Rev. 11 - 20 Sept. 2023

A1515

A1515 Series 1-1.4kV/1-3mA HV Reversible Ch. Boards

CAEN
Tools for Discovery

User Manual

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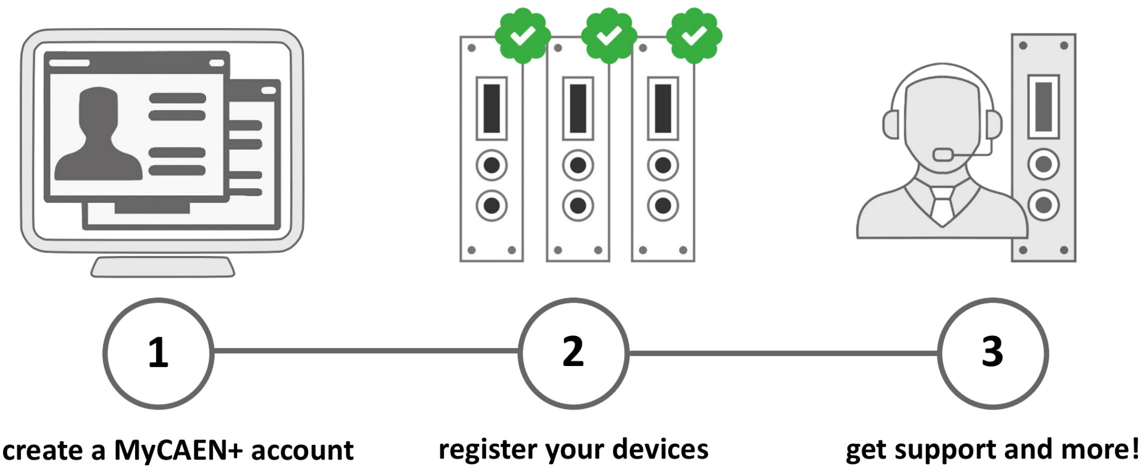

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Purpose of this Manual

This document is the A1515 series 1-1.4kV/1-3mA HV Reversible Ch. Boards user manual; it contains information about the installation, the configuration and the use of the board.

Change Document Record

Date	Revision	Changes
11 November 2015	0	PRELIMINARY Release
10 March 2016	1	Updated Operating modes
10 May 2016	2	Updated Operating modes, Current measure, Channel Characteristic
8 July 2016	3	Updated Channel Characteristic
12 October 2016	4	Updated Output control and monitoring
22 May 2017	5	Updated Operating modes
8 March 2018	6	New specs for A1515QGA
8 February 2019	7	New specs for A1515V
3 December 2020	8	New specs for A1515BTGHP
27 July 2021	9	New specs for A1515B- versions
22 October 2021	10	New front panel pictures
20 September 2023	11	New specs and output power chart for A1515BTGHP

Reference Documents

CAEN SY4527 Universal Multichannel Power Supply System User's Manual

Disclaimer

CAEN will repair or replace any product within the guarantee period if the Guarantor declares that the product is defective due to workmanship or materials and has not been caused by mishandling, negligence on behalf of the User, accident or any abnormal conditions or operations.

CAEN declines all responsibility for damages or injuries caused by an improper use of the Modules due to negligence on behalf of the User. It is strongly recommended to read thoroughly the CAEN User's Manual before any kind of operation. *CAEN reserves the right to change partially or entirely the contents of this Manual at any time and without giving any notice.*

Disposal of the Product *The product must never be dumped in the Municipal Waste. Please check your local regulations for disposal of electronics products.*

Made In Italy: We stress the fact that all the boards are made in Italy because in this globalized world, where getting the lowest possible price for products sometimes translates into poor pay and working conditions for the people who make them, at least you know that who made your board was reasonably paid and worked in a safe environment. (this obviously applies only to the boards marked "Made in Italy", we cannot attest to the manufacturing process of "third party" boards).

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List of Figures

1. General description

A1515 family are single width boards (5 TE wide) that house 14 or 16 independent high voltage Individual Floating channels, delivered through either Radiall or Redel Multipin connectors.

Model	Description	No. of ch.	Output voltage	Current limit	Connector
A1515-B	Floating Board	16	0 ÷ 1 kV	1 mA/100 µA	Radiall 52p
TG-BTG	Floating Board for Triple GEM	14	0 ÷ 1 kV	1 mA/100 µA	Radiall 52p
QG-BQG	Floating Board for Quad GEM	16	0 ÷ 1 kV	1 mA/100 µA	Radiall 52p
QGA-BQGA	Floating Board for Time Projection Chamber	16	0 ÷ 1 kV	1 mA/20 µA	Redel 51p
CG-BCG	Floating Board for Triple Circular GEM	14	0 ÷ 1.3 kV[1]	1 mA/100 µA	Radiall 52p
TGHP-BTGHP	Floating, 3mA (1.5W max) for Triple GEM	14	0 ÷ 1 kV	3mA/300µA (1.5W max)	Radiall 52p
V-BV	Floating Board	16	0 ÷ 1.4 kV	1 mA/100 µA	Radiall 52p

The channels have floating return, independent one from another, insulated up to 5 kV (Full Floating channels).

The output channels offer dual current ranges (software selectable: High Power, High Resolution)

Four special version of the board (A1515TG-BTG, A1515QG-BQG, A1515CG-BCG, A1515TGHP-BTGHP) have been designed specifically for Gas Electron Multiplier (GEM) detectors. These boards have the channels internally stacked to power up 2 independent Triple GEM, Quadruple GEM and Triple Cylindrical GEM chambers. This configuration permits to avoid any possible issue related to the detector discharge and avalanche effects and gives the possibility to fine tune the voltage on each detector layer easily.

A CAEN SY4527 mainframe equipped with 16 A1515TG-BTG, A1515QG-BQG, A1515CG-BCG, A1515TGHP-BTGHP boards can power 32 detectors and the high maximum current available on each channel allows managing the high segmentation of these detectors in the best way. In addition, the 2-quadrant low current range allows a 100 pA current monitoring resolution which allows the monitoring of ion backflow currents and also to perform real-time detector diagnostics.

The A1515QGA is designed to supply Time Projection Chambers.

Safety features includes:

Channels can be enabled or disabled through the Global Interlock logic.

Overvoltage and Undervoltage warning when the output voltage differs from the programmed value.

Safety Board Interlock: this protection disables the HV generation when the HV outputs are not connected to their loads.

Overcurrent detection: when a channel attempts to exceed the programmed current limit, it is signalled to be in "overcurrent" and the channel enter in a TRIP status. The output voltage is varied to keep the current below the programmed limit for a programmable TRIP time. Overcurrent lasting more than set value, causes the following actions:

A1515-B, A1515V-BV or A1515TG-BTG/QG-BQG/QGA-BQGA/CG-BCG/TGHP-BTGHP (not in GEM-mode): the channel is switched off. Output voltage will drop to zero at Ramp-down rate. If TRIP is set to "constant current mode", the channel behaves like a current generator.

A1515TG-BTG/QG-BQG/CG-BCG/ TGHP-BTGHP (in GEM-mode): all stacked channels are switched off following a programmed sequence. Output voltages will drop to zero at Ramp-down rates. If TRIP is set to "constant current mode", the channel behaves like a current generator.

Moreover, are available the following accessories: Mate cable connector and relevant insertion/extraction tool, Multipin to SHV adapter, voltage monitor box.

[1] One channel in each complex channel: 1.3kV; other channels: 1kV

Channel Characteristic Table

Version		V-BV	A1515-B	QG-BQG	QGA-BQGA	TG-BTG	CG-BCG
No. of Channels		16		16 (2 "complex" ch.)		14 (2 "complex" ch.)	
Output Voltage[2]		1.4kV	1 kV				1 kV (ch0, ch7.: 1.3kV)
Polarity		Floating 5 kV					
Max. Output Current	High Power	1 mA					
	High Resolution	100µA			20µA	100µA	100µA
Max. Channel Power		1W	0.7W				
Voltage Set/Monitor Resolution		50 mV	20 mV				50 mV
Current Set Resolution		20 nA					
Current Monitor Resolution	High Power	1 nA			5 nA	1 nA	
	High Resolution	100 pA					
VMAX software		0÷1.4kV	0÷1 kV				0÷1 kV (ch.0, 7: 1.3kV)
VMAX software resolution		1 V					
Ramp Up/Down		1÷100 Volt/sec, 1 Volt/sec step, settable for each channel					
Trip		Max. time an "overcurrent" is allowed to last (seconds); common to all channels in a "complex channel". A channel in "overcurrent" works as current generator: output voltage varies in order to keep the output current lower than the programmed value. "Overcurrent" lasting more than set value, causes the channel to "trip". Output voltage will drop to zero at the Ramp-down rate; in this case the channel is put in the off state. If trip= INFINITE, "overcurrent" lasts indefinitely. TRIP range: 0 ÷ 999.9 s; 1000 s = Infinite. Step = 0.1 s					
Voltage Ripple	differential mode	typical <5mV; max 10mV					
	common mode	typical<10mV; max 15mV					
Voltage Monitor vs. Output Voltage Accuracy		0.2% ±0.2V ±50ppm/°C					
Voltage Set vs. Output Voltage Accuracy		0.2% ±0.2V ±50ppm/°C					
Imon det vs Output current accuracy		0.5% ±5nA ±50ppm/°C with output current from 10% to 100% f.s. and constant voltage 2% ±5nA ±50ppm/°C with output current up to 10% f.s. and constant voltage					
Imon real vs current set accuracy		2% ±100nA					
Power consumption		90W full power for A1515 (16CH); 80W standby consumer					

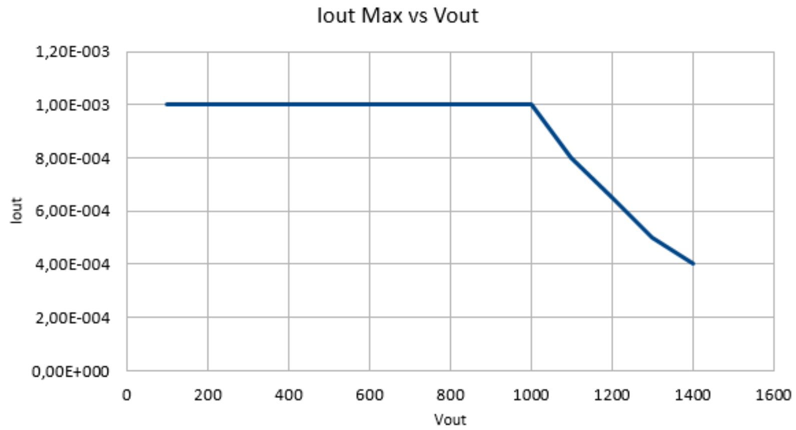
Specifications of models A1515TGHP-BTGHP[3]

No. of Channels		14 (2 "complex" ch.)	
		0, 2, 4, 6, 7, 9, 11, 13	1, 3, 5, 8, 10, 12
Output Voltage		50÷1000 V	50÷600V
Max. Output Current	High Power	500nA÷1mA	500nA÷3mA
	High Resolution	500nA÷100µA	500nA÷300µA
Max Channel Power		0.7W	1.5W
Voltage Set/Monitor Resolution		20mV	20mV
Current Set Resolution		20nA	50nA
Current Monitor	Resolution High Power	1nA	4nA
	Resolution High Resolution	100pA	400pA
Vmax Software		1kV	600V
Voltage Ripple	differential mode	typical <5mV; max 10mV	
	common mode	typical<15mV; max 20mV	

[2] A1515B- versions require minimum set voltage and current 50V and 500nA respectively
[3] All other specifications are the same of other versions

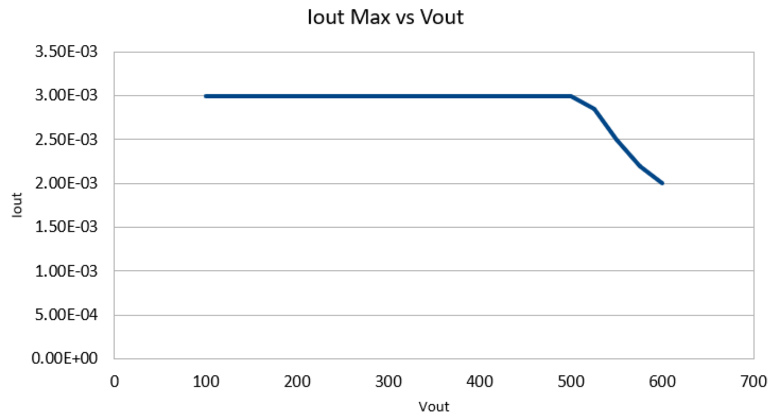
A1515V Output Power vs VSet Chart

Vset (V)	Iout (A)	Power Out (W)
100	1,00E-003	0,1
200	1,00E-003	0,2
300	1,00E-003	0,3
400	1,00E-003	0,4
500	1,00E-003	0,5
600	1,00E-003	0,6
700	1,00E-003	0,7
800	1,00E-003	0,8
900	1,00E-003	0,9
1000	1,00E-003	1
1100	8,00E-004	0,88
1200	6,50E-004	0,78
1300	5,00E-004	0,65
1400	4,00E-004	0,56



A1515BTGHP Output Power vs VSet Chart

Vset (V)	Iout (A)	Power Out (W)
100	3.00E-03	0.3
200	3.00E-03	0.6
300	3.00E-03	0.9
400	3.00E-03	1.2
500	3.00E-03	1.5
525	2.85E-03	1.49625
550	2.50E-03	1.375
575	2.20E-03	1.265
600	2.00E-03	1.2



Front Panel

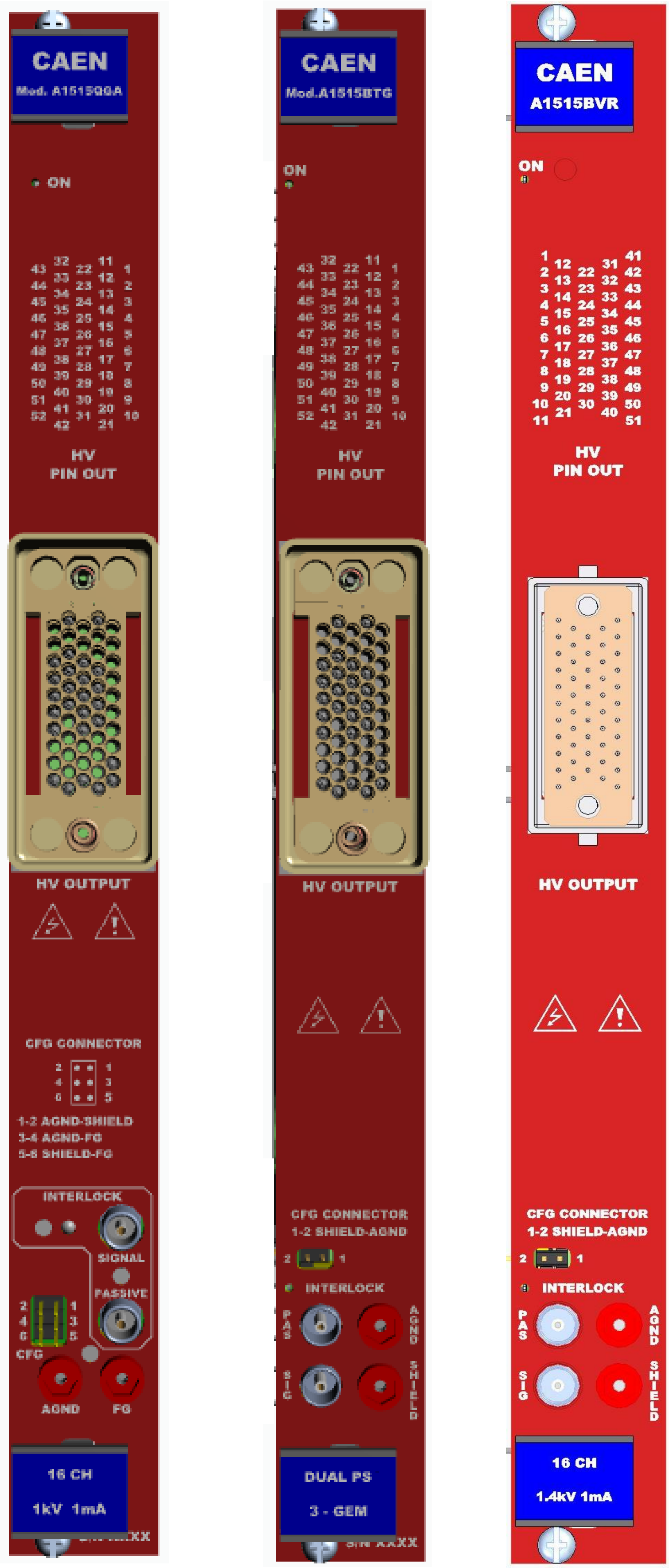


Fig. 1: A1515-, A1515B-, A1515BQGA-BVR Front panel

Packaging

Single width (5 TE); height is 6U.

Displays

ON LED	lights up as at least one channel is on
POWER GOOD	Board correctly powered
WARNING	Warning status detected (over current, over/under voltage, trip, external disable)
INTERLOCK LED	*Function:* Red LED. Lights up as the board is in INTERLOCK (channel are disabled).

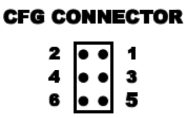
External connections

The function and electro-mechanical specifications of the external connectors are listed in the following subsections.

Output Channels	A1515, -(B)QG, -(B)TG, -(B)TGHP, -(B)CG, -(B)TGHP: Multipin connector Radiall 691803004 type, 52 pin male (to be mated with Radiall 691802002 [*SCEM 09.41.34.700.2*] type[4]); Available accessories: cable connector (Mod. A996) insertion/extraction tool (Mod. A995) A1515 -(B)QGA: Multipin connector REDEL SLG.H51; contact part no.: FFA.05.403.ZLA2 (male), ERA.05.403.ZLL2 (female)
ILK Signal/Passive	No.2 00-type LEMO connector

Configuration jumpers

The Connector Configurator allows to optimize the connection of the shield, of the return and of AGND (Earth); see also p.25.

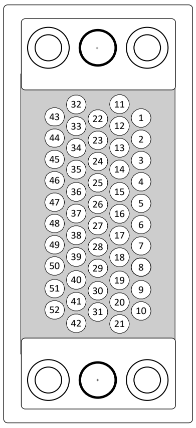


1-2	Agnd - Shield	Connects Agnd (Earth) to HV cable shield	
3-4	Agnd - Return	Connects Agnd (Earth) to HV channels return	Not available on A1515B
5-6	Shield - Return	Connects Shield to HV channels return	Not available on A1515B

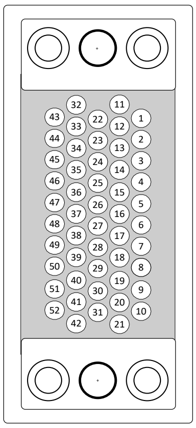
[4] Requires 52 pins Radiall 691804300 [*SCEM 09.41.33.830.7*] type, to be inserted using the insertion/extraction tool Radiall 282549024 [*SCEM 34.95.17.125.3*] type.

Multipin connector pin assignment A1515, [B]QG, [B]TG, [B]TGHP, [B]CG, [B]V

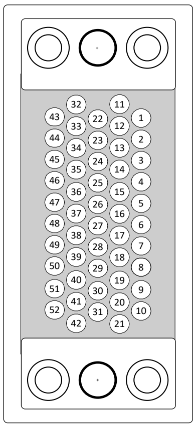
A1515, A1515V									
1	NC	11	RETURN [5]	22	NC	32	RETURN	43	NC
2	NC	12	NC	23	NC	33	NC	44	NC
3	-HVOUT 11	13	NC	24	+HVOUT 6	34	+HVOUT 3	45	+HVOUT 0
4	+HVOUT 12	14	+HVOUT 9	25	-HVOUT 6	35	-HVOUT 3	46	-HVOUT 0
5	-HVOUT 12	15	-HVOUT 9	26	+HVOUT 7	36	+HVOUT 4	47	+HVOUT 1
6	+HVOUT 13	16	+HVOUT 10	27	-HVOUT 7	37	-HVOUT 4	48	-HVOUT 1
7	-HVOUT 13	17	-HVOUT 10	28	+HVOUT 8	38	+HVOUT 5	49	+HVOUT 2
8	+HVOUT 14	18	+HVOUT 11	29	-HVOUT 8	39	-HVOUT 5	50	-HVOUT 2
9	SAFETY LOOP	19	-HVOUT14	30	-HVOUT 15	40	NC	51	NC
10	SAFETY LOOP	20	+HVOUT 15	31	SHIELD	41	NC	52	SHIELD
		21	RETURN			42	RETURN		



A1515QG									
1	NC	11	RETURN	22	NC	32	RETURN	43	NC
2	NC	12	NC	23	NC	33	NC	44	NC
3	NC	13		24	B_Anode	34	A_GEM2 Bot	45	A_Anode
4	NC	14	B_GEM2 Bot	25	B_GEM4 Bot	35	A_GEM2 Top	46	A_GEM4 Bot
5	NC	15	B_GEM2 Top	26	B_GEM4 Top	36	A_GEM1 Bot	47	A_GEM4 Top
6	NC	16	B_GEM1 Bot	27	B_GEM3 Bot	37	A_Cathode	48	A_GEM3 Bot
7	NC	17	B_Cathode	28	B_GEM3 Top	38		49	A_GEM3 Top
8	NC	18	NC	29	NC	39	NC	50	NC
9	SAFETY LOOP	19	NC	30	NC	40	NC	51	NC
10	SAFETY LOOP	20	NC	31	SHIELD	41	NC	52	SHIELD
		21	RETURN			42	RETURN		



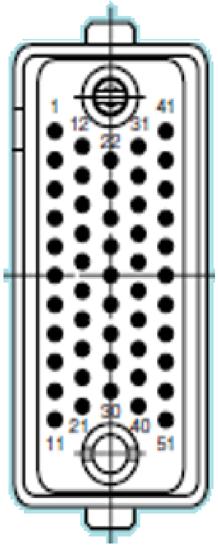
A1515TG/ CG/TGHP / BTGHP									
1	NC	11	RETURN	22	NC	32	RETURN	43	NC
2	NC	12	NC	23	NC	33	NC	44	NC
3	NC	13	NC	24	B_Anode	34	A_GEM1 Bot	45	A_Anode
4	NC	14	B_GEM1 Bot	25	B_GEM3 Bot	35	A_GEM1 Top	46	A_GEM3 Bot
5	NC	15	B_GEM1 Top	26	B_GEM3 Top	36	A_Cathode	47	A_GEM3 Top
6	NC	16	B_Cathode	27	B_GEM2 Bot	37	NC	48	A_GEM2 Bot
7	NC	17	NC	28	B_GEM2 Top	38	NC	49	A_GEM2 Top
8	NC	18	NC	29	NC	39	NC	50	NC
9	SAFETY LOOP	19	NC	30	NC	40	NC	51	NC
10	SAFETY LOOP	20	NC	31	SHIELD	41	NC	52	SHIELD
		21	RETURN			42	RETURN		



[5] Return= ground float channel
Return is a shielding reference for the HV channels; it can be used as reference for external filters, and it is available on the 52pin output connector. If it is not used, it must be wired to AGND via front panel jumpers.
Configuration schemes: the safety rules are the same for both shield and HV modules.

Multipin connector pin assignment A1515 -[B]QGA

PIN	CH	Pin code (Board/Male)	Pin code (Cable/Female)
13	ANODE-0 (AGND)	FFA.05.403.ZLA2	ERA.05.403.ZLL2
2	CH0	FFA.05.403.ZLA2	ERA.05.403.ZLL2
3	CH1	FFA.05.403.ZLA2	ERA.05.403.ZLL2
4	CH2	FFA.05.403.ZLA2	ERA.05.403.ZLL2
5	CH3	FFA.05.403.ZLA2	ERA.05.403.ZLL2
6	CH4	FFA.05.403.ZLA2	ERA.05.403.ZLL2
7	CH5	FFA.05.403.ZLA2	ERA.05.403.ZLL2
8	CH6	FFA.05.403.ZLA2	ERA.05.403.ZLL2
9	CH7	FFA.05.403.ZLA2	ERA.05.403.ZLL2
39	ANODE-1 (AGND)	FFA.05.403.ZLA2	ERA.05.403.ZLL2
50	CH8	FFA.05.403.ZLA2	ERA.05.403.ZLL2
49	CH9	FFA.05.403.ZLA2	ERA.05.403.ZLL2
48	CH10	FFA.05.403.ZLA2	ERA.05.403.ZLL2
47	CH11	FFA.05.403.ZLA2	ERA.05.403.ZLL2
46	CH12	FFA.05.403.ZLA2	ERA.05.403.ZLL2
45	CH13	FFA.05.403.ZLA2	ERA.05.403.ZLL2
44	CH14	FFA.05.403.ZLA2	ERA.05.403.ZLL2
43	CH15	FFA.05.403.ZLA2	ERA.05.403.ZLL2
22	SAFETY LOOP	FGG.2B565.ZZC	EGG.3B.665.ZZM
30	SAFETY LOOP	FGG.2B565.ZZC	EGG.3B.665.ZZM
1	*G.F.C.*	*FGG.2B565.ZZC*	*EGG.3B.665.ZZM*
11	*G.F.C.*	*FGG.2B565.ZZC*	*EGG.3B.665.ZZM*
12	*G.F.C.*	*FGG.2B565.ZZC*	*EGG.3B.665.ZZM*
21	*G.F.C.*	*FGG.2B565.ZZC*	*EGG.3B.665.ZZM*
40	*SHIELD*	*FGG.2B565.ZZC*	*EGG.3B.665.ZZM*
51	*SHIELD*	*FGG.2B565.ZZC*	*EGG.3B.665.ZZM*



ITALIC: pin for HV filter reference (G.F.C.= ground filter connection) and shield; N.B. such connections could not be used and are grounded via jumpers.

Channel organisation

The control software identifies the output channels of the A1515(B)QG, A1515(B)QGA and A1515(B)TG as follows:

Mod.	Ch.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A1515QG-QGA	Pin+/-	45 46	46 47	47 48	48 49	49 34	34 35	35 36	36 37	24 25	25 26	26 27	27 28	28 14	14 15	15 16	16 17
A1515TG/CG/TGHP	Pin+/-	45 46	46 47	47 48	48 49	49 34	34 35	35 36	24 25	25 26	26 27	27 28	28 14	14 15	15 16		

2. Safety and installation requirements

General safety information

N.B. read carefully the "Precautions for Handling, Storage and Installation" document provided with the product before starting any operation!

This section contains the fundamental safety rules for the installation and operation of the board. Read thoroughly this section before starting any procedure of installation or operation of the product.

Injury Precautions

Review the following precautions to avoid injury and prevent damage to this product or any products connected to it. To avoid potential hazards, use the product only as specified. Only qualified personnel should perform service procedures.

Avoid Electric Overload.

To avoid electric shock or fire hazard, do not power a load outside of its specified range.

Avoid Electric Shock.

To avoid injury or loss of life, do not connect or disconnect cables while they are connected to a voltage source.

Do Not Operate Without Covers.

To avoid electric shock or fire hazard, do not operate this product with covers or panels removed.

Do Not Operate in Wet/Damp Conditions.

To avoid electric shock, do not operate this product in wet or damp conditions.

Do Not Operate in an Explosive Atmosphere.

To avoid injury or fire hazard, do not operate this product in an explosive atmosphere.

Do Not Operate with Suspected Failures.

If you suspect this product to be damaged, have it inspected by qualified service personnel.

Safety Terms and Symbols on the Product

These terms may appear on the product:

DANGER indicates an injury hazard immediately accessible as you read the marking.

WARNING indicates an injury hazard not immediately accessible as you read the marking.

CAUTION indicates a hazard to property including the product.

The following symbols may appear on the product:

	**DANGER** **High Voltage**		**WARNING** **Refer to Manual**

Installation

The Mod. A1515 is a SYx527 board. At power ON the SYx527 System, the processor will scan all the slots in the crate to find out where the module is plugged and what kind of module it is.

N.B.: the ventilation fan speed must be set to HIGH or MEDIUM

3. Operating modes

The Mod. A1515 board can be controlled, either locally or remotely, through the SYx527 System software interface. For details on SYx527 System operation, please refer to the User's Manual of this product. The following sections contain a description of commands available for the board control and status monitoring.

Output control and monitoring

OP_Mode: board setting; the A1515-A1515B-TG/QG/CG/TGHP can work either in GEM or FREE mode. In GEM mode when one channel is turned On/Off, all other channel within the same Complex channel are turned On/Off, according to *OnOrder/ OffOrder* setting. In FREE mode the channels are independent.

For each output channel, it is possible, through the System, to access the following parameters:

CHANNEL NAME (settable)	descriptive name for the relevant channel
V0SET (settable)	the first of the two allowed voltage programmable values.
I0SET (settable)	the first of the two allowed current limit programmable values
V1SET (settable)	the second of the two allowed voltage programmable values
I1SET (settable)	the second of the two allowed current limit programmable values
RUp (settable)	the Ramp-Up parameter value, i.e., the maximum voltage programmable increase rate.
RDWn (settable)	the Ramp-Down parameter value, i.e., the maximum voltage programmable decrease rate.
TRIP (settable)	the TRIP parameter value, i.e., the maximum time an Over Current condition is allowed to last.
SVMAX (settable)	the maximum voltage value programmable for the channel. If the value set as SVMAX is less than the current value of the V0SET/ V1SET parameter, the latter will automatically decrease to the SVMAX value.
VMON (monitor)	monitored voltage value
IMON (monitor)	monitored current value
IMonReal *(monitor)*	module calibration current; this parameter is not adjusted; it is factory calibrated and is used for the protection threshold.
ImonDet *(monitor)*	monitors exclusively the current on the GEM
ImRange *(settable):*	Sets current range (high or low). When LOW is selected, ISET can be set in the 0 ÷ 100 µA range for 1000µA channels and in the 0 ÷ 300 µA range for 3000 µA channels
STATUS (monitor)	it displays the channel status.
PW (ON/OFF)	the Power parameter shows the ON/OFF channel status. As this parameter is set ON, the channel is switched on (if the INTERLOCK is not active and if the channel is enabled either locally or remotely) highlighted in green when channel ON; onstate = ON; offstate = OFF
OnOrder (settable)	With A1515TG/QG/CG/TGHP in GEM mode allows to set the turning on sequence (setting: 1st channel and the other ones following in cascade; example A1515TG: 3, 4, 5, 6, 1, 2)
OffOrder (settable)	With A1515TG/QG/CG/TGHP in GEM mode allows to set the turning off sequence (setting: 1st channel and the other ones following in cascade; example A1515TG: 4, 5, 6, 1, 2, 3)
ZCDetect (settable)	On: enable the detection of leakage currents Off: disable the detection of leakage currents
ZCAdjust (settable)	En: the current offset due to leakage currents on cascaded channels is compensated Dis: the current offset due to leakage currents on cascaded channels is not compensated

The following messages may be returned by the SYx527 System when monitoring the channel status:

OFF (channel turned OFF)
RUP (channel ramping up)
RDWN (channel ramping down)
OVC (channel in OVERCURRENT condition)
OVV (channel in OVERVOLTAGE condition)
UNV (channel in UNDERVOLTAGE condition)
EXT_DIS (channel disabled by board INTERLOCK protection)

Moreover, it is possible to monitor board temperature and to check board status; the following messages may be returned by the System when monitoring the board status:

UNDER_TEMP (board temperature < 5°C)
OVER_TEMP (board temperature > 65°C)

GEM Architecture and HV distribution

One GEM (Gas Electron Multiplier) is composed by a drilled kapton sheet coated with copper on both sides.

As the two copper sides are biased, the resulting field intensity ignites avalanche multiplication processes through the holes.

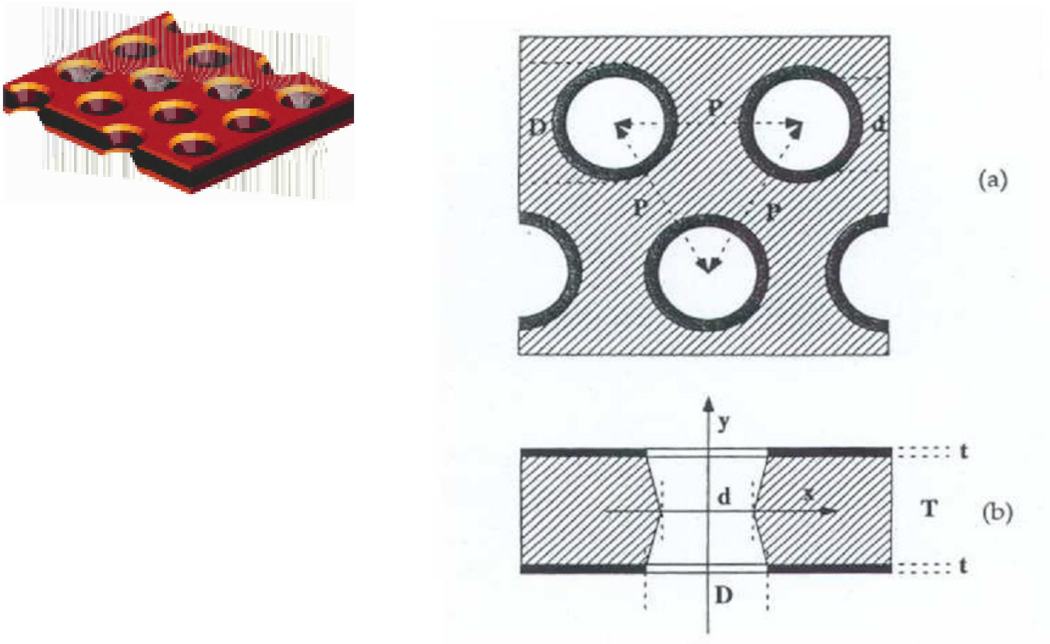


Fig. 2: GEM section

The kapton is typically 50µm thick, the copper coatings are typically 5µm instead. Holes have dual cone section with 70µm and 50µm typical maximum and minimum diameters; pitch is typically 140µm.

Bias voltage is typically in the 300÷500V range, thus producing ~100kV/cm fields inside the holes. Resulting gain is larger than 10000.

When one GEM is placed between two plain parallel electrodes, that is a single GEM detector.

The anode is a PCB collecting the detector signals;

the space between cathode and GEM is called drift gap

the space between GEM and anode is called induction gap

As the anode is grounded and the cathode has negative bias, the electric fields are uniform within the gaps and are called drift field and induction field respectively.

When one ionizing particle shoots through the field, electron-ion couples are produced inside the drift gap.

The ions travel towards the cathode; the electrons enter the GEM holes and are thus multiplied; the ions produced by the multiplication are partially collected by the GEM negative side and partially travel towards the cathode.

With proper electric field values, the multiplication zone is emptied quickly (~100ns).

Only a small number of the multiplied electrons are collected by the GEM positive side; the largest number is led to the induction zone, producing the signal on the anode.

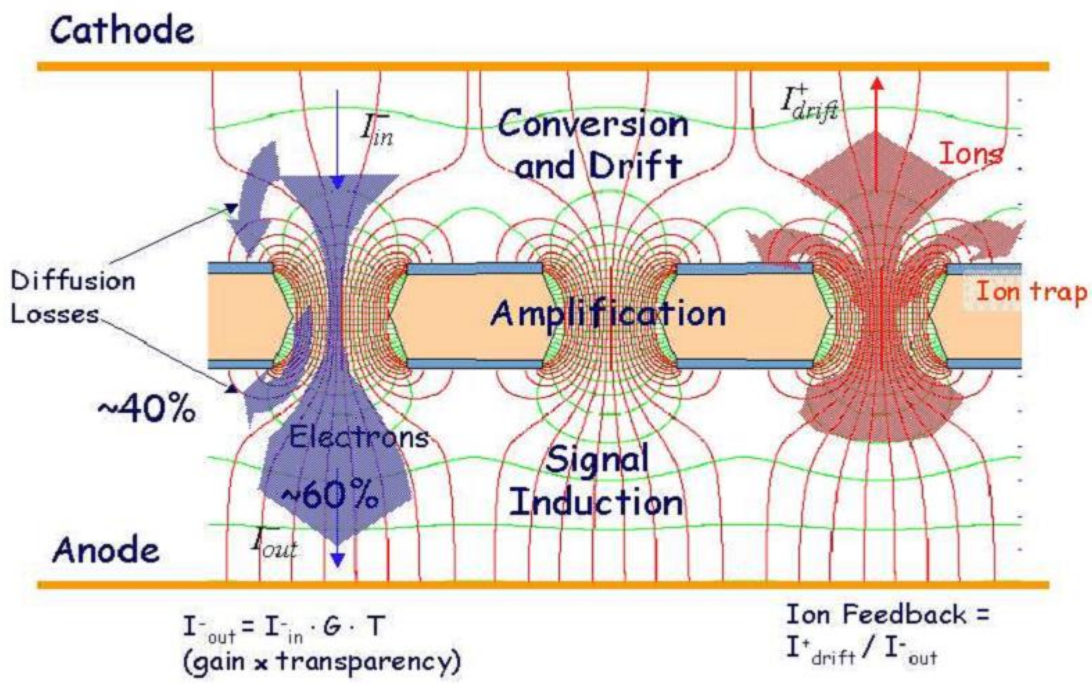


Fig. 3: GEM charge distribution

The single GEM description allows to understand how multiple GEM detectors work: a triple GEM detector is composed by 3 cascaded GEM sheets between cathode and PCB; the use of 3 GEMs allows to obtain larger gain values, and, most importantly, the multiple gain stages, reduce the possibility of discharge phenomena inside the detector.

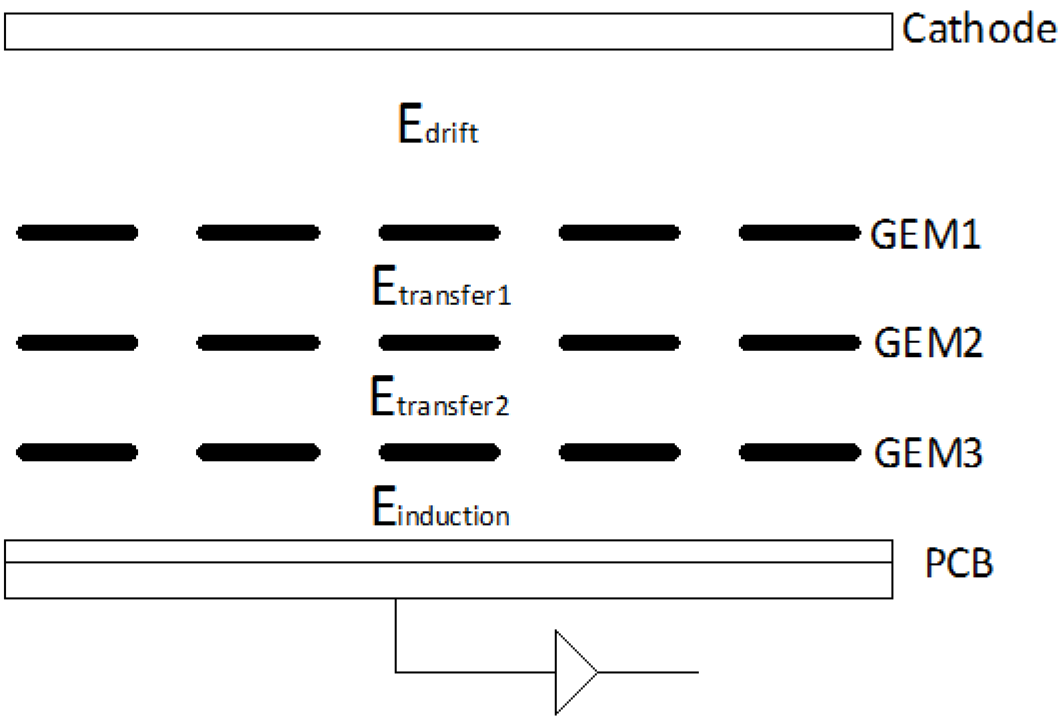


Fig. 4: Triple GEM voltage distribution

GEM HV bias with the A1515

The A1515 allows to set the channels turning on/off priority (ON/OFF order parameter; see p.12.): this feature allows to avoid damages to the GEMs when discharges occur. The reported measures are performed on the A1515TG.

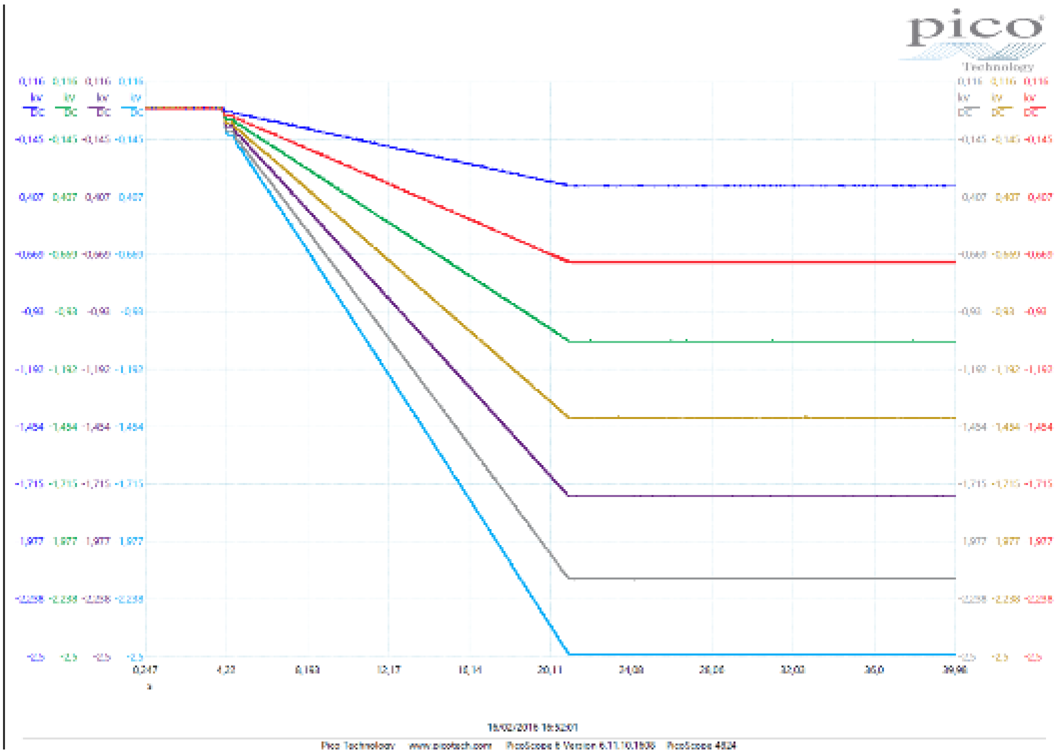


Fig. 5: turning on for 7 channels with same priority

Each trace corresponds to one channel of the GEM macro channel.

Board channel	Trace color	GEM label	HV channel operating zone
ch0	blue	Bottom 3	Induction
ch1	red	Top 3	GEM3
ch2	green	Bottom 2	Transfer2
ch3	yellow	Top 2	GEM2
ch4	violet	Bottom 1	Transfer1
ch5	gray	Top 1	GEM1
ch6	cyan	cathode	Drift

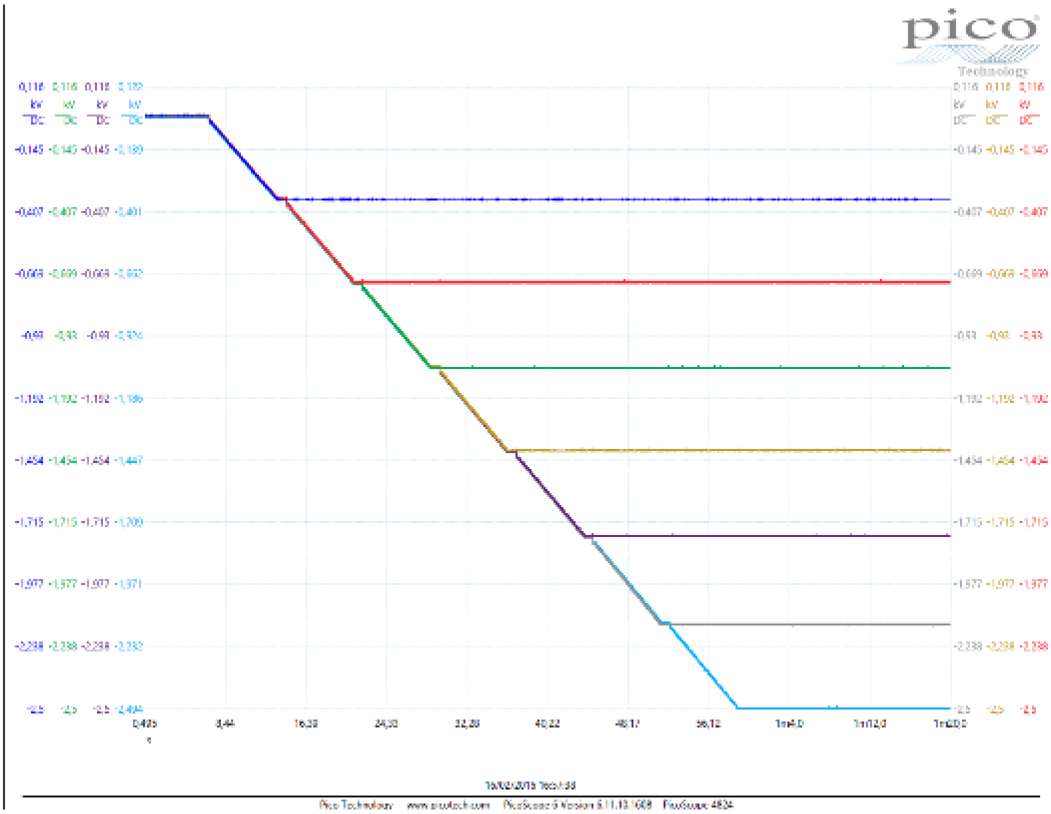


Fig. 6: turning on with ramp priority 1 to 7

The board is set to GEM mode: the two macro channels are independent; the 7 channels of each macro share group settings: all the channels in a macro are turned on as one of them is switched on, but it is possible to set independently ramp speed, turning on/off priority, trip time, iset, izoom, channel offset.

Figure 6 shows the channels without turning on priority (GEM mode turning on); figure 7 shows turning on, with ch0 priority = 1; ch1 priority = 2 (lower number = higher priority).

Figures 8 and 9 show turning off with same settings of figures 6-7.

Figure 10 shows turn off and on sequence with different priorities (usually the Transfers are turned on in the first place; the GEMs are turned on as the Transfers are up and running)

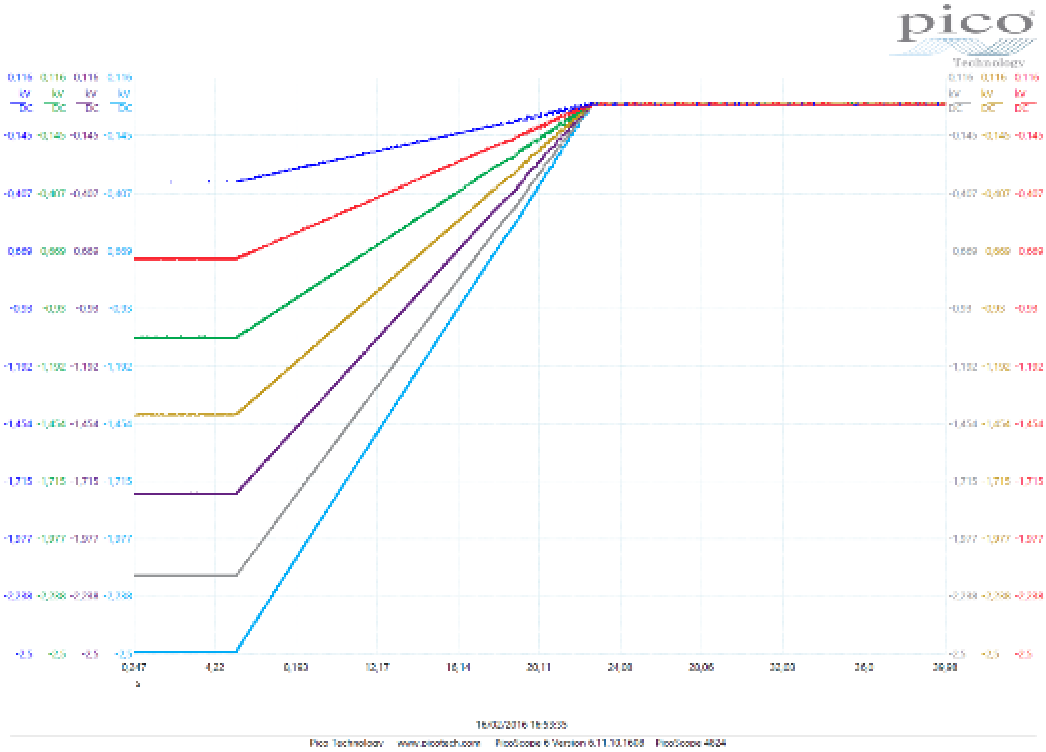


Fig. 7: turning off with ramp and same priority for all channels

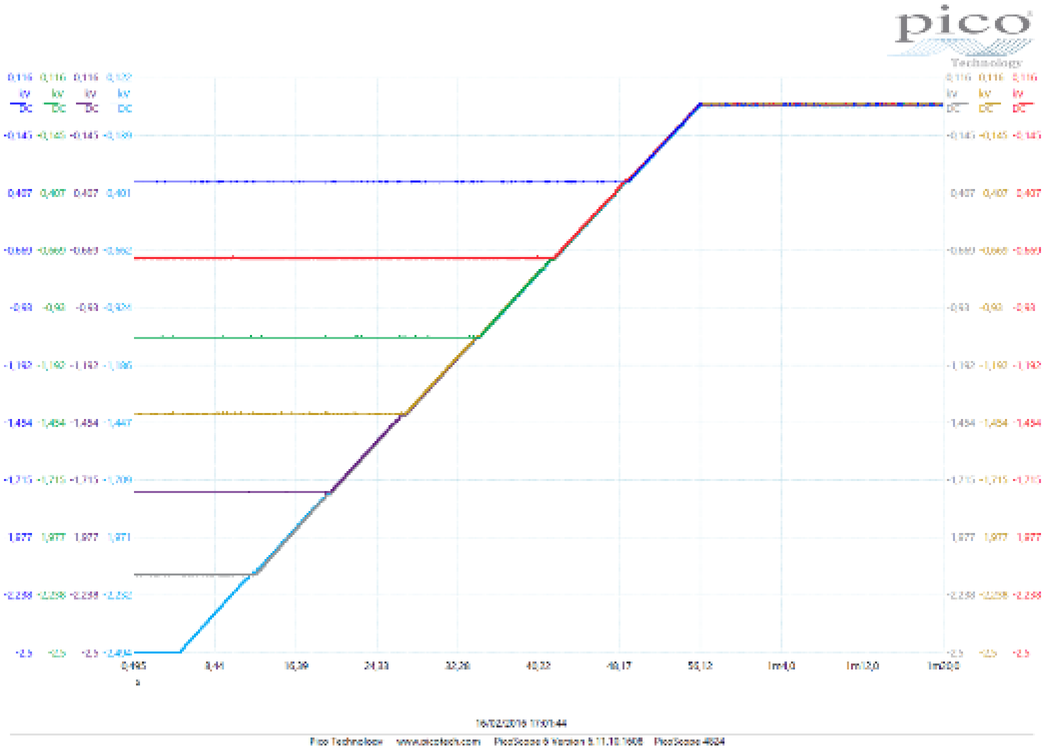


Fig. 8: turning off with ramp and priority 1 to 7 (absolute measure)

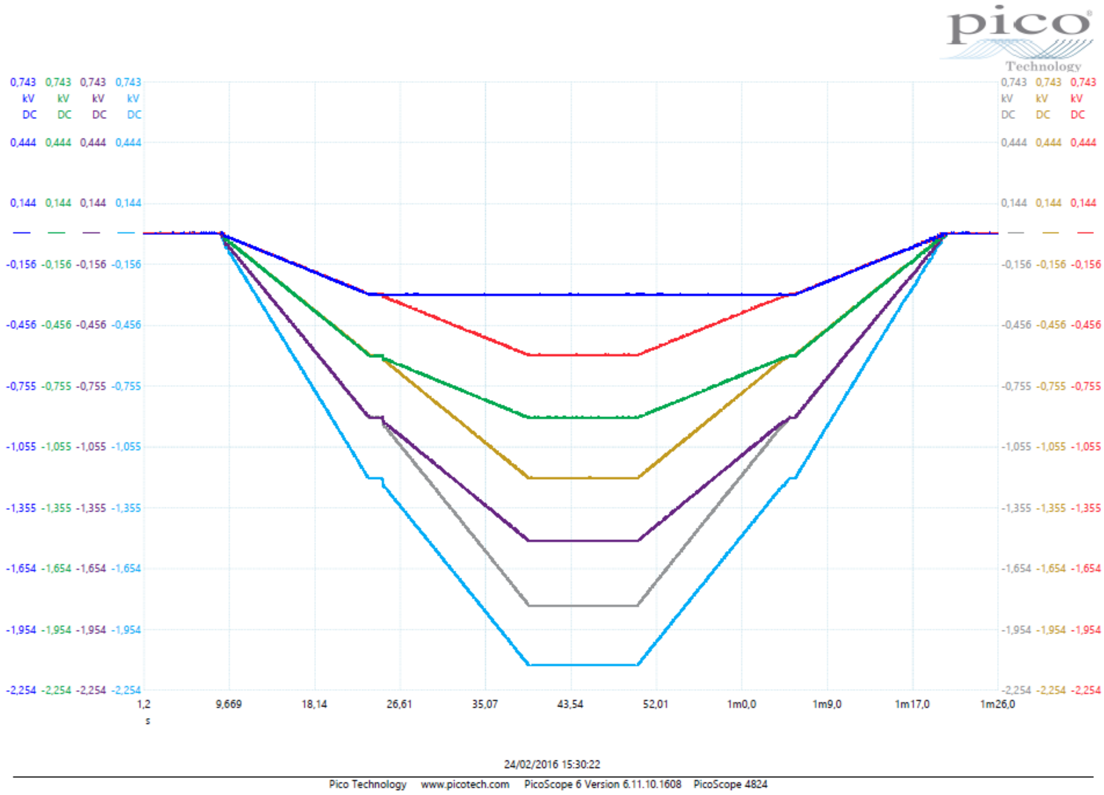


Fig. 9: turning ON/OFF with priority "Transfer GEM and GEM Transfer"

GEM's are simple detectors, but can be damaged by HV discharges during operation. The power supply board must therefore guarantee discharge protection, switching from voltage to current control when needed, as well as to provide turning off with assigned priorities.

To ensure detector long life, the OVC control of the typical HV channel must withstand possible discharges, related to events intensity: the HV board must avoid damages through the protection features: when the channel trip turning off is activated, a new feature damps the "rebound" effect caused by particular working voltage and current.

If we consider a typical discharge event and trace the voltage vs time, the voltage value will decrease until the discharge current will cross the protection threshold; the channel will therefore catch up with the voltage loop until the set value is reached; if the discharge event is repeated, then rebound takes place. At each discharge cycle, the dielectric is damaged, until the detector fails; this may happen especially with long turning off ramps. The anti-rebound feature implemented in the board works as follows:

As the turning off sequence is started, the voltage programmed on the channel in protection mode is reduced by 10%: for this reason, as the channel exits the protection mode, it will not catch up on the starting value minus "ramp down * recovery time" voltage, but it will be 90% of starting value minus "ramp down * recovery time" voltage; from this value, it will start ramping until turning off.

Example:

case without anti rebound:

- programmed voltage =300V
- ramp down =10V/s
- channel recovery time =1sec
- channel will catch up at = 300-10 =290V

case with anti-rebound:

- programmed voltage =300V
- ramp down =10V/s

- channel recovery time =1sec
- protection = 10% of 300V
- channel will catch up at = 300-10-30 =260V

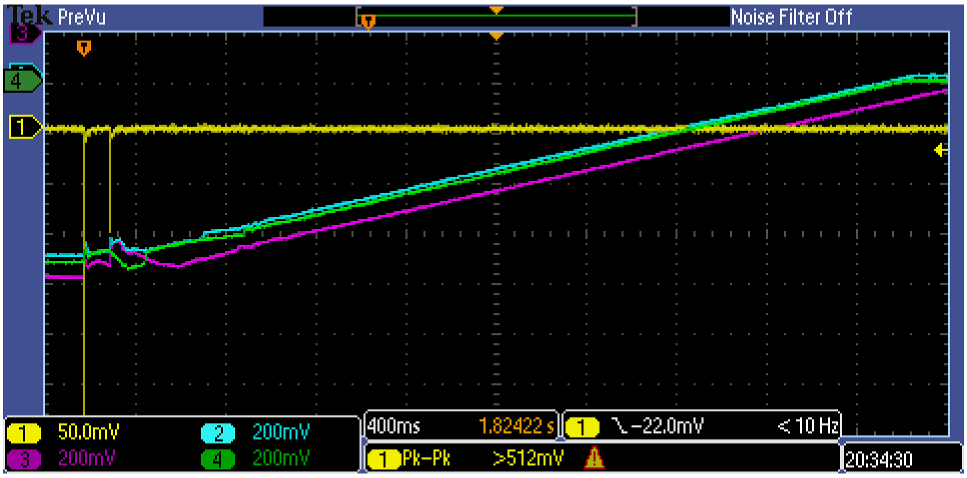


Fig. 10: rebound during turning off (without anti rebound)

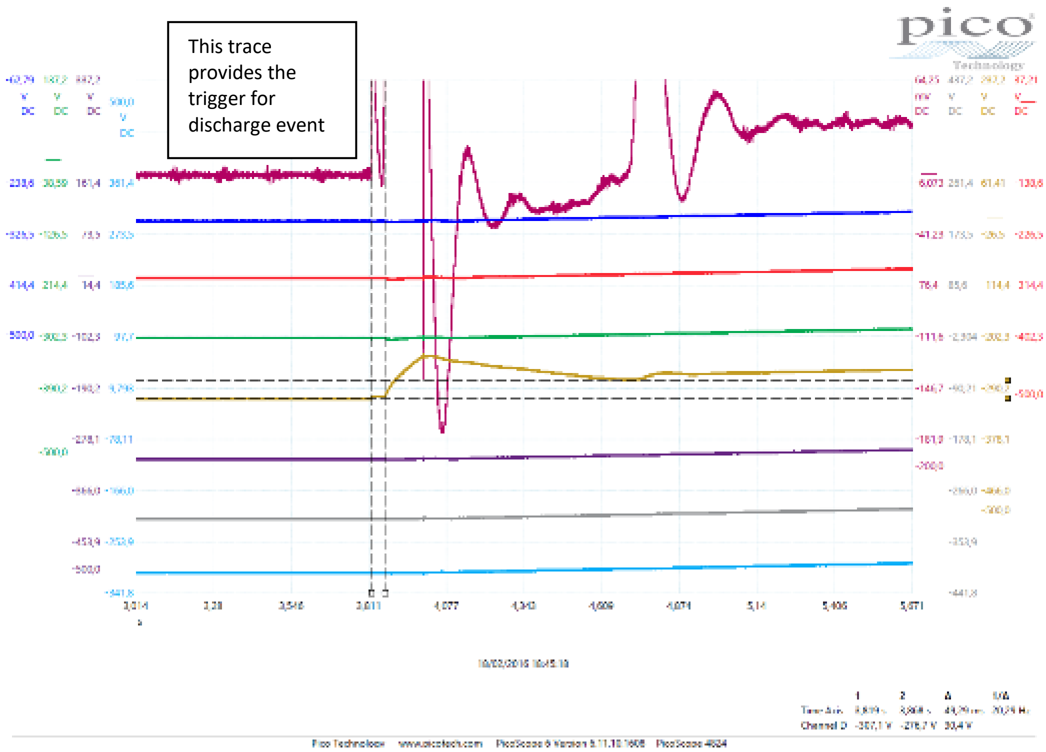


Fig. 11: turning off with trip and anti-rebound (horizontal dotted lines show threshold set after event)

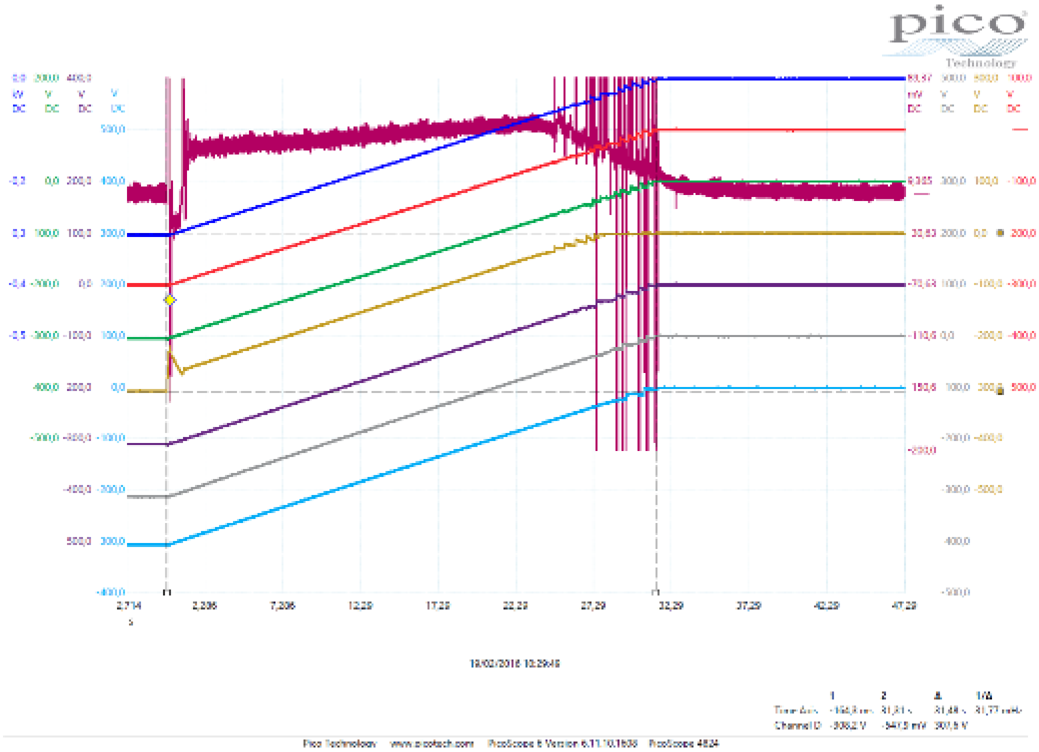


Fig. 12: complete turning off sequence with anti-rebound

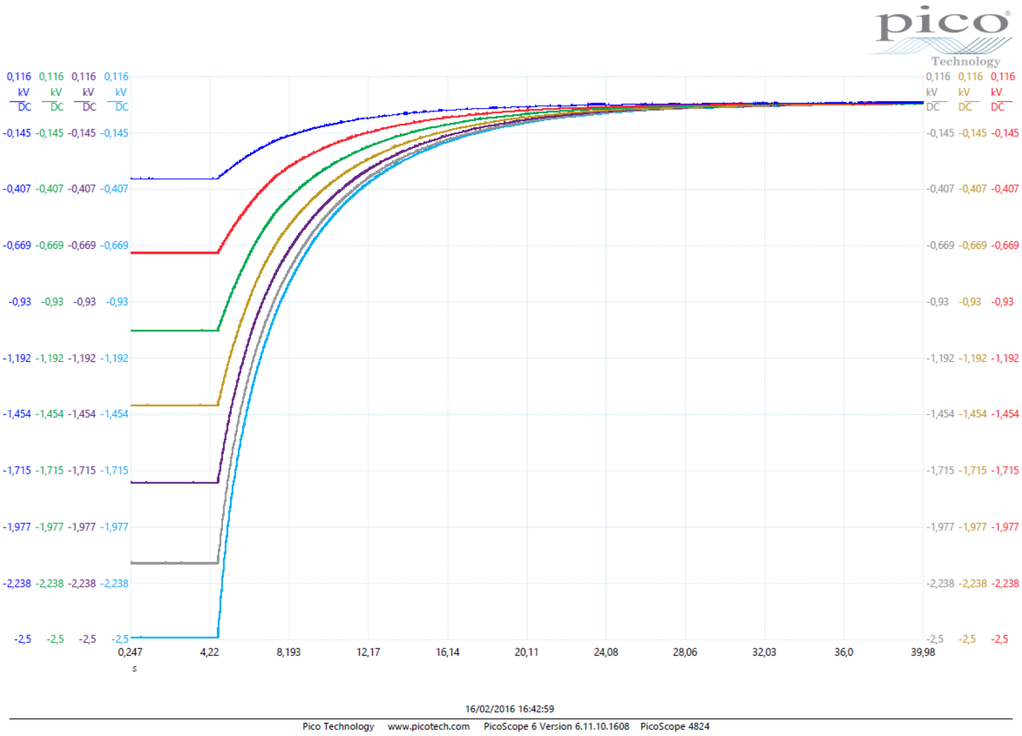


Fig. 13: "Cut-off crate" turning off sequence

Current measure

A very accurate current measurement on each layer of the detector is a key-point to have a flawless trip procedure and to perform on-line detector diagnostics.

If the GEM works fine, the stream currents are ~10nA, but when multiple sectors discharge, they can reach 1mA. In zoom mode, the current monitor resolution is 100pA.

With channel floating up to 5kV, the common mode noise requires filters that, depending on the working voltage, have non-linear loss currents.

To compensate such currents, the board implements a calibration software, that can be used on-line, when the detector is biased and not subject to source.

Three current monitorings are available for each channel:

- "IMonReal" module calibration current; this parameter is not adjusted; it is factory calibrated and is used for the TRIP protection threshold.
- "Imon" channel monitor current; this can be calibrated in working conditions (working voltage and temperature). N.B.: the calibration can be enabled or disabled via the "ZCAdjust" (EN-DIS) option, while "ZCDetect" allows to detect the "zero condition" (both on single channel or group).
- "ImonDet" monitors exclusively the current on the GEM.

Currents are monitored according to the following algorithm:

CH7= Current TOP Gem 0 = Isense Ch7

CH6= Current BOT Gem 0 = Isense Ch6 - Isense Ch7

CH5= Current TOP Gem 1 = Isense Ch5 - Isense Ch6

CH4= Current BOT Gem 1 = Isense Ch4 - Isense Ch5

CH3= Current TOP Gem 2 = Isense Ch3 - Isense Ch4

CH2= Current BOT Gem 2 = Isense Ch2 - Isense Ch3

CH1= Current TOP Gem 3 = Isense Ch1 - Isense Ch2

CH0= Current BOT Gem 3 = Isense Ch0 - Isense Ch1

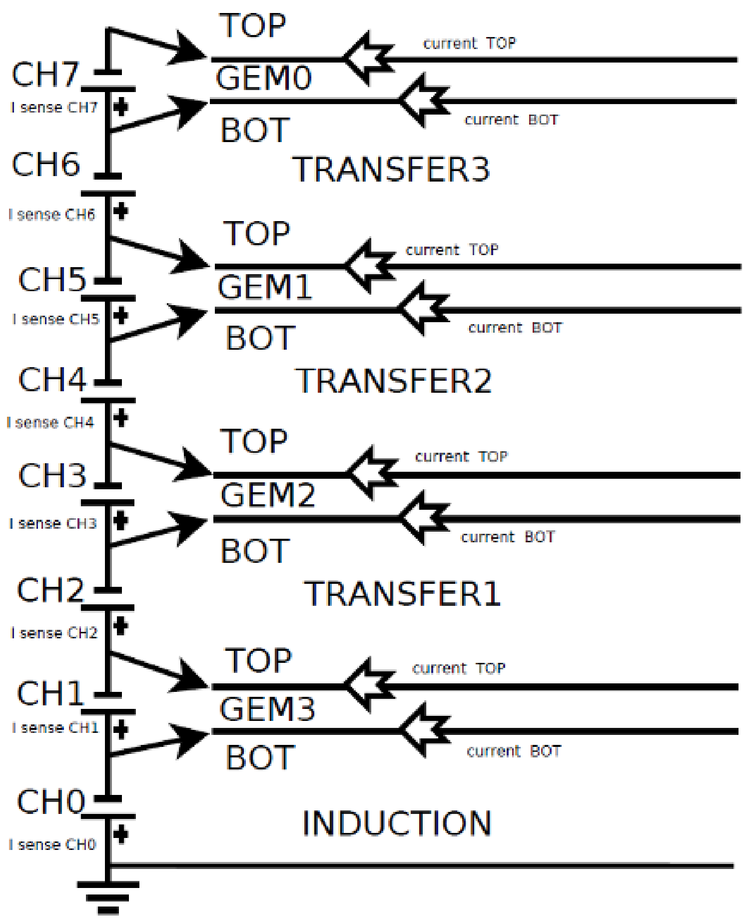


Fig. 14: GEM current distribution

The current readout depends on a few parameters: channel operating voltage referred to AGND (leakage currents), operating temperature (crate ventilation).

In operating temperature conditions, the leakage currents can be compensated by using the "ZCAdjust": such conditions are reached after ~one hour operation.

The typical stability of "Imon Det" is 50ppm/°C; the Imon (Imon real) stability range is 100ppm/°C (constant voltage).

The algorithm that calculates the currents flowing in the circuit branches allows to limit possible dispersion effects due to parasite factors (humidity, dielectric characteristics, resin features, leakage currents, common mode filter capacitances etc.)

The following pictures report the current measurement (Imon and Imon Det), as a function of time with a ~3.75 °C thermal variation.

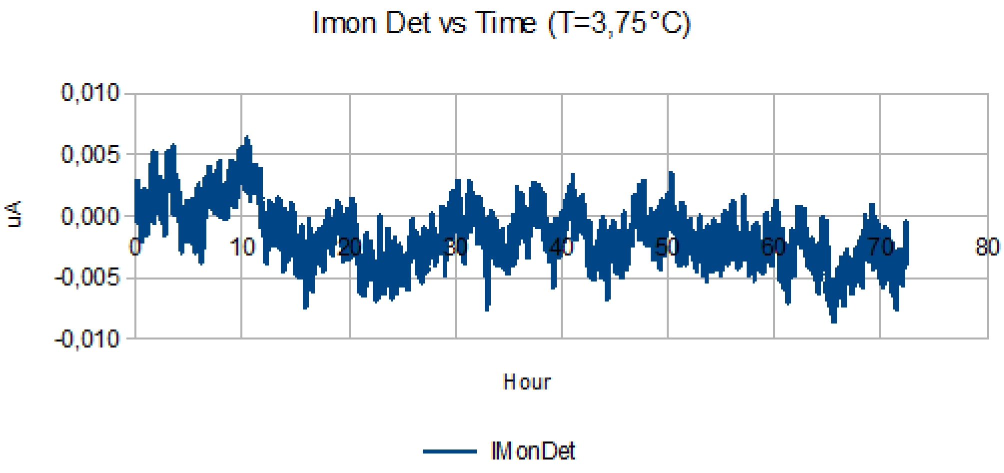


Fig. 15: Imon det thermal variation

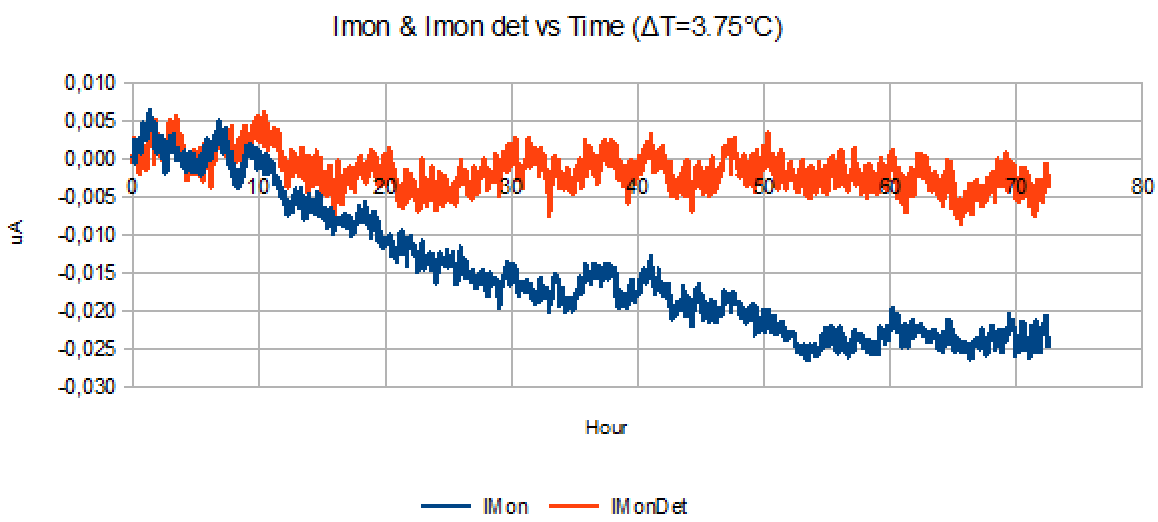


Fig. 16: Imon and Imon det thermal variation

	Imon	Imon det	Vmon	Temp
max=	0,0064	0,0063	500,14	28,75
min=	-0,0265	-0,0085	500	25
Δ=	0,0329	0,0148	0,14	3,75
ppm/°C fs	**87,73**	**39,47**	**37,33**	

Fig. 17: Channel stability (typical)

Set. Volt CH	Max Volt	Vdrop (10M)	I-leakage
25	200	0,035	3,50E-009
50	400	0,065	6,50E-009
100	800	0,13	1,30E-008
150	1200	0,2	2,00E-008
200	1600	0,235	2,35E-008
250	2000	0,27	2,70E-008
300	2400	0,31	3,10E-008
350	2800	0,37	3,70E-008
400	3200	0,43	4,30E-008
450	3600	0,47	4,70E-008
500	4000	0,52	5,20E-008
550	4400	0,58	5,80E-008
600	4800	0,624	6,24E-008
625	5000	0,65	6,50E-008

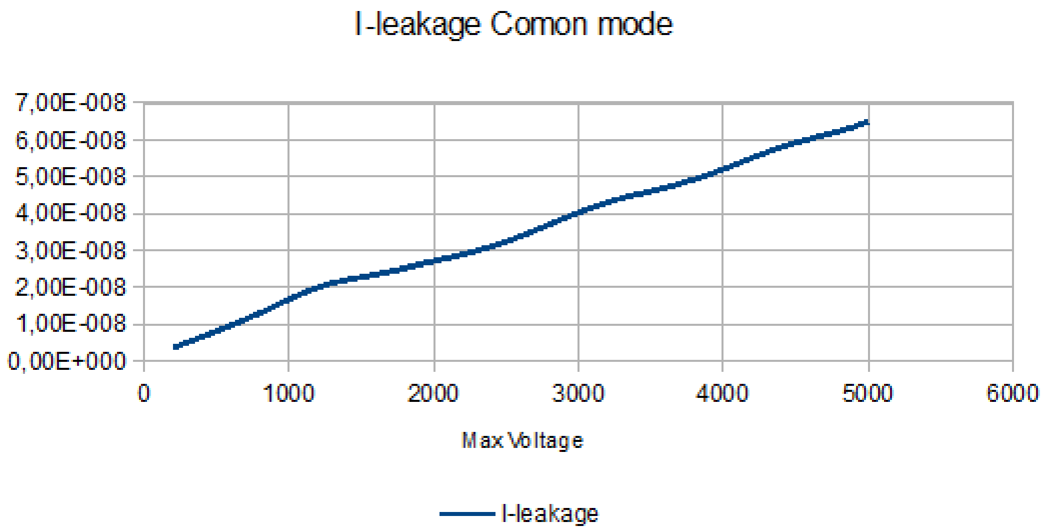


Fig. 18: Global leakage current vs. operating voltage

The leakage current is compensated by the offset recovery; therefore, different channels will show different protection thresholds, since each channel brings a different “addendum” to the leakage current, as shown in the following picture:

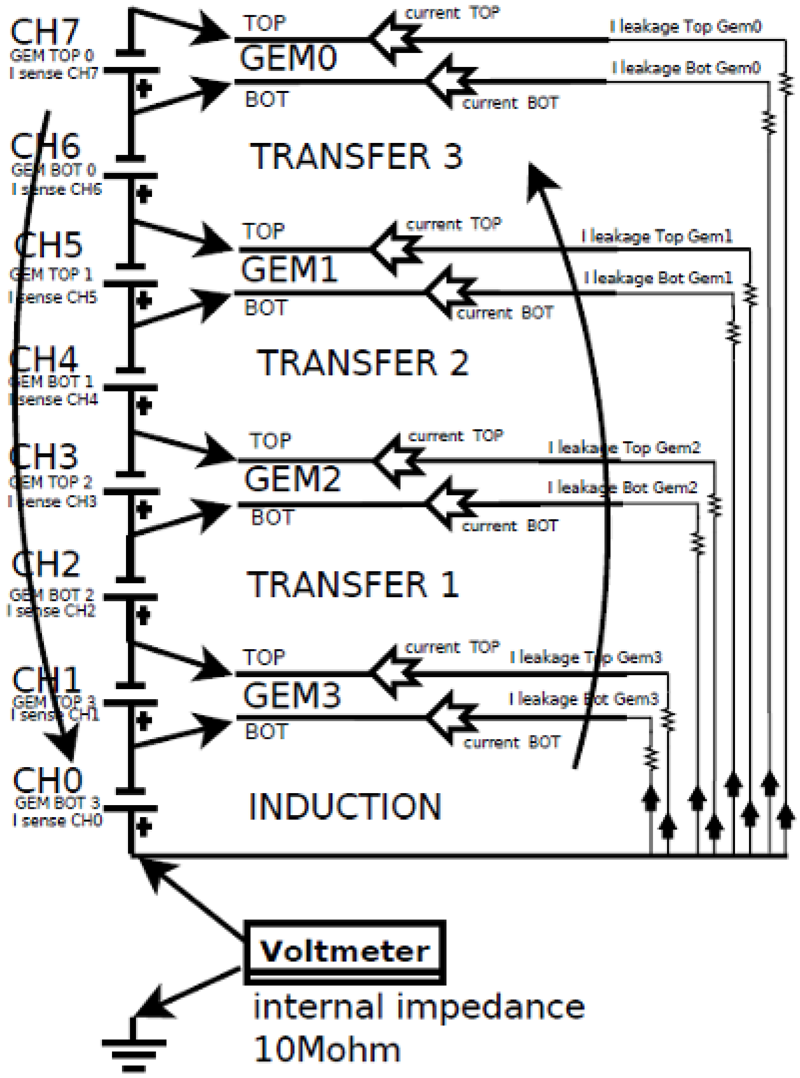


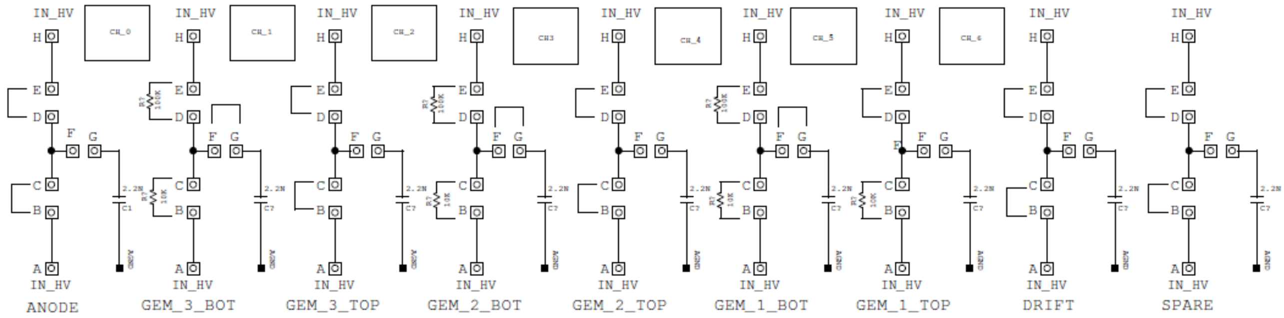
Fig. 19: Functional and leakage currents scheme

Filtering on the load

Although the A1515 ripple is quite low, it is suggested to introduce a R-C-R filter in the detector vicinities, to reduce further common mode noise.

The correct values of the filtering components should be evaluated in the experimental area, with the actual detector and the foreseen gain and rate values.

The following scheme reports the filter used for RD 51 set up (CERN): only BOTTOMs and GEMs are filtered; on the TOPs, the resistors, implemented to limit the discharge inside the GEM, manage to reduce the residual noise.



PAD "A" = INPUT HV FROM A1515
PAD "B-C" = POINT CONNECTION FOR RESISTOR INPUT OR JUMPER
PAD "F-G" = JUMPER FOR CAPACITOR R-C-R
PAD "D-E" = POINT CONNECTION FOR RESISTOR OUTPUT OR JUMPER
PAD "H" = OUTPUT TO GEM

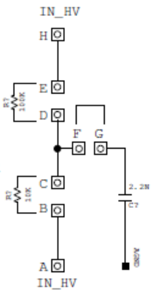


Fig. 20: Load filter (example)

Output Enable

To enable the HV output channels, first it is necessary that pin 9 and 10 (Safety Loop) on the Radial 52pin output connector are short circuited (see p.8); Then the enable procedure is completed in one of the following ways:

– terminating the PASSIVE INTERLOCK [P] connector on 50 Ohm.

– supplying the SIGNAL INTERLOCK [S] connector with a +5 V (3-4mA) signal.

The INTERLOCK LED (red) is turned off as one of the actions above is performed.

When the channels are disabled the voltage outputs drop to zero at the maximum rate available; when the output disable cause is removed (see above), the channels remain OFF until the User turns them ON via software.

Grounding specifications

The Mod. A1515 channels feature reversible polarity and independent floating return. This feature allows on-detector grounding, thus avoiding loops which may increase noise level. The connection of shield and return to Earth is fundamental for User safety; the connection must always be at the level of detector or power supply system.
The best configuration must be determined by the user upon application, the optimal connection depends on many characteristics of the related experiment.
Please note that RETURN (see figure below) is a shielding reference for the HV channels; it can be used as reference for external filters, and it is available on the 52pin output connector. If it is not used, it must be wired to AGND via front panel jumpers. Configuration schemes: the safety rules are the same for both shield and HV modules. Please note that only Jumper 1-2 (Shield to AGND) is available on A1515B models; see also p. 8.

The following diagrams show three examples of configuration, namely:

1. The "closed loop " Earth configuration
2. The "semi-open loop" Earth configuration
3. The RTN to GND configuration
4. The "open loop" Earth configuration

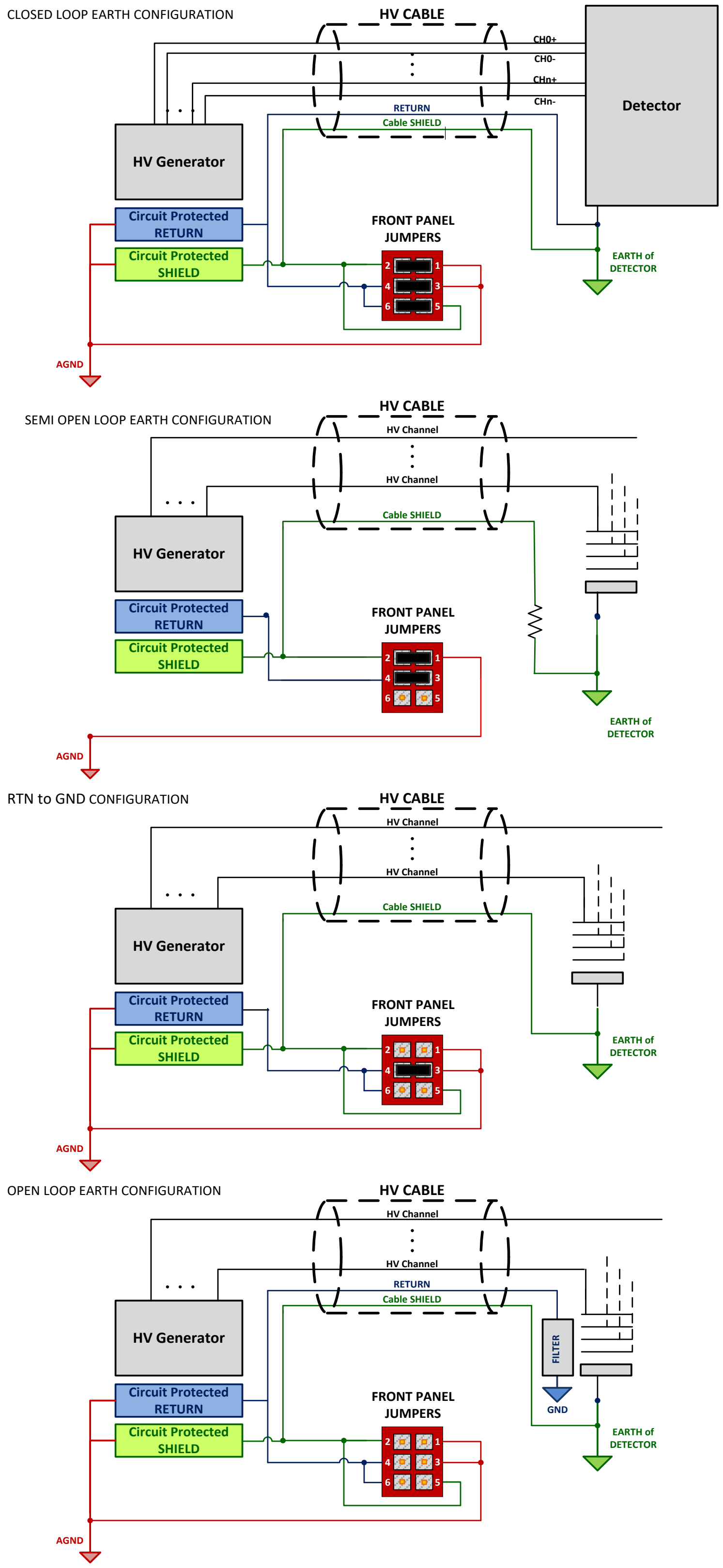


Fig. 21: Earth configuration connection examples

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