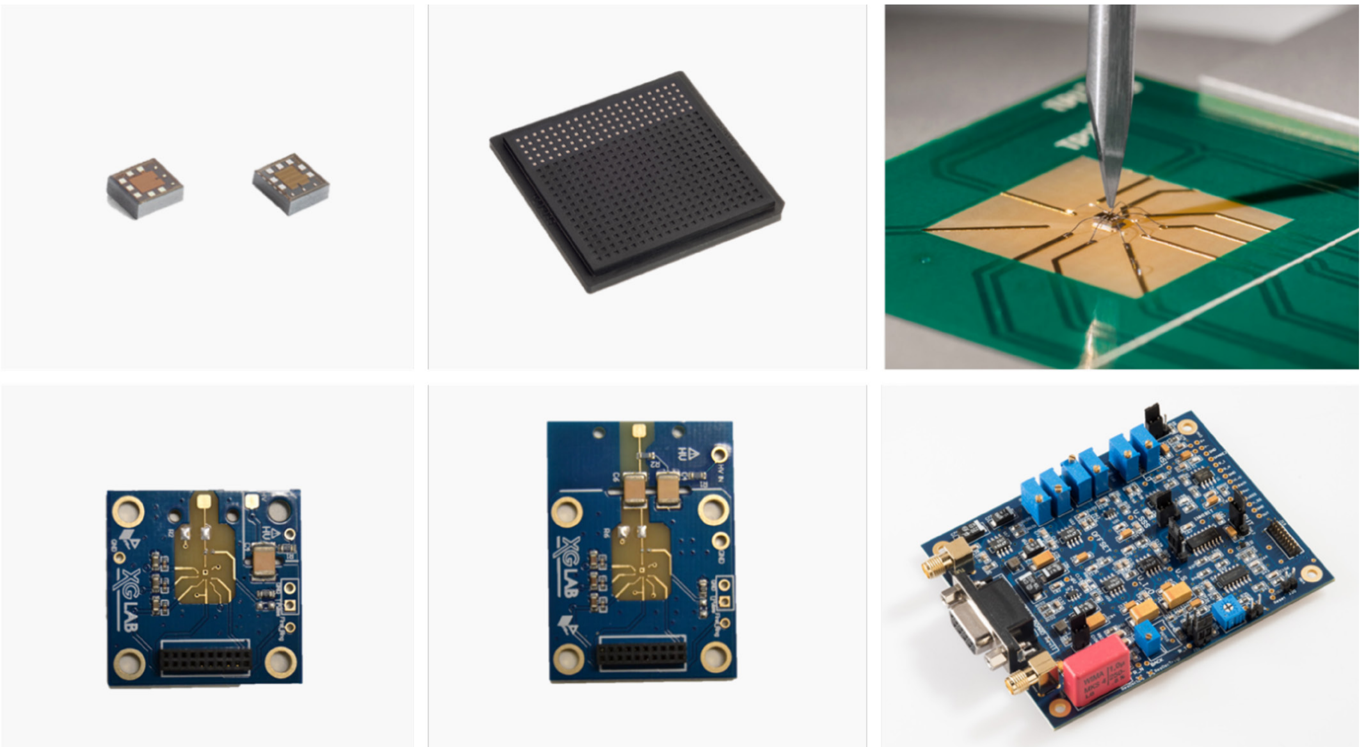
APPLICATION Note # 2

CUBE: How to design the carrier board



Abstract

PCB design may not be a trivial work when you are using high performance circuits. In particular, the design of a carrier board for CUBE, the ultra-low noise CMOS preamplifier for ionizing radiation detectors, requires special considerations to keep the best operating performances.
The goal of this application note is to explain how CUBE can be used and to provide a guideline to design CUBE carrier boards for high performance solutions.

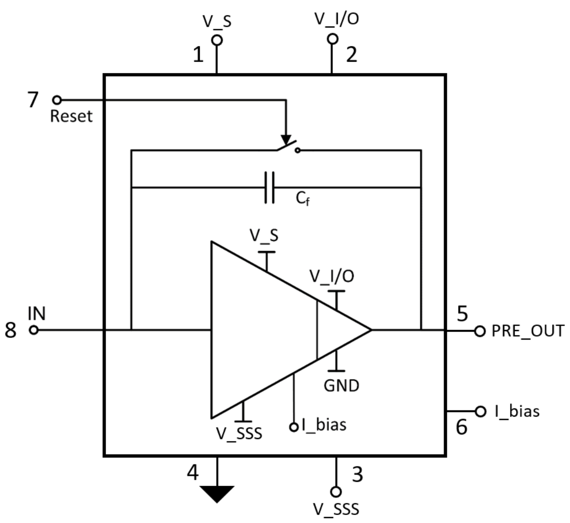
Introduction

CUBE is often supplied as a naked die and it is designed to readout different types of solid-state detectors. The input current is integrated on the feedback capacitor and read as a voltage at the output. The reset signal discharges 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 in most of the applications it is not required.

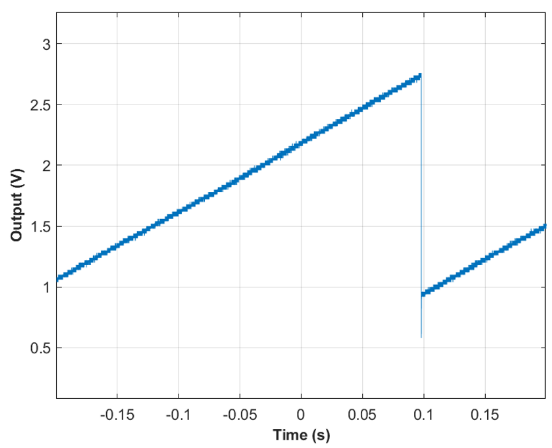
		MIN	NOM.	MAX	UNIT
V_S	Core supply	1.9	2	2.1	V
V_S current	V_S = 2V, V_SSS = -6V		2		mA
V_I/O	I/O supply	4.5	5	5.5	V
V_I/O current	V_I/O = 5V		3		mA
V_SSS	Input current supply	-3	-6	-6	V
V_SSS current	V_S = 2V, V_SSS = -6V		2		mA
I_bias*	Internal current reference control		Not connected		
Reset	Reset signal	0		V_I/O	V
Reset current				1	uA
Temp		-60		50	°C

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

Table 1.



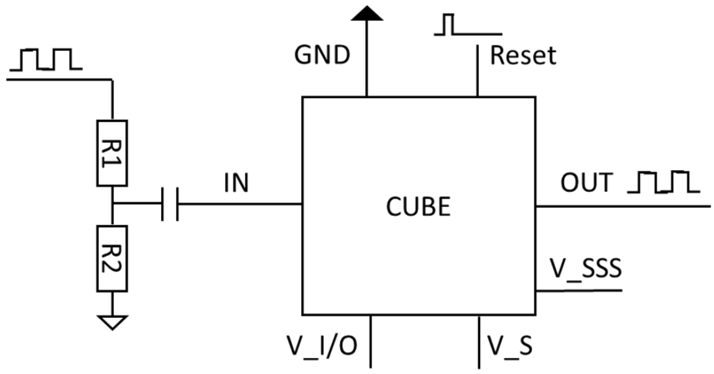
(a)



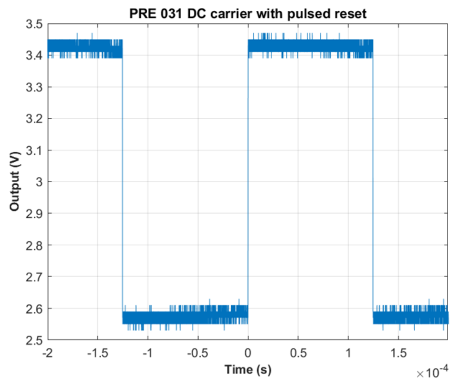
(b)

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.

CUBE can be tested using an AC coupling network connected to the input pad, see **Figure 2**. Using a square waveform signal a charge is induced in the input signal of CUBE which simulates the arrival of charge from the detector. In this case a bipolar signal is produced at the output, equivalent to the injection of positive and negative charges, so this method can be used for any CUBE of the family.



(a)



(b)

Figure 2. (a) CUBE test circuit schematic. (b) Square input test signal and CUBE output. In this case the input signal is a 1Vpp square signal.

Recommended CUBE connections

The bottom surface of the die is connected to the ground pad, thus, it is recommended to have a bottom cooper plate connected to ground and to use conductive or non-conductive resin to fix CUBE to the board. Due to the small dimensions of the dice, thermal expansion is not a big issue in this case, and it is possible to use ceramic or FR4 substrates. The rest of the connections from CUBE to the board and/or detector should be done using wire bonding.

The input signal should be directly bonded to the detector output when possible, otherwise, it is highly recommended to reduce the length of the connection line and to minimize the possible coupling of this signal to noise sources or ground planes.

To improve the stability in the bias voltages of CUBE it is recommended to add additional capacitors between them and ground. Those ceramic capacitors should be placed near CUBE and typical values are 100nF and 10uF.

The I_bias signal does not require a bonding or any input signal. If the signal is bonded, it is recommended to add a ceramic 100nF capacitor.

The output has a maximum driving capability of 30 pF and it is not meant to drive a low resistor. It is recommended to add a buffer stage to separate CUBE from the processing stage. Coupling between the output and the reset signals should be minimized to reduce the charge injection at the end of the reset pulse.

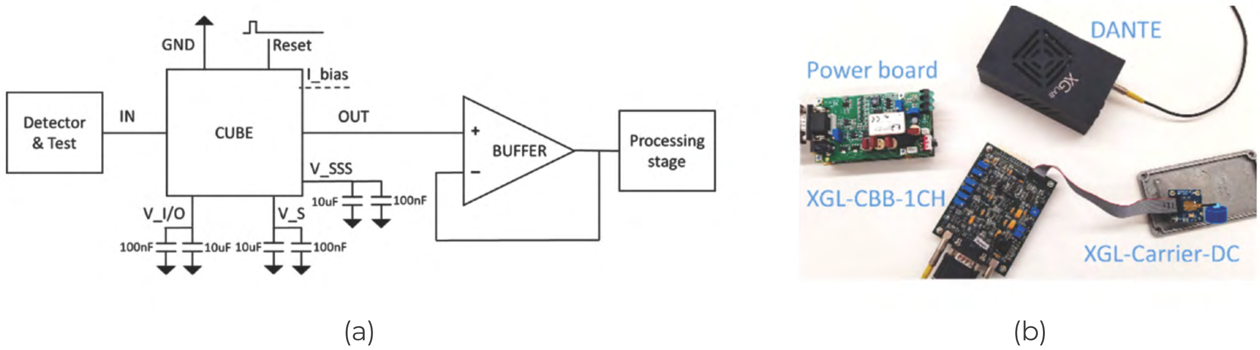


Figure 3. (a) CUBE recommended connections. (b) Example of a setup.

How do I use CUBE with my detector?

The CUBE family offers a wide variety of options (two polarizations, different dynamic range, gain...) to allow the user to find the most appropriate amplifier for his application (see the [App note #1: Find the right amplifier]). When selecting the CUBE, it is important to consider that the performance of the final setup will depend on how CUBE is used, and on the design of the carrier board, but also on the detector performance and the processing of the output signal. The typical setup is composed of a passive filtering of power supply, the detector, CUBE, and a processing stage (**Figure 3**). CUBE is typically used with a pulsed reset signal. The detector leakage current produces a voltage ramp on the output of CUBE (integration of the detector input leakage current) or a voltage step when a charge collection in the detector is produced due to the arrive of radiation (**Figure 4 a**). It is also possible to use CUBE in a continuous mode (no reset signal required) adding a feedback resistor between the output and the input signal. In this case the leakage current of the detector is eliminated while the collected charge produces a peak with a decay period depending on the feedback resistor and the integration capacitor (**Figure 4 b**):

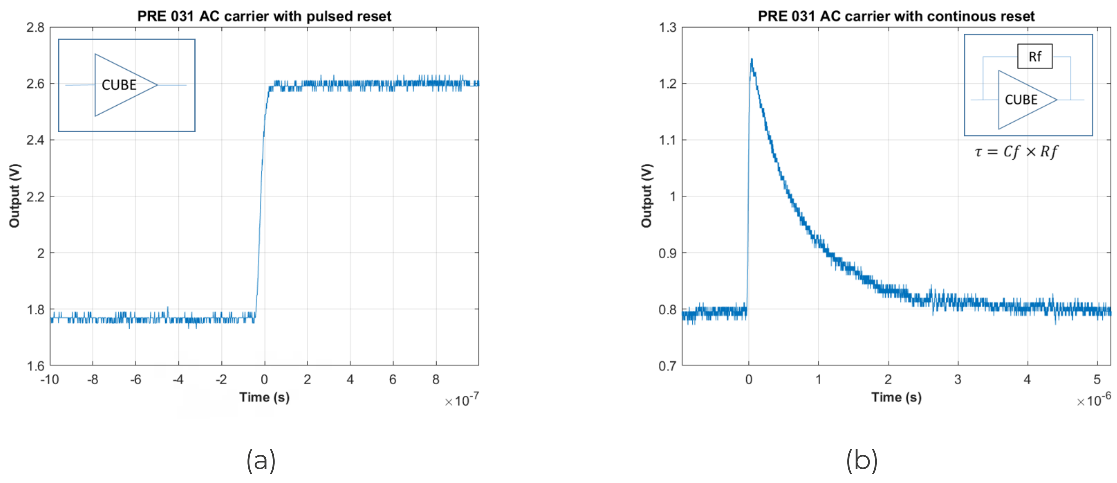


Figure 4. (a) output signal with a pulsed reset. (b) output signal in continuous mode.

The connection of CUBE input to the detector can be done using a direct wire bonding or through a copper line on the board. It has to be taken into account that the noise response of CUBE is strongly dependent on the characteristics of the input connection to the detector, coupling capacitors, length and layout of the input connection. It is also possible to use AC coupling at the input of CUBE if the setup requires so, i.e. when the output of the detector is a high voltage end.

Carrier design considerations:

Considering the requirements of the setup, to design the carrier board for CUBE might consider the following recommendations.

CUBE power supply:

CUBE requires three independent polarizations and a ground connection. It is important the filtering of the power lines to keep CUBE performance. The V_s signal has to be considered as the most critical one and filtering should not be avoided.
Bypass capacitors are used to minimize the high frequency noise into the supply pins of CUBE and should be placed as close as possible to the power pins of CUBE. Capacitors with smaller value (100nF or 1uF) should be placed closer to the device to minimize the influence of the inductance of the trace. It is suggested also to place larger capacitors (10uF) as additional filtering in noisy environment or whnever there is a long connection between the carrier board and the biasing system. See **Figure 5** for an example of a bias filtering network.

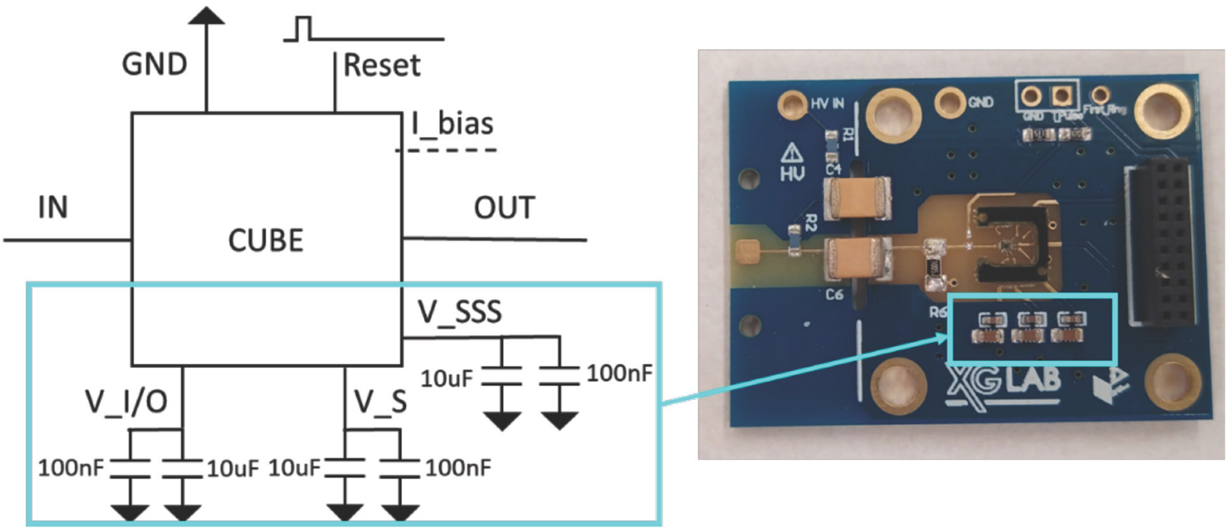
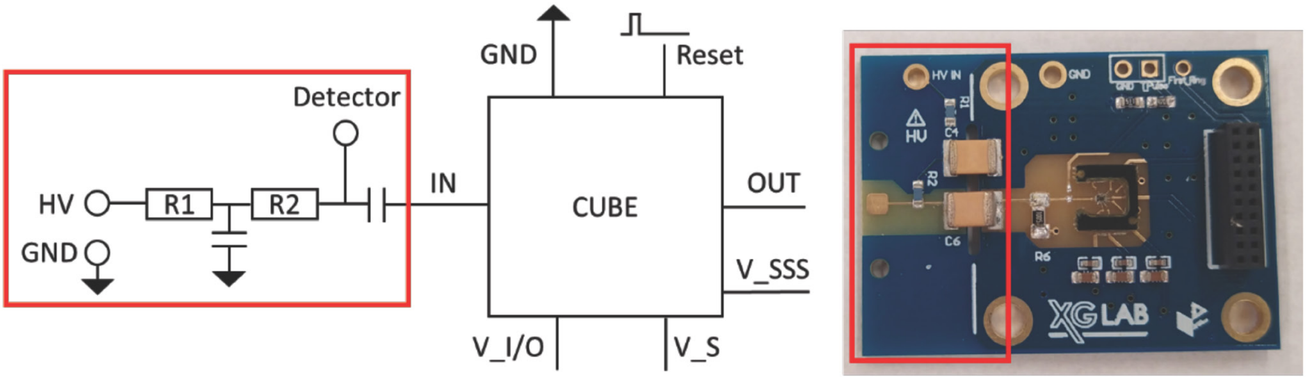


Figure 5. Example of the positioning of the bias filter capacitors in the standard carrier board (XGL-carrier-DC).

High voltage routing:

If the carrier board has high voltage signals to bias the detector it is recommended to keep them separated from the low voltage CUBE routing (**Figure 6**). The first consideration is to separate the ground plane or to eliminate it from the high voltage area to reduce coupling effects. It is also convenient to add a high voltage filter capacitor.
In the case that the detector output to be connected to the CUBE input is connected to the high voltage, it is recommended to use an AC coupling between the high voltage input line and the CUBE input.

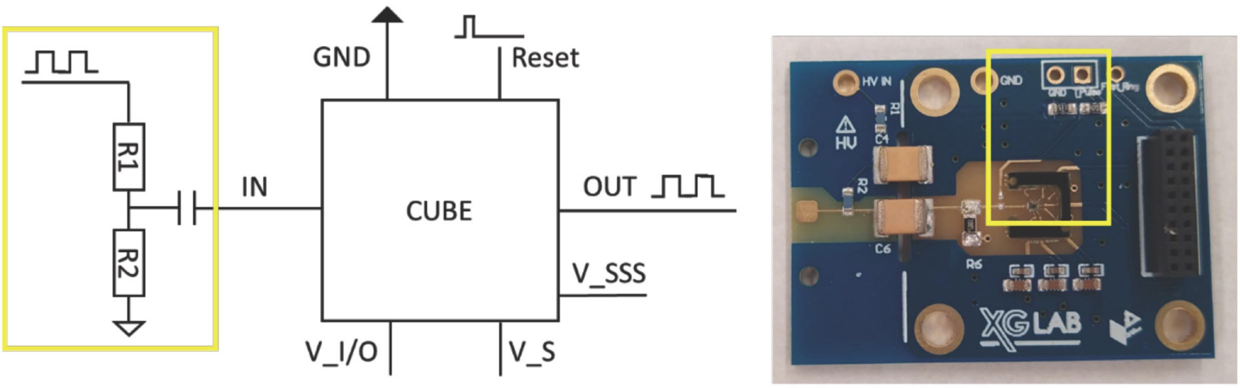


(a) (b)

Figure 6. (a) High voltage AC connection schematic between the detector and CUBE. (b) Standard carrier AC board.

Testing circuit:

To test CUBE behavior, it is possible to couple an AC square signal to the input, see **Figure 7**. It is not required to use a physical capacitor, but it can be used a parasitic capacitor obtained with the solder pads. The test signal line should not be floating when not used. It is recommended to use a voltage divider between the input signal and ground to drive the test line.



(a) (b)

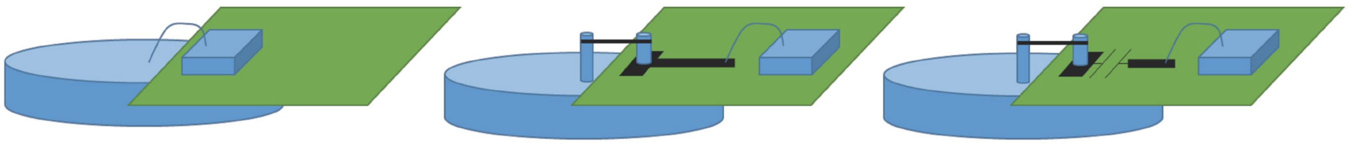
Figure 7. (a) Test circuit schematic. (b) Example of the test circuit in a standard carrier board.

Grounding:

It is important to have a good grounding scheme in CUBE carriers to provide a stable reference without noise. Special care must be taken around the critical lines, the coupling of the ground and the input line should be avoided or reduced as much as possible. It's a good practice to add multiple vias to connect the ground plane on the bottom and top side of the board. Vias can also be used to shield reset line from the output signals.

Input signal routing:

The connection between the detector and the CUBE input should always be as short and direct as possible, see **Figure 8**. As this is not always possible in some cases the connection can be done through the carrier board. These connections add a stray capacitance on CUBE input that reduces the initial performance. The value of this additional capacitance depends on the length of the line, the additional components, and the presence of vias and of course it is also related to the board material. The effect is mainly due to the coupling of the line with the ground plane, for this reason it is recommended to eliminate the ground plane around and under the input line.

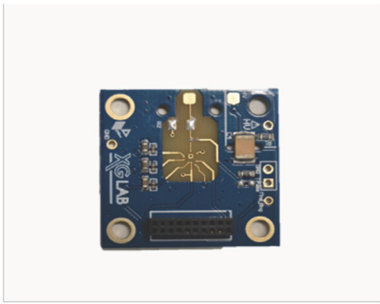


(a) (b) (c)

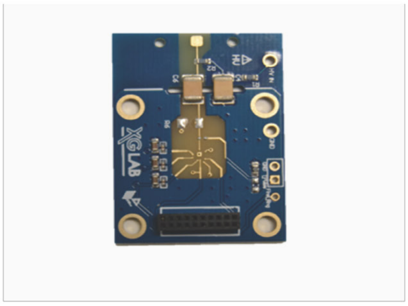
Figure 8. (a) Direct bonding connection between CUBE and a detector.
(b) Wire bonding connection between CUBE and the board, and DC connection between the board and the detector.
(c) Wire bonding connection between CUBE and the board, and AC connection between the board and the detector.

Example of a carrier boards

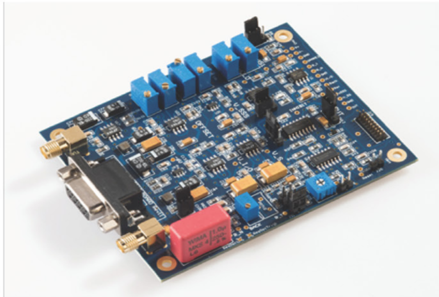
To better understand all the information presented in the previous sections, let's study the standard carriers developed at XGLab for CUBE user beginners, see **Figure 9**. Two different configurations of standard board are available, AC and DC detector connection. The standard board are assembled with one CUBE and can be connected to the 1 channel CUBE bias board (XGL_CBB_1CH) using a high-density flat cable.



XGL-carrier-DC



XGL-carrier-AC



XGL-CBB-1CH for laboratory evaluation

Figure 9. DC standard carrier (XGL-carrier-DC), AC standard carrier (XGL-carrier-AC), 1 channel CUBE bias board (XGL-CBB-1CH).

XGL-Carrier-AC coupled

The schematic of the AC standard carrier is represented in **Figure 10.** The board contains a flat cable connector, a CUBE bonding area (compatible with all the CUBE family), the testing circuit, the power filtering capacitors and the high voltage area to connect the detector output through an AC connection. The board can also be used in a continuous mode by adding the feedback resistor.

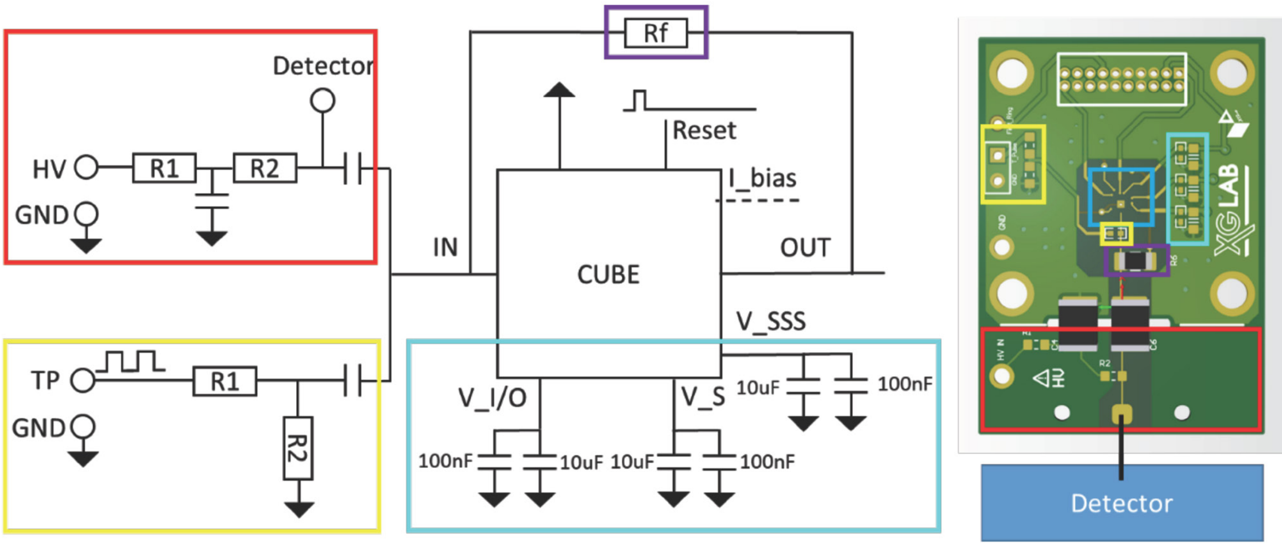


Figure 10. AC standard carrier schematic and layout.

XGL-Carrier-DC coupled:

The schematic of the DC standard carrier is represented in **Figure 11**. The board contains a flat cable connector, a CUBE bonding area (compatible with all the CUBE family), the testing circuit, and the power filtering capacitors. A high voltage area has been added to facilitate the connection to the detector with an additional filter capacitor. Also, in this case it is possible to use the circuit in a continuous mode by adding the feedback resistor.

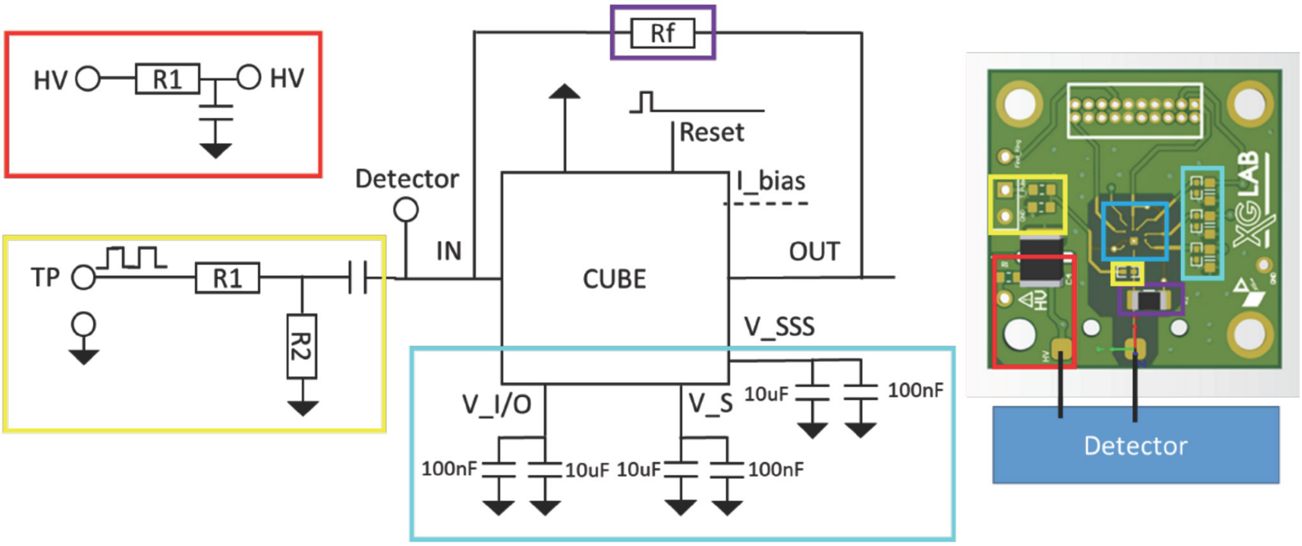


Figure 11. DC standard carrier schematic and layout.

The length of the input line has been minimized to reduce the additional capacitance, and the ground plane around the input has been avoided. A contact plane has been added to allow the connection of the detector avoiding the use of vias, which are an additional source of noise. The test circuit at the input line is also implemented, and the stimulation line is connected to ground when not used. Finally, the board contains the pad opening and the connections to add the feedback resistor and use it a continuous mode.

In both boards, the bypass capacitors are placed near the die polarizations. The typical values are 100nF and 10uF.

Both boards contain a high voltage area with an independent ground plane not connected to CUBE. The high voltage area has an additional bypass capacitor to filter the power line.

The connector is compatible with the one channel bias board, which can provide CUBE polarization, detector high voltages, reset generation and a buffer of the output signal.

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