# IPS-AMP

## Intelligent Position Servo

## User Manual

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# Introduction

Thank you for your interest in the Intelligent Position Servo Amplifier (IPS-AMP). We hope you'll find that it simplifies your positioning needs through its versatile command set, easy to use interface, and its standard form factor.

The IPS-AMP can be used in virtually any RC servo system that uses a permanent magnet motor (approximately 5 volt) and a potentiometer (approximately 5K ohms) to provide output shaft position feedback. To build an IPS servo you will need to remove the old control electronics and replace them with the IPS-AMP. Throughout the manual IPS-AMP refers to the servo electronics and IPS refers to a servo that is using the IPS-AMP.

Depending upon your application, the IPS-AMP can be used with its default settings. However, due to the large number of advanced features, learning to use all its capabilities will take some time. There are many powerful commands and functions available to the experienced user.

The IPS-AMP can be controlled using the standard 1 to 2 millisecond R/C-pulse system (1.5 millisecond center). If you are using it in place of a standard R/C servo, it is literally a plug-and-play device. One exception is that unlike a normal R/C servo that loses its position when the pulse stream ceases, a single pulse may be sent to the IPS-AMP and it will maintain that position until power is removed.

The serial command interface is used for computer-controlled positioning applications. This is the more versatile user interface in that all aspects of the IPS-AMP are available in this mode. Besides the movement parameters, there are Calibration, Communication, Memory and Table functions that are accessible. There are also several Status commands to report various IPS-AMP conditions.

If you want to use the serial command interface, again you may find the IPS-AMP usable as it comes programmed from the factory. However, there are many commands available which modify its performance parameters. They will all be discussed in this manual.

# Device Description

The IPS is based on a standard, commercially available R/C servo, normally used in model cars and aircraft. The electronics have been replaced with state-of-the-art, microprocessor-controlled circuitry greatly expanding the capabilities of the device.

Here is a list of features it shares with standard servos:
- Standard 1 – 2 millisecond pulse input
- Compatible with all modern RC receivers
- Hitec/JR 3-wire connector: V+, Ground and Signal
- 4.8V to 6.0V Operating Voltage

Here is a list of enhanced features:
- Bi-directional serial interface at several selectable baud rates
- Multiple devices can share the same serial communication line
- Holds position even if input signal terminates (unless programmed otherwise)
- User-programmable "Failsafe" feature – will assume defined position and power if input ceases
- Actual position and motor current (load) sensing and reporting
- Programmable over-current protection
- Physical rotation limits can be tailored to each application
- Save and retrieve operating parameters from non-volatile memory
- Can execute any of several user-programmed tables of sequenced moves with a single command
- Access to all internal control-loop parameters

As mentioned above, depending upon your application, your IPS-AMP may be usable just as it comes from the factory. You will have to determine its applicability for you. If you are replacing a standard R/C servo it should be ready to go. However, we hope you selected the IPS-AMP to take advantage of its advanced feature set.

Even if you want to use the standard R/C-pulse interface, you may want to tune some of the operating parameters using the serial interface. While it is not required, we recommend you use the Visual Basic application written specifically for this purpose. This PC-based software is available from GAA Custom Electronics as well as a USB interface module that will perform the voltage conversion between the your PC and the IPS-AMP. The manual contains the technical information that will allow you to develop yours own system to send and receive serial signals to and from the IPS-AMP.

# Getting Started

## Safety
Electro-mechanical devices, such as the IPS, should only be utilized by people having previous experience with similar devices. If you do not have such experience, seek the help of someone who does. The IPS can be programmed by the user to move automatically shortly after power is applied. Therefore, ensure that you are completely clear of the device, and any attached linkages or other moving parts, when you apply power.

## Electrical Power
The IPS-AMP requires only one voltage for power. It should be at least +4.8VDC, and it should NEVER EXCEED +6.0VDC! Higher voltages will damage the device. Newly charged batteries have a higher initial voltage than after a short amount of use. Be sure to carefully measure your power voltage before applying it to the IPS-AMP to prevent damage, especially with newly charged batteries!

## Connecting to the IPS-AMP
The IPS-AMP can be installed in most RC servos, its small size allows it to fit in most standard size servo cases. To build an IPS servo follow these steps:
1.) Select the servo you would like to upgrade by replacing the internal electronics with the IPS-AMP. The servo must use a permanent magnet DC motor and a potentiometer for position feedback, this is true of most servos.
2.) Open the servo case and remove the old control electronics. Remove the connections at the circuit board and keep the interconnection wires because these can likely be used when installing the IPS-AMP.
3.) The IPS-AMP has 8 connections that need to be made, please refer to the IPS hardware documentation for details:
    a.   Install two wires to the motor
    b.   Install three wires to the position feedback potentiometer
    c.   Install three wires to the control cable
4.) Now you are ready to test your new IPS servo, you can do this using the PC application or your RC system. When you test a new installation its possible that the servo direction relative to the position feedback pot it reversed and the servo will run to a limit and stall. Do not leave the servo in this condition because it will draw a lot of current and possibly damage the motor. If this happens, remove power and reverse the two leads to the motor.

The IPS-AMP is not reverse polarity protected and will be destroyed if reverse polarity power is applied. Please check your work carefully before applying power.

### *Selecting the Serial or R/C-pulse Interface*
The IPS-AMP is capable of interfacing with an R/C receiver or computer that is using the 1-2 millisecond R/C-pulse interface, or a computer using a 0-5V serial interface. The IPS-AMP senses the voltage on the signal wire 2 seconds after power-up. If the signal line is at 0V it will operate in the R/C-pulse mode. If the signal line is at +4V or more, it will operate using the serial interface. If the signal line is not stable at the two-second mark, or the signal line is noisy, the IPS-AMP may not choose the correct interface for your intended application.

## Serial Communication Protocol

The serial communication interface uses the same signal line for both transmit and receive – half duplex. Thus only one device can transmit at a time. The IPS-AMP does not send responses unless requested, and responses must be enabled internally. Every command starts with a servo address character that is user-defined (default is 1) allowing several servos to be connected to one control device in a multi-drop configuration. The interface is a logic level low true interface fixed at 8-bits, no parity and 1 stop bit (8N1). The default factory baud rate is 9600, though the user can set it for other baud rates up to 100kBaud.

### Serial Interface Overview

The IPS-AMP serial interface is very simple and has been designed to be controlled by a computer. The input parameters are not range tested, entering values out of range will result in unpredictable behavior.

Each command is preceded by the device's address character. The default address character is '1'. Commands that are sent with an address character of " * " will be processed by all devices on that serial line. They will only respond when they receive a command with their specific address. They will not answer commands that are received with the " * " address character. This is to prevent multiple servos from trying to talk at the same time.

### Command Structure

Each command is three characters long and most commands require an argument. For many commands, sending them without a parameter returns the current value of the parameter. A full list of available commands appears later in the manual.

All commands and address characters are case sensitive. All commands must be terminated with a carriage return <CR>; line feed <LF> characters are ignored on input. All commands that expect a parameter must be delimited with a single space character. Parameters are not range tested, so entering an out of range value can cause unpredictable results. (By the way, do not send the characters "<CR>". They are only there to indicate a Carriage Return.)

Below is an example of a valid command to read the IPS-AMP position:
1RPS<CR>

Here is an example of a valid command to set the IPS-AMP position parameter to –60.5 degrees:
1SPS –60.5<CR>

### Response Structure

If responses are enabled on an IPS-AMP, any command received that starts with its address character will result in a response. The two characters of <CR><LF> will indicate the command was processed and understood. A "?" <CR><LF> indicates the command was not recognized. If the command requires a response it will be sent before the <CR><LF>.

Here is an example response to a Report Position command when the current position is 32.2 degrees:
32.2<CR><LF>

## Connecting Multiple Devices Together

The IPS-AMP was specifically designed to minimize the required computer I/O. Several IPS-AMPs can be connected to the same I/O pin of your computer. The number of devices is limited only by the capabilities of your controller. Each IPS-AMP input drives three high impedance inputs of the microcontroller used in servo amp. This represents a maximum DC load current of 10 micro-amps and an input capacitance of less than 30 pF

Also, the controller must be able to tri-state the output line when it is not transmitting data to one of the devices. Otherwise there will be a conflict between it and any device that is responding to a command. Because the controller's output line is physically closer to the input line, its signal will almost certainly dominate over the IPS-AMP, and nothing will be received.

*Serial Connection Note*

The IPS-AMP uses one line for both the serial input and output. If the serial output line of your microprocessor cannot be tri-stated under software control (high-impedance output state) between command transmissions, it will require additional circuitry to accomplish this. A simple circuit is shown below.
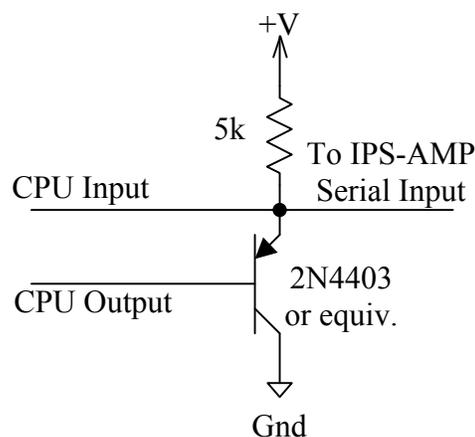


## Fig. 1 - Serial I/O Connection Schematic

## Using the PC Interface Software

As noted previously, the IPS-AMP serial interface was designed to "converse" with a computer, not a human being. Therefore, the interface is not robust. While input parameters need to be within certain ranges, they are not range-checked. There are no text correction characters such as backspace or delete. The commands are all short, 3-character mnemonics. And there is no on-line help available directly from the IPS-AMP.

To make the device easier to test and program, a special VB Application (Orion) has been developed by GAA Custom Electronics. (See Fig. 2 – IDE Screen Shot) The software allows control of configuration of all IPS capabilities and includes a scripting capability to simulate several computer commands issued

sequentially. Additionally a USB interface module is available to provide the hardware connections between the PC and your IPS. Contact GAA Custom Electronics to obtain more information.
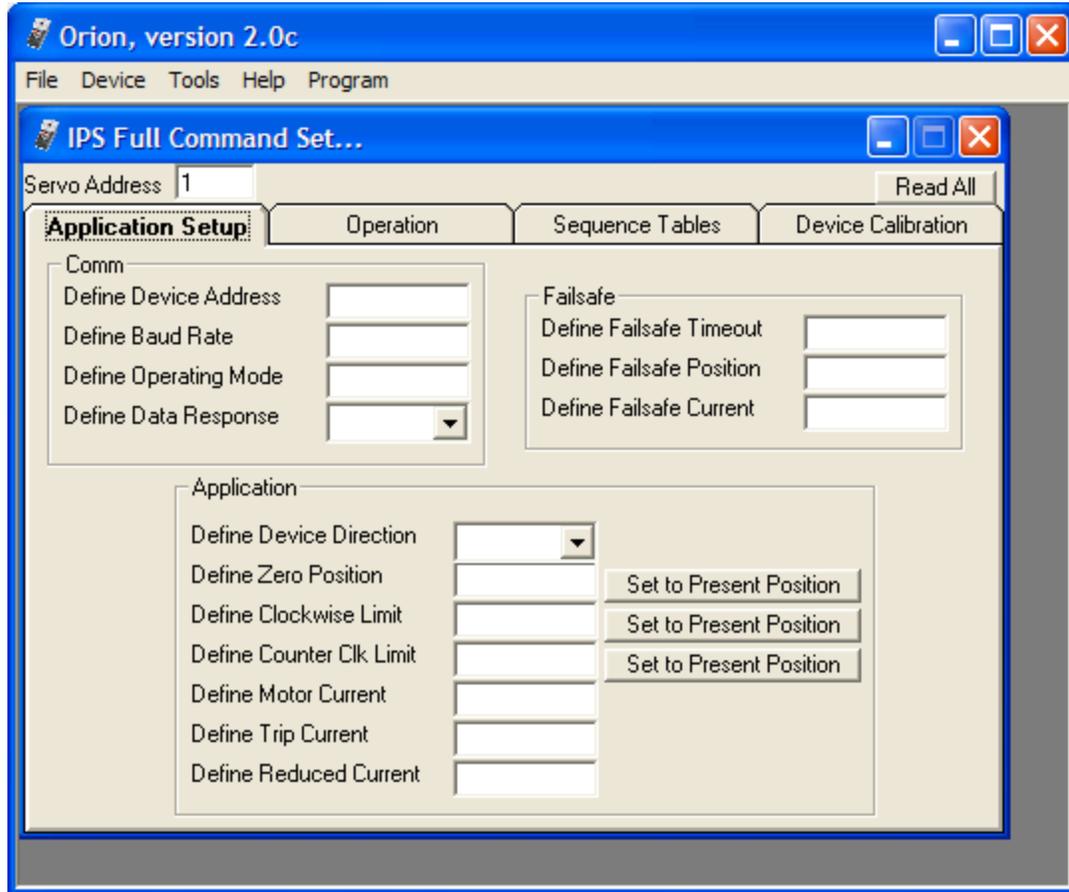


**Fig. 2 – IDE Screen Shot**

# Programming the Basic Device Parameters

To begin using the IPS-AMP there are several basic parameters that must be defined. Next the operating parameters must be set. And finally the movement commands must be given. Define commands start with the letter "D". They are specific to the device and the user application, set once, or very rarely, and left alone. They generally relate to the communication interface, the internal device configuration and external physical device application.

Once those parameters are defined the IPS-AMP is ready for the operation parameters to be set. Set commands begin with the letter "S". They are also used in Tables, which will be discussed later. Finally the Movement command is given. Several IPS-AMPs can be given Set commands, and then one Movement command can begin execution of all devices simultaneously. This feature is useful to coordinate the actions of multiple devices working in unison.

## Defining the Device Address

The IPS-AMP was designed to employ a multi-drop interface – i.e. several devices can all use the same CPU data I/O pin. To route specific commands to the proper devices each IPS-AMP on the same I/O pin must have a unique address. The device address is a single ASCII character. Any character can be used with the exception of " * " which is reserved to indicate that a command applies to all devices on that particular I/O signal line.

The default address that is programmed at the factory is "1". If each IPS-AMP is on its own unique I/O line, it is possible to leave this parameter set to "1". However, it is recommended that each address character in some way reflect its purpose in the application. For instance, if two IPS-AMPs are being used in a pan & tilt mechanism, one could have the address of "P" and the other "T". Since the addresses are case sensitive, if the application has two pan & tilt mechanisms on the same I/O pin, the second could use "p" and "t". This will help make the control software more user-friendly, at least as user-friendly as one-character addresses can be.

Because each address is unique, it must be programmed individually before multiple devices are connected together. The PC software available from GAA Custom Electronics is ideal for performing this function. If this is not available, PC applications are available on the Internet such as Hyperterm. They may be used instead, but it must be remembered that the IPS-AMP interface is not very forgiving regarding typographical errors, so care must be exercised when using these programs.

NOTE:* The IPS-AMP uses different electrical voltages than the RS-232 interface of your PC. It is VERY important that some hardware circuitry be used to convert the PC signal levels to those used by the IPS-AMP. Connecting the device directly to the I/O pins of a PC serial connector will damage the IPS-AMP and void your warranty.

When using Hyperterm, or some other software to Define the address of the IPS-AMP to a lower-case "a", send the following command:

        1DDA a<CR>

The IPS-AMP will respond with a "<CR><LF>" acknowledging your command. From that time on, this IPS-AMP will respond only to commands that begin with the letter "a" (or " * " to indicate the command is for ALL devices on that serial line). Be sure to save the new device address to EEPROM. (See the ESV command.)

## Defining the Mechanical Parameters

The IPS-AMP is a multi-purpose device capable of many functions. Each user application is very likely going to be unique. One way in which an application can be unique is in the range of motion required for operation. Some applications will require the full range of motion of the IPS-AMP. Some will require substantially less. In fact some mechanical systems might be damaged if the full range of motion is used. Additionally, the point that is considered "zero" may not necessarily be in the middle of the range of motion. The IPS-AMP permits any of these situations and makes it easy to tailor each system.

There are four parameters that must be defined to configure the mechanical system constraints. They are the Zero Position, Clockwise Rotation Limit, Counter-Clockwise Rotation Limit, and the Direction of Rotation that will be referred to as "Positive". (If the factory defaults perform in the user system as desired, there is no need to change these parameters.)

There is an internal potentiometer mounted to the output shaft of the IPS that senses its rotational position. The internal microcontroller reads that position constantly and converts that reading to units of degrees to aid the user. The first task is to define the rotational position that the system will refer to as 0.0 degrees. This should be defined once and left alone. All subsequent positions will be referenced from this position.

To accomplish this connect the IPS to power and establish communication with it. Then define the Motor Current to 0% (see the DMC command), which effectively turns the motor off. Now the IPS can be moved to any position in its range of motion manually. Move it to the position that will be considered zero and enter the Define Zero Position command (DZR) with no parameter. Without a parameter the device will assume the current position is the one meant. The basis for all further absolute position commands is now defined.

Now rotate the IPS clockwise to the furthest position you want it to move during operation and enter the Define Limit Position Clockwise command (DLC). Follow this with the counter-clockwise position and the Define Limit Position Counter-Clockwise command (DLK).

Next establish which direction the IPS is to consider the Positive direction. If clockwise rotations are positive in the system, such as compass headings, send the Define Device Direction command (DDD) with CWP (clockwise positive) as the parameter. If counter-clockwise rotations will be considered positive, such as in systems using trigonometric, unit-circle angles, then send the Define Device Direction command with CWN (clockwise negative) as the parameter. (Clockwise Positive is the factory default.)

Once these four parameters have been set, re-establish the motor current with the DMC command and test the mechanical limits. Readjust them as required using this method. Once the parameters are properly tuned, save them in non-volatile memory (see the ESV command).

NOTE:* It is not good practice to set either of the rotational limits of the IPS fully against its internal mechanical stop. It's better to back it off the stop slightly. If the IPS hits a mechanical stop during operation the motor will stall. While it's unlikely this will damage the device, the motor will draw the full current possible. This could overload the electronic system, or cause excessive electrical noise. Minimally it will shorten battery life unnecessarily.

## Setting Operating (Movement) Parameters

There are three parameters that specify the movements that the IPS-AMP is to execute. They are the position to move to (in degrees), the speed at which to move (in degrees per second) and finally the delay (in seconds) between the order to execute (see the GO! command) and when the IPS begins moving. This delay can help coordinate multiple devices working in unison.

There is also a Relative Position parameter (expressed in degrees) that specifies the movement that is to be made relative to the current position. This is different from the standard Position parameter, which is defined in absolute terms, and relative only to the IPS zero position.

These parameters are persistent in that several Position commands may be executed sequentially using the same Speed and Delay parameters without resetting the Speed parameter each time. Only the Position parameter would need to be sent to the device. This can reduce the number of commands that must be sent to the IPS to perform a sequence of move.

Example: Suppose that the following sequence of moves was to be executed starting from any current position. Assume that the IPS address is "a". The last two moves demonstrate a way to reduce the number of commands sent.
1) Move immediately to 0.0 degrees at 10 degrees/second.
   a. aSDL 0.0<CR>        (Delay 0.0 seconds)
   b. aSSP 10.0<CR>        (Speed of 10.0 degrees/second)
   c. aSPS 0.0<CR>        (Absolute Position of 0.0 degrees)
   d. aGO!<CR>        (Execute)
2) Move to 15.0 degrees at 20 degrees/second after a 3.2 second delay.
   a. aSDL 3.2<CR>        (New Delay)
   b. aSSP 20.0<CR>        (New Speed)
   c. aSPS 15.0<CR>        (New Absolute Position)
   d. aGO!<CR>        (Execute)
3) Move immediately to 20.0 degrees at 10 degrees/second.
   a. aSDL 0.0<CR>        (New Delay)
   b. aSSP 10.0<CR>        (New Speed)
   c. aSPS 20.0<CR>        (New Position)
   d. aGO!<CR>        (Execute)
4) Move immediately to 30.0 degrees at 10 degrees/second.
   a. aSRP 10.0<CR>        (Move Relative – Speed and Delay are set from last command)
   b. aGO!<CR>        (Execute)
5) Move immediately to 40.0 degrees at 10 degrees/second.
   a. aSRP 10.0<CR>        (Move Relative – Speed and Delay are set from last command)
   b. aGO!<CR>        (Execute)

NOTE:* The Limit commands (DLC and DLK) set the maximum range of motion of the IPS. If the device is commanded to move beyond either of these values it will stop at the limit and move no farther, and the "E" flag will be set in the Status text string (see the RST command).

## Initiating and Halting Movement

There are two commands that directly control the movement of the IPS. They are "GO!" and "HT!", which stand for "Go Now" and "Halt Now". The GO! command, as shown in the example above, is used to initiate movements that have been setup by sending previous Operational Parameters. It is also used to initiate the execution of a particular table, which also would have been setup using the various Table commands as explained later in this manual.

Another function of the GO! command is to coordinate the movement of several IPS-AMPs. Suppose a system contains three devices with the addresses of "a", "b" and "c" and all of them are on the same I/O line. Each of their movements, while being different, must all begin at the same time. Here is how that might be programmed:

1) Set all devices on this line to a 1.0 second delay.
   a. *SDL 1.0<CR>          (" * " indicates command is for all listening devices)
2) Set Speed and Position for a.
   a. aSSP 10.0<CR>         (Set device "a" to move at 10.0 degrees/second)
   b. aSPS 10.0<CR>         (Set device "a" to move to 10.0 degrees)
3) Set Speed and Position for b.
   a. bSSP 20.0<CR>         (Set device "b" to move at 20.0 degrees/second)
   b. bSPS 20.0<CR>         (Set device "b" to move to 20.0 degrees)
4) Set Speed and Position for c.
   a. cSSP 30.0<CR>         (Set device "c" to move at 30.0 degrees/second)
   b. cSPS 30.0<CR>         (Set device "c" to move to 30.0 degrees)
5) All start at the same time.
   a. *GO!<CR>              (Execute – all 3 listening devices a, b and c)

## Saving and Retrieving Parameters from Non-Volatile Memory

All parameters that control the operation of the IPS are manipulated and managed from the CPU's random access memory (RAM). The advantage of RAM is that it is fast to use and easy to modify. The disadvantage is that it does not maintain its state when power is removed. It would be impractical to require the user to reprogram the IPS-AMP every time it is to be utilized. To prevent this, all parameters are saved in onboard non-volatile memory, called EEPROM.

When power is applied to the IPS-AMP one of the first things it does is to retrieve all parameters from EEPROM memory and place a copy of them into RAM thus restoring the "state" of the device to what it was previously. This is important because it allows users to customize the operation of each IPS in a system.

Here is another way to think about this. When making revisions on a document, it's better to make a copy and do editing on that, thereby keeping the original untouched and safe. Once the revisions are complete, the original document may be replaced with the new one. Even then, it is often a good idea to keep a copy of the original available in case one day it is needed for reference purposes. Directly modifying parameters stored in EEPROM would be like working on the original document. The IPS-AMP does not require this.

There are three commands available for working with non-volatile memory (EEPROM). They are ELD, ESV and ERD. ELD is the Load RAM from EEPROM command. It is used to return all parameters of

the IPS-AMP to the last, previously saved state. This is essentially what the device does every time power is applied but before it begins operating.

The converse of the ELD command is ESV. ESV saves (in EEPROM) a copy of the current parameters from RAM. This allows the user to make modifications to various parameters, test them to ensure they operate as desired, and then save them in non-volatile memory so that they are available whenever the device powers up.

The third EEPROM command is the ERD command. It returns all parameters to the factory defaults. It will probably only be used if sufficient experimentation is done with many parameters such that it would be easier to return the IPS-AMP to a known state with a single command, rather than having to change every parameter individually.

It should be noted that choosing to use the EEPROM commands should be done very carefully. There are several side effects of these commands that might not be immediately obvious. First of all, writing to EEPROM, due to the technology involved, takes time. While performing this task the IPS-AMP is unable to do any movements.

Also, depending upon the values of some of the restored parameters, the device may begin moving immediately. So the user needs to keep clear of all mechanisms involved. Another potential side effect is that the communication parameters also return to their default values. This includes the baud rate, but more importantly, the device address. If the IPS-AMP in question had been assigned a new device address, it will now be back to the factory default of "1", and it will not respond to commands at its previous address.

The bottom line: act carefully and thoughtfully when using the EEPROM commands. They can have unforeseen side effects that may cost considerable time and effort to rectify.

## Programming More-Complex Device Parameters

The next class of commands will largely be used by those who are more familiar with the IPS and wish to experiment with more sophisticated control. They are the various status reporting commands, the motor current controls and those that control the serial interface. There are also a group of commands that manage the IPS if there is a loss of communication, either serial or if using the R/C pulse interface.

### Using the "Report" Commands to Get Device Status

There are four reporting commands available in the IPS. They are Report Version (RVR), Report Position (RPS), Report Current (RCU) and Report Status (RST). With careful consideration the reporting commands can be used to get information on the operating environment of the IPS.

The Report Version command (RVR) will return a text string that shows the current version of firmware that is programmed into the IPS. The manual also has a version number. Make sure they match. Having the correct documentation is necessary when using or debugging the device. Also, the factory can update the IPS-AMP firmware. Check the GAA Custom Electronics web site to see what versions of firmware exist for the IPS-AMP, and what improvements each version makes available. Details on returning your device for updating are on the web site.

The Report Position command (RPS) will return the current position of the IPS in degrees based upon the zero position that was set by the DZR command. If the device is moving (see the Report Status command), the returned value will reflect the actual position at the time of command entry.

The Report Current command (RCU) can be used to determine the load that is on the IPS. The current applied to the motor is pulse-width modulated (PWM), so the average current applied is a function of two things: the peak current of the applied voltage and the duty-cycle of the current. The figure below helps illustrate this. It should be noted that all values of current discussed for this device are in terms of the stall current of the motor (full current applied with no motor movement), which is the maximum current the motor will draw. In the IPS-AMP this is referred to as 100%. All currents reported are in percent of stall current, so the numbers will always be from 1 to 100.
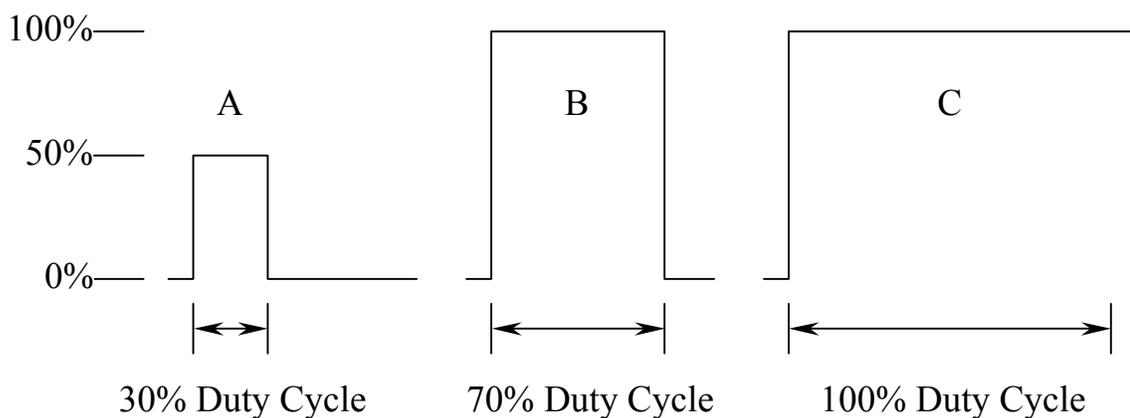


### Fig. 2 – Motor Current PWM Waveforms

Figure 2 shows just three out of thousands of possible motor current PWM waveforms. The first, "A", shows a 30% duty-cycle at 50% of stall (full) current. "B" shows a 70% duty-cycle at 100% of stall

current. And "C" shows a 100% duty-cycle at 100% of full current. For "A" the RCU command would report "15", which is 30% of 50% (0.30 X 0.50 = 0.15 = 15%). For "B" the response would be 70, and for "C" it would be 100. These numbers reflect the approximate load on the IPS motor at any given time.

The IPS-AMP monitors, and attempts to maintain, the speed programmed by the user in the SSP command. It will continue to raise its motor current as required to maintain that speed. If the load on the device continues to increase such that the motor current reaches 100%, and that is still insufficient, the IPS-AMP will not be able to maintain speed. This condition will set the "E" flag in the Report Status string (see the RST command) indicating that either the load momentarily exceeded its normal range, or the IPS-AMP has been asked to perform beyond its physical capabilities. It may be necessary to scale back one or more IPS Operation Parameters.

The "E" flag is also set if the user commands the IPS to move to a position beyond either of the limits set using the DLC and DLK commands. The IPS will move to the limit position, but no farther and the "E" flag will be set.

The final reporting command is the Report Status command (RST). The RST command returns a six-character text string. Each character position in the string represents a status condition. If the condition is false, the character will be a "-". If the status condition is true, a character specific to that condition will hold that position in the string. If all error conditions could be simultaneously true the output would be "FOETMW". If none of them are true the output will be "------". In actuality the M and W flags cannot be set at the same time, but this shows the order of the string.

These are the Flags and their meanings: "F" if a Failsafe Timeout has occurred since the last Status (see the Failsafe commands). "O" if the Motor Trip Current has been exceeded since the last Status (see the DMC command). "E" if the position error has exceeded the Deadband value since the last Report Status (see the RCU command). The "E" flag indicates that the IPS-AMP was unable to keep pace with the programmed Operation Parameters at least once. "T" if the IPS-AMP is currently executing a table (see Using Tables). "M" if the IPS-AMP is moving to a defined position. "W" if the IPS-AMP is waiting for a delay time to expire.

"F", "O" and "E" are latched flags. In other words they are set in the software and remain set until cleared by the user. To clear them send a Report Status command. They are cleared after the response is sent.

## Defining Serial Communication Parameters
Thus far the only serial communication parameter discussed has been the Define Device Address command (DDA). In addition it is also possible to change the baud rate of the communication interface. There are six baud rates available, and each of them has been assigned a parameter number. They are 2400 which corresponds to "1", 4800 which is "2", 9600 is "3", 19200 is "4", 57600 is "5" and 100k baud is "6". Note that 100k baud is not a standard rate. This is the fastest the IPS-AMP hardware allowed using the internal CPU clock. This baud rate should be obtainable by most standard microcontrollers.

NOTE:* The default baud rate of the IPS-AMP is 9600 baud. If the user changes the baud rate, the command takes effect immediately. These considerations must be observed.

- First, the user must immediately change baud rate on the computer that is sending commands to the IPS-AMP to continue communicating with the device.
- Second, if this is the desired future communication rate, the ESV command must be sent to save the new baud rate in non-volatile memory so that it is available whenever the IPS-AMP is powered-up.
- Third, if the ERD command is issued to return the IPS-AMP to the factory defaults, the baud rate also returns to 9600. If the desired baud rate is different, the controlling computer must send at least the DBR command at the 9600 baud rate.

If the user wants to implement the IPS-AMP in an environment where communication from the device to the controlling computer is not desired, it is possible to disable all data responses from the device. To do this send the Define Data Response command (DDR) with the parameter of "NO". From that point forward no serial data will be sent from the IPS-AMP. It must be remembered that this also disables all of the reporting functions.

## Defining Failsafe Behavior

Unlike standard R/C servos, the IPS has the ability to maintain its position even if the information being sent to the device ceases. It does not matter whether the device is using the R/C pulse mode or the serial interface. When the information stream stops, the IPS enters Failsafe Mode and sets the "F" flag in the status string (see the RST command). Often this means moving to a specified position to await resumption of the position data. However, moving to a position may not be desirable in every possible user application. Therefore, the behavior of the device in Failsafe Mode is configurable. In fact, it is possible to completely prevent entry into Failsafe Mode.

Three commands control Failsafe Mode. They are Define Failsafe Timeout (DFT), Define Failsafe Position (DFP) and Define Failsafe Current (DFC). The DFT command sets the acceptable length of time in seconds that the interface signal pin will sit idle before entering Failsafe Mode. The range is from 0.1 to 99.9 seconds. To completely disable entry into Failsafe Mode, define the timeout parameter to 0. This tells the firmware to never enter failsafe mode.

If there is a preferred position for the IPS to assume if the data stream ceases, the DFP command is used to define that position. This could be anywhere in its defined range of motion. The DFC command is used to change the motor drive current if the device enters Failsafe Mode. Again this number is in percent of full current (see the RCU command). If the usual current is lower than 100%, it could be set to the maximum to "lock" the device in a new position.

If it's desirable for the IPS to effectively "float" its position if the data stream stops, set DFC to 0. This will turn off the motor if the Failsafe Timeout is exceeded and the device will back-driven to an equilibrium position by the mechanical system to which it is connected. This could be the internal mechanical stop of the device.

NOTE:* If the desired action when the data stream ceases is to maintain the current position, disable Failsafe Mode by entering 0 as the Failsafe Timeout parameter. In this case nothing changes. This is the factory default.

## Defining the Motor-Current Parameters

The IPS continually monitors the motor drive current for both control and status reasons. The value of the current is available using the RCU command. Additionally it is possible to set some behaviors if the motor drive current exceeds certain user-defined parameters. The motor current commands are Define Motor Current (DMC), Define Trip Current (DTC) and Define Reduced Current (DRC).

The DMC command is used to set the maximum current value that the IPS will use to execute the movements requested by the user. This number is in percent of motor stall current, so the range is 0 to 100. (See the RCU command.) Higher numbers yield the possibility of greater performance. Lower numbers will yield system compliance, but if the number is too low the system may be unable to satisfy the user specified dynamics. Again, if this occurs, the "E" flag will be set and latched in the Status text string. Unless there are reasons to do otherwise, leaving this value at the factory default of 100 is suggested for normal operation.

NOTE*: Defining the motor current to 0 is the way to temporarily allow the IPS to be adjusted manually for setting the various mechanical limits set by the DLC, DLK and DZR commands.

Under certain conditions it may be desirable to specify a maximum motor current such that exceeding this value would be detected, reported and change the behavior of the IPS. Defining a Trip Current will accomplish this. The Trip Current is also specified in percent of stall current (0 to 100). Exceeding the Trip Current causes two actions. First the "O" flag is set in the Status text string, and it will remain latched until the string is read via the RST command.

The other effect is that the value defined by the Define Reduced Current command (DRC) will be moved into the Define Motor Current parameter. Normally this value would be lower than the normal motor current, assuming that the Trip Current is not to be exceeded. However, if the user desired, the trip condition could actually be used to set a higher current, such as to detect and overcome a circumstance that required more mechanical power.

NOTE:* The Reduced Current value will remain in effect until the user sets it back to its "normal" value using the DMC command.

## Using Tables

There are often reasons to execute a particular series of known moves multiple times. It would be advantageous to accomplish this with one simple command rather than to deal with the overhead of continuing to input and execute the sequence manually. The IPS-AMP provides this capability through its Tables.

A Table is simply a pre-programmed sequence of movements that can be entered once and then executed with two commands. There are 10 tables in the IPS-AMP. Each has room for 6 entries. One entry consists of a delay (SDL command), a speed (SSP command) and a position (SPS command). Tables may be executed once, multiple times, or continuously. The RST command can be used to determine the state of table execution, i.e. whether the device is actually executing a table, and within that table, whether or not it is waiting for a delay to expire or currently moving.

There are five commands used to create, maintain and execute tables. They are: the Table Reset command (TRS), the Table Step Enter command (TSE), the Table Report Entries command (TRP), the Table Mode command (TMD) and the Table Ready for GO! command (TRD).

The Table Reset command is the safest way to begin creating a table. It clears all the table entries in the specified table and sets the number of entries for that table to 0. The parameter sent is the table number and a parameter is required for this command, unlike many others.

The Table Step Enter command is used to build the table. In preparation to enter each step, a delay, speed and position must all be set using the SDL, SSP and SPS commands. When all three parameters are set, send the TSE command with a parameter of the table number. This will enter those three values as the next available step in the table. Once again, a parameter of the table number is required for this command.

When all desired steps have been entered, the table entries can be verified using the Table Report Entries command, again with a required parameter of the table number. The output of the TRP command is one line with the number of valid steps in the table. Following that line is one line for each table entry. An example output is shown below.

```
    2
00.0 00.0 –090.6
01.0 05.0   025.0
```

This example shows 2 steps entered. The first is a delay of 00.0 seconds, a speed of 00.0 (as fast as the IPS can move) to a position of –90.6 degrees. The second entry follows the same format.

Once the table has been defined, the Table Mode command tells the IPS how many iterations it is to execute with the one command. The valid number is from 1 to 250. If 0 is entered, the table will execute forever. If this command is sent during an execution sequence without a parameter, it will return the number of remaining iterations.

The final Table command is TRD, which is always sent with a parameter of the table number. It sets a flag indicating that the specified table is to be executed when the next GO! command is sent. Again this allows the coordination of multiple IPSs acting in unison. If this command is sent with a parameter of 0 it will cancel any pending TRD command to clear a previously set Table Mode flag.

## Operating Modes

The IPS-AMP has four operating modes, any of which can be selected using the Define Operating Mode command (DOM). The factory default mode is Mode "1" – Pulse Mode. In Mode "1" the device acts just like a digital R/C servo. Mode "2" is the serial mode, which gives the user access to all the device parameters and more sophisticated operation. Mode "3" uses the pulse interface to select a table for execution. And Mode "4" is an automatic, continuous table execution mode.

If the IPS is programmed to be in pulse mode, the serial mode can get the attention of the internal CPU by holding the input signal wire above 4 Volts for the first two seconds after the IPS-AMP powers up. The IPS-AMP senses the voltage on the signal wire for the first 2 seconds after power-up. If the Operating Mode is set to "1" or "3", and the signal line is at 0 Volts, it will operate in the R/C-pulse mode. If the signal line is at +4V or more, the serial interface will be active, overriding Mode "1" or "3" if they were programmed by the user. If the signal line is not stable at the two-second mark, or the signal line is noisy, the IPS-AMP may not choose the correct interface for your intended application.

In Mode "1" and Mode "3", the IPS-AMP is capable of interfacing with an R/C receiver or computer that is using the 1-2 millisecond R/C-pulse interface, or a computer using a 0-5V serial interface. The pulses must be "positive-pulses" meaning that the normal state of the signal line is 0 Volts. There must be at least 10 milliseconds of 0 Volts between pulses.

In Mode "1" the high-time of the input pulse is measured and the position is calculated based on the pulse length. 1-millisecond (ms) pulses will position the IPS at one end of its travel and 2ms pulses will move it to the other end. A 1.5ms pulse will place it in the center. The exact pulse length required to move to the center position is programmable along with a gain value to define the movement executed for the range of the input pulses. The Define Pulse Gain (DPG) and Define Zero Pulse Length (DPZ) commands accomplish this. However, these are advanced commands and should be used cautiously.

In Mode "3" the IPS-AMP will select one of two sequence tables to execute. If the pulse on the input line is 1ms in length, Table 1 will execute once. If the input pulse is 2ms in length, Table 2 will execute once.

Mode "4" causes Table 1 to begin executing shortly after power-up and to continue executing as long as power is applied. All the capabilities of Mode "2", serial mode, are available in Mode "4".

# Changing the Device Calibration

NOTE:* The following commands are intended only for advanced users because they have the ability to render the device partially or completely non-functional. If these parameters are changed, be prepared to either set them to their factory default values individually, or to use the ERD command to restore all parameters. Also exercise caution when using the ERD command due to the possibility of unforeseen side effects.

## Tuning the R/C Pulse Parameters

There are two commands that change the operation of the IPS when using the R/C pulse interface for Mode "1". They are the Define Zero Pulse Length command (DPZ) and the Define Pulse Gain command (DPG). The DPZ command is used to set the center of the range of motion. The DPG command is used to increase or decrease the total range of motion.

The pulse length of a normal "zero position" pulse is 1.5ms, or 1500 microseconds (µs). Because R/C transmitter may not precisely hit 1500µs for the center position, the IPS-AMP is capable of using a different pulse length to indicate center. The range is from 1000µs to 2000µs.

The user can change the amount that the IPS moves for a given change in pulse length using the DPG command. The higher this number is, the larger the swing will be for a given change in pulse length. There is only one gain for both directions of swing, so it affects both directions equally. To move the movement center position in only one direction away from the signal center position the user will need to modify this parameter in conjunction with the DLC and DLK commands. The pulse gain will have to be high enough to reach farthest position in the direction of swing with the greatest amplitude, and the DLC or DLK commands used to stop the motion on the short side before it hits the internal, mechanical stop in the IPS.

## Tuning the Motor Control-Loop Parameters

There are three parameters that affect the motor movement in the IPS when using serial mode. They are the Define Dead Band command (DDB), the Define Control-Loop Gain command (DCG) and the Define Derivative Gain command (DDG).

The Deadband sets the "error" value that the IPS-AMP will tolerate between the actual and desired arm position before taking action to bring the device back into command compliance. Two or three will usually be sufficient, but tighter accuracy may be obtained by making this number as small as 0. The disadvantage of low numbers is that the IPS will appear to hum or chatter as it skips back and forth over the programmed position to maintain no, or very low, error numbers. This increases the current load placed on the supply to the IPS, potentially shortening battery life if batteries are being used.

The DCG command………

The DDG command………

## **IPS Command Summary**

| Abbr. | Name | Command Type | Parameter Guidelines | Valid Range of Parameter (Range validation is not done) | Factory Default |
|-------|------|--------------|----------------------|--------------------------------------------------------|-----------------|
| DBR | Define Baud Rate | Comm. | Required | 1, 2, 3, 4, 5, 6 | 3 |
| DDA | Define Device Address | Comm. | Required | Any ASCII character except * | 1 |
| DDR | Define Data Response | Comm. | Optional | YES, NO | YES |
| DDD | Define Device Direction | Application | Optional | CWP, CWN | CWP |
| DLC | Define Limit Position Clockwise | Application | Special | -199.9 to 199.9 and manual | 90.0 |
| DLK | Define Limit Position Counter-Clockwise | Application | Special | -199.9 to 199.9 and manual | -90.0 |
| DZR | Define Zero Position | Application | Special | -199.9 to 199.9 and manual | 0.0 |
| DMC | Define Motor Current | Application | Optional | 0 to 100 | 100 |
| DRC | Define Reduced Motor Current | Application | Optional | 0 to 100 | 100 |
| DTC | Define Motor Trip Current | Application | Optional | 0 to 100 | 100 |
| DOM | Define Operating Mode | Application | Optional | 1, 2, 3, 4 | 1 |
| SDL | Set Delay | Operation | Optional | 0.0 to 99.9 | 0.0 |
| SPS | Set Position | Operation | Optional | -199.9 to 199.9 | 0.0 |
| SRP | Set Relative Position | Operation | Optional | -199.9 to 199.9 | 0.0 |
| SSP | Set Speed | Operation | Optional | 0.1 to 500.9 and 0 | 0 |
| GO! | Go Now | Movement | None | N/A | N/A |
| HT! | Halt Now | Movement | None | N/A | N/A |
| DFC | Define Failsafe Current | Failsafe | Optional | 0 to 100 | 0 |
| DFP | Define Failsafe Position | Failsafe | Optional | -199.9 to 199.9 | 0.0 |
| DFT | Define Failsafe Time Out | Failsafe | Optional | 0.1 to 99.9 and 0 | 0 |
| ELD | Load Parameters from EEPROM | EEPROM | None | N/A | N/A |
| ERD | Restore Factory Defaults to EEPROM | EEPROM | None | N/A | N/A |
| ESV | Save Parameters to EEPROM | EEPROM | None | N/A | N/A |
| RCU | Report Current | Report | None | 0 to 100 | N/A |
| RPS | Report Position | Report | None | -199.9 to 199.9 | N/A |
| RST | Report Status | Report | None | F or - O or - E or - T or - M or - W or - | N/A |
| RVR | Report Version | Report | None | Current Software Version | 2.0 |
| TMD | Table Mode | Table | Optional | 1 to 250 and 0 | 1 |
| TRD | Table Ready for GO! | Table | Required | 1 to 10 and 0 | N/A |
| TRP | Table Report Entries | Table | Required | 1 to 10 | N/A |
| TRS | Table Reset | Table | Required | 1 to 10 | N/A |
| TSE | Table Step Enter | Table | Required | 1 to 10 | N/A |
| DCG | Define Control-Loop Gain | Calibration | Optional | -999 to 999 | 100 |
| DDB | Define Dead Band | Calibration | Optional | 0 to 100 | 3 |
| DDG | Define Derivative Gain | Calibration | Optional | -999 to 999 | -150 |
| DPG | Define Pulse Gain | Calibration | Optional | -999 to 999 | -150 |
| DPZ | Define Zero Pulse Length | Calibration | Optional | 1000 to 2000 | 1500 |

On the following pages each command will be discussed in detail. All commands will be shown with the default servo address of "1". X's indicates an input argument and its range is defined for each command.

## Defining Communication Parameters

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DBR | Define Baud Rate | 1, 2, 3, 4, 5, 6 <br> Required | 3 |
| **Format:** | 1DBR  X<CR>          Sets the baud rate for the serial interface. | | |
| **Description:** | In serial mode, the IPS-AMP can communicate at several pre-programmed rates from 2400 baud to 100,000 baud. The baud rate is defined by selecting the proper parameter from the following list: <br>    1 =    2400 baud <br>    2 =    4800 baud <br>    3 =    9600 baud <br>    4 =  19200 baud <br>    5 =  57600 baud <br>    6 = 100000 baud | | |
| **Notes:** | The serial data format is 8-bit, No parity, 1 Stop bit. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DDA | Define Device Address | Any ASCII Character <br> * = All devices on this serial interface line | 1 |
| **Format:** | 1DDA  X<CR>          Sets the IPS-AMP address character. | | |
| **Description:** | This command defines the ASCII character that will be used for the address of this device in serial mode. The character is case sensitive and can be any character except "*". The new address will be in effect for the next command. | | |
| **Notes:** | Since all devices can share the same serial interface, it is important to program the address character for each IPS-AMP independently. <br><br> The "*" address cannot be used as an argument for any command that returns data. This would cause a conflict on the multi-drop bus. Therefore, no data will be returned by the IPS-AMP on commands with "*" as the address. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DDR | Define Data Response | YES, NO<br>Optional | YES |
| **Format:** | 1DDR  YES\<CR\>      Sets IPS-AMP to send responses over the serial link when appropriate. | | |
| **Description:** | The Data Response parameter can be set to NO if for instance the application has multiple IPS-AMPs on the same serial line with the same address. This would be an unusual configuration, but it is allowed. | | |
| **Notes:** | | | |

## Defining Application Parameters

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DDD | Define Device Direction | CWP, CWN<br>Optional | CWP |
| **Format:** | 1DDD<CR>            Returns the current Device Direction.<br>1DDD  CWP<CR>    Defines the IPS-AMP's clockwise movements as positive. | | |
| **Description:** | Defines the sign value of the IPS-AMP's clockwise rotation. The CWP argument defines clockwise movements as positive, the CWN argument defines clockwise movements as negative. | | |
| **Notes:** | This command takes effect immediately. It does NOT wait for the next GO! command. It is best to only change the value of this parameter when the IPS-AMP is stopped and at the 0 position. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DZR | Define Zero Position | -199.9 to 199.9 Special | 0.0 |

| | |
|---|---|
| **Format:** | 1DZR<CR>        Defines the current physical position of the IPS-AMP as the Zero Position.<br>1DZR  XX.X<CR>   Defines the IPS-AMP Zero Position in degrees. |
| **Description:** | This command defines the reference physical position the IPS-AMP for all future position commands. Always define the Zero Position before defining either of the other physical limits of the device using the DLC and DLK commands.<br><br>The zero position for the IPS-AMP can be set using two methods. It can be physically set by turning the IPS-AMP motor current to 0 (DMC command), then physically turning the IPS-AMP to the position that will be referred to as the zero reference and then entering the DZR command with no argument.<br><br>The second method is to set the desired physical zero-position of the IPS-AMP in the system, and then obtain the position value using the RPS command (Report Position) and then entering that number as the argument of the DZR command.<br><br>Once the new Zero Position has been entered, all future references to position including Report Position commands (RPS) and Set Position commands (SPS) will return values based on this new zero. |
| **Notes:** | This value should be set once and left alone. It provides the basis for the Limit commands (DLC and DLK) and all movement. |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DLC | Define Limit Position Clockwise | -199.9 to 199.9<br>Special | 90.0 |

| | |
|---|---|
| **Format:** | 1DLC<CR>          Sets the Clockwise Limit Position to the current physical position of the IPS-AMP.<br>1DLC  XX.X<CR>   Defines the Clockwise Limit Position in degrees. |
| **Description:** | This command defines the maximum physical position the IPS-AMP will attempt to achieve in the clockwise direction. If a command or position pulse is given that exceeds this range, the IPS-AMP will stop at this limit value. This prevents the IPS-AMP from stalling against its physical limit, or a physical limit in the application mechanism, which might damage the unit.<br><br>Always define the Zero Position <u>first</u> by using the DZR command.<br><br>This limit can be physically set by: Turning the IPS-AMP motor current to 0 (DMC command), then turning the IPS-AMP clockwise to the limit you desire. At that point do one of two things: Either enter the DLC command with no argument, or obtain the current position by using the RPS command (Report Position) and then enter that number as the argument of the DLC command. |
| **Notes:** | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DLK | Define Limit Position Counter-Clockwise | -199.9 to 199.9 Special | -90.0 |
| **Format:** | 1DLK<CR>        Sets the Counter-Clockwise Limit Position to the current physical position of the IPS-AMP. <br> 1DLK  XX.X<CR>   Defines the Counter-Clockwise Limit Position in degrees. | | |
| **Description:** | This command defines the maximum physical position the IPS-AMP will attempt to achieve in the counter-clockwise direction. If a command or position pulse is given that exceeds this range, the IPS-AMP will stop at this limit value. This prevents the IPS-AMP from stalling against its physical limit, or a physical limit in the application mechanism, which might damage the unit. <br><br> Always define the Zero Position <u>first</u> by using the DZR command. <br><br> This limit can be physically set by: Turning the IPS-AMP motor current to 0 (DMC command), then turning the IPS-AMP counter-clockwise to the limit you desire. At that point do one of two things: Either enter the DLK command with no argument, or obtain the current position by using the RPS command (Report Position) and then enter that number as the argument of the DLK command. | | |
| **Notes:** | | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DMC | Define Motor Current | 0 to 100 Optional | 100 |
| **Format:** | 1DMC<CR>          Returns the current value of Motor Current Parameter.<br>1DMC  75<CR>     Defines the IPS-AMP's maximum average Motor Current at 75% of the stall-current (maximum draw). | | |
| **Description:** | The Motor Current Parameter sets the maximum average current the motor will draw in normal operation. This will limit the physical torque applied by the IPS-AMP.  This may be useful if the application mechanism cannot tolerate the maximum force the IPS-AMP can apply to the system.<br><br>The combination of the duty-cycle of the applied motor voltage and the instantaneous motor current is the average current drawn by the motor. The IPS-AMP draws maximum current when the motor is stalled and the duty-cycle of the applied voltage is 100%. | | |
| **Notes:** | This Parameter can be changed automatically if the Trip Current is exceeded. (See the DRC and DTC commands.) | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DRC | Define Reduced Motor Current | 0 to 100 Optional | 100 |
| **Format:** | 1DRC<CR>          Returns the current value of Reduced Motor Current Parameter.<br>1DRC  35<CR>     Defines the IPS-AMP's Reduced Motor Current Parameter at 35%<br><br>of the stall-current (maximum draw). | | |
| **Description:** | If the physical load placed on the IPS-AMP exceeds that which can be applied without exceeding the Trip Current (see the DTC command), the value of this parameter will be moved to the Define Motor Current Parameter (see DMC command). This will allow the IPS-AMP to operate in a diminished power mode until the excessive load is removed and the Define Motor Current Parameter is restored to its correct value. | | |
| **Notes:** | If this Parameter is set to 0, the IPS-AMP will stop if the Motor Trip Current is exceeded. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DTC | Define Trip Current | 0 to 100<br>Optional | 100 |
| **Format:** | 1DTC<CR>          Returns the current value of Motor Trip Current Parameter.<br>1DTC  95<CR>     Defines the IPS-AMP's Motor Trip Current Parameter at 95%<br>                          of the stall-current (maximum draw). | | |
| **Description:** | The Motor Trip Current is used in the IPS-AMP like a circuit breaker is used in an electrical panel. If this value is exceeded (it's the combination of the instantaneous current and the duty-cycle of the applied voltage), the value of the Reduced Motor Current Parameter (see the DRC command) will be moved to the Motor Current Parameter (see the DMC command). | | |
| **Notes:** | The factory default for this parameter is 100. In other words, if the parameter is never modified, the trip condition will never occur. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DOM | Define Operating Mode | 1,2,3,4 Optional | 1 |

| | |
|---|---|
| **Format:** | 1DOM<CR>         Returns current Operating Mode.<br>1DOM  X<CR>       Defines IPS-AMP Operating Mode. |
| **Description:** | This command defines the IPS-AMP's operating mode. There are four valid modes as defined below:<br>  1  Pulse mode. This is the default operating mode. In this mode the IPS-AMP expects a input pulse width to define the IPS-AMP position. The pulse width range is 1.0 mSec to 2.0 mSec with 1.5 mSec defining center position.<br>  2  Serial mode. In this mode the IPS-AMP expects to receive commands through the serial interface. Input pulse information is ignored in this mode.<br>  3  Pulse sequence table select. The IPS-AMP contains ten sequence tables that can contain sequences of up to six positions. In this mode the input pulse defines a sequence table to play. If the pulse width is 1 mSec, table 1 will be played. If the pulse width is 2 mSec, table 2 will be played.<br>  4  Auto table play mode. In this mode the IPS-AMP will start playing sequence table 1 shortly after power is applied. |
| **Notes:** | When power is applied to the IPS-AMP and it is in modes 1 or 3, the input line is examined 2 seconds after power-up to determine if it is connected to a pulse source or a serial interface. If the signal line is at 0V it will operate in the R/C-pulse mode. If the signal line is at +4V or more, then the run mode is set to Serial.<br><br>If the signal line is not stable at the two-second mark, or the signal line is noisy, the IPS-AMP may not choose the correct interface for your intended application. |

## Setting Operation Parameters

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| SDL | Set Delay | 0.0 to 99.9<br>Optional | 0.0 |
| **Format:** | 1SDL<CR>            Returns current Delay count.<br>1SDL  XX.X<CR>    Defines IPS-AMP Delay count in seconds. | | |
| **Description:** | This command defines a delay count for the IPS-AMP. This count defines how long it will wait after the GO! command before the new Set Position command begins processing. The units of the delay are in Seconds. | | |
| **Notes:** | This applies only to serial position commands (Operating Mode 2) and sequence table entries. It is not valid for Operating Mode 1. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| SPS | Set Position | -199.9 to 199.9<br>Optional | 0.0 |
| **Format:** | 1SPS<CR>            Returns current value of the Set Position Parameter.<br>1SPS  47.5<CR>    Sets the IPS-AMP Set Position to 47.5 degrees. | | |
| **Description:** | This command defines the position you would like the IPS-AMP to move to at the next GO! command. The IPS-AMP will not move when this command is entered, it will only set a variable. Issuing the GO! command will cause the IPS-AMP to move.<br><br>The position value is based on the Define Zero Position command and the feedback potentiometer in the IPS-AMP. The full range of motion of the IPS-AMP is approximately 180 degrees. If the Zero Position is set near the middle of the range-of-motion, the IPS-AMP can move from approximately –90.0 to 90.0 degrees. If Zero is set at the positive limit of the IPS-AMP, it will move from approximately –180.0 to 0.0 degrees. And if Zero is set near the negative limit, it will move from 0.0 to 180.0 degrees. | | |
| **Notes:** | To determine the maximum range of motion of your IPS-AMP is capable of, take exact measurements of position using the RPS command.<br><br>See the following commands for more explanation: DLC, DLK, and DZR. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| SRP | Set Relative Position | -199.9 to 199.9<br>Required | 0.0 |
| **Format:** | 1SRP  XX.X<CR>     Sets a new position relative to the last set position. | | |
| **Description:** | This command defines a relative position move. The last set position is adjusted by adding this value to the current set position. The IPS-AMP will not move until a GO! command is issued. | | |
| **Notes:** | The IPS-AMP has a limited range of motion defined by the DLC and DLK commands. If a relative position is set which is past either of the limits of motion, the IPS-AMP will move only to that limit. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| SSP | Set Speed | 0.1 to 500.0 or 0<br>Optional | 0 |
| **Format:** | 1SSL<CR>               Returns current Slew Rate.<br>1SSL  XXX.X<CR>  Defines IPS-AMP Slew Rate in degrees per second. | | |
| **Description:** | This command defines the speed the IPS-AMP will use to move from its current position to the next position. This value defines the maximum position step that will be executed every second. For example if this value is set to 1.0 then the IPS-AMP will move 1.0 degree every second. If the next Set Position command is defined to be 90 degrees from where it is now, this will result in 90 degrees of motion in 90 seconds at the next GO! command.<br><br>If this value is set to 0 the IPS-AMP will move at its maximum rate. This speed will be a function of the IPS-AMP's motor current (DMC command), the applied voltage and the load. | | |
| **Notes:** | | | |

## Movement Commands

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| GO! | Go Now | N/A<br>None | N/A |
| **Format:** | 1GO!<CR>    Commands the IPS-AMP to go using the current set parameters. | | |
| **Description:** | This command will cause the IPS-AMP to move to the position set by the Set Position (SPS) command (or the Set Relative Position command – SRP), at the current set speed (SSP), after the current set delay (SDL) has elapsed.<br><br>Or, if a table ready command is pending (TRD) the IPS-AMP will begin the execution of the set sequence table.<br><br>This command is useful in synchronizing the motions of several IPS-AMPs. Each IPS-AMP's parameters can be defined using the unique address of each. Then the GO! command can be issued with a "*" address to cause all IPS-AMPs to start moving at the same time. | | |
| **Notes:** | | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| HT! | Halt Now | N/A<br>None | N/A |
| **Format:** | 1HT!<CR>    Halts the IPS-AMP immediately. | | |
| **Description:** | This command stops the IPS-AMP at its current position. The IPS-AMP will continue to power the motor and hold its current position. This will also halt the execution of any table function.<br><br>HT! will also cancel a pending Table Ready for GO! (TRD) command. | | |
| **Notes:** | | | |

## Defining Failsafe Parameters

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DFC | Define Failsafe Current | 0 to 100 Optional | 0 |
| **Format:** | 1DPW<CR>  Returns the current IPS-AMP Failsafe Current Parameter. <br> 1DPW  10<CR>  Defines the IPS-AMP Current under Failsafe condition to 10% of the stall-current (maximum value). | | |
| **Description:** | If input pulse information, or serial data, is not present on the data pin of the IPS-AMP for a time specified by the Define Failsafe Timeout (DFT) command, the IPS-AMP motor current will be set to this value. | | |
| **Notes:** | If this Parameter is set to 0, the IPS-AMP will stop if the Failsafe Timeout occurs regardless of the value of the Failsafe Position Parameter (see DFP command). | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DFP | Define Failsafe Position | -199.9 to 199.9 Optional | 0.0 |
| **Format:** | 1DFP<CR>  Returns current Failsafe Position. <br> 1DFP  XXX.X<CR>  Defines IPS-AMP Failsafe Position in degrees. | | |
| **Description:** | The IPS-AMP will move to the defined failsafe position if input pulse information, or serial data, is not present on the data pin of the IPS-AMP for a time specified by the Define Failsafe Timeout (DFT) command. This parameter defines the position the IPS-AMP will move to if the timeout occurs. It is measured in degrees. | | |
| **Notes:** | The IPS-AMP will not move if the Define Failsafe Current Parameter is set to 0 (see DFC command). <br><br> The timeout is specified using the Define Failsafe Timeout command (DFT). | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DFT | Define Failsafe Timeout | 0.1 to 99.9 and 0<br>Optional | 0 |
| **Format:** | 1DFT<CR>    Returns current Failsafe Timeout.<br>1DFT  1.0<CR>  Defines IPS-AMP Failsafe Timeout as 1.0 seconds. | | |
| **Description:** | If input position pulse information, or serial data, is not present for a user defined amount of time on the data pin of the IPS-AMP it will move to the defined failsafe position specified by the Define Failsafe Position (DFP) command.<br><br>This parameter defines the amount of time the IPS-AMP will wait for valid information before it enters the failsafe mode. The units of this time are seconds.<br><br>If this parameter is set to 0 there is no timeout. The function is disabled. | | |
| **Notes:** | The IPS-AMP will not move if the Define Failsafe Current Parameter is set to 0 (see DFC command). | | |

## Non-Volatile Memory Commands

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| ELD | Load Parameters from EEPROM | N/A None | N/A |
| **Format:** | 1ELD<CR>    Restores all parameters to the last values saved in EEPROM. | | |
| **Description:** | The IPS-AMP operates on parameters that are stored in Random Access Memory (RAM). Values in RAM are not maintained when power is removed – it is volatile. This command retrieves all IPS-AMP adjustable parameters from nonvolatile EEPROM memory and moves them to RAM.<br><br>If you have made changes to any parameters, and you do not like the current operation, you may use this command to retrieve your most recently saved parameters and restore the device to its last-saved operating state. | | |
| **Notes:** | Be sure to save your final changes using the ESV command or they will be lost when power is removed from the IPS-AMP.<br><br>**USE THIS COMMAND WITH CAUTION – NEVER IN A LIVE SYSTEM!** | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| ERD | Restore Factory Defaults to EEPROM | N/A None | N/A |
| **Format:** | 1ERD<CR>    Restores all parameters to the factory default values. | | |
| **Description:** | This command will restore all IPS-AMP adjustable parameters back to the factory default values. Any changes made since the device was purchased, even if they were previously saved to EEPROM, are lost. | | |
| **Notes:** | This also applies to all serial communications parameters, including the IPS-AMP's address character, so all devices on the same serial line will now respond identically. The baud rate will also be restored to the factory default value of 9600 baud.<br><br>**USE THIS COMMAND WITH CAUTION – NEVER IN A LIVE SYSTEM!** | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| ESV | Save Parameters to EEPROM | N/A<br>None | N/A |
| **Format:** | 1ESV<CR>    Save all adjustable parameters to EEPROM. | | |
| **Description:** | This command will save all IPS-AMP adjustable parameters in nonvolatile EEPROM memory. When the IPS-AMP's power is applied this memory is used to define all operating values. After you have made changes to any parameters you will need to use this command to save your changes or they will be lost when power is removed from the IPS-AMP. | | |
| **Notes:** | This operation will take several seconds to complete. The servo power should be turned off (using the DPW command) before you issue this command.<br><br>**USE THIS COMMAND WITH CAUTION – NEVER IN A LIVE SYSTEM!** | | |

## Reporting Commands

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| RCU | Report Current | 0 to 100<br>None | N/A |
| **Format:** | 1RPS\<CR\>    Reports the IPS-AMP motor current. | | |
| **Description:** | This command reports the product of the peak motor current times the duty-cycle of the applied voltage waveform. This is effectively the average motor current. It is reported in percentage of stall-current (maximum value). | | |
| **Notes:** | The Data Response parameter must be set to "YES" and a valid servo address character must be used to obtain output. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| RPS | Report Position | -199.9 to 199.9<br>None | N/A |
| **Format:** | 1RPS\<CR\>    Reports the current IPS-AMP position. | | |
| **Description:** | This command reports the current IPS-AMP position. The units are degrees. | | |
| **Notes:** | The Data Response parameter must be set to "YES" and a valid servo address character must be used to obtain output. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| RST | Report Status | N/A<br>None | N/A |

| | |
|---|---|
| **Format:** | 1RST\<CR\>     Reports the current IPS-AMP status. |

| | |
|---|---|
| **Description:** | This command reports the current IPS-AMP status. This is useful to determine if the IPS-AMP is moving, delaying or has a position error. The output is always six characters. It is the concatenation of the six different flag values. Listed below are each flag's value and its meaning:<br>F if a Failsafe Timeout has occurred since the last Status. "-" if not.<br>O if the Motor Trip Current has been exceeded since the last Status. "-" if not.<br>E if the position error has exceeded the Deadband value since the last Status. "-" if not.<br>T if the IPS-AMP is currently executing a table. "-" if not.<br>M if the IPS-AMP is moving to a defined position. "-" if not.<br>W if the IPS-AMP is waiting for a delay time to expire. "-" if not.<br><br>If all error conditions could be simultaneously true (the M and W flags cannot be set at the same time) the output would be "FOETMW". If none of them are true the output will be "------".<br><br>"F", "O" and "E" are latched flags. They are only cleared by a Report Status command.<br><br>The "E" flag indicates that the IPS-AMP was unable to keep pace with the programmed Operation Parameters at least once. Either the load momentarily exceeded its normal range, or the IPS-AMP has been asked to perform beyond its physical capabilities. It may be necessary to scale back one or more IPS-AMP Parameters. |

| | |
|---|---|
| **Notes:** | The Data Response parameter must be set to "YES" and a valid servo address character must be used to obtain output. |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| RVR | Report Software Version | Current Software Version None | See Below |
| **Format:** | 1RVR<CR>   Returns the current version of the IPS-AMP software. | | |
| **Description:** | This command is used to ensure that the operating software is at the most up-to-date version, or at least at a known version.<br><br>The typical format is: "GAACE. IPS-AMP V 2.0a" | | |
| **Notes:** | The Data Response parameter must be set to "YES" and a valid servo address character must be used to obtain output.<br><br>Your IPS-AMP may be returned to the factory for software upgrades. Contact the factory for details. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| RVT | Report Voltage | 4.0 to 5.25 None | N/A |
| **Format:** | 1RVR<CR>   Returns the current version of the IPS-AMP software. | | |
| **Description:** | This command is used to measure the voltage being applied to the IPS-AMP. The controlling computer can use it to determine if the batteries are in need of recharging. The voltage may be read either under load or with no load to determine the true state of the batteries. | | |
| **Notes:** | The Data Response parameter must be set to "YES" and a valid servo address character must be used to obtain output.<br><br>Valid voltages are between 4.0 Volts and 5.25 Volts. Voltages under 4.0 Volts will reset the IPS-AMP CPU. Voltages above 5.25 Volts may damage your IPS-AMP and void your warranty. | | |

## Table Commands

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| TMD | Table Mode | 1 to 250 and 0 Optional | 1 |
| **Format:** | 1TMD<CR>　　　　　Returns current Table Mode.<br>1TMD  X<CR>　　　　Defines IPS-AMP Table Mode. | | |
| **Description:** | The IPS-AMP contains ten sequence tables that define a list of IPS-AMP positions with selected Delays and Speeds. These tables can be played from one to 250 times or can repeat forever if Table Mode is set to 0. This command defines the way a table is executed. This value is only valid in modes that use the sequence table(s). This mode applies to whichever table is selected - see the Table Ready command. | | |
| **Notes:** | | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| TRD | Table Ready for GO! | 1 to 10 and 0 Required | N/A |
| **Format:** | 1TDR  X<CR>　　　　Sets a flag that will cause the defined table to play when the next GO! command is received. | | |
| **Description:** | This command will set a flag for the selected table. When the next GO! command (GO!) is received the selected sequence table to play. | | |
| **Notes:** | | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| TRP | Table Report Entries | 1 to 10 Required | N/A |
| **Format:** | 1TRP  X<CR>        Sends table entries for the specified table out the serial port. | | |
| **Description:** | This command is used to verify the table entries in you IPS-AMP. Example output for a table with two entries is shown below. The first line is the number of entries. Each subsequent line contains three 3-digit numbers, the last of which has a sign indicator. The first field of the line is the Delay for that entry from the SDL command. The second field is the Speed from the SSP command. The last field is the Position from the SPS command.<br><br>2<br>00.0 00.0 –090.6<br>01.0 05.0   025.0 | | |
| **Notes:** | The Data Response parameter must be set to "YES" to obtain output.<br><br>Plus signs (+) are not printed for the position or velocity values. If the value is positive, there will be an extra space character before the value instead of the plus sign. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| TRS | Table Reset | 1 to 10 Required | N/A |
| **Format:** | 1TRS  X<CR>        Resets the specified sequence table. | | |
| **Description:** | This command will reset the specified sequence table. It will clear all entries and set the step pointer to the first step in the table. Use this command to begin setting up a new sequence table. | | |
| **Notes:** | See the TSE command for a full description of defining a sequence table. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| TSE | Table Step Enter | 1 to 10<br>Required | N/A |
| **Format:** | 1TSE X<CR>Sets the next entry in the defined sequence table. | | |
| **Description:** | This command will set the next entry in the sequence table defined by the command argument. Each table entry contains a IPS-AMP position, defined by SPS command, a slew rate, defined by the SSL command, and a delay, defined by the SDL command. To define a sequence use the following steps:<br>1. Reset the desired table (TRS command)<br>2. Set the desired IPS-AMP position (SPS command)<br>3. Set the speed (SSP command)<br>4. Set the delay (SDL command)<br>5. Enter values into the sequence table (TSE command)<br>6. Repeat steps 2 through 5 up to six times total | | |
| **Notes:** | You may review the contents of any table by using the Table Report (TRP) command. | | |

## Defining Calibration Parameters

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DCG | Define Control-Loop Gain | -999 to 999 Optional | 100 |

| | |
|---|---|
| **Format:** | 1DCG<CR>       Returns current gain.<br>1DCG  X<CR>      Defines Control-Loop Proportional Gain. |
| **Description:** | This command sets the control-loop proportional gain. This has a great effect on the performance of the IPS-AMP. If you set this value too low the IPS-AMP will move slowly and will maintain a large position error. If the gain is too high the IPS-AMP may oscillate around its final position. The default value of 100 is pretty conservative and will yield acceptable performance in most applications. |
| **Notes:** | This is a command suitable for advanced users only. Improper setting of this parameter can result in poor or erratic performance. |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DDB | Define Deadband | 0 to 100 Optional | 3 |

| | |
|---|---|
| **Format:** | 1DB<CR>    Returns current Deadband.<br>1DB  X<CR>  Defines IPS-AMP Deadband. |
| **Description:** | This command sets the IPS-AMP control loop deadband. It is in Position count units. When the IPS-AMP position is within the deadband of the desired position, the control loop will stop driving the motor. |
| **Notes:** | The smaller this value the more accurate the position control will be, but the more power the IPS-AMP will draw.<br><br>The default value of 3 is a good place to start, values as low as 2 or 0 will give very good performance. If the deadband is very low, the IPS-AMP may have a tendency to chatter or hum as it oscillates back and forth from above to below the desired position. This is normal behavior for low values of Deadband. |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DDG | Define Derivative Gain | -999 to 999<br>Optional | -150 |
| **Format:** | 1DDG<CR>          Returns current Derivative Gain.<br>1DDG X<CR>          Defines IPS-AMP Derivative Gain. | | |
| **Description:** | This command sets the IPS-AMP control derivative loop gain. This parameter helps tune the IPS-AMP for best performance. A value of –150 allows an increased loop gain (DCG) with stable centering and good holding power, and without overshoot. | | |
| **Notes:** | This is a command suitable for advanced users only. Improper setting of this parameter will result in poor or erratic performance. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DIG | Define Integral Gain | -999 to 999<br>Optional | 000 |
| **Format:** | 1DIG<CR>          Returns current IntegralGain.<br>1DIG X<CR>          Defines IPS-AMP IntegralGain. | | |
| **Description:** | This command sets the IPS-AMP control integral loop gain. This parameter helps tune the IPS-AMP for best performance. | | |
| **Notes:** | This is a command suitable for advanced users only. Improper setting of this parameter will result in poor or erratic performance. | | |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DPG | Define Pulse Gain | -999 to 999 Optional | 128 |

| **Format:** | 1DPG<CR>            Returns current Position Gain.<br>1DPG  X<CR>        Defines IPS-AMP Position Gain. |
|---|---|
| **Description:** | The Define Zero Pulse Length (DPZ) and the Define Pulse Gain (DPG) commands are used to convert the input position pulse into an IPS-AMP position value.<br><br>Changing the position gain (DPG) will define the range of motion for the IPS-AMP for given pulse widths based upon the Zero Pulse Length value. |
| **Notes:** | This command is only used in pulse modes – Operating Modes 1 and 3. |

| Mnemonic | Name | Valid Range of Parameter (Range is not checked!) | Default Value |
|---|---|---|---|
| DPZ | Define Zero Pulse Length | 0 to 2000 Optional | 1500 |

| **Format:** | 1DPZ<CR>            Returns current zero pulse length.<br>1DPZ  X<CR>        Defines IPS-AMP zero pulse length. |
|---|---|
| **Description:** | The Define Zero Pulse Length (DPZ) and the Define Pulse Gain (DPG) commands are used to convert the input position pulse into a IPS-AMP position value. This is done by first measuring the input pulse width. This is done in units of 1 uSec, so a pulse width of 1.5 mSec will result in a value of 1500.<br><br>The default value for DPZ is 1500. Changing this value will change the center position of the IPS-AMP in pulse mode (Operating Mode 1). |
| **Notes:** | This command is only used in pulse modes – Operating Modes 1 and 3. |

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Commands