



*LIGO Laboratory / LIGO Scientific Collaboration*

LIGO- E200632-v2

Advanced LIGO

8/2/2012

TwinCAT Library for the  
ALS Laser

Alexa Staley, Daniel Sigg

Distribution of this document:  
LIGO Scientific Collaboration

This is an internal working note  
of the LIGO Laboratory.

**California Institute of Technology**  
**LIGO Project – MS 18-34**  
**1200 E. California Blvd.**  
**Pasadena, CA 91125**  
Phone (626) 395-2129  
Fax (626) 304-9834  
E-mail: info@ligo.caltech.edu

**Massachusetts Institute of Technology**  
**LIGO Project – NW22-295**  
**185 Albany St**  
**Cambridge, MA 02139**  
Phone (617) 253-4824  
Fax (617) 253-7014  
E-mail: info@ligo.mit.edu

**LIGO Hanford Observatory**  
**P.O. Box 159**  
**Richland WA 99352**  
Phone 509-372-8106  
Fax 509-372-8137

**LIGO Livingston Observatory**  
**P.O. Box 940**  
**Livingston, LA 70754**  
Phone 225-686-3100  
Fax 225-686-7189

<http://www.ligo.caltech.edu/>

| <b>Library</b>       |   |
|----------------------|---|
| Title                | ALSLaser  |
| Version              | 1   |
| TwinCAT version      | 2.11  |
| Name space           | –   |
| Author               | Alexa Staley, Daniel Sigg   |
| Description          | <p>Monitors the ALS Laser</p> <p>Controls the crystal and doubler temperature</p> <p>A slow feedback servo is implemented to offload the fast PZT feedback to the slow temperature controls. It implements the following equation:</p> $u_i = u_{i-1} + g \times \begin{cases} e_i & h \leq 0 \\ (e_i - e_{i-1})/h & h > 0 \end{cases} \text{ with}$ $g = \pi f_{ugf} \Delta t \text{ and } h = \pi f_{pf} \Delta t.$ <p><math>\Delta t</math>: sampling interval,<br/> <math>f_{ugf}</math>: unity gain frequency of integrator,<br/> <math>f_{pf}</math>: Knee frequency of proportional gain.<br/> A negative <math>f_{ugf}</math> reverses the sign of the feedback.</p>                              |
| Error codes          | <p>0x0001 – Safety interlock engaged</p> <p>0x0002 – Laser diode 1 guard alarm</p> <p>0x0004 – Laser diode 2 guard alarm</p> <p>0x0008 – Laser diode 1 current out-of-range</p> <p>0x0010 – Laser diode 2 current out-of-range</p> <p>0x0020 – Laser crystal TEC error signal out-of-range</p> <p>0x0040 – Doubler crystal TEC error signal out-of-range</p> <p>0x0080 – Laser diode 1 TEC error signal out-of-range</p> <p>0x0100 – Laser diode 2 TEC error signal out-of-range</p> <p>0x0200 – Noise eater readback signal out-of-range</p> <p>0x0400 – Unity gain frequency too high</p> <p>0x0800 – Proportional gain knee frequency too high</p> <p>0x1000 – Temperature feedback limit exceeded</p> |
| Library dependencies | ReadADC, WriteADC, SaveRestore, Error   |

| Hardware Input Type                 |   |
|-------------------------------------|---|
| TYPE ALSLaserInStruct :             |   |
| STRUCT                              |   |
| LaserDiode1PowerMonitor: INT;       |   |
| LaserDiode2PowerMonitor: INT;       |   |
| LaserCrystalTECErrorSignal: INT;    |   |
| DoublingCrystalTECErrorSignal: INT; |   |
| LaserDiode1TECErrorSignal: INT;     |   |
| LaserDiode2TECErrorSignal: INT;     |   |
| NoiseEaterMonitor: INT;             |   |
| LaserDiode1TempGuard: BOOL;         |   |
| LaserDiode2TempGuard: BOOL;         |   |
| InterLock: BOOL;                    |   |
| END_STRUCT                          |   |
| END_TYPE                            |   |
| Type name                           | ALSLaserInStruct  |
| Description                         | Structure of the hardware input that are wired up for the ALS laser                                 |
| Definition                          | STRUCT  |
| Element                             | Name: LaserDiode1PowerMonitor<br>Type: INT<br>Description: Laser diode 1 power monitor              |
| Element                             | Name: LaserDiode2PowerMonitor<br>Type: INT<br>Description: Laser diode 2 power monitor              |
| Element                             | Name: LaserCrystalTECErrorSignal<br>Type: INT<br>Description: Laser crystal, TEC error signal       |
| Element                             | Name: DoublingCrystalTECErrorSignal<br>Type: INT<br>Description: Doubling crystal, TEC error signal |
| Element                             | Name: LaserDiode1TECErrorSignal<br>Type: INT<br>Description: Laser diode 1, TEC error signal        |
| Element                             | Name: LaserDiode2TECErrorSignal<br>Type: INT<br>Description: Laser diode 2, TEC error signal        |
| Element                             | Name: NoiseEaterMonitor<br>Type: INT<br>Description: Noise eater monitor                            |

|         |  |
|---------|--|
| Element | Name: LaserDiode1TempGuard<br>Type: BOOL<br>Description: Laser diode 1, temp guard |
| Element | Name: LaserDiode2TempGuard<br>Type: BOOL<br>Description: Laser diode 2, temp guard |
| Element | Name: InterLock<br>Type: BOOL<br>Description: InterLock                            |

|   |   |
|---|---|
| <b>Hardware Output Type</b><br>TYPE ALSLaserOutStruct :<br>STRUCT<br>CrystalTemperature:                    INT;<br>DoublerTemperature:                  INT;<br>END_STRUCT<br>END_TYPE |   |
| Type name   | ALSLaserOutStruct   |
| Description   | Structure of the hardware output that are wired up for the ALS laser      |
| Definition  | STRUCT  |
| Element   | Name: CrystalTemperature<br>Type: INT<br>Description: Crystal Temperature |
| Element   | Name: DoublerTemperature<br>Type: INT<br>Description: Doubler Temperature |

| <b>User Interface Type</b>                 |  |
|--|--|
| TYPE ALSLaserFrequencyControlsStruct:      |  |
| STRUCT                                     |  |
| On:                                  BOOL; |  |
| Enabled:                          BOOL;    |  |
| Run:                              BOOL;    |  |
| Reset:                           BOOL;     |  |
| Low:                              LREAL;   |  |
| High:                            LREAL;    |  |
| Range:                           BOOL;     |  |
| Ugf:                              LREAL;   |  |
| P:                                LREAL;   |  |
| END_STRUCT                                 |  |
| END_TYPE                                   |  |
| Type name                                  | ALSLaserFrequencyControlsStruct  |
| Description                                | Structure used in the user interface that are used for the slow temperature controls |
| Definition                                 | STRUCT   |
| In/out Tag                                 | Name: On<br>Type: BOOL<br>Description: On/Off button for temperature feedback        |
| Output Tag                                 | Name: Enabled<br>Type: BOOL<br>Description: Enabled by the autolocker                |
| Output Tag                                 | Name: Run<br>Type: BOOL<br>Description: Servo is running                             |
| In/out Tag                                 | Name: Reset<br>Type: BOOL<br>Description: Reset the integrator and zero the output   |
| In/out Tag                                 | Name: Low<br>Type: LREAL<br>Description: Low limit for feedback controls in Hz       |
| In/out Tag                                 | Name: High<br>Type: LREAL<br>Description: High limit for feedback controls in Hz     |
| Output Tag                                 | Name: Range<br>Type: BOOL<br>Description: Feedback controls exceeds range            |

|            |   |
|------------|---|
| In/out Tag | Name: Ugf<br>Type: LREAL<br>Description: Unity gain frequency of temperature servo in Hz            |
| In/out Tag | Name: Pf<br>Type: LREAL<br>Description: Knee frequency of proportional feedback in Hz; zero is none |

**User Interface Type**

TYPE ALSLaserStruct :

STRUCT

```

    Error:                      ErrorStruct;
    LaserDiode1PowerMonitor:    LREAL;
    LaserDiode2PowerMonitor:    LREAL;
    LaserDiodePowerNominal:     LREAL;
    LaserDiodePowerTolerance:   LREAL;
    LaserCrystalTECErrorSignal: LREAL;
    DoublingCrystalTECErrorSignal: LREAL;
    LaserDiode1TECErrorSignal:  LREAL;
    LaserDiode2TECErrorSignal:  LREAL;
    TECTolerance:               LREAL;
    NoiseEaterMonitor:          LREAL;
    NoiseEaterNominal:          LREAL;
    NoiseEaterTolerance:        LREAL;
    LaserDiode1TempGuard:       BOOL;
    LaserDiode2TempGuard:       BOOL;
    InterLock:                   BOOL;
    CrystalTemperature:          LREAL;
    CrystalCalibration:          LREAL;
    CrystalFrequency:            LREAL;
    FrequencyControl:            ALSLaserFrequencyControlsStruct;
    PZTTuningCoefficient:        LREAL;
    PZTFrequency:                LREAL;
    DoublerTemperature:          LREAL;

```

END\_STRUCT

END\_TYPE

|             |   |
|-------------|---|
| Type name   | ALSLaserStruct  |
| Description | Structure of the user interface tags that are used to control the ALS Laser                   |
| Definition  | STRUCT  |
| Output Tag  | Name: Error<br>Type: ErrorStruct<br>Description: For error handler                            |
| Output Tag  | Name: LaserDiode1PowerMonitor<br>Type: LREAL<br>Description: Laser diode 1 power monitor in A |
| Output Tag  | Name: LaserDiode2PowerMonitor<br>Type: LREAL<br>Description: Laser diode 2 power monitor in A |

|            |  |
|------------|--|
| Input Tag  | Name: LaserDiodePowerNominal<br>Type: LREAL<br>Description: Laser diode power nominal in A                 |
| Input Tag  | Name: LaserDiodePowerTolerance<br>Type: LREAL<br>Description: Laser diode power tolerance in A             |
| Output Tag | Name: LaserCrystalTECErrorSignal<br>Type: LREAL<br>Description: Laser crystal, TEC error signal in C       |
| Output Tag | Name: DoublingCrystalTECErrorSignal<br>Type: LREAL<br>Description: Doubling crystal, TEC error signal in C |
| Output Tag | Name: LaserDiode1TECErrorSignal<br>Type: LREAL<br>Description: Laser diode 1, TEC error signal in C        |
| Output Tag | Name: LaserDiode2TECErrorSignal<br>Type: LREAL<br>Description: Laser diode 2, TEC error signal in C        |
| Input Tag  | Name: TECTolerance<br>Type: LREAL<br>Description: TEC error signal tolerance in C                          |
| Output Tag | Name: NoiseEaterMonitor<br>Type: LREAL<br>Description: Noise eater monitor in V                            |
| Input Tag  | Name: NoiseEaterNominal<br>Type: LREAL<br>Description: Noise eater nominal value in V                      |
| Input Tag  | Name: NoiseEaterTolerance<br>Type: LREAL<br>Description: Noise eater tolerance in V                        |
| Output Tag | Name: LaserDiode1TempGuard<br>Type: BOOL<br>Description: Laser diode 1, temp guard, high is alarm          |
| Output Tag | Name: LaserDiode2TempGuard<br>Type: BOOL<br>Description: Laser diode 2, temp guard, high is alarm          |
| Output Tag | Name: InterLock<br>Type: BOOL<br>Description: InterLock, high represent an interlock                       |



|            |  |
|------------|--|
| In/out Tag | Name: CrystalTemperature<br>Type: LREAL<br>Description: Crystal Temperature in C or V  |
| Output Tag | Name: CrystalCalibration<br>Type: LREAL<br>Description: Crystal temperature coefficient at 1064nm in MHz/C; nominal -3000 MHz/C  |
| In/out Tag | Name: CrystalFrequency<br>Type: LREAL<br>Description: Laser frequency as set by crystal temperature in MHz; updating the CrystalFrequency will update the CrystalTemperature and vis versa |
| In/out Tag | Name: FrequencyControl<br>Type: ALSLaserFrequencyControlsStruct<br>Description: Controls parameters for slow temperature feedback network  |
| Output Tag | Name: PZTTuningCoefficient<br>Type: LREAL<br>Description: PZT tuning coefficient at 1064nm in MHz/V; nominal 1.5 MHz/V   |
| Output Tag | Name: PZTFrequency<br>Type: LREAL<br>Description: Laser frequency as set by the PZT actuator in MHz  |
| Input Tag  | Name: DoublerTemperature<br>Type: LREAL<br>Description: Doubler Temperature  |

|  |   |
|--|---|
| <b>Function Block</b><br>FUNCTION_BLOCK ALSLaserFB<br>VAR_INPUT<br>ALSLaserIn:        ALSLaserInStruct;<br>END_VAR<br>VAR_OUTPUT<br>ALSLaserOut:      ALSLaserOutStruct;<br>END_VAR<br>VAR_IN_OUT<br>ALSLaser:          ALSLaserStruct;<br>END_VAR |   |
| Name   | ALSLaserFB  |
| Description  | Monitors the ALS laser and computes the slow controls feedback  |
| Input argument   | Name: Request<br>Type: SaveRestoreEnum<br>Description: Request for save or restore  |
| Input argument   | Name: ALSLaserIn<br>Type: ALSLaserInStruct<br>Description: Input hardware structure   |
| Input argument   | Name: ControlsEnable<br>Type: BOOL<br>Description: Enables the slow controls feedback<br>Default: FALSE                           |
| Input argument   | Name: PZTVoltage<br>Type: LREAL<br>Description: PZT controls voltage in V (error signal for slow controls feedback)<br>Default: 0 |
| Output argument  | Name: ALSLaserOut<br>Type: ALSLaserOutStruct<br>Description: Output hardware structure  |
| In/out argument  | Name: ALSLaser<br>Type: ALSLaserStruct<br>Description: User Interface structure   |

| Visual                            |                          |                                |             |
|-----------------------------------|--------------------------|--------------------------------|-------------|
| Laser Diode 1 Power Monitor       | %3.3f A                  | Laser Diode Power Nominal      | %3.3f A     |
| Laser Diode 2 Power Monitor       | %3.3f A                  | Laser Diode Power Tolerance    | %3.3f A     |
| Laser Crystal TEC Error Signal    | %3.5f C                  | TEC Tolerance (10s average)    | %3.5f C     |
| Doubling Crystal TEC Error Signal | %3.5f C                  |                                |             |
| Laser Diode 1 TEC Error Signal    | %3.5f C                  |                                |             |
| Laser Diode 2 TEC Error Signal    | %3.5f C                  | Noise Eater Nominal            | %3.3f V     |
| Noise Eater Monitor               | %3.3f V                  | Noise Eater Tolerance          | %3.3f V     |
|                                   |                          |                                |             |
| PZT Frequency                     | %3.5f MHz                | PZT Tuning Coefficient         | %3.3f MHz/V |
| Crystal Temperature               | %3.5f V                  | Doubler Temperature            | %3.5f V     |
| Crystal Frequency                 | %5.2f MHz                | Temperature Coefficient        | %5.2f MHz/V |
| Crystal Low Frequency             | %5.2f MHz                | Crystal High Frequency         | %5.2f MHz   |
|                                   |                          |                                |             |
| Slow Frequency Servo              | ON                       | Reset                          | Enabled     |
|                                   |                          |                                | Running     |
| UGF                               | %3.4f Hz                 | Knee for proportional feedback | %3.4f Hz    |
|                                   |                          |                                |             |
| Laser Diode 1 Temp Guard          | Laser Diode 2 Temp Guard | Interlock                      |             |
| <b>Error</b>                      | %i                       | %s                             |             |

  

|             |   |
|-------------|---|
| Name        | ALSLaserVis   |
| Description | Displays power monitors, TEC error signals, noise eater status, crystal temperatures, slow temperature controls parameters, and alarms for temperature guards, interlock and error. |
| Placeholder | Name: ALSLaser<br>Type: ALSLaserStruct<br>Description: ALS laser structure  |