BURR - BROWN®

OPT301

INTEGRATED PHOTODIODE AND AMPLIFIER

FEATURES

- PHOTODIODE SIZE: 0.090 x 0.090 inch (2.29 x 2.29mm)
- 1MΩ FEEDBACK RESISTOR
- HIGH RESPONSIVITY: 0.47A/W (650nm)
- IMPROVED UV RESPONSE
- LOW DARK ERRORS: 2mV
- BANDWIDTH: 4kHz
- WIDE SUPPLY RANGE: ±2.25 to ±18V
- LOW QUIESCENT CURRENT: 400μA
- HERMETIC TO-99

APPLICATIONS

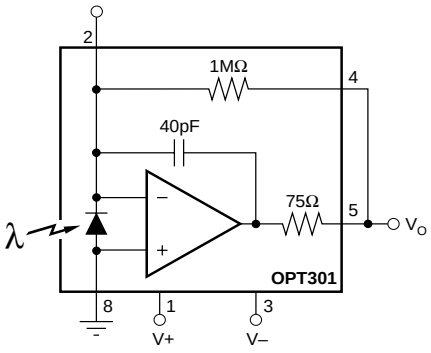
- MEDICAL INSTRUMENTATION
- LABORATORY INSTRUMENTATION
- POSITION AND PROXIMITY SENSORS
- PHOTOGRAPHIC ANALYZERS
- SMOKE DETECTORS

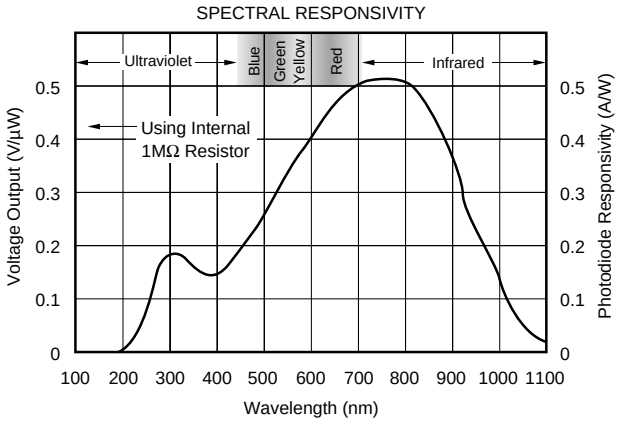
DESCRIPTION

The OPT301 is an opto-electronic integrated circuit containing a photodiode and transimpedance amplifier on a single dielectrically isolated chip. The transimpedance amplifier consists of a precision FET-input op amp and an on-chip metal film resistor. The 0.09 x 0.09 inch photodiode is operated at zero bias for excellent linearity and low dark current.

The integrated combination of photodiode and transimpedance amplifier on a single chip eliminates the problems commonly encountered in discrete designs such as leakage current errors, noise pick-up and gain peaking due to stray capacitance.

The OPT301 operates over a wide supply range (±2.25 to ±18V) and supply current is only 400μA. It is packaged in a hermetic TO-99 metal package with a glass window, and is specified for the –40°C to 85°C temperature range.





International Airport Industrial Park • Mailing Address: PO Box 11400, Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd., Tucson, AZ 85706 • Tel: (520) 746-1111 • Twx: 910-952-1111
Internet: http://www.burr-brown.com/ • FAXLine: (800) 548-6133 (US/Canada Only) • Cable: BBRCORP • Telex: 066-6491 • FAX: (520) 889-1510 • Immediate Product Info: (800) 548-6132

©1994 Burr-Brown Corporation
PDS-1228B
Printed in U.S.A. January, 1994

SPECIFICATIONS

ELECTRICAL

At T_A = +25°C, V_S = ±15V, λ = 650nm, internal 1MΩ feedback resistor, unless otherwise noted.

PARAMETER	CONDITIONS	OPT301M MIN	OPT301M TYP	OPT301M MAX	UNITS
RESPONSIVITY					
Photodiode Current	650nm		0.47		A/W
Voltage Output	650nm		0.47		V/µW
vs Temperature			200		ppm/°C
Unit-to-Unit Variation	650nm		±5		%
Nonlinearity(1)	FS Output = 10V		0.01		% of FS
Photodiode Area	(0.090 x 0.090in)		0.008		in^2
	(2.29 x 2.29mm)		5.2		mm^2
DARK ERRORS, RTO(2)					
Offset Voltage, Output			±0.5	±2	mV
vs Temperature			±10		µV/°C
vs Power Supply	V_S = ±2.25V to ±18V		10	100	µV/V
Voltage Noise	Measured BW = 0.1 to 100kHz		160		µVrms
RESISTOR—1MΩ Internal					
Resistance			1		MΩ
Tolerance			±0.5	±2	%
vs Temperature			50		ppm/°C
FREQUENCY RESPONSE					
Bandwidth, Large or Small-Signal, –3dB			4		kHz
Rise Time, 10% to 90%			90		µs
Settling Time, 1%	FS to Dark		240		µs
0.1%	FS to Dark		350		µs
0.01%	FS to Dark		900		µs
Overload Recovery Time	100% overdrive, V_S = ±15V		240		µs
	100% overdrive, V_S = ±5V		500		µs
	100% overdrive, V_S = ±2.25V		1000		µs
OUTPUT					
Voltage Output	R_L = 10kΩ	(V+) – 1.25	(V+) – 0.65		V
	R_L = 5kΩ	(V+) – 2	(V+) – 1		V
Capacitive Load, Stable Operation			10		nF
Short-Circuit Current			±18		mA
POWER SUPPLY					
Specified Operating Voltage			±15		V
Operating Voltage Range		±2.25		±18	V
Quiescent Current	I_O = 0		±0.4	±0.5	mA
TEMPERATURE RANGE					
Specification		–40		+85	°C
Operating/Storage		–55		+125	°C
Thermal Resistance, θ_{JA}			200		°C/W

NOTES: (1) Deviation in percent of full scale from best-fit straight line. (2) Referred to Output. Includes all error sources.

PHOTODIODE SPECIFICATIONS

At T_A = +25°C, unless otherwise noted.

PARAMETER	CONDITIONS	Photodiode of OPT301 MIN	Photodiode of OPT301 TYP	Photodiode of OPT301 MAX	UNITS
Photodiode Area	(0.090 x 0.090in)		0.008		in^2
	(2.29 x 2.29mm)		5.1		mm^2
Current Responsivity	650nm		0.47		A/W
Dark Current	V_D = 0V(1)		500		fA
vs Temperature			doubles every 10°C		
Capacitance	V_D = 0V(1)		4000		pF

NOTE: (1) Voltage Across Photodiode.

SPECIFICATIONS (CONT)

ELECTRICAL

Op Amp Section of OPT301[1]

At T_A = +25°C, V_S = ±15V, unless otherwise noted.

PARAMETER	CONDITIONS	OPT301 Op Amp MIN	OPT301 Op Amp TYP	OPT301 Op Amp MAX	UNITS
INPUT					
Offset Voltage			±0.5		mV
vs Temperature			±5		µV/°C
vs Power Supply	V_S = ±2.25V to ±18V		10		µV/V
Input Bias Current			1		pA
vs Temperature			doubles every 10°C		
NOISE					
Input Voltage Noise					
Voltage Noise Density, f=10Hz			30		nV/√Hz
f=100Hz			25		nV/√Hz
f=1kHz			15		nV/√Hz
Current Noise Density, f=1kHz			0.8		fA/√Hz
INPUT VOLTAGE RANGE					
Common-Mode Input Range			±14.4		V
Common-Mode Rejection			106		dB
INPUT IMPEDANCE					
Differential			10^{12}||3		Ω||pF
Common-Mode			10^{12}||3		Ω||pF
OPEN-LOOP GAIN					
Open-Loop Voltage Gain			120		dB
FREQUENCY RESPONSE					
Gain-Bandwidth Product			380		kHz
Slew Rate			0.5		V/µs
Settling Time 0.1%			4		µs
0.01%			5		µs
OUTPUT					
Voltage Output	R_L = 10kΩ	(V+) – 1.25	(V+) – 0.65		V
	R_L = 5kΩ	(V+) – 2	(V+) – 1		V
Short-Circuit Current			±18		mA
POWER SUPPLY					
Specified Operating Voltage			±15		V
Operating Voltage Range		±2.25		±18	V
Quiescent Current	I_O = 0		±0.4	±0.5	mA

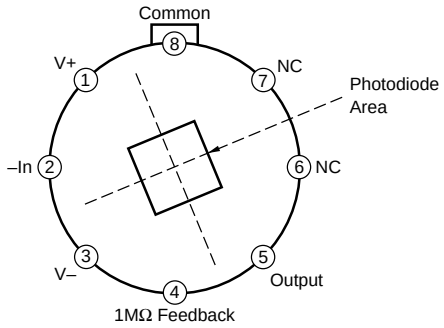
NOTE: (1) Op amp specifications provided for information and comparison only.

6

The information provided herein is believed to be reliable; however, BURR-BROWN assumes no responsibility for inaccuracies or omissions. BURR-BROWN assumes no responsibility for the use of this information, and all use of such information shall be entirely at the user's own risk. Prices and specifications are subject to change without notice. No patent rights or licenses to any of the circuits described herein are implied or granted to any third party. BURR-BROWN does not authorize or warrant any BURR-BROWN product for use in life support devices and/or systems.

PIN CONFIGURATION

Top View



NOTE: Metal package is internally connected to common (Pin 8).

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	±18V
Input Voltage Range (Common Pin)	$\pm V_S$
Output Short-Circuit (to ground)	Continuous
Operating Temperature	–55°C to +125°C
Storage Temperature	–55°C to +125°C
Junction Temperature	+125°C
Lead Temperature (soldering, 10s)	+300°C

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE INFORMATION

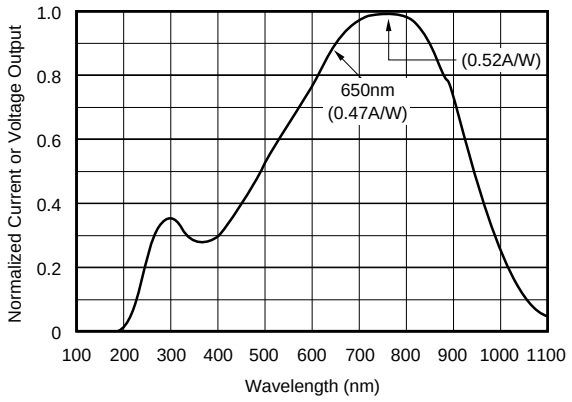
PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER(1)
OPT301M	8-Pin TO-99	001-1

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

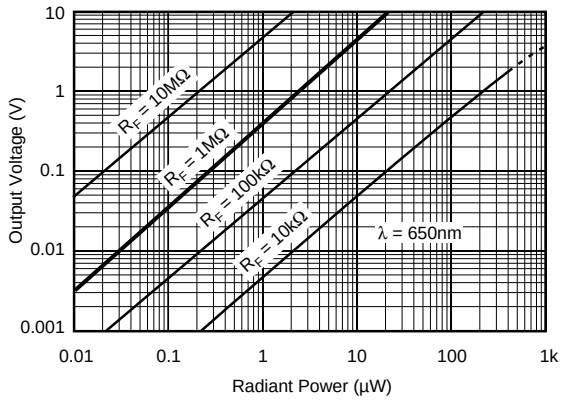
TYPICAL PERFORMANCE CURVES

At T_A = +25°C, V_S = ±15V, λ = 650nm, unless otherwise noted.

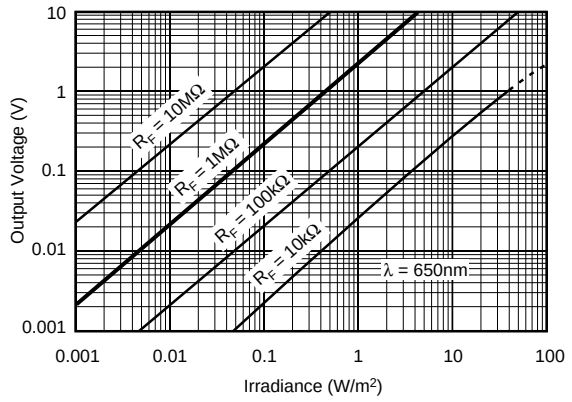
NORMALIZED SPECTRAL RESPONSIVITY



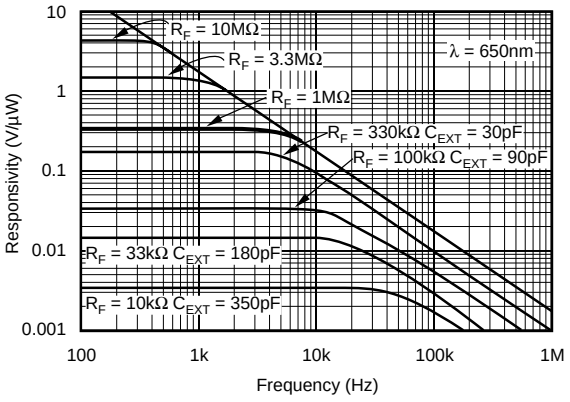
VOLTAGE RESPONSIVITY vs RADIANT POWER



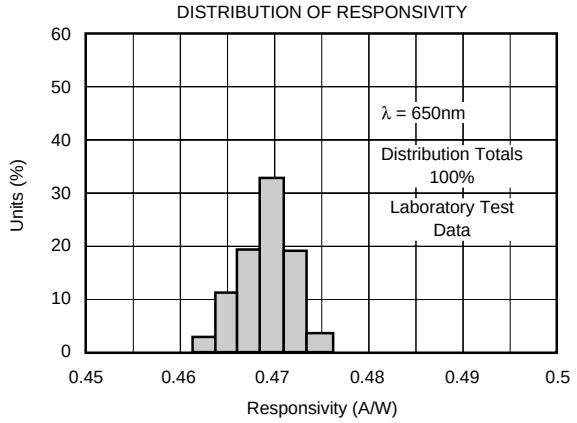
VOLTAGE RESPONSIVITY vs IRRADIANCE



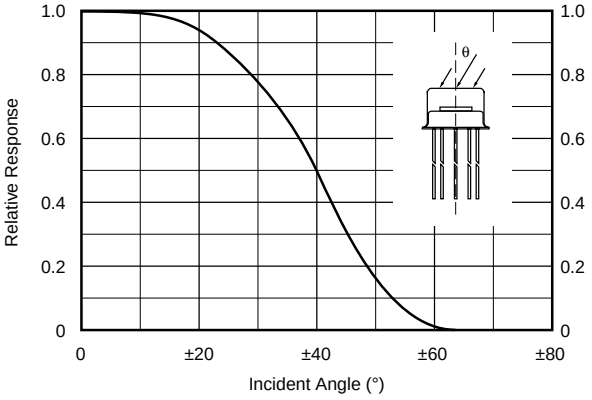
VOLTAGE OUTPUT RESPONSIVITY vs FREQUENCY



DISTRIBUTION OF RESPONSIVITY



RESPONSE vs INCIDENT ANGLE

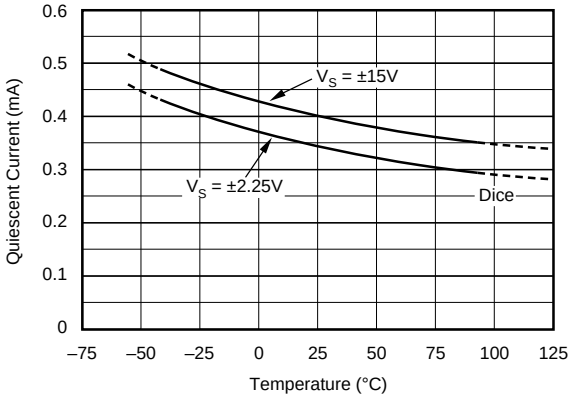


6

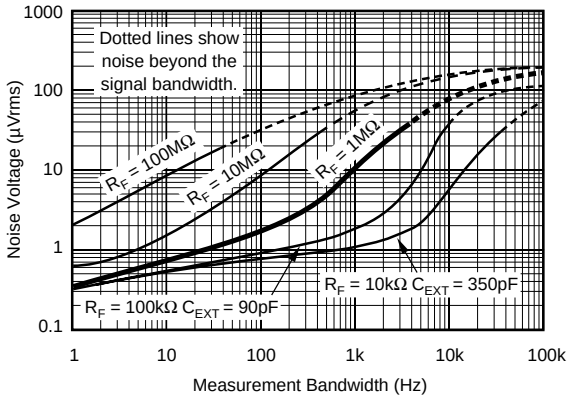
TYPICAL PERFORMANCE CURVES

At T_A = +25°C, V_S = ±15V, λ = 650nm, unless otherwise noted.

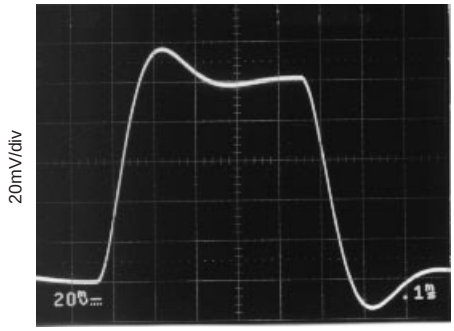
QUIESCENT CURRENT vs TEMPERATURE



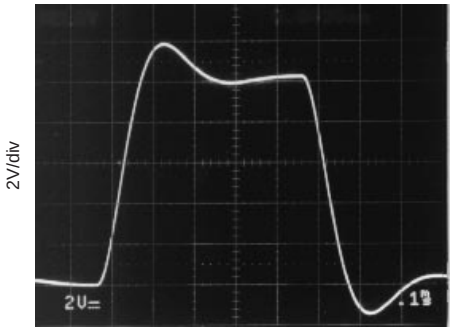
OUTPUT NOISE VOLTAGE vs MEASUREMENT BANDWIDTH



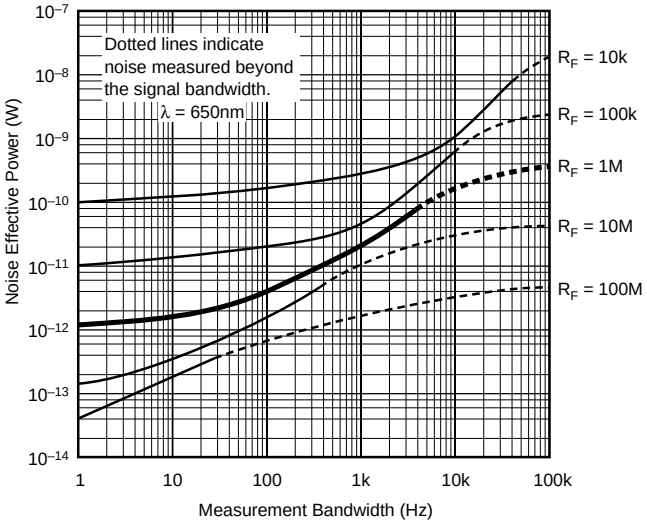
SMALL-SIGNAL DYNAMIC RESPONSE



LARGE-SIGNAL DYNAMIC RESPONSE



NOISE EFFECTIVE POWER vs MEASUREMENT BANDWIDTH



APPLICATIONS INFORMATION

Figure 1 shows the basic connections required to operate the OPT301. Applications with high-impedance power supplies may require decoupling capacitors located close to the device pins as shown. Output is zero volts with no light and increases with increasing illumination.

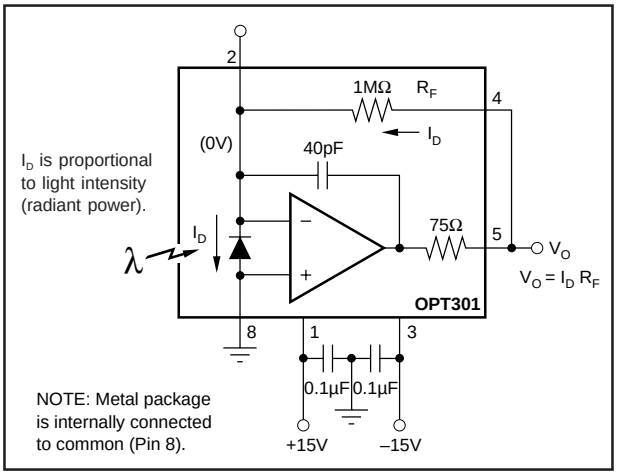


FIGURE 1. Basic Circuit Connections.

Photodiode current, I_D, is proportional to the radiant power or flux (in watts) falling on the photodiode. At a wavelength of 650nm (visible red) the photodiode Responsivity, R_I, is approximately 0.45A/W. Responsivity at other wavelengths is shown in the typical performance curve "Responsivity vs Wavelength."

The typical performance curve "Output Voltage vs Radiant Power" shows the response throughout a wide range of radiant power. The response curve "Output Voltage vs Irradiance" is based on the photodiode area of $5.23 \times 10^{-6} m^2$.

The OPT301's voltage output is the product of the photodiode current times the feedback resistor, ($I_D R_F$). The internal feedback resistor is laser trimmed to 1MΩ ±2%. Using this resistor, the output voltage responsivity, R_V, is approximately 0.45V/µW at 650nm wavelength.

An external resistor can be used to set a different voltage responsivity. For values of R_F less than 1MΩ, an external capacitor, C_{EXT}, should be connected in parallel with R_F (see Figure 2). This capacitor eliminates gain peaking and prevents instability. The value of C_{EXT} can be read from the table in Figure 2.

LIGHT SOURCE POSITIONING

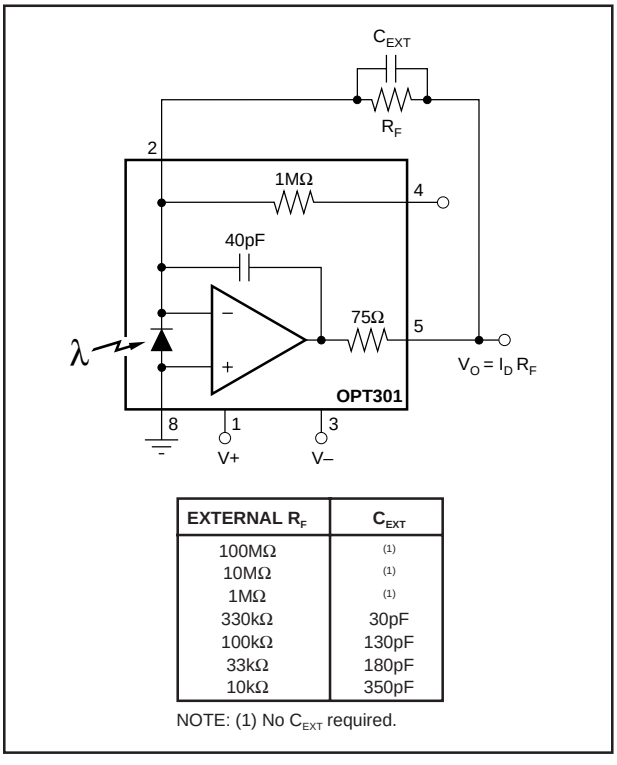
The OPT301 is 100% tested with a light source that uniformly illuminates the full area of the integrated circuit, including the op amp. Although all IC amplifiers are light-sensitive to some degree, the OPT301 op amp circuitry is designed to minimize this effect. Sensitive junctions are shielded with metal, and differential stages are cross-coupled. Furthermore, the photodiode area is very large relative to the op amp input circuitry making these effects negligible.

If your light source is focused to a small area, be sure that it is properly aimed to fall on the photodiode. If a narrowly focused light source were to miss the photodiode area and fall only on the op amp circuitry, the OPT301 would not perform properly. The large (0.090 x 0.090 inch) photodiode area allows easy positioning of narrowly focused light sources. The photodiode area is easily visible—it appears very dark compared to the surrounding active circuitry.

The incident angle of the light source also affects the apparent sensitivity in uniform irradiance. For small incident angles, the loss in sensitivity is simply due to the smaller effective light gathering area of the photodiode (proportional to the cosine of the angle). At a greater incident angle, light is reflected and scattered by the side of the package. These effects are shown in the typical performance curve "Response vs Incident Angle."

DARK ERRORS

The dark errors in the specification table include all sources. The dominant error source is the input offset voltage of the op amp. Photodiode dark current and input bias current of the op amp are approximately 2pA and contribute virtually no offset error at room temperature. Dark current and input bias current double for each 10°C above 25°C. At 70°C, the error current can be approximately 100pA. This would produce a 1mV offset with R_F = 10MΩ. The OPT301 is useful with feedback resistors of 100MΩ or greater at room temperature. The dark output voltage can be trimmed to zero with the optional circuit shown in Figure 3.



EXTERNAL R_F	C_{EXT}
100MΩ	(1)
10MΩ	(1)
1MΩ	(1)
330kΩ	30pF
100kΩ	130pF
33kΩ	180pF
10kΩ	350pF

NOTE: (1) No C_{EXT} required.

FIGURE 2. Using External Feedback Resistor.

When used with very large feedback resistors, tiny leakage currents on the circuit board can degrade the performance of the OPT301. Careful circuit board design and clean assembly procedures will help achieve best performance. A "guard trace" on the circuit board can help minimize leakage to the critical non-inverting input (pin 2). This guard ring should encircle pin 2 and connect to Common, pin 8.

DYNAMIC RESPONSE

Using the internal 1MΩ resistor, the dynamic response of the photodiode/op amp combination can be modeled as a simple R/C circuit with a –3dB cutoff frequency of 4kHz. This yields a rise time of approximately 90µs (10% to 90%). Dynamic response is not limited by op amp slew rate. This is demonstrated by the dynamic response oscilloscope photographs showing virtually identical large-signal and small-signal response.

Dynamic response will vary with feedback resistor value as shown in the typical performance curve "Voltage Output Responsivity vs Frequency." Rise time (10% to 90%) will vary according to the –3dB bandwidth produced by a given feedback resistor value—

$$t_R \approx \frac{0.35}{f_C} \quad (1)$$

where:

t_R is the rise time (10% to 90%)

f_C is the –3dB bandwidth

LINEARITY PERFORMANCE

Current output of the photodiode is very linear with radiant power throughout a wide range. Nonlinearity remains below approximately 0.02% up to 100µA photodiode current. The photodiode can produce output currents of 1mA or greater with high radiant power, but nonlinearity increases to several percent in this region.

This excellent linearity at high radiant power assumes that the full photodiode area is uniformly illuminated. If the light source is focused to a small area of the photodiode, nonlinearity will occur at lower radiant power.

NOISE PERFORMANCE

Noise performance of the OPT301 is determined by the op amp characteristics in conjunction with the feedback components and photodiode capacitance. The typical performance curve "Output Noise Voltage vs Measurement Bandwidth" shows how the noise varies with R_F and measured bandwidth (1Hz to the indicated frequency). The signal bandwidth of the OPT301 is indicated on the curves. Noise can be reduced by filtering the output with a cutoff frequency equal to the signal bandwidth.

Output noise increases in proportion to the square-root of the feedback resistance, while responsivity increases linearly with feedback resistance. So best signal-to-noise ratio is achieved with large feedback resistance. This comes with the trade-off of decreased bandwidth.

The noise performance of a photodetector is sometimes characterized by Noise Effective Power (NEP). This is the radiant power which would produce an output signal equal to the noise level. NEP has the units of radiant power (watts). The typical performance curve "Noise Effective Power vs Measurement Bandwidth" shows how NEP varies with R_F and measurement bandwidth.

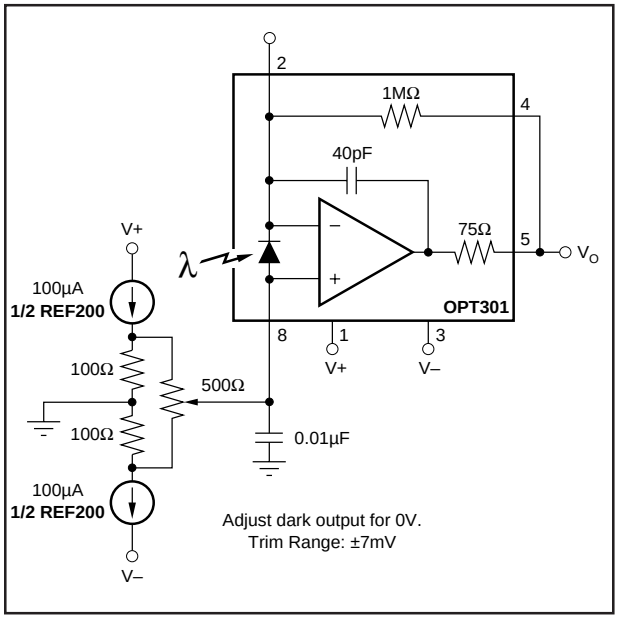


FIGURE 3. Dark Error (Offset) Adjustment Circuit.

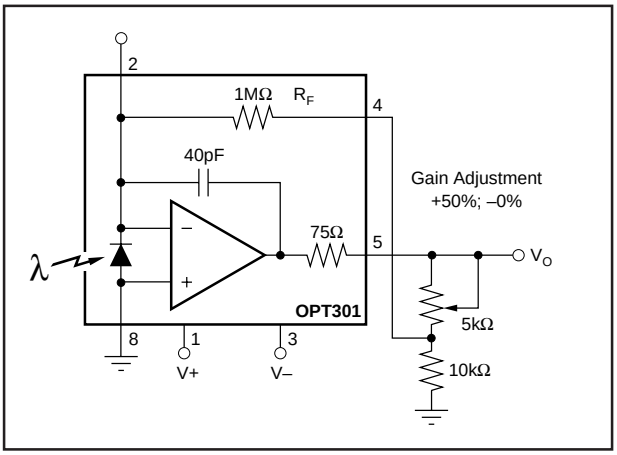
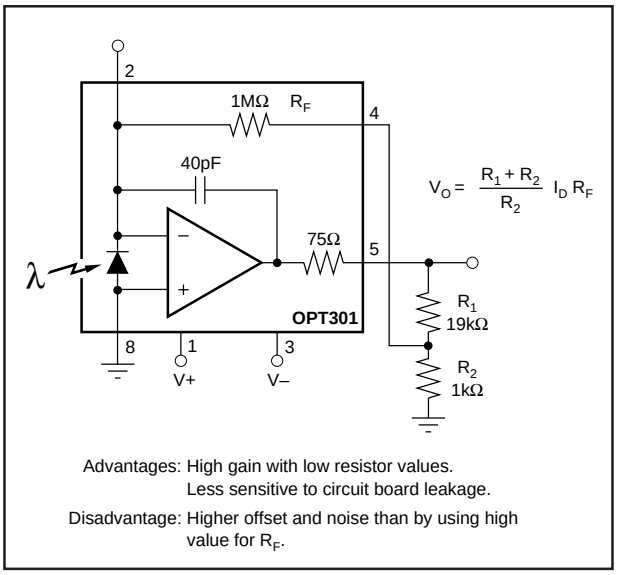


FIGURE 4. Responsivity (Gain) Adjustment Circuit.



Advantages: High gain with low resistor values.
Less sensitive to circuit board leakage.

Disadvantage: Higher offset and noise than by using high value for R_F.

FIGURE 5. "T" Feedback Network.

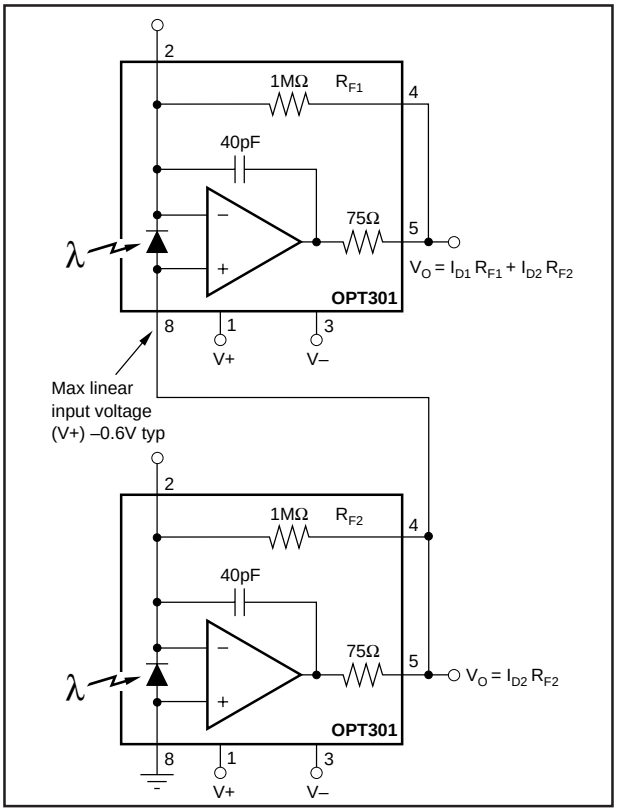


FIGURE 6. Summing Output of Two OPT301s.

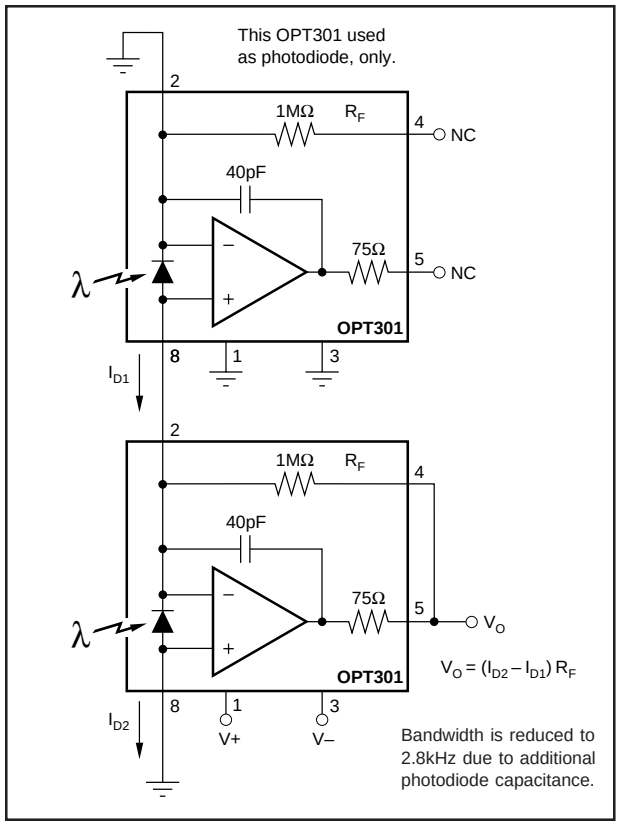


FIGURE 7. Differential Light Measurement.

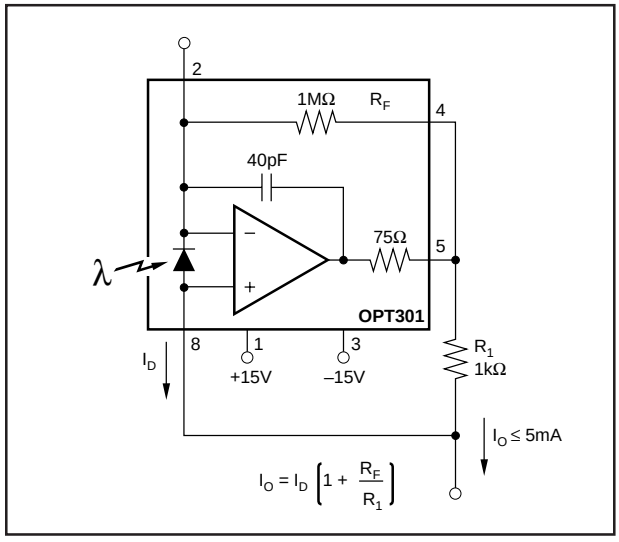


FIGURE 8. Current Output Circuit.

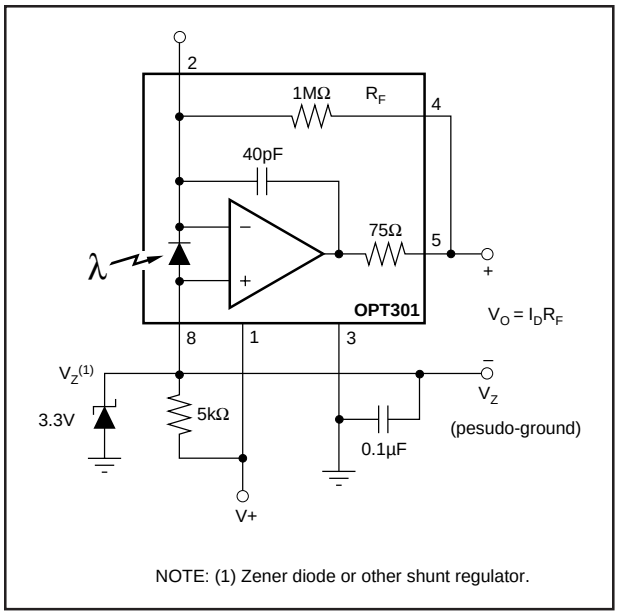


FIGURE 9. Single Power Supply Operation.

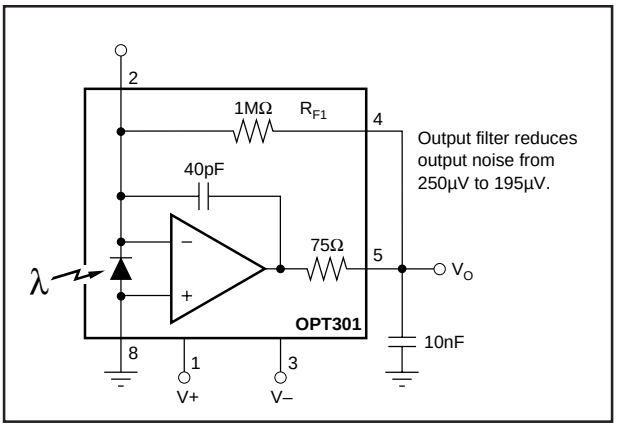


FIGURE 10. Output Filter to Reduce Noise.

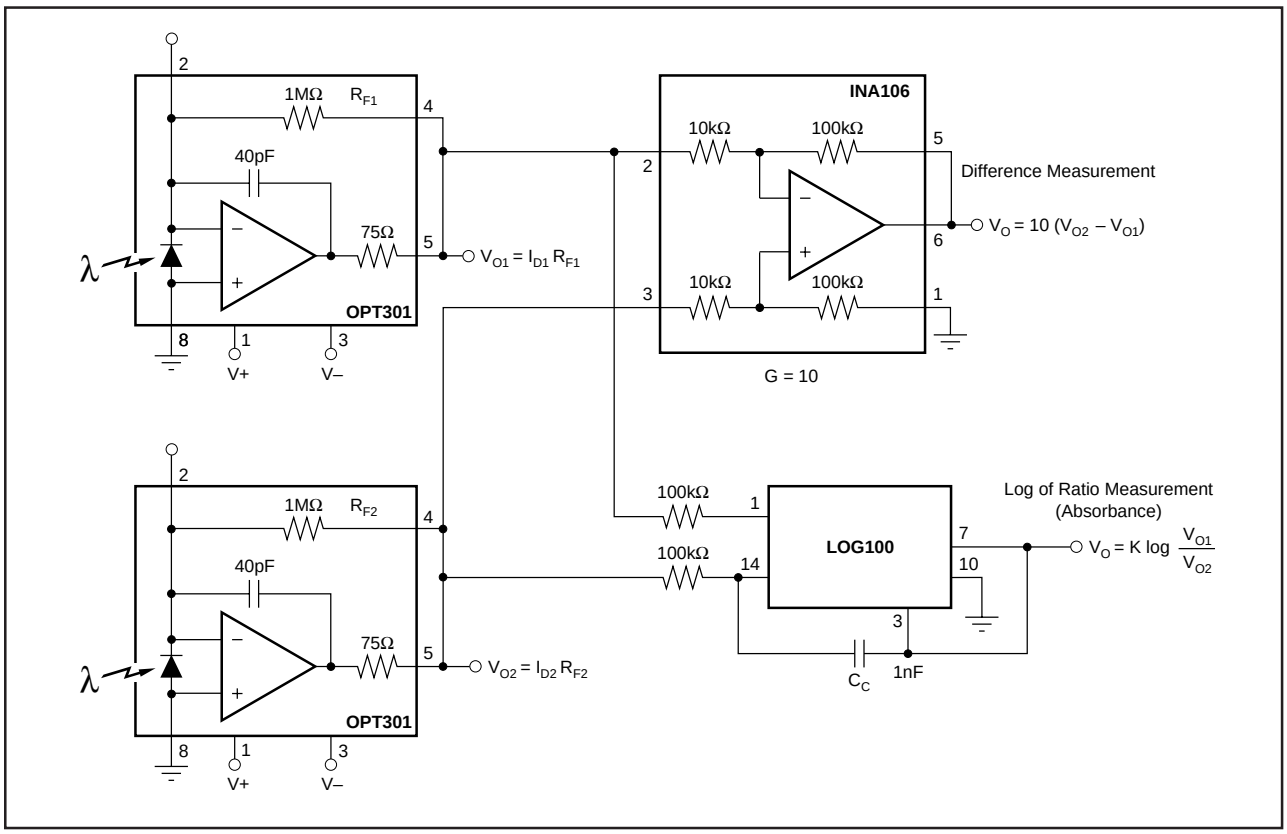


FIGURE 11. Differential Light Measurement.

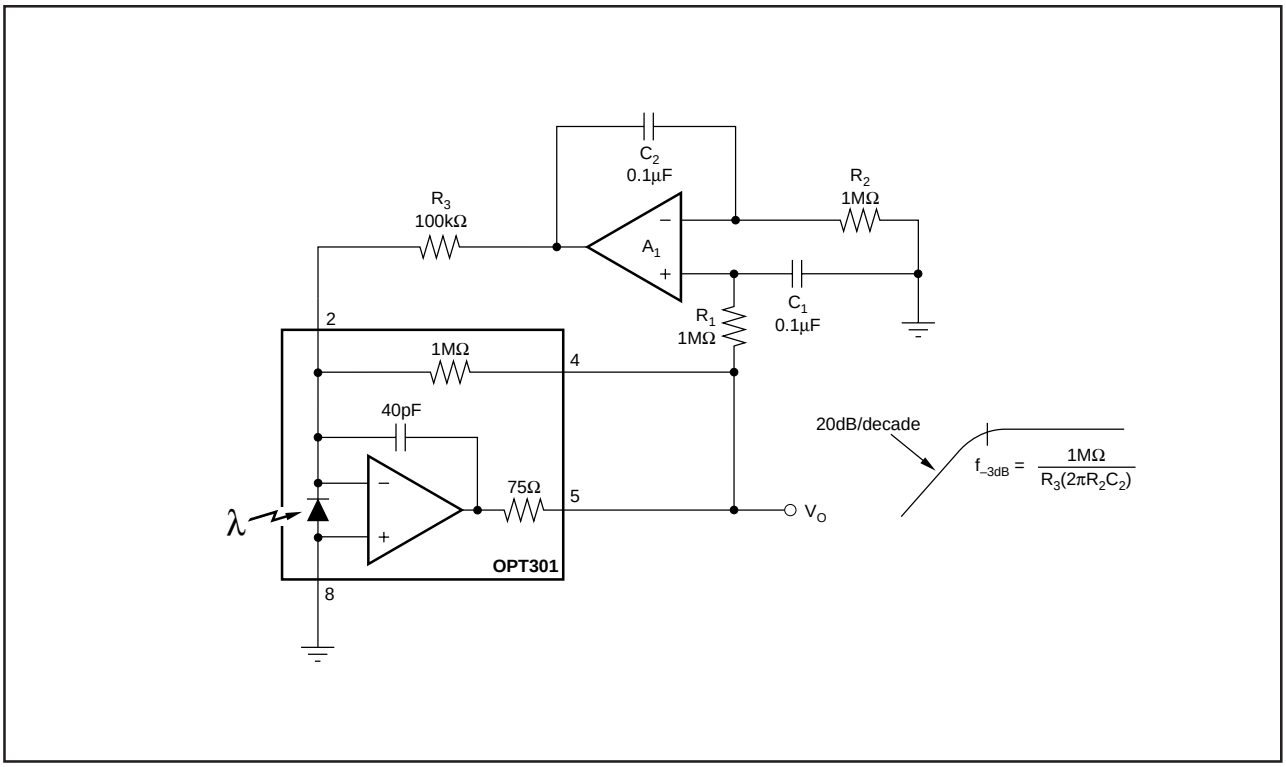


FIGURE 12. DC Restoration Rejects Unwanted Steady-State Background Light.

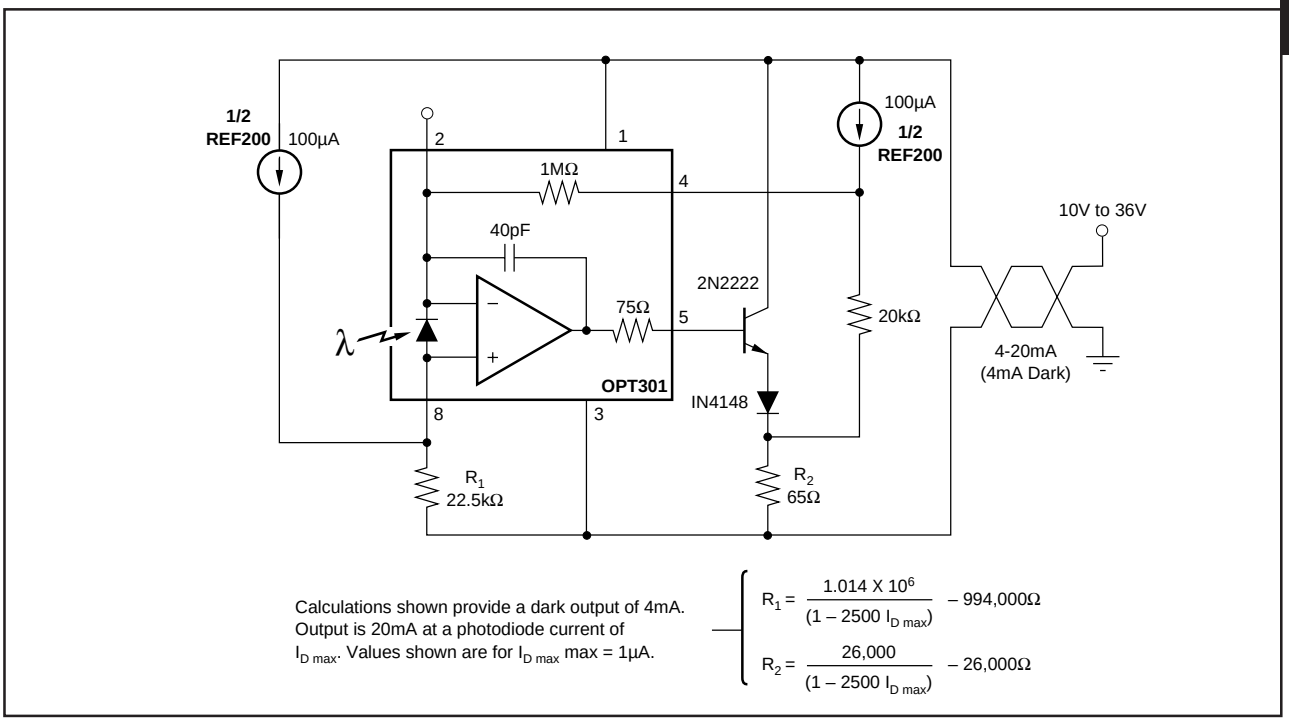


FIGURE 13. 4-20mA Current-Loop Transmitter.

IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.

Copyright © 2000, Texas Instruments Incorporated