PRIMARY DEVELOPER: Glenn Wisniewski – HFC Industrial Trainer
Wes Bye – Mechatronics SME

Mechapracticum Capstone Outline

Capstone Project: Build

Topic: Capstone Project: Build

Estimated completion time: 160 hours.

Purpose:

This Mechapracticum is intended to enable the participant to demonstrate hands-on proficiency, using the training gained in this course of study, to safely implement a typical automation application, described in this document, that the Mechatronic Technician would expect to encounter in nearly any manufacturing facility.

Instructional Outcomes:

The participant will demonstrate the abilities to:

- Recognize situations, conditions, practices or material uses that may present actual or potential damage or injury to personnel, equipment, property, or the environment, and to act to communicate and resolve any unsafe condition or circumstance before proceeding.
- Design and draw electrical and pneumatic schematic diagrams that address the needs of a specific application.
- Design an electrical interface to connect a linear motion potentiometer to an analog input on a programmable logic controller.
- Design a mechanical detail or details to complete an automated mechanical device.
- Machine or fabricate a mechanical detail in order to complete an automated mechanical system.
- Design a ladder logic program to direct the operation of an automated mechanical system.
- Assemble mechanical, electrical and pneumatic details and components to create an automated mechanical system.
- Layout, drill, taps, assemble and wire an electrical control panel, terminal box and operator pushbutton station.
- Interconnect the various electrical devices on an automated mechanical system to the electrical control panel.
- Perform initial electrical and pneumatic power application to an automated mechanical system, verifying proper power consumption and correct interconnections of electrical and pneumatic devices and presetting actuators at an initial safe speed.
- Access programming software on a computer, establish communications between the computer and the programmable logic controller, and download the ladder logic program from the computer to the controller.
- Methodically verify that the program satisfies the needs of the automated mechanical system, editing the ladder logic program as needed.

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- Accurately document and annotate the elements and logic flow of the ladder logic program.
- Troubleshoot introduced faults in the ladder logic program or on the automated mechanical system.
- Establish Ethernet communications between the controller and a central control system.
- Design, program and troubleshoot product flow and status reporting on a network.
- Reporting/Documentation…
- Perform orderly decommissioning/disassembly and disposition of reusable machine components and the disposal or recycling of obsolete or consumable material.

Instructions to Participants

Electrical Design

- The participant must prepare an electrical schematic using ANSI/ISO/IEC symbols and control panel layout drawings. Drawings may be CAD or hand rendered, but are expected to be accurate and legible.

Electronic Design

- The participant must design an electronic circuit to interface a 10,000 Ohm linear motion potentiometer, operating from the 24VDC control circuit voltage, to supply a 0 to 10 Volt input signal to the analog input of the programmable controller. The schematic of this design must be included on the electrical design drawings.

Fluid Power Design

- The participant must prepare a pneumatic schematic using ANSI/ISO symbols and calculate air CFM consumption. Electrical devices related to each cylinder should be included and referenced back to the electrical drawing.

Mechanical Design

- The participant must prepare a working drawing of one of the mechanical details required for operation of the system.

Machining

- The participant must machine or fabricate a mechanical detail necessary for the operation of the system.

Electronic Fabrication

- The participant must assemble an interface circuit on a prototyping perforated circuit board using proper soldering techniques and connect a 10,000 Ohm linear motion potentiometer. The circuit board will then be connected to the control system.

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Electrical Fabrication & Wiring

- A new control enclosure backplate will be presented to each participant. The participant must layout and drill and tap mounting holes in the backplate to accept the various control components, demonstrating basic planning, layout and drilling and tapping proficiency.
- The participant will assemble the components on the backplate and make all interconnecting wiring connections. Each wire shall be identified with wire markers.
- The participant will install and wire the pushbuttons and selector switch.
- The participant will demonstrate orderly wire routing practices when connecting external control devices and the terminals inside the pushbutton enclosure using strain relief wiring devices where wiring passes through the enclosure wall.
- The participant will route and connect the network wiring between the local PLC controller and the central controller.

Fluid Power Assembly

- The participant must select and assemble the pneumatic devices, fittings and tubing.

Programming

- The participant must design and download the ladder logic and network communications program to the PLC.

Troubleshooting

- After the participant has completed construction and startup, various electrical, mechanical and pneumatic faults and malfunctions will be introduced by the evaluator. The participant must troubleshoot to discover and repair the faults.

Presentation

- The participant must prepare and deliver a presentation about the project, describing the function and operation and detailing successes, shortcoming.

Decommissioning/disassembly

- The participant must disassemble all components, returning reusable items to storage and properly disposing of, or recycling, obsolete or consumable material.

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Scenario for the Build Project

A group of recirculating puck/pallet transfers, each with a probe station, is required for a multi-station part gauging and inspection operation. Each station will report production rates and pass/fail ratios via Ethernet to a central controller.

Parts are loaded and unloaded by the operator who then begins the transfer and probe operation with two cycle buttons.

The basic transfer components, and empty control and pushbutton enclosures, will be presented to the participant, who must assemble and connect all of the devices. The control enclosure and pushbutton/terminal box will have adequate holes pre-punched to accept cords connectors, pushbuttons, pilot lights and other wiring devices as necessary.

One or more mechanical details will be omitted requiring the participant to design and machine replacements.

The Start and Stop pushbuttons and the Power On pilot light will operate at 120VAC.

All pilot-duty controls (inductive proximity switches, photoelectric sensor, cycle touch switch) shall operate on 24VDC.These prescribed voltages will require the participant to demonstrate the knowledge and ability to work with multiple voltage sources and levels commonly found in the typical control system.

Network data reporting for the work stations shall be included for fault condition, part status and tracking, and production rate monitoring.

Sequence of Machine Operation

- Upon power and air application, all cylinders will move to the returned position.
- Pushing the RESET/HOME pushbutton will cause the pushers to initialize the puck/pallet locations
- Pushing the CYCLE INITIALIZE pushbutton will enable the palm buttons for operation
- The operator will load a part into the pallet at the load position and then simultaneously actuate both L.CYCLE AND R.CYCLE buttons. Two-hand anti-tiedown, anti-repeat logic programming must be employed.
- Pushers A through D will sequentially advance and return, advancing all pallets one position

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Capstone Project: Build

- After a transfer cycle, the probe will advance, and record a reading N seconds after probe motion ceases.
- Upon each transfer the recorded probe reading must be transferred by a shift register to follow each part to the unload station. Actual data or flag bits may be transferred.
- At the unload station, the data or flag bits must be decoded to light a HIGH, PASS, or LOW indicator light.
- This application will require the use of two-hand anti-tie down anti-repeat logic for the cycle buttons and shift register logic to track part status from the probe station to the unload station.

Part tracking logic for network communication between workstations will be required.
(specifics needed here)

Instructions to Evaluator:

A drawing and documents illustrating general system layout and functional requirements will be presented to the participant.

The participant will be required to design a detail or circuit, but must not necessarily be required to machine the part or build the circuit as designed. A defect in the design could subsequently hinder the participant during the remainder of the build. The evaluator must asses the design to determine if the part or circuit can be used without causing damage to other equipment.

The participant will be required to:

- Identify a blown fuse and its cause. (Faulty power supply, pinched cord, stray wire, sensor, etc.)
- Identify and replace defective switch or sensor
- Identify and replace a broken or open wire
- Identify and replace or substitute a defective PLC output.
- Identify and replace or substitute a defective PLC input.
- Identify and repair or replace a stuck valve
- Identify and repair or replace a defective cylinder
- Identify and repair plugged or leaking hoses and fittings
- Other TBD
- Some limited logic and network communications troubleshooting with this equipment will be required.

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Fault methodologies will be developed and documented to aid the evaluator in quickly inflicting the faults on the system. The evaluator should also "disturb," and possibly replace but not disable, other wiring and devices to visually camouflage actual faults from the participant.

At the end of the examination, the participant must disassemble the project and return reusable components to their respective storage containers.

The control enclosure backplate will be reused only for early training purposes. This is to prevent subsequent participants from relying on clues from previous screw hole locations when developing their own panel layout during the Capstone exercise.

Used hookup wire and pneumatic tubing will be placed in appropriate bins for reuse and recycling.

Sensor cords may be reused several times until they become too short or develop internal broken conductors.

Tools and Equipment

- Measuring tape
- Hammer
- Center punch
- Drills
- Taps
- Hacksaw
- Electric hand drill
- Wire cutters/strippers
- Multimeter
- Screwdrivers
- Allen wrenches
- End wrenches

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Control Elements

External:

- Power On pilot light
- Master Start pushbutton
- Master Stop pushbutton
- Step/ Run selector switch
- Home/Step Pushbutton
- Reset Pushbutton
- High Pilot Light
- Pass Pilot Light
- Low Pilot Light
- In Cycle Pilot Light
- 2 Cycle Pushbuttons
  - *Note: ordinary pushbuttons are used as a cost-saving measure, bearing mind that they would be ergonomically unsuitable for long-term production use due to the possibility of repetitive-stress injury.*
- 4 Pneumatic cylinders configured to push a line of puck/pallets in a rectangular path
  - Each cylinder will be equipped with a magnetic piston and advanced and returned position magnetic sensors
- Interconnecting wire and cords
- Linear Potentiometer coupled to a pneumatic cylinder in the probe station to monitor cylinder position, providing an analog signal to the PLC

Control Panel backplate mounted devices:

- Lockable Fusible Disconnect
- Control Fuse(s)
- 24V Power Supply
- PLC controller with DC discrete I/O, Analog input and Ethernet capability
- DIN Rail Terminal Strip
- Wireway
- Wire and wire markers
- Fuses and/or circuit breakers

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Pneumatic:

- Lockout Air Valve
- Filter
- Regulator
- 5 manifold-mounted Single-Solenoid Directional Valves.
- 2 Exhaust Mufflers
- 5 Cylinders
- Hose, tubing & fittings

A limited number of "defective" components must be prepared or "sacrificed" for troubleshooting purposes.

System power required

- Single-phase electricity,120VAC
- Compressed air.

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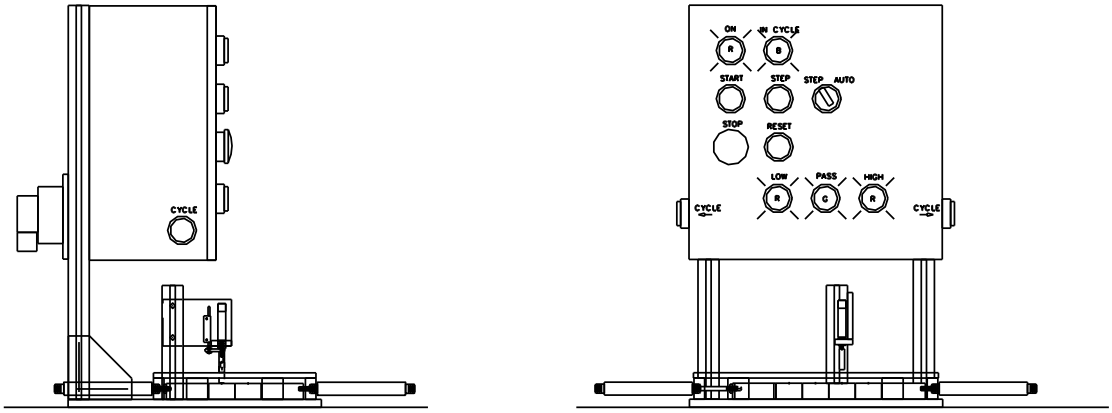
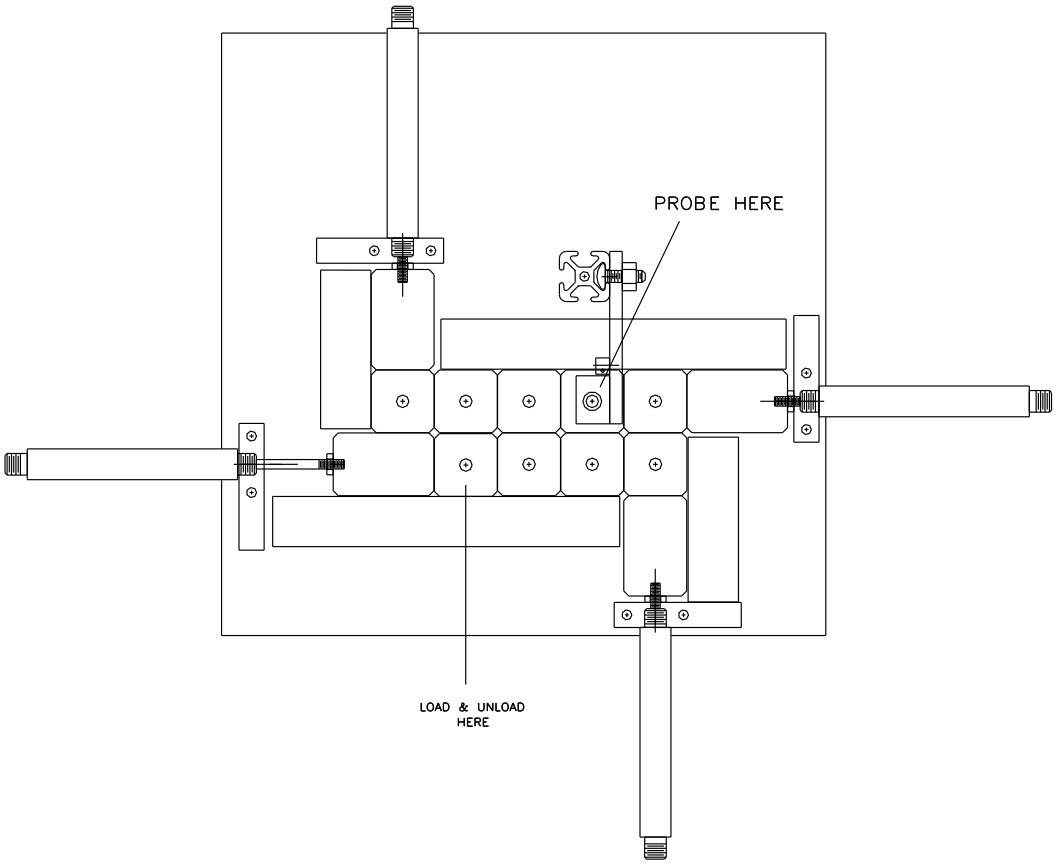
Reference - General Layout

This page to be provided to participant at the beginning of the exercise.



The student will mark sensor and valve locations, I/O assignments and actuator designations on the following drawing.



Mechapracticum Capstone Outline

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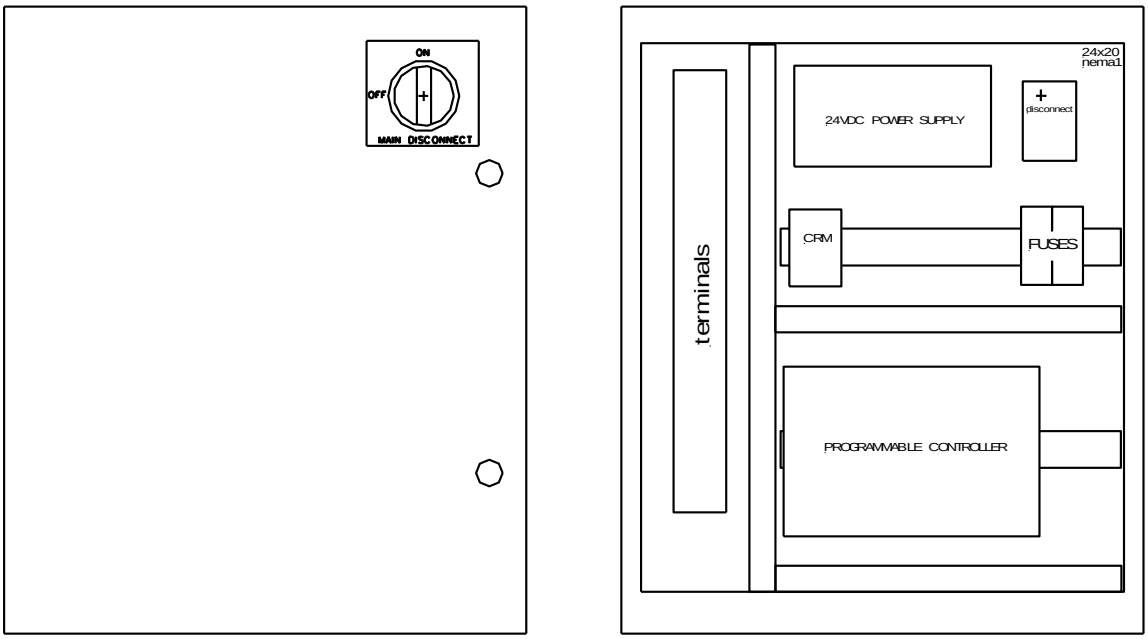
Reference Control Enclosure Layout

This drawing is for evaluator reference only and will not be shown to the participant.

The participant's layout need not be identical to this design, but must function in a substantially similar manner.

The through-the-door disconnect location on the backplate will be determined by the handle location in the door. All other device locations to be determined by the participant.



Mechapracticum Capstone Outline

Capstone Project: Build

Reference Electrical Schematic

This drawing is for evaluator reference only and will not be shown to the participant.
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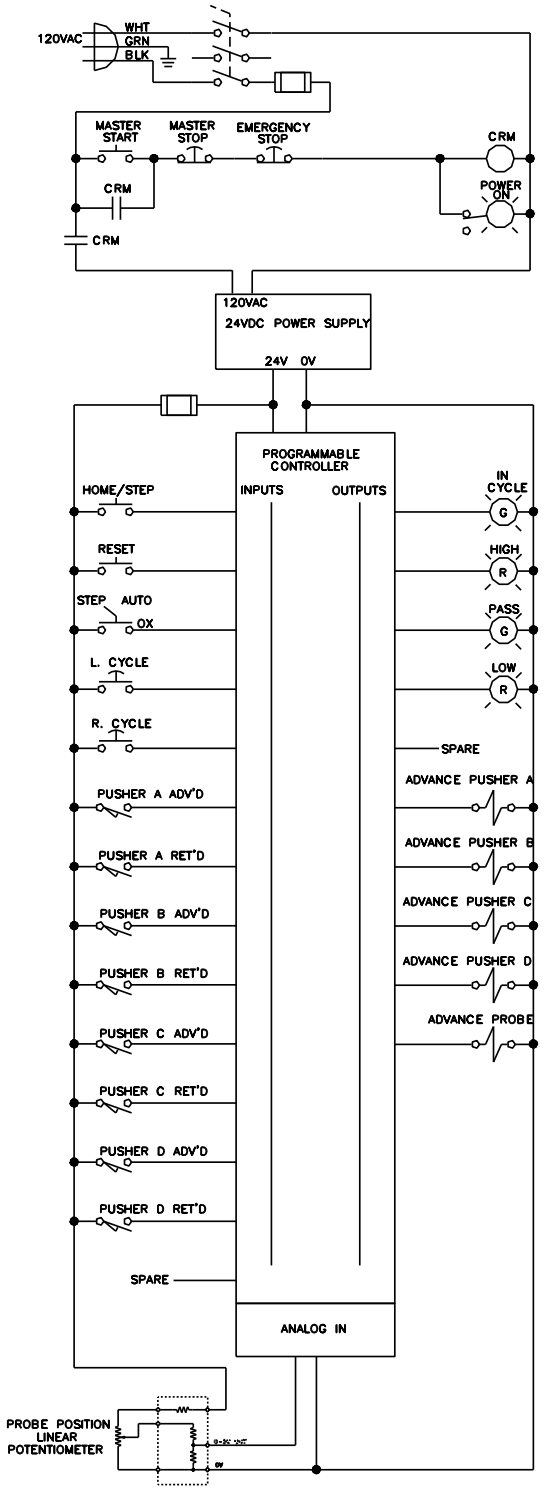

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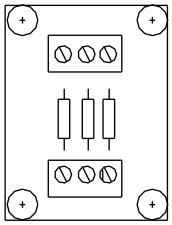
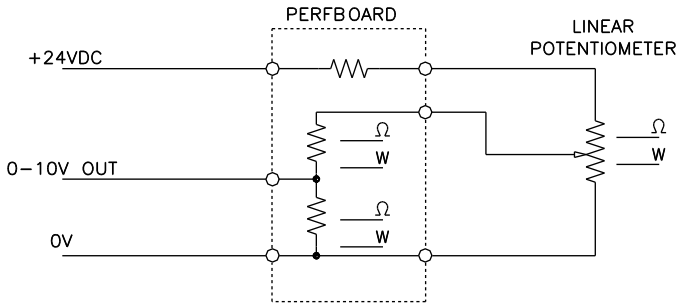
Reference Electronic Schematic – Linear Motion Potentiometer Interface

This drawing is for evaluator reference and will not be shown to the participant.





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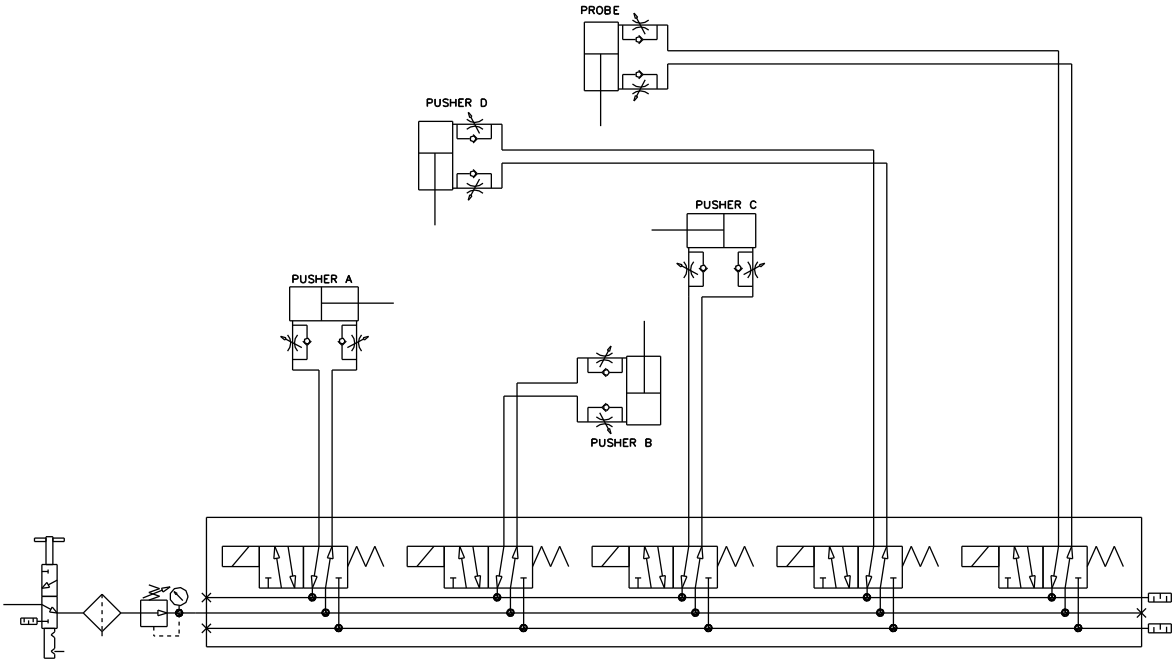
Reference Pneumatic Schematic

This drawing is for evaluator reference and will not be shown to the participant.



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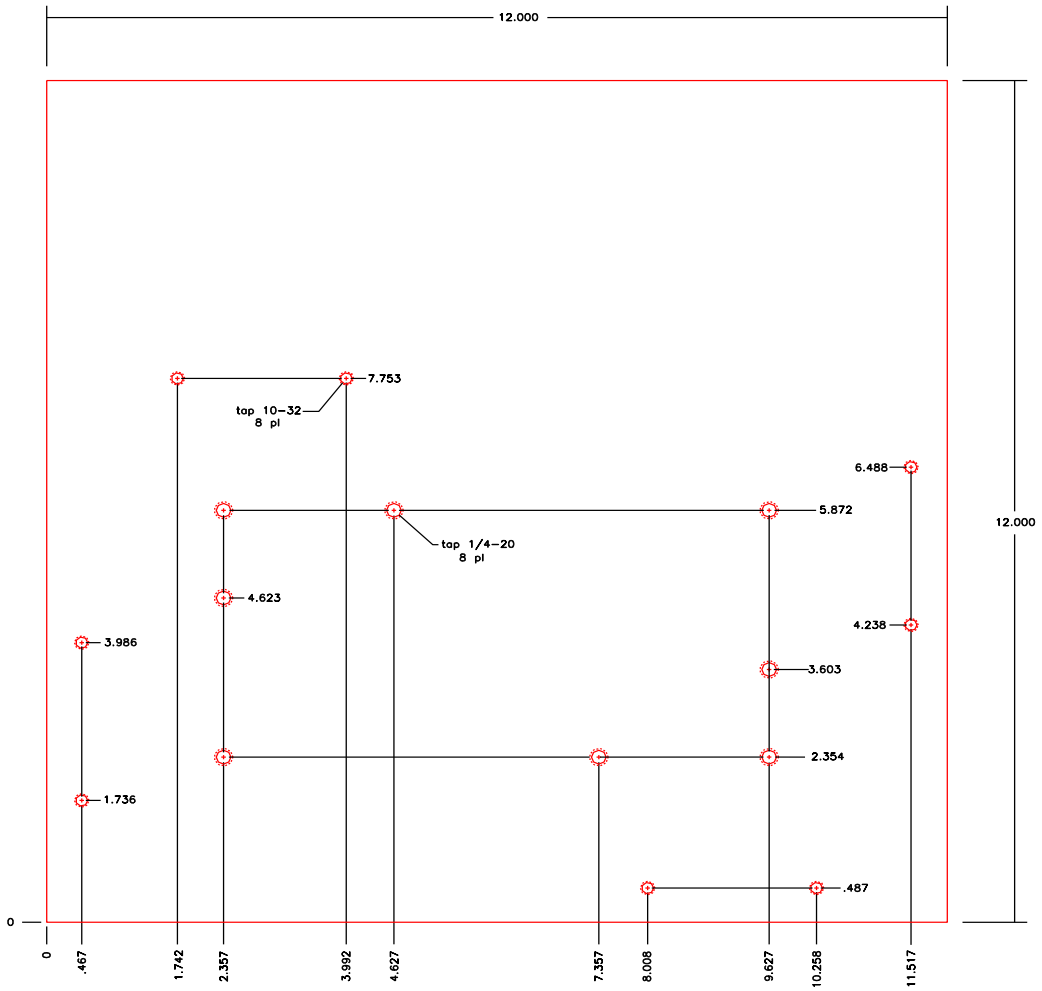
Reference – Transfer Detail



Note: additional holes needed for probe station
& terminal box mounting

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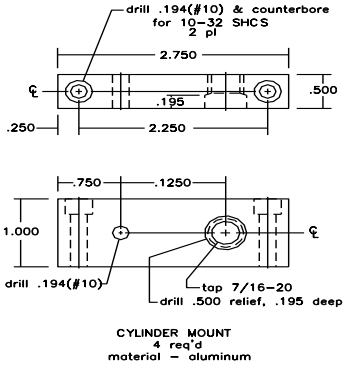
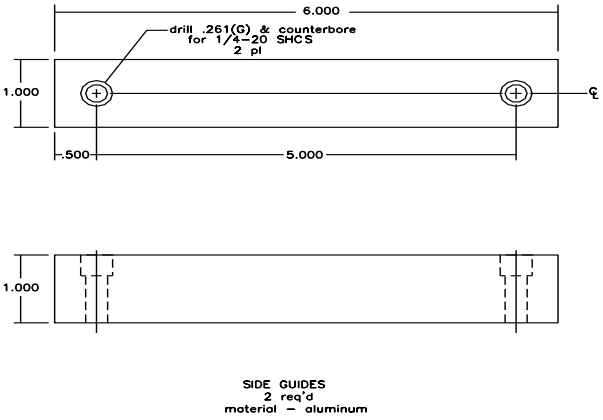
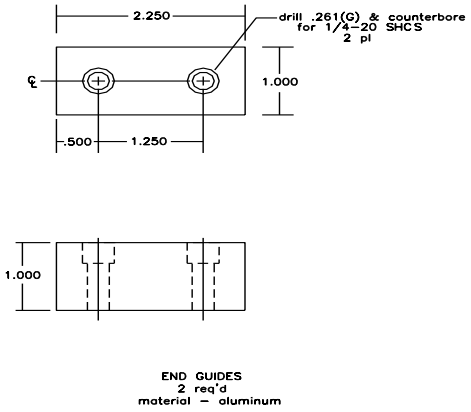
Reference – Transfer Details



CYLINDER MOUNT
4 req'd
material – aluminum



SIDE GUIDES
2 req'd
material – aluminum



END GUIDES
2 req'd
material – aluminum

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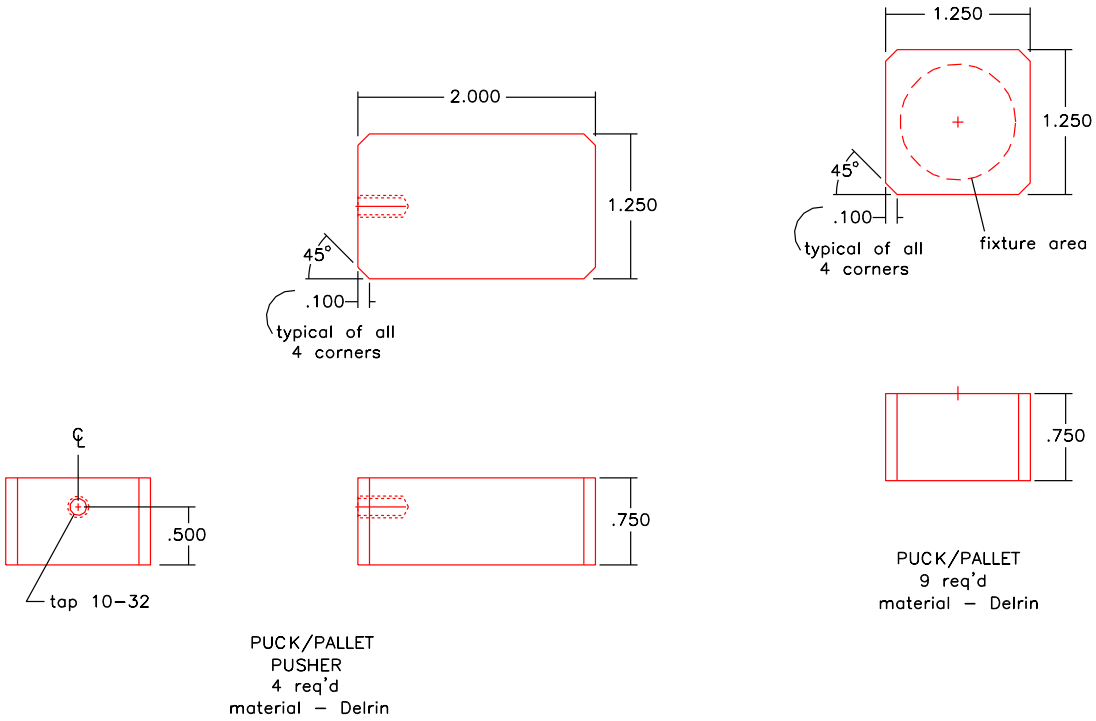
Reference – Transfer Details



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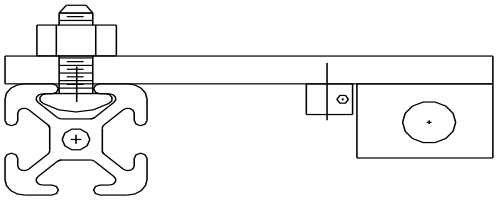
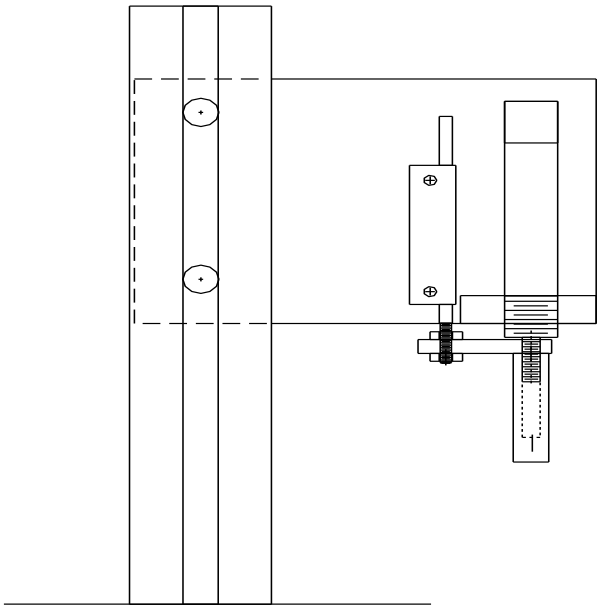
Reference – Probe Station Assembly

*****Detail design to be completed*****





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Bill of Materials:

	MAT2 Capstone Pallet/Puck Transfer & Probe			1/23/2015
Qty	Item Description	Source	Each	Total
1	NEMA 1 Control Enclosure, 20"H x 16"W x 7"D	McM #7561K49	$196.41	$ 196.41
1	Enclosure Panel, 17"H x 14.5"W	McM #7561K921	$ 22.81	$ 22.81
1	NEMA 1 Terminal Enclosure, 12H x 12W x 4D	McM #7561K38	$ 78.55	$ 78.55
1	Enclosure Panel, 10-1/4" x 10-1/4"	McM #7561K861	$ 11.98	$ 11.98
1	Disconnect	McM #7277K52	$ 62.97	$ 62.97
1	6' Wire Duct	Allied #70163162	$ 32.03	$ 32.03
1	6' Duct Cover	Allied #70162892	$ 4.88	$ 4.88
1	DIN Rail	Allied # 70169109	$ 5.47	$ 5.47
1	24VDC, 2.5A Power Supply	Allied #70211350	$163.73	$ 163.73
5	Fuse Block	McM #7641K36	$ 10.74	$ 53.70
1	Fuses, pk of 5	McM #7085K46	$ 2.72	$ 2.72
2	Fuse Block	McM #6113T11	$ 11.39	$ 22.78
2	Fuses	McM #72035K512	$ 14.03	$ 28.06
1	Relay	Allied #70056518	$ 37.75	$ 37.75
100	terminals	Allied #70169571	$ 1.01	$ 101.00
1	Pilot Light, Red 120VAC	McM #7380K4	$ 18.25	$ 18.25
2	Pilot Light, Red 24VDC	McM #7380K3	$ 18.25	$ 36.50

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1	Pilot Light, Green 24VDC	McM #7380K3	$ 18.25	$ 18.25
5	Pushbutton, Black	McM #6749K25	$ 14.74	$ 73.70
1	Pushbutton, Red Mushroom Head	McM #6749K92	$ 27.15	$ 27.15
1	Selector Switch	McM #6749K96	$ 20.59	$ 20.59
1	37-socket Amphenol Circular Connector	Newark #90WX9529	$ 23.96	$ 23.96
1	37-pin Amphenol Circular Connector	Newark #92F5585	$ 52.33	$ 52.33
1	Cable Clamp, Amphenol Circular Connector	Newark #96F4482	$ 5.71	$ 5.71
1	Cord Grip,	Allied #70074405	$ 3.51	$ 3.51
14	Cord Grip,	Allied #70074444	$ 0.96	$ 13.44
1	Potentiometer, Linear Motion, 10K	Newark #04B2321	$ 37.89	$ 37.89
1	Pneumatic Lockout Valve	McM #48125K52	$127.34	$ 127.34
1	Pneumatic Filter	McM #4958K26	$ 54.38	$ 54.38
1	Pneumatic Regulator, 2-125PSI	McM #41735K12	$ 31.30	$ 31.30
1	Pressure Gauge	McM #3847K72	$ 10.84	$ 10.84
5	Pneumatic Single Solenoid Directional Valve, 24VDC	McM #62165K83	$ 53.10	$ 265.50
1	Manifold, 5 sta.	McM #6196K5	$ 64.62	$ 64.62
4	Pneumatic Cylinders, 2" stroke	McM #4952K657	$ 53.08	$ 212.32
1	Pneumatic Cylinder, 1/2" stroke	McM #6498K322	$ 18.98	$ 18.98
10	Flow Control, 10-32 port	McM #4076K29	$ 20.81	$ 208.10
10	Tube Fitting 1/8" tube to 1/8" npt	McM #5779K102	$ 2.76	$ 27.60

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12	Nylon Tubing 1/8"	McM #5097T312	$ 0.44	$ 5.28
1	Aluminum Plate, 12" x 12" x 1/2"	McM #9246K33	$ 46.51	$ 46.51
1	Aluminum Rectangle, 1/4" x 4" x 1'	McM #8975K514	$ 9.72	$ 9.72
1	Aluminum Rectangle, 1" x 1" x 3'	McM #9008K14	$ 17.92	$ 17.92
1	Aluminum Rectangle, 1" x 1/2" x 1'	McM #8975K11	$ 4.99	$ 4.99
1	Aluminum T-Slot Extrusion	McM# 47065T101	$ 19.79	$ 19.79
4	90° T-slot Plate	McM #47065T117	$ 6.70	$ 26.80
7	T-Slot Fasteners, pk of 4	McM #47065T142	$ 2.30	$ 16.10
1	Delrin, white, 3/4" x 1-1/2" x 2'	McM #8739K43	$ 12.60	$ 12.60
1	Polycarbonate Sheet, 12" x 12" x 3/8"	McM #8574K31	$ 29.23	$ 29.23
1	Programmable Controller, Siemens S7 1200	Siemens	$325.00	$ 325.00
	w/programming software (school discount, 6 packages for $1945)			
1	Misc Materials (screws, pipe fittings)		$100.00	$ 100.00
1	Misc Consumables (wire, tags, etc)		$ 75.00	$ 75.00
			Total	$ 2,866.04

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Rubric:

Mecapractica Rubric		**Student Name**				**Date**			
MAT2 Capstone Mechapracticum									

	Design	**PTS**	**(A) Highly Proficient**	**(B) Competent**	**(C) Partially Competent/ Developing**	**(D) Limited**	**(E) Major Improvement Required**	**Possible points**	**Ratings A - E**	**Points Awarded**
1	Mechanical Design		Design accurately dimensioned & drawn. Completely understandable if another person had to build from the design		Design adeqquate - critical dimnensions in place		Missing or inaccurate critical dimensions, weak structure, inappropriate materials selected			
	Electrical Design		Electrically functional & efficient. Logical layout, presentation & flow for easy understanding. All components and wires accurately identified and		Design adequate for function. Some components or wires may not be clearly identified. Wiring changes may be necessary at startup.		System will not function electrically as designed, electrical device damage may result.			

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			numbered.							
	Pneumatic Design		Accurate, complete functonal design. Air requiremen ts defined.		Design adequate for function, but identifying labels missing or symbols inaccurately drawn		System will not function pneumatically as designed, mechanical device damage may result.			
	Fabrication	**P T S**	**(A) Highly Proficient**	**(B) Compe tent**	**(C) Partially Competent/ Developing**	**(D) Limited**	**(E) Major Improvement Required**			
2	Layout & prepare details for drilling & milling		accurate layout & center punch		Approximate spacing & centering		Inacurate location			
3	Mill detail(s) to shape									
4	Drill required holes		all holes drilled on location		minor location deviation - minor compensatio n may be required		major location deviation - rework or modification may be required			

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	Fixture Assembly	**PTS**	**(A) Highly Proficient**	**(B) Competent**	**(C) Partially Competent/ Developing**	**(D) Limited**	**(E) Major Improvement Required**			
5	Assemble or mount mechanical, electrical and pneumatic details		all devices securely positioned & aligned		some minor misalignment		numerous assembly & alignment errors, mechanical jamming			
	Electrical Wiring	**PTS**	**(A) Highly Proficient**	**(B) Competent**	**(C) Partially Competent/ Developing**	**(D) Limited**	**(E) Major Improvement Required**			
	Electrical connections inside enclosures		All conductors correctly terminated - no troubleshooting or rewiring required		Most conductors correctly terminated - minimal troubleshooting or rewiring required		Multiple wiring errors - extensive troubleshooting & rewiring required			
	Wire routing inside enclosures		All conductors neatly routed, wire markers uniformly placed & readable without		Conductors adequately routed but may be irregularly bunched or clustered, markers may be difficult to read, stray		Careless or haphazard routing, wires too short or too long, numerous loose wire strands or loose			

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			manipulating wires, wires securely captured in terminals with no loose strands.		strands of wire visible at terminals.		terminations.			
	Field wiring		All cords and conductors well routed, secured and dressed, conforming to structural elements and secured away from moving machinery, excess cordage neatly bundled in terminal box		Cords adequately routed but may be irregularly bunched or clustered		Careless or haphazard routing, cords too short or too long, cords may be in danger of damage from moving machinery			
	Pneumatic piping	**PTS**	**(A) Highly Proficient**	**(B) Competent**	**(C) Partially Competent/ Developing**	**(D) Limited**	**(E) Major Improvement Required**			

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	Threaded fittings		All threaded fittings correctly assembled with no air leaks or excessive pipe sealant, no cross-threaded or rounded-over fittings		Functional assembly but some leaks or loose fittings may be present, excessive or insufficient sealant		cross-threaded or loose fittings with numerous leaks, excessive or insufficient pipe sealant, overtightened fittings resulting in damage to fittings or devices			
	Flexible tubing		tubing ends squarely cut, routed with no sharp bends or kinks, conforming to structural elements and secured away from moving machinery		Functional assembly but some leaks may be present, tubing lengths may be slightly short or long, kinks or bends possible		tubing cut end ragged or at an angle, creased or pinched, insufficient or excessive length resulting in kinks or damage from moving machinery. poorly routed and secured.			
	Logic Development	**PTS**	**(A) Highly Proficient**	**(B) Competent**	**(C) Partially Competent/ Developing**	**(D) Limited**	**(E) Major Improvement Required**			

Mechapracticum Capstone Outline

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	Design & Presentation		logic satisfies all functional requirements, is well documented and well structured to be easily understood and followed by others.		logic satisfies most functional requirements but may lack adequate descriptions and labels, may be randomly structured, making understanding of the intent of the logic flow difficult		logic does not address all functional requirements, may have safety issues, has numerous omission of descriptions and labels, difficult to follow and understand the flow & intent			
	Troubleshooting	**PTS**	**(A) Highly Proficient**	**(B) Competent**	**(C) Partially Competent/ Developing**	**(D) Limited**	**(E) Major Improvement Required**			
	Initial electricity/air application, preliminary motion testying by manually actuating valves, setting flow control speeds, verifying sensor function & location, step logic function, auto cycle		student readily discovered and corrected construction errors and instructor-inflicted faults using methodical & systematic analysis. Full machine operation		Student had to be prompted occasionally during startup and fault discovery. Most machine functions achieved		Student was unable to solve numerous problems, even with prompting, exhibited no method or system for troubleshooting, rather, randomly probing or wiggling wires or forcing actuators or valves. Failure to			

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	logic function.		achieved.				achieve full machine function.			
	Safety Habits	**P T S**	**(A) Highly Proficient**	**(B) Competent**	**(C) Partially Competent/ Developing**	**(D) Limited**	**(E) Major Improvement Required**			
6	Safe Work Practices		Used appropriate PPE; practiced common safety practices		Most safety practices used		Demonstrated unsafe working practices			
7	Safety Attitude		Work practices demonstrated safety consciousness in all procedures; looked out for safety of others		Most of the time worked safely and showed some concern for safety of others		Dangerous worker; did not look out for safety of others			
8	Machining safety		Guards & safe workholding used on drill press or mill		Had to be prompted		Dangerous worker; did not look out for safety of others			

Mechapracticum Capstone Outline

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	WORK HABITS	**PTS**	**(A) Highly Proficient**	**(B) Competent**	**(C) Partially Competent/ Developing**	**(D) Limited**	**(E) Major Improvement Required**			
12	Work Attitude		Alert to finding and correcting problem		Honestly attempted to find and correct problems		Showed frustration in finding and correctly problem			
13	Work Procedure		Always followed standard procedures ; demonstrated planning and organization skills in correcting the problem		Complied with standard procedures; Showed some plan and organization in working		Did not follow standard procedures; Disorganized and slipshod methods;			
14	Professionalism		Work showed pride in accomplishment		Tried hard and shows promise		Work lacks praiseworthy factors			
15	Self-confidence		Appeared comfortable and posed when performing tasks		Fairly self-confident; occasionally disconnected		Hesitant, timid, uncertainty			
16	Knowledge of job		Has an exceptionally thorough		Has good knowledge but needed		Has inadequate knowledge of			

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			knowledge of the job		coaching		job			
						Total Possible Points		0		
						Score of Total Points			0	
						Final Grade Percent			#DIV/0!	
						Final Letter Grade Mechapractica			#DIV/0!	

Mechapracticum Capstone Outline

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