Current sensor demonstrator by Ingenieurbüro Kirill Klein

is based on a development of the current sensor from

Fraunhofer IZM listed on pages 4ff.

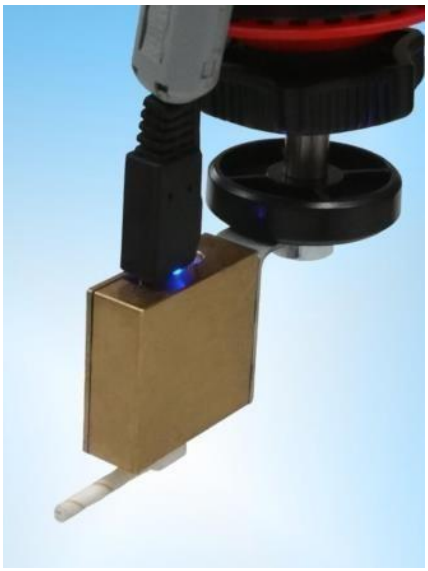


Comparison to IZM (Gen3 rev 3.73):
+ 4.4x smaller footprint on board: 4x20mm
+ 2.5x (8dB) better CM rejection (6mV/A versions compared)
+ MMCX jack (MMCX-BNC 0.5m cable incl.)
+ compatibility to 1X (50Ω) Tektronix IsoVu Tip
+ higher sensitivity possible
- Coil is less mechanically protected => requires accurate handling
V4.2:
+ twice smaller (better) f_{low} /sensitivity-ratio: 20kHz/(mV/A) vs. 45kHz/(mV/A)

Valid for both generations (Gen3 and Gen4) Some hardware changes (like the number of windings and integrator circuit configuration) allow to achieve different versions:
• Standard versions: 200A…450A BW 300/150kHz...450MHz
Fast Versions: 60A…200A BW 300/200kHz…>500/450MHz
Slow Versions: 450A…2400A BW 100/10kHz…400/260MHz

The final choice of the best configuration depends on Your requirements like - Required current rating - less/more sensitivity - maximal lower bandwidth & min. upper bandwidth

Example for Gen4 110A sensor

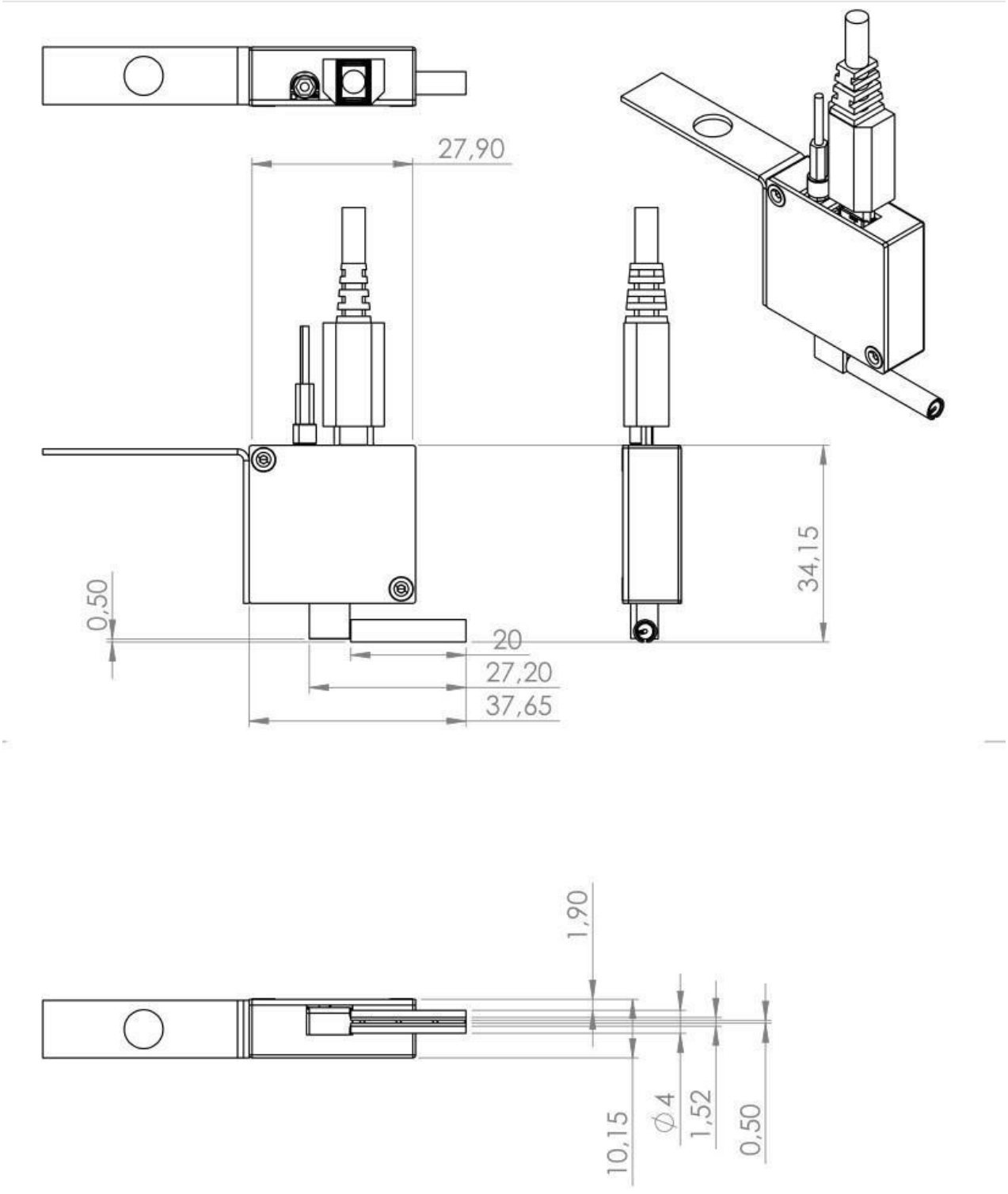


• rev 4.02 (GaN optimized)

•110A-version: +125A/-110A BW:

260kHz..>500MHz sensitivity: 6mV/A

offset: ~ 54mV



Current sensor demonstrator by IZM (last rev. 3.73)

Rev 1.8
15.12.2019

TYPICAL APPLICATIONS

- Current measurement in commutation cell
- Monitoring of switching behavior of Si, SiC, GaN, or similar semiconductor devices
- Measuring of current pulses
- Analysis of power electronic devices

Fig. 1: Isometric view of the current sensor

FEATURES

- Inductive current shunt (active)
- Galvanically isolated (placeable in every part of the system)
- low insertion inductance of 300 pH
- Typical bandwidths from 70 kHz to 500 MHz
- Coil peak voltage isolation capability up to 5 kV
- Current measurement range from ±80 A to ±1000 A,
- High slew-rate of 5.5 V/ns
- 5 Vdc power supply (power supply included in delivery)
- Instantaneous ±0.8 V peak to peak output to plug directly into scope, power recorders or data acquisition equipment
- SMB-Output (SMB-BNC- Adapter cable included in delivery)
- Directly connectable to an oscilloscope with 50 Ω termination

Measurement setup

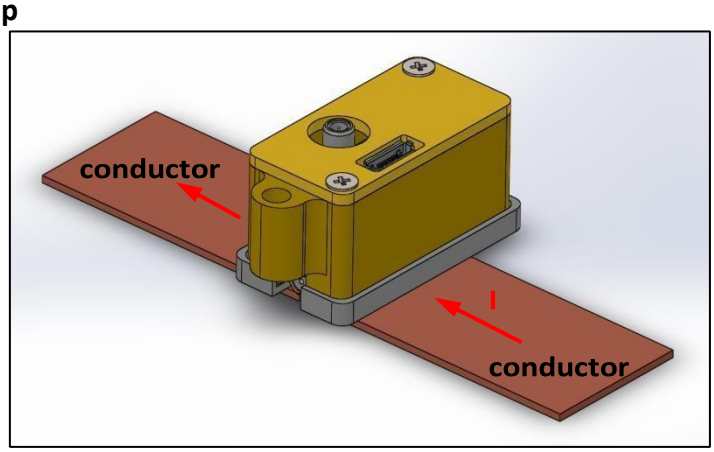


Fig. 2: Current sensor mounted on a conductor

Description

The presented inductive current shunt consists of a slotted cylinder of brass which can be soldered in a current path at any point in the system under test. The receiver coil including the active measurement unit is pushed sideways on the brass cylinder. The measurement signal is amplified with high impedance so that the device under test (DUT) is minimally affected, only by an insertion inductance of 300 pH. The signal from the receiver coil is integrated and actively amplified by an operational amplifier.

With the inductive current shunt, a current can be measured in a bandwidth of 160 kHz to 500 MHz. Therefore the current sensor is particularly suitable for the measurement and characterization of the switching behavior of fast switching semiconductor devices such as silicon carbide or gallium nitride transistors.
There are two variants of the current sensors available with different measuring ranges from ±20A to 1000A. On request, versions with a higher measuring range can be customized. The current sensor is powered by an external isolated 5 Vdc power supply with µUSB connector type B jack.
The measurement output signal is connected by a 50 Ω SMB connector.

Scope of delivery: Inductive current shunt with brass cylinder, SMB RG174 cable extension (1m), SMB - BNC adapter, power supply with µUSB type B connector (220Vac/5Vdc isolated)

Performance Characteristics

Brass cylinder and receiver coil

The current sensor is available with three different coil-types shown in Fig. 3. The lower the number of turns N of the coils, the greater the current range. In contrast, more turns increase sensitivity.

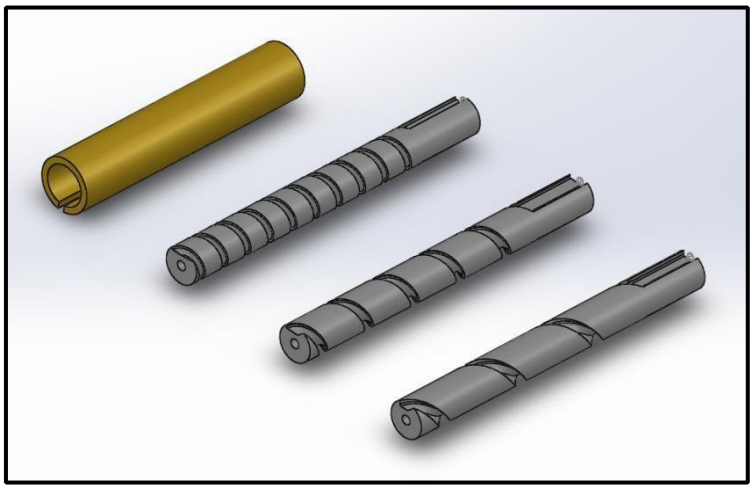


Fig. 3: shows the brass cylinder and the different coil bodies[1]

Current sensor

The current sensor is available with two different constants of integration. The Advantage of fast integration is the upper cut-off frequency of 500 MHz. Compared to the slow integration, fast integration can resolve only currents with a frequency higher than 480 kHz.

Performance Characteristics

Current sensor with N=5

Table 1

Electrical characteristics of a brass cylinder and coil with N=5 (T_A = 25 °C)				
Parameter	**Test conditions**	**Symbol**	**Value**	**Unit**
brass cylinder inductivity	@ 100MHz	L_{prim}	0.36	nH
coil inductivity	@ 100MHz	L_{sec}	23.8	nH
coupling inductivity	@ 100MHz	M	0.98	nH

[1] Only one of the receiver coils is included in the scope of delivery

Current sensor with N=3

Table 2

Electrical characteristics of brass cylinder and coil with N=3 (T_A = 25 °C)				
Parameter	**Test conditions**	**Symbol**	**Value**	**Unit**
brass cylinder inductivity	@ 100MHz	L_{prim}	0.368	nH
coil inductivity	@ 100MHz	L_{sec}	19.665	nH
coupling inductivity	@ 100MHz	M	0.59	nH
coupling factor	@ 100MHz	k	0.22	-
brass cylinder impedance	@ 100MHz	Z_{prim}	1.4	mΩ
coil impedance	@ 100MHz	Z_{sec}	140	mΩ

For all versions:

Table 3

Electrical characteristics of the current sensor with N=5 (T_A = 25 °C)			
Parameter	**Symbol**	**Value**	**Unit**
supply voltage	V_{cc}	5	V_{dc}
input current	I_{in}	70	mA
output voltage range	V_{out}	±0.8	V
Slew rate	SR	5.5	V/ns
Peak coil voltage isolation	V_{iso}	5000	V

Sensitivity = 700mV / $I_{detectionmax}$

Bandwidth results from integrator design: f_{low} = 70kHz…500kHz (low sensitivity -> high sensitivity) f_{high} = 200MHz…500MHz (low sensitivity -> high sensitivity)

the offset voltage is in range 30mV… 200mV

Each current sensor is individually developed and checked before delivery.

The exact current and bandwidth ratings can be adjusted to your requirements.

Special forms, ratings are possible and can be developed additionally individually – write us an E-Mail with Your requirements (desired bandwidth and maximal detectable current) and we will send You an offer best matched to Your requirements based on our experience.

Ratings and characteristic curves

Burst-Generator-Test (time domain)

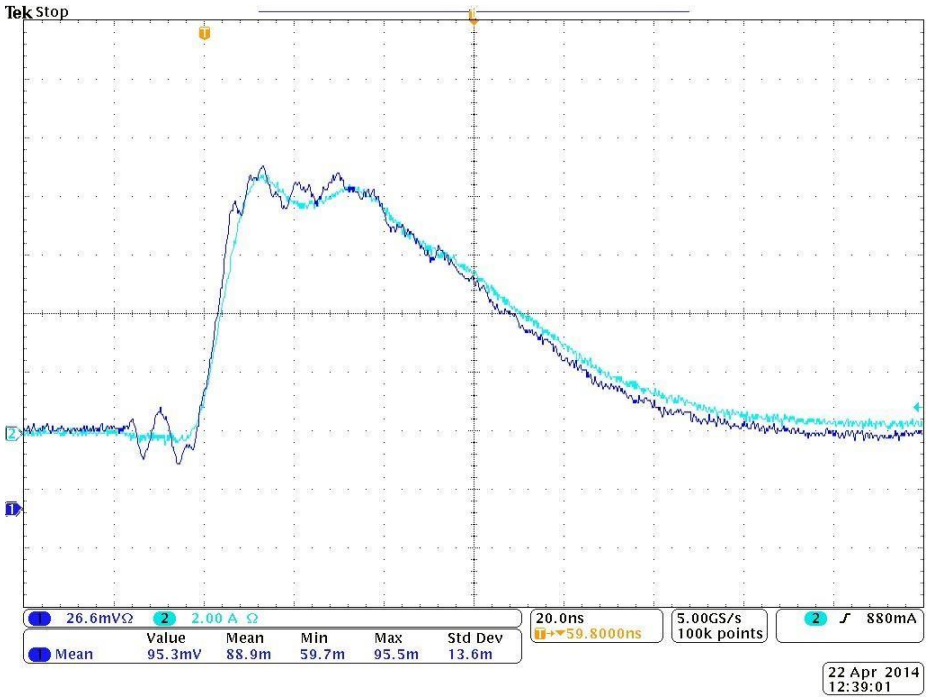
EM Test - EFT800

T

figures show measurement results

est equipment:

The following of the comparison between the IZM-shunt (N=10) with slow integration and the 2 GHz coaxial shunt SDN-414-10.



Slow Integration:

- **IZM-shunt (300 MHz)**
- **SDN-414-10 (2 GHz)**

Ratings and characteristic curves

Burst-Generator-Test (time domain)

Test equipment: EM Test - EFT800

Rev 1.6

figures show measurement results

Fig. 4: burst pulse 500 V, 50 Ω system

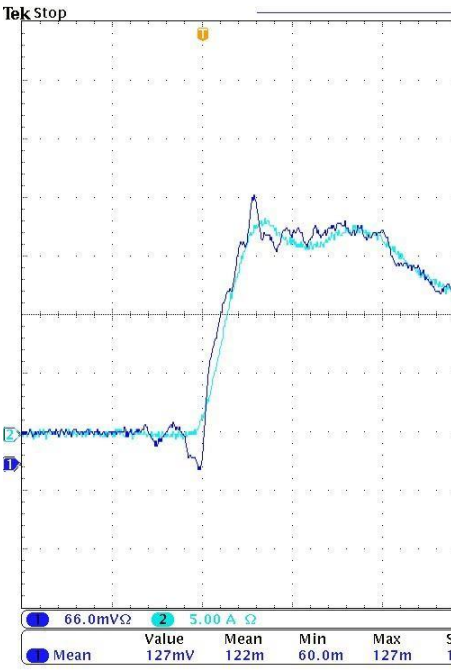


Fig. 5: burst pulse 1000 V, 50 Ω system
+ custom made HF-transformer

The following of the comparison between the IZM-shunt (N=3) with ultra-slow integration and the 400 MHz coaxial shunts SBNC A-2-01.

Ultra Slow Integration:

figures show measurement results

- IZM-shunt (200 MHz)
- A-2-01 (400 MHz)

Ratings and characteristic curves

Burst-Generator-Test (time domain)

Test equipment: EM Test - EFT800

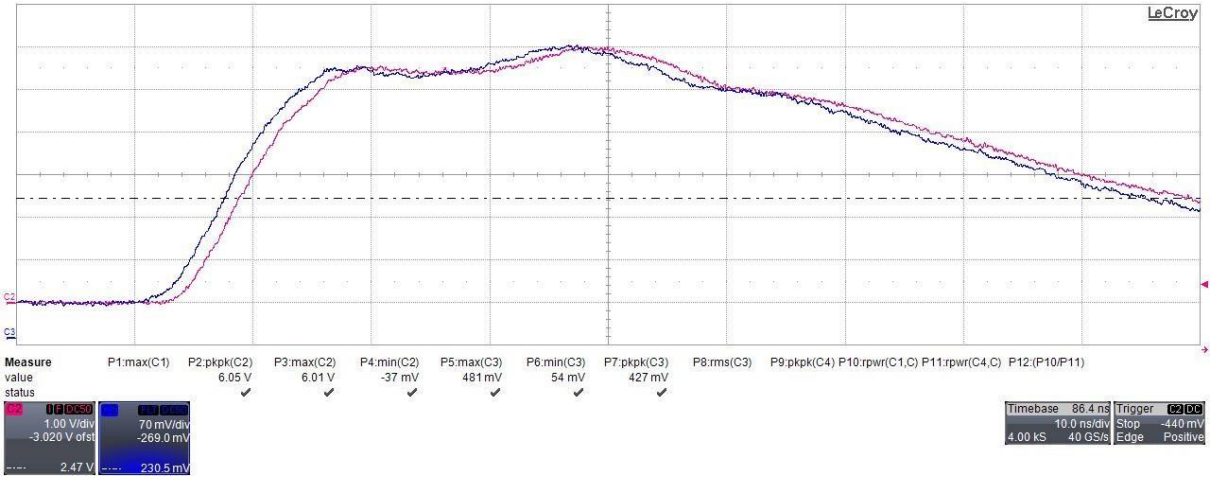
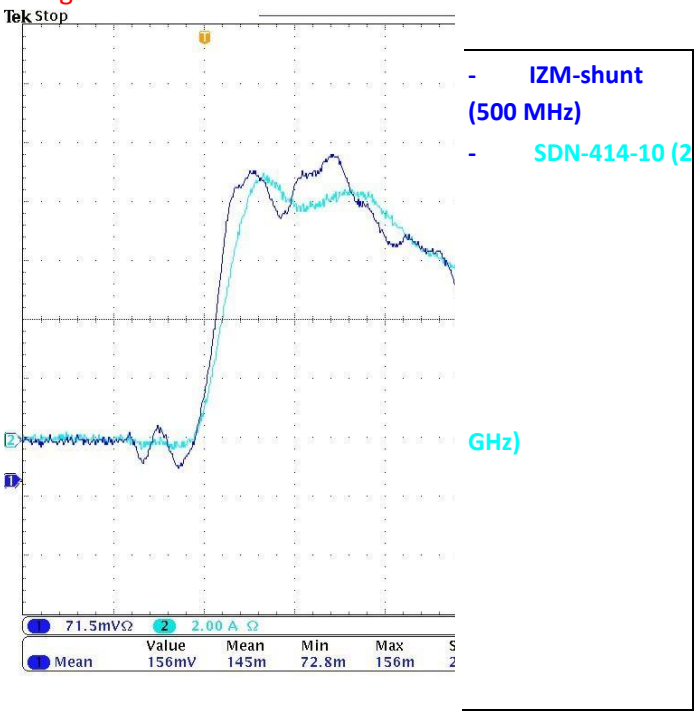


Fig. 6: burst pulse 500 V transformed to 600A

The following of the comparison between the IZM-shunt (N=10) with fast integration and the 2 GHz coaxial shunt SDN-414-10.

Fast Integration:



Rev 1.6

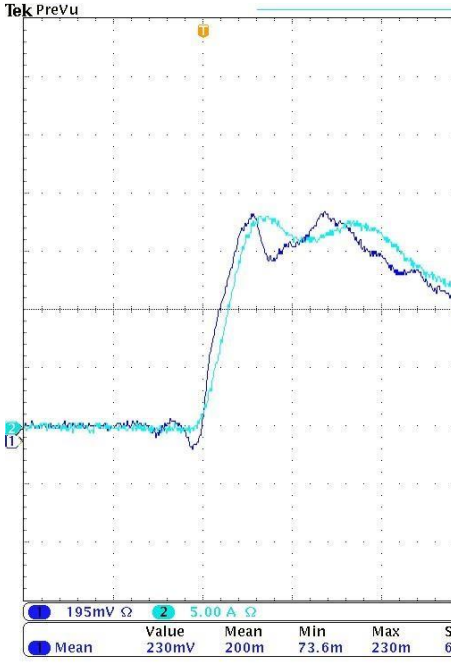
figures show measurement results

Fig. 7: burst pulse 500 V, 50 Ω system

Ratings and characteristic curves

Burst-Generator-Test (time domain)

Test equipment: EM Test - EFT800



- IZM-shunt (500 MHz)
- SDN-414-10 (2 GHz)

Fig. 8: burst pulse 1000 V, 50 Ω system

Ratings and characteristic curves

Common-Mode-Test (time domain)

Test equipment: EM Test - EFT800

Test setup: The following two pictures show the common-mode-test configuration.

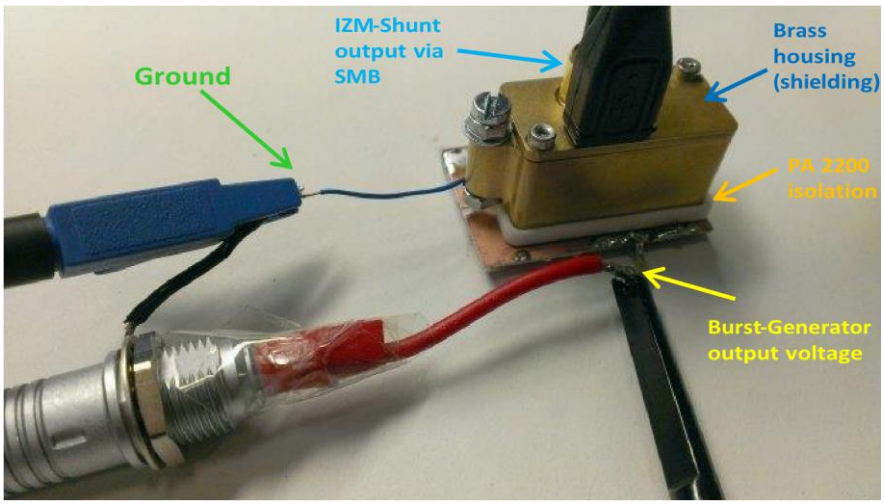


Fig. 9 : common-mode-test configuration

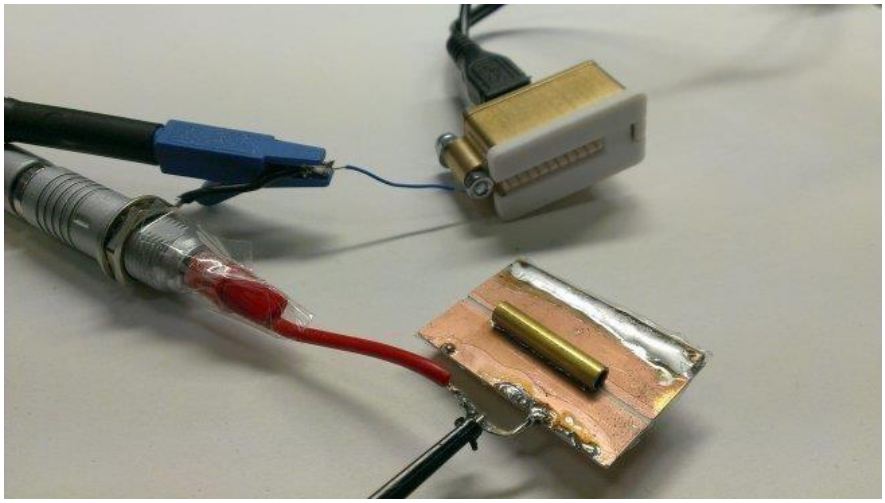


Fig. 10 : common-mode-test configuration

The following figures show measurement results of the comparison between the IZMshunt (N=10) with fast integration and the 2 GHz coaxial shunt SDN-414-10.

Ratings and characteristic curves

Common-Mode-Test (time domain)

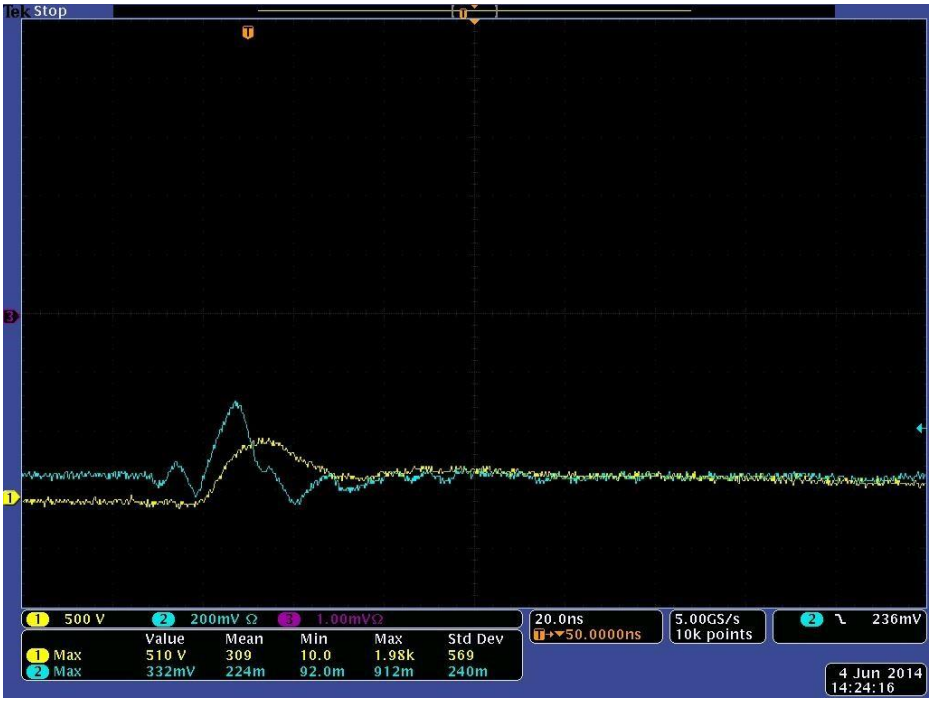
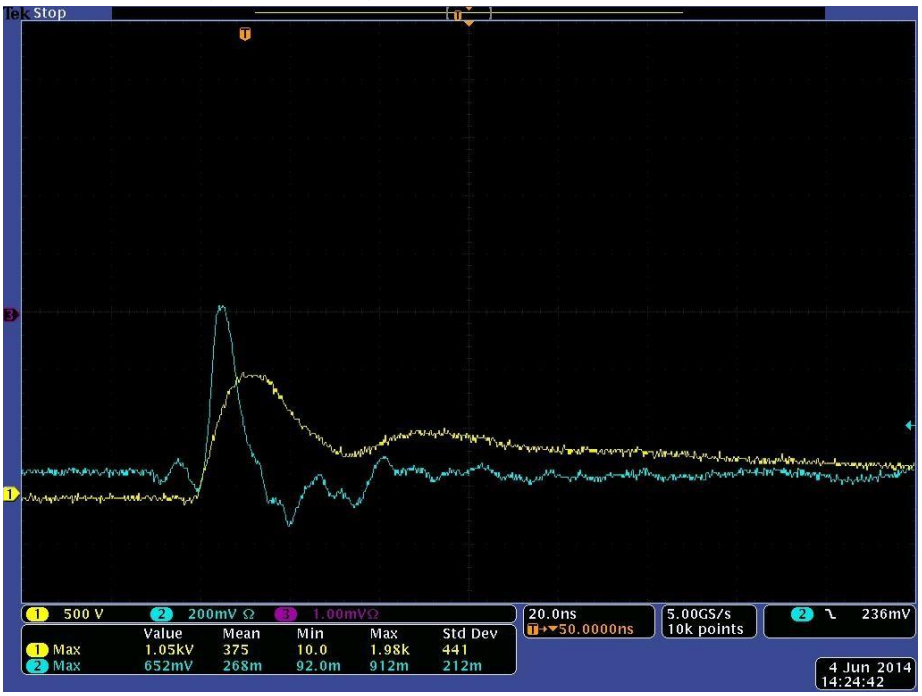


Fig. 11 : burst pulse 500 V, 50 Ω system

Ratings and characteristic curves

Common-Mode-Test (time domain)



- Burst-Generator output voltage - IZM-shunt (500 MHz)

Fig. 12 : burst pulse 1000 V, 50 Ω system

Ratings and characteristic curves

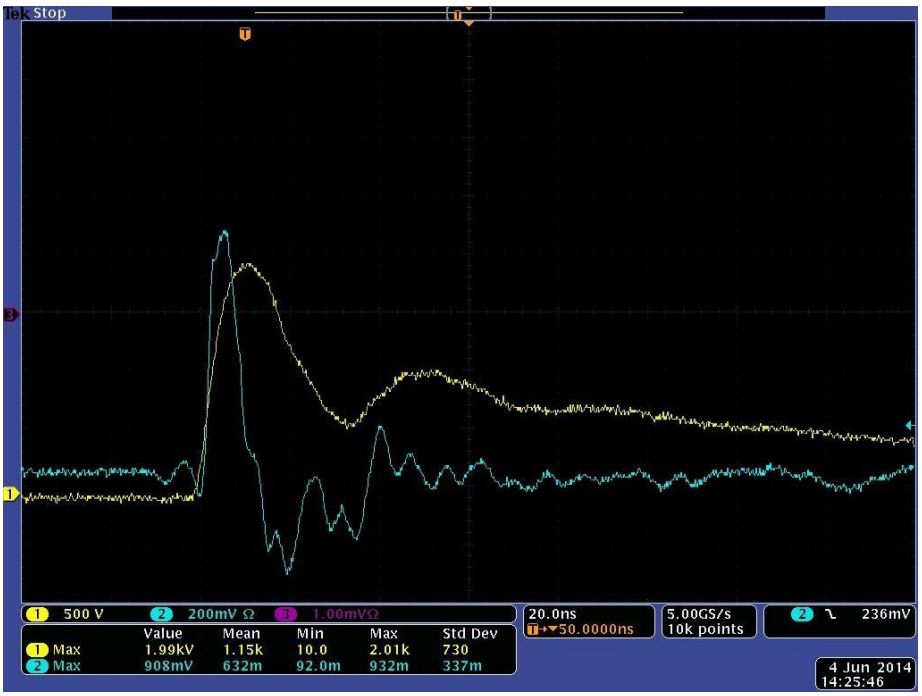
Common-Mode-Test (time domain)



Fig. 13 : burst pulse 1500 V, 50 Ω system

Ratings and characteristic curves

Common-Mode-Test (time domain)

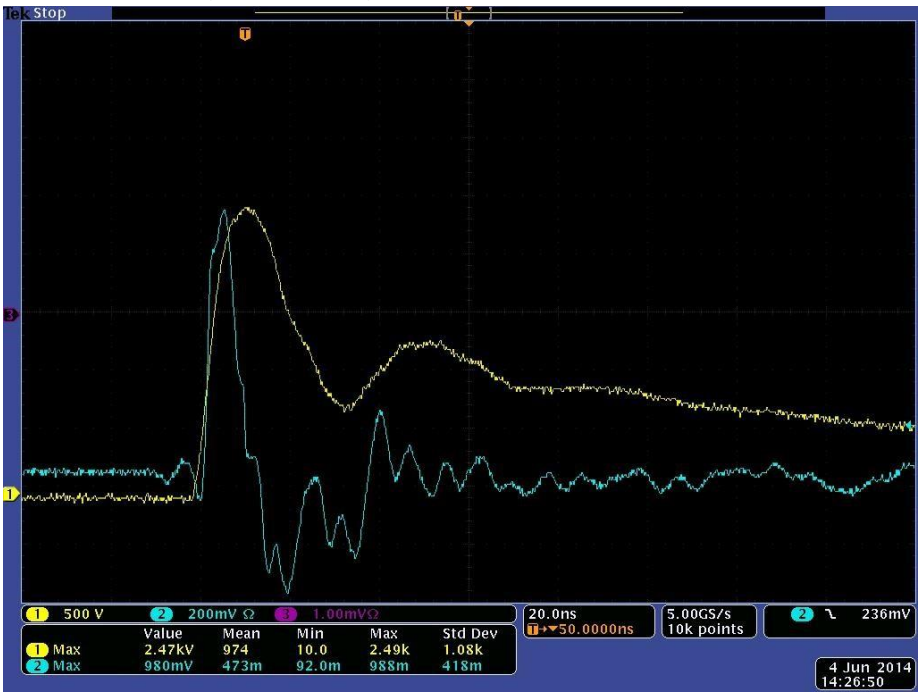


- Burst-Generator output voltage - IZM-shunt (500 MHz)

Fig. 14 : burst pulse 2000 V, 50 Ω system

Ratings and characteristic curves

Common-Mode-Test (time domain)



- Burst-Generator output voltage - IZM-shunt (500 MHz)

Fig. 15 : burst pulse 2500 V, 50 Ω system

The common-mode measurements shown are for the variant with 10 turns. For the versions with fewer turns, due to the lower coupling capacitance between coil and slotted brass cylinder to expect a better performance.

Ratings and characteristic curves

Common-Mode-

~~Test (frequency domain)~~

Test equipment: Agilent 4395A – Network/Spectrum/Impedance Analyzer

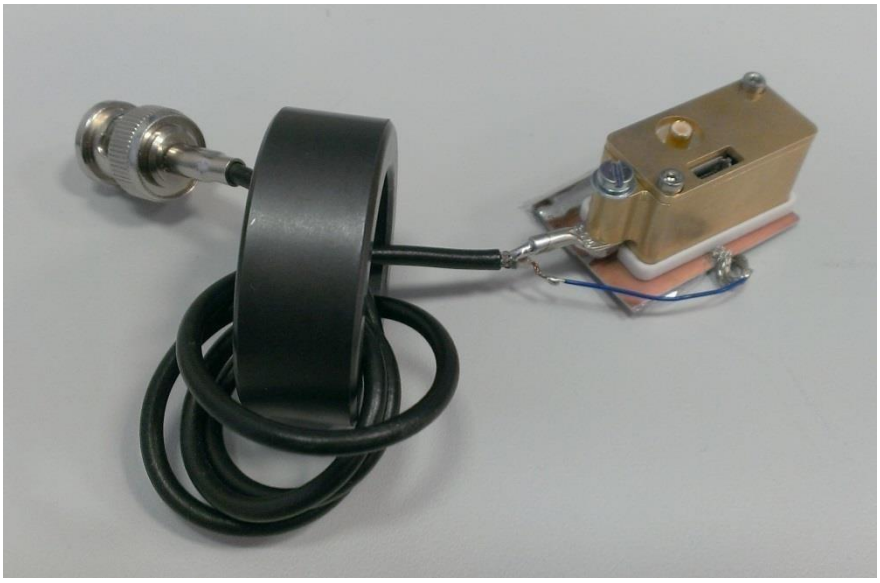


Fig. 16 : photo of the test setup

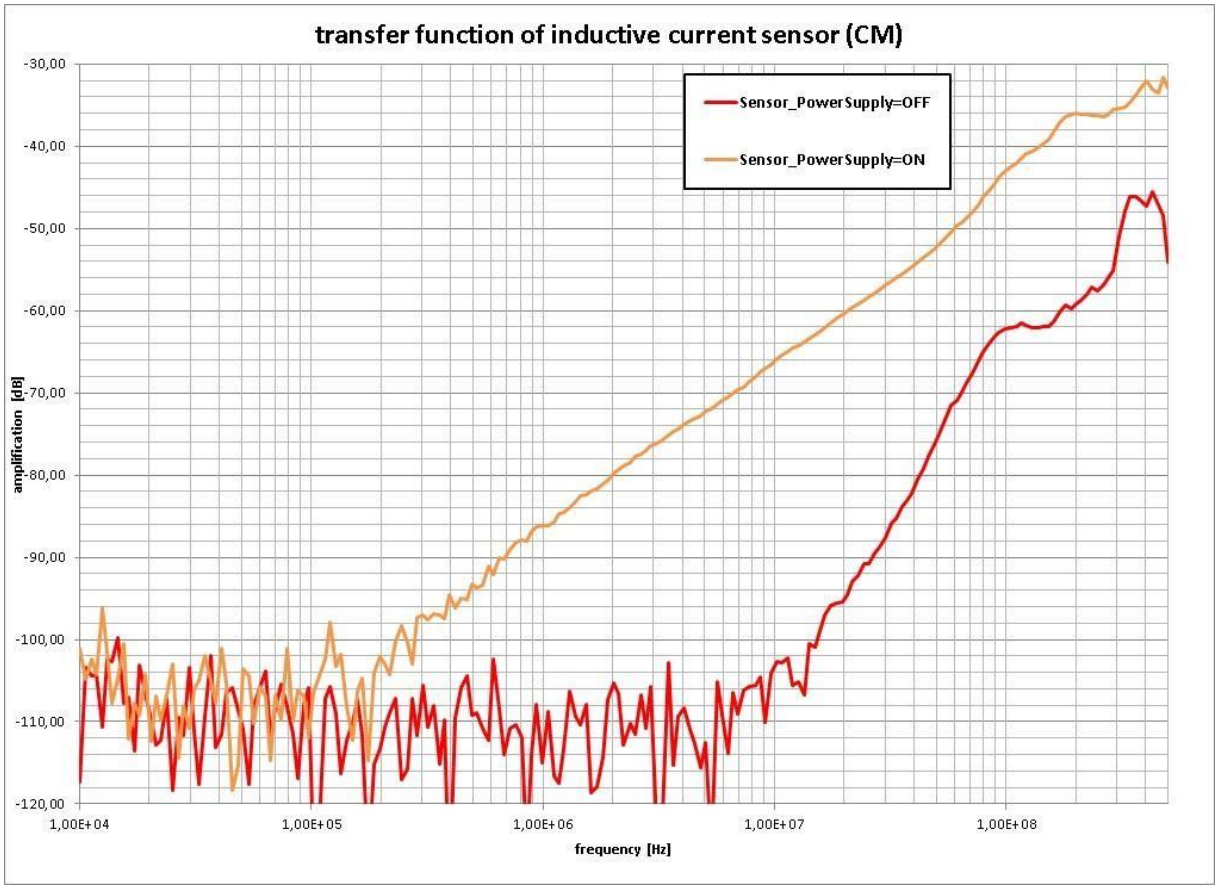


Fig. 17: common-mode measurement with and without power supply

Description of measurement characteristic

The fast integrator has a time constant of $\tau=R\cdot C=336ns$. This means that the measuring signal charges and discharges the capacitor of the integrator with that time constant. In the case of the slower integrator, the time constant is approximately three times higher. On the one hand, that enables the measurement of lower frequencies but on the other hand, the upper cutoff frequency is the only 300MHz.

When comparing the figures Fig. 4 and Fig. 7, this difference is clearly visible.

Ratings and characteristic curves

Mounting

The following steps describe the mounting process of the current sensor

(1) Solder the brass cylinder on your prepared footprint

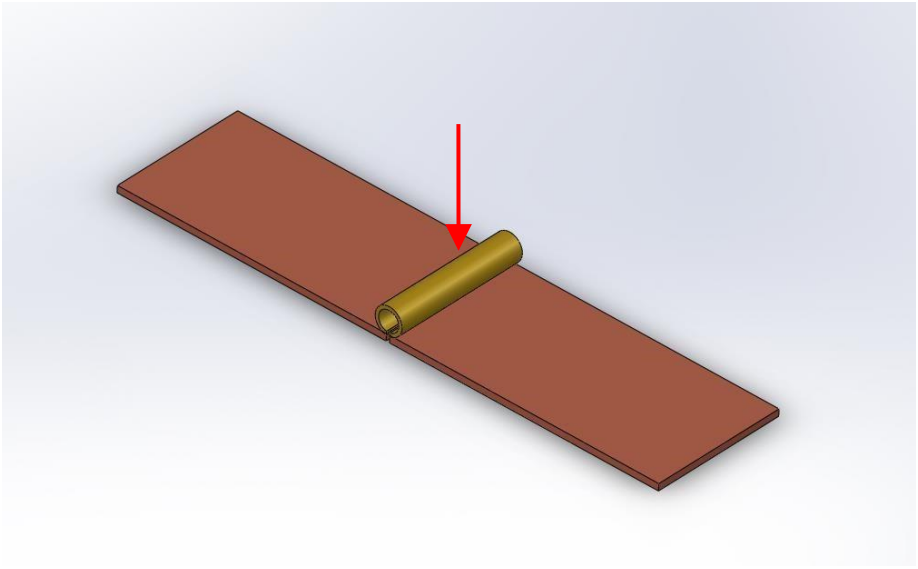


Fig. 18

(2) Put the coil with the package into the brass cylinder

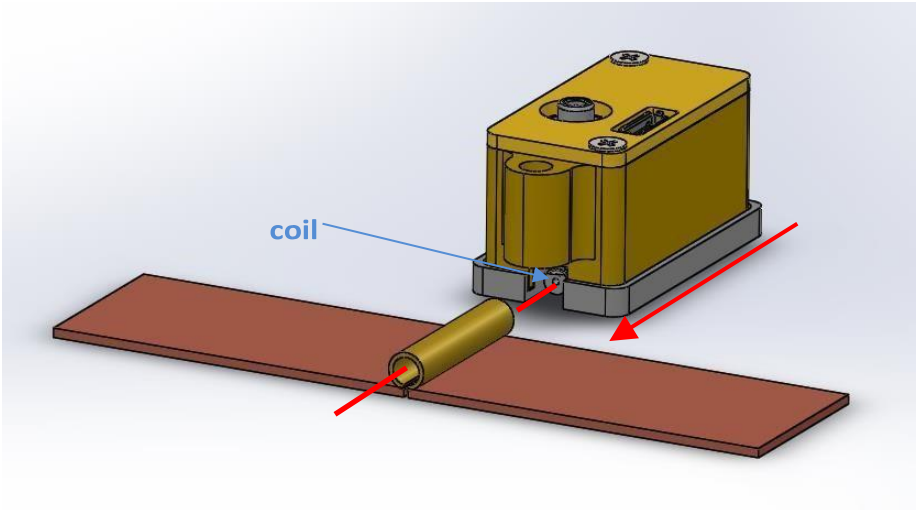


Fig. 19

Application Note

Safe mounting with a screw

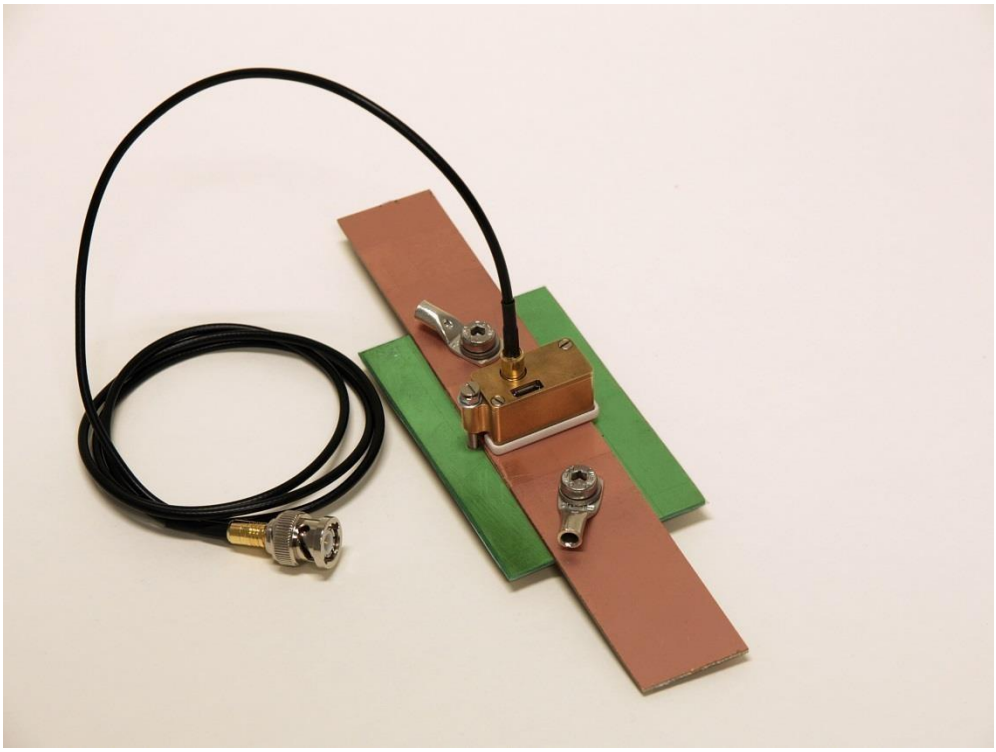


Fig. 20: shown is one example of the mounting

Low commutation inductance

The commutation inductance behaves for $X_L=\omega \cdot L$ as a low-pass. When measuring with the shunt it is to make sure that the inductance of the commutation cell, in which are the currents to be measured, is sufficiently low. Otherwise, high-frequency currents are too high damped by the commutation inductance.

Use Instructions

Power supply

Only use the included power supply! (The power supply must provide an isolated voltage of 5Vdc)

Mounting

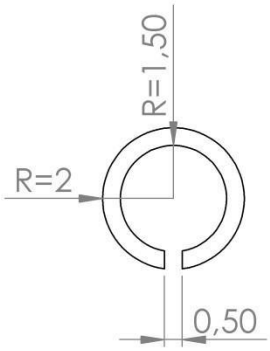
When the shunt was pushed into the brass cylinder, the shunt should be mounted with a screw on the experimental set-up, so that the receiver coil does not break off due to strong mechanical stress.

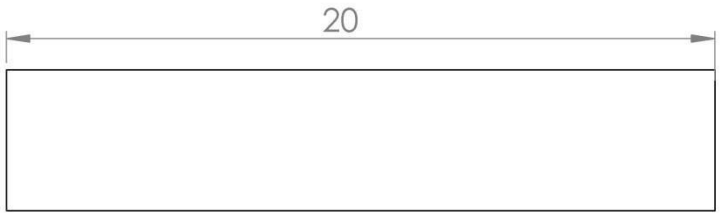
Connection to measurement equipment

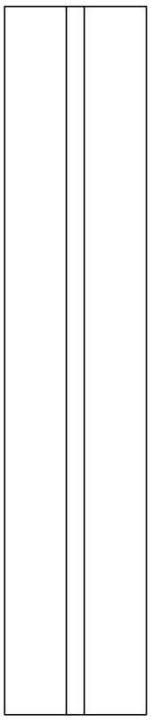
The connection to the measurement equipment like an oscilloscope must be ensured with a 50 Ω termination.

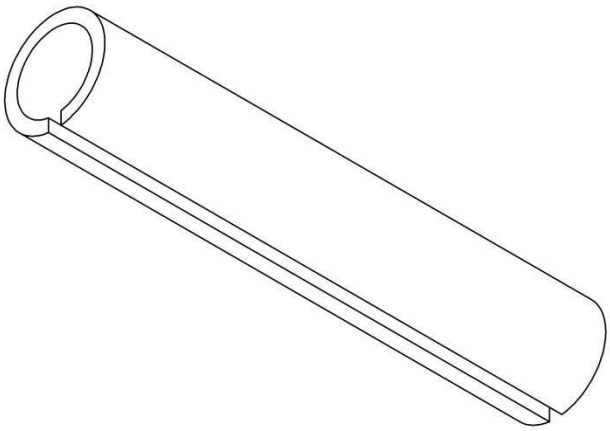
Footprint/Dimensions

Brass Cylinder







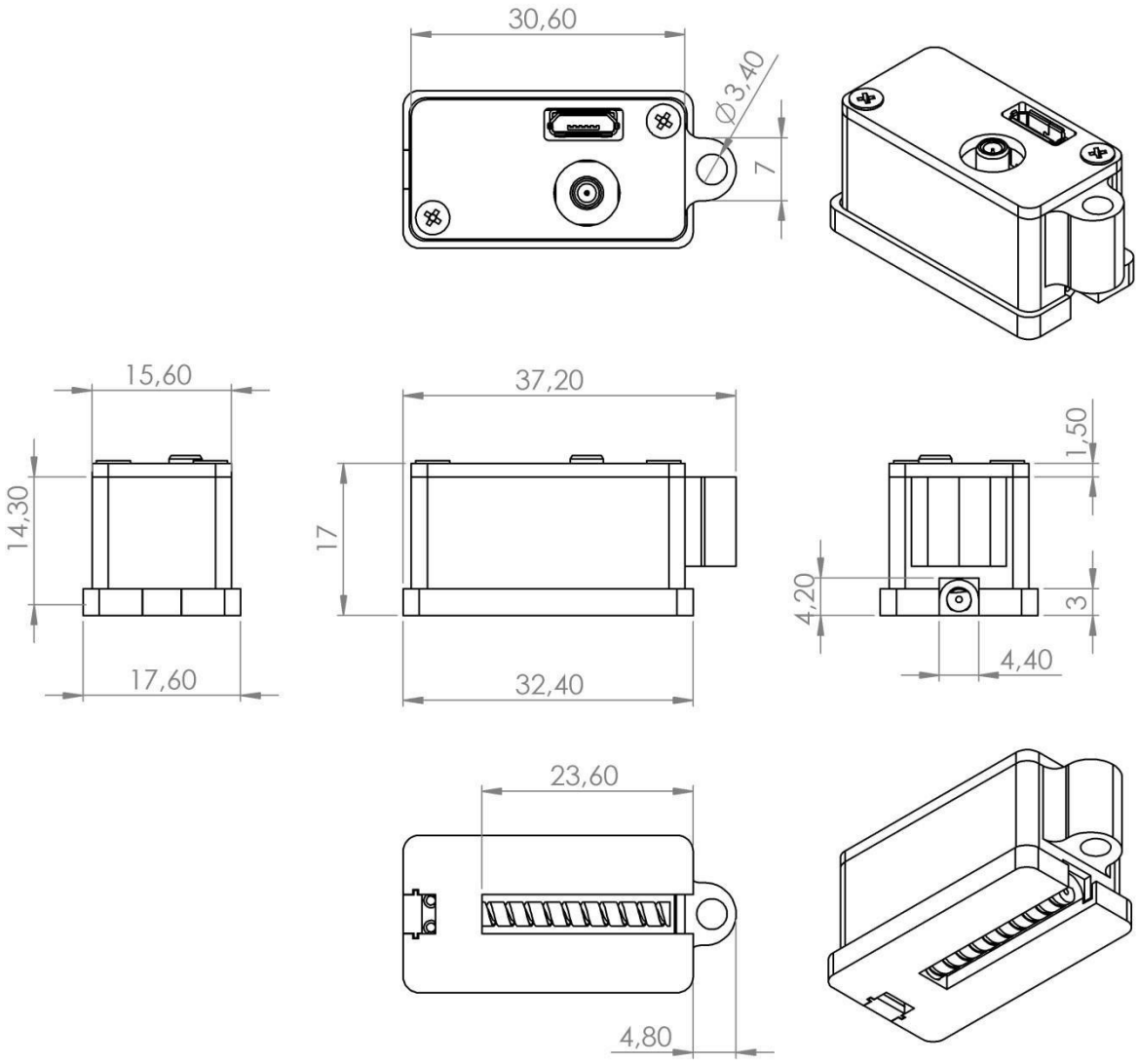


Units: mm

Material: brass

Footprint/Dimensions

Current Sensor



Units: mm

Material: brass, PA 2200, copper

Published by

Fraunhofer Institute for Reliability and Micro integration

System Integration & Interconnection Technologies

Power Electronic Systems

Gustav-Meyer-Allee 25

13355 Berlin

Website: http://www.izm.fraunhofer.de