2015

PID Control Demo

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By
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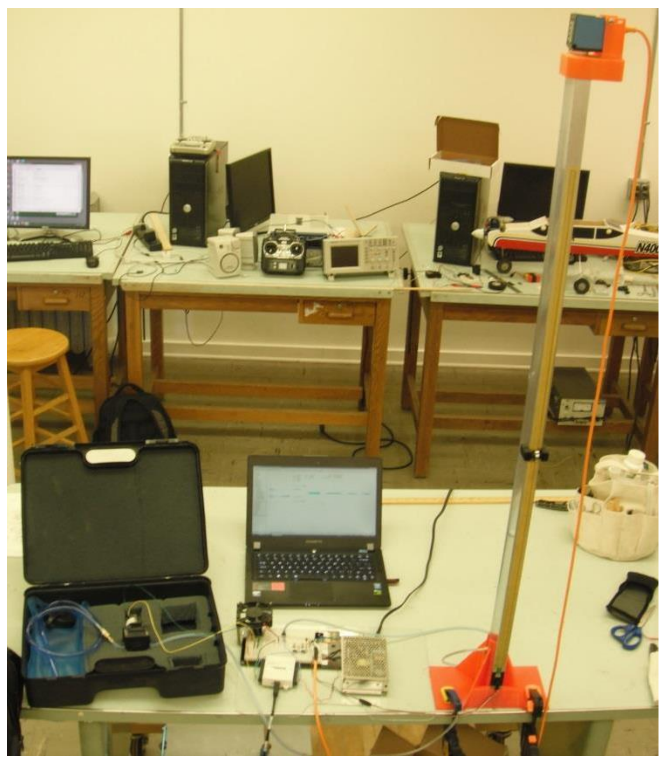
Fall 2014 – Spring 2015



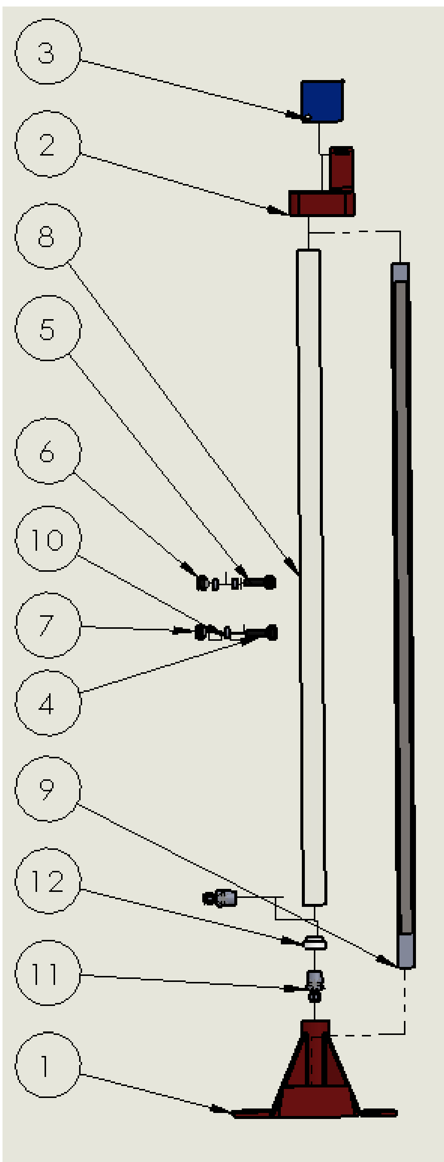
Dedicated to Martha:

When a man loves a woman

And a woman loves a horse

And a man loves a woman while riding a horse

Things get awfully complicated.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	tank base5	3D Printed	1
2	laser mount2	3D Printed	1
3	laser	Sick Sensor	1
4	right-slide1-half	3D Printed	1
5	right-slide1-half2	3D Printed	1
6	left-slide2half	3D Printed	1
7	left-slide2half2	3D Printed	1
8	Tube	1"x 40" Clear PVC Tube	1
9	membrane resistor	1meter Resistor	1
10	Bearing	.25" ID Bearing	3
11	straight fitting	BRASS TUBE FITTING - STRAIGHT - #B-400-1-8	2
12	end fitting	Custom Fitting to Tube & Base	1

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Introduction:

The purpose of this project was to give students taking Process Instrumentation and Control (INC) a visual demonstration of a PID control system. This system was to implement an automatic water level control loop that would be based on a user defined external set point. For example, if the water tank was empty, and the user wanted the water level to go to the top, the system would do this automatically based on the users set point.

The system must be able to fill a 507 mL cylinder in under a minute. The water pump must be able to pump forwards, backwards, and maintain a water level. Setting the point to fill or drain to must be set by the user and must be part of the physical system. All components must be able to be able to be carried by one person easily. The power supply to be used will need to be able to run all components in the system. All components that must be purchased will need to be within the budget of $300.

Deliverables:

- Must be a tank system with transducers for closed loop control of water level
- *VisSim 8.0* software will be used to implement the control algorithm
- *Solid Edge* software must be used to model the physical aspects of the system and to create the files necessary for 3D printing on a *Makerbot* 3D printer
- Final report must be in .docx format for *Microsoft Word*
- Final project must be completed by the beginning of Texpo

Design:

The block diagram, shown in Figure 1, is the overview of the control loop for the system. The power supply in Block 1 powers the membrane potentiometer voltage divider in Block 2, the motor control chip circuit in Block 4, the pressure transducer in Block 7, and the laser level sensor in Block 8. The data acquisition system (DAQ) in Block 3 takes inputs from the set point from Block 2, the pressure transducer from Block 7, and the laser sensor overflow protection in Block 8. These input signals are then interpreted by the *VisSim* simulation, which in turn runs the control algorithm and outputs a pulse width modulated (PWM) digital signal to the motor control chip circuit in Block 4. This signal is then transferred to the peristaltic water pump in Block 5, which then pumps water into the cylinder, or process, in Block 6. The pressure transducer in Block 7 senses the water level by transducing water pressure into a voltage signal which is then transferred to the DAQ and in turn to the controller. Block 8 implements the overflow protection via a laser range sensor, which will sense the level at which overflow is imminent and override the system by shutting it off.

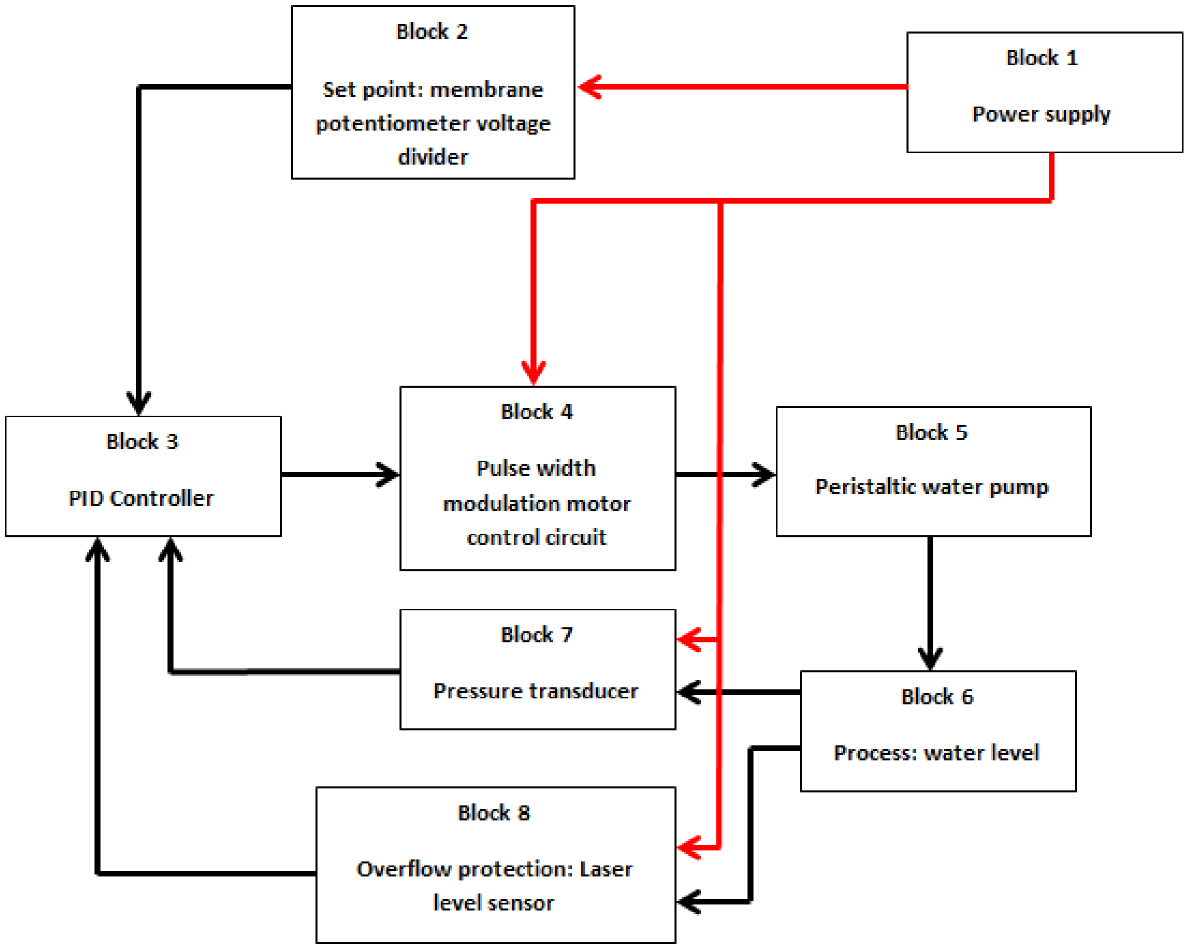


Figure 1: Block Diagram of Closed Loop Control System

Simulation:

Before testing the actual system, a *VisSim 8.0* simulation was used to model the system. This is shown in Figure 2. All components were made into transfer functions implemented in each block of the control loop. The system response time would be would be under a minute, according to the simulation.

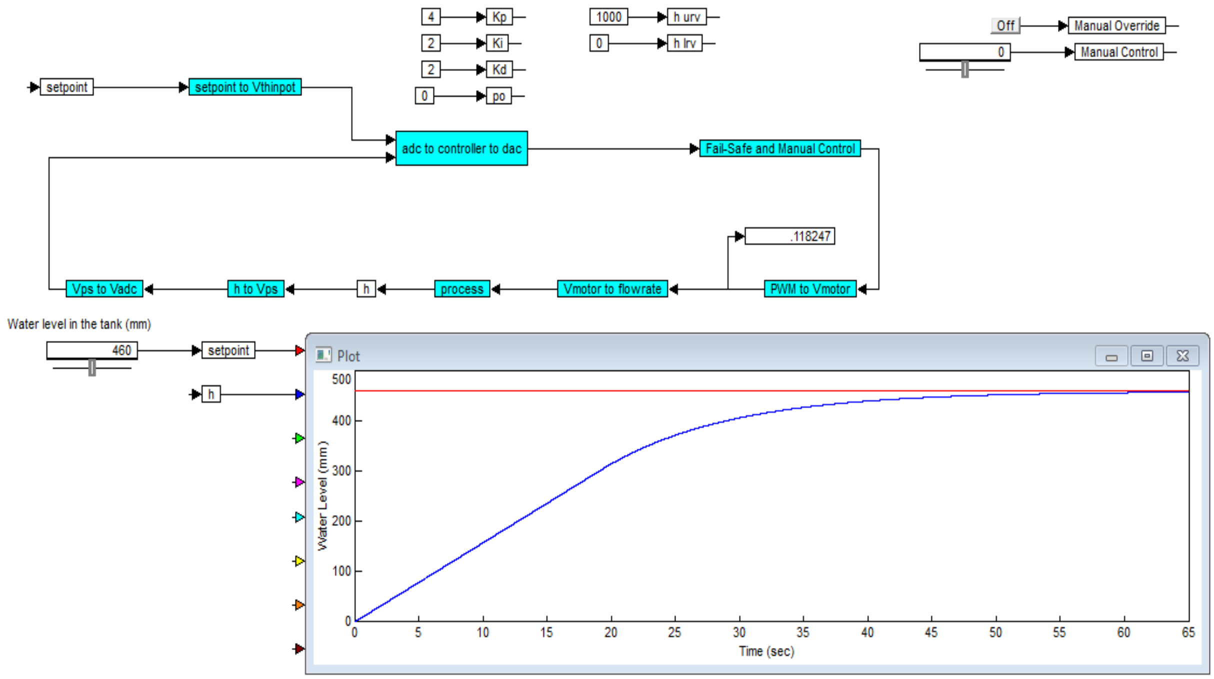


Figure 2: *VisSim* Control System Simulation

Block 1: Power Supply

The power supply chosen is a 60W supply that outputs +5V at 3A, +15V at 0.5A, -15V at 0.5A, and +24V at 1.25A. There was more than enough power available from this supply for all the components. The max power rating of the membrane potentiometer is 1W. The L293E motor driver chips dissipates 5W max power. The *Honeywell* pressure transducer only requires 18.4 mW of power maximum. The maximum power consumed by the laser sensor is 1.85 W. This adds up to 7.87 W, which is much less than the maximum output of the supply.

This supply was already available from the Electrical Engineering department and did not need to be purchased. There were three commons, or zero volt reference ports, for the outputs. One each for the +5V, +24V, and +15V/-15V. These commons were bridged together in order to give a common 0V reference for all components powered by this supply.

Block 2: Membrane Potentiometer Voltage Divider Set point

A membrane potentiometer, pictured in Figure 3, was chosen to implement the set point. The *Spectra Symbol* SPL0751033%ST SoftPot was chosen because of affordability, durability, and its 1 m length. This was purchased for $24.39 from *Digikey*. The partial datasheet for the SoftPot is in Appendix A. The potentiometer was to be placed on a meter long plate of aluminum for structural integrity, as the membrane potentiometer is not stiff enough to stand on its own. The potentiometer had an adhesive tape on its back side, which was used to mount it on the aluminum plate. Membrane potentiometers change resistance based on where a pressure point is being applied anywhere on its range. This means a linear change in resistance, and therefore voltage, from the low-end to the top-end of this resistor. The power supply of Block 1 supplies 0V and 5V for the outer pins (1 and 3), while the output voltage, varying between 0V and 5V, is obtained from pin 2. The voltage output of the potentiometer would then go to the Controller, Block 3, which in turn would interpret where the water lever would be raised or lowered to. This particular potentiometer is accurate within +-3%, which means +-3 cm over the range of 1 m. As the water level range itself is one meter also.

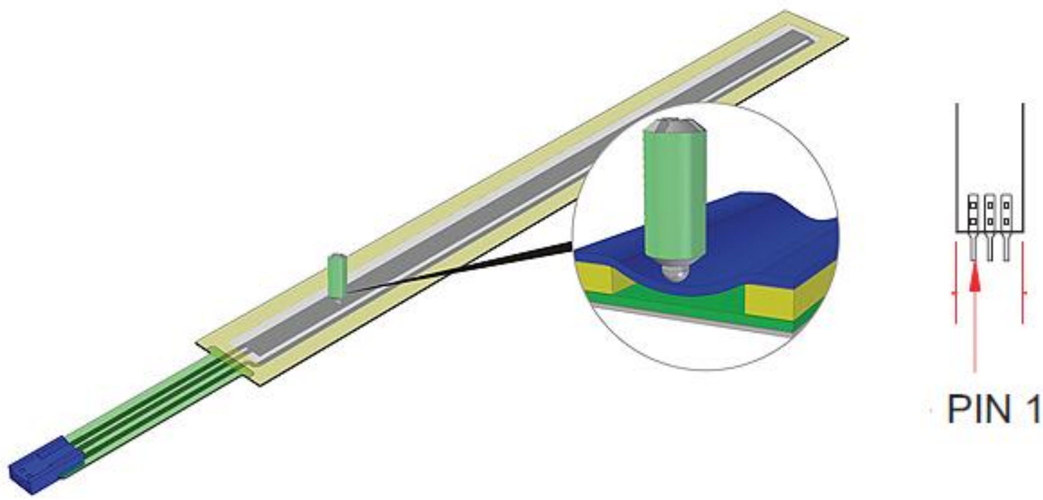
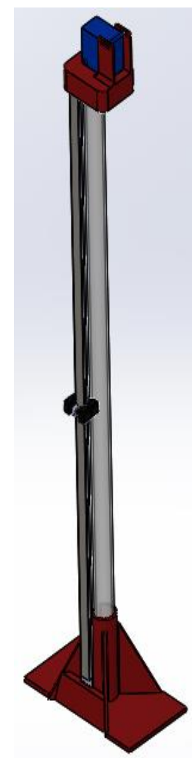


Figure 3: Membrane Potentiometer



In order to implement a pressure point that could be moved up or down and hold its position, a slider mechanism, Figure 4, was designed in *Solid Edge* and printed via the *Makerbot* 3D printer. This uses three skateboard wheel bearings to allow it to slide up and down. One bearing would roll on the membrane potentiometer on the front, and two on the back of the aluminum plate. The pressure can be varied on the slider mechanism by pressing it together or pulling it apart.

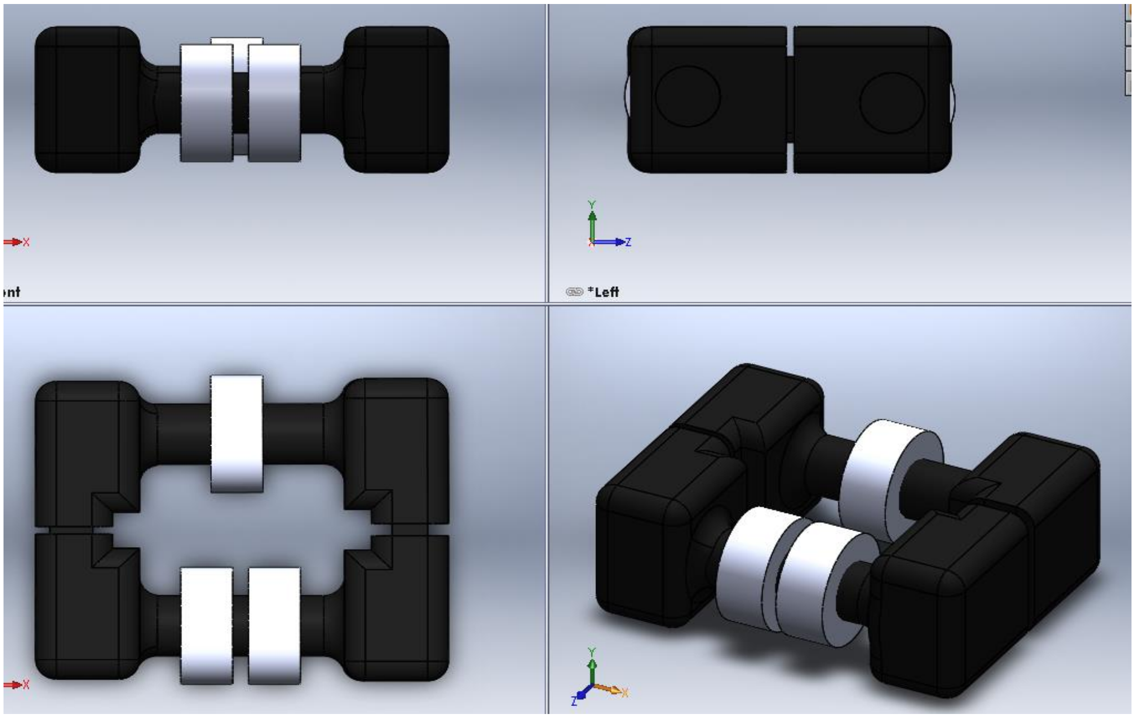


Figure 4: Slider Mechanism

Block 3: PID Controller and *VisSim* Program

The PID controller for this project is programed into *VisSim 8.0*. A *National Instruments* NI USB6009 DAQ is used to feed the data from the system to the controller. The inputs of the membrane potentiometer set-point, the pressure transducer, and the laser sensor overflow protection are sent to the DAQ. After which the controller adjusts the water level by controlling the motor, through a PWM signal that is output though the DAQ. The DAQ used was selected due to its availability at the Electrical Engineering department. It is a 14 bit DAQ, with a percent resolution of 0.0061%. This is more than accurate enough for this application.

The program used to control the DAQ and implement the control algorithm is *VisSim 8.0*. *VisSim* is available on almost all Montana Tech computers and is very user friendly. It is also heavily used in INC. Figure 5 shows the control algorithm simulation in *VisSim*.

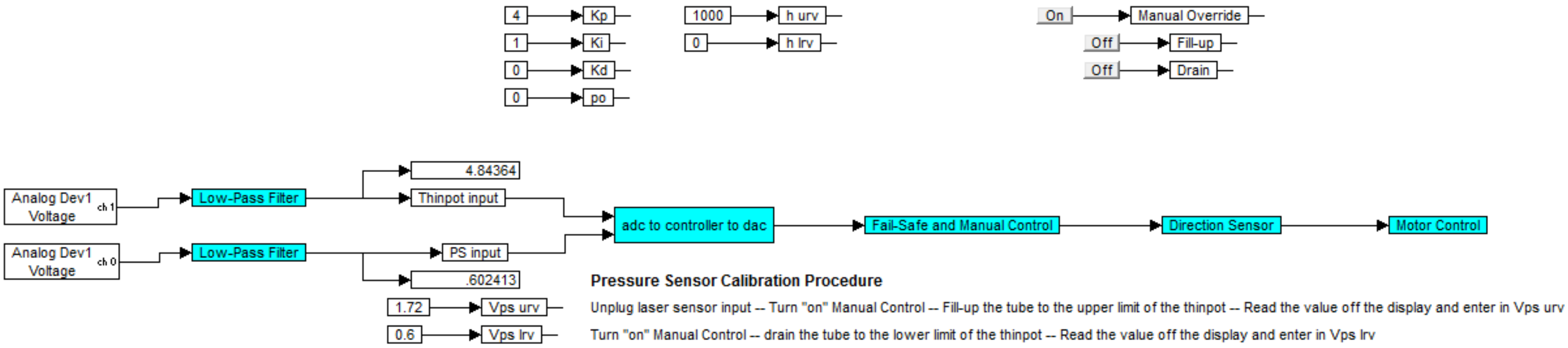


Figure 5: *VisSim* PID Control Loop

The controller block takes inputs from the membrane potentiometer voltage divider circuit in Block 2, the pressure transducer circuit in Block 7, and the laser sensor overflow protection circuit in Block 8. These three inputs are the basis of the control of the PWM circuit in Block 4.

Block 4: Pulse Width Modulation Motor Control

PWM was used to run the motor by varying the duty cycle of a 12V square wave. The chip used is the *ST Microelectronics* L293E push-pull four channel motor driver. This chip was also supplied by Montana Tech. The circuit diagram for the PWM motor control is pictured in Figure 6. The datasheet for the L293E is in Appendix A.

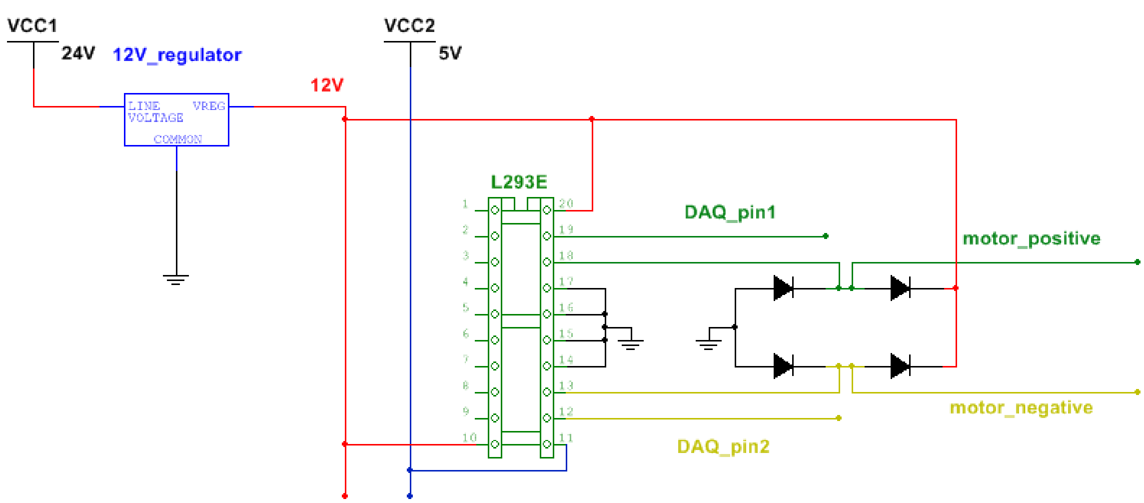


Figure 6: Motor Control Circuit

Block 5: Peristaltic Water Pump

A peristaltic pump was chosen to drain and fill the water tank. Peristaltic pumps are unique in the fact that they can run in both directions and also hold the water level if stopped. A flexible silicon line runs inside of the pump, while rollers push fluid by pinching off the line. The PWM in Block 4 controls the rate at which the motor controlling the pump moves. The water pump in turn controls the water level, or process, in Block 6 by pulling water from a water reservoir located in the suitcase. The principle of how a peristaltic pump works is shown in Figure 7. The pump chosen is the *Boxer* 15002 DC motor driven pump, purchased from *Clark Solutions* for $171.23. This is also shown in Figure 7. This has a maximum flow rate of 529.2 ml/min which should have been able to fill the 507 mL water tube in about 57 seconds. This datasheet for the 15002 is in Appendix A.

Transfer function for peristaltic pump: FR = 16(ml/min*V)Vin (flow rate = 16*voltage in)

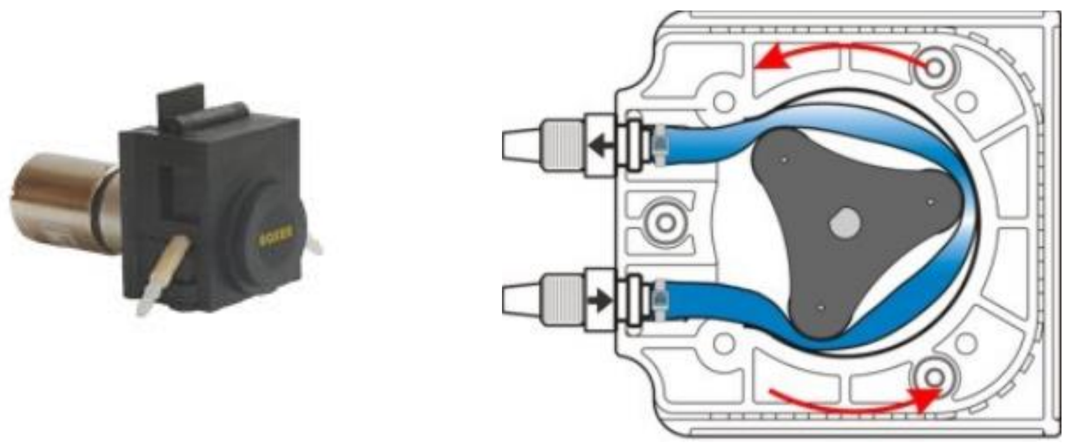


Figure 7: Boxer 15002 Peristaltic Pump with Operation Example

Block 6: Process

The process of water level is contained in a one meter long one inch diameter clear PVC pipe, purchased from ACE Hardware. A base to hold the tube was designed in Solid Edge and printed on the *Makerbot* 3D printer. The slide potentiometer and aluminum plate it's attached to is also fitted into this base. At the top there is another 3D printed bracket that holds the top of the aluminum plate, the top of the tube, and the Laser Level Sensor. These components are shown in Figure 8. The process of water filling or draining to a certain level is then interpreted in water pressure by the pressure sensor in Block 7. If the water level goes too high, the entire system will be overridden by the laser level sensor in Block 8. The *VisSim* transfer function for the water level process is shown in Figure 9. A picture of the water level reaching the set-point is shown in Figure 10.

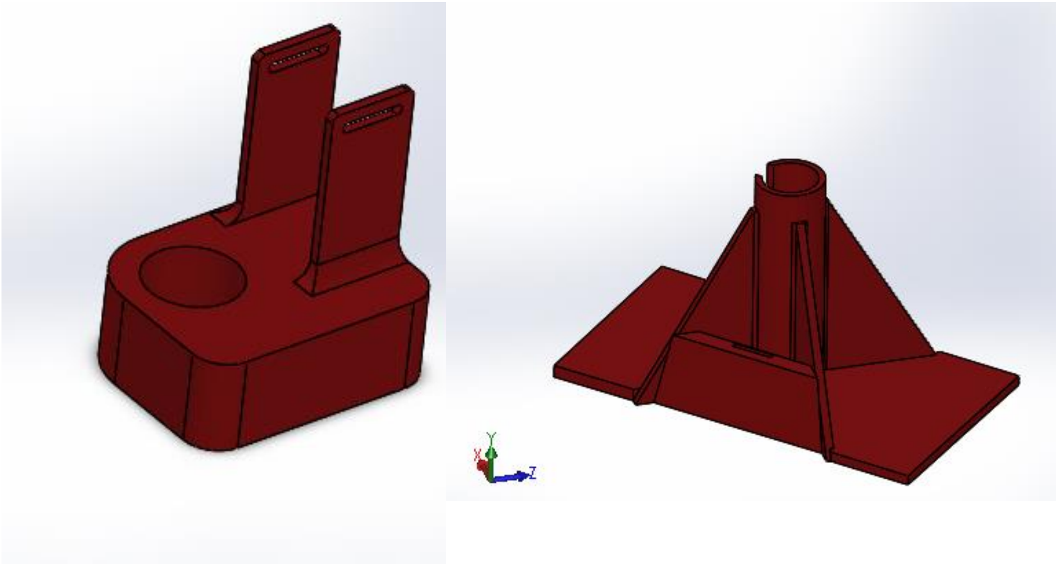


Figure 8: ***Solid Edge*** **3D Renderings of the Base and Top Bracket**

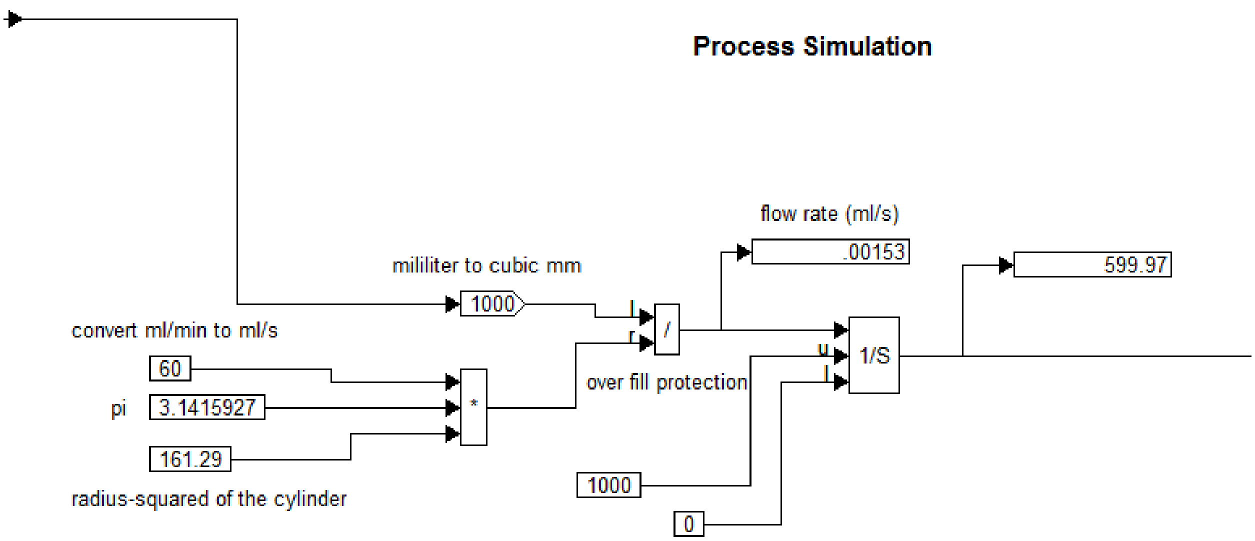


Figure 9: Process Transfer Function

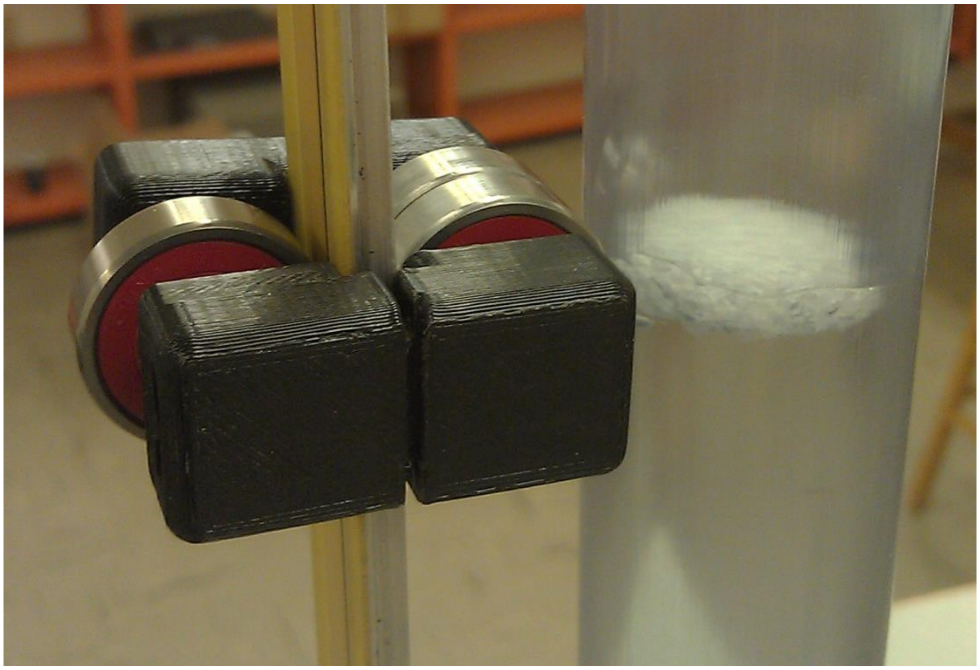


Figure 10: Water Level Reaching Set-Point

Block 7: Pressure Transducer

The pressure transducer chosen is the Honeywell SSCDANV005PGAA5 (datasheet in Appendix A). This sensor was chosen because the output was an analog 0.5V to 4.5V over its range of 0-5 psig. This allowed for excellent resolution and a linear output signal. This transducer provides feedback about the process to the controller in Block 3. This was purchased from Mouser Electronics for $45.66. The accuracy of this transducer is +-0.25%. Figure 11 shows the pressure transducer.

Pressure sensor transfer function: Vps = 0.005(V/mm)*H (pressure sensor voltage = 0.005 V/mm * height in mm)

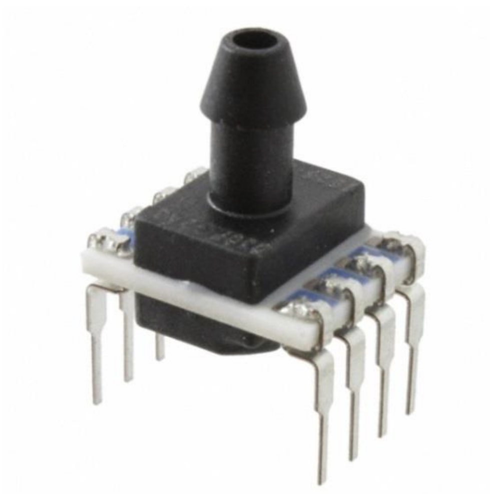


Figure 11: Honeywell SSC Series Pressure Transducer

Block 8: Laser Level Sensor Overflow Protection

The SICK DS50 laser level sensor is the instrument used for the overflow protection system. It outputs either logic 0, zero volts, or logic 1, five volts, at a user specified distances. Once the water level reaches that distance, threatening overflow, a function in the controller will override the rest of the system and shut off the water pump. The input circuit for the laser sensor to the DAQ, as well as the sensor itself, is pictured in Figure 12. This circuit takes the 12V output of the sensor and gains it to 5V. This pump was donated for the project by Montana Precision Products.

Transfer function of laser sensor: process = process * Q1'

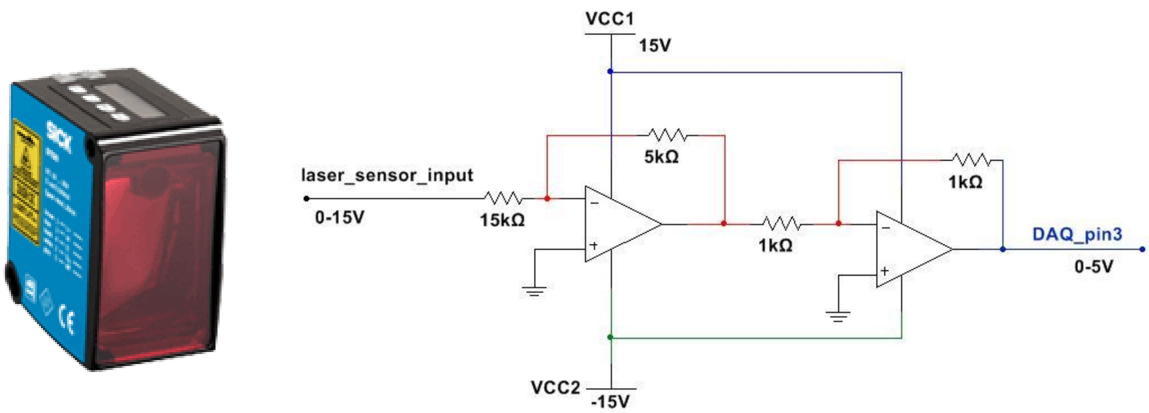


Figure 12: Laser Sensor and Input Circuit

Bill of Materials:

The following, Figure 13, is a list of materials bought for this project. Many components were already available within the Electrical Engineering department. Other components were purchased either online or at the local hardware store.

Mechanical Portion				
Component	**Description**	**Quantity**	**Price/component**	**Total**
Peristaltic pump	Flow rate: 700 ml/min inlet/outlet OD: 4.8mm	1	$171.23	$171.23
Tubing	ID: 4.8mm	1 m	$5.00	$5.00
Tubing barbs	OD: 4.8mm	2	$0.75	$1.50
Clear PVC Tube	ID:1" length: 36"	3 ft	$3.65	$10.95
Reservoir bladder	Capacity: 1 L	1	$6.92	$6.92
Level Sensor	SICK 200 laser level sensor	supplied	$0.00	$0.00
Mounting material	clear plastic sheet	supplied	$0.00	$0.00
Fasteners	Screws, bolts, nuts, etc…	supplied	$0.00	$0.00

Electrical Portion				
Component	**Description**	**Quantity**	**Price/component**	**Total**
Power Supply		supplied	$0.00	$0.00
DAQ	Acquisition system	supplied	$0.00	$0.00
Resistors		supplied	$0.00	$0.00
PWM Motor Driver Chip	PWM	supplied	$0.00	$0.00
Pressure Transducer	Honeywell	1	$45.66	$45.66
Membrane Potentiometer	Spectra Symbol	1	$24.39	$24.39
			Grand Total	$265.65

Figure 11: Bill of Materials

Data and Results:

The design requirement of filling up from empty in under a minute could not be accomplished. In reality, it takes almost three minutes. Realistically the peristaltic pumps flow rate is much slower than expected, about 179 mL/min as compared to the claimed 529 mL/min. This is partially due to the 12V voltage regulator only putting out 11.2V. Max flow rate is attained at 12V. Also, it is possible the max flow rate when the company tested it is 529 mL/min. Perhaps the average flow rate would be different. This max rate may not account for a load on the pump and may be during an ideal scenario too. The slow flow rate was an unfortunate set back, and this late in the game there is nothing left to do. Also, the maximum flow rate is probably calculated with ideal conditions, i.e. no load on the motor. The silicon tubing and the weight of the water may have put a load on the motor and slowed it down.

Controller tuning has taken many iterations through trial and error. A root locus design would have been very helpful, but it was determined that manual tuning would be a faster process. Figure 12 shows the un-tuned response. Notice the overshoot and oscillation. This is with complete PID control. The proportional gain KP was set to 12, integral gain KI set to 8, and derivative gain KD set to 2.

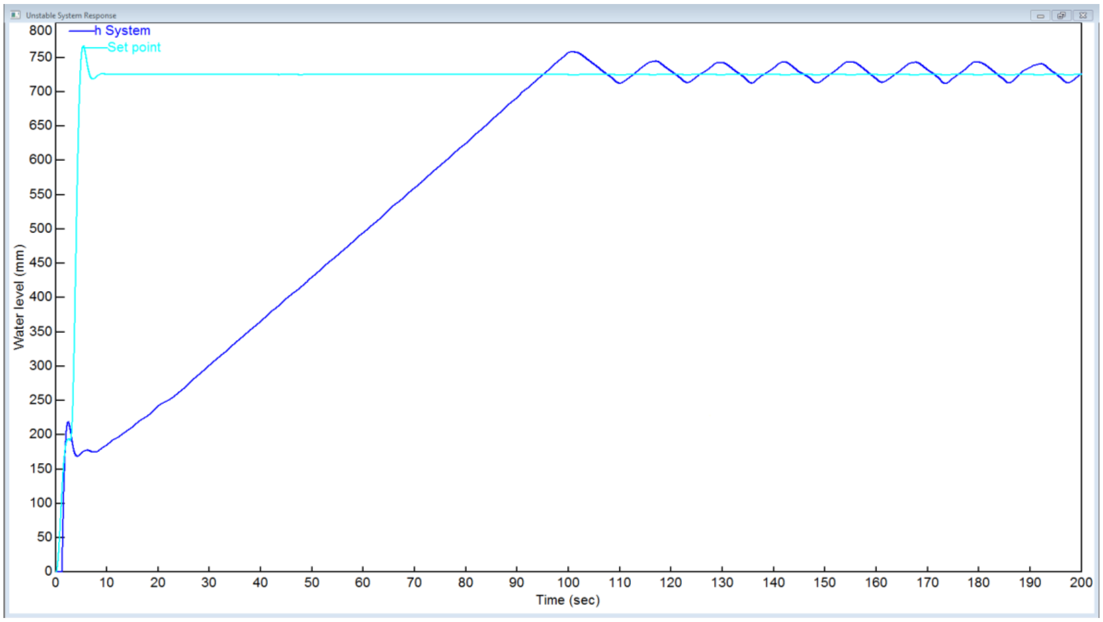


Figure 12: Un-Tuned System Response

This tune was not going to work. Tuning started with setting KI and KD to zero, and setting KP to 1. KP was increased until the system showed a better response. The system did not oscillate, but steady-state error was quite evident. KI was set to 0.5 and this eliminated steady state error, but the response was not fast enough. KI was then increased by increments of 0.1 until a fast enough response was achieved. KD was left at zero because adding KD did not affect the response. The tuned response is shown in Figure 13. KD was set to 4 and KI was set to 1.

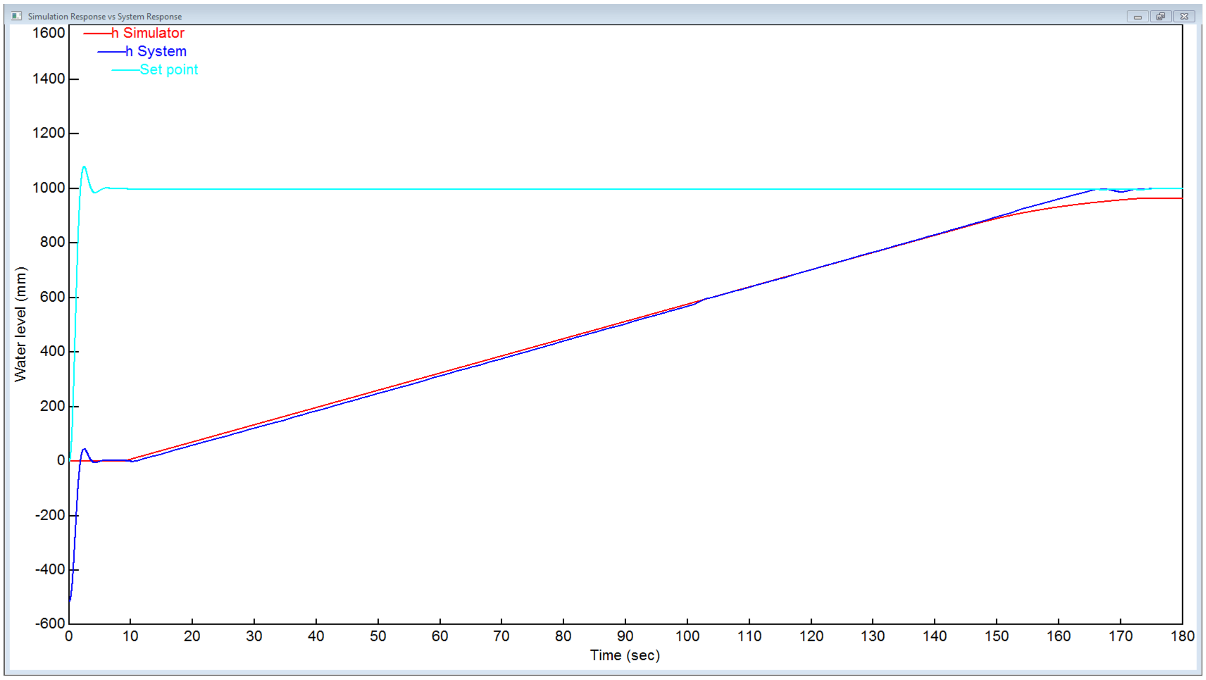


Figure 13: Tuned Controller Response

One problem with the pressure transducer is the fact that you have you have to calibrate it before each use. These instructions are in Appendix A. Also, the pressure transducers signal ended up having a lot of noise. This is due to the vibrations transmitted by the peristaltic pump creating pressure spikes each time a roller pushes an amount of water into the tube. A built in filter function in *VisSim* was used to create a third-order Butterworth low pass filter to smooth out the signal from the transducer. The filtered signal did have windup, but smoothed out nicely. The filtered signal versus unfiltered signal is shown in a *Matlab* plot in Figure 13. The transfer function for the filter is shown in Figure 14.

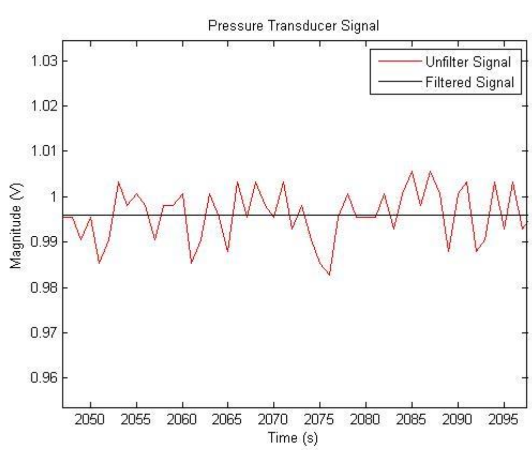


Figure 13: Matlab Plot of Filtered vs. Unfiltered Pressure Transducer Signal

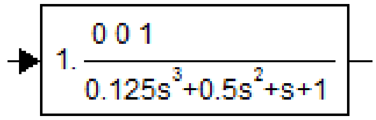


Figure 14: Third Order Butterworth Low-Pass Filter

Summary:

This project will make an excellent visual demonstration of a PID control system for INC students. This implements automatic water level control fairly well, and demonstrates a control loop. The system did not fill in under a minute. If a faster water pump could be purchased this would most likely fix this problem. Perhaps a root locus design would aid in a faster response as well. The pressure transducer is far too sensitive to environmental factors and the calibration process is time consuming. If time and budget weren't a factor, perhaps a less sensitive pressure sensor could be purchased. It would also be nice to implement water level feedback via an analog laser range sensor. This would be able to implement overflow protection and feedback, therefore eliminating the pressure sensor entirely.

Appendix A

Setup Procedure

Setting Voltage Range of the Pressure Transducer:

Use the manual control setting in *VisSim* to move the water level to the upper and lower bounds to determine the voltage output readings of the pressure transducer at these points. Enter the voltage at the upper range point into “Vps urv” and enter the lower range voltage into “Vps lrv”. These directions are reiterated in The *VisSim* PID control program.

-Data Sheets:

Spectra Symbol SPL0751033%ST:

spectrasymbol

SoftPot SP

Features

- Linear Position Sensor
- IP65 Dust Proof, Water Proof (Intense Spray)
- Polyester Substrate
- 3M Pressure Sensitive Adhesive (PSA)
- Upon Request
  - Male or Female Nicomatic or Berg Connectors
  - Wiper of 1-3 Newton Force to Actuate Part
  - Higher Temperature and/or Contactless Options Available

Mechanical Specifications

-Life Cycle: >1 million
-Height: ≤0.51mm (0.020")
-Actuation Force (with a 10mm wide active cavity):
-40°C 0.8 to 1.8 N
-25°C 0.8 to 1.8 N
+23°C 0.6 to 1.5 N
+50°C 0.6 to 1.5 N

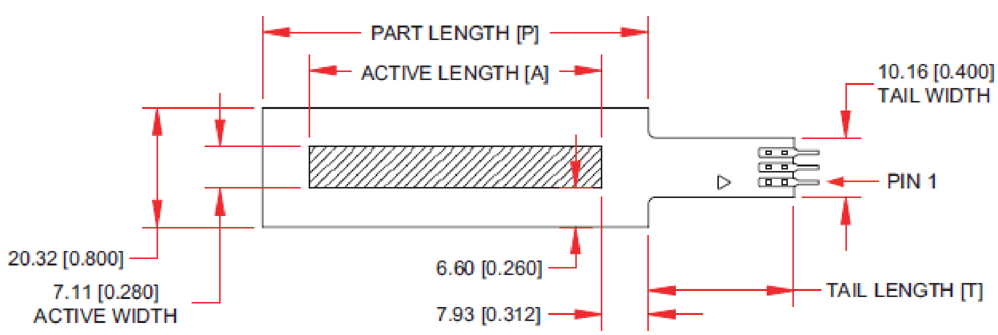
Environmental Specifications

-Operating Temperature: -40°C to +50°C
-Humidity: No affect @ 95% RH, 4hrs 50°C
-IP Rating of Active Area: IP65

Electrical Specifications

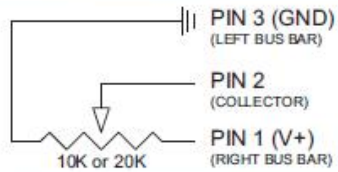
-Resistance - Standard: 10k Ohms (lengths >300mm = 20k Ohms)
-Resistance - Custom: 1k to 100k Ohms
-Resistance Tolerance: ±20%
-Effective Electrical Travel: 8 to 2000mm
-Linearity (Independent): Linear ±1% & 3%
Rotary ±3% & 5%
-Repeatability: No hysteresis, but with any wiper looseness some hysteresis will occur
-Power Rating (depending on size, varies with length and temperature): 1 Watt max. @ 25°C, ≤0.5 Watt recommended
-Resolution: Analog output theoretically infinite; affected by variation of contact wiper surface area.
-Dielectric Value: No affect @ 500VAC for 1 minute

Dimensional Diagram - Stock Linear SoftPot

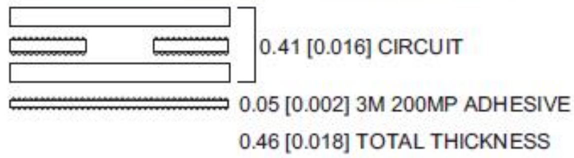


A	12.50mm 0.492"	25.00mm 0.984"	50.00mm 1.969"	100.00mm 3.937"	150.00mm 5.906"	170.00mm 6.693"	200.00mm 7.874"	300.00mm 11.811"	400.00mm 15.748"	500.00mm 19.685"	750.00mm 29.528"	1000.00mm 39.370"
P	28.36mm 1.117"	40.86mm 1.609"	65.86mm 2.593"	115.86mm 4.562"	165.86mm 6.531"	185.86mm 7.318"	215.86mm 8.499"	315.86mm 12.436"	415.86mm 16.373"	515.86mm 20.310"	765.86mm 30.153"	1015.86mm 39.995"
T	12.70mm 0.500"		24.89mm 0.980"									

Electrical Schematic



Material Cross-Section



How to Order - Linear SoftPots

SP — L — 0050 — 103 — 3% — ST

Series
- SP = SoftPot

Model
- L = Linear

Active Length
- 0012 = 12,5mm
- 0025 = 25mm
- 0050 = 50mm
- 0100 = 100mm
- 0150 = 150mm
- 0170 = 170mm
- 0200 = 200mm
- 0300 = 300mm
- 0400 = 400mm
- 0500 = 500mm
- 0750 = 750mm
- 1000 = 1000mm

Resistance
- Active Lengths ≤ 300mm: 103 = 10 KOhm
- Active Lengths > 300mm: 203 = 20 KOhm

Ind. Linearity
- 1% = ±1%
- 3% = ±3%

Connectors
- ST = Solder Tab
- MP = Male Pins
- RH = Receptacles w/Plain Housing
- RL = Receptacles w/Latch Housing
- RD = Receptacles w/Detent Housing
- B = FCI/Berg Clincher

Standard Connector Options


Crimpflex Solder Tab (ST)


Crimpflex Short Male Pins (MP)


Crimpflex Female Receptacles with a Plain Housing (RH)


Crimpflex Female Receptacles with a Latch Housing (RL)


Crimpflex Female Receptacles with a Detent Housing (RD)

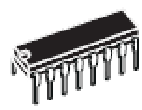

FCI/Berg Clincher (B)

ST Microelectronics L293E:

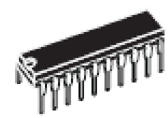
L293B
L293E

PUSH-PULL FOUR CHANNEL DRIVERS

- OUTPUT CURRENT 1A PER CHANNEL
- PEAK OUTPUT CURRENT 2A PER CHANNEL (non repetitive)
- INHIBIT FACILITY
- HIGH NOISE IMMUNITY
- SEPARATE LOGIC SUPPLY
- OVERTEMPERATURE PROTECTION



DIP16



POWERDIP(16+2+2)

ORDERING NUMBERS:

L293B L293E

DESCRIPTION

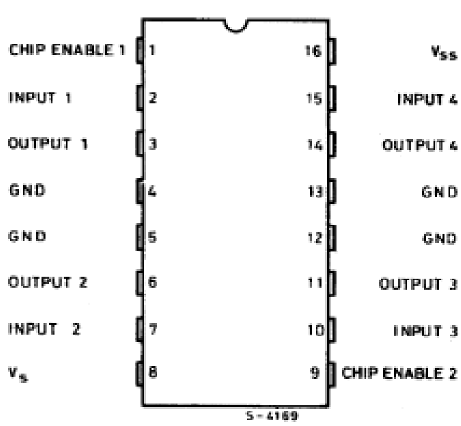
The L293B and L293E are quad push-pull drivers capable of delivering output currents to 1A per channel. Each channel is controlled by a TTL-compatible logic input and each pair of drivers (a full bridge) is equipped with an inhibit input which turns off all four transistors. A separate supply input is provided for the logic so that it may be run off a lower voltage to reduce dissipation.

Additionally, the L293E has external connection of sensing resistors, for switchmode control.

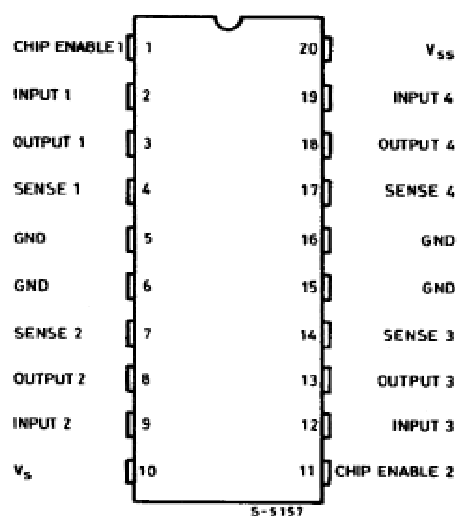
The L293B and L293E are package in 16 and 20-pin plastic DIPs respectively ; both use the four center pins to conduct heat to the printed circuit board.

PIN CONNECTION (Top view)

DIP16 - L293B

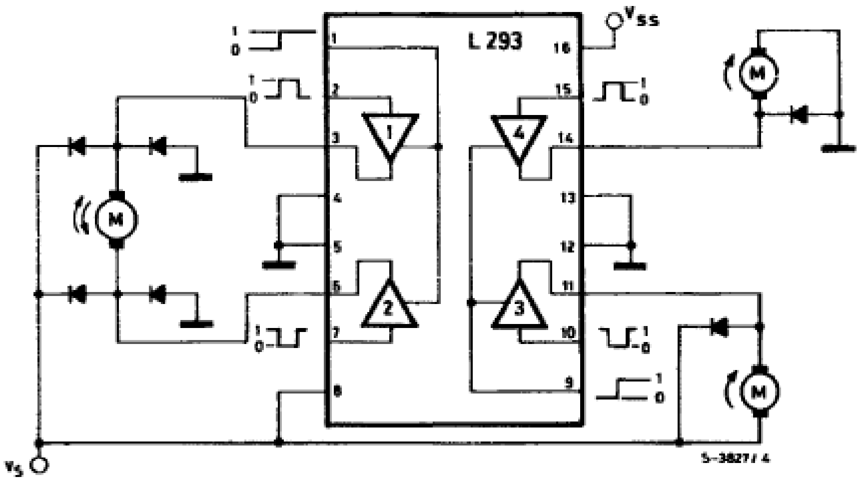


POWERDIP (16+2+2) - L293E

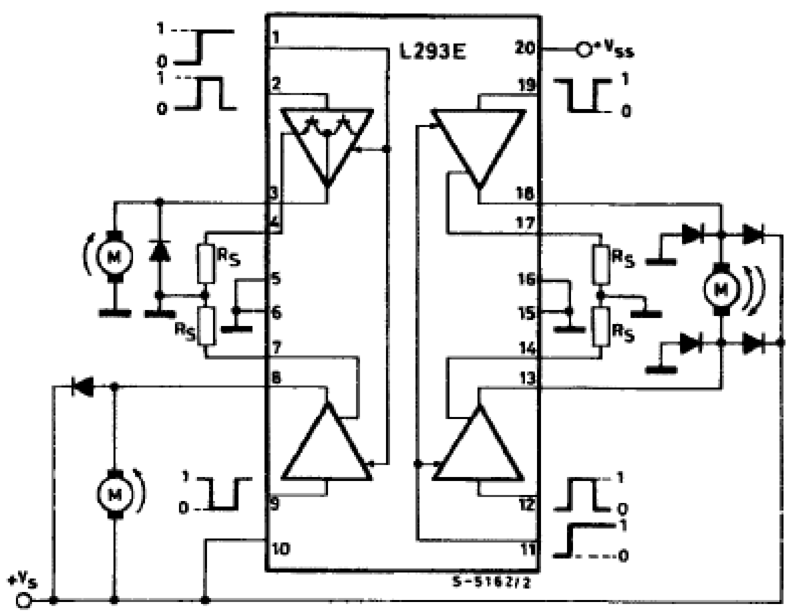


BLOCK DIAGRAMS

DIP16 - L293B



POWERDIP (16+2+2) - L293E

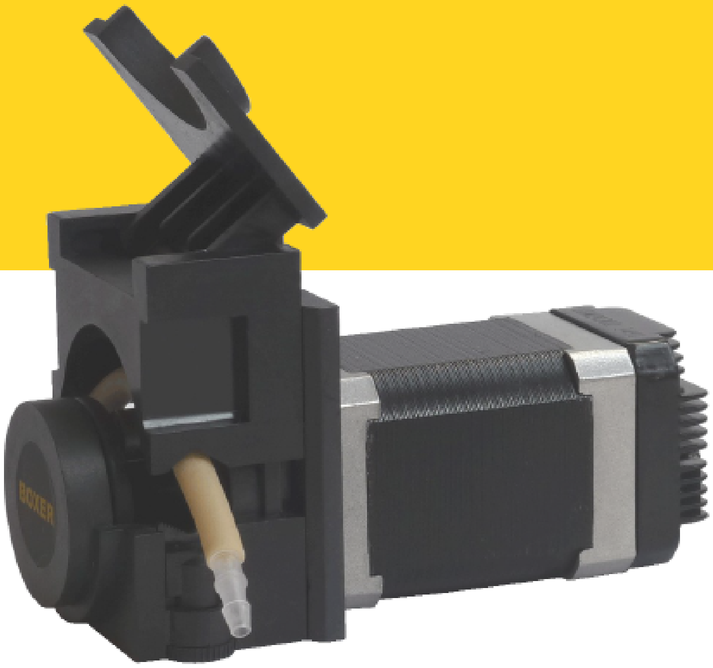


Boxer 15002:

uno. BOXER® PUMPS

BOXER 15000
Peristaltic Pump

DC, AC or Stepper Motor
oem peristaltic pumps
for accurate dispense
of liquids.
From 20µl to 700ml/min



- Clamshell design—easy tube change
- Clip-on pump head
- Continuous tube length
- 3 to 6 roller system
- Planetary gearbox on DC motor
- Stepper with integrated driver (optional)
- Choice of 4 different tube diameters
- Adjustable tube clips
- Suitable for continuous operation
- Anti tamper locking screw
- Front panel mounting
- No lubrication—no service
- Self priming
- CE marked

DC Motor:	6V DC-24V DC max 420rpm
AC Motor	230V 0r 110V max 40rpm*
Stepper Motor	24V 2A max 550rpm
Current at full speed (DC)	450mA
Max ambient operational temperature	50°C
Tubes	Santoprene, Pharmed, ED-Plex or Silicone
Max pressure	2 bar
Weight	402g (DC) / 409g(AC) / 694g(Stepper)
Life expectancy	>1000 hours (DC) >10000 (AC+Stepper)

Tube wall must be 1.6mm (1/16")
Use the following data to calculate your requested rotor speed:
Flow per 360° rotor revolution—3 roller rotor (4 roller rotor) 6 roller rotor

ID Ø0.51mm tube	23.19µl/rev (21.57µl/rev)20.87µl/rev
ID Ø1.6mm tube	175µl/rev (165µl/rev)148µl/rev
ID Ø2.4mm tube	415µl/rev (320µl/rev)163µl/rev
ID Ø3.2mm tube	650µl/rev (566µl/rev)466µl/rev
ID Ø4.8mm tube	1260µl/rev (1146µl/rev) 800µl/rev

Above figures for guidance only.
Note that flow rate is among others subject to rotor speed and tube age.
Various gear box ratios available upon request
subject to MOQ.

Honeywell SSCDANV005PGAA5:

Analog Operating Specifications

Table 5. Analog Operating Specifications

Characteristic	Min.	Typ.	Max.	Unit
Supply voltage (V_{supply}):[1, 2, 3]				
pressure ranges ≥60 mbar | 6 kPa | 1 psi:				
3.3 Vdc	3.0	3.3	3.6	Vdc
5.0 Vdc	4.75	5.0	5.25	Vdc
pressure ranges ≤40 mbar | 4 kPa | 20 inH_2O:				
3.3 Vdc	3.27	3.3	3.33	Vdc
5.0 Vdc	4.95	5.0	5.05	Vdc
Supply current:				
3.3 Vdc	—	2.1	2.8	mA
5.0 Vdc	—	2.7	3.5	mA
Operating temperature range[4]	-40 [-40]	—	85 [185]	°C [°F]
Compensated temperature range[5]	-20 [-4]	—	85 [185]	°C [°F]
Startup time (power up to data ready)	—	—	5	ms
Response time	—	1	—	ms
Clipping limit:				
upper	—	—	97.5	%Vsupply
lower	2.5	—	—	%Vsupply
Accuracy[6]	—	—	±0.25	%FSS BFSL[8]
Output resolution	0.03	—	—	%FSS
Orientation sensitivity (±1 g):[7, 9]				
pressure ranges ≤40 mbar | 4 kPa | 20 inH_2O	—	±0.1	—	%FSS[8]
pressure ranges ≤2.5 mbar | 250 Pa | 1 inH_2O	—	±0.2	—	%FSS[8]

[1]Sensors are either 3.3 Vdc or 5.0 Vdc based on the catalog listing selected.

[2]Ratiometricity of the sensor (the ability of the device output to scale to the supply voltage) is achieved within the specified operating voltage.

[3]The sensor is not reverse polarity protected. Incorrect application of supply voltage or ground to the wrong pin may cause electrical failure.

[4]Operating temperature range: The temperature range over which the sensor will produce an output proportional to pressure.

[5]Compensated temperature range: The temperature range over which the sensor will produce an output proportional to pressure within the specified performance limits.

[6]Accuracy: The maximum deviation in output from a Best Fit Straight Line (BFSL) fitted to the output measured over the pressure range at 25 °C [77 °F]. Includes all errors due to pressure non-linearity, pressure hysteresis, and non-repeatability.

[7]Orientation sensitivity: The maximum change in offset of the sensor due to a change in position or orientation relative to Earth's gravitational field.

[8]Full Scale Span (FSS): The algebraic difference between the output signal measured at the maximum (Pmax.) and minimum (Pmin.) limits of the pressure range. (See Figure 4 for ranges.)

[9]Insignificant for pressure ranges above 40 mbar | 4 kPa | 20 inH_2O.

Nomenclature and Order Guide

Figure 4. Nomenclature and Order Guide

For example, **SSCDNNN150PGAA3** defines an SSC Series TruStability® Pressure Sensor, DIP package, NN pressure port, no special options, 150 psi gage pressure range, analog output type, 10% to 90% of Vsupply transfer function, 3.3 Vdc supply voltage.

SSC D NN N 150PG A A 3

Product Series

SSC	Standard Accuracy, Compensated/Amplified

Package

D	DIP (Dual Inline Pin)
M	SMT (Surface Mount Technology)
S	SIP (Single Inline Pin)

Pressure Port

DIP	SMT	SIP
NN No ports	**NN** No ports	**NN** No ports
—	—	**AA** Dual axial barbed ports, opposite sides
AN Single axial barbed port	**AN** Single axial barbed port	**AN** Single axial barbed port
LN Single axial barbless port	**LN** Single axial barbless port	**LN** Single axial barbless port
—	—	**FF** Fastener mount, dual axial barbed ports, opposite sides
—	—	**FN** Fastener mount, single axial barbed port
—	—	**GN** Ribbed fastener mount, single axial barbed port
—	—	**NB** Fastener mount, dual axial ports, same side
RN Single radial barbed port	**RN** Single radial barbed port	**RN** Single radial barbed port
RR Dual radial barbed ports, same side	**RR** Dual radial barbed ports, same side	**RR** Dual radial barbed ports, same side
DR Dual radial barbed ports, opposite sides	**DR** Dual radial barbed ports, opposite sides	**DR** Dual radial barbed ports, opposite sides
JN Single radial barbless port	**JN** Single radial barbless port	**JN** Single radial barbless port
JJ Dual radial barbless ports, same side	**JJ** Dual radial barbless ports, same side	**JJ** Dual radial barbless ports, same side
—	—	**HH** Fastener mount, dual radial barbed ports, same side
—	—	**HN** Fastener mount, single radial barbed port
—	—	**MN** Manifold mount, outer diameter seal
—	—	**SN** Manifold mount, inner diameter seal

Options[5, 6]

N	Dry gases only, no diagnostics
D	Dry gases only, diagnostics on
T	Liquid media on Port 1, no diagnostics
V	Liquid media on Port 1, diagnostics on

Supply Voltage

3	3.3 Vdc
5	5.0 Vdc

Transfer Function[1]

A	10% to 90% of Vsupply (analog), 2^{14} counts (digital)
B	5% to 95% of Vsupply (analog), 2^{14} counts (digital)
C	5% to 85% of Vsupply (analog), 2^{14} counts (digital)
F	4% to 94% of Vsupply (analog), 2^{14} counts (digital)

Output Type[2]

A	Analog	**4**	I^2C, Address 0x48
S	SPI	**5**	I^2C, Address 0x58
2	I^2C, Address 0x28	**6**	I^2C, Address 0x68
3	I^2C, Address 0x38	**7**	I^2C, Address 0x78

Pressure Range[3, 4]

±1.6 mbar to ±10 bar		±160 Pa to ±1 MPa		±0.5 inH_2O to ±150 psi	
Absolute		*Absolute*		*Absolute*	
001BA	0 bar to 1 bar	**100KA**	0 kPa to 100 kPa	**015PA**	0 psi to 15 psi
1.6BA	0 bar to 1.6 bar	**160KA**	0 kPa to 160 kPa	**030PA**	0 psi to 30 psi
2.5BA	0 bar to 2.5 bar	**250KA**	0 kPa to 250 kPa	**060PA**	0 psi to 60 psi
004BA	0 bar to 4 bar	**400KA**	0 kPa to 400 kPa	**100PA**	0 psi to 100 psi
006BA	0 bar to 6 bar	**600KA**	0 kPa to 600 kPa	**150PA**	0 psi to 150 psi
010BA	0 bar to 10 bar	**001GA**	0 kPa to 1 MPa		
Differential		*Differential*		*Differential*	
1.6MD	±1.6 mbar	**160LD**	±160 Pa	**0.5ND**	±0.5 inH_2O
2.5MD	±2.5 mbar	**250LD**	±250 Pa	**001ND**	±1 inH_2O
004MD	±4 mbar	**400LD**	±400 Pa	**002ND**	±2 inH_2O
006MD	±6 mbar	**600LD**	±600 Pa	**004ND**	±4 inH_2O
010MD	±10 mbar	**001KD**	±1 kPa	**005ND**	±5 inH_2O
016MD	±16 mbar	**1.6KD**	±1.6 kPa	**010ND**	±10 inH_2O
025MD	±25 mbar	**2.5KD**	±2.5 kPa	**020ND**	±20 inH_2O
040MD	±40 mbar	**004KD**	±4 kPa	**030ND**	±30 inH_2O
060MD	±60 mbar	**006KD**	±6 kPa	**001PD**	±1 psi
100MD	±100 mbar	**010KD**	±10 kPa	**005PD**	±5 psi
160MD	±160 mbar	**016KD**	±16 kPa	**015PD**	±15 psi
250MD	±250 mbar	**025KD**	±25 kPa	**030PD**	±30 psi
400MD	±400 mbar	**040KD**	±40 kPa	**060PD**	±60 psi
600MD	±600 mbar	**060KD**	±60 kPa		
001BD	±1 bar	**100KD**	±100 kPa		
1.6BD	±1.6 bar	**160KD**	±160 kPa		
2.5BD	±2.5 bar	**250KD**	±250 kPa		
004BD	±4 bar	**400KD**	±400 kPa		
Gage		*Gage*		*Gage*	
2.5MG	0 mbar to 2.5 mbar	**250LG**	0 Pa to 250 Pa	**001NG**	0 inH_2O to 1 inH_2O
004MG	0 mbar to 4 mbar	**400LG**	0 Pa to 400 Pa	**002NG**	0 inH_2O to 2 inH_2O
006MG	0 mbar to 6 mbar	**600LG**	0 Pa to 600 Pa	**004NG**	0 inH_2O to 4 inH_2O
010MG	0 mbar to 10 mbar	**001KG**	0 kPa to 1 kPa	**005NG**	0 inH_2O to 5 inH_2O
016MG	0 mbar to 16 mbar	**1.6KG**	0 kPa to 1.6 kPa	**010NG**	0 inH_2O to 10 inH_2O
025MG	0 mbar to 25 mbar	**2.5KG**	0 kPa to 2.5 kPa	**020NG**	0 inH_2O to 20 inH_2O
040MG	0 mbar to 40 mbar	**004KG**	0 kPa to 4 kPa	**030NG**	0 inH_2O to 30 inH_2O
060MG	0 mbar to 60 mbar	**006KG**	0 kPa to 6 kPa	**001PG**	0 psi to 1 psi
100MG	0 mbar to 100 mbar	**010KG**	0 kPa to 10 kPa	**005PG**	0 psi to 5 psi
160MG	0 mbar to 160 mbar	**016KG**	0 kPa to 16 kPa	**015PG**	0 psi to 15 psi
250MG	0 mbar to 250 mbar	**025KG**	0 kPa to 25 kPa	**030PG**	0 psi to 30 psi
400MG	0 bar to 400 mbar	**040KG**	0 kPa to 40 kPa	**060PG**	0 psi to 60 psi
600MG	0 bar to 600 mbar	**060KG**	0 kPa to 60 kPa	**100PG**	0 psi to 100 psi
001BG	0 bar to 1 bar	**100KG**	0 kPa to 100 kPa	**150PG**	0 psi to 150 psi
1.6BG	0 bar to 1.6 bar	**160KG**	0 kPa to 160 kPa		
2.5BG	0 bar to 2.5 bar	**250KG**	0 kPa to 250 kPa		
004BG	0 bar to 4 bar	**400KG**	0 kPa to 400 kPa		
006BG	0 bar to 6 bar	**600KG**	0 kPa to 600 kPa		
010BG	0 bar to 10 bar	**001GG**	0 kPa to 1 MPa		

[1] The transfer function limits define the output of the sensor at a given pressure input. By specifying Pmin. and Pmax., the output at Pmin. and Pmax., the complete transfer function of the sensor is defined. See the graphical representations of the transfer function in Figure 2. For other available transfer functions contact Honeywell Customer Service.

[2] SPI output function is not available in SIP package.

[3] Custom pressure ranges are available. Contact Honeywell Customer Service for more information.

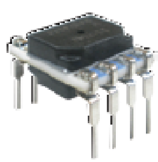
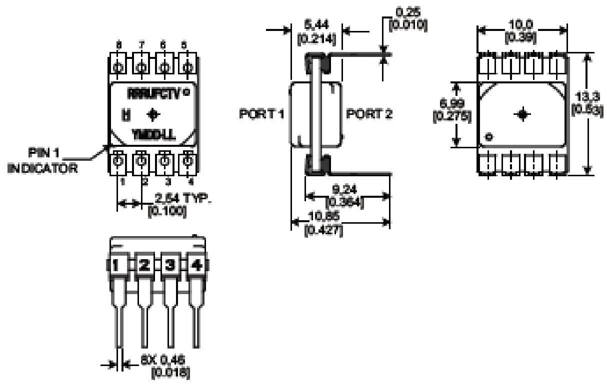
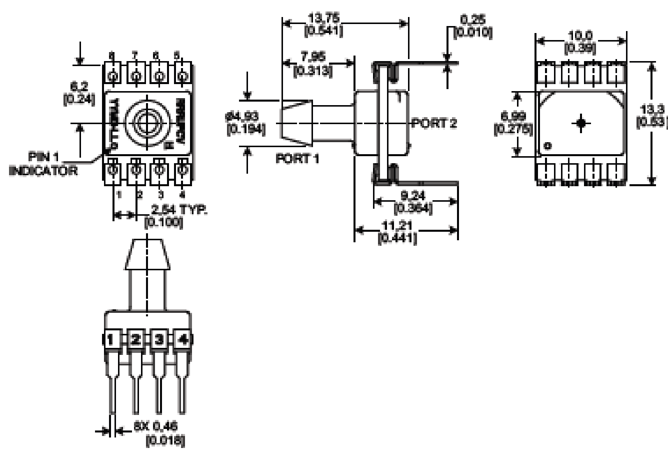
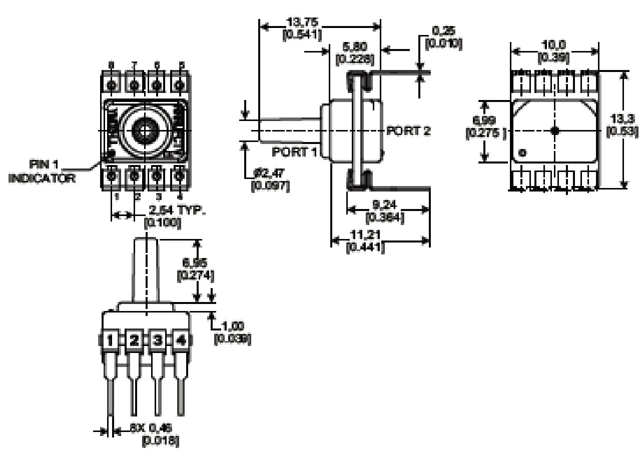
[4] See the explanation of sensor pressure types in Table 4.

[5] See the CAUTION in this document.

[6] Options T and V are only available on pressure ranges ±60 mbar to ±10 bar | ±6 kPa to ±1 MPa | ±1 psi to ±150 psi.

Dimensional Drawings
DIP Packages

Figure 6. DIP Package Dimensional Drawings (For reference only: mm [in].)

<table>
<tr><th colspan="2">Dimensions</th></tr>
<tr><td>DIP NN: No ports
</td><td>
</td></tr>
<tr><td>DIP AN: Single axial barbed port
</td><td>
</td></tr>
<tr><td>DIP LN: Single axial barbless port
</td><td>
</td></tr>
</table>

SICK DS50:

SICK
Sensor Intelligence.

Mid range distance sensors Dx50, DS50

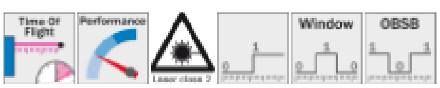
Model Name > DS50-P1112
Part No. > 1047402

At a glance

- HDDM™ technology provides the best reliability, safety to ambient light and price/performance ratio
- Reliable detection up to 10 m
- High switching repeatability (2.5 mm)
- Two discrete outputs with up to 50 Hz switching frequency
- Three switching modes: “Distance to Object,” “Window” or “Object Between Sensor and Background” - detect any object
- Immune to cross talk for use with multiple sensors
- Superior background suppression

Your benefits

- Precise detection at a safe distance reduces scrap and increases throughput
- Immune to any type of ambient light - allows for use in optically challenging environments
- Widest temperature range allows for outdoor use without additional cooling or heating
- Intuitive setup via display or remote teach reduces installation time and costs
- Red light and an optional alignment bracket reduces installation time
- Metal housing withstands harsh environments, saving replacement costs
- Dx50 product family is based on a common platform, which offers multiple performance levels, making it easy to accommodate future changes
- Low investment costs and high performance guarantee short return on investment



CE CDRH

Performance

Measurement range:	200 mm ... 10,000 mm, 90 % remision 200 mm ... 4,000 mm, 6 % remission 200 mm ... 6,000 mm, 18 % remission
Resolution [1]:	1 mm
Repeatability [2], [3], [4]:	5 mm ⁄ 2.5 mm
Accuracy [5], [6]:	± 10 mm
Response time [7]:	10 ms ⁄ 50 ms
Switching frequency [8]:	50 Hz ⁄ 10 Hz
Light source:	Laser, red
Typ. light spot size (distance):	15 mm x 15 mm (10 m)

Additional function:	Switch-off display Unique measurement value Set switching mode: Distance to object (DtO)/Window (Wnd)/Object between sensor and background (ObSB) Teach-in of switching output Set moving average: fast/slow Set hysteresis Crosstalk safety Teach-in of switching outputs Lock user interface Reset to factory default Multifunctional input: laser off/external teach/inactive Switching output invertible
Laser class:	2 (EN 60825-1) [9]
Laser service life (MTTF at 25 °C):	100,000 h

[1) 5)] Related to distance value on the display [2)] Equivalent to 1 σ [3)] 6 % ... 90 % remission [4) 7) 8)] Dependent on the set average: fast/slow [6)] 90 % remision [9)]

Wavelength: 658 nm; max. output: 180 mW; pulse duration: 5 ns; pulse repetition rate: 1/200

Interfaces

Output type::	2 x PNP (100 mA) [1) 2)]
Hysteresis:	1 mm ... 9,999 mm
Multifunctional input (MF) [3)]; [4)]:	1 x

[1)] Output Q short-circuit protected [2)] PNP: HIGH = V_S - (< 2.5 V)/LOW = 0 V [3)] Response time ≤ 60 ms [4)] PNP: HIGH = V_S/ LOW = ≤ 2.5 V

Mechanics/electronics

Supply voltage Vs [1)]:	DC 10 V ... 30 V
Ripple [2)]:	≤ 5 Vpp
Power consumption [3)]:	≤ 1.85 W
Initialization time:	≤ 350 ms
Warm-up time:	≤ 15 min
Housing material:	Die-cast zinc housing (ZNAL4CU1) acrylic glass (PMMA)
Connection type:	Male connector, M12, 5-pin
Indication:	2 x LED, LC display
Weight:	200 g

[1)] Limit values, reverse-polarity protected, operation in short-circuit protected network: max. 8 A [2)] May not fall short of or exceed V_S tolerances [3)] Without load

Ambient data

Enclosure rating:	IP 65
Protection class:	III
Ambient temperature:	Operation: -30 ... +65 °C, Storage: -40 ... +75 °C
Max. rel. humidity (not condensing):	≤ 95 %
Vibration resistance:	EN 60068-2-6/EN 60068-2-64
Shock resistance:	EN 60068-2-27
Typ. ambient light safety:	40 klx