



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

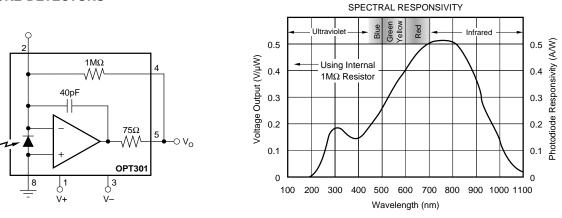
- MEDICAL INSTRUMENTATION
- LABORATORY INSTRUMENTATION
- POSITION AND PROXIMITY SENSORS
- PHOTOGRAPHIC ANALYZERS
- SMOKE DETECTORS

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 0.09×0.09 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 $\pm 18V$) 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.



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SPECIFICATIONS

ELECTRICAL

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

		OPT301M			
PARAMETER	CONDITIONS	MIN TYP		МАХ	UNITS
RESPONSIVITY		İ			
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	$(0.090 \times 0.090in)$		0.008		in ²
	(0.030 x 0.03011) (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	$V_{S} = \pm 2.25V$ to $\pm 18V$		10	100	μV/V
Voltage Noise	Measured BW = 0.1 to 100 kHz		160	100	μVrms
•			100		μνιπο
RESISTOR—1MΩ Internal					110
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, $V_S = \pm 15V$		240		μs
	100% overdrive, $V_S = \pm 5V$		500		μs
	100% overdrive, $V_{\rm S} = \pm 2.25V$		1000		μs μs
	100 % Overdrive, $v_{s} = \pm 2.25 v$		1000		μ5
OUTPUT					
Voltage Output	$R_{L} = 10k\Omega$	(V+) – 1.25	(V+) – 0.65		V
	$R_L = 5k\Omega$	(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_{IA}			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 $T_A = +25^{\circ}$ C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	ТҮР	MAX	UNITS
Photodiode Area	(0.090 x 0.090in)	1	0.008		in ²
	(2.29 x 2.29mm)		5.1		mm ²
Current Responsivity	650nm		0.47		A/W
Dark Current	$V_{\rm D} = 0V^{(1)}$		500		fA
vs Temperature			doubles every 10°C		
Capacitance	$V_{D} = 0V^{(1)}$		4000		pF

NOTE: (1) Voltage Across Photodiode.



SPECIFICATIONS (CONT)

ELECTRICAL

At $T_{A} = +25^{\circ}C$, $V_{S} = \pm 15V$, unless otherwise noted.

Op Amp Section of OPT301⁽¹⁾

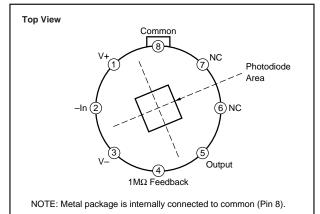
		OPT301 Op Amp				
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	
INPUT						
Offset Voltage			±0.5		mV	
vs Temperature			±5		μV/°C	
vs Power Supply	$V_{S} = \pm 2.25 V \text{ to } \pm 18 V$		10		μV/V	
Input Bias Current	3		1		pA	
vs Temperature			doubles every 10°C			
NOISE						
Input Voltage Noise						
Voltage 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	$R_L = 10k\Omega$	(V+) – 1.25	(V+) - 0.65		V	
	$R_L = 5k\Omega$	(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	$I_{\Omega} = 0$		±0.4	±0.5	mA	

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

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PIN CONFIGURATION



ABSOLUTE MAXIMUM RATINGS

Supply Voltage	±18V
Input Voltage Range (Common Pin)	±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)	

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

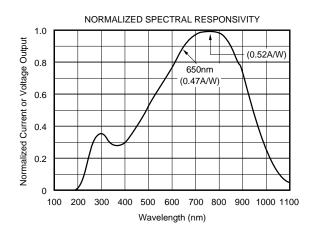
PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER ⁽¹⁾
OPT301M	8-Pin TO-99	001-1

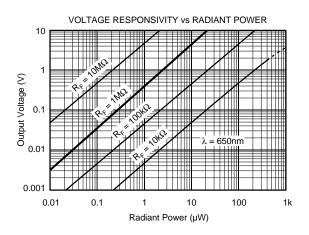
NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

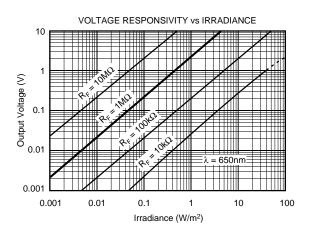


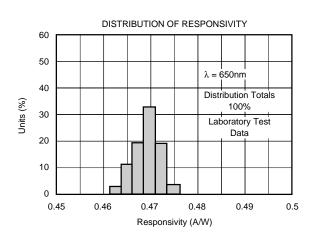
TYPICAL PERFORMANCE CURVES

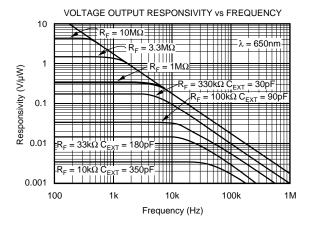
At $T_{_{A}}$ = +25°C, $V_{_{S}}$ = ±15V, λ = 650nm, unless otherwise noted.

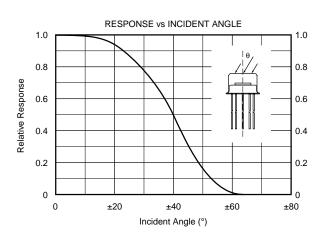








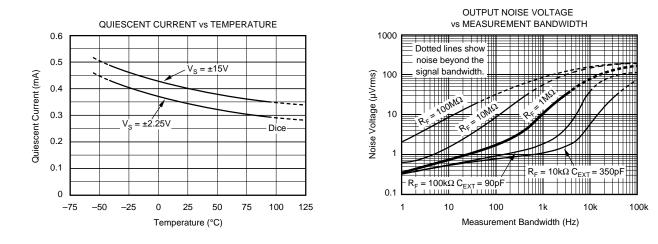




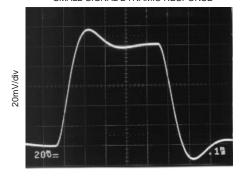
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TYPICAL PERFORMANCE CURVES

At $T_{_{A}}\text{=}$ +25°C, $V_{_{S}}\text{=}\pm\text{15V},$ λ = 650nm, unless otherwise noted.

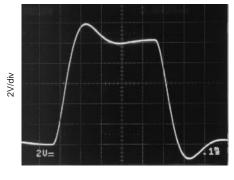


SMALL-SIGNAL DYNAMIC RESPONSE

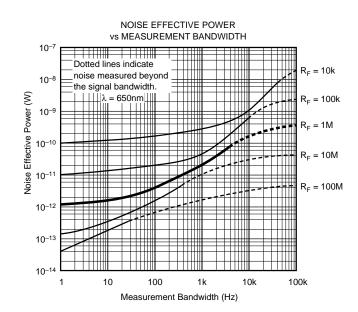














APPLICATIONS INFORMATION

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.

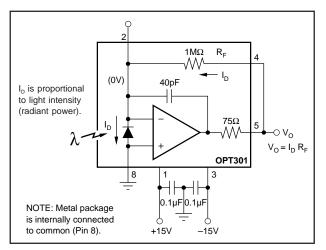


FIGURE 1. Basic Circuit Connections.

Photodiode current, I_p , 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_1 , 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 5.23×10^{-6} m².

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 $1M\Omega \pm 2\%$. Using this resistor, the output voltage responsivity, R_v , is approximately $0.45V/\mu W$ at 650nm wavelength.

An external resistor can be used to set a different voltage responsivity. For values of R_F less than 1M Ω , 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 $(0.090 \times 0.090$ 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 $R_F = 10M\Omega$. The OPT301 is useful with feedback resistors of 100M Ω or greater at room temperature. The dark output voltage can be trimmed to zero with the optional circuit shown in Figure 3.

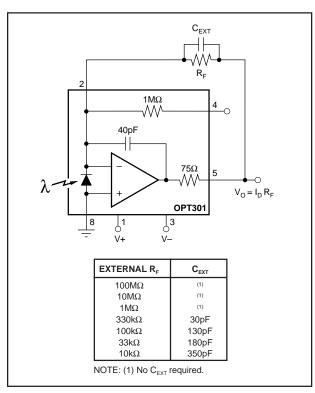


FIGURE 2. Using External Feedback Resistor.



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 $1M\Omega$ 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—

$$t_{\rm R} \approx \frac{0.35}{f_{\rm C}} \tag{1}$$

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

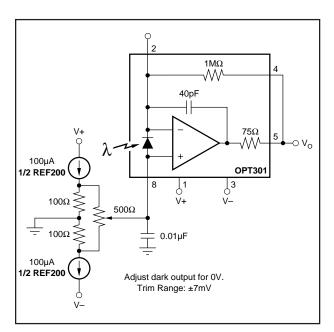


FIGURE 3. Dark Error (Offset) Adjustment Circuit.

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 $R_{\rm F}$ and measurement bandwidth.

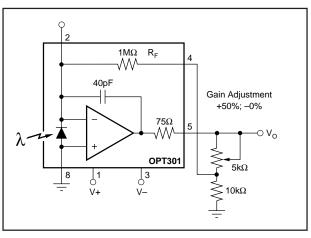


FIGURE 4. Responsivity (Gain) Adjustment Circuit.



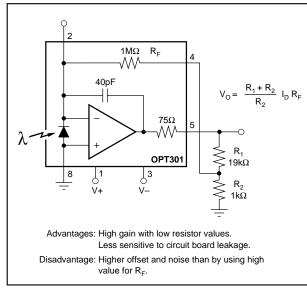


FIGURE 5. "T" Feedback Network.

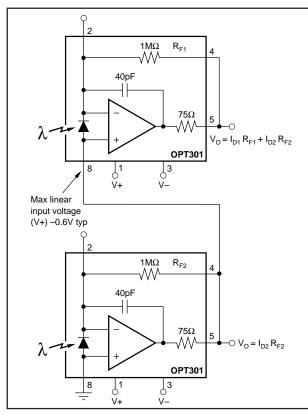


FIGURE 6. Summing Output of Two OPT301s.

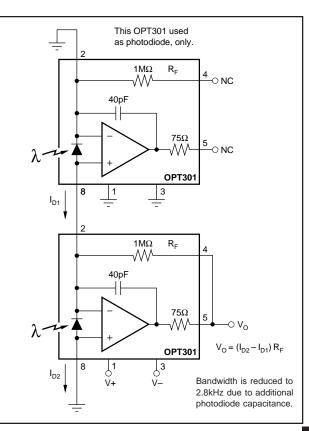


FIGURE 7. Differential Light Measurement.

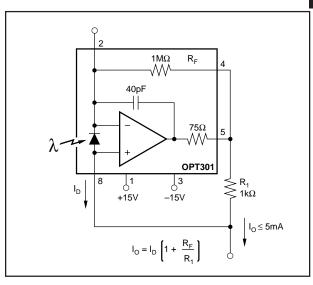
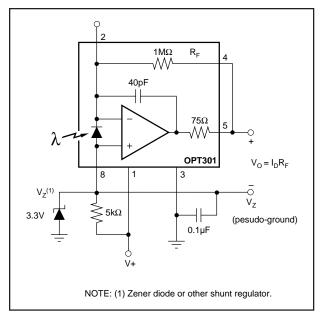


FIGURE 8. Current Output Circuit.





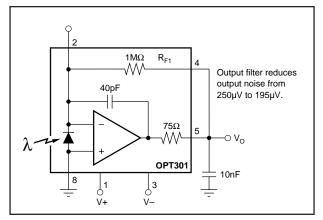


FIGURE 10. Output Filter to Reduce Noise.

FIGURE 9. Single Power Supply Operation.

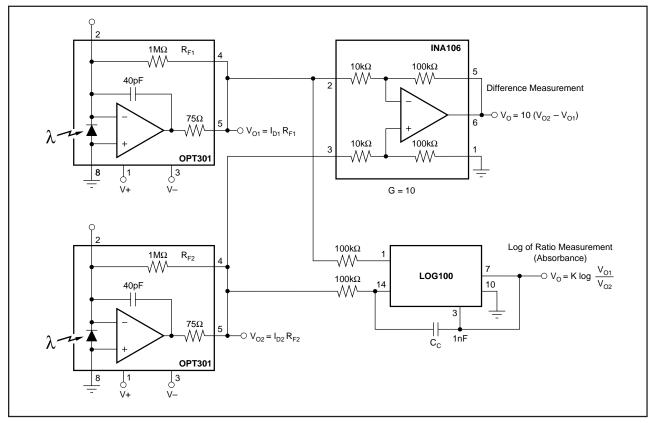


FIGURE 11. Differential Light Measurement.



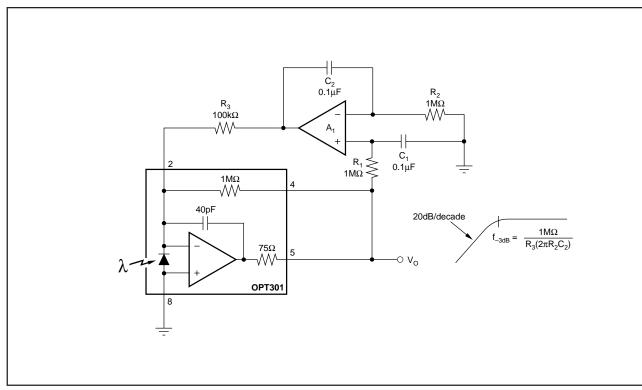


FIGURE 12. DC Restoration Rejects Unwanted Steady-State Background Light.

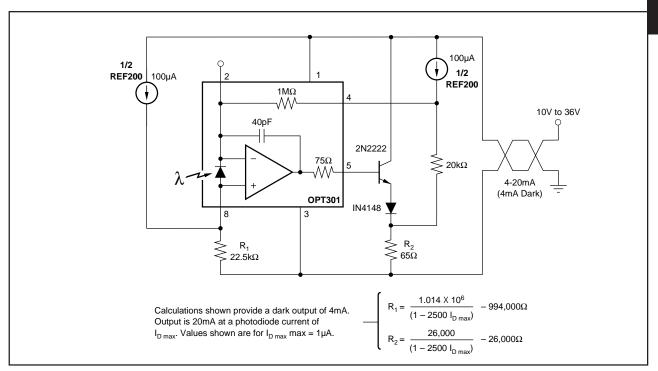


FIGURE 13. 4-20mA Current-Loop Transmitter.



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PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins P	ackage Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
OPT301M	NRND	ТО	LMD	8	20	Green (RoHS & no Sb/Br)	a 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.

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⁽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.

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

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RFID	www.ti-rfid.com	Video & Imaging	www.ti.com/video
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Wireless	www.ti.com/wireless

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