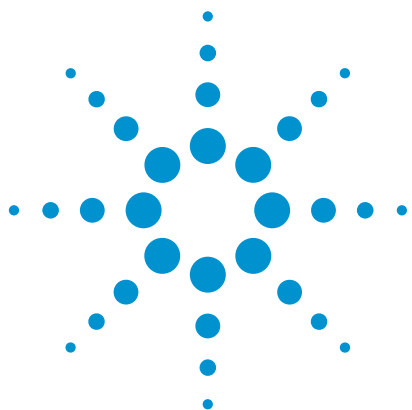




# Agilent U1730 Series Handheld LCR Meters

Take your expectations higher with  
the latest LCR meters

Data Sheet



Agilent's U1730 Series handheld LCR meters allow you to measure at frequencies as high as 100 kHz—a capability typically found only in benchtop meters. Get measurements done faster using the one-touch automatic identification function button which displays component type and more detailed component analysis such as Z, ESR, and DCR. Ideal for testing on the go, these LCR meters operate on a battery that lasts up to 16 hours. With the U1730 Series that is built for your convenience, you can perform quick and basic LCR measurements at an affordable price.



**Agilent Technologies**

# Features

## Key features

- 20,000 counts resolution
- 0.2% basic accuracy
- Wide LCR ranges with three to five selectable test frequencies (up to 100 kHz for U1733C)
- Auto identification (Ai) automatically determines and displays component type and measurements
- Detailed component analysis with DCR, ESR, Z, D, Q, and  $\theta$  functions
- Battery life of 16 hours/ AC-powered
- IR-to-USB connectivity for data logging to PC

## Frequency up to 100 kHz

The test frequency now extends as high as 100 kHz, providing more flexibility to test a wider range of components. A higher test frequency, for example 100 kHz, is useful for applications such as testing aluminum electrolytic capacitors used in switching power supply circuits.

## Automated identification

With Ai the testing and measuring experience is easy; eliminating unnecessary trial and error time—with just a single push of a button. This unique feature automatically specifies L, C, or R with parallel and series mode, without the need to manually change buttons.

## Detailed component analysis

The handheld LCR meters allows you to test various component types, including secondary components of Dissipation Factor (D), Quality Factor (Q), and Angle Indication of Impedance ( $\theta$ ). This new handheld series also includes other functions that result in a more detailed component analysis. For example, the built-in Equivalent Series Resistance (ESR) function helps you better understand the inherent resistance behavior typically found in capacitors across selected frequencies. DCR is a built-in DC resistance measurement that eliminates the use of a separate digital multimeter (DMM) for component test.



Figure 1. Automate the recording of continuous readings when you hook the U1731C/U1732C/U1733C to a PC

## Take a Closer Look

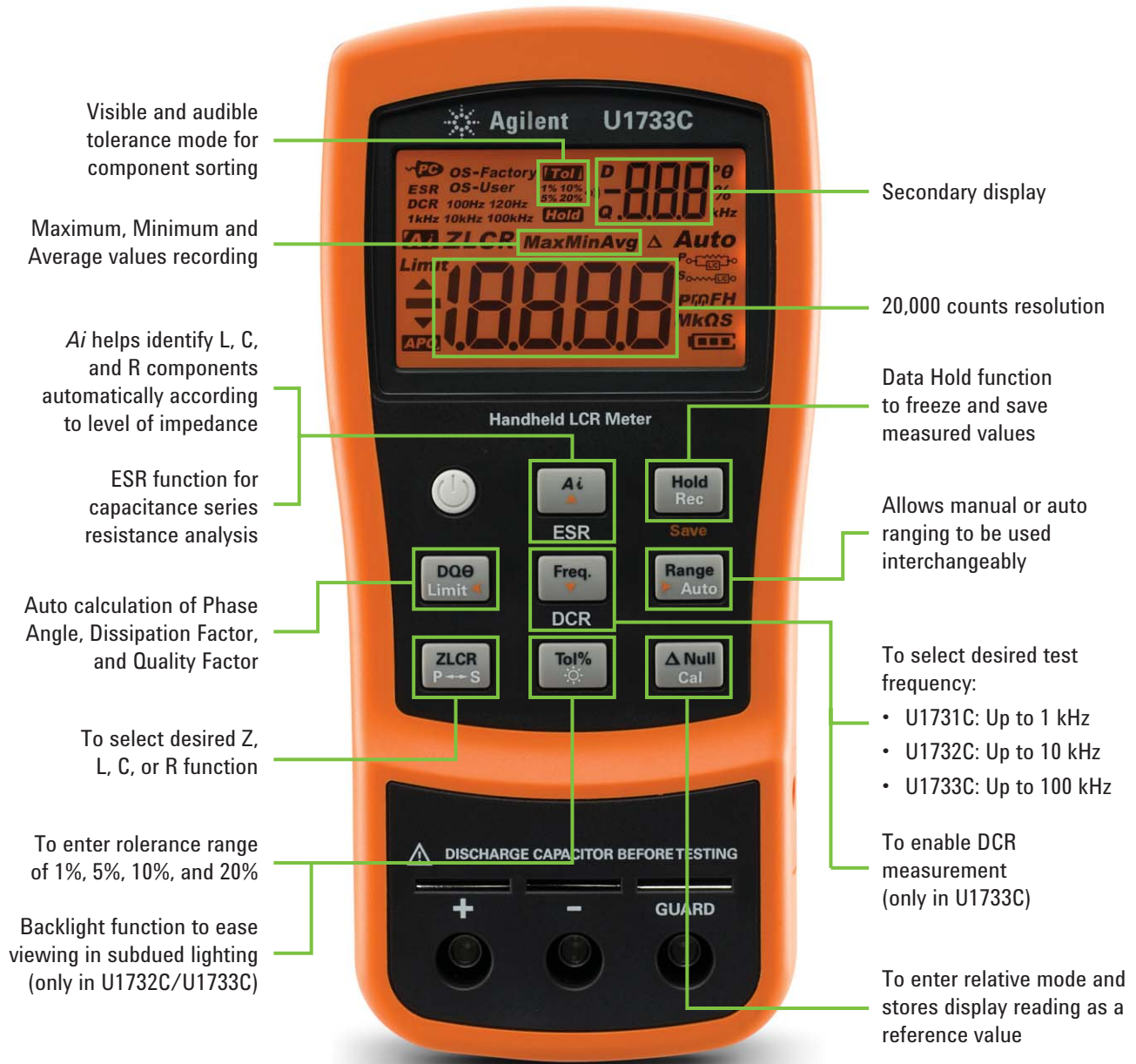


Figure 2. Front view of the U1733C

# U1731C/U1732C/U1733C Electrical Specifications

Accuracy is given as  $\pm$ (% of reading + counts of least significant digit) at  $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ , with relative humidity less than 80%. Please refer to the User Guide about the measuring mode specified for each range of L/C/R, series or parallel mode. Measurements performed at the test socket and necessary Open and Short corrections must prior be done. The accuracy is verified by design and specified type tests.

| Impedance/Resistance |                  |                        |           |           |               |           |           |
|----------------------|------------------|------------------------|-----------|-----------|---------------|-----------|-----------|
| Range                | Resolution       | Accuracy = AZ + Offset |           |           |               |           |           |
|                      |                  | U1731C/U1732C/U1733C   |           |           | U1732C/U1733C | U1733C    |           |
|                      |                  | 100 Hz                 | 120 Hz    | 1 kHz     | 10 kHz        | 100 kHz   | DCR       |
| 2 $\Omega^1$         | 0.0001 $\Omega$  | 0.7% + 50              | 0.7% + 50 | 0.7% + 50 | 0.7% + 50     | 1.0% + 50 | 0.7% + 50 |
| 20 $\Omega^1$        | 0.001 $\Omega$   | 0.7% + 8               | 0.7% + 8  | 0.7% + 8  | 0.7% + 8      | 0.7% + 8  | 0.7% + 8  |
| 200 $\Omega^1$       | 0.01 $\Omega$    | 0.2% + 3               | 0.2% + 3  | 0.2% + 3  | 0.2% + 3      | 0.5% + 5  | 0.2% + 3  |
| 2000 $\Omega$        | 0.1 $\Omega$     | 0.2% + 3               | 0.2% + 3  | 0.2% + 3  | 0.2% + 3      | 0.5% + 5  | 0.2% + 3  |
| 20 k $\Omega$        | 0.001 k $\Omega$ | 0.2% + 3               | 0.2% + 3  | 0.2% + 3  | 0.2% + 3      | 0.5% + 5  | 0.2% + 3  |
| 200 k $\Omega$       | 0.01 k $\Omega$  | 0.5% + 5               | 0.5% + 5  | 0.5% + 5  | 0.5% + 5      | 0.7% + 8  | 0.5% + 5  |
| 2000 k $\Omega$      | 0.1 k $\Omega$   | 0.5% + 5               | 0.5% + 5  | 0.5% + 5  | 0.7% + 5      | NA        | 0.5% + 5  |
| 20 M $\Omega$        | 0.001 M $\Omega$ | 2.0% + 8               | 2.0% + 8  | 2.0% + 8  | 5.0% + 8      | NA        | 2.0% + 8  |
| 200 M $\Omega$       | 0.01 M $\Omega$  | 6.0% + 80              | 6.0% + 80 | 6.0% + 80 | NA            | NA        | 6.0% + 80 |

1. This accuracy for the ranges of 2~ 200  $\Omega$  is specified after Math Null which is used to substrate the resistance of test leads and the contact resistance.

Notes:

- For the ranges of 20 M $\Omega$  and 200 M $\Omega$ , the R.H. is specified for < 60%
- Resistance is specified to  $Q < 10$  and  $D > 0.1$ , otherwise the accuracy is  $(AZ + \text{Offset}) \times \sqrt{1 + Q^2}$
- Equivalence Series Resistance (ESR) measurement is determined by impedance measurement and range. The maximum display is up to 199.99 k $\Omega$  and the accuracy is  $(AZ + \text{Offset}) \times \sqrt{1 + Q^2}$

| Capacitance          |               |                        |           |           |               |           |
|----------------------|---------------|------------------------|-----------|-----------|---------------|-----------|
| Range                | Resolution    | Accuracy = AC + Offset |           |           |               |           |
|                      |               | U1731C/U1732C/U1733C   |           |           | U1732C/U1733C | U1733C    |
|                      |               | 100 Hz                 | 120 Hz    | 1 kHz     | 10 kHz        | 100 kHz   |
| 20 mF                | 0.001 mF      | 0.5% + 8               | 0.5% + 8  | NA        | NA            | NA        |
| 2000 $\mu$ F         | 0.1 $\mu$ F   | 0.5% + 5               | 0.5% + 5  | 0.5% + 8  | NA            | NA        |
| 200 $\mu$ F          | 0.01 $\mu$ F  | 0.3% + 3               | 0.3% + 3  | 0.5% + 5  | 0.5% + 8      | NA        |
| 20 $\mu$ F           | 0.001 $\mu$ F | 0.2% + 3               | 0.2% + 3  | 0.2% + 3  | 0.5% + 5      | 5.0% + 10 |
| 2000 nF              | 0.1 nF        | 0.2% + 3               | 0.2% + 3  | 0.2% + 3  | 0.2% + 3      | 0.7% + 10 |
| 200 nF               | 0.01 nF       | 0.2% + 3               | 0.2% + 3  | 0.2% + 3  | 0.5% + 3      | 0.7% + 10 |
| 20 nF                | 0.001 nF      | 0.5% + 5               | 0.5% + 5  | 0.2% + 3  | 0.5% + 3      | 0.7% + 10 |
| 2000 pF <sup>1</sup> | 0.1 pF        | 0.5% + 10              | 0.5% + 10 | 0.5% + 5  | 0.5% + 3      | 2.0% + 10 |
| 200 pF <sup>1</sup>  | 0.01 pF       | NA                     | NA        | 0.5% + 10 | 0.8% + 10     | 2.0% + 10 |
| 20 pF <sup>1</sup>   | 0.001 pF      | NA                     | NA        | NA        | 1.0% + 20     | 2.5% + 10 |

1. This accuracy for the ranges of 20 pF~2000 pF is specified after Math Null which is used to substrate the stray capacitances for test leads.

Notes:

- The accuracy for the ceramic capacitor will be influenced depending on the dielectric constant (K) of the material used to make the ceramic capacitor. For related influence factors, please refer to the *Component dependency factors* section in the *Impedance Measurement Handbook*, downloadable for free at <http://www.agilent.com/find/lcmmeters>

## U1731C/U1732C/U1733C Electrical Specifications

| Inductance   |               |                        |           |          |               |           |
|--------------|---------------|------------------------|-----------|----------|---------------|-----------|
| Range        | Resolution    | Accuracy = AL + Offset |           |          |               |           |
|              |               | U1731C/U1732C/U1733C   |           |          | U1732C/U1733C | U1733C    |
|              |               | 100 Hz                 | 120 Hz    | 1 kHz    | 10 kHz        | 100 kHz   |
| 20 $\mu$ H   | 0.001 $\mu$ H | NA                     | NA        | NA       | 1.0% + 5      | 2.5% + 20 |
| 200 $\mu$ H  | 0.01 $\mu$ H  | NA                     | NA        | 1.0% + 5 | 0.7% + 3      | 2.5% + 20 |
| 2000 $\mu$ H | 0.1 $\mu$ H   | 0.7% + 10              | 0.7% + 10 | 0.5% + 3 | 0.5% + 3      | 0.8% + 20 |
| 20 mH        | 0.001 mH      | 0.5% + 3               | 0.5% + 3  | 0.2% + 3 | 0.3% + 3      | 0.8% + 10 |
| 200 mH       | 0.01 mH       | 0.5% + 3               | 0.5% + 3  | 0.2% + 3 | 0.2% + 3      | 1.0% + 10 |
| 2000 mH      | 0.1 mH        | 0.2% + 3               | 0.2% + 3  | 0.2% + 3 | 0.5% + 5      | 1.0% + 10 |
| 20 H         | 0.001 H       | 0.2% + 3               | 0.2% + 3  | 0.5% + 5 | 1.0% + 5      | 2.0% + 10 |
| 200 H        | 0.01 H        | 0.7% + 5               | 0.7% + 5  | 1.0% + 5 | 2.0% + 8      | NA        |
| 2000 H       | 0.1 H         | 1.0% + 5               | 1.0% + 5  | 2.0% + 8 | NA            | NA        |

| Phase Angle of Impedance |            |                               |                |                  |
|--------------------------|------------|-------------------------------|----------------|------------------|
| Range                    | Resolution | Accuracy ( $\theta_e$ )       | Condition      |                  |
| -180° ~ 180°             | 0.1°/1°    | (AZ + Offset/Zx) x 180/ $\pi$ | D < 1 or Q > 1 |                  |
| Impedance                | Zx         | AZ                            | Offset         | $\theta_e$       |
| 1999.9 $\Omega$          | 19999      | 0.2%                          | 3              | $\pm 0.12^\circ$ |
| 199.9 $\Omega$           | 1999       | 0.2%                          | 3              | $\pm 0.20^\circ$ |
| 19.9 $\Omega$            | 199        | 0.2%                          | 3              | $\pm 0.98^\circ$ |
| 1.9 $\Omega$             | 19         | 0.2%                          | 3              | $\pm 9.16^\circ$ |

### Notes:

- Specifications are applicable to all models (U1731C, U1732C, and U1733C) unless specified
- The "AZ" and Offset are the accuracy specified at impedance
- The " $\pi$ " is approximately 3.14159

| Dissipation/Quality Factor |           |                           |                |            |
|----------------------------|-----------|---------------------------|----------------|------------|
| Function                   | Range     | Accuracy (De)             | Condition      |            |
| Z                          | 0.001~999 | AZ + Offset/Zx x 100% + 3 | D < 1 or Q > 1 |            |
| L                          | 0.001~999 | AL + Offset/Lx x 100% + 3 | D < 1 or Q > 1 |            |
| C                          | 0.001~999 | AC + Offset/Cx x 100% + 3 | D < 1 or Q > 1 |            |
| Capacitance                | Cx        | AC                        | Offset         | De         |
| 88.88 $\mu$ F              | 8888      | 0.2%                      | 3              | 0.203% + 3 |

### Notes:

- Specifications are applicable to all models (U1731C, U1732C, and U1733C) unless specified
- The "AZ, AL, AC" and Offset are the accuracy specified at Impedance, Inductance, and Capacitance, respectively
- The Zx, Lx, and Cx are the display count of the reading. For example, the Cx is 8888 as if the capacitance is 88.88  $\mu$ F for the range of 200  $\mu$ F.
- The Quality Factor is the reciprocal of Dissipation Factor

## U1731C/U1732C/U1733C Electrical Specifications

| Test Signal          |           |                   |           |                |          |
|----------------------|-----------|-------------------|-----------|----------------|----------|
| Model                | Selection | Test signal level |           | Test frequency |          |
|                      |           | Level             | Accuracy  | Frequency      | Accuracy |
| U1731C/U1732C/U1733C | 100 Hz    | 0.74 Vrms         | 0.05 Vrms | 100 Hz         | 0.01%    |
|                      | 120 Hz    | 0.74 Vrms         | 0.05 Vrms | 120.481 Hz     | 0.01%    |
|                      | 1 kHz     | 0.74 Vrms         | 0.05 Vrms | 1 kHz          | 0.01%    |
| U1732C/1733C         | 10 kHz    | 0.70 Vrms         | 0.05 Vrms | 10 kHz         | 0.01%    |
| U1733C               | 100 kHz   | 0.70 Vrms         | 0.05 Vrms | 100 kHz        | 0.01%    |
|                      | DCR       | +1.235 V          | 0.05 V    | NA             | NA       |

| Source Impedance of Impedance/Resistance Measurement |                          |                |                |                |              |                |
|------------------------------------------------------|--------------------------|----------------|----------------|----------------|--------------|----------------|
| Range                                                | Typical source impedance |                |                |                |              |                |
|                                                      | U1731C/U1732C/U1733C     |                |                | U1732C/U1733C  | U1733C       |                |
|                                                      | 100 Hz                   | 120 Hz         | 1 kHz          | 10 kHz         | 100 kHz      | DCR            |
| 2 $\Omega$                                           | 100 $\Omega$             | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$ | 100 $\Omega$   |
| 20 $\Omega$                                          | 100 $\Omega$             | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$ | 100 $\Omega$   |
| 200 $\Omega$                                         | 100 $\Omega$             | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$ | 100 $\Omega$   |
| 2000 $\Omega$                                        | 1 k $\Omega$             | 1 k $\Omega$   | 1 k $\Omega$   | 1 k $\Omega$   | 1 k $\Omega$ | 1 k $\Omega$   |
| 20 k $\Omega$                                        | 10 k $\Omega$            | 10 k $\Omega$  | 10 k $\Omega$  | 10 k $\Omega$  | 1 k $\Omega$ | 10 k $\Omega$  |
| 200 k $\Omega$                                       | 100 k $\Omega$           | 100 k $\Omega$ | 100 k $\Omega$ | 10 k $\Omega$  | 1 k $\Omega$ | 100 k $\Omega$ |
| 2000 k $\Omega$                                      | 100 k $\Omega$           | 100 k $\Omega$ | 100 k $\Omega$ | 10 k $\Omega$  | NA           | 100 k $\Omega$ |
| 20 M $\Omega$                                        | 100 k $\Omega$           | 100 k $\Omega$ | 100 k $\Omega$ | 100 k $\Omega$ | NA           | 100 k $\Omega$ |
| 200 M $\Omega$                                       | 100 k $\Omega$           | 100 k $\Omega$ | 100 k $\Omega$ | NA             | NA           | 100 k $\Omega$ |

| Source Impedance of Capacitance Measurement |                          |                |                |                |              |
|---------------------------------------------|--------------------------|----------------|----------------|----------------|--------------|
| Range                                       | Typical source impedance |                |                |                |              |
|                                             | U1731C/U1732C/U1733C     |                |                | U1732C/U1733C  | U1733C       |
|                                             | 100 Hz                   | 120 Hz         | 1 kHz          | 10 kHz         | 100 kHz      |
| 20 mF                                       | 100 $\Omega$             | 100 $\Omega$   | NA             | NA             | NA           |
| 2000 $\mu$ F                                | 100 $\Omega$             | 100 $\Omega$   | 100 $\Omega$   | NA             | NA           |
| 200 $\mu$ F                                 | 100 $\Omega$             | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   | NA           |
| 20 $\mu$ F                                  | 100 $\Omega$             | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$ |
| 2000 nF                                     | 1 k $\Omega$             | 1 k $\Omega$   | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$ |
| 200 nF                                      | 10 k $\Omega$            | 10 k $\Omega$  | 1 k $\Omega$   | 100 $\Omega$   | 100 $\Omega$ |
| 20 nF                                       | 100 k $\Omega$           | 100 k $\Omega$ | 10 k $\Omega$  | 1 k $\Omega$   | 100 $\Omega$ |
| 2000 pF                                     | 100 k $\Omega$           | 100 k $\Omega$ | 100 k $\Omega$ | 10 k $\Omega$  | 1 k $\Omega$ |
| 200 pF                                      | NA                       | NA             | 100 k $\Omega$ | 10 k $\Omega$  | 1 k $\Omega$ |
| 20 pF                                       | NA                       | NA             | NA             | 100 k $\Omega$ | 1 k $\Omega$ |

## U1731C/U1732C/U1733C Electrical Specifications

| Source Impedance of Inductance Measurement |                          |                |                |                |                |
|--------------------------------------------|--------------------------|----------------|----------------|----------------|----------------|
| Range                                      | Typical source impedance |                |                |                |                |
|                                            | U1731C/U1732C/U1733C     |                |                | U1732C/U1733C  | U1733C         |
|                                            | <b>100 Hz</b>            | <b>120 Hz</b>  | <b>1 kHz</b>   | <b>10 kHz</b>  | <b>100 kHz</b> |
| 20 $\mu$ H                                 | NA                       | NA             | NA             | 100 $\Omega$   | 100 $\Omega$   |
| 200 $\mu$ H                                | NA                       | NA             | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   |
| 2000 $\mu$ H                               | 100 $\Omega$             | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   |
| 20 mH                                      | 100 $\Omega$             | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   | 100 $\Omega$   |
| 200 mH                                     | 100 $\Omega$             | 100 $\Omega$   | 100 $\Omega$   | 1 k $\Omega$   | 1 k $\Omega$   |
| 2000 mH                                    | 100 $\Omega$             | 100 $\Omega$   | 1 k $\Omega$   | 10 k $\Omega$  | 1 k $\Omega$   |
| 20 H                                       | 1 k $\Omega$             | 1 k $\Omega$   | 10 k $\Omega$  | 10 k $\Omega$  | 1 k $\Omega$   |
| 200 H                                      | 10 k $\Omega$            | 10 k $\Omega$  | 100 k $\Omega$ | 100 k $\Omega$ | NA             |
| 2000 H                                     | 100 k $\Omega$           | 100 k $\Omega$ | 100 k $\Omega$ | NA             | NA             |

## General Specifications

| Parameter                                                   | U1731C                                                                                                                                                                            | U1732C                        | U1733C                                 |
|-------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------|
| Measurements                                                | Z/L/C/R/D/Q/θ/ESR                                                                                                                                                                 | Z/L/C/R/D/Q/θ/ESR             | Z/L/C/R/D/Q/θ/ESR/DCR                  |
| Display                                                     | Primary display: Maximum display 19,999 counts<br>Secondary display: Maximum display 999 counts<br>Automatic polarity indication                                                  |                               |                                        |
| Test frequency (Accuracy = ± 0.1% of actual test frequency) | 100 Hz, 120 Hz, 1 kHz                                                                                                                                                             | 100 Hz, 120 Hz, 1 kHz, 10 kHz | 100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz |
| Backlight                                                   | No                                                                                                                                                                                | Yes                           | Yes                                    |
| Test signal level                                           | Selection                                                                                                                                                                         | Test signal level             | Test frequency                         |
|                                                             | 100 Hz                                                                                                                                                                            | 0.74 Vrms                     | 100 Hz                                 |
|                                                             | 120 Hz                                                                                                                                                                            | 0.74 Vrms                     | 120.481 Hz                             |
|                                                             | 1 kHz                                                                                                                                                                             | 0.74 Vrms                     | 1 kHz                                  |
|                                                             | 10 kHz <sup>1</sup>                                                                                                                                                               | 0.74 Vrms                     | 10 kHz                                 |
|                                                             | 100 kHz <sup>2</sup>                                                                                                                                                              | 0.74 Vrms                     | 100 kHz                                |
|                                                             | DCR <sup>2</sup>                                                                                                                                                                  | +1.235 V                      | NA                                     |
| Tolerance mode                                              | 1%, 5%, 10%, 20%                                                                                                                                                                  |                               |                                        |
| Ranging mode                                                | Auto and manual                                                                                                                                                                   |                               |                                        |
| Measurement rate                                            | 1 time/second, nominal                                                                                                                                                            |                               |                                        |
| Response time                                               | Approximately 1 second/DUT (Device Under Test)                                                                                                                                    |                               |                                        |
| Auto power-off                                              | ~0-99 mins without operation                                                                                                                                                      |                               |                                        |
| Power supply                                                | Single standard 9 V battery (alkaline or carbon-zinc) or optional power adaptor                                                                                                   |                               |                                        |
| Power consumption                                           | 225 mVA maximum without backlight                                                                                                                                                 |                               |                                        |
| Input protection fuse                                       | Resettable over-current protection                                                                                                                                                |                               |                                        |
| Battery life                                                | 16 hours based on alkaline battery                                                                                                                                                |                               |                                        |
| Low battery indicator                                       | [  ] will appear when voltage drops below ~7.2 V                                               |                               |                                        |
| Operating temperature                                       | -10 to 55 °C, 0 to 80% R.H.                                                                                                                                                       |                               |                                        |
| Storage temperature                                         | -20 to 70 °C, 0 to 80% R.H. without battery                                                                                                                                       |                               |                                        |
| Temperature coefficient                                     | 0.1 × (specified accuracy)/°C (from -10 to 18 °C or 28 to 55 °C)                                                                                                                  |                               |                                        |
| Relative humidity                                           | Maximum 80% R.H. for temperature up to 30 °C decreasing linearly to 50% R.H. at 55 °C                                                                                             |                               |                                        |
| Weight                                                      | 337 grams with battery                                                                                                                                                            |                               |                                        |
| Dimensions (H x W x D)                                      | 184 mm x 87 mm x 41 mm                                                                                                                                                            |                               |                                        |
| Safety and EMC Compliance                                   | In compliance with EN61010-1 (IEC61010-1:2001) for low voltage directive and Pollution Degree II Environment. Susceptibility and Emissions (EMC): Commercial Limits per EN61326-1 |                               |                                        |
| Calibration                                                 | One-year calibration cycle recommended                                                                                                                                            |                               |                                        |
| Warranty                                                    | <ul style="list-style-type: none"> <li>• 3 years for main unit</li> <li>• 3 months for standard shipped accessories</li> </ul>                                                    |                               |                                        |

1. Only applicable for U1732C/U1733C

2. Only applicable for U1733C



## Ordering Information



### Standard shipped items

Standard U1731C, U1732C, and U1733C ordering include:

- Quick Start Guide
- Certificate of Calibration (CoC)
- Alligator clip leads
- 9 V alkaline battery

### Recommended accessories

U1731P



Combo Kit

Includes one U1731 Series handheld and four accessories:

- U5491A soft carrying case
- U1173A IR-USB cable
- U1780A AC adaptor
- U1782A SMD tweezer

U1732P



Combo Kit

Includes one U1732 Series handheld and four accessories:

- U5491A soft carrying case
- U1173A IR-USB cable
- U1780A AC adaptor
- U1782A SMD tweezer

U1733P



Combo Kit

Includes one U1733 Series handheld and four accessories:

- U5491A soft carrying case
- U1173A IR-USB cable
- U1780A AC adaptor
- U1782A SMD tweezer

U1174A



Soft carrying case

U5481A



IR-to-USB cable

U1782A



SMB tweezer

U1780A



Power adaptor and cord (according to country)

U1781A



Alligator clip leads