MODS Mask Select Data Sheet

General Description
The MODS Mask Select mechanism translates the 24 position mask storage magazine to align the requested mask with the Mask Insert rails. This places the requested mask where it can be transferred to the science position by the Mask Insert drive. The Mask Select mechanism is a 24 position indexed linear drive. The position of the mask storage magazine is determined with 6 proximity sensors actuated by a grid of stainless steel pins, 5 for the “Position Code” bits and one for the “Position Valid” bit. The Mask Select drive also has two limits for the ends of travel.
Drive Motor
Motor Type  Size 34 Step motor, 200 full steps per revolution, double-ended shaft
(modified for rear mounted brake)
Part #  Superior # KML092F07
Rated Current: 3.25 amps/phase parallel (RMS)
Rated Holding Torque: 770 in*oz
Torque at Operating Speed & Current ~500 in*oz

Motor Connection Diagram (for CW rotation viewed from motor front with positive command)
A Red/White (Pin13)
A Red (Pin12)
B Black (Pin11)
B Black/White (Pin10)

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
Daughterboards: Isolated Digital I/O

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 = 60 Acceleration Current = 60% = 4.2 amps peak
MRC = 42 Run Current = 2.1 amps RMS*1.4 = 2.9 amps peak (2.9/7 = 42% )
MHC = 0 Motor Hold Current is zero
ACLT=1 linear acceleration (default
ACCL=DECL = 50 acceleration rate (rev/sec^2)
LDECL = 500 limit deceleration rate (rev/sec^2)
Overtravel at Limit = ScrewPitch * VM^2/(2*LDECL) = 0.25mm (pitch =10mm and VM=5
rev/sec, LDECL=500 rev/sec^2)
Beware overtravel when seeking limits, must not decelerate hard into limits
Maximum Permitted Overtravel ~ 0.5mm ~ 0.020"

VM = 4 running speed (rev/sec)
VM = 0.5 Homing speed to assert limits

Motor Controller I/O Connections
Vpull: not used
GND: 24 volt Gnd
I/O 21: CW LIMIT sensor
I/O 22: CCW LIMIT sensor
I/O 23: STOWED Position Interlock Relay status (from Mask Insert mechanism)
I/O 24: MASK SELECT drive is busy (IOS 24 = 18,1,1 , output to Mask Insert)
I/O 25: not used
I/O 26: Brake relay coil (internal pull-up switch opened)
Output defaults to NO, Brake is wired to NO contacts on relay
Brake is applied with power off and default state of drive output

Daughterboard I/O
Vpull:  not used
GND:  24 volt Gnd
I/O 31:  1’s  LSB of Position code bit
I/O 32:  2’s  Position code bit
I/O 33:  4’s  Position code bit
I/O 34:  8’s  Position code bit
I/O 35:  16’s  MSB Position code bit
I/O 36:  “Position Valid” sensor

**Motor Controller DIP switch settings**
Upgrade = ON: OFF
Address 0: OFF
Address 1: OFF
Address 2: OFF
I/O 21: OFF
I/O 22: OFF
I/O 23: ON
I/O 24: ON
I/O 25: OFF
I/O 26: OFF
I/O 31: OFF
I/O 32: OFF
I/O 33: OFF
I/O 34: OFF
I/O 35: OFF
I/O 36: OFF

**Input Sensors**
Model  P&F # NBB1.5-8GM50-E0-V3
8mm Inductive proximity sensor, Normally Open Sinking output (Type E0), 24 VDC supply
Used for Position Code bits on 5mm stainless steel pins
Used for Position Valid bit on 3mm stainless steel pin
Used for CW Limit & CCW limit

Connection for P&F E0 Sensors (3 wire)
Brown  +24 volts
Blue   24 volt ground
Black  to input of controller

Sensor Alignment Notes
The gap between the 8mm proximity sensors and the position code pins should be set to 0.4mm - 0.5 (0.016 – 0.020”) with mechanism on its handling cart.
Be sure to adjust the CW and CCW limits such that they allow adequate overtravel (~3mm req’d) for centering on the “Position Valid” pin. This is especially true for the CCW limit which is tight.

**Output Devices**
Failsafe Brake, Brake is on with power off.
Electroid # BFSB-15-6  24 volt, 0.42 amps
Holding Torque  240 in*oz.
**Drive Mechanics**
The Mask Select mechanism uses a THK Model KR4610A+940L-00000 linear actuator with a right hand 10mm pitch ballscrew. This screw is directly coupled to the step motor described above. This combination gives:

**Actuator motion = 0.05 mm per full motor step**

Position Datum
- Mask Number “0” establishes position datum
- Magazine is toward motor end of actuator
- CCW (NEG) motor rotation viewed from front of motor

Range of Motion
- 438 mm = 24 spaces *(18mm/space) + (3mm overtravel * 2 ends)

**Performance**
- Maximum Travel Time: ~ 11 seconds, (438mm, 10mm/rev, 5rev/sec )
- Typical Travel Time for move of ~ 200mm: ~ 6 seconds
- Position Repeatability: +/- 75 micron error due to centering
- Position Hysteresis: < 25 micron (backlash in screw)

**Software Notes**
**Position Code Bits**
Since all the position code bits are connected to I/O Group 30, the decimal value of the cassette magazine position can be determined by Group, e.g. “IO 30” returns the decimal value of the cassette magazine position plus 32 from the “Position Valid” bit.
The cassette magazine slots are numbered from 0 to 24. Slot 12 is a center brace and cannot be used to hold a mask cassette.

**Mask Magazine Centering**
The “Position Valid” sensor is an 8mm proximity sensor actuated by a 3mm steel dowel with a nominal gap of 0.4mm. This arrangement indicates a “valid” position for a Select drive travel of about 4.0mm (+/- 2.0mm centered on the pin). This +/- 2.0mm range is too large to properly align the masks in the storage magazine with the insert guide rail. The magazine to guide rail alignment can be greatly improved by executing a simple routine at the end of each magazine index move that centers the magazine relative to the 3mm Position Valid pin. This routine will locate the de-assert transitions of the Position Valid sensor in both directions and move to the position centered between the two de-assert transition edges. The “Magazine Centered” variable will then be set True.

**Software Interlocks**
The Mask Select Drive is inhibited from moving in both directions unless the Insert Drive is in the “STOWED” position. This interlock prevents all Select Drive motion when a mask is in the SCIENCE position or if the Insert drive actuator is not fully retracted to the STOWED position. This interlock is implemented in software by checking that the STOWED Position sensor is true (from the Mask Insert/Retract drive controller) prior to making a Mask Select move.

**Hardware Interlocks**
Two of the Mask Select Drive motor phase wires (A and B) are interrupted by two N.O. contacts on a relay. When the Mask Insert mechanism’s STOWED Position Sensor is asserted, the relay is energized and movement of the Mask Select mechanism is enabled. This hardware interlock prevents driving of the Mask Select mechanism motor whenever the Mask Insert STOWED Position Sensor is de-asserted.
A third N.O. contact of the same relay interrupts the brake control circuit. The brake solenoid must be energized to release the brake and allow movement of the Mask Select Cassette Magazine. This hardware interlock precludes releasing the brake whenever the Mask Insert STOWED Position Sensor is de-asserted.

A fourth N.O. contact of the same relay goes to IO 23 of the Mask Select mechanism for read back of the relay status.
The MODS1 SELECT drive field failure was analyzed and attempts were made to duplicate the failure using MODS2 SELECT in the lab.

**Problem #1**
The velocity of the SELECT had been increased from 3 rev/sec on the mechanism data sheet to 8 revs/sec in the actual installed Microlynxx code. 8 revs/sec is a very undesirable speed because it is near the motor resonance speed resulting in audible drive noise and vibration.

**Potential Problem #2**
The brake control relay (which is on the motor drive PCB in the IEB) may have failed resulting in a situation where the brake never releases. This duplicates the observed behavior in the field by causing failures at 8 revs/sec. The brake control relay is small but it is protected with a 4140 free wheeling diode to clamp the back EMF produced when the brake is de-energized.

**Lab Testing**
The table below summarizes the lab testing of the MODS2 Select mechanism. 55 pounds was suspended from a pulley to simulate the gravity load of a fully loaded Cassette.
Normal running at 8 revs/sec exhibited some noise and vibration due to resonance. If the brake is then disabled the drive fails.
The drive fails at 11 revs/sec even with the brake operating. This indicates that the Select drive has a low velocity margin.

However, it may be the case that the MODS1 unit is somewhat more marginal and causing it to fail at 8 revs/sec, even with the brake operating properly.

**Recommendations**
1. Modify the SELECT Microlynxx code to have VNORM=4. 8 revs/sec appears to be a very smooth speed and it has large torque and speed performance margins.
2. Check the brake control relay on the SELECT channel for proper operation. Replace the relay if it is found to be damaged and explore long term solution.

Please note that the drive will function even with a disabled brake at the new speed of 4 revs/sec. So a subsequent relay failure would be a “soft failure” allowing continued operation but making the failure difficult to detect.
**MODS2 Mask Select Testing**

October 5, 2011

MODS1 Mask Select failed in field with a full complement of masks for larger moves.

Select did not fail with 12 Mask Frames loaded.

Speed had been set to 8 rev/sec in violation of the Mechanism data sheet which called for 3 revs/second.

All lab testing had been done at 3 rev/sec.

<table>
<thead>
<tr>
<th>Description</th>
<th>Weight (lbf)</th>
<th>MRC % of 7amps peak</th>
<th>VNORM (rev/sec)</th>
<th>Brake</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline in program</td>
<td>55</td>
<td>42</td>
<td>8</td>
<td>operating</td>
<td>Operates OK, substantial noise from incipient resonance, adding &gt;25 pounds by pulling on weights does not stall motor</td>
</tr>
<tr>
<td>Current margin</td>
<td>55</td>
<td>30</td>
<td>8</td>
<td>operating</td>
<td>Operates OK, sounds MUCH better than 42%</td>
</tr>
<tr>
<td>Current margin</td>
<td>55</td>
<td>16</td>
<td>8</td>
<td>operating</td>
<td>Operates OK, sounds good, very slight noise, 100% Failure while climbing</td>
</tr>
<tr>
<td>Current margin</td>
<td>55</td>
<td>12</td>
<td>8</td>
<td>operating</td>
<td></td>
</tr>
</tbody>
</table>

| Speed & Resonance            | 55           | 42                  | 3               | operating  | Operates OK, very slight "growling" noise from incipient resonance |
| Speed & Resonance            | 55           | 42                  | 4               | operating  | Operates OK, Zero noise from incipient resonance            |
| Speed & Resonance            | 55           | 42                  | 6               | operating  | Operates OK, slight noise & vibration from incipient resonance |
| Speed & Resonance            | 55           | 42                  | 7               | operating  | Operates OK, slight noise & vibration from incipient resonance |
| Baseline in program          | 55           | 42                  | 8               | operating  | Operates OK, substantial noise from incipient resonance      |
| Speed & Resonance            | 55           | 42                  | 9               | operating  | Operates OK, some noise from incipient resonance             |
| Speed & Resonance            | 55           | 42                  | 10              | operating  | Operates OK, no noise from incipient resonance               |
| Speed & Resonance            | 55           | 42                  | 11              | operating  | Fails Uphill 100% but sounds smooth                         |
| Speed & Resonance            | 55           | 42                  | 12              | operating  | Fails Uphill 100% but sounds smooth                         |
| Brake disabled               | 55           | 42                  | 3               | disabled    | Operates OK, Zero noise from incipient resonance             |
| Brake disabled               | 55           | 42                  | 4               | disabled    | Operates OK, Zero noise from incipient resonance             |
| Brake disabled               | 55           | 42                  | 6               | disabled    | Operates OK, not smooth, rough descending                     |
| Brake disabled               | 55           | 42                  | 8               | disabled    | Fails 100% uphill & downhill                               |