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

# C-Series SiPM Sensors

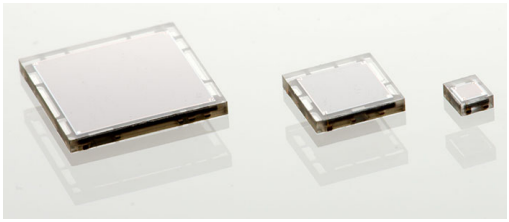


**Figure 1. C−Series Sensors**

**ORDERING INFORMATION**

See detailed ordering and shipping information on page 14 of this data sheet.

The C−Series low-light sensors from **onsemi** 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.

**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 | | $2 \times 10^5$ | | |
| | 20μ | | | | $1 \times 10^6$ | | |
| | 35μ | | | | $3 \times 10^6$ | | |
| 3 mm | 20μ | | | | $1 \times 10^6$ | | |
| | 35μ | | | | $3 \times 10^6$ | | |
| | 50μ | | | | $6 \times 10^6$ | | |
| 6 mm | 35μ | | | | $3 \times 10^6$ | | |
| 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 ($\tau$)
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 | $1 \times 1$ mm$^2$ | $3 \times 3$ mm$^2$ | $6 \times 6$ mm$^2$ |
| No. of microcells | 10010: 2880<br>10020: 1296<br>10035: 504 | 30020: 10998<br>30035: 4774<br>30050: 2668 | 60035: 18980 |
| Microcell fill factor | 10010: 28%<br>10020: 48%<br>10035: 64% | 30020: 48%<br>30035: 64%<br>30050: 72% | 60035: 64% |

**Table 3. PACKAGE PARAMETERS**

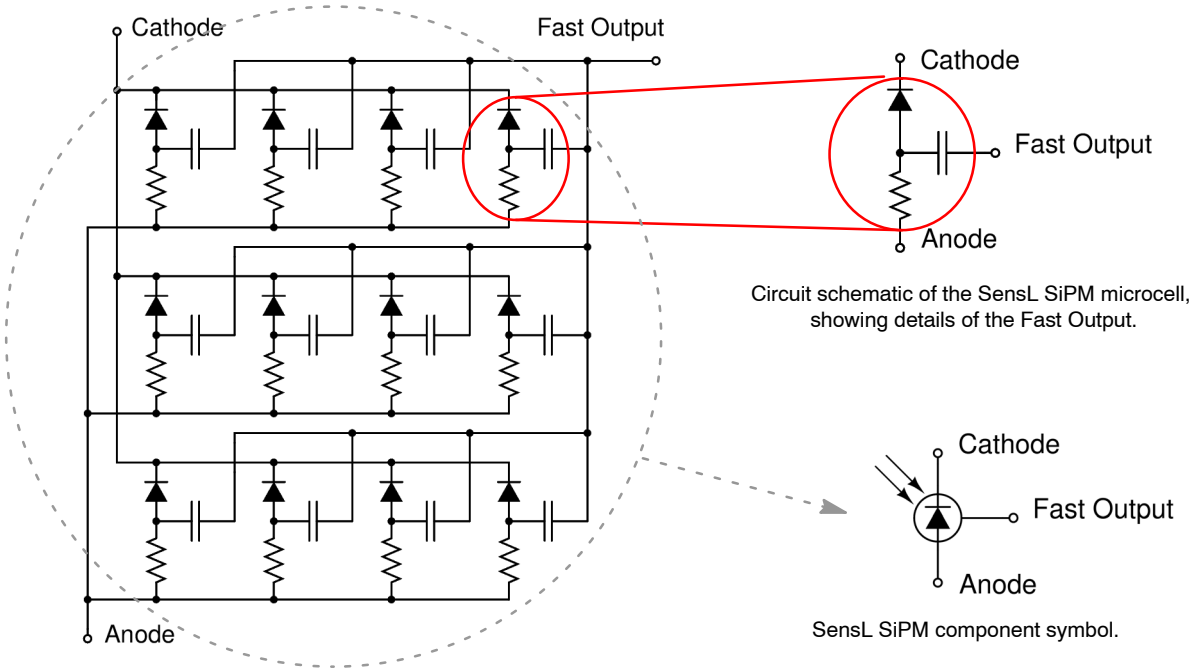
| | 1 mm | 3 mm | 6 mm |
|---|---|---|---|
| | **10010, 10020, 10035** | **30020, 30035, 30050** | **60035** |
| Package dimensions | $1.5 \times 1.8$ mm$^2$ | $4 \times 4$ mm$^2$ | $7 \times 7$ mm$^2$ |
| Recommended operating temperature range | −40°C to +85°C | | |
| Maximum storage temperature | +105°C | | |
| Soldering conditions | Lead−free, reflow soldering process compatible<br>(MSL 3 for tape & reel quantities; MSL 4 for tape only qty.)<br>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

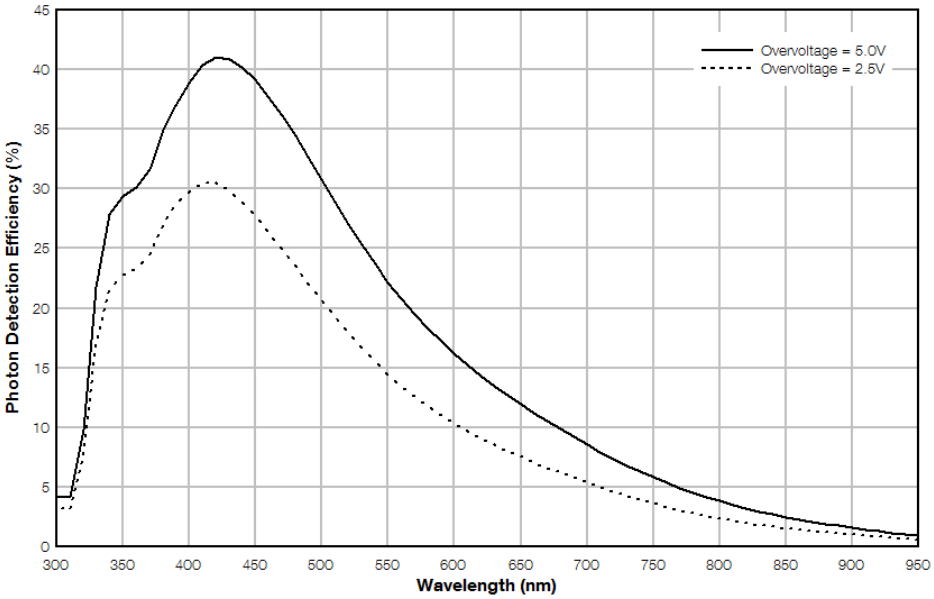



**Figure 3. PDE versus Wavelength**
(MicroFC−30035−SMT)

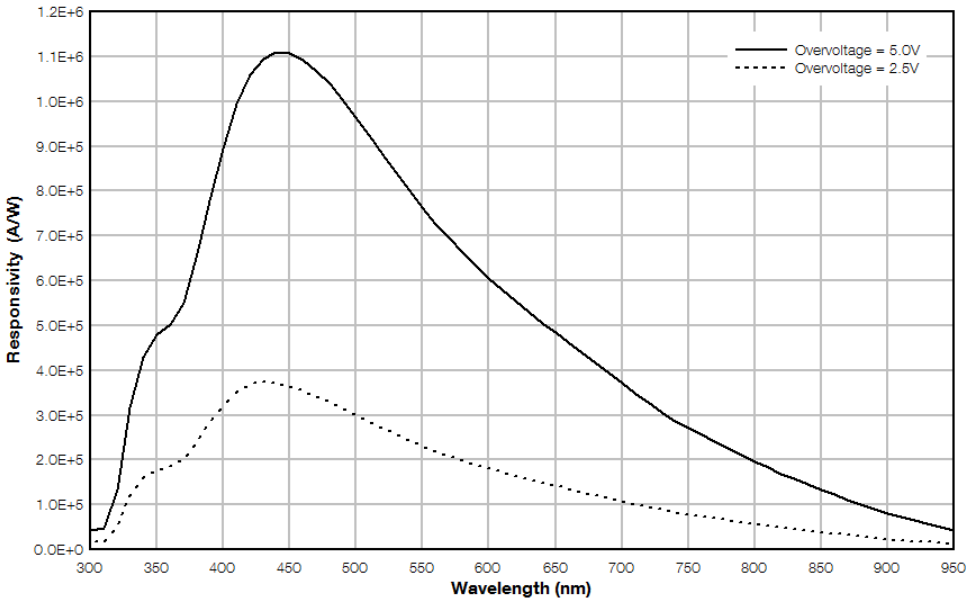



**Figure 4. Responsivity versus Wavelength**
(MicroFC−30035−SMT)

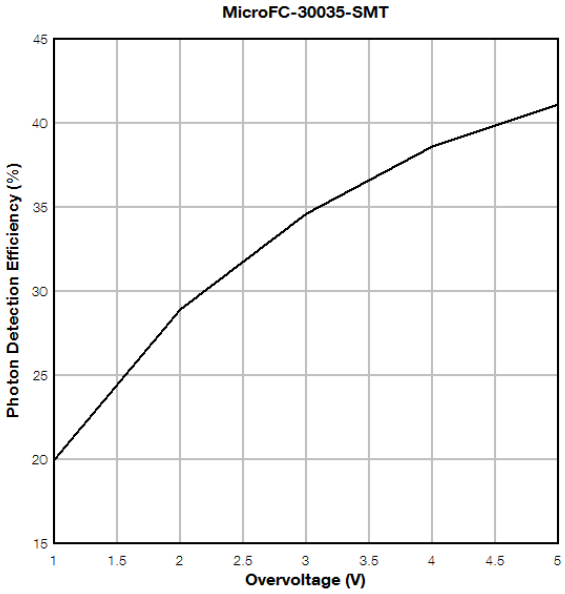



**Figure 5. PDE at 420 nm versus Voltage**

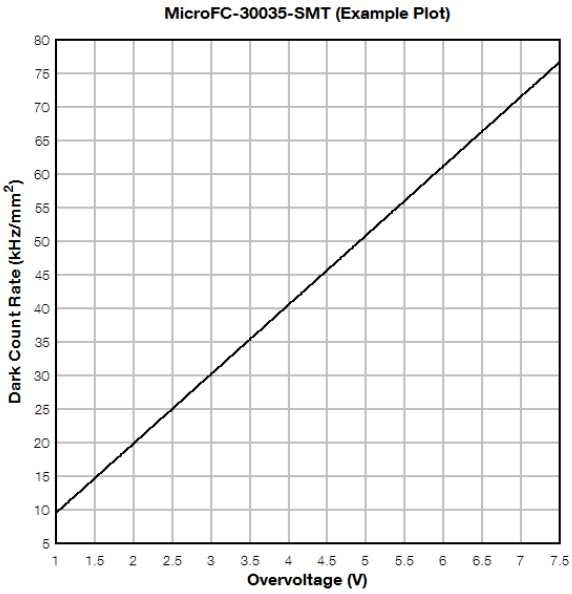



**Figure 6. Dark Count Rate versus Overvoltage**

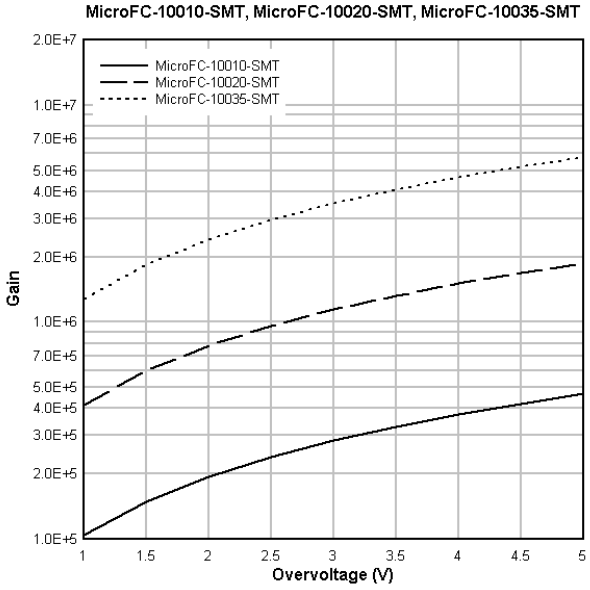



**Figure 7. Gain versus Overvoltage**

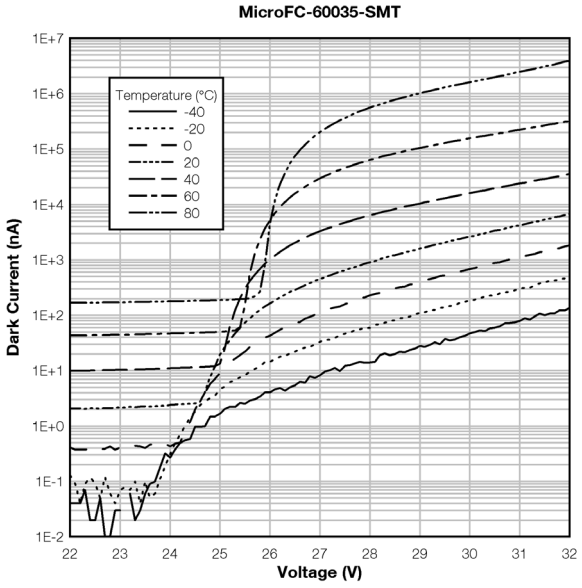



**Figure 8. Dark Current versus Voltage and Temperature**

## 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 AND9809/D.

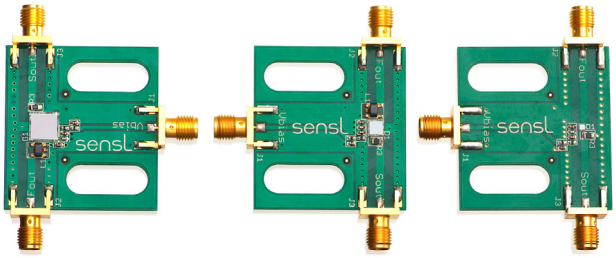


**Figure 9. SMA Biasing Board**

| 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 AND9809/D.



**Figure 10. Pin Adapter**

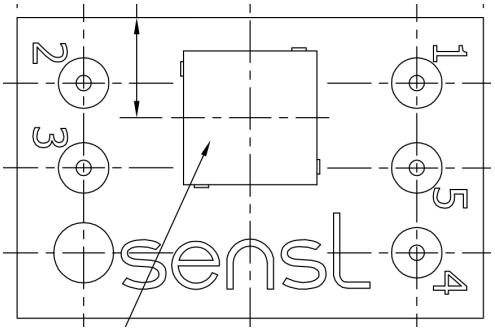


**Figure 11. MicroFC−SMTPA−XXXXX**

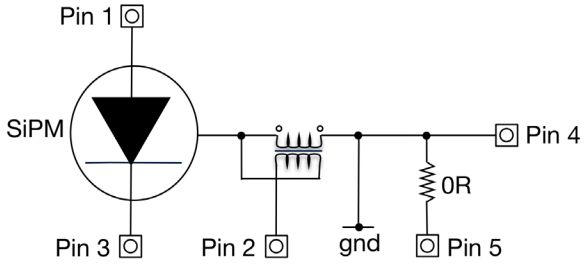


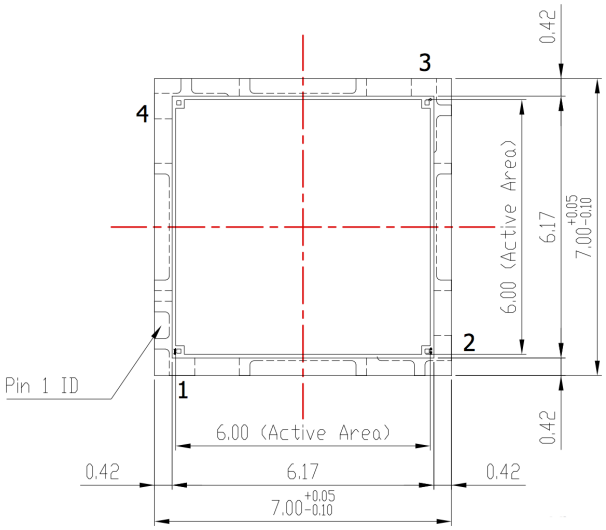

**Figure 12. SMTPA Board Circuit Schematic**

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

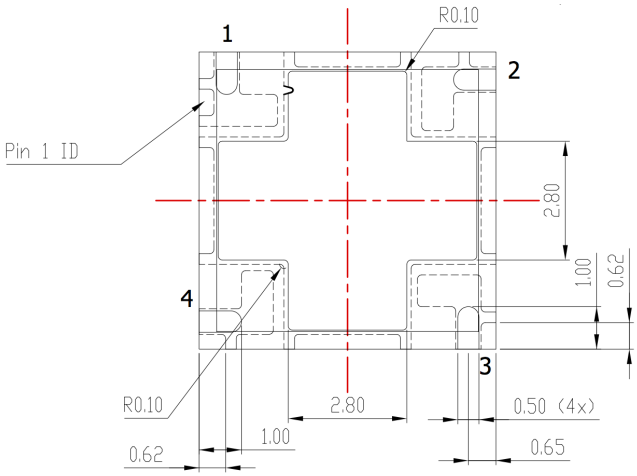
## PACKAGE DIMENSIONS

(All Dimensions in mm)

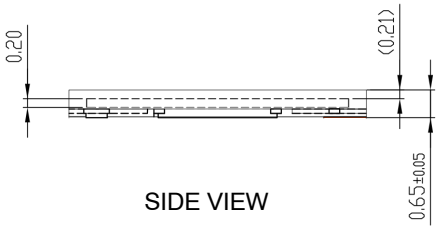
**MicroFC−60035−SMT**




TOP VIEW




BOTTOM VIEW




SIDE VIEW

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

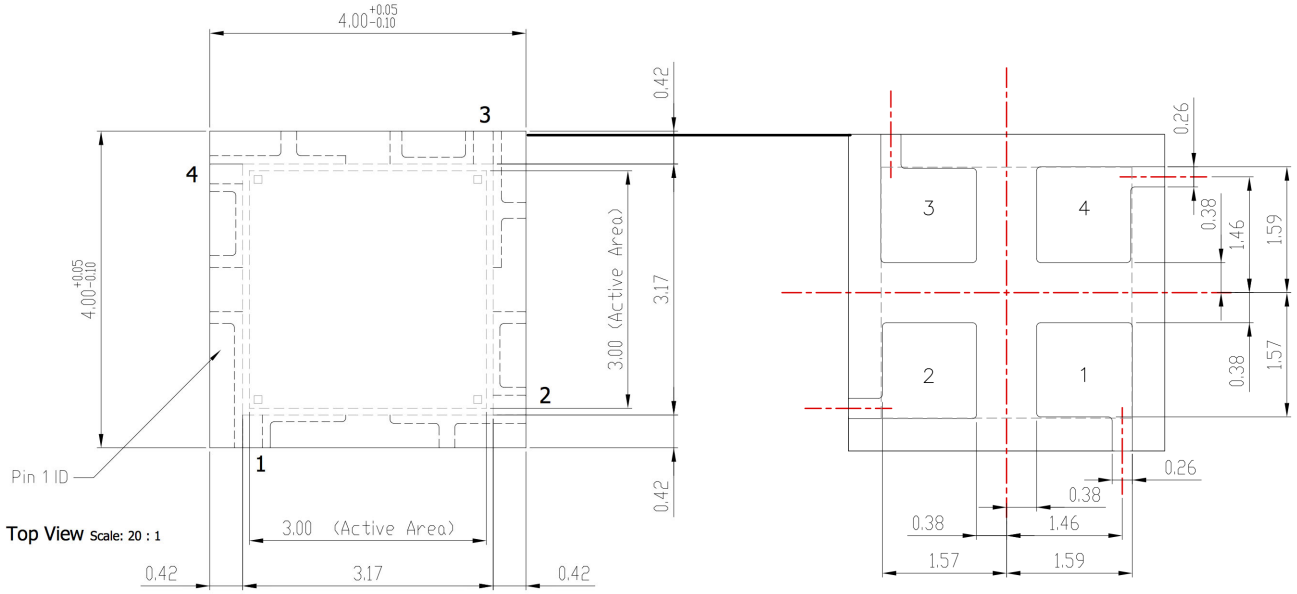
*The ‘No Connect’ pin 4 should be soldered to the PCB. This pin can be connected to ground but it can also be left floating without affecting the dark noise. It is recommended that the Pin 5 paddle is NOT soldered to the PCB and is left floating to achieve optimal soldering on pins 1 to 4. Please note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

The complete MicroFC−60035−SMT POD is available to download here.

## PACKAGE DIMENSIONS

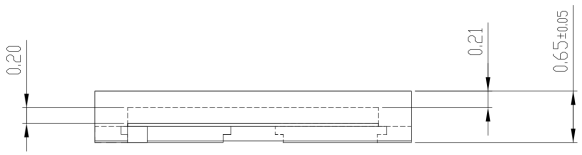
(All Dimensions in mm)

**MicroFC−30020−SMT, MicroFC−30035−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* |

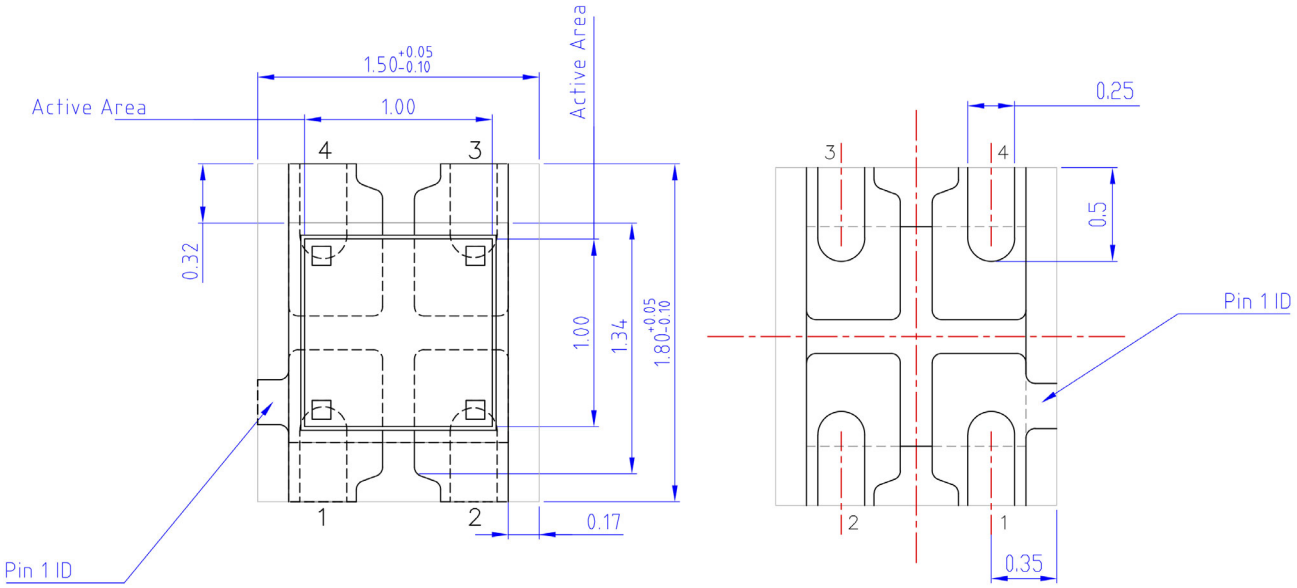
*The ‘No Connect’ pin 4 should be soldered to the PCB. It can be connected to ground but it can also be left floating without affecting the dark noise.

The complete MicroFC−300xx−SMT POD is available to download here.

## PACKAGE DIMENSIONS

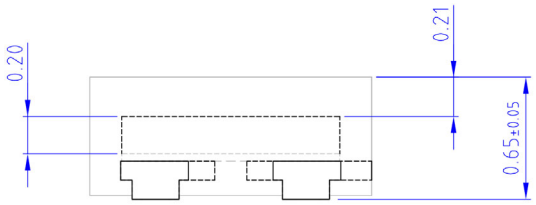
(All Dimensions in mm)

**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* |

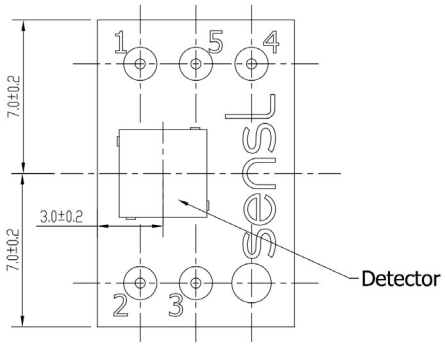
*The ‘No Connect’ pin 4 should be soldered to the PCB. It can be connected to ground but it can also be left floating without affecting the dark noise.

The complete MicroFC−100XX−SMT POD is available to download here.

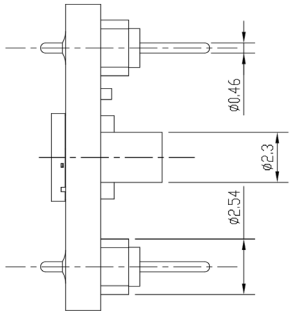
## PACKAGE DIMENSIONS

(All Dimensions in mm)

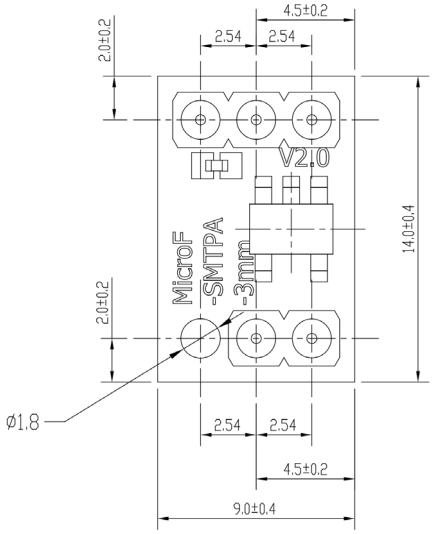
### MicroFC−SMTPA Board




TOP VIEW



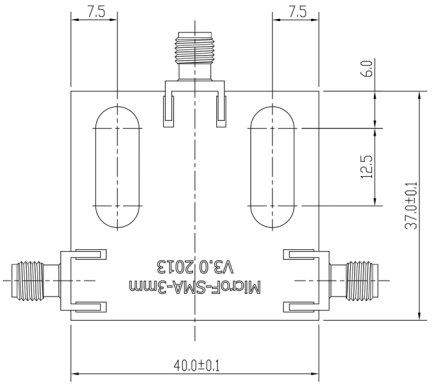

SIDE VIEW



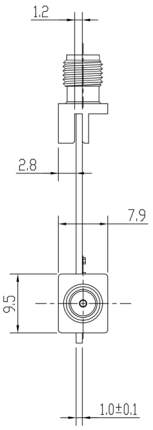

BOTTOM VIEW

The electrical schematics for the SMTPA board is available in AND9809/D.

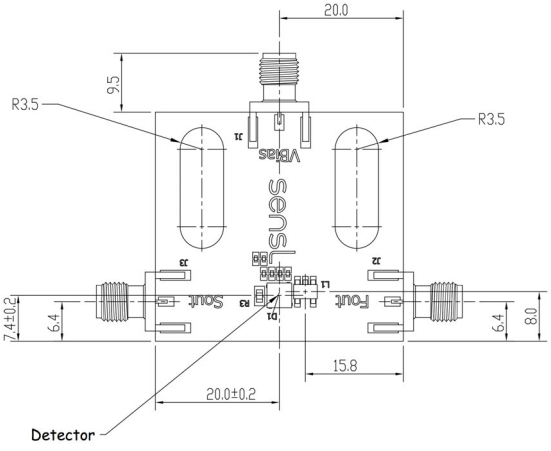
### MicroFC−SMA Board




BOTTOM VIEW




SIDE VIEW




TOP VIEW

The electrical schematics for the SMA board is available in AND9809/D.

## 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.

## 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−GEVB | | | SMT sensor mounted onto a PCB with SMA connectors for bias and output. | PK |
| MICROFC−SMTPA−10010−GEVB | | | 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−GEVB | | | SMT sensor mounted onto a PCB with SMA connectors for bias and output. | PK |
| MICROFC−SMTPA−10020−GEVB | | | SMT sensor mounted onto a pin adapter board. | PK |
| MICROFC−10035−SMT | 35 μm (504 microcells) | | 4-side tileable, surface mount package (SMT) | TR1, TR |
| MICROFC−SMA−10035−GEVB | | | SMT sensor mounted onto a PCB with SMA connectors for bias and output. | PK |
| MICROFC−SMTPA−10035−GEVB | | | 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−GEVB | | | SMT sensor mounted onto a PCB with SMA connectors for bias and output. | PK |
| MICROFC−SMTPA−30020−GEVB | | | 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−GEVB | | | SMT sensor mounted onto a PCB with SMA connectors for bias and output. | PK |
| MICROFC−SMTPA−30035−GEVB | | | 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−GEVB | | | SMT sensor mounted onto a PCB with SMA connectors for bias and output. | PK |
| MICROFC−SMTPA−30050−GEVB | | | 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−GEVB | | | SMT sensor mounted onto a PCB with SMA connectors for bias and output. | PK |
| MICROFC−SMTPA−60035−GEVB | | | 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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