

LCR - Meter HM8018

Handbuch / Manual

Deutsch / English





HAMEG
Instruments

DECLARATION OF CONFORMITY

Manufacturer HAMEG Instruments GmbH
Industriestraße 6
D-63533 Mainhausen

The HAMEG Instruments GmbH herewith declares conformity of the product

Product name LCR-Meter

Type: HM8018
with: HM8001-2
Options: -

with applicable regulations
EMC Directive 89/336/EEC amended by
91/263/EWG, 92/31/EEC

Low-Voltage Equipment Directive 73/23/EEC
amended by 93/68/EEC

Harmonized standards applied

Safety
EN 61010-1:2001 / (IEC 61010-1:2001)
Overvoltage category: II
Degree of pollution: 2

Electromagnetic compatibility
EN 61326-1/A1
Radiation: table 4; Class B
Immunity: table A1

EN 61000-3-2/A14
Harmonic current emissions: Class D

EN 61000-3-3
Voltage fluctuations and flicker

Date: 20.02.2006

Signature

Manuel Roth
Manager

General information regarding the CE marking

HAMEG instruments fulfill the regulations of the EMC directive. The conformity test made by HAMEG is based on the actual generic and product standards. In cases where different limit values are applicable, HAMEG applies the strictest standard. For emission the limits for residential, commercial and light industry are applied. Regarding the immunity (susceptibility) the limits for industrial environment have been used.

The measuring and data lines of the instrument have much influence on emission and immunity and therefore on meeting the acceptance limits. For different applications the lines and/or cables used may be different. For measurement operation the following hints and conditions regarding emission and immunity should be observed:

1. Data cables

For the connection between instruments resp. their interfaces and external devices, (computer, printer etc.) sufficiently screened cables must be used.

Maximum cable length of data lines must not exceed 3 m. The manual may specify shorter lengths. If several interface connectors are provided only one of them may be used at any time.

Basically interconnections must have a double screening. For IEEE-bus purposes the double screened cable HZ72 from HAMEG is suitable.

2. Signal cables

Basically test leads for signal interconnection between test point and instrument should be as short as possible. Without instruction in the manual for a shorter length, signal lines must be less than 3 meters long.

Signal lines must be screened (coaxial cable - RG58/U). A proper ground connection is required. In combination with signal generators double screened cables (RG223/U, RG214/U) must be used.

3. Influence on measuring instruments.

In the presence of strong high frequency electric or magnetic fields, even with careful setup of the measuring equipment an influence can not be excluded.

This will not cause damage or put the instrument out of operation. Small deviations of the measuring value (reading) exceeding the instrument's specifications may result from such conditions in some cases.

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Deutsch	2
English	
General information regarding CE-marking	14
LCR Meter HM8018	16
Specifications	17
Important hints	18
Safety	18
Operating conditions	18
Warranty and Repair	18
Maintenance	19
Operation of the module	19
Control elements	20
Operation of the HM8018	21
Frequency	21
Test voltage	21
Measuring range	22
Auto-ranging	22
Manual range	22
Polarisation (Bias)	23
Measuring function selection	23
Auto-measurement function	23
Calculation functions	23
Component to test connexion	24
Open/short compensation	24
To perform an open or short calibration:	24
Default settings	24
Factory default parameters	24
Mains frequency setting	24

LCR - Meter HM8018



Measurement functions: L, C, R, θ , Q, D, |Z|

Basic accuracy 0.2%

5 measurement frequencies: 100 Hz, 120 Hz, 1 kHz, 10 kHz, 25 kHz

Max. Resolution: 0.001 Ω , 0.001 pF, 0.01 μ H

2- and 4-wire measurement

Measurement of series and parallel components

Bias voltage for electrolyt capacitors

Mainframe HM8001-2 required for operation

Mainframe HM8001-2



Option HZ18 Kelvin test lead



Option HZ19 SMD Test Tweezers



LCR-METER HM8018

Valid at 23 degrees C after a 30 minute warm-up period

Display

Messbare Kenngrößen:	R, L, C, Θ , Q/D, Z
Schaltungsart:	seriell, parallel
Messart:	2-Draht, 4-Draht
Measuring ranges:	R: 0.001 Ω - 99,9 M Ω C: 0.001 pF - 99,9 mF L: 0.01 μ H - 9999 H Q: 0.0001 - 99,9 D: 0,0001 - 9,9999 Θ : -180.00° - +180.00°
Basic accuracy:	0,2 %
Measuring frequencies:	100 Hz, 120 Hz, 1 kHz, 10 kHz, 25 kHz
Freq. accuracy:	± 100 ppm except 120 Hz (120.2 Hz ± 100 ppm)
Measuring voltage:	0.5 V_{rms} $\pm 10\%$ (unloaded)
Measuring rate:	2 measurements/second
Range changing:	automatic, manual
DC Bias voltage:	1V $\pm 10\%$
Zero setting:	Open/short circuit compensation
Compensation limits:	Short: R < 10 Ω Z < 15 Ω Open: Z > 10 k Ω

Measurement accuracy

with D < 0.1 or Q > 10:	C: $A_e = A_f(1 + C_x/C_{max} + C_{min}/C_x)$ L: $A_e = A_f(1 + L_x/L_{max} + L_{min}/L_x)$ Z: $A_e = A_f(1 + Z_x/Z_{max} + Z_{min}/Z_x)$ R: $A_e = A_f(1 + R_x/R_{max} + R_{min}/R_x)$
with D ≥ 0.1:	$A_e = \sqrt{1 + D_x^2}$
with he parameters:	C_x = measurement value $A_f = 0.2\%$ at f = 100 Hz, 120 Hz, 1 kHz $A_f = 0.3\%$ at f = 10 kHz $A_f = 0.5\%$ at f = 25 kHz
Parameter	Auto Range
C_{max}	160 μ F/f
C_{min}	53 pF/f
L_{max}	480 H/f
Z_{max}, R_{max}	3 M Ω
Z_{min}, R_{min}	1 m Ω

Dissipation factor accuracy:	$D_e = \pm \frac{A_e}{100}$
Quality factor accuracy:	$Q_e = \pm \frac{Q_x^2 \cdot D_e}{1 \pm Q_x \cdot D_e}$
Phase angle accuracy:	$\Theta_e = \frac{180}{\pi} \cdot \frac{A_e}{100}$

Display

5-digits 7 segment LEDs with sign

Display parameters:

Value	} Calculation from measurement value and reference value stored
% value	
Deviation	
% Offset	

Miscellaneous

The inputs are short-circuit-proof and overvoltage protected up to 100 V_{DC} with a maximum energy consumption of 1J. One configuration can be saved.

Ambient temperature: +10°C ... 40°C

Max. Relative humidity: 80%

Supply voltages (from HM8001-2):

+5 V/300 mA
+5.2 V/50 mA
-5.2 V/50 mA
(Σ) = 2W

Dimensions (without connector):

(W x H x D) 135 x 68 x 228 mm

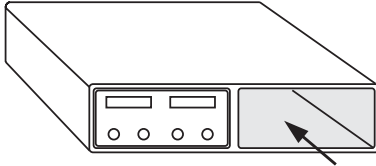
Weight: approx. 500 g

Included in delivery: LCR Meter HM8018, Operating manual

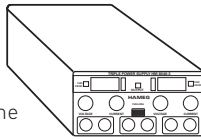
Optional accessories: HZ33/HZ34 BNC Test Cable, HZ20 BNC banana adapter,

Important hints

The operator is requested to carefully read the following instructions and those of the mainframe



me HM8001-2, to avoid any operating errors and mistakes and in order to become acquainted with the module.



After unpacking the module, check for any mechanical damage or loose parts inside. Should there be any transportation damage, inform the supplier immediately and do not put the module into operation. This plug-in module is primarily intended for use in conjunction with the Mainframe HM8001-2. When incorporating it into other systems, the module should only be operated with the specified supply voltages.

Safety

This instrument has been designed and tested in accordance with IEC Publication 1010-1, Safety requirements for electrical equipment for measurement, control, and laboratory use. It corresponds as well to the the CENELEC regulations EN 61010-1. All case and chassis parts are connected to the safety earth conductor. Corresponding to Safety Class 1 regulations (three-conductor AC power cable). Without an isolating transformer, the instrument's power cable must be plugged into an approved three-contact electrical outlet, which meets International Electrotechnical Commission (IEC) safety standards.

Warning!

Any interruption of the protective conductor inside or outside the instrument or disconnection of the protective earth terminal is likely to render the instrument dangerous. Intentional interruption is prohibited.

The instrument must be disconnected and secured against unintentional operation if there is any suggestion that safe operation is not possible.

This may occur:

- if the instrument shows visible damage,
- if the instrument has loose parts.
- if the instrument does not function,
- after long storage under unfavourable circumstances (e.g. outdoors or in moist environments),
- after excessive transportation stress (e.g. in poor packaging).

When removing or replacing the metal case, the instrument must be completely disconnected from the mains supply. If any measurement or calibration procedures are necessary on the opened-up instrument, these must only be carried out by qualified personnel acquainted with the danger involved.

Symbols marked on equipment



ATTENTION refer to manual.



DANGER High voltage.



Protective ground (earth) terminal.

Operating conditions

The ambient temperature range during operation should be between +10 °C and +40 °C and should not exceed -40 °C or +70 °C during transport or storage. The operational position is optional, however, the ventilation holes on the HM8001-2 and on the plug-in modules must not be obstructed.

Warranty and Repair

HAMEG instruments are subjected to a strict quality control. Prior to leaving the factory, each instrument is burnt-in for 10 hours. By intermittent operation during this period almost all defects are detected. Following the burn-in, each instrument is tested for function and quality, the specifications are checked in all operating modes; the test gear is calibrated to national standards.

The warranty standards applicable are those of the country in which the instrument was sold. Reclamations should be directed to the dealer.

Only valid in EU countries

In order to speed reclamations customers in EU countries may also contact HAMEG directly. Also, after the warranty expired, the HAMEG service will be at your disposal for any repairs.

Return material authorization (RMA):

Prior to returning an instrument to HAMEG ask for a RMA number either by internet (<http://www.hameg.com>) or fax. If you do not have an original shipping carton, you may obtain one by calling the HAMEG sales dept (+49-6182-800-300) or by sending an email to vertrieb@hameg.com.

Maintenance

The most important characteristics of the instruments should be periodically checked according to the instructions provided in the sections "Operational check and "Alignment procedure. To obtain the normal operating temperature, the mainframe with inserted module should be turned on at least 60 minutes before starting the test. The specified alignment procedure should be strictly observed. When removing the case detach mains/line cord and any other connected cables from case of the mainframe HM8001-2. Remove both screws on rear panel and, holding case firmly in place, pull chassis forward out of case. When later replacing the case, care should be taken to ensure that it properly fits under the edges of the front and rear frames. After removal of the two screws at the rear of the module, both chassis covers can be lifted. When reclosing the module, care should be taken that the guides engage correctly with the front chassis.

Operation of the module

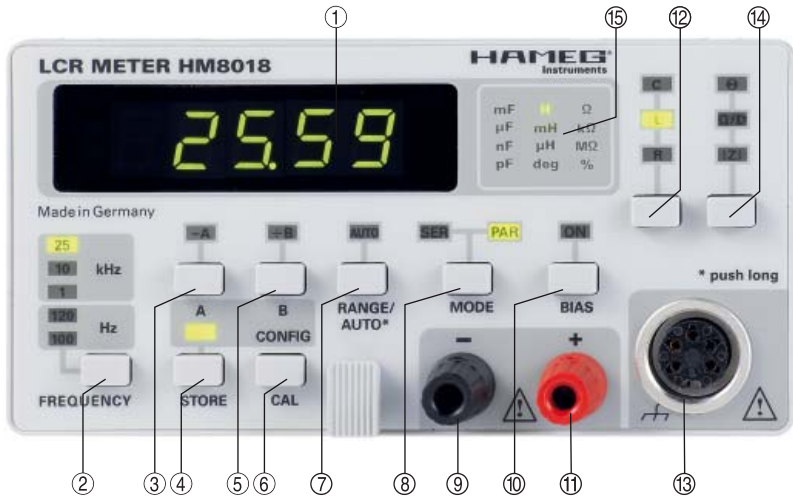
Provided that all hints given in the operating instructions of the HM8001-2 Mainframe were followed especially for the selection of the correct mains voltage start of operation consists practically of inserting the module into the right or left opening of the mainframe. The following pre-cautions should be observed:

Before exchanging the module, the mainframe must be switched off. A small circle (o) is now revealed on the red power button in the front centre of the mainframe.

If the BNC sockets at the rear panel of the HM8001-2 unit were in use before, the BNC cables should be disconnected from the basic unit for safety reasons. Slide in the new module until the end position is reached.

Before being locked in place, the cabinet of the instrument is not connected to the protective earth terminal (banana plug above the mainframe multipoint connector). In this case, no test signal must be applied to the input terminals of the module.

Generally, the HM8001-2 set must be turned on and in full operating condition, before applying any test signal. If a failure of the measuring equipment is detected, no further measurements should be performed. Before switching off the unit or exchanging a module, the instrument must be disconnected from the test circuit.



Control elements

① Digital display (7-segment LEDs)

The measurement value is displayed with a resolution of 5 digit. The most adapted unit is displayed in the area ⑮. Any overflow indication is displayed by -----.

② FREQUENCY (pushbutton)

Measuring frequency selection: 100 Hz, 120 Hz, 1 kHz, 10 kHz, 25 kHz

③ A (pushbutton) and -A (LED)

Allows to save the current measurement value in memory (volatile memory) of the instrument if the instrument is in storage mode (STORE LED is on). The measurement value can be saved in non-volatile memory (see the description of the CAL button). In relative mode (-A LED is on), the instrument displays the relative value $Measurement-A$, or, if the -A and ÷B LED are on, $100 * (Measurement-A)/B$. The relative mode is left by pushing the button A again.

④ STORE (pushbutton)

By depressing this key the LED indicator located above it lights up and the instrument is in storage mode. Then you can press the following keys A, B or CONFIG in order to save the measurement value in memory A, B or

the settings in the configuration memory. The display will shortly show STO. A, STO. B or STO. C. If you press any other key the storage mode will be left. The LED Indicator turns off in both cases.

⑤ B (pushbutton) and ÷B (LED)

In storage mode (STORE LED lights) the current measurement value will be stored in memory B (volatile memory) if the button B is pushed. The measurement value can be saved in non-volatile memory (see the description of the CAL button). In relative mode (LED ÷B is on) the instrument displays the percentage $100 * Measurement/B$ or $100 * (Measurement-A)/B$ if the LEDs -A and ÷B are active. The relative mode is left by pushing the button B again.

⑥ CAL (pushbutton)

In normal mode, this button allows to perform Open/Short circuit calibration with respectively the keys ③ and ⑦. Allows saving the current settings configuration in non-volatile memory if the instrument is in storage mode (STORE LED lighted up).

⑦ RANGE/AUTO* (pushbutton)

In manual mode (AUTO LED is off) this key allows to select the impedance range of the instrument. A message RNG. X (X = 1...6) is fleetingly displayed at every press of the key to indicate the new range. A long press on this key

switches the instrument to autorange mode. Then the AUTO LED is lighted up. If this key is pressed during the instrument is in the auto-range mode it will cause a hold of the current range which will be fleeting displayed.

- ⑧ **MODE (pushbutton)**
This key allows selection of the series or parallel model for parameters calculation.
- ⑨ ⑪ **-/+ Connection terminals**
(4 mm banana socket)
Terminals to connect the components to test.
- ⑩ **BIAS (pushbutton) and ON (LED)**
Press this key to apply a 1V_{DC} bias voltage to the terminals ⑨⑪. If the BIAS function is activated the ON LED lights up. This function is recommended for polarized capacitors measurements in order to avoid polarity inversion because of the alternating measuring voltage. If the BIAS button is pushed again the BIAS function will be deactivated and the
- ⑫ **FUNCTION (pushbutton)**
This key allows the selection of the main function of the instrument. If series mode is selected this key gives access to the following parameters C_p, L_p and R_s. In parallel mode the instrument displays the value of C_p, L_p or R_p.
- ⑬ **Kelvin input (5 pole diode socket)**
Terminal for connection of the 4 wire Kelvin Test Leads HZ18
- ⑭ **FUNCTION (pushbutton)**
This key allows the selection of the secondary functions of the instrument. It gives access to: phase angle measurement (-180° to +180°), impedance module, quality factor or dissipation factor. In the last two last cases the dissipation factor will be displayed, if the capacitance measurement is activated. The quality factor will be displayed on the other cases.
- ⑮ **UNIT AREA**
Display of the current unit.

Operation of the HM8018

Frequency

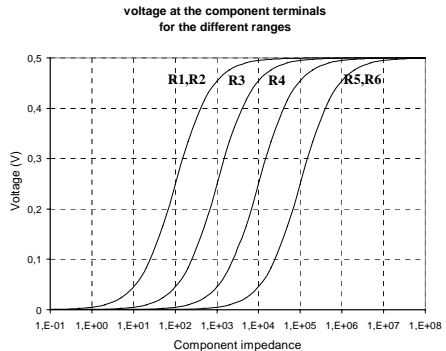
The HM8018 offers five different test frequencies: 100Hz, 120Hz, 1kHz, 10kHz, 25kHz. The frequency accuracy is ±0.01%. The test frequency is selected by pressing several times the FREQUENCY key ② until the corresponding indicator lights up. A change of the frequency can introduce a model change (series to parallel or parallel to series), if the instrument is in automatic mode and if the impedance measurement exceeds the 1000Ω threshold.

For high impedances and with 50Hz mains frequency and 120Hz test frequency, there may occur a small instability in measurement due to a bad mains frequency rejection. It is the same for a 60Hz mains frequency, when a 100Hz test frequency is selected. According to the mains frequency, the test frequency will have to be set as shown in the chart below:

Mains 50 Hz	100 Hz	1 kHz	10 kHz	25 kHz
Mains 60 Hz	120 Hz	1 kHz	10 kHz	25 kHz

Test voltage

The HM8018 generates a 0.5V_{rms} sine test voltage (unloaded). The level accuracy is ±5% for frequencies up to 10 kHz, and ±10% for 25 kHz. The voltage is applied to the component to test by a source



resistance, thus the voltage at the component terminals will be always below 0.5 V. The source resistance is as a function of the impedance range. The graph shows the voltage evolution at the component terminals as function of its impedance and the measuring range (R1 range 15Ω, R6 range 100 MΩ).

Measuring range

The HM8018 offers 6 impedance ranges (R1-R6). The measuring range can be selected either manually or automatically. Each range has a source resistance approximately equal to half of the impedance of the current range. The extreme ranges R1 and R6 use the source resistances of the R2 and R5 ranges.

Note: The measuring ranges determine the impedance ranges (and not capacitance or inductance value ranges), the ranges of capacitance and inductance depend upon the test frequency. The high capacitance values as the low inductance values will be measured on a low impedance range, whereas the low capacitance values as the high inductance values will be measured on the higher ranges.

The chart below gives the measurement range according to the component type and the frequency range.

Range	R source	Re-sistance	Induc-tance (H)	Capaci-tance
R1	100 Ω	1mΩ – 15Ω	0.01 μH – 2.4/f	99.9 mF – 10.6/f mF
R2	100 Ω	15Ω – 330Ω	2.4/f – 52.5/f	10.6/f mF – 482/f μF
R3	1 kΩ	330Ω – 3.3 kΩ	52.5/f – 525/f	482/f μF – 48.2/f μF
R4	10 kΩ	3.3 kΩ – 33 kΩ	525/f – 5252/f	48.2/f μF – 4.82/f μF
R5	100 kΩ	33 kΩ – 330 kΩ	5252/f – 52520/f	4.82/f μF – 0.48/f μF
R6	100 kΩ	330 kΩ – 100 MΩ	52520/f – 9999	0.48/f μF – 0.001 pF

f is the test frequency (Hz)

Auto-ranging

In normal operation the HM8018 selects the most appropriate range for an accurate measurement. When the instrument measures impedance that it is out of its current range, the instrument switches one range up or one range down and makes a new

measurement. If this measurement is within the validity domain of this new range the instrument will display the value. If not, the range change process will be repeated. There is a built in hysteresis in the order of 10% to prevent multiple range changes if a component is on the limit of range boundary. The chart below gives the limits of range changes.

Range Change	Z	Range Change	Z
1 to 2	Z > 15 Ω	2 to 1	Z < 13.5 Ω
2 to 3	Z > 330 Ω	3 to 2	Z < 300 Ω
3 to 4	Z > 3.3 kΩ	4 to 3	Z < 3 kΩ
4 to 5	Z > 33 kΩ	5 to 4	Z < 30 kΩ
5 to 6	Z > 330 kΩ	6 to 5	Z < 300 kΩ

Remarks:

If certain types of inductors are measured it may occur that the HM8018 switches indefinitely between two ranges. Due to the fact that generally the inductor value depends of the current going through, the HM8018 will give different values from one range to an other because the source resistance changes. This variation from one range to another may be higher than the automatic mode hysteresis that creates irresolution. So it is necessary to switch to manual mode to fix the range

Manual range

When an important quantity of similar components has to be tested, the automatic mode process duration time can be avoided. While a component is measured in automatic mode, press the AUTO button. The current range (selected by the instrument) is hold and displayed for a short time. It is possible to save the configuration settings for a further use by pressing the STORE button and then CONFIG key. If the impedance of the component is higher than 50 times the nominal value for the range (given by R source resistance), the message **OFL** is displayed. Then you must change the range. This not applies to the 15Ω range for which overtaking is obtained for an impedance of approx. 18Ω. As far the higher range R6 allows measurements up to 99.9 MΩ.

The manual range mode, thus, is to be reserved to precise cases. To avoid measurement instability and additional uncertainty the instrument should be ever working in automatic range mode.

Polarisation (Bias)

A DC bias voltage can be superposed to the test signal. Electrolytic and tantalum capacitors need a positive bias voltage for accurate measurement, although the test voltage of the HM8018 is not high enough to damage the components. The internal 1 V_{DC} bias voltage or an external bias voltage up to 100V allow to perform measurements as close as possible to reality. The internal bias voltage in addition allows performing measurements on semiconductors junctions. To activate the bias voltage, press the BIAS button ⑩. The ON LED indicator will light up. Pressing this key a second time disables the bias voltage.

However, make certain that the capacitor being tested is connected with the correct polarity, DC voltage positive pole is applied on the red terminal. The bias voltage works only when the instrument on capacitance measurement mode.

Measuring function selection

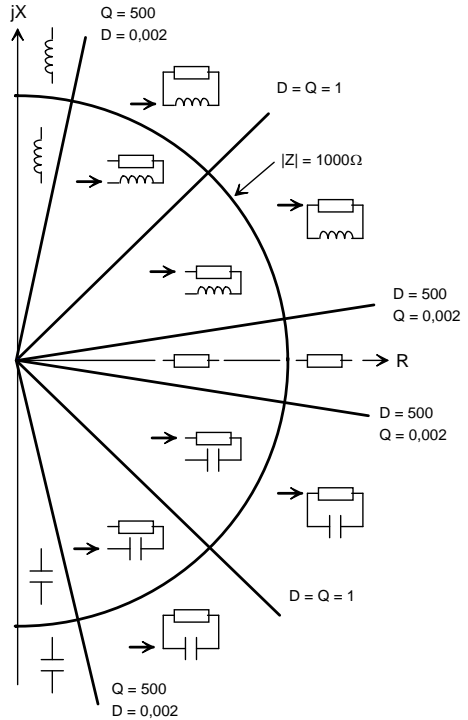
The desired test function is selected by push buttons ⑫ and ⑭. The push button ⑫ gives access to the main parameter (R, L or C). The push button ⑭ allows a secondary parameter measurement (Q/D, impedance or phase).

In order to measure D parameter the instrument needs at first to be set to capacitance measurement mode, on the other way, Q parameter will be displayed.

Auto-measurement function

The HM8018 is able to automatically determine the component type in most cases. 3 different automatism exist: the automatic impedance range selection (see the section Auto-ranging), the automatic mode (series/parallel) selection and the automatic function selection. These three automatism are simultaneously activated when the instrument is set in automatic mode with the AUTO key ⑦. Then the user can change function or mode that disables their respective automatism. The manual range selection disables the three automatism.

When the instrument is on automatic mode the function choice depends on the impedance module, phase angle as well as the quality factor. The following diagram shows the choice made by the instrument.



Calculation functions

Apart from displaying normal values as resistance, inductance or capacitance, the HM8018 can display relative deviations and percentages. It is not possible to use these calculation modes for other functions than the three previous values. The deviations and percentages are displayed in relation to the two stored values A and B.

The procedure to obtain relative measurement is as follows:

- 1) Connect the component corresponding to the reference value.
- 2) Store the value (memory A) by pressing the STORE key and then button A.
- 3) Press button A. The A LED lights up and the display shows the value *Measure - A*.

A direct percentage measurement is possible, it is only to use the ÷B key instead of the -A key in the

previous procedure. Then the instrument displays the value $100 * \text{Measure} / B$ in %.

To obtain a deviation in % proceed as follows:

- 1) Connect the component corresponding to the reference value.
- 2) Store the value (memory A) by pressing on the STORE key, then press the A key.
- 3) Store the same value (memory B) by pressing on the STORE key then press the B key.
- 4) Press the A key then the B key. The -A and +B LED indicators light up. The display shows the value $100 * (\text{Measure} - A) / B$ in %, with a 0.01% resolution.

In any case the percentage result can not exceed the -100.00% / +999.99% limits.

Component to test connexion

The components to test can be connected in two different ways to the HM8018. Two 4 mm banana jacks are available for a quick measurement. The tested object is either plugged in or fixed below the screw type terminals. However this quick method is not always accurate enough. To perform high accuracy measurement it is recommended to use the HZ18 Kelvin Test Leads offered in our accessories range. This probe uses a Kelvin connexion which minimizes the parasitic impedances. After changing the connection configuration it is necessary to perform an open/short calibration. This point also is valid when changing frequency from the extreme ranges.

REMARK: When a measurement is in progress, especially for high impedances, keep your hands or any other object away from the test connector because the measurement accuracy may be affected.

Open/short compensation

The parasitic impedance compensation from the connection system to the device to test is performed by an open and short calibration. This allows cables and other parasitic capacitance impedance compensation. Calibration is performed for the current frequency. It is better to perform the open/short calibration in the same conditions like the component measurement will be made, trying to

do not change the lead positions. In other respects keep any objects away from the test connection, as your hands or metallic parts which could influence measurement.

To perform an open or short calibration:

Press on the CAL key. The display indicates **OP.-Sh.** Press on the -A key to start the open circuit calibration, or on the AUTO key to start the short circuited calibration. The process lasts few seconds, then the **PASS** message is displayed if the process has been successful, in the opposite case the **FAIL** message will be displayed. Short circuit calibration is valid if the impedance is below 15Ω and if the resistance is below 10Ω. Open circuit calibration is valid if the impedance above 10kΩ.

Default settings

To press on the CAL key ⑥ at power on, until the **dEFLT** message appears allows to initiate the instrument with the factory default configuration. This function will not modify the calibration parameters. The current configuration may be saved in a non-volatile memory by pressing on the STORE key then on the CONFIG key.

Factory default parameters:

AUTO	ON
Frequency	1kHz
Bias	OFF
Equivalent circuit	AUTO
Impedance range	AUTO
Display	L/C/R (AUTO)
Memory A	0.0
Memory B	1.0

Mains frequency setting

The HM8018 includes a dual slope A/D converter which needs to be set according to the mains frequency in order to obtain a good frequency rejection.

Press on the FREQUENCY key ② at power on until the message **50.-60** appears.

Then press on the -A key ③ for a 50Hz mains, or on the AUTO key ⑦ for a 60Hz mains. The decimal point is placed on the right position of the active frequency.

Press on the STORE key to save the frequency in a non-volatile memory, or any other key to exit without saving.

Measurement accuracy

(with $D < 0,1$ or $Q > 10$)

$$C: A_e = A_f (1 + C_x/C_{max} + C_{min}/C_x)$$

$$L: A_e = A_f (1 + L_x/L_{max} + L_{min}/L_x)$$

$$Z: A_e = A_f (1 + Z_x/Z_{max} + Z_{min}/Z_x)$$

$$R: A_e = A_f (1 + R_x/R_{max} + R_{min}/R_x)$$

$A_f = 0,2\%$ for $f = 100$ Hz, 120 Hz and 1 kHz

$A_f = 0,3\%$ for $f = 10$ kHz

$A_f = 0,5\%$ for $f = 25$ kHz

Parameter	Range Auto
C_{max}	160 μ F/f
C_{min}	53 pF/f
L_{max}	480 H/f
L_{min}	0.16 mH/f
Z_{max}, R_{max}	3 M Ω
Z_{min}, R_{min}	1 m Ω

With $D_x \geq 0,1$ accuracy becomes

$$A_e = \sqrt{1 + D_x^2}$$

Dissipation factor accuracy :

$$D_e = \pm \frac{A_e}{100}$$

Quality factor accuracy :

$$Q_e = \pm \frac{Q_x^2 \cdot D_e}{1 \pm Q_x \cdot D_e}$$

Phase angle accuracy :

$$\Theta_e = \frac{180}{\pi} \cdot \frac{A_e}{100}$$

Oscilloscopes



Spektrum Analyzer



Power Supplies



Modular System
Series 8000



Programmable Instruments
Series 8100

