

## Technical Note

English



# GEN series 1 kV Input Cards GN610 and GN611 Isolation and Type Testing

## 1 International standards for test equipment safety

### 1.1 Measurement categories

- The international standards for test equipment safety are the IEC 61010-1 and the IEC 61010-2-030.
- IEC 61010-1 defines three overvoltage categories (CAT II, CAT III, and CAT IV) on the power supply side of an instrument.
- IEC 61010-2-030 defines three measurement categories (CAT II, CAT III, and CAT IV) on the measurement input side of an instrument, for measurement inputs which can be directly connected to mains.
- All measurement inputs, which are not specified to be connected to mains, have no CAT rating and are referred to as O (like Others).

#### Categories according to IEC 61010-2-030:2010

Electrical equipment, specifically measurement tools can according to IEC 61010-2-030:2010 be assigned into 4 categories. These measurement categories are indicated with the terms O (previously CAT I), CAT II, CAT III and CAT IV. Originally these categories are used to indicate the overvoltage or surge voltage that is likely to occur and can be sustained by the equipment. Actually the category indicates the amount of energy that can be released in the event of a short circuit. A higher category number indicates a higher energy level that can occur and can be sustained by the equipment.

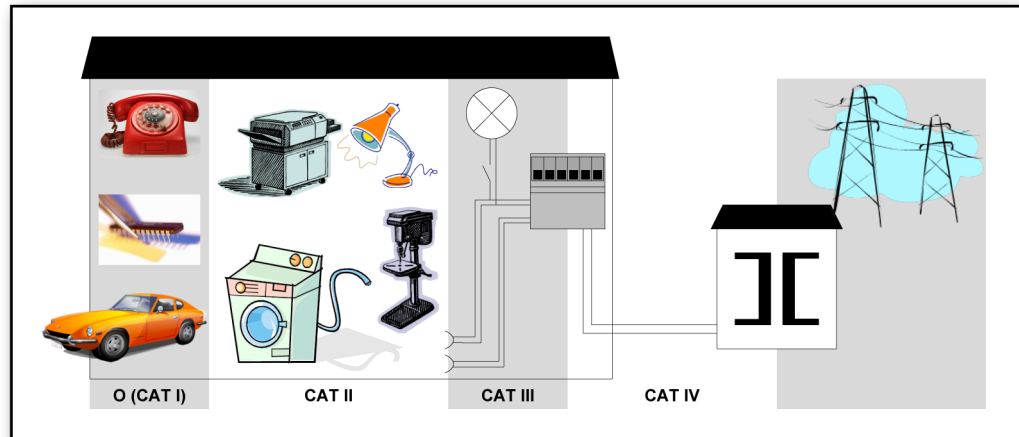
**O (Other)** (previously referred to as **CAT I**): This category is for measurements not directly connected to mains. Think of measurement of: signal levels, regulated low voltage circuits or protected secondary circuits. For this category there are no standard over voltage or surge impulse levels defined.

**CAT II**: This category is for measurements directly connected to low-voltage mains. Think of measurement of: mains sockets in household applications or portable tools. This category is expecting to have a minimum of three levels of over current protection between the transformer and connection point of the measurement. (See Figure 1.1).

**CAT III**: This category is for measurements directly connected to the distribution part of a low-voltage mains installation. Think of measurement of: circuit breakers, wiring, junction boxes etc. This category is expecting to have a minimum of two levels of over current protection between the transformer and connection point of the measurement. (See Figure 1.1).

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**CAT IV:** This category is for measurements directly connected to the source of a low-voltage mains installation. Think of measurement of: over current protection devices, ripple control units etc. This category is expecting to have a minimum of one level of over current protection between the transformer and connection point of the measurement circuit. (See Figure 1.1).



**Figure 1.1:** Category indication according to IEC 61010-2-030:2010

**Example:** A measurement device is specified as 600 V CAT II, maximum input voltage 1000 V DC.

*Table 1.1: Insulation test voltages according to IEC 61010-2-030:2010*

Nominal Voltage (V RMS or V DC)	IEC 61010-2-030:2010					
	5 sec. AC test (V RMS)			Impulse test (V)		
	CAT II	CAT III	CAT IV	CAT II	CAT III	CAT IV
≤ 150	840	1.390	2.210	1.550	2.500	4.000
> 150 ≤ 300	1.390	2.210	3.310	2.500	4.000	6.000
> 300 ≤ 600	2.210	3.310	4.260	4.000	6.000	8.000
> 600 ≤ 1 000	3.310	4.260	6.600	6.000	8.000	12.000

Using the above table one can deduce that this specification informs the user the device passed the insulation tests; 5 sec at 2.210 V RMS and impulse 4.000 V. The maximum operating input voltage is 1000 V DC. This device is to be used to measure CAT II circuitry up to 600 V.



## **WARNING**

Measurement inputs of this instrument should not be used to measure high-energy signals of measurement categories CAT II, CAT III or CAT IV (IEC 61010-2-30:2010) (e.g. mains measurements) , unless specifically stated for the specific input.

## 1.2 Basic versus reinforced insulation

For reference below one can find the basic insulation and supplementary insulation as well as the reinforced insulation test values for CATII.

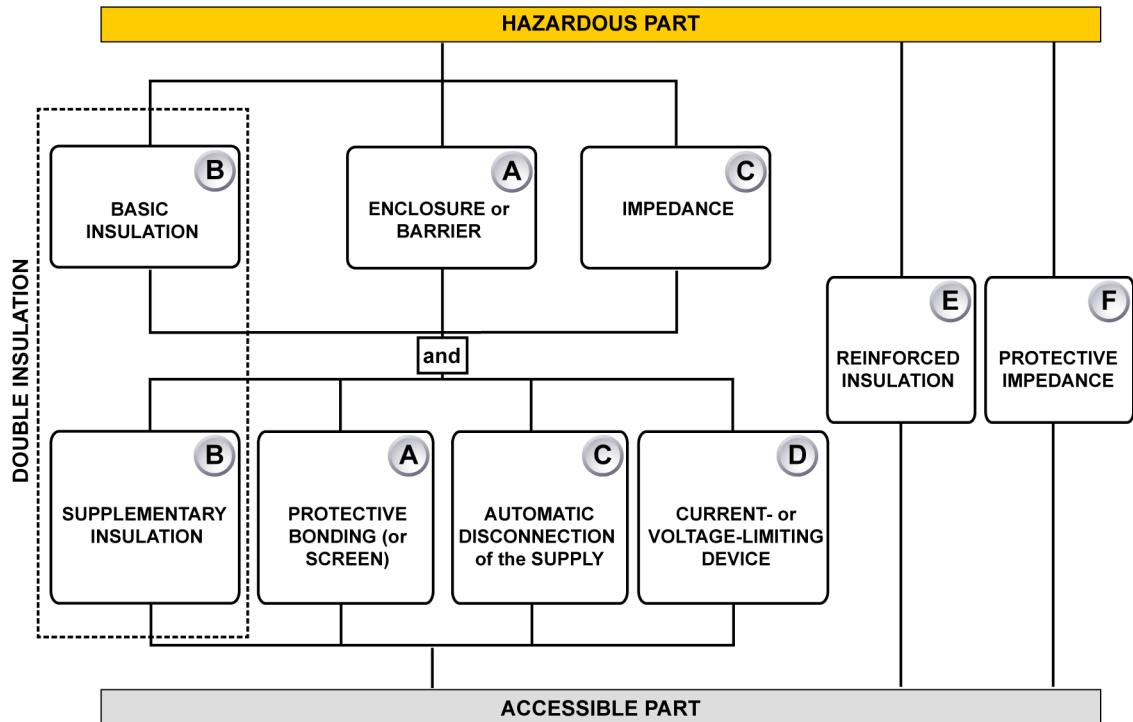
*Table 1.2: Test voltages for testing electric strength of solid insulation in measuring circuits of measurement category II (IEC 61010-2-30:2010)*

Nominal voltage line to neutral a.c r.m.s. or d.c. of MAINS being measured. (V)	Test voltage			
	5 s a.c. test V a.c. r.m.s.		Impulse test V peak	
	Basic insulation and supplementary insulation	Reinforced insulation	Basic insulation and supplementary insulation	Reinforced insulation
≤ 150	840	1390	1550	2500
> 150 ≤ 300	1390	2210	2500	4000
> 300 ≤ 600	2210	3510	4000	6400
> 600 ≤ 1000	3310	5400	6000	9600

To protect a user from hazardous voltages there are several means of protection possible. As one can see below basic insulation + supplementary insulation is a possibility but also reinforced isolation is a means of protection. The test voltages are different per means as can be found in the above table.

## Additional means of protection in case of single fault conditions

Accessible parts shall be prevented from becoming HAZARDOUS LIVE IN SINGLE FAULT CONDITION. The primary means of protection (see Figure 1.2) shall be supplemented by one of **A**, **B**, **C** or **D**. Alternatively one of the single means of protection **E** or **F** shall be used. See Figure 1.2.



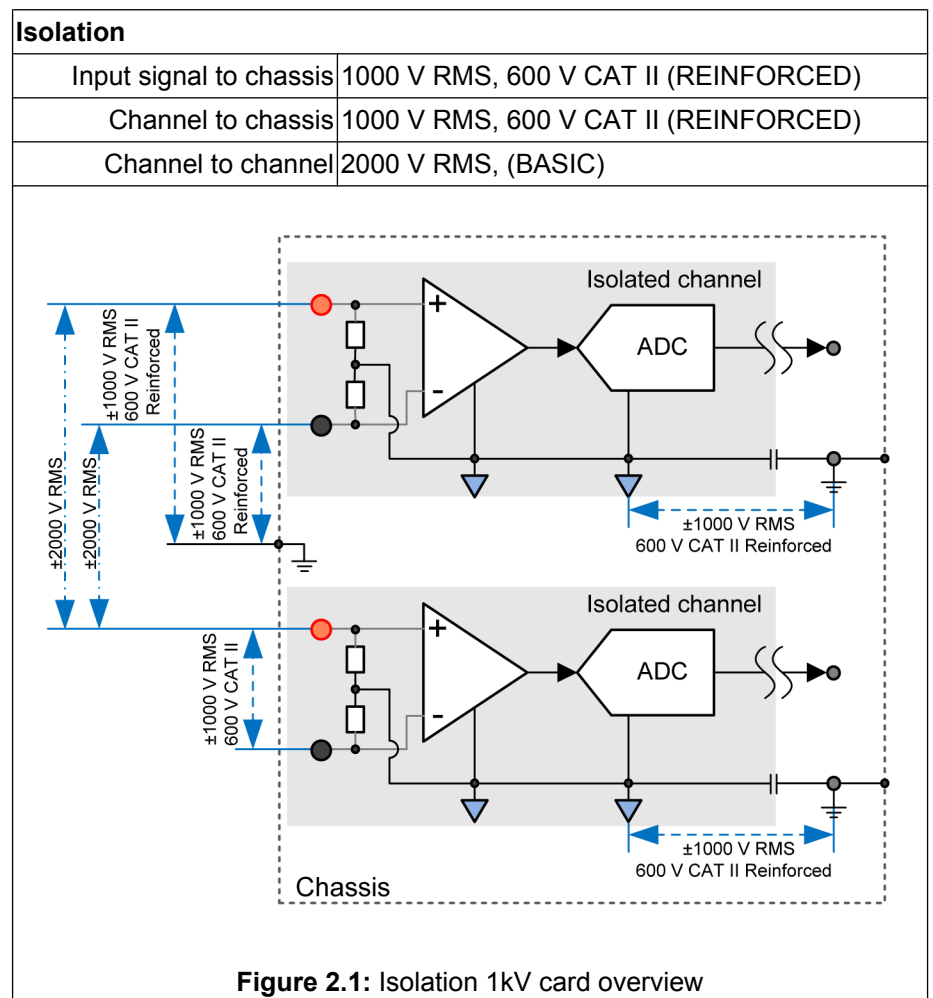
**Figure 1.2:** Acceptable arrangement of protective means against electric shock

Example: A measurement device is specified as 600 V CAT II reinforced insulation, maximum input voltage 1000 V DC. Using the above information one can deduce that this specification informs the user that the measurement device is tested on input to chassis ground 5 s at 3.510 V RMS and impulse 6.400 V. The maximum operating input voltage is 1000 V DC. This device is to be used to measure CAT II circuitry up to 600 V.

## 2 GEN series 1 kV input cards GN610, GN611

### 2.1 Isolation and input of the GN610, GN611

An overview of the GN610, GN611 card isolation and input is given below (see Figure 2.1). The isolation of the channel to chassis is 1000 V RMS and is also qualified as 600 V CAT II (or 300 V CAT III). The common mode of the differential input channel (isolated GND) can be 1000 V RMS with respect to the chassis. If one channel has common mode at +1000 V and one at -1000 V (with respect to chassis), the voltage between the two channels is 2000 V. The standards at which the card is certified is IEC61010-1:2010 and IEC61010-2-30:2010.



- The isolation between channel and chassis is classified as **REINFORCED**. This can be seen as double isolation, which is necessary because the chassis might be accessible (conductive parts can be touched) to users (personal safety).

## GN610, GN611 Isolation and type testing

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- Isolation between channels is **BASIC**, since a channel is not accessible and there is therefore no direct risk for a user (product safety).
- **REINFORCED** or **DOUBLE** isolation has higher test values than **BASIC** isolation.

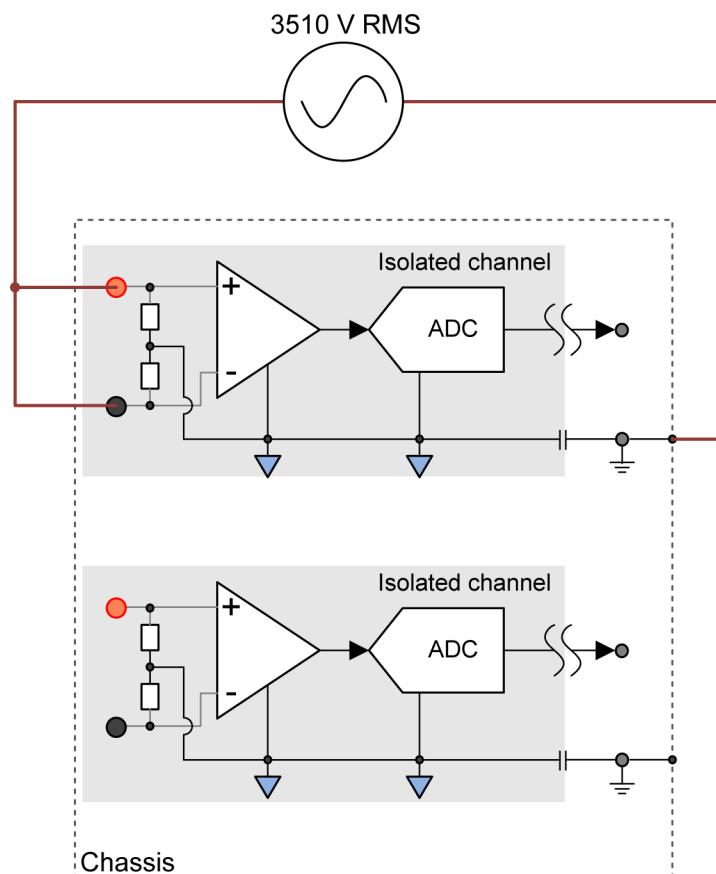


## 3 Type testing

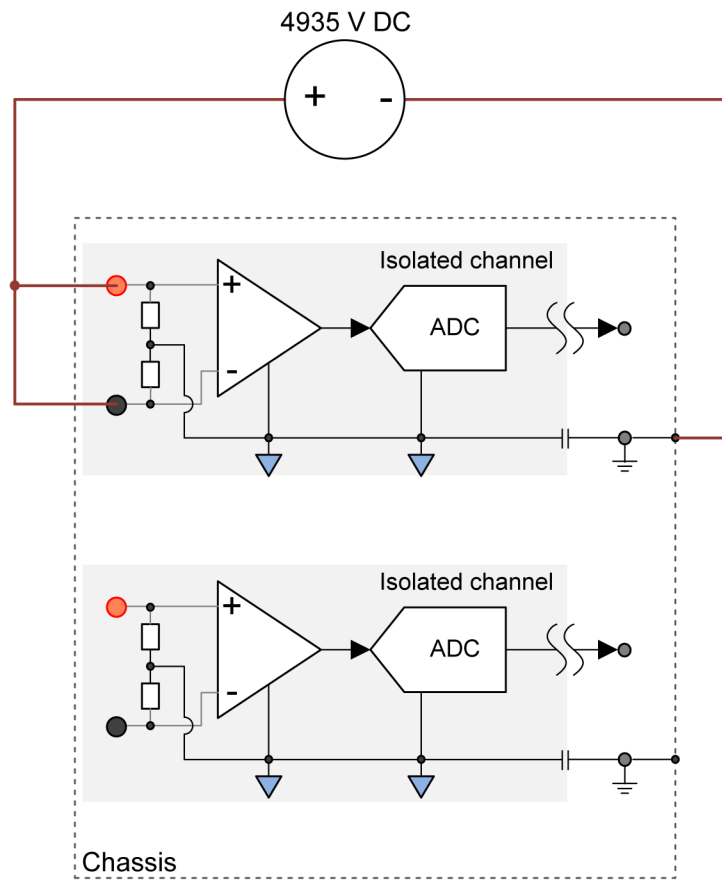
### 3.1 Channel to chassis isolation test

To qualify the isolation as 1000 V RMS and 600 V CAT II (REINFORCED), certain tests are performed on some cards during the engineering design qualification phase. These tests are known as type tests. These tests are described in the IEC61010-1:2010 and IEC61010-2-30:2010 standards. The principle of the tests is given below.

For the isolation barrier test, both the DC and AC tests below (see Figure 3.1 and Figure 3.2) are used with DC voltage  $\sqrt{2}$  higher than the AC voltage. The test value meets the requirements for 600 V CAT II REINFORCED, the test value for 1000 V RMS is lower and therefore also covered with this test. Tests are conducted for one minute, see IEC61010 for details.



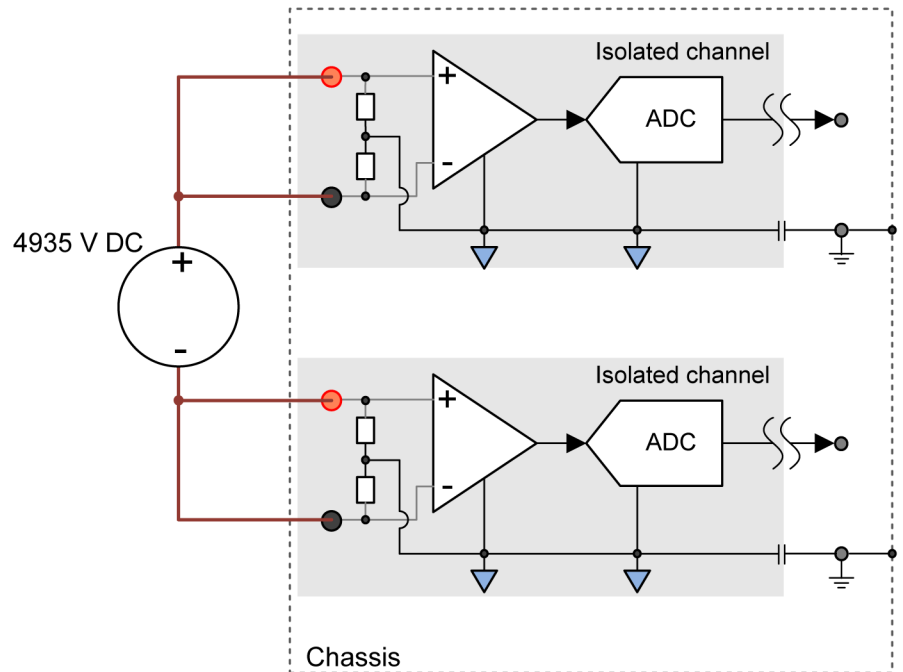
**Figure 3.1:** AC Type test Channel to Chassis



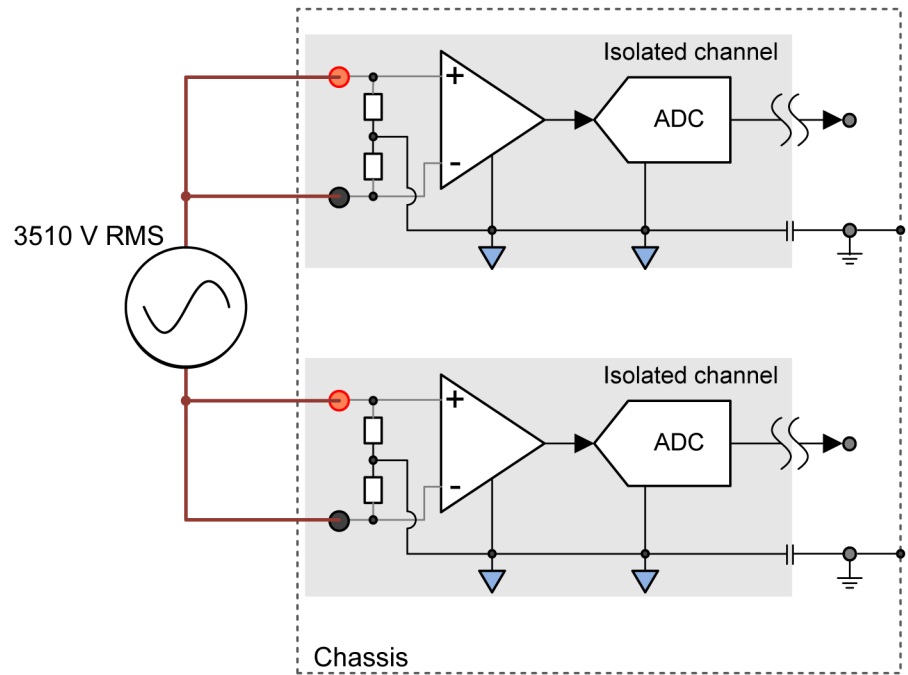
**Figure 3.2:** DC Type test Channel to Chassis

## 3.2 Channel to channel isolation test

For the channel to channel test, both the DC and AC tests below (see Figure 3.3 and Figure 3.4) are used with DC voltage  $\sqrt{2}$  higher than the AC voltage. The test value meets the requirements for 600 V CAT II REINFORCED, the value for 2000 V RMS BASIC is lower and therefore also covered with this test. Tests are conducted for one minute, see IEC61010-1 for details.



**Figure 3.3:** DC Type test Channel to Channel



**Figure 3.4:** AC Type test Channel to Channel

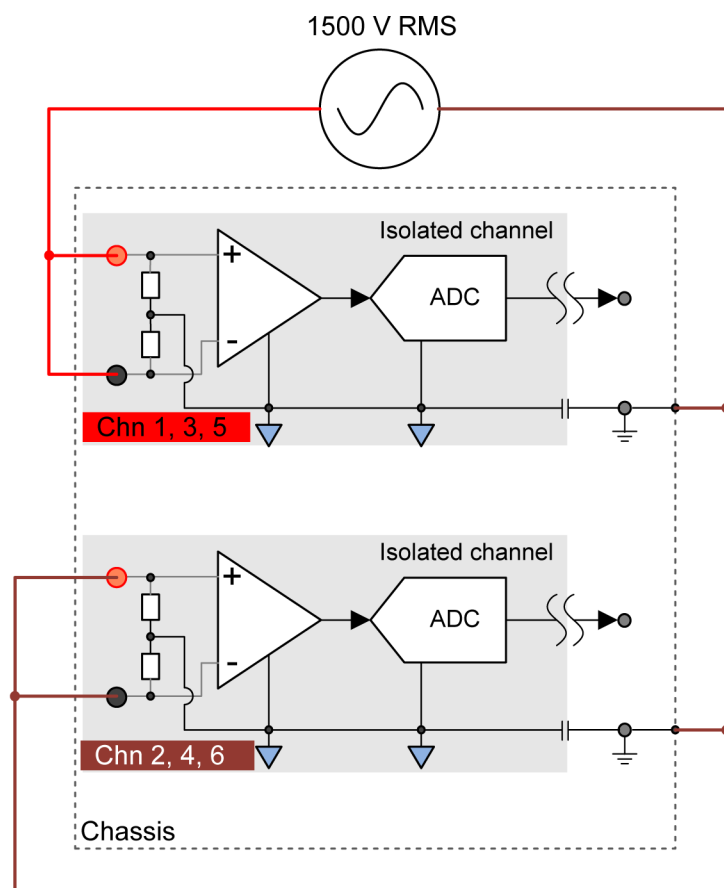
## 4 Production tests

### 4.1 High potential test

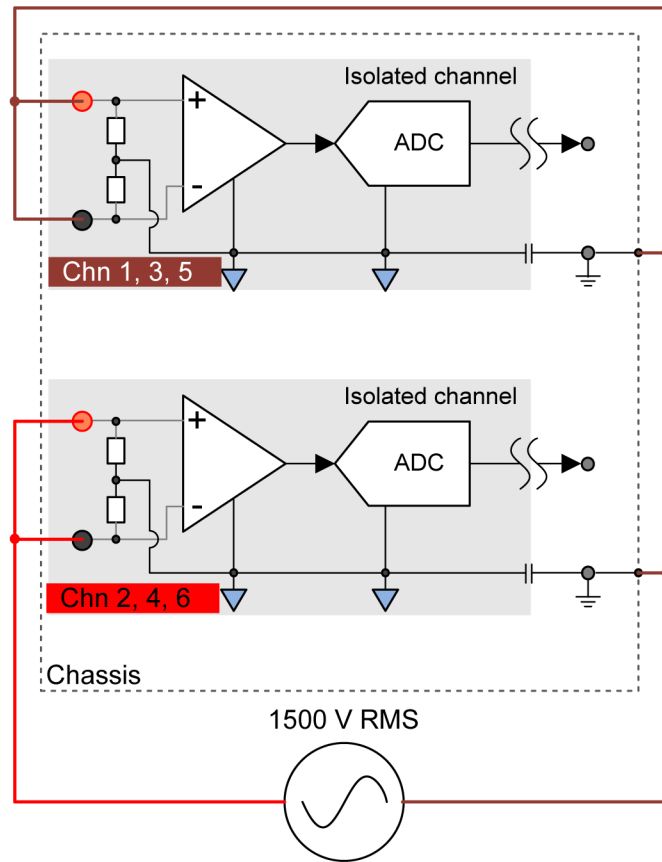
The type tests are performed on a selection of cards to prove the design. Every produced card will undergo a production test, to verify the correct construction and safety of the card. The tests called “hipot” (high potential) tests (see Figure 4.1 and Figure 4.2).

The test are performed in two steps to make sure the channels that are side by side on the card can with stand the high potential voltages.

- 1 The inputs of channel 1, 3 and 5 are tested using a 1500 V RMS common mode signal with ground attached to chassis ground and the inputs of channel 2, 4 and 6 all connected to chassis ground.
- 2 The inputs of channel 2, 4 and 6 are tested using a 1500 V RMS common mode signal with ground attached to chassis ground and the inputs of channel 1, 3 and 5 all connected to chassis ground.



**Figure 4.1:** Hipot testing channels 1, 3 and 5



**Figure 4.2:** Hipot testing channels 2, 4 and 6

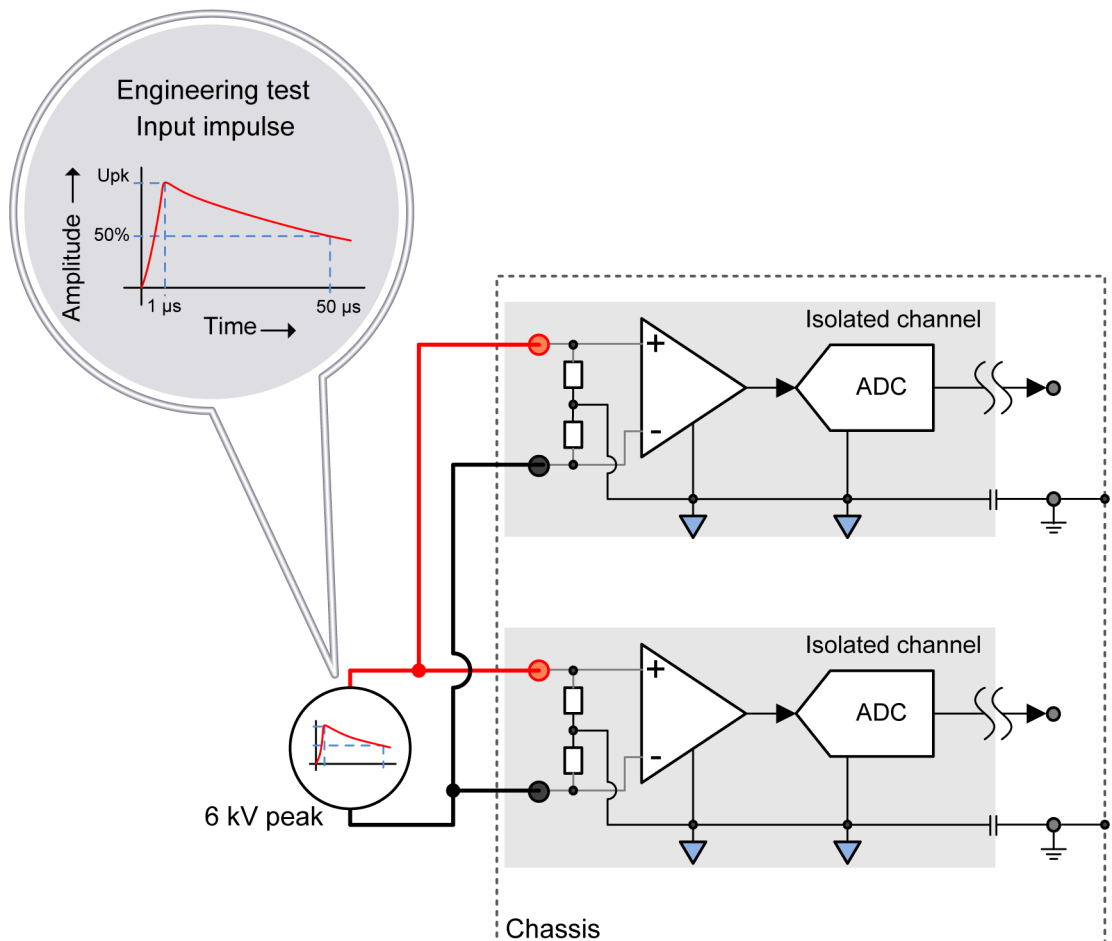
## 5 Engineering tests

### 5.1 Overview

Besides the type tests and the production tests, HBM has also performed several engineering tests to verify the robustness of the design during the engineering design qualification phase.

#### Component tests

Every component crossing the isolation barrier is tested and/or examined to make sure it will pass the type test. The test voltage used is the same high voltage DC as used for the type tests as well as an additional impulse voltage up to 6 kV, using a 1.2  $\mu$ s rise time and an amplitude reduction to 50 % of the maximum peak voltage in 50  $\mu$ s after the peak has been reached.

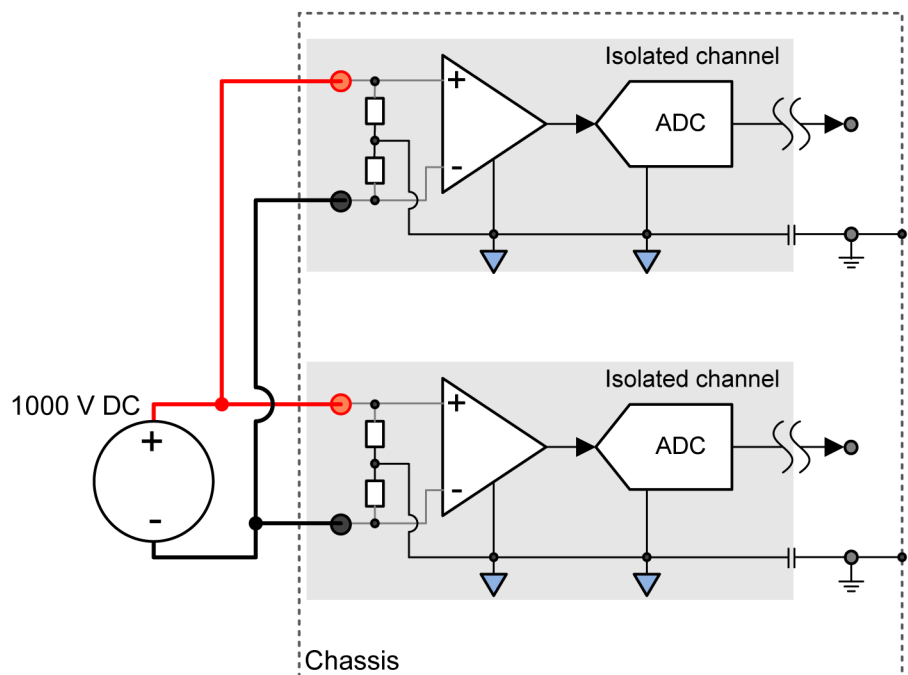


**Figure 5.1:** Example of 1.2/50  $\mu$ s impulse

## Active input switch test

To guarantee the stability of the channels, the input relays are tested with the maximum input voltage (1000 V) applied. The inputs of the channels have been switched from isolated GND to DC by the input relay, resulting in the 1000 V being applied to the input as a step pulse.

This test is done with the highest input range ( $\pm 1000$  V) and also repeated with the lowest input range ( $\pm 20$  mV), both with an input voltage of 1000 V and repeated for over 1000 times. These tests all passed successfully.



**Figure 5.2:** Engineering test input switching



## 6 GN610, GN611 Protection mechanisms

### 6.1 Overview

#### Overvoltage and current protection

All signal inputs are protected against voltage overload. This is specified at  $\pm 1000$  V for all ranges except for the  $\pm 1000$  V range that is limited to  $\pm 1250$  V. Exceeding these limits can damage the input card.

#### GN610 and GN611 input overload protection

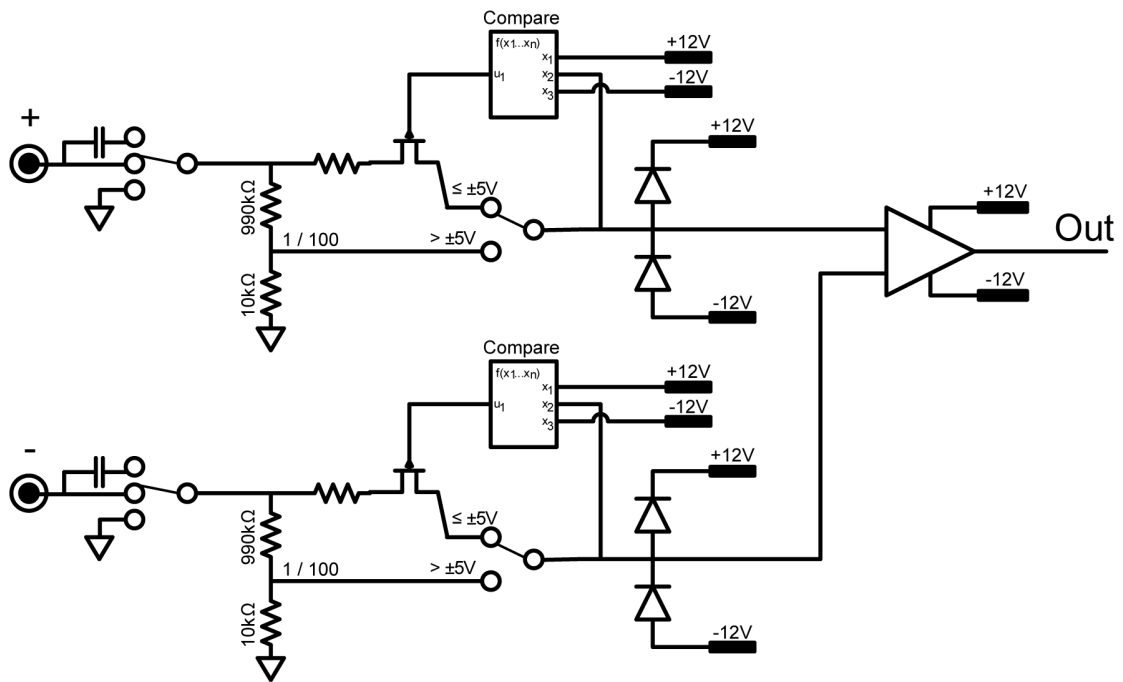
The input section has several methods to protect against voltage overload on the input.

Every selected input range allows a 200 % overload without any change of input resistance or auto ranging. This 200 % overrange is designed to allow for smaller voltage overloads without effecting the measurement. Within this 200 % overload the amplifier is also able to respond with normal rise/fall times to signal being restored within the standard selected range.

When exceeding the 200 % overload condition, the input impedance might start to increase. The impedance increase will lower the input current with the positive effect of lowering the dissipated heat. It is the excessive heat dissipation that typically damages the input channel.

**The first action** of the system will be to add an additional current load on the input signal to create an extra voltage drop on the input series resistance. The actual additional current depends on several factors and is therefore not predictable. A negative side effect of this additional current is the extra power dissipated in the input section which in turn results in additional heat dissipation.

**Secondly**, within the lower ranges of the amplifier ( $\leq \pm 5$  V ranges) the input section will start switching to disconnect from the input signal to reduce the power dissipated.



**Figure 6.1:** Input Overload protection - Schematic diagram

### Thermal monitor of the input channels

Any overload condition has the same end result: extra heat generated within the channel. Not only because of the extra current through the input resistance, but also because internal amplifier sections will be driving their local output to maximum levels creating excessive heating within the amplifier.

**As a third** protective mechanism every input is equipped with a thermal sensor to monitor the local temperature. When the local temperature reaches maximum levels the system will automatically start changing the user selected input range to reduce the dissipated heat. As the heat dissipation will not immediately start the auto ranging, short overloads will not result in auto ranging. Longer overload conditions will lead to higher local temperature and this will start the auto ranging process.

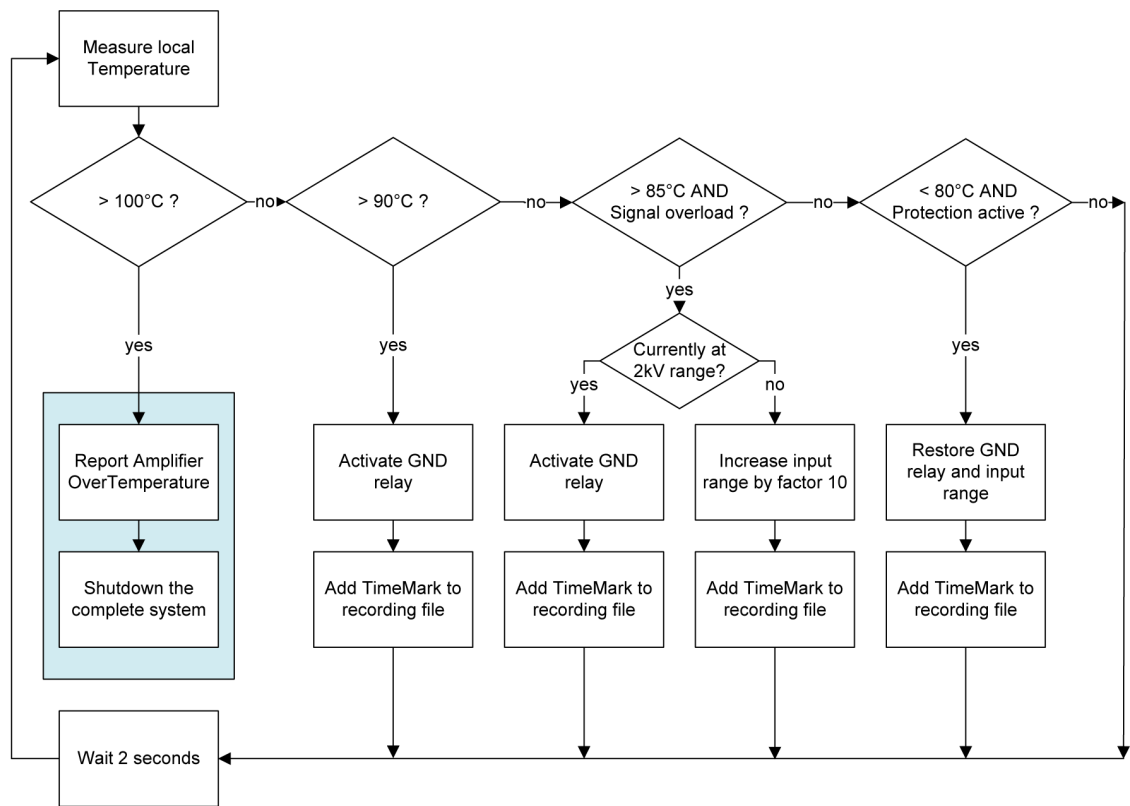
Whenever an overload condition pushes local temperature to above the maximum level, the input range will be adapted to a factor 10 less sensitive range. E.g. User selected  $\pm 40$  mV range, when required the system will change the range to  $\pm 400$  mV. As this might not be enough due to an even higher overvoltage, the system keeps on monitoring the local temperature. If the local temperature doesn't reduce within the expected response time, the system will automatically increase the input range with a factor of 10 for a second, third or how many times required to reach a safe condition not to increase local temperature anymore.

Every one of the automatic range changes will be identified within the measurement data. Not only will the measured input be scaled correctly with the adapted input range, but also the exact moment the automatic range change happens is identified within Perception software.

As the highest selectable range is  $\pm 1$  kV the ultimate protection for the system will be to disconnect the input from the external signal source. This step will only be executed if the system is in the  $\pm 1$  kV range and local temperature is still outside maximum operating limits. Disconnecting from the external signal source is done by grounding the input. When inputs are grounded, the only connections to the external signal are the input connectors and the input pin of the ground relay.

### **Thermal shutdown in critical conditions**

This protective scheme allows for any overload condition the input would be confronted with during normal operation. For any other failure condition that would result in excessive heat dissipation, the GEN series mainframe has a last protective stage built in. When local temperatures reach a critical condition the system will turn-off the mains power automatically to prevent damage to the system or other systems near the GEN series system. Maximum and critical temperature conditions are defined as such that it is very unlikely the system will ever reach this critical condition when operating within its specified conditions.



**Figure 6.2:** Automatic thermal overload response

### Automatic restore of user selected range

As the GEN series system is designed to measure 24 hours per day, 7 days per week, the automatic ranges switching has the negative side effect of reduced sensitivity of the amplifier. During the actual overload condition the channel will not be able to measure the input signal anyhow, so no extra negative side effects are introduced. If the overload condition disappears and the system is running unattended, the automatic selected input range will not be the best measurement range. Therefore the amplifier will remember the original selected user range and restore this user selection as soon as regular thermal conditions are restored. Temporary large overload conditions will then only result in temporary adjusted input sensitivity.

It is expected that the thermal conditions might only be restored because of the automatic range adaption of the input channel. So the actual overload condition might not have disappeared yet. If this would be the case, the thermal increase would re-trigger the automatic range adaption process and the overload is handled exactly the same way as before.

In case the overload condition is permanent, the system keeps on automatic ranging to reduce the dissipated heat, then restores the user selected range with the effect of overheating again therefore restarting the automatic ranging process again. This cycle will repeat forever until the overload condition disappears.

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