ISC-2425-25+
Programming Manual

AN-50-002

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1 Introduction

This document provides detailed information about the use of application and system-level commands supported by the firmware of the Mini-Circuits ISC-2425-25+ high power signal source board. The ISC-2425-25+ is a solid state connectorized signal source and system controller module which can be used in a wide range of industrial, scientific, and medical applications in the 2400-2500 MHz ISM band. ISC products can be paired with a compatible amplifier to create an RF Energy Generator sub-system.

The ISC, RFS, and RFX series can be operated by sending text commands over their serial interface(s). These commands are part of a non-proprietary command protocol made to be both legible by humans and suitable for process automation through software. The serial command set enables users to get started quickly and communicate directly with ISC-2425-25+ using nothing more than a standard USB cable and PC. Though this document is specific to the ISC-2425-25+, most of the commands and functions described in this document are shared between products in the ISC, RFS, and RFX series.

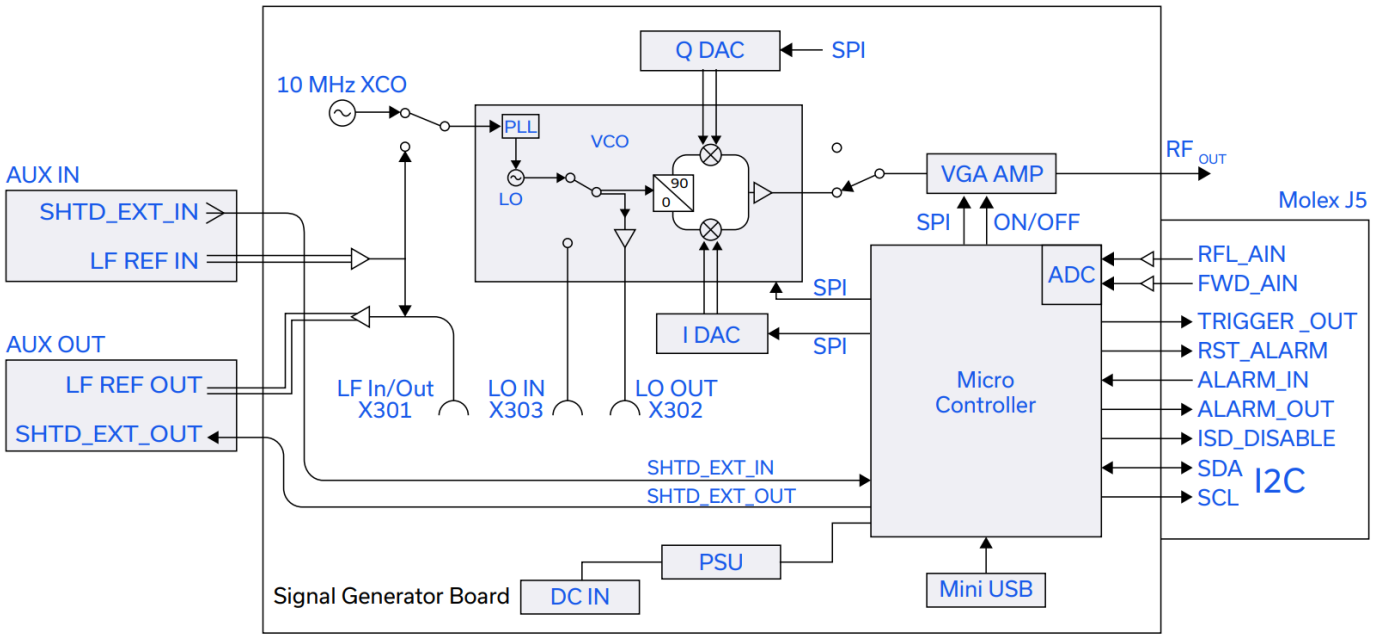
1.1 Style Conventions

This document uses the following style conventions:

`Monospace`	Denotes text that is entered at a keyboard, such as commands, file names, and source code
`[bracketed]`	Denotes a named argument in a command
`(bracketed)`	Denotes text that is optional or an optional argument in a command.

1.2 System Overview

ISC-2425-25+ Block Diagram



Functional Description

The ISC-2425-25+ is a system controller and signal source capable of outputting up to +25 dBm to drive one or more PAs in RF Energy applications. All functions needed to monitor and control the ISC-2425-25+ are accessible through the serial command set. A serial connection can be made over the USB Mini AB port[1]. In addition to the serial interface, the ISC-2425-25+ offers several functions through dedicated pins on the 20-pin Molex Connector as well as the Aux In and Aux Out connectors. A full description of these interfaces is outside of the scope of this document. The ISC-2425-25+ communicates to devices in the system through I^2C. Many serial commands in this command-set manual are simply wrappers for reading from or writing to devices on the I^2C Bus.

Compatible I^2C target devices include:

PA: ZHL-2425-250X+ 250W Power Amplifier

Splitter: SPL-2G42G50W4+ Active 4-Way Power Splitter with Amplitude and Phase control.

PSU: PSUs supporting PMBus. Eg: OmniOn CC2725AC34TZL

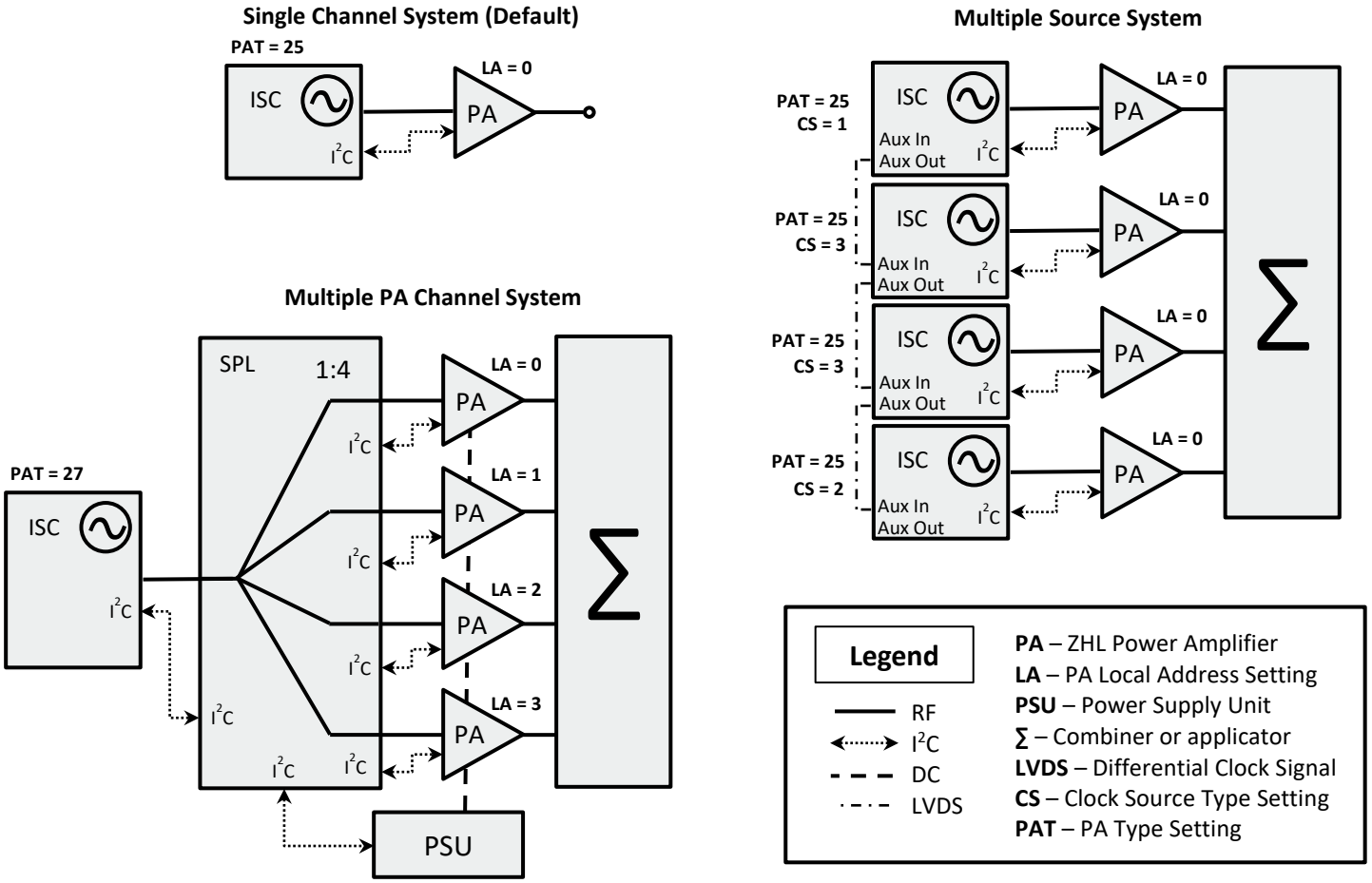
[1] A 3.3V TTL UART interface is also available upon request. The same text-based serial commands are used to communicate with the module for both USB and UART mode and only one communication mode can be active at a time with the default being USB. Refer to the $COMS command in this document for switching between USB and UART communication modes.

System Application Examples

The default configuration of the ISC-2425-25+ is for a single ISC and single ZHL PA 250W generator sub-system. Higher system powers can be achieved by adding PA Channels or by adding sources. Examples of each are shown in the figure below. If the application requires power combining and by extension a well-defined phase offset between channels, it is recommended to use a single source with multiple PA channels. If the application requires channels to operate at multiple frequencies simultaneously, multiple sources are needed.

For multiple source systems, the only thing that needs to be configured is the "Clock Source" setting using the $CSS command. The first ISC should be configured as clock source type 1 (master); the last should be configured as clock source type 2 (slave); the in-between ISCs should be configured as clock source type 3 (in-line slave).

In a multiple PA Channel system, the PAs need to be configured to have unique I^2C Addresses. This is done by configuring the "Local Address" setting on the ZHL PA (see $ZHLAS). In addition, the ISC needs to be configured to read power, temperature, status, voltage, current, etc. from all PA channels instead of just one as well as set the frequency on all channels in response to a frequency change. All of this is done by changing the "PA Type" setting from default, 25, to the type for a four-channel system, 27. See $PATS for more information on this setting.



Setting up Communication

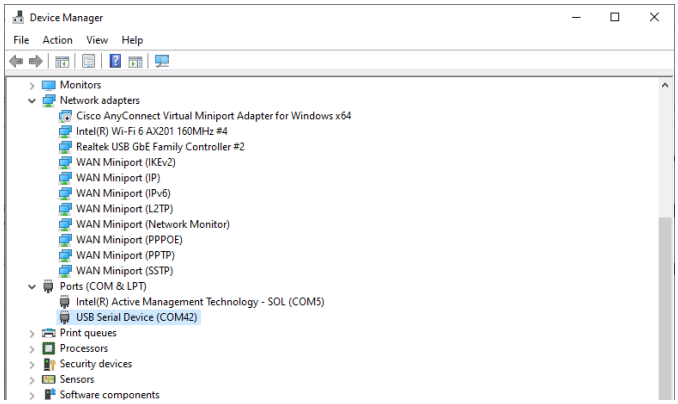
Setting up the communication between user and ISC-2425-25+ board over USB is a straightforward process. Below is an example using PuTTY on a Windows or Linux PC.

USB Serial Connection with PuTTY

- Plug the ISC-2425-25+ into the PC using a USB A to USB Mini-B cable.
- The ISC-2425-25+ will appear as a virtual COM port. Find the port name of the device.

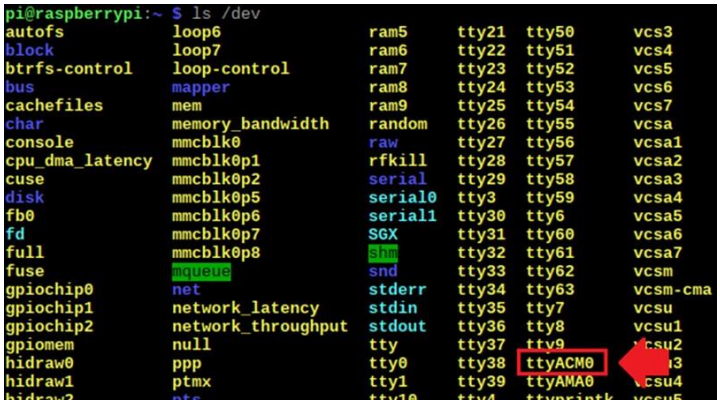
Windows:

Open the 'Device Manager' in Windows and find the port name of your device. It will show up as "USB Serial Device", followed by the port name.



Linux:

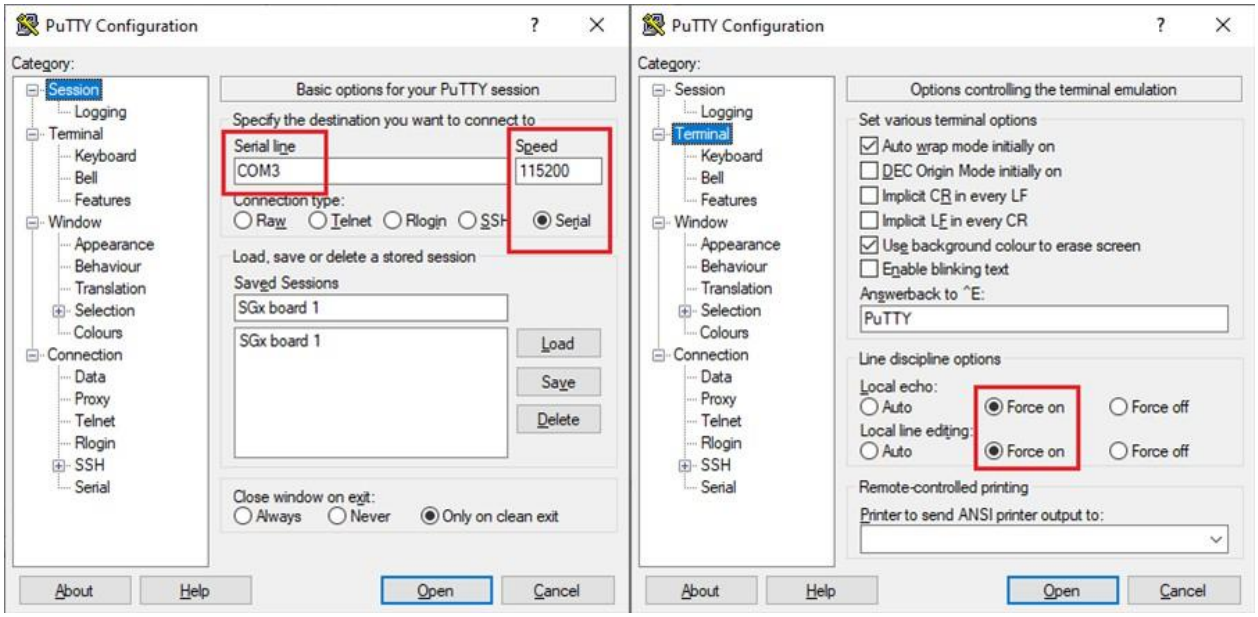
Open a terminal (CTRL + ALT + T) and use the `"ls /dev"` command to view available devices. The ISC-2425-25+ should appear as a `"ttyACM"` device followed by a number.



- Open PuTTY on your PC and provide the necessary information for the connection with the device.

Baud rate:	115200
Data bits:	8
Parity bits:	0
Stop bits:	1
Flow control:	none

- It is highly recommended to configure the “Terminal” category settings: “Local echo” and “Local line editing” to “Force on”.
- **Remark:** Linux requires the full path to the port (e.g. “/dev/ttyACM0”).



- Save the session, so that it won’t need to be reconfigured again in the future and press ‘Open’ to start a connection with the ISC-2425-25+.
- A blank terminal window will pop up. Communication with the ISC board should now be established.

1.3 Sending a command

The command set can be divided into three categories:

- **Set commands** – These are used to write the setpoints and configurations of the ISC board and typically end with the letter 'S'. For example: setting the RF power level (PWRS), enabling DLL mode (DLES), etc.
- **Get commands** – These are used to read the values of the ISC board and, with a few exceptions, typically end with the letter 'G'. For example: printing out setpoints (PWRG), getting the temperature (PTG), etc.
- **Execute commands** – A few remaining commands that don't fall in either of the above categories. They will usually execute actions such resetting the board (RST) or performing a frequency sweep (SWP).

The general syntax for a command is as follows:

```
$[command],[channel],(parameter1),(parameter2),(...)\r\n
```

The protocol uses the '$' symbol as an indicator for the start of a command. A message sent without the '$' symbol will not be recognized as a command. Similarly, '\r\n' (new line) marks the end of a command. Without at least a '\r' or a '\n' the device will keep waiting for more bytes indefinitely.

There is one parameter that is used in every command: the channel identifier.

Each ISC is assigned a numeric channel identifier. The default value is 1, but when using more than one ISC in a multi-channel setup, it may be desirable to assign a unique number to each device beforehand so that they can be identified and differentiated during runtime.

When sending a command, it is necessary to include the correct channel number of the board. Otherwise, the message is ignored under the assumption that it is intended for a different device.

The channel '0', is accepted by every ISC device regardless of the assigned number. In single-channel systems, as well as in multi-channel systems where each ISC device has a dedicated serial connection, it is sufficient to always use channel identifier '0' when sending a command. In multi-channel systems that broadcast serial commands to multiple units over a bus, care should be taken to use the correct channel identifier.

1.4 Receiving a response

The ISC board provides feedback when a command succeeds. A successful set command will always reply with an OK:

```
$[command],[channel],OK\r\n
```

A successful get command will simply return the requested information:

```
$[command],[channel],[parameter1],(parameter2),(...)\r\n
```

Miscellaneous commands do not have a standardized way of relaying successful results but will in most cases be similar to the above examples or some combination of both.

All command response strings will include the name of the command sent and the channel id of the device sending the response. If a command is sent to channel '0', the response will return with the channel the connected device is set to, never channel '0'.

It is also possible for the execution of a command to fail. There can be several reasons for this:

- A mistake could be made when writing out a command.
- The command may not be executable on the device type or configuration.
- A runtime problem occurs.

If something goes wrong during command execution, the ISC board will reply with an error code, indicating that the action has failed. An error response looks as follows:

```
$[command],[channel],ERR##\r\n
```

The possible error codes and their respective descriptions are listed in the following:

Hex code	Error Description
0x01	Reserved
0x02	The serial message exceeded the maximum length.
0x03	The serial message had too few arguments.
0x04	The message had too many arguments.
0x05	The system could not accept this message is the current mode.
0x06	The system was busy and cannot process this message at this time.
0x07	The message was recognized but is not yet implemented in the codebase.
0x10	An argument was in error with the lower nibble indicating the argument number.
0x11	Argument 1 was invalid / out of range.
0x12	Argument 2 was invalid / out of range.
0x13	Argument 3 was invalid / out of range.
0x14	Argument 4 was invalid / out of range.
0x15	Argument 5 was invalid / out of range.

0x16	Argument 6 was invalid / out of range.
0x17	Argument 7 was invalid / out of range.
0x18	Argument 8 was invalid / out of range.
0x19	Argument 9 was invalid / out of range.
0x7E	Command execution failed.
0x7F	An error occurred that is not covered by any of the other error codes.

An example of an error response would be the following

Input:	$VER,1,1
Output:	$VER,1,ERR04

Hex code 0x04 indicates that the input command had too many arguments. This is correct, as the $VER command requires no additional arguments beyond the channel identifier.

1.5 Protocol

The protocol of the command set is straight forward:

1. Send a command.
2. Wait until a full response with a '\r\n' at the end is read.

It is instrumental to always wait for a complete reply from the device before sending another command. Sending commands without waiting for a full reply can result in communication problems. Sending commands in quick succession without waiting for the response may additionally overburden the ISC board with a growing list of tasks to complete, leaving it no time to perform safety operations and resulting in an automatic reset to break the cycle.

2 Basic Functions

These are the essential commands core to microwave generator system functionality.

2.1 $ECG – Get RF output enable state

This command returns the enable state of the ISC board's RF output. Enable state can be set with $ECS, but there are also many status conditions that turn RF output OFF for safety reasons. Check $ST for details.

Syntax:

Input:	$ECG,[channel]
Output:	$ECG,[channel],[enable]

- **[channel]** – Channel identification number.
- **[enable]** – The RF output enable state.

  0 – OFF

  1 – ON

Example:

Input:	$ECG,1
Output:	$ECG,1,0

This indicates the ISC board's RF power output is disabled (default state)

2.2 $ECS – Set RF output enable state

This command sets the RF output enable state of the ISC board to ON or OFF.

Syntax:

Input:	$ECS,[channel],[enable]
Output:	$ECS,[channel],OK

- **[channel]** – Channel identification number.
- **[enable]** – The RF output enable state.

  0 – OFF

  1 – ON

Example

Input:	$ECS,1,1
Output:	$ECS,1,OK

This enables the RF power output of the ISC board.

2.3 $FCG – Get frequency

This command returns the frequency of the ISC board's RF output in MHz.

Syntax:

Input:	$FCG,[channel]
Output:	$FCG,[channel],[frequency]

- **[channel]** – Channel identification number.
- **[frequency]** – The current frequency of the RF signal (MHz).

Example:

Input:	$FCG,1
Output:	$FCG,1,2450.000

This indicates the frequency is set to 2450 MHz (default setting)

2.4 $FCS – Set frequency

This command sets the frequency of the ISC board's RF output to the desired value in MHz.

Syntax:

Input:	$FCS,[channel],[frequency]
Output:	$FCS,[channel],OK

- **[channel]** – Channel identification number.
- **[frequency]** – The desired frequency setting for the RF signal (MHz).

Example:

Input:	$FCS,1,2450
Output:	$FCS,1,OK

This sets the frequency to 2450 MHz.

2.5 $PAG – Get power readings as ADC counts

This command returns the forward and reflected power ADC counts. Depending on the PA Type, these ADC counts are either converted from the analog voltage inputs on the ISC board, or from the ADCs on the ZHL-2425-250X+ (See $PATS). If the source of the ADC count is the ISC board, ADC measurements are averaged over 10 samples. Otherwise, a single sample is returned.

Syntax:

Input:	$PAG,[channel]
Output:	$PAG,[channel],[fwd power],[rfl power]

- **[channel]** – Channel identification number.
- **[fwd power]** – The forward power ADC count 0 to 4095.
- **[rfl power]** – The reflected power ADC count 0 to 4095.

Example:

Input:	$PAG,1
Output:	$PAG,1,507.50000,433.70000

The forward and reflected analog power ADC counts are 507.5 and 433.7 respectively.

2.6 $PCG – Get phase

This command returns the current phase value of the ISC board's RF output in degrees (°).

Syntax:

Input:	$PCG,[channel]
Output:	$PCG,[channel],[phase]

- **[channel]** – Channel identification number.
- **[phase]** – The phase value in degrees (°); between 0 and 359.

Example:

Input:	$PCG,1
Output:	$PCG,1,0

This indicates that the phase is set to 0° (default).

2.7 $PCS – Set phase

This command sets the phase of the ISC board's RF output in degrees (°). The phase setting is referenced to the selected clock source (see $CSS command).

Syntax:

Input:	$PCS,[channel],[phase]
Output:	$PCS,[channel],OK

- **[channel]** – Channel identification number.
- **[phase][2]** – The desired phase value in degrees (°); between 0 and 359.

Example:

Input:	$PCS,1,25
Output:	$PCS,1,OK

[2] Firmware versions prior to 2.0.14 have inverted polarity. The phase shift induced by "$PCS,0,90" from earlier firmware now matches the shift induced by "$PCS,0,-90" instead.

This sets the phase to 25°.

2.8 $PIG – Read PA Current

This command returns the DC current reading of the ISC in Amps.

Syntax:

Input:	$PIG,[channel]
Output:	$PIG,[channel],[current]

- **[channel]** – Channel identification number.
- **[current]** – DC current reading (A).

Example:

Input:	$PIG,1
Output:	$PIG,1,12.45

This indicates the DC Current is 12.45 A

2.9 $PPDG – Get PA forward and reflected power in dBm

This command returns the measured forward and reflected power of the PA in dBm.

Syntax:

Input:	$PPDG,[channel]
Output:	$PPDG,[channel],[forward power],[reflected power]

- **[channel]** – Channel identification number.
- **[forward power]** – The measured RF power output of the PA (dBm).
- **[reflected power]** – The measured RF power reflected back into the PA (dBm).

Example:

Input:	$PPDG,1
Output:	$PPDG,1,47.00000,27.00000

This indicates the PA is outputting 47dBm of forward power, but 27dBm is being reflected back. This corresponds to an S11 of -20dB.

2.10 $PPG – Get PA forward and reflected[3] power in Watt

This command returns the measured forward and reflected power of the PA in Watt.

Syntax:

Input:	$PPG,[channel]

[3] Reflected power readings include power going into the amplifier "RF Output" port from reflections of mismatched loads as well as from external sources

Output:	$PPG,[channel],[forward power],[reflected power]

- **[channel]** – Channel identification number.
- **[forward power]** – The measured RF power output of the PA (W).
- **[reflected power]** – The measured RF power reflected back into the PA (W).

Example:

Input:	$PPDG,1
Output:	$PPDG,1,50.00000,0.50000

This indicates the PA is outputting 50W of forward power, and 0.5W is being reflected back. This corresponds to an S11 of -20dB.

Note: Reflected power readings include power going into the amplifier from other sources

2.11 $PTG – Get PA temperature

This command returns the temperature of the PA in degrees C.

Syntax:

Input:	$PTG,[channel]
Output:	$PTG,[channel],[temperature]

- **[channel]** – Channel identification number.
- **[temperature]** – The current temperature in °C.

Example:

Input:	$PTG,1
Output:	$PTG,1,42.7

This indicates that the current temperature of the PA is 42.7°C.

2.12 $PVG – Read PA Voltage

This command returns the measured DC Voltage of the PA in Volts.

Syntax:

Input:	$PVG,[channel]
Output:	$PVG,[channel],[voltage]

- **[channel]** – Channel identification number.
- **[voltage]** – The current voltage (V).

Example:

Input:	$PVG,1
Output:	$PVG,1,32.00

This indicates that the current voltage of the PA is 32.00V.

2.13 $PWRDG – Get PA output power setpoint in dBm

This command returns the configured output power setpoint in dBm. In autogain mode, output power is adjusted so the forward power reading tracks the output power setpoint. In feedforward mode, the output power setpoint maps to a static internal bias and attenuation setting (See $AGES/$AGEG)

Syntax:

Input:	$PWRDG,[channel]
Output:	$PWRDG,[channel],[power]

- **[channel]** – Channel identification number.
- **[power]** – The current output power setpoint (dBm).

Example:

Input:	$PWRDG,1,
Output:	$PWRDG,1,0.000000

This indicates that the output power setpoint is configured to 0 dBm (default setting).

2.14 $PWRDS – Set PA output power setpoint in dBm

This command configures the output power setpoint in dBm. In autogain mode, output power is adjusted so the forward power reading tracks the output power setpoint. In feedforward mode, the output power setpoint maps to a static internal bias and attenuation setting (See $AGES/$AGEG)

Syntax:

Input:	$PWRDS,[channel],[power]
Output:	$PWRDS,[channel],OK

- **[channel]** – Channel identification number.
- **[power]** – Output power setpoint (dBm).

Example:

Input:	$PWRDG,1,47
Output:	$PWRDG,1,OK

This configures the output power setpoint to 47 dBm.

2.15 $PWRG – Get PA output power setpoint in Watts

This command returns the configured output power setpoint in Watts. In autogain mode, output power is adjusted so the forward power reading tracks the output power setpoint. In feedforward mode, the output power setpoint maps to a static internal bias and attenuation setting (See $AGES/$AGEG)

Syntax:

Input:	$PWRG,[channel]
Output:	$PWRG,[channel],[power]

- **[channel]** – Channel identification number.
- **[power]** – The current output power setpoint (W).

Example:

Input:	$PWRG,1
Output:	$PWRG,1,0.001000

This indicates that the output power setpoint is configured to 0.001W (default setting).

2.16 $PWRS – Set PA output power setpoint in Watts

This command configures the output power setpoint in Watts. In autogain mode, output power is adjusted so the forward power reading tracks the output power setpoint. In feedforward mode, the output power setpoint maps to a static internal bias and attenuation setting (See $AGES/$AGEG)

Syntax:

Input:	$PWRS,[channel],[power]
Output:	$PWRS,[channel],OK

- **[channel]** – Channel identification number.
- **[power]** – Output power setpoint (W).

Example:

Input:	$PWRS,1,50
Output:	$PWRS,1,OK

This configures the output power setpoint to 50W.

3 Information Request

Request information about the RF Generator Board

3.1 $IDN – Get device identification string

This command returns the identification string signal source.

Syntax:

Input:	$IDN,[channel]
Output:	$IDN,[channel],[manufacturer],[device name],[serial number]

- **[channel]** – Channel identification number.
- **[manufacturer]** – Name of the manufacturer:
  Mini-Circuits
- **[device name]** – Name of the signal generator or system controller. The following types are possible:
  ISC-2425-25+[4]
  RFS-2G42G5050+
- **[serial number]** – unique serial number of the board.

Device name template:

[AAA]-[LLL][HHH][PPP](X)+

- **[AAA]** – Device type identifier. Possibilities are: ISC, RFS, RFX.
  ISC: Industrial System Controller & Small-Signal Source (<1W)
  RFS: RF Energy Power Amplifier & High Power Source (10W+)
- **[LLL]** – Lower frequency limit. 2G4 indicates 2.4GHz. G90 indicates 900 MHz
- **[HHH]** – Upper frequency limit. 2G5 indicates 2.5GHz. G93 indicates 930 MHz
- **[PPP]** – Maximum RF output power of the signal generator board. For RFS device types, the power is in Watts. For ISC and RFX device types, the power is in dBm.
- **(X)** – An "X" in the device name indicates that the device needs to be mounted to an additional heat sink or cooling plate to operate. "X" versions of amplifiers are "non-heatsink" options.

Example:

Input:	$IDN,1
Output:	$IDN,1,Mini-Circuits,ISC-2425-25+,MN0003402403

This indicates the connected device is an ISC-2425-25+ for use in the 2450 MHz ISM band, with serial number MN0003402403.

[4] ISC-2425-25+ device name does not strictly adhere to the established naming convention

3.2 $RTG – Get uptime of the ISC board

This command returns the uptime of the ISC board since its initialization. The uptime count restarts when the board is reset.

Syntax:

Input:	$RTG,[channel]
Output:	$RTG,[channel],[uptime]

- **[channel]** – Channel identification number.
- **[uptime]** – The uptime in seconds.

Example:

Input:	$RTG,1
Output:	$RTG,1,51

This indicates that the ISC board has been running for 51 seconds.

3.3 $TCG – Get temperature of the microcontroller / ISC board.

This command returns the temperature of the microcontroller on the ISC board.

Syntax:

Input:	$TCG,[channel]
Output:	$TCG,[channel],[temperature]

- **[channel]** – Channel identification number.
- **[temperature]** – The temperature of the ISC microcontroller in °C.

Example:

Input:	$TCG,1
Output:	$TCG,1,31.24739

This indicates that the ISC board 31.24739°C.

3.4 $VER – Get firmware version

This command returns the current version of the firmware.

Syntax:

Input:	$VER,[channel]
Output:	$VER,[channel],[manufacturer identifier],[major revision], [minor revision],[build],(hotfix),[date stamp],[time stamp]

- **[channel]** – Channel identification number.
- **[manufacturer identifier]** – Firmware developer identifier.
- **[major revision]** – The version's major revision number.
- **[minor revision]** – The version's minor revision number.
- **[build]** – The version's build number.
- **(hotfix)** – (optional) The version's hotfix number.
- **[date stamp] –** The date on which the firmware was compiled.
- **[time stamp]** – The time at which the firmware was compiled.

Example:

Input:	$VER,1
Output:	$VER,1,Mini-Circuits,2,7,8,Sep 21 2023,12:44:20

This indicates the firmware version is 2.7.8, compiled on September 21st, 2023.

4 Pulse-Width Modulation

Pulse Width Modulation allows the user to control the average power output of the system by turning the signal ON and OFF at a set rate and duty cycle. The ISC-2425-25+ has the capability to output Pulse Width Modulated (PWM) waveform as well as send out pulses to trigger the forward power and reflected power reads during the pulse.

PWM is defined by two parameters:

PWM frequency –How often the signal switches between ON and OFF.

PWM duty cycle –The time ratio between ON and OFF each period.

Depending on the duty cycle, the average power output of the system will decrease to a percentage of its set output. For example, 50% duty cycle at 250W power setting results in an average RF power output of 125W. To ensure sufficient measurement time of the RF signal, the pulses generated by any PWM scheme must not be too short. Hence, the permissible PWM frequency and duty cycle are dependent on each other. The PWM frequency can vary between 1000 Hz – 19800Hz. To ensure accurate power readings (and therefore accurate power output), the minimum value of the duty cycle changes along with the PWM frequency according to the following formula:

$$DC_{min} = \mathrm{f_{PWM}} * \mathrm{T_{min\_pulse}}$$

Where:

DC_{min} is the minimum duty cycle expressed as a percentage.

f_{PWM} is the PWM frequency between 1000 and 19800 Hz.

T_{min_pulse} is the minimum pulse width. The minimum pulse width to ensure sufficient measurement time of the RF signal is system dependent. For applications using the ZHL-2425-250X+, the minimum pulse width is 62us

This means that at 1000 Hz, the minimum duty cycle is 7% and at 19800 Hz it is 99%. Going over this frequency value would effectively disable PWM, as the minimum duty cycle becomes 100%. The user needs to keep these limitations in mind – the system will not check for the limits. For a reasonable control range, PWM frequencies between 1 and 2 kHz are recommended.

4.1 $DCFS – Set PWM Frequency

This command sets the frequency of the PWM signal

Syntax:

Input:	$DCFS,[channel],[frequency],[reserved]
Output:	$DCFS,[channel],OK

- **[channel]** – Channel identification number.
- **[frequency]** – PWM frequency in Hz.
- **[reserved]** – Reserved. This parameter should only be written 0.

Example:

Input:	$DCFS,1,1200,0
Output:	$DCFS,1,OK

This sets the PWM frequency to 1200 Hz.

4.2 $DCG – Get PWM Duty Cycle

This command returns all the settings relating to PWM.

Syntax:

Input:	$DCG,[channel]
Output:	$DCG,[channel],[frequency],[reserved],[trigger mode], [reserved],[reserved],[reserved],[reserved],[reserved],[duty cycle]

- **[channel]** – Channel identification number.
- **[frequency]** – The current PWM frequency.
- **[trigger mode]** – The current operational mode of the PWM triggering.
  1 – free running
  2 – Reserved. Parameter should be ignored.
  3 – Reserved. Parameter should be ignored.
- **[duty cycle]** – The current duty cycle percentage value.
- **[reserved]** – Reserved. Parameters should be ignored.

Example:

Input:	$DCG,1
Output:	$DCG,1,1000,0,1,255,255,255,255,0.000000,50

This indicates that the operational mode is configured to 'free running'.

The PWM signal is configured to a frequency of 1000 Hz with a duty cycle of 50%.There is no correction factor and no delay.

4.3 $DCS – Set PWM Duty Cycle

This command sets the PWM duty cycle between 0% and 100%.

Note: This command doubles as a PWM ON/OFF switch. Setting the duty cycle to 100% is the same as turning PWM off entirely. There is no dedicated PWM Enable command

Syntax:

Input:	$DCS,[channel],[duty cycle]
Output:	$DCS,[channel],OK

- **[channel]** – Channel identification number.
- **[duty cycle]**[5] – PWM duty cycle in %.

Example:

Input:	$DCS,1,50

[5] Please note that the duty cycles that would result in a pulse width of less than 50µs will be rejected

Output:	$DCS,1,OK

This sets the PWM duty cycle to 50%.

4.4 $ECST – Set Timed RF enable in microseconds

This command initiates a single timed enable of specified duration. This function is not related to the built-in PWM feature described in this section, but it is included because it can be used to create pulses.

Syntax:

Input:	$ECST,[channel],[enable],[duration]
Output:	$ECST,[channel],OK

- **[channel]** – Channel identification number.
- **[enable]** – The RF Enable state. Should always be 1.
- **[duration]** – Duration of the timed enable in microseconds.

Example:

Input:	$ECST,1,5000000
Output:	$ECST,1,OK

Initiates a timed enable of duration 5s

5 DLL and Sweep

In RF energy systems, frequency adjustment is used to optimize power transfer into the load. There are two built-in frequency adjustment routines that help the user find, then switch to the optimal frequency.

The sweep function performs a sweep over a user defined frequency range and reports back the forward and reflected powers. The user can request that data be returned on all the frequency points or just request the data on the frequency point with the best forward to reflected power ratio. This document will use the terms Return Loss, S11, and reflection coefficient interchangeably to denote the forward to reflected power ratio. The forward to reflected power ratio can be called Return Loss or S11. The sweep function searches the entire range for the optimal S11, so it will find the global minimum within the granularity of the step size. If a sweep is executed in the middle of a sensitive process, the fluctuating power delivered to the load caused by the sweep itself may not be tolerable, in which case, DLL mode may be preferred. The output of the sweep functions, $SWP or $SWPD, can be used to generate S11 plots similar to a network analyzer.

Digital Locked Loop (DLL) mode is another way to optimize frequency that is intended to be used during a process application. If the measured S11 is less than the threshold (poor match), then DLL will continuously sweep the frequency from 'lower frequency' to 'upper frequency' in steps of 'frequency step' until S11 exceeds the threshold (good match). While S11 exceeds the threshold, the DLL will use a local search strategy to fine-tune the frequency. Every step of the DLL, the current frequency is updated to the frequency with the best S11 of the three points (current frequency +/- frequency step). This way, the DLL can track optimal frequencies that move with changes in cavity temperature, pressure, or contents over the duration of a process application.

When DLL mode enabled, the only thing that changes operation-wise are the constant automatic adjustments to frequency setting, so it is possible to mix and match with other modes such as feed-forward mode or PWM mode.

5.1 $DLCG – Get DLL configuration

This command returns the configured parameters of the DLL mode.

Syntax:

Input:	$DLCG,1
Output:	$DLCG,[channel],[lower frequency],[upper frequency],[start frequency],[frequency step],[threshold],[main delay]

- **[channel]** – Channel identification number.
- **[lower frequency]** – The lower boundary of the bandwidth for DLL in MHz.
- **[upper frequency]** – The upper boundary of the bandwidth for DLL in MHz.
- **[start frequency]** – The frequency at which the DLL starts its activities in MHz.
- **[frequency step]** – The step size of the DLL in MHz.
- **[threshold]** – The match/efficiency threshold in dB to be met before DLL latches onto a frequency.
- **[main delay]** – The delay between complete runs of the DLL in ms.

Example:

Input:	$DLCG,1
Output:	$DLCG,1,2400.000000,2500.000000,2450.000000,1.000000,0.000000,1

This indicates that DLL is configured to function within the range of 2400-2500 MHz, starting off initially at a frequency of 2450MHz. It makes 1MHz steps with a threshold of 0dB. There is 1ms of delay between DLL runs (default).

5.2 $DLCS – Set DLL configuration

This command configures the parameters of DLL mode.

Syntax:

Input:	$DLCS,[channel],[lower frequency],[upper frequency], [start frequency],[frequency step],[threshold],[main delay]
Output:	$DLCS,[channel],OK

- **[channel]** – Channel identification number.
- **[lower frequency]** – The lower boundary of the bandwidth for DLL in MHz.
- **[upper frequency]** – The upper boundary of the bandwidth for DLL in MHz.
- **[start frequency]** – The frequency at which the DLL starts its activities in MHz.
- **[frequency step]** – The step size of the DLL in MHz.
- **[threshold]** – The match/efficiency threshold in dB to be met before DLL latches onto a frequency.
- **[main delay]** – The delay between complete runs of the DLL in ms.

Example:

Input:	$DLCS,1,2400,2500,2410,5,0.5,25
Output:	$DLCS,1,OK

This sets lower frequency to 2400 MHz, upper frequency to 2500 MHz, start frequency to 2410 MHz, frequency step to 5MHz, threshold to 0.5 dB and the main delay to 25 ms.

5.3 $DLEG – Get DLL enable state

This command indicates whether DLL mode is currently turned ON or OFF.

Syntax:

Input:	$DLEG,[channel]
Output:	$DLEG,[channel],[enable]

- **[channel]** – Channel identification number.
- **[enable]** – The current enable state of the DLL mode.

  0 – OFF (default)

  1 – ON

Example:

Input:	$DLEG,1
Output:	$DLEG,1,0

This indicates that the DLL is currently not enabled (default).

5.4 $DLES – Set DLL enabled / disabled

This command sets the enable state of the DLL. If DLL is disabled, the amplifier is said to be in CW mode.

Syntax:

Input:	$DLES,[channel],[enable]
Output:	$DLES,[channel],OK

- **[channel]** – Channel identification number.
- **[enable]** – The enable state of the DLL.

  0 – OFF (default)

  1 – ON

Example:

Input:	$DLES,1,1
Output:	$DLES,1,OK

This turns on DLL mode.

5.5 $SWP – Perform frequency sweep with powers in Watts

This command executes a user defined frequency sweep at an output power defined in Watts. Forward and reflected power is measured at every point in the sweep and are also reported in Watts.

The completion time of the command will increase as the number of frequency steps increases. This can make it seem as if the ISC board has become unresponsive for some time.

This command offers two output modes, which have different output syntaxes.

Syntax:

Input:	$SWP,[channel],[start frequency],[stop frequency],[step frequency],[power watt],[output mode]
Output (mode 0):	$SWP,[channel],[measurement frequency 0],[forward power 0], [reflected power 0] $SWP,[channel],[measurement frequency 1],[forward power 1], [reflected power 1] … $SWP,[channel],OK
Output (mode 1):	$SWP,[channel],[measurement frequency],[forward power], [reflected power]

- **[channel]** – Channel identification number.
- **[start frequency]** – The beginning of the sweep bandwidth in MHz.
- **[stop frequency]** – The end of the sweep bandwidth in MHz.
- **[step frequency]** – The size of the steps taken between each measurement in MHz.
- **[power watt]** – The output power at which the sweep is performed in Watt.
- **[output mode]** – Dictates what the sweep will output.

  0 – Return all sweep results. It returns one line of text for every point in the sweep, as well as an OK message at the end. All responses arrive simultaneously when the command finishes.

1 – Returns only the best match sweep result. The current frequency and the DLL start frequency is set to this value after the completion of the sweep.

- **[measurement frequency]** – The frequency at which is measured in MHz. The output frequency value is rounded to the 2nd decimal.
- **[forward power]** – The forward power measured at [measurement frequency] in Watt.
- **[reflected power]** – The reflected power measured at [measurement frequency] in Watt.

Example 1:

Input:	$SWP,1,2400,2500,10,100,0
Output:	$SWP,1,2400,10.01,2.01 $SWP,1,2410,9.84,2.00 $SWP,1,2420,9.88,1.95 $SWP,1,2430,9.97,1.97 $SWP,1,2440,10.10,1.98 $SWP,1,2450,9.87,1.87 $SWP,1,2460,9.99,0.75 $SWP,1,2470,9.91,0.21 $SWP,1,2480,10.00,0.69 $SWP,1,2490,9.84,1.44 $SWP,1,2500,9.83,1.89 $SWP,1,OK

This executes an S11 sweep in the 2400 - 2500 MHz range with a step size of 10 MHz, at 100 W output power.

At 2400 MHz the forward power is 100.01 W and the reflected power is 20.12 W. At 2410 MHz, the forward power is 99.84 W and the reflected power is 20.08 W. etc...

When the sweep has run through the entire frequency band “$SWP,1,OK” is returned to indicate it is finished.

Example 2:

Input:	$SWP,1,2400,2500,10,100,1
Output:	$SWP,1,2470,99.91,2.15

This executes an S11 sweep in the 2400 - 2500 MHz range with a step size of 10 MHz, at 100 W output power. However, this time output mode 1 is used, which returns only the best match result.

At 2470 MHz, the forward power is 99.91 W and the reflected power is 2.15 W. This frequency offers the best match or ratio between forward and reflected powers. The current frequency setting and the DLL start frequency are now set to 2470MHz.

5.6 $SWPD – Perform frequency sweep with powers in dBm

This command executes a user defined frequency sweep at an output power defined in dBm. Forward and reflected power is measured at every point in the sweep and are also reported in dBm.

The completion time of the command will increase as the number of frequency steps increases. This can make it seem as if the ISC board has become unresponsive for some time.

This command offers two output modes, which have different output syntaxes.

Syntax:

Input:	$SWPD,[channel],[start frequency],[stop frequency],[frequency step],[power watt],[output mode]
Output (mode 0):	$SWPD,[channel],[measurement frequency 0],[forward power 0], [reflected power 0] $SWPD,[channel],[measurement frequency 1],[forward power 1], [reflected power 1] … $SWPD,[channel],OK
Output (mode 1):	$SWPD,[channel],[measurement frequency],[forward power], [reflected power]

- **[channel]** – Channel identification number.
- **[start frequency]** – The beginning of the sweep bandwidth in MHz.
- **[stop frequency]** – The end of the sweep bandwidth in MHz.
- **[frequency step]** – The size of the steps taken between each measurement in MHz.
- **[power dbm]** – The output power at which the sweep is performed in dBm.
- **[output mode]** – Dictates what the sweep will output.

  0 – Return all sweep results. It returns one line of text for every point in the sweep, as well as an OK message at the end. All responses arrive simultaneously when the command finishes.

  1 – Returns only the best match sweep result. The current frequency and the DLL start frequency is set to this value after the completion of the sweep.
- **[measurement frequency]** – The frequency at which is measured in MHz. The output frequency value is rounded to the 2nd decimal.
- **[forward power]** – The forward power measured at [measurement frequency] in dBm.
- **[reflected power]** – The reflected power measured at [measurement frequency] in dBm.

Example 1:

Input:	$SWPD,1,2400,2500,10,40,0
Output:	$SWPD,1,2400,40.02,33.03 $SWPD,1,2410, 40.10,33.01 $SWPD,1,2420, 40.04,32.90 $SWPD,1,2430, 39.98,32.94 $SWPD,1,2440,40.07,32.97 $SWPD,1,2450,39.89,32.72 $SWPD,1,2460,39.97,28.75 $SWPD,1,2470,40.01,23.22 $SWPD,1,2480,40.12,28.39 $SWPD,1,2490,40.05,31.58 $SWPD,1,2500,39.99,32.76 $SWPD,1,OK

This executes a measurement sweep in the 2400 - 2500 MHz range with a step size of 10 MHz, at 40 dBm output power.

At 2400 MHz the forward power is 40.02 dBm and the reflected power is 33.03 dBm. At 2410 MHz the forward power is 40.10 dBm and the reflected power is 33.01 dBm. etc...

When the sweep has run through the entire frequency band “$SWPD,1,OK” is returned to indicate it is finished.

Example 2:

Input:	$SWPD,1,2400,2500,10,40,1
Output:	$SWPD,1,2470,40.01,23.22

This executes an S11 sweep in the 2400 - 2500 MHz range with a step size of 10 MHz, at 40 dBm output power. However, this time output mode 1 is used, which returns only the best match result.

At 2470 MHz the forward power is 40.01 dBm and the reflected power is 23.22 dBm. The current frequency setting and the DLL start frequency are now set to 2470MHz.

6 Manual Power Control

In the default operation of the ISC-2425-25+, a power is set by the user with the $PWRS/$PWRDS command and the autogain feedback control loop will adjust the output power of the generator to minimize the difference between the power measured by the forward power detectors and the set power. The ISC-2425-25+ has two complementary methods for output power adjustment that work together to provide continuous adjustment over the full operating range. The Digital Step Attenuator (DSA) 'Gain' component provides the coarse method to control power in steps of 0.25 dB over a 31.75 dB range. The modulator biasing 'Magnitude' component provides near-continuous fine-tuning adjustment over about a 15 dB range. The autogain algorithm is constantly adjusting the DSA and bias settings to match the power set by the user. In doing so, autogain compensates for system drifts caused by fluctuations in temperature, DC Voltage, or other factors.

Although it is not recommended for the general use-case, it is possible to disable the autogain feedback control loop and stop automatic updates of the DSA and bias settings. These settings can then be controlled manually. This manual power control mode is called *Feed-Forward* mode, as the feedback has been removed. In feed-forward mode, $PWRS/$PWRDS commands are still used to set the forward power, but their function changes. When a power is set using $PWRS/$PWRDS in feed forward mode, the DSA is set to the attenuation that would result in the requested power. The mapping between the power setting and the DSA setting is defined by the feed-forward calibration performed at the factory. The feed-forward calibration is defined over frequency and over power at a specified default modulator bias setting (50%) and at 28V, 25°C, into a matched load. The DSA attenuation and the modulator bias setting states can also be changed directly or requested which can be useful for special cases or for system debugging.

6.1 $AGEG – Get auto-gain enabled / disabled

This command returns the enable state of the auto-gain algorithm.

Syntax:

Input:	$AGEG,[channel]
Output:	$AGEG,[channel],[enable]

- **[channel]** – Channel identification number.
- **[enable]** – The current enable state of the auto-gain algorithm.

  0 – OFF

  1 – ON

Example:

Input:	$AGEG,1
Output:	$AGEG,1,1

This indicates the auto-gain algorithm is enabled (default)

6.2 $AGES – Set auto-gain enabled / disabled

This command turns the auto-gain algorithm ON or OFF.

The auto-gain algorithm automatically regulates the power output of the ISC board by configuring the DSA and Modulator bias according to calibrations that are stored in the device's EEPROM and feedback from the PA.

When auto-gain is enabled, the user can simply request an arbitrary amount of power (in Watt / dBm) from their RF system, and the requested power will be accurately generated (As long as the calibration is good and there are no unexpected interferences).

When auto-gain is disabled, the user can take manual control of the DSA and Modulator bias. Operating manually is not recommended in most situations but can be useful for troubleshooting and characterizing RF systems.

Disabling auto-gain has consequences for a variety of commands:

- $PWRS and $PWRDS set the DSA state according to the static feed-forward calibration stored in the EEPROM
- Power can be regulated manually using commands like $MCS and $GCS to control the DSA and Modulator bias directly.
- $SWP and $SWPD ignore the [Sweep Power] argument. Sweeps are performed at whatever power output is configured through the DSA and IQ Modulator at the time.

Syntax:

Input:	$AGES,[channel],[enable]
Output:	$AGES,[channel],OK

- **[channel]** – Channel identification number.
- **[enable]** – The desired enable state of the auto-gain algorithm.
  0 – OFF
  1 – ON

Example:

Input:	$AGES,1,0
Output:	$AGES,1,OK

This disables auto-gain. Putting the generator in “feed-forward” mode

6.3 $GCG – Get DSA attenuation in dB

This command returns the configured attenuation value of the DSA which regulates the ISC board's power output. The higher the value, the lower the power output.

Syntax:

Input:	$GCG,[channel]
Output:	$GCG,[channel],[attenuation]

- **[channel]** – Channel identification number.
- **[attenuation]** – The current attenuation value of the DSA.
  Attenuation Range: 0 – 31.75 dB
  Minimum step size: 0.25 dB

Example:

Input:	$GCG,1
Output:	$GCG,1,10

This indicates the configured attenuation of the DSA is 10dB.

6.4 $GCS – Set DSA attenuation in dB

This command sets the attenuation of the DSA which regulates the ISC board's power output. The higher the value, the lower the power output.

The power output of the ISC board is a result of both the DSA and the IQ modulator working together. The DSA provides a coarse method to control power, whereas the IQ modulator provides a fine method.

To use this command, auto-gain must be disabled first (see $AGES).

Syntax:

Input:	$GCS,[channel],[attenuation]
Output:	$GCS,[channel],OK

- **[channel]** – Channel identification number.
- **[attenuation]** – The desired attenuation value of the DSA.

  Attenuation Range: 0 – 31.75 dB

  Minimum step size: 0.25 dB

Example:

Input:	$GCS,1,7
Output:	$GCS,1,OK

This will set the attenuation of the DSA to 7dB.

6.5 $MCG – Get magnitude in percent

This command gets the magnitude of the IQ modulator.

Syntax:

Input:	$MCG,[channel]
Output:	$MCG,[channel],[magnitude]

- **[channel]** – Channel identification number.
- **[magnitude]** – The current magnitude configuration of the modulator bias in percent.

Example:

Input:	$MCG,1
Output:	$MCG,1,50

This indicates the magnitude of the modulator bias is configured to 50%.

6.6 $MCS – Set magnitude in percent

This command sets the modulator bias magnitude setting which regulates the ISC board's power output. The higher the value, the higher the power output.

The power output of the ISC board is a result of both the DSA and the modulator bias working together. The DSA “gain” setting provides a coarse method to control power, whereas the modulator bias “magnitude” setting provides a fine method.

The valid range of magnitudes for the ISC-2425-25+ is 0%-100%. If the magnitude setting is out of the valid range, then the magnitude will be set to the closest value in the valid range. The default magnitude setting is 50%. Check the ISC datasheet for output power curves.

To use this command, auto-gain must be disabled first (see $AGES).

Syntax:

Input:	$MCS,[channel],[magnitude]
Output:	$MCS,[channel],OK

- **[channel]** – Channel identification number.
- **[magnitude]** – The desired magnitude of the modulator bias in percent.

Example:

Input:	$MCS,1,50.3
Output:	$MCS,1,OK

This will set the magnitude of the modulator bias to 53.1%.

6.7 $PWRSGDG – Get last configured ISC board output power setting in dBm

This command returns the last power set using the $PWRSGDS command. The last power set does not indicate the current state of the VGA and IQ Modulator which could have changed due to calls to $MCS, $GCS, or any other function that affects these settings.

Syntax:

Input:	$PWRSGDG,[channel]
Output:	$PWRSGDG,[channel],[power]

- **[channel]** – Channel identification number.
- **[power]** – The last configured small signal output power setting in dBm.

Example:

Input:	$PWRSGDG,1,
Output:	$PWRSGDG,1,20

This indicates that the last power setting ISC board 20 dBm (0.1 watt).

6.8 $PWRSGDS – Set ISC board's output power in dBm

This command provides a coarse method to control the small signal output power of the ISC board by configuring the VGA and IQ Modulator to achieve roughly the requested power. This command is used as an alternative to setting the VGA and IQ Modulator settings explicitly using $MCS and $GCS. $PWRSGDS has the advantage of working as expected in feedforward mode without a dependency on a feedforward calibration. The disadvantage of this method is that power accuracy is not guaranteed to be better than a few dB. If a valid feedforward calibration is present, consider using $PWRS/$PWRDS to set the output power instead.

To use this command, auto-gain must be disabled first (see $AGES).

Syntax:

Input:	$PWRSGDS,[channel],[power]
Output:	$PWRSGDS,[channel],OK

- **[channel]** – Channel identification number.
- **[power]** – The desired small signal output in dBm.

Example:

Input:	$PWRSGDS,1,20
Output:	$PWRSGDS,1,OK

This will set the power output of the ISC board to about 20 dBm (0.1 watt).

7 Safe Operating Area

The “Safe Operating Area” (SOA) feature defines limits on operating conditions for the RF generator/Amplifier which assure the reliability, longevity, and safe operation of the device. Operating the generator “outside” of the SOA limits could potentially damage the unit or at least reduce its expected lifetime. All Minicircuits generator devices will take self-protection actions that make them robust against accidental misuse.

7.1 Introduction

As of the latest firmware[6], there are 10 SOA types as shown in the below table. Most SOA types have “high” and “shutdown” limits defined. If a parameter exceeds the shutdown limit, RF will be disabled and the appropriate status register bit will be set to 1 (see $ST). The status bits will remain high until the next call to clear the errors (See $ERRC). If a parameter exceeds the warning limit, the appropriate status bit will be set to 1, but RF will remain enabled. For most SOAs, the purpose of the high limit is informational only. A warning can be displayed to notify the user that they are operating close to the limit. In the case of temperature or reflection SOA, exceeding the high limit may result in throttling of the forward power (see $SPG and $STG for detail).

SOA Type	Description	Default State in ISC-2425-25+	Status Bit High Limit Exceeded	Status Bit Shutdown Limit Exceeded
0	Temperature SOA	Enabled	0x0000000002	0x0000000004
1	Internal Watchdog	Enabled	-	-
2	Reflection SOA	Enabled	0x0000000008	0x0000000010
3	External Watchdog	Disabled	-	0x0000010000
4	Dissipation SOA	Disabled	0x0000080000	0x0000100000
5	PA status	Enabled	-	0x0004000000
6	IQ modulator IQ lock	N/A	0x0008000000	-
7	Current SOA	Disabled	0x0010000000	0x0020000000
8	Voltage SOA (Min)	Disabled	0x0200000000	0x0100000000
	Voltage SOA (Max)	Disabled	0x0400000000	0x0800000000
9	Forward Power SOA	Disabled	0x0040000000	0x0080000000

SOA settings in the ISC-2425-25+ are initialized at boot and should not be modified during operation. The defaults above are for the ISC configured to PA types 25, 26, 27, or 30.

For the sake of avoiding redundancy, this section combines the getters and setters in a single description. All the descriptions reference the getter command, the syntax of the corresponding setter input is as follows:

Syntax:

	Getter	Corresponding Setter
Input:	$[GetCMD],[Getter Input]	$[SetCMD],[Getter Output]
Output:	$[GetCMD],[Getter Output]	$[SetCMD],[channel],OK

[6] Firmware versions 2.7.0 and later

- **[GetCMD]** – The setter command (ex. “SCG”)
- **[SetCMD]** – The setter command (ex. “SCS”)
- **[Getter Input]** – The input of the getter
- **[Getter Output]** – The output of the getter
- **[channel]** – Channel identification number.

Example:

	Getter	Corresponding Setter
Input:	$SOG,1	$SOA,1,9,1
Output:	$SOG,1,9,1	$SOA,1,OK

The getter example above indicates that SOA #9 for forward power is enabled.

7.2 $SCG/SCS – Get/Set current SOA configuration

This command returns the currents at which SOA takes action. One of the features of the SOA is protection against improper application of DC Current. Current SOA protects against overcurrent conditions.

The SOA has two reactions to excessive current, depending on the severity

- If the current is higher than the normal operating range, but still tolerable: Raise a ‘SOA High Current’ error.
- If the current is dangerously high: Raise a ‘SOA Shutdown Maximum Current’ error and shutdown RF power.

Syntax:

Input:	$SCG,[channel]
Output:	$SCG,[channel],[high current],[shutdown current]

- **[channel]** – Channel identification number.
- **[high current]** – The current at which the ‘SOA High Current’ condition is signaled by the SOA. Units in Amps.
- **[shutdown current]** – The current at which the ‘SOA Shutdown Current’ condition is signaled by the SOA. Units in Amps.

Example:

Input:	$SCG,1
Output:	$SCG,1,5.50,6.00

This indicates that the ‘High Current’, and ‘Shutdown Current’ protection limits are configured to 5.5A, and 6A respectively (default).

7.3 $SDG/SDS – Get/Set dissipation SOA configuration

One of the features of the SOA is protection against excessive power dissipation inside a generator. Excessive power dissipation occurs when an RF system draws a disproportionate amount of current from its power supply (PSU) relative to the amount RF energy that is transmitted into a load. High dissipations can be reached when the system is poorly matched or when the system is well matched but still operating with poor efficiency. At the system level, dissipation is the rate that heat needs to be removed from the generator by means of heat sink or cooling plate to maintain a stable temperature. The dissipation SOA could be used in systems with limited cooling capacity to issue a warning to the user or shut the generator down before it has a chance to heat up to the temperature shutdown limit.

Dissipation is measured in Watts. The formula used to calculate it is the following:

Dissipation(W) = PSU Power(W) - FWD Power(W) + RFL Power(W)

The SOA has two reactions to excessive dissipation, depending on the severity

- If the dissipation is high, but still tolerable:
  Raise a 'High Dissipation' error.
- If the dissipation is dangerously high:
  Raise a 'Shutdown Dissipation' error and shutdown RF power.

Note: Dissipation SOA is not enabled in the default configuration of the ISC-2425-25+ (see $SOG).

Syntax:

Input:	$SDG,[channel]
Output:	$SDG,[channel],[high dissipation],[shutdown dissipation]

- **[channel]** – Channel identification number.
- **[high dissipation]** – The dissipation value in W at which the 'High Dissipation' reaction is performed by the SOA.
- **[shutdown dissipation]** – The dissipation value in W at which the 'Shutdown Dissipation' reaction is performed by the SOA.

Example:

Input:	$SDG,1
Output:	$SDG,1,47.25000,47.400000

This indicates the 'High Dissipation' and 'Shutdown Dissipation' protection values are both configured to 0W (default). Since this SOA is not enabled by default, these values have no effect on the system operation.

7.4 $SFG/SFS – Get/Set Forward Power Limits (W)

One of the features of the SOA is protection against excessive forward power. This command returns the forward power values at which SOA takes action.

The SOA has two reactions to excessive forward power, depending on the severity

- If the forward power is high, but still tolerable:
  Raise a 'High Forward Power' error.
- If the forward power is dangerously high:
  Raise a 'Shutdown Forward Power' error and shutdown RF power.

Syntax:

Input:	$SFG,[channel]
Output:	$SFG,[channel],[high forward power],[shutdown forward power]

- **[channel]** – Channel identification number.
- **[high forward power]** – The forward power value in dBm at which the 'High Forward Power' reaction is performed by the SOA.
- **[shutdown forward power]** – The forward power value in dBm at which the 'Shutdown Forward Power' reaction is performed by the SOA.

Example:

Input:	$SFG,1
Output:	$SFG,1,47.40,48.15

This indicates the 'High Forward power' and 'Shutdown Forward Power' protection values are configured to 47.40 dBm (55W) and 48.15 dBm (65W) respectively (default).

7.5 $SOG/SOA – Get/Set SOA configuration enable status

This command returns the enable state of the SOA's protection systems. SOA limits will only trigger a protection response if that SOA is enabled. Otherwise it will do nothing.

Recommended Syntax:

Input:	$SOG,[channel],[soa type]
Output:	$SOG,[channel],[soa type],[enable]

- **[channel]** – Channel identification number.
- **[soa type]** – SOA Type. Used in the recommended syntax. The alternative syntax only supports SOA types 0-7
  0 – Temperature SOA (See $STG/STS)
  1 – Watchdog (this input is ignored, the MCU watchdog is always enabled)
  2 – Reflection SOA (See $SPG/SPS)
  3 – External Watchdog (not used in ISC-2425-25+)
  4 – Dissipation SOA (See $SDG/SDS)
  5 – PA status (See $PSG)
  6 – IQ modulator IQ lock
  7 – Current SOA (See $SCG/SCS)
  8 – Voltage SOA (See $SVG/SVS)
  9 – Forward Power SOA (See $SFG/SFS)
- **[enable]** – SOA Enable Status
  0 – OFF
  1 – ON

Example:

Input:	$SOG,1,4
Output:	$SOG,1,4,0

This indicates the Dissipation SOA is disabled

Alternative Syntax:[7]

Input:	$SOG,[channel]
Output:	$SOG,[channel],[temperature enable],[software watchdog enable], [reflected enable],[external watchdog enable],[dissipation enable],[PA status enable],[IQ lock detect enable],[current enable]

- **[temperature enable]** – The current enable state of the temperature protection system.
  0 – OFF
  1 – ON
- **[software watchdog enable]** – The current enable state of the software timeout protection system.
  This parameter always reports 0 and can be ignored.
- **[reflected enable]** – The current enable state of the reflected power protection system.
  0 – OFF
  1 – ON
- **[external watchdog enable]** – The current enable state of the board status polling protection system.
  0 – OFF
  1 – ON
- **[dissipation enable]** – The current enable state of the dissipation protection system.
  0 – OFF
  1 – ON
- **[PA status enable]** – The current enable state of the PA status monitoring protection system.
  0 – OFF
  1 – ON
- **[IQ lock detect enable]** – The current enable state of the IQ lock detection protection system.
  0 – OFF
  1 – ON
- **[current enable]** – The current enable state of the current protection system.
  0 – OFF
  1 – ON

Example:

Input:	$SOG,1
Output:	$SOG,1,1,0,1,0,0,0,0,1

This indicates the reflected power, temperature, and current protection systems are enabled, but the other protections systems are disabled (default). Voltage and forward power SOA enable statuses are not shown.

7.6 $SOAGS – Set SOA grace timer

This command configures the grace period for the SOA's protection systems.

There may be situations where it is desirable to permit a grace period before SOA acts and potentially shuts down everything. The SOA grace timer may be used to allow temporary violations of the reflection, dissipation, and temperature limits for a configurable period. Only a continuous uninterrupted violation longer than the grace timeout will trigger a reaction from the SOA.

[7] Alternative syntax only supports SOA types 0-7. It does not support Voltage SOA or Forward Power SOA.

Syntax:

Input:	$SOAGS,[channel],[grace period]
Output:	$SOA,[channel],OK

- **[channel]** – Channel identification number.
- **[grace period]** – The period in milliseconds that SOA should tolerate violations before taking action.

Example:

Input:	$SOAGS,1,500
Output:	$SOAGS,1,OK

This configures a grace period of 500ms for the SOA. Reflection, temperature, and dissipation limit violations will be tolerated for 500ms, after which the SOA will act as usual.

7.7 $SPG/SPS – Get/Set reflected power SOA configuration

This command returns the reflected power values at which SOA takes action. One of the features of the SOA is protection against excessive reflected power. Excessive reflection occurs when there is a bad match at the output and RF returns to the generator.

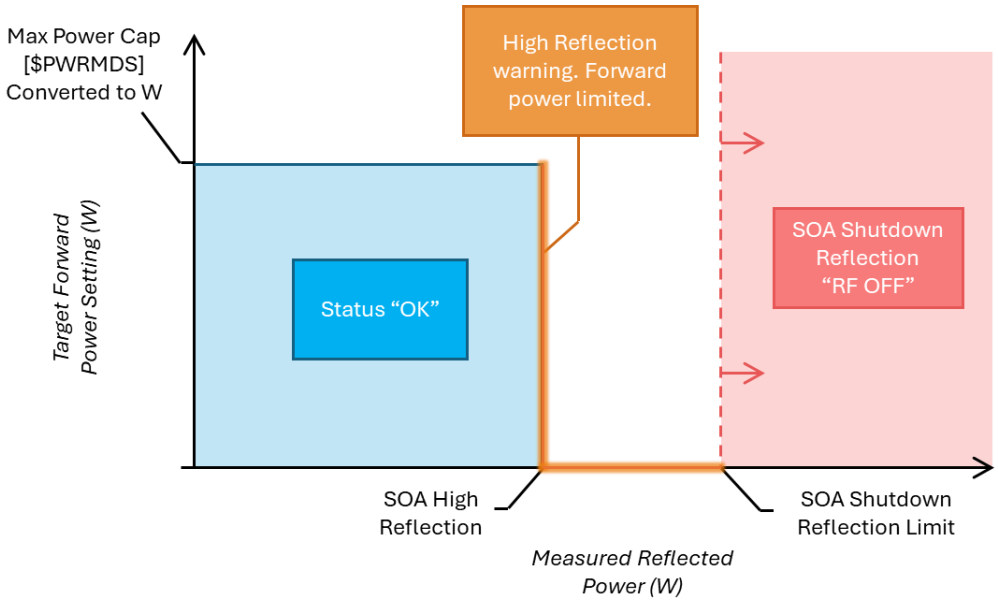
The SOA has two reactions to excessive reflection, depending on the severity

- If the reflection is high, but still tolerable:

  Raise a 'High Reflection' error and throttle the forward power when in autogain mode.
- If the reflection is dangerously high:

  Raise a 'Shutdown Reflection' error and shutdown RF power.

The high reflection condition affects the auto-gain control loop by adding forward power throttling. Normally, the auto-gain algorithm continuously adjusts the output power so that measured forward power is equal to the power setting. When reflected power is greater than the reflected power SOA high limit, autogain will instead reduce/adjust the output power so that the reflected power is equal to the reflected power SOA high limit. If the reflected power reading is coming from a poor VSWR and not an external source, power throttling provides a graceful degradation of performance that will allow continuous operation without damage or interruption into poor VSWR loads. The figure below shows the three operating regions defined by the reflected power SOA.



Syntax:

Input:	$SPG,[channel]
Output:	$SPG,[channel],[high reflection],[shutdown reflection]

- **[channel]** – Channel identification number.
- **[high reflection]** – The reflection value in dBm at which the 'High Reflection' reaction is performed by the SOA.
- **[shutdown reflection]** – The reflection value in dBm at which the 'Shutdown Reflection' reaction is performed by the SOA.

Example:

Input:	$SPG,1
Output:	$SPG,1,47.25000,47.400000

This indicates the 'High Reflection' and 'Shutdown Reflection' protection values are configured to 47.25 dBm (53W) and 54 dBm (55W) respectively (default).

7.8 $STG/STS – Get/Set temperature SOA configuration

This command configures the temperature values at which SOA takes action. One of the features of the SOA is protection against excessive temperatures. Excessive temperatures can occur for any number of reasons: side effects of high RF power reflection, faulty cooling, excessive use, etc. The SOA has two reactions to excessive temperatures, depending on the severity:

- If the temperature is high, but still tolerable:

  Raise a 'High Temperature' error.
- If the temperature is dangerously high:

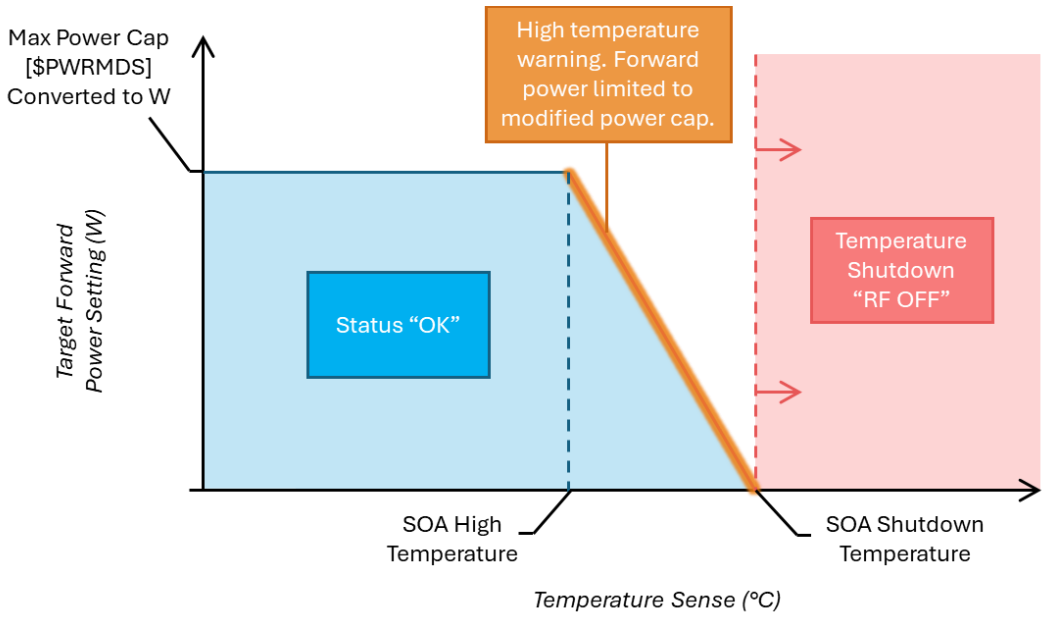
  Raise a 'Shutdown Temperature' error and shutdown RF power.

The high temperature condition affects the auto-gain control loop by adding forward power throttling. Normally, the auto-gain algorithm continuously adjusts the output power so that measured forward power is equal to the power setting. When the PA temperature is greater than the temperature SOA high limit, throttling will limit the forward power if the forward power exceeds the modified max power cap. The modified max power cap is the standard max power cap ($PWRMDG) at temperatures below the high threshold. At temperatures between the high and shutdown thresholds, the modified max power cap is calculated with a linear derating:

$$MPC'(W) = MPC(W) * \frac{T_{shutdown} - T_{final}}{T_{shutdown} - T_{high}}$$

Where:

MPC is the original max power cap in Watts
MPC' is the modified max power cap in Watts
T_{final} is the measured PA temperature in °C
$T_{shutdown}$ T_{high} are the shutdown and high temperature SOA limits in in °C



The above figure provides a visualization of the max power cap derating defined by the Temperature SOA. Power throttling provides a graceful degradation of performance that will allow continuous operation without damage or interruption.

Syntax:

Input:	$STG,[channel]
Output:	$STG,[channel],[high temperature],[shutdown temperature]

- **[channel]** – Channel identification number.
- **[high temperature]** – The temperature value in °C at which the 'SOA High Temperature' condition is signaled by the SOA.
- **[shutdown temperature]** – The temperature value in °C at which the 'SOA Shutdown Temperature' reaction is performed by the SOA.

Example:

Input:	$STG,1
Output:	$STG,1,55.0,65.0

This indicates the 'High Temperature' and 'Shutdown Temperature' protection values are configured to 55°C and 65°C respectively.

7.9 $SVG/SVS – Get/Set Voltage Limits (V)

This command returns the voltages at which SOA takes action. One of the features of the SOA is protection against improper application of DC Voltage. Voltage SOA protects against both undervoltage and overvoltage conditions.

The SOA has two reactions to excessive voltage, depending on the severity

- If the voltage is outside of the normal operating range, but still tolerable:

  Raise a 'SOA High Voltage' or a 'SOA Low Voltage' error.
- If the voltage is dangerously low or high:

  Raise a 'SOA Shutdown Minimum Voltage' or 'SOA Shutdown Maximum Voltage' error and shutdown RF power.

Syntax:

Input:	$SVG,[channel]
Output:	$SVG,[channel],[shutdown min voltage],[low voltage],[high voltage],[shutdown max voltage]

- **[channel]** – Channel identification number.
- **[shutdown min voltage]** – The voltage at which the 'Min Voltage Shutdown' condition is signaled by the SOA. Units in Volts.
- **[low voltage]** – The voltage at which the 'Low Voltage' condition is signaled by the SOA. Units in Volts.
- **[high voltage]** – The voltage at which the 'High Voltage' condition is signaled by the SOA. Units in Volts.
- **[shutdown max voltage]** – The voltage at which the 'Max Voltage Shutdown' condition is signaled by the SOA. Units in Volts.

Example:

Input:	$SVG,1
Output:	$SVG,1,24.00,26.00,36.00,38.00

This indicates that the 'Shutdown Min Voltage', ' Low Voltage', 'High Voltage', and 'Shutdown Max Voltage' protection limits are configured to 24V, 26V, 30V, and 32V respectively (default).

7.10 $SWES – Set software watchdog enabled / disabled

This command turns the software watchdog ON or OFF.
The software watchdog is a function of the firmware which ensures that the various software components of the firmware keep working as intended.

The following software components are guarded by the watchdog:

- Serial command interpreter / UART bus
- I^2C bus
- PWM trigger
- Safe Operating Area
- Auto-gain
- DLL algorithm
- USB bus
- Debug thread

The software watchdog sends requests to each of the components to confirm whether they are still running. If the components fail to respond too many times in a row, the watchdog triggers and the ISC board is automatically reset.

Syntax:

Input:	$SWES,[channel],[enable]
Output:	$SWES,[channel],OK

- **[channel]** – Channel identification number.
- **[enable]** – Enable state of the software watchdog

  0 – OFF

  1 – ON

Example:

Input:	$SWES,1,0
Output:	$SWES,1,OK

The software watchdog has been disabled.

8 Error Handling

8.1 $ERRC – Clear error

An error on the ISC board is accompanied by an informative error code ($ST). To ensure the code can be viewed, it stays in memory until manually cleared away. For safety purposes, depending on the exact value, further RF output of the ISC board may be blocked for as long as that non-zero error status remains.

The $ERRC command clears the error state and resets the protective systems that impede the ISC board while an error is present.

The process of status checking and error clearing is the core of error handling. The error status of the ISC board is polled to retrieve current information about any errors that have occurred during operation. This information can be used to decide an appropriate response. After the problem has been resolved, the errors reported by the ISC board should be cleared to signal to the device that the error status is no longer actual.

A situation may occur where an error state appears to persist despite attempts to clear it. In fact, the error is getting cleared properly but is immediately reactivated again because the underlying cause of the error is still present.

Syntax:

Input:	$ERRC,[channel]
Output:	$ERRC,[channel],OK

- **[channel]** – Channel identification number.

Example:

Input:	$ERRC,1
Output:	$ERRC,1,OK

This clears the error state of the ISC board.

If the root cause of the problem has been resolved, the error code will be 0 the next time the error state of the ISC board is polled. If the root cause of the problem remains (e.g. the external shutdown remains triggered),the error state will keep reverting back to a non-zero value until it has been dealt with appropriately.

8.2 $PSG – Read PA Errors

Gets the status of the PA. If the status is 0, this indicates normal operation. If the status is non-zero, one or more PA internal protection limits have been triggered. Typically, this means that the PA will have already shut itself down in self-protection. When the PA error code of a system is non-zero, it raises the “PA Error” (see $ST) and triggers SOA#5 (See $SOA). If an alarm signal is sent from the PA to the ISC, the “Alarm In” error will also be raised (See $ST). In multi-channel systems, the returned error code status is a bitwise OR of the statuses of each channel.

Syntax

Input:	$PSG,[channel]
Output:	$PSG,[channel],[pa error code]

- **[channel]** – Channel identification number.
- **[pa error code]** – Error code of the PA displayed in decimal. For Reference, the error codes of the ZHL-2425-250X+ are shown below:

  2 bytes value where each bit represents an alarm cause as follows. (bits 8, 9, 12,13,14, and 15 are reserved)
  bit0: Reflected Power > Upper Limit
  bit1: Reflected Power < Lower Limit
  bit2: Forward Power > Upper Limit[1]
  bit3: Forward Power < Lower Limit[1]
  bit4: Current > Upper Limit
  bit5: Current < Lower Limit[1]
  bit6: V_Supply > Upper Limit
  bit7: V_Supply < Lower Limit
  bit10: Temperature > Upper Limit
  bit11: Temperature < Lower Limit
  [1] There is no protection limit set, so there should never be an internal alarm for these parameters.

Example

Input:	$PSG,1
Output:	$PSG,1,128

Indicates that the error code is 128. This code converted to binary is 0000 0000 1000 0000 indicating that V_Supply < Lower Limit.

8.3 $ST – Request status

The $ST command is used to monitor the status of the ISC board.

It returns hexadecimal codes that can be compared against bitmasks to provide an overview of the system status.

Error status:

ISC boards have a safety feature called the 'Safe Operating Area' (SOA). If a fault occurs during operation, the SOA raises an error and takes action to protect the system. This is indicated by a red LED on the board. An error on the ISC board is accompanied by an informative error code which can be used to trace the problem.

To ensure the error code can be viewed, it stays in memory until manually cleared away. Error codes that shutdown RF will set the enable state to 0 and will also block the RF power from being turned on again until the error is cleared with $ERRC. Clearing the error will not enable the generator, but it will allow the generator to be re-enabled as long as the error remains cleared. If the user wants to see the current status of the PA, they must clear the errors before requesting status. In some applications, it may be desirable to periodically clear errors so that error statuses displayed always reflect the current state of the system.

The following table provides an overview of the error status bitmask:

Bit #	Hex Status Code	System Status	System Response
N/A	0x000000000	No Errors or Warnings	-
0	0x000000001	Unspecified Error	RF output OFF; Reset controller
1	0x000000002	High PA Temperature	With autogain enabled, unit throttles output power (see SOA section for more detail)
2	0x000000004	Shutdown PA Temperature	RF output OFF
3	0x000000008	High Reflected Power	With autogain enabled, unit throttles output power (see SOA section for more detail)
4	0x000000010	Shutdown Reflected Power	RF output OFF

5	0x000000020	Reset Detected	Warning only; no action
6	0x000000040	Temperature Read-out Error	RF output OFF
7	0x000000080	Power Measurement Failure	RF output OFF
8	0x000000100	RF Enable Failure	Warning only; no action
9	0x000000200	Multiplexer Failure	RF output OFF
10	0x000000400	External Shutdown Triggered	RF output OFF (Non-Blocking)
11	0x000000800	Out of Memory	Warning only; no action
12	0x000001000	I2C Communication Error	RF output OFF in case of critical measurements
13	0x000002000	SPI Communication Error	RF output OFF in case of critical measurements
14	0x000004000	Reserved/Not Applicable	RF output OFF
15	0x000008000	SOA Measurement Error	RF output OFF
16	0x000010000	External Watchdog Timeout	RF output OFF
17	0x000020000	Calibration Missing	RF output OFF
18	0x000040000	External Protection Triggered	Warning only; no action
19	0x000080000	SOA High Dissipation	Warning only; no action
20	0x000100000	SOA Shutdown Dissipation	RF output OFF
21	0x000200000	Calibration EEPROM outdated	RF output OFF
22	0x000400000	PA Error	RF output OFF
23	0x000800000	PA Reset Failure	RF output OFF
24	0x001000000	PA High Current	RF output OFF
25	0x002000000	Reserved/Not Applicable	RF output OFF
26	0x004000000	Alarm In	RF output OFF
27	0x008000000	Reserved/Not Applicable	Warning only; no action
28	0x010000000	SOA High Current	Warning only; no action
29	0x020000000	SOA Shutdown Current	RF output OFF
30	0x040000000	SOA High Forward Power	Warning only; no action
31	0x080000000	SOA Shutdown Forward Power	RF output OFF
32	0x100000000	SOA Shutdown Minimum Voltage	RF output OFF
33	0x200000000	SOA Low Voltage	Warning only; no action
34	0x400000000	SOA High Voltage	Warning only; no action
35	0x800000000	SOA Shutdown Maximum Voltage	RF output OFF

Note: Unless otherwise stated, all commands that turn RF output OFF are blocking. “Blocking” here means that the RF output is switched off and it remains off until the $ERRC command clears the error. Only then can the RF output be switched on again.

Syntax 1:

Input:	$ST,[channel]

Output:	$ST,[channel],[reserved],[error status code]

- **[channel]** – Channel identification number.
- **[reserved]** – Reserved. Will always return 0.
- **[error status code]** – A hexadecimal value representing various errors which have occurred on the ISC board.

Example 1:

Input:	$ST,1
Output:	$ST,1,0,460

The codes returned by the command represent combinations of several statuses. To decipher a code, it must be converted from hexadecimal to binary and compared against the bitmask to see which bits are high.

The error status code is 0x460. The code is comprised of three separate errors summing up to 0x460:

0x20 = 0b000000**1**00000 – Reset detected.

0x40 = 0b00000**1**000000 – Temperature read-out error.

0x400 = 0b0**1**0000000000 – External shutdown triggered.

The error status code will remain in memory until an error clear command has been sent.

Syntax 2:

This command supports an alternative syntax which displays errors in a more user-friendly format.

Input:	$ST,[channel],(output mode)
Output:	$ST,[channel],[error status message]... $ST,[channel],OK

- **[channel]** – Channel identification number.
- **(output mode)** – (optional)

  0 – bitmasked error codes (same output as syntax 1)

  1 – list of legible errors messages (multi-line output)
- **[error status message]** – A hexadecimal value representing various errors which have occurred on the ISC board.

Example 2:

Input:	$ST,1,1
Output:	$ST,1,RESET_DETECTED $ST,1,TEMPERATURE_MEASUREMENT_FAILURE $ST,1,EXTERNAL_SHUTDOWN_DETECTED $ST,1,OK

This time, the optional (output mode) argument is used. The ISC board has encountered the following problems:

Reset detected.

Temperature read-out error.

External shutdown triggered.

The error status code will remain in memory until an error clear command has been sent.

9 System Configuration

System configuration commands define the system-level behavior of the ISC Board.

9.1 $CHANG – Get channel identifier

This command returns the channel number assigned to the ISC board.

Remark: This command does not adhere to established syntax. It does not accept a channel argument at the input.

Syntax:

Input:	$CHANG
Output:	$CHANG,[channel]

- **[channel]** – Channel identifier.

Example:

Input:	$CHANG
Output:	$CHANG,1

This indicates that the channel identifier is 1 (default state).

9.2 $CHANS – Set channel identification number

Every ISC board is assigned a numeric value as a channel identifier for communication. The default value of the identifier is '1', which serves its purpose in single-channel systems. In setups that deploy more than one ISC board, it is often necessary to assign a unique number to each board beforehand, so that they can all be commanded as separate entities. An ISC board will not respond to commands intended for a different channel.

The $CHANS command assigns a channel identification number to an ISC board.

Syntax:

Input:	$CHANS,[channel],[new channel]
Output:	$CHANS,[channel],OK

- **[channel]** – Channel identifier (default = 1)
- **[new channel]** – New desired channel identification number.

Example:

Input:	$CHANS,1,2
Output:	$CHANS,2,OK

This assigns the channel identification number '2' to the ISC board.

From now on, this board can only be addressed by providing '2' as the [channel] argument for commands.

E.g. “$VER,2”

9.3 $COMS – Set Communication Interface

This command sets the communication interface to UART (3.3V TTL) or USB. Only one communication interface can be active at a time. The default communication interface is USB. If the user switches to UART by sending a $COMS,1,1 command, the USB serial port will no longer be active. Communication may only resume over UART during that session. There is no difference in serial command syntax between UART and USB communication interfaces. Rebooting will return the unit back to its default communication interface.

Syntax:

Input:	$COMS,[channel],[interface]
Output:	$COMS,[channel],OK

- **[channel]** – Channel identifier.
- **[interface]** – Serial communication interface.

  1 – UART (TTL 3.3V)

  2 – USB

Example:

Input:	$COMS,1,2
Output:	$COMS,2,OK

This configures the ISC board to communication mode 2, USB serial communication. This is the default mode.

9.4 $CSG – Get clock source

This command returns the clock source configuration or “coherency mode” of the ISC board.

Syntax:

Input:	$CSG,[channel]
Output:	$CSG,[channel],[clock source]

- **[channel]** – Channel identification number.
- **[clock source]** – Numeric value assigned clock source configuration.

  0 – Standalone (default): Use onboard XCO. Do not output reference signal.

  1 – Leader: Use onboard XCO. Output reference signal to followers using LVDS.

  2 – Follower: Use external clock reference from LVDS. Do not output reference signal.

  3 – Follower inline: Use external clock reference from LVDS. Output reference signal to downstream Follower using LVDS.

  4 – Reserved. Do not use.

  5 – Reserved. Do not use.

Example:

Input:	$CSG,1
Output:	$CSG,1,0

This indicates that the clock source is configured to standalone mode (default).

9.5 $CSS – Set clock source

This command sets the clock source configuration or "coherency mode" of the ISC board.

An ISC board can either use its own internal 10MHz Crystal Controlled Oscillator (XCO), or it can accept an external clock reference from another ISC board. The clock signal can be transmitted and received using a Low Voltage Differential Signaling (LVDS) transceiver accessible through the AUX IN and AUX OUT interface.

The clock source is required to synchronize signal phase of ISC boards in coherent multi-channel systems. See the Apps Note on Coherence (AN50-004) for more configuration details.

Syntax:

Input:	$CSS,[channel],[clock source]
Output:	$CSS,[channel],OK

- **[channel]** – Channel identification number.
- **[clock source]** – Numeric value assigned clock source configuration.

  0 – Standalone (default): Use onboard XCO. Do not output reference signal.

  1 – Leader: Use onboard XCO. Output reference signal to followers using LVDS.

  2 – Follower: Use external clock reference from LVDS. Do not output reference signal.

  3 – Follower inline: Use external clock reference from LVDS. Output reference signal to downstream followers using LVDS.

  4 – Reserved. Do not use.

  5 – Reserved. Do not use.

Example:

Input:	$CSS,1,3
Output:	$CSS,1,OK

This configures the clock source to inline follower mode.

9.6 $PODG– Get Power Offset in dB

This command sets the power offset of the system. Check the setter ($PODS), for more detail on power offset.

Syntax:

Input:	$PODG,[channel],[offset]
Output:	$PODG,[channel],OK

- **[channel]** – Channel identifier.
- **[offset]** – Power offset in dB.

Example:

Input:	$PODG,1
Output:	$PODG,1,0

This indicates that the offset is 0 dB (default).

9.7 $PODS– Set Power Offset in dB

This command sets the power offset of the system. Power offset is used when there is a fixed attenuation at the output of the generator and the user would like to see power referenced to the plane after that attenuation. For example, an offset setting of 3 would mean that there is 3dB of loss between the generator output and the new reference plane. This affects the behavior of several functions:

- PPG and PPDG normally return the forward and reflected powers. Now forward powers are reduced by [offset] dB and reflected powers are increased by [offset] dB. Note that this means that any calculation of Return loss will be 2 * [offset] dB lower than normal.
- In both auto-gain and feed-forward modes, PWRS and PWRDS are now referencing the power at the new reference plane. The minimum and maximum power settings are adjusted accordingly (reduced by the offset).

Syntax:

Input:	$PODS,[channel],[offset]
Output:	$PODS,[channel],OK

- **[channel]** – Channel identifier.
- **[offset]** – Power offset in dB.

Example:

Input:	$PODS,1,10
Output:	$PODS,1,OK

This sets the offset to 10dB. Now all powers are referenced to the location after the 10dB attenuation. Forward power readings are reduced by 10dB and reflected power readings are increased by 10dB. The new range of power settings is. Setting the power to 5W will result in 50W coming out of the generator.

9.8 $PWRMDG – Get maximum output power cap in dBm

This command gets the maximum output power cap. This is the setting that limits the forward power setpoint ($PWRS / $PWRDS) to be no larger than the configured maximum value.

Syntax:

Input:	$PWRMDG,[channel]
Output:	$PWRMDG,[channel],[power cap]

- **[channel]** – Channel identifier.
- **[power cap]** – The maximum permitted forward power setting in dBm

Example:

Input:	$PWRMDG,1
Output:	$ PWRMDG,1,47.1

This indicates that the maximum output power cap is set to 47.1 dBm (default setting)

9.9 $PWRMDS – Set maximum output power cap in dBm

This command configures a maximum output power cap. This prevents inputting a forward power setpoint ($PWRS / $PWRDS) beyond the configured maximum value. Useful for configuring or ignoring limits in special situations.

Syntax:

Input:	$PWRMDS,[channel],[power cap]
Output:	$PWRMDS,[channel],OK

- **[channel]** – Channel identifier.
- **[power cap]** – The maximum permitted forward power setting in dBm

Example:

Input:	$PWRMDS,1,47.1
Output:	$ PWRMDS,1,OK

This configures the maximum output power cap to 47.1dBm (default setting)

9.10 $PWRMINDG – Get minimum output power setting limit in dBm

This command gets the minimum output power cap. This is the setting that limits the forward power setpoint ($PWRS / $PWRDS) to be no lower than the configured minimum value. This minimum power limit ensures that power setting inputs stay within the valid calibration range of the instruments.

Syntax:

Input:	$PWRMINDG,[channel]
Output:	$PWRMINDG,[channel],[power cap]

- **[channel]** – Channel identifier.
- **[power cap]** – The minimum permitted forward power setting in dBm

Example:

Input:	$PWRMINDG,1
Output:	$ PWRMINDG,1,-30.000000

This indicates that the minimum output power limit is set to -30 dBm (default setting)

9.11 $PWRMINDS – Set minimum output power setting limit in dBm

This command configures the minimum output power cap. This is the setting that limits the forward power setpoint ($PWRS / $PWRDS) to be no lower than the configured minimum value. This minimum power limit ensures that power setting inputs stay within the valid calibration range of the instruments. This is especially important when operating in feedforward mode where the internal attenuation settings are only well-defined for powers within the operating range

Syntax:

Input:	$PWRMINDS,[channel],[power cap]

Output:	$PWRMINDS,[channel],OK

- **[channel]** – Channel identifier.
- **[power cap]** – The minimum permitted forward power setting in dBm

Example:

Input:	$PWRMINDS,1,-30
Output:	$PWRMINDS,1,OK

This configures the minimum output power limit to -30 dBm (default setting)

9.12 $RST – Execute system reset

This command executes a reset of the ISC board. All board settings will return to their default states.

Following a reset, whether intentional or as the result of a fault, the 'reset detected' error flag (0x20) will beraised.

Syntax:

Input:	$RST,[channel]
Output:	$RST,[channel],OK

- **[channel]** – Channel identifier.

Example:

Input:	$RST,1
Output:	$RST,1,OK

After sending the $RST command, the board returns an OK and then promptly resets.The 'reset detected' error flag (0x20) is raised.

9.13 $UARTS – Set UART baud rate

This command sets the baud rate used for communication through UART. Any value can be entered, but unsurprisingly, ongoing communication will break the moment this value is changed.

Changing the baud rate affects communication speed. Lowering it can cause noticeable communication delay, while increasing it can speed up communication and leave a larger CPU time-slice for other tasks. However, setting the baud rate too high may cause communication issues to arise, as the UART transceivers have limitations.

Remark: This setting does not affect communication through USB, only through UART.

Syntax:

Input:	$UARTS,[channel],[baud rate]
Output:	<Command Does Not Reply>

- **[channel]** – Channel identifier.
- **[baud rate]** – Baud rate in symbols per second. For UART to work, the baud rate on the Tx and the Rx side must be configured to the same value.

Example:

Input:	$UARTS,1,115200
Output:	

This sets the baud rate of the UART to 115200 baud. After changing the baud rate, the communication line needs to be reinitialized on the user side with the updated baud value as well. There is no response to this command that indicates successful configuration of the setting.

9.14 $ZHLDS – Set ZHL Trigger Delay

Sets the Trigger delay on the ZHL in µs. Refer to the datasheet of the ZHL-2425-250X+ for details on this parameter. The ISC sends triggers to trigger measurements while PWM, DLL, or Sweep features are active. This delay parameter should generally not be changed.

Syntax

Input:	$ZHLDS,[channel],[delay]
Output:	$ZHLDS,[channel],OK

- **[channel]** – Channel identification number.
- **[delay]** – Trigger delay on the ZHL in µs. This is the delay between receiving a trigger and performing an ADC acquisition.

Example

Input:	$ZHLDS,1,30
Output:	$ZHLDS,1,OK

The ZHL trigger delay was set to 30 µs.

10 Multiple PA Channels

The ISC-2425-25+ standard operating mode (PA Type 25) is to control and drive a single ZHL-2425-250X+ PA. By adding an RF and I^2C splitter, the ISC-2425-25+ can be configured to control and drive 2, 4, or 8 ZHL-2425-250X+ PAs on the same I^2C bus (PA Types 26, 27, and 30 respectively). The following commands are used in applications where one system controller is driving 2 or more PAs.

10.1 $PAG2 – Get forward and reflected power ADC counts per PA channel

This command returns the forward and reflected power ADC counts for each separate RF channel connected to the ISC board. Depending on the PA Type, these ADC counts are either converted from the analog voltage inputs on the ISC board, or from the ADCs on the ZHL-2425-250X+ (See $PATS). If the source of the ADC count is the ISC board, ADC measurements are averaged over 10 samples. Otherwise, a single sample is returned. This command returns the forward and reflected power in Watts for

When the analog voltage source is the ISC board in a multiple PA channel setup, forward power ADC count is the same for all channels as well as for reflected.

Syntax:

Input:	$PPG2,[channel]
Output:	$PPG2,[channel],[fwd power],[rfl power],(fwd power 2),(rfl power 2),(etc...)

- **[channel]** – Channel identification number.
- **[fwd power]** – The forward power ADC count of the first channel. 0 to 4095.
- **[rfl power]** – The reflected power ADC count of the first channel. 0 to 4095.
- **(fwd power 2)** – The forward power ADC count of the second channel. 0 to 4095.
- **(rfl power 2)** – The reflected power ADC count of the second channel. 0 to 4095.

Example:

Input:	$PAG,1
Output:	$PAG,1,507.50000,433.70000,507.50000,433.70000

This indicates the forward and reflected ADC counts are 507.5 and 433.7 respectively. This is the response from a two-channel system (PA Type 26), so the forward and reflected ADC counts are taken from the ISC board, averaged over 10 samples, and copied two times.

10.2 $PATG – Get PA Type

Get the PA type. Power amplifier (PA) type is a parameter that allows an ISC board to operate with different system configurations, interfaces, and capabilities. 25 is the default PA type for the ISC-2425-25+ configured in the EEPROM. See $PATS for valid configurations.

Syntax:

Input:	$PATG,[channel]
Output:	$PATG,[channel],[pa type]

- **[channel]** – Channel identifier.
- **[pa type]** – The PA Type defining the operating mode or system configuration.

  1 – Standalone PA type

  25 – 1 x ZHL-2425-250+ (default)

  26 – 2 x ZHL-2425-250+

  27 – 4 x ZHL-2425-250+

  30 – 8 x ZHL-2425-250+

Example:

Input:	$PATG,1
Output:	$PATG,1,25

This indicates that the PA Type is set to 25 (default)

10.3 $PATS – Set PA Type

Set the PA type. Power amplifier (PA) type is a parameter that allows an ISC board to operate with different system configurations, interfaces, and capabilities. It is used to select the number of PA channels in the system. PA type will typically be configured in the ISC EEPROM. The ISC-2425-25+ will always have PA type 25 configured in the EEPROM, but this can be changed for applications where more than one PA is in use.

PA Type affects the behavior of several commands including PPG, PAG, PVG, PTG, PIG, PSG as well as some system defaults. The typical single channel configuration is PA type 25. In multi-channel configurations (PA types 26, 27, 30), Behavior changes as follows:

Command	Single Channel Behavior (PA type 25)	Multi-Channel Behavior (PA Types 26, 27, 30)
$PPG/$PPDG	Returns the forward and reflected power of the ZHL PA	Returns the total forward and total reflected power across all configured PAs
$PPG2/$PPDG2	Same as $PPG/$PPDG Single Channel Behavior	Returns the forward and reflected powers for each of the individual channels
$PAG	Returns ADC count of forward and reflected power measured on the **ZHL** PA board	Returns the ADC counts from **ISC** inputs FWD_AIN & RFL_AIN averaged over 10 samples and multiplied by number of channels
$PAG2	Same as $PAG Single Channel Behavior	Returns the forward and reflected **ISC** ADC counts copied for each channel
$PAEG,[ch],0	Returns the ADC counts from **ISC** inputs FWD_AIN & RFL_AIN	Returns the ADC counts from **ISC** inputs FWD_AIN & RFL_AIN multiplied by number of channels
$PVG	Returns voltage supplied to the PA	Returns average voltage across all PA channels
$PTG	Returns temperature of the PA	Returns max temperature across all PA channels
$PIG	Returns current supplied to the PA	Returns sum of current across all PA channels
$PSG	Returns PA status	Returns bitwise OR of PA Status across all channels
$PWRMDG	Default power cap is 54dBm (250W)	Default power cap is 57, 60, and 63 dBm for 2, 4, and 8 channel PA types respectively.

An additional PA type that can be useful for debugging purposes is PA type 1 – Standalone Mode. This is the PA type that must be used if no ZHL PAs are connected to the device. None of the functions in the above table that request information from the ZHL PA will return valid results and the ISC must be operating in feedforward mode in this PA type. Power can be controlled by adjusting the magnitude and gain settings either through $MCS/$GCS, $PWRSGDS, or $PWRS/$PWRDS. In order to use $PWRS/$PWRDS in this mode, the #IQICS, #VGACCS, and #FFCCS commands must be present in the EEPROM.

Syntax:

Input:	$PATS,[channel],[pa type]
Output:	$PATS,[channel],OK

- **[channel]** – Channel identifier.
- **[pa type]** – The PA Type defining the operating mode or system configuration.

  1 – Standalone PA type

  25 – 1 x ZHL-2425-250+ (default)

  26 – 2 x ZHL-2425-250+

  27 – 4 x ZHL-2425-250+

  30 – 8 x ZHL-2425-250+[8]

Example:

Input:	$PATS,1,25
Output:	$PATS,1,OK

This indicates that the PA Type is set to 25 (default)

10.4 $PDG – Get PA Debug Information

Gets all ADC readings of the ZHL PA on the specified PA Channel. See the datasheet of the ZHL-2425-250X+ for more information on the available ADC readings. If there is no PA with specified PA channel on the I^2C bus, the command will return with an error. This command can be used to determine the local address of a connected ZHL PA by sending a PDG command to each of the 8 possible PA channels. The channels that not return errors are present on the bus.

Syntax

Input:	$PDG,[channel],[pa channel]
Output:	$PDG,[channel],[fwd],[rfl],[current],[vds],[reserved],[t_final]

[8] 8-channel PA type Added in FW version 2.8.10

- **[channel]** – Channel identification number.
- **[pa channel]** – Power amplifier channel. This is the "Local Address" of the ZHL PA to be read. Integer from 0 to 7.
- **[fwd]** –Forward power detector ADC reading from the ZHL PA. Count from 0 to 4095.
- **[rfl]** – Reflected power detector ADC reading from the ZHL PA. Count from 0 to 4095.
- **[current]** – DC current ADC reading from the ZHL PA. Count from 0 to 4095.
- **[vds]** – DC voltage ADC reading from the ZHL PA. Count from 0 to 4095.
- **[reserved]** –Reserved ADC reading from the ZHL PA. Do not use.
- **[t final]** – Temperature ADC reading from the ZHL PA output stage. Count from 0 to 4095.

Example

Input:	$PDG,1,0
Output:	$PDG,1,72,214,67,2324,4027,2776

This shows the ADC counts of the ZHL PA at local address 0

10.5 $PPG2 – Get PA forward and reflected power per PA channel in Watt

This command returns the forward and reflected power in Watts for each separate RF channel connected to the ISC board.

This command may be used to get individual power measurements from PAs behind an RF splitter. For PA type 26 (2-channel), PA type 27 (4-channel), and PA type 30 (8-channel) configurations. Use the $PATS command to set PA type.

Syntax:

Input:	$PPG2,[channel]
Output:	$PPG2,[channel],[fwd power],[rfl power],(fwd power 2),(rfl power 2),(etc...)

- **[channel]** – Channel identification number.
- **[fwd power]** – The RF power output of channel 1 of the PA in watts.
- **[rfl power]** – The RF power being reflected back into channel 1 of the PA in watts.
- **(fwd power 2)** – (optional) The RF power output of channel 2 of the PA in watts.
- **(rfl power 2)** – (optional) The RF power being reflected back into channel 2 of the PA in watts.
- **(etc...)** – (optional) Additional FWD and RFL powers may be appended depending on the PA configuration.

Example:

Input:	$PPG2,1
Output:	$PPG2,1,95.50400,11.65300,104.41200,13.51000

This indicates the powers are as follows:

Channel 1 FWD = 95.504 W

Channel 2 FWD = 104.412 W

Channel 1 RFL = 11.653 W

Channel 2 RFL = 13.51 W

The resulting values can be summed up to roughly 200W forward power and 25W reflected power, the same value that the $PPG command would return.

10.6 $PPDG2 – Get PA forward and reflected power per PA channel in dBm

This command returns the forward and reflected power in dBm for each separate RF channel connected to the ISC board.

This command may be used to get individual power measurements from PAs behind an RF splitter. For PA type 26 (2-channel), PA type 27 (4-channel), and PA type 30 (8-channel) configurations. Use the $PATS command to set PA type.

Syntax:

Input:	$PPDG2,[channel]
Output:	$PPDG2,[channel],[fwd power],[rfl power],(fwd power 2),(rfl power 2),(etc...)

- **[channel]** – Channel identification number.
- **[fwd power]** – The RF power output of channel 1 of the PA in dBm.
- **[rfl power]** – The RF power being reflected back into channel 1 of the PA in dBm.
- **(fwd power 2)** – (optional) The RF power output of channel 2 of the PA in dBm.
- **(rfl power 2)** – (optional) The RF power being reflected back into channel 2 of the PA in dBm.
- **(etc...)** – (optional) Additional FWD and RFL powers may be appended depending on the PA configuration.

Example:

Input:	$PPDG2,1
Output:	$PPDG2,1, 49.80000,50.18700, 40.66400, 41.30600

This indicates the powers are as follows:

Channel 1 FWD = 49.800 dBm
Channel 2 FWD = 50.187 dBm
Channel 1 RFL = 40.664 dBm
Channel 2 RFL = 41.306 dBm

The resulting values can be summed up to roughly 53dBm forward power and 44dBm reflected power, the same value that the $PPDG command would return.

10.7 $ZHLAS – Change ZHL Address

Changes the local address of the connected ZHL. If there are more than one ZHL with the same local address on the I^2C bus, this command will not work, so it is necessary to connect the ZHLs to the I^2C bus one at a time when configuring the addresses for the first time. The PA must be power cycled before any commands sent to the new address are recognized. This command is used to configure ZHLs for use in a multi-channel system setup. The default local address of the ZHL PA is 0, which is the required address for single channel systems. For two-channel systems, local addresses 0 and 1 are used. Four channel systems use local addresses 0 to 3 and 8-channel systems use local addresses 0 to 7.

Syntax

Input:	$ZHLAS,[channel],[from address],[to address]
Output:	$ZHLAS,[channel],OK

- **[channel]** – Channel identification number.
- **[from address]** – The original “Local Address” of the ZHL PA. Integer from 0 to 7.
- **[to address]** – The new “Local Address” of the ZHL PA. Integer from 0 to 7.

Example

Input:	$ZHLAS,1,0,3
Output:	$ZHLAS,1,OK

This changes the ZHL PA local address from the default “0” to the fourth and last address in a four channel system “3”

11 Splitter Control

To achieve higher power levels, some setups require the outputs of multiple PAs be combined coherently. The RF channels can be combined into a single large output or be used to provide multiple lesser RF signals at the applicator. To achieve optimal efficiency in such systems, each PA's output needs to be phase and magnitude adjusted.

When the whole setup is controlled by a single ISC board, this cannot easily be done without the use of a phase and gain active splitter board. This type of splitter allows each PA in a combined system to be programmatically aligned in magnitude and phase to minimize combining losses. It also enables I^2C communication between the ISC controller and all connected target devices including the splitter itself. The 4-channel phase-gain splitter board SPL-2G42G50W4+ is supported by ISC-2425-25+ and can be controlled by the below commands.

11.1 $MCDS – Set Splitter RF Channel Amplitude/Phase DAC Value (See $RSRS)

This command allows low-level control of an RF splitter's phase and gain values by directly configuring the DACs. $MCDS is an alias of $RSRS.

Syntax:

Input:	$MCDS,[channel],[target],[count]
Output:	$MCDS,[channel],OK

- **[channel]** – Channel identification number.
- **[target]** – Integer code corresponding to the magnitudes or phases of each of the RF channels or to the RF Enable Switch function

  1: Channel 1 Attenuation
  5: Channel 2 Attenuation
  6: Channel 3 Attenuation
  2: Channel 4 Attenuation
  3: Channel 1 Phase
  7: Channel 2 Phase
  4: Channel 3 Phase
  0: Channel 4 Phase
  14: Assert (Enable) RFEN
  15: De-assert (Disable) RFEN
- **[count]** – DAC count to assign to the target

  Attenuation DAC Channels:
  Count is an integer from 0-63. Sets the attenuation of the channel, 0.5dB per LSB.

  Phase DAC Channels:
  Count is an integer from 0-511
  In the range of 0-255, count sets the phase delay of the channel, 0.7° per LSB typ.
  Add 256 to count to activate the 180deg bit.

  RF Enable (RFEN):
  Count is not used here. Set count to zero.

Example 1:

Input:	$MCDS,1,6,32
Output:	$MCDS,1,OK

Sets the attenuation of RF channel 3 to 16dB

Example 2:

Input:	$MCDS,1,4,384

Output:	$MCDS,1,OK

Sets the phase DAC Count of RF channel 3 to 384 (i.e. count of 126 with the 180deg bit flipped)

11.2 $MCIES – Set I2C Switch in Splitter

This command allows the user to connect any combination of PA Control ports 1-4 to the I^2C bus on the splitter. This is useful for configuring 4 ZHLs connected on the same bus to have different local addresses (See the $ZHLAS command). Or controlling 4 devices that have the same local address one at a time.

Syntax:

Input:	$MCIES,[channel],[multiplex_bits]
Output:	$MCIES,[channel],OK

- **[channel]** – Channel identification number.
- **[multiplex_bits]** – I2C Switch Multiplexer bitmask. A bitmask that is in integer or hex format 0-15 or 0x00-0x0f:

  0bXXX1 – Enables I2C Channel 1 0bXXX0 – Disables I2C Channel 1
  0bXX1X – Enables I2C Channel 2 0bXX0X – Disables I2C Channel 2
  0bX1XX – Enables I2C Channel 3 0bX0XX – Disables I2C Channel 3
  0b1XXX – Enables I2C Channel 4 0b0XXX – Disables I2C Channel 4

Example 1:

Input:	$MCIES,1,4
Output:	$MCIES,1,OK

Enable I^2C Channel 3 and disable all other channels.

Example 2:

Input:	$MCIES,1,0x0F
Output:	$MCIES,1,OK

Enable all 4 I^2C channels.

11.3 $RSG – Get splitter configuration

This command sets the splitter type of the RF system. Check $RSS for description of splitter configuration.

Syntax:

Input:	$RSG,[channel]
Output:	$RSG,[channel],[splitter type]

- **[channel]** – Channel identifier.
- **[splitter type]** – Type of splitter in the system. Splitter mode is inactive when splitter type is 0.

  0 : No splitter configuration

  3 : SPL-2G42G50W4+ 4-Way Active Power Splitter 360° Variable Phase shift, 30dB, 0.5dB steps

Example:

Input:	$RSG,1
Output:	$RSG,1,0

This indicates that the splitter type is set to 0, indicating that no splitter configuration is set (default)

11.4 $RSS – Set splitter configuration

This command sets the splitter type of the RF system. An active splitter may be used for systems that deploy a single ISC board to drive multiple RF channels. Active splitters enable phase and gain control of the individual PA channels. Setting a splitter type allows phases and magnitudes of the PA channels to be set through the $PCS/$PCG and $MCS/$MCG commands instead of the $RSRS/$RSRG commands.

When a splitter configuration is set, the behaviors of several commands ($PCS, $PCG, $MCS, $MCG) are altered to facilitate the new functionality. The ISC board will respond as 4 independent RF channels with regards to magnitude and phase.

Inputs to phase ($PCS, $PCG) and magnitude ($MCS and $MCG) are redirected to the RF splitter board instead of being executed by the ISC's onboard RF chain. The [channel] argument that usually points to the channel number of the ISC board will now instead point towards the individual RF channels of the RF splitter board.

For example, if an ISC board is configured as channel 1, all phase and magnitude commands pertaining to channels 1, 2, 3 and 4 will be accepted by the ISC board and redirected to the RF splitter board. The responses received back from the ISC board will also use the numbers 1 through 4. If the ISC board is configured as channel 2, it will accept channels 5, 6, 7 and 8, and so on.

When an RF splitter is configured, using the broadcast channel number '0' will set the phase/magnitude on all splitter channels, not the ISC's onboard RF chain. If changing phase or magnitude of the ISC's onboard RF chain is desired, the reserved channel numbers of 200 or greater can be used instead. For all commands whose behavior is affected by the RF splitter, channel 200 will acts as ISC broadcast channel 0, 201 as ISC channel 1, 202 as ISC channel 2, etc.

Only $PCS, $PCG, $MCS and $MCG are redirected. All other commands remain unaffected. During operation with an RF splitter board, these commands can be used alongside auto-gain. Auto-gain will only affect the ISC's onboard RF chain, while these commands will only affect the RF splitter channels.

Syntax:

Input:	$RSS,[channel],[splitter type]
Output:	$RSS,[channel],OK

- **[channel]** – Channel identifier.
- **[splitter type]** – Type of splitter in the system. Splitter mode is inactive when splitter type is 0.

  0 : No splitter configuration

  3 : SPL-2G42G50W4+ 4-Way Active Power Splitter 360° Variable Phase shift, 30dB, 0.5dB steps

Example:

Input:	$RSS,1,3
Output:	$RSS,1,OK

This sets the splitter type to 3, configuring the system for an application using the SPL-2G42G50W4+

11.5 $RSRG – Get Splitter RF Channel Amplitude/Phase DAC Value

This command gets an RF splitter's phase and gain value setting.

Syntax:

Input:	$RSRG,[channel],[target]
Output:	$RSRG,[channel],[target],[count]

- **[channel]** – Channel identification number.
- **[target]** – Integer code corresponding to the magnitudes or phases of each of the RF channels

  1: Channel 1 Attenuation 3: Channel 1 Phase
  5: Channel 2 Attenuation 7: Channel 2 Phase
  6: Channel 3 Attenuation 4: Channel 3 Phase
  2: Channel 4 Attenuation 0: Channel 4 Phase
- **[count]** – DAC count to assign to the target

  Attenuation DAC Channels:
  Count is an integer from 0-63. Sets the attenuation of the channel, 0.5dB per LSB.

  Phase DAC Channels:
  Count is an integer from 0-511
  In the range of 0-255, count sets the phase delay of the channel, 0.7° per LSB typ.
  Add 256 to count to activate the 180deg bit.

Example 1:

Input:	$RSRG,1,6,32
Output:	$RSRG,1,OK

Sets the attenuation of RF channel 3 to 16dB

Example 2:

Input:	$RSRG,1,4
Output:	$RSRG,1,4,384

Indicates that the phase DAC Count of RF channel 3 is set to 384 (i.e. count of 126 with the 180deg bit flipped)

11.6 $RSRS – Set Splitter RF Channel Amplitude/Phase DAC Value (See $MCDS)

This command allows low-level control of an RF splitter's phase and gain values by directly configuring the DACs. This command is an alias of MCDS.

Syntax:

Input:	$RSRS,[channel],[target],[count]
Output:	$RSRS,[channel],OK

- **[channel]** – Channel identification number.
- **[target]** – Integer code corresponding to the magnitudes or phases of each of the RF channels or to the RF Enable Switch function

  1: Channel 1 Attenuation 3: Channel 1 Phase 14: Assert (Enable) RFEN
  5: Channel 2 Attenuation 7: Channel 2 Phase 15: De-assert (Disable) RFEN
  6: Channel 3 Attenuation 4: Channel 3 Phase
  2: Channel 4 Attenuation 0: Channel 4 Phase

- **[count]** – DAC count to assign to the target

  Attenuation DAC Channels:

  Count is an integer from 0-63. Sets the attenuation of the channel, 0.5dB per LSB.

  Phase DAC Channels:

  Count is an integer from 0-511
  In the range of 0-255, count sets the phase delay of the channel, 0.7° per LSB typ.
  Add 256 to count to activate the 180deg bit.

  RF Enable (RFEN):

  Count is not used here. Set count to zero.

Example 1:

Input:	$RSRS,1,6,32
Output:	$RSRS,1,OK

Sets the attenuation of RF channel 3 to 16dB

Example 2:

Input:	$RSRS,1,4,384
Output:	$RSRS,1,OK

Sets the phase DAC Count of RF channel 3 to 384 (i.e. count of 126 with the 180deg bit flipped)

12 EEPROM Commands

Commands to interact with the EEPROM Command Sequence of the ISC board. The EEPROM command sequence runs every time the ISC board is powered ON. Commands in the sequence are prepended with "#" instead of the standard "$".

12.1 $EECSP – Print EEPROM command sequence

This command returns the contents of the initialization command sequence. This command has multi-line output

Syntax:

Input:	$EECSP,[channel]
Output:	CS-Actual command sequence: [command sequence] [additional information] $EECSP,[channel],OK

- **[channel]** – Channel identifier.
- **[command sequence]** – The sequence of commands currently stored in the EEPROM. Commands stored in the EEPROM are prepended by a # instead of a $.
- **[additional information]** – See example for full printout

Example:

Input:	$EECSP,1
Output:	$EECSP,0 CS-Actual command sequence: #CHANS,1 #PATS,0,25 #VER,0 #IDNS,0,SN02311280001,RFS-2G42G51K0+,Mini-Circuits CS-Source: INTERNAL (Chip EEPROM) CS-Valid: 1 CS-Free: 1969 bytes CS-Control commands: CS- $EECSP: Print sequence and more CS- $EECSE: Init and erase sequence CS- $EECSA: Add commands to sequence CS- $EECSD: Delete last command from sequence CS- $EECSX: Execute command sequence CS- $EESEL: Select memory source $EECSP,1,OK

13 Revision History

Revision	Date	FW Version	Description
A	10/18/24	2.8.18	Added the following commands: AGEG,AGES,COMS,DCFS,ECST,EECSP,MCDS,MCIES,PAG,PAG2,PATG,PATS,PDG,PIG,PODG,PODS,PPDG2,PPG2,PSG,PVG,PWRMDG,PWRMDS,PWRMINDG,PWRMINDS,PWRSGDG,RSG,RSRG,RSRS,RSS,SCG,SCS,SDG,SDS,SFG,SFS,SOA,SOAGS,SOG,SPG,SPS,STG,STS,SVG,SVS,SWES,TCG,UARTS,ZHLAS,ZHLDS Improved document format, updated section descriptions, updated commands with added options or return values, added system application examples
OR	11/01/21	1.10.8	Release to Web