Replacement of the LURE Telescope Controller Using Commercial Off-The-Shelf Components

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Abstract:
The original 1972 vintage telescope controller at LURE (HOLLAS) had been replaced in March 2000 with a system designed and constructed by a sub-contractor. This system did not meet specifications, and before it could be fixed, the sub-contractor went out of business. A few weeks of research convinced us that a replacement could be designed and constructed using only commercial off-the-shelf components, and could be completed in less time and for less money by using University technicians and engineers rather than going out for bid and engaging another sub-contractor. The performance of the University designed system met or exceeded the original technical specifications. The final product could be used as designed by any telescope system that uses Inductosyn® transducers, or position sensors that output A quad B signals, and is driven by DC torque motors. This paper will identify the commercial products used, the basic design of the controller, and the performance attained.
Luna-Stat Mirror and Control Boxes

Control Box 1

- 20pps Synchronization input from the XL-DC TrueTime Rb Clock.
- Connection for the Inductosyn® and Resolver sensors on the mount.
- Farrand® Azimuth and Elevation Resolver to Digital Converters. (Inductosyn Pre-Amplifiers located beneath the Resolver to Digital Converters.)
Control Box 2

- Galil® Motion Control Computer.
- Farrand® Azimuth and Elevation Inductosyn® to Digital Converters.
- Inland® Motors Azimuth and Elevation Servo Amplifiers.
- Servo Amplifier Temperature Monitor and Displays.
- Galil Opto-Isolated Inter-Connect Module.
- Optical Fiber to 10BaseT Media Converter.
- DC Power Supplies.
Galil DMC-2120 Motion Controller Specifications

- 2 Axis control.
- Ethernet Connectivity and 1 RS232 port up to 115kb.
- Accepts up to 12MHz encoder frequency.
- Advanced PID (Proportional/Integral/Derivative) compensation.
- Velocity and Acceleration feedforward, Integration limits, Notch and Low-Pass filtering.
- Sample time of 125.0 microseconds.
- Multitasking for concurrent execution of up to 8 on-board application programs.
- Modes of Motion include Jogging, Linear and Circular interpolation and Absolute and Relative Positioning.
- 8 Uncommitted inputs and 8 outputs. Optional Interconnect Module Supplies an Additional 64 I/O Ports.
**Farrand Inductosyn to Digital Converter Specifications**

- 20,000 Divisions per Inductosyn Cycle (0.18 Arc Second Resolution).
- +/- 2 Arc Minute Conversion. (0.333 Arc Second Accuracy).
- 10KHz Excitation Output Frequency.
- 15.6 Degrees per Second Maximum Tracking Speed.

**Farrand Resolver to Digital Converter Specifications**

- 16 Bit Cyclic Resolution (0.00549 Degree Precision)
- +/- 8 Arc Minute Conversion (0.133 Degree Accuracy)
- 2.4KHz Excitation Output Frequency.
Performance

The following tables and graphs illustrate performance while pointing to a ground target and while tracking an 82° PCA TOPEX/Poseidon pass.

Ground Target Performance

These Mount Ground Target data were extracted at one-second intervals during 6 calibrations taken over an eight-hour period. All angle data are in units of degrees.

<table>
<thead>
<tr>
<th></th>
<th>Azimuth</th>
<th>Elevation</th>
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</thead>
<tbody>
<tr>
<td>Command Angles</td>
<td>148.6715</td>
<td>-5.0821</td>
</tr>
<tr>
<td>Minimum</td>
<td>148.6714</td>
<td>-5.0825</td>
</tr>
<tr>
<td>Maximum</td>
<td>148.6718</td>
<td>-5.0817</td>
</tr>
<tr>
<td>Samples</td>
<td>6081</td>
<td>6081</td>
</tr>
<tr>
<td>Mean</td>
<td>148.67154</td>
<td>-5.08209</td>
</tr>
<tr>
<td>Median</td>
<td>148.67150</td>
<td>-5.08210</td>
</tr>
<tr>
<td>RMS</td>
<td>148.67154</td>
<td>5.08209</td>
</tr>
<tr>
<td>Std Deviation</td>
<td>0.000090</td>
<td>0.000170</td>
</tr>
</tbody>
</table>

Satellite Tracking Performance

Representative Mount Tracking Error Data from a Topex/Poseidon Pass culminating at 82° Elevation. A Sample of the Pointing Error was taken once per second during the entire pass. All angle values are in units of degrees.

<table>
<thead>
<tr>
<th></th>
<th>Azimuth Tracking Error Statistics</th>
<th>Elevation Tracking Error Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>-0.0008</td>
<td>-0.0011</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.0006</td>
<td>0.0007</td>
</tr>
<tr>
<td>Samples</td>
<td>840</td>
<td>840</td>
</tr>
<tr>
<td>Mean</td>
<td>-0.000061</td>
<td>-0.000053</td>
</tr>
<tr>
<td>Median</td>
<td>-0.000100</td>
<td>-0.000100</td>
</tr>
<tr>
<td>RMS</td>
<td>0.000220</td>
<td>0.000290</td>
</tr>
<tr>
<td>Std Dev</td>
<td>0.000210</td>
<td>0.000280</td>
</tr>
</tbody>
</table>
Azimuth Pointing Error vs. Commanded Rate

Elevation Pointing Error vs. Commanded Rate
Functional Overview

Analog Sine and Cosine signals from the Inductosyn sensors are converted to A Quad B signals by the Farrand I/D converter. These digital outputs are then read by the Galil Motion Controller and converted to Azimuth and Elevation angles by University of Hawai`i supplied software resident on the Galil.

The Galil Motion Controller interprets the digital inputs and provides both direction and magnitude of axis motion.

The Resolver signals are converted by the Farrand R/D Converter to a 16-bit representation of the angle. The Resolver is used for “HOMING” the mount only.

The Inductosyn is used to monitor axis position once the “HOME” has been established.

Physical communication layer between Tracking Computer and Galil Controller is an optical fiber and a 10Mbs Ethernet connection.

Satellite Tracking Software is synchronized with the Galil Controller using a 20pps output of the Station Rubidium Clock.

A TCP/IP Socket connection is established between the tracking computer and the Galil controller. Position and command information is sent/received 20 times a second (every 50milliseconds) via this connection.

The Galil “JOG” mode is used to command the mount to move while tracking a satellite or star. The JOG rate is calculated by an algebraic combination of the calculated rate, the current pointing error, and a factor that is a function of the calculated rate.

Positioning to Ground Targets is achieved by the Galil “Position Absolute” mode.