PRECISION COMPONENT ANALYZER
6430B / 6440B

Product Specification

Issue B

USA
Wayne Kerr Electronics Inc.
165L New Boston Street
Woburn MA 01801-1744
Tel: 781 938 8390
Fax: 781 933 9523
email: sales@waynekerr.com
www.waynekerrtest.com

UK
Wayne Kerr Electronics
Vinnetrow Business Park
Vinnetrow Road
Chichester
West Sussex PO20 1QH
Tel: +44 (0)1243 792200
Fax: +44 (0)1243 792201
email: sales@wayne-kerr.co.uk
email: service@wayne-kerr.co.uk
www.waynekerrtest.com

Asia
Wayne Kerr Asia
A604 Pengdu Building,
Guimiao Road,
Nanshan District,
Shenzhen, Guangdong
China
Tel: +86 130 66830676
Fax: +86 755 26523875
Email: sales@waynekerr.com
service@waynekerr.com

CONTENTS

1 6430 SPECIFICATION

Wayne Kerr Electronics Limited reserves the right to change specification without notice

1.1 Measurement Parameters

Any of the following parameters can be measured and displayed.

DC Functions

Resistance (Rdc).

AC Functions

Capacitance (C), Inductance (L), Resistance (R), Conductance (G), Susceptance (B), Reactance (X), Dissipation Factor (D), Quality Factor (Q), Impedance (Z), Admittance (Y) and Phase Angle (θ).

The following display formats are available.

Series or Parallel Equivalent Circuit

C+R, C+D, C+Q, L+R, L+Q

Series Equivalent Circuit Only

X+R, X+D, X+Q

Parallel Equivalent Circuit Only

C+G, B+G, B+D, B+Q

Polar Form

Z + Phase Angle, Y + Phase Angle

1.2 Test Conditions

1.2.1 AC Drive

Frequency Range

20Hz to 500kHz >1000 steps

Accuracy of set frequency ±0.005%

Pre-set frequencies

20, 25, 30, 40, 50, 60, 80, 100, 120, 150; repeats for each decade.

Step size is 1% or better through the frequency range when the 6430B Analysis option is fitted.

Drive Level (AC Measurements)

Open Circuit Voltage	Short Circuit Current	Frequency Range
1mV to 10V rms	50µA to 200mA rms	up to 300kHz
1mV to 5V rms	50µA to 100mA rms	up to 500kHz

Signal source impedance: 50Ω nominal

Step Size

Voltage Drive		Current Drive	
Step size	up to drive level	Step size	up to drive level
1mV	100mV	50µA	5mA
2mV	200mV	100µA	10mA
5mV	500mV	200µA	20mA
10mV	1V	500µA	50mA
20mV	2V	1mA	100mA
50mV	5V	2mA	200mA *
100mV	10V *		

* Drive levels are reduced to 9V and 180mA at 40Hz or below.

User-selectable Automatic Level Control (ALC) ensures that the drive level at the device under test (DUT) is ±2% ±1mV of set voltage or ±2% ±0.1mA of set current at or above 100Hz.

Drive level accuracy degrades below 100Hz: ±3% ±1mV or ±3% ±0.1mA at 50Hz

±5% ±1mV or ±5% ±0.1mA at 20Hz

With DC bias applied the maximum drive voltages indicated above are halved.

1.2.2 DC Bias Voltage

A DC bias voltage derived from an internal or external source can be applied to capacitors during AC measurements.

Internal

DC bias of 2V ±5%.

Peak short circuit current <90mA.

External

External bias of up to ±60V is provided by connecting an external power supply to the rear panel bias terminals. The voltage required at the rear terminals is 5% higher than the voltage at the DUT.

A bias load of 220Ω is permanently connected across the rear panel bias terminals.

Steady state short circuit load: 70Ω.

A resettable trip protects the bias circuit against a continuous short circuit.

1.2.3 Drive Level (Rdc)

Two selectable drive levels:

Open circuit voltage	Short circuit current
100mV ±7%	1mA
1V ±7%	10mA

Source resistance: 100Ω nominal.

1.3 Measurement Speeds

Four selectable speeds for all measurement functions. Selecting slower measurement speed increases reading resolution and reduces measurement noise by averaging.

The following measurement periods apply for Rdc or for AC measurements ≥100Hz.

Maximum speed (intended for automatic sorting) ≈ 50ms.
Fast speed (for non-critical measurements) ≈ 100ms.
Medium speed (for improved resolution) ≈ 300ms.
Slow speed (for best resolution and enhanced supply frequency rejection) ≈ 900ms.

1.3.1 Capacitor Mode

Two frequency measurement ≈ 180ms.

1.4 Measurement Ranges

R, Z, X	0.01mΩ to >2GΩ
G, Y, B	0.01nS to >2kS
L	0.1nH to >2kH
C	1fF to >1F
D	0.00001 to >1000
Q	0.00001 to >1000
Rdc	0.1mΩ to >10MΩ

For L and C, the lower range is available at 10kHz and 100kHz; the upper range is available at 100Hz and below.

1.5 Hardware Ranges

The hardware range used is determined by the impedance being measured, the frequency and the level. The table below lists the boundaries of operation for AC measurement functions. The hardware range being used is indicated in the top-left-hand-corner of the instrument display.

Range number	Impedance coverage	Frequency coverage up to
1	<1Ω	100kHz
2	<10Ω	500kHz
3	<50Ω	500kHz
4	>50Ω	500kHz
5	>250Ω	500kHz
6	>2.5kΩ	500kHz
7	>25kΩ	100kHz
8	>250kΩ	10kHz

For drive levels below 100mV, the highest range at each frequency is not available.
For drive levels below 20mA, range 1 is not available.
For drive levels below 0.5mA, range 2 is not available.

1.6 Modes Of Operation

1.6.1 MEASUREMENT

Selection of any measurement parameter and test condition.

Single-level function-menu controlled by keypad and soft keys.

Single and repetitive measurements displaying major and minor terms.

Analogue scale with configurable Hi/Lo limits giving PASS/FAIL indication (connected to logic output on binning option).

1.6.2 DEVIATION

Similar to MEASUREMENT MODE but relative or percentage deviation from nominal value displayed for major or minor term. There is no analogue scale in DEVIATION MODE.

1.6.3 MULTI FREQUENCY

Measurement parameters and test conditions set using MEASUREMENT MODE.

Up to 8 frequencies with configurable major and minor term limits.

PASS/FAIL indication (connected to logic output on binning option).

1.6.4 BINNING (Optional)

Measurement parameters and test conditions set using MEASUREMENT MODE.

8 PASS bins with absolute or percentage limits and 1 FAIL bin. Up to 99 sets of limits may be saved.

Bin count function logs the number of components in each bin.

Separate dedicated output for PASS/FAIL indication driven by analogue scale limits in MEASUREMENT MODE or by test limits in MULTI FREQUENCY MODE.

Trigger input with pull-up, operates on logic low or contact closure.

Handshake outputs indicating measure busy and data valid status.

25-way D-type interface connector.

Output Levels (B1 Option)

Output High:	>4V	Output Low:	<1V
Input High:	>3.5V	Input Low:	<1.5V

Drive capability typically is 10mA sink (low) and 30µA (high).

Output Levels (B2 Option)

This option provides an opto-coupled interface.

Output On state current:	up to 10mA at 24V	Output Off state current:	<0.5mA
Output On state voltage:	Input voltage –1.5V at 10mA		
Input High current:	>3mA	Input Low current:	<1.25mA
Input High voltage:	>15.4V	Input Low voltage:	<8V

1.6.5 CAPACITOR (Optional)

Combines the Multi Frequency and Binning modes for efficient testing of capacitors.

Measurement parameters and test conditions set using MEASUREMENT MODE.

Up to 8 frequencies with configurable major and minor term limits. The first frequency may be tested against up to 9 bins. The Major term is tested to a tolerance limit while the Minor term is compared to a relative limit. Measurements at subsequent frequencies may be compared to a single reject limit. A measurement term swap function is available if the minor term is required to be tested against a tolerance limit.

1.7 Measurement Connections

4 front panel BNC connectors permit 2-, 3- and 4-terminal connections with the screens at ground potential.

Terminals withstand connection of charged capacitor up to following limits:

- any value capacitor charged up to 50V, either polarity;

- a capacitor charged to between 50V and 500V with a stored energy of less than 0.25J, either polarity.

1.8 Measurement Accuracy

The accuracy statements given apply when the instrument is used under the following measurement conditions.

1V (DUT >50Ω) or 20mA (DUT <50Ω), slow speed, 4-terminal measurement. The instrument must have warmed up for at least 30 minutes at a steady ambient temperature of between 15°C and 35°C. The instrument must have been trimmed with Wayne Kerr Kelvin leads or a Wayne Kerr 1006 fixture at the measurement frequency.

For frequencies above 20kHz with the Analysis option fitted , HF lead compensation must have been performed.

For other frequencies and speeds see section 1.9—Accuracy Charts.

1.8.1 Resistance / Reactance (R / X)

Frequency	Accuracy % (for Q < 0.1)	Range for specified accuracy
100Hz /120Hz	0.05	1Ω to 1.6MΩ
1kHz (Notes 1, 2)	0.02	10Ω to 100kΩ
1kHz	0.05	1Ω to 1.6MΩ
10kHz	0.05	2Ω to 700kΩ
10kHz	0.1	0.3Ω to 4.7MΩ
100kHz	0.2	1.1Ω to 100kΩ

For Q ≥0.1 multiply accuracy figures by (1+Q).

1.8.2 Conductance / Susceptance (G / B)

Frequency	Accuracy % (for Q < 0.1)	Range for specified accuracy
100Hz /120Hz	0.05	0.63µS to 1S
1kHz (Notes 1, 3)	0.02	10µS to 0.1S
1kHz	0.05	0.63µS to 1S
10kHz	0.05	1.4µS to 0.5S
10kHz	0.1	0.22µS to 3.3S
100kHz	0.2	10µS to 0.9S

For Q ≥0.1 multiply accuracy figures by (1+Q).

1.8.3 Capacitance (C)

Frequency	Accuracy % (for D < 0.1)	Range for specified accuracy
100Hz /120Hz	0.05	1nF to 1mF
1kHz	0.05	100pF to 100µF
10kHz	0.05	60pF to 10µF
100kHz	0.2	10pF to 1µF

For D ≥0.1 multiply accuracy figures by (1+D).

1.8.4 Inductance (L)

Frequency	Accuracy % (for Q > 10)	Range for specified accuracy
100Hz /120Hz	0.05	1mH to 1000H
1kHz	0.05	100µH to 100H
10kHz	0.05	20µH to 10H
100kHz	0.2	4µH to 200mH

For Q ≤10, multiply the accuracy figure by (1+1/Q).

1.8.5 Dissipation Factor (D)

Frequency	Accuracy (A_d)	Range for specified accuracy
100Hz /120Hz	0.0005	1nF to 1mF
1kHz (Note 1)	0.0002	1nF to 100µF
1kHz	0.0005	100pF to 1mF
10kHz	0.0005	100pF to 10µF
100kHz	0.002	10pF to 3µF

For capacitors within the ranges shown above , D accuracy = $\pm A_d (1+D^2)$.

1.8.6 Quality Factor (Q)

Frequency	Accuracy % (A_L)	Range for specified accuracy
100Hz /120Hz	0.05	4mH to 1000H
1kHz	0.05	100µH to 100H
10kHz	0.05	20µH to 10H
100kHz	0.2	4µH to 200mH

For inductors within the ranges shown above , Q accuracy = $\pm A_L (Q+1/Q)$.

1.8.7 DC Resistance (Rdc)

Drive Level	Accuracy %	Range for specified accuracy
100mV	0.25	10Ω to 10kΩ
1V	0.1	1Ω to 100kΩ

Notes:

1) Accuracy is typical for 15°C to 35°C, guaranteed for 20°C to 30°C.
2) Accuracy applies to resistance only.
3) Accuracy applies to conductance only.

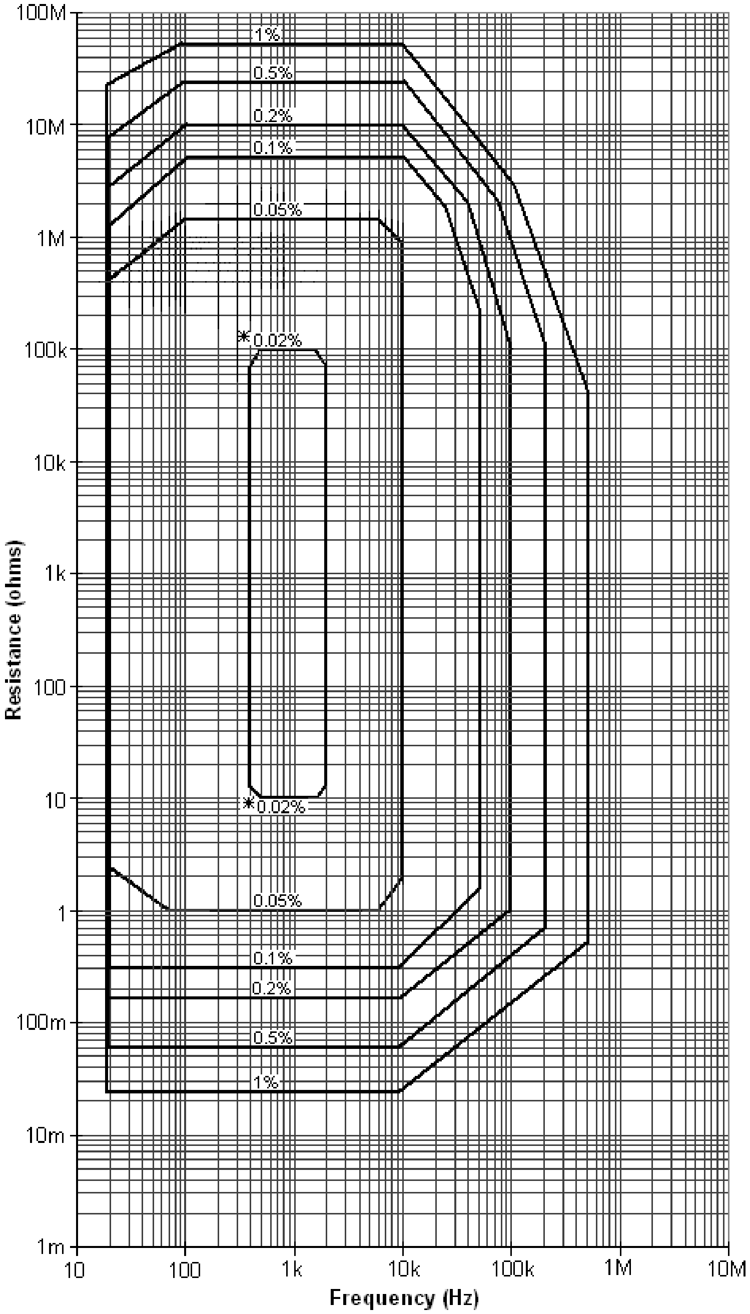
1.9 Accuracy Charts

Iso-accuracy charts define the measurement ranges available, at specified accuracies, over the available frequency band. All curves assume that Slow measurement speed is used, that the analyzer has been trimmed at the frequency used for measurements, that both factory calibration and self calibration are valid and that the component under test is pure. Beside each chart is a summary of these conditions and the information on the accuracy applicable when some or all of the conditions change.

For above and below the ranges indicated in the following charts, the accuracy degrades linearly with increasing/decreasing DUT value. For example, 470MΩ and 2.5mΩ measured at 10kHz are both a factor of 10 beyond the indicated range for 1% and will each have an accuracy of 10%.

Measurement accuracy for the optional Capacitor mode conforms to the maximum speed setting.

1.9.1 R / G / Z* Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Analyzer trimmed at measurement frequency.
Q ≤0.1
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

* R / G Only

typical figure for 25 ±10ºC,
guaranteed for 25 ±5ºC.

O/C and S/C trim corrections under various conditions of interpolation, speed and level are given in the table following these iso-accuracy charts.

For impure components, and for measurements of the highest and lowest available ranges, full accuracy expressions, shown below, apply.

If 1 > Q > 0.1, multiply R accuracy by (1+Q).
For Q > 1 (loss resistance of inductor) see Q accuracy chart.
For D < 1 (loss resistance of capacitor) see D accuracy chart.

High resistance values

Accuracy = ± (A + 100Y_T . R_X) %.

Low resistance values

Accuracy = ± (A + 100R_T / R_X) %

where:
A = accuracy from adjacent chart.
R_X = measured value of unknown component.
R_T = sum of Z_I, Z_L (as appropriate, from section 1.10.2).
Y_T = sum of Y_I, Y_L (as appropriate, from section 1.10.1).

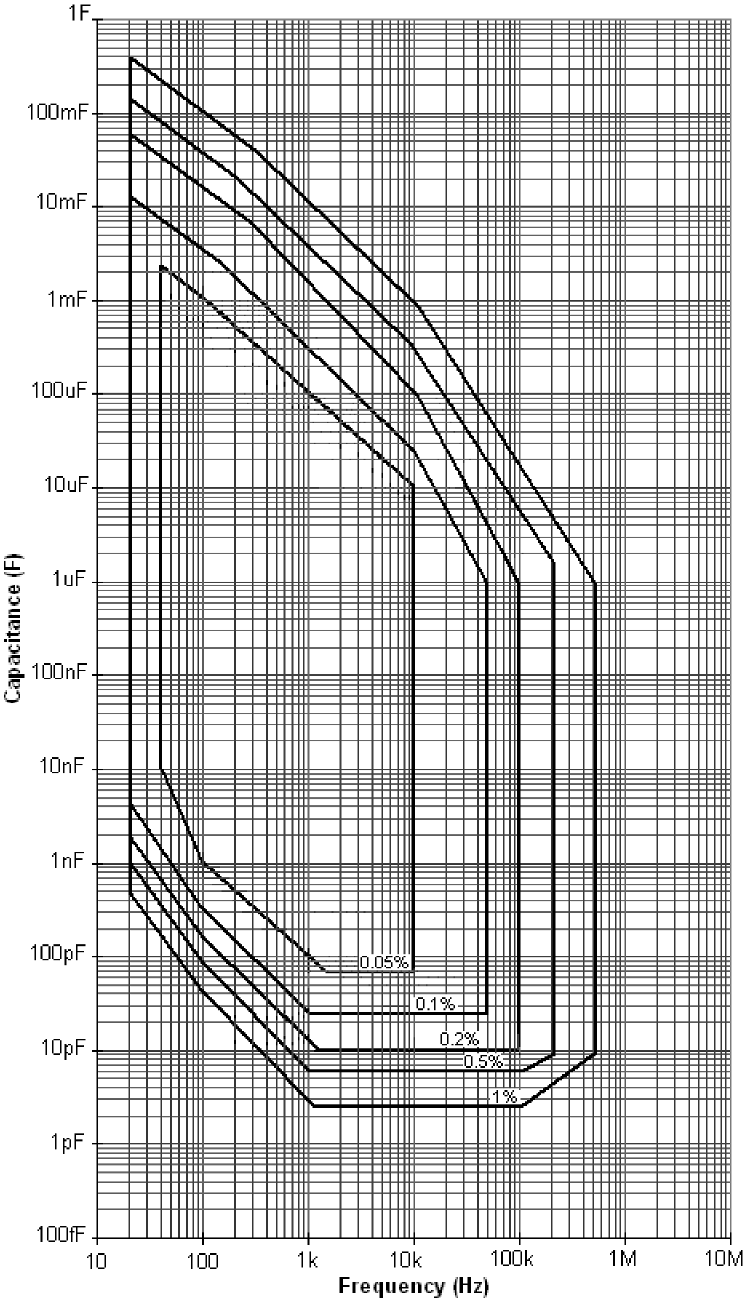
Conductance (G)

Find accuracy for equivalent R value from R = 1/G.

Admittance (Y)

Find accuracy for equivalent Z value from Z = 1/Y.

1.9.2 C Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Analyzer trimmed at measurement frequency.
D ≤0.1
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

O/C and S/C trim corrections under various conditions of interpolation, speed and level are given in the table following these iso-accuracy charts.

For impure components, and for measurements of the highest and lowest available ranges, full accuracy expressions, shown below, apply.

If D >0.1, multiply C accuracy by (1+D).

High capacitance values

Accuracy = ± (A + 100 X_T . ω C_X) %

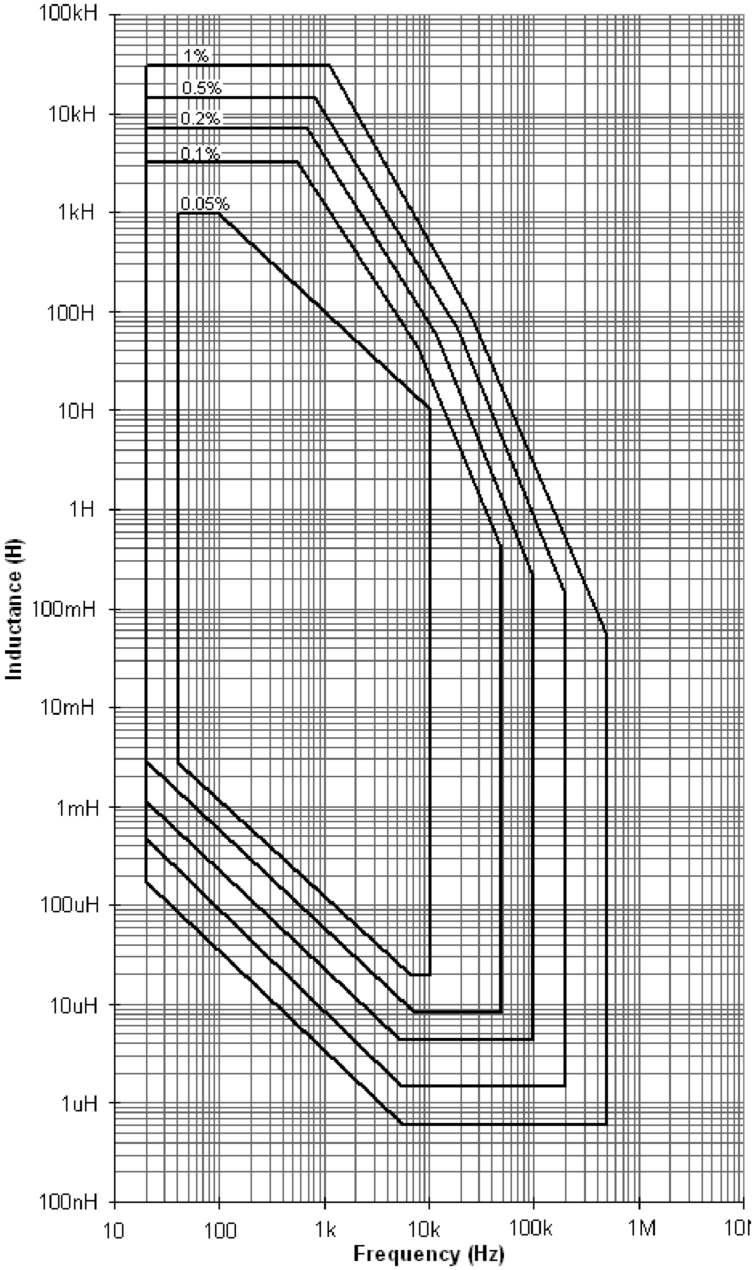
Low capacitance values

Accuracy = ± (A + 100 C_T / C_X) %

where

A = accuracy from adjacent chart
C_X = measured value of unknown component.
X_T = sum of Z_I, Z_L (as appropriate, from section 1.10.2)
C_T = sum of C_I, C_L (as appropriate, from section 1.10.1)
ω = 2π . frequency

1.9.3 L Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Analyzer trimmed at measurement frequency.
Q ≥10
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

O/C and S/C trim corrections under various conditions of interpolation, speed and level are given in the table following these iso-accuracy charts.

For impure components, and for measurements of the highest and lowest available ranges, full accuracy expressions, shown below, apply.

If Q <10, multiply L accuracy by (1+1/Q).

High inductance values

Read accuracy direct from chart

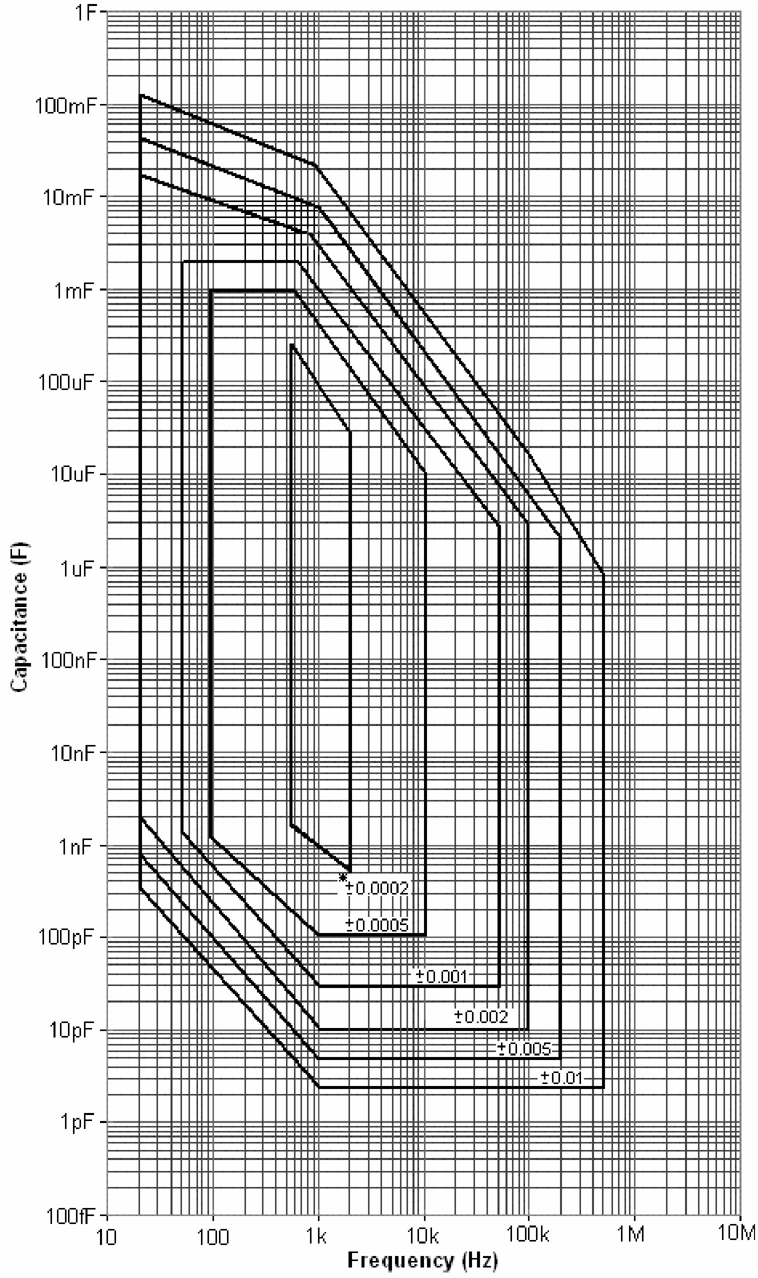
Low inductance values

Accuracy = ± (A + 100 L_T / L_X) %

where

A = accuracy from adjacent chart
L_X = measured value of unknown component.
L_T = sum of L_I, L_L (as appropriate, from section 1.10.2)

1.9.4 D Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Analyzer trimmed at measurement frequency.
D ≤0.1
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

* typical figure for 25 ±10ºC, guaranteed for 25 ±5ºC.

O/C and S/C trim corrections under various conditions of interpolation, speed and level are as given in the table following these iso-accuracy charts.

For impure components, and for measurements of the highest and lowest available ranges, full accuracy expressions, shown below, apply.

If D >0.1, multiply accuracy by $(1+D^2)$.

High capacitance values

D accuracy = $\pm (A + R_T \,.\, \omega\, C_X)$

Low capacitance values

D accuracy = $\pm (A + Y_T / \omega\, C_X)$.

Capacitor series loss resistance (esr)

Accuracy = $\pm (A/\omega\, C_X)\ \Omega$

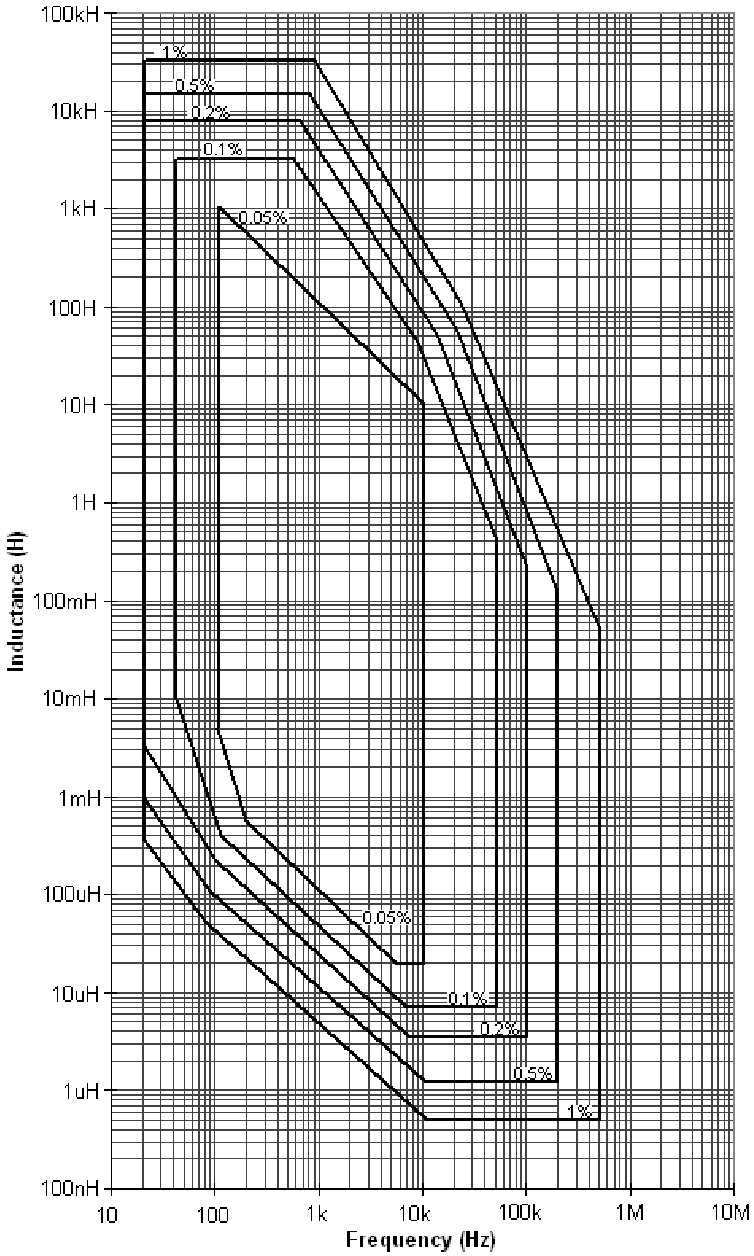
Capacitor parallel loss resistance (epr)

Accuracy = $\pm (100A\, R_X \,.\, \omega\, C_X)\ \%$

where:

A = accuracy from adjacent chart
C_X = measured value of unknown component.
R_X = measured value of unknown component.
R_T = sum of Z_I, Z_L (as appropriate, from section 1.10.2)
Y_T = sum of Y_I, Y_L (as appropriate, from section 1.10.1)
$\omega = 2\pi$. frequency

1.9.5 Q Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Analyzer trimmed at measurement frequency.
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

O/C and S/C trim corrections under various conditions of interpolation, speed and level are given in the table following these iso-accuracy charts.

For all Q values

Q accuracy =A(Q + 1/Q)

High inductance values

Read Q accuracy direct from chart

Low inductance values

Q accuracy = $\pm((A + 100R_T/\omega L_X)(Q+1/Q))$ %

Inductor series loss resistance

Accuracy = $\pm$ (A. $\omega L_X/R_X$) %

Inductor parallel loss resistance

$$\text{Accuracy} = \pm\frac{A\,.\,R_x}{\omega\,L_x}\%$$

where

A = accuracy from adjacent chart
L_X = measured value of unknown component.
R_X = measured value of unknown component.
R_T = sum of Z_I, Z_L (as appropriate, from section 1.10.2).
$\omega = 2\pi$. frequency

1.10 Additional Corrections

The following tables give the additional corrections which need to be applied to measurements when some or all the measurement conditions specified in the Iso_Accuracy charts are not used.

1.10.1 Open Circuit Trim Correction

f = frequency in kHz

Frequency range (Hz)	Interpolation		Level 1.02 - 10V	
	Y_I (nS)	C_I (pF)	Y_L (nS)	C_L (pF)
20-250	1	0.15 / f	1	0.015 / f
300-10k	0.2	0.03 / f	0.2	0.03 / f
12k-100k	0.12 x f	0.02	0.12 x f	0.02
120k - 300k	0.31 x f	0.05	0.31 x f	0.05
302k-500k (1)	0.31 x f	0.05	0.31 x f	0.05

f = frequency in kHz, V= drive level in V

Frequency range (Hz)	Level 0.1 - 0.98V		Level < 0.1V	
	Y_L (nS)	C_L (pF)	Y_L (nS)	C_L (pF)
20-250	0.4 / V	0.06 / (f x V)	0.4 / V	0.06 / (f x V)
300-10k	0.1 / V	0.015 / (f x V)	0.1 / V	0.015 / (f x V)
12k-100k	0.12 x f	0.02	0.012 x f / V	0.002 / V
120k - 300k	0.31 x f	0.05	0.031 x f / V	0.005 / V
302k-500k (1)	0.31 x f	0.05	0.031 x f / V	0.005 / V

1.10.2 Short Circuit Trim Correction

f = frequency in kHz

Frequency range (Hz)	Interpolation		Level 2 - 200mA		
	Z_I (μΩ)	L_I (nH)	Z_L (μΩ)	L_L (nH)	
20	1500	240 / f	1500	240 / f	For drive levels below 2mA multiply level corrections in previous column by 2 / (level in mA).
25-80	1000	160 / f	1000	160 / f	
100	500	80 / f	500	80 / f	
120-10k	250	40 / f	250	40 / f	
12k-300k	18 x f	3	18 x f	3	
302k-500k (1)	18 x f	3	18 x f	3	

(1) Level restricted to 5V/100mA

1.11 General

1.11.1 Power Supply

Input Voltage	115V AC ±10% or 230V AC ±10% (selectable)
Frequency	50/60Hz
VA rating	150VA max
Input fuse rating	115V operation: 2AT
	230V operation: 1AT
	The input fuse is in the fuse holder drawer integral to the IEC input connector.

1.11.2 Display

High contrast black and white LCD module 320 x 240 pixels with CPL back lighting.

Visible area 115 x 86mm.

1.11.3 Printer Output

Centronics/parallel printer port for print-out of measurement results or bin count data.

1.11.4 Remote Control

Designed to GPIB IEEE-488.2 and SCPI 1992.0.

1.11.5 Remote Trigger

Rear panel BNC with internal pull-up, operates on logic low or contact closure.

1.11.6 Mechanical

Height	150mm (5.9")
Width	440mm (17.37")
Depth	525mm (20.5")
Weight	11kg (24.25lbs)

1.12 Environmental Conditions

This equipment is intended for indoor use only in a non-explosive and non-corrosive atmosphere.

1.12.1 Temperature Range

Storage:	-40°C to +70°C.
Operating:	0°C to 40°C.
Normal accuracy:	15°C to 35°C. See section 1.8—Measurement Accuracy for full specification.

1.12.2 Relative Humidity

Up to 80% non-condensing.

1.12.3 Altitude

Up to 2000m.

1.12.4 Installation Category

II in accordance with IEC664.

1.12.5 Pollution Degree

2 (mainly non-conductive)

1.12.6 Safety

Complies with the requirements of EN61010-1.

1.12.7 EMC

Complies with EN61326 for emissions and immunity.

2 6440 SPECIFICATION

Wayne Kerr Electronics Limited reserves the right to change specification without notice

2.1 Measurement Parameters

Any of the following parameters can be measured and displayed:

DC Functions

Resistance (Rdc).

AC Functions

Capacitance (C), Inductance (L), Resistance (R), Conductance (G), Susceptance (B), Reactance (X), Dissipation Factor (D), Quality Factor (Q), Impedance (Z), Admittance (Y) and Phase Angle (θ).

The following display formats are available:

Series or Parallel Equivalent Circuit

C+R, C+D, C+Q, L+R, L+Q

Series Equivalent Circuit Only

X+R, X+D, X+Q

Parallel Equivalent Circuit Only

C+G, B+G, B+D, B+Q

Polar Form

Z + Phase Angle, Y + Phase Angle

2.2 Test Conditions

2.2.1 AC Drive

Frequency Range

20Hz to 3MHz >1800 steps

Accuracy of set frequency ±0.005%

Pre-set frequencies

Coarse step setting

20, 25, 30, 40, 50, 60, 80, 100, 120, 150; repeats for each decade.

Fine step setting

Step size 1% or better throughout range.

Drive Level (AC Measurements)

Open Circuit Voltage	Short Circuit Current	Frequency Range
1mV to 10V rms	50µA to 200mA rms	up to 300kHz
1mV to 5V rms	50µA to 100mA rms	up to 500kHz
1mV to 2.5V rms	50µA to 50mA rms	up to 3MHz

Signal source impedance: 50Ω nominal

Step Size

Voltage Drive		Current Drive	
Step size	up to drive level	Step size	up to drive level
1mV	100mV	50µA	5mA
2mV	200mV	100µA	10mA
5mV	500mV	200µA	20mA
10mV	1V	500µA	50mA
20mV	2V	1mA	100mA
50mV	5V	2mA	200mA *
100mV	10V *		

* Drive levels are reduced to 9V and 180mA at 40Hz or below.

Automatic Level Control (ALC) ensures that the drive level at the device under test (DUT) is ±2% ±1mV of set voltage or ±2% ±0.1mA of set current between 100Hz and 500kHz.

Drive level accuracy degrades below 100Hz: ±3% ±1mV or ±3% ±0.1mA at 50Hz
±5% ±1mV or ±5% ±0.1mA at 20Hz

Drive level accuracy degrades above 500kHz: ±4% ±1mV or ±4% ±0.1mA at 1MHz
±8% ±1mV or ±8% ±0.1mA at 3MHz

With DC bias applied the maximum drive voltages indicated above are halved.

2.2.2 DC Bias Voltage

A DC bias voltage derived from an internal or external source can be applied to capacitors during AC measurements.

Internal

DC bias of 2V ±5%.

Peak short circuit current <90mA.

External

External bias of up to ±60V is provided by connecting an external power supply to the rear panel bias terminals. The voltage required at the rear terminals is 5% higher than the voltage at the DUT.

A bias load of 220Ω is permanently connected across the rear panel bias terminals.

Steady state short circuit load: 70Ω.

A resettable trip protects the bias circuit against a continuous short circuit.

2.2.3 Drive Level (Rdc)

Two selectable drive levels:

Open circuit voltage	Short circuit current
100mV ±7%	1mA
1V ±7%	10mA

Source resistance: 100Ω nominal.

2.3 Measurement Speeds

Four selectable speeds for all measurement functions. Selecting slower measurement speed increases reading resolution and reduces measurement noise by averaging.

The following measurement periods apply for Rdc or for AC measurements ≥100Hz.

Maximum speed (intended for automatic sorting) ≈ 50ms.
Fast speed (for non-critical measurements) ≈ 100ms.
Medium speed (for improved resolution) ≈ 300ms.
Slow speed (for best resolution and enhanced supply frequency rejection) ≈ 900ms.

2.3.1 Capacitor Mode

Two frequency measurement ≈ 180ms.

2.4 Measurement Ranges

R, Z , X	0.01mΩ to >2GΩ
G, Y, B	0.01nS to >2kS
L	0.05nH to >2kH
C	0.5fF to >1F
D	0.00001 to >1000
Q	0.00001 to >1000
Rdc	0.1mΩ to >10MΩ

For L and C, the lower range is available at 10kHz, 100kHz and 1MHz; the upper range is available at 100Hz and below.

2.5 Hardware Ranges

The hardware range used is determined by the impedance being measured, the frequency and the level. The table below lists the boundaries of operation for AC measurement functions. The hardware range being used is indicated in the top-left-hand-corner of the instrument display.

Range Number	Impedance coverage	Frequency coverage up to
1	<1Ω	100kHz
2	<10Ω	1MHz
3	<50Ω	3MHz
4	>50Ω	3MHz
5	>250Ω	3MHz
6	>2.5kΩ	1MHz
7	>25kΩ	100kHz
8	>250kΩ	10kHz

For drive levels below 100mV, the highest range at each frequency is not available.
For drive levels below 20mA, range 1 is not available.
For drive levels below 0.5mA, range 2 is not available.

2.6 Modes Of Operation

2.6.1 MEASUREMENT

Selection of any measurement parameter and test condition.

Single-level function-menu controlled by keypad and soft keys.

Single and repetitive measurements displaying major and minor terms.

Analogue scale with configurable Hi/Lo limits giving PASS/FAIL indication (connected to logic output on binning option).

2.6.2 DEVIATION

Similar to MEASUREMENT MODE but relative or percentage deviation from nominal value displayed for major or minor term. There is no analogue scale in DEVIATION MODE.

2.6.3 MULTI FREQUENCY

Measurement parameters and test conditions set using MEASUREMENT MODE.

Up to 8 frequencies with configurable major and minor term limits.

PASS/FAIL indication (connected to logic output on binning option).

2.6.4 GRAPH

Measurement parameters and test conditions set using MEASUREMENT MODE.

Graphical sweep vs. frequency with selection of start frequency, stop frequency and step size. Linear/linear and linear/log scaling available on all measurement parameters. Log/log scaling available on Z/Y parameters.

Graph may be directly plotted on a printer or saved to a file over GPIB.

2.6.5 BINNING (Optional)

Measurement parameters and test conditions set using MEASUREMENT MODE.

8 PASS bins with absolute or percentage limits and 1 FAIL bin. Up to 99 sets of limits may be saved.

Bin count function logs the number of components in each bin.

Dedicated output for PASS/FAIL indication. Driven by analogue scale limits in MEASUREMENT MODE or by test limits in MULTI FREQUENCY MODE.

Trigger input with pull-up, operates on logic low or contact closure.

Handshake outputs indicating measure busy and data valid status.

25-way D-type interface connector.

Output Levels (B1 Option)

Output High:	>4V	Output Low:	<1V
Input High:	>3.5V	Input Low:	<1.5V

Drive capability typically is 10mA sink (low) and 30µA (high).

Output Levels (B2 Option)

This option provides an opto-coupled interface.

Output On state current:	up to 10mA at 24V	Output Off state current:	<0.5mA
Output On state voltage:	Input voltage –1.5V at 10mA		
Input High current:	>3mA	Input Low current:	<1.25mA
Input High voltage:	>15.4V	Input Low voltage:	<8V

2.6.6 CAPACITOR (Optional)

Combines the Multi Frequency and Binning modes for efficient testing of capacitors.

Measurement parameters and test conditions set using MEASUREMENT MODE.

Up to 8 frequencies with configurable major and minor term limits. The first frequency may be tested against up to 9 bins. The Major term is tested to a tolerance limit while the Minor term is compared to a relative limit. Measurements at subsequent frequencies may be compared to a single reject limit. A measurement term swap function is available if the minor term is required to be tested against a tolerance limit.

2.7 Measurement Connections

4 front panel BNC connectors permit 2-, 3- and 4-terminal connections with the screens at ground potential.

Terminals withstand connection of charged capacitor up to following limits:

- any value capacitor charged up to 50V, either polarity;
- a capacitor charged to between 50V and 500V with a stored energy of less than 0.25J, either polarity.

2.8 Measurement Accuracy

The accuracy statements given apply when the instrument is used under the following measurement conditions.

1V (DUT >50Ω) or 20mA (DUT <50Ω), slow speed, 4-terminal measurement. The instrument must have warmed up for at least 30 minutes at a steady ambient temperature of between 15°C and 35°C. The instrument must have been trimmed with its measuring leads and fixture at the measurement frequency. For frequencies above 20kHz, HF lead compensation must have been performed.

For other frequencies and speeds see section 2.9—Accuracy Charts.

2.8.1 Resistance / Reactance (R / X)

Frequency	Accuracy % (for Q < 0.1)	Range for specified accuracy
100Hz /120Hz	0.05	1Ω to 1.6MΩ
1kHz (Notes 1, 2)	0.02	10Ω to 100kΩ
1kHz	0.05	1Ω to 1.6MΩ
10kHz	0.05	1Ω to 1.6MΩ
10kHz	0.1	0.3Ω to 4.7MΩ
100kHz	0.05	25Ω to 100kΩ
100kHz	0.1	2.5Ω to 500kΩ
1MHz	0.1	30Ω to 16kΩ
1MHz	0.2	12Ω to 30kΩ

For Q ≥0.1 multiply accuracy figures by (1+Q).

2.8.2 Conductance / Susceptance (G / B)

Frequency	Accuracy % (for Q < 0.1)	Range for specified accuracy
100Hz /120Hz	0.05	0.63µS to 1S
1kHz (Notes 1, 3)	0.02	10µS to 0.1S
1kHz	0.05	0.63µS to 1S
10kHz	0.05	0.63µS to 1S
10kHz	0.1	0.22µS to 3.3S
100kHz	0.05	10µS to 0.04S
100kHz	0.1	2µS to 0.4S
1MHz	0.1	62.5µS to 67mS
1MHz	0.2	33µS to 83mS

For Q ≥0.1 multiply accuracy figures by (1+Q).

2.8.3 Capacitance (C)

Frequency	Accuracy % (for D <0.1)	Range for specified accuracy
100Hz /120Hz	0.05	1nF to 1mF
1kHz	0.05	100pF to 100µF
10kHz	0.05	50pF to 10µF
100kHz	0.05	50pF to 100nF
100kHz	0.1	25pF to 350nF
1MHz	0.1	60pF to 2.5nF
1MHz	0.2	30pF to 10nF

For D ≥0.1 multiply accuracy figures by (1+D).

2.8.4 Inductance (L)

Frequency	Accuracy % (for Q >10)	Range for specified accuracy
100Hz /120Hz	0.05	1mH to 1000H
1kHz	0.05	100µH to 100H
10kHz	0.05	20µH to 10H
100kHz	0.1	8µH to 160mH
1MHz	0.2	2µH to 4mH

For Q ≤10, multiply the accuracy figure by (1+1/Q).

2.8.5 Dissipation Factor (D)

Frequency	Accuracy (A_d)	Range for specified accuracy
100Hz /120Hz	0.0005	1nF to 1mF
1kHz (Note 1)	0.0002	1nF to 100µF
1kHz	0.0005	100pF to 400µF
10kHz	0.0005	100pF to 10µF
100kHz	0.0005	100pF to 60nF
100kHz	0.001	25pF to 600nF
1MHz	0.001	25pF to 2.5nF
1MHz	0.002	10pF to 10nF

For capacitors within the ranges shown above , D accuracy = $\pm A_d (1+D^2)$.

2.8.6 Quality Factor (Q)

Frequency	Accuracy % (A_L)	Range for specified accuracy
100Hz /120Hz	0.05	4mH to 1000H
1kHz	0.05	100µH to 100H
10kHz	0.05	20µH to 10H
100kHz	0.1	7µH to 160mH
1MHz	0.2	3.5µH to 4mH

For inductors within the ranges shown above , Q accuracy = $\pm A_L$ (Q+1/Q)

2.8.7 DC Resistance (Rdc)

Drive Level	Accuracy %	Range for specified accuracy
100mV	0.25	10Ω to 10kΩ
1V	0.1	1Ω to 100kΩ

Notes

1) Accuracy is typical for 15°C to 35°C, guaranteed for 20°C to 30°C.
2) Accuracy applies to resistance only.
3) Accuracy applies to conductance only.

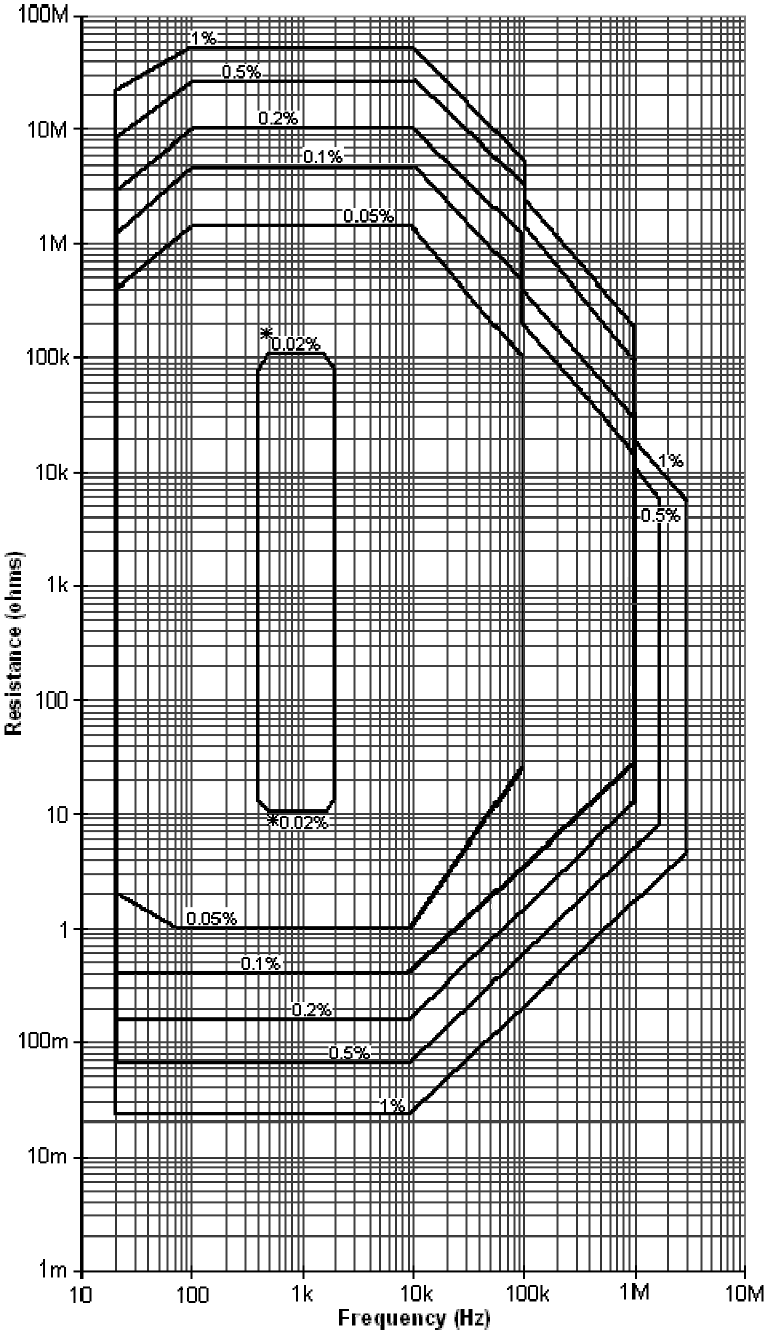
2.9 Accuracy Charts

Iso-accuracy charts define the measurement ranges available, at specified accuracies, over the available frequency band. All curves assume that Slow measurement speed is used, that the analyzer has been trimmed at the frequency used for measurements, that both factory calibration and self calibration are valid, that HF compensation has been performed on the fixture configuration being used and that the component under test is pure. Beside each chart is a summary of these conditions and the information on the accuracy applicable when some or all of the conditions change.

For above and below the ranges indicated in the following charts, the accuracy degrades linearly with increasing/decreasing DUT value. For example, 470MΩ and 2.5mΩ measured at 10kHz are both a factor of 10 beyond the indicated range for 1% and will each have an accuracy of 10%.

Measurement accuracy for the optional Multi Frequency capacitor mode conforms to the maximum speed setting.

2.9.1 R / G / Z* Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Coarse Step frequencies.
Analyzer trimmed at measurement frequency.
Q ≤0.1
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

* R / G Only

typical figure for 25 ±10ºC,
guaranteed for 25 ±5ºC.

O/C and S/C trim corrections under various conditions of interpolation, speed and level, and corrections for fine frequency settings are as given in the table following these iso-accuracy charts.

For impure components, and for measurements of the highest and lowest available ranges, full accuracy expressions, shown below, apply.

If 1 > Q > 0.1, multiply R accuracy by (1+Q).
For Q > 1 (loss resistance of inductor) see Q accuracy chart.
For D < 1 (loss resistance of capacitor) see D accuracy chart

High resistance values

Accuracy = ± (A + A_F + 100Y_T . R_X) %

Low resistance values

Accuracy = ± (A + 100R_T / R_X) %

where

A = accuracy from adjacent chart
A_F = fine frequency setting correction (as appropriate from section 2.10.3).
R_X = measured value of unknown component.
R_T = sum of Z_I, Z_L (as appropriate, from section 2.10.2)
Y_T = sum of Y_I, Y_L, G_F (as appropriate, from sections 2.10.1 and 2.10.3)

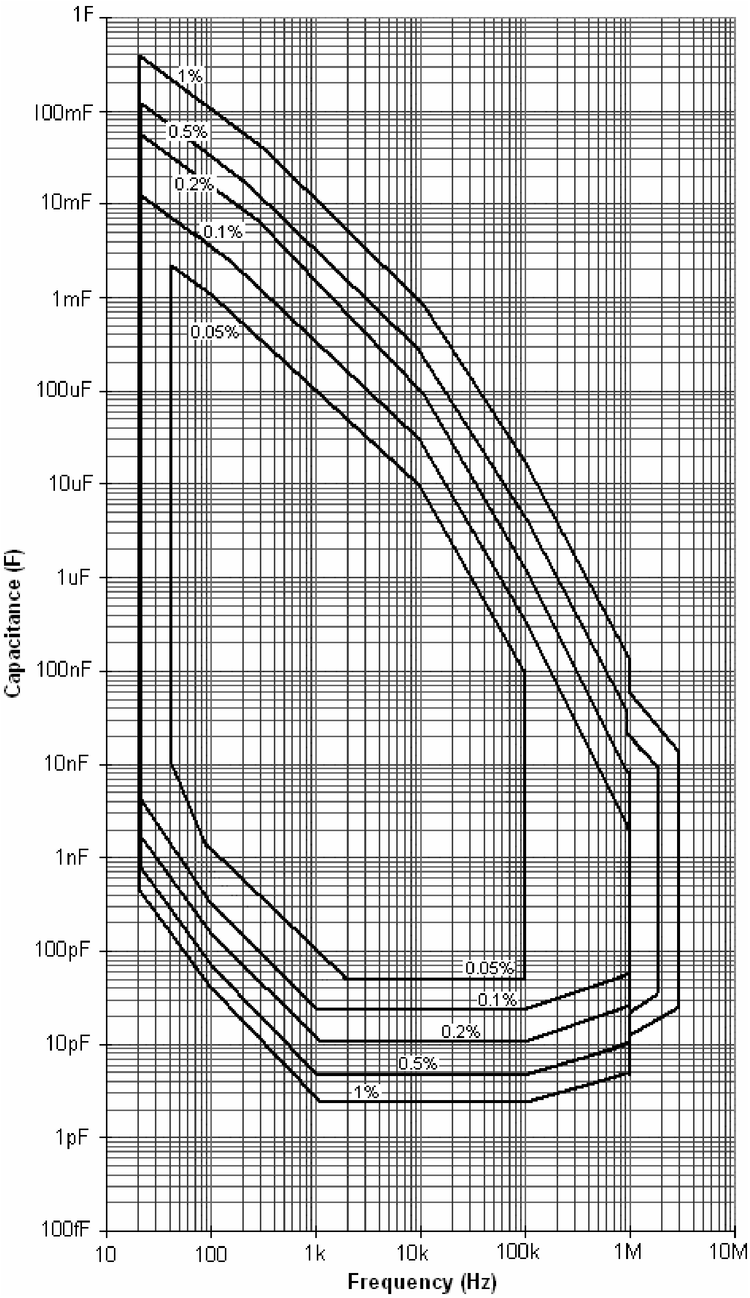
Conductance (G)

Find accuracy for equivalent R value from R = 1/G

Admittance (Y)

Find accuracy for equivalent Z value from Z = 1/Y.

2.9.2 C Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Coarse Step frequencies.
Analyzer trimmed at measurement frequency.
D ≤0.1
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

O/C and S/C trim corrections under various conditions of interpolation, speed and level, and corrections for fine frequency settings are as given in the table following these iso-accuracy charts.

For impure components, and for measurements of the highest and lowest available ranges, full accuracy expressions, shown below, apply.

If D > 0.1, multiply C accuracy by (1+D).

High capacitance values

Accuracy = $\pm$ (A + A_F + 100 X_T . ω C_X) %

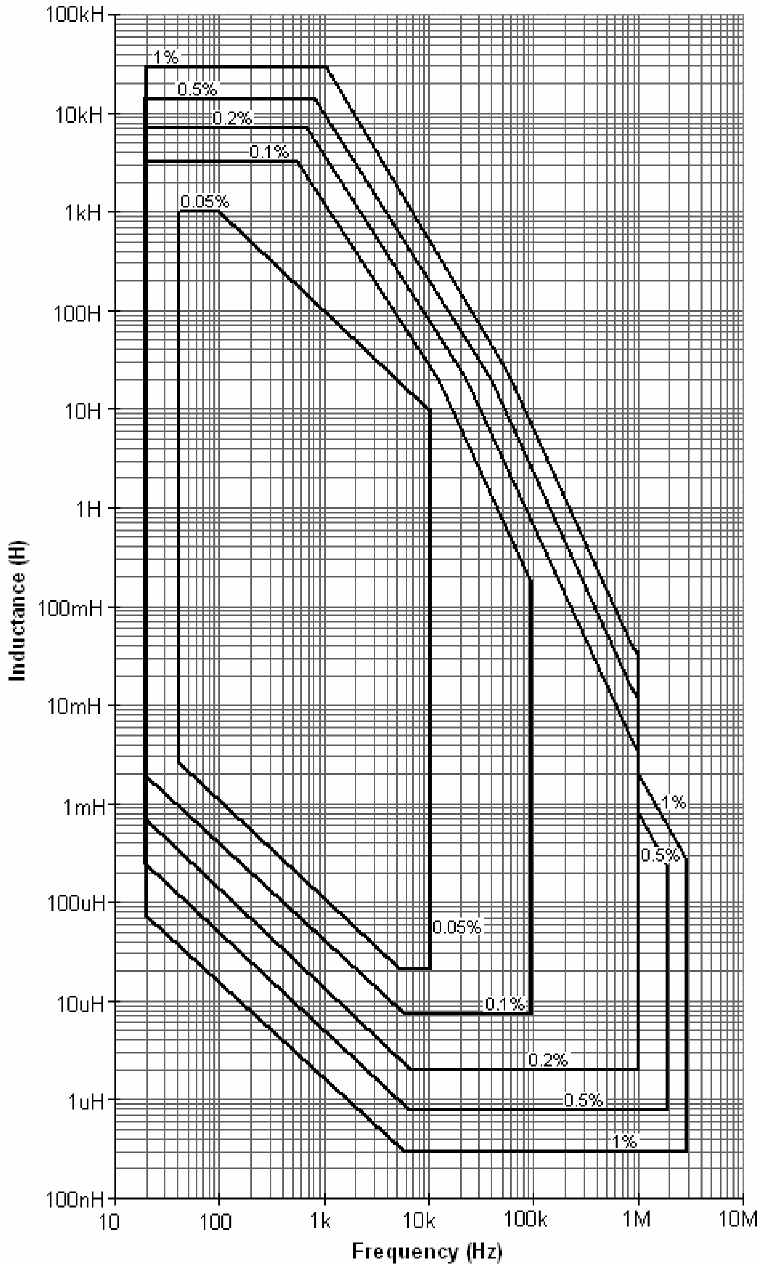
Low capacitance values

Accuracy = $\pm$ (A + 100 C_T / C_X) %

where

A = accuracy from adjacent chart
A_F = fine frequency setting correction (as appropriate from section 2.10.3).
C_X = measured value of unknown component.
X_T = sum of Z_I, Z_L (as appropriate, from section 2.10.2)
C_T = sum of C_I, C_F, C_L (as appropriate, from sections 2.10.1 and 2.10.3)
$\omega = 2\pi$. frequency

2.9.3 L Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Coarse Step frequencies.
Analyzer trimmed at measurement frequency.
Q ≥10
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

O/C and S/C trim corrections under various conditions of interpolation, speed and level, and corrections for fine frequency settings are as given in the table following these iso-accuracy charts.

For impure components, and for measurements of the highest and lowest available ranges, full accuracy expressions, shown below, apply.

If Q < 10, multiply L accuracy by (1+1/Q).

High inductance values

Read accuracy direct from chart

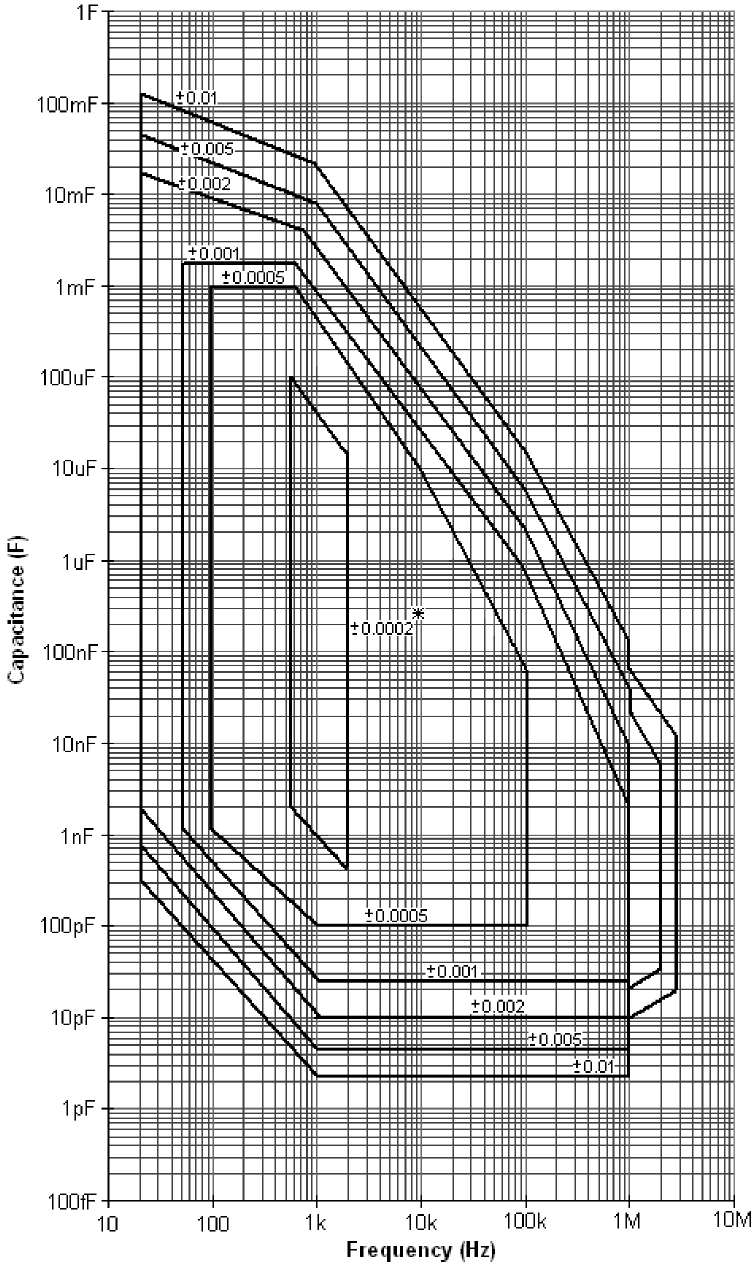
Low inductance values

Accuracy = ± (A + 100 L_T / L_X) %

where

A = accuracy from adjacent chart
L_X = measured value of unknown component.
L_T = sum of L_I, L_L (as appropriate, from section 2.10.2)

2.9.4 D Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Coarse Step frequencies.
Analyzer trimmed at measurement frequency.
D ≤0.1
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

* typical figure for 25 ±10ºC, guaranteed for 25 ±5ºC.

O/C and S/C trim corrections under various conditions of interpolation, speed and level, and corrections for fine frequency settings are as given in the table following these iso-accuracy charts.

For impure components, and for measurements of the highest and lowest available ranges, full accuracy expressions, shown below, apply.

If D > 0.1, multiply D accuracy by $(1+D^2)$.

High capacitance values

D accuracy = $\pm (A + R_T \,.\, \omega\, C_X)$

Low capacitance values

D accuracy = $\pm (A + Y_T / \omega\, C_X)$

Capacitor series loss resistance (esr)

Accuracy = $\pm (A/\omega\, C_X)\ \Omega$

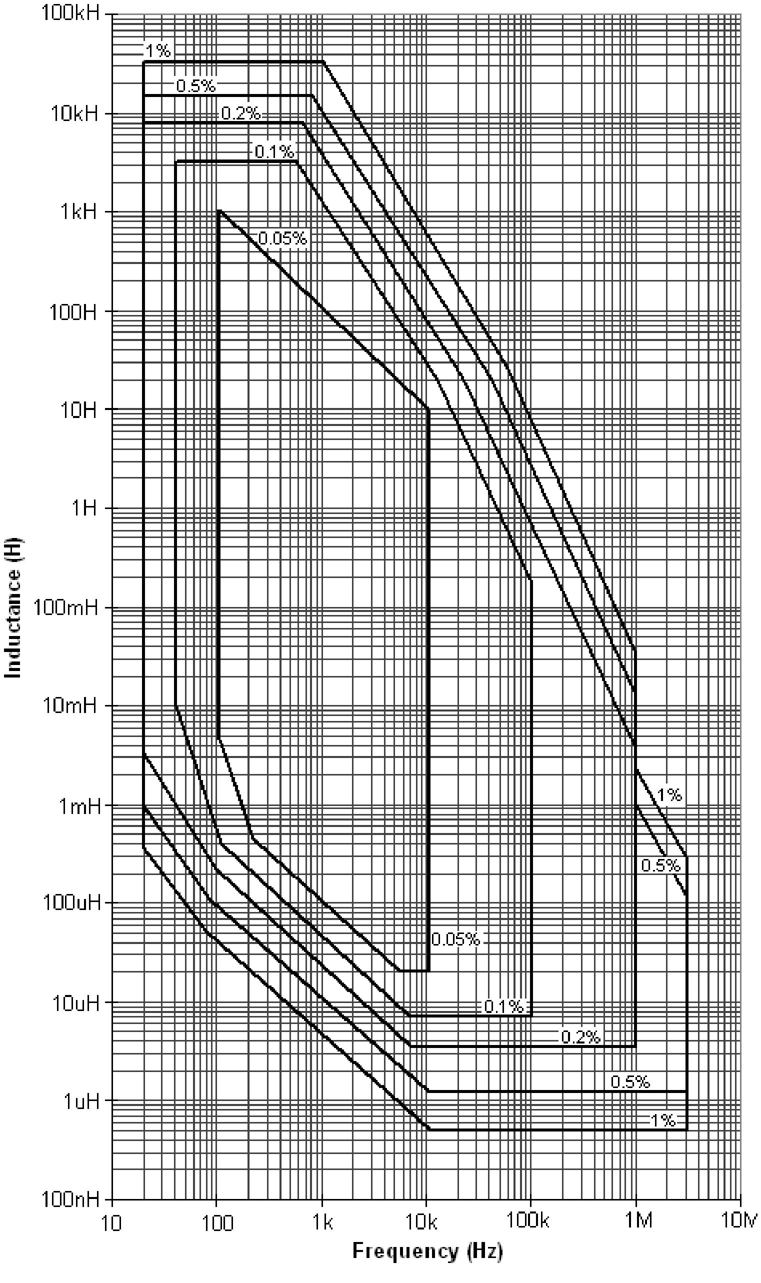
Capacitor parallel loss resistance (epr)

Accuracy = $\pm (100A\, R_X \,.\, \omega\, C_X)$ %

where

A = accuracy from adjacent chart
C_X = measured value of unknown component
R_X = measured value of unknown component
R_T = sum of Z_I, Z_L, $1/G_F$ (as appropriate, from sections 2.10.2 and 2.10.3)
Y_T = sum of Y_I, Y_L (as appropriate, from section 2.10.1)
$\omega = 2\pi$. frequency

2.9.5 Q Accuracy



Conditions

AC Drive Level: 1V/20mA
Slow Speed. 4-Terminal Mode.
Coarse Step frequencies.
Analyzer trimmed at measurement frequency.
Temperature range 25 ±10ºC.

Except on the highest and lowest hardware measurement ranges, the adjacent iso-accuracy chart also applies to Medium measurement speed.

For Fast speed, on all ranges, the Medium speed figures must be doubled. Supply frequency rejection is also reduced causing additional unquantifiable errors dependent on lead layout, particularly at frequencies below 600Hz and at lower AC drive levels.

O/C and S/C trim corrections under various conditions of interpolation, speed and level, and corrections for fine frequency settings are as given in the table following these iso-accuracy charts.

For all Q values

Q accuracy =A (Q + 1/Q)

High inductance values

Read Q accuracy direct from chart

Low inductance values

Q accuracy = ± ((A + $100R_T$ / ωL_X) (Q+1/Q)) %

Inductor series loss resistance

Accuracy = ± (A. $\omega L_X / R_X$) %

Inductor parallel loss resistance

$$\text{Accuracy} = \pm \frac{A \,.\, R_X}{\omega L_X} \%$$

where

A = accuracy from adjacent chart
L_X = measured value of unknown component
R_X = measured value of unknown component
R_T = sum of Z_I, Z_L (as appropriate, from section 2.10.2)
$\omega = 2\pi$. frequency

2.10 Additional Corrections

The following tables give the additional corrections which need to be applied to measurements when some or all the measurement conditions specified in the Iso_Accuracy charts are not used.

2.10.1 Open Circuit Trim Correction

f = frequency in kHz

Frequency range (Hz)	Interpolation		Level 1.02 - 10V	
	Y_I (nS)	C_I (pF)	Y_L (nS)	C_L (pF)
20 - 250	1	0.15 / f	1	0.015 / f
300 - 10k	0.2	0.03 / f	0.2	0.03 / f
12k - 100k	0.12 x f	0.02	0.12 x f	0.02
120k - 300k	0.31 x f	0.05	0.31 x f	0.05
302k - 1M (1)	0.31 x f	0.05	0.31 x f	0.05
1.01M - 3M (2)	3.1 x f	0.5	3.1 x f	0.5

f = frequency in kHz, V= drive level in V

Frequency range (Hz)	Level 0.1 - 0.98V		Level < 0.1V	
	Y_L (nS)	C_L (pF)	Y_L (nS)	C_L (pF)
20 - 250	0.4 / V	0.06 / (f x V)	0.4 / V	0.06 / (f x V)
300 - 10k	0.1 / V	0.015 / (f x V)	0.1 / V	0.015 / (f x V)
12k - 100k	0.12 x f	0.02	0.012 x f / V	0.002 / V
120k - 300k	0.31 x f	0.05	0.031 x f / V	0.005 / V
302k - 640k (1)	0.31 x f	0.05	0.031 x f / V	0.005 / V
645k - 1M (1)	0.31 x f	0.05	0.31 x f / V	0.05 / V
1.01M - 3M (2)	3.1 x f	0.5	0.31 x f / V	0.05 / V

2.10.2 Short Circuit Trim Correction

f = frequency in kHz

Frequency range (Hz)	Interpolation		Level 2 - 200mA	
	Z_I (μΩ)	L_I (nH)	Z_L (μΩ)	L_L (nH)
20	1500	240 / f	1500	240 / f
25-80	1000	160 / f	1000	160 / f
100	500	80 / f	500	80 / f
120 -10k	250	40 / f	250	40 / f
12k - 300k	18 x f	3	18 x f	3
302k -1M (1)	18 x f	3	18 x f	3
1.01M - 3M (2)	36 x f	6	36 x f	6

For drive levels below 2mA multiply level corrections in previous column by 2 / (level in mA).

(1) Level restricted to 5V/100mA
(2) Level restricted to 2.5V/50mA

2.10.3 Fine Frequency Setting Corrections

Drive level = 1V

Frequency range (Hz)	C_F (fF)	A_F (%)	G_F (nS)	A_F (%)
20k - 100k	10	0.02	0.063 x f	0.02
101k - 1M	20	0.035	0.126 x f	0.035
1.01M - 3M	100	0.065	0.630 x f	0.065

Drive level <1V

Frequency range (Hz)	C_F (fF)	A_F (%)	G_F (nS)	A_F (%)
20k - 100k	10 / level in V	0.02 / level in V	0.063 x f / level in V	0.02 / level in V
101k - 1M	20 / level in V	0.035 / level in V	0.126 x f / level in V	0.035 / level in V
1.01M - 3M	100 / level in V	0.065 / level in V	0.630 x f / level in V	0.065 / level in V

Drive level >1V

Frequency range (Hz)	C_F (fF)	A_F (%)	G_F (nS)	A_F (%)
20k - 100k	30	0.03	0.19 x f	0.03
101k - 1M	100	0.04	0.63 x f	0.04
1.01M - 3M	900	0.175	5.65 x f	0.175

2.11 General

2.11.1 Power Supply

Input Voltage	115V AC ±10% or 230V AC ±10% (selectable)
Frequency	50/60Hz
VA rating	150VA max
Input fuse rating	115V operation: 2AT
	230V operation: 1AT
	The input fuse is in the fuse holder drawer integral to the IEC input connector.

2.11.2 Display

High contrast black and white LCD module 320 x 240 pixels with CPL back lighting.

Visible area 115 x 86mm.

2.11.3 Printer Output

Centronics/parallel printer port for print out of measurement results, bin count data and graphical display.

2.11.4 Remote Control

Designed to GPIB IEEE-488.2 and SCPI 1992.0.

2.11.5 Remote Trigger

Rear panel BNC with internal pull-up, operates on logic low or contact closure.

2.11.6 Mechanical

Height	150mm (5.9")
Width	440mm (17.37")
Depth	525mm (20.5")
Weight	11kg (24.25lbs)

2.12 Environmental Conditions

This equipment is intended for indoor use only in a non-explosive and non-corrosive atmosphere.

2.12.1 Temperature Range

Storage: -40°C to +70°C.
Operating: 0°C to 40°C.
Normal accuracy: 15°C to 35°C. See section 2.8—Measurement Accuracy for full specification.

2.12.2 Relative Humidity

Up to 80% non-condensing.

2.12.3 Altitude

Up to 2000m.

2.12.4 Installation Category

II in accordance with IEC664.

2.12.5 Pollution Degree

2 (mainly non-conductive).

2.12.6 Safety

Complies with the requirements of EN61010-1.

2.12.7 EMC

Complies with EN61326 for emissions and immunity.

3 THEORY REFERENCE

3.1 Abbreviations

B	Susceptance (= 1/X)	R	Resistance
C	Capacitance	X	Reactance
D	Dissipation factor (tan δ)	Y	Admittance (= 1/Z)
E	Voltage	Z	Impedance
G	Conductance (= 1/R)	ω	2π x frequency
I	Current		
L	Inductance	Subscript s ($_s$) = series	
Q	Quality (magnification) factor	Subscript p ($_p$) = parallel	

3.2 Formulae

$$Z = \frac{E}{I} \qquad \text{(all terms complex)}$$

$$Y = \frac{I}{E} = \frac{1}{Z}$$

$$Z_s = R + jX = R + j\omega L = R - \frac{j}{\omega C}$$

$$|Z_s| = \sqrt{(R^2 + X^2)}$$

$$|Z_p| = \frac{RX}{\sqrt{(R^2 + X^2)}}$$

$$Y_p = G + jB = G + j\omega C = G - \frac{j}{\omega L}$$

$$|Y_p| = \sqrt{(G^2 + B^2)}$$

$$|Y_s| = \frac{GB}{\sqrt{(G^2 + B^2)}}$$

where $X_L = \omega L$ $\quad X_C = \frac{1}{\omega C}$ $\quad B_C = \omega C$ $\quad B_L = \frac{1}{\omega L}$

$$Q = \frac{\omega L_S}{R_S} = \frac{1}{\omega C_S R_S} \qquad \text{(series R, L, C values)}$$

$$Q = \frac{R_P}{\omega L_P} = \omega C_P R_P \qquad \text{(parallel R, L, C values)}$$

$$D = \frac{G_P}{\omega C_P} = \omega L_P G_P \quad \text{(parallel G, L, C values)}$$

$$D = \frac{R_S}{\omega L_S} = \omega C_S R_S \quad \text{(series R, L, C values)}$$

Note : The value $Q = \frac{1}{D}$ is constant regardless of series/parallel convention

3.3 Series/Parallel Conversions

$$R_S = \frac{R_P}{\left(1+Q^2\right)} \qquad R_P = R_S\left(1+Q^2\right)$$

$$C_S = C_P\left(1+D^2\right) \qquad C_P = \frac{C_S}{\left(1+D^2\right)}$$

$$L_S = \frac{L_P}{\left(1+\frac{1}{Q^2}\right)} \qquad L_P = L_S\left(1+\frac{1}{Q^2}\right)$$

Conversions using the above formulae will be valid only at the test frequency.

3.4 Polar Derivations

$$R_S = |Z|\cos\theta \qquad G_P = |Y|\cos\theta$$

$$X_S = |Z|\sin\theta \qquad B_P = |Y|\sin\theta$$

Note that, by convention, +ve angle indicates an inductive impedance or capacitive admittance.

If capacitance is measured as inductance, the L value will be –ve.

If inductance is measured as capacitance, the C value will be –ve.

$D = \tan\delta$ where $\delta = (90 - \theta)^\circ$ admittance measurement.

$Q = \frac{1}{\tan\delta}$ where $\delta = (90 - \theta)^\circ$ impedance measurement.