M550

Impedance Calibrator

Operation manual

MEATEST

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1. Basic information

M550 Impedance calibrator is a test device designed for LCR meter verification and calibration. The calibrator integrates partial resistance standards in decade series in the range of values from 100 mΩ up to 100 MΩ, capacitance standards in range 10 pF to 100 µF and inductive standards in the range 10 µH to 10 H. For test leads and unit under test electrical zero compensation the calibrator is equipped with reference positions of short-circuit terminals SHORT and open-circuit terminals OPEN. Summary frequency range covers band from 20 Hz to 1 MHz, however some partial standards have lower applicable frequencies. Partial standards feature low temperature coefficient, excellent long term stability and low frequency dependency.

The calibrator offers two banks of standards. The more accurate bank is equipped with four output BNC connectors. It is aimed for calibration of LCR meters based on auto-balancing bridge principle using four-pair-terminal technique (4TP) of test terminal connection. The second bank (4W/2W) is equipped with 4mm output banana terminals. The bank is aimed for calibration of LCR meters based on I-V method with non-coaxial test terminals. Practically this bank can be used in four-wire (4W) or two-wire (2W) measurements.

M550 has a built-in test signal level meter which can be easily used for verification of test signal voltage, current and frequency. Large front panel color graphic LCD display show parameters of a selected standard, set-up configuration, calibration data accuracy and another useful information.

Impedance calibrator should be periodically recalibrated. Recommended recalibration interval is 1 year. Internal calibration data are accessible via front panel keyboard. Calibration memory is protected with a calibration password.

All functions of the calibrator can be controlled by IEEE-488 interface or via RS-232 serial line.

2. Preparation for operation

2.1 Inspecting package content, selecting the installation location

Basic package includes the following items:

• M550 Impedance calibrator	1 pc
• Mains supply cord	1 pc
• Coaxial cables BNC-BNC	4 pcs
• Test lead banana-banana	4 pcs
• Adaptor BNC/banana	4 pcs
• Operation manual	1 pc
• Spare fuse	1 pc
• RS232 cable	1 pc
• Test report	1 pc

The calibrator should be powered by 230/115 V – 50/60 Hz mains. It is a laboratory instrument whose parameters are guaranteed at 23±2 ^{o}C. Before powering on the instrument, place it on a level surface. Do not cover the vents at the bottom side and the fan opening at the rear panel.

2.2 Power-on

Before connecting the calibrator to the mains, check the position of the mains voltage selector located at the rear panel. Select either 115V or 230V position according to your nominal mains voltage.

- Plug one end of the power cord into the connector located at the rear panel and connect the other end of the power cord into a wall outlet.
- Switch on the mains switch located at the rear panel. LCD display is lit.
- The calibrator performs internal hardware checks for 5 seconds. During initialization label M550 Impedance calibrator is displayed.
- After the test is finished, the calibrator resets to its reference state, i.e. the following parameters are set:

Bank of standards	4TP (coaxial output)
Function	Resistance standard
Nominal value	100 Ω
Frequency	1 kHz
Displayed parameters	R_s - L_s
Equivalent circuit	series
Meter function	ON
Correction	OFF
Output terminals	OFF

GPIB address of the calibrator is factory-preset to 2. This value is valid until the user changes it.

2.3 Warm-up time

The calibrator works after it is switched on and the initial checks complete. Specified parameters are guaranteed after the instrument warms up for 10 minutes.

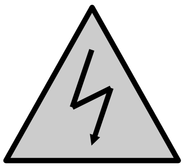
3. Safety precautions

The instrument has been designed in Safety Class I according to EN 61010-1. The design reflects the requirements of A2 amendment of the standard. Safety is ensured by the design and by the use of specific component types.

The manufacturer is not liable for the damage caused by modification of the construction or replacement of parts with non-original ones.

Safety symbols used on the equipment

Warning, reference to the documentation



Warning - risk of electric shock

4. Description of control

4.1 Front panel

M550 front panel is equipped with TFT color display, control buttons and output terminals.

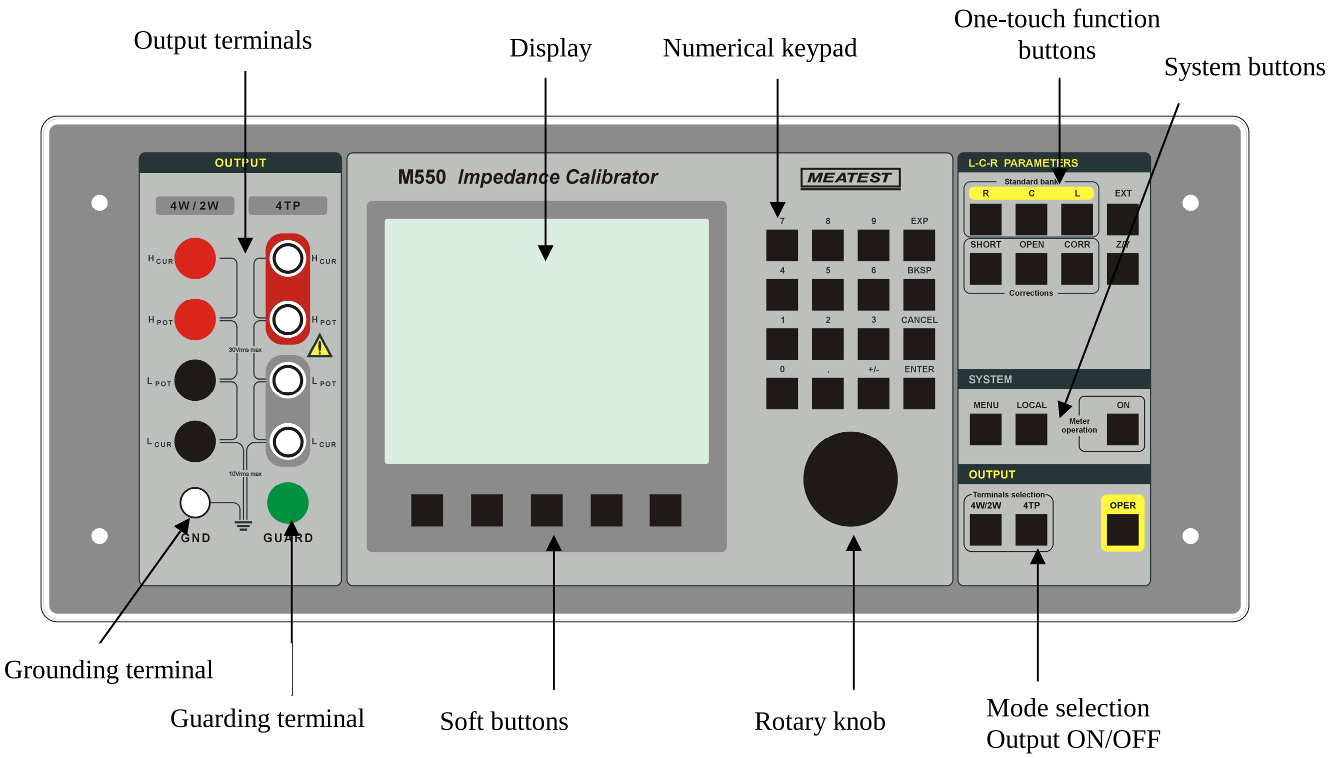


Fig. 1 Front panel

1. *Output terminals*

Calibrator contains two sets of output terminals. Both sets are electrically isolated from each other.

4TP coaxial BNC output for calibration of BNC terminal LCR meters. Shielding of the BNC connectors is isolated and connected together inside the bank of standards in one point to obtain the lowest frequency dependency. 4TP output is suitable for calibration of LCR meters with coaxial input connectors.

Note: The shielding of the output terminals is not galvanically connected to any metal part of the device!

4W/2W 4mm banana non-coaxial output for calibration of four and two wire LCR meters. While in 4W mode all four terminals are applied for DUT connection , in 2W mode only H_{CUR} and L_{CUR} terminals have defined impedance parameter.

Note: In 2W mode both $H_{CUR} – L_{CUR}$ and $H_{POT} – L_{POT}$ terminals are connected to internal partial standard however calibration values are defined between $H_{CUR} – L_{CUR}$ terminals.

Meaning of individual terminals is as follows:

H_{CUR}	high source current terminal
H_{POT}	high sense voltage terminal
L_{POT}	low sense voltage terminal
L_{CUR}	low sense current terminal

GUARD Guarding terminal. It is connected to shielding of the 4TP coaxial output connectors. It has no function in 4W or 2W mode.

GND Grounding post is joined to metal parts of housing and to protective earth in power line socket.

2. Soft buttons

There are five buttons below the display, which meaning changes depending on the content of the display. These buttons usually call up local menu with parameters setting, modes, etc. or enable to close currently opened function or menu.

3. Rotary knob

The rotary knob integrates several functions. By turning the knob to the left or right, the user can:

- step through the options in menus
- select L-C-R partial standard according to its nominal value
- enter numerical values

When making a menu selection, pushing in on the knob is equivalent to pressing the SELECT soft key. When editing a number, pressing in on the knob will switch between moving the cursor between characters and changing the selected character’s value. Arrow icons above and below the selected digit indicate which of the two modes are active.

4. Numerical keyboard

The keyboard allows writing the numerical values on the display directly. ENTER button is used to confirm the selection. CANCEL button is used to cancel the entry.

5. L-C-R Parameters (one touch function buttons)

Function buttons can be used to call up the functions of the calibrator directly. The following buttons are provided:

Function	*Key*
Resistance bank selection	R
Capacitance bank selection	C
Inductance bank selection	L
External standard	EXT
Reference SHORT	SHORT
Reference OPEN	OPEN
Correction ON/OFF	CORR
Z or Y parameters displaying	Z/Y

Tab. I. List of one touch buttons

6. System buttons

Group of buttons enable access to system parameters

Function	*Key*
Entering to main setup menu	MENU
Return from remote mode to local mode	LOCAL
Activation of internal meter ot test signal level	F/U

Tab. II. List of system buttons

7. Terminals selection & ON/OFF buttons

The buttons enable selection one of two outputs either 4TP or 4W/2W and switching output terminals ON/OFF.

Function	*Key*
Four terminal pair coaxial output selection	4TP
Four/two wire banana output selection	4W/2W
Output terminals ON/OFF	OPER

Tab. III. Mode selection

8. *Display*

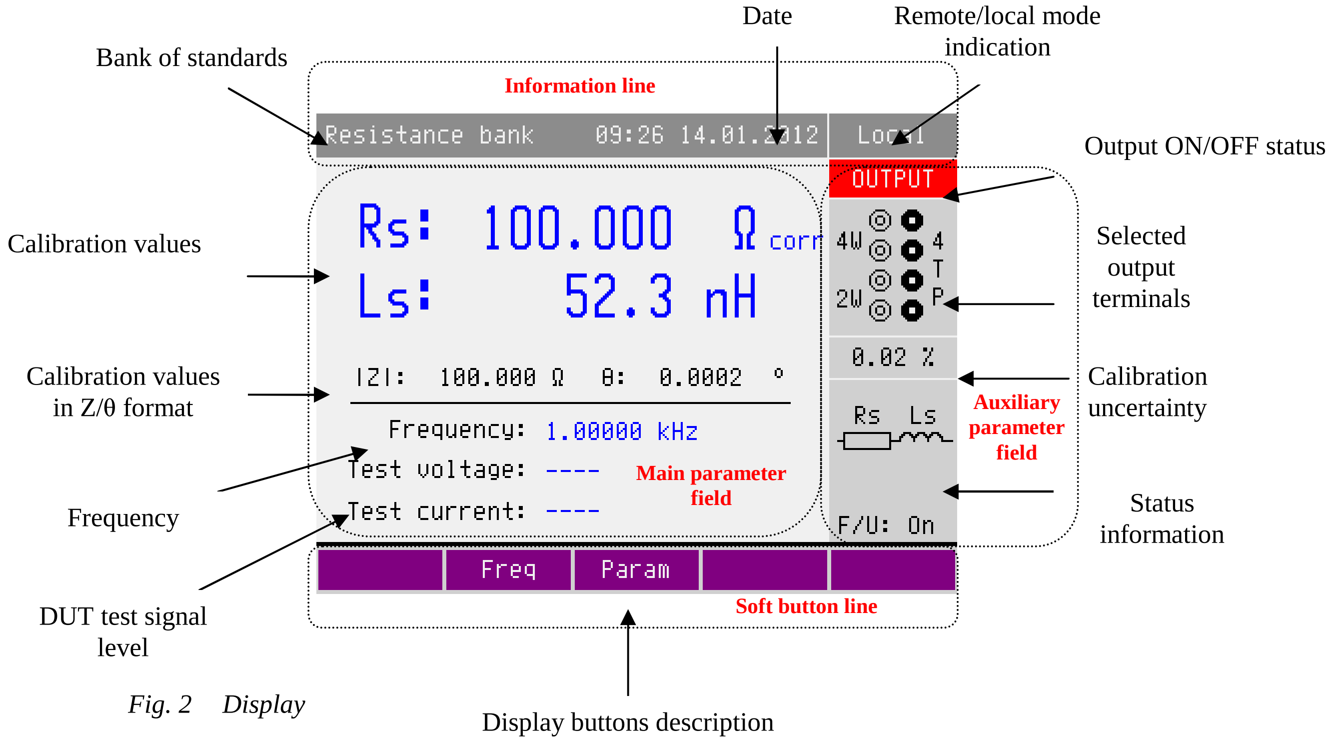


Fig. 2 Display

The display has several separated fields with following information displayed:

Information line:

- type of selected bank Resistance, Capacitance, Inductance
- current date/time. Displaying of the date and time can set to be hidden in setup menu.
- local/remote mode status indication

Main parameter field:

- both main complex parameters of selected standard in selected frequency point including type of displayed values. In the upper line primary parameter, in the bottom line secondary parameter is always displayed.
- indication of function CORRECTION ON or OFF. Symbol “corr” is displayed beside the main parameter if Correction is ON.
- Z/θ normalized polar format calibration values of the selected standard
- selected (or measured) test frequency
- measured test voltage and frequency sourced by DUT
- calculated test current

Auxiliary parameter field:

- status of output terminals ON or OFF
- selected output terminals and basic mode 4TP or 4W/2W indication
- calibration uncertainty of the selected standard at selected frequency
- parallel or serial equivalent circuit of the displayed calibration values
- working mode of built-in test signal level meter ON/OFF

Soft button line:

- soft buttons description. If there is no description above soft button, the button is not active in selected function.

Colors on display

Common rules are used for an applied color of labels and values.

- red color is applied, when displayed value is measured by M550 calibrator.

- blue color is applied for parameters or values, which can be set up or modified
- black color is used for fixed values, labels, notes, parameters which cannot be modified and for other fixed text with a general information purpose.

4.2 Rear panel

Rear panel includes ventilation hole, power line socket, power line fuse and power line voltage selector 115/230V integrated in power entry module, interface connectors GPIB, RS232, metal central grounding post and four coaxial connectors for external standard (function EXT).

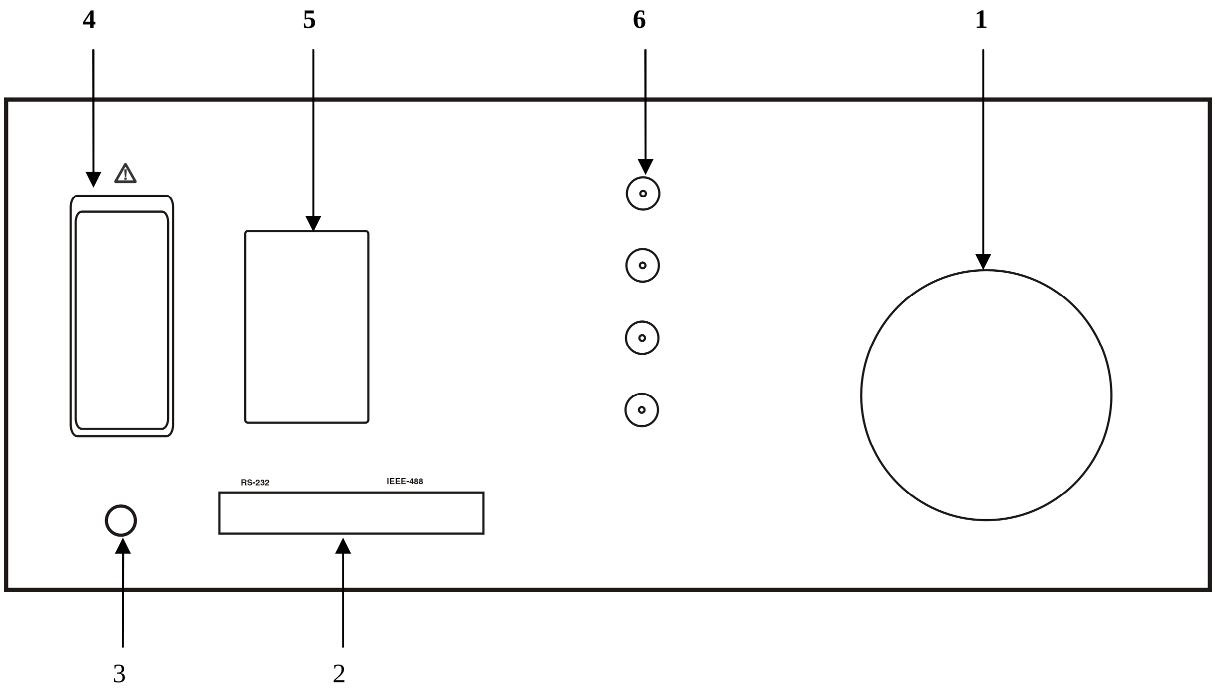


Fig. 3 Rear panel

1 forced ventilation holes
2 GPIB, RS-232 connectors
3 central grounding post
4 power entry module with power line switch, power line with fuse and voltage selector
5 model plate
6 EXT input with four BNC connectors

5. Principle of operation

M550 Impedance calibrator is designed for calibration of LCR meters. It contains partial standards of resistance, capacitance and inductance of fixed decimal values. The calibrator offers two outputs:

- 4TP coaxial output for calibration of LCR meters which are equipped with BNC coaxial terminals.
- 4W/2W 4 mm terminal output for calibration of non-coaxial LCR meters with 2 or 4 banana input terminals. 4W/2W output offers two-wire or four-wire connection.

Overview of available modes, displayed parameters, applicable ranges and frequency bands is shown in table V.

5.1 Terminology

Important factor in impedance calibration is correct connection of test cables between source of standard value (like M550 calibrator) and DUT. Four cables typically used for the connection have specific purpose and must not be swapped. M550 operation manual uses for description symbols H_{CUR}, H_{POT}, L_{POT}, L_{CUR} however some LCR meter manufacturers use different symbols. Table IV shows equivalency of those commonly used symbols.

LCR meter / M550 terminal description	***Symbol used in M550 operation manual***	***Another version used by some LCR meter manufacturers***
High current source terminal	H_{CUR}	H_i, H_C
High voltage sense terminal	H_{POT}	H_u, H_P
Low voltage sense terminal	L_{POT}	L_u, H_P
Low current sense terminal	L_{CUR}	L_i, L_C

Tab. IV Symbols

Mode	**Output terminals**	**Type of standard**	**R/CL range**	**Applicable frequency range** [*1]	**Connection**	**Calibration values**	**Displayed parameter pairs**	**Application**
4TP	4 TP $H_{CUR} – H_{POT}$ $L_{POT} – L_{CUR}$	Resistance	0.1Ω to 100MΩ	20 Hz to 1 MHz	Coaxial 4 x BNC	Separated for CORR ON and CORR OFF	Rs-Ls, Rs-Cs Rp-Cp, Rp-Lp G-B, R-X Z-θ, Y-θ	4 terminal coaxial LCR meters calibration
		Capacitance	100pF to 100µF	20 Hz to 1 MHz			Cp-Rp, Cp-Gp Cs-Rs, Cp-D, Cs-D Z-θ, Y-θ	
		Inductance	10µH to 10H	20 Hz to 100 kHz			Ls-Rs,Ls-Q	
4W	4W/2W $H_{CUR} – H_{POT}$ $L_{POT} – L_{CUR}$	Resistance	0.1Ω to 100MΩ	20 Hz to 100 kHz [*3]	4 x banana	Separated for CORR ON and CORR OFF	Rs-Ls, Rs-Cs Rp-Cp, Rp-Lp G-B, R-X Z-θ, Y-θ	4 terminal banana LCR meters calibration
		Capacitance	100pF to 100µF	20 Hz to 100 kHz [*3]			Cp-Rp, Cp-Gp Cs-Rs, Cp-D, Cs-D Z-θ, Y-θ	
2W	4W/2W $H_{CUR} – L_{CUR}$	Resistance	0.1Ω to 100MΩ	1 kHz [*2]	2 x banana	No correction available	R	2 terminal banana LCR meters calibration
		Capacitance	100pF to 100µF	1 kHz [*2]			C	

Tab. V Modes of operation

[*1] Applicable frequency range may not cover all partial standards, see full specification for details.
[*2] Applicable frequency range is wider however calibration value is defined only at 1 kHz frequency. Typical applicable frequency range is form 20 Hz to approx. 1 kHz.
[*3] Calibration uncertainty is guaranteed at frequency 1 kHz. In full frequency range 20 Hz to 100 kHz calibration values considering typical frequency characteristic are displayed.

5.2 4TP Four terminal pair standards

5.2.1 Internal partial standards description

4TP coaxial block consists of standards with coaxial connection of partial standards, coaxial SHORT and coaxial OPEN positions. The block contains resistance bank, capacitance bank and inductance bank. Resistance and capacitance partial standards are formed by single resistance and capacitance components. Only resistance value 100 MΩ is designed as simulator of T-resistance type:

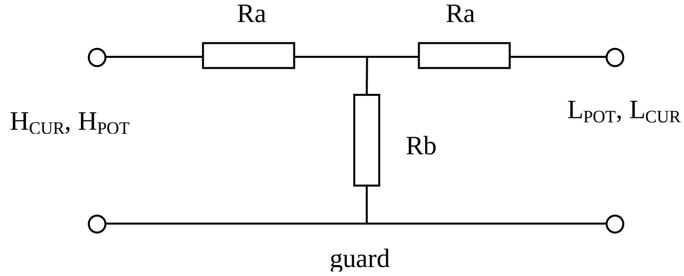


Fig. 4 T resistance network

with simulated resistance $R_{21} = 2*Ra + Ra^2/Rb$

Inductance bank does not contain any physical inductors. All inductance values are simulated using T network of RC type

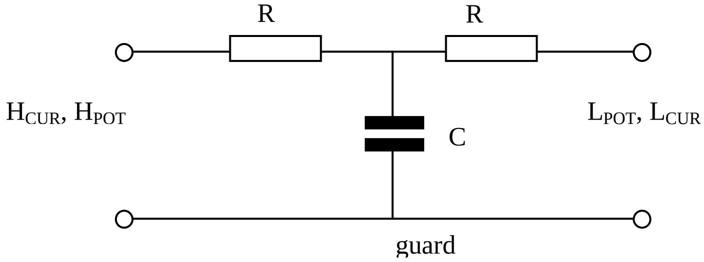


Fig. 5 T inductance network

with simulated serial inductance value $L_{21} = C*R^2$ and quality factor $Q = \omega*C*R/2$. Application of simulated inductance standards is limited to LCR meters which use four terminal pair technique (4TP).

Partial standards are connected to the output terminals using signal relays which switch both signal and shielding wire in all four terminals H_{CUR}, H_{POT}, L_{POT}, L_{CUR}. Coaxial connection of measuring traces inside the calibrator is made of coaxial PTFE 2 mm cable. Components are placed on printed circuit boards with RF strip line design.

The following types of components are used in individual positions:

Resistance

Nominal value	Type of segment
0.1 Ohm	Foil resistor
1 Ohm	Foil resistor
10 Ohmů	Foil resistor
100 Ohmů	Foil resistor
1000 Ohmů	Foil resistor
10k	Foil resistor
100k	Foil resistor
1M	Wraparound resistor
10M	Wraparound resistor
100M	T network 10MΩ - 1.25MΩ - 10MΩ

Tab. VI 4TP Resistance

Capacitance

Nominal value	Type of segment / dielectricum
10 pF	ceramic chip C0G
100 pF	ceramic chip C0G
1000 pF	ceramic chip C0G
10nF	ceramic chip C0G
100nF	ceramic chip C0G
1uF	ceramic chip C0G
10uF	compensated foil capacitor / polyproplen+polyester
100uF	compensated foil capacitor / polyproplen+polyester

Tab. VII 4TP Capacitance

Inductance

Nominal value	Type of segment
10uH	T-network 55Ω - 33nF – 55Ω
100uH	T-network 100Ω - 10nF - 100Ω
1mH	T-network 316Ω - 10nF - 316Ω
10mH	T-network 316Ω - 100nF - 316Ω
100mH	T-network 1k - 100nF – 1k
1H	T-network 10k - 10nF - 10k
10H	T-network 10k - 100nF - 10k

Tab. VIII 4TP Inductance

5.2.2 4TP connection of the impedance calibrator to DUT

The four–terminal pair method is applied in many LCR meters which use coaxial inputs. It solves problems with mutual coupling among test cables. The reverse test current flows through shielding of the current coaxial cables and so it eliminates an effect of the magnetic flow, arising as measuring current flow though inner current conductors sequence. The function of individual connectors on calibrator side and on checked LCR meter as well is un-exchangeable.

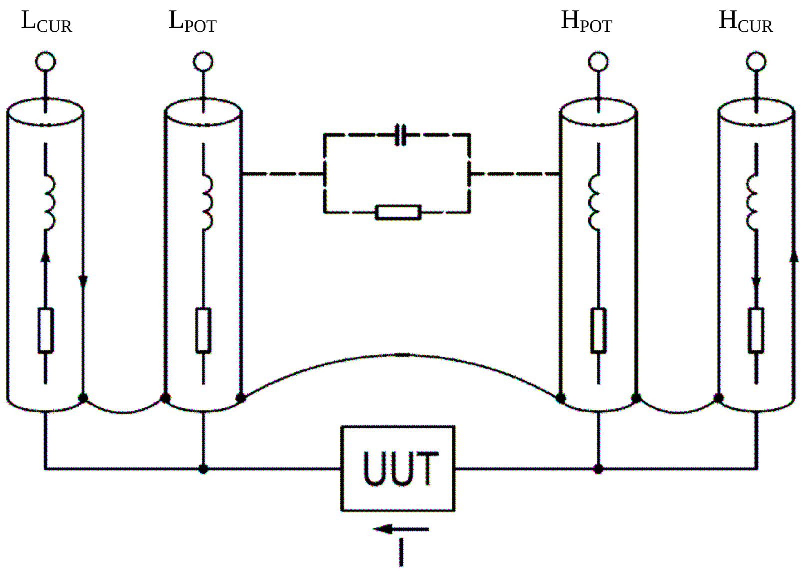


Fig. 6 Principle of 4TP test lead connection

The 4TP measurement circuit outer conductors of instrument's H_{CUR}, H_{POT}, L_{POT}, and L_{CUR} terminals are isolated. By connecting the outer shielding conductors to each other at the ends of the coaxial cables, the current loop is formed. The test signal current flows through the inner conductor of the H_{CUR} cable, to the DUT, and the inner conductor of L_{CUR} cable, and then returns to signal source through the outer shielding conductors of the L_{CUR} and H_{CUR} cables. Since the same current flows in opposite directions through the inner and outer conductors of the coaxial cables, the magnetic flux generated by the inner conductor is cancelled out by that of the outer shielding conductor, as shown in Figure 3-8 (e). As a result, the mutual coupling problem is eliminated. The 4TP configuration can improve the impedance measurement range to below 1 mΩ. The measurement range achieved by this configuration depends on how well the 4TP configuration is strictly adhered to up to the connection point of the DUT.

Use four coaxial test leads to connect Impedance calibrator to unit under test, see fig. 7.

Note: Shielding conductors of the coaxial test cables must be connected neither to each other nor to ground potential GND. If the shielding conductors are not interconnected properly, accurate loop current does not flow through the cables and, as a result, the measurement range will be limited, or in some cases, measurements cannot be made.

Shielding conductors of the front panel BNC connectors are interconnected inside the calibrator. Do not allow any other connection of the shielding conductors !

Note: Some types of LCR meters and LF impedance analyzers do not meet requirements of four terminal pair principle, especially in connection of shielding conductors. This can result in unexpected deviations of impedance measurements on higher frequencies, typically above 100 kHz.

Non correct interconnection of the coaxial test cables results in sensitivity of mutual position of all four test cables to result of measurement, typically at frequencies above 100 kHz.

DUT LCR meter

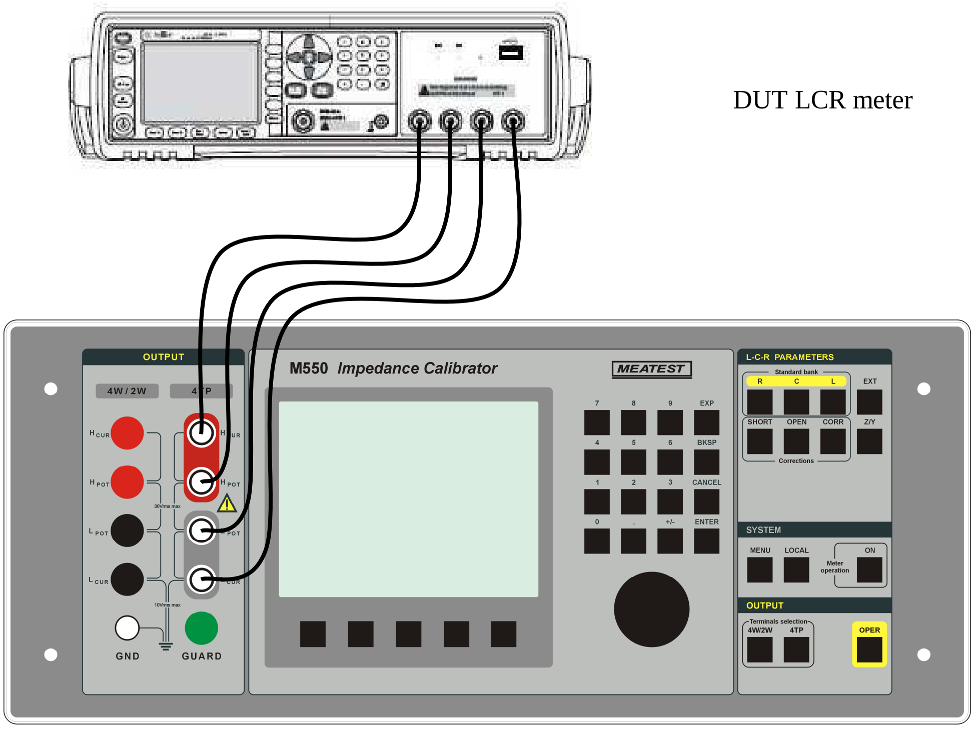


Fig. 7 DUT connection in 4TP mode

4TP technique is mostly used in modern LCR meters. Typical feature is 4 coaxial input terminals usually labeled H_i (or H_{CUR}), H_u (of H_{POT}), L_u (or L_{POT}), L_i (or L_{CUR}).

Example of LCR meters with four terminal pair connection:

- HP/Agilent 4263B, 4268A, 4275A, 4274A, 4284A, 4276A, 4277A, E4980A,
- WAYNE-KERR 3255B, 6425, 6430, 6440, 6450, 6500B

5.3 4W/2W Two/four wire standards

5.3.1 Internal standards description

4W/2W non-coaxial block of standards consists of bank of resistors and a bank of capacitors The 4W/2W block is fully separated from the coaxial 4TP block, except values 10 µF and 100 µF which are shared in both coaxial 4TP and non-coaxial 4W/2W modes. The 4W/2W block contains only two terminal partial standards. No method of simulation is applied.

Range of resistor standards is from 0.1 Ω to 100 MΩ, range of capacitance standards is limited from 100 pF to 100 uF.

The following types of components are used in individual positions:

Nominal value	***Type of segment***
0.1 Ohm	Foil resistor
1 Ohm	Foil resistor
10 Ohmů	Foil resistor
	Foil resistor
100 Ohmů	Foil resistor
1000 Ohmů	Foil resistor
10k	Foil resistor
100k	Foil resistor
1M	Wraparound resistor
10M	Thin-layer metal resistor
100M	Thin-layer metal resistor

Tab. IX 4W/2W Resistance

Nominal value	***Type of segment/dielectric***
100 pF	ceramic chip C0G
1000 pF	ceramic chip C0G
10nF	ceramic chip C0G
100nF	ceramic chip C0G
1uF	compensated foil capacitor/ polyproplene+polyester
10uF	compensated foil capacitor/ polyproplene+polyester
100uF	compensated foil capacitor / polyproplene+polyester

Tab. X 4W/2W Capacitance

5.3.2 4W Four wire connection of the impedance calibrator to DUT

4W connection is mostly used in older LCR meters. They have typically four non-shielded banana terminals on the front panel. Accuracy of these meters is obviously worse than an accuracy of 4TP meters and frequency range is limited to approx. 1 kHz.

The four-terminal method reduces substantially influence of test cables between the Impedance calibrator and DUT. The four-terminal connection is suitable to use from impedance values about 1Ω. When measuring on lower impedance values the result of calibration can be distorted by mutual feedback between current and voltage conductors, especially in mode when higher measuring current is used. The impedance calibrator is connected by four standard cables. This connection is not suitable for measuring with frequency higher than 1 kHz. However even at lower measuring frequency use it is suitable to ensure minimum feedback among current and voltage conductors. At measuring values lower than 100Ω it is recommended to twist both current L_{CUR} – H_{CUR} and both voltage L_{POT} – H_{POT} cables, at measuring of values over 100Ω cables L_{POT} – L_{CUR} and H_{POT} – H_{CUR}.

Four wire and two wire connection has limited capabilities to avoid stray parameters, and influence of test lead.

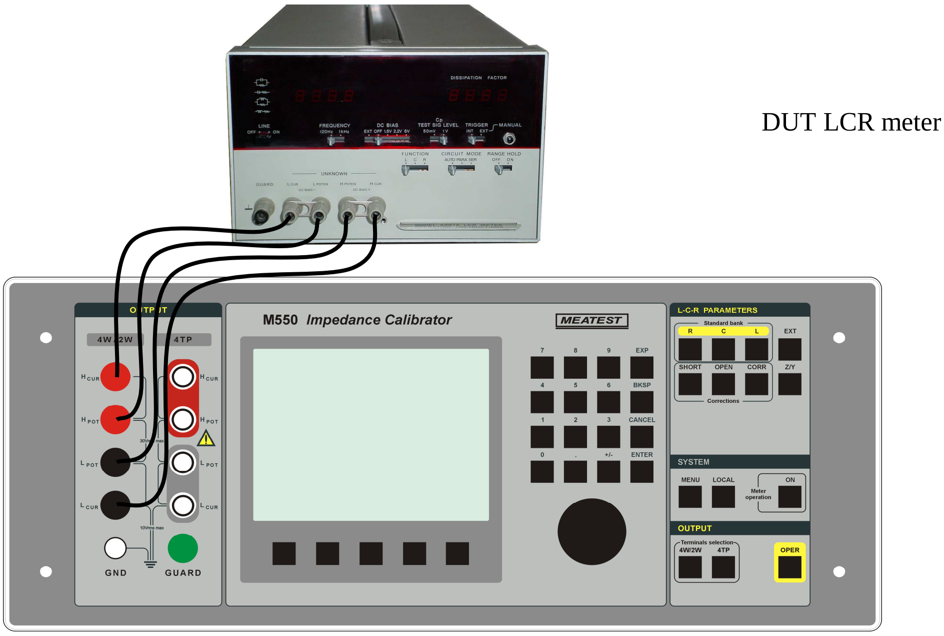


Fig. 8 Four wire connection

5.3.3 2W Two wire connection of the impedance calibrator to DUT

This way of the Impedance calibrator connection to the tested LCR meter is the simplest method however it is influenced by a lot of factors resulting in worse accuracy comparing to four-terminal or four terminal pair method. To the measurement result there are added errors by series resistance and inductance of test leads and parallel capacity and conductance between the two leads. The two-terminal connection is normally applied only in case when a high accuracy of calibration is not required. The calibrator is connected by single test leads to the H_{CUR} and L_{CUR} terminals. M550 calibration data does not offer residual parameters correction (OPEN and SHORT) at all in this mode. Partial standards are suitable for application only bellow 1 kHz.

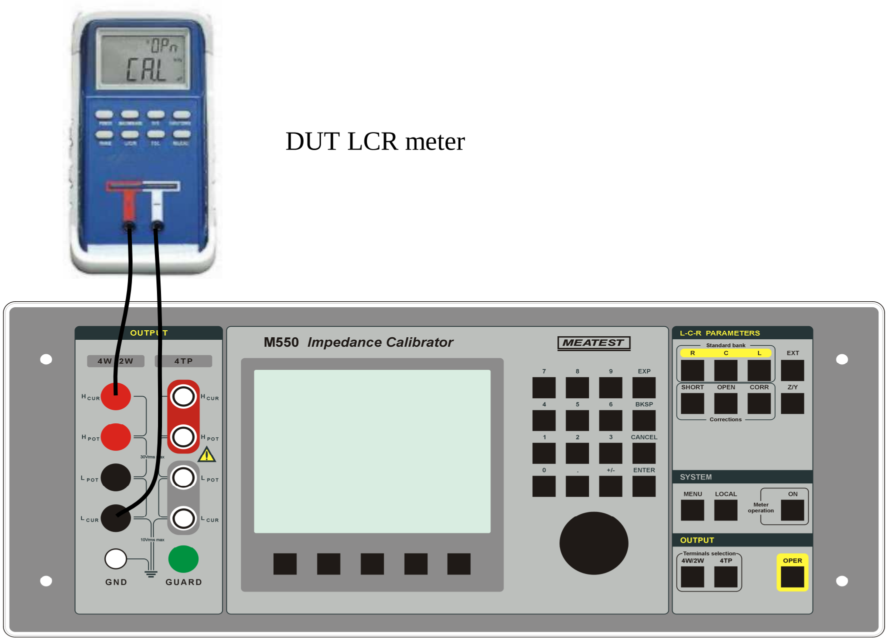


Fig. 9 Two wire connection

6. Control of the calibrator

6.1 Partial standard selection

Any of built-in partial standards can be connected to the output terminals and appropriate calibration data is displayed on the display.

a. L-C-R mode selection

After pressing one of the buttons R, C, L the calibrator switches to the selected mode resistance, capacitance or inductance, sets the last set-up standard and displays its calibration values. Whenever function is changed, calibrator remains with output terminals on until Output ON/OFF or Terminals selection button is pushed. Selected bank is indicated in top line of the display.

b. Partial standard selection

In any function and mode one of available partial standards can be chosen. Selection is possible in one of following ways:

- by typing nominal value of the requested standard from numeric keyboard. When non-correct value is entered, calibrator selects that standard which has the closest value to the entered value.
- using rotary button.

Push OPER button to connect the selected partial standard to the output terminals.

c. Displayed parameters setting

Use PARAM soft button to modify type of parameters pair to be displayed as calibration values. After pushing the PARAM button list of available parameter pairs is displayed in rolling window. Select requested pair using rotary button and confirm by pushing the soft button SELECT.

Note: List of available parameters contains only frequently used parameter, see Tab. V.

d. Frequency selection

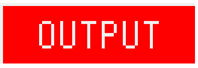
Push the soft button FREQ to change frequency. Window for frequency entering appears.

- Type the requested frequency and confirm with soft button Hz, kHz or MHz. Calibration data is shown on the display. Output terminals will stay ON or OFF during changing the frequency depending on previous status. If frequency out of specified frequency range is entered calibrator will show error message “Frequency too high.” or “Frequency too low.”
- Another way of frequency setting is available using the rotary button. Push the rotary button. Arrows above and under the active position appear enabling to change the active position. Push the button again to set requested value.

6.2 Output terminals ON/OFF

Push the OPER button to switch output terminals on. The selected partial standard is available at the output terminals either coaxial or banana terminal depending on the selected mode 4TP or 4W/2W. Status of the output terminals is shown on the display with following meaning:

output terminals OFF



output terminals ON

6.3 Change of the bank mode 4TP to 4W/2W

4TP coaxial mode is setup as default after switching on. Partial standards are available on coaxial output terminals. Symbols in Auxiliary parameter window indicate position of these active output terminals. Push

4W/2W button to switch over to 4W/2W mode. Switch OPER button. Now selected partial standard is connected to banana 4 mm terminals in 4W mode. Indicated position of the active terminals has been changed.
Push the 4W/2W button again. Calibrators goes over to 2W two wire mode. Auxiliary parameter window shows active terminals again.

6.4 Correction ON/OFF

Using CORR button calibration values of selected standard with or without correction can be displayed. Correction function is available for 4TP and 4W mode. 2W mode does not have this option.

When CORR ON mode is selected, calibrator shows calibration values relatively to internal reference positions SHORT and OPEN. When CORR OFF is selected, calibration values are defined in plane of output terminal and without any SHORT/OPEN compensations.

Push the button CORR to display calibration values with corrections. Symbol “corr” is attached to the main calibration value on the front panel display. Push the button CORR again to switch off corrections. Symbol “corr” disappears.

Open/Short/Load correction technique

Open/short/load compensation is an advanced compensation technique that can be applied to minimize influence of residual parameters. To carry out the open/short/load compensation, three measurements are required before measuring the DUT, with the test fixture terminals opened, shorted, and with a reference load connected to DUT. Follow instructions of LCR meter – DUT for correct compensation.

In the lower frequency region, using the open/short compensation function can minimize most of test lead residuals. In the RF region, practically for frequencies above 50 kHz however, this is not enough to reduce the effect of the test leads residuals. The wavelength of RF frequencies is short and is not negligible compared to the physical transmission line length of the test leads and calibrator internal connection. A phase shift induced error will occur as a result of the electrical length between DUT and partial calibrator standards. This error cannot be reduced by using open/short compensation. The phase shift can be compensated using LOAD correction.

Note: LOAD correction makes sense to use only if DUT – LCR meter is equipped with LOAD correction function.

Note: There is no difference in connection between CORR ON and CORR OFF in M550. The only difference is in displayed calibration values.

Note: Calibration values CORR ON and CORR OFF are often identical. Slight differences can be visible between the values especially at higher frequencies.

Relation between CORR ON and CORR OFF calibration values

Calibration values of type CORR ON and CORR can differ depending on type of partial standard connection mode (4TP, 4W, 2W) and frequency. The difference between these CORR ON and CORR OFF calibration values is given by influence in internal OPEN/SHORT reference position parameters and typical difference caused by electrical length of internal coaxial cabeling.

Simplified equation shows the structure of difference:

$$Z_{CORR\ OFF} = Z_{CORR\ ON} + 1/Y_{OPEN} + Z_{SHORT} + Z_{difference}$$

Where
$Z_{CORR\ OFF}$ is by M550 calibrator calculated calibration value CORR OFF
$Z_{CORR\ ON}$ is source calibration value saved in M550 calibration memory
Y_{OPEN} is residual admittance parameter of m550 reference position OPEN
Z_{SHORT} is residual impedance parameter of M550 reference position SHORT
$Z_{difference}$ is typical difference of partial standard for CORR ON and CORR OFF mode.

6.5 SHORT/ OPEN

SHORT and OPEN corrections are mostly applied compensations made in LCR meters to improve accuracy in low impedance range (SHORT) and high impedance range (OPEN).
To simplify calibration of LCR meters M550 calibrator is equipped with both of these reference positions enabling compensation without disconnection of DUT to M550. The positions can be selected by pushing the buttons OPEN or SHORT. Those output terminals are shorted or opened depending on which mode 4TP or 4W/2W is selected. Status of the calibrator is indicated by OPEN or SHORT label displayed on the display.

Residual parameters of OPEN/SHORT positions are specified in chapter Specification. OPEN and SHORT parameters are not specified in 2W mode.

Note: When OPEN or SHORT corrections are selected internal signal level meter readings are not available.

6.6 External input

The calibrator contains four additional BNC connector located on the rear panel. Using the connectors one external standard can be connected to the calibrator and through the calibrator to the front panel output terminals. The feature can be useful when a special value of standard is requested for automatic calibration of DUTs. Parameters of the external standard cannot be written and saved in the M550. Interconnection between rear panel coaxial connectors and front panel 4TP connector is arranged in four-terminal pair technique, i.e. both signal and shielding wires are switched separately for all four terminals.

6.7 Z/Y switch

Calibrator front panel display shows the selected partial standard calibration value at selected frequency and in selected pair of main parameters. Under the main parameters normalized calibration value is always displayed in exponential form either impedance $|Z| \cdot e^{j\theta}$ or admittance $|Y| \cdot e^{-j\theta}$. The Z/Y button enables to change indication from impedance to admittance form.

6.8 Meter operation

By pushing the button Meter ON in System buttons field internal voltmeter & counter can be temporarily activated to measure DUT test signal level. After pushing the button the meter is connected for approx. 5 second to the $H_{CUR} – L_{CUR}$ output terminals. During this time the meter measures a test signal level sourced from DUT - LCR meter and displays live readings of the measured frequency, test voltage, and evaluated test current. Measured values are displayed in red color. Frequency cannot be manually changed during this period. When the time interval has elapsed, readings are frozen, change color to blue and appropriate calibration values of the selected partial standard at frequency just measured are displayed. New test signal level and frequency measuring can be launched by pushing the ON button or new frequency can be entered manually.

Internal level meter always measures test signal on those output terminals which are selected in mode selection, either 4TP or 4W/2W terminals.

Meter function can be disabled using METER item in the main setup menu.

Note: Calibration values of a selected partial standard shown on the display are not valid during period when meter is connected to the output terminals. Meter nominal input impedance is 100 kΩ.

6.9 Main MENU

Press the MENU button to enter to main system MENU.

6.9.1 General Menu

Submenu contains basic parameters of display and keyboard.

a. Volume ***0 … 15***

This parameter sets the beeper volume. Rotary button or numerical keyboard allow to set the value in the range of 0 to 15. Press the Write soft key to set the beeper volume and return to the General menu.

b. Brightness ***0 … 7***

This parameter sets the display brightness. Rotary button or numerical keyboard allow to set the value in the range of 0 to 7. Press the Write soft key to set the display's brightness and return to the General menu.

c. Phase unit ***deg/rad***

Polar parameters can be displayed with phase angle expressed either in degrees (deg) or radians (rad).

d. Beeper ***ON/OFF***

This parameter enables / disables the signalization of pressed key. Possible states are „Beep On“ and „Beep Off“. Press the Select soft key or press the rotary knob to set the selected state.

e. Password setting ***xxxxx***

This item enables to change the calibration password. Calibration password is a five-digit number which must be entered to access the calibration mode. Default factory calibration password is set to "55000". Select the Password setting to change the code. You will be prompted to enter the currently valid calibration password. Use numerical keyboard and confirm with ENTER button. Now change of the calibration password can be performed.

Rotary knob or numeric keyboard allow setting the value in the range from 00000 to 99999.

Note: It is advisable to write down the actual calibration code if changed. If you forget the calibration code, you have to send the calibrator to the manufacturer.

f. Time ***HH:MM:SS***

Setting the real time. The parameter can be changed using rotary button or numeric keyboard.

g. Date ***DD:MM:YYYY***

Setting the date. The parameter can be changed using rotary button or numeric keyboard.

h. Date/Time ***ON/OFF***

The item enables or disables displaying the Date and Time values in Information field.

i. Device Information

Viewing the device information. It displays serial number and firmware version.

6.9.2 Interface Menu

Submenu contains remote control parameters.

1. ***Active interface***

Sets the type of interface used to remote control the calibrator. By selecting an item from the list IEEE488 or RS232 can be selected. The calibrator can be remotely controlled only using the selected interface.

2. ***IEEE488 address***

Sets IEEE488 (GPIB) address of the calibrator. Rotary button or numerical keyboard allows to set the value in the range of 0 to 31. Press the Write soft key to set the address and return to the Interface menu. Address 02 is set by the manufacturer.

3. ***Baud rate***

Sets the communication speed of RS232 bus. By selecting an item from the list 1200, 2400, 4800, 9600, 19200, 38400, 76800 or 115200 Bd the desired rate can be chosen.

6.9.3 Meter

Submenu contains setting of built-in volt meter / counter to position:

- Off meter is disabled
- On reading of meter is enabled

6.9.4 Calibration

Access to calibration memory is enabled through this item. See chapter 8. for detailed information.

6.10 Local/Remote operation

By pushing the LOCAL button the calibrator can be switched over to local control mode while in remote mode.

7. Calibration of LCR meter

7.1 LCR meter calibration with four terminal pair connection (4TP)

Application without SHORT/OPEN/LOAD corrections

a. Connect LCR meter to M550 calibrator using BNC-BNC coaxial cables from M550 accessory. Use M550 4TP output. Make sure to connect corresponding terminals (H_{CUR}, H_{POT}, L_{POT}, L_{CUR}) correctly.
b. Select requested frequency, test level and parameters in DUT LCR meter
c. Select 4TP mode in M550 using 4TP button.
d. Select requested bank of standards using R, L, C buttons
e. Select requested partial standards using either
    a. Rotary button
    b. Typing of nominal value of partial standard on numerical keypad
f. Select requested pair of parameters and frequency in M550. Optionally, use test signal level meter to measure test frequency, see chapter 7.4 for details.
g. Push OPER button to switch the output terminals ON.
h. Compare reading of DUT with displayed calibration values in M550 calibrator.

Application of SHORT/OPEN/LOAD corrections

When calibration with SHORT/OPEN/LOAD corrections is requested perform before measurements the corrections:

i. SHORT correction
    a) Push SHORT button on M550 calibrator. M550 display shows SHORT label.
    b) Push OPER button to switch M550 output terminals ON.
    c) Use instructions in DUT operation manual to make SHORT correction.
ii. OPEN correction
    d) Push OPEN button on M550 calibrator. M550 display shows OPEN label.
    e) Push OPER button to switch M550 output terminals ON.
    f) Use instructions in DUT operation manual to make OPEN correction
iii. LOAD correction
    g) Perform LOAD correction of DUT if it is equipped with it. Follow instructions described in DUT operation manual.

7.2 LCR meter calibration with four terminal connection (4W)

a) Connect LCR meter to M550 calibrator using banana-banana test cables. Use M550 4W/2W output. Make sure to connect corresponding terminals (H_{CUR}, H_{POT}, L_{POT}, L_{CUR}) correctly.
b) Select requested frequency, test level and parameters in DUT LCR meter
c) Select 4W mode in M550 using 4W button.
d) Select requested bank of standards using R, L, C buttons
e) Select requested partial standards using either
    (1) Rotary button
    (2) Typing of nominal value of partial standard on numerical keypad
f) Select requested pair of parameters and frequency in M550. Optionally, use test signal level meter to measure test frequency, see chapter 7.4 for details.
g) Push OPER button to switch the output terminals ON.
h) Compare reading of DUT with displayed calibration values in M550 calibrator.

When calibration with correction SHORT/OPEN are requested perform it before measurement:

i) SHORT correction
    a) Push SHORT button on M550 calibrator. M550 display shows SHORT label.
    b) Push OPER button to switch M550 output terminals ON.
    c) Use instructions in DUT operation manual to make SHORT correction.

ii) Perform OPEN correction
   d) Push OPEN button in M550 calibrator. M550 display shows OPEN label.
   e) Push OPER button to switch M550 output terminals ON.
   f) Use instructions in DUT operation manual to make OPEN correction

7.3 LCR meter calibration with two terminal connection (2W)

a) Connect LCR meter to M550 calibrator using two banana-banana test cables. Use M550 4W/2W output. Make sure to connect corresponding terminals (H_{CUR}, L_{CUR}) correctly.
b) Select requested frequency, test level and parameters in DUT LCR meter
c) Select 2W mode in M550 using 4W/2W button.
d) Select requested bank of standards using R, L, C buttons, parameter pair and frequency
e) Push OPER button to switch the output terminals ON.
f) Compare reading of DUT with displayed calibration values in M550 calibrator.

Note: Correction function and reference positions SHORT/OPEN are not available in 2W mode.

7.4 Application of signal level meter

Test signal voltage and frequency can be measured directly when M550 meter of test signal level meter is activated. Activation can be setup in SETUP menu.

a) Push the button METER ON. M550 starts to measure test signal.
b) Test voltage line on M550 display becomes red indicating in this way that test signal level measurement is in process. Live reading of M550 level meter and counter is displayed. The measurement takes about 5 seconds.
c) When measurement is finished displayed values of frequency, test voltage and test current are frozen and calibration data corresponding to measured frequency are displayed automatically.
d) If test signal voltage is not high enough (over 200 mV) or frequency is out of meter range (above 100 kHz), instead of meter readings symbol "-----" is displayed showing that meter could not make successful measurement. Test frequency value is returned to the original value before measuring had started.
e) New measurement of test level and frequency can be launched or another frequency can be entered manually using FREQ soft button numerical keypad.

Note: M550 output terminals are loaded with 100 kOhm resistor during process of measurement. DUT can display non-correct readings during this time.

Note: Test signal level meter works in frequency range band 20 Hz to 100 kHz and for test voltage higher than 200 mV_{rms}. When calibrating low impedance values, test current sourced by DUT may not create enough high voltage on selected standard to be measured by M550 calibrator.

Note: Anytime frequency can be set up manually except period when meter is proceeding measurement.

8. Recalibration

The impedance calibrator requires periodical recalibration. Recommended recalibration interval is 1 year. The recalibration process is based on measuring of M550 partial standards using either direct method of measurement with standard LCR meter and standard multimeter or using comparison method with set of single standard resistors, capacitors and inductors of decimal nominal values and entering and saving new calibration values.

For recalibration purpose the calibrator includes calibration procedure. Recalibration can be performed using the front panel buttons and calibration menu.

Note: M550 partial standards cannot be re-adjusted.

8.1 Requested equipment

1. Set of the resistance standards in frequency band up to 1 MHz with calibration uncertainty better than 0.01% (1 kHz), like Agilent 16074A set
2. Set of the capacitance standards in frequency band up to 1 MHz with calibration uncertainty better than 0.01%, e.g. Agilent 16380A, Agilent 16380C.
3. LCR meter Agilent 4284A, Agilent E4980A, Wayne Kerr 6440/6450 with accuracy 0.02 to 0.05%
4. 81/2 digit multimeter Fluke 8508A, Agilent 3458A or similar
5. Multifunction calibrator Meatest M140/M142 or Fluke 5500A/5520A or similar
3. Test leads and BNC adapters from M550 accessory

8.2 Access to recalibration

Access to calibration function is protected with password. To enter the procedure:

- Push SETUP button and select CALIBRATION item in the list. Window for password entering appears.
- Write correct password and confirm using OK soft button.
- Menu with functions for recalibration appears

Note: default factory password is "55000". The password can be modified in SETUP menu, see chapter 6.9.1.

8.3 Recalibration structure

Basic calibration menu contains two items:

Discrete standards calibration	Proceed through this item to R, C, L partial standard calibration data. Discrete standard recalibration offers two methods, Full and Offset recalibration.
Meter calibration	Select this item when built in meter of test signal voltage is to be recalibrated.

8.3.1 Discrete standard calibration

Calibration structure consists of three calibration levels:

- Selection of type of calibration
- Selection of mode (type of connection) 4TP or 4W/2W and standard bank R or C or L
- Individual partial standard selection

I. level

Select either Full or Offset calibration.

- *Full calibration*

The item enables to modify both complex calibration values (primary and secondary) of all R, C, L partial standards, and reference positions SHORT/OPEN as well in spot frequencies. Any of calibration values can be modified and saved independently.

Spot frequencies is line of fix frequencies at which calibration data are defined. The line of spot frequencies is as follows:
30, 50, 100, 300, 500, 1 000, 3 000, 5 000, 10 000, 30 000, 50 000, 100 000, 300 000, 500 000, 1 000 000 Hz

- *Offset calibration*
  The item enables to modify only main parameter (primary) of partial standard at 1 kHz frequency. When the parameter is changed, the deviation against original calibration value is calculated and with this deviation main parameter is shifted at all applicable spot frequencies. In memory stored frequency characteristic is not influenced.

Note: Not all spot frequencies may be accessible for all partial standards. See frequency range of partial standards to check valid frequency band.

Frequency characteristics of partial standards have been carefully measured and stored during calibration process in manufacturer laboratory.

It is recommended to prefer Offset calibration method to avoid unexpected change of the characteristic. Use Full calibration method only if you can measure frequency characteristic with appropriate accuracy.

II. level
Partial standards in one of three modes 4TP, 4W, 2W can be modified. List of item in this level is as follows:

- Resistance bank 4TP — partial resistance standard calibration values in 4TP mode can be edited
- Capacitance bank 4TP — partial capacitance standard calibration values in 4TP mode can be edited
- Inductance bank 4TP — partial inductance standard calibration values in 4TP mode can be edited

- Resistance bank 4W — partial resistance standard calibration values in 4W mode can be edited
- Capacitance bank 4W — partial capacitance standard calibration values in 4W mode can be edited

- Resistance bank 2W — partial resistance standard calibration values in 2W mode can be edited. Only main parameter is defined in 2W mode
- Capacitance bank 2W — partial capacitance standard calibration values in 2W mode can be edited. Only main parameter is defined in 2W mode

III. level
The III level contains list of partial standards of selected bank in selected connection mode. The partial standards are identified with their nominal value. Select requested standard to enable editing calibration data. III. level is not available for OPEN and SHORT positions.

8.3.2 Signal level meter adjustment

Meter item serves for internal test signal level meter adjustment. Only voltage ranges can be adjusted. Frequency function has fix setting which cannot be changed. Accuracy of measurement of frequency is given by applied quartz oscillator.

Select item Meter calibration in basic calibration level. Following possibilities appears:

- Zero calibration
  Access to calibration of zero point of voltage scale
- Full scale calibration
  Access to recalibration of full scale point.

8.3.3 History

M550 Impedance calibrator is equipped with memory of history of calibration values of partial standards. Calibrator records and keeps past calibration values of primary and secondary parameters at frequency 1 kHz. This is helpful tool for time stability of partial standards evaluation.

Access to the History is in Calibration section. Open Calibration system using correct password and select History. Select from the list of modes and list of partial standards that one you want to check. Calibration values of the selected standard will appear in form Table with following columns:

- Date of calibration
- Primary parameter value
- Secondary parameter value

10Ω		History
Date	Rs	Ls
11.06.2012	10.0023 Ω	6.0 nH
05.01.2012	10.0022 Ω	6.0 nH
28.06.2011	10.0020 Ω	6.0 nH
13.01.2011	10.0019 Ω	6.0 nH
04.08.2010	10.0018 Ω	6.0 nH
16.01.2010	10.0016 Ω	6.0 nH
23.06.2009	10.0015 Ω	6.0 nH
14.01.2009	10.0014 Ω	6.0 nH
03.06.2008	10.0013 Ω	6.0 nH
22.01.2008	10.0013 Ω	6.0 nH
Resistance bank 4TP		

Next | Previous | | | Exit

Fig 10 Calibration values history

Type of displayed primary and secondary parameter cannot be changed. For resistance standards pair R_s-L_s or R_p-C_p, for capacitance standards C_p-D and for inductance L_s-R_s parameter pair is always applied.

New calibration value is added to the history automatically if date of previous calibration of the selected standard is older than seven days. If new calibration is performed within next seven days after the last calibration, calibrator offers either to replace the last value with a new one or to append it.

Maximum number of stored calibration pairs is 30 records per standard. When maximum number is being crossed over during calibration, calibrator deletes the oldest calibration parameter pair and adds the newest one. Warning is displayed before deleting the old data with option to delete it or not to save the new calibration values.

8.4 Recalibration procedure

Use the procedure to change calibration values of any of partial standard. Switch the calibrator ON and leave it until warm up time has released. Connect it to appropriate output terminals standard LCR-meter.

8.4.1 OFFSET calibration method (preferred)

- Push MENU button, select CALIBRATION item.

- Select DISCRETE STANDARD CALIBRATION
- Select OFFSET CALIBRATION in next step
- Select type of bank (resistance, capacitance, inductance) and type of connection (4TP, 4W or 2W)
- Select nominal value of partial standard which calibration values are requested to modify.
- Screen with main parameter of selected standard at 1 kHz frequency will appear.
- Push the OPER button. Use one of following method to define new calibration value:
  a. Direct measurement method: Measure the selected partial standard using standard meter. For resistance standards from 0.1 Ω to 10 MΩ 81/2 digit multimeter in high precise mode can be applied. Use four-wire true ohm measurement mode. For standard 100 MΩ standard LCR meter should be applied.
  b. Comparison method:
     i. Measure the selected partial standard using standard meter.
     ii. Disconnect standard meter and connect calibration standard of the same type and the same nominal value.
     iii. Evaluate deviation of the standard meter by comparing its reading to calibration standard calibration values
     iv. Correct values measured in point (i.) with the deviation evaluated in point (iii.).
- Write new calibration value of the main parameter at 1 kHz frequency and confirm with WRITE soft button. New calibration values have been saved.
- Push EXIT to select another partial standard.
- When recalibration is finished, push EXIT button repetitively until calibration menu is left and main screen is displayed.

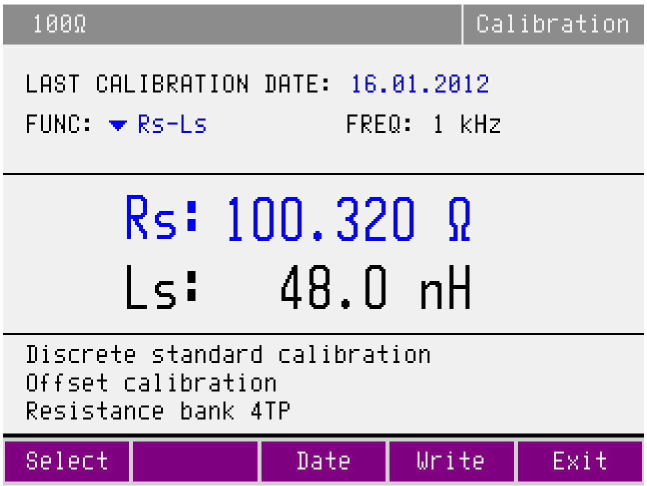


Fig. 11 Offset calibration

Note: Secondary parameter is not available for editing in OFFSET calibration mode.

8.4.2 FULL calibration method

- Push MENU button, select CALIBRATION item.
- Select DISCRETE STANDARD CALIBRATION
- Select FULL CALIBRATION in next step
- Select type of bank (resistance, capacitance, inductance) and type of connection (4TP, 4W or 2W)
- Select nominal value of partial standard which calibration values are requested to modify.
- Screen with main parameter of selected bank of standard at default frequency will appear.
- Select spot frequency from the list of available values using soft button FREQ and rotary button.
- Select pair of complex parameters in which the new calibration values will be entered.
- Push the OPER button. Use one of following method to define new calibration value:
  a. Direct measurement method: Measure the selected partial standard using standard mean of measurement.
  b. Comparison method:
     i. Measure the selected partial standard using standard LCR meter.

ii. Disconnect standard LCR meter and connect it to single calibration standard of the same type and the same nominal value.
iii. Evaluate deviation of the standard LCR meter by comparing its reading to calibration standard calibration values
iv. Correct values measured in point (i.) with the deviation evaluated in point (iii.).

- Enter new calibration values either both complex parameters or any of them, and confirm with soft button WRITE. New calibration values have been saved.
- Select another spot frequency and edit calibration values. If another partial standard or another bank or another type of connection is to be calibrated go back in calibration level structure using soft button EXIT.
- When recalibration is finished, push EXIT button repetitively until calibration menu is left and main screen is displayed.

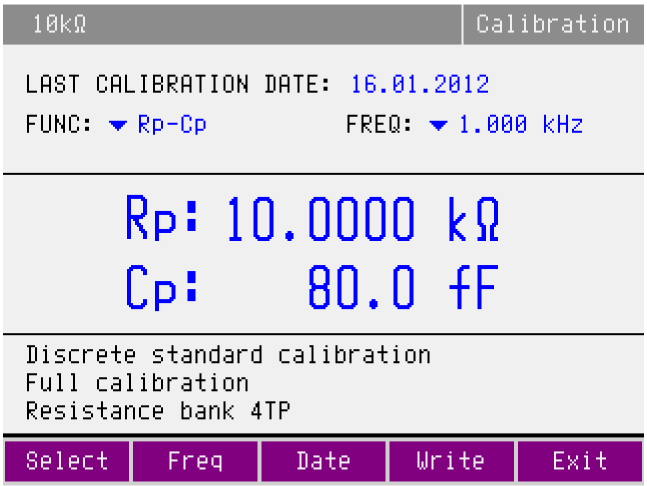


Fig. 12 Full calibration

Note: Calibration process can be interrupted in any point of the calibration procedure. New calibration values are saved in memory always after pushing the soft button Write.

Note: Frequency dependency of partial standards has been calibrated during production. It is given mostly by design of internal blocks and applied components. Don't do calibration of secondary values if it is really not necessary.

8.4.3 Signal level meter calibration

- Select 4TP mode. Use BNC-banana adapters. Switch output terminals ON
- Make short between H_{CUR} – L_{CUR} terminals
- Push MENU button, select CALIBRATION item.
- Select METER CALIBRATION
- Select ZERO CALIBRATION
- Screen with ZERO point calibration appears. Live reading of internal voltmeter in digits is displayed. Push the WRITE soft button to save ZERO calibration value.
- Push EXIT to go over to previous level.
- Select item FULL SCALE CALIBRATION.
- Screen with FULL SCALE point calibration appears. Live reading of internal voltmeter in digits is displayed.
- Connect multifunction calibrator voltage output to H_{CUR} – L_{CUR} coaxial terminals.
- Set amplitude 5Vrms, frequency 1 kHz. Calibrator display shows reading of input AC voltage in digits.
- Push the WRITE soft button to save FULL SCALE calibration value.
- When recalibration is finished, push EXIT button repetitively until calibration menu is left and main screen is displayed.

9. Verification procedure

Following section describes the procedure used to verify the M550 Impedance calibrator is operating correctly and within specifications. Ensure the calibrator has been in a temperature suitable environment for at least one hour before starting the verification process.

The verification procedure is in simplified form. It enables easy verifying of the M550 calibrator main parameter of partial standards at signed frequency. The verification procedure requests following standard devices:

- Standard LCR meter with accuracy 0.05 % like WK6440B, Agilent E4980A
- Standard 81/2 digit multimeter like Agilent 3458A, Fluke 8508A

Verification procedure is based on direct measurement of the partial bank using standard meter.

9.1 4TP output verification

9.1.1 Resistance standard verification

- Connect standard multimeter to the M550 4TP output terminals. Use terminal adapters BNC/banana. Use four terminal connection, set the most accurate mode of four terminal resistance measurement in the multimeter, TRUE RMS mode
- Set 4TP mode and Correction ON in M550.
- Set SHORT position in M550 and make ZERO correction in the standard multimeter.
- Measure the partial resistance bank of the M550 from 100 mΩ to 10 MΩ.
- Connect standard LCR meter to the M550 output terminals. Use four terminal coaxial connection. Set test frequency 1 kHz, test voltage 1 V.
- Set SHORT position in M550 and make SHORT correction in the standard LCR meter.
- Set OPEN position in M550 and make OPEN correction in the standard LCR meter.
- Set position 100 MΩ in M550 calibrator.
- Measure the value using standard LCR meter
- Measured values should be within limits as follows:

Nominal value	***Resistance limits***	***Standard***	***Test frequency***
Ω	***Ω***	***-***	***Hz***
0.1	R_{cal} +/- 0.000 2	81/2 dig multimeter	DC
1.0	R_{cal} +/- 0.001	81/2 dig multimeter	DC
10	R_{cal} +/- 0.005	81/2 dig multimeter	DC
100	R_{cal} +/- 0.02	81/2 dig multimeter	DC
1 k	R_{cal} +/- 0.2	81/2 dig multimeter	DC
10 k	R_{cal} +/- 2	81/2 dig multimeter	DC
100 k	R_{cal} +/- 20	81/2 dig multimeter	DC
1 M	R_{cal} +/- 300	81/2 dig multimeter	DC
10 M	R_{cal} +/- 5 000	81/2 dig multimeter	DC
100 M	R_{cal} +/- 100 000	LCR meter	1000

Tab. XI 4TP Resistance verification test

where R_{cal} is R_s parameter calibration value at frequency 30 Hz, mode CORR ON

9.1.2 Capacitance standard verification

- Connect standard LCR meter to the M550 4TP output terminals. Use four terminal coaxial connection. Set test frequency 1 kHz, test voltage 1 V.
- Set SHORT position in M550 and make SHORT correction in the standard LCR meter.
- Set OPEN position in M550 and make OPEN correction in the standard LCR meter.
- Set partial capacitance bank step by step and measure both complex parameter Cp and D.
- Compare it with M550 calibration values at frequency 1 kHz. (C_{cal} is calibration value at frequency 1 kHz).

Nominal value	Cp Capacitance limits	Dissipation factor limits	Standard	Test frequency
F	F	-	-	Hz
10 p	C_{cal} +/- 0.05 p	< 0.0020	LCR meter	1000
100 p	C_{cal} +/- 0.1 p	< 0.0010	LCR meter	1000
1 n	C_{cal} +/- 0.5 p	< 0.0005	LCR meter	1000
10 n	C_{cal} +/- 5 p	< 0.0005	LCR meter	1000
100 n	C_{cal} +/- 50 p	< 0.0005	LCR meter	1000
1 µ	C_{cal} +/- 500 p	< 0.0010	LCR meter	1000
10 µ	C_{cal} +/- 5 n	< 0.0050	LCR meter	1000
100 µ	C_{cal} +/- 100 n	< 0.0200	LCR meter	1000

Tab. XII 4TP Capacitance verification test

where C_{cal} is C_p calibration value, mode CORR ON

9.1.3 Inductance standard verification

- Set partial inductance bank step by step and measure both complex parameter Ls and Rs at frequencies signed in the table bellow.
- Compare it with M550 calibration values at signed frequency (L_{cal} is calibration value at signed frequency).

Nominal value	Rs Inductance limits	Rs typicalvalue	Standard	Test frequency
H	H	Ω	-	Hz
10 µ	L_{cal} +/- 0.1 µ	66	LCR meter	50 kHz
100 µ	L_{cal} +/- 0.2 µ	200	LCR meter	50 kHz
1 m	L_{cal} +/- 1.0 µ	660	LCR meter	50 kHz
10 m	L_{cal} +/- 10 µ	660	LCR meter	10 kHz
100 m	L_{cal} +/- 100 µ	2 000	LCR meter	10 kHz
1 H	L_{cal} +/- 1.0 m	20 000	LCR meter	1 kHz
10 H	L_{cal} +/- 10 m	20 000	LCR meter	100 Hz

Tab. XIII 4TP Inductance verification test

where L_{cal} is L_s parameter calibration value at signed frequency, mode CORR ON

9.2 4W output verification

9.2.1 Resistance standard verification

- Connect standard multimeter to the M550 4/2W output terminals. Use four single banana-banana test leads. Connect them as follows:

Standard multimeter	M550
V	H_{CUR}
COM	L_{CUR}
+ SENSE	H_{POT}
- SENSE	L_{POT}

- Use four terminal connection, set the most accurate mode of four terminal resistance measurement in the multimeter, TRUE RMS mode
- Set 4W mode in M550.
- Set SHORT position in M550 and make ZERO correction in the standard multimeter.
- Measure partial resistance standards of the M550 from 100 mΩ to 100 MΩ.

- Measured values should be within limits in table XIV.

Nominal value	Resistance limits	Standard	Test frequency
Ω	Ω	-	Hz
0.1	R_{cal} +/- 0.000 5	81/2 dig multimeter	DC
1.0	R_{cal} +/- 0.001	81/2 dig multimeter	DC
10	R_{cal} +/- 0.005	81/2 dig multimeter	DC
100	R_{cal} +/- 0.05	81/2 dig multimeter	DC
1 k	R_{cal} +/- 0.2	81/2 dig multimeter	DC
10 k	R_{cal} +/- 2	81/2 dig multimeter	DC
100 k	R_{cal} +/- 100	81/2 dig multimeter	DC
1 M	R_{cal} +/- 1 k	81/2 dig multimeter	DC
10 M	R_{cal} +/- 2 k	81/2 dig multimeter	DC
100 M	R_{cal} +/- 1 M	81/2 dig multimeter	DC

Tab. XIV 4W Resistance verification test

where R_{cal} is R_s parameter calibration value at 1 kHz, mode CORR ON.

9.2.2 Capacitance standard verification

Connect standard LCR meter to the M550 4/2W output terminals. Use four terminal Kelvin cable adpater from standard LCR meter accessory. Connect the clips to H_{CUR}, H_{POT} and L_{POT}, L_{CUR} terminals. When autobalance bridge is applied for 4W verification, connect standard LCR meter terminals to M550 4/2W output according to following picture.

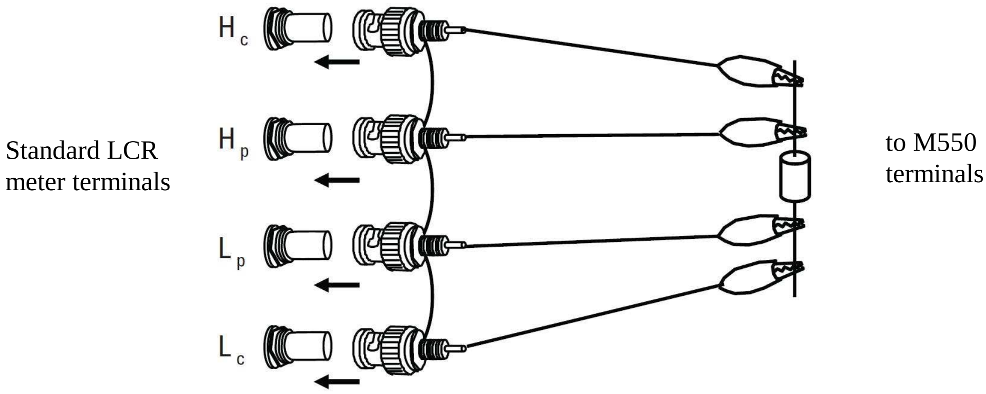


Fig. 13 Standard LCR meter connection for 4W capacitance standard verification

- Set test frequency 1 kHz, test voltage 1 V.
- Set 4W mode in M550
- Set SHORT position in M550 and make SHORT correction in the standard LCR meter.
- Set OPEN position in M550 and make OPEN correction in the standard LCR meter.
- Set partial capacitance standards step by step and measure both complex parameter Cp and D.
- Compare it with M550 calibration values at frequency 1 kHz:

Nominal value	Cp Capacitance limits	Standard	Test frequency
F	F	-	Hz
100 p	C_{cal} +/- 1 p	LCR meter	1000
1 n	C_{cal} +/- 1 p	LCR meter	1000
10 n	C_{cal} +/- 5 p	LCR meter	1000
100 n	C_{cal} +/- 50 p	LCR meter	1000
1 µ	C_{cal} +/- 500 p	LCR meter	1000
10 µ	C_{cal} +/- 10 n	LCR meter	1000
100 µ	C_{cal} +/- 200 n	LCR meter	1000

Tab. XV 4W Capacitance verification test where C_{cal} is C_p calibration value at frequency 1 kHz, mode CORR ON.

9.3 2W output verification

9.3.1 Resistance standard verification

- Connect standard multimeter to the M550 4/2W output terminals. Use four single banana- banana test leads. Connect them as follows:

Standard multimeter	M550
V	H_{CUR}
COM	L_{CUR}
+ SENSE	H_{CUR}
- SENSE	L_{CUR}

- Use four terminal connection, set the most accurate mode of four terminal resistance measurement in the multimeter, TRUE RMS mode.
- Set 2W mode in M550.
- Set SHORT position in M550 and make ZERO correction in the standard multimeter.
- Measure the partial resistance standards of the M550 from 1 Ω to 10 MΩ.
- Measured values should be within limits as follows (R_{cal} is calibration value at 1 kHz):

Nominal value	***Resistance limits***	***Standard***	***Test frequency***
Ω	***Ω***	**-**	***Hz***
1.0	R_{cal} +/- 0.05	81/2 dig multimeter	DC
10	R_{cal} +/- 0.05	81/2 dig multimeter	DC
100	R_{cal} +/- 0.1	81/2 dig multimeter	DC
1 k	R_{cal} +/- 1	81/2 dig multimeter	DC
10 k	R_{cal} +/- 10	81/2 dig multimeter	DC
100 k	R_{cal} +/- 100	81/2 dig multimeter	DC
1 M	R_{cal} +/- 2 k	81/2 dig multimeter	DC
10 M	R_{cal} +/- 50 k	81/2 dig multimeter	DC

Tab. XVI 2W Resistance verification test

9.3.2 Capacitance standard verification

- Connect standard LCR meter to the M550 4/2W output terminals. Use Kelvin cable adapter from standard LCR meter accessory. Connect the clips to H_{CUR} and L_{CUR} terminals. If the adapter is not available, use connection according to following picture.

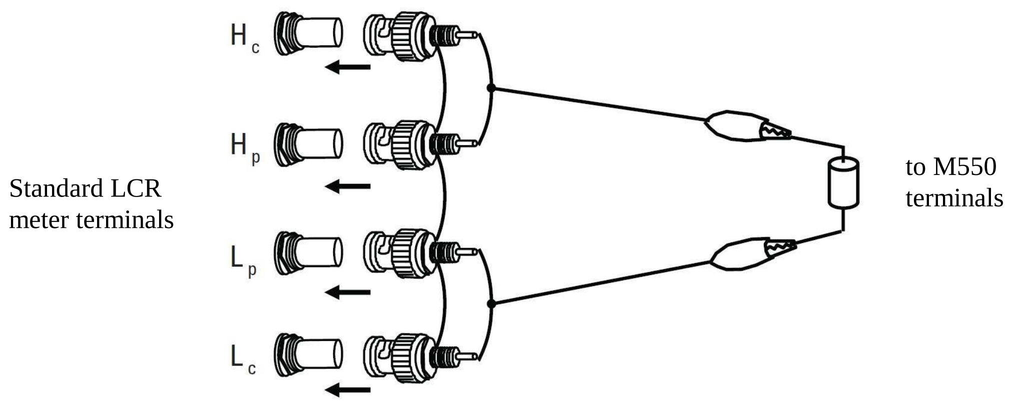


Fig. 14 Standard LCR meter connection for 2W capacitance standard verification

- Set test frequency 1 kHz, test voltage 1 V.
- Set 2W mode in M550
- Set SHORT position in M550 and make SHORT correction in the standard LCR meter.
- Set OPEN position in M550 and make OPEN correction in the standard LCR meter.
- Set partial capacitance standards step by step and measure both complex parameter Cp and D.
- Compare it with M550 calibration values at frequency 1 kHz. (C_{cal} is calibration value at frequency 1 kHz).

Nominal value	*Cp Capacitance limits*	*Standard*	*Test frequency*
F	***F***	**-**	***Hz***
100 p	C_{cal} +/- 5 p	LCR meter	1000
1 n	C_{cal} +/- 10 p	LCR meter	1000
10 n	C_{cal} +/- 20 p	LCR meter	1000
100 n	C_{cal} +/- 200 p	LCR meter	1000
1 µ	C_{cal} +/- 2 n	LCR meter	1000
10 µ	C_{cal} +/- 50 n	LCR meter	1000
100 µ	C_{cal} +/- 1 000 n	LCR meter	1000

Tab. XVII 2W Capacitance verification test

10. Remote control of the calibrator

The calibrator is equipped with RS232 serial line and IEEE-488 bus. System connectors are located at the rear panel. For the remote control to work properly, interface parameters must be set in the system menu. For RS232 line communication speed can be set (1200 to 115200 Bd). For IEEE-488 bus, an address from range 0 to 30 is allowed. The calibrator can be only controlled by one of interfaces at a time. It is therefore necessary to select one of the interfaces (RS232 /IEEE488) using the system menu.

10.1 IEEE-488 bus properties

The instrument performs the following functions based on IEEE488 bus commands:

SH1, AH1, T5, L3, RL1, DC1, SR1

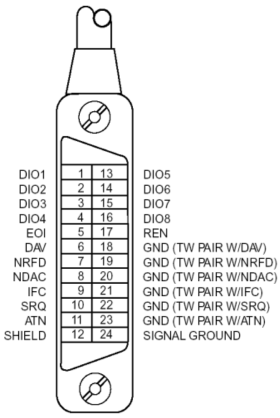


Fig. 15 IEEE488 connector

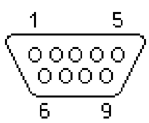
The instrument also recognizes the following general commands:

DCL	Device Clear	reset the calibrator
SDC	Selected Device Clear	reset the calibrator
EOI	End or Identify Message Terminator	close the message
GTL	Go To Local	close remote control mode
LLO	Local Lock Out	local control locked
SPD	Serial Poll Disable	close serial message status
SPE	Serial Poll Enable	release serial message status

10.2 RS232 serial line setting

To transfer the data using RS232 bus, 8N1 data format is used, i.e. each data word includes 8 bits, no parity and one stop bit. The communication speed can be set using the system menu. Available values: 1200, 2400, 4800, 9600, 19200, 38400, 76800 and 115200 Bd.

RS-232 connector layout



Pin	*Name*	*Direction*	*Description*
2	TXD	Output	Transmitter
3	RXD	Input	Receiver
5	GND	-	Ground

Fig 16 9-pin connector D-SUB FEMALE

PC	*D-Sub 1*	*D-Sub 2*	*Calibrator*
Receiver	2	2	Transmitter
Transmitter	3	3	Receiver
Ground	5	5	Ground

Tab. XVIII Cable between the calibrator and PC (configuration 1:1)

Note:
It is not possible to send or receive data over RS232 when the calibrator is not in remote mode. You should use the command SYST:REM or SYST:RWL.

10.3 Command syntax

The commands described in this chapter can be issued through all buses (RS232/Ethernet/IEEE488).
All commands listed in this chapter are explained in two columns:
KEYWORD and PARAMETERS.
KEYWORD column includes the name of the command. Each command includes one or more keywords. If a keyword is in brackets ([ ]), it is not mandatory. Non-mandatory commands are used only to achieve compatibility with language standard SCPI.
Capitals designate the abbreviated form of the commands; extended form is written in lowercase.
Command parameters are in brackets (<>); each parameter is separated using a comma. Parameters in brackets ([ ]) are not mandatory. Line (|) means “or” and is used to separate several alternative parameters.
Semicolon ‘;’ is used to separate more commands written on one line.
E.g. :SAF:LR 100.5;:OUTP ON
Note (only for RS232 and Ethernet):
Each command must end in <cr> or <lf>. Both codes <crlf> can be used at the same time. The calibrator performs all commands written on one line of the program after it receives <cr>, <lf> or <crlf> code. Without this code, the program line is ignored.

Description of abbreviations

<DNPD> =	Decimal Numeric Program Data, this format is used to express decimal number with or without the exponent.
<CPD> =	Character Program Data. Usually, it represents a group of alternative character parameters. E.g. {ON | OFF | 1 | 0}.
<SPD> =	String Program Data. String value consists from more parts. It is used for date/time setting.
? =	A flag indicating a request for the value of the parameter specified by the command. No other parameter than the question mark can be used.
(?) =	A flag indicating a request for the parameter specified by the command. This command permits a value to be set as well as requested.
<cr> =	carriage return. ASCII code 13. This code executes the program line.
<lf> =	line feed. ASCII code 10. This code executes the program line.

OUTPut subsystem

This subsystem enables to configure and activate / deactivate the calibrator output.

Keyword	Parameters
OUTPut	
[:STATe](?)	<CPD> { ON | OFF | 1 | 0 }
:CORRection (?)	<CPD> { ON | OFF | 1 | 0 }

OUTP[:STAT](?) <CPD> { ON | OFF | 1 | 0 }
This command activates or deactivates output terminals.

- ON or 1 - activates the output
- OFF or 0 - deactivates the output

If query is sent, calibrator returns 1 if the output is active or 0 if it is inactive
Example: OUTP ON - activates the output
OUTP? - the calibrator returns 1 or 0

OUTP:CORR(?) <CPD> { ON | OFF | 1 | 0 }
This command activates or deactivates correction of residual parameters.

- ON or 1 - activates correction
- OFF or 0 - deactivates correction

If query is sent, calibrator returns 1 if correction is active or 0 if it is inactive
Example: OUTP:CORR ON - activates correction
OUTP:CORR? - the calibrator returns 1 or 0

SOURce subsystem

This subsystem allows controlling the individual functions of the calibrator.

Keyword	Parameters
[SOURce]	
:MODE?	{ R4W | R2W | R4P | C4W | C2W | C4P | L4W | L2W | L4P | SHOR | OPEN | EXT | SIM }
:R4W	
:POSition(?)	<DNPD>
:TYPE(?)	<CPD> { RSLS | RSCS | RPLP | RPCP | ZTD | ZTR | YTD | YTR | RX | GB }
[:VALUe] (?)	<DNPD> [,<DNPD>]
:R2W	
:POSition(?)	<DNPD>
:TYPE(?)	<CPD> { RSLS | RSCS | RPLP | RPCP | ZTD | ZTR | YTD | YTR | RX | GB }
[:VALUe] (?)	<DNPD> [,<DNPD>]
:R4P	
:POSition(?)	<DNPD>
:TYPE(?)	<CPD> { RSLS | RSCS | RPLP | RPCP | ZTD | ZTR | YTD | YTR | RX | GB }
[:VALUe] (?)	<DNPD> [,<DNPD>]
:C4W	
:POSition(?)	<DNPD>
:TYPE(?)	<CPD> { CSD | CSRS | CPD | CPGP | CPRP | ZTD | ZTR | YTD | YTR }
[:VALUe] (?)	<DNPD> [,<DNPD>]

:C2W	
:POSition(?)	<DNPD>
:TYPE(?)	<CPD> { CSD | CSRS | CPD | CPGP | CPRP | ZTD | ZTR | YTD | YTR }
[:VALUe] (?)	<DNPD> [,<DNPD>]
:C4P	
:POSition(?)	<DNPD>
:TYPE(?)	<CPD> { CSD | CSRS | CPD | CPGP | CPRP | ZTD | ZTR | YTD | YTR }
[:VALUe] (?)	<DNPD> [,<DNPD>]
:L4P	
:POSition(?)	<DNPD>
:TYPE(?)	<CPD> { LSQ | LSRS | ZTD | ZTR | YTD | YTR }
[:VALUe] (?)	<DNPD> [,<DNPD>]
:SH4W	
:SH2W	
:SH4P	
:OP4W	
:OP2W	
:OP4P	
:EXTernal	
:FREQ(?)	<DNPD>
:SYNChronize	

[SOUR]:MODE?

This command returns selected mode of the calibrator { R4W | R2W | R4P | C4W | C2W | C4P | | L4P | SH4W | SH2W | SH4P | OP4W | OP2W | OP4P | EXT }.

- R4W – Resistance 4W mode
- R2W – Resistance 2W mode
- R4P – Resistance 4P mode
- C4W – Capacitance 4W mode
- C2W – Capacitance 2W mode
- C4P – Capacitance 4P mode
- L4P – Inductance 4P mode
- SH4W – Short 4W mode
- SH2W – Short 2W mode
- SH4P – Short 4P mode
- OP4W – Open 4W mode
- OP2W – Open 2W mode
- OP4P – Open 4P mode
- EXT – External mode

Example: MODE?

[SOUR]:R4W:POS(?) <DNPD>

This command selects one of the 10 available resistances in 4W configuration. Index of resistance is from 1 (100mΩ) to 10 (100MΩ).
<DNPD>
Parameter represents index of required resistance. Acceptable range is 1 … 10.
If query is sent, calibrator returns the index of selected resistance.
Example:
R4W:POS? Calibrator return “4”

Example:
Resistance index 4 (100Ω) in 4W configuration:
R4W:POS 4
Note:
Command set 100Ω in Resistance 4W mode.

[SOUR]:R4W:TYPE(?) <CPD> { RSLS | RSCS | RPLP | RPCP | ZTD | ZTR | YTD | YTR | RX | GB }

This command selects type of displayed parameters.
If query is sent, calibrator returns actual Resistance 4W parameter type.
Example:
Select Rs-Ls resistance 4W parameter type:
R4W:TYPE RSLS
Note:
Command switches the calibrator in Resistance 4W mode.

[SOUR]:R4P[:VAL](?) <DNPD> [,<DNPD>]

This command sets the resistance value in 4W configuration.
<DNPD>
Parameter represents the value of the resistance expressed in units of selected parameter type. Calibrator selects the nearest resistance value.
If query is sent, calibrator returns the set value of resistance using standard exponential format. Example: 105.547mΩ is returned as 1.055470e-001.
Example:
Resistance 100mΩ:
R4P:VAL?
calibrator return "+1.00000e-001,+3.40000e-009:

FREQ(?) <DNPD>

This command sets the frequency. Displayed parameters are automatically recalculated according to this frequency.
<DNPD>
Parameter represents the value of frequency expressed in Hz.
If query is sent, calibrator returns the value of frequency using standard exponential format. Example: 50Hz is returned as 5.00000e+001.
Example:
Frequency 60Hz:
FREQ 60

FREQ:SYNC

This command sets the frequency according to the measuring frequency of connected RLC meter. Displayed parameters are automatically recalculated according to this frequency.
Example:
FREQ:SYNC synchronized the frequency with connected RLC meter

SYSTem subsystem

The subsystem enables to control various functions from the MENU.
SYSTem

:DATE(?)	<DNPD>,<DNPD>,<DNPD>
:TIME(?)	<DNPD>,<DNPD>,<DNPD>
:ERRor?	
:REMote	
:RWLock	
:LOCal	

SYST:DATE(?) <DNPD>,<DNPD>,<DNPD>

This command sets system date of the calibrator.
<DNPD>,<DNPD>,<DNPD>
Represents date in format YYYY, MM, DD.
If query is sent, calibrator returns current value of system date in format YYYY,MM,DD.
where YYYY = year (2000..2099)
MM = month (01..12)
DD = day (01..31)

SYST:TIME(?) <DNPD>,<DNPD>,<DNPD>

This command sets time of the calibrator.
<DNPD>,<DNPD>,<DNPD>
Represents time in format HH,MM,SS.
If query is sent, calibrator returns current value of system time in format HH,MM,SS.
where HH hour (00..23)
MM minute (00..59)
SS second (00..59)

SYST:REM

This command places the calibrator in the remote mode for RS232 or Ethernet operation. All keys on the front panel, except the LOCAL key, are disabled.
Note:
It is not possible to send or receive data over RS232 or Ethernet when the calibrator is not in remote mode.

SYST:RWL

This command places the calibrator in the remote mode for RS232 or Ethernet operation. All keys on the front panel, including the LOCAL key, are disabled.

SYST:LOC

This command returns the calibrator in the local mode. This command is for RS232 and Ethernet interfaces.

IEEE488.2 Common Commands

I/D (instrument identification)
***IDN?**
This command returns the identification of the manufacturer, model, serial number and firmware revision.
The reply is formatted as follows:
MEATEST,M550,100002,1.22

Operation complete
***OPC**
This command sets the OPC bit in the ESR (Event Status Register) when all pending operations are complete.

Operation complete?
***OPC?**
This command returns “1” to the output queue after all pending operations are complete.

Wait-to-Continue command
***WAI**
Prevents the instrument from executing any further commands or queries until all previous remote commands have been executed.

Reset
***RST**
This command resets the calibrator to its initial status.

Test operation
***TST?**
This command launches an internal self-test. Return the self-test result (“0” for pass or “1” for fail).

Status byte reading
***STB?**
This query returns number in range 0 to 255 with information about content of register STB, which carries the MSS bit status.

Service Request Enable
***SRE <value>**
This command sets condition of the Service Request Enable register. Since bit 6 is not used, the maximum value is 191.

Service Request Enable reading
***SRE?**
This query returns the Service Request Enable Register number.

Event Status Register reading
***ESR?**
This query returns the contents of the Event Status Register and clears the register.

Event Status Enable setting
***ESE <value>**
This command programs the Event Status Enable register bits. Parameter “value” is number in range 0 – 255.

Event Status Enable reading
***ESE?**
This query returns the Event Status Enable register.

Clear status
***CLS**
This command clears the Event Status Register and the Status Byte Register except the MAV bit and output queue. Output line is not reset.

10.4 Standard Status Data Structures

Calibrator meets standard protocol according to the standard IEEE488.2. The protocol can be used for checking of error and status behavior of the calibrator. It enables single-wire transmitting of SRQ command. The conditions on which SRQ signal (local control request) is sent can be set with parameters *STB?, *SRE?, *SRE, *ESR?, *ESE?, *ESE a *CLS.

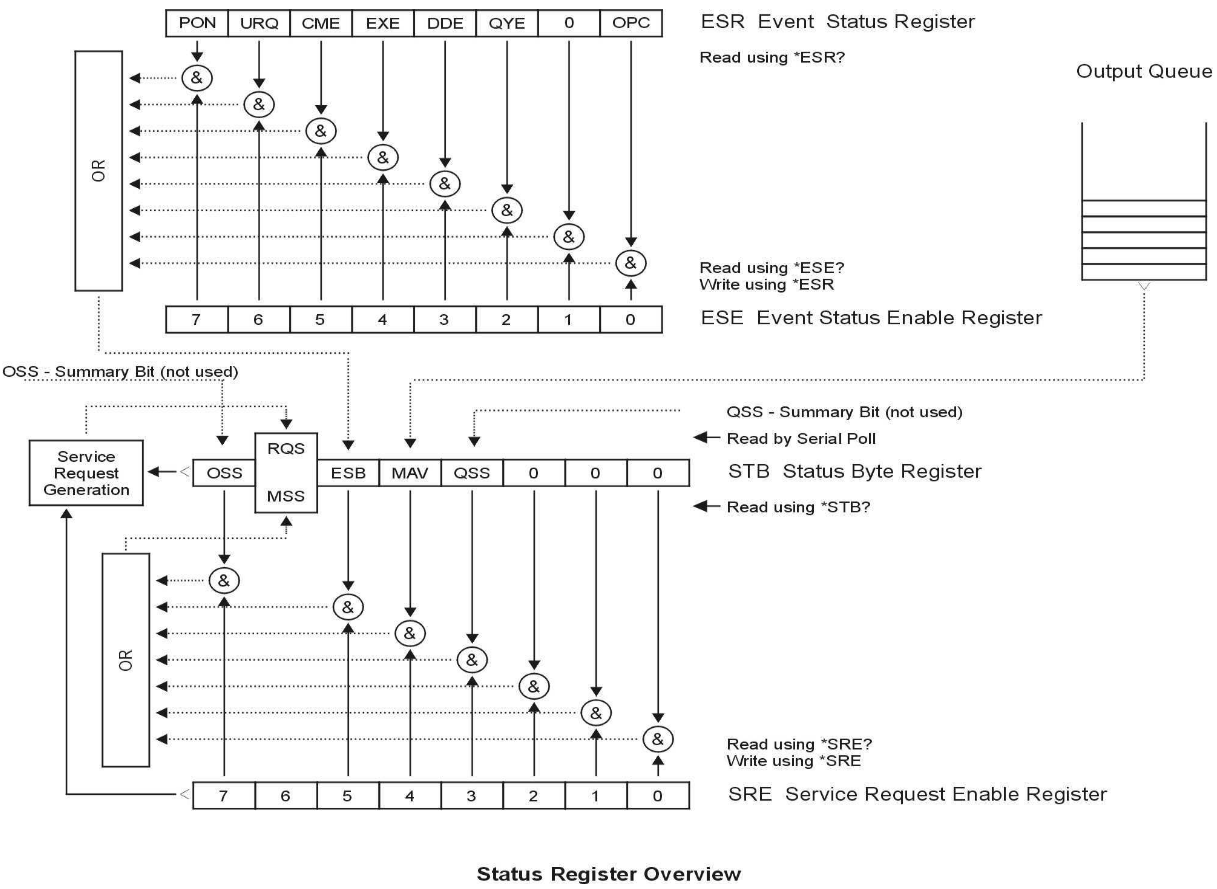


Fig. 17 Status register overview

Status data structure contains following registers:
STB – Status Byte Register
SRE – Service Request Enable Register
ESR – Event Status Register
ESE – Event Status Enable Register
Output Queue

STB Status Byte Register

STB is main register where information from other status registers and from output queue is collected. Value of STB register is reset after switching on the calibrator or after sending command *CLS. This command reset the STB register except bit MAV, which remains set if the output queue is not empty. STB register value can be read via serial message or through general query *STB? .

Bit configuration of Status Byte Register :

OSS Operation Summary Status, bit 7. SCPI-defined. The OSS bit is set to 1 when the data in the OSR (Operation Status Register) contains one or more enabled bits which are true.

RQS Request Service, bit 6. The bit is read as a part of status byte only when serial message is sent.

MSS Master Summary Status, bit 6. The MSS bit is set to 1 whenever bits ESB or MAV are 1 and enabled (1) in the SRE. This bit can be read using the *STB? command. His value is derived from STB and SRE status.

ESB Event Summary Bit, bit 5. His value is derived from STB and SRE status. The ESB bit is set to 1 when one or more enabled ESR bits are set to 1.

MAV Message Available, bit 4. The MAV bit is set to 1 whenever data is available in the IEEE488 Output Queue (the response on query is ready).

QSS Questionable Summary Status, bit 3. SCPI-defined. The QSS bit is set to 1 when the data in the QSR (Questionable Status Register) contains one or more enabled bits which are true.

SRE Service Request Enable Register

The Service Request Enable Register suppresses or allows the STB bits. “0” value of a SRE bit means, that the bit does not influence value of MSS bit. Value of any unmask STB bit results in setting of the MSS bit to the level “1” . SRE bit 6 is not influenced and its value is “0”. The SRE register value can be set via the command *SRE followed by mask register value (0 – 191). The register can be read with the command *SRE?. The register is automatically resets after switching the calibrator on. The register is not reset by the command *CLS.

ESR Event Status Register

Every bit of the EventStatusRegister corresponds to one event. Bit is set when the event is changed and it remains set also when the event passed. The ESR is cleared when the power is turned on (except bit PON which is set), and every time it is read via command *ESR? Or cleared with *CLS.

Bit configuration of Event Status Register :

PON	Power On, bit 7. This event bit indicates that an off-to-on transition has occurred in the device’s power supply.
URQ	User Request, bit 6. Bit is not used and it is always “0”.
CME	Command Error, bit 5. This event bit indicates that an incorrectly formed command or query has been detected by the instrument.
EXE	Execution Error, bit 4. This event bit indicates that the received command cannot be executed, owing to the device state or the command parameter being out of limits.
DDE	Device Dependent Error, bit 3. This event bit indicates that an error has occurred which is neither a Command Error, a Query Error, nor an Execution Error. A Device-specific Error is any executed device operation that did not properly complete due to some condition, such as overload.
QYE	Query Error, bit 2. The bit is set if the calibrator is addressed as talker and output queue is empty or if control unit did not pick up response before sending next query.
OPC	Operation Complete, bit 0. This event bit is generated in response to the *OPC command. It indicates that the device has completed all selected pending operations.

ESE Event Status Enable Register

The Event Status Enable Register allows one or more events in the Event Status Register to be reflected in the ESB summary-message bit. This register is defined for 8 bits, each corresponding to the bits in the Event Status Register. The Event Status Enable Register is read with the common query *ESE?. Data is returned as a binary-weighted value. The Event Status Enable Register is written to by the common command, *ESE. Sending the *ESE common command followed by a zero clears the ESE. The Event Status Enable Register is cleared upon power-on.

It suppresses or allows bits in ESR register. Value „0“ of a bit of ESE register suppresses influence of appropriate bit of ESR register on value of sum bit of ESB status register. Setting of any unmask bit of ESR register results in setting of ESB status register. ESE register value can be modified by command *ESE followed by value of mask register (integer in range 0 –255). Reading of the register can be performed with command *ESE?. The register is automatically reset after switching on. The register is not reset with *CLS command.

Operation Status Register

Not used in the calibrator.

Questionable Status Register

Not used in the calibrator.

Output Queue

The Output Queue stores response messages until they are read from control unit. If there is at minimum one sign in the output queue, MAV register (message available) is set. The Output Queue is cleared upon power-on and after reading all signs from output queue.

11. Instruction for maintenance

This chapter explains how to perform the routine maintenance and calibration tasks required to keep your Calibrator in optimal operating condition. The tasks covered in this chapter include the following:

- Replacing the fuse
- Cleaning the air filter and external surfaces

11.1 Replacement of the fuse

The Calibrator uses fuses to protect the line-power input. The following sections describe the replacement procedure. To replace the line power fuse:

- Unplug the power cord from the Calibrator.
- Locate the fuse holder which is a part of power line entry module on the rest panel. Of the calibrator.
- Inserting a flat-blade screwdriver in the slot in the end of the fuse holder, remove the fuse holder from the module..
- Replace the fuse with the same type rated for the selected line voltage 230 V - F 400 mA
- Reinsert the fuse holder.

11.2 Exterior cleaning

To keep the calibrator looking like new, clean the case, front panel keys, and lens using a soft cloth slightly dampened with either water or a non-abrasive mild cleaning solution that is not harmful to plastics.

11.3 Air filter cleaning

The air filter should be removed and cleaned at least every year, or more frequently if the calibrator is operated in a dusty environment. The air filter is accessible from the rear panel of the calibrator.
To clean the air filter, proceed as follows:

- Unplug all connections to the front panel of the Calibrator.
- Unplug the power cord from the Calibrator.
- Remove the filter by grasping the outside edges of the filter and pulling straight out.
- Remove the filter element from the filter frame.
- Clean the filter by washing it in soapy water. Rinse and dry the filter element thoroughly before reinstalling.
- Reinstall the filter element into the filter frame.
- Snap the filter frame back on to the fan housing.

12. List of error messages

Calibrator shows error message always when:

- Non-correct or out of specification data are entered.
- Non correct combination of parameters is asked.
- Test signal level meter is overloaded.
- Wrong remote commend is applied in remote controlled mode.

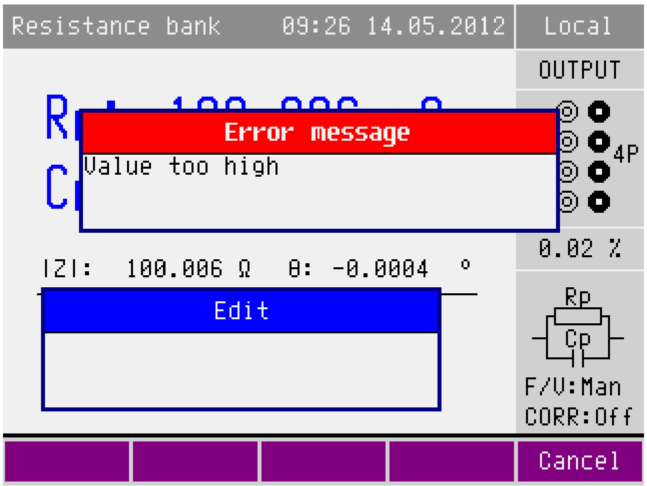


Fig. 18 Error message

According to error description follow the instruction in next Table to resolve the problem

Message	***Description***	***Hint***
Function is not available	The selected function is not available in the calibrator	--
Value too low	Attempt to setup lower value then is specified range	Set value within specified limits
Value too high	Attempt to setup higher value then is specified range	Set value within specified limits
Turn output terminals ON	Output terminals are OFF while test level meter has been activated.	Turn the output terminals ON
Wrong password	Non-correct password has been entered in calibration mode	Enter correct calibration password
Function METER is OFF	The message will occur when test signal level meter is set to OFF in SETUP menu and F/U button is pushed to activate measuring.	Select position ON in SETUP menu before activating the level meter.

Tab. XIX Error message description

13. Specification

Modes:	4TP four terminal pair	R/L/C coaxial output for coaxial four terminal and four terminal pair applications
	4W four terminal	R/C non-coaxial for four wire applications
	2W two terminal	R/C non-coaxial for two wire applications
Output terminals	4 x BNC connectors for coaxial output (4TP)	
	4 x banana terminal for non-coaxial output (4W/2W)	
Frequency range	20Hz to 1 MHz	
Reference positions:	SHORT, OPEN	

Resistance

Range	0.1 Ω to 100 MΩ	fix decimal values in 4TP mode
	0.1 Ω to 100 MΩ	fix decimal values in 4W mode
	1 Ω to 10 MΩ	fix decimal values in 2W mode
Deviation to nominal value	0.05 % to 10 % depending on value, mode and frequency	
Calibration uncertainty	0.02 % to 2 % at 1 kHz depending on value and mode	
Temperature coefficient	2 to 25 ppm/°C	
Displayed parameter pairs	Z/ɵ, Y/ɵ, R_s/L_s, R_s/C_s, R_p/C_p, R_p/L_p, R/X, G/B	

Capacitance

Range	10 pF to 100 µF	fix decimal values in 4TP mode
	10 pF to 100 µF	fix decimal values in 4W mode
	100 pF to 100 µF	fix decimal values in 2W mode
Deviation to nominal value	< 5%	
Calibration uncertainty	0.05 % to 5.0 % at 1 kHz depending on value and mode	
Temperature coefficient	30 to 100 ppm/°C	
Displayed parameter pairs	Z/ɵ, Y/ɵ, C_s/D, C_s/R_s, C_p/D, C_p/R_p, C_p/G	

Inductance (simulated in 4TP mode only)

Range	10 µH pF to 10 H	fix decimal values in 4TP mode
Deviation to nominal value	< 15 %	
Calibration uncertainty	0.15 % to 4.0 % at 1 kHz depending on value and mode	
Temperature coefficient	50 ppm/°C	
Displayed parameter pairs	Z/ɵ, Y/ɵ, L_s/Q, L_s/R_s	

Test level meter

Displayed values	frequency, test voltage, test current
Frequency range	20 Hz to 100 kHz
Test frequency resolution	6 digit
Test frequency accuracy	0.01% +1 mHz
Test voltage range	200 mV to 10 V rms
Test voltage resolution	4 digits
Test voltage accuracy	5 % in range 200 mV – 1 V
	2 % in range 1 V – 10 V
Test current range	1 nA to 500 mA
Test current resolution	4 digits
Test current accuracy	not specified

1. 4TP Resistance standards (coaxial output)

Stability and working parameters

Nominal value of serial resistance R_s / Resolution	*1 year stability (typical)*	*Maximal deviation to nominal value at 1 kHz*	*Temperature coefficient T_k (maximal)*	*Max. test Voltage / Current*
Ω	*%*	*%*	*%/℃*	*V/mA*
0.10000	0.001	2.00	0.0050	200 mA
1.00000	0.001	1.00	0.0002	100 mA
10.0000	0.001	0.50	0.0002	50 mA
100.000	0.001	0.10	0.0002	15 mA
1.00000 k	0.001	0.10	0.0002	5 V
10.0000 k	0.001	0.10	0.0002	15 V
100.000 k	0.001	0.10	0.0002	30 V
1.00000 M	0.003	0.10	0.0002	30 V
10:0000 M	0.010	0.20	0.0010	30 V
100.000 M *1	0.010	1.00	0.0050	30 V

*Frequency flatness *5 *14*

	*With OPEN/SHORT/LOAD correction *2*				*Without OPEN/SHORT/LOAD correction *3*			
Nominal value of serial resistance R_s / Resolution	*Max. resistance deviation at 1 kHz to DC value*	*Max. resistance deviation at 10 kHz to DC value*	*Max. resistance deviation at 100 kHz to DC value*	*Max. resistance deviation at 1 MHz to DC value*	*Max. resistance deviation at 1 kHz to DC value*	*Max. resistance deviation at 10 kHz to DC value*	*Max. resistance deviation at 100 kHz to DC value*	*Max. resistance deviation at 1 MHz to DC value*
Ω	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
0.10000	0.02	0.10	--	--	0.10	4.00	--	--
1.00000	0.01	0.02	0.50	--	0.05	0.20	5.00	--
10.0000	0.01	0.01	0.10	0.50	0.01	0.05	0.20	1.00
100.000	0.01	0.01	0.02	0.50	0.01	0.01	0.03	1.00
1.00000 k	0.01	0.01	0.02	0.50	0.01	0.01	0.05	1.00
10.0000 k	0.01	0.01	0.02	0.70	0.01	0.01	0.03	1.50
100.000 k	0.01	0.01	0.02	1.00	0.01	0.01	0.10	--
1.00000 M	0.01	0.01	0.03	--	0.01	0.02	1.00	--
10.0000 M	0.05	0.10	--	--	0.05	4.00	--	--
100.000 M *1	0.02	2.00	---	--	0.20	5.00 *11	--	--

Resistance calibration value uncertainty [*13]

Standard (Ω)	*0.1*	*0.1*	*1*	*1*	*10*	*10*	*100*	*100*	*1k*	*1k*	*10k*	*10k*	*100k*	*100k*	*1M*	*1M*	*10M*	*10M*	*100M*	*100M*
Correction ON/OFF	*corr OFF*	*corr ON*	*corr OFF*	*corr ON*	*corr OFF*	*corr ON*	*corr OFF*	*corr ON*	*corr OFF*	*corr ON*	*corr OFF*	*corr ON*	*corr OFF*	*corr ON*	*corr OFF*	*corr ON*	*corr OFF*	*corr ON*	*corr OFF*	*corr ON*
f [Hz]	*Calibration uncertainty [%]*																			
20 - 39	0,30	0,20	0,10	0,10	0,05	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,05	0,10	0,10
40 - 74	0,30	0,20	0,10	0,10	0,05	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,05	0,10	0,10
75 – 199	0,30	0,20	0,10	0,10	0,05	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,05	0,10	0,10
200 – 399	0,30	0,20	0,10	0,10	0,05	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,05	0,20	0,10
400 – 749	0,30	0,20	0,10	0,10	0,05	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,05	0,50	0,20
750 – 1 999	0,30	0,20	0,10	0,10	0,05	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,05	1,00	0,50
2 000 – 3 999	0,50	0,30	0,10	0,10	0,05	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,05	2,00	1,00
4 000 – 7 499	1,00	0,50	0,10	0,10	0,05	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,10	0,05	3,00 [*11]	2,00 [*11]
7 500 – 19 999	4,00 [*8]	1,00 [*8]	0,15	0,10	0,05	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,05	0,02	0,05	0,05	0,50 [*8]	0,25 [*8]	--	--
20 000 – 39 999	--	--	0,20	0,10	0,07	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,10	0,05	0,20	0,10	--	--	--	--
40 000 – 74 999	--	--	0,50	0,15	0,10	0,05	0,05	0,02	0,02	0,02	0,02	0,02	0,20	0,05	0,50	0,20	--	--	--	--
75 000 – 199 999	--	--	2,00 [*12]	0,20	0,20	0,05	0,05	0,02	0,05	0,02	0,03	0,05	0,30 [*12]	0,10 [*12]	1,00 [*12]	0,50 [*12]	--	--	--	--
200 000 – 399 999	--	--	--	--	0,30	0,10	0,07	0,10	0,07	0,03	0,07	0,10	--	--	--	--	--	--	--	--
400 000 – 749 999	--	--	--	--	0,50	0,15	0,20	0,20	0,20	0,05	0,20	0,20	--	--	--	--	--	--	--	--
750 000 – 1 000 000	--	--	--	--	1,00	0,50	1,00	0,50	1,00	0,15	1,00	0,35	--	--	--	--	--	--	--	--

2. 4TP Capacitance standards (coaxial output)

Stability and working parameters

Nominal value of parallel capacitance C_p / Resolution	*1 year stability (typical)*	*Maximal deviation to nominal value at 1 kHz*	*Temperature coefficient T_k (maximal)*	*Dissipation factor at 1kHz*	*Max. Voltage / Current*
F	%	%	%/°C	-	V/mA
10.000 p	0.010	0.5 pF	0.005	< 0.0020	30V
100.000 p	0.010	5	0.005	< 0.0010	30V
1.00000 n	0.010	5	0.005	< 0.0005	30V
10.0000 n	0.010	5	0.005	< 0.0005	30V
100.000 n	0.010	5	0.005	< 0.0005	20V
1.00000 µ	0.010	5	0.005	< 0.0010	10V
10.0000 µ	0.015	5	0.010	< 0.0050	100mA
100.00 µ	0.015	5	0.010	< 0.0200	200 mA

C frequency flatness *6 *15

	With OPEN/SHORT/LOAD correction *2					*Without OPEN/SHORT/LOAD correction* *3				
Nominal value of parallel capacitance C_p / Resolution	*Typ. capacitance deviation at 100 Hz to 1 kHz value*	*Reference capacitance deviation at 1 kHz*	*Typ. capacitance deviation at 10 kHz to 1 kHz value*	*Typ. capacitance deviation at 100 kHz to 1 kHz value*	*Typ. capacitance deviation at 1 MHz to 1 kHz value*	*Typ. capacitance deviation at 100 Hz to 1 kHz value*	*Reference capacitance deviation at 1 kHz*	*Typ. capacitance deviation at 10 kHz to 1 kHz value*	*Typ. capacitance deviation at 100 kHz to 1 kHz value*	*Typ. capacitance deviation at 1 MHz to 1 kHz value*
F	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*	*%*
10.000 p	+0.10	0.00	-0.10	-0.15	--	+0.10	0.00	-0.10	-0.10	--
100.000 p	+0.01	0.00	-0.01	-0.02	+0.20	+0.01	0.00	-0.01	-0.02	+0.35
1.00000 n	0.00	0.00	0.00	0.00	+0.10	0.00	0.00	0.00	0.00	+0.30
10.0000 n	+0.02	0.00	-0.02	0.00	+0.10	+0.02	0.00	-0.02	+0.01	+0.30
100.000 n	+0.02	0.00	-0.02	+0.02	+1.00	+0.03	0.00	-0.02	+0.03	+2.00
1.00000 µ	0.00	0.00	0.00	+0.10	--	0.00	0.00	0.00	+0.20	--
10.0000 µ	+0.35	0.00	-0.10	--	--	0.45	0.00	-0.10	--	--
100.00 µ	+0.18	0.00	1.00	--	--	+0.30	0.00	+1.00	--	--

Capacitance calibration value uncertainty [*13]

Standard (F)	10p	10p	100p	100p	1n	1n	10n	10n	100n	100n	1µ	1µ	10µ	10µ	100µ	100µ
Correction ON/OFF	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON
f [Hz]	Calibration uncertainty [%]															
20 - 39	1,00	0,50	0,30	0,30	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
40 - 74	1,00	0,50	0,30	0,30	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
75 – 199	1,00	0,50	0,30	0,30	0,05	0,05	0,05	0,05	0,10	0,10	0,05	0,05	0,05	0,05	0,10	0,10
200 – 399	1,00	0,50	0,20	0,20	0,05	0,05	0,05	0,05	0,10	0,10	0,05	0,05	0,05	0,05	0,10	0,10
400 – 749	1,00	0,50	0,20	0,20	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,10	0,10
750 – 1 999	1,00	0,50	0,10	0,10	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,10	0,10
2 000 – 3 999	1,00	0,50	0,10	0,10	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,10	0,10	0,20	0,10
4 000 – 7 499	1,00	0,50	0,10	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,15	0,10	0,50	0,20
7 500 – 19 999	1,00	0,50	0,10	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,30 [*8]	0,20 [*8]	1,00 [*8]	0,50 [*8]
20 000 – 39 999	1,00	0,50	0,10	0,05	0,05	0,05	0,05	0,05	0,10	0,05	0,15	0,10	--	--	--	--
40 000 – 74 999	1,00	0,50	0,10	0,05	0,05	0,05	0,05	0,05	0,10	0,10	0,25	0,15	--	--	--	--
75 000 – 199 999	1,00	0,50	0,10	0,10	0,10	0,10	0,05	0,05	0,30	0,20	0,50 [*12]	0,25 [*12]	--	--	--	--
200 000 – 399 999	1,00	0,50	0,15	0,10	0,15	0,10	0,10	0,10	0,50	0,40	--	--	--	--	--	--
400 000 – 749 999	1,00	1,00	0,35	0,25	0,20	0,15	0,15	0,15	1,00	0,60	--	--	--	--	--	--
750 000 – 1 000 000	2,00	1,00	0,70	0,50	0,35	0,25	0,20	0,20	2,00	1,50	--	--	--	--	--	--

3. 4TP Inductance standards (coaxial output)

Stability and working parameters

Nominal value of serial inductance L_s / Resolution	*1 year stability (typical)*	*Maximal deviation to nominal value at 1 kHz*	*Calibration uncertainty at 1 kHz*	*Temperature coefficient T_k (maximal)*	*Serial resistance R_s (typical)*	*Max. Voltage / Current*
H	*%*	*%*	*%*	*%/°C*	*Ω*	*V/mA*
10.0000 µ	0.01	15	0.10	0.005	66	50 mA
100.000 µ	0.01	15	0.10	0.005	200	30 mA
1.00000 m	0.01	15	0.10	0.005	660	5 V / 20 mA
10.0000 m	0.01	15	0.10	0.005	660	5 V / 10 mA
100.000 m	0.01	15	0.10	0.005	2 000	10 V
1.00000	0.01	15	0.20	0.005	20 000	10 V
10.0000	0.01	15	0.05	0.005	20 000	10 V

L frequency flatness *7 *14

	*With OPEN/SHORT/LOAD correction *2*			*Without OPEN/SHORT/LOAD correction *3*		
Nominal value of serial inductance L_s / Resolution	*Max. inductance deviation at 100 Hz to 1 kHz value*	*Max. inductance deviation at 10 kHz to 1 kHz value*	*Max. inductance deviation at 100 kHz to 1 kHz value*	*Max. inductance deviation at 100 Hz to 1 kHz value*	*Max. inductance deviation at 10 kHz to 1 kHz value*	*Max. inductance deviation at 100 kHz to 1 kHz value*
H	%	%	%	%	%	%
10.0000 µ	--	0.01	0.10	--	0.01	0.10
100.000 µ	0.01	0.01	0.10	--	0.01	0.10
1.00000 m	0.01	0.01	0.00	0.01	0.01	0.10
10.0000 m	0.01	0.01	0.05	0.01	0.01	0.10
100.000 m	0.01	0.01	0.05	0.01	0.01	4.00
1.00000	0.01	0.01	--	0.01	0.01	--
10.0000	0.01	0.01	--	0.01	0.01	--

Inductance calibration value uncertainty *13

Standard (H)	10µ	10µ	100µ	100µ	1m	1m	10m	10m	100m	100m	1	1	10	10
Correction ON/OFF	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON	corr OFF	corr ON
f [Hz]	Uncertainty [%]													
20 - 39	0,50	0,30	0,30	0,20	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
40 - 74	0,50	0,30	0,30	0,20	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
75 – 199	0,50	0,30	0,30	0,20	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
200 – 399	0,50	0,30	0,30	0,20	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
400 – 749	0,50	0,30	0,30	0,20	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
750 – 1 999	0,50	0,30	0,30	0,20	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
2 000 – 3 999	0,50	0,30	0,30	0,20	0,10	0,10	0,10	0,10	0,10	0,10	0,20	0,10	0,20	0,10
4 000 – 7 499	0,50	0,30	0,30	0,20	0,10	0,10	0,10	0,10	0,10	0,10	0,50	0,10	0,50	0,10
7 500 – 19 999	0,50	0,30	0,30	0,20	0,10	0,10	0,10	0,10	0,10	0,10	1,00*8	0,20*8	1,00 *8	0,20 *8
20 000 – 39 999	0,50	0,30	0,30	0,20	0,10	0,10	0,20	0,10	0,30	0,10	--	--	--	--
40 000 – 74 999	1,00	0,30	0,50	0,20	0,20	0,10	0,50	0,10	1,00	0,10	--	--	--	--
75 000 - 100 000	2,00	0,50	1,00	0,50	0,50	0,15	1,00	0,15	4,00	0,15	--	--	--	--

4. Resistance standards 4W and 2W (banana output)

Stability and working parameters

Nominal value of serial resistance R_s / Resolution	*1 year stability (typical)*	*Temperature coefficient T_k (maximal)*	*Max. test Voltage / Current*	*4W mode Maximal deviation to nominal value at 1 kHz*	*4W mode - CORR OFF* [*4] *Calibration uncertainty at 1 kHz*	*4W mode - CORR ON* [*4] *Calibration uncertainty at 1 kHz*	*2W mode* [*10] *Calibration uncertainty at 1 kHz*
Ω	*%*	*%/°C*	*V/mA*	*%*	*%*	*%*	*%*
0.10000	0.001	0.0050	200 mA	2.0	1.00	0.50	--
1.00000	0.001	0.0002	500 mA	1.5	0.50	0.10	5.0
10.0000	0.001	0.0002	150 mA	1.0	0.10	0.05	0.5
100.000	0.001	0.0002	50 mA	1.0	0.05	0.05	0.1
1.00000k	0.001	0.0002	10 V	1.0	0.02	0.02	0.1
10.0000 k	0.001	0.0002	30 V	1.0	0.02	0.02	0.1
100.000 k	0.001	0.0002	50 V	1.0	0.10	0.05	0.1
1.00000 M	0.003	0.0002	50 V	1.0	0.2	0.20	0.2
10.0000 M	0.010	0.0010	50 V	2.0 [*16]	0.2 [*16]	0.2 [*16]	0.5
100.000 M	0.010	0.0025	50 V	10.0 [*16]	1.0 [*16]	1.0 [*16]	--

4W Frequency flatness [*5] [*14] [*9]

	4W connection			
Nominal value of serial resistance R_s / Resolution	*Max. deviation at 100 Hz to DC value*	*Max. deviation at 1 kHz to DC value*	*Max. deviation at 10 kHz to DC value*	*Max. deviation at 100 kHz to DC value*
Ω	%	%	%	%
0.10000	0.10	0.50	--	--
1.00000	0.02	0.10	0.10	--
10.0000	0.02	0.02	0.05	0.20
100.000	0.02	0.02	0.05	0.10
1.00000 k	0.02	0.02	0.05	0.50
10.0000 k	0.02	0.02	0.20	--
100.000 k	0.02	0.20	2.00	--
1.00000 M	0.20	1.50	--	--
10.0000 M	0.50	10	--	--
100.000 M	30	--	---	--

5. Capacitance standards 4W and 2W (banana output)

Stability and working parameters

Nominal value of parallel capacitance C_p / Resolution	*1 year stability (typical)*	*Temperature coefficient T_k (maximal)*	*Max. Voltage / Current*	*4W mode maximal deviation to nominal value at 1 kHz*	*4W mode – CORR OFF* [*4] *Calibration uncertainty at 1 kHz*	*4W mode – CORR ON* [*4] *Calibration uncertainty at 1 kHz*	*4W mode – CORR ON Dissipation factor at 1kHz*	*2W mode* [*10] *Calibration uncertainty at 1 kHz*
F	%	%/°C	V/mA	%	%	%	-	%
100.00 p	0.015	0.050	30V	10	5.00	1.0	< 0,005	5.0
1.00000 n	0.010	0.010	30V	10	0.50	0.10	< 0,002	1.0
10.0000 n	0.010	0.050	30V	10	0.10	0.05	< 0,001	0.2
100.000 n	0.010	0.050	20V	10	0.10	0.05	< 0,001	0.2
1.00000 µ	0.010	0.050	10V	10	0.10	0.05	< 0,005	0.2
10.0000 µ	0.015	0.010	100mA	10	0.20	0.10	< 0,015	0.5
100.000 µ	0.150	0.010	200 mA	10	0.30	0.20	< 0,030	1.0

Frequency flatness [*6 *14 *9]

	4W connection		
Nominal value of parallel capacitance C_p / Resolution	*Capacitance C_p max. deviation at 100 Hz to 1 kHz value*	*Capacitance C_p max. deviation at 10 kHz to 1 kHz value*	*Capacitance C_p max. deviation at 100 kHz to 1 kHz value*
F	%	%	%
100.00 p	0.20	0.50	--
1.00000 n	0.50	0.30	1.00
10.0000 n	0.05	0.05	0.20
100.000 n	0.03	0.10	2.00
1.00000 µ	0.50	1.00	7.00
10.0000 µ	0.50	1.00	--
100.000 µ	1.00	--	--

6. OPEN/SHORT parameters

OPEN

4TP Residual capacitance	< 0.5 pF at 10 kHz
4TP Residual conductance	< 10 nS at 10 kHz
4W Residual capacitance	< 40 pF at 1 kHz
4W Residual conductance	< 10 nS at 1 kHz

SHORT

4TP Residual resistance	< 1 mΩ at 10 kHz
4TP Residual inductance	< 10 nH at 10 kHz
4W Residual resistance	< 1 mΩ at 1 kHz
4W Residual inductance	< 200 nH at 1 kHz

List of notes:

Note [*1]	Simulation using T resistance network, nominal resistance values 10MΩ – 1.25MΩ – 10MΩ
Note [*2]	Parameters are valid when OPEN/SHORT calibration is performed in DUT using OPEN/SHORT positions from the M550 calibrator before calibration. Parameters are valid when applied coaxial test cables delivered with the calibrator, length 50 cm.
Note [*3]	Specification is valid without performing OPEN/SHORT corrections. Calibration values are valid in plane of M550 calibrator coaxial output terminals.
Note [*4]	Calibration uncertainty ,is displayed in for frequency range from 900 Hz to 1100 Hz.
Note [*5]	Serial resistance is specified. Frequency deviations are related to DC reference value.
Note [*6]	Parallel capacitance is specified. Relative frequency deviations are related to reference value at 1 kHz.
Note [*7]	Serial inductance is specified. All inductances are simulated using T-type RC networks. Frequency deviations are related to reference value at 1kHz.
Note [*8]	Specified to 10 kHz.
Note [*9]	Values are valid both for CORR ON and CORR OFF mode.
Note [*10]	Two wire connection. Only primary parameter is displayed at frequency 1 kHz.
Note [*11]	Specified to 5 kHz.
Note [*12]	Specified to 100 kHz.
Note [*13]	Specification is valid for four terminal pair measuring principle. If DUT uses a different measure method, an additional deviation can effects result of calibration in frequency range above 100 kHz.
Note [*14]	The table shows maximal frequency dependency of partial standards. See calibration values in M550 for exact value.
Note [*15]	4TP frequency flatness table show typical frequency dependency of partial standards. Depending on type of applied components the frequency deviation can be different in individual serial numbers. Use calibration values data in M550.
Note [*16]	Specified at frequency 100 Hz.

Comment

1. Calibration values define impedance parameters of internal partial standards. They do not cover potential additional deviations caused by test cables between DUT and M550 calibrator.

2. Calibration uncertainty is specified for temperature range 23 °C ± 2 °C and for RH < 80 % working condition. In temperature range out of 23 °C ± 2 °C limits, and within range of operating temperatures add additional uncertainty given by specified temperature coefficient and operating temperature difference:

   $$Unc = Unc\ (\text{reference conditions})\ (\%) \ + \ T_k\ (\%/°C) \ * \ dT\ (°C)$$

   Where
   - Unc is calibration uncertainty
   - T_k is temperature coefficient of the partial standard
   - dT is deviation between operating temperature and limit of reference condition band.

3. Uncertainty of calibration values is guaranteed for sin wave test signal of DUTs. When calibrated LCR meters based on charging/discharging principle, undefined deviation against calibration values can occur.

4. Uncertainty of calibration values is guaranteed for main parameter. Auxiliary parameter calibration value is typical.

5. Calibration values between spot frequencies are calculated using three point quadrature approximation. Additional uncertainty due to the approximation formula is lower than 0.005%.

General data

Interface	RS232, GPIB
Reference conditions:	23 +/- 2 °C, RH < 80%
Operating temperatures:	15 to 30 °C
Storage temperatures:	-10 to +55 °C
Power line:	115/230 V – 50/60 Hz
Power consumption:	40 VA
Warm up time:	15 minutes
Dimension:	450 (W) x 430 (D) x 150 (H) mm
Weight	12 kg
Power line:	110/115/120/125 - 220/230 V – 50/60 Hz
Safety class:	I according to EN 1010-1
Used external fuses:	T500mL250V for 230 VAC power supply voltage, 1 pc T1L250V for 115 VAC power supply voltage, 1 pc

Manufacturer:

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