Product
Document

am **OSRAM**

TCS3200

Programmable
Color Light-to-Frequency Converter

General Description

The TCS3200 programmable color light-to-frequency converter combines configurable silicon photodiodes and a current-to-frequency converter on a single monolithic CMOS integrated circuit. The output is a square wave (50% duty cycle) with frequency directly proportional to light intensity (irradiance).

The full-scale output frequency can be scaled by one of three preset values via two control input pins. Digital inputs and digital output allow direct interface to a microcontroller or other logic circuitry. Output enable ($\overline{OE}$) places the output in the high-impedance state for multiple-unit sharing of a microcontroller input line.

In the TCS3200, the light-to-frequency converter reads an 8×8 array of photodiodes. Sixteen photodiodes have blue filters, 16 photodiodes have green filters, 16 photodiodes have red filters, and 16 photodiodes are clear with no filters.

The four types (colors) of photodiodes are interdigitated to minimize the effect of non-uniformity of incident irradiance. All photodiodes of the same color are connected in parallel. Pins S2 and S3 are used to select which group of photodiodes (red, green, blue, clear) are active. Photodiodes are 110μm × 110μm in size and are on 134μm centers.

Ordering Information and *Content Guide* appear at end of datasheet.

Key Benefits & Features

The benefits and features of TCS3200 Programmable Color Light-to-Frequency Converter are listed below:
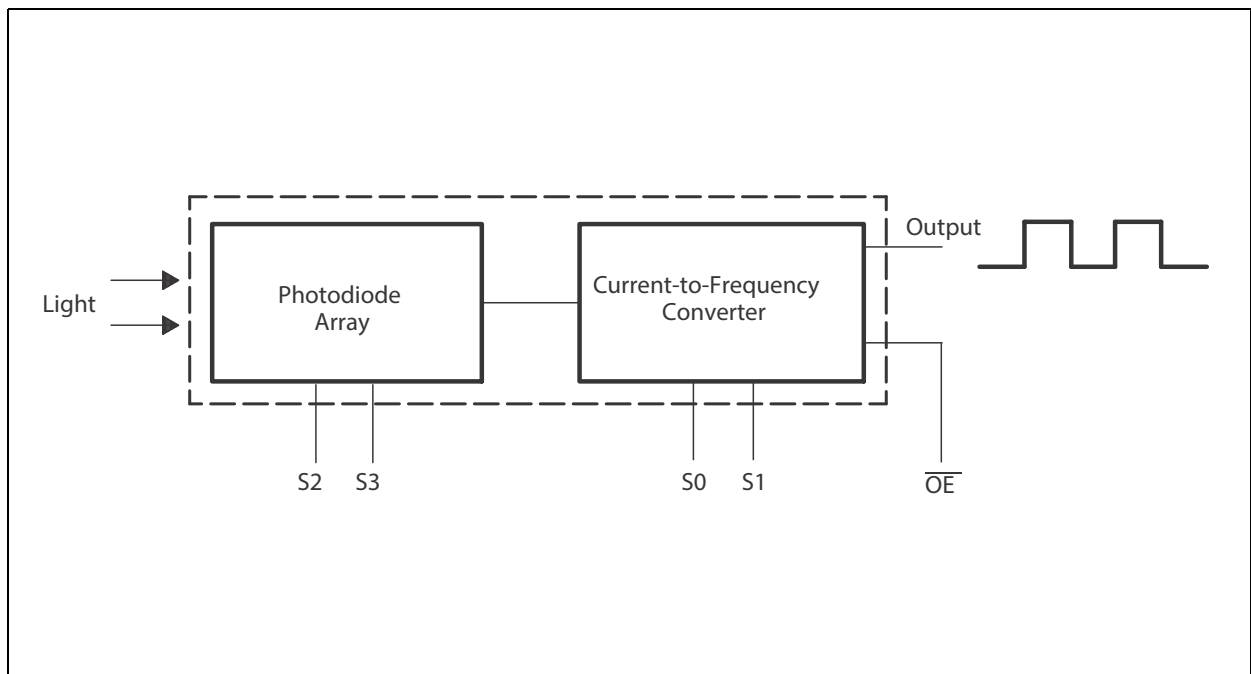
Figure 1:
Added Value of Using TCS3200

Benefits	Features
• Enables High-Resolution Conversion of Light Intensity to Frequency	• Programmable Color Light-to-Frequency Converter
• Disables the Output into a Hi-Impedance State when OE Input Pin is Low	• Output Enable (OE) Pin
• Enables Output Range to be Optimized for a Variety of Low-Cost Measurement Techniques	• Output Frequency Scaling
• Reduces Board Space Requirements while Simplifying Designs	• Available in 5mm x 6.2mm SOIC (D) Package

- Programmable Color and Full-Scale Output Frequency

- Communicates Directly with a Microcontroller

- Single-Supply Operation (2.7V to 5.5V)

- Power Down Feature

- Nonlinearity Error Typically 0.2% at 50kHz

- Stable 200ppm/°C Temperature Coefficient

- Low-Profile Lead (Pb) Free and RoHS Compliant Surface-Mount Package

Block Diagram

The functional blocks of this device are shown below:

Figure 2:
TCS3200 Block Diagram

Pin Assignments

The TCS3200 pin assignments are described below:
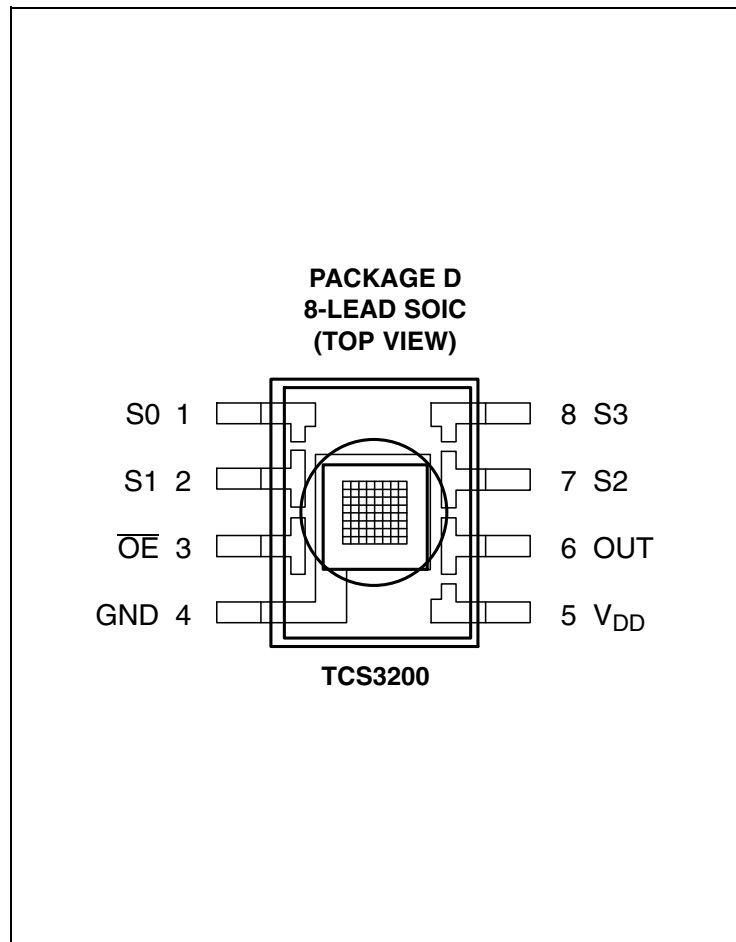
Figure 3:
Pin Diagram of TCS3200

PACKAGE D
8-LEAD SOIC
(TOP VIEW)

S0 1   8 S3

S1 2   7 S2

$\overline{OE}$ 3   6 OUT

GND 4   5 V_{DD}

TCS3200

Figure 4:
Terminal Functions

Terminal		I/O	Description
Name	**No.**		
S0, S1	1, 2	I	Output frequency scaling selection inputs
$\overline{OE}$	3	I	Enable for f_o (active low)
GND	4		Power supply ground. All voltages are referenced to GND.
V_{DD}	5		Supply voltage
OUT	6	O	Output frequency (f_o)
S2, S3	7, 8	I	Photodiode type selection inputs

Figure 5:
Selectable Options

S0	S1	Output Frequency Scaling (f_o)	S2	S3	Photodiode Type
L	L	Power down	L	L	Red
L	H	2%	L	H	Blue
H	L	20%	H	L	Clear (no filter)
H	H	100%	H	H	Green

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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 Recommended Operating Conditions is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Figure 6:
Absolute Maximum Ratings Over Operating Free-Air Temperature Range (unless otherwise noted)

Symbol	Parameter	Min	Max	Unit
V_{DD}	Supply voltage [1]		6	V
V_I	Input voltage range, all inputs	-0.3	$V_{DD} + 0.3$	V
T_A	Operating free-air temperature range [2]	-40	85	°C
T_{STRG}	Storage temperature range [2]	-40	85	V
	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.

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 7:
Recommended Operating Conditions

Symbol	Parameter		Min	Nom	Max	Unit
V_{DD}	Supply voltage		2.7	5	5.5	V
V_{IH}	High-level input voltage	V_{DD} = 2.7V to 5.5V	2		V_{DD}	V
V_{IL}	Low-level input voltage	V_{DD} = 2.7V to 5.5V	0		0.8	V
T_A	Operating free-air temperature range		-40		70	°C

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

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{OH}	High-level output voltage	I_{OH} = -2mA	4	4.5		V
V_{OL}	Low-level output voltage	I_{OL} = 2mA		0.25	0.40	V
I_{IH}	High-level input current				5	µA
I_{IL}	Low-level input current				5	µA
I_{DD}	Supply current	Power-on mode		1.4	2	mA
		Power-down mode			0.1	µA
	Full-scale frequency [1]	S0 = H, S1 = H	500	600		kHz
		S0 = H, S1 = L	100	120		kHz
		S0 = L, S1 = H	10	12		kHz
	Temperature coefficient of responsivity	$\lambda \leq 700$nm, -25°C $\leq T_A \leq$ 70°C		±200		ppm/°C
k_{SVS}	Supply voltage sensitivity	V_{DD} = 5V ±10%		±0.5		%/V

Note(s):

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

Figure 9:

Operating Characteristics at V_{DD} = 5V, T_A = 25°C, S0 = H, S1 = H (unless otherwise noted) [1], [2], [3], [4]

Symbol	Parameter	Test Conditions	Clear Photodiode S2 = H, S3 = L			Blue Photodiode S2 = L, S3 = H			Green Photodiode S2 = H, S3 = H			Red Photodiode S2 = L, S3 = L			Unit
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
f_O	Output frequency [5]	E_e = 47.2μW/cm^2 λ_p = 470nm	12.5	15.6	18.7	61%		84%	22%		43%	0%		6%	kHz
		E_e = 40.4μW/cm^2 λ_p = 524nm	12.5	15.6	18.7	8%		28%	57%		80%	9%		27%	
		E_e = 34.6μW/cm^2 λ_p = 640nm	13.1	16.4	19.7	5%		21%	0%		12%	84%		105%	
R_e	Irradiance responsivity [6]	λ_p = 470nm		331		61%		84%	22%		43%	0%		6%	Hz/ (μW/ cm^2)
		λ_p = 524nm		386		8%		28%	57%		80%	9%		27%	
		λ_p = 640nm		474		5%		21%	0%		12%	84%		105%	
	Saturation irradiance [7]	λ_p = 470nm		1813			--			--			--		μW/ cm^2
		λ_p = 524nm		1554			--			--			--		
		λ_p = 640nm		1266			--			--			--		
f_D	Dark frequency	E_e = 0		2	10		2	10		2	10		2	10	Hz

Symbol	Parameter	Test Conditions	Clear Photodiode S2 = H, S3 = L			Blue Photodiode S2 = L, S3 = H			Green Photodiode S2 = H, S3 = H			Red Photodiode S2 = L, S3 = L			Unit
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
	Nonlinearity [8]	f_O = 0 to 5kHz		±0.1			±0.1			±0.1			±0.1		%F.S.
		f_O = 0 to 50kHz		±0.2			±0.2			±0.2			±0.2		
		f_O = 0 to 500kHz		±0.5			±0.5			±0.5			±0.5		
	Recovery from power down			100			100			100			100		µs
	Response time to output enable ($\overline{OE}$)			100			100			100			100		ns

Note(s):

1. Optical measurements are made using small-angle incident radiation from a light-emitting diode (LED) optical source.

2. The 470nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics:
   peak wavelength λ_p = 470nm, spectral halfwidth $\Delta\lambda\frac{1}{2}$ = 35nm, and luminous efficacy = 75lm/W.

3. The 524nm input irradiance is supplied by an InGaN light-emitting diode with the following characteristics:
   peak wavelength λ_p = 524nm, spectral halfwidth $\Delta\lambda\frac{1}{2}$ = 47nm, and luminous efficacy = 520lm/W.

4. The 640nm input irradiance is supplied by a AlInGaP light-emitting diode with the following characteristics:
   peak wavelength λ_p = 640nm, spectral halfwidth $\Delta\lambda\frac{1}{2}$ = 17nm, and luminous efficacy = 155lm/W.

5. Output frequency Blue, Green, Red percentage represents the ratio of the respective color to the Clear channel absolute value.

6. Irradiance responsivity R_e is characterized over the range from zero to 5kHz.

7. Saturation irradiance = (full-scale frequency)/(irradiance responsivity) for the Clear reference channel.

8. 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
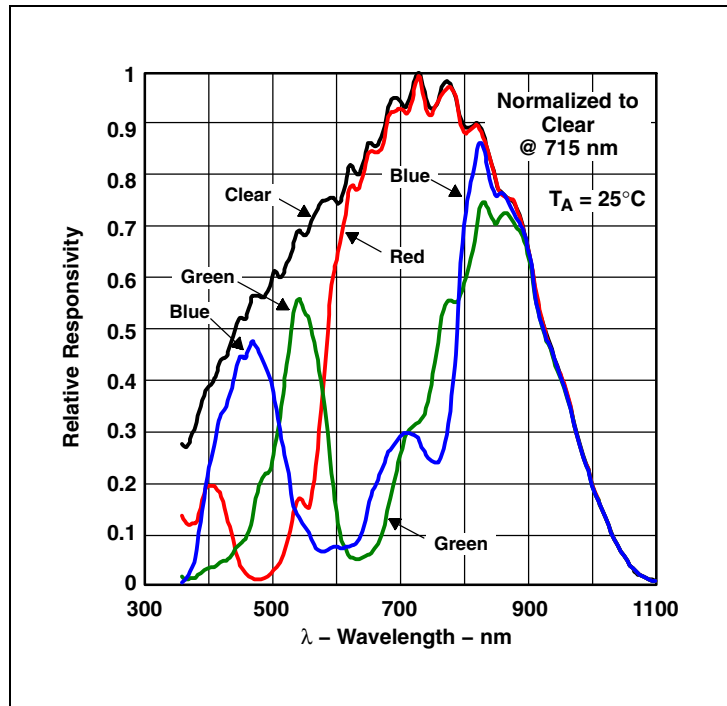
Figure 10:
Photodiode Spectral Responsivity

Figure 11:
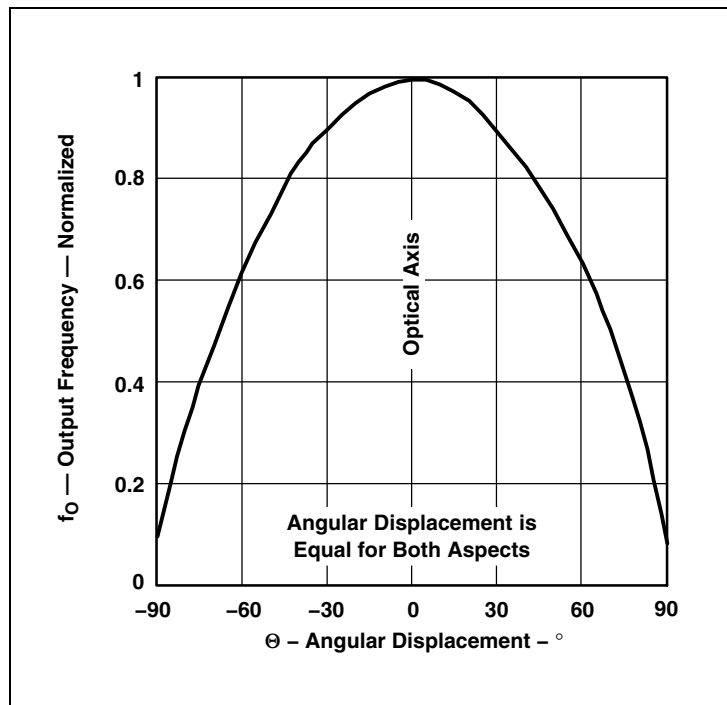**Normalized Output Frequency vs. Angular Displacement**

Figure 12:
I_{DD} vs. V_{DD} vs. Temperature
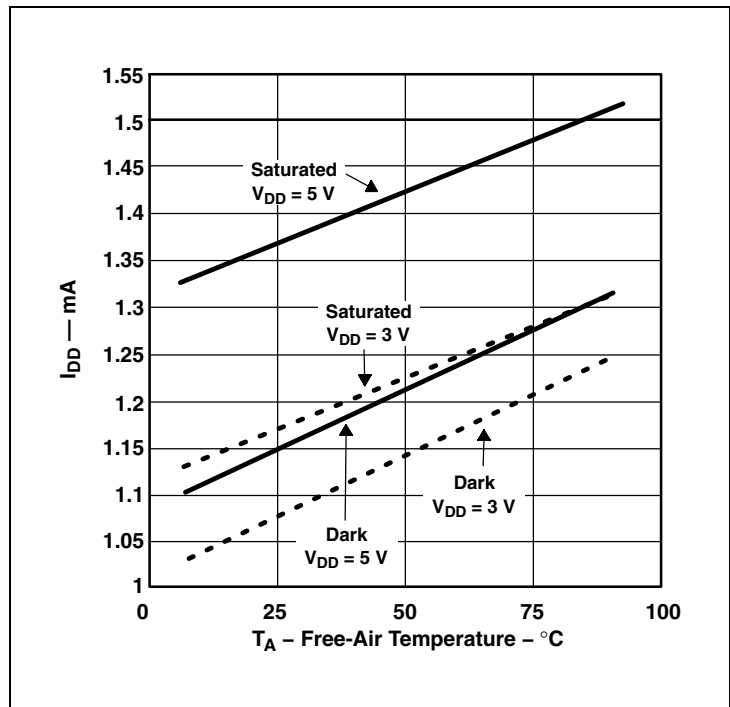

Figure 13:
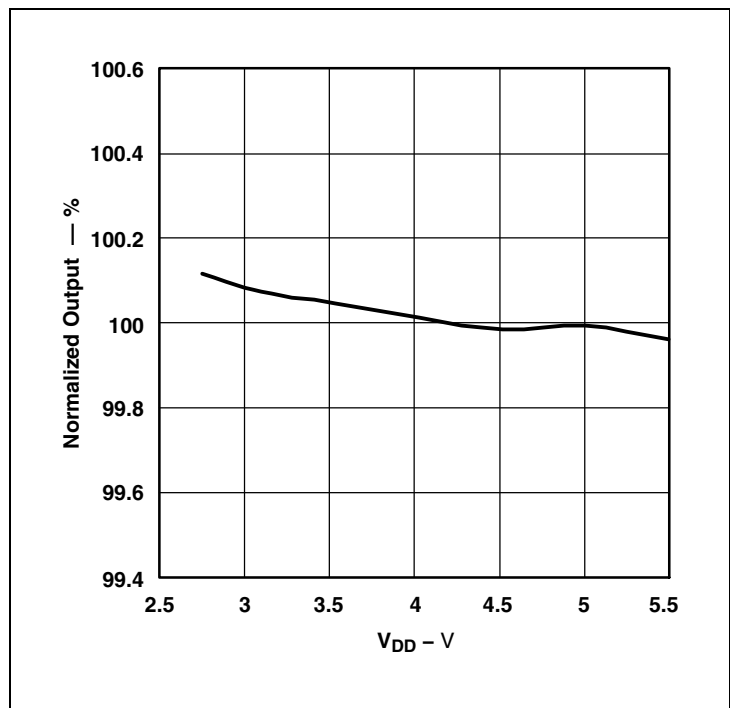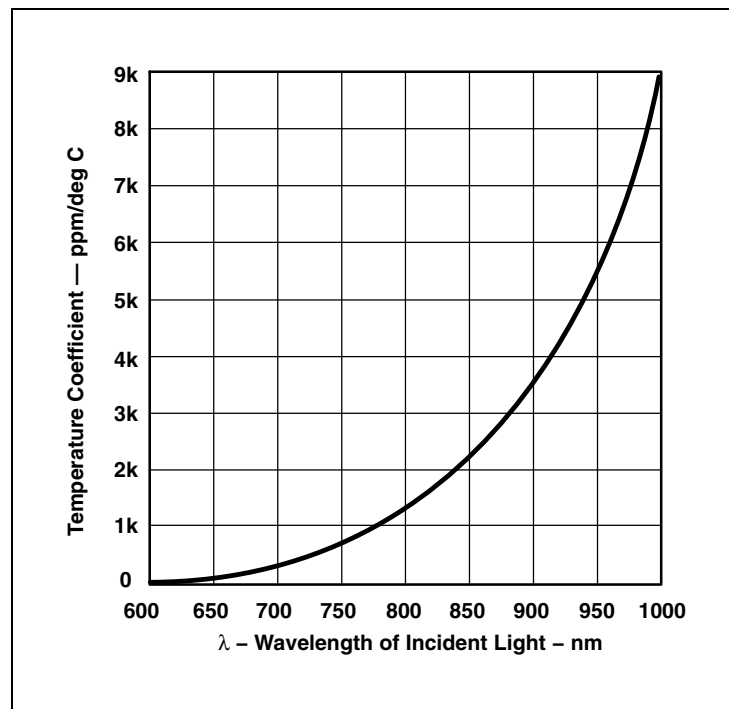**Normalized Output vs. V_{DD}**

Figure 14:
Photodiode Responsivity Temperature Coefficient vs. Wavelength Of Incident Light

Application Information

Power Supply Considerations

Power supply lines must be decoupled by a 0.01µF to 0.1µF capacitor with short leads mounted close to the device package.

Input Interface

A low-impedance electrical connection between the device $\overline{OE}$ pin and the device GND pin is required for improved noise immunity. All input pins must be either driven by a logic signal or connected to VDD or GND - they should not be left unconnected (floating).

Output Interface

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

A high state on Output Enable (OE) places the output in a high-impedance state for multiple-unit sharing of a microcontroller input line.

Power Down

Powering down the sensor using S0/S1 (L/L) will cause the output to be held in a high-impedance state. This is similar to the behavior of the output enable pin, however powering down the sensor saves significantly more power than disabling the sensor with the output enable pin.

Photodiode Type (Color) Selection

The type of photodiode (blue, green, red, or clear) used by the device is controlled by two logic inputs, S2 and S3 (see Figure 5).

Output Frequency Scaling

Output-frequency scaling is controlled by two logic inputs, S0 and S1. The internal light-to-frequency converter generates a fixed-pulsewidth pulse train. Scaling is accomplished by internally connecting the pulse-train output of the converter to a series of frequency dividers. Divided outputs are 50%-duty cycle square waves with relative frequency values of 100%, 20%, and 2%. Because division of the output frequency is accomplished by counting pulses of the principal internal frequency, the final-output period represents an average of the multiple periods of the principle frequency.

The output-scaling counter registers are cleared upon the next pulse of the principal frequency after any transition of the S0, S1, S2, S3, and $\overline{OE}$ lines.

The output goes high upon the next subsequent pulse of the principal frequency, beginning a new valid period. This minimizes the time delay between a change on the input lines and the resulting new output period. The response time to an input programming change or to an irradiance step change is one period of new frequency plus 1µs. The scaled output changes both the full-scale frequency and the dark frequency by the selected scale factor.

The frequency-scaling function allows the output range to be optimized for a variety of measurement techniques. The scaled-down outputs may be used where only a slower frequency counter is available, such as low-cost microcontroller, or where period measurement techniques are used.

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.

Output data can be collected at a rate of twice the output frequency or one data point every microsecond for full-scale output. Period measurement requires the use of a fast reference clock with available resolution directly related to reference clock rate. Output scaling can be used to increase the resolution for a given clock rate or to maximize resolution as the light input changes. Period measurement is used to measure rapidly varying light levels or to make a very 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 D package are shown in Figure 15.

Figure 15:
**Suggested D Package PCB Layout**
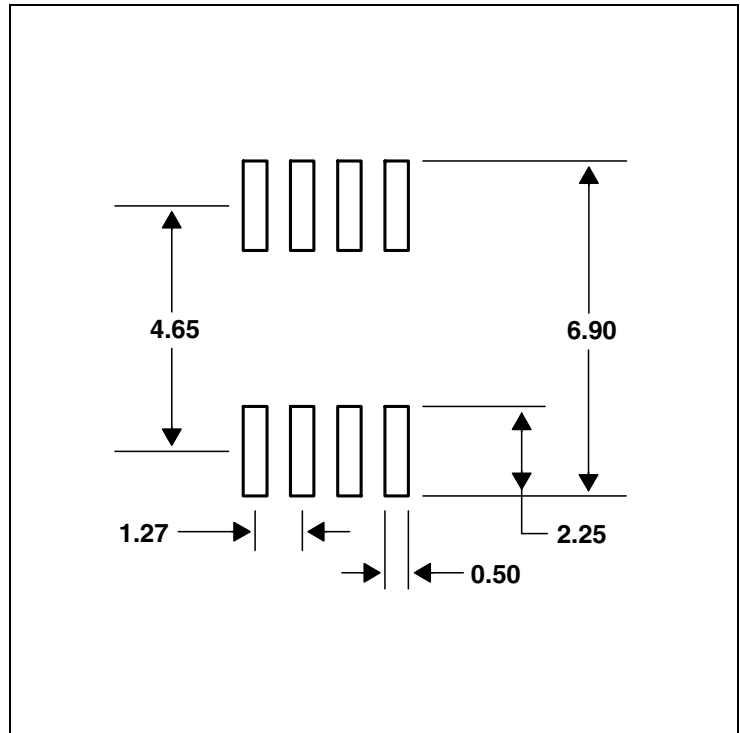
Note(s):

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

Packaging Mechanical Data

This SOIC package consists of an integrated circuit mounted on a lead frame and encapsulated with an electrically nonconductive clear plastic compound. The TCS3200 has an 8 × 8 array of photodiodes with a total size of 1mm by 1mm. The photodiodes are 110µm × 110µm in size and are positioned on 134µm centers.

Figure 16:
Package D - TCS3200 Plastic Small Outline IC Packaging Configuration
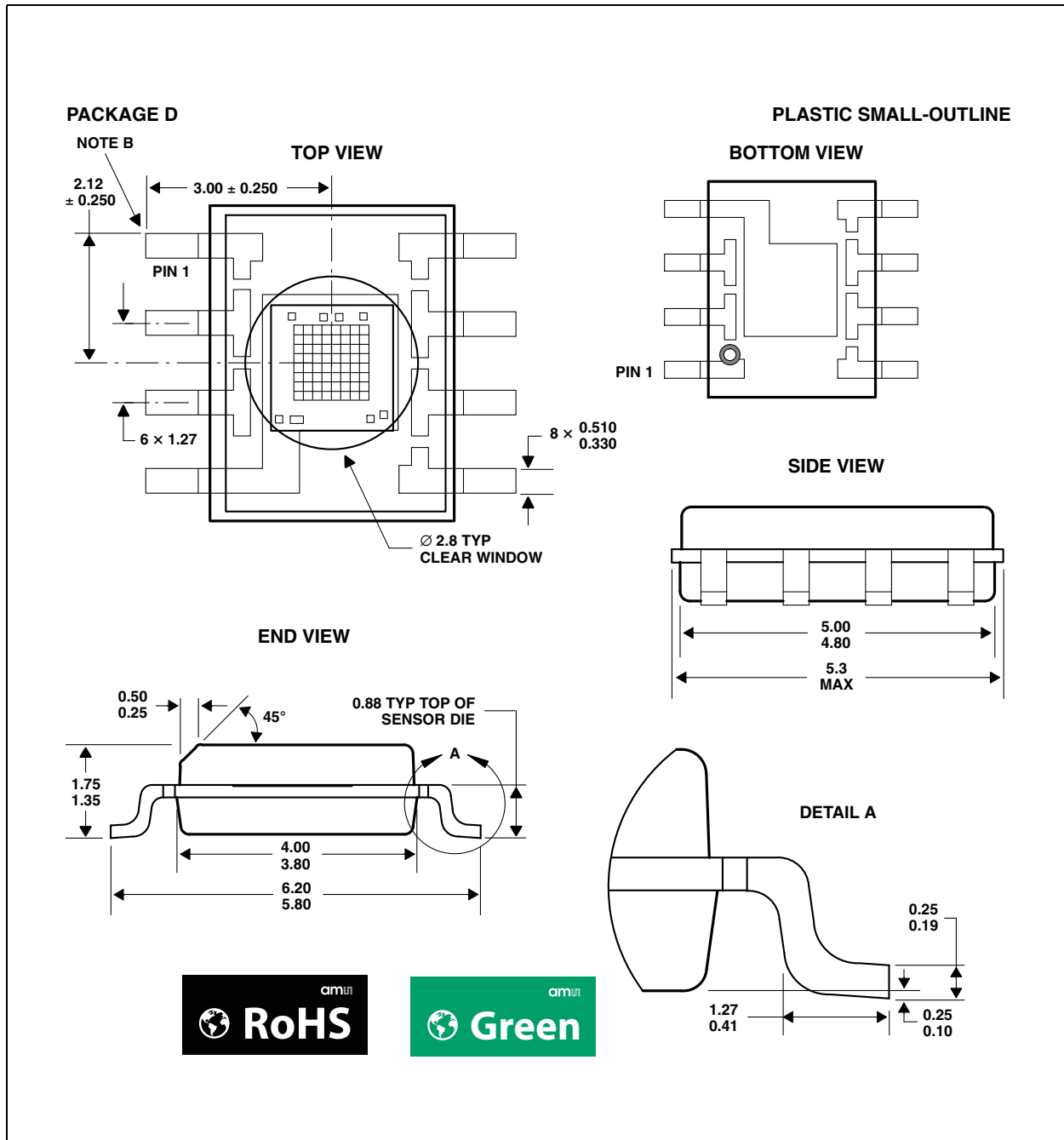
Note(s):

1. All linear dimensions are in millimeters.

2. The center of the 1mm by 1mm photo-active area is referenced to the upper left corner tip of the lead frame (Pin 1).

3. Package is molded with an electrically nonconductive clear plastic compound having an index of refraction of 1.55.

4. This drawing is subject to change without notice.

Figure 17:
Package D Carrier Tape

SIDE VIEW

K_O 2.11 ± 0.10 [0.083 ± 0.004]

0.292 ± 0.013
[0.0115 ± 0.0005]

TOP VIEW

END VIEW

∅ 1.50

8 ± 0.1
[0.315 ± 0.004]

4 ± 0.1
[0.157 ± 0.004]

2 ± 0.05
[0.079 ± 0.002]

1.75 ± 0.10
[0.069 ± 0.004]

B

5.50 ± 0.05
[0.217 ± 0.002]

A   A

B

12 + 0.3 − 0.1
[0.472 + 0.12 − 0.004]

DETAIL A

6.45 ± 0.10
[0.254 ± 0.004]

A_O

DETAIL B

5.13 ± 0.10
[0.202 ± 0.004]

B_O
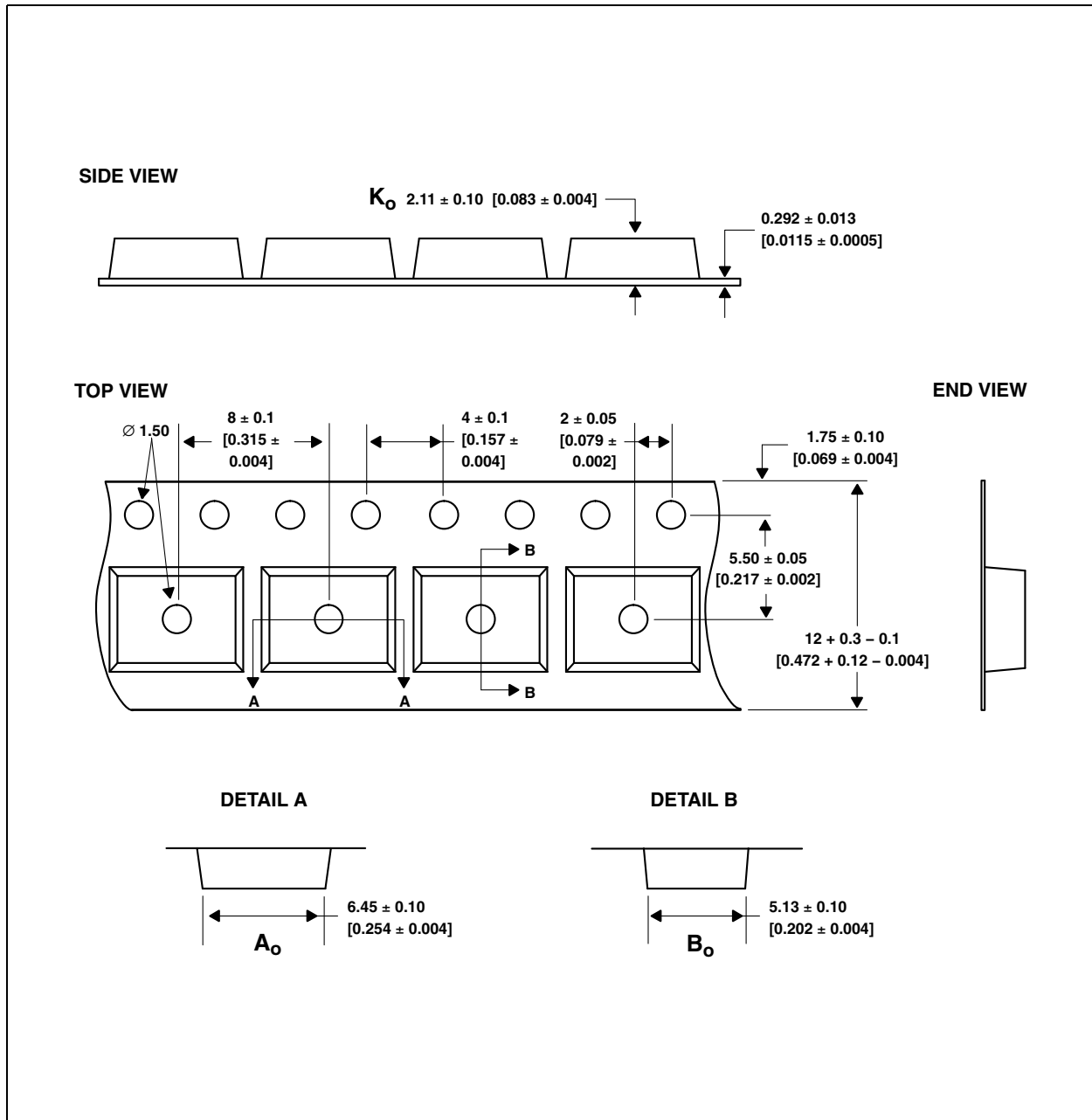
Note(s):

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 18:
TCS3200 Solder Reflow Profile

Parameter	Reference	TCS32x0
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 19:
TCS3200 Solder Reflow Profile Graph
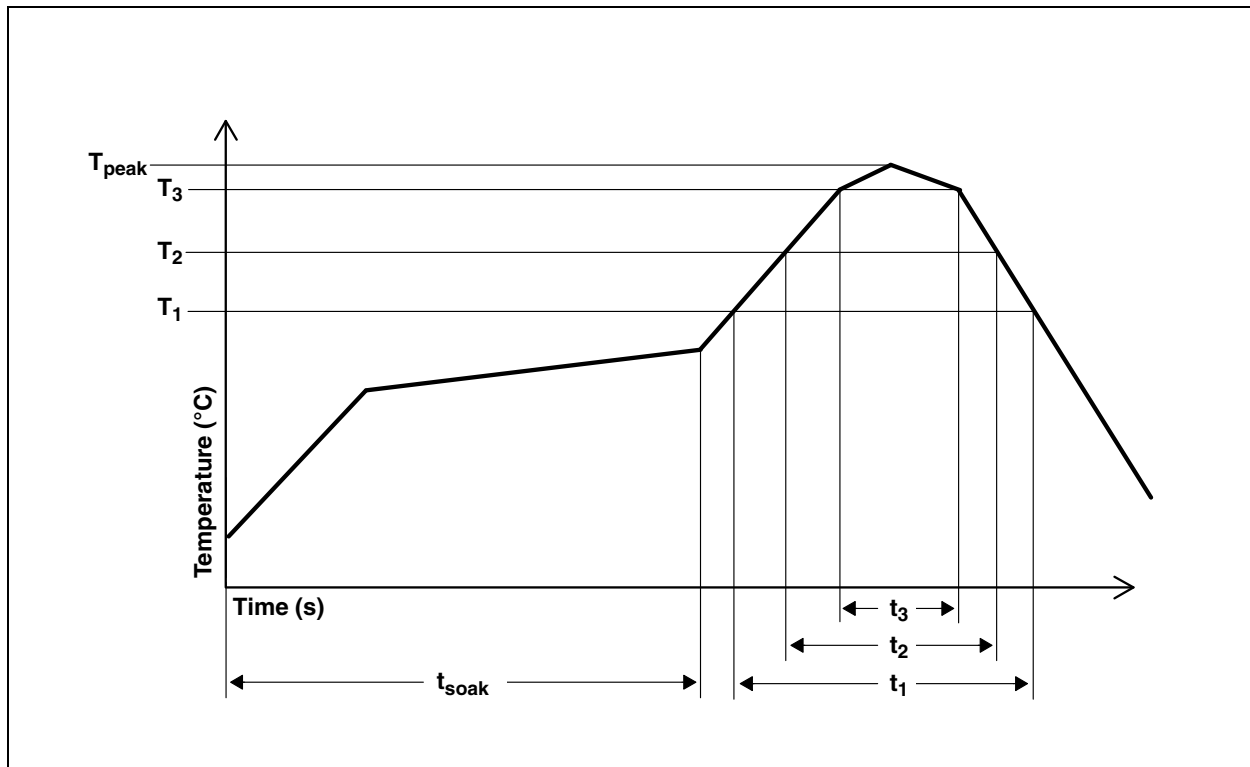
Moisture Sensitivity

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. To ensure the package contains the smallest amount of absorbed moisture possible, each device is baked prior to being dry packed for shipping. Devices are dry packed in a sealed aluminized envelope called a moisture-barrier bag with silica gel to protect them from ambient moisture during shipping, handling, and storage before use.

Shelf Life

The calculated shelf life of the device in an unopened moisture barrier bag is 12 months from the date code on the bag when stored under the following conditions:

- Shelf Life: 12 months
- Ambient Temperature: < 40°C
- Relative Humidity: < 90%

Rebaking of the devices will be required if the devices exceed the 12-month shelf life or the Humidity Indicator Card shows that the devices were exposed to conditions beyond the allowable moisture region.

Floor Life

The D package has been assigned a moisture sensitivity level of MSL 5a. As a result, the floor life of devices removed from the moisture barrier bag is 24 hours from the time the bag was opened, provided that the devices are stored under the following conditions:

- Floor Life: 24 hours
- Ambient Temperature: < 30°C
- Relative Humidity: < 60%

If the floor life or the temperature/humidity conditions have been exceeded, the devices must be rebaked prior to solder reflow or dry packing.

Rebaking Instructions

When the shelf life or floor life limits have been exceeded, rebake at 60°C for 24 hours.

Ordering & Contact Information

Figure 20:
Ordering Information

Ordering Code	Device	T_A	Package - Leads	Package Designator
TCS3200D-TR	TCS3200	-40°C to 85°C	SOIC - 8	D

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ams Green (RoHS compliant and no Sb/Br): ams Green defines that in addition to RoHS compliance, our products are 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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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
Datasheet	Production	Information in this datasheet is based on products in ramp-up to full production or full production which conform to specifications in accordance with the terms of ams AG standard warranty as given in the General Terms of Trade
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 1-00 (2016-Jul-13) to current revision 1-01 (2018-Mar-14)	Page
Removed all instances of TCS3210	

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