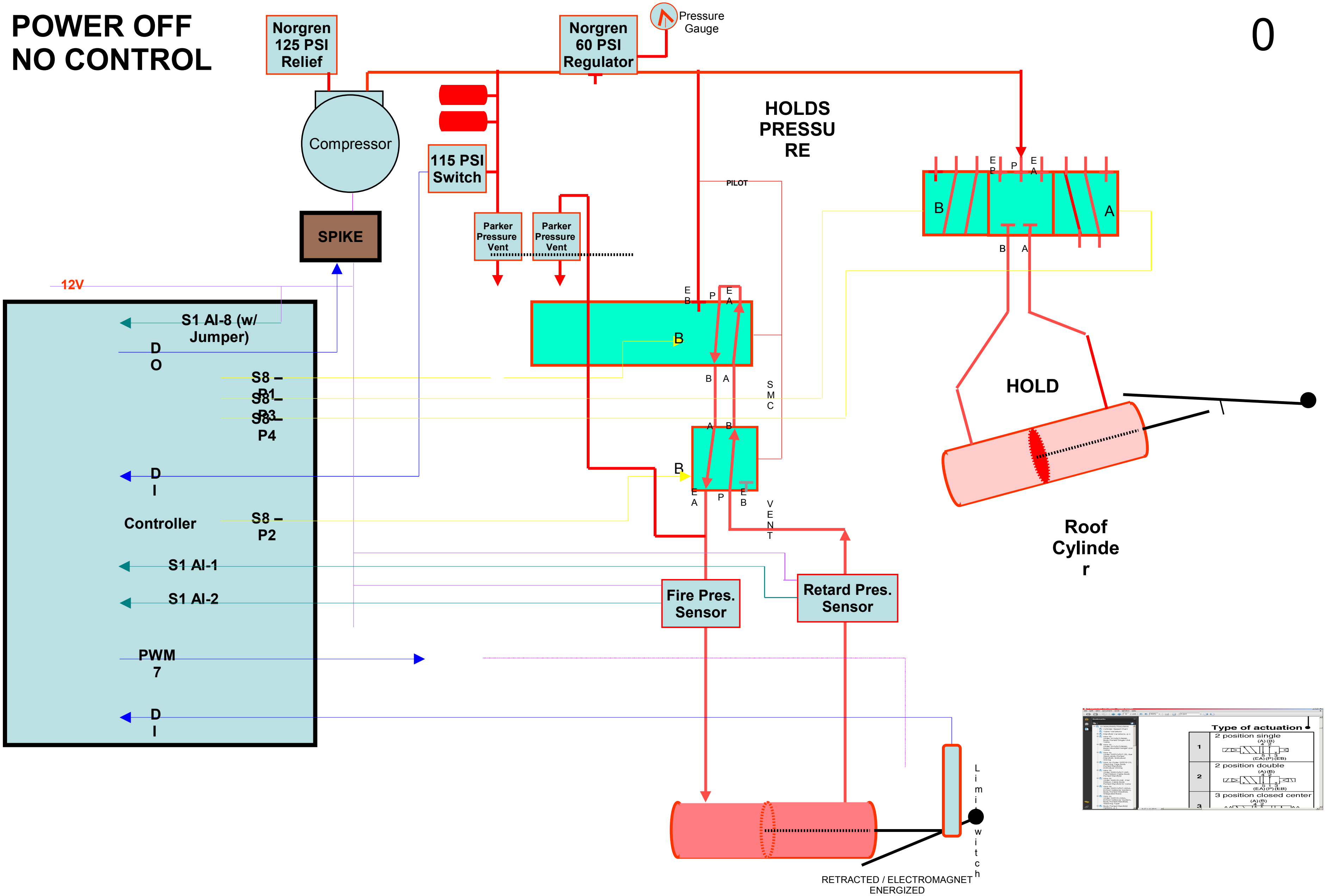
Pneumatic Kicker and Roof/Ramp System

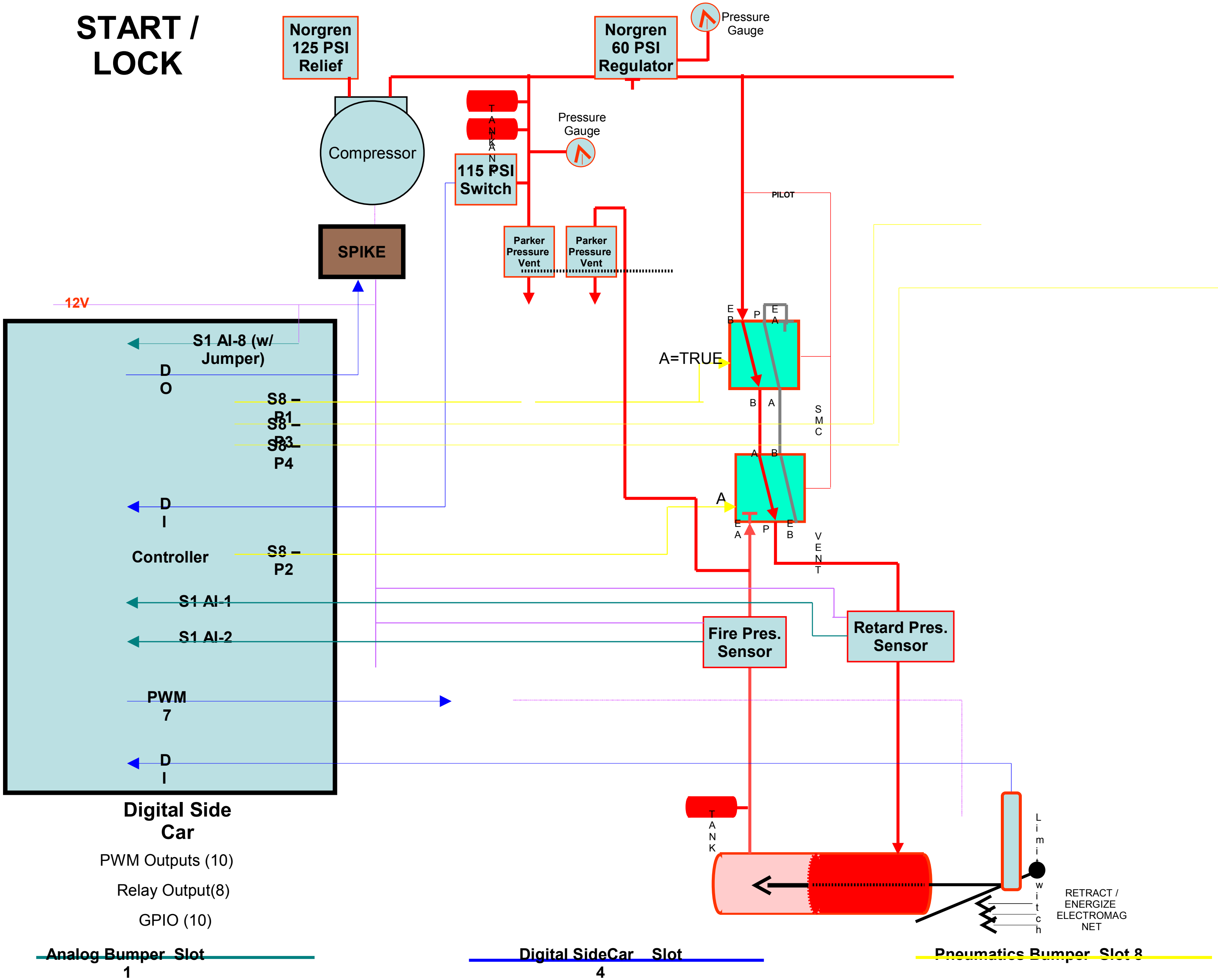
A variable pressure kicker and multi-position "Roof"/Ramp system with air re-use.

www.team2053.org/Soccerates/pneumatics/index.html

POWER OFF
NO CONTROL

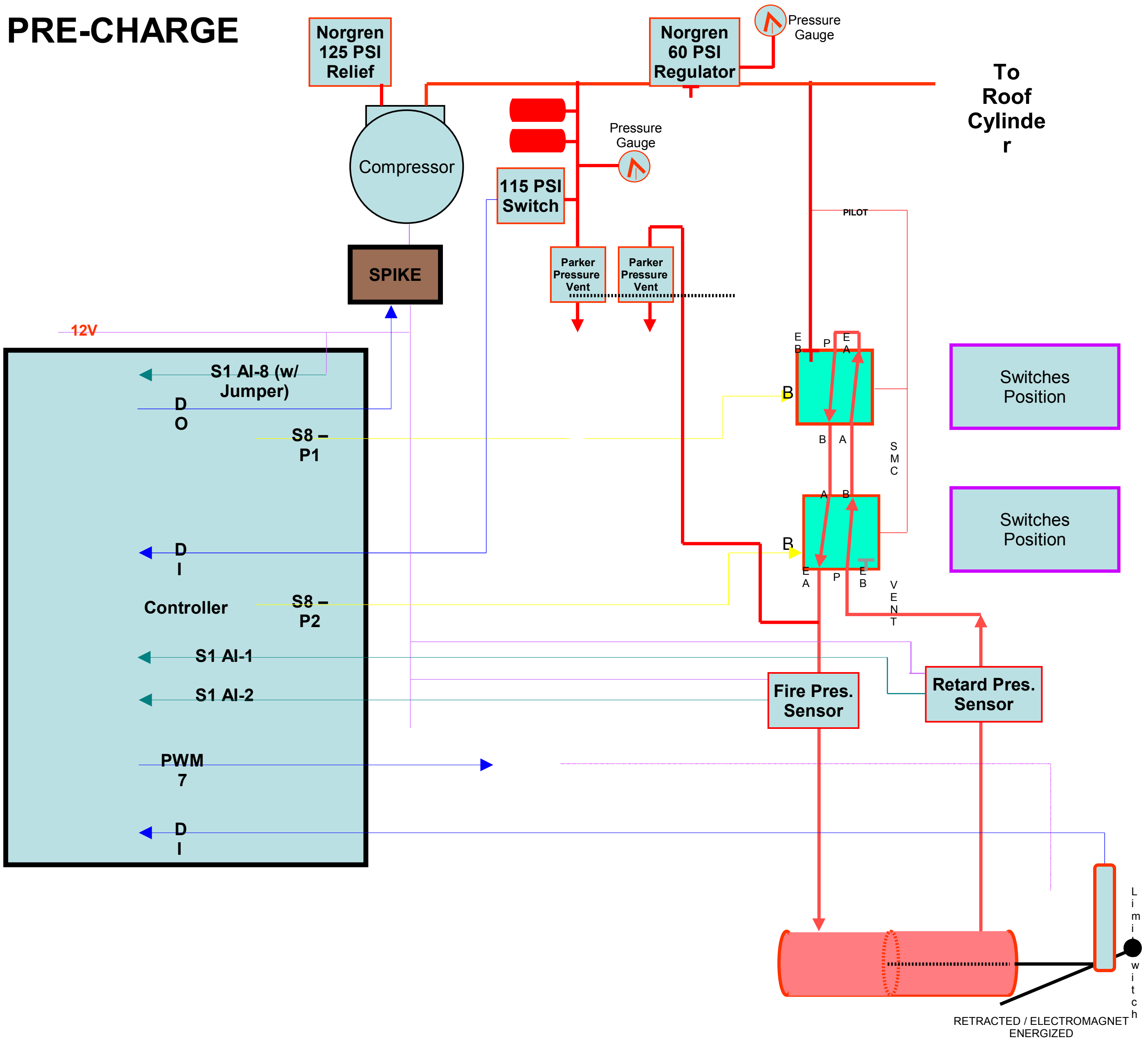


START / LOCK



Norgren 125 PSI Relief
Norgren 60 PSI Regulator
Pressure Gauge
Compressor
TANK
TANK
115 PSI Switch
Pressure Gauge
SPIKE
Parker Pressure Vent
Parker Pressure Vent
PILOT
12V
S1 AI-8 (w/ Jumper)
DO
S8 – P1
S8 – P3
S8 – P4
DI
Controller
S8 – P2
S1 AI-1
S1 AI-2
PWM 7
DI
Digital Side Car
PWM Outputs (10)
Relay Output(8)
GPIO (10)
A=TRUE
EB
P
EA
B
A
SMC
A
B
A
EA
P
EB
VENT
Fire Pres. Sensor
Retard Pres. Sensor
TANK
Limit switch
RETRACT / ENERGIZE ELECTROMAGNET
Analog Bumper Slot 1
Digital SideCar Slot 4
Pneumatics Bumper Slot 8

PRE-CHARGE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Norgren 60 PSI Regulator
Pressure Gauge
To Roof Cylinde r
Compressor
Pressure Gauge
115 PSI Switch
SPIKE
Parker Pressure Vent
Parker Pressure Vent
PILOT
12V
S1 AI-8 (w/ Jumper)
D O
S8 – P1
D I
Controller
S8 – P2
S1 AI-1
S1 AI-2
PWM 7
D I
E B
P
E A
B
B A
S M C
A B
B
E A
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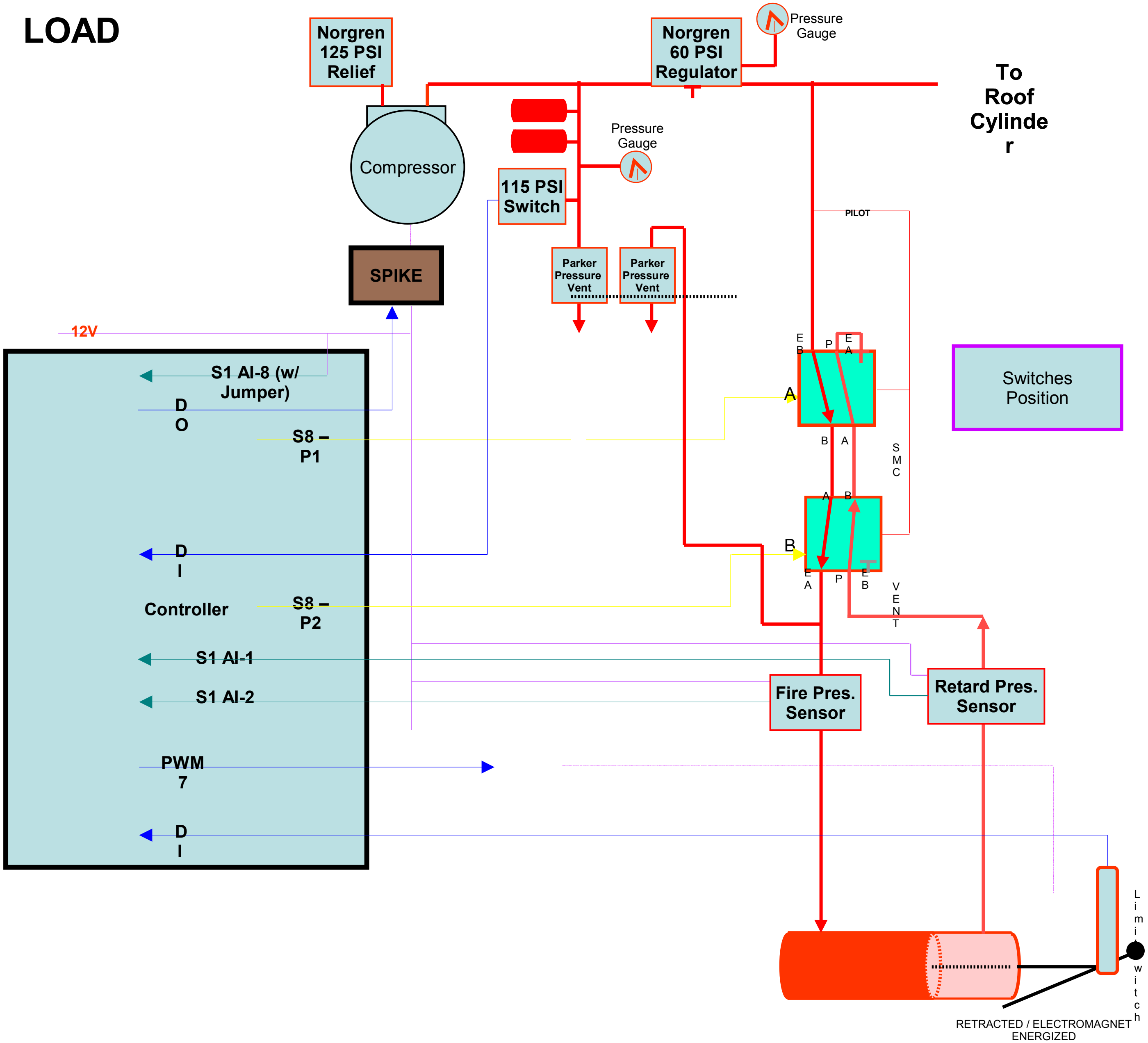
E B
V E N T
Switches Position
Switches Position
Fire Pres. Sensor
Retard Pres. Sensor
Limit switch
RETRACTED / ELECTROMAGNET ENERGIZED

LOAD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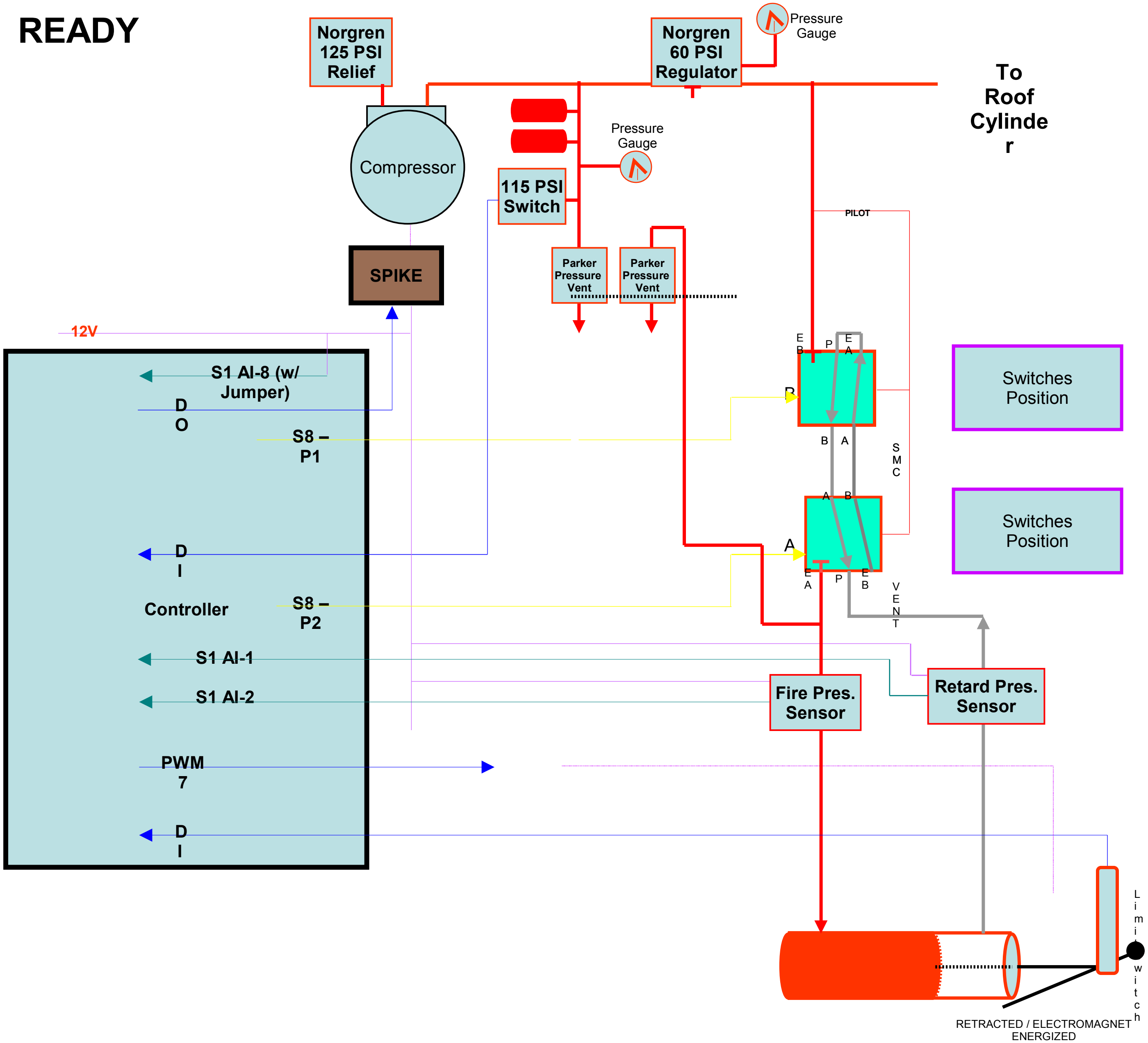
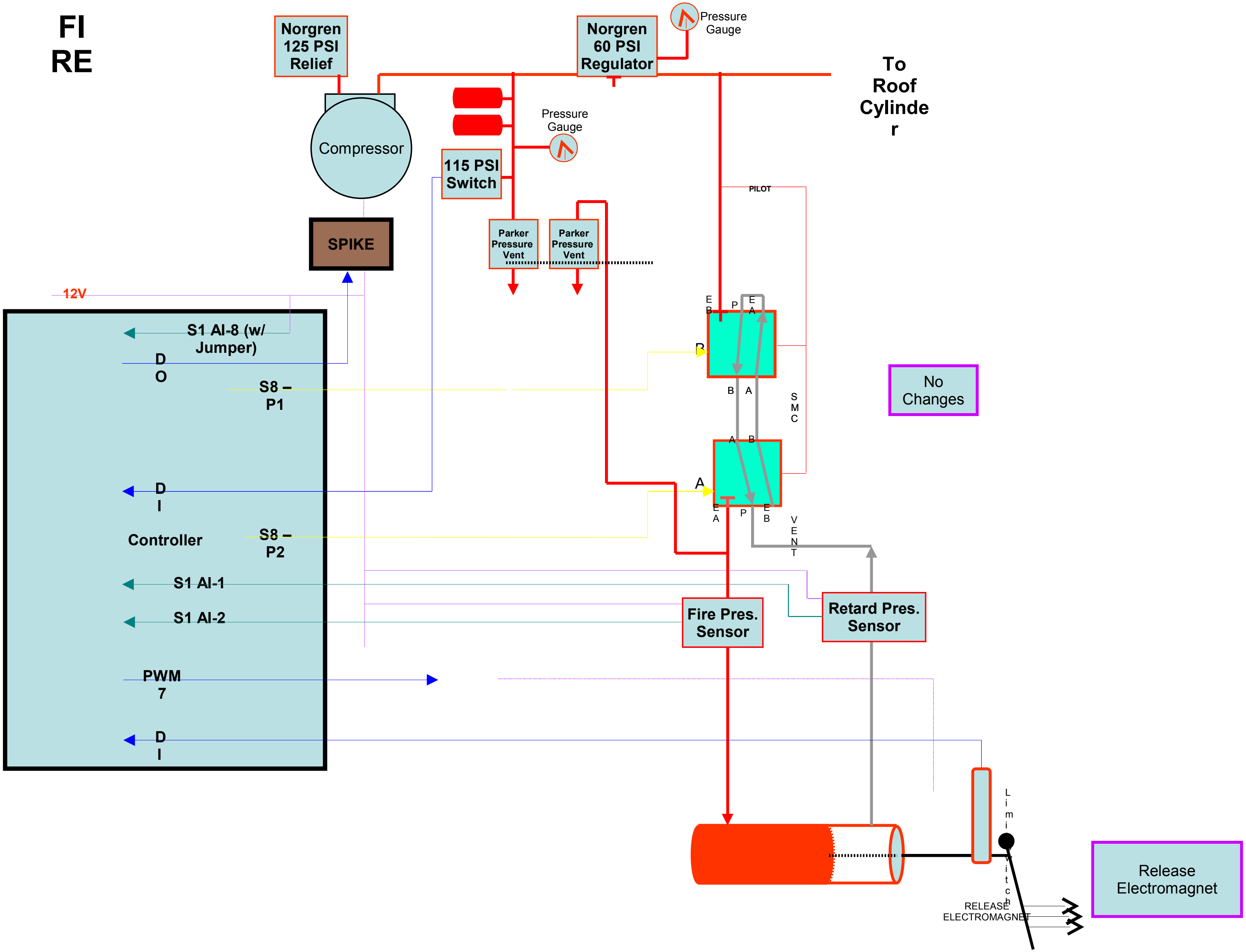
Norgren 60 PSI Regulator
Pressure Gauge
To Roof Cylinder
Compressor
Pressure Gauge
115 PSI Switch
SPIKE
Parker Pressure Vent
Parker Pressure Vent
PILOT
12V
S1 AI-8 (w/ Jumper)
DO
S8 – P1
Switches Position
SMC
A
B
DI
Controller
S8 – P2
VENT
S1 AI-1
S1 AI-2
Fire Pres. Sensor
Retard Pres. Sensor
PWM 7
DI
Limit switch
RETRACTED / ELECTROMAGNET ENERGIZED

READY



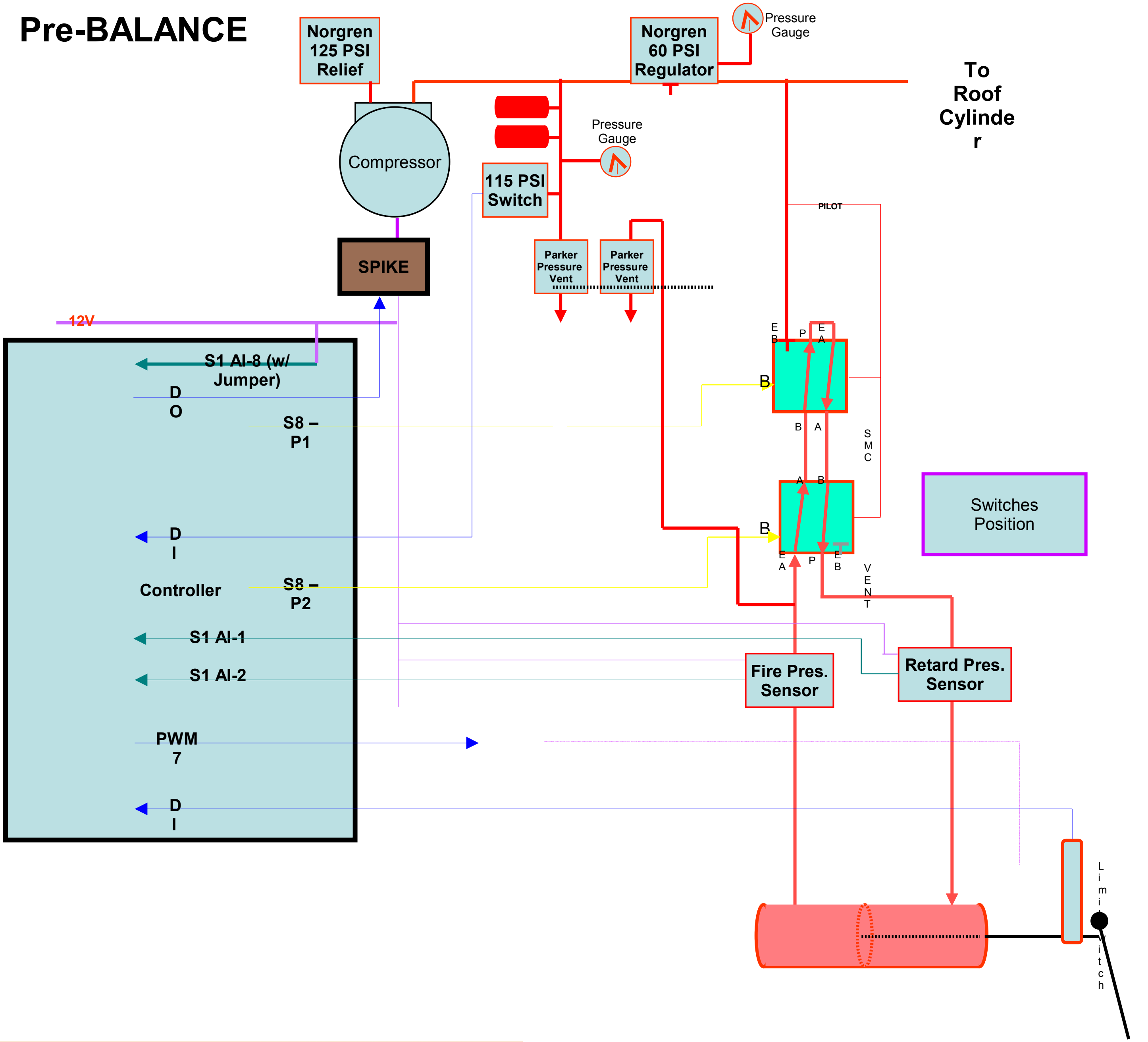
Norgren 125 PSI Relief
Norgren 60 PSI Regulator
Pressure Gauge
To Roof Cylinder
Compressor
Pressure Gauge
115 PSI Switch
SPIKE
Parker Pressure Vent
Parker Pressure Vent
PILOT
12V
S1 AI-8 (w/ Jumper)
D O
S8 – P1
D I
Controller
S8 – P2
S1 AI-1
S1 AI-2
PWM 7
D I
E B
P
E A
B A
S M C
A B
A
E A
P
E B
V E N T
Switches Position
Switches Position
Fire Pres. Sensor
Retard Pres. Sensor
Limit Switch
RETRACTED / ELECTROMAGNET ENERGIZED

FI
RE



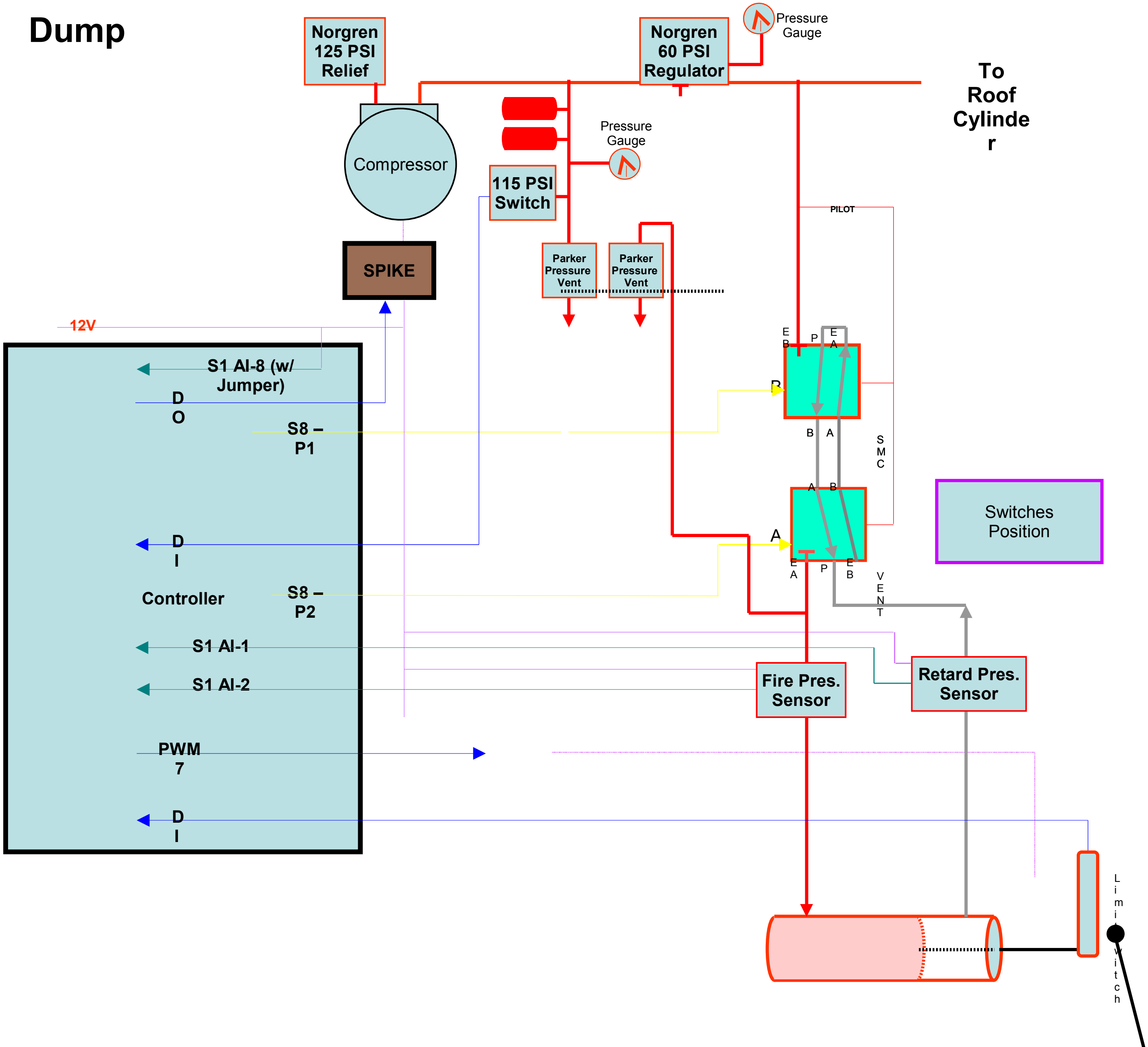
Norgren 125 PSI Relief
Norgren 60 PSI Regulator
Pressure Gauge
To Roof Cylinde r
Compressor
Pressure Gauge
115 PSI Switch
SPIKE
Parker Pressure Vent
Parker Pressure Vent
PILOT
12V
S1 AI-8 (w/ Jumper)
D O
S8 – P1
E B
P
E A
B A
S M C
A B
A
E A
P
E B
V E N T
No Changes
D I
Controller
S8 – P2
S1 AI-1
S1 AI-2
Fire Pres. Sensor
Retard Pres. Sensor
PWM 7
D I
Limit Switch
RELEASE ELECTROMAGNET
Release Electromagnet

Pre-BALANCE



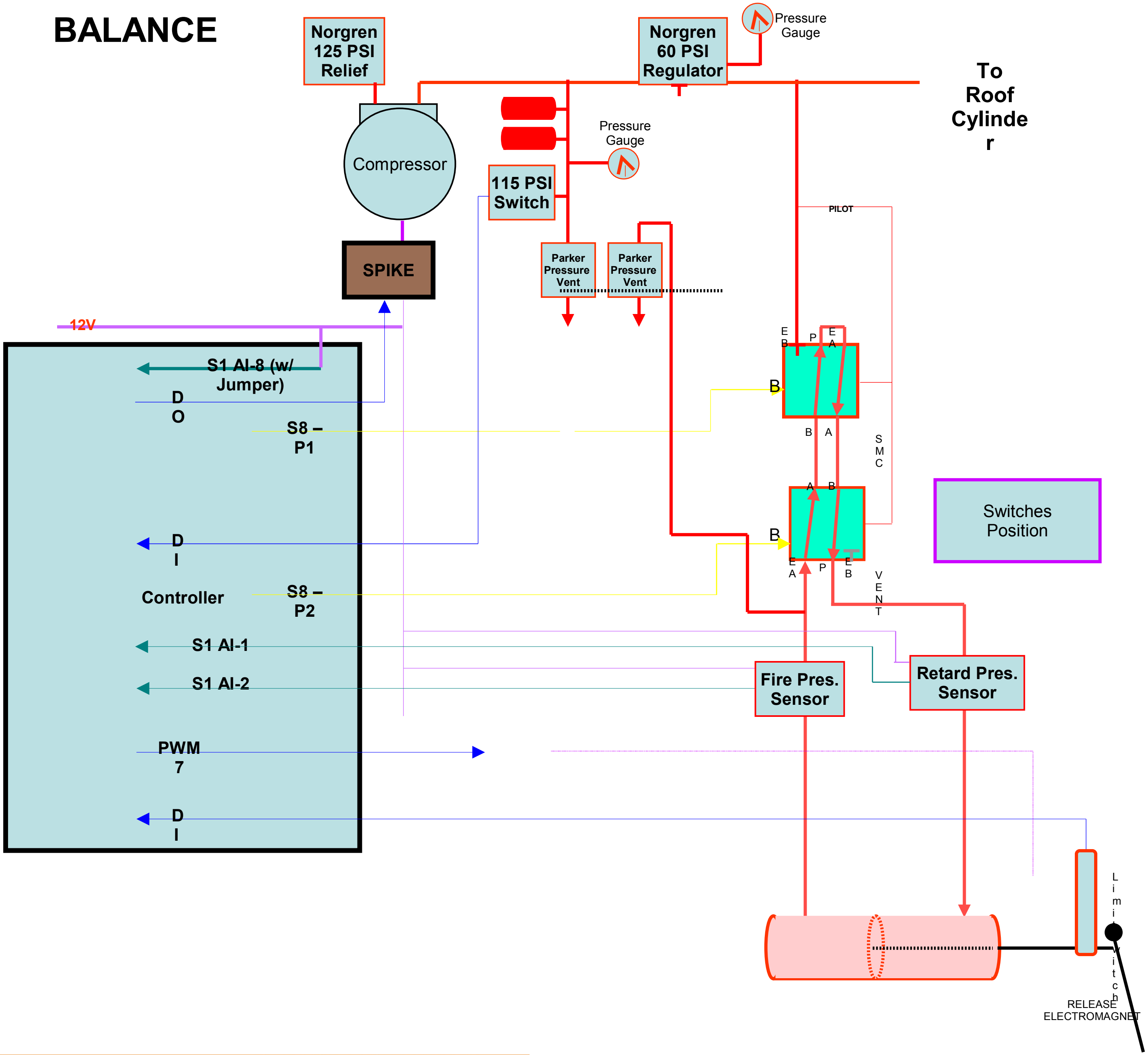
Norgren 125 PSI Relief
Norgren 60 PSI Regulator
Pressure Gauge
To Roof Cylinder
Compressor
Pressure Gauge
115 PSI Switch
SPIKE
Parker Pressure Vent
Parker Pressure Vent
PILOT
12V
S1 AI-8 (w/ Jumper)
D O
S8 – P1
E B
P
E A
B
B A
SMC
A B
B
E A
P
E B
VENT
Switches Position
D I
Controller
S8 – P2
S1 AI-1
S1 AI-2
Fire Pres. Sensor
Retard Pres. Sensor
PWM 7
D I
Limit Switch

Dump

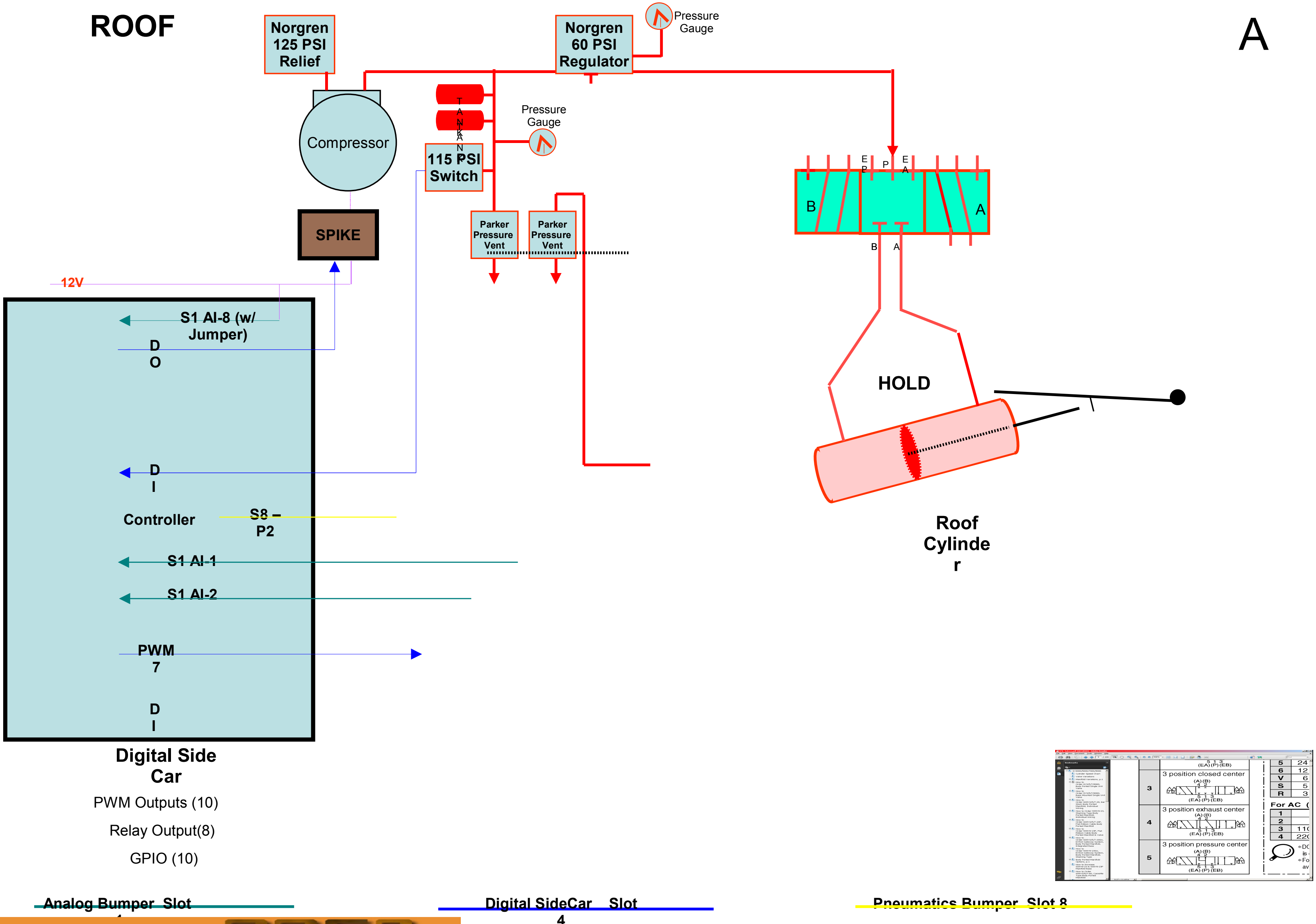


Norgren 125 PSI Relief
Norgren 60 PSI Regulator
Pressure Gauge
To Roof Cylinder
Compressor
Pressure Gauge
115 PSI Switch
SPIKE
Parker Pressure Vent
Parker Pressure Vent
PILOT
12V
S1 AI-8 (w/ Jumper)
DO
S8 – P1
DI
Controller
S8 – P2
S1 AI-1
S1 AI-2
PWM 7
DI
SMC
VENT
Switches Position
Fire Pres. Sensor
Retard Pres. Sensor
Limit Switch

BALANCE

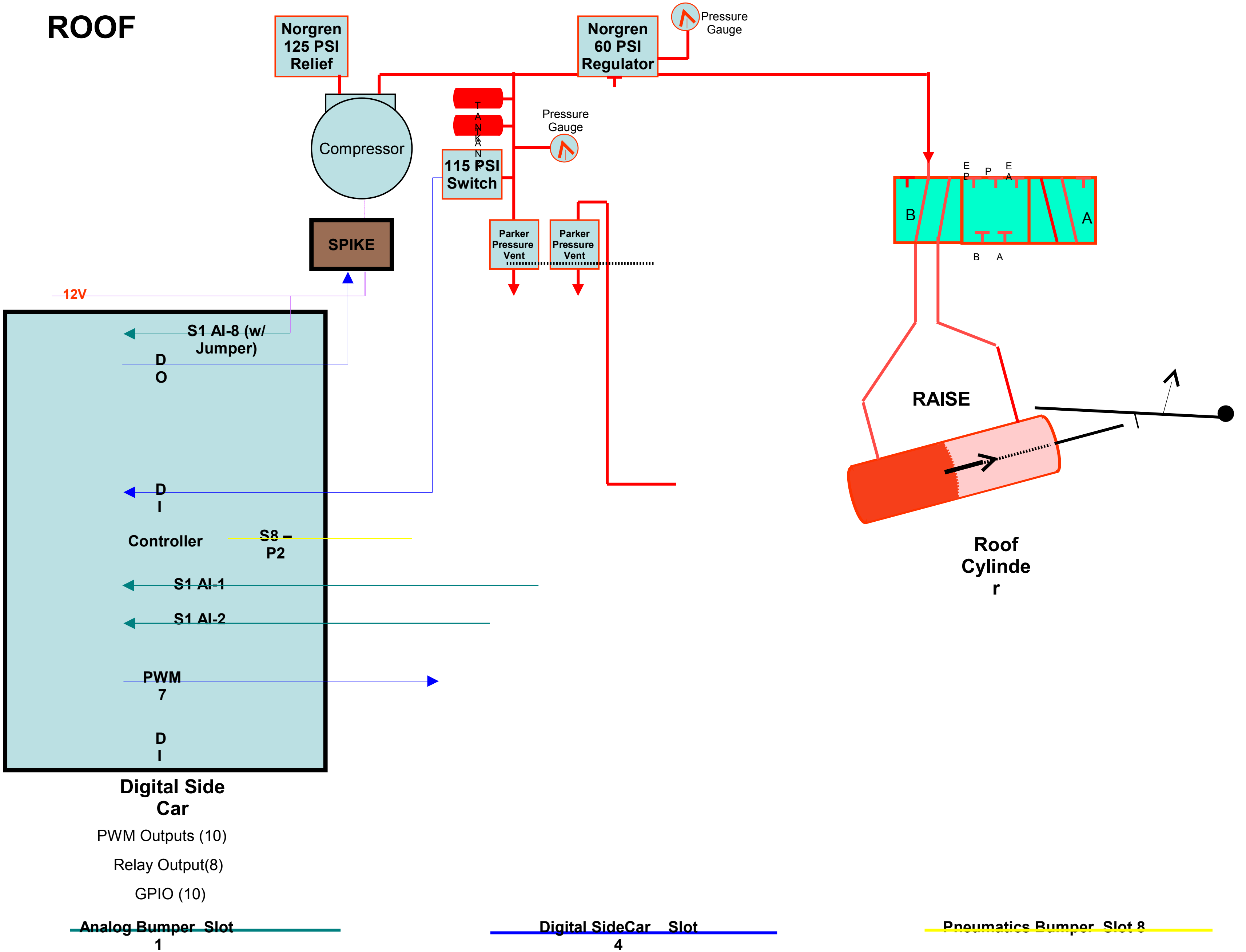

Norgren 125 PSI Relief
Norgren 60 PSI Regulator
Pressure Gauge
To Roof Cylinde r
Compressor
Pressure Gauge
115 PSI Switch
SPIKE
Parker Pressure Vent
Parker Pressure Vent
PILOT
12V
S1 AI-8 (w/ Jumper)
D O
S8 – P1
E B
P
E A
B
B A
S M C
A B
B
E A
P
E B
V E N T
Switches Position
D I
Controller
S8 – P2
S1 AI-1
S1 AI-2
Fire Pres. Sensor
Retard Pres. Sensor
PWM 7
D I
Limit Switch
RELEASE ELECTROMAGNET

ROOF


A
Norgren 125 PSI Relief
Norgren 60 PSI Regulator
Pressure Gauge
Compressor
TANK
TANK
Pressure Gauge
115 PSI Switch
SPIKE
Parker Pressure Vent
Parker Pressure Vent
E P
P
E A
B
A
B
A
HOLD
Roof Cylinder
12V
S1 AI-8 (w/ Jumper)
DO
DI
Controller
S8 – P2
S1 AI-1
S1 AI-2
PWM 7
DI
Digital Side Car
PWM Outputs (10)
Relay Output(8)
GPIO (10)
Analog Bumper Slot
Digital SideCar Slot 4
Pneumatics Bumper Slot 8
3 position closed center
3 position exhaust center
3 position pressure center
For AC

ROOF

B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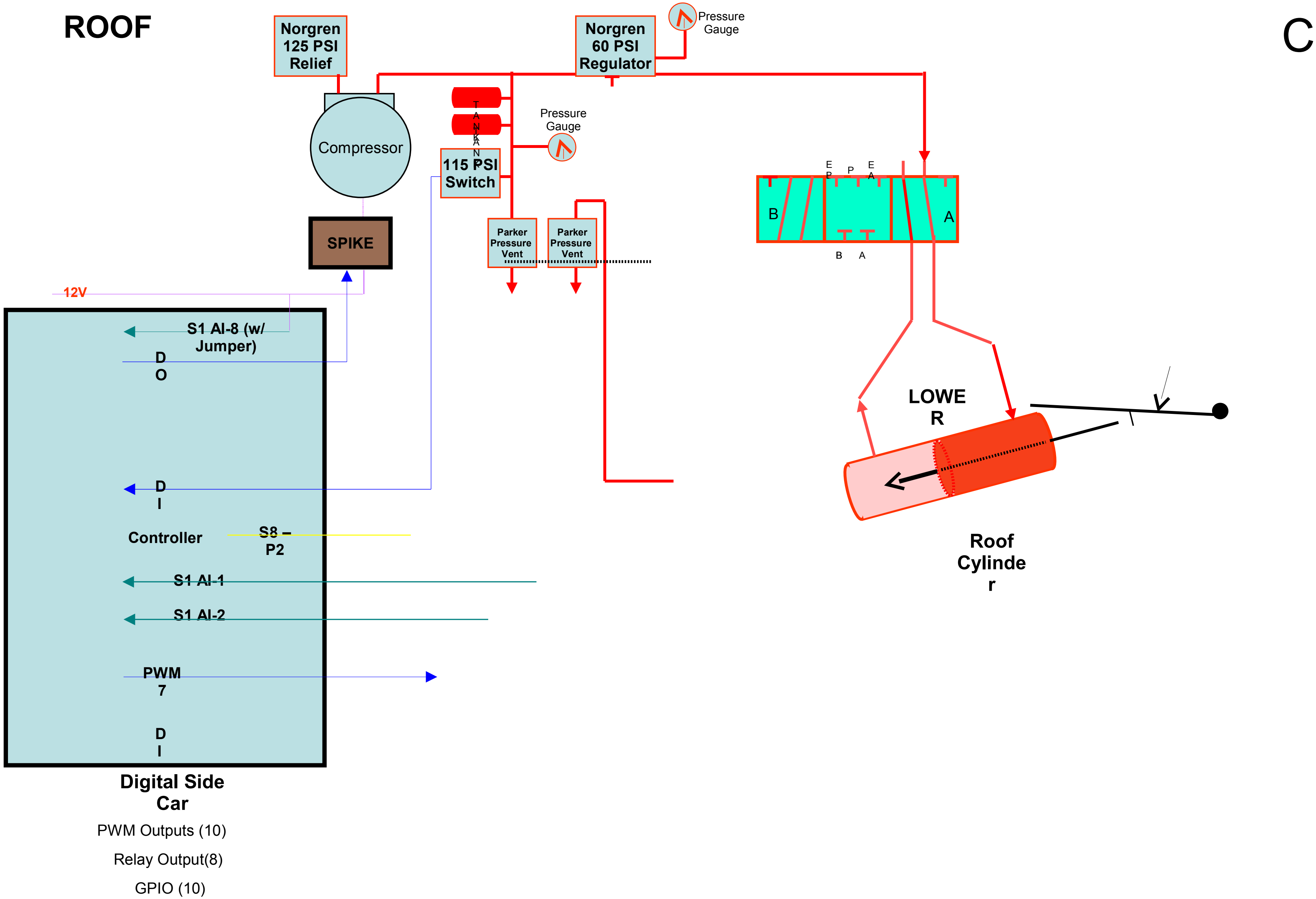
Norgren 60 PSI Regulator
Pressure Gauge
Compressor
Pressure Gauge
115 PSI Switch
SPIKE
Parker Pressure Vent
Parker Pressure Vent
12V
E P
P
E A
B
A
B
A
RAISE
Roof Cylinde r
S1 AI-8 (w/ Jumper)
D O
D I
Controller
S8 – P2
S1 AI-1
S1 AI-2
PWM 7
D I
Digital Side Car
PWM Outputs (10)
Relay Output(8)
GPIO (10)
Analog Bumper Slot 1
Digital SideCar Slot 4
Pneumatics Bumper Slot 8



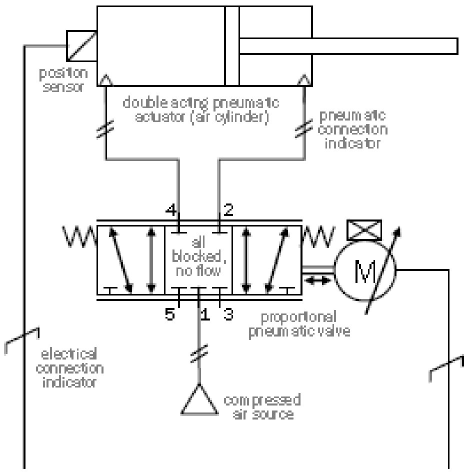
Analog Bumper Slot 1

Digital SideCar Slot 4

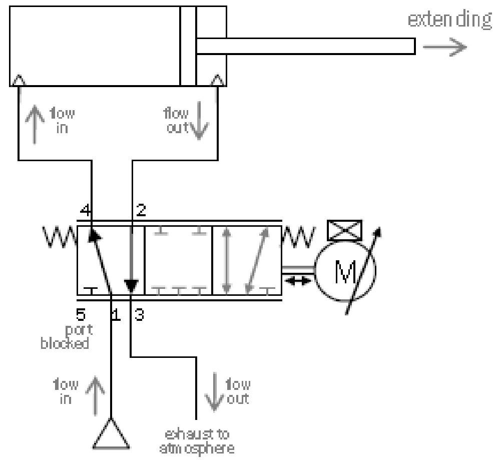
Pneumatics Bumper Slot 8

ROOF

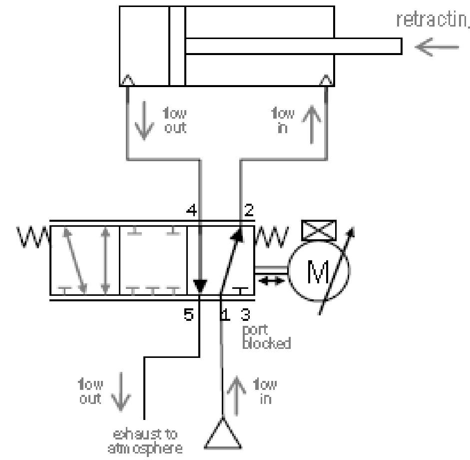
Scenario 1: system at rest in stable state
with actuator extended 2/3



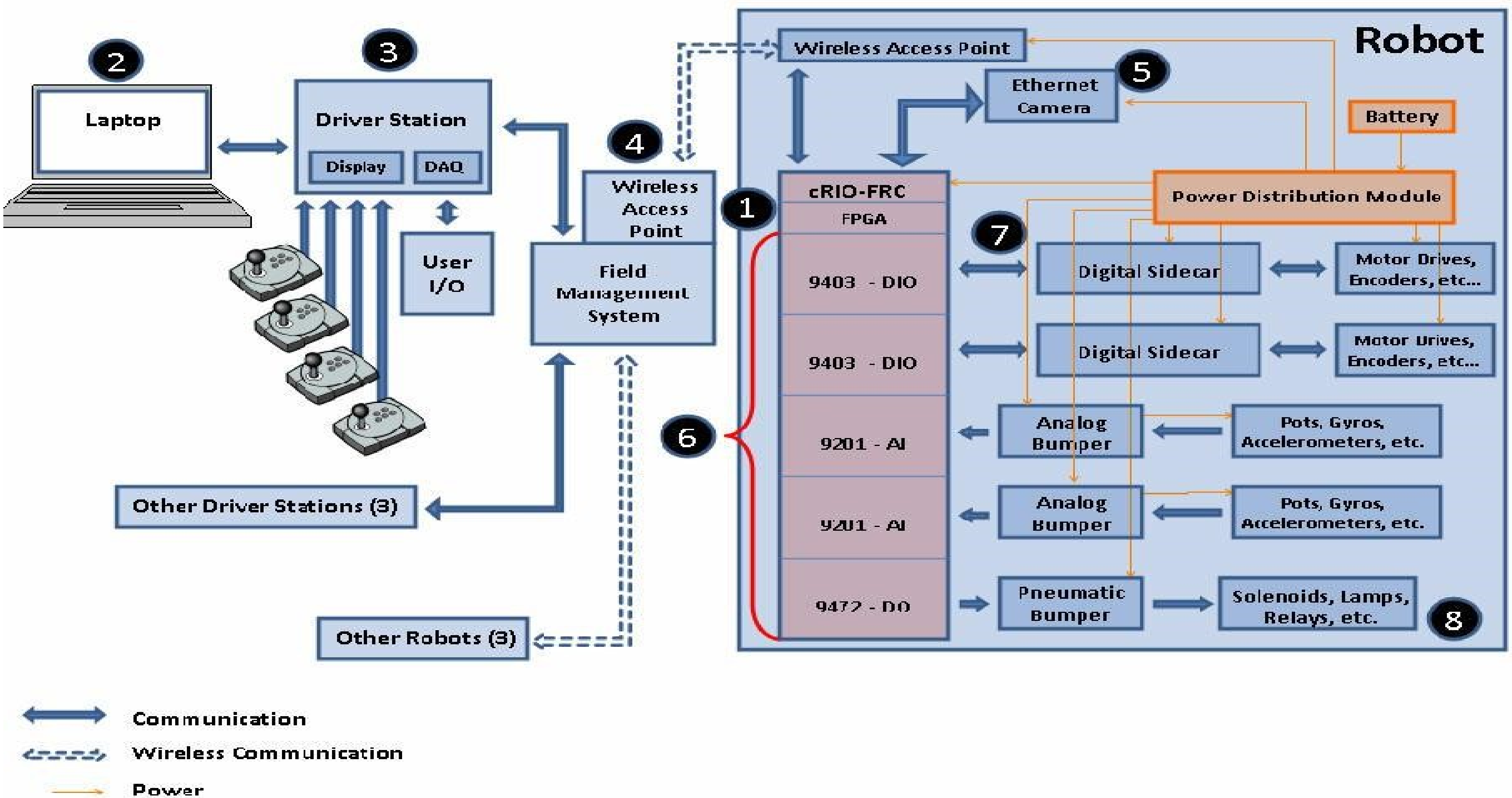
Scenario 2: shift valve to
extended actuator further



Scenario 3: shift valve to
retract actuator



FRC Topology



Choosing a Cylinder

First and foremost consider the total cylinders/vacuums you plan on using. There is only so much compressed air available during the short 2 minute matches we play. It gets used fast, but replenished slowly. You want to be sure you don't end up with a design that uses more air too fast than you've got.

Air available from a storage tank = tank volume (18.85 in^3) * (tank pressure(120psi) - working pressure that will remain in the storage tank (60psi)) / working pressure (60psi)

You can use a lower working pressure, usually 30-60psi, in the above equation to conserve pressure. And it's unusual, but possible to have a tank on the low pressure side and that would make the tank pressure in the above calculation also 30-60psi.

Second, use the smallest cylinder with the shortest stroke that gets the job done. For example, a large 2" diameter cylinder with a 12" stroke requires ($3.14*1^2*12"$ =) 38 cu. in. of air. At a working pressure of 60psi, that's the same amount of air available in two 18.85 cu-in storage tanks (2tanks * 18.85 * (120psi-60psi)/60psi = 38 cu. in.). You'd be able to use this cylinder once then have to wait for the compressor to replenish it. Replace it with a ¾" x 12" cylinder and you'd need ($3.14*(.75/2)^2*12"$ =) 5 cu. in. of air and two storage tank will supply enough air to open or close it seven times.

It's not quite as bad as it sounds. The compressor replenishes air at roughly an average of .4 cubic foot per minute or 11 cu. in./sec. supplying enough air to use the small cylinder twice a second and the large one once every 3 or 4 seconds. However, when you plan for multiple cylinders you can see that the air can get used up fast.

Another variation in your design is the working pressure. Using the above example, if instead of 60psi you design for 30psi, then the big 2"x12" cylinder can be used three times – open (once) and close (twice), and open (three times). The small ¾" x 12" cylinder can be used 22 times.
The difference in using the 2" vs. ¾" is the force you'll get out of the cylinder. At 60 psi the 2" one will produce ($60psi * 3.14*(1)^2$=) 188 lbs, while the ¾" cylinder will give you ($60psi * 3.14*(.75/2)^2$=) 26 lbs. Of course, dropping the working pressure to 30 psi produces ($30psi * 3.14*(1)^2$=) 94 lbs and ($30psi * 3.14*(.75/2)^2$=) 13 lbs respectively. The force is the difference between lifting a robot (once) and grabbing a light ball.

- Force – will vary with pressure drop as actuators use up air reserve.
- Mechanical advantage
- Rods are not hardened steel. They will bend if forced.
- Length/diameter – using smaller cylinders has a side effect of reducing overall robot weight. See the FIRST Pneumatics Manual for help in calculating the overall dimensions of a cylinder from end-to-end: http://team358.org/files/pneumatic/2007FRCPneumaticsManual.pdf
- Pressure
- Speed/time – flow control valve can slow things down. You'll need to experiment with your real application to get a feel for the time required as it varies due to resistance and friction.
- Special options – magnetic reed switches have been an option for a few years. They give feedback for when the piston is at one end or another (usually), but the sensor can be positioned anywhere along the piston's travel. If it's in-between ends be careful that the piston doesn't flash by too fast to register. These sensors are wired as any other switch would be – signal/ground to a Digital Input on the RC. The software can just check the switch value each cycle and do what you want done.
- Halfway positions - The pneumatics system is designed for cylinders to go to one extreme or the other, not halfway. However, you can route the exhausts from a solenoid to another single-action solenoid and by controlling the exhaust in-between positions can be achieved. If the rules permit,

then SMC has special valves you can order to do the job, e.g., 3 Position Closed Center (stiff when both coils are off) or a 3 Position, Exhaust Center (limp when both coils are off).

Cylinder Force Available

Force = Pressure x cylinder area

cylinder area = pi x $(bore/2)^2$

bore = the diameter of the cylinder

e.g., Force = 60psi x 3.14 x $(3/4"/2)^2$ = 26.49 lbs

When a piston is being pushed out air is forced against the full area of the piston's circular disk, but when it's being pulled closed pressure on the space occupied by the rod is lost (1/4" rod for the 3/4" bore cylinder). That's why pistons push with a little more force than they pull with. A smaller cylinder will add less weight to your robot and conserve air, so don't use a larger cylinder than you need to get the job done. The theoretical forces in the table will work out to be a little less in actual use, due to friction, and other conflicting demands on your pneumatic system, so over design a little.

	3/4" Bore	**3/4" Bore**	**1-1/2" Bore**	**1-1/2" Bore**	**2" Bore**	**2" Bore**	**90deg rotary**
Pressure (lbs/sq. in.)	*Force Extended (lbs)*	*Force Retracted (lbs)*	*Force Extended (lbs)*	*Force Retracted (lbs)*	*Force Extended (lbs)*	*Force Retracted (lbs)*	*Torque (in. lbs)*
20	9	8	35	32	63	57	3.32
25	11	10	44	40	79	71	4.15
30	13	12	53	48	94	85	4.98
35	15	14	62	57	110	99	5.81
40	18	16	71	65	126	113	6.64
45	20	18	79	73	141	128	7.47
50	22	20	88	81	157	142	8.30
55	24	22	97	89	173	156	9.13
60	26	24	106	97	188	170	9.96

Cylinder Air Volume Required

Volume = cylinder area x stroke
cylinder area = pi x (bore/2)²
e.g., Volume = 3.14 x $(3/4"/2)^2$ x 12" = 5.3 cu. in.

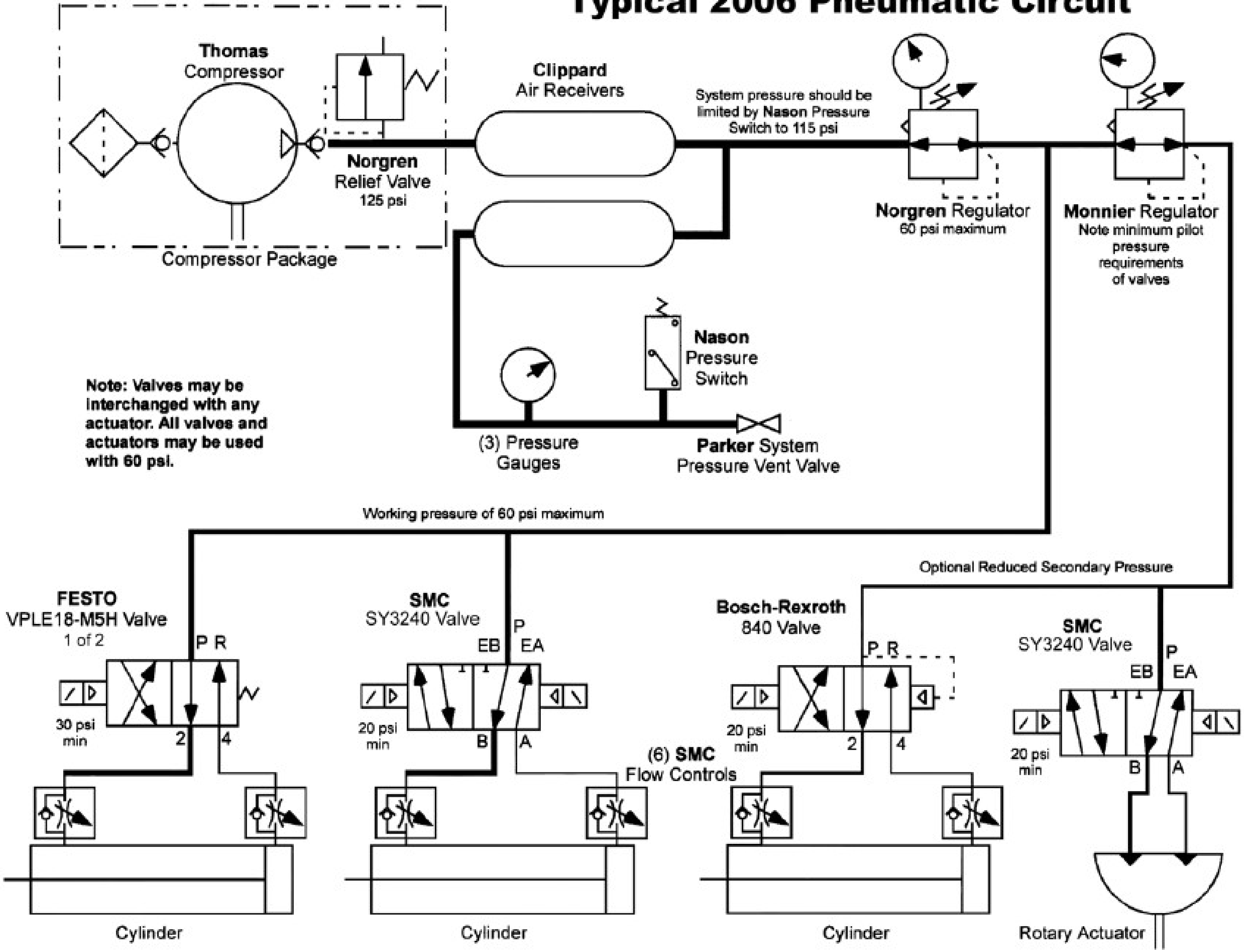
Table entries are left blank where the cylinder is not allowed with that stroke, based on 2007 FIRST rules. This is, however, subject to yearly rule changes. Also, these are the volumes at full extension and retraction and in practice can be limited by outside mechanical stops, so, for instance, if a cylinder only extends halfway before being stopped by the maximum movement of an arm, then only half the volume listed in the table below will be necessary. The piston takes up some of the air volume, so retracted a cylinder has less volume and less force too.

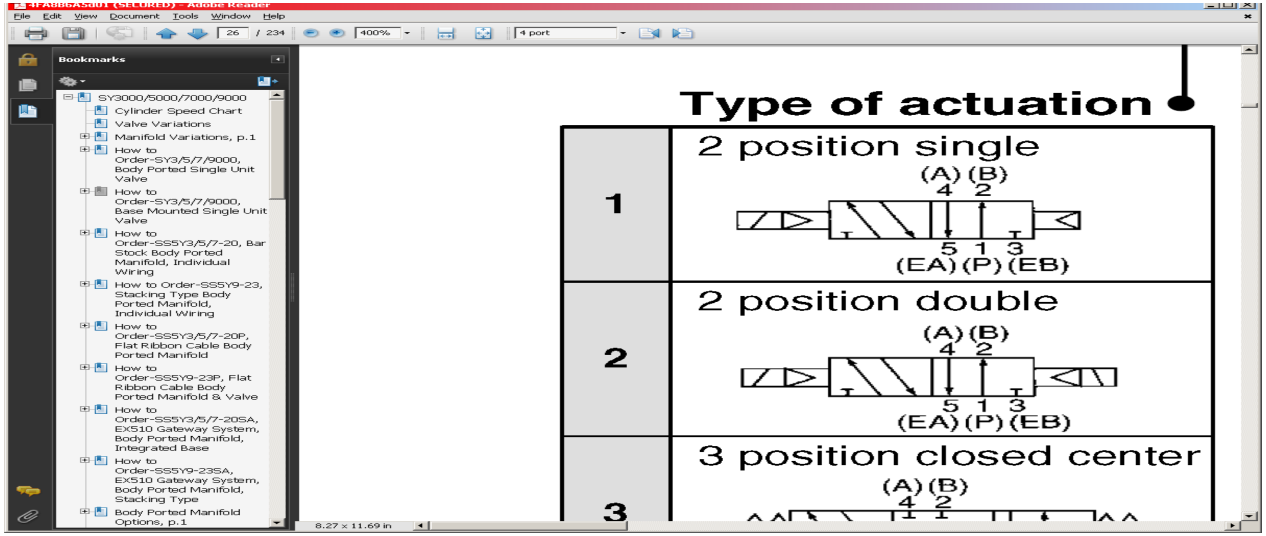
This information is most relevant by relating it to:

- Stored compressed air (18.85 cu-in per storage tank)
- Pressure (120psi storage vs. 30-60psi in the cylinder)
- Compressor (roughly 11 cu. in./sec on average at 60psi)

	3/4" Bore	3/4" Bore	1-1/2" Bore	1-1/2" Bore	2" Bore	2" Bore
Stroke (in)	*Volume in^2 Extended*	*Volume in^2 Retracted*	*Volume in^2 Extended*	*Volume in^2 Retracted*	*Volume in^2 Extended*	*Volume in^2 Retracted*
0.5	0.2	0.2	0.9	0.8	1.6	1.4
1.0	0.4	0.4	1.8	1.6	3.1	2.8
1.5	0.7	0.6	2.6	2.4	4.7	4.3
2.0	0.9	0.8	3.5	3.3	6.3	5.7
2.5	1.1	1.0	4.4	4.1	7.9	7.1
3.0	1.3	1.2	5.3	4.9	9.4	8.5
4.0	1.8	1.6	7.1	6.5	12.6	11.4
5.0	2.2	2.0	8.8	8.1	15.7	14.2
6.0	2.6	2.4	10.6	9.7	18.8	17.0
7.0	3.1	2.8	12.4	11.3	22.0	19.8
8.0	3.5	3.2	14.1	12.9	25.1	22.7
9.0	4.0	3.6	15.9	14.6	28.3	25.5
10.0	4.4	4.0	17.7	16.2	31.4	28.3
11.0	4.9	4.4	19.4	17.8	34.5	31.2
12.0	5.3	4.8	21.2	19.4	37.7	34.0
24.0	10.6	9.6	42.4	38.8	75.4	68.0

Typical 2006 Pneumatic Circuit

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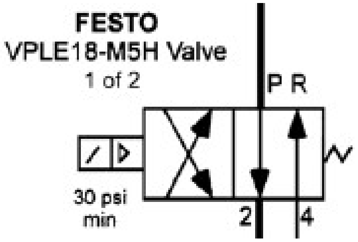
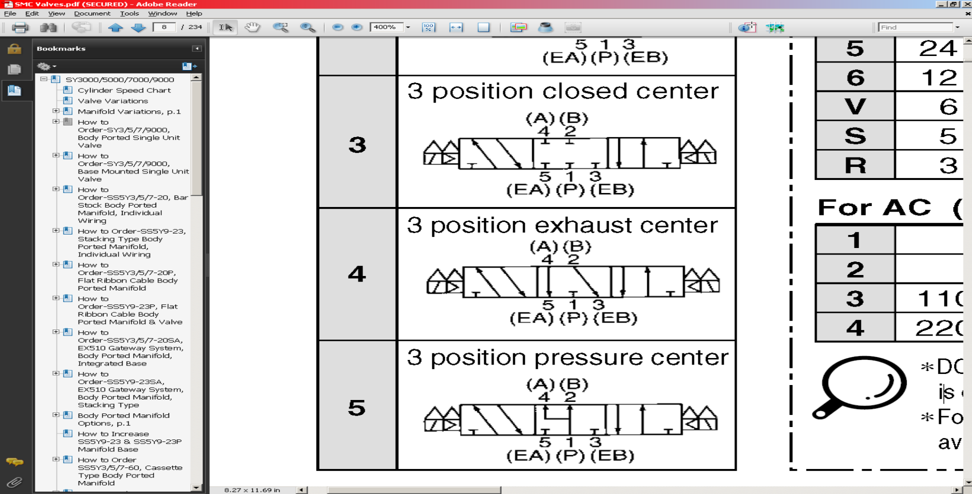
File Edit View Document Tools Window Help
Bookmarks
SY3000/5000/7000/9000
Cylinder Speed Chart
Valve Variations
Manifold Variations, p.1
Type of actuation
1
2 position single
(A) (B)
4 2
5 1 3
(EA) (P) (EB)
2
2 position double
(A) (B)
4 2
5 1 3
(EA) (P) (EB)
3
3 position closed center
(A) (B)
4 2
8.27 x 11.69 in


FESTO
VPLE18-M5H Valve
1 of 2
P R
30 psi
min
2
4


SMC Valves.pdf (SECURED) - Adobe Reader
Bookmarks
3 position closed center
(A) (B)
4 2
5 1 3
(EA) (P) (EB)
3 position exhaust center
(A) (B)
4 2
5 1 3
(EA) (P) (EB)
3 position pressure center
(A) (B)
4 2
5 1 3
(EA) (P) (EB)
3
4
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6
V
S
R
24
12
6
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3
For AC (
1
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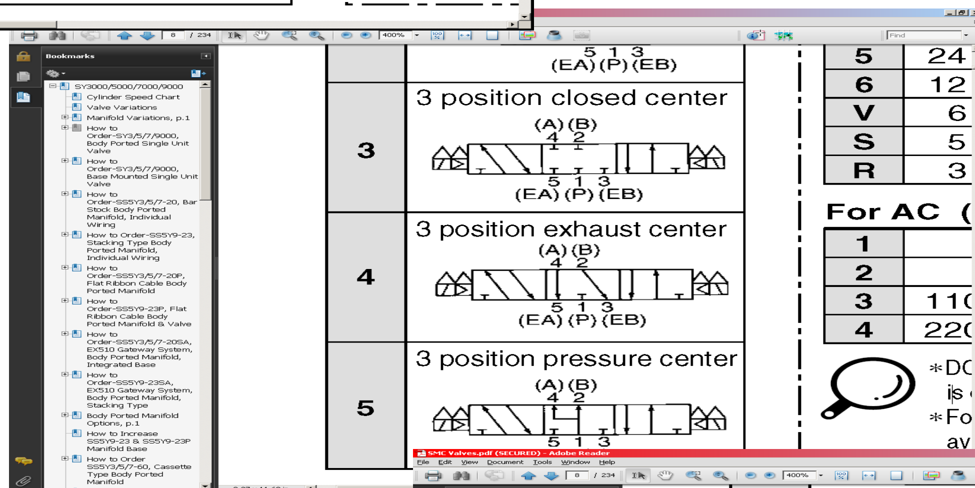
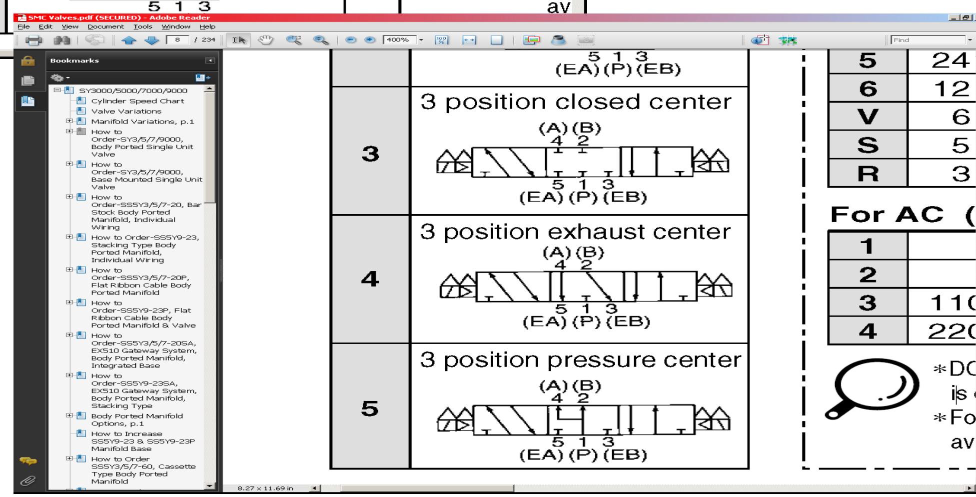
11(
22(
8.27 x 11.69 in

Bookmarks
3 position closed center
3 position exhaust center
3 position pressure center
(A) (B)
4 2
5 1 3
(EA) (P) (EB)
For AC (
8.27 x 11.69 in

SMC Valves.pdf (SECURED) - Adobe Reader
Bookmarks
3 position closed center
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(A) (B)
4 2
5 1 3
(EA) (P) (EB)
3 position pressure center
(A) (B)
4 2
5 1 3
(EA) (P) (EB)
For AC (
8.27 x 11.69 in