MODS Shutter Data Sheet

General Description
The MODS Shutters are integrated into the spectrograph cameras immediately behind the corrector where they mount to the inside surface of the corrector cell. The shutters use a pair of rotating blades to obstruct the light entering the camera. The shutter blades are driven from a common motor but with different gear ratios so each blade has a different range of travel. The BLUE and RED shutters are very similar but are mirror images regarding drive placement and have different gear ratios. Also, the sign of the motor moves is opposite between BLUE and RED;

BLUE negative move = Closes Shutter
RED positive move = Closes Shutter

This affects the Limit Switch definitions and the signs of the move commands in the software.

The blades are held in the open or closed positions with the motor power off using a spring loaded roller detent. Each shutter blade has two micro-switches that are used for OPEN and CLOSED indication. The OPEN and CLOSED limits are then derived using diode logic to OR the OPEN and CLOSED switches for each blade.

Because the shutters open from the center outward along the slit, the edge of the field receives less light than the center. However, the shutter is quite close to the pupil so this effect is very small. For a 1.0 second exposure time the top and bottom of the slit receive 0.4% less light than the center. The percentage shading gets smaller for longer exposures. There is no shading at all in the dispersion direction.

Rendering of Red Shutter Asm.
Drive Motor
Motor Type  Size 23 Step motor, 200 full steps per revolution, double-ended shaft
Part # Superior # KML061F05 - D
Rated Current: 2.7 amps/phase parallel (RMS)
Rated Holding Torque: 170 in*oz

Motor Connection Diagram
A+ Red/White
A- Red
B+ Black/White
B- Black

Motor Controller Specifications
Manufacturer & Model: IMS MicroLYNX 7 (#MX-CS100-701)
Rated Current: 5amps RMS/phase, 7 amps peak/phase
Rated Voltage: 24 to 75 VDC
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Daughterboards: Isolated Digital I/O (6 points)

Motor Controller Settings
MSEL = 10 10usteps/fullstep = 2000 microsteps/rev
MUNIT = 2000 sets units to (2000 usteps/rev) gives velocity and accelerations in rev/sec
MAC = 65 Acceleration Current = 65% = 4.5 amps peak
MRC = 54 Run Current = 2.7 amps RMS *1.4 = 3.8 amps peak (3.8/7 = 54% )
MHC = 0 Motor Hold Current is zero

ACLT=1 linear acceleration (default)
ACCL=DECL = 20 acceleration rate (rev/sec^2)
LDECL = 500 limit deceleration rate (rev/sec^2)
Overtravel at Limit = (2*Pi* Blade Radius) * (Gear Reduction)* VM^2/(2*LDECL) = 4.9mm
(Blade Radius = 170mm, Gear Reduction = 16/87, VM=5 rev/sec, LDECL=500 rev/sec^2)
Beware overtrave, must not decelerate shutter blades hard into limits
Maximum Permitted Overtravel at Blade tips ~ 5mm

VM= 5 max running speed (rev/sec)
VM= 0.5 Homing speed to assert limit (rev/sec)

Motor Controller I/O Connections
Vpull: Must set DIP switches to use internal Pull-up to 6 VDC (not the default)
GND: Microswitch Gnd
I/O 21: Shutter Closed LIMIT sensor (two blade inputs OR’d with blocking diodes)
  Active Low
I/O 22: Shutter Open LIMIT sensor (two blade inputs OR’d with blocking diodes),
  Active Low

Must set DIP switches for I/O 21 and 22 to use internal Pull-up to 6 VDC (not the default)

Blocking Diodes Required for Multiple Input connections from switches to LIMIT inputs, See Schematic

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Extended I/O on Daughterboard

Vpull: Must set DIP switches to use internal Pull-up to 6 VDC (not the default)
GND: Microswitch Gnd

I/O 31: Blade 1 CLOSED (also to CLOSED Limit)
I/O 32: Blade 2 CLOSED (also to CLOSED Limit)
I/O 33: Blade 1 OPEN (also to OPEN Limit)
I/O 34: Blade 2 OPEN (also to OPEN Limit)
I/O 35: Shutter + INPUT

Input Sensors
11SM2-T micro-switches with roller end and flex leaf, wired to Normally Closed (NC) terminals

Output Devices
None

Drive Mechanics
- Single Stepper motor drive with gear reduction and 1:1 HTD timing belt final drive to graphite/epoxy foam core blades
- Counter-rotation achieved with fixed ratio gearing which provides different travel for each blade. The different gear ratios are required due to the “tilted” corrector cells which are different for the red and blue cameras
- Blue Shutter motor.blade ratios are 16/84 for the bottom blade, Travel = 86 degrees
  16/78 for the top blade, Travel = 93 degrees
  **Blue Motor Steps = 200steps/rev * (84/16) * (86/360) = 251 full steps**
- Red Shutter motor.blade ratios are 16/90 for the bottom blade, Travel = 79 degrees
  16/72 for the top blade, Travel = 99 degrees
  **Red Motor Steps = 200steps/rev * (90/16) * (79/360) = 247 full steps**
- Hard overtravel limiting end stops to protect blades in open and closed positions
- Roller detent at end positions to maintain blade position with motor power off
- Limit switches on both blades for open and closed positions, CW AND CCW Limits
- Knob for manual override

Performance
With a Shutter Opening time of ~0.5 seconds and Closing time of ~0.5 seconds, an effective exposure time of 0.45 seconds is realized. This requires motor average velocity of ~ 500 fullsteps/sec and peak speed of ~1000 fullsteps/sec (VM=5) for a triangular velocity profile.

A table (or computational algorithm) will be required to list VM and ACCL, DECL for a range of desired effective exposure times.

Shutter Motion Control
There are two roller micro-switches switches and cams on each blade to provide OPEN and CLOSED position feedback information and limit switch inputs. The cams have notches in their outer surface to actuate the switches. Switches are always asserted between cam notches, this prevents “flapping” of switch roller blades.

Normal Operation Position Feedback requirements
- Narrow angle indication of SHUTTER OPEN on each blade

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• Narrow angle indication of SHUTTER CLOSED on each blade
• Inputs from Blade#1 and Blade#2 are logically OR’d and sent to LIMIT inputs

Switch, Cam, and Drive Controller Setup
• Each blade will have two cams with a narrow notch to de-assert the switch. One cam will have its notch centered with the blade closed the other cam will have its notch centered with the blade open.
• The switches will be adjusted so that the cam notch is centered on the switch roller in the final detented position. The switch bracket is adjusted on its slots to provide balanced over-travel and under-travel of the switches. It is important to verify that the switches are not de-asserted before the detent roller cam is in its notch.
• The switches will be wired to the NORMALLYCLOSED terminal. The switches will be in the NORMAL position (OPEN) when the shutter blades are at their limits of travel. This will pull down the drive inputs to ground when the switch roller is in the notch.

This switch configuration assures detection of all normal states for both blades independently, prevents over-travel with Limits, and provides a wealth of diagnostic information in response to shutter mechanical and electrical failures.

Fault Conditions and Detection Method
1. Either drive gear slips on ¼” gear shaft, producing incorrect phase angle between blades. Blade tips could collide at closure if not detected. Detected by OPEN or CLOSED bits not asserting (detection angle must be quite narrow)
2. A blade drive belt breaks, producing one blade moving and one blade flapping free. Blade tips could collide near closure if not detected. Detected by OPEN or CLOSED bits not asserting or a limit asserting at the wrong time.
3. OPEN or CLOSED indicator cam slips on blade shaft
   If a single OPEN or CLOSED cam slips, the corresponding cam on the other blade will still provide a LIMIT indication and prevent over-travel
4. Motor stalls, electrically fails, or pinion gear slips
   The Expected OPEN or CLOSED position will not be reached in commanded number of steps, a fault will be reported
5. Shutter is placed in an invalid position and then a move is executed
   Verify with status inquiry that shutter is in a valid OPEN or CLOSED position before initiating a move.
6. A microswitch fails OPEN
   Invalid state is indicated, alerting software.
7. Double Switch Bracket is mis-adjusted so that switches remain in Asserted position even when centered on cam notches.
   Both switches will indicated OPEN or CLOSED, an invalid state

Software Issues
We have prior knowledge of the number of steps required to move from OPEN to CLOSED positions for both the BLUE and RED shutters. This information will be used to compute a
trapezoidal velocity vs. time profile which will be executed precisely the same way for every opening or closing of a shutter.

**Wiring Schematic**

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