



### Features

- Optocoupler, precision reference and error amplifier in single package
- Low voltage operation 2.7V
- 1.240V  $\pm$  2.5% reference
- CTR Matching 15%
- >70dB THD
- 70dB CMRR
- 3,750V<sub>rms</sub> isolation

### Applications

- Power supply feedback
- Telecom central office supply
- Telecom bricks
- Modem transformer replacement
- Digital telephone isolation

### Block Diagram



### Description

The LIA120 Optically Isolated Reference Amplifier combines IXYS IC Division's linear optical coupler technology with an industry standard 431 type precision programmable shunt regulator to provide very linear high gain with excellent temperature stability for a total gain error of less than 2dB. By using optical feedback, the LIA120 essentially eliminates temperature and gain variations due to current transfer ratio (CTR) changes in optocouplers while increasing the bandwidth up to 10X and easing engineering design constraints.

The LIA120 is very well suited for high gain feedback amplifiers that require excellent linearity and low temperature variation such as isolated power supply feedback stages, modem audio transformer replacement, isolated industrial control signals, and sensor feedback.

By using the LIA120, system designers can save precious board space and reduce component count. Available in an 8-pin surface mount package.

### Approvals

- UL 1577 Recognized Component: File E76270

### Ordering Information

Part #	Description
LIA120S	8-Pin Surface Mount, Tubed (50/Tube)
LIA120STR	8-Pin Surface Mount, Tape and Reel (1000/Reel)



**Absolute Maximum Ratings (@ 25°C)**

Parameter	Symbol	Ratings	Units
Photodiode Cathode-Anode Voltage	$V_{KAO}$	20	V
Photodiode Anode-Cathode Voltage	$V_{AKO}$	0.5	V
Input Voltage	$V_{LED}$	9	V
Input DC Current	$I_{LED}$	20	mA
Total Power Dissipation (note 1)	$P_D$	145	mW
Operating Temperature	T	-40 to +85	°C
Storage Temperature	T	-40 to +125	°C

<sup>1</sup> Derate linearly from 25°C at a rate of 2.42 mW/°C.

*Absolute Maximum Ratings are stress ratings. Stresses in excess of these ratings can cause permanent damage to the device. Functional operation of the device at conditions beyond those indicated in the operational sections of this data sheet is not implied.*

**Electrical Characteristics:**

Parameter	Conditions	Symbol	Min	Typ	Max	Units	
<b>Input Characteristics @ 25°C</b>							
LED forward voltage	$I_{LED} = 5 \text{ mA}, V_{COMP} = V_{FB}$ (Fig.1)	$V_F$	0.8	1.2	1.4	V	
Reference voltage	$I_{LED} = 10 \text{ mA}, V_{COMP} = V_{FB}$ (Fig.1)	$V_{REF}$	$T_A = -40 \text{ to } +85^\circ\text{C}$	1.210	-	1.265	V
			$T_A = 25^\circ\text{C}$	1.228	1.24	1.252	
			$T_A = -40 \text{ to } +85^\circ\text{C}$	-	32	-	
Deviation of $V_{REF}$ over temperature - See Note 1	$T_A = -40 \text{ to } +85^\circ\text{C}$	$V_{REF(DEV)}$	-	32	-	mV	
<b>Transfer Characteristics @ 25°C</b>							
Current Transfer Ratio in Feedback ( $I_{REF}/I_{LED}$ )	$I_{LED} = 5 \text{ mA}, V_{REF} = 0.5 \text{ V}$ (Fig.2)	$K_1$	1.0	2	3.0	%	
Current transfer ratio ( $I_{KA}/I_{LED}$ )	$I_{LED} = 5 \text{ mA}, V_{COMP} = V_{FB}, V_{KA} = 5 \text{ V}$ (Fig. 4)	$K_2$	1.0	2	3.0	%	
Current Transfer Ratio Matching ( $I_{KA}/I_{REF}$ )	$I_{LED} = 5 \text{ mA}, V_{KA} = 5.0 \text{ V}$	$K_3$	85	100	115	%	
Feedback input current	$I_{LED} = 10 \text{ mA}, R_1 = 10 \text{ k}\Omega$ (Fig.2)	$I_{REF}$	-	226	-	$\mu\text{A}$	
Deviation of $I_{REF}$ over temperature - See Note 1	$T_A = -40 \text{ to } +85^\circ\text{C}$	$I_{REF(DEV)}$	-	110	-	$\mu\text{A}$	
Minimum drive current	$V_{COMP} = V_{FB}$ (Fig.1)	$I_{LED(MIN)}$	1	-	-	mA	
Off-state error amplifier current	$V_{IN} = 6 \text{ V}, V_{FB} = 0$ (Fig.3)	$I_{OFF}$	-	0.001	0.1	$\mu\text{A}$	
Error amplifier output impedance - See Note 2	$I_{LED} = 0.1 \text{ mA to } 15 \text{ mA}, V_{COMP} = V_{FB}, f < 1 \text{ kHz}$ (Fig.1)	$ Z_{OUT} $	-	0.21	-	$\Omega$	
<b>Output Characteristics @ 25°C</b>							
Cathode dark current	$V_{IN} = \text{Open}, V_{KA} = 10 \text{ V}$ (Fig. 3)	$I_{KAO}$	-	0.3	100	nA	
Cathode-Anode voltage breakdown	$I_{KA} = 1 \mu\text{A}$	$BV_{KA}$	20	-	-	V	
<b>Isolation Characteristics @ 25°C</b>							
Withstand insulation voltage	$RH \leq 50\%, T_A = 25^\circ\text{C}, t = 1 \text{ min}$ (Note 3)	$V_{ISO}$	3750	-	-	$V_{rms}$	
Resistance (input to output)	$V_{I-O} = 500 \text{ V}_{DC}$ (Note 3)	$R_{I-O}$	-	$10^{12}$	-	$\Omega$	
<b>AC Characteristics @ 25°C</b>							
Bandwidth (LED) - See Note 4	-	$B_W$	-	100	-	kHz	
Common mode rejection ratio - See Note 5	$I_{LED} = 1.0 \text{ mA}, R_L = 100 \text{ k}\Omega, f = 100 \text{ Hz}$ (Fig. 5)	CMRR	-	70	-	dB	
Linearity	$I_{LED} = 5 \text{ mA}, 100 \text{ mV}_{PP}$	THD	-	70	-	dB	

1. The deviation parameters  $V_{REF(DEV)}$  and  $I_{REF(DEV)}$  are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage,  $\Delta V_{REF}$ , is defined as:

$$|\Delta V_{REF}| \text{ (ppm/}^\circ\text{C)} = \{V_{REF(DEV)}/V_{REF}(T_A = 25^\circ\text{C})\} \times 10^6 / \Delta T_A$$

where  $\Delta T_A$  is the rated operating free-air temperature range of the device.

2. The dynamic impedance is defined as  $|Z_{OUT}| = \Delta V_{COMP}/\Delta I_{LED}$ , for the application circuit in Figure 6,  $|Z_{OUT}| = K_1 R_1$

3. Device is considered as a two terminal device: Pins 1, 2, 3 and 4 are shorted together and Pins 5, 6, 7 and 8 are shorted together.

4. See compensation section for calculating bandwidth of LIA120.

5. Common mode transient immunity at output high is the maximum tolerable (positive)  $dV_{cm}/dt$  on the leading edge of the common mode impulse signal,  $V_{cm}$ , to assure that the output will remain high. Common mode transient immunity at output low is the maximum tolerable (negative)  $dV_{cm}/dt$  on the trailing edge of the common pulse signal,  $V_{cm}$ , to assure that the output will remain low.

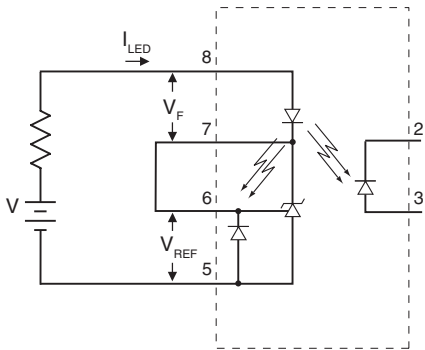


FIG. 1.  $V_{REF}$ ,  $V_F$ ,  $I_{LED}$  (MIN) TEST CIRCUIT

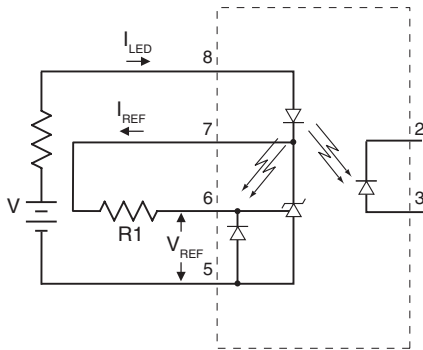


FIG. 2.  $I_{REF}$  TEST CIRCUIT

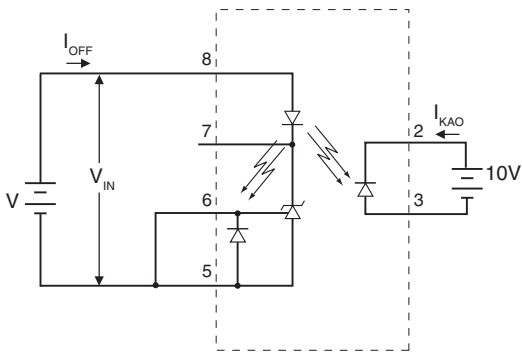


FIG. 3.  $I_{OFF}$ ,  $I_{KAO}$  TEST CIRCUIT

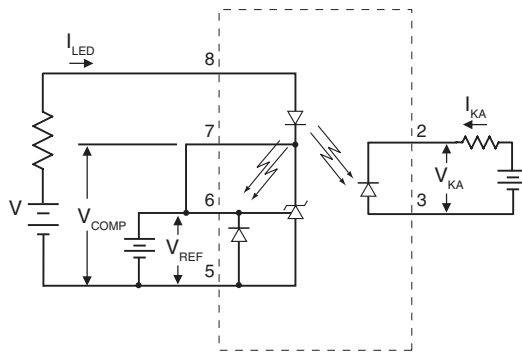


FIG. 4. CTR TEST CIRCUIT

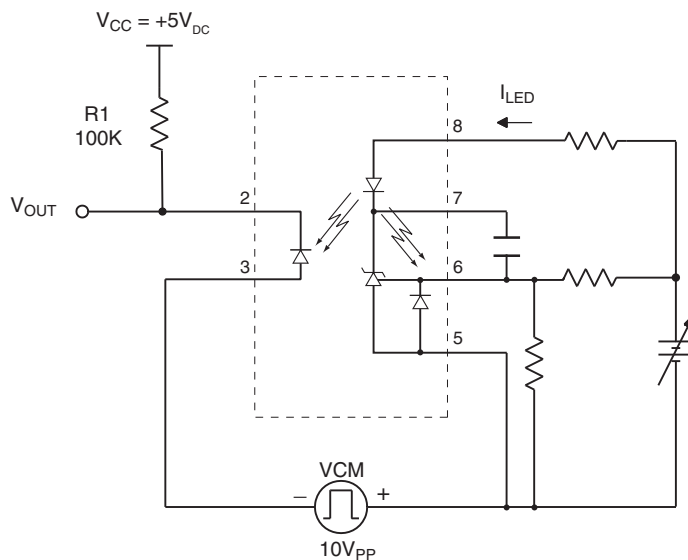
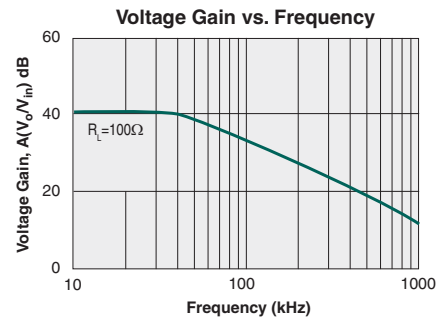
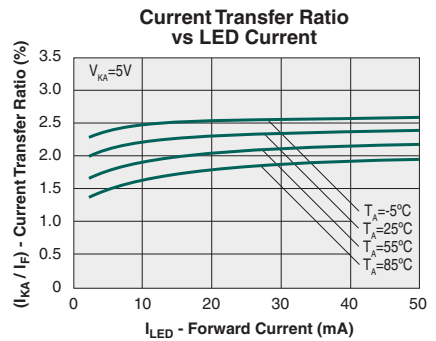
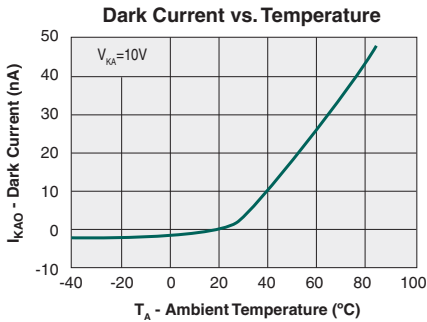
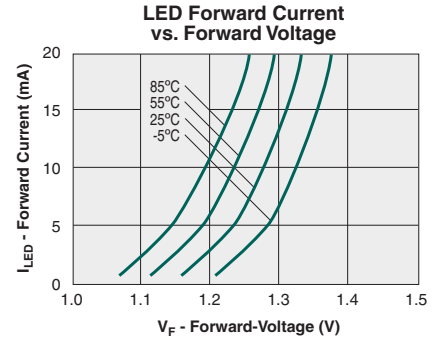
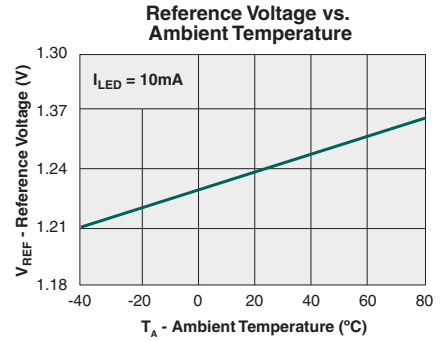


Fig. 5. CMRR Test Circuit

**PERFORMANCE DATA\***



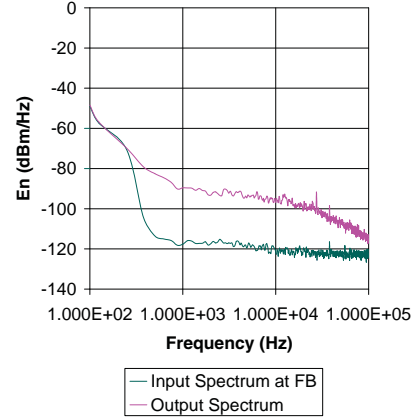
\*The Performance data shown in the graphs above is typical of device performance. For guaranteed parameters not indicated in the written specifications, please contact our application department.

PERFORMANCE DATA\*

Output Linearity  
 THD for 40dB Setup



Noise Spectrum for 40dB Gain Setup  
 (220K/2.2K Gain)



\*The Performance data shown in the graphs above is typical of device performance. For guaranteed parameters not indicated in the written specifications, please contact our application department.



Fig. 6. Power Supply Feedback Application Circuit

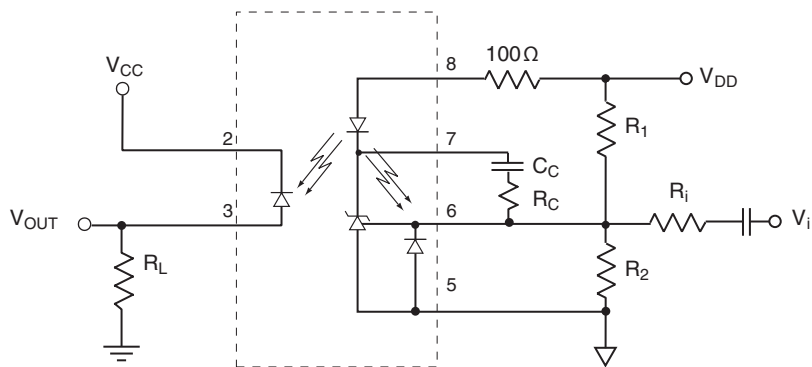


Fig. 7. Non-inverting Linear Amplifier Circuit

**The LIA120**

The LIA120 is an optically-coupled isolated linear error amplifier. It integrates three of the most fundamental elements necessary to make an isolated power supply: a reference voltage, an error amplifier, and an isolated coupling device. It is functionally equivalent to a 431 type shunt regulator plus a linear optical amplifier.

**Powering the Isolated Input**

The isolated input of the LIA120 is powered through the LED pin (pin 8) via the part to its isolated ground at pin 5. The typical operating current of the device is determined by the output voltage and current requirements as well as the CTR of the linear optocoupler. For Figure 7, the LED current requirement is set by the following equation.

$$I_{LED} = \frac{V_{out,bias}}{R_L \cdot K_1}$$

The output voltage is typically constrained by the user to satisfy the design requirements of the application circuit. Design considerations must also take into account that  $R_L$  affects the total gain and that CTR gains vary with process. Nominally the LED current should be around 1-2mA but can be as high as 10-15mA if the user requires.

LED current is limited by the resistor in series with pin 8, the LED pin, to the supply and is typically 10-100 ohms for operating currents of 1-2mA. The minimum operating voltage of 2.74V for the LIA120 from pin 8 to pin 5 is based on the sum of the voltage drop of the LED and the operational voltage headroom of the 431. Minimum operating voltage for the application circuit is therefore the sum of the LIA120 minimum operating voltage plus the voltage drop of the current limiting resistor. For a design with 1mA of LED current and a current limiting resistor of 100 ohms, the minimum operating voltage is calculated to be  $2.74 + (0.001)(100) = 2.84V$ .

**Feedback**

Setting the gain for the LIA120 is accomplished simply by setting two resistors. The application circuit in Figure 6 shows a resistor divider feeding the FB pin, so the operating conditions for the gain are governed by:

$$\frac{R_1}{R_2} = \frac{V_{in}}{V_{ref}} - \left( \frac{V_{out}}{V_{ref}} \cdot \frac{R_1}{R_L} \right) \cdot \frac{1}{K_3} - 1$$

$K_3$  is taken from the datasheet as 1 nominally. The AC gain of the setup can be represented by:

$$A_v (V_{OUT}/V_{IN}) = \frac{R_L}{R_1} \cdot \left( \frac{R_2 || R_1 || \left( \frac{1}{G_m \cdot CTR_{FB}} \right)}{\left( \frac{1}{G_m \cdot CTR_{Forward}} \right)} \right)$$

Where:

- $G_m = 1/Z_{OUT}$  which is ~ 3 Siemens
- $CTR_{FB}$  is approximately  $CTR_{Forward} = 0.02$  nominally
- $CTR_{FB} = K_1$ ,  $CTR_{FORWARD} = K_2$ ,  $CTR_{FORWARD}/CTR_{FB} = K_3$

This calculation provides a more accurate gain calculation, but is only necessary when the voltage divider resistor's impedance is becoming close to the optical output impedance of the shunt regulator.

**Compensation**

The LIA120 is relatively easy to compensate but two factors must be considered when analyzing the circuit. The frequency response of the LIA120 can be as high as 40kHz, but must be limited because of the closed loop optical feedback to the input signal. In the localized optical feedback there are two poles to consider, the 431 dominant pole and the linear optical coupler pole. The open loop gain of the optical loop (for the application diagram) is:

$$A_{v, OPTICAL} = G_m \cdot CTR_{FB} \cdot R_1 || R_2$$

The open loop gain is affected by the selection of  $R_1$  and  $R_2$ , and without any compensation the circuit may oscillate. The addition of a compensation network ( $C_c$  and  $R_c$ ) control the maximum bandwidth so that open loop gain is rolling off long before the optical pole causes the circuit to oscillate. The optical pole is at ~180kHz so the bandwidth is typically limited to less than 40kHz.

While there is flexibility in the part to change the compensation technique, the upper limit on frequency response is generally desired to be such that the circuit will not oscillate for a large selection of  $R_1$  and  $R_2$ . Therefore the compensation capacitor should not be less than 100pF, which gives adequate bandwidth for most designs.

The bandwidth through the part will be:

$$BW(Hz) = \frac{Gm \cdot CTR_{FB} \cdot R_I \parallel R_2}{2 \cdot \pi \cdot \left( Gm \cdot R_{LED} \cdot C_C \cdot R_I \parallel R_2 + \frac{1}{P_1} \right)} \leq BW(Hz)_{MAX}$$

Where:

$P_1$  max is 1kHz (6.28krad/s) due to the internal compensation of the 431.

CTR is the current transfer ratio of the feedback optocoupler (0.001-0.003).

$R_{LED}$  is the combined impedance of the limiting resistor and the LED resistance (25 ohms) and Gm is the transconductance of the 431 (3 Siemens).

However, since some of these elements vary over operating conditions and temperature, the bandwidth should be practically limited to less than 40kHz to avoid oscillations, which is the value computed by 100pF.

### Photodiode

The output of the LIA120 is a photodiode capable of withstanding high voltages. For the most accurate results, attempt to bias the voltage across the cathode anode the same as  $V_{REF}$ . The load resistors can be placed in series with the cathode or anode for desired output polarity.



**Manufacturing Information**

**Moisture Sensitivity**



All plastic encapsulated semiconductor packages are susceptible to moisture ingress. IXYS Integrated Circuits Division classified all of its plastic encapsulated devices for moisture sensitivity according to the latest version of the joint industry standard, **IPC/JEDEC J-STD-020**, in force at the time of product evaluation. We test all of our products to the maximum conditions set forth in the standard, and guarantee proper operation of our devices when handled according to the limitations and information in that standard as well as to any limitations set forth in the information or standards referenced below.

Failure to adhere to the warnings or limitations as established by the listed specifications could result in reduced product performance, reduction of operable life, and/or reduction of overall reliability.

This product carries a **Moisture Sensitivity Level (MSL) rating** as shown below, and should be handled according to the requirements of the latest version of the joint industry standard **IPC/JEDEC J-STD-033**.

Device	Moisture Sensitivity Level (MSL) Rating
LIA120S	MSL 1

**ESD Sensitivity**



This product is **ESD Sensitive**, and should be handled according to the industry standard **JESD-625**.

**Reflow Profile**

This product has a maximum body temperature and time rating as shown below. All other guidelines of **J-STD-020** must be observed.

Device	Maximum Temperature x Time
LIA120S	250°C for 30 seconds

**Board Wash**

IXYS Integrated Circuits Division recommends the use of no-clean flux formulations. However, board washing to remove flux residue is acceptable. Since IXYS Integrated Circuits Division employs the use of silicone coating as an optical waveguide in many of its optically isolated products, the use of a short drying bake could be necessary if a wash is used after solder reflow processes. Chlorine- or Fluorine-based solvents or fluxes should not be used. Cleaning methods that employ ultrasonic energy should not be used.

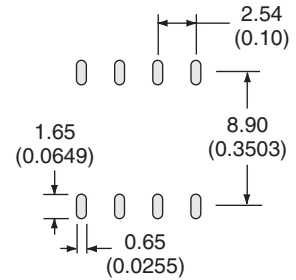


Mechanical Dimensions

LIA120S

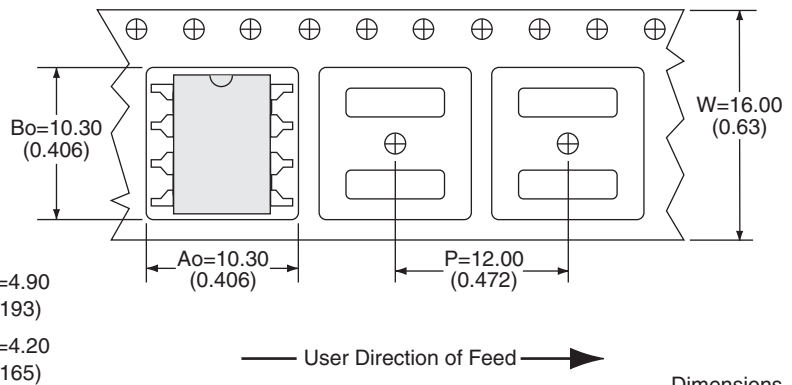


PCB Land Pattern



Dimensions  
mm  
(inches)

LIA120STR Tape & Reel



Dimensions  
mm  
(inches)

NOTES:

1. Dimensions carry tolerances of EIA Standard 481-2
2. Tape complies with all "Notes" for constant dimensions listed on page 5 of EIA-481-2

For additional information please visit our website at: [www.ixysic.com](http://www.ixysic.com)

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