TM1000

PERIPHERAL INSTRUMENT SYSTEM

AF1010 MODULE
100 MHZ ARBITRARY FUNCTION GENERATOR

November 2000

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1.0 Introduction

The AF1010 is a 100 MHz Arbitrary Function Generator instrument module for use with the Data Design TM1000 system base unit. The module has two output channels with 128K 12-bit offset binary samples each. The channels have a common waveform period and a common internal or external trigger, but can be programmed with otherwise independent waveforms. Each channel has an independent marker output which can be programmed to occur at any point within the period. Each channel has independent 10-bit offset and gain settings.

The AF1010 software allows easy assembly of standard and complex waveforms, loading of custom waveforms, and easy operation of module features. Waveforms are entered graphically as a prototype waveform of a given period and over a –1V to +1V range. The prototype waveform is loaded to the module where it is presented at the output connectors and repeated on each internal or external trigger. Internal trigger or free run presents the waveform in a continuous periodic fashion. External trigger presents the waveform once for each 5V TTL positive edge received on the front panel trigger input or from an equivalent manual trigger. The amplitude and offset of each channel can be controlled in real time.

1.1 Features

Resolution
12-bit Offset Binary

Memory Depth
128K Samples Per Channel

Analog Outputs
+/-5 Volts From 50 Ohms

Marker Outputs
5 Volt TTL Level

Sample Rate
100 MHz Maximum Sample Rate
256 Step Sample Rate Divider
10 MHz Maximum Practical Output Frequency

Offset And Gain
10-bit Offset Binary Resolution Over Analog Range

Trigger Input
Rising Edge 5 Volt TTL Level Into 470 Ohms

Trigger Output
Rising Edge 5 Volt TTL Level

2.0 Front Panel Connections

2.1 Inputs

Trigger is the external trigger input. This input is a 5V TTL level signal with a 470 ohm impendence. The external trigger is ignored unless set by software as active. When the AF1010 is in external trigger mode, a single cycle of the programmed waveform will be presented at the output following a rising edge on the trigger input. Additional rising edges are ignored until the entire waveform cycle is completed. This trigger event is equivalent to a manual trigger activated from software.

2.2 Outputs

Channel A and Channel B are the respective analog outputs. These signals can be up to +/- 5 volts depending on the offset and gain settings and have a 50 ohm source impedance.

Marker A and Marker B are the marker outputs related to the respective channel. These outputs are 5V TTL level signals. They are typically used to mark a particular time point in the waveform. The width will be one sample time which is defined by the sample rate in use.

Trigger Out presents a 5V TTL level rising edge on the occurrence of internal or external trigger. This signal will therefore always occur just prior to the first sample of the waveform cycle.

3.0 Using AF1010 Software

The AF1010 software can not function by itself. It must be installed as part of the Data Design TM1000 system. All software for Data Design modules, including the AF1010, will be installed when the base unit software is installed. There are no additional installation steps. All that is required is to start the TM1000 system manager. Upon installing the module in a connected TM1000 base unit, the module should be identified by the system manager shown in Figure 3.1 below.

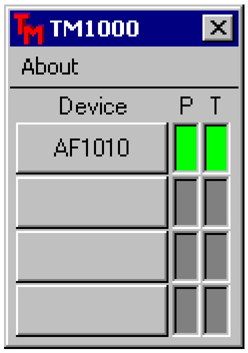

Figure 3.1 TM1000 System Manager

Start the AF1010 control panel application by clicking on the button labeled AF1010. A splash screen will appear while the module is configured. After a moment the main window will appear as shown in Figure 3.2 below.

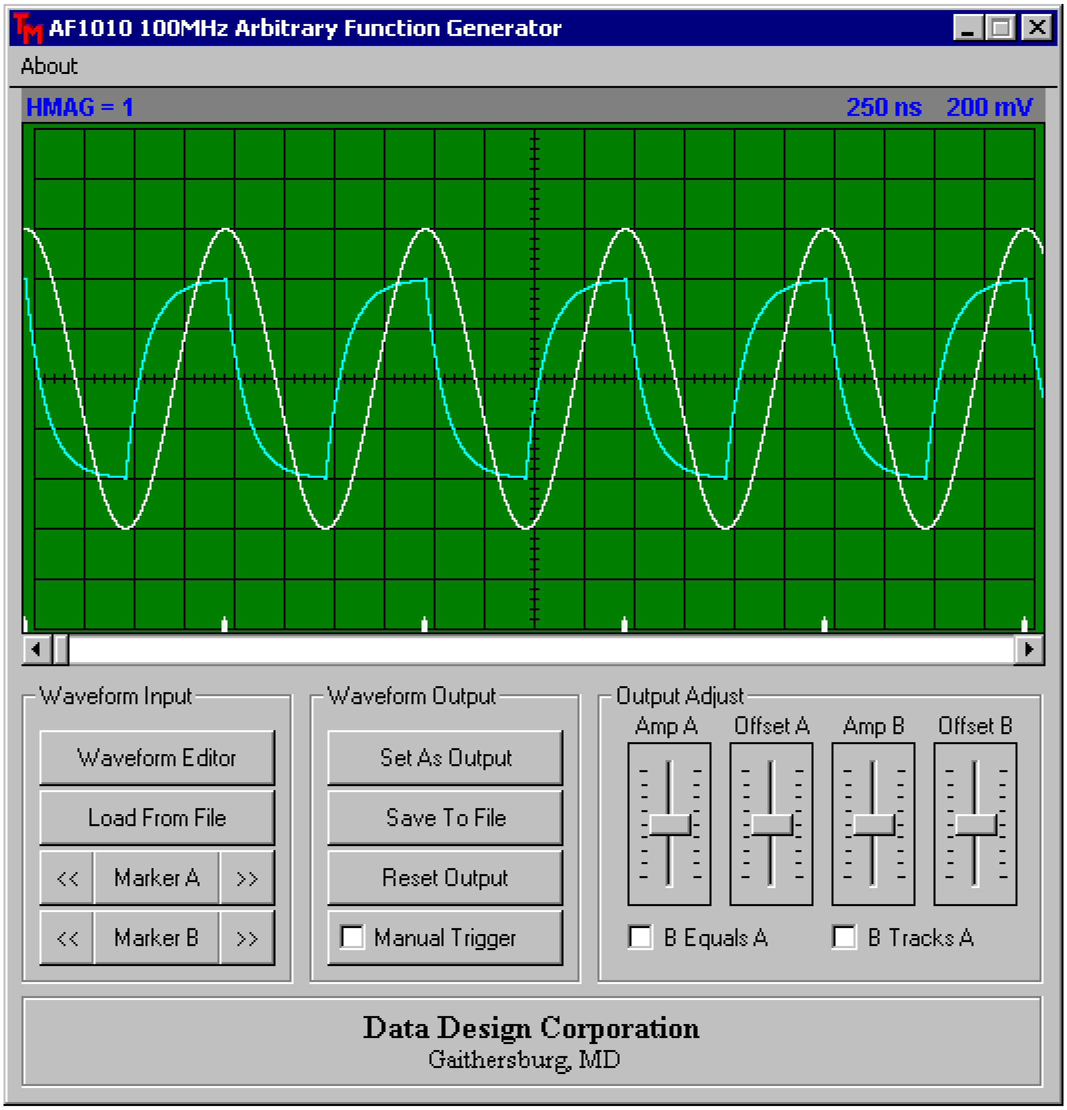

Figure 3.2 AF1010 Software Main Window

3.1 AF1010 Software Basics

There are three basic steps to operating the AF1010 arbitrary function generator. These steps are summarized here and detailed in the following sections.

1) Create and examine prototype waveforms with the waveform input controls
2) Output waveforms to the AF1010 using the waveform output controls
3) Adjust the output as needed using the waveform adjustment controls

Prototype waveforms are created with a voltage range of –1000 mV to +1000 mV. There is one prototype for each channel. Each channel must have the same number of samples per cycle (period) as the other channel, but can have an arbitrarily different wave shape.

As waveforms are entered they are examined in the waveform display on the main window. The characteristics of this display can be changed by double clicking it to obtain the dialog shown in Figure 3.3 below. This dialog allows the selection of elements to display and the colors of those elements. Click on a color box to change it. Check or uncheck a display item box to display or remove the item. Saving the configuration as the default will cause the new settings to be restored the next time the software is started. These are also the settings recalled when the *Restore Defaults* button is clicked.

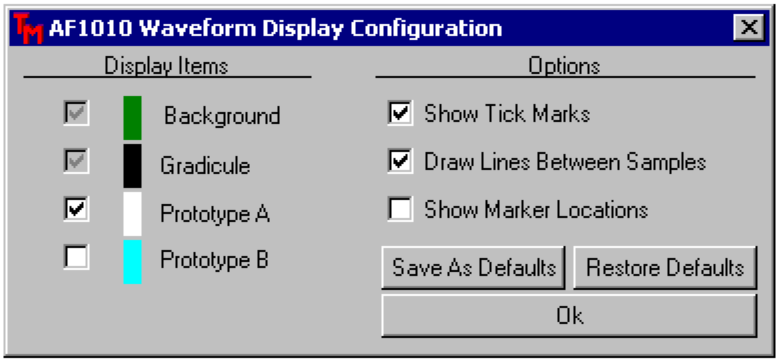

Figure 3.3 Waveform Display Configuration Dialog

The displayed waveform can be zoomed using the HMAG function. This indicator is shown in the upper left corner of the waveform display. The number represents the number of samples in the actual waveform skipped between samples displayed. The number ranges from 1 to 256 and can be increased by left clicking the indicator and decreased by right clicking the indicator. The software will automatically attempt to curtail screen aliasing by limiting the range as appropriate for the waveform being displayed.

The indicators in the upper right corner of the display represent the metrics of the prototype waveforms being displayed. These numbers are per gradicule division similar to those presented on an oscilloscope.

Only a single period of a waveform is ever written to the module. However, it can be useful to view multiple cycles on the screen. The waveform display is designed to resemble the entire memory of the module regardless of how many samples are actually loaded. Therefore, the waveform display will allow the user to “scroll through memory.” The slider at the bottom of the waveform display represents what would be the entire memory. The size of the slide control represents the portion currently being viewed. The HMAG and slider controls can be used to zoom in on a portion of a waveforms which take a substantial portion of the physical memory or to give the impression of time for shorter period waveforms which take less of the physical memory. The waveform display can also be scrolled by clicking an holding the left mouse button on the waveform display and moving the mouse.

3.2 Waveform Input

Waveform input is initiated from the controls at the lower left of the main window. Standard and complex waveforms can be created using the *Waveform Editor* dialog or a custom waveform can be a read from a file. Waveform input is the process of creating a prototype for each channel which can be loaded to the AF1010 hardware. The prototype waveform has an overall maximum signal swing of –1 volt to +1 volt. Distortion of the output waveform is minimized when as much of this signal range as possible is used in the prototype.

3.2.1 Waveform Editor

Click the *Waveform Editor* button on the main window and the dialog of Figure 3.4 appears. This dialog allows the current prototype waveform to be established or altered. In working with the waveform editor, the user creates an imaginary waveform called the editor waveform as described by a list of attributes. These attributes are the period information at the lower right of the dialog and the information in the *Waveform Geometry* frame.

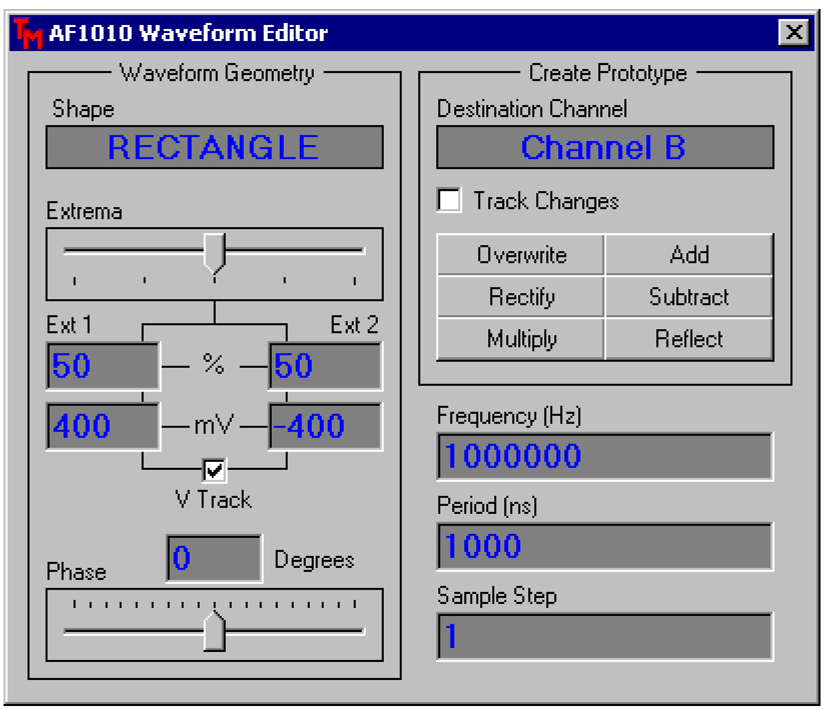

Figure 3.4 Waveform Editor Dialog

The frequency of the editor waveform can be set in terms of frequency or period. Changing one automatically changes the other. The period is in fact the governing factor as this number will in effect specify the number of samples in a single cycle of the waveform. The sample step alters the frequency without altering the period by specifying the number of samples of each cycle of the described waveform to skip in generating each cycle of the editor waveform. The sample step control thereby creates a waveform which appears to have a higher frequency than the editor waveform period would imply.

3.2.1.1 Modifying The Prototype Waveforms

The *Create Prototype* frame determines which prototype waveform is to be affected and in what way. The following is a description of each control.

Destination Channel

The *Destination Channel* box specifies which channel's prototype waveform will be affected by other controls in the *Create Prototype* frame.

Overwrite

The *Overwrite* button causes the editor waveform to be written to the prototype waveform for the channel specified. The waveform can then be observed in the main window display. The other channel prototype will also be overwritten if the editor waveform has a different period than the existing prototypes. Otherwise, just the specified channel is affected.

Track Changes

If *Track Changes* is checked, then every time a changes is made to the editor waveform the changes are automatically written to the prototype waveform of the specified channel just as if *Overwrite* had been pressed. This feature allows the user to monitor changes on the main window waveform display as they are made.

Add

The *Add* button causes the editor waveform to be added to the prototype of the specified channel. This is a point by point addition which allows complex additive waveforms to be created. The final period will be the longer of the two.

Subtract

The *Subtract* button acts in reverse to addition as a point by point subtraction for the same purpose.

Multiply

The *Multiply* button performs a point by point multiplication of the editor waveform and the prototype of the specified channel. The resulting period will be the longer of the two. This function allows signals to beat together such as in amplitude modulation.

Rectify

The *Rectify* button sets all negative samples of the specified prototype waveform to zero. The editor waveform is not used in any way.

Reflect

The *Reflect* button changes the sign of all samples of the specified prototype waveform. The editor waveform is not used in any way.

3.2.1.2 Specifying The Editor Waveform

The *Waveform Geometry* frame allows the user to parametrically describe the editor waveform to be used in modifying the prototype waveforms. The following is a description of these controls.

Shape

The *Shape* control specifies the shape of the elementary cycle of the editor waveform. The shape is selected by clicking the control. The available shapes are rectangle, triangle, sine, exponential, and noise. The noise shape presents pseudorandom numbers for each sample. The seed for these numbers is set by the phase control, so the sequence is always repeatable.

Extrema

With the exception of the noise wave shape, there are two extrema per elementary cycle. The controls in the group under the label *Extrema* specify the relationship between the two extrema. The extrema are defined as *Ext 1* and *Ext 2*. The sample step control could be used to effectively increase the number of extrema in a single cycle by adding elementary cycles. However, the waveform geometry will define a single elementary cycle.

The box marked *%* controls the percentage of each period's samples used in the transition between one extreme and the other. The box under *Ext 1* specifies the portion of a period required to transition from *Ext 1* to *Ext 2*. The *Ext 2* value is the return trip and will always be 100 minus the *Ext 1* value. For the rectangle wave shape, the values represent the number of samples spent an each extreme and therefore the duty cycle. These values can be entered manually or can be adjusted with the slider.

The box marked *mV* represents the voltage of each extreme in the range of –1000 to +1000 millivolts as required by the prototype. Generally, waveforms should be created with the full available amplitude but may need to be smaller for use with the prototype math functions. If *V Track* is checked, each time a voltage setting is changed the opposite extreme will automatically switch to the same voltage with the opposite polarity. If *V Track* is not checked, the extrema bear no such relationship.

Phase

The editor waveform is created starting at *Ext 1*, going to *Ext 2*, and returning to *Ext 1*. The final editor waveform can be shifted from this starting point by a given number of degrees using the *Phase* control. The phase shift can be –180 to +180 degrees and can be entered manually or with the slider. For the noise wave shape, the phase sets the seed value of the pseudorandom number generator.

3.2.1.3 Waveform Editor Examples

The parametric creation of waveforms can be very powerful. The following examples may be useful in getting started with the waveform editor.

Example 1 – Create a 1000 Hz positive ramp for channel A.

Type a frequency of 1000 Hz in the *Frequency* control box. Press enter or click somewhere else and the period will change accordingly. In the *Waveform Geometry* frame, select a *Shape* of triangle. Under *Extrema*, make sure *V Track* is checked. Under *Ext 2* enter 0 in the *%* box. The *Ext 1 %* box will adjust to 100. Enter a large positive value in the *Ext 2 mV* box. A negative value of the same size will appear n the *Ext 1 mV* box. In the *Create Prototype* frame, select channel A and click *Overwrite*. The positive ramp will appear on the waveform display.

Example 2 – Create a 1 MHz sine wave on channel A with noise at a signal to noise ratio of 10.

Type a frequency of 1000000 Hz in the *Frequency* control box. Press enter or click somewhere else and the period will change accordingly. In the *Waveform Geometry* frame, select a *Shape* of sine. Under *Extrema*, make sure *V Track* is checked. Under *Ext 1* enter 50 in the *%* box. The *Ext 2 %* box will adjust to 50. In the *Ext 1 mV* box enter 800. The *Ext 2 mV* box will adjust to –800. In the *Create Prototype* frame, select channel A and click *Overwrite*. The sine wave will appear on the waveform display. Select a *Shape* of noise. Under *Ext 1 mV* box enter 80. The *Ext 2 mV* box will adjust to –80. In the *Create Prototype* frame, select channel A and click *Add*. The final noisy waveform will appear in the waveform display.

Example 3 – Create an AM modulated waveform on channel A with a 1 MHz sine wave carrier and a 10 KHz sine wave modulation.

Type a frequency of 1000000 Hz in the *Frequency* control box. Press enter or click somewhere else and the period will change accordingly. In the *Waveform Geometry* frame, select a *Shape* of sine. Under *Extrema*, make sure *V Track* is checked. Under *Ext 1* enter 50 in the *%* box. The *Ext 2 %* box will adjust to 50. In the *Ext 1 mV* box enter 600. The *Ext 2 mV* box will adjust to –600. In the *Create Prototype* frame, select channel A and click *Overwrite*. The carrier sine wave will appear on the waveform display. Type a frequency of 10000 Hz in the *Frequency* control box. Uncheck the *V Track* box. Under *Ext 1 mV* enter 300. Under *Ext 2 mV* enter 400. In the *Create Prototype* frame, select channel A and click *Multiply*. The final modulated waveform will appear in the waveform display.

Example 4 – Create 10 KHz square waves on channels A and B in quadrature.

Type a frequency of 10000 Hz in the *Frequency* control box. Press enter or click somewhere else and the period will change accordingly. In the *Waveform Geometry* frame, select a *Shape* of rectangle. Under *Extrema*, make sure *V Track* is checked. Under *Ext 1* enter 50 in the *%* box. The *Ext 2 %* box will adjust to 50. In the *Create Prototype* frame, select channel A and click *Overwrite*. The square wave will appear in the waveform display. Set the *Phase* control to 90. In the *Create Prototype* frame, select channel B and click *Overwrite*. The two prototype waveforms in quadrature will now appear in the waveform display.

Example 5 – Create a 10 KHz sine wave on channel A and a 20 KHz sine wave on channel B

Type a frequency of 10000 Hz in the *Frequency* control box. Press enter or click somewhere else and the period will change accordingly. In the *Waveform Geometry* frame, select a *Shape* of sine. Under *Extrema*, make sure *V Track* is checked. Under *Ext 1* enter 50 in the *%* box. The *Ext 2 %* box will adjust to 50. In the *Create Prototype* frame, select channel A and click *Overwrite*. The sine wave will appear in the waveform display. Set the *Sample Step* control to 2. In the *Create Prototype* frame, select channel B and click *Overwrite*. A sine wave with 20 KHz frequency will appear the waveform display as the channel B prototype while the channel A remains at 10 KHz.

3.2.2 Loading A Waveform From A File

Often times it is desirable to load a waveform from a file created manually or stored from a recording device such as an oscilloscope or chart recorder. This can be accomplished on the AF1010 using the *Load From File* button on the main window. A standard file dialog will appear allowing the input file to be selected.

The waveform file is an ASCII text format as specified in a Appendix A. All data must be translated to this format to be used. The file is a point by point representation of the prototype waveform. The waveform is loaded into the prototypes of both channels. The waveform editor can be used to add information to the waveform with the same rules as any other waveform.

The waveform editor derives the sample rate from the specified period by selecting the fastest rate possible which still allows the entire cycle to fit in the physical memory. In contrast, the waveform file specifically specifies a sample rate. The period in seconds is determined by this rate and the number of samples in the file. The number of samples is limited only by the physical memory size of 131072 samples.

3.2.3 Marker Locations

The marker is a positive going 5V TTL pulse which is time correlated to the output waveform of each channel. The marker pulse will always appear at the marker output at some point during the cycle. By default the marker appears at the same time as the first sample of the cycle. The location of the marker with respect to the cycle can be viewed on the main window waveform display if enabled in the display configuration. The marker is portrayed as a small icon at the bottom of the view box with one such icon shown for each cycle of each channel in the color of the prototype waveform for the corresponding channel.

The controls *Marker A* and *Marker B* are used to set the location of the marker for the corresponding channel. Click the center button to move the marker by ten percent of the cycle. Click the arrow buttons to move the marker by one sample time.

3.3 Waveform Output

After prototype waveforms are created for each channel they can be output to the AF1010 module or saved to a file for later retrieval. The *Waveform Output* frame on the main window contains controls for this process. These are straight forward and are described briefly below.

Set As Output

The *Set As Output* button converts the prototype waveforms to samples usable by the AF1010 and sends them to the module. Clicking this button causes the prototype waveform information to appear on the analog and marker outputs. Both channels are loaded. Note that the output waveforms will follow the prototypes in shape only. The amplitude and offset will be affected by the output adjustment controls as described in section 3.4 below.

Save To File

The *Save To File* button brings up a standard file dialog allowing the prototype for channel A to be saved to a file in an ASCII text format as described in Appendix A. This file can be loaded as waveform input at a later time as described in section 3.2.2 above.

Reset Output

The *Reset Output* button causes the prototype waveforms to be reset to all zeros and outputs them to the AF1010 module. This can be used as a means of turning off and clearing the instrument and the user interface. Any offset will still apply.

Manual Trigger

The *Manual Trigger* button is a two stage control. Although the manual trigger can be initiated at any time, it won't do anything until the check box is checked. When the check box is not checked, the AF1010 is free running and automatically retriggers a new cycle as each cycle ends. When the check box is checked the AF1010 is in external trigger mode. An external trigger can be issued with a 5V TTL positive edge on the front panel trigger input or by clicking the *Manual Trigger* button. Either source of external trigger will cause a single cycle of the installed waveform to be output. At all other times the output will be inactive. Any offset will still apply.

3.4 Output Adjustments

The controls in the *Output Adjust* frame of the main window can be used to adjust the amplitude and offset of waveforms already installed in the AF1010 module. The controls are uncalibrated adjustments intended to be used in conjunction with an external measuring device such as an oscilloscope. These controls will also be affected by any amplitude and offset information built into the prototype waveform itself. For added flexibility, tracking functionality is built into the control panel as follows.

B Tracks A

If the *B Tracks A* control is checked, moving the A controls will move the B controls in unison. Differences between amplitude A and amplitude B will be maintained as will differences in the offset controls. The B controls can be moved without affecting the A controls, thereby allowing the differences to be changed.

B Equals A

If the *B Equals A* control is checked, then *B Tracks A* is set by definition, but also the controls for channel B are set to be equal to the controls for channel A. The channel B controls are disabled as long as *B Equals A* is checked. All control will be from channel A controls.

Appendix A Waveform Data File Format

The waveform data file is a raw text file containing a single column of data for a waveform with one data point on each line. The first two lines indicate special information about the waveform to be loaded. The format is as follows.

Line 1 contains the text string "AF1010" and no other characters. This line provides some level of indication that the file is intended for the AF1010.

Line 2 contains the sample rate. More specifically it contains the sample clock divisor which means that the number given represents the number of 10ns periods between samples.

Line 3 to Line N contain sample values of the prototype waveform expressed in millivolts in the range –1000 to +1000. The number of samples in the waveform will be determined by the number of lines as N-2.