Chapter 8

Performance Tests

8.1 Preparation for Performance Tests

This section explains about necessary preparations for performing performance tests of the FG100 Series instrument.

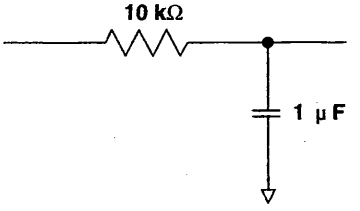
Purpose of Performance Tests

These tests are designed to verify if the FG100 Series Synthesized Function Generators meet the necessary specifications. When any of the measurement exceeds a criteria, the instrument needs adjustment or repair. Contact your nearest Yokogawa representative for adjustment and repairs.

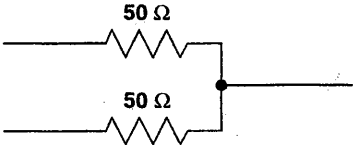
Equipments Necessary for Performance Tests

Listed below are equipment necessary for the purpose of performance tests under Section 8.2 and thereafter.

Digital multimeter	KEITHLEY 2001 or equivalent
Digital oscilloscope	Yokogawa DL1300 or equivalent
Spectrum analyzer	HP3588A or equivalent (EXT CLK connected to CLK OUT of the time interval analyzer)
Time interval analyzer	HP53310A (with 010 option) or equivalent
50Ω field-through	Hirose MR201 (0.5 W) or equivalent
Attenuator (6 dB)	Hirose AT506 (2 W) or equivalent
Attenuator (20 dB)	Hirose AT520 (2 W) or equivalent
Low-pass filter	(10 kΩ ±1%, 1 μF ±10%)



Electric power synthesizer (50 Ω ±0.2%, 1 W×2)



Coaxial cable	50 Ω BNC, 1 m

Environments for Performance Tests

- **Warm-up time for performance test equipment and the FG100 Series being tested**
  - 30 minutes or longer [2 days or longer for HP53310A (with 010 option)]

- **Operational conditions for performance tests**
  - Ambient temperature : 23° C ±2° C
  - Ambient humidity : 50 ±10%RH
  - Source voltage : 100 V ±1%
  - Use coaxial cables to connect the FG100 Series to measuring equipment.

8.2 Performance Tests

8.2.1 Amplitude Accuracy

This section explains the procedure of testing the accuracy of 1 kHz sine wave (under high-impedance load).

- **Equipment used for testing**
  Digital multimeter

- **Testing Procedure**
  1. Set the FG100 Series and the digital multimeter as written below.
  - On FG120, test both channels separately.

  - The FG100 Series settings
    Output mode : Continuous signal output mode (CONT)
    Output waveform : Sine wave
    Frequency : 1 kHz
    Offset : 0 V

  - Digital multimeter settings
    AC voltage measurement
    AC coupling
    AUTO range

  2. Connect OUTPUT of the FG100 Series to INPUT of the digital multimeter.

- **Criteria**
  ±(0.5% of setting + 0.2% of the range)

  - When the setting range is 10 V

Set voltage	Criteria
7.071 Vrms	7.071 Vrms ±49 mVrms
3.535 Vrms	3.535 Vrms ±31 mVrms
1.768 Vrms	1.768 Vrms ±22 mVrms
707 mVrms	707 mVrms ±17 mVrms
353 mVrms	353 mVrms ±15 mVrms
176 mVrms	176 mVrms ±14 mVrms
70 mVrms	70 mVrms ±14 mVrms
35 mVrms	35 mVrms ±14 mVrms
17 mVrms	17 mVrms ±14 mVrms

  - When the setting range is 1 V

Set voltage	Criteria
707 mVrms	707 mVrms±4.9 mVrms

8.2.2 Output Impedance

This section explains the procedure of performance test of output impedance.

- **Equipment used for testing**
  Digital multimeter
  50 Ω field-through

- **Testing Procedure**
  1. Using the digital multimeter, measure the resistance component Rcable and 50 Ω field-through R50 of the cable.
     - On FG120, test both channels separately.

  2. Set the FG100 Series and the digital multimeter as written below.

     - The FG100 Series settings
       Output mode : Continuous signal output mode (CONT)
       Output waveform : Sine wave
       Frequency : 1 kHz
       Offset : 0 V

     - Digital multimeter settings
       AC voltage measurement
       AC coupling

  3. Using the digital multimeter, measure the output of the FG100 Series.
     - "VOUTHi" is used to represent the measured value.

  4. Connect the 50 Ω field-through and using the digital multimeter, measure the output of the FG100 Series.
     - "VOUT50" is used to represent the measured value.

  - **"Rout" of the output impedance is defined as the following:**
    $Rout = (VOUTHi/VOUT50 - 1) \times R50 - Rcable$

- **Criteria**
  50 Ω ±1%

  - When the range is 10 V (with range ATT OFF)

Set voltage	Criteria
20 Vp-p	50 Ω ±0.5 Ω

  - When the range is 1V (with range ATT ON)

Set voltage	Criteria
2 Vp-p	50 Ω ±0.5 Ω

8.2.3 Amplitude Frequency Characteristics

This section explains the procedure of testing frequency characteristics at 1 kHz of the sine wave, square wave, triangular wave, ramp wave and pulse wave under a load of 50 Ω.

- **Equipment used for testing**
  Digital multimeter
  50 Ω field-through
  Attenuator (6 dB)

- **Testing Procedure**
  1. Set the FG100 Series and the digital multimeter as written below.
  - On FG120, test both channels separately.

  - The FG100 Series settings

Output mode	: Continuous signal output mode (CONT)
Output waveform	: Sine wave
Amplitude	: 10 V
Offset	: 0 V
Scaling	: 0.5

  - Digital multimeter settings
    AC voltage measurement
    AC coupling
    AUTO range

  2. Connect the output of the FG100 Series to the digital multimeter via attenuator and 50 Ω field-through.
  - This measures the ratio of fluctuation the AC voltage due to the frequency using the AC voltage at 1 kHz as the reference.

- **Criteria**
  - Sine waves

Set voltage	Criteria
1 kHz (reference)	
100 Hz	±0.1 dB
10 kHz	±0.1 dB
100 kHz	±0.2 dB
1 MHz	±0.5 dB
2 MHz	±1.0 dB

  - Square waves, pulse waves (duty ratio 50%)

Set voltage	Criteria
1 kHz (reference)	
100 Hz	±2%
10 kHz	±2%

  - Triangular waves, ramp waves

Set voltage	Criteria
1 kHz (reference)	
100 Hz	±3%
10 kHz	±3%

8.2.4 Voltage Accuracy of the Direct Current Mode

This section explains the procedure of performance test of voltage accuracy of the direct current mode (under high-impedance load).

- **Equipment used for testing**
  Digital multimeter

- **Testing Procedure**
  1. Set the FG100 Series and the digital multimeter as written below.
  - On FG120, test both channels separately.

    - The FG100 Series settings
      Output mode: Direct current mode (DC)

    - Digital multimeter settings
      DC voltage measurement
      AUTO range

  2. Connect the output of the FG100 Series to the input of the digital multimeter.

- **Criteria**
  ±(0.3% of setting + 0.1% of the range)

  - When the setting range is 10V

Set voltage	Criteria
+10 V	+10 V ±40 mV
+1 V	+1 V ±13 mV
+100 mV	+100 mV ±10 mV
0 V	0 V ±10 mV
−100 mV	−100 mV ±10 mV
−1 V	−1 V ±13 mV
−10 V	−10 V ±40 mV

8.2.5 Offset Voltage Accuracy

This section explains the procedure of performance test of the (DC + AC) offset voltage (under high-impedance load).

- **Equipment used for testing**
  Digital multimeter
  Low-pass filter

- **Testing Procedure**
  1. Set the FG100 Series and the digital multimeter as written below.
  - On FG120, test both channels separately.

  - The FG100 Series settings
    Output mode : Continuous signal output mode (CONT)
    Output waveform : Sine wave
    Frequency : 1 kHz

  - Digital multimeter settings
    DC voltage measurement
    AUTO range

  2. Connect the output of the FG100 Series to the input of the digital multimeter via low-pass filter.

- **Criteria**
  ±(0.3% of setting + 0.2% of the range + 0.2% of set amplitude)

Set amplitude	Set voltage	Criteria
20 V	+0 V	0 V ±60 mV
10 V	+5 V	+5 V ±55 mV

8.2.6 Sine Wave Purity

Harmonic Level and Harmonic Distortion Ratio

This section explains the procedure of testing the harmonic level and harmonic distortion ratio.

- **Equipment used for testing**
  Spectrum analyzer
  Attenuator (20 dB)

- **Testing Procedure**
  1. Set the FG100 Series and the spectrum analyzer as written below.
  - On FG120, test both channels separately.

  - The FG100 Series settings
    Output mode : Continuous signal output mode (CONT)
    Output waveform : Sine wave
    Amplitude : 10 V
    Offset : 0 V
    Scaling : 0.5

  - Spectrum analyzer settings
    Range : +10 dBm
    CF : The FG100 Series set frequency and 2×, 3×, 4× and 5× frequencies

Set frequency	RES BW	F span
10 kHz	9.1 Hz	1 kHz
100 kHz	36 Hz	1 kHz
2 MHz	290 Hz	10 kHz

  2. Connect the output of the FG100 Series to the input of the spectrum analyzer via attenuator (20 dB).
  The following holds true when the harmonic levels of the set frequency and the nth degrees of frequencies are expressed by e_1, e_2, e_3, e_4, and e_5 (dBM):

  - Harmonic level
    Highest nth degree of harmonic level = $e_n - e_1$ (dBc)
    Measure the maximum level of the 2nd, 3rd, 4th and 5th degrees of harmonic levels.

  - Harmonic distortion ratio
    Determine the harmonic distortion ratio from the following equation.

$$\text{Harmonic distortion ratio} = \frac{\sqrt{\left(10^{\frac{e_2}{20}}\right)^2 + \left(10^{\frac{e_3}{20}}\right)^2 + \left(10^{\frac{e_4}{20}}\right)^2 + \left(10^{\frac{e_5}{20}}\right)^2}}{10^{\frac{e_1}{20}}} \times 100\%$$

- **Criteria**
  - Harmonic level
    - Standard model

Frequency	Criteria Harmonic level
10 kHz	–55 dBc max
100 kHz	–50 dBc max
2 MHz	–35 dBc max

    - Low distortion model (DIST1, DIST2 = optional spec.)

Frequency	Criteria Harmonic level
10 kHz	–70 dBc max
100 kHz	–60 dBc max
2 MHz	–40 dBc max

  - Harmonic distortion level
    - Standard model

Frequency	Criteria
10 kHz	0.3% max

    - Low distortion model (DIST1, DIST2 = optional spec.)

Frequency	Criteria
10 kHz	0.05% max

Spurious Level

This section explains the procedure of performance test of the spurious level.

- **Equipment used for testing**
  Spectrum analyzer
  Attenuator (20 dB)

- **Testing Procedure**
  1. Set the FG100 Series and the spectrum analyzer as written below.
  - On FG120, test both channels separately.

  - The FG100 Series settings

Output mode	: Continuous signal output mode (CONT)
Output waveform	: Sine wave
Frequency	: 100 kHz
Amplitude	: 10 V
Offset	: 0 V
Scaling	: 0.5

  - Spectrum analyzer settings

Start frequency	: 1 kHz
Stop frequency	: 20 MHz
RES BW	: 290 Hz

  2. Connect the output of the FG100 Series to the input of the spectrum analyzer via attenuator (20 dB).

  3. Measure the maximum spurious level at frequencies from 1 kHz through 20 MHz other than standard waves and harmonic components.

- **Criteria**
  - Standard model

Frequency	Criteria
100 kHz	–55 dBc max

  - Low distortion model (DIST1, DIST2 = optional spec.)

Frequency	Criteria
100 kHz	–65 dBc max

8.2.7 Pulse Characteristics

Rise Time and Overshoot

This section explains the procedure of performance test of the rise time and overshoot of square waves and pulse waves.

- **Equipment used for testing**
  Digital oscilloscope
  50 Ω field-through

- **Testing Procedure**
  1. Set the FG100 Series and the digital oscilloscope as written below.
     - On FG120, test both channels separately.

     - The FG100 Series settings

Output mode	: Continuous signal output mode (CONT)
Output waveform	: Square wave or pulse wave
Frequency	: 10 kHz
Amplitude	: 10 V
Offset	: 0 V
Scaling	: 0.5

     - Digital oscilloscope settings

V/div	: 2 V/d
TIME/div	: 200 ns/d
MEASURE	: AUTO, rise time, overshoot

  2. Connect the output of the FG100 Series to the digital oscilloscope via 50 Ω field-through.

- **Criteria**
  - Rise time
    - Square waves
      100 ns max(10% to 90%)
    - Pulse waves (duty ratio 50%)
      200 ns max(10% to 90%)
  - Overshoot
    - Square waves
      Within +5% of output (p-p) value
    - Pulse waves (duty ratio 50%)
      Within +5% of output (p-p) value

Duty Ratio

This section explains the procedure of performance test of duty ratio of pulse waves.

- **Equipment used for testing**
  Time interval analyzer

- **Testing Procedure**
  1. Set the FG100 Series as written below.
     - On FG120, test both channels separately.

     - The FG100 Series settings

Output mode	: Continuous signal output mode (CONT)
Output waveform	: Pulse wave
Frequency	: 10 kHz
Amplitude	: 10 V
Offset	: 0 V
Scaling	: 0.5
Duty ratio	: 50%

  2. Connect the output of the FG100 Series to the time interval analyzer.

- **Criteria**

Waveform	Criteria	
Pulse wave	(1/set frequency) ±0.2%	50 µs ±0.2 µs

8.2.8 Cross-Talk Between Channels (FG120 only)

This section explains the procedure of performance test of cross-talk between channels.

- **Equipment used for testing**
  Spectrum analyzer
  Attenuator (20 dB)
  50 Ω field-through

- **Testing Procedure**
  1. Set the FG120 and the spectrum analyzer as written below.

  - FG120 settings

	CH1	CH2
Output mode	Continuous signal output mode (CONT)	Continuous signal output mode (CONT)
Frequency	2 MHz	1.5 MHz
Amplitude	10 V	10 V
Phase	0 deg	0 deg
Offset	0 V	0 V
Scaling	0.5	0.5

  - Spectrum analyzer settings
    Range : +10 dBm
    F span : 1 kHz
    RES BW : 150 Hz

  2. Connect the CH2 output of the FG120 to the input of the spectrum analyzer via attenuator (20 dB).

  3. Connect the CH1 output of the FG120 to the 50 Ω field-through.

  4. Set the spectrum analyzer at "CF1.5 MHz" and measure the basic wave signal level ($e_{1.5}$).

  5. Set the spectrum analyzer at "CF2 MHz" and measure the level (e_2) at which cross-talk occurs from CH1 output to CH2 output "namely, cross-talk between channels (dB) = $e_2 - e_{1.5}$".

- **Criteria**
  –70 dB max.

8.2.9 Offset Phase Between Channels (FG120/DIST2 only)

This section explains the procedure of performance test of phase offset between channels by the 180-degree phase testing method using an electric power synthesizer.

- **Principle of measurement**
  - **The objective is achieved by determining a phase error when the offset phase between CH1 and CH2 is 180 degrees.**
    Assuming that amplitude A of CH1 is identical to that of CH2, that the offset phase error is θ^1 when the CH1 phase and CH2 phase are set to 0 deg and 180 deg respectively, and further that the offset phase error is θ^2 when the CH2 phase is set to 0 deg,

    - Signal of CH1
      $S1 = A\sin(\omega t)$
    - Signal of CH2 at 180 deg setting
      $S2 = A\sin(\omega t + \pi + \theta^1)$
    - Signal of CH2 at 0 deg setting
      $S2 = A\sin(\omega t + \theta^2)$
    - Addition of CH1 and CH2 with CH2 phase set at 180 deg
      $X(\pi) = S1 + S2 = -2 \cdot A \cdot \sin(\frac{\theta^1}{2}) \cos(\omega t + \frac{\theta^1}{2})$
    - Addition of CH1 and CH2 with CH2 phase set at 0 deg
      $X(0) = S1 + S2 = 2 \cdot A \cdot \cos(\frac{\theta^2}{2}) \sin(\omega t + \frac{\theta^2}{2})$
    - Since $\theta^2 \approx \theta^1 \approx 0$, the voltage ratio of $X(\pi)$ and $X(0)$
      $X(\pi)\ \text{rms} / X(0)\ \text{rms} = \sin(\frac{\theta^1}{2}) / \cos(\frac{\theta^1}{2})$
      $\approx \tan(\frac{\theta^1}{2})$
    - Phase error θ^1 with offset phase at 180 deg setting
      $\theta^1 = 2\tan^{-1}(X(\pi)\ \text{rms} / X(0)\ \text{rms})$

    Therefore, the phase error θ^1 can be determined by measuring the output value of the electric power synthesizer that combines CH1 and CH2 when CH1 and CH2 outputs are identical and the offset phase is set at 180 and 0 degree.

- **Equipment used for testing**
  Spectrum analyzer
  Attenuator (20 dB)
  Electric power synthesizer

- **Testing Procedure**

1. Set the FG120 and the spectrum analyzer as written below.

- FG120 settings

	CH1	CH2
Output mode	Continuous signal output mode (CONT)	Continuous signal output mode (CONT)
Amplitude	9.9 V	9.9 V
Phase	0 deg	180 deg
Offset	0 V	0 V
Scaling	0.5	0.5
Separate OFF		

- Spectrum analyzer settings

Frequency : Same as FG120 frequency setting
Range : –20 dBm
Span : 0 kHz
RES BW : 18 Hz

2. Connect the CH1 and CH2 output of the FG120 to the electric power synthesizer, and connect its output to the input of the spectrum analyzer via attenuator (20 dB).

3. While monitoring the spectrum analyzer, adjust the amplitude of CH2 so that the added level becomes the smallest. This value is expressed as A(π) for the purpose of this test.

4. Change the FG120 and spectrum analyzer settings as written below, and determine the level as above. This value is expressed as A(0) for the purpose of this test.

- FG120 settings

	CH1	CH2
Phase	0 deg	0 deg

- Spectrum analyzer settings

Range : +10 dBm

- Voltage ratio of X(π) and X(0) is X(π) rms / X(0) rms = 10((A(π)–A(0)) / 20)
- Phase error θ^1 at 180 deg offset phase setting
  $\theta^1 = 2\tan^{-1}$ (X(π) rms / X(0) rms)

Confirm if the measurement at specified measuring points meets the criteria.

- **Criteria**

Set frequency	Criteria
1 kHz	0.02 deg
10 kHz	0.1 deg

8.2.10 Frequency

This section explains the procedure of performance test of frequency.

- **Equipment used for testing**
  Time interval analyzer

- **Testing Procedure**
  1. Set the FG100 Series as written below.
  - On FG120, test both channels separately.

  - The FG100 Series settings

Output mode	: Continuous signal output mode (CONT)
Output waveform	: Sine wave
Frequency	: 2 MHz
Amplitude	: 10 V
Offset	: 0 V
Scaling	: 0.5

  2. Connect the CH1 output of the FG100 Series to the A input of the time interval analyzer.

- **Criteria**
  - Standard model
    ±20 ppm 2 MHz ±40 Hz

  - High stability frequency reference model (/XTAL = optional spec.)
    ±1 ppm 2 MHz ±2 Hz