*LIGO Laboratory / LIGO Scientific Collaboration*

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TwinCAT Library for Low Noise VCO

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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  The corresponding temperature readout has the calibration  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-range  0x02 – Reference RF power level out-of-range  0x04 – Divider RF power level out-of-range  0x08 – Output RF power level out-of-range  0x10 – Excitation switch enabled  0x20 – Invalid frequency  0x40 – RF Power is on  0x80 – Controls error  Frequency difference mixer:  0x01 – Power supply voltages out-of-range  0x02 – Reference RF power level out-of-range  0x04 – Input RF power level out-of-range  0x08 – Output RF power level out-of-range  Fixed ratio frequency source:  0x01 – Power supply voltages out-of-range  0x02 – Output RF power level out-of-range  0x04 – PLL unlocked  Controls errors:  0x01 – Unity gain frequency too high  0x02 – Unity gain frequency too low  0x04 – High limit reached  0x08 – Low limit reached  0x10 – Invalid error signal  0x20 – 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\_STRUCT  END\_TYPE | |
| Type name | LowNoiseVcoInStruct |
| Description | Structure of the hardware inputs that are wired up for the low noise VCO |
| Definition | STRUCT |
| Element | Name: ReferenceMon  Type: INT  Description: Monitors the RF power at the reference input |
| Element | Name: DividerMon  Type: INT  Description: Monitors the RF power at the divider input |
| Element | Name: OutputMon  Type: INT  Description: Monitors the RF power after the output amplifier |
| Element | Name: ReferenceTemp  Type: INT  Description: Monitors the temperature of the reference RF detector |
| Element | Name: DividerTemp  Type: INT  Description: Monitors the temperature of the divider RF detector |
| Element | Name: OutputTemp  Type: INT  Description: Monitors the temperature of the output RF detector |
| Element | Name: TuneMon  Type: INT  Description: Monitor for the frequency offset |
| Element | Name: Spare  Type: INT  Description: 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: Frequency  Type: LREAL  Description: Measured frequency |
| Element | Name: ExcitationSwitch  Type: BOOL  Description: Monitors the excitation input enable |
| Element | Name: PowerOk  Type: BOOL  Description: Voltage monitor readback |
| Element | Name: FrequencyLive  Type: BOOL  Description: 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\_STRUCT  END\_TYPE | |
| Type name | FixedRatioFrequencySourceInStruct |
| Description | Structure of the hardware inputs that are wired up for the fixed ratio frequency source |
| Definition | STRUCT |
| Element | Name: OutputMon  Type: INT  Description: Monitors the RF power after the output amplifier |
| Element | Name: TuneMon  Type: INT  Description: PLL voltage monitor |
| Element | Name: Alarm  Type: INT  Description: PLL lock status, TTL |
| Element | Name: OutputTemp  Type: INT  Description: Monitors the temperature of the output RF detector |
| Element | Name: PowerOk  Type: BOOL  Description: Voltage monitor readback |

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| **Hardware Output Type**  TYPE LowNoiseVcoOutStruct :  STRUCT  TuneOfs: INT;  ExcitationEn: BOOL;  END\_STRUCT  END\_TYPE | |
| Type name | LowNoiseVcoOutStruct |
| Description | Structure of the hardware outputs that are wired up for the low noise VCO |
| Definition | STRUCT |
| Element | Name: TuneOfs  Type: INT  Description: Setpoint for the frequency offset |
| Element | Name: ExcitationEn  Type: BOOL  Description: 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\_STRUCT  END\_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: Error  Type: ErrorStruct  Description: For error handler |
| Output Tag | Name: VCOType  Type: LowNoiseVcoTypeEnum  Description: VCO or FDD |
| Output Tag | Name: HasRelay  Type: BOOL  Description: Implements a VCO relay board |
| Output Tag | Name: ReferenceMon  Type: LREAL  Description: Monitors the RF power at the reference input in dBm |
| Input Tag | Name: ReferenceNom  Type: LREAL  Description: Nominal value for the RF power at the reference input in dBm |
| Output Tag | Name: DividerMon  Type: LREAL  Description: Monitors the RF power at the divider input in dBm |
| Input Tag | Name: DividerNom  Type: LREAL  Description: Nominal value for the RF power at the divider input in dBm |
| Output Tag | Name: OutputMon  Type: LREAL  Description: Monitors the RF power after the output amplifier dBm |
| Input Tag | Name: OutputNom  Type: LREAL  Description: Nominal value for the RF power at the output amplifier in dBm |
| Output Tag | Name: ReferenceTemp  Type: LREAL  Description: Monitors the temperature of the reference RF detector in C |
| Output Tag | Name: DividerTemp  Type: LREAL  Description: Monitors the temperature of the divider RF detector in C |
| Output Tag | Name: OutputTemp  Type: LREAL  Description: Monitors the temperature of the output RF detector in C |
| Input Tag | Name: TuneOfs  Type: LREAL  Description: Setpoint for the frequency offset in V |
| Output Tag | Name: TuneMon  Type: LREAL  Description: Monitor for the frequency offset in V |
| Input Tag | Name: TuneLimit  Type: LREAL  Description: Limit for the frequency offset in V |
| Input Tag | Name: ExcitationEn  Type: BOOL  Description: Enables the excitation input |
| Output Tag | Name: ExcitationSwitch  Type: BOOL  Description: Monitors the excitation input enable |
| Input Tag | Name: PowerDisable  Type: BOOL  Description: Disable RF power, if VCO relay is implemented |
| Output Tag | Name: PowerOk  Type: BOOL  Description: Voltage monitor readback |
| Output Tag | Name: PowerVCO  Type: LowNoiseVcoPowerEnum  Description: True if the VCO is powered on (relay only) |
| Output Tag | Name: PowerFDD  Type: LowNoiseVcoPowerEnum  Description: True if the FDD is powered on (relay only) |
| Output Tag | Name: Frequency  Type: LREAL  Description: Frequency of the VCO output |
| Output Tag | Name: FrequencyFault  Type: BOOL  Description: Indicates if the frequency of the VCO is no longer updating correctly |
| Input Tag | Name: Controls  Type: LowNoiseVcoControlsStruct  Description: 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\_STRUCT  END\_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: Error  Type: ErrorStruct  Description: For error handler |
| Output Tag | Name: FDDStages  Type: DINT  Description: Number of FDD stages |
| Output Tag | Name: UseSigmaDelta  Type: BOOL  Description: Uses a sigma-delta algorithm to control the frequency |
| Output Tag | Name: Fault  Type: BOOL  Description: Indicated a servo fault |
| Input Tag | Name: SetFrequency  Type: LREAL  Description: Set frequency in Hz |
| Input Tag | Name: SetFrequencyOffset  Type: LREAL  Description: Set frequency offset in Hz |
| Output Tag | Name: DiffFrequency  Type: LREAL  Description: Difference between measured and set frequency in Hz |
| Input Tag | Name: Enable  Type: BOOL  Description: Enable the servo |
| Input Tag | Name: UnityGain  Type: LREAL  Description: Unity gain frequency in Hz |
| Input Tag | Name: ClearInt  Type: BOOL  Description: 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: VCO  Description: Standard VCO |
| Enum Tag | Name: FDD  Description: 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: Unknown  Description: Unknown state of power supply |
| Enum Tag | Name: Off  Description: Power is off |
| Enum Tag | Name: On  Description: 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\_STRUCT  END\_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: Error  Type: ErrorStruct  Description: For error handler |
| Output Tag | Name: ReferenceMon  Type: LREAL  Description: Monitors the RF power at the reference input in dBm |
| Input Tag | Name: ReferenceNom  Type: LREAL  Description: Nominal value for the RF power at the reference input in dBm |
| Output Tag | Name: InputMon  Type: LREAL  Description: Monitors the RF power at the input in dBm |
| Input Tag | Name: InputNom  Type: LREAL  Description: Nominal value for the RF power at the input in dBm |
| Output Tag | Name: OutputMon  Type: LREAL  Description: Monitors the RF power after the output amplifier dBm |
| Input Tag | Name: OutputNom  Type: LREAL  Description: Nominal value for the RF power at the output amplifier in dBm |
| Output Tag | Name: ReferenceTemp  Type: LREAL  Description: Monitors the temperature of the reference RF detector in C |
| Output Tag | Name: InputTemp  Type: LREAL  Description: Monitors the temperature of the input RF detector in C |
| Output Tag | Name: OutputTemp  Type: LREAL  Description: Monitors the temperature of the output RF detector in C |
| Output Tag | Name: PowerOk  Type: BOOL  Description: 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\_STRUCT  END\_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: Error  Type: ErrorStruct  Description: For error handler |
| Output Tag | Name: OutputMon  Type: LREAL  Description: Monitors the RF power after the output amplifier dBm |
| Input Tag | Name: OutputNom  Type: LREAL  Description: Nominal value for the RF power at the output amplifier in dBm |
| Output Tag | Name: OutputTemp  Type: LREAL  Description: Monitors the temperature of the output RF detector in C |
| Output Tag | Name: Locked  Type: BOOL  Description: Indicates that the PLL is locked |
| Output Tag | Name: TuneMon  Type: LREAL  Description: Monitors the voltage of the OCXO control signal in V |
| Output Tag | Name: PowerOk  Type: BOOL  Description: Voltage monitor readback |

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| **Function Block**  FUNCTION\_BLOCK LowNoiseVcoFB  VAR\_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\_VAR  VAR\_OUTPUT  LowNoiseVcoOut: LowNoiseVcoOutStruct;  END\_VAR  VAR\_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: LowNoiseVcoType  Type: LowNoiseVcoTypeEnum  Description: Type of low noise VCO chassis  Default: VCO |
| Input argument | Name: Request  Type: SaveRestoreEnum  Description: Save restore command |
| Input argument | Name: LowNoiseVcoIn  Type: LowNoiseVcoInStruct  Description: Input hardware structure |
| Input argument | Name: Frequency  Type: LREAL  Description: Externally measured frequency of VCO  Default: 0 |
| Input argument | Name: FrequencyError  Type: BOOL  Description: Externally measured frequency is invalid  Default: TRUE (invalid) |
| Input argument | Name: ExtUpdateRate  Type: INT  Description: 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: FddStages  Type: INT  Description: Number of frequency difference dividers used. This is to normalize the gain of the frequency servo.  Default: 1 |
| Input argument | Name: VcoGain  Type: LREAL  Description: Vco gain in Hz/V. First stage only.  Default: 140E3 |
| Input argument | Name: VcoMin  Type: LREAL  Description: Minimum of VCO frequency range in Hz.  Default: 78.159E6 |
| Input argument | Name: VcoMax  Type: LREAL  Description: Maximum of VCO frequency range in Hz.  Default: 80.276E6 |
| Input argument | Name: UseSigmaDelta  Type: BOOL  Description: Use a sigma delta modulator for averaging the control signal  Default: TRUE |
| Input argument | Name: UseRelay  Type: BOOL  Description: True if VCO implements relay board  Default: FALSE |
| Input argument | Name: DefaultExcitation  Type: BOOL  Description: Default excitation is on (TRUE) or off (FALSE)  Default: FALSE |
| Output argument | Name: LowNoiseVcoOut  Type: LowNoiseVcoOutStruct  Description: Output hardware structure |
| In/out argument | Name: LowNoiseVcoInit  Type: LowNoiseVcoStruct  Description: Save/restore variables in persistent memory |
| In/out argument | Name: LowNoiseVco  Type: LowNoiseVcoStruct  Description: User Interface structure |

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| **Function Block**  FUNCTION\_BLOCK FrequencyDifferenceMixerFB  VAR\_INPUT  Request: SaveRestoreEnum;  FrequencyDifferenceMixerIn: LowNoiseVcoInStruct;  END\_VAR  VAR\_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: Request  Type: SaveRestoreEnum  Description: Save restore command |
| Input argument | Name: FrequencyDifferenceMixerIn  Type: LowNoiseVcoInStruct  Description: Input hardware structure |
| In/out argument | Name: FrequencyDifferenceMixerInit  Type: FrequencyDifferenceMixerStruct  Description: Save/restore variables in persistent memory |
| In/out argument | Name: FrequencyDifferenceMixer  Type: FrequencyDifferenceMixerStruct  Description: User Interface structure |

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| **Function Block**  FUNCTION\_BLOCK FixedRatioFrequencySourceFB  VAR\_INPUT  Request: SaveRestoreEnum;  FixedRatioFrequencySourceIn: FixedRatioFrequencySourceInStruct;  END\_VAR  VAR\_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: Request  Type: SaveRestoreEnum  Description: Save restore command |
| Input argument | Name: FixedRatioFrequencySourceIn  Type: LowNoiseVcoInStruct  Description: Input hardware structure |
| In/out argument | Name: FixedRatioFrequencySourceInit  Type: FixedRatioFrequencySourceStruct  Description: Save/restore variables in persistent memory |
| In/out argument | Name: FixedRatioFrequencySource  Type: FixedRatioFrequencySourceStruct  Description: 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: LowNoiseVCO  Type: LowNoiseVCOStruct  Description: Low Noise VCO structure |