

Alpha-A High Resolution Dielectric, Conductivity, Impedance and Gain- Phase Modular Measurement System

Technical Specification Alpha-A Mainframe ZGS, ZG4 and ZG2 Test Interfaces

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These specifications apply to Novocontrol Technologies Alpha-A series analyzers of Rev. C, indicated by XXX > 700 in the serial number scheme, e.g., 6.4_200_40_XXX_ANBF_14062017.

Table of Contents

1. Mainframe frequency response analyzer unit.....	4
1.1. Mainframe sine wave generator.....	4
1.1.1. Analyzer models.....	4
1.1.2. Frequency resolution and accuracy.....	4
1.1.3. Output voltages for ZGS, ZG4, ZG2 or G22 test interfaces.....	5
1.2. ZGS, ZG4 or ZG2 test interface current-to-voltage converter.....	5
1.2.1. ZGS, ZG4 or ZG2 test interface reference capacitors.....	5
1.2.2. ZG4 interface differential voltage inputs V+, V-.....	5
2. Measurement Ranges and Accuracy.....	6
2.1. Accuracy of Impedance Measurement.....	6
2.2. Accuracy of Gain-Phase Measurement.....	9
2.3. Test Sample Results.....	10

1. Mainframe frequency response analyzer unit

Two voltage input channel digital frequency response analyzer with sine wave and dc bias generator

Voltage input channels 1 and 2	
Frequency range	3 μ Hz .. 40 MHz ac or dc coupled
Voltage ranges (rms):	32 V, 17 V, 10V, 5.6 V, 3.2 V, 1.7 V, 1 V, 560 mV, 320 mV, 170 mV, 100 mV, 56 mV, 32 mV
Amplitude and phase resolution and accuracy	cf " Measurement Ranges and Accuracy, Accuracy of Gain-Phase Measurement "
Input impedance	Resistance: 1 M Ω , Capacity < 20 pF
Measured parameters	Dc, ac base and higher harmonic components V1*, V2* of the both input channels at generator frequency, phase angle of (V1*, V2*)
Measurement rate:	Up to up to 600 impedance points per second via USB-GPIB ¹ adapter BDS 1501 with mainframe option F (high speed). Up to 10.5 impedance or 19 gain-phase data points per second via GPIB port without option F.

1.1. Mainframe sine wave generator

The sine wave generator operates by direct digital synthesis (DDS).

1.1.1. Analyzer models

Analyzer Model	Minimum frequency	Maximum Frequency
Alpha-AL	3 μ Hz	0.3 MHz
Alpha-AK	3 μ Hz	3 MHz
Alpha-AN	3 μ Hz	20 MHz
Alpha-AT	3 μ Hz	40 MHz

1.1.2. Frequency resolution and accuracy

Frequency range	Frequency resolution
40 MHz to 20 MHz	23 mHz
20 MHz to 1.25 MHz	12 mHz
1.25 MHz to 78 kHz	0.73 mHz
78 kHz to 4.8 kHz	45 μ Hz
4.8 kHz to 3 μ Hz	3 μ Hz
Absolute frequency accuracy	10^{-4} of selected frequency

¹The value depends on the adapter type.

1.1.3. Output voltages for ZGS, ZG4, ZG2 or G22 test interfaces

Ac voltage amplitude	0 – 3 V (rms) below 10 MHz 0 – 2 V (rms) above 4 MHz for ZG4 and G22 0 – 1 V (rms) above 10 MHz
Ac voltage resolution	0.7 mV from 3 V .. 100 mV 6 μ V below 100 mV
Ac voltage accuracy	$\pm(10^{-2} + 10^{-2}/\text{MHz})$ of selected voltage $\pm 20 \mu\text{V}$
Ac voltage distortion	$2 \cdot 10^{-3}$ of selected voltage below 100 kHz at 1V rms
Dc bias voltage range with	$\pm 40\text{V}$ (requires Option B)
Dc bias voltage resolution	1 mV
Dc bias voltage accuracy	$\pm 10 \text{ mV}$
Dc bias current limit	about $\pm 70 \text{ mA}$
Output impedance (ac and dc bias)	50 Ω

1.2. ZGS, ZG4 or ZG2 test interface current-to-voltage converter

Frequency range	3 μHz to 40 MHz
Current ranges (rms)	40 mA, 15 mA, 1.5 mA, 150 μA , 15 μA , 1.5 μA , 150 nA, 15 nA, 1.5 nA, 150 pA, 15 pA, 1.5 pA
Current resolution (reproducibility)	$\pm 5 \text{ fA} \pm 10^{-5}$ of current range $\pm 30 \text{ fA/Hz} \cdot \text{frequency of measurement}$
Capacity range	$10^{-15} - 10 \text{ F}$
Impedance range	0.01-- $2 \cdot 10^{14} \Omega$
Inductance range	100 nH – 1 kH
Accuracy in $\tan(\delta)$ for capacitive samples	$\pm 3 \cdot 10^{-5} \pm 10^{-3}$ of measured value for frequencies between 10 Hz and 100 kHz and sample capacity between 50 pF and 2 nF

For more detailed impedance measurement ranges and accuracy limits refer to the "[Measurement Ranges and Accuracy, Accuracy of Impedance Measurement](#)" chapter.

1.2.1. ZGS, ZG4 or ZG2 test interface reference capacitors

63 build in low loss precision reference capacitors from 25 pF .. 2 nF

1.2.2. ZG4 interface differential voltage inputs V+, V-

Common mode rejection	> 80 db below 100 kHz > 60 db below 1 MHz
Input bias current	$< 2 \cdot 10^{-12} \text{ A}$
Input impedance	$> 10^{-12} \Omega$ in parallel $< 10 \text{ pF}$

2. Measurement Ranges and Accuracy

2.1. Accuracy of Impedance Measurement

The specification below applies for

- Temperature between 15 °C and 25 °C, Relative Humidity < 40 %, Oscillator level 1 Vrms
- Reference measurement mode enabled
- Auto reference capacitor mode enabled
- Low impedance load short calibration enabled
- Low capacity open calibration enabled

Impedance measured at the active cell sample ZGS electrodes or at the BNC impedance inputs of the interfaces ZG4 and ZG2 in two-wire mode.

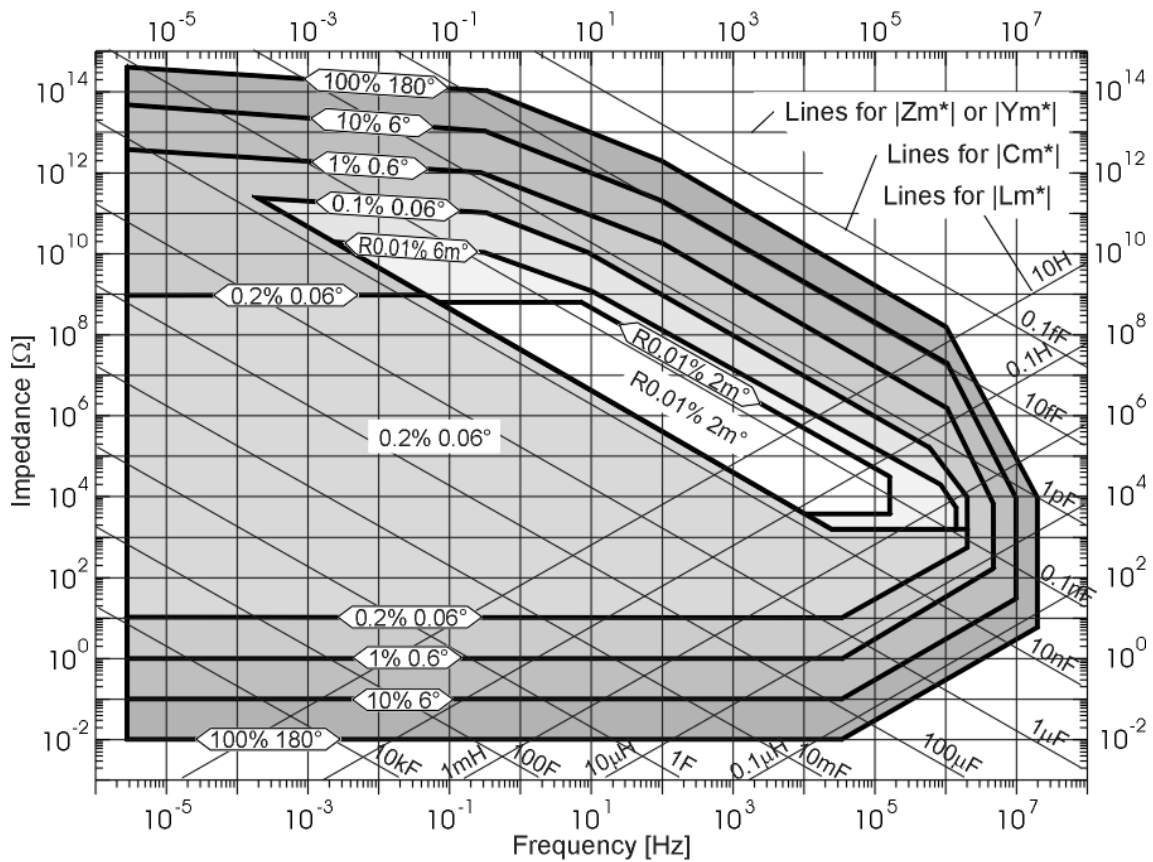


Fig. 1. Alpha impedance measurement accuracy specification

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

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

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

For the mainframe types -AL and -AK the upper frequency limit is 0.3 and 3 MHz.

How to use the impedance accuracy specification

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

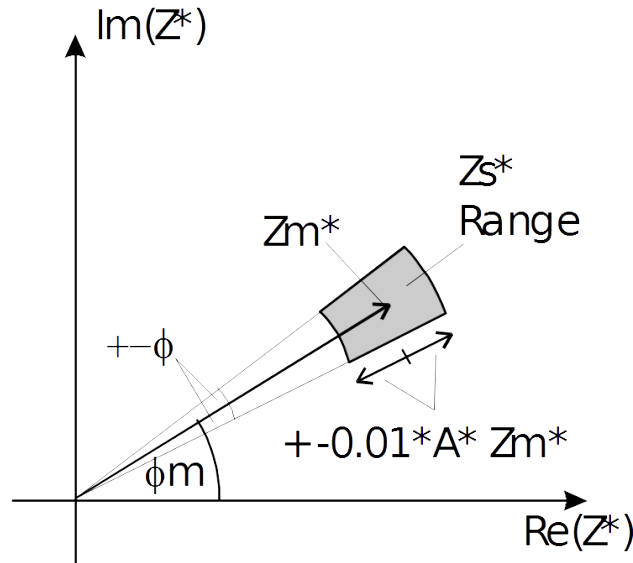


Fig. 2. Definition of accuracy area in dependence of amplitude and phase accuracy.

The true sample impedance Z_s^* is in the shaded area.

A and ϕ depend on the frequency and impedance range of Z_m^* . 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 $ Z_s^* $ in percentage of the measured value and absolute phase angle accuracy ϕ . $ Z_s^*(\omega) = (1 \pm A/100) Z_m^*(\omega) $ $\phi_s = \phi_m \pm \phi$
RA% $\phi\%$	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. $\phi=2m^\circ$ corresponds to an absolute accuracy in loss factor $\tan(\delta)$ of $3 \cdot 10^{-5}$.

Example:

Consider a measured data point Z_m^* with $|Z_m^*| = 2 \cdot 10^{11} \Omega$ at 1 Hz. It is located in the accuracy diagram between the constant accuracy line $0.1\% \ 0.06^\circ$ and $1\% \ 0.6^\circ$. By logarithmic extrapolation between the lines one gets the accuracy of about

$\pm 0.33\%$ of $|Z_m^*|$ for the $|Z_s^*|$ absolute accuracy

and

$\pm 0.22^\circ$ for the absolute Z_s^* phase accuracy.

In addition to Z_m^* , the accuracy may be determined in the other representations measured capacity C_m^* , measured inductance L_m^* or measured admittance Y_m^* . These quantities are related to Z_m^* by

$$C_m^* = -\frac{j}{\omega Z_m^*} \quad (1)$$

$$L_m^* = \frac{Z_m^*}{j \omega} \quad (2)$$

$$Y_m^* = \frac{1}{Z_m^*} \quad (3)$$

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 $\pm 90^\circ$ (L_m^* , C_m^*) or leave the phase angle unchanged (Y_m^*). 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 $|C_m^*|$ (linear decreasing impedance with ω) and L_m^* (linear increasing impedance with ω) are shown in the accuracy specification. The lines for $|Y_m^*|$ correspond to the horizontal lines for $|Z_m^*|$ if inverted. From these lines, the accuracy can be determined for all representations.

Example: Frequency and capacity range with loss factor $\tan(\delta)$ absolute accuracy of $\pm 10^{-4}$.

$\tan(\delta) = \pm 10^{-4} \leftrightarrow \delta = \pm 6 \text{ m}^\circ$. As can be seen from the impedance specification this applies for capacities from 20 pF to 5 nF. For e. g. 100 pF the frequency range for $\delta \pm 6 \text{ m}^\circ$ is 0.2 Hz to 1 MHz. As this range is labelled with R0.01%, the relative accuracy with respect to each other of all $|C_m^*|$ values within this labelled area will be 10^{-4} , too. E. g. $|C_m^*|$ of an ideal capacitor would be measured flat to $\pm 0.01\%$ over the specified frequency range. The absolute accuracy of $|C_m^*|$ is 0.1% as the R0.01% area is inside the 0.1% area.

2.2. Accuracy of Gain-Phase Measurement

The absolute voltage amplitude ratio and phase accuracy of input channel 1 and 2 in gain-phase mode can be determined from the diagram below. For the interfaces ZG4 and POT/GAL, channel 1 refers to the differential voltage $V_{\text{high}} - V_{\text{low}}$ respectively. For the interface G22, channel 1 and 2 refer to the differential voltages $V_{\text{high}} - V_{\text{low}}$ of the corresponding channel.

The following limits of measurement refer to 1 V generator voltage, inputs dc coupled, auto range selection enabled, input voltages between 20 mV and 3.2 V.

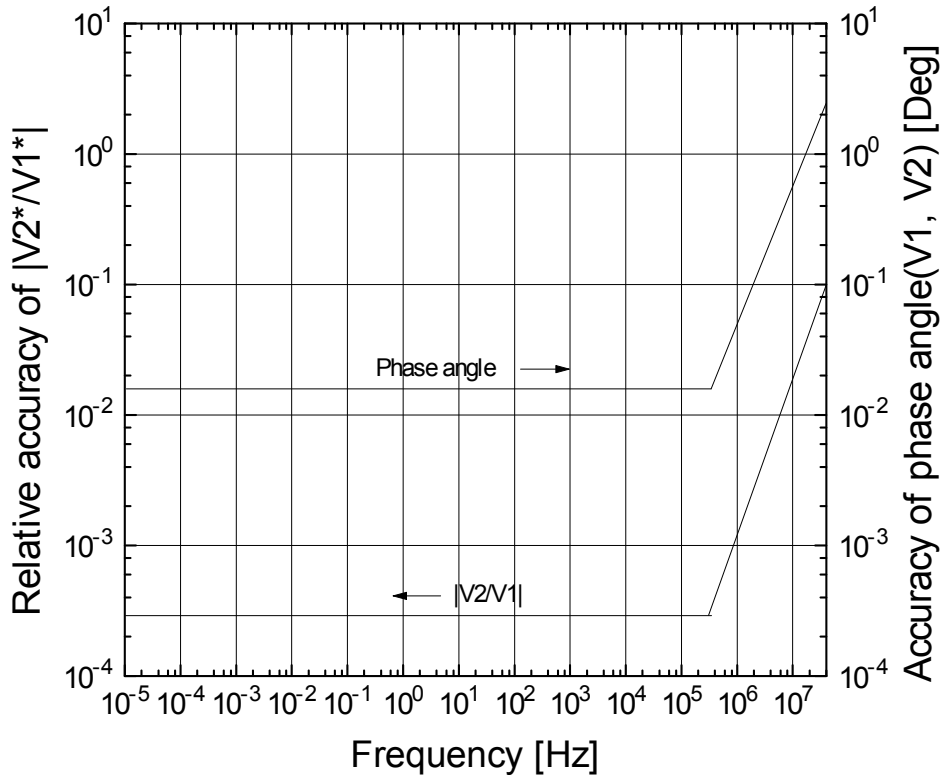


Fig. 3. Alpha analyzer accuracy for gain-phase measurements.

For the mainframe types -AL, -AK and -AN the upper frequency limit is 0.3, 3 and 20 MHz.

Amplitude ratio ($|V1^*/V2^*|$) and phase resolution (reproducibility):

- 10^{-5} of selected range, 10^{-3} degrees below 1 MHz
- 10^{-4} of selected range, 10^{-2} degrees from 1 MHz .. 10 MHz
- 10^{-3} of selected range, 10^{-1} degrees above 10 MHz

2.3. Test Sample Results

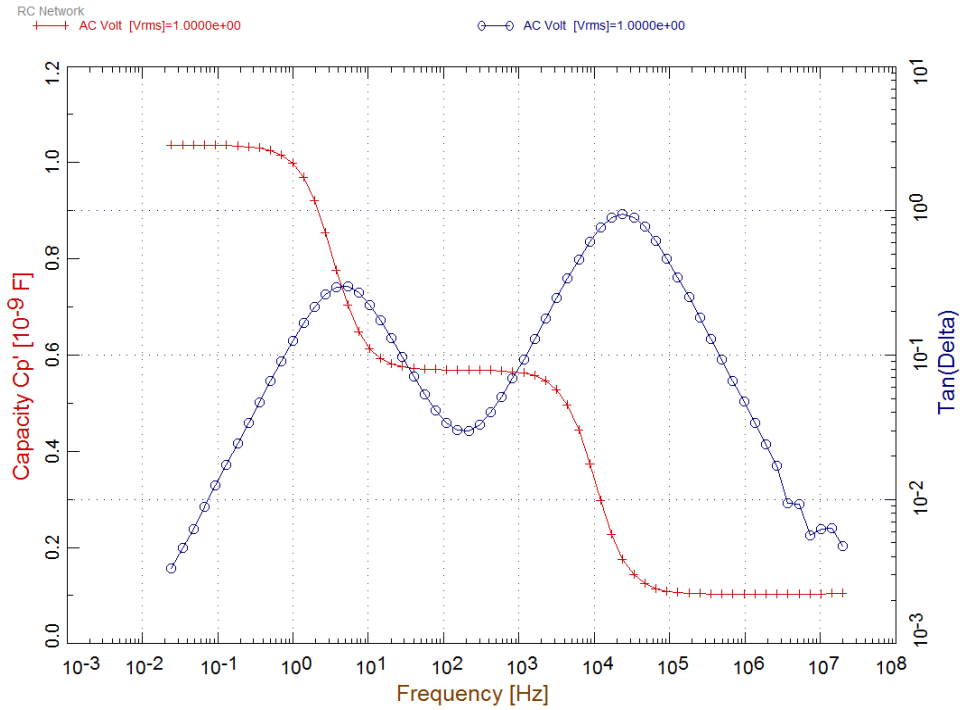


Fig. 4. Typical results of the RC test sample network.

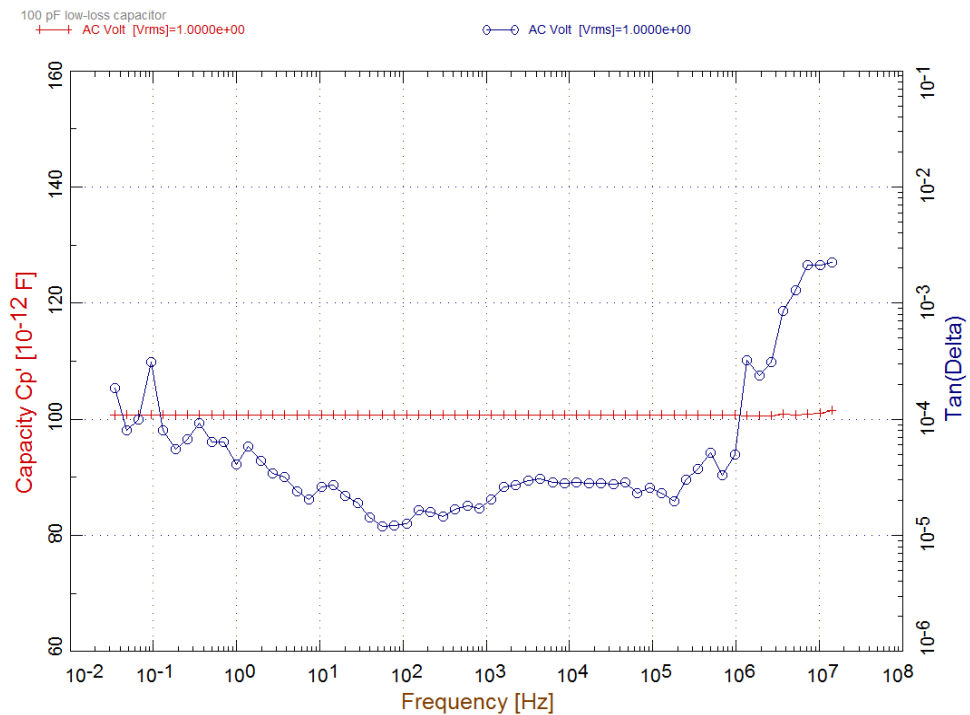


Fig. 5. Typical results of the low loss test sample.