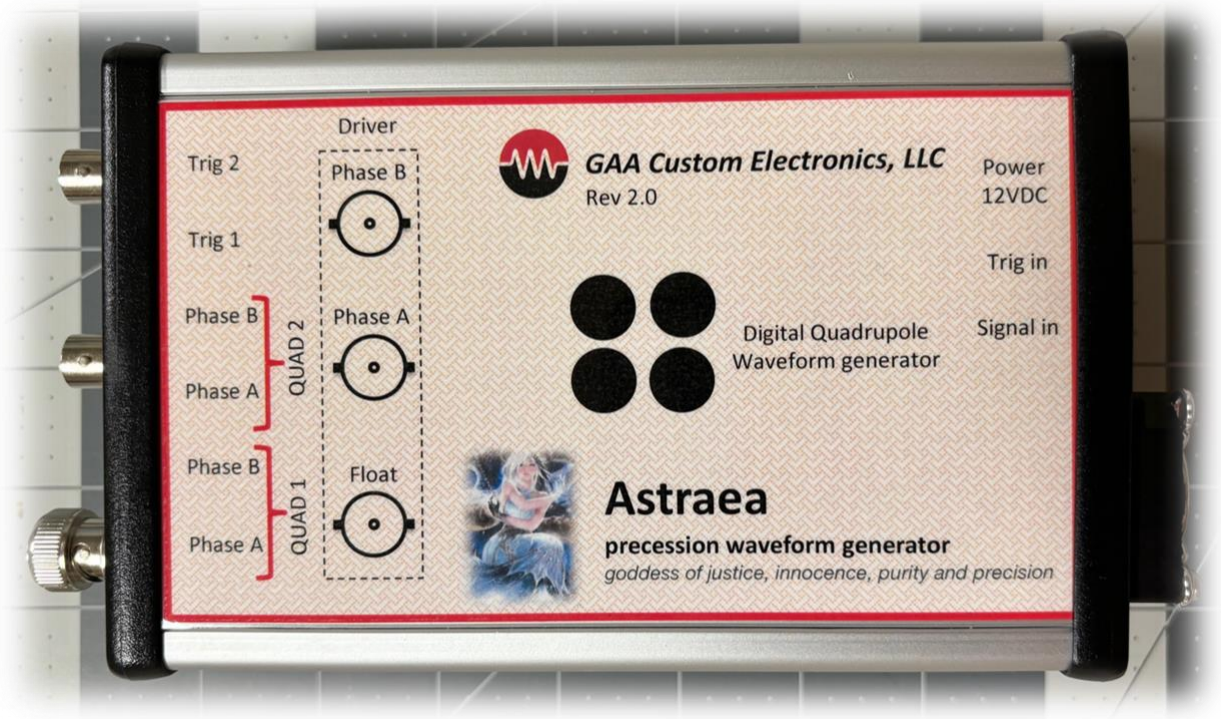
Astraea

Precession Waveform Generator

Operations Manual
Rev 1.0, January 26, 2024
Revised June 1, 2024



GAA Custom Electronics, LLC
www.GAACustom.com
gaa@gaa-ce.com

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WARNING

TO REDUCE THE RISK OF FIRE OR ELECTRICAL SHOCK DO NOT EXPOSE THIS EQUIPMENT TO RAIN OR MOSITURE.

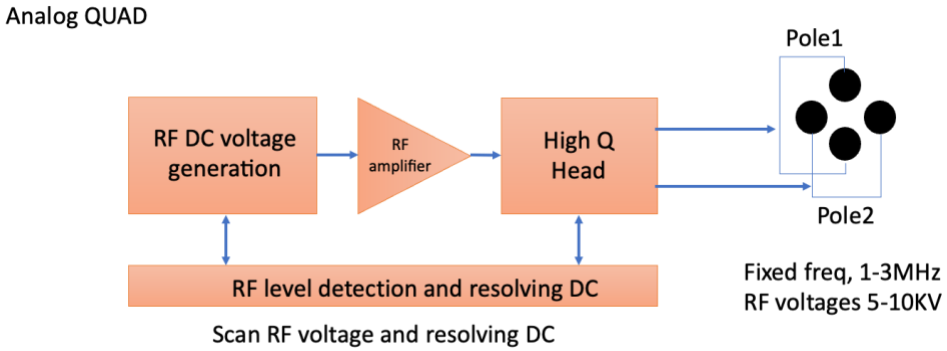
WARNING

Only qualified electrical workers should operate and install this system.
Avoid spilling liquids onto/into the unit.
Do not expose to excessive heat or moisture.
Do not open – there are no user serviceable parts inside.
Do not block the chassis vent slots or the fan inlet.
Do not operate in an explosive environment.

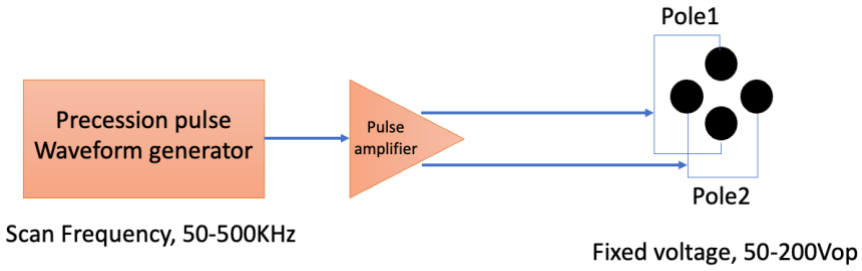
Introduction

Astraea is a precision waveform generator designed to generate variable frequency variable duty cycle digital waveforms to control a quadrupole, often called digital quads. Astraea's low voltage output waveforms are then amplified using pulse amplifiers before coupling to a quadrupole.

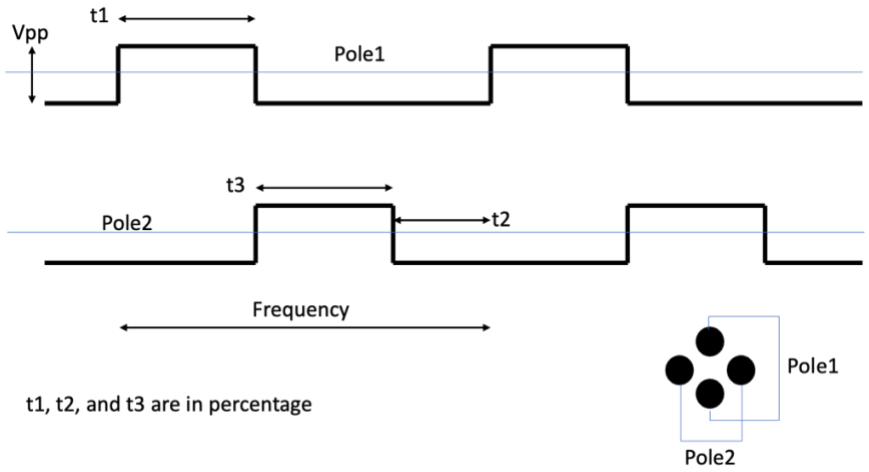
Analog or conventional RF quadrupole systems use high Q resonate circuits to develop high voltage RF signals (sinusoidal) that are applied to the quadrupole along with resolving DC voltage. The RF frequency and voltage coupled with the DC voltage will allow a specific m/z rage to pass through the quadrupole to a detector. A m/z spectrum is generated by scanning the RF amplitudes and DC voltages. The diagram below shows the key elements of a conventional quadrupole system.



Digital quad system supported by Astraea control the quadrupole using variable pulse width signals with fixed amplitudes at much lower voltages. The m/z scanning is performed by varying the frequency. The diagram below shows the key elements of a digital quadrupole system.

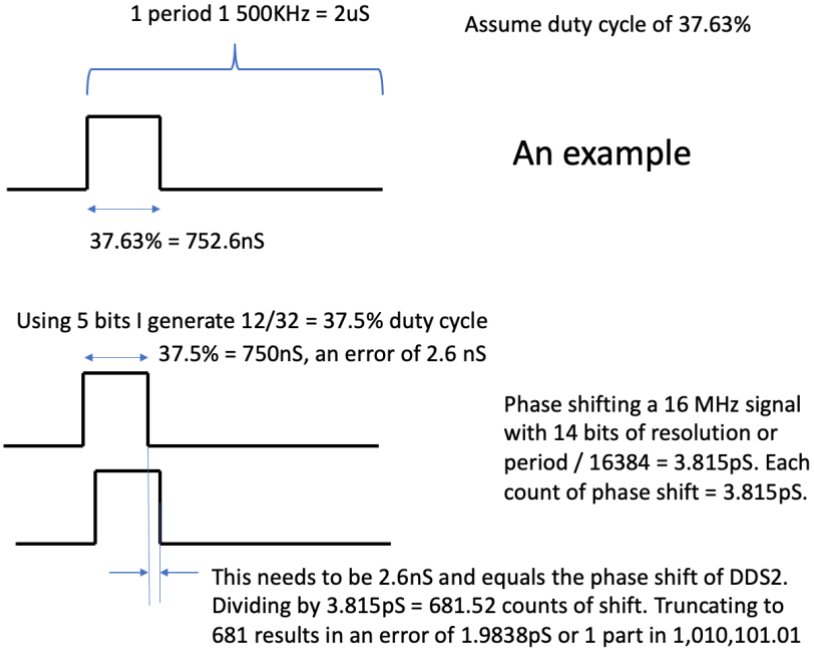


The waveforms that are applied to the quadrupole poles have user definable duty cycles, the diagram below shows details and the parameters used to describe the waveforms.



Astraea is a hybrid precision waveform generator that uses digital counters to create a low-resolution approximation of the waveform and then combines phase delayed copies of the waveform to achieve high precision. Finally, the errors are minimized by optimizing the ratio of the low-resolution waveforms and the phase delayed copies. This technique is used to generate precision Pulse Width Modulated (PWM) waveform to support digital quadrupoles.

High precession and low jitter waveforms are required to enable high system performance and allow operation in higher stability zones. Astraea generates the waveforms using a combination of high-speed FPGA, multichannel DDS and high-speed microcontroller. Below is an example of how Astraea generates a 1ppm duty cycle signal.



Digital quadrupole technology promises to allow access to higher stability zones by adjusting the waveform duty cycles. The paper referenced below defines the operation details and advantages of this technology.

> *Will the Digital Mass Filter Be the Next High-Resolution High-Mass Analyzer? Peter T. A. Reilly,* Sumeet Chakravorty, Conner F. Bailey, Fatima O. Obe, and Adam P. Huntley*

Astraea's control features allow the user to dynamically change the waveform (agility), for example you can generate a waveform sequence where you define number of waveform cycles then change the waveform duty cycle and generate another user defined number of cycles. This allows you to rapidly transition between different stability zones.

Relationship between m/z and frequency.

$m/z = ((9.775e6)Vo\text{-}p)/(Q * Ro^2 * F^2)$

Where:

Vo-p	= The voltage base to peak applied to the Quadrupole poles
Q	= Quadrupole Q parameter
Ro	= Inscribed Quadrupole radius in mm
F	= Frequency in Hz

Features

Astraea has been designed to support the development and demonstration of Digital quadrupole system. Below is a list of features currently supported:

- Low voltage waveform generation for 2 quads
- 50KHz to 500KHz frequency operation
- 5% to 95% duty cycle control
- Independent control of each quad pole duty cycle
- Independent control for each quad
- Both quad channels can be locked or synced
- Ability to define quad parameters
- Calculates m/z and frequency using quad parameters
- Agility control features allowing complex waveform dynamic sequences
- Two trigger outputs
- One trigger input
- ADC channel for data acquisition
- Can be externally triggered
- Can generate a control trigger signal
- Scanning capability, frequency, m/z, or duty cycle scanning

- Optional internal +/-100V pulse amplifier for one quad channel
- Small size
- Low power, wall supply
- USB interface to host computer
- Host computer interface application
- FPGA and embedded microcontroller can be upgraded to add new features

Models

Astraea is available in two configurations: a low voltage waveform generator only and a version that includes the optional +/-100V pulse amplifier. Throughout this document, the illustrations will showcase the model that includes the pulse amplifier. This pulse amplifier is internally connected to the Quad 1 outputs of the low voltage waveform generator.

Scanning

Astraea supports scanning over a defined frequency or m/z range as well as scanning duty cycle parameters. A scan is described by defining the start and stop for the scan range, the number of scan steps to perform and the number of waveform cycles to dwell at each scan point. Analog data from the signal input is collected during a scan and plotted in real time when using the host application.

Astraea generates two sets of quad signals. Scanning can be applied to either quad set. The two quad sets can be synced and thus scanned together or one of the quads can stay at a defined frequency or m/z value.

Agility

Agility refers to Astraea ability to define complex waveform sequences. This is done by first defining states where a state is a set of quad parameters:

- Name (single lower case alpha character name)
- Quad channel reference
- Q
- t1
- t3
- Number of waveform cycles

Additionally, each state support optional parameters, these parameters are disabled when the initial state is created.

- Fmult, this is a multiplier applied to the calculated frequency

- Fixed m/z, this option allows the state to operate at a user defined fixe m/z value that is not changed during a scan

After defining all the necessary states for your implementation, you can create a state sequence table that outlines the order in which you should execute these states. This table enables the generation of trigger signals, waiting for external triggers, and defining data acquisition cycles. These features facilitate the construction of systems comprising multiple Astraea systems and controlling multiple quads.

A state table is a sequence of user-defined states and commands that instruct the state processor to perform specific actions. The state table is processed in a sequential manner, starting from the beginning of the string and proceeding until the end. Valid state table options and examples are provided below.

a thru z, define a state to be set
D, delays in milliseconds
W, wait for trigger input rising edge
T, generate output trigger pulse on Trig2
/, Trig2 output high
\, Trig2 output low
C, collect flag, collect data on next event
R, report data and clear the accumulator
H, set flag to wait for host reply on report, only use for non-buffered scanning
[, start of a loop
], end of loop
E, enable quad outputs, followed by 1 or 2
O, disable quad outputs, followed by 1 or 2

All state commands can be followed by a value. If no value is specified, a default value of 1 is used. During the processing of the state table, some commands may block or halt the table processing until the command completes.

- a through z state commands will block until the specified number of waveforms are generated. If the number of waveforms is set to zero for a state, the system will not block, and the state parameters will be set. This option should only be used when synchronizing two quads.
- The D command will delay the table processing for the defined delay time in mS.
- The W wait for trigger command will stop the table processing while the system wait for a trigger input pulse.

Example sequence tables.

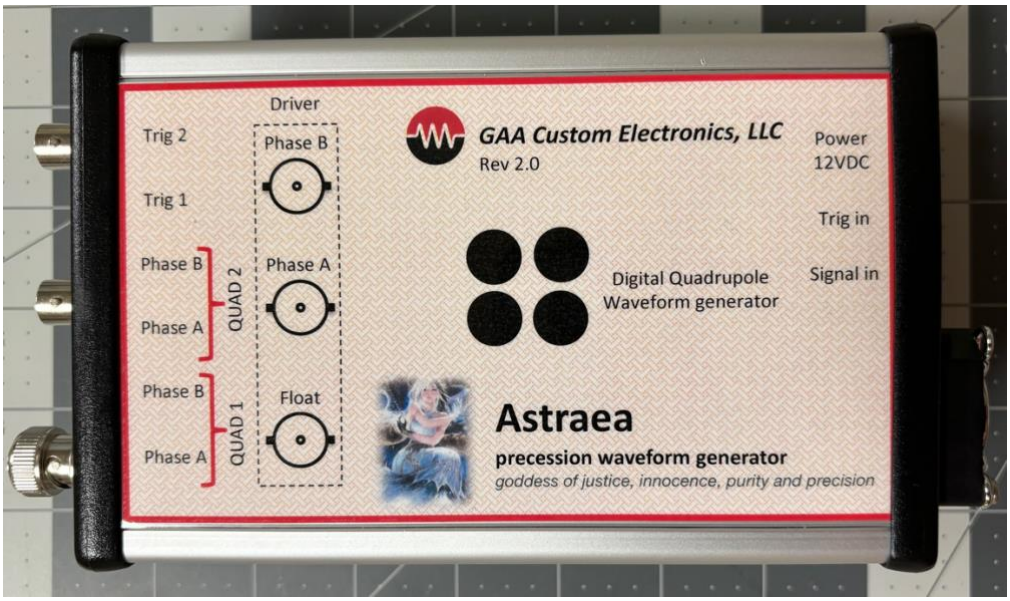
ab	Simple table that executes state a followed by state b
a10b4	State a is executed 10 times followed by state b that is executed 4 times

ab[rt]10	States a and b are executed one time and then a loop is entered where states r and t are executed in sequence and repeated 10 times
WaCbR	The state processor waits for an external trigger and then executes state a, sets a flag to cause data collection on the next state and executes state b while collecting a data point and finally report the data

Three separate sequenced can be defined in Astraea: the main sequence that is processed for every point during a m/z scan, the pre-scan sequence processed before a scan starts, and the post-scan sequence processed after a scan completes.

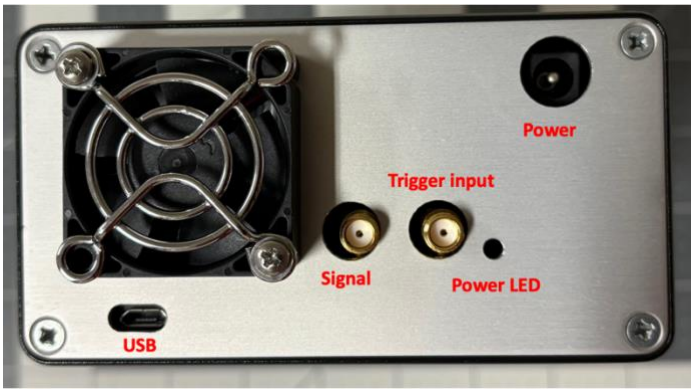
Connections

The input and output connections to Astraea are on the two side panels. The top cover label identifies the connections, the side panels are not labeled. The connection details are defined below. The documentation below shows Astraea with the internal +/-100V pulse amplifier option installed.



Astraea top cover

Right Side Connections



Power

12VCD power input (center positive) wall supply connections. A 40-watt 12-volt wall supply is provided with your system. If the internal pulse amplifier module is installed. A 7.5VDC wall supply will be used for the model without the pulse amplifier; only use the supply provided.

Power LED

This is a green LED indicator that will light when power is applied.

Trigger input

TTL logic level trigger input, SMA coax connection.

Signal

Detector signal input, analog 0 to 2.5V, SMA connection.

USB

USB micro connection to host control computer. A USB cable is provided with your system.

Left Side Connections

The top row of BNC connectors supports the optional pulse amplifier. These connections will enable Astraea to directly drive a quadrupole.

Float

The pulse amplifier is isolated and this input allows application of a float voltage, +/-250V. The Phase A and B outputs will be

referenced to this float input voltage. Do not leave this input open, a shorting BNC cap is installed on this connector with your system. **Only install this shorting cap on the float input!**

Phase A

Phase B

The phase outputs connect to your quadrupole. These connections should be a short as possible to minimize the capacitive load on the driver. 50-ohm coax cable is 30 pF per foot, the capacitance per foot reduces as the cable impedance increases. We recommend using RG62, 93-ohm cable. The total capacitive load to ground on each phase should be less than 100pF.

The second row of SMA connectors supports the Astraea's low voltage waveform signals and trigger outputs.

Quad 1

Quad 1 Phase A and B output control signals. These are 0-to-5-volt fast rise and fall time signals intended to drive a pulse amplifier. These outputs are intended to drive a 50-ohm coax cable that is properly terminated to prevent ringing. Note Quad 1 signal are internally routed to the optional +/-100V pulse amplifier option. If this option is installed these phase outputs are still operational and these phase signals also control the internal pulse amplifier.

Quad 2

Quad 2 Phase A and B output control signals. These are 0-to-5-volt fast rise and fall time signals intended to drive a pulse amplifier. These outputs are intended to drive a 50-ohm coax cable that is properly terminated to prevent ringing.

Trig 1

Trig 2

The Trig 1 and 2 outputs are TTL level trigger outputs that Astraea uses to signal external system. These outputs are not designed to drive 50-ohm loads.

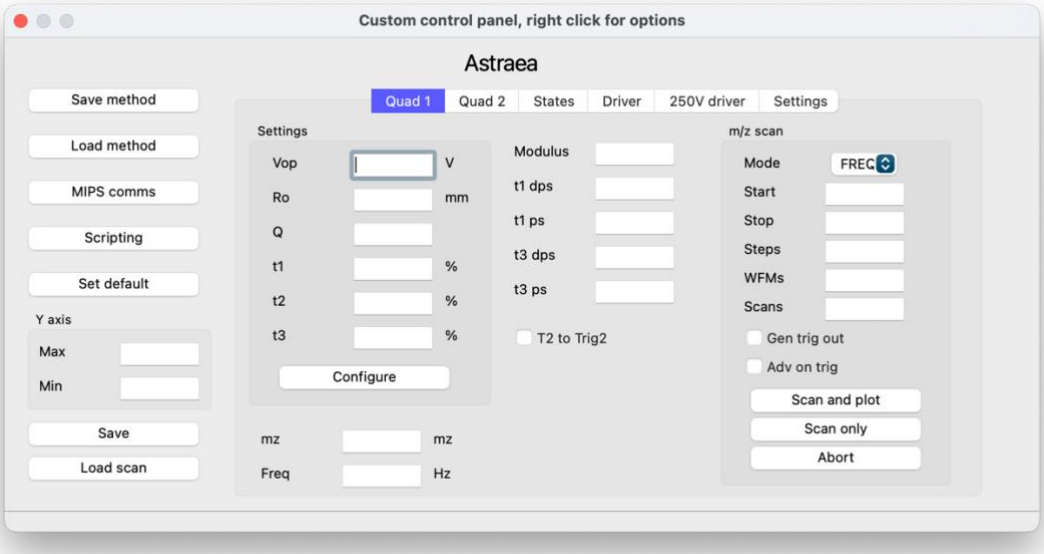
QUAD Driver Module

The optional +/-100V quad driver or pulse amplifier module enables Astraea to drive a quadrupole without the need for any external systems. The output voltage can be programmed using the host interface provided with your system. This driver allows you to control the positive and negative voltage levels for each of the quadrupole's phases. For instance, you can set phase A to be +100V and phase B to be -90V if required in your application. This independent voltage control enables the application of resolving DC and offset voltages, which are useful in tuning your system.

The power required by the pulse amplifier depends on the load capacitance. It is important to keep this capacitance as low as possible by using high-impedance cable and minimizing the length of the connections.

Operation

The USB interface and host commands, as outlined in Appendix B, can be used to control Astraea. The MIPS host application, which utilizes the Astraea control panel, offers a user-friendly interface that seamlessly integrates with the Astraea low-voltage waveform generator, the internal rod driver, and the external +/-250V rod driver. This interface provides scanning support for both quads, data collection, and plotting capabilities. For more information, refer to the AstraeaUserGuide.



Warrantee

GAA Custom Electronics, LLC warrantees the Astraea system to be free from defects in materials and workmanship and will repair or replace the unit for a period of one year. This warrantee assumes the system is operated in compliance with the procedures and recommendation outlines in this document. GAA Custom Electronics, LLC will also provide free phone support and firmware bug fixes for up to one year. The addition of new features is not covered in this warrantee.

Liability

The liability of GAA Custom Electronics, LLC hereunder or otherwise is solely and exclusively limited to replacement, repair or credit at the purchase price, as GAA Custom Electronics, LLC may elect, for any product which is returned by Buyer during the applicable warranty period, or services for which timely notice of defect has been given by Buyer, and which are found by GAA Custom Electronics, LLC to be subject to adjustment under this warranty. IN NO EVENT SHALL GAA Custom Electronics, LLC BE LIABLE FOR SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES, LOSS OF ANTICIPATED PROFIT OR OTHER ECONOMIC LOSS OR FOR ANY DAMAGES ARISING IN TORT WHETHER BY REASON OF STRICT LIABILITY, NEGLIGENCE OR OTHERWISE.

Appendix A, Specifications

Appendix B, Host Computer Interface

All commands are ASCII text.
All commands sent to Astraea are terminated with a carriage return (CR) or line feed (LF) character.
All messages sent from Astraea are terminated with a CR and LF.
After a command is received (after the CR or LF is received) Astraea will respond with an ASCII ACK (0x06) then a CR or an ASCII NAK (0x15) then a "?" character and a finally a CR. A NAK indicates the command or its arguments was not understood.
When a NAK is sent the "?" character is sent to inform users communicating with a terminal emulator that the command was not understood.

General Commands

GVER

Returns the current version string.

GERR

Returns an integer error code indicating the reason for the last NAK. This value is never cleared and always indicates the communications last error.

SNAME,<Name>

This command will set the Astraea system name. The Name value is a user defined string. Make sure you issue a Save command to save the changes to non-volatile memory or this name will be lost when power is cycled.

GNAME

Returns a string that contains the name of the MIPS system.

GCMDS

This command will cause the Astraea system to report a list of valid commands that it understands.

DELAY,<Value>

This command will result in a delay of the defined number of millisec. This function is useful for defining macros where you are gradually changing voltage, for example ramping up the voltage on a system.

Where:

Value = number of millisec to delay.

RESET

This command will cause the Astraea control computer to reboot.

MUTE, <Value>

This command will stop all messages from the Astraea system to the host computer. The received commands will still be processed but no response will be issued. The value parameter turns this mode on and off where:

Value = OFF to turn the responses on and ON to silence the Astraea system.

ECHO,<TRUE or FALSE>

Setting ECHO true will cause Astraea to include the command with all responses.

THREADS

The Astraea system uses a threading control and each module runs on its own Thread as well as a number of threads for control functions. This command displays all the threads and few key parameters. This command is used to monitor the system and check status, mainly a diagnostic tool.

STHRDENA,<Thread name>,<TRUE or FALSE>

This command allows you to enable or disable a Thread. This is done by using the thread name and defining it as TRUE or FALSE. If set to FALSE then the thread will stop. This is a development and diagnostic tool.

BLOAD

This command will start the bootloader and allow uploading new firmware to the microcontroller using a programming application on your host computer.

Save and Restore Commands

SAVE

This command will save the Astraea controller parameters to the non-volatile memory. These stored settings are automatically loaded when the Astraea system starts.

RESTORE

This command will load the settings from the non-volatile memory. These are the same parameters loaded when the system starts.

SAVECAL

LOADCAL

FORMAT

This command will format the flash memory file system, erasing all saved data. No warning will be displayed after entering this command.

General Operational Commands

Most of the following commands support setting the parameter (the command starting with S) and retrieving the current value of the parameter (the command starting with G). The chan parameter selects the quadrupole channel for the command, and its valid range is 1 or 2.

SSYN,TRUE or FALSE

GSYN

The SSYN command will set the quad sync flag to TRUE or FALSE. If TRUE then the two quads will be synchronized and their frequencies are waveform starting phases will be matched. When this sync flag is TRUE changing the frequency of either quad will automatically change the other. The GSYN command will return the current status of the sync flag.

SMOD,chan,value

GMOD,chan

The SMOD command will set the modulus value used in calculation of the waveform. This is basically the multiplier of the base frequency the system will generate. As an example, if the modulus is set to 10 and the frequency is 100KHz then the DDS frequency will be 1MHz. This command in included for testing and

development, it should now be used in normal operation. The system will automatically determine the optimal modulus to use.

SPHM,value

GPHM

The SPHM sets the phase margin used in the DDS to generate the PWM signals. This parameter is crucial during development and should not be altered without factory recommendations.

SMINF,value

GMINF

The SMINF command enables you to set the minimum output frequency that the Astraea system will generate in Hertz. The default value for this parameter is 10000.

SMAXF,value

GMAXF

The SMAXF command enables you to set the minimum output frequency that the Astraea system will generate in Hertz. The default value for this parameter is 500000.

SSCNTST,TRUE or FALSE

GSCNTST

During scanning, Astraea will disregard the maximum frequency limit if this parameter is set to FALSE, which is the default value for this parameter.

SMINM,chan,value

GMINM,chan

The SMINM command sets the minimum value the system will use for the modulus when it is automatically determining the optimal operating point. This can be used to define the minimum frequency that we be used in the DDS. The system frequency range is 10KHz to 500KHz so a minimum modulus if 10 would limit the lower frequency of the DDS to 100KHz. This command in included for testing and development, it should not be used in normal operation.

SMAXM,chan,value

GMAXM,chan

The SMAXM command sets the maximum value the system will use for the modulus when it is automatically determining the optimal operating point. This can be used to define the maximum frequency that we be used in the DDS. The system frequency range is 10KHz to 500KHz so a maximum modulus if 10 would limit the upper frequency of the DDS to 5MHz. This command in included for testing and development, it should not be used in normal operation.

SFREQ,chan,value

GFREQ,chan

The SFREQ command sets the output frequency (in Hz) of the selected channel, the duty cycle parameters are not changed, only the frequency is updated.

SMZ,chan,value

GMZ,chan

The SMZ command sets the output frequency of the selected channel, the duty cycle parameters are not changed, only the frequency is updated. The frequency is calculated from the m/z value using the following equation:

m/z = ((9.775e6)Vo-p)/(Q * Ro^2 * F^2)

Commands listed below allow the user to define the parameters in this equation.

SV,chan,value

GV,chan

The SV command sets the Vo-p (the base to peak pole voltage) used in the conversion between m/z and frequency.

SRo,chan,value

GRo,chan

The SRo command sets the Quadrupole inscribed radius in mm. This value is used in the conversion between m/z and frequency.

SQ,chan,value

GQ,chan

The SQ command sets the Quadrupole Q parameter. This value is used in the conversion between m/z and frequency.

St1,chan,value

Gt1,chan

The St1 command sets the t1 parameter, in percentage, used in the generation of the output waveform. When t1 is define t2 is set to 0 and t3 is defined as 100 – t1. Note the waveform will not be updated until the CONFIG command is issued.

St3,chan,value

Gt3,chan

The St3 command sets the t3 parameter, in percentage, used in the generation of the output waveform. When t3 is define t2 is calculated as t1 – t3. Note the waveform will not be updated until the CONFIG command is issued.

Gt2,chan

The Gt2 command will report the t2 parameter, in percentage. This parameter cannot be directly defined, it is automatically calculated from t1 and t3.

ST2ENA,chan,TRUE or FALSE

GT2ENA,chan

The ST2ENA command will result in the generation of a pulse on the trigger 2 output that follows (mirrors) the t2 period. If value is TRUE the trigger output signal is generated, if FALSE the signal generation stops.

CONFIG

The CONFIG command uses the t1, t2, and t3 parameters to calculate the internal parameters needed to generate the waveform and updates the hardware to start the waveform generation.

SPHASE,DDSchan,phase

The SPHASE command is a debug command and should not be used, its intended for developers of the system. This command sets the DDS phase offset for the defined DDS channel, 0 thru 1. The phase shift value range is 0 to 16383.

ALINE

The ALINE command is a debug command and should not be used, its intended for developers of the system. This command sets the DDS phase offset to zero for all channels and pulses the DDS reset line.

Monitor Parameter Commands

The following commands monitor system parameters The chan parameter selects the quadrupole channel for the command, the valid range is 1 or 2.

GT1DPS,chan

The GT1DPS command will report the digital phase shift used to generate the t1 signal. This value is used to monitor the system's calculation of the internal parameters used to generate the waveforms.

GT1PS,chan

The GT1PS command will report the DDS phase shift used to generate the t1 signal. This value is used to monitor the system's calculation of the internal parameters used to generate the waveforms.

GT3DPS,chan

The GT3DPS command will report the digital phase shift used to generate the t3 signal. This value is used to monitor the system's calculation of the internal parameters used to generate the waveforms.

GT3PS,chan

The GT3PS command will report the DDS phase shift used to generate the t3 signal. This value is used to monitor the system's calculation of the internal parameters used to generate the waveforms.

GADC

This command returns the raw ADC counts. This is the ADC used for acquiring data from the detector.

Scanning Commands

SSCH,chan

GSCH

This command sets the channel you wish to scan, 1 or 2. This corresponds to Quadrupole 1 or 2.

SSTYP,type

GSTYP

The SSTYP command sets the type for scan or what parameter you intent to change during a sweep. The valid options are:

FREQ = Frequency scan

MZ = m/z scan

T1 = scan of the t1 parameter in percentage

T3 = scan of the t3 parameter in percentage

SSTRT,value

GSTRT

The SSTRT command sets the scan starting value, for example if this is a m/z scan this would be the m/z value at the start of the sweep.

SSTP,value

GSTP

The SSTP command sets the scan stopping value, for example if this is a m/z scan this would be the m/z value at the end of the sweep.

SSTEPS,value

GSTEPS

The SSTEPS command define the number of steps in a scan.

SWPTS,value

GWPTS

The SWPTS command define the number of waveform cycles for each step in the scan or sweep. This constant number of waveforms is used at each point and as a result the lower frequency points require more time per point that the higher frequency points.

SCAN

The SCAN command will start a scan or sweep using the parameters define above. When the system is scanning the signal input (connected to the ADC) is read and averaged. At the end of each scan point a record is sent to the host, the format of this record is:

Step,Xaxis,Signal

Step = the scan step value, 1 thru number of steps

Xaxis = the X axis value for this data point

Signal = ADC average value from ADC reading the signal input value

After this record is sent to the host, the system will wait for a message (any string that is CR LF terminated). If a response is not received within 5 seconds the scan will terminate.

SCANB

SCANABRT

The SCANABRT command will stop or terminate a scan that is in progress.

SSTRG,TRUE or FALSE

GSTRG

The SSTRG command will enable (if TRUE) the generation of a 1uS trigger output pulse, on the trigger 1 output, when a scan data point has been sent to the host while its waiting for a response to signal continuation of the scan. Setting the argument to FALSE will stop the generation of this 1uS trigger signal.

SSWAIT,TRUE or FALSE

GSWAIT

The SSWAIT command will cause (if TRUE) the scan to wait for an advance positive edge pulse on the trigger input before starting the data acquisition on the next step in the scan. Setting the argument to FALSE will stop the system for waiting for an advance pulse during a scan.

SSWAITN,TRUE or FALSE

GSWAITN

Trigger Commands

TRIG,chan,value

The TRIG command will generate an output signal on the selected trigger output. Chan defines the trigger output 1 or 2. Value defines the action:
HIGH = Sets the output trigger to logic 1 or high, 5V
LOW = Sets the output trigger to logic 0 or low, 0V
PULSE = Generates a 1uS pulse

TRIGIN

The TRIGIN command returns the status of the trigger input:
HIGH = Trigger input is logic 1 or high, 5V
LOW = Trigger input is logic 0 or low, 0V

Conversion Commands

CMZ2FREQ,quad,mz

This command converts the entered mz value to frequency and reports the frequency. The quad value, which can be 1 or 2, determines the quad settings used in the calculation.

CFREQ2MZ,quad,freq

This command converts the entered freq value to mz and reports the mz. The quad value, which can be 1 or 2, determines the quad settings used in the calculation.

Agility Commands

DEFST,name,chan,q,t1,t3,num

This command defines a state where:

name	This is the sate name, a through z, must be lower case
chan	Quad channel reference for this state
q	q value used in this state
t1	t1 duty cycle in percent
t3	t3 duty cycle in percent
num	number of waveform cycles in this state

SFMULT,state,mult

GFMULT,state

The SFMULT command will set a frequency multiplier, mult, to the defined state (a-z). This multiplier is applied after the state's frequency has been calculated. The default value is 0, which disables the application of the multiplier.

SENAFMZ,state,TRUE or FALSE

GENAFMZ,state

The SENAFMZ command enables or disables the fixed frequency for a state (a-z), depending on its value. By default, the value is FALSE when a state is created.

SFMZ,state,freq

GFMZ, state

The SFMZ command will set the fixed frequency for the selected state (a-z) in Hz. This will be applied only if the SENAFMZ command is TRUE for this state.

CUR2ST,state,num

This command will copy the current Quad 1 parameters to the state (a-z), the num value is used to set the number of waveforms.

CLRST

This command will clear all defined states in the system.

NUMST

This command will report the number of defined states in the system. The maximum number of states that can be defined is 12.

REPST,state

This command will report the parameters of the selected state (a-z). This report is one string that is comma-delimited: name,quad channel,q,t1,t3,NumWaveforms.

REPSTS

This command will report the parameters for all defined states in the system. Each state will be one line in the format shown if REPST.

APPST,state

This command will apply a state (a-z) and update the hardware to start executing the state.

SSTTBL,table

GSTTBL

The SSTTBL command enables you to specify the primary sequence table string. The maximum length for this table is 130 characters. Any errors encountered in the table are disregarded during execution. This table is executed at every point of a state-based scan.

SPRETBL,table

GPRETBL

The SPRETBL command enables you to create a sequence table that is executed before a state-based scan is processed. The maximum length of this table is 130 characters.

SPOSTTBL,table

GPOSTTBL

The SPOSTTBL command enables you to create a sequence table that is executed after a state-based scan has completed. The maximum length of this table is 130 characters.

SSYNCCMP,TRUE or FALSE

GSYNCCMP

The SSYNCCMP command specifies the system's behavior when responding to asynchronous events. If the system is waiting for an external trigger and this command is set to TRUE, it will wait for the completion of the current number of waveforms before processing the trigger event. However, if the state being processed has a large number of waveforms, this can lead to substantial jitter

between the trigger event and the anticipated action. Conversely, if the command is set to FALSE, the current state will be interrupted by the event. By default, the value is set to TRUE.

EXEST

This command will execute the primary state table.

EXEONTRG,TRUE or FALSE

If this command is TRUE, it will execute the primary state table when a trigger event is detected on the trigger input.

ABRTST

This command will abort an executing sequence table.

ISEXE

This command will return TRUE is a sequence table is executing or FALSE when it has completed.

SSTMZ,state,mz

This command calculates the state frequency and DDS setting for the specified mz value. The calculated parameters are prepared for execution, but the state itself is not applied to the hardware.

SASTMZ,mz

This command calculates all the state frequencies and DDS settings for the specified mz value. The calculated parameters are prepared for execution, but the states themselves are not applied to the hardware. This mz value is the global value used in the state scanning process.

GGLBMZ

This command will return the global mz value used during state scanning.

STRSTSCN

The STRSTSCN command initiates a state-based scan or sweep, allowing users to specify the scan range and resolution using parameters such as scan start, stop, and steps. The actual data collection process is defined in the state table, for instance, the sequence aCbRH will execute state a then acquire data during state b, report the results (R), and wait for the host's acknowledgment (H). The host acknowledges the receipt of the data my sending a n to Astraea.

STRSTSCNB

The STRSTSCNB command initiates a state-based scan or sweep, similar to the STRSTSCN, except that the data is buffered in the Astraea system. This enables the storage of all scan data in the Astraea system and subsequent retrieval using the RENTRIES command. It is crucial to avoid using the H command when utilizing the buffered scan mode, as it can lead to reduced efficiency due to increased communication overhead. Buffered scanning significantly expedites the process.

RNUMENT

The RNUMENT command provides information about the number of points recorded in the scan buffer. This command is specifically designed for buffered scanning.

RENTRIES,index,num

The RENTRIES command returns the number of data points requested by num and starting at index in the scan buffer. If the scan buffer is empty or does not contain the requested number of entries, the command returns ?. The list or values returned are comma delimited. This command is specifically designed for buffered scanning.

QUAD Driver Commands

SINST,TRUE or FALSE

GINST

The SINST command is a configuration command set at the factory, this value is TRUE if a QUAD Driver is installed in your system. The user should not change this parameter. TRUE indicate the QUARD driver is installed.

SENA,TRUE or FALSE

GENA

The SENA command will enable the generation of output pulses if TRUE, FALSE will disable and stop the generation of pulses.

SVOP,value

GVOP

The SVOP command will set the base to peak voltage of the output pulse. If the value is set to 50 then a 0 to 50 or +/-50V output pulse is generated. The signal source for this driver is Quad channel 1.

SVRES,value

GVRES

The SVRES command will allow you to define a pole differential voltage, much like resolving DC on a conventional quadrupole. This is done by adjusting the positive and negative pulse voltage values on each of the poles. The intent with digital QUADs it to move the stability zone onto the axis, this command allows you to make small adjustments for cases when you are not exactly on the axis.

SVP,chan,value

GVP,chan

The SVP command allows you to adjust the positive voltage level for the output pulse. Chan defines pole 1 or 2 of the quadrupole, value is the voltage you are requesting. Generally, you can use the SVOP command to set these voltages but this command allows you to define any desired value.

SVN,chan,value

GVN,chan

The SVN command allows you to adjust the negative voltage level for the output pulse. Chan defines pole 1 or 2 of the quadrupole, value is the voltage you are

requesting. Generally, you can use the SVOP command to set these voltages but this command allows you to define any desired value.

GVPA,chan

The GVPA command is a readback command that will read the actual positive output voltage. Chan defines pole 1 or 2 of the quadrupole.

GVNA,chan

The GVPA command is a readback command that will read the actual negative output voltage. Chan defines pole 1 or 2 of the quadrupole.

Calibration commands. The following calibration commands are for factory setup and configuration, do not use these commands!

CALVP

Calibrates the positive pole voltage regulators.

CALVN

Calibrates the negative pole voltage regulators.

Debug and System Commands

RWDDSR,reg,value

This command will write value (in HEX) to the DDS selected reg (in HEX)

SVDAC,chan,value

This command will write to the DAC used to control the internal pulse driver, the defined value is written to chan.

RVADC,chan

This command will read the ADC used to control the internal pulse driver, the defined chan is read and its value reported.

SCFG,reg,value

GCFG,reg

The SCFG command transmits the selected register to the FPGA. Valid reg values are SYS, SCAN, PWM1, or PWM2. Before transmission, the value parameter (in HEX) is set in the selected structure.

LOAD

This command will issue a load pulse to the FPGA causing it to load any transmitted updates.

UPDATE

This command will issue a update pulse to the DDS causing it to load any transmitted updates.

Contact GAA Custom Electronics, LLC

Email, gaa@gaa-ce.com
Phone, 509.628.6851
Mailing address

GAA Custom Electronics, LLC
101904 Wiser Parkway, Suite 105

Kennewick WA, 99338