IC TEST SYSTEM

User manual
Probe Set

ESD magnetic field injection set

ESD magnetic field source
P1202-2

CE

The field source can only be operated in conjunction with the BPS 203.

LANGER	DE-01728 Bannewitz	P1202-2
EMV-Technik	mail@langer-emv.de	
	www.langer-emv.com	

Table of contents: **Page**

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

1 ESD field source for magnetic fields

The *P1202-2* probe is a field source. The field source allows the user to couple defined and reproducible ESD fields to IC housings (**Figure 3**).
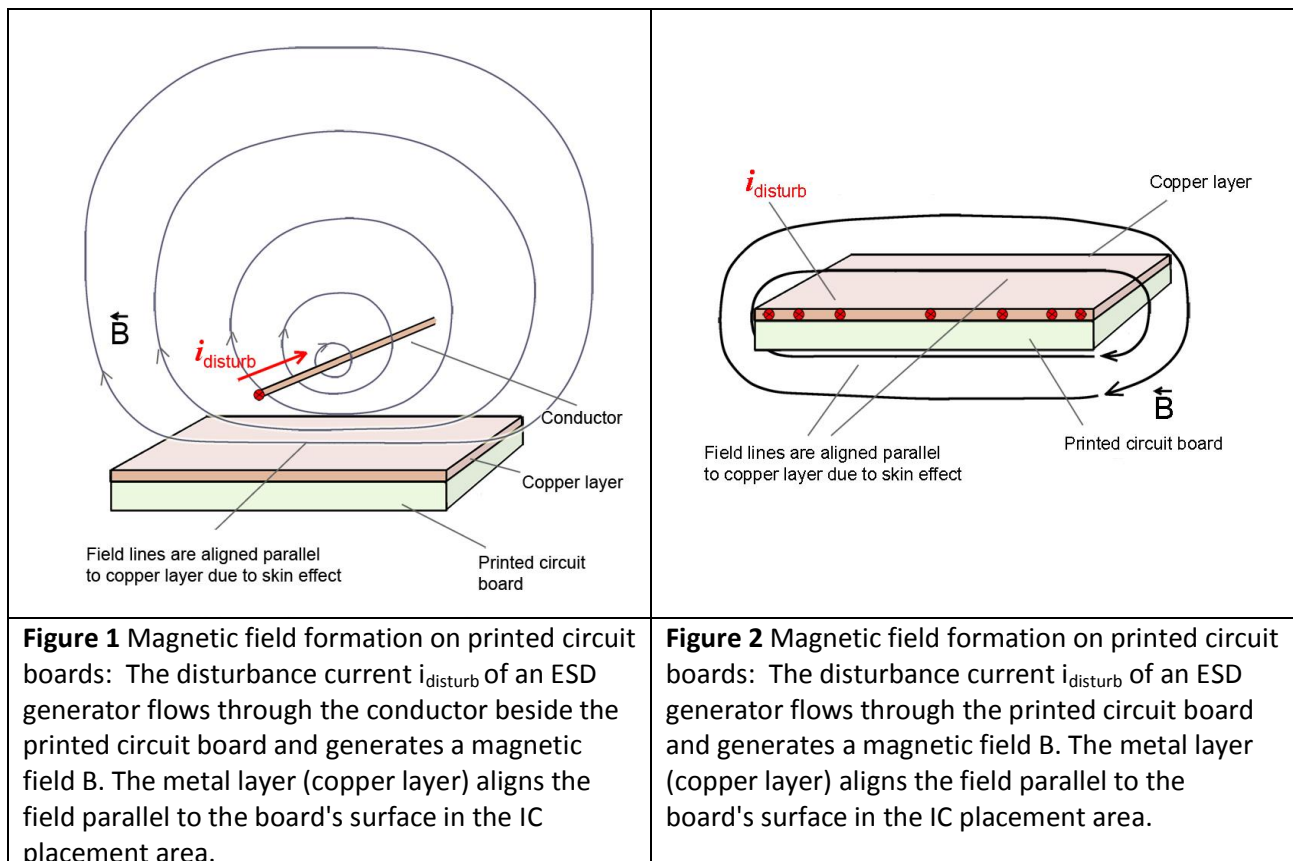
Modules and devices are tested according to the ESD standard IEC 61000-4-2. During this test, the ESD generator is discharged onto the device.

Electric and magnetic fields develop during the ESD discharge. These fields may penetrate the device under test and its electronic system and even penetrate IC housings and result in interference in the ICs.

Therefore, field coupled interference (inductive / capacitive) are also a source of interference with ICs besides the conductive coupling.[1].

The field source *P1202-2's* design is based on how the ESD (IEC 61000-4-2) is coupled to the IC through fields.

The shape of the fields in the IC's placement area is mainly determined by the inner metallic structure (layout) of the printed circuit board. Printed circuit boards usually contain continuous copper layers which shape the fields.

Figure 1 Magnetic field formation on printed circuit boards: The disturbance current $i_{disturb}$ of an ESD generator flows through the conductor beside the printed circuit board and generates a magnetic field B. The metal layer (copper layer) aligns the field parallel to the board's surface in the IC placement area.	**Figure 2** Magnetic field formation on printed circuit boards: The disturbance current $i_{disturb}$ of an ESD generator flows through the printed circuit board and generates a magnetic field B. The metal layer (copper layer) aligns the field parallel to the board's surface in the IC placement area.

Magnetic fields are aligned parallel to the printed circuit board due to the flux displacement effect (associated with the skin effect) (**Figure 1** and **Figure 2**). These directional fields affect the ICs in the IC placement area. The field lines align parallel to the IC housing. The field sources have to simulate this magnetic field orientation (**Figure 5**).

---

[1] Conducted EFT/burst tests of ICs are performed with the P200 and P300 probe families from Langer EMV-Technik GmbH

LANGER

EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

Field lines that are perpendicular to the IC housing only occur in special cases. The **BS 04 DB-h** and **BS 05 DB-h** field sources in the "H3 set of burst field sources for generators according to the standard EN 61000-4-4" from Langer EMV-Technik GmbH can be used to generate these fields.

Electric fields are always emitted orthogonally from metallic surfaces. Hence, it follows that the copper layers inside a printed circuit board are responsible for this orthogonal field orientation. E-field sources have to simulate this orthogonal field orientation to the printed circuit board and test IC. Local fields can be generated with the **ES 05 D-h** field source ("H3 set of burst field sources for generators according to the standard EN 61000-4-4" from Langer EMV-Technik GmbH).

The field source must be operated with the **BPS 203** burst power station. The **BPS 203** burst power station controls and supplies the **P1202-2** field source (1.3 Set-up of the test bench / system set-up).

The variation over time of the field source's field is equal to that of an ESD generator's discharge pulse current. The waveform of the discharge current pulse is defined in the standard IEC 61000-4-2 (**Figure 6**).

The field source can only be operated in conjunction with the BPS 203 burst power station!
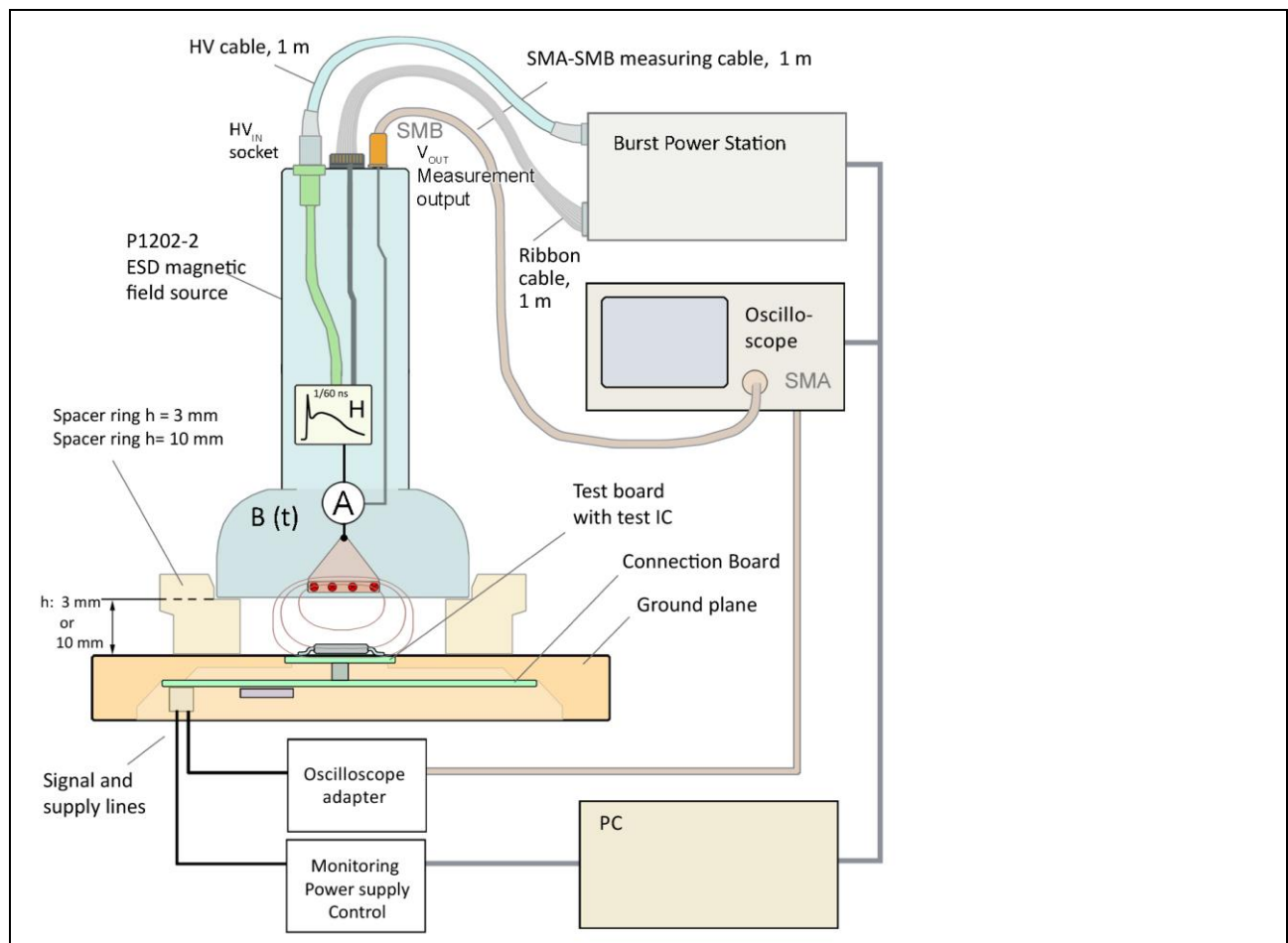

Figure 3 Test equipment: ICE1[2] test environment with **P1202-2** and measuring instruments.

The test equipment comprises the **P1202-2** field source of the probe set, the ICE1 test environment and measuring instruments.

---

[2] **GNDA 02** ground adapter, **GND 25** ground plane and **CB 0708** connection board are included in the **ICE1** IC test environment. www.langer-emv.de The test board is described in the "**IC test instruction manual"**, www.langer-emv.de.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

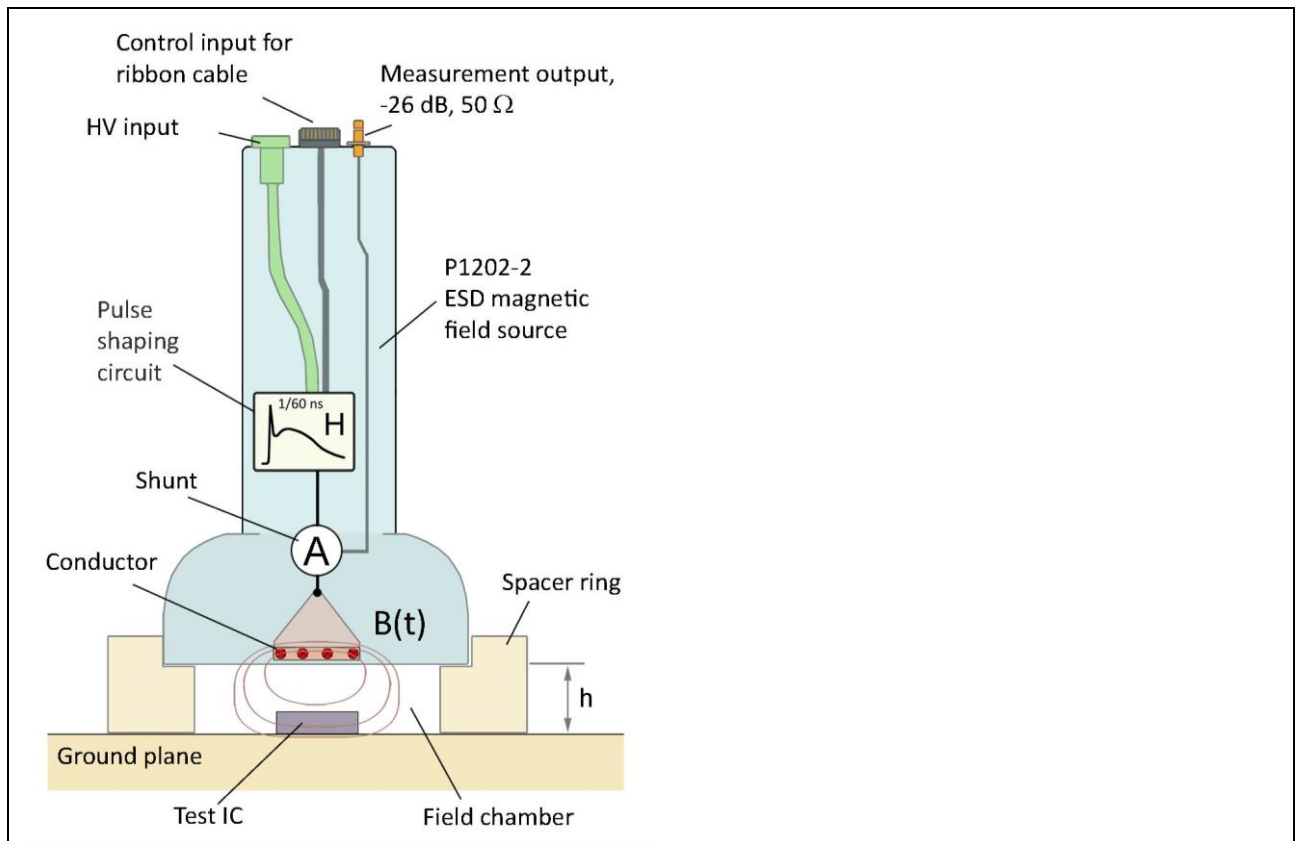## 1.1 Design of the P1202-2 magnetic field source
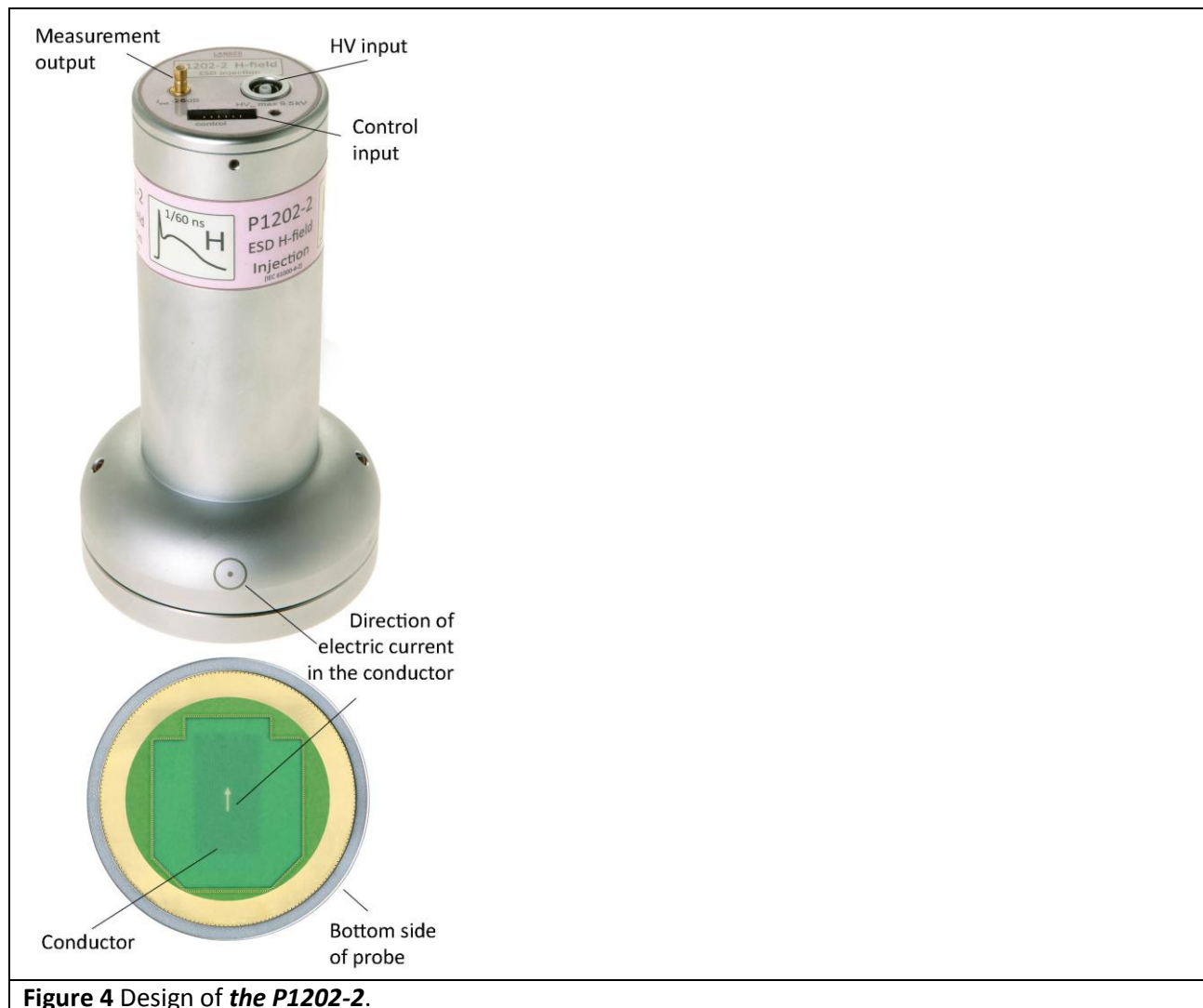
Figure 4 Design of *the P1202-2*.

The field source has an HV input (Fischer socket, D103A023) on its top to connect an HV cable. A high voltage is supplied from the *BPS 203* burst power station to the field source via this HV cable. The HV input is connected to the pulse shaper circuit inside the field source. The pulse shaping circuit uses this voltage to produce the discharge current. The waveform of the discharge current corresponds to the waveform of the discharge current according to the standard IEC 61000-4-2 **(Figure 6)**. The discharge current from the pulse shaper circuit is supplied to the field source's electric conductor (**Figure 4**).

The electric conductor is at the bottom of the field source. It uses the discharge current to generate the magnetic ESD test field which is emitted from the bottom of the field source. A shunt is located in the electric conductor of the field source to measure the discharge current (i_P) (**Figure 5**).

The output voltage of the shunt can be measured through the field source's measurement output. The measurement output is terminated with 50 Ω in the field source. A field chamber encloses the magnetic field which is generated by the electric conductor in the field source. The field cell comprises the bottom of the field source, the spacer ring and the ground plane. The test IC is located inside the field cell. It is mounted on the test board (**Figure 3**). The test board is inserted into the ground plane.

The pulse shaper circuit is connected to the **BPS 203** burst power station via the "control" socket (**Figure 5, Figure 3**) and ribbon cable. The **BPS 203** burst power station controls the pulse shaper circuit via this connection.

Figure 5 Design of the **P1202-2**

1.2   Function of the P1202-2 magnetic field source

The **BPS 203** burst power station is connected to the HV input via the HV cable (**Figure 3**). The HV current flows from the **BPS 203** burst power station through the HV cable to the HV input which is connected to the pulse shaper circuit. The pulse shaping circuit uses this voltage to produce the discharge current. The waveform of the discharge current (**Figure 6**) corresponds with IEC 61000-4-2. The discharge current of the **P1202-2** field source is 10.5 times higher than the current specified in the standard IEC 61000-4-2 with the same high voltage.
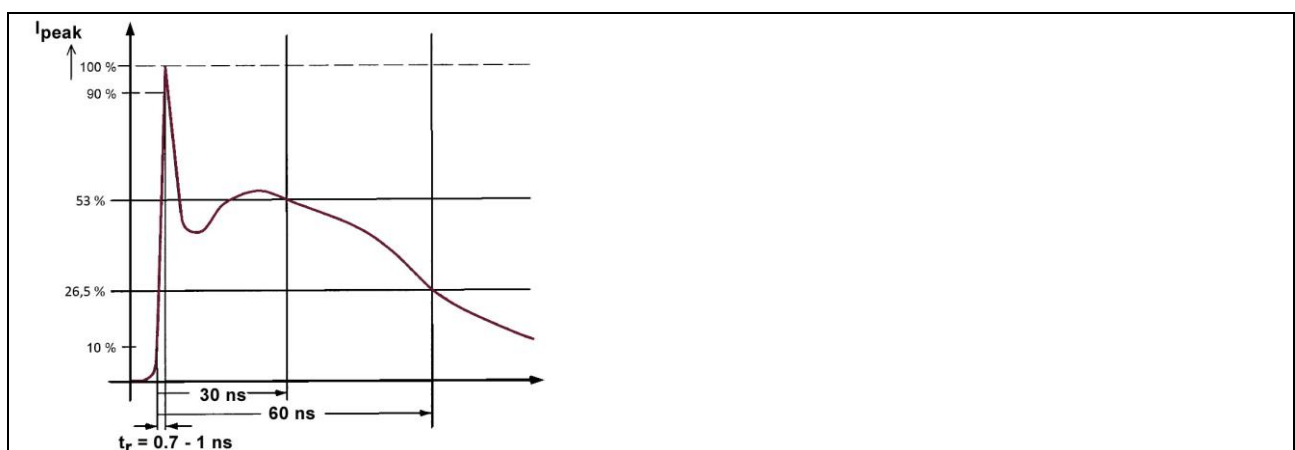
Figure 6 Waveform of the discharge current according to the standard IEC 61000-4-2.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

The discharge current generates the magnetic field B around the electric conductor in the field cell which is applied to the test IC during the test (**Figure 5**).

The strength of the magnetic field and the voltage induced in the test IC can be determined in the following ways:

- Table 4 Disturbances of the **P1202-2** magnetic field source depending on the high voltage UP.
- Calculation of the probe current I_P from the high voltage U_P
- Measurement of the current $i_P(t)$ at the shunt of the **P1202-2** field source
- Calculation of the magnetic flux in the area of the test IC from the current i_P and the probe constant K1 (Table 4) of the **P1202-2** field source
- Calculation of the voltage U_{IC} induced in the test IC from the current I_P and the probe constant K2 of the field source (**Table 3**)
- Calculation of the voltage u_{IC} induced in the test IC from the coupling inductance L_h between the electric conductor and test IC and from di_P/dt
- Calculation of the current i_{IC} transferred to the IC on the basis of the probe current i_P of the **P1202-2** field source and the probe constant K3 (coupling factor, see **Figure 22**)

1.2.1 Determination of the current i_P in the electric conductor of the field source

The probe current i_P of the field source is required to calculate the magnetic field. There are two ways to determine the current i_P.

1. Calculation of i_P from the set high voltage U_P

The parameters of the discharge current (first discharge current peak, current at 30 ns, current at 60 ns) are calculated with the following equations:

$$I_P = U_P \cdot K \qquad\qquad\qquad \text{(Eq 1)}$$

$K_{\text{First discharge current peak}}$	36 A/ kV
K_{30ns}	19.2 A/ kV
K_{60ns}	9.6 A/ kV
Table 1 Current constants	

The aforementioned equation (Eq 1) and the current constants (**Table 1**) allow the calculation of the current I_P, of the **P1202-2** field source, in the electric conductor from the high voltage U_P.

The variation of the current i_P over time can be measured with the shunt and an oscilloscope.

2. Measurement of the current i_P

The current i_P is measured in the field source with a shunt (0.1 Ohm). The measurement output is matched to 50 Ohm. The oscilloscope's input has to be set to 50 Ohm to obtain correct values during the measurement. The attenuator is set to 26 dB (x20) in the vertical menu of the oscilloscope. **Make sure that the measurement signal does not exceed the oscilloscope's maximum permissible input voltage.** An external attenuator should be used if necessary.

Figure 7 Current measurement at the shunt with an oscilloscope.
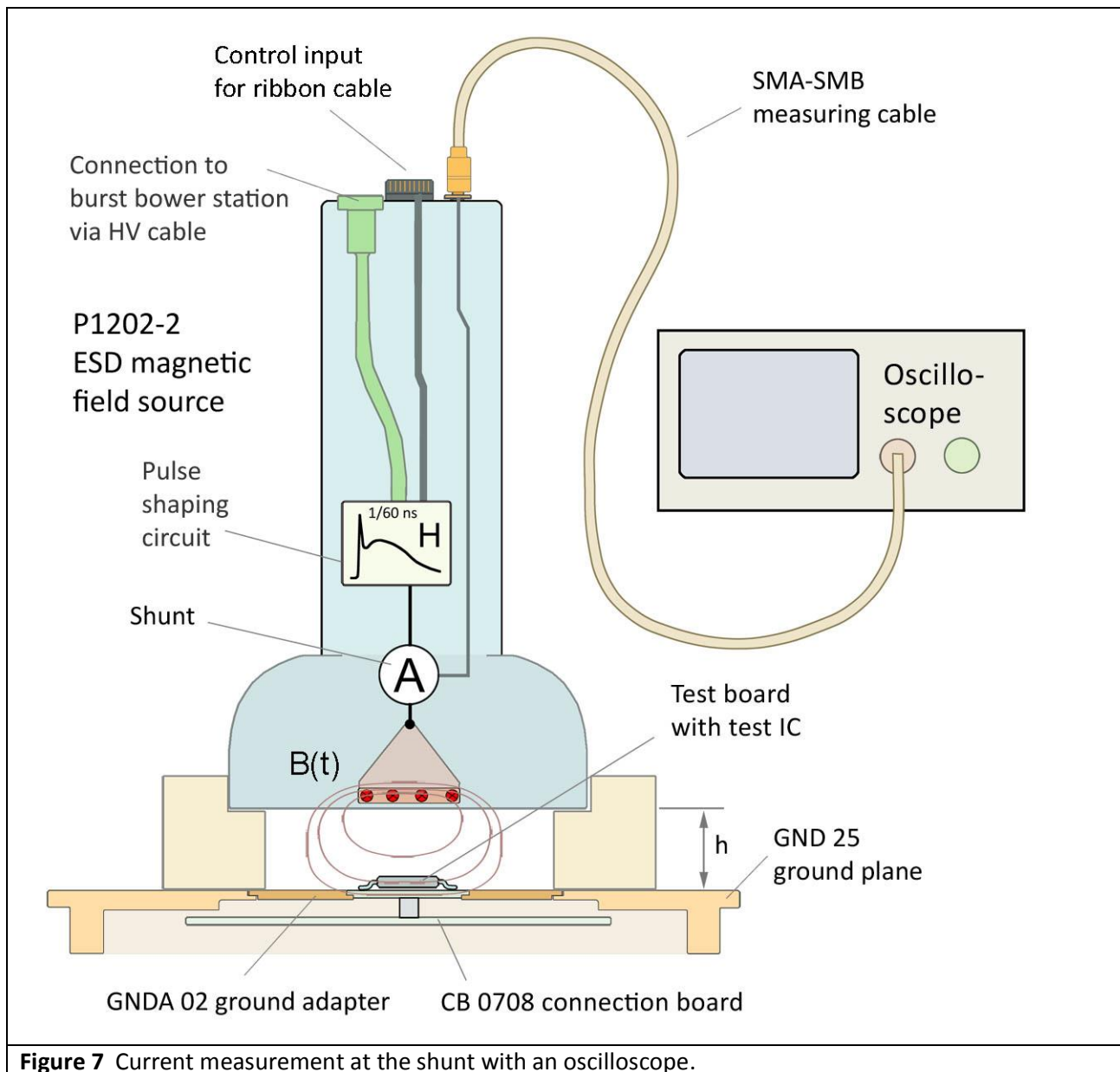
The current measurement is much more precise than the calculation from the voltage set at the *BPS 203* burst power station.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com
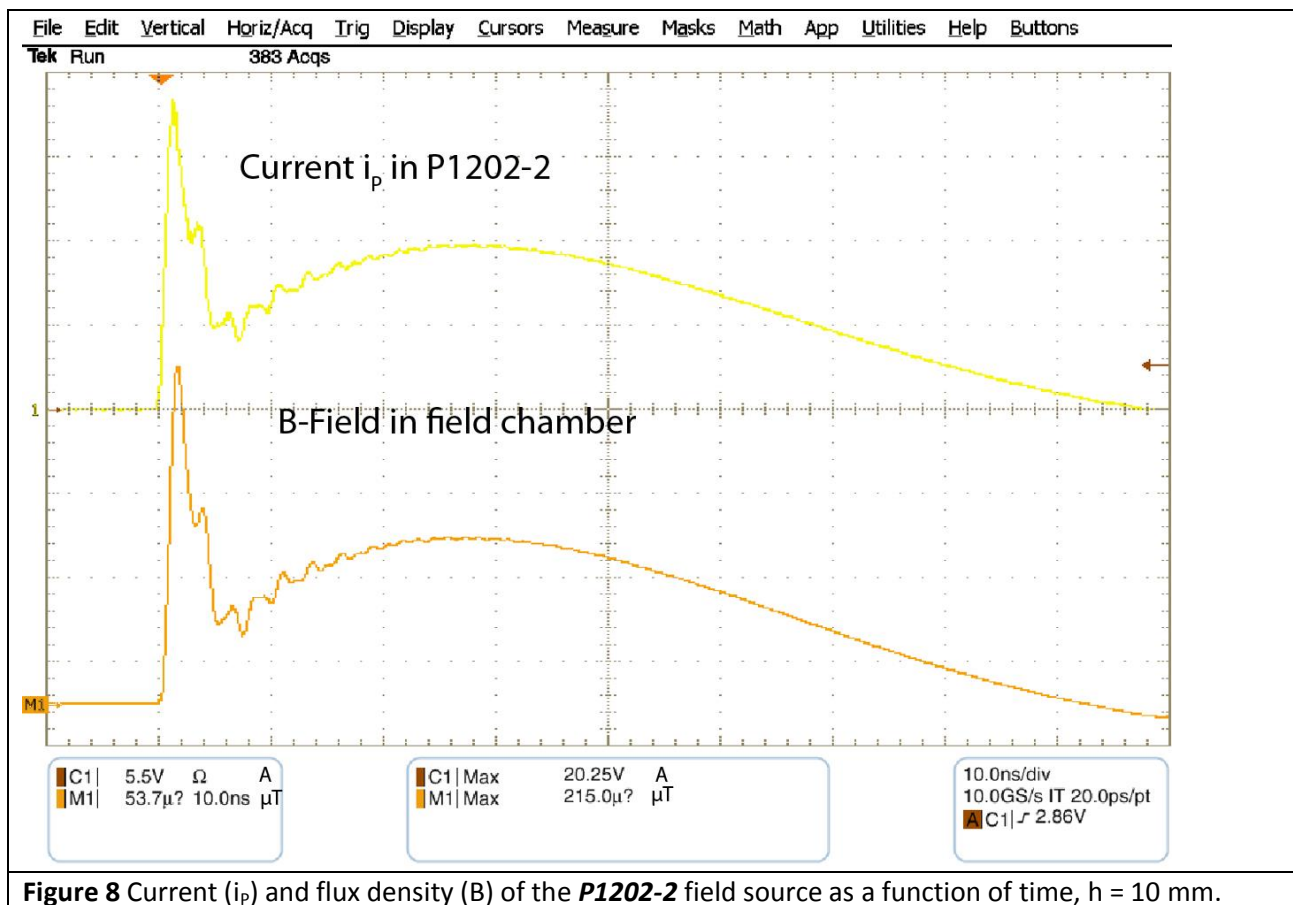
P1202-2

Figure 8 Current (i_P) and flux density (B) of the ***P1202-2*** field source as a function of time, h = 10 mm.

Figure 8 shows the current (i_P) and the flux density (B) of the ***P1202-2*** field source as a function of time; and the proportionality of the probe current i_P and flux density B variation over time in the field cell.

1.2.2 Disturbance mechanism of the magnetic field B

A magnetic field is generated in the field chamber of the field source when a current flows in the electric conductor of the field source. The vortex magnetic field penetrates the test IC (**Figure 5**).
The test IC contains conductor loops (**Figure 9**). The largest conductor loops of the test IC are formed by the pins, bond wires, lead frames and the die. A_{IC} is the cross-section of a current loop. The vortex magnetic field B penetrates the conductor loop and induces the disturbance voltage u_{ind} in this loop.
This induced disturbance voltage u_{ind} can have a direct effect on signals inside the IC or drive a disturbance current through the IC[3]. The disturbance current can affect the Vdd / Vss supply systems and trigger faults and/or generate voltage differences between different circuit sections.

---

[3] Dipl. Ing. Gunter Griessbach und Dipl. Ing. Gunter Langer, „Integrierte Schaltkreise (IC) sind heute die EMV-Schwachstellen elektronischer Geräte." Elektronik, 2014

LANGER	DE-01728 Bannewitz	P1202-2
EMV-Technik	mail@langer-emv.de	
	www.langer-emv.com	
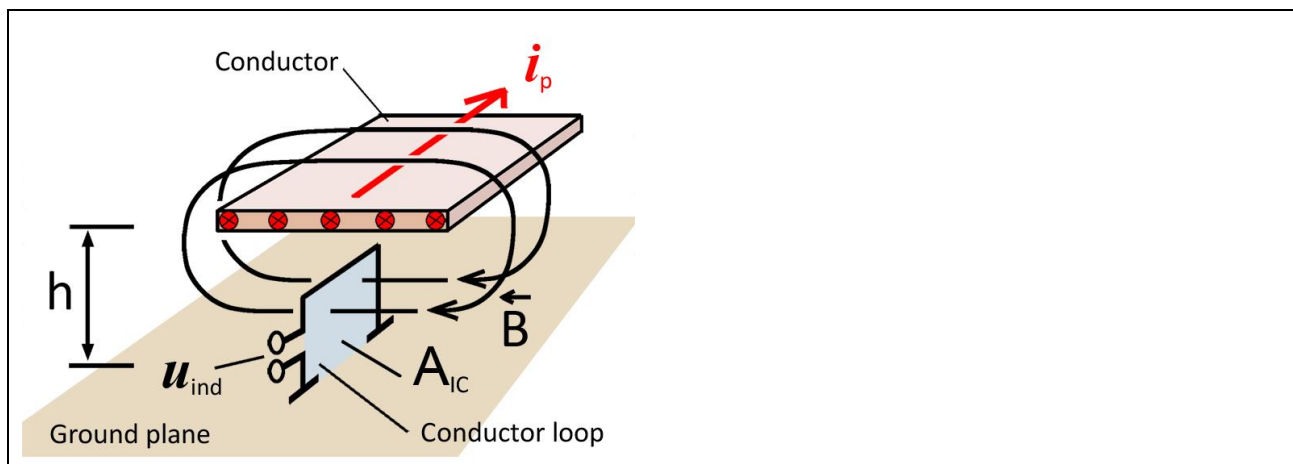
Figure 9 Operational principle behind field coupling to the test IC.

The open IC loop which is shown in **Figure 9** is closed by the resistance R_{IC} (not shown in the figure). The resistance R_{IC} is formed by pull-up/pull-down resistance, driver resistance and the IC's internal resistance. The ohmic resistance of the line network establishes the resistance in supply loops (**Figure 22**).

The magnetic field's effect on the IC loop is best if the magnetic field B penetrates the loop at a 90 degree angle. The loops inside the IC may have different orientations. It is thus important that the magnetic field's direction can be changed so that all critical loops can be identified. The field source can be rotated in the spacer ring for this purpose. The direction of the magnetic field that penetrates the test IC can thus be changed gradually in all directions from 0-360°. The different settings therefore allow the application of a maximum field to the loops with different orientations inside the IC via the pin connections or in the die. Furthermore, the orientation of critical loops in the IC can be determined.

The level of the voltage induced in the device under test and its resulting interference effect depend on parameters such as:
- value set for the high voltage (U_P)
- size of the conductor loop in the IC (A_{IC})
- distance (h) from the ground plane to the electric conductor of the field source
- angle between the electric conductor and the conductor loop

1.2.3 Calculation of the magnetic field B

The magnetic flux in the area of the test IC can be calculated with the following equation:

$$B[\mu T] = K1 \cdot i_P[A]$$

(Eq 2)

Whereby K1 is a probe constant which depends on the metallic structure of the field cell and electric conductor (**Figure 5**). The field chamber can be set to two different heights with the spacer rings (10 mm, 3 mm). All other dimensions of the field chamber and electric conductor are identical for all field sources. Consequently, there are two probe constants K1 of the field sources which can be assigned to the heights of 10 mm and 3 mm (**Table 3**).

These constants K1 are identical for all magnetic field sources (burst, ESD, RF) of the IC test system from Langer EMV-Technik GmbH.

The magnetic flux density B in the area of the test IC can also be found in Table 4.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

1.2.4 Measurement of the magnetic field B

The **BFM 02-B** [4] B-field meter can be used to measure the magnetic flux density B in the field chamber at the test IC location (**Figure 10**). The B-field meter is inserted into the ground adapter instead of the test IC. The **BFM 02-B** B-field meter fits into the **GNDA 02**[5] ground adapter and has to be inserted into the **GND 25** [6] ground plane for the measurement (see **ICE1** IC test environment user manual).
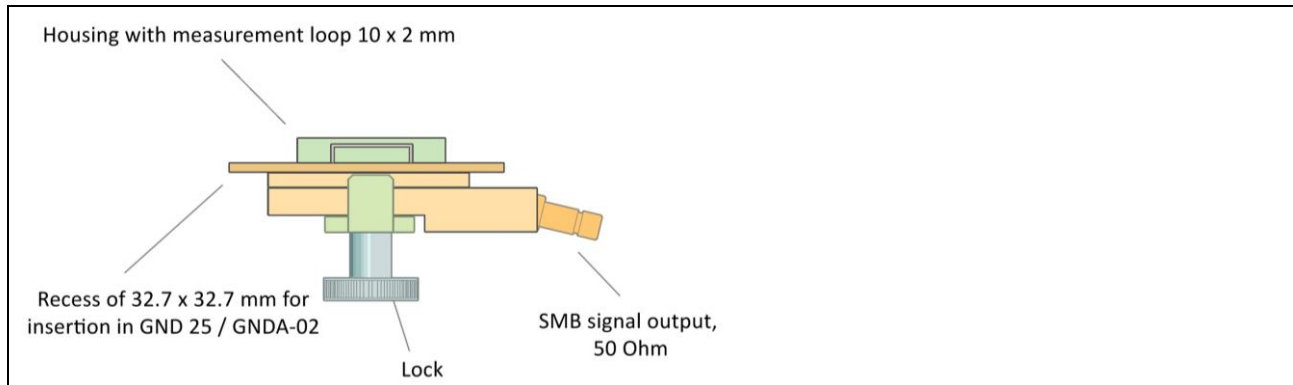

Figure 10 Flux density meter to measure the magnetic flux B.

The SMB output of the B-field meter is connected to the input of the oscilloscope via the 50 Ohm SMA-SMB measuring cable (**Figure 11**). The measurement output is matched to 50 Ohm. The oscilloscope's input has to be set to 50 Ohm to obtain correct values during the measurement. The attenuator value shown on the B-field meter is entered in the vertical menu of the oscilloscope. The flux density is displayed on the oscilloscope in µT (or pVs/mm²) with this attenuator value.
Ensure that the measurement signal does not exceed the oscilloscope's maximum input voltage.
An external attenuator should be used if necessary. A pre-amplifier can be used if the signal is too weak (**PA 303**, 30 dB, www.langer-emv.com).
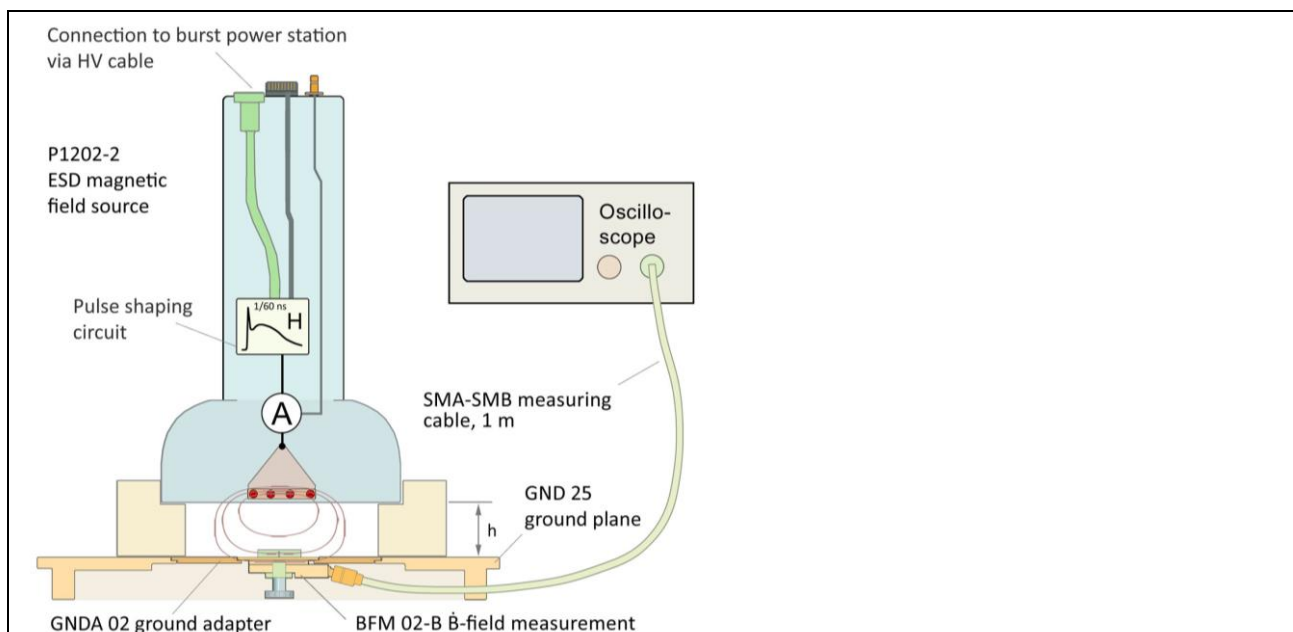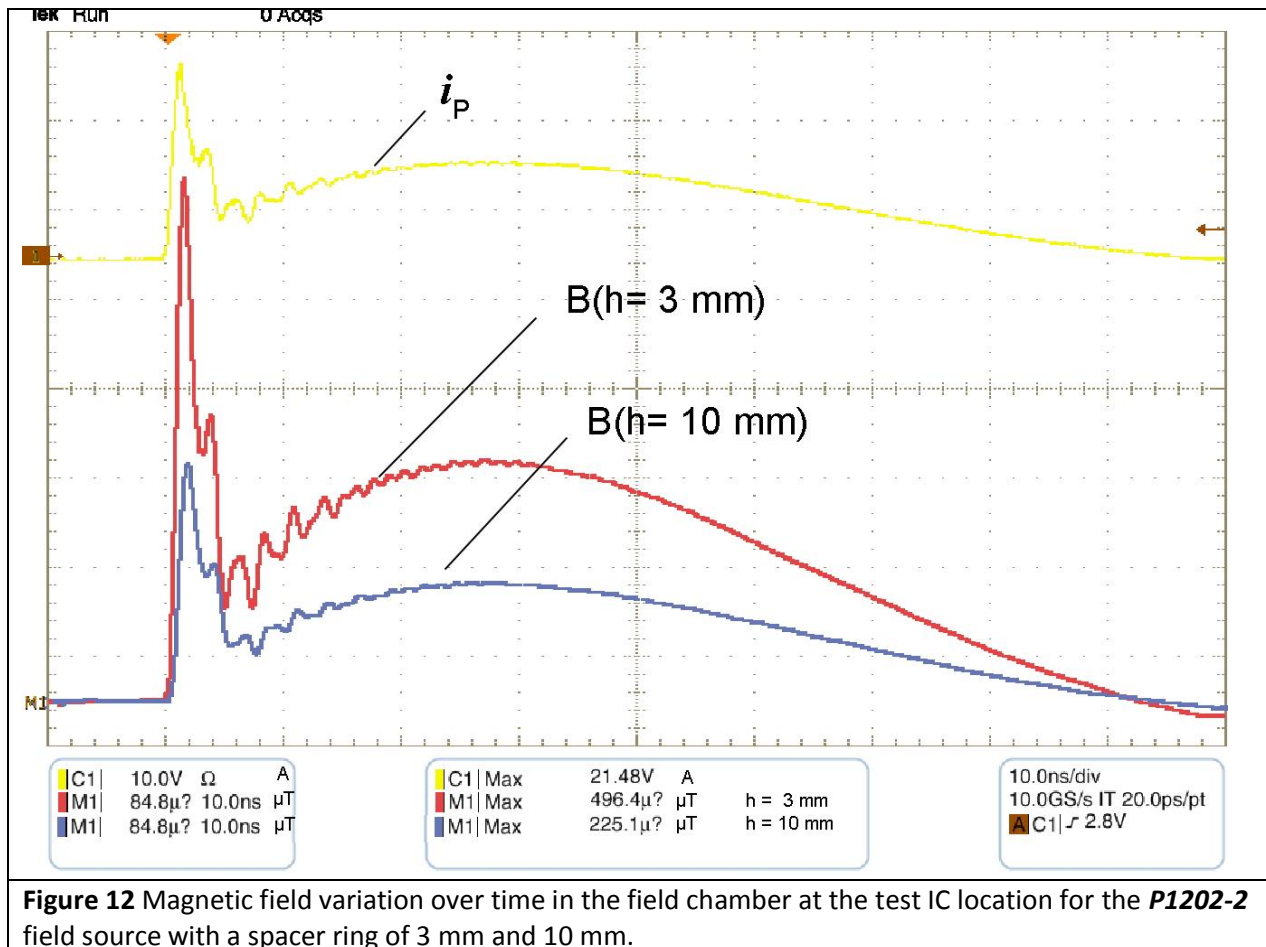

Figure 11 Measurement of the magnetic flux density of the **P1202-2** field source with the **BFM 02-B** .

---

[4] The BFM 02-B not included in the probe set's scope of delivery; can be ordered separately.

[5] The GNDA 02 is included in the **ICE1's** scope of delivery. www.langer-emv.com

[6] The GND 25 ground plane is included in the **ICE1's** scope of delivery. www.langer-emv.com

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

Figure 12 shows the flux density curves for a high voltage U_P = 0.57 kV and a current i_P = 20 A for a 3 mm and 10 mm spacer ring.

Figure 12 Magnetic field variation over time in the field chamber at the test IC location for the **P1202-2** field source with a spacer ring of 3 mm and 10 mm.

### 1.2.5 Measurement of the induction dB /dt

The **BPM 02** $\dot{B}$-field meter can be used to measure the dB /dt = $\dot{B}$ value in the field chamber at the test IC location (**Figure 13**). The dΦ/dt flux variation over time in the IC conductor loop and the voltage u_{ind} induced in the IC can be calculated on the basis of dB / dt ($\dot{B}$) and the cross-section A_{IC} of the IC conductor loop:

$$A_{IC} \cdot \frac{dB}{dt} = \frac{d\Phi}{dt} = -u_{ind} = -u_{IC}$$

(Eq 3)

whereby Φ is the magnetic flux which penetrates the IC conductor loop.
The **BPM 02** $\dot{B}$-field meter is inserted into the ground adapter instead of the test IC. The **BPM 02** $\dot{B}$-field meter fits into the **GNDA 02**[7] ground adapter and has to be inserted into the **GND 25** ground plane for the measurement (see **ICE1** IC test environment user manual).


[7] The GNDA 02 is part of the ICE1.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2
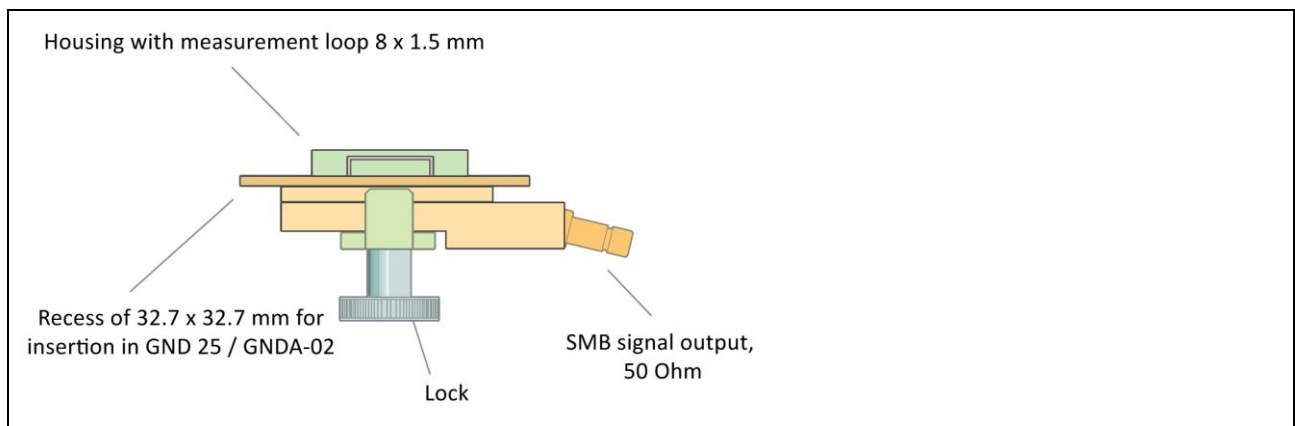
Figure 13 Ḃ-field meter to measure the magnetic flux density Ḃ variation.

The SMB output of the Ḃ-field meter is connected to the input of the oscilloscope via the 50 Ohm SMA-SMB measuring cable (**Figure 15**). The measurement output is matched to 50 Ohm. The oscilloscope's input has to be set to 50 Ohm to obtain correct values during the measurement. The voltage u_{AV} which is present in the oscilloscope is converted to Ḃ for the **BPM 02** Ḃ-field meter with the following equation:

$$\dot{B} = \frac{dB}{dt} = 1 \cdot 10^{6} \cdot u_{AV} \left[\frac{T}{s} \right]$$

(Eq 4)

The attenuator value $1 \cdot 10^{6}$ has to be entered in the vertical menu of the oscilloscope, **Figure 14**.
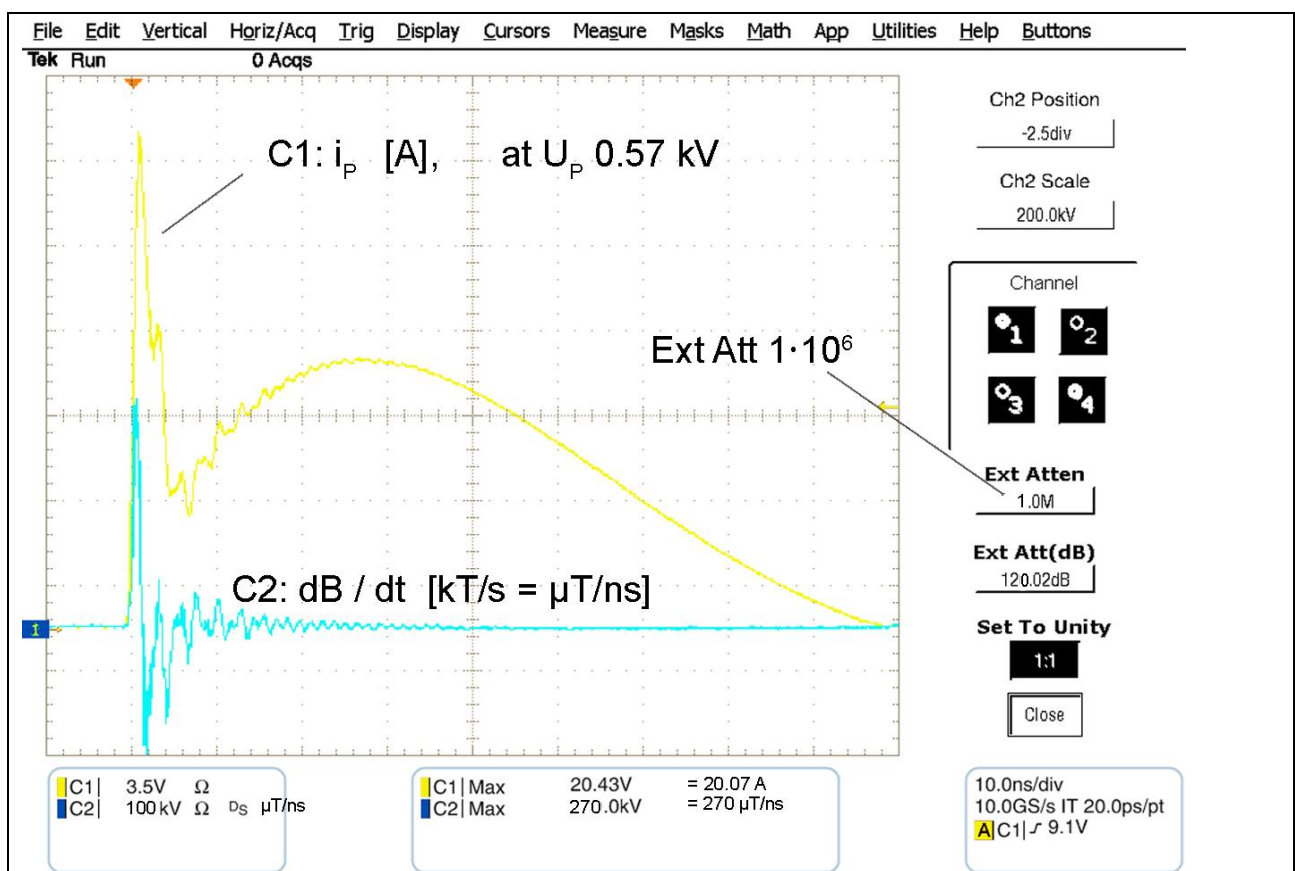
Figure 14 Input of the attenuator value in the vertical menu of the oscilloscope, [T/s] unit of measurement.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

If a Ḃ-field meter with another attenuator value is used, this has to be entered in the vertical menu of the oscilloscope. Ḃ is displayed on the oscilloscope in T / s with the respective attenuator value. Ḃ is displayed in V (Volt) or kV if the unit of measurement is not changed from V (Volt) to T or µT in the channel of the oscilloscope (**Figure 14**). Ḃ = 270 kV is displayed, for example. The value displayed in this form has to be converted using the "Meter-Kilogram-Second-Ampere system" (MKSA system) to display the value in T / s. T / s can be resolved in Vs/m² s by converting k from kV to µ/n. µVs/ m² ns = µT / ns is now the channel's unit of measurement.

Ensure that the measurement signal does not exceed the oscilloscope's maximum input voltage.

An external attenuator should be used if necessary. A pre-amplifier can be used if the signal is too weak (*PA 303*, 30 dB, www.langer-emv.com).

Figure 15 Ḃ measurement of the *P1202-2* field source with the *BPM 02* Ḃ-field meter.
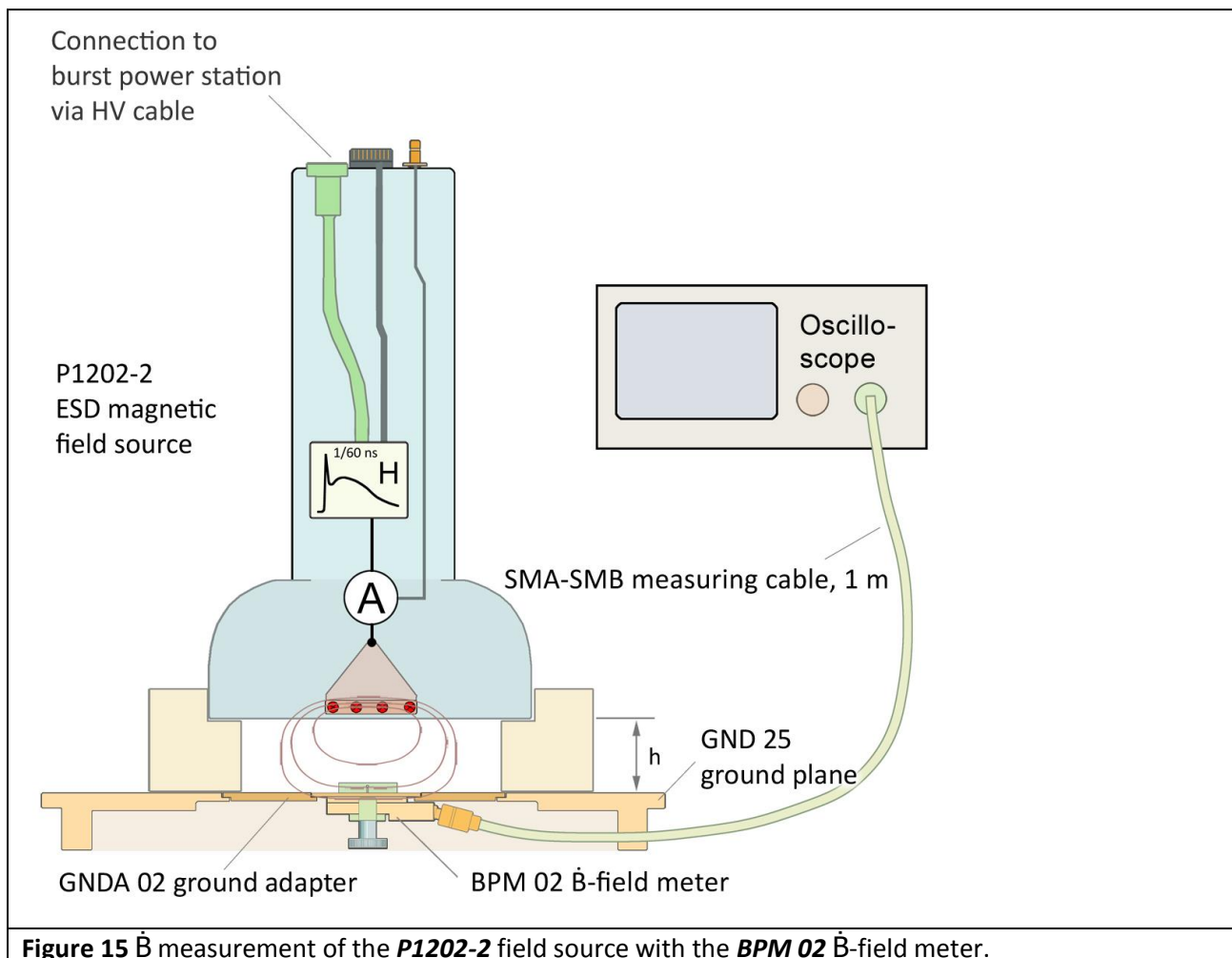
Figure 16 shows Ḃ as a function of time for an ESD generator voltage U_{VG} = 0.57 kV and a current i_P = 20 A for a spacer ring of 3 mm and 10 mm.
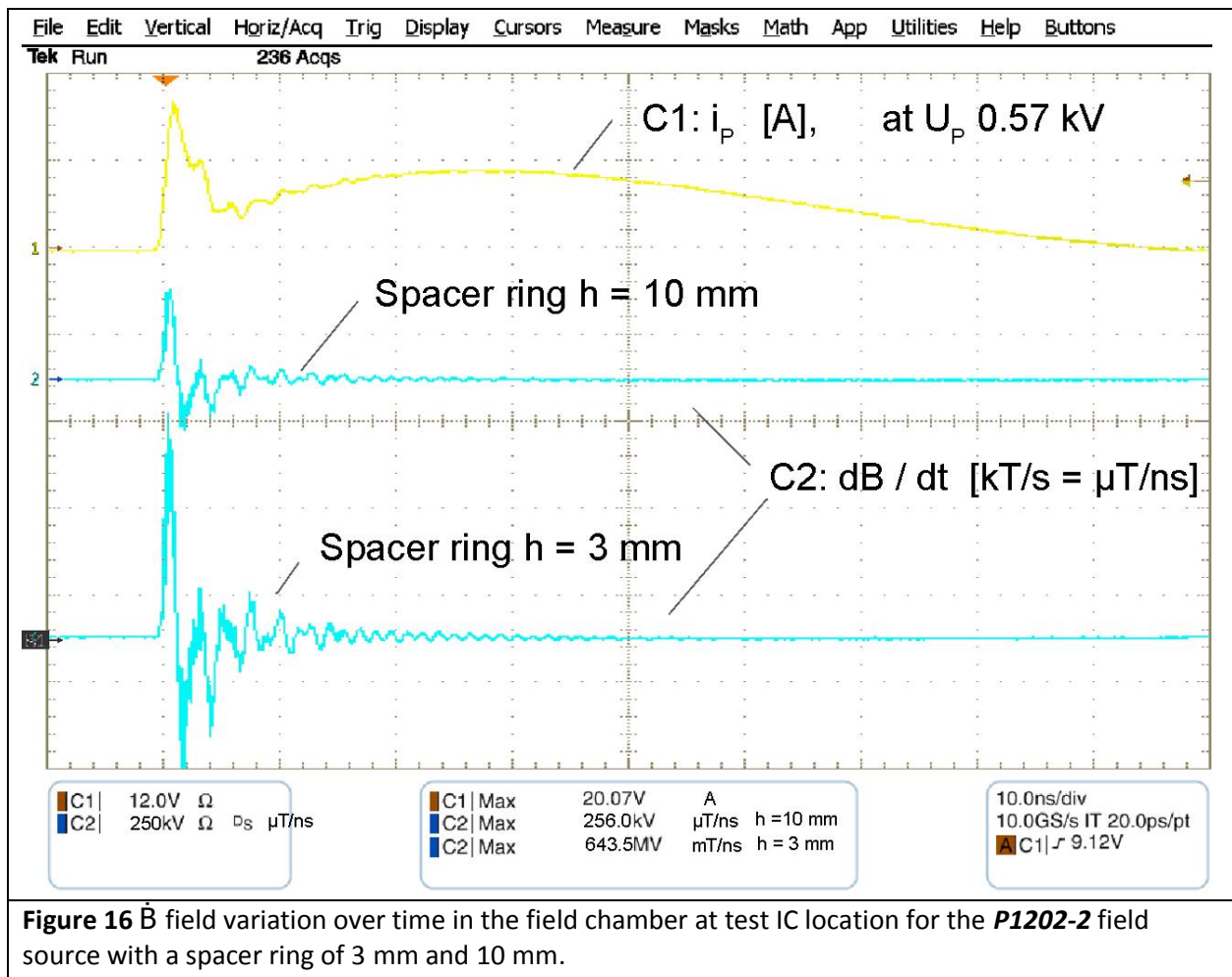
Figure 16 Ḃ field variation over time in the field chamber at test IC location for the **P1202-2** field source with a spacer ring of 3 mm and 10 mm.

The voltage which is induced in an IC can be determined if the effective cross-section A_{IC} of the IC loop is known.

$$u_{ind} = -A_{IC}\left[mm^2\right]\cdot 10^{-6}\cdot\frac{dB}{dt} = -A_{IC}\left[mm^2\right]\cdot 10^{-6}\cdot\dot{B} \qquad\text{(Eq 5)}$$

u_{ind} can be calculated from Ḃ with a mathematical function in the oscilloscope (**Figure 17**).

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com
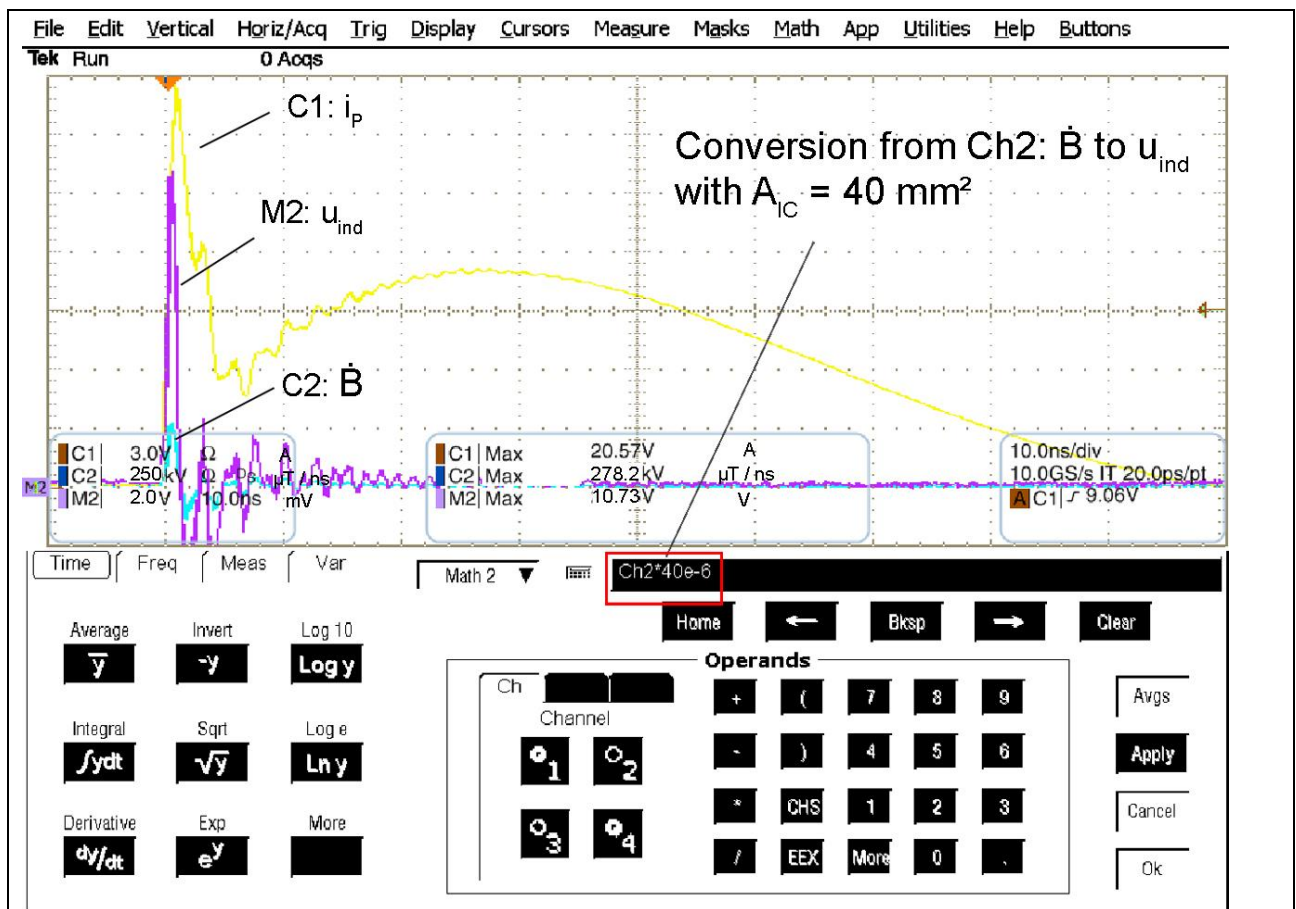
P1202-2

Figure 17 Calculation of the voltage u_{ic} induced in the IC on the basis of $\dot{B}$, whereby: A_{IC} = 2 mm x20 mm = 40 mm² is the cross-section of the IC loop, $\dot{B}$ is generated by the ***P1202-2*** field source, the spacer ring height is 10 mm, a current i_P = 20 A flows in the electric conductor of the field source (U_P = 0.57 kV). A voltage of 10.7 V is induced in the IC loop.

The largest IC conductor loops are formed by the pins, bond wires, lead frames and the die. A voltage of 10.7 V is induced in a loop of 2 mm by 20 mm at an ESD current of 20 A and a spacer ring height of h = 10 mm.

$\dot{B}$ as a function of time can be converted to the flux density B by integration.

$$B = \int \dot{B} \cdot dt + C \qquad \text{(Eq 6)}$$

whereby C is the constant of integration. The integration can be performed in the oscilloscope (**Figure 18**). The unit of measurement of the result calculated in the oscilloscope is T.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2
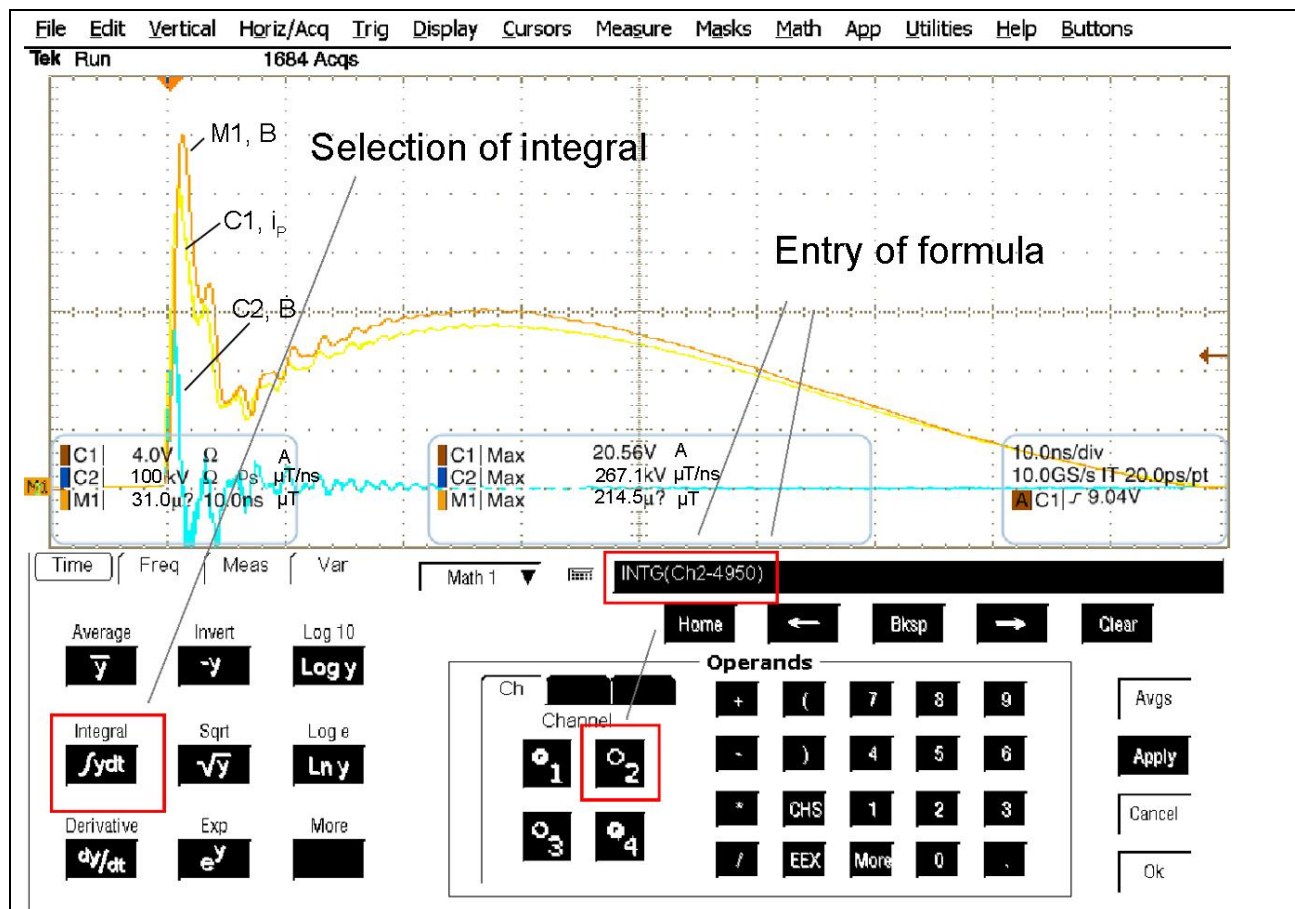
Figure 18 Input of the integration formula in the mathematical menu of the oscilloscope, C1: Ip, C2: Ḃ, M1: B.

The value of the constant of integration C has to be entered in the equation of the oscilloscope by hand. The final value of the constant of integration is determined by iteration. 0, for example, can be used as the initial value. If the value of the constant of integration C is too low, the measured curve will drop relative to the expected variation (**Figure 19**). The expected variation is proportional to the variation of the current i_P in the electric conductor **Figure 18**. The constant of integration C has to be increased if the measured curve drops instead. If the measured curve rises, however, the value of the constant of integration C is too large (**Figure 19**) and then has to be reduced by hand. The value of the constant of integration has to be gradually adjusted by hand until the variation over time for C2: Ḃ is proportional to that of the current C1: i_P (**Figure 18**).

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2
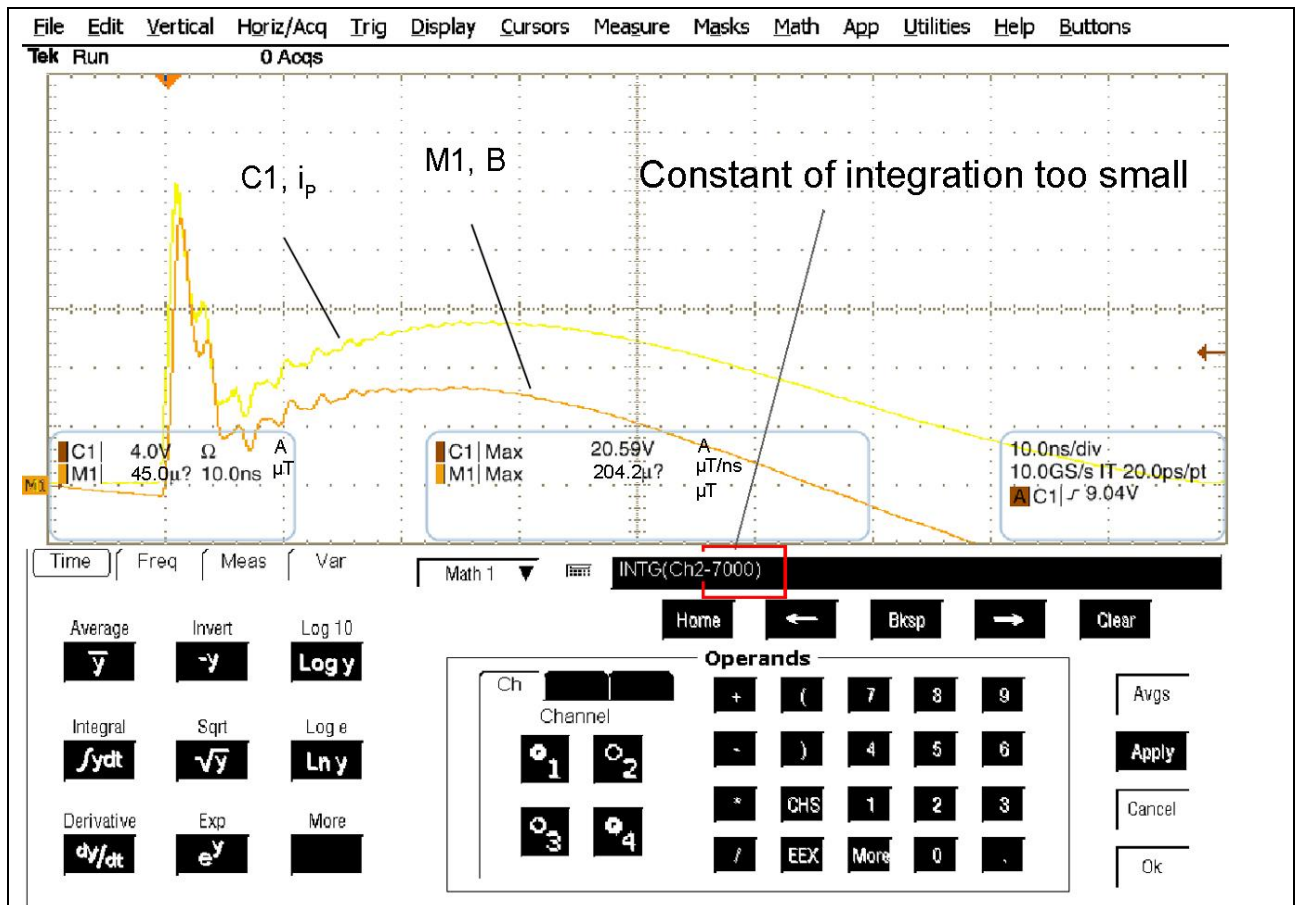
Figure 19 B-field curve calculated from C2 by integration M1. The flux density B should be proportional to the current i_P. In contrast, B (M1) drops relative to i_P (C1). This is due to the integration constant being too small -7000. The constant of integration has to be increased to -1000, for example.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2
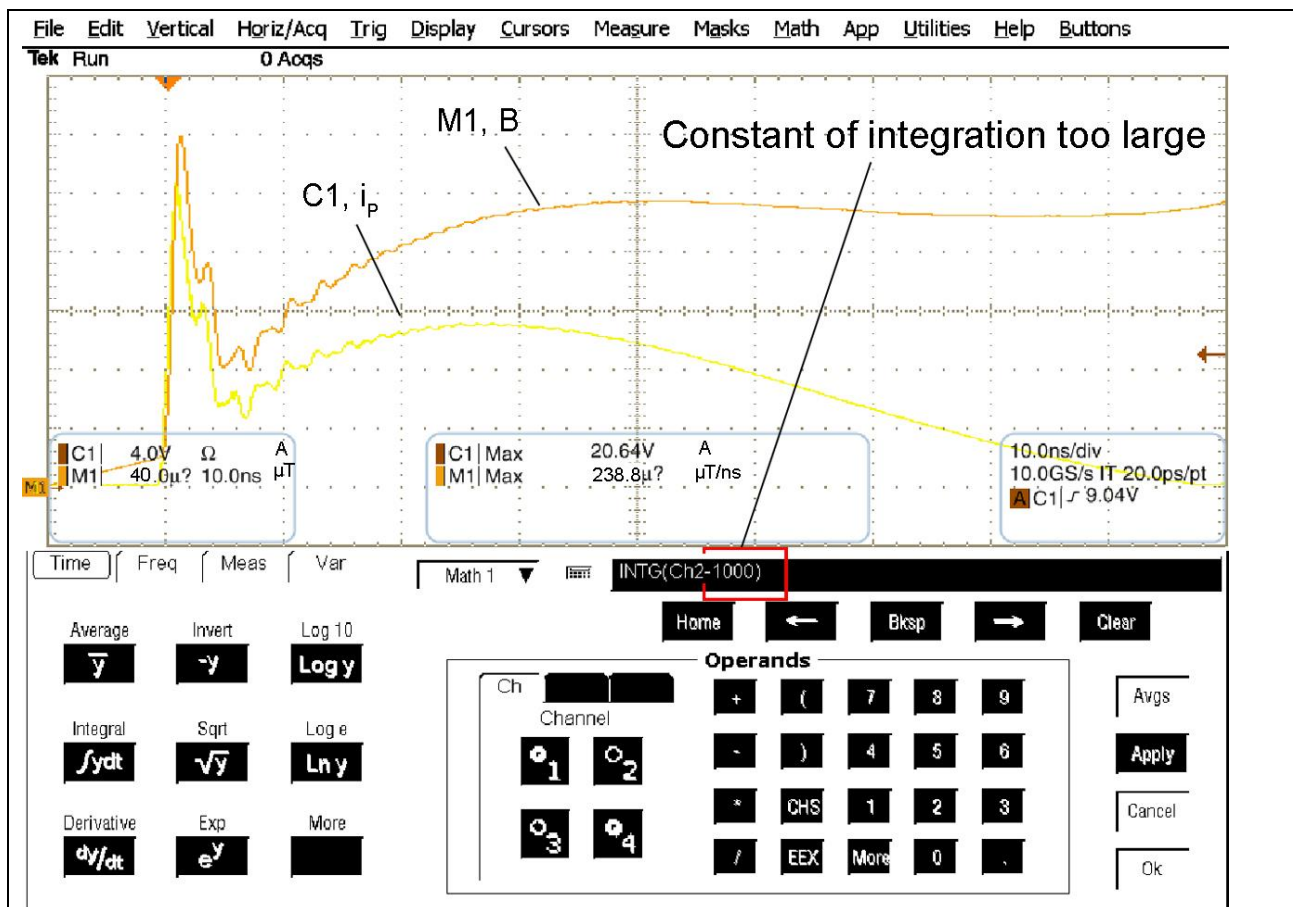
Figure 20 B-field curve calculated from C2 by integration M1. The flux density B should be proportional to the current i_P. In contrast, B (M1) rises relative to i_P (C1). This is due to the integration constant being too large -1000. The constant of integration has to be reduced to -4950, for example (**Figure 18**).

If the attenuator value (Ch2) that has been entered in the oscilloscope converts the measured signal U_{AV} to T / ns, A_{IC} has to be entered in m² in the equation of the oscilloscope. The unit of measurement of the result displayed on the oscilloscope is then T.

If the attenuator value which has been entered in the oscilloscope converts the measured signal U_{AV} to mV/mm², A_{IC} has to be entered in mm² in the equation of the oscilloscope. The unit of measurement of the result displayed by the oscilloscope is then Vs/mm².

1.2.6 Mechanism of inductive coupling from the P1202-2 field source to the test IC

Regarding inductive coupling it is important to distinguish between current coupling and voltage coupling (**Figure 21** and **Figure 22**).
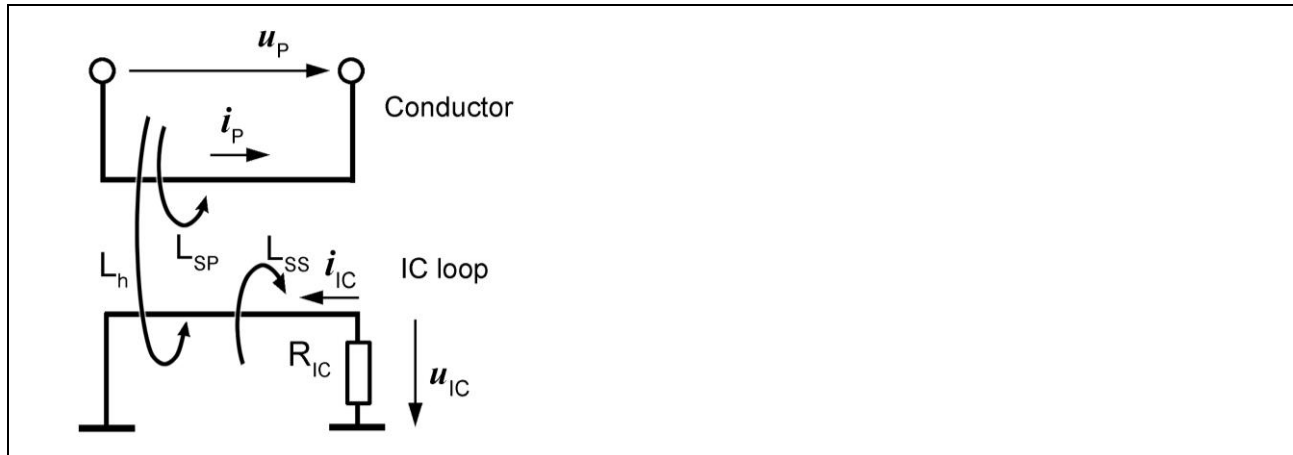
Figure 21 Connection of the electric conductor of the *P1202-2* field source and the IC loop.

The current i_P in the electric conductor generates a vortex magnetic field. The share of the vortex magnetic field which penetrates the IC loop is assigned to the principal inductance L_h. The principal inductance L_h mediates between the current i_P of the field source and the voltage u_{IC} which is induced in the IC loop.

$$u_{ind} = -L_h \cdot \frac{di_P}{dt}$$

(Eq 7)

The IC loop has the self-inductance L_{SS}. The connection between *P1202-2* and the electric conductor shown in **Figure 21** can be transferred to a lumped-element transformer equivalent circuit (**Figure 22**).
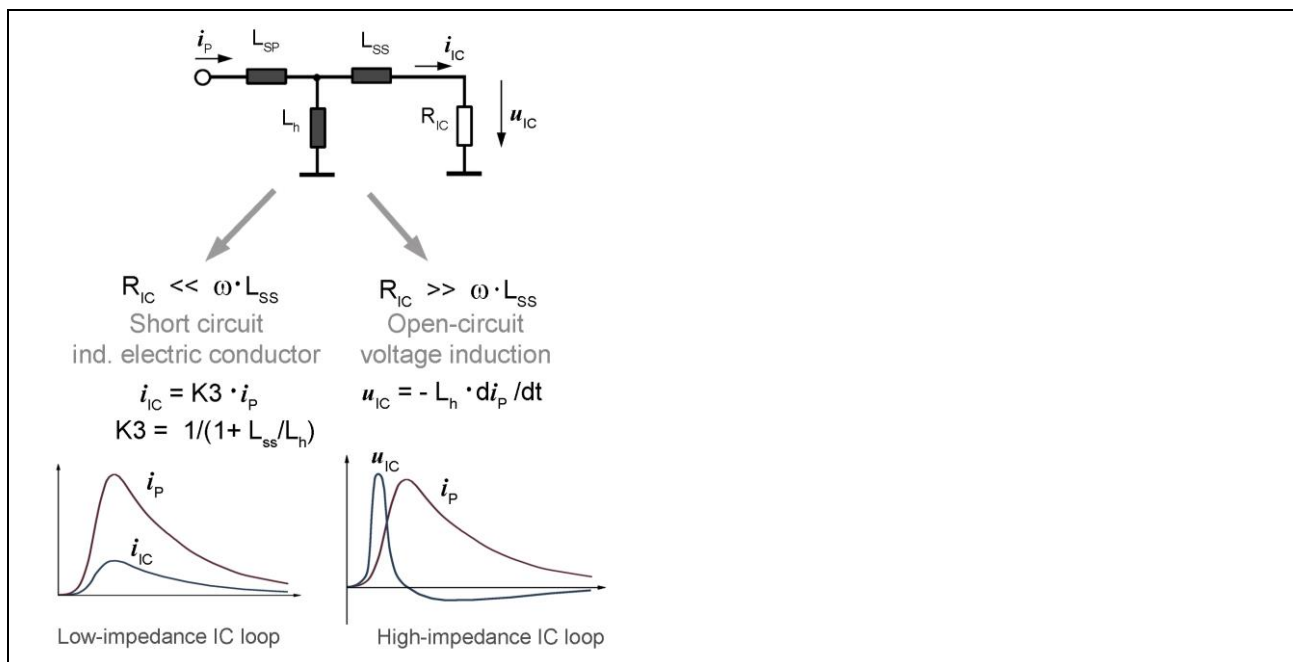
Figure 22 Transformer equivalent circuit of coupling between the electric conductor of the *P1202-2* field source and the IC loop; main types of coupling by case distinction.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

Distinction of cases:

1. Current coupling

The circuit operates under short-circuit conditions if $R_{IC} \ll \omega L_{ss}$. The inductances L_h and L_{ss} form a current divider. The currents are divided at the ratio L_h / L_{ss} independent of the frequency (reduced from $L_{ss} \gg L_h$: $1/(1+L_{ss}/L_h) = L_h/L_s$). The waveform of the current pulse in the IC is thus equal to that of the discharge current in the electric conductor of the field source. This means that a current pulse i_{IC} of 1/60 ns flows in the IC. The peak value is attenuated by the coupling factor K3 (**Figure 22**). R_{IC} must be in the range of 0.1 Ohm so as to transfer all frequency components of the discharge current. This is implemented in Vdd / Vss loops.

2. Voltage coupling

The circuit operates like a voltage transformer under open-circuit conditions if $R_{IC} \gg \omega L_{ss}$. The voltage induced on the inductance L_h is present in the IC (open-circuit voltage). It changes depending on the frequency according to the law of induction.

$$u_{ind} = -\omega \cdot L_h \cdot i_P \qquad \text{(Eq 8)}$$

The induced voltage u_{ind} is proportional to the frequency of the current i_p. This is particularly important for ESD coupling as the current consists of higher frequency parts than the EFT/Burst current.

1.2.7 Current coupling to the IC

The L_h / L_s ratio (reduced from $L_{ss} \gg L_h$: $1/(1+L_{ss}/L_h) = L_h/L_s$) determines the coupling of current to an IC loop (**Figure 22**). The ratio remains practically unchanged if the width of a conductor loop is changed. Changing the loop's height and line diameter would result in a change of L_{ss}. As a result, L_{ss} does not clearly depend on the loop area A_{IC}. A normalisation could only be performed under the aforementioned conditions and has not been performed in this case.
The resistance R_{IC} essentially determines the effectiveness of current coupling. Current coupling is effective for supply loops due to their low resistance.
L_h can be determined on the basis of the inductance per unit length L' and A_{IC} for calculations. L_{ss} has to be determined on the basis of the IC design.

$$i_{IC} = K3 \cdot i_P \qquad \text{(Eq 9)}$$
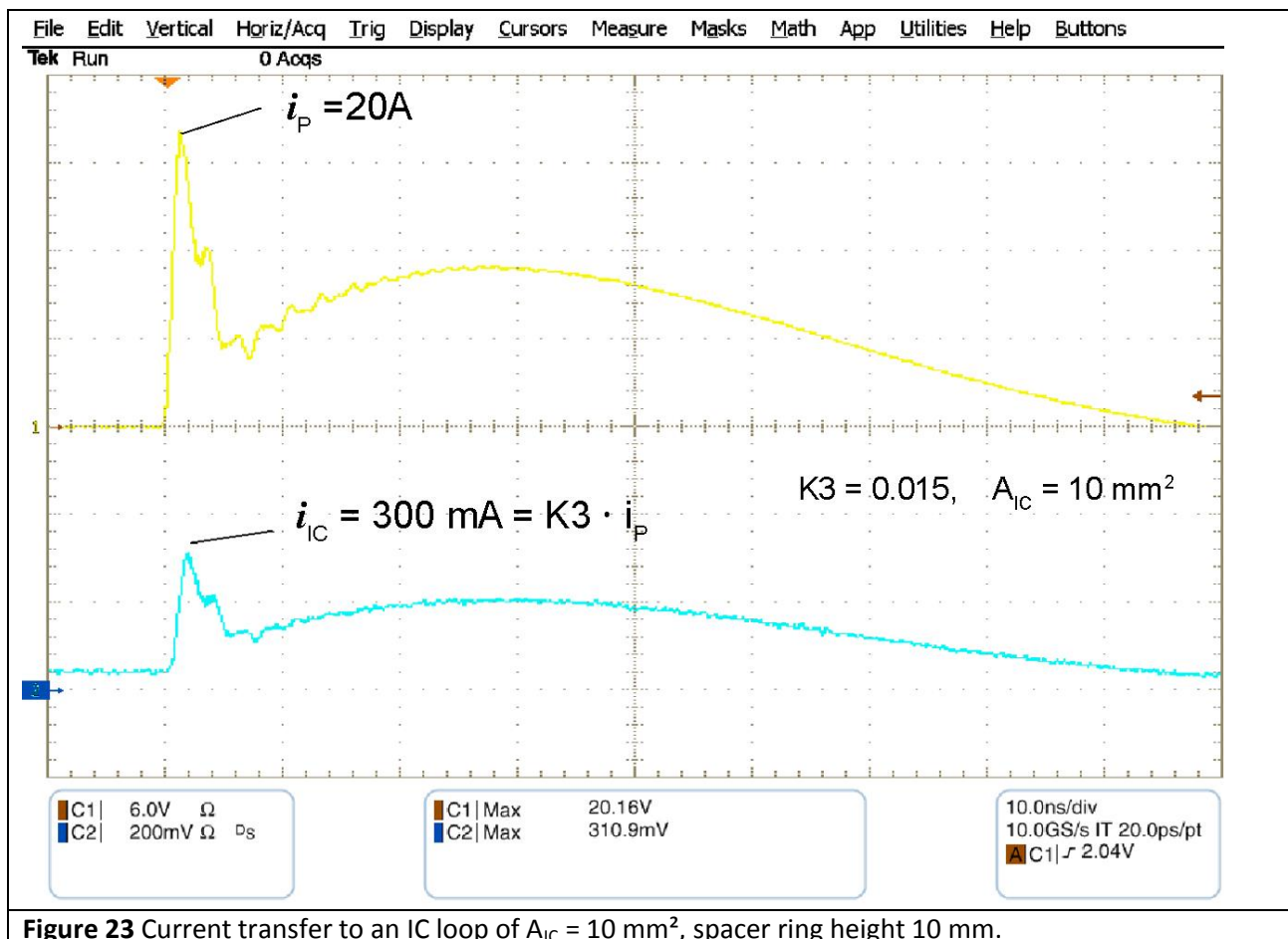
K3 has been determined by measurements in **Figure 23**.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

Figure 23 Current transfer to an IC loop of A_{IC} = 10 mm², spacer ring height 10 mm.

1.2.8 Voltage coupling to the IC

The electric conductor of the field source is coupled inductively to the conductor loop in the test IC. The coupling effect is described by the law of induction,

$$u_{ind} = -L_h \cdot \frac{di_P}{dt}$$

(Eq 10)

Whereby the inductance L_h is the measure of coupling between the electric conductor and the loop of the test IC.
The specific inductance $L_h{'}$ is the ratio between the inductance L_h and the effective surface area of the test-IC loop.
This specific inductance $L_h{'}$ is a constant for the field chamber and is listed in Table 3 for a field chamber height h of 3 mm and 10 mm. The induced voltage is calculated with the equation,

$$u_{ind} = -L_h{'} \cdot A_{IC} \cdot \frac{di_P}{dt}$$

(Eq 11)

whereby $L_h{'}$ is the specific inductance of the field chamber at the test IC location. A_{IC} is the effective cross-section of the test IC loop. The cross-sections A_{IC} of the loops in the test IC can be determined on the basis of its design. The voltage which is induced in the loop of the test IC can be calculated from this value, the inductance per unit length and the current differential di_P / dt. These values can be used for a simulation on the IC.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

di_P / dt for ESD can be roughly calculated from the rise time of the pulse Δt and the peak value of the current Δi_P of the first discharge peak,

$$\frac{\Delta i_P}{\Delta t} = \frac{i_P}{0.8 ns}$$ (Eq 12)

with $K2 = L_h´ / \Delta t$ and $u_{ind} = - L_h´ \cdot A_{IC} \cdot di_P / dt$ it is possible to calculate the maximum voltage (depending on the first discharge peak).

$$U_{ind} = K2 \cdot A_{IC} \cdot I_P$$ (Eq 13)

The values of K2 can be found in **Table 3**.

di_P / dt can also be measured with an oscilloscope according to the measuring method 1.2.4.
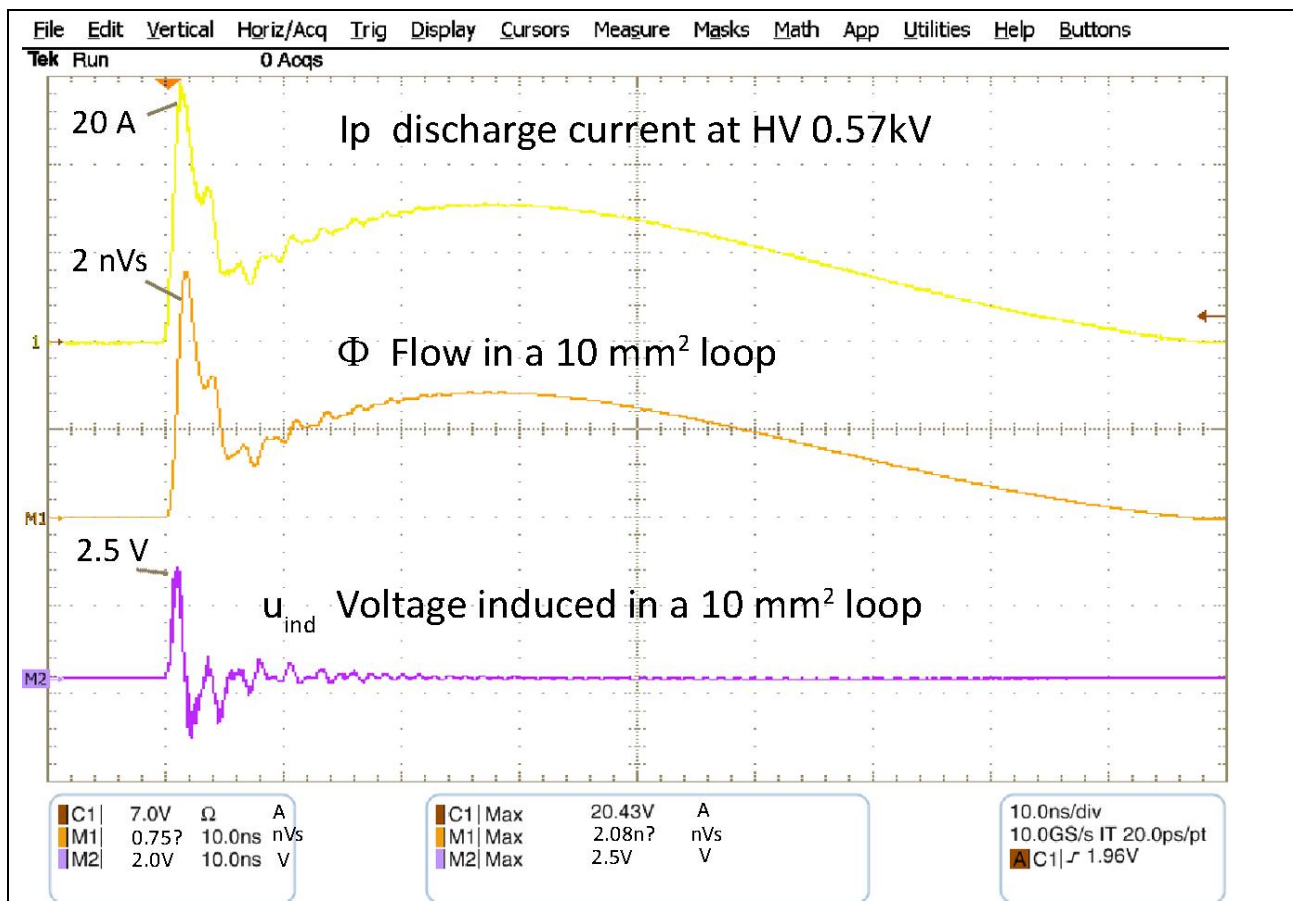
Figure 24 Magnetic flux φ and voltage u_{ind} induced in the conductor loop of a test IC with a spacer ring of 10 mm and the **P1202-2** field source.

Figure 24 shows the variations of the induced voltages over time for a test conductor loop of $A_{IC} = 10$ mm².

The induced voltage can be calculated directly from the flux density in the area of the test IC.

$$u_{ind} = - A_{IC} \cdot \frac{dB}{dt}$$ (Eq 14)

The equation establishes a direct relationship between the magnetic field B and the induced voltage u_{ind}.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

1.2.9 E-field suppression of the ESD magnetic field sources

A weak electric field E_P is generated in the field chamber of the **P1202-2** field sources as a parasitic effect when a magnetic field is generated. The electric field depends linearly on the supply current I_P and the spacer ring height h. **Figure 25** shows the electric field as a function of time. It corresponds to the first derivative of the current on account of the inductive voltage drop in the electric conductors of the field source, amongst other things.
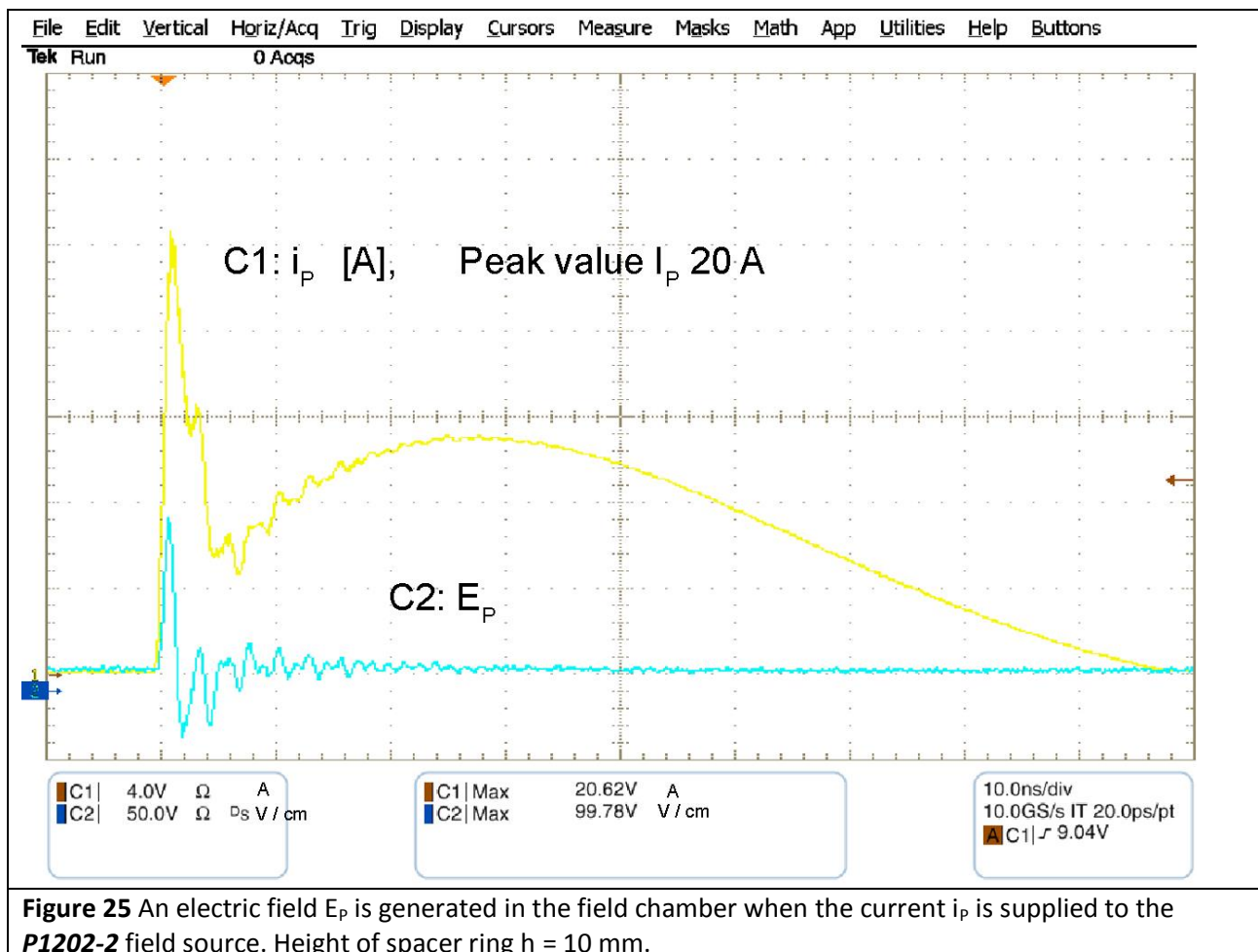
Figure 25 An electric field E_P is generated in the field chamber when the current i_P is supplied to the **P1202-2** field source. Height of spacer ring h = 10 mm.

The associated electric voltage U_P to ground is independent of the height of the spacer ring:

$$\frac{U_P}{I_P} = 4{,}8 \left[\frac{V}{A} \right]$$

(Eq15)

(P1202-2, h = 10   **Figure 25**)

However the electric field in the area of the test-IC is dependant from the height of the spacer ring (given a constant voltage U_P) (**Table 6**)

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

1.3   Set-up of the test bench / system set-up

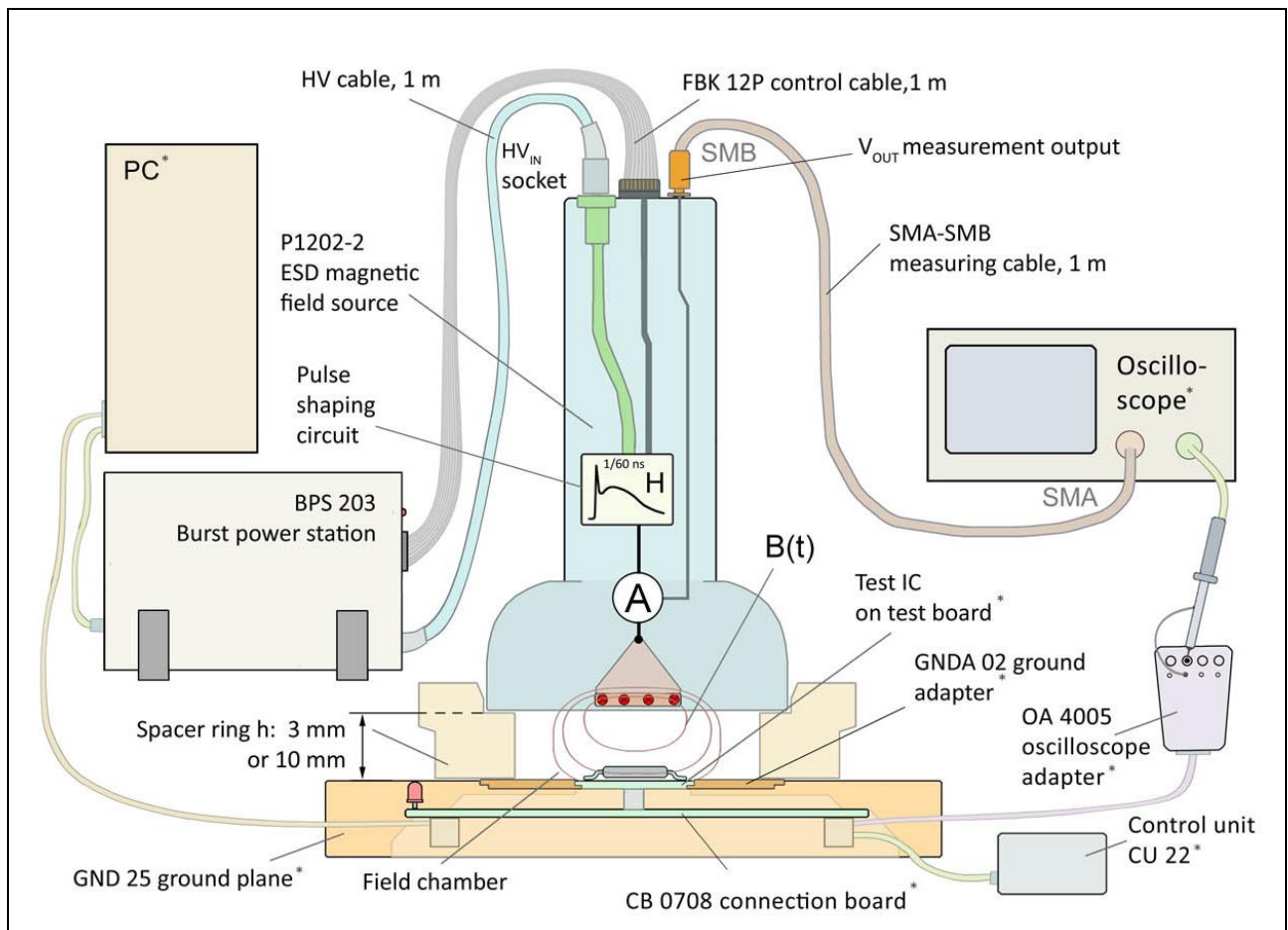**Figure 26** *P1202-2* field source in the *ICE1* test environment

Components marked * are not included in the scope of delivery of the ESD magnetic field injection probe set.

Figure 26 shows the set-up of the test bench with the *ICE1* test environment (Table 2) and the *P1202-2* field source. The *BPS 203* burst power station generates the high voltage required to operate the *P1202-2* field source.

The HV port of the BPS 203 burst power station is connected to the HV_{IN} input of the field source via the *HV FI FI 1 m* cable. In addition, the Control output of the field source is connected to the Probe port of the *BPS 203* via the control cable (FBK 12P 1 m). The *BPS 203* is connected to a PC via the USB B cable. The *BPS 203-Client* software and Windows drivers are installed on the PC (*BPS 203* user manual). The *BPS 203* is controlled from a PC via its USB interface.

The ESD magnetic field is generated in the *P1202-2* field source from the high voltage which is supplied by the *BPS 203*. The ESD magnetic field acts on the housing of the test IC inside the field chamber.

The test IC is mounted on a test board. Manufacturing the test board is described in Chapter 3 of the Guide line IC EFT immunity (mail@langer-emv.de). The test board is inserted into the *GND 25* ground plane and connected to the *CB 0708* connection board via a plug connector (**Figure 26**).

The ground plane and connection board are components of the ICE1 IC test environment (ICE1 user manual).

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

Two different spacer rings are included in the scope of delivery. The spacer rings have a height of 3 mm and 10 mm respectively. The height of the field source can be defined by selecting the respective spacer. The 3 mm spacer ring leads to a higher field strength in the field chamber but the electrode or the electric conductor is closer to the test IC.
The proximity to the test IC causes a stronger field distortion with 3 mm than with 10 mm. The measuring accuracy is thus higher when using the 10 mm spacer ring. The 3 mm spacer ring can be used if the field strength is not sufficient to interfere with the test IC at the maximum generator voltage.
When using the 3 mm instead of the 10 mm spacer, the magnetic flux density is increased by the factor 2 (neglecting the test IC interaction).

The chosen spacer ring is mounted on the **GND 25** ground plane (**Figure 26**). The **P1202-2** field source is then inserted into the recess of the spacer ring. The field source can be rotated in the spacer ring. The direction of the magnetic field that penetrates the test IC can thus be changed gradually in all directions from 0-360°.

The **OA 4005** oscilloscope adapter and the **CB 0708** connection board can be used to evaluate signals from the test IC.
The **CB 0708** connection board and a control unit can be used to control the test IC. The **ICE1** user manual provides information on how to use and wire these components. **Figure 27** shows the set-up of a practical test bench.

Figure 27 Test set-up with the **P1202-2** probe set and ICE1 test environment.

LANGER	DE-01728 Bannewitz	P1202-2
EMV-Technik	mail@langer-emv.de	
	www.langer-emv.com	
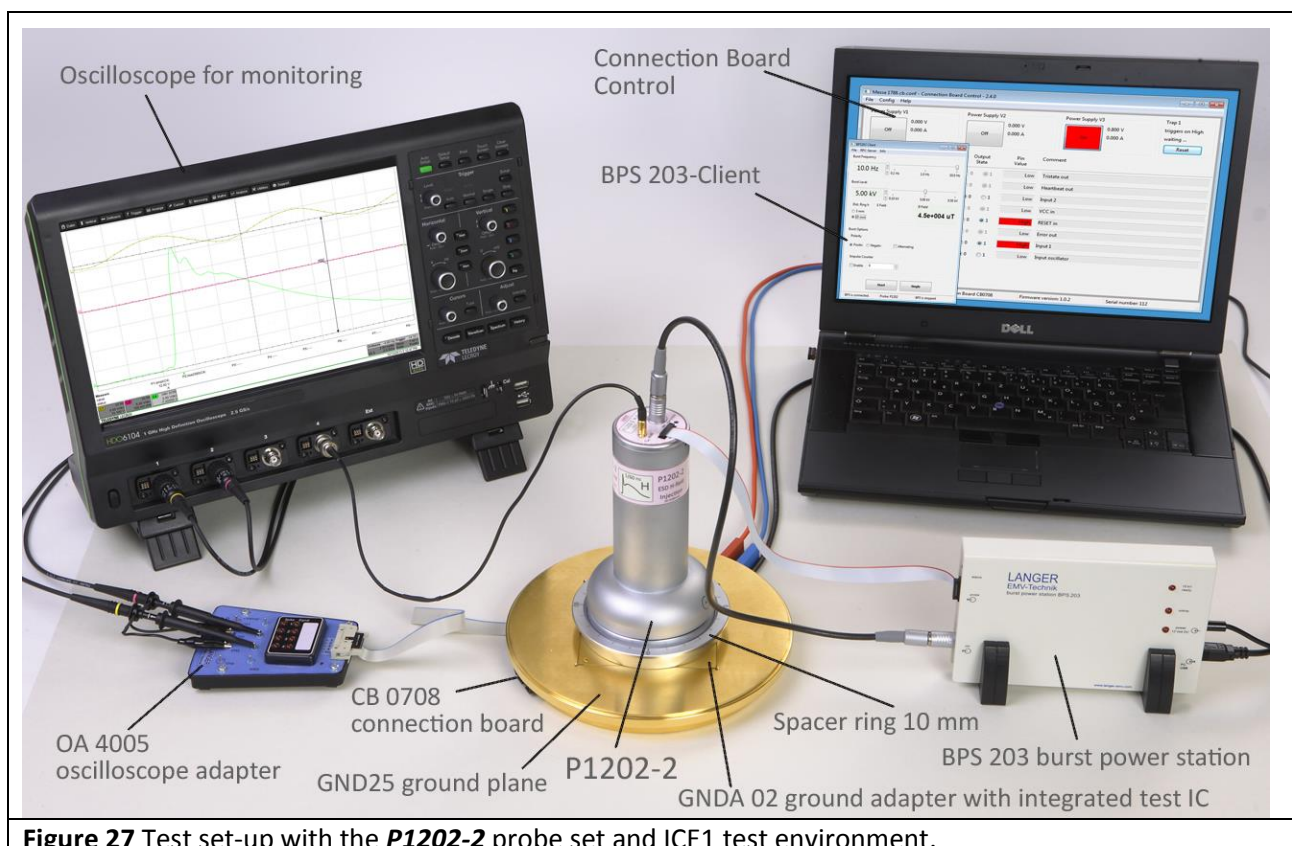
The devices listed in the table are described in their respective instruction manuals:

Task	Instruction manual
• Instructions for the development of the test board • Test process	Guideline IC EFT immunity (scope of delivery ICE1)
• BPS 203	BPS 203 user manual (scope of delivery)
• GND 25 ground plane • CB 0708 connection board • OA 4005 oscilloscope adapter • Monitoring and controlling the test IC • CU 22 control unit	ICE1 user manual (scope of delivery ICE1)
• Oscilloscope • PC	Operating instructions of the manufacturer

Table 2 Documentation

1.4 Performance of the test

There are two ways of using the test bench:

1. Manual control of the test bench

The **BPS 203** and thus the **P1202-2** are controlled via the user interface of the **BPS 203-Client** software. The pulse parameters are set on the software user interface. The monitoring signals (sources: oscilloscope, oscilloscope adapter, connection board or proprietary solution of the user) have to be evaluated by the user.

2. Automated or semi-automated test bench

Since an automated test bench depends on the type of test IC monitoring signals, it is up to the user to develop automated or semi-automated solutions (advice from Langer EMV-Technik GmbH, mail@langer-emv.de).

The test bench PC must allow an evaluation of the monitoring signals of the test IC. The sources of the monitoring signals are the oscilloscope in conjunction with the **OA 4005** oscilloscope adapter and the connection board or proprietary solutions of the user.

BPS 203 and Connection board **CB 0708** can be controlled remotely by a DLL (included in scope of delivery) via LABView or Vee (Keysight). Please refer to the **BPS 203** user manual and **ICE1** user manual (**CB 0708** connection board for a description).

BPS 203 features an external trigger input. With this input the user can trigger a pulse at the P1202-2 with a provided logic signal.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

1.4.1 Test procedure

The test IC is tested in operation (this may require a customized firmware, see "Guideline IC-Test"). In general, the disturbance (ESD – magnetic field) is gradually increased in the course of the test.
The pulse repetition frequency is set in the BPS 203 client software. A defined number of pulses or a test duration can be set.
The period over which the disturbance is applied to the test IC depends on the probability of disturbing crucial signals in the test IC. Experience has shown that test periods of approx. 1 minute are sufficient in most cases. Longer test periods are needed if the probability of disturbing a critical signal / operating state of the IC under test is low. The test periods also depend on the safety demands in terms of the subsequent IC use.
The procedure is described in Chapter 3 of the Guide line IC EFT immunity (scope of delivery *ICE1)*. In general, the *P1202-2* should be switched off if the test IC signals any interference via its monitoring signals (monitoring *OA 4005* oscilloscope adapter, LEDs of the *GND 25* ground plane, *CB 0708* connection board with transmission to the PC, user solutions). In particular cases, the voltage can be further increased until other faults occur (monitoring *OA 4005* oscilloscope adapter, LEDs of the *GND 25* ground plane, *CB 0708* connection board with transmission to the PC, user solutions). **The IC can be destroyed in this case**. The risk can be reduced by monitoring or limiting the IC's power supply (connection board). The supply voltage can be interrupted in the case of a fault by an emergency shut-off function. The emergency shut-off can be triggered manually via a control unit or a proprietary solution of the user (automatically from the PC).

The disturbance field is generated in the field chamber of the field source when operating the test bench. Make sure that the field chamber is not opened during the test for safety reasons. The field source may only be operated with the field chamber closed by the spacer ring and ground plane.

1.4.2 Verifying the waveform of the test pulse

The waveform of the test pulse has to be verified prior to every major measuring job. Provided the waveform does not deviate from the given parameters, the field source only has to be calibrated every two years by **Langer EMV-Technik GmbH**.

The chapters **1.2.4** and **1.2.5** describe how to verify the waveform.

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

2 Safety instructions

This product meets the requirements of the following directives of the European Union: 2004/108/EC (EMC directive) and 2006/95/EC (low-voltage directive).
When using a product from Langer EMV Technik GmbH, please observe the following safety instructions to protect yourself from electric shock or the risk of injuries.

Read and follow the user manual and keep them in a safe place for later consultation. The device may only be used by personnel who are qualified in the field of EMC and who are fit to work under the influence of disturbance voltages and (electric and magnetic) ESD fields.

- Observe the operating and safety instructions for all devices used in the set-up.

- Never use any damaged or defective devices.

- Carry out a visual check before using a measurement set-up with a Langer EMV-Technik GmbH product. Replace any damaged connecting cables before starting the product.

- Never leave a product from Langer EMV-Technik GmbH unattended whilst this is in operation.

- The Langer EMV-Technik GmbH product may only be used for its intended purpose. Any other use is prohibited.

- People with a pace-maker are not allowed to work with this device.

- The test set-up should always be operated via a filtered power supply.

- **Attention! Functional near fields and interference emissions may occur when the field source is operated. The user is responsible for taking measures to prevent any interference to the correct function of products outside the operational EMC environment (in particular through interference emissions).**
  This can be achieved by:
  - observing an appropriate safety distance,
  - use of shielded or shielding rooms.

The disturbance field is generated in the field chamber of the field source when operating the test bench. Make sure that the field chamber is not be opened during the test for safety reasons. The field source may only be operated with the field chamber closed by the spacer ring and ground plane.

We cannot assume any liability for damage due to improper use.

- The disturbances that are injected into the modules can destroy the device under test (latch-up) if their intensity is too high. Protect the device under test by:
  - connecting a protective resistor in the IC's incoming power supply
  - increasing the disturbance gradually and stopping when a functional fault occurs,
  - interrupting the power supply to the device under test in the event of a latch-up.

Attention! Make sure that internal functional faults are visible from outside. The device under test may be destroyed due to an increase in the injection intensity if the faults are not visible from outside. Take the following measures as necessary:

- monitoring of representative signals in the device under test,
- special test software
- visible reaction of the device under test to inputs (reaction test of the device under test).

We cannot assume any liability for the destruction of devices under test!

LANGER	DE-01728 Bannewitz	P1202-2
EMV-Technik	mail@langer-emv.de	
	www.langer-emv.com	

3 Warranty

Langer EMV-Technik GmbH will remedy any fault due to defective material or defective manufacture, either by repair or by delivery of replacement, during the statutory warranty period.

This warranty is only granted on condition that:

- the information and instructions in the user manual have been observed.

The warranty will be forfeited if:

- an unauthorized repair is performed on the product,
- the product is modified,
- the product is not used according to its intended purpose.

4 Technical specifications

P1202-2 field source	
Dimensions (height/width/depth)	180 x 95 x 95 mm
Weight P1202-2	850 g
Maximum pulse current I_P	360 A
Generated max. magnetic flux density B (h = 3 mm)	8.3 mT
Pulse repetition frequency	0.1 – 10 Hz
Pulse shape (**Figure 6**)	1 / 60 ns
Voltage range U_P	0.1 – 9.5 kV
Shunt	0.1 Ω
Measurement output	50 Ω (SMB)
Current correction factor on the oscilloscope	26 dB

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

4.1 Characteristics of the P1202-2 magnetic field source

4.1.1 P1202-2 magnetic field source, probe constants

h [mm]	K1 [μT/A] oder [pVs/mm²A]	K2 [mV/mm²A]	$L_h{}'$ [pH/mm²]
3	24.4	25.7	24.4
10	12.4	12.7	12.4
	$B = K1 \cdot i_P$	$U_{ind} = K2 \cdot A_{IC} \cdot I_P$	$u_{ind} = L_h{}' \cdot A_{IC} \cdot \dfrac{di_P}{dt}$

Table 3 *P1202-2* magnetic field source, probe constants

4.1.2 Disturbances of the P1202-2 magnetic field source depending on the high voltage U_P

U_P [kV]	1	2	3	4	5	6	7	8	9	9.5
i_P [A]	36	72	108	144	181	217	253	289	325	340
B [mT] h = 3 mm	0.878	1.77	2.6	3.5	4.4	5.3	6.2	7	7.9	8.3
B [mT] h = 10 mm	0.44	8.9	1.3	1.75	2.2	2.6	3.1	3.5	3.9	4.15
U_{IC} [V] A_{IC} = 10 mm² h = 10 mm	4.45	8.9	13.4	17.8	22.3	26.7	31.2	35.6	40	42.3

Table 4 Disturbances of the *P1202-2* magnetic field source depending on the high voltage U_P.

4.1.3 Shunt 0.1 Ohm P1202-2

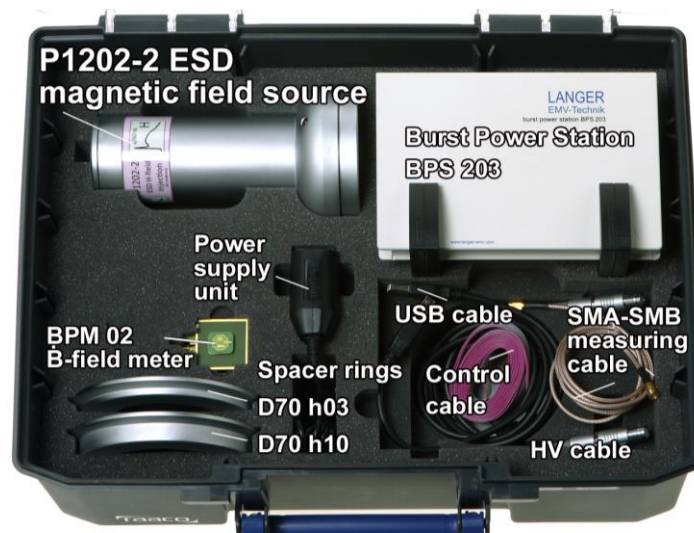| Bandwidth	3 GHz
Error	approx. 10 %
Maximum pulse current	360 A

Table 5 Shunt 0.1 Ohm *P1202-2*.

4.1.4 E-field suppression of P1202-2

	U_P / I_P [V / A]	E_P / I_P [V / cm A] h = 3 mm	E_P / I_P [V / cm A] h = 10 mm
P1202-2	4.8	16	4.8

Table 6 E-field suppression E_P / I_P of the *P1202-2* field sources depending on the peak value of the supply current I_P, (**Figure 25**).

LANGER
EMV-Technik

DE-01728 Bannewitz
mail@langer-emv.de
www.langer-emv.com

P1202-2

5 Scope of delivery

Item	Designation	Type	Qty.
1	ESD magnetic field source	**P1202-2**	1
2	Spacer 3 mm	**D70 h03**	1
3	Spacer 10 mm	**D70 h10**	1
4	High-voltage cable (HV cable)	**HV FI FI 1 m**	1
5	Measuring cable	**SMA-SMB 1 m**	2
6	Control cable	**FBK 12P 1 m**	1
7	Ḃ-field meter	**BPM 02**	1
8	Burst power station	**BPS 203**	1
9	USB cable	**USB B**	1
10	Power supply unit	12 V, 1 A	1
11	CD with software	**BPS203-Client**	1
	Driver for Windows, DLL		
12	Case		1
13	Quick guide		1
14	User manual	BPS 203	1
15	User manual	P1202-2	1

LANGER
EMV-Technik GmbH

Nöthnitzer Hang 31
DE-01728 Bannewitz
www.langer-emv.de

Tel.: +49(0)351/430093-0
Fax: +49(0)351/430093-22
mail@langer-emv.de