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LIGO-E1300482-v2

advanced LIGO

10/15/2013

ALS Laser Locking Library

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LIGO Scientific Collaboration

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Library	
Title	ALSLaserLocking
Version	2
TwinCAT version	V2.11.0
Name space	
Author	Sheila Dwyer
Description	Autolocking for ALS PLL at end station. See following section for more details.
Error Code	<p>1 — Communications error (lost communication from corner PLC1 or cornerPLC2, or there is an error from the timing system)</p> <p>2 — Reference cavity transmission PD error</p> <p>4 — Reference cavity transmission below the limit (limit set in this autolocker)</p> <p>8 — Fiber launch PD (in the fiber distribution box, internal.DC) error</p> <p>16 — Fiber launch power below the limit (limit set in this autolocker)</p> <p>32 — Fiber trans PD error (the limits are enforced in the DC PD library for the local PDs)</p> <p>64 — Fiber trans PD limits not set, they need to be set correctly</p> <p>128 — Fiber rejected polarization PD error</p> <p>32768 — Fiber rejected PD limits not set</p> <p>256 — % of the fiber light that is in the wrong polarization is too large</p> <p>512 — Power transmitted by fiber in the correct polarization to interfere with ALS laser is too small</p> <p>1024 — ALS Laser IR power PD error</p> <p>65536 — ALS Laser IR power PD limits not set</p> <p>2048 — Phase Frequency Discriminator Error</p> <p>4096 — Beat note power too low</p> <p>8192 — Beat note out of range of frequency comparator</p> <p>131072 — ALS Laser Error</p> <p>262144 — AutoLocker Failed</p>
Library Dependencies	ErrorHandler, SaveRestore, ReadADC, WriteDAC, ALSCommunication, ALSStateMachine, DCPower, Demodulator,

	CommonModeServo, ALSLaser
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1. Library Description:

This library includes an autolocker for the ALS end station lasers, as well as a function block called temperature controls taken from Alexa Staley's ALSLaser library that implements a slow servo feeding back to the laser crystal temperature.

It implements the following equation, which results in a 1/f filter if TemperatureControls.PF is zero OR a 1/f response with a zero at Pf, which is intended to compensate for the thermal pole of the laser crystal:

$$u_i = u_{i-1} + g \times e_i \quad h \leq 0 \quad (e_i - e_{i-1}) / h \quad h > 0 \quad \text{with}$$

$$g = \pi f_{ug} f \Delta t \quad \text{and} \quad h = \pi f_{Pf} \Delta t.$$

Δt : sampling interval,

f_{ug} : unity gain frequency of integrator,

f_{Pf} : Knee frequency of proportional gain.

There is also a polarity switch that reverses the sign of the feedback, and an enum (TemperatureControls.ErrorSignal) which allows the user to choose what to use as an error signal: the options are the beat note frequency error measured by the frequency comparator ($\text{beat.frequency} - \text{beat.vcofrequency} / 2$), the signal sent to the laser PZT calibrated in MHz, or the fast mon from the servo, also calibrated in MHz. There is also a reset that clears the integrator, and range limits for the output of the slow feedback.

The library also includes an error checking function block called locking conditions, which checks for a large number of error conditions that may prevent the PLL from locking, and sets the bit Logic.Conditions to FALSE if any of the locking conditions are not met.

The variable 'locked' is set to true if the common mode servo is not saturated and the beatnote is within tolerance.

A state diagram for the autolocker is below. The user can enable the autolocker so that it will run when the locking conditions are met, or force it so that it will disregard errors from the locking conditions function block. The user can also choose a polarity to lock the ALS laser above or below the PSL in frequency. This sets the polarity on the servo, the phase frequency discriminator, and the temperature feedback.

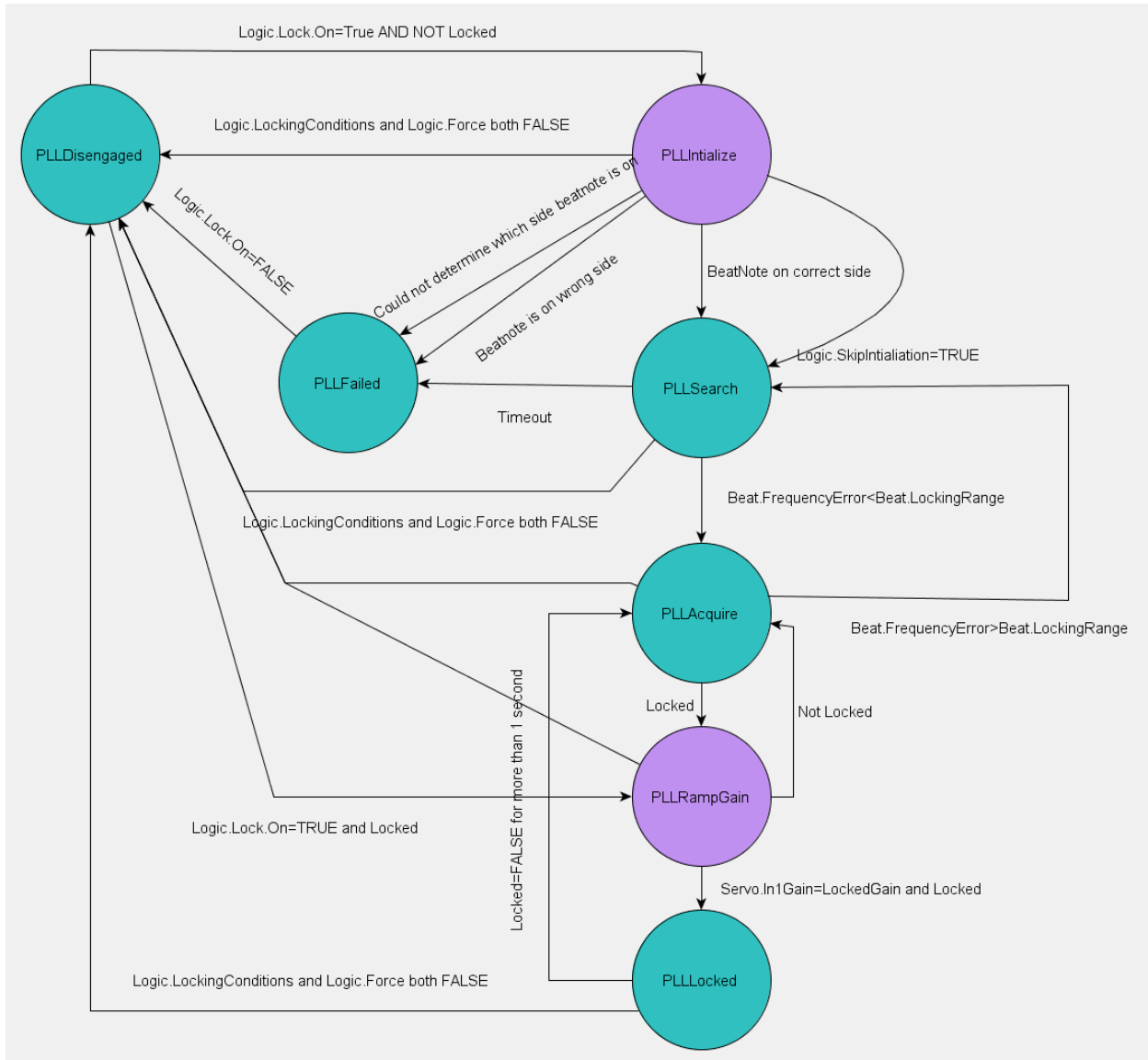


Figure 1: State diagram for PLL autolocking, transitional states in purple

When the autolocker state machine begins running, it either passes to the PLLInitialize state if the pll is unlocked or to the PLLGainRamp state if it is locked.

The user can choose to skip initialization or to initialize the autolocker, in which case it begins by increasing the laser crystal temperature, waiting 30 seconds and determining based on the response of the beat note measured by the frequency comparator if the laser is above or below the PSL in frequency. If the laser is on the wrong side, or the autolocker cannot determine what side it is on, it goes to the failed state, and the user needs to manually tune the crystal temperature. Once the temperature is manually tuned the user can disengage the autolocker and re-engage it to begin the locking process.

When the laser is on the correct side, the autolocker passes to the PLLSearch state, and uses the temperature servo with the beat note measured by the frequency comparator as an error signal, with the common mode board feedback to the PZT disengaged. If the beat note error become

less than beat.LockingRange the state machine passes to PLLacquire, or if 20 minutes pass without the beatnote coming into range the autolocker goes to the PLLfailed state.

In the PLLacquire state the common mode board feeds back to the laser PZT with low gain and the temperature servo continues to use the beatnote error as measured by the frequency comparator as an error signal. If the beat notes goes out of the locking range, the state returns to PLLSearch, if the PLL locks it passes to PLLRampGain.

In PLLRampGain the temperature servo error signal is switched to the PZT feedback, and the input gain of the common mode board is ramped at 1dB per second until it reaches the gain used for locking. If the PLL is locked at the locking gain for 1 second, the state transitions to PLLLocked,

It will stay in the locked state unless the PLL becomes unlocked for more than 1 second, in which case it passes to PLLacquire, or if the locking conditions are no longer met it will pass to disengaged.

2. Example Usage:

AlsEndFibrLockFB (

```

    FromCornerPLC1:=RecieveFromCornerPLC1,
    FromCornerPLC2:=RecieveFromCornerPLC2,
    ALSLaserLocking := Ifo.ALS.End.Fibr.Lock,
    ALSLaser:=Ifo.ALS.End.Laser.Head,
    Request := Request,
    ALSLaserLockingInit := AlsEndFibrLockInit,
    FiberTrans:=Ifo.ALS.End.Fibr.Trans.Dc,
    FiberRejected:=Ifo.ALS.End.Fibr.Rejected.Dc,
    LaserIR:=Ifo.ALS.End.Laser.Ir.Dc,
    Demod := Ifo.ALS.End.Fibr_A.Demod,
    CommunicationsError:= Ifo.Sys.Communication.Y.Error,
    Servo := Ifo.ALS.End.Fibr.Servo);

```

ALS Laser Locking Type	
TYPE ALSLaserLockingEnum : (PLLDisengaged, PLLInitialize, PLLSearch, PLLAcquire, PLLRampGain, PLLLocked, PLLFailed)	
END_TYPE;	
Type Name	ALSLaserLockingEnum
Description	Specifies the state for the PLL
Definition	ENUM

Element	Name: PLLDisengaged Description: The autolocker is disengaged
Element	Name: PLLInitialize Description: Initialize the PLL autolocker
Element	Name: PLLSearch Description: Searching for resonance
Element	Name: PLLAcquire Description: PLL lock is acquired
Element	Name: PLLRampGain Description: Increase the gain of the PLL Common Mode Board
Element	Name: PLLLocked Description: PLL is locked
Element	Name: PLLFailed Description: Autolocker has failed to lock the auxiliary laser

User Interface Type	
TYPE ALSLaserLockingBeatNoteStruct :	
STRUCT	
RFMin:	LREAL;
Frequency:	LREAL;
VcoFrequency:	LREAL;
Tolerance:	LREAL;
LockingRange:	LREAL;
Low:	LREAL;
High:	LREAL;
Sign:	BOOL;
FrequencyError:	LREAL;
SmoothedFrequencyError:	LREAL;
END_STRUCT;	
END_TYPE;	
Type Name	ALSLaserLockingBeatNoteStruct
Description	Structure used in the user interface type to control the autolocker
Definition	STRUCT
Output Tag	Name: RFMin Type: LREAL Description: Beat note threshold
Output Tag	Name: Frequency Type: LREAL Description: Beat note frequency
Output Tag	Name: VcoFrequency

	Type: LREAL Description: VCO frequency
Output Tag	Name: Tolerance Type: LREAL Description: Beat note frequency tolerance
Output Tag	Name: LockingRange Type: LREAL Description: Frequency range for locking
Output Tag	Name: Low Type: LREAL Description: Low cut-off for acquisition
Output Tag	Name: High Type: LREAL Description: High cut-off for acquisition
Input Tag	Name: Sign Type: BOOL Description: Sign of laser frequency
Input Tag	Name: FrequencyError Type: LREAL Description: Frequency error of beat note
Input Tag	Name: SmoothedFrequencyError Type: LREAL Description: Frequency error of beat note smoothed

User Interface Type	
TYPE ALSLaserLockingFiberStruct :	
STRUCT	
LaunchLim: LREAL;	
PolarizationPercent: LREAL;	
PolLim: LREAL = 30;	
TransRightPol: LREAL;	
TransRightPolLim: LREAL;	
END_STRUCT;	
END_TYPE;	
Type Name	ALSLaserLockingFiberStruct
Description	Structure used in the user interface type to control the fiber
Definition	STRUCT
Input Tag	Name: LaunchLim Type: LREAL

	Description: Lower limit for launched fiber power
Input Tag	Name: PolarizationPercent Type: LREAL Description: Fiber trans in the wrong polarization
Input Tag	Name: PolLim Type: LREAL Description: Limit for wrong polarization light
Output Tag	Name: TransRightPol Type: LREAL Description: Fiber trans power in right polarization
Input Tag	Name: TransRightPolLim Type: LREAL Description: Fiber trans power in right polarization limit

User Interface Type	
TYPE ALSLaserLockingLogicStruct :	
STRUCT	
Conditions: BOOL;	
Enable: BOOL;	
Force: BOOL;	
On: BOOL;	
TemperatureForce: BOOL;	
TemperatureOn: BOOL;	
Polarity: BOOL;	
SkipInitialization: BOOL;	
END_STRUCT;	
END_TYPE;	
Type Name	ALSLaserLockingLogicStruct
Description	Structure used in the user interface type to control the laser locking logic
Definition	STRUCT
Output Tag	Name: Conditions Type: BOOL Description: Pre-conditions for locking
Input Tag	Name: Enable Type: BOOL Description: Enable autolocker
Input Tag	Name: Force Type: BOOL Description: Force autolocker on even if conditions are not met
Input Tag	Name: On Type: BOOL

	Description: Autolocker on
Input Tag	Name: TemperatureForce Type: BOOL Description: Force autolocker on despite temperature
Input Tag	Name: TemperatureOn Type: BOOL Description: Slow servo on
Output Tag	Name: Polarity Type: BOOL Description: Polarity for ALS Laser PLL
Input Tag	Name: SkipInitialization Type: BOOL Description: Check laser on right size

User Interface Type	
TYPE ALSLaserLockingStruct :	
STRUCT	
Error:	ErrorStruct;
State:	ALSLaserLockingEnum;
RefCavTransLim:	LREAL;
Fiber:	ALSLaserLockingFiberStruct;
Beat:	ALSLaserLockingBeatNoteStruct;
Logic:	ALSLaserLockingLogicStruct;
TemperatureControls:	TemperatureControlsStruct;
LockLosses:	INT;
ResetLockLosses:	BOOL;
END_STRUCT;	
END_TYPE;	
Type Name	ALSLaserLockingStruct
Description	Structure used in the user interface type to control the laser locking
Definition	STRUCT
Input/Output Tag	Name: Error Type: ErrorStruct Description: Calls error handler
Input/Output Tag	Name: State Type: ALSLaserLockingEnum Description: Autolocker state
Input/Output Tag	Name: RefCavTransLim Type: LREAL Description: Lower limit for reference cavity transmission
Input/Output Tag	Name: Fiber

	Type: ALSLaserLockingFiberStruct Description: Structure of limits and calculations for fiber transmission
Input/Output Tag	Name: Beat Type: ALSLaserLockingBeatNoteStruct Description: Structure for achieving a beat note
Input/Output Tag	Name: Logic Type: ALSLaserLockingLogicStruct Description: Structure for logic behind autolocker
Input/Output Tag	Name: TemperatureControls Type: TemperatureControlsStruct Description: Temperature controls structure
Output Tag	Name: LockLosses Type: INT Description: Counts the number of times lock has been lost
Input Tag	Name: ResetLockLosses Type: BOOL Description: Resets the lock loss counter

User Interface Type	
TYPE TemperatureControlsStruct :	
STRUCT	
On: BOOL;	
Enabled: BOOL;	
Run: BOOL;	
Reset: BOOL;	
Low: LREAL;	
High: LREAL;	
Range: BOOL;	
Ugf: LREAL;	
Pf: LREAL;	
Polarity: BOOL;	
ErrorSignal: TemperatureErrorSignalEnum;	
END_STRUCT;	
END_TYPE;	
Type Name	TemperatureControlsStruct
Description	Structure used in the user interface type to control the laser temperature
Definition	STRUCT
Input Tag	Name: On Type: BOOL Description: On/off button

Input Tag	Name: Enabled Type: BOOL Description: Controls enabled button
Output Tag	Name: Run Type: BOOL Description: Temperature feedback running
Input Tag	Name: Reset Type: BOOL Description: Reset the integrator
Input Tag	Name: Low Type: LREAL Description: Low control value in Hz
Input Tag	Name: High Type: LREAL Description: High control value in Hz
Input Tag	Name: Range Type: BOOL Description: Controls range exceeded
Output Tag	Name: Ugf Type: LREAL Description: Unity gain frequency in Hz
Output Tag	Name: Pf Type: LREAL Description: Knee of proportional gain in Hz
Output Tag	Name: Polarity Type: BOOL Description: Polarity of slow feedback
Input/Output Tag	Name: ErrorSignal Type: TemperatureErrorSignalEnum Description: Error signal for temperature feedback

ALS Laser Locking Type	
TYPE TemperatureErrorSignalEnum : (PZTfrequency, BeatNoteError, SplitMon) END_TYPE;	
Type Name	TemperatureErrorSignalEnum
Description	Allows the user to specify what to use as an error signal for the temperature feedback
Definition	ENUM
Element	Name: PZTfrequency Description: Laser PZT actuation

Element	Name: BeatNoteError Description: Difference between the beat neat and half the VCO frequency
Element	Name: SplitMon Description: Split mon of the common mode board which can be used when fast feedback is engaged

<p>Function Block</p> <pre> TYPE ALSLaserLockingFB : VAR_INPUT Request: SaveRestoreEnum; Demod: DemodulatorLscStruct; FromCornerPLC2: CornerPLC2toEndStruct; FromCornerPLC1: CornerPLC1toEndStruct; FiberTrans: DCPowerStruct; FiberRejected: DCPowerStruct; LaserIR: DCPowerStruct; Fibr_A: DCPowerStruct; PDHServo: CommonModeStruct; END_VAR; VAR_IN_OUT ALSLaser: ALSLaserStruct; ALSLaserLockingInit: ALSLaserLockingStruct; ALSLaserLocking: ALSLaserLockingStruct; Servo: CommonModeStruct; END_VAR; END_TYPE; </pre>	
Type Name	ALSLaserLockingFB
Description	Function block for the autolocker
Definition	Function Block
Input Argument	Name: Request Type: SaveRestoreEnum Description: Request save/restore/safemood or noop
Input Argument	Name: Demod Type: DemodulatorLscStruct Description: User interfce structure
Input Argument	Name: FromCornerPLC2 Type: CornerPLC2toEndStruct Description: Communication between corner PLC2 and end station
Input Argument	Name: FromCornerPLC1 Type: CornerPLC2toEndStruct Description: Communication between corner PLC1 and end station

Input Argument	Name: FiberTrans Type: DCPowerStruct Description: PD monitoring total fiber transmission power
Input Argument	Name: FiberRejected Type: DCPower Struct Description: PD monitoring total fiber rejected power
Input Argument	Name: LaserIR Type: DCPowerStruct Description: PD monitoring the ALS laser power in IR path
Input Argument	Name: Fibr_A Type: DCPowerStruct Description: DC output of broad band PD
Input Argument	Name: PDHServo Type: CommonModeStruct Description: User interface structure
In/Out Argument	Name: ALSLaser Type: ALSlaserStruct Description: User interface structure
In/Out Argument	Name: ALSLaserLockingInit Type: AlsLaserLockingStruct Description: Save/restore variable in persistent memory
In/Out Argument	Name: ALSLaserLocking Type: ALSLaserLockingStruct Description: User interface structure
In/Out Argument	Name: Servo Type: CommonModeStruct Description: User interface structure

Function Block

TYPE LockingConidtionsFB :

VAR_INPUT

```

    CommunicationsError:    ErrorStruct;
    Demod:                  DemodulatorLscStruct;
    FromCornerPLC2:        CornerPLC2toEndStruct;
    FiberTrans:            DCPowerStruct;
    FiberRejected:        DCPowerStruct;
    LaserIR:              DCPowerStruct;
    Fibr_A:                DCPowerStruct;
    Servo:                 CommonModeStruct;
    Laser:                 ALSLaserStruct;

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END_VAR;

<pre> VAR_IN_OUT ErrorHandler: ErrorHandlerFB; ALSLaserLocking: ALSLaserLockingStruct; END_VAR; END_TYPE; </pre>	
Type Name	LockingConditionsFB
Description	Function block for the conditions of the autolocker
Definition	Function Block
Input Argument	Name: CommunicationsError Type: ErrorStruct Description: Checks for a communications error
Input Argument	Name: Demod Type: DemodulatorLscStruct Description: User interface structure
Input Argument	Name: FromCornerPLC2 Type: CornerPLC2toEndStruct Description: Communication between corner PLC2 and end station
Input Argument	Name: FiberTrans Type: DCPowerStruct Description: PD monitoring total fiber transmission power
Input Argument	Name: FiberRejected Type: DCPower Struct Description: PD monitoring total fiber rejected power
Input Argument	Name: LaserIR Type: DCPowerStruct Description: PD monitoring the ALS laser power in IR path
Input Argument	Name: Fibr_A Type: DCPowerStruct Description: DC output of broad band PD
Input Argument	Name: Servo Type: CommonModeStruct Description: User interace structure
Input Argument	Name: Laser Type: ALSlaserStruct Description: User interface structure
In/Out Argument	Name: ALSLaserLocking Type: ALSLaserLockingStruct Description: User interface structure
In/Out Argument	Name: ErrorHandler Type: ErrorHandlerFB Description: Calls error handler FB

Function Block TYPE PflLoopFB : VAR_INPUT Input: LREAL; Auto: BOOL; Polarity: BOOL; END_VAR; VAR_IN_OUT Reset: BOOL; Ratio: LREAL; PropConst: LREAL; IntConst: LREAL; END_VAR; VAR_OUTPUT Output: LREAL; Error: BOOL; Message: STRING; END_VAR; END_TYPE;	
Type Name	PFLoopFB
Description	This object represents a simple PI Loop
Definition	Function Block
Input Argument	Name: Input Type: LREAL Description: Main input variable
Input Argument	Name: Auto Type: BOOL Description: Default values flag
Input Argument	Name: Polarity Type: BOOL Description: Polarity flaf
In/out Argument	Name: Reset Type: BOOL Description: Reset flag
In/out Argument	Name: Ratio Type: LREAL Description: Manual entry for P/I mixing ratio
In/out Argument	Name: PropConst Type: LREAL Description: Manual entry for proportionality constant
In/out Argument	Name: IntConst

	Type: LREAL Description: Manual entry for integration constant
Output Argument	Name: Output Type: LREAL Description: Main output variable
Output Argument	Name: Error Type: BOOL Description: Error flag
Output Argument	Name: Message Type: STRING Description: Information message out

Function Block	
TYPE TemperatureControlsFB :	
VAR_INPUT	
Request:	SaveRestoreEnum;
FromCornerPLC1:	CornerPLC1toEndStruct;
Servo:	CommonModeStruct;
END_VAR;	
VAR_IN_OUT	
ALSLaser:	ALSLaserStruct;
ALSLaserLocking:	ALSLaserLockingStruct;
END_VAR;	
END_TYPE;	
Type Name	TemperatureControlsFB
Description	Function block for temperature readback
Definition	Function Block
Input Argument	Name: Request Type: SaveRestoreEnum Description: Request save/restore/safemood or noop
Input Argument	Name: FromCornerPLC1 Type: CornerPLC1toEndStruct Description: Communication from corner PLC1 to end station
Input Argument	Name: Servo Type: CommonModeStruct Description: User interface type
In/out Argument	Name: ALSLaser Type: ALSLaserStruct Description: User interface type
In/out Argument	Name: ALSLaserLocking Type: ALSLaserLockingStruct

	Description: User interface type
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