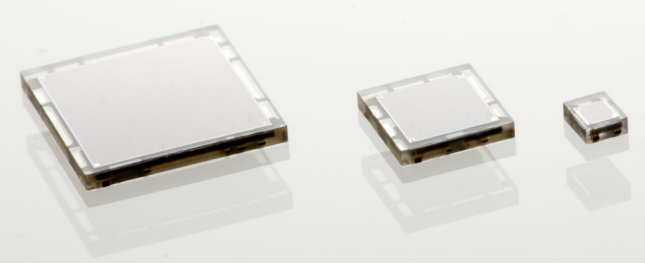
Low Noise, Fast, Blue-Sensitive Silicon Photomultipliers

SensL's C-Series low-light sensors feature an industry-leading low dark-count rate, combined with high PDE that extends 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, previously introduced in SensL's M-Series & B-Series sensors. These fast signals can have rise times of 300ps and pulse widths 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 C-Series devices 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]		24.40	24.65	24.90	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		800	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 parabolic line fit to the current vs. voltage characteristic curve.*
[4] *SMT package spectral range is limited from 320nm to 800nm. X13 package extends UV response to 300nm.*

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	Gain (fast terminal readout)	Vbr + 2.5V		$5.2x10^3$		
	20µ				$4.3x10^4$		
	35µ				$4.3x10^4$		
	50µ				$4.3x10^4$		
3mm	20µ				$4.3x10^4$		
	35µ				$4.3x10^4$		
	50µ				$4.3x10^4$		
6mm	35µ				$4.3x10^4$		
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	17497	nA

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

Sensor Size	Microcell Size	Parameter	Overvoltage	Min.	Typ.	Max.	Units
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
1mm	10µ, 20µ, 35µ, 50µ	Rise Time - Fast Output [7]	Vbr + 2.5V		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)	Vbr + 2.5V		0.6		ns
3mm	20µ, 35µ, 50µ				1.5		ns
6mm	35µ				3.2		ns
1mm	10µ	Microcell recovery time [8]	Vbr + 2.5V		10		ns
	20µ				90		ns
	35µ				180		ns
	50µ				350		ns
3mm	20µ				90		ns
	35µ				180		ns
	50µ				350		ns
6mm	35µ				210		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

[7] Measured as time to go from 10% to 90% of the peak amplitude.
[8] Time for microcell to recharge (90% to 10% of pulse peak amplitude).
[9] Internal capacitance of the sensor. Typically add 2-3pF for sensor in package. Listed by unique microcell size for each part version.

Sensor Size	Microcell Size	Parameter	Overvoltage	Min.	Typ.	Max.	Units
1mm	10µ, 20µ, 35µ, 50µ	Temperature dependence of Vbr [10]			21.5		mV/°C
3mm	20µ, 35µ, 50µ						
6mm	35µ						
1mm	10µ, 20µ, 35µ, 50µ	Temperature dependence of Gain [11]			-0.8		%/°C
3mm	20µ, 35µ, 50µ						
6mm	35µ						
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		%

[10] Calculated as the change in Vbr extracted from pulsed laser gain measurements.
[11] Quoted as the percentage change per degree C from the measured value at 21°C.

GENERAL PARAMETERS

	10000 series	30000 series	60000 series
	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: 576 10050: 324	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			
	10000 series	30000 series	60000 series
	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		
Recommended storage temperature range	-40°C to +85°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	1.54 @ 589nm		

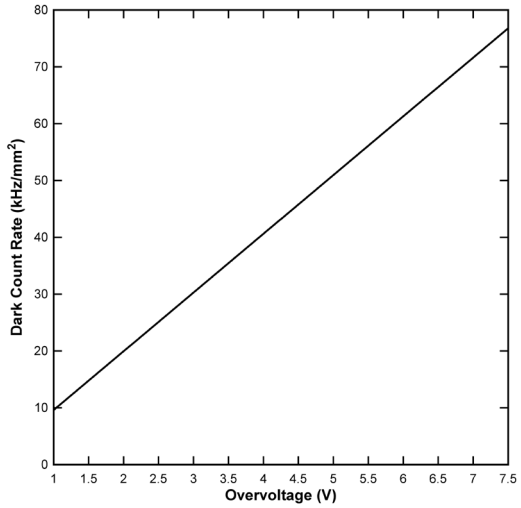
X18 Package Specifics (1mm only)			
	10000 series	30000 series	60000 series
	10010, 10020, 10035, 10050	30020, 30035, 30050	60035
Recommended operating temperature range	-40°C to +85°C		
Recommended storage temperature range	-40°C to +95°C		
Soldering conditions	Soldering iron, maximum of 260°C for no more than 10 sec. See the Soldering Tech Note for more details.		

X13 Package Specifics (3mm & 6mm only)			
	10000 series	30000 series	60000 series
	10010, 10020, 10035, 10050	30020, 30035, 30050	60035
Recommended operating temperature range		0°C to +40°C	
Recommended storage temperature range		-20°C to +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	

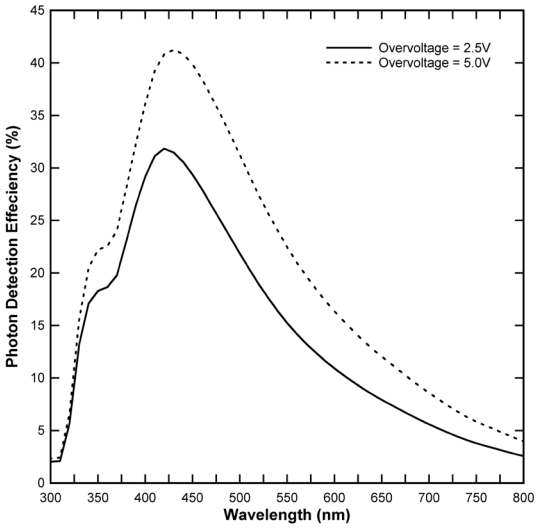
Maximum current levels for each sensor size and package type			
Package type	10000 series 10010, 10020, 10035, 10050	30000 series 30020, 30035,30050	60000 series 60035
SMT	2mA	15mA	20mA
X18	4mA	-	-
X13	-	3mA	5mA

PERFORMANCE

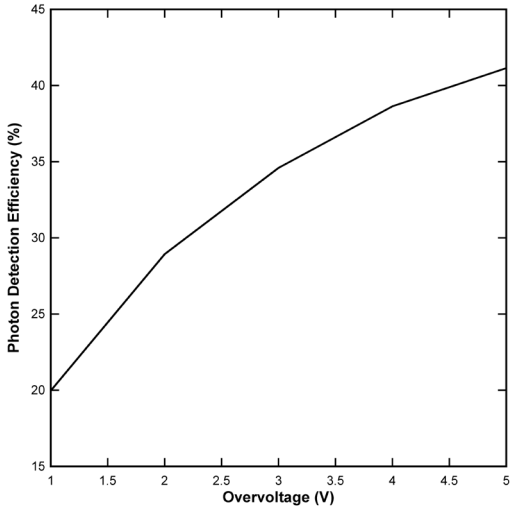
Dark Count Rate versus Overvoltage
MicroFC-30035-SMT (Example Plot)



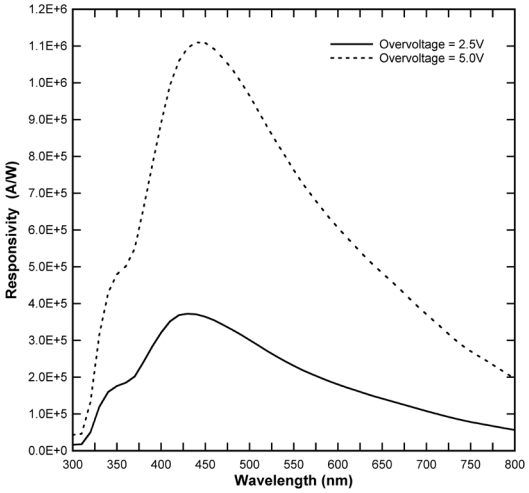
PDE versus Wavelength
MicroFC-30035-SMT



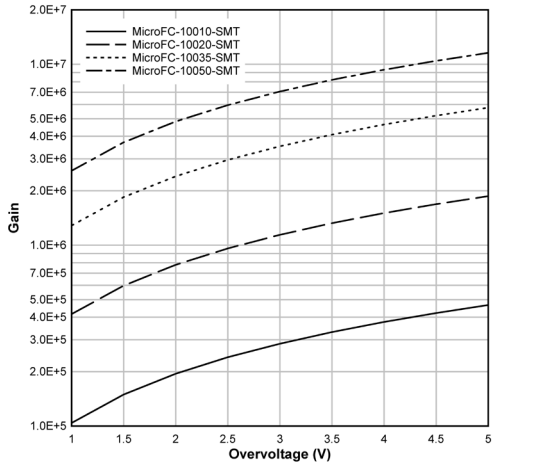
PDE at 420nm versus Voltage
MicroFC-30035-SMT



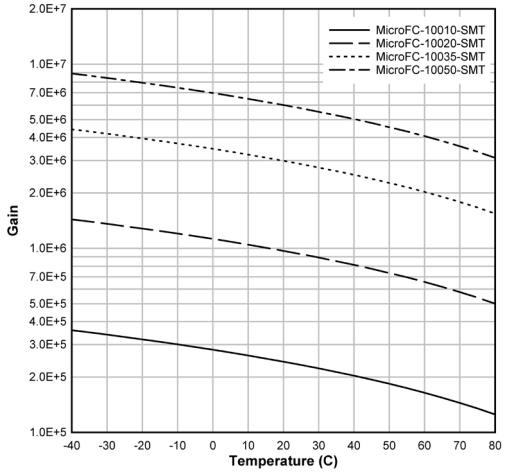
Responsivity versus Wavelength
MicroFC-30035-SMT



Gain versus Overvoltage
MicroFC-10010-SMT, MicroFC-10020-SMT, MicroFC-10035-SMT, MicroFC-10050-SM



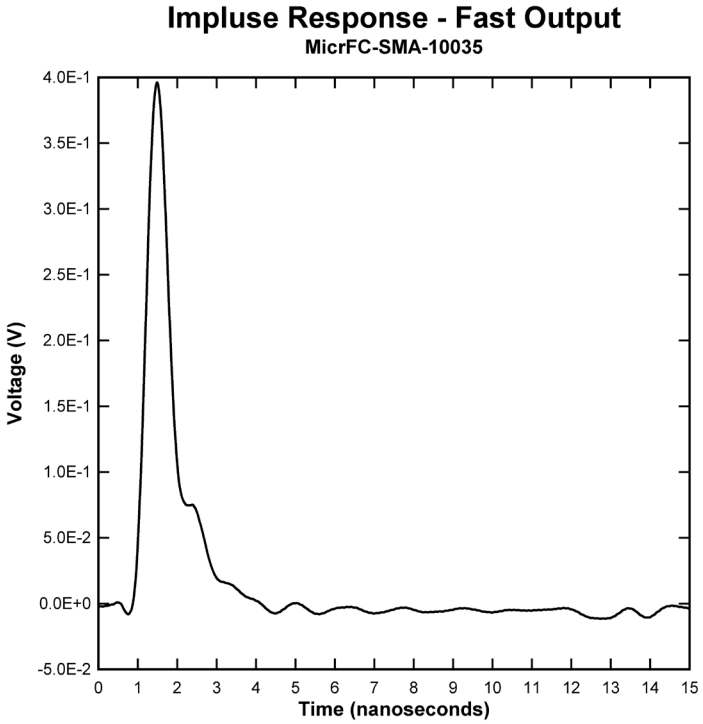
Gain versus Temperature *
MicroFC-10010-SMT, MicroFC-10020-SMT, MicroFC-10035-SMT, MicroFC-10050-S

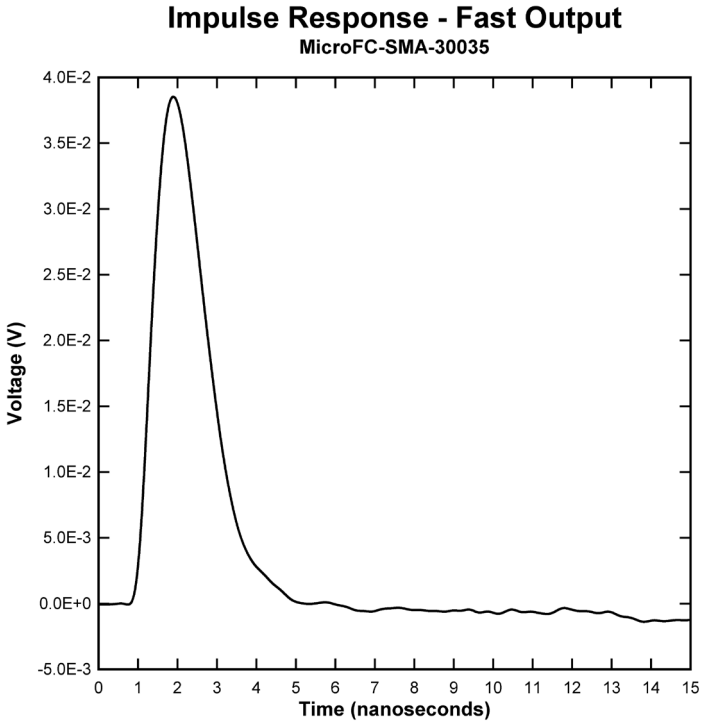


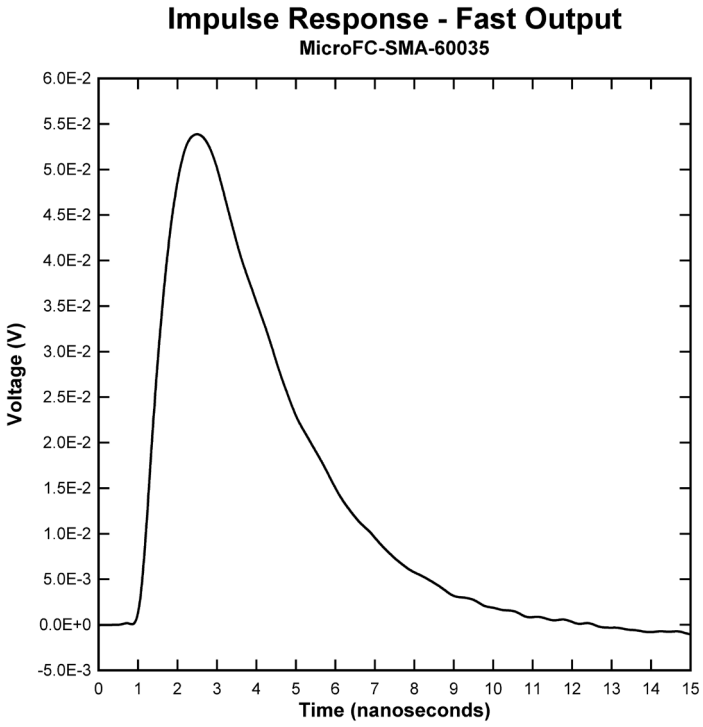
* *This data is acquired at a fixed overvoltage (2.5V above the VBr at room temperature, which is typicallly ~27V).*

FAST OUTPUT SIGNALS

The oscilloscope graphs below show examples of measured waveforms from the fast output of 1mm, 3mm and 6mm sensors mounted on the SensL SMA product boards; the MicroFC-SMA-10035, MicroFC-SMA-30035 and MicroFC-SMA-60035. All measurements are obtained using a 2.5GHz bandwidth oscilloscope and a 50MHz, 50ps red (650nm) laser. No amplifier was used, and the output of the SMA product boards was directly connected to the oscilloscope using a 1m long, 50Ω coaxial cable.







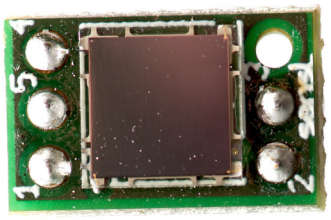
EVALUATION BOARD OPTIONS

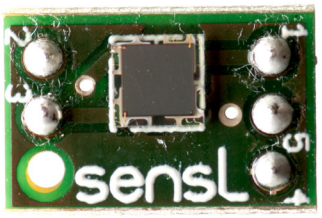
SMA BIASING BOARD (MicroFC-SMA-XXXXX)

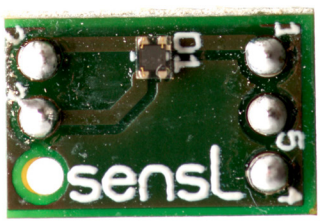
The MicroFC-SMA is a simple board designed to allow evaluation of the MicroFC SMT range of SiPM sensors. The board has three female SMA connectors for connecting the bias voltage, standard output from the anode and the fast output signal. The biasing and output line is laid out in such a way as to preserve 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 FC-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. The table below lists the SMA board connections.

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





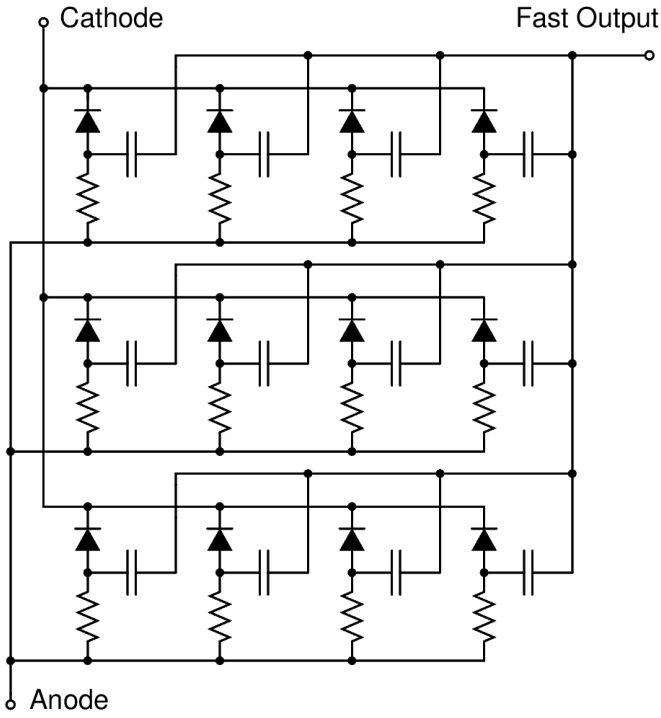


PIN ADAPTER (MicroFC-SMTPA-XXXXX)

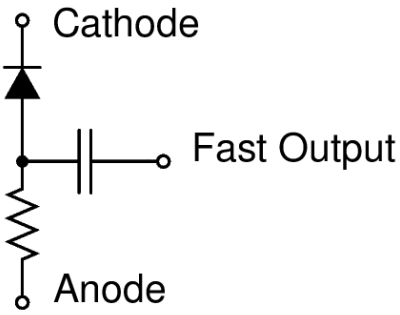
The SMT Pin Adapter board (SMTPA) is a small PCB board that houses the SMT sensor and has through-hole pins to allow its use with standard sockets or probe clips. This product is useful for those needing a quick way to evaluate the SMT package without the need for specialist surface-mount soldering. 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.

Pin No.	Connection	Function	
		Positive bias	Negative bias
1	anode	standard output (*if unused connect to zero V*)	negative bias input
2	fast	fast output (*if unused can be left open*)	fast output (*if unused can be left open*)
3	cathode	positive bias input	standard output (*if unused connect to zero V*)
4	gnd	PCB gnd	PCB gnd
5	n/c	do not connect	do not connect

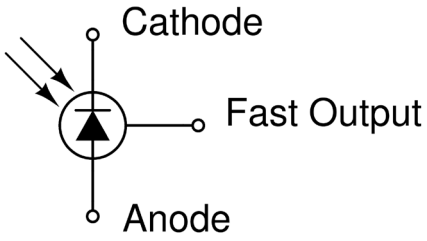
CIRCUIT SCHEMATICS



Simplified circuit schematic of the SensL SiPM showing only a 12 microcell example.



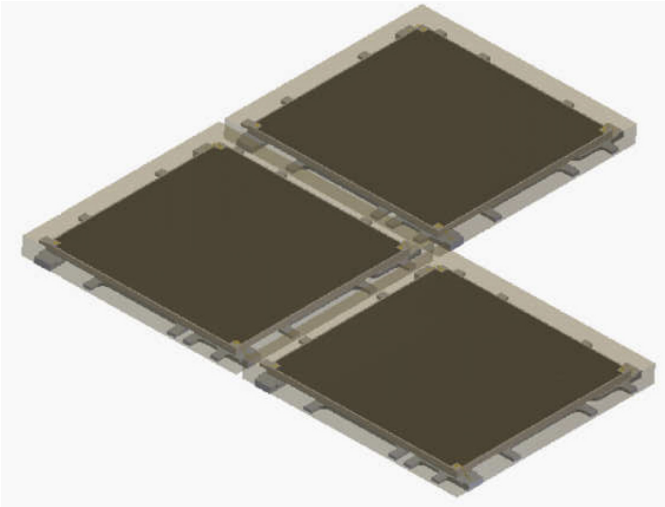
Circuit schematic of the SensL SiPM microcell, showing details of the Fast Output.



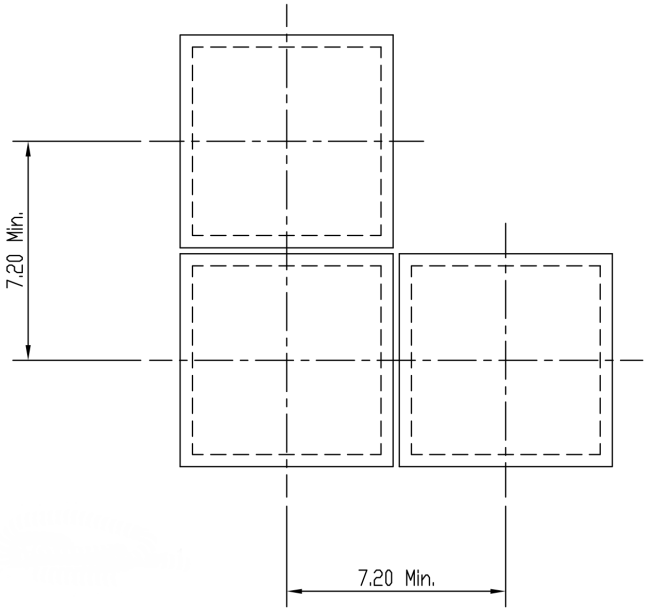
SensL SiPM component symbol.

TILING OF THE SMT PACKAGE

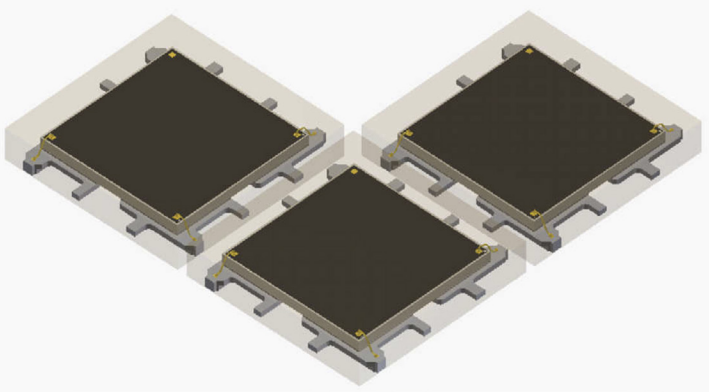
SensL has developed a market-leading, custom SMT package for the C-Series sensors. It is a compact, leadless, chip-scale package that is compatible with lead-free, reflow soldering processes. A clear encapsulant is used for optimal coupling to scintillators or fibre optic elements.



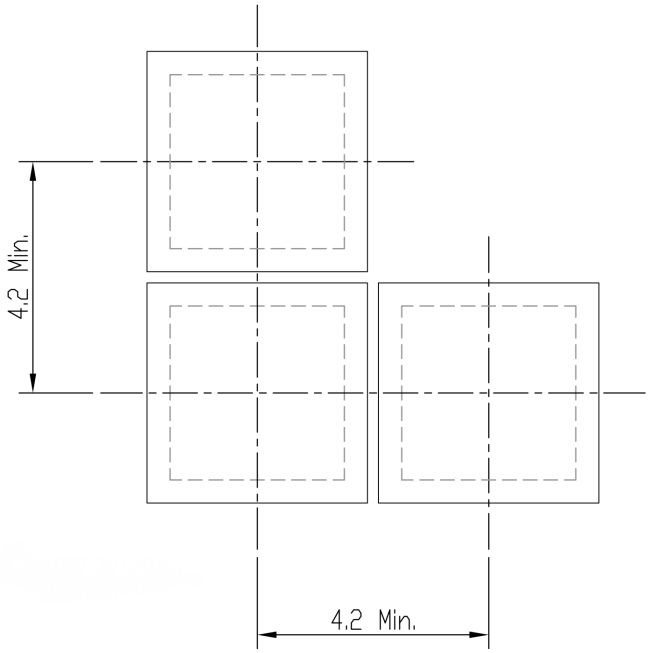
6mm SMT tiling.

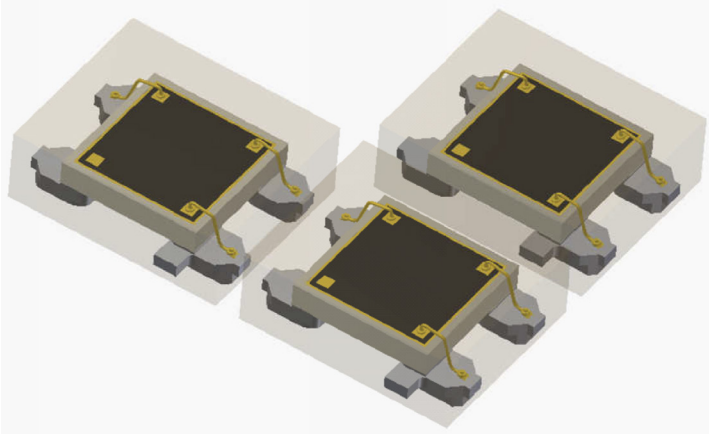


The dead-space between the sensor chip and the edge of the package has been minimized resulting in a package that can be tiled on 4 sides. This allows multiple devices to be configured into unique layouts for a wide range of custom applications. Two-dimensional tiling examples are illustrated for the 1mm, 3mm and 6mm packages. The distance between active areas is typically 1.2mm when tiled, but actual alignment and placement tolerances will depend on the accuracy of the user's assembly process. A Technical Note is available that gives advice on creating arrays of the SMT sensors.

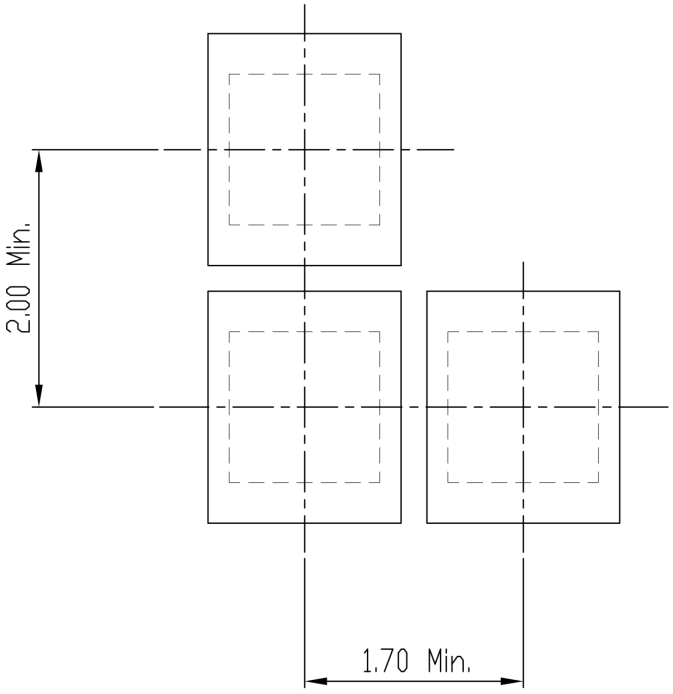


3mm SMT tiling.



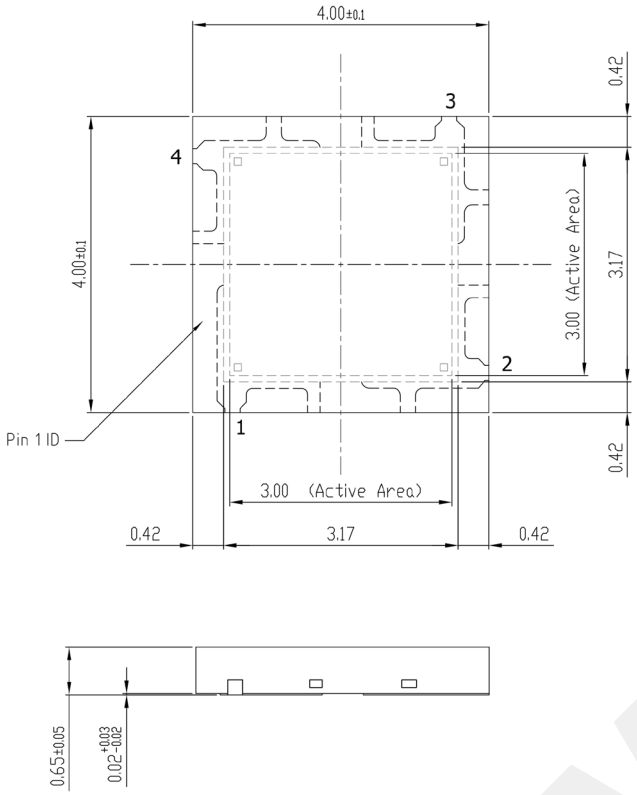


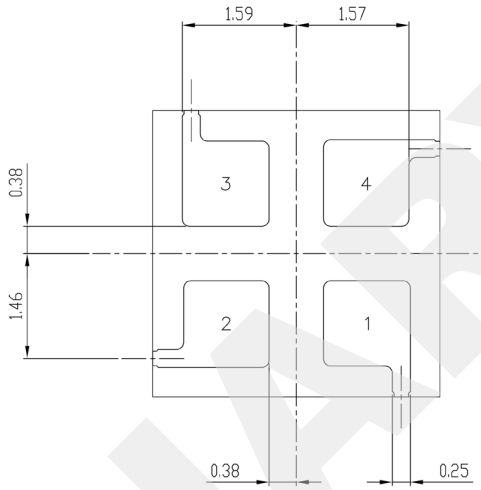
1mm SMT tiling.



SCHEMATICS (All Dimensions in mm)

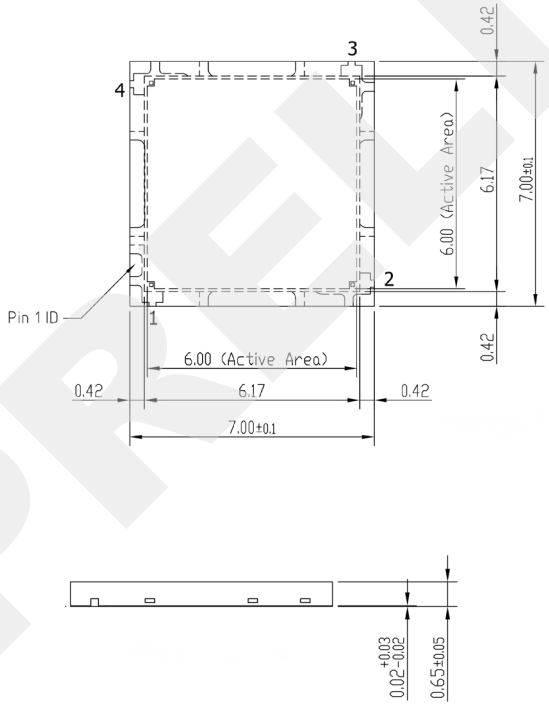
MicroFC 30000 Series SMT Package

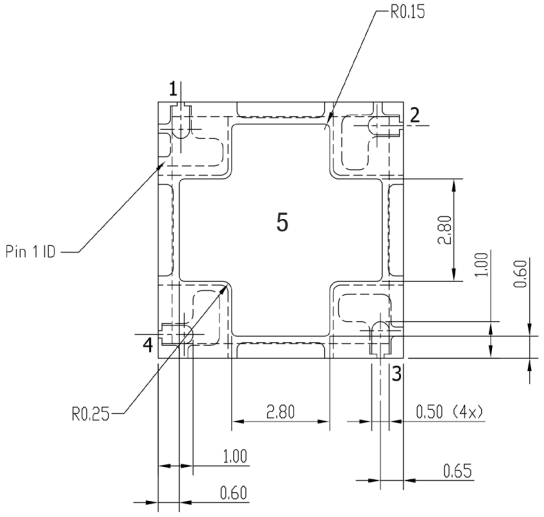




Pin Assignments	
Pin #	C-Series
1	Anode
2	Fast Output
3	Cathode
4	No Connect

MicroFC 60000 Series SMT Package

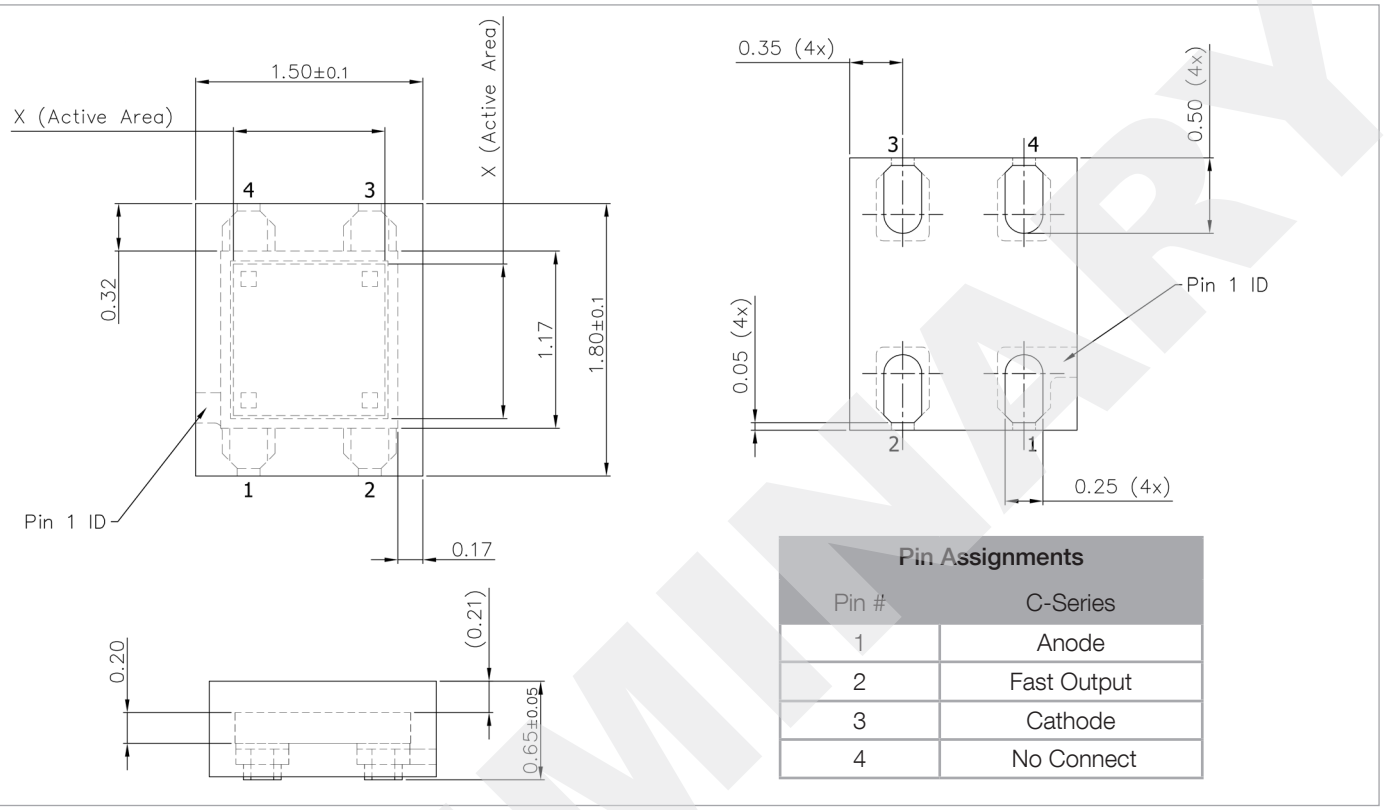




Pin Assignments	
Pin #	C-Series
1	Anode
2	Fast Output
3	Cathode
4, 5	No Connect

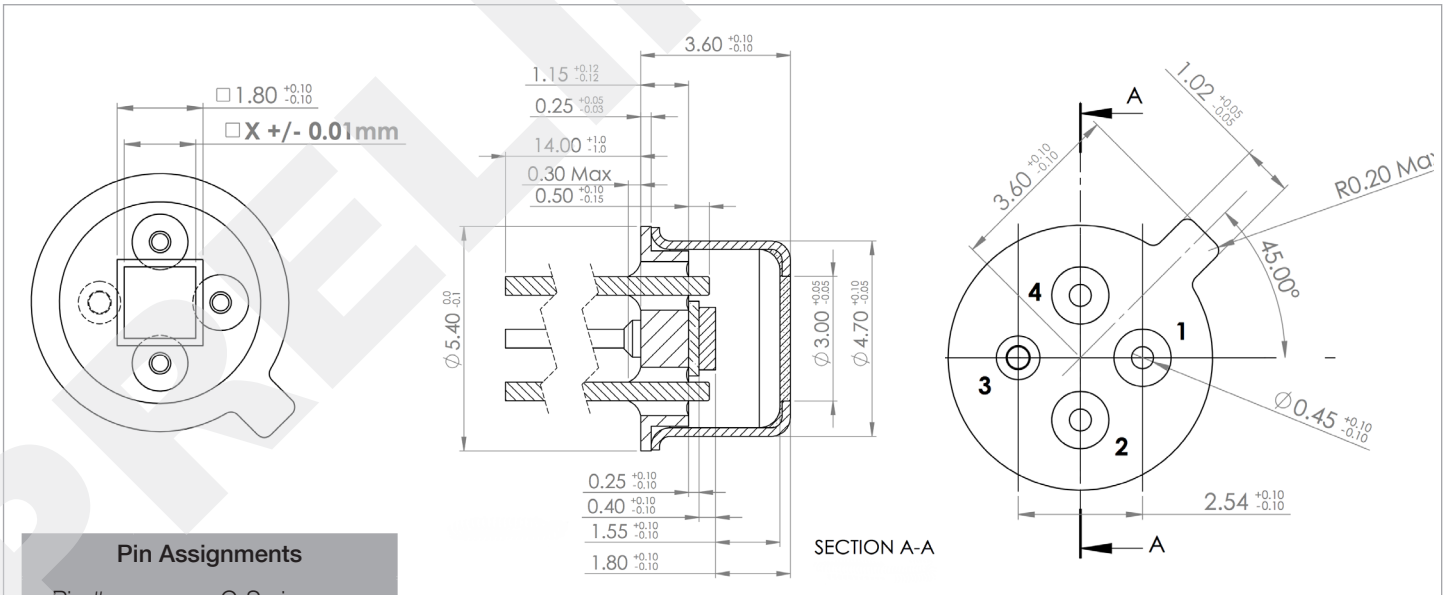
SCHEMATICS (All Dimensions in mm) - Continued

MicroFC 10000 Series SMT Package



Pin Assignments	
Pin #	C-Series
1	Anode
2	Fast Output
3	Cathode
4	No Connect

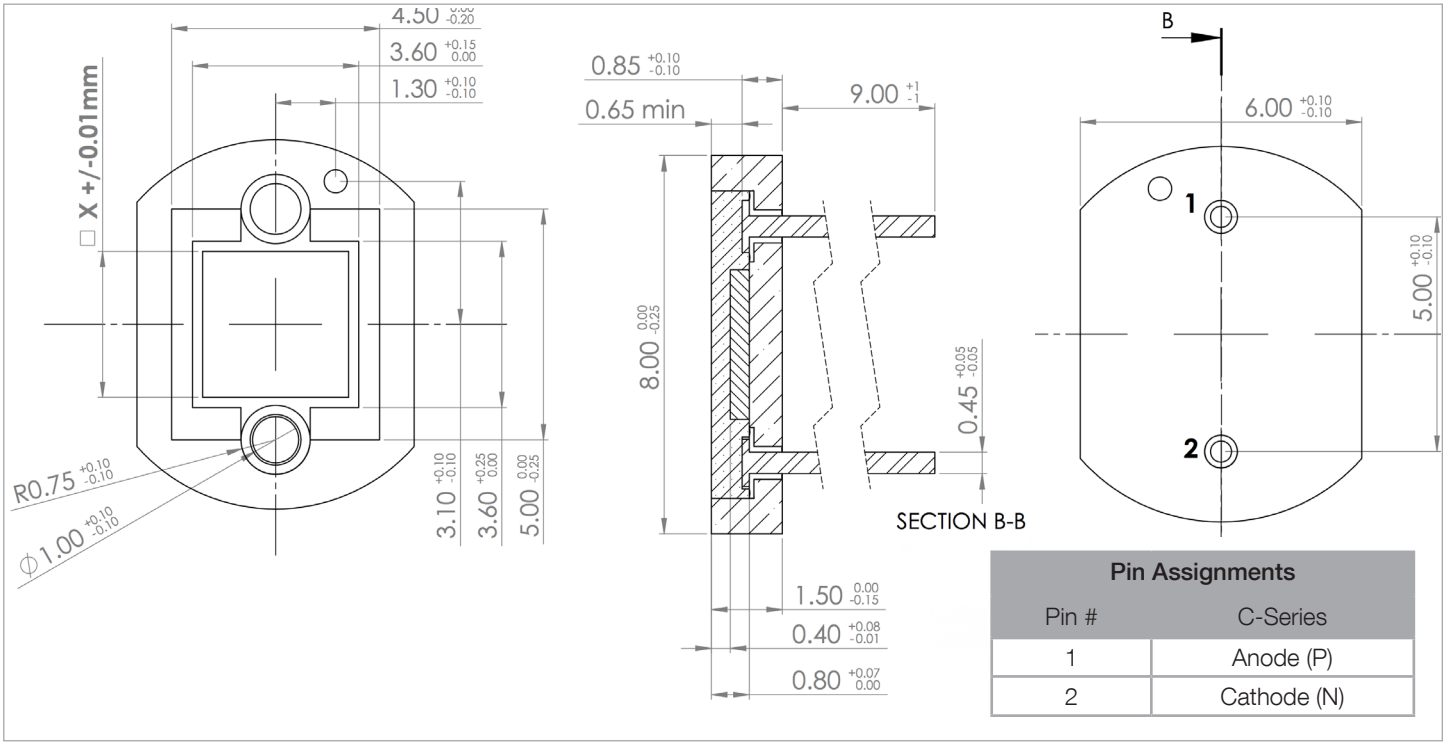
MicroFC 10000 Series TO18 Package



Pin Assignments	
Pin #	C-Series
1	Fast Output
2	Cathode (N)
3	GND
4	Anode (P)

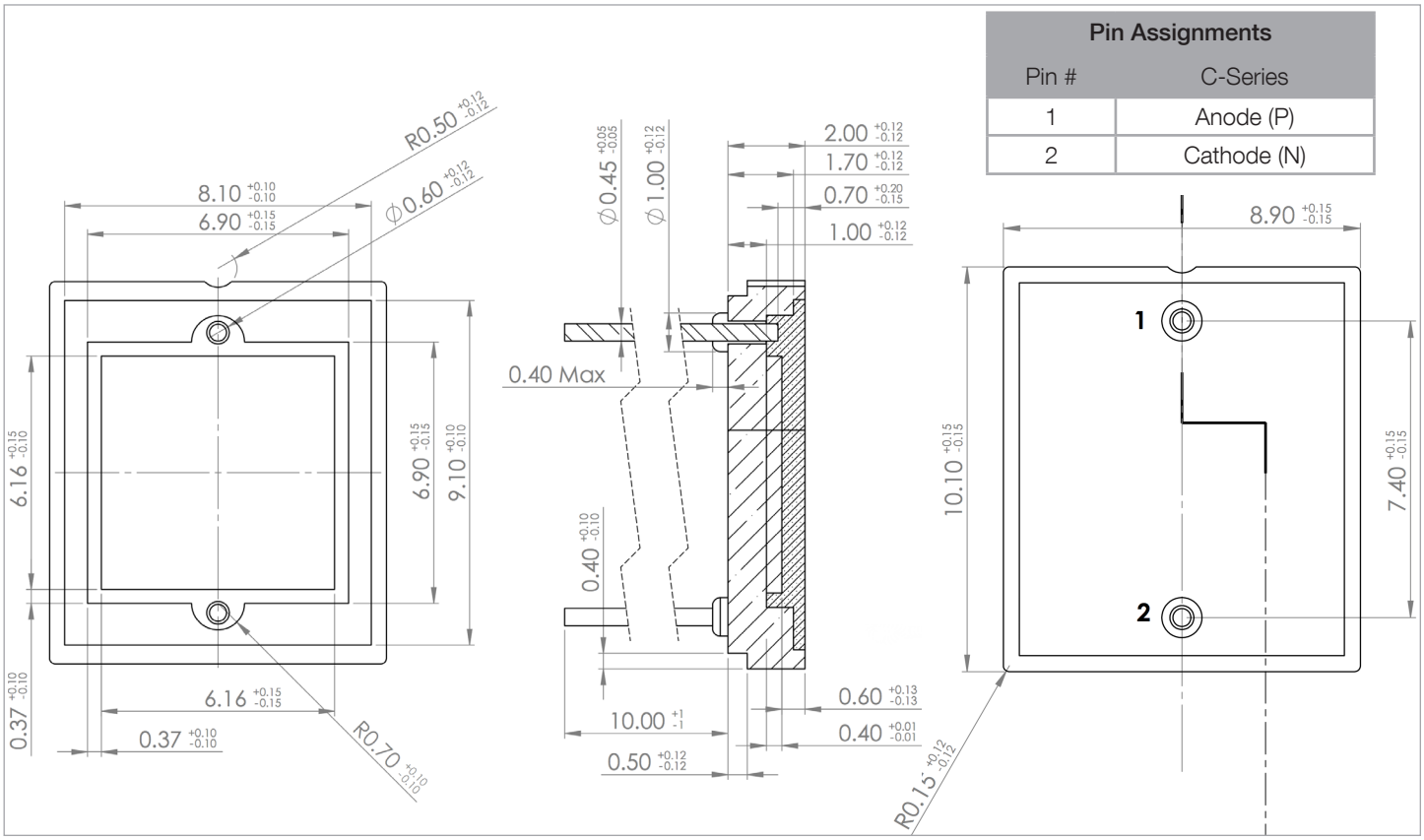
SCHEMATICS (All Dimensions in mm) - Continued

MicroSC 30000 Series X13 Ceramic Package



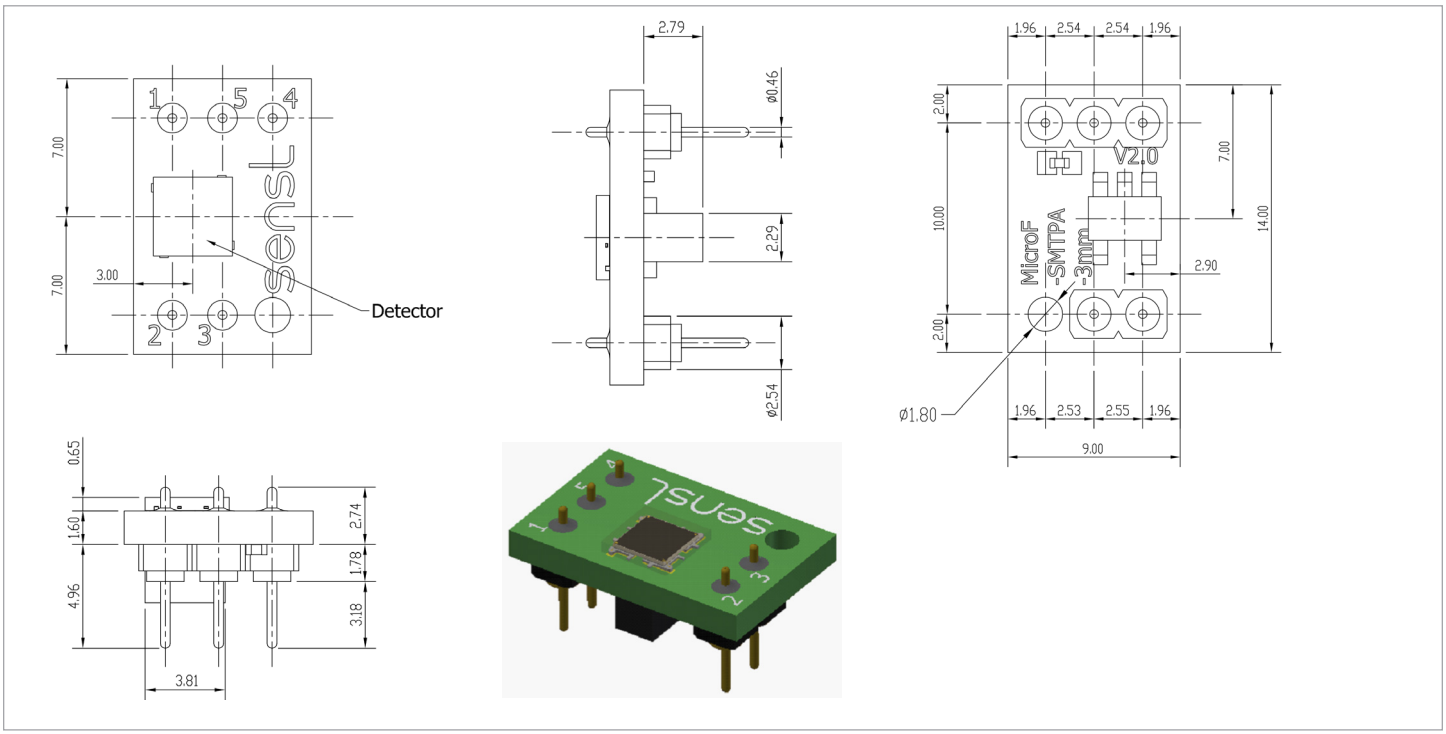
Pin Assignments	
Pin #	C-Series
1	Anode (P)
2	Cathode (N)

MicroSC 60000 Series X13 Ceramic Package

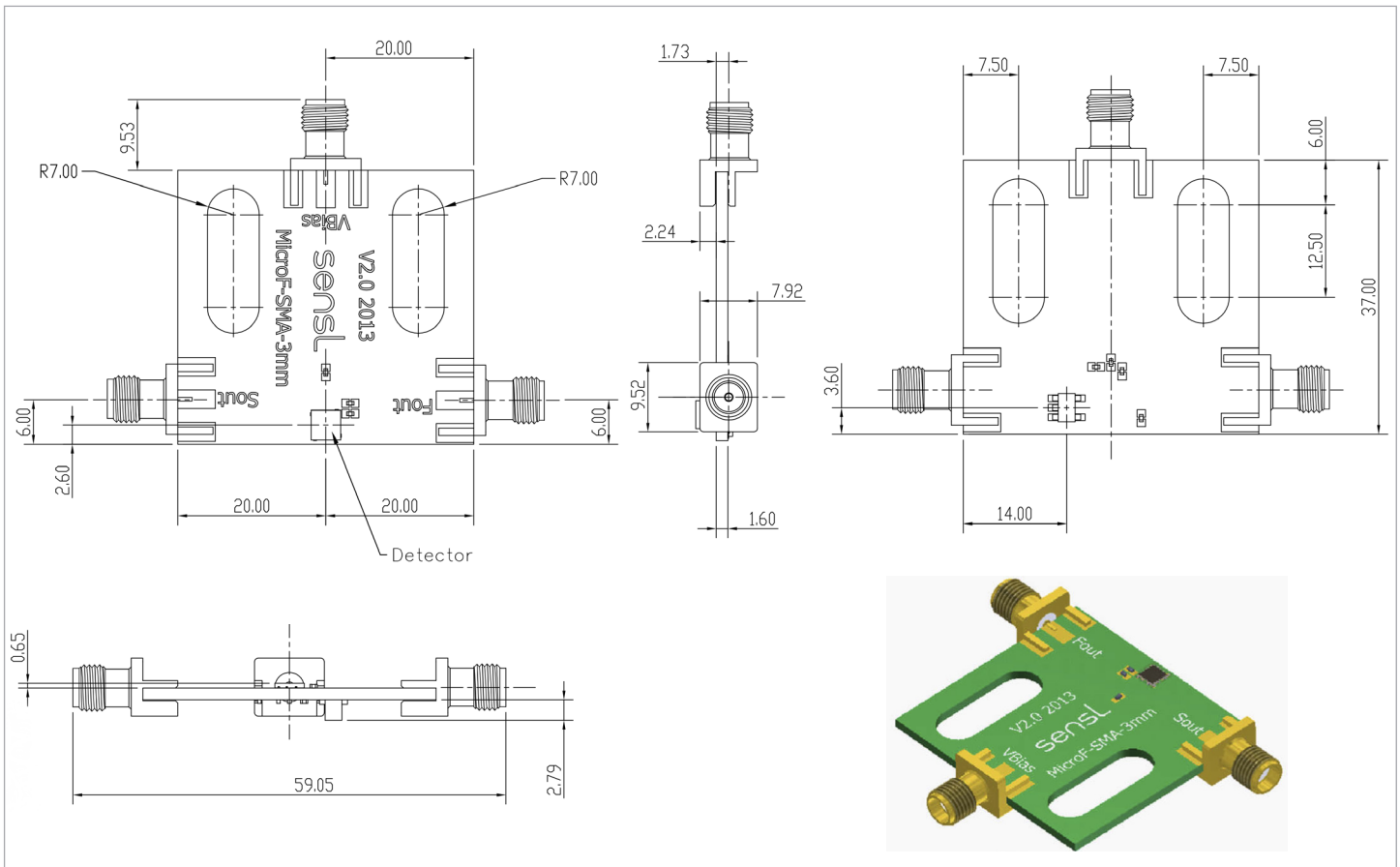


Pin Assignments	
Pin #	C-Series
1	Anode (P)
2	Cathode (N)

MicroFC-SMTPA Board *



MicroFC-SMA Board *



* Schematics shown for 3mm versions. If the schematics for the other sizes are required then please contact support@sensl.com

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)	GP, TA, TR [b]
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-10010-X18			3-pin TO-18 package	PK
MicroFC-10020-SMT	20µm (1296 microcells)		4-side tileable, surface mount package (SMT)	GP, TA, TR [b]
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)	GP, TA, TR [b]
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 [d]			2-pin ceramic package, epoxy fill	PK
MicroFC-10050-SMT	50µm (324 microcells)		4-side tileable, surface mount package (SMT)	GP, TA, TR [b]
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

[a] The two-letter delivery option code should be appended to the order number, e.g) to recieve a MicroFC-60035-SMT in a Gel Pack, use MicroFC-60035-SMT-GP. The codes are as follows:

PK = ESD Package
GP = Gel Pack
WP = Waffle Pack [c]
TA = Tape
TR = Tape and Reel [b]

[b] The TR (Tape and Reel) delivery option has a minimum order quantity (MOQ) of 3000, and is available in multiples thereof.

[c] WP option only available for small quantity orders, please discuss with SensL sales.

[d] NOTE: The 'SC' products have only 2 pins (anode and cathode) and therefore do not feature the fast output signal.

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)	WP [c], TA, TR [b]
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)	WP [c], TA, TR [b]
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 [d]			2-pin ceramic package, epoxy fill	PK
MicroFC-30050-SMT	50µm (2668 microcells)		4-side tileable, surface mount package (SMT)	WP [c], TA, TR [b]
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)	GP, TA, TR [b]
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 [d]			2-pin ceramic package, epoxy fill	PK

[a] The two-letter delivery option code should be appended to the order number, e.g) to recieve a MicroFC-60035-SMT in a Gel Pack, use MicroFC-60035-SMT-GP. The codes are as follows:

PK = ESD Package
GP = Gel Pack
WP = Waffle Pack [c]
TA = Tape
TR = Tape and Reel [b]

[b] The TR (Tape and Reel) delivery option has a minimum order quantity (MOQ) of 3000, and is available in multiples thereof.

[c] WP option only available for small quantity orders, please discuss with SensL sales.

[d] NOTE: The 'SC' products have only 2 pins (anode and cathode) and therefore do not feature the fast output signal.

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