IC TEST SYSTEM

P1202-4 EFT/burst H-field probe
P1302-4 EFT/burst E-field probe

Operating instructions

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ATTENTION!
An EFT/burst generator supplies the devices with a high voltage. Please pay attention to the instruction manual of the respective generator used. The HV cable must be plugged into the probe before starting the measuring system. The measuring system may not be started if the probe or HV cable is defective or damaged.

1 System components

1 - Case		
2 - Instruction sheet		
3 - EFT/burst H-field probe		P1202-4
EFT/burst H-field probe		P1202-4 50R (with 50 Ω terminating resistor)
4 - EFT/burst E-field probe		P1302-4
EFT/burst E-field probe		P1302-4 50R (with 50 Ω terminating resistor)
5 - Spacer	3 mm	D70 h03
6 - Spacer	10 mm	D70 h10
7 - HV cable	1 m	with Fischer connectors at both ends
8 - Measuring cable	1 m	SMB-SMA

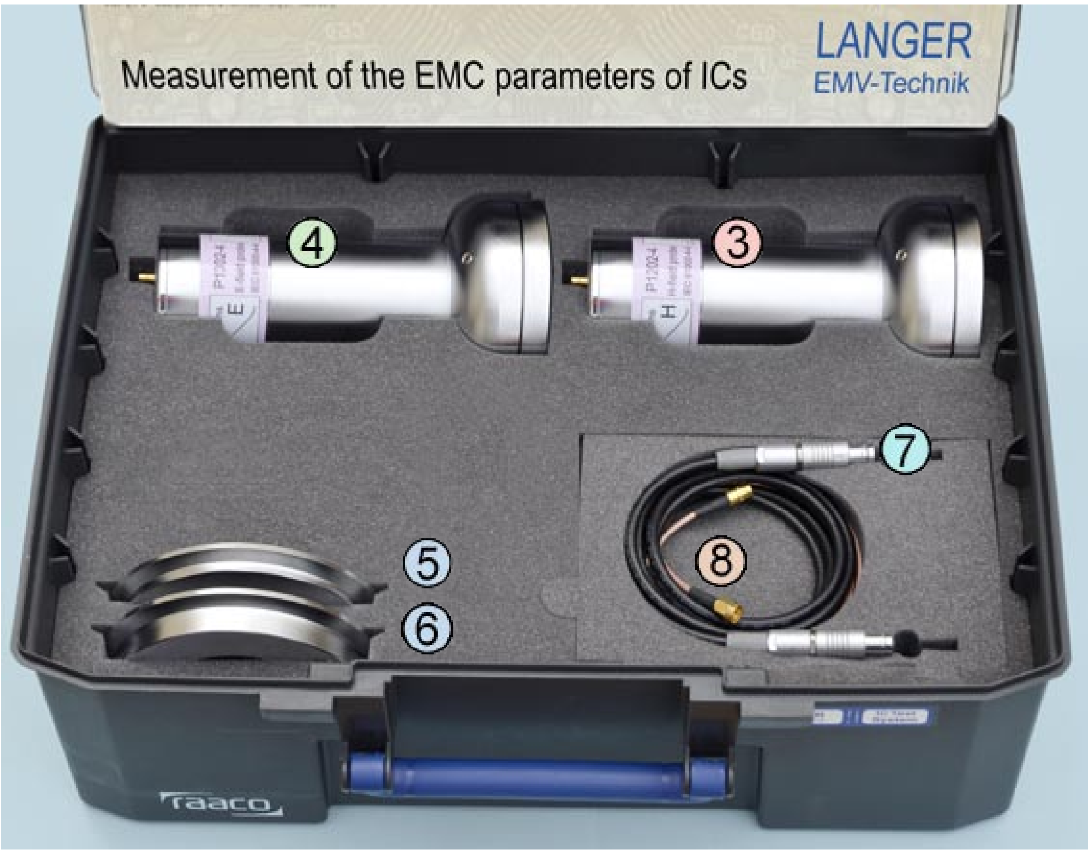

Figure 1 - P1202-4 / P1302-4 case

2 Measuring method

The P1202-4/P1302-4 probes are optional auxiliary instruments which can be used with an EFT/burst generator. They can be used to determine an IC‘s immunity to burst disturbance fields with a wave shape according to IEC 61000-4-4.

The integrated circuit is fixed to the ground plane with its test adapter and connected to the connection board. All supply and measuring devices needed to start the circuit are also connected to the connection board, which can be controlled from a PC via the USB interface.
The probe is placed over the circuit at a height which is defined by a spacer. The spacer chosen depends on the size of the device under test and the interference effect to be achieved.
The EFT/burst generator is connected to the probe via the enclosed HV cable. The permissible maximum generator voltage is 8 kV.
The 50R measurement output is connected to an oscilloscope to monitor the burst pulse which is present on the probe and/or use this pulse as a trigger signal.
The circuit‘s functions are controlled and monitored with the supply and measuring devices connected to the connection board. The user thus receives a direct feedback if any functional faults occur under the influence of burst disturbance fields. The immunity level which is determined on this basis allows the user to compare ICs in terms of their immunity to H/E-fields.

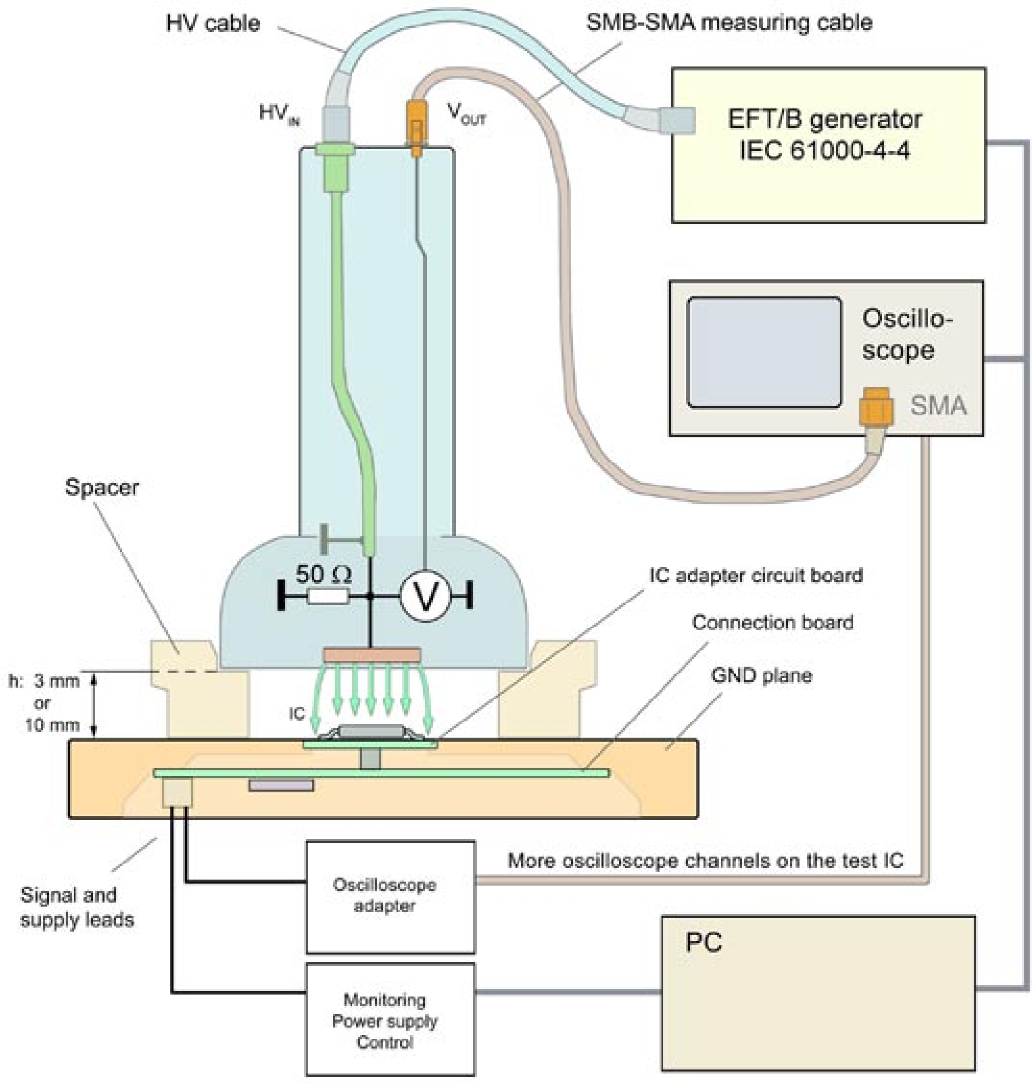

Figure 2 – Test set-up

3 Probe description

3.1 P1202-4 / P1202-4 50R H-field probe

The P1202-4 / P1202-4 R50 probe is used to generate magnetic disturbance fields.
It has two connectors:

- 1x HV input (Fischer D103A023)
- 1x measurement output (male SMB)

The HV socket is connected to the EFT/burst generator via the enclosed HV cable. The probe is designed for a maximum pulse voltage of 8 kV according to IEC 61000-4-4.
Depending on the probe type, its input is fitted with a 50R terminating resistor (marked as 50R).

An oscilloscope is connected to the 50 Ohm SMB measurement output to monitor the burst pulses or to trigger on them.

The direction of the current flow in the conductor (technical direction of the current flow) is marked on the probe housing.

Direction of the current flow – tip of the arrow

Direction of the current flow – end of the arrow

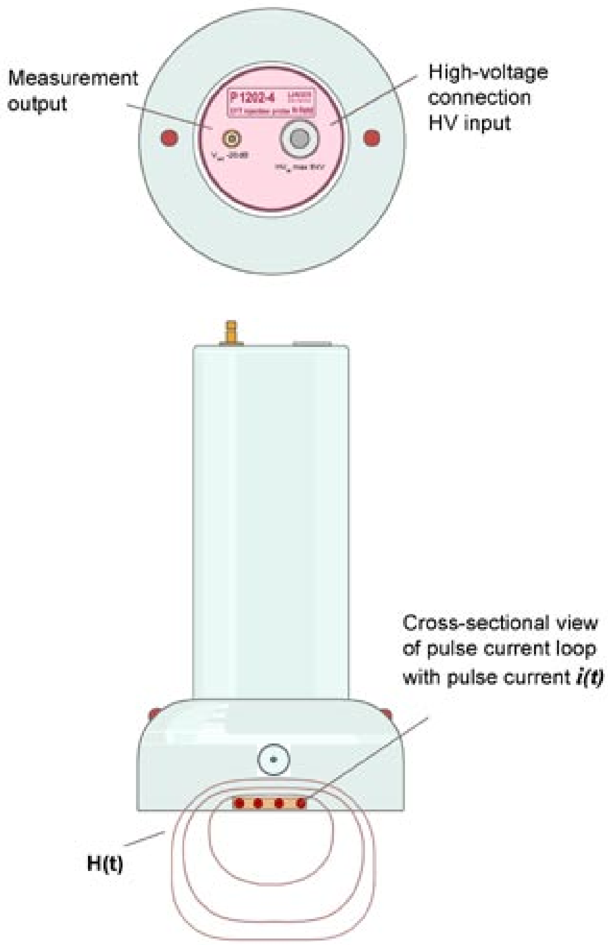

Figure 3 – P1202-4 / P1202-4 50R H-field probe

The direction of the current flow is also shown on the probe's bottom by an arrow.

The field angle can be adjusted by rotating the probe in the spacer and read off on the spacer scale in degrees.

Figure 4 – Bottom of the H-field probe

3.2 P1302-4 / P1302-4 50R E-field probe

The P1302-4 / P1302-4 R50 probe is used to generate electric disturbance fields.

It has two connectors:

- 1x HV input (Fischer D103A023)
- 1x measurement output (male SMB)

The HV socket is connected to the EFT/burst generator via the enclosed HV cable. The probe is designed for a maximum pulse voltage of 8 kV according to IEC 61000-4-4.
Depending on the probe type, its input is fitted with a 50R terminating resistor (marked as 50R).

The E-field electrode is connected to the measurement output via a voltage divider which is fitted with a 50 Ohm terminating resistor. An oscilloscope is connected to monitor the burst pulses or trigger on them.

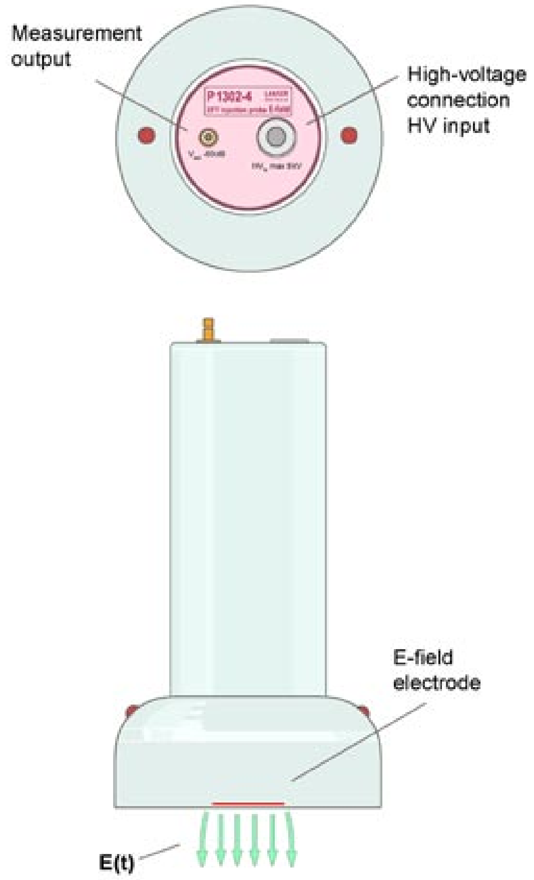

Figure 5 – P1302-4 / P1302-4 50R E-field probe

There are no direction marks on this probe. The electric field is independent of the probe‘s angle of rotation.

Figure 6 – Bottom of the E-field probe

3.3 Spacers

The spacers are used to maintain a defined gap between the probe‘s field electrode and the ground plane.

Gaps of h = 3 mm and h = 10 mm can be selected.

A field chamber is created between the probe and ground plane.
The scale on the top of the spacer is used to adjust the field angle in conjunction with the P1202-4 / P1202-4 50R probe.

The spacer‘s field angle and height have a direct influence of the interference effect.
(see Chapter 4 „Design / Mechanism of action“)

Figure 7 – Top view of spacer

Spacer - 10 mm

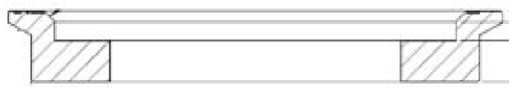

Figure 8 – Sectional view of 10 mm spacer

Spacer - 3 mm

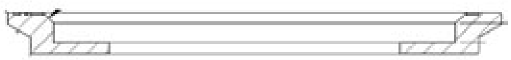

Figure 9 – Sectional view of 3 mm spacer

4 Design / Mechanism of action

4.1 P1202-4 / P1202-4 50R H-field probe

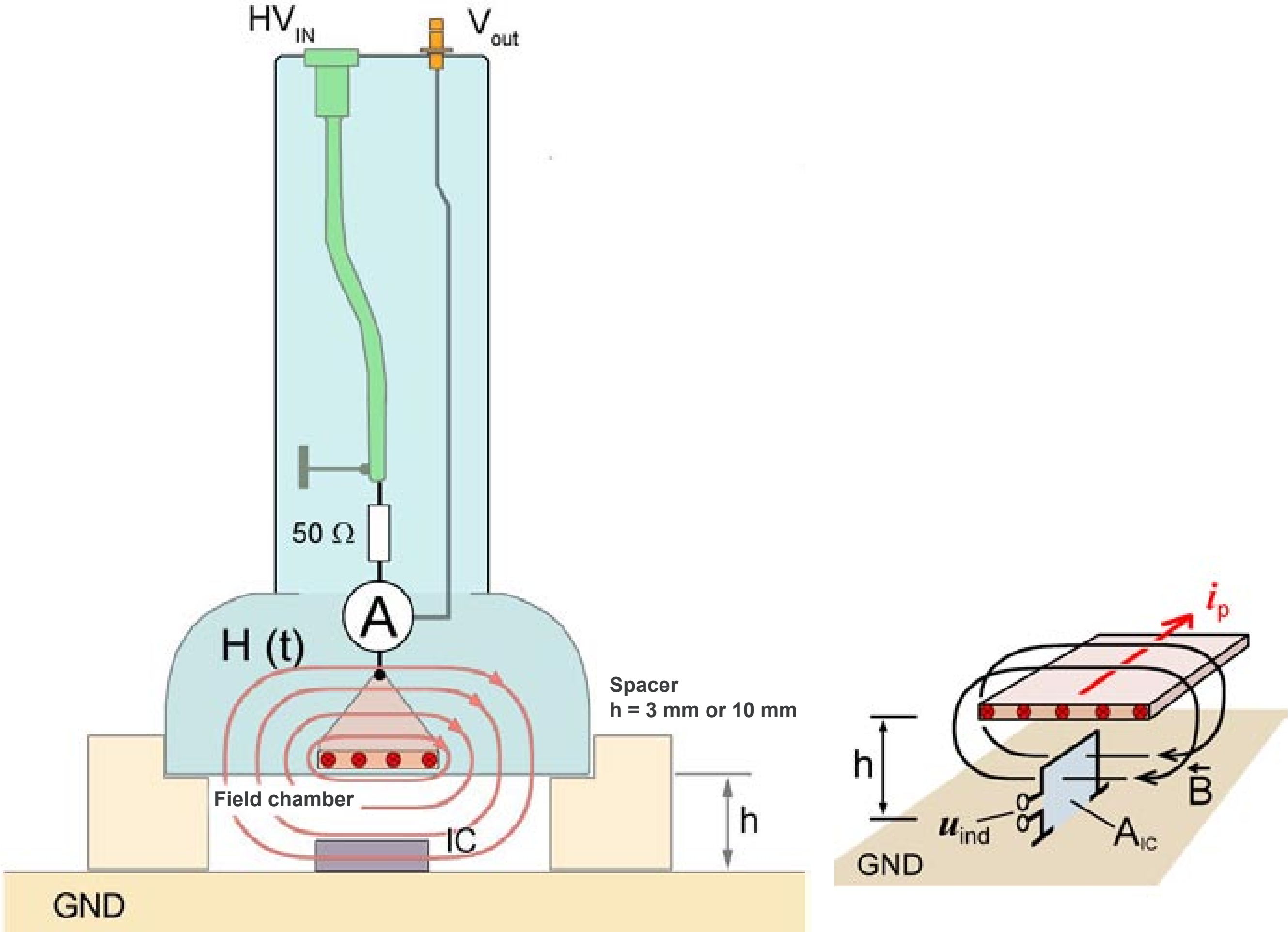

Figure 10 – Inner design of the P1202-4 / P1202-4 50R probe

The HV input of the P1202-4 50R probe has an internal 50R terminating resistor whereas the P1202-4‘s HV input is connected to the wave guide via a short circuit (probe‘s internal magnetic field source).

The current which is injected directly into the probe by the EFT/burst generator flows through the conductor and generates a magnetic vortex field B in the field chamber. The magnetic field B penetrates the test IC. A disturbance voltage u_{ind} is induced in the current loops A_{ic} of the IC.
The induced disturbance voltage u_{ind} may interfere with signals or the supply voltage in the IC and cause faults or inject a disturbance current into the loop and thus interfere with the circuit.

The level of the voltage induced in the device under test and its resulting interference effect depend on parameters such as:

- Level of the set generator voltage
- Distance to the probe‘s conductor
- Angle of the wave guide relative to the conductor loop in the device under test
- Size of the conductor loop in the device under test

The IC pins form the biggest loops in connection with the die and the bond wires.

The electrical parameters and/or the correlation between the voltage set on the EFT/burst generator and the interference effect caused on the IC can be determined in the following way.

The equivalent circuit diagram P1202-4 50R (Figure 11) corresponds approximately to the measurement set-up described earlier.

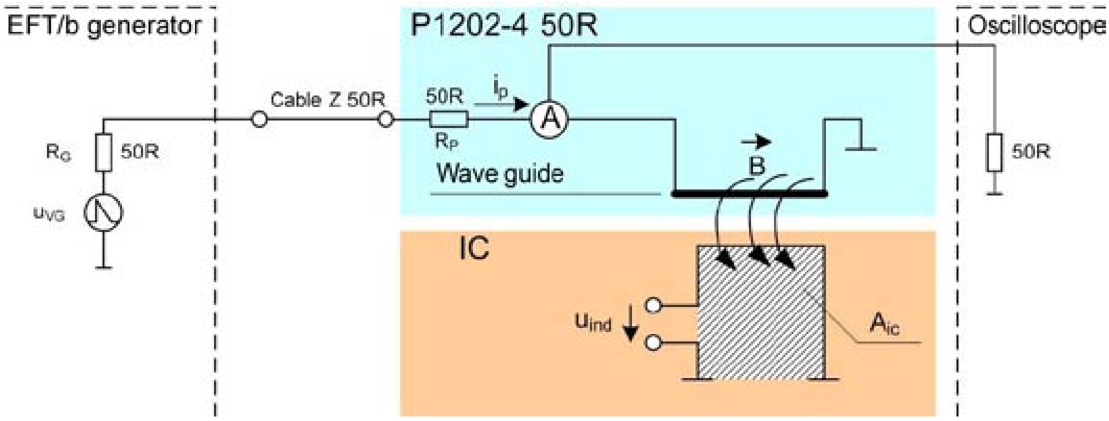

Figure 11 – Equivalent circuit diagram P1202-4 50R

i_p: Current through the wave guide
u_{VG}: Generator voltage
R_G: Internal generator resistance
R_p: Internal probe resistance
u_{ind}: Voltage induced in the IC‘s conductor loop
A_{IC}: Surface area of the IC‘s conductor loop
B: Magnetic field generated by the probe and penetrating the IC
L_{IC}: Inductance of the IC‘s conductor loop

The following probe-specific constants have been introduced to facilitate the determination of the voltage induced and/or flux density occurring in the conductor loop.

L‘: Inductance of the IC‘s conductor loop per surface area — $L' = L_{ic} / A_{IC}$
K1: Correlation between the flux density and current i_p — $K1 = B / i_p$
K2: Correlation between the induced voltage u_{ind}, area A_{IC} and current i_p at a burst event (rise time of 5 ns) — $K2 = u_{ind} / (A_{IC} * ip)$

Please refer to Table 1 „Probe constants“ for the precise numerical values depending on the respective spacer used.

h [mm]	K1 [µT/A] oder [pVs/mm²A]	K2 [mV/mm²A]	L´ [pH/mm²]
3	31	4,7	25
10	15,5	2,3	12
	$B = K1 \cdot i_p$	$U_{ind} = K2 \cdot A_{IC} \cdot Ip$	$U_{ind} = L' \cdot A_{IC} \cdot di_p / dt$

Table 1 – P1202-4 / P1202-4 50R probe constants

The following correlations apply:

$i_p = u_{VG} / (R_G + R_p)$
$U = L * di/dt$

This results in the induced voltage u_{ind}:

$u_{ind} = L' * A_{IC} * dip / dt$

Numerical example:
Given: P1202-4 50R probe (internal 50R terminating resistor), 10 mm spacer, conductor loop enclosing a surface area of 40 mm², standard burst pulse (rise time of 5 ns), peak voltage of 3 kV
Find: u_{ind}; B

Solution:
i_p = 3 kV / (50 R + 50 R) = 30 A
L' = 12 pH / mm² (see Table 1 „Probe constants")
A_{IC} = 40 mm²
K1 = 15.5 µT / A

u_{ind} = 12 pH / mm² * 40 mm² * 30 A / 5 ns
u_{ind} = 2.88 V

B = 15.5 pVs/mm² A * 30 A
B = 465 pVs/mm² = 465 µT

The same correlations apply to the P1202-4 probe without internal 50 Ohm terminating resistor.

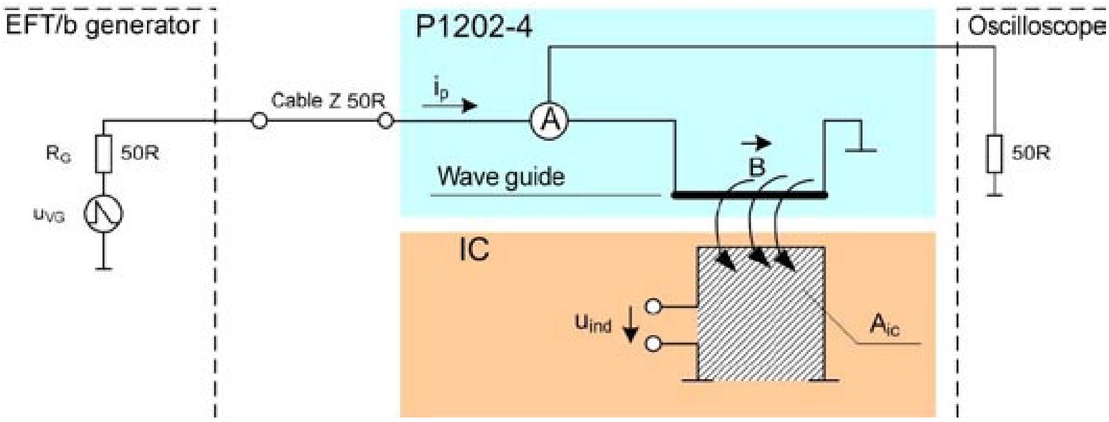

Figure 12 – Equivalent circuit diagram P1202-4

The calculation of the current i_p is simplified as shown in Figure 12:

$i_p = u_{VG} / R_G$

According to the aforementioned numerical example, the resulting induction voltage would be twice as big (5.96 V) for a probe without an internal 50 Ohm terminating resistor than for a probe with a terminating resistor.

The probe without terminating resistor generates a deformed curve due to a second reflexion on the EFT generator which is misadjusted in this case. Since the EFT/burst generator operates under short-circuit conditions, the interference effect is twice as big as for the probe with a terminating resistor.

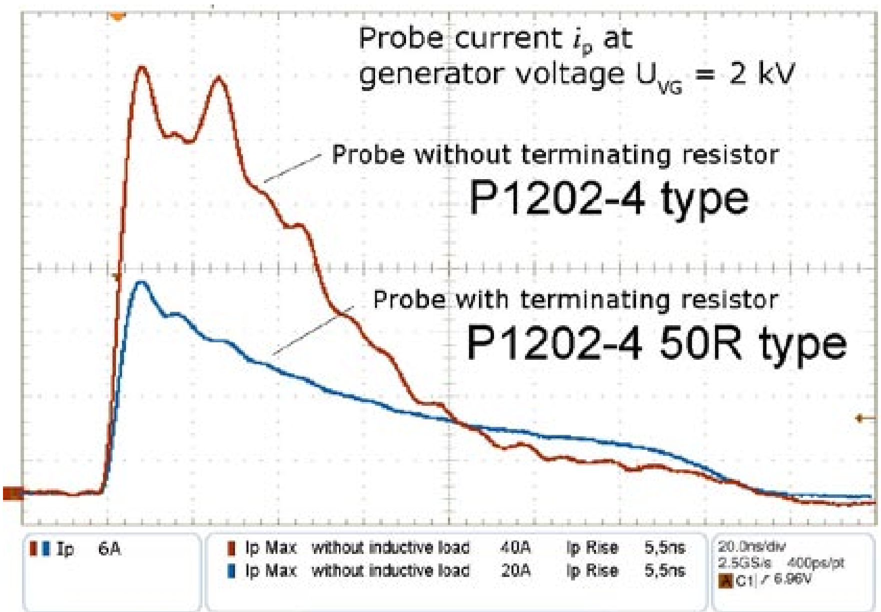

Figure 13 – Current characteristic of P1202-4 / P1202-4 50R

The current characteristic of the respective probe is monitored by an oscilloscope via the measurement output. The output has a 50 Ohm terminating resistor. The attenuation is 26 dB.

ATTENTION!
An external attenuator must be connected in the oscilloscope‘s incoming circuit as of a generator voltage of 4 kV, otherwise the voltages which are present on the measurement output may lead to the destruction of the measurement input and/or entire oscilloscope.

The following table contains reference values for the measured voltages. The measured values depend on the respective EFT/burst generator and are subject to the usual variation which is described in the standard.

Generator voltage U_{vg}	Voltage at the measurement output of P1202-4	Voltage at the measurement output of P1202-4 50R
1 kV	1 V	0.5 V
3 kV	3 V	1,5 V
4 kV	4 V	2 V
6 kV	6 V	3 V
8 kV	8 V	4 V

Table 2 – Voltage values at the measurement output of P1202-4 / P1202-4 50R

4.2 P1302-4 / P1302-4 50R E-field probe

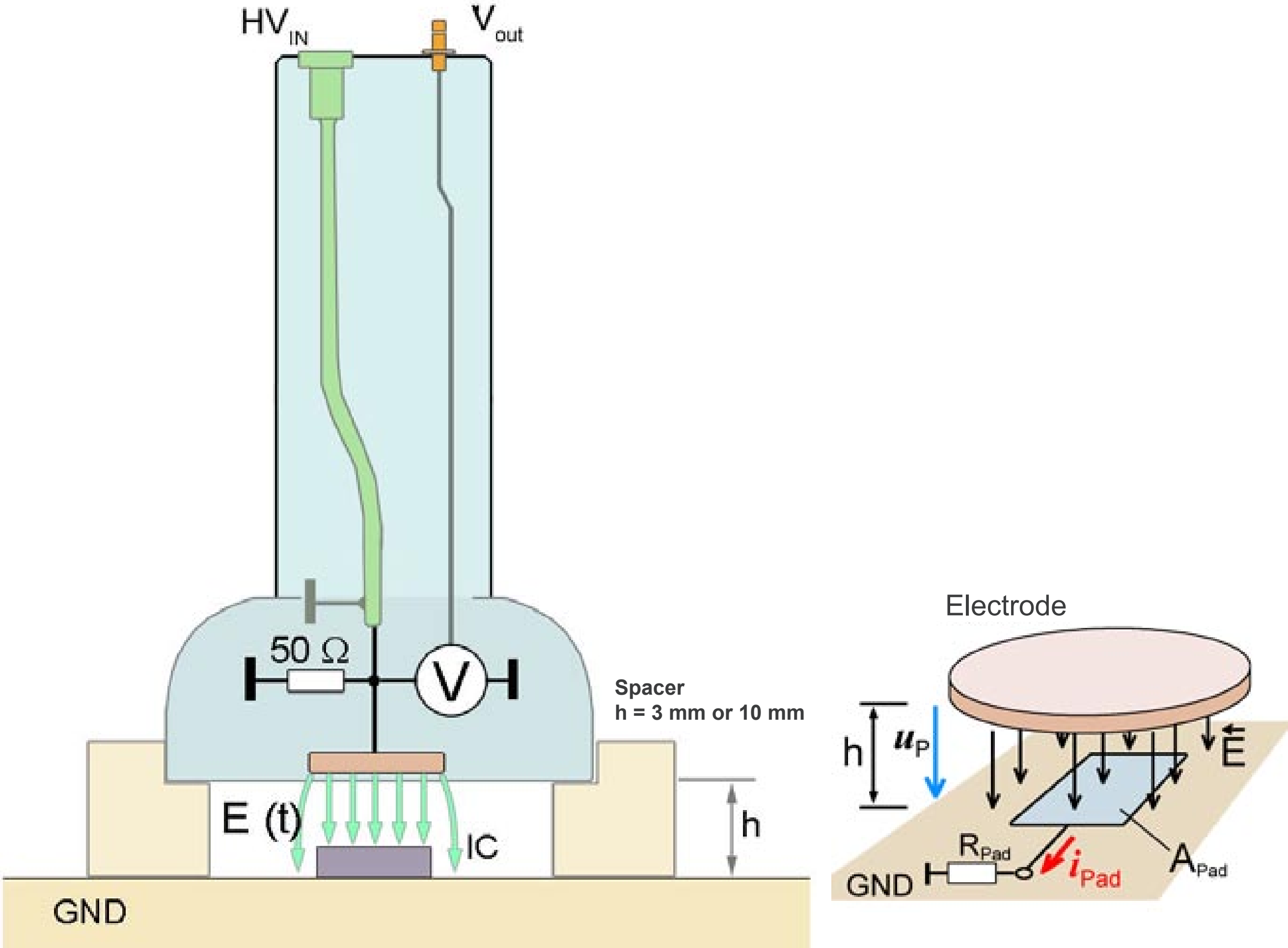

Figure 14 – Inner design of the P1302-4 / P1302-4 50R probe

The HV input of the P1302-4 50R probe has an internal 50R terminating resistor whereas the P1302-4 probe has no internal terminating resistor.

The voltage applied to the probe‘s HV input reaches the electrode. It is present between the electrode and GND plane and generates an electric field depending on the distance h (spacer). The field is proportional to the burst voltage.
The electric field lines end on the IC‘s metal parts A_{Pad} (pad pin, bond wire, die).
They conduct a displacement current into these surfaces.

The strength of the electric field and the resulting interference effect depend on the following parameters among other things:

- Level set for the burst voltage
- Distance to the probe‘s coupling electrode
- Surface area of the IC‘s pad

The electrical parameters and/or the correlation between the voltage set on the EFT/burst generator and the interference effect caused on the IC can be determined in the following way (the pad's GND capacitance can be ignored).
The equivalent circuit diagram of P1302-4 50R (Figure 15) corresponds approximately to the measurement set-up described earlier.

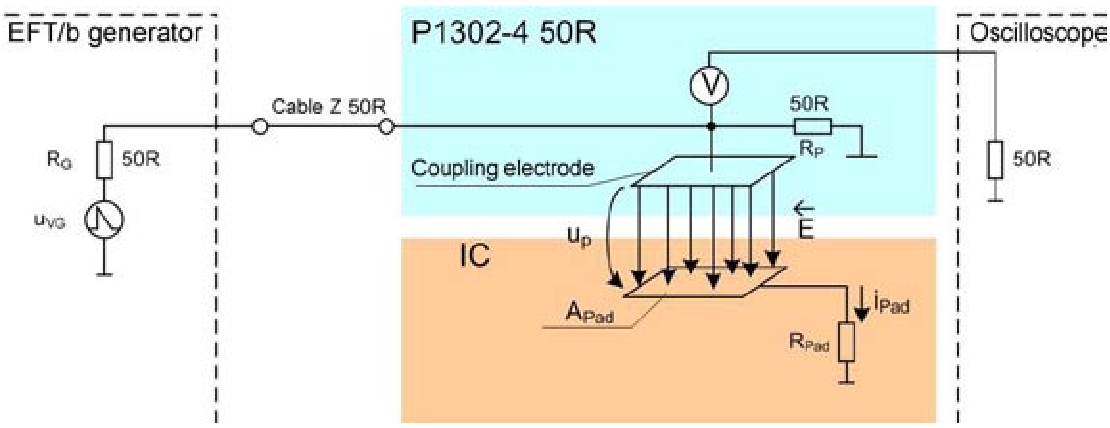

Figure 15 – Equivalent circuit diagram of P1302-4 50R

u_P: Voltage between the probe's coupling electrode and the IC's coupling surface area
u_{VG}: Generator voltage
R_G: Internal generator resistance
R_P: Internal probe resistance
E: Electric field strength between the probe's coupling electrode and the IC's coupling surface area
A_{Pad}: Coupling surface area of the IC
R_{Pad}: Pad resistance
h: Gap between the coupling electrode and IC pad

The following probe-specific constants have been introduced to facilitate the estimation of the displacement current which is generated and/or field strength occurring in the pad surface area.

C': Coupling capacity between the pad and electrode per pad surface area $C' = C_{Pad} / A_{Pad}$

Please refer to Table 3 „Probe constants" for the precise numerical values depending on the respective spacer used.

h [mm]	C' [f F/mm²]
3	5
10	1,35
$u_{Pad} = R_{Pad} \cdot i_{Pad}$	$i_{Pad} = C' \cdot A_{Pad} \cdot du_P / dt$

Table 3 – P1302-4 / P1302-4 50R probe constants

The following correlations apply:

$$i = C * dU / dt$$
$$u_{Pad} = R_{Pad} * ic$$
$$E = u / h$$

The following thus applies to the pad current i_{Pad}:

$$i_{Pad} = C' * A_{Pad} \, du_p / dt$$

and the electric field strength between the pad and the coupling electrode:

$$E = u_p / h$$

The voltage difference du_p / dt allows the current i_{Pad} to flow into the pad via the pad capacitance C_{Pad}. This current drains towards GND (or VCC) via the pad resistor R_{Pad} (e.g. pull up, pull down resistor) causing a voltage drop u_{Pad} on the IC. The current i_{Pad} can also penetrate deeper into the die via internal clipping diodes and cause interferences there.

Numerical example:
Given: P1302-4 50R probe (with internal 50R terminating resistor), 3 mm spacer, pad surface area of 2 mm², standard burst pulse (rise time of 5 ns), peak voltage of 2 kV
Find: : i_{Pad} ; E

Solution:
$u_p = 1/2 \, u_{VG} = 1$ kV
$A_{Pad} = 2$ mm²
C‘ = 5 fF / mm² (see Table 3 „P1302-4 / P1302-4 50R probe constants“)

i_{Pad} = 5 fF / mm² * 2 mm² * 1 kV / 5 ns
i_{Pad} = 2 mA

E = 1 kV / 0.003 m
E = 333.33 kV / m

The same correlations apply to the P1302-4 probe without internal 50 Ohm terminating resistor.

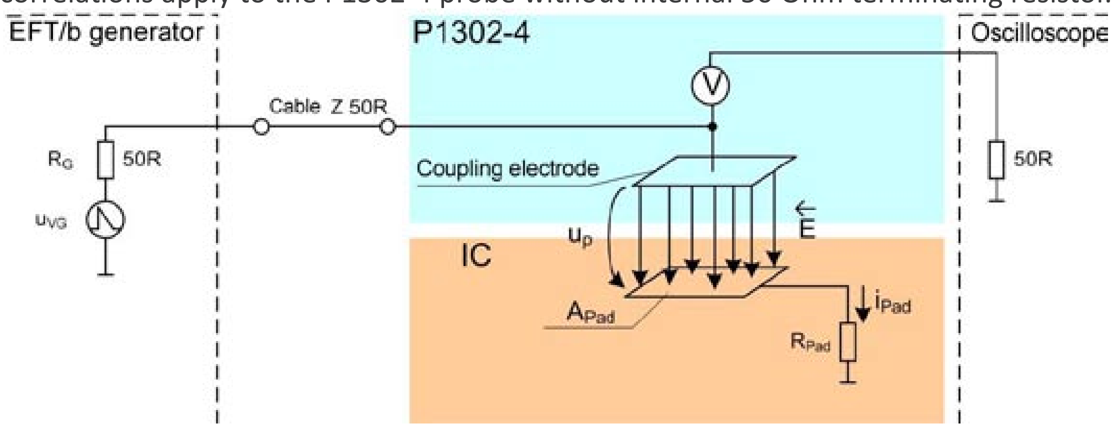

Figure 16 – Equivalent circuit diagram of P1302-4

The voltage on the coupling electrode of the probe without terminating resistor is twice as big as for the probe with a terminating resistor.

The probe without terminating resistor generates a deformed curve due to a second reflexion on the EFT generator which is misadjusted in this case. Since the EFT/burst generator operates under open-circuit conditions, the interference effect is twice as big as for the probe with an internal terminating resistor.

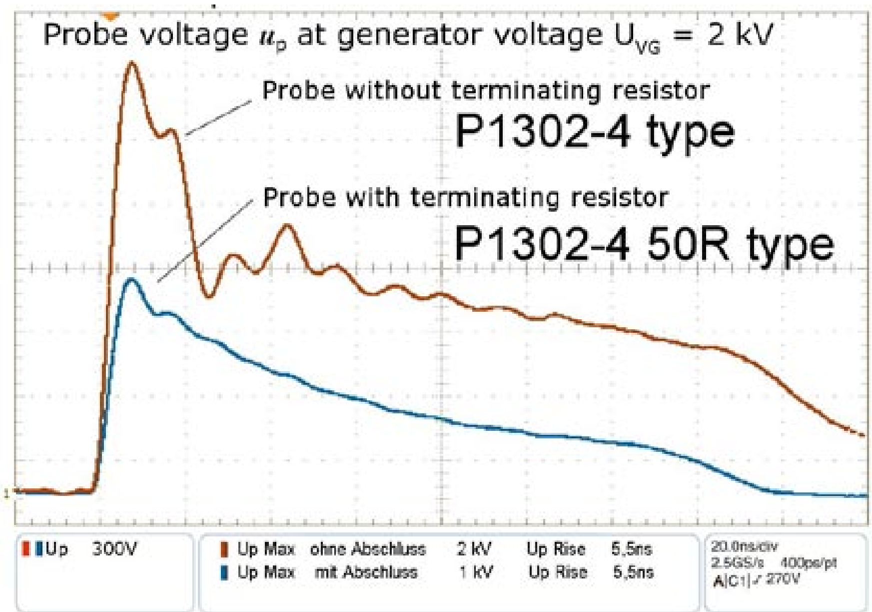

Figure 17 – Voltage characteristic of P1302-4 / P1302-4 50R

The voltage characteristic of the respective probe is monitored by an oscilloscope via the measurement output. The output has a 50 Ohm terminating resistor. The attenuation is 60 dB.

ATTENTION!
An external attenuator must be connected in the oscilloscope‘s incoming circuit as of a generator voltage of 4 kV, otherwise the voltages which are present on the measurement output may lead to the destruction of the measurement input and/or entire oscilloscope.

The following table contains reference values for the measured voltages. The measured values depend on the respective EFT/burst generator and are subject to the usual variation which is described in the standard.

Generator voltage U_{vg}	Voltage at the measurement output of P1302-4	Voltage at the measurement output of P1302-4 50R
1 kV	1 V	0.5 V
3 kV	3 V	1,5 V
4 kV	4 V	2 V
6 kV	6 V	3 V
8 kV	8 V	4 V

Table 4 – Voltage values at the measurement output of P1302-4 / P1302-4 50R

5 Application example

The micro-controller 80C51 from three different manufacturers was the object of the following test aimed at comparing the three ICs in terms of their immunity to magnetic fields.

The following parameters apply for the measurement:

- Identical package pin-out (VQFP44)
- Comparable functionality -> all three are 8051-compatible
- Identical test adapter (packaged with the same filter elements)
- Same test program

Preparation:

The integrated circuit is tested during operation. The test program is selected so that each component in the circuit (timer / Uart / watchdog, etc.) is used and the corresponding test signals on the pins provide information about their functionality. The control and monitoring components which are required depend on the respective circuit under test.

A pin was continually toggled (heartbeat signal) and a static signal sent to the outside for demonstration purposes in the present example. An oscilloscope is sufficient to monitor this test set-up. In addition, the outputs were connected to LEDs to receive a visual feedback about the operating state of the device under test.
The individual operating states of the IC were controlled from a PC via the connection board.

The test program runs in the following way:
LED_01 (heartbeat) flashes slowly while LED_02 comes on permanently during the start of the IC. Depending on its firmware, the IC changes over to another operating mode which lets LED_01 (heartbeat) flash faster and switches LED_02 off should a crash and subsequent reset occur. Irregularities of the heartbeat signal indicate an internal program sequence problem.

5.1 Measurement set-up:

The subsequent figures show the measurement set-up used for the test (see Figure 2 „Test set-up“).

Figure 18 – Measurement set-up with the device under test in the test adapter

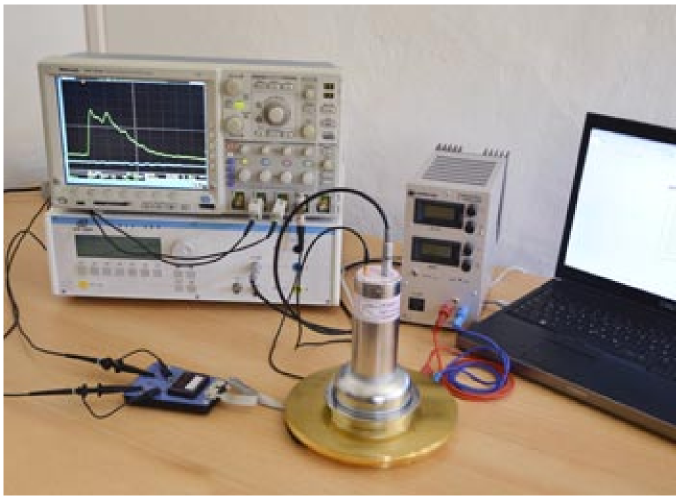

Figure 19 – Measurement set-up with the P1202-4 probe in position

The following components are used:
- EFT/burst generator with a maximum voltage of 4.4 kV
- GND 25 ground plane and the integrated CB 0708 connection board with the DUT inserted in the test adapter
- P1202-4 probe (without terminating resistor) with a 3 mm spacer
- Oscilloscope and OA 4005 oscilloscope adapter
- IC power supply / connection board

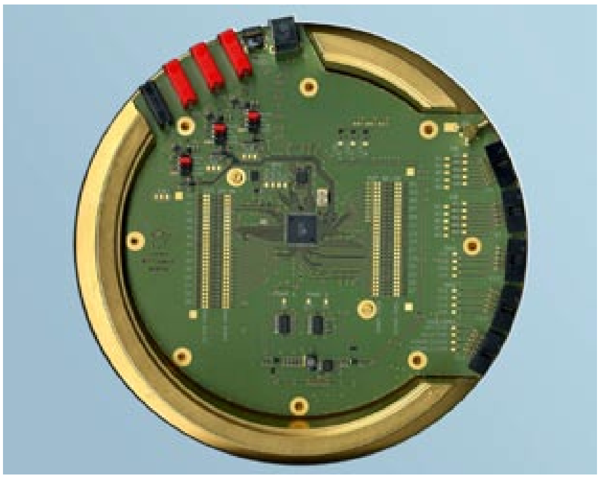

Figure 20 – Bottom of the ground plane and connection board

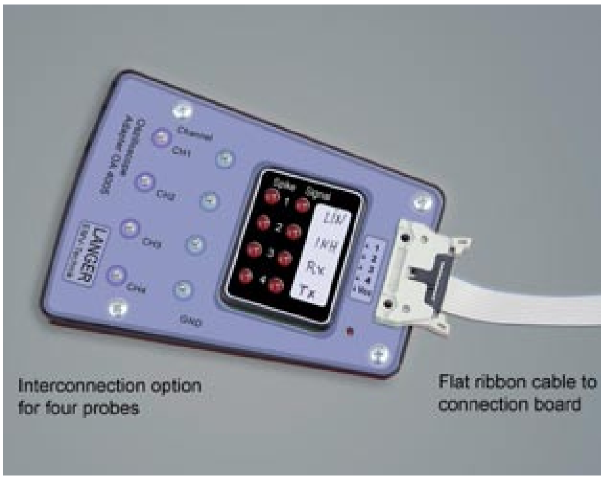

Figure 21 – Oscilloscope adapter

The IC is connected to the CB 0708 connection board via the test adapter. This allows the user to monitor and control the IC. The CB 0708 is controlled from a PC via its USB interface.
The present measurement set-up also comprises the OA 4005 oscilloscope adapter which makes it easier to connect the oscilloscope‘s probe heads.
The measurement set-up is supplied with power by a controlled switched-mode power supply unit with an internal current limiting function intended to protect the IC from destruction in the event of a malfunction.
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The P1202-4 probe (without terminating resistor) was used for the measurement in this case and connected to the EFT/burst generator via the enclosed HV cable. The 50 Ohm measurement output is connected to the oscilloscope to monitor the injected pulses.

5.2 Measurement process:

1. Start the IC program sequence.
2. Monitor the function using an oscilloscope and connection board.
3. Place a probe over the centre of the integrated circuit with a spacer (see Figure 18 and 19).
   - Align the mark showing the direction of the current flow on the probe with the scale on the spacer (e.g. 0°).
   - You must choose the same probe orientation for each device under test to ensure that the results are comparable.
   - You need not adjust the field angle if an electric field is coupled in.
4. Adjust the EFT/burst generator to the desired severity (burst according to the standard IEC 61000-4-4).
   - Select the polarity
   - Start with the lowest amplitude so as not to destroy the device under test.
5. Increase the severity (amplitude) until a fault occurs.
6. Switch over the polarity and repeat items 4 and 5.
7. Readjust the field angle and repeat items 4 to 6.
   - It is sufficient to turn the probe by 90° just once for a rough estimate of the disturbance immunity.

The following table contains the results of the measurements described above. The results show at which voltage amplitude, polarity and field angle a reset occurred for the different IC‘s. The integrated circuits were subjected to the disturbance for one minute in each of the test runs.

Manufacturer	Polarity	Generator voltage at the moment the circuit failed		
		Angle 0°	Angle 90°	Angle 180°
Manufacturer 1	positive	2040 V	No failure	No failure
	negative	No failure	No failure	2000 V
Manufacturer 2	positive	4000 V	No failure	No failure
	negative	No failure	No failure	4000 V
Manufacturer 3	positive	3600 V	No failure	800 V
	negative	800 V	No failure	3300 V

Table 5 – Immunity levels determined by the test

5.3 Evaluation:

The circuits' different immunity levels become visible straight away. The 8051 IC from Manufacturer 2 could only be caused to crash at 4 kV while the IC from Manufacturer 3 carried out a reset at a value as low as 1 kV. Since all test conditions (test set-up, interconnection, test program, etc.) were identical, the differences must be inherent to the circuits themselves.
The measurements at a field angle of 180° provide the same results as the measurements at a field angle of 0° with the opposite generator polarity.
The deviations which occur and are clearly visible in the table can be explained by variations within the generator. These can be verified on the basis of the wave shape generated at the oscilloscope's measurement output.
None of the integrated circuits could be influenced at a field angle of 90°.
The heartbeat signal was not influenced during any of the measurements, i.e. the IC's were functional until the reset. In view of these findings it seems reasonable to assume that the circuits' power supply was disturbed.

The Vcc and Vss pins are on opposite sides of the IC package in the present example. A maximum voltage is induced in this loop at a field angle of 0° and/or 180°, leading to an IC power supply failure and thus a reset.

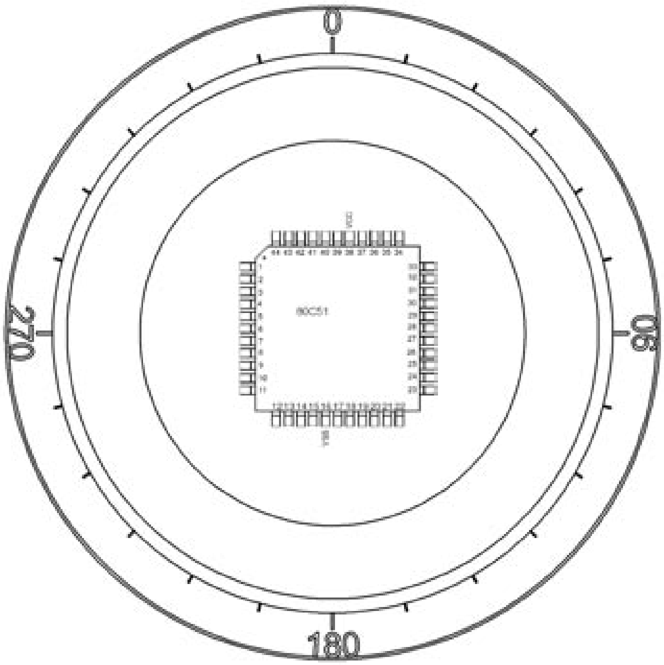

Figure 22 – Position of the 8051 power supply pins / field angle

The process described above is identical for the E-field probe. Rotating the probe is unnecessary since the electric field is independent of the angle of rotation.

6 Technical specifications

Maximum values of the EFT injection probes

Probetyp	P1202-4 50R		P1202-4		P1302-4 50R	P1302-4
U_{VG}	I_{pmax}	B_{max} h-3 mm	I_{pmax}	B_{max} h-3 mm	E_{max} h-3 mm	
4000 V	40 A	1.24 mT	80 A	2.48 mT	650 kV/m	1300 kv/m
8000 V	80 A	2.48 mT	160A	5 mT	1300 kV/m	2600 kV/m

The actual currents and voltages can be checked at the measurement output.

Limit values / load factor of H-field probes

Parameter	P1202-4 50R	P1202-4
Pulse voltage	8 kV	8 kV
Continuous output P_{Vor} (1 GHz)	5 W	30 W
Impedance, measurement output	50 Ω	50 Ω
Correctionfactor,measurement output	26 dB	26 dB

Limit values / load factor of E-field probes

Parameter	P1302-4 50R	P1302-4
Pulse voltage	8 kV	8 kV
Continuous output P_{Vor} (1 GHz)	5 W	30 W
Impedance, measurement output	50 Ω	50 Ω
Correctionfactor,measurement output	60 dB	60 dB

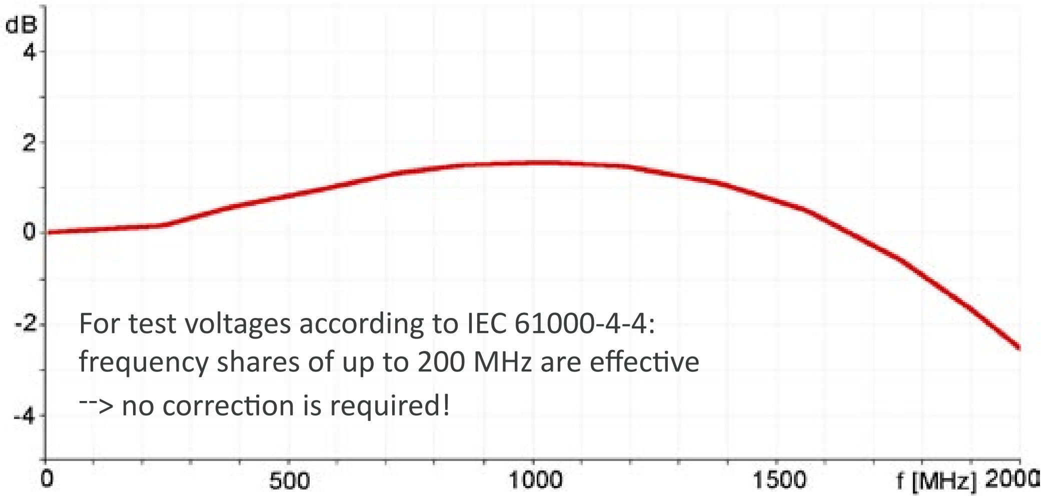

Figure 23 – Correction curve for P1302-4 / P1302-4 50R measurement output

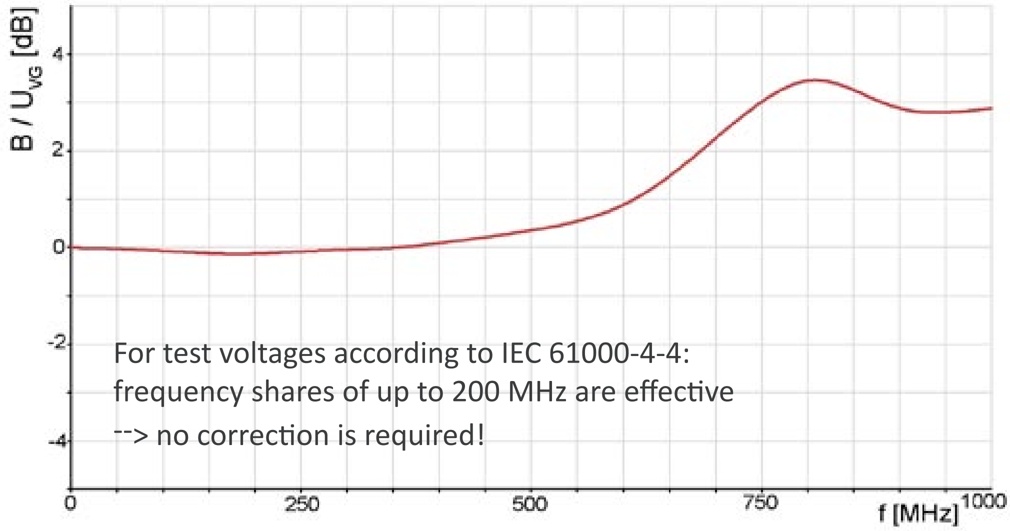

Figure 24 – Frequency response U_{VG} / P1202-4 / P1202-4 50R H-field probe

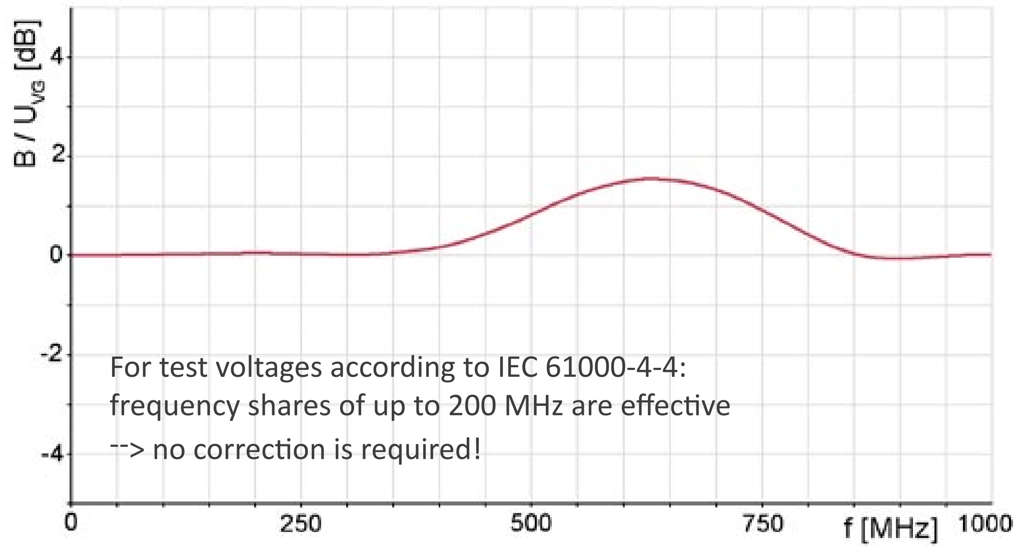

Figure 25 – Frequency response U_{VG} / P1302-4 / P1302-4 50R E-field probe

7 Safety and warranty

This product meets the requirements of the following directives of the European Union:
2004/108/EEC (EMC Directive) and 2006/95/EEC (Low Voltage Directive).

7.1 Safety instructions

- When using a LANGER EMV Technik product, please observe the following safety instructions to protect yourself from electric shock or the risk of injuries:

- Read and follow the operating instructions 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) burst fields.
  Persons with a pace-maker, for example, are excluded from this work.

- Observe the safety instructions and warnings provided on the product.

- Visually inspect the LANGER EMV-Technik product before using it. - Never leave a Langer EMV-Technik product unattended whilst this is in operation.

- Read the information on the symbols on the product in the operating instructions.

- The LANGER EMV-Technik product may only be used for its intended purposes.
  Any other use is prohibited.

- Do not switch the LANGER EMV-Technik product on until it has been fully installed.
  Replace any damaged connecting cables before starting the product.

- **Attention!**
  Functional near fields and radiated interference may occur when the LANGER EMV-Technik product is operated, in particular in connection with a test set-up. 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 radiated interference).

7.2 Safety symbols

This symbol in connection with another symbol, terminal or device indicates that the user should refer to the operating instructions for more information in order to avoid personal injuries and material damage in connection with the LANGER EMV-Technik product.

This ATTENTION symbol indicates a potentially dangerous situation which results from ignoring minor damage to the LANGER EMV-Technik product.

7.3 Warranty

We will remedy any defect which is due to defective materials or defective manufacture, either by repair or supply of spare parts, during the legal warranty period. The warranty period is subject to the applicable law of the country where the LANGER EMV-Technik product was purchased.

Warranty is only granted on condition that:
- The LANGER EMV-Technik product is handled with care.
- The operating instructions are observed.
- Only original spare parts are used.
- External components such as power supply units, connecting cables, etc. have separate warranty terms and conditions which apply for the respective manufacturer.

Warranty is forfeited if:
- Unauthorized repairs have been made on the LANGER EMV-Technik product.
- The LANGER EMV-Technik product has been modified.
- The LANGER EMV-Technik product has not been used correctly.