POT/GAL 15 V 10 A
and
POT/GAL 30 V 2 A

Electrochemical Impedance Potentiostat Galvanostat Test Interface for Alpha-A Analyzer

Technical Specification

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1. Technical Data POT/GAL 15 V 10 A

General

Line voltage	220 - 240 V ac, 50 - 60 Hz or 110 V ac, 50 - 60 Hz (see instrument rear)
Power consumption	< 400 W
Environment	
Operating temperature	0 ° to 40 °C
Storage temperature	-10 ° to 60 °C
Specification limits	15 ° to 25 °C

Counter Electrode Polarization

Voltage	+-15 Vp dc and / or ac
DC Accuracy	1mV + 10^{-4} of value
Resolution	
DC	0.5 mV
AC	10 µV
Current	+-10 Ap dc and / or ac
DC Accuracy	10^{-3} of value + $3 \cdot 10^{-4}$ of range + 2 pA
Resolution	+-1/32768 of current range, 0.1 pA min.
Output Power	120 W max
Internal Power Dissipation	10 A Current into shorted load without overheating
Output Resistance	0.1 .. 1 kΩ in factors of 10
Bandwidth	DC .. 1 MHz
Voltage Limit	1 .. 20V
Accuracy	0.5 V
Current Limit	1 mA .. 10.5 A
Accuracy	10 % of value + 5 % of range

Reference Voltage Inputs

Configurations	Single or differential configuration with selectable driven shields
Voltage Range	+-15 Vp
DC Accuracy	100 µV + 10^{-4} of value
DC Resolution	10 µV
Input impedance	> 10^{12} Ω | 10 pF
Common Mode Rejection	< 10^{-4} below 100 kHz < 10^{-3} below 1 MHz
Input Bias Current	< $2 \cdot 10^{-12}$ A
Bandwidth	DC .. 10 MHz

Working Electrode Current Input

Current Ranges	100 pA .. 10 A in factors of 10
DC Accuracy	10^{-3} of value + $3 \cdot 10^{-4}$ of range + 1 pA
Resolution	10^{-5} of range, 0.1 pA min.
Bandwidth	dc .. 10 MHz

Main Control Loop

Operation modes	Potentiostat, Galvanostat and Direct Voltage
DC accuracy	100 µV + 10^{-4} of value
Time constants	0.3 ms .. 3 s in factors of 3.33
Bandwidth	DC .. 10 MHz
Electrolyte Rs compensation	Automatic Rs detection by high frequency EIS Rs compensation or correction

Impedance Measurement

Frequency range	3 µHz .. 1 MHz
Impedance range	10^{-3} .. 10^{13} Ω
Capacitance range	1 fF ... 1 F
Basic Accuracy	
Relative Impedance, Capacity, Loss factor tan(δ)	< $2 \cdot 10^{-4}$ ***, Phase Angle < 6 m° ***
Resolution	
Relative Impedance, Capacity, Loss factor tan(δ)	< 10^{-5}, Phase Angle < 0.6 m

Internal Reference Capacitors 100 pF, 1 nF

*** For details, refer to the specification charts in the "Impedance Measurement Ranges and Accuracy" chapter.

2. Technical Data POT/GAL 30 V 2 A

General

Line voltage	220 - 240 V ac, 50 - 60 Hz or 110 V ac, 50 - 60 Hz (see instrument rear)
Power consumption	< 300 W
Environment	
Operating temperature	0 ° to 40 °C
Storage temperature	-10 ° to 60 °C
Specification limits	15 ° to 25 °C

Counter Electrode Polarization

Voltage	+-30 Vp dc and / or ac
DC Accuracy	2 mV + 10^{-4} of value
Resolution	
DC	1 mV
AC	20 µV
Current	+-2 Ap dc and / or ac
DC Accuracy	10^{-3} of value + $3 \cdot 10^{-4}$ of range + 0.5 pA
Resolution	+-1/32768 of current range, 0.1 pA min.
Output Power	60 W max
Internal Power Dissipation	2 A Current into shorted load without overheating
Output Resistance	1 .. 1 kΩ in factors of 10
Bandwidth	DC .. 1 MHz
Voltage Limit	2 .. 40V
Accuracy	0.5V
Current Limit	2 mA .. 2.1 A
Accuracy	10 % of value + 5 % of range

Reference Voltage Inputs

Configurations	Single or differential configuration with selectable driven shields
Voltage Range	+-30 Vp
DC Accuracy	200 µV + 10^{-4} of value
DC Resolution	20 µV
Input impedance	> 10^{12} Ω | 10 pF
Common Mode Rejection	< 10^{-4} below 100 kHz < 10^{-3} below 1 MHz
Input Bias Current	< $2 \cdot 10^{-12}$ A
Bandwidth	DC .. 10 MHz

Working Electrode Current Input

Current Ranges	20 pA .. 2 A in factors of 10
DC Accuracy	10^{-3} of value + $3 \cdot 10^{-4}$ of range + 0.5 pA
Resolution	10^{-5} of range, 0.05 pA min.
Bandwidth	dc .. 10 MHz

Main Control Loop

Operation modes	Potentiostat, Galvanostat and Direct Voltage
DC accuracy	200 μV + 10^{-4} of value
Time constants	0.3 ms .. 3 s in factors of 3.33
Bandwidth	DC .. 10 MHz
Electrolyte Rs compensation	Automatic Rs detection by high frequency EIS Rs compensation or correction

Impedance Measurement

Frequency range	3 μHz .. 1 MHz
Impedance range	10^{-3} .. 10^{13} Ω
Capacitance range	1 fF ... 1 F
Basic Accuracy	
Relative Impedance, Capacity, Loss factor tan(δ)	< $2 \cdot 10^{-4}$ ***, Phase Angle < 6 m° ***
Resolution	
Relative Impedance, Capacity, Loss factor tan(δ)	< 10^{-5}, Phase Angle < 0.6 m

Internal Reference Capacitors	100 pF, 1 nF

*** For details, refer to the specification charts in the "Impedance Measurement Ranges and Accuracy" chapter.

3. Impedance Measurement Ranges and Accuracy

3.1. Accuracy of Impedance Measurement POT/GAL 15 V 10 A

The specifications below applies for

Temperature 15 °C .. 25 °C
Direct Voltage, Potentiostat or Galvanostat* modes, time constant 1 µs, no dc voltage or current, auto ranging for impedance measurements on.
Ac sample voltage 1 Vrms for |Z| >= 1 Ω or 1 Arms ac sample current for |Z| < 1 Ω
Low Capacity Open calibration enabled, All- and Load Short calibrations done.
Impedance measured for a sample connected by BNC cables with 25 cm length to the POT/GAL terminals.

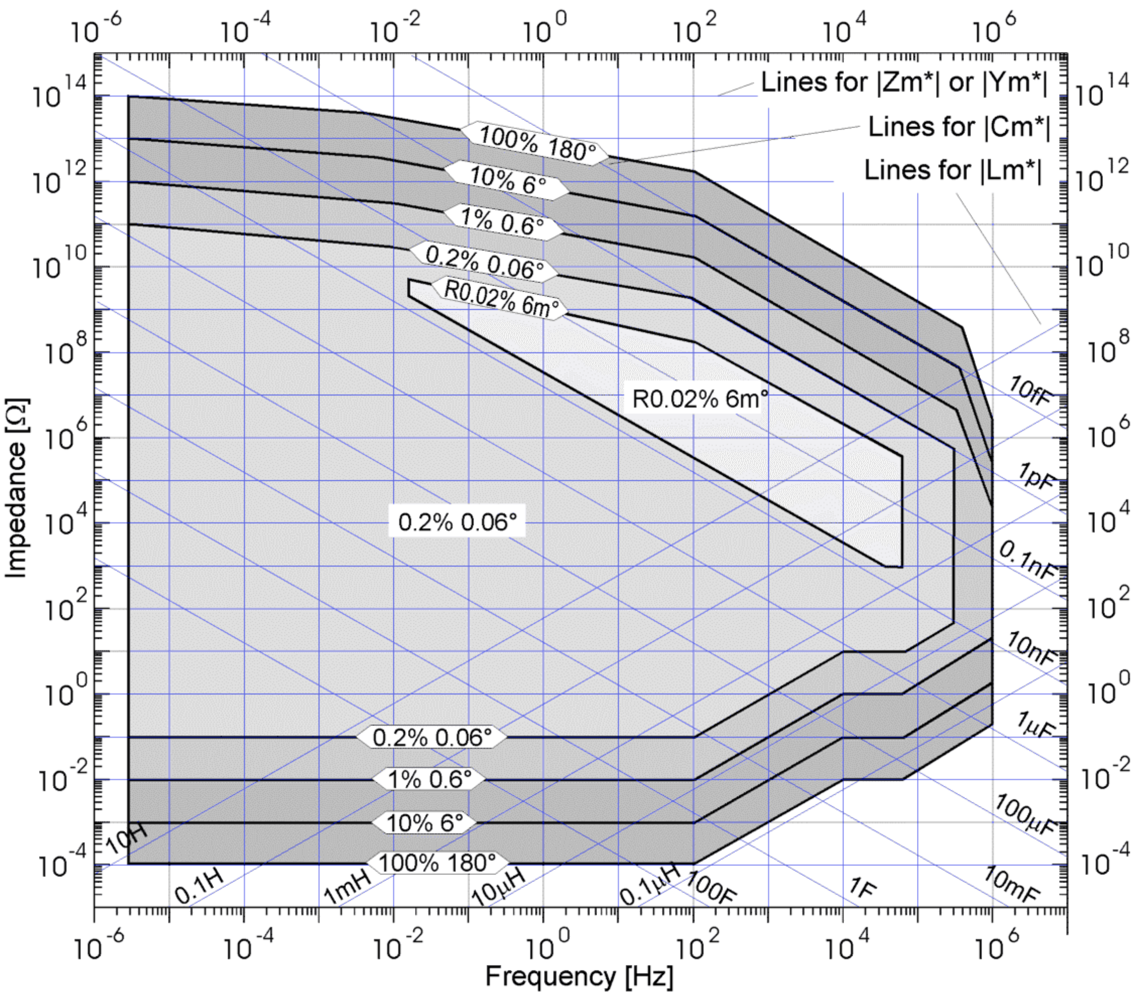

Fig. 1. POT/GAL 4-wire mode impedance measurement accuracy. For details see text below.

*For capacitate samples measured in Galvanostat mode the auto ranging procedure does not use current ranges below 1 mA. If for such kind of samples significantly lower currents in Galvanostat mode have to be measured, manual selection of current range and time constant may be required. For details refer to the POT/GAL user's manual "Current Range Selection and Switching" chapter.

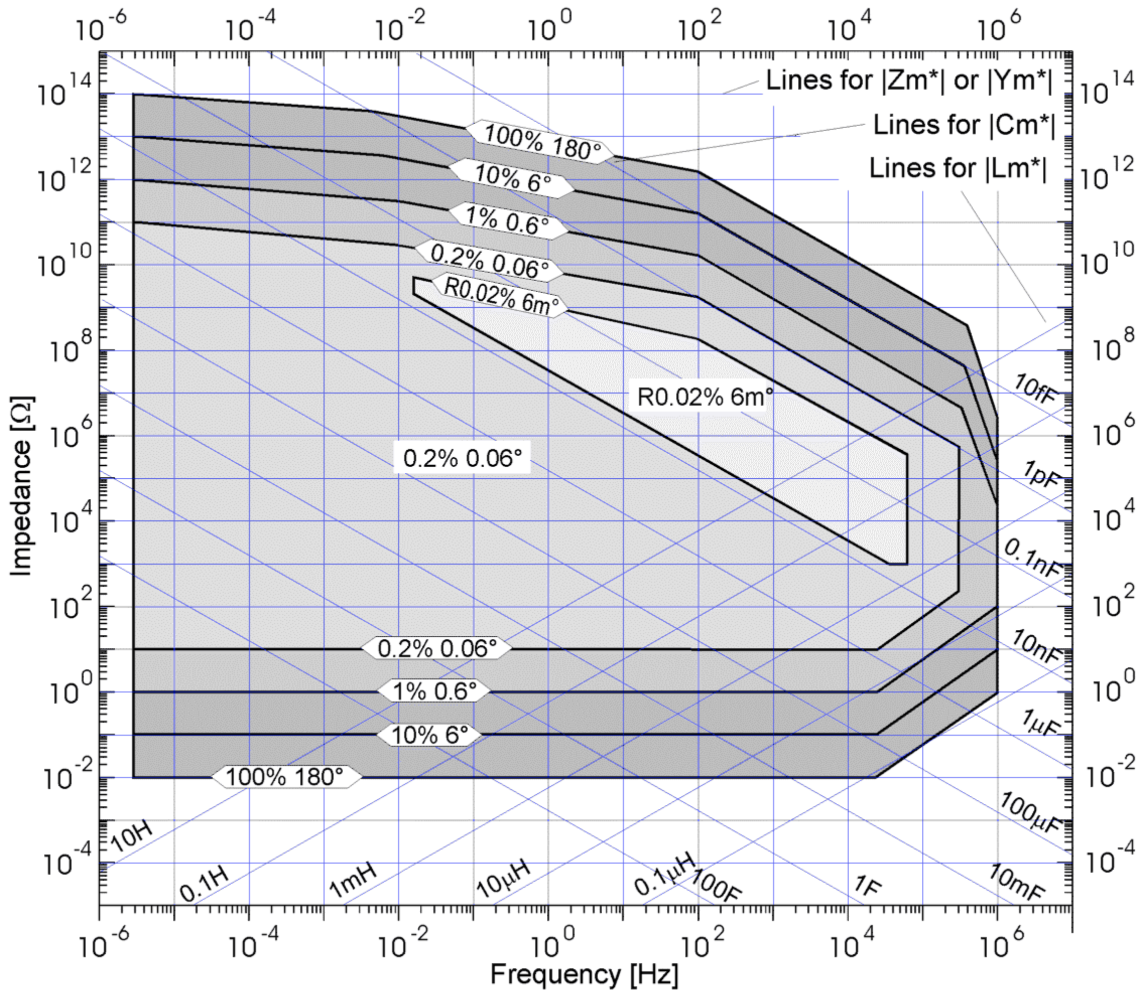

Fig. 2. POT/GAL 2-wire mode impedance measurement accuracy. For details see text below.

For impedance points in the areas between the lines of constant accuracy, the accuracy should be interpolated from the neighboured lines of constant accuracy.

The labels in the two inner areas show the accuracy within the entire areas.

R denotes linearity within the labelled area or line. See details below.

The R0.02 % areas apply for measurements with activated reference measurement mode in Direct Voltage mode only.

3.2. Accuracy of Impedance Measurement POT/GAL 30 V 2 A

The specifications below applies for

Temperature 15 °C .. 25 °C
Direct Voltage, Potentiostat or Galvanostat* modes, time constant 1 µs, no dc voltage or current, auto ranging for impedance measurements on.
Ac sample voltage 1 Vrms for |Z| >= 1 Ω or 1 Arms ac sample current for |Z| < 1 Ω
Low Capacity Open calibration enabled, All- and Load Short calibrations done.
Impedance measured for a sample connected by BNC cables with 25 cm length to the POT/GAL terminals.

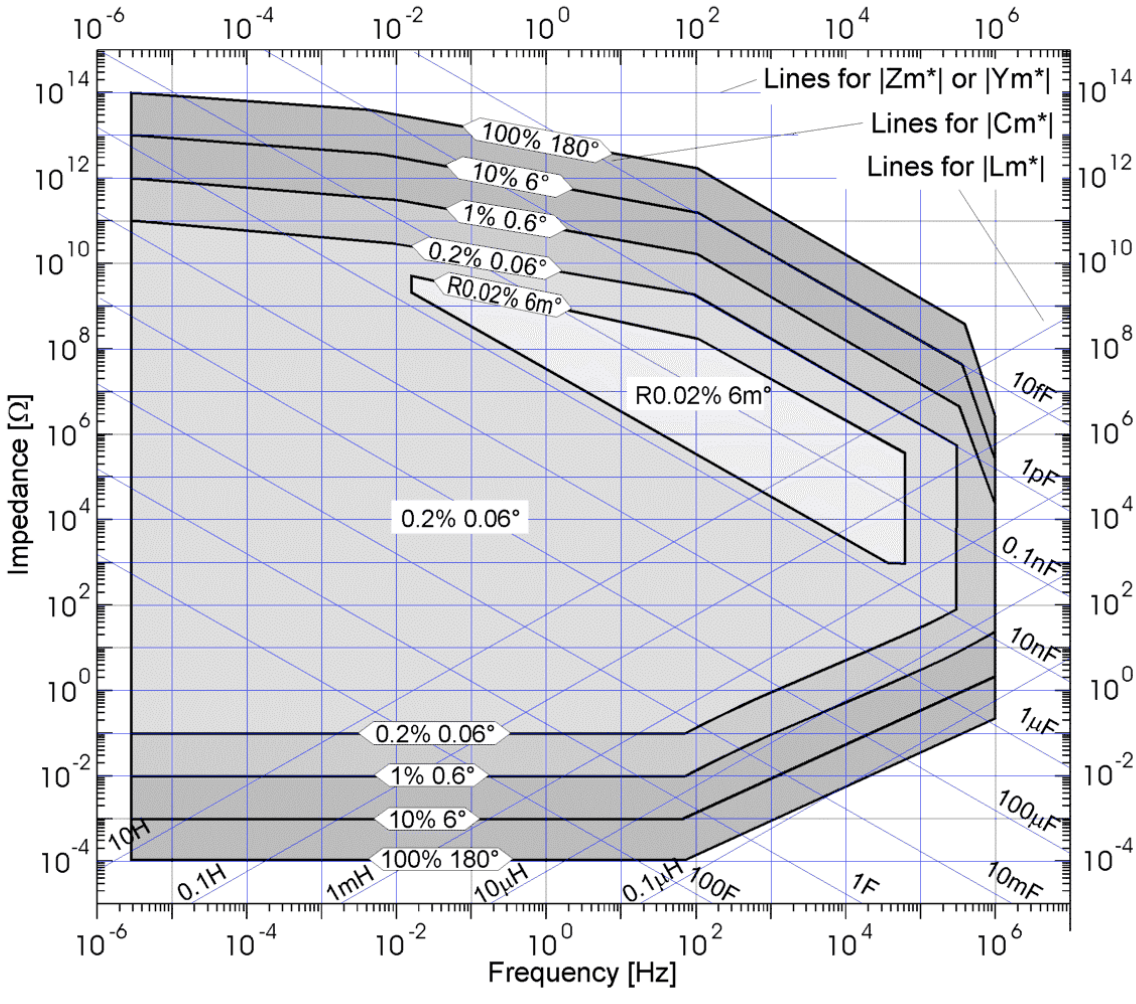

Fig. 3. POT/GAL 4-wire mode impedance measurement accuracy. For details see text below.

*For capacitate samples measured in Galvanostat mode the auto ranging procedure does not use current ranges below 2 mA. If for such kind of samples significantly lower currents in Galvanostat mode have to be measured, manual selection of current range and time constant may be required. For details refer to the POT/GAL user's manual "Current Range Selection and Switching" chapter.

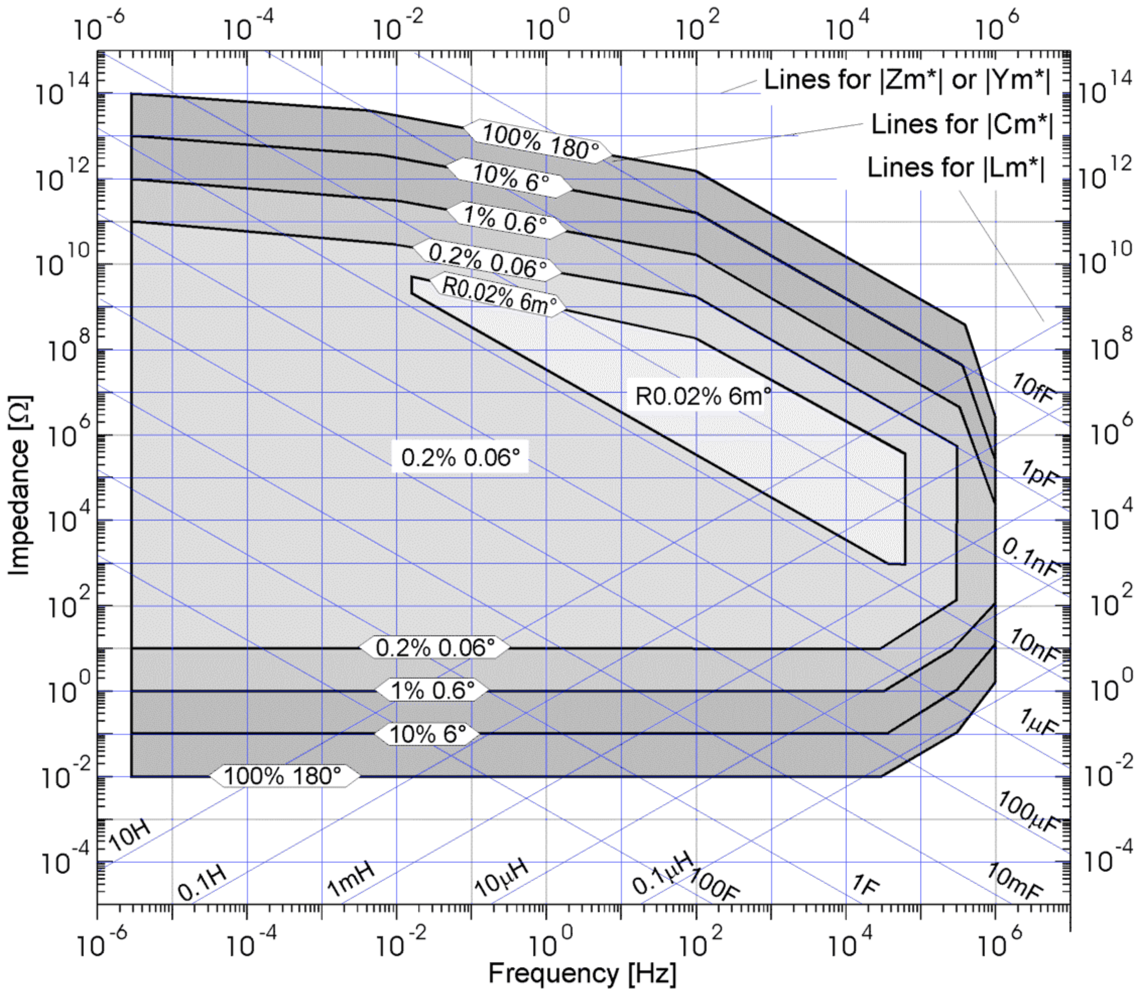

Fig. 4. POT/GAL 2-wire mode impedance measurement accuracy. For details see text below.

For impedance points in the areas between the lines of constant accuracy, the accuracy should be interpolated from the neighboured lines of constant accuracy.

The labels in the two inner areas show the accuracy within the entire areas.

R denotes linearity within the labelled area or line. See details below.

The R0.02 % areas apply for measurements with activated reference measurement mode in Direct Voltage mode only.

3.3. How to use the impedance accuracy specification

Consider a measured impedance point Zm* represented by its absolute value |Zm*| and phase angle ϕm. The accuracy of Zm* can be defined by a percentage factor A with respect to |Zm*| and a phase deviation ϕ.

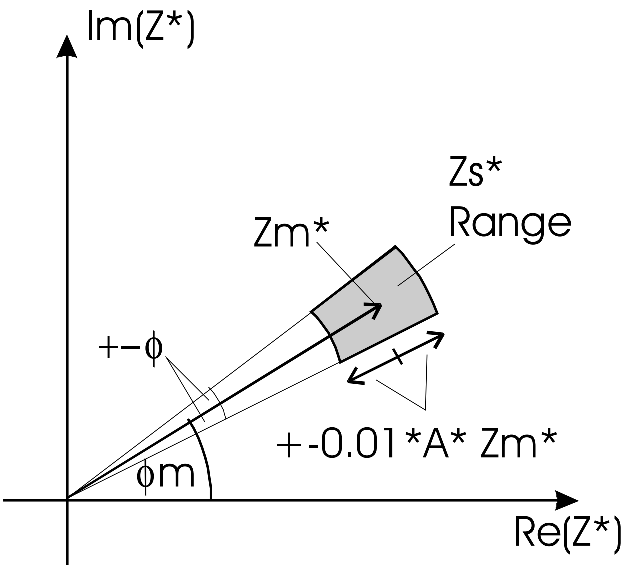

Fig. 5. Definition of accuracy area in dependence of amplitude and phase accuracy.

The true sample impedance Zs* is in the shaded area.

A and ϕ depend on the frequency and impedance range of Zm*. They are shown in the diagram on the previous page as lines of constant accuracy. Each line of constant accuracy is labelled by an accuracy specification. The different labels have following meaning:

Line Label	Accuracy Definition on Labelled Line
100 % 180 °	Limit of the available impedance range measured either by an open sample (top line) or a short sample (bottom line).
A % ϕ °	Specifies absolute accuracy A for |Zs*| in percentage of the measured value and absolute phase angle accuracy ϕ . $\|Zs^*(\omega)\| = (1 +- A/100) \|Zm^*(\omega)\|$ $\phi s = \phi m +- \phi$
RA % ϕ %	Like above, but RA species relative accuracy instead of absolute accuracy. E.g. Inside the area surrounded by the R0.01 % line, impedance values will be linear to 0.01 % to each other but may have 0.1 % error in absolute value. Linearity applies both in frequency and impedance direction. ϕ specifies the absolute phase accuracy like above. E.g. ϕ=6 m° corresponds to an absolute accuracy in loss factor tan(δ) of 10^{-4}.

Example :

Consider a measured data point Zm* with |Zm*| = $2 \cdot 10^{11}$ Ω at 1 Hz. It is located in the accuracy diagram between the constant accuracy line 1 % 0.6 ° and 10 % 6 °. By logarithmic extrapolation between the lines one gets the accuracy of about

+-3.3 % of |Zm*| for the |Zs*| absolute accuracy

and

+-2.2 ° for the absolute Zs* phase accuracy.

In addition to Zm*, the accuracy may be determined in the other representations measured capacity Cm*, measured inductance Lm* or measured admittance Ym*. These quantities are related to Zm* by

$$Cm^* = -\frac{j}{\omega \; Zm^*}$$

$$Lm^* = \frac{Zm^*}{j\,\omega}$$

$$Ym^* = \frac{1}{Zm^*}$$

with $\omega = 2\,\pi$ frequency and j = imaginary unit.

As can be seen from the above equations, all conversion only affect the phase angle by constant shift of +-90 ° (Lm*, Cm*) or leave the phase angle unchanged (Ym*). Therefore the phase accuracy is the same for all four representations and the amplitude accuracy is only affected by the absolute value of each representation. The corresponding lines for |Cm*| (linear decreasing impedance with ω) and Lm* (linear increasing impedance with ω) are shown in the accuracy specification. The lines for |Ym*| correspond to the horizontal lines for |Zm*| if inverted. From these lines, the accuracy can be determined for all representations.

Example : Frequency and capacity range with loss factor tan(δ) absolute accuracy of $\pm 10^{-4}$.
tan(δ) = +- 10^{-4} <-> δ = +-6 m°. As can be seen from the impedance specification this applies for capacities from 10 pF .. 5 nF. For e. g. 100 pF the frequency range for δ +-6 m° is 1 Hz .. 50 kHz. As this range is labelled with R0.02 %, the relative accuracy with respect to each other of all |Cm*| values within this labelled area will be $2 \cdot 10^{-4}$. E. g. |Cm*| of an ideal capacitor would be measured flat to +-0.02 % over the specified frequency range. The absolute accuracy of |Cm*| is 0.2 % as the R0.02 % area is inside the 0.2 % area.

3.4. Accuracy of Gain Phase Measurement

Refer to the gain phase specification in the Alpha-A mainframe manual or Alpha-A technical specification.