ZA-1 Precision Impedance Analyzer

Operating Manual



Document ZA1-UM-011, Revision B

For instruments with front-panel firmware 1.x and analog board Rev B

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1 About this manual

This manual explains how to install and operate the ZA-1 Precision Impedance Analyzer. It is written for anyone who measures components or materials with the instrument, from a technician sorting parts on a production bench to an engineer characterising a new sensor. No previous experience with LCR meters is assumed; where a measurement idea needs explaining, the explanation is given at the point where you need it.

The manual follows the order in which most people meet the instrument. Chapter 4 walks around the front and rear panels. Chapters 5 to 7 take you from unpacking to a first reliable measurement. Chapters 8 to 13 cover the features you will use as your work becomes more demanding: cable correction, sweeps and graphs, triggering, sorting, stored settings and remote control. Maintenance, troubleshooting and the specifications close the manual.

1.1 Conventions

Keys on the front panel are printed in small capitals, for example **PRESET** or **MEAS SETUP**. Softkeys, whose function is shown on the screen next to the six keys to the right of the display, are printed in a box, for example [FREQ]. Text that appears on the screen is printed in the same way. Numbers in parentheses, such as (7), refer to the callout numbers in the figure being discussed.

Three kinds of notice are used:

WARNING draws attention to a hazard that could injure you.

CAUTION draws attention to something that could damage the instrument or the part you are measuring.

NOTE gives information that makes a task easier or a result more reliable.

2 Safety information

Read this chapter before you connect the instrument to the mains. The ZA-1 is a Safety Class I instrument: its metal ground plate and the outer shells of all front-panel connectors are connected to the protective earth conductor of the power cord.

WARNING Connect the instrument only to a mains outlet that has a protective earth contact, using a three-wire power cord with an IEC 60320 C13 connector. Do not defeat the earth connection with an adapter.

WARNING Do not operate the instrument with any cover removed. The power supply inside the case carries mains voltage even when the front-panel power key is in standby. Switch off the rear power switch and pull the power cord before opening the case.

CAUTION The UNKNOWN terminals are measurement inputs, not voltage inputs. Never connect them to a live circuit, a charged battery, or the mains. The maximum voltage between any UNKNOWN terminal and ground is 42 V peak.

CAUTION Discharge every capacitor before you connect it. The input protection absorbs the energy of a capacitor of up to 100 µF charged to 42 V, but repeated or larger discharges shorten its life and can destroy the input circuit.

2.1 Fuses

The power inlet on the rear panel contains two fuses of type **T2 A L 250 V, 5 × 20 mm** (time-lag, low breaking capacity), one in each supply conductor. Replace them only with fuses of the same type and rating; the procedure is described in section 14.2. A further fuse on the internal power-supply board (T3.15 A) protects the power modules and is not user-replaceable.

2.2 Environment

The instrument is intended for indoor use in a laboratory or on a production bench, at 0 °C to 40 °C and a relative humidity of up to 80 % without condensation. Keep the ventilation slots on the rear panel and on the underside free. Do not stand the instrument on its rear panel while it is running.

2.3 Symbols on the instrument

Table 1. Symbols used on the instrument.

Symbol	Meaning
⚠	Caution. Refer to this manual. Next to the UNKNOWN terminals it marks the 42 V peak limit.
⏚ (earth symbol)	Protective earth terminal (rear panel) and front GND terminal, both connected to the chassis earth.
~	Alternating current (on the rear rating label).
I / O	Rear power switch on / off.

3 Introduction

The ZA-1 measures *impedance*: the opposition that a component offers to an alternating current. From one measurement it calculates the quantities you are usually interested in, such as capacitance and dissipation factor for a capacitor, inductance and quality factor for a coil, or resistance and phase angle for a resistor or a sensor. The test frequency can be set anywhere from 20 Hz to 1 MHz and the test signal from 5 mV to 2 V rms, so the conditions of the measurement can match the conditions the part will see in service.

3.1 Typical applications

- Incoming inspection and sorting of capacitors, inductors, resistors and transformers.
- Characterising parts over frequency: equivalent series resistance of capacitors, self-resonance of inductors, resonance of ceramic resonators and piezo elements.
- Development and test of capacitive, inductive and resistive sensors.
- Measurements on materials in suitable fixtures (dielectric constant, loss) and on cables and connectors.

3.2 How the instrument measures

The ZA-1 applies a sine-wave test signal to the part and measures, at the same instant, the voltage across the part and the current flowing through it. Impedance is the ratio of the two. The voltage is sensed with a separate pair of connections (Hpot and Lpot) that carry no test current, so the resistance of the test leads and contacts does not enter the result. The current is returned through the Lcur terminal into an amplifier that keeps the low side of the part at zero volts and passes all of the current through one of four precision range resistors. This arrangement, called an auto-balancing bridge, is the method used by laboratory LCR meters.

Both signals are digitised by two 18-bit converters that sample simultaneously and share a common reference. A digital correlator then extracts the amplitude and phase of each signal at the test frequency and rejects noise and harmonics. Finally the instrument applies its factory calibration and any correction you have made for your test leads (chapter 8), and converts the result into the parameters you have selected.

4 The instrument at a glance

This chapter names every key, indicator and connector. Figure 1 shows the front panel as a whole; the sections that follow show each area in close-up and describe what each item does.

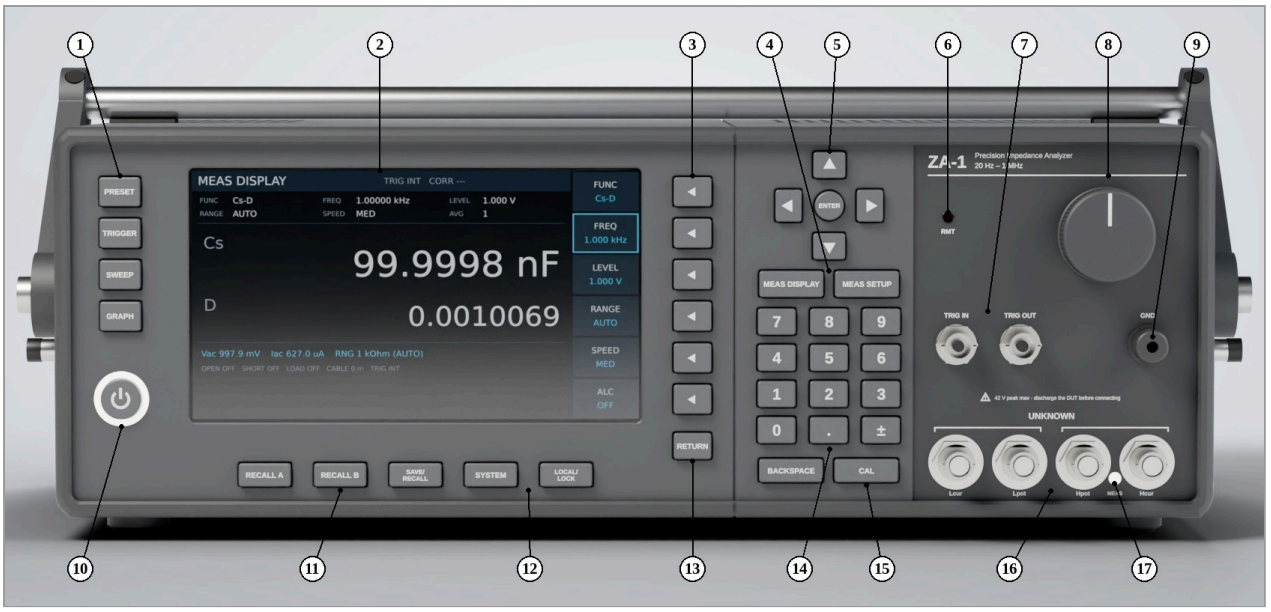


Figure 1. Front panel.

Table 2. Front-panel items in Figure 1.

No.	Item	Described in
1	Instrument keys: **Preset**, **Trigger**, **Sweep**, **Graph**	4.1
2	7-inch colour display	4.2
3	Softkeys (six keys whose function is shown on the screen)	4.2
4	**Meas Display** and **Meas Setup** page keys	4.3
5	Navigation keys and **Enter**	4.3
6	RMT (remote) indicator	4.4
7	TRIG IN and TRIG OUT connectors	4.4
8	Rotary knob	4.3
9	GND terminal (4 mm)	4.4
10	Power key with standby light ring	4.1
11	**Recall A**, **Recall B** and **Save/Recall**	4.2
12	**System** and **Local/Lock**	4.2
13	**Return**	4.2
14	Numeric keypad	4.3
15	**Backspace** and **Cal**	4.3
16	UNKNOWN terminals: Lcur, Lpot, Hpot, Hcur	4.4
17	MEAS indicator	4.4

4.1 Instrument keys and power key

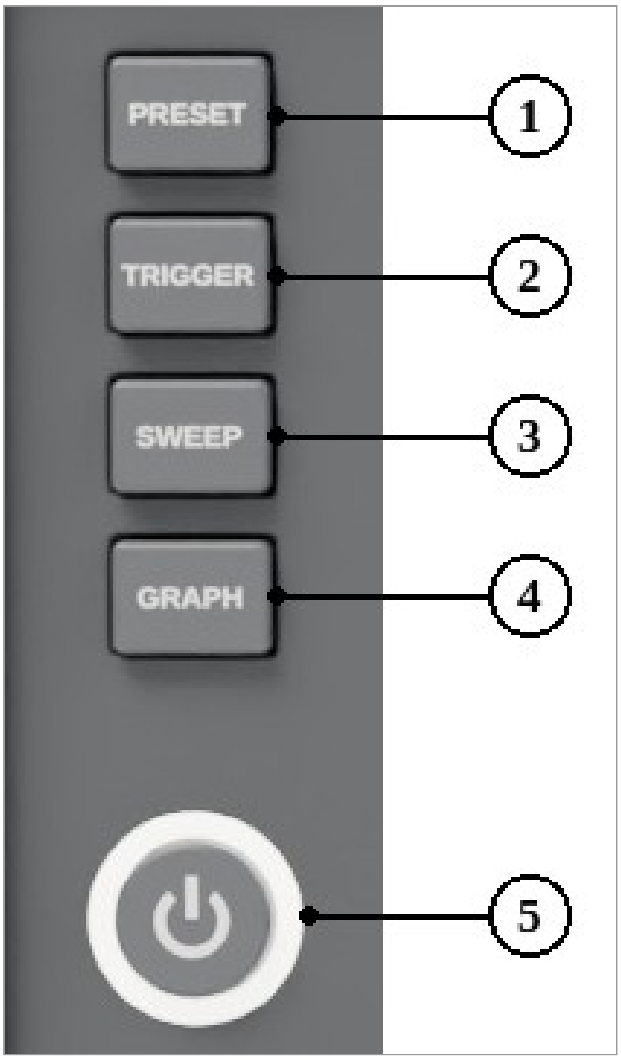


Figure 2. Instrument keys and power key.

The four keys at the left edge (Figure 2) act on the instrument as a whole.

(1) **PRESET** returns all measurement settings to their factory defaults (Table 7). Because this discards your settings, the instrument asks for confirmation: press **PRESET** again, or **ENTER**, within three seconds. Network settings and stored cable-correction data are kept, but correction is switched off.

(2) **TRIGGER** starts one measurement when the trigger source is set to HOLD (section 10.2). In the other trigger modes it has no effect.

(3) **SWEEP** opens the sweep page, where you set up and run a sweep over frequency or test level and see the results as a list (chapter 9).

(4) **GRAPH** plots the most recent sweep (section 9.3).

(5) The round power key switches the instrument between operation and standby. In standby the ring around the key is lit; the instrument is then still connected to the mains and must be switched off with the rear power switch before the case is opened.

4.2 Display, softkeys and the keys below the display



Figure 3. Display with the MEAS DISPLAY page, softkey labels and softkeys.

The display (Figure 3) always has the same layout. The **title bar** (1) names the page and shows the trigger source and whether correction is active. The **settings summary** (2) lists the measurement settings that are in force. On the MEAS DISPLAY page the result is shown in two large lines: the **primary parameter** (3), for example capacitance Cs, and the **secondary parameter** (4), for example the dissipation factor D. The **monitor line** (5) shows the actual rms voltage across the part (Vac), the current through it (Iac) and the range in use. The **status line** (6) shows the state of the OPEN, SHORT and LOAD corrections, the cable length and the trigger source.

Along the right edge of the screen, the **softkey labels** (7) show what each of the six softkeys (8) does on the page that is open. A highlighted label marks the field that is currently selected. The label also shows the present value, so you can read the most important settings without opening a menu. **RETURN** (9) closes an editor without making a change, cancels a request such as a pending PRESET, and clears messages.

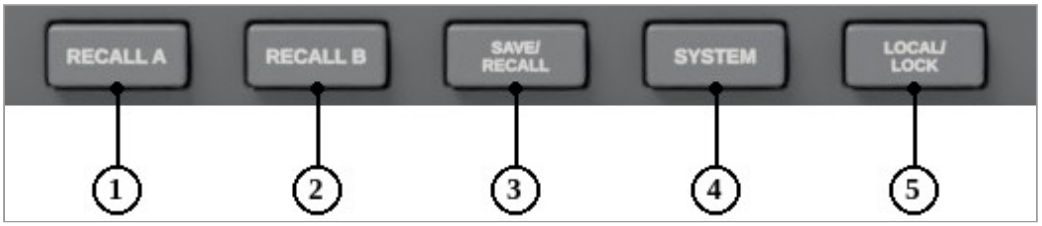


Figure 4. Keys below the display.

The five keys below the display (Figure 4) are used less often. **RECALL A** (1) and **RECALL B** (2) restore a stored set of settings with one key press, from any page. **SAVE/RECALL** (3) opens the page on which settings are stored and the power-on state is saved (chapter 11). **SYSTEM** (4) opens the system page: firmware version, network address, internal temperature, beeper and self-test (chapter 12). **LOCAL/LOCK** (5) returns control to the front panel after the instrument has been controlled from a computer.

4.3 Page keys, navigation, keypad and knob

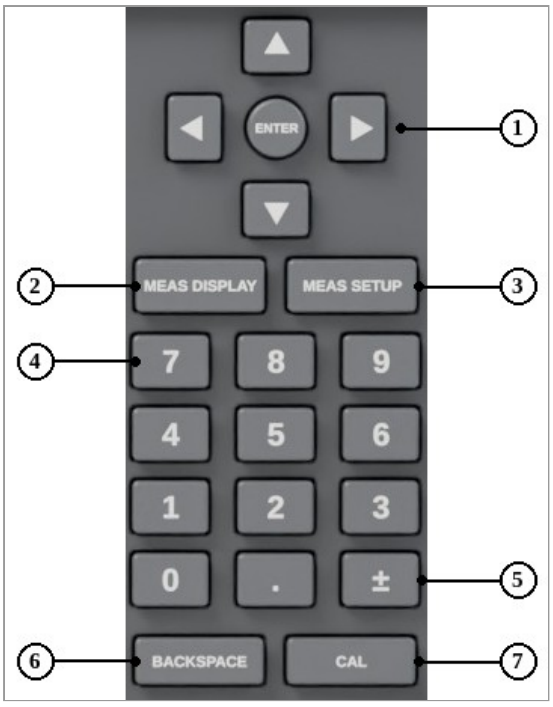


Figure 5. Navigation keys, page keys and keypad.

(1) The four arrow keys move the selection from one field to the next and, while a number is being edited, move the digit that is changed. **ENTER** in the middle opens the selected field for editing and confirms an entry.

(2) **MEAS DISPLAY** opens the main measurement page, the page you will use most.

(3) **MEAS SETUP** opens the page with the settings that are changed less often: trigger source, averaging, delay, the comparator and the cable length (chapter 10).

(4) The numeric keys enter values directly. Typing a digit while a numeric field is selected starts the entry; the softkeys then offer the units, for example Hz, kHz and MHz for frequency (section 6.3).

(5) The decimal point and the sign key complete the keypad.

(6) **BACKSPACE** deletes the last character typed.

(7) **CAL** opens the correction page, where the effect of test leads and fixtures is measured and removed (chapter 8).

The rotary knob to the right of the keypad (Figure 1, item 8) changes the selected value in steps; pressing the knob has the same effect as **ENTER**. When no field is open on the MEAS DISPLAY page, turning the knob steps the test frequency through the sequence 1, 2, 5, 10, 20, 50 and so on. On the GRAPH page it moves the marker.

4.4 Terminal section



Figure 6. Terminal section.

(1) **RMT** lights while the instrument is under remote control over USB or the network. The front-panel keys are then locked, apart from **LOCAL/LOCK**.

(2) The rotary knob (section 4.3).

(3) **TRIG IN** accepts an external trigger: a rising edge at 3.3 V logic level (5 V tolerant) starts a measurement when the trigger source is EXT.

(4) **TRIG OUT** delivers a short pulse (about 2 µs, 3.3 V from 50 Ω) at the end of every measurement, for example to step a component handler.

(5) **GND** is a 4 mm socket connected to the chassis and protective earth. Use it for the guard terminal of a fixture or for cable shields.

(6) The warning label repeats the 42 V peak limit of the UNKNOWN terminals.

(7)–(10) The four **UNKNOWN** BNC connectors, **Lcur**, **Lpot**, **Hpot** and **Hcur**, form the measurement port. They are grouped as L (low side) and H (high side), in the order and at the 22 mm spacing used by standard four-terminal-pair fixtures and Kelvin-clip cables.

(11) **MEAS** lights while the test signal is connected to Hcur. When it is dark, the source is disconnected and the part can be changed.

Table 3. Function of the UNKNOWN terminals.

Terminal	Function
Hcur	Test-signal output. Drives the test current into the high side of the part through a 100 Ω source resistance.
Hpot	Senses the voltage at the high side of the part. Carries almost no current.
Lpot	Senses the voltage at the low side of the part, which the instrument holds at 0 V.
Lcur	Current return. The current through the part flows back into the instrument here and is measured.

4.5 Rear panel

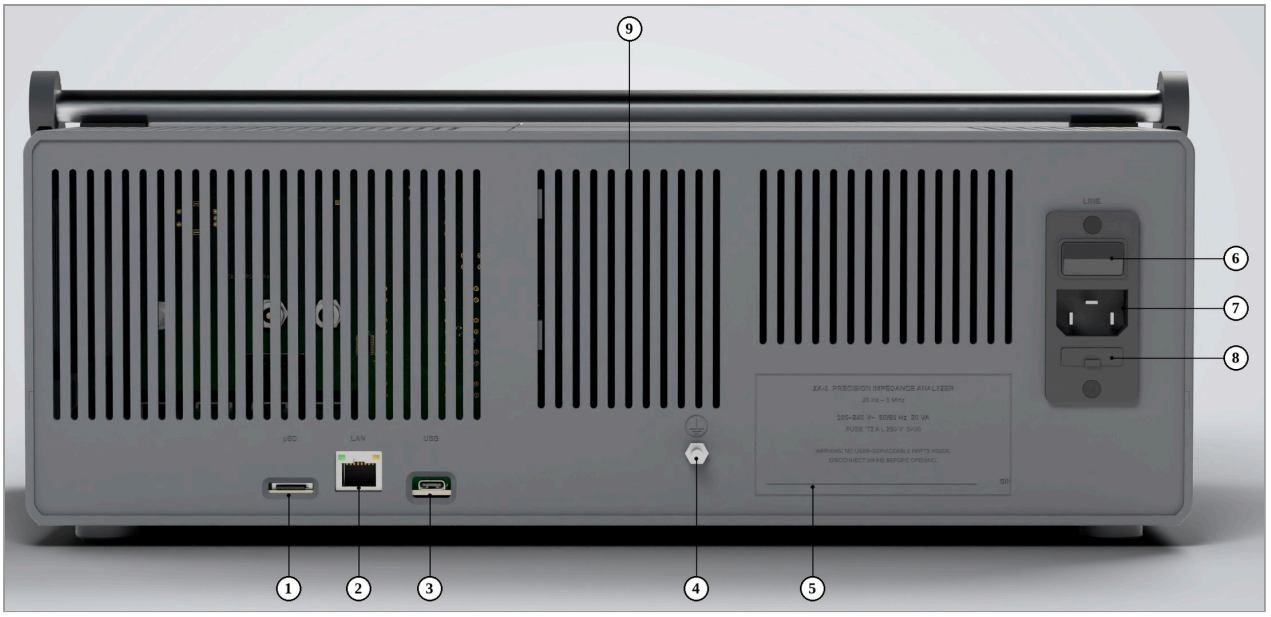


Figure 7. Rear panel.

Table 4. Rear-panel items in Figure 7.

No.	Item	Function
1	microSD card slot	Stores settings, screenshots and sweep data.
2	LAN (RJ-45)	10/100 Mbit/s Ethernet for remote control (SCPI on TCP port 5025).
3	USB-C	USB-TMC device port for remote control from a computer.
4	Protective earth terminal	For bonding the instrument to the earth of a test system.
5	Rating label	Supply rating (100–240 V~, 50/60 Hz, 30 VA) and fuse rating (T2 A L 250 V).
6	Power switch	Disconnects the instrument from the mains (I = on, O = off).
7	Power inlet	IEC 60320 C14 inlet for the three-wire power cord.
8	Fuse drawer	Holds the two mains fuses (section 14.2).
9	Ventilation slots	Keep clear. Natural convection only; the instrument has no fan.

5 Installation and first switch-on

5.1 Unpacking

Check the contents against Table 5 and inspect the instrument for transport damage before you connect it. Keep the packing if you may need to ship the instrument for calibration.

Table 5. Items supplied.

Item	Quantity
ZA-1 Precision Impedance Analyzer	1
Power cord, IEC C13, for the country of use	1
USB-C cable	1
Spare fuses T2 A L 250 V, 5 × 20 mm	2
Operating manual (this document)	1
Calibration certificate	1

5.2 Where to put the instrument

Place the instrument on a firm, level bench with at least 10 cm of free space behind it and on both sides. The case is cooled by natural convection through the slots in the rear panel and the base. Keep it away from strong magnetic fields (large transformers, motors) and from equipment that radiates strongly, such as induction heaters, because they can disturb measurements of high impedances.

The carrying handle has three positions: carrying, folded flat over the top, and tilted under the case to raise the front by about 9°. To move the handle, pull both hub caps outward slightly and turn the handle until it clicks into the next position.

5.3 Connecting the power

1. Check that the rear power switch is in the O (off) position.
2. Plug the power cord into the inlet on the rear panel and into an earthed mains outlet. The instrument accepts any supply voltage from 100 V to 240 V at 50 Hz or 60 Hz; there is no voltage selector.
3. Switch the rear power switch to I. The instrument goes into standby and the ring around the front power key lights.

5.4 Switching on

Press the front power key. The ring goes dark, the display starts and, after a few seconds, the MEAS DISPLAY page appears with the settings that were saved as the power-on state (on a new instrument, the factory defaults of Table 7). During start-up the instrument loads its measurement hardware and checks its calibration data. If the title bar shows NO AFE or UNCAL, see chapter 15.

> **NOTE** For measurements to the full specified accuracy, let the instrument warm up for 30 minutes after switching on. The internal temperature, shown on the SYSTEM page, settles during this time.

5.5 Self-test

A self-test checks the measurement hardware, the calibration memory and the temperature sensor. Press **SYSTEM** and then the SELF TEST softkey. The result is shown as a message; a failure code identifies the part that did not respond (see chapter 15).

6 Working with the front panel

6.1 Pages

Everything the instrument can do is organised in seven pages. Each page is opened with its own key, and on every page the six softkeys take on the functions listed in Table 6.

Table 6. Pages and their softkeys.

Page	Opened with	Softkeys (top to bottom)
MEAS DISPLAY	**MEAS DISPLAY**	FUNC, FREQ, LEVEL, RANGE, SPEED, ALC
MEAS SETUP	**MEAS SETUP**	TRIG, AVG, DELAY, COMP, NOMINAL, CABLE
SWEEP	**SWEEP**	TYPE, START, STOP, POINTS, SPACING, RUN
GRAPH	**GRAPH**	FORMAT, AUTOSCALE, AXES, MARKER, SWEEP, MKR SEARCH
CORRECTION	**CAL**	MEAS OPEN, MEAS SHORT, MEAS LOAD, OPEN, SHORT, LOAD
SAVE / RECALL	**SAVE/RECALL**	STORE A, STORE B, RECALL A, RECALL B, SAVE (power-on), CLEAR
SYSTEM	**SYSTEM**	DHCP, BEEPER, SELF TEST, SAVE

Softkeys are of three kinds. A softkey for a *numeric setting* (FREQ, LEVEL, START) opens an editor for the value. A softkey for a *choice* (FUNC, RANGE, SPEED) opens a list of the possible values. A softkey for an *action* or an on/off setting (ALC, RUN, MEAS OPEN) acts immediately.

6.2 Selecting a field

On pages with settings, one softkey label is highlighted: that is the selected field. Press a softkey to select its field and open it at the same time, or move the highlight with the arrow keys and open the field with **ENTER** or by pressing the knob.

6.3 Entering a value with the keypad

Typing is the quickest way to set a value. As an example, to set the test frequency to 10 kHz:

1. On the MEAS DISPLAY page, press FREQ. The field is selected.
2. Type **1 0** on the keypad. The softkeys change to show the units: Hz, kHz and MHz.
3. Press the kHz softkey. The frequency is set to 10 kHz and the measurement continues at the new frequency.

ENTER instead of a unit key uses the basic unit (Hz for frequency, V for level). **BACKSPACE** corrects a typing error and **RETURN** abandons the entry. If you enter a value outside the permitted range, the instrument sets the nearest permitted value and says so in a message.

6.4 Changing a value with the knob

Open a numeric field with **ENTER** or by pressing the knob. One digit of the value is underlined: turning the knob, or pressing the up and down arrows, changes that digit. The left and right arrows move the underline to another digit. Press **ENTER** or the knob to accept the new value, or **RETURN** to

restore the old one. Choice fields work the same way: turn the knob to step through the choices and press to accept.

6.5 Default settings

PRESET restores the settings in Table 7. They are also the settings of a new instrument.

Table 7. Factory default settings.

Setting	Default	Setting	Default
Function	Cp-D	Trigger source	INT (continuous)
Frequency	1 kHz	Trigger delay	0 s
Test level	1 V rms	Averaging	1
Level control (ALC)	Off	Comparator	Off
Range	Auto	Sweep	Frequency, 100 Hz to 1 MHz, 101 points, logarithmic
Speed	MED	Beeper	On

6.6 Messages

Short messages appear at the bottom of the screen for a few seconds, for example to confirm that a setting has been stored or to report that a value was limited to its permitted range. **RETURN** clears a message at once.

7 Making measurements

7.1 A first measurement

The following example measures a 100 nF film capacitor at 1 kHz. It shows the sequence you will follow for most measurements.

1. Switch on and let the instrument warm up (section 5.4). Press **PRESET** twice to start from the default settings.
2. Connect a four-terminal-pair Kelvin-clip cable or a test fixture to the UNKNOWN terminals. Match the BNC markings: Lcur to Lcur, Lpot to Lpot, Hpot to Hpot, Hcur to Hcur.
3. If you have not done so for this cable, carry out an OPEN and a SHORT correction (chapter 8). It takes about a minute and removes the effect of the cable.
4. Press FUNC and choose **Cs-D** with the knob, then press the knob. The instrument will now report series capacitance and dissipation factor.
5. Clip the capacitor into the fixture or connect the Kelvin clips to its leads, as close to the body as practical.
6. Read the result. The primary line shows about 100 nF, the secondary line the dissipation factor, typically below 0.001 for a film capacitor.



Figure 8. MEAS DISPLAY page during the measurement of a 100 nF capacitor at 1 kHz and 1 V.

7.2 Choosing the measurement function

A real component is never a pure capacitance, inductance or resistance. The instrument therefore describes it with an *equivalent circuit*: either a series combination of an ideal element and a resistance, or a parallel combination. Both describe the same measured impedance; they differ in which small effect is expressed as a resistance. The function you choose (Table 8) selects the circuit and the pair of values displayed.

Table 8. Measurement functions.

Function	Primary / secondary	Use for
Cp-D, Cp-Q, Cp-G, Cp-Rp	Parallel capacitance with dissipation factor, quality factor, conductance or parallel resistance	Small capacitors (below about 10 nF at 1 kHz), where leakage is the main loss

Function	Primary / secondary	Use for
Cs-D, Cs-Q, Cs-Rs	Series capacitance with D, Q or equivalent series resistance (ESR)	Large capacitors (above about 10 µF at 1 kHz) and electrolytic capacitors, where the series resistance matters
Lp-D, Lp-Q, Lp-G, Lp-Rp	Parallel inductance with D, Q, G or Rp	Large inductances and cored inductors at higher frequencies
Ls-D, Ls-Q, Ls-Rs	Series inductance with D, Q or series resistance	Small inductances and air-cored coils; the usual choice for chokes
R-X	Resistance and reactance	Resistors, and any part where you want the impedance in rectangular form
Z-θ (deg or rad)	Magnitude of impedance and phase angle	General characterisation, sensors, cables
G-B	Conductance and susceptance	Parallel models, dielectric and insulation measurements
Y-θ (deg or rad)	Magnitude of admittance and phase angle	Very high impedances, where admittance is more convenient

When in doubt, use this rule: if the impedance of the part at the test frequency is below about 100 Ω, choose a series function; if it is above about 10 kΩ, choose a parallel function. Between the two, either is fine and the choice follows the convention of the part's data sheet.

7.3 Test frequency

Set the frequency with FREQ. Components are usually specified at a standard frequency: 1 kHz for most capacitors above 10 nF, 100 Hz or 120 Hz for electrolytic capacitors, 100 kHz or 1 MHz for small capacitors and inductors. Measure at the frequency the data sheet names, or at the frequency the part will see in your circuit. The instrument accepts any frequency from 20 Hz to 1 MHz with a resolution of 0.01 Hz.

7.4 Test level and level control

LEVEL sets the open-circuit rms voltage of the test signal, from 5 mV to 2 V. The voltage that actually appears across the part is lower, because the source has an internal resistance of 100 Ω; it is shown as Vac on the monitor line. Many parts, including ceramic capacitors with high permittivity and inductors with ferrite cores, change their value with the applied voltage. For them, switch on automatic level control with ALC. The instrument then adjusts the source until the voltage across the part equals the set level. If it cannot reach the level, for example because the part has a very low impedance, the monitor line shows ALC in the status area.

7.5 Measurement range

The instrument selects one of four range resistors (100 Ω, 1 kΩ, 10 kΩ and 100 kΩ) and a gain for each measurement channel, so that the signals use as much of the converter range as possible. With RANGE set to AUTO this happens automatically. When you measure many similar parts, you can hold the range: choose the range whose value is closest to the impedance of the parts. Holding the range saves the time of range changes and avoids a range change in the middle of a series of measurements.

The 10 kΩ range can be used up to 500 kHz and the 100 kΩ range up to 100 kHz. Above these frequencies the instrument uses a lower range automatically.

7.6 Speed and averaging

SPEED sets how long each measurement collects data. A longer measurement averages away more noise. Table 9 gives the times at frequencies of 1 kHz and above; at lower frequencies each measurement lasts at least eight periods of the test signal. For still quieter readings, set AVG on the MEAS SETUP page to average several measurements.

Table 9. Measurement speed.

Setting	Time per measurement	Typical use
SHORT	about 6 ms	Fast sorting of parts with a comfortable tolerance
MED	about 56 ms	General use; the setting at which the basic accuracy is specified
LONG	about 280 ms	Low test levels, very high or very low impedances, highest resolution

7.7 Reading the result

The primary and secondary values are shown with engineering prefixes (p, n, µ, m, k, M). If the measurement is out of range the value is replaced by OVERLOAD, and OVL appears on the monitor line; the usual cause is a part whose impedance is too high or too low for a held range, or a part that is not properly connected. The monitor line also shows Vac and Iac, which are useful for checking that the part really sees the conditions you intended.

7.8 Connecting parts

For the best results, keep the connection between the four cables and the part as short as possible and join the cable shields close to the part. Standard four-terminal-pair fixtures and Kelvin-clip cables do this for you. With Kelvin clips, attach both jaws of each clip to the same lead, one on each side if possible. Keep the H and L cables apart from each other near the part when you measure small capacitances, because the capacitance between the cables adds to the reading unless it is corrected with an OPEN correction.

CAUTION Never connect a part that is powered or that holds a charge. Discharge capacitors through a suitable resistor first.

8 Correcting for cables and fixtures

The factory calibration makes the instrument accurate at its own front-panel connectors. Anything you connect between the connectors and the part, such as a cable, a fixture or a pair of clips, adds a little capacitance, inductance and resistance of its own. Correction measures these effects and removes them from every later reading. Correct again whenever you change the cable, the fixture, or the way it is laid out on the bench.

8.1 OPEN correction

An OPEN correction measures what the fixture adds *in parallel* with the part, mainly stray capacitance. It matters most for small capacitances and high impedances.

1. Press **CAL**.
2. Leave the fixture empty, or hold the Kelvin clips apart in the position they will have during the measurement. Do not touch the clips.
3. Press [MEAS OPEN]. The instrument measures at 64 frequencies across its range; this takes about a minute. A message reports when it has finished.
4. Press [OPEN] so that the label shows ON.

8.2 SHORT correction

A SHORT correction measures what the fixture adds *in series* with the part, mainly lead resistance and inductance. It matters most for large capacitances, small inductances and low resistances.

1. Press **CAL**.
2. Insert the shorting bar of the fixture, or clip the Kelvin clips firmly onto a short piece of thick copper wire (or onto each other).
3. Press [MEAS SHORT] and wait for the message.
4. Press [SHORT] so that the label shows ON.

8.3 LOAD correction

A LOAD correction uses a reference part whose value you know accurately, measured at the frequencies you use. It corrects the remaining errors of complex fixtures and gives the highest accuracy. The value of the reference part is entered from a computer (command `:CORRection:LOAD:REFerence`, chapter 13). Then connect the reference part, press [MEAS LOAD] and switch [LOAD] ON.

8.4 Cable length

If you use the standard four-terminal-pair cables, set the cable length on the MEAS SETUP page ([CABLE]: 0 m, 1 m or 2 m) before you correct. Use 0 m for a fixture that is plugged directly into the front panel. Cables up to 4 m can be used; the instrument stays stable, but always make an OPEN and SHORT correction with the actual cable.

NOTE Correction data and on/off states are part of the saved power-on state. After correcting, press Save/Recall and then SAVE if you want the correction to be active the next time the instrument is switched on.

9 Sweeps and graphs

A sweep measures the part at a series of frequencies or test levels and shows how it behaves over the whole range, for example how the equivalent series resistance of a capacitor changes with frequency, or where an inductor resonates.

9.1 Setting up a sweep

1. Press **SWEEP**.
2. With [TYPE] choose FREQ (frequency sweep) or VOLT (test-level sweep).
3. Set [START] and [STOP], for example 100 Hz and 1 MHz.
4. Set the number of [POINTS], from 2 to 1601. 101 points are enough for most purposes; use more for sharp resonances.
5. With [SPACING] choose LOG for frequency sweeps over several decades, LIN for narrow ranges.
6. Press [RUN]. The measured points appear in a list as they are taken; the knob scrolls the list.

The sweep uses the measurement function, test level, speed and correction set on the other pages.

9.2 Graph page



Figure 9. GRAPH page showing a frequency sweep.

Press **GRAPH** to plot the sweep (Figure 9). The plot also updates while a sweep is running. The softkeys work as follows:

Table 10. GRAPH page softkeys.

Softkey	Function
FORMAT	Steps through the plot formats: |Z| and θ, R and X, Cs and D, Ls and Q, and the Nyquist plot (−X against R).
AUTOSCALE	ON rescales the plot continuously. OFF holds the scales, so that a second sweep can be compared with the first.
AXES	Selects logarithmic or linear axes.
MARKER	Switches the marker on and off. The knob and the left and right arrows move it one point; the up and down arrows move it one tenth of the sweep.

Softkey	Function
SWEEP	Starts or stops a sweep without leaving the graph.
MKR SEARCH	Moves the marker to the maximum of the displayed curve; press again for the minimum.

The marker readout gives the frequency (or level) at the marker and both values plotted at that point.

9.3 Example: self-resonance of an inductor

1. Choose the function Z-θ, set a frequency sweep from 1 kHz to 1 MHz with 401 logarithmic points, and run it.
2. Press **GRAPH**. If necessary, press [FORMAT] until |Z| and θ are shown.
3. Press [MKR SEARCH]. The marker jumps to the maximum of |Z|, the self-resonant frequency, where the phase passes through zero.

10 Measurement setup, triggering and the comparator

10.1 The MEAS SETUP page

Table 11. MEAS SETUP settings.

Softkey	Setting	Range
TRIG	Trigger source (section 10.2)	INT, EXT, BUS, HOLD
AVG	Number of measurements averaged into one result	1 to 256
DELAY	Waiting time between the trigger and the start of the measurement	0 to 60 s
COMP	Comparator on or off (section 10.3)	ON, OFF
NOMINAL	Nominal value for the comparator's tolerance limits	any value
CABLE	Length of the four-terminal-pair cable	0 m, 1 m, 2 m

10.2 Trigger sources

- **INT** (internal): the instrument measures continuously, one measurement after the other.
- **HOLD**: one measurement each time you press **TRIGGER**. The last result stays on the screen.
- **EXT** (external): one measurement on each rising edge at TRIG IN, for example from a foot switch or a component handler.
- **BUS**: one measurement on each trigger command from a computer (`*TRG`).

Whatever the source, TRIG OUT delivers a pulse when each measurement is complete. A handler can use this pulse to move the next part into the fixture. Set DELAY if the part needs time to settle after it has been connected, for example because a contact must stop bouncing.

10.3 Comparator and bin sorting

The comparator compares each result with limits and sorts the part into one of ten bins, or OUT if it fits none. It is used for sorting parts by tolerance. The limits can be set as absolute deviations from the nominal value (ATOL), as percentage deviations (PTOL), or as a sequence of absolute values (SEQ). The secondary parameter can be checked against its own limits at the same time. On the front panel you can switch the comparator on and off and set the nominal value; the limits themselves are set from a computer with the `:COMParator` commands. The beeper can sound on a pass or on a failure.

11 Saving and recalling settings

Two complete sets of settings, A and B, can be stored in the instrument. A stored set includes all measurement settings and the on/off state of the corrections, but not the network settings.

- To store the present settings, press **SAVE/RECALL** and then STORE A or STORE B.
- To recall them, press **RECALL A** or **RECALL B** at any time, or use RECALL A and RECALL B on the SAVE / RECALL page. If the store is empty, a message says so.
- SAVE stores the present settings as the power-on state, which the instrument uses every time it is switched on.
- CLEAR empties both stores.

A convenient way to work is to keep two test set-ups, for example 1 kHz Cs-D for capacitors in A and 100 kHz Ls-Q for inductors in B, and switch between them with one key.

12 System settings

SYSTEM opens a page that shows the firmware and measurement-hardware versions, the state of the factory calibration and the serial number, the network address and the temperature inside the instrument. The softkeys are:

Table 12. SYSTEM page softkeys.

Softkey	Function
DHCP	ON: the instrument obtains its network address automatically from the network. OFF: it uses the fixed address set from a computer.
BEEPER	Switches the key and comparator beeper on and off.
SELF TEST	Runs the self-test (section 5.5).
SAVE	Saves the present settings as the power-on state.

13 Remote control

Every function of the instrument can be controlled from a computer with SCPI commands, the standard command language of test instruments. The command set follows that of widely used laboratory LCR meters, so existing test programs need little change.

13.1 Connections

USB. Connect the rear USB-C port to the computer. The instrument appears as a USB-TMC test instrument and is found by VISA software (for example NI-VISA or PyVISA) without an additional driver on current operating systems.

Network. Connect the LAN port to your network. With DHCP on, the instrument obtains an address automatically; the address is shown on the SYSTEM page. Commands are sent over a raw TCP connection to port 5025.

While a computer is in control, RMT is lit and the keys are locked. Press **LOCAL/LOCK** to return to the front panel.

13.2 Frequently used commands

Table 13. Frequently used SCPI commands.

Command	Effect
`*IDN?`	Returns manufacturer, model, serial number and firmware version.
`*RST`	Restores the default settings (as PRESET).
`:FUNCtion:IMPedance CSD`	Selects Cs-D (other values: CPD, CPQ, CPG, CPRP, CSQ, CSRS, LPD, LPQ, LPG, LPRP, LSD, LSQ, LSRS, RX, ZTD, ZTR, GB, YTD, YTR).
`:FREQuency 10E3`	Sets the test frequency to 10 kHz.
`:VOLTage 0.5`	Sets the test level to 0.5 V rms.
`:AMPLitude:ALC ON`	Switches on automatic level control.
`:FUNCtion:IMPedance:RANGe:AUTO ON`	Automatic range selection.
`:APERture LONG,4`	LONG measurement time, averaging of 4.
`:TRIGger:SOURce BUS`	Trigger from the computer.
`*TRG`	Takes one measurement (with trigger source BUS).
`:FETCh?`	Returns the last result: primary value, secondary value, status (0 = valid).
`:CORRection:OPEN`, `:CORRection:SHORt`	Runs an OPEN or SHORT correction.
`:SWEep:INITiate`, `:SWEep:DATA?`	Runs the sweep and returns its data.
`:SYSTem:ERRor?`	Reads the error queue.

13.3 Example program

The following Python program measures a capacitor at three frequencies over the network. It requires the PyVISA package.

```
import pyvisa
rm = pyvisa.ResourceManager()
za = rm.open_resource("TCPIP::192.168.1.50::5025::SOCKET", read_termination="\n",
write_termination="\n")
print(za.query("*IDN?"))
za.write(":FUNC:IMP CPD")
za.write(":VOLT 1.0")
za.write(":TRIG:SOUR BUS")
for f in (100, 1e3, 10e3):
    za.write(f":FREQ {f}")
    za.write("*TRG")
    c, d, status = za.query(":FETC?").split(",")
    print(f"{f:8.0f} Hz   Cp = {float(c):.6e} F   D = {float(d):.5f}")
```

A PC application for the instrument is also available. It shows live readings, runs sweeps with Bode and Nyquist plots, fits equivalent-circuit models to sweep data and exports results as CSV files.

14 Maintenance

14.1 Cleaning

Switch off and pull the power cord. Clean the case and the front panel with a soft cloth, dry or slightly damp with water. Do not use solvents, and do not let liquid enter the ventilation slots or the connectors. Clean the display window with a lens cloth. The gold-plated contacts of the BNC connectors can be cleaned with a cotton bud and isopropyl alcohol.

14.2 Replacing the mains fuses



Figure 10. Power inlet with power switch (top) and fuse drawer (bottom).

1. Switch the rear power switch to O and pull the power cord out of the inlet. The fuse drawer cannot be opened while the cord is inserted.
2. Insert a small flat screwdriver into the slot of the fuse drawer below the inlet and pull the drawer out.
3. Remove both fuses and check them. Replace any blown fuse with a fuse of type T2 A L 250 V, 5 × 20 mm. Two spare fuses are supplied with the instrument.
4. Push the drawer back until it clicks, reconnect the cord and switch on.

WARNING If a new fuse blows immediately, do not fit another. The instrument has a fault and must be repaired by qualified personnel.

14.3 Calibration

The recommended calibration interval is one year. Calibration requires traceable four-terminal-pair impedance standards and is carried out by a calibration laboratory; the calibration data are stored in the instrument and protected by a password. The SYSTEM page shows whether valid calibration data are present and the serial number they belong to.

15 Troubleshooting

Most problems have a simple cause. Work through Table 14 before you contact service.

Table 14. Problems and remedies.

Symptom	Possible cause	Remedy
Nothing lights up, not even the ring around the power key.	No mains; rear switch off; blown fuses.	Check the outlet and the cord; switch the rear switch to I; check the fuses (14.2).
The ring lights but the instrument does not start.	Power key not pressed long enough.	Press the power key once, firmly.
NO AFE in the title bar.	The measurement board does not respond.	Switch off and on again. If the message remains, the instrument needs service.
UNCAL in the title bar.	Calibration data missing or invalid.	Measurements are possible but not to specification. Have the instrument calibrated.
OVERLOAD instead of a reading.	Part not connected, broken lead, or range held too low or too high.	Check the connections; set RANGE to AUTO.
Readings unstable or noisy.	Interference, poor contacts, cables moving, very low test level.	Keep cables still and short; clean contacts; increase the level; use SPEED LONG or averaging; connect GND to the fixture guard.
Small capacitances read too high.	Stray capacitance of the fixture not corrected.	Make an OPEN correction with the fixture as it is used (8.1).
Low resistances or large capacitances read wrong.	Lead resistance and inductance not corrected; Kelvin clips poorly attached.	Make a SHORT correction (8.2); attach clips firmly.
Readings drift after switching on.	Instrument not warmed up.	Allow 30 minutes of warm-up.
The keys have no effect and RMT is lit.	The instrument is under remote control.	Press Local/Lock.
ALC shown on the monitor line.	The set level cannot be reached across the part.	Reduce the level or switch ALC off.
Self-test reports a failure.	Hardware fault.	Note the code and contact service.

16 Specifications

Specifications apply after 30 minutes of warm-up at 23 °C ± 5 °C, within one year of calibration, with OPEN and SHORT correction made.

Table 15. Measurement.

Characteristic	Specification
Test frequency	20 Hz to 1 MHz, resolution 0.01 Hz; frequency accuracy ±0.005 %
Test level	5 mV to 2.0 V rms open-circuit, resolution 1 mV; accuracy ±(5 % + 1 mV), ±1 % with ALC
Source resistance	100 Ω ± 1 %
Basic accuracy	±0.1 % of |Z|, ±0.06° (1 kHz, 1 V, 10 Ω to 100 kΩ, MED)
Repeatability	0.01 % (1σ) under the same conditions
Displayed range	|Z| from 10 mΩ to 100 MΩ; best accuracy from 1 Ω to 1 MΩ
Measurement time	SHORT about 6 ms, MED about 56 ms, LONG about 280 ms (at 1 kHz and above)
Parameters	Cp, Cs, Lp, Ls, R, X, |Z|, θ, G, B, |Y|, D, Q, Rs, Rp
Ranges	100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, each with gain 1, 10, 100; automatic or held
Correction	OPEN, SHORT, LOAD at 64 frequencies; cable length 0, 1, 2 m
Sweep	Frequency or level, 2 to 1601 points, linear or logarithmic

Table 16. General.

Characteristic	Specification
Display	7-inch colour IPS, 1024 × 600 pixels
Interfaces	USB-C (USB-TMC), Ethernet 10/100 (SCPI, port 5025), microSD, TRIG IN, TRIG OUT
UNKNOWN terminals	4 BNC, four-terminal-pair, 22 mm spacing; maximum 42 V peak to ground; charged capacitor up to 100 µF at 42 V
Mains supply	100 V to 240 V, 50/60 Hz; about 10 W typical, 16 W maximum; fuses 2 × T2 A L 250 V
Operating conditions	0 °C to 40 °C, up to 80 % RH without condensation
Dimensions	400 mm × 135 mm × 250 mm (width × height × depth, without handle and feet)
Weight	about 2.5 kg

Appendix A Glossary

Table 17. Terms used in this manual.

Term	Meaning
Admittance (Y)	The reciprocal of impedance. Its real part is the conductance G, its imaginary part the susceptance B.
ALC	Automatic level control: the instrument adjusts its source so that the set voltage appears across the part.
Dissipation factor (D)	The ratio of the loss to the stored energy of a capacitor or inductor; the reciprocal of Q. A small D means a low-loss part.
ESR	Equivalent series resistance, the Rs of the series model of a capacitor.
Four-terminal pair (4TP)	A connection with four shielded cables in which current and voltage are carried separately and the shields return the current; it removes the effect of the cables.
Impedance (Z)	The opposition of a part to an alternating current, with a magnitude |Z| and a phase angle θ, or a resistance R and a reactance X.
Kelvin clips	Test clips with two insulated jaws, one for current and one for voltage sensing.
Quality factor (Q)	The ratio of stored energy to loss; the reciprocal of D. A high Q means a low-loss part.
Self-resonance	The frequency at which the inductance of a part and its stray capacitance resonate; above it an inductor behaves like a capacitor.

Appendix B Parameter relations

The instrument measures the complex impedance Z = R + jX at the angular frequency ω = 2πf. The displayed parameters follow from it:

$\lvert Z\rvert = \sqrt{R^2 + X^2}$	$\theta = \arctan(X / R)$		
Series capacitance:	$Cs = -1 / (\omega X)$	$Rs = R$	$D = R / \lvert X\rvert$
Series inductance:	$Ls = X / \omega$	$Rs = R$	$Q = X / R$
Admittance:	$Y = 1 / Z = G + jB$		
Parallel capacitance:	$Cp = B / \omega$	$Rp = 1 / G$	$D = G / B$
Parallel inductance:	$Lp = -1 / (\omega B)$	$Rp = 1 / G$	$Q = -B / G$
Series and parallel:	$Cp = Cs / (1 + D^2)$	$Ls = Lp / (1 + 1/Q^2)$	

The last line shows why the series and parallel values differ only noticeably for parts with high losses: for a capacitor with D = 0.01 the difference between Cs and Cp is 0.01 %.