

# TSL237

## High-Sensitivity Light-to-Frequency Converter

### General Description

The TSL237 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. The device has been temperature compensated for the ultraviolet-to-visible light range of 320nm to 700nm and responds over the light range of 320nm to 1050nm. The TSL237 is characterized for operation over the temperature range of -40°C to 85°C and is supplied in a 3-lead clear plastic side-looker package with an integral lens. 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 TSL237, High-Sensitivity Light-to-Frequency Converter are listed below:

**Figure 1:**  
Added Value of Using TSL237

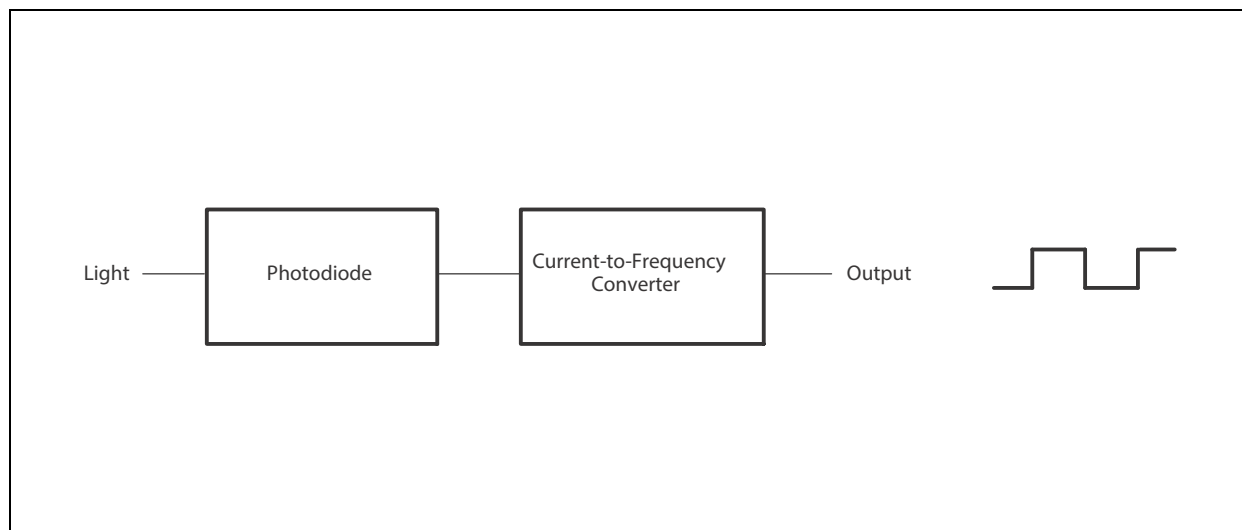
Benefits	Features
<ul style="list-style-type: none"> <li>High-Resolution Conversion of Light Intensity to Frequency with No External Components</li> </ul>	<ul style="list-style-type: none"> <li>5M:1 Input Dynamic Range</li> </ul>
<ul style="list-style-type: none"> <li>Provides Low Light Level Operation</li> </ul>	<ul style="list-style-type: none"> <li>Low Dark Frequency of 0.1 Hz (typical)</li> </ul>
<ul style="list-style-type: none"> <li>Provides for High Sensitivity to Detect a Small Change in Light</li> </ul>	<ul style="list-style-type: none"> <li>High Irradiance Responsivity 2.3kHz/(<math>\mu\text{W}/\text{cm}^2</math>) @ <math>\lambda_p = 524\text{nm}</math></li> </ul>
<ul style="list-style-type: none"> <li>Provides Additional Sensitivity Advantages</li> </ul>	<ul style="list-style-type: none"> <li>2x Gain Lens</li> </ul>

- Low Dark Frequency: < 2Hz at 50°C
- Single-Supply Operation: 2.7V to 5.5V
- Stable 200ppm/°C Temperature Coefficient
- Interfaces Directly to a Microcontroller
- RoHS Compliant (-LF Package Only)

## Functional Block Diagram

The functional blocks of this device are shown below:

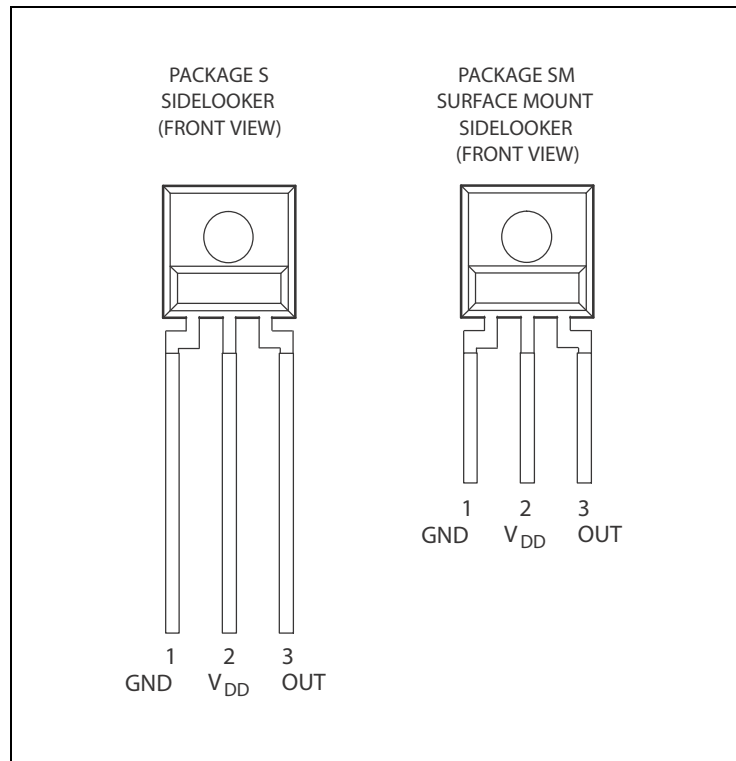
**Figure 2:**  
**TSL237 Block Diagram**



## Pin Assignment

The TSL237 pin assignments are described below.

**Figure 3:**  
**Pin Diagram**



**Figure 4:**  
**Terminal Functions**

Terminal		Type	Description
No.	Name		
1	GND		Power supply ground (substrate). All voltages are referenced to GND.
2	V <sub>DD</sub>		Supply voltage
3	OUT	O	Output frequency

## Absolute Maximum Ratings

Stresses beyond those listed under [Absolute Maximum Ratings](#) may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under [Electrical Characteristics](#) is not implied. Exposure to absolute maximum rating 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	Unit
$V_{DD}$	Supply voltage <sup>(1)</sup>		6	V
$T_A$	Operating free-air temperature range <sup>(2)</sup>	-40	85	°C
$T_{STRG}$	Storage temperature range <sup>(2)</sup>	-40	85	°C
	Lead temperature 1.6mm (1/16 inch) from case for 10 seconds (S Package)		260	°C
	Reflow solder, in accordance with J-STD-020C or J-STD-020D (SM Package)		260	°C

**Note(s):**

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.

## Electrical Characteristics

All limits are guaranteed. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

**Figure 6:**  
**Recommended Operating Conditions**

Symbol	Parameter	Min	Nom	Max	Unit
$V_{DD}$	Supply voltage	2.7	5	5.5	V
$T_A$	Operating free-air temperature	-40		70	°C

**Figure 7:**  
**Electrical Characteristics at  $V_{DD} = 5V$ ,  $T_A = 25^\circ C$  (unless otherwise noted)**

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
$V_{OH}$	High-level output voltage	$I_{OH} = -1mA$	4	4.5		V
$V_{OL}$	Low-level output voltage	$I_{OL} = 1mA$		0.25	0.4	V
$I_{DD}$	Supply current			2	3	mA
	Full-scale frequency <sup>(1)</sup>		500		1000	kHz
	Temperature coefficient of responsivity	Wavelength < 600nm, $f_O = 50kHz$		$\pm 200$		ppm/°C
$k_{SYS}$	Supply-voltage sensitivity	$V_{DD} = 5V \pm 10\%$		$\pm 0.5$		%/V

**Note(s):**

1. Full-scale frequency is the maximum operating frequency of the device without saturation.

**Figure 8:**  
Operating Characteristics at  $V_{DD} = 5V$ ,  $T_A = 25^\circ C$ ,  $\lambda_p = 524nm$  (unless otherwise noted)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
$f_O$	Output frequency	$E_e = 21.8\mu W/cm^2$	40	50	60	kHz
$f_D$	Dark frequency	$E_e = 0\mu W/cm^2$	0	0.1		Hz
		$E_e = 0\mu W/cm^2$ , $T_A = 50^\circ C$	0		2	Hz
$R_e$	Irradiance responsivity			2.3		kHz/( $\mu W/cm^2$ )
	Nonlinearity <sup>(1)</sup>	$f_O = 0kHz$ to $10kHz$		$\pm 1\%$		%F.S.
	Step response to full-scale step input		1 pulse of new frequency plus $1\mu s$			

**Note(s):**

1. Nonlinearity is defined as the deviation of  $f_O$  from a straight line between zero and full scale, expressed as a percent of full scale.

## Typical Operating Characteristics

Figure 9:  
Output Frequency vs. Irradiance

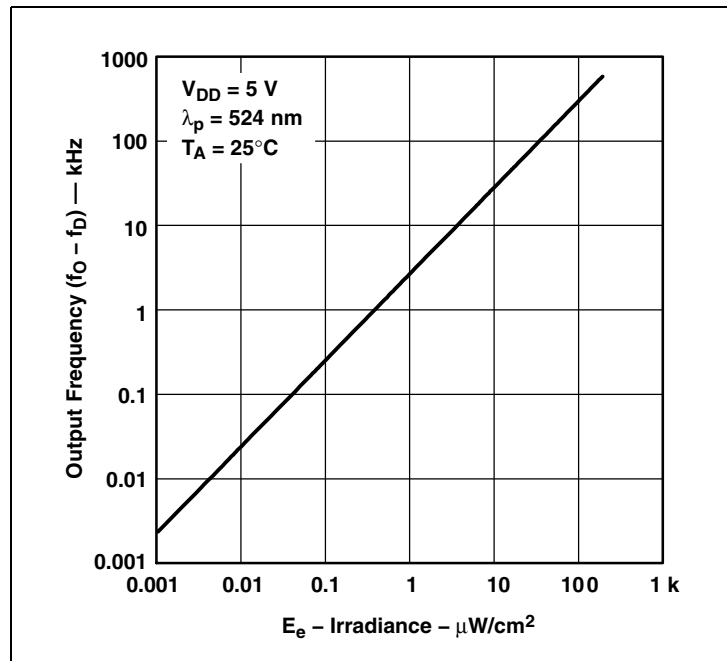
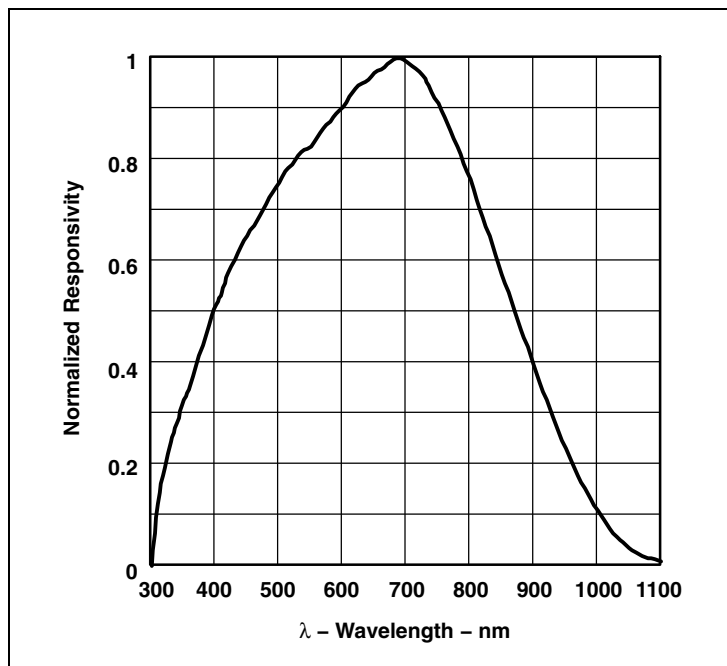
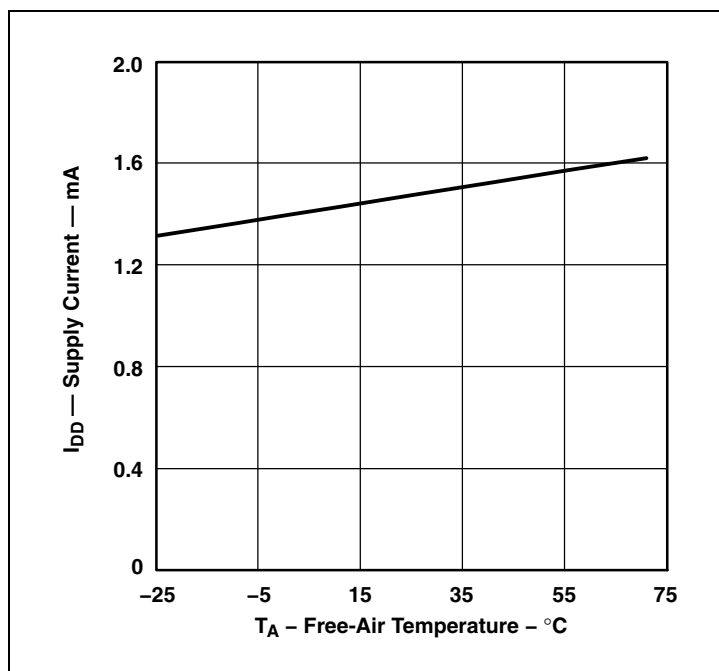


Figure 10:  
Photodiode Spectral Responsivity



**Figure 11:**  
Supply Current vs. Free-Air Temperature



**Figure 12:**  
Output Frequency vs. Free-Air Temperature

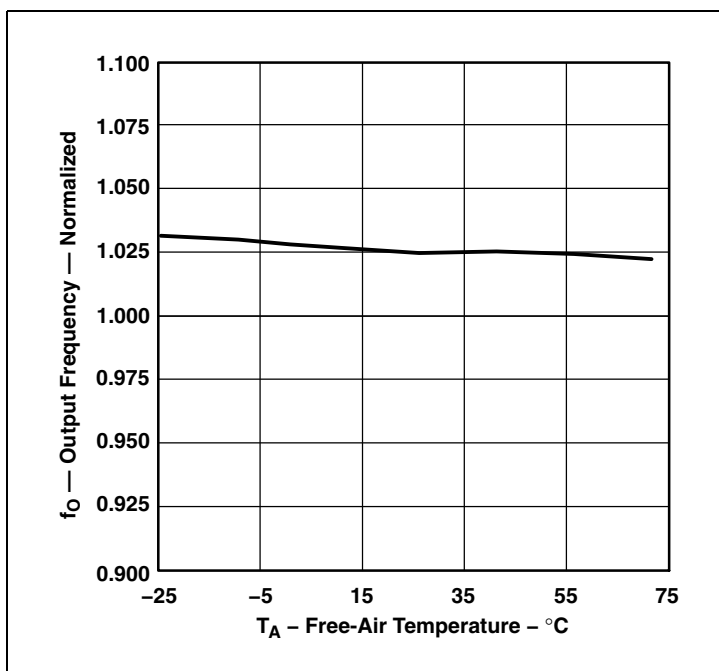




Figure 13:  
Output Frequency vs. Vertical Angular Displacement

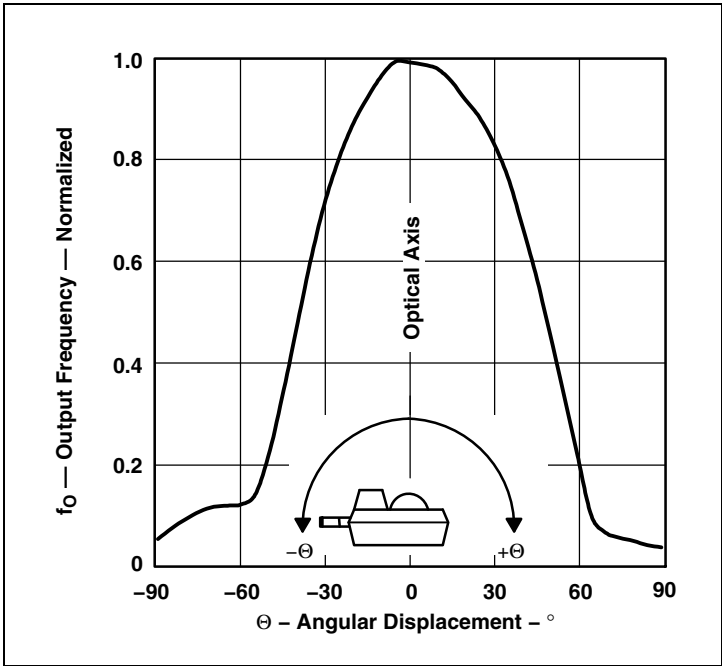
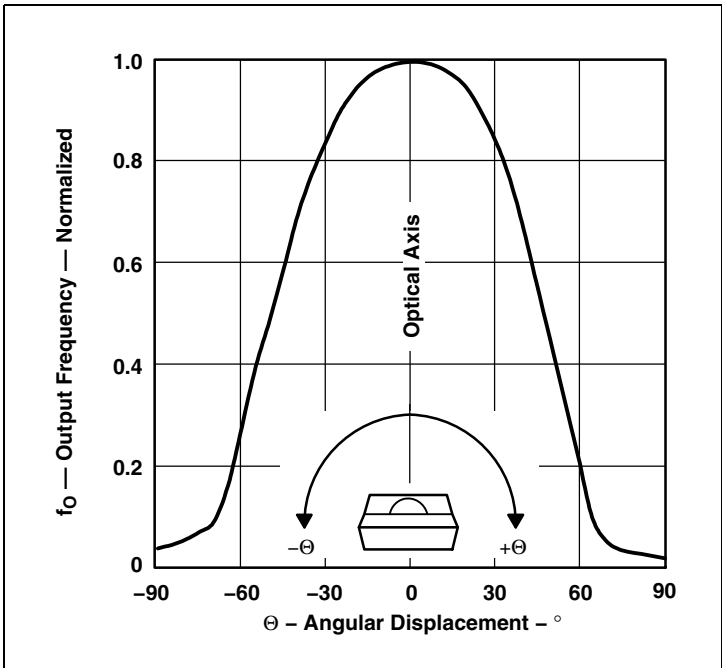
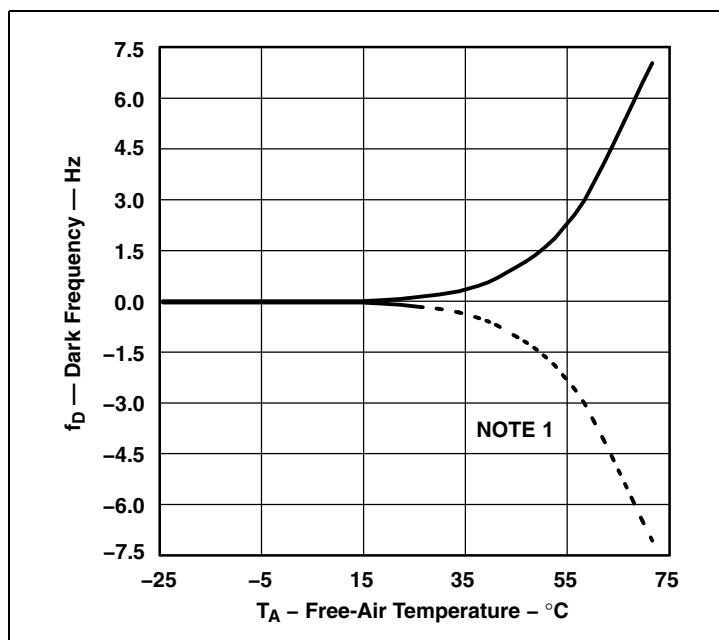


Figure 14:  
Output Frequency vs. Horizontal Angular Displacement



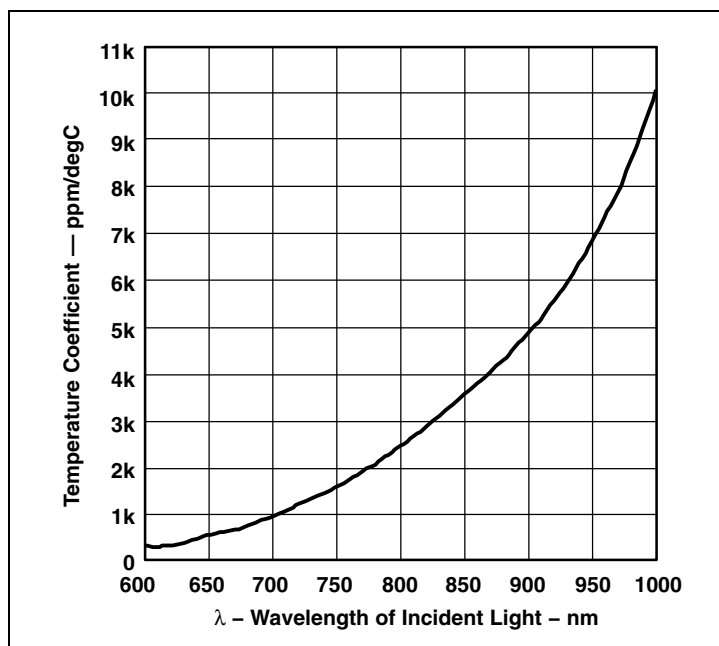
**Figure 15:**  
**Dark Frequency vs. Free-Air Temperature**



**Note(s):**

1. 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 16:**  
**Photodiode Responsivity Temperature Coefficient vs. Wavelength of Incident Light**

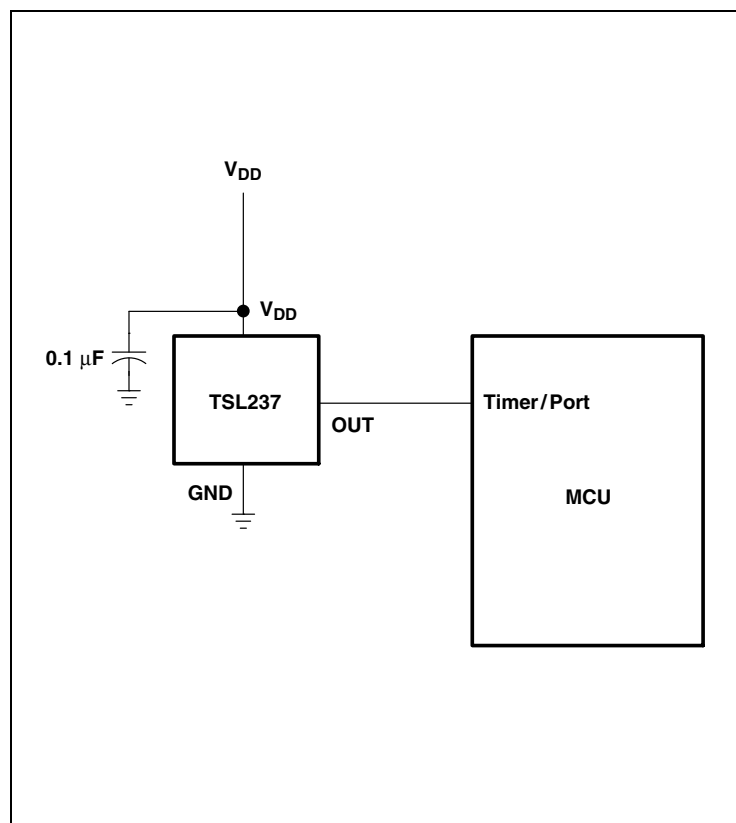


## Application Information

### 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 TSL237 (Figure 17). A low-noise power supply is required to minimize jitter on output pulse.

**Figure 17:**  
Typical TSL237 Interface to a Microcontroller



### Device Operational Details

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

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

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 TSL237 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.

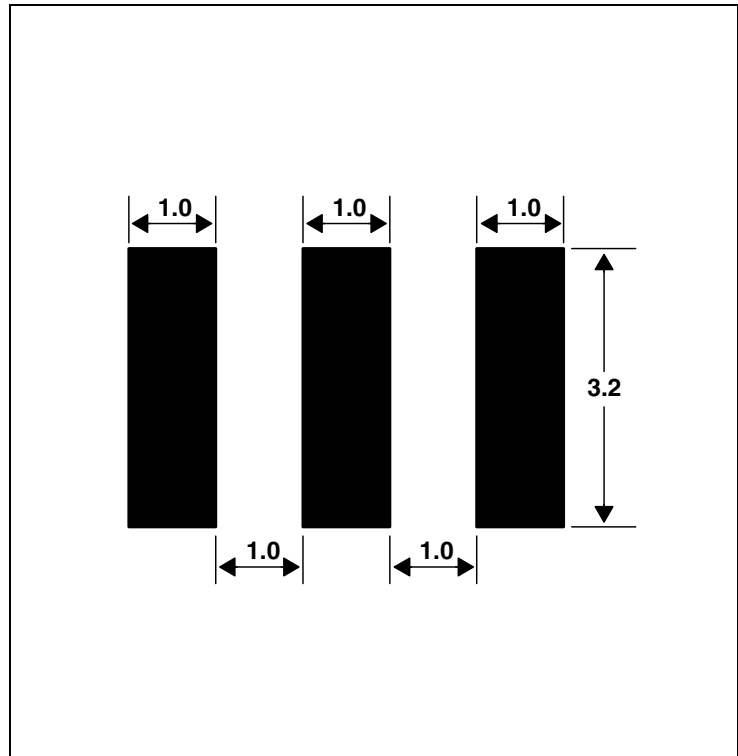
Period measurement requires the use of a fast reference clock with available resolution directly related to the reference-clock rate. The technique is employed to measure rapidly varying light levels or to make a fast measurement of a constant light source.

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.

## PCB Pad Layout

Suggested PCB pad layout guidelines for the SM surface mount package are shown in [Figure 18](#).

**Figure 18:**  
**Suggested SM Package PCB Layout**



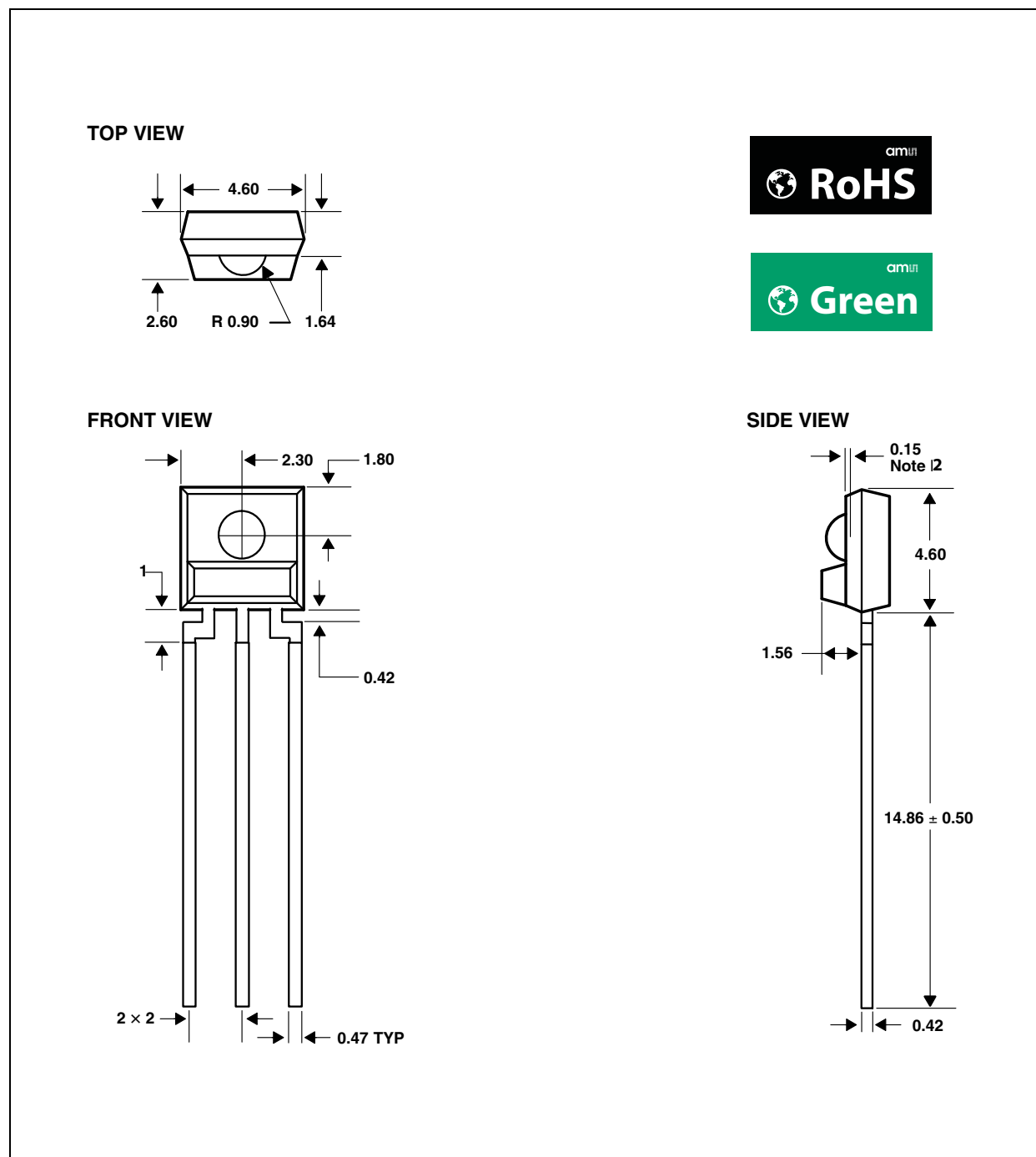
**Note(s):**

1. All linear dimensions are in millimeters.
2. This drawing is subject to change without notice.

## Mechanical Information

The device is supplied in a clear plastic three-lead through-hole package.

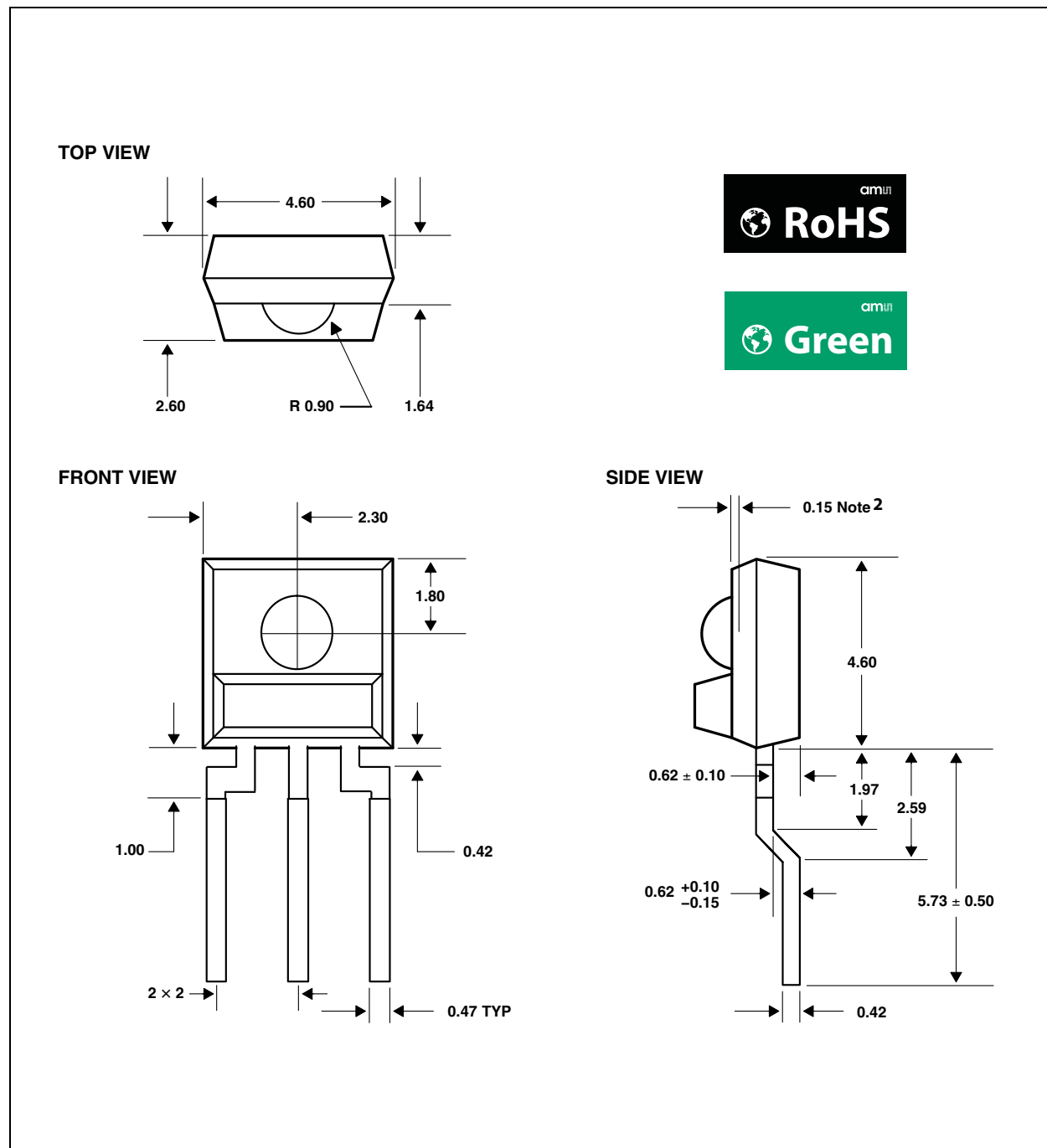
**Figure 19:**  
Package S - Plastic Single-In-Line Side-Looker Package Configuration



### Note(s):

1. All linear dimensions are in millimeters; tolerance is  $\pm 0.25\text{mm}$  unless otherwise stated.
2. Dimension is to center of lens arc, which is located below the package face.
3. The integrated photodiode active area is typically  $0.92\text{mm}^2$  in size and is located in the center of the lens and  $0.97\text{mm}$  below the top of the lens surface.
4. Index of refraction of clear plastic is 1.55.
5. Lead finish for TSL237-LF: solder dipped, 100% Sn.
6. This drawing is subject to change without notice.

**Figure 20:**  
**Package SM - Surface Mount Side-Looker Package Configuration**



**Note(s):**

1. All linear dimensions are in millimeters; tolerance is  $\pm 0.25\text{mm}$  unless otherwise stated.
2. Dimension is to center of lens arc, which is located below the package face.
3. The integrated photodiode active area is typically located in the center of the lens and 0.97mm below the top of the lens surface.
4. Index of refraction of clear plastic is 1.55.
5. Lead finish for TSL237SM-LF: solder dipped, 100% Sn.
6. This drawing is subject to change without notice.

## Ordering & Contact Information

**Figure 21:**  
**Ordering Information**

Ordering Code	Device	T <sub>A</sub>	Package-Leads	Package Designator
TSL237S-LF	TSL237	-40°C to 70°C	3-lead Sidelooker - Lead (Pb) Free	S
TSL237SM-LF	TSL237	-40°C to 70°C	3-lead Surface-Mount Sidelooker - Lead (Pb) Free	SM

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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
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## Revision Information

Changes from 052J (2008-Sep) to current revision 1-00 (2016-Jul-22)	Page
Content of TAOS datasheet was converted to the latest <b>ams</b> design	
Added Figure 1	1
Updated Figure 21	16

**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.

## Content Guide

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