**OVERVIEW**

Signal sources apply standard signals to circuits or equipment to check whether they are working correctly. Many types of signal sources are available to suit specific application requirements, and of these the arbitrary waveform generator or function generator is one of the most common instruments used to create waveforms. For example, when a simple sine wave generating circuit is to be configured, various oscillating methods (Table 1) are available. Recently, high-resolution D/A converters have been developed, so signal generators with a direct digital synthesizer (DDS) are now widely used.

**FUNCTION GENERATORS**

Function generators are signal sources which can generate various types of waveforms and frequencies including sine, rectangular, and triangular waveforms, with a frequency ranging from several µHz to several 10 MHz. Using external signals, they can easily control and modulate waveforms. Function generators are therefore used for a range of applications in electronics, mechatronics, civil and construction, chemicals, biochemicals, and medical science.

**OPERATING PRINCIPLE OF DDS FUNCTION GENERATORS**

**DDS**

Figure 1 shows a block diagram of the DDS. The DDS consists of a standard clock, an address computing unit, a waveform memory with waveform data of one cycle, a D/A converter, and a low-pass filter.

Using the standard clock, the address computing unit that determines the phase angle in real-time generates addresses in the waveform memory. The waveform memory stores a one-cycle waveform, so address values correspond to the phase angle of the waveform. The D/A converter accepts waveform data from the waveform memory and converts them into an analog waveform together with the low-pass filter.

The address computing unit consists of an N-bit full-adder that overflows with the values of Y, and a latching circuit, totalizing a phase increment X synchronizing with the standard clock Fclk. This is called the phase accumulator.

The output frequency \( F_{out} \) is given by the following equation:

\[
F_{out} = \frac{X}{Y} \times F_{clk}
\]

For example, assuming that the standard clock is 10.24 MHz using a 10-bit phase accumulator, then:

\[
Y = 2^{10} = 1024 \\
F_{clk} = 10.24 \text{ MHz}
\]

Assuming that \( X = 1 \), then:

\[
F_{out} = \frac{1}{1024} \times 10.24 \text{ MHz} = 10 \text{ kHz}
\]

Assuming that \( X = 33 \), then:

\[
F_{out} = \frac{33}{1024} \times 10.24 \text{ MHz} = 330 \text{ kHz}
\]

Assuming that \( X = 200 \), then:

\[
F_{out} = \frac{200}{1024} \times 10.24 \text{ MHz} = 2 \text{ MHz}
\]

As shown above, setting the phase angle increment \( X \) allows an arbitrary frequency \( F_{out} \) to be generated. The frequency resolution \( F_{res} \) that can be set is given by:

\[
F_{res} = \frac{F_{clk}}{Y}
\]

Hence, in principle, the frequency resolution increases as the value of \( Y \) increases.
**OVERVIEW**

- **OPERATING PRINCIPLE OF FG100 SERIES**
  - Figure 2 Shows a Block Diagram of the FG100 Series
    In this circuit, a crystal oscillator generates a standard clock of 11.728 MHz. The DDS uses a 48-bit address computing unit to generate a frequency signal ranging from 1 µHz to 2 MHz with a frequency resolution of 1 µHz. The waveform memory has a horizontal resolution of 8-K point addresses and a 12-bit vertical resolution. To output a wave with the specified frequency, the clock signal from the CPU is stopped, a specific waveform is written to the waveform memory, then the clock is restarted to operate the DDS circuit.

- As a low-pass filter, an anti-aliasing filter is used for sine or rectangular waves meeting the sampling definition. For triangular and ramp waves as well as for duty-changeable pulses, “vessel-type” anti-aliasing filters are used to avoid ringing or lingering. The rectangular waveform generating comparator creates rectangular waveforms from sine waves and provides synchronous outputs for individual waveforms.

- The attenuator circuit sets the amplitude combining a 2-dB step resistance attenuator and a D/A converter for amplitude adjustment, which interpolates the attenuator. The trigger/gate control circuit starts or stops the address computing unit with an external trigger/gate signal used for trigger/gate operations.

- **FG100 Series Features**
  - The FG100 Series Function Generator is a compact, high-accuracy function generator. It offers the basic functions of a function generator with two output signals. All items can be set quickly through the GP-IB interface, allowing the FG100 Series to be used in automated production lines. The FG100 Series is used to evaluate mechatronics equipment as well as power equipment.

- **FG200/FG300 Series Features**
  - Figure 3 shows a block diagram of the FG200/FG300 Series. The operating principle of this series is the same as that of the FG100 Series, except that the FG200/FG300 Series provide the following additional signals:
    - A maximum of 15 MHz of sine and rectangular waves
    - Sweep and modulation signals for each parameter
    - External analog and digital signals for controlling sweep and modulation signals
    - Amplitude and duty cycles can be varied continuously

---

**Fig. 2 Block Diagram of FG100 Series**

**Fig. 3 Block Diagram of FG200 and FG300 Series**
OVERVIEW

• Synchronized signals over multi-channels can be provided
• Arbitrary waveforms and sweep functions are possible with the FG300 Series

The FG200/FG300 Series use a large LCD panel and touchscreen to allow multiple parameters to be set easily. This series of function generators is thus much easier to use than conventional function generators.

The FG200/FG300 Series are widely used for evaluating electronic circuitry as well as mechatronics equipment.

About Arbitrary Waveform Generators

Various different waveform generators are used depending on the application, such as function generators, video signal generators, pulse-pattern generators and noise generators. But even with these generators, dependable signal sources cannot always be obtained for special waveforms in electronic circuitry, or repeatability may not be possible for standard signals to which environmental noise signals are added.

This series of arbitrary waveform generators is suitable for such cases.

VARIOUS TYPES OF ARBITRARY WAVEFORM GENERATORS

Simple Arbitrary Waveform Generators

The basic structure of these arbitrary generators is the same as that of DDS function generators. In principle, the waveform memory sampling frequency is fixed. Frequency changes are provided by jumped readings of waveform memory or repetitive occurrence of waveform data in the same address, so this type of arbitrary generator cannot provide waveforms that are strictly defined. However, if an output waveform is not so complex, arbitrary waveform generators can be used. This type of waveform generator is cost effective for providing simple arbitrary waveforms, as exemplified by the FG300 Series with simple arbitrary waveform generating functions.

Arbitrary Waveform Generators with Variable Clock Frequency

This type of arbitrary waveform generator uses a variable clock frequency to output the contents of waveform memory data that are defined, independently of the generating frequency. The generator requires a large waveform memory capacity.

Arbitrary Waveform Generators with Sequence Function

If arbitrary waveform generators with only waveform memory are combined with some waveform elements to create a waveform, the waveform memory will not be used effectively. To overcome this problem, this generator has two independent memory areas—one memory area that has waveform elements for configuring waveforms, and another area that has a sequence program linking waveform elements.

Figure 4 shows a block diagram of the AG1200 Arbitrary Waveform Generator. This type of generator is ideal for creating a wide range of applications that require arbitrary waveforms.

CREATING WAVEFORMS

Arbitrary waveform generators must define waveforms. The waveform definition depends on the waveform data that are created, so the generators provide some way of defining the waveform. The AG1200 has no limit on data length of waveforms that can be defined, making it easy to define waveforms.

Definition Functions

When waveforms can be defined logically, define waveform data using functional expressions. For this, the arbitrary waveform generators offer various arithmetic computation and trigonometric functions. When complex waveforms such as video signals must be defined, functional expressions consisting of more than 100 lines are required. The AG1200 incorporates a special editor that allow you to define such functional expressions.

Scope Draw

If waveforms cannot be defined by functional expressions, or if waveforms defined by another means need to be modified, you can use the generator screen to define the waveform data. The waveforms can be easily created or modified by linking or directly linking the points that are defined.

Downloading

If waveform data are created on an external computer or captured by a digital oscilloscope, the data must be downloaded. The waveform data captured by a digital oscilloscope can be transferred to the arbitrary waveform generator through a GP-IB interface. Various software packages are supplied for creating waveform data on a personal computer:

• Data conversion software
• Pattern generator utility
• Disk waveform generating utility
• Data transfer utility

Creating Sequence Programs

Sequence programs can be used to create the desired waveform by linking multiple waveform data that are defined, as shown in Figure 5.

AG1200 Features

The AG1200 is widely used in mechatronics, power equipment, liquid-crystal material production, and medical science. In these fields, multiple analog waveforms and waveforms mixed with analog and digital forms are required, so the AG1200 provides up to 16 analog outputs with parallel connection functions and 32-bit digital signals synchronized with analog signals.

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### AG1200 ARBITRARY WAVEFORM GENERATOR

<table>
<thead>
<tr>
<th>Model</th>
<th>AG1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Analog Outputs</td>
<td>1, 2, or 4</td>
</tr>
<tr>
<td>No. of Digital Pattern Outputs</td>
<td>32 bits</td>
</tr>
<tr>
<td>No. of Event Outputs</td>
<td>1 bit</td>
</tr>
<tr>
<td>Maximum Clock Frequency</td>
<td>10 MHz</td>
</tr>
<tr>
<td>Clock Frequency Resolution</td>
<td>10 mHz</td>
</tr>
<tr>
<td>Sweep Functions in Clock Frequency</td>
<td>Provided</td>
</tr>
<tr>
<td>Resolution of Output Amplitude</td>
<td>12 bits</td>
</tr>
<tr>
<td>Maximum Output Amplitude</td>
<td>±10 V (with no load)</td>
</tr>
<tr>
<td>Rise Time</td>
<td>70 ns</td>
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<tr>
<td>Waveform Memory Capacity</td>
<td>32 k words/channel</td>
</tr>
<tr>
<td>No. of Maximum Waveform Elements</td>
<td>16</td>
</tr>
<tr>
<td>No. of Maximum Sequence Steps</td>
<td>255</td>
</tr>
<tr>
<td>No. of Maximum Sequence Programs</td>
<td>12</td>
</tr>
<tr>
<td>Parallel Synchronizing Operation</td>
<td>Possible</td>
</tr>
<tr>
<td>GP-IB Interface</td>
<td>Provided as standard</td>
</tr>
</tbody>
</table>

### SELECTION GUIDE FOR FG SERIES FUNCTION GENERATORS

<table>
<thead>
<tr>
<th>Model</th>
<th>FG100 Series</th>
<th>FG200</th>
<th>FG300</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Signal Outputs</td>
<td>1, 2</td>
<td>1, 2</td>
<td>1, 2</td>
</tr>
<tr>
<td>Output Waveform</td>
<td>Sine, rectangular, triangular, ramp and pulse</td>
<td>Sine, rectangular, triangular, ramp and pulse</td>
<td>Sine, rectangular, triangular, ramp, pulse, and arbitrary waveforms</td>
</tr>
<tr>
<td>Operation Mode</td>
<td>Continuous, trigger, gate, and direct current</td>
<td>Continuous, trigger, gate, and direct current</td>
<td>Continuous, trigger, gate, and direct current</td>
</tr>
<tr>
<td>Oscillating Frequency Range</td>
<td>Sine and rectangular waves: 1 µHz to 2 MHz Other waveforms: 1 µHz to 100 kHz</td>
<td>Sine and rectangular waves: 1 µHz to 15 MHz Other waveforms: 1 µHz to 200 kHz</td>
<td>Sine and rectangular waves: 1 µHz to 15 MHz Other waveforms: 1 µHz to 200 kHz</td>
</tr>
<tr>
<td>Frequency Resolution</td>
<td>1 µHz or 10 digits</td>
<td>1 µHz or 9 digits</td>
<td>1 µHz or 9 digits</td>
</tr>
<tr>
<td>Maximum Output Range</td>
<td>±10 V</td>
<td>±10 V</td>
<td>±10 V</td>
</tr>
<tr>
<td>Sweep Function</td>
<td>No functions</td>
<td>Linear, log Linear steps Log steps</td>
<td>Linear, log Linear steps Log steps Arbitrary patterns</td>
</tr>
<tr>
<td>Sweep Mode</td>
<td>None</td>
<td>Frequency, amplitude, offset, phase, duty ratio, and frequency and amplitude at a time</td>
<td>Frequency, amplitude, offset, phase, duty ratio, and frequency and amplitude at a time</td>
</tr>
<tr>
<td>Modulation Function</td>
<td>None</td>
<td>AM, DSB-AM, FM, φM, Offset, PWM</td>
<td>AM, DSB-AM, FM, φM, Offset, PWM</td>
</tr>
<tr>
<td>Simple Arbitrary Waveform Function</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sequence Function</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Synchronous Operation</td>
<td>Disabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>GP-IB Interface</td>
<td>Standard</td>
<td>Standard</td>
<td>Standard</td>
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</table>