# TSL2550EVM

# User's Guide

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## An Evaluation System for the TSL2550 Ambient Light Sensor

### INTRODUCTION

TAOS' Ambient Light Sensor (ALS) solution can be used to automatically adjust the brightness level for a computer display under a wide range of lighting conditions. As one of the primary benefits of using TAOS' ALS, battery life can be significantly increased by minimizing the power required to illuminate a display under various ambient lighting conditions. In PC notebooks, for example, the display panel and inverter (which delivers the power to the display panel) account for approximately 33% of the total power consumption. TAOS' ALS helps control the display backlight and keypad illumination in portable equipment like notebooks, PDAs, and cell phones. There are other applications supported by the ALS that include street light control, security lighting, digital cameras, sunlight harvesting, automotive instrument clusters, and projection and big-screen televisions.

TAOS' ALS can also help extend the longevity of the LCD lamp life by automatically controlling the display brightness or luminance. Lamp life depends strongly on the lamp current and is directly proportional to display brightness levels. Unnecessarily over-driving the display with high operating currents and excessive brightness will prematurely degrade the lamp life of a display. Automatically controlling the illuminance to extend lamp life is beneficial in a variety of applications:

- Mobile users who frequently use notebook computers in different ambient lighting conditions
- Digital monitors with on-screen controls to extend the display life and lower power consumption
- Kiosks that continuously operate 24/7 in sunlight or artificial lighting
- Automatically adjusting automobile display clusters (e.g. for navigation system) for safety to retain the driver's eyes on the road ahead at all times and eliminate glare to achieve better visibility at night

Thirdly, since TAOS' ALS closely approximates the response of the human eye, it can also help improve visual performance. While eyestrain is not believed to permanently damage one's eyes or cause a loss of vision, it can be very uncomfortable and lead to a loss of productivity. Using TAOS' ALS, excessive display brightness can be eliminated and productivity can be increased by maintaining an optimal brightness level under various lighting conditions.

The TSL2550EVM helps facilitate evaluation of the TAOS Ambient Light Sensor (ALS). Two evaluation module options are available which simply connect to a personal computer via a PCMCIA card slot or serial communication port. Both evaluation modules include application software allowing the user to easily control various features of the TSL2550 device. Figure 1 is a group picture of both evaluation modules.

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**Figure 1**.  TSL2550EVM PCMCIA and Serial Evaluation Modules

## PCMCIA EVM HARDWARE DESCRIPTION

The specification and system requirements for the hardware portion of the TSL2550 PCMCIA EVM module follow:

**System Requirements:**  Notebook or Desktop PC running Windows 98, 2000, NT4.0, XP
**Slot(s) Required:**  PCMCIA Type II
**Environmental Parameters:**  Temperature: 0°C - 55°C Humidity: 10 - 90%
**Software Installation:**  CD-ROM

When the PC is turned off, the TSL2550 PCMCIA EVM card should be inserted into a PCMCIA card slot that allows light to reach the clear plastic aperture on top of the card.  If possible, the ALS card should be placed on top.  On the card is inserted, the computer can be powered on so that it runs the normal boot-up process.  During the boot-up process, the system should beep to acknowledge the insertion of a new card.  See "Getting Started" topic for installing the software.

## SERIAL EVM HARDWARE DESCRIPTION

The TSL2550 Serial evaluation module comes assembled and consists of three main parts:

1.  A **motherboard** housed in a plastic DB9 module which includes a Ubicom SX microcontroller and power-conditioning circuitry,
2.  A **daughterboard** with the TSL2550 ambient light sensor, and
3.  A **flex cable** carrying power and two-wire signals to join the motherboard and daughterboard

To operate the Serial EVM, the motherboard should be plugged into an available RS232 port on the host PC.  A straight-through 9-pin male-to-female extender cable may be used between the host PC and the Serial EVM.

The flex cable should be connected to the daughterboard with the conductive side facing up.  "Up" on the daughterboard is relative to the surface where the components are mounted.  On the motherboard, "up" is relative to the side with pins 1-5 of the DB9 connector.

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Plugging the motherboard into an active RS232 port (supporting RTS and DTR) will power the mother and daughter boards. No external power is required unless SMBus devices requiring more than a couple milliamps are attached to the 5-pin SMBus headers (also on the motherboard), or if the onboard SX microcontroller is in debug mode or is being programmed.

To provide more power (*not to exceed 100 ma*) to the motherboard, an external supply can be connected to the DB9 as follows:

1. Pins 4 *and* 7: +6 to +7.5VDC. (**Note:** Connect both pins.)
2. Pin 5: Ground.

To provide more power to the motherboard *and communicate with a PC at the same time*, an adapter will have to be made incorporating the above connections in a DB9 male plug, plus a DB9 female with pins 2, 3, and 5 *only* connected to the same pins on the male plug. The Ubicom SX is programmed by removing the jumper on the 5-pin right-angle programming connector and installing the SXKey which is available from Parallax, Inc. at www.parallax.com. With the DB9 connector at 12 o'clock and the SXKey sticking out at 9 o'clock, use the four bottom header pins. Vss is the bottom pin. The external SMBus header pins (two identical 5-pin headers) are labeled on the housing's panel cutout: +5 for Vdd, D for data, G for ground, and C for clock. See Figure 2 for a schematic diagram of the TSL2550 Serial EVM.

## GETTING STARTED

On most PCs, installation will automatically start when the CD-ROM is inserted into the drive. If the installation does not begin:

- Click **Start**
- Click **Run**
- Type **D:\setup** and press **Enter.** IMPORTANT: Use the appropriate drive letter in the above command to install the software. CD-ROMs are commonly **D:**
- The installation program will guide you through the product installation

Refer to the ReadMe file on CD for the latest installation instructions.

**Note:** After inserting the PCMCIA card into the appropriate card slot, a message will be displayed on the screen indicating that a new card was found and a driver needs to be installed. Follow the instructions to install the driver and software. Below are some additional guidelines when using the TSL2550 PCMCIA EVM:

- Close the EVM application program before removing the PCMCIA card
- Close the EVM application program when the computer is not in use so that the program is not active when your computer goes into sleep mode
- If more than one PCMCIA EVM card is used:
  - Close the EVM Software
  - Remove PCMCIA EVM card
  - Insert new PCMCIA EVM card
  - Activate EVM Software

**Note:** The TSL2550 Serial EVM software will automatically search for an available RS232 communication port until the serial EVM hardware is located.
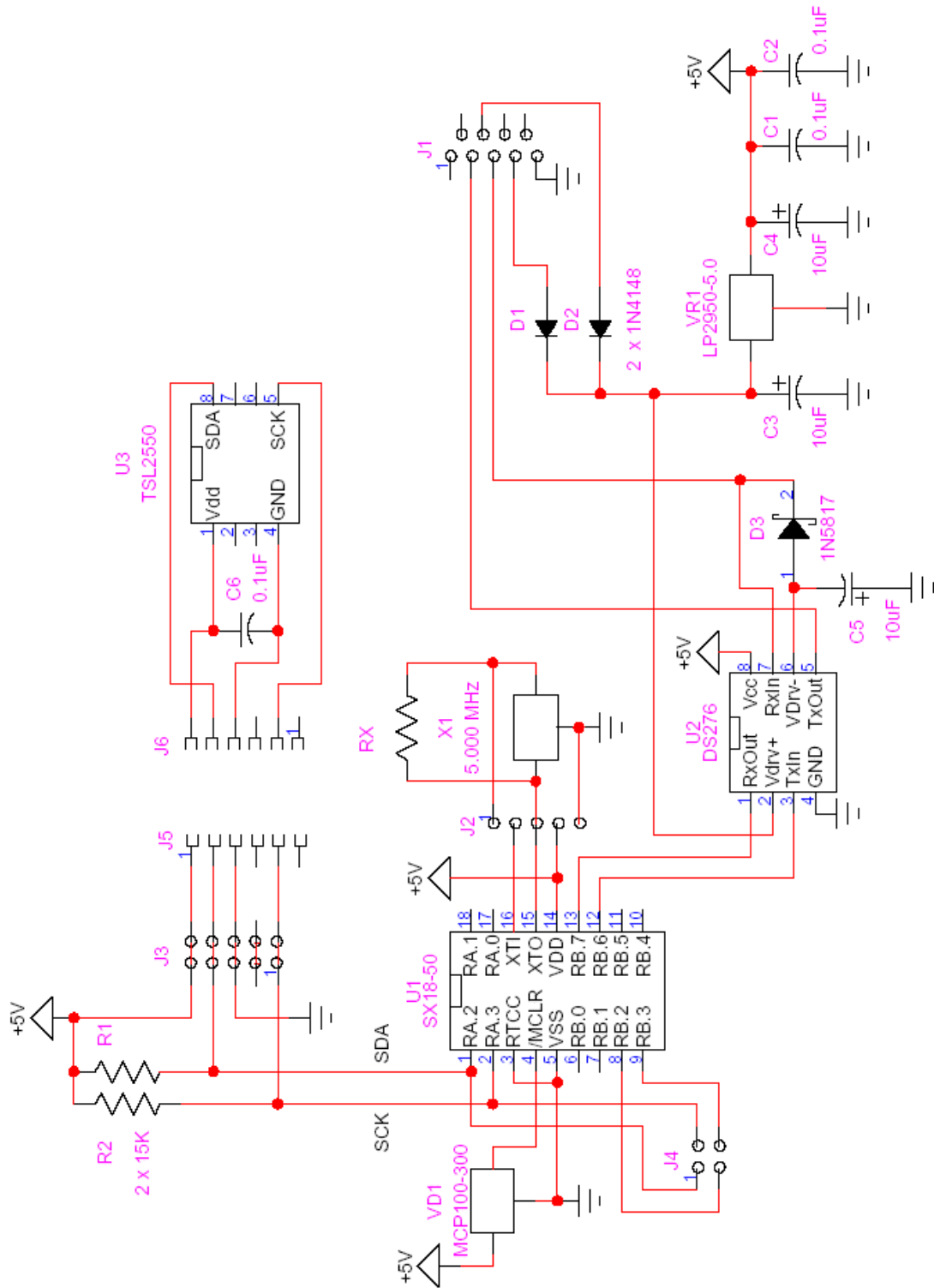
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**Figure 2.** TSL2550 Serial EVM Schematic

## SOFTWARE DESCRIPTION

To start the TSL2550EVM software, click:
    Start -> Programs -> TSL2550EVM -> TSL2550 Evaluation Module.

See Figure 3 regarding a sample screen capture of the software.

The EVM application constantly monitors the ambient light level through the use of two photodiodes on the TSL2550.  One of the photodiodes (Channel 0) is sensitive to both visible and infrared light, while the second photodiode (Channel 1) is sensitive primarily to infrared light.  An integrating ADC converts the photodiode currents to Channel 0 and Channel 1 digital outputs.  Channel 1 digital output is used to compensate for the effect of the infrared component of light on the Channel 0 digital output.
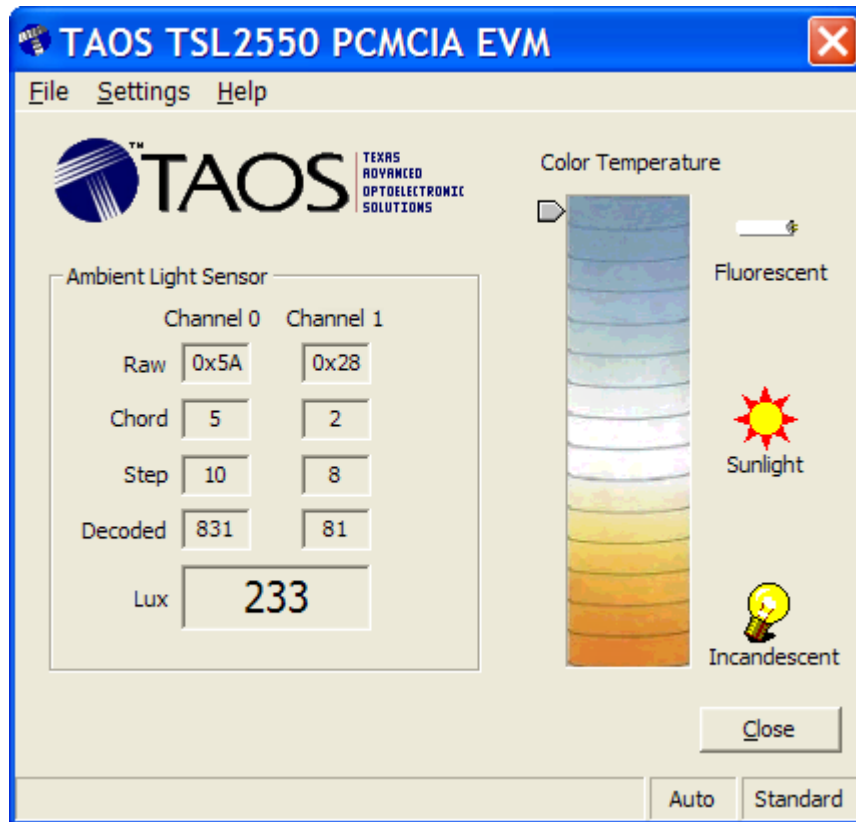


**Figure 3.**  TSL2550 EVM Application

## LUX EQUATION

The TSL2550 is designed for use with broad wavelength light sources, and the formula to obtain illuminance describes a best fit curve for fluorescent, incandescent, and sunlight ambient conditions to approximate the human eye response.

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The TSL2550 contains two ADC registers (channel 0 and channel 1). Each of the two ADC value registers contains seven bits. Bits 6 through 0 contain the 7-bit code representing the ADC count value that is proportional to the photodetector current.

Each ADC register contains two components to determine the logarithmic ADC count value: "Chord" bits and "Step" bits. The Chord bits correspond to the most significant portion of the ADC value and specifies a segment of the piece-wise linear approximation to a log function. The Step bits correspond to the least significant portion of the ADC count value and specify a linear value within a segment. The transfer function is broken into 8 Chords of 16 Steps each. This function is very similar to mu-law encoding used in audio compression and differs in that it does not have a sign bit and it is not inverted. When Chord and Step bits all equal to 0, this condition corresponds to a light level that is below the detection limit of the sensor. When Chord and Step bits all equal to 1, this condition corresponds to an overflow (i.e. saturation).

Tables 1 and 2 show the relationship between the Chord and Step bits and the Chord and Step numbers and values.

| Chord Bits (B6, B5, B4) | Chord Number | Chord Value | Step Value |
|---|---|---|---|
| 000 | 0 | 0 | 1 |
| 001 | 1 | 16 | 2 |
| 010 | 2 | 49 | 34 |
| 011 | 3 | 115 | 8 |
| 100 | 4 | 247 | 16 |
| 101 | 5 | 511 | 32 |
| 110 | 6 | 1039 | 64 |
| 111 | 7 | 2095 | 128 |

**Table 1.** Chord Numbers and Values

| Step Bits (B3, B2, B1, B0) | Step Number |
|---|---|
| 0000 | 0 |
| 0001 | 1 |
| 0010 | 2 |
| 0011 | 3 |
| 0100 | 4 |
| 0101 | 5 |
| 0110 | 6 |
| 0111 | 7 |
| 1000 | 8 |
| 1001 | 9 |
| 1010 | 10 |
| 1011 | 11 |
| 1100 | 12 |
| 1101 | 13 |
| 1110 | 14 |
| 1111 | 15 |

**Table 2.** Step Numbers and Values

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The Count Value for each channel is obtained by the following equation:

Count Value = Chord Value + (Step Number x Step Value)                                    **Eq. 1**
Count Value = (INT (16.5 x ($2^{Chord\ Number} - 1$)) + (Step Number x $2^{Chord\ Number}$)     **Eq. 2**

Illuminance (i.e. ambient light brightness) is derived using the values read from Channel 0 and Channel 1 in the units of Lux to approximate the human eye response. The formula follows:

Light Level (lux) = Ch0 Counts x 0.46 x $e^{-3.13(Ch1\ Counts/Ch0\ Counts)}$          **Eq. 3**
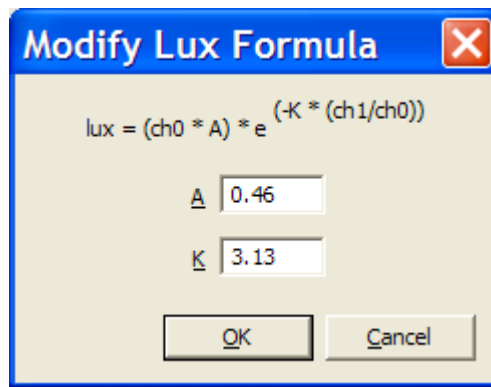


**Figure 4.** Modify TSL2550 Equation

The coefficients of the equation can be modified from the 'Settings/Lux Formula' pull down menu item. See Figure 4.

## COLOR TEMPERATURE

As shown on Figure 3, a relative indication of the color temperature of the light source can be made for the purpose of light source classification. Color temperature can be estimated by taking the ratio of infrared light to the combination of visible and infrared light (i.e. Ch1/Ch0). Fluorescent lighting, for example, represents almost all visible light. Incandescent lighting, on the other hand, represents a combination of visible and infrared light (i.e. about half-visible and half-infrared).

| Light Source | Lux | Ch0 Counts | Ch1 Counts | Ch1/Ch0 |
|---|---|---|---|---|
| Fluorescent | 300 | 831 | 68 | 0.082 |
| Daylight (shade) | 100 | 895 | 343 | 0.38 |
| Incandescent | 50 | 959 | 671 | 0.7 |

**Table 3.** TSL2550 Sensor Output Summary

From Figure 3, the correlated color temperature of the ambient light source is roughly proportional to Ch0/Ch1 (i.e. the inverse of the ratio described in Table 3). This information may be useful in certain applications such as computer displays and television screens to perform color balance.

## RANGE

The TSL2550 device has the ability to operate in "Standard" or "Extended" range mode.  Normally the device operates in standard range.  In standard range, the device can respond to ambient light conditions from, for example, approximately 0 to 1400 Lux under certain fluorescent lighting conditions. After about 1400 Lux, the device saturates and cannot produce valid results.

In extended range, the device integrates for 1/5 the time (i.e. sampled at 5x the rate of standard mode).  This allows the device to respond to ambient light conditions 5x greater than in standard mode and respond to light level up to approximately 7000 lux under certain fluorescent lighting conditions.

The TSL2550 EVM defaults to automatically select the appropriate range.  The EVM application starts in Standard range and will change to extended range (or vice versa) when necessary.  This is called 'Auto'.  'Auto' can be turned off by unselecting the 'Auto' menu item on the 'Settings->Range' pull down menu (See Figure 5).  In 'Manual' mode, the 'Standard' or 'Extended' menu item can be selected to manually control ranging.
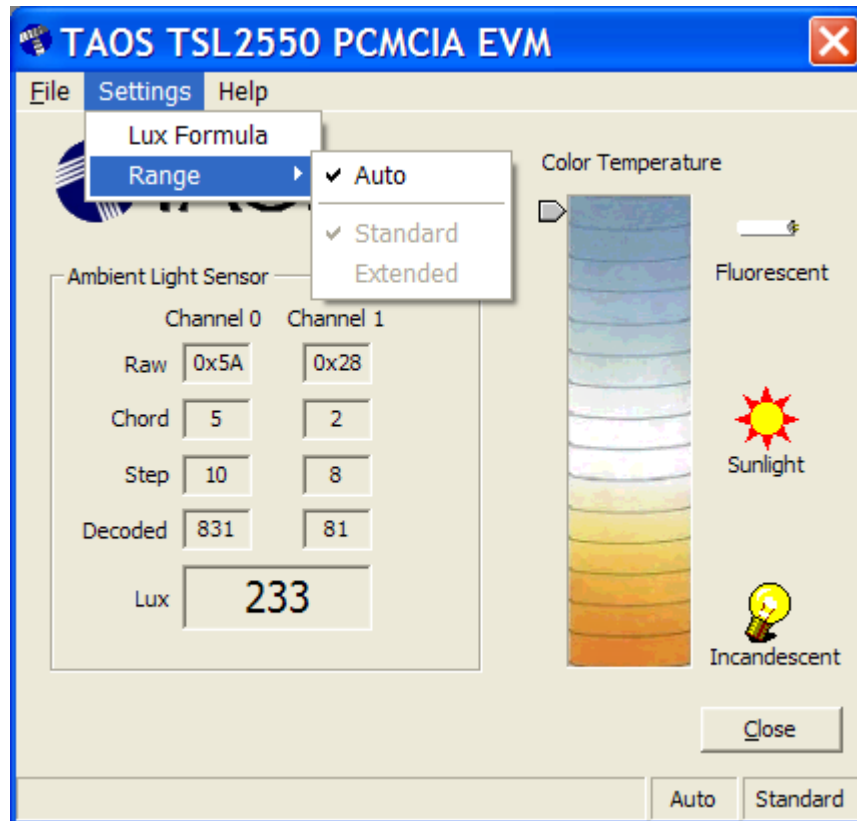
**Figure 5.**  ALS Standard and Extended Range Modes