Operating Manual

LB1005 High-Speed Servo Controller

New Focus™

Bookham

2584 Junction Ave.

San Jose, CA 95134

(408) 919-1500

Item No. P2102297 Rev. A

Contents

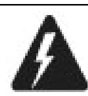
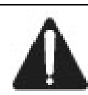
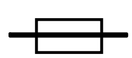
Chapter 1: Introduction

This manual contains information for operating the New Focus LB1005 High-Speed Servo Controller. The LB1005 is a high-performance, standalone instrument that provides the appropriate analog signal conditioning for achieving stable feedback control. The LB1005 is particularly suited for high-bandwidth filtering required to stabilize the intensity and frequency of many laser systems. This chapter addresses pertinent safety issues and correct usage of this instrument, as well as defines all front and rear panel connections. Please carefully read this chapter before using the LB1005. Chapter 2 helps users immediately get started using the LB1005 in their application, while Chapter 3 has more complete details of the operation of the LB1005.

Safety Considerations

The LB1005 is a versatile instrument that can be used in a variety of feedback control applications. However**, the LB1005 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 LB1005 in accordance with any applicable laws, codes, regulations, and standards pertaining to their specific application. Bookham is not liable for any consequential damage due to misapplication or failure of the LB1005.

Table of Symbols

~	Alternating current
	Caution – risk of electric shock
	Caution – refer to manuals
	Fuse
|	On (AC voltage supply)
○	Off (AC voltage supply)

Parts List

The LB1005 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:

- LB1005 Servo Controller
- LB1005 Operating Manual
- AC Power Cord

Electrical Fuse & Voltage Selection

The LB1005 is pre-configured at the factory to work with the AC mains voltages for your region. Before supplying electrical power to the LB1005, confirm that the power entry module located on the rear panel is installed with the proper fuses and set to the correct wallplug AC voltage. Use Table 1 to determine the appropriate fuse and voltage settings.

Table 1: Fuse & Voltage Settings

AC Mains* V~	Tolerance V~	Fuse Rating**	Module Voltage Wheel Setting
100	90—110	250 V 0.50 A T	100Vac
120	108—132		120Vac
220	198—242	250 V 0.25 A T	220Vac
230-240	207—264		240Vac

* 50/60 Hz only. **Module only accepts dual metric 5 x 20 mm fuses.

To operate at another AC mains voltage, follow the procedure below:

- With a small screwdriver, pry open fuse cover of the power entry module on rear panel. The AC power cord must be removed from module socket before opening fuse cover.
- Carefully pull out the voltage selection wheel from the module. Re-insert so that correct AC voltage setting is facing outwards.
- Pull out the two fuse holders located below voltage selection wheel. Insert correct fuses into each fuse holder and re-insert back into module. Install fuse holders so that arrows on fuse cover and fuse holder align.
- Snap fuse cover back into place. Verify that the correct AC mains voltage can be read through fuse panel before attaching the AC power cord.

Front Panel Connections & Controls

Figure 1: LB1005 Front Panel

1. **A, -B:** The error signal is generated from the voltage difference of these BNC inputs. Both voltage channels have 1-MΩ input impedance and an input voltage range of ±10 V. For single-ended operation, these BNC connectors auto-terminate upon disconnection of cables.

   ***Warning**: For proper operation, cables attached to either of these inputs must be driven with a voltage source or terminate into a low impedance. Make sure that any attached BNC cable connectors are fully inserted and fastened to the panel connector.*

2. **Input Offset:** This 10-turn locking knob controls a stable offset voltage that can be added or subtracted from the voltage difference of the A and –B inputs. This offset can be adjusted over a range of either ±1 V or ±10 V, selected by the rear panel Input Offset Range switch. The Input Offset can also be disabled. The offset voltage corresponds linearly to the dial readout: $V_{Offset} = (0.2n - 1) \times V_{MaxRange}$, where n is the number of turns read from the dial indicator. For example, a dial value of n = 5.00 indicates a (near) zero offset voltage.

3. **Error Monitor:** This BNC output connector is a voltage monitor for the error signal generated by the input difference amplifier. The DC-coupled error monitor has unity gain with a nominal output voltage range of ±10 V and a bandwidth of 10 MHz.

4. **Sweep In:** This BNC input allows a low frequency periodic sweep signal to be added to the output of the LB1005. The input impedance is 1 MΩ and the

input voltage range is ±10 V. See Sweep Center and Sweep Span controls discussed below for more details.

5. **Output:** This BNC output is the control signal from the proportional-integral (P-I) filter, summed with the sweep and modulation signals. This output has an impedance of 50 Ω and a drive current of ±20 mA.
6. **Sweep Center (Output Offset):** This 10-turn knob adjusts the offset voltage of the signal from Output. The offset voltage can be adjusted from the negative voltage limit (fully counter clockwise) to the positive voltage limit (fully clockwise). See the section *Setting Output Voltage Limits* in Chapter 3 for more details on setting the output voltage limits.
7. **Sweep Span:** This 1-turn knob controls the attenuation of the Sweep In signal. Attenuation is near linear from zero (Off, fully counter-clockwise) to unity gain (fully clockwise). This knob is used to adjust the amplitude of the sweep input signal.
8. **P-I Corner:** This 12-position switch sets the proportional-integral (P-I) corner frequency of the filter. See the section *Filter Transfer Functions* in Chapter 3 for details.
9. **LF Gain Limit:** This 9-position switch controls the low frequency gain limit (LFGL) of the loop filter. This knob is only active when the Acquire switch is in LFGL mode. See the section *Filter Transfer Functions* in Chapter 3 for details.
10. **Gain:** This 10-turn knob continuously controls the overall feedback gain of the loop filter from -40 dB (fully counter clockwise) to +40 dB (fully clockwise). Gains from -30 dB to +30 dB have a dial indicator reading that is near linear from indices n = 2 to 8 (~10 dB/turn).
11. **Acquire switch:** This 3-position switch is used to acquire lock. Table 2 shows the function for each switch position.

Table 2: Functions for Acquire Switch

Position	Function
Lock Off	Integrator is reset. No control signal is summed into output signal.
LFGL	P-I filter is enabled with a low frequency gain limit determined by LF Gain Limit switch. See the section *Filter Transfer Functions* in Chapter 3.
Lock On	P-I filter is enabled with full integrator. Low frequency gain limit is disabled.

12. **LED lock indicator:** This LED light indicates the operating status of the LB1005. Table 3 shows the correspondence of the LED color to the operating conditions of the LB1005.

Table 3: LED Lock Indicator

LED Color	Condition
Unlighted	**OFF**: LB1005 is either disconnected from the AC mains supply, or the rear panel power switch is in Off position (0).
Green	**LOCKED:** Acquire switch is placed in either LFGL or Lock On position, *AND* Error signal voltage is within ±0.33 V. *AND* Output signal voltage is NOT within 10% (scaled to full voltage range) of either the positive or negative output voltage limits.
Red	**UNLOCKED:** All remaining operating conditions.

Rear Panel Connections & Controls

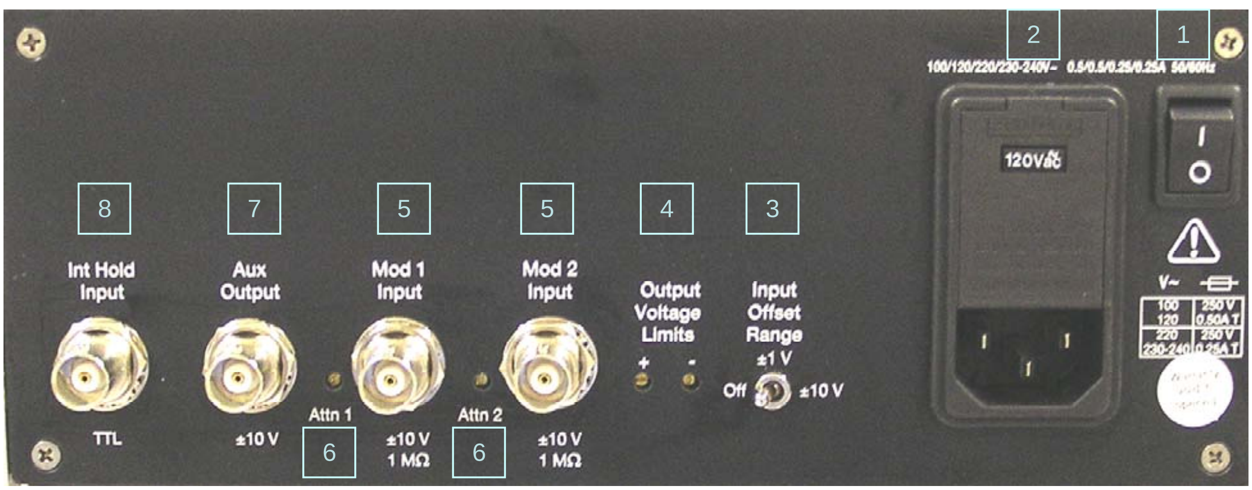


Figure 2: LB1005 Rear Panel

1. **Power switch:** This switch is pushed up to **|** position to turn on AC mains power to LB1005.
2. **Power entry module:** The AC power cord must be connected between this instrument receptacle and a properly grounded mains receptacle. The LB1005 can be configured to operate with the following AC mains voltages: 100, 120, 220, and 230-240 VAC. Please carefully read the preceding section *Electrical Fuse & Voltage Selection* for instructions on installing the proper fuses and setting the correct AC supply voltage.

3. **Input Offset Range**: This 3-position switch determines the voltage range for the Input Offset front panel knob. For more information, please see the above section *Front Panel Connections & Controls*). Selecting the Off position disables the Input Offset control so that no voltage offset is added.
4. **Output Voltage Limits:** These 15-turn trimpots determine the output voltages that clamp the positive and negative voltage rails of the Output. See section *Setting Output Voltage Limits* in Chapter 3 for more details.
5. **Mod 1 Input, Mod 2 Input:** Input signals to these BNC connectors are summed into the Output signal. Each modulation input has an input voltage range of ±10V, 1-MΩ input impedance, and 1-MHz bandwidth. See the section *Applying Modulation Inputs* in Chapter 3 for more details.
6. **Attn 1, Attn 2:** These 15-turn trimpots attenuate the corresponding input modulation signals from off (fully counter-clockwise) to unity gain (fully clockwise). See the section *Applying Modulation Inputs* in Chapter 3 for more details.
7. **Aux Output:** This BNC connector is the control voltage output directly from the P-I filter section, bypassing the summing amplifier. The Output Voltage Limits do not apply to this output. The output range is ±10 V with 50-Ω output impedance.
8. **Int Hold Input:** This TTL logic input switches off the error signal input to the P-I filter and holds the integrator output voltage at its current value. Table 4 shows logic levels for this input. Since this input is pulled low, the BNC can be left unconnected for normal operation.

Table 4: Logic Levels for Int Hold Input

TTL Logic Level	Function
Low (<0.8 V)	Normal P-I filter operation.
High (>2.4 V)	No error input to filter. Integrator holds its current voltage value.

Chapter 2: Getting Started

This chapter explains the typical setup and operation of the LB1005 Servo Controller. This chapter should help less experienced users rapidly adapt the LB1005 to their specific servo application. Keep in mind that while the LB1005 has a flexible architecture that lends itself well to many feedback control applications, not all types of operation can be adequately addressed in this manual. The following are general guidelines for operating the LB1005, and some deviation from these procedures may be required to meet specific application needs. Demanding applications will require familiarity with feedback control theory and good characterization of all system components.

The primary function of the LB1005 is to condition an input signal from a detector and to provide an output signal to a transducer that controls a system parameter. The output control signal forces the system parameter to a desired value regardless of external disturbances, such as thermal fluctuations or mechanical noise, which invariably affect the system. The difference between the desired value and the actual value of the controlled parameter is typically called the error signal. For instance, the parameter to be controlled might be the intensity of a diode laser that has its optical output detected by a photodiode. The LB1005 generates an error signal from the photodiode signal and then filters this error signal to provide a control signal that changes the injection current to the diode laser such that a stable optical power is maintained.

Typical Setup

The LB1005 is designed to easily integrate with other instruments and devices. This section describes the various electrical signal connections that might be made to and from the LB1005. Some typical signal connections between common instruments are shown in Figure 3. Pay careful attention not to exceed any damage thresholds when making connections between instruments.

NOTE: Before powering the LB1005, make sure that the fuse and voltage settings are correct for your region's wallplug electrical power (see the *Electrical Fuse & Voltage Selection* section of Chapter 1.)

1. **Detector output to LB1005 A & –B inputs:** To provide feedback, the parameter to be stabilized must first be detected. For example, a simple photodiode might suffice for detecting optical intensity. For instances where the laser wavelength is stabilized, spectrometers based on atomic/molecular or interferometer resonances are needed to detect optical wavelength shifts. The common characteristic of all detectors is that they produce a nonzero slope that is locally monotonic around the desired lock point.

The input section of the LB1005 is a high-impedance, differential amplifier stage that offers flexibility in interfacing to many types of detector outputs. The A and -B inputs can be used together with differential signals to remove common-mode noise and systematics. Single-ended signals can also be connected, as shown by connection 1a, by simply leaving the unused channel unconnected, or, as depicted by connection 1b, by attaching a stable voltage source that generates an external setpoint voltage. Alternatively, the Input Offset knob can provide DC offset to the detector signals. To invert either differential or single-ended signals, reverse the A & -B connections.

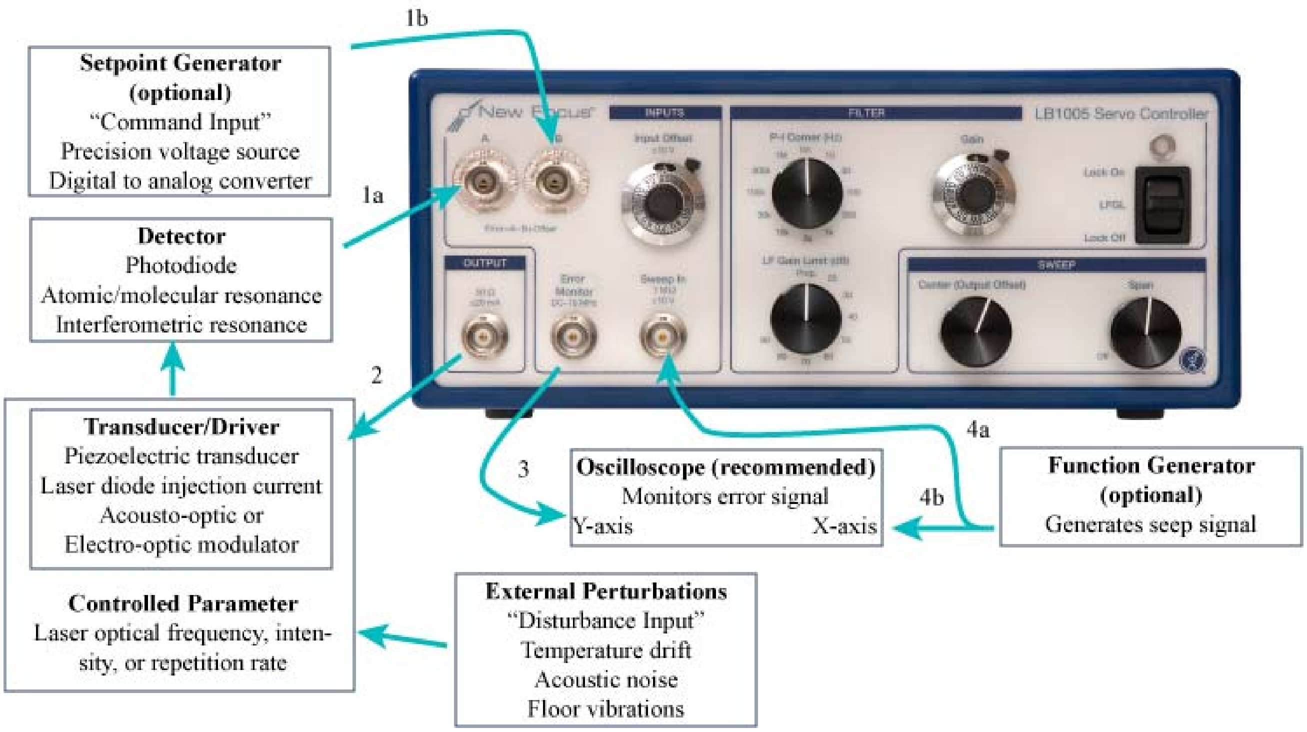


Figure 3: Typical signal connections for LB1005

2. **LB1005 Output to transducer input:** To close the feedback loop, an electrically tuned transducer is necessary for varying the controlled parameter. For example, a piezoelectric transducer (PZT) to which a cavity mirror is mounted can tune the wavelength of a laser. Typically, the output of the LB1005 does not interface with the transducer directly but instead provides the input to an amplifier system that conditions the control signal to properly drive the transducer. For the PZT discussed above, the control signal from the LB1005 Output will usually feed a high-voltage amplifier that connects to the PZT. Be careful not to exceed any input voltage limits of the transducer. If necessary, the Output voltage of the LB1005 can be limited by

setting the Output Voltage Limit trimpots located on the rear panel. See section *Setting Output Voltage Limits* in Chapter 3 for more details.

3. **LB1005 Error Monitor output to oscilloscope**: The Error Monitor allows the user to view the actual error signal that is being processed by the P-I filter. Since integral feedback forces the error signal to zero voltage, the parameter that is being controlled will assume whatever value corresponds to zero error (equal to zero volts). Observing the Error Monitor enables the user to adjust offsets so that the locking point corresponds to the desired value of the controlled parameter. The error signal is also an excellent diagnostic for monitoring the lock condition and optimizing the feedback gain. Because the time domain behavior of the error signal is so important to understanding the feedback control, viewing the Error Monitor output on an oscilloscope is highly recommended.

4. **Function generator output to LB1005 Sweep In**: For detector signals that are derived from optical resonances, it is convenient to sweep the transducer so that the optical frequency scans over the resonance. Observing the resonance on an oscilloscope often makes it easier to offset the error signal so that the locking point (at zero volts) aligns with the desired optical frequency (see Figure 4 below for an example). Furthermore, sweeping the transducer helps to locate the resonance and place the optical frequency within the locking range of the servo system. To add sweep capability, connect a low-frequency (30—60 Hz is usually sufficient) triangle waveform from a function generator to the Sweep In connector, as shown by connection 4a. The sweep signal will then be output to the transducer, with its amplitude controlled by the Sweep Span knob. To synchronize the sweep with the Error Monitor signal, also connect the function generator output to the oscilloscope's timebase trigger, shown by connection 4b.

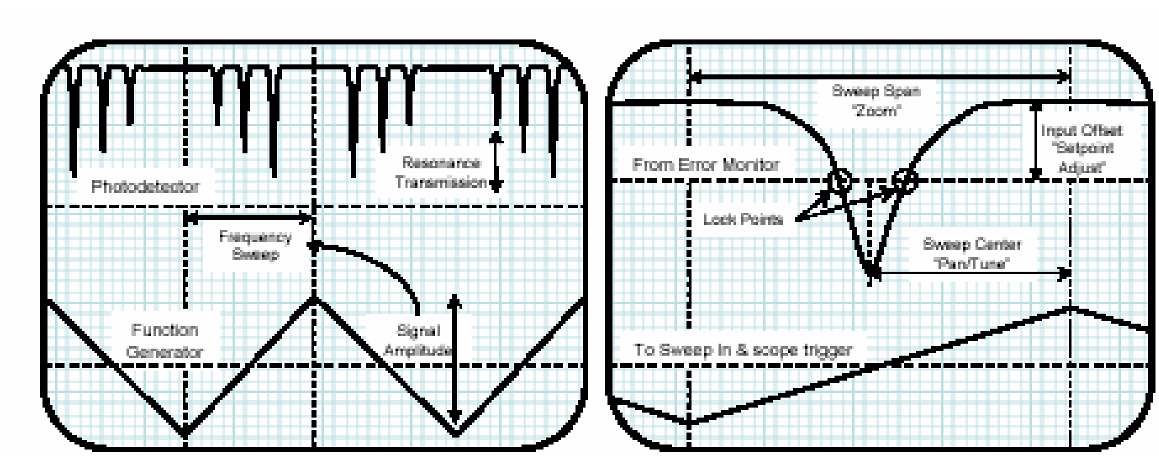


Figure 4: Typical oscilloscope signals are shown for locking to the side of an optical resonance. The dashed horizontal lines indicate ground for denoted signals. a) A triangle

waveform from a function generator sweeps the optical frequency transducer over multiple resonances. A photodetector measures the corresponding transmission response. b) The Sweep Span reduces the frequency sweep so that only one resonance is shown on the Error Monitor signal. The Sweep Center tunes the frequency to locate a particular resonance, and "center" the lock point prior to applying the feedback. The Input Offset locates the lock point on the slope of the resonance. Note that the two lock points have opposite gain signs.

Typical Operation

The controls of the LB1005 are conveniently arranged for acquiring and optimizing lock. In this section, five steps are suggested that will meet the needs of most applications. Figure 5 shows the controls that are most likely to be adjusted for each step. The solid lines indicate controls that are used most often, while the dashed lines show controls that are less frequently adjusted.

1. **Reset integrator:** Before locking, reset the integrator by moving the Acquire switch to the Lock Off position.
2. **Find the locking point**: Many applications will require the user to search for the locking point, such as the side or center of an optical resonance. Turn on sweeping by clicking the Sweep Span knob from its Off position, adjusting it for a wide span. Use the Sweep Center knob to adjust the transducer bias so that the lock feature is "centered" within the scan. If needed, the desired lock point can be adjusted to zero voltage with the Input Offset knob while monitoring the error signal. Adjust both the Sweep Center and Sweep Span controls so that the oscilloscope scan shows the discriminator slope of the lock feature. Figure 4 illustrates these concepts for a "side lock" to a resonance.
3. **Acquire lock:** The Acquire toggle switch offers two gain settings for turning on the feedback control. When acquiring lock, sometimes it is helpful to limit the DC gain of the integrator. The LFGL position is an intermediate lock mode that applies the P-I filter with a low frequency gain limit (see section *Filter Transfer Functions* of Chapter 3 for details). The LF Gain Limit front panel switch determines the setting for this gain limit, and is typically only set once for a specific servo application.

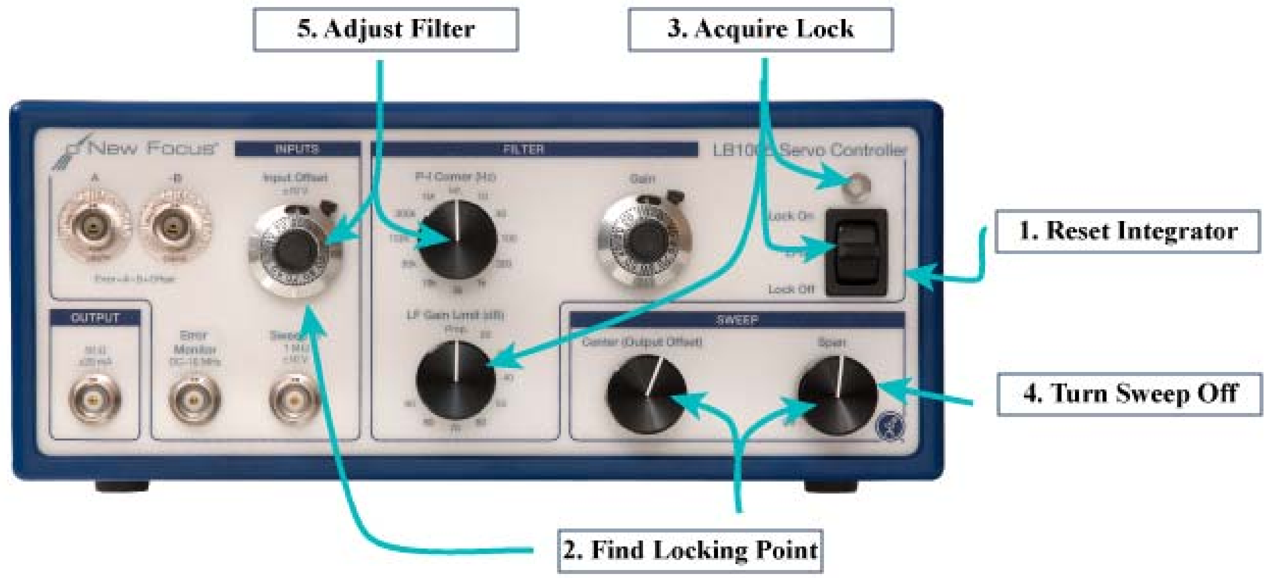


Figure 5: Typical Operation of Controls

The Lock On position disables the low-frequency gain limit and applies the full integrator gain to the output. Most servo systems should be locked in this position to minimize DC errors. When correctly locked, the Error Monitor signal should be very near zero volts, and the LED indicator light should be green (see Figure 6 for more details.)

4. **Turn off sweep**: If the output was swept to find the lock point, then it is good practice to turn the Sweep Span knob to Off after acquiring lock. This completely disables the sweep signal, and prevents the feedback from working "overtime" to correct the error induced by the sweep signal.

5. **Adjust filter**: The P-I Corner frequency can be tuned for optimal performance and stability. Once optimized, it rarely needs to be revisited. However, re-tuning the Gain knob is done fairly often to find the maximum gain setting. A common procedure is to increase the gain until an oscillation is observed on the Error Monitor, and then reduce the gain until the oscillation just barely stops.

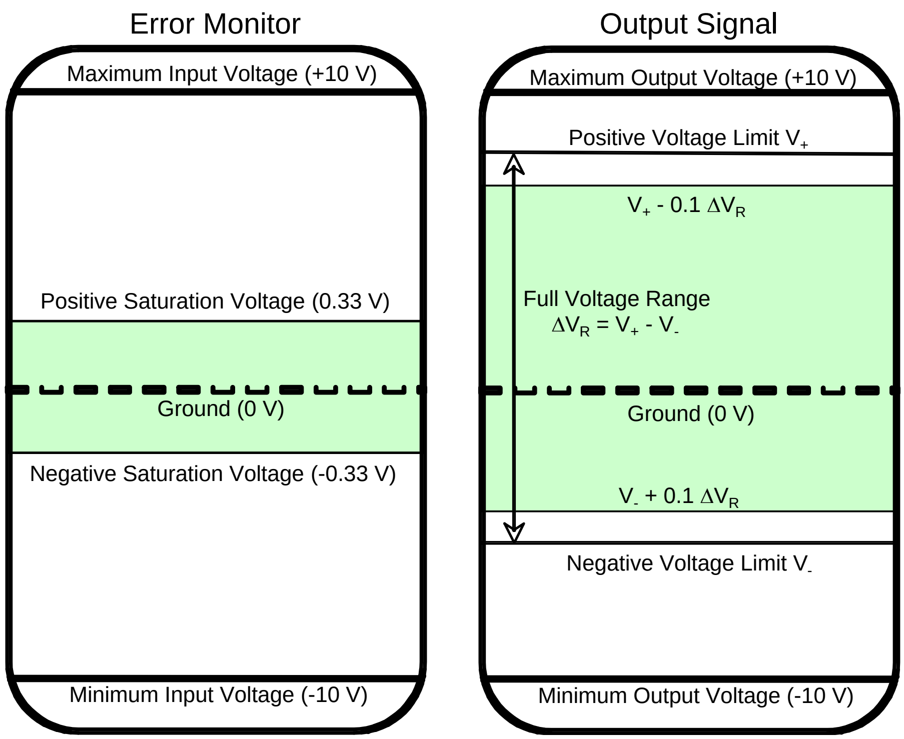


Figure 6: Voltage limits for the LED Lock Indicator. This LED indicator monitors when the Error signal exceeds the input saturation voltage range or when the Output signal is nearing an output rail. The LED lights green ("Locked") when the Acquire switch is in either the Lock On or LFGL position, *and* both the Error and Output signal voltages fall within the shaded areas above. For all the other conditions ("Unlocked"), the LED lights red. These conditions are good indicators when the feedback control is (or is close to) misbehaving.

Chapter 3 : Detailed Operation

Signal Architecture

The LB1005 is comprised of three stages of analog signal processing. Figure 7 shows the different sections and how the various input signals are used to derive the output signal. Each section is briefly described below. See Appendix A for more detailed specifications.

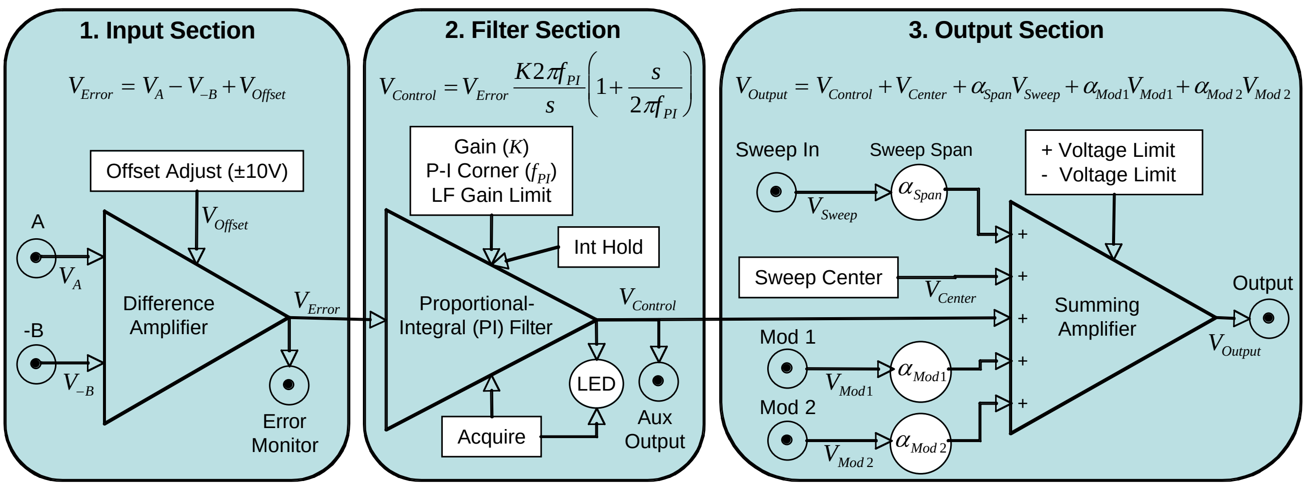


Figure 7: Schematic of LB1005 Signal Architecture

1. **Input Section:** The input section is a difference amplifier with an adjustable voltage offset. Common-mode voltages ranging from ±10V can be subtracted. Error signals (observed at the Error Monitor) that exceed the voltage range ±330 mV saturate the filter amplifier.
2. **Filter Section:** This section converts the error signal to a control signal with a proportional-integral (P-I) filter. Front panel controls adjust the overall loop gain, the P-I corner frequency, and an optional low-frequency gain limit. A toggle switch is used to disable/enable the output of the P-I filter for acquiring lock. See the next section for more details about the transfer functions available from this filter. An optional TTL input can be used to disable the error signal input and hold the P-I filter output at its current value.
3. **Output Section:** The output section is a summing amplifier that adds the P-I control signal to other auxiliary signals, such as external sweep and modulation inputs. The output voltage range of this section can be limited by rear panel trimpot adjustments.

Filter Transfer Functions

This section describes the transfer functions available from the P-I filter, which are shown in Figure 8. The filter is specifically designed to have independent control over the three main parameters that shape the filter frequency response:

- **P-I Corner (f_{PI}):** This is the 3-dB break frequency beyond which proportional gain dominates over integral gain. For the switch setting Int, the filter becomes a true integrator with no proportional gain term. In this case, the integral gain matches that of the 3 kHz P-I Corner setting.
- **Gain (*K*):** This is the amount of proportional gain. The gain can be adjusted continuously on a log scale. Changing this gain does not alter any of the corner frequencies of the filter.
- **LF Gain Limit (*g*):** This is the gain limit for low frequencies, as measured from the proportional gain value. The integrator is turned off for frequencies lower than the following 3-dB corner frequency: $f_{LFGL} = f_{PI} \times 10^{-[g(dB)/20dB]}$. For the switch setting Prop, the integral gain is completely turned off ($g = 0$), and the filter operates only in proportional mode.

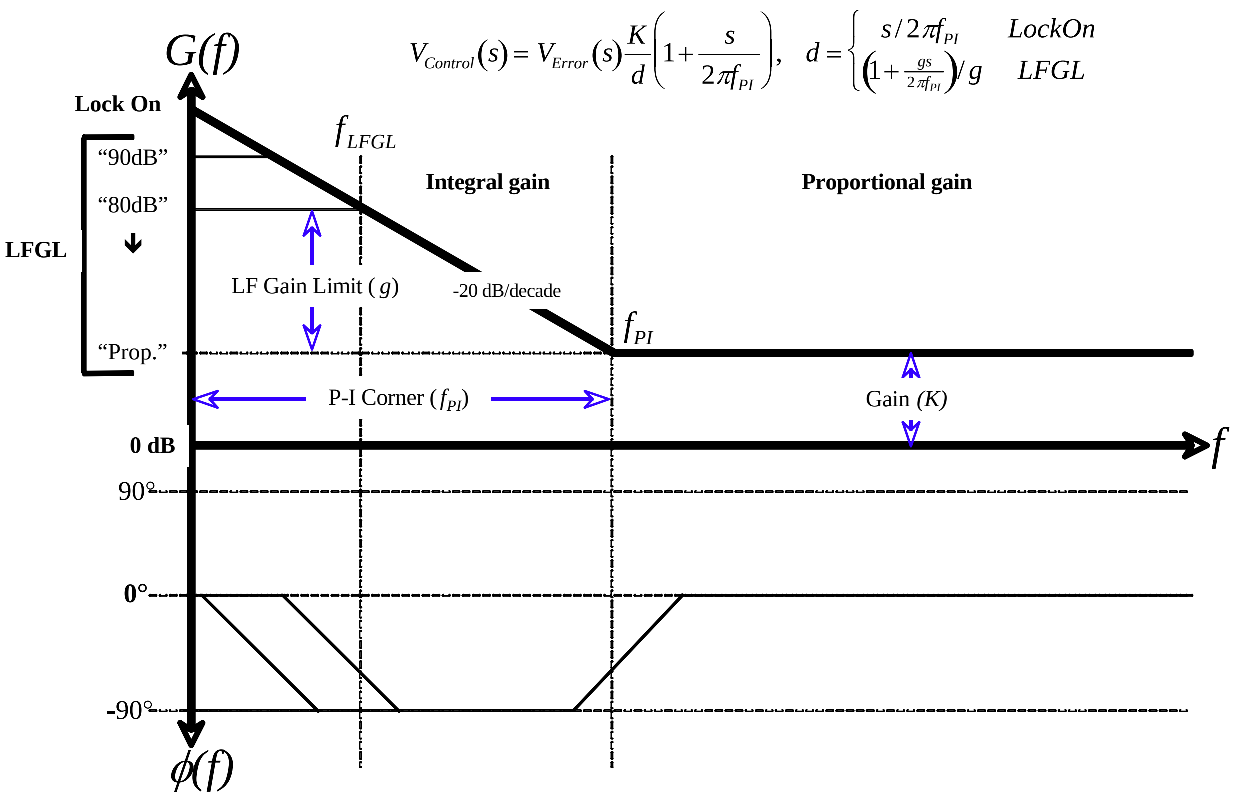


Figure 8: Proportional-integral Filter Gain with Low Frequency Gain Limit

The design of the P-I filter minimizes transient behaviors when switching between corner values. Under most circumstances, switching corner frequencies can be performed without losing lock, which aids in searching for optimal operation. However, the gain change when switching in and out of Int mode is fairly large, and re-locking will typically be necessary to use the integrator-only mode.

The Acquire toggle switch controls the output of the filter section:

- **Lock Off:** The integrator is reset. The control voltage is zero.
- **LFGL:** The P-I filter output is enabled, but the low frequency gain is limited according to the LF Gain Limit switch. This mode is useful for acquiring lock and situations where limiting the DC gain is necessary.
- **Lock On:** The integrator of the P-I filter is fully enabled. The LF Gain Limit is disabled.

The LB1005 operating bandwidth refers to the frequency where the proportional gain falls off by 3 dB. The filter functions specified in Figure 8 are guaranteed to the minimum specified bandwidth of 10 MHz. Behavior of the filter response beyond this frequency is unspecified.

Setting Output Voltage Limits

The positive and negative voltage limits of the LB1005 Output can be independently adjusted with the Output Voltage Limit trimpots located on the rear panel. The following procedure can be used to set the output voltage limits:

1. To set the positive (negative) limit, turn the Sweep Center (Output Offset) knob fully clockwise (counter-clockwise). The Output signal should now be at the positive (negative) voltage limit.
2. Monitoring the Output voltage on an oscilloscope or voltmeter, turn the + (-) trimpot on the rear panel until the desired positive (negative) output limit voltage is reached. Clockwise adjustment of these trimpots results in a more positive voltage.

When adjusting both output voltage limits, specified operation only occurs if the voltage difference between the negative and positive limits is greater than 2 V. Unspecified behavior occurs if this condition is violated.

The total 10-turn range of the Sweep Center knob is automatically adjusted to correspond to the full output voltage range as determined by the positive and negative output voltage limits.

> ***Warning****: Carefully measure output voltages from the LB1005 before connecting to a device that can be damaged by overvoltage.*

Using the Integrator Hold

The LB1005 has a feature that allows the user to electronically trigger the integrator output to "hold" its current value. When a TTL digital "high" signal is applied to the rear panel Int Hold BNC connector, the error signal input to the filter stage integrator is disabled until the TTL signal goes to a "low" state. (The Int Hold BNC can remain unconnected for normal operation.) This feature is useful for dealing with exceptional perturbations to the controls system that would force it to misbehave, such as coming permanently unlocked.

One possible application of the Int Hold function uses a digital signal that toggles to its high state when the error signal exceeds some maximum allowable excursion limit. For example, if certain operating regions of the error signal result in indeterminate behavior of the controls system (such as railing the integrator), more reliable operation can be obtained if the feedback is temporarily switched off during the time that the error signal is in these regions. When a disturbance causes the error to exceed a specified limit, the Int Hold is toggled high to disable the feedback and hold the integrator output (control signal) at its current value. The (uncontrolled) output is now prevented from following the large error perturbation that would otherwise have driven the control system into an unrecoverable state. Instead, the control voltage is maintained at a safe, fixed value until the disturbance recedes. When the disturbance passes and the error signal returns to its normal operating window, the digital signal to Int Hold reverts to its low state and feedback control resumes.

Applying Modulation Inputs

The LB1005 has two external modulation inputs that are independently available for such applications as adding a modulation frequency to the output for lock-in detection or summing in a feedforward correction signal for improving the command response of the feedback control. The signals applied to these inputs are summed with the sweep and control signals to form the output signal. Rear panel trimpots located near each of the modulation BNC connectors provide adjustable attenuation of these signals. Turn fully clockwise for unity gain and fully counter-clockwise to turn off the modulation. When a modulation input is not in use, its attenuation trimpot should be turned fully counter-clockwise to prevent unwanted "pick-up" from the other modulation channel.

Appendix A: Specifications

A.1. Performance specifications

Parameter	***Sym***	***Min***	***Typ***	***Max***	***Unit***	***Condition***
Signal bandwidth (-3 dB)		10	18		MHz	
Propagation delay				50	ns	<10 MHz
Input Section: Difference amplifier	$V_{Error}=(V_A-V_{-B})+V_{Offset}$					
Input impedance (A, -B)			1M		Ω	
Input voltage (A, -B)	V_A, V_{-B}	-10		10	V	
Input voltage noise density (A, -B)			10		nV $Hz^{-1/2}$	>1 kHz
Common mode rejection ratio (A-B)		60			dB	<10 kHz
Input offset voltage	V_{Offset}	-10		10	V	Range selectable
Error monitor output impedance			50		Ω	
Error monitor bandwidth		10			MHz	
Error monitor gain			1		V/V	
Error monitor output voltage	V_{Error}	-11		11	V	
Filter Section: P-I controller	$V_{Control}(s)=V_{Error}(s)\frac{K}{d}\left(1+\frac{s}{2\pi f_{PI}}\right),\quad d=\begin{cases} s/2\pi f_{PI} & LockOn \\ \left(1+\frac{gs}{2\pi f_{PI}}\right)/g & LFGL \end{cases}$					
Gain range	K	-40 0.01		40 100	dB V/V	Log scale, continuous adjust
P-I corner frequency range	f_{PI}	10		1M	Hz	Half-log steps
Low frequency gain limit range	g	20		90	dB	10-dB steps
Filter parameter accuracy			10		%	
Aux output impedance			50		Ω	
Aux output voltage	$V_{Control}$	-11		11	V	
Integrator hold "on" level		2.4			V	TTL
Integrator hold "off" level				0.8	V	TTL
Output Section: Summing amplifier	$V_{Output}=V_{Control}+V_{Center}+\alpha_{Span}V_{Sweep}+\alpha_{Mod1}V_{Mod1}+\alpha_{Mod2}V_{Mod2}$					
Output voltage	V_{Output}	-11 (V_-)		11 (V_+)	V	Unclamped Clamped
Positive output limit voltage	V_+	0		10	V	$V_+ - V_- \geq 2V$
Negative output limit voltage	V_-	-10		0	V	
Output impedance			50		Ω	
Output current		-20		20	mA	
Sweep input impedance			1M		Ω	
Sweep input bandwidth		10			kHz	
Sweep input voltage	V_{Sweep}	-10		10	V	
Sweep span attenuation	α_{Span}	0		100	%	
Sweep center bias voltage	V_{Center}	-10		10	V	
Modulation input impedance (1, 2)			1M		Ω	
Modulation input bandwidth (1, 2)		1			MHz	<1 Vp-p
Modulation input (1, 2)	$V_{Mod1,2}$	-10		10	V	
Modulation attenuation (1, 2)	$\alpha_{Mod1,2}$	0		100	%	

A.2. Environmental Specifications

Parameter	*Min*	*Typ*	*Max*	*Unit*	*Condition*
Operating temperature	10		40	°C	
Transportation/storage temperature	-40		80	°C	
Maximum relative humidity			80	%	
Maximum operating altitude			2000	m	
Instrument weight		3		kg	

A.3. Electrical Specifications

Parameter	*Classification*
Use type	Indoor Use Only
Protection	Ordinary Protection (Not protected against ingress of moisture)
Equipment class	Class I (Grounded Type)
Electrical rating	100/120/220/230-240V~ 0.5/0.5/0.25/0.25A 50/60Hz
Voltage tolerance	±10% of nominal supply voltage
Fuse rating	250V 0.5A T or 250V 0.25A T (Metric sizing only: 5mm x 20mm)
Ambient pollution	Pollution Degree 2
Transient overvoltages	Installation Category II

Appendix B: Service & Maintenance

The LB1005 is designed to be maintenance free. No user-serviceable parts are inside the unit. No further calibrations are necessary for the LB1005 to meet its accuracy specifications over the lifetime of the product. Opening the instrument case voids the warranty and exposes to user to hazardous voltages that are present inside the instrument case.

Cleaning instructions: Instrument case can be safely cleaned with slightly moistened cloth soaked in water or isopropyl alcohol.

For service or repairs:

1. Telephone or email New Focus customer service department at (+1) (408) 919-2740 or techsupport@newfocus.com, which will determine if the equipment requires service, repair, calibration, or replacement. Factory office hours are 9:00 am-5:00 pm PT.
2. If the unit must be returned to Bookham, ask for a Return Merchandise Authorization (RMA) from customer service. **Never send any unit back to Bookham without a Return Merchandise Authorization (RMA).**
3. Return the unit, postage prepaid, to Bookham. Do not forget to write the RMA on the shipping label. Bookham will refuse and return any package that does not bear an RMA.
4. Pack the unit in its original shipping material (if possible) with at least 1 inch of compressible packing material. Be sure to include an ownership tag and a description fully detailing the defect and the conditions under which it was observed.
5. After repair, the equipment will be returned with a repair report. If the equipment was 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. Bookham 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 Bookham recommends, is at the customer’s expense.

Appendix C: Warranty

Bookham warrants its New Focus LB1005 to be free of material and workmanship defects for one year from the date of original shipment. This warranty is in lieu of all other guarantees expressed or implied, including any implied warranty of merchantability or fitness for any particular purpose. Bookham shall not be liable for any special, incidental or consequential loss.

During the warranty period, Bookham will repair or replace the unit, or issue credit, at our option, without charge. Bookham's liability shall not in any case exceed the cost of correcting defects in the products as explained here, and this service is the sole remedy of the buyer.

This warranty does not apply to defects caused by abuse, accident, modifications, Acts of God, or to use of the product for which it was not intended. Bookham shall not be liable for damages resulting from the use of the product, nor shall be responsible for any failure in the performance of other items to which the purchased product is connected or the operation of any system of which the purchased product may be a part. The LB1005 should not be used in a manner not specified by the manufacturer.