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**User's  
Manual**

**FG410/FG420  
Arbitrary/Function Generator  
User's Manual(Application)**

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## Preface


Thank you for purchasing the **FG410/FG420 Arbitrary/Function Generator**.

To ensure safe and proper use of this electric equipment, please read first **Safety Precautions** on the following pages.

### ● Caution Symbols Used in This Manual


The following caution symbols are used in this manual. Be sure to observe these caution symbols and their contents to ensure the safety of the user and avoid damage to the equipment.

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 **WARNING** This mark indicates information for the avoidance of a hazard such as electric shock that may endanger human life or cause injury during handling of the equipment.


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 **AVERTISSEMENT** Ce signe indique des informations visant à éviter les accidents tels que les chocs électriques risquant de provoquer des blessures ou la mort lors de l'utilisation de l'équipement.


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 **CAUTION** This mark indicates information for the avoidance of damage to the equipment during handling.

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 **ATTENTION** Ce signe indique des informations permettant d'éviter d'endommager l'appareil lors de son utilisation.

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### ● This manual has the following chapter organization.

Instruction manuals of the FG410/FG420 are divided to two volumes, Basics and Application. Instructions for remote control (GPIB and USB) are provided separately.

If reading this manual for the first time, start from **1. OVERVIEW** of the Basics Instruction Manual.

#### Basics

##### 1. OVERVIEW

Briefly describes and explains the features and brief operation principles of the FG410/FG420.

##### 2. PREPARATIONS BEFORE USE

Describes various cautions regarding preparations to be made before using the FG410/FG420, ranging from installation to connection of the power supply.

##### 3. PANELS AND I/O TERMINALS

Describes the functions and operations of the switches and I/O terminals of the panel controls.

##### 4. BASIC OPERATION

Describes how to use basic functions.

##### 5. SAVING AND RECALLING SETTINGS

Describes how to store and retrieve the settings.

##### 6. LIST OF INITIAL SETTINGS

Describes initial settings.

##### 7. SPECIFICATIONS

Lists the specifications (functions and performance) of the FG410/FG420.

## **8. Recommended Part Replacement**

List of the recommended part replacement.

### **Application**

#### **1. DETAILS OF PARAMETER-VARIABLE WAVEFORMS**

Explains the meanings of each parameter of parameter-variable waveforms and waveform examples.

#### **2. CREATING ARBITRARY WAVEFORMS**

Explains how to input and edit arbitrary waveforms from the panel control.

#### **3. HANDY USE OF 2-CHANNEL DEVICE (FG420 ONLY)**

Explains how to operate two channels at the same time.

#### **4. SYNCHRONIZING MULTIPLE UNITS**

Describes how to configure a multi-phase oscillator by connecting multiple units of this product.

#### **5. USING EXTERNAL FREQUENCY REFERENCE**

Describes how to use external frequency reference.

#### **6. USING SEQUENCE OSCILLATION**

Describes how to set and operate sequence oscillation.

#### **7. USING USER-DEFINED UNITS**

Explains the units that can be optionally set by users.

#### **8. OTHER UTILITY SETTINGS**

Explains error messages and how to set display and operational details.

#### **9. TROUBLESHOOTING**

Explains error messages and how to respond to cases where a failure is suspected.

#### **10. MAINTENANCE**

Explains the operational inspection and performance test.

## Safety Precautions

To ensure safe use, be sure to observe the following warnings and cautions.

Yokogawa Test & Measurement Corporation shall not be held liable for damages that arise from a failure to observe these warnings and cautions.

This product is a Class I product (with protective conductor terminal) that conforms to the JIS and IEC insulation standards.

### ● Use the Instrument Only for Its Intended Purpose

The FG410/FG420 is designed to generate sine waveforms, rectangular waveforms, and other various types of voltage waveforms. Use the FG410/FG420 only for this purpose.

### ● Check the Physical Appearance

Do not use the instrument if there is a problem with its physical appearance.

### ● Be sure to observe the contents of this instruction manual.

This instruction manual contains information for the safe operation and use of this product. Be sure to read this information first before using this product.

All the warnings in the instruction manual must be heeded to prevent hazards that may cause major accidents.

### ● Be sure to ground the product.

This product uses a line filter and must be grounded to avoid the risk of electric shock.

To prevent electric shock, be sure to safely implement grounding such that ground resistance is 100  $\Omega$  or lower.

The FG410/FG420 is automatically grounded when the 3-prong power plug is connected to a 3-prong power outlet with a protective grounding contact.

### ● Check the power supply voltage.

This product operates on the power supply voltage shown in “2.3 Grounding and Power Supply Connection” in the Basics Instruction Manual.

Prior to connecting the power supply, check that the voltage of the power supply matches the rated power supply of the product.

### ● In case of suspected anomaly

If this product emits smoke, an abnormal smell, or abnormal noise, immediately power it off and stop using it.

If such an anomaly occurs, do not use this product until it has been repaired, and immediately report the problem to the location of purchase (either Yokogawa Test & Measurement Corporation or your distributor).

### ● Do not use this product when gas is present.

An explosion or other such hazard may result.

### ● Do not remove the cover.

This product contains high-voltage parts. Absolutely never remove its cover.

Even when the inside of this product needs to be inspected, do not touch the inside. All such inspections are to be performed by service technicians designated by Yokogawa Test & Measurement Corporation.

### ● Do not modify this product.

Absolutely never modify this product, as this may cause new hazards and may disqualify this product from repair in case of failure.

## ● Install or Use the Instrument in Appropriate Locations

- This instrument is designed to be used indoors. Do not install or use it outdoors.
- Install the instrument so that you can immediately remove the power cord if an abnormal or dangerous condition occurs.

## ● Safety-related symbols

The general definitions of the safety-related symbols used on this product and in the instruction manual are provided below.



### Instruction Manual Reference Symbol

This symbol is displayed to alert the user to potential danger and refer him/her to the instruction manual.



### Electric Shock Danger Symbol

This symbol indicates locations that present a risk of electric shock under specific conditions.



### Warning Symbol

This symbol indicates information for avoiding danger to human life or bodily injury while handling this product.



### CAUTION Caution Symbol

This symbol indicates information for preventing damage to the product when handling it.

## ● Other symbols



This symbol indicates that the external conductor of the connector is connected to the case.



This symbol shows that the external conductor of the connector is insulated from the case.

It shows, however, that the potential difference from the grounding potential is restricted to 42 Vpk or lower for safety. (Since this product is grounded when used, the potential of the case equals the grounding potential.)

## ● Waste disposal

To help ensure environmental protection, use a professional industrial waste contractor to dispose of this product. A battery is not used for this product.

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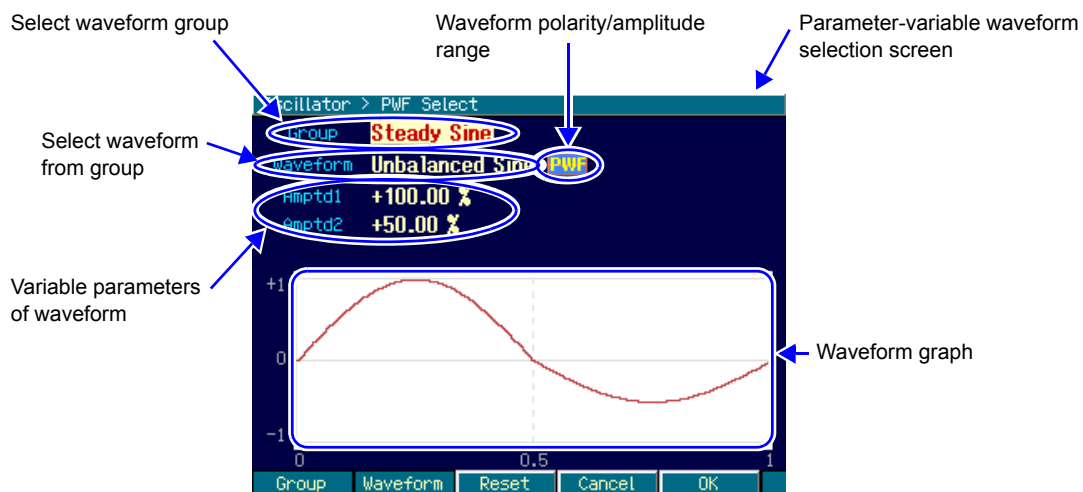


# 1. DETAILS OF PARAMETER-VARIABLE WAVEFORMS

## 1.1 Classification

Parameter-variable waveforms, which are of various types, are classified into six groups.

By selecting a waveform group in the parameter-variable waveform selection screen (☞ “4.5 Using Parameter-Variable Waveforms” in the Basics Instruction Manual), a waveform can be selected for output from the waveforms in that group.



The six parameter-variable waveform groups are as described below.

The names of these groups are uniquely assigned exclusively for the equipment and for usage convenience. Similarly, all the waveform names and parameter names, except for a few, are uniquely assigned to the equipment. These names and the descriptions in this chapter do not restrict the way in which these waveforms are used.

### ■ Steady sine group

This group consists of waveforms created based on a sine wave. Repeated output of these waveforms is assumed.

### ■ Transient sine group

This group consists of waveforms created based on a sine wave. Use of these waveforms as 1 cycle of the start or end of a continuous sine wave during sequence oscillation is assumed.

### ■ Pulse group

This group consists of pulse waveforms.

### ■ Transient response group

This group consists of waveforms that simulate the system's transient response.

### ■ Surge group

This group consists of waveforms that simulate surge signals.

### ■ Other waveform group

This group consists of waveforms other than those of the above groups.

### 1.2 Meaning of Each Parameter and Waveform Examples

#### 1.2.1 Outline

Section 1.2 outlines the various waveforms, explains the meaning of each parameter, and shows waveform examples.

The waveform examples show 1 cycle of the waveform written to the waveform memory. The polarity of the waveform is normal. The amplitude range depends on the waveform, and is set to the amplitude range considered normal when using the waveform in question (initial setting value).

The vertical axis of  $\pm 1$  corresponds to the amplitude full scale  $\pm FS$  of the waveform memory. The horizontal axis is the time axis. The time interval corresponding to one cycle is denoted by 1 unit. The horizontal axis is also the phase axis, ranging from  $0^\circ$  to  $360^\circ$ .

One cycle's time is called "basic period", and its reciprocal "basic frequency" in this manual. These are respectively the oscillation period and the oscillation frequency of that entire waveform.

#### Check

The waveform may disappear depending on the parameter settings.  
If you do not know how to restore the waveform display, press the [Reset] soft key in the center. This will return each parameter value to the factory default.  
The polarity and amplitude range remain unchanged.

1.2.2 Steady sine group

a) Unbalanced sine (Unbalanced Sine)

■ Outline

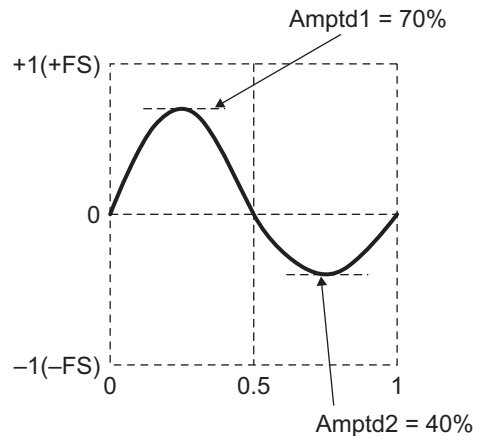
This is a sine wave whose amplitude can be set independently for the first half cycle and second half cycle.

Application examples:

- Simulation of the output waveform of a system with different gains on the plus side and minus side
- Simulation of full-wave rectified waveforms and half-wave rectified waveforms

■ Meaning of each parameter

The following example is for the amplitude range of  $\pm FS$ .



- First-half amplitude (Amptd1)

This is the amplitude of the first half cycle.

When 100%, the amplitude is that of the original sine wave.

Variable range: -100.00% to 100.00%

- Second-half amplitude (Amptd2)

This is the amplitude of the second half cycle.

When 100%, the amplitude is that of the original sine wave.

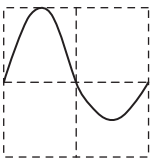
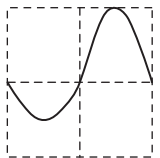
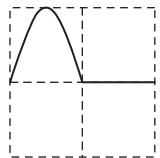
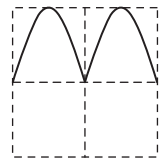
Variable range: -100.00% to 100.00%

Note that when the respective amplitudes are changed, the top and bottom peak values of the waveform change.

Also note that when the first-half amplitude and second-half amplitude differ, the average value of 1 cycle is not zero, so that a DC component results.

■ Waveform examples

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.

			
Amptd1 = 100 Amptd2 = 50	Amptd1 = -50 Amptd2 = -100	Amptd1 = 100 Amptd2 = 0	Amptd1 = 100 Amptd2 = -100

**b) Clipped sine (Clipped Sine)**

■ **Outline**

This is a sine wave having an amplitude with clipped top and bottom.

Application examples:

- Simulation of waveforms clipped with an input clamp circuit
- Simulation of amplifier output waveforms saturated with power supply voltage

■ **Meaning of each parameter**

The following example is for the amplitude range of  $\pm FS$ .

- **Clip ratio (Clip)**

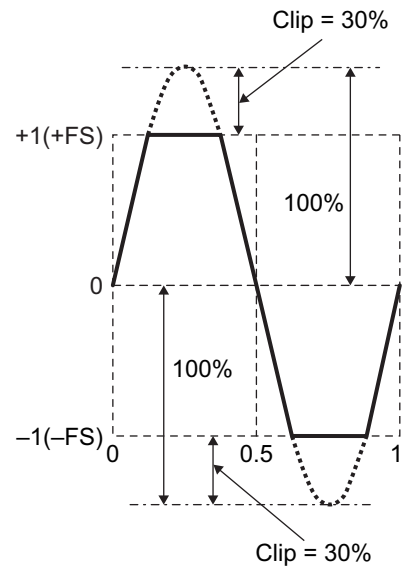
This is the ratio of clipping of the top and bottom of the original sine wave.

The peak value of the original sine wave is 100%.

When the clip ratio is 0%, the waveform is the original sine wave.

Variable range: 0.00% to 99.99%

The peak value is fixed to  $\pm FS$ .



■ **Waveform examples**

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.

Clip = 10	Clip = 20	Clip = 40	Clip = 80

### c) CF controlled sine (CF Ctrl Sine)

#### ■ Outline

This is a sine wave whose amplitude is extended, extracting only the neighborhood of  $90^\circ$  and  $270^\circ$ .

Application examples:

- Simulation of current waveform of capacitor input rectifier

#### ■ Meaning of each parameter

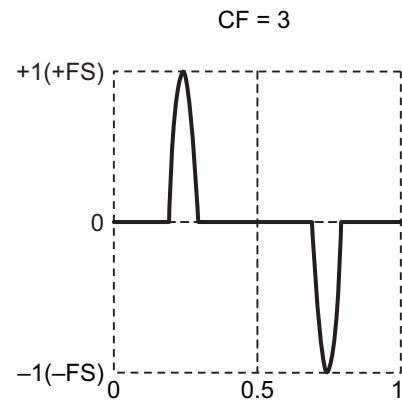
The following example is for the amplitude range of  $\pm FS$ .

- Crest factor (CF)

The crest factor is a value that expresses peak value/RMS value. When this value is 1.41, the waveform is almost identical to the original sine wave.

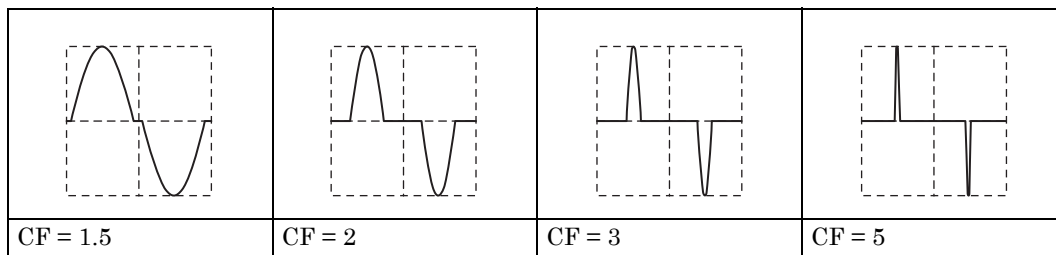
Variable range: 1.41 to 10.00

The peak value is fixed to  $\pm FS$ .



#### ■ Waveform examples

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.



**d) Conduction angle controlled sine (Angle Ctrl Sine)**

**■ Outline**

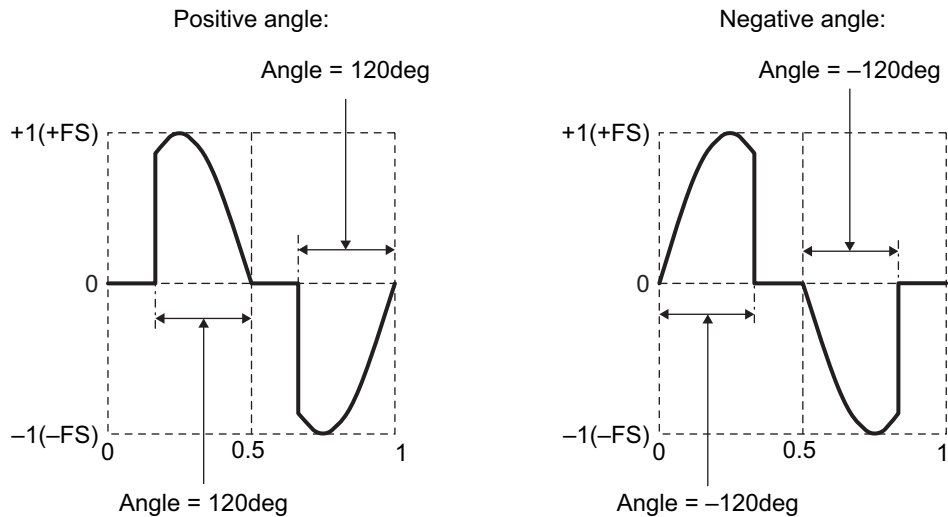
This is a sine wave obtained by extracting part of the back or the front of each half cycle of a sine wave.

Application example:

- Simulation of thyristor control waveforms

**■ Meaning of each parameter**

The following example is for the amplitude range of  $\pm FS$ .



- Conduction angle (Angle)

When the conduction angle is positive, the waveform is obtained by extracting the conduction angle from the back of each half cycle of a sine wave.

When the conduction angle is negative, the waveform is obtained by extracting the absolute value of the conduction angle from the front of each half cycle of a sine wave.

Variable range:  $-180.00^\circ$  to  $180.00^\circ$

The amplitude of the original sine wave is fixed to  $\pm FS$ . Note that the amplitude may drop below  $\pm FS$  depending on the value of the conduction angle.

**■ Waveform examples**

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.

Angle = 45	Angle = 150	Angle = -45	Angle = -150

### e) Staircase sine (Staircase Sine)

#### ■ Outline

This is a staircase shaped sine wave.

Application example:

- Simulation of pseudo sine wave output waveform of UPS (uninterruptible power supply), etc.

#### ■ Meaning of each parameter

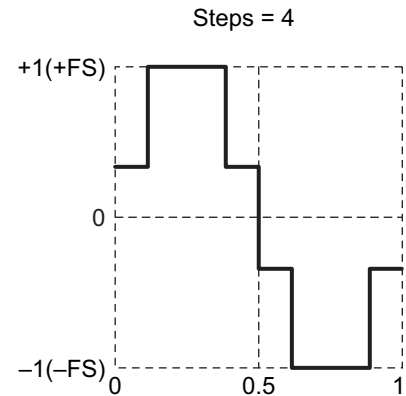
The following example is for the amplitude range of  $\pm FS$ .

- Steps (Steps)

This is the number of values. Shown in the example on the right is a 4-value pseudo sine wave.

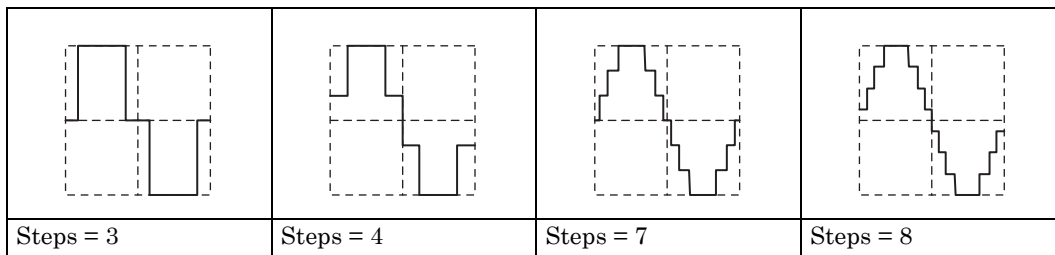
Variable range: 2 to 100

The peak value is fixed to  $\pm FS$ .



#### ■ Waveform examples

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.



**f) Multi-cycle sine (Multi-Cycle Sine)**

**■ Outline**

This is a waveform consisting of multiple concatenated sine wave cycles.

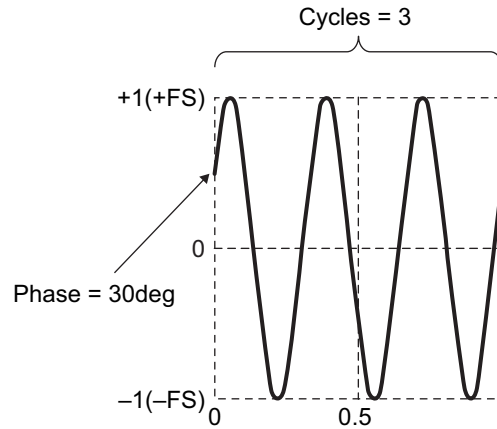
Application example:

- Substitution for burst wave

**■ Meaning of each parameter**

The following example is for the amplitude range of  $\pm FS$ .

- Number of cycles (Cycles)  
This is the number of cycles included in one period of the basic cycle.  
Variable range: 0.01 to 50.00
- Start phase (Phase)  
This is the start position phase.  
It is the phase at the frequency of the basic frequency multiplied by the above number of cycles.  
Variable range:  $-360.00^\circ$  to  $360.00^\circ$



The peak value is fixed to  $\pm FS$ .

**■ Waveform examples**

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.

Cycles = 3 Phase = 0	Cycles = 2.5 Phase = 0	Cycles = 3 Phase = -90	Cycles = 2.5 Phase = -90





**b) Off-phase controlled sine (Off-Ph Ctrl Sine)**

■ **Outline**

This is a sine wave with a slope into off state.

Application example:

- Simulation of output waveform of AC power supply device whose rising/falling time is limited

■ **Meaning of each parameter**

The following example is for the amplitude range of  $\pm FS$ .

- Off-phase (OffPhase)

The original sine wave ends at this phase.

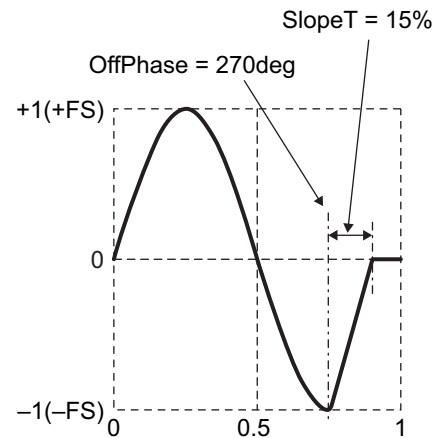
Variable range:  $0.00^\circ$  to  $360.00^\circ$

- Off-slope time (SlopeT)

The amplitude changes linearly over this time, from the off-phase amplitude to zero level.

Variable range: 0.00% to 50.00% of basic period

The amplitude of the original sine wave is fixed to  $\pm FS$ . Note that the amplitude may drop below  $\pm FS$  depending on the value of the off-phase.



■ **Waveform examples**

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.

OffPhase = 90 SlopeT = 10	OffPhase = 210 SlopeT = 20	OffPhase = 240 SlopeT = 20	OffPhase = 270 SlopeT = 10

**c) Chattering-on sine (Chattering-On Sine)**

**■ Outline**

This is a sine wave with chattering into on state.

Application example:

- Simulation of output waveform of AC power supply device with switch or relay chattering at output start.

**■ Meaning of each parameter**

The following example is for the amplitude range of  $\pm FS$ .

- On-phase (OnPhase)

The original waveform starts coming in with chattering from this phase. Before that, it is fixed to zero.

Variable range:  $0.00^\circ$  to  $360.00^\circ$

- Number of chatterings (ChatterN)

This is the number of on/off switchings. The first state is on. On and off are repeated each with the same duration.

Variable range: 0 to 3

- On-state time (Ton)

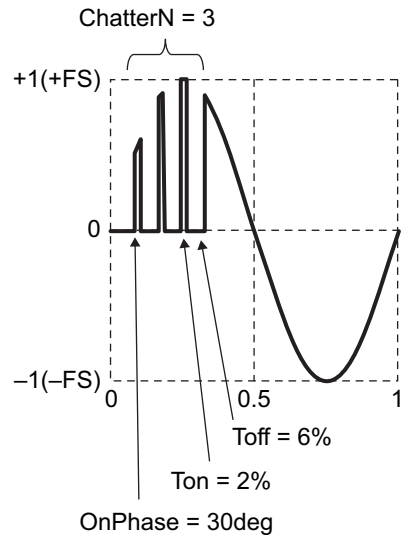
This is the on time for one chattering.

Variable range: 0.00% to 20.00% of basic period

- Off-state time (Toff)

This is the off time for one chattering.

Variable range: 0.00% to 20.00% of basic period



The amplitude of the original sine wave is fixed to  $\pm FS$ . Note that the amplitude may drop below  $\pm FS$  depending on the parameter settings.

**■ Waveform examples**

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.

OnPhase = 30 ChatterN = 0 Ton = 2 Toff = 6	OnPhase = 30 ChatterN = 1 Ton = 2 Toff = 6	OnPhase = 30 ChatterN = 2 Ton = 2 Toff = 6	OnPhase = 30 ChatterN = 3 Ton = 2 Toff = 6

**d) Chattering-off sine (Chattering-Off Sine)**

**■ Outline**

This is a sine wave with chattering into off state.

Application example:

- Simulation of output waveform of AC power supply device with switch or relay chattering when output is stopped

**■ Meaning of each parameter**

The following example is for the amplitude range of  $\pm FS$ .

- Off-phase (OffPhase)
 

The original sine wave starts cutting off from this phase with chattering.

Variable range:  $0.00^\circ$  to  $360.00^\circ$
- Number of chattering (ChatterN)
 

This is the number of on/off switchings. The first state is off. On and off are repeated each with the same duration.

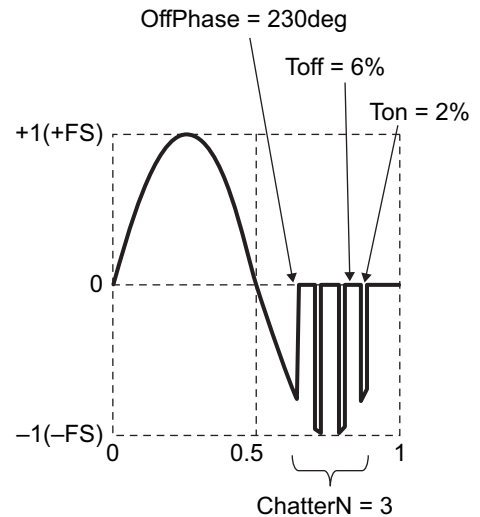
Variable range: 0 to 3
- On-state time (Ton)
 

This is the on time for one chattering.

Variable range: 0.00% to 20.00% of basic period
- Off-state time (Toff)
 

This is the off time for one chattering.

Variable range: 0.00% to 20.00% of basic period



The amplitude of the original sine wave is fixed to  $\pm FS$ . Note that the amplitude may drop below  $\pm FS$  depending on the parameter settings.

**■ Waveform examples**

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.

OffPhase = 230 ChatterN = 0 Ton = 2 Toff = 6	OffPhase = 230 ChatterN = 1 Ton = 2 Toff = 6	OffPhase = 230 ChatterN = 2 Ton = 2 Toff = 6	OffPhase = 230 ChatterN = 3 Ton = 2 Toff = 6

1.2.4 Pulse group

a) Gaussian pulse (Gaussian Pulse)

■ Outline

This is a Gaussian distribution waveform.

■ Meaning of each parameter

The following example is for the amplitude range of 0/+FS.

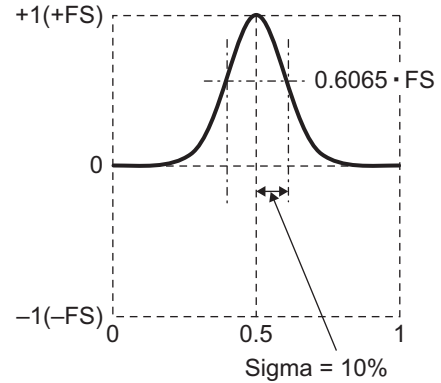
- Standard deviation (Sigma)

This is  $\sigma$  of the Gaussian function.

Variable range: 0.01% to 100.00% of basic period

The peak value is fixed to +FS at the center of the horizontal axis.

The start and end do not decrease all the way down to zero. Note that the larger the standard deviation, the higher the start and end are above the zero level. In the case of a standard deviation of 16.47% or lower, the start is  $0.01 \cdot FS$  or lower.



■ Waveform examples

The polarity is normal and the amplitude range is 0/+FS for all the waveforms shown below.

Sigma = 5	Sigma = 10	Sigma = 15	Sigma = 20

■ Remark

The half value of the width is  $2 \cdot \text{Sigma} \cdot \sqrt{2 \cdot \ln(2)} \cong 2.35 \cdot \text{Sigma} (\%)$ .

Letting the horizontal and vertical axes be x and y, respectively, this can be expressed with the following formula (in the case of amplitude range 0/+FS).

$$y = FS \cdot \exp\left(-\frac{1}{2} \cdot \left(\frac{100}{\text{Sigma}} \cdot (x - 0.5)\right)^2\right)$$

**b) Lorentz pulse (Lorentz Pulse)**

■ **Outline**

This is a Lorentz waveform.

■ **Meaning of each parameter**

The following example is for the amplitude range of 0/+FS.

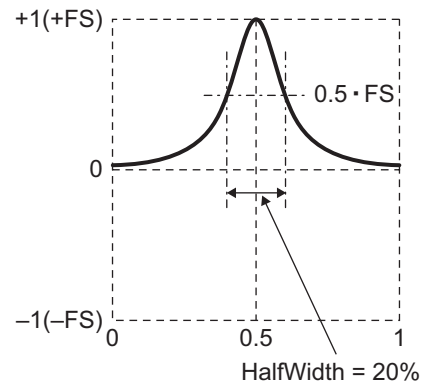
- Half value of width (HalfWidth)

This is the half value of the width of the Lorentz function.

Variable range: 0.01% to 100.00% of basic period

The peak value is fixed to +FS at the center of the horizontal axis.

The start and end do not decrease all the way down to zero. Note that the larger the half value of the width, the higher the start and end are above the zero level. In the case of a half value of the width of 10.05% or lower, the start is 0.01 · FS or lower.



■ **Waveform examples**

The polarity is normal and the amplitude range is 0/+FS for all the waveforms shown below.

HalfWidth = 5	HalfWidth = 10	HalfWidth = 15	HalfWidth = 20

■ **Remark**

Letting the horizontal and vertical axes be x and y, respectively, this can be expressed with the following formula (in the case of amplitude range 0/+FS).

$$y = FS \cdot \frac{1}{1 + \left( \frac{200}{\text{HalfWidth}} \cdot (x - 0.5) \right)^2}$$

**c) Haversine (Haversine)**

■ **Outline**

This is a  $\text{Sin}^2$  pulse. It is a waveform obtained by adding an offset signal on the range of  $-90^\circ$  to  $270^\circ$  of a sine wave.

■ **Meaning of each parameter**

The following example is for the amplitude range of  $0/+FS$ .

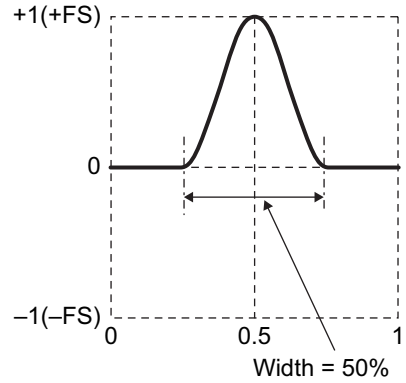
• **Width (Width)**

This is the width of 1 cycle of a sine wave in the range of  $-90^\circ$  to  $270^\circ$ .

Outside this range, the level is fixed to zero.

Variable range: 0.01% to 100.00% of basic period

The peak value is fixed to  $+FS$  at the center of the horizontal axis.



■ **Waveform examples**

The polarity is normal and the amplitude range is  $0/+FS$  for all the waveforms shown below.

Width = 10	Width = 20	Width = 50	Width = 100

■ **Remark**

The half value of the width is  $\text{Width}/2$  (%).

Letting the horizontal and vertical axes be  $x$  and  $y$ , respectively, this can be expressed with the following formula (in the case of amplitude range  $0/+FS$ ).

In the range  $x = 0.5 \pm \frac{\text{Width}}{200}$ ,

$$y = \frac{FS}{2} \cdot \left( 1 + \cos \left( 2\pi \cdot \frac{100}{\text{Width}} \cdot (x - 0.5) \right) \right)$$

**d) Half-sine pulse (Half-Sine Pulse)**

■ **Outline**

This is a half-sine pulse, consisting of a half-cycle waveform in the range of 0° to 180° of a sine wave.

■ **Meaning of each parameter**

The following example is for the amplitude range of 0/+FS.

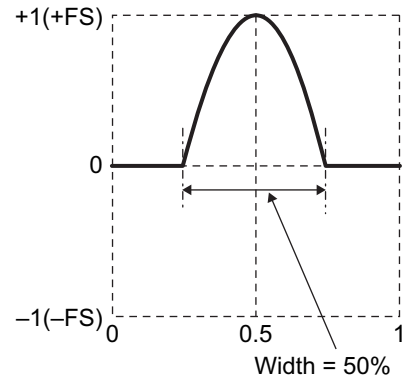
• **Width (Width)**

This is the width of the range of 0° to 180° of a sine wave.

Outside this range, the level is fixed to zero.

Variable range: 0.01% to 100.00% of basic period

The peak value is fixed to +FS at the center of the horizontal axis.



■ **Waveform examples**

The polarity is normal and the amplitude range is 0/+FS for all the waveforms shown below.

Width = 10	Width = 20	Width = 50	Width = 100

■ **Remark**

The half value of the width is  $2 \cdot \text{Width}/3$  (%).

Letting the horizontal and vertical axes be x and y, respectively, this can be expressed with the following formula (in the case of amplitude range 0/+FS).

In the range  $x = 0.5 \pm \frac{\text{Width}}{200}$ ,

$$y = \text{FS} \cdot \cos\left(\pi \cdot \frac{100}{\text{Width}} \cdot (x - 0.5)\right)$$



**e) Trapezoid pulse (Trapezoid Pulse)**

**■ Outline**

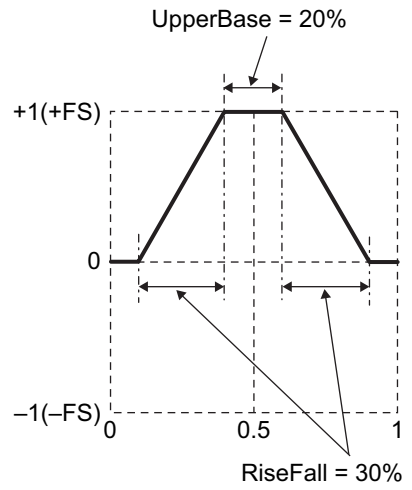
This is a trapezoid pulse.

**■ Meaning of each parameter**

The following example is for the amplitude range of 0/+FS.

- Slope width (RiseFall)  
This is the width of the hypotenuse.  
Variable range: 0.00% to 50.00% of basic period
- Upper base width (UpperBase)  
This is the width of the upper base.  
Variable range: 0.00% to 100.00% of basic period

The peak value is fixed to +FS at the upper base at the center of the horizontal axis. Note that when [(Slope width × 2) + Upper base width] exceeds 100%, the start and end exceed zero.



**■ Waveform examples**

The polarity is normal and the amplitude range is 0/+FS for all the waveforms shown below.

RiseFall = 25 UpperBase = 50	RiseFall = 20 UpperBase = 20	RiseFall = 0 UpperBase = 20	RiseFall = 20 UpperBase = 0

**f) Sin(x)/x (Sin(x)/x)**

■ **Outline**

This is a Sin(x)/x waveform. It is called sinc function.

■ **Meaning of each parameter**

The following example is for the amplitude range of ±FS.

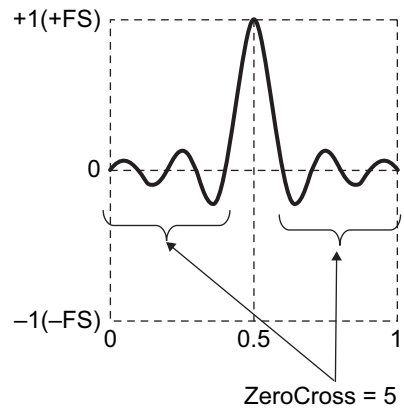
- Number of zero crossings (ZeroCross)

This is the number of zero crossings on single side.

Variable range: 1 to 50

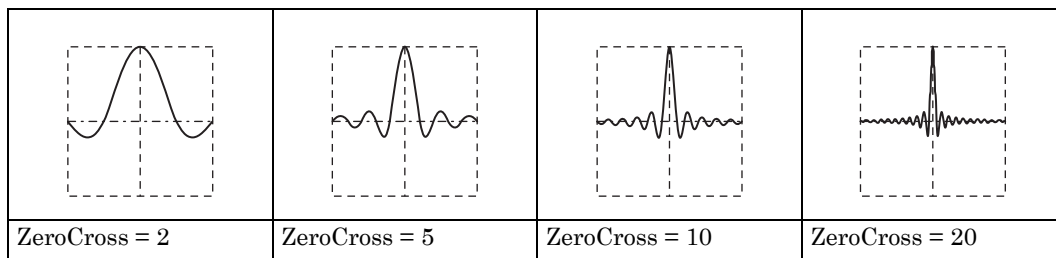
The peak value is fixed to +FS at the center of the horizontal axis.

This waveform has a frequency band that is approximately the basic frequency multiplied by the number of zero crossings.



■ **Waveform examples**

The polarity is normal and the amplitude range is ±FS for all the waveforms shown below.



■ **Remark**

Letting the horizontal and vertical axes be x and y, respectively, this can be expressed with the following formula (in the case of amplitude range ±FS).

$$y = FS \cdot \frac{\sin(2\pi \cdot \text{ZeroCross} \cdot (x - 0.5))}{2\pi \cdot \text{ZeroCross} \cdot (x - 0.5)}$$

1.2.5 Transient response group

a) Exponential rise (Exponential Rise)

■ Outline

This is a first-order LPF step response waveform.

Application example:

- Simulation of first-order delay system's step output waveform

■ Meaning of each parameter

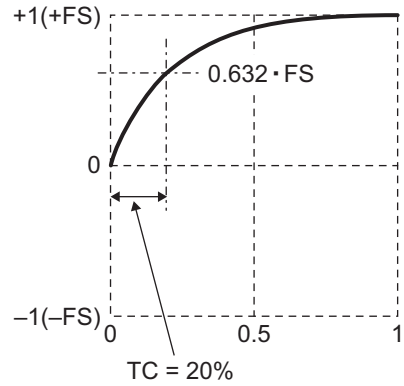
The following example is for the amplitude range of 0/+FS.

- Time constant (TC)

This is the time constant of the exponential function.

Variable range: 0.01% to 100.00% of basic period

The amplitude over infinite time is +FS. The end does not rise up to +FS. Note that the larger the time constant, the smaller the end value. When the time constant is 21.71% or lower, the end is 0.99 · FS or higher.



■ Waveform examples

The polarity is normal and the amplitude range is 0/+FS for all the waveforms shown below.

TC = 5	TC = 10	TC = 20	TC = 50

■ Remark

Letting the horizontal and vertical axes be x and y, respectively, this can be expressed with the following formula (in the case of amplitude range 0/+FS).

$$y = FS \cdot \left( 1 - \exp\left(-\frac{100}{TC} \cdot x\right) \right)$$

**b) Exponential fall (Exponential Fall)**

■ **Outline**

This is a first-order HPF step response waveform.

Application example:

- Simulation of first-order system's step output waveform

■ **Meaning of each parameter**

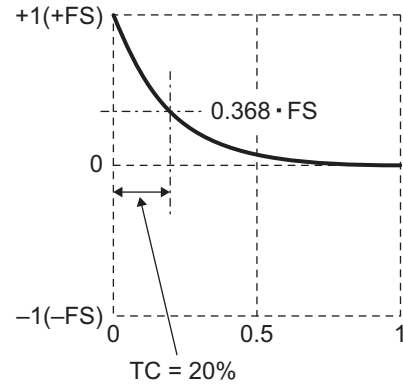
The following example is for the amplitude range of 0/+FS.

- Time constant (TC)

This is the time constant of the exponential function.

Variable range: 0.01% to 100.00% of basic period

The start begins from +FS, but the end does not decrease all the way down to zero. Note that the larger the time constant, the larger the end offset. When the time constant is 21.71% or lower, the end is 0.01 · FS or lower.



■ **Waveform examples**

The Polarity is normal and the amplitude range is 0/+FS for all the waveforms shown below.

TC = 5	TC = 10	TC = 20	TC = 50

■ **Remark**

Letting the horizontal and vertical axes be x and y, respectively, this can be expressed with the following formula (in the case of amplitude range 0/+FS).

$$y = FS \cdot \exp\left(-\frac{100}{TC} \cdot x\right)$$

### c) Second-order LPF step response (2nd Ord LPF Step)

#### ■ Outline

This is the second-order LPF step response waveform.

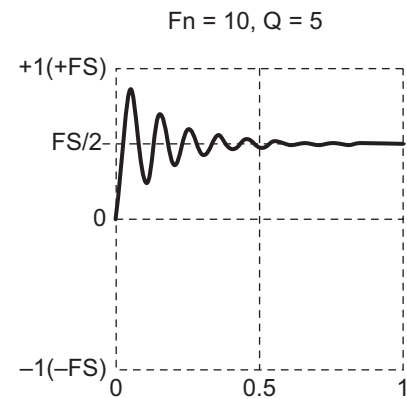
Application example:

- Simulation of step output waveform of transmission system with ringing or overshoot

#### ■ Meaning of each parameter

The following example is for the amplitude range of 0/+FS.

- LPF natural frequency ( $F_n$ )  
The frequency of the oscillation component is lower than  $F_n$ .  
Variable range: 1.00 to 50.00 times basic frequency
- LPF Q ( $Q$ )  
When  $Q = 0.5$ , the oscillation component disappears.  
Variable range: 0.50 to 50.00



The amplitude over infinite time is  $FS/2$ . The peak value is lower than  $+FS$ .

#### ■ Waveform examples

The polarity is normal and the amplitude range = 0/+FS for all the waveforms shown below.

$F_n = 5$ $Q = 0.5$	$F_n = 5$ $Q = 1$	$F_n = 10$ $Q = 5$	$F_n = 15$ $Q = 20$

#### ■ Remark

The oscillation frequency is expressed with the following formula (basic frequency as a reference).

$$F_n \cdot \sqrt{1 - \frac{1}{4 \cdot Q^2}}$$

**d) Damped oscillation (Damped Oscillation)**

■ **Outline**

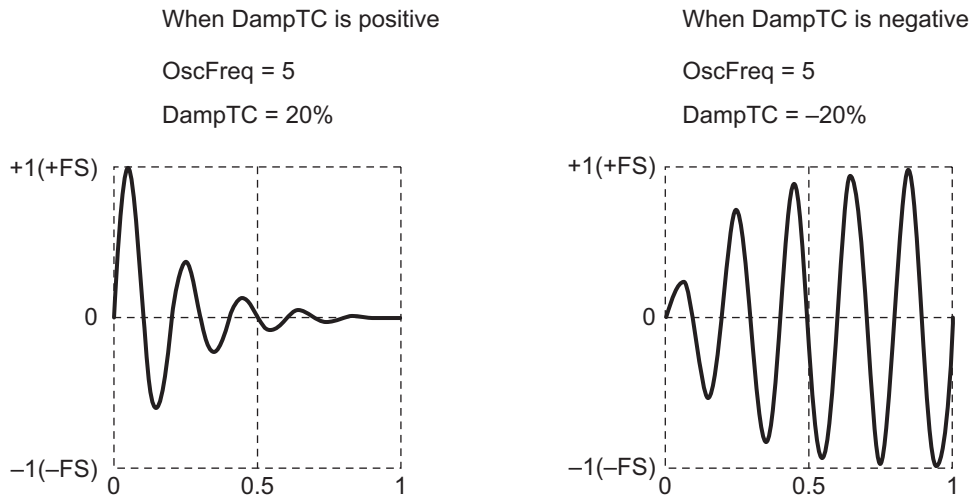
This is an oscillation waveform whose amplitude is damped exponentially. An oscillation waveform whose amplitude increases exponentially can also be generated.

Application example:

- Simulation of pulse response waveform with oscillation

■ **Meaning of each parameter**

The following example is for the amplitude range of  $\pm FS$ .



- Oscillation frequency (OscFreq)  
Variable range: 0.01 to 50.00 times basic frequency
- Damping time constant (DampTC)  
When positive, the oscillation is exponentially damped with this time constant.  
When negative, the oscillation increases exponentially with this time constant.  
Variable range: -100.00% to 100.00% of basic period

When the damping time constant is positive, the peak value is fixed to +FS.

When the damping time constant is negative, the amplitude over infinite time is  $\pm FS$ .

■ **Waveform examples**

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.

OscFreq = 5 DampTC = 10	OscFreq = 10 DampTC = 20	OscFreq = 5 DampTC = -10	OscFreq = 10 DampTC = -20

1.2.6 Surge group

a) Oscillation surge (Oscillation Surge)

■ Outline

This is simulation of a surge waveform with damped oscillation.

This is a step response waveform of first-order HPF and second-order LPF cascaded connection circuits.

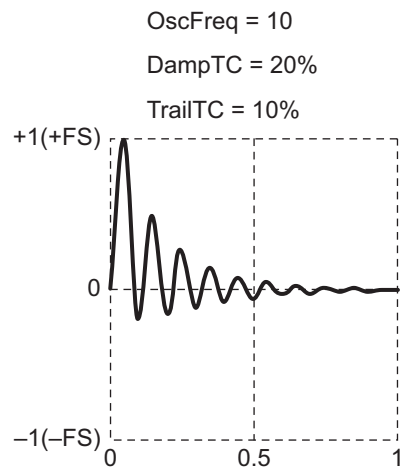
Application examples:

- Simulation of surge waveform superimposed on power supply
- Simulation of inrush current waveform of power supply

■ Meaning of each parameter

The following example is for the amplitude range of  $\pm FS$ .

- Oscillation frequency (OscFreq)  
Variable range: 0.01 to 50.00 times basic frequency
- Damping time constant (DampTC)  
The amplitude of the oscillation component is dampened exponentially with this time constant.  
Variable range: 0.01% to 100.00% of basic period
- Trailing time constant (TrailTC)  
This is the damping time constant excluding the oscillation component (time constant of first-order HPF)  
Variable range: 0.01% to 100.00% of basic period



The peak value is fixed to +FS. Note that the amplitude also swings to the negative side.

■ Waveform examples

The polarity is normal and the amplitude range is  $\pm FS$  for all the waveforms shown below.

OscFreq = 10 DampTC = 20 TrailTC = 5	OscFreq = 10 DampTC = 20 TrailTC = 30	OscFreq = 10 DampTC = 5 TrailTC = 20	OscFreq = 10 DampTC = 30 TrailTC = 20

**b) Pulse surge (Pulse Surge)**

■ **Outline**

This is the simulation of a pulsed surge waveform. It does not have an oscillation component.

Application example:

- Simulation of overvoltage waveform of automotive battery

■ **Meaning of each parameter**

The following example is for the amplitude range of 0/+FS.

- Rising time (Tr)

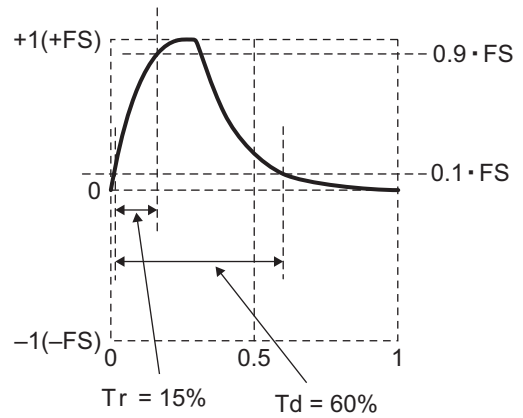
This is the time during which the amplitude rises from 10% to 90% of the peak value.

Variable range: 0.01% to 100.00% of basic period

- Duration time (Td)

This is the pulse interval during which the amplitude exceeds 10% of the peak value.

Variable range: 0.01% to 100.00% of basic period

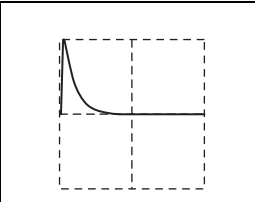
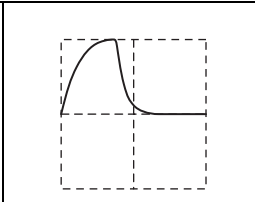
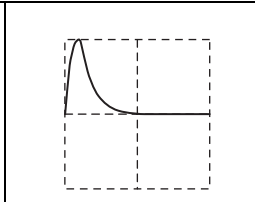
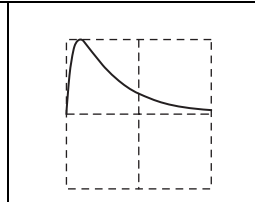


The peak value is fixed to +FS.

The end does not decrease all the way down to zero. The larger the duration time, the higher the end is above the zero level.

■ **Waveform examples**

The polarity is normal and the amplitude range is 0/+FS for all the waveforms shown below.

			
Tr = 1 Td = 20	Tr = 20 Td = 50	Tr = 5 Td = 30	Tr = 5 Td = 80

■ **Remark**

The waveform differs from the predefined waveform when the following condition is not met:  $1.839 \text{ (approx.)} < Td / Tr$ .



1.2.7 Other waveform group

a) Trapezoid with offset (Trapezoid with Offset)

■ Outline

This is a trapezoid wave with offset in the amplitude direction.

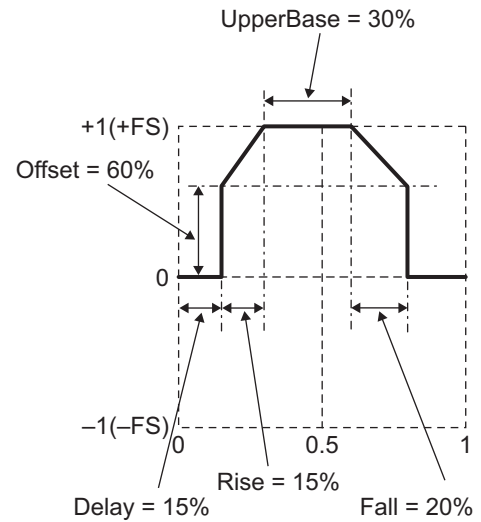
Application example:

- Simulation of voltage and current waveforms of switching power supply circuit

■ Meaning of each parameter

The following example is for the amplitude range of 0/+FS.

- Leading delay (Delay)  
This is the start position of the rise of the trapezoid wave.  
Variable range: 0.00% to 100.00% of basic period
- Rising-slope width (Rise)  
This is the width of the rising portion.  
Variable range: 0.00% to 100.00% of basic period
- Upper base width (UpperBase)  
This is the width of the upper base.  
Variable range: 0.00% to 100.00% of basic period
- Falling-slope width (Fall)  
This is the width of the falling portion.  
Variable range: 0.00% to 100.00% of basic period
- Offset (Offset)  
This is the amplitude direction offset of the entire trapezoid.  
Variable range: 0.00% to 100.00%



The peak value is fixed to +FS at the upper base.

■ Waveform examples

The polarity is normal and the amplitude range is 0/+FS for all the waveforms shown below.

Delay = 15 Rise = 10 UpperBase = 20 Fall = 30 Offset = 0	Delay = 15 Rise = 40 UpperBase = 0 Fall = 0 Offset = 60	Delay = 15 Rise = 0 UpperBase = 20 Fall = 30 Offset = 0	Delay = 20 Rise = 40 UpperBase = 0 Fall = 0 Offset = 0

**b) Half-sine edge pulse (Half-Sine Edge Pulse)**

**■ Outline**

This is a pulse wave with variable leading-edge time, trailing-edge time, and pulse width duty.

The rise and fall shapes are the same half-sine shape as the pulse wave of the standard waveform (half cycle of sine wave). Since, during sequence oscillation, the pulse wave of the standard waveform cannot be used, this waveform is used instead by loading it to an arbitrary wave.

**■ Meaning of each parameter**

The following example is for the amplitude range of 0/+FS.

• **Leading-edge time (LE)**

This is the time during which the amplitude rises from 10% to 90% of the peak value.

Variable range: 0.00% to 100.00% of basic period

• **Trailing-edge time (TE)**

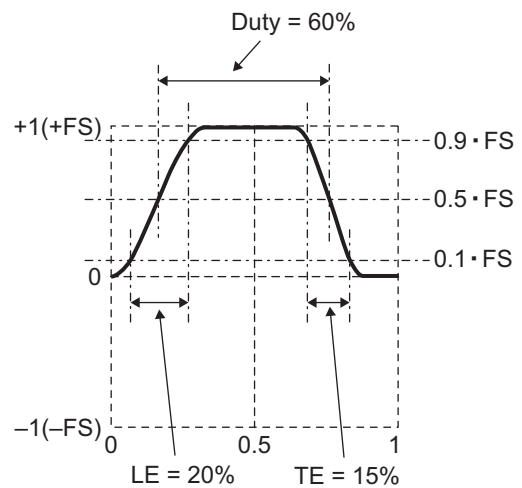
This is the time during which the amplitude falls from 90% to 10% of the peak value.

Variable time: 0.00% to 100.00% of basic period

• **Duty (Duty)**

This is the pulse width duty at which the amplitude is 50% or more of the peak value.

Variable range: 0.00% to 100.00%



The peak value is fixed to +FS.

**■ Waveform example**

The polarity is normal and the amplitude range is 0/+FS for all the waveforms shown below.

LE = 10 TE = 20 Duty = 40	LE = 30 TE = 5 Duty = 60	LE = 10 TE = 10 Duty = 20	LE = 10 TE = 0 Duty = 70

**■ Remark**

The waveform differs from the predefined waveform when the following condition is not met:

$$(LE + TE) \cdot 0.85 \leq Duty \leq 100 - (LE + TE) \cdot 0.85$$

### c) Bottom referenced ramp (Bottom Referenced Ramp)

#### ■ Outline

This is a ramp waveform using the bottom level as reference.

#### ■ Meaning of each parameter

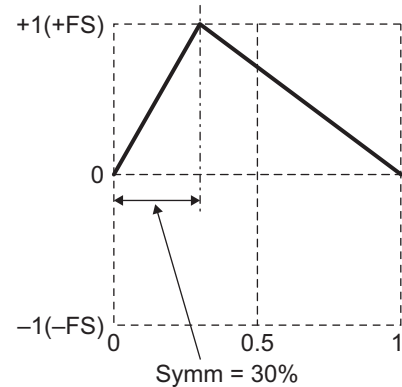
The following example is for the amplitude range of  $0/+FS$ .

##### • Symmetry (Symm)

This is the ratio of the rising portion.

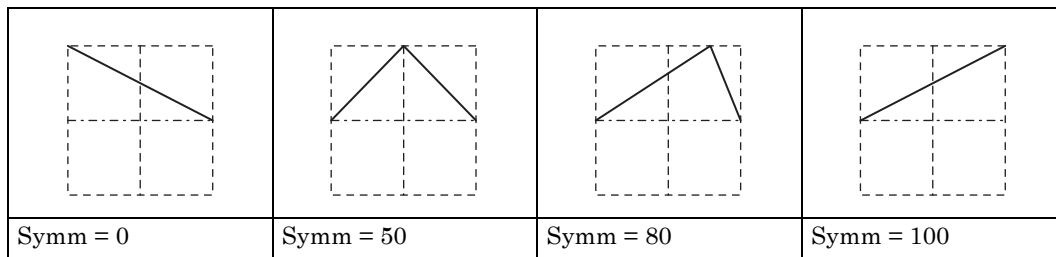
Variable range: 0.00% to 100.00%

The peak value is fixed to  $+FS$ .



#### ■ Waveform examples

The polarity is normal and the amplitude range is  $0/+FS$  for all the waveforms shown below.



#### ■ Remark

Except when the symmetry is 0%, the phase zero position is fixed to the bottom level.

On the other hand, in the case of a ramp wave of the standard waveform, the phase zero position is fixed to the zero center position of the amplitude.

☞ "4.4.16 Setting the ramp wave symmetry" in the Basics Instruction Manual.

# 2. CREATING ARBITRARY WAVEFORMS

## 2.1 Basics

There are two main arbitrary waveform creating methods:

- Creating on a PC using the supplied arbitrary waveform editing software
- Input of waveform data from the panel

Here, arbitrary waveform creation method using the main unit's panel is explained.

At the outset, please familiarize yourself with the following points regarding the arbitrary waveforms of this equipment.

### ■ 2 data formats

The arbitrary waveform data of this product is of the two following types.

- Array format

This consists of data strings corresponding to waveform memory addresses.

The array format is used when the waveform captured with an oscilloscope is used as an arbitrary waveform as is.

The waveform captured with an oscilloscope can be transferred to the equipment using the supplied arbitrary waveform editing software.

Array format data cannot be created/edited from the panel.

The array format wavelength ranges from 4 K to 512 Kwords ( $2^n$ ,  $n = 12$  to  $19$ ).

- Control point format

A waveform is created by performing linear interpolation between specified points (control points).

The data values of individual memory address cannot be specified directly.

Relatively simple arbitrary waveforms can be created and edited manually from the panel.

The number of control points used for control point format is between 2 and 10,000 points.

The time axis direction of created waveforms is fixed to 0 to 1 per cycle, and the amplitude axis to  $\pm 1$  (equivalent to  $\pm FS$  of waveform memory).

### ■ Arbitrary waveform saving location

Arbitrary waveform data is saved to the following two locations (separate from the 512 Kword output waveform memory). In the case of the FG420, each memory is used in common for both channels.

- Saving memory

This is non-volatile memory for saving arbitrary waveforms.

Up to 128 waveforms, for a total amount of 4 Mwords (8192 KB) of arbitrary waveform data, can be saved.

Both array format and control point format data can be saved.

For the memory capacity required for saving, [☞ p. 32](#)

- Edit memory

This is volatile memory for creating control point format arbitrary waveforms. The number of control points can be changed in the range of 2 to 10,000 points.

Creating or editing an arbitrary waveform from the panel is done by manipulating the data in this edit memory. Only one waveform can be manipulated in the edit memory at one time.

**■ Selecting the arbitrary waveform to be output**

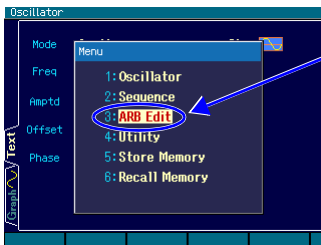
When the output waveform is set to arbitrary waveform on the Oscillator setting screen, the waveform to be output can be selected from the saved arbitrary waveforms. The waveform that can be selected at this time is either a waveform in the saving memory described above, or the waveform in the edit memory.

The selected waveform is written to the output waveform memory of a maximum length of 512 Kwords.

When the edit memory is selected for the output waveform, the waveform currently being created/edited appears as is in the output.

**2.2 Arbitrary Waveform Creating/Editing Screen Display Procedure and Screen Outline**

Arbitrary waveform creating and editing is done on the ARB Edit screen.



Select [ARB Edit] in the top menu and then press the ENTER key

1. Press the **[MENU]** MENU key to display the top menu window. In this window, select [ARB Edit] and then press the **[ENTER]** ENTER key to open the ARB Edit screen.

2. The ARB Edit screen features two different display formats. One is list display, in which values are displayed lined up, and the other is graph display.

These two types of display can be switched with the tabs on the left end of the screen.

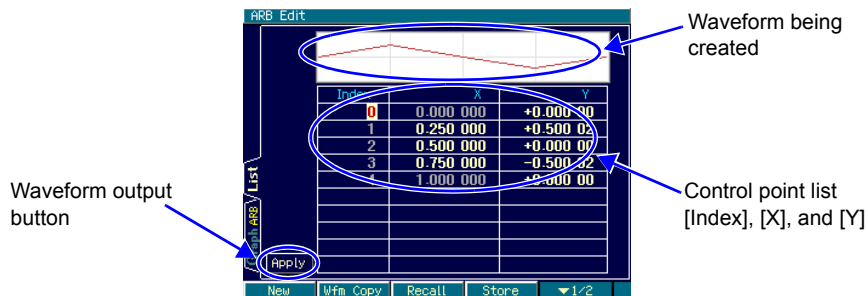
[Index] is the control point number, which starts from 0. The start is fixed to X = 0.000000, and the end is fixed to X = 1.000000. The Y value of the start and end is the same value (same point).

When the output waveform is set to the arbitrary waveform in the edit memory, the waveform currently being created appears in the output as is. If another waveform has been set, press the [Apply] button and then the **[ENTER]** ENTER key to make the output waveform setting the arbitrary waveform in the edit memory, so that the waveform currently being created is output.

**■ List display**

In list display, the waveform currently being created and the list of control points are displayed.

The shape of the waveform is created by setting the X and Y values of control points.

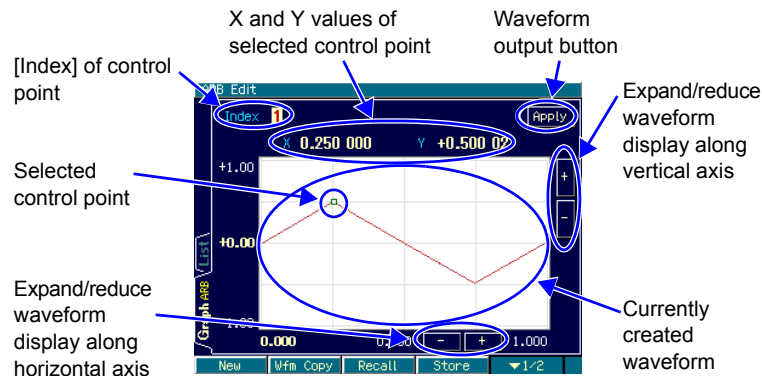


### ■ Graph display

In graph display, the waveform currently being created is displayed in large size. The X value and Y value of the currently selected control point are also displayed.

Similarly to list display, the waveform is created by setting the X value and Y value of each control point.

The waveform display can be expanded both along the horizontal and vertical axes with the selected control point at the center of the display.



### ■ Soft keys

1st stage ([ ▼ 1/2] displayed at right end)

[New]: Clears the edit memory and sets the initial status.

[Wfm Copy]: Copies the standard waveform to the edit memory.

[Recall]: Copies an already saved control point format arbitrary waveform to the edit memory.

[Store]: Saves the waveform currently in the edit memory.

2nd stage ([ ▼ 2/2] displayed at right end)

[Index -1]: Decrements the [Index] value by 1.

[Index +1]: Increments the [Index] value by 1.

[Delete]: Deletes the selected control point.

[Insert]: Inserts a new control point in the center between the selected control point and the preceding control point.

## 2.3 Creating a New Arbitrary Waveform

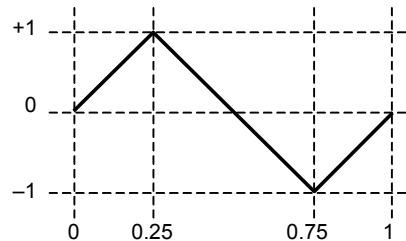
A new arbitrary waveform can be created using one of the three methods described below.

- Creating a completely new arbitrary waveform  
First, press the [New] soft key to clear the edit memory. Then input the control points. Creating examples are given on the following page.
- Creating an arbitrary waveform by editing the standard waveform  
First, press the [Wfm Copy] soft key to copy the standard waveform to the edit memory. Then edit the control points. The control point manipulation method is the same as when creating a completely new arbitrary waveform.  
However, the noise and DC of the standard waveform cannot be copied. Moreover, square waves and pulse waves are copied as ideal square waves that maintain duty.
- Creating an arbitrary waveform by editing a saved arbitrary waveform  
First, press the [Recall] soft key to copy the saved control point format arbitrary waveform to the edit memory. Then edit the control points. The control point manipulation method is the same as when creating a completely new arbitrary waveform.

## 2.4 Simple Arbitrary Waveform Creating Examples

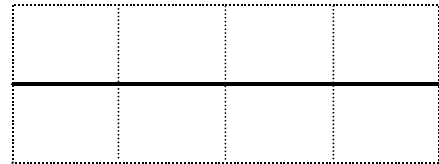
Simple waveforms are actually created in this section. The descriptions are done using displays in list format.

The arbitrary waveforms to be created are triangular waveforms such as the one shown below. The number of control points of this waveform is 3. In this section, create the waveform with 2 control points first, then increase control points to 3 points.



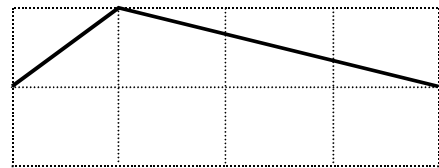
1. When the [New] soft key is pressed and the number of control points is set to 2, the following setting results.

Index	X	Y
0	0.000000	+0.000000
1	0.500000	+0.000000
2	1.000000	+0.000000



2. Change the Index = 1 setting to X = 0.25, Y = +1.

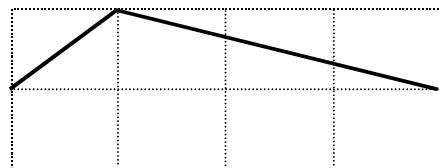
Index	X	Y
0	0.000000	+0.000000
1	0.250000	+1.000000
2	1.000000	+0.000000



3. Select the Y value field of the end line (Index = 2, X = 1) and then press the [Insert] soft key.

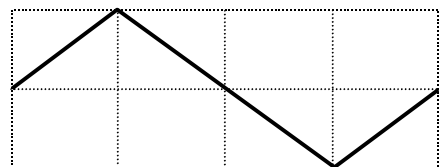
The control point with X = 0.625000, Y = +0.49998 is newly created. The values rounded to 16-bit units are displayed as the Y values, assuming  $\pm 32767$  to be  $\pm 1$ .

Index	X	Y
0	0.000000	+0.000000
1	0.250000	+1.000000
2	0.625000	+0.49998
3	1.000000	+0.000000



4. Change the Index = 2 setting to X = 0.75, Y = -1. This completes the procedure.

Index	X	Y
0	0.000000	+0.000000
1	0.250000	+1.000000
2	0.750000	-1.000000
3	1.000000	+0.000000



**✓ Check**

- Set each X value so that it is between the preceding and following control points. Each X value cannot be set exceeding this range.
- The Y value will be rounded in 16-bit units.
- To change the Y value in step fashion, set the variation width of the adjacent X values to the 0.000001 minimum.

## 2.5 Outputting the Created Arbitrary Waveform

Select the [Apply] button on the screen (in the case of the FG420, a separate button for each channel), and then press the ENTER key.

The output waveform setting becomes the arbitrary waveform of the edit memory, and the waveform currently being created is output.

If the output waveform is set to the arbitrary waveform of the edit memory, the waveform currently being created appears as is in the output.

## 2.6 Saving the Created Arbitrary Waveform

Press the [Store] soft key to open the window for saving. Select the proper memory number (from 1 to 128), and perform the saving operation. The waveform can also be named.

## 2.7 Identifying the Memory Capacity Required for Saving the Arbitrary Waveform

Up to 128 waveforms or 4 Mwords (8192 KB) can be saved in non-volatile memory.

The memory capacity required for saving each data of array format and control point format is obtained with the following formulas in KB units.

Array format:  $(2 \times \text{wavelength (word)} + 768) / 1024$  (Digits below the decimal point are rounded up.)

Control point format:  $(8 \times \text{number of control points} + 768) / 1024$  (Digits below the decimal point are rounded up.)

The memory capacity required for saving an arbitrary waveform in array format is shown below:

Waveform size	4 KW	8 KW	16 KW	32 KW	64 KW	128 KW	256 KW	512 KW
Memory capacity required for saving	9 KB	17 KB	33 KB	65 KB	129 KB	257 KB	513 KB	1025 KB

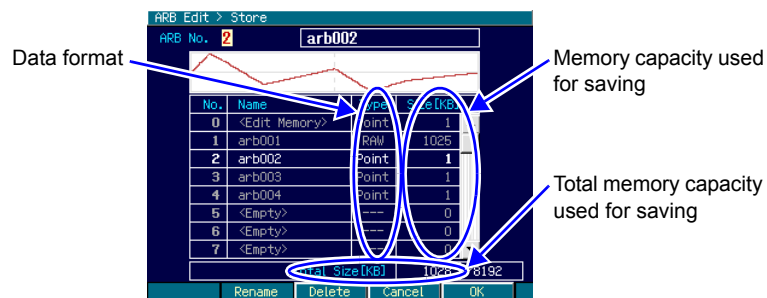
The memory capacity required for saving an arbitrary waveform in control point format is shown below:

Control point	2	10	100	300	1,000	2,000	5,000	10,000
Memory capacity required for saving	1 KB	1 KB	2 KB	4 KB	9 KB	17 KB	40 KB	79 KB



On the arbitrary waveform selection screen (common for storing and retrieving), the waveform number [No.], name [Name], and the following items are displayed.

- Data format [Type]: The waveform of the array format is displayed as [RAW] and the waveform of the control point format is displayed as [Point].  
The edit memory of No. 0 is saved in the control point format; therefore, [Point] is displayed.
- Memory capacity for saving [Size]: For the arbitrary waveforms of No. 1 to No. 128, the memory capacity used for saving is displayed in KB units. For the edit memory of No. 0, the memory capacity required for saving is displayed in KB units.
- Total memory capacity for saving [Total Size]: Total memory capacity used for saving the current arbitrary waveforms of No. 1 to No. 128 is displayed in KB units. The size of the edit memory of No. 0 is not included in the total capacity.



## 3. HANDY USE OF 2-CHANNEL DEVICE (FG420 ONLY)

The FG420, which is a 2-channel device, each of the two channels can be used as an independent oscillator, but both channels can also be used by linking their settings and operation.

The following functions specific to a 2-channel device are available.

- Parameter copy function

Copies the settings of one channel to the other channel.

The settings of each channel can also be interchanged. ☞ p. 35

- Two-channel same value setting function

The same setting values, such as amplitude and DC offset, can be set for both channels.

Output on/off switching, etc., can also be performed simultaneously for both channels. ☞ p. 37

- Phase synchronization function

Initializes the oscillation phase of each channel. This function is used in the continuous oscillation mode during independent operation of the two channels. ☞ p. 38

- Two-channel ganged function with 2-phase

Maintains the same frequency and synchronization relationship. Also controlled to maintain the same frequency and synchronization relationship during frequency modulation and frequency sweep. ☞ p. 39

- Two-channel ganged function with constant frequency difference

Maintains a constant frequency difference, while the frequency can be changed. Also controlled to maintain a constant frequency difference during frequency modulation and frequency sweep. ☞ p. 41

- Two-channel ganged function with constant frequency ratio

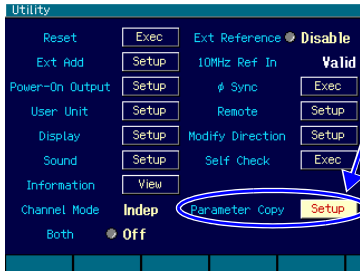
Maintains a constant frequency ratio and synchronization relationship, while the frequency can be changed. Also controlled to maintain a constant frequency ratio during frequency modulation and frequency sweep. ☞ p. 43

- Two-channel ganged function with differential output

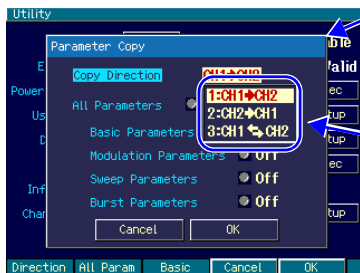
Outputs a reverse phase waveform with the same frequency, amplitude, and DC offset. Also controlled to maintain reverse-phase waveform during modulation and sweep. ☞ p. 45

## 3.1 Copying Settings Between Channels

Copying of settings between channels is done on the Utility screen.



1. On the Utility screen, select [Parameter Copy] and then press the **[ENTER]** ENTER key.

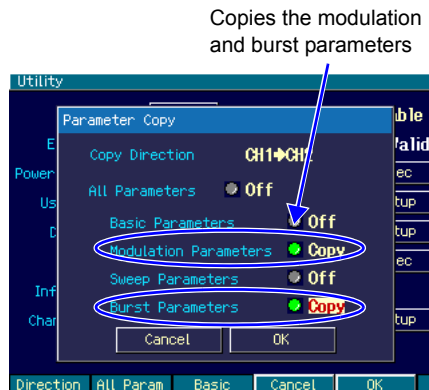
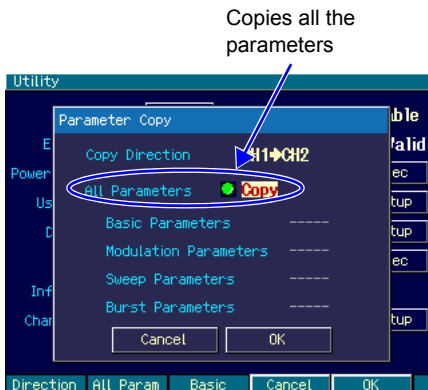


2. The parameter copy window opens, so select the [Copy Direction] field and then press the **[ENTER]** ENTER key. The copy direction choice list opens. One of three copy directions can be selected: [CH1 ⇒ CH2] for copying from CH1 to CH2, [CH2 ⇒ CH1] from CH2 to CH1, and [CH1 ⇔ CH2] for exchanging. Select the desired direction and then press the **[ENTER]** ENTER key.

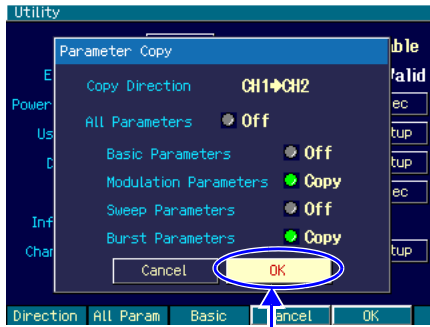
3. Next, select the parameters to be copied.

Select the parameters to be copied from [All Parameters] (all parameters) or the parameters of individual oscillation modes. In the case of the parameters of individual oscillation modes, there are four choices, namely [Basic Parameters] (parameters of continuous oscillation mode), [Modulation Parameters] (parameters of modulated oscillation mode), [Sweep Parameters] (parameters of sweep oscillation mode), and [Burst Parameters] (parameters of burst oscillation mode).

Select the desired parameter type and then press the **[ENTER]** ENTER key to set the copy target. [Copy] is displayed. Press the **[ENTER]** ENTER key again to deselect the copy target. [Off] is displayed.



### 3. HANDY USE OF 2-CHANNEL DEVICE (FG420 ONLY)



Select [OK] and then press the ENTER key to execute copying.

4. Once the above settings have been completed, select [OK] at the bottom of the window and then press the **ENTER** key to execute copying.

To not execute copying, select [Cancel] at the bottom of the window and then press the **ENTER** key, or press the **CANCEL** key.

#### ■ Remark

Even if all parameters of [Basic Parameters], [Modulation Parameters], [Sweep Parameters], and [Burst Parameters] are copied, the setting differs from that of copying [All Parameters].

The following items can be copied only when [All Parameters] is copied .

- Output on/off condition
- Oscillation mode
- External addition setting
- User-defined units
- Output on/off setting at power-on
- Waveform parameter settings of all waveforms (Copying [Basic Parameters] copies only the waveform parameter setting of the current waveform)
- Amplitude/DC offset setting or High level/low level setting

## 3.2 Unifying Settings of 2 Channels

### ■ Procedure and operation

First, at the Utility screen, enable the 2-channel same value setting function.

Perform the settings of the items that you want to duplicate across the two channels. When the settings for one channel are done, those same settings are applied to the other channel. In addition to frequency, phase, amplitude, and DC offset, this applies also to oscillation mode, waveform, etc. Other settings that can also be unified for both channels include output on/off, burst trigger, and sweep start/stop.

This function is enabled until the 2-channel same value setting function is switched off.

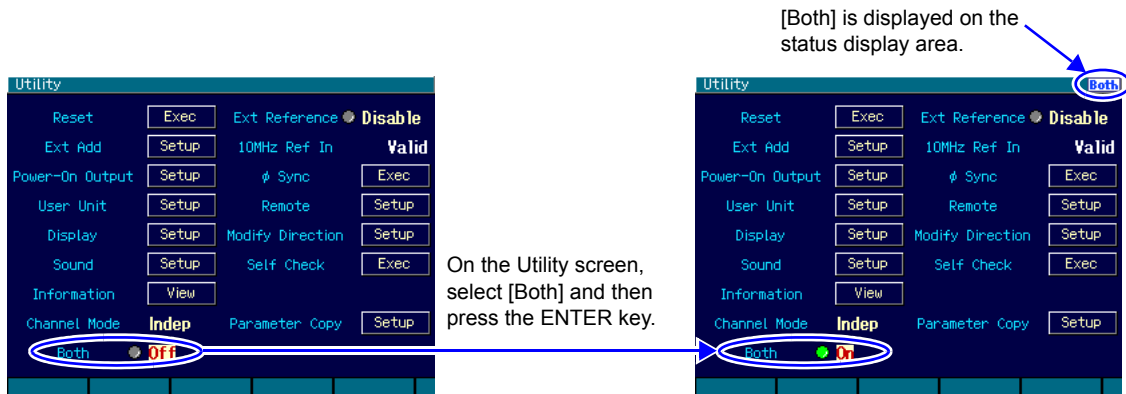
### ■ Switching 2-channel same value setting function on/off

The 2-channel same value setting function is switched on/off on the Utility screen.

On the Utility screen, select [Both] and then press the **[ENTER]** ENTER key to switch the function from [Off] to [On].

As a result, the 2-channel same value setting function is on.

To switch the function back to [Off], press the **[ENTER]** ENTER key again.



On screens other than the Utility screen, the function can be switched on/off by pressing the [CH1/CH2] key for at least 2 seconds.

### 3.3 Phase Synchronization Between Channels

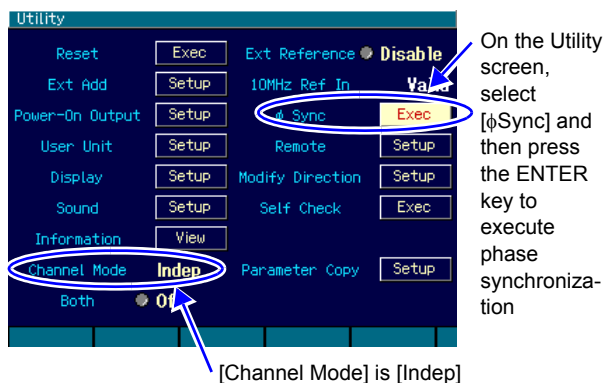
Even when the same frequency and phase settings are applied to both channels through the 2-channel same value setting function, the phase relationships of the output waveforms of the two channels vary moment to moment. To match the phase between the two channels requires phase synchronization.

Phase synchronization is used for independent operation of two channels (when the channel mode setting is [Indep] (independent)).

When phase synchronization by maintaining the same frequency or frequency ratio is required, use the 2-channel ganged function. [☞ pp. 39, 43](#)

For the synchronization of multiple units, [☞ p. 46](#)

#### ■ Performing synchronization



First, set the independent channel mode, and make the frequency setting the same for both channels.

The synchronization operation is done on the Utility screen. On this screen, select [φSync] and then press the **ENTER** key to execute phase synchronization. At this time, the oscillation stops briefly for both channels, causing momentary phase discontinuity.

#### ■ Phase relationship after synchronization

Through synchronization, the oscillation phase of each channel is initialized. The phase difference of the output waveform is the difference between the phase settings of each channel.

Even when synchronization has been executed, if the frequency is later changed, the synchronization relationship is then lost. In this case, execute synchronization again if necessary.

#### ■ Operation limitations

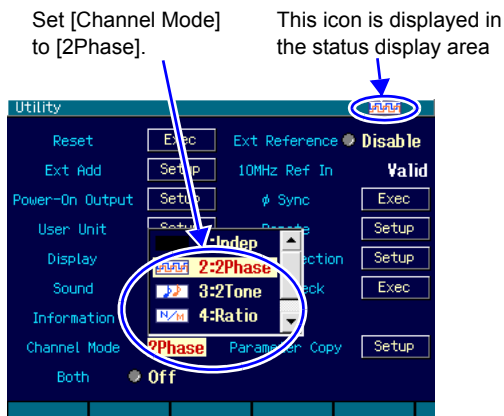
The limitations listed in the following table apply to synchronization. Synchronization is used in the case of independent operation of two channels. Even if invalid, the oscillation of both channels stops momentarily when synchronization is performed.

Item	Limitation
Waveform	Invalid for noise, DC
Modulated oscillation mode	Invalid for FM, FSK
Sweep oscillation mode	Invalid for frequency sweep. Invalid for gated single-shot sweep.
Burst oscillation mode	Invalid
Sequence oscillation mode	Cannot be used

### 3.4 Maintaining Both Channels to Same Frequency (2-Channel Ganged Operation, 2-Phase)

When the channel mode is [2Phase] (2-phase), if the frequency of Channel 1 is changed, the frequency of Channel 2 is automatically adjusted accordingly while maintaining the synchronization relationship between the two channels. The same applies during frequency modulation and frequency sweep. However, burst oscillation and gated single-shot sweep cannot be executed.

#### ■ Selecting 2-channel ganged operation



On the Utility screen, set [Channel Mode] (channel mode) to [2Phase] (2-phase) (normally, [Indep] (independent) is set). As a result, 2-phase oscillation is set.

The frequencies of both channels become the same and phase synchronization is performed automatically. The synchronization relationship is maintained even if the frequency is changed.

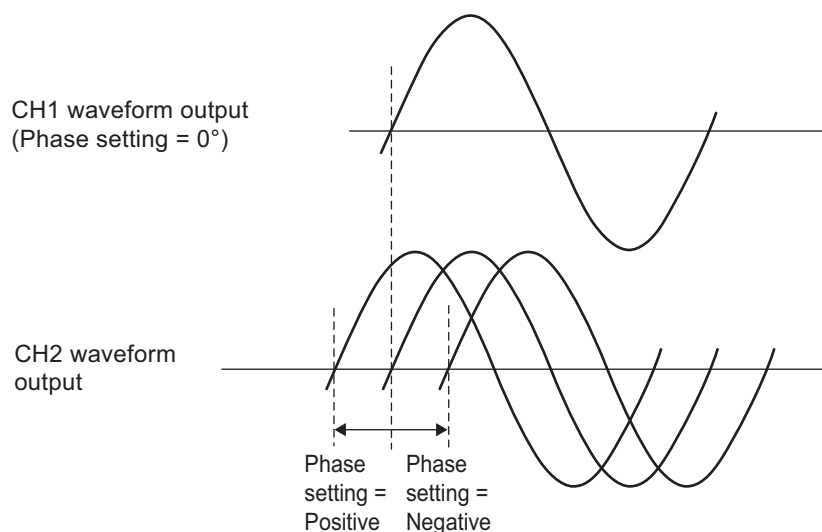
The same frequency and synchronization relationships are controlled to be maintained even during frequency modulation and frequency sweep.

In the case of 2-phase oscillation, frequency-related settings can be performed only for Channel 1.

#### ■ Changing the phase difference between the two channels

On the Oscillator setting screen, the phase can be independently set for each channel. The phase difference between channels is the difference between the respective phase settings.

Normally, the phase of the channel to be used as the phase reference, for example Channel 1, is set to  $0^\circ$ , and only the phase setting of Channel 2 is changed. At this time, the phase setting of Channel 2 becomes the phase of Channel 2 using Channel 1 as reference. As shown in the following figure, if the phase setting of Channel 2 is positive, Channel 2 precedes Channel 1. If the phase setting of Channel 2 is negative, Channel 2 follows Channel 1.



#### ■ Operation limitations

To maintain the same frequency and synchronization relationship, the limitations listed in the following table apply.

Item		Limitation
Waveform		Noise and DC cannot be used.
Modulated oscillation mode	FM	FM for both channels. Common peak deviation. The modulation source is internal only. Common internal modulation waveform and internal modulation frequency.
	FSK	FSK for both channels. Common hop frequency. The modulation source is internal only. Common internal modulation frequency.
	PM	PM for both channels. Independent modulation setting for each channel.
	PSK	PSK for both channels. Independent modulation setting for each channel.
	AM	AM for both channels. Independent modulation setting for each channel.
	DC offset modulation	DC offset modulation for both channels. Independent modulation setting for each channel.
	PWM	PWM for both channels. Independent modulation setting for each channel.
Sweep oscillation mode	Frequency sweep	Frequency sweep for both channels. Common sweep function, sweep range, sweep time, and sweep mode. Gated single-shot sweep not possible. Common trigger source and internal trigger oscillator for sweep during single-shot sweep. The external trigger source is valid only for CH1.
	Phase sweep	Phase sweep for both channels. Independent sweep setting for each channel.
	Amplitude sweep	Amplitude sweep for both channels. Independent sweep setting for each channel.
	DC offset sweep	DC offset sweep for both channels. Independent sweep setting for each channel.
	Duty sweep	Duty sweep for both channels. Independent sweep setting for each channel.
Burst oscillation mode		Cannot be used.
Sequence oscillation mode		Cannot be used.

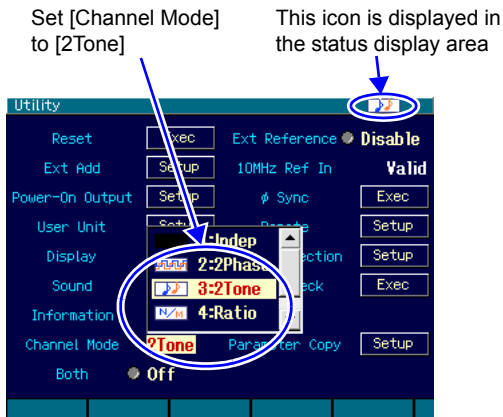
During modulation and sweep, both channels are set to the same type of modulation and sweep. If modulation (other than FM, FSK) and sweep (other than frequency sweep) are not required for the other channel, use that channel with its modulation width and sweep width set to zero.



### 3.5 Keeping Frequency Difference Constant (2-Channel Ganged Operation, 2-Tone)

When the channel mode is [2Tone] (two-tone), the frequency can be changed while maintaining the frequency difference between the two channels. When the frequency of Channel 1 is changed, the frequency of Channel 2 is automatically changed accordingly. The same applies during frequency modulation and frequency sweep. However, burst oscillation and gated single-shot sweep cannot be executed.

#### ■ Selecting 2-channel ganged operation



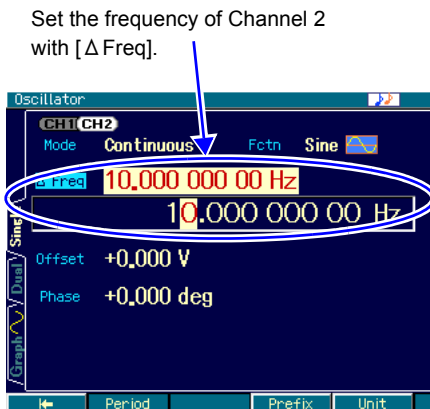
On the Utility screen, set [Channel Mode] (channel mode) to [2Tone] (2-tone) (normally, [Indep] (independent) is set). As a result, fixed frequency difference oscillation is set.

The frequency difference between the two channels is maintained.

The same frequency difference is controlled to be maintained, even during frequency modulation and frequency sweep.

In the case of fixed frequency difference oscillation, the frequency of Channel 2 cannot be set directly.

#### ■ Setting the frequency difference



On the Oscillator setting screen, set the frequency of Channel 2 with [ $\Delta$  Freq].

The frequency of Channel 2 is the sum of the frequency of Channel 1 and that frequency difference.

#### ■ Operation limitations

To maintain the frequency difference, the limitations listed in the following table apply.

Item		Limitation
Waveform		Noise and DC cannot be used.
Modulated oscillation mode	FM	FM for both channels. Common peak deviation. The modulation source is internal only. Common internal modulation waveform and internal modulation frequency.
	FSK	FSK for both channels. Hop frequency according to frequency difference. The modulation source is internal only. Common internal modulation frequency.
	PM	PM for both channels. Independent modulation setting for each channel.
	PSK	PSK for both channels. Independent modulation setting for each channel.
	AM	AM for both channels. Independent modulation setting for each channel.
	DC offset modulation	DC offset modulation for both channels. Independent modulation setting for each channel.
	PWM	PWM for both channels. Independent modulation setting for each channel.
Sweep oscillation mode	Frequency sweep	Frequency sweep for both channels. Sweep range according to frequency difference. Common sweep function, sweep time, and sweep mode. Gated single-shot sweep not possible. Common trigger source and internal trigger oscillator for sweep during single-shot sweep. The external trigger source is valid only for CH1.
	Phase sweep	Phase sweep for both channels. Independent sweep setting for each channel.
	Amplitude sweep	Amplitude sweep for both channels. Independent sweep setting for each channel.
	DC offset sweep	DC offset sweep for both channels. Independent sweep setting for each channel.
	Duty sweep	Duty sweep for both channels. Independent sweep setting for each channel.
Burst oscillation mode		Cannot be used.
Sequence oscillation mode		Cannot be used.

During modulation and sweep, both channels are set to the same type of modulation and sweep. If modulation (other than FM, FSK) and sweep (other than frequency sweep) are not required for the other channel, use that channel with its modulation width and sweep width set to zero.

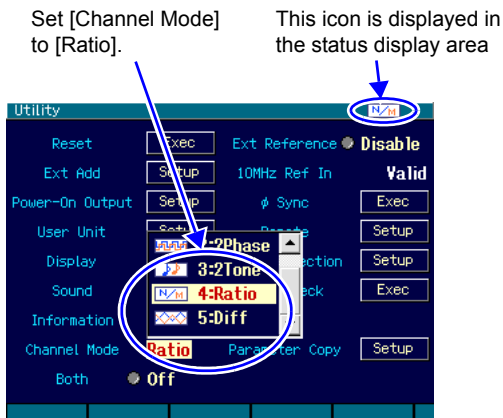
The frequency difference of the hop frequency in FSK is limited by the setting resolution of the hop frequency.

If logarithmic sweep is selected for frequency sweep, logarithmic sweep is executed for Channel 1, but since Channel 2 follows with the fixed frequency difference, the sweep is not logarithmic.

## 3.6 Keeping Frequency Ratio Constant (2-Channel Ganged Operation, Ratio)

When the channel mode is [Ratio] (ratio), the frequency can be changed while maintaining the frequency ratio of the two channels. When the frequency of Channel 1 is changed, the frequency of Channel 2 is automatically changed accordingly. The same applies during frequency modulation and frequency sweep. However, burst oscillation and gated single-shot sweep cannot be executed.

### ■ Selecting 2-channel ganged operation



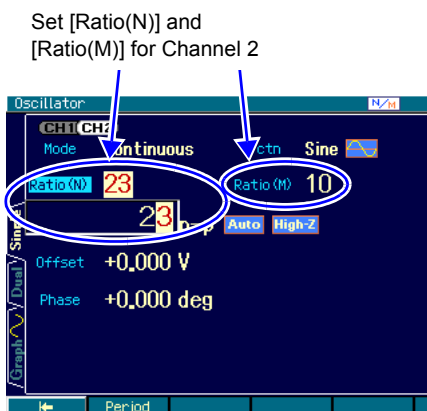
On the Utility screen, set [Channel Mode] (channel mode) to [Ratio] (ratio) (normally, [Indep] (independent) is set).

As a result, constant frequency ratio oscillation is set.

The frequency ratio of the two channels is maintained. The same frequency ratio is controlled to be maintained, even during frequency modulation and frequency sweep.

In the case of constant frequency ratio oscillation, the frequency of Channel 2 cannot be set directly.

### ■ Setting the frequency ratio



On the Oscillator screen, set the frequency ratio with [Ratio(N)] and [Ratio(M)] for Channel 2.

The ratio of [frequency of Channel 2]:[frequency of Channel 1] becomes [N:M].

When the frequency ratio is changed, the oscillation stops briefly for both channels, causing momentary phase discontinuity.

#### ■ Operation limitations

To maintain the frequency ratio, the limitations listed in the following table apply.

Item		Limitation
Waveform		Noise and DC cannot be used.
Modulated oscillation mode	FM	FM for both channels. Peak deviation according to frequency ratio. The modulation source is internal only. Common internal modulation waveform and internal modulation frequency.
	FSK	FSK for both channels. Hop frequency according to frequency ratio. The modulation source is internal only. Common internal modulation frequency.
	PM	PM for both channels. Independent modulation setting for each channel.
	PSK	PSK for both channels. Independent modulation setting for each channel.
	AM	AM for both channels. Independent modulation setting for each channel.
	DC offset modulation	DC offset modulation for both channels. Independent modulation setting for each channel.
	PWM	PWM for both channels. Independent modulation setting for each channel.
Sweep oscillation mode	Frequency sweep	Frequency sweep for both channels. Sweep range according to frequency ratio. Common sweep function, sweep time, and sweep mode. Gated single-shot sweep not possible. Common trigger source and internal trigger oscillator for sweep during single-shot sweep. The external trigger source is valid only for CH1.
	Phase sweep	Phase sweep for both channels. Independent sweep setting for each channel.
	Amplitude sweep	Amplitude sweep for both channels. Independent sweep setting for each channel.
	DC offset sweep	DC offset sweep for both channels. Independent sweep setting for each channel.
	Duty sweep	Duty sweep for both channels. Independent sweep setting for each channel.
Burst oscillation mode		Cannot be used.
Sequence oscillation mode		Cannot be used.

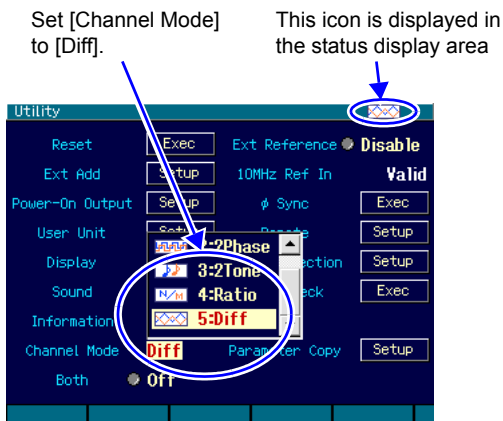
During modulation and sweep, both channels are set to the same type of modulation and sweep. If modulation (other than FM, FSK) and sweep (other than frequency sweep) are not required for the other channel, use that channel with its modulation width and sweep width set to zero.

Frequency ratios on peak deviation in FM and hop frequency in FSK are limited by each frequency setting resolution, respectively.

## 3.7 Obtaining Differential Output (2-Channel Ganged Operation, Differential)

When the channel mode is [Diff] (differential), the settings can be changed while maintaining the differential output of the two channels. When the settings of Channel 1 are changed, the settings of Channel 2 are automatically changed accordingly. The same applies during various modulations and various sweeps. However, burst oscillation and gated oscillation single sweep cannot be executed.

### ■ Selecting 2-channel ganged operation



On the Utility screen, set [Channel Mode] (channel mode) to [Diff] (differential) (normally, [Indep] (independent) is set). As a result, differential output oscillation is set.

The frequency, phase, amplitude, and DC offset settings of the two channels are made to match, and the output waveforms are inverted.

The differential output relationship is maintained even if the settings are changed.

The differential output relationship is controlled to be maintained even during various modulation and various sweep.

In the case of differential output oscillation, settings can be performed only for Channel 1 (operation as oscillator of a single channel).

### ■ Operation limitations

To maintain differential output, the limitations listed in the following table apply.

Item	Limitation
Waveform	Noise and DC cannot be used.
Modulated oscillation mode	Internal modulation source only
Sweep oscillation mode	Gated single-shot sweep not possible. External trigger source of CH1 only is valid.
Burst oscillation mode	Cannot be used
Sequence oscillation mode	Cannot be used
External addition	Cannot be used

#### ✓ Check

The output DC offset of both channels has the same value and same polarity. Differential output for AC, but not for DC.

# 4. SYNCHRONIZING MULTIPLE UNITS

By synchronizing multiple FG410 and FG420 units, an oscillator of up to 12 phases (using six FG420 units) can be configured. The phase and amplitude can be independently changed for each phase.

Set the same frequency for all the units and all the channels.

## 4.1 Connection Procedure

The FG410 or FG420 unit that serves as the synchronization reference is called the master unit. The other FG410 and FG420 units are called slave units.

### ■ Connectors

Use the external 10 MHz frequency reference input (10MHz REF IN) and frequency reference output (REF OUT) on the rear panel.

### ■ Cable

Cable type: Coaxial cable of 50  $\Omega$  characteristic impedance with BNC connector (RG-58A/U, etc.)

Cable length restriction: 1 m max. between units, total length of 3 m max.

### ■ Connection method

One of two connection methods can be used (connection method 1 and connection method 2).

In the case of a large number of units, connection method 1 minimizes the time difference between slave units. However, this method requires, in addition to coaxial cables, T dividers and 50  $\Omega$  termination resistor.

Connection method 2 is simpler in that it allows connection using coaxial cables only. However, the time difference between slave units is larger than for connection method 1. Moreover, the maximum number of units that can be connected with this method is smaller compared to connection method 1.

Either the internal crystal oscillator or an external 10 MHz clock can be used as the frequency reference of the master unit. When an external 10 MHz clock is used as the reference, the frequencies of the slave units have the same accuracy as the external reference.

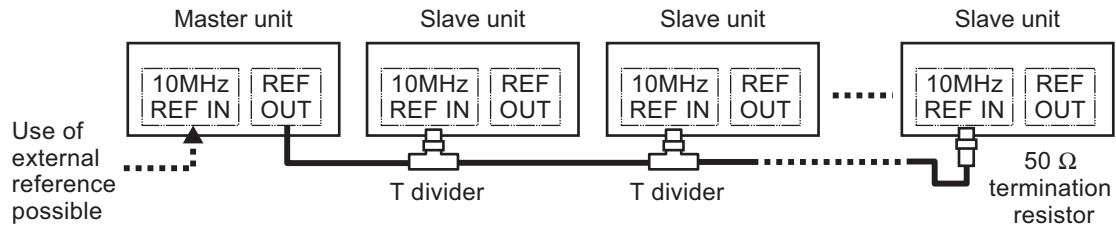
- **Connection method 1**

Connect the reference output of the master unit in parallel to the reference inputs of the slave units using T dividers.

Use a 50  $\Omega$  termination resistor for the reference input of the end slave unit.

The time difference between the slave units depends on the length of the connection cables (approx. 6 ns/m).

Up to 6 units (master unit + slave units) can be connected.

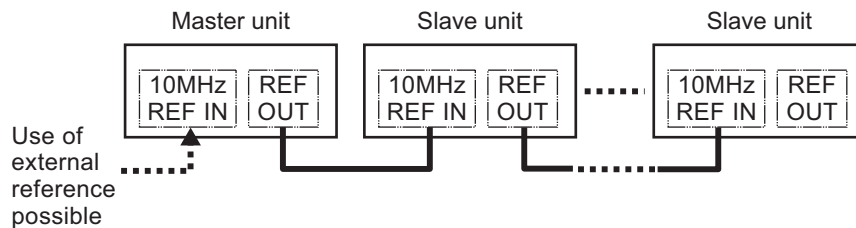


- **Connection method 2**

Connect the reference outputs of the master unit or slave unit to the next-stage reference input of the slave unit.

The time difference between the slave units depends on the internal unit delay (approx. 25 ns) and the connection cable length (approx. 6 ns/m).

Up to 4 units (master unit + slave units) can be connected.



## 4.2 Synchronization

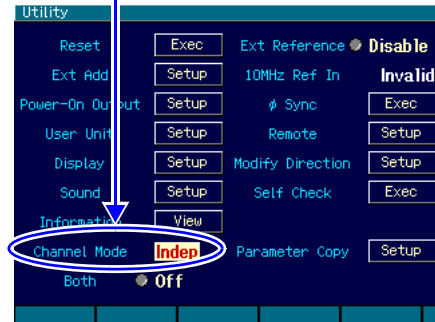
### ■ Before performing synchronization

Once the master unit and slave units have been connected, perform the following settings.

#### Master unit

- Set 2-channel independent operation or 2-phase operation (set channel mode to [Indep] (independent) or [2Phase] (2-phase) on the Utility screen) (FG420 only).
- If the frequency reference of the master unit is external, enable the external frequency reference (set the external reference to [Enable] on the Utility screen). [p. 50](#)
- Set the frequency of each channel to the frequency used for the synchronized operation of the various units (same frequency setting for all channels of all units).

Set [Channel Mode] to [Indep] or [2Phase] (FG420 only).

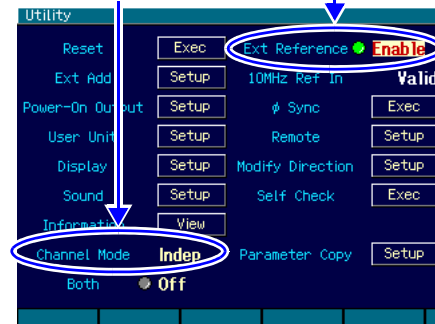


#### Slave units

- Set 2-channel independent operation or 2-phase operation (set channel mode to [Indep] (independent) or [2Phase] (2-phase) on the Utility screen) (FG420 only).
- Enable the external frequency reference (on the Utility screen, set the external reference to [Enable]).
- Set the frequency of each channel to the frequency used for the synchronized operation of the multiple units (same frequency setting for all channels of all units).

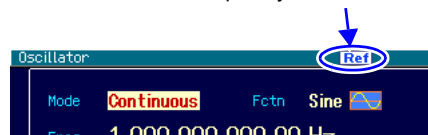
Set [Channel Mode] to [Indep] or [2Phase] (FG420 only).

Set [Ext Reference] to [Enable].



Check that all the slave units operate with the external frequency reference. If the [Ref] icon in the status display area at the top of the screen is displayed without blinking, this indicates operation at the external frequency reference.

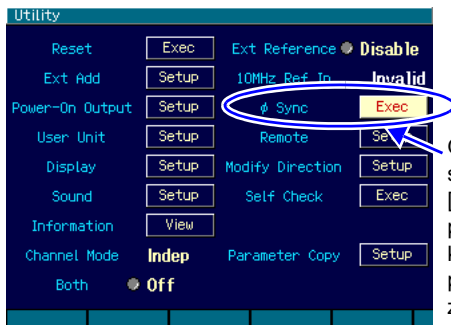
[Ref] icon is displayed without flashing in the case of operation at the external frequency reference





## ■ Performing synchronization

Synchronization is performed on the master unit.



On the Utility screen, select [φSync] and then press the ENTER key to perform phase synchronization.

Synchronization is performed on the Utility screen of the master unit.

On the Utility screen, select [φSync] and then press the **ENTER** key to perform phase synchronization.

At this time, oscillation stops briefly for all the channels, causing momentary phase discontinuity.

Once phase synchronization is performed, a message is displayed on each unit.

## ■ Phase relationship after synchronization

Through synchronization, the oscillation phase of each channel is initialized. The phase difference of the output waveform is the difference between the phase settings of each channel.

Even when synchronization has been executed, if the frequency is later changed, the synchronization relationship is then lost. Even if the synchronization relationship is lost, no message to this effect is displayed. In this case, execute synchronization again if necessary.

When the cables used to connect the master unit to the slave units, and the slave units to one another, are disconnected, the synchronization relationship is lost. The synchronization relationship is also lost if the channel mode and the external frequency reference settings are changed.

## ■ Operation limitations

The limitations listed in the following table apply to synchronization. Even if invalid, the oscillation of both channels stops momentarily when synchronization is performed.

Item	Limitation
Waveform	Invalid for noise, DC
Modulated oscillation mode	Invalid for FM, FSK
Sweep oscillation mode	Invalid for frequency sweep. Invalid for gated single-shot sweep.
Burst oscillation mode	Invalid
Sequence oscillation mode	Cannot be used

# 5. USING EXTERNAL FREQUENCY REFERENCE

## 5.1 Purpose of Using External Frequency Reference

This equipment uses an internal crystal oscillator as the frequency reference, but can also use an external 10 MHz clock for this purpose.

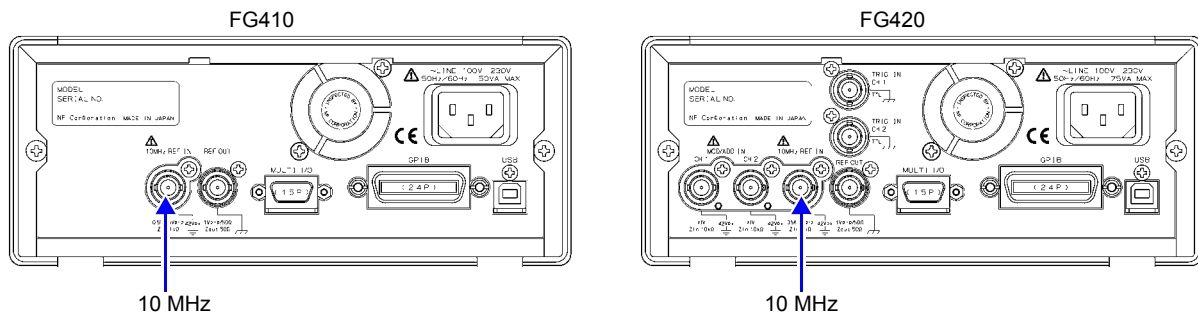
Generally, an external frequency reference is used for the following purposes.

- To increase frequency accuracy and stability through the use of a frequency reference that has greater accuracy than the frequency reference built in this equipment (for example, rubidium frequency standard)
- To use a common frequency accuracy, by sharing the same frequency reference with other units
- To obtain synchronization with other FG410 or FG420 units. For details on the synchronization of multiple units, [☞ p. 46](#)

## 5.2 External Frequency Reference Signal Connection and Usage Procedures

### ■ Connecting a 10 MHz signal

Connect an external 10 MHz signal to the external 10 MHz frequency reference input (10MHz REF IN) BNC terminal on the rear panel.



The input characteristics are as follows.

Input voltage	0.5 Vp-p to 5 Vp-p
Maximum allowed input	10 Vp-p
Input impedance	1 k $\Omega$ , AC coupled
Input frequency	10 MHz ( $\pm 0.5\%$ ( $\pm 50$ kHz))
Input waveform	Sine wave or square wave (50 $\pm 5\%$ duty)
Signal GND	Insulated from housing and each channel's waveform output (42 Vpk max.)

The input impedance is not 50  $\Omega$ , so if reverberation seems likely to be a problem, use a termination resistor.

The external 10 MHz frequency reference input signal ground is insulated from the housing. Therefore, the connection to the frequency standard is not influenced by noise caused by a ground loop. Neither is there influence from noise caused by a ground loop in the case of synchronized connection of multiple FG410 and FG420 units.

However, in all cases, the floating voltage is limited to 42 Vpk (DC + AC peak) max. in order to avoid electric shock.

For cautions on floating ground connection, see “3.3 Cautions on Floating Ground Connection” in the Basics Instruction Manual.

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**⚠ WARNING** To prevent electric shocks, do not apply a voltage exceeding 42 Vpk (DC + AC peak) between the ground of the BNC connectors insulated from the housing and the housing.

Also, do not apply a voltage exceeding 42 Vpk (DC + AC peak) between the grounds of the BNC connector groups insulated from the housing. "BNC connector group," as used here, refers to multiple BNC connectors that are connected to a common ground.

If such a voltage were to be applied, the internal voltage limiting elements will try to curb the working voltage, but if the voltage is too large, equipment burnout may result.

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**⚠ AVERTISSEMENT** Pour éviter les chocs électriques, n'appliquez pas de tension supérieure à 42 Vpk (c.c. + c.a. crête) entre la terre des connecteurs BNC isolés du logement et le logement lui-même.

En outre, n'appliquez pas une tension supérieure à 42 Vpk (c.c. + c.a. crête) entre les mises à la terre des groupes de connecteurs BNC isolés du logement. L'expression « groupe de connecteurs BNC » se réfère à plusieurs connecteurs BNC branchés sur une même mise à la terre.

Si de telles tensions sont appliquées, les composants de limitation de tension interne tentent de diminuer la tension de fonctionnement. Mais la tension est trop élevée, l'appareil risque de griller.

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**⚠ CAUTION** If there is a difference in potential between the ground of a BNC connector insulated from the housing and the housing, do not short circuit the hot side of that BNC connector and the housing, as this may damage the equipment.

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**⚠ ATTENTION** En cas de différence de potentiel entre la terre d'un connecteur BNC isolé du logement et le logement, ne mettez pas en court-circuit le côté chaud de ce connecteur BNC et du logement : vous risqueriez d'endommager l'appareil.

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**⚠ CAUTION** If a difference in potential exists between the grounds of the BNC connectors, do not short circuit these BNC connector grounds, as this may damage the equipment.

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**⚠ ATTENTION** En cas de différence de potentiel entre les terres et les connecteurs BNC, ne mettez pas en court-circuit ces terres de connecteurs BNC : vous risqueriez d'endommager l'appareil.

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### ■ Enabling the external frequency reference

The external frequency reference can be enabled/disabled on the Utility screen.

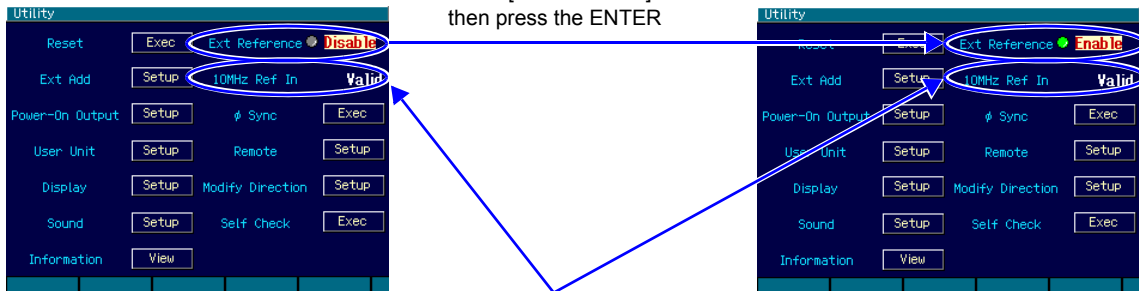
On the Utility screen, select [Ext Reference] and then press the **ENTER** ENTER key to switch

## 5. USING EXTERNAL FREQUENCY REFERENCE

from [Disable] to [Enable]. The external frequency reference is enabled as a result.

To go back to [Disable], press the **ENTER** ENTER key again.

On the Utility screen,  
select [Ext Reference] and  
then press the ENTER



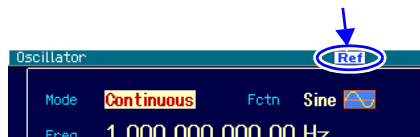
If a usable frequency reference is input, [Valid] is displayed in the [10MHz Ref In] field.  
If not, then [Invalid] is displayed.

When the [Ext Reference] setting is [Enable] and the [10MHz Ref In] status is [Valid], this product operates by using the signal input to the external 10 MHz frequency reference terminal as the frequency reference.

However, if the external frequency reference signal is interrupted at some point, the internal frequency reference is automatically switched to. Then, if the external frequency reference signal recovers, operation using the external frequency as the reference resumes.

Which signal is used as the frequency reference is always displayed in the status display area at the top of the screen.

[Ref] icon is displayed if the current frequency reference is external.  
If the reference input status is [Invalid], this icon blinks.

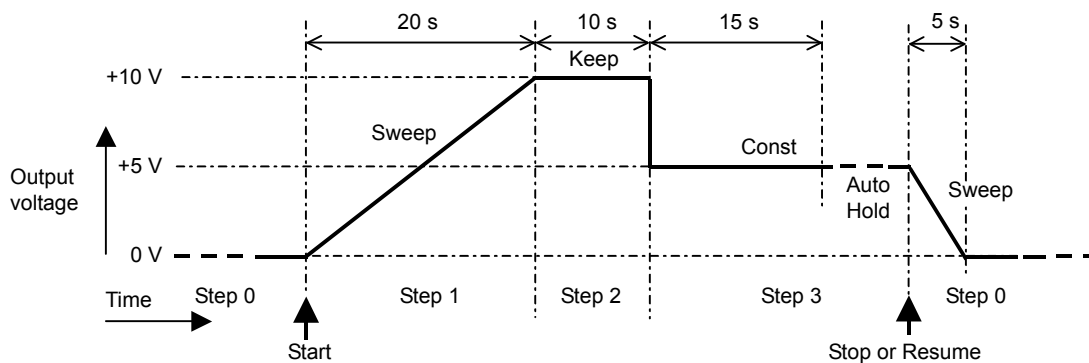


# 6. USING SEQUENCE OSCILLATION

## 6.1 Sequence Oscillation Example

As a simple example of sequence oscillation, let us set up a sequence that changes the DC voltage in stages, as shown in the following figure.

(First, restore the initial settings on the Utility screen.)



Set the sequence as follows.

Step No.	Step Control Parameters			Intra-Step Channel Parameters
0	Time: 5 s	StopPhs: Off	StepCode: Don't care	Fctn: DC Offset: 0V    Action: Sweep
1	Time: 20 s	AutoHold: Off StopPhs: Off StateB: Off EventB: Off	JumpTo: Off StepTerm: Continue StepCode: Don't care	Fctn: DC Offset: +10V    Action: Sweep
2	Time: 10 s	AutoHold: Off StopPhs: Off StateB: Off EventB: Off	JumpTo: Off StepTerm: Continue StepCode: Don't care	Fctn: DC Offset:        Action: Keep
3	Time: 15 s	AutoHold: On StopPhs: Off StateB: Off EventB: Off	JumpTo: Off StepTerm: End StepCode: Don't care	Fctn: DC Offset: +5 V    Action: Const

The operation is described below using the step sequence.

### Step 0

These are the output settings before the sequence starts and after the sequence ends.

In this case, in the DC 0 V state, the system waits for the sequence to start.

Since [Time] and [Action] are valid only when the sequence is stopped, they will be explained later.

### Step 1

When the sequence starts, the sequence goes to Step 1. Since [Time] is 20 s, [Offset] is +10 V, and [Action] of [Offset] is [Sweep], the output voltage rises linearly from 0 V to +10 V over 20 s.

Once +10 V has been reached after 20 s, since [StepTerm] is [Continue], the sequence moves on to the next step, Step 2.

### Step 2

Since [Time] is 10 s and [Action] of [Offset] is [Keep], the last value of the previous step, Step 1, in other words +10 V, is held for 10 s.

After the lapse of 10 s, since [StepTerm] is [Continue], the sequence moves on to the next step, Step 3.

### Step 3

Since [Time] is 15 s, [Offset] is +5 V, and [Action] of [Offset] is [Const], a constant value, i.e., +5 V, is held for 15 s. When the sequence moves on from Step 2 to Step 3, the output voltage abruptly changes from +10 V to +5 V.

After the lapse of 15 s, since [AutoHold] is [On], the sequence enters standby as is.

Next, when Stop is executed, the sequence moves to Step 0.

Since [StepTerm] is set to [End], the sequence moves to Step 0 even if Resume is executed.

Note that if [StepTerm] is set to [Continue], the sequence moves to Step 4 when Resume is executed.

### Step 0

Since [Time] is 5 s, [Offset] is 0 V, and [Action] of [Offset] is [Sweep], the output voltage declines linearly from +5 V to 0 V over 5 s.

Once the output voltage has reached 0 V after 5 s, the sequence goes into standby in this state. At this time, if Start is executed, the same sequence is repeated.

## 6.2 Basics

The basics that must be known when using sequence oscillation are explained below.

### a) Differences between sequence oscillation and normal oscillation

During sequence oscillation, the equipment operates on individual waveform, frequency, and amplitude settings independent from normal oscillation (continuous, modulated, sweep, burst). Regarding sequence oscillation and normal oscillation, assume that each operates as a separate oscillator.

### b) Step control parameters and intra-step channel parameters

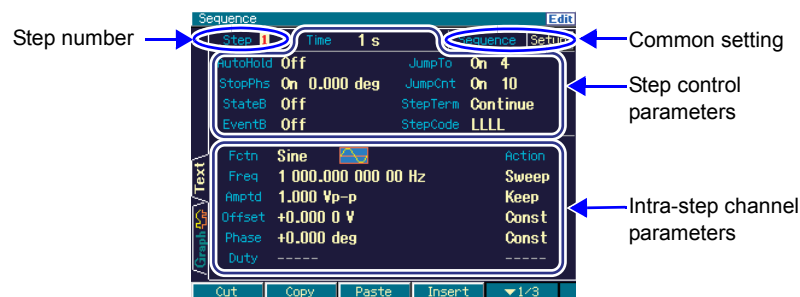
Sequence oscillation has the following two main types of parameters.

- Step control parameters

Sequence oscillation consists of multiple steps linked to each other. The step flow is controlled by the step control parameters, which determine the step continuation time and the next step. For convenience, the step synchronization code setting is also included in the step control parameters.

- Intra-step channel parameters

This parameter determines the output status within each step. Along with basic parameters such as waveform, frequency, and amplitude, it determines how these parameters change within each step.



### c) Intra-step parameter change pattern

There are the following three patterns in intra-step channel parameters with respect to value changes in a step, other than the waveform. These are called action settings. In the case of the waveform parameter, the setting done in that step is always applied, not the action setting.

- Constant [Const]

The value is fixed to that set in that step.

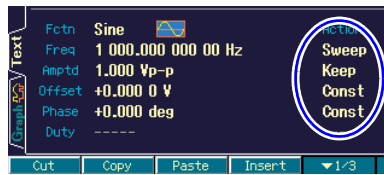
- Keep [Keep]

The value immediately before that step is entered is kept. In other words, the value changes according to the status of the previous step.

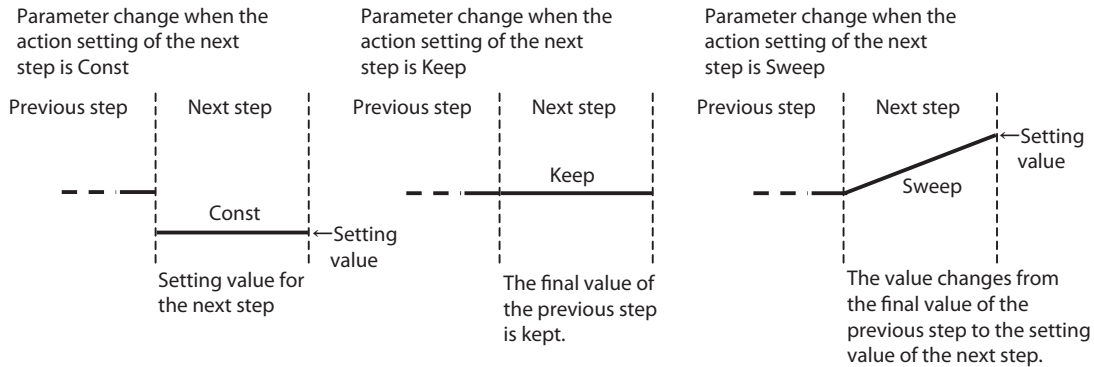
Even when the action setting is [Keep], parameter values can be set but they are invalid during sequence execution.

• Sweep [Sweep]

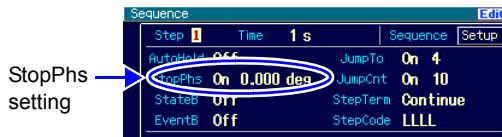
The value changes linearly over the step time from the value immediately before that step is entered to the value set in that step. In other words, after the lapse of the step time in that step, the value reaches the set value. The start value changes according to the status of the previous step.



Action settings



d) Phase at step end [StopPhs]



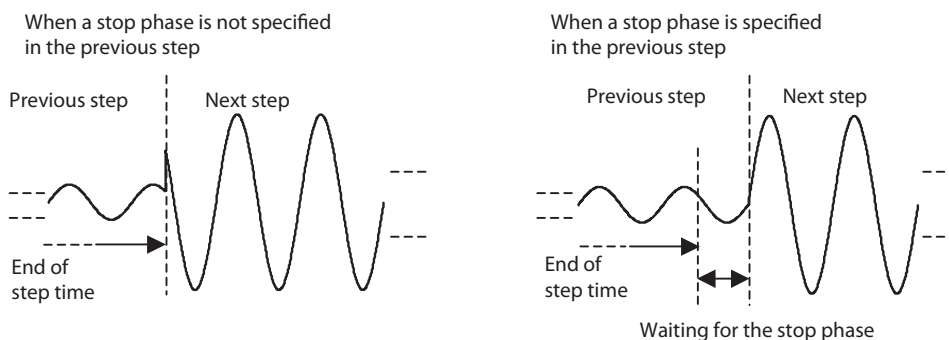
StopPhs setting

Normally, when the prescribed step time has elapsed, the sequence moves on to the next step regardless of the oscillation phase. However, if transition to the next step following completion of one cycle of the waveform, for example, is desired, the end phase (stop phase) can be specified.

Note that the phase is valid only for the phase of channel 1 in the FG420. No stop phase can be set for channel 2.

When the stop phase is specified, following the lapse of the prescribed step time, the sequence moves on to the next step after the specified phase has been reached, with the output setting maintained as is (sweep is not performed during this interval). As a result, the actual step time is longer than the specified step time. The sequence moves on to the next step with a continuous phase regardless of the stop phase setting.

The following figures show examples of a case in which a stop phase is specified and a case in which it is not specified when the amplitude is changed abruptly during steps. Both the phase setting value and the stop phase setting value are 0° in the example when a stop phase is specified. In either case, the phase is continuous at the transitions of the steps.





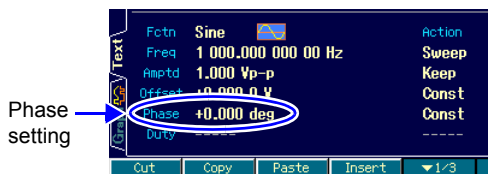
The stop phase specified here is the phase value based on the oscillation reference phase (oscillation phase of DDS). The end phase that appears in the actual output is equal to [phase setting value of that step] + [stop phase setting value]. Normally, if any is set to  $0^\circ$ , the sequence moves on to the next step following the completion of 1 cycle. At this time, the step does not end with the final amplitude value of the waveform but with the top ( $0^\circ$  position) amplitude value of the waveform.

When the waveform is a square wave, a stop phase can be set but the step is transferred to the next step without waiting for the stop phase. In addition, a stop phase can be set but it is invalid when the waveform is a noise or DC.

### ✓ Check

- Stop phase setting is invalid for a square wave, noise, and DC.
- The sequence changes to the next step after 200 ns (equivalent to  $0.072^\circ$  in 1 kHz) have elapsed from the specified stop phase. In channel 2 of the FG420, the sequence changes to the next step after approximately  $3.7 \mu\text{s}$  have elapsed since channel 1 changed.
- Once a step for which stop phase specification is valid has been passed, the step change in channel 2 of the FG420 is fixed to approximately  $3.7 \mu\text{s}$  later than that in channel 1 (it is not released or accumulated until the sequence ends).

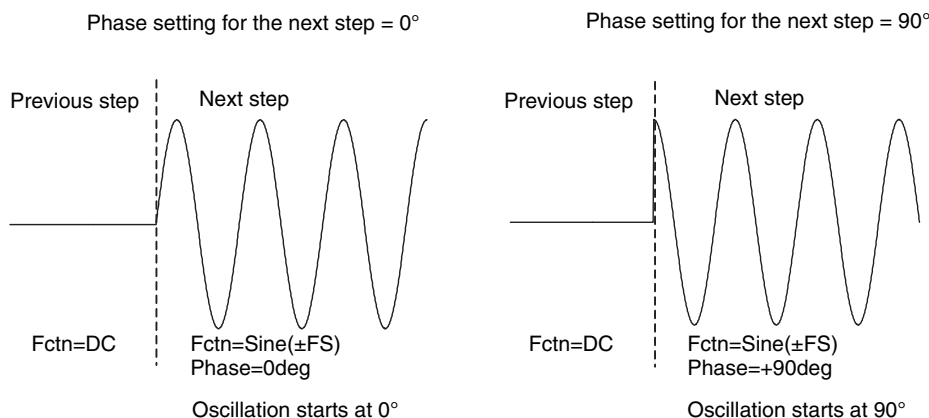
### e) Phase at step start



If the waveform of the previous step is DC or noise, oscillation in the next step starts from phase  $0^\circ$ .

Phase  $0^\circ$  here is the phase value based on the oscillation reference phase (oscillation phase of DDS), as in the case of the phase at step end (stop phase). The start phase that appears in the actual output is the phase setting value of that step. Normally, if the phase is set to  $0^\circ$ , oscillation starts from  $0^\circ$ .

The following figures show examples when the phase is set to  $0^\circ$  and  $90^\circ$  and the step after DC is the sine wave.



### ✓ Check

Set the previous step to DC to specify a start phase.

### f) Two types of branches

The control flow can be changed through manipulation from the panel or an external signal. This is called branching. For example, the sequence may be made to move to a different step in response to a change in the status of the equipment under test.

There are two types of branches, as follows.

- State branch [StateB]

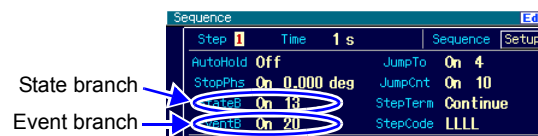
The operation branches to the specified step through a signal from a multi-I/O connector (pin 14). [☞ p. 60](#)

However, the signal from the multi-I/O connector is checked only after the specified step time of that step has elapsed (the time being held is not included). [☞ p. 61](#)

- Event branch [EventB]

The operation branches immediately to the specified step through soft key manipulation or the signal from a multi-I/O connector (pin 11). Even if the stop phase has been set, it is ignored.

For example, it can be used for saving processes when a failure is detected.



### g) Step 0 prior to start and upon end

The step in the standby state prior to sequence start is called Step 0. Step 0 is also the state at sequence end. When the mode changes from the normal oscillation mode to the sequence oscillation mode, the status changes to the Step 0 output status.

Since this is a special step, the items and meanings that can be set to the step control parameters differ from those of other steps.

Only the following three items can be set for the step control parameters.

- Step time: At the start of a sequence, the sequence changes to the next step (normally, step 1) without waiting for this time. The step time is valid when parameters are swept at the sequence end. If sweep is set for the intra-step channel parameters of step No. 0, sweeping is performed for this time. [☞ p. 56](#)
- Stop phase: When the sequence is started, the phase specified here is waited for and the sequence changes to the next step (normally, step 1). It is invalid for a square wave, noise, and DC.
- Step synchronization code output: Step synchronization code output of step No. 0.

The intra-step channel parameter action settings consist only of [Const] (constant) and [Sweep] (sweep), and do not include [Keep] (keep). In other words, the same output setting always applies to the start and end.

### h) Usable waveform limitation

The waveforms that can be used for sequence oscillation are limited to sine wave, square wave (both normal and extended possible as variable duty range), noise, DC, and arbitrary waveform.

If using a ramp wave or parameter-variable waveform is desired, on the ARB Edit screen, copy the desired waveform to the arbitrary waveform and save it in advance as an arbitrary waveform. During sequence oscillation, ramp wave symmetry and the various parameters for parameter-variable waveform cannot be specified.

If wishing to use a pulse waveform, save the half-sine edge pulse of the parameter-variable waveform as an arbitrary waveform.

### i) Waveform size

The waveforms used in the sequence are not written to the waveform memory each time the step is executed. Prior to the sequence execution, the waveforms are expanded to the 512 Kword waveform memories (per channel) when compilation is executed. Therefore, if many types of waveforms are used, a memory size allocated to each waveform becomes consequently smaller. Note that DC and a square wave are created during executing steps (regardless of whether the variable duty range is normal or extended) so that they do not use the waveform memory. In addition, the required memory size is the same when the same waveform is repeatedly used. The number of types of waveforms that can be used is limited to 128.

Note the following:

- When the allocatable memory size becomes small, the characteristics of the waveforms may be lost in an arbitrary waveform in the control point format and with many abrupt changes.
- When a large waveform is used in an arbitrary waveform in the array format, the memory size allocated for other waveforms decreases.

The following table shows the memory size that can be allocated for each waveform.

Waveform	Size	Size adjustment
DC	0 W	Fixed
Square wave	0 W	Fixed
Sine wave	4 KW, 8 KW, 16 KW, 32 KW, 64 KW, 128 KW, 256 KW, 512 KW	Variable
Noise	32 KW	Fixed
Arbitrary waveform (control point format)	4 KW, 8 KW, 16 KW, 32 KW, 64 KW, 128 KW, 256 KW, 512 KW	Variable
Arbitrary waveform (array format)	4 KW, 8 KW, 16 KW, 32 KW, 64 KW, 128 KW, 256 KW, 512 KW	Fixed

If a parameter-variable waveform, square waveform, pulse waveform, or ramp waveform is copied to an arbitrary waveform, it becomes an arbitrary waveform in control point format.

Noise is always used in 32 Kwords, of which size is fixed. However, it does not repeat the same pattern during the output.

An arbitrary waveform in the array format is used with the waveform size transferred from USB or GPIB, and the size is fixed.

A sine wave and an arbitrary waveform in the control point format are allocated to the remaining area which is the 512 Kwords minus the total amount of the size of the fixed-length waveforms above. The waveform size is adjusted based on the free memory space and the number of waveforms. Note that all the memory sizes allocated to each variable-length waveform are the same.

The arbitrary waveforms in the control point format are spread out to the memories, not just decimated but with the characteristics of the waveform retained, as much as possible.

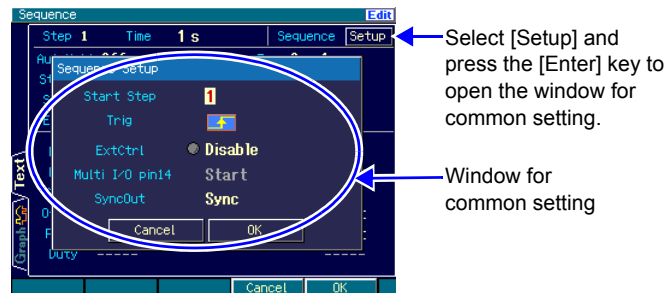
**Caution:** In the initial setting, waveforms in all steps are sine waves, and [Continue] is set for the step termination. If a 512 Kword arbitrary waveform in the array format is specified for an arbitrary step, with the initial setting remaining, an error occurs when compiling due to the lack of memory space to allocate the sine wave to the waveform memory. When using a 512 Kword arbitrary waveform in the array format, compose a sequence which does not go through the steps requiring another waveform memory.

### j) Channel ganged operation (FG420 only)

The step control parameters are common to both channels. The sequence moves to the same steps for both channels. However, the stop phase can be controlled only on the Channel 1 side, so that the end phase of Channel 2 does not necessarily match the desired value. Also note that even once a stop phase is specified, the subsequent step switching time of channel 2 is fixed to approximately 3.7  $\mu$ s later than that of channel 1.

On the other hand, the intra-step channel parameters can be set independently for each channel.

### k) Common sequence settings



Select [Setup] and press the [Enter] key to open the window for common setting.

Window for common setting

The following items are common settings within one sequence.

- Start step [Start Step]
 

The number of the next step to which the sequence is to move to after Step 0 can be specified. Normally, 1 is set as this number.
- External trigger polarity [Trig]
 

When using the external trigger input (BNC terminal) as the sequence start trigger, specify its polarity. In the case of non-use, set this item to [Off].  
Only the trigger input terminal on the channel 1 side is valid in the FG420.
- External control [ExtCtrl]
 

Enable this item to control sequence start, stop, hold/resume, and branch with the signals from the multi-I/O connector (set to [Enable]). When not using the multi-I/O connector, disable this setting (set to [Disable]). [☞ p. 64](#)
- Allocation of pin 14 of multi-I/O connector [Multi I/O pin 14]
 

Pin 14 of the multi-I/O connector can be allocated either to sequence start (set to [Start]) or state branch (set to [StateBranch]). [☞ p. 64](#)
- Sync output [SyncOut]
 

Select whether to output waveform sync signal (set to [Sync]) or LSB (set to [StepCode(LSB)]) of the step sync code to the sync/sub-output terminal. For step sync code, [☞ p. 68](#).  
If LSB of the appropriate step sync code is set to H and output, it can be used as the trigger source and the simplified check for sequences can be executed by an oscilloscope.

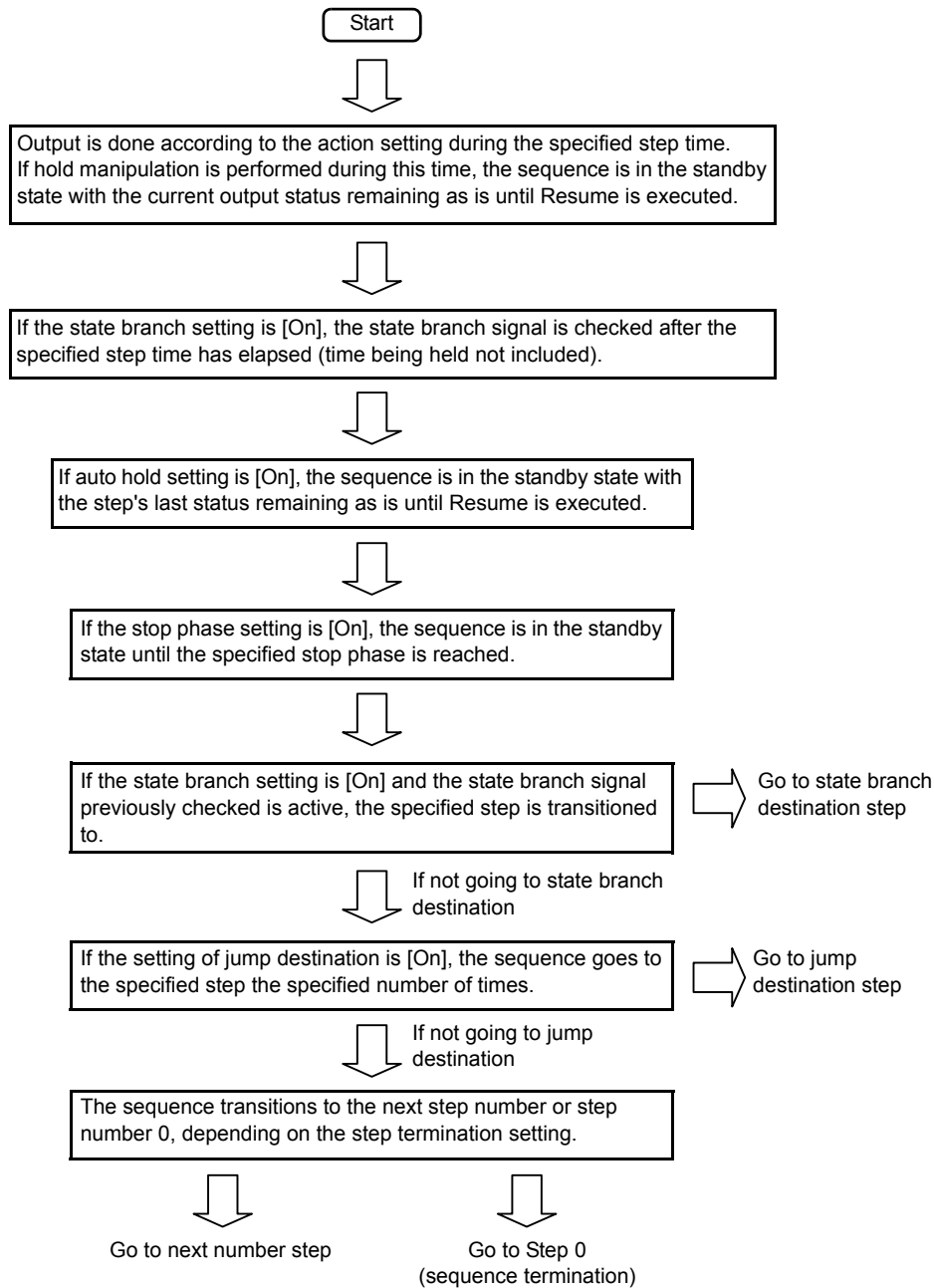
For multi-I/O connectors, [☞ “3.2.7 Multi-I/O \(MULTI I/O\)”](#) in the Basics Instruction Manual.

### l) Other limitations

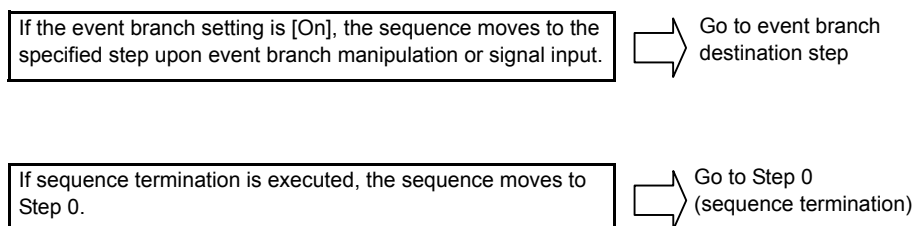
- The amplitude range is automatically determined according to the maximum output level of the overall sequence. Range switching does not occur during sequence execution.
- The external addition function is forcibly set to off.
- The value set in the oscillator screen is applied for the amplitude and DC offset load impedance conditions.

## 6.3 In-Step Processing Flow

The flow of processing within one step is shown below.

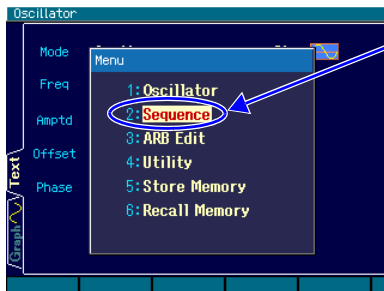


The following transitions occur as the result of event branching or termination execution, regardless of the intra-step flow.



## 6.4 Setting and Manipulation Procedures

### a) Switching to sequence oscillation mode



In the top menu, select [Sequence] and then press the ENTER key.

1. Press the **MENU** MENU key to open the top menu window. In that window, select [Sequence] and then press the **ENTER** ENTER key to switch to the sequence oscillation mode.
2. The dialog box to confirm whether to transit to the sequence oscillation mode is displayed. Select [OK] and press the **ENTER** ENTER key to transit to the sequence oscillation mode. The sequence creating & editing screen is displayed, and the output setting becomes that of Step 0.

### b) Creating & editing a sequence

To use an already saved sequence, press the [Recall] soft key and select the sequence to be used.

To create a new sequence, perform the settings one step at a time.

To reuse setting contents, either copy and paste in their entirety the step control parameters and intra-step channel parameter settings, or copy and paste the intra-step channel parameters only (using a soft key).

During editing, the contents of the selected step can be output.

On the sequence creating/editing screen, [Edit] is displayed at the upper right on the screen. The items of the soft keys on the sequence creating screen are as shown below.

#### Soft key in [Edit] status

1st stage

Cut	Copy	Paste	Insert	▼ 1/3
-----	------	-------	--------	-------

Step parameters (both step control parameter and intra-step channel parameter) corresponding to the step number currently displayed can be copied and pasted, and the step itself can be cut and inserted. Even if a step is cut or inserted, the step numbers referenced at each step (jump destination or branch destination) are not changed.

2nd stage (Text screen or Single and Dual screen of FG420)

Step -1	Step +1	CH Copy	CH Paste	▼ 2/3
---------	---------	---------	----------	-------

Step numbers are increased and decreased by using [Step +1] and [Step -1].

Intra-step channel parameters corresponding to the step number currently displayed can be copied and pasted by using [CH Copy] and [CH Paste]. In the FG420, these soft keys function are on active channel.

2nd stage (Graph screen)

Step	AutoScale	TRC Setup		▼ 2/3
------	-----------	-----------	--	-------

The input field corresponding to the step number can be opened by [Step].

Use [AutoScale] to adjust the vertical axis scale of the graph display so that it will not saturate.

The setting screen for the display item and the display scale is opened by [TRC Setup].

3rd stage

Compile	Reset	Recall	Store	▼ 3/3
---------	-------	--------	-------	-------

A sequence can be saved and retrieved by using [Store] and [Recall], respectively.

All sequence settings are initialized by using [Reset].

A sequence becomes executable by using [Compile].

### c) Performing sequence execution preparations

Just calling up a sequence or creating/editing it does not by itself make a sequence executable.

When the [Compile] (compilation) soft key in the [Edit] status is pressed, whether the setting contents are appropriate is checked, the waveform data allocation and optimum output range setting are performed, and the sequence becomes executable (Ready state).

As a result of compilation, an error message is displayed if any settings not preferable for execution are detected. When the compilation has successfully completed and the sequence becomes executable, [Rdy] is displayed at the upper right on the screen. The items of the soft keys in this status are as follows.

#### Soft keys in [Rdy] status

Start			Edit	
-------	--	--	------	--

Sequence execution is started by [Start].

Returns to the creating and editing sequence screen by [Edit].

The created/edited sequence is cleared if the power is cut off, so be sure to save it as needed. To do so, press the [Store] soft key in the [Edit] status to open the Save Settings window. Saving can be done either before or after compilation. (Only in the [Edit] status)

### d) Executing the sequence

Press the [Start] soft key on the [Rdy] screen to start the sequence execution.

When the sequence is started, [Run] is displayed at the upper right on the screen. The items of the soft keys in this status are as follows.

#### Soft keys in [Run] status

	Stop	Hold	EventBra	ImmedStop
--	------	------	----------	-----------

### e) Pausing sequence execution

Press the [Hold] soft key in [Run] status to pause the sequence, going into standby with the output status maintained as is. To resume, press the [Resume] soft key in the [Hold] status.

[Hold] is displayed at the upper right on the screen during the sequence hold status. The items of the soft keys in this status are as follows.

#### Soft keys in [Hold] status

Resume	Stop		EventBra	ImmedStop
--------	------	--	----------	-----------

### f) Executing an event branch

Press the [EventBra] soft key in the [Run] or [Hold] status to execute an event branch. If event branch is set to [On] during the step under execution, the sequence moves to the specified step.

### g) Terminating the sequence

Press the [Stop] soft key in the [Run] or [Hold] status to terminate the sequence, causing it to move to Step 0.

[Rdy] is displayed at the upper right on the screen and the sequence can be restarted at any time.

### h) Forcibly terminating the sequence without waiting for the stop phase or sweep



Press the [ImmedStop] soft key in the [Run] or [Hold] status to immediately terminate the sequence without stop phase wait or sweep execution, switching to the Step 0 settings.

### i) Editing the sequence again

Press the [Stop] soft key in the [Run] or [Hold] status to terminate the sequence. When it has terminated, press the [Edit] soft key in [Rdy] status to allow sequence creation and editing.

To execute the sequence, press the [Compile] soft key in [Edit] status again.

### j) Returning to normal oscillation mode

Select other than [Sequence] (such as [Oscillator]) at the top menu and press the  ENTER key. The dialog box to confirm whether to exit from the sequence oscillation mode is displayed. Select [OK] and press the  ENTER key

In the sequence oscillation mode, displaying the other items of the top menu means switching to the normal oscillation mode.

### k) Controlling the start, stop, and pause of the sequence by using an external logic signal

Set the external control [ExtCtrl] in common settings to [Enable] (be enabled) to manipulate the sequence by the TTL level logic input to the multi-I/O connector on the rear panel.

☞ p. 60

It is recommended to disable ([Disable]) [ExtCtrl] when the control by the external signal is not used, to prevent a malfunction due to an external noise.

For the multi-I/O connectors and their terminal allocation, ☞ “3.2.7 Multi-I/O (MULTI I/O)” in the Basics Instruction Manual.

When the external trigger input (BNC terminal) is used, only the sequence start manipulation can be performed. ☞ p. 60

The following manipulations are available.

#### ■ Starting sequences

Falling input in [Rdy] status starts the sequence. This is invalid in [Run] or [Hold] status.

#### ■ Stopping sequences

Falling input in [Run] or [Hold] status ends the sequence and switches to Step 0.

#### ■ Holding/resuming sequence

Falling input in the [Run] status pauses the sequence. Rising input in the [Hold] status resumes the sequence from where it has been paused.

#### ■ Event branch of the sequence

In [Run] or [Hold] status, falling input during the step where event branch is set to [On] generates an event branch. The sequence changes to the specified branch destination step.



**■ State branch of the sequence**

In [Run] or [Hold] status, a low level input during the step where state branch is set to [On] generates a state branch. The sequence changes to the specified state branch destination step. For the timing to check the low level, see p. 61.

Controlling both the sequence start and the state branch via the multi-I/O connector is not possible (see p. 60). When using the multi-I/O connector for the state branch, use the external trigger input (BNC terminal) for the sequence start operation.

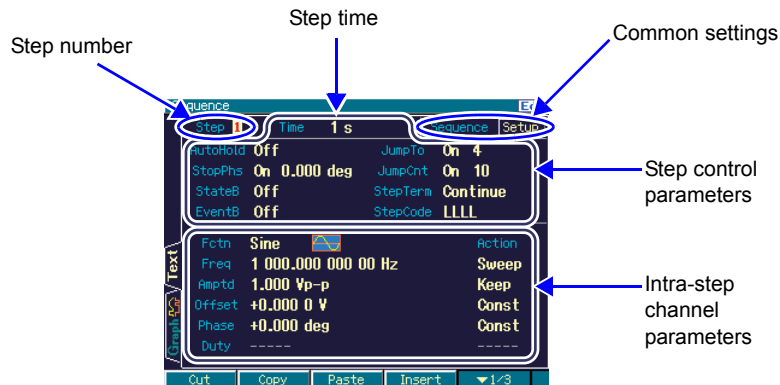
**✓ Check**

- Start, stop, and event branch operations via the multi-I/O connector cause a delay of approximately 0.2 ms to 2 ms and fluctuations.
- Start manipulations by the external trigger input cause a delay of approximately  $4.5 \mu\text{s} \pm$  a few 10 ns and fluctuations upon the waveform output and a delay of approximately  $6 \mu\text{s}$  to  $7 \mu\text{s}$  and the fluctuations upon the DC output. This start manipulation operates quicker than that of the multi-I/O connectors.

## 6.5 Screen Outline

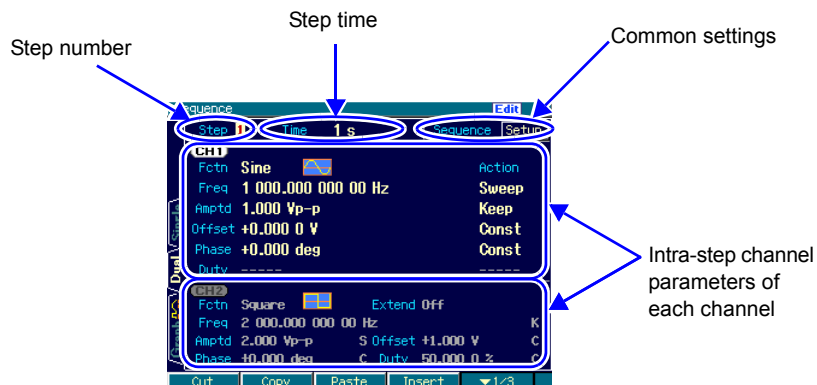
### ■ Text display [Text] (FG410) or [Single] (FG420)

The step control parameters of one step and the intra-step channel parameters of 1 channel are displayed simultaneously.



### ■ Simultaneous 2-channel display [Dual] (FG420 only)

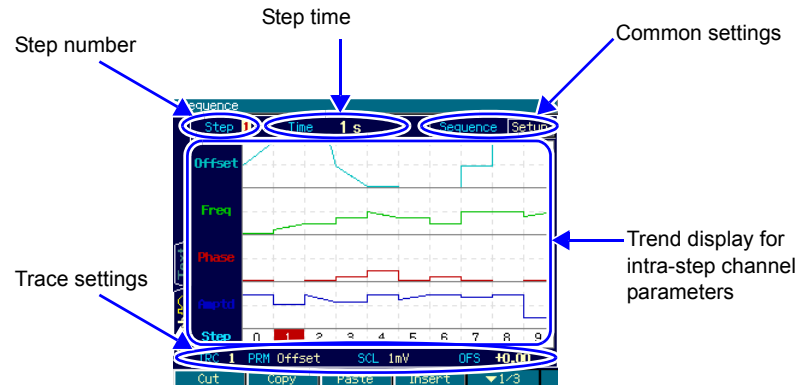
The intra-step channel parameters of one step are displayed simultaneously for two channels. The only step control parameter that is displayed is the step time.



### ■ Graph display [Graph]

Graph display shows the trends along step progress for four intra-step channel parameters. However, the trend shown is that progressing onward in numerical sequence from Step 0. Statuses of sequences executed not in the order due to jump and branch cannot be displayed.

Which parameters to display for each trace can be changed through trace settings.



[PRM] and [SCL] displayed in the trace settings indicate the display item and the height of the trace frame, respectively. [OFS] indicates the bottom values in the trace frame for frequency, amplitude, and duty, and the center value in the trace frame for the offset and phase.

In the [TRC Setup] soft key at the second stage, the settings for four traces and the graph colors can be changed collectively.

The [AutoScale] soft key at the second stage adjusts the vertical-axis scales in the graph display, including unused steps, to avoid saturation.

### 6.6 Description of Step Control Parameters

#### Step time [Time]

Set the step duration.

#### Auto hold [AutoHold]

Normally set to [Off].

To not go to the next step after the lapse of the specified step time, and enter the standby state instead, set [On]. This is useful to move the sequence along while checking the status of the equipment under test one step at a time.

Upon Resume execution or reception of the Resume signal, the processing resumes.

#### Stop phase [StopPhs]

When set to [On], the phase at the end of that step can be specified.

After the lapse of the specified step time, that step ends after the specified phase has been reached.

#### Jump destination [JumpTo]

When set to [On], the step to which the sequence is to go to upon completion of the current step can be specified.

By specifying [JumpCnt] (jump count), it is possible to configure a loop consisting of a repetition of the same steps.

#### Jump count [JumpCnt]

When set to [On], it is possible to specify the number of jumps to the step specified with [JumpTo] (jump destination). When set to [Inf], an infinite loop results.

Note that the number of times that the same step is repeated is [jump count + 1].

#### State branch [StateB]

When set to [On], the state branch signal of the multi-I/O connector (pin 14) is checked, and if the signal is active, the specified step is jumped to. However, the state branch signal can be checked only after the specified step time has elapsed (except for the time being held).

☞ pp. 58, 61

#### Event branch [EventB]

When set to [On], the soft keys or the event branch signal of the multi-I/O connector (pin 11) is checked, and if the signal is active, the specified step is jumped to. ☞ pp. 58, 61

#### Step termination [StepTerm]

Specifies whether to jump to the next number step ([Continue]), or go to Step 0 and end the sequence ([End]), upon termination of the step.

#### Step sync code output [StepCode]

Sets the 4-bit logic signal that is output to the multi-I/O connector while on that step. The right-most bit is D0 (LSB).

For the multi-I/O connector, ☞ “3.2.7 Multi-I/O (MULTI I/O)” in the Basics Instruction Manual.

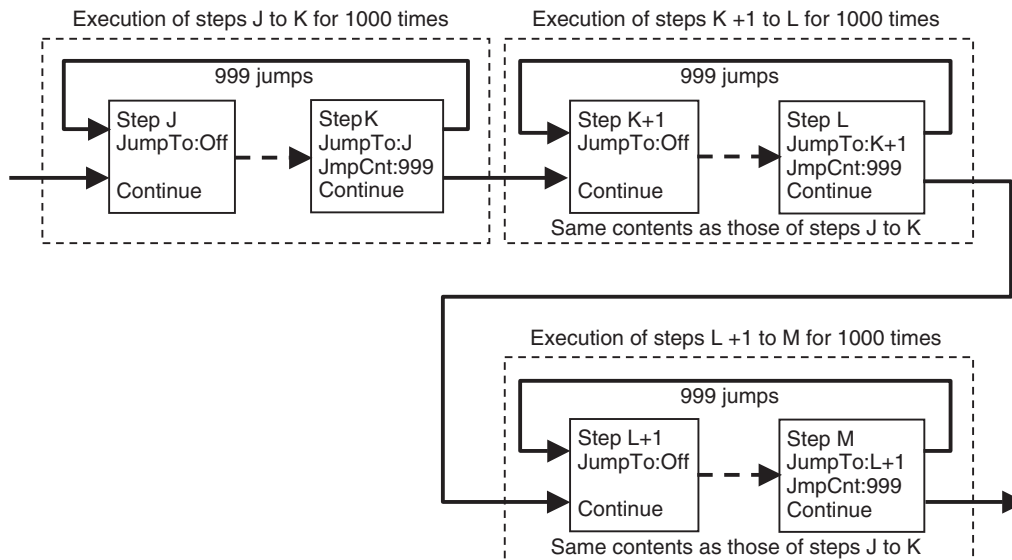
D0 (LSB) can be output to the sync/sub-output terminal. ☞ p. 60

## 6.7 Tips for Sequence Creation

### a) Repeating the same pattern for more than 1000 times

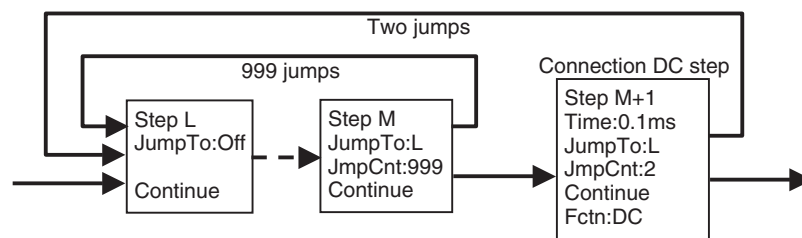
The maximum value for setting the jump count is 999; therefore, up to 1000 times of step patterns can be repeated. To repeat more than 1000 times, the following methods can be performed. Here, the cases of the repetition for 3000 times are described.

#### ■ Aligning the same patterns



Steps with the same contents can be created easily by using the [Copy] and [Paste] soft keys. Create the steps with the same contents then revise only the required portions.

#### ■ Creating a multiplex loop by inserting steps to connect the step patterns



If any pause periods of DC can be inserted without a problem, insert a 0.1 ms step, which lasts the minimum time, to configure a multiplex loop. This allows repetition of the internal loop for integral multiple times. Adding such steps which connect the step patterns can configure the loop multiplied for any number of times. Note, however, the following.

- At the step immediately after DC, the phase is initialized. ☞ p. 57
- The total step time is extended for the repeated number of the steps which connect the step patterns.

**b) Applying unipolar waveform (when changing both amplitude and offset simultaneously)**

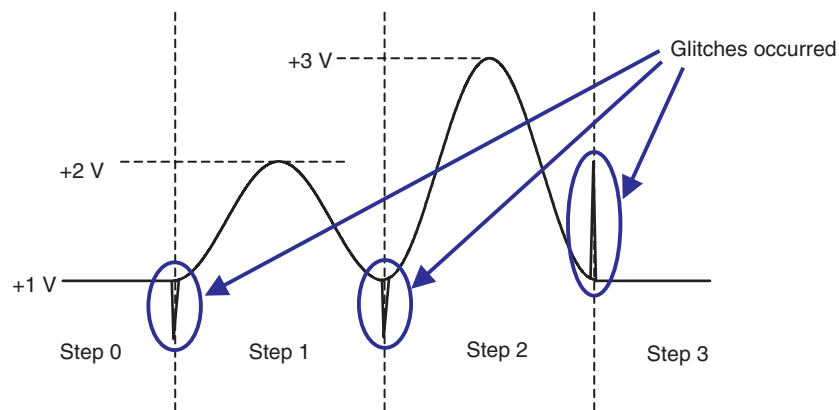
When the amplitude range of a waveform is set to  $\pm FS$ , if both the amplitude and DC offset are changed between steps, unintended glitches may occur at the transitions of steps. This is because amplitude and DC offset cannot be changed completely at the same time. Normally, the amplitude is changed first and this causes the glitch.

In this case, using a unipolar waveform (set the amplitude range to  $0/+FS$  or  $-FS/0$ ) may solve the problem.

The following describes a sequence with a waveform in which the lower voltage is fixed as shown in the figure below. Assume that the output waveform is a sine wave starting from  $-90^\circ$ , with the amplitude changing at every cycle. If the step prior to the sine wave is set to DC, the step of the sine wave starts at the specified phase. In addition, to complete a step in one cycle, set the step time shorter than one cycle and set the stop phase to  $0^\circ$ .

The following shows the waveform and intra-step channel parameters when the amplitude range of the sine wave is set to Norm  $\pm FS$ . Amplitude, offset, and phase are all specified to the constant value (Const). The description of step control parameters is omitted.

When the amplitude range of the sine wave is  $\pm FS$

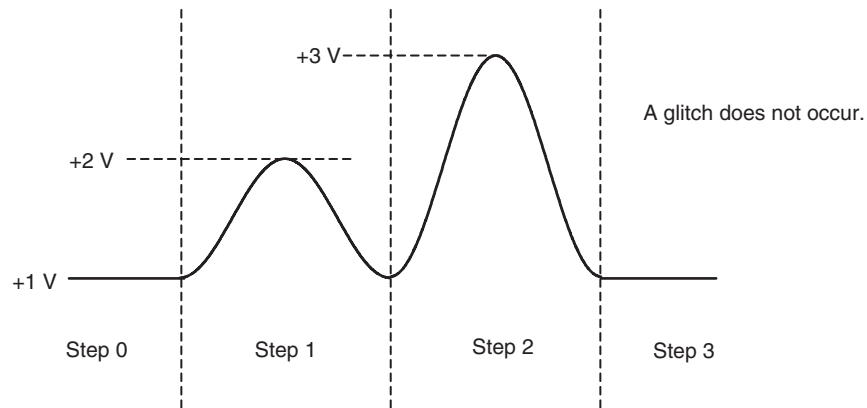


Fctn	DC	Sine ( $\pm FS$ )	Sine ( $\pm FS$ )	DC
Amptd	---	1 Vp-p	2 Vp-p	---
Offset	+1 V	+1.5 V	+2 V	+1 V
Phase	---	$-90\text{deg}$	$-90\text{deg}$	---

In this case, both the amplitude and DC offset change at the transitions of steps, resulting in a glitch occurrence.

The following describes the waveform and intra-step channel parameters when the amplitude range of the sine wave is set Norm 0/+FS. Amplitude, offset, and phase are all specified to the constant value (Const). The description of step control parameters is omitted.

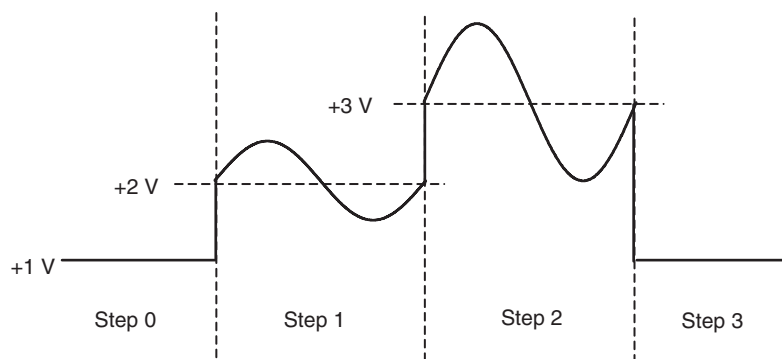
When the amplitude range of the sine wave is 0/+FS



Fctn	DC	Sine (0/+FS)	Sine (0/+FS)	DC
Amptd	---	1 Vpk	2 Vpk	---
Offset	+1 V	+1 V	+1 V	+1 V
Phase	---	-90deg	-90deg	---

In this case, glitches don't occur, because only the amplitude changes at the transitions of the steps.

In the case shown in the figure below, even if the amplitude range of waveform is  $\pm$ FS, changing both the amplitude and DC offset between steps does not cause any problems. This is because the amplitude and DC offset change at the timing of the waveform level 0.



Fctn	DC	Sine ( $\pm$ FS)	Sine ( $\pm$ FS)	DC
Amptd	---	1 Vp-p	2 Vp-p	---
Offset	+1 V	+2 V	+3 V	+1 V
Phase	---	0deg	0deg	---

# 7. USING USER-DEFINED UNITS

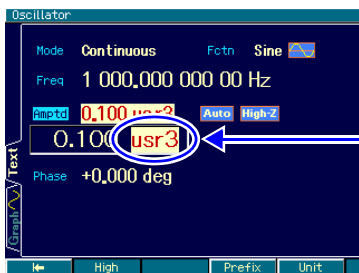
## 7.1 Definition of User-Defined Unit

It is possible, for example, to set the frequency in rpm (number of rotations over 1 minute) instead of setting the frequency in Hz. It is also possible to set the voltage by converting it to a mechanical deviation amount or output voltage after power amplifier output, etc., and set that instead of the voltage.

By defining such conversion formulas, the defined units can be used just like regular units. These units are called user-defined units in this equipment.

User-defined units can be used for the following six parameters: Frequency, period, amplitude, DC offset, phase, and duty.

## 7.2 Displaying and Setting User-Defined Units



Select the user-defined unit

When the input field of the desired parameter is open, place the cursor over the right-most unit and change the unit with the up/down arrow keys or the modify knob. The unit name that is displayed can be freely set.

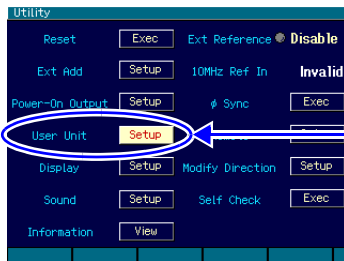
Even if the unit is changed, only the display unit changes, and the actual output values remain unchanged.



## 7.3 Defining User-Defined Units

### ■ Setting screen

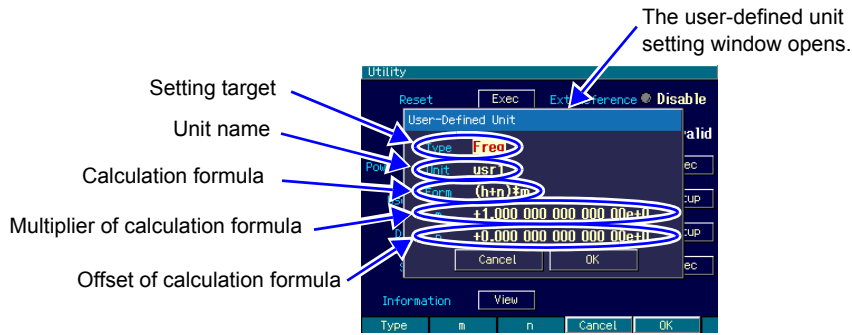
The settings are done on the Utility screen.



On the Utility screen, select [User Unit] and then press the ENTER key

1. Select the [User Unit] field on the Utility screen and then press the **ENTER** ENTER key.

2. The user-defined unit setting window opens. Select the desired setting item and then press the **ENTER** ENTER key to perform that setting. The input field can also be opened by pressing the corresponding soft key.



The following items can be set in this window.

#### Setting target [Type]

Frequency, period, amplitude, DC offset, phase, and duty can be chosen from.

#### Unit name [Unit]

The unit name can consist of up to 4 characters. Input one character at a time by moving the cursor over the desired position with the **↑** **↓** up/down arrow keys or the **↻** modify knob, or perform input with the numeric keypad.

#### Calculation formula [Form]

Select either  $[(h+n)*m]$  or  $[(\log(h)+n)*m]$  as the unit conversion calculation formula. “h” is the original value of the setting target. The values converted with these formulas are the setting values that appear on the screen when actually using user-defined units.

The unit for h is fixed as described in the following table according to the setting target.

Setting Target	Unit for h
Frequency	Hz
Period	s
Amplitude	V <sub>p-p</sub> if the amplitude range is $\pm$ FS V <sub>pk</sub> if the amplitude range is 0/+FS, -FS/0 (in either case, value for the specified load impedance condition)
DC offset	V Value for the specified load impedance condition
Phase	deg
Duty	%

log is the common logarithm with base 10. Caution is required when using the log calculation formula for values that can be negative, such as DC offset and phase. In the case of a value that is zero before conversion to a user-defined unit, upon conversion to a user-defined unit using log, “-Inf” is displayed. Likewise, in the case of a value that is negative before conversion to a user-defined unit, upon conversion to a user-defined unit using log, “Over” is displayed.

Calculation formula multiplier and offset [m], [n]

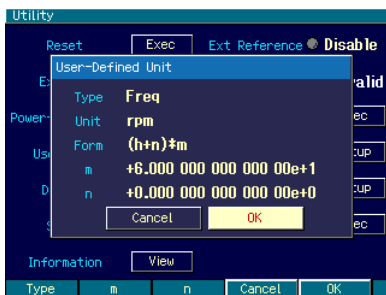
Set multiplier [m] and offset [n] in the selected calculation formula.

Once every parameter has been set, select [OK] in the lower part of the window and then press the **ENTER** key.

**Check**  
 When using a user-defined unit, the setting resolution may be lower depending on the multiplier and offset setting.

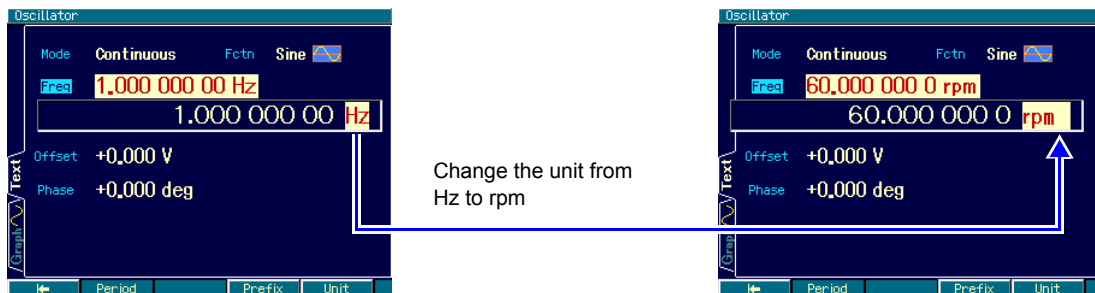
■ **Setting the frequency in rpm**

As an example, to enable display and setting of the frequency of 1 Hz as 60 rpm, do the following settings and then select [OK].



Type: Freq  
 Unit: rpm  
 Form: (h+n)\*m  
 m: 60  
 n: 0

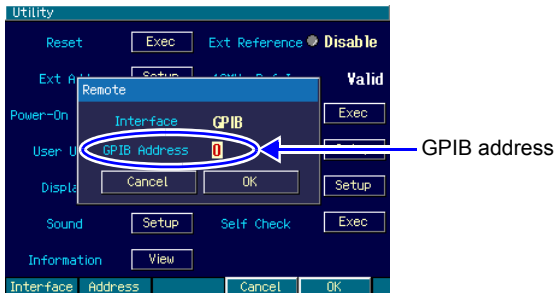
Next, on the Oscillator screen, open the frequency input field and change the unit from Hz to rpm.



As a result, it is now possible to display and set rpm values.

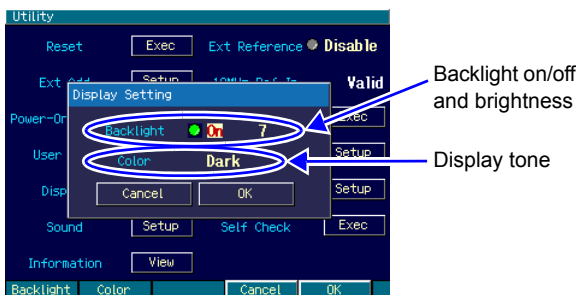
# 8. OTHER UTILITY SETTINGS

## 8.1 Selecting Remote Interface [Remote]



The remote control interface can be selected from USB or GPIB. When USB is selected, USB ID is displayed. When GPIB is selected, the GPIB address is set in the range of 0 to 30.

## 8.2 Display Settings [Display]

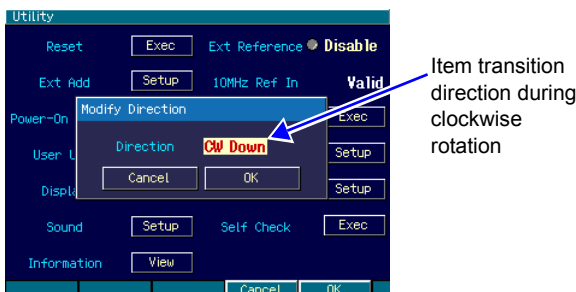


Set backlight on/off and the brightness when the backlight is on.

This setting switches the display tone between bright lettering against a dark background and dark lettering against a bright background.

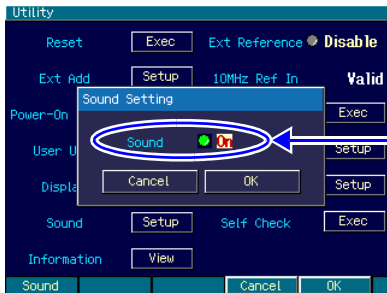
If the display contents are invisible for the backlight out, press on the [MENU] key for a while to light up the backlight forcibly.

## 8.3 Modify Knob and Modify Direction Setting [Modify Direction]



Select whether the selected items move downward or upward as the modify knob is rotated clockwise (CW) with the choice list of the oscillation mode or the waveform displayed.

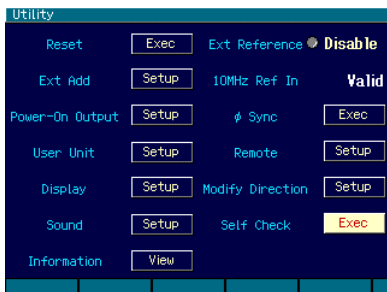
### 8.4 Operation Sound Setting [Sound]



Set whether or not to output a beep upon key input, modify knob operation or occurrence of an error.

Operation sound

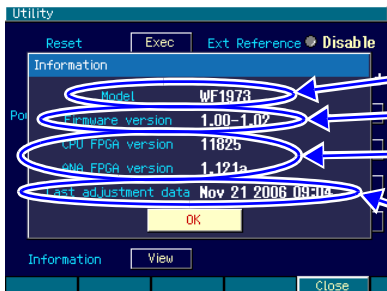
### 8.5 Self Check [Self Check]



Check the internal status. Remove from the equipment all cables except the power cable before checking.

If there is a problem, consult Yokogawa Test & Measurement Corporation or the distributor.

### 8.6 Product Information Display [Information]



This is only a display of this equipment's information, and not a setting.

- Model
- Firmware version
- Internal parts versions
- Last calibration date

# 9. TROUBLESHOOTING

## 9.1 Error Messages When Power Is Applied

The equipment performs a self-check when the power is applied, and if an anomaly is detected, an error message is displayed. In case of failure, contact Yokogawa Test & Measurement Corporation or your distributor. If a message indicating the shutdown was executed due to overheating, check that the installation location is appropriate (check that the ambient temperature is so high as to cause overheating, etc.).

Hardware initialization failed

Internal error. Failure of the device.

OSC-Block error

Internal error. Failure of the device.

RAM error

Internal memory error. Failure of the device.

ROM error

Internal memory error. Failure of the device.

Last shutdown caused by overheat

The previous power-off was caused by internal overheating.

Check the use environment and the state of the device.

Output not turned on due to overload

The startup output setting was on, but output was not turned on because overload of sync/sub-output was detected.

The output terminal may be connected to an external voltage source. Check the connection. Resolve the overload state, and turn on the output again.

Output overload detected; Output turned off

Output was turned on once according to the startup output setting, but output was turned off because overload of waveform output or sync/sub-output was detected.

The output terminal may be connected to an external voltage source. Check for correct connection. Resolve the overload state, and turn on the output again.

### 9.2 Error Messages During Execution

Error messages during execution are displayed mainly when the setting exceeds the output range. For example, when the frequency is attempted to set to 30 MHz while a square wave is being output, an error is displayed and the frequency is set to the maximum frequency for the square wave.

Error messages are also displayed upon detection of internal overheating and output overload. This section describes them in the order of error numbers displayed in the dialog window.

12005: Internal overheat detected

Internal overheating.

The ambient temperature may be too high, or the device may fail. It is recommended to turn off the power to this device.

14006: Internal temperature too high; Auto-shutdown will occur

Internal overheating reached the limit, and this device will be automatically turned off.

The ambient temperature may be too high, or the device may fail.

22017: Function changed to Sine by changing Channel Mode

The waveform of the channel changed to a sine wave because the 2-channel ganged mode was selected when the waveform is Noise or DC.

22018: Mode changed to Continuous by changing Channel Mode

The mode changed to the continuous oscillation mode because the 2-channel ganged mode was selected in the burst mode.

The burst mode cannot be used in the 2-channel ganged mode.

22019: Modulation Source changed to Internal due to Channel Mode

The modulation source changed to Internal due to the 2-channel ganged mode.

When the 2-channel ganged mode is selected, the modulation source is once set to internal regardless of the modulation type.

When the channel mode is 2-phase, constant frequency difference, or constant frequency ratio, the modulation source of FM and FSK is restricted to internal. Since there is no restriction for other types of modulation sources, make the setting again. When the channel mode is differential, the modulation source is set to internal, regardless of the modulation type.

22020: External addition turned off by changing Channel Mode

External addition was turned off because differential is selected for the channel mode when external addition was used.

External addition cannot be used in the differential mode.

22021: SwpMode changed to Single by changing Channel Mode

The sweep mode changed to single-shot sweep because 2-phase, constant frequency difference, constant frequency ratio, or differential is set for the channel mode when the sweep oscillation mode is gated single-shot.

Gated single-shot sweep cannot be used in the 2-channel ganged mode.

22022: Mode changed to Continuous by changing Function

The mode changed to the continuous oscillation mode because a waveform that does not match the current oscillation conditions was selected in the modulation, sweep, or burst mode.

For example, when the waveform is changed to pulse during FM with a sine wave, the mode changes to continuous oscillation because FM cannot be done with a pulse. To perform PWM with a pulse, change the mode to the modulation mode, and then change the modulation type to PWM.

**22024: Start-locked occurred due to setting conflict**

The specified oscillation cannot be started due to an inappropriate operation setting in the modulation, sweep, or burst mode.

The message regarding the inappropriate setting is displayed when the left [?] soft key is pressed.

**22025: SyncOut selection changed to Sync by selection of external modulation**

The reference phase synchronization [Sync] was assigned to sync/sub-output because of switching from internal modulation to external modulation.

Modulation synchronization [ModSync] and the modulation waveform [ModFctn] can be selected as sync/sub-output only for internal modulation.

**22028: Edge time changed due to Width**

The edge time was reduced because the current edge time (LE, TE) did not allow achievement of the specified pulse width time.

Pulse width time has a higher priority than edge time.

**22029: Edge time changed due to Duty**

The edge time was reduced because the current edge time (LE, TE) did not allow achievement of the specified pulse width duty.

Pulse width duty has a higher priority than edge time.

**22030: Edge time and/or Width changed due to Frequency**

The edge time and/or pulse width time were changed because the current edge time (LE, TE) and pulse width time did not allow achievement of the specified frequency.

Frequency has a higher priority than edge time and pulse width time.

**22031: Edge time and/or Duty changed due to Frequency**

The edge time and/or pulse width duty were changed because the current edge time (LE, TE) and pulse width duty did not allow achievement of the specified frequency.

Frequency has a higher priority than edge time and pulse width duty.

**22032: Selected ARB is missing; Edit Memory ARB assigned**

The specified arbitrary wave does not exist, so the arbitrary wave in the edit memory was assigned instead.

This phenomenon occurs when the arbitrary wave previously used was deleted while not in use. Arbitrary waves are identified by number only.

**22033: Too narrow or too wide Duty specified; Amplitude may decrease or pulse may be lost**

The duty setting is too narrow or too wide, so the amplitude may decrease or the pulse may be lost.

This phenomenon occurs when the pulse width in the high or low side becomes narrower than about 8.4 ns in a square wave with an extended duty variable range.

**22034: Frequency reduced due to Function**

The frequency was changed to a lower value according to the waveform.

The frequency upper limit varies according to the waveform.

### 22035: Duty changed due to Extend-Off

The duty was changed to a value restricted by the frequency because the duty variable range of the square wave changed to normal.

When the duty variable range is normal, the variable range of the duty changes according to the frequency.

### 22036: Duty changed due to Frequency

The duty was changed to a value restricted by the frequency because the duty variable range of the square wave was normal.

When the duty variable range is normal, the variable range of the duty changes according to the frequency.

### 22037: High level changed due to Low level

The High level was changed due to the change of Low level in relation to the output range.

### 22038: Low level changed due to High level

The Low level was changed due to the change of the High level in relation to the output range.

### 22039: Not acceptable due to another CH limitation

The specified setting could not be done due to the restriction of another channel in a 2-channel same value setting.

### 22040: Frequency and/or DeltaFreq changed due to Function

The frequency and/or frequency difference were changed according to the upper limit frequency for the waveform when the channel mode was a constant frequency difference.

### 22041: Frequency of CH1 changed due to DeltaFreq

The frequency of CH1 was changed to maintain the frequency difference when the channel mode was a constant frequency difference.

The frequency difference has a higher priority than the frequency of CH1.

### 22042: Frequency changed due to Function

The frequency was changed according to the upper limit frequency for the waveform when the channel mode was a constant frequency ratio.

### 22043: Frequency of CH1 changed due to Ratio

The frequency of CH1 was changed to maintain the frequency ratio when the channel mode was a constant frequency ratio.

The frequency ratio has a higher priority than the frequency of CH1.

### 22044: Output not turned on due to overload

Output was not turned on because overload of sync/sub-output was detected.

The output terminal may be connected to an external voltage source. Check the connection. Resolve the overload state, and turn on the output again.

### 22149: Modulation Source of CH2 changed to Internal by changing CH1 or CH2 setting

The modulation source of CH2 was changed to internal, according to a change of CH1 or CH2 setting although the modulation source of CH2 had been set to CH1 external in FSK or PSK.

The modulation source of CH2 can be set to CH1 external only when CH1 and CH2 are in the same modulation type and external is selected for the modulation source of CH1.



**22150: Trigger of CH2 changed to Internal by changing CH1 or CH2 setting**

Trigger source of CH2 was changed to internal according to a change of CH1 or CH2 setting although the trigger source of CH2 had been set to CH1 external in sweep or burst.

The trigger source of CH2 can be set to CH1 external only when external is selected for the trigger source of CH1 under the following conditions.

- CH1 and CH2 are in the same sweep type. CH1 and CH2 are in the same sweep mode (except for continuous sweep).
- CH1 and CH2 are in the same burst mode (except for auto burst).

**23045: Data out of range; Data discarded**

The input value was discarded because setting of a value outside the setting range was attempted.

**23129: MOD/ADD IN connector used by external addition now**

The external modulation/addition input connector is currently used for external addition. It cannot be used for external modulation simultaneously.

**23130: MOD/ADD IN connector used by external modulation now**

The external modulation/addition input connector is currently used for external modulation. It cannot be used for external addition simultaneously.

**23133: Output overload detected; Output turned off**

Output was turned off because overload of waveform output or sync/sub-output was detected.

The output terminal may be connected to an external voltage source. Check for correct connection. Resolve the overload state, and turn on the output again.

**23134: Self Check failed; Auto-shutdown will occur**

Self check failed. The power is turned off.

The device may fail.

**32004: Not able to delete this ARB; This ARB is in current use**

The arbitrary wave currently being output or used cannot be deleted.

In the modulated oscillation mode, the arbitrary wave used as the internal modulation waveform also cannot be deleted.

**35005: File-system error**

Internal error. The device has failed.

**60001: Sequence under editing not stored; Shutdown?**

The sequence being edited has not been saved yet.

Save it, if necessary. It will be erased when the power is turned off.

**60002: ARB waveform under editing not stored; Shutdown?**

The arbitrary wave being edited has not been saved yet.

Save it, if necessary. It will be erased when the power is turned off.

**61056: Data beyond lower limit; Value clipped to lower limit**

Setting a value below the lower limit value was attempted, so the lower limit value was set.

**61057: Data beyond upper limit; Value clipped to upper limit**

Setting a value above the upper limit value was attempted, so the upper limit value was set.

61058: Zero data not allowed

A zero value cannot be set for the parameter.

61059: Invalid operation

Invalid operation. Insertion of a control point was attempted for where it was not allowed during editing of an arbitrary wave.

61060: Invalid operation

Invalid operation. Deletion of a control point that cannot be deleted was attempted during editing of an arbitrary wave.

## 9.3 Conflict Messages for Modulation

These messages are displayed when the [?] soft key is pressed when the specified modulation cannot be executed, due to inappropriate setting (conflict state). The messages describe the inappropriate setting.

HopFreq beyond upper limit for current Function

The hop frequency exceeds the output range for the current waveform in FSK.

Lower the hop frequency.

MOD/ADD IN connector used by external addition now

The external modulation/addition input connector is currently used for external addition, so it cannot be used for external modulation.

Turn off external addition.

Modulated peak or bottom value out of range

[Carrier Value + Deviation] or [Carrier Value – Deviation] exceeds the output range in FM, PM, OFSM, or PWM.

Change the carrier value, or lower the deviation.

Modulated peak or bottom phase out of range

[Carrier Value + Deviation] exceeds the output range in PSK.

Lower the carrier value or deviation.

Modulation Type not compatible with current Function

The modulation type does not match the current waveform. For example, PWM is specified for a sine wave.

Change the modulation type.

### 9.4 Conflict Messages for Sweep

These messages are displayed when the [?] soft key is pressed when the specified sweep cannot be executed due to inappropriate setting (conflict state). The messages describe the inappropriate setting.

Frequency beyond upper limit for Gated sweep

The frequency exceeds the upper limit frequency for gated sweep.

Lower the frequency.

Gated sweep not available for DC

Gated sweep is not available for DC waveforms.

Change the sweep mode to continuous or single-shot.

Start value out of range

The start value exceeds the output range.

Change it to a value within the output range.

Stop value out of range

The stop value exceeds the output range.

Change it to a value within the output range.

Sweep Type not compatible with current Function

The sweep type does not match the current waveform. For example, duty sweep is specified for a sine wave.

Change the sweep type.

## 9.5 Conflict Messages for Burst

These messages are displayed when the [?] soft key is pressed when the specified burst cannot be executed due to an inappropriate setting (conflict state). The messages describe the inappropriate setting.

### BrstMode not compatible with current Function

The mode of burst oscillation does not match the current waveform. For example, when trigger burst is specified for noise.

Change the mode of burst oscillation.

### Frequency beyond upper limit for current Function

The frequency exceeds the upper limit frequency for the current waveform.

Lower the frequency.

## 9.6 Compile Error Messages for Sequence

These messages are displayed when an unexecutable setting is found as a result of sequence compilation.

Amptd-Offset conflict

CH:N Step:M

Amptd (Step K) - Offset (Step L)

The amplitude and offset do not satisfy mutual restriction in step M of channel N. The amplitude is set at step K, and the offset is set at step L.

Lower the amplitude or offset.

Fctn-Freq conflict

CH:N Step:L-M

The frequency exceeds the upper limit for the waveform between step L and step M of channel N.

Lower the frequency.

Fctn-Freq-Duty conflict

CH:N Step:M

Freq (Step K) - Duty (Step L)

The frequency and duty of the square wave do not satisfy mutual restriction in step M of channel N. The frequency is set at step K, and the duty is set at step L.

Lower the frequency, or bring the duty close to 50%.

Selected ARB is missing

CH:N Step:M

The arbitrary wave specified at step M of channel N does not exist.

Specify another arbitrary wave.

Selected ARB loading failed

CH:N Step:M

The arbitrary wave could not be read in step M of channel N.

Internal error. The device failed.

Too complex to check

The sequence was too complex to be checked.

Simplify the sequence structure.

Too many or too large Functions used

The number of waveforms used exceeds 128, or the total exceeds 512 Kwords.

Reduce the number of waveforms, or the number of data points of the arbitrary wave in the array format. [P.59](#)

## 9.7 Suspected Failure

When an anomaly is suspected, perform one of the actions listed below. If this fails to correct the problem, contact Yokogawa Test & Measurement Corporation or the distributor.

Contents	Possible Cause	Action	Reference
Power cannot be applied	The power supply used exceeds the rated range.	Use a power supply within the rated range.	"2.3 Grounding and Power Supply Connection" in the Basics Instruction Manual.
	A malfunction occurred due to external noise, etc.	Set the equipment in a satisfactory location.	"2.2 Installation" in the Basics Instruction Manual.
Panel operation is not possible	The remote status is set.	Set the local status.	—
	The keys or the modify knob are damaged.	Notify Yokogawa Test & Measurement Corporation for repair.	—
The output level is abnormal.	The ambient temperature or ambient humidity is outside the guaranteed operation range.	Use the equipment in an environment within the specifications.	"2.2 Installation" in the Basics Instruction Manual.
	Sufficient warming up has not been performed.	Perform warming up for at least 30 minutes after power application.	—
	DC offset is added.	Set DC offset to 0 V.	"4.4.8 Setting DC offset" in the Basics Instruction Manual.
	User-defined unit is used.	Select a standard unit.	"4.4.7 Setting the amplitude" in the Basics Instruction Manual.
	The load impedance function is used.	Set Hi-Z.	"4.4.12 Setting the load impedance" in the Basics Instruction Manual.
Setting through remote control is not possible.	A different interface setting has been selected.	Perform the settings in accordance with the interface to be used.	p. 75
	The GPIB address or USB ID differs from the program.	Make the GPIB address or USB ID match the program.	p. 75
	The same GPIB address or USB ID as that of another unit is used.	Set a GPIB address and USB ID not the same as those of other units.	p. 75
The operation differs from that described in the instruction manual.	Setting initialization has not been executed.	The descriptions in the instruction manuals assume that the settings have been initialized. Therefore, execute setting initialization.	"4.3.8 Restoring the initial settings" in the Basics Instruction Manual.
	The channel to be manipulated is the other channel.	Check whether the channel is CH1 or CH2.	"4.3.6 CH1/CH2 switching key and active channel (FG420 only)" in the Basics Instruction Manual.
Display contents are invisible for the backlight out.	The setting of the back light is lighting out.	Press the [MENU] key for a while to light up the backlight forcibly.	"4.2.3 Top menu / a) Displaying the top menu" in the Basics Instruction Manual.

# 10. MAINTENANCE

## 10.1 Outline

### ■ Operation Contents

The following maintenance actions are required to ensure optimum use of this equipment.

- **Operation check:** Checks whether the equipment works properly.
- **Performance check:** Checks whether the equipment meets its ratings.
- **Adjustments & Calibration:** When the equipment does not meet its ratings, have it adjusted or calibrated by Yokogawa Test & Measurement Corporation to restore its performance.
- **Fault repair:** If this fails to remedy the problem, have Yokogawa Test & Measurement Corporation investigate the cause of the problem and repair it.

This instruction manual describes easy-to-perform operation checks and performance tests. For more advanced checks, adjustments, calibrations, and fault repairs, consult Yokogawa Test & Measurement Corporation or a distributor.



This product contains high-voltage parts. Never remove the cover. All internal inspections of this product are to be performed only by service technicians qualified by Yokogawa Test & Measurement Corporation.



Cet appareil contient des pièces sous haute tension. N'ouvrez jamais le couvercle. Toute inspection interne de cet appareil doit être effectuée exclusivement par des techniciens de service qualifiés par Yokogawa Test & Measurement Corporation.

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## ■ Equipment Used

Operation checks and performance tests require the following instruments.

	Required Performance	Recommended Instrument	Usage Purpose
Digital multimeter	AC voltage TrueRMS Accuracy: $\pm 0.1\%$ (1 kHz to 100 kHz) DC voltage Accuracy: $\pm 0.1\%$	Agilent 3458A	Measurement of AC voltages of 100 kHz or lower, and DC voltage
Power meter and power sensor	100 kHz to 30 MHz 5 $\mu$ W to 250 mW (-23 dBm to +24 dBm) Accuracy: 0.02 dB Resolution: 0.01 dB	R&S NRVS, NRV-Z5	Measurement of AC voltages of 100 kHz and higher
Universal counter	Accuracy: 0.1 ppm	Agilent 53131A Opt 010 (High-stability TB)	Frequency, duty, and inter-channel time difference measurement
Oscilloscope	300 MHz or higher, 2 GS/s, 50 $\Omega$ input	Agilent DSO6032A	Leading-edge time and trailing-edge time measurement
Spectrum analyzer	10 kHz to 1 GHz Resolution: 100 Hz	Agilent E4411B Opt 1DR (Narrow RBW)	Harmonic and non-harmonic spurious measurement
BNC cable	Characteristic impedance: 50 $\Omega$ Length: 1 m	RG-58A/U	—
BNC(f)-Banana conversion adapter	—	—	For connecting a BNC cable to the binding post of a digital multimeter
BNC(f)-N(m) conversion adapter	Characteristic impedance: 50 $\Omega$	—	For connecting a BNC cable to a spectrum analyzer
BNC(f)-N(f) conversion adapter	Characteristic impedance: 50 $\Omega$	—	For connecting a BNC cable to a power sensor

## 10.2 Operation Checks

### ■ Items to verify before operation check

Verify the following items before performing an operation check.

- Is the power supply voltage within the rated range?
- Is the temperature range within the 0 to +40°C range?
- Is the relative ambient humidity within the 5 to 85%RH range (and the absolute humidity within the range of 1 to 25 g/m<sup>3</sup>)?
- Is there no condensation?

### ■ Function checks

#### ● Checks upon power application

Check if there is no error display at power application.

When an error message is displayed, [☞ p. 77](#).

In the case of an abnormal display at power application, switch off the power, and switch it back on 5 or more seconds later.

#### ● Self-check

Execute [Self Check] on the Utility screen.

[☞ p. 76](#)

#### ● Major functions check

To prevent erroneous settings, first perform setting initialization (execute [Reset] on the Utility screen).

Next, connect FCTN OUT to an oscilloscope using a coaxial cable with characteristic impedance of 50 Ω, and monitor the output.

In this state, change the following settings a number of times to check whether the unit functions normally. The items that require a numeric value to be set, such as the frequency, can be checked more accurately by using both the numeric keypad and the modify knob.

- Waveform ( **FCTN** FCTN shortcut key)
- Frequency ( **FREQ** FREQ shortcut key)
- Amplitude ( **AMPTD** AMPTD shortcut key)
- DC offset ( **OFFSET** OFFSET shortcut key)
- Output on/off ( **OUT** )

#### ● GPIB and USB checks

Perform some of the setting changes implemented in the major functions check above from the GPIB or USB interface, and verify that the same output changes result.

At this time, check that either [GPIB] or [USB] is displayed in the status display area at the top of the screen.

Also, with either [GPIB] or [USB] displayed in the status display area, press the [Local] soft key, and check that the above status display has disappeared and that the local status is returned to (when the status is other than local lockout).

## 10.3 Performance Tests

### ■ Performance tests

Performance tests are done as part of preventive maintenance to prevent performance degradation of the equipment.

Perform performance tests when required, such as for performance checks during acceptance inspections, periodic inspections, and after repairs.


If the specifications are found to be unmet as the result of a performance test, repair is required. In this case, contact either Yokogawa Test & Measurement Corporation or a distributor.

### ■ Items to verify before performance test

Verify the following items before performing a performance test.

- Is the power supply voltage within the rated range?
- Is the temperature range within the +20 to +30°C range?
- Is the relative ambient humidity within the 20 to 70%RH range?
- Is there no condensation?
- Has the unit been warmed up for at least 30 minutes?

### ■ Preparations before performance test

- The signal cable to be used is a coaxial cable terminated at both ends with BNC connectors, with characteristic impedance of 50 Ω, thickness of RG-58A/U or greater, and a length of 1 meter or less.
- In the case of items that specify 50 Ω termination, set the input impedance of the connected measuring device to 50 Ω.
- For equipment that cannot be set to 50 Ω input, attach a 50 Ω termination to the input of the measuring device (feedthrough terminator).
- Signals of up to approx. 24 dBm can be measured (when amplitude setting = 20 Vp-p/open). Use a separate coaxial attenuator if needed to ensure that the allowed input of the measuring device is not exceeded. Particularly in the case of power meter (power sensor) and spectrum analyzer, use caution as these types of equipment are easily damaged.
- The setting for each test item describes the items to be additionally changed after setting initialization (executing [Reset] on the Utility screen) followed by setting the output to [On] (LED lights when  is pressed).

#### 10.3.1 Frequency accuracy test

- Connection: FCTN OUT → Universal counter input (50 Ω termination)  
Use a coaxial cable.
- Setting: After initialization of the settings, set the frequency to 1 MHz and the amplitude to 10 Vp-p/open.
- Measurement: Set the universal counter to the frequency measurement mode and measure the frequency.
- Judgment: The results are normal if within the following ranges.  
However, annual variation of up to ±1 ppm/year is possible, so that one year after shipping, the accuracy may have deteriorated within the range of ±4 ppm (999.996 kHz to 1.000004 MHz).

Rated range
0.999997 MHz to 1.000003 MHz

### 10.3.2 Sine wave amplitude accuracy test

- Connection: FCTN OUT → Digital multimeter (AC voltage TrueRMS measurement)  
Use a coaxial cable.
- Setting: After initialization of the settings, set the amplitude as detailed in the table below (frequency is set to 1 kHz).
- Measurement: Measure the output voltage for each waveform with the RMS value.
- Judgment: The results are normal if within the ranges listed in the table below.

Amplitude Setting (Open Load Value)	Rated Range
20 V <sub>p-p</sub> (7.071 V <sub>rms</sub> )	7.000 V <sub>rms</sub> to 7.142 V <sub>rms</sub>
5 V <sub>p-p</sub> (1.768 V <sub>rms</sub> )	1.749 V <sub>rms</sub> to 1.786 V <sub>rms</sub>
3 V <sub>p-p</sub> (1.061 V <sub>rms</sub> )	1.049 V <sub>rms</sub> to 1.072 V <sub>rms</sub>
1 V <sub>p-p</sub> (0.3536 V <sub>rms</sub> )	0.3493 V <sub>rms</sub> to 0.3578 V <sub>rms</sub>
0.3 V <sub>p-p</sub> (0.1061 V <sub>rms</sub> )	104.3 mV <sub>rms</sub> to 107.8 mV <sub>rms</sub>
0.1 V <sub>p-p</sub> (35.36 mV <sub>rms</sub> )	34.29 mV <sub>rms</sub> to 36.42 mV <sub>rms</sub>
0.02 V <sub>p-p</sub> (7.071 mV <sub>rms</sub> )	6.293 mV <sub>rms</sub> to 7.849 mV <sub>rms</sub>

### 10.3.3 DC offset accuracy test

#### ■ DC only

- Connection: FCTN OUT → Digital multimeter (DC voltage measurement)
- Setting: After initialization of the settings, set the waveform to DC. The DC offset settings are as listed in the table below.
- Measurement: Measure the output voltage with DC.
- Judgment: The results are normal if within the ranges listed in the table below.

DC Offset Setting (Open Load Value)	Rated Range
±10 V	±9.895 V to ±10.105 V
±3 V	±2.965 V to ±3.035 V
±1 V	±0.9850 V to ±1.0150 V
0 V	-5.000 mV to +5.000 mV

#### ■ AC+DC

- Connection: FCTN OUT → Digital multimeter (DC voltage measurement)
- Setting: After initialization of the settings, set the oscillation mode to burst oscillation, the burst mode to gate, and the trigger to external off (sine wave oscillation stops at 0°). The amplitude setting is as detailed in the figure below. The DC offset setting remains unchanged at 0 V.
- Measurement: Measure the output voltage with DC.
- Judgment: The results are normal if within the ranges listed in the table below.

Amplitude Setting (Open Load Value)	Rated Range
6.4 V <sub>p-p</sub>	-37.00 mV to +37.00 mV
3.5 V <sub>p-p</sub>	-22.50 mV to +22.50 mV
1.3 V <sub>p-p</sub>	-11.50 mV to +11.50 mV

### 10.3.4 Sine wave amplitude/frequency characteristics test

#### ■ 100 kHz and lower

- Connection: FCTN OUT → Digital multimeter (AC voltage TrueRMS measurement, 50 Ω termination)  
Use a coaxial cable.
- Setting: After initialization of the settings, set the amplitude and frequency as detailed in the table below.
- Measurement: Measure the output voltage for each frequency with the RMS value.
- Judgment: Regarding the various amplitude settings, the results are normal if the error at each frequency using the measurement value at 1 kHz as the reference is within the ranges listed in the table below.

Amplitude Setting (Open Load Value)	Measurement Value at 1 kHz	Error at 50 kHz	Error at 100 kHz	Error at 100 kHz for Each Amplitude Named as Follows
20 V <sub>p-p</sub>	Reference value	±0.1 dB	±0.1 dB	X1 (dB)
5 V <sub>p-p</sub>	Reference value	±0.1 dB	±0.1 dB	X2 (dB)
3 V <sub>p-p</sub>	Reference value	±0.1 dB	±0.1 dB	X3 (dB)
1 V <sub>p-p</sub>	Reference value	±0.1 dB	±0.1 dB	X4 (dB)
0.3 V <sub>p-p</sub>	Reference value	±0.1 dB	±0.1 dB	X5 (dB)
0.1 V <sub>p-p</sub>	Reference value	±0.1 dB	±0.1 dB	X6 (dB)

#### ■ 100 kHz and higher

- Connection: FCTN OUT → Power meter (power sensor)  
Use a coaxial cable. Signals of up to approx. 24 dBm can be measured. Use a separate coaxial attenuator to ensure that the allowed input of the power sensor is not exceeded.
- Setting: After initialization of the settings, set the amplitude and frequency as listed in the table below.
- Measurement: Measure the output voltage or power for each frequency.
- Judgment: Regarding the various amplitude settings, the results are normal if the error at each frequency using the measurement value at 100 kHz as the reference is within the ranges listed in the table below. The error at 100 kHz X<sub>n</sub> (n = 1 to 6) measured in advance with the digital multimeter is added to the measurement range.  
For example, when X<sub>1</sub> = -0.05 dB, the judgment range at 20 V<sub>p-p</sub>, 5 MHz is -0.1 dB to 0.2 dB.

Amplitude Setting (Open Load Value)	Measurement Value at 100 kHz	Error at 300 kHz	Error at 1 MHz	Error at 5 MHz	Error at 10 MHz	Error at 20 MHz	Error at 30 MHz
20 V <sub>p-p</sub>	Reference value	-X1 ±0.15 dB	-X1 ±0.15dB	-X1 ±0.15 dB	-X1 ±0.3 dB	-X1 ±0.3 dB	-X1 ±0.8 dB
5 V <sub>p-p</sub>	Reference value	-X2 ±0.15 dB	-X2 ±0.15dB	-X2 ±0.15 dB	-X2 ±0.3 dB	-X2 ±0.3 dB	-X2 ±0.5 dB
3 V <sub>p-p</sub>	Reference value	-X3 ±0.15 dB	-X3 ±0.15dB	-X3 ±0.15 dB	-X3 ±0.3 dB	-X3 ±0.3 dB	-X3 ±0.5 dB
1 V <sub>p-p</sub>	Reference value	-X4 ±0.15 dB	-X4 ±0.15dB	-X4 ±0.15 dB	-X4 ±0.3 dB	-X4 ±0.3 dB	-X4 ±0.5 dB
0.3 V <sub>p-p</sub>	Reference value	-X5 ±0.15 dB	-X5 ±0.15dB	-X5 ±0.15 dB	-X5 ±0.3 dB	-X5 ±0.3 dB	-X5 ±0.5 dB
0.1 V <sub>p-p</sub>	Reference value	-X6 ±0.15 dB	-X6 ±0.15dB	-X6 ±0.15 dB	-X6 ±0.3 dB	-X6 ±0.3 dB	-X6 ±0.5 dB

### 10.3.5 Sine wave total harmonic distortion test

- Connection:** FCTN OUT → Spectrum analyzer  
Use a coaxial cable. Signals of up to approx. 24 dBm can be measured. Use a separate coaxial attenuator to ensure that the allowed input of the spectrum analyzer is not exceeded.
- Setting:** After initialization of the settings, set the frequency to 20 kHz. Set the amplitude as listed in the table below.
- Measurement:** Measure the harmonic spurious up to the 7th order, and obtain the total harmonic distortion through calculation. Using X2 to X7 (dBc) as the relative values of the harmonic spurious up to the 7th order, using the 20 kHz basic wave as the fundamental harmonic, total harmonic distortion THD is obtained with the following formula.

$$\text{THD} = \sqrt{10^{\frac{X2}{10}} + 10^{\frac{X3}{10}} + 10^{\frac{X4}{10}} + 10^{\frac{X5}{10}} + 10^{\frac{X6}{10}} + 10^{\frac{X7}{10}}}$$

X2 to X7 are the relative levels of 40 kHz, 60 kHz, 80 kHz, 100 kHz, 120 kHz, and 140 kHz, respectively.

Increase the input attenuator of the spectrum analyzer until the relative level of the harmonic spurious stabilizes.

- Judgment:** The results are normal if within the following ranges.

Amplitude Setting (Open Load Value)	Total Harmonic Distortion
20 V <sub>p-p</sub>	0.2% or lower
3 V <sub>p-p</sub>	0.2% or lower
1 V <sub>p-p</sub>	0.2% or lower

### 10.3.6 Sine wave harmonic spurious test

- Connection:** FCTN OUT → Spectrum analyzer  
Use a coaxial cable. Signals of up to approx. 24 dBm can be measured. Use a separate coaxial attenuator to ensure that the allowed input of the spectrum analyzer is not exceeded.
- Setting:** After initialization of the settings, set the amplitude and the frequency as listed in the table below.
- Measurement:** Measure the harmonic spurious up to the 5th order.  
Increase the input attenuator of the spectrum analyzer until the relative level of the harmonic spurious stabilizes.
- Judgment:** The results are normal if within the following ranges.

Amplitude Setting (Open Load Value)	Maximum Harmonic Spurious Level up to 5th Order for Frequency Setting of 100 kHz	Maximum Harmonic Spurious Level up to 5th Order for Frequency Setting of 1 MHz	Maximum Harmonic Spurious Level up to 5th Order for Frequency Setting of 10 MHz	Maximum Harmonic Spurious Level up to 5th Order for Frequency Setting of 30 MHz
20 V <sub>p-p</sub>	-60 dBc or lower	-60 dBc or lower	-43 dBc or lower	-30 dBc or lower
3.5 V <sub>p-p</sub>	-60 dBc or lower	-60 dBc or lower	-50 dBc or lower	-40 dBc or lower

### 10.3.7 Sine wave non-harmonic spurious test

- Connection: FCTN OUT → Spectrum analyzer  
Use a coaxial cable. Signals of up to approx. 24 dBm can be measured. Use a separate coaxial attenuator to ensure that the allowed input of the spectrum analyzer is not exceeded.
- Setting: After initialization of the settings, set the amplitude and frequency as listed in the table below.
- Measurement: Measure the maximum value of the non-harmonic spurious.
- Judgment: The results are normal if within the following ranges.

Amplitude Setting (Open Load Value)	Maximum Non-Harmonic Spurious Level for Frequency Setting of 100 kHz	Maximum Non-Harmonic Spurious Level for Frequency Setting of 1 MHz	Maximum Non-Harmonic Spurious Level for Frequency Setting of 10 MHz	Maximum Non-Harmonic Spurious Level for Frequency Setting of 30 MHz
20 V <sub>p-p</sub>	-60 dBc or lower	-60 dBc or lower	-50 dBc or lower	-45 dBc or lower
3.5 V <sub>p-p</sub>	-60 dBc or lower	-60 dBc or lower	-50 dBc or lower	-45 dBc or lower
1 V <sub>p-p</sub>	-60 dBc or lower	-60 dBc or lower	-50 dBc or lower	-45 dBc or lower

### 10.3.8 Square wave duty accuracy test

- Connection: FCTN OUT → Universal counter (50 Ω termination)  
Use a coaxial cable.
- Setting: After initialization of the settings, set the waveform to square wave and the amplitude to 20 V<sub>p-p</sub>/open. The variable duty range, frequency, and duty settings are as listed in the table below.
- Measurement: Set the universal counter to the duty measurement mode. Set the trigger level of the universal counter to 0 V. Since the measured values are subject to fluctuation due to jitter (particularly when the variable duty range is extended), perform averaging.
- Judgment: The results are normal if within the following ranges.

#### ■ Normal variable duty ranges

Frequency	Duty		
100 kHz	0.9% to 1.1% when 1% is set	49.9% to 50.1% when 50% is set	98.9% to 99.1% when 99% is set
1 MHz	4% to 6% when 5% is set	49% to 51% when 50% is set	94% to 96% when 95% is set
3 MHz	37% to 43% when 40% is set	47% to 53% when 50% is set	57% to 63% when 60% is set

#### ■ Extended variable duty ranges

Frequency	Duty		
100 kHz	0.9% to 1.1% when 1% is set	49.9% to 50.1% when 50% is set	98.9% to 99.1% when 99% is set
1 MHz	4% to 6% when 5% is set	49% to 51% when 50% is set	94% to 96% when 95% is set
3 MHz	37% to 43% when 40% is set	47% to 53% when 50% is set	57% to 63% when 60% is set

**10.3.9 Square wave rising/falling time test**

Connection: FCTN OUT → Oscilloscope (50 Ω termination)  
Use a coaxial cable.

Setting: After initialization of the settings, set the waveform to square wave and the amplitude to 20 V<sub>p-p</sub>/open. The variable duty ranges are as listed in the table below.

Measurement: Monitor the waveform and measure the rising and falling times.

Judgment: The results are normal if within the following ranges.

Variable Duty Range	Rising Time, Falling Time
Normal	17 ns or less
Extended	17 ns or less

**10.3.10 Time difference between channels for 2-phase (FG420 only)**

Connection: CH1 FCTN OUT → Universal counter, input 1 (50 Ω termination)  
CH2 FCTN OUT → Universal counter, input 2 (50 Ω termination)  
Use coaxial cables of the same type and length.

Setting: After initialization of the settings, set the channel mode to 2PHASE, the amplitude to 20 V<sub>p-p</sub>/open, the CH2 phase to 180°, and the frequency to 10 MHz. The waveform settings are as detailed in the table below.

Measurement: Set the universal counter to the time interval mode between input 1 and input 2, and measure the time difference between CH1 and CH2. Set the trigger level of the universal counter to 0 V for both inputs 1 and 2, and set the trigger polarity to rising for both inputs. Since the measurement values are subject to fluctuations, average them.

Judgment: The results are normal if within the following ranges.

Waveform	Rated Range
Sine wave	30 ns to 70 ns
Square wave (normal variable duty range)	30 ns to 70 ns
Square wave (extended variable duty range)	30 ns to 70 ns



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## Revisions

April 2014	1st Edition
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If there are any misplaced or missing pages, we will replace the manual. Contact the sales representative.

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