ams

TSL238

High-Sensitivity Light-to-Frequency Converter

General 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 ($\overline{OE}$) 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°C to 85°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 **ams** for information.

Ordering Information and Content Guide appear at end of datasheet.

Key Benefits & Features

The benefits and features of TSL238, High-Sensitivity Light-to-Frequency Converter are listed below:

Figure 1:
Added Value of Using TSL238

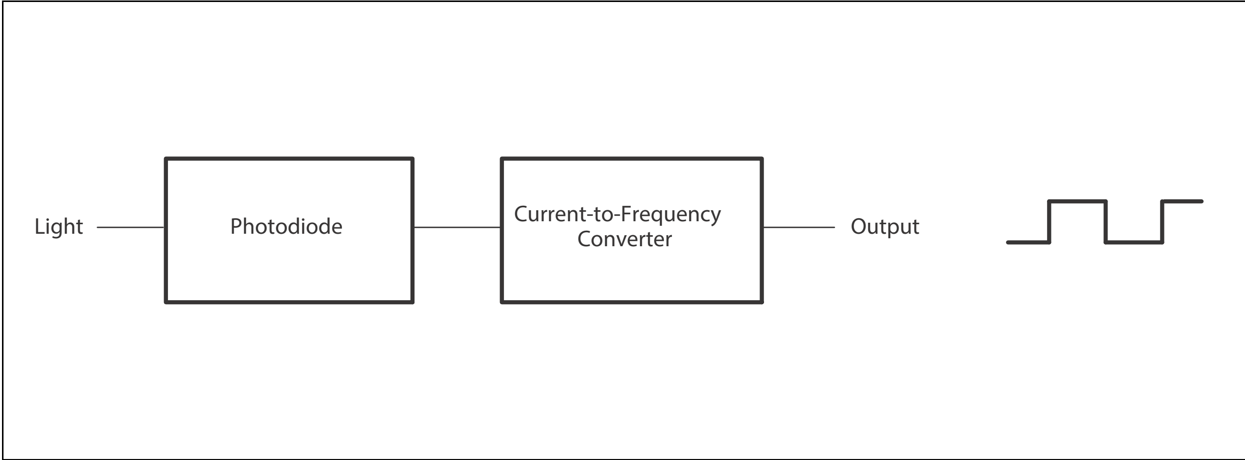
Benefits	Features
• Detects Light Intensity at a High Resolution	• 850000:1 Input Dynamic Range
• Provides Low Light Level Operation	• Low Dark Frequency < 2 Hz at 25°C
• Reduces Board Space Requirements while Simplifying Designs	• 5mm x 6.2mm SOIC (D) Package

- High-Resolution Conversion of Light Intensity to Frequency with No External Components
- High Irradiance Responsivity: 2.3kHz/(mW/cm^2) λ_p = 524 nm
- Single-Supply Operation: 2.7 V to 5.5 V
- Stable 200 ppm/°C Temperature Coefficient
- Interfaces Directly to a Microcontroller
- Lead (Pb) Free Package, RoHS Compliant

Block Diagram

The functional blocks of this device are shown below:

Figure 2:
TSL238 Block Diagram



Pin Assignment

Figure 3:
Package D 8-Lead SOIC (Top View)

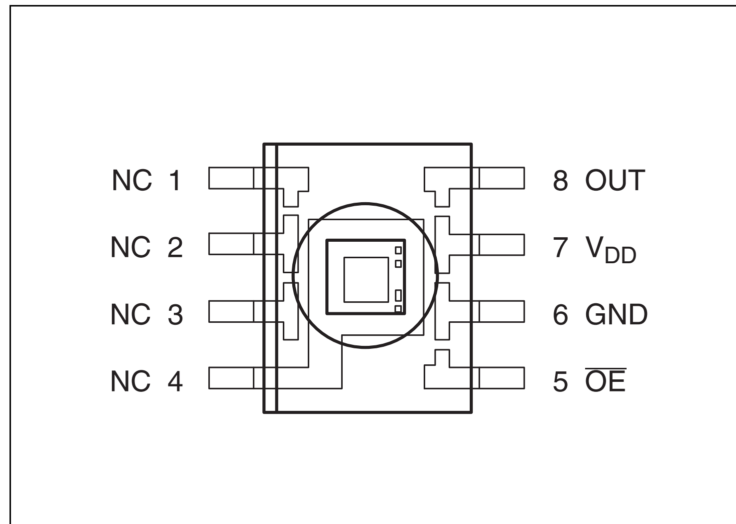


Figure 4:
Terminal Functions

Terminal		Type	Description
Name	D Pkg No.		
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

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.

Figure 5:
Absolute Maximum Ratings over Operating Free-Air Temperature Range (unless otherwise noted)

Symbol	Parameter	Min	Max	Units
V_{DD}	Supply voltage [1]		6	V
V_I	Input voltage range	-0.3	V_{DD}+0.3	V
I_O	Output current		±5	mA
	Short circuit of output to ground duration		5	s
T_A	Operating free-air temperature range [2]	-40	85	°C
T_{strg}	Storage temperature range [2]	-40	85	°C
	Solder conditions in accordance with JEDEC J-STD-020A, maximum temperature [3]		260	°C

Note(s):

1. All voltages 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.

Figure 6:
Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Units
V_{DD}	Supply voltage	2.7	5	5.5	V
V_{IH}	High-level input voltage	$0.8 \times V_{DD}$		V_{DD}	V
V_{IL}	Low-level input voltage	0		0.5	V
T_A	Operating free-air temperature	-40		70	°C

Electrical Characteristics

Figure 7:
Electrical Characteristics at V_{DD} = 5 V, T_A = 25°C [1] (unless otherwise noted)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{OH}	High-level output voltage	I_{OH} = -1 mA	4	4.5		V
V_{OL}	Low-level output voltage	I_{OL} = 1 mA		0.25	0.4	V
I_{IH}	High-level input current		-10		10	µA
I_{IL}	Low-level input current		-10		10	µA
I_{DD}	Supply current	E_e = 21.2 µW/cm^2		2	3	mA
	Full-scale frequency [2]	T_A = 50°C [3]	500		1000	kHz
	Temperature coefficient of responsivity	Wavelength < 600nm, f_O = 50 kHz		±200		ppm/°C
k_{SVS}	Supply-voltage sensitivity	V_{DD} = 5 V ± 10%		±0.5		%/V

Note(s):

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 µW/sqcm 524-nm irradiance. During production testing, devices are not tested at this very high irradiance level.
3. Measured at wafer probe using 50°C hot chuck.

Figure 8:
Operating Characteristics at V_{DD} = 5 V, T_A = 25°C, λ_p = 524 nm (unless otherwise noted)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
f_O	Output frequency	$E_e = 21.2\ \mu W/cm^2$	40	50	60	kHz
f_D	Dark frequency	$E_e = 0\ \mu W/cm^2$	0		1.2	Hz
		$E_e = 0\ \mu W/cm^2$, $T_A = 50°C$ [(1)]	0		6	Hz
R_e	Irradiance responsivity			2.3		kHz/(μW/cm²)
λ_p	Peak response wavelength			700		nm
	Nonlinearity [(2)]	f_O = 0 kHz to 10 kHz		± 1%		%F.S.
	Step response to full-scale step input		1 pulse of new frequency plus 1 μs			
	Time from $\overline{OE}$ low to output enabled		1 period of output frequency			

Note(s):

1. Measured at wafer probe using 50°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 Operating Characteristics

Figure 9:
Output Frequency vs Irradiance

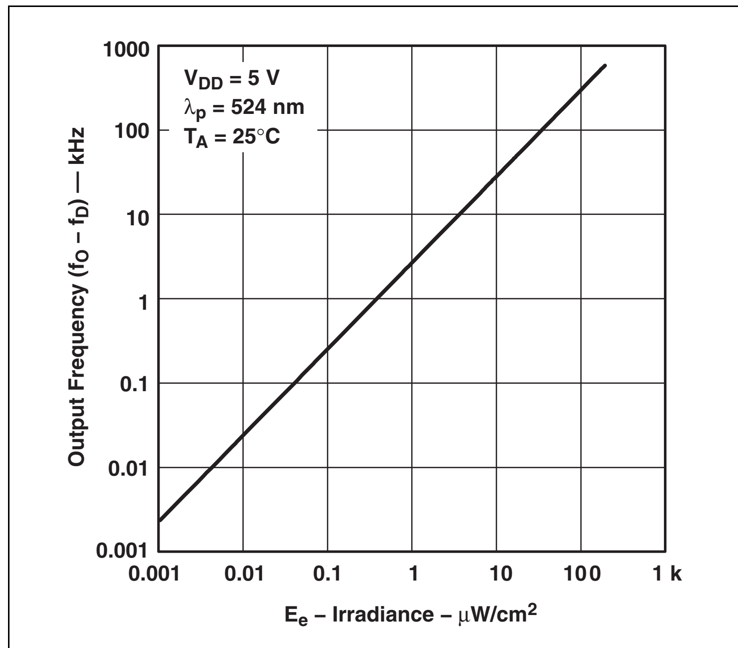


Figure 10:
Photodiode Spectral Responsivity

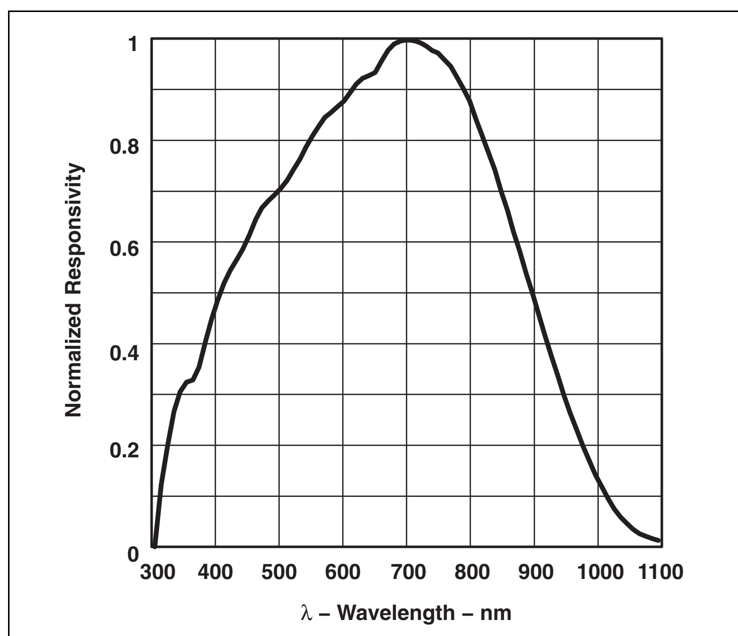


Figure 11:
Supply Current vs. Free-Air Temperature

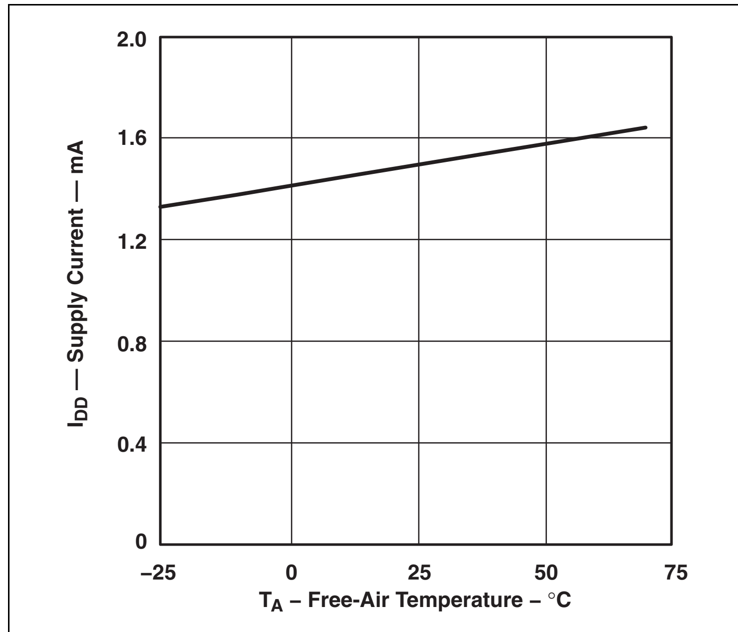


Figure 12:
Output Frequency vs. Free-Air Temperature

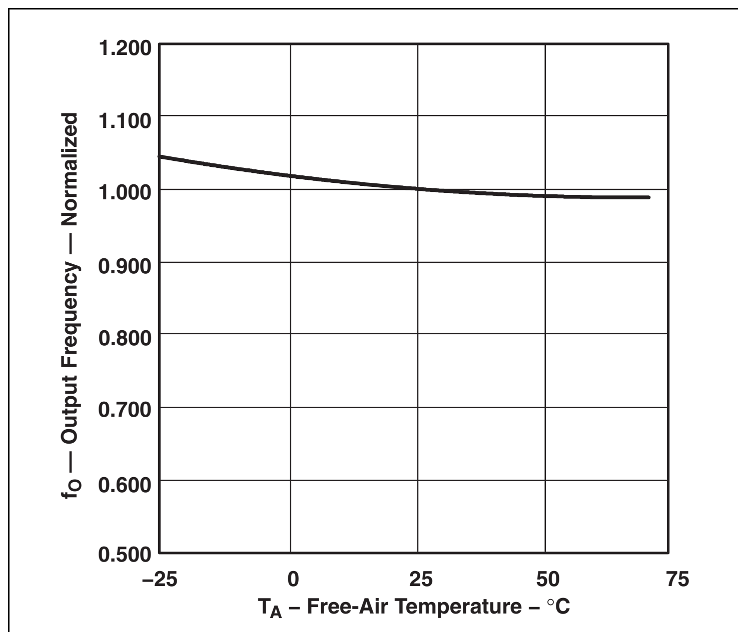


Figure 13:
Normalized Output Frequency vs. Angular Displacement

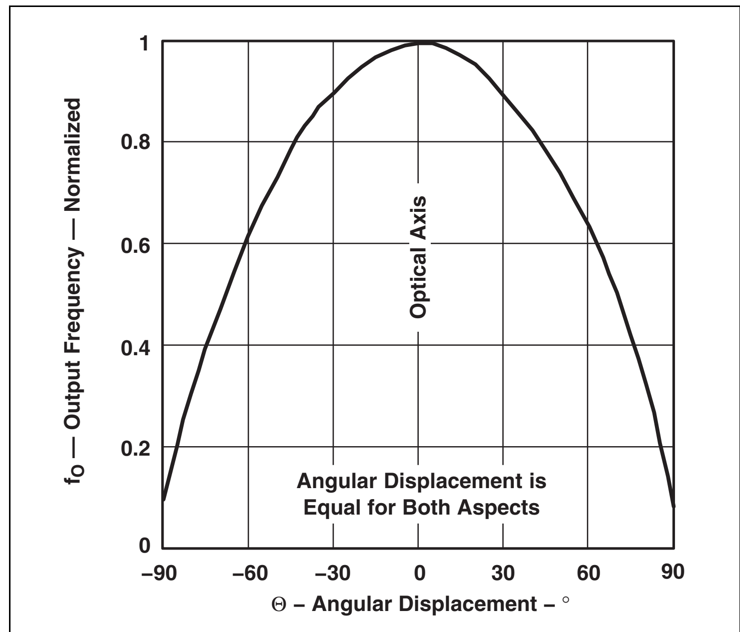
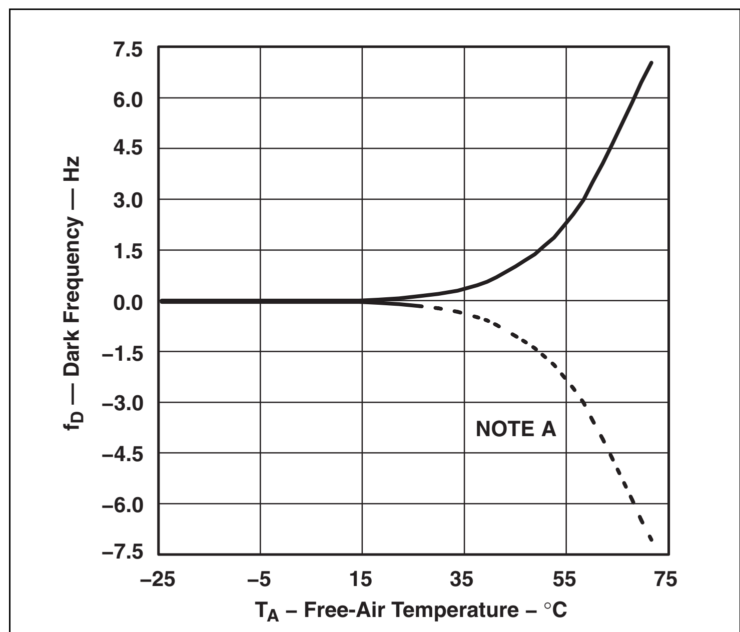
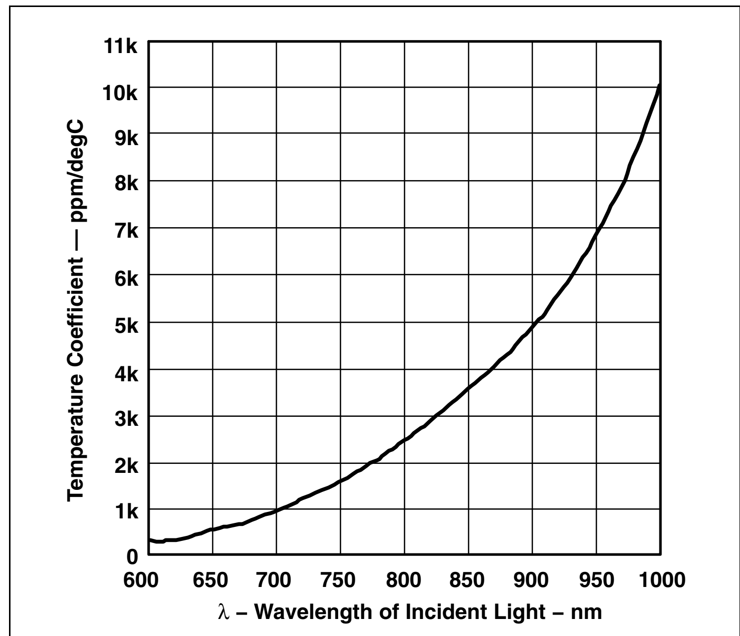


Figure 14:
Dark Frequency vs. Free-Air Temperature



Note(s): 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.

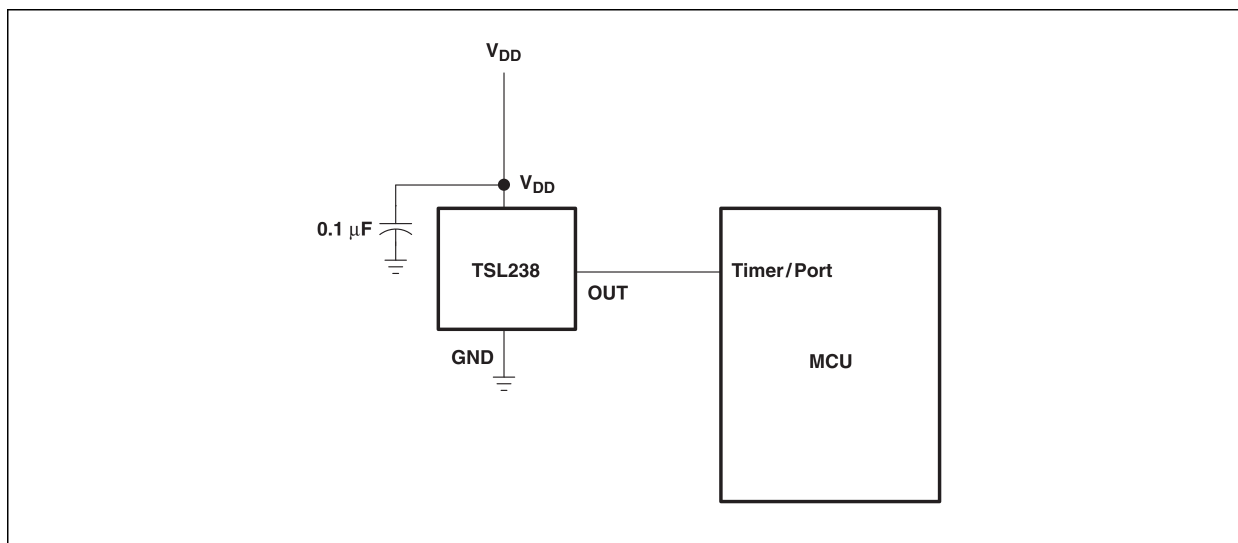
Figure 15:
Photodiode Responsivity Temperature Coefficient vs. Wavelength Of Incident Light



Application Information

Power-supply lines must be decoupled by a 0.01-µF to 0.1-µF capacitor with short leads placed close to the TSL238 (Figure 16). A low-noise power supply is required to minimize jitter on output pulse.

Figure 16:
Typical TSL238 Interface to a Microcontroller



Device Operational Details

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

(EQ1) $$f_O = f_D + (R_e) \cdot (E_e)$$

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 kHz/(µW/cm^2)

E_e is the incident irradiance in µW/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.

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.

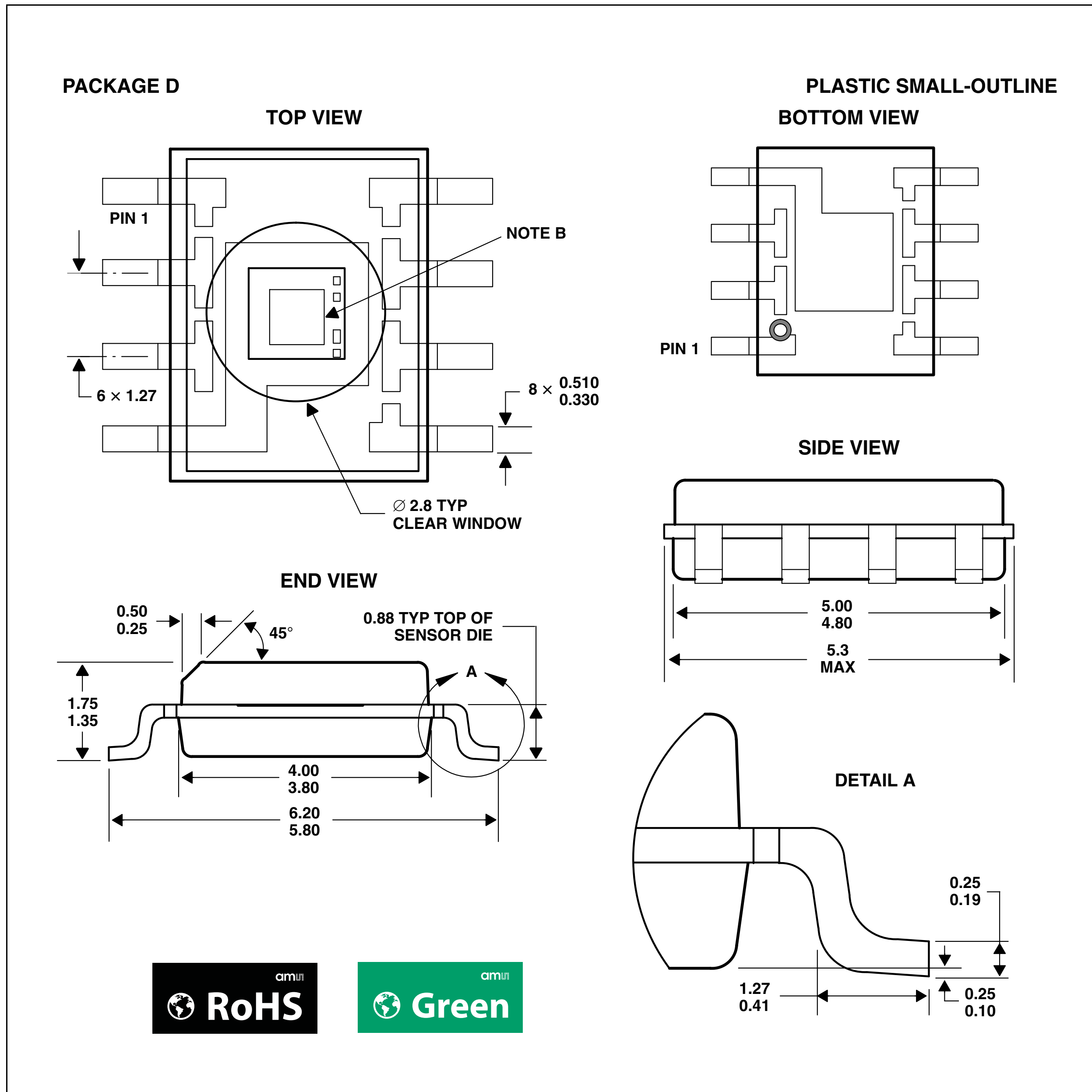
Maximum resolution and accuracy may be obtained using frequency-measurement, pulse-accumulation, or integration techniques. Frequency measurements provide the added benefit of averaging out random- or high-frequency variations (jitter) resulting from noise in the light signal. Resolution is limited mainly 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.

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.

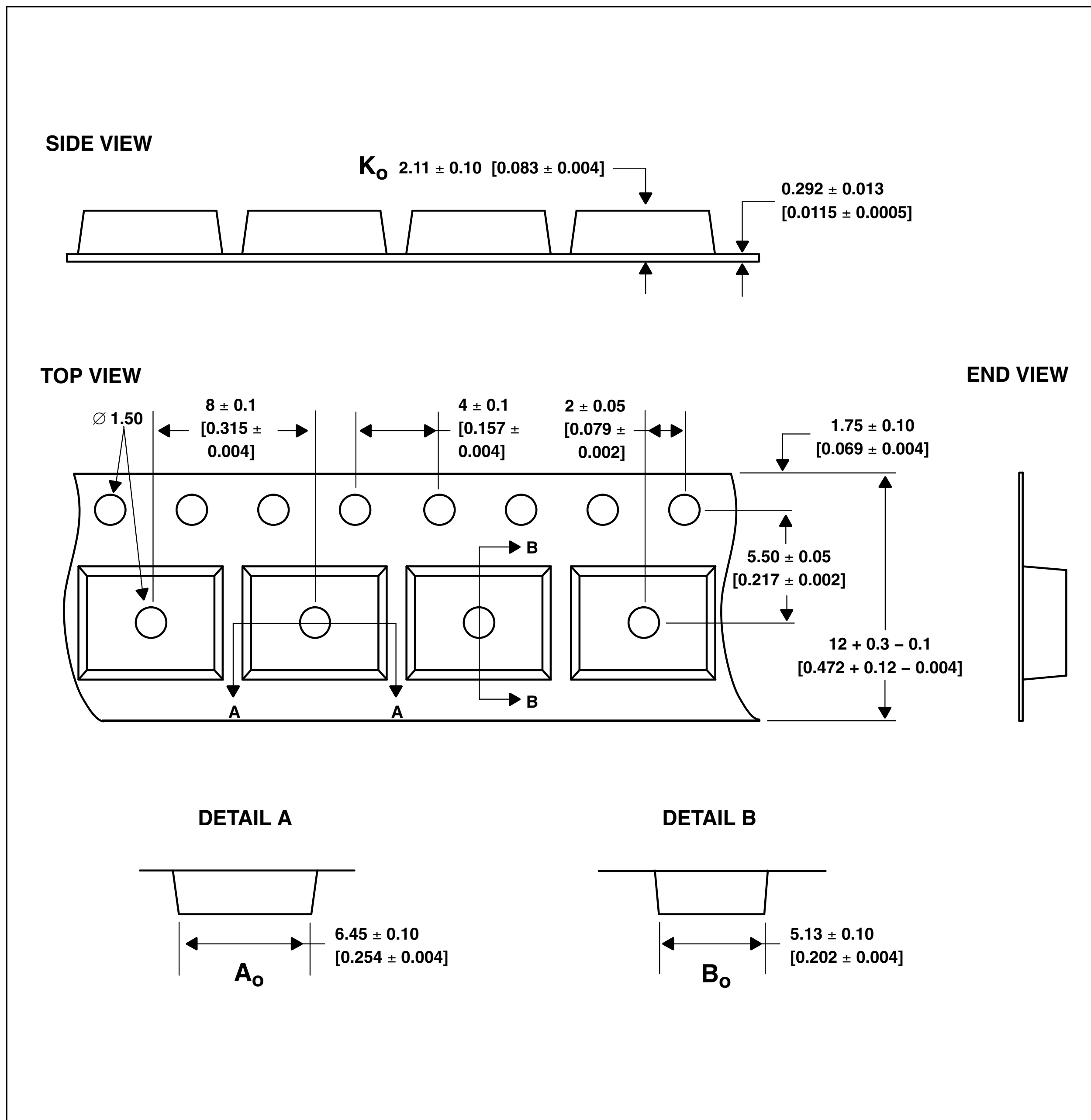
Figure 17:
Package D — Plastic Small Outline IC Packaging Configuration



Note(s):

1. All linear dimensions are in millimeters.
2. The center of the 0.84-mm by 0.84-mm photo-active area is located in the center of the package ± 0.25 mm.
3. 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.
4. Leads are plated with Pd (min 0.1 µ inch) + Ni (min 10 µ inch) + Au (min 0.1 µ inch).
5. This drawing is subject to change without notice.

Figure 18:
Package D Carrier Tape



Note(s):

1. All linear dimensions are in millimeters [inches].
2. The dimensions on this drawing are for illustrative purposes only. Dimensions of an actual carrier may vary slightly.
3. Symbols on drawing A_O, B_O, and K_O are defined in ANSI EIA Standard 481-B 2001.
4. Each reel is 178 millimeters in diameter and contains 1000 parts.
5. **ams** packaging tape and reel conform to the requirements of EIA Standard 481-B.
6. This drawing is subject to change without notice.

Manufacturing Information

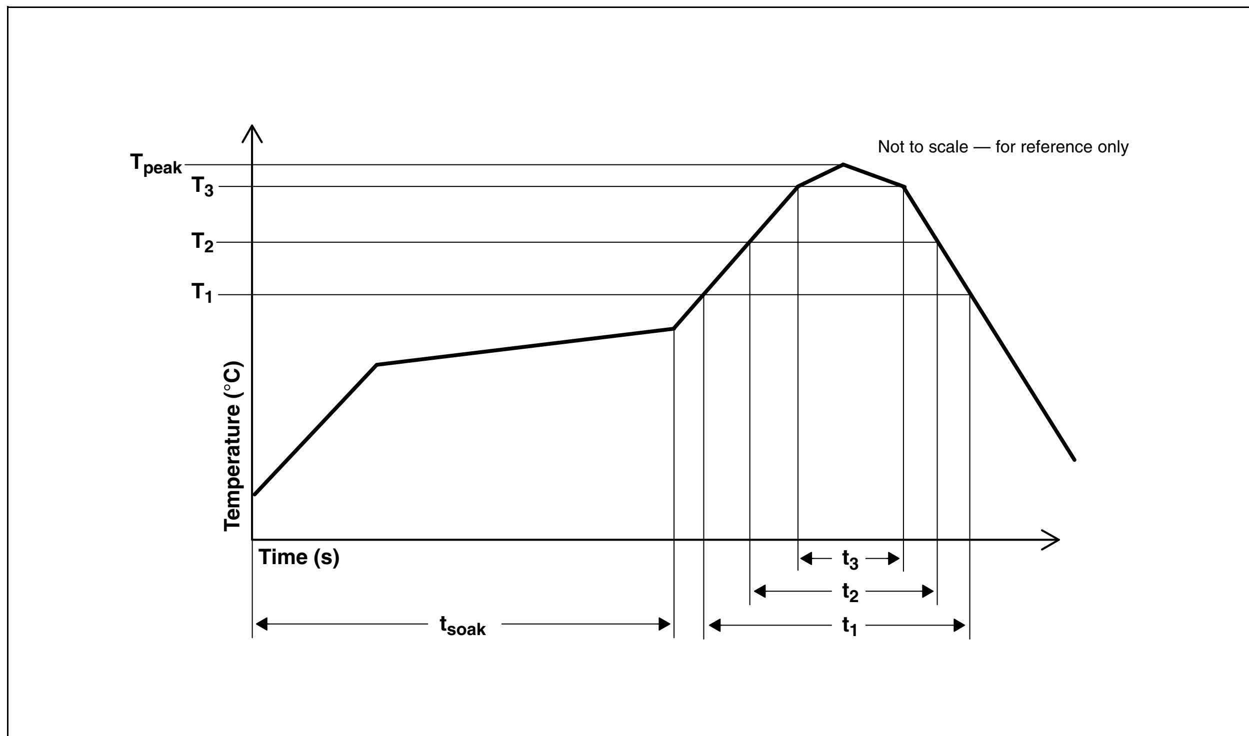
The Plastic Small Outline IC package (D) has been tested and has demonstrated an ability to be reflow soldered to a PCB substrate.

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.

Figure 19:
TSL238 Solder Reflow Profile

Parameter	Reference	TSL238
Average temperature gradient in preheating		2.5°C/s
Soak time	t_{soak}	2 to 3 minutes
Time above 217°C	t_1	Max 60 s
Time above 230°C	t_2	Max 50 s
Time above T_{peak} −10°C	t_3	Max 10 s
Peak temperature in reflow	T_{peak}	260°C (−0°C/5°C)
Temperature gradient in cooling		Max −5°C/s

Figure 20:
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).

Ordering & Contact Information

Figure 21:
Ordering Information

Ordering Code	Device	T_A	Package − Leads	Package Designator
TSL238D-TR	TSL238	-25°C to 70°C	8-lead Plastic Small Outline IC	D

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Document Status

Document Status	Product Status	Definition
Product Preview	Pre-Development	Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice
Preliminary Datasheet	Pre-Production	Information in this datasheet is based on products in the design, validation or qualification phase of development. The performance and parameters shown in this document are preliminary without any warranty and are subject to change without notice
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Datasheet (discontinued)	Discontinued	Information in this datasheet is based on products which conform to specifications in accordance with the terms of ams AG standard warranty as given in the General Terms of Trade, but these products have been superseded and should not be used for new designs

Revision Information

Changes from 073J (2008-Sep) to current revision 1-00 (2016-Aug-30)	Page
Content of TAOS datasheet was updated to latest **ams** design	
Added Figure 1	1

Note(s):

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.

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2 Functional Block Diagram

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