Driver/Controller
Development Assistance Package
For
Rheodyne MLP777 Series of Fluidic Assemblies

Rheodyne LLC · A Unit of IDEX Corporation · 600 Park Court, Rohnert Park, CA 94928, USA · (707) 588-2000 · Fax (707) 588-2020
www.rheodyne.com

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Driver/Controller Development Assistance Package for Rheodyne Motorized Valves Proprietary Letter

This Driver/Controller Development Assistance Information Package ("Information") consists of the following documents for the MLP777 series of fluidic assemblies:

1. Rheodyne MLP777 Controller Description
2. MLP777 Driver Profile
3. MLP777 Dimensional Drawing

This Information is proprietary to Rheodyne, L.L.C., and is provided by Rheodyne as a service to assist Rheodyne OEM customers in the development of drive and control circuitry to be used in conjunction with Rheodyne motorized valves. By requesting and accepting this Information, the recipient agrees to make no other use of this Information, and not to disclose this Information to persons not involved in the development of such control circuitry.

This Information is provided as a convenience to Rheodyne OEM customers for the sole purpose of allowing those customers who wish to do so to develop their own electronic circuitry to drive and control Rheodyne motorized valves. This Information is not warranted in any way.

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Rheodyne assumes no obligation to update this Information at any time in the future.

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Introduction

This document describes the MLP777 Series of Fluidic Assemblies. It includes driver specifications related to Rheodyne's MLP777 driver board PN 7770016, recommended stepper motor driver profiles, and valve specifications to assist OEM users interface with the platform. Please contact Rheodyne, L.L.C. if additional drawings or firmware information are required. Engineering documents can be sent electronically in the following formats: Pro E, SolidWorks, STEP, IGES, DXF, or DWG, depending on the specific document.

1.0 Driver Specifications for MLP777 Series of Fluidic Assemblies

The following Stepper Motor Driver Specifications pertain only to the hardware and firmware that is provided by Rheodyne. Please refer to Section 2.0 if you want to develop your own version of firmware to drive the MLP777. Please refer to Figure 1 at the end of this section for component locations.

1.1 Connectors/Pin-Outs

Stepper Motor Driver/Controller Board (PN 7770016) Headers

- J1: 2-pin Header Customer Power Interface: keyed, C Grid, Vertical, 0.1" pocket
- J2: 10-pin Header for interface between motor, sensor board and PCB
- J3: 8-pin PIC Flash Programming and Future Panel Header
  One connector is used for both flash programming and panel inputs
- J4: 12-pin Header Customer I/O Interface – shrouded, double row, 2mm.

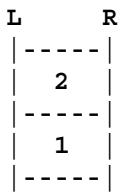
The connector pin call-outs for Rheodyne's Stepper Motor Driver Board (PN 7770016) are defined below.

J1: 2-pin keyed Header for customer power interface, Molex Header P/N = 70543-0001 (use Molex Connector P/N 50-57-9402 to interface with this header).

Pin	Description
J1-1	GND
J1-2	+24 VDC

Layout of 2-pin connector:
(C Grid, Vertical, 0.1" pocket)

top row



bottom row

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J2: 10-pin connector for interface between the motor, sensor board, and PCB, Molex P/N 70543-0009 (use Molex 14-56-2102 to interface with this header)

Pin	Color*	Description
J2-1	Red	Motor Red
J2-2	Grey	Motor Grey
J2-3	Black	Motor Black
J2-4	Yellow	Motor Yellow
J2-5	Red	GND
J2-6	Yellow	Sensor 3
J2-7	Black	Sensor 2
J2-8	Orange	Sensor 1
J2-9	White	Sensor 0
J2-10	Brown	+5VDC

***Color designation is for motor/sensor cable of Model MLP777 between J2, stepper motor, and valve sensor board.**

J3: 8-pin PIC Flash Programming and Future Panel Header, Molex P/N 87331-0820 (use Molex P/N 51110-0850 to interface with this header).

Pin	Description
J3-1	CW/CCW Input
J3-2	Strobe
J3-3	+5 VDC
J3-4	GND
J3-5	Data
J3-6	Clock
J3-7	Vpp (programming voltage)
J3-8	Remote/Local

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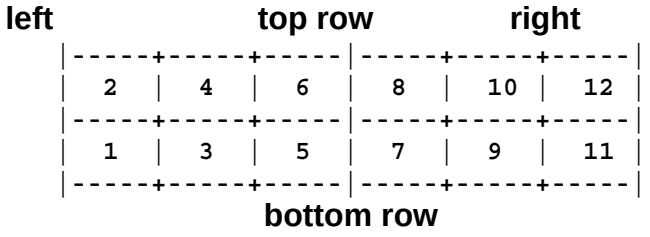
J4: I/O 12-pin Header, Molex Header P/N = 87331-1242 (use Molex P/N 51110-1260 to interface with this header). Note: The firmware is factory programmed via the PIC's flash memory using J3. The pin-outs for J4 are as follows:

Pin	Color*	Description
J4-1	Orange	BCD FB0
J4-2	Violet	BCD FB1
J4-3	White	BCD FB2
J4-4	Grey	BCD FB3
J4-5	Pink	ErrorFB
J4-6	Tan	Spare In**
J4-7	Brown	DoneFB
J4-8	Green	BCD CMD3
J4-9	Black	GND
J4-10	Blue	BCD CMD2
J4-11	Yellow	BCD CMD1
J4-12	Red	BCD CMD0

***Color Designation is for TitanEX™ Control Cable (P/N 7770-051), which connects J4 to TTL contact closures.**
****Not used in Rev. A or B firmware**

Layout of 12-pin connector: (shrouded, double row, 2-mm)



1.2 Control/Status Feedback *(for Rev. B firmware and all subsequent versions until updated)*

1.2.1 4-Line BCD Control

This enables the user to actuate the valve to any position available, via connector J4 pins 8, 10, 11, and 12. A 4-bit parallel binary control signal is read using these pins. (Note: The term "BCD" is carried over from when 10 position commands were used.) The pin-outs for this are as follows:

Pin #	Control Pins
J4-8	BCD CMD3
J4-10	BCD CMD2
J4-11	BCD CMD1
J4-12	BCD CMD0

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The logic is based on non-inverted or active high Binary format (2^0=1, 2^1=2, 2^2=4, 2^3=8) and all 4 bits must be properly set. When controlled with relays using normally closed contacts, the following outputs will be produced as each relay is energized:

	Pin #			
	J4-8	**J4-10**	**J4-11**	**J4-12**
External Event Relay #	4	3	2	1
Number Produced	8	4	2	1

When numerous relays are energized simultaneously these numbers become additive, so they can be programmed as follows. The command format is a non-inverted Binary (active high) as listed below where 0=Logic Lo, Closed, or Ground, and 1= Logic Hi, Open, or +5 VDC.

	Pin #			
Position	**J4-8**	**J4-10**	**J4-11**	**J4-12**
1	X	0	0	1
2	X	0	1	0
3	X	0	1	1
4	X	1	0	0
5	X	1	0	1
6	X	1	1	0

NOTE: X = Irrelevant

1.2.2 Status Feedback Lines

There are two lines of status feedback; an Error feedback line (J4-5) and a Done feedback line (J4-7).

Pin #s	Status Feedback	Description
J4-7, J4-5	DoneFB 1, ErrorFB 0	Valve has completed last motion. No error detected during last motion process
J4-7, J4-5	DoneFB 1, ErrorFB 1	Valve has completed last motion. Error detected during last motion process
J4-7, J4-5	DoneFB 0, ErrorFB X	Valve is busy. Error feedback line NOT valid.

1.2.3 Position Feedback Lines

There are four lines providing position feedback: BCD FB0, FB1, FB2, and FB3 (pins J4-1, J4-2, J4-3, and J4-4 respectively. The position feedback is updated after the valve has completed the last move.

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1.3 Logic Flow *(for Rev. B firmware and all subsequent versions until updated)*

1.3.1 Startup Mode

On power up, the circuit goes through initialization and configures itself based on the programmed firmware. The startup routine runs next, where the position reading from the sensors is taken and the sensor reading determines the next step of the startup routine. If the sensor reading is a valid position value, the valve sets the current position to this reading, it does not move at all and it monitors the command lines for a valid position command. If the sensor reading is an invalid value, the valve searches for home, the closest position in the CW direction (decreasing position number rotation), sets the current position to the number of the position found, and then monitors the command lines for a valid position command. Once done with the startup routine, the circuit will set the "done feedback" line high. The circuit will then begin monitoring the input lines waiting for a valid position command. If it detects a valid position command, it will then do the following if the valve is not already in the commanded position:

1. Clear the "done feedback status line" to indicate the unit is busy and will not accept any new commands
2. Move the valve to the appropriate position using a preset motion profile.
3. Check for errors.
4. When the commanded position is reached the "done feedback status line is set high again to indicate the unit is available for the next command.

1.3.2 Error Handler Mode

If the valve is not able to find the commanded position, the circuit will enter "error handler mode" and the "error feedback" status line will be set to high indicating a valve error. Subsequently, the valve will attempt to move in a CCW direction for a limited angular rotation of 30 degrees and if a position is found the "error feedback" status will be cleared and the "done feedback" line will be set high. At this point the circuit will return to the normal routine and attempt to move to the commanded position. If the valve does not reach a position after entering the "error handler mode", it will stop and wait for a "clear command" – BCD 7 input signal.

Upon receipt of the "clear command" the "error feedback" status line will be cleared and the "done feedback" status line will be set to high. Finally, the circuit will return to the normal routine and wait for a valid position command.

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1.4 Board Layout and Ground Plain Details

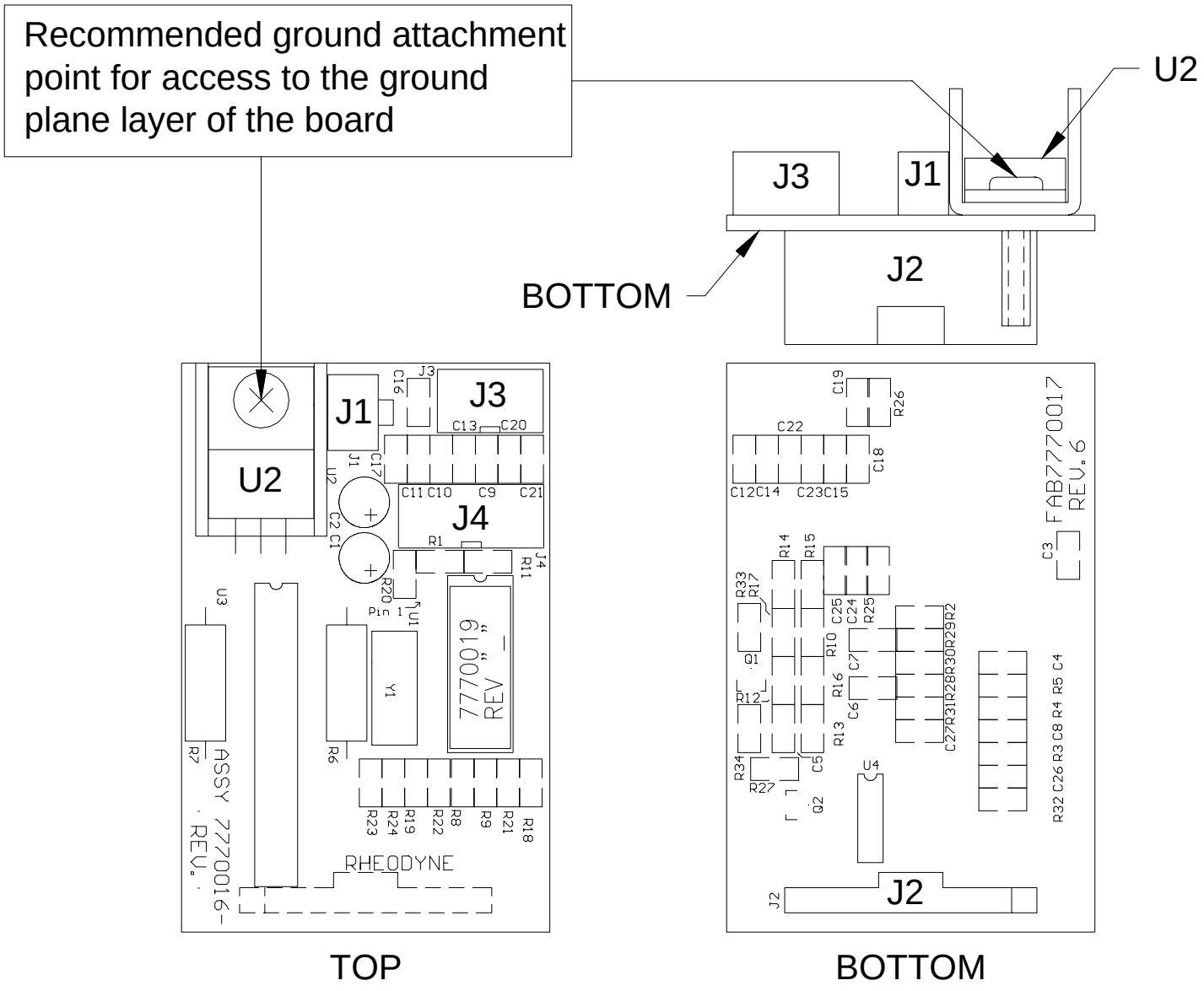

Fig. 1. Connector locations and ground-plane connection detail

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2.0 MLP777 Driver Information

The following profile specifications apply to those OEM customers that wish to use their own firmware with the MLP777. The profile is based on testing a six-position, 60 degrees-between-ports MLP777.

2.1 Suggested Driver Profile Specifications

Step Motor	Thomson AIRPAX S42L048-S09-MI
Motor/Driver Configuration	4 Lead Full Coil, 2 Phase, 5 Ohms per winding
Mechanical Advantage	3.5:1 or 12.25:1 depending upon valve configuration
Angular Rotation of Motor Shaft	735 degrees @ 12.25:1 gearbox, 210 degrees @ 3.5:1 gearbox
Degrees between Ports	60 degrees

The following driver specifications are based on the Rheodyne Driver Board PN 7770016 with firmware 7770019 revision B used during profile development and testing:

Drive Circuit	2-phase bipolar chopper (dual H-bridge, PWM-controlled constant current drive)
Chopping Rate	~30 kHz nominal
Operating Power	24 VDC +/- 5%@ 1.0 Amp
Step Mode	half-step (96 steps/rev or 3.75 deg/step)
Current output of the Driver Chip	± 850 mA per phase
Quiescent Current	20 mA
Motor Control Outputs	4 current mode chopper lines per axis
Waveform Shape	trapezoidal
Waveform Period	280 ms +/- 10ms (nominal)
Duty Cycle	0.5 Hz (1 cycle = move from start position to adjacent position)
Homing Velocity	500 steps/sec, always in clockwise direction

Recommended motion profile data for a 6-port valve with a 12.25:1 gearbox (all data based on half-step mode of operation):

Total number of steps (port-to-port):	196 steps
Backlash compensation:	5 steps @ 500 steps/sec
Acceleration:	15 steps; 35,000 steps/sec/sec
Peak velocity:	128 steps @ 1200 steps/sec
Deceleration:	15 steps; 35,000 steps/sec/sec
Sensor seek:	variable number of steps; 500 steps/sec

In order to minimize the effects of possible noise coupling onto the sensor lines, the valve should be driven in open-loop fashion until the end of the deceleration phase is reached. At that point, sensor lines are sampled after each step until the final port position is found. Sensors can be turned off during the open-loop operation to minimize power dissipation.

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2.2 Motion Profile of Motorized Valve During Switching

The driver board controlling the motorized valves instructs the motor to change from one position to another. Each position change has the same typical motion profile (a graph showing the velocity at a given time) from the one valve position to the next valve position.

The driver board begins moving the motor at a low initial velocity, V(s). The motor continues to accelerate until it reaches a peak velocity, V(f). When the motor reaches this V(f), the 5V power is applied to the sensor board and the motor remains at the peak velocity for most of the motion profile.

After a predetermined number of steps, the driver board begins to decelerate the motor and monitor the position feedback lines from the sensor board. When the sensor board detects the correct code, the driver board disables the motor, and the valve remains in the new position.

When valve position switching reverses direction, the motor requires an additional phase at the beginning of the motion profile called “backlash compensation.” The function of this phase is to start the valve at a given backlash velocity, V(b), and remain at that velocity until the motor and gears remove the backlash. Once the motor and gears remove the backlash, the driver board can begin the normal motion profile as described above.

Figures 2 and 3 show the motion profiles of the motorized valve with and without backlash compensation as the valve switches from one position to the next.

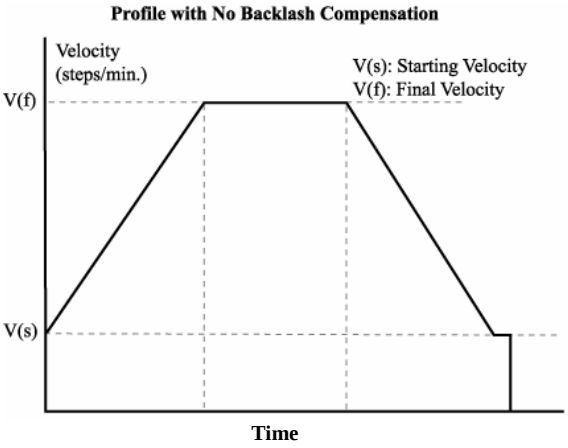

Fig. 2. A typical Rheodyne motorized valve profile during position switching (one position change) without backlash compensation.

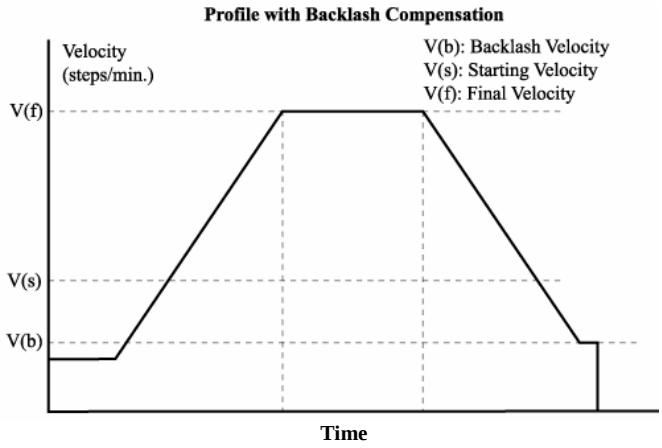

Fig. 3. A typical Rheodyne motorized valve profile during position switching (one position change in reverse) with backlash compensation.

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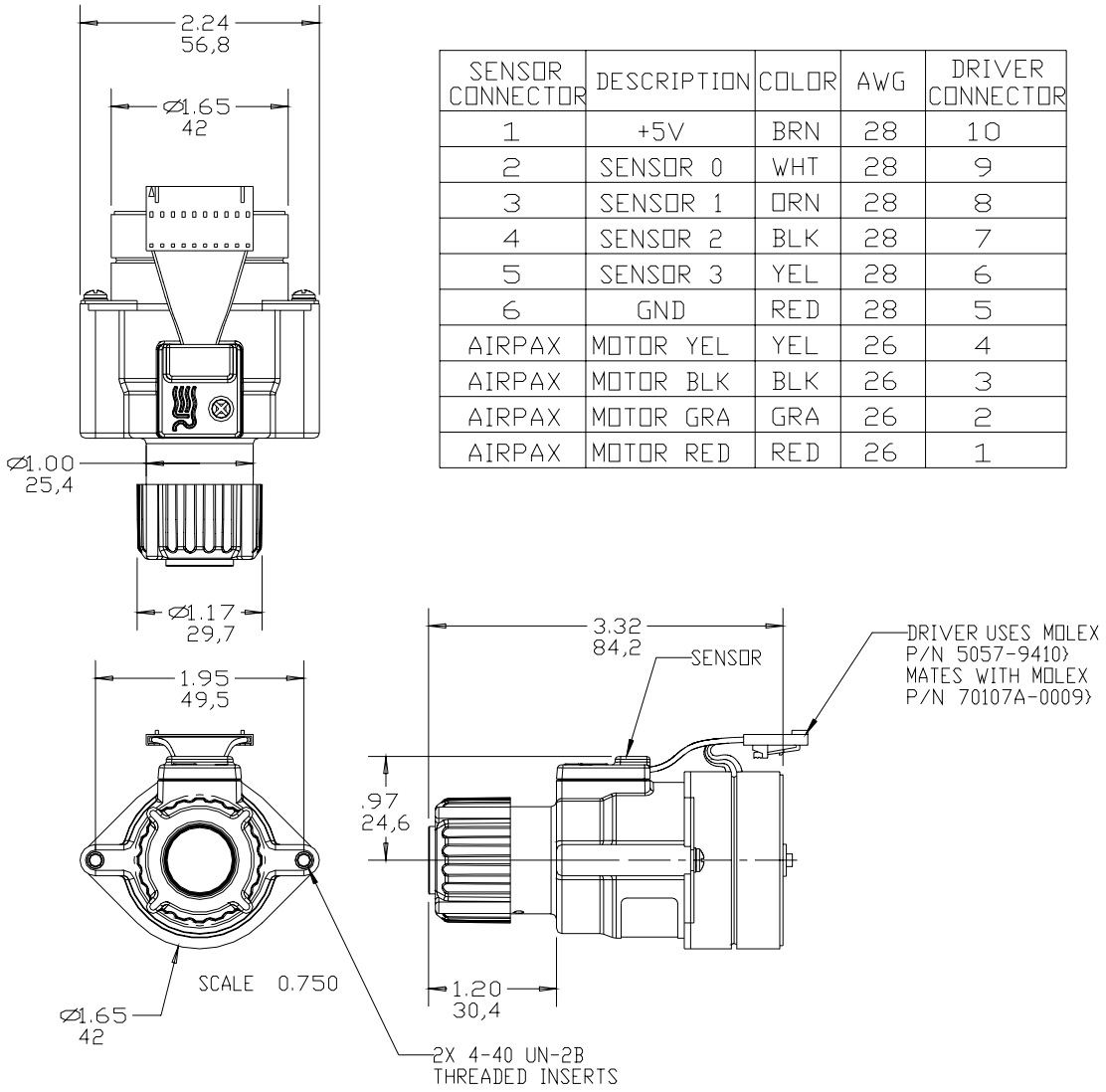
3.0 Additional Specifications

3.1 Dimensional Drawing and Cable Detail of MLP777

Dimensions are in inches/millimeters



SENSOR CONNECTOR	DESCRIPTION	COLOR	AWG	DRIVER CONNECTOR
1	+5V	BRN	28	10
2	SENSOR 0	WHT	28	9
3	SENSOR 1	ORN	28	8
4	SENSOR 2	BLK	28	7
5	SENSOR 3	YEL	28	6
6	GND	RED	28	5
AIRPAX	MOTOR YEL	YEL	26	4
AIRPAX	MOTOR BLK	BLK	26	3
AIRPAX	MOTOR GRA	GRA	26	2
AIRPAX	MOTOR RED	RED	26	1

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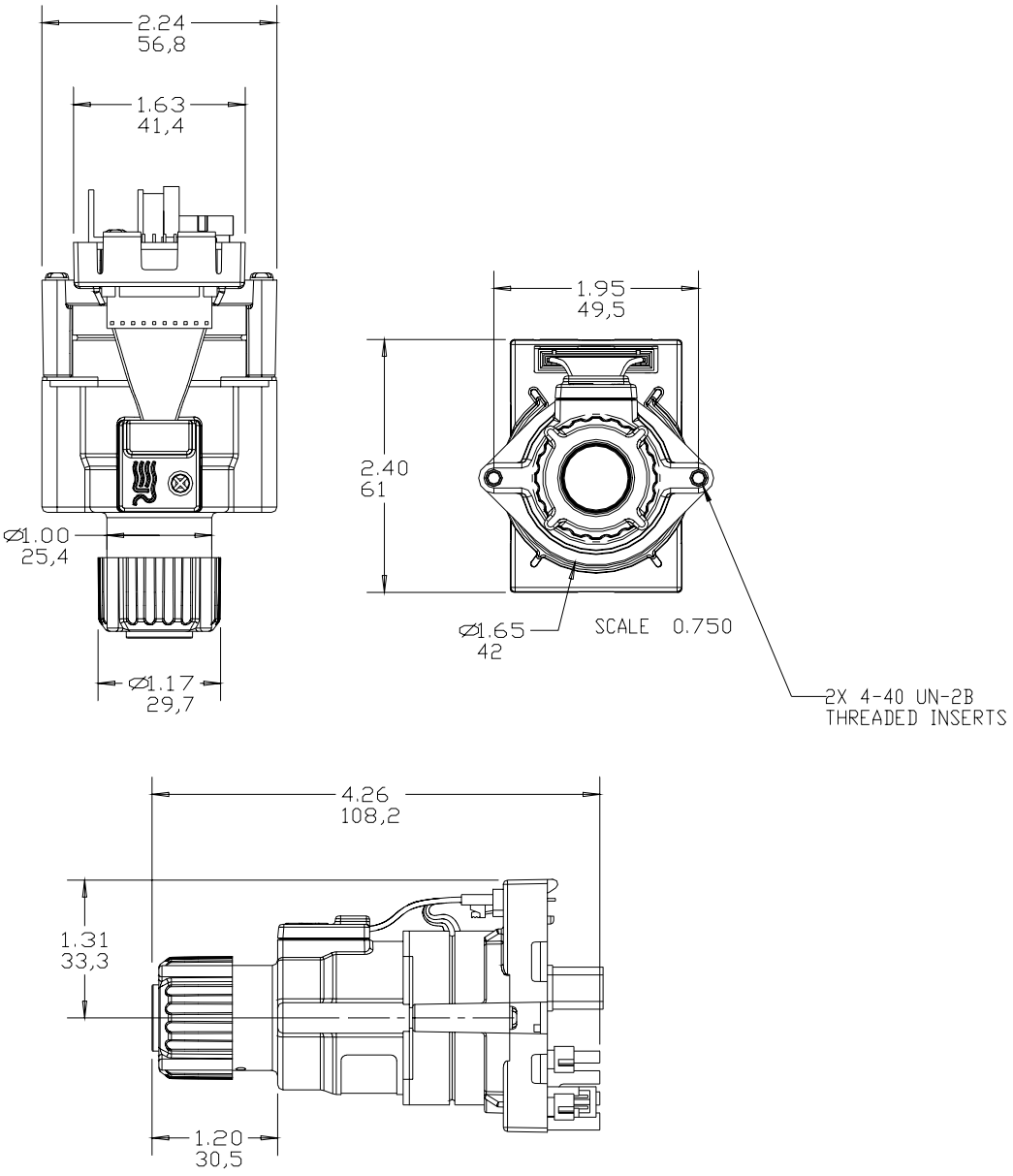
3.2 Dimensional MLP777 Drawing with Rheodyne Board

Dimensions are in inches/millimeters



3.3 Demonstration Kit

Rheodyne, L.L.C. offers a Demonstration Kit (P/N 7770-052) as a convenience to assist OEM customers in development. This Kit contains all necessary components to drive the valve including:

1. Universal Power Supply (input is 100-240VAC, 50-60 Hz, output is 24VDC, 1.7A.
2. Power Line Cord
3. Power Supply Adapter Cable (P/N 7900-901)
4. Control Cable (P/N 7770-051)

Please contact Rheodyne, L.L.C for additional information on this Kit

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