VAREDAN
TECHNOLOGIES

LAD Series Linear Servo Amplifier

LAD-310S

Technical Reference Manual

Manual Part Number: 4092-42-001

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Document Revision History

Revision	Release Date	Notes
A	03-31-2022	Initial release.

CAUTION! READ THIS SECTION BEFORE PROCEEDING.

- Warning! Potentially lethal voltages exist within the amplifier when power is applied. Never attempt to handle or probe the amplifier with power applied.
- This product contains static sensitive devices and requires proper handling with ESD protection.
- Hazardous voltages are present at the motor output terminals, input power connection, and within the sheet metal enclosure. Disconnect the power before plugging / unplugging any connections or before servicing or disassembling the enclosure.
- These amplifiers can produce large amounts of energy. Serious injury or death can result from improper motor or load movement.
- Do not connect the motor to the system load during initial testing and installation.
- These amplifiers require customer supplied airflow for proper operation. Operation of the amplifier without proper cooling will void the warranty. Contact the factory for information on adequate airflow for your application.
- Be sure power is off when inserting or removing connectors or connections.

Contents

1 Introduction

LAD 300S series are compact 4 axis digital input linear current amplifiers designed to drive up to 4 single phase loads such as brush-type motors or voice coils. LAD-300S are the perfect choices for systems requiring low radiated noise, zero distortion, and low drifting from the drive electronics. These high-power current mode linear amplifiers are well suited to drive low inductance/resistance loads.

With the true class AB linear output stage, the amplifier is extremely quiet and provide the ultimate in zero cross-over distortion for smooth output positioning. The power section of the amplifiers is constructed onto an insulated metal substrate circuit board which allows the highest power density available in today's marketplace. The design of these amplifiers includes an on-board high-speed DSP which monitors all key system functions in real time and provides protection for the outputs by only allowing output power within the "Safe Operating Area" of the output transistors. The DSP also provide self-driven features for customers who want to perform bench evaluations. The self-driven features can also be used to diagnose the amplifier functionality and integrity directly in system without remove the amplifier. An intelligent user interface allows setup and storage of all system parameters via the serial interface. Non-volatile memory provides storage of the parameters during power off conditions. A 7-segment LED display provides a visual indication of system status.

The LAD 300S amplifiers are powered by a single external +15 to +56 VDC unipolar bus. A 20 MHz salve SPI interface is designed to receive up to 4 channel digital current references. 4 channel 16-bit DAC with full resolution converts the digital current references to analog current commands.

LAD 310S has 4 current loop gain settings, selectable via front edge DIP switch. Customers can utilize this feature to drive 4 different loads or drive one load with 4 different bandwidth settings.

LAD 310S has 4 current transconductance ratios, selectable via front edge DIP switch. Customers can utilize this feature to set current transconductance which best matches their applications.

Varedan offers 3 different packages, standard, DC stand alone and AC standalone. Standard module is an excellent selection for OEM applications. DC standalone module has a full covered enclosure with a cooling fan integrated. AC standalone integrates a 300W linear power supply and 2 cooling fans into the package, in which 110/240VAC power can directly apply.

1.1 Safe Operation Area

The LA amplifiers include a sophisticated algorithm that protects the outputs from over power conditions. This algorithm is matched to the power characteristics of the output transistors in each amplifier model. With linear servo amplifiers (as opposed to PWM amplifiers), it is very important to provide over-power protection (rather than simple over-current protection) due to the linear nature of the output control. In the case of PWM amplifiers, only over-current protection is required since the outputs are operating in saturation mode or "full on mode". This mode provides very little voltage drop across the output transistors, so simple current monitoring is sufficient to provide protection of the outputs.

With linear servo amplifiers, the outputs are operating in their linear region, so the voltage across the output transistors can be a substantial contribution to the total power dissipated by the device. To properly protect the amplifier from damage, the amplifier must provide protection by monitoring the power

(voltage * current) in the output devices. To put this in perspective, the outputs used in the LAD-300S amplifiers can handle upper to 10A under the proper conditions - it's the power that has to be kept under control.

The DSP in the LAD series amplifiers monitors the power of each output device in real time as the device is switched on by the control circuitry. This instantaneous power measurement is compared with the transistor manufactures recommended "safe operating area" curve (published in all transistor specifications) stored in the DSP memory. The amplifier is shut down in the event that the measured power exceeds the recommended ratings of the output devices.

Our Safe Operating Area (SOA) algorithm has proven to be very effective in protecting the amplifier from damage due to over power conditions. While the user may experience "nuisance" tripping of the SOA protective function during system development and testing, it is likely that the conditions causing these "nuisance" trips may have destroyed the amplifier without this SOA protection.

2 Specifications

2.1 Electrical Specification

Parameter	LAD-310S
Peak Output Current	10A
Continuous Output Current	3A
Peak Output Power (25℃)	600W
Continuous Power Dissipation (25℃)	300W
Bus Voltage – Unipolar	+24 to +56 VDC (note)
Max. Heat Sink Temperature	70℃
Current Loop Bandwidth	up to 10KHz
Current Command Signal	18 bits SPI, up to 20MHz, RS422
Current Transconductance	10 Amp/32768 default. Four transconductance selections depending on user jumper settings.

Note: The bus voltage can be higher than +56V and the settings can be customized. please contact the factory for details.

Power specification for AC standalone module.

Power Requirement	LAD-310S-4A-ACSA	Notes
AC Input	115VAC	100VAC – 120VAC, 47-63Hz
	230VAC	208VAC – 240VAC, 47-63Hz
Motor bus voltage option	+35V, +42V, +/-49V, +56V, Or specified by customers	300VA linear unregulated power supply.

2.2 Mechanical Specification

Parameters	LAD-310S-4A	LAD-310S-4A-DCSA	LAD-310S-4A-ACSA
Length	7.15 inch (181.6 mm)	10.17 inch (258.3 mm)	11.18 inch (284.0 mm)
Width	3.45 inch (87.6 mm) without mounting bracket	3.82 inch (97.0 mm)	5.70 inch (144.8 mm)
Height	2.7 inch (68.6 mm)	3.67 inch (93.2 mm)	7.14 inch (181.4 mm)
Weight	2.0 lb (0.91 kg)	3.4 lb (1.54 kg)	15.0 lb (6.8 kg)

3 Model Numbering

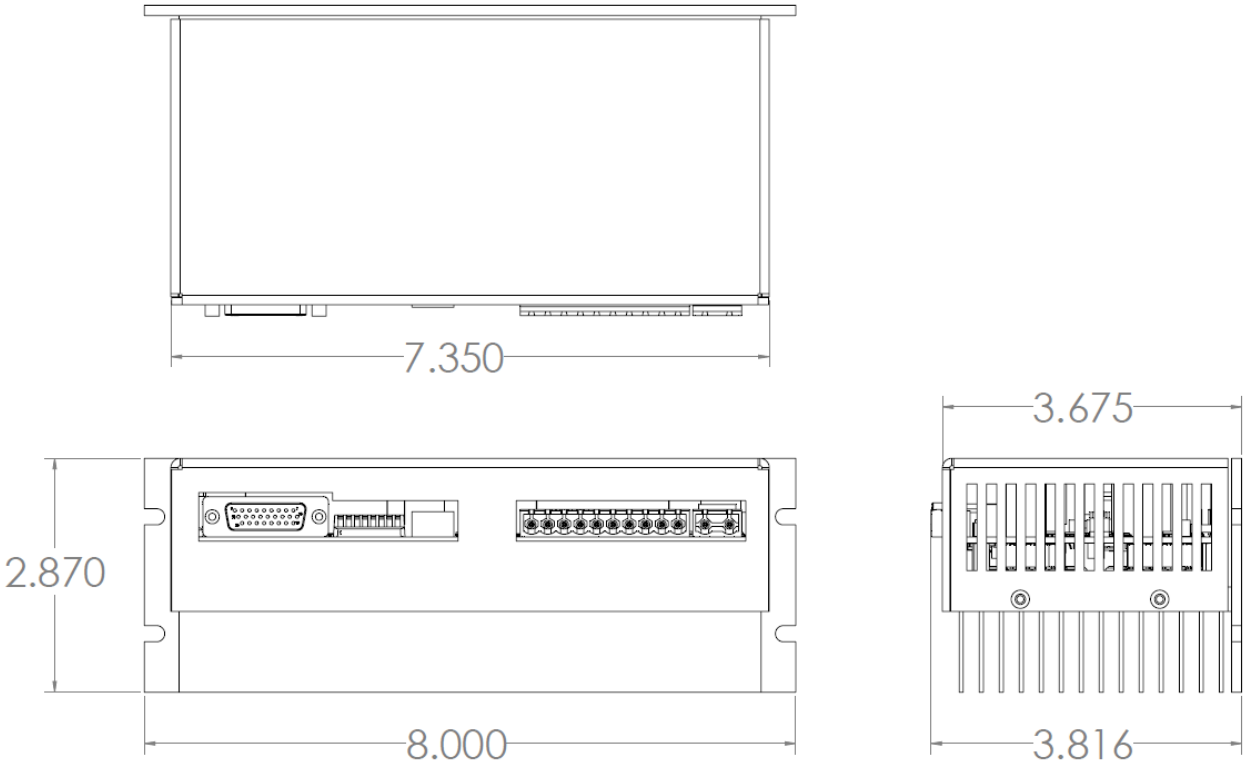
Model number breakdown: **LAD-CCCW-XX-YYYY-ZZZ**

Field Number	Description	Available Options	Notes
LAD	Varedan Digital Linear Servo Amplifier	LAD	Product Series
CCC	Power and Current Level	310 – 300W, 10A peak	
W	Drive Mode Configuration	S – Single phase, H bridge	
XX	Number of axes	4A – Four single phase	
YYYY	Package selection	N/A – Standard package DCSA – DC standalone package ACSA – AC standalone package	Without package spec, standard module is default.
ZZZ	Customer configure code	Contact factory	Optional

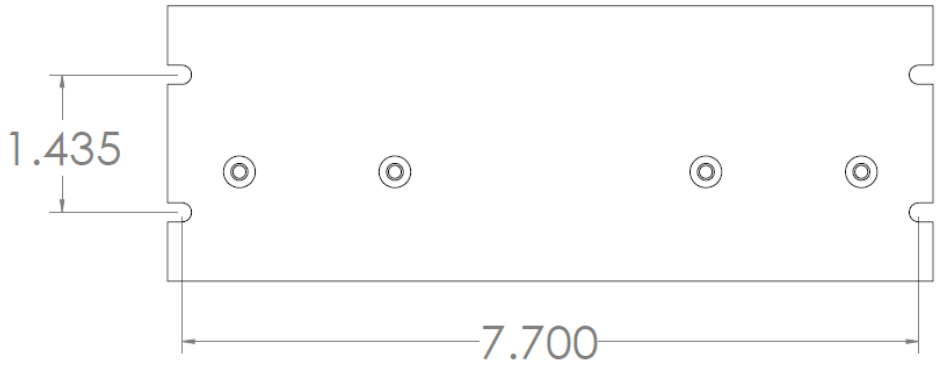
4 Package Information and Spec

4.1 Standard Module

4.1.1 Mechanical dimensions

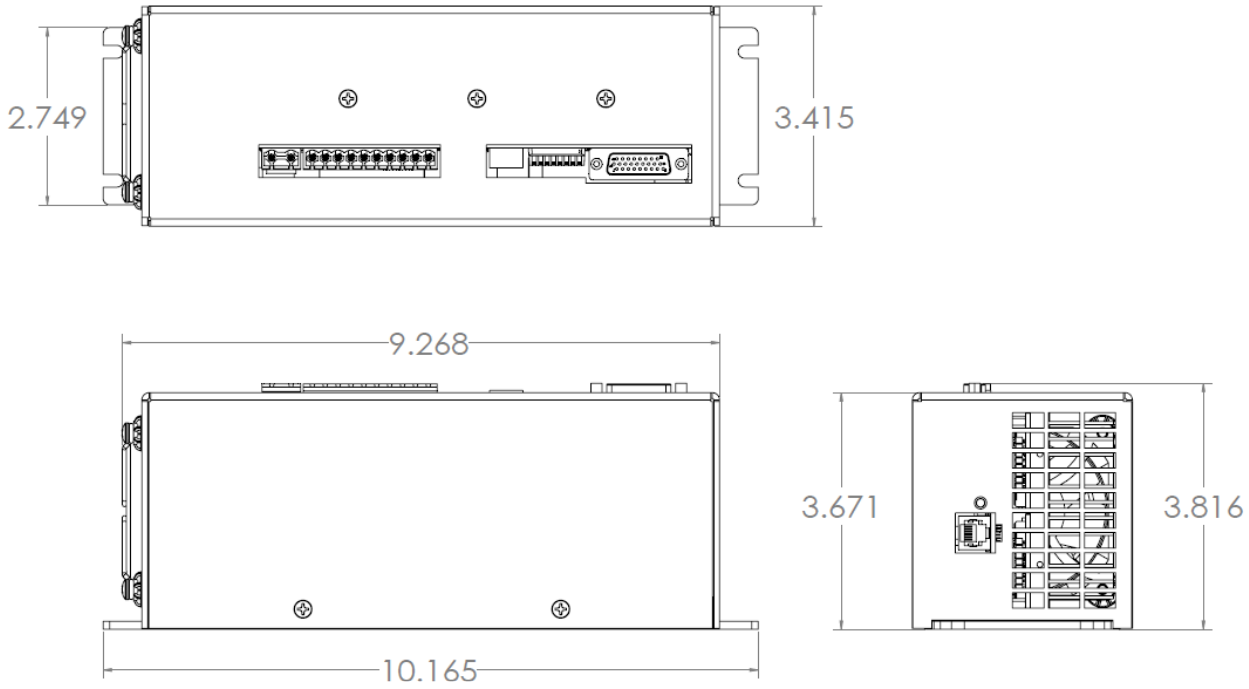


4.1.2 Mounting bracket – optional



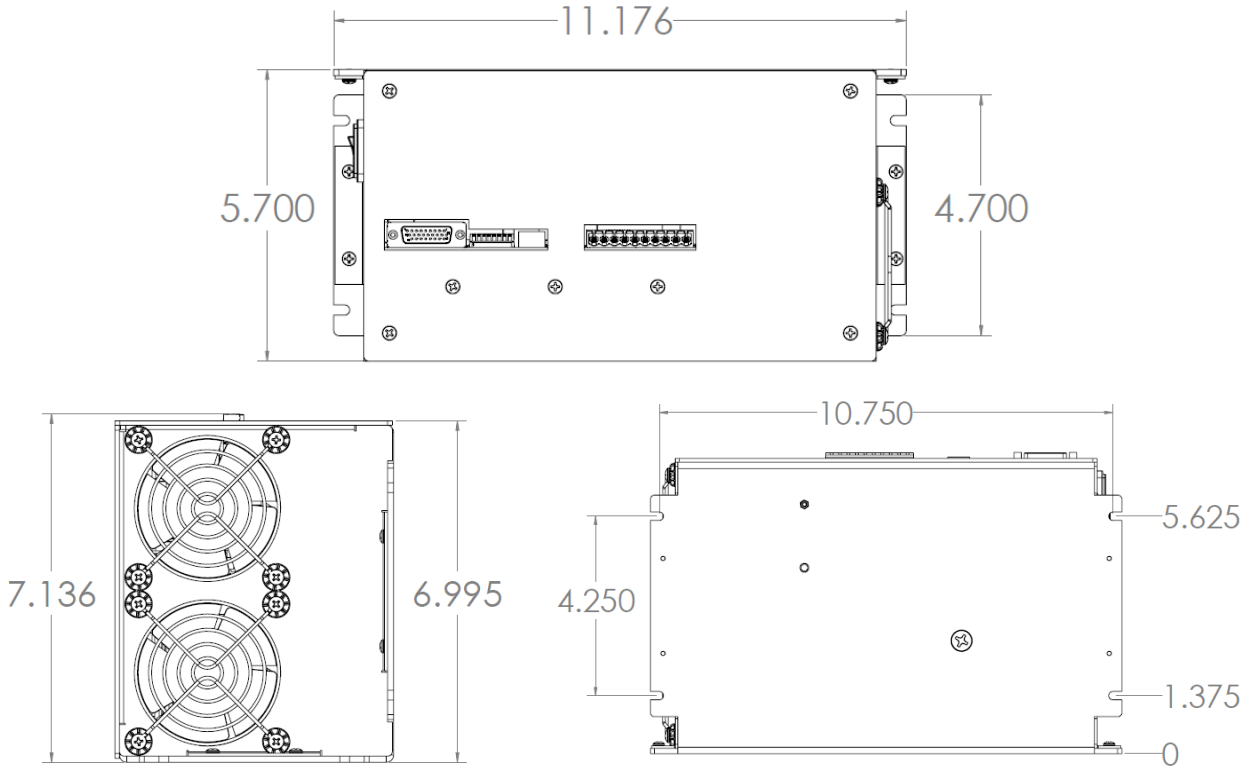
4.2 DC Standalone Module

4.2.1 Mechanical dimensions



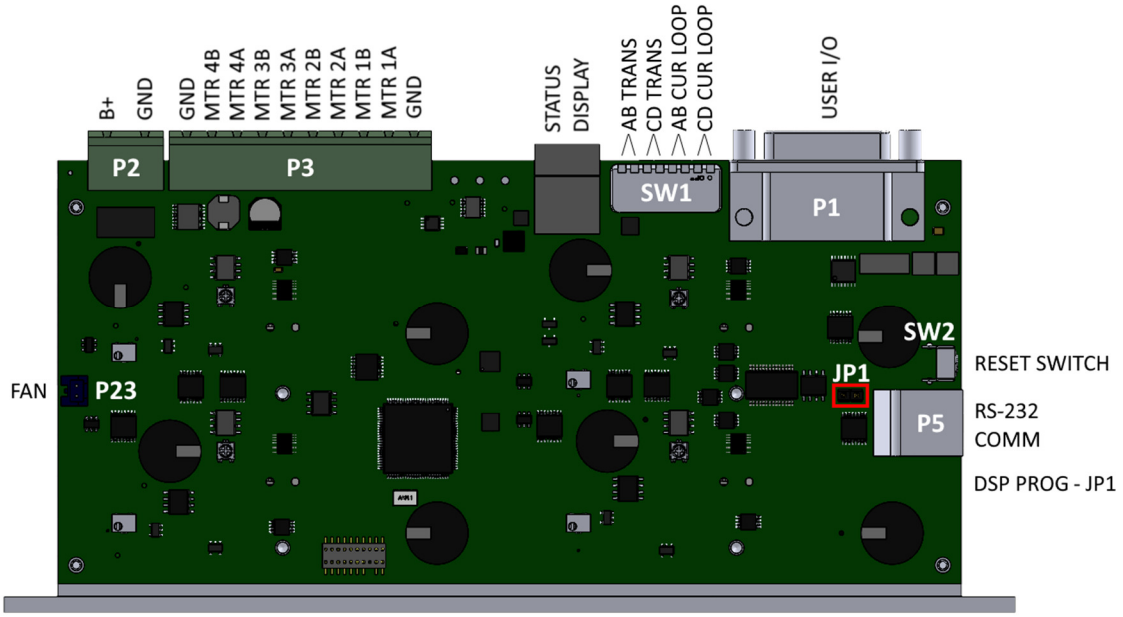
4.3 AC Standalone Module

4.3.1 Mechanical dimensions



5 Interface Connections

5.1 Connector Locations



5.2 P1 – User Signal I/O Connector

The connector is 26 position high density D-Sub. Mating Connector = Amphenol 10090769-P264ALF or equivalent.

Pin Number	Signal	Direction	Voltage Level	Description
1	SCLK+	Input	+3.3V	SPI Clock, differential
2	SCLK-	Input	+3.3V	SPI Clock, differential
3	SDI+	Input	+3.3V	SPI Serial Data In, differential
4	SDI-	Input	+3.3V	SPI Serial Data In, differential
5	GND	---	---	Ground reference
6	CSn+	Input	+3.3V	SPI Chip Select, differential, active low
7	CSn-	Input	+3.3V	SPI Chip Select, differential, active low
8	LDACn+	Input	+3.3V	Load DAC Strobe, differential
9	LDACn-	Input	+3.3V	Load DAC Strobe, differential
10	Current 1	Output	+/-5V	Motor 1 current monitor, 2A/1V.
11	Voltage 1	Output	+/-10V	Motor 1 phase voltage monitor, 1V/11V
12	Current 2	Output	+/-5V	Motor 2 current monitor, 2A/1V.
13	Voltage 2	Output	+/-10V	Motor 2 phase voltage monitor, 1V/11V

14	Current 3	Output	+/-5V	Motor 3 current monitor, 2A/1V.
15	Voltage 3	Output	+/-10V	Motor 3 drive voltage monitor, 1V/11V
16	Current 4	Output	+/-5V	Motor 4 current monitor, 2A/1V.
17	Voltage 4	Output	+/-10V	Motor 4 drive voltage monitor, 1V/11V
18	GND	---	---	Ground reference
19	GND	---	---	Ground reference
20	Enable	Input	5-24V	Opto-Isolated Input - (Note1)
21	User Input	Input	5-24V	Opto-Isolated Input - (Note1)
22	IN COM	---	---	Return for Opto-Isolated Inputs - (Note1)
23	OUT COM	---	---	Return for Opto-Isolated Outputs - (Note2)
24	Fault	Output	5-24V	Opto-Isolated Output - (Note2)
25	User Output	Output	5-24V	Opto-Isolated Output - (Note2)
26	GND	---	---	Ground reference

5.3 P2 – Bus Power Connector

P2 is a 2-position terminal block header.

P2 mating connector = Wurth 691351400002 or equipment.

Pin Number	Signal	Direction	Voltage Level	Description
1	GND	---	---	Bus common (GND)
2	B+	In	+24V to +56 VDC	+Bus power

5.4 P3 – Motor Connector

P3 is a 10-position terminal block header.

P3 mating connector = Wurth 691351500010 or equivalent.

Pin Number	Signal	Direction	Description
1	GND	---	Motor cable shield or frame ground (tied to Amp ground)
2	Motor 1 Phase A	Out	Motor 1 lead A
3	Motor 1 Phase B	Out	Motor 1 lead B
4	Motor 2 Phase A	Out	Motor 2 lead A
5	Motor 2 Phase B	Out	Motor 2 lead B
6	Motor 3 Phase A	Out	Motor 3 lead A
7	Motor 3 Phase B	Out	Motor 3 lead B
8	Motor 4 Phase A	Out	Motor 4 lead A
9	Motor 4 Phase B	Out	Motor 4 lead B

10	GND	---	Motor cable shield or frame ground (tied to Amp ground)

5.5 P4 – Bias Power Connector (optional for 100V Bus)

Mating Connector = Wurth 691351500003 or equivalent.

Pin Number	Signal	Direction	Voltage Level	Description
1	-15V	In	-14V to -16 VDC	-15V voltage input, max 200mA
2	GND	---	---	Ground
3	+15V	In	+14 to +16 VDC	+15V voltage input, max 500mA

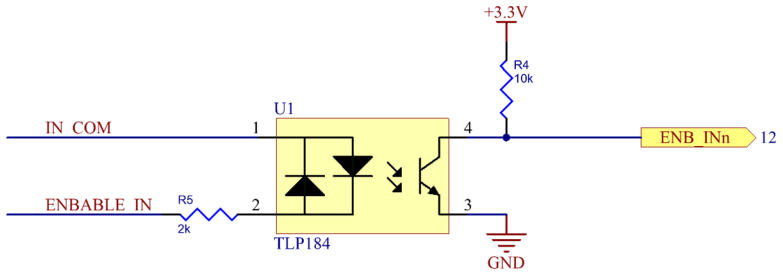
5.6 P5 – RS232 Serial Communication Connector

Mating Connector = Standard RJ11

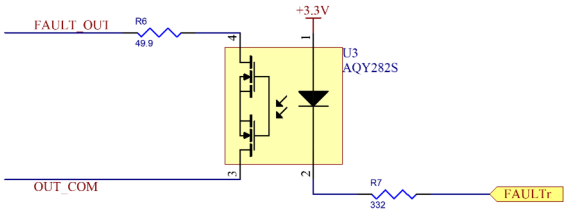
Pin Number	Signal	Direction	Voltage Level	Description
1	No Connect	---	---	
2	TXD	Input	+/-15V	Host TX, Amp RX. Data out from host.
3	RXD	Output	+/-15V	Host RX, Amp TX. Data into host.
4	GND	---	---	System Common
5	DSP program	----	---	Short to GND for DSP programming. Leave open for normal operation.
6	GND	---	---	System Common

5.7 I/O Notes

Note1: Each Opto-isolated Input has the following circuit with bi-directional Opto-isolator. The Input circuit can be either pulled up or pulled down using the “IN COM” pin.



Note2: Each Opto-isolated Output has the following circuit with a solid-state relay capable of 100mA load current. The Output circuit can be either pulled up or pulled down using the “OUT COM” pin.

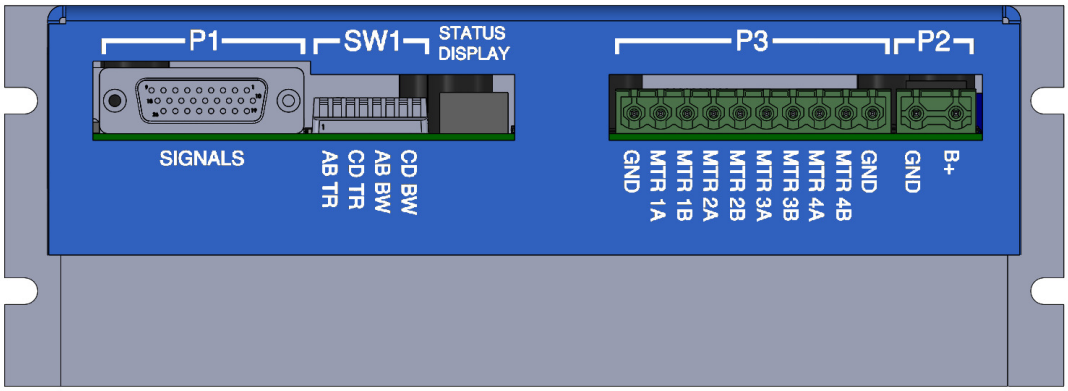


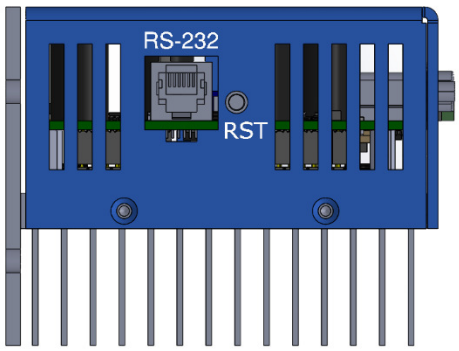
Note3: Shell of DSUB connector is Chassis Ground Referenced to the amplifier's heat sink.

5.8 Connector part numbers

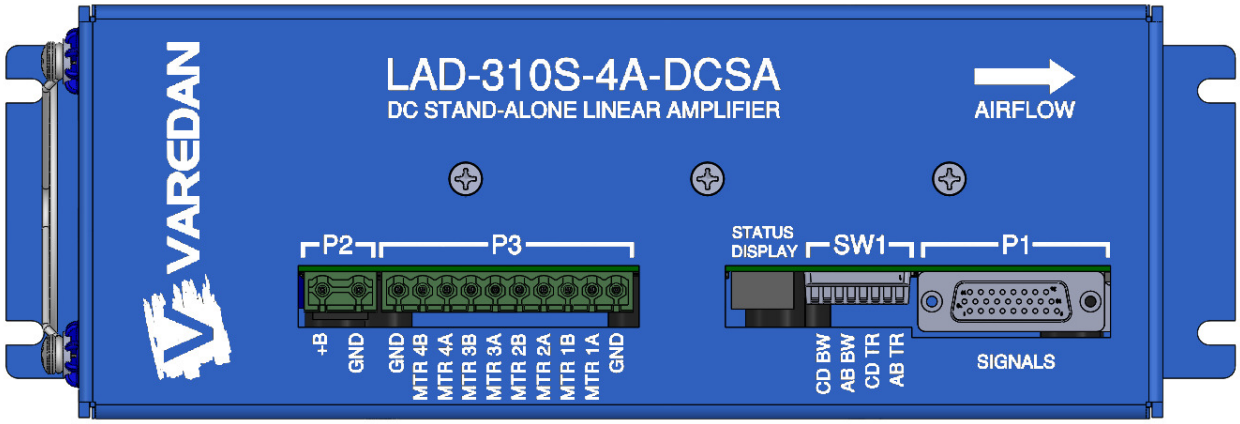
Connectors	Part number	Manufacturer	Mating P/N
P1	ICD26S13E4GV00LF	Amphenol	D-Sub HD 26 position
P2	691313410002	Würth Elektronik	691351400002
P3	691313510010	Würth Elektronik	691351500010
P4 (optional)	691313510003	Würth Elektronik	691351500003
P5	5555165-1	TE Connectivity AMP	6p6c RJ12

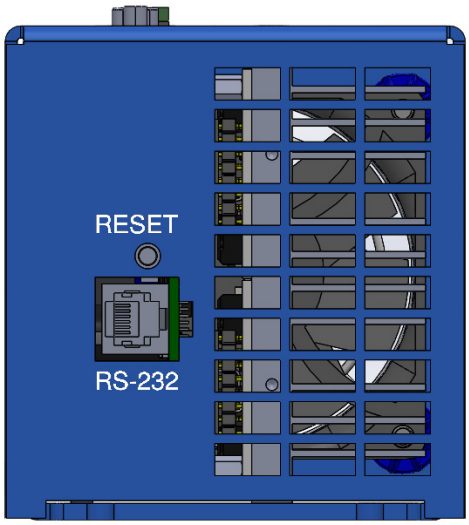
5.9 Standard Module Interface





5.10 DC Standalone Module Interface





5.11 AC Standalone Module Interface

5.11.1 AC Connector

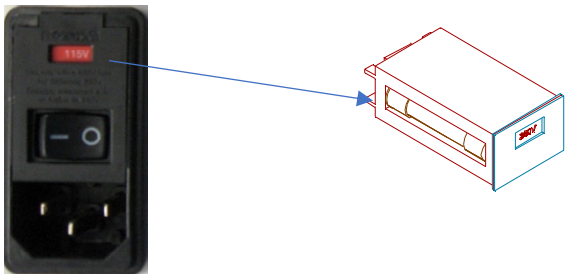
LAD 300S series AC standalone module accepts AC input directly. AC input voltages of 100-120VAC or 208-240VAC at 47-63Hz. AC standalone module incorporated unregulated pure linear power supplies to provide motor bus voltages and bias voltages. Different bus voltages are available based on the customer applications.

5.11.2 Change the AC input configuration

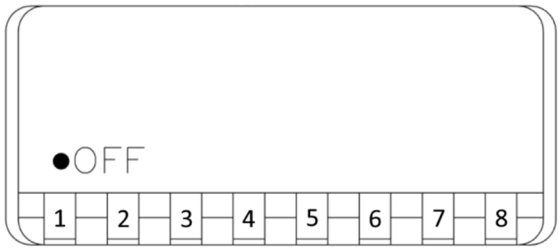
AC inlet block contains 2 of 8A fuses.

- Remove power from the AC Inlet
- Use a flat tipped screwdriver to open the window that covers the red voltage value.
- Use the screwdriver to remove the fuse block.

- Reinstall the fuse module such that the correct voltage value will show through the window.
- Close the window.



6 User Jumper Settings – SW1



6.1 Motor 1 and 2 transconductance ratio settings

Transconductance convert ratio from the digital command to current in Amp.

Ratio	SW1-1	SW1-2	Description
1.0	OFF	OFF	10A/32768, maximum current command +/-10A.
0.75	OFF	ON	7.5A/32768, maximum current command, +/-7.5A.
0.5	ON	OFF	5A/32768, maximum current command, +/-5A.
0.25	ON	ON	2.5A/32768, maximum current command, +/-2.5A.

6.2 Motor 3 and 4 transconductance ratio settings

Ratio	SW1-3	SW1-4	Description
1.0	OFF	OFF	10A/32768, maximum current command +/-10A.
0.75	OFF	ON	7.5A/32768, maximum current command, +/-7.5A.
0.5	ON	OFF	5A/32768, maximum current command, +/-5A.
0.25	ON	ON	2.5A/32768, maximum current command, +/-2.5A.

6.3 Motor 1 and 2 current loop bandwidth settings

The bandwidth setting is used to select different current PI controller gains. There are total 4 different PI gain selections. They can be used to set 4 different bandwidth for the same load or 4 different loads.

Output channels 1 and 2 share the same gain settings.

Bandwidth	SW1-5	SW1-6	Description
BW1	OFF	OFF	Current PI gains select 1, lowest current loop gains.
BW2	OFF	ON	Current PI gains select 2, higher than gains in BW1.
BW3	ON	OFF	Current PI gains select 3, higher than gains in BW2.
BW4	ON	ON	Current PI gains select 4, highest current loop gains.

Bandwidth settings can be customized for the given customer load. Contact factory for details.

6.4 Motor 3 and 4 current loop bandwidth settings

Output channels 3 and 4 share the same gain settings.

Bandwidth	SW1-7	SW1-8	Description
BW1	OFF	OFF	Current PI gains select 1, lowest current loop gains.
BW2	OFF	ON	Current PI gains select 2, higher than gains in BW1.
BW3	ON	OFF	Current PI gains select 3, higher than gains in BW2.
BW4	ON	ON	Current PI gains select 4, highest current loop gains.

Bandwidth settings can be customized for the given customer load. Contact factory for details.

7 LED Status Display

The LED Display indicates the status of the drive. Following a power-on or system reset, the LED will flash all display segments. The display will then show the drive status including any active faults. The drive is fully functioning when the status “C” or “0” is shown. However, when a fault is shown, the drive is disabled and cannot be enabled until the fault is cleared. A Reset (software or hardware) or ALARMRESET command is sufficient to clear most of the faults. A Bus Undervoltage (U) fault, on the other hand, will be automatically cleared when the bus is raised to the proper operating voltage.

7.1 LED Code

The following table lists the LED codes and corresponding meanings. If multiple errors are present, the display will cycle through all error codes, displaying each for 1 second.

LED Code	Description
0	No faults – motor current **enabled**. This is the “normal” display when enabled.
1	DSP Fault – set when the DSP checksum detects an internal fault.
2	NVM Fault – set when NVM checksum fails following reset. Parameter defaults are set.
3	I^2C Fault – set when I^2C interface detects a fault.
4	Undefined Fault - contact factory.
5	ABS Overcurrent Fault – set when instantaneous overcurrent condition is detected.
6	SOA Fault – set when Safe Operating Area protection detects over-power condition.
A	Undefined Fault – contact factory.
b	Bus Over Voltage Fault – set when bus voltage is greater than the programmed trip level. Note: each leg (+ and -) is checked against this value.
C	No faults – motor current **disabled**. This is the normal display when the amplifier is not enabled.
d	-12V Ref Fault – set when the -12V reference supply is out of range.
H	Amp Over Temp Fault – set when the heat sink temperature is above 110°C (max) or user-defined value.
L	I^2T Fault – set when the I^2T motor thermal protection (continuous overcurrent) reaches an overload condition.
U	Bus Under Voltage Fault – set when the bus voltage is less than +/-12 Vdc. Note: Each leg (+ and -) is checked against this value. 1.5V hysteresis.
u	+15V Supply Fault – set when +15 supply is outside allowable range. Note: The tolerance of this supply must be within +/-1.00vdc.

C	+12V Ref Fault – set when the +12V reference supply is out of range.
0.	Decimal point on – indicates an I^2T active condition. The phase current(s) is above the continuous current limit but below the peak current limit.
E	External Fault – set when an external controller asserts a system fault intended to propagate to the amplifier.
8.	Decimal point on – amplifier in the reset status

8 RESET Button

The push button SW2 is used for the Reset function. Pressing and releasing this button resets the drive. The reset is performed upon the initial press of the button.

9 SPI DAC Command Interface

LAD-310S uses 18-bit SPI slave interface to receive up to 4 channel digital current commands. The first 2 significant bits are address and the last 16-bit data is current command. The 16-bit data follows unsigned straight binary format, using a midrange offset to accommodate both positive and negative current command values. Therefore, sending a 16-bit value of 32,768 (midrange) is equivalent to 0, while value 0 represents the maximum negative current command and the value 65535 represents the maximum positive current command. A four channel 16-bit DAC with full resolution converts the digital current commands to analog current commands.

MSB																	LSB
B17	B16	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
A1	A0	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

The address bits A1 and A1 are decoded to match the corresponding current command inputs.

A1	A0	Output Channel
0	0	Motor 1 current command
0	1	Motor 2 current command
1	0	Motor 3 current command
1	1	Motor 4 current command

The current command in Amp is converted as:

Current command (A) = (16-bit-data/32768 – 1)*10*(Transconductance ratio)

Where the transconductance ratio is depending on the front edge switch SW1 settings.

For example, given the transconductance ratio is 1.0, and user would like to send 5.0A current command. The 16-bit data would be 16384. If the current command needs to send motor 2, the full 18-bit command in hex data format is 0x1C000.

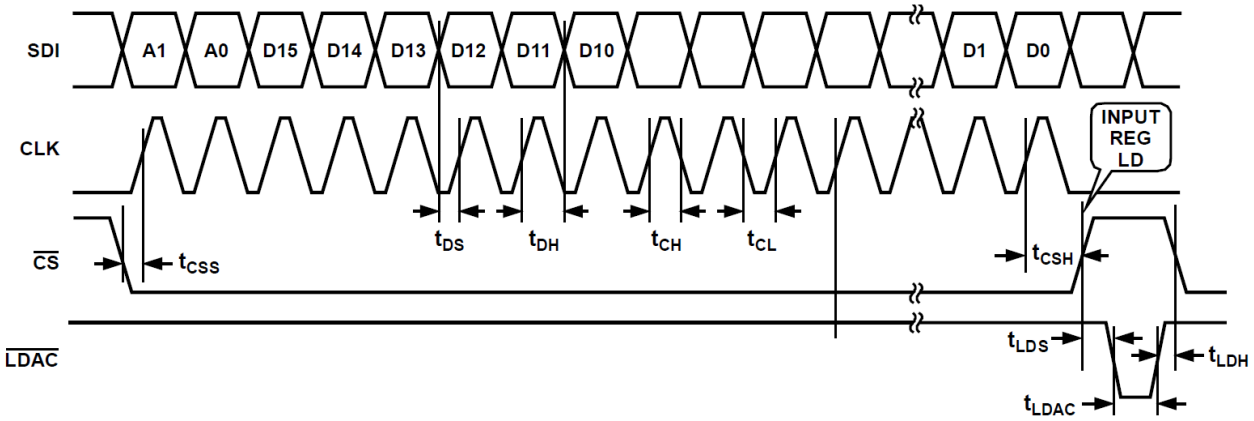
9.1 SPI communication protocol

The differential SPI receivers are +3.3V powered using the RS422 standards. Maximum clock rate should be less than 20MHz depending on the cable length. Total user input signals are 4 differential pairs, serial data in SDI+/-, chip select CSn+/-, clock SCLK+/-, and load DAC strobe LDACn+/-. LDACn, an asynchronous active low signal, allows the simultaneous update all DAC outputs from previously loaded inputs.

Mnemonic	Description
SDI	Serial data input.
SCLK	Clock input. The positive edge clocks data into the shift register.
CSn	Chip select, active low input. Disable shift register loading when high.
LDACn	Load DAC strobe, asynchronous, active low. Transfer all input register data to DAC registers.

9.2 SPI Interface timing

Parameter	Symbol	Min	Max	Unit
Clock width high	t_{CH}	25		ns
Clock width low	t_{CL}	25		ns
CSn to clock setup	t_{CSS}	0		ns
Clock to CSn Hold	t_{CSH}	25		ns
Load DAC pulse width	t_{LDAC}	25		ns
Data setup	t_{DS}	20		ns
Data hold	t_{DH}	20		ns
Load setup	t_{LDS}	5		ns
Load hold	t_{LDH}	25		ns



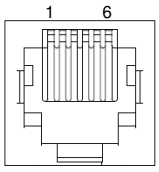
9.3 Serial Data interface

Serial data is clocked into the serial shift register in 18-bit data-word format. The data bit is clocked into the register on the positive clock edge and MSB bits are loaded first. Data is clocked in only while CSn chip select is active low. Only the last 18 bits clocked into the shift register are valid when the CSn returns to high. The positive edge of CSn initiates the transfer data to the decoded DAC input register, determined by the address bit A1 and A0. The low state of LDACn updates all DAC outputs. If simultaneous update of all DAC outputs is not needed, LDACn can be tied to logic low.

CSn	CLK	LDACn	Serial shift register	Input Register	DAC register
High	Don't care	High	No effect	Latched	Latched
Low	Pos edge	High	Advance one bit	Latched	Latched
Pos edge	Low	High	No effect	Updated with current shift register content	Latched
High	Don't care	Low	No effect	Latched	Transparent

10Serial Communication Interface

10.1 RS232 Serial Interface



P5 is a standard RJ11 connector which brings out RS232 level signals. The amplifier can communicate with a host via RS-232 using a three wire DTE to DTE cross over a serial cable. The communication setting is 115.2K baud rate, 8 bit data, no parity, no handshake.

The on-board DSP allows setting and viewing of all parameters and switch settings via a terminal interface such as TeraTerm or Windows Hyper Terminal. The DSP utilizes NVM memory to store the serial parameter settings for recall on the next power up or following a reset.

10.1.1 PC based terminal software options

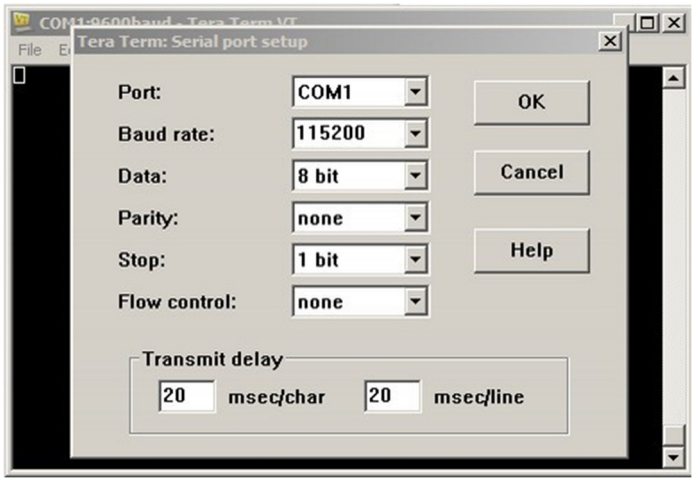
Many terminal programs can be used to communicate with the LA series amplifiers over the serial port. Varedan recommends the use of the freely available open source TeraTerm.
TeraTerm can be downloaded from the following link: https://ttssh2.osdn.jp/

10.1.2 RS232 serial port software configuration

The COM port settings for LAD-300 series amplifier are:

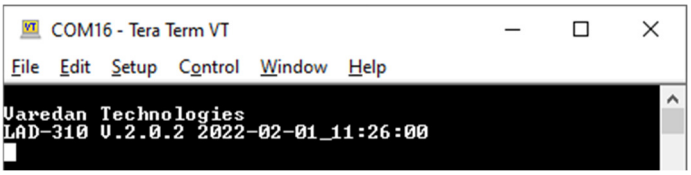
Baud Rate = 115200
Data = 8bit
Parity = none
Stop = 1bit
Flow Control = none

If using TeraTerm, it is recommended to apply a transmit delay of 20ms/char and 20ms/line while sending configuration files. Substitute your active COM port in the setup information shown.

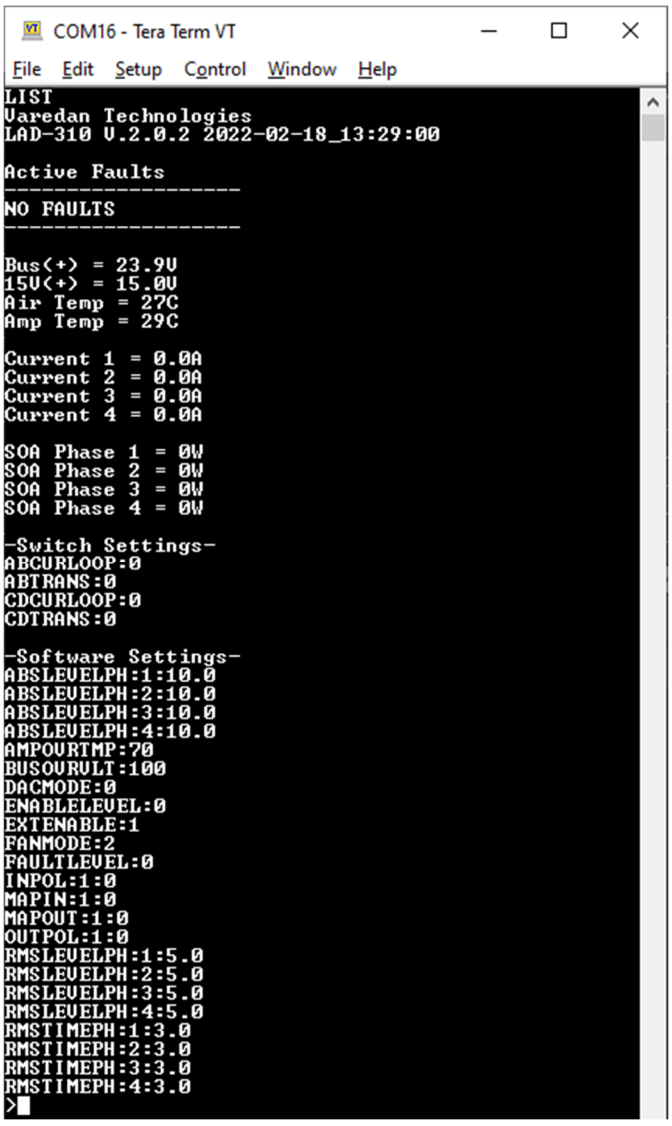


10.1.3 Host Communication Protocol

Once the host communication program is properly configured and the host cable is connected, apply power to the amplifier. The amplifier should respond with the sign-on message and software version which should look like the following text in the terminal window.



When the amplifier is ready to accept a new command, the user prompt character "**>**" will be shown. Commands can now be entered. The example below shows the reply from the **LIST** command. All voltages, currents, drive mode, and user settings are shown in the list.



Commands are entered using ASCII characters from the terminal. To enter a command with a user entered data field, the command name is followed by a "**:**" followed by the data for the command, followed by Enter (carriage return). As a minimum, all commands must be terminated by the carriage return character (ASCII 13). The line feed (ASCII 10) is optional and is not used by the amplifier.

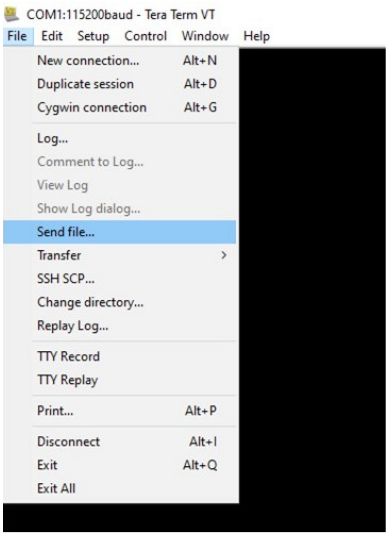
10.1.4 Load parameter file to drive NVM

The user settings and parameters can be saved into a text file (.txt) and loaded to the amplifier NVM memory. For example, use the text transfer utility of TeraTerm to load the following text file. Be sure to add a WRITE command + Enter at the end of the text file to save the settings.

Note: if the WRITE command is not followed by Enter (carriage return), the parameters will not be saved to NVM.

```
ABSLEVELPH:1:10.0
ABSLEVELPH:2:10.0
ABSLEVELPH:3:10.0
ABSLEVELPH:4:10.0
AMPOVRTMP:70
BUSOVRVLT:100
DACMODE:0
ENABLELEVEL:0
EXTENABLE:1
FANMODE:2
FAULTLEVEL:0
INPOL:1:0
MAPIN:1:0
MAPOUT:1:0
OUTPOL:1:0
RMSLEVELPH:1:5.0
RMSLEVELPH:2:5.0
RMSLEVELPH:3:5.0
RMSLEVELPH:4:5.0
RMSTIMEPH:1:3.0
RMSTIMEPH:2:3.0
RMSTIMEPH:3:3.0
RMSTIMEPH:4:3.0

WRITE
```

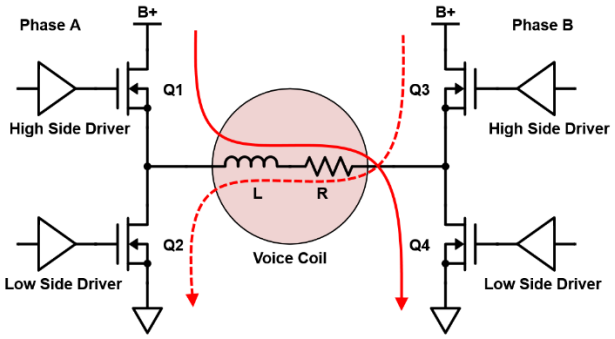


11Applications Information

The LAD-300S series amplifier current loop control is configured as S mode, H-bridge, to drive up to 4 independent single-phase motors, or 4 voice coils.

11.1 S mode, H-bridge, single phase current control

In S mode, each of 4 current control channels is configured as an H bridge to drive a single-phase motor, a brushed DC motor, or a voice coil. Motor leads connect to phase A and phase B of each channel outputs.



11.2 SPI Loopback Test

The LAD-300S can generate an SPI loopback data stream for basic power testing and debugging. This can be useful for initial setup and validation, or to debug issues with the SPI interface. The onboard DSP will generate the selected test waveform type and output the data stream onto the DAC SPI bus for all 4 channels. Each channel can be enabled/disabled independently for flexibility.

There are five test waveforms to choose from: SINE, SQUARE, SAWTOOTH, TRIANGLE, and DC. All the AC waveforms are centered on 0V, and therefore the issued command amplitude can be positive or negative. For example, a command voltage of -4.5V will result in a SINE wave with a positive peak of 4.5V and a negative peak of -4.5V. However, the DC waveform utilizes both the positive and negative command range. Therefore a -4.5V command will result in a DC output at -4.5V.

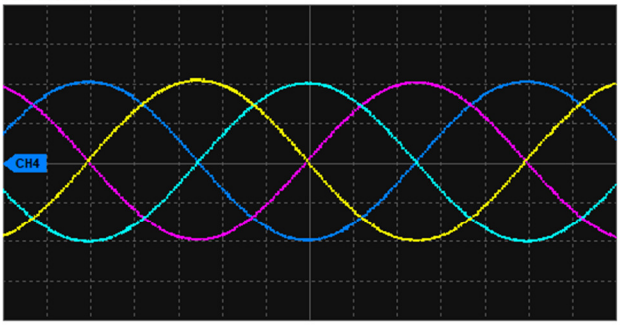
The AC test waveforms have a limited frequency range of 1 to 25Hz [1, 25]Hz. The SPI data stream is updated every 1ms, so there will be noticeable steps in the output at higher frequencies and amplitudes.

Issue the following serial commands to configure and utilize the test waveforms:

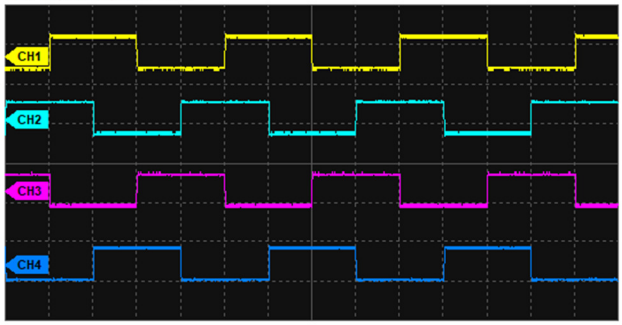
1. Issue the DISABLE command to disable all 4 channels.
2. Issue the DACMODE:n command to set the desired waveform. The options are as follows:
    a. 0 = External SPI data stream
    b. 1 = SINE
    c. 2 = SQUARE
    d. 3 = SAWTOOTH
    e. 4 = TRIANGLE
    f. 5 = DC
3. Issue the DACFREQ:n command to set the desired waveform frequency. The range is limited to [1, 25]Hz.

4. Issue the DACCMD:f command to set the desired waveform amplitude in Volts. For AC waveforms, the sign does not matter - the waveform is centered on 0V. For the DC waveform, positive and negative values are utilized. The range is [-10.0, 10.0]V.
5. Enable the desired channels, either using a GPIO or the serial command depending on the enable method configuration. Using the serial commands, all four channels can be enabled using the ENABLE command, or individual channels can be enabled using the ENABLEPH:n command.

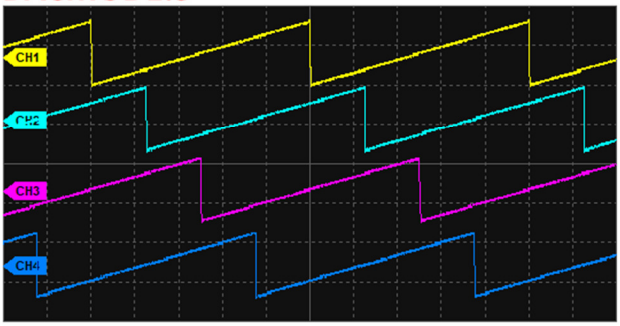
DACMODE:1



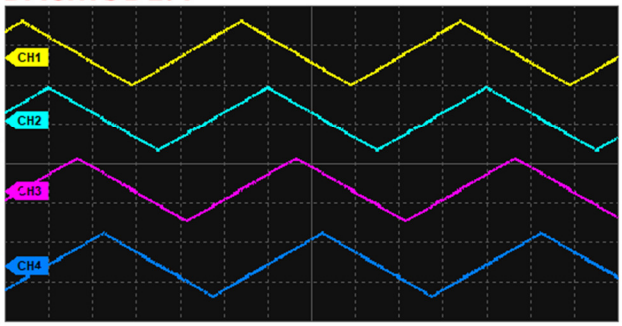
DACMODE:2



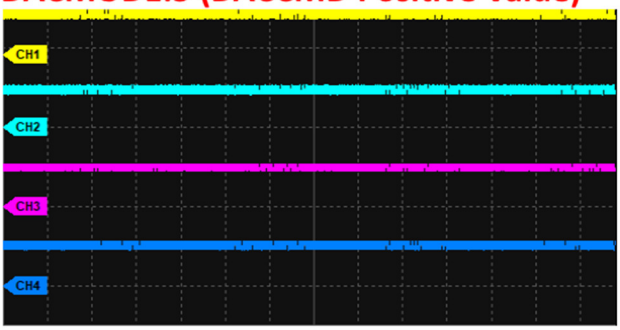
DACMODE:3



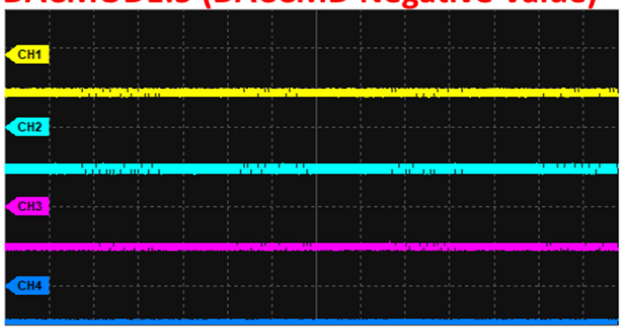
DACMODE:4



DACMODE:5 (DACCMD Positive Value)



DACMODE:5 (DACCMD Negative Value)



12 The Protection Functions

The amplifier utilizes real-time protective features to protect both the amplifier and the connected load. In the event of an active fault, the amplifier is disabled, and the corresponding error status is shown on LED display.

12.1 Faults

12.1.1 NVM Fault

A checksum key is generated and appended to the user parameters whenever data is written to the flash memory. When the data in flash memory is loaded into RAM during a power-on or system reset, the checksum is calculated and compared against the checksum key. A mismatch of the two checksum values is indicative of an unsuccessful attempt to copy the contents of the flash memory into RAM, and an NVM error is asserted. The factory default parameters will be loaded into RAM.

12.1.2 Amplifier Over Temp Fault

Software shutdown – the DSP continuously checks the amplifier temperature against a user-configurable temperature trip level. If the measured temperature exceeds the trip level, the software will disable the drive and assert an active fault.

12.1.3 Absolute Over Current Fault

The DSP prevents the amplifier modules from outputting phase currents exceeding the user-configurable peak current limits for more than 50ms. This feature is designed to protect the connected load from damage caused by exceeding the peak current specifications of the load. If an excess phase current is detected on any of the modules for a duration longer than 50ms, the software will disable the drive and assert an active fault.

12.1.4 I2T Fault

The I2T limit is defined by the continuous current limit (RMSLEVEL), peak current limit (ABSLEVEL), and duration (RMSTIME).

I2T Limit = $(ABSLEVEL^2 - RMSLEVEL^2) * RMSTIME$

When the phase current exceeds the continuous current level, the software accumulates the i^2t at a rate determined by the real time measured current. If at any time the accumulator exceeds the I2T limit, the DSP will disable the drive and assert an active fault. If, however, the phase current drops below the continuous current level before the I2T limit is reached, the software dissipates the i^2t by the same means and prevents a fault from occurring.

For single phase motor: $i2t = (I^2 – RMSLEVEL^2) * t$

12.1.5 Bus Over Voltage Fault

The LAD-310S amplifiers have a maximum bus voltage rating of +/-100VDC. The user-configurable parameter OVLEVEL is used as the trip threshold to compare against the measured bus voltage. If the Bus (+) exceeds the OVLEVEL, or if the Bus (-) exceeds the negative OVLEVEL, the DSP disables the drive and asserts an active fault. Unlike the Bus Under Voltage Fault, this fault requires a system reset or ALARMRESET command to clear.

12.1.6 Bus Under Voltage Fault

The LAD-310S amplifiers have a minimum bus voltage rating of +/-20VDC. This setting is not user configurable. There is a 1.5V hysteresis applied to the trip level, meaning that the bus voltage must exceed +/-20V to clear the fault, but can go down to 18.5V before tripping a fault. When the Bus Under Voltage fault is active, the DSP disables the drive and asserts an active fault. However, this fault is automatically cleared once the bus voltage exceeds +/-20V.

12.1.7 +15V Supply Fault

The +15V supply is used to generate other reference voltages, power on-board ICs, and power the fan circuit (when used). The supply requirements are +15VDC +/-1.0V. The DSP continuously monitors the supply voltages. If the measured supply voltages are outside of their range, the DSP will disable the drive and assert an active fault. This fault requires a system reset or ALARMRESET command to clear.

12.1.8 +/-12V Ref Fault

The +/-12V reference is generated on-board using the +/-15V references. If the bias supply is out of range or if there is a hardware malfunction within the +/-12V reference circuit, the DSP will disable the drive and assert an active fault. This fault requires a system reset or ALARMRESET command to clear. If the fault is caused by a hardware failure, the fault will continue to recur after it is cleared manually.

12.1.9 SOA Fault

The DSP monitors the power of each output device in real time as the device is switched on by the control circuitry. This instantaneous power measurement is compared with the transistor manufacture's recommended "safe operating area" curve (published in all transistor specifications) stored in the DSP memory. If the instantaneous measured power exceeds the recommended ratings of the output devices for a specified number of time intervals, the DSP disables the drive and asserts an active fault.

12.1.10 I2C Fault

The I2C bus is used as a communication bus between the DSP, on-board IO Expander, and 7-segment LED display. During power up, the DSP initializes the I2C bus and then periodically sends data to the IO Expander and LED Display. If at any time during the initialization routine or periodic data transfers the DSP receives an unexpected bus event, the DSP will assert an active fault but will not disable the drive.

12.1.11 External Fault

The user I/O can be configured (using RS-232) to act as a fault input from an external controller. If a user input is configured for External Fault, an "active" signal (based on the configured active level) will trigger a fault and disable the amplifier. See 13.3.33 (INPOL) and 13.3.35 (MAPIN) to configure a user input for an external fault.

13 Serial Command List

13.1 Command Category

The serial commands are grouped as 3 categories, immediate, configuration, and status. Immediate commands tell the amplifier executes the command immediately. Configuration commands define the amplifier and motor parameters. Status commands monitor the status of the amplifier.

13.2 Command format

Commands are entered using ASCII characters from the terminal. A typical command has the following ASCII format. Control characters are shown in **<>**:

ABSLEVEL?<Cr><Lf>

As a minimum, all commands must be terminated by the carriage return character (ASCII 13). The line feed (ASCII 10) is optional and is not used by the amplifier.

To enter a command with a data field, the command name is followed by a "**:**" followed by the data for the command, followed by Enter (carriage return), i.e. COMMAND + ":" + data + <Cr>

Example: RMSLEVEL:3.5

To query a command configuration or state, the command name is followed by a "?", followed by Enter (carriage return). Typically, Configuration and Status commands can be queried, while Immediate commands cannot. An exception is the ENABLE command which can be queried for the active enable status.

Example: ABSLEVEL?

All characters sent to the amplifier are echoed back if echo has been enabled. When the amplifier has accepted the command, the prompt "**>**" is returned.
Commands and values are case sensitive with commands requiring upper case convention. If the amplifier encounters a problem with any command it receives, it will respond with the following error states:

Error Message	**Description**
Invalid Command	Command was not recognized as a valid command
Invalid Parameter	Command parameter was not in the proper format
Invalid Mode	Requested operation is not valid in current operating mode
Invalid While Enabled	Requested operation is not available while amplifier is Enabled
Data Range Error	Command parameter is outside the valid range

13.3 Command List

13.3.1 ABCURLOOP

Displays the Phase A/B Current Loop gain setting that was configured using hardware SW1. This command can only be queried.

Category	Configuration
Parameter	N/A

13.3.2 ABSLEVEL:f

Sets the peak current limit for all phases using the same value. Use ABSLEVELPH to set unique values for individual phases. This value is used both as a peak current trip threshold and as part of the I2T protection algorithm.

Category	Configuration
Parameter	Float
Range	[RMSLEVEL, 10.0]

13.3.3 ABSLEVELPH:n:f

Sets the peak current limit for a specified phase. Use the ABSLEVEL command if all phases have the same peak current limit. This value is used both as a peak current trip threshold and as part of the I2T protection algorithm.

Category	Configuration
Parameter	Integer, Float
Range	n[1, 4], f[RMSLEVEL, 10.0]
n	**Description**
0	Phase 1
1	Phase 2
2	Phase 3
3	Phase 4
f	**Description**
float	Peak current limit for specified phase

13.3.4 ABTRANS

Displays the Phase A/B Transconductance setting that was configured using hardware SW1. This command can only be queried.

Category	Configuration
Parameter	N/A

13.3.5 ALARMREST

Clear all faults and warnings.

Category	Immediate
Parameter	N/A

13.3.6 AMPOVRTMP:f

Sets the amplifier over temperature fault threshold in degC.

Category	Configuration
Parameter	Float
Range	[40.0, 80.0] degC

13.3.7 BUSOVRVLT:f

Sets the bus over voltage fault threshold in Volts.

Category	Configuration
Parameter	Float
Range	[15, 100] Volts

13.3.8 CDCURLOOP

Displays Phase C and Phase D Current Loop gain settings that were configured using hardware SW1. This command can only be queried.

Category	Configuration
Parameter	N/A

13.3.9 CDTRANS

Displays Phase C and Phase D Transconductance settings that were configured using hardware SW1. This command can only be queried.

Category	Configuration
Parameter	N/A

13.3.10 DACCMD:f

Sets the DAC peak output in volts when using internally generated SPI command references during testing and debugging. This command is used when DACMODE is set to a non-zero value.

Category	Configuration
Parameter	Float
Range	[-10.0, 10.0]
f	**Description**
float	Peak DAC output in volts. DC test signal can use -10 to +10V range. AC signals respond the same to (+) and (-) values and are centered around 0.0V

13.3.11 DACFREQ:n

Sets the DAC output frequency in Hz when using internally generated SPI command references during testing and debugging. This command is used when DACMODE is set to a non-zero value.

Category	Configuration
Parameter	Integer
Range	[1, 25]
n	**Description**
integer	DAC output frequency in Hz for use with internally generated AC test signals. DC test signal unaffected.

13.3.12 DACMODE:n

Sets the 4-channel DAC to use either the external SPI for normal operation, or to use one of several internally generated SPI command references for testing and debugging. This command uses the DACCMD and DACFREQ commands when DACMODE is set to a non-zero value.

Category	Configuration
Parameter	Integer
Range	[1, 25]
n	**Description**
0	DAC output: external SPI (user input)
1	DAC output: SINE wave (for testing)
2	DAC output: SQUARE wave (for testing)
3	DAC output: SAWTOOTH wave (for testing)
4	DAC output: TRIANGLE wave (for testing)
5	DAC output: DC (for testing)

13.3.13 DEFAULTS

Sets all the user parameters to the factory default values. Issuing a WRITE command following this command will save the factory default values to the flash NVM.

Category	Immediate
Parameter	N/A

13.3.14 DISABLE

Disables the drive outputs. This command works in conjunction with the external enable command (EXTENABLE) and will only assert a disable if the external enable is turned off (EXTENABLE:0).

Category	Immediate
Parameter	N/A

13.3.15 DISABLEPH:n

Disables the drive outputs only for the specified phase. This command works in conjunction with the external enable command (EXTENABLE) and will only assert a disable if the external enable is turned off (EXTENABLE:0). To disable all of the phases simultaneously, use the DISABLE command instead.

Category	Immediate
Parameter	Integer
Range	[1, 4]
n	**Description**
integer	Specify the phase to be disabled

13.3.16 ECHO:n

Enable or disable the serial port echo for user-issued commands. Enabling the echo allows the user to see typed characters when using a serial port emulator like TeraTerm.

Category	Configuration
Parameter	Integer

Range	[0, 1]
n	**Description**
0	Amplifier does NOT return user-issued characters to the serial port
1	Amplifier returns user-issued characters to the serial port

13.3.17 ENABLE

Enables the drive outputs. This command works in conjunction with the external enable command (EXTENABLE) and will only assert an enable if the external enable is turned off (EXTENABLE:0). This command can be queried for the active enable status. Additionally, the drive will not enable if there is an active fault.

Category	Immediate
Parameter	N/A

13.3.18 ENABLEPH:n

Enables the drive outputs for a specified phase. To enable all of the phases simultaneously, use the ENABLE command instead. This command works in conjunction with the external enable command (EXTENABLE) and will only assert an enable if the external enable is turned off (EXTENABLE:0). This command can be queried for the active enable status. Additionally, the drive will not enable if there is an active fault.

Category	Configuration
Parameter	Integer
Range	[1, 4]
n	**Description**
integer	Specify the phase to be enabled

13.3.19 ENABLELEVEL:n

Sets the external enable Active Hi/Lo level. This command works in conjunction with the external enable command (EXTENABLE) and will not affect the software ENABLE command.

Category	Configuration
Parameter	Integer
Range	[0, 1]
0	Input Lo = Enable, Input Hi = Disable
1	Input Lo = Disable, Input Hi = Enable

13.3.20 EXTENABLE:n

Sets the enable control to utilize the hardware input or software command. This command works in conjunction with the external enable command (EXTENABLE) and will not affect the software ENABLE/DISABLE commands.

Category	Configuration
Parameter	Integer
Range	[0, 1]
n	**Description**
0	Software command is used to enable/disable drive

1	Hardware Input is used to enable/disable drive

13.3.21 FANENABLE:n

Manually Enable/Disable the fan. This command works in conjunction with the fan mode command (FANMODE) and is only asserted when FANMODE:0 (Manual On/Off).

Category	Configuration
Parameter	Integer
Range	[0, 1]
n	**Description**
0	Disable fan
1	Enable fan

13.3.22 FANMODE:n

Sets the fan operating mode. This command works in conjunction with the following commands: FANENABLE, FANOUTLVL, and FANTEMP.

Category	Configuration
Parameter	Integer
Range	[0, 3]
n	**Description**
0	Manual On/Off control
1	Automatic On/Off control. Uses FANTEMP and FANOUTLVL.
2	Variable control. Turns on @ 30℃ (30% output) and ramps to 100% @ 70℃
3	PI control. Maintains temperature setpoint while reducing on/off fan cycling

13.3.23 FANOUTLVL:n

Sets the fan output level (%). This command works in conjunction with the fan mode command (FANMODE) and is only used in FANMODE:0 (Manual On/Off) and FANMODE:1 (Auto On/Off).

Category	Configuration
Parameter	Integer
Range	[30, 100] %

13.3.24 FANTEMP:n

Sets the fan temperature threshold (℃). This command works in conjunction with the fan mode command (FANMODE) and is only used in FANMODE:1 (Auto On/Off) and FANMODE:3 (PI control).

Category	Configuration
Parameter	Integer
Range	[0, 100]

13.3.25 FANGAINS:f1:f2

Sets the fan P & I gains. This command works in conjunction with the fan mode command (FANMODE) and is only used in FANMODE:3 (PI control). The first data field sets the Kp gain. The second data field sets the Ki gain.

Category	Configuration
Parameter	Float
Range	f1[0, 5000.0], f2[0, 1.0]
f	**Description**
f1	Fan control Kp gain
f2	Fan control Ki gain

13.3.26 FAULTS

Displays the active faults and warnings. This command can only be queried.

Category	Status
Parameter	N/A

13.3.27 FAULTSB

Send the active faults as a binary number. This command can only be queried.

Category	Status
Parameter	N/A

13.3.28 FAULTLEVEL:n

Sets the Active Hi/Lo level of the hardware Fault output.

Category	Configuration
Parameter	Integer
Range	[0, 1]
n	**Description**
0	Active fault = Lo
1	Active fault = Hi

13.3.29 FAULTMASK:n1:n2

Masks or enables the selected fault bits. The fault bits make up a 16-bit word

Category	Configuration
Parameter	Integer, Integer
Range	n1[0, 15], n2[0, 1]
n1	**Description**
0	Bit 0 – DSP – not used
1	Bit 1 – NVM – error writing/reading Nonvolatile Memory
2	Bit 2 – AMP TEMP – amplifier over temperature
3	Bit 3 – ABSI – peak current exceeded
4	Bit 4 – I2T – i2t limit exceeded
5	Bit 5 – BUS OV – bus over voltage
6	Bit 6 – BUS UV – bus undervoltage ***fault clears automatically***
7	Bit 7 – POS 15V – positive 15V supply outside range
8	Bit 8 – POS 12V – positive 12V reference outside range
9	Bit 9 – NEG 12V – negative 12V reference outside range
10	Bit 10 – SOA – safe operating area of any output transistor exceeded
11	Bit 11 – I2C – I2C bus communication error

12	Bit 12 – EXTERNAL FAULT – input from external controller
13-15	Bit [13-15] – RESERVED – not used
n2	**Description**
0	Fault bit will be masked
1 (default)	Fault bit will be unmasked

13.3.30 HELP

Sends a list of all available software commands.

Category	Immediate
Parameter	N/A

13.3.31 HISTORY

Displays previous fault history.

Category	Status
Parameter	N/A

13.3.32 I

Displays all phase currents in amps. This command can only be queried.

Category	Status
Parameter	N/A

13.3.33 INPOL:n1:n2

Configures the user input(s) signal level to Active HI or Active LO. Should be used in conjunction with MAPIN to set the desired input function.

Category	Configuration
Parameter	Integer
Range	n1[1, num of user inputs], n2[0, 3]
n1	**Description**
1	User Input 1
n2	**Description**
0	Active Low – user input is ACTIVE when opto isolator is OFF
1	Active High – user input is ACTIVE when opto isolator is ON
2	Rising Edge – user input is ACTIVE during rising edge event
3	Falling Edge – user input is ACTIVE during falling edge event

13.3.34 LIST

Displays all monitored measurements as well as the user parameter configurations.

Category	Status
Parameter	N/A

13.3.35 MAPIN:n1:n2

Configures the user input(s) for a desired function. Should be used in conjunction with INPOL to set the active level.

Category	Configuration
Parameter	Integer, Integer
Range	n1[1, num of user inputs], n2[0, 3]
n1	**Description**
1	User Input 1
n2	**Description**
0	Ignore input
1	Enable amplifier
2	Reset amplifier
3	External fault (causes amplifier to assert a fault and disable)

13.3.36 MAPOUT:n1:n2

Configures the user output(s) for a desired function. Should be used in conjunction with OUTPOL to set the active level.

Category	Configuration
Parameter	Integer, Integer
Range	n1[1, num of user outputs], n2[0, 6]
n1	**Description**
1	User Output 1
n2	**Description**
0	No output
1	Fault out (output active when internal fault is active
2	Reserved
3	Reserved
4	I2T out (output active when I2T is over threshold)
5	Reserved
6	Disable out (output active when drive is disabled)

13.3.37 OUTPOL:n1:n2

Configures the user output(s) signal level to Active HI or Active LO. Should be used in conjunction with MAPOUT to set the desired output function.

Category	Configuration
Parameter	Integer, Integer
Range	n1[1, num of user outputs], n2[0, 6]
n1	**Description**
1	User Output 1
n2	**Description**
0	Active Low – signal is low when output is active
1	Active High – signal is high when output is active

13.3.38 RESET

Asserts a system reset on the drive. All status flags, faults, and unsaved user parameters will be reset. The RESET command and the hardware reset switch (SW2) utilize the same reset strategy.

Category	Immediate
Parameter	N/A

13.3.39 RMSLEVEL:f

Sets the continuous current limit for all phases. Use the RMSLEVELPH command if any of the phases have a unique limit. This value is used for the I2T protection algorithm. Specifically, when the measured current exceeds the RMSLEVEL, the i^2t accumulates. When the measured current drops below the RMSLEVEL, the i^2t dissipates. If the i^2t accumulator reaches the I2T Limit, an I2T Fault is asserted.

Category	Configuration
Parameter	Float
Range	[0, ABSLEVEL]

13.3.40 RMSLEVELPH:n:f

Sets the continuous current limit for the specified phase. Use the RMSLEVEL command instead if all phases have the same current limit. This value is used for the I2T protection algorithm. Specifically, when the measured current exceeds the RMSLEVEL, the i^2t accumulates. When the measured current drops below the RMSLEVEL, the i^2t dissipates. If the i^2t accumulator reaches the I2T Limit, an I2T Fault is asserted.

Category	Configuration
Parameter	Integer, float
Range	n[1, 4], f[0, ABSLEVEL]
n	**Description**
integer	Specify the phase to be enabled

13.3.41 RMSTIME:f

Sets the i2t duration (seconds) for all phases. Use RMSTIMEPH if any phase needs a unique value. This value is used for the I2T protection algorithm. See Section 11.1.5 I2T Fault for more information.

Category	Configuration
Parameter	Float
Range	[0, 25.0]

13.3.42 RMSTIMEPH:n:f

Sets the continuous current limit for the specified phase. Use the RMSLEVEL command instead if all phases have the same current limit. This value is used for the I2T protection algorithm. See Section 11.1.5 I2T Fault for more information.

Category	Configuration
Parameter	Integer
Range	n[1, 4], f[0, 25.0]

n	Description
integer	Specify the phase to be enabled

13.3.43 SHOWTRIP

Displays the most recent SOA fault data. This data is saved to the flash NVM.

Category	Status
Parameter	N/A

13.3.44 WRITE

Saves the user parameter settings to flash memory.

Category	Immediate
Parameter	N/A

14 Sales and Services

Varedan Technologies warrants this product to be free of manufacturing defects for a period of 1 year. If your product requires services, please contact our factory for troubling information and if needed, return material authorization (RMA) information.

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