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1. Device usage

The impedance calibrator M 500B is a device aimed for RLC measuring instruments check-up. It contains 9 resistance standards in range of values 100 mOhm up to 10 MOhm in decade series, 7 partial capacity standards in range of values 10 pF to 10uF in decade series and 5 partial inductive standards in range of values 1 mH to 10 H in decade series. For lead-in conductors and own background of the RLC meter effects elimination is the calibrator equipped by referential positions of the short-circuit terminals SHORT and open-circuit terminals OPEN. Basic connection of the impedance calibrator to the checked-up meter is the coaxial four-pair terminal one, by BNC connectors mediation. Large-area graphic LCD display enables to project complete set-up of the impedance calibrator (calibration data in main and residual components, frequency, calibration uncertainty and another data). Entry of new calibration data is done from keyboard of the device. Access to the calibration data and their change execution is protected by software. All functions of the calibrator except calibration procedures may be controlled by means of standard IEEE-488 bus.

2. Accessories

Mains supply cord	1 pc
Coaxial cables BNC-BNC	4 pcs
BNC adapter - banana plug	2 pcs
Operation manual	1 pc
Fuse	1 pc

3. Technical data

3.1 General data

Range of values:

Resistance 100 m Ω , 1 Ω , 10 Ω , 100 Ω , 1 k Ω , 10 k Ω , 100 k Ω , 1 M Ω , 10 M Ω

Capacitance 10 pF, 100 pF, 1 nF, 10 nF, 100 nF, 1 μ F, 10 μ F

Inductance 1 mH, 10 mH,
100 mH (for frequencies 10 kHz and 20 kHz),
1 H (for frequencies 1 kHz, 2 kHz, 4 kHz)
10 H (for frequencies 100 Hz, 200 Hz, 400 Hz)

Referential position: SHORT and OPEN

Frequency range: 100 Hz - 20 kHz

Calibration data on
fixed frequencies: 100 (120), 200, 400, 1k, 2k, 4k, 10k, 20 kHz

Display functions:

A) Measuring mode MEANS

- 1) Projection of calibration data
 - main component (R, C, L)
 - residual parameter (Q, D, Cs, Cp, Rs, Rp, Ls, Lp)
- 2) Projection of calibrator setting-up
 - function
 - frequency
 - range
 - data
 - type of connection
 - external switch
- 3) Projection of another data
 - date of calibration
 - maximum voltage
 - maximum current
 - calibration uncertainty of the main component
 - calibration uncertainty of the residual component

B) Calibration mode CAL

- 1) Projection of calibration data
 - main component
 - residual parameter (Q, D, Cs, Cp, Rs, Rp, Ls, Lp)
- 2) Projection of calibrator setting-up
 - function
 - frequency
 - range

- 3) Projection of another data
 - way of calibration
 - way of connection
 - date of calibration
 - calibration uncertainty of the main component
 - calibration uncertainty of the residual component
- C) System mode SYS
 - GPIB address
 - code of calibration
 - tests
 - manufacturing number

Output terminals: 4 coaxial BNC terminals
H_{CUR} - current supply terminal Hi
H_{POT} - voltage sensing terminal Hu
L_{POT} - voltage sensing terminal Lu
L_{CUR} - current sensing terminal Li

Measuring voltage: < 50 V in dependency on impedance value by the specification

Measuring current: < 0.5 A in dependency on impedance value by the specification

Note: Maximum voltage between measuring terminals (H_{CUR}, H_{POT}, -L_{POT}, L_{CUR}, screening and device chassis is 50 V.

3.2 Specification

Standards of resistance - 4W

Nominal value	12 months stability	Accuracy *	Calibration uncertainty R*	Max. temp. coeff.	Q*	Calibration uncertainty Q*	I _{max}
Ohm	ppm	%	%	ppm/°C	10 ⁻⁵	10 ⁻⁵	mA
SHORT	50 µOhm	-	-	-	-	-	500
0.1	30	0.1	0.05	2	< 100	60	500
1.0	30	0.1	0.01	2	< 10	6	200
10	30	0.05	0.005	2	< 1	1	50
100	30	0.05	0.005	2	< 1	1	15
1 k	30	0.05	0.005	2	< 1	1	5
10 k	30	0.05	0.005	2	< 5	1	1.5
100 k	30	0.05	0.005	2	< 50	3	0.50
1.0 M	30	0.1	0.05	2	< 500	20	0.05
10 M	100	0.2	0.1	50	< 50	200	0.005

* For f = 1 kHz

Standards of capacity - 4W

Nominal value	12 months stability	Accuracy *	Calibration uncertainty C*	Max. temp. coeff.	D* max.	Calibration uncertainty D*	U _{max}
F	ppm	%	%	ppm/°C	10 ⁻⁴	10 ⁻⁴	V
OPEN	5 fF	-	-	-	-	-	50
10 p	100	2.0	0.1	20	500	10	50
100 p	100	0.2	0.01	20	50	1	50
1 n	100	0.05	0.01	20	10	1	50
10 n	100	0.05	0.01	20	5	1	50
100 n	100	0.05	0.01	20	5	1	50
1 u	200	0.1	0.1	-150	10	2	15
10 u	200	0.1	0.1	-150	50	10	1.5

* For f = 1 kHz

Standards of inductance - 4W

Nominal value	12 months stability	Accuracy *	Calibration uncertainty L*	Max. Temp. coeff.	Q* Min.	Calibration uncertainty Q*	I _{max}
H	ppm	%	%	ppm/°C	-	-	mA
1 m	200	0.5	0.1	100	10	0.1	100
10 m	200	0.5	0.1	100	10	0.1	100
100 m	100	0.5	0.1	20	-	-	-
1 H	100	0.5	0.1	100	2.5	0.1	80
10 H	100	0.5	0.1	100	-	-	-

- * For f = 1 kHz (1 mH, 10 mH, 1 H)
 For f = 10 kHz (100 mH)
 For f = 100 Hz (10 H)

Standards of resistance - 2W (H_{CUR} - L_{CUR} terminals)

Nominal value	12 months stability	Accuracy *	Calibration uncertainty R*	Maximum temp. coeff.	I _{max}
Ohm	ppm	%	%	ppm/°C	mA
SHORT	50 mOhm	-	-	-	500
10	5000	0.5	0.1	2	50
100	500	0.05	0.05	2	15
1.0 k	50	0.05	0.01	2	5
10 k	30	0.05	0.01	2	1.5
100 k	30	0.5	0.05	2	0.50
1.0 M	30	5.0	0.3	2	0.05

- * For f = 1 kHz

Standards of capacity - 2W (H_{CUR} - L_{CUR} terminals)

Nominal value	12 months stability	Accuracy*	Calibration uncertainty C*	Maximum temp. coeff.	U _{max}
F	ppm	%	%	ppm/°C	V
OPEN	fF	-	-	-	50
100 p	100	50	0.5	20	50
1 n	100	5.0	0.1	20	50
10 n	100	0.5	0.1	20	50
100 n	100	0.1	0.1	20	50
1 u	200	0.5	0.2	-150	15
10 u	200	5.0	0.5	-150	1.5

* For f = 1 kHz

Standards of inductivity - 2W (H_{CUR} - L_{CUR} terminals)

Nominal value	12 months stability	Accuracy*	Calibration uncertainty L*	Maximum temp. coeff.	I _{max}
H	ppm	%	%	ppm/°C	mA
1 m	200	1.0	0.2	100	100
10 m	200	1.0	0.1	100	100

* For f = 1 kHz

Accuracy data are valid for surrounding temperature 23 ± 1 °C, relative humidity lower than 70% and $0.1 U_{MAX}$. or $0.1 I_{MAX}$. respectively.

Temperature coefficient is determined for temperature range 20°C to 30°C.

3.3 Data output and remote control

Interface:	IEEE-488
Remote controlled functions:	All functions coming out from requirement on the control equipment except calibration procedures.
Interface function:	SH1, AH1, T5, L4

3.4 Working conditions

Range of operating temperatures:	15°C to 30°C
Range of storing temperatures:	-10°C to 55°C
Reference temperature:	23 ± 1 °C
Relative humidity:	70% as maximum
Outer magnetic field:	Negligible
Outer electric field:	Negligible
Power supply:	220 - 230 V ± 10%
Frequency of the power supply:	50/60 Hz
Power input:	65 VA
Protection:	Cut-out fuse 230 V - F 400 mA

3.5 General data

Protection class:	1 according EN1010
Degree of anti-jamming:	R 02
Weight of the device:	12 kg
Outline dimensions:	450 x 135 x 480mm

4. Function principle

Electric part of the impedance calibrator M-500B consists of analogue measuring path, containing standard resistors, capacitors, inductors and from managing and control circuits. Individual standards are contacted as four-terminals and connected to the measuring terminals by relays. The impedance calibrator is equipped by reference positions OPEN and SHORT, which serve for residual wire effect elimination and for correction on checked-up RLC meter background. The SHORT circuits are created by coaxial relays.

Analogue measuring path is quite galvanic separated from the control electronic. Analogue measuring ground is galvanic connected with the terminal L_{CUR} shielding. Base of control

electronic circuits is the microprocessor board, which enables active state of the control push buttons on the front panel sensing, indication of the calibration data on the display, relevant relays switching on and communication on the GPIB bus. The calibration data are stored in the EEPROM memory. Access to the calibration data is protected through software by a code.

5. Instruction for device start-up

Unwrap the device from the package and if it was stored at temperature under 0°C, let it climates for 16 hours interval in operation working conditions. For device switching on push the power supply button. The device is designed to be supplied from 230 V power network. Metal parts accessible to finger touch are connected to the protective conductor and the GND terminal (except measuring terminals H_{CUR}, H_{POT}, L_{POT}, L_{CUR}), which is placed on the rear panel.

Note: The analogue measuring ground is not galvanic connected with metal parts of the device!

6. Operation instructions

6.1 Description of control elements

6.1.1 Front panel

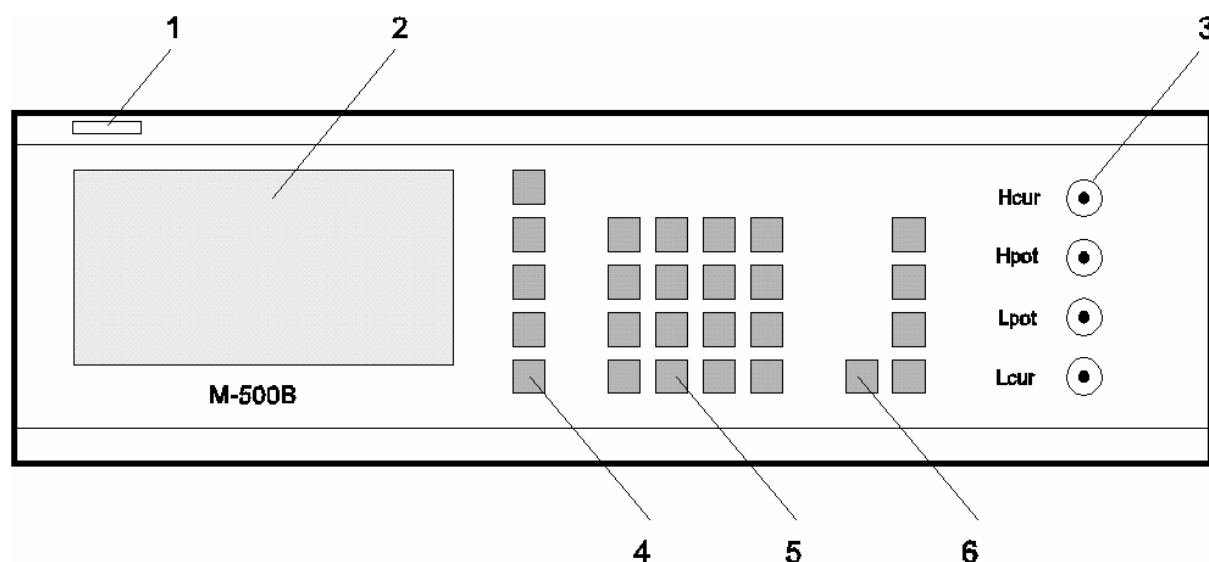
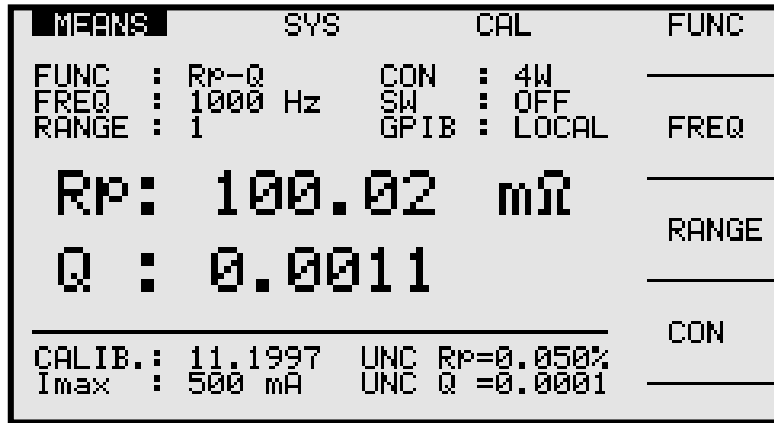


Fig.1. Front panel

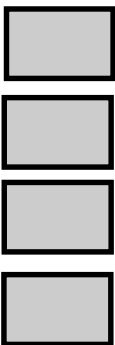
- 1 Power supply switch
- 2 Large-area LCD display



- 3 Terminals for device connection to a tested object

H_{CUR} - current supply terminal Hi
 H_{POT} - voltage sensing terminal Hu
 L_{POT} - voltage sensing terminal Lu
 L_{CUR} - current sensing terminal Li

- 4 Push buttons of the menu



Four push buttons of the menu enable basic attendance of the calibrator. Actual meaning of individual push button responds to description in the left part of the large-area LCD display.

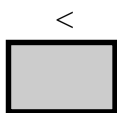
CANCEL



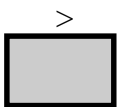
LOCAL

Enables device control from the front panel at remote control. In the second function deleting if given operation.

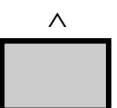
5 Push buttons of the numeric keyboard



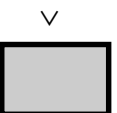
Push button for cursor movement towards left.



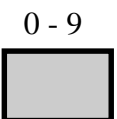
Push button for cursor movement towards right.



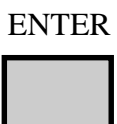
Push button for cursor movement up.



Push button for cursor movement down.

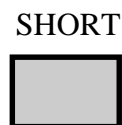


Push buttons 0 - 9 of the numeric keyboard.

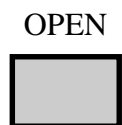


Push button for given operation endorsement.

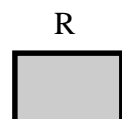
6 Push button of function selection



Push button for referential position SHORT engagement. After push button pressing comes to coaxial shortening of the calibrator output terminals. Further see the SHORT correction.

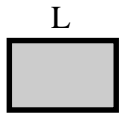


Push button for referential position OPEN engagement. After push button pressing comes to mutual connection of terminal pairs H_{CUR} , H_{POT} , L_{POT} , L_{CUR} . Further see the OPEN correction.

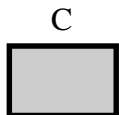


Push button for resistance standards engagement. After push button pressing comes to connection of the resistance

standard, which was engaged as the last. Further see Function selection.



Push button for inductance standards engagement. After push button pressing comes to connection of the induction standard, which was engaged as the last. Further see Function selection.



Push button for capacitance standards engagement. After push button pressing comes to connection of the capacity standard, which was engaged as the last. Further see Function selection.

6.1.2 Rear panel

- 1 Connector for switch control
- 2 Grounding terminal
- 3 GPIB bus connector
- 4 Power supply plug with fuse pack
- 5 Fan

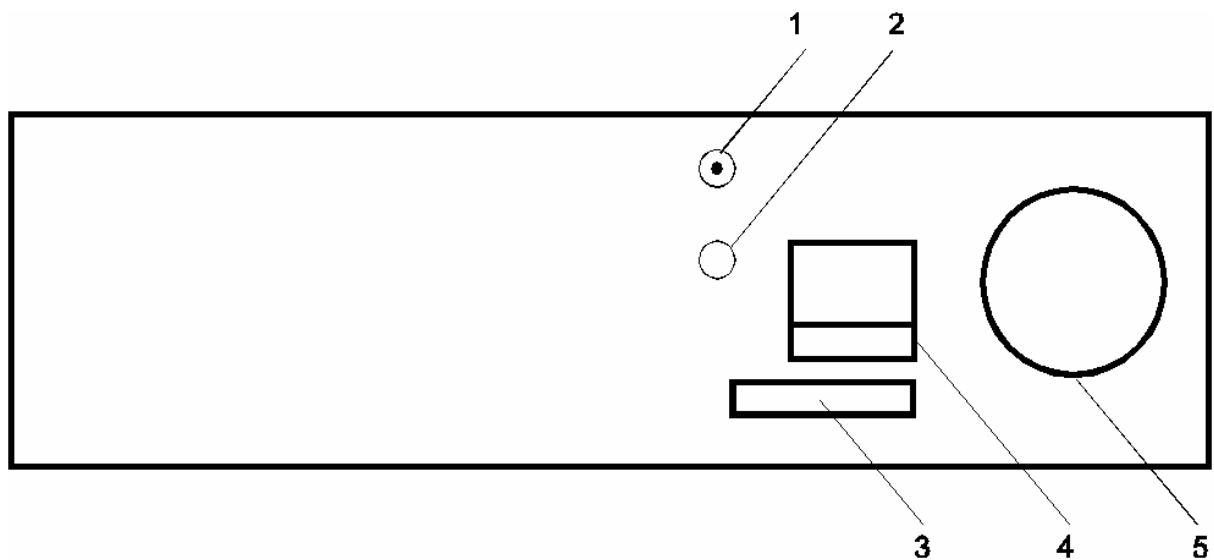


Fig.2. Rear panel

6.2 Device start-up

By the power supply cord connect the device to the supply voltage. By power supply button pressing put it into operation. After switching on is the following configuration set-up .

MEANS	SYS	CAL	FUNC
FUNC : Rp-Q	CON : 4W		
FREQ : 1000 Hz	SW : OFF		FREQ
RANGE : 1	GPIB : LOCAL		
Rp: 100.02 mΩ			RANGE
Q : 0.0011			
CALIB.: 11.1997			CON
Imax : 500 mA			
UNC Rp=0.050%			
UNC Q =0.0001			

6.3 Calibrator control

MEANS mode

6.3.1 Input value selection

By the R, C, L push buttons select the standard character.

FUNCTION selection

By the MENU push button, which belongs the sign FUNC, select one of four possible types of the calibration data projection. The data marked with „s“ index respond to the series equivalent circuit, the data marked „p“ respond to the parallel equivalent circuit.

MEANS	SYS	CAL	RP-Q
FUNC : Rp-Q	CON : 4W		
FREQ : 1000 Hz	SW : OFF		Rs-Q
RANGE : 1	GPIB : LOCAL		
Rp: 100.02 mΩ			Rp-Cp
Q : 0.0011			
CALIB.: 11.1997			Rs-Ls
Imax : 500 mA			
UNC Rp=0.050%			
UNC Q =0.0001			

Return to the basic MENU execute by the cursor arrow „^“, towards up.

FREQUENCY selection

Push the **FREQ** button and by **MENU UP** and **DOWN** step by series of discrete frequencies, on which are shown calibration data.

MEANS	SYS	CAL	
FUNC : Rp-Q	CON : 4W		
FREQ : 1000 Hz	SW : OFF		
RANGE : 1	GPIB : LOCAL		UP
Rp: 100.02 mΩ			DOWN
Q : 0.0011			
CALIB.: 11.1997 UNC Rp=0.050%			EXIT
Imax : 500 mA UNC Q =0.0001			

Return to the basic MENU by pushing the button corresponding to marking EXIT.

Selection of RANGE

Push the **RANGE** button and by push buttons **MENU UP** and **DOWN** set-up required value of standard.

MEANS	SYS	CAL	
FUNC : Rp-Q	CON : 4W		
FREQ : 1000 Hz	SW : OFF		
RANGE : 1	GPIB : LOCAL		UP
Rp: 100.02 mΩ			DOWN
Q : 0.0011			
CALIB.: 11.1997 UNC Rp=0.050%			EXIT
Imax : 500 mA UNC Q =0.0001			

Return to the basic MENU by pushing the button corresponding to marking EXIT.

Note: In case of synthetic inductor standards (100 mH, 1 H and 10 H) selection must be relevant value set-up by the frequency change. The value of synthetic inductor depends on a frequency range.

Note: All previous functions may be controlled both directly through the MENU push buttons and through the cursor arrows.

Selection of type of the connection

By the cursor arrows set up the cursor on sign CON and by the MENU push buttons 4W and 2W select type of the impedance calibrator connection to the checked RCL meter and as well projection of corresponding calibration data are displayed.

MEANS	SYS	CAL	
FUNC : Rp-Q		CON : 4W	
FREQ : 1000 Hz		SW : OFF	
RANGE : 1		GPIB : LOCAL	4W
Rp: 100.02 mΩ			2W
Q : 0.0011			
CALIB.: 11.1997 UNC Rp=0.050%			EXIT
Imax : 500 mA UNC Q =0.0001			

Return to the basic MENU by pushing the button corresponding to marking EXIT.

Selection of the external switch control

By the cursor arrows set up the cursor on the SW sign and through the MENU push buttons OFF and ON switch over output for external switch control, e.g. M-510A from ON to OFF and vice versa.

MEANS	SYS	CAL	
FUNC : Rp-Q		CON : 4W	
FREQ : 1000 Hz		SW : OFF	
RANGE : 1		GPIB : LOCAL	OFF
Rp: 100.02 mΩ			ON
Q : 0.0011			
CALIB.: 11.1997 UNC Rp=0.050%			EXIT
Imax : 500 mA UNC Q =0.0001			

Return to the basic MENU by pushing the button corresponding to marking EXIT.

6.3.2 Selection of the correction SHORT

At the SHORT button pressing are by coaxial way interconnected the measuring terminals H_{CUR} , H_{POT} , L_{POT} , L_{CUR} . Measured residual parameters have to be at RLC meter check-up subtracted from the measured value.



6.3.3 Selection of the correction OPEN

At the OPEN button pressing are mutually connected corresponding pairs of terminals H_{CUR} , H_{POT} , L_{POT} , L_{CUR} . Measured rest parameters must be at RLC meter check-up subtracted from the measured value.



ATTENTION

All calibration data relate to referential positions SHORT and OPEN.

6.3.4 Calibration value setting up**CAL mode**

By the cursor arrows select the CAL mode.

MEANS	SYS	CAL	
FUNC :		CON :	4W
FREQ :	1000 Hz	SW :	OFF
RANGE :		GPIB :	LOCAL
▼ 00000 ▲			
CALIB.: 11.1997			EXIT
I _{max} :			

From the numeric keyboard enter the calibration code and push the ENTER button. In case of false entered code it is necessary to repeat this step.

MEANS	SYS	CAL	FUNC
FUNC :	Rs-Ls	CON :	4W
FREQ :	1000 Hz	SW :	OFF
RANGE :	1	GPIB :	LOCAL
Rs: 100.02 mΩ		FREQ	
Ls: 0.017 μH		RANGE	
CALIB.: 11.1997		CAL	
I _{max} : 500 mA		UNC Rs=0.050%	
		UNC Ls=1.0 nH	

Selection of calibration

The impedance calibrator may be calibrated by following ways:

ALL mode

It serves for calibration of impedance components (real and imaginary parts) in the whole frequency band. This mode has to be selected always at the first calibration or at some of standards exchange and similarly.

OFS mode

It serves for calibration by so called off-set only on frequency 1000 Hz in the main component. The calibration data on another frequencies are moved with this off-set automatically.

These two ways of calibration may be quite independently combined.

Process at the ALL calibration

As the first set up the calibrator into such mode, in which you wish to execute the calibration (FUNC, FREQ, RANGE, CON).

Push the button corresponding the CAL sign in the basic MENU.

MEANS	SYS	CAL	
FUNC : Rs-Ls	CON : 4W		
FREQ : 1000 Hz	SW : OFF		ALL
RANGE : 1	GPIB : LOCAL		
Rs: 100.02 mΩ			OFS
Ls: 0.017 μH			EXIT
CALIB.: 11.1997		UNC Rs=0.050%	
Imax : 500 mA		UNC Ls=1.0 nH	

Select type of the ALL calibration.

MEANS	SYS	CAL	
FUNC : Rs-Ls	CON : 4W		
FREQ : 1000 Hz	SW : OFF		
RANGE : 1	GPIB : LOCAL		
Rs: 100.020 mΩ			
Ls: 0.017 μH			
CALIB.: 11.1997		UNC Rs=0.050%	EXIT
Imax : 500 mA		UNC Ls=1.0 nH	

Now through the cursor arrows and numeric keyboard enter a new calibration value of the main component and confirm by the ENTER push button pressing. The flashing cursor arrows move to the date of the residual component. New calibration value rewriting proceed in the same way as in the previous case.

Note: In case of negative residual component entry use for entry the minus sign of the cursor arrow „down“. For rewriting of negative sign on the positive one use the cursor arrow „up“.

After new calibration data entering press the Enter push button, select another calibration point (FUNC, FREQ, RANGE, CON), way of calibration (ALL, OFS) and go on in the same way.

The calibration mode leave by the cursor arrow right or left pressing or by transfer to the SYS or MEANS mode.

MEANS	SYS	CAL	UP MONTH
FUNC : Rs-Ls	CON : 4W		UP YEAR
FREQ : 1000 Hz	SW : OFF		DOWN YEAR
RANGE : 1	GPB : LOCAL		O.K.
Rs: 100.02 mΩ			
Ls: 0.017 μH			
CALIB: 11/1997		UNC Rs=0.050%	
Imax : 500 mA	UNC Ls=1.0 nH		

Through the keys MENU: UP MONTH, UP YEAR and DOWN YEAR set-up date of calibration and confirm it by the OK. push button.

Note: At wrong value entry from the numeric keyboard may be always made rewriting by the cursor arrows and numeric keyboard. Calibration finishing in given calibration point without calibration data entry enables the EXIT push button.

Process of OFS calibration

First set-up calibrator such mode, in which you wish to execute the calibration (FUNC, FREQ, RANGE, CON).

Press the push button corresponding to CAL sign in the basic MENU.

MEANS	SYS	CAL	
FUNC : Rs-Ls	CON : 4W		
FREQ : 1000 Hz	SW : OFF		
RANGE : 1	GPIB : LOCAL		ALL
Rs: 100.02 mΩ			OFS
Ls: 0.017 μH			
CALIB.: 11.1997 UNC Rs=0.050%			EXIT
Imax : 500 mA UNC Ls=1.0 nH			

Select way of the OFS calibration.

MEANS	SYS	CAL	
FUNC : Rs-Ls	CON : 4W		
FREQ : 1000 Hz	SW : OFF		
RANGE : 1	GPIB : LOCAL		
Rs: 100.020 mΩ			
Ls: 0.017 μH			
CALIB.: 11.1997 UNC Rs=0.050%			EXIT
Imax : 500 mA UNC Ls=1.0 nH			

Now by mediation of the cursor arrows and the numeric keyboard entry new calibration value of the main component and confirm it by the ENTER push button pressing, select another calibration mode (FUNC, FREQ, RANGE, CON), way of calibration (ALL, OFS) and go on in a same way. Left the calibration mode through the cursor arrows left or right, selection the SYS or MEANS mode and entry of the calibration date UP MONTH, UP YEAR and DOWN YEAR and confirm it by the OK. push button.

Note: At wrong value entry from the numeric keyboard may be always made rewriting by the cursor arrows and numeric keyboard. Calibration finishing in given calibration point without calibration data entry enables the EXIT push button.

6.3.5 System set-up of the calibrator

SYS mode

Serves for GPIB address setting up, calibrator coding-in and test procedures start.

MEANS	SYS	CAL	GPIB
GPIB : 2	TEST :		
CODE : 00000	BEEP : ON		
DEVICE : 50007	KONTR. : 42		CODE
CALIB. : 11.1997	VOLUME : 6		
			TEST

Another information

Manufacturing No.: DEVICE

Date of calibration: CALIB.

GPIB address setting up

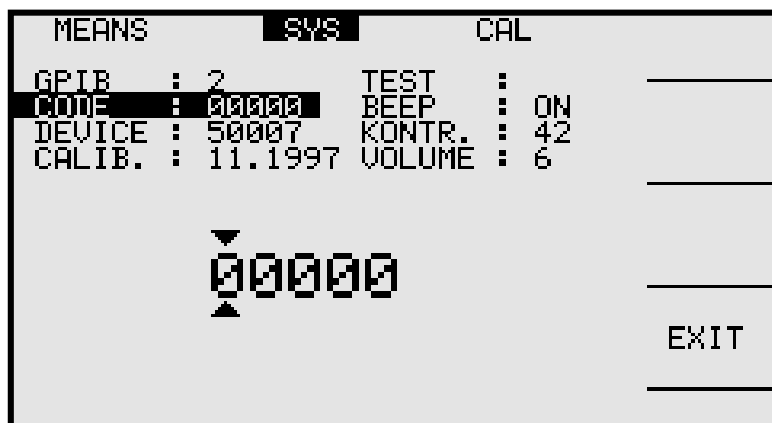
In the SYS mode press the key corresponding to the GPIB description.

MEANS	SYS	CAL	
GPIB : 2	TEST :		
CODE : 00000	BEEP : ON		
DEVICE : 50007	KONTR. : 42		UP
CALIB. : 11.1997	VOLUME : 6		
			DOWN
			EXIT

Through UP and DOWN push buttons set up required GPIB address in range 0 - 30.

Code setting up

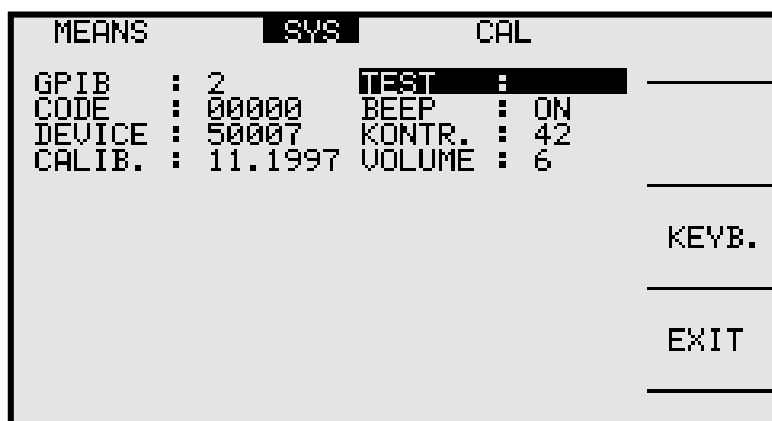
In the SYS menu press the key corresponding to the CODE description.



Through the numeric keyboard set up required code for entry into the calibration mode. It is necessary to record this code, because it will be never shown again. Set up code confirm by the ENTER push button. Calibrator coding-in is indicated in the SYS MENU by the sign CODE: SECRET. Calibration data unlock without right code is possible only at the manufacturer facilities. If the coding is not used, for entry into the calibration mode is possible to use up „visible code 00000“, which is sufficient to confirm by the ENTER push button pressing.

Tests setting up

In the SYS MENU press the key corresponding to the TEST description.



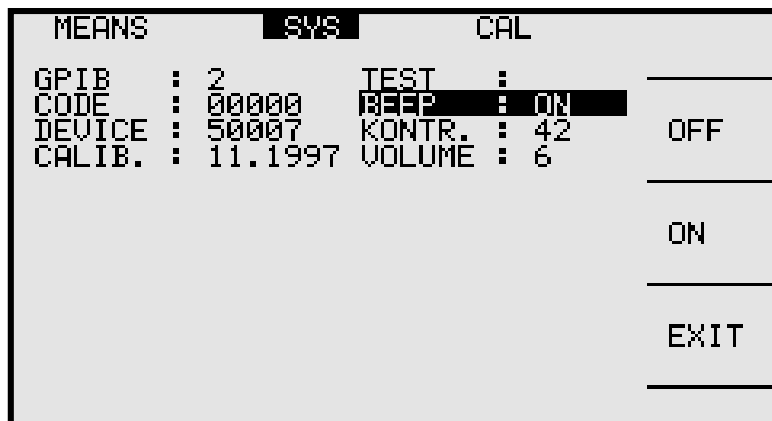
The KEYB. push button enables to check-up all keys of the keyboard. After push button pressing is on the display shown name of the last pressed key.



The keyboard test leave by the EXIT push button pressing.

BEEP function setting up

In the SYS mode select the BEEP function through the cursor arrows.



By push buttons with signs ON and OFF you may switch on or switch off respectively the accompanying sound by any key pressing.

Function KONTR

In the **SYS** mode select the KONTR function through the cursor arrows.
By push buttons with signs ON and OFF you may set desired contrast of display.

MEANS	SYS	CAL	
GPIB : 2	TEST :		
CODE : 00000	BEEP : ON		
DEVICE : 50007	KONTR. : 42		UP
CALIB. : 11.1997	VOLUME : 6		
			DOWN
			EXIT

Function VOLUME

In the **SYS** mode select the VOLUME function through the cursor arrows.
By push buttons with signs ON and OFF you may set desired volume of beeper.

MEANS	SYS	CAL	
GPIB : 2	TEST :		
CODE : 00000	BEEP : ON		
DEVICE : 50007	KONTR. : 42		UP
CALIB. : 11.1997	VOLUME : 6		
			DOWN
			EXIT

Note: All functions set-up in the SYS mode are preserved even at the impedance calibrator switching off.

6.4 Impedance calibrator connection

At impedance calibrator utilisation for analogue and numeric RLC meters checking-up it is necessary for high accuracy reaching to observe basic rules of proper connection. Proper connection of shielding and object grounding substantially suppress influence of external electric field, suitable measuring cables suppress possible magnetic induction into the measuring path. For proper use of the calibrator it is necessary to observe following principles:

1. Power line cord of the calibrator and checked-up RLC meter connect into the same point.
2. Do not mutually connect chassis of the calibrator and the RLC meter, do not admit unsuitable connection of another devices a grounding loops occurrence.
3. The impedance calibrator and check-up RLC meter place on conductive pad (plate, semi-conductor sheet) and connect the pad with grounding pin of the power network.
4. For interconnection of the impedance calibrator and checked-up RLC meter are the most suitable coaxial cables, e.g. from the calibrator accessories.

6.4.1 Four-pair terminal connection of the impedance calibrator

It solves problems among measuring cables. The reverse measuring current flows through outer input of the current coaxial cables and such it eliminates effect of the magnetic flow, arising as measuring current flow through inner current conductors consequence. This way of connection is suitable for checking of the most accurate electronic RLC meters. The function of individual connectors is on calibrator side and as well on checked RLC meter unexchangeable.

Example of RLC meters with fourterminal pair connection:

HEWLETT-PACKARD HP 4275A, 4274A, 4284A, 4276A, 4277A

ESI 2150, 2160

WAYNE-KERR 6425

TESLA BK 134, BK 136, BM 595

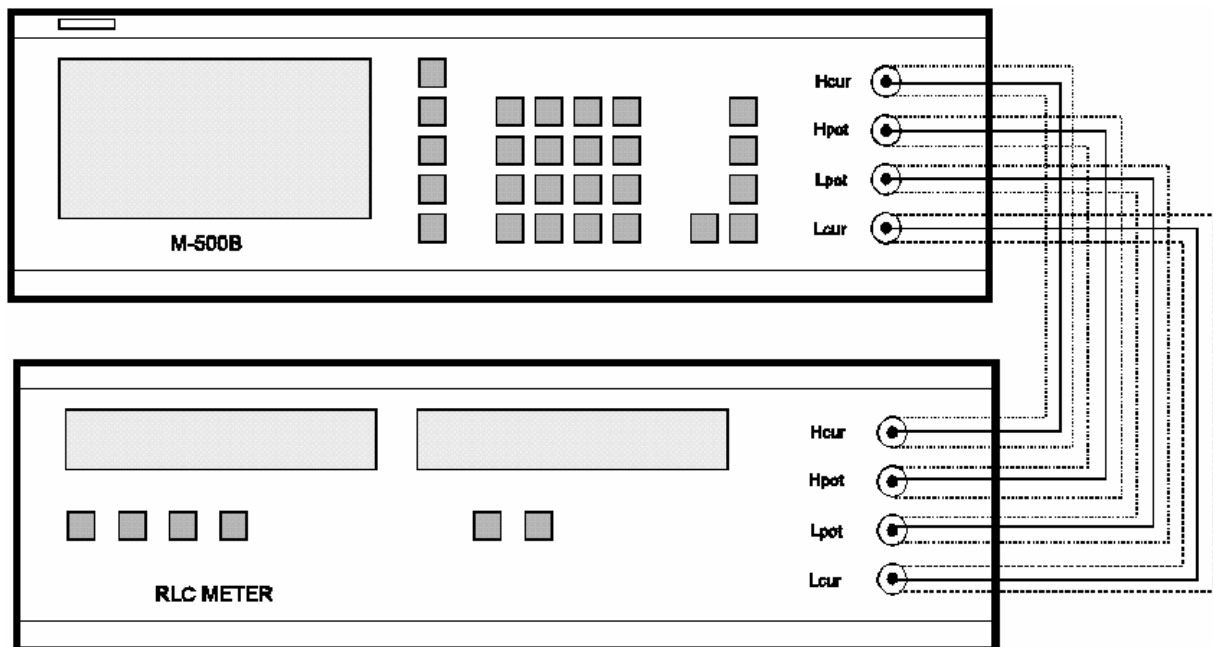


Fig.3. Four-pair terminal connection

6.4.2 Four-terminal connection of the calibrator

It reduces substantially influence of measuring cables between the impedance calibrator and checked RLC meter, because the current supply circuit and sensing voltage loop are independent. Four-terminal connection is commonly used, especially at older RLC meters and at very precise calibration sets for impedance measurement (bridges and AC impedance compensators). The four-terminal connection is suitable to use from impedance values about 1Ω . At measuring of lower impedance values may be result of measurement distorted by mutual feedback between current and voltage conductors, especial 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} .

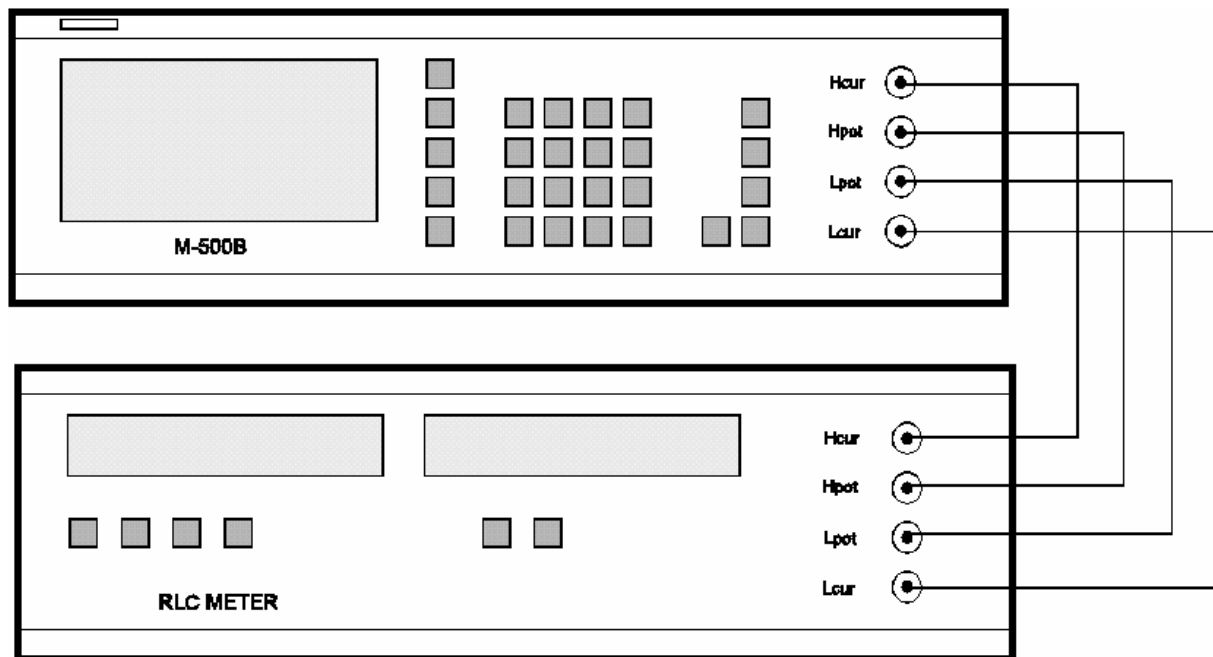


Fig.4. Four terminal connection

6.4.3 Three-terminal connection of the calibrator

Three-terminal connection of the impedance calibrator enables to eliminate above all influence of residual parallel capacity and conductivity. The outside conductor (shielding) of the coaxial cable is connected to the L_{CUR} terminal and on RLC meter side usually to its chassis. The connection is suitable for higher values of impedance, because at lower values there is a negative effect of residual inductance and resistance of cables. Regarding different impedance definition are not valid calibration data of residual components. The three-terminal connection may be used for checking of service and another less accurate RLC meters.

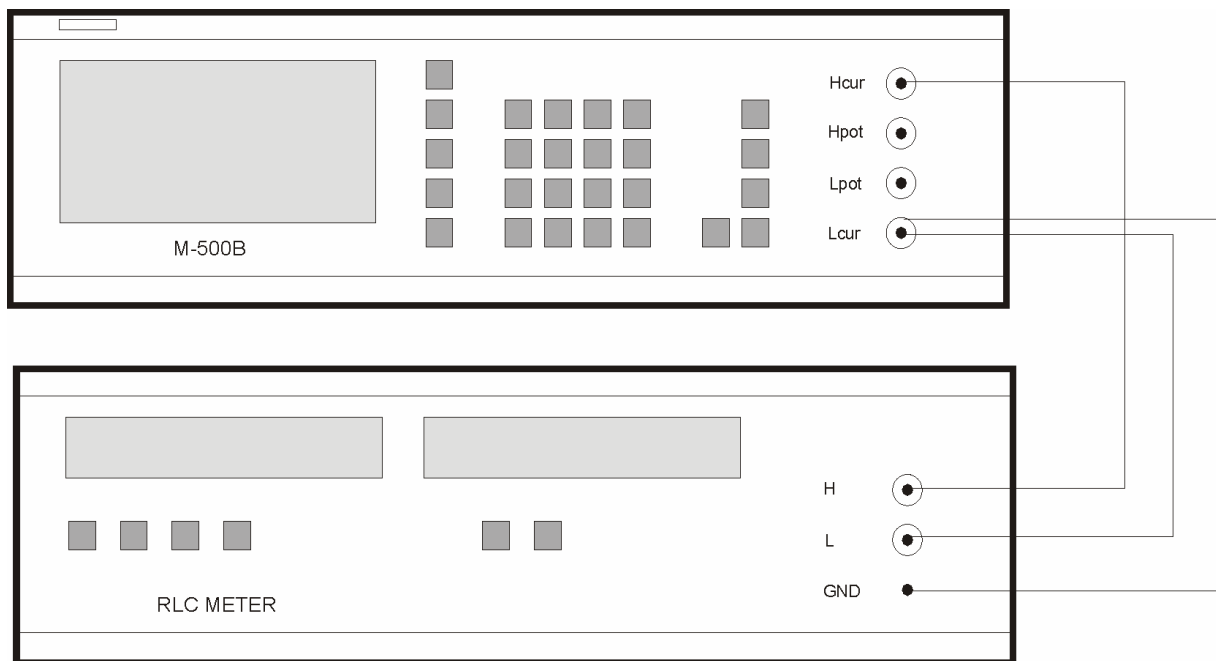


Fig.5. Three terminal connection

6.4.4 Two-terminal connection of the calibrator

This way of the impedance calibrator connection to the checked RLC meter is the simplest possible, however it is burdened by significant errors. To the measurement result are added errors by series resistance and inductance of lead-in wires and parallel capacity and conductance between two terminals. The two-terminal connection is used only in cases when high accuracy of calibration is not required. The calibrator is connected by coaxial or common conductors to the H_{POT} and L_{POT} terminals. At individual standards is not in the 2W mode of connection defined residual component of the impedance. Standards are suitable to be utilised only up to the frequency of 1 kHz for calibration of analogue and digital multimeters of corresponding class of accuracy.

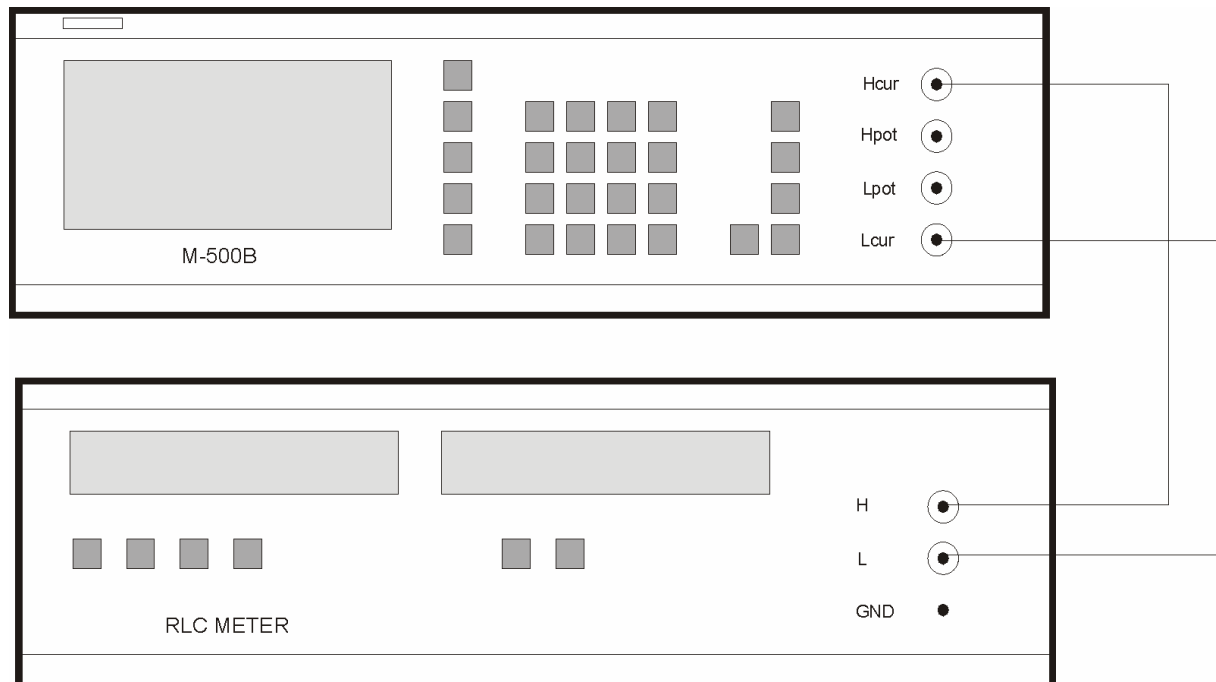


Fig.6. Two terminal connection

6.5 Remote control of the calibrator

Format of commands: AXAXAX...

A code of controlled function (character)

X Code of this function state (number)

Permitted commands:

Function	Function code	State code	Meaning
Equivalent connection	A	1	Rp-Q Lp-D Cp-D
		2	Rs-Q Ls-D Cs-D
		3	Rp-Cp Lp-Rp Cp-Rp
		4	Rs-Ls Ls-Rs Cs-Rs
Peeping of the keyboard	B	0	switched off
		1	switched on
Frequency	F	1	100 Hz
		2	120 Hz
		3	200 Hz
		4	400 Hz
		5	1000 Hz
		6	2000 Hz
		7	4000 Hz
		8	10000 Hz
		9	20000 Hz
Capacity	C	1	10 pF
		2	100 pF
		3	1 nF
		4	10 nF
		5	100 nF
		6	1 μ F
		7	10 μ F
Inductance	L	1	1 mH
		2	10 mH
		3	10 H [100 Hz - 400 Hz]
			1 H [1 kHz - 4 kHz] 100 mH [10 kHz - 20 kHz]
Resistance	R	1	100 m Ω
		2	1 Ω
		3	10 Ω
		4	100 Ω
		5	1 k Ω
		6	10 k Ω
		7	100 k Ω
		8	1 M Ω
		9	10 M Ω

Function	Function code	State code	Meaning
Terminals	T	0	OPEN
		1	SHORT
Connection	S	0	4W (four-terminals)
		1	2W (two-terminals)
Operation	O	5	coaxial switch ON
		6	coaxial switch OFF
Verification	V	0	value of standard
		1	state of device
		2	manufacturing No.
		3	date of calibration
		4	standard uncertainty
		5	maximum load

Format of read data:

At V0 function use:

FN X.XXXXX[X]EZXX FN X.XXXXX[X]EZXX CR LF

F - variable

R - resistance

C - capacity

L - inductance

Q - quality factor

D - loss factor

N - spare diagram

S - series

P - parallel

At V1 function use:

State of the device

AxBxCxFxLxRxSxTxOx CR LF

At V2 function use:

Number of device

NXXXXXX CR LF

At V3 function use:

Number of device

D MM.RRRR CR LF

MM - month

RRRR - year

At V4 function use:

FN X.XXX% FN {X.XXX%/X.XXXXX} CR LF

F - variable

R - resistance

C - capacity

L - inductance

Q - quality factor

D - loss factor

N - spare diagram

S - series

P - parallel

At V5 function use:

Maximum load

Umax: X[XX] [m]V CR LF

(or Imax: X[XX] [m]A CR LF)

7. Description of connection

Basic description of the device function is introduced in the Chapter 4. Following description relates to wiring diagrams, which are part of user's documentation.

7.1 Microcontroller unit

The unit consists of three blocks:

- a) micro-computer - includes microprocessor 80C537, protection circuits LTC699 (circuit watching the supply voltage) and memories U24, U3 and U21. The micro-computer controls all activity of the calibrator. It directly ensures managing of the keyboard and display. Program software is stored in memory U3, calibration data in the EEPROM U24 memory.
- b) GPIB circuits - ensure communication on the GPIB bus-bar. Used are circuits Intel 8291A (U30 combined circuit receiver/transmitter) and power exciter Intel 8293A (U28, U29).
- c) LT 1026 circuit generates negative voltage -15 V, necessary for LCD display operation. Optocouplers OPT1 and OPT2 together with circuit gates U19 check presence of alternating supply current.

7.2 Display unit

The unit consists of the large-area graphic display with built-in control unit and micro-controller. The display is transilluminated by high voltage discharge tube. An independent part is the high voltage converter 5 V/1 kV.

7.3 Keyboard unit

The unit contains 26 keys, arranged in matrix 5 x 7. Their state is periodically sensed and evaluated by the microprocessor.

7.4 Source and selector unit

The source unit ensures voltage +5 V VCC for the microprocessor board and display power supply, +5 V RE for supply relay connecting individual standards, placed in low-impedance and high-impedance box, +15 V and -15 V for electronic circuits of equipotential power supply and unstabilized voltage about 9 V for fan power supply. Together with transformers and rectifiers creates one mechanical block. On the sources board is placed as well selector of individual relays, created by circuits U1 through U9. Way of communication in the microprocessor board is series. RE1 relay, controlled by the T1 transistor, enables program control of external coaxial switch.

7.5 Standard unit

7.5.1 Low-impedance box

In this box are placed resistance standards in range of $100\text{ m}\Omega$ - $100\ \Omega$, capacity standards 100 nF - $10\ \mu\text{F}$, synthetic inductance standards 100 mH - 10 H , SHORT circuits and switches among individual boxes. Standard resistors are foil type. Standard capacitors are of mica (100 nF) or with polypropylene dielectric. These capacitors are simultaneously used up in circuits of synthetic inductance. All standards before use undergo to artificial ageing and selection on minimum thermal coefficient. Standards are placed in boxes from tinfoil, through which passes the measuring bus-bar (H_{CUR} , L_{CUR} , H_{POT} , L_{POT}). Mechanical distribution of individual conductors is designed such the current conductors would create pseudo-coaxial arrangement (reason is to get minimum external magnetic field) and high-impedance voltage conductors should create small area of a loop, into which could induce the noise voltage. Result is reaching of very low time constant of individual standards.

7.5.2 High-impedance box

In this box are placed resistance standards in range of $1\text{ k}\Omega$ - $10\text{ M}\Omega$, capacity standards 10 pF - 10 nF , inductance standards 1 mH and 10 mH and OPEN circuits. Standard resistors are foil type. The resistance standard $10\text{ M}\Omega$ is created by resistance T network, see Fig. Reason is time constant minimalization a frequency dependence of the standard. Standard condensers have mica dielectric. Inductance standards are created by coils, placed in magnetic circuit. All standards before use undergo to artificial ageing and selection on minimum thermal coefficient. Standards are placed in boxes from tinfoil, through which passes the measuring bus-bar (H_{CUR} , L_{CUR} , H_{POT} , L_{POT}). Mechanical distribution of individual conductors is designed such the pair of conductors H_{CUR} , L_{CUR} , H_{POT} , L_{POT} would not be placed in mutual vicinity (the reason is minimalization of rest conductivity and capacity). Result is reaching of very low time constant of individual standards.

 L_{pot} H_{pot}

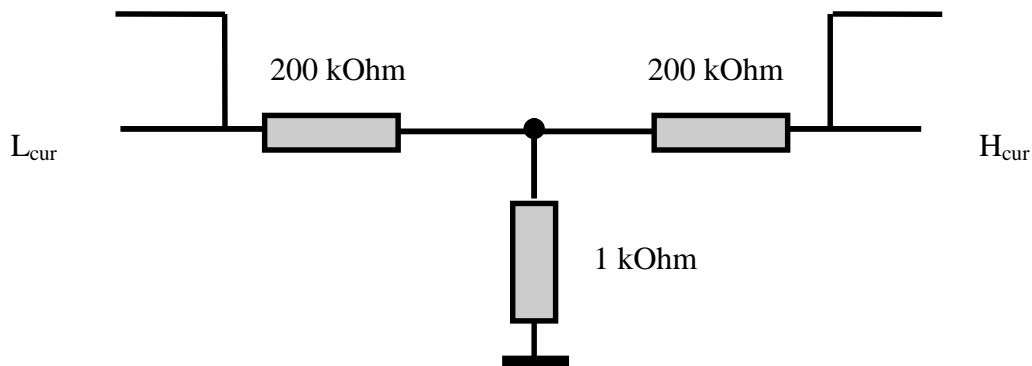


Fig.7. Simulation of the resistance standard 10 MΩ by T network.

8. Mechanical construction

The device itself is built into standard metal housing. Access into the device is possible from the top or the bottom side after top or bottom cover removal. The covers are tightened by four screws. The rear panel is removed after undoing four screws on the rear wall. Similarly, the front panel may be removed after six screws disengaging from metal profiles on top and bottom side. The display and keyboard units are part of the front panel.

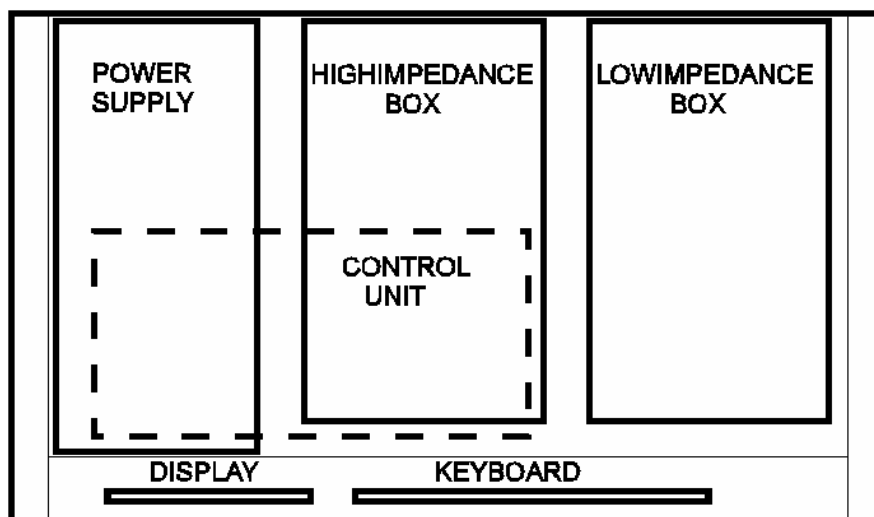


Fig.8. Mechanical construction

9. Instruction for maintenance

9.1 Mechanical maintenance

With exception of the push buttons, power supply switch and fan the device does not contain movable parts and therefore it is not necessary to make any mechanical maintenance.

10. Calibration

The impedance calibrator requires periodical verification. Recommended recalibration interval is 1 year. The calibrations are aimed on determination of new calibration data in whole range of values.

10.1 Necessary equipment

1. Verified set of the impedance standards in frequency band up to 20 kHz with accuracy better than 0.005% (1 kHz), e.g. HP 16380A, HP 16380C, HP 16074A.
2. RLC meter, used as a comparator, e.g. HP 4284A, WK 6425, ESI 2150 and similar ones.
3. Connecting coaxial conductors.

For automatic calibration over it:

4. Coaxial switch M-510A.
5. PC AT computer.
6. Program accessories - calibration software.

10.2 Process of calibration

1. Place all devices and standards into air-conditioned room with temperature $23^{\circ}\text{C} \pm 1^{\circ}\text{C}$, connect as on the Fig. and let them to stabilise temperature for at least 2 hours.

Note: Do not put devices one on the other.

2. Connect to the RLC-meter Impedance calibrator according Fig 9. On the Impedance calibrator select desired type of impedance (R, C, L), range and frequency.
3. At the RLC meter - comparator set-up such parameters (integration time, range, results averaging) to be introduced into the state with highest specified accuracy on given frequency.
4. On the impedance calibrator set-up value of calibrated standard. Record measured values of main A_{DUT} and residual components B_{DUT} .
5. Connect to the RLC-meter corresponding standard according Fig 10. Record measured values of main A_{STD} and residual components B_{STD} .
6. Calculate new calibration values of partial standard of the impedance calibrator A_X , B_X

$$A_X = (A_{\text{STD}} - A_{\text{DUT}}) + A_{\text{CAL}}$$

$$B_X = (B_{\text{STD}} - B_{\text{DUT}}) + B_{\text{CAL}}$$

where A_{CAL} is calibration value of standard main component.

B_{CAL} is calibration value of standard residual component

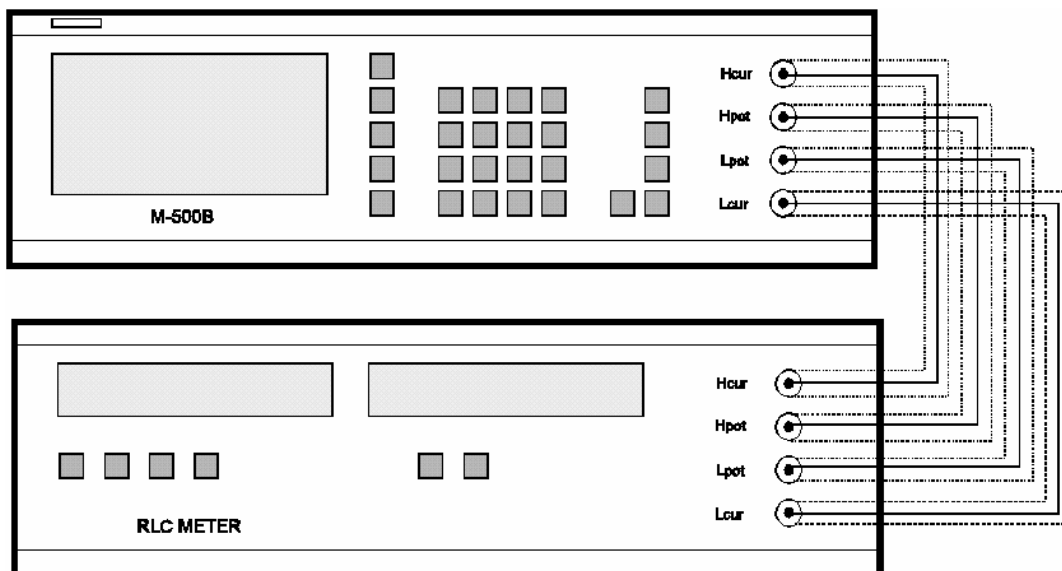


Fig. 9. Impedance calibrator connected to comparator RLC-meter

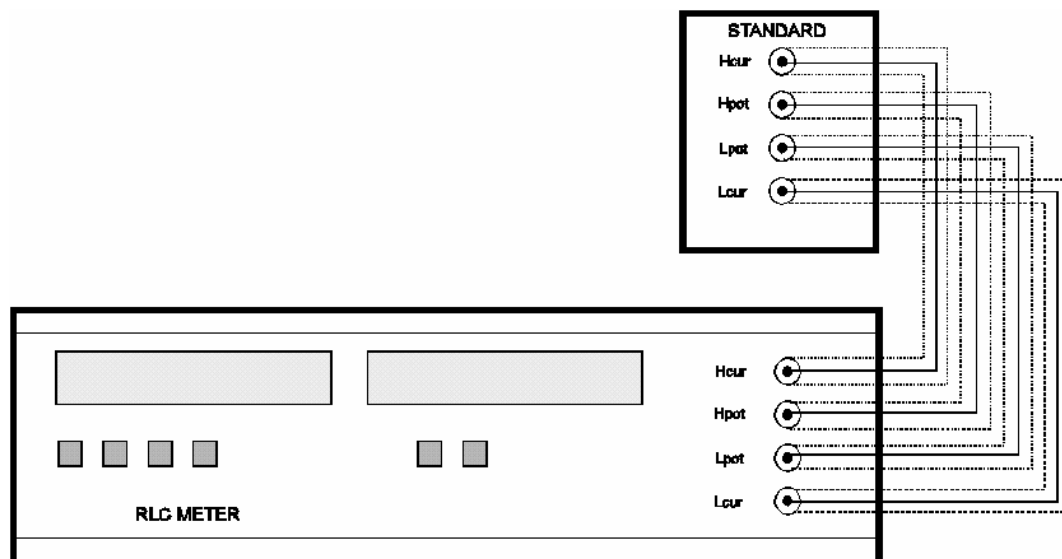


Fig.10. Standard connected to comparator RLC-meter

5. Measurement repeat on all partial frequencies at the same impedance value.
6. On the impedance calibrator select another value of impedance and repeat steps 5 - 7.
7. From all measured values subtract the rest parameters SHORT and OPEN, which determine by direct measurement (applies only at margin values of impedance). If is measurement and calculation done regularly, set of calibration data is created.
8. Record of the calibration data into calibrator memory execute by the Chapter 6.3.4.

10.3 Control process of RLC meters

1. Place the devices in reference temperature, connect by the Chapter 6.4, switch on and let stabilise.
2. On the checked-up RLC meter set-up the measuring frequency and relevant impedance range or let in the mode AUTORANGE (by RLC meters checking requirement).
3. On the impedance calibrator select consecutively referential position SHORT and OPEN. If the checked-up RLC meter enables record of these correction values, than execute the record, if not than it is necessary these valued write down and subtract from measured values.

4. On the impedance calibrator set-up required value of impedance.

5. On the RLC meter read measured values A_x and B_x .

6. Calculate error of the RLC meter by following relation:

$$t_A = (A_x/A_N - 1) \cdot 100 [\%] \quad \text{for the main component}$$
$$t_B = B_x - B_N \quad \text{for residual component in form D, Q}$$

7. Repeat steps 2 - 6 for remaining impedance values and remaining measuring frequencies.

