Alpha and Beta
Dielectric, Conductivity, Impedance
and
Gain Phase
Analyzers

Technical Specification
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1. Technical Data

Line voltage: 220 - 240 V ac, 50 - 60 Hz or 110 V ac, 50 - 60 Hz (see instrument rear)
Power consumption: < 100 W

Environment
- operating temperature: 0° to 40°C
- storage temperature: -10° to 60°C
- specification limits: 15° to 25°C

GPIB IEEE 488 interface
can be addressed as: talker / listener
pre set device address: 10

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 μHz .. 40 MHz ac or dc coupled
Voltage ranges (Vrms):
- 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
- See chapter "Measurement Ranges and Accuracy, Accuracy of Gain Phase Measurement"

Input impedance
- Alpha V1, V2, Beta V2: Resistance: 1 MΩ, Capacity < 100 pF
- Beta V1H, V1L: Resistance: 1 TΩ, Capacity < 10 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 10.5 impedance or 19 gain phase data points per second via GPIB port.

Sine wave generator
Principle of operation
- Direct digitally synthesized from 3 μHz .. 0.3, 3, 20, or 40 MHz for -L, -K, -N or –T types

Frequency resolution
- 23 mHz for 40 MHz .. 20 MHz
- 12 mHz for 20 MHz .. 1.25 MHz
- 0.73 mHz for 1.25 MHz .. 78 kHz
- 45 μHz for 78 kHz .. 4.8 kHz
- 3 μHz for 4.8 kHz .. 3 μHz
Absolute frequency accuracy
    \(10^{-4}\) of selected frequency

**Output voltages**

**Ac voltage amplitude**
- 0 .. 3 V (rms) below 10 MHz
- 0 .. 2 V (rms) above 4 MHz
- 0 .. 1 V (rms) above 10 MHz

**Ac voltage resolution**
- 0.7 mV from 3 V .. 100 mV
- 0.7 \(\mu\)V below 100 mV

**Ac voltage accuracy**
\(+(-10^{-2} + 10^{-2}/MHz)\) of selected voltage \(+- 0.1\) mV

**Ac voltage distortion**
\(2 \times 10^{-3}\) of selected voltage below 100 kHz at 1V rms

**Dc bias voltage range with CGS, Z**
\(+/- 40\) V

**Dc bias voltage resolution**
10 mV

**Dc bias voltage accuracy**
\(+/- 50\) mV

**Dc bias current limit**
about \(+/- 70\) mA

**Output impedance (ac and dc bias)**
50 \(\Omega\)

**Current to voltage converter**

**Frequency range**
3 \(\mu\)Hz .. 20 MHz

**Current ranges (rms)**
- 40 mA, 15 mA, 1.5 mA, 150 \(\mu\)A, 15 \(\mu\)A, 1.5 \(\mu\)A,
- 150 nA, 15 nA, 1.5 nA, 150 pA, 15 pA, 1.5 pA

**Current resolution (reproducibility)**
\(+/- 5\) fA \(+/- 10^{-5}\) of current range
\(+/- 30\) fA/Hz \(*\) frequency of measurement

**Capacity range**
\(10^{-15}\) - 1 F

**Resistance range**
0.01 - 2 \(\times\) 10\(^{14}\) \(\Omega\)

**Accuracy in tan(\(\delta\)) for capacitive samples:**
\(+/- 3 \times 10^{-5}\) \(+/- 10^{-3}\) of measured value
for frequency between 10 Hz .. 100 kHz and
sample capacity between 50 pF .. 2 nF
For more detailed impedance measurement ranges and accuracy limits refer to the "Measurement Ranges and Accuracy, Accuracy of Impedance Measurement" chapter.

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

**Beta differential voltage inputs V1H, V1L**

Common mode rejection
- > 80 db below 100 kHz
- > 60 db below 1 MHz

Input bias current
- < $2 \times 10^{-12}$ A

Input impedance
- > $10^{-12}$ Ω in parallel < 10 pF
2. Measurement Ranges and Accuracy

2.1. Accuracy of Impedance Measurement

The specification below applies for:
- Temperature 15 °C .. 25 °C
- 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 Alpha or Beta analyzer BNC impedance inputs in 2-wire mode.

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 area.
R denotes linearity within the labelled area or line. See details below.
For the types -L and -K 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 $\phi_m$. The accuracy of $Z_{m^*}$ can be defined by a percentage factor $A$ with respect to $|Z_{m^*}|$ and a phase deviation $\phi$.

The true sample impedance $Z_{s^*}$ is in the shaded area. $A$ and $\phi$ 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:

<table>
<thead>
<tr>
<th>Line Label</th>
<th>Accuracy Definition on Labelled Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% 180°</td>
<td>Limit of the available impedance range measured either by an open sample (top line) or a short sample (bottom line).</td>
</tr>
<tr>
<td>A% $\phi$°</td>
<td>Specifies absolute accuracy $A$ for $</td>
</tr>
<tr>
<td>RA% $\phi$%</td>
<td>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.</td>
</tr>
</tbody>
</table>
Example:
Consider a measured data point $Z_m^*$ with $|Z_m^*| = 2 \cdot 10^{11}$ Ω at 1 Hz. It is located in the accuracy diagram between the constant accuracy line 0.1% 0.06° and 1% 0.6°. By logarithmic extrapolation between the lines one gets the accuracy of about
+0.33% of $|Z_m^*|$ for the $|Z_s^*|$ absolute accuracy
and
+0.22° 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

$$C_m^* = -\frac{j}{\omega Z_m^*}$$

$$L_m^* = \frac{Z_m^*}{j\omega}$$

$$Y_m^* = \frac{1}{Z_m^*}$$

with $\omega = 2\pi$ frequency and $j = \text{imaginary unit}$.

As can be seen from the above equations, all conversion only affect the phase angle by constant shift of +90° ($L_m^*, C_m^*$) 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 $\omega$) and $L_m^*$ (linear increasing impedance with $\omega$) 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 $+10^{-4}$.

$\tan(\delta) = +10^{-4} \leftrightarrow \delta = +6$ m°. As can be seen from the impedance specification this applies for capacities from 20 pF .. 5 nF. For e. g. 100 pF the frequency range for $\delta = +6$ m° is 0.2 Hz .. 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 $+0.01\%$ 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 Alpha analyzer input channel 1 and 2 in gain phase mode can be determined from the diagram below. For the Beta analyzer, channel 1 refers to the differential voltage V1H – V1L respectively.

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.

For the types –L, -K and -N the upper frequency limit is 0.3, 3 and 20 MHz.

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

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

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