

Logosol Intelligent Piezo Motor Servo Drive LS-139

Features

- ❑ **Motors supported:**
 - Standard Picomotors™
 - Tiny Picomotors™
- ❑ **Closed loop Position and Velocity modes**
- ❑ **Open loop Step and Velocity modes**
- ❑ **Trapezoidal profile generator**
- ❑ **Velocity range 2 Hz to 2 KHz**
- ❑ **32-bit position counter**
- ❑ **Incremental encoder interface**
- ❑ **Forward and reverse over travel inputs**
- ❑ **Analog input for absolute positioning**
- ❑ **Hardware stop input**
- ❑ **Motor output short protection**
- ❑ **Missing motor detection**
- ❑ **Single 24VDC power supply**
- ❑ **Member of Logosol's distributed control network (LDCN)**
- ❑ **Communication speed 19.2 to 115.Kbps**
- ❑ **Command rate up to 1000/sec**
- ❑ **Small footprint (5" x 3.3" x 0.85")**



Description

LS-139 is an intelligent Piezo Motor Servo Drive designed for applications requiring a compact, high-resolution positioner. The drive controls Standard or Tiny Picomotors™ manufactured by NewFocus®, Inc.

The drive is a member of Logosol's distributed control network (LDCN). Up to 31 LDCN devices can be controlled over a multi-drop full duplex RS-485 network. Standard RJ-45 connectors and commercially available cables are used to connect modules into a network.

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TECHNICAL SPECIFICATIONS rated at 25°C ambient, POWER (+) = 24VDC

POWER SUPPLY VOLTAGE	21 to 29 VDC
POWER SUPPLY CURRENT	Max average 0.8 Amp DC Peak 1.25A / 200us per CW step Peak 2.5A / 100us per CCW step
OUTPUT FREQUENCY RANGE	Min = 1.907 Hz to Max = 1.953 KHz
MAXIMUM OUTPUT FREQUENCY W/O FORCED COOLING	$\frac{3}{4}$ Max freq. @ 100% duty cycle Max freq. @ 50 % duty cycle (ON time max 120sec)
SERVO RATE	0.512 msec
ENCODER FEEDBACK	Quadrature with index, filtered to 150,000 counts per sec
COMMUNICATION PROTOCOL	Logosol network protocol (LDCN)
MAXIMUM NUMBER OF MODULES PER NETWORK	31
COMMUNICATION INTERFACE	RS-485
SERIAL BAUD RATE	19.2 to 115.2 Kbps
LED (TWO INTENSITY LEVELS)	Power 'OK' – low intensity Ready – high intensity
PROTECTION Output short (Motor Output to GND) Overtemperature	Shutdown if motor output is shorted Shutdown at 70 °C
FIRE SAFETY Internal fuse	3A Quick blow
THERMAL REQUIREMENTS Storage temperature range Operating temperature range	-30 to +85 °C 10 to 45 °C
MECHANICAL Size Weight	L=5", H=0.85", D=3.3" 0.55lb. (250gr.)
MATING CONNECTORS Power supply Picomotor™ Encoder, Limits and ADC inputs Stop Input Communication	2 x Phoenix MSTB 2.5/2-ST-5.08 4 pin RJ-22 HD-Sub 15pin Male connector Molex 22-01-3027 housing with 08-50-0114 pins (2 pcs.) 8 pin RJ-45

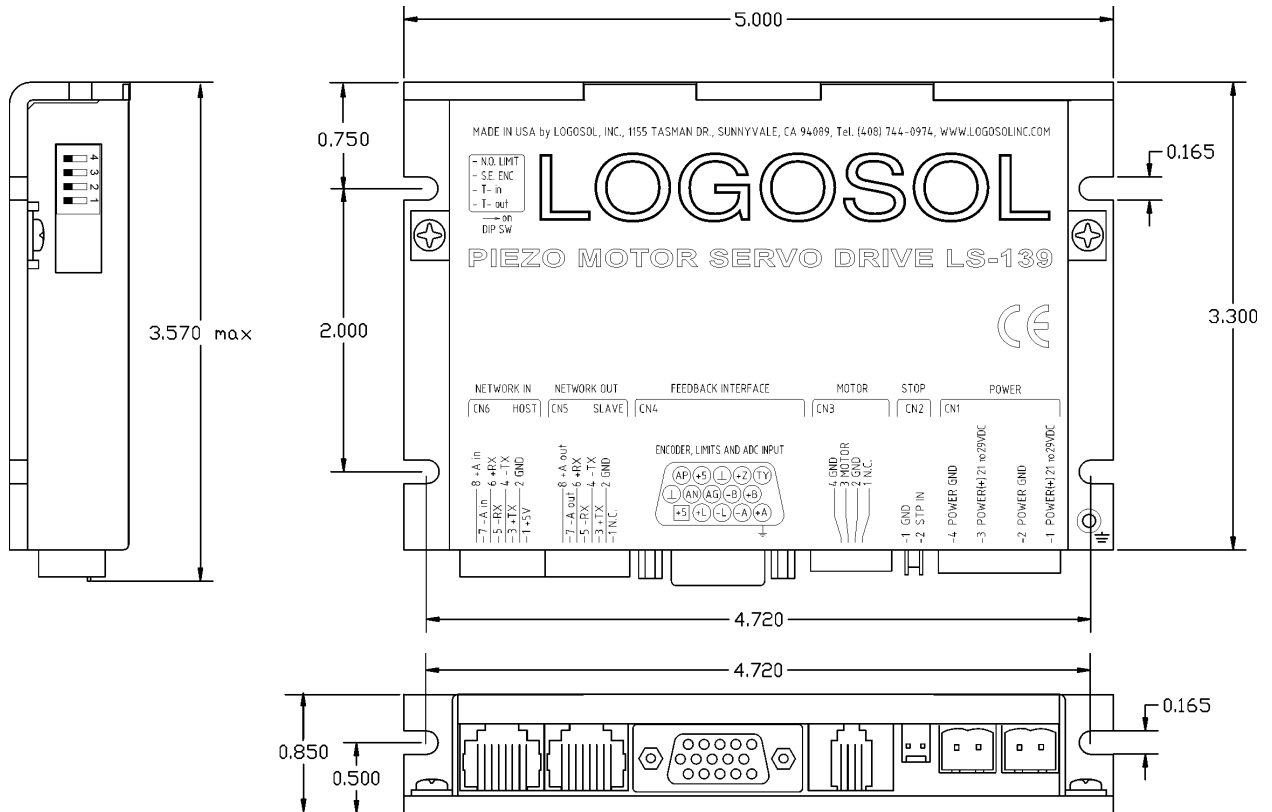
ORDERING GUIDE

PART NUMBER	MODEL	DESCRIPTION
912139001	LS-139	Intelligent Piezo Motor Servo Drive
230138001	LS-137/138-CN	Power connector kit for LS-137/138
131320015	LS-C8005-YW	5' Network cable
131320022	LS-C8036-YW	3' Network cable
131320032	LS-C8120-YW	10' Network cable
921801001	LS-801	RS-232 to LDCN NODE Converter
964010008	PSS-45W240	24V / 2A Switching power supply
921102401	LS-1024	24V / 10A Power supply
921232401	LS-2324	24V / 23A Power supply

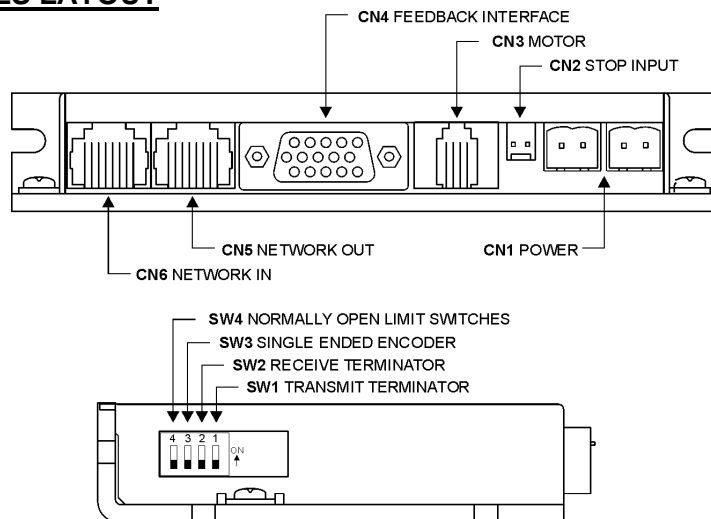
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DIMENSIONAL DRAWING



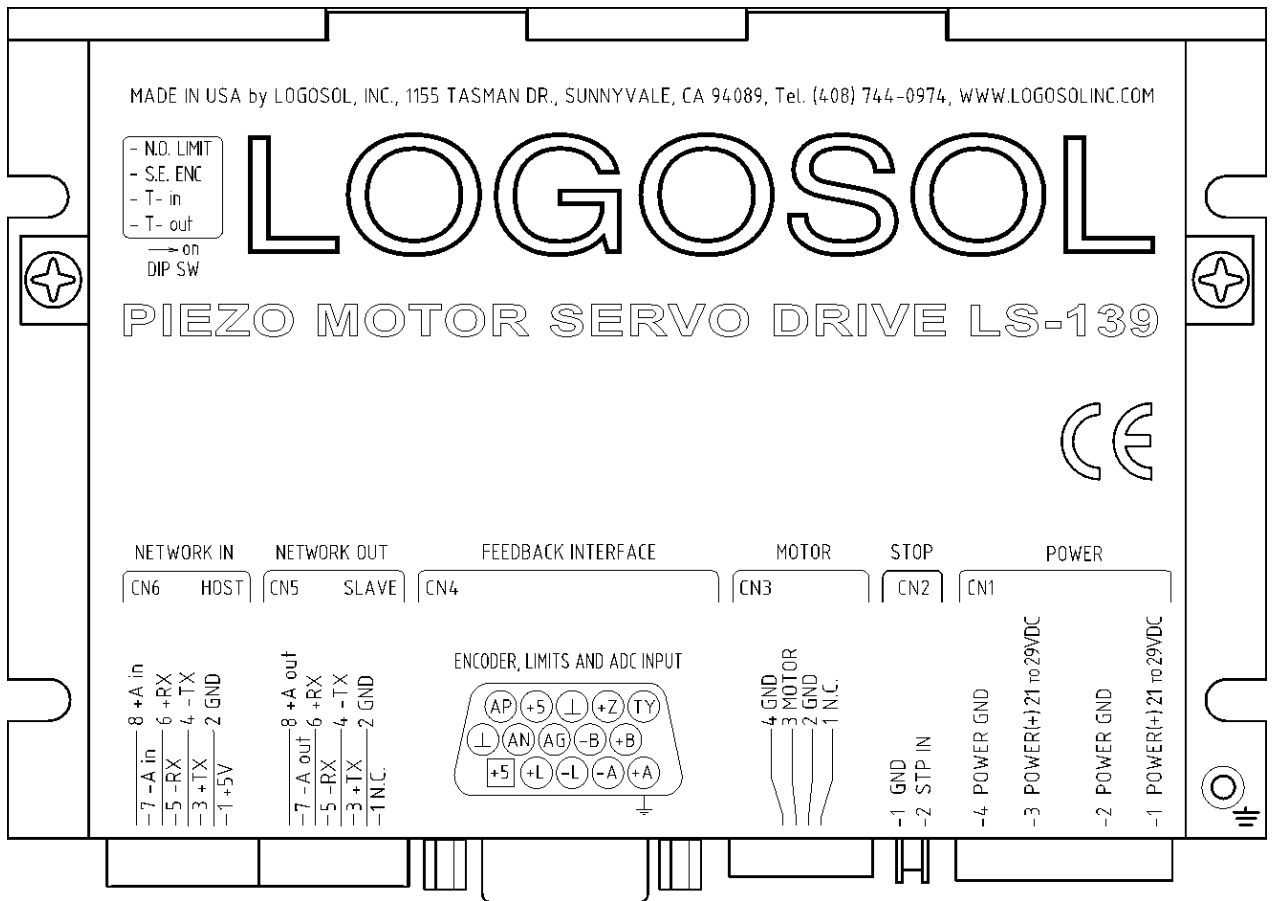
CONNECTORS AND CONTROLS LAYOUT



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CONNECTORS AND PINOUTS



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CN1 – POWER

PIN	SIGNAL	DESCRIPTION
1,3	POWER (+)21 to 29VDC	+21 to +29VDC power supply, positive terminals
2,4	POWER GND*	Power supply ground terminals

CN2 – STOP

PIN	SIGNAL	DESCRIPTION
1	GND*	Interface ground
2	STP IN	Stop input. Connect to GND to enable the motor

CN3 – MOTOR

PIN	SIGNAL	DESCRIPTION
1	N.C.	Not connected
2	GND*	Power ground
3	MOTOR	Motor output
4	GND*	Motor ground

CN4 – FEEDBACK INTERFACE

PIN	SIGNAL	DESCRIPTION
1	+5**	+5V Limit sensors power supply
2	+L	Forward limit input
3	-L	Reverse limit input
4	-A	Encoder phase -A
5	+A	Encoder phase +A
6	⊥*	Interface ground
7	AN	Analog input
8	AG	Analog input ground
9	-B	Encoder phase -B
10	+B	Encoder phase +B
11	AP	Analog +5V
12	+5**	+5V Encoder power supply
13	⊥*	Interface ground
14	+Z	Encoder index
15	TY	Piezo Motor type (Open = Standard, GND = Tiny)

CN5 – NETWORK OUT (SLAVE)

PIN	SIGNAL	DESCRIPTION
1	N.C.	Not connected
2	GND*	Interface ground
3	+TX	(+) Transmit data
4	-TX	(-) Transmit data
5	-RX	(-) Receive data
6	+RX	(+) Receive data
7	-A out	(-) Address output
8	+A out	(+) Address output

* POWER GND and GND are electrically connected. Drive's case is isolated from the drive's circuitry and may be grounded externally.

** 0.25A Max for all outputs combined.

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CN6 – NETWORK IN (HOST)

PIN	SIGNAL	DESCRIPTION
1	+5V**	RS-232 adapter power supply
2	GND*	Interface ground
3	+TX	(+) Transmit data
4	-TX	(-) Transmit data
5	-RX	(-) Receive data
6	+RX	(+) Receive data
7	-A in	(-) Address input
8	+A in	(+) Address input

DIP SWITCH

SW	SIGNAL	DESCRIPTION
1	T-in	Receive line terminator
2	T-out	Transmit line terminator
3	S.E. ENC	OFF = Differential encoder connected ON = Single ended encoder or no encoder connected
4	N.O. LIMIT	OFF = Normally closed limit switches ON = Normally open limit switches

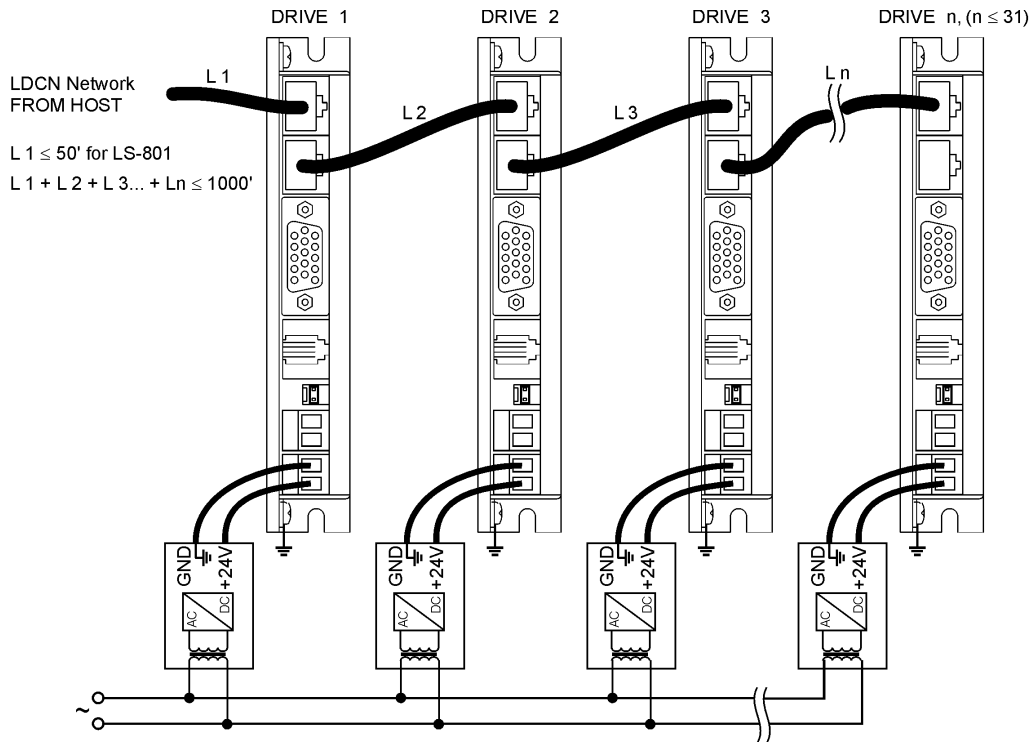
** 0.25A Max for all outputs combined.

* POWER GND and GND are electrically connected. Drive's case is isolated from the drive's circuitry and may be grounded externally.

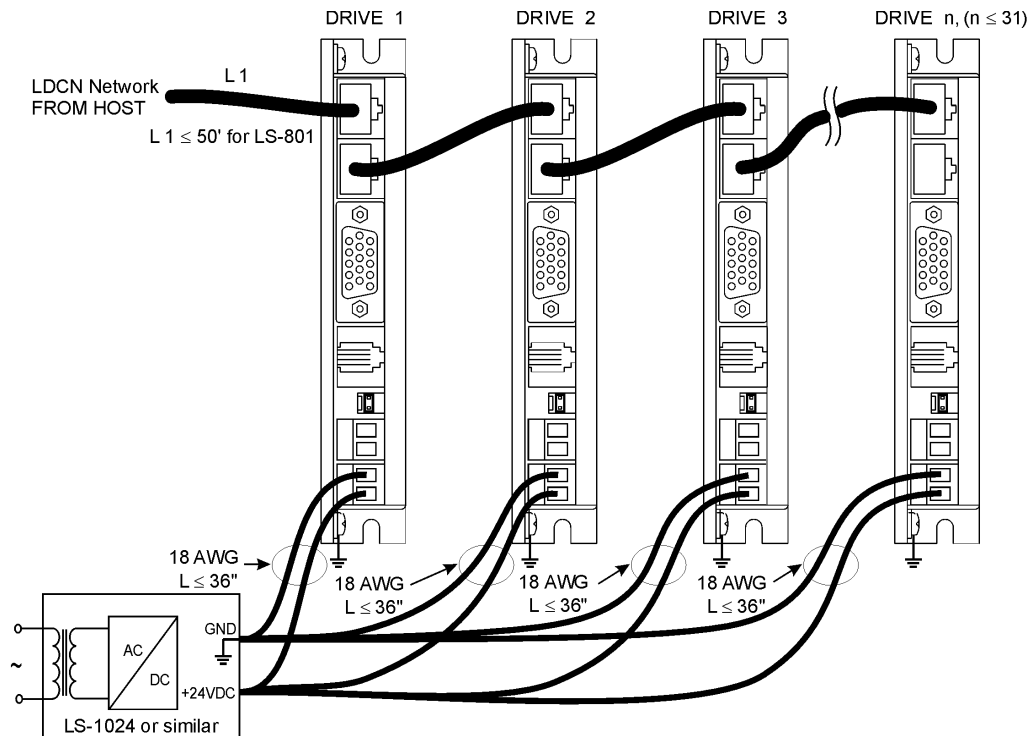
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APPLICATION NOTES



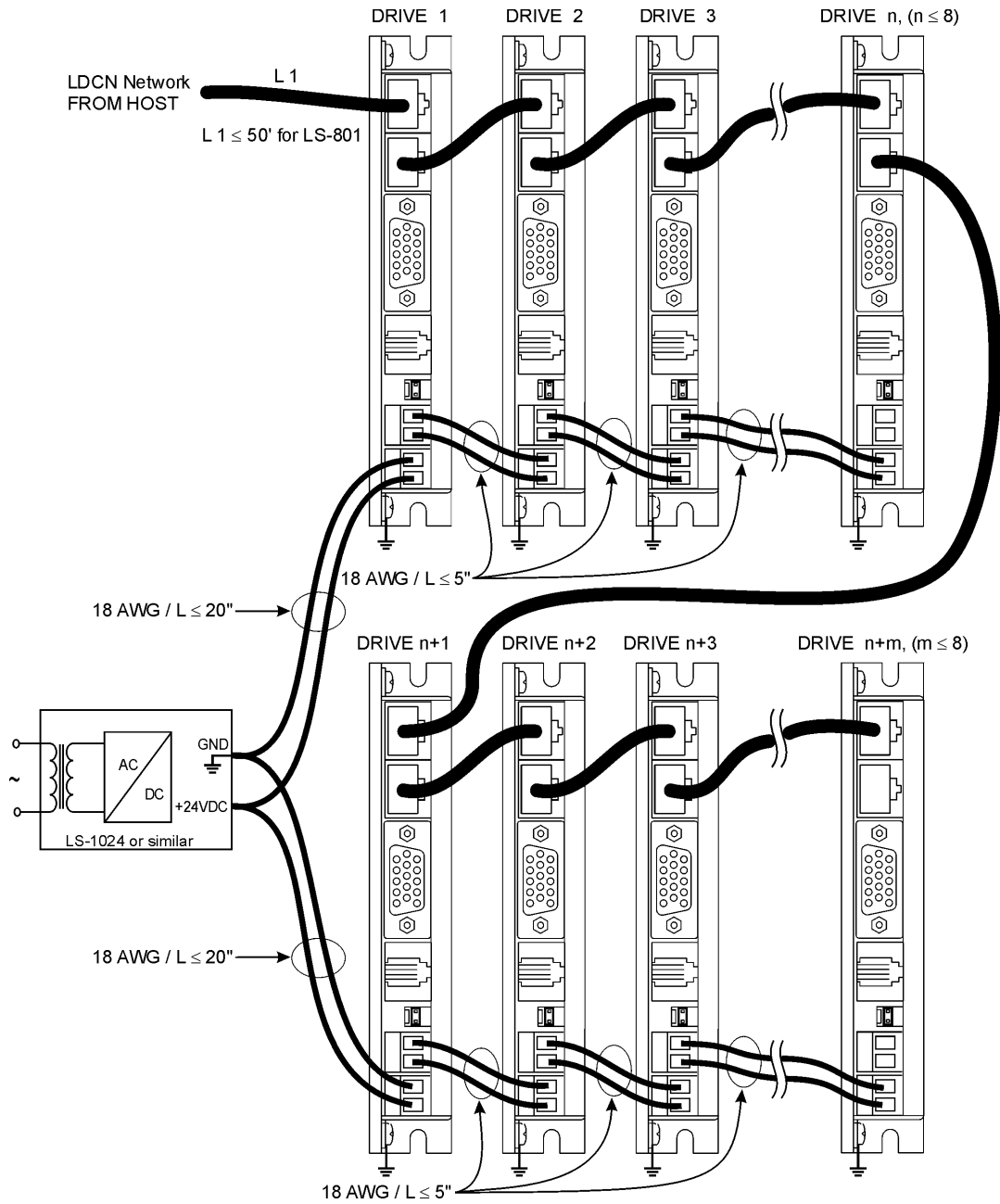
A. Independent power supply wiring and limitations



B. Radial power supply wiring and limitations
(up to 12 drives for LS-1024, up to 31 drives for LS-2324)

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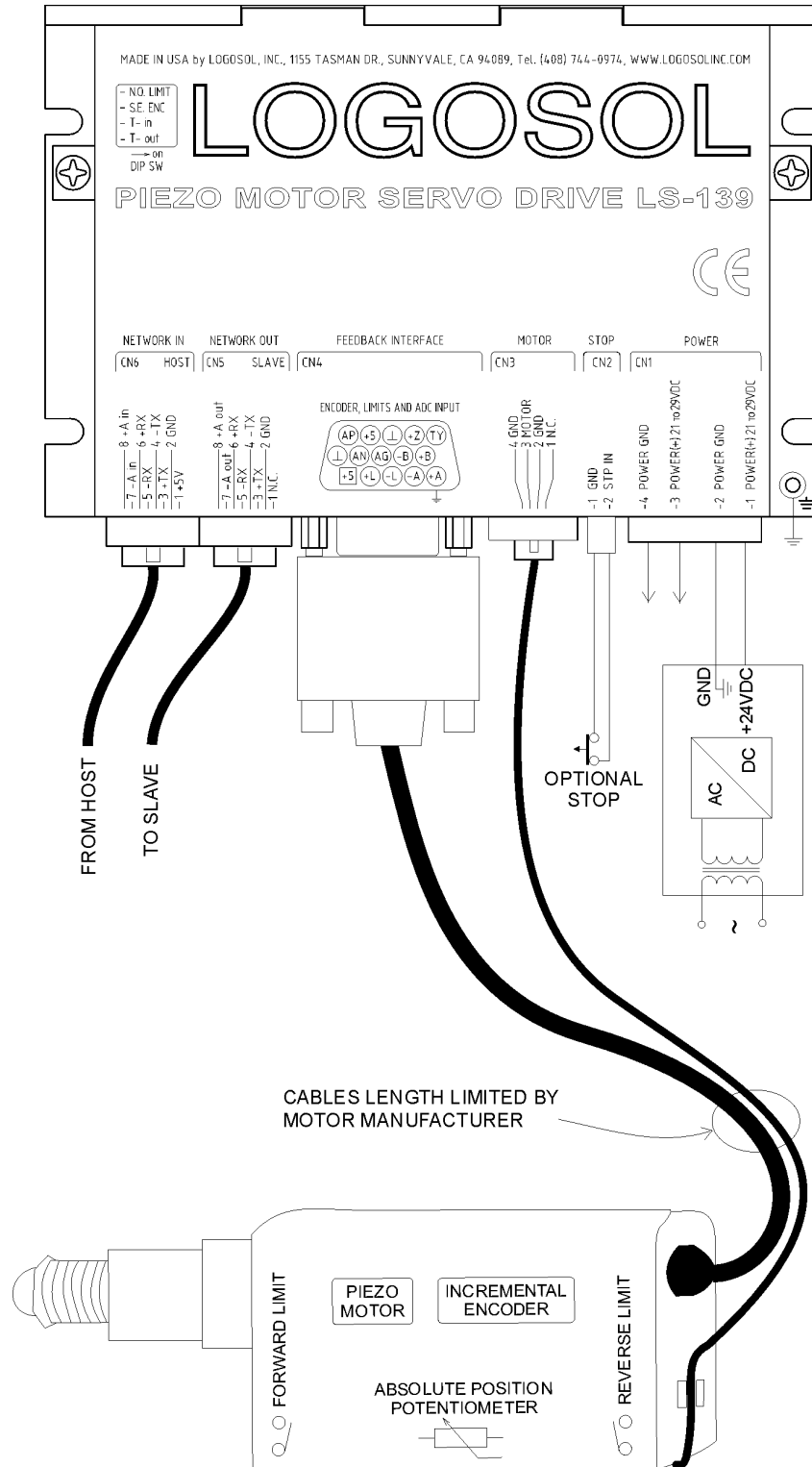
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C. Daisy-chained power supply wiring and limitations
(up to eight drive per group, up to 31 drives per network,
up to 12 drives for LS-1024, up to 31 drives for LS-2324)

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D. Motor wiring and limitations

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LOGOSOL LS-139 QUICK START GUIDE

Hardware Setup

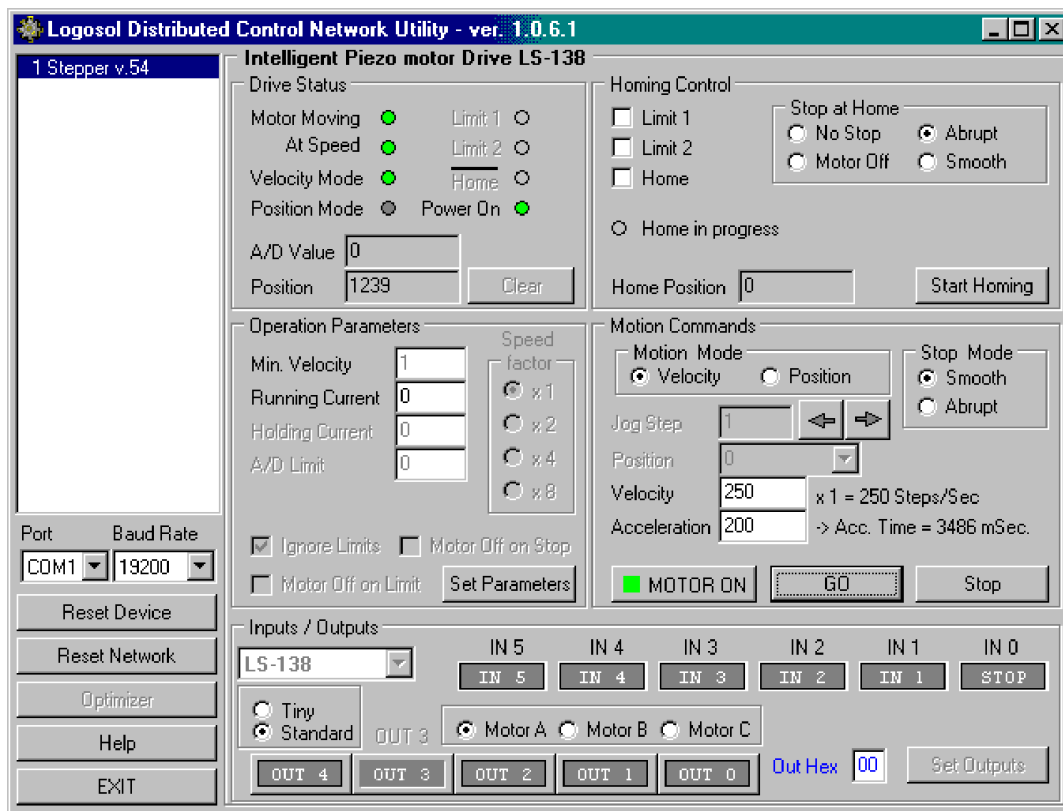
1. Connect your Piezo motor and feedback interface.
2. Set DIP switch S.E. ENC to ON if single ended incremental encoder is used, or no encoder is connected. Set this DIP switch to OFF when differential incremental encoder is used.
3. Set DIP switch N.O. LIMIT to ON if normally open limit switches is used or no limit switches are present.
4. Connect RS-232 adapter and RJ-45 network cable between LS-139 and your host computer.
5. Set DIP switches T-in and T-out to ON. If more than one device is connected, only the last one must have T-in and T-out set to ON. All of the rest must have T-in and T-out set to OFF.
6. Connect power supply 24 VDC to LS-139.

Software Installation

1. Installation and using Logosol Distributed Control Network Utility

A. Installation

1. Insert the Logosol Distributed Control Network Utility installation disk into the floppy drive.
2. Select Run from the Windows 95/98/NT Start menu.
3. Type a:\dcnsetup and then click OK (a: represents the drive letter).
4. The installation wizard will guide you through the setup process.



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B. Initial Connection to the Host

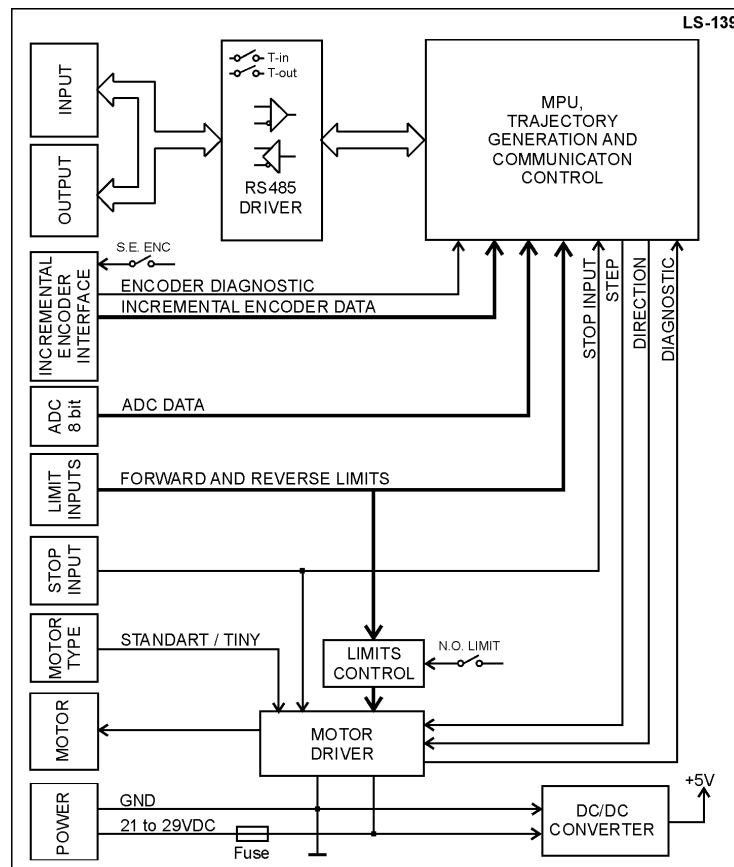
1. Turn on the power supply.
2. Run the Logosol Distributed Control Network Utility.
3. Choose the proper COM port and select the baud rate (default value is 19200).
4. Click "MOTOR ON" button.
5. Click "GO" button. The motor should rotate slowly in positive direction. Click "Stop" to interrupt the motion. More information about using LDCN utility is available in LDCN Help.

LS-139 ARCHITECTURE

Overview

The LS-139 Intelligent Piezo Motor Servo Drive is a highly integrated servo control module including a motion controller, piezo motor driver, serial communication interface, incremental encoder interface, limit switch inputs, and protection circuit. It supports RS-232 (with LS-801 adapter) or multi-drop RS-485 serial interface using the same communications protocol as the other members of Logosol Distributed Motion Control Network. LS-139 supports velocity and trapezoidal position mode, using a 32-bit position counter and open loop step count and step velocity modes.

A network of up to 31 controllers can be connected directly to a single standard serial port (RS-232 adapter may be required).



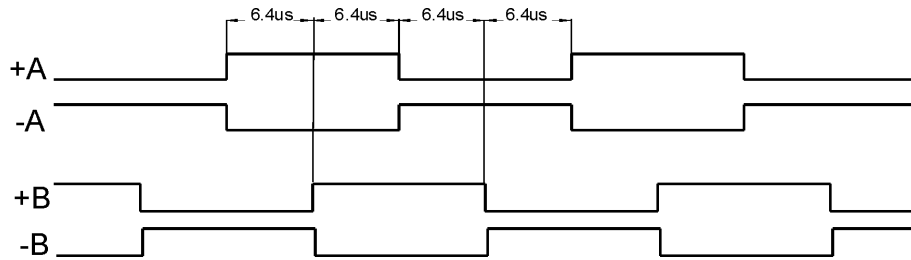
Functional Diagram

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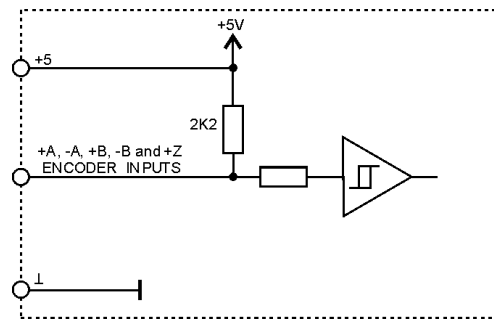
Encoder Input

The encoder interface accepts two square wave inputs, +A, +B (+A, -A, +B, -B for differential encoder) from an incremental encoder. Ideally, these square waves are 50% duty cycle and exactly +/-90 degrees out of phase. In any case, the time between encoder state transitions should be not less than 6.4uS. With ideally formed encoder pulses, this would correspond to a 1250-line encoder (5000 counts/rev) rotating at 1,875 RPM.



Encoder signals waveforms (CW motor direction)

When a single ended incremental encoder (with only A and B wires connected to drive +A and +B inputs) is used the DIP switch S.E. ENC must be ON to disable the encoder presence check.



Encoder inputs schematics

Some incremental encoders are equipped with Index output Z. The index signal is activated once per motor revolution and can be used for precise homing.



Index signal waveform

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Limit Inputs

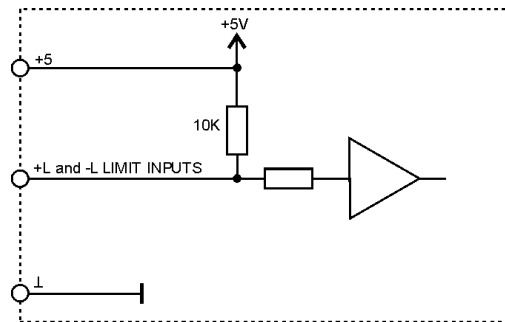
There are two limit inputs +L(Forward limit) and -L(Reverse limit). When a limit switch is activated the motor driver is disabled after 15 pulses moving in the same direction. After that, the motor can be moved only in opposite direction (see the table below). These Limit inputs can be used as “Home switches” also. (Refer to “Set Homing Mode” commands in the “Command Description” section in this document).

SWITCH STATE	READ AS	DIP SW N.O. LIMIT	MOTOR DRIVER	DESCRIPTION
CLOSED	1	OFF	ACTIVE	In safe zone (NCS)*
		ON	DIRECTION DISABLED	Limit activated (NOS)*
OPEN	0	OFF	DIRECTION DISABLED	Limit activated (NCS)*
		ON	ACTIVE	In safe zone (NOS)*

*** Notes;**

NCS – normally closed limit switch
 NOS – normally open limit switch

Hardware limit switches function table.

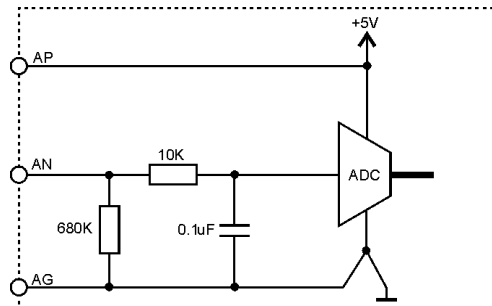


Limit inputs schematics

Analog input

This 8 bit analog input can be read through LDCN interface by user software. By using a coupled to motor shaft potentiometer, the user software can read the motor absolute position.

(Refer to “Read Status” and “Define Status” commands in the “Command Description” section in this document).



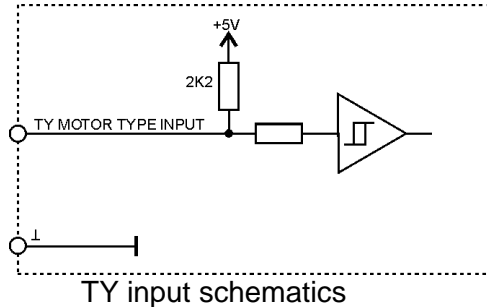
Analog input schematics

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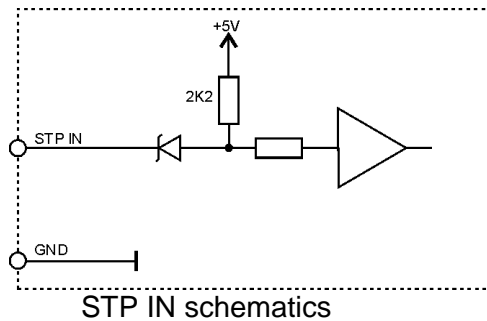
TY input

This input selects the motor drive signal. Connect TY input to GND for **Tiny Picomotor™** or leave it OPEN for **Standard Picomotor™**.



Stop input

This input can be used to disable the motor driver. When STP IN is connected to GND, the motor driver is enabled. To disable the motor driver, leave STP IN open or connect it to +5Vdc to +30Vdc voltage source.



Serial Command Interface

The serial communication with the LDCN Nodes adheres to a full-duplex (4 wire) 8 bit asynchronous protocol with one start bit, followed by 8 data bits (lsb first), followed by a single stop bit. The communication protocol also supports a full-duplex multi-drop RS-485 interface, which allows multiple LDCN Nodes to be controlled over a single RS-485 port. In this case, the host sends commands over its RS-485 transmit line and receives all status data back over the shared RS-485 receive line. The command protocol is a strict master/slave protocol in which the host master sends a command packet over the command line to a specific LDCN Node. The Node sends back a status packet. Typically, the host does not send another command until a status packet has been received to insure that it does not overwrite any previous command data still in use.

Each command packet consists of following:

Header byte (0xAA)

Address byte - individual or group (0x00 - 0xFF)

Command byte

0 - 15 data bytes

Checksum byte

The command byte is divided into upper and lower nibbles: the lower nibble is the command value; the upper nibble is the number of additional data bytes, which will follow the command byte. The checksum byte is 8-bit sum of the address byte, the command byte and the data bytes.

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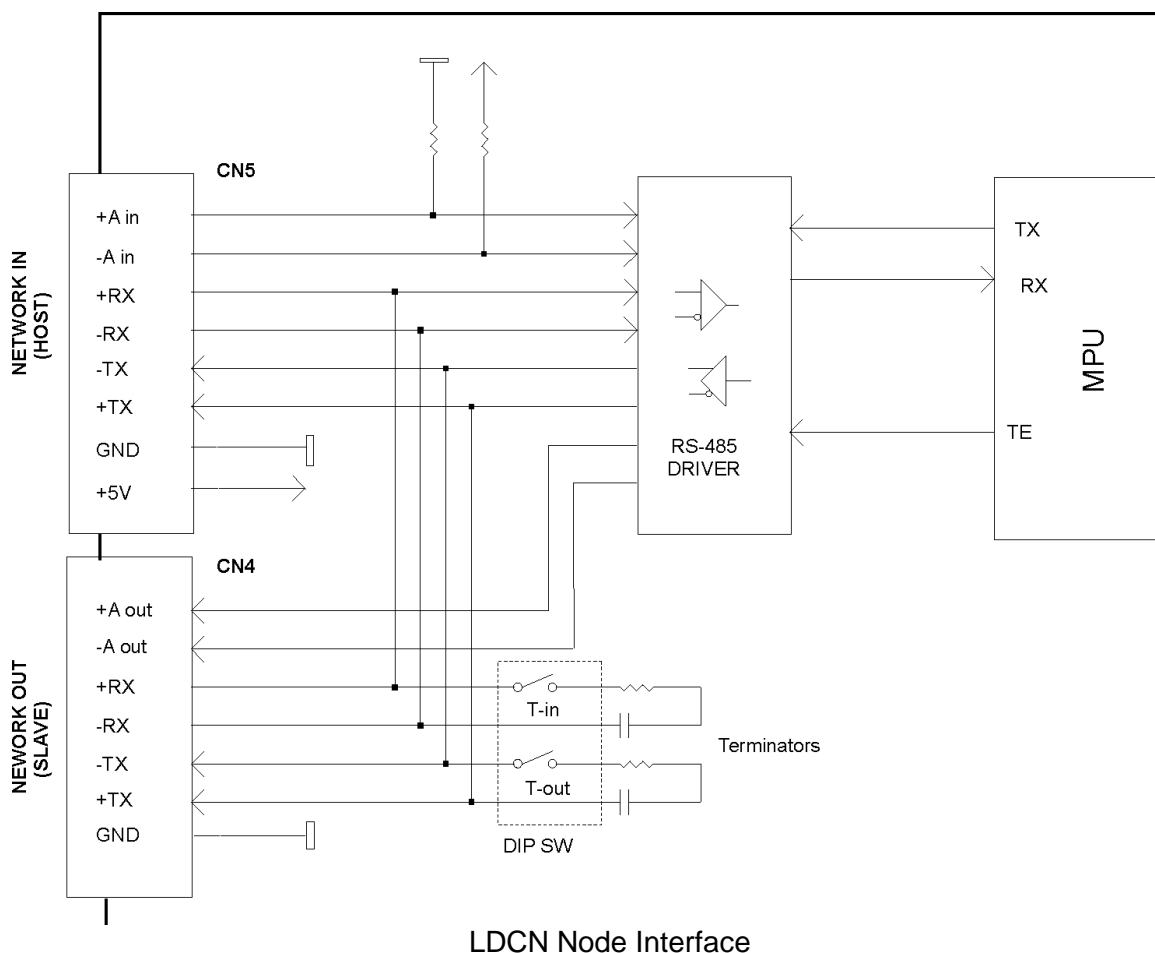
The number of data bytes depends on the particular command chosen. After a command is issued, the corresponding controller will send back a status packet consisting of:

Status byte

0-16 optional bytes of status data

Checksum byte

The Status Byte contains basic status data about the LDCN Node, including a checksum error flag for the command just received. The number and the meaning of Optional Status Data Bytes are programmable by the user and may include any, none or all of data available from the module. The checksum byte is the 8-bit sum of the status byte and the additional optional status data bytes. All 16-bit and 32-bit data is sending with the least significant byte first.



Terminators

DIP switches T-in and T-out, are used to turn ON/OFF receive and transmit lines terminators. In a network of Logosol devices only the last one (at the remote end) is supposed to have its line terminators ON. All other devices located between this device and the host must have their terminators set to OFF. The maximum network cable length is limited to 1000'.

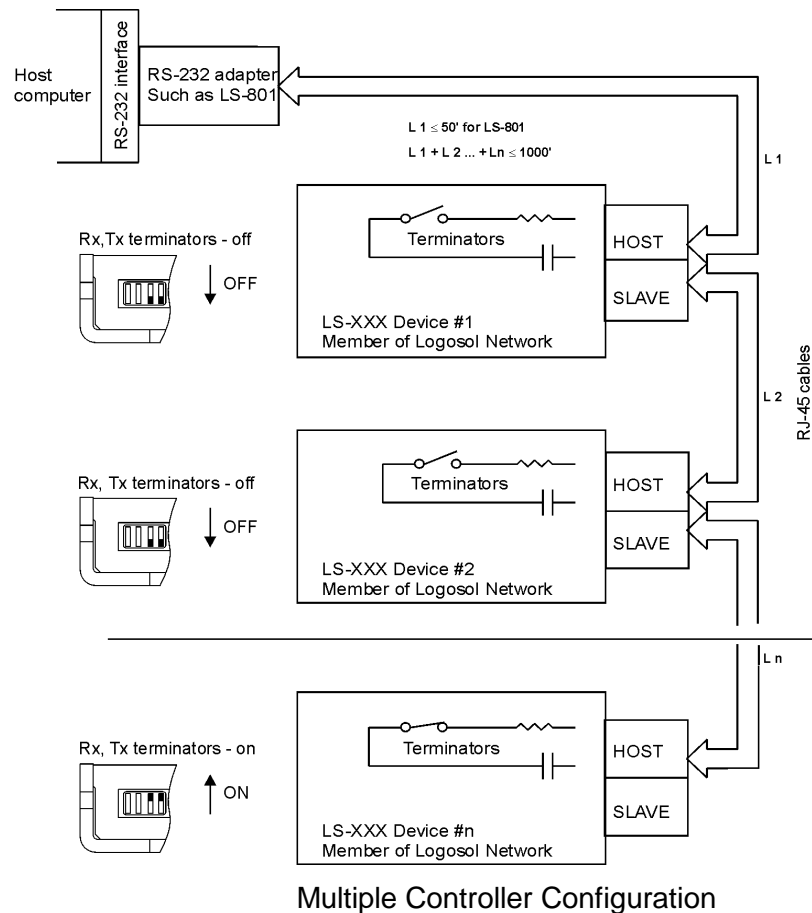
Addressing

Rather than using hard-wired or switch-selected address of each LDCN Node, the host dynamically sets the address of each node with the aid of the daisy-chained "A in" and "A out" lines. This allows additional LDCN Nodes to be added to an RS-485 network with no hardware

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changes. On Power-up, "A in" of the first LDCN Node is pulled low, its communication is enabled and the default address is 0x00. When the *Set Address* command is issued to give this node a new unique address, it will lower its "A out" line. Connecting "A out" to the "A in" of the next node on the network will enable its communication at default address of 0x00. Repeating this procedure allows a variable number of nodes present to be given unique addresses.



Group Addresses

In addition to the individual address, each node has a secondary group address. Several LDCN nodes may share a common group address. This address is useful for sending commands, which must be performed simultaneously by a number of nodes (e.g. *Set Baud Rate*, etc.). When a node receives a command sent to its group address, it will execute the command but not send back a status packet. This prevents data collisions on the shared response line. When programming group addresses, however, the host can specify that one member of the group is the "group leader". The group leader will send back a status packet just like it would for a command sent to its individual address. The group address is programmed at the same time as unique individual address using the *Set Address* command.

Changing Communications Rates

The default baud rate after power-up is 19.2 Kbps. Baud rates up to 115.2 Kbps may be used. After communication has been established with all the controllers on a single network, the baud rate may be changed to a higher value with the *Set Baud Rate* command.

THEORY OF OPERATION

Closed loop modes

The closed loop (PI filter) works only while the motor is not moving and generates output to the motor in order to minimize the position error. This mode is entered automatically after finishing a position mode motion or when the motor stops after issuing Stop smoothly command while moving in closed loop velocity mode. Enabling the amplifier (see Stop Motor command) also enters this mode.

Velocity Profile Mode

Velocity profile mode is used to smoothly accelerate from one velocity to another. Commanded velocities are specified as integer values between 2 and 2000 Hz. The acceleration or deceleration is achieved by adding (or subtracting) the acceleration value (in Hz per servo tick) to (from) the velocity value until the goal velocity is reached.

Position Profile Mode

Position profile mode is used to move the motor from its current position to certain commanded position. The controller generates acceleration and deceleration parts of the motion as well as motion with constant (commanded) velocity using the commanded velocity and acceleration. It calculates at which position to enter constant velocity mode and at which position to start decelerating.

In both closed loop position and velocity profile modes, the frequency depends only on the calculated velocity. During such motions the servo loop does not try to compensate the following error because of the nature of the motor. The controller, however, monitors if the motor is moving in the desired direction and will disable the motor in case the motor is not moving.

Open loop modes

Open loop Step Velocity Mode

Open loop velocity profile mode is used to send pulses to the motor at certain commanded frequency. In this mode, the controller does not check if the motor is moving. This mode is suitable for running a motor without an encoder.

Open loop Step Count Mode

This mode can be used to send certain number of pulses (up to 255) to the motor in either direction. The steps are generated at 1 KHz. In this mode, the controller does not check if the motor is moving. This mode is suitable for running a motor without encoder, or for fine positioning of the motor within one encoder count.

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Status Bits and LED

Bit 3 (Power_on), bit 5 (Reverse Limit) and bit 6 (Forward Limit) of Status Byte and bit 0 (Index) of Auxiliary Status byte are used for reading input signals and drive diagnostics as shown on tables below.

Power Driver OFF condition (*Stop motor* command Pic_ae=0)

Diagnostic bits

Status byte			Condition	LED
Bit 6 (Forward Limit)	Bit 5 (Reverse Limit)	Bit 3 (Power_on)		
1	0	1	STP IN ACTIVATED	Low intensity
0	1	1	OVERHEAT	Low intensity
0	0	1	STP IN ACTIVATED OVERHEAT	Low intensity
1	1	1	OK CONDITION	Low intensity

Diagnostic codes

Status byte			
Pos_error =1	Pos_error =0	Index	Fault code description
59h	49h	1	STP IN ACTIVATED
39h	29h	1	OVERHEAT
19h	09h	1	STP IN ACTIVATED OVERHEAT
79h	69h	1	OK CONDITION

Power Driver ON condition (*Stop motor* command Pic_ae=1)

Status byte			Drive inputs	LED
Bit 6 (Forward Limit)	Bit 5 (Reverse Limit)	Bit 3 (Power_on)		
0	1	1	+L=HIGH -L=LOW	High intensity
1	0	1	+L =LOW -L =HIGH	High intensity
0	0	1	+L =HIGH -L =HIGH	High intensity
1	1	1	+L =LOW -L =LOW	High intensity

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Power Driver Fault condition (Stop motor command Pic_ae=1)

Diagnostic bits

Status byte			Condition	LED
Bit 6 (Forward Limit)	Bit 5 (Reverse Limit)	Bit 3 (Power_on)		
1	0	0	STP IN (LATCHED) ENCODER ERROR	Low intensity
0	1	0	MOTOR SHORT	Low intensity
0	0	0	NO MOTOR	Low intensity
1	1	0	OVERHEAT	Low intensity

Diagnostic codes

Status byte	Index	Fault code description
51h	1	STP IN
	0	ENCODER ERROR
31h	1	MOTOR SHORT
11h	1	HARDWARE CURRENT LIMIT
71h	1	OVERHEAT

To restore the normal operation, if bit 3 (Power_on) is set to 0, Pic_ae must be cycled to 0 and 1. If there are no more fault conditions Power_on will be set to 1.

Power-up and Reset Conditions

On Power-up or reset, the following state is established:

Motor position is reset to zero;

Velocity and acceleration values are set to zero;

All parameters are set to zero;

All outputs are cleared;

The Motor driver is disabled;

The default status data is the status byte only;

The individual address is set to 0x00;

The group address to 0xFF (group leader not set);

Communications are enabled or disabled depending on "A in";

"A out" is HIGH disabling the next drive communications;

The baud rate is set to 19.2 KBPS;

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COMMAND SPECIFICATION

List of Commands

Command	CMD Code	# Data bytes	Description	While Moving?
Reset position	0x0	0	Sets position counter to zero.	No
Set address	0x1	2	Sets the individual and group addresses	Yes
Define status	0x2	1	Defines which data should be sent in every status packet	Yes
Read status	0x3	1	Causes particular status data to be returned just once	Yes
Load trajectory	0x4	1-13	Loads motion trajectory parameters	Maybe*
Start motion	0x5	0	Executes the previously loaded trajectory	Maybe**
Set gain	0x6	14	Sets the PI gains and operating limits	Yes
Stop motor	0x7	1	Stops the motor in one of three manners	Yes
Reserved	0x8	0	Reserved. Do not use this command	Yes
Set home mode	0x9	1	Sets conditions for capturing the home position	Yes
Set baud rate	0xA	1	Sets the baud rate (group command only)	Yes
Clear bits	0xB	0	Clears the sticky status bits	Yes
Save as home	0xC	0	Saves the current position in the home position register	Yes
Nop	0xD	0	Simply causes the defined status data to be returned	Yes
Nop	0xE	0	Simply causes the defined status data to be returned	Yes
Hard reset	0xF	0	Resets the controller to its power-up state.	Yes

*Only allowed while moving if the "start motion now" bit of the trajectory control word is not set or if the "profile mode" bit is set for velocity mode.

**Only allowed while moving if the previously loaded trajectory has the "profile mode" bit set for velocity mode.

Command Description

Reset Position

Command value: 0x0
Number of data bytes: 0
Command byte: 0x00

Description:

Resets the 32-bit encoder counter to 0. Also resets the internal command position to 0 to prevent the motor from jumping abruptly if the position servo is enabled. Do not issue this command while executing a trapezoidal profile motion.

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Set Address

Command value: 0x1

Number of data bytes: 2

Command byte: 0x21

Data bytes:

1. Individual address: 0x01-0x7F (initial address 0x00)
2. Group Address: 0x80-0xFF (initial value 0xFF)

Description:

Sets the individual address and group address. Group addresses are always interpreted as being between 0x80 and 0xFF. If a Drive is to be a group leader, clear bit 7 of the desired group address in the second data byte. The module will automatically set bit 7 internally after flagging the Drive as a group leader. (If bit 7 of the second data byte is set, the module will default to being a group member.) The first time this command is issued after power-up or reset, it will also enable communications for the next Drive in the network chain by lowering the it's "A out" signal.

Define Status

Command value: 0x2

Number of data bytes: 1

Command byte: 0x12

Data bytes:

1. Status items: (default: 0x00)

- | | | |
|-----|----|--------------------------------------------------------------------------------------------------------------------|
| Bit | 0: | send position (4 bytes) |
| | 1: | send A/D value (1 byte) |
| | 2: | send actual velocity (2 bytes - no fractional component) |
| | 3: | send auxiliary status byte (1 byte) |
| | 4: | send home position (4 bytes) |
| | 5: | send device ID and version number (2 bytes)
(Piezo motor controller device ID = 0, version number = 100 to 109) |
| | 6: | send current position error (2 bytes) |
| | 7: | don't care |

Description:

Defines what additional data will be sent in the status packet along with the status byte. Setting bits in the command's data byte will cause the corresponding additional data bytes to be sent after the status byte. The status data will always be sent in the order listed. For example if bits 0 and 3 are set, the status packet will consist of the status byte followed by four bytes of position data, followed by the aux. status byte, followed by the checksum. The status packet returned in response to this command will include the additional data bytes specified. On power-up or reset, the default status packet will include only the status byte and the checksum byte.

Note: The actual velocity is a positive number when moving in reverse direction and a negative number when moving in forward direction.

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Read Status

Command value: 0x3
Number of data bytes: 1
Command byte: 0x13
Data bytes:

1. Status items:

Bit	0:	send position (4 bytes)
	1:	send A/D value (1 byte)
	2:	send actual velocity (2 bytes - no fractional component)
	3:	send auxiliary status byte (1 byte)
	4:	send home position (4 bytes)
	5:	send device ID, version number (2 bytes) (Piezo motor controller device ID = 0, version number = 100 to 109)
	6:	send current position error (2 bytes)
	7:	don't care

Description:

This is a non-permanent version of the *Define Status* command. The status packet returned in response to this command will incorporate the data bytes specified, but subsequent status packets will include only the data bytes previously specified with the *Define Status* command.

Note: The actual velocity is a positive number when moving in reverse direction and a negative number when moving in forward direction.

Load Trajectory

Command value: 0x4
Number of data bytes: $n = 1-13$
Command byte: 0xn4
Data bytes:

1. Control byte:

Bit	0:	load position data ($n = n + 4$ bytes)
	1:	load velocity data ($n = n + 4$ bytes)
	2:	load acceleration data ($n = n + 4$ bytes)
	3:	not used. Should be 0.
	4:	servo mode - 0 = open loop mode, 1 = closed loop mode
	5:	profile mode - 0 = trapezoidal profile, 1 = velocity profile
	6:	velocity/step count mode direction - 0 = FWD, 1 = REV
	7:	start motion now

Description:

All motion parameters are set with this command. Setting one of the first three bits in the control byte will require additional data bytes to be sent (as indicated) in the order listed. The position data (range +/- 0x7FFFFFFF) is used as goal position in trapezoidal profile mode. In open loop step mode, the position data (range 0 to 255) is used as number of pulses to be sent to the motor. The velocity data (range 0 to 1023) is used as the goal velocity in open loop and closed loop velocity modes or as the maximum velocity in trapezoidal profile mode. Velocity is given in pulses per second. The acceleration data (range 0x00000000 to 0x7FFFFFFF) is used in both trapezoidal and velocity closed loop modes. Acceleration is given in pulses per second per servo tick.

Bit 4 of the control byte specifies whether closed loop modes should be used or if the open loop mode should be entered. In open loop mode, setting bit 0 will enter open loop step count mode. Bit 5 specifies whether a trapezoidal profile motion should be initiated or if the velocity profiler is used. Trapezoidal profile motions should only be initialized when the motor velocity is 0. (Bit 0 of the status byte indicates when a trapezoidal profile motion has been completed, or in velocity

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mode, when the command velocity has been reached.) Bit 6 indicates the direction of closed loop velocity, open loop velocity, or open loop step count mode and is ignored in closed loop position profile mode. If bit 7 is set, the command will be executed immediately. If bit 7 is clear, the command data will be buffered and it will be executed when the *Start Motion* command is issued. For example to load only new position data and acceleration data but not to start the motion yet, the command byte would be 0x94, the control byte would be 0x15, followed by 4 bytes of position data (least significant byte first), followed by 4 bytes of acceleration data.

If in the middle of a trapezoidal position move, a new *Load Trajectory* command is issued with new position data downloaded, new position data will be used as a relative offset to modify the goal position. For example, if in the middle of a move to position 50,000, a new *Load Trajectory* command with new position data of 10,000 is loaded, the motor will stop at final position of 60,000. The relative offset can be either positive or negative. The new *Load Trajectory* command must be issued while the motor is running at a constant velocity – issuing the command while accelerating or decelerating will cause a position error to occur. If more than one *Load Trajectory* is issued before the end of move, the goal position will be modified by the sum of relative offsets.

* While the position may range from -0x7FFFFFFF to +0x7FFFFFFF, the goal position should not differ from the current position by more than 0x7FFFFFFF.

Start Motion

Command value: 0x5
Number of data bytes: 0
Command byte: 0x05

Description:

Causes the trajectory information loaded with the most recent Load Trajectory command to execute. This is useful for loading several Drives with trajectory information and then starting them simultaneously with a group command.

Set Gain

Command value: 0x6
Number of data bytes: 14
Command byte: 0xE6
Data bytes:
1,2. Position gain KP (0 - 0x7FFF)
3,4. Not used. Set to 0
5,6 Integral gain KI (0 - 0x7FFF)
7,8. Integration limit IL (0 - 0x7FFF)
9. Output limit OL (0 - 0xFF) (typically recommended 0xFA)
10. Not used. Set to 0
11,12 Position error limit EL (0 - 0x3FFF)
13. Servo rate divisor SR (1 - 0xFF)
14. Not used. Set to 0.

Description:

Sets all parameters and limits governing the behavior of the position servo. KP, KI and IL are PI filter parameters. OL limits the maximal PWM output value to $0 < \text{PWM} \leq \text{OL}$ in position servo modes. The position error limit (EL) will cause the position servo to be disabled should the position error grow beyond the limit. The servo rate divisor sets the servo tick time to be a multiple of 0.512 msec (1.953 KHz). For example SR=3 gives a servo rate of 651 Hz. The servo

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tick rate is also used as the profiling timebase, although command processing is always performed at the maximum tick rate.

Stop Motor

Command value: 0x7
Number of data bytes: 1 or 5
Command byte: **0x17 or 0x57**

Data bytes:

1. Stop control byte

Bit 0: Pic_ae (Power Driver enable)
1: Turn motor off
2: Stop abruptly
3: Stop smoothly
4: Stop here
5-7: Clear all to 0

2-5. Stopping position (only required if bit 4 above is set)

Description:

Stops the motor in the specified manner. If bit 0 of the Stop Control Byte is set, Power Driver will be enabled. If bit 0 is cleared Power Driver will be disabled, regardless of the state of the other bits. Pic_ae also controls the meaning of bit 3 (Power_on), bit 5 (Limit 1 (Reverse)), and bit 6 (Limit 2 (Forward)) of status byte (refer to *Status Bits* section of *Safety Features* in this document). If bit 1 is set, the position servo will be disabled, the PWM output value will be set to 0, and bits 2, 3 and 4 are ignored. If bit 2 is set, the current command velocity and the goal velocity will be set to 0, the position servo will be enabled, and velocity mode will be entered. If the velocity servo was previously disabled, the motor will simply start servoing to its current position. If the motor was previously moving in one of the profiling modes, it will stop moving abruptly and servo to its current position. This stopping mode should only be used as an emergency stop where the motor position needs to be maintained. Setting bit 3 enters a more graceful stop mode - this sets the goal velocity to 0 and enters velocity mode, causing the motor to decelerate to a stop at the current acceleration rate. If bit 4 is set, the motor will move to the specified stopping position abruptly with no profiling. This mode can be used to cause the motor to track a continuous string of command positions. Note that if the stopping position is too far from the current position, a position error will be generated. Only one of the bits 1, 2, 3 or 4 should be set at the same time. The *Stop Motor* command must be issued initially to set Pic_ae before other motion commands are issued.

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Set Homing Mode

Command value: 0x9

Number of data bytes: 1

Command byte: **0x19**

Data bytes:

1. Homing control byte

Bit 0: Capture home position on change of Limit 1 (Reverse)

1: Capture home position on change of Limit 2 (Forward)

2 Turn motor off on home

3: Capture home on change of Index

4: Stop abruptly on home

5: Stop smoothly on home

6: Capture home position when an excess position error occurs

7: Capture home position when current limiting occurs

Description:

Causes the Drive to monitor the specified conditions and capture the home position when any of the flagged conditions occur. The home_in_progress bit in the status byte is set when this command is issued and it is then lowered when the home position has been found. Setting one (and only one) of bits 2, 4 or 5 will cause the motor to stop automatically in the specified manner once the home condition has been triggered. This feature can also be used as a safety shutoff.

Set Baud Rate

Command value: 0xA

Number of data bytes: 1

Command byte: **0x1A**

Data bytes:

1. Baud rate divisor, BRD

sample values:

9600 BRD = 0x81

19200 BRD = 0x3F

57600 BRD = 0x14

115200 BRD = 0x0A

Description:

Sets the communication baud rate. All drives on the network must have their baud rates changed at the same time; therefore this command should only be issued to a group including all of the controllers on the network. A status packet returned from this command would be at the new baud rate, so typically (unless the host's baud rate can be accurately synchronized) there should be no group leader when this command is issued.

Clear Sticky Bits

Command value: 0xB

Number of data bytes: 0

Command byte: **0x0B**

Description:

The missing motor and position error bits in the status byte and the position wrap and servo timer overrun bits in the auxiliary status byte will stay set unless cleared explicitly with this command.

Save Current Position as Home

Command value: 0xC

Number of data bytes: 0

Command byte: **0x0C**

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Description:

Causes the current position to be saved as the home position. This command is typically issued to a group of controllers to cause their current positions to be stored synchronously. The stored positions can then be read individually by reading the home position

No Operation

Command value: 0xD or 0xE
Number of data bytes: 0
Command byte: **0x0D or 0x0E**

Description:

Does nothing except cause a status packet with the currently defined status data to be returned.

Hard Reset

Command value: 0xF
Number of data bytes: 0
Command byte: **0x0F**

Description:

Resets the control module to its power-up state. No status will be returned. Typically, this command is issued to all the modules on the network, although if the baud rate is set at the default, it is possible to reset and re-initialize the addresses of a contiguous sub-chain of modules.

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STATUS BYTE AND AUXILIARY STATUS BYTE DEFINITIONS

Status Byte

<u>Bit</u>	<u>Name</u>	<u>Definition</u>
0	Move_done	Clear when in the middle of a trapezoidal profile move or in velocity mode, when accelerating from one velocity to the next. This bit is set otherwise, including while the position servo is disabled
1	Cksum_error	Set if there was a checksum error in the just received command packet
2	No_motor	Set if missing motor is detected. Must be cleared by user with <i>Clear Sticky Bits</i> command
3	Power_on/diag. bit	Refer to <i>Status Bits and LED</i> section in this document
4	Pos_error	Set if the position error has exceeded the position error limit. It is also set whenever the position servo is disabled. Must be cleared by user with <i>Clear Sticky Bits</i> command
5	Limit 1 (Reverse) / diag. bit	Reverse Limit or diagnostic bit (refer to <i>Status Bits and LED</i> section in this document).
6	Limit 2 (Forward) / diag. bit	Forward Limit or diagnostic bit (refer to <i>Status Bits and LED</i> section in this document).
7	Home_in_progress	Set while searching for a home position. Reset to zero once the home position has been captured

Auxiliary Status Byte

<u>Bit</u>	<u>Name</u>	<u>Definition</u>
0	Index/diag. bit	Compliment of the value of the index input or diagnostic bit (refer to <i>Status Bits and LED</i> section in this document).
1	Pos_wrap	Set if the 32-bit position counter wraps around. Must be cleared with the <i>Clear Sticky Bits</i> command
2	Servo_on	Set if the position servo is enabled, clear otherwise
3	Accel_done	Set when the initial acceleration phase of a trapezoidal profile move is completed. Cleared when the next move is started
4	Slew_done	Set when the slew portion of a trapezoidal profile move is complete. Cleared when the next move is started
5	Servo_overrun	At the highest baud rate and servo rate, certain combinations of calculations may cause the servo, profiling, and command processing to take longer than 0.512 msec, in which case, this bit will be set. This is typically not serious, only periodically introducing a small fraction of a millisecond delay to the servo tick time. Cleared with the <i>Clear Sticky Bits</i> command

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INITIALIZING PROCEDURE AND PROGRAMMING EXAMPLES FOR SERVO DRIVES

To ensure a proper operation of all Servo drives connected to the network, the following initializing steps should be executed:

1. Reset all modules with *Hard Reset* command.
2. Set the addresses for all connected drives.
3. Set the individual gains (KP, KI, IL, OL, EL, and SR). Minimal requirements are: KP <> 0, EL <> 0 and SR <> 0.
4. Use *Load trajectory* command to set the target position, velocity acceleration with start motion now in trapezoidal mode. Minimal requirements are acceleration <> 0 and target position = 0. This command does not start any motion. It is necessary to initialize internal registers of the module.
5. Close the servo loop by using *Stop Motor* command (Pic_ae=1 and Stop abruptly=1).

Understanding the Serial Communication with Servo drives

The Serial Communication with Servo drives is strictly master-slave and matches repeatedly two elements:

- Sending a command to the specified drive's address;
- Receiving answer to the sent command – Status Byte(s).

Note: During the communication all bytes are sent with LSB first.

Commands

There are 16 commands managing Servo drives (refer to Command Description). Each command as shown in the following two tables includes header, address, command, data bytes and one checksum byte. Checksum does not include header byte.

Structure of Read Status command

Byte 1	Byte 2	Byte 3		Byte 4	Byte 5
Header	Address (Individual or Group)	Command Code		Data Byte	CheckSum = Byte 2 + Byte 3 + Data Byte
		High 4 bits No. of data bytes	Low 4 bits command code		
AA	01	1	3	01	15

Examples

Cmd. Bytes	Byte 1	Byte 2	Byte 3	Byte 4 – N	Byte N+1
Command	Header	Address	Cmd. Code	Data Byte(s)	Checksum
Reset position	AA	01	0 0		01
Define status	AA	05	1 2	05	1C
Set address	AA	01	2 1	07 FF	21
Load trajectory	AA	01	5 4	91 00 28 00 00	0E
Set gain	AA	01	E 6	64 00 00 00 00 00 00 00 FF 00 00 08 01 00	57

Status Data

The structure of the returned status information depends on *Define Status* or *Read Status* commands (refer to Command Description). By default only the Status byte and Checksum are returned to the host.

Examples

Byte 1	Optional Bytes 0-16	CheckSum
Status Byte	Additional Status Bytes as position, velocity, home position, A/D auxiliary byte, version and position error.	CheckSum = Byte 1+ Optional Bytes
09	no additional status bytes requested	09
09	00 28 00 00 – four additional status bytes	31

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Addressing

Each drive in the daisy-chained network has two addresses:

- Individual - for individual control of each drive. Its range is from 01h to 7Fh.
- Group - for simultaneous control of all group members by sending a single command to their group address. It is in the range of 80h to FFh.

Both these addresses have to be set during the initialization process.

The group may have Group leader responsible to send status data. Its address is:

Group leader address = Group address - 80h.

If there is no group leader - no status data will be send after a group command.

Set Baud Rate command must be sent only as a group command with no group leader, otherwise communication problems may occur.

Set Address command format

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
Header	Preset Address	Command code	Individual Address	Group Address	Checksum
AA	00	21	01	FF	21

Setting the Addresses

After power-up and *Hard Reset* command all drives have their address set to 00h and only the first drive (starting from the host) has its communication enabled. Consecutive *Set Address* commands are sent to address 00h until all drives are addressed. This procedure can be executed once after *Hard Reset*. The table below shows the steps to address 3-drives network.

Example of sequential addressing for three Servo drives

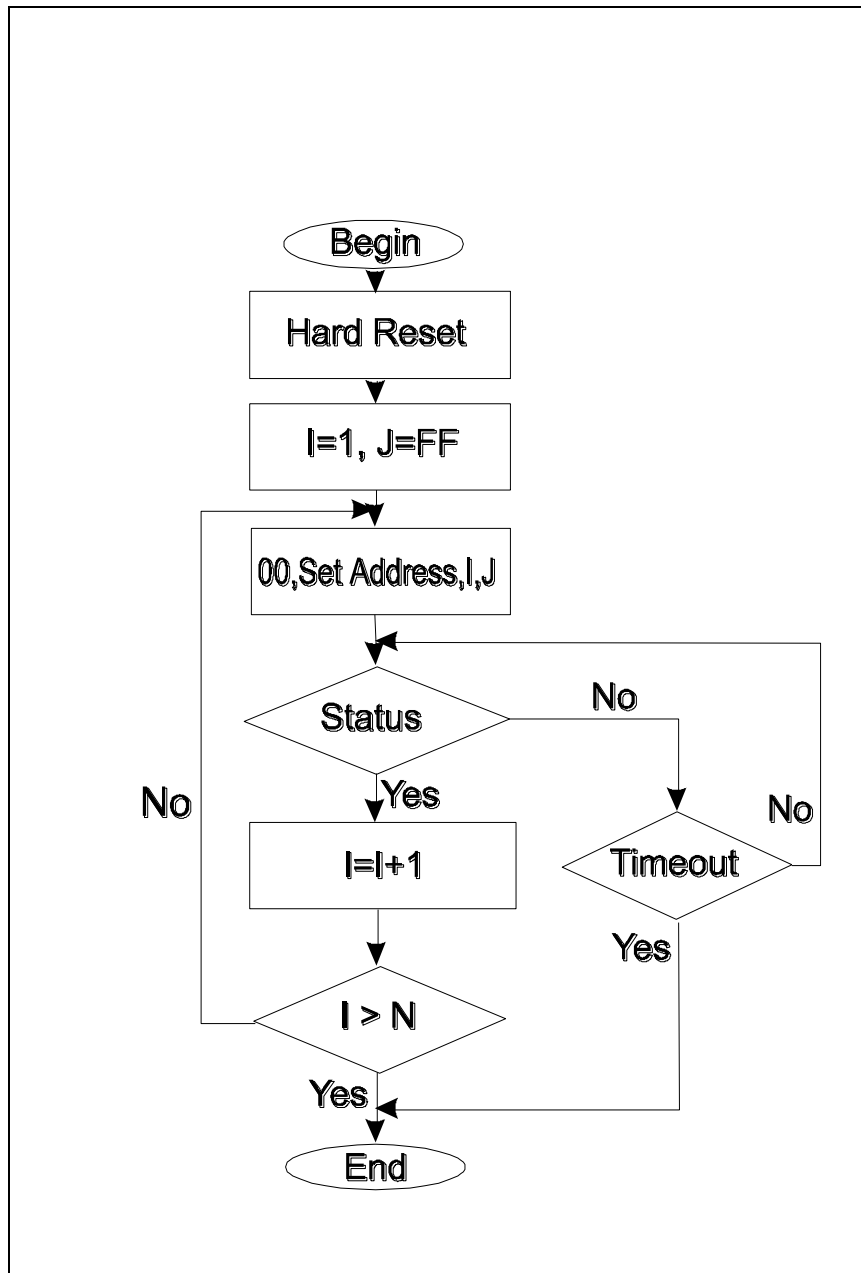
Step	Command	Set address Hexadecimal Code	Drive 1		Drive 2		Drive 3	
			Individual address	Group address	Individual address	Group address	Individual address	Group address
0	Power-up							
1	Hard Reset	AA FF 0F 0E	address=00 communication <i>enabled</i>		address=00 communication <i>disabled</i>		address=00 communication <i>disabled</i>	
2	Set Address Drive1 = 01	AA 00 21 01 FF 21	01	FF	address=00 communication <i>enabled</i>		address=00 communication <i>disabled</i>	
3	Set Address Drive2 = 02	AA 00 21 02 FF 22	01	FF	02	FF	address=00 communication <i>enabled</i>	
4	Set Address Drive3 = 03	AA 00 21 03 FF 23	01	FF	02	FF	03	FF

Note: Before start addressing *Hard Reset* command must be issued.

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The flowchart shows the addressing procedure of N drives network. There is no group leader and the group address is FF.



I - Individual Address; *J* - Group Address = FF;
Status - Status Data sent to the Host; *Timeout* - Greater than one servo circle.

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Examples of Managing Two Piezo Motor Servo-Drives

- # 1 – Resets all modules with group command.
- # 2 and # 3 - Set the addresses of drives 1 and 2.
- # 4 and # 6 - Set PID parameters of drives 1 and 2.
- # 6 and # 7 - Starts motion in trapezoidal mode with target position=0, velocity=0, acceleration=1 and PWM=0.
- # 8 and # 9 - Close servo loops of drives 1 and 2. Initialization is complete at this point.
- # 10 and # 10 - Load trajectories (positions, velocities and accelerations) for drives 1 and 2.
- # 12 and # 13 - Load and execute new trajectory for drive 1.
- # 14 and # 15 - Read additional status bytes from drives 1 and 2.
- # 16, # 17 and #18 - Load new trajectories for drives 1 and 2 and execute them with one command sent to the drives' group address.

Examples

#	Hexadecimal code of command	Comments
1	AA FF 0F 0E	<i>Hard Reset</i>
2	AA 00 21 01 FF 21	<i>Set Address 01h for drive 1. Group address=FFh.</i>
3	AA 00 21 02 FF 22	<i>Set Address 02h for drive 2. Group address=FFh.</i>
4	AA 01 E6 E8 03 00 00 64 00 E8 03 FF 00 00 32 01 00 53	<i>Set Gains of drive 1 – defines PID parameters: KP=1000, KI=100, IL=1000, OL=255, EL=50, SR=1.</i>
5	AA 02 E6 E8 03 00 00 64 00 E8 03 FF 00 00 32 01 00 54	<i>Set Gains of drive 2 – defines PID parameters: KP=1000, KI=100, IL=1000, OL=255, EL=50, SR=1,</i>
6	AA 01 D4 97 00 00 00 00 00 00 00 00 01 00 00 00 66	<i>Load trajectory for drive 1 – target position=0, velocity=0, acceleration=1 and start motion now</i>
7	AA 02 D4 97 00 00 00 00 00 00 00 00 01 00 00 00 67	<i>Load trajectory for drive 2 – target position=0, velocity=0, acceleration=1 and start motion now</i>
8	AA 01 17 05 1D	<i>Stop Motor - closes servo loop of drive 1 with Power Driver enable and Stop Abruptly in Command byte.</i>
9	AA 02 17 05 1E	<i>Stop Motor - closes servo loop of drive 2 with Power Driver enable and Stop Abruptly in Command byte.</i>
10	AA 01 D4 97 00 00 00 00 FF 03 00 00 64 00 00 00 D2	<i>Load Trajectory of drive 1 with Pos=0, Vel=1023, Acc=100, servo mode=1, start now = 1.</i>
11	AA 02 D4 97 00 00 00 00 FF 03 00 00 64 00 00 00 D3	<i>Load Trajectory of drive 2 with Pos=0, Vel=1023, Acc=100, servo mode=1, start now = 1.</i>
12	AA 01 54 11 00 28 00 00 8E	<i>Load Trajectory of drive 1 with new position=2800h.</i>
13	AA 01 05 06	<i>Start Motion - executes previously loaded trajectory.</i>
14	AA 01 13 05 19	<i>Read Status from drive 1 (plus position and velocity).</i>
15	AA 02 13 05 1A	<i>Read Status from drive 2 (plus position and velocity).</i>
16	AA 01 54 11 20 4E 00 00 D4	<i>Load Trajectory of drive 1 with new position=4E20h.</i>
17	AA 02 54 11 E0 B1 FF FF F6	<i>Load Trajectory of drive 2 with new position=FFFFB1E0h (-4E20h).</i>
18	AA FF 05 04	<i>Start Motion – executes previously loaded trajectories. The command is sent to the drives' group address FFh.</i>

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Procedure Initialize

AA FF 0F 0E	Hard reset
AA 00 21 01 FF 21	Set address
AA 00 21 02 FF 22	Search for more modules until no response received
AA 01 13 20 34	Read Device ID and Version number
AA 01 13 FF 13	Read all status data
AA 01 E6 E8 03 00 00 64 00 E8 03 FF 00 00 32 01 00 53	Set Gain parameters
AA 01 D4 97 00 00 00 00 00 00 00 00 01 00 00 00 66	Set Trajectory parameters
AA 01 17 05 1D	Close servo loop

Procedure FindHomePosition

AA 01 E6 E8 03 00 00 64 00 E8 03 FF 00 00 32 01 00 53	Set gain parameters: KP=1000, KI=100, IL=1000, Output limit=255, Position error limit=50, Servo rate divisor=1
AA 01 17 09 21	Close the servo loop (Stop smoothly and amplifier enable)
AA 01 94 36 FF 03 00 00 64 00 00 00 31	Load trajectory: Velocity mode, Forward direction, Velocity=1023 (2000 Hz), Acceleration = 100
AA 01 19 12 2C	Set home mode - capture home position on change of Forward Limit and stop abruptly
AA 01 05 06	Start motion
wait while home_in_progress bit=1	Home position is found on change of Forward Limit
AA 01 19 18 32	Set home mode - capture home position on change of Index and stop abruptly
AA 01 94 76 FF 03 00 00 64 00 00 00 71	Load trajectory: Velocity mode, Reverse direction
AA 01 05 06	Start motion
wait while home_in_progress bit=1	Home position is found on change of Index