Hardware Manual

HBM-S1-B

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High Power Pulse Instruments GmbH
Stadlerstrasse 6A
D-85540 Haar
Germany

Phone : +49 (0)89 8780698 - 440
Fax : +49 (0)89 8780698 - 444
E-Mail : info@hppi.de
Internet : https://www.hppi.de/

Contents

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Internet: www.hppi.de
E-mail: info@hppi.de

1 Introduction

1.1 Safety Instructions

This instruction is dedicated only to electrical experts and people with a suitable technical education, are familiar with electrical risks and who can keep the risk for themselves and for others as low as possible. Only authorized personal as mentioned above should be allowed to operate the pulse generators and motion systems.

The pulse generator, depending on type, create very high voltages, high currents and / or very high power for a short period of time! Convince yourself first, that nothing and nobody can be endangered by this voltage before operating the pulse generator units.

1.1.1 Before Operating the Pulse Generator Units, make sure to read the following Safety Instruction

HPPI GmbH makes every effort to keep the safety standard of our products up to date and to offer our customers the highest possible degree of safety. Our products and the auxiliary equipment required for them are designed and tested in accordance with the relevant safety Standards. Compliance with these Standards is continuously monitored. The product described here has been designed and tested in accordance with the EC Certificate of Conformity and has left the manufacturer's plant in a condition fully complying with safety Standards. To maintain this condition and to ensure safe Operation, observe all instructions and warnings provided in this manual. If you have any questions regarding these safety instructions, HPPI will be happy to answer them.

Furthermore, it is your responsibility to use the product in an appropriate manner. This product is designed for use solely in industrial and laboratory environments or in the field and must not be used in any way that may cause personal injury or property damage. You are responsible if the product is used for an intention other than its designated purpose or in disregard of the manufacturer's instructions. The manufacturer shall assume no responsibility for such use of the product. The product is used for its designated purpose if it is used in accordance with its product documentation and within its performance limits (see data sheet, documentation, the following safety instructions).

Using the product requires technical skills and a basic knowledge of English. It is therefore essential that the product be used exclusively by skilled and specialized staff or thoroughly trained personnel with the required skills. If personal safety gear is required for using HPPI products, this will be indicated at the appropriate place in the product documentation.

This instruction is dedicated only to electrical experts and people with a suitable technical education, who are familiar with electrical risks and who can keep the risk for themselves and for others as low as possible. Only authorized personal as mentioned above should be allowed to operate the pulse generators.

The pulse generator, depending on type, create very high voltages, high currents and / or very high power for a short period of time! Convince yourself first, that nothing and nobody can be endangered by this voltage before operating the pulse generator units.

Before Operating the Pulse Generator Units make sure that you have read and understood the operating instruction manual! Ensure that you observe all the hints and warning contained within it.

In not following the operating instructions, you contravene the safety regulations for operating units for this type. HPPI accepts no liability for consequences arising form the failure to follow these safety instructions.

Symbols and Safety Labels:


Observe product documentation


Danger of electric shock


PE terminal


Ground


Ground terminal

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E-mail: info@hppi.de

Observing the safety instructions will help prevent personal injury or damage of any kind caused by dangerous situations. Therefore, carefully read through and adhere to the following safety instructions before putting the product into Operation. It is also absolutely essential to observe the additional safety instructions on personal safety that appear in relevant parts of the product documentation. In these safety instructions, the word “product” refers to all merchandise sold and distributed by HPPI GmbH, including instruments, systems and all accessories.

Tags and their meaning

DANGER This tag indicates a definite hazard carrying a high risk of death or serious injury if not avoided.

WARNING This tag indicates a possible hazard carrying a medium risk of death or (serious) injury if not avoided.

CAUTION This tag indicates a hazard carrying a low risk of minor or moderate injury if not avoided.

ATTENTION This tag indicates the possibility of incorrect use that can cause damage to the product.

NOTE This tag indicates a situation where the user should pay special attention to while operating the product but which does not lead to damage.

These tags are in accordance with the Standard definition for civil applications in the European Economic Area. Definitions that deviate from the standard definition may also exist in other economic areas or military applications. It is therefore essential to make sure that the tags described here are always used only in connection with the related product documentation and the related product. The use of tags in connection with unrelated products or documentation can result in misinterpretation and thus contribute to personal injury or material damage.

Basic safety instructions

1. Applicable local or national safety regulations and rules for the prevention of accidents must be observed in all work performed. The product may be opened only by authorized, specially trained personnel. Prior to performing any work on the product or opening the product, the product must be disconnected from the supply network. Any adjustments, replacements of parts, maintenance or repair must be carried out only by technical personnel authorized by HPPI. Only original parts may be used for replacing parts relevant to safety (e.g. power switches, power transformers, fuses). A safety test must always be performed after parts relevant to safety have been replaced (visual inspection, PE conductor test, insulation resistance measurement, leakage current measurement, functional test).

2. As with all industrially manufactured goods, the use of substances that induce an allergic reaction (allergens, eg. nickel) such as aluminum cannot be generally excluded. If you develop an allergic reaction (such as a skin rash, frequent sneezing, red eyes or respiratory difficulties), consult a physician immediately to determine the cause.

3. If products/components are mechanically and/or exothermically processed in a manner that goes beyond their intended use, hazardous substances (heavy-metal dust such as lead, beryllium, nickel) may be released. For this reason, the product may only be disassembled, e.g. for disposal purposes, by specially trained personnel. Improper disassembly may be hazardous to your health. National waste disposal regulations must be observed.

4. If handling the product yields hazardous substances that must be disposed of in a special way, the safety instructions of the manufacturer of the hazardous substances and the applicable regional waste disposal regulations must be observed. Also observe the relevant safety instructions in the product documentation.

5. Operating the products requires special training and intense concentration. Make certain that persons who use the products are physically, mentally and emotionally fit enough to handle operating the products; otherwise injuries or material damage may occur. It is the responsibility of the employer to select suitable personnel for operating the products.

6. Prior to switching on the product, it must be ensured that the nominal voltage setting on the product matches the nominal voltage of the AC supply network. If a different voltage is to be set, the power fuse of the product may have to be changed accordingly.

7. Operation is permitted only on sockets with earthing contact and protective earth connection.

8. Intentionally breaking the protective earth connection either in the feed line or in the product itself is not permitted. Doing so can result in the danger of an electric shock from the product. If extension cords or connector strips are implemented, they must be checked on a regular basis to ensure that they are safe to use.

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9. Never use the product if the power cable is damaged. Check the power cable on a regular basis to ensure that it is in proper operating condition. By taking appropriate safety measures and carefully laying the power cable, ensure that the cable cannot be damaged and that no one can be hurt by e.g. tripping over the cable or suffering an electric shock.
10. Do not replace the detachable mains supply cord by an inadequately rated cord.
11. Do not insert the plug into sockets that are dusty or dirty. Insert the plug firmly and all the way into the socket. Otherwise, this can result in sparks, fire and/or injuries.
12. Do not overload any sockets, extension cords or connector strips; doing so can cause fire or electric shocks.
13. It is not allowed to open the generator pulse units unless expressly permitted. Never remove the cover or any part of the housing while the product is in Operation. Doing so will expose circuits and components and can lead to injuries, fire or damage to the product.
14. The unit contains capacitors and cables, which discharge themselves only very slowly or, in worst case, do not discharge at all. Maintenance or repair of these units should be only carried out by HPPI.
15. If a product is to be permanently installed, the connection between the PE terminal on site and the product's PE conductor must be made first before any other connection is made. The product may be installed and connected only by a license electrician.
16. Use suitable over-voltage protection to ensure that no over-voltage (such as that caused by a thunderstorm) can reach the product. Otherwise the operating personnel will be endangered by electric shocks.
17. Do not insert any objects into the openings in the housing that are not designed for this purpose. Never pour any liquids onto or into the housing. This can cause short circuits inside the product and/or electric shocks, fire or injuries.
18. HPPI products are not protected against penetration of water, unless otherwise specified. If this is not taken into account, there exists the danger of electric shock for the user or damage to the product, which can also lead to personal injury.
19. Never use the product under conditions in which condensation has formed or can form in or on the product, e.g. if the product was moved from a cold to a warm environment.
20. The units are air cooled by convection. Therefore ensure that an adequate air-flow is available. Do not place the product on soft surfaces such as sofas or rugs or inside a closed housing, unless this is well ventilated.
21. Do not place the product on heat- generating devices such as radiators or fan heaters. The temperature of the environment must not exceed the maximum temperature specified in the data sheet.
22. Please be aware that in the event of a fire, toxic substances (gases, liquids etc.) that may be hazardous to your health may escape from the product.
23. The product can be very heavy. Be careful when moving it to avoid back or other physical injuries.
24. Do not place the product on surfaces, vehicles, cabinets or tables that for reasons of weight or stability are unsuitable for this purpose. Always follow the manufacturer's Installation instructions when installing the product and fastening it to objects or structures (e.g. walls and shelves).
25. Handles on the products are designed exclusively for personnel to hold or carry the product. It is therefore not permissible to use handles for fastening the product to or on means of transport such as cranes, fork lifts, wagons, etc. The user is responsible for securely fastening the products to or on the means of transport and for observing the safety regulations of the manufacturer of the means of transport. Noncompliance can result in personal injury or material damage.
26. If you use the product in a vehicle, it is the sole responsibility of the driver to drive the vehicle safely. Adequately secure the product in the vehicle to prevent injuries or other damage in the event of an accident. Never use the product in a moving vehicle if doing so could distract the driver of the vehicle. The driver is always responsible for the safety of the vehicle. The manufacturer assumes no responsibility for accidents or collisions.
27. Operation is permitted only with the accessory parts of HPPI. Using other parts happens on own risk.

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1.1.2 Operating Environment

The units may only be operated in a clean, dry environment. Ensure that no objects or liquids can get into the case though the ventilation slits. Because of the risk of sparks the pulse generator units should not be operated in the vicinity of flammable gases of fumes.

1.1.3 Cooling

The units are air cooled by convection. Therefore ensure that an adequate air-flow is available.

1.1.4 Opening the Unit

It is not allowed to open the generator pulse units.

ATTENTION!

The unit contains capacitors and cables, which discharge themselves only very slowly or, in worst case, do not discharge at all. Maintenance or repair of these units should be only carried out by HPPI.

1.1.5 Cleaning the Instrument

To clean the instrument, use a damp cloth or mild, water-based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument.

1.2 Operating Conditions

Power Supply Line	:	Input voltage range: nominal 100 - 240 VAC
EMI	:	Due to the steepness of the pulses generated by the units electromagnetic disturbance may occur.
Operating Conditions	:	Only usable in inner rooms
Temperature	:	0 °C up to 40 °C
Storage (Non Operating)	:	−10 °C to 75 °C
Humidity	:	85 % rel. max. (non condensing)
Air Pressure	:	Altitude up to 2000 m above sea level
Pollution Degree	:	2 corresponding IEC 664

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E-mail: info@hppi.de

2 Quick-Start

2.1 How to Setup a HBM Measurement

This section explains briefly how to set-up the hardware and software for measurement:

1. Decide if you want to go for simple "*2-wire setup*" (Fig. 12, p. 17) or "*4-wire Kelvin DUT voltage measurement setup*" (Fig. 15, p. 19). For comparison of the two methods please refer to Sect. 5.1, p. 21.
2. Select appropriate attenuator **A1**. For 6 kV test system no attenuator is required, because maximum output voltage of the current sensor will be less than 5 V. But for 10 kV system $A1 \geq 3$ dB is required in order to avoid oscilloscope input overloading[1].
3. Connect hardware components according the hardware setup block diagram (Fig. 12, p. 17 or Fig. 15, p. 19). The interconnection cables of the HBM-S1-B can/should be connected in the order presented in Sect. 4.4.1, p. 16, for easy assembly procedure.
4. Install and start HBM software.
5. Check *File / Hardware Settings* if all connected equipment is listed and select correct bus address. If necessary, refer to the software manual for further details.
6. Open the settings dialog and check the *General* tab. It should look like this:

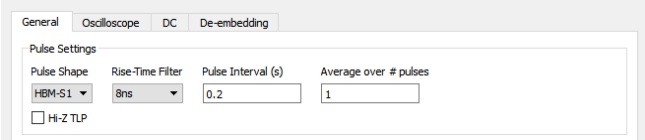

Figure 1: *Settings dialog / General* tab

7. Check the *Oscilloscope* tab and define correct scaling factors and oscilloscope channel assignment (Fig. 2).

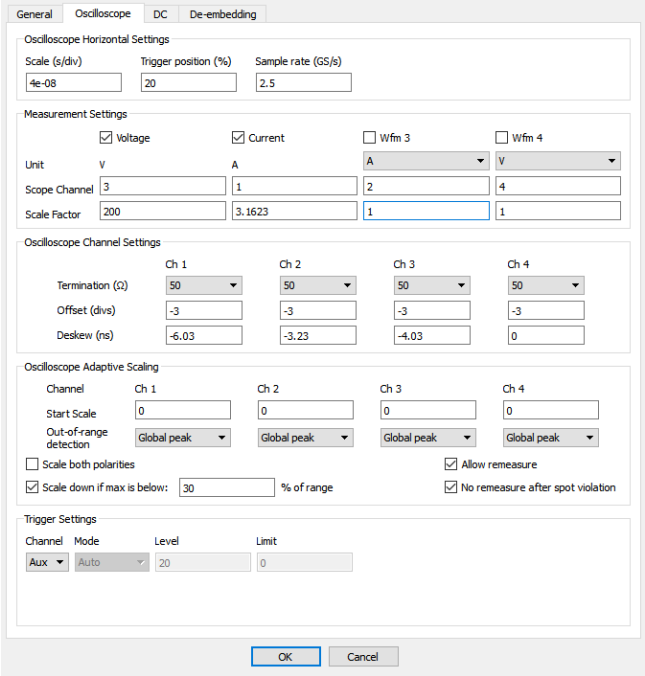

Figure 2: *Settings dialog / Oscilloscope* tab (shown for 2-pin setup)

[1] 10 kV HBM corresponds to 6.7 A peak current [1], which results in 6.7 V peak output voltage of the current sensor. This is slightly above the maximum input voltage of 5 V of typical 50 Ω digital oscilloscopes. The attenuator **A1** helps to keep the voltage at the digital oscilloscope input below 5 V by an attenuation factor of $10^{(-A1[dB]/20)}$.

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- Note that the *Voltage Scale Factor* has to be 100 in case of Kelvin-method using the 5k Picoprobe tip
- Depending on the value of the attenuator **A1** set the current *Scale Factor* of scope channel 1:

$$\text{Scale Factor} = 10^{\frac{A1[\text{dB}]}{20}} \tag{1}$$

Attenuator A1	Scale Factor
0 dB (= no attenuator)	1
3 dB	1.4125
6 dB	2
10 dB	3.1623

Table 1: Scale factor

8. Check the settings in the *De-embedding* tab. Activate the *Oscilloscope Offset Correction*:

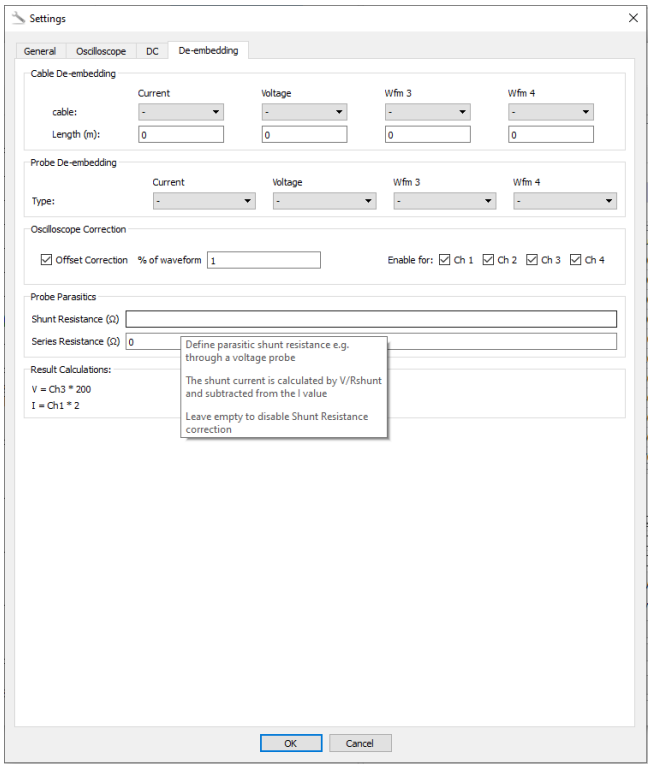

Figure 3: *De-embedding* tab

9. Connect a short circuit as device under test (DUT).
10. Go to *Tools / Calibration* and start a *Deskew* at 1000 V pulse voltage.
11. Open the settings dialog and check the *DC* tab in case of DUT DC test requirements.
12. Connect real DUT and start the measurement.

2.2 Precaution

- Do not operate the pulse unit >2 kV into open load or DUT voltage >2 kV

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3 Features

The HBM-S1-B is a Human-Body-Model (HBM) 2-pin tester according ANSI/ESDA/JEDEC JS-001 standard [1] with C=100 pF, R=1.5 kΩ discharge network. It can be used as an optional extension for the HPPI TLP-3010C, 4010C, 8010A/C and TLP-12010A/C systems.

Recommended measurement setup: see Sect. 4.6 on page 19.

- ±6 kV Human-Body-Model (HBM) 2-pin tester according ANSI/ESDA/JEDEC JS-001 standard with C=100 pF, R=1.5 kΩ discharge network
- True HBM: the classical discharge network according the standard ensures compliant waveforms for all load conditions
- Suppression of trailing pulses
- Integrated charge removal resistor
- Integrated DUT current sensor, with 1 V/A sensitivity, for real time HBM DUT current monitoring
- Integrated DUT voltage sensor, with $\frac{1}{200}$V/V sensitivity, for real time DUT voltage monitoring
- Integrated DC test DUT switch
- Integrated 50 Ω hardware trigger output
- Integrated overvoltage protection of voltage sense and DC test interfaces for oscilloscope and SMU protection during high voltage HBM testing
- Optionally available upgrade for all HPPI TLP-3010C, 4010C, 8010A/C and 12010A/C hardware systems and software (upgrade on request)
- Fast and efficient HBM measurements including transient waveform data management using the HPPI TLP software
- Compact size 145 mm x 82.5 mm x 44 mm

4 Description

4.1 Physical Dimensions

Fig. 4 shows the physical dimensions of the HBM-S1-B in [mm].

4.1.1 Fixation

For the fixation of the HBM-S1-B on the probestation there is a interface available shown in Fig. 5.

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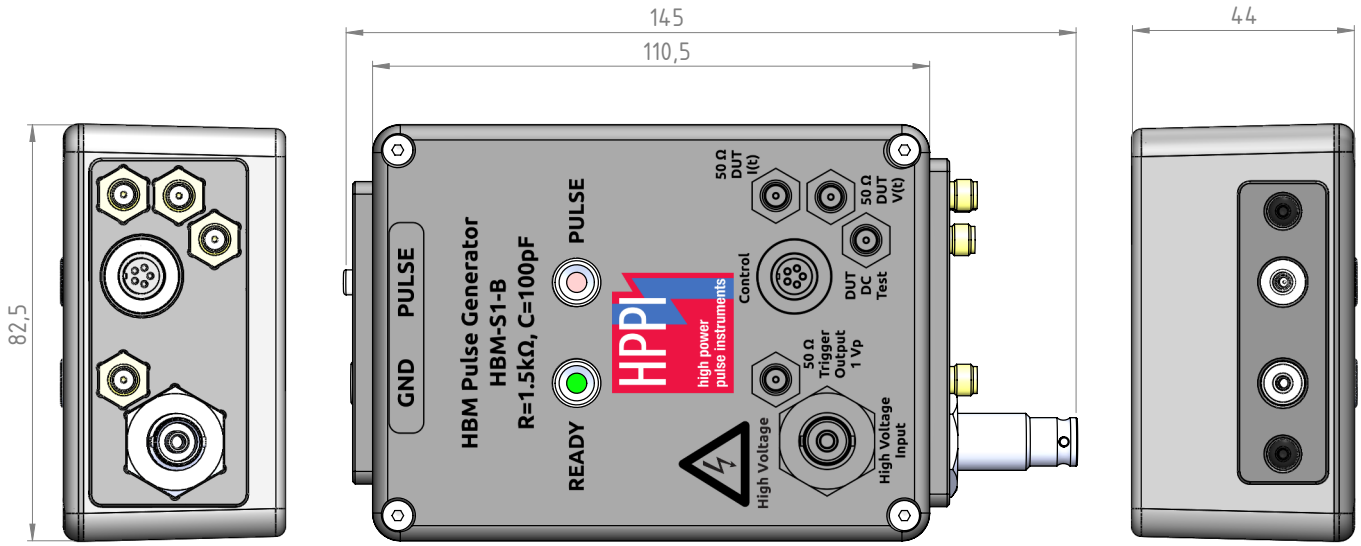

Figure 4: HBM-S1-B physical dimensions in [mm].

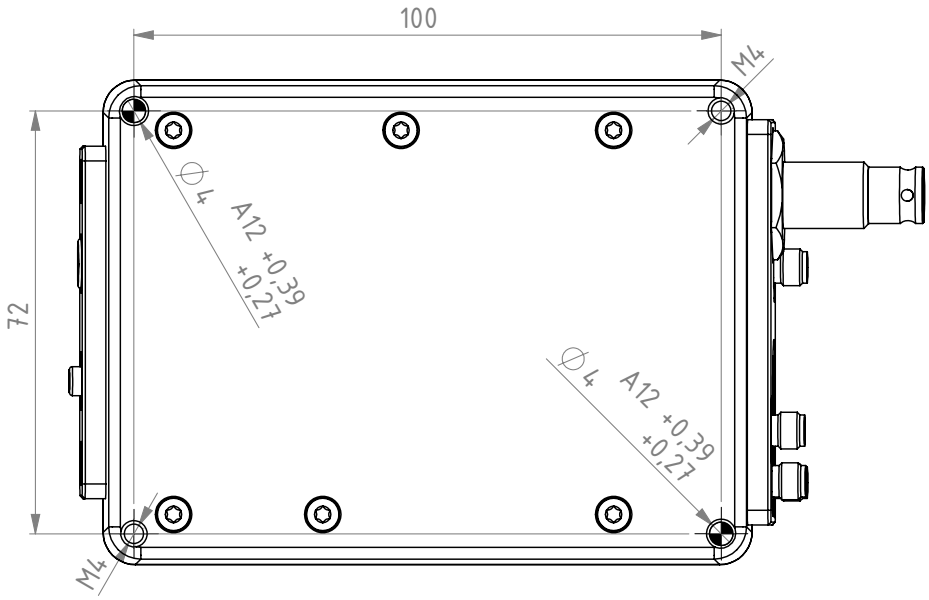

Figure 5: HBM-S1-B fixation interface bottom view [mm].

The pulse unit accessories fixture kit AF-37.5 shown in Fig. 6(a) is used to mount the HBM-S1-B on a Ø 37.5 mm pillar as presented in Fig. 6(b).

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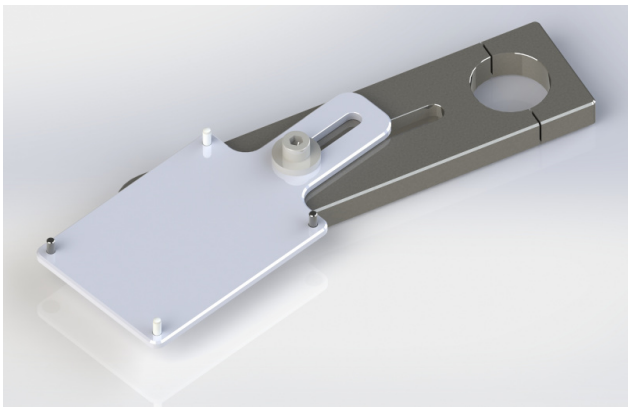
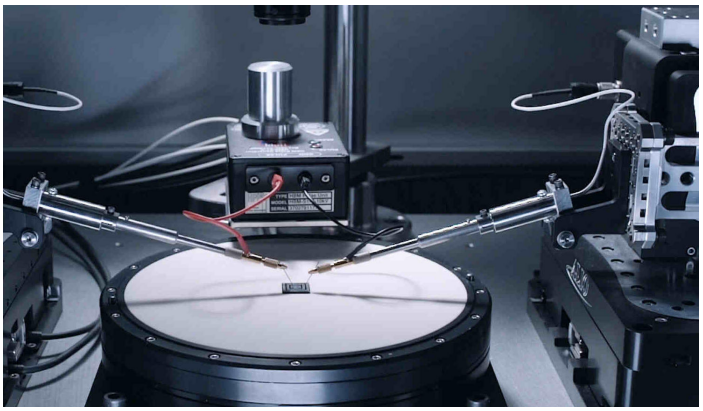


(a) Pulse unit accessories fixture kit AFK-37.5



(b) Example: HBM-S1-B mounted on the HBM tester

Figure 6: Accessories fixture kit

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4.2 Schematic Diagram

Fig. 7 and Fig. 8 show connectors and schematic diagram of the HBM-S1-B.

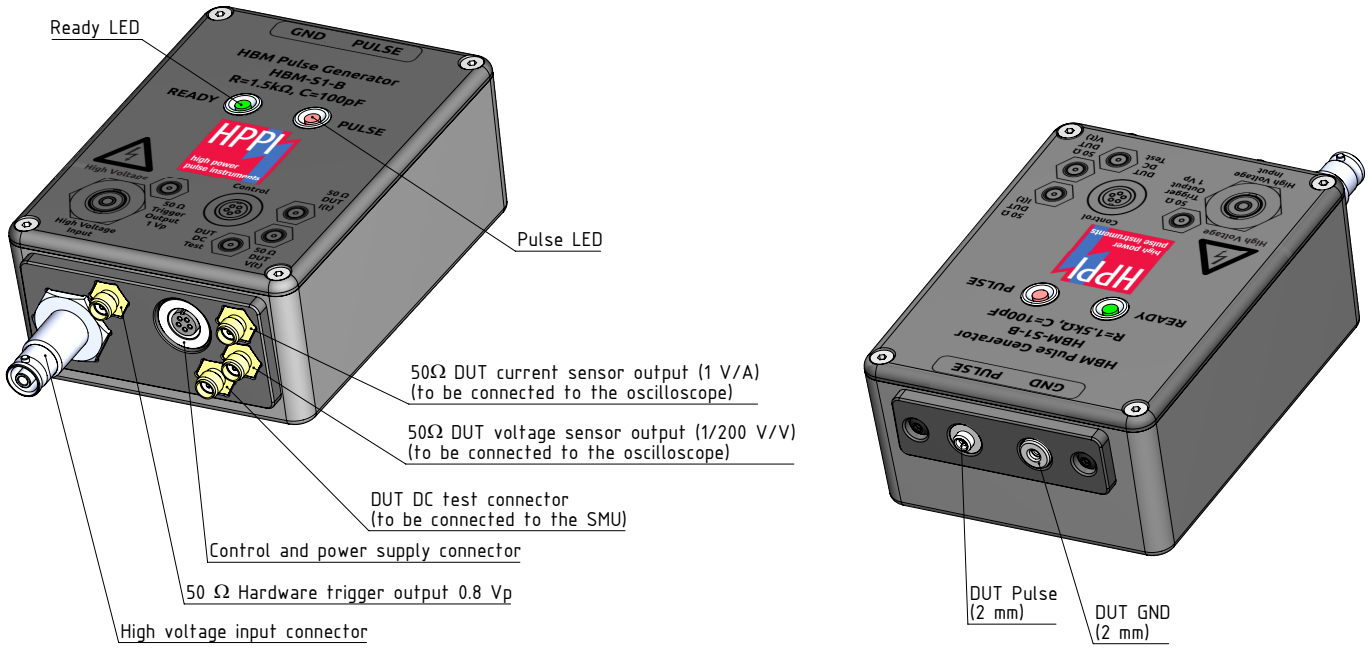

Figure 7: HBM-S1-B connectors.

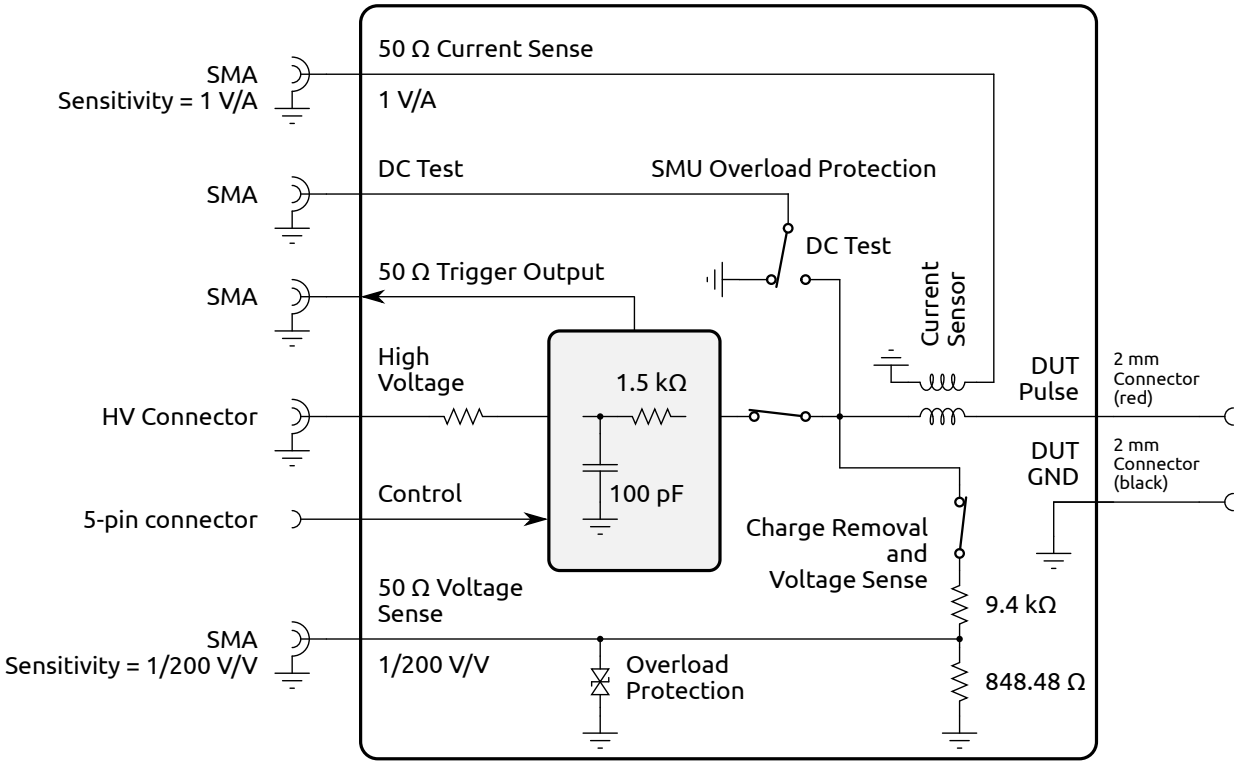

Figure 8: HBM-S1-B schematic diagram.

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4.3 Electrical Characteristics

4.3.1 Specifications

Tab. 2 shows the specifications of the HBM-S1-B.

Parameter	Symbol	Limit Values			Unit	Remarks
		Min.	Typ.	Max.		
Compliant to HBM standard	ANSI/ESDA/JEDEC JS-001 (C=100 pF, R=1.5 kΩ)					
Maximum HBM test voltage	$V_{HBM,max}$	−6.0		+6.0	kV	
Minimum HBM test voltage	$V_{HBM,min}$	−100		+100	V	
HBM test voltage step size	V_{Δ}		1		V	digital programmable
DUT voltage range	V_{DUT}	−1.2		+1.2	kV	open load condition
DUT current range	I_{DUT}	−4		+4	A	according to ±6 kV HBM
Charge removal resistance	R_{CR}		9447		Ω	Voltage sense output to be terminated with 50 Ω
Voltage sense output sensitivity	k_V		$\frac{1}{200}$		V/V	±10 % into a 50 Ω load
Maximum voltage sense output voltage	$V_{max,V}$	−8		+8	V	internally clamped by a bi-directional TVS diode
Current sense output sensitivity	k_I		1		V/A	±3 % into a 50 Ω load
Maximum current sense output voltage	$V_{max,I}$	−8		+8	V	internally clamped by a bi-directional TVS diode
Internal current sensor series load impedance	Z_{CS}		50		mΩ	current sense output to be terminated with 50 Ω
Trigger Output Voltage	V_{TR}		1		V_P	50 Ω
Measurement pulse repetition time	t_m		500		ms	state dependent, digital programmable.
Supply voltage	V_{DC}		12		V	DC (5-pin control connector)
Supply current	I_{DC}			0.5	A	DC (5-pin control connector)
Physical dimensions		145 x 82.5 x 44			mm^3	

Table 2: HBM-S1-B electrical characteristics

The internal current sensor (current sense) is used to measure the DUT current. The sensitivity of the current sensor is 1 V/A if the current sense output is connected to the 50 Ω oscilloscope input. In addition a 3 dB attenuator is recommended to scale the maximum 6.7 V output below the 5 V input voltage range of the oscilloscope input. Please make sure that the oscilloscope input impedance is set to 50 Ω. A peak current of 2/3 A correlates to 1 kV HBM level.

The integrated DUT voltage sense output has a large scale sensitivity of 1/200 V/V = 0.005 V/V which enables DUT voltage measurements up to about 1200 V at maximum 6 V oscilloscope input voltage. Please note that the integrated voltage sensor is intended to be used for coarse DUT voltage measurements. Also the parasitic inductance of the interconnection cables add significant voltage drop to the measurement result. Therefore, if accurate DUT voltage measurement is of interest, the Kelvin-setup with separate pulse sense arrangement is recommended, as presented in Fig. 15 and Fig. 16.

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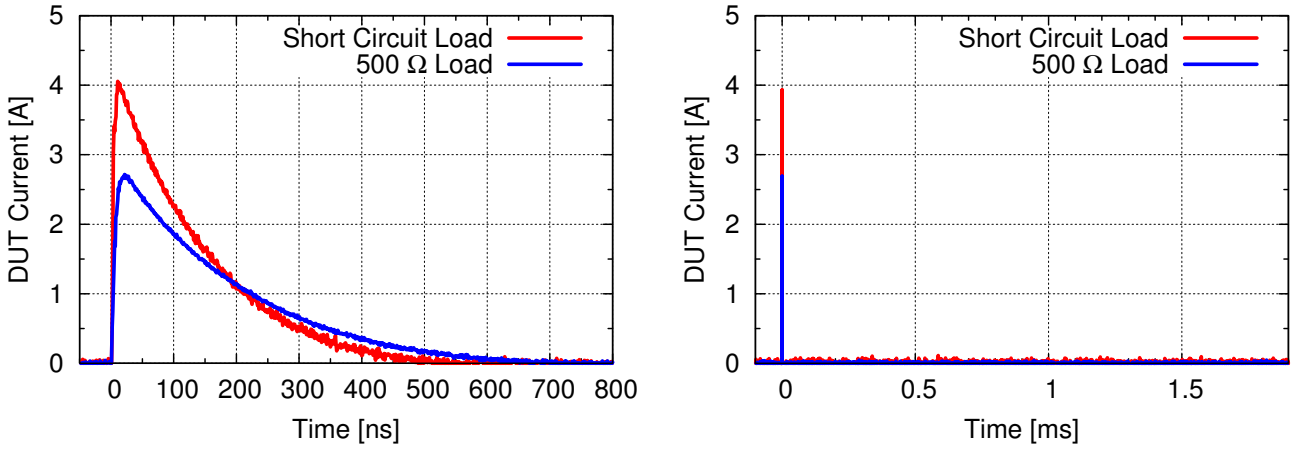
4.3.2 HBM Transient Output Current Waveforms

Fig. 9 shows the typical current transient waveforms for short circuit and 500 Ω load condition.



(a) Short circuit and 500 Ω output current at 10 kV.

(b) DUT current at 10 kV HBM. Long (2 ms) time axis shows no trailing pulses.

Figure 9: Typical DUT output current waveforms

4.3.3 Precaution: Do Not Test >2 kV at Open Load Condition

The HBM-S1-B has been designed and can be operated up to its maximum ratings of ±6 kV, if the clamping voltage of the DUT does not exceed 2 kV. Therefore the HBM-S1-B shall not operated >2 kV at open load condition. Otherwise unexpected breakdown may occur.

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4.4 Interface Connections

4.4.1 Recommended Interface Connection Procedure

The HBM-S1-B is very small and has 6 interface connections on the front panel. For easy connection procedure the order presented in Fig. 10 is recommended:

1. connect DC cable
2. connect V(t) cable
3. connect I(t) cable
4. connect control cable
5. connect trigger cable
6. connect high-voltage cable

For disconnection follow the reverse order.

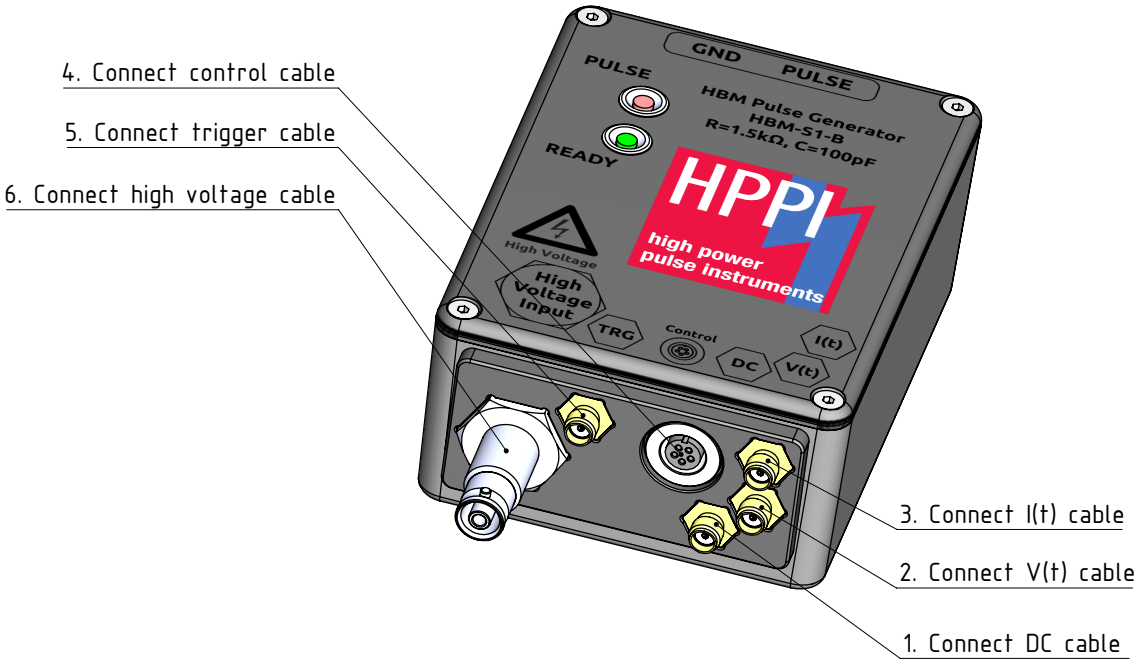

Figure 10: Recommended interface connection procedure

4.4.2 High Voltage Interconnection Cable

According to Fig. 12 or Fig. 15 the 3 m long high voltage interconnection cable HV10-300A shall be connected as shown in Fig. 11. Both connectors are of same type and can be exchanged.

Figure 11: High voltage interconnection cable HV10-300A (3 m long).

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4.5 HBM (2-Wire) Measurement Setup

Fig. 12 shows how the HBM-S1-B is connected in the measurement system in direct pulse sense (2-wire) configuration.

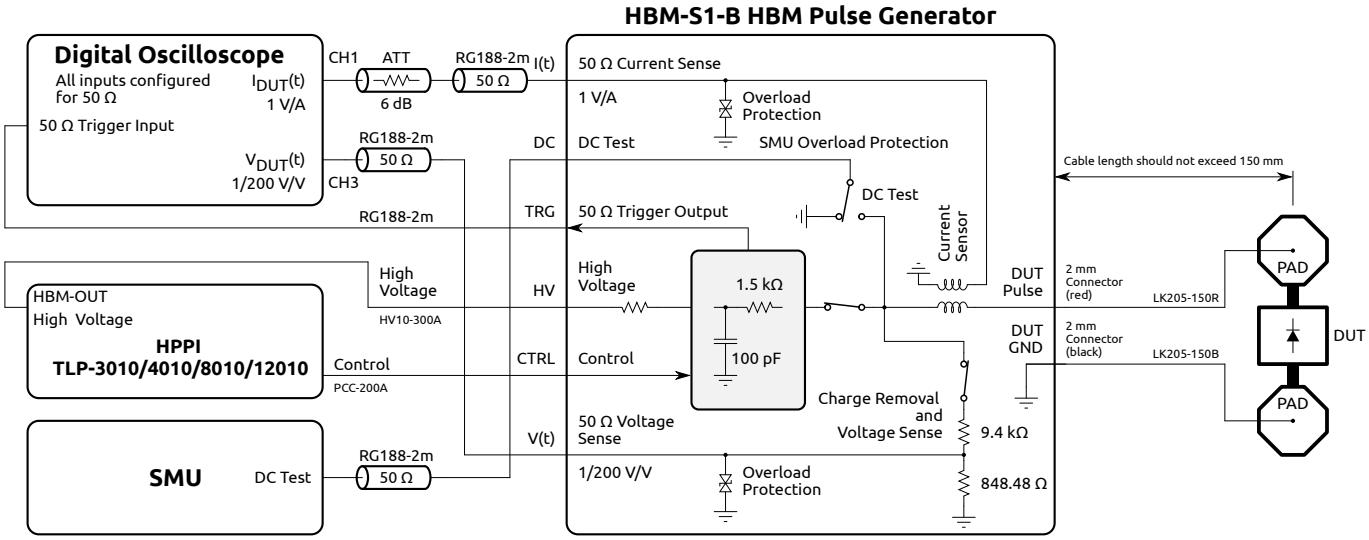

Figure 12: HBM-S1-B direct pulse sense (2-wire) measurement setup.

Fig. 13 shows the HBM-S1-B used standalone. Simply connect the DUT with the DUT-Pulse and DUT-GND cables, and the control cables of the HBM-S1-B as shown in Fig. 12.

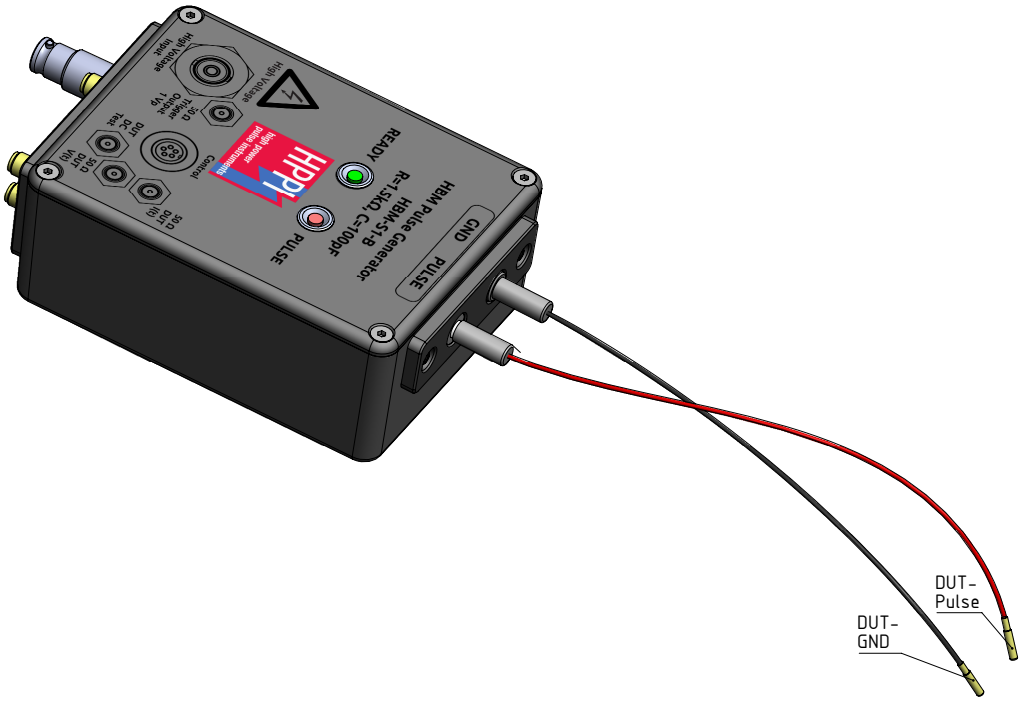

Figure 13: HBM-S1-B standalone direct pulse sense (2-wire) measurement setup. For lower parasitic inductance the cables are slightly crossed. The length of the cables should not exceed 150 mm, which results in best waveform quality due to low parasitic inductance.

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Fig. 14 shows the HBM-S1-B arranged on a wafer probing station using flexible-pitch probe-tips HPPI TPA-GFG. The HBM-S1-B integrated DUT voltage sensor and current sensor is used to measure the DUT transient voltage and current waveforms.

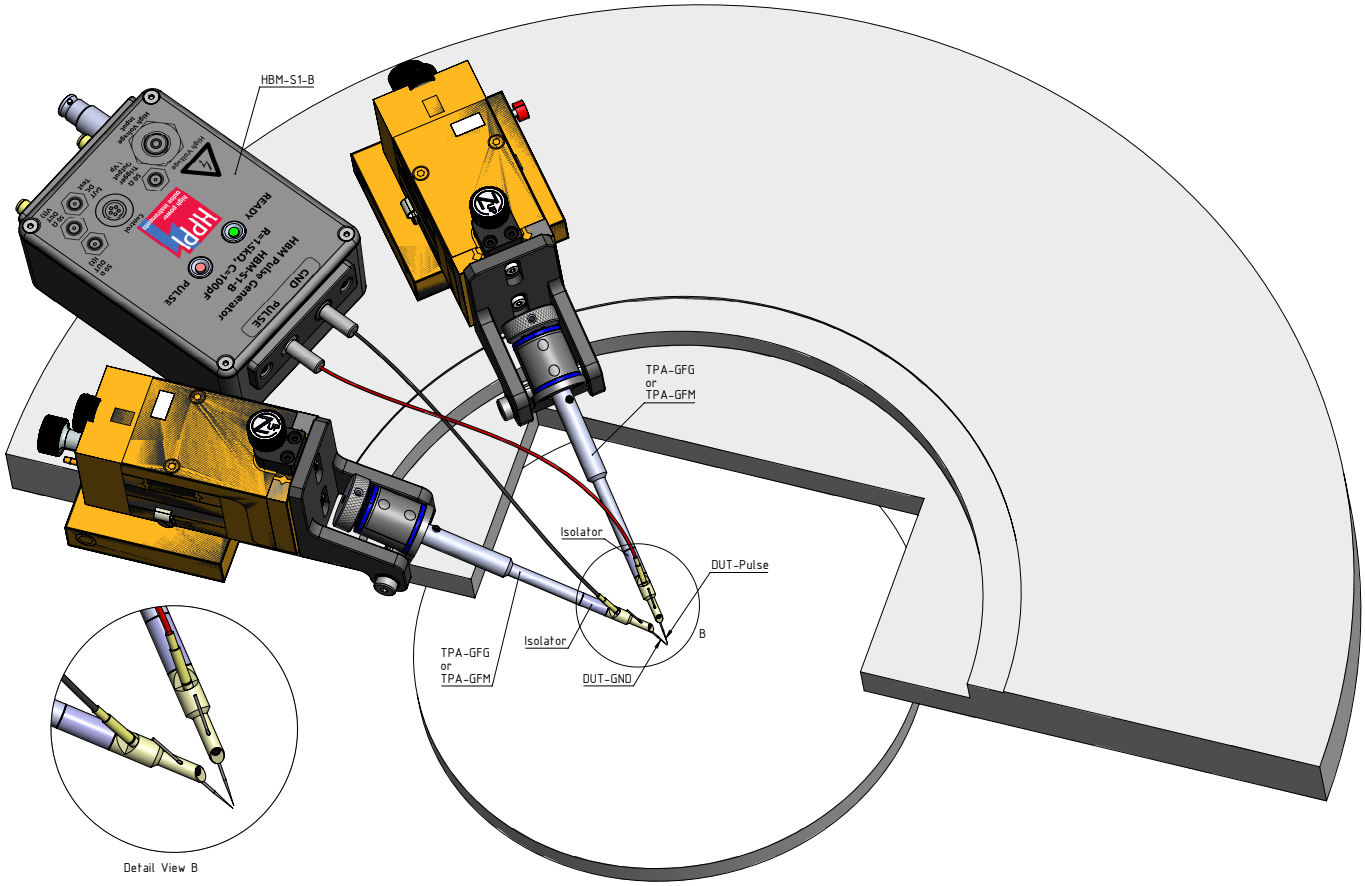

Figure 14: HBM-S1-B on a wafer probing station using flexible pitch solution (HPPI TPA-GFG or TPA-GFM). For lower parasitic inductance the cables should be twisted.

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4.6 HBM Kelvin (4-Wire) Pulse Sense Measurement Setup (Recommended)

This setup results in most accurate DUT voltage measurement, because of Kelvin-type voltage sensing. Fig. 15 shows how the HBM-S1-B is connected in the measurement system in kelvin (4-wire) pulse sense configuration. The DUT voltage is measured using a separate pulse sense channel based on the HPPI flexible pitch probe arms PHD-3001A, TPA-GFG (or TPA-GFM) and GF-A. Fig. 16 shows the physical interconnection of the DUT switch.

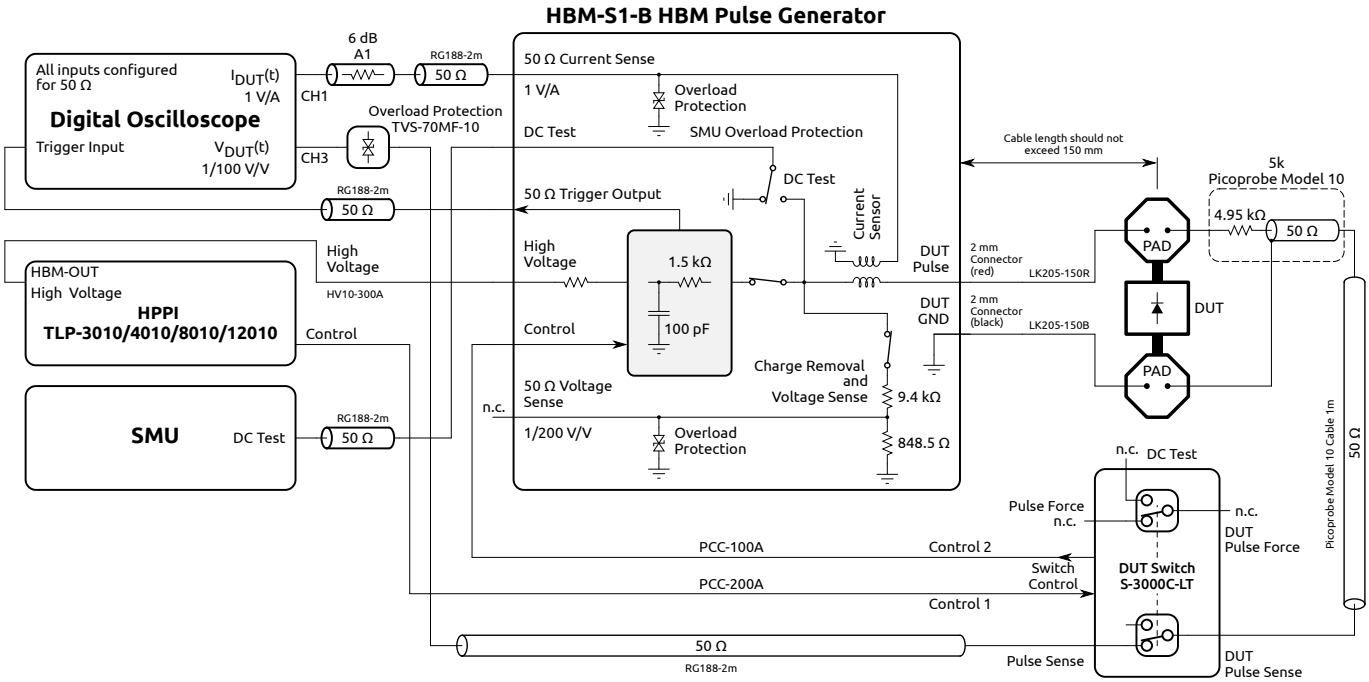

Figure 15: HBM-S1-B Kelvin (4-wire) pulse sense measurement setup

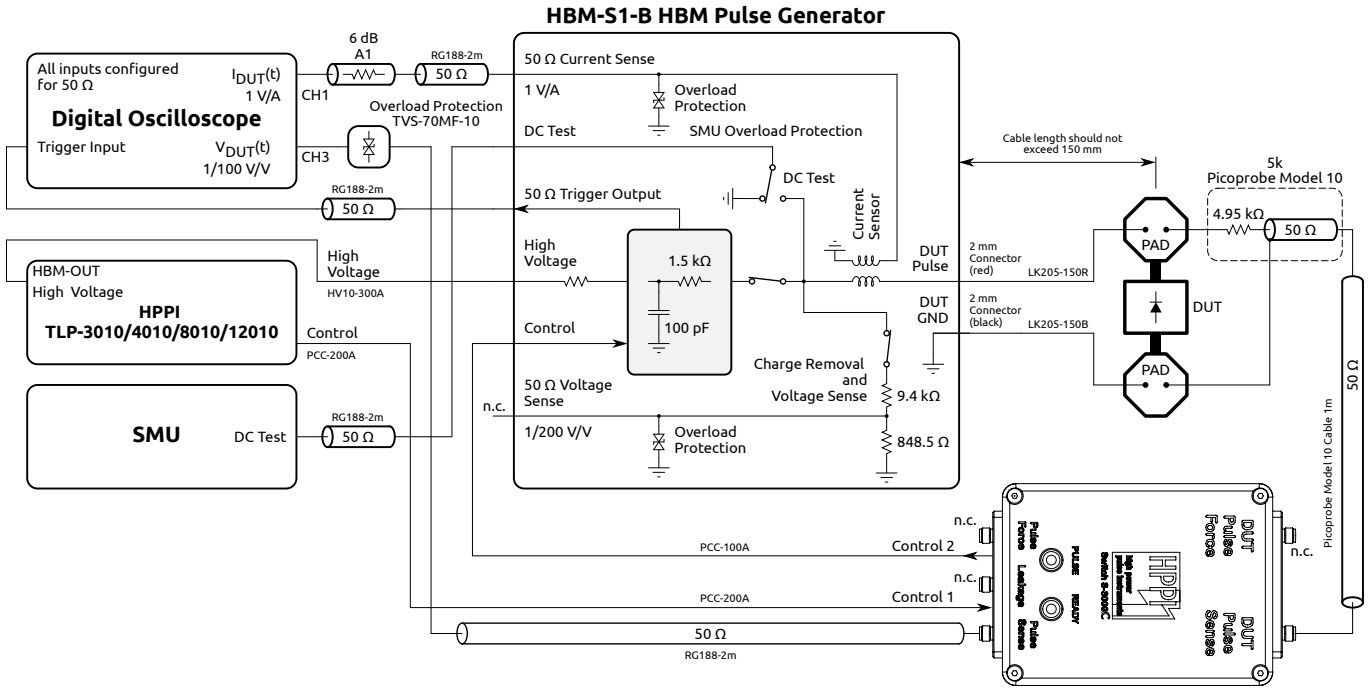

Figure 16: HBM-S1-B Kelvin (4-wire) pulse sense measurement setup (including DUT switch hardware illustration)

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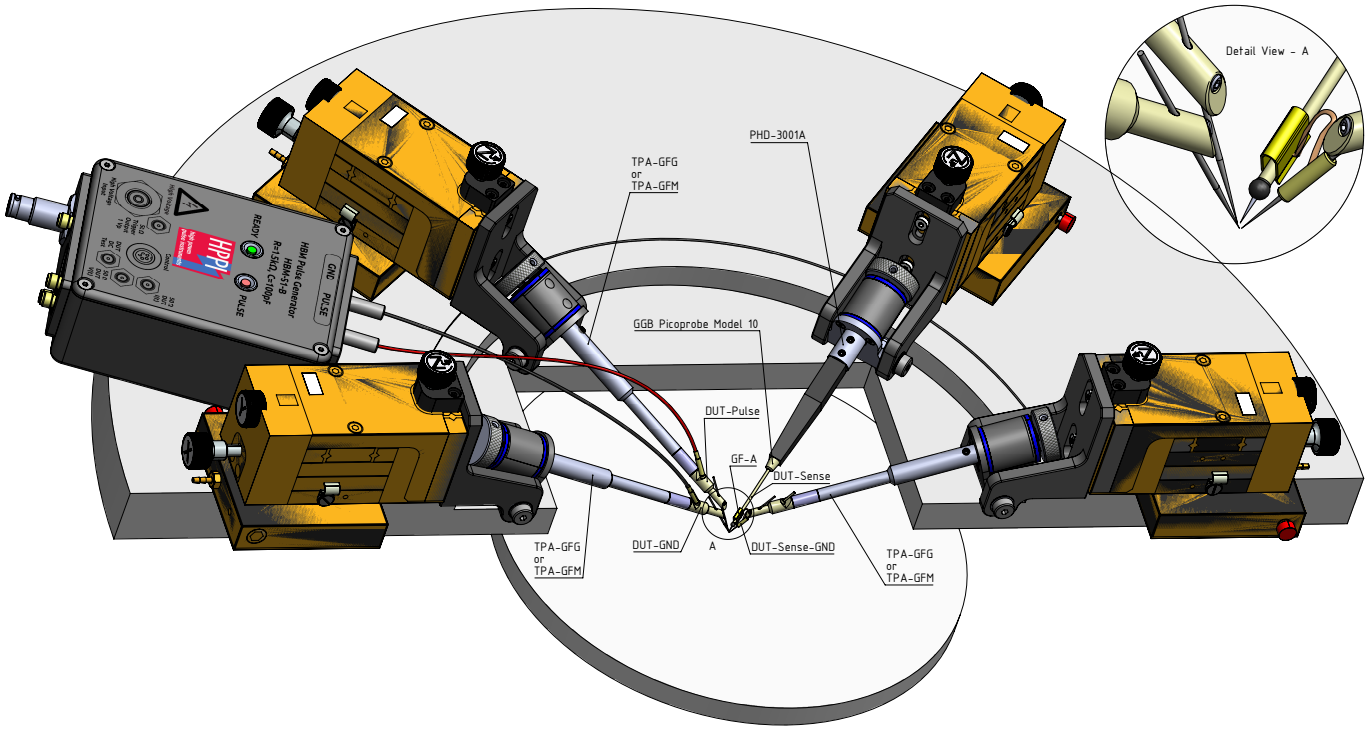

Figure 17: HBM-S1-B on a wafer probing station using flexible pitch pulse force solution (HPPI TPA-GFG) and separate pulse sense channel. For lower parasitic inductance the cables are slightly crossed.

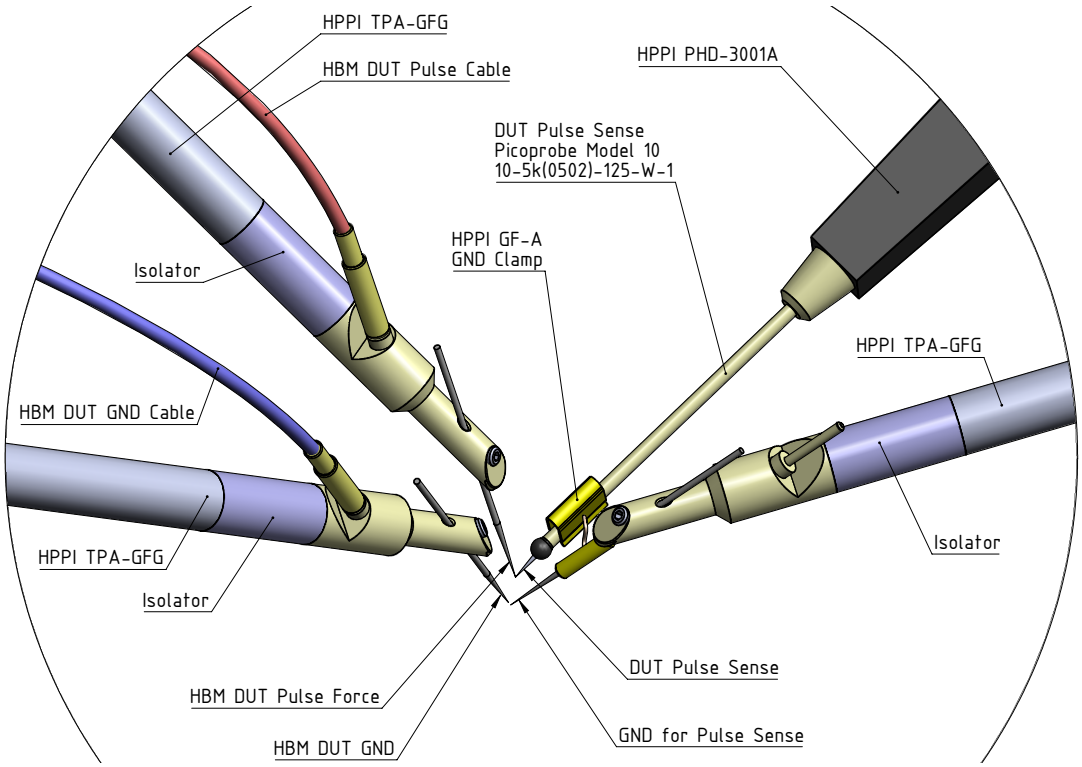

Figure 18: Detail view of the flexible pitch setup of Fig. 17.

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5 Application Note

5.1 2-Pin versus 4-Wire (Kelvin) DUT Voltage Measurement

This application note explains the advantage of the Kelvin voltage probing method versus 2-pin method.

Classical 2-Pin Setup

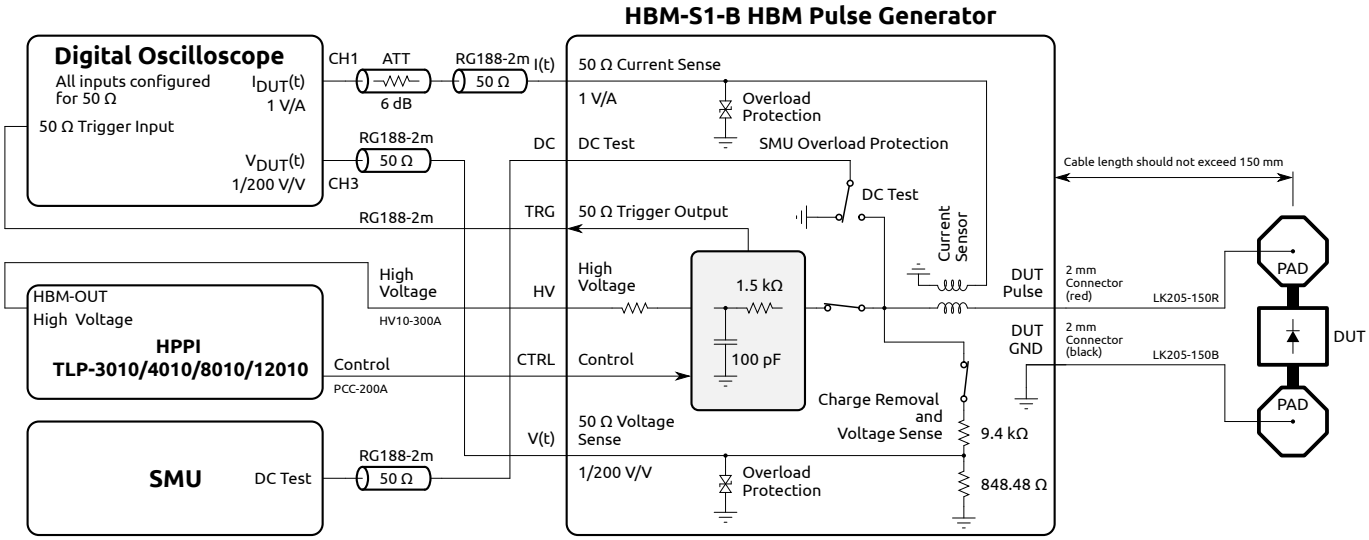

Figure 19: Classical 2-pin setup

Kelvin 4-Wire Voltage Probing Setup

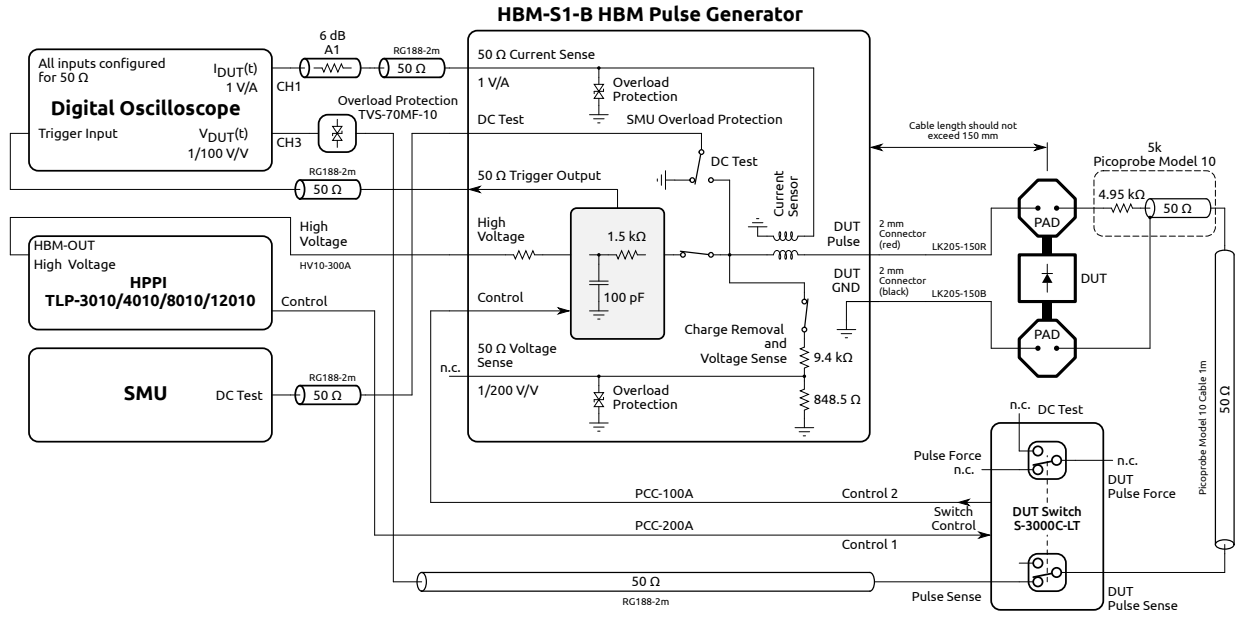

Figure 20: Kelvin 4-wire voltage probing setup

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Simple Lab-Desk Setup

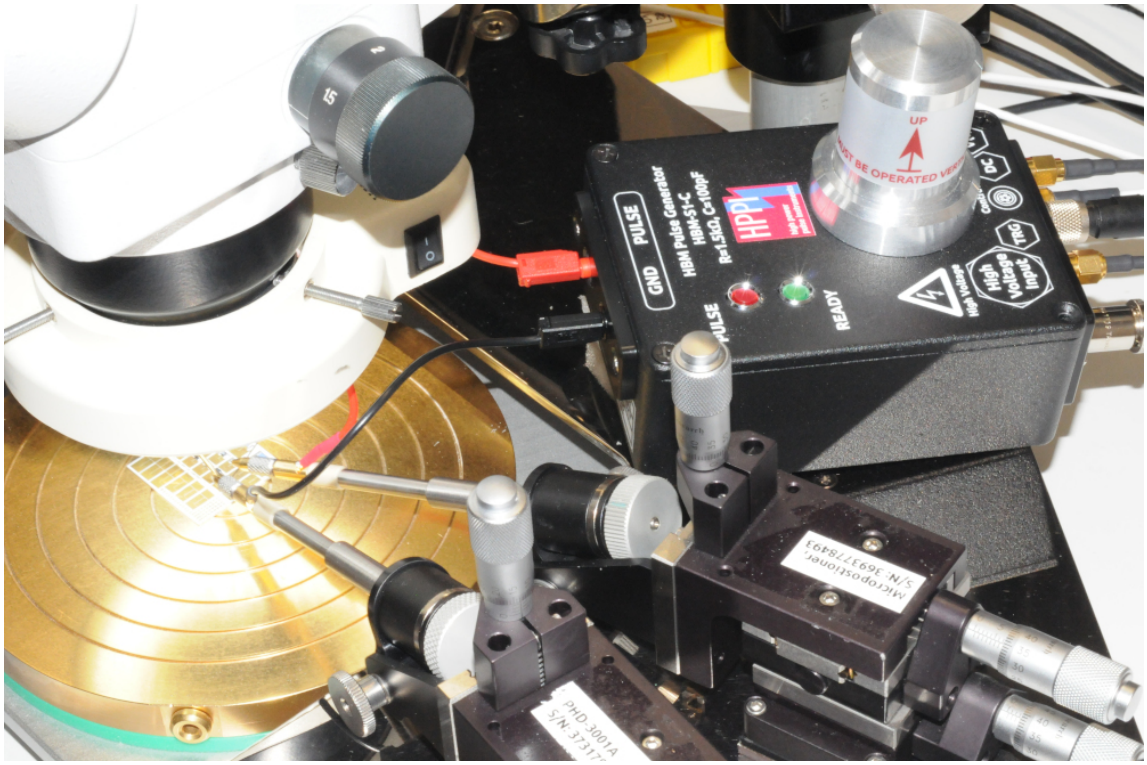

Figure 21: Simple lab-desk setup

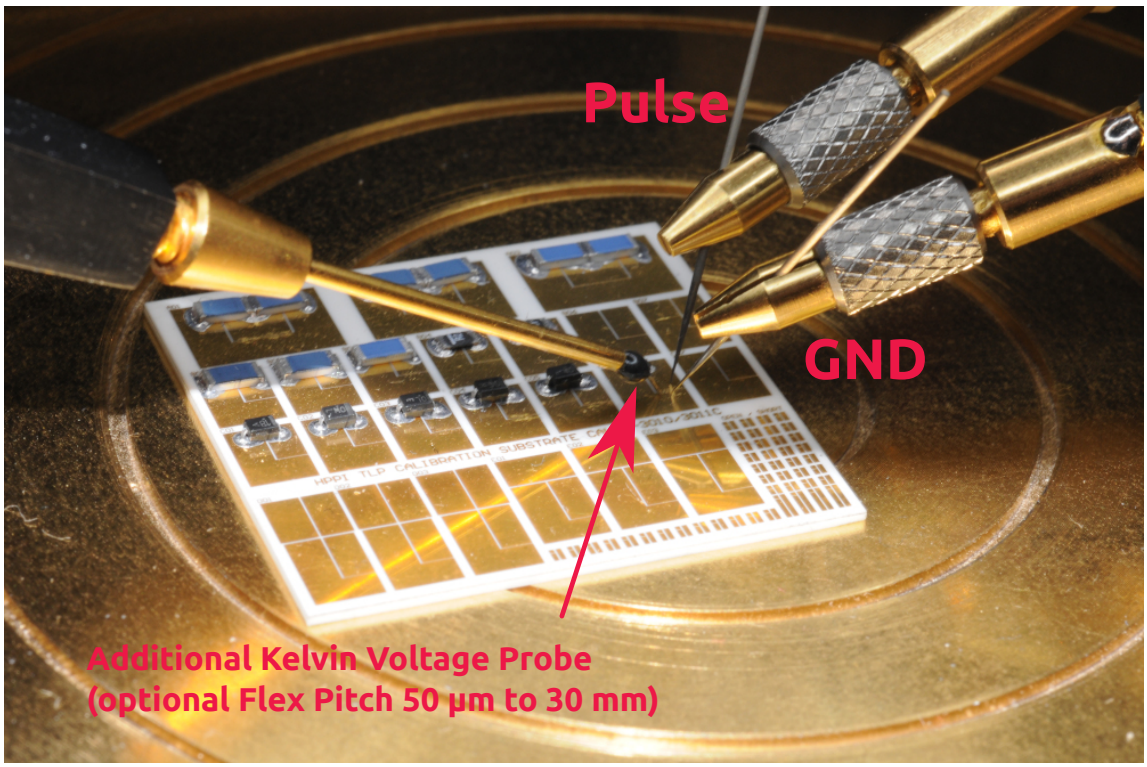

Figure 22: Right: HBM-PULSE and HBM-GND, Left: pulse sense (voltage sense probe)

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Current Waveform at 1 kV

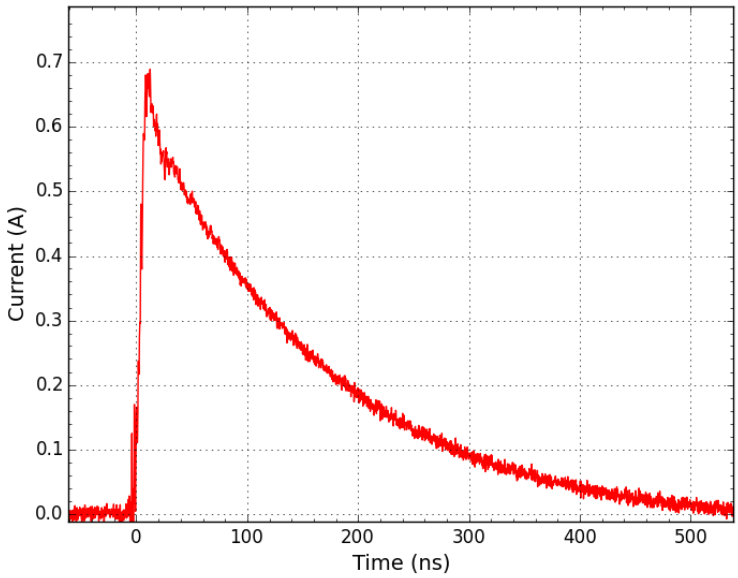

Figure 23: Current test waveform at 1 kV

5.1.1 Comparison: 2-pin versus 4-Wire (Kelvin) Voltage Probing

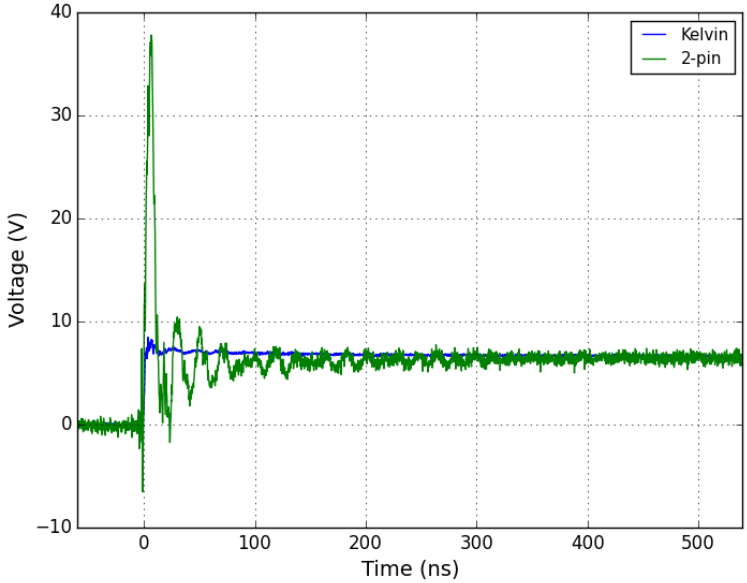

Figure 24: Comparison: 2-pin versus Kelvin voltage probing

- The classical 2-pin setup results in ringing because the voltage probe shares pulse-force and pulse-GND cables and the voltage drop of the parasitic cable inductance tampers the measurement result.

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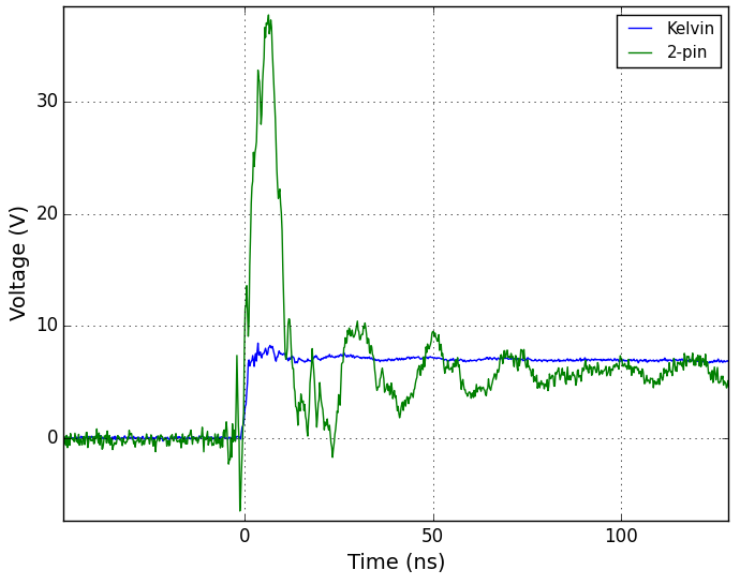

Figure 25: Comparison: 2-pin versus Kelvin voltage probing (zoom view)

- Zoom view: the classical 2-pin setup results in ringing because of the parasitic inductance of the pulse-force and pulse-GND cables

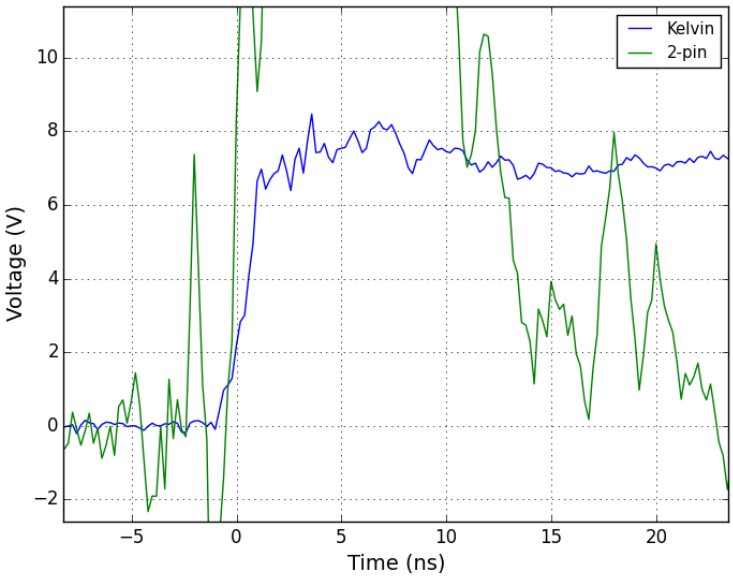

Figure 26: Comparison: 2-pin versus Kelvin voltage probing (close zoom view)

- Only the Kelvin voltage probing results in accurate measurement of the DUT voltage in the nano-second range

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5.1.2 Conclusions

- The Kelvin 4-wire voltage probing method outperforms the classical 2-pin probing method
- If accurate HBM DUT clamping and turn-on voltage measurement is of interest, the Kelvin method is must have
- If the transient DUT voltage is not of interest, and only the HBM pass/fail information is needed as a result, then the classical 2-pin setup is sufficient

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References

[1] ANSI/ESDA/JEDEC, *ESDA/JEDEC Joint Standard for Electrostatic Discharge Sensitivity Testing - Human Body Model (HBM) - Component Level*, https://www.jedec.org/, Apr. 2012.

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