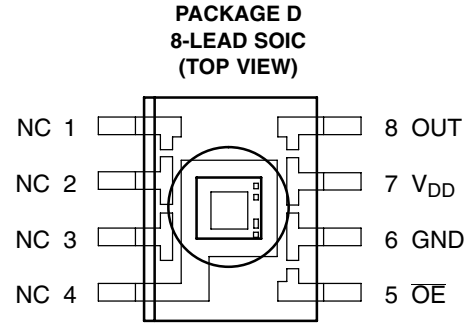


- High-Resolution Conversion of Light Intensity to Frequency With No External Components
- High Irradiance Responsivity . . . 2.3 kHz/( $\mu\text{W}/\text{cm}^2$ ) at  $\lambda_p = 524 \text{ nm}$
- Low Dark Frequency . . .  $< 2 \text{ Hz}$  at  $25^\circ \text{ C}$
- Single-Supply Operation . . . 2.7 V to 5.5 V
- Stable 200 ppm/ $^\circ\text{C}$  Temperature Coefficient
- Interfaces Directly to a Microcontroller
- Lead (Pb) Free Package
- RoHS Compliant



### Description

The TSL238 light-to-frequency converter combines a silicon photodiode and a current-to-frequency converter on a single monolithic CMOS integrated circuit. Output is a square wave (50% duty cycle) with frequency directly proportional to light intensity (irradiance) on the photodiode. The digital output allows direct interface to a microcontroller or other logic circuitry. Output enable ( $\overline{\text{OE}}$ ) places the output in a high-impedance state for multiple-unit sharing of a microcontroller input line. The device has been temperature compensated for the ultraviolet-to-visible light range of 320 nm to 700 nm and responds over the light range of 320 nm to 1050 nm. The TSL238 is characterized for operation over the temperature range of  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  and is supplied in an 8-lead plastic small outline package. When supplied in the lead (Pb) free package, the device is RoHS compliant.

For automotive and other extended temperature applications, please contact TAOS for information.

### Functional Block Diagram



### Available Options

DEVICE	T <sub>A</sub>	PACKAGE – LEADS	PACKAGE DESIGNATOR	ORDERING NUMBER
TSL238	$-25^\circ\text{C}$ to $70^\circ\text{C}$	8-lead Plastic Small Outline IC	D	TSL238D

# TSL238 HIGH-SENSITIVITY LIGHT-TO-FREQUENCY CONVERTER

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## Terminal Functions

TERMINAL NAME	D PKG NO.	TYPE	DESCRIPTION
GND	6		Power supply ground. All voltages are referenced to GND.
NC	1, 2, 3		No connection.
NC	4		Substrate. Pin 4 is resistively connected to the substrate of the die, which is at the same potential as pin 6. Pin 4 must either be connected to pin 6 or left unconnected. Pin 4 cannot be used for a ground connection by itself.
$\overline{OE}$	5	I	Enable for $f_O$ (active low).
OUT	8	O	Output frequency.
$V_{DD}$	7		Supply voltage.

## Absolute Maximum Ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>

Supply voltage, $V_{DD}$ (see Note 1)	6 V
Input voltage range, $V_I$	-0.3 V to $V_{DD} + 0.3$ V
Output current, $I_O$	$\pm 5$ mA
Short circuit of output to ground duration	5 s
Operating free-air temperature range, $T_A$ (see Note 2)	-40°C to 85°C
Storage temperature range, $T_{stg}$ (see Note 2)	-40°C to 85°C
Solder conditions in accordance with JEDEC J-STD-020A, maximum temperature (see Note 3)	260°C

<sup>†</sup> Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values are with respect to GND.  
 2. Long-term storage or operation above 70°C could cause package yellowing that will lower the sensitivity to wavelengths < 500nm.  
 3. The device may be hand soldered provided that heat is applied only to the solder pad and no contact is made between the tip of the solder iron and the device lead. The maximum time heat should be applied to the device is 5 seconds.

## Recommended Operating Conditions

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{DD}$	2.7	5	5.5	V
High-level input voltage, $V_{IH}$	$0.8 \times V_{DD}$		$V_{DD}$	V
Low-level input voltage, $V_{IL}$	0		0.5	V
Operating free-air temperature range, $T_A$	-40		70	°C

**Electrical Characteristics at  $V_{DD} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$  (Note 1) (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OH}$	High-level output voltage	$I_{OH} = -1\text{ mA}$	4	4.5		V
$V_{OL}$	Low-level output voltage	$I_{OL} = 1\text{ mA}$		0.25	0.4	V
$I_{IH}$	High-level input current		-10		10	$\mu\text{A}$
$I_{IL}$	Low-level input current		-10		10	$\mu\text{A}$
$I_{DD}$	Supply current	$E_e = 21.2\ \mu\text{W}/\text{cm}^2$		2	3	mA
	Full-scale frequency (Note 2)	$T_A = 50^\circ\text{C}$ (Note 3)	500		1000	kHz
	Temperature coefficient of responsivity	Wavelength < 600nm, $f_O = 50\text{ kHz}$		$\pm 200$		ppm/ $^\circ\text{C}$
$k_{SVS}$	Supply-voltage sensitivity	$V_{DD} = 5\text{ V} \pm 10\%$		$\pm 0.5$		%/V

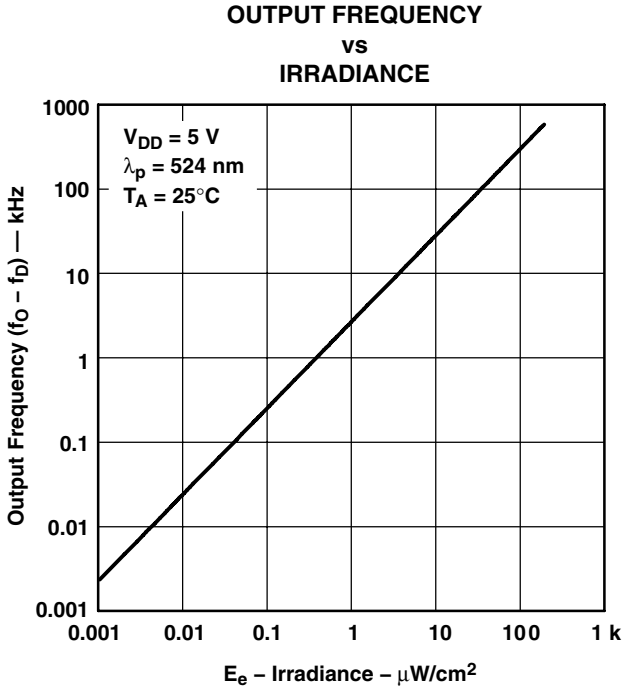
- NOTES: 1. The input irradiance is supplied with green LED light source with peak wavelength = 524 nm.  
 2. Full-scale frequency is the maximum frequency of the device without saturation. Higher irradiance will not result in any additional increase of output frequency. The output frequency will remain at approximately the saturation frequency to a minimum of 1000  $\mu\text{W}/\text{sqcm}$  524-nm irradiance. During production testing, devices are not tested at this very high irradiance level.  
 3. Measured at wafer probe using 50 $^\circ\text{C}$  hot chuck.

**Operating Characteristics at  $V_{DD} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $\lambda_p = 524\text{ nm}$  (unless otherwise noted)**

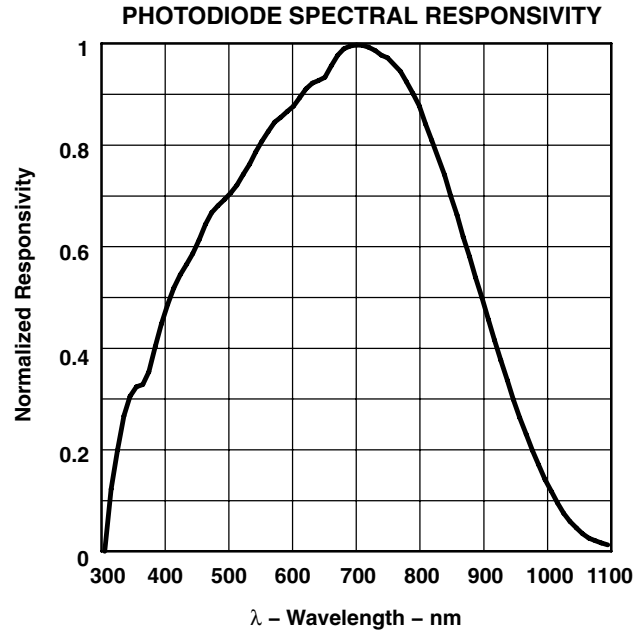
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$f_O$	Output frequency	$E_e = 21.2\ \mu\text{W}/\text{cm}^2$	40	50	60	kHz
$f_D$	Dark frequency	$E_e = 0\ \mu\text{W}/\text{cm}^2$	0		1.2	Hz
		$E_e = 0\ \mu\text{W}/\text{cm}^2$ , $T_A = 50^\circ\text{C}$ (Note 1)	0		6	Hz
$R_e$	Irradiance responsivity			2.3		kHz/( $\mu\text{W}/\text{cm}^2$ )
$\lambda_p$	Peak response wavelength			700		nm
	Nonlinearity (Note 2)	$f_O = 0\text{ kHz to } 10\text{ kHz}$		$\pm 1\%$		%F.S.
	Step response to full-scale step input			1 pulse of new frequency plus 1 $\mu\text{s}$		
	Time from $\overline{\text{OE}}$ low to output enabled			1 period of output frequency		

- NOTES: 1. Measured at wafer probe using 50 $^\circ\text{C}$  hot chuck.  
 2. Nonlinearity is defined as the deviation from a straight line between zero and maximum of stated range, expressed as a percent of stated range.

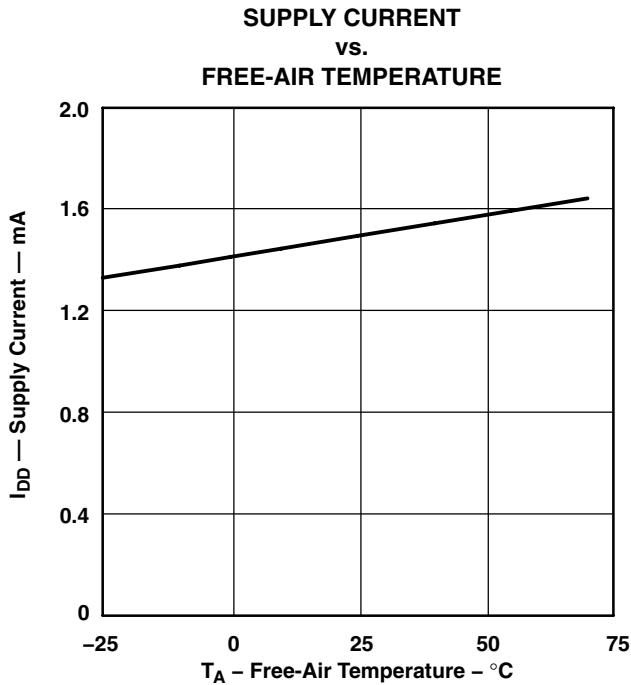
**TYPICAL CHARACTERISTICS**



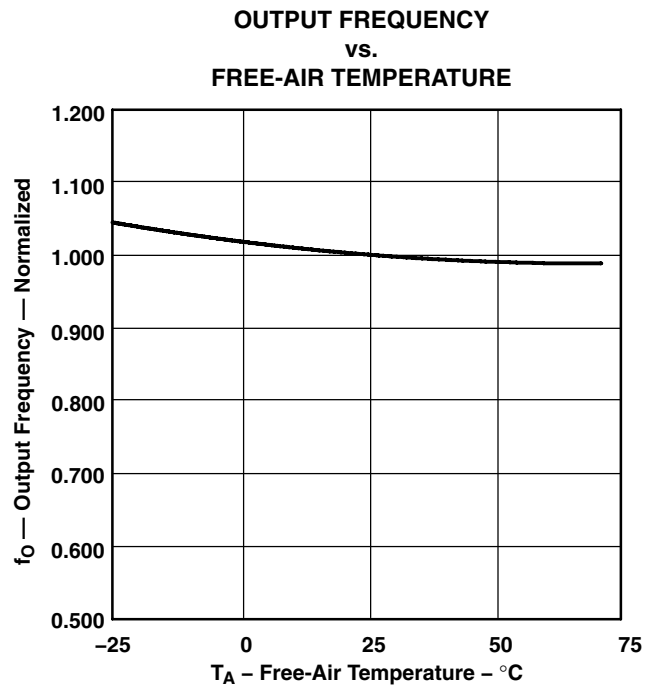
**Figure 1**



**Figure 2**

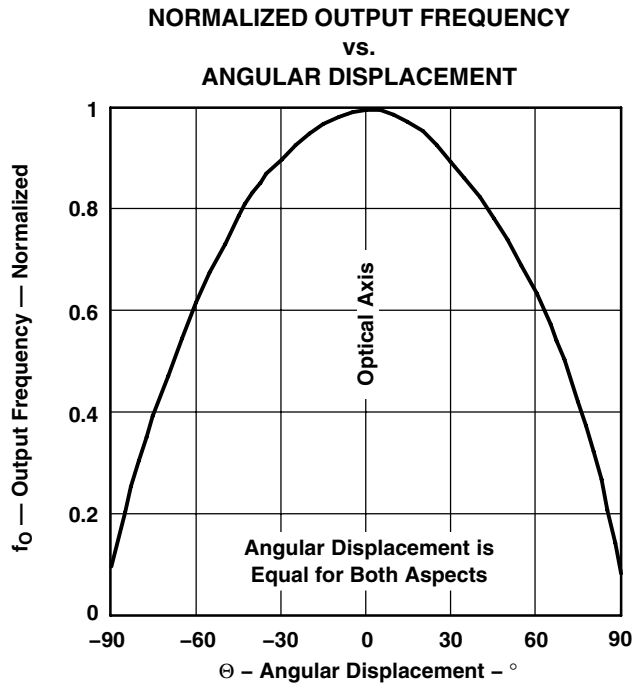


**Figure 3**

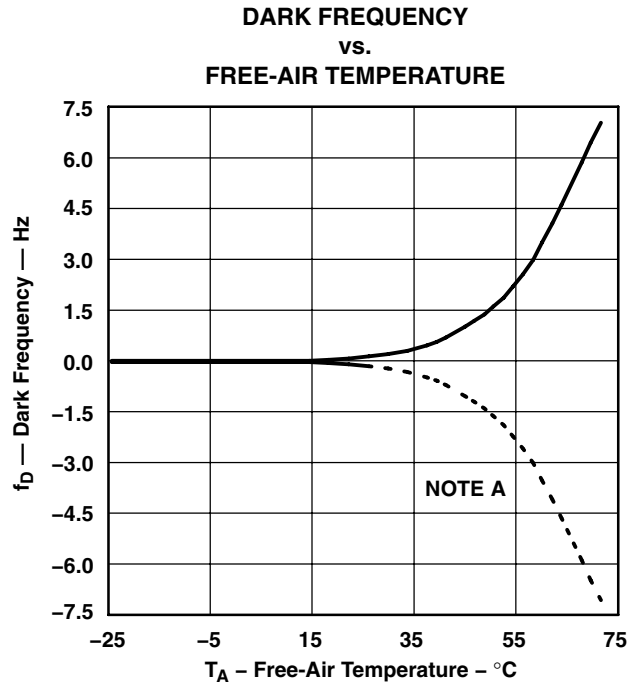


**Figure 4**

**TYPICAL CHARACTERISTICS**



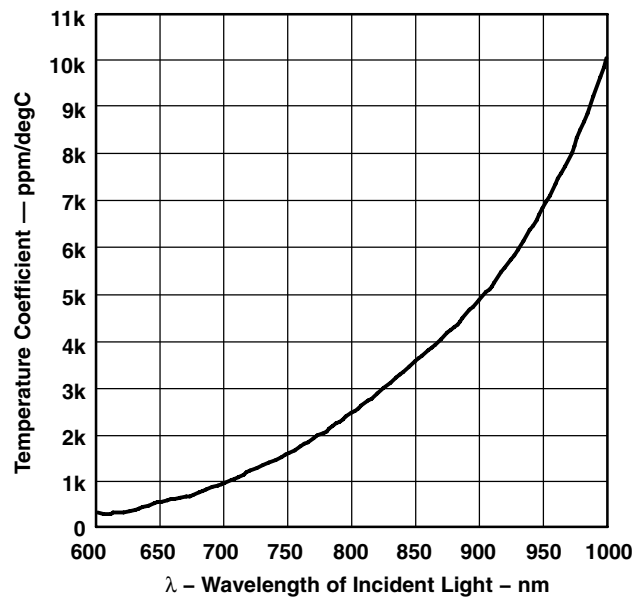
**Figure 5**



**Figure 6**

NOTE A: Internal offsets that result in dark frequency can be both positive and negative. The dashed line represents the case of negative offset in which an equivalent amount of light signal is required to obtain a non-zero output frequency.

**PHOTODIODE RESPONSIVITY TEMPERATURE**  
**COEFFICIENT** vs.  
**WAVELENGTH OF INCIDENT LIGHT**

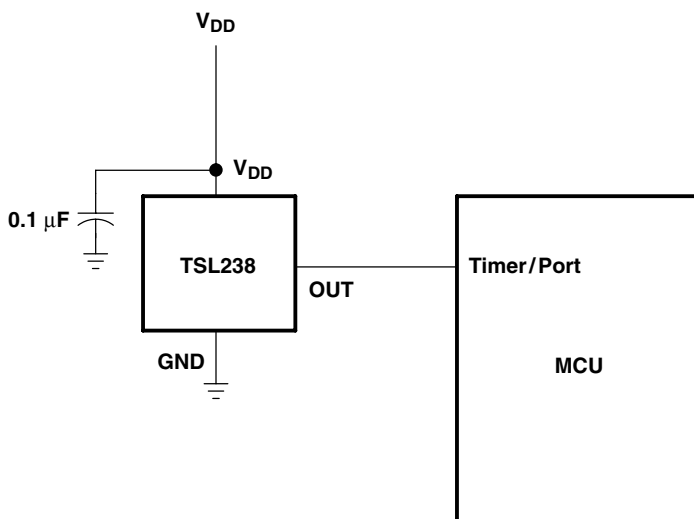


**Figure 7**

**APPLICATION INFORMATION**

**Power-Supply Considerations**

Power-supply lines must be decoupled by a 0.01- $\mu\text{F}$  to 0.1- $\mu\text{F}$  capacitor with short leads placed close to the TSL238 (Figure 8). A low-noise power supply is required to minimize jitter on output pulse.



**Figure 8. Typical TSL238 Interface to a Microcontroller**

**Device Operational Details**

The frequency at the output pin (OUT) is given by:

$$f_O = f_D + (R_e) (E_e)$$

where:

- $f_O$  is the output frequency
- $f_D$  is the output frequency for dark condition ( $E_e = 0$ )
- $R_e$  is the device responsivity for a given wavelength of light given in  $\text{kHz}/(\mu\text{W}/\text{cm}^2)$
- $E_e$  is the incident irradiance in  $\mu\text{W}/\text{cm}^2$

$f_D$  is a constant error term in the output frequency calculation resulting from leakage currents, and is independent of light intensity. The TSL238 die is trimmed to minimize the magnitude of this dark frequency component so that it can be neglected in the transfer function calculation. In many applications, measurement of the actual dark frequency may be impractical due to measurement times ranging from several seconds to several minutes, and the fact that some devices may never transition (zero dark frequency).

**Output Interface**

The output of the device is designed to drive a CMOS logic input over short distances. If lines greater than 12 inches in length are used on the output, a buffer or line driver is recommended.

## APPLICATION INFORMATION

### Measuring the Frequency

The choice of interface and measurement technique depends on the desired resolution and data-acquisition rate. For maximum data-acquisition rate, period-measurement techniques are used.

Period measurement requires the use of a fast reference clock with available resolution directly related to the reference-clock rate. The technique is employed to measure rapidly varying light levels or to make a fast measurement of a constant light source.

Maximum resolution and accuracy may be obtained using frequency-measurement, pulse-accumulation, or integration techniques. Frequency measurements provide the added benefit of averaging out random- or high-frequency variations (jitter) resulting from noise in the light signal. Resolution is limited mainly by available counter registers and allowable measurement time. Frequency measurement is well suited for slowly varying or constant light levels and for reading average light levels over short periods of time. Integration, the accumulation of pulses over a very long period of time, can be used to measure exposure — the amount of light present in an area over a given time period.

Output enable ( $\overline{OE}$ ) places the output in a high-impedance state for multiple-unit sharing of a microcontroller input line. When the  $\overline{OE}$  line goes low, the device resynchronizes the output to an integration cycle. The rising edge of the output signal (OUT) will occur exactly one period of the output frequency after  $\overline{OE}$  goes low.

**TSL238**  
**HIGH-SENSITIVITY**  
**LIGHT-TO-FREQUENCY CONVERTER**

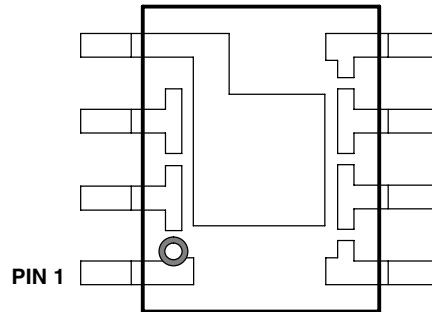
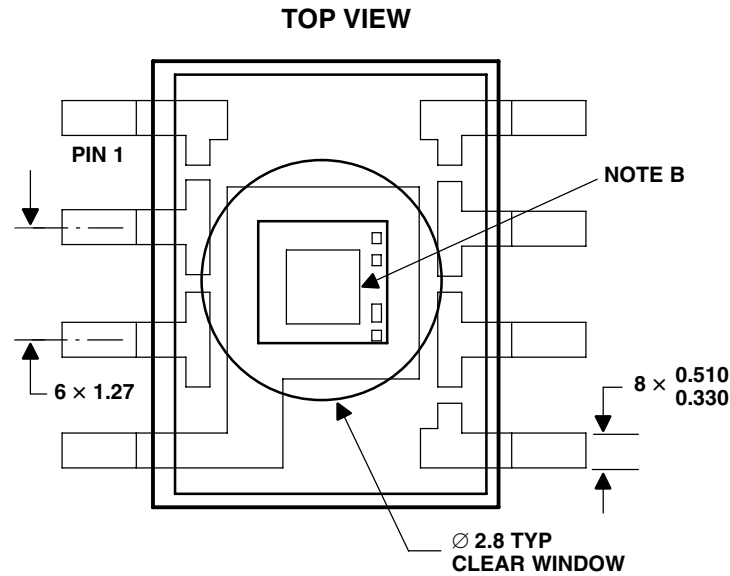
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**MECHANICAL DATA**

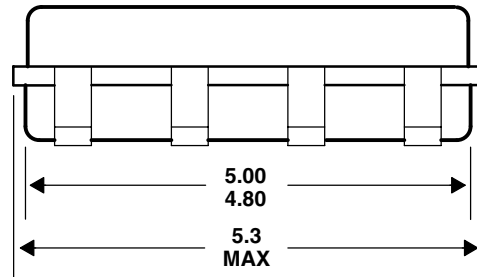
This SOIC package consists of an integrated circuit mounted on a lead frame and encapsulated with an electrically nonconductive clear plastic compound having an index of refraction of 1.55.

**PACKAGE D**

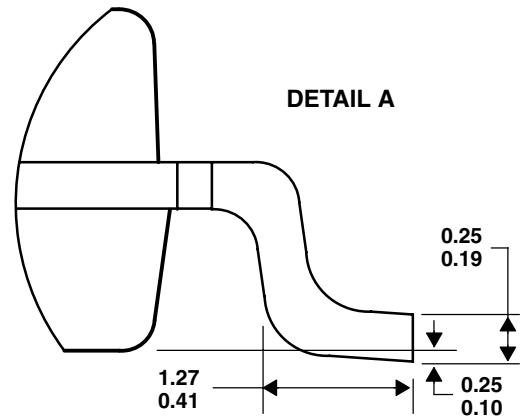
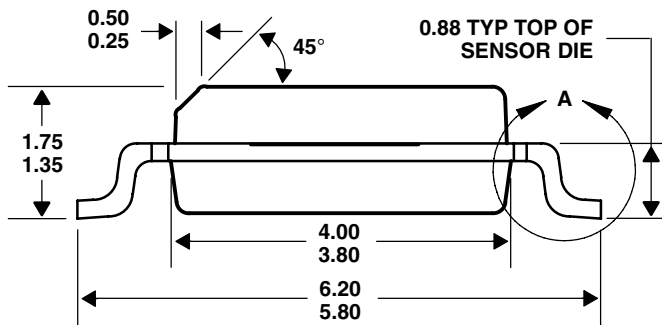
**PLASTIC SMALL-OUTLINE  
 BOTTOM VIEW**



**SIDE VIEW**



**END VIEW**



Lead Free

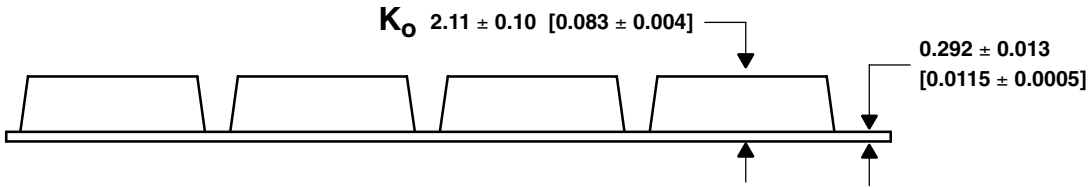
- NOTES: A. All linear dimensions are in millimeters.  
 B. The center of the 0.84-mm by 0.84-mm photo-active area is located in the center of the package  $\pm 0.25$  mm.  
 C. Pin 4 is resistively coupled to the substrate of the die, which is at the same potential as Pin 6. Pin 4 must either be connected to Pin 6 or left unconnected. Pin 4 cannot be used as the sole ground connection.  
 D. Leads are plated with Pd (min 0.1  $\mu$  inch) + Ni (min 10  $\mu$  inch) + Au (min 0.1  $\mu$  inch).  
 E. This drawing is subject to change without notice.

**Figure 9. Package D — Plastic Small Outline IC Packaging Configuration**

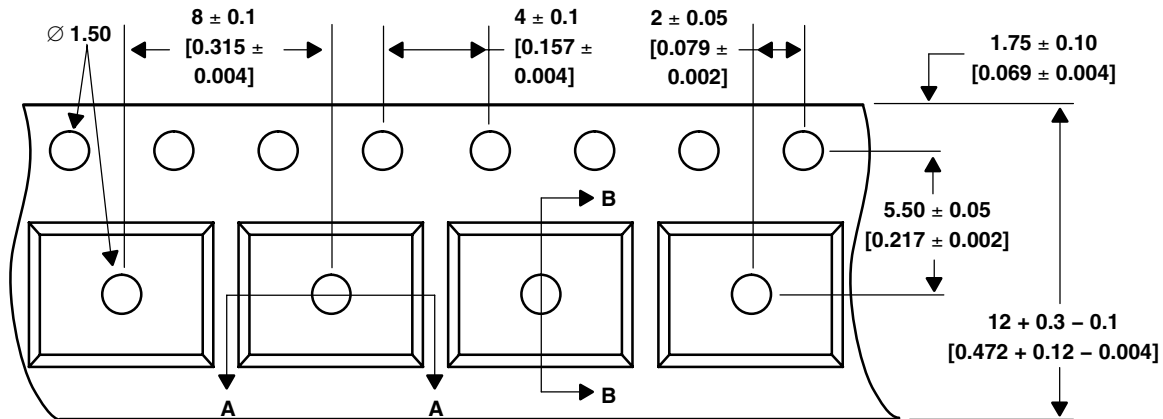


**MECHANICAL DATA**

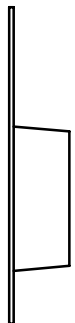
**SIDE VIEW**



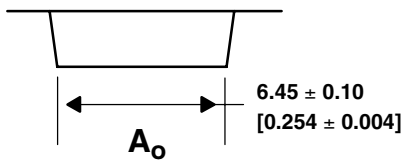
**TOP VIEW**



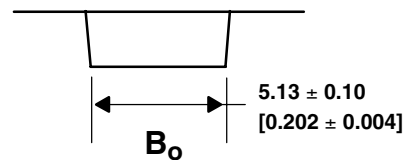
**END VIEW**



**DETAIL A**



**DETAIL B**



- NOTES: A. All linear dimensions are in millimeters [inches].  
 B. The dimensions on this drawing are for illustrative purposes only. Dimensions of an actual carrier may vary slightly.  
 C. Symbols on drawing  $A_O$ ,  $B_O$ , and  $K_O$  are defined in ANSI EIA Standard 481-B 2001.  
 D. Each reel is 178 millimeters in diameter and contains 1000 parts.  
 E. TAOS packaging tape and reel conform to the requirements of EIA Standard 481-B.  
 F. This drawing is subject to change without notice.

**Figure 10. Package D Carrier Tape**

**TSL238**  
**HIGH-SENSITIVITY**  
**LIGHT-TO-FREQUENCY CONVERTER**

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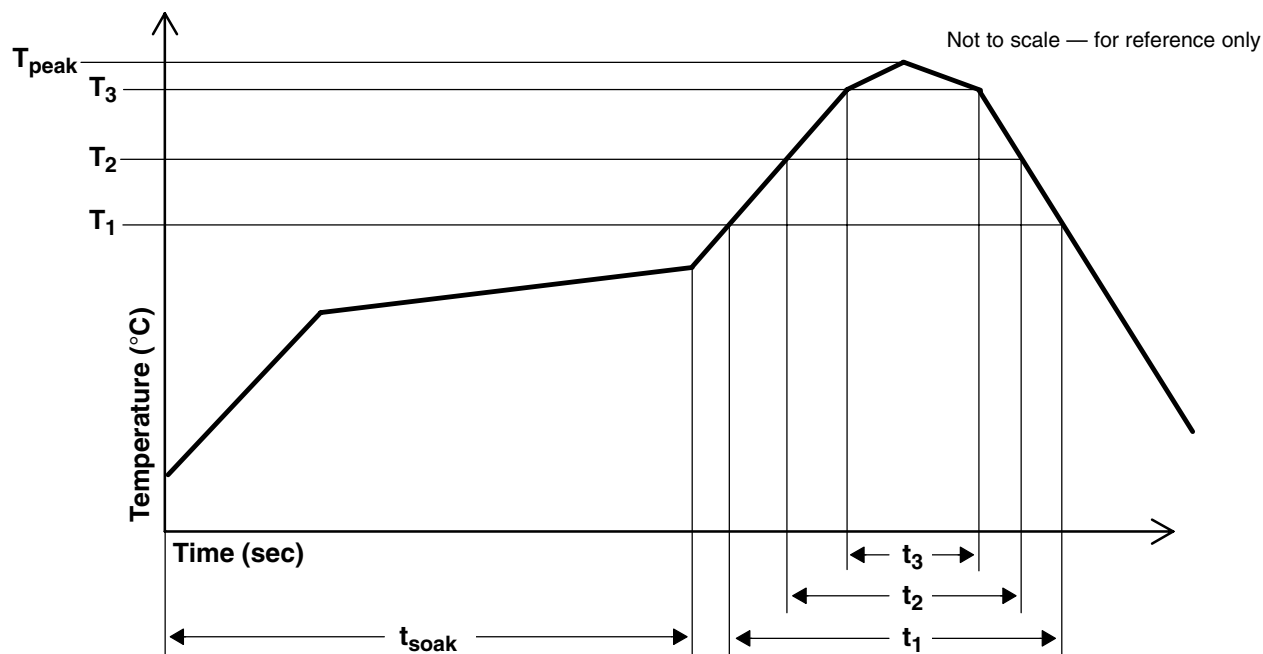
**MANUFACTURING INFORMATION**

The Plastic Small Outline IC package (D) has been tested and has demonstrated an ability to be reflow soldered to a PCB substrate.

The solder reflow profile describes the expected maximum heat exposure of components during the solder reflow process of product on a PCB. Temperature is measured on top of component. The component should be limited to a maximum of three passes through this solder reflow profile.

**Table 1. TSL238 Solder Reflow Profile**

PARAMETER	REFERENCE	TSL238
Average temperature gradient in preheating		2.5°C/sec
Soak time	$t_{soak}$	2 to 3 minutes
Time above 217°C	$t_1$	Max 60 sec
Time above 230°C	$t_2$	Max 50 sec
Time above $T_{peak} - 10^\circ\text{C}$	$t_3$	Max 10 sec
Peak temperature in reflow	$T_{peak}$	260° C (-0°C/+5°C)
Temperature gradient in cooling		Max -5°C/sec



**Figure 11. Solder Reflow Profile Graph**

## Moisture Sensitivity

Optical characteristics of the device can be adversely affected during the soldering process by the release and vaporization of moisture that has been previously absorbed into the package molding compound. To prevent these adverse conditions, all devices shipped in carrier tape have been pre-baked and shipped in a sealed moisture-barrier bag. No further action is necessary if these devices are processed through solder reflow within 24 hours of the seal being broken on the moisture-barrier bag.

However, for all devices shipped in tubes or if the seal on the moisture barrier bag has been broken for 24 hours or longer, it is recommended that the following procedures be used to ensure the package molding compound contains the smallest amount of absorbed moisture possible.

### ***For devices shipped in tubes:***

1. Remove devices from tubes
2. Bake devices for 4 hours, at 90°C
3. After cooling, load devices back into tubes
4. Perform solder reflow within 24 hours after bake

Bake only a quantity of devices that can be processed through solder reflow in 24 hours. Devices can be re-baked for 4 hours, at 90°C for a cumulative total of 12 hours (3 bakes for 4 hours at 90°C).

### ***For devices shipped in carrier tape:***

1. Bake devices for 4 hours, at 90°C in the tape
2. Perform solder reflow within 24 hours after bake

Bake only a quantity of devices that can be processed through solder reflow in 24 hours. Devices can be re-baked for 4 hours in tape, at 90°C for a cumulative total of 12 hours (3 bakes for 4 hours at 90°C).

# TSL238 HIGH-SENSITIVITY LIGHT-TO-FREQUENCY CONVERTER

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**PRODUCTION DATA** — information in this document is current at publication date. Products conform to specifications in accordance with the terms of Texas Advanced Optoelectronic Solutions, Inc. standard warranty. Production processing does not necessarily include testing of all parameters.

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**Pb-Free (RoHS)** TAOS' 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, TAOS Pb-Free products are suitable for use in specified lead-free processes.

**Green (RoHS & no Sb/Br)** TAOS 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).

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