

Silicon Photomultipliers (SiPM), High PDE and Timing Resolution Sensors in a TSV Package



J-Series SiPM Sensors

onsemi's J-Series low-light sensors feature a high PDE (photon detection efficiency) that is achieved using a high-volume, P-on-N silicon foundry process. The J-Series sensors incorporate major improvements in the transit time spread which results in a significant improvement in the timing performance of the sensor. J-Series sensors are available in different sizes (3 mm, 4 mm and 6 mm) and use a TSV (Through Silicon Via) process to create a package with minimal deadspace, that is compatible with industry standard lead-free, reflow soldering processes.

The J-Series Silicon Photomultipliers (SiPM) combine high performance with 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 J-Series sensors please refer to the [website](#).

ORDERING INFORMATION

See detailed ordering and shipping information on page 11 of this data sheet.

Table 1. GENERAL PARAMETERS

| Parameter (Note 1) | Minimum | Typical | Maximum | Unit |
|-------------------------------------|---------|---------|---------|-------|
| Breakdown Voltage (Vbr) (Note 2) | 24.2 | | 24.7 | V |
| Overvoltage (OV) | 1 | | 6 | V |
| Operating Voltage (Vop = Vbr + OV) | 25.2 | | 30.7 | V |
| Spectral Range (Note 3) | 200 | | 900 | nm |
| Peak PDE Wavelength (λ_p) | | 420 | | nm |
| Temperature dependence of Vbr | | 21.5 | | mV/°C |

- All measurements made at 21°C unless otherwise stated.
- 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.
- The range where PDE > 2.0% at Vbr + 6.0 V.

Table 2. PHYSICAL PARAMETERS

| Parameter | 3 mm | 4 mm | 6 mm |
|-----------------------|-------------------------------|-----------------------------|-----------------------------|
| | 30020, 30035 | 40035 | 60035 |
| Active Area | 3.07 × 3.07 mm ² | 3.93 × 3.93 mm ² | 6.07 × 6.07 mm ² |
| No. of Microcells | 30020: 14,410 30035: 5,676 | 40035: 9,260 | 60035: 22,292 |
| Microcell Fill Factor | 30020: 62% 30035: 75% | 40035: 75% | 60035: 75% |

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Table 3. PERFORMANCE PARAMETERS

| Parameter (Note 4) | 30035 | | 40035 | | 60035 | | Unit |
|---|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|---------------------|
| | Overvoltage | | | | | | Unit |
| | +2.5 V | +6 V | +2.5 V | +6 V | +2.5 V | +6 V | |
| PDE (Note 5) | 38 | 50 | 38 | 50 | 38 | 50 | % |
| Dark Count Rate | 50 | 150 | 50 | 150 | 50 | 150 | kHz/mm ² |
| Gain (anode-cathode) | 2.9×10^6 | 6.3×10^6 | 2.9×10^6 | 6.3×10^6 | 2.9×10^6 | 6.3×10^6 | |
| Dark Current – typical | 0.23 | 1.9 | 0.35 | 3.0 | 0.9 | 7.5 | μA |
| Dark Current – maximum | 0.31 | 3.00 | 0.45 | 4.0 | 1.25 | 12.0 | |
| Rise Time (Note 6) – anode-cathode output | 90 | 110 | 90 | 110 | 180 | 250 | ps |
| Microcell Recharge Time Constant (Note 7) | 45 | | 48 | | 50 | | ns |
| Capacitance (Note 8) (anode output) | 1070 | | 1800 | | 4140 | | pF |
| Capacitance (Note 8) (fast output) | 40 | | 70 | | 160 | | pF |
| Fast Output Pulse Width (FWHM) | 1.5 | | 1.7 | | 3.0 | | ns |
| Crosstalk | 8 | 25 | 8 | 25 | 8 | 25 | % |
| Afterpulsing | 0.75 | 5.0 | 0.75 | 5.0 | 0.75 | 5.0 | % |
| Parameter (Note 4) | 30020 | | | | | | Unit |
| | Overvoltage | | | | | | |
| | +2.5 V | | | +5 V | | | |
| PDE (Note 5) | 30 | | | 38 | | | % |
| Dark Count Rate | 50 | | | 125 | | | kHz/mm ² |
| Gain (anode-cathode) | 1.0×10^6 | | | 1.9×10^6 | | | |
| Dark Current – typical | 0.1 | | | 0.45 | | | μA |
| Dark Current – maximum | 0.2 | | | 0.72 | | | |
| Rise Time (Note 6) – anode-cathode output | 130 | | | 160 | | | ps |
| Microcell Recharge Time Constant (Note 7) | 15 | | | | | | ns |
| Capacitance (Note 8) (anode output) | 1040 | | | | | | pF |
| Capacitance (Note 8) (fast output) | 50 | | | | | | pF |
| Fast Output Pulse Width (FWHM) | 1.4 | | | | | | ns |
| Crosstalk | 2.5 | | | 7.5 | | | % |
| Afterpulsing | 0.75 | | | 5.0 | | | % |

4. All measurements made at 21°C unless otherwise stated.

5. PDE does not contain afterpulsing or crosstalk, and is quoted at the peak wavelength (λ_p).

6. Measured as time to go from 10% to 90% of the peak amplitude and measured over a 1 Ω series output resistor.

7. RC charging time constant of the microcell (τ).

8. Capacitance values are for the complete TSV package.

Table 4. TVS PACKAGE SPECIFICS

| | 3 mm | | 4 mm | | 6 mm | |
|---|-----------------------------|--|-----------------------------|--|-----------------------------|--|
| | 30020, 30035 | | 40035 | | 60035 | |
| Package Dimensions | 3.16 × 3.16 mm ² | | 4.00 × 4.00 mm ² | | 6.13 × 6.13 mm ² | |
| Recommended Operating Temperature Range | –40°C – +85°C | | | | | |
| Soldering Conditions | Reflow Solder | | | | | |
| Cover Material | Glass | | | | | |
| Cover Refractive Index | 1.53 @ 436 nm | | | | | |
| Moisture Sensitivity Level | Tape & reel | | MSL3* | | | |
| | Cut tape | | MSL4* | | | |
| Maximum Average Current | 10 mA | | 10 mA | | 15 mA | |

*Please refer to the [TSV Handling and Soldering](#) guide for more information on MSL for different delivery options.

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PERFORMANCE PLOTS

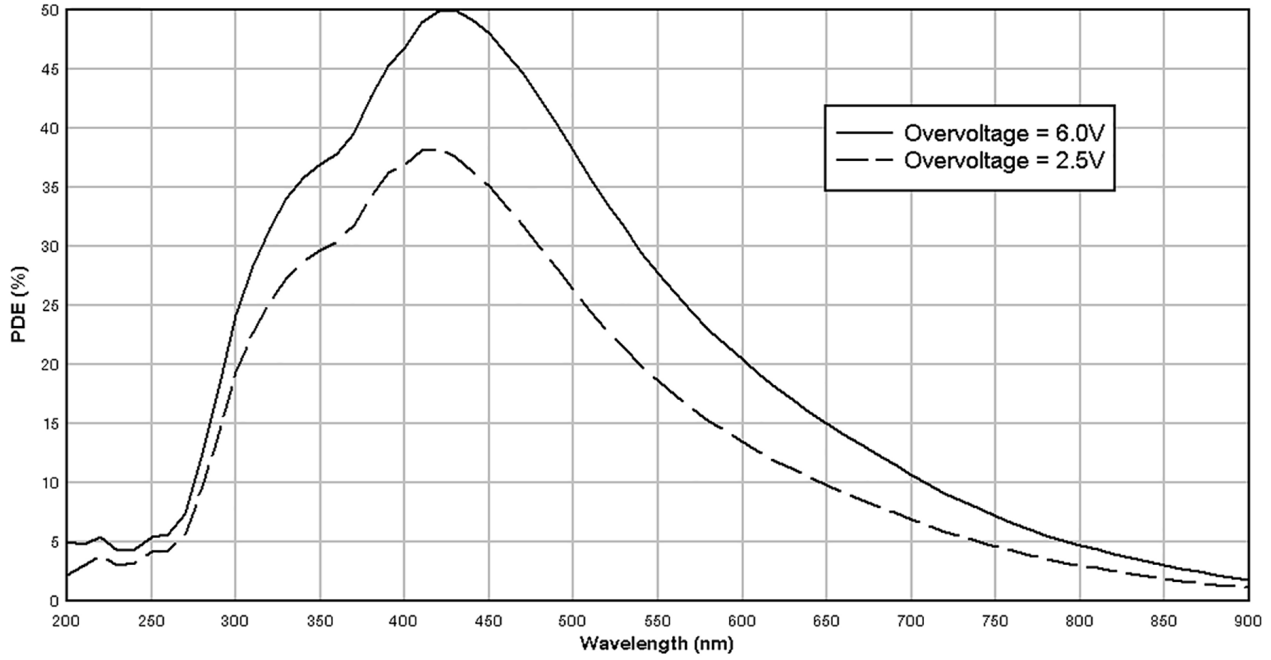


Figure 1. Photon Detection Efficiency (PDE)
(MicroFJ-60035-TSV)

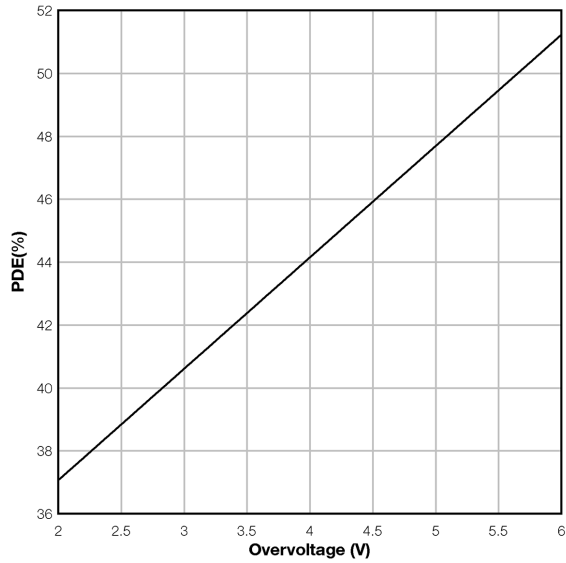


Figure 2. PDE vs. Overvoltage
(MicroFJ-60035-TSV)

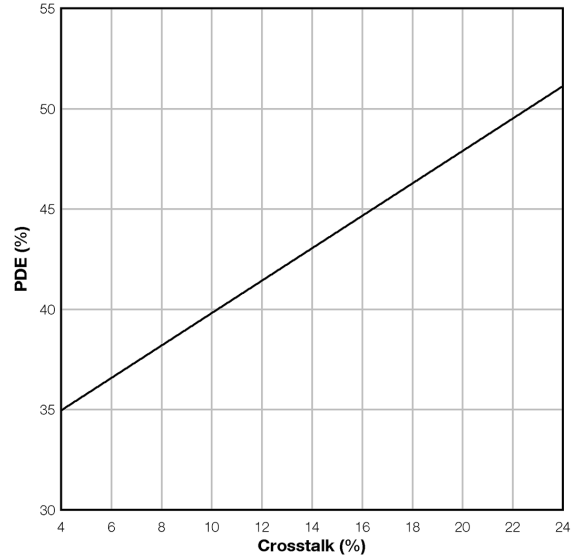


Figure 3. PDE vs. Crosstalk
(MicroFJ-60035-TSV)

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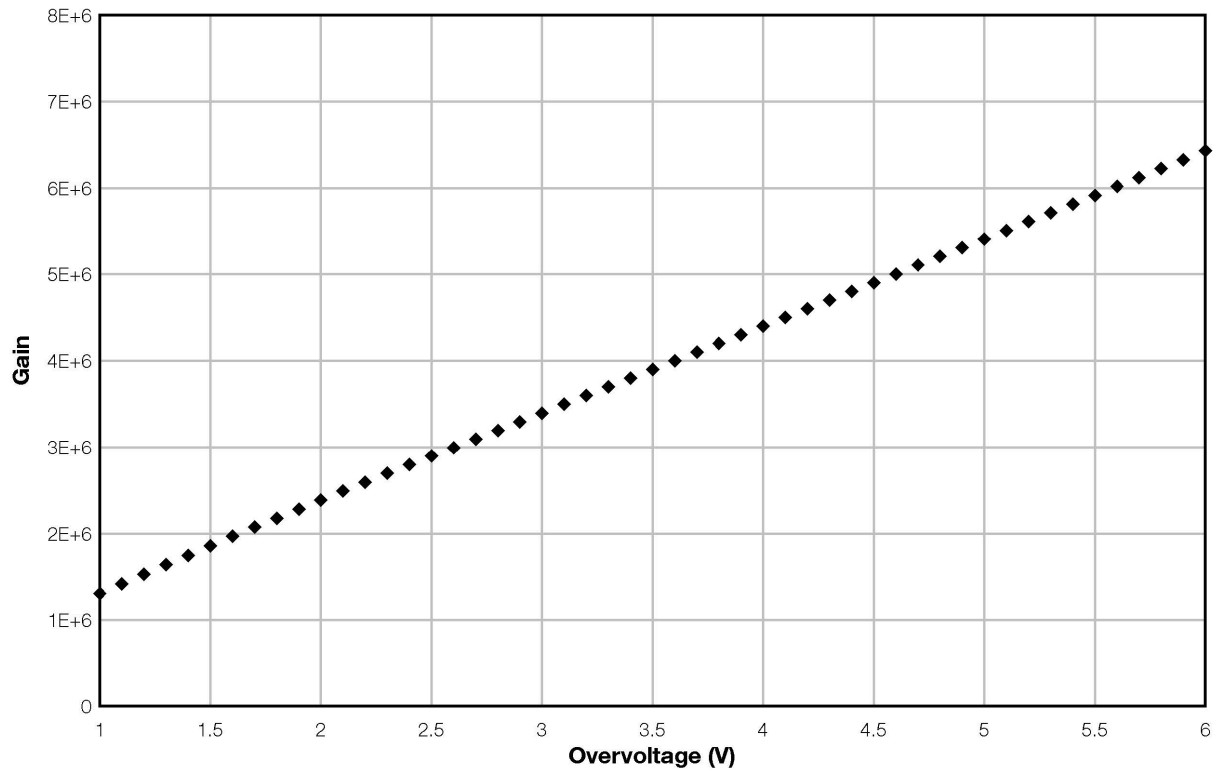


Figure 4. Gain vs. Overvoltage
(MicroFJ-30035-TSV)

MicroFJ-30035, MicroFJ-40035, MicroFJ-60035
Vbr + 2.5 V, 10 Ω Sense Resistor

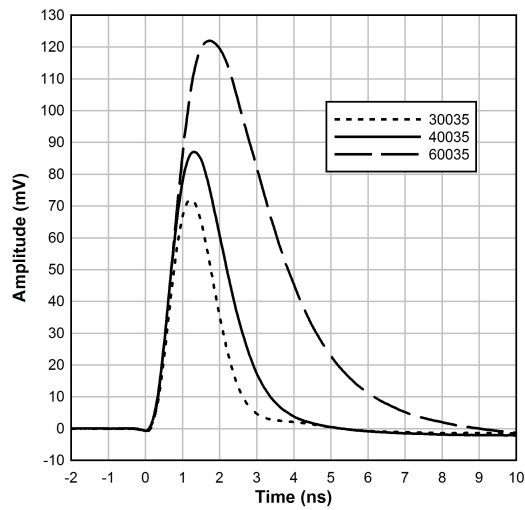


Figure 5. Fast Output Pulse Shape
(MicroFJ-30035, MicroFJ-40035, MicroFJ-60035)
Vbr + 2.5 V, 10 Ω Sense Resistor

MicroFJ-30035, MicroFJ-40035, MicroFJ-60035
Vbr + 2.5 V, 10 Ω Series Resistor

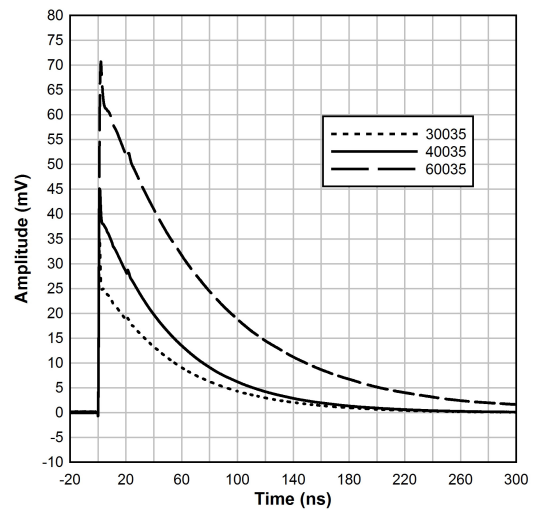


Figure 6. Standard Output Pulse Shape
(MicroFJ-30035, MicroFJ-40035, MicroFJ-60035)
Vbr + 2.5 V, 10 Ω Series Resistor

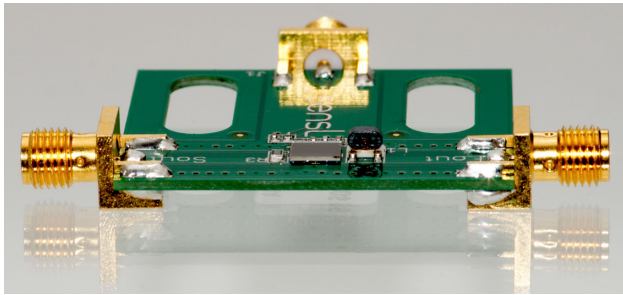
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EVALUATION BOARD OPTIONS

SMA BIASING BOARD (MicroFJ-SMA-XXXXX)

The MicroFJ-SMA is a printed circuit board (PCB) that can facilitate the evaluation of the J-Series 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 MicroFJ-SMA is recommended for users who require a plug-and-play set-up to quickly evaluate J-Series TSV 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 [AND9808/D](#) document.



| MicroFJ-SMA-XXXXX | |
|-------------------|-------------------------------|
| Output | Function |
| Vbias | Positive bias input (cathode) |
| Fout | Fast output |
| Sout | Standard output (anode) |

PIN ADAPTER (MicroFJ-SMTPA-XXXXX)

The TSV Pin Adapter board (SMTPA) is a small PCB board that houses the TSV 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 TSV 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 MicroFJ-SMA-XXXXX is recommended. The SMTPA

circuit schematic is shown in Figure 8. Please consult the [Readout and Biasing Application Note](#) for further information on biasing. The SMTPA board electrical schematics are available to download in the [AND9808/D](#).

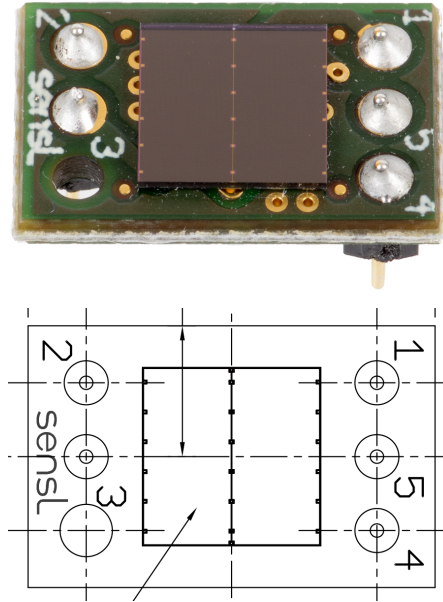


Figure 7. Top View of the SMTPA Board Showing the Pin Numbering

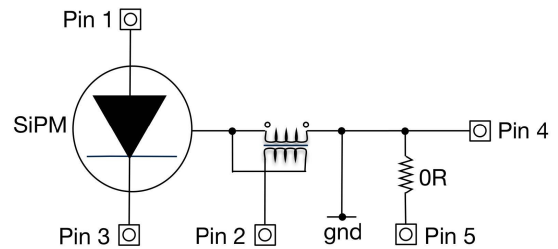


Figure 8. SMTPA Circuit Schematic

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

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CIRCUIT SCHEMATICS

An SiPM is formed of a large number (hundreds or thousands) of microcells. Each microcell (Figure 9) 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 (Figure 10). The array of microcells can thus be considered as a single photodiode sensor with three terminals: anode, cathode and fast output, as shown in Figure 11.

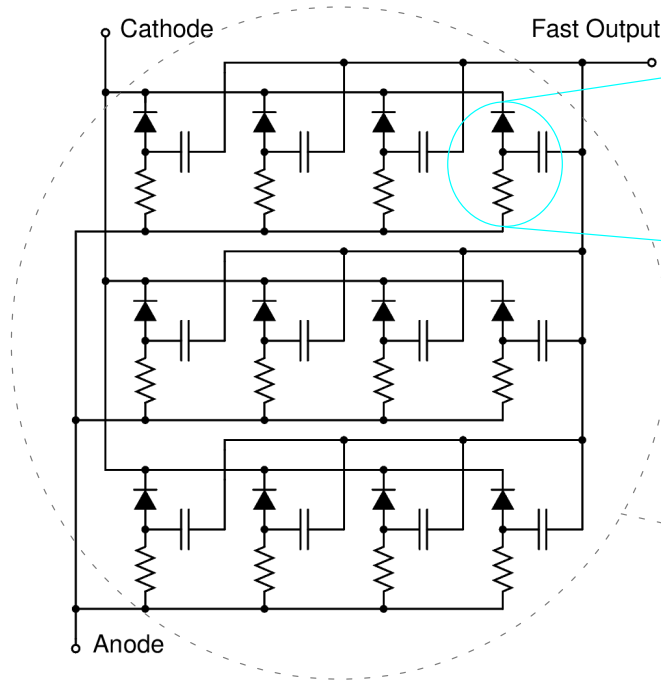


Figure 10. Simplified Circuit Schematic of the onsemi SiPM showing only a 12 Microcell Example. Typically, SiPM Sensors have Hundreds or Thousands of Microcells

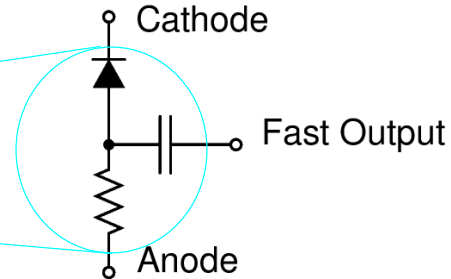


Figure 9. Circuit Schematic of the onsemi SiPM Microcell, showing Details of the Fast Output

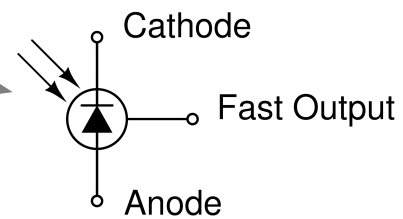


Figure 11. onsemi SiPM Component Symbol

TILING OF THE TSV PACKAGE

For the J-Series, **onsemi** has developed a market-leading, high-performance package using a TSV process. It is a chip-scale package that is compatible with lead-free, reflow soldering processes. The glass cover is ideal for coupling to scintillators or fibre optic elements.

The dead-space between the sensor active area and the edge of the package has been minimized, resulting in a package that can be tiled on 4 sides with high fill-factor.

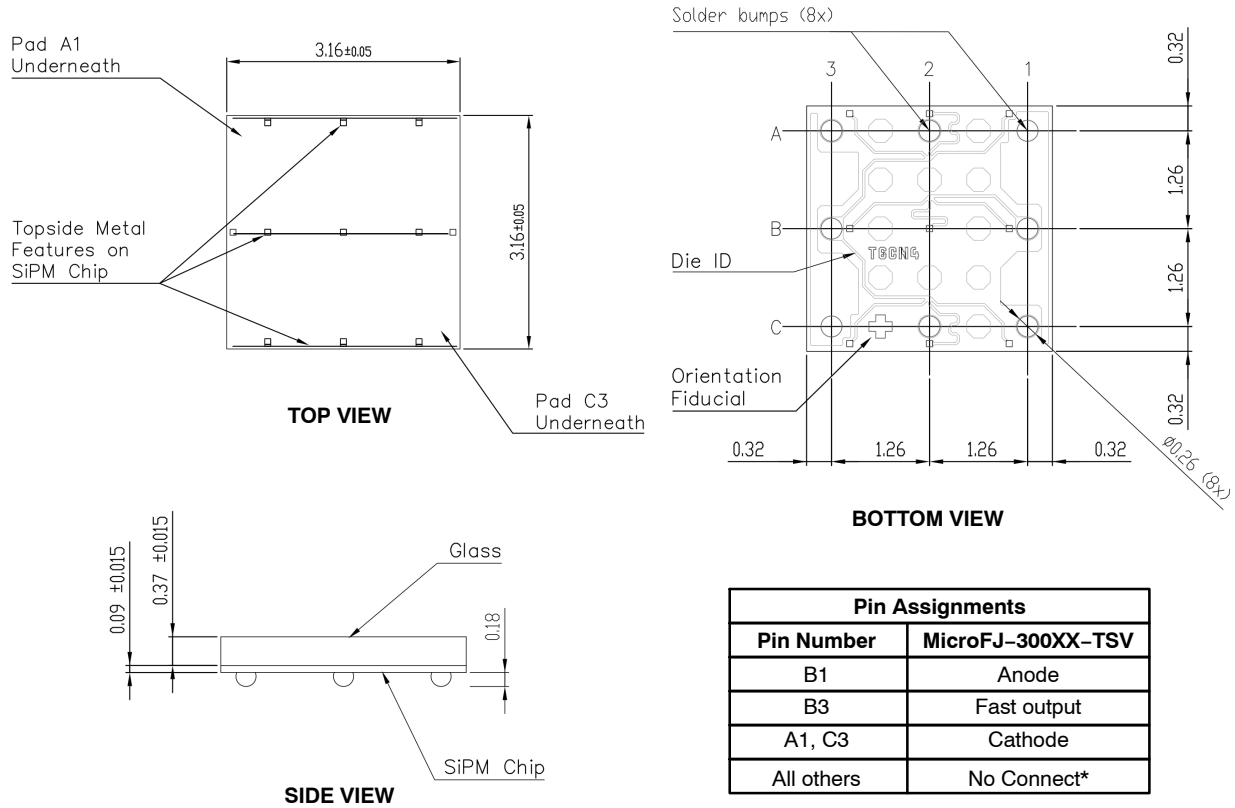
This allows multiple sensors to be configured into unique layouts for a wide range of custom applications. The distance between sensor packages can be as little as 200 μm when tiled, but actual alignment and placement tolerances will depend on the accuracy of the user's assembly process. An [Application Note](#) is available that gives advice on creating arrays of the TSV sensors.

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PACKAGE DIMENSIONS

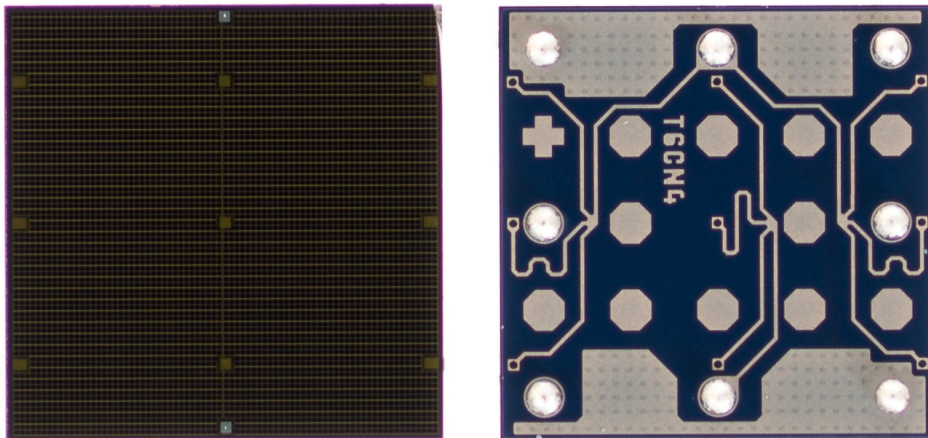
(All Dimensions in mm)

MicroFJ-300XX-TSV



*The 'No Connect' pins are electrically isolated and should be soldered to a ground (or bias) plane to help with heat dissipation.

The MicroFJ-300XX-TSV-A2 CAD, and solder footprint, is available to download [here](#).

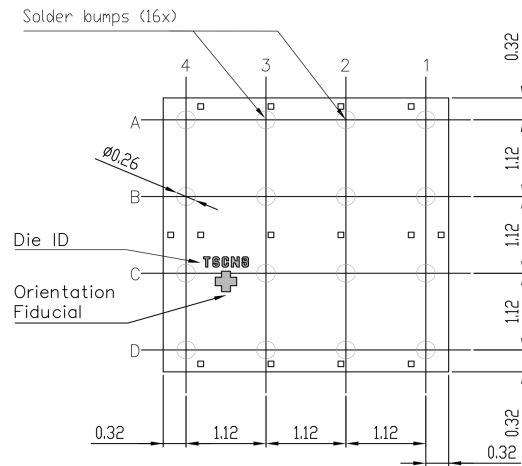
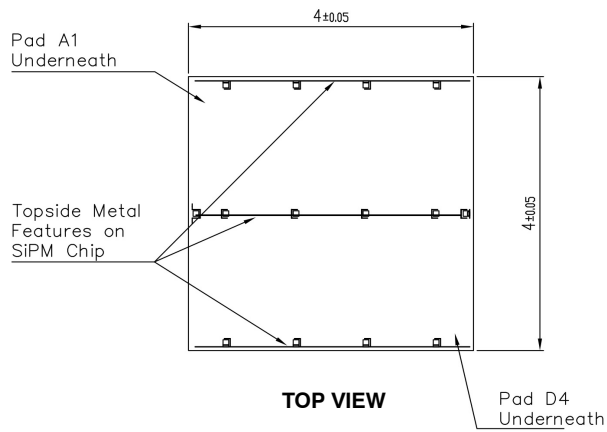


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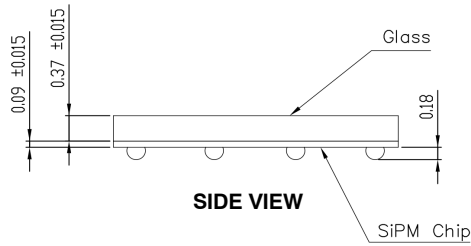
PACKAGE DIMENSIONS

(All Dimensions in mm)

MicroFJ-40035-TSV



BOTTOM VIEW



SIDE VIEW

| Pin Assignments | |
|-----------------|-------------------|
| Pin Number | MicroFJ-40035-TSV |
| B1, C1 | Anode |
| B4, C4 | Fast output |
| A1, D4 | Cathode |
| All others | No Connect* |

*The 'No Connect' pins are electrically isolated and should be soldered to a ground (or bias) plane to help with heat dissipation.

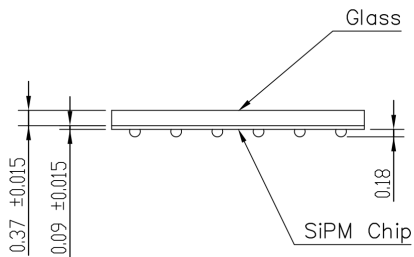
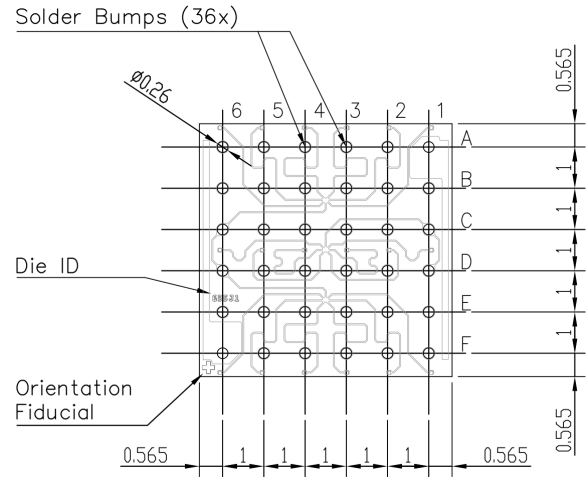
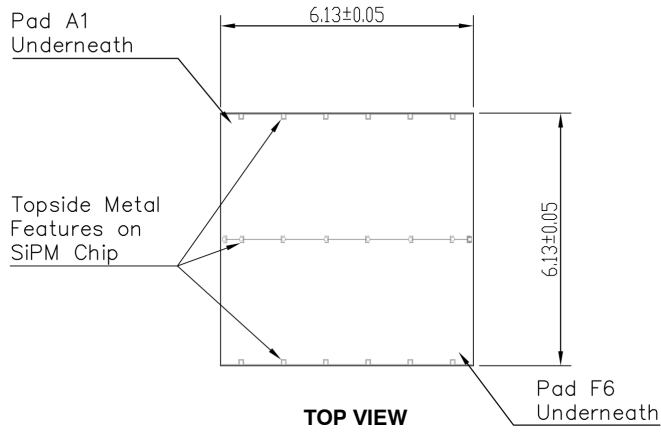
The MicroFJ-40035-TSV CAD, and solder footprint, is available to download [here](#).

J-Series SiPM Sensors

PACKAGE DIMENSIONS

(All Dimensions in mm)

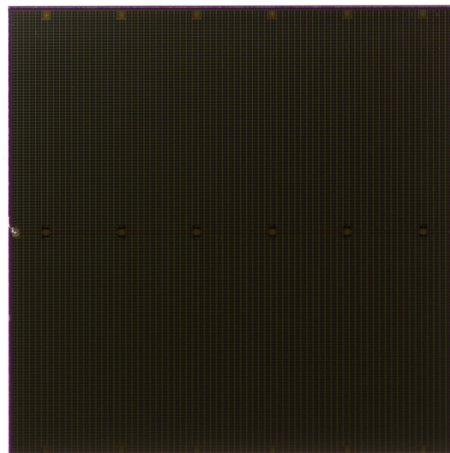
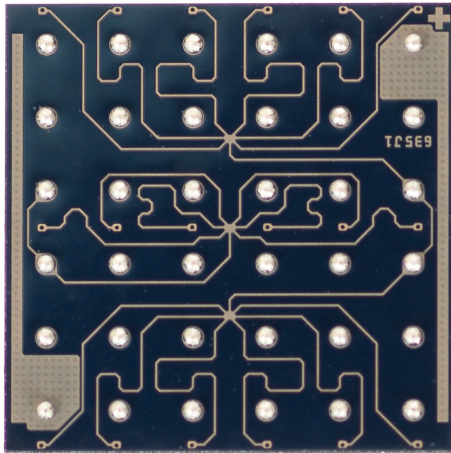
MicroFJ-60035-TSV



| Pin Assignments | |
|-----------------|-------------------|
| Pin Number | MicroFJ-60035-TSV |
| C1, D1 | Anode |
| A1, F6 | Cathode |
| C6, D6 | Fast output |
| All others | No Connect* |

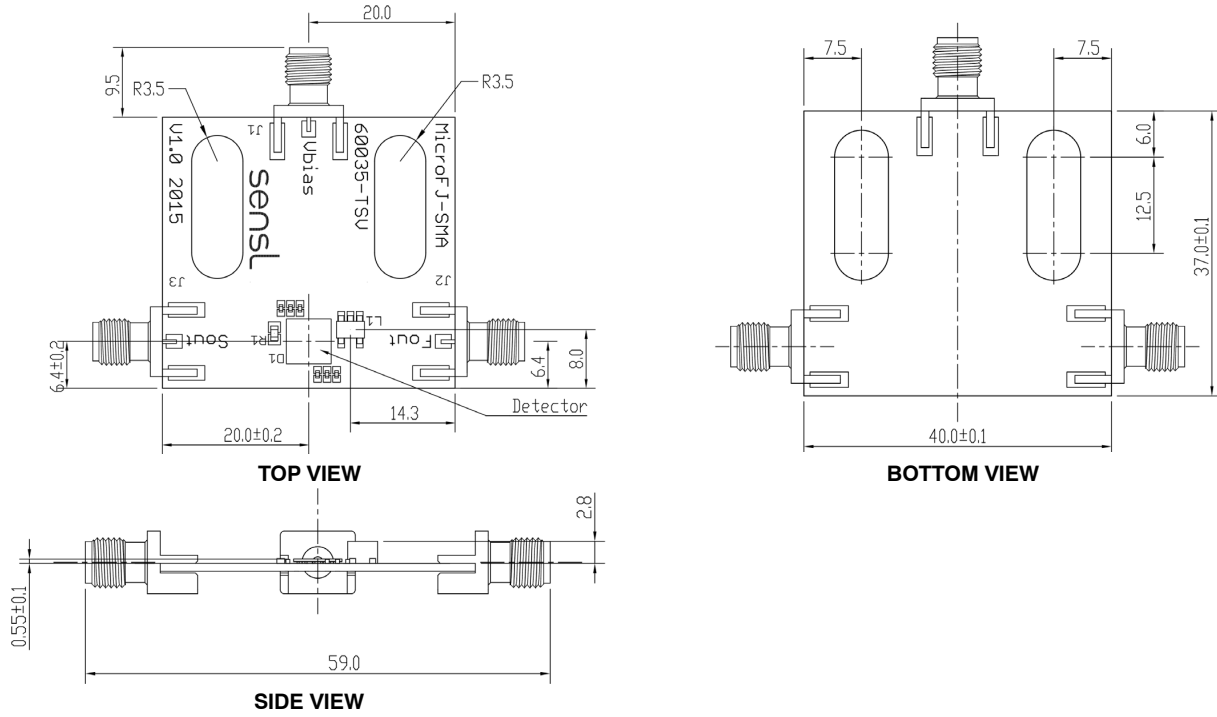
*The 'No Connect' pins are electrically isolated and should be soldered to a ground (or bias) plane to help with heat dissipation.

The MicroFJ-60035-TSV CAD, and solder footprint, is available to download [here](#).



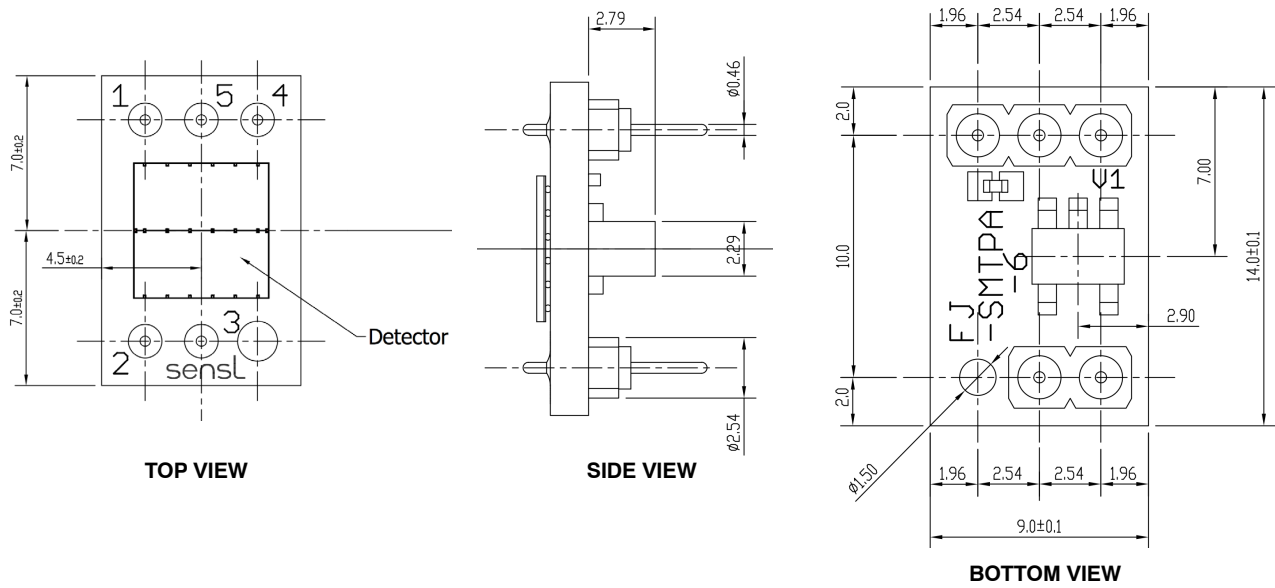
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MicroFJ-SMA-60035 Board



The complete CAD for the SMA boards can be downloaded from the website: [3 mm](#), [4 mm](#) and [6 mm](#) versions.

MicroFJ-SMTPA-60035 Board



The complete CAD for the SMTPA boards can be downloaded from the website: [3 mm](#) and [6 mm](#) versions.

J-Series SiPM Sensors

ORDERING INFORMATION

Table 5. ORDERING INFORMATION

| Product Code | Microcell Size (No. of Microcells) | Sensor Active Area | Description | Delivery Option (Note 9) |
|--------------------------|---------------------------------------|--------------------------|--|--------------------------------|
| 3 mm Sensors | | | | |
| MICROFJ-30020-TSV | 20 μm (14,410) | 3.07 \times 3.07 mm | 4-side tileable, chip scale package with through-silicon vias (TSV) | TR1, TR |
| MICROFJ-SMA-30020-GEVB | | | TSV sensor mounted onto a PCB with three SMA connectors for bias, standard output and fast output | PK |
| MICROFJ-SMTPA-30020-GEVB | | | TSV sensor mounted onto a pin adapter board | PK |
| MICROFJ-30035-TSV | 35 μm (5,676) | | 4-side tileable, chip scale package with through-silicon vias (TSV) | TR1, TR |
| MICROFJ-SMA-30035-GEVB | | | TSV sensor mounted onto a PCB with three SMA connectors for bias, standard output and fast output | PK |
| MICROFJ-SMTPA-30035-GEVB | | | TSV sensor mounted onto a pin adapter board | PK |
| 4 mm Sensors | | | | |
| MICROFJ-40035-TSV | 35 μm (9,260) | 3.93 \times 3.93 mm | 4-side tileable, chip scale package with through-silicon vias (TSV) | TR1, TR |
| MICROFJ-SMA-40035-GEVB | | | TSV sensor mounted onto a PCB with three SMA connectors for bias, standard output and fast output. | PK |
| 6 mm Sensors | | | | |
| MICROFJ-60035-TSV | 35 μm (22,292) | 6.07 \times 6.07 mm | 4-side tileable, chip scale package with through-silicon vias (TSV) | TR1, TR |
| MICROFJ-SMA-60035-GEVB | | | TSV sensor mounted onto a PCB with three SMA connectors for bias, standard output and fast output | PK |
| MICROFJ-SMTPA-60035-GEVB | | | TSV sensor mounted onto a pin adapter board | PK |

9. The two-letter delivery option code should be appended to the order number, e.g.) to receive a MICROFJ-60035-TSV on tape and reel, use MICROFJ-60035-TSV-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. Quantities less than this are available on tape (-TR1). The TR option is only available in multiples of the MOQ.

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