User Manual

SLICE-OPL Offset Phase Lock Servo

Revision 04

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Contents

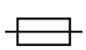
1 Introduction

This manual contains information for operating the Vescent SLICE-OPL Offset Phase Lock Servo. The SLICE-OPL is a high-performance, standalone instrument that provides the appropriate analog signal condition for stable feedback control. The SLICE-OPL is particularly suited for stabilizing the phase and frequency of many laser systems.

This section has information for safely operating the SLICE-OPL. Please carefully read this section before using the SLICE-OPL. Section 2 introduces the user to the instrument and defines all hardware connections. Section 3 discusses the graphical user interface (GUI) for the SLICE-OPL. Section 4 helps users immediately get started using the SLICE-OPL in their application by showing an example of typical setup and operation. Section 5 contains further detail about the operation of the SLICE-OPL. Section 6 covers remote operation of the SLICE-OPL. Troubleshooting help can be found in Section 7. For further information, including product specifications, additional resource links, and warranty information, see the appendices.

1.1 Symbol Definitions

The following symbols may be encountered in this manual or on the device.

Symbol	Description
	Caution: Follow instructions to avoid injury or damage to equipment
	Caution: Risk of electric shock
	Alternating Current
	Fuse
	The user manual should be referenced when operating this device
	WEEE: Separate collection for waste electric and electronic equipment is required
	Circle Indicator: Indicates relevant item in image
	Pointer Indicator: Points to relevant item in image

1.2 Safety

1. This instrument is intended for use by qualified personnel who recognize shock hazards and laser hazards and are familiar with safety precautions required to avoid possible injury. Read the instruction manual thoroughly before using to become familiar with the instrument's operations and capabilities.

2. If this instrument is used in a manner not specified by the manufacturer in this manual or other relevant literature, protection provided by the instrument may be impaired.

3. For indoor use only, within a (maximum) Pollution Degree 2, Overvoltage Category II, 30°C ($T_{amb,max}$), with the SLICE-OPL installed on a flat, level surface.

4. The SLICE-OPL is not intended for fail-safe operation in hazardous environments or life-threatening situations. The user assumes full responsibility for correct and safe usage of the SLICE-OPL in accordance with any applicable laws, codes, regulations, and standards pertaining to their specific application. Vescent is not liable for any consequential damage due to misapplication or failure of the SLICE-OPL.

5. Proper grounding must be ensured prior to energization of the SLICE-OPL.

6. To avoid electrical shock hazard, connect the instrument to an approved, TN-S configured, properly earth-grounded, three prong receptacle only. Failure to observe this precaution can result in severe injury or death.

7. Backup short-circuit protection is to be provided via the building branch circuit overcurrent protective device. The fuse within the SLICE-OPL is for overload protection only, but has been selected, and is only considered valid, as a high-interrupt capacity fuse (per IEC 60127).

8. Before replacing the fuse on the SLICE-OPL, turn off the power switch and disconnect the unit from mains power.

9. Except for the fuse, there are no field-serviceable parts inside the instrument. Maintenance on the SLICE-OPL is to be performed by trained personnel only, and with the power cord to the SLICE-OPL removed. Maintenance performed by non-Vescent personnel will void the warranty.

10. All additional Lockout/Tagout (LOTO) conditions (in addition to the above-mentioned removal of the input power cord), in accordance with all local codes and jurisdictional requirements, are also to be followed.

11. Any input/output connections to the SLICE instrument, other than the AC MAINS inlet, must be derived from a Safety Extra Low Voltage (SELV) source.

12. Do not obstruct the fan exhaust. Leave clearance around fan for proper ventilation.

13. Do not exceed the input power limitations listed in the SLICE-OPL specifications. Overpowering the input ports may damage the SLICE-OPL. Never provide a radio-frequency signal in excess of 10 dBm to the SLICE-OPL.

14. No flammable liquids are permitted to be used on the SLICE-OPL (for cleaning or maintenance).

15. The SLICE-OPL is intended to be recycled at the end of its lifecycle, per all local codes and jurisdictional requirements.

2 Hardware

This section discusses the hardware features and connections of the SLICE-OPL and the other items that are shipped with the unit.

2.1 Package Contents

The SLICE-OPL is shipped in a package designed to provide excellent protection. The shipping box should be saved for future transportation or storage needs.

Carefully remove and inspect the following items that are contained in the shipping box:

- SLICE-OPL Servo Controller
- AC Power Cord, region specific
- Final Test Documentation

2.2 Controls and Connections

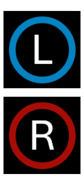
This section introduces all the hardware controls and connection ports on the SLICE-OPL.

2.2.1 Front Panel

1. Touchscreen

The primary way to interact with the SLICE-OPL is via its front panel touchscreen. General instructions for touchscreen control are discussed in Section 3.

2. Parameter Input Adjustment Knobs



Two rotary knobs allow the user to quickly cycle through parameter list settings and enter numeric inputs. In general, the right knob changes the current selection or the value of a digit, and the left knob changes the selected digit. Additionally, an L or R symbol (see left) on the touchscreen display indicates the matching knob control can be used. During ramp tuning the buttons can be pushed in to change the selected digit.

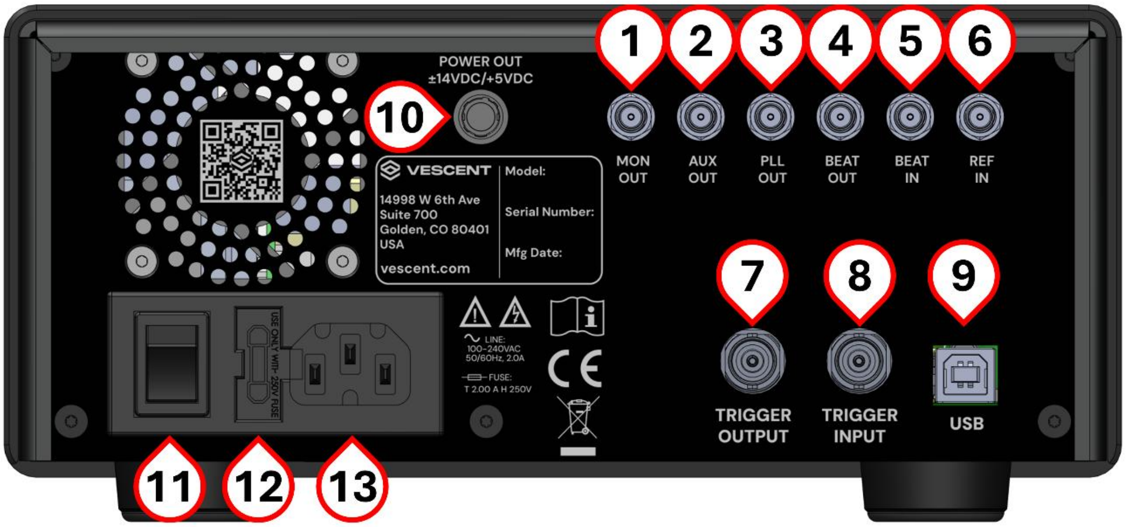
3. Selectable Input Ports (BNC)

Two BNC connectors on the front panel provide optional alternative functionality that is specific to the type of SLICE product. This functionality can be selected on the I/O Programming screen (see Section 3.3.2) and impedance is chosen on the System Settings screen (see Section 3.3.3). Both channels have an input voltage range of ±10 V and a selectable input impedance of 1 MΩ or 50 Ω.

4. Selectable Output Ports (BNC)

Two BNC connectors on the front panel provide signal monitor outputs that are selectable on the I/O programming screen (see Section 3.3.2). The output voltage range of these channels is ±10 V and the maximum current output is 30 mA.

2.2.2 Rear Panel



1. Monitor Output (SMA)

The monitor output port can be used to observe the DDS Reference Frequency, the DDS Output Frequency, the Phase Error, and the Divided Beat Signal. Change the output by going to *CH 1 Detail screen → Settings → Monitor Output*. Select the desired output from the drop-down menu.

2. AUX Servo Output (SMA)

The AUX Servo Output signal is generated by integrating the voltage difference between the PLL Servo Output and a value provided by the user. Its purpose is to keep the primary PLL Servo Output voltage centered in its operating range by controlling a slow drifting parameter such as plant temperature.

3. PLL Servo Output (SMA)

This is the primary output port. The PLL Servo Output provides a control voltage that can be used to change the frequency of the controlled plant. In the case of phase-locking a follower laser to a leader laser, this voltage will control the frequency output of the follower laser.

4. Beat Signal Output (SMA)

This monitor port provides a digitized version of the beat signal input.

5. Beat Signal Input (SMA)

This is the primary input port. An RF beat signal between 10 MHz and 9.8 GHz is provided to this port. In the case of phase-locking a leader and a follower laser, this will be the measured heterodyne beat signal between the two lasers.

The beat signal input power range is ±10 dBm.

6. Reference Frequency Input (SMA)

This port is used to supply an external frequency reference. An externally supplied frequency between 10 MHz and 300 MHz can either be supplied directly to the phase frequency discriminator (PFD) or be used as a clock reference for the onboard direct digital synthesizer (DDS).

The reference frequency input range is ±10 dBm.

7. Trigger Output (BNC)

The Trigger Output can be configured to show a square wave that is synchronous with the ramp signal. Set up the Trigger Output signal on the I/O programming screen. See Section 3.3.2.

8. Trigger Input (BNC)

The Trigger Input signal initiates an Integrator Hold. Configure the Trigger Input signal on the I/O programming screen. See Section 3.3.2.

9. Serial Port (USB-B)

Use a standard USB-A to USB-B cable to connect the SLICE-OPL to a computer for remote operation and updating firmware. For further information see Section 6.

10. Accessory Power Output (Hirose)

The Accessory Power Supply provides power to the D2-260 Beat Note Detector.

11. Power Switch

While the Power port is connected to mains power, toggle this switch from O to | to turn on the SLICE-OPL.

12. Fuse

The SLICE-OPL has a factory-installed fuse. To replace the fuse, follow the procedure below:

- Flip the SLICE-OPL Power switch off.
- Disconnect the SLICE-OPL from mains power.
- Remove the fuse cover.
- Replace the blown fuse with a high breaking capacity 5mm x 20mm fuse rated to 250 V and 2A.
- Replace the fuse cover.

13. Power Port

Use the provided AC power cord to connect this port to a properly grounded mains receptacle.

3 Graphical User Interface

This section discusses how the user interacts with the SLICE graphical user interface (GUI) and introduces the different types of buttons, windows, and screens a user will see on the touchscreen display.

3.1 Control Bar

On the left edge of the SLICE-OPL touchscreen is the Control Bar. The table below briefly explains the functionality of each Control Bar button.

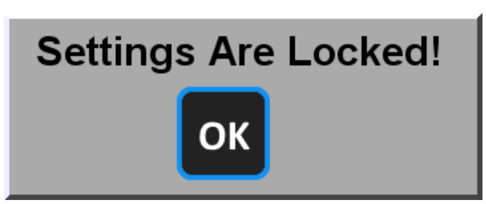
Symbol	Button Name	Function When Tapped
	Home	Returns to Home screen. Home is the screen which appears when the user powers up the unit. See Section 3.3.1.
	Back	Returns to previous screen.
	Parameter Lock	Toggles the Parameter Lock. The Parameter Lock prevents certain fields from being edited. See Section 3.1.1.
	Input/Output	Enters the I/O Programming screen. See Section 3.3.2.
	System Settings	Enters the System Settings screen. See Section 3.3.3.

3.1.1 Parameter Lock

The Parameter Lock is a toggle button that helps prevent accidental settings changes.

The symbol to the left indicates the Parameter Lock is in the unlocked state. In the unlocked state, it is possible to interact with any field bordered in blue. Tap the symbol to switch the Parameter Lock to the locked state.

The symbol to the left indicates the Parameter Lock is in the locked state. In the locked state, certain fields will be locked so they cannot be changed until the lock is released. Interacting with a locked button will open the following alert window:



Navigation buttons and many toggle buttons will still be operable in the locked state. Tap the symbol to switch the Parameter Lock to the unlocked state.

3.2 Button Types

The types of GUI buttons and their functionality are discussed here.

Tap a button to interact. It is possible to select the functionality or edit the values of a field bordered in blue. Some buttons have a second parameter edit mode that activates after touching and holding the button for a couple of seconds. Interacting with a button will cause the unit to beep.

3.2.1 Navigation Buttons

Navigation buttons change the screen shown on the display.

Tapping a Navigation button will take the GUI to the corresponding screen. Most Navigation buttons are in the Control bar (see Section 3.1) located on the left of all screens.

3.2.2 Toggle Buttons

Toggle buttons allow the user to switch a parameter between two states.

Tapping a toggle button will switch its state between two options or between a disabled and an enabled state.

For a toggle button which toggles between enabled and disabled states, the button background and text indicate the current state of the button. White text on a black background indicates the toggle is in the disabled state. Black text on a colored background indicates the toggle is in the enabled state.

3.2.3 Dropdown Menus

Dropdown menus allow the user to choose a parameter setting from a list of values.

Tapping a dropdown menu will reveal the list of available choices. The current selection will be bordered in white. Tapping one of the choices selects it and closes the dropdown menu. Tapping outside the dropdown menu closes the dropdown menu and retains the original choice.

3.2.4 Choice Selectors

Choice selectors allow the user to choose a parameter setting from a list of values with rotary knob editing mode.

Tapping a choice selector will change its button border from blue to yellow. Rotary knob editing mode is active while the border is yellow. Rotate the R-knob until the button shows the desired value. Tap anywhere on the display to disable rotary knob editing mode and change the button border back to blue.

If the rotary knob editing mode is active for 60 consecutive seconds without user input, then the unit will beep and rotary knob editing mode will deactivate. The border of the choice selector will turn red for a few seconds before returning to blue.

Touching and holding a choice selector will either reveal a dropdown menu (see Section 3.2.3) or a choice selection menu.

When a choice selection menu launches, the current selection will have black text and a white background. Tapping the current selection will deselect it. Selecting a new choice will deselect the current selection.

To exit the choice selection menu, tap its Back button.

3.2.5 *Numeric Fields*

Numeric fields allow the user to choose a custom numeric value for a given parameter.

Tapping a numeric field will change its border from blue to yellow. Rotary knob editing mode is active while the border is yellow. The underlined digit is the currently active digit. Rotating the L-knob changes the currently active digit. Rotating the R-knob changes the value of the currently active digit. Tap anywhere on the display to disable rotary knob editing mode and change the field border back to blue.

If the rotary knob editing mode is active for 60 consecutive seconds without user input, then the unit will beep and rotary knob editing mode will deactivate. The border of the button will turn red momentarily before returning to blue.

Touching and holding a numeric field launches the numeric keypad. The desired value can be typed into the numeric field by using the keypad. Tapping the Confirm key confirms the value and updates the parameter. When an invalid value is entered into a keypad, the value will be coerced to the nearest valid value. Keypad buttons are described in the table on the following page.

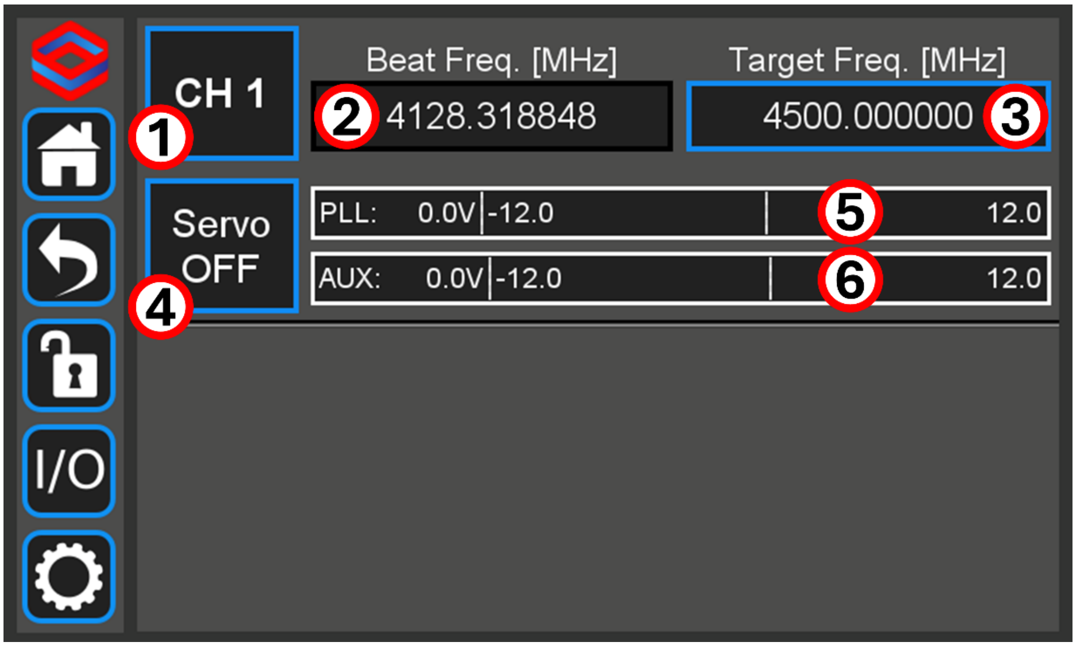
Numeric Keypad Buttons

Symbol	Button Name	Function When Tapped
	Plus/Minus	Changes sign of the value.
	Numeric	Inputs tapped number as the next digit.
	Decimal Point	Inputs decimal point as the next digit.
	Delete	Deletes last digit in the numeric field.
	Clear	Clears numeric field.
	Back	Exits keypad without accepting changes.
	Confirm	Accepts value in numeric field and exits keypad.

3.3 Screens

Each of the following sections introduces a screen encountered during operation of the SLICE-OPL and describes the function of the contained displays and controls.

3.3.1 Home Screen



After start-up the SLICE-OPL will display the Home screen. This view summarizes the current state of the SLICE-OPL.

1. CH 1: Navigates to the Channel 1 Detail screen. See Section 3.3.4.

2. Beat Freq. [MHz]: Shows the measured frequency on the beat signal input port. If the beat signal is too low or out of frequency range, the readout will change to '---'. If this occurs, make sure the Input Divider is properly selected (see Section 3.4.1).

3. Target Freq. [MHz]: When using the internal DDS for frequency reference, this numeric field sets the desired frequency for the beat signal. The SLICE-OPL applies a signal to the PLL servo output to drive Beat Freq. to this value.

When using an external frequency reference, this control will become a display that shows the measured frequency of the reference signal. In this mode, 'Ext' will also appear in the display.

4. Servo ON/OFF: Enables and disables feedback control. The text displays the current state. While ON, the button background will be one of three colors, each indicating the following:

Solid Green - The Phase Error voltage lies within the PLL Settings Lock Range.

Solid White - The Phase Error voltage is outside, but close to, the PLL Settings Lock Range. Try optimizing the Filter Settings to improve the lock.

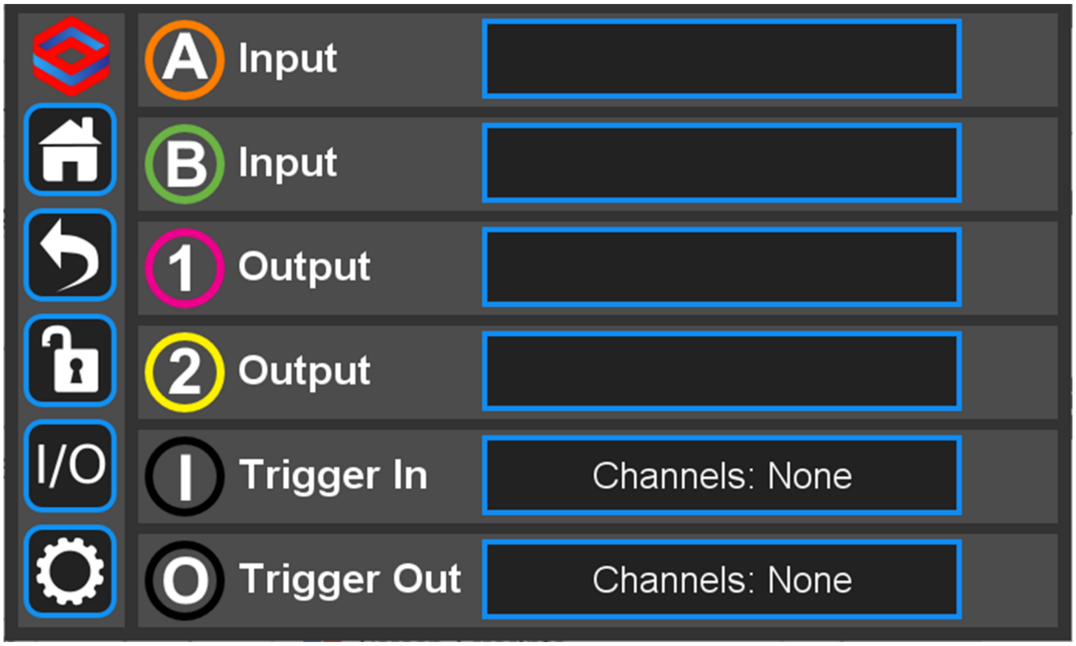
Flashing Red - The Phase Error voltage is far outside the PLL Settings Lock Range. Likely the PLL servo output signal is railed.

5. PLL voltage indicator bar: Shows the primary Phase Lock Loop output voltage numerically (left) and in bar format (right). The bar indicator has a vertical line marking the middle of the PLL servo range. The blue bar extends from that line to represent the present voltage. If the blue bar fills the left (right) side of the bar, then the PLL servo is at its lower (upper) voltage limit. The PLL voltage limits can be set in *CH 1 Detail screen → Settings*.

6. AUX voltage indicator bar: Shows the Auxiliary Output voltage numerically (left) and in bar format (right). The bar indicator has a vertical line marking the middle of the AUX servo range. The blue bar extends from that line to represent the present voltage. If the blue bar fills the left (right) side of the bar, then the AUX servo is at its lower (upper) voltage limit. The AUX voltage limits can be set in *CH 1 Detail screen → Settings*.

The AUX Voltage indicator will be greyed out when the AUX Servo is disabled.

3.3.2 I/O Programming Screen



The Input/Output (I/O) button navigates the user to I/O Programming screen. Each of the input, output, and trigger ports can be programmed to deliver or receive signals by tapping its blue-outlined control box and selecting an option from the menu. Selecting Off will disable the port. Other options for each port are as follows:

A Input: With PLL Modulation active, the voltage supplied to this port will be summed with the PLL servo output signal.

B Input: With Aux Modulation active, the voltage supplied to this port will be summed with the AUX servo output signal.

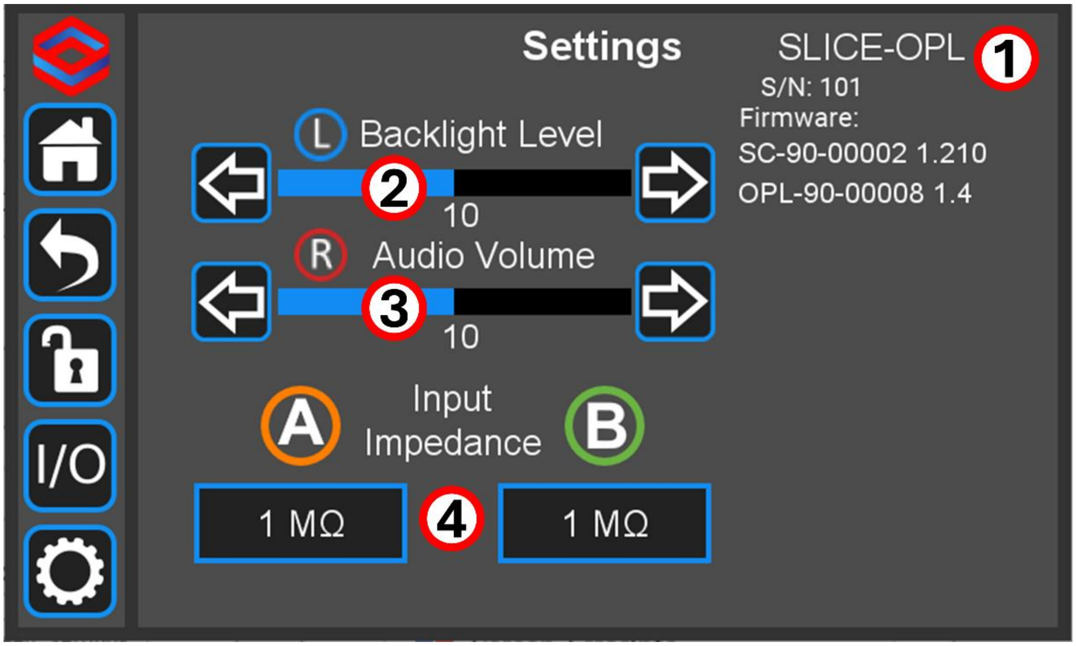
1 Output: Sweep Output allows the user to monitor the sweep signal.

2 Output: Select the desired output signal: PLL Servo Output, AUX Servo Output, or the Phase Error signal. Ground connects the output port to ground. It is recommended that users with sensitive equipment connected to this port use Ground rather than Off.

I Trigger In: While Integrator Hold is active, supplying a +5 V TTL signal will activate the Integrator Hold. Check the Inv. box to activate the integrator on an inverted TTL signal.

O Trigger Out: Check the Ramp Trigger Output box to deliver a trigger coincident with the ramp signal. The default is to output a positive trigger. Checking the Inv. box will change this to an inverted trigger signal.

3.3.3 System Settings Screen



The System Settings (gear) icon navigates the user to the System Settings screen. This screen displays information specific to the unit and has controls for general settings.

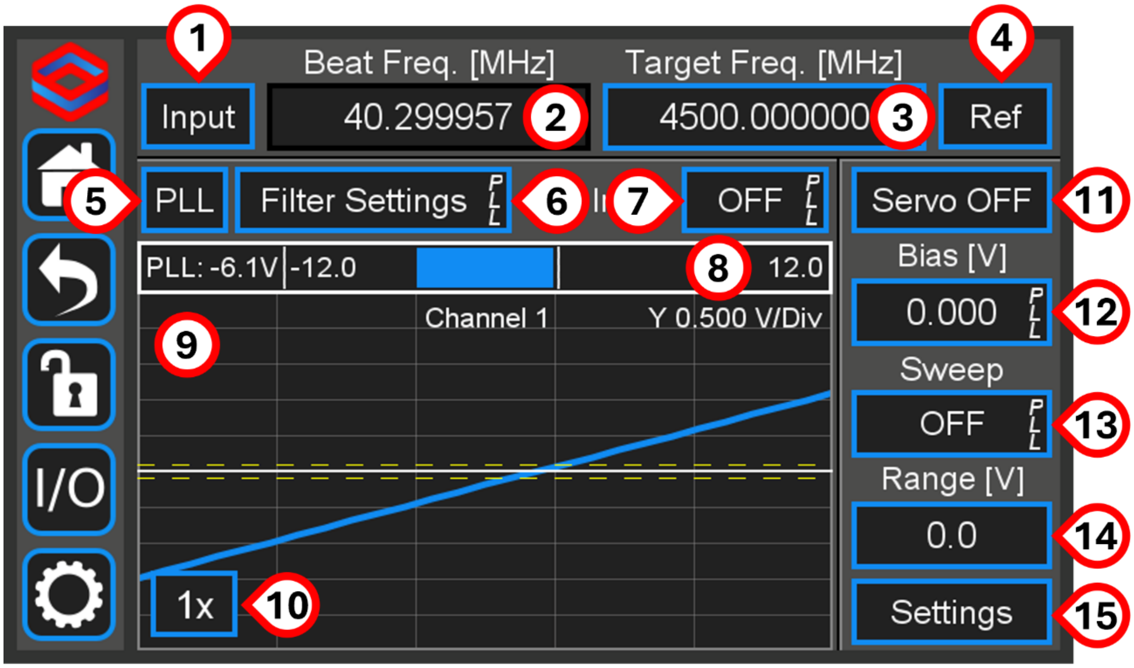
1. Unit Information: Includes the Serial Number (S/N) of the unit and the current SLICE (SC) and OPL firmware versions.

2. Backlight Level: The arrows adjust the backlight level of the touchscreen display. The Left knob also adjusts the backlight level.

3. Audio Volume: The arrows adjust the volume of the feedback beeps. The Right knob also adjusts the volume. To completely mute the unit, turn the volume all the way down.

4. Input Impedance: Sets the input impedance for the front panel input ports.

3.3.4 Channel Detail Screen



The Channel Detail screen has the controls for setting up a phase lock servo. Below is a summary of readouts and controls, as labeled above.

1. Input settings: Opens the Input Settings window. See Section 3.4.1.

2. Beat signal frequency indicator: Shows the measured frequency on the beat signal input port. If the beat signal is too low or out of frequency range, the readout will change to '---'. If this occurs, make sure the Input Divider is properly selected (see Section 3.4.1).

3. Target frequency control: When using the internal DDS for frequency reference, this numeric field sets the desired frequency for the beat signal. The SLICE-OPL applies a signal to the PLL servo output to drive Beat Freq. to this value.

When using an external frequency reference, this control will become a display that shows the measured frequency of the reference signal. In this mode, 'Ext' will also appear in the display.

4. Reference settings: Opens the Reference Settings window. See Section 3.4.2.

5. PLL/AUX toggle: Toggles GUI focus between PLL and AUX. Text on the following features will either display PLL or AUX to indicate the current focus. The current focus determines the target of the following controls: Filter Settings, Invert, and Bias. Additionally, the Voltage Indicator bar displays according to the current focus.

6. Filter settings: Opens the PLL or AUX Settings window. The opened window depends on the state of the PLL/AUX toggle. See Section 3.4.3 and Section 3.4.4.

7. Invert toggle: Flips the sign of the error signal so the servo will drive the plant voltage in the correct direction for locking.

8. PLL/AUX voltage indicator bar: Shows the output voltage numerically (left) and in bar format (right) for the indicated servo. The bar indicator has a vertical line marking the middle of the servo range. The blue bar extends from that line to represent the present voltage. If the blue bar fills the left (right) side of the bar, then the servo is at its lower (upper) voltage limit. The PLL and AUX voltage limits can be set in *CH 1 Detail screen → Settings*. To change the displayed indicator bar, tap the PLL/AUX toggle.

9. Phase error graph: Shows a rolling update plot of the Phase Error voltage as a blue line. In Sweep mode this becomes a sweeping oscilloscope style graph of the error signal, like shown in Section 4.3. The solid white horizontal line at center is 0 V, representing no phase error between the Beat Freq. and the Target Freq. The dotted yellow lines are the Lock Range as set in the PLL Settings window.

10. Phase error graph zoom: Toggles the graph zoom (1x/8x).

11. Servo enable: Enables and disables feedback control. The text displays the current state. While ON, the button background will be one of three colors, each indicating the following:

Solid Green - The Phase Error voltage lies within the PLL Settings Lock Range.

Solid White - The Phase Error voltage is outside, but close to, the PLL Settings Lock Range. Try optimizing the Filter Settings to improve the lock.

Flashing Red - The Phase Error voltage is far outside the PLL Settings Lock Range. Likely the PLL servo output signal is railed.

12. Bias voltage control: Sets the voltage offset for the indicated servo output. Tune to place the Beat Freq. near the Target Freq.

13. Sweep mode control: Engages or disengages the sweep function. Engaging the sweep will ramp the voltage of the indicated output to help the user find the zero-crossing point of the phase error. To switch between ramping the PLL Servo and the AUX Servo go to *CH 1 Detail screen → Settings* and toggle the Sweep Channel button.

The default sweep is a 45 Hz triangle wave. While a ramp is active, the Phase Error graph will trigger on the ramp and show the output during the rising portion of the wave. The sweep rate can be changed by external computer control via the USB interface (see Section 6).

The sweep function has four operational modes:

OFF - The sweep is off. The Phase Error Graph returns to a time-voltage graph.

ON - The sweep is on. The ramp bias and range can be edited normally.

Tune - The sweep is on. Knob control is enabled for the ramp bias and range. Rotate the knob to increase or decrease the underlined digit. Press the knob in to change the selected digit.

Tap Lock - The sweep is on. Knob control is enabled as above. Tapping the screen adjusts the Bias voltage to the voltage at the horizontal position of the tap and turns the servo on. If the servo loop successfully locks, then the servo will stay on. If not, then the servo will automatically disengage and the SLICE-OPL will return to Tap Lock mode.

14. Range adjust control: Sets the voltage range for the sweep.

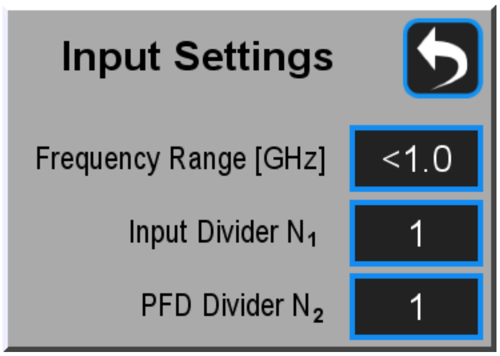
15. Settings: Opens the Channel Settings window. See Section 3.4.5.

3.4 Settings Windows

Several of the controls on the Channel Detail screen open additional settings windows. Those windows and their controls are described here.

For a visual representation of the relationship between these settings, see the OPL Signal Architecture diagram in Section 5.

3.4.1 *Input Settings Window*

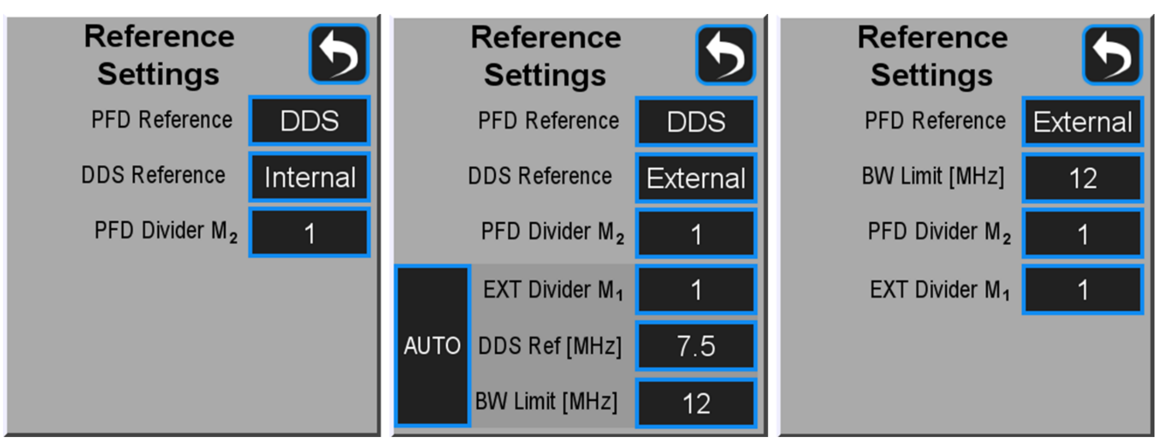


Frequency Range [GHz]: Routes the input beat signal to signal conditioning circuitry according to frequency. Three signal ranges are available: Low Range (< 1 GHz), Mid Range (< 3 GHz), and High Range (< 10 GHz). Best performance is usually achieved by choosing the smallest suitable range for the application.

Input Divider N_1: Selects the value of the input signal pre-scaler that divides the input beat signal frequency (f_{IN}). A pre-scaler value should be chosen so that f_{IN}/N_1 is less than 175 MHz.

PFD Divider N_2: Divides the input signal again before the phase frequency discriminator. Provides for fine tuning of the overall input frequency division.

3.4.2 *Reference Settings Window*



The layout of the Reference Settings window will change depending on the PFD Reference and DDS Reference Settings. The three possible layouts are shown above.

PFD Reference: The phase frequency discriminator can have a reference frequency derived from either the onboard direct digital synthesizer (DDS) or an external frequency signal supplied on the Ref. In port.

DDS Reference: The DDS either references an internal temperature-compensated crystal oscillator (TCXO) clock or an external clock signal provided on the Ref. In port.

PFD Divider M_2: Divides the frequency of the reference signal before the phase frequency discriminator.

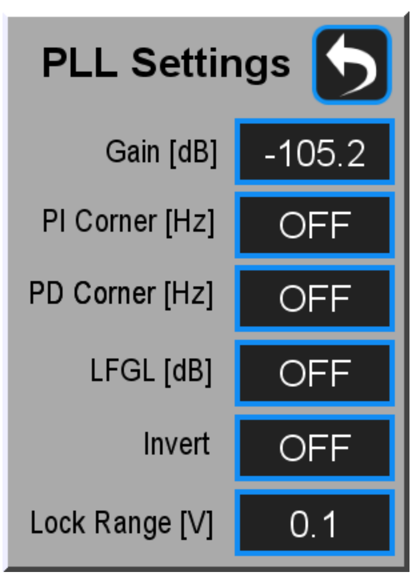
EXT Divider M_1: Pre-scaler divider value for the external reference frequency (f_{EXT}). A pre-scaler value should be chosen so that f_{EXT}/M_1 is less than 175 MHz.

DDS Ref [MHz]: Reference frequency for the DDS. Valid values are 7.5, 8, 10, 12, or 12.5 MHz. The value f_{EXT}/M_1 should be chosen to be near one of the valid values.

BW Limit [MHz]: Low-pass filter bandwidth for the external reference signal. Filters high frequency noise. Valid values are 12, 40, 125, and 300 MHz.

AUTO: Tap once to let the SLICE-OPL automatically determine the values for EXT Divider, DDS Ref, and BW Limit based on the detected reference frequency.

3.4.3 PLL Settings Window



The PLL Settings window allows the user to tune the parameters of the PID loop filter. For more information about the loop filter transfer function, see Section 5.3.

Gain [dB]: Sets the proportional gain (K_P). Changing the gain does not alter the corner frequencies of the loop filter.

PI Corner [Hz]: Sets the proportional-integral corner frequency (f_{PI}). OFF disables the integrator.

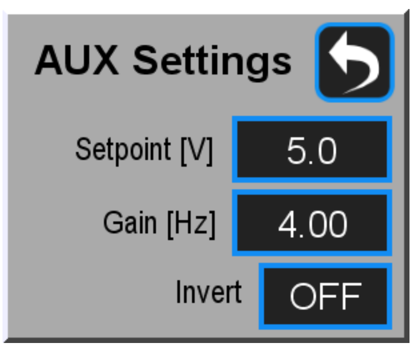
PD Corner [Hz]: Sets the proportional-derivative corner frequency (f_{PD}). OFF disables the derivative component.

LFGL [dB]: Enables and disables the Low Frequency Gain Limit. ON clamps the integral gain to 20 dB above the proportional gain.

Invert: Inverts the sign of the phase error signal.

Lock Range [V]: Sets range of error voltages for which the system will be considered locked. Shown as a yellow dotted line on the Phase Error graph.

3.4.4 AUX Settings Window



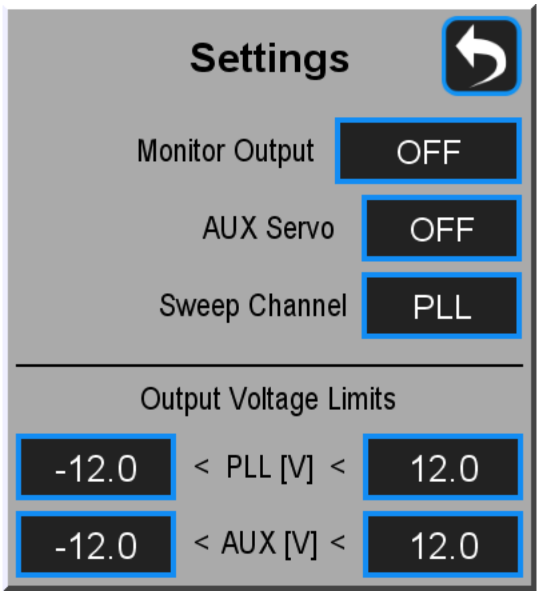
The auxiliary (AUX) output is the integrated difference between the primary PLL servo output voltage and a user-chosen setpoint voltage.

Setpoint [V]: Target setpoint voltage for the AUX servo. When enabled, the AUX servo will drive the plant's secondary transducer to keep the primary PLL output voltage at this setpoint voltage.

Gain [Hz]: Integral gain for the AUX servo.

Invert: Inverts the AUX error signal.

3.4.5 Channel Settings Window



Monitor Output: Chooses the signal to be output from the rear panel monitor port. The available options are PFD Error signal, Divided BN, DDS Ref Frequency, and DDS Output.

AUX Servo: Engages or disengages the auxiliary loop.

Sweep Channel: Toggles the sweep between ramping either the PLL or AUX outputs.

PLL Output Voltage Limits [V]: Sets the voltage limits for the PLL servo. These limits will be displayed on the PLL Voltage Indicator bar.

AUX Output Voltage Limits [V]: Sets the voltage limits for the AUX servo. These limits will be displayed on the AUX Voltage Indicator bar.

4 Getting Started

This section explains typical use of the SLICE-OPL Offset Phase Lock Servo for new users. A brief theory of operation is followed by an example typical setup and operation for offset phase locking two lasers. Keep in mind that the following are general guidelines for operating the SLICE-OPL. Exact settings will vary for your application and hardware.

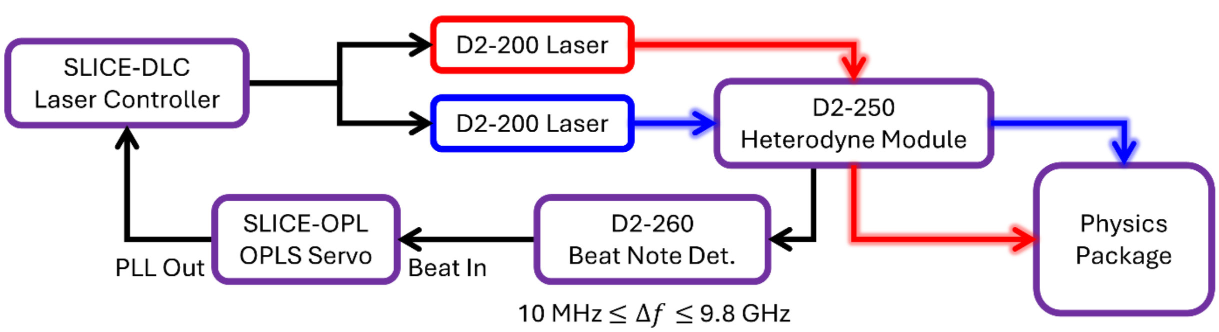
4.1 Theory of Operation

The SLICE-OPL is a complete system designed to receive an input frequency from a plant and to provide a control voltage that will drive the plant signal toward a target frequency. The enabling technology at the core of the SLICE-OPL is a phase frequency discriminator (PFD) that takes the input frequency and a reference signal and outputs a voltage that is proportional to the phase difference between them. When this voltage is zero, the signal is not only frequency commensurate with, but also phase locked to, the reference signal.

The SLICE-OPL is highly versatile, having additional features to condition the input signal, generate a reference signal, and optimize loop filter parameters. Furthermore, the software can automatically calculate optimal settings for the onboard DDS and frequency dividers, reducing the time required to quickly implement an offset phase lock feedback loop.

4.2 Typical Setup: Offset Phase Locking

A typical use of the SLICE-OPL is to phase lock two lasers to have a programmed frequency tuning between them. The SLICE-OPL takes a heterodyne beat signal from the two lasers, conditions it, and then phase locks the beat signal to a reference frequency, as shown in the figure below.



In this example, a SLICE-DLC laser controller operates two D2-200 laser modules. The leader laser (red) is combined with the follower laser (blue) in a D2-250 heterodyne module and fed to a D2-260 high-speed beat-note detector. The electronic beat signal is provided to the Beat In port on the SLICE-OPL. The SLICE-OPL PLL Out port is connected to the follower's Servo In port on the SLICE-DLC, completing the loop.

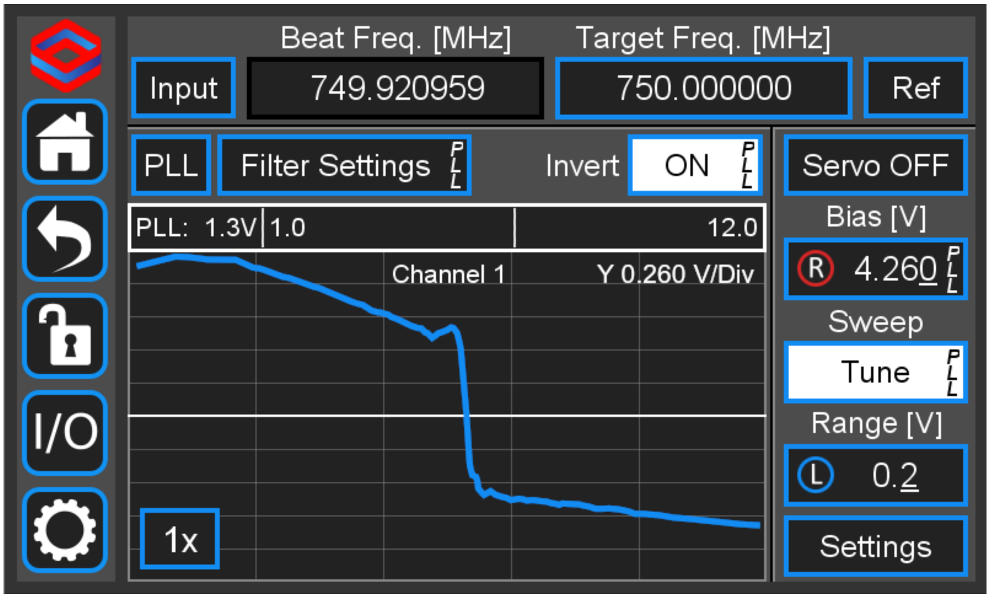
NOTE: The above configuration fixes the frequency difference between the two lasers, but it does not dictate the absolute frequency of either laser. For absolute frequency locking, first lock the leader laser to a spectroscopy module (e.g. D2-210) before combining the beams.

4.3 Typical Operation: Offset Phase Lock

To perform an offset phase lock, follow these instructions:

- Open the CH 1 Detail screen.
- Tap the Settings button to open the Channel Settings window.
    - To prevent damage, set appropriate PLL Output Voltage Limits for your equipment.
    - Toggle the Sweep Channel to PLL.
    - Tap the Back button to return to the CH 1 Detail window.
- Tap the Ref button to open the Reference Settings window.
    - Set the PFD Reference to DDS.
    - Set the DDS reference to Internal.
    - Tap the Back button to return to the CH 1 Detail window.
- Tap the Target Freq. button to set the target frequency.
    - Setting the target frequency will automatically update the Input Frequency Range; dividers N1, N2, and M2; and the DDS frequency to optimal values.
- Set the PLL/AUX toggle to PLL.

- Tap the Sweep button and select Tune.



  - Tune the Bias and Range so the blue error line crosses zero on the Phase Error graph, as demonstrated above.
    - Start with a large Range and search for the crossing by tuning Bias.
    - Once the crossing has been located, repeatedly decrease Range and use Bias to center the crossing on the graph.
    - The crossing left to right should go from high to low. If the signal is low to high, tap the Invert button to flip the error signal.
  - When done, tap the Sweep button and select OFF.
- Toggle the Servo Enable button to Servo ON.

If the Servo ON button turns permanently green, then the system has successfully locked the beat signal to the target frequency. More likely, the error signal will not lock or may oscillate. In all cases, the lock can be improved by tuning the settings in the PLL Settings window (tap the Filter Settings button). When tuning PID settings, an understanding of PID control theory is useful. For more details about tuning PID settings, see Section 5.3.

5 Detailed Operations

This section provides additional detail about the operation of the SLICE-OPL.

5.1 Signal Architecture

The block diagram schematic on the following page shows the signal architecture for the SLICE-OPL. The operation of the SLICE-OPL can be broken down into four primary functions: signal conditioning, reference generation, phase detection, and loop filtering.

Beat signal conditioning prepares the input beat signal (Beat In) for phase detection. The primary function of this subsystem is to condition the input beat signal to have a frequency that is compatible with the downstream phase/frequency detector. The input signal (f_{IN}) is frequency divided and filtered by circuitry that is optimized for a given bandwidth range. The divided frequency (f_{IN}/N_1) is then passed to a phase-frequency discriminator (PFD).

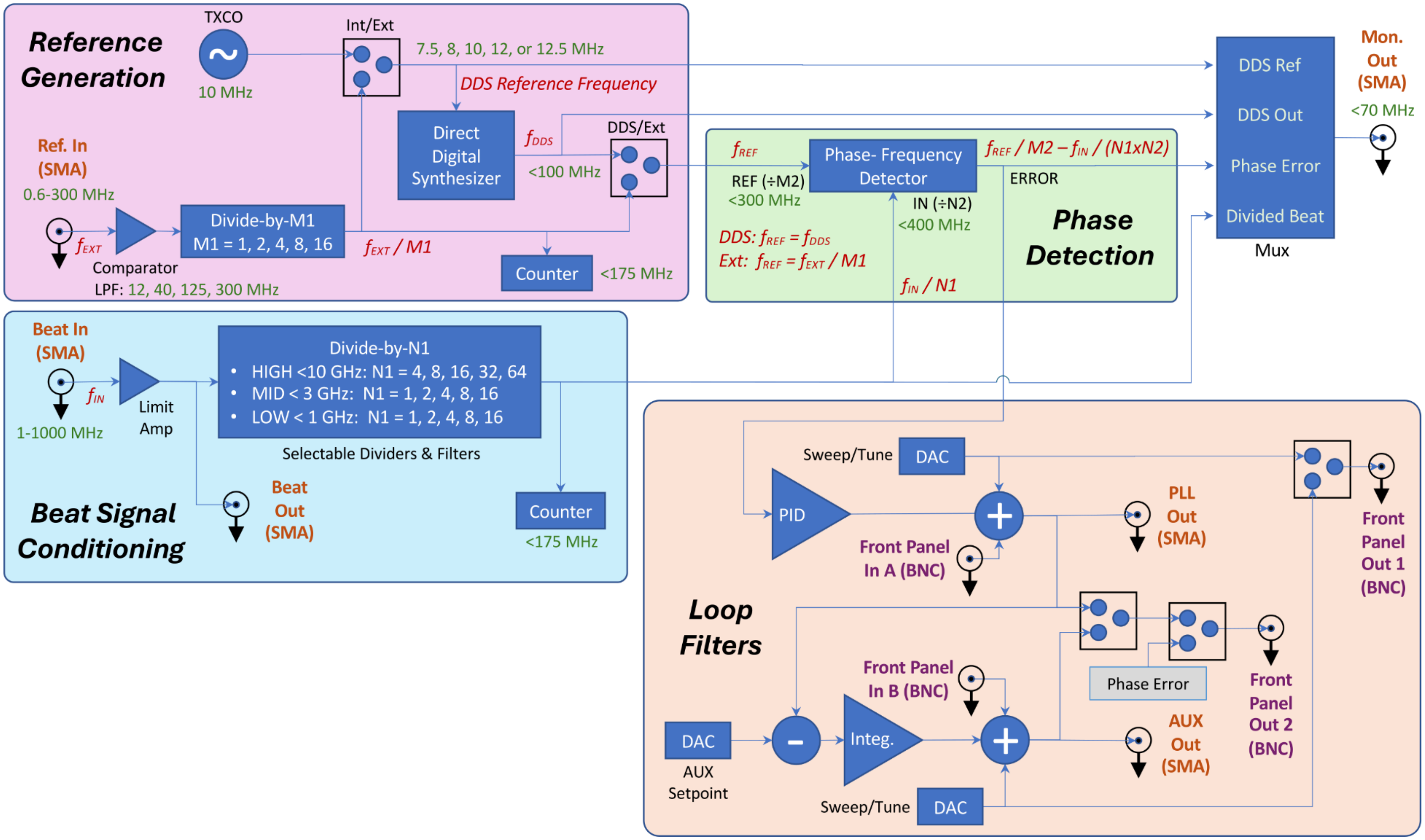
Reference generation prepares a reference signal for phase detection. The reference signal originates from one of two sources: the onboard direct digital synthesizer (DDS) or an external frequency source. The frequency reference passed to the PFD (f_{REF}) is either the direct output frequency of the DDS (f_{DDS}) or the external reference after frequency division has been applied (f_{EXT}/M_1).

Phase detection compares the divided beat signal to the reference signal and generates an output that is proportional to the phase difference between them. Prior to the phase comparison, there is an extra step of frequency division for both signals. When using the internal DDS, the SLICE-OPL helps the user by calculating ideal values for these dividers when the target frequency is set. The output of the phase detection subsystem is a phase error signal

The loop filter subsystem conditions the phase error signal to create an output control signal (PLL Out) that will drive a frequency transducer (typically of a laser). The loop filter transfer function (see Section 5.3) is optimized to stably drive the phase error to zero. This subsystem also provides capability for sweeping and externally modulating the frequency transducer. The SLICE-OPL also includes an auxiliary servo (AUX Out) that can provide slow feedback to a second frequency transducer (see Section 5.4).

5.2 Divider Determination

For a given target frequency, there are several valid ways to set up the DDS and configure dividers such that the PFD will generate a suitable output. If using the onboard DDS for reference frequency generation, when a Target Frequency is chosen by the user, the SLICE-OPL helps users by calculating an optimal set of reference parameters — that is, a set which can achieve the requested frequency while minimizing total division for each signal



SLICE-OPL Signal Architecture

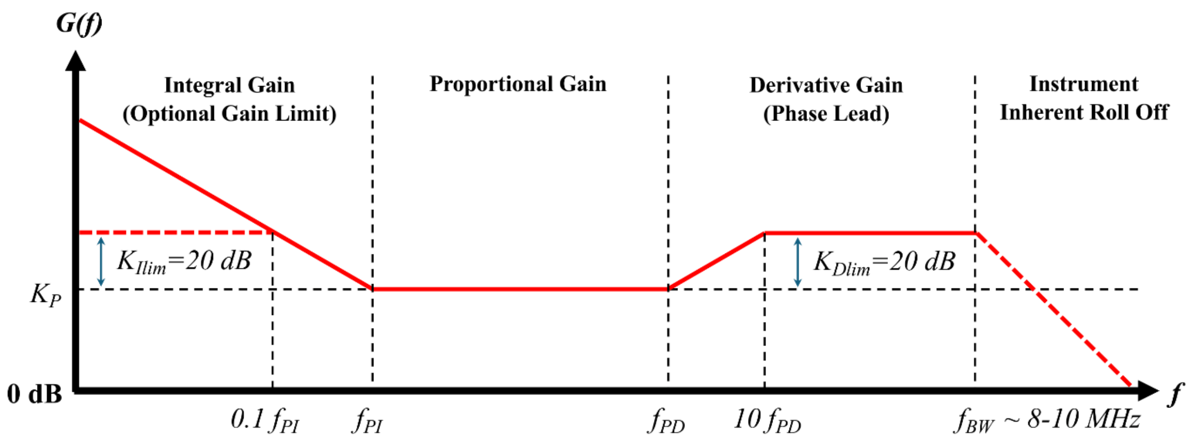
and ensuring all frequencies are within hardware limitations. After updating the target frequency, the SLICE-OPL will calculate and update values for the input frequency range; DDS frequency; and dividers N1, N2, and M2.

The SLICE-OPL assumes the beat frequency is close to the target frequency. If the two values are quite different, the Beat Freq. display may show an inaccurate value after the parameters update. To solve this, coarsely tune the plant so the input frequency is within several percent of the target frequency.

Alternatively, the PFD reference signal may be derived from an externally supplied reference signal. In this case, the signal dividers must be configured manually. Refer to the signal architecture schematic when calculating parameter values. In general, it is desirable to minimize the total division of each frequency signal. Keep in mind that the effective target frequency, f_{EFF}, will be:

$$f_{EFF} = f_{EXT} * \frac{N_1 N_2}{M_1 M_2}$$

5.3 Filter Transfer Function



The SLICE-OPL loop filter is a proportional-integral-derivative (PID) filter. The performance of the filter is represented by the transfer function shown above. The filter parameters are defined below. Filter parameters that the user can tune or enable in the PLL Settings window (see Section 3.4.3) are marked with an *asterisk.

K_P: Proportional gain. Changing the gain does not alter the corner frequencies of the filter.

f_{PI}: Proportional-integral corner frequency. This is the frequency beyond which proportional gain dominates over integral gain. Turning this corner frequency OFF removes the integral filter, leaving only proportional gain at low frequencies.

K_{Ilim}: Integral Low Frequency Gain Limit (LFGL). When the LFGL is turned on, the integral gain will be limited to 20 dB relative to proportional gain. By design the gain limit will be clamped for frequencies below $f_{PI}/10$.

f_{PD}: Proportional-derivative (phase lead) corner frequency. This is the frequency beyond which derivative gain dominates over proportional gain. By design, the derivative gain is clamped at 20 dB (K_{Dlim}) above the proportional gain. Turning this corner frequency OFF removes the derivative filter, leaving only proportional gain in this region.

K_{Dlim}: Derivative gain limit. This compensation is designed into the derivative filter and limits the derivative gain to 20 dB relative to proportional gain. The derivative gain limit will affect the gain profile at frequencies above 10 f_{PD}.

f_{BW}: The inherent electronics roll-off of the open-loop gain occurs around 8-10 MHz, depending on the exact loop filter settings. Filter performance beyond this bandwidth limit is not guaranteed.

A basic understanding of feedback control theory will greatly aid in optimizing the PID loop filter parameters. Users who are inexperienced with PID tuning may wish to try the following simple procedure.

Start by turning off the integral and derivative gain sections (select the f_{PI} and f_{PD} corner frequencies to be OFF). Then turn on the servo and slowly turn up the proportional gain. As the gain is increased, the phase error voltage should drive toward zero. If this does not occur, try inverting the signal. Raise the gain until oscillations are observed, and then reduce the gain by around 20 dB. Next, turn up the f_{PI} corner frequency, so the filter can correct for accumulated error. Tighter phase locking may occur by enabling derivative (phase lead) gain and optimizing the f_{PD} corner frequency.

5.4 Auxiliary Servo

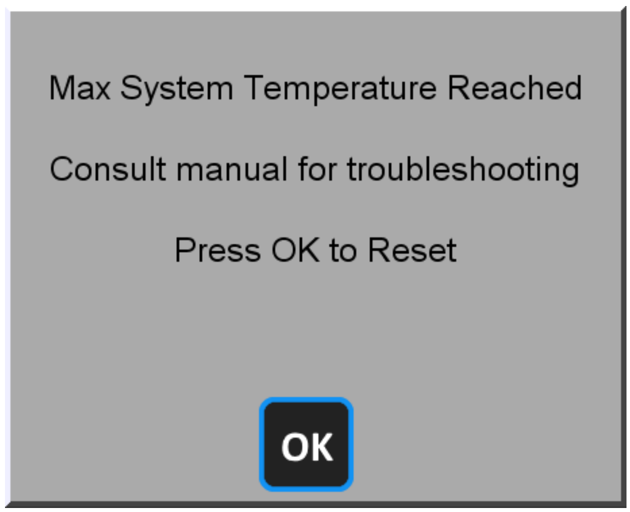
The purpose of the auxiliary feedback controller is to maintain a (near) constant output voltage of the primary PLL loop by controlling a slower secondary frequency transducer that has a larger dynamic tuning range than the primary transducer. In the case of a laser, this may be the laser temperature or the voltage on a piezoelectric transducer. Using the auxiliary servo is particularly useful in maintaining phase locks over extended periods of time by keeping the primary PLL transducer in its operating range.

When setting up an auxiliary servo, first go to the Channel Settings window and set the AUX voltage output limits for your auxiliary hardware. Once the voltage limits are set, toggle AUX Servo on in the same window.

To access other auxiliary servo settings, toggle the PLL/AUX button to AUX. The displays with relevant information will have 'AUX' labels. The Filter Settings button now opens the AUX Settings window (Section 3.4.4) where the user can set the auxiliary setpoint and integral gain for this secondary feedback loop.

5.5 Errors

The SLICE-OPL will display an error window if the Maximum System Temperature is reached. Any enabled servo channels will be disabled, and a warning message will display on the touchscreen. The warning will read:



Ensure the SLICE-OPL is properly ventilated, the fan is operating, and the ambient temperature is below 30°C. If applicable, remove the SLICE-OPL from an extreme temperature environment.

6 Remote Operation

This section describes how to set up a remote connection for the SLICE-OPL.

6.1 Setting up a Remote Connection

Start by connecting the SLICE-OPL to a computer with a USB-A to USB-B cable. Plug the USB-B connector into the USB port on the SLICE-OPL and the USB-A connector to a free port on the computer.

In Windows systems, the SLICE-OPL will appear as a COM Port. In UNIX-like systems (Linux, MacOS), it will appear as a serial port in the /dev/ folder.

Using a serial terminal application, such as Tera Term or Putty, connect to the SLICE-OPL with the following parameters:

- Speed: 115200
- Data Length: 8-bit
- Parity: None
- Stop Bits: 1
- New Line Receive: AUTO
- New Line Transmit: CR

Test your connection by sending a command, such as "***IDN?"**

You should see a response like: **Vescent,SLICE-OPL,000026,S-V1.242,OPL-V1.27**

You are now ready to control the SLICE-OPL via serial API commands. For a complete list of commands, see the SLICE-OPL Serial API Guide.

7 Troubleshooting

The following table describes typical issues that may be encountered while using the SLICE-OPL and recommended actions to solve the problems.

Problem	Recommended Actions
Numeric field does not increase when right rotary knob is turned clockwise -or- Numeric field does not decrease when right rotary knob is turned counterclockwise.	Value likely exceeds a software or user-defined limit. For user-defined limits, adjust the limit to increase the parameter range.
Beat Freq display does not accurately read the input frequency (f_{IN}).	Check the Input Settings window. First, set the Frequency Range to an appropriate value for the input signal. Then choose the minimum value for Input Divider N_1 so that f_{IN}/N_1 is less than the frequency limit of the Beat Freq. counter, 175 MHz.
Frequency measurement of external reference frequency is not accurate.	Check the Reference settings window. First, make sure PFD Reference is set to External. Then choose the minimum value for EXT Divider M_1 so that f_{EXT}/M_1 is less than the frequency limit of the external frequency counter, 175 MHz.
Cannot find error crossing when applying a PLL sweep.	Check that the PLL Output Voltage Limits (Section 3.4.5) are set wide enough so the plant can reach the target frequency.

A Specifications

A.1 General

Parameter	Value	Units
Number of Channels	1	
Input/Output Impedance	50	Ω
Output Voltage Range	±10	V
Front Panel Input Voltage Limit	±10	V

A.2 Beat Signal

Parameter	Value	Units
Min. Beat Signal Power	-10	dBm
Max. Beat Signal Power	10	dBm
Min. Offset Frequency	10	MHz
Max. Offset Frequency	9.5	GHz

A.3 Reference Frequency

Parameter	Value	Units
Min. Reference Power	-10	dBm
Max. Reference Power	10	dBm
Min. Reference Frequency	10	MHz
Max. Reference frequency	300	MHz

A.4 Loop Filter

Parameter	Value	Units
Loop Filter Transfer Function	Proportional-Integral-Derivative	
Proportional Gain	100+ dB dynamic range	
PI Corner Values	50, 100, 200, 500, 1k, 2k, 5k, 10k, 20k, 50k, 100k, 200k, 500k, 1M, 2M, 5M	Hz
PD Corner Values	150, 300, 600, 1.5k, 3k, 6k, 15k, 30k, 60k, 150k, 300k, 600k, 1.5M, 3M, 6M	Hz
Open-Loop Bandwidth	>8	MHz

A.5 Input Voltage

Parameter	Value	Units
Overvoltage Category	2	
Input Line Voltage	100 - 240	VAC
Mains Supply Voltage Fluctuations	±10	%
Frequency	50 - 60	Hz
Phase	1 phase	
Maximum Input Current	2	A
User-Serviceable Fuse	HBC 2.0 A 250 V	

A.6 Environmental

Parameter	Min. Value	Max. Value	Units	Comments
Indoor or Outdoor Use	Indoor Use Only			Dry Location Only
Pollution Degree of Environment		2		
Operating Altitude		10000 (3048)	ft (m)	
Operating Temperature	15	30	°C	
Operating Relative Humidity	20	60	%	Non-condensing
Dew Point		15	°C	

B Additional Resources

QR Code	Details
	Vescent Home vescent.com Additional resources are available at vescent.com

C Service & Maintenance

The SLICE-OPL is designed to be maintenance free. No user-serviceable parts are inside the unit. No further calibrations are necessary for the SLICE-OPL to meet its accuracy specifications over the lifetime of the product. Opening the instrument case voids the warranty and exposes the user to hazardous voltages that are present inside the instrument case.

Cleaning instructions: Do *not* clean outside surfaces of any Vescent products with solvents such as acetone. Front panels on electronics modules may be cleaned with a mild soap and water solution.

For service or repairs:

1. Contact Vescent customer service via telephone at (+1) 303-296-6766, online at vescent.com/support, or via email at info@vescent.com. Customer service will determine if the equipment requires service, repair, calibration, or replacement. Factory office hours are 9:00 am-5:00 pm MST.

2. If the unit must be returned to Vescent, ask for a Return Merchandise Authorization (RMA) from customer service. **Never send any unit back to Vescent without a completed Return Merchandise Authorization (RMA).**

3. Pack the unit in its original shipping material (if possible) with at least 1 inch of compressible packing material on all sides. Be sure to include an ownership tag and enter a description on the RMA form fully detailing the defect and the conditions under which it was observed.

4. Return the unit, postage prepaid, to Vescent. Do not forget to return a hard copy of the completed RMA form with the unit and write the RMA number on the shipping label. Vescent will refuse and return any package that does not bear an RMA.

5. After repair, the equipment will be returned with a repair report. If the equipment is out of warranty but operates within specifications, a test set-up fee will be charged to the customer. If the equipment is not under warranty, the customer will be invoiced for the cost appearing on the repair report.

6. Vescent is responsible for shipping the unit back to the customer if the unit is under warranty. **Shipping damage is not covered by this warranty,** and shipping insurance, which Vescent recommends, is at the customer's expense.

D Warranty

Vescent hereby warrants to Buyer, that during the applicable Warranty Period (as defined below) the Products will conform to Vescent's published specifications and will be free of defects in materials or workmanship when used, installed and maintained in accordance with Vescent's published specifications. Vescent's sole liability and Buyer's sole and exclusive remedy for breach of warranty shall be limited to, at Vescent's option, either repairing or replacing the defective components of the Product or crediting Buyer for the amount Buyer has paid to Vescent for the applicable Product. Vescent's liability shall apply only to Products which are returned to the factory or authorized repair point, with shipping charges prepaid by Buyer, and which are, after examination, determined to Vescent's satisfaction to be defective due to defects in materials or workmanship. Vescent will only accept returns authorized by a Vescent customer service representative and with a valid RMA number. This warranty does not apply to Products which are designated by Vescent as "Pre-Production Products", e.g. Alpha, Beta or Prototypes or are Products which have been repaired or modified without Vescent's written approval, or subjected to unusual physical, thermal, optical or electrical stress, improper installation or cleaning, misuse, abuse, accident or negligence in use, storage, transportation or handling. The "Warranty Period" during which this warranty applies varies with Product type as follows:

a. For standard Vescent lasers in which a counter is incorporated (i.e. lasers with counters for which Vescent has published a datasheet and which have not been obsoleted by the time of order placement): one (1) year after the date of original shipment or 3,000 hours of use, whichever occurs first;

b. For standard Vescent products other than lasers with counters, (i.e. products for which Vescent has published a datasheet and which have not been obsoleted by the time of order placement): one (1) year after the original shipment;

c. For any other Product including, without limitation, all product types as set forth in sections a. and b. of this clause 5 which are in any way customized, build-to-order, otherwise non-standard and/or are subject of a blanket purchase order: one (1) year after the date of original shipment unless otherwise agreed to in writing on a case by case basis. If, in relation to any Product Vescent offers as an additional purchase option, a warranty period over and above that which is set out in sections b. and c. of this clause 5 ("Extended Warranty") and Buyer exercises such option then the Warranty Period shall be the duration as specified on such Extended Warranty commencing on the date of original shipment. Any Extended Warranty option is only available at the time of and on the same order as the original Product purchase.

d. For any non-warranty Product that has been repaired, Vescent will extend the applicable Warranty Period by sixty (60) calendar days for the specific characteristic of the Product that is repaired by Vescent. Other characteristics of the non-warranty Product will remain uncovered by any warranty.

e. For Products that are discontinued, Vescent's liability shall terminate at the end of the applicable Warranty Period or one (1) year from the date of discontinuity, whichever occurs first.

f. Except for the warranty stated herein and to the extent permitted by applicable law Vescent specifically disclaims any and all warranties, express or implied, including, but not limited to, any warranties of merchantability, fitness for a particular purpose, or noninfringement.

EU Declaration of Conformity

In accordance with EN ISO/IEC 17050-1:2010

This declaration is issued under the sole responsibility of the manufacturer.

Manufacturers Name:	**Vescent Technologies, Inc.**
Manufacturers Address:	14998 W. 6th Ave., Suite 700 Golden, Colorado 80401 U.S.A.
Product:	**SLICE Offset Phase Lock Controller**
Product Model Number:	**SLICE-OPL**

The object of the declaration described above is in conformity with the relevant Union harmonization Legislation:

Application of Council Directives:

EMC	2014/30/EU
RoHS 2	2011/65/EU
Low Voltage Directive	2014/35/EU

Standards:

EMC	EN 55011:2016 – Emissions Class A EN 61326-1:2013 – Immunity
RoHS 2 Technical Documentation	EN 50581:2012
Safety Requirements	EN 61010-1:2010

We, the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards.

Location:	Golden, Colorado	Signature:	
Date:	07/26/2024	Full Name:	Scott Rommel
		Title:	COO