Magellan Deployable Calibration Unit

Rev	Date	Notes	Author
0.0	2013-03-08	Initial release	Uomoto
0.1	2013-03-12	More detail; changed name to DCU	Uomoto
0.2	2013-03-20	Added override solenoid, Issues summary table, signals & power lines, PLC description	Jones, Birk, Uomoto
0.3	2013-03-28	Removed heat-producing solenoids from the DCU, added incandescent lamp plans, new PLC description	Uomoto
0.4	2013-04-05	Modified pricing info, removed override solenoid, minor pneumatic layout changes	Uomoto, Birk, Hare
0.5	2013-05-20	Updated PLC info, removed temp sensor & DCU sense line	Uomoto, Jones
0.6	2013-08-05	Updated pneumatic circuits	Uomoto

Overview

The M2FS multi-fiber spectrograph requires a calibration lamp system (MCal) placed near the Clay telescope prime focus. MCal sends light upwards to the secondary mirror that subsequently illuminates the M2FS input fiber optics.

While in use MCal blocks incoming starlight so sky observations require removing it from the beam. This document describes the Deployable Calibration Unit (DCU) that moves MCal in and out of the telescope beam.

An existing calibration screen, “FF Screen,” which is the flat field light target, will be upgraded to use the new DCU control system. The term “DCU” describes both the Mcal and FF Screen deployment systems. The MCal and FF Screen will be controlled with the same hardware and software.

Requirements

Item	Value	Units	Justification	Notes
Fail-safe collision prevention with flat field screen, MagAO CRO truss, etc.	100%	N/A	Collisions can eject hardware that could damage the primary mirror	A simple override or reset system is desirable
Maximum deployment time into active position	15	Secs	Observing efficiency	Interacts with settle time
Maximum retraction time to stow position	15	Secs	Observing efficiency	
Maximum settle time after deployment into active position	5	Secs	Observing efficiency	Tyson will compute frequency and dampen if neeeded.
Position repeatability on deployment	2,2,2	mm	Fibers should be illuminated consistently between calibrations	Ask Mario for these number
System replicated on Baade	100%	N/A	Having identical systems is good for consistent operations	Baade will not have an MCal unit
Operating temperature range	-10 to 30	C	Expected temperature range at the secondary cage	Confirmed at 2013-03-14 telecon

Existing Flat Field Screen Deployment System

The existing flat field screen provided the baseline mechanical design for the new DCU. The flat field screens use:

1. Two tandem (dual-cylinder) 90-degree pneumatic rotary actuators from PHD (phdinc.com), part number R21A6090-P-D-A-E. These weigh about 16 lbs each.
2. Two sense switches on the pneumatic cylinders: PHD model 17503-2-06 "solid state" (Hall effect) devices with sinking (NPN) output. They run on 10 to 30 VDC and are held in place by a bracket, PHD part number 17000-38-0 (for 5000 and 6000 series actuators).
3. Clippard Mouse poppet valves (two) are used to operate the pneumatic cylinder.
4. The Mouse valve solenoids are powered through Opto-22 G4ODC24A solid state relays (SSRs).
5. The Opto-22 SSRs are triggered by a DGH D1712 I/O module. The D1712 has 15 open collector output bits capable of sinking 100 mA at up to 30 VDC. They can also be programmed as input bits. Commanding is through an RS-485 interface. This device requires 10-30 VDC unregulated at up to 0.75W.
6. The D1712 I/O commands are received from an Adam 4520 RS-232 to RS-422/RS-485 converter that in turn received the RS-232 from a MiLan print server. We are now challenging Rube Goldberg. This device requires 10-30 VDC for power.
7. Operations summary: the observer's computer sends a command over Ethernet to the MiLAN print server model MIL-P3720/IN where the command stream is converted to RS-232. The RS-232 commands are sent to an Adam 4520 RS-232 to RS-485 converter. The RS-485 signal is sent by copper wire to the Top Ring Box where the DGH D1712 I/O module receives and interprets it.
8. Software on the observer's computer talks to the MiLAN. It was originally written by Skip Schaller and modified and maintained by Glenn Eychaner.

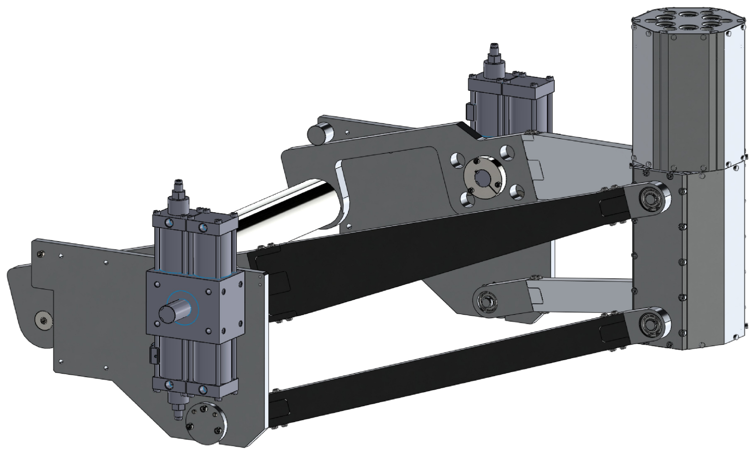
Existing constraints and concerns

1. The DCU must not interfere with MagAO (Magellan Adaptive Optics) CRO truss installation or use. The CRO truss is inserted from the primary mirror side of the secondary cage and physical access to the mounting points should not be blocked by the MCal DCU. Mechanical interference with the retracted Mcal unit must also be avoided.
2. The existing flat field screen (FF Screen) in its stowed position must not interfere with MCal deployment.
3. The existing FF Screen is actuated by pneumatics. The MCal system should also use pneumatic actuators to ease retrofitting the FF Screen system which will be integrated with the new MCal system.
4. When air pressure fails, the existing flat field screen can float. This has not been a safety problem during normal operations but adding the new DCU creates collision possibilities. With both the MCal and FF Screen DCUs available a safety interlock system is required to prevent collisions.

Design Concept

Mechanical

Here's an overview of the DCU mechanical design by Tyson Hare.

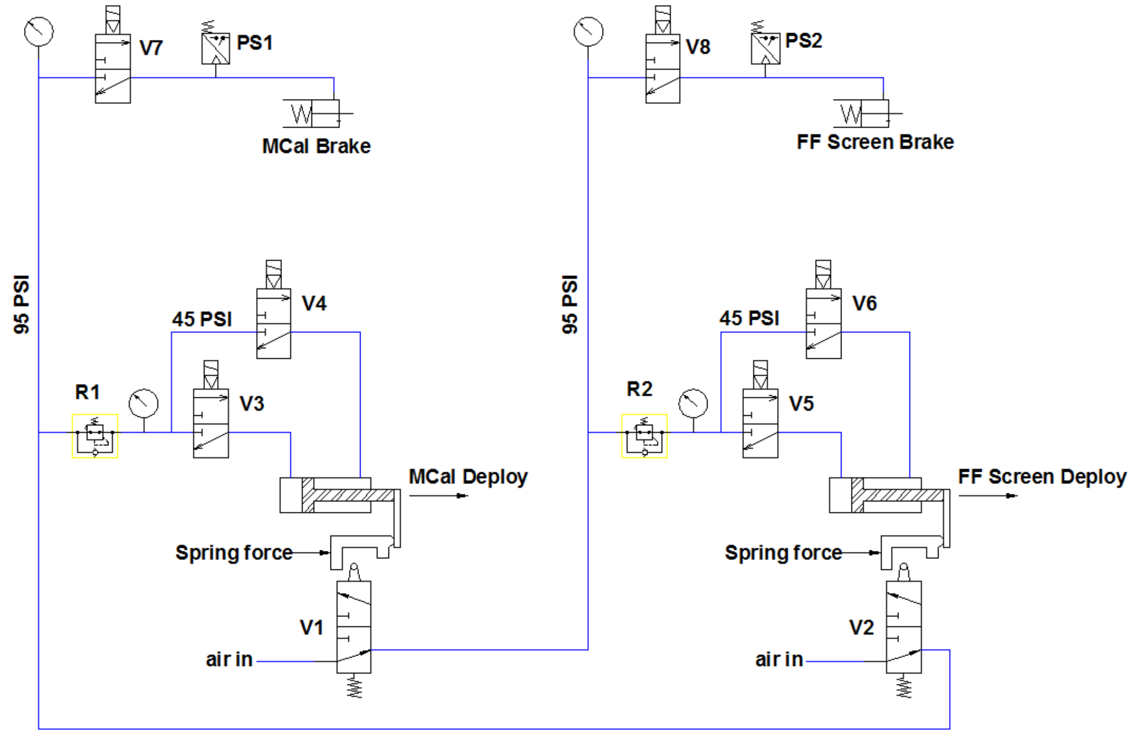


1. The motion is driven by two pneumatic tandem rotary actuators, the same product used on the flat field screen.
2. One actuator will have two piston position sensors to detect end-of-travel in both directions.
3. A spring-applied pneumatic-release caliper disk brake (not shown here) holds the system in place while stowed or deployed.
4. The DCU is fixed to the secondary mirror support structure with clamps similar to those on the FF Screen (clamps not shown here).

Mechanical Actuators and State Sensing

Concept Overview

This diagram describes the pneumatic actuator plumbing. Some items such as flow controls, the tandem cylinders, etc., are not shown to minimize clutter. The left and right portions of the diagram are functionally identical and represent the separate MCal and the FF Screen DCU systems.



In the lower part of the diagram there are two “air in” locations, one on each DCU. Air at 95 psi is piped from the Top Ring Box and supplied to the valves V1 and V2. These are 3-way normally open valves that control the air supply to the opposite DCU. That is, V1 on the MCal DCU supplies air to the FF Screen actuators and V2 on the FF Screen system supplies air to the MCal DCU. Their function, described later, is a safety interlock.

The regulators R1 and R2 reduce the 95 psi to something appropriate for the rotary actuators (45 psi at this writing).

Valves V3, V4, V5, and V6 are 3-way normally-closed solenoid valves that deploy or retract their associated rotary cylinders. The two cylinders labeled MCal Deploy and FF Screen Deploy (flat field screen) represent the rotary pneumatic actuators. In this diagram both MCal and FF Screen are in the stow position, outside the telescope beam. Moving the pistons to the right deploys them.

The valves V7 and V8, also 3-way normally closed solenoid valves, control the brakes. Applying air pressure releases the brake. Pressure sensors PS1 and PS2 trip when the pressure in the line exceeds about 85 psi, indicating that the brakes are off (the brakes release at >85 psi).

The valves V1 and V2 reduce the possibility of both MCal *and* FF Screen deploying at the same time. These pneumatic valves are 3-way normally-open cam-lever-actuated spring-return valves. In their un-actuated state, when MCal and FF Screen are stowed, they allow compressed air to flow.

Here’s how the air interlock works. When MCal is in the stow position (as in the diagram), V1 is open (the lever is not pressed) and compressed air can flow to the FF Screen control valves V5 and V6 and also to the FF Screen brake control valve V8. Similarly, when the FF screen is stowed, V2 is open and compressed air is supplied to the Mcal control valve V3 and V4 and its corresponding brake valve V7. So when *both* MCal and FF Screen are in stow position, both are enabled for motion.

Suppose MCal is commanded to deploy by energizing V3 after releasing the brake with V7. As MCal moves away from the stow position the L-shaped arm next to V1 is pushed towards the V1 lever by an external spring.[1] When V1 is activated it blocks the compressed air source to the FF Screen control valves V5 and V6 and vents that supply line. With no air on V5 or V6, FF Screen cannot move under air pressure control. Furthermore, without air the FF Screen brake is on and cannot be released regardless of the state of V8.

The same thing happens when the FF Screen is deployed while MCal is stowed.

Sensors

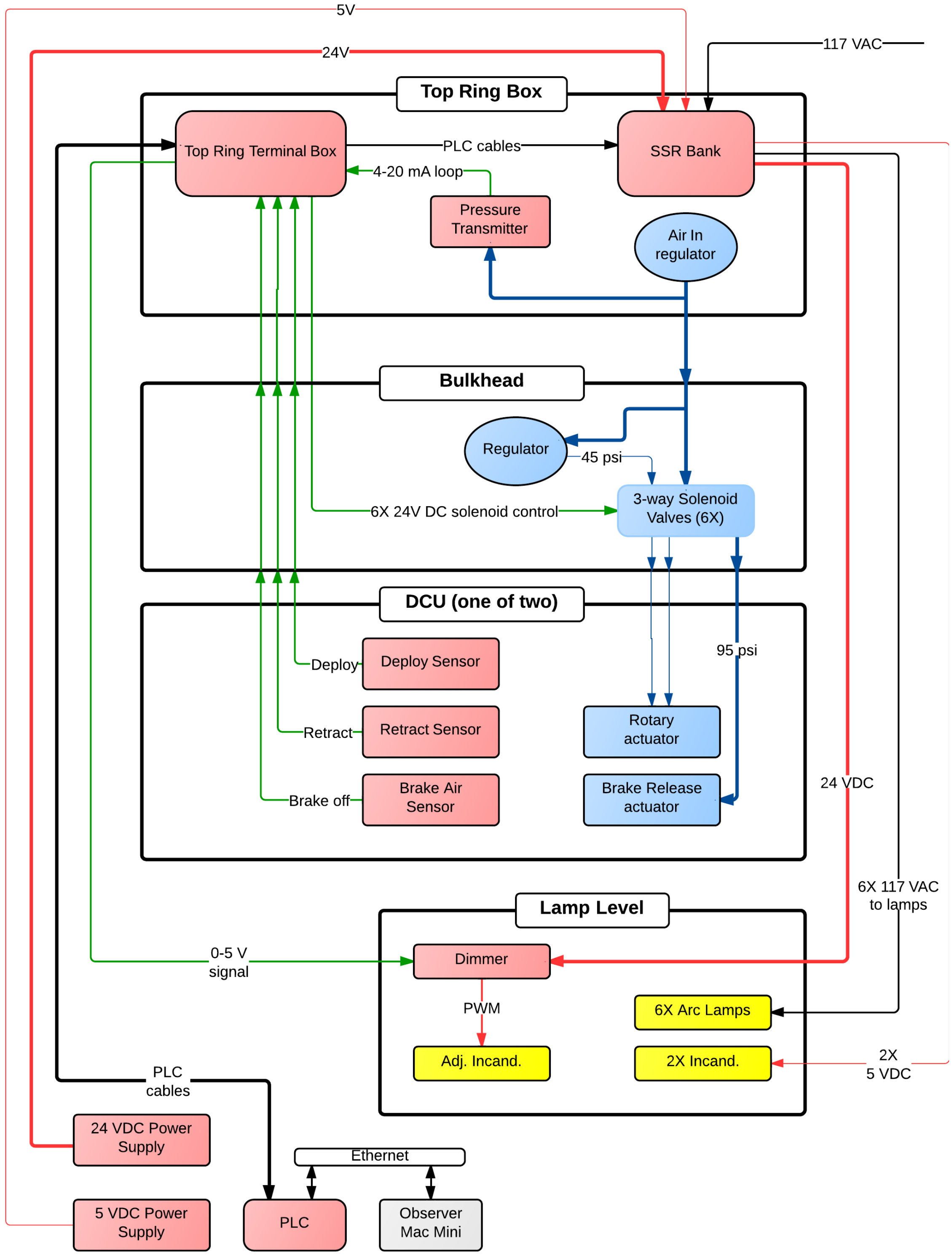
Hall Effect sense switches on the actuating cylinders indicate when a DCU is fully retracted or deployed.

Air pressure switches (PS1 and PS2 in the diagram) are surrogates for sensing whether or not the brakes are applied. The brakes require >85 psi to release. These electrical switches change state when a particular pressure is attained.

Electronic Controls

The following figure is an air and electrical schematic of the DCU control system.

1 In the final design the lever is actuated by a shaft-driven divot (cam) mechanism, not an external spring.



The four boxes ("Top Ring Box," "Bulkhead," "DCU," and "Lamp Level") represent four separate locations on the telescope (five locations if you have two DCUs).

The Top Ring Box is the nexus for all incoming utility and PLC data connections. It contains an air pressure regulator, an air pressure transmitter, and solid-state relays for controlling calibration lamps and the air solenoid valves.

The DCU control components include the two air-piloted spring-return air valves (brake and deploy/retract), and three electrical sensors (brake, deploy, and retract).

On the Lamp Level there is a dimmer control to adjust lamp flux as well as terminal connections for the arc lamps and non-dimmed incandescents.

This table summarizes the required electrical signals and current supplies.

Signals and power from the PLC I/O unit for two DCUs					
Item	**DC In**	**DC Out**	**Relay**	**Analog In**	**Analog Out**
Brake air pressure sensor switch (1 per DCU)	2				
Deployed sensor (1 per DCU)	2				
Retracted sensor (1 per DCU)	2				
Pressure transmitter				1	
Solenoid valve for deploy (2 per DCU)			4		
Solenoid valve for brake-release (1 per DCU)			2		
Arc lamps 117 VAC power (6X lamp banks)		6			
Incandescent lamps signal (2X lamp banks)		2			
Lamp dimmer signal (1X lamp bank on 24 VDC)					1
Total	**6**	**8**	**6**	**1**	**1**

- The Brake Air Pressure Sensor Switch is a SPDT mechanical switch that closes when sufficient pressure to release the brake is available (>85 PSI). It's purpose is to indicate that the brake has been released and moving the DCU is possible. An open condition on this switch is not a reliable indicator that the brake is applied, however. It should be wired to present +24 VDC when the brake is applied, <1.0 V when the brake is released.
- The Deployed and Retracted sensors are Hall Effect switches presenting an open collector signal (+24 VDC) to the PLC.
- The Pressure Transmitter reads the supply air pressure (should be 95 PSI) being delivered to the DCUs. This is a 4-20 mA current loop. A 200 Ω resistor can be used to shunt on a 0-5 VDC analog input port.
- The Solenoid Valve for Deploy lines activate the two Clippard Mouse valves that provide air to the rotary actuator.
- The Solenoid Valve for Brake-release activates a Clippard Mouse valve that provides air to the brake release valve.
- The six banks of arc lamps are controlled by turning their 117 VAC supplies on and off with solid state relays.
- Two banks of 5 V incandescent lamps are switched on and off with solid state relays.
- The Lamp Dimmer Signal is an analog voltage that controls the current through the adjustable incandescent lamps. Supply power for these 5 V lamps is taken directly

from the system +24 VDC power supply. A +4.8 V signal on the lamp dimmer provides the rms-equivalent current for full-on lamp brightness.

Subsystem Details

This DCU and Cal Lamp systems will operate on both Baade and Clay, although on Baade only one DCU, the FF Screen, will be present. The hardware and software on both telescopes, minus the MCal DCU on Baade, will be identical.

The FF Screen and MCal have similar deployment requirements so their operational logic will be identical. We will call the deployment portion the Deployable Calibration Unit (DCU) with the items being deployed named the FF Screen and Mcal.

FF Screen (convert to DCU system)

This deployment system exists. We will retrofit the FF Screens on both telescopes to use the new DCU system.

MCal (on the new DCU)

The MCal is a cylindrical package carrying an array of upward-looking calibration lamps. This assembly is inserted into the telescope beam near the prime focus and must be removed from the beam for sky observations.

The MCal lamps are controlled by M2FS-specific software; their operation is not controlled by the Observer's Software described below or by the DCU control system.

The MCal DCU is mounted opposite the FF Screen on the secondary support cage. MCal and the FF screen sweep through the same space when deployed so we need a reliable way to prevent collisions.

Calibration Lamp System

There are six banks of gas discharge lamps powered by switched 117 VAC lines. There are currently three banks of incandescent halogen bulbs powered by switching their +5 VDC lines.

One of the three banks of incandescent lamps will be converted to a flux-controlled system by adding current control. A 0-4.8VDC control signal from the PLC (arriving via the Top Ring Box) controls current from the +24 VDC power supply through a PWM LED/Halogen lamp dimmer (an Anigmo DMS-500-X). Although the existing lamps are designed for 5 VDC supply power, the equivalent rms current can be derived from the +24 VDC supply through the lamp dimmer.

We are anticipating an upgraded FF lamp system that controls flux through an adjustable aperture instead of changing the lamp current, which changes the color temperature. (We prefer to keep the spectrum as hot as possible.) The analog signal will control the apertures in front of a bank of full-on 24 VDC lamps (eliminating the 5 VDC supply).

Control software

The PLC I/O controls will be programmed and tested by mountain staff.

Observer's Software

The new interface will be a new GUI running on the observer's Mac Mini computers. Besides controlling the mechanical motions, it will also control the non-M2FS calibration lamps.

Details of this software TBD (Christoph and Patricio should confer, then write the requirements here).

TCSIS communications

The observer's software will send status data from the PLC to the TCSIS so other systems can know the state of the calibration lamps and DCUs.

Operation Scenario

This is a list of a possible operational sequence used to deploy and retract MCal or FF Screen.

Deploy

Assume both MCal and FF Screen DCUs are in stow position. This means the brake is on, air pressure is available and V1, V2, V3, and V4 are unactuated. The Hall Effect sensors on the pneumatic cylinders are indicating correctly and correct air pressure is sensed.

Assume we're deploying MCal.

1. Check that "both-stowed" status is correct (see above), air pressure is correct, lamps are off, etc.
2. Release the MCal DCU brake.
3. Wait for an interrupt from brake sensor indicating that the brake is OFF. [Note: this action happens quickly so it might be OK just to wait a second and check the brake sensor]
4. Energize V3, initiating air flow into the MCal DCU pneumatic cylinder deploy side.
5. Start a timer that interrupts after a time-out period.
6. On interrupt from the retracted sensor on the MCal DCU cylinder (change of state from "retracted" to "not-retracted") set status bits to "MCal in-transit."
7. Wait for interrupt from the "deployed" sensor on the MCal DCU cylinder.
8. On interrupt from MCal DCU "deployed" sensor, start a timer to wait for the settle time.
9. After a few seconds settle time interval, set the brake by releasing the brake air pressure.
10. Set status bits to either "MCal deployed" or "MCal deploy timeout."

Retract

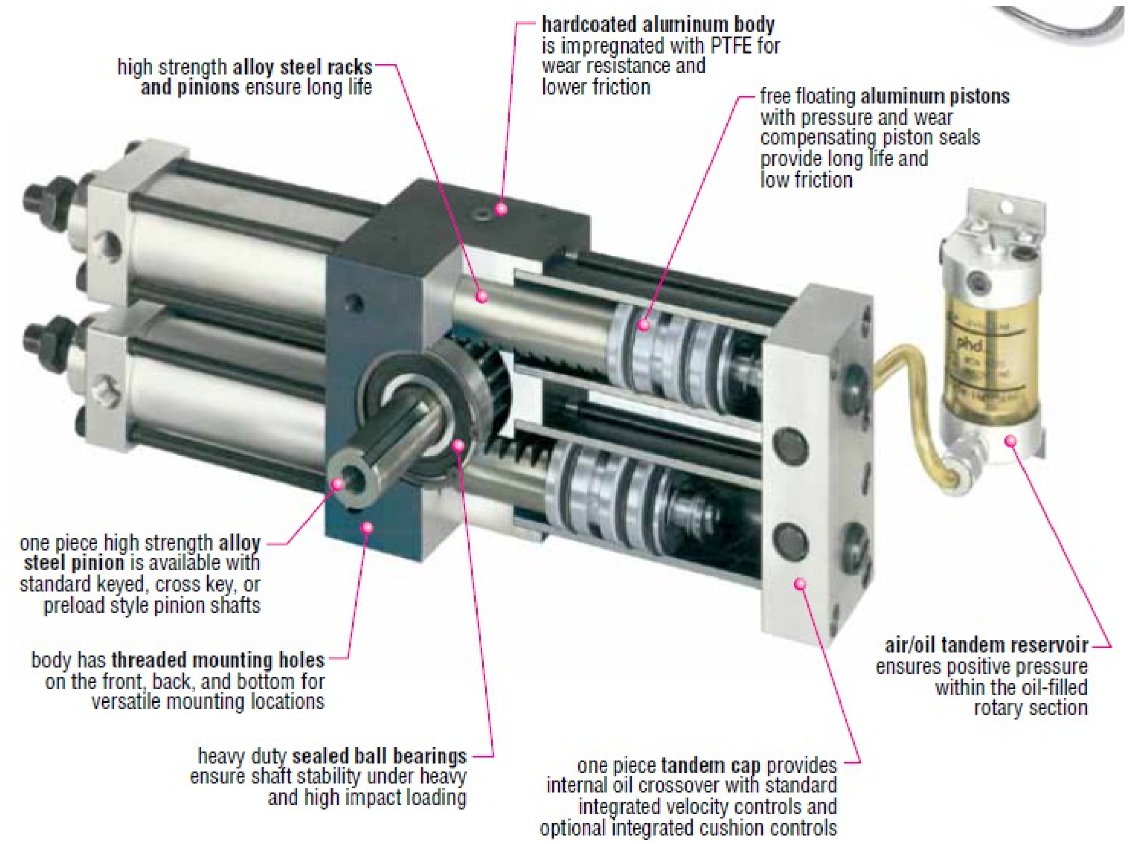
Assume we're retracting MCal.

1. Check that “MCal deployed” status is correct, air pressure is correct, lamps are off, etc.
2. Release the brake.
3. Wait for interrupt from brake sensor indicating the brake is OFF. [Note: this action happens quickly so it might be OK just to wait a second and check the brake sensor]
4. De-energize V3 and energize V4, venting the extend side of the MCal DCU cylinder and pressurizing the retract side.
5. Start a timer that interrupts after a time-out period.
6. On interrupt from the retracted sensor on the MCal DCU cylinder (change of state from “deployed” to “not-deployed”) set status bits to “MCal in-transit.”
7. Wait for an interrupt from the “retracted” sensor on the MCal DCU cylinder.
8. On interrupt from the MCal DCU “retracted” sensor, start a timer to wait for the settle time.
9. After a few seconds settle time interval, set the brake by releasing the brake air pressure.
10. Check status then set status bits to “Both retracted” or “MCal retract timeout.”

Component Descriptions

Rotary Actuator

The pneumatic rotary actuator is a 6000-series PHD R21A6090P-D-A-E. The part number breakout describes this as a Double Shaft (R2), Imperial (1), Pneumatic (A), 2-inch Double Bore Rack (6), 90-degree rotation (090), with built-in Flow Control in both directions (P, exhaust only), Cushions in both directions (D), Angle adjustment on both ends (A), and Magnetic Piston (E). The shaft diameter is 1.125 inches. The shaft has an 0.25 inch keyway for a square insert (but ours seems to be a bit smaller than 0.25 inches). Operating temperature is -29 C to +82 C.



Rotary Actuator Magnetic Sensor

These Hall Effect sensors sink current when near a magnet and require +10 VDC to +24 VDC for power. Used to note position of the unit (retracted, deployed, or in-transit). Both units sensing active would be a hardware fault.

The operating temperature range for these is 0 C to +80 C, so the low temperature limit does not meet our requirements. One suspects the effect is primarily in sensitivity so a one-time position adjustment might be needed at some point.

3-way Cam-driven Valve

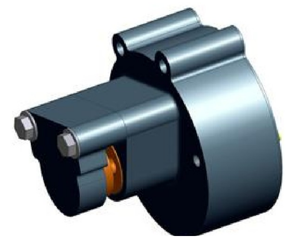
These are Bimba/Mead MV-15 normally open valves (Mead calls it a switch). They shut off air to the opposite unit (MCal or FF Screen DCU) when the current unit is deployed as a collision avoidance lockout.

- Steel roller requiring 1.3 lbs to close the valve
- C_V = 0.11
- 1/8” NPT ports
- Temperature range (Mead says the components are the same as in their LTV valves which are rated for 0F to +115F, or -18 C to +46 C)
- 120 PSI maximum air pressure

Spring-applied disk brake

This is a W. C. Branham model PFS47AF caliper disk brake. When there's no air pressure, the brake is ON.

- Single acting (one-sided). So it needs a sliding mount.
- Belleville stack holding spring
- Requires 85 PSI or more to release
- 5/32-inch rotor thickness
- 100 PSI maximum pressure
- Telephone inquiry to Branham reports -20F to +200F (-29 C to +93 C) operating temperature range
- 465 lbs tangential holding force maximum. An 8-inch diameter brake disk has an effective holding radius of 3.13 inches so the braking torque is 3.13x465=1455.5 in-lbs. Each rotary actuator might put out as much as 4.72 in-lbs/PSI so at 100 PSI the torque is 472 in-lbs per actuator. There are two actuators so the total torque is 944 in-lbs, less than the 1455.5 in-lbs holding ability of the brake.
- If we use a 10-inch diameter brake disk we can guess that the effective holding radius is 4.13 inches so the braking torque is 4.13x465=1920 in-lbs.



Disk brake disk

W. C. Branham can supply a 5/32 inch thick disk for the PFS47AF brake. Part number 4803-0020 is for a 10.0 inch diameter disk. This disk includes a hub with a bore diameter of 1.25 inches (same as the rotary actuator shaft) and a 1/4x1/4 inch keyway (same as the rotary actuator shaft). It's made of 1010 carbon steel and may rust in our low-use application. We would make our own disk out of stainless steel if rust becomes a problem.

3-way Solenoid Valve

The Clippard Mouse is a small solenoid-driven poppet valve that pilots our actuator valves. We will use the model ET-3M-24 manifold mounted version. The solenoid requires only 0.67 watts of power (27 mA at 24 VDC). The pressure range allowed is from vacuum to 105 PSI; we will run at 95 PSI. We need three for each DCU: two for the deployment actuator and one for the brake.

These valves are not rated for operation below 0 C although the existing FF Screen system uses these valves, unprotected, apparently without problem.

Pressure Switch

Knowing if the brake is on or off can be inferred from the air pressure in the brake line. If there is more than 85 PSI in the brake line, we assume the brake is off.

Our suggested sensor is an A-Series Miniature SPDT from Ashcroft. Deconstruct the part number APA-N4-1G-024L-S-01-100#-90R as follows:

- APA means the setpoint is field-adjustable
- N4 is a watertight 316 stainless steel body
- 1G SPDT action with gold contacts, 0.1 A max current at 125 VAC or 30 VDC
- 024L indicates three 18AWG wires from the body, 24” long
- S means 316 SS welded diaphragm seal, max 200 PSI
- 01 means 1/8” NPT male fitting
- 100# is the pressure range in PSI
- 90R is the setpoint and direction (90 PSI rising, but it’s adjustable)

Pressure Transmitter

We want to read the system air pressure at the Top Ring Box. There are many options including the Ashcroft A2-S-C-M01-42-F2-150#-G. Operating temperature range is -40 C to +125 C. Deconstructing the part number:

- A2 is the transducer style (there are a few others; this one looks fine)
- S is a basic enclosure (no zero-out adjustment, etc.)
- C is 1% accuracy (-20C to +85C). We can go as fine as 0.25% if we want.
- M01 means 1/8 NPT male fitting
- 42 means a 4-20 mA output signal.
- F2 means a 3-foot shielded cable. We could also choose a connector.
- 150# is a 0-150 PSI pressure range.
- G means gauge pressure

The specific sensor in use at Clay has serial number 3050441. The instruction sheet suggests that a 24 VDC supply voltage can drive a loop resistance of no more than about 600 Ω with a 200 Ω resistor giving a wide range of usable loop voltages (from about 16.5 VDC to 36 VDC. Across a 200 Ω (nominal) resistor the transmitter will drop about 2.8 volts, a little above mid-range for the 0 VDC to 5 VDC range on the ADC. The resolution with this resistance is about 17 DN per PSI, which is good enough for our purposes.

This table shows the expected output signal from the Clay transmitter based on calibration data received from the manufacturer for this specific device. We assume a 200 Ω (nominal) load resistor and a 20 KΩ input impedance on the A/D converter. The data number (DN) values are assuming 12-bit resolution across 0 VDC to 5 VDC.

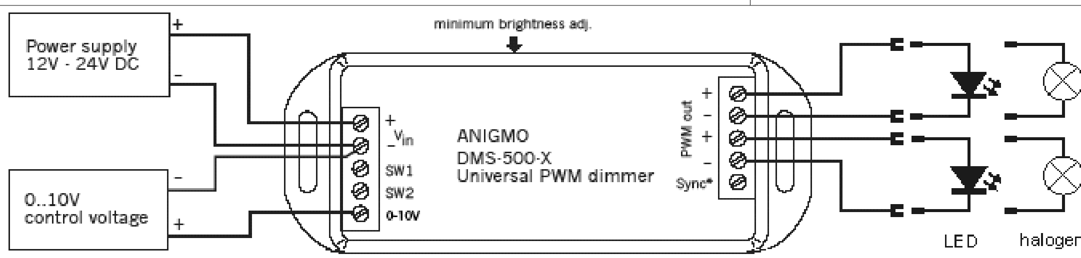
Pressure (PSI)	Output (mA)	Output (Volts)	DN
75	12.06	2.389	1957
80	12.60	2.494	2043
85	13.13	2.600	2130
90	13.66	2.705	2216
95	14.19	2.811	2302
100	14.73	2.916	2389
105	15.26	3.021	2475
110	15.79	3.127	2562
115	16.32	3.232	2648
120	16.86	3.338	2734

Lamp Dimmer

One bank of incandescent lamps needs to be adjustable. To do this, we will use a commercial low-voltage lamp dimmer. One example is the Anigmo DMS-500-X. This dimmer takes a 0 VDC to 10 VDC input signal to control current on a 390 Hz PWM circuit.

The dimmer will be mounted close to the lamps and be powered by the high-current 24 VDC supply. Lamp current is adjusted with a signal from one of the analog outputs on the PLC. Our lab experiments suggest that a 4.8 VDC input signal provides the equivalent current for full-intensity on the 5 VDC lamps.

Operating temperature range is -20 C to +50 C (-4 F to 122 F).



Controller (PLC)

PLC & I/O unit

The PLC choice is the Direct Logic D0-06DD1 unit. Operating temperature range is 0 C to +55 C, which does not meet our specifications but since this item will be enclosed in a box, it might never see temperatures outside this range. This unit has:

Inputs: 20 DC inputs (12 VDC to 24 VDC sourcing or sinking). ON voltage level is > 10.0 VDC, OFF voltage level is < 2.0 VDC. Input current at 24VDC is 8.5 mA for ports X4-X23 and 13 mA for ports X0-X3. Input impedance is 2.8K for ports X4-X23 and 1.8K for ports X0-X3.

Outputs: 16 DC outputs (12 VDC to 24 VDC sinking, up to 1.0A/point)

Analog I/O

F0-4AD2DA-2 analog I/O module with 4 channels input, 2 channels output, 12 bits, 0-5 VDC or 0-10 VDC input. NB: Absolute maximum input rating is +/-15 VDC. Input impedance is > 20K.

Relays

F0-04TRS 4-point relay, 5 VDC - 30 VDC or 5 VAC - 125 VAC, 3A/point, fused.

Relays

D0-08TR 8-point relay, 6 VDC - 27 VDC or 6 VAC - 240 VAC, 3A/point, fused.

Ethernet

H0-ECOM100 Ethernet Module

Transient Suppression

ZL-TSD8-24 Ziplink 8-channel transorb module (flywheel diodes), 24 VDC

Power Supply

The Rhino PSP24-120C from Automation Direct provides 24 VDC at up to 5 A (120W) in a DIN-rail mountable package. The operating temperature range is -10 C to +70 C.

The primary high-current draw for this system is the incandescent lamp system, which totals 36 W. So a 120 W supply should be fine.

This supply will also supply power to some of the Top Ring Box equipment.