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

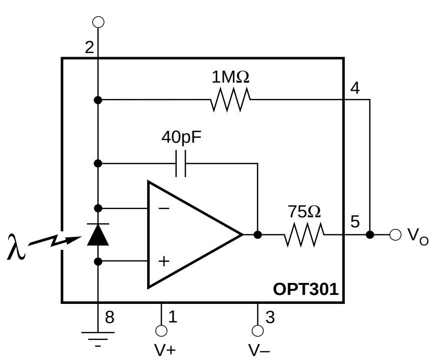
- MEDICAL INSTRUMENTATION
- LABORATORY INSTRUMENTATION
- POSITION AND PROXIMITY SENSORS
- PHOTOGRAPHIC ANALYZERS
- SMOKE DETECTORS

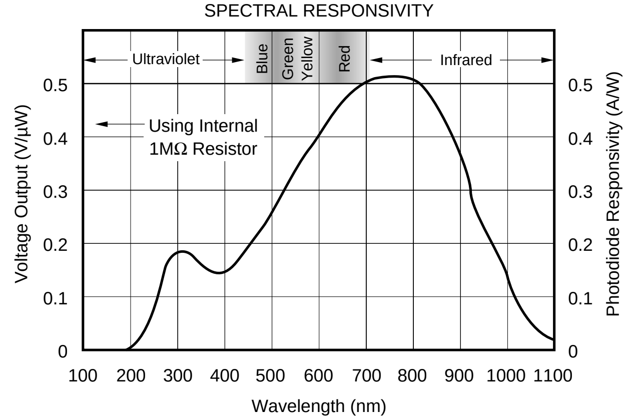
DESCRIPTION

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

PDS-1228B

Printed in U.S.A. January, 1994

SBBS001

SPECIFICATIONS

ELECTRICAL

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

PARAMETER	CONDITIONS	OPT301M			UNITS
		MIN	TYP	MAX	
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			UNITS
		MIN	TYP	MAX	
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.

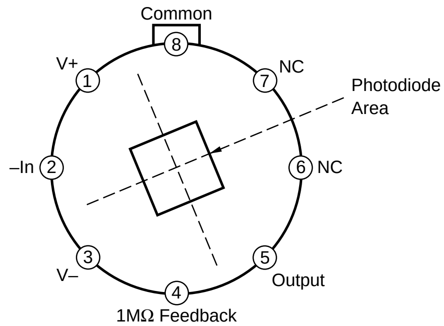
PARAMETER	CONDITIONS	OPT301 Op Amp MIN	TYP	MAX	UNITS
INPUT					
Offset Voltage			±0.5		mV
vs Temperature			±5		μV/°C
vs Power Supply	V_S = ±2.25V to ±18V		10		μV/V
Input Bias Current			1		pA
vs Temperature			doubles every 10°C		
NOISE					
Input Voltage Noise					
Voltage Noise Density, f=10Hz			30		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

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

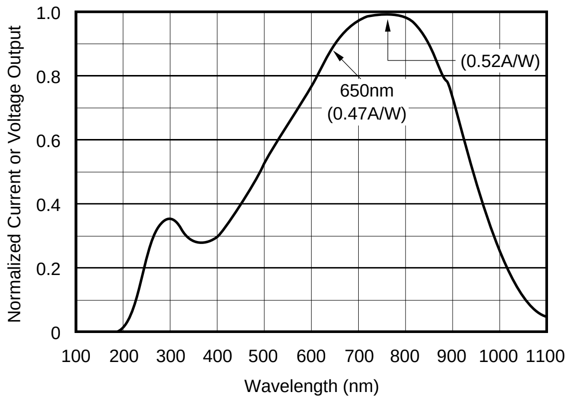
PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER[1]
OPT301M	8-Pin TO-99	001-1

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

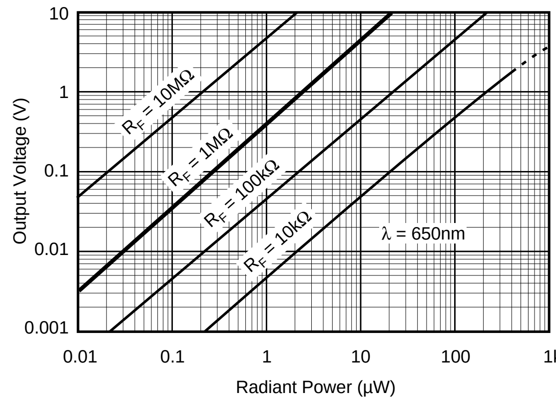
TYPICAL PERFORMANCE CURVES

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

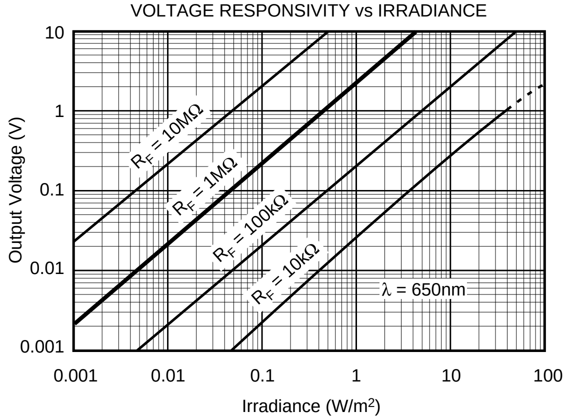
NORMALIZED SPECTRAL RESPONSIVITY



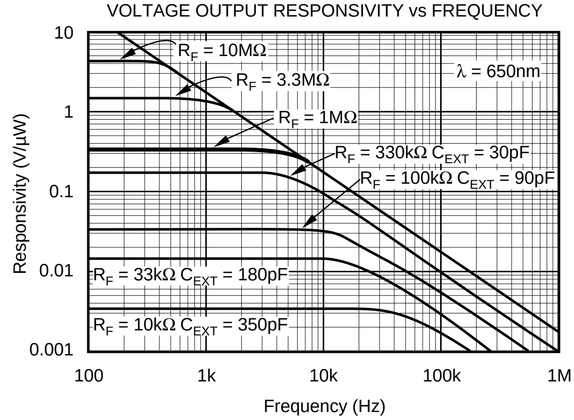
VOLTAGE RESPONSIVITY vs RADIANT POWER



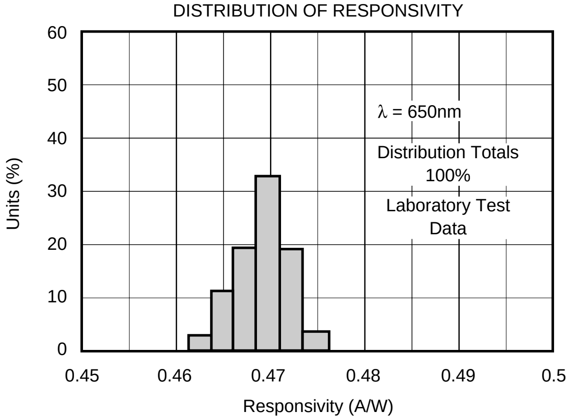
VOLTAGE RESPONSIVITY vs IRRADIANCE



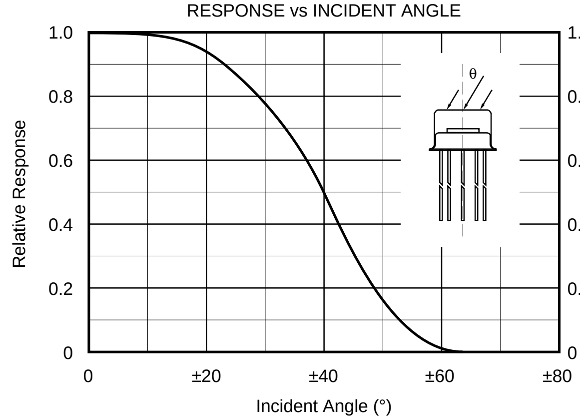
VOLTAGE OUTPUT RESPONSIVITY vs FREQUENCY



DISTRIBUTION OF RESPONSIVITY



RESPONSE vs INCIDENT ANGLE

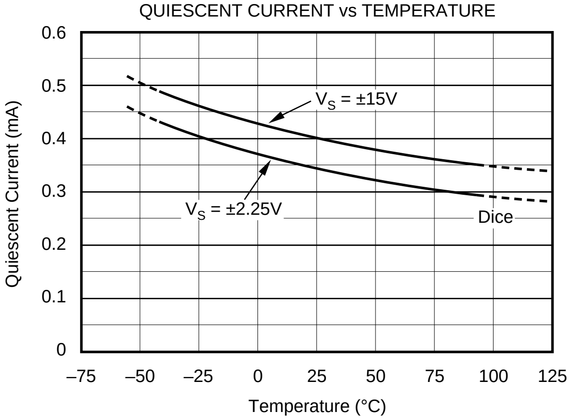


6

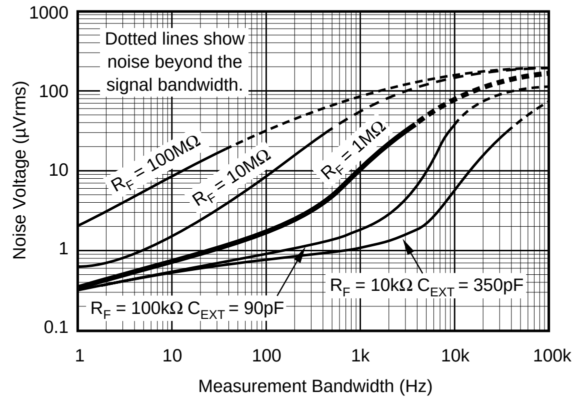
TYPICAL PERFORMANCE CURVES

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

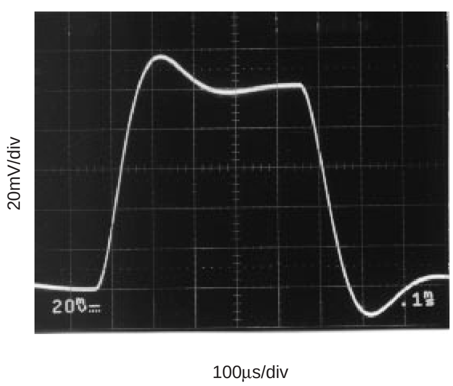
QUIESCENT CURRENT vs TEMPERATURE



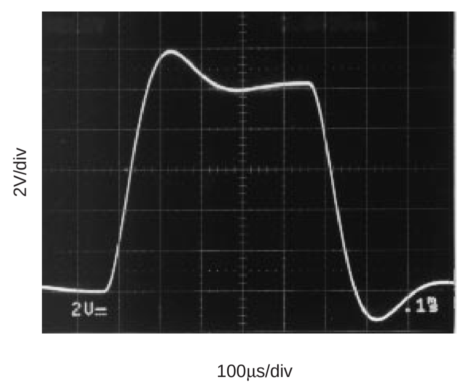
OUTPUT NOISE VOLTAGE
vs MEASUREMENT BANDWIDTH



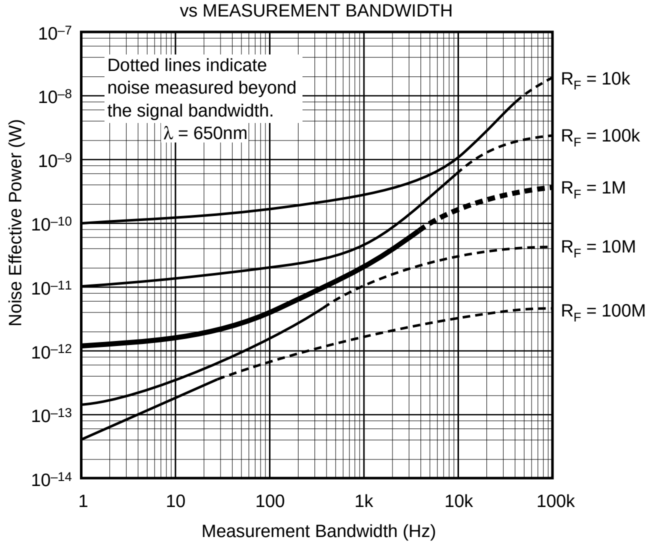
SMALL-SIGNAL DYNAMIC RESPONSE



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.

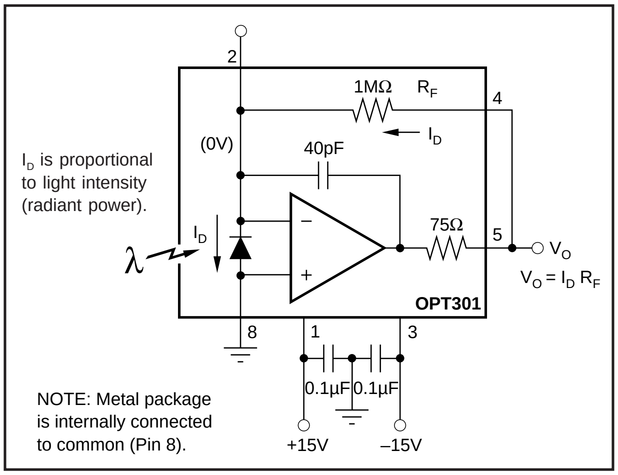


FIGURE 1. Basic Circuit Connections.

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

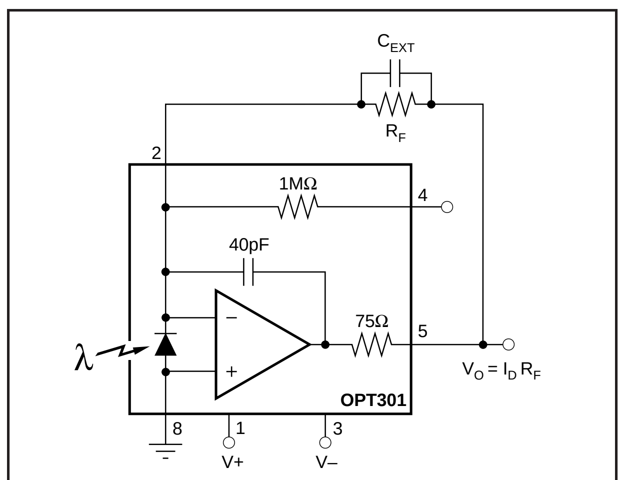
The OPT301 is 100% tested with a light source that uniformly illuminates the full area of the integrated circuit, including the op amp. Although all IC amplifiers are light-sensitive to some degree, the OPT301 op amp circuitry is designed to minimize this effect. Sensitive junctions are shielded with 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.

6

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.

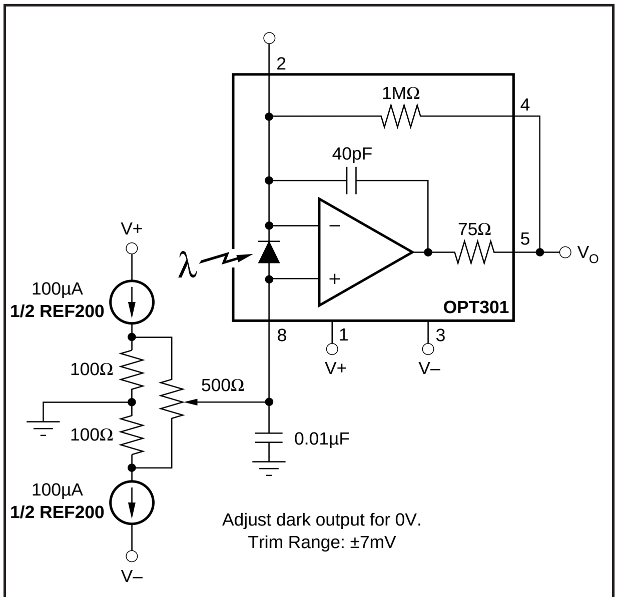


FIGURE 3. Dark Error (Offset) Adjustment Circuit.

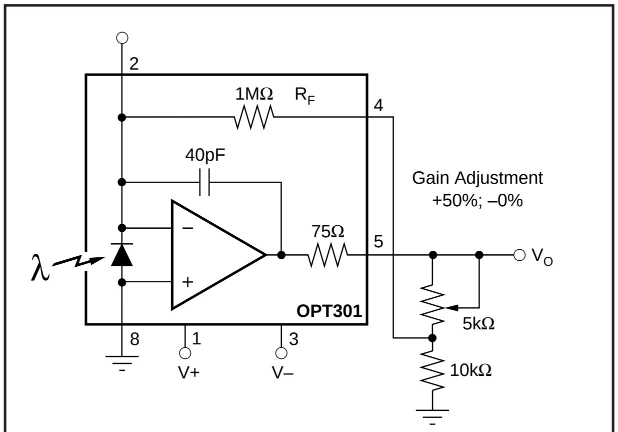


FIGURE 4. Responsivity (Gain) Adjustment Circuit.

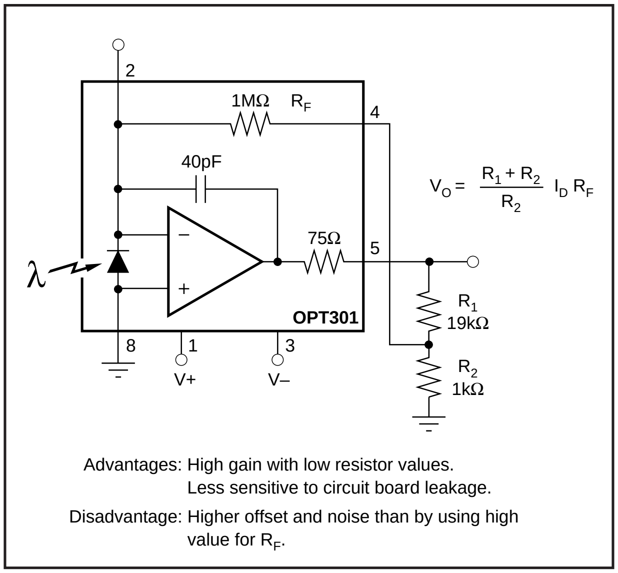


FIGURE 5. "T" Feedback Network.

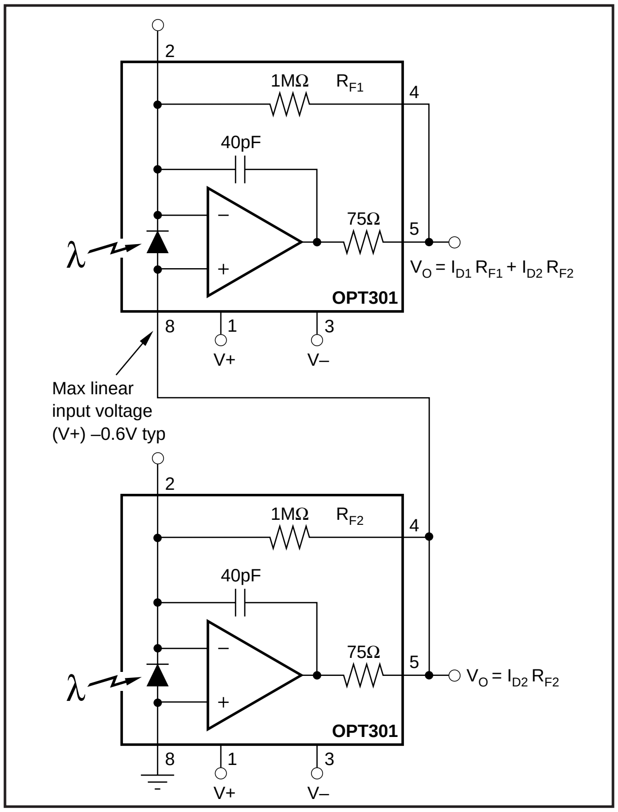


FIGURE 6. Summing Output of Two OPT301s.

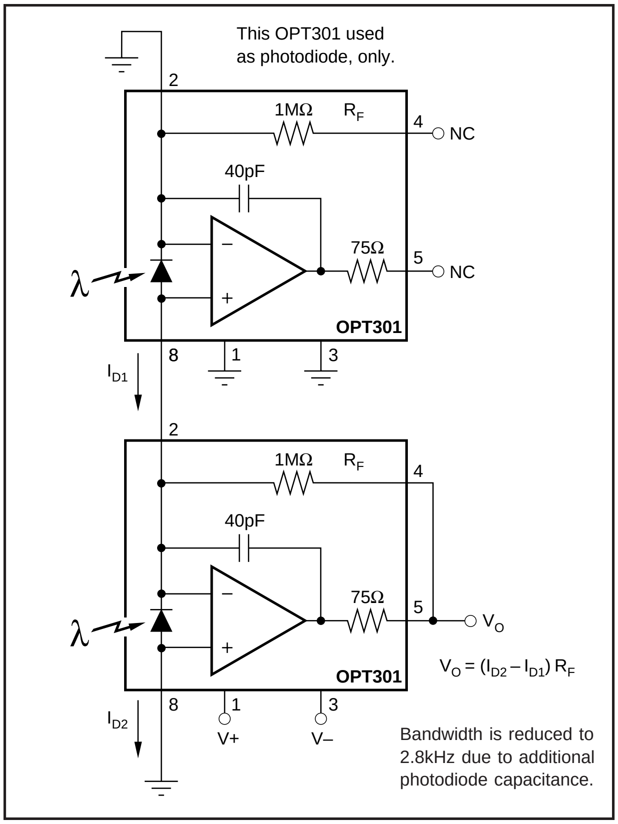


FIGURE 7. Differential Light Measurement.

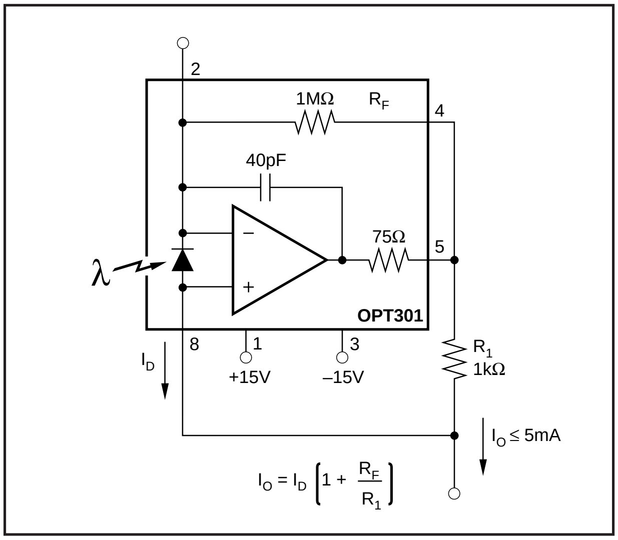


FIGURE 8. Current Output Circuit.

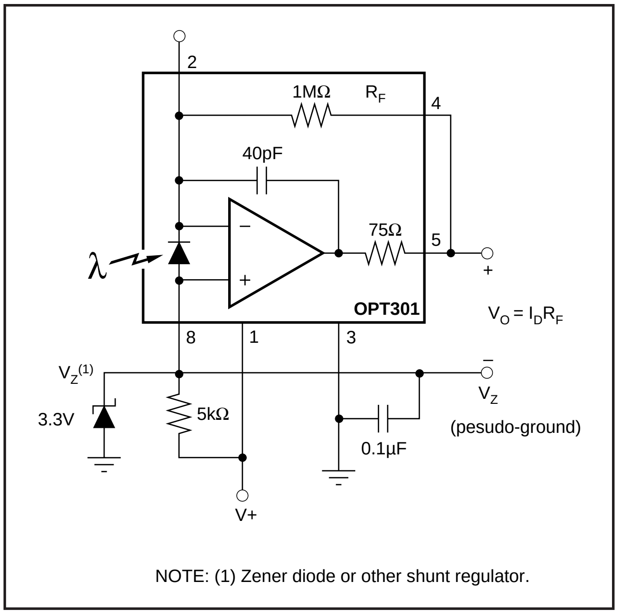


FIGURE 9. Single Power Supply Operation.

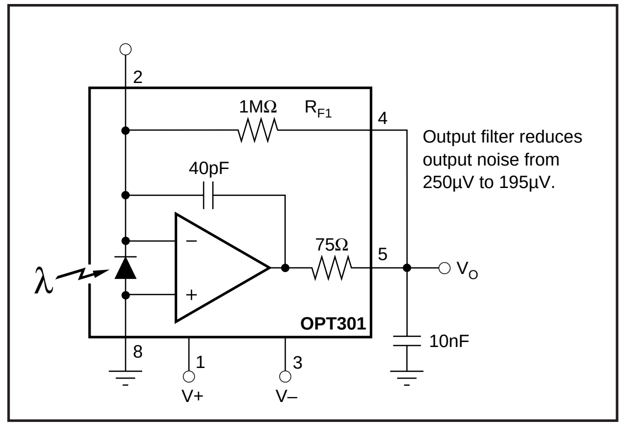


FIGURE 10. Output Filter to Reduce Noise.

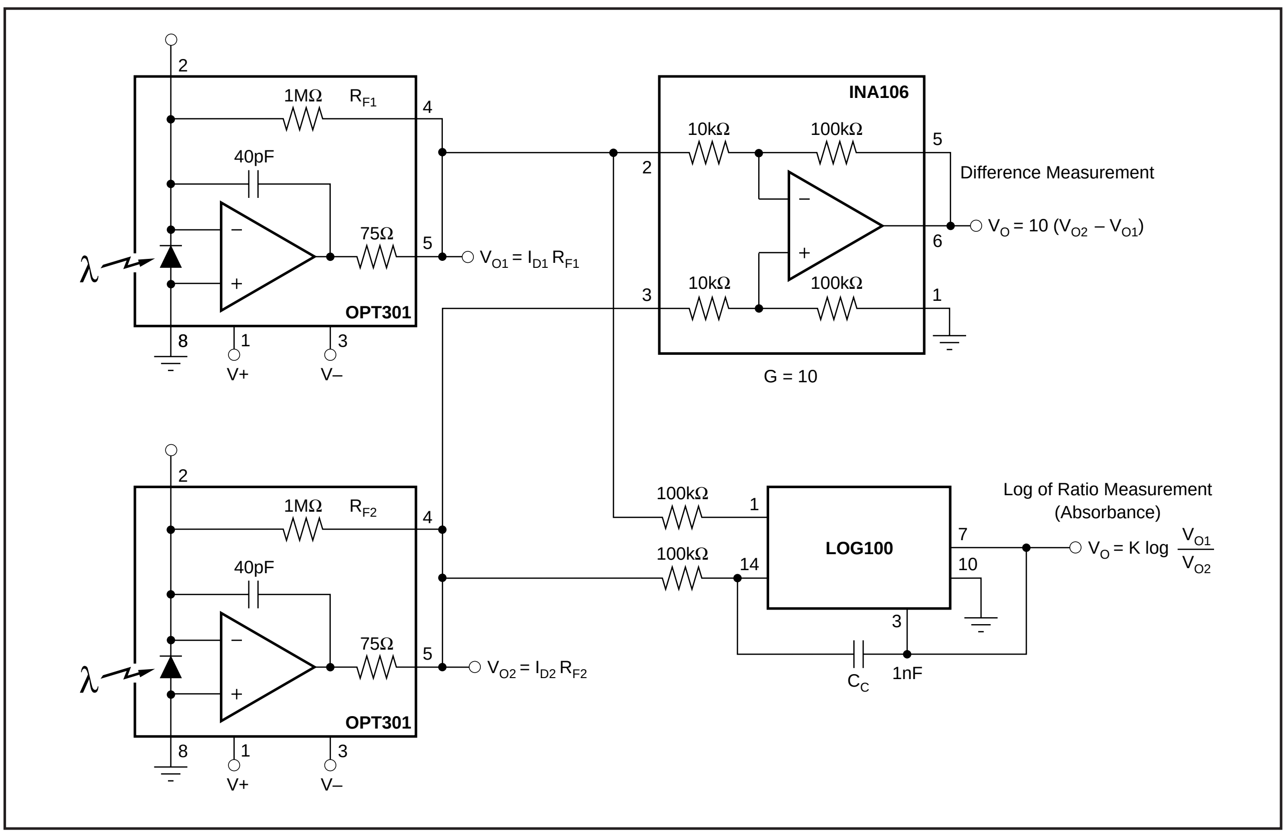


FIGURE 11. Differential Light Measurement.

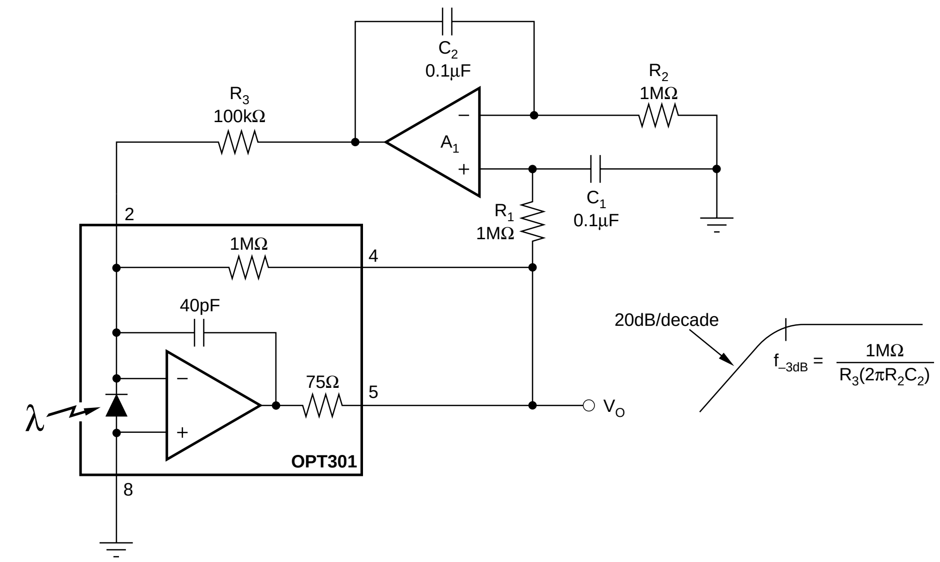


FIGURE 12. DC Restoration Rejects Unwanted Steady-State Background Light.

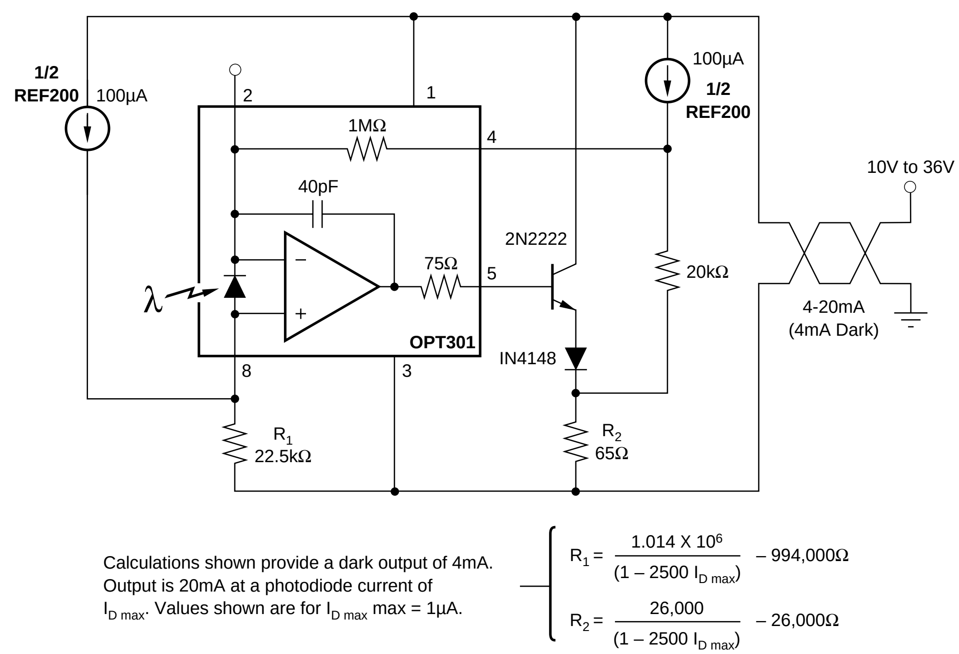


FIGURE 13. 4-20mA Current-Loop Transmitter.

6

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
OPT301M	NRND	TO	LMD	8	20	Green (RoHS & no Sb/Br)	AU	N / A for Pkg Type

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Telephony	www.ti.com/telephony
Low Power Wireless	www.ti.com/lpw	Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265