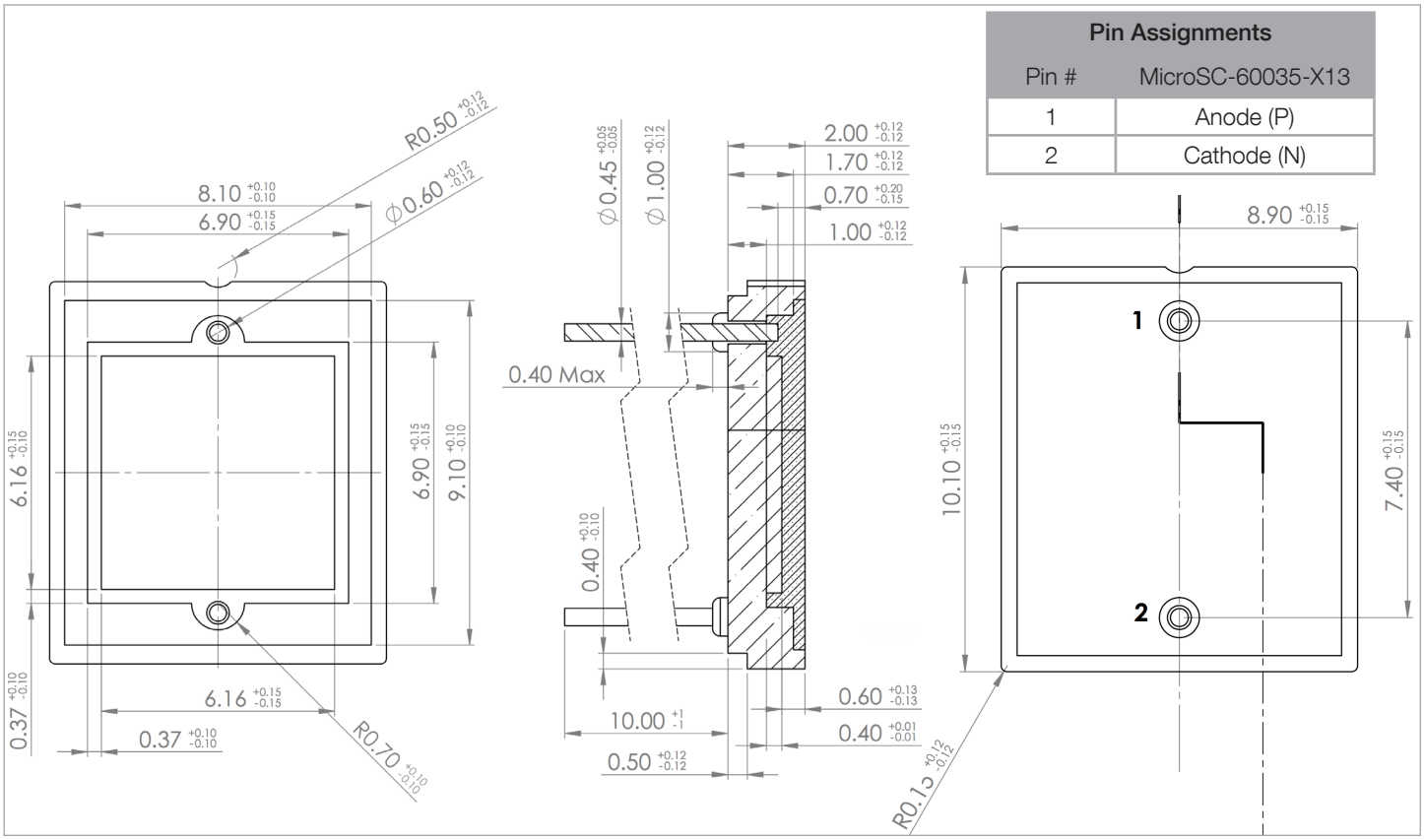
Pin Assignments	
Pin #	MicroFC-100XX-X18
1	Fast Output
2	Cathode (N)
3	GND
4	Anode (P)

MicroSC-30035-X13 (Note: MicroSC-10035-X13 package is the same but with smaller sensor size.)



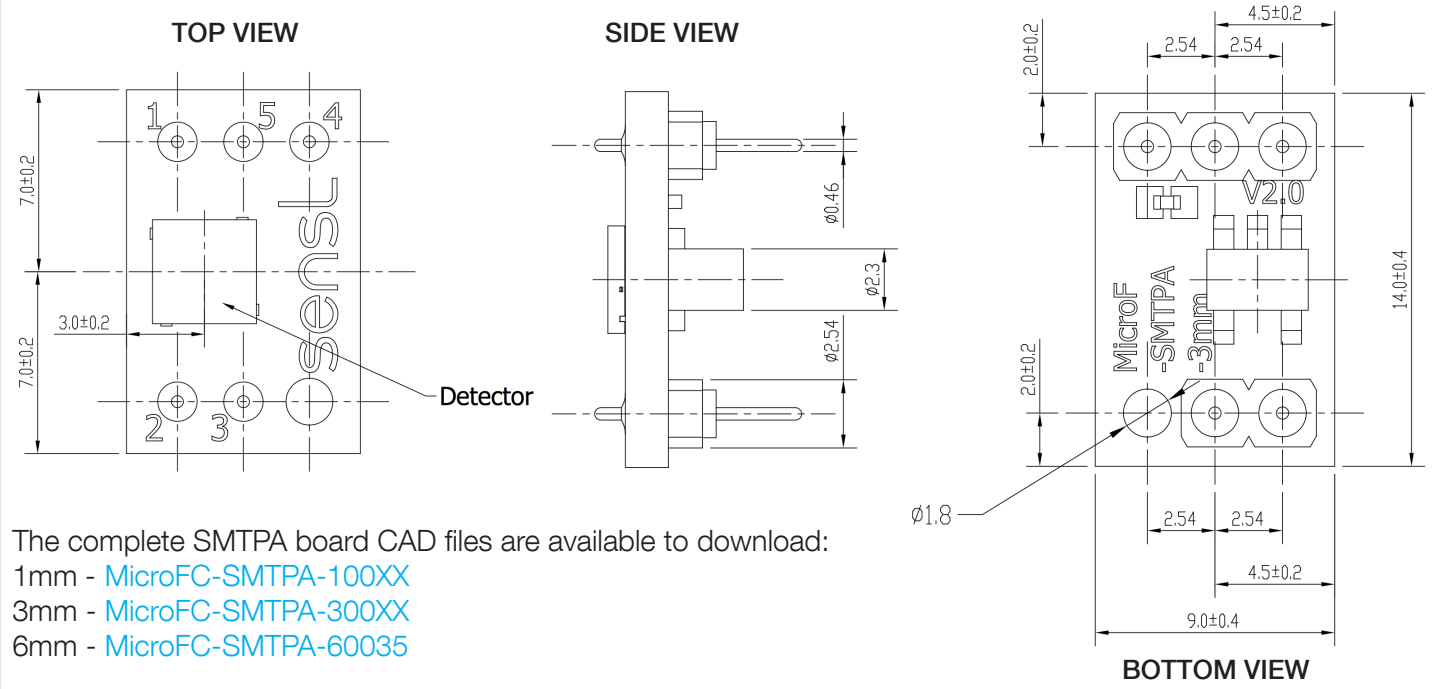
Pin Assignments	
Pin #	MicroSC-XXXXX-X13
1	Anode (P)
2	Cathode (N)

MicroSC-60035-X13



Pin Assignments	
Pin #	MicroSC-60035-X13
1	Anode (P)
2	Cathode (N)

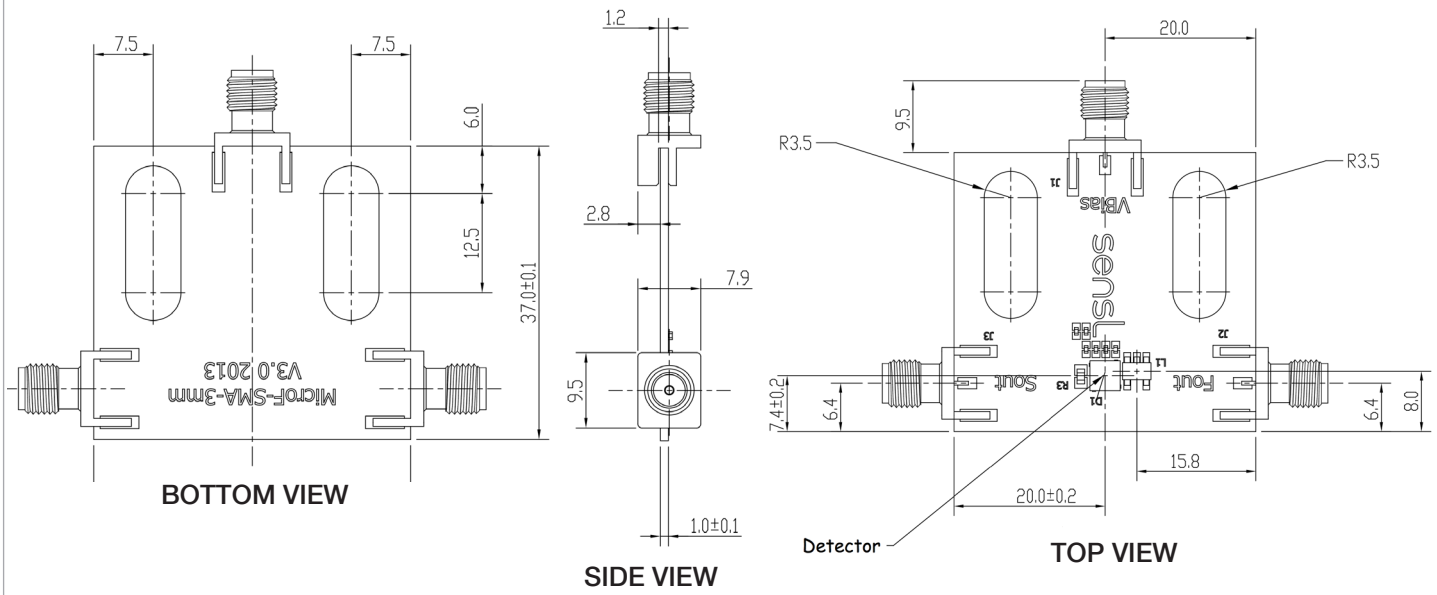
MicroFC-SMTPA Board



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

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

MicroFC-SMA Board



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

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

ORDERING INFORMATION

Product Code	Microcell size (Total number)	Sensor active area	Package type	Delivery options [a]
10000 Series				
MicroFC-10010-SMT	10µm (2880 microcells)	1mm x 1mm	4-side tileable, surface mount package (SMT)	TA, 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	20µm (1296 microcells)		4-side tileable, surface mount package (SMT)	TA, 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-10020-X18			3-pin TO-18 package	PK
MicroFC-10035-SMT	35µm (576 microcells)		4-side tileable, surface mount package (SMT)	TA, 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
MicroFC-10035-X18			3-pin TO-18 package	PK
MicroSC-10035-X13			2-pin ceramic package, epoxy fill (no fast output)	PK
MicroFC-10050-SMT	50µm (324 microcells)		4-side tileable, surface mount package (SMT)	TA, TR
MicroFC-SMA-10050			SMT sensor mounted onto a PCB with SMA connectors for bias and output.	PK
MicroFC-SMTPA-10050			SMT sensor mounted onto a pin adapter board.	PK
MicroFC-10050-X18			3-pin TO-18 package	PK

Ordering information continues on the next page...

ORDERING INFORMATION (Continued)

Product Code	Microcell size (Total number)	Sensor active area	Package type	Delivery options [a]
30000 Series				
MicroFC-30020-SMT	20µm (10998 microcells)	3mm x 3mm	4-side tileable, surface mount package (SMT)	TA, 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	35µm (4774 microcells)		4-side tileable, surface mount package (SMT)	TA, 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
MicroSC-30035-X13			2-pin ceramic package, epoxy fill (no fast output)	PK
MicroFC-30050-SMT	50µm (2668 microcells)		4-side tileable, surface mount package (SMT)	TA, 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	35µm (18980 microcells)	6mm x 6mm	4-side tileable, surface mount package (SMT)	TA, 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
MicroSC-60035-X13			2-pin ceramic package, epoxy fill (no fast output)	PK

[a] 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
TA = Tape
TR = Tape and Reel

There is a minimum order quantity (MOQ) of 3000 for the tape and reel (TR) option. Quanitites less than this are available on tape which will ship according to the table below:

Sensor size	-TA			-TR
	Cut tape (no reel)	Tape loaded onto a generic reel	Tape loaded onto product-specific reel *	Tape and reel MOQ **
1mm	<50	50 < 3000	-	3000
3mm	<50	50 < 2000	2000 < 3000	3000
6mm	<50	50 < 1000	1000 < 3000	3000

** The CAD for the product-specific tape and reels are given in the product CAD files (see pages 10 - 14).*

*** The TR option is only available in multiples of the MOQ.*

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All specifications are subject to change without notice