*LIGO Laboratory / LIGO Scientific Collaboration*

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TwinCAT Library for Low Noise VCO

Daniel Sigg

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| **California Institute of Technology****LIGO Project – MS 18-34****1200 E. California Blvd.****Pasadena, CA 91125**Phone (626) 395-2129Fax (626) 304-9834E-mail: info@ligo.caltech.edu | **Massachusetts Institute of Technology****LIGO Project – NW22-295****185 Albany St****Cambridge, MA 02139**Phone (617) 253-4824Fax (617) 253-7014E-mail: info@ligo.mit.edu |
| **LIGO Hanford Observatory****P.O. Box 159****Richland WA 99352**Phone 509-372-8106Fax 509-372-8137 | **LIGO Livingston Observatory****P.O. Box 940****Livingston, LA 70754**Phone 225-686-3100Fax 225-686-7189 |

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

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| **Library** |
| Title | LowNoiseVco |
| Version | 8 |
| TwinCAT version | 2.11 |
| Name space | – |
| Author | Daniel Sigg |
| Description | Controls the low noise VCO, [D0900605](https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?.submit=Number&docid=D0900605&version=), the frequency difference mixer, [D1600499](https://dcc.ligo.org/LIGO-D1600499), and the fixed ratio frequency source, [D1700475](https://dcc.ligo.org/LIGO-D1700475).The low noise VCO is based on a frequency difference divider. It requires a 71MHz/10dBm reference source and a VCO source at either 125MHz or 79MHz. Both RF levels as well as the RF level at the output of the frequency difference divider are monitored. The only set value is an offset into the VCO which translates into a frequency offset at the output. A binary output is used to enable the excitation input. Additional monitors are available for the tune voltage, the state of the excitation switch, and a power ok bit.If a frequency counter has been setup through the timing system, the measured frequency can be stabilized by feeding back to the bias offset. This then allows the user to select a fixed output frequency.The frequency difference mixer is using the same RF mixer circuit but without a divider and a VCO. It implements none of the extra frequency controls of the VCO neither. The fixed ratio frequency source locks an OCXO to an RF signal using an internal PLL, in order to generate a clean higher order harmonics.The 3 RF power monitors which have the calibration$$P=12 dBm-10 dBm/V×(U-4 V)$$The corresponding temperature readout has the calibration$$T=20°C+50°C/V×(U\*1.10-6 V)$$The factor 1.10 is due to the voltage divider at the temperature readout.The RF power levels should be alarmed when outside ±1dBm of nominal. |
| Error codes | Low Noise VCO:0x01 – Power supply voltages out-of-range0x02 – Reference RF power level out-of-range0x04 – Divider RF power level out-of-range0x08 – Output RF power level out-of-range0x10 – Excitation switch enabled0x20 – Invalid frequency0x40 – RF Power is on0x80 – Controls errorFrequency difference mixer:0x01 – Power supply voltages out-of-range0x02 – Reference RF power level out-of-range0x04 – Input RF power level out-of-range0x08 – Output RF power level out-of-rangeFixed ratio frequency source:0x01 – Power supply voltages out-of-range0x02 – Output RF power level out-of-range0x04 – PLL unlockedControls errors:0x01 – Unity gain frequency too high0x02 – Unity gain frequency too low0x04 – High limit reached0x08 – Low limit reached0x10 – Invalid error signal0x20 – Invalid set frequency |
| Library dependencies: | Error, SaveRestore, ReadADC. WriteDAC |

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| **Hardware Input Type**TYPE LowNoiseVcoInStruct :STRUCT ReferenceMon: INT; DividerMon: INT; OutputMon: INT; ReferenceTemp: INT; DividerTemp: INT; OutputTemp: INT; TuneMon: INT; Spare: INT; Frequency: LREAL; (\* not used \*) ExcitationSwitch: BOOL; PowerOk: BOOL; FrequencyLive: BOOL; (\* not used \*)END\_STRUCTEND\_TYPE |
| Type name | LowNoiseVcoInStruct |
| Description | Structure of the hardware inputs that are wired up for the low noise VCO |
| Definition | STRUCT |
| Element | Name: ReferenceMonType: INTDescription: Monitors the RF power at the reference input |
| Element | Name: DividerMonType: INTDescription: Monitors the RF power at the divider input |
| Element | Name: OutputMonType: INTDescription: Monitors the RF power after the output amplifier |
| Element | Name: ReferenceTempType: INTDescription: Monitors the temperature of the reference RF detector |
| Element | Name: DividerTempType: INTDescription: Monitors the temperature of the divider RF detector |
| Element | Name: OutputTempType: INTDescription: Monitors the temperature of the output RF detector |
| Element | Name: TuneMonType: INTDescription: Monitor for the frequency offset |
| Element | Name: SpareType: INTDescription: Readback of RF power status: 0V: VCO and FDD off -3V: VCO on and FDD off -6V: VCO off and FDD on -9V: VCO on and FDD on |
| Element | Name: FrequencyType: LREALDescription: Measured frequency |
| Element | Name: ExcitationSwitchType: BOOLDescription: Monitors the excitation input enable |
| Element | Name: PowerOkType: BOOLDescription: Voltage monitor readback |
| Element | Name: FrequencyLiveType: BOOLDescription: Keep alive for frequency measurement |

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| **Hardware Input Type**TYPE FixedRatioFrequencySourceInStruct :STRUCT OutputMon: INT; TuneMon: INT; Alarm: INT; OutputTemp: INT; PowerOk: BOOL;END\_STRUCTEND\_TYPE |
| Type name | FixedRatioFrequencySourceInStruct |
| Description | Structure of the hardware inputs that are wired up for the fixed ratio frequency source |
| Definition | STRUCT |
| Element | Name: OutputMonType: INTDescription: Monitors the RF power after the output amplifier |
| Element | Name: TuneMonType: INTDescription: PLL voltage monitor |
| Element | Name: AlarmType: INTDescription: PLL lock status, TTL |
| Element | Name: OutputTempType: INTDescription: Monitors the temperature of the output RF detector |
| Element | Name: PowerOkType: BOOLDescription: Voltage monitor readback |

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| **Hardware Output Type**TYPE LowNoiseVcoOutStruct :STRUCT TuneOfs: INT; ExcitationEn: BOOL;END\_STRUCTEND\_TYPE |
| Type name | LowNoiseVcoOutStruct |
| Description | Structure of the hardware outputs that are wired up for the low noise VCO |
| Definition | STRUCT |
| Element | Name: TuneOfsType: INTDescription: Setpoint for the frequency offset |
| Element | Name: ExcitationEnType: BOOLDescription: Enables the excitation input; This is used by the relay to turn on and off the RF power |

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| **User Interface Type**TYPE LowNoiseVcoStruct :STRUCT Error: ErrorStruct; VCOType: LowNoiseVcoTypeEnum;  HasRelay: BOOL; ReferenceNom: LREAL; DividerMon: LREAL;  DividerNom: LREAL; OutputMon: LREAL;  OuptutNom: LREAL; ReferenceTemp: LREAL;  DividerTemp: LREAL; OutputTemp: LREAL; TuneOfs: LREAL; TuneMon: LREAL; TuneLimit: LREAL; ExcitationSwitch: BOOL; ExcitationEn: BOOL; PowerDisable: BOOL; PowerOk: BOOL; PowerVCO: LowNoiseVcoPowerEnum;  PowerFDD: LowNoiseVcoPowerEnum; Frequency: LREAL; FrequencyFault: BOOL; Controls: LowNoiseVcoControlsStruct;END\_STRUCTEND\_TYPE |
| Type name | LowNoiseVcoStruct |
| Description | Structure of the user interface tags that are used to control the low noise VCO |
| Definition | STRUCT |
| Output Tag | Name: ErrorType: ErrorStructDescription: For error handler |
| Output Tag | Name: VCOTypeType: LowNoiseVcoTypeEnumDescription: VCO or FDD |
| Output Tag | Name: HasRelayType: BOOLDescription: Implements a VCO relay board |
| Output Tag | Name: ReferenceMonType: LREALDescription: Monitors the RF power at the reference input in dBm |
| Input Tag | Name: ReferenceNomType: LREALDescription: Nominal value for the RF power at the reference input in dBm |
| Output Tag | Name: DividerMonType: LREALDescription: Monitors the RF power at the divider input in dBm |
| Input Tag | Name: DividerNomType: LREALDescription: Nominal value for the RF power at the divider input in dBm |
| Output Tag | Name: OutputMonType: LREALDescription: Monitors the RF power after the output amplifier dBm |
| Input Tag | Name: OutputNomType: LREALDescription: Nominal value for the RF power at the output amplifier in dBm |
| Output Tag | Name: ReferenceTempType: LREALDescription: Monitors the temperature of the reference RF detector in C |
| Output Tag | Name: DividerTempType: LREALDescription: Monitors the temperature of the divider RF detector in C |
| Output Tag | Name: OutputTempType: LREALDescription: Monitors the temperature of the output RF detector in C |
| Input Tag | Name: TuneOfsType: LREALDescription: Setpoint for the frequency offset in V |
| Output Tag | Name: TuneMonType: LREALDescription: Monitor for the frequency offset in V |
| Input Tag | Name: TuneLimitType: LREALDescription: Limit for the frequency offset in V |
| Input Tag | Name: ExcitationEnType: BOOLDescription: Enables the excitation input |
| Output Tag | Name: ExcitationSwitchType: BOOLDescription: Monitors the excitation input enable |
| Input Tag | Name: PowerDisableType: BOOLDescription: Disable RF power, if VCO relay is implemented |
| Output Tag | Name: PowerOkType: BOOLDescription: Voltage monitor readback |
| Output Tag | Name: PowerVCOType: LowNoiseVcoPowerEnumDescription: True if the VCO is powered on (relay only) |
| Output Tag | Name: PowerFDDType: LowNoiseVcoPowerEnumDescription: True if the FDD is powered on (relay only) |
| Output Tag | Name: FrequencyType: LREALDescription: Frequency of the VCO output |
| Output Tag | Name: FrequencyFaultType: BOOLDescription: Indicates if the frequency of the VCO is no longer updating correctly |
| Input Tag | Name: ControlsType: LowNoiseVcoControlsStructDescription: VCO frequency controls parameters |

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| **User Interface Type**TYPE LowNoiseVcoControlsStruct:STRUCT Error: ErrorStruct; FDDStages: DINT; UseSigmaDelta: BOOL;  Fault: BOOL; SetFrequency: LREAL; SetFrequencyOffset: LREAL; DiffFrequency: LREAL; Enable: BOOL; UnityGain: LREAL; ClearInt: BOOL;END\_STRUCTEND\_TYPE |
| Type name | LowNoiseVcoControlsStruct |
| Description | Structure of the user interface that is used to control the frequency of the low noise VCO |
| Definition | STRUCT |
| Output Tag | Name: ErrorType: ErrorStructDescription: For error handler |
| Output Tag | Name: FDDStagesType: DINTDescription: Number of FDD stages |
| Output Tag | Name: UseSigmaDeltaType: BOOLDescription: Uses a sigma-delta algorithm to control the frequency |
| Output Tag | Name: FaultType: BOOLDescription: Indicated a servo fault |
| Input Tag | Name: SetFrequencyType: LREALDescription: Set frequency in Hz |
| Input Tag | Name: SetFrequencyOffsetType: LREALDescription: Set frequency offset in Hz |
| Output Tag | Name: DiffFrequencyType: LREALDescription: Difference between measured and set frequency in Hz |
| Input Tag | Name: EnableType: BOOLDescription: Enable the servo |
| Input Tag | Name: UnityGainType: LREALDescription: Unity gain frequency in Hz |
| Input Tag | Name: ClearIntType: BOOLDescription: Clear the history of the integrator |

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| **User Interface Type**TYPE LowNoiseVcoTypeEnum: (VCO, FDD);END\_TYPE |
| Type name | LowNoiseVcoTypeEnum |
| Description | Enumerated type to describe the type of the low noise VCO |
| Definition | ENUM |
| Enum Tag | Name: VCODescription: Standard VCO |
| Enum Tag | Name: FDDDescription: Frequency-difference divider |

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| **User Interface Type**TYPE LowNoiseVcoPowerEnum :  LowNoiseVcoPowerUnknown, LowNoiseVcoPowerOff, LowNoiseVcoPowerOn);END\_TYPE |
| Type name | LowNoiseVcoPowerEnum |
| Description | Enumerated type to describe the power type of the low noise VCO |
| Definition | ENUM |
| Enum Tag | Name: UnknownDescription: Unknown state of power supply |
| Enum Tag | Name: OffDescription: Power is off |
| Enum Tag | Name: OnDescription: Power is on |

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| **User Interface Type**TYPE FrequencyDifferenceMixerStruct :STRUCT Error: ErrorStruct; ReferenceMon: LREAL;  ReferenceNom: LREAL; InputMon: LREAL;  InputNom: LREAL; OutputMon: LREAL;  OuptutNom: LREAL; ReferenceTemp: LREAL;  InputTemp: LREAL; OutputTemp: LREAL; PowerOk: BOOL;END\_STRUCTEND\_TYPE |
| Type name | FrequencyDifferenceMixerStruct |
| Description | Structure of the user interface tags that are used to control the frequency difference mixer |
| Definition | STRUCT |
| Output Tag | Name: ErrorType: ErrorStructDescription: For error handler |
| Output Tag | Name: ReferenceMonType: LREALDescription: Monitors the RF power at the reference input in dBm |
| Input Tag | Name: ReferenceNomType: LREALDescription: Nominal value for the RF power at the reference input in dBm |
| Output Tag | Name: InputMonType: LREALDescription: Monitors the RF power at the input in dBm |
| Input Tag | Name: InputNomType: LREALDescription: Nominal value for the RF power at the input in dBm |
| Output Tag | Name: OutputMonType: LREALDescription: Monitors the RF power after the output amplifier dBm |
| Input Tag | Name: OutputNomType: LREALDescription: Nominal value for the RF power at the output amplifier in dBm |
| Output Tag | Name: ReferenceTempType: LREALDescription: Monitors the temperature of the reference RF detector in C |
| Output Tag | Name: InputTempType: LREALDescription: Monitors the temperature of the input RF detector in C |
| Output Tag | Name: OutputTempType: LREALDescription: Monitors the temperature of the output RF detector in C |
| Output Tag | Name: PowerOkType: BOOLDescription: Voltage monitor readback |

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| **User Interface Type**TYPE FixedRatioFrequencySourceStruct :STRUCT Error: ErrorStruct; OutputMon: LREAL;  OuptutNom: LREAL; OutputTemp: LREAL; Locked: BOOL; TuneMon: LREAL;  PowerOk: BOOL;END\_STRUCTEND\_TYPE |
| Type name | FixedRatioFrequencySourceStruct |
| Description | Structure of the user interface tags that are used to monitor the fixed ratio frequency source |
| Definition | STRUCT |
| Output Tag | Name: ErrorType: ErrorStructDescription: For error handler |
| Output Tag | Name: OutputMonType: LREALDescription: Monitors the RF power after the output amplifier dBm |
| Input Tag | Name: OutputNomType: LREALDescription: Nominal value for the RF power at the output amplifier in dBm |
| Output Tag | Name: OutputTempType: LREALDescription: Monitors the temperature of the output RF detector in C |
| Output Tag | Name: LockedType: BOOLDescription: Indicates that the PLL is locked |
| Output Tag | Name: TuneMonType: LREALDescription: Monitors the voltage of the OCXO control signal in V |
| Output Tag | Name: PowerOkType: BOOLDescription: Voltage monitor readback |

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| **Function Block**FUNCTION\_BLOCK LowNoiseVcoFBVAR\_INPUT LowNoiseVcoType: LowNoiseVcoTypeEnum := VCO; Request: SaveRestoreEnum; LowNoiseVcoIn: LowNoiseVcoInStruct; Frequency: LREAL := 0.0; FrequencyError: BOOL := TRUE; ExtUpdateRate: INT := 1; FddStages: INT := 1; VcoGain: LREAL := 140E3; VcoMin: LREAL := 78.159E6; VcoMax: LREAL := 80.276E6; UseSigmaDelta: BOOL := TRUE; UseRelay: BOOL := FALSE; DefaultExcitation: BOOL := FALSE;END\_VARVAR\_OUTPUT LowNoiseVcoOut: LowNoiseVcoOutStruct;END\_VARVAR\_IN\_OUT LowNoiseVcoInit: LowNoiseVcoStruct; LowNoiseVco: LowNoiseVcoStruct;END\_VAR |
| Name | LowNoiseVcoFB |
| Description | Controls the low noise VCO. One function block for each low noise VCO chassis needs to be instantiated. An FDD unit is usually the second stage of a multi stage VCO/FDD setup. It does not implement a frequency servo. |
| Input argument  | Name: LowNoiseVcoTypeType: LowNoiseVcoTypeEnumDescription: Type of low noise VCO chassisDefault: VCO |
| Input argument  | Name: RequestType: SaveRestoreEnumDescription: Save restore command |
| Input argument | Name: LowNoiseVcoInType: LowNoiseVcoInStructDescription: Input hardware structure |
| Input argument | Name: FrequencyType: LREALDescription: Externally measured frequency of VCODefault: 0 |
| Input argument | Name: FrequencyErrorType: BOOLDescription: Externally measured frequency is invalidDefault: TRUE (invalid) |
| Input argument | Name: ExtUpdateRateType: INTDescription: How much is the update rate of external frequency readback slower than the processing clock. For 10 ms processing clock, a value of 100 corresponds to 1s updates, such as through the timing system.Default: 1 (10ms) |
| Input argument | Name: FddStagesType: INTDescription: Number of frequency difference dividers used. This is to normalize the gain of the frequency servo.Default: 1 |
| Input argument | Name: VcoGainType: LREALDescription: Vco gain in Hz/V. First stage only.Default: 140E3 |
| Input argument | Name: VcoMinType: LREALDescription: Minimum of VCO frequency range in Hz.Default: 78.159E6 |
| Input argument | Name: VcoMaxType: LREALDescription: Maximum of VCO frequency range in Hz.Default: 80.276E6 |
| Input argument | Name: UseSigmaDeltaType: BOOLDescription: Use a sigma delta modulator for averaging the control signalDefault: TRUE |
| Input argument | Name: UseRelayType: BOOLDescription: True if VCO implements relay boardDefault: FALSE |
| Input argument | Name: DefaultExcitation Type: BOOLDescription: Default excitation is on (TRUE) or off (FALSE)Default: FALSE |
| Output argument | Name: LowNoiseVcoOutType: LowNoiseVcoOutStructDescription: Output hardware structure |
| In/out argument | Name: LowNoiseVcoInitType: LowNoiseVcoStructDescription: Save/restore variables in persistent memory |
| In/out argument | Name: LowNoiseVcoType: LowNoiseVcoStructDescription: User Interface structure |

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| **Function Block**FUNCTION\_BLOCK FrequencyDifferenceMixerFBVAR\_INPUT Request: SaveRestoreEnum; FrequencyDifferenceMixerIn: LowNoiseVcoInStruct;END\_VARVAR\_IN\_OUT FrequencyDifferenceMixerInit: FrequencyDifferenceMixerStruct; FrequencyDifferenceMixer: FrequencyDifferenceMixerStruct;END\_VAR |
| Name | FrequencyDifferenceMixerFB |
| Description | Controls the frequency difference mixer. One function block for each frequency difference mixer chassis needs to be instantiated.  |
| Input argument  | Name: RequestType: SaveRestoreEnumDescription: Save restore command |
| Input argument | Name: FrequencyDifferenceMixerInType: LowNoiseVcoInStructDescription: Input hardware structure |
| In/out argument | Name: FrequencyDifferenceMixerInitType: FrequencyDifferenceMixerStructDescription: Save/restore variables in persistent memory |
| In/out argument | Name: FrequencyDifferenceMixerType: FrequencyDifferenceMixerStructDescription: User Interface structure |

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| **Function Block**FUNCTION\_BLOCK FixedRatioFrequencySourceFBVAR\_INPUT Request: SaveRestoreEnum; FixedRatioFrequencySourceIn: FixedRatioFrequencySourceInStruct;END\_VARVAR\_IN\_OUT FixedRatioFrequencySourceInit: FixedRatioFrequencySourceStruct; FixedRatioFrequencySource: FixedRatioFrequencySourceStruct;END\_VAR |
| Name | FixedRatioFrequencySourceFB |
| Description | Controls the fixed ratio frequency source. One function block for each fixed ratio frequency source chassis needs to be instantiated.  |
| Input argument  | Name: RequestType: SaveRestoreEnumDescription: Save restore command |
| Input argument | Name: FixedRatioFrequencySourceInType: LowNoiseVcoInStructDescription: Input hardware structure |
| In/out argument | Name: FixedRatioFrequencySourceInitType: FixedRatioFrequencySourceStructDescription: Save/restore variables in persistent memory |
| In/out argument | Name: FixedRatioFrequencySourceType: FixedRatioFrequencySourceStructDescription: User Interface structure |

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| **Visual** |
| Name | LowNoiseVcoVis |
| Description | Displays several MON and temperature readings, power and excitation status, and error alarms |
| Placeholder | Name: LowNoiseVCOType: LowNoiseVCOStructDescription: Low Noise VCO structure |