Probing PMK

For Technical Audience

Revision 1.0 11-May-2025

Created by: PMK General

PROPRIETARY
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Agenda

- Company overview HIAG
- General probing topics
- Application Information SiC and GAN
- Current Measurements

HIAG Overview

Company structure | HIAG

HEIMANN INDUSTRIES AG

Mark Heimann
Executive Board

Dr. Michael Rautenberg
Supervisory Board

Hendrik J. Ansink
Supervisory Board

Ingo Ley
Chairman of the Supervisory Board

PMK
Mess- und Kommunikationstechnik GmbH

M. Heimann
N. Frabasile
Managing Director

P. Pálffy-Daun
N. Lääperi
Authorized Officer

PMK America
Corporation Portland, USA

M. Mende
President

N. Lääperi
VP Sales

PMK
Service und Produktions GmbH

M. Heimann
N. Frabasile
Managing Director

P. Pálffy-Daun
N. Lääperi
Authorized Officer

IWATSU Test Instruments Europe GmbH

M. Heimann
K. Matsumoto
Managing Director

History

- Portland

- Tokyo

HEIMANN INDUSTRIES AG

- Bad Soden am Taunus
- Sulzbach (Taunus)
- Groß-Umstadt

1991

Founded by
Dipl.-Ing. Peter Heimann

PMK
Probing Solutions. Made in Germany.

1998

The founder's sons,
Mark and Jens Heimann,
take over management
of the company

2003

Launch of the first
compact 2.5 mm
PML probe series

2006

Launch of the first
high impedance
active probes
1.5 GHz TETRIS®

2010

Market launch of
2.5 GHz active probe
TETRIS®

2011

Foundation of
HF Instruments GmbH
Sulzbach (Taunus)

HFI

Foundation of
Heimann Industries AG

2017

Launches:
- 2000V differential probe series BumbleBee®
- 4 GHz active probe TETRIS

Foundation of
IWATSU Test Instruments Europe GmbH

IWATSU
TEST INSTRUMENTS EUROPE GmbH

2021

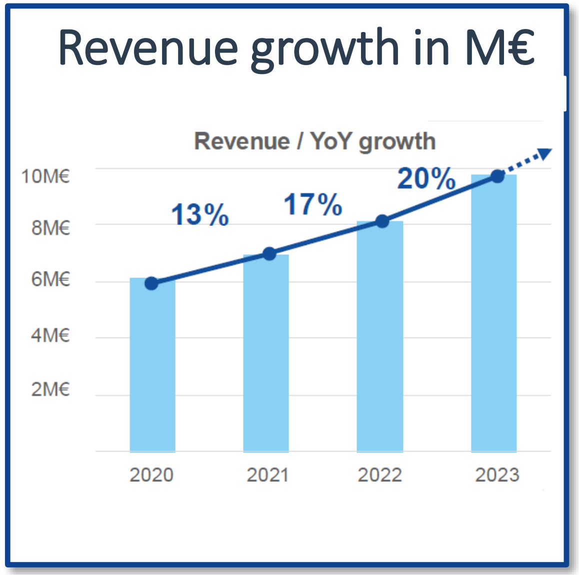
PMK
Probing Solutions. Made in Germany.

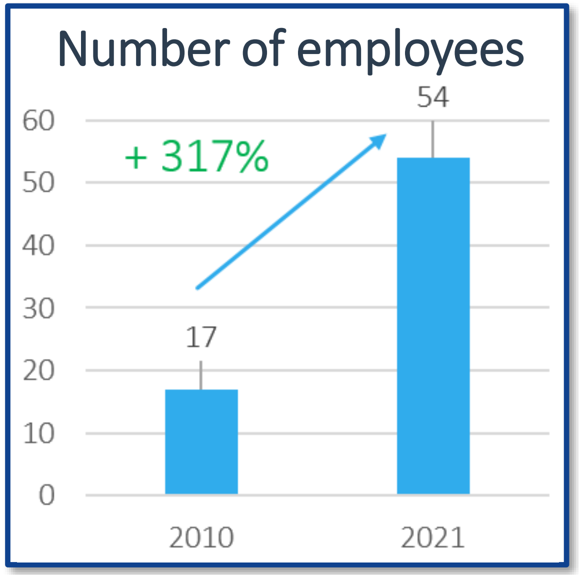
Foundation of
PMK America Corporation
Portland, USA

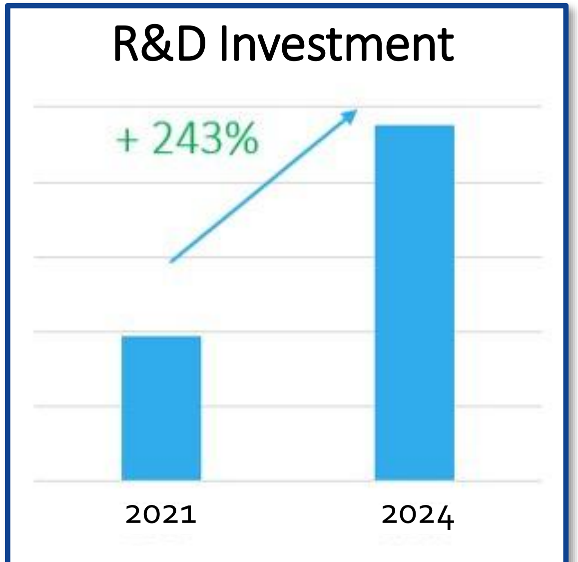
2022

Launches:
- Optical-isolated probe FireFly®
- Differential probe series HSDP
- MMCX-probe series

PMK Overview & Capability







About PMK:

- PMK is an independent manufacturer of electronic measuring devices
- Specialist for high quality probes
- Successfully represented in the market for over 30 years
- Owner-managed family business
- International customer base
- German mid-sized companies

Innovative probing solutions for research, development, manufacturing, and service to partners worldwide.

- Power electronics
- Semiconductor Industry
- Aerospace
- Regenerative energies
- E-mobility (electric drives)
- Autonomous driving

Our partners are well-known manufacturers and market leaders from the field of test and measurement.

Impressions

Bad Soden – Headquarters

Sulzbach – Manufacturing Center

Sulzbach – Site

Sulzbach – RnD Center

Meeting Room Design Project

PMK – Team Germany

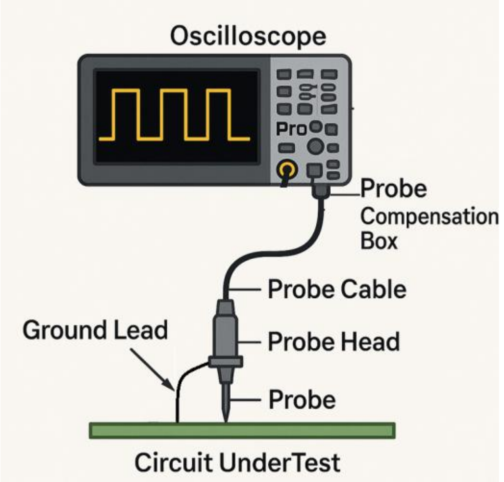
Unique Probing Solutions

Trade Shows

General probing topics

What is a probe?

A probe for use with an oscilloscope is a tool that connects the oscilloscope to the circuit under test



Signal Interface Tool: A probe is the physical link between the oscilloscope and the device or circuit being measured, allowing the oscilloscope to capture electrical signals.

Types of Probes: Common types include passive probes (simple and affordable), active probes (amplified for high-speed signals), differential probes (for measuring voltage between two points not referenced to ground), and current probes (AC/DC or Rogowski).

Attenuation Factor: Probes often have attenuation settings like 1x or 10x, which reduce the signal amplitude to prevent overloading the oscilloscope and to extend measurement range.

Bandwidth and Impedance: A probe's bandwidth (e.g., 100 MHz) and input impedance (typically 10 MΩ) must match or exceed the oscilloscope and signal requirements to ensure accurate measurement.

Compensation Adjustment: Most probes include a small trimmer capacitor to adjust for frequency response mismatches between the probe and oscilloscope input, ensuring accurate signal reproduction.

The ideal probe

In an ideal world, the ideal probe would offer the following key attributes:

1. **Infinite Input Impedance**: So it draws no current from the circuit and causes zero loading effect.

2. **Zero Capacitance**: To prevent any influence on the signal frequency response or circuit behavior.

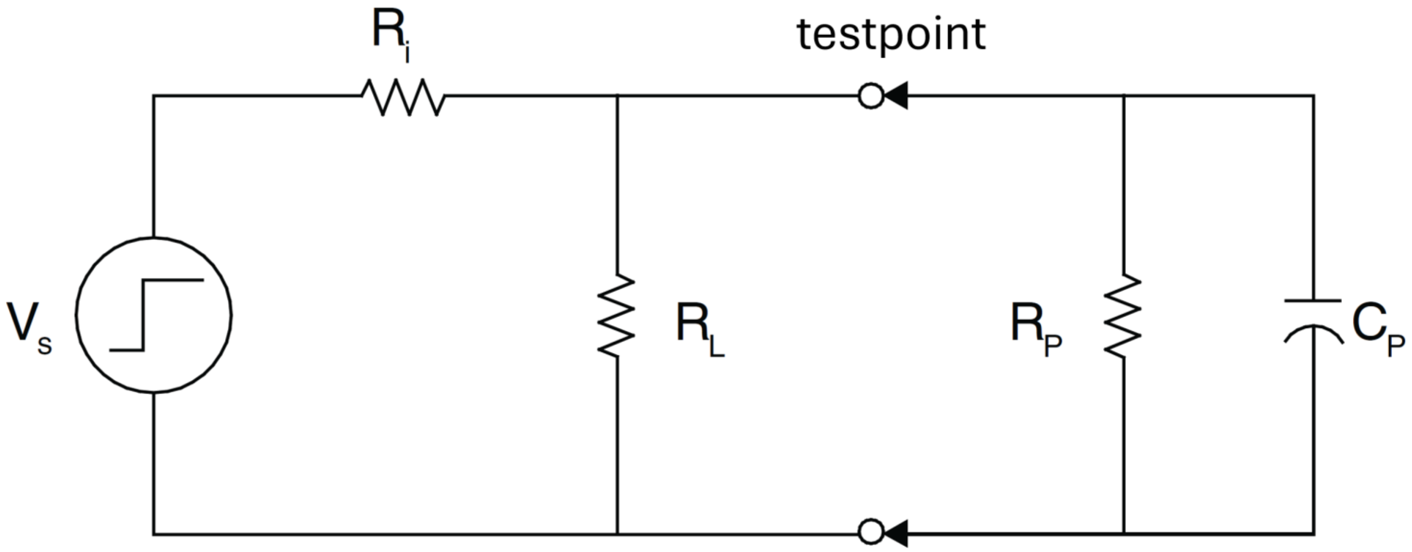
3. **Flat Frequency Response across an infinite bandwidth**: meaning it can accurately reproduce any signal, from DC to very high-frequency components.

4. **Zero Time Delay**: It transfers the signal to the oscilloscope instantly, with no phase shift or distortion.

5. **Perfect Common-Mode Rejection**: Especially in differential measurements, it would reject all unwanted noise and only display the true differential signal.

General probe load

equivalent circuit diagram

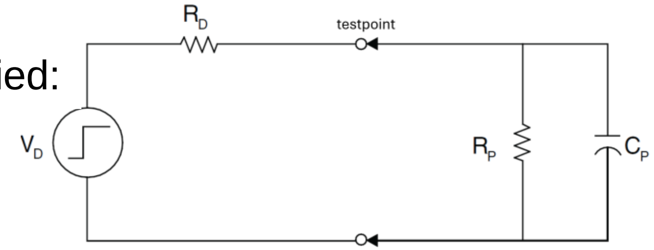


The probe loading indicates how the probe affects the device under test. The device under test can be a signal source (Vs) with an input resistance (Ri) and a load (RL). The probe can be a resistor (Rp) and a capacitor (Cp).

Important factors of the probe:

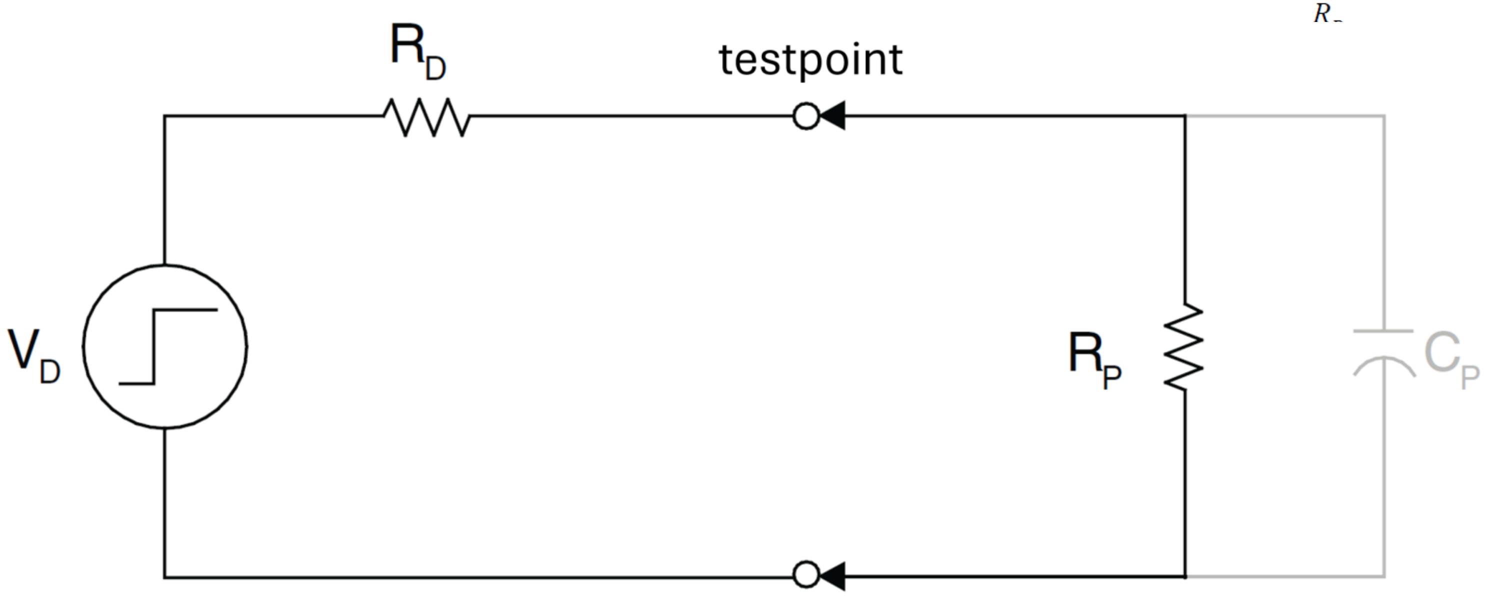
- Input resistance
- Input capacity
- the probe inductance

simplified:



General probe load

Effects of input resistance Rp



$$V_{Meas} = V_D \frac{R_P}{R_P + R_D}$$

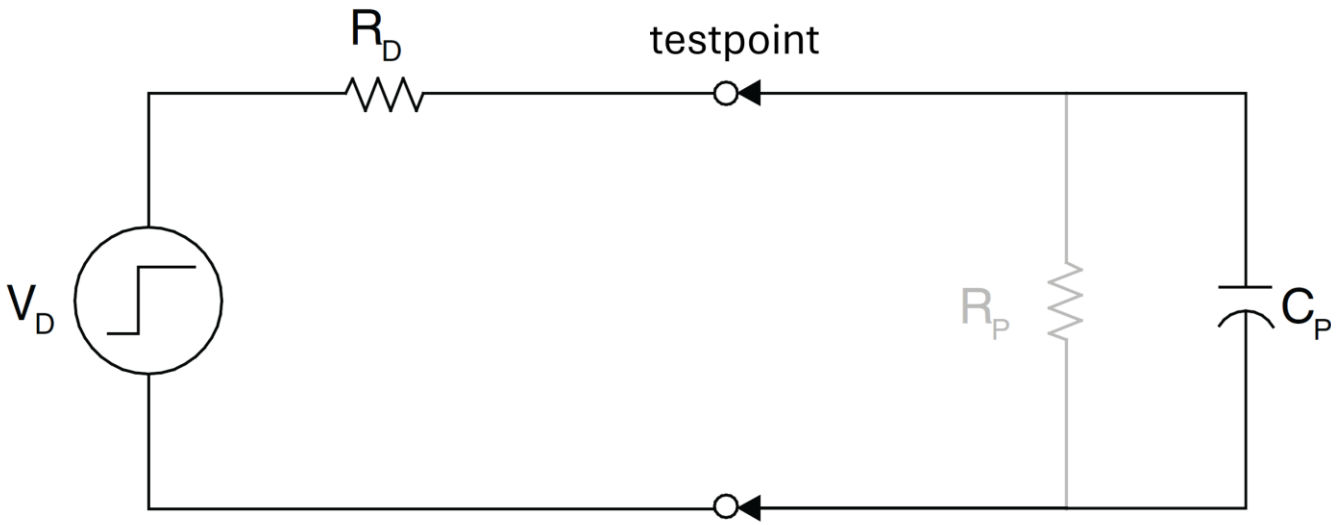
Signal testpoint

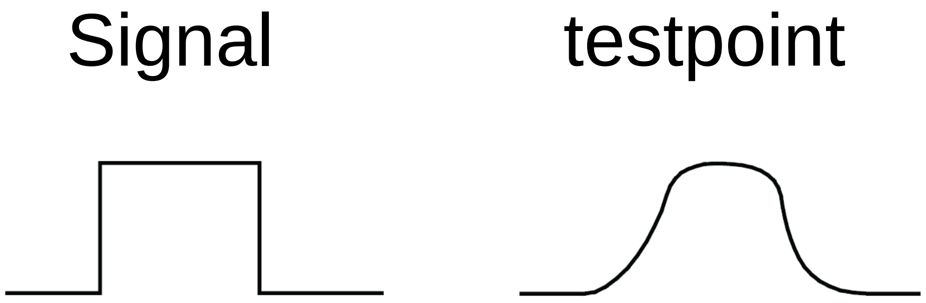
For DC current, the reactive impedance of the probe's input capacitance is unlimited and does not cause any loading of the device under test. This means that the probe loading is caused solely by the effects of the probe's input resistance.

Ideally, Vmeas = VD would be ideal. In practice, the voltage divider between the device under test and the probe's input resistance results in a reduction in the measured voltage. You can reduce the resistance loading by using a probe with a higher resistance or by measuring the signal at a test point with a lower input resistance.

General probe load

Effects of input capacity





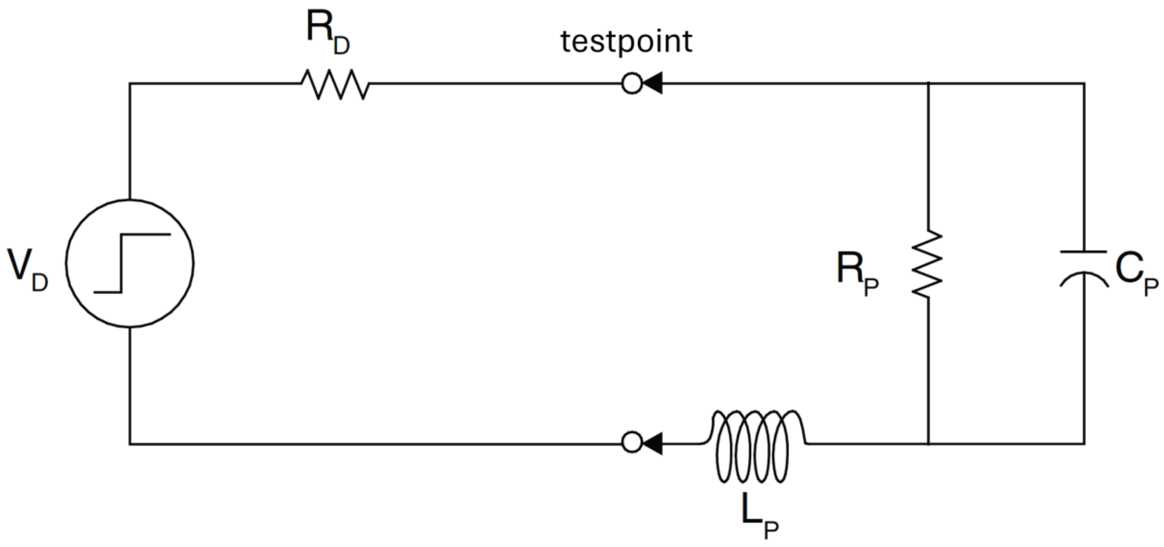
- At higher frequency the capacitive load increases the rise and fall times
- Effect can be lowered by using a probe with a lower impedance or measuring at a point with lower impedance
- Capacity reduce the risetime (RC-network):

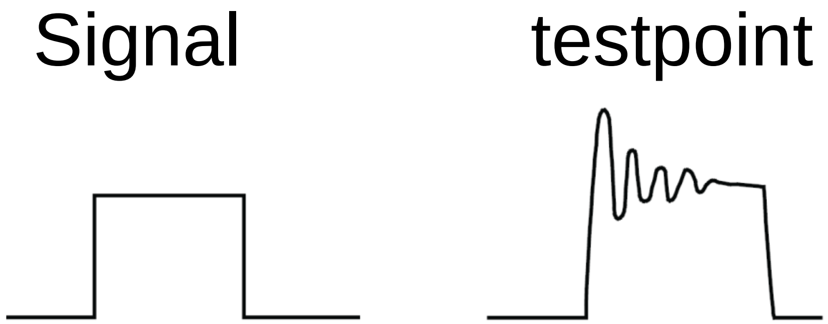
$$t_r = 2{,}2(R_D C_P)$$

Example:
Cp = 100pF and Rd = 1kOhm -> tr = 220ns
Cp = 10pF and Rd = 1kOhm -> tr = 22ns

General probe load

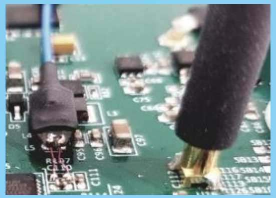
Effects of probe inductance





- The ground lead, being a wire, has some distributed inductance
- This inductance interacts with the probe's capacitance, forming an LC circuit
- The LC circuit causes ringing — a decaying sinusoidal oscillation. Ringing appears as a sinusoidal overlay on signal
- Ringing frequency depends on the values of inductance and capacitance
- The ground lead is an additional inductance which also results in an overshoot
- To avoid grounding problems use always shortest ground lead provided with the probe. Otherwise it can result in overshoot and ringing

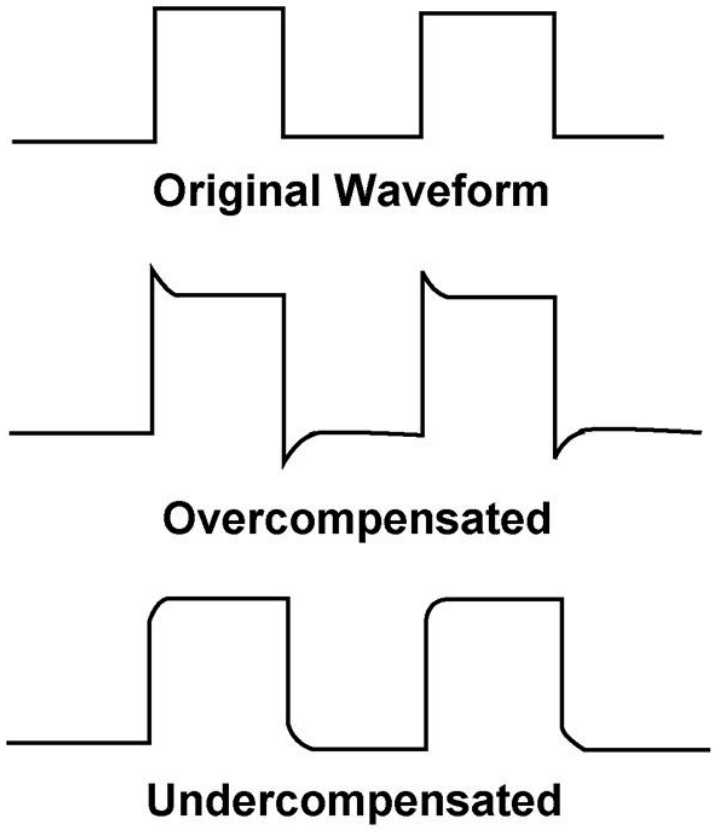
Low Loading, Single-Ended MMCX Probes
Active and Passive Models



- **Ideal for Test, Debug, and Design Validation**
- **Up to >1GHz Bandwidth**
- **± 42V Peak, 30V RMS, 60V DC**
- **Lowest <4pF Capacitive Loading**
- **Highest Signal Fidelity**
- **Universal BNC - Use with any Oscilloscope**

Probe adjustment

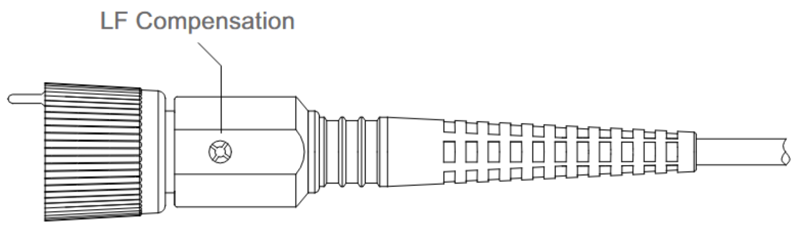
LF Compensation



When the probe is connected to the oscilloscope input the first time probes cable capacitance needs to be matched to the oscilloscope input capacitance. This matching assures good amplitude accuracy from DC to the probes bandwidth.

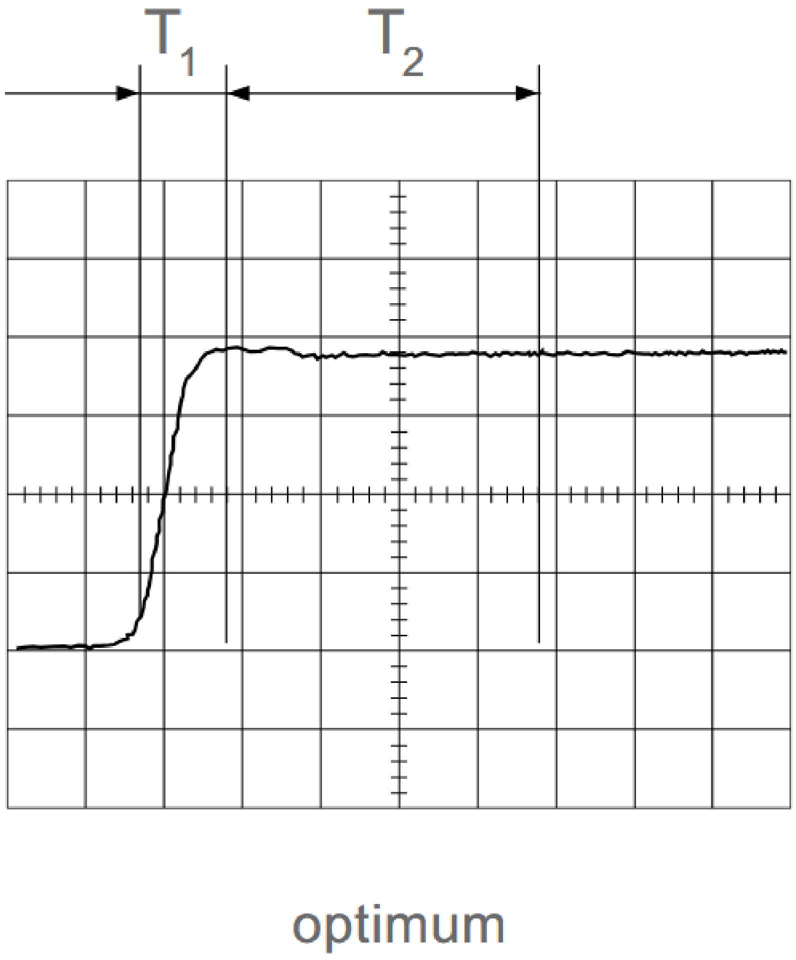
A poorly compensated probe clearly influences the overall system performance (probe + scope)
and causes measurement errors resulting in inaccurate readings and distorted waveforms.

LF compensation is performed by connecting the probe to the CAL (output on the oscilloscope front panel or exernal source) and adjusting the LF compensation trimmer to optimum square wave response.



Probe adjustment

HF Compensation

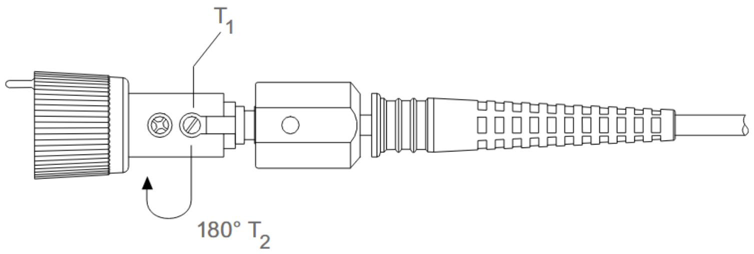


Overshoot doesn´t necessarily need to be adjusted when connecting the probe to your oscilloscope for the first time.

We recommend to use the following equipment for proper HF compensation: Rectangular waveform generator with a rise time faster than 700 ps, 50 Ω feed through and probe BNC adapter. If you do not have the appropriate equipment PMK are pleased to help you.

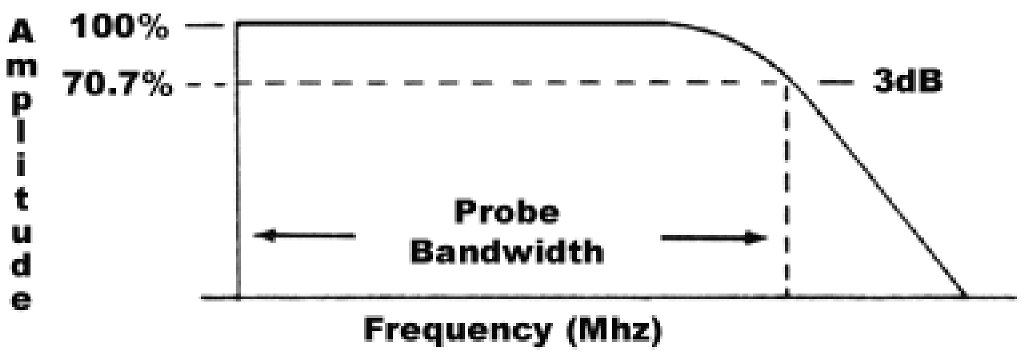
HF adjustment is performed by connecting the probe to the rectangular wave generator.

Adjust trimmers (T1 and T2) for optimum square wave response.



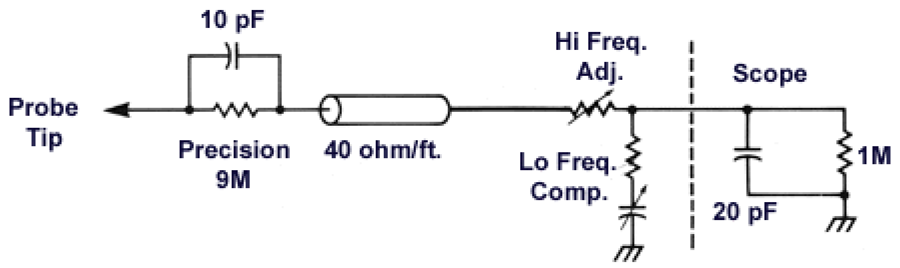
T1 and T2 are used for HF compensation.

Bandwidth and Rise Time Limitations



All oscilloscope probes are rated by bandwidth capability. Bandwidth is the point on an Amplitude versus Frequency curve, where the amplitude drops to less than 3 dB (70.7%) of its beginning low frequency amplitude.

$$Probe\ bandwidth \geq Oscilloscope\ bandwidth$$



Risetime is the time required for the leading edge of a pulse to rise 10% to 90% of its final value.

$$tr_{,system} = \sqrt{tr_{Probe}^2 + tr_{Scope}^2}$$

Source Pictures: probemaster.com

Common Mode Rejection

Short overview

Common Mode:

- In a **differential measurement**, the probe has two inputs connected to two points in a circuit.
- The **common mode signal** is the part of the signal that is **identical** on both inputs.
- The **differential signal** is the **voltage difference** between the two inputs.
- A probe with good **common mode rejection** will **suppress** or **ignore** the common signal and show only the voltage difference.

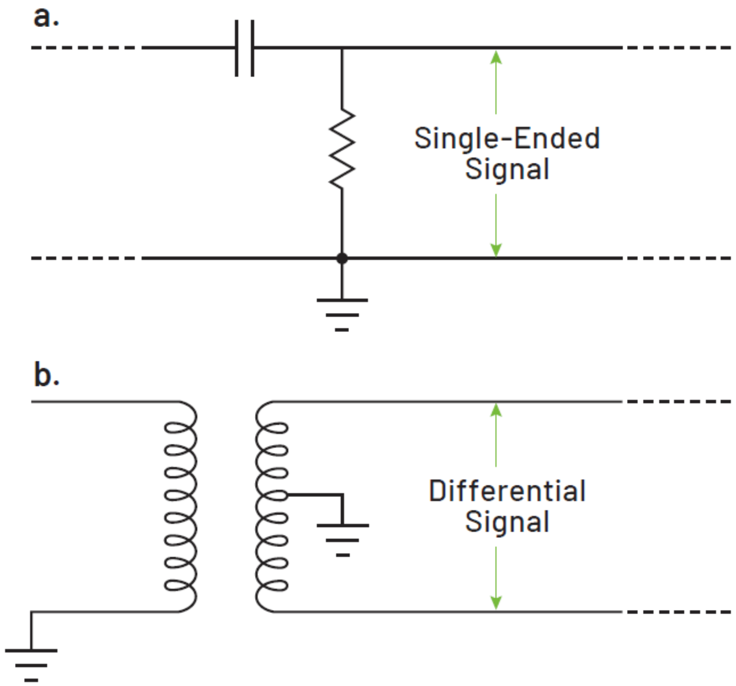
Why it matters:

- It's especially important when measuring small signals **on large common-mode voltages** (e.g., switching noise).
- Poor common mode rejection can introduce **error or noise** in the measurement, making it hard to see the true differential signal.

Specification:

- It's often quantified as **Common Mode Rejection Ratio (CMRR)**, expressed in **dB**.
- A higher CMRR means **better rejection** of common mode signals.

Single ended and differential probe



a. Single-ended signals are referenced to ground

b. Differential signals are the difference between two signal lines or test points

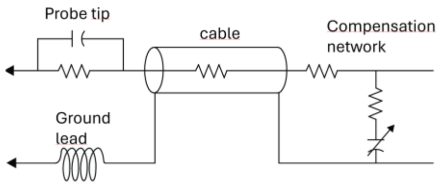
Different types of probes

Overview

Voltage Passive Probes

Advantages:
- Low cost
- mechanical resistance
- wide dynamic range
- high input resistance
- No external power

Disadvantages:
- high input capacitance
- Directly ground referenced

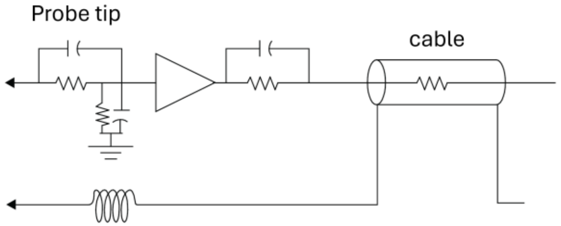


Schematics of a passive probe

Voltage Active Probes

Advantages:
- Low input capacitance
- High bandwidth
- better signal accuracy
- high input resistance

Disadvantages:
- Higher cost
- limited dynamic range
- lower mechanical resistance
- External power needed
- Directly ground referenced

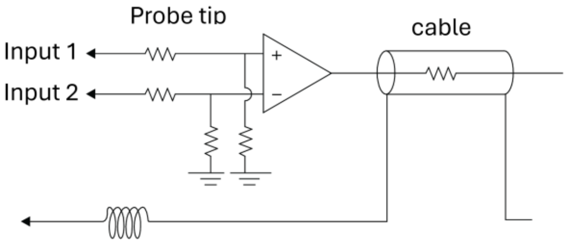


Schematics of a active probe

Voltage Differential Probes

Advantages:
- Low input capacitance
- large DC common mode rejection ratio (CMRR)
- Can measure ungrounded voltages
- minimal distortion between inputs
- high input resistance

Disadvantages:
- Higher cost
- limited dynamic range
- External power needed



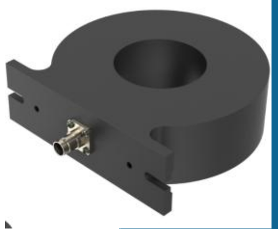
Schematics of a differential probe

Current Probes

Two Types:
- AC active probes:

- AC/DC probes active:

- AC/DC probes passive:



Power your probe

Different interfaces for each scope vendor

Tektronix: Tek VPI

LeCroy: ProBus/ProLink

Keysight: AutoProbe

Rohde&Schwarz:

Advantage: Easy to use. No external power supply needed.

Disadvantage: Probe can be only used for 1 brand.

Power your probe

All PMK probes are universal BNC

All probes from PMK are universal BNC. So you can easily share your probes within the lab no matter which Oscilliscop brand your colleague is using. You can save much more money in buying universal BNC probe.

PMK Power supply:

- 100-240 V AC, 47-63 Hz input voltage
- 550 mA /Channel max output current
- 8 mV / 4 mV noise
- 2 or 4 channels (8 coming soon!)
- ± 9 V output voltage, 20 W power

Choose the right termination

50 ohm or 1 Meg

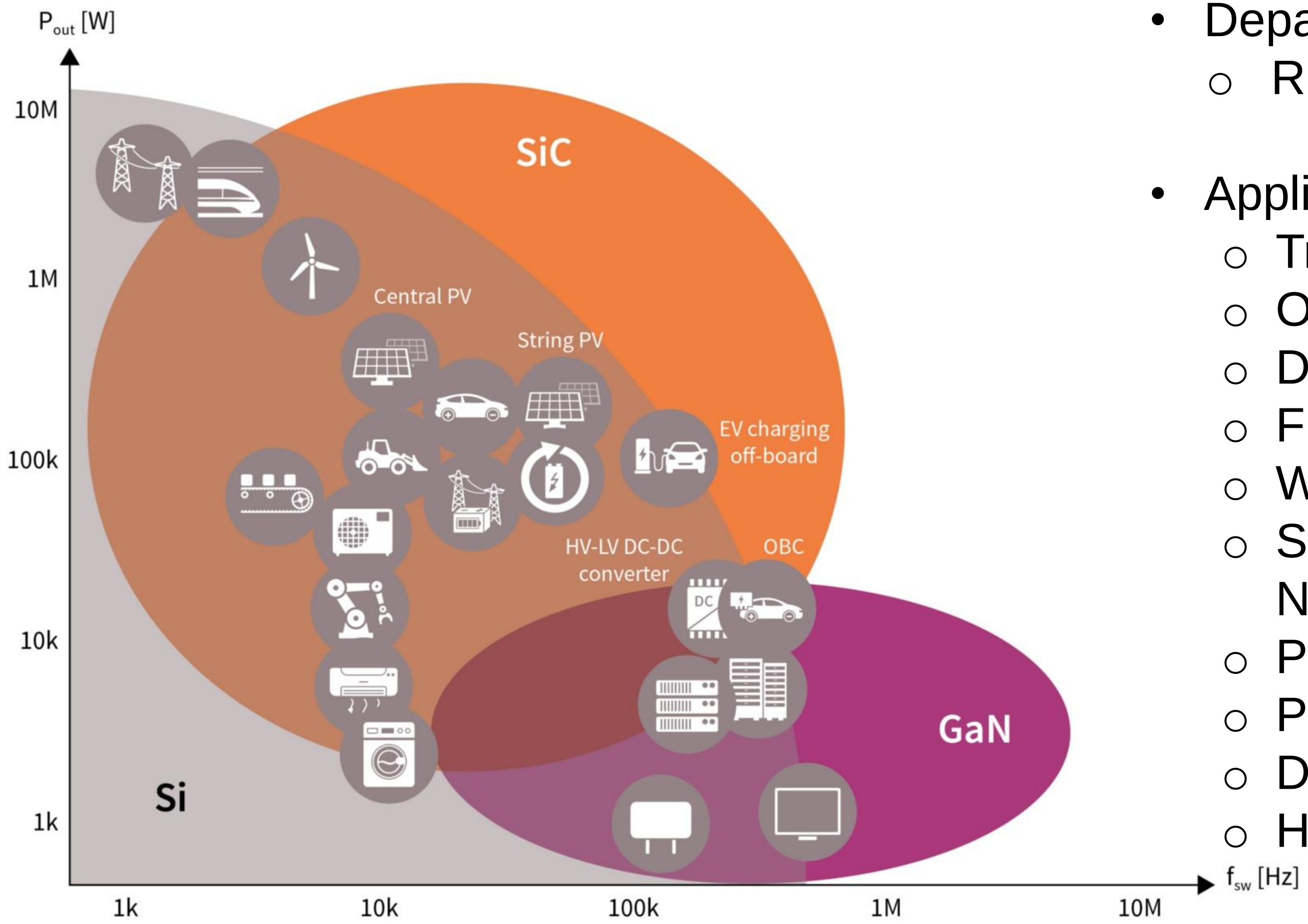
All „passive probes“ need a 1 MegOhm termination

All „active probes“ need a 50 ohm termination for full performance

50Ω BNC feedthrough

Application Information

Target Applications



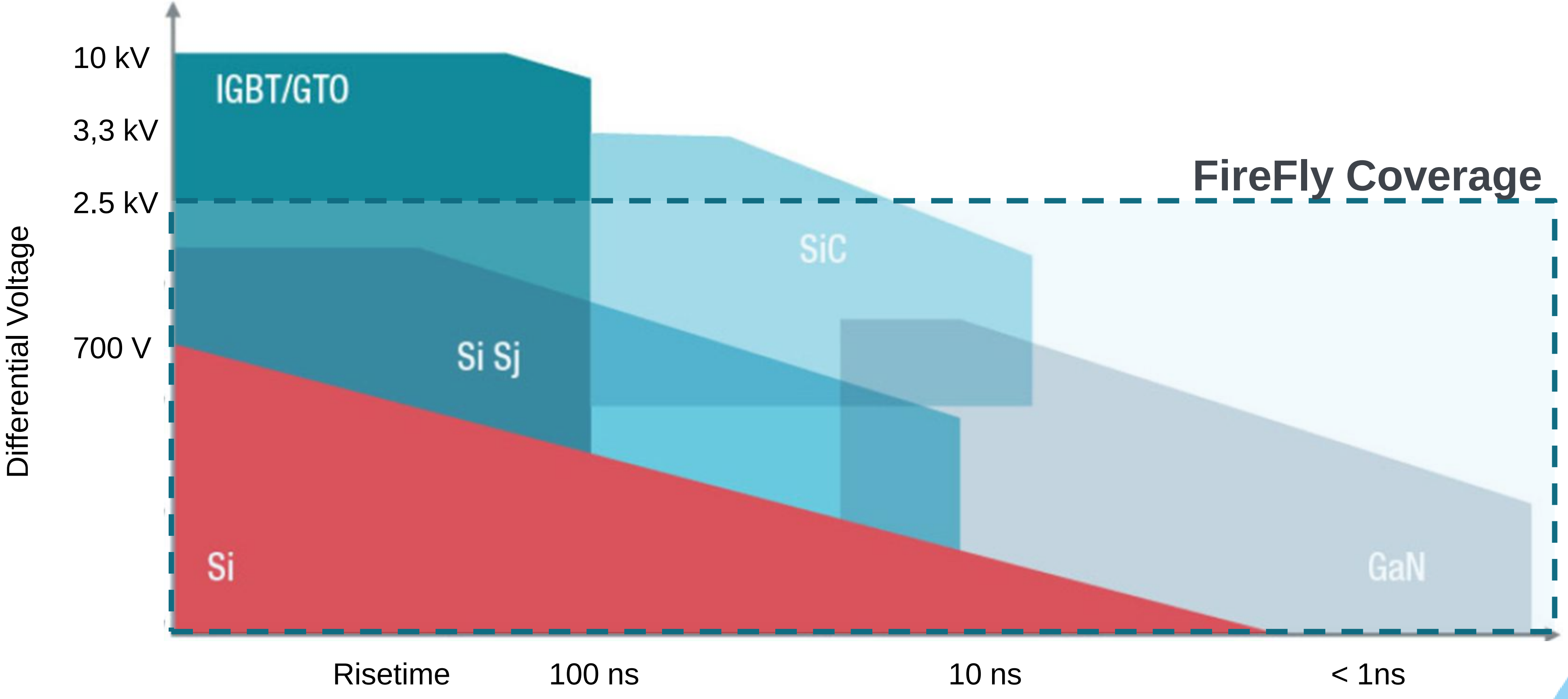
Source: https://www.infineon.com/cms/de/product/technology/wide-bandgap-semiconductors-sic-gan/

- Departments:
  - RnD / Design / Verification / Qualification

- Applications / Buzz Words
  - Traction Inverters
  - On-Board Chargers (OBC)
  - DC-DC Converters
  - Full-Bridge / Half-Bridge Converter
  - Wide Band Gap (WBG) Semiconductors
  - Silicon Carbide (SiC) & Gallium Nitride (GaN)
  - Power Conversion
  - Photovoltaic
  - Double-Pulse Testing
  - High-Side VGS Measurement

Power Landscape

Power designers need the **COMBINATION** of **Performance**, **Voltage Range**, **CMRR**, and **Input Impedance**



Overview

SiC and GaN Devices are Superior to Si

GaN

- < 650V Devices
- Faster Switching than SiC/Si
- Ideal for < 20 kW Applications
- Typical Applications: DC-DC Power Converters

SiC

- > 1000V Devices
- High Voltage and Temperature Properties
- Ideal for < 20 MW Applications
- Typical Applications: EV & PV Inverters, Motor Control

Test Methods Overview

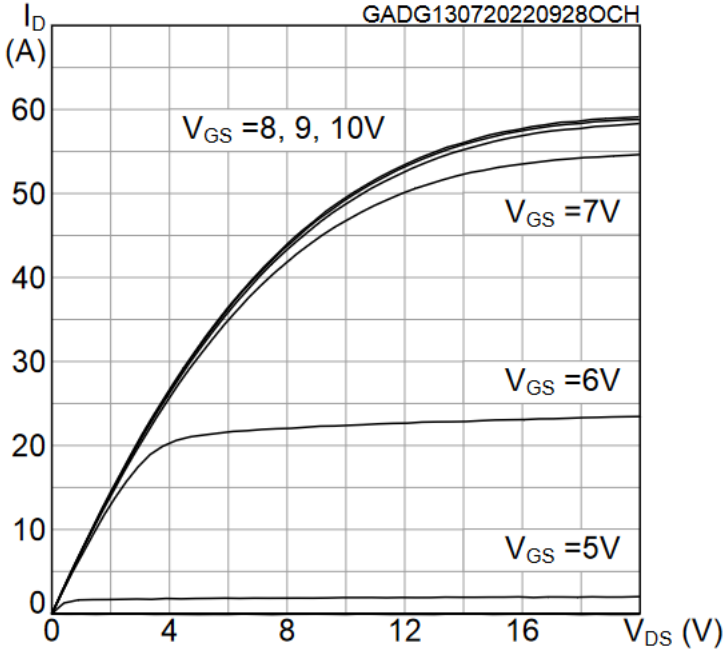
Basic Parameters

Static testing:
current/voltage characteristics, capacitances, resistances, gate charge

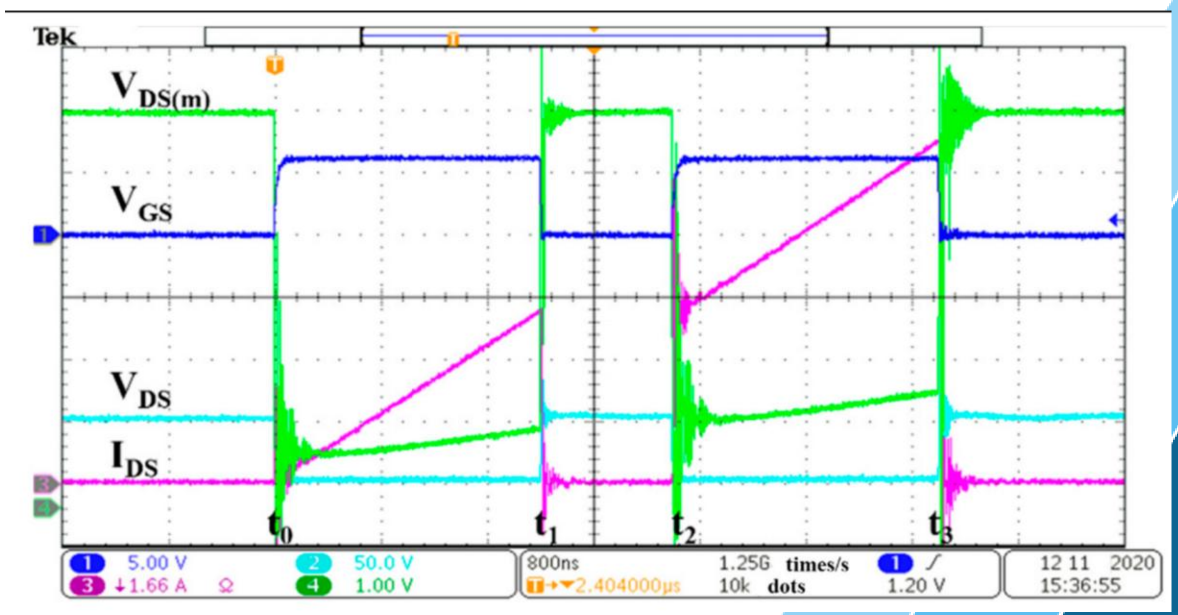
Dynamic characterization:
switching losses and switching time, gate charge

Classic solution is Double Pulse Test

Figure 3. Typical output characteristics



ST Micro: STP65N150M9



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Simplified Switching Behaviour

Double Pulse Testing

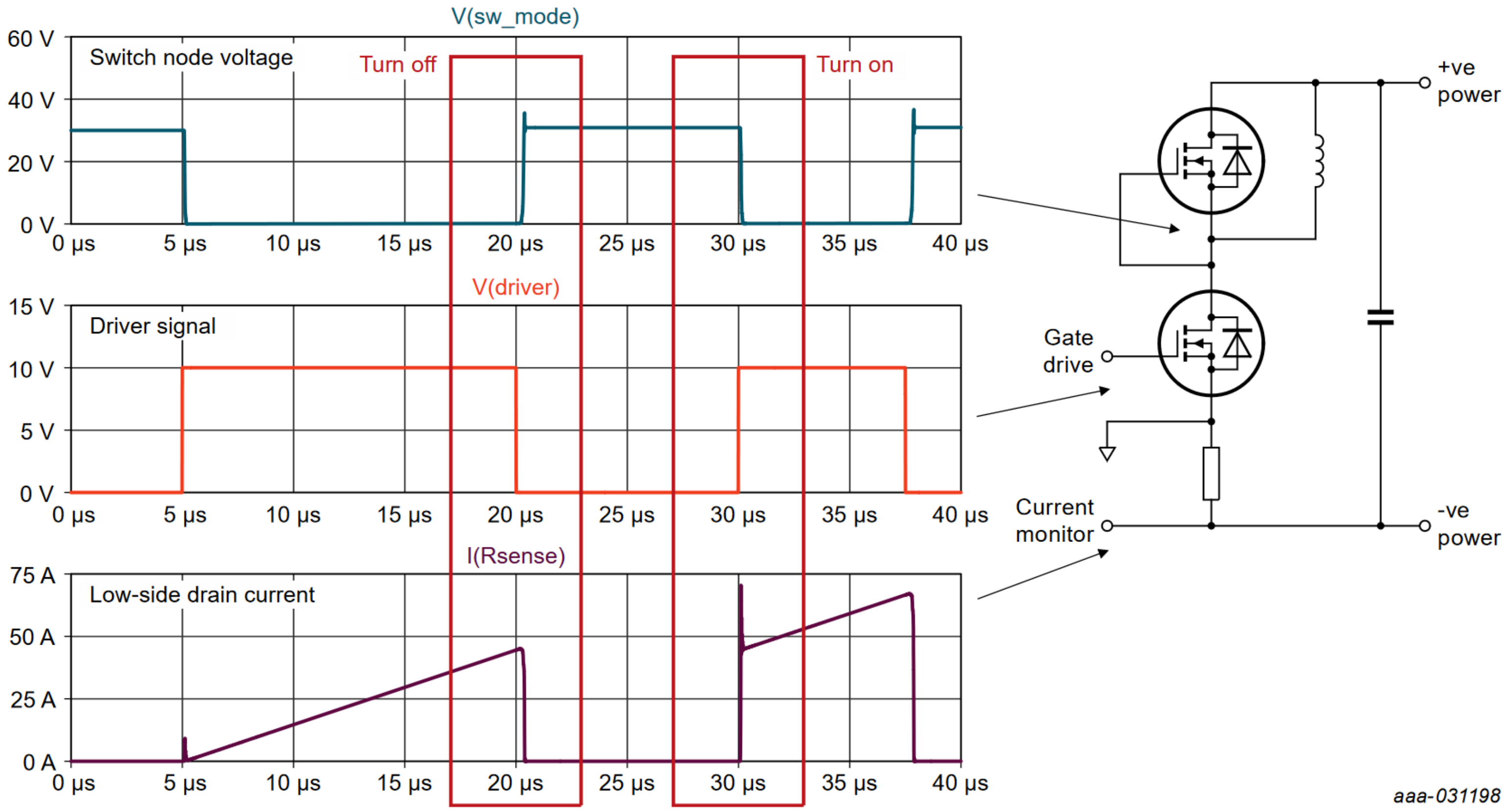
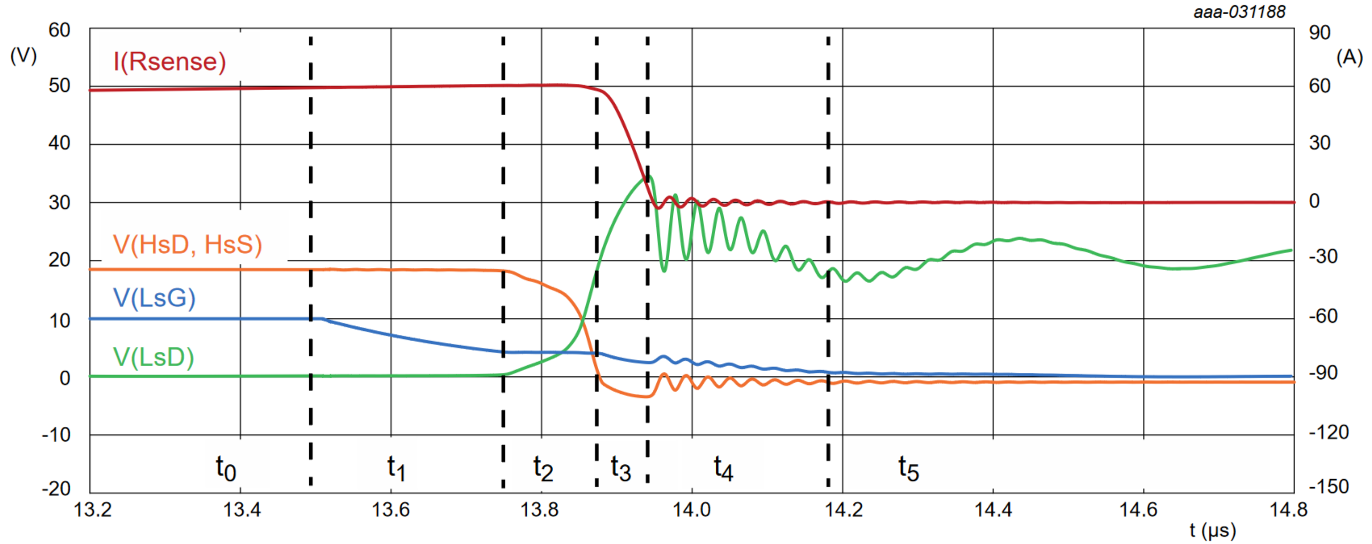


Fig. 2. Simplified switching behaviour

The behaviour of the MOSFETs during the switching event strongly influences efficiency and electromagnetic interference (emissions) goals.

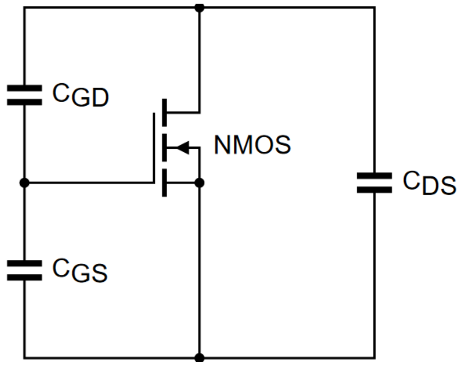
Turn-off waveform description

MOSFET



I(Rsense) = low-side MOSFET drain current
V(HsD, HsS) = high-side MOSFET drain to source voltage
V(LsG) = low-side MOSFET gate to source voltage
V(LsD) = low-side MOSFET drain to source voltage

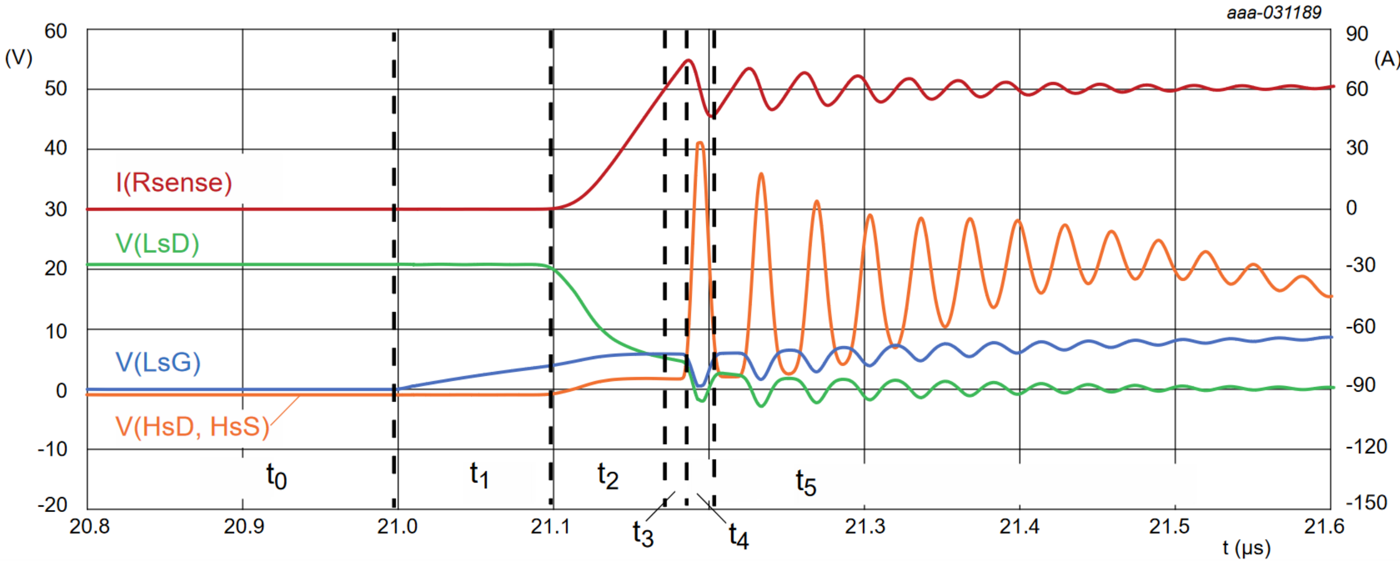
MOSFET internal capacitances



- t0: low side is on, high side off -> steady state condition
- t1: start turn-off process. Gate driver removes charge from gate capacitance CISS = CGS + CGD
  Gate source Voltage starts to fall, VDS rise, RDS begins to increase
- t2: VGS falls to minimum value, VGS approx constant („Miller Plateau“)
- t3-t4: ID in the low-side MOSFET reaches zero. All the current has transferred to the high-side MOSFET body diode.
- t5: MOSFET turn-off switching transition is complete

Turn-on waveform description

MOSFET



Copyright: From Nexperia AN90011

I(Rsense) = low-side MOSFET drain current
V(LsD) = low-side MOSFET drain to source voltage
V(LsG) = low-side MOSFET gate to source voltage
V(HsD, HsS) = high-side MOSFET drain to source voltage

- t0: low side is off, current flowing in body diode of high side MOSFET
- t1: gate voltage low side MOSFET starts to rise. Nothing happens until threshold voltage is reached
- t2: the gate voltage continues to rise until significant current starts to flow
- t3: the current in the low-side MOSFET increases beyond the load current.
- t4: high-side VDS will begin to increase. The low-side VDS will fall. The low-side drain current will still increase
- t5: high-frequency decaying oscillation is observed superimposed on a lower frequency DC link oscillation.
  - high-frequency oscillation is due to the resonance of the high-side COSS
  - Low frequency oscillation is due to rhe resonace of DC capacitors, inductance of elco capacitors and connection circuitry (e.g. Busbar)

FireFly® Series – Short Introduction

High Voltage Optically Isolated Probe

FireFly® Series – Key Specification

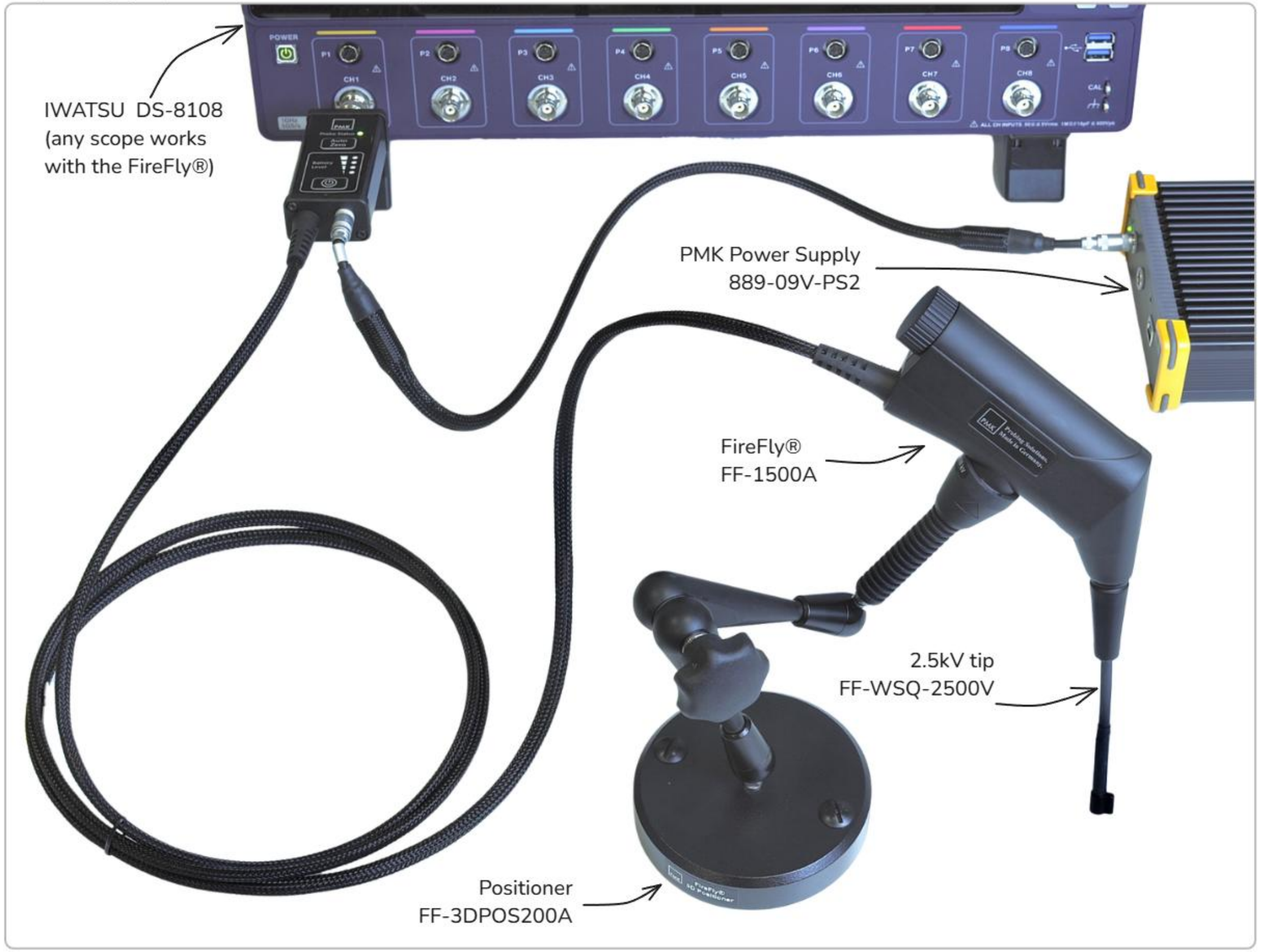
High Voltage Optically Isolated Probe

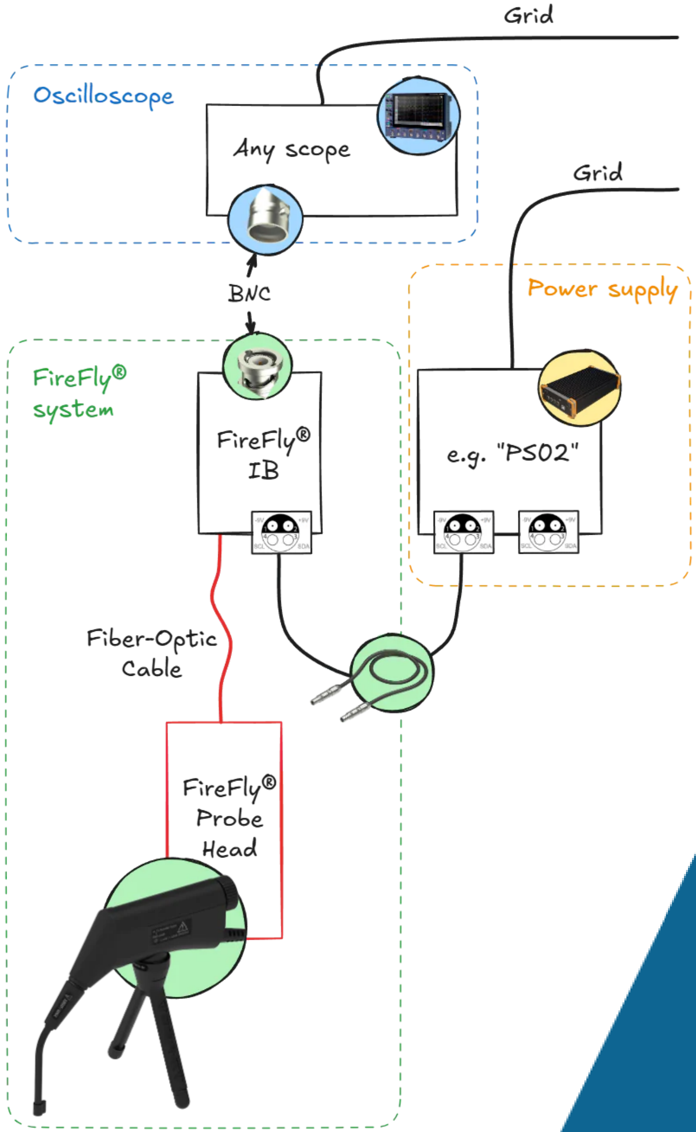
- Ideal for GaN / SiC characterization
- >1.5GHz (tr<280ps) for capturing high frequency distortions BEST-IN-CLASS
- >180dB CMRR for high-side VGS measurements BEST-IN-CLASS
- Ultra-low temperature drift of < 0.05%/°C
- ± 60kV common mode voltage
- Small and compact probe head for hard-to-reach test points
- Universal BNC – output for use with any oscilloscope
- Very fast Auto Zero function – less than 1 second

FireFly® Series – Connectivity

High Voltage Optically Isolated Probe

Complete FireFly system, connected to an IWATSU oscilloscope, overview





Configure each FireFly® Probing System 1/2

Most applications require additional tip cables for different input signals. See the next slide for more information about the probe tip selection for best signal fidelity

Step 1) Select probe FF-1500 and add tip cables for different input ranges as needed

Hint: The input voltage range should be as low as possible for best performance.

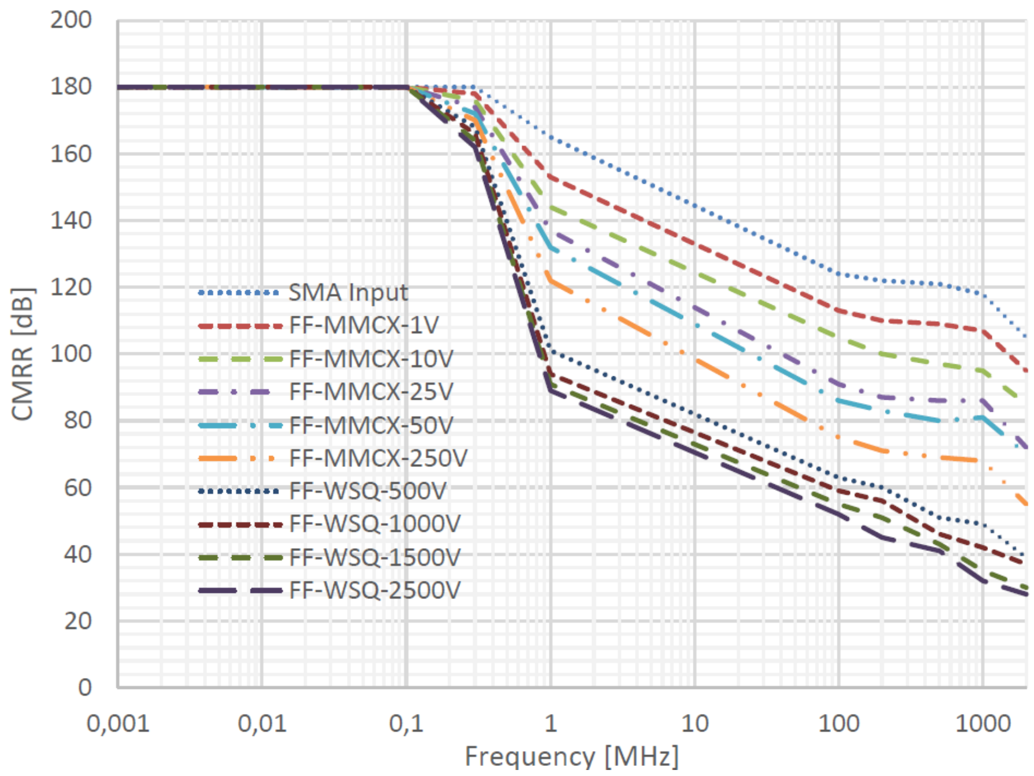
All tips optional	**Differential Input Voltage (DC+Peak AC)**	**Bandwidth (-3dB)**	**Rise time (10% - 90%)**	**Input Impedance**	**Tip Interface**
FF-1500	± 1 V	> 1.5 GHz	<250 ps	200 kΩ || 4.0 pF	MMCX
FF-MMCX-1V	± 1 V	> 1.5 GHz	<250 ps	50 Ω	MMCX
FF-MMCX-10V	±10 V	> 1.3 GHz	<280 ps	2 MΩ || 3.4 pF	MMCX
FF-MMCX-25V	± 25 V	> 1.3 GHz	<280 ps	4.9 MΩ || 2.1 pF	MMCX
FF-MMCX-50V	± 50 V	> 1.3 GHz	<280 ps	10 MΩ || 2 pF	MMCX
FF-MMCX-250V	± 250 V	> 1.3 GHz	<280 ps	20 MΩ || 2.1 pF	MMCX
FF-WSQ-500V	± 500 V	> 1.0 GHz	<300 ps	40 MΩ || 2.1 pF	5.08mm (0.2”) Square Pins
FF-WSQ-1000V	± 1000 V	> 1.0 GHz	<300 ps	40 MΩ || 2.8 pF	5.08mm (0.2”) Square Pins
FF-WSQ-1500V	± 1500 V	> 1.0 GHz	<300 ps	40 MΩ || 2.7 pF	5.08mm (0.2”) Square Pins
FF-WSQ-2500V	± 2500 V	> 1.0 GHz	<300 ps	40 MΩ || 2.5 pF	5.08mm (0.2”) Square Pins

Common Mode Rejection Ratio

Typical values for specific tips

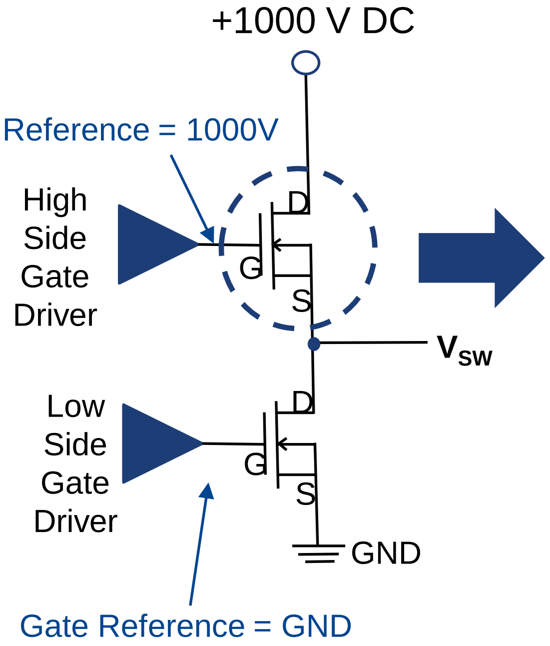
Common Mode Rejection Ratio	DC	1 MHz	100 MHz	200 MHz	500 MHz	1 GHz
SMA Input	> 180 dB	165 dB	124 dB	122 dB	121 dB	118 dB
FF-MMCX-1V	> 180 dB	153 dB	113 dB	110 dB	109 dB	107 dB
FF-MMCX-10V	> 180 dB	144 dB	105 dB	100 dB	97 dB	95 dB
FF-MMCX-25V	> 180 dB	137 dB	91 dB	87 dB	86 dB	86 dB
FF-MMCX-50V	> 180 dB	132 dB	86 dB	83 dB	80 dB	81 dB
FF-MMCX-250V	> 180 dB	122 dB	75 dB	71 dB	69 dB	68 dB
FF-WSQ-500V	> 180 dB	101 dB	63 dB	60 dB	51 dB	49 dB
FF-WSQ-1000V	> 180 dB	94 dB	59 dB	56 dB	46 dB	42 dB
FF-WSQ-1500V	> 180 dB	91 dB	55 dB	51 dB	43 dB	35 dB
FF-WSQ-2500V	> 180 dB	89 dB	52 dB	45 dB	41 dB	32 dB

Typical Common Mode Rejection Ratio (CMRR)



High-Side Measurement: Common Mode Error

Common mode voltage is the voltage which is common to both test points

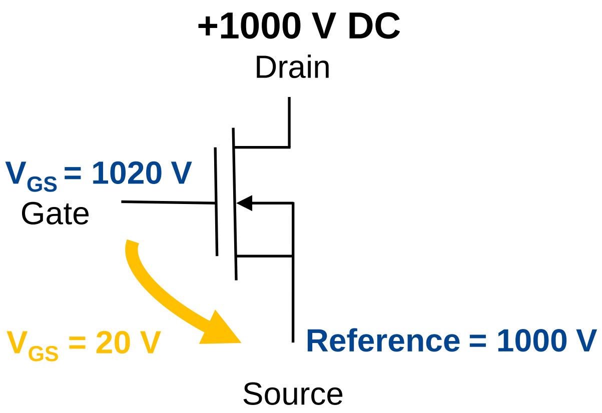


The voltage at the switch node (V_{SW}) swings between the supply voltage (1000V) and the low-side reference voltage (GND)

Common Mode Voltage = 1000V

Differential Voltage (HS V_{GS}) = 1020V – 1000 V = 20V

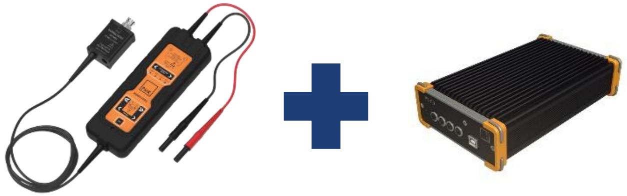
Reference Voltage at high side (HS)



Resulting Common Mode error:

Bandwidth	CMRR FireFly 25V Tip	Resulting Common Mode Error FireFly 25V Tip	CMRR BumbleBee	Resulting Common Mode Error BumbleBee
1 MHz	142 dB = 7079457 : 1	**1000 V** / 7079457 = 141 µV	70 dB = 316 : 1	**1000 V** / 3162 = 316 mV
100 MHz	91 dB = 35481 : 1	**1000 V** / 35481 = 28 mV	40 dB = 56 : 1	**1000 V** / 35 = 10 V
400 MHz	86 dB = 19952 : 1	**1000 V** / 19952 = 50 mV	35 dB = 17 : 1	**1000 V** / 17 = 18 V
1 GHz	86 dB = 19952 : 1	**1000 V** / 19952 = 50 mV	NA	**NA**

Never use HSDP on high side, just example



High Voltage Differential Probes
BumbleBee® Series

- **400MHz/ 500MHz Bandwidth BEST-IN-CLASS**
- **±200V to ±2000V Input Ranges**
- **High Common Mode Rejection**
- **High Accuracy and Low Noise**
- **Up to 7m Cable Length BEST-IN-CLASS**
- **Universal BNC - Use with any Oscilloscope**

NEW MODELS

PMK

High Voltage Differential Probes

HORNET® Series

- **Ideal for switching power sipplies, IGBTs, Si /Sic**
- **±4000V Input Ranges, >300 MHz**
- **High Common Mode Rejection**
- **High Accuracy and Low Noise**
- **Four user selectable input attenuator ranges**
- **Universal BNC - Use with any Oscilloscope**

High-Side Measurement: Attenuation

Measuring small signals with a large common mode component.

- Due to isolation, the Firefly does not have to "process" the common mode signals.
- A differential probe (Bumblebee) "processes" the common mode and subtracts it from the desired signal.
- With the firefly you can use lower attenuation (A) for better noise performance.

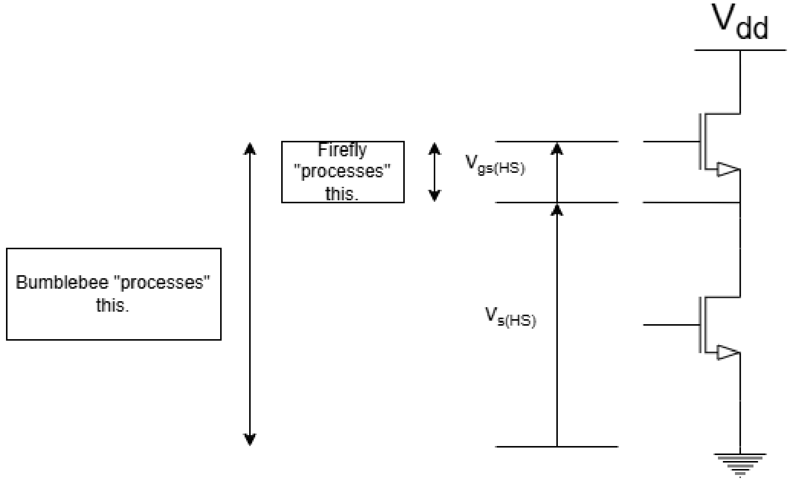
$$V_{out(Firefly)} = \frac{V_{gs}}{A}$$

For $V_{gs} < 25\ V$ and $V_s < 60\ kV$ only 25X attenuation (25 V range) is needed.

$$V_{out(Bumblebee)} = \frac{V_{gs}+V_s}{A} - \frac{V_s}{A}$$

For $V_{gs} < 25\ V$ and $V_s < 975\ V$ 250X attenuation (1 kV range) is needed.

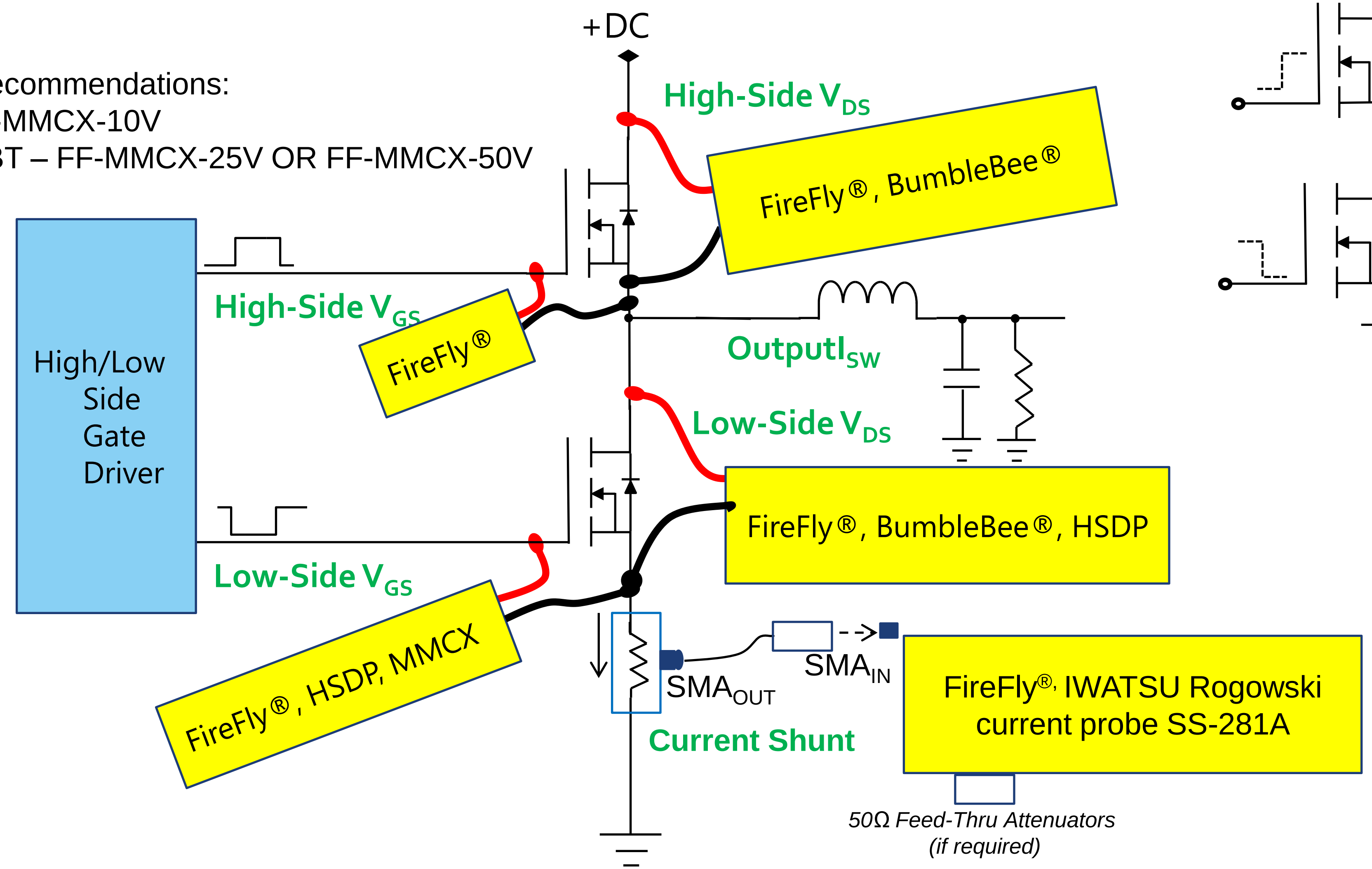
Less attenuation = Better Signal to noise ratio at oscilloscope!

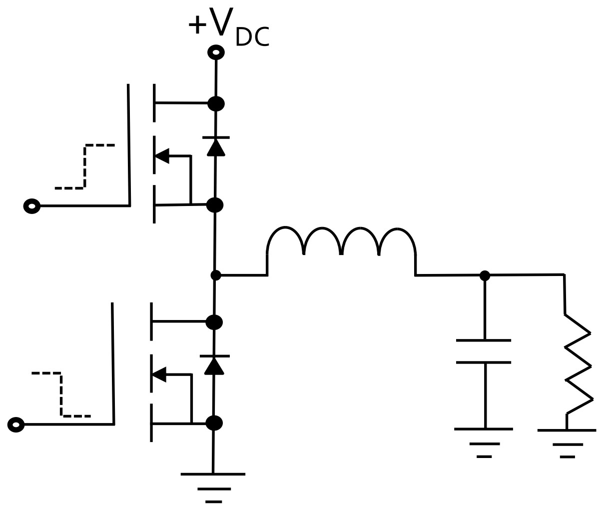


Typical Measurement Setup

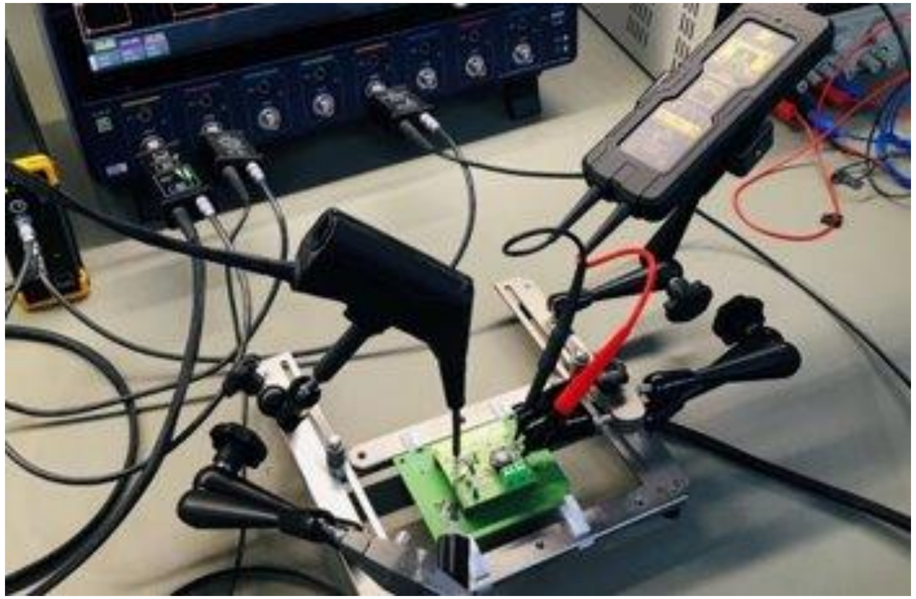
Using the Right Probing Solution depends on the measurement & application

V_{GS} Tip Recommendations:
GaN – FF-MMCX-10V
SiC/Si/IGBT – FF-MMCX-25V OR FF-MMCX-50V





The Measurement Setup



Choosing the right Oscilloscope (FireFly)

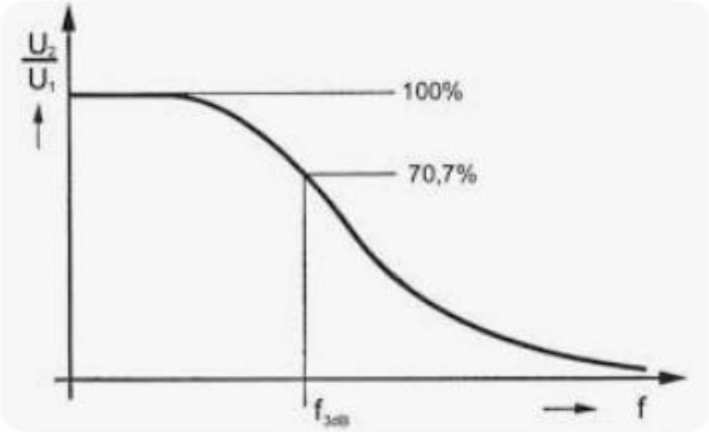
- FireFly is compatible with ***ANY*** oscilloscope. Requires a 50Ω input termination (Use scope‘s internal 50Ω input termination or an external BNC 50Ω feed-thru termination with 1MΩ scope input)

- The higher the vertical resolution of the oscillscope, the lower is the quantization error of the captured signal, caused by the AD conversion in the oscillscope. 12bit or higher resolution is recommended.

- The bandwidth is specified as frequency where the signal is degraded by 3dB. The oscilloscope should have sufficient bandwidth to not degrade the >1.5GHz input signal of FireFly.

- **Why hide your signal?: Oscilloscopes with >4GHz are recommended for full >1.5GHz performance.**

$$tr_{,system} = \sqrt{tr_{Probe}^2 + tr_{Scope}^2}$$



Oscilloscope Considerations for FireFly

- **Why do I need the 1.5 GHz probe and not use a lower bandwidth version?**

System Bandwidth FireFly + Oscilloscope

$$tr_{,system} = \sqrt{tr_{Probe}^2 + tr_{Scope}^2}$$

FireFly risetime (0.42)	Scope risetime (0.4 - 0.4025)	Max System Risetime (tr system)	System Bandwidth (used tr formula: 0.4)	System Bandwidth (used BW formula)
1.5 GHz = 280 ps	350 MHz = 1.15 ns	1.18 ns	338 MHz	340 MHz
1.5 GHz = 280 ps	500 MHz = 800 ps	847 ps	472 MHz	474 MHz
1.5 GHz = 280 ps	1 GHz = 400 ps	488 ps	819 MHz	832 MHz
1.5 GHz = 280 ps	2 GHz = 225 ps	359 ps	1.11 GHz	1.20 GHz
1.5 GHz = 280 ps	2.5 GHz = 160 ps	322 ps	1.24 GHz	1.28 GHz
1.5 GHz = 280 ps	**4 GHz = 100 ps**	297 ps	1.34 GHz	1.40 GHz
1.5 GHz = 280 ps	6 GHz = 66.67 ps	287 ps	1.39 GHz	1.45 GHz
1.5 GHz = 280 ps	8 GHz = 50 ps	284 ps	1.40 GHz	1.47 GHz
1.5 GHz = 280 ps	10 GHz = 40 ps	280 ps	1.42 GHz	1.48 GHz

All the values above are estimations and not considered as 100% correct.

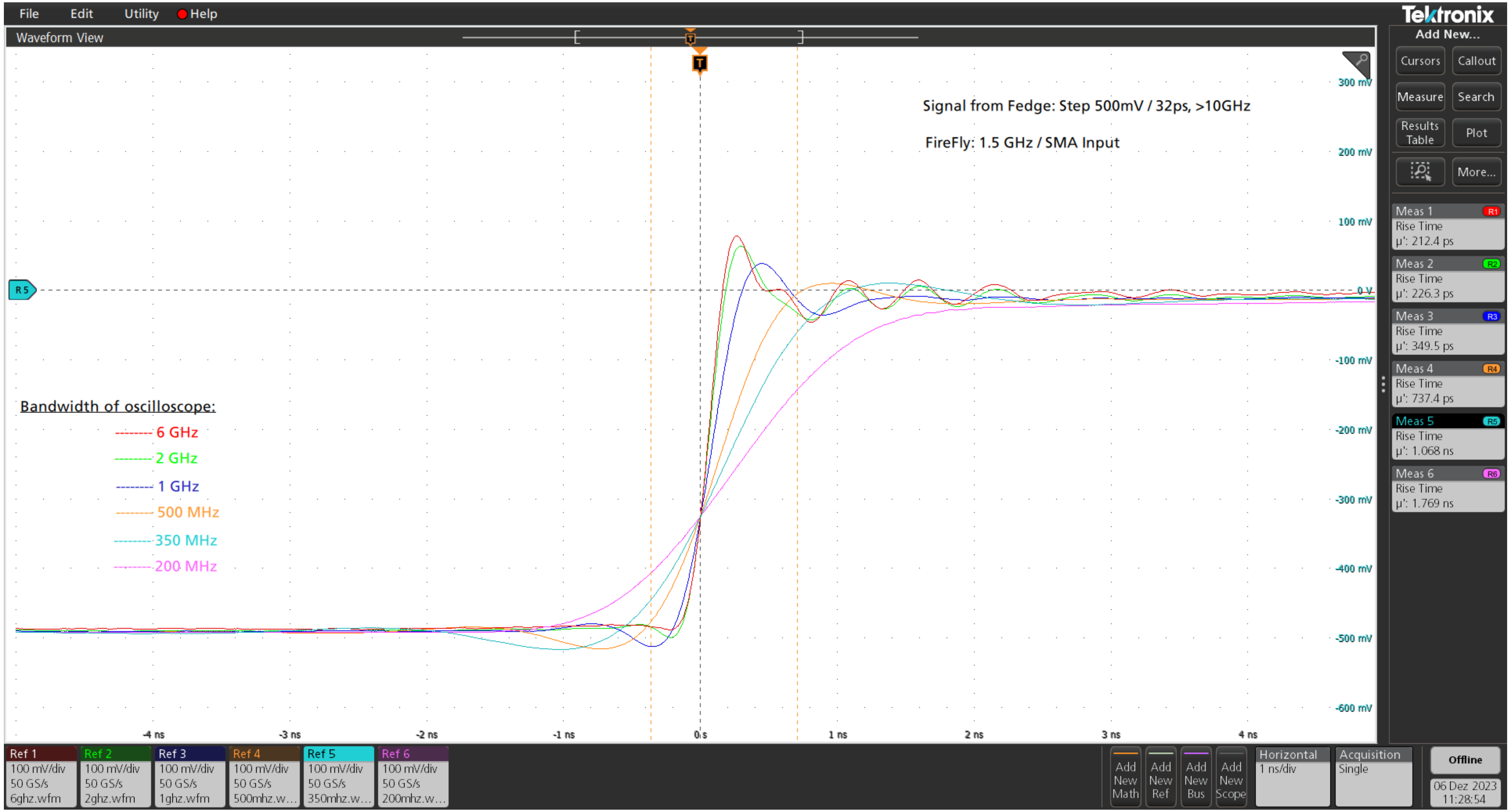
Probe risetime (factor)	Scope risetime (0.4 - 0.4025)	Max System Risetime (tr system)	System Bandwidth (used tr formula: 0.4)	System Bandwidth (used BW formula)
200 MHz (0.4)			Factor 0,4	
200 MHz = 2 ns	350 MHz = 1.15 ns	2.31 ns	173 MHz	173 MHz
200 MHz = 2 ns	500 MHz = 800 ps	2.15 ns	180 MHz	185 MHz
200 MHz = 2 ns	1 GHz = 400 ps	2.03 ns	197 MHz	196 MHz
200 MHz = 2 ns	2.5 GHz = 160 ps	2.00 ns	200 MHz	199 MHz

All the values above are estimations and not considered as 100% correct.

The probe shouldn't be a LP filter within the system. See all high frequency components of the real signal

Oscilloscope Considerations for FireFly

- **Measured the system rise time with different oscilloscope filters:**



Slew rate vs rise time

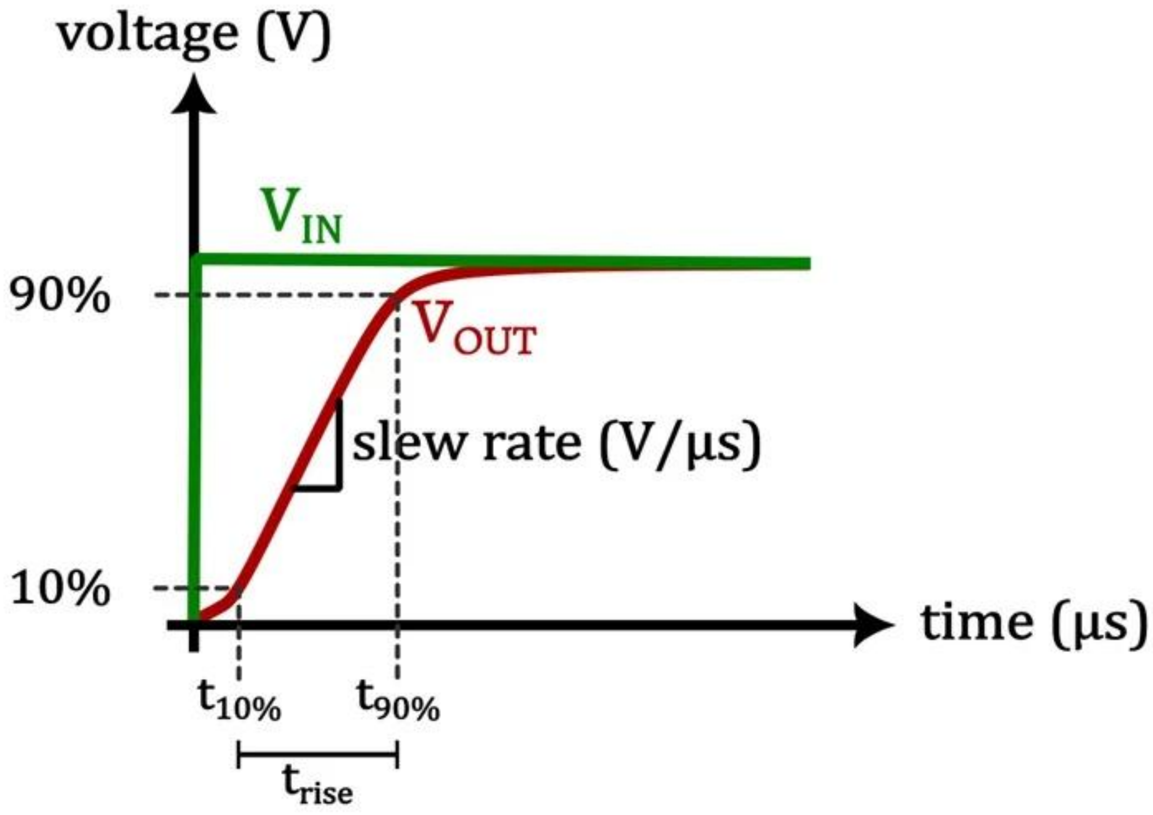


Image used courtesy of Robert Keim

Slew rate is a rate of change:
- indicate the amount of amplitude change
- units of volts (or amps) per second

Rise time is a time:
- How long it takes from a low to a high level
- Units of seconds

Both cases levels are defined
- Most often 10% (low) and 90% (high)

Example:
Customer has request for 50 kV/µs = 50 V/ns
DC voltage 400V

$$t_{rise} = \frac{90\%\ Operating\ voltage}{Slew\ rate} = \frac{320\ V}{50\frac{V}{ns}}$$

$$t_{rise} = 6.4\ ns$$

$$BW = \frac{0.4}{t_{rise}} = 62{,}5\ MHz \Rightarrow x5\ times\ higher = 312\ MHz$$

Configure each FireFly® Probing System

The connectivity accessories depend on customer's DUT.

Positioning

Recommended & Optional

FF-3DPOS200A

10kV Insulating 3D Positioning System

Many more adapters available…

We are continuosly developing more connectivity options…

Power Supply

Required

Power Supply Series PS2/PS3

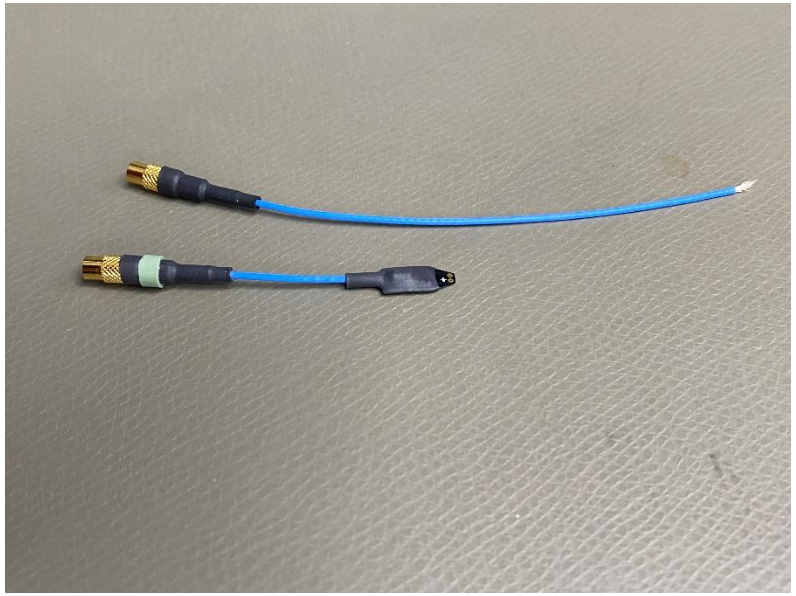
2ch with USB interface
2ch with USB & LAN interface
4ch with USB interface
4ch with USB & LAN interface

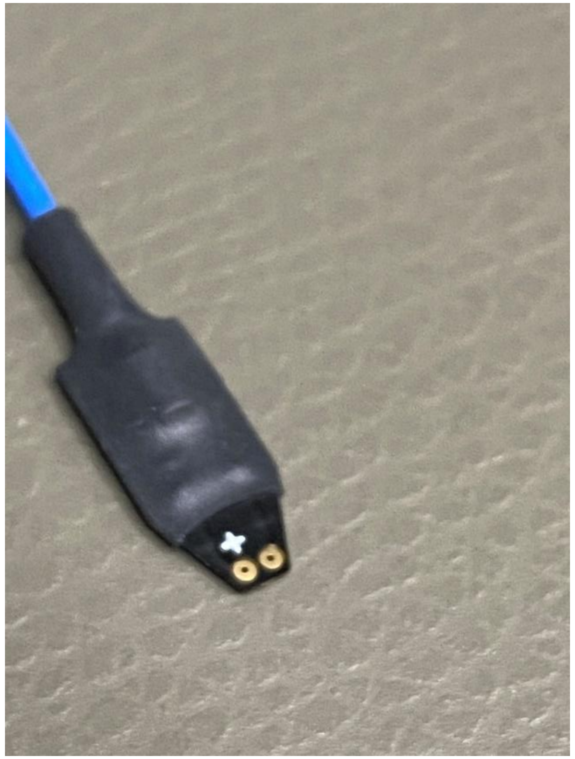
NEW

High Voltage Optically Isolated Probe
FireFly® Series: Power-Over-Fiber Adpater

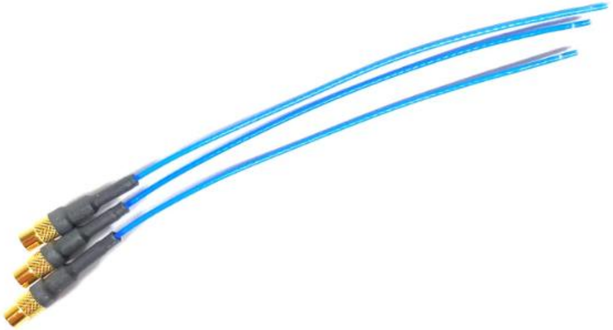
- **Interchangeable with the FireFly® battery**
- **24/7 continuous operation**
- **Ideal for production line testing and automation**
- **Retrofittable, backward compatible**
- **maintains galvanic isolation**
- **Requires its own PS02/03 power supply channel**

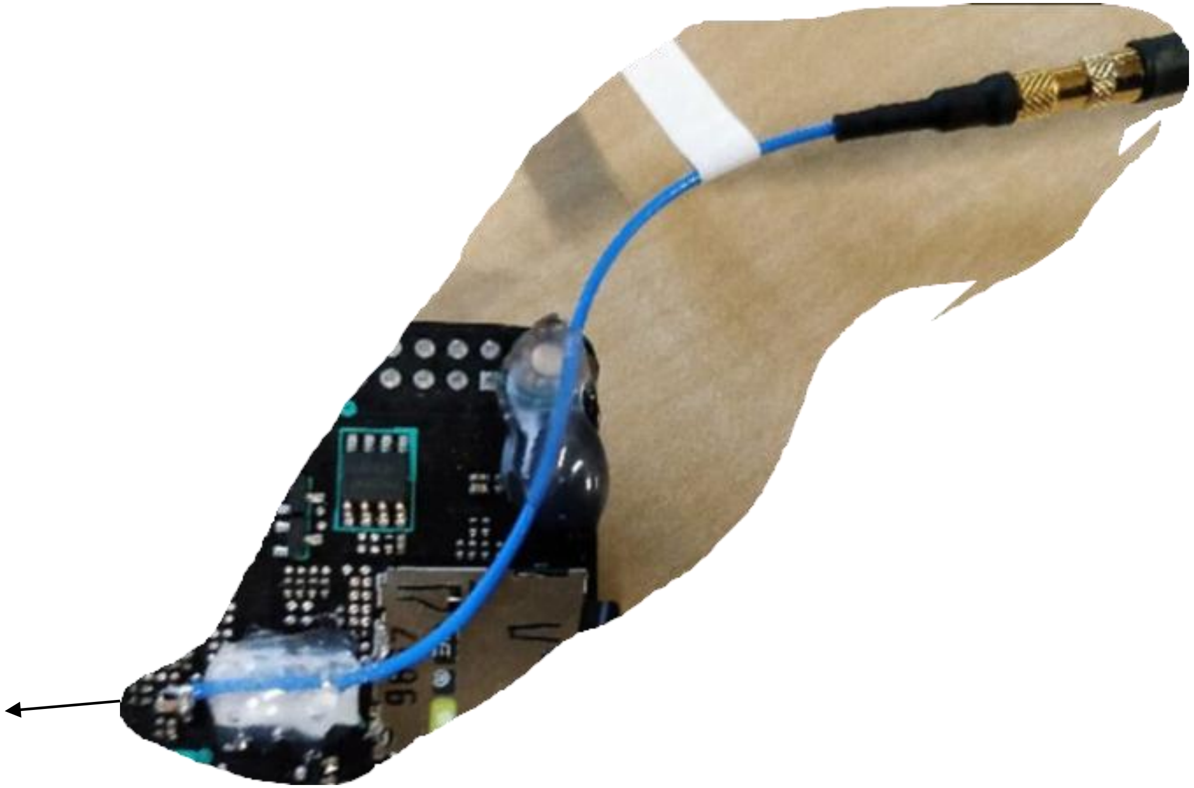
Accessory Pictures & Information



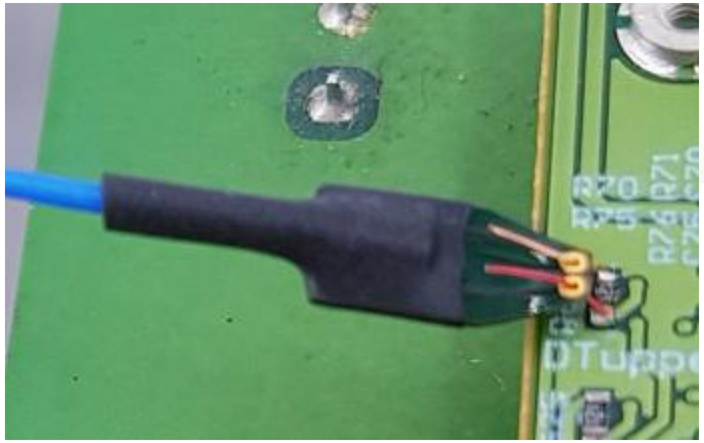


Accessory Pictures & Information





Accessory Pictures & Information



Power Module Connectivity (lead adapters)

The MMCX to Spade tip accessory (left) limits the BW and it will typically be degraded to around 200-400MHz depending on if the input leads are kept together or if they are separated when connecting to the DUT. With the added tip inductance you will see peaking (more overshoot) above 100-200MHz (risetimes in the 2-4ns range). For IGBTs this will not be an issues and it will work fine. Keep the leads together as best as possible to minimize the CM interference and preserve as much bw as possible. As for the CMRR performance, below 1MHz it will be great 90dB or better. At 10MHz the CMRR will start to degrade to around 50-60dB, at 100MHz to around 40-50dB. Still better than any other solutions in the market.

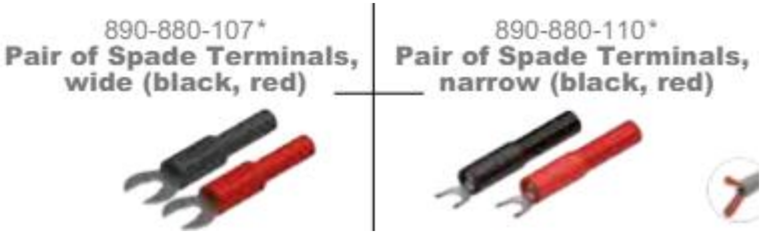
For the larger 0.2" (5.08mm) pitch square pin to Spade tip accessory (left) the BW will typically be degraded to around 100-300MHz depending on if the input leads are kept together or if they are separated when connecting to the DUT, same as above. With the added tip inductance you will see peaking (more overshoot) above 50-100MHz (risetimes in the 4-7ns range). For IGBTs this will not be an issues and it will work fine. Keep the leads together as best as possible to minimize the CM interference and preserve as much bw as possible. As for the CMRR performance, below 1MHz it will be in the 80-90dB or better. At 10MHz the CMRR will start to degrade to around 40-60dB, at 100MHz to around 20-40dB. Still better than any other solutions in the market.

Some other ways to improve the CM immunity:

- Twist the leads or keep them side-by-side as best as possible.
- Add ferrites over both leads forming a CM choke. Material 31 to 61 will give you ~10+ dB improvement typically in the CMRR about 10MHz.

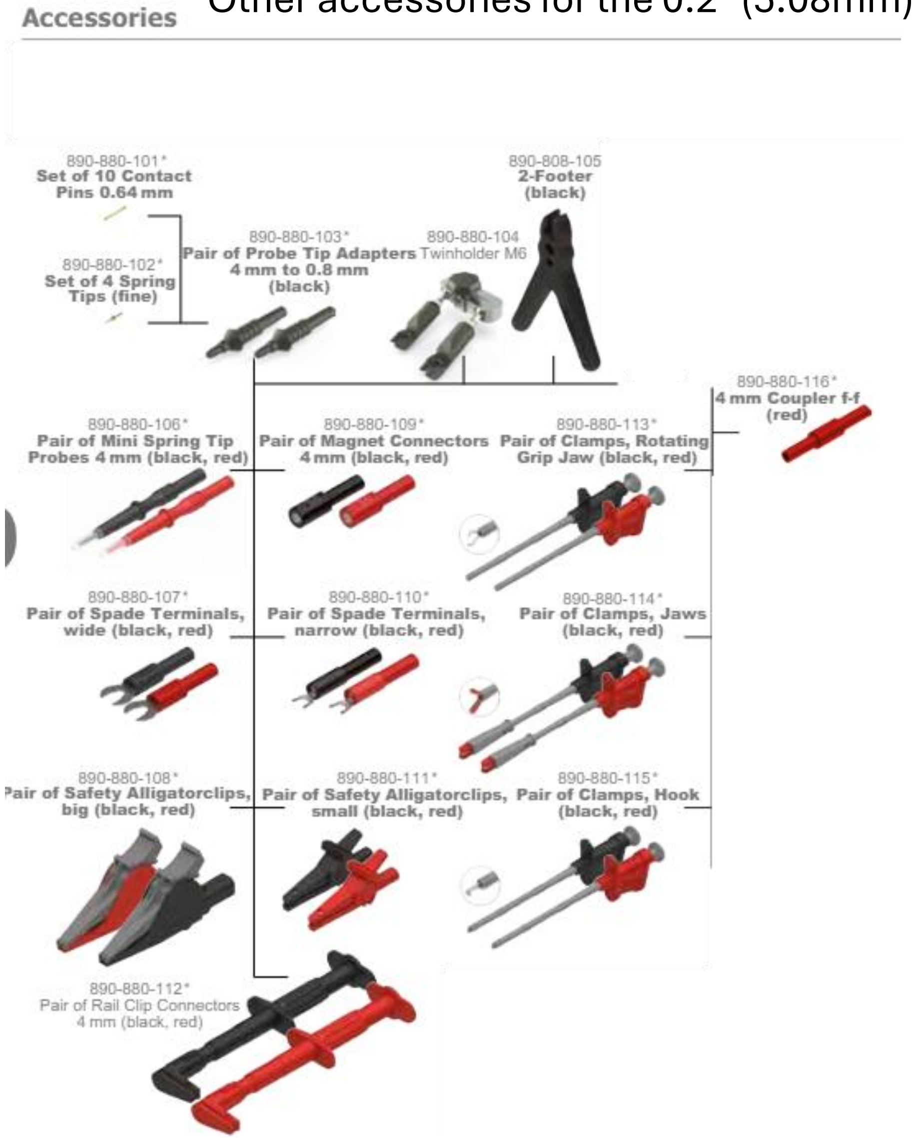
Power Module Connectivity (banana leads)

To extend the leads for wider test points, we would recommend using the 0.2" (5.08mm) pitch square pin to banana lead accessory (above) and then adding banana couplers and banana lead sections as required. Of course the BW and CMRR will be degraded but this is still better than any other probing solution. Again, following our advice of twisting and adding ferrites will get you acceptable results.



Banana Lead Accessories

Other accessories for the 0.2" (5.08mm) pitch square pin to banana lead accessory



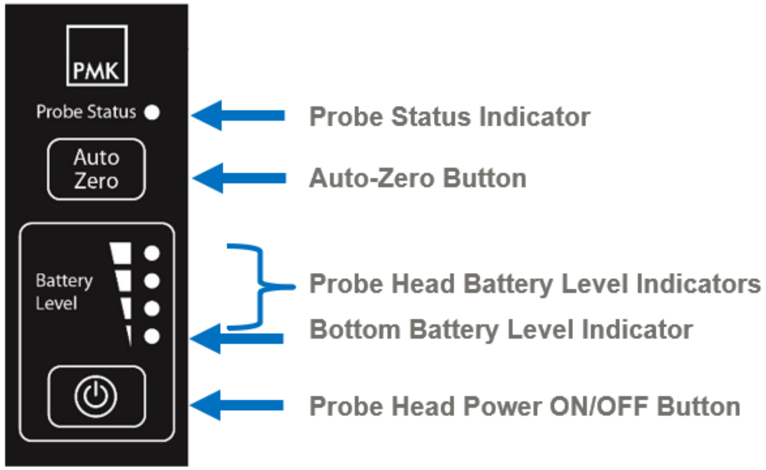
- Reliable connections to MMCX, SMA, BNC, square pin,...
- Specified PMK probe bandwidth remains valid

https://www.pmk.de/en/products/testpoint4mmadapter

Probe Indicators Overview

Probe Status Indicator

Indicator		Status	Action/Information
	Green (Solid)	READY Probe Head Power ON	Successful powered up and probe head is on and warmed up. Ready for measurements.
	Green (Blinking)	Probe Head Warm Up	Probe head has successfully powered up and warming up Probe head not ready. Do not energize your circuit under test.
	Red (Blinking)	Probe Head OFF – Empty Battery	Caution – Empty or missing battery. Probe Head is powered OFF and not able to pass a signal. Probe head not ready.
	Yellow (Solid)	Probe Head Power OFF	Caution - Probe Head is powered OFF and not able to pass a signal. Probe head not ready.
	Blue (Solid)	Auto-Zero In Process	Auto-Zero is in process - Very fast. Probe head not ready. De-energized circuit under test before performing an Auto-Zero required.
	Red Blue (Blinking)	Error Condition	An error condition has occurred - Power cycle the probe & check probe head battery. Probe head not ready. Do not energize your circuit under test. If power cycling not successful, please contact our support.



Probe Head Battery Level Indicators

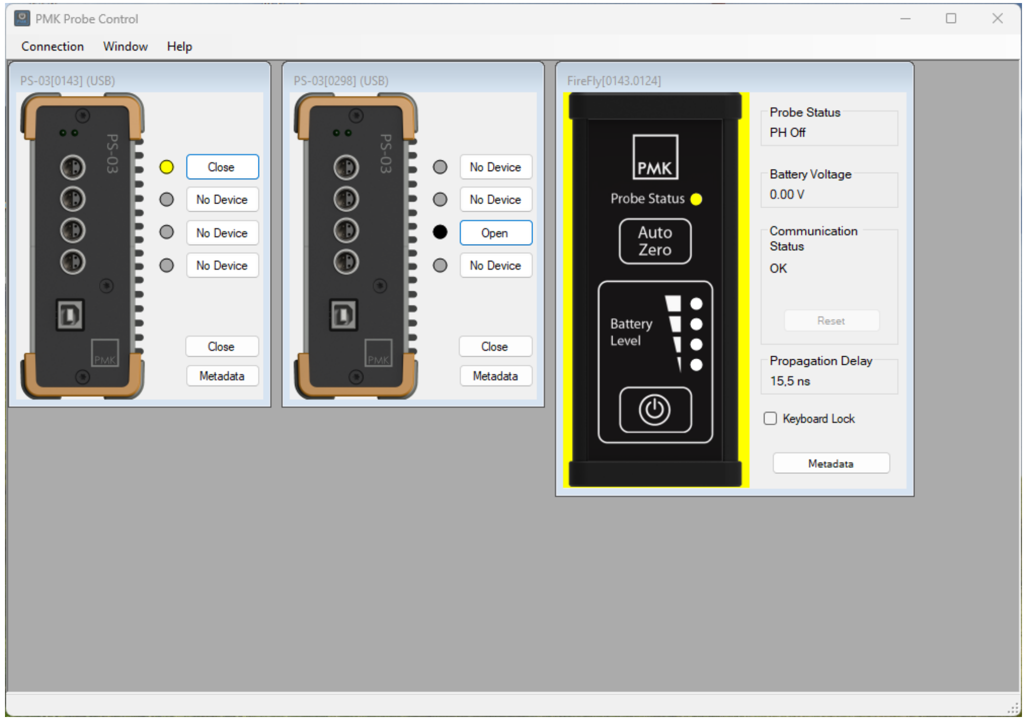
The Battery Level Indicators will illuminate after the Probe Head is turned on.

Indicator		Status	Action/Information
	Green (Solid)	Normal Operation 1 - 4 Green LEDs	Ready for measurements. Four (4) Solid Green LEDs indicates the battery is full and One (1) Solid Green LED indicates the battery will soon need to be replaced.
	Bottom Orange (Solid)	Low Battery (Warning)	Battery replacement recommended.
	Bottom Red (Blinking)	Low Battery (Critical)	Warning - Battery needs to be changed.
	All OFF	Empty or NO Battery Installed	Action required: Probe Head is NO longer in operation and passing a signal - De-energize your circuit - Check and replace battery

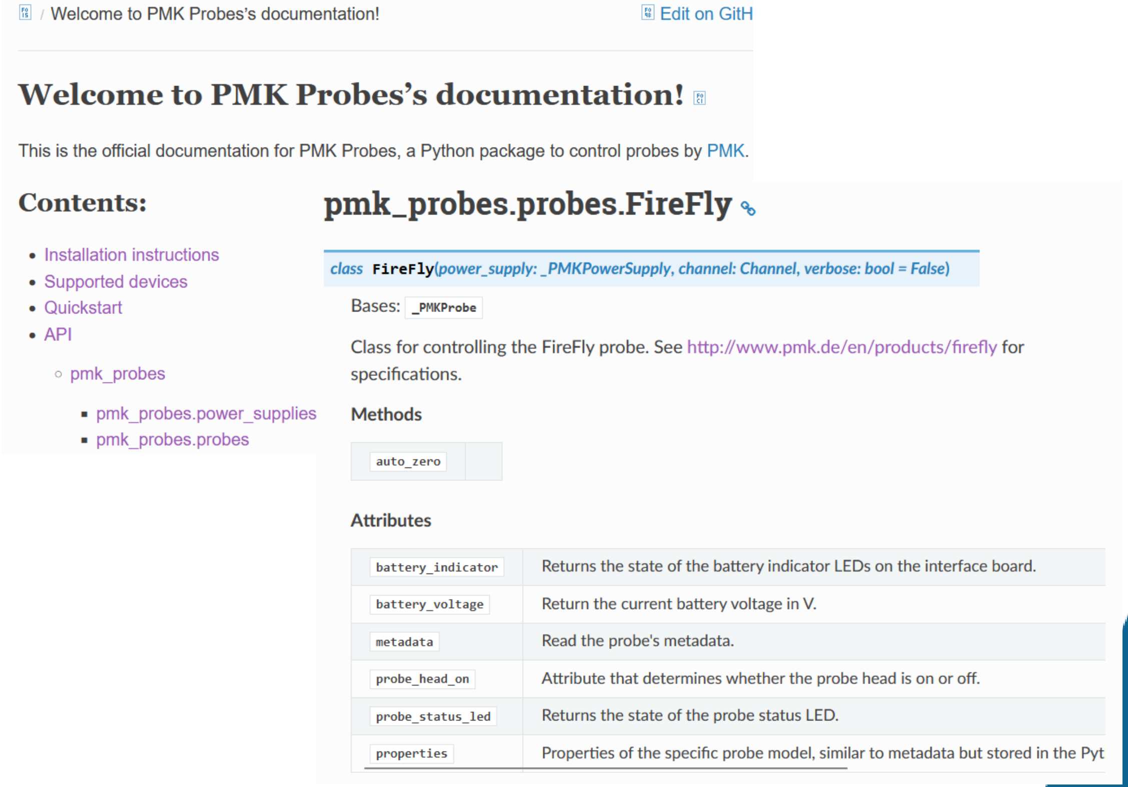
Remote Control of FireFly

Remote control possible via power supply (USB/Ethernet)

PMK probe control – free of charge



PMK Github – phython libary



https://pmk-probes.readthedocs.io/en/latest/index.html

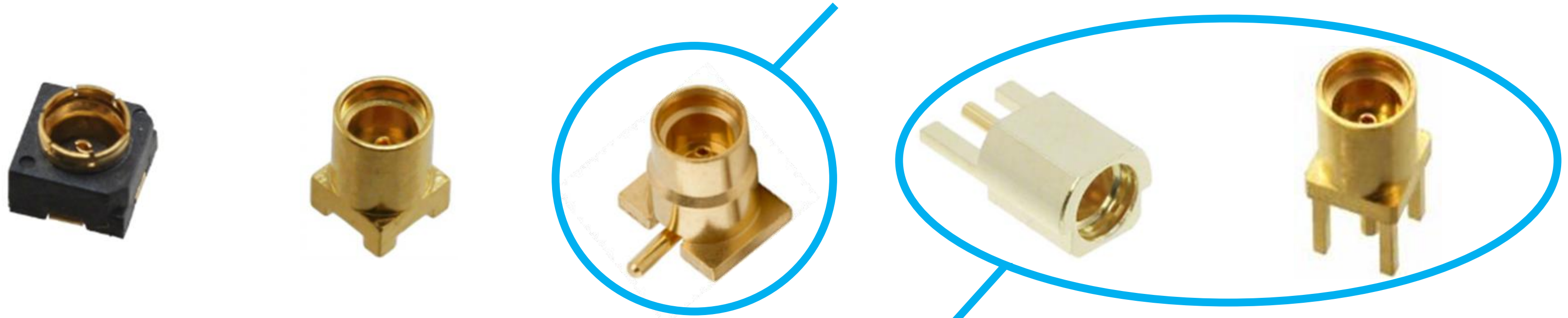
MMCX Connectors

MMCX = Secure, hands-free, shielded connection to the test points to achieve repeatable measurements with best signal fidelity

- **INSERT**: When using an MMCX connector, insert the tip cable's MMCX plug straight into the mating socket until a “click” sound occurs to indicate a proper connection between the plug and socket.

- **REMOVE**: When removing the tip cable from the MMCX socket, grasp the tip cable's MMCX connector and pull straight out, taking care not to wiggle the connector side-to-side to prevent excessive stresses on the socket and its connection to the DUT.

Robust & Good CMRR Performance - Huber Suhner 82_MMCX-50-0-8/111_O



Engagement Force	< 30 N	Einrasten
Disengagement Force	> 8 N @ 1 - 5 Mating Cycles >4 N @ 100 - 500 Mating Cycles	Auszugskraft

Molex & Amphenol thru-hole options – Great for unplanned test point solder-ins (cut leads as needed to attached to test points)

- PMK’s recommendations for MMCX connector vendors: Würth, Huber Suhner, Molex and Amphenol

MMCX extender cables - recommendation

Digikey part number

DigiKey order number:

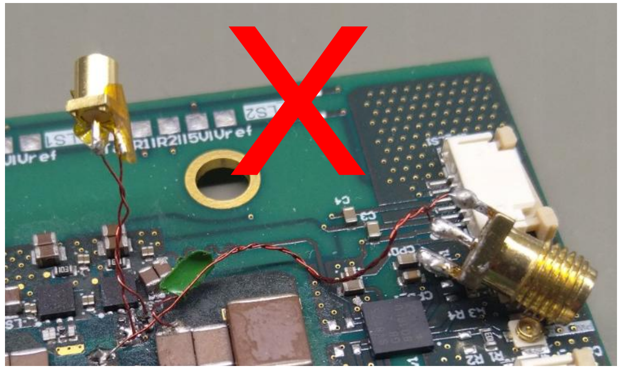
- 732-14204-ND (Würth)
- 732-14206-ND (Würth)
- 732-14205-ND (Würth)
- ASMK025ZM174S11-ND (Siretta Ltd)

Making High-Frequency High CMRR Measurements

Tips for Making the Measurements

Tips for making the highest signal fidelity measurements

- Best CMRR performance
  - **Make sure to tighten the tip cable to probe SMA connection**
- **Measure as close as possible** to the desired measurement point to not degrade the performance
- If using a tip cable adapter/accessory with input leads, **twist the input leads** together to reduce the input inductance and improve the CMRR of the test setup.



- **Avoid fiber movement** when making a measurement
- **Add external ferrite beads** over the tip cable, or adapter/accessory, as close as possible to the test points, will **improve** the CMRR and common mode loading **at higher frequencies**.

Achieve the Best Performance

How to connect to the Test Points (Circuit-Under-Test)

- **Best electrical performance, CMRR performance and EMI susceptibility**
  - Place probe tip as close as possible to test point to achieve best performance and shielding
  - Provides stable and repeatable measurements
  - We highly recommend using MMCX connector soldered on board
    - MMCX connectors provide best shielding performance

- **Minimize effects of common mode loading of probe head/tip cable and maximize CMRR**
  - Connect the **coaxial (common) shield** of the tip cable to the test point that has the **least dynamic signal**, with respect to earth ground, relative to the tip cable signal (center) test point in the circuit-under-test.
  - The **coaxial (common) shield** of the tip cable and tip cable adapters should always be connected to the **lowest impedance point** (usually a circuit common or power supply rail) in the circuit-under-test (relative to the tip cable/center conductor) to obtain the most accurate waveform.

- **Reduce the parasitic capacitance** by increasing the physical distance between probe head/tip cable and any conductive surface.

Environmental Testing Probes

High Temperature Range Single-Ended Probe

ENVI® Series

- -55°C to +155°C Range BEST-IN-CLASS
- 350MHz Bandwidth, 400V / 1.25kV Peak
- High Input Impedance
- Wide Range of High Temperature Accessories
- Pollution Degree 3 BEST-IN-CLASS

Making Current Measurements

Current Shunt Measurement

Why use FireFly for shunt measurement?

Why Shunts?
Rogowski coils or Current Transformer are limited:
- Only measures AC current
- Maximum Bandwidth of 100 MHz

Current measurement	Maximum achievable bandwidth	Suitability	Features
Common I-shunt/Coaxial Shunt	<500 MHz	AC / DC	+ High bandwidth and accuracy - no galvanic isolation, large in size, additional loop inductance
Current Transformer (LILCO)	200 MHz	AC	+ isolated measurement - large in size, saturation effect, additional loop inductance
Rogowski Coil	100 MHz	AC	+ Isolated measurements, no saturation effect - Additional integrator required, low bandwidth
PMK UFCS Shunt	> 1 GHz	AC / DC	+ Very High bandwidth and accuracy, small in size, very low insertion inductance

Best practice for shunt masurements:

FireFly

+

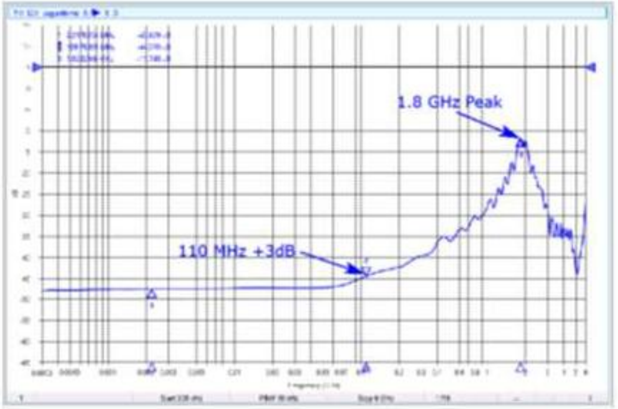
PMK's UFCS

- Market-leading >**1GHz** Bandwidth
- Ultra-low **<200 pH** Insertion Inductance
- **Various sizes** available: 1mΩ, 5mΩ, 11mΩ, 24mΩ, 52mΩ
- For WBG switching loss and pulse current measurements

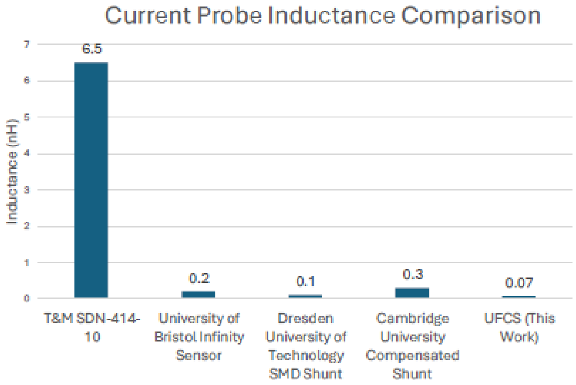
UFCS shunts from PMK

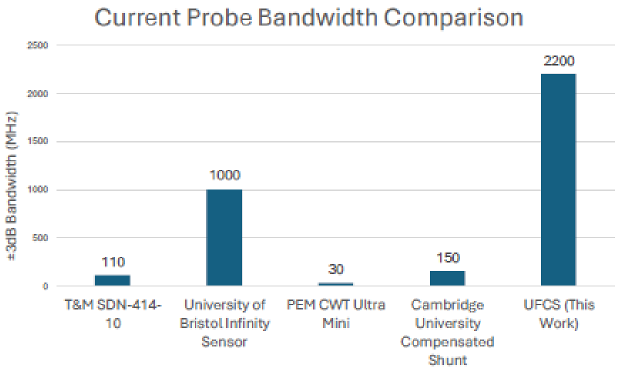
Issues With Switching Loss Measurement

- Existing measurements either have insufficient bandwidth, high inductance or an inconvenient connection method.



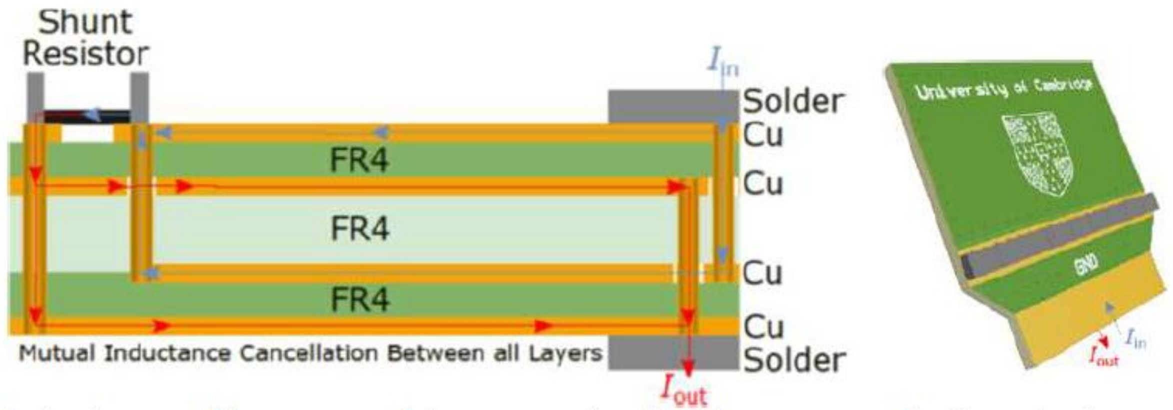
Bandwidth measurement of a commonly used coaxial current shunt.

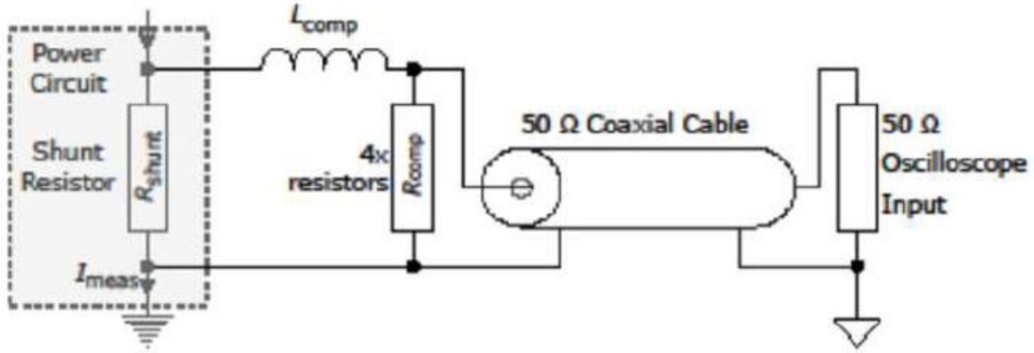




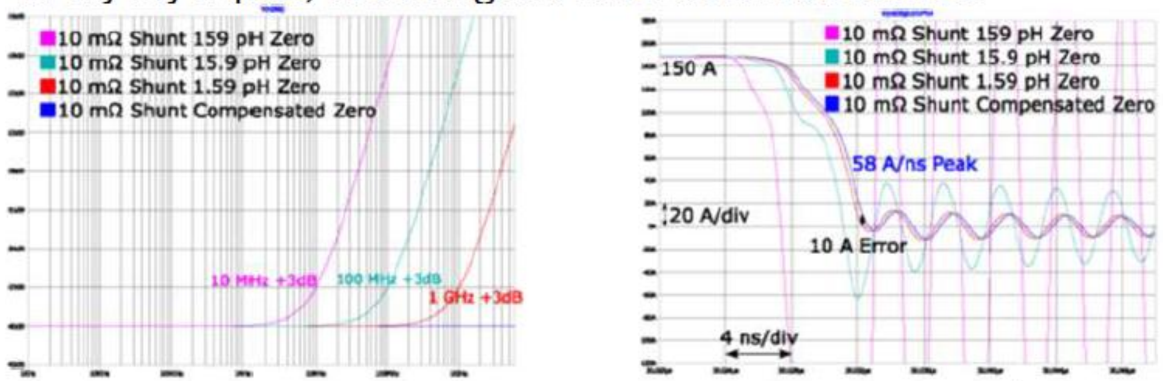
- High inductance can cause voltage overshoot under high di/dt.
- Low or distorted bandwidth can cause significant measurement error.

UFCS shunts from PMK



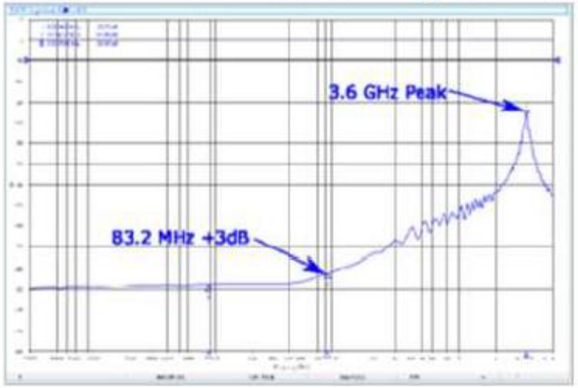


- Interleaved layers achieve magnetic flux cancellation between every layer pair, reducing the insertion inductance.

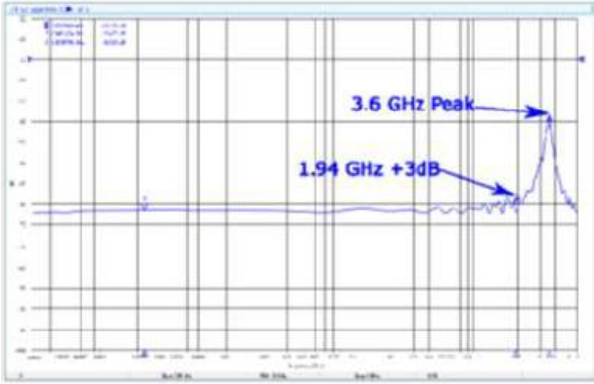


- Inductive zero present in frequency response can cause overshoot and ringing.

- Low pass filter to remove the differentiating effects of the inductive zero and improve bandwidth.



- Uncompensated Bandwidth

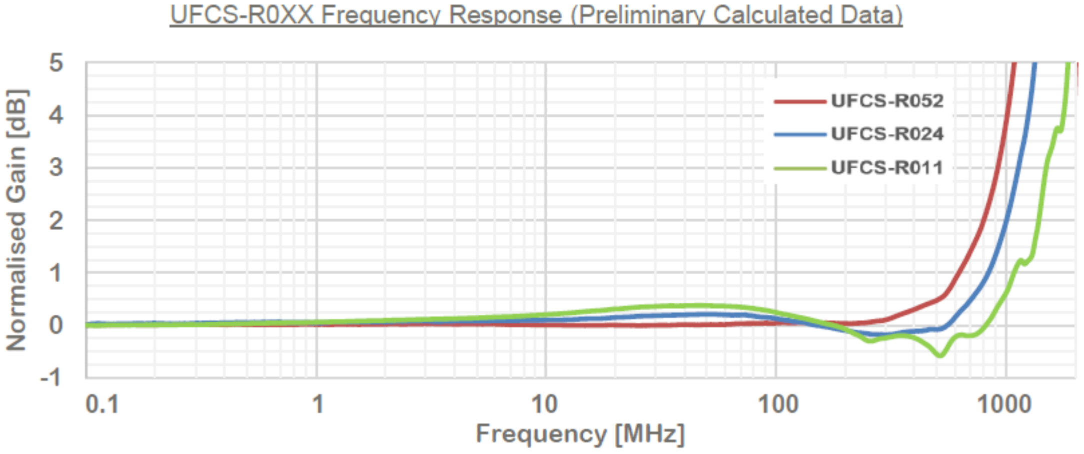


- Compensated Bandwidth

UFCS shunts from PMK

Datasheet

Frequency Response



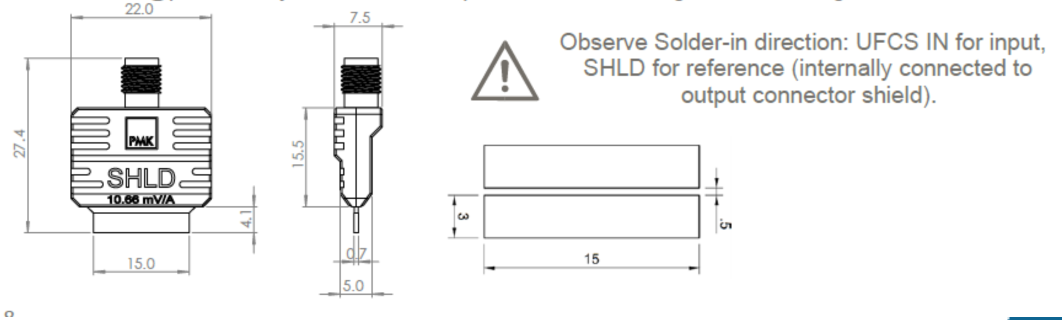
Order number	Shunt Resistance	Gain	Bandwidth (3dB)	Typical Insertion Inductance [3]
UFCS-R001	1 mΩ	TBD	TBD	TBD
UFCS-R005	5 mΩ	TBD	>800 MHz	TBD
UFCS-R011	11 mΩ	10.7 mV/A	>1 GHz	110 pH
UFCS-R024	24 mΩ	23.7 mV/A	>1 GHz	140 pH
UFCS-R052	52 mΩ	51.1 mV/A	>900 MHz	150 pH

Order number	Maximum 1us Pulse Current [2]	Maximum 100us Pulse Current [2]	Continuous Current [2, 4]
UFCS-R001	TBD	TBD	TBD
UFCS-R005	TBD	TBD	TBD
UFCS-R011	340 A	105 A	7.3 A
UFCS-R024	230 A	70 A	4.9 A
UFCS-R052	160 A	50 A	3.4 A

The UFCS shunt can most simply be considered as a 4-wire resistor. Current goes into and out of the Input terminals (IN and SHLD). The output voltage is measured across the "SMA output connector" which must be terminated into a 50 Ω load.

Dimensional Drawing and Recommended Footprint

The schematical drawing and all dimensions in the recommended footprint drawing are shown in [mm]. Contact sales@pmk.de or your local PMK representative for design files. Drawings not to scale.

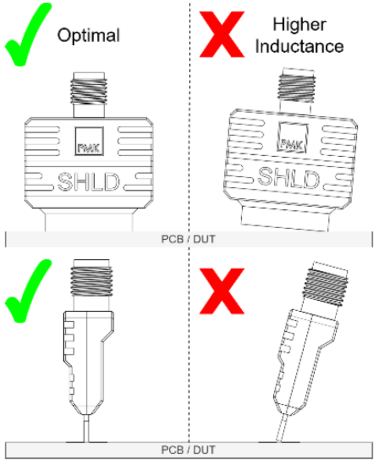


UFCS shunts from PMK

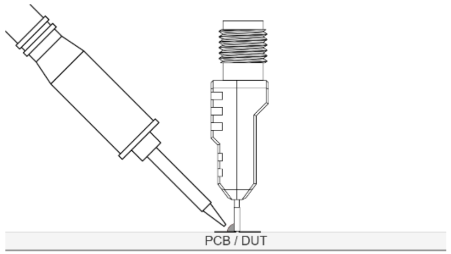
Recommended soldering Technique and other connection options

Follow the steps 1 to 4.

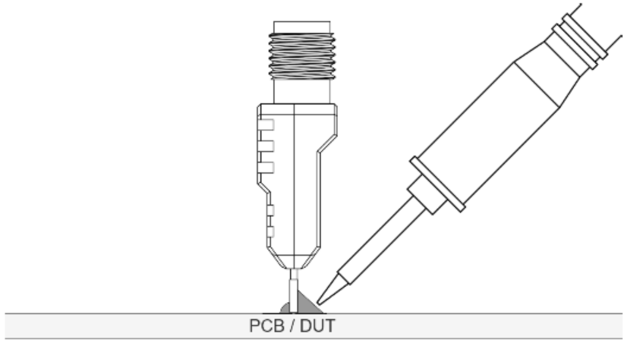
1. Hold the shunt perpendicular to the PCB and aligned to the footprint, avoid any gaps between the shunt and the PCB - these will increase insertion inductance.



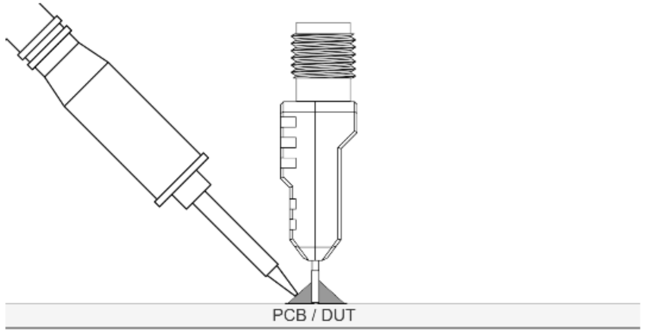
2. “Tack” one side of the shunt with solder to hold it into position. It may be helpful to “tin” the shunt and PCB pad on this side first.



3. Solder the opposite side of the probe with a complete solder fillet.

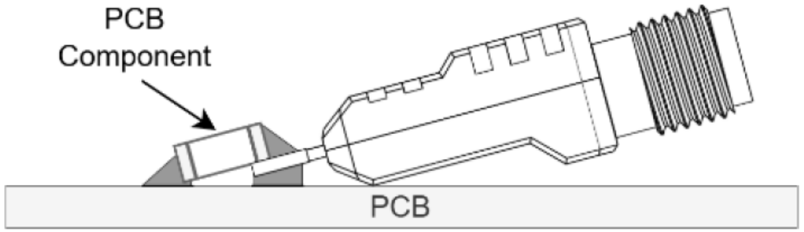


4. Resolder the tacked side of the probe with a complete solder fillet.



The shunt can also be soldered between a component and the PCB.

Example

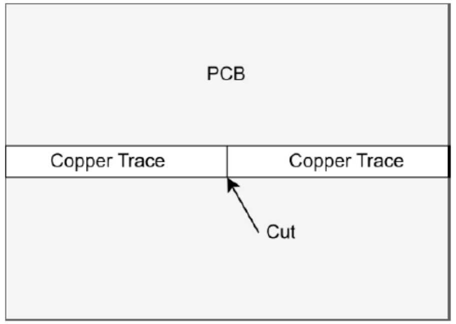


UFCS shunts from PMK

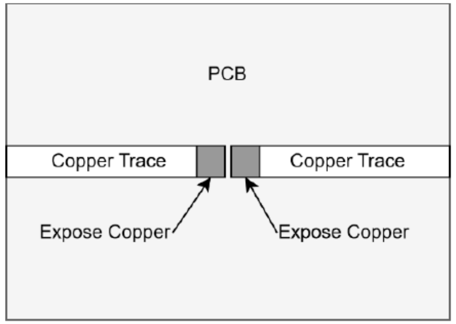
Recommended soldering Technique and other connection options

If it is not possible to use the recommended footprint then it is possible to solder the shunt across an existing PCB trace.

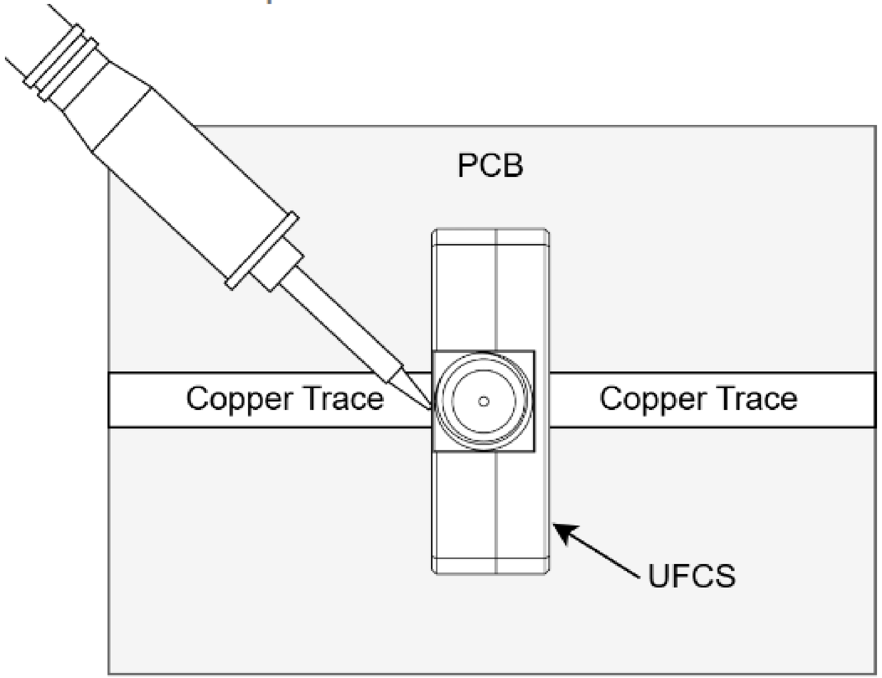
1. Carefully cut the PCB trace where you wish to install the UFCS.



2. Remove solder mask to expose some copper each side of the trace, “tin” the exposed copper with solder.



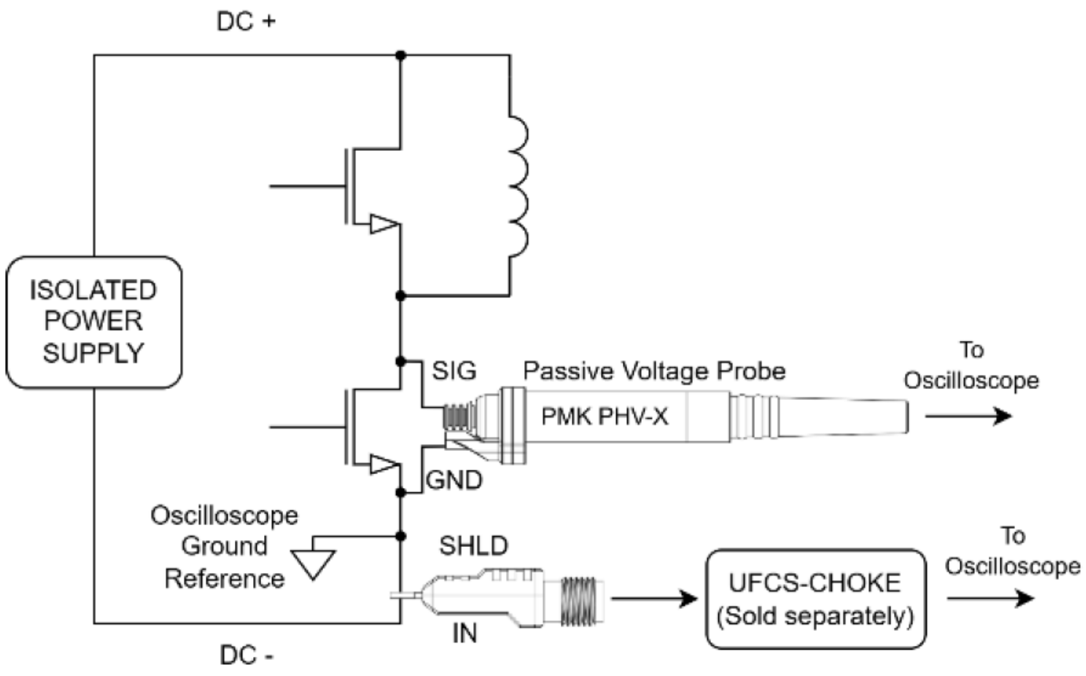
3. Solder the probe across the cut in the trace.



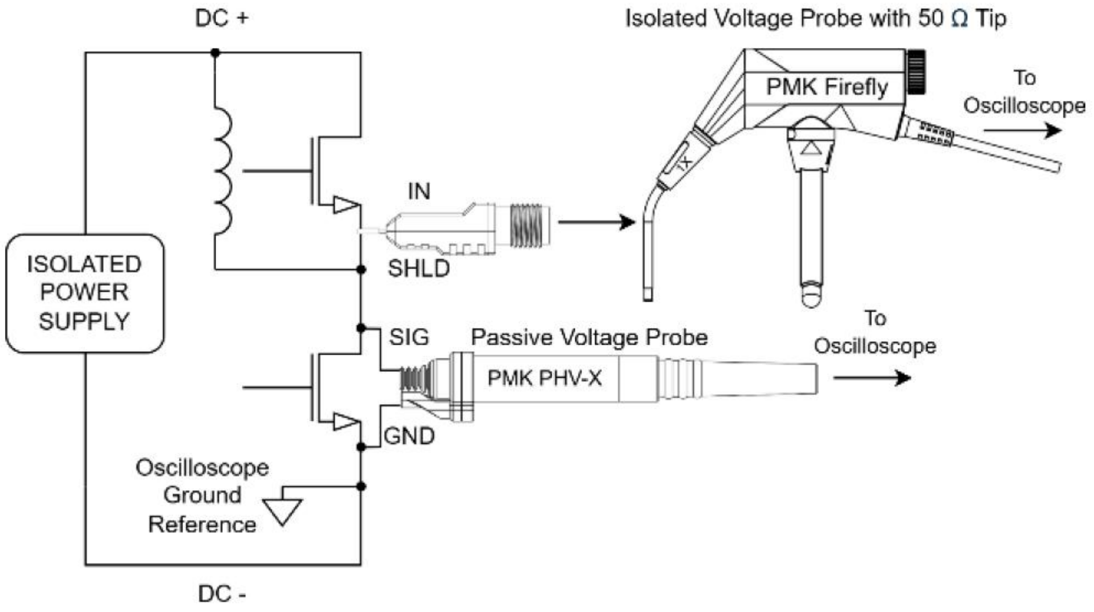
UFCS shunts from PMK

Some test configuration

Typical non-isolated double pulse test configuration



Typical isolated “high side” current measurements in a double pulse test configuration



Standard 50 Ω transmission line accessories, such as attenuators and overvoltage line protectors may be used in conjunction with the UFCS.

High Voltage Single-Ended Passive Probes

PHVX Series for tester applications

- ± 4000V Input Voltage
- >600MHz Bandwidth
- Very low <3pF Capacitive Loading, 50MΩ Input
- >360° rotational GND connection
- Variety of Connectivity Solutions
- Universal BNC - Use with any Oscilloscope

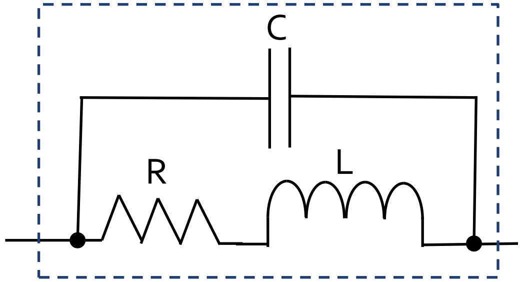
Hints for Current Shunt Measurements

- **Observe**
  - **Using Direct SMA input**: Place 50Ω Feed-Thru on probe's SMA input
  - **Using FF-MMCX-1V tip cable**: No Feed-Thru needed

- Use a **small value resistor as a current shunt to make very high frequency current measurements** while minimizing the insertion impedance *CAUTION: Surface mount resistors have different power ratings; care must be taken not to exceed these ratings when using them as current shunts. Paralleling resistors will reduce the series inductance and increase the power rating.*

- Example: In a typical application, a 0.025 Ω resistor might be used to measure a transient current of 10 A, resulting in a voltage swing of 0.25 V, which can be measured with the measurement system using a FF-MMCX-1V, 1X, Tip Cable.

Best Practise: If the current is a low frequency signal, use Bandwidth limit* and High-Resolution acquisition on the oscilloscope (or Averaging if the signal is repetitive). *
FireFly®'s 2mV$_{RMS}$ noise is at full bandwidth and limits the minimum voltage levels that can be accurately measured.



SMT Resistor Model

A typical surface mount resistor, R, can have a series inductance, L, of less than 0.2 nH and series capacitance, C, of less than 0.04 pF, resulting in much lower impedance at high frequency than could be obtained with a conventional current probe.

Go to http://www.vishay.com/docs/60107/freqresp.pdf for models of different types of surface mount resistors.

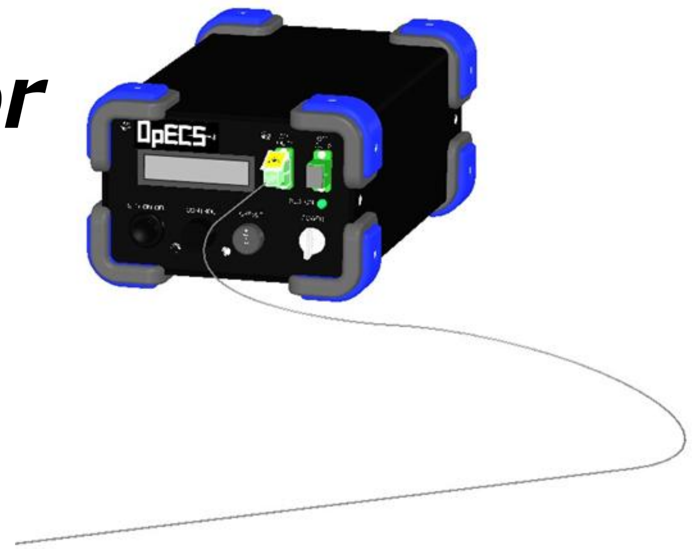
IWATSU

PMK

OpECS

OpECS

Optical-Electric-Current-Sensor



DC to > 150MHz

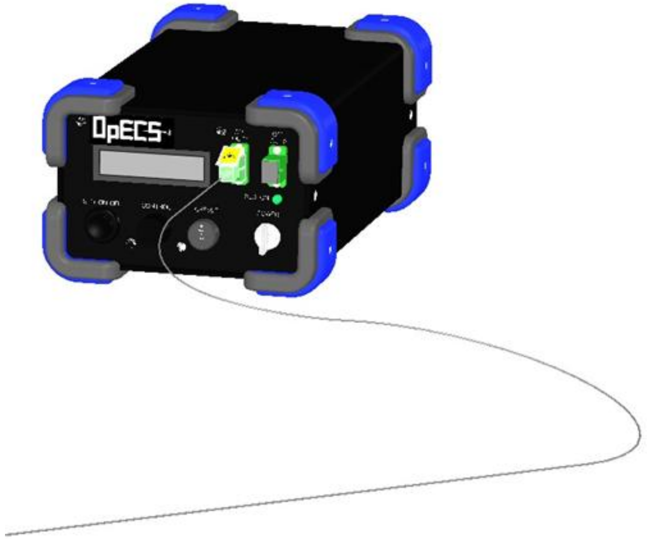
Low Currents to >100A

No Derating

No Insertion Impedance

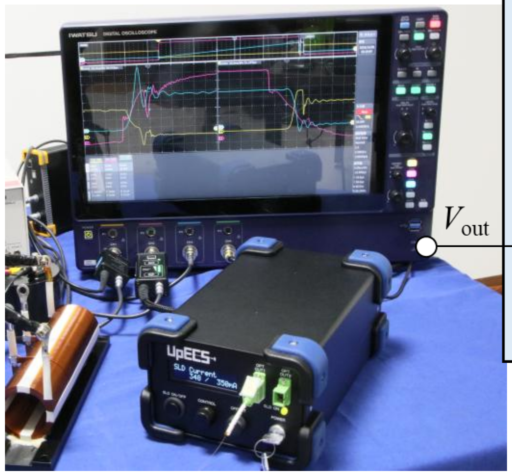
Smallest probe tip Φ <1㎜

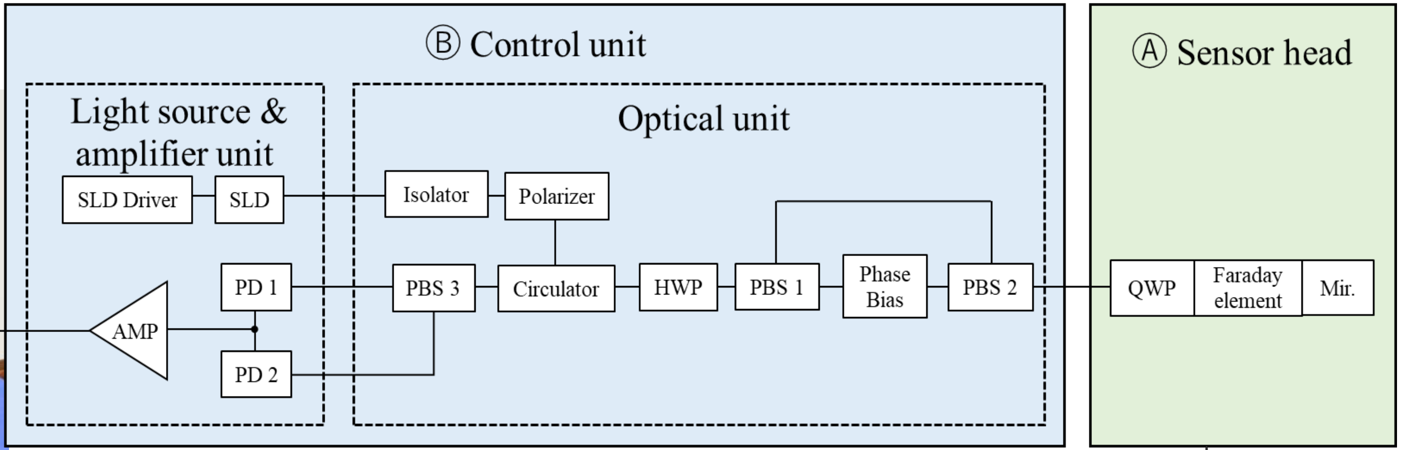
Items	Specification	Note
【Main unit】		
Frequency Bandwidth	DC ～ 150 MHz (-3dB)	-
Measurable current	±140 A ※	When making measurements that exceed the measurable current shown at left, see the graph of measurable current on page 3.※Measured by contacting φ0.5mm copper wire
Sensitivity	25.78 mV/A ※1 (0.073 mV/A・m^{-1})	※Measured by contacting φ0.5mm copper wire
Output Voltage Range	±4.7 V	-
Noise	6.3 mVrms	With no input, at 200MHz bandwidth instrument
Linearity	±1 %	※Measured by contacting φ0.5mm copper wire
Output Connector	BNC (50ΩTermination)	-
Operating Temperature Range	-10 ～ 50 ℃	Sensor Head part
Operating Temperature Range	15 ～ 35 ℃	Control unit part
Power input range	AC100 ～ 240V (50/60 Hz)	-
Power consumption	11 W	-

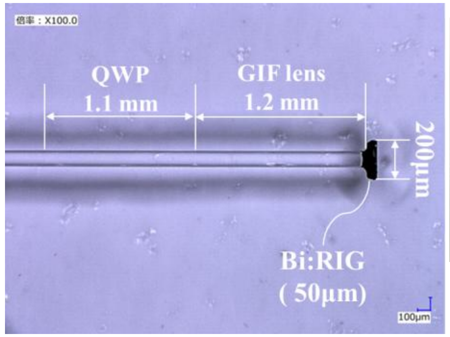


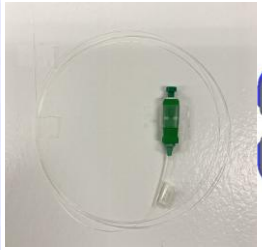
How does the optical current probe

IWATSU DS-8000



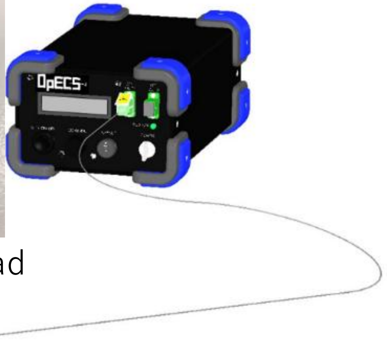






Ⓐ Sensor head

Ⓑ Control unit



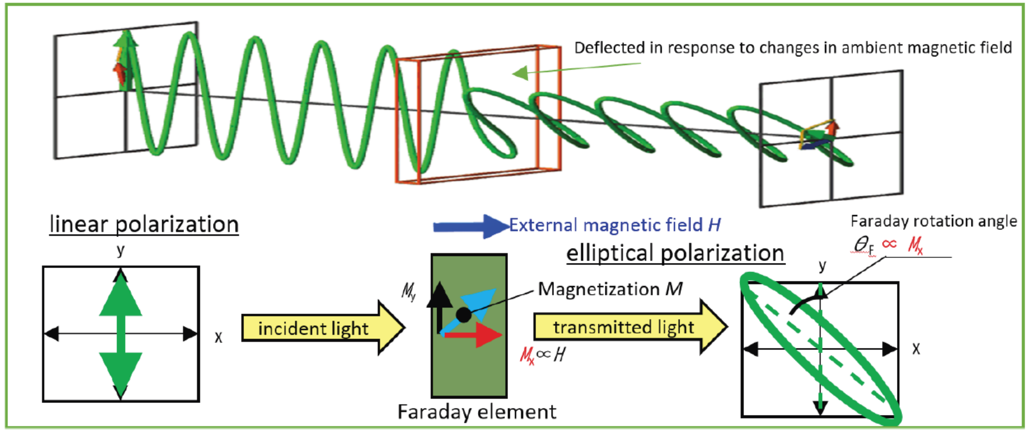
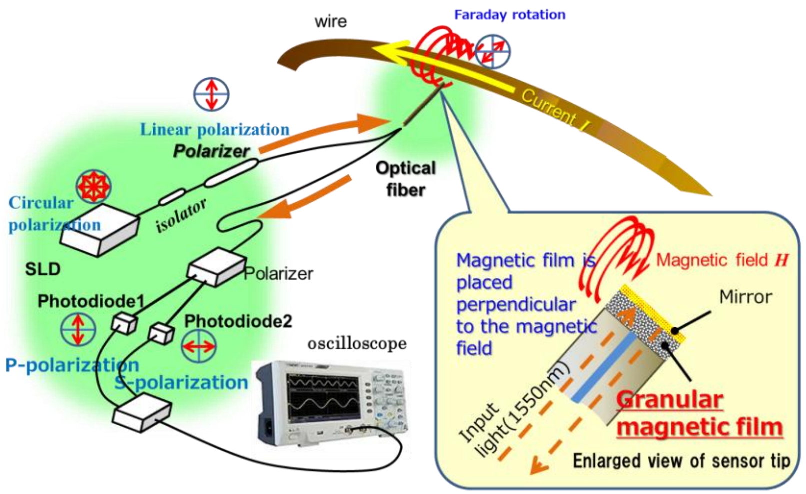


Fig.1. Principle of Optical Current Sensor

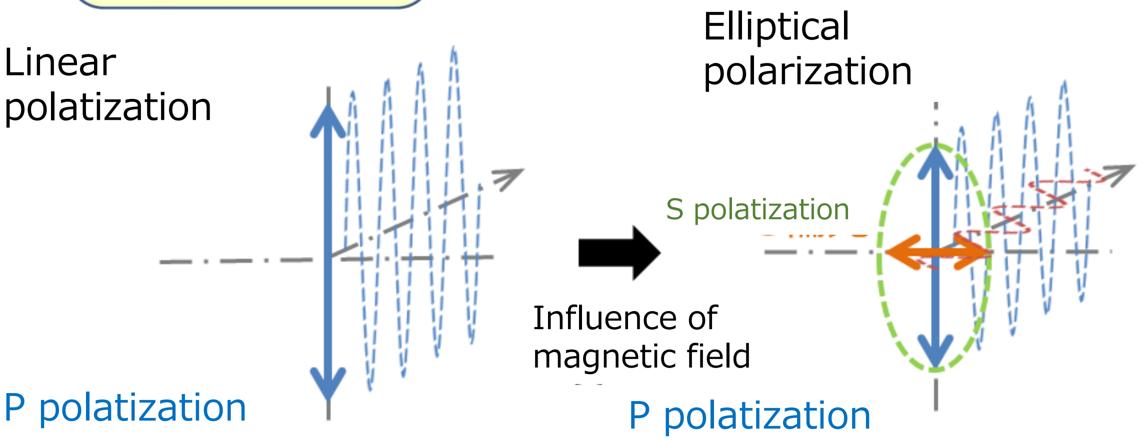
OpECS Principle Details

Measurement principle



Magnetic field generated by the current makes the Linearly polarized light passing through granular magnetic film to be elliptically polarized light by the Faraday effect.

The Faraday effect is a function of the P and S polarization.
The current is measured by



・Magnetic field changes linear polarization into elliptical polarization (Faraday effect)
・The strength of the magnetic field is proportional to the Faraday rotation angle
・Detects the strength of the magnetic field (current) by taking the difference between P and S polarization

OpECS features

About measurement position

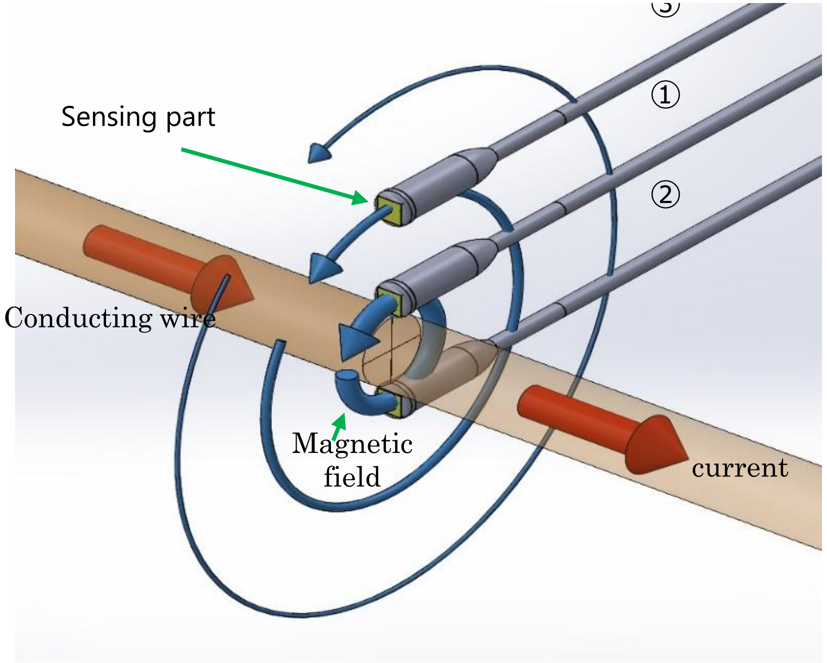


Fig1　measurement position

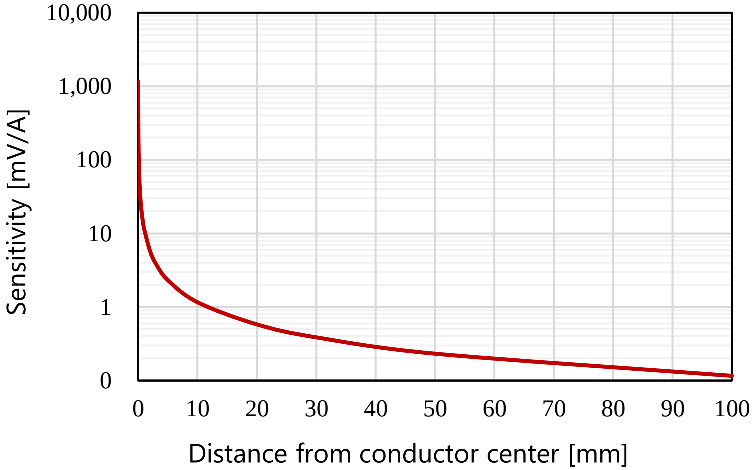


Fig2　Sensitivity graph

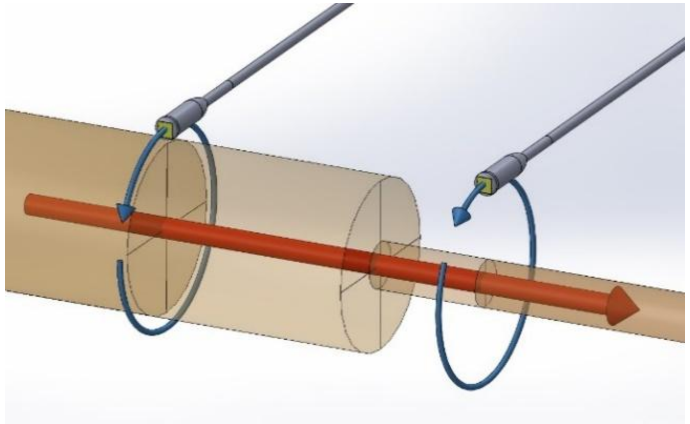


Fig3　Relationship between sensing section and conductor diameter

・Sensitivity is maximized when the sensing part contacts the center of the conductor as shown in Figure 1①.

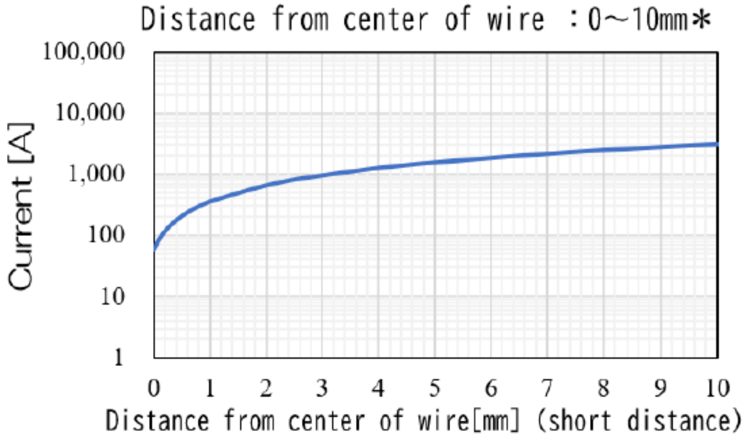
・As shown in ③, when the sensing part is at a distance from the conductor, the sensitivity becomes weaker according to the graph in Figure 2.

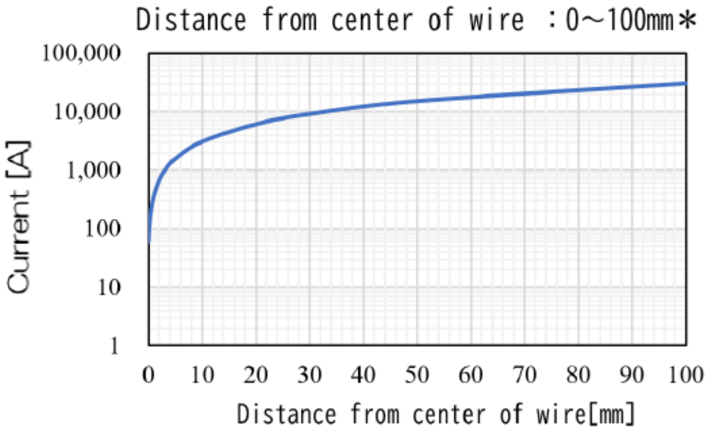
・Positive value is output when placed as in ① for the current flowing in the conductor. Negative value is output when placed as ②.

If the distance between the center of the conductor and the sensing area is constant, the sensitivity does not change even if the conductor diameter is changed, as shown in Figure 3.

OpECS Sensor

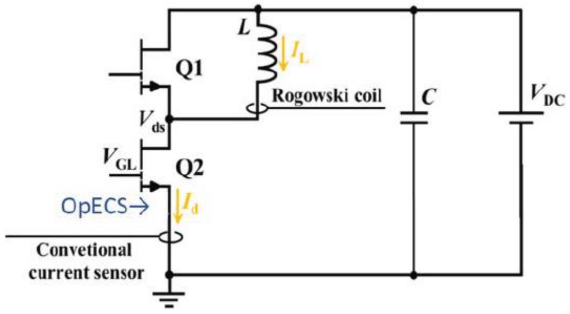
(3)Measurable Current range

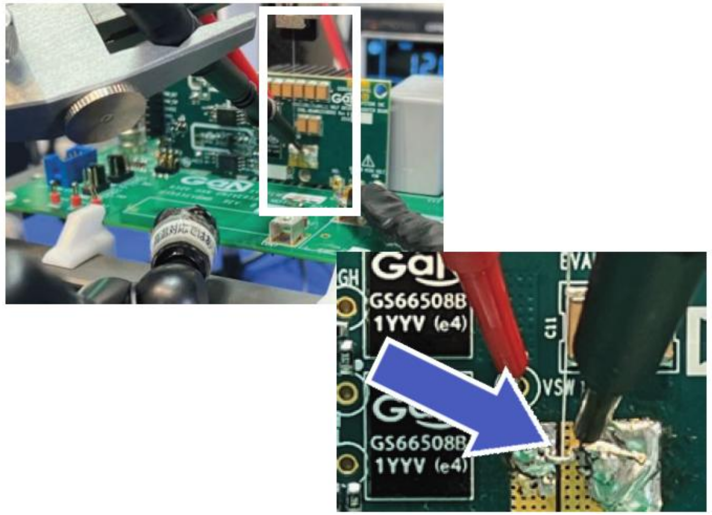




* Measured by contacting a 0.5 mm dia. copper wire

(2) Double-pulse test of a GaN half-bridge circuit (Vds = 100 V)





OpECS Sensor head Variations

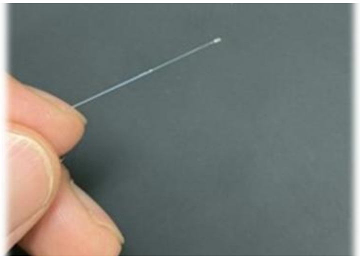
There are three types of heads

- ・Tip Φ0.45mm fiber type Horizontal
- ・Tip Φ0.80mm fiber type Vertical
- ・Clip type

Fiber type head

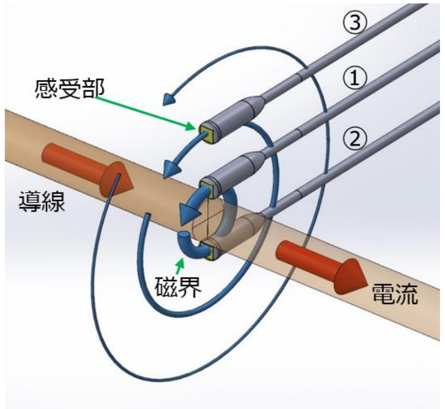
Head with fiber-optic cable intact, suitable for measurement in narrow space.

Two types are available depending on the measurement point:
Horizontal type and Vertical type



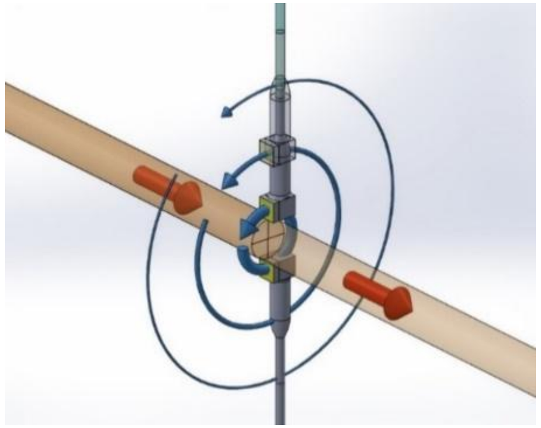
Horizontal type

A head in which the sensitive part is located on the front of the fiber.
For insertion measurement in extremely narrow spaces, such as inside a coil.



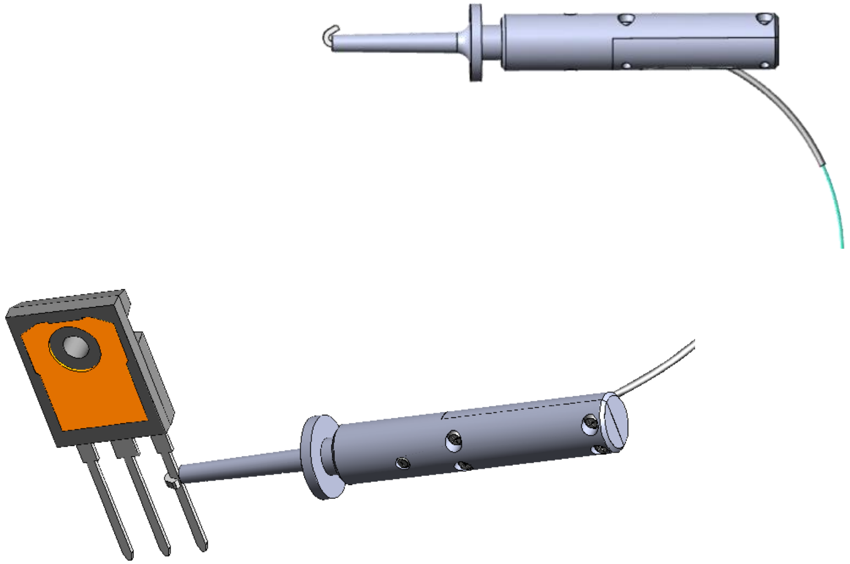
Vertical type

Head with the sensing part located on the side of the fiber.
Easy access to the sensor from above, such as circuit boards.



Clip type head

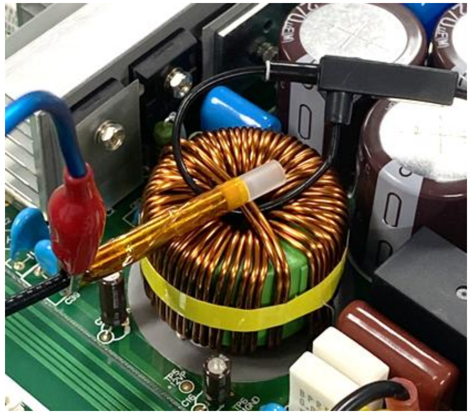
The clip-type head can maintain a constant distance between the object to be measured and the sensing section, resulting in high measurement reproducibility.

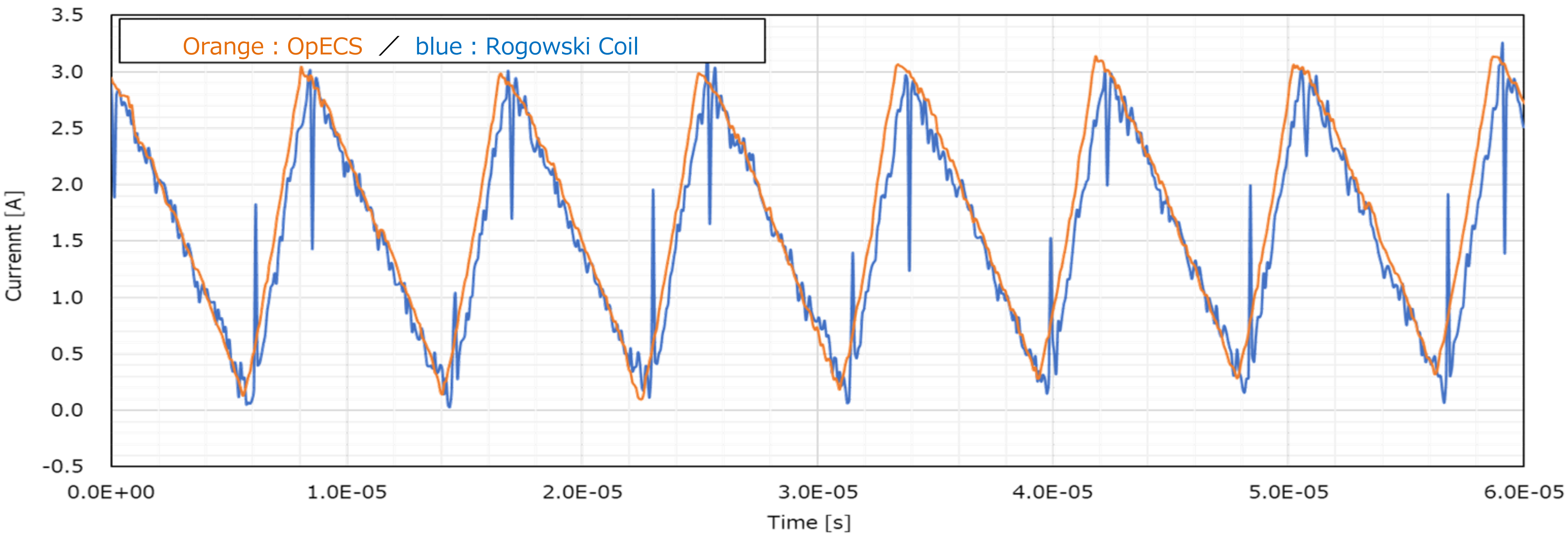


Measurement of components in a regulated power supply

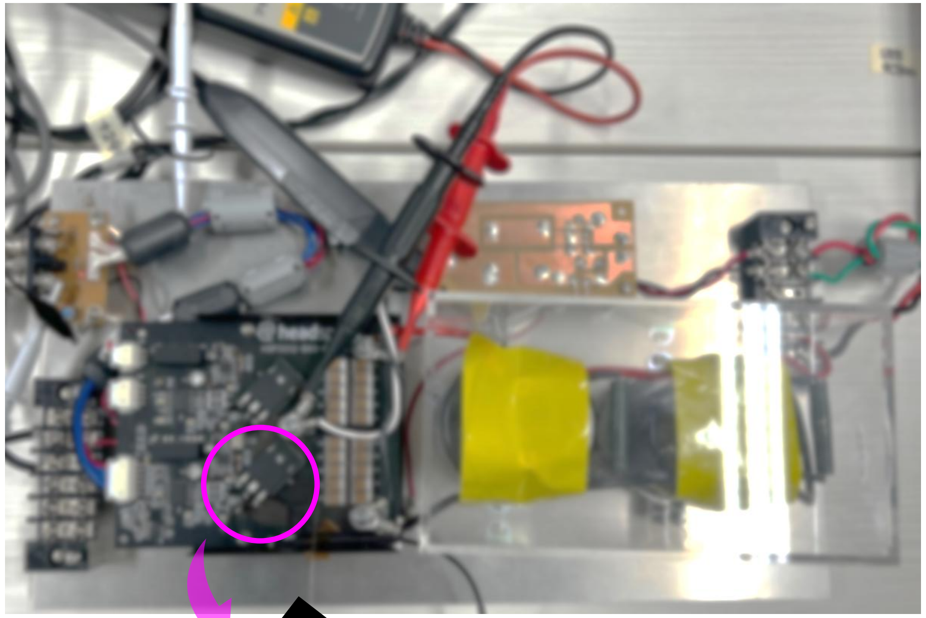
switching regulator

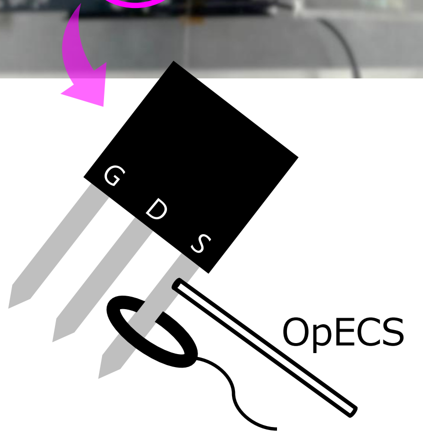
Choke coil measurement in switching power supplies





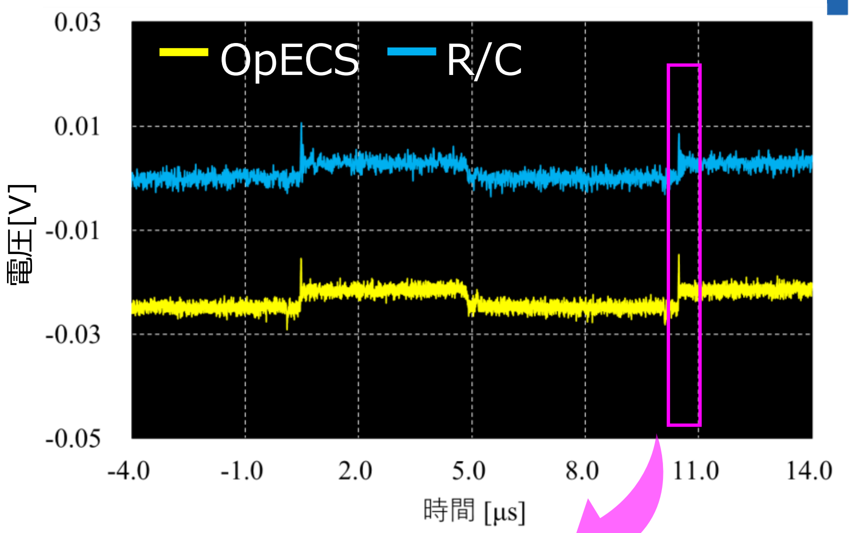
Comparison of superimposed electromagnetic noise

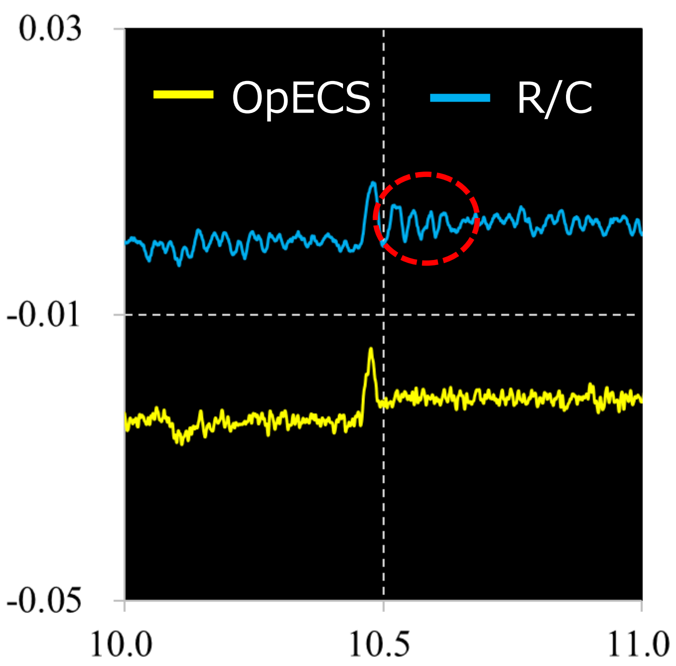




<Current>
Ipp ≒ 2A
f ≒ 100kHz

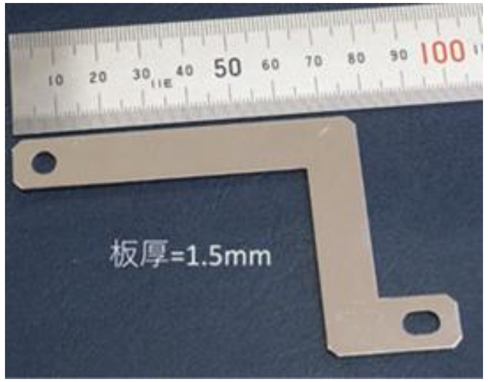
Image of measurement

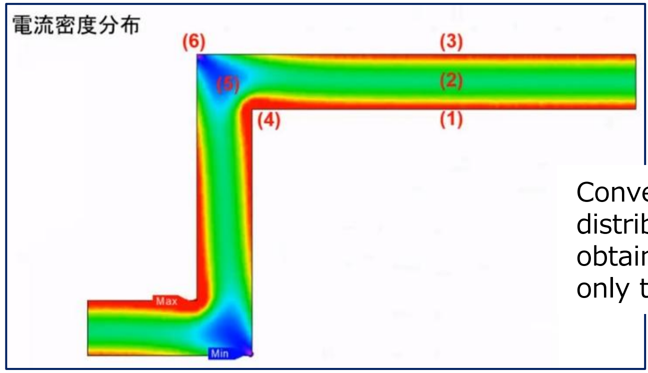




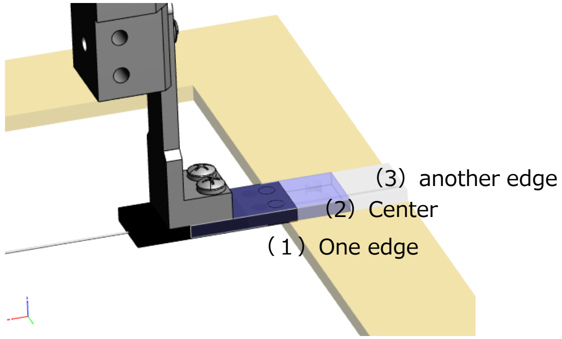
Rogowski coil has superimposed electromagnetic noise
There is no real ringing.

Comparison of superimposed electromagnetic noise

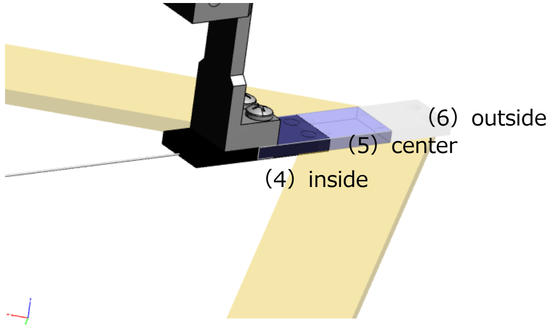




Conventionally, only the relative current density distribution could be obtained by the contour diagram obtained by Simulation.
only the relative current density distribution was known.



Straight section (3-point measurement by moving the sensor head)

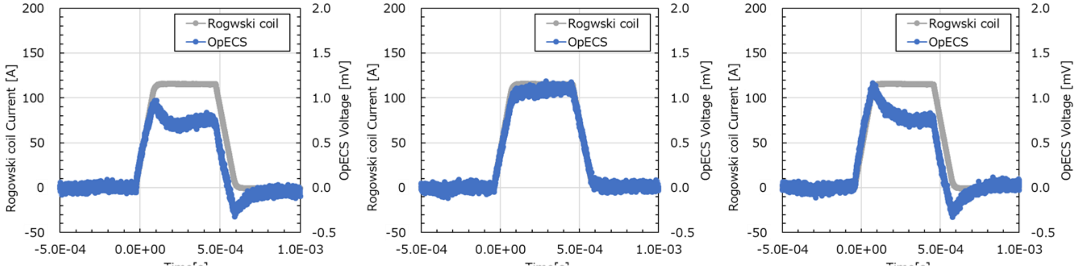


Elbow section (3-point measurement by moving the sensor head)

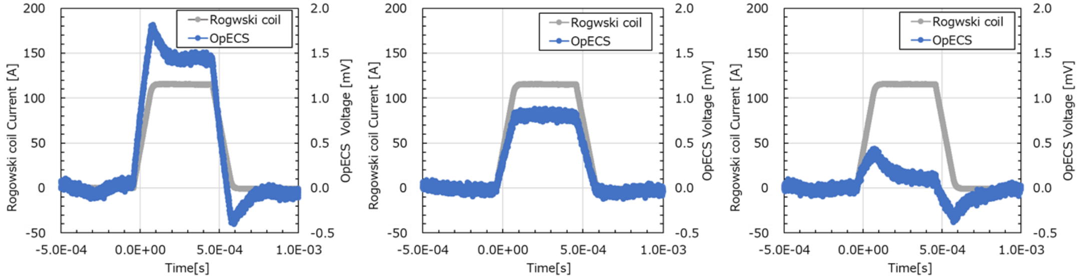
Measure the entire busbar with Rogowski coils for comparison

With OpECS, waveforms at each point are visible.

(1) One edge　(2) Center　(3) another edge

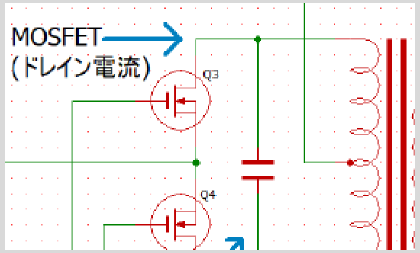


(4) inside　(5) center　(6) outside

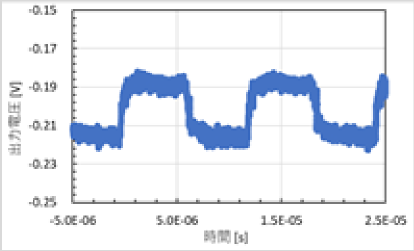


Measurement of switching FET: Micro currents

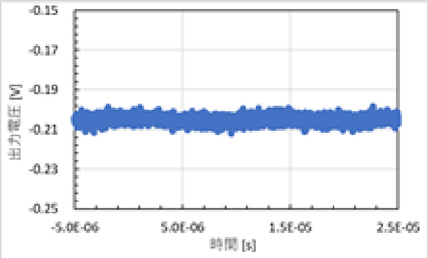
Mesurement circuit



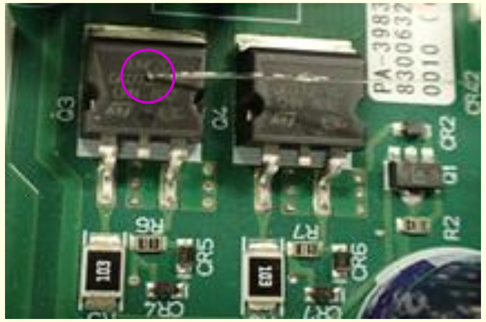
Source port

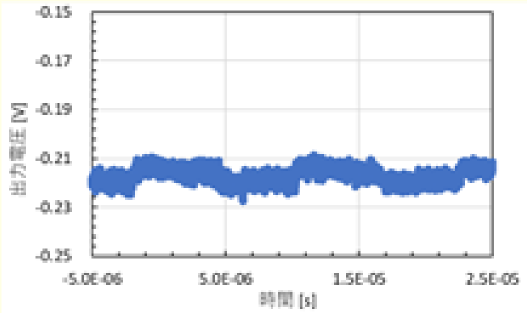


Gate port

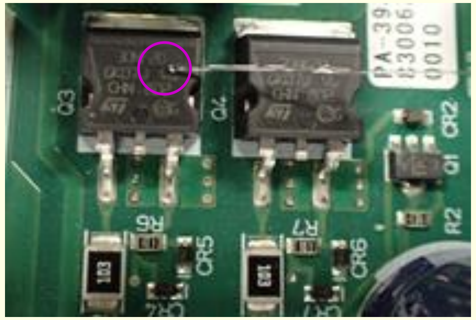


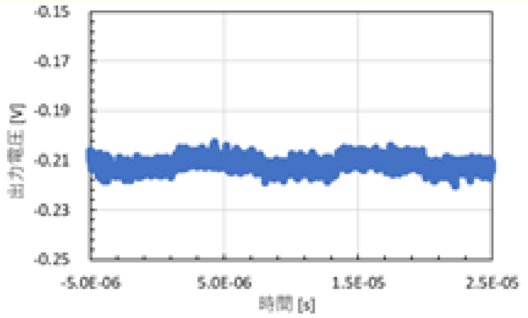
FET-Body center



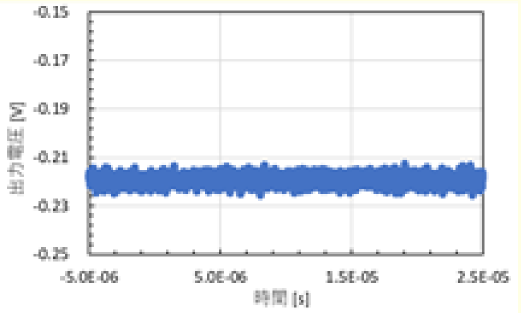


FET-Body right side



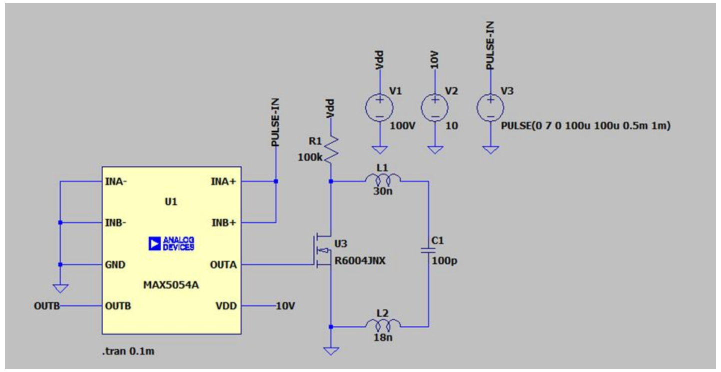


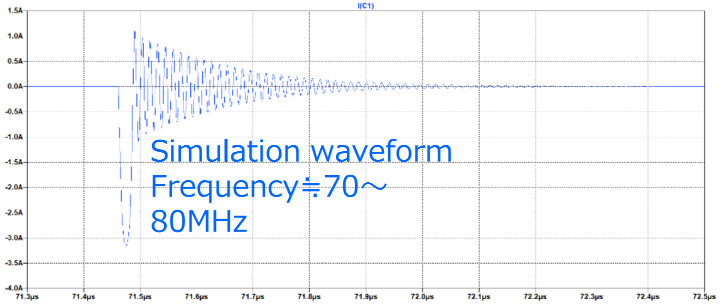
FET-Body right edge



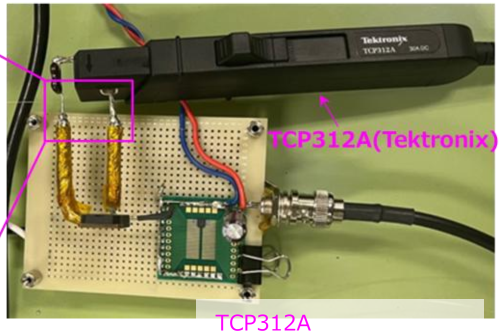
Measurement Example 5

Measurement of high-frequency currents

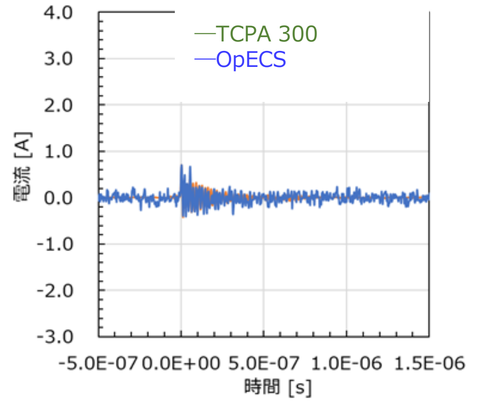
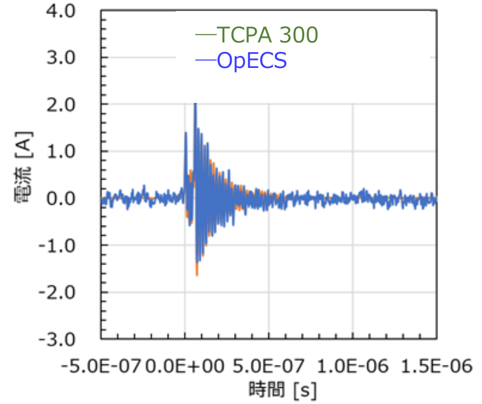
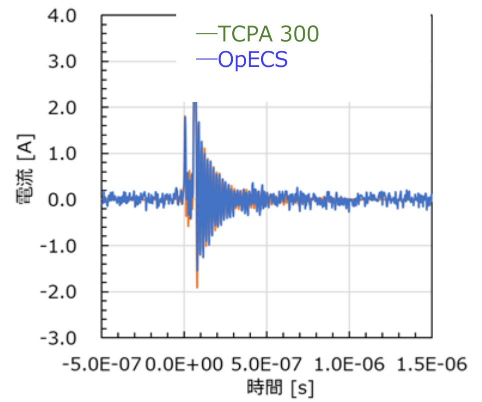
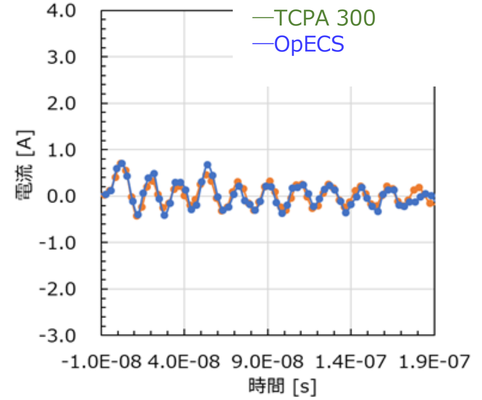
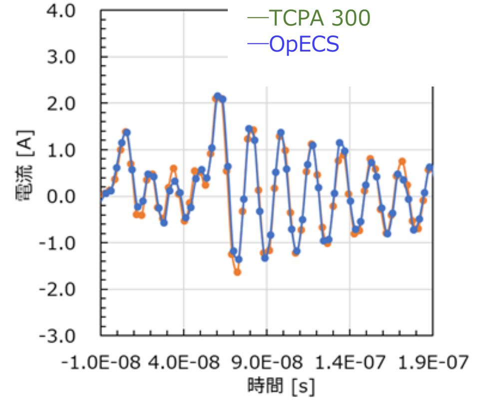
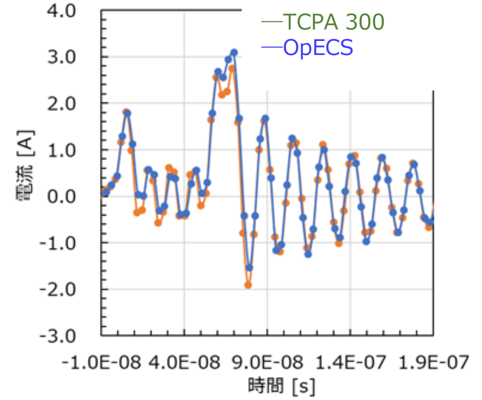




光プローブ電流センサ

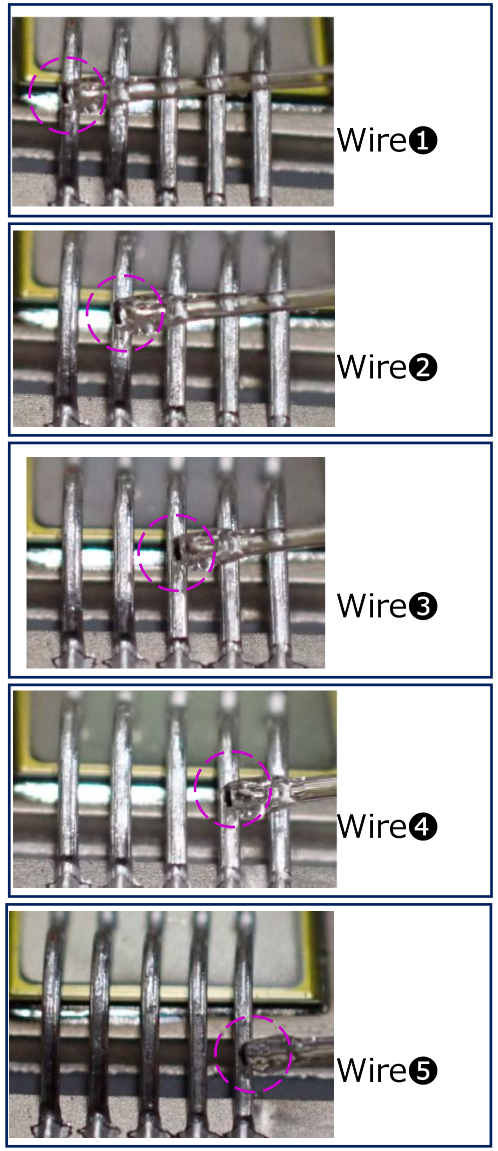


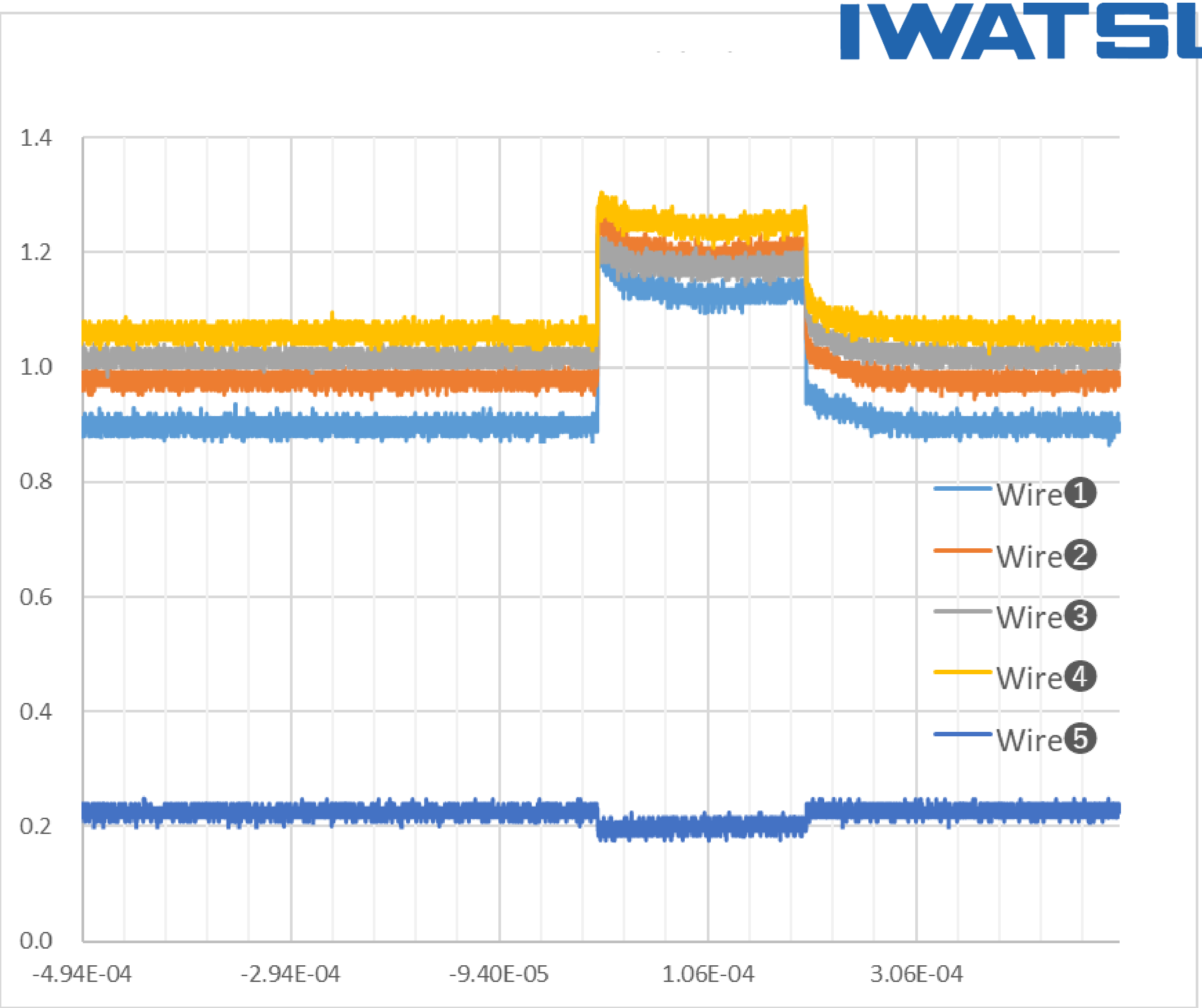
TCP312A
・Band ＝ DC~100MHz
・minimum i ＝ 1mA
・accuracy ＝ ±3%

Voltage	100V	300V	600V
Overall			
Ringing Section			
Peak current	1.5A	4A	5A
Frequency	80MHz	80MHz	80MHz

Measurement of bonding wires

□5mm
SiC Power Device
Wiring Pitch0.5mm



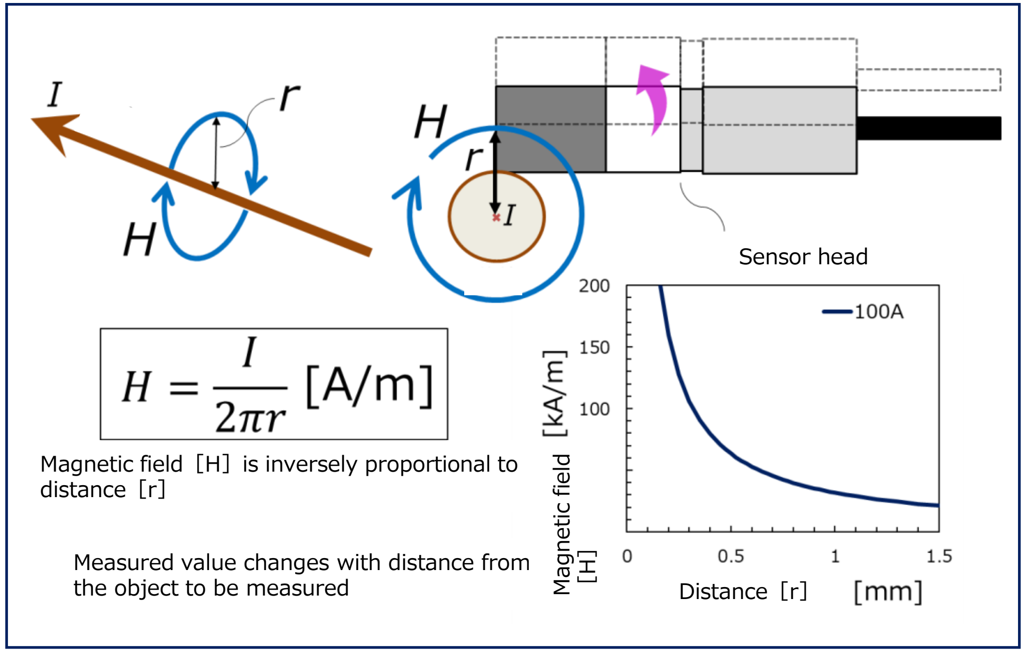


OpECS can detect wire bonding defects non-destructibely

Measurement of bonding wires

- ✓ Clampless
- ✓ Insertion impedance-less
- ✓ Pinpoint measurement
- ✓ Real Waveform Measurement
- ✓ DC Measurement

Clampingless means ････
Measurements are relative values



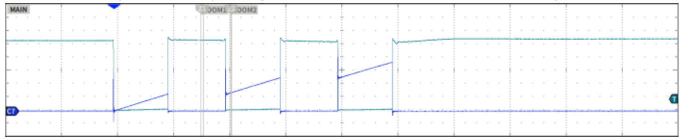
If you want to use it as an absolute value measurement, it is necessary to measure at a fixed distance from the object to be measured.

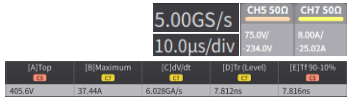
Conversely, if you want to measure large currents (e.g., lightning), you can measure at a greater distance.

shunt resistors , optical isolation , and Rogowski

[GS66508T evaluation board for](#)

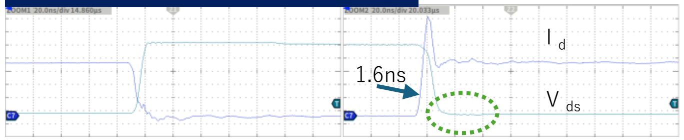
UFCS broadband shunt resistor, OpECS optical isolation current probe, SS-283A Rogowski coil current probe
GaN device (GS66508T) using This is an example of measuring the low side current of an H -bridge circuit.





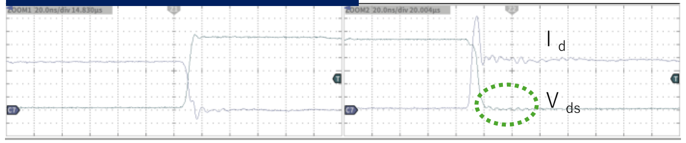
Shunt resistance 10.68mV/A UFCS

Insert a shunt resistor into the current line



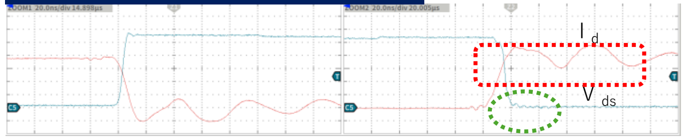
OpECS High Sensitivity Sensor

A jumper 5mm high, 2mm in length is inserted to measure the conductor current.



SS-283A Rogowski coil current probe

a jumper 10mm high, 3mm in length , and clamping the conductor.



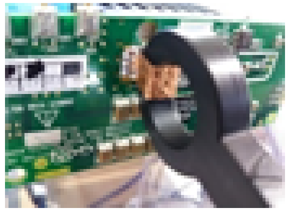
→ The limit of the Rogowski coil current probe is exceeded (resonance)
→ Difference in the influence of jumper wiring on the current detection section

[Key points for current measurement]
- Keep the current detection wiring as short as possible
・Select the most suitable current sensor for the measurement target
- Avoid applying low impedance loads to voltage and current probes

Features of each probe
[High impedance probe] Optically isolated current probe OpECS
[Wideband current measurement probe] Wideband Shunt Resistor UFCS Series
[Easy-to-use current measurement probe] Rogowski coil current probe (30MHz band, 100MHz band)

岩崎通信機株式会社
T&Mカンパニー T&M営業部 URL: https://www.iwatsu.co.jp/tme
■計 測 営 業 課 〒168-8501 東京都杉並区久我山1-7-41 TEL 03-5370-5474 FAX 03-5370-5492
■アカウント営業課 〒168-8501 東京都杉並区久我山1-7-41 TEL 03-5370-5474 FAX 03-5370-5492
■国 際 営 業 課 〒168-8501 東京都杉並区久我山1-7-41 TEL 03-5370-5483 FAX 03-5370-5492
■西 日 本 営 業 所 〒550-0005 大阪府大阪市西区西本町2-3-6山岡ビル1F TEL 06-6535-9200 FAX 06-6535-9215

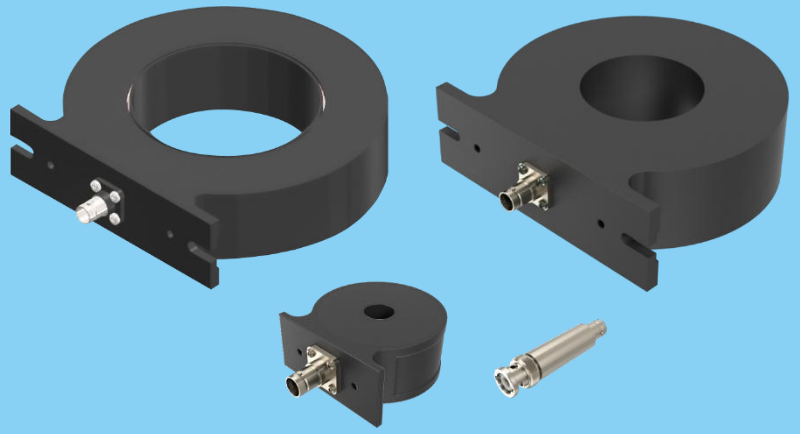
Use current probes for different purposes

	Optical Isolation CITIZEN 	Rogowski Coil IWATSU 	Rogowski Coil IWATSU 	CT PMK 	Holl Effect + CT IWATSU 	Coaxial Shunt PMK 
Sensing	non-contact probing	Feed-through	Clamping	Feed-through	Clamping	Insertion
Isolation	◎	◎	◎	○	○	×
DC measurement	◎	×	×	×	◎	○short time
High Frequency Range	◎DC-150MHz	◎100MHz	○~30MHz	200MHz/ 50MHz	◎2MHz~120MHz	◎~1GHz
Insertion Impedance	◎	○	○	○	○	○
Derationg in BW	◎	○	○	△	△	○short time
insertion space	Tiny	Small	Very Small~Small	Small~Large	Large	Medium
Magnetic Saturation	◎	◎	◎	×	×	◎

Current Probes

Precision Wide-Band Current Transformers

LILCO ® Series



- **100MHz, 24kA Galvanic isolated Measurements**
- **High Accuracy from 0.0004Hz to 60MHz**
- **Ultra-low Droop**
- **Very high Saturation Currents**
- **High I-t Capability up to 24As**
- **Optional Attenuator to lower LF cut-off**

IWATSU

PMK

IWATSU Rogowski Coil Current Probes

SS-280, SS-290, SS-280 Series, SS-280 Series, SS-280 Series

- **Bandwidths from 0.4Hz to 100MHz**
- **Peak Currents up to 12kA, 12kV Max**
- **14mm to 700mm Coil Lengths**
- **Ø1mm ultra thin sensor coil diameter**
- **-40ºC to +150ºC Temperature Ranges**
- **Customized Models on Request**

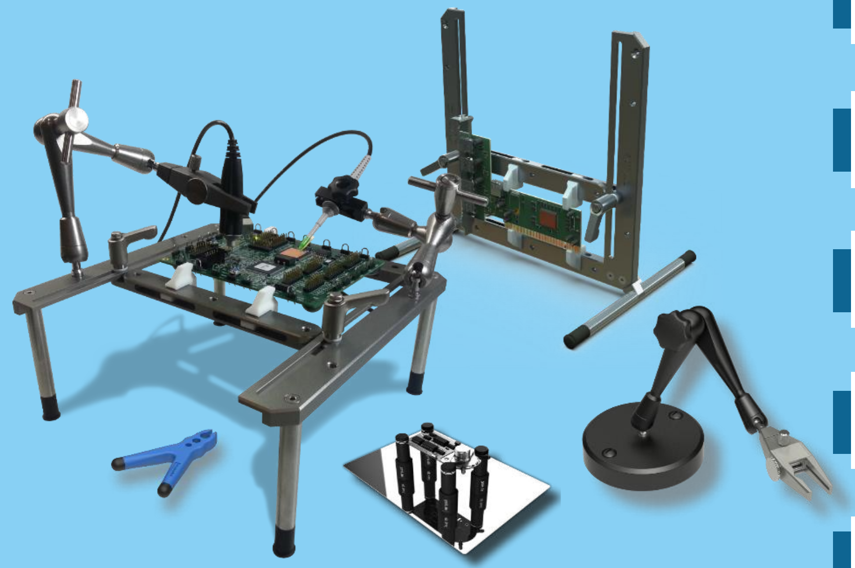
IWATSU Wideband Precision AC/DC Current Probes

SS-500 Series

- **Bandwidths from DC to 120MHz**
- **0.5A rms to 500A rms Ranges**
- **Low Noise**
- **Ideal for 100µA Ripple Currents in Switching Power Supplies**
- **Service Center in Germany**

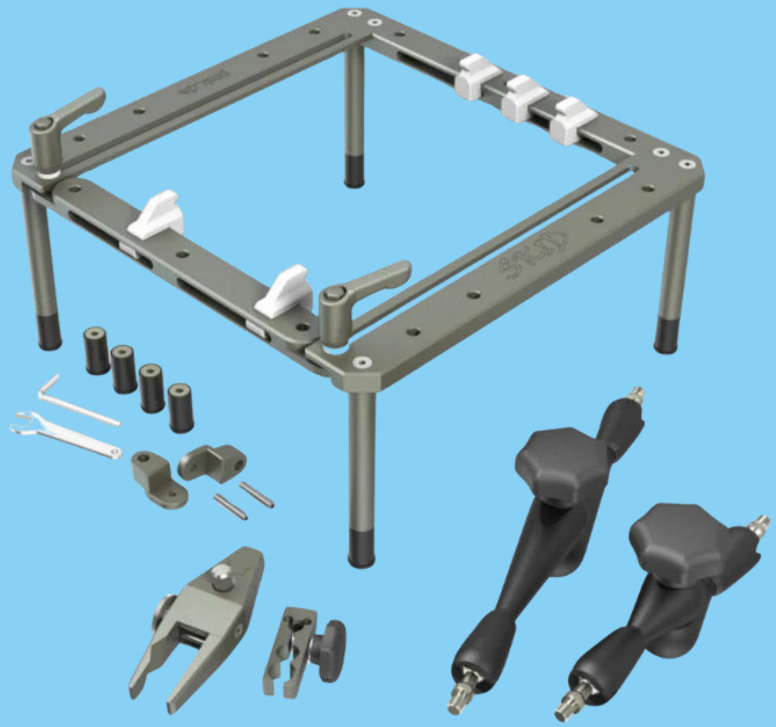
Hands-Free 3D Probe Positioning Systems

Probe 3D Hands-free Positioning Systems
SKID Series, MSU 1500, and more…



- The 3rd Helping Hand in any Lab
- For Hands-free Probing or Soldering
- Stepless Adjustable Positioning
- Span Widths up to 200mm
- Multiple Holders for various Probes
- Ready to Use and Free Configurable

SKID®
Hands-Free Testing & Debugging



- **Compact & Robust Design**
- **Modular Design for Individual Needs**
- **Up to -55°C to +155°C Models**
- **Frame size up to 300mm x 340mm**
- **Fast and Universal Setups**
- **Intuitive Clamping System**

3D Postioner models®
Different models available

	MSA 100, 3D Measuring Tripod with Steelbase, 200 mm Span Width	MSA 130, 3D Measuring Tripod with Steelbase, 130 mm Span Width	MSB 40, 3D Measuring Tripod with Tableclamp, 200 mm Span Width	MSC 85, 3D Measuring Tripod with Vacuumbase, 200 mm Span Width
Order-Number	 893-350-001	 893-350-008	 893-350-002	 893-350-003
	MSU 1500, 3D Measuring Tripod with Steelbase, 200 mm Span Width bothsided M6 incl. Uniholder	MSM 130, 3D Measuring Tripod with Magnetfoot, 130 mm Span Width	MSM 200, 3D Measuring Tripod with Magnetfoot 200 mm Span Width	MST 200, 3D Measuring Tripod with Steelbase, 200 Span Width bothsided M6 incl. Twinholder
Order-Number	 893-350-006	 893-350-004	 893-350-005	 893-350-010

Probe Calibration Generators - Current

High-Current Probe Calibration Generators for precision testing

Current Probe Calibration Generators KSZ
KSZ Series

- **KSZ 100D**
- **20A to 100A**
- **2% Accuracy**
- **Rise time 15ns (20A) - 80ns (100A)**
- **Manual or Remote Operation**
- **Optional Interlock**

Probe Calibration Generators - Voltage

High-Voltage Probe Calibration Generators for laboratory testing

Current Probe Calibration Generators KSZ
KHT Series

- **KHT 1000D: ± 100 V to ± 1000 V**
- **KHT 6000C/D: 500 V - 6000 V**
- **High Accuracy <0.5%**
- **Rise time 14ns (KHT1000D) - 45ns (KHT6000)**
- **Manual or Remote Operation**
- **Optional Interlock**

Questions? Feedback? Always Welcome!

If you need technical advice or assistance with measurement setup, please contact our Technical Sales Team.

We also welcome any feedback, ideas for new features, or comments.

Please reach out to your local PMK representative or contact us via sales@pmk.de

PMK

WE DRIVE THE **GREEN EVOLUTION** IN POWER ELECTRONICS