Arbitrary Waveform Generator

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The AG arbitrary waveform generator makes it easy to create complex, periodic and transient, high-frequency waveforms that would be impossible to generate using conventional oscillators or function generators. This paper provides an overview of the new product.

1. INTRODUCTION

Recently, electronic instruments and related systems have gradually become more complex. The test signals required to evaluate these systems have also become more complex. The number of electronic instruments which can not be sufficiently evaluated using conventional function generators and synthesizers as signal sources is increasing. Examples include instruments using digital signals, and analog signals from applications such as optics, magnetic disks, video, radar, "mechatronics" and automobiles. Therefore, actual waveform signals must be used for evaluation or it must be possible to define these required waveforms. When using actual waveforms, the following weakpoints exist:

- The ideal waveform can not be created.
- Lack reproducibility.
- Can not create limiting waveform.
- Can not modify waveform.

On the other hand, a significant amount of time and money is required to define a test signal. Furthermore, it is very difficult to change or modify the signal for a new test. Our paper introduces the AG Series, arbitrary waveform generator, which has been developed as an answer to these problems. This series was developed with high quality, simple operation and advanced functions as goals. AG series instruments contain a CRT display, and floppy disk for storage.

- Interactive operation using CRT and front panel key. All operations can be easily learned in short term.
- Numerous waveform generation methods

Waveforms are stored as digital data, and a D-A converter is used to create analog signals. The following three waveform generation methods are available:

- Mathematical Formulas
- Scope Draw
  Spline interpolation or linear interpolation is used to create waveforms according to points set on the CRT screen by the user.
- Downloading actual waveforms from digital oscilloscopes.

Currently, hard disk drive tests require an expensive standard disk as the signal source. This results in problems with maintenance, reproducibility, and reliability. The AG waveform generator solves these problems, and provides an ideal signal for evaluation of hard disk drive circuits.

An external view of the waveform generator appears in Figure 1.

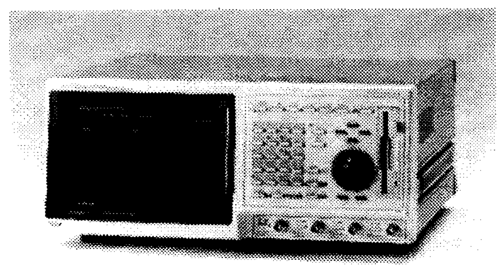


Figure 1. External View of the AG1200

2. CONSTRUCTION

There are currently three models in the AG series. They provide different clock speed and resolutions to suit your needs.

Model	Clock Rate	Resolution
AG2100	100 MHz	10 bit
AG2200	200 MHz	8 bit
AG1200	10 MHz	12 biit

CH2940-5/91/0000-0251 $1.00 C 1991 IEEE

2.1 Overview

A block diagram of the AG1200 is shown in Figure 2. The system can be divided into a control subsystem and a signal generating subsystem. The control subsystem is in charge of control of the AG1200 as a whole as well as of the man-machine interface.

The signal generating subsystem generates arbitrary analog signals. Below we give a simple explanation of the construction of the signal generating subsystem.

2.2 Clock Generating Unit

The clock generating unit is a synthesizer which can generate clock pulses at frequencies of up to 10 MHz, with 0.01 Hz resolution. The frequency is synthesized by a digital phase generator circuit and a D/A converter.

2.3 Address Generator Unit

The address generator unit is the heart of arbitrary waveform control. It generates waveform data addresses in the order in which they are stored in the waveform memory in accordance with instructions from a sequence program stored in the sequence memory.

2.4 Signal Output Unit

Models can be provided with either two or four signal output units that consist of a waveform memory and D/A converter. The waveform memory has capacity sufficient for four channels of 12 bits • 32000 words each. Data supplied to the D/A converter from the waveform memory is converted into analog signals at a maximum clock rate of 10 MHz; the latter pass through an amplifier before being output. Five different low pass filters are available; these filters produce negligible transient overshoot or undershoot , in keeping with the purpose of the AG1200 as a waveform generator. The full scale of each signal can be set between 0 and 10V with high-resolution.

3. FUNCTIONS AND OPERATIONS

3.1 Man-Machine Interface

All the functions of this model, from waveform creation to output sending, are accessible from the front panel. Operations are performed by using function keys to choose functions from menus, and by using rotary knob for settings. Such conversational operation via the CRT and front panel makes it easy to learn how to use the various functions.

3.2 Abundant Functions for Waveform Creation

The AG enables easy creation of waveforms through special functions designed for this purpose. There are three methods of waveform creation described below.

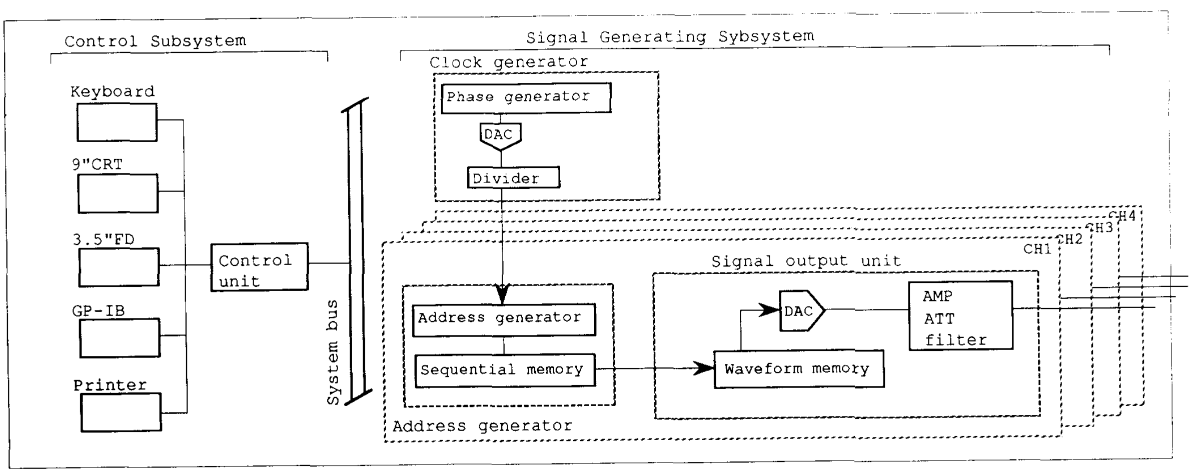


Figure 2. Block Diagram of the AG1200

(l) *Mathematical Formulas*

You can define waveforms as a variable function of time, in terms of mathematical functions. In addition to the basic arithmetic operations, functions can also he defined using trigonometric functions, logarithms and exponential functions, square roots, white noise and many other functions and operations. Combining these functions enables a high degree of freedom in creating waveforms. Figure 3(a) is an example of a program used to create a waveform by function definition; Figure 3(b) shows the waveform thus created.

(2) *Scope Draw*

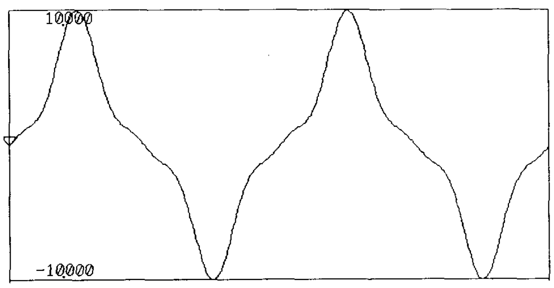
The AG implements a new concept called "scope draw", in which waveforms are defined and modified (spline-interpolated and linearly interpolated) on the CRT display. Figure 4 shows an example of waveform modified by this method.

(3) *Actual Waveforms*

Actual waveforms captured by a digital oscilloscope may be downloaded to the AG via GP-IB interface. Once a waveform has been recorded by such downloading, the same waveform can be reproduced at will.

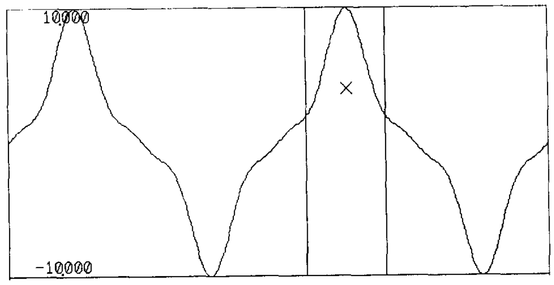
```
SIZE 400;
FOR O TO 4*PI {
CH1( SIN(T)-(1/3)*SIN(T*3)
                              +(1/9)*SIN(T*5) );
}
END;
```

(a) Program for waveform creation by function definition

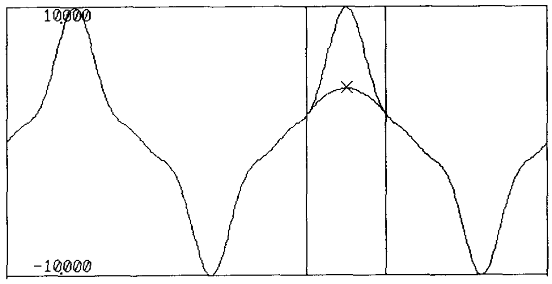


(b) Example of created waveform

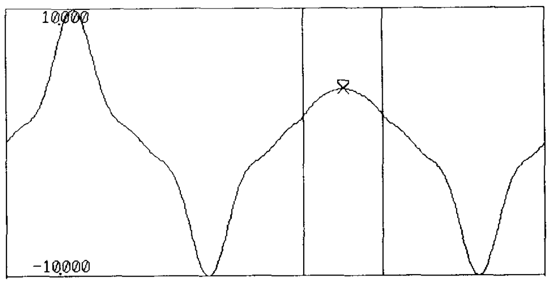
Figure 3. Example of Function Definition



(a) Setting of area and point for modification



(b) Comparison of spline-interpolated waveform and original waveform



(c) Waveform after modification

Figure 4. Example of Modification by "Scope Drawing"

3.3 High-Speed operations

In order to perform high-speed compiling, interpolating and other operations, fast processing speeds are required. The AG achieves the necessary processing speeds by expressing all operations in assembler language, instead of using a processor for numerical operations. This makes it possible to calculate sine wave data consisting of approx. 8000 points in 3.5 sec, reducing the time which the user must wait for a result.

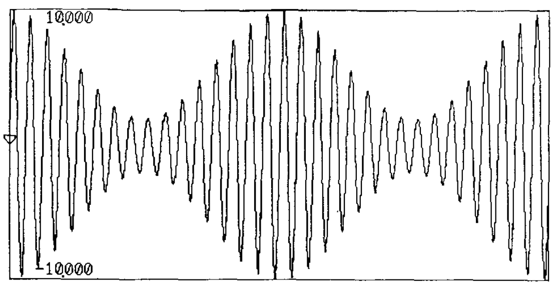
3.4 Sequence Programs

Sequence programs define the format (order) of waveform elements defined by the methods described above.

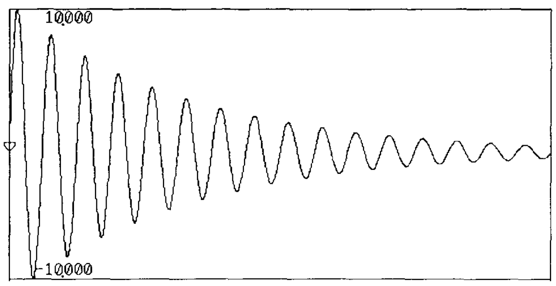
Figure 5 is an example of the simplest sequence definition using two different waveform elements. The sequence program of Figure 5(a) issues a command to connect the waveform elements AMSIN (Figure 5(b)) and DUMPSIN (Figure 5(c)). This procedure causes the AG to connect the two waveform elements and output them repeatedly. The actual output waveform is shown in Figure 5(d).

```
001   AMSIN,1;
002   DUMPSIN,1,1;
003   END;
```

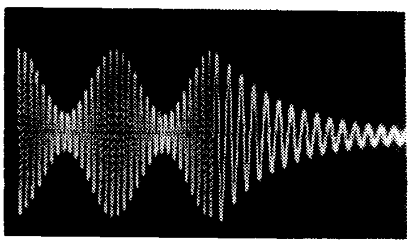
(a) Sequence program



(b) AMSIN



(c) DUMPSIN



(d) Output example

Figure 5. Example of Sequence Definition

Apart from this, sequence programs can be used to specify the number of loops or the number of repetitive movement for each waveform element and the line number to which the procedure to jump. These functions make it possible to treat waveform elements as interchangeable parts, so you can use wave memory most effectively.

3.5 Open Data Architecture Through Use of a 3.5" Floppy Disk Drive

The AG has a built-in 3.5-inch floppy disk drive for external memory. The format of this drive is compatible with the standard MS-DOS format. Thus spreadsheet and other software running on personal computers can easily be used to modify arbitrary waveform data and to write programs for waveform creation.

4. Merits of Arbitrary Waveform Generator

As described above, the functions of this Arbitrary Waveform Generator enable it to easily handle a wide variety of applications that can't be handled by conventional signal generators. The merits of this series are as follows:

4.1 Simulation Functions Facilitate Engineering Design Evaluation

This general-purpose arbitrary waveform generator can simulate complex real-life waveforms and special mathematically-derived waveforms without requiring any special-purpose equipment. Situations that can't be evaluated with simple waveforms from function generators can be quickly and easily evaluated by this arbitrary function generator.

4.2 Can Replace a Lot of Special-Purpose Signal Generators

For engineering design and manufacturing, it used to be necessary to design new signal generators whenever a special waveform was required. This costs much time and money. You can save them by using a general-purpose arbitrary waveform generator.

4.3 Can Generate Standard Signals

By using the large memory and DAC of this arbitrary waveform generator, it is possible to directly synthesize complex signals with very high accuracy (e.g. signals which require fast settling, wide-deviation FM signals, two-phase signals which require accurate phase differentials.) This arbitrary waveform generator can thus meet a very wide range of user needs. Some actual application examples are described below.

5. Actual Application Examples of Arbitrary Waveform Generator

5.1 Ultra-Small Waveform Peak Shift Generated by Mathematical Function

This arbitrary waveform generator offers considerable control over the time-axis of a waveform generated from a mathematical function. Parameters such as rise time, pulse width and time-axis granularity can be defined with great accuracy. For example, we simulated the peak shift of a read signal from a fast hard disk. If peak shift is ignored, a simple model for the read signal is:

$$Y(T) = \sin(T) - 1/3 \bullet \sin(3T) + 1/9 \bullet \sin(5T)$$

where T is time, and Y(T) is the corresponding amplitude signal.

On our Arbitrary Waveform Generator, the program to display this waveshape is as follows:

```
Size 64;
For 0 To 8*PI
{
Sin(T)-1/3*Sin(3*T)+1/9*Sin(5*T);
}
End;
```

This is the same format as the example program in the section AND OPERATION, but there's a large difference in the number of samples in the waveshape. Because the disk signal is a very high speed signal, not so many samples can be captured. We used 16 points per period - which is enough to represent the fifth order component of the wave, and is useful for disk signal simulation.

In general, magnetic storage devices use the position of peaks on the time axis in reading data. It is useful, in evaluating such devices, to test the effect of slightly varying the peak position. For the peak-shifted waveshape, the peak of each waveform is slightly shifted. Consider the following expression:

"a" in this expression represents a phase offset along the time axis, and by varying this phase offset we can vary the peak position.

$$Y = \sin(T-a) - 1/3 \bullet \sin(3(T-a)) + 1/9 \bullet \sin(5(T-a))$$

By combining this waveform with an waveform with no peak shift, the peak can be shifted by any necessary amount – but some discontinuities become apparent if this is attempted. However, we notice that the third and fifth order components have much more effect on the phase than the first order component – so we can use the third and fifth order components to set the phase, and the first order component to minimize discontinuities. The expression is as follows:

$$Y = \sin(T-4a/9) - 1/3 \bullet \sin(3(T-a)) + 1/9 \bullet \sin(5(T-a))$$

For this expression, if the shift a is small enough compared with the period, little discontinuity is evident. By combining this expression with the expression for no peak shift, the peak shift can be varied as necessary. The program and wave shape are shown below. (The variable A0 is shown in the program below, but in our Arbitrary Waveform Generator, a number rather than a variable would be used).

```
Size 64;
Window 1,8;
A0 = 0.01;
For 0 To PI
{
Sin(T-4/9*A0)-1/3*Sin(3*(T-A0))+
                 1/9*Sin(5*(T-A0));
}
Window  9,64;
For PI To 8*PI
{
Sin(T)-1/3*Sin(3*T)+1/9*Sin(5*T);
}
End;
```

The peak shift signal, peak shift amount, and actual wave shape are shown in the diagram. The sampling period is 5 ns.

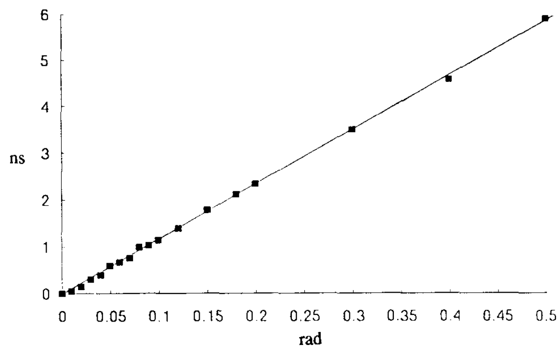


Figure 6. Phase Offset, Peak Shift and Actual Measured Values

The figure confirms that peak shifts that are small compared with the sampling period can be easily achieved by changing the parameters. We have explained that when generating a waveshape by function generator, the sampling period does not normally have to be considered, but we should check the effects of sampling and the quantizing noise of the DAC, and the analog LPF connected to the output.

Particular care is required when a high frequency signal like the disk signal is generated.

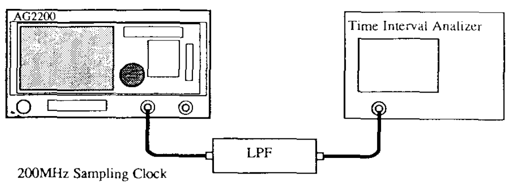


Figure 7. Configuration of Test System

The filter should attenuate the sampling clock frequency sufficiently, and have good group delay characteristics. An external filter that causes neither overshoot nor undershoot should be used.

5.2 Waveform Download / Power Supply Waveform Simulation using Scope Draw

A computer no-break power supply simulation using waveform downloading functions Is described below. Computer errors occurred during testing of the system, so the purpose of the study was to ensure the long-term reliability and stability of the system. Power supply troubles are the most frequent cause of such problems – spikes, noise or power supply interruptions can cause computer errors.

However, the reproducibility of such errors is poor, so they are difficult to analyze and confirm.

Our Arbitrary Function Generator is a great help in analyzing such abnormalities, and is ideal for use with power supply test circuitry such as shown in Fig. 8.

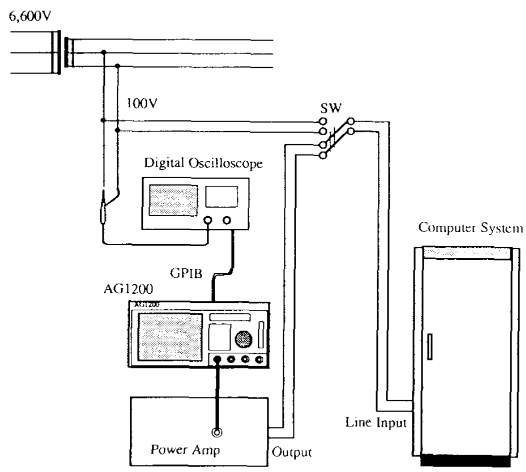


Figure 8. System Configuration Diagram

Power supply DL AG High-Speed Power Amplifier Computer System

The conventional way of finding the cause of computer errors is to monitor the power supply waveshape and capture many samples of the transients that cause errors, in order to determine a common pattern.

In general, the most helpful way to confirm that a particular transient (waveform) is the cause of such an error is simulation.

In this system, the abnormal waveform is downloaded via the GP-IB to the AG series waveform generator, which can "replay" the waveform as many times as required to confirm that it indeed is the problem. Not only can the waveform downloaded to the generator be replayed "as is", but it can also be freely modified to determine which component of it is causing trouble. The power supply simulation waveshape used in this dsystem is shown in Fig. 9.

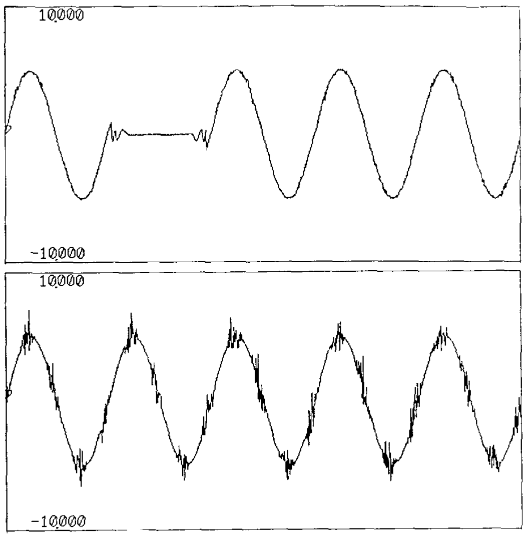


Figure 9 . Waveshape used for General Power Supply Simulation

6. CONCLUSION

The arbitrary waveform generator answers the needs of a new generation, and makes possible test evaluation of actual users needs in many fields. It will be very effective in shortening development time and increasing quality.