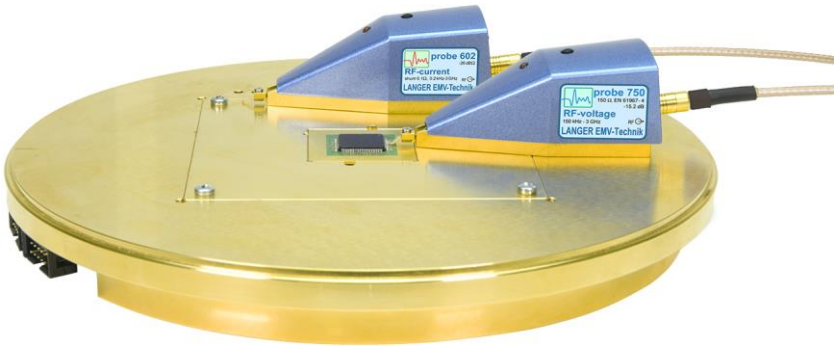
LANGER
EMV-Technik

IC TEST SYSTEM

User manual

P600 / P750 set

RF conducted measurement
Analysis



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1 Safety Instructions

Read and follow the operating instructions carefully and keep them in a safe place for later consultation. The devices may only be used by personnel who are qualified in the field of electromagnetic compatibility (EMC) and who are eligible to carry out this work.

When using a product from Langer EMV-Technik GmbH, please observe the following safety instructions to protect yourself from electric shocks and the risk of injuries and to protect the devices used and the test IC from destruction.

- 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 forbidden.

- Only use a neutral detergent for cleaning the P603 / P750 set.

Attention: Function-related near fields and disturbance emissions may develop, particularly in connection with a test set-up while operating the product of the LANGER EMV-Technik GmbH. The user is responsible for measures to ensure that the intended use of products which are installed outside the companys EMC environment is not adversely effected (particularly by disturbance emission).

Attention: We assume no liability for damaged or destroyed devices under test.

2 Scope of Delivery

Item	Designation	Type	Quantity
1	RF current probe 0.1 ohm	P602	1
2	RF current probe 1 ohm	P603	1
3	RF current probe 0.1 ohm active	P622	1
4	RF current probe 1 ohm active	P623	1
5	RF voltage probe 150 ohm	P750	1
6	Measurement cable	SMA-SMB 1 m	1
7	ChipScan-ESA software	CS-ESA	1
8	Licence dongle	Dongle	1
9	User manual	P600 / P750 m	1
10	Case insert/Quick guide	P600 / P750 qg	1
11	System case	P600 / P750 case	1

Figure 1: System case

3 Technical Parameters

3.1 P602 Probe

Shunt	0.1 Ω
Current correction factor R	-26 dBΩ
Max. power dissipation shunt	2.5 W
Coupling capacitance	8 µF
Inductance of RF input	1 nH
RF measuring output	50 Ω (SMB)
Frequency range	0.2 kHz – 3 GHz

Table 1: P602 technical parameters

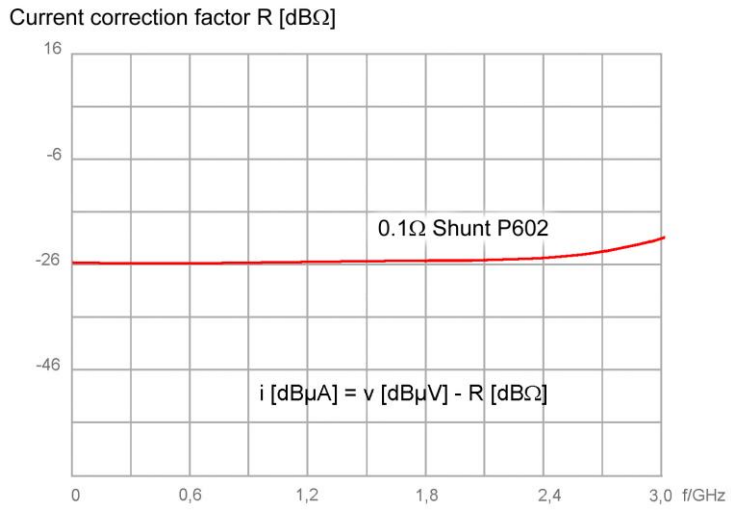

Figure 2: P602 characteristic

3.2 P603 Probe

Shunt	1 Ω
Transfer factor V_{out} / V_{in}	-6 dB
Current correction factor R	-6 dBΩ
Max. power dissipation shunt	2.5 W
Coupling capacitance	8 µF
Inductance of RF input	1 nH
RF measuring output	50 Ω (SMB)
Frequency range	0.2 kHz – 3 GHz

Table 2: P603 technical parameters

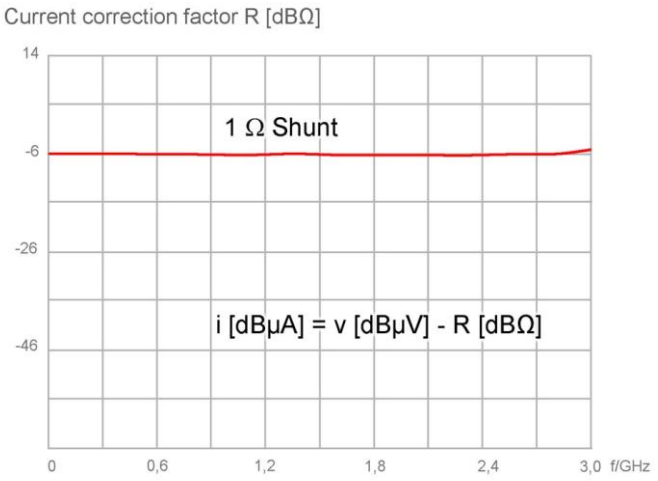

Figure 3: P603 characteristic

3.3 P622 Probe

Shunt	0.1 Ω
Amplification	20 dB
Current correction factor R	0 dBΩ
Max. power dissipation shunt	2.5 W
Coupling capacitance	8 µF
Inductance of RF input	1 nH
RF measuring output	50 Ω (SMB)
Frequency range	0.2 kHz – 3 GHz

Table 3: P622 technical paramters

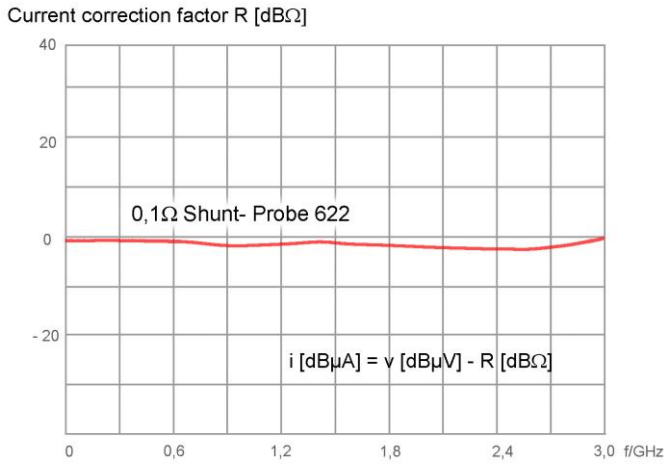

Figure 4: P622 characteristic

3.4 P623 Probe

Shunt	1 Ω
Amplification	20 dB
Current correction factor R	20 dBΩ
Max. power dissipation shunt	2.5 W
Coupling capacitance	8 µF
Inductance of RF input	1 nH
RF measuring output	50 Ω (SMB)
Frequency range	0.2 kHz – 3 GHz

Table 4: P623 technical parameters

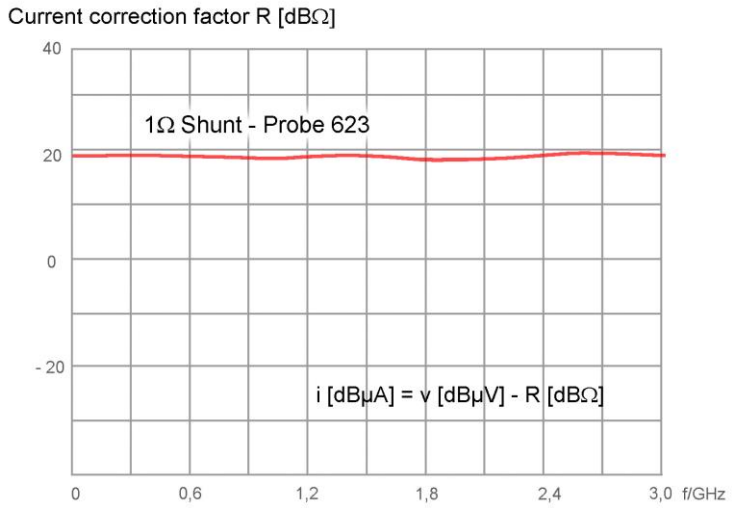

Figure 5: P623 characteristic

3.5 P750 Probe

Transfer factor V_{out} / V_{in}	-15.2 dB
RF measuring output	50 Ω (SMB)
Input resistance	150 Ω
Max. input voltage for RF	3.5 V
Max. input voltage for DC	50 V
Frequency range	150 kHz to 3 GHz

Table 5: P750 technical parameters

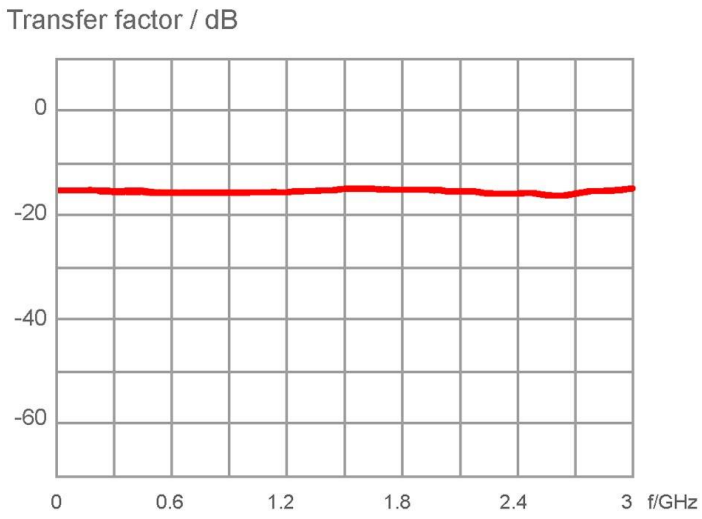

Figure 6: P750 characteristic

4 Intended Use

The **P603, 603, P622, P623** and **P750** probes have been developed to measure conducted emissions from integrated circuits (ICs) with direct 1 Ohm/150 Ohm coupling. The probes can be used to perform measurements on ICs according to IEC 61967-4 (**Figure 7**). The **P603** probe corresponds to the 1 Ohm RF current probe head.
The **P750** probe corresponds to the impedance matching network according to IEC 61000-4-6. It has an input impedance of 150 Ohm.
The **P750** probe can be used to perform RF voltage measurements and the **P603** probe can be used for RF current measurements on IC pins. The probes P622 and P623 are an extension of the set P603 and P750. The internal preamplifier allows a measurement of signals with a lower strength.

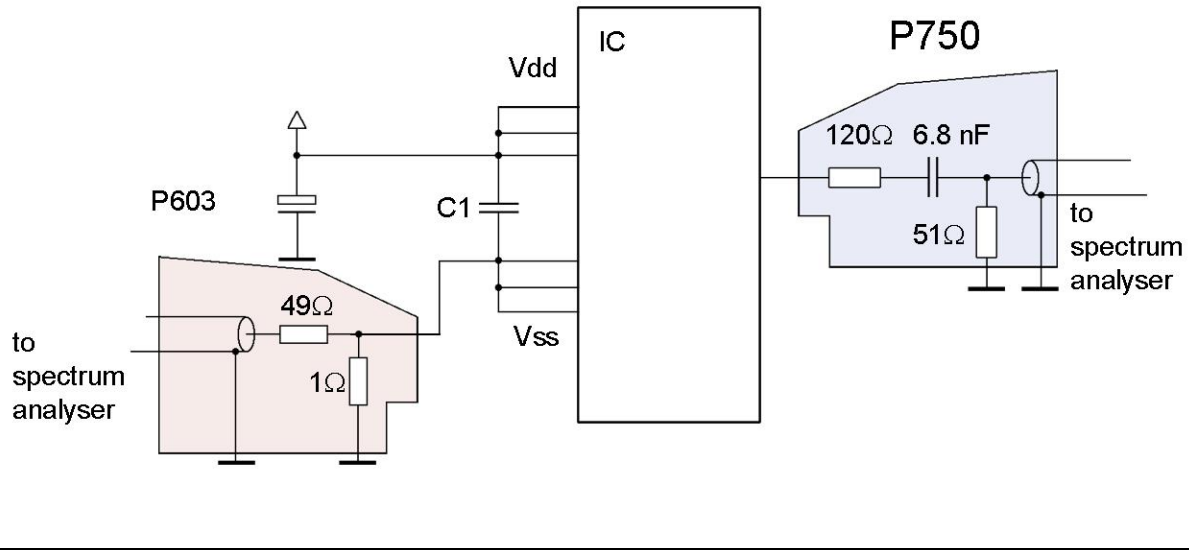

Figure 7: Test set-up according to IEC 61967-4 with the P603 1 Ohm RF current probe head (current measurement) and the P750 impedance matching network (voltage measurement).

The **P603** and **P750** probe can also be used for other measurement tasks:

1. Current measurement (**P603**) on concatenated Vdd pins, **Figure 8**
2. Current measurement (**P603**) on a single Vss pin, **Figure 9**
3. Current measurement (**P603**) on a single Vdd pin, **Figure 10**
4. Voltage measurement (**P750**) on a signal pin while this is in operation, **Figure 11**
5. Current measurement (**P603**) on a signal pin while this is in operation, **Figure 12**
6. Voltage measurement (**P750**) on a Vdd or Vss pin, **Figure 13**

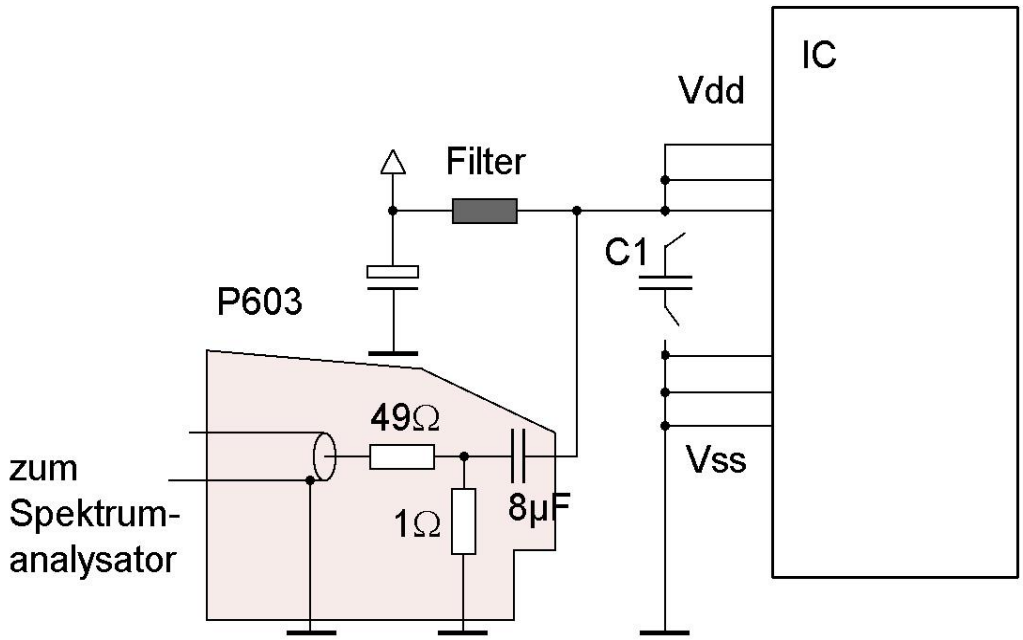

Figure 8: P603, current measurement with a direct current block on concatenated Vdd pins.

An 8 µF capacitor is integrated into the **P603** probe as a direct current block. It backs up the IC in the circuit diagrams **Figure 8** and **Figure 10**.

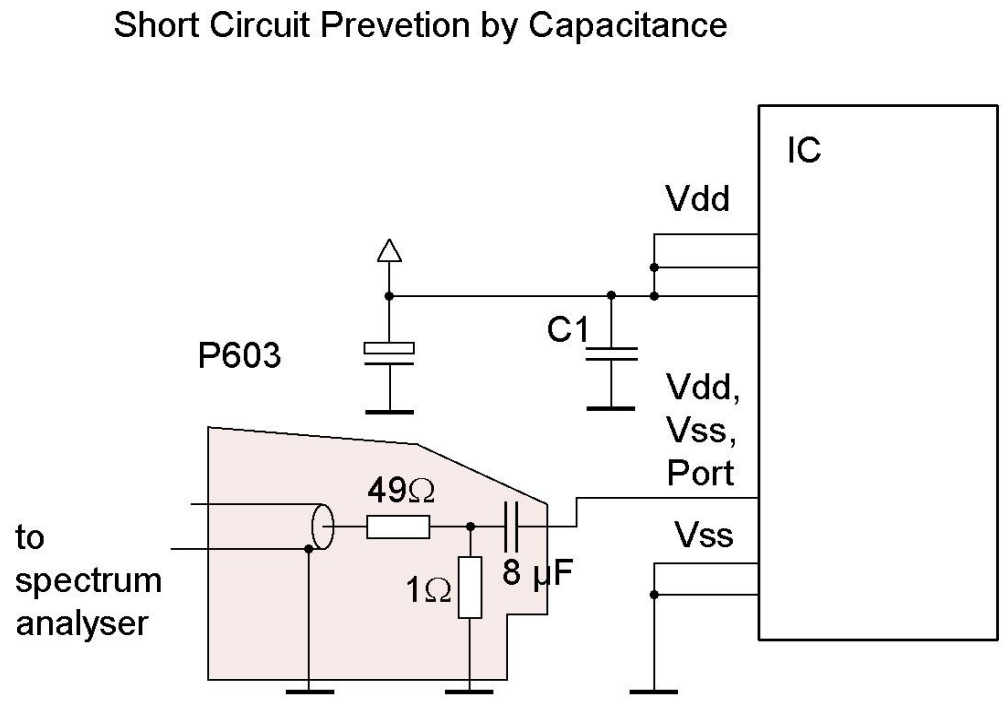

Figure 9: P603, current measurement on a single Vss pin.

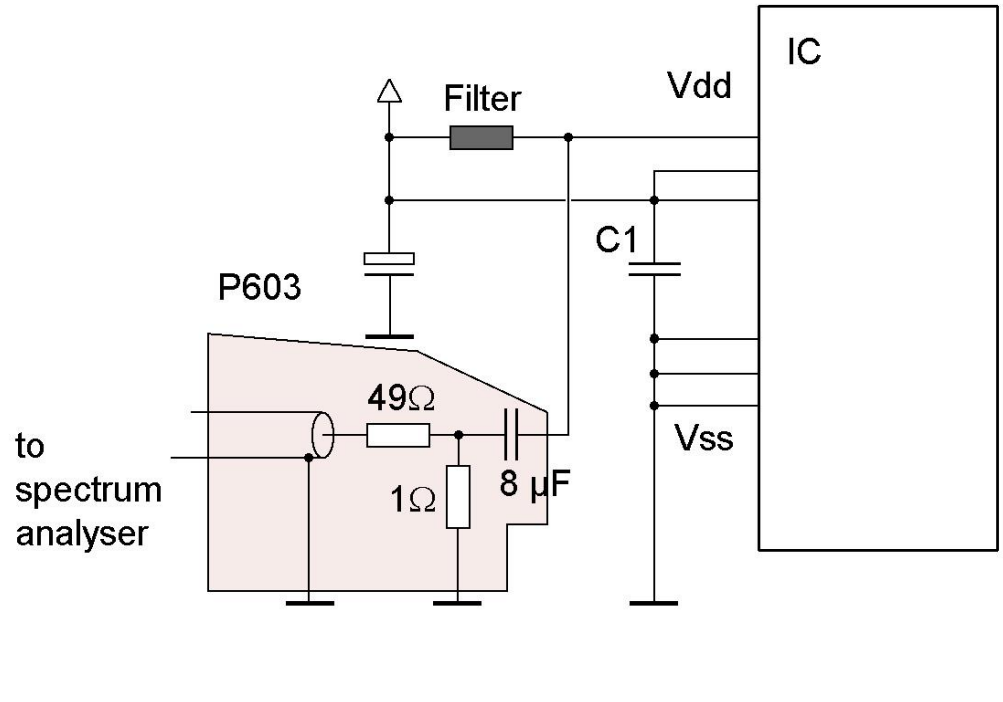

Figure 10: P603, current measurement on a single Vdd pin.

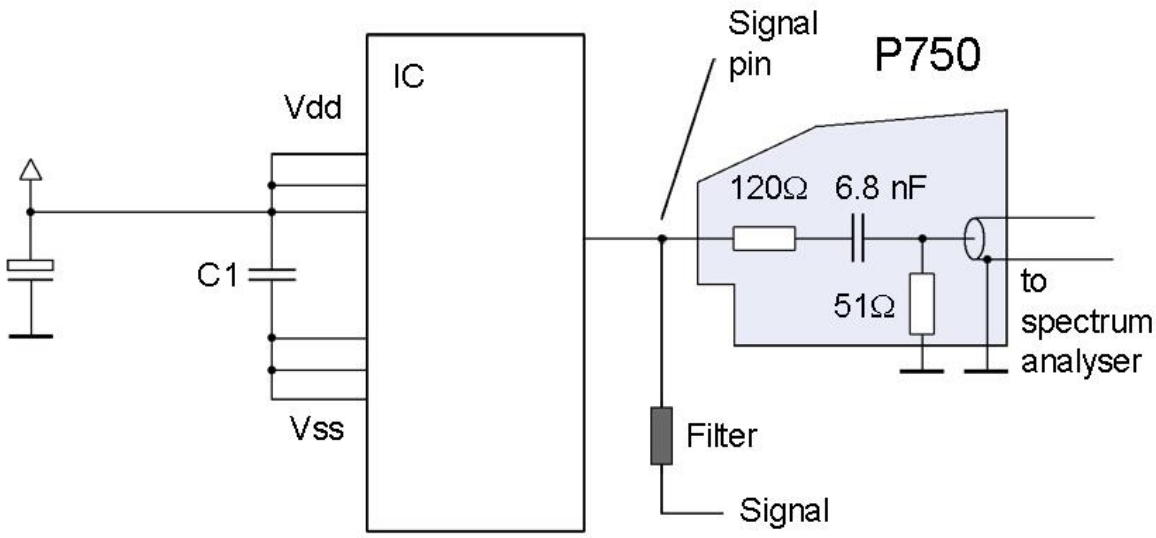

Figure 11: P750, voltage measurement on a signal pin while this is in operation.

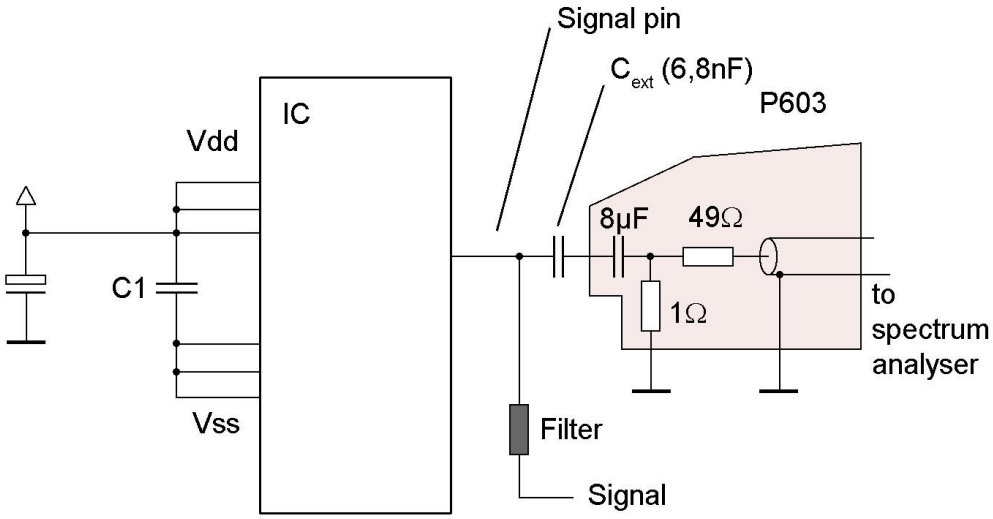

Figure 12: P603, current measurement on a signal pin while this is in operation.

The external capacitor C_{ext} can reduce the stress on the signal pin caused by the probe's low impedance (1 Ohm) (**Figure 12**) during current measurements on signal pins.
The impedance of the capacitor C_{ext} should be at least 3 dB smaller than the shunt's 1 Ohm resistance.

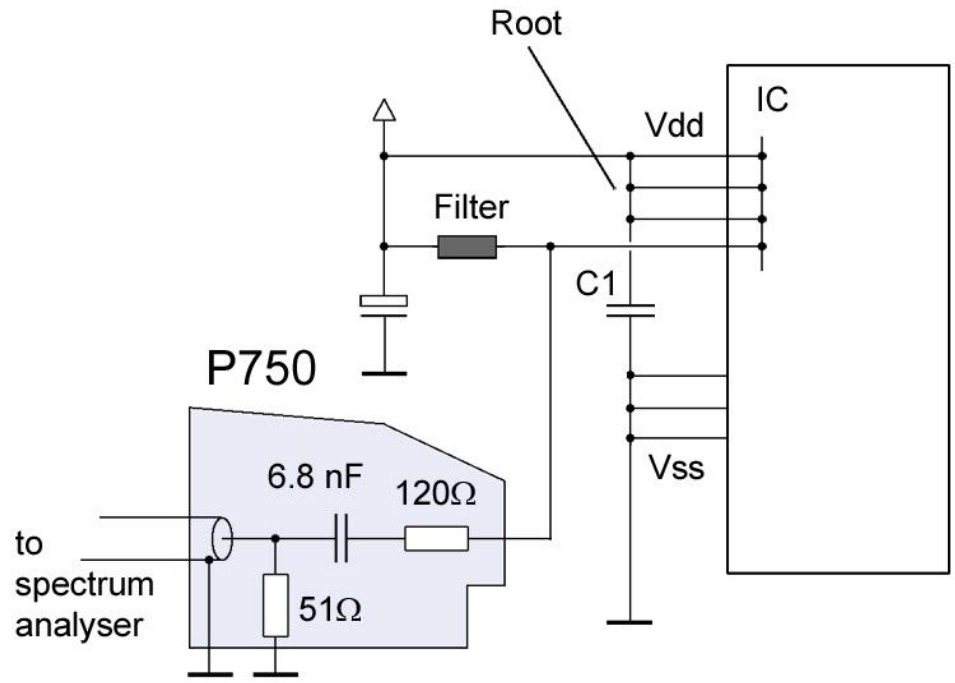

Figure 13: P750, voltage measurement on a Vdd pin; analogous current measurement with the P603 probe.

An IC internal connection to other Vdd supply pins is assumed for a voltage measurement on a Vdd pin (**Figure 13**). This measurement enables the determination of voltage dips on the IC's internal Vdd network.

The test IC is soldered to the test board[1] (**Figure 14**). The **P603** and **P750** probes can be moved freely on the **GND 25** ground plane or **GNDA** ground adapter [2] (**Figure 14**). Unlike the measurement set-up according to IEC 61967-4, this set-up ensures that the **P603** or **P750** probe's pin contact can reach and contact each IC pin. The probes are fixed on the ground plane with magnets. Filter elements and bridges are located on the underside (bottom) of the test board to prepare the measurement set-up for contact with the probe (**Figure 16**).

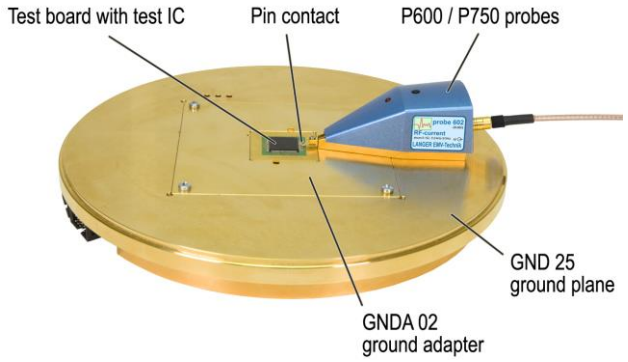

Figure 14: Measurement set-up according to the 1 Ohm method with P603 and the 150 Ohm method with P750.

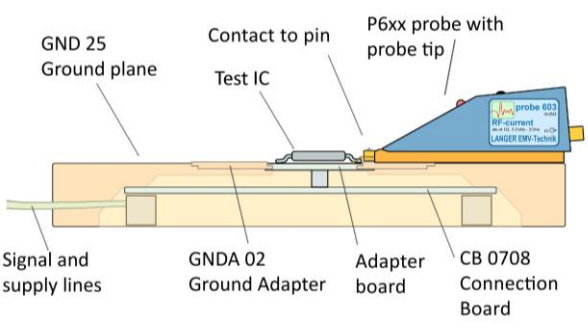

Figure 15: Sectional view of the measurement set-up.

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

The same test board is used for all measurement methods (1 Ohm, 150 Ohm). Bridges are provided to the Vdd / Vss root at the Vdd / Vss pins in the initial state. The associated bridge to the root is removed and the corresponding filter becomes active if a Vdd / Vss pin is measured.

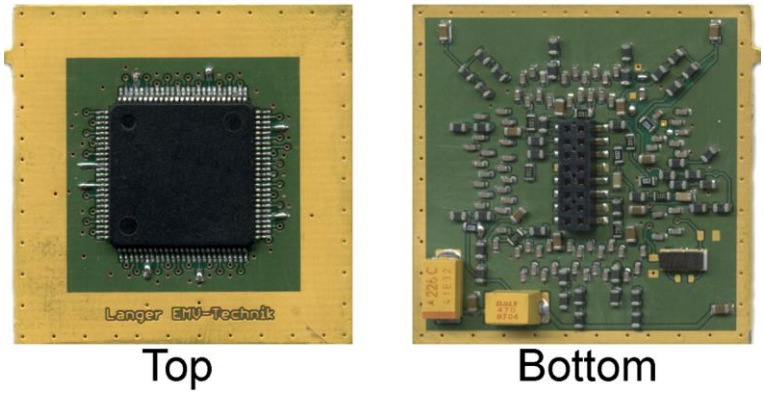

Figure 16: Design of the test board; top with Vss bridges, bottom with back-up capacitors, filters and quartz crystal oscillator circuit.

5 P602 Probe

5.1 General Description

The **P602** probe is an RF current probe head to measure conducted RF currents on IC pins.
The **P602** has been designed for measurements on supply (Vdd / Vss) and signal pins. The measurement is performed with a 0.1 Ohm shunt.

Figure 17: P602 probe

5.2 Design and Function of the P602 Probe

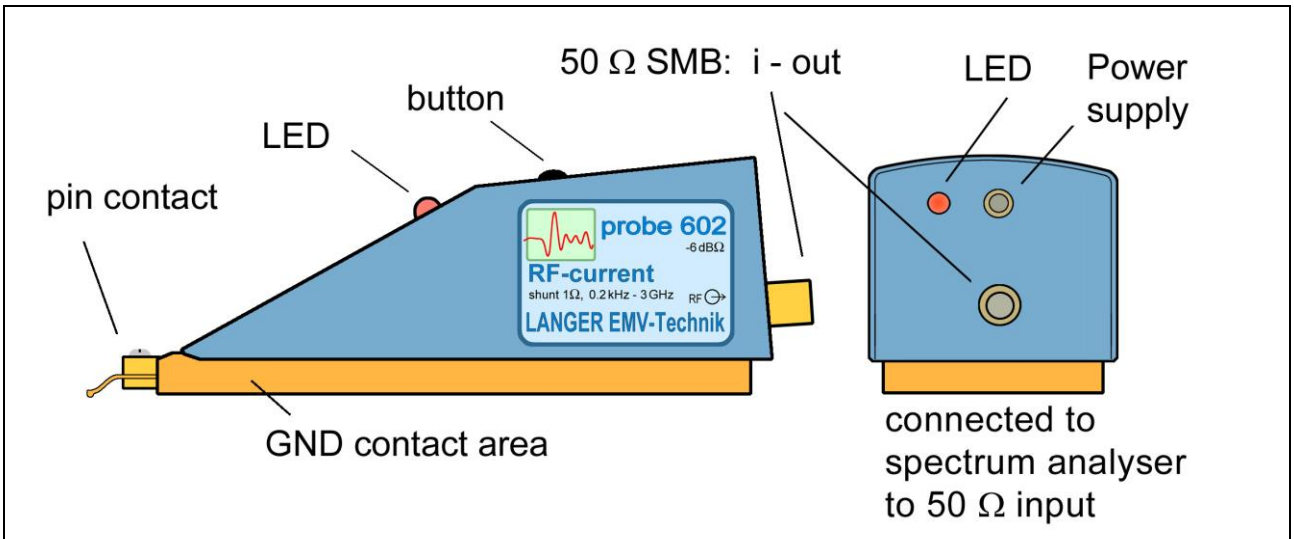

Figure 18: Design of the P602 probe

The **P602** probe contains a 0.1 Ohm current probe head. The input of the current probe head is connected to the probe's pin contact (**Figure 18**). The output of the current probe head is connected to the 50 Ohm SMB port at the rear end of the probe.
A cable is used to connect the probe's output to a measuring instrument such as a spectrum analyzer. The voltage measured is equivalent to the current measured.

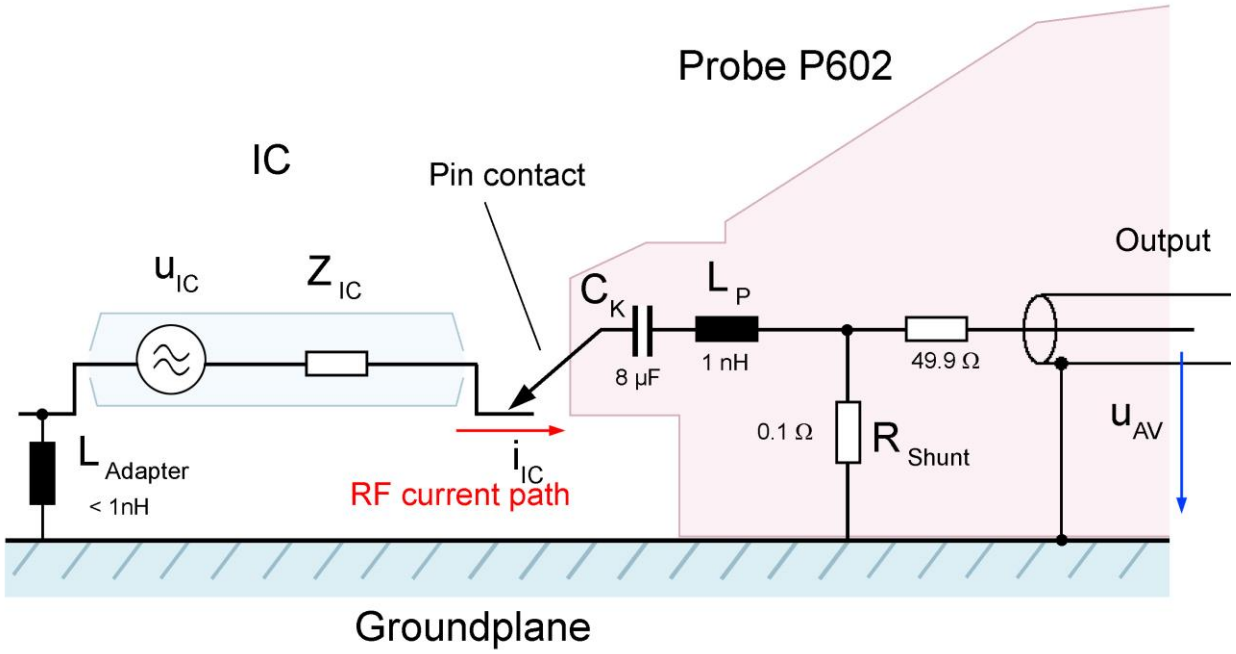

Figure 19: Internal P602 design

Figure 19 shows the equivalent circuit diagram of the **P602** probe. The current probe head comprises a 0.1 Ohm shunt, 49.9 Ohm matching resistor and 8 µF coupling capacitor.
The capacitor C_k (IEC 61967-4 direct current block) disconnects the direct current between the test IC and the probe. An additional capacitor C_{ext} can be inserted between the test IC and the probe to reduce the stress on the signal pins caused by the 0.1 Ohm shunt. The **P602** current probe head has an inductance L_P of 1 nH in the line from the tip of the probe contact to the shunt. This value and the associated measurement error are much smaller than the value achieved with the set-up according to IEC 61967-4.
The pin contact of the probe has to be brought into contact with the respective test IC pin to perform the measurement. Please refer to the “ICE1 user manual”[1] and “IC test instructions”[2].

[1] mail@langer-emv.de
[2] mail@langer-emv.de

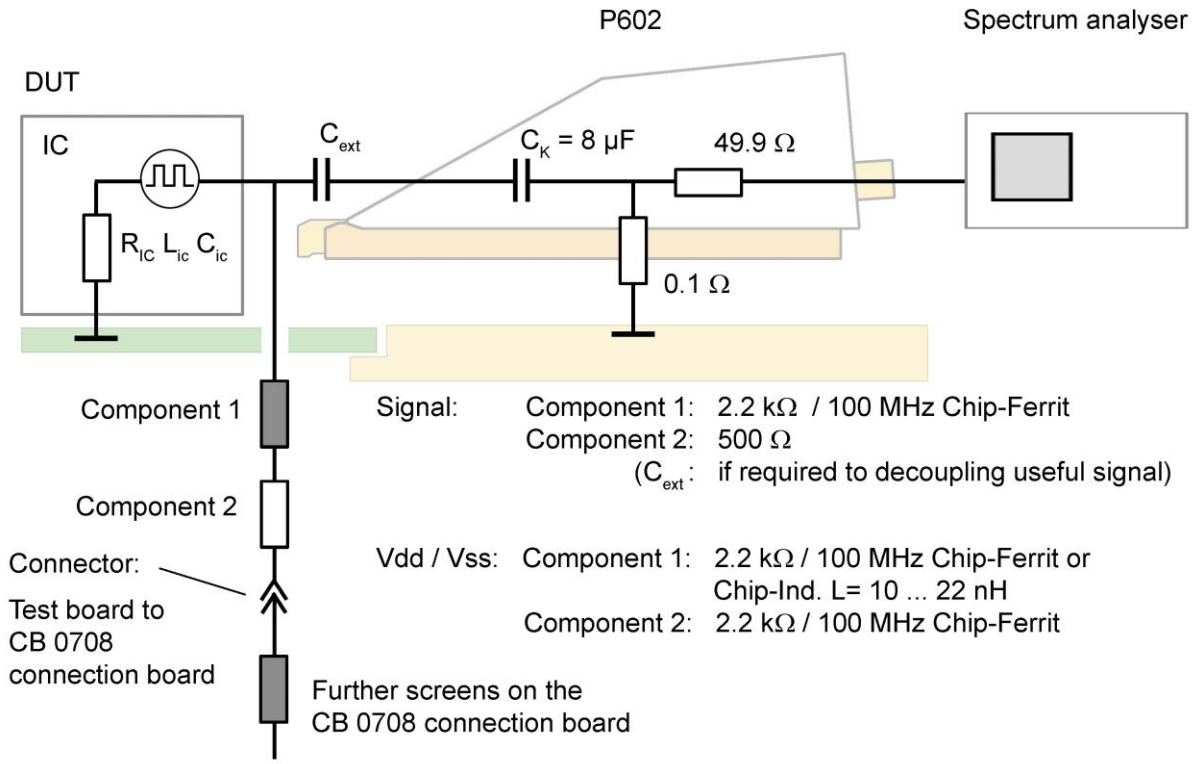

Figure 20: Design of the P602 Vdd / Vss and signal pin filters

Figure 20 shows the design of the Vdd / Vss and signal pin filters which are located on the bottom of the test board. Please refer to the “IC test instructions”[1] for a guideline on how to set up a test board.

[1] mail@langer-emv.de

6 P603 Probe

6.1 General Description

The **P603** probe is an RF current probe head to measure conducted RF currents on IC pins.
The **P603** has been designed for measurements on supply (Vdd / Vss) and signal pins. The measurement is performed with a 1 Ohm shunt.

Figure 21: P603 probe

6.2 Design and Function of the P603 Probe

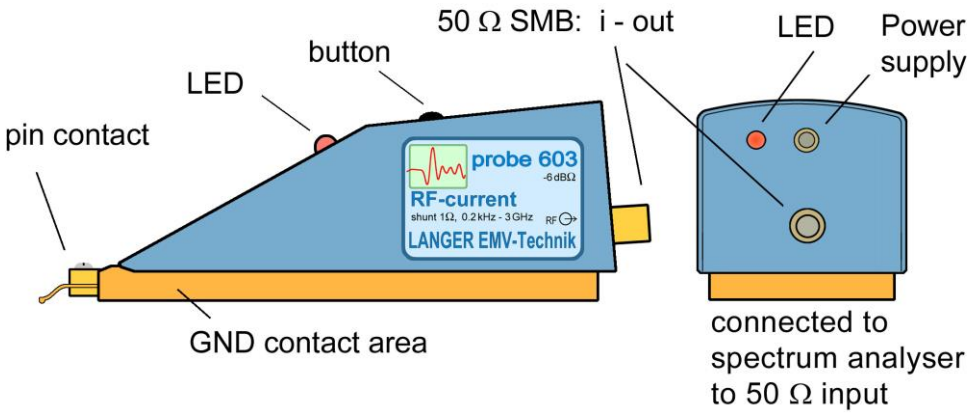

Figure 22: Design of the P603 probe

The **P603** probe contains a 1 Ohm current probe head. The input of the current probe head is connected to the probe's pin contact (**Figure 22**). The output of the current probe head is connected to the 50 Ohm SMB port at the rear end of the probe.
A cable is used to connect the probe's output to a measuring instrument such as a spectrum analyzer. The voltage measured is equivalent to the current measured.

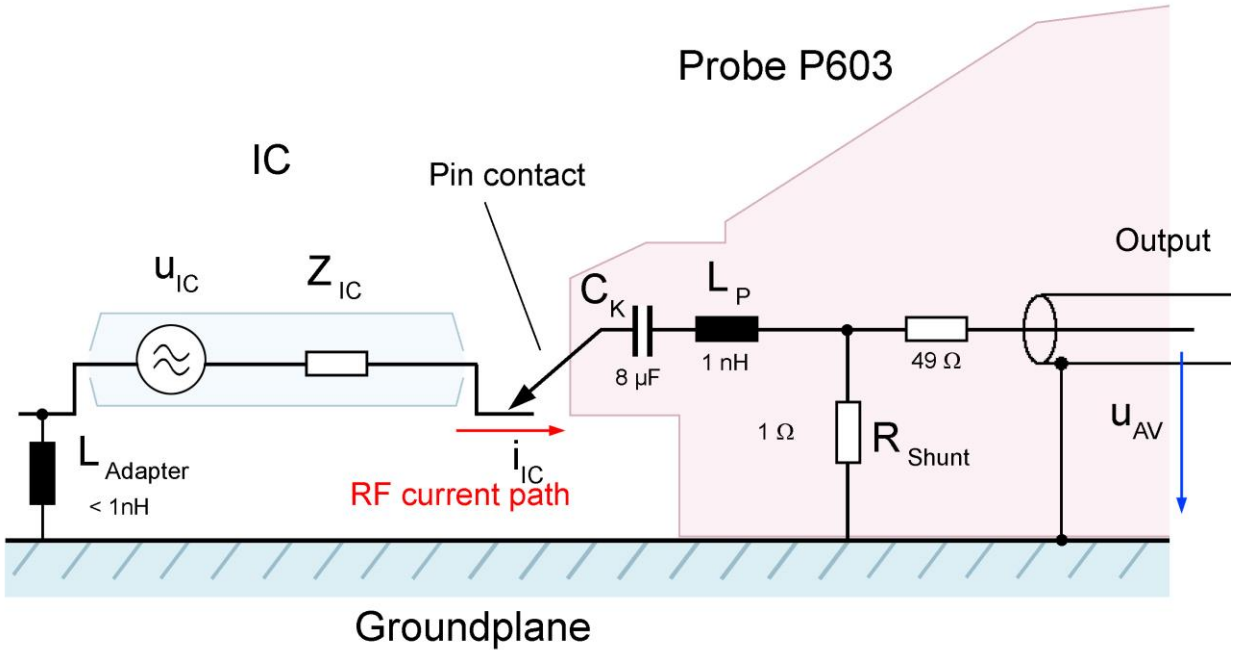

Figure 23: Internal P603 design

Figure 23 shows the equivalent circuit diagram of the **P603** probe. The current probe head comprises a 1 Ohm shunt, 49 Ohm matching resistor and 8 µF coupling capacitor.
The capacitor C_k (IEC 61967-4 direct current block) disconnects the direct current between the test IC and the probe. An additional capacitor C_{ext} can be inserted between the test IC and the probe to reduce the stress on the signal pins caused by the 1 Ohm shunt. The **P603** current probe head has an inductance L_P of 1 nH in the line from the tip of the probe contact to the shunt. This value and the associated measurement error are much smaller than the value achieved with the set-up according to IEC 61967-4.
The pin contact of the probe has to be brought into contact with the respective test IC pin to perform the measurement. Please refer to the “ICE1 user manual”[1] and “IC test instructions”[2].

[1] mail@langer-emv.de
[2] mail@langer-emv.de

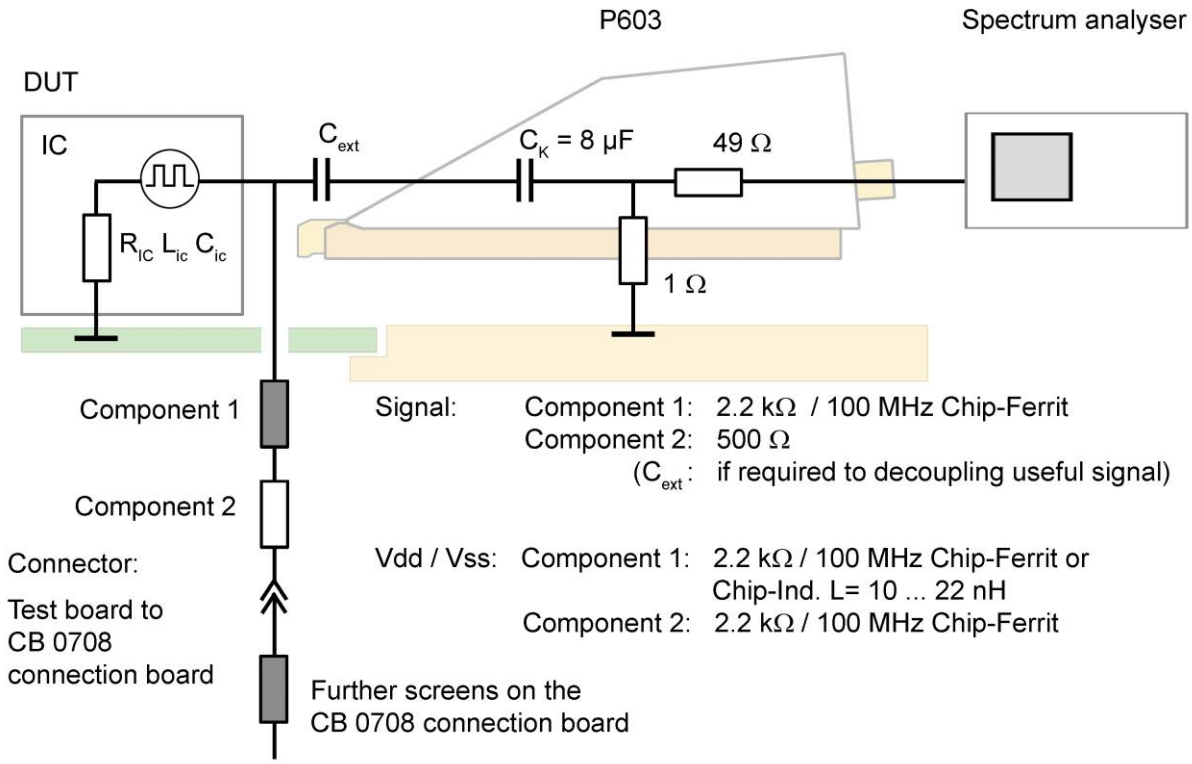

Figure 24: Design of the P603 Vdd / Vss and signal pin filters

Figure 24 shows the design of the Vdd / Vss and signal pin filters which are located on the bottom of the test board. Please refer to the “IC test instructions”[1] for a guideline on how to set up a test board.

[1] mail@langer-emv.de

7 P622 Probe

7.1 General Description

The **P622** probe is an RF current probe head to measure conducted RF currents on IC pins.
The **P622** has been designed for measurements on supply (Vdd / Vss) and signal pins. The measurement is performed with a 0.1 Ohm shunt. The internal preamplifier increased the output level round 20dB.

Figure 25: P622 probe

7.2 Design and Function of the P622 Probe

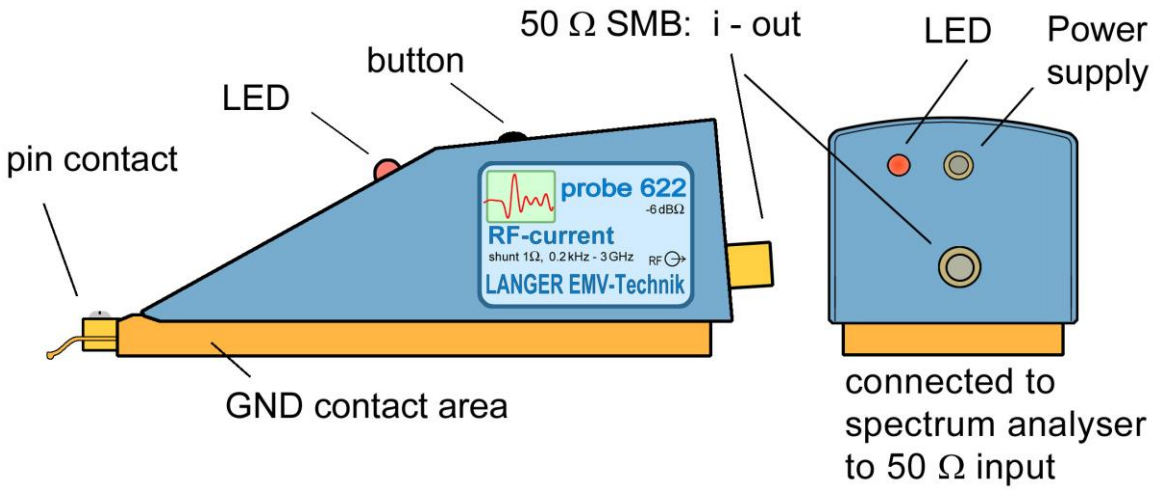

Figure 26: Design of the P622 probe

The **P622** probe contains a 0.1 Ohm current probe head. The input of the current probe head is connected to the probe's pin contact (Figure 26). The output of the current probe head is connected to the 50 Ohm SMB port at the rear end of the probe.
A cable is used to connect the probe's output to a measuring instrument such as a spectrum analyzer. The voltage measured is equivalent to the current measured.

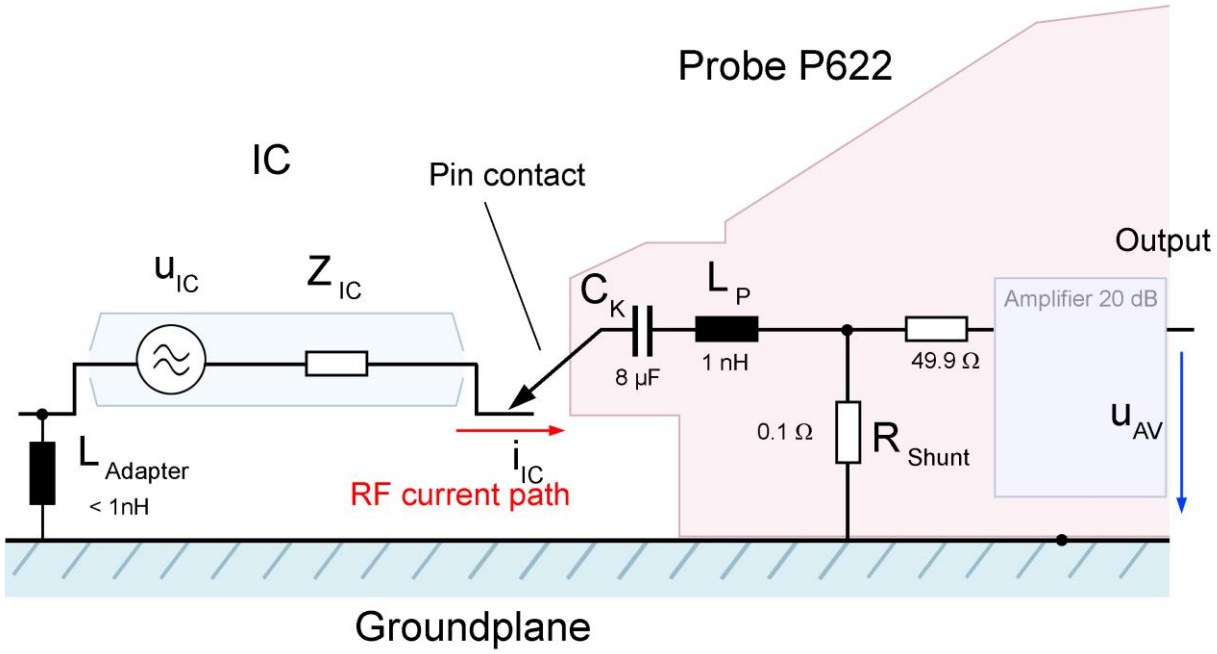

Figure 27: Internal P622design

Figure 27 shows the equivalent circuit diagram of the **P622** probe. The current probe head comprises a 0.1 Ohm shunt, 49.9 Ohm matching resistor and 8 µF coupling capacitor.
The capacitor C_k (IEC 61967-4 direct current block) disconnects the direct current between the test IC and the probe. An additional capacitor C_{ext} can be inserted between the test IC and the probe to reduce the stress on the signal pins caused by the 0.1 Ohm shunt. The **P622** current probe head has an inductance L_P of 1 nH in the line from the tip of the probe contact to the shunt. This value and the associated measurement error are much smaller than the value achieved with the set-up according to IEC 61967-4.
The pin contact of the probe has to be brought into contact with the respective test IC pin to perform the measurement. Please refer to the “ICE1 user manual”[1] and “IC test instructions”[2].

[1] mail@langer-emv.de
[2] mail@langer-emv.de

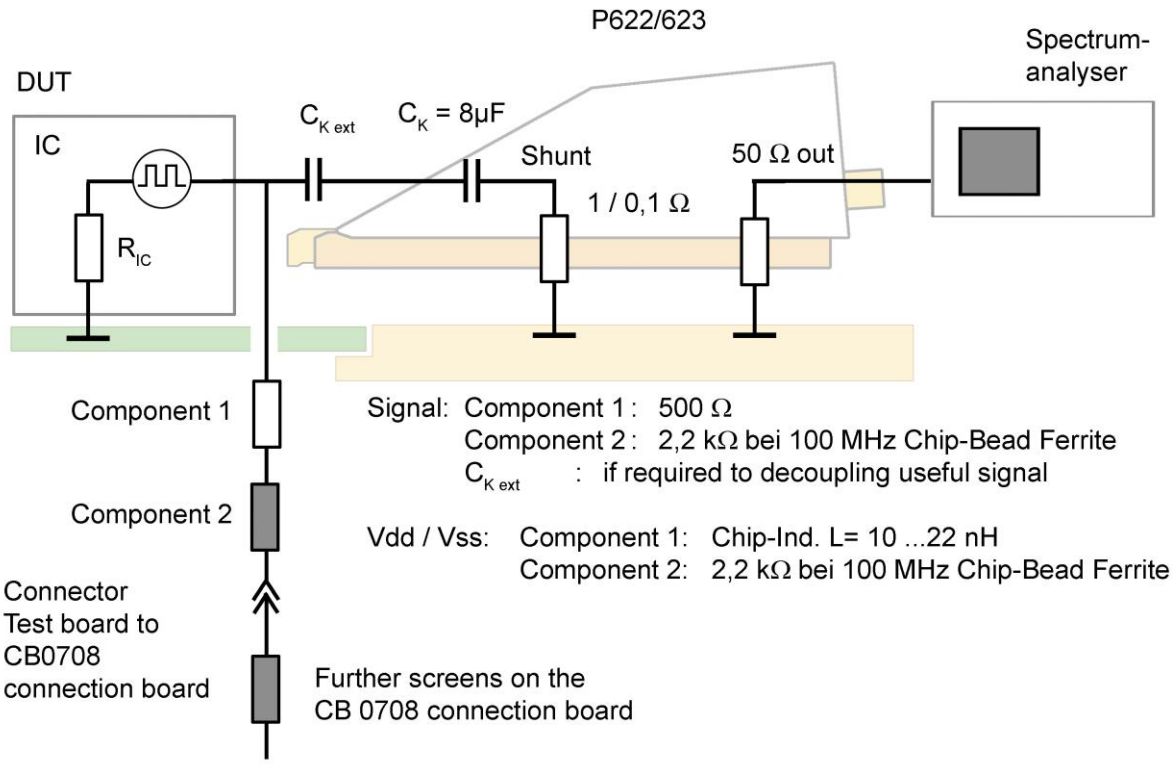

Figure 28: Design of the P622 Vdd / Vss and signal pin filters

Figure 28 shows the design of the Vdd / Vss and signal pin filters which are located on the bottom of the test board. Please refer to the “IC test instructions”[1] for a guideline on how to set up a test board.

[1] mail@langer-emv.de

8 P623 Probe

8.1 General Description

The **P623** probe is an RF current probe head to measure conducted RF currents on IC pins.
The **P623** has been designed for measurements on supply (Vdd / Vss) and signal pins. The measurement is performed with a 1 Ohm shunt. The internal preamplifier increased the output level round 20dB.

Figure 29: P623 probe

8.2 Design and Function of the P623 Probe

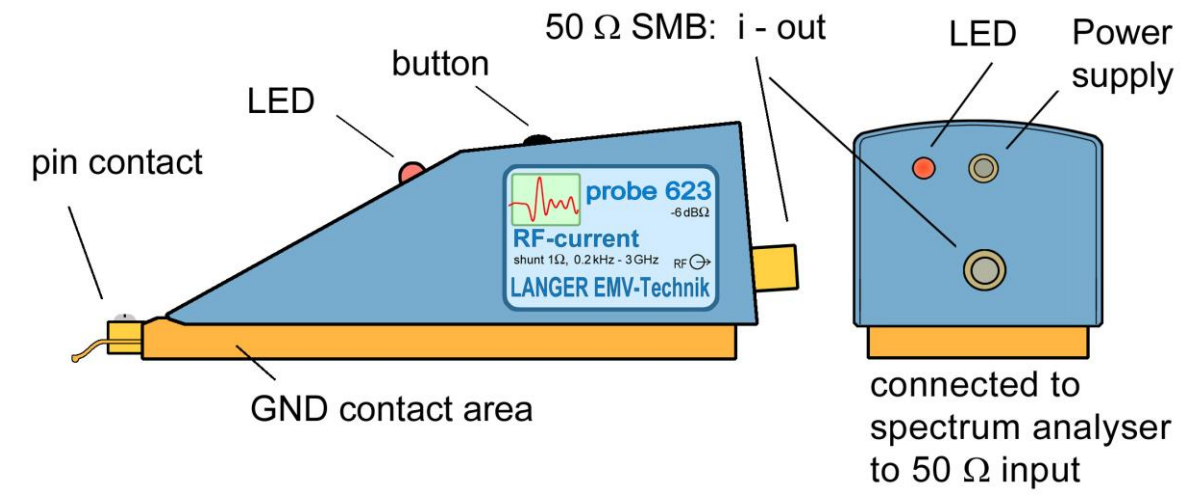

Figure 30: Design of the P623 probe

The **P623** probe contains a 1 Ohm current probe head. The input of the current probe head is connected to the probe's pin contact (Figure 30). The output of the current probe head is connected to the 50 Ohm SMB port at the rear end of the probe.
A cable is used to connect the probe's output to a measuring instrument such as a spectrum analyzer. The voltage measured is equivalent to the current measured.

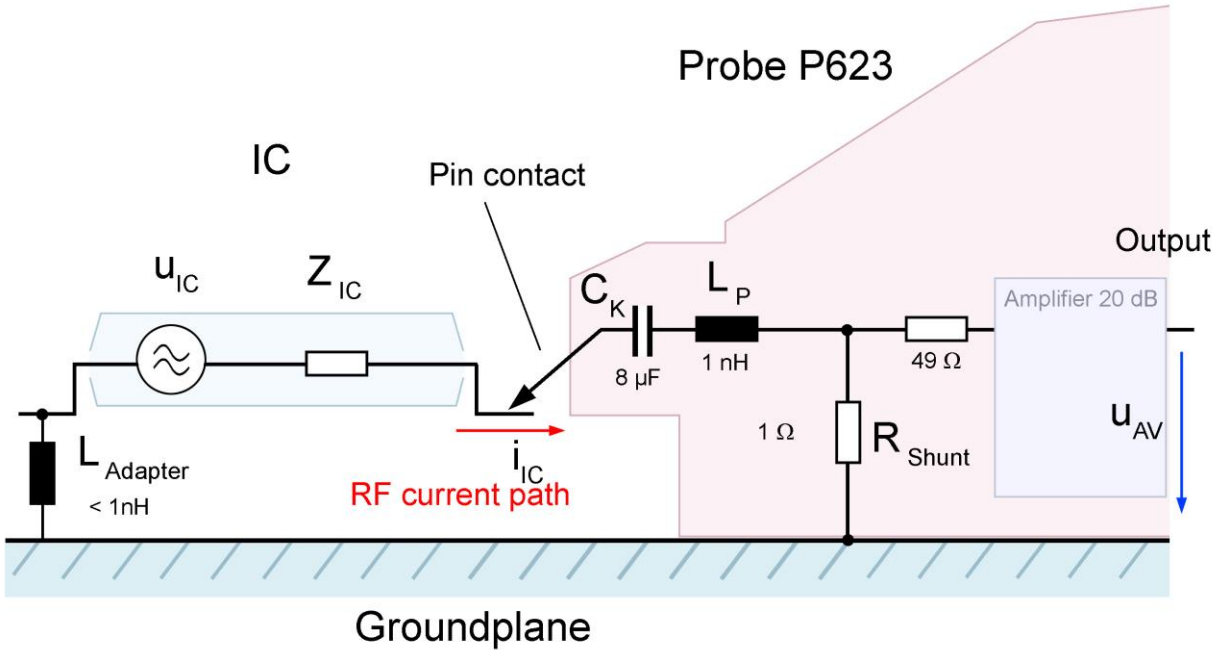

Figure 31: Internal P623design

Figure 31 shows the equivalent circuit diagram of the **P623** probe. The current probe head comprises a 1 Ohm shunt, 49 Ohm matching resistor and 8 µF coupling capacitor.
The capacitor C_k (IEC 61967-4 direct current block) disconnects the direct current between the test IC and the probe. An additional capacitor C_{ext} can be inserted between the test IC and the probe to reduce the stress on the signal pins caused by the 1 Ohm shunt. The **P623** current probe head has an inductance L_P of 1 nH in the line from the tip of the probe contact to the shunt. This value and the associated measurement error are much smaller than the value achieved with the set-up according to IEC 61967-4.
The pin contact of the probe has to be brought into contact with the respective test IC pin to perform the measurement. Please refer to the “ICE1 user manual”[1] and “IC test instructions”[2].

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[2] mail@langer-emv.de

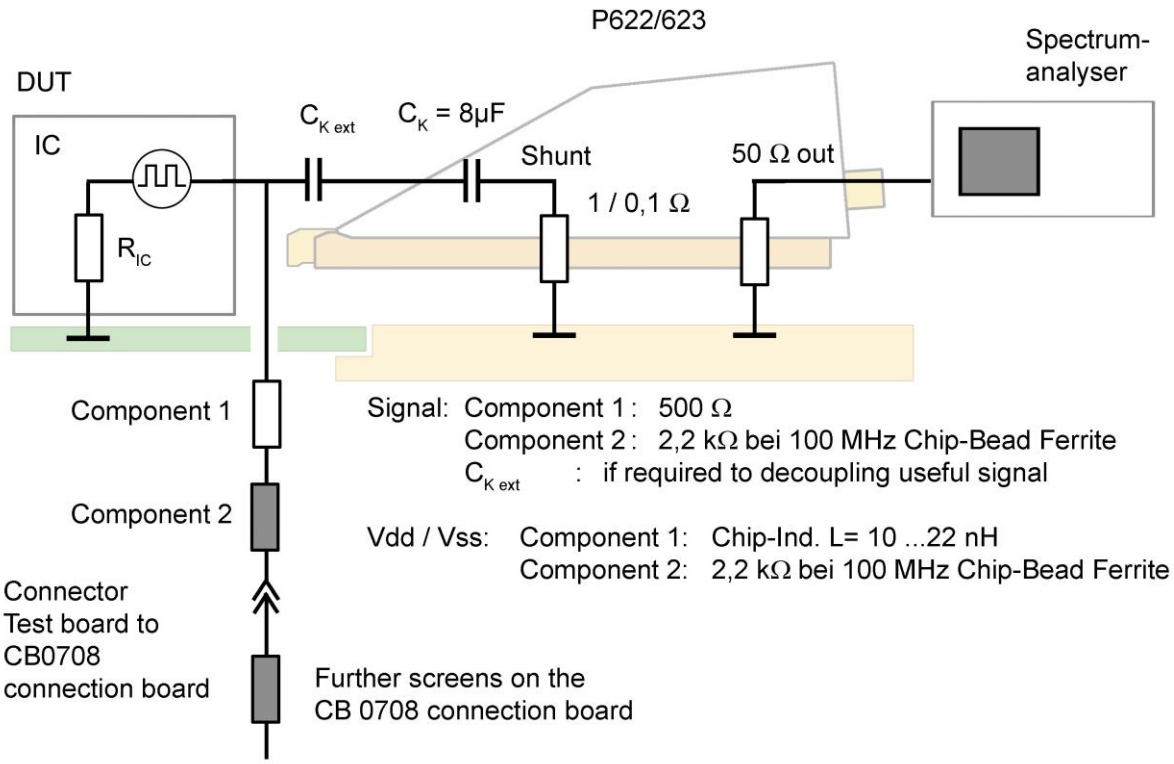

Figure 32: Design of the P623 Vdd / Vss and signal pin filters

Figure 32 shows the design of the Vdd / Vss and signal pin filters which are located on the bottom of the test board. Please refer to the “IC test instructions”[1] for a guideline on how to set up a test board.

[1] mail@langer-emv.de

9 P750 Probe

9.1 General Description

The **P750** probe is a matching network to measure conducted RF voltages on IC pins according to IEC 61967-4.
The **P750** has been designed for measurements on supply (Vdd / Vss) and signal pins. The measurement is performed with a 150 Ohm voltage divider.

Figure 33: P750 probe

9.2 Design and Function of the P750 Probe

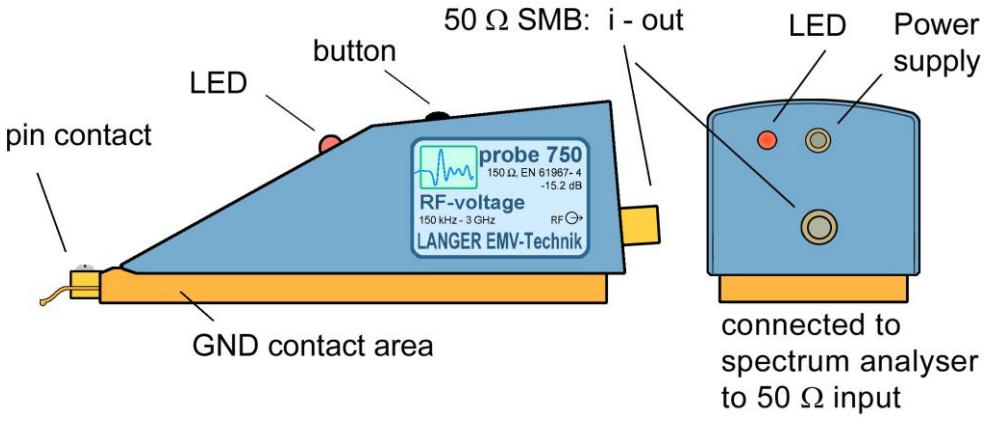

Figure 34: Design of the P750 probe

The **P750** probe contains a 150 Ohm matching network (IEC 61967-4). The input of the matching network is connected to the probe's pin contact (**Figure 34**). The output of the matching network is connected to the 50 Ohm SMB port at the rear end of the probe.
A cable is used to connect the probe's output to a measuring instrument such as a spectrum analyzer.

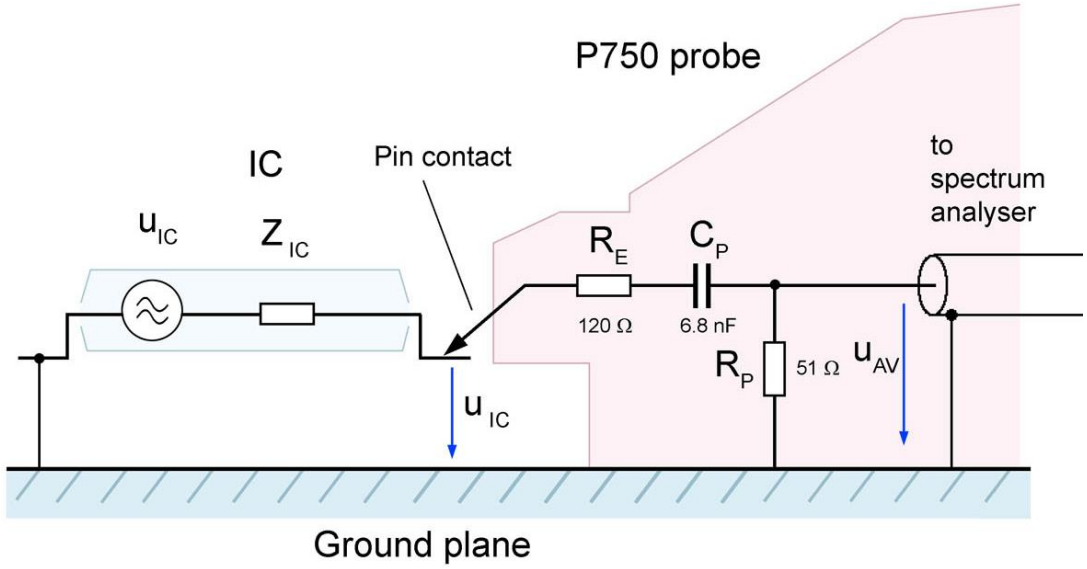

Figure 35: Internal P750 design

Figure 35 shows the equivalent circuit diagram of the **P750** probe. The matching network comprises a 120 Ohm – 51 Ohm voltage divider and a 6.8 nF coupling capacitor.
The pin contact of the probe has to be brought into contact with the respective test IC pin to perform the measurement. Please refer to the "ICE1 user manual" and "IC test instructions"[1].

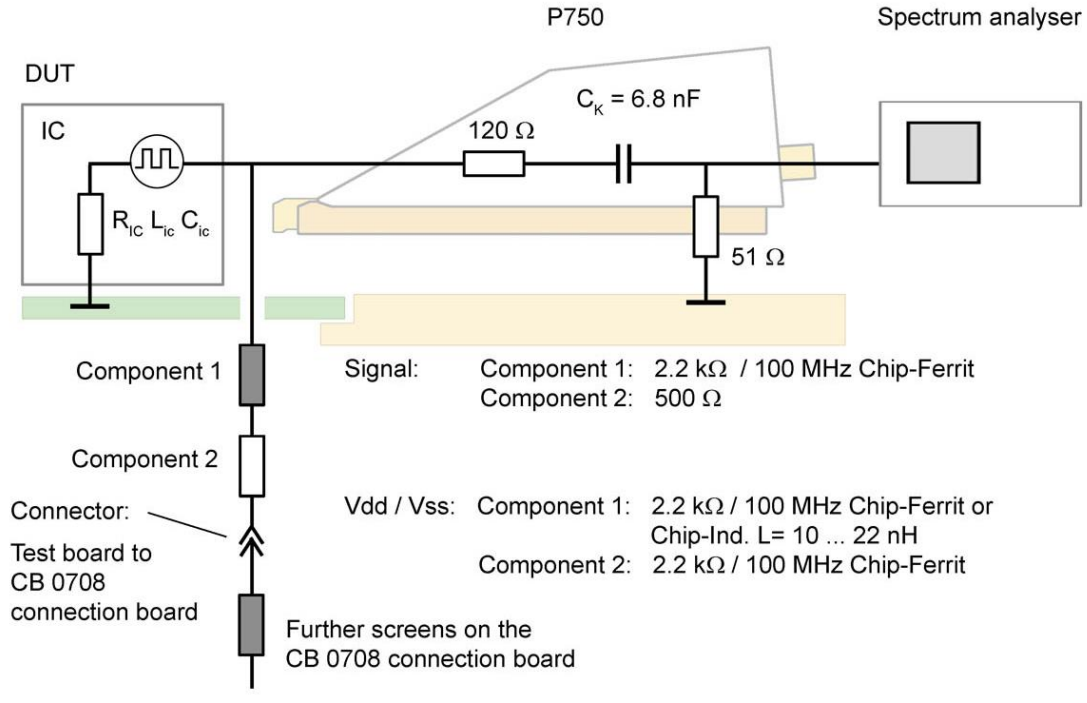

Figure 36: Design of the P750 Vdd / Vss and signal pin filters

Figure 30 shows the design of the Vdd / Vss and signal pin filters which are located on the bottom of the test board. Please refer to the "IC test instructions" for a guideline on how to set up a test board.

[1] mail@langer-emv.de

10 Contact Detection

The contact detection is used to detect a galvanic connection of the probe tip with a IC pin automatically.

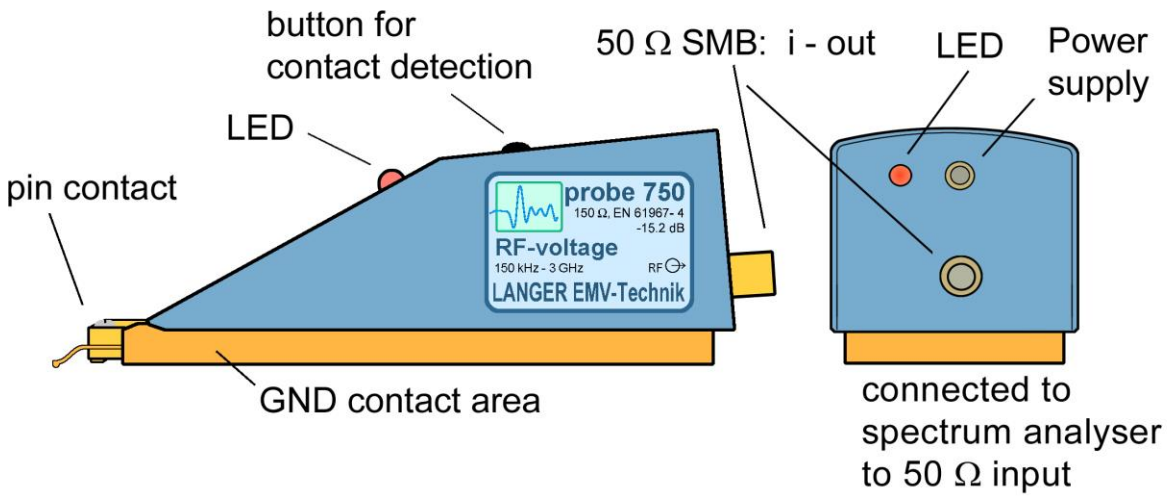

Figure 37: Design of the P750 probe with button for contact detection

The probe tip is forward biased to a potential of -5 V by pushing the button for contact detection. Is there a galvanic connection between the probe tip and the IC-pin the voltage level on the probe tip decreases due to the structure of the internal IC circuit. The voltage drop is detected and the contact is indicated by the LED at the upper section of the probe housing.

NOTE: Not connected Pins (NC) could not be detected.

11 Measurement Set-up

11.1 Performing the Measurement

Figure 38 shows the measurement set-up to measure conducted emissions from integrated circuits (ICs). The test IC is mounted on the test board. The test board is inserted into the corresponding ground adapter such as **GNDA 02**[1]. The signal and supply connections to the test IC are established through a plug connector on the test board. The test IC is supplied via the test board and controlled via the connection board. The associated **Connection Board Control** software can be used to control and monitor the test IC from a PC.
The **P603** or **P750** probe is placed on the **GND 25**[2] ground plane with the **GNDA 02** ground adapter. The respective pin of the test IC can be contacted with the pin contact by moving the probe manually. The microscope camera (**Figure 38**) optically detects if and when contact is made. The camera's image is displayed on the PC monitor via the **ChipScan-ESA** software (**Figure 40**). The video image on the PC monitor enables the user to assess the connection to the respective IC pin. The spectrum analyzer displays the RF signal that occurs if and when contact is made. The pins of the test IC can also be contacted automatically if an **ICT1** automatic IC tester is available. The **ICT1** automatic tester enables automatic measurements.
The AV input of the spectrum analyzer is connected to the SMB output of the probe via an SMA-SMB 1 m RF cable.
The **ChipScan-ESA** software makes it easy to perform and document the measurements (see also: “ChipScan-ESA operating instructions”).

[1] The ***GNDA 02*** ground adapter is included in the ***ICE1*** IC test environment. www.langer-emv.de
[2] The ***GND 25*** ground plane is included in the ***ICE1*** IC test environment. www.langer-emv.de

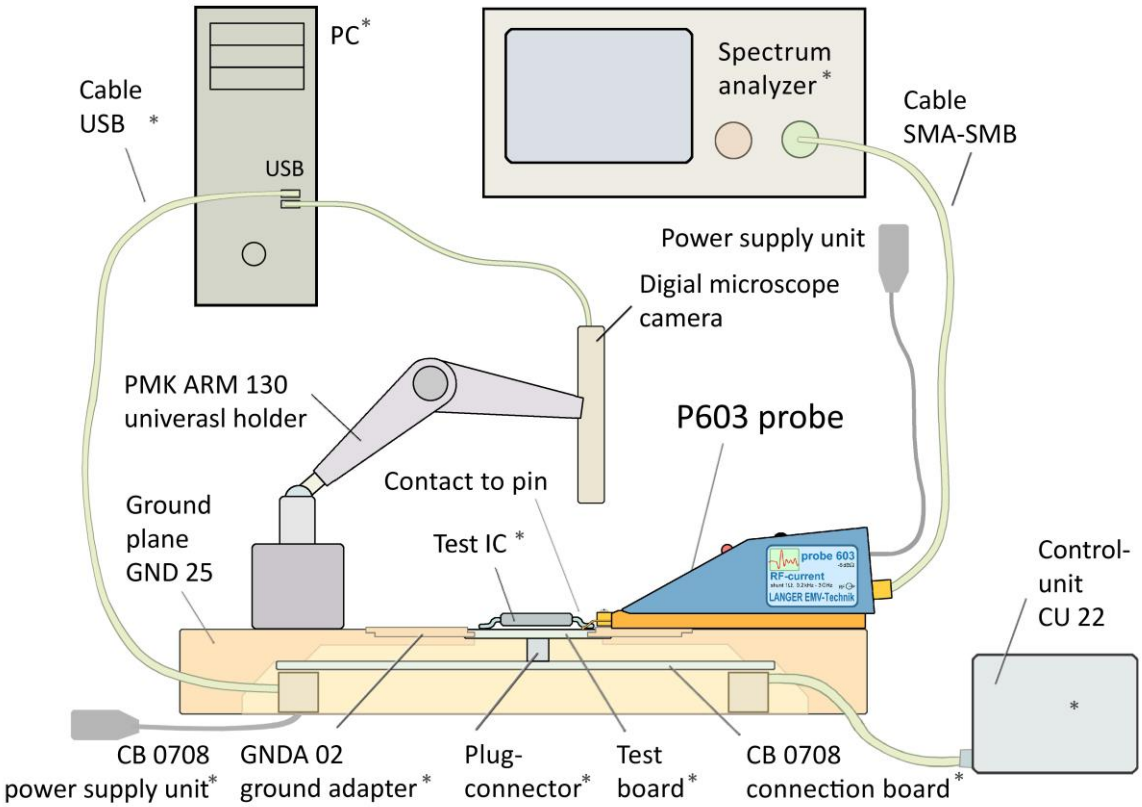

Figure 38: Measurement set-up to measure conducted emissions from integrated circuits (ICs) with the IC test system. Components marked * are not included in the scope of delivery of the "P603 and P750 RF conducted emissions IEC 61967-4" probe set.

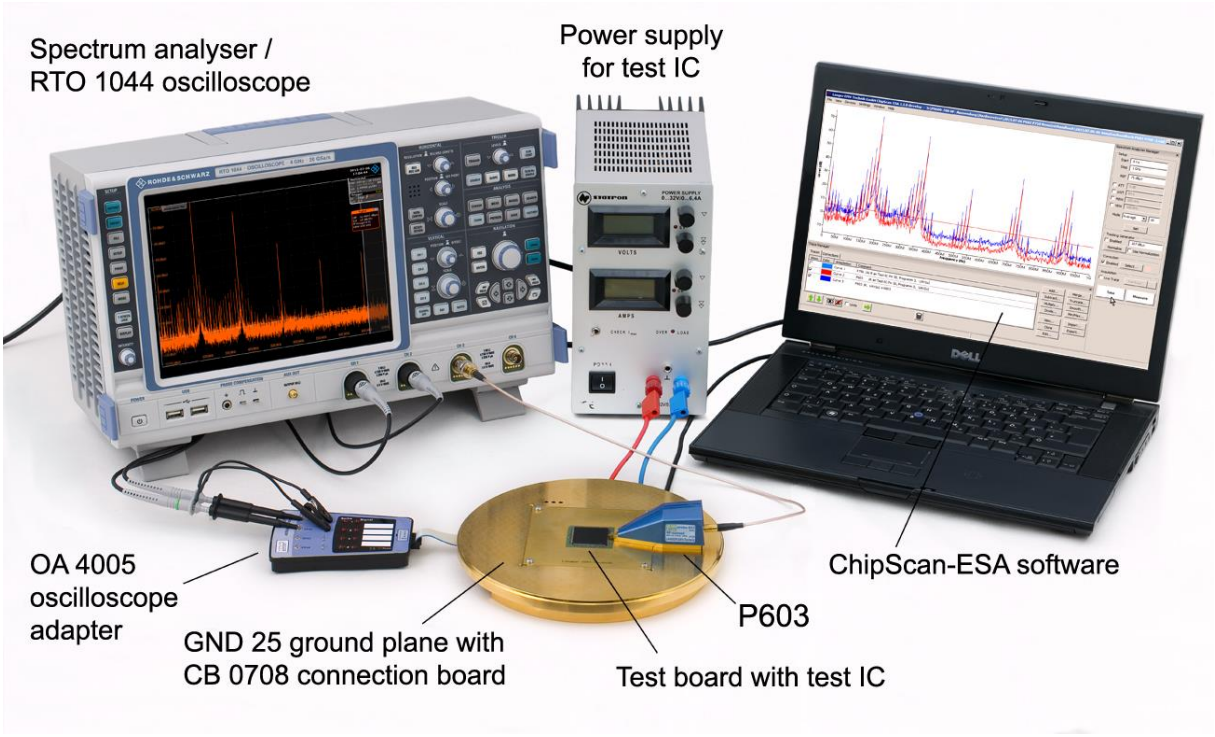

Figure 39: Test set-up with the P603 probe set and ICE1 test environment without a control unit and microscope camera.

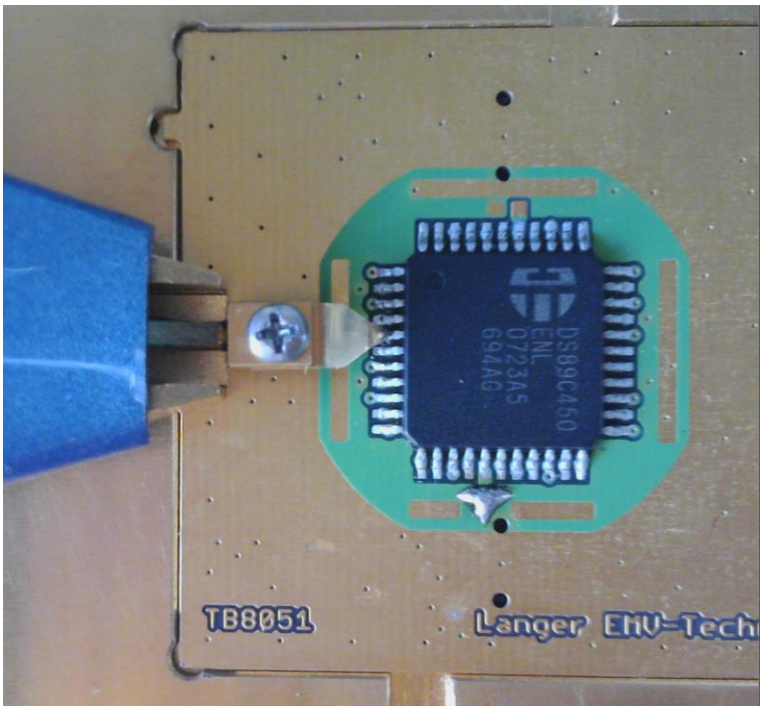

Figure 40: Pin contact visualized with the digital microscope camera.

11.2 Using the ChipScan-ESA Software

The spectrum analyzer is sought automatically with "Devices/Devices Manager/Detected Devices" via the respective interface and connected to the PC (**Figure 42**).

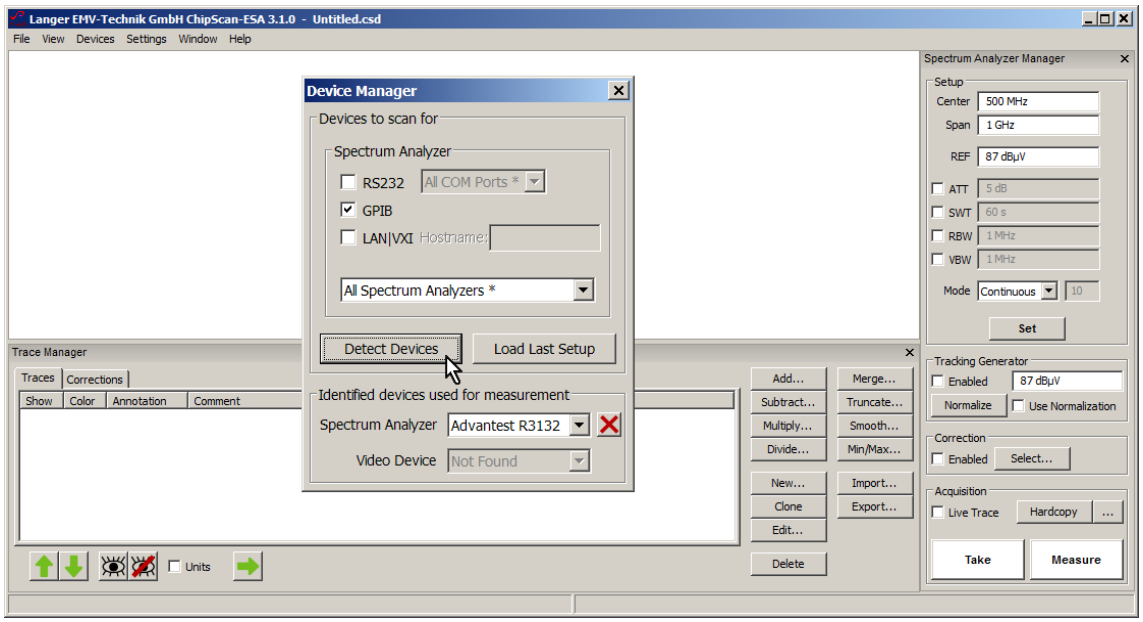

Figure 41: Connecting the spectrum analyzer to the PC.

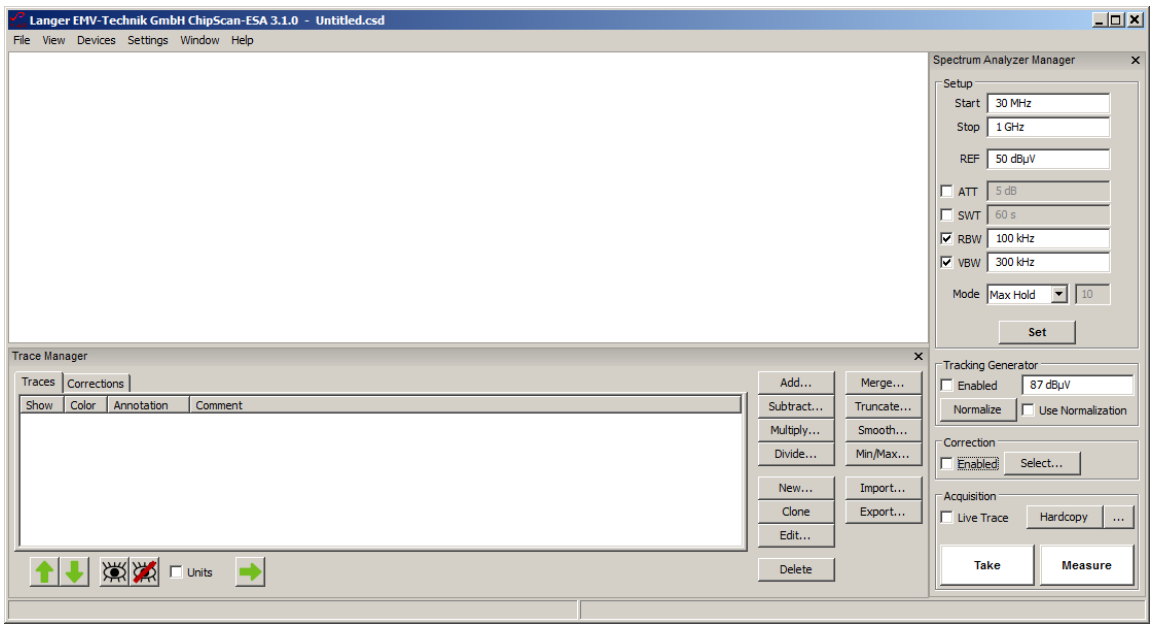

Figure 42: Main settings of the spectrum analyzer in the "Spectrum Analyzer Manager" (right side).

The main settings of the spectrum analyzer have to be defined in the "Spectrum Analyzer Manager" (**Figure 42**). The correction curve K603 or K750 has to be used to correct the frequency response of $U_{AV}(\omega)$ measured with the **P603** or **P750** probe. $U_{AV}(\omega)$ can be converted to I_{IC} (ω) and $U_{IC}(\omega)$ automatically under "Correction" in the "Spectrum Analyzer Manager". The correction curve K603 or K750 has to be used for this purpose.

Mathematical functions can also be used (**Figure 43**): division by ω in the time domain, for example. This corresponds to a subtraction of 20 Log ω in the logarithmic form.
You can find the correction curve (- 20 Log ω) in the "Corrections" list of the "Trace Manager".
Click the "Select" button (mouse cursor ① **Figure 43**) under "Correction" in the "Spectrum Analyzer Manager" to select the respective correction curve.

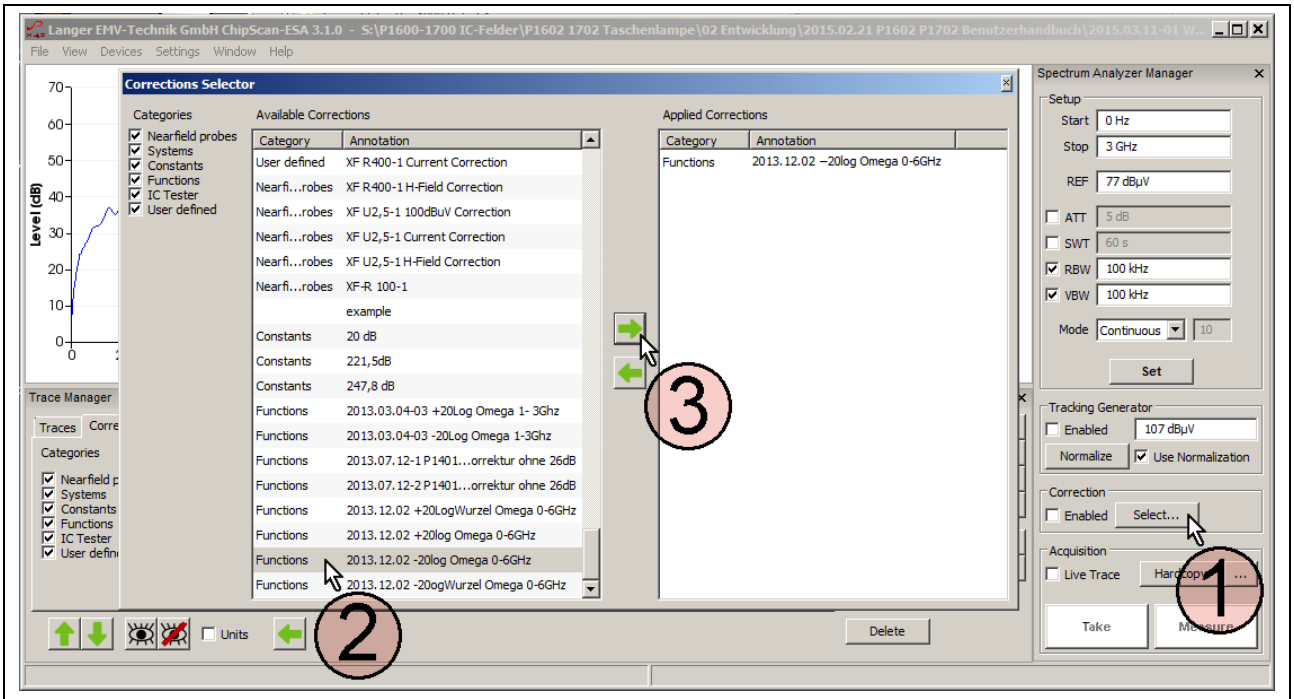

Figure 43: Using mathematical functions by activation in the "Corrections Selector".

The "Corrections Selector" window opens **Figure 43**. Click and activate the correction curve -20 Log ω with the mouse cursor ②. Click the "Arrow right" ③ button to move the correction curve to the "Applied Corrections" list. Other correction factors and correction curves (**Figure 44**) such as K603 or K750 can be loaded in the same way or selectively (**Figure 44**).

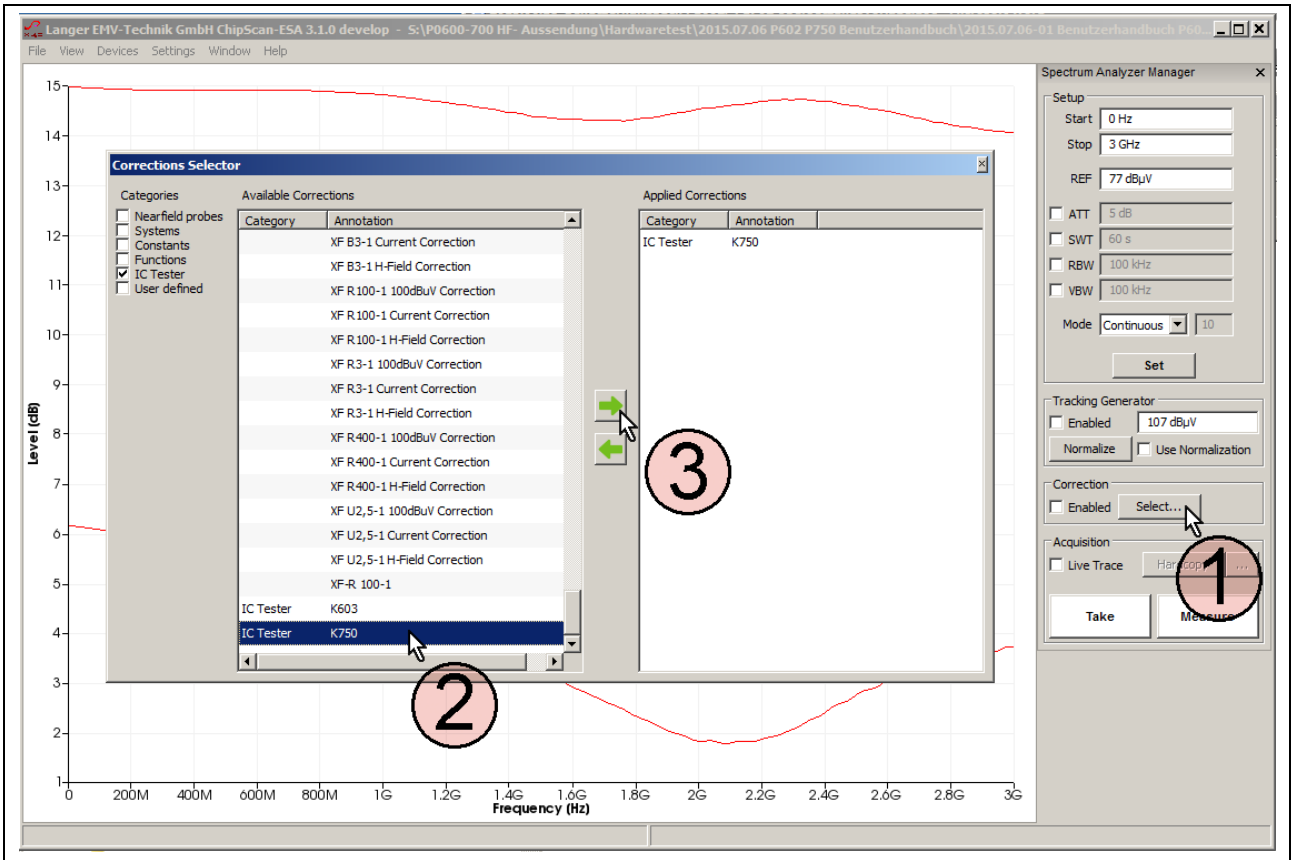

Figure 44: Loading the correction curves K750 to the "Corrections Selector".

The correction curve K603 is loaded to the "Corrections Selector" if the **P603** probe is used for the measurement. Activate the "Enabled" box in the "Correction" field in the "Spectrum Analyzer Manager" with the mouse cursor ① (**Figure 45**). The field ② flashes if the correction is active **Figure 45**. Click "Take" or "Measure" (mouse cursor ③ **Figure 45)** to transfer the current measurement curve ④ $I_{IC}(\omega)$ from the spectrum analyzer to the PC.
The calculation: $I_{IC}(\omega) = U_{AV}(\omega) + K603$ is automatically performed at the same time. The curve $I_{IC}(\omega)$ is added to the bottom of the "Traces" list in the "Trace Manager". A measurement log can be kept in the free text field under "Comment".
Delete the check mark from the "Enabled" box if you only want to measure $U_{AV}(\omega)$; the field ② then stops flashing.

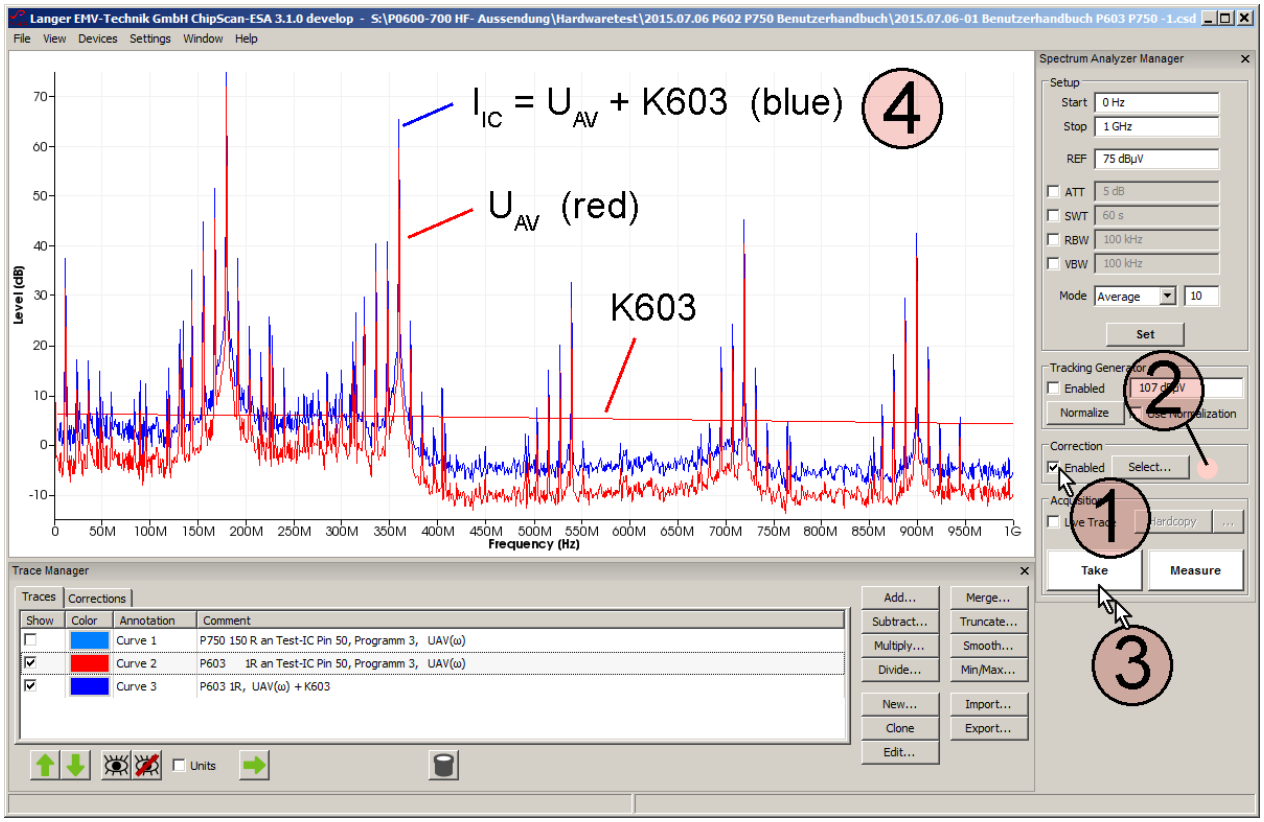

Figure 45: Measurement with the P603 RF current probe head using the correction curve K603.

The "Curve" number is counted automatically (Curve 3) under "Annotation". The measurement log can be kept in the respective free text field under "Comment".

The correction can also be made later on if the measurement has been carried out using the **P750** probe without any correction. The correction curve $U_{IC}(\omega) = U_{AV}(\omega)$ +K750 has then to be added.

You can find the correction curve K750 in the "Corrections" list of the "Trace Manager".
Click the "Select" button (mouse cursor ① **Figure 46**) under "Correction" in the "Spectrum Analyzer Manager" to select the respective correction curve.

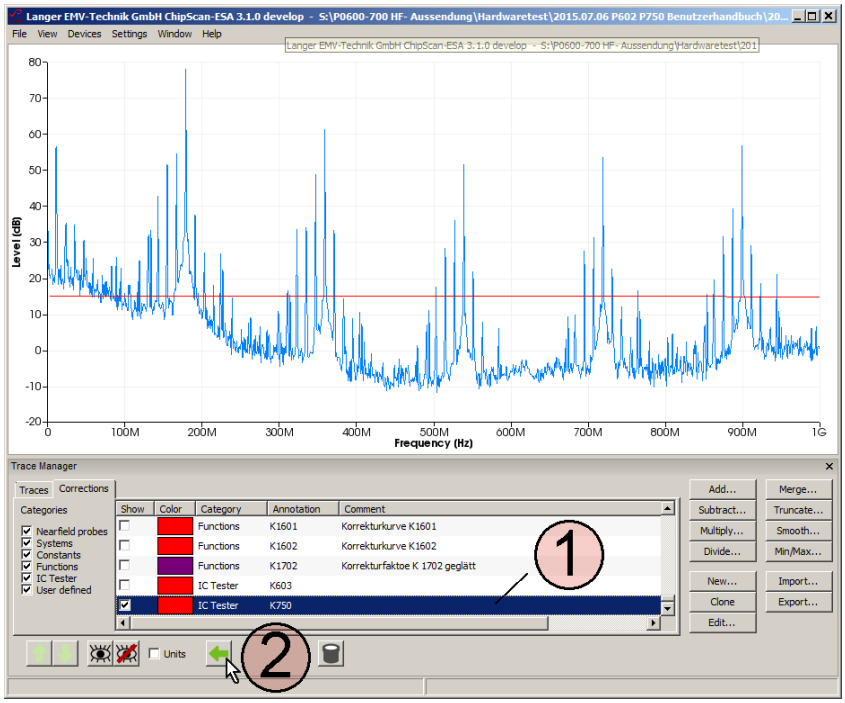

Figure 46: Correction after the measurement; copying K750 from the "Corrections" list to the "Traces" list

Mark the "Curve 1" (U_{AV}) curve and the "K750" curve in the "Traces" list **Figure 47** in the "Trace Manager" with the mouse cursor ①**.** Open the mathematical operation "Add…" (addition) and activate "Sum up all Plots" (**Figure 47** mouse cursor ③). Click OK ④ to perform the addition U_{AV} + K750.

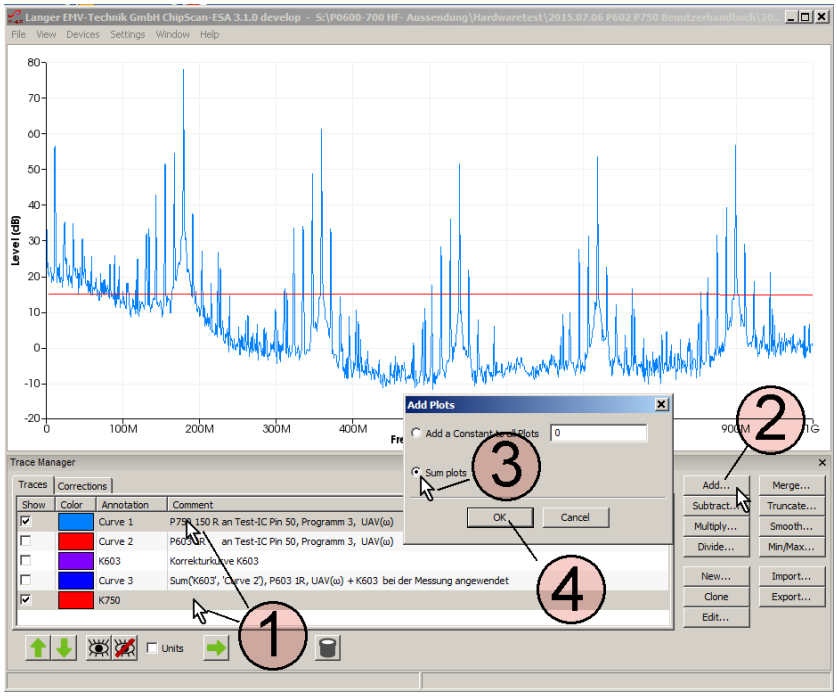

Figure 47: Correction after the measurement; performing the addition U_{IC} = U_{AV} + K750

The calculation creates the entry (① **Figure 48**) at the bottom of the "Traces" list and is displayed as "Curve 5" (② **Figure 48**).

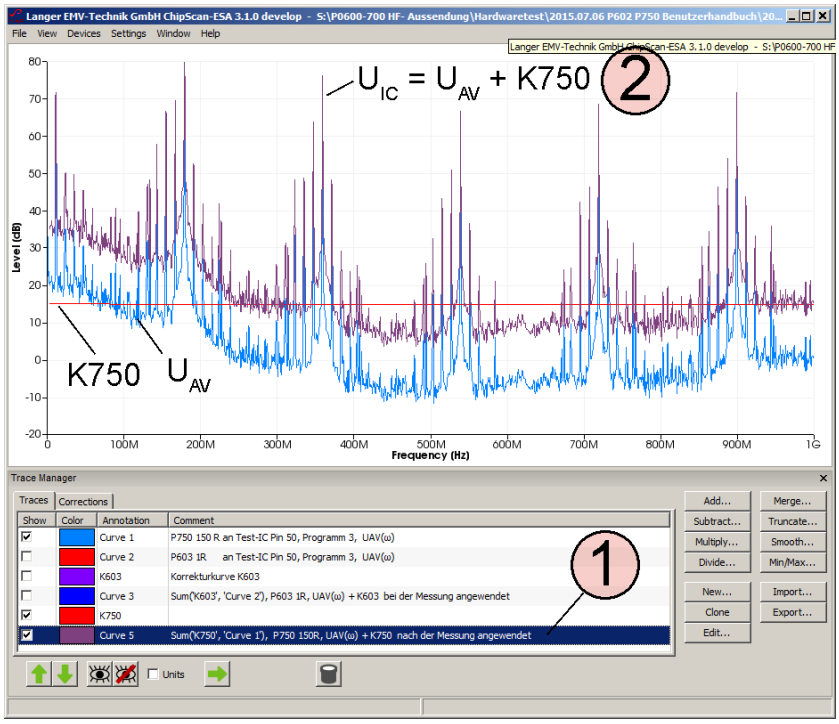

Figure 48: Correction after the measurement; result of the addition $U_{IC} = U_{AV} + K750$

The user manuals for the respective devices are listed in the following table:

Task	**Operating instructions**
• Instructions for the development of the adapter board • Test process	IC test guideline (Langer EMV-Technik GmbH)
• GND 25 ground plane • CB 0708 connection board • OA 4005 oscilloscope adapter • TH 22 probe head holder • Monitoring and controlling the test IC	ICE1 user manual

Table 6: User manuals for respective devices

12 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.

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