Specifications
The complete Agilent Technologies 4284A specifications are listed in this data sheet. These specifications are the performance standards or limits against which the instrument is tested. When shipped from the factory, the Agilent 4284A meets the specifications listed here.

Measurement Functions
Measurement parameters

| |Z| = Absolute value of impedance  
| |Y| = Absolute value of admittance  
L = Inductance  
C = Capacitance  
R = Resistance  
G = Conductance  
D = Dissipation factor  
Q = Quality factor  
R_s = Equivalent series resistance  
R_p = Parallel resistance  
X = Reactance  
B = Susceptance  
\( \theta \) = Phase angle

Combinations of measurement parameters

| |Z|, |Y| | L, C | R | G |
|---|---|---|---|---|
| \( \theta \) (deg), \( \theta \) (rad) | D, Q, R, R_s, G | X | B |

Mathematical functions
The deviation and the percent of deviation of measurement values from a programmable reference value.

Equivalent measurement circuit
Parallel and series

Ranging
Auto and manual (hold/up/down)

Trigger
Internal, external, BUS (GPIB), and manual

Delay time
Programmable delay from the trigger command to the start of the measurement, 0 to 60.000 s in 1 ms steps.

Measurement terminals
Four-terminal pair

Test cable length
Standard 0 m and 1 m selectable
With Option 4284A-006 0 m, 1 m, 2 m, and 4 m selectable

Integration time
Short, medium, and long (see Supplemental Performance Characteristics for the measurement time)

Averaging
1 to 256, programmable
**Test Signal**

**Frequency**
20 Hz to 1 MHz, 8610 selectable frequencies

**Accuracy**
±0.01%

**Signal modes**

**Normal** – Program selected voltage or current at the measurement terminals when they are opened or shorted, respectively.

**Constant** – Maintains selected voltage or current at the device under test (DUT) independent of changes in the device’s impedance.

**Signal level**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Range</th>
<th>Setting accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>Non-constant</td>
<td>5 mV&lt;sub&gt;rms&lt;/sub&gt; to 2 V&lt;sub&gt;rms&lt;/sub&gt; ±(10% + 1 mV&lt;sub&gt;rms&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>10 mV&lt;sub&gt;rms&lt;/sub&gt; to 1 V&lt;sub&gt;rms&lt;/sub&gt; ±(6% + 1 mV&lt;sub&gt;rms&lt;/sub&gt;)</td>
</tr>
<tr>
<td>Current</td>
<td>Non-constant</td>
<td>50 µA&lt;sub&gt;rms&lt;/sub&gt; to 20 mA&lt;sub&gt;rms&lt;/sub&gt; ±(10% + 10 µA&lt;sub&gt;rms&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>100 µA&lt;sub&gt;rms&lt;/sub&gt; to 10 mA&lt;sub&gt;rms&lt;/sub&gt; ±(6% + 10 µA&lt;sub&gt;rms&lt;/sub&gt;)</td>
</tr>
</tbody>
</table>

1. Automatic Level Control Function is set to ON.

**Output impedance**

100 Ω, ±3%

**Test signal level monitor**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Range</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>Non-constant</td>
<td>5 mV&lt;sub&gt;rms&lt;/sub&gt; to 2 V&lt;sub&gt;rms&lt;/sub&gt; ±(3% of reading + 0.5 mV&lt;sub&gt;rms&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>0.01 V&lt;sub&gt;rms&lt;/sub&gt; to 5 mV&lt;sub&gt;rms&lt;/sub&gt; ±(11% of reading + 0.1 mV&lt;sub&gt;rms&lt;/sub&gt;)</td>
</tr>
<tr>
<td>Current</td>
<td>Non-constant</td>
<td>50 µA&lt;sub&gt;rms&lt;/sub&gt; to 20 mA&lt;sub&gt;rms&lt;/sub&gt; ±(3% of reading + 0.5 µA&lt;sub&gt;rms&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>0.001 µA&lt;sub&gt;rms&lt;/sub&gt; to 50 µA&lt;sub&gt;rms&lt;/sub&gt; ±(11% of reading + 1 µA&lt;sub&gt;rms&lt;/sub&gt;)</td>
</tr>
</tbody>
</table>

1. Add the impedance measurement accuracy [%] to the voltage level monitor accuracy when the DUT’s impedance is < 100 Ω.
2. Add the impedance measurement accuracy [%] to the current level monitor accuracy when the DUT’s impedance is ≥ 100 Ω.

Accuracies apply when test cable length is 0 m or 1 m. The additional error when test cable length is 2 m or 4 m is given as

\[ f_m \times \frac{L}{2} [%] \]

where:

\[ f_m = \text{Test frequency [MHz]} \]
\[ L = \text{Test cable length [m]} \]

For example,

DUT’s impedance: 50 Ω
Test signal level: 0.1 V<sub>rms</sub>
Measurement accuracy: 0.1%

Then, voltage level monitor accuracy is

±(3.1% of reading + 0.5 mV<sub>rms</sub>)

**Display Range**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z</td>
</tr>
<tr>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>C</td>
<td>0.01 fF to 9.99999 fF</td>
</tr>
<tr>
<td>L</td>
<td>0.01 nH to 9.99999 kH</td>
</tr>
<tr>
<td>D</td>
<td>0.000001 to 9.99999</td>
</tr>
<tr>
<td>Q</td>
<td>0.01 to 99999.9</td>
</tr>
<tr>
<td>θ</td>
<td>-180.000° to 180.000°</td>
</tr>
<tr>
<td>∆</td>
<td>-999.999% to 999.999%</td>
</tr>
</tbody>
</table>
Absolute Accuracy
Absolute accuracy is given as the sum of the relative accuracy plus the calibration accuracy.

|Z|, |Y|, L, C, R, X, G, and B accuracy
|Z|, |Y|, L, C, R, X, G, and B accuracy is given as

\[ A_e + A_{cal} \% \]

where:

\[ A_e = \text{Relative accuracy} \]
\[ A_{cal} = \text{Calibration accuracy} \]

L, C, X, and B accuracies apply when \( D_x \) (measured D value) \( \leq 0.1 \). R and G accuracies apply when \( Q_x \) (measured Q value) \( \leq 0.1 \). G accuracy described in this paragraph applies to the G-B combination only.

D accuracy
D accuracy is given as

\[ D_e + \theta_{cal} \]

where:

\[ D_e = \text{the relative D accuracy} \]
\[ \theta_{cal} = \text{the calibration accuracy [radian]} \]

Accuracy applies when \( D_x \) (measured D value) \( \leq 0.1 \).

Q accuracy
Q accuracy \( Q_e \) is given as

\[ Q_e = \pm \frac{Q_x \times D_x}{1 + Q_x \times D_x} \]

where:

\[ Q_x = \text{Measured Q value} \]
\[ D_x = \text{D accuracy} \]

Q accuracy applies when \( Q_x \times D_x < 1 \).

θ accuracy
θ accuracy is given as

\[ \theta_e + \theta_{cal} [deg] \]

where:

\[ \theta_e = \text{Relative θ accuracy [deg]} \]
\[ \theta_{cal} = \text{Calibration accuracy [deg]} \]

G accuracy
When \( D_x \) (measured D value) \( \leq 0.1 \)

G accuracy is given as

\[ B_x \times D_x [S] \]
\[ B_x = 2 \pi f C_x = \frac{1}{2 \pi f L_x} \]

where:

\[ B_x = \text{Measured B value [S]} \]
\[ C_x = \text{Measured C value [F]} \]
\[ L_x = \text{Measured L value [H]} \]
\[ D_x = \text{Absolute D accuracy} \]
\[ f = \text{Test frequency [Hz]} \]

G accuracy described in this paragraph applies to the C_G and L_G combinations only.

R_p accuracy
When \( D_x \) (measured D value) \( \leq 0.1 \)

R_p accuracy is given as

\[ R_p = \pm \frac{R_{pl} x D_x}{D_s + D_a} [\Omega] \]

where:

\[ R_{pl} = \text{Measured R_p value [Ω]} \]
\[ D_s = \text{Measured D value} \]
\[ D_a = \text{Absolute D accuracy} \]
**R_s accuracy**
When $D_s$ (measured $D$ value) $\leq 0.1$

$R_s$ accuracy is given as

$$X_s \times D_s \ [\Omega]$$

$$X_s = 2 \pi f l_x = \frac{1}{2 \pi f C_x}$$

where:

$X_s$ = Measured $X$ value $[\Omega]$

$C_s$ = Measured $C$ value $[F]$

$L_s$ = Measured $L$ value $[H]$

$D_s$ = Absolute $D$ accuracy

$f$ = Test frequency $[Hz]$

**Relative Accuracy**
Relative accuracy includes stability, temperature coefficient, linearity, repeatability, and calibration interpolation error. Relative accuracy is specified when all of the following conditions are satisfied:

1. Warm-up time: $\geq 30$ minutes

2. Test cable length: 0 m, 1 m, 2 m, or 4 m
   (Agilent 16048 A/B/D/E)

For 2 m or 4 m cable length operation, test signal voltage and test frequency are set according to Figure 1-1. (2 m and 4 m cable can only be used when Option 4284A-006 is installed.)

3. OPEN and SHORT corrections have been performed.

4. Bias current isolation: Off

   (For accuracy with bias current isolation, refer to supplemental performance characteristics.)

5. Test signal voltage and DC bias voltage are set according to Figure 1-2.

6. The optimum measurement range is selected by matching the DUT's impedance to the effective measuring range. (For example, if the DUT's impedance is 50 k$\Omega$, the optimum range is the 30 k$\Omega$ range.)

   Range 1: Relative accuracy can apply.

   Range 2: The limits applied for relative accuracy differ according to the DUT's DC resistance. Three dotted lines show the upper limits when the DC resistance is 10 $\Omega$, 100 $\Omega$ and 1 k$\Omega$.

   Range 3: The limits are not applicable.

![Figure 1-2. Test signal voltage and DC bias voltage upper limits apply for relative accuracy](image)

![Figure 1-1. Test signal voltage and test frequency upper limits to apply relative accuracy to 2 m and 4 m cable length operation](image)
\(|Z|, |Y|, L, C, R, X, G, and B accuracy\)

\(|Z|, |Y|, L, C, R, X, G, and B accuracy \(A_e\) is given as

\[ A_e = \pm \left[ A + (K_a + K_{aa} + K_b x K_{bb} + K_c) x 100 + K_d x K_e \right] \% \]

\(A\) = Basic accuracy (refer to Figure 1-3 and 1-4)
\(K_a\) = Impedance proportional factor (refer to Table 1-1)
\(K_{aa}\) = Cable length factor (refer to Table 1-2)
\(K_b\) = Impedance proportional factor (refer to Table 1-1)
\(K_{bb}\) = Cable length factor (refer to Table 1-3)
\(K_c\) = Calibration interpolation factor (refer to Table 1-4)
\(K_d\) = Cable length factor (refer to Table 1-6)
\(K_e\) = Temperature factor (refer to Figure 1-5)

L, C, X, and B accuracies apply when \(D_x\) (measured \(D\) value) \(\leq 0.1\).

R and G accuracies apply when \(Q_x\) (measured \(Q\) value) \(\leq 0.1\).

When \(D_x \geq 0.1\), multiply \(A_e\) by \(\sqrt{1 + D_x^2}\) for L, C, X, and B accuracies.

When \(Q_x \geq 0.1\), multiply \(A_e\) by \(\sqrt{1 + Q_x^2}\) for R and G accuracies.

G accuracy described in this paragraph applies to the G-B combination only.

\(D\) accuracy

\(D\) accuracy \(D_e\) is given as

\[ D_e = \pm \frac{A_e}{100} \]

Accuracy applies when \(D_x\) (measured \(D\) value) \(\leq 0.1\).

When \(D_x > 0.1\), multiply \(D_e\) by \((1 + D_x)\).

\(Q\) accuracy

\(Q\) accuracy is given as

\[ \pm \frac{Q_x x D_e}{1 + Q_x x D_e} \]

where:

\(Q_x\) = Measured \(Q\) value
\(D_e\) = Relative \(D\) accuracy

Accuracy applies when \(Q_x \times D_e < 1\).

\(\theta\) accuracy

\(\theta\) accuracy is given as

\[ \frac{180 \times A_e}{\pi x 100} [\text{deg}] \]

\(G\) accuracy

When \(D_x\) (measured \(D\) value) \(\leq 0.1\)

\(G\) accuracy is given as

\[ B_x \times D_e [\text{S}] \]

\[ B_x = 2 \pi f C_x = \frac{1}{2 \pi l_x} \]

where:

\(B_x\) = Measured \(B\) value [S]
\(C_x\) = Measured \(C\) value [F]
\(L_x\) = Measured \(L\) value [H]
\(D_e\) = Relative \(D\) accuracy
\(f\) = Test frequency [Hz]

\(G\) accuracy described in this paragraph applies to the \(C_p\)-G and \(L_p\)-G combinations only.
**R**<sub>p</sub> accuracy

When \( D_x \) (measured D value) \( \leq 0.1 \)

\[ R_{px} = \frac{R_p x D_e}{D_x + D_e} \quad [\Omega] \]

where:

\( R_{px} \) = Measured \( R_p \) value [\( \Omega \)]
\( D_x \) = Measured D value
\( D_e \) = Relative D accuracy

**R**<sub>s</sub> accuracy

When \( D_x \) (measured D value) \( \leq 0.1 \)

\[ X_s = \frac{X x D_e}{2 \pi f C_x} \quad [\Omega] \]

where:

\( X_s \) = Measured X value [\( \Omega \)]
\( C_x \) = Measured C value [F]
\( L_s \) = Measured L value [H]
\( D_e \) = Relative D accuracy
\( f \) = Test frequency [Hz]

---

**Example of C-D Accuracy Calculation**

**Measurement conditions**

- **Frequency**: 1 kHz
- **C measured**: 100 nF
- **Test signal voltage**: 1 V\(_{\text{rms}}\)
- **Integration time**: MEDIUM
- **Cable length**: 0 m

Then:

\[ A = 0.05 \]

\[ |Z_m| = \frac{1}{2\pi \times 1 \times 10^3 \times 100 \times 10^{-6}} \]

\[ = 1590 \quad [\Omega] \]

\[ K_a = \frac{1 \times 10^{-3}}{1590} \left( 1 + \frac{200}{1000} \right) \]

\[ = 7.5 \times 10^{-7} \]

\[ K_b = 1590 \times 1 \times 10^{-9} \left( 1 + \frac{70}{1000} \right) \]

\[ = 1.70 \times 10^{-6} \]

\[ K_c = 0 \]

Therefore,

\[ C_{\text{accuracy}} = \pm \left[ 0.05 + (7.5 \times 10^{-7} + 1.70 \times 10^{-6}) \times 100 \right] \]

\[ = \pm 0.05 \quad [\%] \]

\[ D_{\text{accuracy}} = \pm \frac{0.05}{100} \]

\[ = \pm 0.0005 \]
On boundary line apply the better value.

Example of how to find the A value:

0.05 = A value when $0.3 \leq V_{\text{rms}} \leq 1$ $V_{\text{rms}}$ and integration time is MEDIUM and LONG.

(0.1) = A value when $0.3 \leq V_{\text{rms}} \leq 1$ $V_{\text{rms}}$ and integration time is SHORT.

$A_1$ = A value when $V_s < 0.3 V_{\text{rms}}$ or $V_s > 1 V_{\text{rms}}$.

To find the value of $A_1$, $A_2$, $A_3$, and $A_4$ refer to the following table.

where:

$V_s$ = Test signal voltage
The following table lists the value of $A_1$, $A_2$, $A_3$, and $A_4$. When $A_{ti}$ is indicated find the $A_{ti}$ value using Figure 1-4.

### Test signal voltage

<table>
<thead>
<tr>
<th>Medium/long</th>
<th>5m</th>
<th>12m</th>
<th>0.1</th>
<th>0.15</th>
<th>0.3</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>20 [Vrms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1 = A_{ti}$</td>
<td>$A_1 = A_{ti}$</td>
<td>$A_1 = A_{ti}$</td>
<td>$A_1 = A_{ti}$</td>
<td>$A_1 = A_{ti}$</td>
<td>$A_1 = A_{ti}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_2 = A_{ti}$</td>
<td>$A_2 = A_{ti}$</td>
<td>$A_2 = A_{ti}$</td>
<td>$A_2 = A_{ti}$</td>
<td>$A_2 = A_{ti}$</td>
<td>$A_2 = A_{ti}$ **</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_3 = A_{ti}$</td>
<td>$A_3 = 0.25$</td>
<td>$A_3 = 0.25$</td>
<td>$A_3 = 0.25$</td>
<td>$A_3 = 0.25$</td>
<td>$A_3 = 0.25$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_4 = A_{ti}$</td>
<td>$A_4 = A_{ti}$</td>
<td>$A_4 = A_{ti}$</td>
<td>$A_4 = A_{ti}$</td>
<td>$A_4 = A_{ti}$</td>
<td>$A_4 = A_{ti}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Short</th>
<th>5m</th>
<th>33m</th>
<th>0.15</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>20 [Vrms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1 = A_{ti}$</td>
<td>$A_1 = A_{ti}$</td>
<td>$A_1 = A_{ti}$</td>
<td>$A_1 = A_{ti}$</td>
<td>$A_1 = A_{ti}$ **</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_2 = A_{ti}$</td>
<td>$A_2 = A_{ti}$</td>
<td>$A_2 = A_{ti}$</td>
<td>$A_2 = A_{ti}$</td>
<td>$A_2 = A_{ti}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_3 = A_{ti}$</td>
<td>$A_3 = 0.3$</td>
<td>$A_3 = 0.3$</td>
<td>$A_3 = 0.3$</td>
<td>$A_3 = 0.3$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_4 = A_{ti}$</td>
<td>$A_4 = A_{ti}$</td>
<td>$A_4 = 0.5 X A_{ti} + 0.1$</td>
<td>$A_4 = A_{ti}$</td>
<td>$A_4 = A_{ti}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Multiply the A values as follows, when the test frequency is less than 300 Hz.

100 Hz $\leq f_m < 300$ Hz: Multiply the A values by 2.

$f_m < 100$ Hz: Multiply the A values by 2.5.

** Add 0.15 to the A values when all of the following measurement conditions are satisfied.

Test frequency: $300$ kHz $< f_m \leq 1$ MHz

Test signal voltage: $5 \text{ V}_{\text{rms}} < V_s \leq 20 \text{ V}_{\text{rms}}$

DUT: Inductor, $|Z_m| < 200$ Ω ($|Z_m|$: impedance of DUT)

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Figure 1-4. Basic accuracy A (2 of 2)
$K_a$ and $K_b$ values are the incremental factors in low impedance and high impedance measurements, respectively. $K_a$ is practically negligible for impedances above 500 $\Omega$, and $K_b$ is negligible for impedances below 500 $\Omega$.

Table 1-1. Impedance proportional factors $K_a$ and $K_b$

<table>
<thead>
<tr>
<th>Integration time</th>
<th>Frequency</th>
<th>$K_a$</th>
<th>$K_b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEDIUM LONG</td>
<td>$f_m &lt; 100$ Hz</td>
<td>( \left( \frac{1 \times 10^{-2}}{</td>
<td>Z_m</td>
</tr>
<tr>
<td>100 Hz $\leq f_m \leq 100$ kHz</td>
<td>( \left( \frac{1 \times 10^{-3}}{</td>
<td>Z_m</td>
<td>} \right) \left( 1 + \frac{200}{V_s} \right) )</td>
</tr>
<tr>
<td>100 kHz $&lt; f_m \leq 300$ kHz</td>
<td>( \left( \frac{1 \times 10^{-3}}{</td>
<td>Z_m</td>
<td>} \right) \left( 2 + \frac{200}{V_s} \right) )</td>
</tr>
<tr>
<td>300 kHz $&lt; f_m \leq 1$ MHz</td>
<td>( \left( \frac{1 \times 10^{-3}}{</td>
<td>Z_m</td>
<td>} \right) \left( 3 + \frac{200}{V_s} + \frac{V_s^2}{10^8} \right) )</td>
</tr>
<tr>
<td>SHORT</td>
<td>$f_m &lt; 100$ Hz</td>
<td>( \left( \frac{2.5 \times 10^{-3}}{</td>
<td>Z_m</td>
</tr>
<tr>
<td>100 Hz $\leq f_m \leq 100$ kHz</td>
<td>( \left( \frac{2.5 \times 10^{-3}}{</td>
<td>Z_m</td>
<td>} \right) \left( 1 + \frac{200}{V_s} \right) )</td>
</tr>
<tr>
<td>100 kHz $&lt; f_m \leq 300$ kHz</td>
<td>( \left( \frac{2.5 \times 10^{-3}}{</td>
<td>Z_m</td>
<td>} \right) \left( 2 + \frac{200}{V_s} \right) )</td>
</tr>
<tr>
<td>300 kHz $&lt; f_m \leq 1$ MHz</td>
<td>( \left( \frac{2.5 \times 10^{-3}}{</td>
<td>Z_m</td>
<td>} \right) \left( 3 + \frac{200}{V_s} + \frac{V_s^2}{10^8} \right) )</td>
</tr>
</tbody>
</table>

$V_s$ : Test signal voltage [mV rms]

$K_{oa}$ is practically negligible for impedances above 500 $\Omega$.

Table 1-2. Cable length factor $K_a$

<table>
<thead>
<tr>
<th>Test signal voltage</th>
<th>Cable length</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 2$ V rms</td>
<td>0 m</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$&gt; 2$ V rms</td>
<td>0</td>
</tr>
</tbody>
</table>

$V_m$ : Test frequency [MHz]

$|Z_m|$ : Impedance of DUT [\Omega]

$K_a$ : Impedance proportional factor
Table 1-3. Cable length factor $K_{bb}$

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Cable length</th>
<th>0 m</th>
<th>1 m</th>
<th>2 m</th>
<th>4 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_m \leq 100$ kHz</td>
<td>1</td>
<td>1 + 5 $f_m$</td>
<td>1 + 10 $f_m$</td>
<td>1 + 20 $f_m$</td>
<td></td>
</tr>
<tr>
<td>100 kHz &lt; $f_m \leq 300$ kHz</td>
<td>1</td>
<td>1 + 2 $f_m$</td>
<td>1 + 4 $f_m$</td>
<td>1 + 8 $f_m$</td>
<td></td>
</tr>
<tr>
<td>300 kHz &lt; $f_m \leq 1$ MHz</td>
<td>1</td>
<td>1 + 0.5 $f_m$</td>
<td>1 + 1 $f_m$</td>
<td>1 + 2 $f_m$</td>
<td></td>
</tr>
</tbody>
</table>

$f_m$: Test Frequency [MHz]

Table 1-4. Calibration interpolation factor $K_c$

<table>
<thead>
<tr>
<th>Test frequency</th>
<th>$K_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct calibration frequencies</td>
<td>0</td>
</tr>
<tr>
<td>Other frequencies</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

Table 1-5. Preset calibration frequencies

<table>
<thead>
<tr>
<th>Test frequency</th>
<th>100</th>
<th>120</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal level</td>
<td>1</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>[MHz]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1-6. Cable length factor $K_d$

<table>
<thead>
<tr>
<th>Test signal level</th>
<th>1 m</th>
<th>2 m</th>
<th>4 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Vrms</td>
<td>2.5 x 10^-4 (1 + 50 $f_m$)</td>
<td>5 x 10^-4 (1 + 50 $f_m$)</td>
<td>1 x 10^-3 (1 + 50 $f_m$)</td>
</tr>
<tr>
<td>&gt; 2 Vrms</td>
<td>2.5 x 10^-3 (1 + 16 $f_m$)</td>
<td>5 x 10^-3 (1 + 16 $f_m$)</td>
<td>1 x 10^-2 (1 + 16 $f_m$)</td>
</tr>
</tbody>
</table>

Figure 1-5. Temperature factor $K_e$

<table>
<thead>
<tr>
<th>Temperature [°C]</th>
<th>5</th>
<th>8</th>
<th>18</th>
<th>28</th>
<th>38</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_e$</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
Agilent 4284A Calibration Accuracy

Calibration accuracy is shown in the following figure:

\[ f_m = \text{test frequency} \ [\text{kHz}] \]

On boundary line apply the better value:

Upper value (\( A_{\text{cal}} \)) is \(|Z|, |Y|, L, C, R, X, G, \) and B calibration accuracy [%]

Lower value (\( \theta_{\text{cal}} \)) is phase calibration accuracy in radians.

\[
A_{\text{cal}} = 0.03 + 1 \times 10^{-3} f_m \quad \text{[\( \Omega \)]}
\]

\[
\theta_{\text{cal}} = (100 + 20f_m) \times 10^{-6} \quad \text{[rad]}
\]

Test frequency

* \( A_{\text{cal}} = 0.1\% \) when Hi-PW mode is on.

** \( A_{\text{cal}} = (300 + f_m) \times 10^{-6} \) [rad] when Hi-PW mode is on.

Phase calibration accuracy in degree, \( \theta_{\text{cal}} \) [deg] is given as,

\[
\theta_{\text{cal}} \ [\text{deg}] = \frac{180}{\pi} \theta_{\text{cal}} \ [\text{rad}]\]
Additional Specifications

When measured value < 10 mΩ, |Z|, R, and X accuracy $A_e$, which is described on page 5, is given as following equation.

$$|Z|, R, and X accuracy: \quad A_e = \pm \left( (K_a + K_{aa} + K_c) \times 100 + K_d \right) \times K_e \quad (\%)$$

Where
- $K_a$: Impedance proportional factor (refer to Table 1-1)
- $K_{aa}$: Cable length factor (refer to Table 1-2)
- $K_c$: Calibration interpolation factor (refer to Tables 1-4 and 1-5)
- $K_d$: Cable length factor (refer to Table 1-6)
- $K_e$: Temperature factor (refer to Figure 1-5)

$X$ accuracy apply when $D_x$ (measured $D$ value) ≤ 0.1
$R$ accuracy apply when $Q_x$ (measured $Q$ value) ≤ 0.1
When $D_x > 0.1$, multiply $A_e$ by $\sqrt{1 + D_x^2}$ for $X$ accuracy.
When $Q_x > 0.1$, multiply $A_e$ by $\sqrt{1 + Q_x^2}$ for $R$ accuracy.

When measured value < 10 mΩ, calibration accuracy $A_{cal}$, which is described on page 11, is given as follows.

Calibration accuracy:
- When 20 Hz ≤ $f_m$ ≤ 1 kHz, calibration accuracy is 0.03 [%].
- When 1 kHz < $f_m$ ≤ 100 kHz, calibration accuracy is 0.05 [%].
- When 100 kHz < $f_m$ ≤ 1 MHz, calibration accuracy is $0.05 + 5 \times 10^{-5} \times f_m$ [%].
  - $f_m$: test frequency [kHz]
  - $* A_{cal} = 0.1\%$ when Hi-PW mode is on.

Correction Functions

Zero open
Eliminates measurement errors due to parasitic stray impedances of the test fixture.

Zero short
Eliminates measurement errors due to parasitic residual impedances of the test fixture.

Load
Improves the measurement accuracy by using a working standard (calibrated device) as a reference.

List Sweep
A maximum of 10 frequencies or test signal levels can be programmed. Single or sequential test can be performed. When Option 4284A-001 is installed, DC bias voltages can also be programmed.

Comparator Function
Ten bin sorting for the primary measurement parameter, and IN/OUT decision output for the secondary measurement parameter.

Sorting modes
Sequential mode. Sorting into unnested bins with absolute upper and lower limits

Tolerance mode. Sorting into nested bins with absolute or percent limits

Bin count
0 to 999,999

List sweep comparator
HIGH/IN/LOW decision output for each point in the list sweep table.

DC Bias
0 V, 1.5 V, and 2 V selectable

Setting accuracy
±5% (1.5 V, 2 V)
Other Functions

Store/load
Ten instrument control settings, including comparator limits and list sweep programs, can be stored and loaded from and into the internal non-volatile memory. Ten additional settings can also be stored and loaded from each removable memory card.

GPIB
All control settings, measured values, comparator limits, list sweep program. ASCII and 64-bit binary format. GPIB buffer memory can store measured values for a maximum of 128 measurements and output packed data over the GPIB bus. Complies with IEEE-488.1 and 488.2. The programming language is TMSL.

Interface functions
SH1, AH1, T5, L4, SR1, RL1, DC1, DT1, C0, E1

Self test
Softkey controllable. Provides a means to confirm proper operation.

Options
Option 4284A-001 (power amp/DC bias)
Increases test signal level and adds the variable DC bias voltage function.

Test signal level monitor

<table>
<thead>
<tr>
<th>Mode</th>
<th>Range</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage(^1)</td>
<td>&gt; 2 V(_{rms})</td>
<td>±(3% of reading + 5 mV)</td>
</tr>
<tr>
<td></td>
<td>5 mV to 2 V(_{rms})</td>
<td>±(3% of reading + 0.5 mV)</td>
</tr>
<tr>
<td></td>
<td>0.01 mV to 5 mV(_{rms})</td>
<td>±(11% of reading + 0.5 mV)</td>
</tr>
<tr>
<td>Current(^1)</td>
<td>&gt; 20 mArms</td>
<td>±(3% of reading + 50 µA)</td>
</tr>
<tr>
<td></td>
<td>50 µA to 20 mArms</td>
<td>±(3% of reading + 5 µA)</td>
</tr>
<tr>
<td></td>
<td>0.001 µA to 50 µArms</td>
<td>±(11% of reading + 1 µA)</td>
</tr>
</tbody>
</table>

1. Add the impedance measurement accuracy [%] to the voltage level monitor accuracy when the DUT’s impedance is < 100 Ω
2. Add the impedance measurement accuracy [%] to the current level monitor accuracy when the DUT’s impedance is ≥ 100 Ω.

Accuracies apply when test cable length is 0 m or 1 m. Additional error for 2 m or 4 m test cable length is given as:

\[
f_m \times \frac{L}{2} \%
\]

where:

- \(f_m\) is test frequency [MHz]
- \(L\) is test cable length [m]

DC bias level
The following DC bias level accuracy is specified for an ambient temperature range of 23 °C ±5 °C. Multiply the temperature induced setting error listed in Figure 1-5 for the temperature range of 0 °C to 55 °C.

Test signal level ≤ 2 V\(_{rms}\)

<table>
<thead>
<tr>
<th>Voltage range</th>
<th>Resolution</th>
<th>Setting accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>±(0.000 to 4.000) V</td>
<td>1 mV</td>
<td>±(0.1% of setting + 1 mV)</td>
</tr>
<tr>
<td>±(4.002 to 8.000) V</td>
<td>2 mV</td>
<td>±(0.1% of setting + 2 mV)</td>
</tr>
<tr>
<td>±(8.005 to 20.000) V</td>
<td>5 mV</td>
<td>±(0.1% of setting + 5 mV)</td>
</tr>
<tr>
<td>±(20.01 to 40.00) V</td>
<td>10 mV</td>
<td>±(0.1% of setting + 10 mV)</td>
</tr>
</tbody>
</table>

Output impedance
100 Ω, ±6%
Test signal level > 2 Vrms

<table>
<thead>
<tr>
<th>Voltage range</th>
<th>Resolution</th>
<th>Setting accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>±(0.000 to 4.000) V</td>
<td>1 mV</td>
<td>±(0.1% of setting + 3 mV)</td>
</tr>
<tr>
<td>±(4.002 to 8.000) V</td>
<td>2 mV</td>
<td>±(0.1% of setting + 4 mV)</td>
</tr>
<tr>
<td>±(8.005 to 20.000) V</td>
<td>5 mV</td>
<td>±(0.1% of setting + 7 mV)</td>
</tr>
<tr>
<td>±(20.01 to 40.00) V</td>
<td>10 mV</td>
<td>±(0.1% of setting + 12 mV)</td>
</tr>
</tbody>
</table>

Setting accuracies apply when the bias current isolation function is set to OFF. When the bias current isolation function is set to on, add ±20 mV to each accuracy value (DC bias current ≤ 1 μA).

Bias current isolation function
A maximum DC bias current of 100 mA (typical value) can be applied to the DUT.

DC bias monitor terminal
Rear panel BNC connector

Other Options
Option 4284A-700 Standard power (2 V, 20 mA, 2 V DC bias)
Option 4284A-001 Power amplifier/DC bias
Option 4284A-002 Bias current interface
  Allows the 4284A to control the 4284A bias current source.
Option 4284A-004 Memory card
Option 4284A-006 2 m/4 m cable length operation
Option 4284A-201 Handler interface
Option 4284A-202 Handler interface
Option 4284A-301 Scanner interface
Option 4284A-710 Blank panel
Option 4284A-907 Front handle kit
Option 4284A-908 Rack mount kit
Option 4284A-909 Rack flange and handle kit
Option 4284A-915 Add service manual
Option 4284A-ABJ Add Japanese manual
Option 4284A-ABA Add English manual

Furnished Accessories
Power cable Depends on the country where the 4284A is being used.
Fuse Only for Option 4284A-201, Part number 2110-0046, 2 each

Power Requirements
Line voltage
100, 120, 220 Vac ±10%, 240 Vac +5% – 10%

Line frequency
47 to 66 Hz

Power consumption
200 VA max

Operating Environment
Temperature
0 °C to 55 °C

Humidity
≤ 95% R.H. at 40 °C

Dimensions
426 (W) by 177 (H) by 498 (D) (mm)

Weight
Approximately 15 kg (33 lb., standard)

Display
LCD dot-matrix display

Capable of displaying
Measured values
Control settings
Comparator limits and decisions
List sweep tables
Self test message and annunciations

Number of display digits
6 digits, maximum display count 999,999
Supplemental Performance Characteristics
The 4284A supplemental performance characteristics are not specifications but are typical characteristics included as supplemental information for the operator.

Stability
MEDIUM integration time and operating temperature at 23 °C ±5 °C

\[ |Z|, \ |Y| \ L, C, R, < 0.01%/day \]

\[ D < 0.0001/day \]

Temperature Coefficient
MEDIUM integration time and operating temperature at 23 °C ±5 °C

\[
\begin{array}{c|c|c}
\text{Test signal level} & |Z|, |Y|, L, C, R & D \\
\hline
\geq 20 \text{ mV}_{\text{rms}} & < 0.0025%/^\circ\text{C} & < 0.000025/^\circ\text{C} \\
< 20 \text{ mV}_{\text{rms}} & < 0.0075%/^\circ\text{C} & < 0.000075/^\circ\text{C} \\
\end{array}
\]

Settling Time
Frequency \( f_m \)
< 70 ms \( f_m \geq 1 \text{ kHz} \)
< 120 ms \( 100 \text{ Hz} \leq f_m < 1 \text{ kHz} \)
< 160 ms \( f_m < 100 \text{ Hz} \)

Test signal level
< 120 ms

Measurement range
< 50 ms/range shift \( f_m \geq 1 \text{ kHz} \)

Input Protection
Internal circuit protection, when a charged capacitor is connected to the UNKNOWN terminals.

The maximum capacitor voltage is:

\[ V_{\text{max}} = \sqrt{\frac{1}{C}} \ [\text{V}] \]

where:

\[ V_{\text{max}} \leq 200 \text{ V} \]

\[ C \text{ is in Farads} \]

Measurement Time
Typical measurement times from the trigger to the output of EOM at the handler interface.
(EOM: end of measurement)

<table>
<thead>
<tr>
<th>Integration time</th>
<th>100 Hz</th>
<th>1 kHz</th>
<th>10 kHz</th>
<th>1 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHORT</td>
<td>270 ms</td>
<td>40 ms</td>
<td>30 ms</td>
<td>30 ms</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>400 ms</td>
<td>190 ms</td>
<td>180 ms</td>
<td>180 ms</td>
</tr>
<tr>
<td>LONG</td>
<td>1040 ms</td>
<td>830 ms</td>
<td>820 ms</td>
<td>820 ms</td>
</tr>
</tbody>
</table>

Display time
Display time for each display format is given as

- MEAS DISPLAY page: Approx. 8 ms
- BIN No. DISPLAY page: Approx. 5 ms
- BIN COUNT DISPLAY page: Approx. 0.5 ms

GPIB data output time
Internal GPIB data processing time from EOM output to measurement data output on GPIB lines (excluding display time).

Approx. 10 ms

DC Bias (1.5 V/2 V)
Output current: 20 mA max.
Option 4284A-001 (Power Amp/DC Bias)

DC bias voltage

DC bias voltage applied to DUT \((V_{dut})\) is given as

\[ V_{dut} = V_b - 100 \times I_b \quad [V] \]

Where, 
- \(V_b\) is DC bias setting voltage [V]
- \(I_b\) is DC bias current [A]

DC bias current

DC bias current applied to DUT \((I_{dut})\) is given as

\[ I_{dut} = \frac{V_b}{100 + R_{dc}} \quad [A] \]

where:
- \(V_b\) is DC bias setting voltage [V]
- \(R_{dc}\) is the DUT’s DC resistance [Ω]

Maximum DC bias current when the normal measurement can be performed is as follows.

<table>
<thead>
<tr>
<th>Measurement range</th>
<th>10 Ω</th>
<th>100 Ω</th>
<th>300 Ω</th>
<th>1 kΩ</th>
<th>3 kΩ</th>
<th>10 kΩ</th>
<th>30 kΩ</th>
<th>100 kΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bias current isolation</td>
<td>On</td>
<td>100 mA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off</td>
<td>2 mA</td>
<td>2 mA</td>
<td>2 mA</td>
<td>1 mA</td>
<td>300 µA</td>
<td>100 µA</td>
<td>30 µA</td>
<td>10 µA</td>
</tr>
</tbody>
</table>

Relative accuracy with bias current isolation

When the bias current isolation function is set to on, add the display fluctuation \((N)\) given in the following equation to the \(A_e\) of relative accuracy. (Refer to “relative accuracy” of specification.)

The following equation is specified when all of the following conditions are satisfied.

- DUT impedance \(\geq 100 \, Ω\)
- Test signal level setting \(\leq 1 \, V_{rms}\)
- DC bias current \(\geq 1 \, mA\)
- Integration time: MEDIUM

\[ N = P \times \frac{DUT \_impedance \ [Ω]}{Measurement \_range \ [Ω]} \times \frac{DC \_bias \_current \ [mA]}{Test \_signal \_level \ [V_{rms}]} \times \frac{1}{\sqrt{n}} \times 10^{-4} \quad [%] \]

where:
- \(P\) is the coefficient listed on Table 1-7.
- \(n\) is the number of averaging.
When the DC bias current is less than 1 mA, apply N value at 1 mA. When integration time is set to SHORT, multiply N value by 5. When integration time is set to LONG, multiply N value by 0.5.

### Table 1-7. Coefficient related to test frequency and measurement range

<table>
<thead>
<tr>
<th>Meas. range</th>
<th>Test frequency $f_m$ [Hz]</th>
<th>20 $\leq f_m &lt; 100$</th>
<th>100 $\leq f_m &lt; 1 k$</th>
<th>1 k $\leq f_m &lt; 10 k$</th>
<th>10 k $\leq f_m &lt; 1 MHz$</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 $\Omega$</td>
<td></td>
<td>0.75</td>
<td>0.225</td>
<td>0.045</td>
<td>0.015</td>
</tr>
<tr>
<td>300 $\Omega$</td>
<td></td>
<td>2.5</td>
<td>0.75</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>1 k$\Omega$</td>
<td></td>
<td>7.5</td>
<td>2.25</td>
<td>0.45</td>
<td>0.15</td>
</tr>
<tr>
<td>3 k$\Omega$</td>
<td></td>
<td>25</td>
<td>7.5</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>10 k$\Omega$</td>
<td></td>
<td>75</td>
<td>22.5</td>
<td>4.5</td>
<td>1.5</td>
</tr>
<tr>
<td>30 k$\Omega$</td>
<td></td>
<td>250</td>
<td>75</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>100 k$\Omega$</td>
<td></td>
<td>750</td>
<td>225</td>
<td>45</td>
<td>15</td>
</tr>
</tbody>
</table>

**Calculation Example**

**Measurement conditions**

- **DUT**: 100 pF
- Test signal level: 20 mVrms
- Test frequency: 10 kHz
- Integration time: MEDIUM

Then:

DUT's impedance $= 1/(2\pi \times 10^4 \times 100 \times 10^{-12}) = 159$ k$\Omega$

Measurement range is 100 k$\Omega$

DC bias current $<< 1$ mA

$P = 15$ (according to Table 1-7)

$A_e$ of relative accuracy without bias current isolation is $\pm 0.22 \%$. (Refer to “relative accuracy” of specification.)

Then, $N = 15 \times (159 \times 10^3)/(100 \times 10^3) \times 1/(20 \times 10^3) \times 10^{-4} = 0.12 \%$

Therefore, relative capacitance accuracy is:

$\pm (0.22 + 0.12) = \pm 0.34 \%$

---

**DC Bias Settling Time**

When DC bias is set to on, add the settling time listed in the following table to the measurement time. This settling time does not include the DUT charge time.

<table>
<thead>
<tr>
<th>Test frequency ($f_m$)</th>
<th>Bias current isolation</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Hz $\leq f_m &lt; 1$ kHz</td>
<td>210 ms 20 ms</td>
</tr>
<tr>
<td>1 kHz $\leq f_m &lt; 10$ kHz</td>
<td>70 ms 20 ms</td>
</tr>
<tr>
<td>10 kHz $\leq f_m &lt; 1$ MHz</td>
<td>30 ms 20 ms</td>
</tr>
</tbody>
</table>

Sum of DC bias settling time plus DUT (capacitor) charge time is shown in the following figure.

**Figure 1-6. Measurement time**
Rack(Handle) Installation
The Agilent 4284A can be rack mounted and used as a component of a measurement system. The following figure shows how to rack mount the 4284A.

Table 1-8. Rack mount kits

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Kit part number</th>
</tr>
</thead>
<tbody>
<tr>
<td>4284A-907</td>
<td>Handle kit</td>
<td>5061-9690</td>
</tr>
<tr>
<td>4284A-908</td>
<td>Rack flange kit</td>
<td>5061-9678</td>
</tr>
<tr>
<td>4284A-909</td>
<td>Rack flange and handle kit</td>
<td>5061-9684</td>
</tr>
</tbody>
</table>

Figure 1-7. Rack mount kits installation

1. Remove the adhesive-backed trim strips (1) from the left and right front sides of the 4284A.

2. HANDLE INSTALLATION: Attach the front handles (3) to the sides using the screws provided and attach the trim strip (4) to the handle.

3. RACK MOUNTING: Attach the rack mount flange (2) to the left and right front sides of the 4284A using the screws provided.

4. HANDLE AND RACK MOUNTING: Attach the front handle (3) and the rack mount flange (5) together on the left and right front sides of the 4284A using the screws provided.

5. When rack mounting the 4284A (3 and 4 above), remove all four feet (lift bar on the inner side of the foot and slide the foot toward the bar).
Storage and repacking

This section describes the environment for storing or shipping the Agilent 4284A, and how to repack- age the 4284A far shipment when necessary.

Environment

The 4284A should be stored in a clean, dry envi- ronment. The following environmental limitations apply for both storage and shipment:

Temperature: –20 °C to 60 °C
Humidity: ≤ 95% RH (at 40 °C)

To prevent condensation from taking place on the inside of the 4284A, protect the instrument against temperature extremes.

Original packaging

Containers and packing materials identical to those used in factory packaging are available through your closest Agilent sales office. If the instrument is being returned to Agilent for servic- ing, attach a tag indicating the service required, the return address, the model number, and the full serial number. Mark the container FRAGILE to help ensure careful handling. In any correspond- dence, refer to the instrument by model number and its full serial number.

Other packaging

The following general instructions should be used when repacking with commercially available materials:

1. Wrap the 4284A in heavy paper or plastic. When shipping to an Agilent sales office or service center, attach a tag indicating the service required, return address, model number, and the full serial number.
2. Use a strong shipping container. A double- walled carton made of at least 350 pound test material is adequate.
3. Use enough shock absorbing material (3- to 4-inch layer) around all sides of the instrument to provide a firm cushion and to prevent movement inside the container. Use cardboard to protect the front panel.
4. Securely seal the shipping container.
5. Mark the shipping container FRAGILE to help ensure careful handling.
6. In any correspondence, refer to the 4284A by model number and by its full serial number.

Caution

The memory card should be removed before packing the 4284A.
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