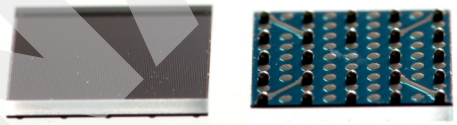
High-Density Fill Factor Silicon Photomultipliers

SensL's J-Series low-light sensors feature an industry-leading low dark count rate and a high PDE that extends much further into the blue part of the spectrum using a high-volume, P-on-N silicon process. Improvements have been made to both the standard (anode-cathode) rise time and the recovery time, in addition to the inclusion of SensL's unique fast output that offers sub-nanosecond pulse widths. J-Series sensors are available in different sizes (3mm and 6mm) and use TSV (Through Silicon Via) technology to create a CSP (Chip Scale Package) with minimal deadspace, that is compatible with industry standard, lead-free, reflow soldering processes.

The J-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 J-Series sensors please refer to the datasheet.



Overview

J-Series SiPM sensors from SensL are based on a P-on-N diode structure (Figure 1), which provides optimized PDE at the blue end of the visible spectrum, and feature a number of significant performance upgrades:

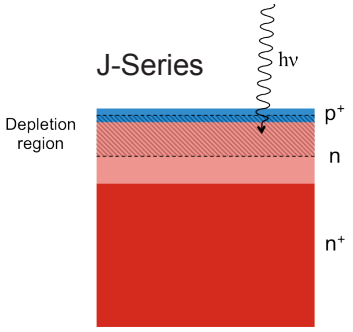


Figure 1, P-on-N sensor structure

PDE: J-Series sensors feature increased microcell density, giving an overall improvement to PDE (with a peak at >50%), along with other optimizations that extend the sensitivity into the UV, (>5% PDE at 250nm). This PDE improvement is achieved while keeping the dark count rate <100kHz/mm^2.

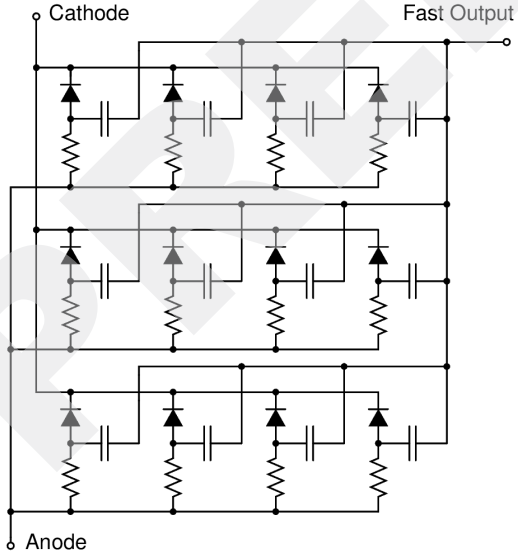


Figure 2, Simplified microcell level schematic of the J-Series SiPM.

Timing: J-Series sensors feature reduced microcell recovery time and *standard* signal rise time. All J-Series sensors also feature SensL's proprietary *fast output* terminal (Figure 2), which is the derivative of the internal fast switching of the microcell in response to the detection of a single photon, which has sub-nanosecond rise times and pulse-widths.

Package: J-Series sensors are available as either a 3mm or 6mm chip packaged using a TSV (through-silicon via) process to create a CSP (Chip Scale Package) with minimal deadspace. The TSV sensors have a number of ball contacts on the reverse, giving access to the *fast output* as well as the *anode* and *cathode*.

Contents

Biasing and Readout

Recommended Biasing

The *cathode* needs to be held at a positive bias with respect to the *anode*, as in Figure 3. It is recommended that bias voltage decoupling, such as the examples shown in Figure 4, is used to provide a stable operating condition. Please refer to the Appendix for further information on biasing schemes and the resulting signal polarities.

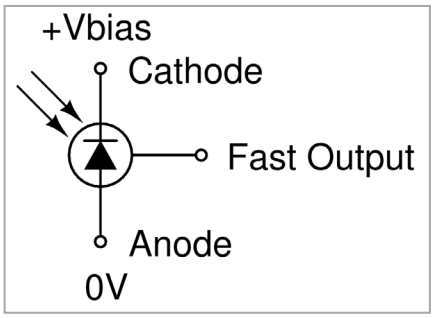


Figure 3, Recommended biasing

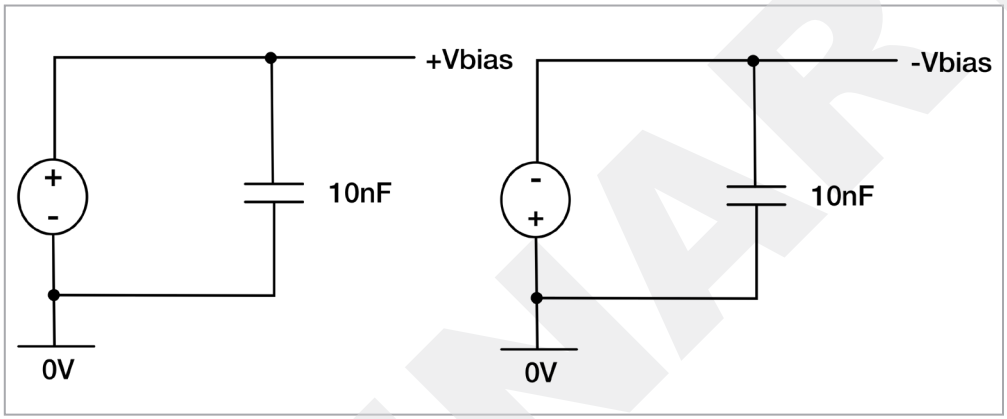


Figure 4, Generic biasing set-up with decoupling capacitors.

Recommended Readout and Amplification

Figure 5 shows how the J-Series sensors can be connected to a standard high-speed amplifier, such as the OPA656, to convert the standard output signal current to a voltage. This particular arrangement is suitable for either the 3mm or 6mm sensors.

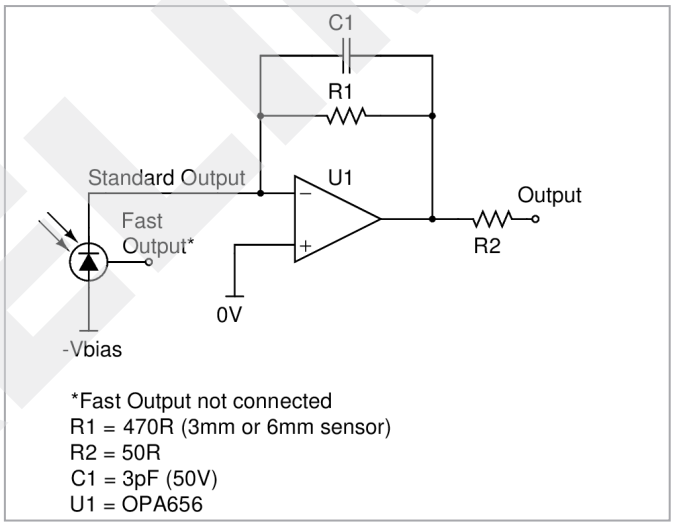


Figure 5, Example circuit for readout of individual sensors.

Readout of the Fast Output

For extensive information about the *fast output* and its readout, please consult pages 4-8 of the C-Series User Manual. In addition, Appendix A of this document shows the resulting signal polarities when various biasing schemes are used.

J-Series Mounted Sensors

MicroFJ-SMA

J-Series sensors are available ready-mounted on test boards, to allow for easy evaluation. The MicroFJ-SMA-*XXXX* sensors (Figure 6) feature the TSV-packaged SiPM sensor reflow-soldered onto a small PCB. The board is simple to use, having just three SMA (female) connectors: one delivers the bias voltage (*Vbias*) and the other two provide the output signals: standard output from the *anode* (*Sout*) and the *fast output* (*Fout*). The SMA board requires a positive bias, which allows the *standard output* to be referenced to ground rather than the bias. For the complete circuit schematic, please consult the TSV Board Reference Design document.

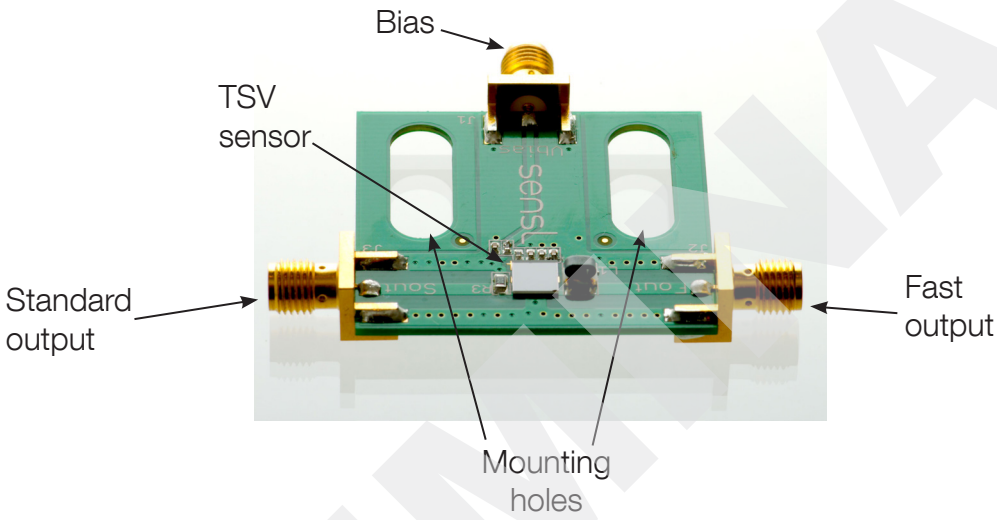


Figure 6, The MicroFJ-SMA-300XX board.

Output	Connector	Function	Comments
Vbias	Standard female SMA connector	bias input (cathode)	positive bias input
Fout		fast output	if unused can be left open
Sout		standard output (anode)	if unused can be left open

Table 1, SMA Connections

The MicroFJ-SMA board is for users who require a plug-and-play set-up to quickly evaluate the TSV sensors with optimal timing performance. The board provides outputs which can be connected directly to the oscilloscope or measurement device. The board also allows the standard output from the *anode* to be observed at the same time as the *fast output*. Table 1 summarizes the connections to the SMA board. Each board has two mounting holes to allow secure placement during testing.

For more discussion regarding the readout of the *fast output* signals, please consult pages 4-8 of the C-Series User Manual. In addition Appendix A of this document shows the signal output polarities when various biasing schemes are used.

MicroFJ-SMTPA

The MicroFJ-SMTPA-XXXXX, or Pin Adapter board (Figure 7), features a TSV-packaged J-Series sensor (type specified by the XXXXX digits) mounted onto a small PCB board. The PCB has five through-hole pins that allow easy electrical connections to the electrodes of the TSV sensor. The pins are labeled on the PCB with numbers 1 - 5. Each of the numbered pins is connected as listed in Table 2, with the option to use either a positive or negative bias. For the complete circuit schematic, please consult the TSV Board Reference Design document.

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

Table 2, Pin assignments for the MicroFC-SMTPA board

The does not include any on-board decoupling on the bias line. Therefore, bias decoupling, such as that in Figure 4, should be included on the bias line at the relevant pin (see Table 2). The standard output can be connected directly to an amplifier or 50Ω load oscilloscope. If the standard output is not used, then that pin should be connected to zero Volts.

Due to the presence of the pins on the SMTPA board, it is not optimal for evaluation testing where timing with the *fast output* signal is critical. For evaluations where the timing performance of the *fast output* is critical, the use of the SMA board is recommended.

The connectors from Samtec used are:

BBL-103-G-E

BBL-102-G-E

Compatible sockets from Samtec are:

SL-103-G-10

SL-102-G-10

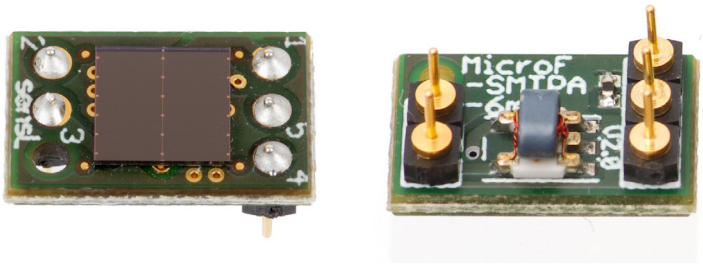


Figure 7, The top and bottom of the MicroFJ-SMTPA-60035 board showing the through-hole pins.

For more discussion regarding the readout of the *fast output* signals, please consult pages 4-8 of the C-Series User Manual. In addition Appendix A of this document shows the signal output polarities when various biasing schemes are used.

Handling and Soldering

Safe Handling of Sensors

- When unpacking, care should be taken to prevent dropping or misorienting the sensors. The specific items contained in the package and the type of packaging will depend on the parts ordered.
- Remember that the SiPM is a sensitive optoelectronic instrument; always handle the sensor as carefully as possible.
- The sensor should be disconnected from the bias supply when not in use.
- SiPM sensors are ESD sensitive. The following precautions are recommended:

    - Ensure that personal grounding, environmental controls and work surfaces are compliant with recommendations in JESD625.
    - Ensure that all personnel handling these devices are trained according to the recommendations in JESD625.
    - Devices must be placed in an ESD approved carrier during transport through an uncontrolled area.
- Complete handling information can be found in the TSV Handling and Soldering guide.

Product Packaging

The sensors are shipped in moisture barrier bags (MBBs) according to J-STD 033 standard. An unopened MBB should be stored at a temperature below 40°C and relative humidity <90%. After the MBB has been opened, the devices must be reflow soldered within a period of time depending on the moisture sensitivity level (MSL), which is **MSL3**. See Table 3 for details.

MSL	Exposure time	Condition
3	168 hours	≤30 °C/60% RH

Table 3, MSL definitions applicable to the J-Series sensors (reference J-STD 020).

Cleaning

The parts can be cleaned using Isopropyl alcohol.

Solder Reflow Conditions

The J-Series sensors must be mounted according to specified soldering pad patterns as given on pages 8 and 9. The 'No Connect' pins are electrically isolated and should be soldered to a ground (or bias) plane to help with heat dissipation.

Solder paste must be evenly applied to each soldering pad to insure proper bonding and positioning of the component. After soldering, allow at least three minutes for the component to cool to room temperature before further operations.

Solder reflow conditions must be in compliance with J-STD-20, table 5.2. This is summarized in Figure 8. The number of passes shall not be more than 2.

Complete soldering information can be found in the TSV Handling and Soldering guide.

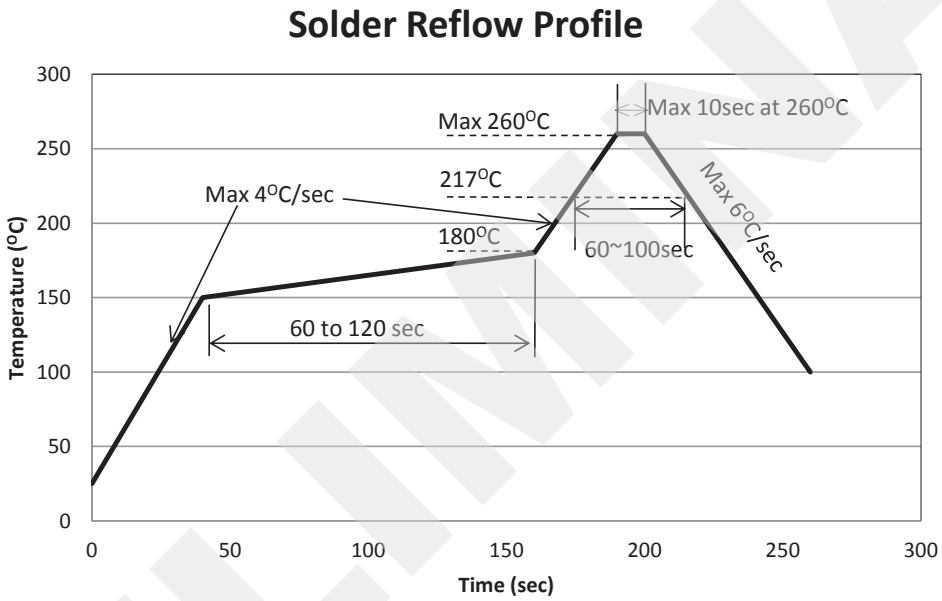
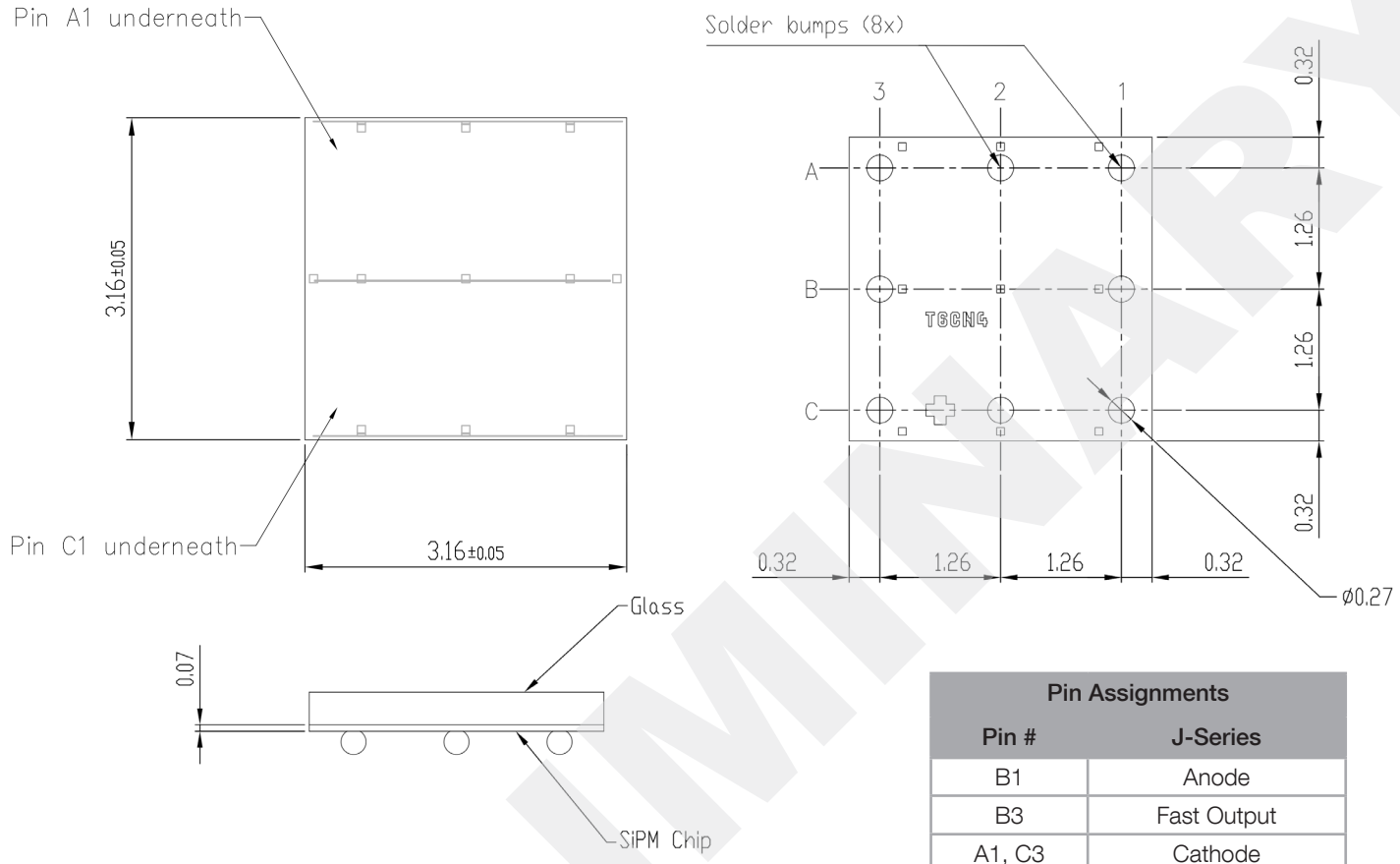


Figure 8, Reflow solder profile for use with J-Series sensors.

Package Drawings (All Dimensions in mm)

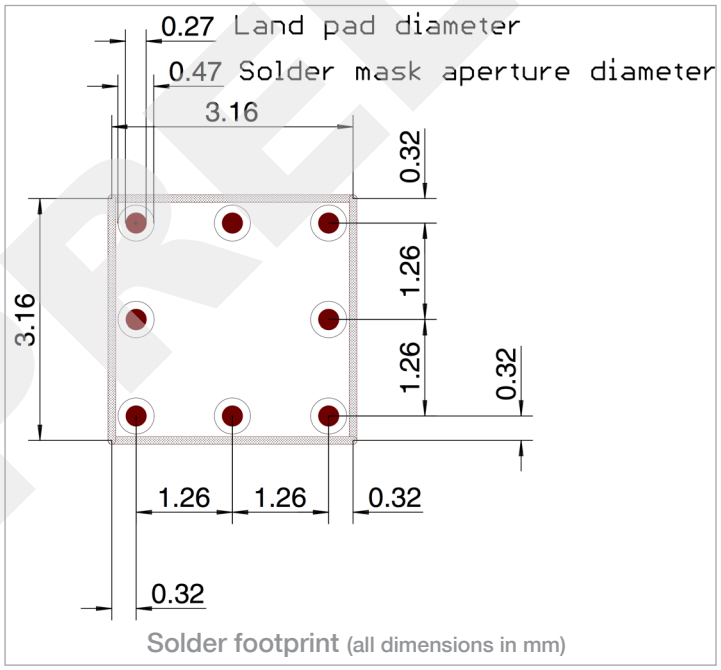
MicroFJ-300XX-TSV Package & Solder Footprint



The complete MicroFJ-300*XX*-TSV CAD can be downloaded from the website, here.

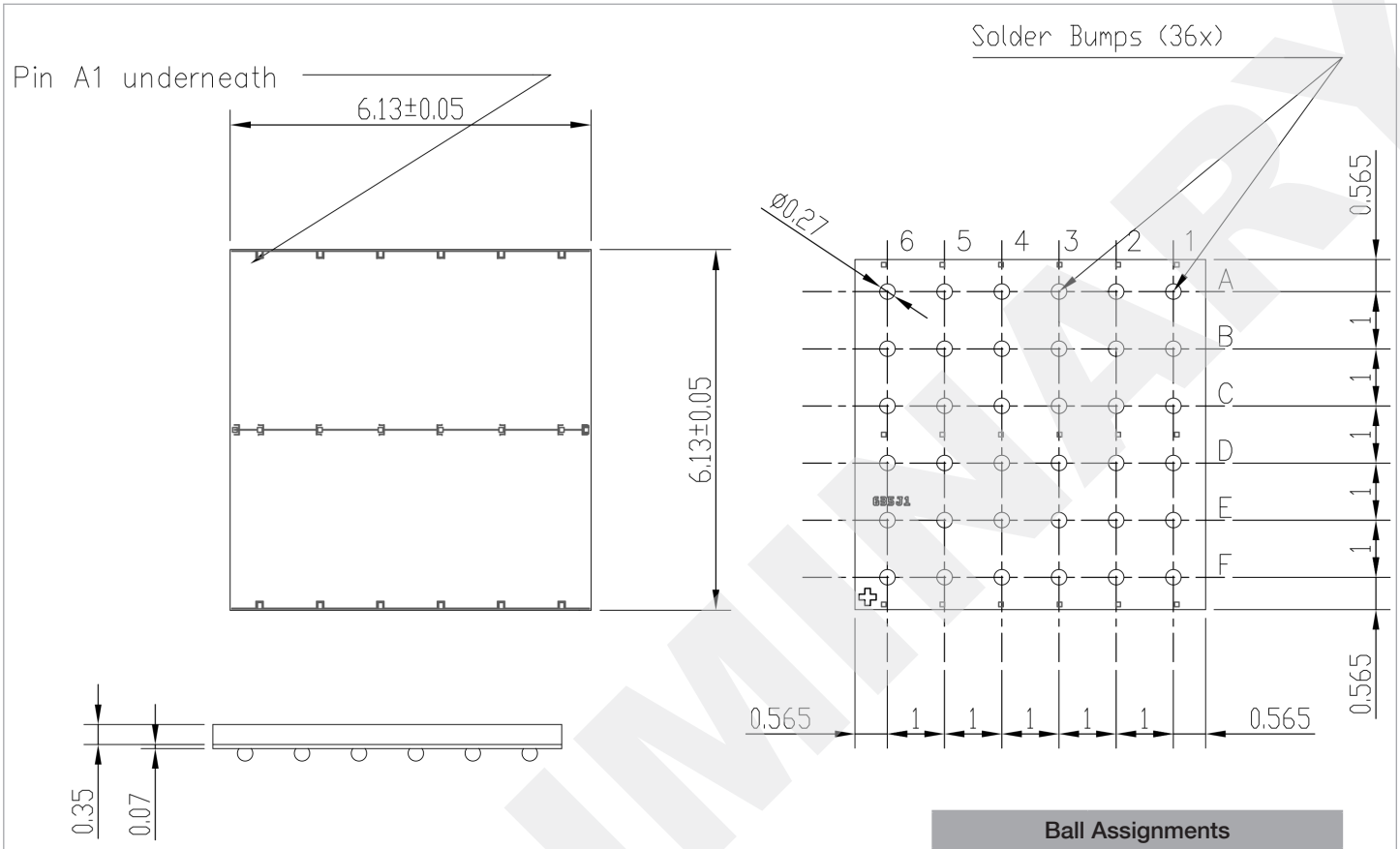
Pin Assignments	
Pin #	**J-Series**
B1	Anode
B3	Fast Output
A1, C3	Cathode
All others	No Connect *

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



Solder footprint (all dimensions in mm)

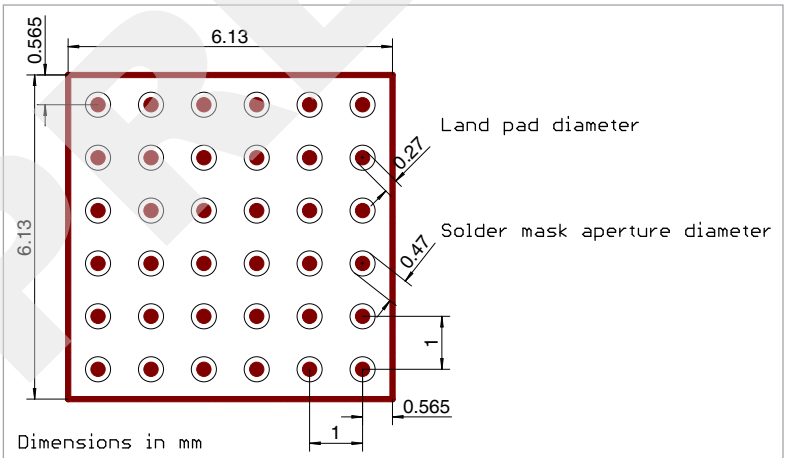
MicroFJ-60035-TSV Package & Solder Footprint



Ball Assignments	
Ball #	**MicroFJ-60035-TSV**
C1, D1	Anode
A1, F6	Cathode
C6, D6	Fast Output
All others	No Connect *

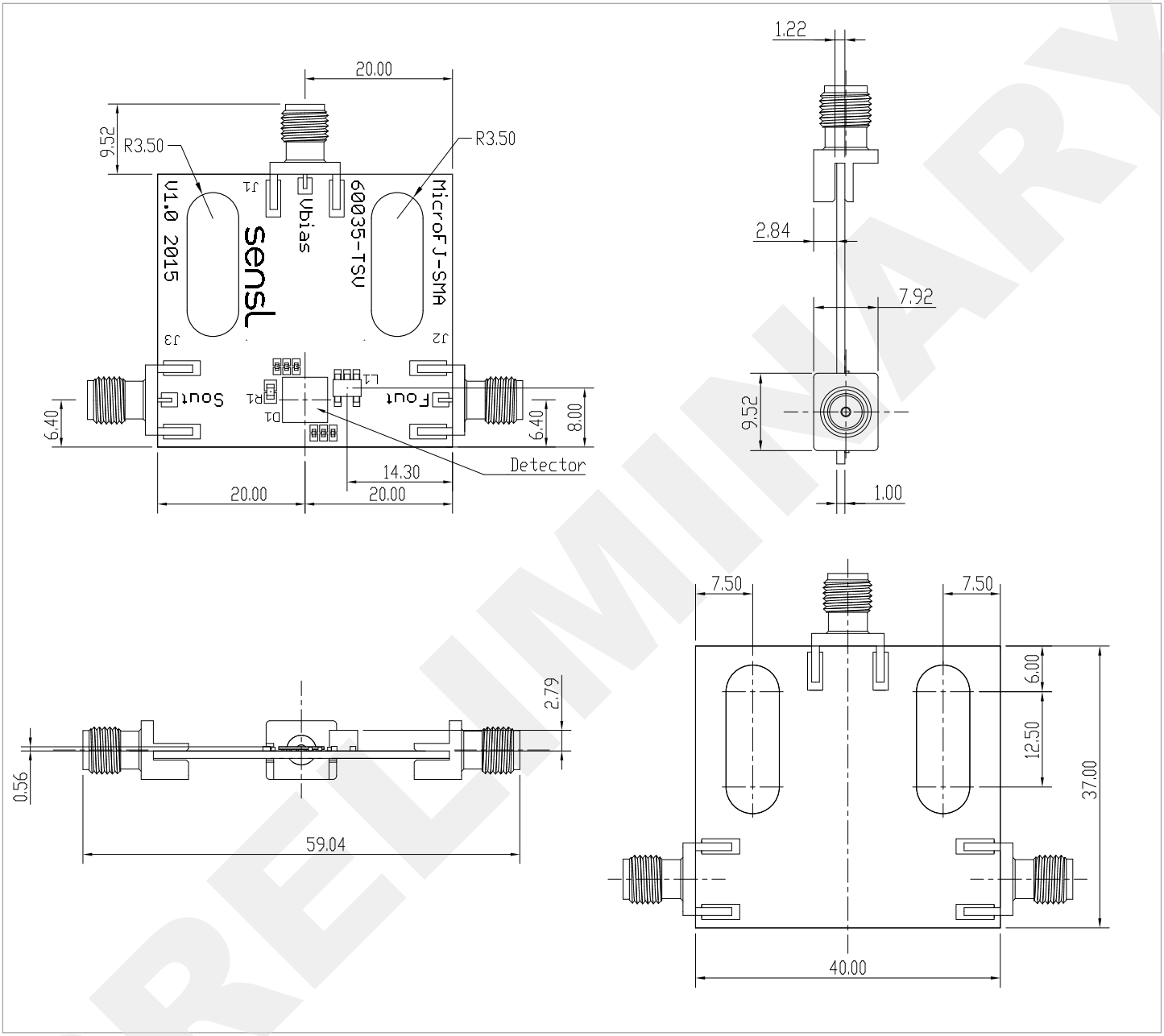
** The 'No Connect' pins are electrically isolated and should be soldered to a ground (or bias) plane to help with heat dissipation.*

The complete MicroFJ-60035-TSV CAD can be downloaded from the website, here.



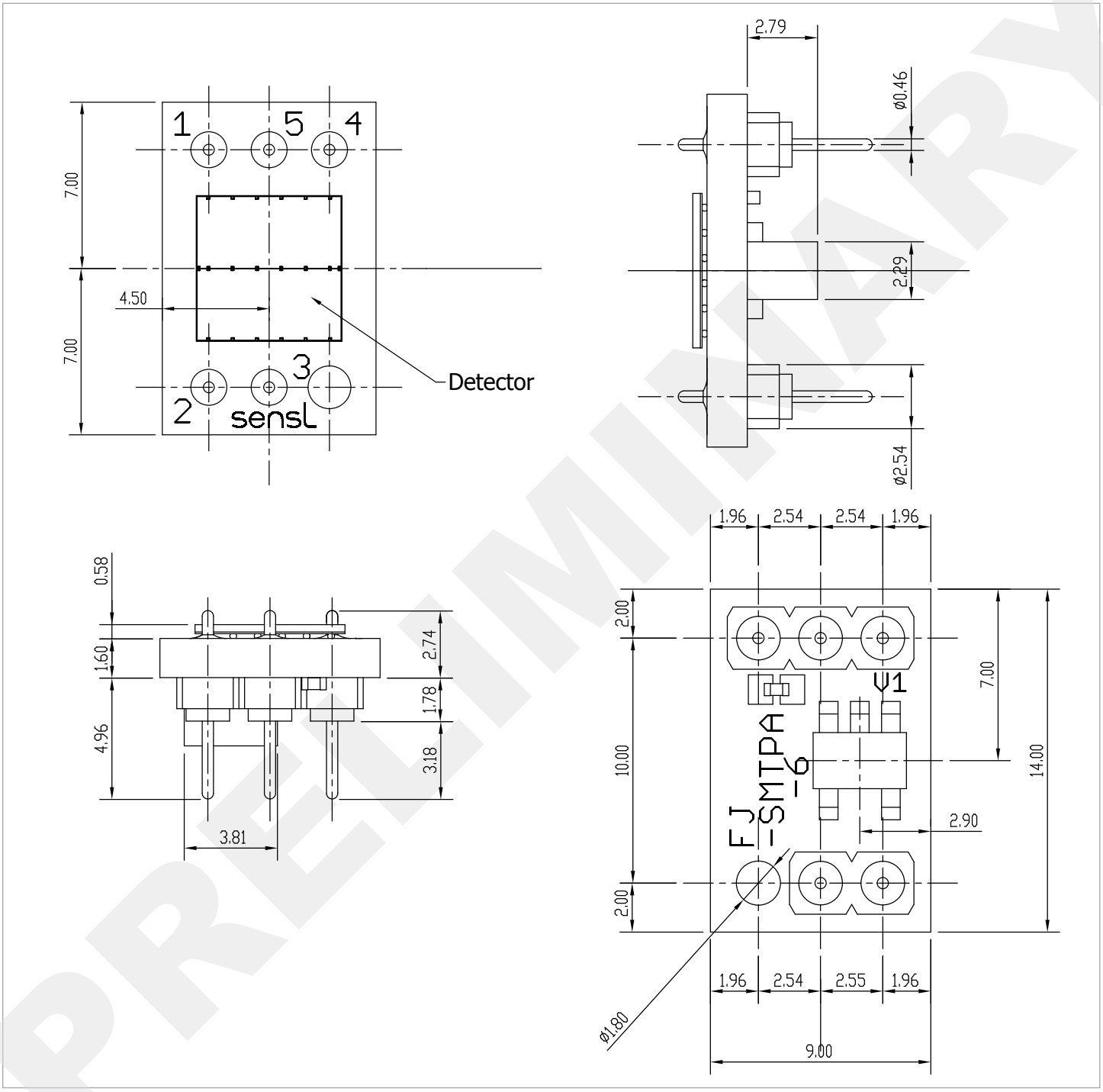
Solder footprint (all dimensions in mm)

MicroFJ-SMA-60035



Full CAD schematics are available to download, for both the 3mm and 6mm versions of the SMA board.

MicroFJ-SMTPA-60035



Full CAD schematics are available to download, for both the 3mm and 6mm versions of the SMTPA board.

Further Help

If more help is required in the set-up or operation of J-Series sensors, there are several SensL resources that can help.

• The J-Series Datasheet contains more detailed information on the physical and performance characteristics of the sensors.

• A variety of Tech Notes are available on the website, www.sensl.com, such as:

- The TSV Handling and Soldering guide.
- The TSV Board Reference Design document.
- A guide on creating arrays of close-packed sensors.
- An extensive library of technical and scientific papers on the use of SensL SiPM sensors.

• If additional help is needed, please contact support@sensl.com

www.sensl.com
sales@sensl.com
+353 21 240 7110 (International)
+1 650 641 3278 (North America)

Appendix A - Biasing Alternatives & Signal Polarity

This Appendix lists all of the possible ways in which a J-Series SiPM can be biased. For each biasing arrangement, the *standard* and *fast* signal polarities are given. *A* and *B* are the recommended configurations. *C* and *D* will work, but are not recommended for use with the *fast output*. The following abbreviations are used throughout:

V_{bias} = bias voltage

Sout = standard output

Fout = fast output

R_S = load resistor for the standard output

R_f = load resistor for the fast output

V_S = standard output voltage

V_f = fast output voltage

R_Q = quench resistor (included on the SiPM die)

C1 = decoupling capacitor 10nF (50V), low ESR, ceramic