uniphase

USER'S MANUAL

MODEL 310B

Wideband O/E Converter

1. INTRODUCTION

GENERAL DESCRIPTION

The Model 310B is a wideband, high speed optical-to-electrical (O/E) conversion instrument with other useful features. It is designed for general laboratory use, with a 100-to-240 VAC power source.

The instrument consists of three main independent blocks:point is rear-panel adjustable for limited control over extinction ratio and waveform details.

1. High Gain Wideband O/E Converter
2. Linear Amplifier
3. ECL Limiting Amplifier

The O/E Converter function is a DC-coupled detector/amplifier combination that exhibits the highest conversion gain in the industry, in combination with bandwidth exceeding 1.5GHz. Optical signal waveforms from less than 100 nanowatts to more than 100 microwatts can be accurately reproduced and analyzed with this function. Both the output signal amplitude and zero-optical reference levels are adjustable by the user for best oscilloscope display.

The AC-coupled Linear Amplifier feature is included for the rare occasions where even more conversion gain is required. The amplifier is also useful as a general laboratory wideband gain block.

The ECL Limiting Amplifier is a unique feature, not found on any other O/E converter instrument. This feature extends the utility of the basic O/E Converter to those situations where full optical receiver functionality is required, such as for optical source bit error rate (BER) testing. This feature also enables the Model 310B to be used as a general purpose, bit rate transparent laboratory receiver from less than 10 Mbps to more than 1500 Mbps.

SAFETY CONSIDERATIONS

To ensure safe operation of this equipment and personnel using this equipment, the cautions and warnings in this manual should be followed. This equipment has been manufactured and tested according to international safety standards. No user serviceable parts are contained within the instrument.

WARNING.

Failure to ground this instrument properly can result in personal injury or equipment damage. Connect the power cord only to a receptacle with a protective safety ground. Do not defeat the earth grounding protection by use of an extension cord or other device that defeats the connection of the safety ground

WARNING.

This instrument should be protected from direct electro-static discharge (ESD) directly into the electrical connectors as it should damage the equipment. Use of this equipment at an ESD workstation following procedures such as MIL-STD-1686 for ESD control is recommended.

SPECIFICATIONS

Table 1

Detector

Parameter	Silicon APD (Options 0XXX and 5XXX)	InGaAs APD (Options 3XXX)	Comments
Bandwidth	0-1000 MHz	0-1500 MHz	-3dB, minimum
Rise/Fall Time	0.4 nsec.	0.25 nsec.	10-90%, maximum
Conversion Gain	25,000 V/W (820 nm)	10,000 V/W (1550 nm)	Minimum, gain control set to max, low optical input power.
Operating Wavelength	600-900 nm	1100-1600 nm	Useful wavelength range.
Minimum Discernible Signal	4 nW	20 nW	Peak optical signal for output SNR = 1.0 in full O/E BW
Fiber Interface	200/230 µm (option 0XXX) 1000 µm (option 5XXX)	50/125 microns	Optical power is routed from the front panel to the internal detector by means of a fiber pigtail. The core/cladding dimensions are as indicated.
Recommended Maximum Input Operating Power	-20 dBm	-13 dBm	For best linear performance, gain set for no overload

Table 2, Specifications

Detector	
Polarity	Non-inverting
DC Offset	Adjustable ± 50mV (minimum) around zero with 50 ohm DC-coupled load.
Overload Indicator	Typically alarms at 50 microwatts average power with gain set to maximum. Overload threshold increases as gain is reduced.
Maximum Safe Optical Input Power for no damage	1.0 Milliwatt
Linear Amplifier	
Gain	20dB, minimum
Bandwidth	0.1 to 1500 MHz, minimum
Maximum Linear Output	1.0 Vpp, minimum
Polarity	Non-inverting
Input Impedance	50 ohms, AC-coupled
Absolute Maximum Safe Input Level	1.0 Vpp
ECL Limiting Amplifier	
Bit Rate (NRZ)	10 to 1500 Mbps, minimum
Input Dynamic Range	2 to 1000mV p-p, minimum (10^{-9} BER)
Output Signal Levels	Complementary ECL, -0.9 to -1.7V, typical (10K/100K ECL Logic compatible)
Output Termination	50 ohms to -2V, or 50 ohms AC-coupled
Input Impedance	50 ohms, AC-coupled
Input Data Pattern	Since the amplifier is AC-coupled, the input data must have a long-term running 1/0 balance between 60/40 and 40/60 (50/50 for optimum performance). Also, transition density should average at last one every ten bits.
Absolute Maximum Safe Input Level	1.0 Vpp
General	
I/O Panel Connectors	SMA Female or N Female
Power Ratings	100/240 VAC, 50-60Hz 25 watts maximum
Power Input Connector	IEC-320 receptacle on unit. Line cord with appropriate plug for country use.
Temperature Range Operating Storage	 10 to 40°C -20 to 70°C
Dimensions	10.13" wide, 10.39" deep, 4.54" high
Weight	5 pounds

Table 3
Ordering Information:

Model 310B-XXXX

Detector Option
0 = Si APD (200µm)
3 = InGaAs APD
4 = Special
5 = Si APD (1000µm)

Optical Connector Adaptor Option
1 = SMA 905/906
2 = ST/PC
3 = FC/PC
4 = Biconic
5 = SC
6 = DIN 46256
7 = D4 (2mm)
8 = DIAMOND HMS-0(3.5mm)
9 = DIAMOND HMS-10(2.5mm)
A = DIAMOND HMS-10/A
B = DIAMOND HMS-10/M
F = Special (Contact BCP)

Chassis Option
T = Table Top
R = Rack Mount

RF Connector Option
S = SMA
N = Type N

2. OPERATING INSTRUCTIONS

CONTROLS, INDICATORS AND CONNECTORS

Table 4 describes the front and rear panel controls, indicators and connectors illustrated in Figure 2.

Table 4

Item	Description	Function
1	OPTICAL IN Connector	Optical input to the O/E converter detector function. Screw-on adaptor for each connector type.
2	GAIN Control	Sets the O/E conversion gain. Locking 10-turn vernier.
3	OFFSET Control	Sets the O/E conversion output dc offset level. Locking 10-turn vernier.
4	DETECTOR OUT Connector	Electrical signal output from the O/E detector. (SMA or N)
5	OVERLOAD Indicator	Indicates activation of internal protection circuitry to minimize the risk of damage to the detector caused by excessive input optical power.
6	IN 50Ω Connector	Input connector to the 20dB linear amplifier function. (SMA or N)
7	OUT 50Ω Connector	Output connector from the 20dB linear amplifier function. (SMA or N)
8	IN 50Ω Connector	Input connector to the ECL Limiting Amplifier function. (SMA or N)
9	ENABLE/DISABLE Toggle Switch	Enables or disables the ECL Limiting Amplifier.
10	$\overline{\text{DATA}}$ Output Connector	Inverted ECL data output from the ECL Limiting Amplifier. (SMA or N)
11	DATA Output Connector	Non-inverted ECL data output from the ECL Limiting Amplifier. (SMA or N)

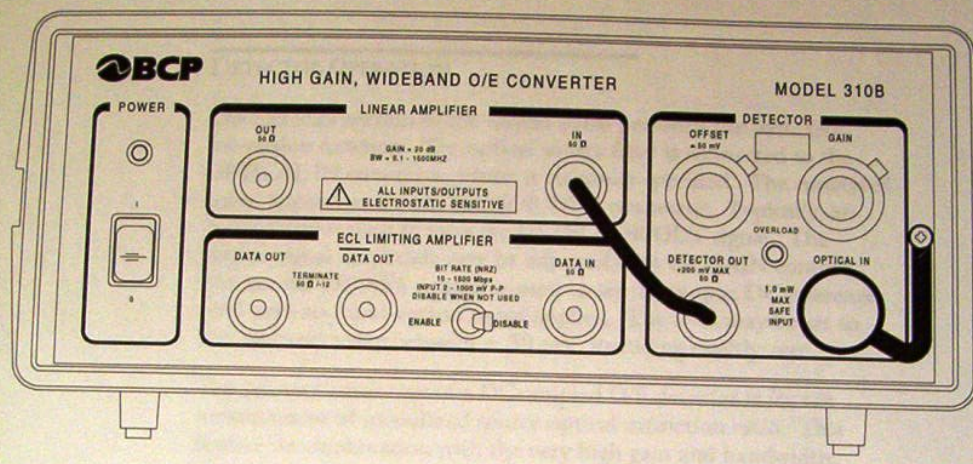
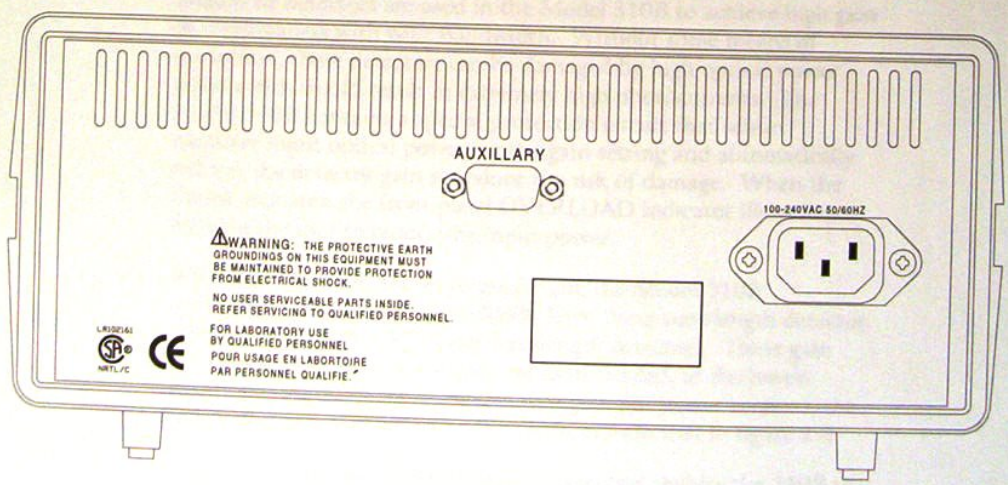


Figure 1, Model 310B Front and Rear Panels



DETECTOR OPERATION

The Detector section of the Model 310B performs the basic O/E conversion function. The optical source fiber is connected to the OPTICAL IN connector, which is customer specified. The converted signal appears at the DETECTOR OUT connector. Typically, an oscilloscope is used to view the DETECTOR OUT signal. The output signal amplitude may be adjusted with the GAIN control. The vernier OFFSET control is used to set the output DC reference level with no input optical signal applied. The level may be set to any arbitrary value between ± 50 mV, including exactly zero.

The primary advantage of a DC-coupled O/E detector is for the measurement of modulated source optical extinction ratio. This feature, in combination with the very high gain and bandwidth, enables accurate extinction ratio measurement of kilobit-to-gigabit sources, of power levels from tens of nanowatts to more than a hundred microwatts.

Avalanche detectors are used in the Model 310B to achieve high gain in combination with wide bandwidth. Without some means of protection, these detectors can be damaged by high optical power levels which would result in extremely high photocurrents. The Model 310B contains a special protection circuit that senses excessive input optical power for the gain setting and automatically reduces the detector gain to reduce the risk of damage. When the circuit activates, the front panel OVERLOAD indicator illuminates, warning the user to reduce the input power.

With the GAIN control set to maximum, the Model 310B conversion gain is more than 10,000 V/W (long wavelength detector options) or 25,000 V/W (short wavelength detector). These gain figures are applicable where they are most needed, at the lowest input optical power levels. As the average input power is raised, the conversion gain is designed to compress, as indicated in figure 2.2.

This feature not only protects the detector, but enables the 310B to be used for relatively high input power waveform measurements without the user having to set the gain control optimally. Even though the conversion gain is a function of average input power level, the 310B can still be calibrated for accurate instantaneous pulse amplitude power measurements by using an average-reading optical power meter and compensating for the effective pulse duty cycle, as follows:

$$\text{Peak Power (Watts)} = \frac{\text{Average Power (Watts)}}{\text{Duty Cycle}}$$

The instantaneous pulse peaks displayed on the oscilloscope are then calibrated in watts.

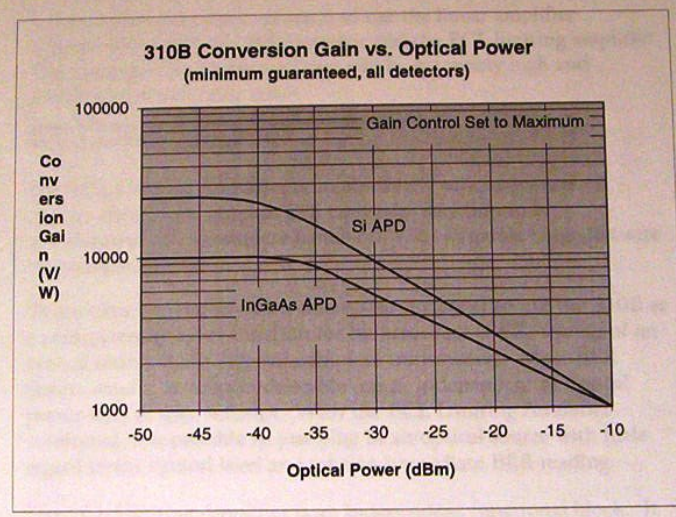


Figure 2, 310B Conversion Gain vs. Optical Power (Minimum guaranteed, All Detectors)

LINEAR AMPLIFIER OPERATION

The Linear Amplifier is included in the Model 310B for general purpose use. It may be connected to the detector output to provide a factor of ten (20dB) increase in conversion gain, or it may be used as an independent general purpose laboratory amplifier. The amplifier is AC-coupled and has a 3dB bandpass exceeding 0.1 - to - 1500 MHz. The maximum linear output is 1.0 Vpp into 50 ohms.

It is not advisable (nor necessary) to use the linear amplifier connected between the O/E Detector and the ECL limiting amplifier. The composite linear channel gain will be extremely high and unstable operation may result.

ECL LIMITING AMPLIFIER

The ECL Limiting Amplifier is an absolutely unique feature. It enables the general purpose O/E converter function to be transformed into a complete hands-off, wide dynamic range, bit-rate transparent receiver.

This makes it extremely convenient (for instance) to use the 310B as a transparent receiver function for bit error rate (BER) testing of an optical source (LED, laser or complete transmitter). Most BER testers require an amplitude-stable input, independent of optical power level or gain settings. With the ECL Limiting Amplifier connected, it is possible to just plug in an optical source with little regard to the optical level and take an immediate BER reading.

The ECL Limiting Amplifier is an independent functional block. It may be used either with the O/E detector function, or as a stand-alone ECL limiter for general lab use. When it is used in combination with the O/E Detector function, a short coax cable is connected from DETECTOR OUT to the ECL Limiting Amplifier IN connector. The Detector GAIN control should be set to maximum (fully clockwise or below overload). Either or both of the DATA output connectors may be connected to a 50 ohm coax cable which is terminated by either an AC-coupled 50 ohms, or a standard 50 ohms/-2VDC ECL termination. In order to improve performance, terminate the unused output to 50 ohms/-2VDC. The ENABLE/DISABLE switch should be set to ENABLE. When set up in this fashion, the ECL outputs will be stable and usable over a very wide input optical dynamic range. The purpose of the ENABLE/DISABLE switch is to power down the Limiting Amplifier when not in use.

This not only reduces internal power dissipation, it eliminates possible noise-driven "chatter" of the high gain limiter with the input open. It is possible for limiter chatter to crosstalk at a low level into the detector output and show up as a spurious low-level "spike" on a spectrum analyzer display connected to the DETECTOR OUT port. Therefore, when not in use, the limiter should be disabled.

Both ECL DATA outputs are active when the ECL Limiting Amplifier is enabled. The highest quality waveforms will be obtained when both outputs are terminated. If only one output is used and the other is left unterminated, a small amount of switching crosstalk may be noticed if a multi-gigahertz oscilloscope is used. For best performance, terminate the unused output to 50 ohms/-2VDC.

It should never be necessary to use the Linear Amplifier between the O/E Detector and the ECL Limiting Amplifier. The O/E Detector has sufficient output at full gain and very low optical input levels to drive the ECL Limiting Amplifier directly. If more sensitivity is required, (at very low bit rates for instance) the Linear Amplifier may be used if necessary, but it is recommended that an external in-line lowpass filter (500 MHz, -3dB) be connected between the Linear Amplifier output and the ECL Limiting Amplifier input. A Bessel response is recommended. In-line 50 ohm low pass filters are available from Mini-Ckts and K&L.

As previously mentioned, the Detector gain control is normally set to maximum (or below overload)when the ECL Limiting Amplifier is used with the Detector. It is possible that this gain setting will be slightly beyond the optimum gain setting for very low bit error rate performance at very low optical input power levels. If the absolute maximum sensitivity is required (lowest optical power for a given BER), reduce the Detector gain slowly while observing the bit error rate. If it improves at lower gain, search for the optimum gain manually and then lock the GAIN control at that setting.

Excessive input optical power levels are sensed by monitoring the average detector photocurrent flowing in the bias voltage line. The average photocurrent is affected by both gain and optical input level, and so there is an interaction between the GAIN control and the OVERLOAD threshold. The instrument is adjusted to indicate overload at a high but safe photocurrent level regardless of the GAIN setting or input power. If the overload indicator comes on at lower than the desired input optical power level, a lower GAIN setting will generally extinguish the overload indication. If not, the optical power should be reduced for guaranteed linear operation. There is no risk of detector damage as long as the absolute input power level is kept below the figure specified in section 1. Note that linear operation is not guaranteed in an overload condition.

Avalanche detector gain is affected by temperature at a fixed bias voltage setting. This temperature effect is approximately compensated by a temperature sensor which exercises vernier control over the detector bias voltage.

The variable HV regulator has a tracking input from the variable offset regulator. The purpose of this signal is to avoid significant detector gain change as the amplifier offset is adjusted

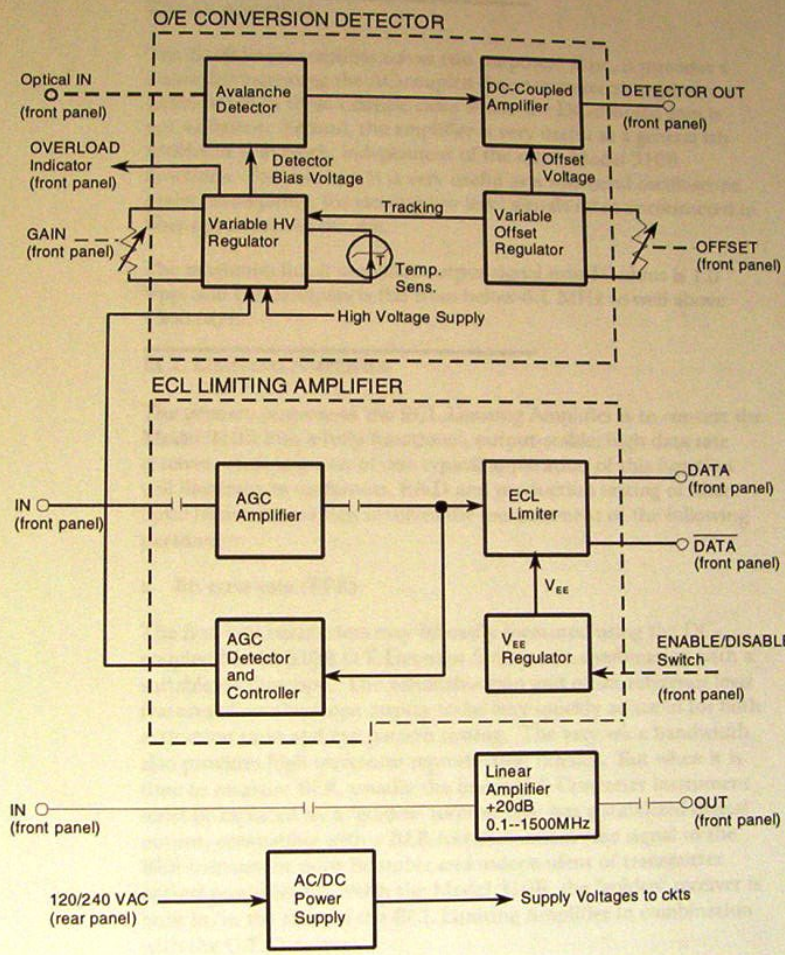


Figure 3, Model 310B Block Diagram

LINEAR AMPLIFIER

The 20dB linear amplifier serves two purposes. First, it provides a means for increasing the AC-coupled detector conversion gain by a factor of ten in those extreme cases where the DC-coupled gain is not sufficient. Second, the amplifier is very useful as a general lab wideband gain block, independent of the other Model 310B functions. For instance, it is very useful as a wideband oscilloscope probe preamplifier, for viewing low level signals often encountered in fiber optic receiver circuits.

The maximum linear amplifier output signal into 50 ohms is 1.0 Vpp, and the bandpass is flat from below 0.1 MHz to well above 1500 MHz.

ECL LIMITING AMPLIFIER

The primary purpose of the ECL Limiting Amplifier is to convert the Model 310B into a fully functional, output-stable, high data rate receiver. A description of one typical application of this function will illustrate its usefulness. R&D and production testing of fiber optic transmitters often involves the measurement of the following parameter:

a. Bit error rate (BER)

The first two parameters may be easily measured using the DC-coupled Model 310B O/E Detector function in combination with a suitable oscilloscope. The adjustable gain and offset reference level features allow the scope display to be very quickly adjusted for both extinction ratio and eye pattern testing. The very wide bandwidth also provides high waveform reproduction fidelity. But when it is time to measure BER, usually the linear O/E Converter instrument must be replaced by a "golden" receiver that has a stabilized digital output, compatible with a BER test instrument (the signal to the BER instrument must be stable and independent of transmitter optical power level). With the Model 310B, the "golden" receiver is built in, in the form of the ECL Limiting Amplifier in combination with the O/E Detector.

Reference figure 3.0. The first component block of the ECL Limiting Amplifier is a wideband, AC-coupled, automatic gain controlled (AGC) amplifier. The amplitude-stable output from this amplifier drives an ECL limiter (comparator), which slices the AGC amplifier output at the mid-point and generates complementary standard ECL output signal levels.

The AGC amplifier analog output is sampled by the AGC detector block and compared to a reference level. If a differential exists, an error amplifier adjusts the gain control level to the AGC amplifier so as to drive the output to the required level.

In addition to controlling the AGC amplifier, the AGC detector also outputs a level that controls the gain of the O/E detector. This further extends the input optical dynamic range over which the detector/ECL limiting amplifier combination can operate error-free. When the detector output is connected to the limiting amplifier input, the detector gain control should be set to maximum to allow the AGC to automatically take control of the full detector gain range. The setting of the offset control has no effect since the AGC amplifier is AC-coupled.

With the detector output connected to the limiting amplifier, both the detector and AGC amplifier are at maximum gain with no optical input. When a very low level optical signal is applied,an ECL output signal will appear prior to any gain reduction. As the optical level increases, the detector gain is first reduced to a minimum level and then the AGC amplifier gain begins to fall. The ECL output remains stable and clean, with no evidence of the internal detector and amplifier gain changes. The optical input may be raised from less than 100 nanowatts to more than 100 microwatts with no effect on the ECL output, except for a reduction in transition jitter.

The ECL limiter is supplied by a Vee supply voltage regulator, that is controlled by the front panel ENABLE/DISABLE switch. In the DISABLE position, the power is removed from the limiter, effectively squelching its operation. The primary reason for this feature is to prevent output ECL "chatter" when the ECL limiting amplifier is not in use. This objective could have been accomplished by limiter threshold hysteresis, but the price would have been reduced dynamic range for zero bit error rate performance. Squelching by power switching also has the benefit of eliminating unnecessary internal power consumption and heating when the ECL Limiting Amplifier is not in use.

4. INPUT LINE VOLTAGE MAINTENANCE AND OPTICS CLEANING

INPUT LINE VOLTAGE CONVERSION

The Model 310B contains no internal jumper options or user-accessible adjustments. The power supply for the model 310B adjust automatically for any AC input from 100 to 240 VAC.

OPTICS CLEANING

The Model 310B uses a "universal" fiber optic connector that is configured for any standard connector by screw-on adapters. If the universal connector becomes contaminated, simply remove the screw-on adaptor and clean the exposed ferrule with lens cleaning fluid (Isopropyl alcohol) and a tightly woven Q-tip or lint free swab. Dry the ferrule thoroughly with moisture-free compressed air, or by evaporation. Do not blow on the ferrule.

MAINTENANCE

No preventative maintenance is required for the instrument. The unit may be cleaned externally with a damp cloth, if required, after disconnecting from the AC power source.