

Industrial Assembly Line

Airplane Mobility

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1. Summary

The “Two Minute Airplane Factory” is a sculpture that was revealed at the London’s Tate Gallery in 1999 by artist Chris Burden. The concept was to design a machine that autonomously assembled and launched tissue paper and balsa wood airplanes at a rate of one every two minutes. Unfortunately, the airplane factory never worked, and was never able to completely assemble and launch an airplane. It however was still entertaining for the public to watch so it was left on display for some time before being shipped to California. It was left in storage for 11 years before Ohio State received it in Fall 2010. Once it arrived at Ohio State, a team of mechanical engineering students and a team of electrical engineering students were assigned with the task of attempting to make the factory operational. The teams’ were given the goals of learning as much as possible about the airplane factory then attempting to get it assembled and in working order.

Later in the year, the Airplane Factory was disassembled and moved to another warehouse, where it was up to our team to reassemble the Airplane Factory, and get whatever possible working.

This report describes the accumulated work accomplished on the airplane factory by the electrical engineers headed by Professor Steven Bibyk. This report records the history of the airplane factory, how it works, a progress report of steps taken, a design and parts description, difficulties that occurred, and recommendations for future groups.

2. Introduction

The automated Airplane Factory sculpture is an art piece designed by Chris Burden. The airplane factory is a moving assembly line that was designed with the function to construct a balsa wood plane autonomously in two minutes. The industrial assembly lines of the airplane factory are autonomously operated using air a pressure system, Festo Pneumatic devices, and Aerotech motion control technology.

2.1 – History

In 1999 Chris Burden, an American artist, collaborated with Studio S on the Two Minute Airplane Factory. The machine was complimented by Festo for their outstanding mechanical manufacturing marvel in both complexity and size. Unfortunately the two minute Airplane was non-functional for at least two months of the installation, leading News to question the intent of the piece: was this meant to show humans would never be replaced with machines? Despite the countless efforts to fix the Two Minute Airplane Factory, it never worked completely. Crowds would surround the airplane factory, mesmerized by the movement of the machine and listen to its working robotic parts.

By not functioning, the work illustrated that robots do not rule everything and engineers are therefore required in order to find solutions for the machine. The Ohio State University Art and Sciences department hope to work together to make Chris Burden's Airplane Factory fully operation.

2.2 - How it works

The airplane factory primarily operates by a computer user interface program from Aerotech. This will allow the computer machine and airplane factory to be as automated as possible, with the least amount of human intervention as possible. The Aerotech Central Processing Unit (CPU) consists of a BA-Intellidrive (BAI). This BAI is a single axis indexer/sine wave commutation amplifier that controls the Festo E.IPC Bush board shown in figure 2.21. The Festo E.IPC Bushboard controls three modules shown in figure 2.22, that are designed to install into the E.IPC bush board similar to a computer's motherboard and a PCI card.

The BA-Intellidrive runs by using serial commands generated by a user program in ASCII format. The BAI and the Festo E.IPC board are connected through a RS232/432 standard serial binary telecommunication wire (blue wire) to control the input signals from the user to the Festo machine (figure 2.23). The airplane factory primary units to activate the machinery are the CPV valve terminals (Figure 2.24). The CPV valve terminals are intended for fitting into a machine or automated system that control by the Festo E.IPC board, which are communicated with the BA-Intellidrive input drive from the user interface.

The CPV drives the terminals using two main components: the air pressure and the electrical address/signal from the intelligence box. The air pressure constantly flows through the Festo CPV valve terminal (the machine) but in order for the valve terminal to be activated, the electrical signal must first activate the CPV to allow pressure to flow through the device and trigger the existing lane.

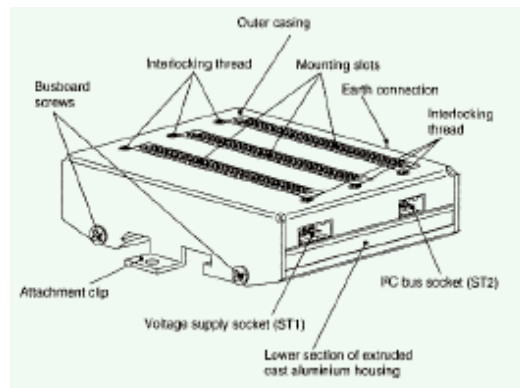


Figure 2.21

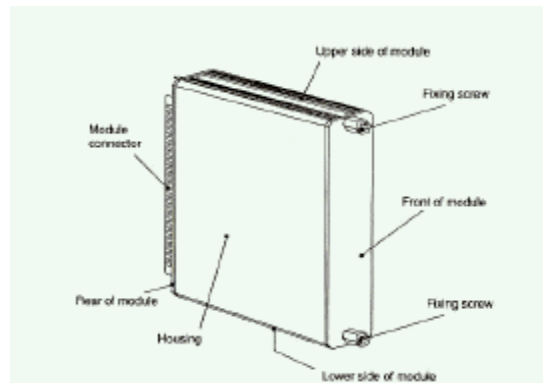


Figure 2.22

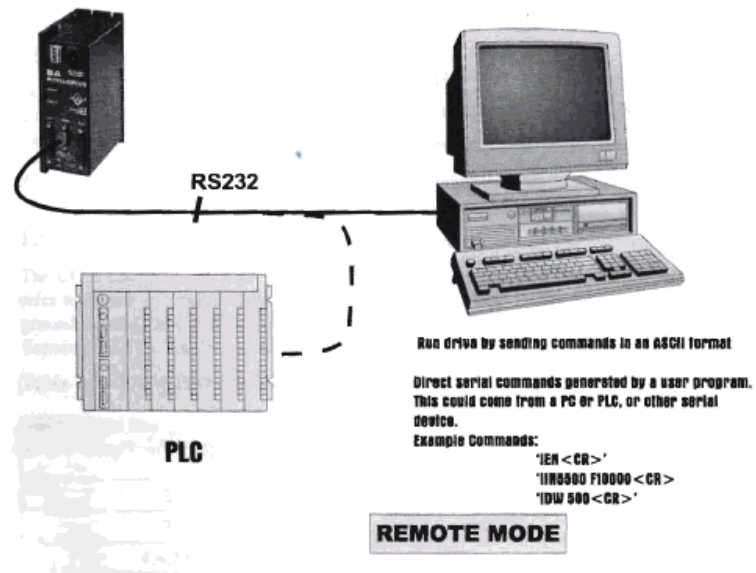


Figure 2.23

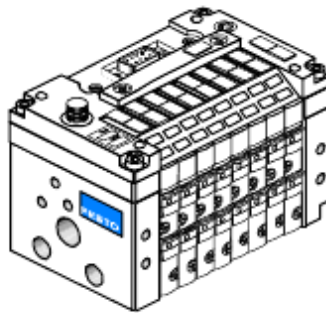


Figure 2.24

3. Tasks Description

3.1 - Progress Report

As a group we:

- 1) Completed the assembly of the airplane factory.
- 2) Connected up all wiring to devices.
- 3) Connected European power supplies then routed them to a European power strip connected to a converter box.
- 4) Attempted to get air pressure system working, eventually succeeding by improvising several air pressure connections to main the air input allow air to flow through system.
- 5) Fixed air pressure input box by putting in a sawed off screw so as to allow valve to be properly opened when pressed.

3.2 – Difficulties

Like most projects, there will be at least some difficulties. One of the main difficulties is that we did not start with an overall layout drawing of the structure. Therefore, it was very hard for us to see all the connections in one picture. So, we do not really know how the air flows throughout structure. The group only has some ideas where the air leaks. But, it is really hard for us to find where the other air leaks are without using colored smoke or scented air.

Moreover, some wires or parts are damaged from the shipping. For instance, the air pressure gauge is possibly damaged or broken. When we were able to flood the system with air, the gauge did was not taking a reading. Furthermore, there is no power plug from the European-to-US power converter that is attached to the European power strip. As a result, we are not able to plug the devices in to test. Lastly, we did not have mechanical students to work with.

4. Parts Descriptions

4.1 - BA-INTELLIDRIVE:

The BA-Intellidrive (BAI) is a single indexer/sine wave commutation amplifier. It could control either brush or brushless motors. The BAI consists of an amplifier, control board, and internal power supply. The indexer card is coupled with Aerotech's BA series amplifiers and these are what control the motors. This card could be used with few different amplifiers and they are BA10/BA20/BA30 (switching Pulse Width Modulation (PWM amplifiers), and BAL1600 (linear amplifier).

When it is working as a velocity/torque amplifier, the BAI could read in differential +/-10 volt signal and commutate a brushless motor with a sine wave command. The input signal could be a current command or a velocity command. Operating parameters are changed using the RS-232/432 interface.

The BAI could act as a single axis indexer, meaning that the card is able to do point to point motion by specifying a reference position, velocity, and acceleration. Other commands that are available are freerun (FR), home (HO), change output, and teach mode. The BAI can execute programs that are stored in the flash memory. The BAI could operate in local mode or remote mode.

The BAI software package is stored on a 1.44MB floppy disk ('BAI software package'). The software includes a HT terminal emulator (com_bai.exe), a program to control the BAI in remote mode and the source files. com_bai.exe execute programs or individual commands.

The BAI consists of: two power connections (motor power and input power, two LED indicator lamps, and three D style connectors (Figure 1.3).

To avoid the possibility of electrical shock, ensure that the motor is decoupled from the mechanical system. When you get the "!" mark warning, make sure that the motor is completely disconnected from the amplifier and the associated mechanical system before performing the

following steps. Ensure that no person comes in contact with the circuitry. Make sure that all the electrical power switches are in the off position before making any mechanical adjustments.

The jumper selects between brush and brushless motors. If the user is switching between brushless motors, the power board jumpers must be reconfigured on the amplifier.

Commands are sent to the BAI by either local mode or remote mode. Local mode depends on the menu screens to control the BAI but the remote mode depends of the commands set by the user through the RS-232/432 port.

The BAI has a few menu commands that allow the user to perform specific functions. One of these is the C-change parameter which allows the user to change a parameter displayed on the screen. Another command is the D-display tracking information.

The O-other menus are options that are used to run programs, read/write parameters, read registers, and examine system error messages.

The motion commands could be used to program or sent the indexer with the emote command "I".

The teach mode lets the user specify up to 100 learned positions. Each learned point consists of a position, a federate, and a bit pattern. A move from a position to the next position is done by toggling the I/O lines.

All parameters are entered as numbers. They should be entered as its ASCII decimal equivalent.

Performance of the BAI's servo loop is dictated by the servo loop parameters. The proportional velocity gain KIP provides proportional gain adjustment to the velocity error mode of the PID control loop. The integral velocity gain KI provides integral gain adjustment to the velocity error mode of the PID control loop. The proportional position gain KPOS provides proportional gain adjustment to the position error mode of the PID control loop.

Limit parameters include limit check, limit type, home direction, home type, home velocity, home ending offset, home marker velocity, negative software limit, positive software

limit, deceleration distance, +/- limit reset distance, check move against software limits, marker type, and offset to marker.

The communications/startup parameters are the baud rate, service request (SRQ) character, displayable digits, unit address, enable/disable daisy chain (places in remote mode), autorun program on powerup, bootup program name, amplifier status on power up, external enable polarity, and display type.

The miscellaneous parameters are the position scale factor, default ramp time, and filter cutoff.

The BAI registers on allow the user to read various operating parameters. Those registers are program bytes remaining (indicates number of bytes remaining for program storage), BAI status (returns 32 bit status register of the BAI), position feedback (contains the position feedback in encoder counts), velocity feedback, position command, position error, current command, and the firmware version (contains the current version of the firmware in flash memory).

The BAI modes of operation are velocity, current, indexing, and clock and direction.

4.2 - CPU Modules E.IPC –HC15 / HC16/ HC17:

CPU Modules E.IPC –HC15 / HC16/ HC17 concept individual system components can be suited to very different areas of application. This system's modularity has minimal space requirements with high PC capacity and maintenance and purchasing costs. Existing systems are freely extendible and flexible. The modularity of the system includes minimal logistic requirements. For instance, it has the same basic building blocks: bus board, CPU, I/O and communication modules. All the main plugs in the IPC are in accordance with the standard for industrial PCs.

CPU is the heart of FESTO IPC. The PC compatibles CPU modules E.IPC include the CGA graphic controller, 1MB main memory, an integrated serial interface module with RS232/432 standard adapter, I* I C bus controller and a bootable silicon disk. With the PLC programming systems which are available, the CPU module can be programmed and used like a PLC. The decoupling from the PC/XT bus of the bus boards, the CPU modules are capable of

multiprocessing and can be operated in master/slave mode with other E.IPC modules. The I*IC bus has a transfer rate up to 90Kbit/s and controls the communication between the master and slave modules. There is also a hardware watchdog timer. It is for industrial use to monitor the running of the program together with the SuperState BIOS.

4.3 - The Interface Module Profibus/Festo Field Bus E. IPC-CP60/61:

This module is an open interface and it is indispensable in today's networked IPC. The installer and the system operator are able to define the network parameters and technology. The interface module is a dual-port RAM module. It has a microcontroller which allows high-speed communication with partner IPC independently of the central processing unit. The loadable software adapts the hardware to the protocol, allowing flexibility to the user. The ISA communication processor card was developed to permit operation of both the Festo field bus and the Profibus as a master or slave. The software allows the processor card to take routine protocol work away from the PC.

E.IPC-CP60/61 is an electrically isolated RS485 interface with two 9 pin SUB-D sockets. It has a microcontroller 80C51 FA. The software is a loadable user program via dual-port RAM. There is 1KB dual-port RAM for data communication with the PC. The module includes 32KB main memory and 32 KB program memory. Inside it includes an interrupt selection by software (INT), loading program, 12 and 16MHz system frequency, and serial EEPROM.

4.4 - The busboard E.IPC-BP11:

The busboard has 3 module slots and an integrated voltage supply. It is simply meant to mount on the rail using latching feet or directly onto the wall. It has: an integrated voltage supply with +10-36 V DC power range, an integrated IC bus for multi-processor operation, and intelligent networking with input and output equipment. It also has a high noise immunity.

The E.IPC-BP11 busboard forms the heart of every standard E.IPC installation. Connections between the CPU module, I/O modules and communication modules on the busboard are effected by a 62-pin PC/XT bus and stable edge connection. Data and control lines are transmitted by this bus.

It is designed as a base for all Festo IPC modules. Choices are available on the busboard E.IPC-BP11 with three module locations and an internal voltage transformer. Both modules operate with a DC voltage that is generated by the internal voltage transformer. E.IPC CPU modules can be decoupled from the PC/XT, and a few of these CPU modules can be plugged into a busboard. This would make a multiprocessor system. I²C bus affects the communication between the CPU modules.

4.5 - The digital input/output module E.IPC – OM20:

It has 8 opto-isolated digital outputs, 8 opto-isolated digital inputs, indicator LEDs for supply voltage and overload. It is easy to configure with rotary switch and bridge connector underneath the module. It has high noise immunity.

Direct I/Os form part of the most important modules in the E.IPC family and make the IPC concept a real process computer. The E.IPC-CPU could acquire process data using input/output modules directly and influence the process flow. The E.IPC-OM20 is a universal digital I/O module with one input and one output group each, and they are opto-isolated by group from one another. E.IPC-OM20 is designed for processing of digital signals. Module could be operated using the E.IPC-PCA1PC adapter on a standard PC with ISA bus.

Section 4.6 - Airplane Factory Figures

Figure 4.1 – Physical Layout

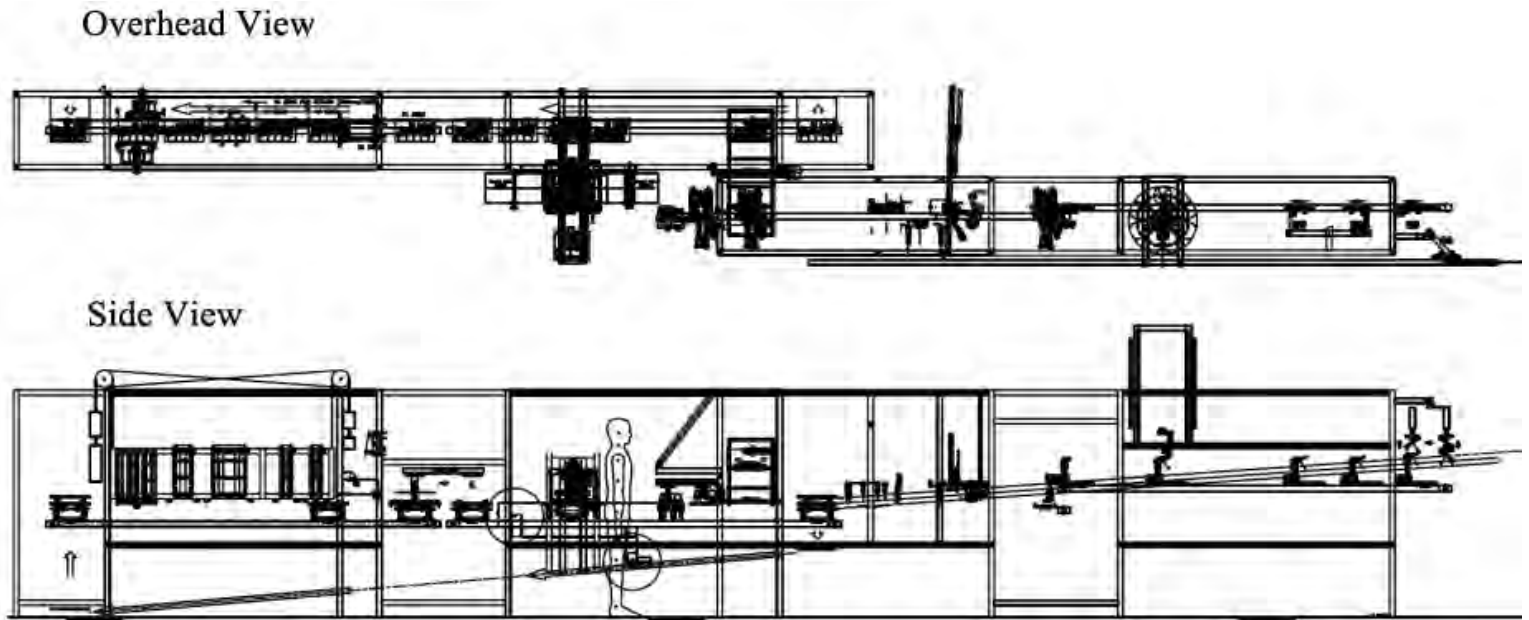


Figure 4.2 – Parts Used

#	Lane/ Section	Actuator Label (Box#.Port#)	Original Label	Actuator Brand	Model #	Type	Quant.	Festo Box	Port	Actuator Description (from Festo docum.)
1	1	1.1		SMC	MKB20-20R		2	1	1	Lane 1 - carriage platten clamps
2	1	-		Festo	VAD-M5 19293	Vac	24	1	2A- 6A 2B- 6B	Lane 1 - carriage vacuums
3	1	2.1		Hoerbiger	74995		1	2	1	Lane 1 - platten elevator up/down
4	1	2.2		Festo	Can't see		1	2	2	Lane 1 - platten elevator advance
5	1	2.3		Festo	EGZ-10-15		4	2	3	Lane 1 - platten elevator clamp pins
6	1	2.4		Festo	DZF-25-100-PA		1	2	4	Lane 1 - hopper 1 - ribs and wing tips
7	1	2.5		Festo	DZF-25-100-PA		1	2	5	Lane 1 - hopper 2 - ribs and wing tips
8	1	2.6		Festo	ADVU-16-5-PA		2	2	6	Lane 1 - hopper 3 - main wing inner spar
9	1	3.1		Festo	ADVU-16-5-PA		2	3	1	Lane 1 - hopper 4 - rear wing spar
10	1	3.2		Festo	ADVU-16-5-PA		2	3	2	Lane 1 - hopper 5 - main wing spar
11	1	3.3		Festo	DSNU-20-80P-A		2	3	3	Lane 1 - hopper gantry - lower/raise
12	1	4.1		Festo	ADVU-16-5-PA		2	4	1	Lane 1 - hopper 6
13	1	4.2		Festo	ADVU-16-5-PA		2	4	2	Lane 1 - hopper 7
14	1	4.3		Festo	ADVU-16-5-PA		2	4	3	Lane 1 - hopper 8
15	1	4.5A*		Festo	EGZ-16-5		1	4	5A	Lane 1 - glue pens - drop/lift
16	1	4.5B*				Glue		4	5B	Lane 1 - glue pen 1
17	1	4.6A				Glue		4	6A	Lane 1 - glue pen 2
18	1	4.6B				Glue		4	6B	Lane 1 - glue pen 3
19	1	4.7				Glue		4	7	Lane 1 - glue pen 4
20	1	4.8B (?)						4	8B	Lane 1 - activator feed
21	2	5.1		SMC	MKB20-20R		2	5	1	Lane 2 - carriage platten clamps

22	1/2	5.2								Lane 1 to 2 changeover clamp pins
23	1/2	5.3								Lane 1 to 2 changeover advance
24	1/2	5.4								Lane 1 to 2 changeover lift/drop
25	2	6.1								Lane 2 - heater/cutter advance
26	2	6.2								Lane 2 - cutter drop/lift
27	2	6.3								Lane 2 - heater drop/lift
28	2	6.4		Festo	ADVUL-20-30-PA		2	6	4	Lane 2 - carriage pins lift/drop
29	2	6.5		Festo Festo	ADVUL-32-80-PA ADVUL-20-30-PA		2 1	6	5	Lane 2 - stamps
30	2	7.1		Festo	DSNU-25-50B		1	7	1	Lane 2 - platten elevator up
31	2	7.2		Festo	Can't see		1	7	2	Lane 2 - platten elevator advance
32	2	7.3 PINS		Festo	DSNU-20-80P-A		4	7	3A	Lane 2 - platten elevator clamp pins
33	2	7.3B		Festo	EGZ-6-5		6	7	3B	Lane 2 - flipover wing clamps
34	2	7.4		Festo	DSR-40-180-P		1	7	4	Lane 2 to 3 flipover rotate
35		7.5		Festo	ADVU-20-30-PA		2	7	5	Platten conveyor ends drop/lift
36		7.6					2	7	6	Flipover break
37	3	8.1A		Festo	EGZ-16-5		1	8	1A	Lane 3 - carriage - tail fin rotate ?
38	3	8.2		Festo	HGR-16-5 (?)		4	8	2	Lane 3 - carriage - main wing clamp and fin clamp
39	3	8.3		Festo	HGR-16-5 (?)		1	8	3	Lane 3 - carriage - tail clamp
40	3	8.4		Festo	DSR-16-180-P		1	8	4	Lane 3 - carriage - right wing break
41	3	8.5		Festo	DSR-16-180-P		1	8	5	Lane 3 - carriage - lift wing break
42	3	8.6		Festo	DSM-16-270-P		1	8	6	Lane 3 - carriage - tail fin rotate
43	3	10.1	1	Festo	ADVUL-20-50-PA		1	10	1	Lane 3 - wing tab pick-up drop/lift
44	3	10.2		Hoerbiger	102459		1	10	2	Lane 3 - wing tab pick-up advance/return
45	3	10.3		Festo	Can't see	Vac	1	10	3	Lane 3 - wing tab pick-up vacuum
46	3	10.6		Festo	ADVUL-20-5-PA		2	10	6	Lane 3 - PVA pens drop/lift
47	3	10.7		Festo	ADVUL-32-20-PA		1	10	7	Lane 3 - wing break clamp drop/lift
48	3	11.1		Festo	ADVUL-20-20-PA		1	11	1	Lane 3 - wing break glue pens plunge
49	3	11.2				Glue		11	2	Lane 3 - wing break glue activator
50	3	11.3		Festo	ADVUL-20-20-PA		1	11	3	Lane 3 - wing break glue activator pens plunge
51	3	11.4		Festo	ADVUL-20-20-PA		1	11	4	Lane 3 - fin to tail glue pen drop
52	3	11.5		Festo	ADVUL-20-40-PA			11	5	Lane 3 - fin to tail glue pen run
53	3	11.6A				Glue		11	6A	Lane 3 - fin to tail glue
54	3	11.6B		Festo	EGZ-6-5		1	11	6B	Lane 3 - tail pick-up press drop/lift
55	3	11.7		Festo	ADVUL-20-40-PA		1	11	7	Lane 3 - tail pick-up drop/lift
56	3	11.8		Festo	HGP-16-A		1	11	8	Lane 3 - tail pick-up clamp
57	3	12.1		Festo	ADVUL-20-20-PA		1	12	1	Lane 3 - tail to fuselage glue pens plunge
58	3	12.2		Festo	ADVUL-20-40-PA		1	12	2	Lane 3 - tail to fuselage glue pen run
59	3	12.3				Glue		12	3	Lane 3 - tail to fuselage glue
60	3	13.1						13	1	Lane 3 - fuselage pushrod advance
61	3	13.2A				Glue		13	2A	Lane 3 - fuselage to cabin & tail hook glue
62	3	13.2B			EMML-16-10-PA		1	13	2B	Lane 3 - fuselage to cabin & tail hook glue pens drop/lift
63	3	13.3	3					13	3	Lane 3 - cabin plunger
64	3	13.4	4					13	4	Lane 3 - tail hook plunger
65	3	13.5	5					13	5	Lane 3 - fuselage clamp open/close
66	3	13.6				Glue		13	6	Lane 3 - nose doubler to fuselage & wing to cabin glue
67	3	13.8	7	Festo	DZH-25-100-PPV-A		1	13	8	Lane 3 - nose doubler to fuselage & wing to cabin glue pens drop/lift
68	3	14.2	6				1	14	2	Lane 3 - fuselage rotate to carriage
69	3	14.3					1	14	3	Lane 3 - fuselage clamp head advance

70	3	14.4B	11					14	4B	Lane 3 - nose doubler plunger
71	3	14.5 14.5	12	Festo Festo	ADVUL-20-20-PA DSR-16-180-P		1 1	14	5	Lane 3 - nose doubler rotate
72	3	14.6						14	6	Lane 3 - nose doubler advance
73	3	14.7				Vac	1	14	7	Lane 3 - nose doubler advance vacuum
74	4	15.1		Festo	HGP-16-A			15	1	Lane 4 - carriage head grip open/close
75	4	15.2	16					15	2	Lane 4 - carriage head extend/retract
76	4	15.3	17					15	3	Lane 4 - carriage head rotate
77	4	15.4	18	Festo	DSM-25-270-P		1	15	4	Lane 4 - carousel rotate
78	4	15.5	19	Festo	ADVU-16-30-PA		1	15	5	Lane 4 - nose hopper stop/release
79	4	15.6	20	Festo	ADVUL-20-20-PA		1	15	6	Lane 4 - nose hopper pin eject
80	4	15.7A	21A	Festo	AEVULQ-16-15		1	15	7A	Lane 4 - carousel locate pin
81	4	15.7B	21B	Festo	Can't see		1	15	7B	Lane 4 - nose deliver hopper clamp pin
82	4	16.1	22	Festo	DSR-16-180-P		1	16	1	Lane 4 - nose deliver hopper rotate
83	4	16.2	23	Festo	DSNU-25-160P-A		1	16	2	Lane 4 - nose fitter pushrod & band catch rotate
84	4	16.3	24					16	3	Lane 4 - band opener rotate
85	4	16.4	25					16	4	Lane 4 - band opener advance
86	4	16.5	26					16	5	Lane 4 - band opener
87	4	16.6	27	Festo	HGP-16-A		1	16	6	Lane 4 - end arm grip open/close
88	4	16.7	28	Festo	DSR-16-180-P			16	7	Lane 4 - end arm rotate
89	4	17.1						17	1	Lane 4 - propeller winder motor forward
90	4	17.2						17	2	Lane 4 - retracted launch pole clamp open/close
91	4	17.3						17	3	Lane 4 - retracted launch pole propeller stop pin in/out
92	4	17.4						17	4	Lane 4 - extended launch pole clamp open/close
93	4	17.5						17	5	Lane 4 - extended launch pole propeller stop pin in/out
94	4	17.6						17	6	Lane 4 - launch pole stop
95	4	17.7	29	Festo	DZF-25-125-PA			17	7	Lane 4 - end arm clamp drop/lift
96	4	17.8						17	8	Lane 4 - band wind clamp open/close

*Note: A or B on actuator label denotes front or back port on Festo Box, respectively

Figure 4.3 – Wiring Layout

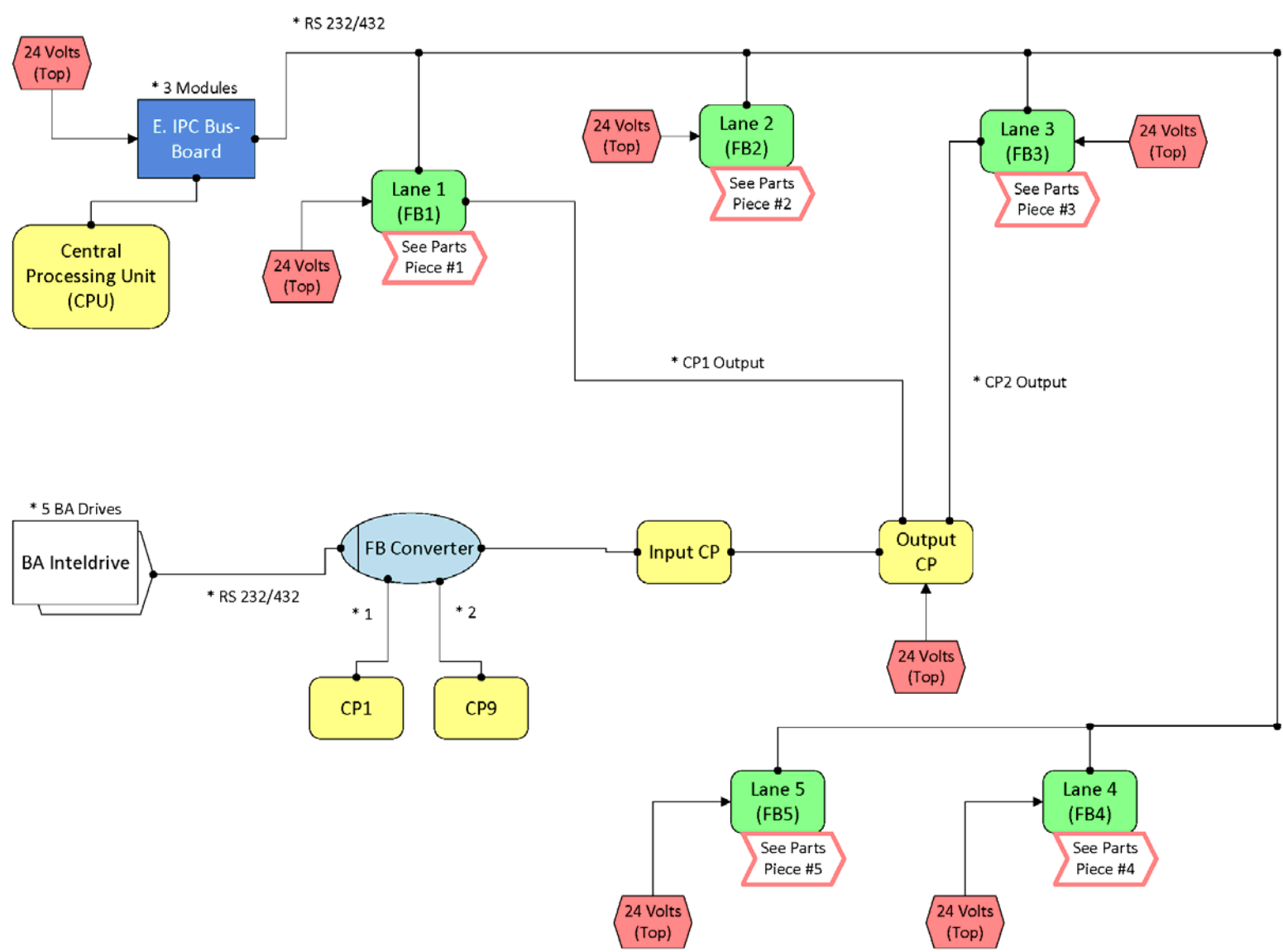
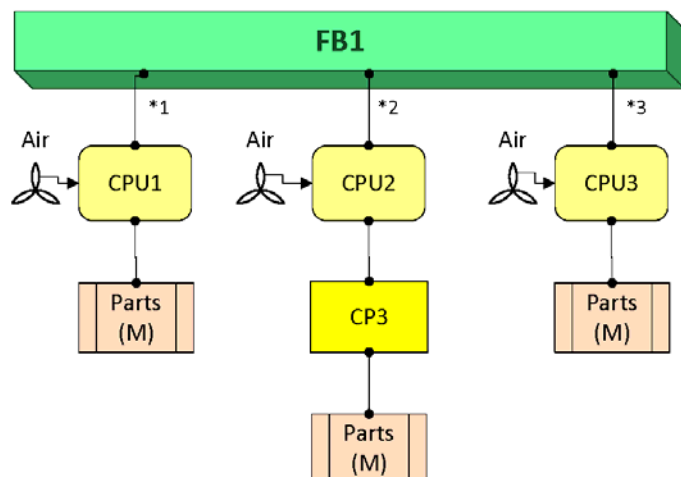
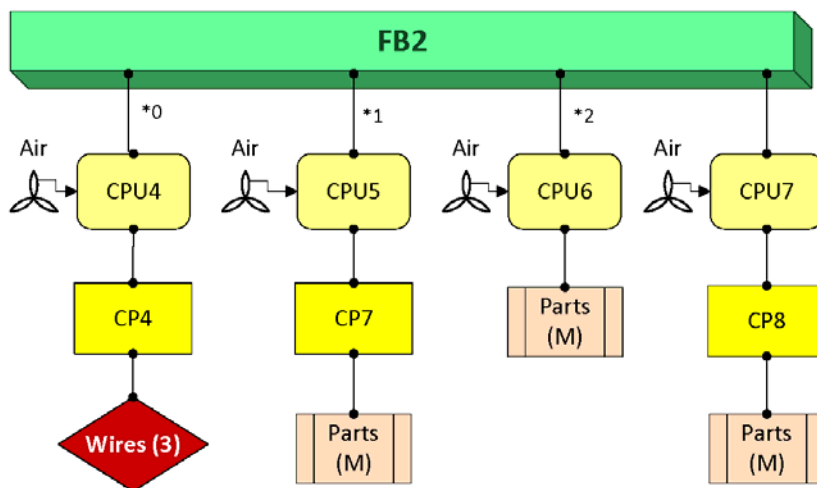
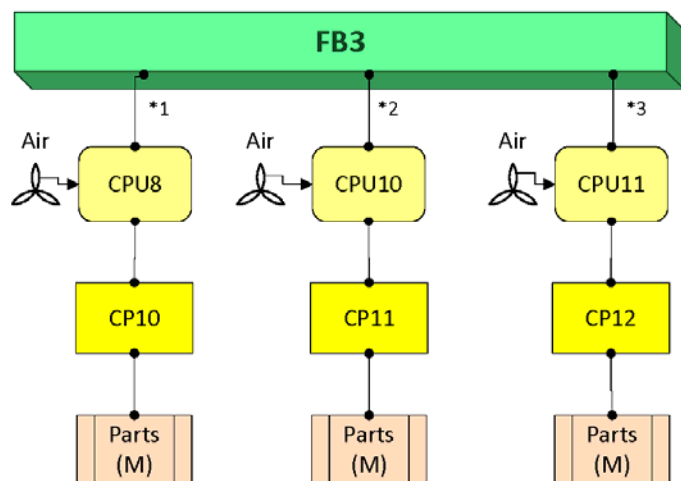
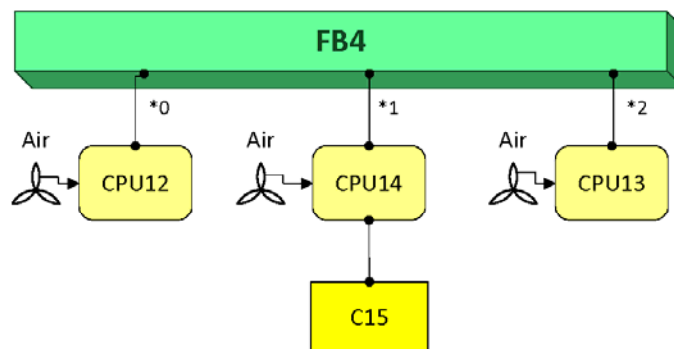
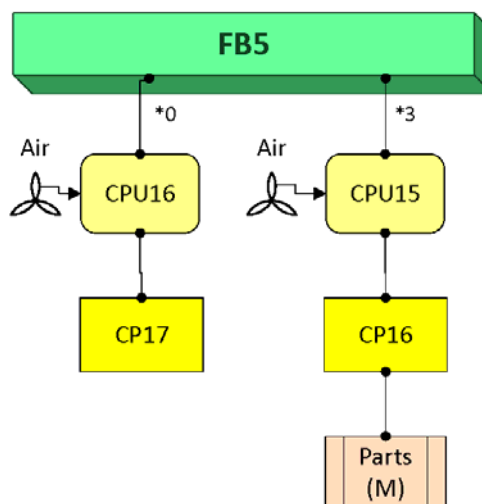


Figure 4.4 – Wiring Layout: Parts

Parts Piece #1*Parts Piece #2**Parts Piece #3**Parts Piece #4**Parts Piece #5*

5. Recommendations for Future Groups

Try to collaborate with Mechanical Engineering students. It would be a lot better if a group of ECE students and ME students would work together on that project. They should try to work with each other at the same time. Try to get as many students as possible to work on the project.

Try to get the main ideas of the assembly line first. Do not go too deep into details when you start working on the project, but instead try to get the 'big picture' by understanding the main mechanical parts, main connections, and the brain box. After getting the big picture, try to draw a map or a diagram that simplifies the assembly line, then try to figure out what needs to be done and set specific goals that you need to accomplish, then split those goals on each group member or on every 2 group members.

Bring a laptop to the warehouse so you can try to use the software. Contact Festo and Aerotech to understand their products better. You should ask Aerotech about the software for the BA-Intellidrive (control boxes) software.

Try to finish the main power connections. Try to explore how the assembly line works or how any of its sections works.

6. Conclusion

Overall, the whole group agrees that this project is one of the best projects that we ever have had. We learned a lot about how things operate and the electrical system in the machines or devices. Furthermore, we gained some knowledge in the mechanical area. For instance, we learned how the whole structure connects together. Lastly, we believe all the labels on the wires make the tasks much simpler because we are able to know where to connect.