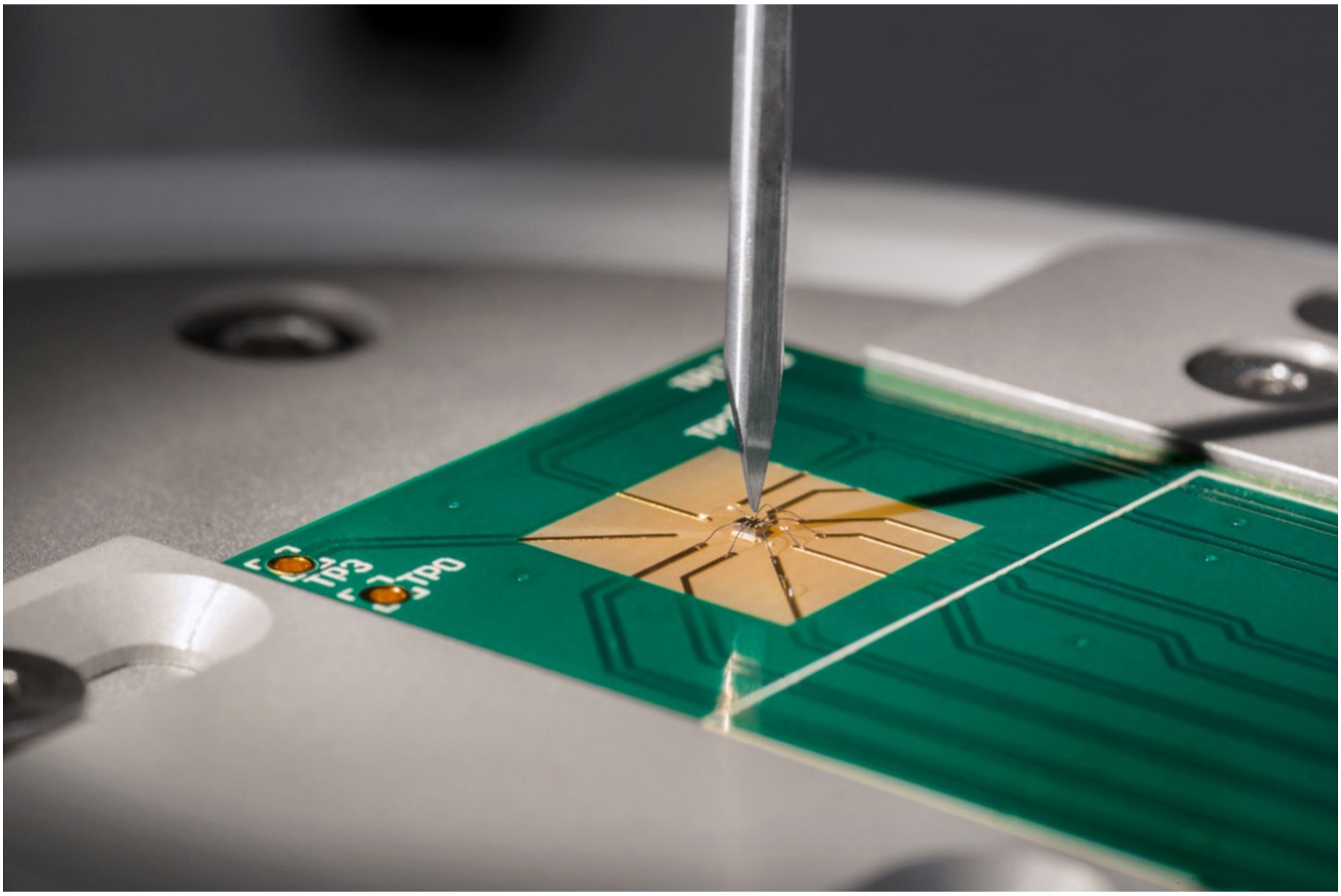
APPLICATION Note # 3

CUBE: Mounting guide



Abstract

Managing naked die CUBE preamplifiers is not a trivial issue and requires some special considerations. CUBE is an ESD sensible component with tiny dimensions of 750um by 750um and a thickness of 250um. In this document, the recommended procedures to mount and use the CUBE naked die are given. A step-by-step guide about the assembly, the connections and the recommended tests is presented.

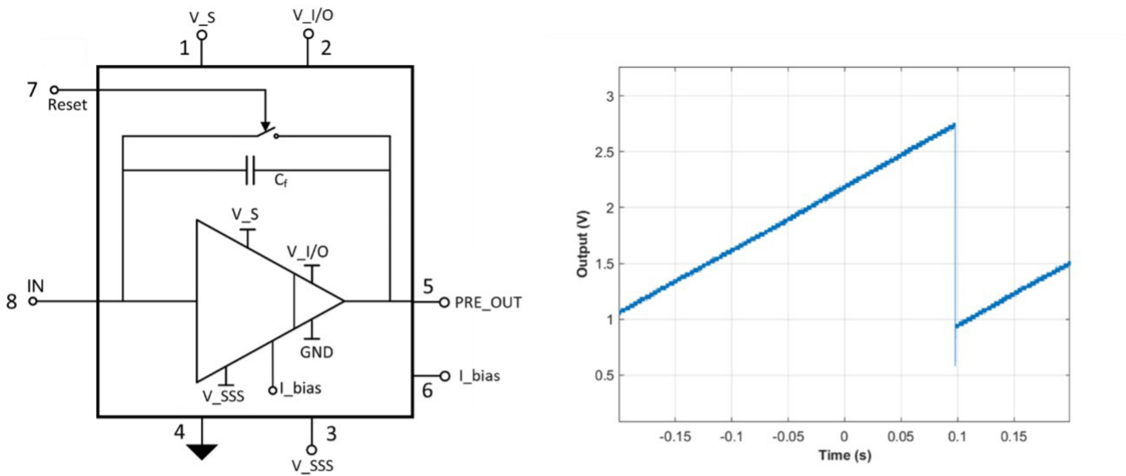
Introduction

CUBE is a naked die charge-sensitive amplifier designed to readout different types of solid-state detectors. CUBE has a dimension of 750um x 750um and a thickness of 250um. The input current is integrated on the feedback capacitor and read as a voltage at the output. The charge on the feedback capacitor can be reset by means of continuous or pulsed reset. In pulsed reset mode, a reset signal is required to return the feedback capacitor to the initial state eliminating the integrated charge (see **Figure 1**). CUBE requires three polarizations in the low voltage range and a ground connection (see **Table 1**). The internal current reference can be modified using the I_bias signal, but it is recommended only for special application and should be left not connected.

Signal		MIN	NOM.	MAX	UNIT
V_S	Core supply	1.9	2	2.1	V
V_S current	V_S = 2V, V_SSS = -6V		2		mA
V_I/O	I/O supply	4.5	5	5.5	V
V_I/O current	V_I/O = 5V		3		mA
V_SSS	Input current supply	-3	-6	-6	V
V_SSS current	V_S = 2V, V_SSS = -6V		2		mA
I_bias*	Internal current reference control	Not connected			
Reset	Reset signal	0		V_I/O	V

** The bonding of this signal is not required for normal operation of the device.*

Table 1. Voltage supply and reset signal required for CUBE operation

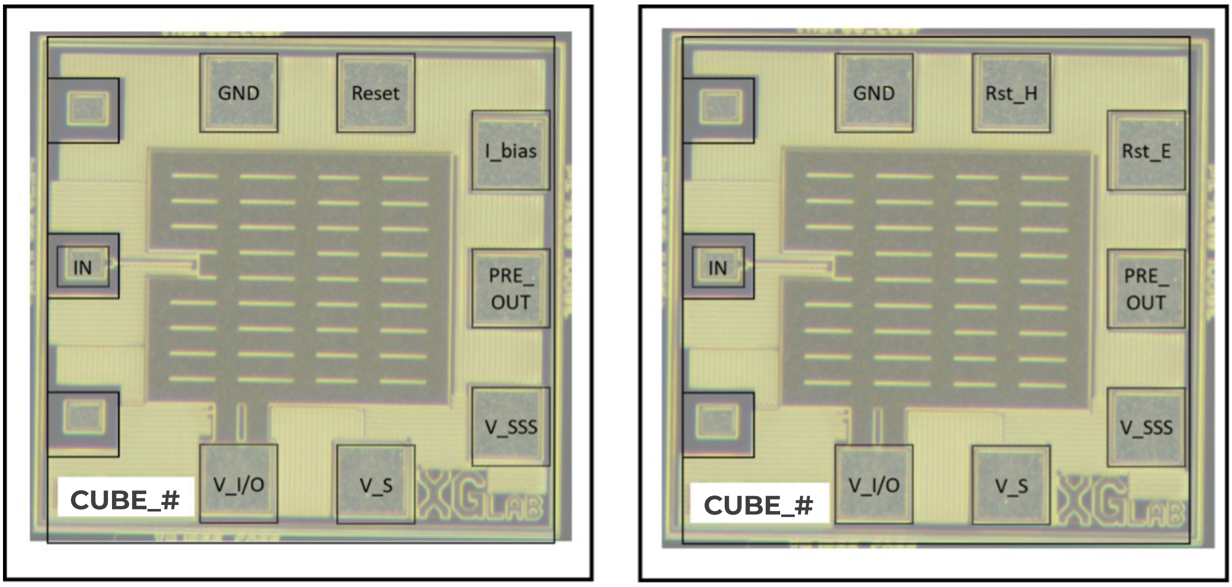


(a) (b)

Figure 1. a) Functional block diagram and pads for a generic CUBE.
(b) Typical output signal for an electron collection detector using CUBE with pulsed reset.

A detailed information for each different type of CUBE and how to choose the correct version can be found on the APPLICATION Note # 1: Find the right CUBE.

As an example, it is represented in **Figure 2** the position of the pads for two different CUBE types. One is a single polarity readout (holes or electrons), while the second one is a dual polarity readout CUBE (holes and electrons).



(a) (b)

Figure 2. (a) Single polarization CUBE pad position. (b) Dual polarization CUBE pad postion.

The passivation opening of the input pad depends on the CUBE version with a minimum size of 40um by 30um and a maximum size of 55um by 40um. The remaining pads used for the power, the control and output signals have a passivation opening of 85um by 85um.

CUBE Packaging and Manipulation

CUBE is supplied as a naked die in 2” waffle packs closed in a vacuum ESD protected plastic bags, see **Figure 3**. CUBE must be considered an **ESD sensible device**. Therefore, the general precaution of ESD sensible devices shall be applied when handling the CUBE and during mounting operations. It is highly recommended to manipulate them in an ESD protected environment inside a cleanroom and to use ESD-safe equipment.
The recommended ESD protections when manipulating CUBE are:

- Grounding wrist straps to eliminate static buildup on the manipulator
- ESD work surface mats that assist with discharge
- Anti-Static\resistive clothing
- Gloves and finger cots
- ESD-safe equipment to handle CUBE, tweezers and/or vacuum pumps.

Additional ESD protections are welcome.

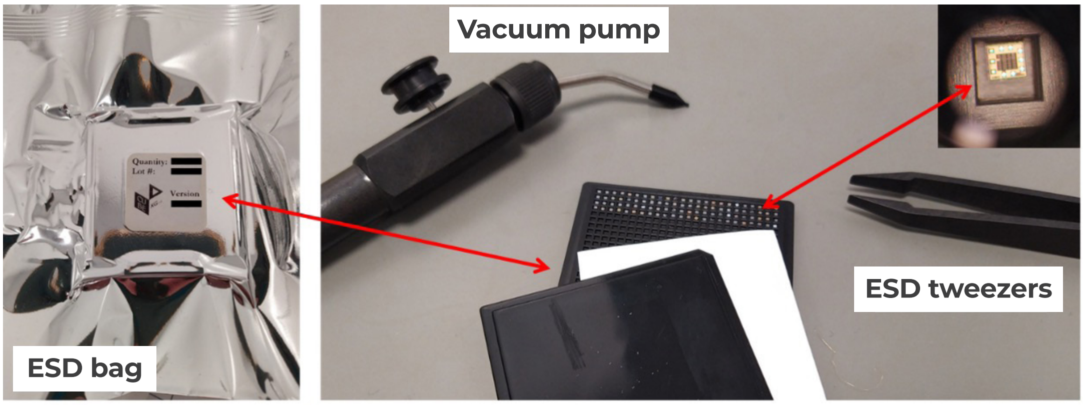


Figure 3. CUBE packaging and recommended CUBE manipulation instruments.

All the CUBE’s pads (except the IN) have a built-in ESD (Electro-Static Discharge) protection. The IN pad has instead a very small protection circuit, which cannot withstand the delivery of energy typical of HBM (human body model).
Most of mis-functioning cases of the CUBE are generally related to ESD issues due to bad handling.

Mounting considerations

The CUBE can be glued on Ceramic and FR4 substrates. There are no issues in gluing the CUBE as long as the bonding pads remain clean from resin residues. The maximum heating temperature recommended for CUBE gluing is +150 °C. Since the CUBE dimensions are very small, the thermal expansion coefficients do not play a relevant role.
The bottom surface of the die (substrate) is connected to the GND pad. It is possible to attach CUBE using conductive or non-conductive glues. In case a conductive glue is used, the bottom plate should be connected to GND. Otherwise, if a non-conductive glue is used , the bottom plate can be left floating. Regardless the glue type, CUBE substrate-biasing is still provided through the GND pad.

Note: During the assembly process and after the final assembly, the CUBE GND shall be always electrically connected to the detector ground (when the anode/input bonding is present).

At the contrary, if CUBE and detector grounds are not always connected, there could be a build-up charge at the CUBE input which can degrade the oxide and lead to a leakage current.
For additional recommendations on how to design the carrier board for CUBE you can refer to (APPLICATION Note # 2 CUBE: How to design the carrier board).

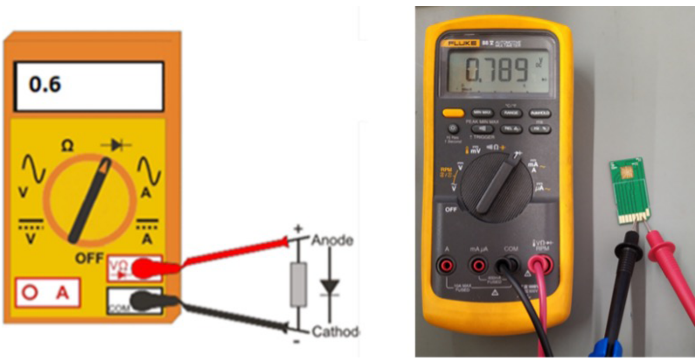
Recommended bonding and test procedure

The safest bonding order is to bond CUBE Ground, supply voltages and the detector bias voltage first, and then bond the IN PAD to the detector at last.
Direct bonding from IN to the detector chip is highly recommended to achieve the best resolution. Any additional component between the detector and the amplifier will add parasitic capacitance on the input, reducing the performance of the final component.
Considering the IN pad dimensions, the wire bonding diameter recommended is 17.5µm, although it is also possible to use a 25µm wire. This is possible because all the structures around the input pad are covered by a passivation layer, and there is no risk of short circuits even though the bonding footprint exceeds the pad area.
Special care has to be taken with the chip edges and the lateral sides of the dies, as those areas are not passivated, and it is possible to short circuit the signal with the substrate.
The recommended procedure to bond and test CUBE is detailed here, while a detailed explanation of the different steps is given in the following sections:

1. Begin the bonding procedure with the GND pad (see **Figure 1**). Continue the bonding procedure clockwise, leaving unbonded the IN pad (see **Figure 1**). Note: only one of the two reset options should be bonded, the other one can be left unbonded or bonded to GND.
2. Check the continuity of the bonding and the possible short circuits. Detailed information in the section "test procedure after CUBE bonding".
3. Power the CUBE and check the output. Detailed information in the section "Power on sequence" and "Test procedure without detector".
4. Bond the input signal to the detector using a direct wire bonding. In case that the connection of the IN PAD to the detector is done through a board, it is possible to check the continuity test detailed in the section "Test procedure after CUBE bonding", taking special case, as this is the most sensible signal.
5. Power CUBE and detector and check the output. Detailed information in the section "Test procedure with detector".

Test Procedure after CUBE bonding

After bonding the CUBE, it is possible to check the proper electrical connection of the bonding with 2-probes measurements. This test does not require to power up CUBE, but only the use of a two-probe multimeter. The multimeter is used in the diode measurement modality (see **Figure 4**). The multimeter gives a voltage measure when applying 1mA of current through the two connected terminals. The other terminals of CUBE (and of the detector) are left floating.



(a) (b)

Figure 4. (a) Connection of the multimeter with the parallel resistor. (b) Image of a real measure without parallel resistor.

Test must be considered as an on/off measurement with the only purpose to check the bonding electrical connections. In each CUBE manual it is reported a table with the expected values for each signal (typical values in **Table 2**). The voltages reported in the table may change by tens of mV according to temperature and CUBE variation.

Note: Be aware that most of the multi-meter in the test-diode function can provide up to 8 V in open circuit. This exceeds the maximum absolute voltage range. Thus, if the instrument delivers 1mA, a resistor of 4 kOhm can be added in parallel to limit the maximum voltage to 4V.

Pin Checked	Positive Term. (red probe)	Negative Term. (black probe)	Measurement	Note
V_DD - GND	GND	V_DD	0.67 V	big diode
V_S	GND	V_S	0.7/0.8 V	diode
V_SSS*	GND	V_SSS	2.0 V	with 4kohm
PRE_OUT	GND	PRE_OUT	0.71 V	big diode
Reset		Reset	0.78 V	diode
IN*	GND	substrate (IS, OS)	2.5 V	with 4kOhm

** Measure affected by the presence of the 4 kOhm resistor.*

Table 2. Example of the multimeter values obtained when checking a CUBE bonding continuity.

Power on sequence

To power-on CUBE, the supply voltages can be applied at the same time. If this is not possible, it is recommended to apply first the V_DD and GND, and with some delay the V_S and V_SSS (last two can be exchanged). It is also recommended to keep the reset applied at the beginning of the operation to ensure the circuit is set to the correct operation point. If this is not possible, it is recommended to apply a reset pulse

Note: Providing V_S and V_SSS without V_DD and GND applied can cause chip damage: it is possible that some junctions inside CUBE would be forwardly biased, and this create an excess of current from the V_S. On the other side, providing the V_DD and GND and keep V_S and V_SSS unconnected does not introduce any risk.

Test procedure without detector

A good way to check the CUBE proper functionality, without a detector connected, is to power-on the device and observe the PRE_OUT signal. The output signal should be a ramp of several seconds long. The ramp is due to the CUBE input leakage current which should be close to zero, it also may have the opposite directions from the expected leakage in the detector. To test CUBE without detector, it is recommended to use a periodic pulsed reset as in this case, the electronics which provide the reset may not be able to generate the reset and the output may saturate to one of the supplies.
During the reset pulse, the output signal shows a voltage drop/increase if the ramp is increasing/ decreasing. After the reset, the output signal will show a small voltage step (see **Figure 5**).

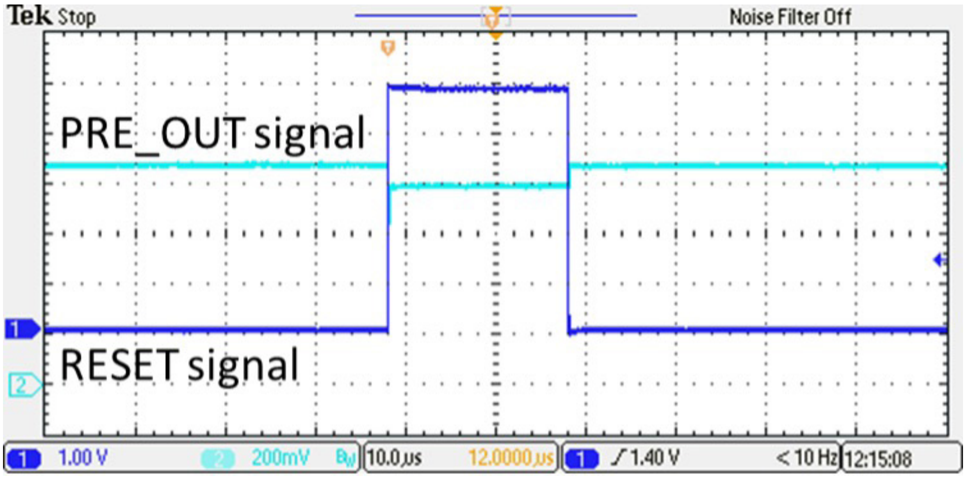


Figure 5. Example of the CUBE output signal drop during the reset pulse.

A second possibility to test the functionality of CUBE without detector is to use a strong light source (torch light or 5mW laser pointer). The light produces photogenerated charge in the silicon that can be collected at the preamplifier input. The charge produces a positive/negative slope ramp (electrons/ hole collection) with a shorter period in the order of milliseconds, depending on the light intensity, directionality, and position (see **Figure 6**). Changes on the light intensity will produce a change in the ramp slope. It is important to notice that in some cases due to the ramp direction and charge collection CUBEs might saturate in a short time.

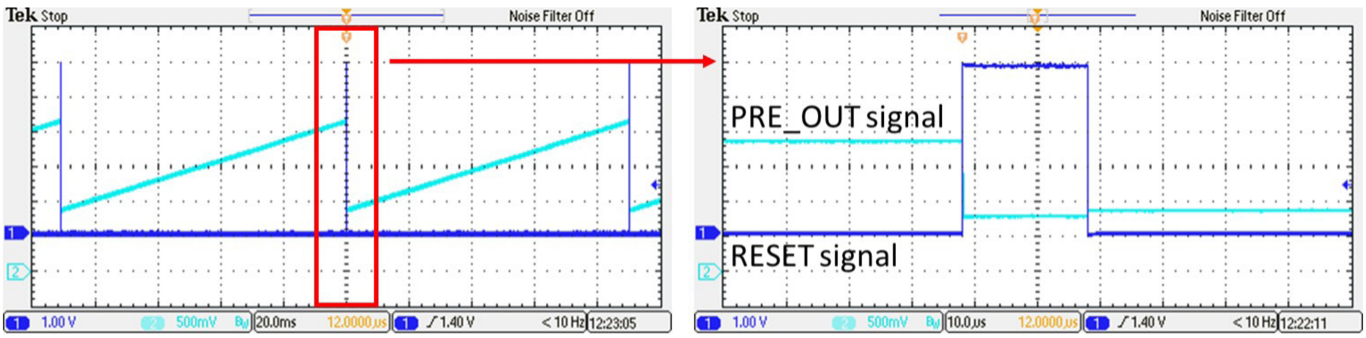


Figure 6. Example of the CUBE output signal without detector when it is illuminated with a torch light.
In the left image the ramps due to the light are visible, while in the right image a zoom of the reset pulse shows the PRE_OUT signal reset.

Mounting of the detector

When manipulating the carrier board always consider that CUBE is an ESD sensible device. In all operations required to mount the detector or any additional component, it is highly recommended to connect all the components to ground and to use the recommended ESD protections, see **Figure 7**. Even taking this consideration, discharge all the instruments before using them on the CUBE area, event those connected to the earth reference.

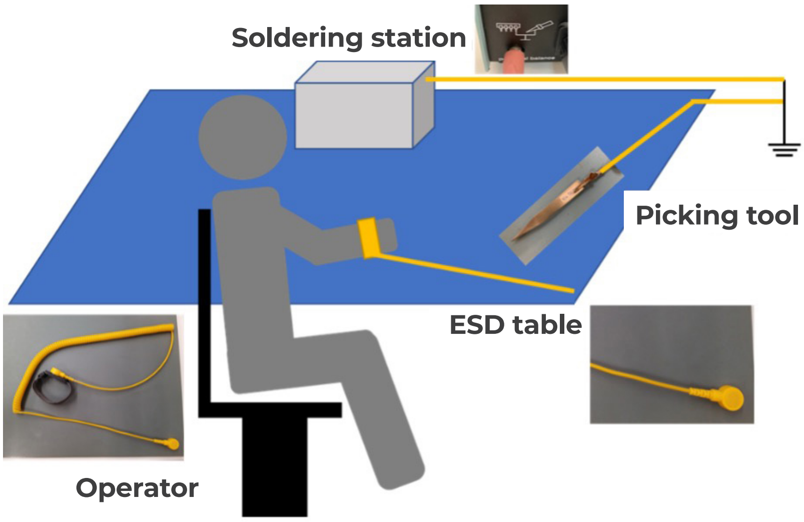


Figure 7. Recommended ground connections to prevent ESD problems during manipulation and detector mounting.

When connecting the detector to CUBE it is highly recommended to have a direct connection with the shortest possible line. If the direct connection is not possible, reduce the length of the connections.

Test procedure with detector

Before powering on the system, it is important to consider the whole system operation requirements and operation conditions of the final instrument. This means vacuum conditions, cooling of the detector, power requirements, and electrical and optical shielding.
Once the settings of the whole system are achieved, it is recommended to power-up first CUBE and check the correct functionality previously described. The next step is to power-up the detector and check the output signal of CUBE. The leakage of the detector will produce a ramp with a shortest time scale than CUBE alone. The reset generator should be designed to generate the pulse signal when the output reaches a certain value (near V_DD for electron collection, and near GND for hole collection).

Trouble shoot ESD damage with Detector

In case of abnormal leakage current at CUBE OUT, the procedure to determine the origin of the problem is hereafter suggested:

- Option 1: with the detector and CUBE fully biased, measure the ramp slope. Change the V_S by several hundreds of mV (or V_SSS by some Volts). The ramp slope should be constant (Detector leakage), if the slope changes significantly there is a leak contribution from CUBE (damaged FET).
- Option 2: Remove the IN bonding and bias the CUBE; note that this a destructive operation. For a good CUBE with no detector the ramp should be of several seconds.

NOTE: CUBE is light sensible: keep CUBE in a light-proof environment during measurements.

Still in doubt? Contact us https://www.xglab.it/contact-us/.