

MIPS

Modular Intelligent Power Sources

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

WARNING

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.

Introduction

Thank you for purchasing MIPS, Modular Intelligent Power Source. This document describes the installation and operation of your MIPS system. MIPS systems are configured for your application with the specific options you have selected. This document describes all modules that are available and your specific system may not contain all the features described here.

MIPS produces DC and RF voltages designed for mass spectrometry applications. The MIPS system is controlled by a powerful ARM embedded controller running at a clock frequency of 84 MHz. This processor controls the output voltages as well as monitors the output to ensure proper operation. Digital IO is provided as well as the ability to generate complex pulse sequences for advanced control applications.

MIPS provides a USB interface to a host computer and through this interface you can control and monitor all the MIPS modules.

The document describes the operation of the MIPS system and how to connect and operate your system. Please contact us if you have any question that are not addressed in this document.

MIPS User Interface

The MIPS user interface (UI) consists of a multiline color graphics display and a single control knob located on the front panel. The display will show various dialog boxes with parameters you can control and monitor. When a dialog box is displayed you can rotate the control knob to highlight a selection. If you press the knob when a selection is highlighted then the parameter is selected and its value is highlighted. With the parameters value highlighted you can now rotate the control knob to change the parameter. If you rotate the knob quickly the parameter will change with larger steps allowing you to rapidly move through the adjustable parameters range. When you have finished making changes to a parameter press the button to accept your changes.

The control knob will change color based on the voltages being generated by the MIPS system. The intent is to provide a quick visual indication of the outputs as a safety aid. Below you will find a description of the different knob color's meaning:

- 1.) Off, all outputs a 0 volts.
- 2.) Blue indicates outputs are on and above 0 volts.
- 3.) Red indicates outputs above 50 volts.
- 4.) Flashing red indicates outputs above 75 volts.

MIPS main menu

The MIPS UI implements a menu selection system that allows you to select a module for control and monitoring. The main menu supports the following menu selections:

MIPS configuration
RF driver module
DC bias module
Twave module
DIO module

To select a module, use the control knob to highlight the option you would like to work with and then press the knob to select. You will then see a dialog box specific to the option you selected. The main menu will only show the modules that are present in your specific MIPS configuration. Each module's dialog box contains an option to return you to this main menu for selection of another module.

When the MIPS systems starts up it will automatically select a module's dialog for display. This selection depends on the modules present in your system. If multiple modules are present the module displayed has the following priority:

RF driver module
DC bias module
Twave module
DIO module

Each module and its parameters are described in this document.

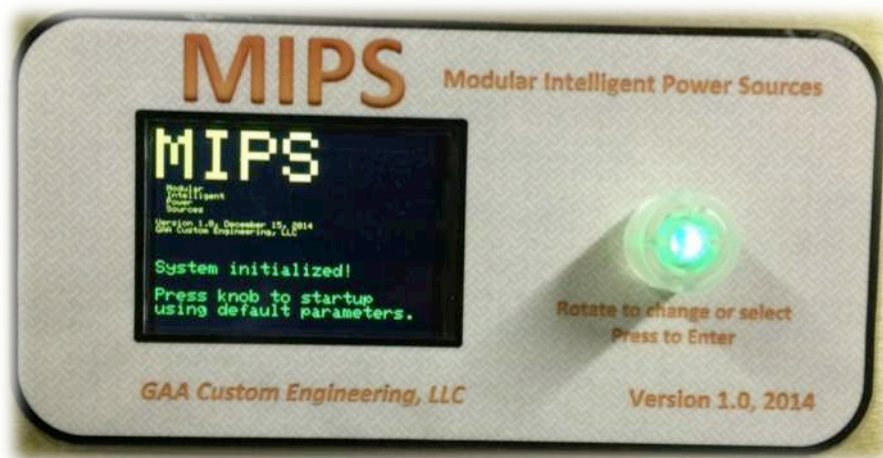
The MIPS system can communicate with a host computer using the USB interface found on the rear panel. All modules and most functions can be controlled through the MIPS UI can be controlled through this USB interface. Additionally, pulse sequences can be defined and downloaded to the MIPS system; this is one of the very powerful control functions of the MIPS system. The host interface and pulse sequence generation are described later and in the appendix of this document.

Powering up the MIPS system

The MIPS power switch is located on the rear panel next to the power cord. Before you power on the MIPS system ensure the following:

- 1.) The proper AC power is available to operate the system.
- 2.) All connections between the MIPS box and your instrument are complete and no wires are exposed.
- 3.) Ensure all instrument connections present loads that are appropriate for the MIPS system to drive. Make sure that DC bias outputs are not shorted to ground, all RF connection are correct etc.
- 4.) Note: depending on the modules installed up to 500 volts can appear on the rear panel BNC connectors so make sure all users have the proper institutional training needed to safely operate this system. The system's rear panel will indicate the maximum output voltage and current level the system is capable of developing.

After you are sure the system is ready to operate turn the power switch on. The MIPS system will display a sign on message and the control knob will be flashing green after it has initialized and is ready to start. The startup behavior of the MIPS system can be configured using the MIPS configuration option. The default behavior is to delay for 10 seconds and then startup and load all the module's last saved settings automatically. If you press the button while it's flashing green, during the 10-second startup delay, it will start using the default parameters and not load any saved settings. This is not something you will likely want to do because none of the system calibration parameters will be loaded. This does however provide a safe startup mode and the individual modules can be selected and their parameters loaded manually.



The MIPS configuration will allow you to change the startup behavior and these options are described in the MIPS configuration section of this manual.

Powering down the MIPS system

The MIPS power switch is located on the rear panel next to the power cord. You can turn off the MIPS power at anytime and it requires no specific power down sequence. However your system may have specific requirements to reduce voltages before powering down and that is application specific and thus not possible to discuss here.

Please note: when you turn the MIPS system off you need to wait at least 15 seconds before powering the system back up, this allows all the internal power supplies to discharge before power is reapplied and properly resets all internal electronics.

MIPS configuration

The MIPS configuration main menu selection allows you to change system configuration parameters. These parameters affect the overall behavior of the

system. Some of these options are designed for initial system setup when modules are added to the system and should not be needed in normal system operation. Each option is discussed below:

Controller rev

This parameter to set at the factory and it defines the hardware revision level of the MIPS controller. The user should not change this parameter.

Config modules

This function is used to initialize new modules. Each module contains non-volatile memory that is used to identify the module to the system and to hold all its configuration and calibration data. This function allows initial formatting of this memory and is intended for use in the factory to setup new modules for the first time. The user should not select this option.

Startup delay

The default startup behavior for the MIPS system includes a delay of 10 seconds. This delay can be adjusted using this option.

Startup hold

This option allows you to change the startup behavior of the MIPS system. If this option is set to "Yes" when the MIPS system is powered up it will wait for the user to press the control knob and then it will startup and load each modules saved parameters. If this option is set to Yes then the startup delay parameter is not used and its ignored.

DCbias supply

The power source option allows you to turn on or off the power source that enables the DC bias module. This function is only available on +- 250 volt and higher DC bias modules. The +- 50 volt DC bias module will set all the channels and offset to zero if the DCbias supply command is set to off but the +- 50 volt supplies will not be turned off.

DCbias trip, %FS

This is a safety feature that will turn off the DC bias power supply in the event of a voltage read back error. MIPS monitors the output voltages and compares them to the requested voltages if an error is detected above the limit defined by this parameter then the power supplies are shut down and an error message displayed on the UI. The units of this parameter are percent of full scale, so if this is set to 1 then the trip point will be +- 2.5 volts for the +- 250 volt DC bias module. Setting this parameter to 0 will disable this function.

Reboot

Selecting Reboot will restart the MIPS system as if you powered it down and backup. Remember that any setting you have changed are not permanently changed until you have selected the Save settings option.

Save settings

Selecting this option will save all the MIPS configuration data to a default startup file in the SD memory card on the MIPS controller. You will see a popup menu indicating the status of this save operation. You need to use this option to record any changes you make to the MIPS configuration.

Restore settings

This option will reload the MIPS configuration settings that were saved to SD memory. This function is automatically called when the MIPS system powers up.

Return to main menu

Selecting this option will return to the MIPS main menu.

RF driver module

The MIPS system can generate high voltage RF waveforms designed to drive RF ion guides and ion funnels. The MIPS system can drive up to 4 RF high Q heads, these heads couple to your system and develop the RF voltages using signals from the RF driver module located in the MIPS box. The high Q head connects to the MIPS box using a 15 pin D cable provided with you system. This cable runs from the back of the MIPS box to the high Q head and should be installed before you power up your MIPS system.

The RF driver module's UI contains two pages of options for control and monitoring of the RF voltage generation.

Dialog box page one options:

RF channel

This entry allows you to select the RF channel whose parameters you wish to control and monitor.

Freq, Hz

This entry allows you to define the RF frequency. When changing this parameter you should monitor the RF output voltage and power. Details of tuning the RF high Q head are provided later in this document.

Drive %

The Drive % parameter determines the output voltage of the RF driver. The higher this parameter the higher the output RF voltage assuming the RF head has been resonated with the load. When changing this parameter you should monitor the RF output voltage and power.

RF+ Vpp

This parameter monitors the positive phase of the RF high Q head. This is a display only parameter and cannot be directly adjusted. Changing the drive level and frequency will impact this voltage.

RF- Vpp

This parameter monitors the negative phase of the RF high Q head. This is a display only parameter and cannot be directly adjusted. Changing the drive level and frequency will impact this voltage.

Power W

This parameter monitors the power being drawn by the RF high Q head. This is a display only parameter and cannot be directly adjusted. Changing the drive level and frequency will impact this voltage.

Next page

Selecting this option will display the second page of the RF driver module dialog box.

Return to main menu

Selecting this option will return to the MIPS main menu.

Dialog box page two options:

Drive limit, %

This option allows you to define a maximum drive level that can be set with the drive % found on page one. This allows you to prevent accidentally increasing the drive to a level that could damage your system due to over voltage or damage the high Q head due to over power.

Power limit, W

The power limit is a safety setting that allows you to limit the maximum power that the high Q head can draw. If this value is exceeded the MIPS system will reduce the drive level until the power falls below this limit. This is very useful to prevent damage due to a failure of the RF device being driven.

Save settings

Selecting this option will save the entire RF driver configuration data to non-volatile memory chip on the RF driver module. You will see a popup menu indicating the status of this save operation. You need to use this option to record any changes you have made to the RF parameters or they will be lost when power is cycled or the system is rebooted.

Restore settings

This option will reload RF driver configuration settings that were saved to non-volatile memory. This function is automatically called when the MIPS system powers up.

First page

Selecting this option will display the first page of the RF driver module dialog box.

Return to main menu

Selecting this option will return to the MIPS main menu.

DC bias module

The MIPS DC bias module allows the generation of up to 16 DC output channels. The specific hardware modules that are installed in your MIPS system define the number of channel and the voltage ranges.

The DC bias driver module's UI contains multiple pages of options for control and monitoring of the DC voltage generation. Each bank of eight output channels contains its own page for monitoring and control. A final page of parameter is provided that applies to all DC bias channels.

Dialog box page one (and page two if 16 DC bias channels are installed in your system.) options:

Ch 1, V, through Ch 8, V

These eight entries allow you to control output channels 1 through 8 of the DC bias voltage generation. The voltages are available on BNC connectors are the rear panel of the MIPS box and are labeled channel 1 through 8. Each entry allows you to define the requested voltage and displays the actual output voltage that is read by the MIPS output monitors.

Offset V

The offset voltage is controlled with this parameter; the offset applies to all eight channels and is a DC voltage that is used to define the absolute output voltage minimum and maximum value. For example a +- 250 volt DC bias board can output -250 to +250 volts on any of its 8 channels assuming the offset voltage is set to 0. If the offset is set to 100 volts then each of the 8 channels can output -150 to +350 volts. Adjusting the offset will not change any of the 8 output channels, assuming they all remain in range; it will only redefine the minimum and maximum output voltages. The output offset voltage is not monitored by the MIPS box and its assumed that the actual output matched the requested value.

Next page

Selecting this option will display the second page of the DC bias module dialog box. This next page could be channel 9 through 16 if your system is equipped with 16 channels or it will display the general DC bias parameters that apply to all channels.

Return to main menu

Selecting this option will return to the MIPS main menu.

The last page of the DC bias dialog box defines parameters and functions that apply to all channels of the DC bias module. Each option is defined below:

Calibrate channel

This option allows calibration of each output channel and its read back monitor. This is not an option you would normally use and its used at the factory when the system is initially fabricated. The calibration procedure is defined in more detail in the appendix of this document.

Calibrate offset

This option allows calibration of the offset voltage that is applied to each group of 8 output channels. This is not an option you would normally use and it is used at the factory when the system is initially fabricated. The calibration procedure is defined in more detail in the appendix of this document.

Power source

The power source option allows you to turn on or off the power source that enables the DC bias module. This function is only available on +- 250 volt and higher DC bias modules.

Save settings

Selecting this option will save the entire DC bias module configuration data to a non-volatile memory chip on the DC bias module. You will see a popup menu indicating the status of this save operation. You need to use this option to record any changes you have made to the DC bias parameters or they will be lost when power is cycled or the system is rebooted.

Restore settings

This option will reload the DC bias configuration settings that were saved to non-volatile memory. This function is automatically called when the MIPS system powers up.

First page

Selecting this option will display the first page of the RF driver module dialog box.

Return to main menu

Selecting this option will return to the MIPS main menu.

Twave module

The MIPS Traveling Wave generator enables the user to define any 8-bit binary pattern that will be used to generate 8 output waveforms. An internal adjustable clock is used to rotate this bit pattern to the left on each clock cycle as illustrated in the sequence below:

```
00000011
00000110
00001100
00011000
00110000
01100000
11000000
10000001
```

At each clock pulse the pattern rotates one bit position to the left with the most significant bit rotating back to the least significant bit. Each bit position defines a waveform for a total of 8 waveforms. Each waveform is identical but shifted one clock cycle from its neighbor. These 8 waveforms appear on the 8 output BNC connectors on the rear panel of the MIPS Twave power supply.

The user can control the pulse peak voltage (high state) from 7 to 100 volts and the pulse resting voltage (low state) from 0 to 93 volts. The pulse voltage must always exceed the resting voltage by 7 volts for the power supply to operate properly.

The Twave sequence generation can be synchronized using a trigger signal applied to the trigger input on the rear panel of the MIPS box. This trigger signal is rising edge sensitive and initialized the sequence to the user defined pattern.

The Twave module's UI provides one page of parameters used to control the Twave waveform generation. Each option is defined below:

Clock freq, Hz

This parameter is the clock frequency in Hz use to advance the Twave waveform.

Sequence

This sequence is an 8 bit binary sequence that defines the initial output bit pattern. This pattern is rotated one bit to the left on each clock pulse. The least significant through most significant bits appear on channels 1 through 8 of the MIPS system's rear panel.

Pulse voltage

The pulse voltage is the output voltage generated by Twave module when the bit sequence defines an output state of 1. The pulse voltage can be adjusted from 7 to 100 volts. The pulse voltage must always be 7 volts higher that the resting voltage.

Resting voltage

The resting voltage is the output voltage generated by Twave module when the bit sequence defines an output state of 0. The resting voltage can be adjusted from 0 to 93 volts. The resting voltage must always be 7 volts lower that the pulse voltage.

Guard 1

Guard 2

The guard outputs are fixed voltages used to confine ions. This values can be independently adjusted between 0 and 100 volts.

Save settings

Selecting this option will save the entire Twave module configuration data to a non-volatile memory chip on the Twave module. You will see a popup menu indicating the status of this save operation. You need to use this option to record any changes you have made to the DC bias parameters or they will be lost when power is cycled or the system is rebooted.

Restore settings

This option will reload the Twave configuration settings that were saved to non-volatile memory. This function is automatically called when the MIPS system powers up.

Return to main menu

Selecting this option will return to the MIPS main menu.

DIO module

The DIO module is present in every MIPS system. There are a total of 16 digital outputs generated by the MIPS controller and 8 digital inputs are monitored. The number of these digital inputs and outputs that are available on the rear panel of a MIPS system depends on the configuration of your specific system. The digital outputs are labeled A through P and the digital inputs are labeled Q through X. Digital input Q is also used as an external clock and R can be used as an external

trigger. You can determine the number of signals available on your system by simply inspecting the rear panel.

The DIO module UI dialog box allows you to monitor the digital inputs and set the digital outputs. The digital inputs and outputs use 0 to 5 volt logic levels with 0 volts indicating logic 0.

Two pages of options are provided, one to monitor inputs and the second to control outputs.

Digital input monitor dialog box options:

Input Q (CLK)

Input R (TRG)

Input S through Input X

These display entries monitor the digital inputs and display 1 or 0 depending on the input status. These are monitor only inputs.

Digital outputs

Selecting this option will change the dialog box to allow control of the digital outputs.

Return to main menu

Selecting this option will return to the MIPS main menu.

Digital output control dialog box options:

Output A through Output P

The output options allow you to define the state of each of the 16 digital outputs. The output options are 0 or 1 and set the output to 0 or 5 volts respectively.

Digital inputs

Selecting this option will change the dialog box to allow control of the digital outputs.

Return to main menu

Selecting this option will return to the MIPS main menu.

The DIO dialog box allows you to monitor and set the digital IO but the real power of the digital IO is illustrated in the generation of pulse sequences. Pulse sequences, described later, allow the generation of complex multichannel digital and analog output signals.

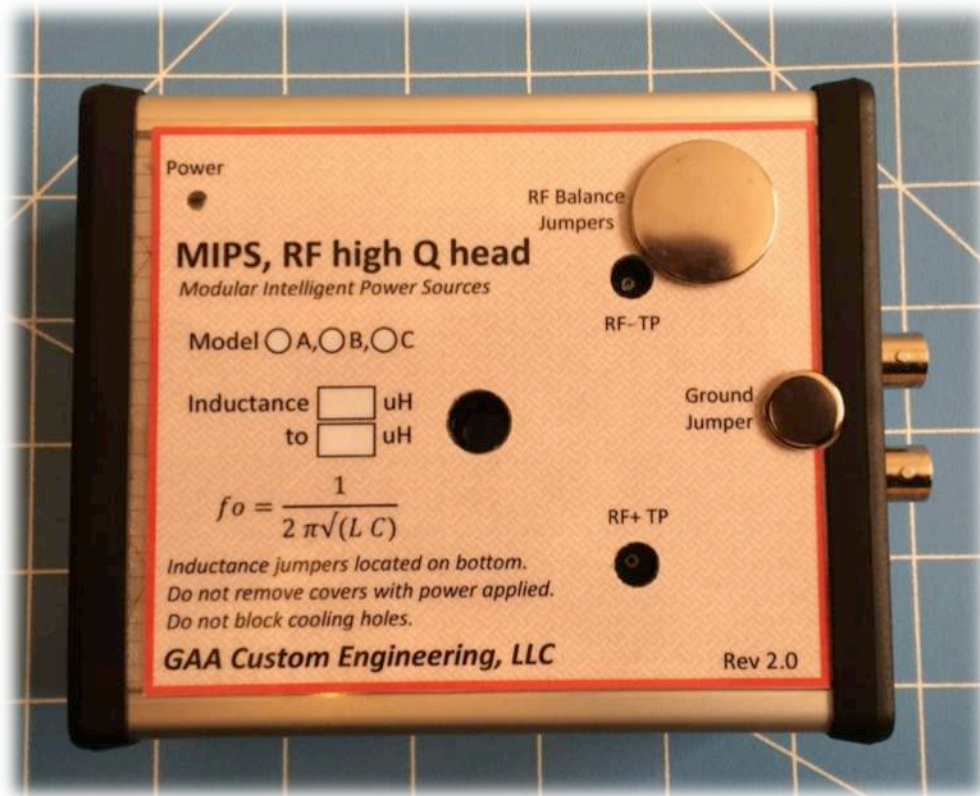
Connection and tuning of High Q RF heads

The MIPS system is capable of generating RF voltages typically used to drive RF ion guides including RF ion funnels. RF generation requires the RF driver module in the MIPS box and a RF high Q head for each RF signal you intend to generate. Each RF high Q head generates a balanced output, two output phases with 180 degrees of

shift between each phase. These phases connect to electrodes in ion guides. These electrodes present a capacitive load to the high Q head. The high Q head contains inductance that resonates with the ion guides capacitance. This resonance allows the high Q head to generate a few hundred volts peak to peak (Vpp).

The goal of this section is to provide general guidance to connect the RF high Q head to your system and a procedure for tuning your system.

Two BNC connectors on the RF high Q head provide the two phases of RF output and should be connected to your ion guide. The typical capacitance seen in these systems vary between 100 to 300 pF. The high Q head will resonate between 700 KHz to 3 MHz depending on the inductance of the head and your load capacitance.



RF high Q head. RF-TP and RF+TP are test points where you can insert a scope probe to monitor the RF signal. The BNC connectors are the RF output phases that should be connected to your RF device.

The following procedure provides a step-by-step process that can be used to setup a new RF high Q head:

- 1.) With the MIPS power off connect the MIPS box to the high Q head using the 15 pin D cable provided with your system.
- 2.) The RF high Q head is connected with two BNC cables that you provide. Check the capacitance from the center of one cable to the center of the other then use the inductance of the high Q head and the formula on the high Q head to calculate the resonate frequency. This will give you a starting point

for tuning. You do not have to measure the capacitance but if you can it will test the load and provide a starting point. Use a multi-meter and make sure the load is not shorted to ground or very low resistance. When you are sure the load is correct then connect the cables.

- 3.) Turn on the MIPS box and select the RF module. Set the drive level to 10 %.
- 4.) Adjust the frequency to achieve a maximum RF voltage. You can monitor the RF voltage using the reading on the MIPS box or use a scope and monitor the test points on the RF high Q head. Using a scope will also allow you to inspect the quality of the RF signals. I would recommend using a scope on initial setup but it is not necessary for routine operation. It is best to start tuning from a low frequency working toward higher frequencies. Monitor the RF head power and ensure it remains under a watt through this process.
- 5.) After the peak is found you can increase the drive level as needed to reach the desired RF voltages. The resonate frequency will change with power level so you will need to make fine adjustments in frequency as you increase drive. The resonate frequency may also change as your system warms due to capacitance changes etc.
- 6.) Remove the scope and use the MIPS voltage readings to do the final tuning. The next step is to balance the two phases. If the RF voltage +Vpp and -Vpp do not match with in your requirements you can use the balance jumpers to make corrections. The scope needs to be removed because the capacitance of the probes can change the balance and can slightly change the resonate frequency. The front of the RF high Q head has hole plug covering a set of balance jumpers. These jumpers enable capacitance to be added to the -Vpp side of the RF head to ground. The figure below shows the jumpers and lists the capacitance options depending on the number of jumpers installed. Increasing the capacitance will lower the voltage on the -Vpp phase and raise it on the +Vpp phase. Changing the capacitance will also slightly change the resonate frequency. Adjust the jumpers to achieve the desired balance. Make sure the power is off before the jumpers are changed. Also make sure you save the RF module parameters before you turn off the power.



Install a jumper to add capacitance from the negative RF phase to ground. The capacitance for each jumper position is listed below. Multiple jumpers can be installed to increase total capacitance.

1 = 12 pF
2 = 22 pF
3 = 47 pF
4 = 82 pF

Note! Install and remove jumpers with MIPS power off.

- 7.) The RF high Q heads inductance can be adjusted with in a limited range if the resonate frequency needs to change. There is a hole plug covering a jumper block on the bottom of the RF head as shown in the figure below. Its critical that only one jumper is installed on the jumper block. There are 4 inductance options on each RF head. Lower inductance results in higher resonate frequency. The RF heads highest efficiency is achieved at its highest inductance so you should try to operate at this inductance if possible.



Inductance selection jumpers. One and only one jumper must be installed. Highest output voltage is achieved with the jumper in position 1. Highest inductance is position 1, lowest is position 4.

Note! Install and remove jumpers with MIPS power off.

- 8.) The RF head BNC connector's outer shell is connected to ground. This ground connection can be removed and the shell floated if needed on your system. The figure below shows the jumper that needs to be removed to float the BNC shells.



- 9.) After you have made all the needed adjustment and tuned you system allow it to operate for several minutes to stabilize. I recommend you then send the drive level limit and power limit slightly above the operating levels of the system. This will provide a level of system protection.

This procedure provides general guidelines for tuning a RF high Q head and should help you perform general system setup. RF high Q head power dissipation should not exceed 12 watts. In most applications you will only need 1 to 2 watts of power to produce the needed voltages.

If your system requires special needs please contact us, we can build custom inductances to match your specific needs.

A number of custom configurations are possible with the RF head including the addition of a DC bias on the RF outputs and gating the RF on and off with an external signal. If you need this capability please contact us and we will help you setup your system as needed.

Connecting DC bias channels

DC bias output of the MIPS system are designed to drive electrodes in mass spectrometry systems with maximum output currents of a few milliamps. This includes driving RF ion funnels, biasing conductance limits, applying offset DC voltages on quads etc. Each DC bias output is available on a BNC connector located on the rear panel of the MIPS system.



MIPS rear panel connections. Note the black cap-plugs installed of DC bias outputs as a safety precaution.

The goal of this section is to provide general guidance to connect the DC bias channels to your system.

Connection in this case is pretty simple just follow these steps:

- 1.) Check each load with an ohmmeter and measure the resistance to ground at each BNC connection. The resistance should be 100K ohms or greater.
- 2.) Make sure all BNC DC bias connections are complete before you apply power to the MIPS system.
- 3.) Your MIPS system was shipped with cap-plugs on all DC bias output for safety, please leave these in place on unused channels.

- 4.) After applying power to the MIPS system select the DC bias module and slowly set each voltage at the desired level. Monitor the channels read back to ensure the DC bias channel is properly driving the load and developing the desired output.

All DC bias boards can be floated with an externally supplied voltage. Your MIPS system may have a float input BNC on the rear panel if that option was requested. This input will allow you to apply an external float or offset voltage that will be added to all the board's DC outputs. The MIPS system will have a BNC shorting plug installed on the BNC connector when shipped from the factory, you must leave this in place if you are not using the float feature.

The float input has a low impedance connection to the DC bias boards common. You should apply your float input using some kind of current limit to protect the system in the event of an electrical breakdown.

If your system contains only one DC bias board, 8 DC outputs, then you cannot use a DC bias output connected to the float input, this will damage the MIPS system.

If your system contains two DC bias boards, 16 DC outputs, then you can use one DC bias board output as a float input. For example you could use DC output 1 as a float input for DC bias board 2. However you cannot then use DC output 9 to float board 1. Only one of the two DC bias boards can be floated using internal DC bias channels.

Pulse sequence generation

The MIPS system can generate pulse sequences using digital outputs and DC bias outputs. A pulse sequence allows the user to change the digital output and DC bias voltages at user programmed time points. These pulse sequences can use an internal programmable clock or an external clock; additionally a pulse sequence can be started using a command from the host computer or from an external source. Pulse sequences can contain internal loops where a defined sequence can be repeated a programmed number of times. Loops can be nested as well at a maximum depth of 5.

The pulse sequence generation capability uses the timer counter capability in the ARM microcontroller at the heart of the MIPS system. This timer counter has the capability to generate an output pulse when its count matches the value in a compare register. This trigger is then used to change the digital and DC bias output levels via hardware in the MIPS system. This provides a low jitter and deterministic pulse sequence generation capability.

Pulse sequences are defined through the USB interface to the MIPS system. The commands used to define a pulse sequence can be found in appendix B of this document. To communicate with the MIPS system from your host computer and issues commands to the MIPS system you can use a terminal emulator application

such as putty.exe on a PC or CoolTerm on a MAC. If your using a PC you will need to install USB drivers to communicate with the MIPS system, the necessary drivers are already installed on MAC systems. This link provides details on installing the drivers, <http://arduino.cc/en/Guide/ArduinoDue> .

After you have installed the terminal emulator software you can use it to send commands, defined in appendix B, to the MIPS system and also display the systems response. A good way to test the connection to the MIPS system is to issue a simple command such as GVER, to get the firmware version number. If this command is recognized MIPS will return its current version number. Please note, if you cycle power on the MIPS system while the terminal emulator software is running you will lose communications, in this case you will need to stop and restart the terminal emulation software.

With the terminal emulation software installed and tested you are now ready to send a pulse sequence command to the MIPS system. The following steps provide an example:

- 1.) Develop your pulse sequence table command as defined in appendix B. Here is an simple table command you can try:
STBLDAT;0:[1:2,1000:1:25:A:1,3000:1:5:A:0]; This table will generate a pulse sequence with two pulses on both digital output A and DC bias channel 1.
- 2.) Next use the STBLTRG command to select the trigger mode, default is software trigger.
- 3.) Define the clock using the STBLCLK command; the default is internal at 656,250 Hz.
- 4.) Place the system in table mode using the SMOD,TBL command. After this command is sent the MIPS display will indicate the system is in the table mode. The system is now ready for a trigger.
- 5.) If you used the software trigger mode then the following command will play the pulse sequence defined by the table command, TBLSTRT.
- 6.) You can exit the table mode using the SMOD,LOC command or by pressing the control knob button on the MIPS system.

Hecate software Inc, <http://www.hecate.com>, has developed a windows application called MIPSY that will allow you to build and download pulse sequences to the MIPS system without the need of a terminal emulator application. MIPSY is available at this link <http://www.hecate.com/projects>. This application greatly simplifies the generation of pulse sequences and provides an example of higher-level control capabilities when coupling MIPS to a host computer. Contact Hecate for you custom application needs.

Development details

This section discusses the tools used to develop the MIPS system and the technical data that you will find on the USB thumb drive provided with your system. GAA Custom

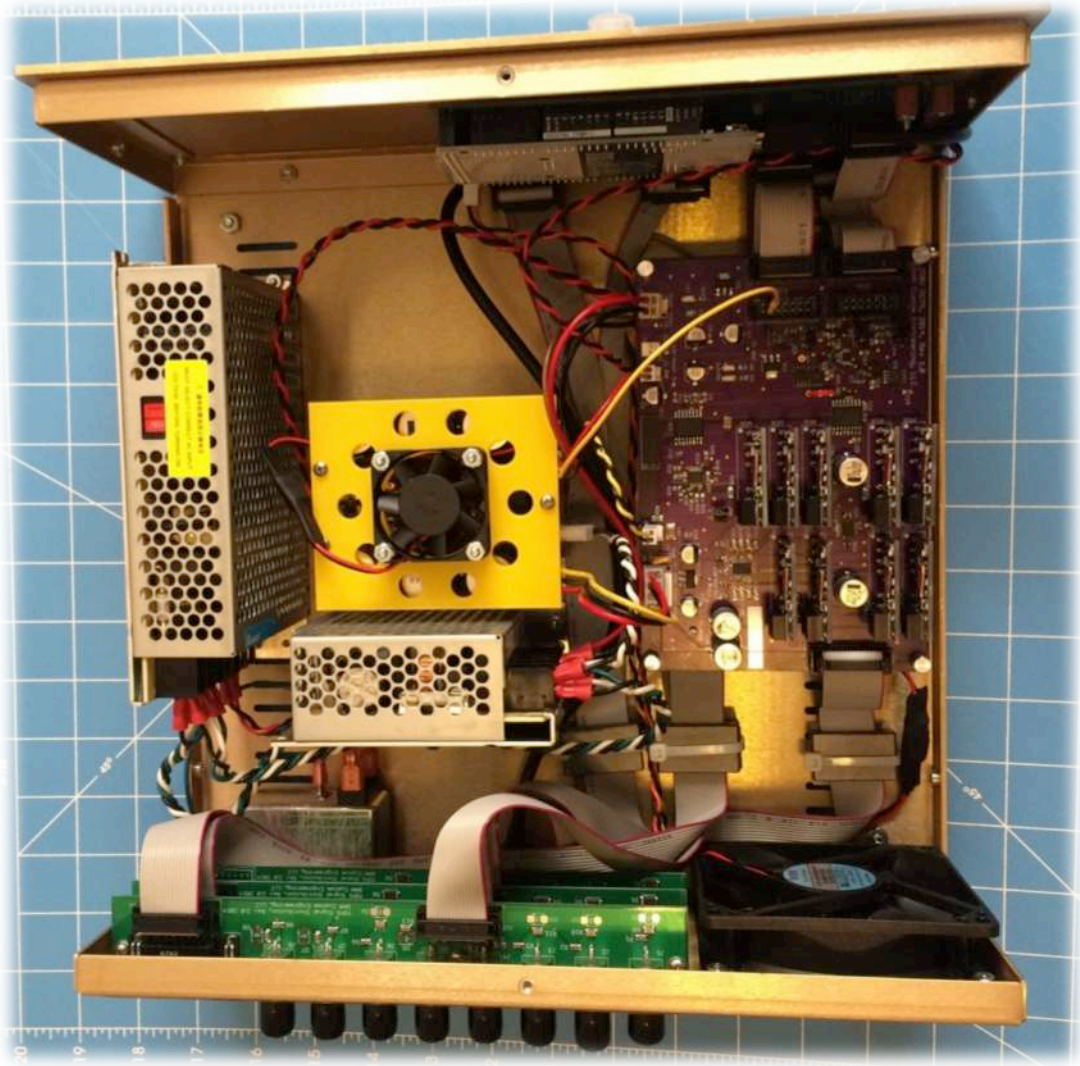
Engineering's company philosophy is to provide all technical details of the design including all engineering drawings, parts lists, and even source code. Enough information is included to allow someone skilled in the art to reproduce the MIPS system. It is our expectation that customers will honor our intellectual property and contact us when needing additional systems and information. This detail is provided to allow you to fully understand the operation of the system and provide product life cycle support even in the event of GAA Custom Engineering ceasing operation.

The hardware design was performed using eagle schematic capture and board layout software. The design files can be found in the MIPS directory. Each module has a sub directory with the design files for that particular module and any associated designs that support the module. Each directory contains the schematics and board files in the cad software's format as well as PDF files for hardcopy in some cases. Each directory also contains excel spreadsheets with full parts list including links to the vendors used to provide all the parts. Each schematic contains a final sheet with specific fabrication note and this includes any modifications that were necessary. All version of each design are included in the directories. The module's directories contain sub directories with the gerber files that were sent to the PCB printing facilities.

The MIPS system is controlled using an Arduino Due. The Due plugs into the MIPS controller PC board. The USB port used to communicate with the MIPS system is also used to download the firmware. The Due has two USB ports and the native port is used by the MIPS system. The software was developed using the Arduino IDE version 1.57 running on a MAC and this software can be downloaded on the Arduino web site, <http://arduino.cc/en/Main/Software>. The source code for the MIPS controller is located at MIPS/Arduino. This directory is structured as the IDE requires and can be loaded as a project using the IDE. The software was all written in C++. The development environment will take some setup to make operational, it is assumed this would be done by someone skilled in the art and the details are not covered here.

Please note, read the MIPS.ion main file's comment header very carefully before making any changes. It is necessary to change the variant.h header file before you can build and update the MIPS firmware.

GAA Custom Engineering, LLC is not responsible for firmware changes made by the customer, please use caution when changing the firmware!



Warrantee

GAA Custom Engineering, LLC warrants the MIPS 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 Engineering, 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.

Appendix A, DC bias channel calibration procedure

The MIPS DC bias output channels have been calibrated at the factory and no additional calibration should be necessary unless components have been replaced on the DC bias boards. The +- 250 volt and above DC bias board contains plug in amplifier modules for each output and one additional module for the offset control. These modules are all labeled as to the location they belong. The design of each module is identical but they are calibrated for each specific location and should not be swapped without recalibration.

Calibration should only be performed by a qualified and trained electrical worker.

Before starting the procedure remove the MIPS system and disconnect all the DC bias channels. You will need to remove the cover of the MIPS system to complete this procedure.

Use a calibrated multi-meter to perform this procedure and preferably a 5 ½ digit meter.

The first step is to calibrate the offset control. This will require connecting the multi-meters positive lead to the DC bias boards TP_AGND test point. The negative lead should connect to chassis ground. After this connection has been made performing the following steps:

- 1.) Power up the MIPS system and set all channels to 0 volts and set the offset to zero volts.
- 2.) On page two of the DC bias dialog box you will find a Calibrate Offset option, select this option and then select channel 1. Channel 1 through 8 use the same offset control.
- 3.) Next you will see the calibration dialog. Select the first option, it will say "Set the output to 0", now rotate the control knob until the meter reads 0 volts, then press the control knob.
- 4.) Select the second option and repeat the above procedure setting the output as directed using the multi-meter to monitor the output.
- 5.) Repeat steps 3 and 4 as necessary, there will be a little interaction between these two steps.
- 6.) When finished select Exit to accept the changes or Abort if you do not want to use the new calibration parameters.
- 7.) Make sure you save settings on the DC bias dialog of the updated calibration will be lost when power is cycled.

The MIPS system cover can now be installed; the remaining calibration steps are done through the rear panel connectors. Power down the system, remove the multi-meter connections and re-attach the cover.

Each DC bias channel is calibrated using the multi-meter connected to each channels output. Channels are calibrated one at a time. If you have a BNC cable that will connect to you multi-meter that would be ideal and speed the calibration process.

Calibrate each output channel using the following procedure:

- 1.) Power up the MIPS system and set all channels to zero volts and set the offset to zero volts.
- 2.) On page two of the DC bias dialog box you will find a Calibrate channel option, select this option and then select the channel you wish to calibrate.
- 3.) Next you will see the calibration dialog. Select the first option, it will say "Set the output to 0", now rotate the control knob until the meter reads 0 volts, then press the control knob.
- 4.) Select the second option and repeat the above procedure setting the output as directed using the multi-meter to monitor the output.
- 5.) Repeat steps 3 and 4 as necessary, there will be a little interaction between these two steps.
- 6.) When finished select Exit to accept the changes or Abort if you do not want to use the new calibration parameters.
- 7.) Make sure you save settings on the DC bias dialog of the updated calibration will be lost when power is cycled.

Repeat the above procedure for each channel in your MIPS system.

If your MIPS system contains 2 DC bias modules, 16 DC bias outputs, you will need to complete the offset and channel calibration again for the second board. In the case of the second board the offset channel selected will be 9, and you will calibrate channels 9 through 16.

Appendix B, Host computer interface

All commands are ASCII text.

All commands sent to the MIPS box are terminated with a carriage return (CR) or line feed (LF) character.

All messages sent from the MIPS box are terminated with a CR and LF.

After a command is received (after the CR or LF is received) MIPS 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.

GCHAN,<system>

Returns the number of channels for the selected system, where system can be RF or DCB. RF indicates the number of RF driver channels 0, 2, or 4 and DCB indicates the number of DC bias channels 0, 8 or 16.

SAVE

This command will save the MIPS controller parameters to the SD memory card.

RESET

This command will cause the MIPS control computer to reboot.

MUTE, <Value>

This command will stop all messages from the MIPS 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 = ON to turn the responses on and OFF to silence the MIPS system.

TRIGOUT, <Value>

This command allows you to control the trigger output if it is available on your MIPS system. This command allows you to set the trigger output high, low, or generate an output pulse. The pulse will be low going high if the output state is low or it will be high going low if the output state is high. The pulse width will be 1 millisecond wide.

Where:

Value = LOW to set output to 0 volts, HIGH to set output to 5 volts, or PULSE to generate an output pulse 1 mS wide.

GCMDS

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

DCbias board commands:

SDCB,<Chan>,<Value>

Sets the DC bias channel output voltage set point. This is the value that the DC bias board will attempt to reach.

Where:

Chan = the selected channel 1 through the maximum number of channels. (integer)

Value = the output voltage requested. (float)

GDCB,<Chan>

Returns (float) the DC bias channel output voltage set point. This is the value that the DC bias board is attempting to reach.

Where:

Chan = the selected channel 1 through the maximum number of channels. (integer)

GDCBV,<Chan>

Returns (float) the DC bias channel's actual output voltage. This is the value that the DC bias board's read back detection circuitry has detected.

Where:

Chan = the selected channel 1 through the maximum number of channels. (integer)

SDCBOF,<Chan>,<Value>

Sets the DC bias channel output voltage offset set point. This is the value that the DC bias board will attempt to reach for the offset.

Where:

Chan = the selected channel 1 through the maximum number of channels. (integer)

Value = the output voltage offset requested. (float)

GDCBOF,< Chan >

Returns (float) the DC bias channel output voltage offset set point. This is the value that the DC bias board is attempting to reach for the offset.

Where:

Chan = the selected channel 1 through the maximum number of channels. (integer)

GDCMIN,< Chan >

Returns (float) the DC bias channel output voltage maximum value. This is the maximum output voltage the DC bias board is capable of generating.

Where:

Chan = the selected channel 1 through the maximum number of channels. (integer)

GDCMAX,< Chan >

Returns (float) the DC bias channel output voltage minimum value. This is the minimum output voltage the DC bias board is capable of generating.

Where:

Chan = the selected channel 1 through the maximum number of channels. (integer)

SDCPWR,<Value>

The command will turn on and off the power sources to all DC bias board in your system. This command is only effective on +- 250 volt bias boards and higher.

Where:

Value = ON to turn the supplies on, or OFF to turn the supplies off.

GDCPWR

This command will return the state of the power sources to all DC bias board in your system. This command is only effective on +- 250 volt bias boards and higher. This command will return ON or OFF.

Note! Each DC bias board has offset capability. This offset is applied to all channels on a board (8 total per board) and is set using the SDCBOF. The GDCMIN and GDCMAX return the range of the offset and the range of each channel if the offset is set to 0. If the offset value is set to a non-zero value then each channel's minimum and maximum are adjusted by the offset value defined. For example a +-250 volt DC bias board can output 0 to 500 volts if the offset is set to 250 volts. The set and get output voltage commands factor in the offset voltage and set or return actual output voltages. You need to use the get min and max commands with care because they define the min and max of the offset so the actual channel values can be twice this value. Remember, the offset applies to all channels on a given DC bias board.

RF driver commands:

SRFFRQ,<Chan>,<Freq>

Sets the RF driver channel output drive frequency in Hz.

Where:

Chan = the selected RF driver channel, 1 through maximum RF channels. (integer)

Freq = the output frequency in Hz. (integer)

SRFDRV,<Chan>,<Drv>

Sets the RF driver channel output drive level in percent.

Where:

Chan = the selected RF driver channel, 1 through maximum RF channels. (integer)

Drv = the output drive level in percent of full drive. (float)

GRFFRQ,<Chan>

Returns (integer) the RF driver channel output drive frequency in Hz.

Where:

Chan = the selected RF driver channel, 1 through maximum RF channels. (integer)

GRFDRV,<Chan>

Returns (float) the RF driver channel output drive level in percent of full drive level.

Where:

Chan = the selected RF driver channel, 1 through maximum RF channels. (integer)

GRFPPVP,<Chan>

Returns (float) the RF driver channel output peak-to-peak RF voltage level on the positive output phase.

Where:

Chan = the selected RF driver channel, 1 through maximum RF channels. (integer)

GRFPPVN,<Chan>

Returns (float) the RF driver channel output peak-to-peak RF voltage level on the negative output phase.

Where:

Chan = the selected RF driver channel, 1 through maximum RF channels. (integer)

DIO commands:

SDIO,<Chan>,<Value>

Sets the digital output state for the selected output. Digital output can be set to 0 or 1. MIPS supports 16 digital outputs and the channels are labeled A through P. The channel names are case sensitive.

Where:

Chan = the selected digital output channel, A through P.
(character)

Value = the output logic level, 0 or 1. (integer)

GDIO,<Chan>

Returns (integer) the state (0 or 1) for the selected digital input or output channel. MIPS supports 16 digital outputs and the channels are labeled A through P, MIPS also supports 8 digital inputs labeled Q through X. The channel names are case sensitive. Reading the digital output will return its current state, reading the digital input will return the logic level of the selected channel.

Where:

Chan = the selected digital output channel, A through X.
(character)

Table commands (Pulse sequence generation):

STBLDAT;<table definition string>;

This command defines a table that is used to generate an output pulse sequence. This is the only MIPS command that does not need to be terminated with a CR or LF, the closing semicolon defines the end of

the table definition and when the semicolon is detected the table is processed. The format of the table definition string (TDS) is defined later in this document. The TDS allows the user to define DC bias channel and values as well as digital output channels and states to be set at predefined points in time. The TDS can define looping tables and nested tables allowing complex pulse sequence generation.

STBLCLK,<clock>

This command will define the clock mode for the table system. The clock is used to advance the counter in the table system; this can be done using an internal clock or using a clock input on the rear panel of the MIPS box.

Where:

- clock = "EXT" indicating external clock input.
- = "MCK2" internal clock input master clock / 2.
- = "MCK8" internal clock input master clock / 8.
- = "MCK32" internal clock input master clock / 32.
- = "MCK128" internal clock input master clock / 128.

GTBLFRQ

This command returns (integer) the frequency in Hz if the table clock is set to one of the internal options.

STBLTRG,<trigger>

This command will define the trigger mode for the table system. The trigger is used to start the table execution; this can be done by a software command or by using the trigger input on the rear panel of the MIPS box.

Where:

- trigger = "SW" indicating software trigger.
- = "EDGE" indicating hardware trigger on any edge.
- = "POS" indicating hardware trigger on positive edge.
- = "NEG" indicating hardware trigger on negative edge.

TBLABRT

This command will cause the system to exit the table mode and abort any table processing that is in progress. The message "ABORTED" will be issued when the table mode is exited and the system returns to local mode.

SMOD,<mode>

Sets the system table mode. There are two value modes, local mode where the system is not ready to execute a table and is in normal operating mode, table mode where the loaded table is prepared for execution and system enters table mode. In the table mode the MIPS display will indicate table mode and disable all manual control. You can exit this mode by pressing the control knob to abort. If this is done a message will be issued indicating the table mode was aborted by the user ("ABORTED by user").

When the table mode is entered the system will setup the table for execution based of the parameters that have been defined. When the

system is ready to play the table (accept a trigger) the message "TBLRDY" will be issued.

Where:

mode = LOC for local or TBL for table mode.

TBLSTRT

This command will issue a software trigger and start the execution of a table if the system is in table mode and the trigger is set to software. After the table execution has finished the message "TBLCMPT" will be issued then the system will be prepared for another trigger and the message "TBLRDY" will be issued.

Macro commands:

Macros are collections of commands that are saved to a file on the MIPS controller. These macros can then be played resulting in all the commands recorded in the macro to be executed. The following series of commands support this macro capability.

MRECORD,<Filename>

The command will open a macro file and enable recording of commands. The filename needs to be unique and should not include an extension. The MIPS controller will add an extension of .mac automatically. After this command is issued all following commands will be recorded.

MSTOP

This command will stop the macro recording and close the file. At this point the macro file is ready to play.

MPLAY,<Filename>

After you have created a macro file all the commands recorded in the macro file can be executed with this MPLAY command. The filename should not include an extension; the MIPS controller will add an extension of .mac automatically.

MLIST

This command will list all the macro files that have been recorded by the MIPS system. After all filenames have been sent the MIPS system will send "End of macro file list." to indicate the end of the file list.

MDELETE,<Filename>

You can remove a macro file from the system by issuing this command. The filename should not include an extension; the MIPS controller will add an extension of .mac automatically.

Table Definition String (TDS)

The Table Definition String (TDS) defines channels and their values to be set at defined time points. The time points are defined by clock cycle counts. The simplest TDS is defined below:

<count>:<channel>:<value>...,<count>:<channel>:<value>...

In this example at the count, defined by the number of clock cycles after the trigger, the listed channel to set to the value. At any given time point you can set as many channel value pairs as desired. The list of channel and value are separated with a colon. A comma defines the end of a defined count and the start of a new count section.

Loops are defined using square brackets. An opening square bracket defines the start of a table loop.

<count>:[<name>:<repeat>,<count>:<channel>:<value>...

Count defines the starting time of this table (defined by the number of clock cycles after the trigger). The “[” character defines the start of the table. Name is a single character name assigned to the table. Repeat is an integer used to define how many times this table will be repeated.

Loops are closed with a “]” character. The closing square bracket is placed where a <channel> value would normally appear.

Loops can be nested up to 5 deep. There is no limit to how many loops can be placed in series.

Below is a list of valid full table commands:

```
STBLDAT;100:1:10;
STBLDAT;100:1:10,150:2:33;
STBLDAT;200:1:1,300:1:0,400:1:1,500:1:0;
STBLDAT;200:A:1,300:A:0,400:A:1,500:A:0;
STBLDAT;200:A:1,300:A:0,400:A:1,700:A:0;
STBLDAT;100:A:1,150:A:0,200:A:1,250:A:0;
STBLDAT;0:[3:3,100:A:1,150:A:0,225:A:1,250:A:0,301:];
STBLDAT;100:1:10:2:20:3:123,150:2:33,250:2:0;
STBLDAT;100:1:15:3:123,150:2:33,400:[3:5,0:1:30:2:10,100:1:10:2:30,150:];
STBLDAT;100:1:15:3:123,150:2:33,400:[3:5,0:1:30:2:10,100:1:10:2:30,150:],
0:1:15,50:1:5;
STBLDAT;0:[3:5,0:1:30:2:10,100:1:10:2:30,150:];
STBLDAT;0:[1:20,0:1:10:2:30,50:3:70,100:[2:40,0:1:30:2:10,100:1:10:2:30,2
00:W],0:1:0:2:0,150:A:1,200:A:0,400:W];
```

Current error codes read with the GERR command:

```
// This group of error codes are shared between MIPS and AMPS. MIPS
// does not use all of these codes.
ERR_BADCMD          1    // invalid command
ERR_BADARG          2    // invalid argument
ERR_LOCALREADY      3    // System already in LOC mode
ERR_TBLALREADY      4    // System already in TBL mode
ERR_NOTBLLOADED     5    // No tables have been loaded
ERR_NOTBLMODE       6    // System is not in table mode
ERR_TBLNOTREADY     7    // Table not ready
ERR_TOKENTIMEOUT    8    // Timed out waiting for token
ERR_EXPECTEDCOLON   9    // Expected to see a :
ERR_TBLTOOBIG      10   // Table too big!
```

ERR_CHLOWORBRD	11	// Channel number too low or // board not present
ERR_CHHIORBRD	12	// Channel number too high or // board not present
ERR_CHHIGH	13	// Requested channel number too // high
ERR_BRDLOWORBRD	14	// Board number too low or board // not present
ERR_BRDHIORBRD	15	// Board number too high or board // not present
ERR_BRDHIGH	16	// Board number too high
ERR_BRDNOTSUPPORT	17	// Command not support on this // board rev
ERR_BADBAUD	18	// Invalid baud rate requested
ERR_EXPECTEDCOMMA	19	// Expected comma
ERR_NESTINGTOODEEP	20	// Table nesting too deep
ERR_MISSINGOPENBRACKET	21	// Table] without corresponding [
ERR_INVALIDCHAN	22	// Invalid channel request
ERR_DIOHARDWARENOTPRESENT	23	// DIO hardware not found
ERR_TEMPRANGE	24	// Temp range error
ERR_ESIHVOUTOFRANGE	25	// ESI HV out of range
ERR_TEMPCONTROLLOOPGAIN	26	// Temp control loop gain range // error
ERR_NOTLOCMODE	27	// System is not in local mode
ERR_WRONGTRGMODE	28	// Wrong trigger mode
// These error codes are specific to MIPS		
ERR_VALUERANGE	101	// Requested value is out of range
ERR_NOSDCARD	102	// No SD card present in system
ERR_CANTCREATEFILE	103	// Can't create the file on SD card
ERR_FILENAMETOOLONG	104	// Filename defined is too long
ERR_CANTOPENFILE	105	// Can't open file
ERR_CANTDELETEFILE	106	// Can't delete file
ERR_NOTSUPPORTINREV	107	// Not supported in this MIPS controller revision