TSL2560/61 EVM

User's Guide TAOS

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An Evaluation System for the TSL2560/61 LTD Ambient Light Sensor

ALS INTRODUCTION

TAOS' Light-to-Digital (LTD) Ambient Light Sensor (ALS) solution can be used to automatically adjust the brightness level of 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 extended by minimizing the necessary power required to luminate a display under various lighting conditions. In PC notebooks, for example, the display panel and inverter (which delivers the power to the display panel) comprise approximately one-third (1/3) 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 which include street light control, security lighting, sunlight harvesting, machine vision and automotive instrumentation clusters.

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.

EVALUATION MODULE OVERVIEW

The TSL2560/61 EVM helps facilitate evaluation of the TAOS' LTD ALS. A Universal Serial Bus (USB) evaluation module is available which simply connects to the USB port of a personal computer. Figure 1 is a picture of the USB evaluation module.

The TSL2560/61 device combines a visible light blocking photodiode with a broadband photodiode on a single CMOS integrated circuit. This combination enables either device to be used to calculate light intensity in lux over an effective 20-bit dynamic range with a 16-bit resolution without the use of an expensive filter. Two integrating analog-to-digital converters (ADC) convert the photodiode currents

to an SMBus (TSL2560) or I^{2}C (TSL2561) digital output that represents the irradiance measured on each channel. This output data can be input to a microprocessor where illuminance (i.e. ambient light level) in lux is derived using an empirical formula. In general, the TSL2560 (SMBus interface) device is intended for use in notebook and tablet PCs while the TSL2561 (I^{2}C interface) device is ideal for most other light-to-digital applications.

USB EVM HARDWARE AND DRIVER DESCRIPTION

USB Mini-B Connector

TMB Daughterboard
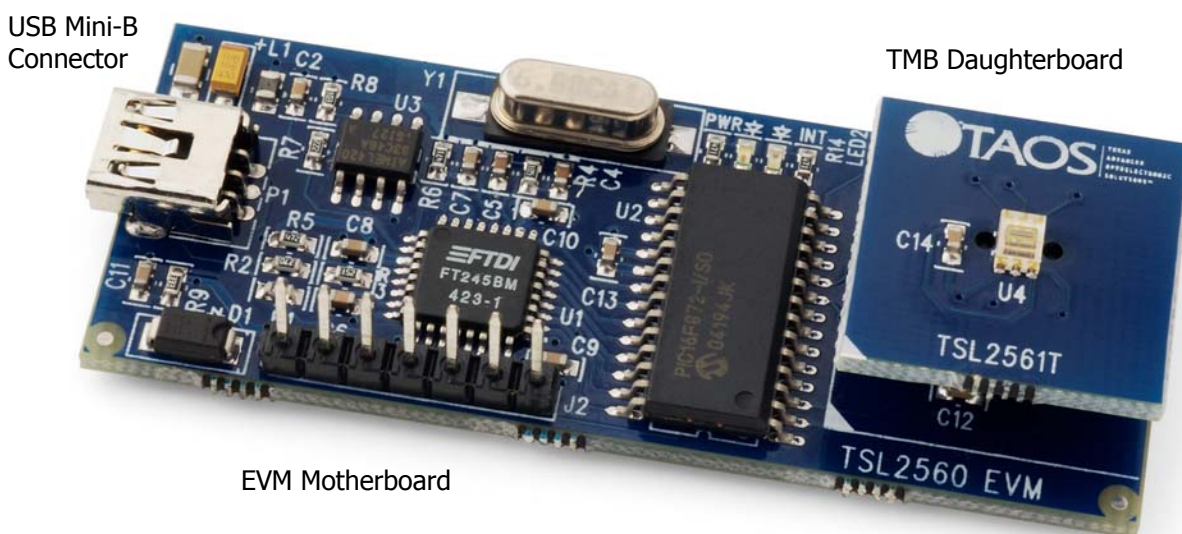
EVM Motherboard

Figure 1. TSL2560/61 EVM USB Evaluation Module

The specification and system requirements for the hardware portion of the TSL2560/61 USB EVM module follow:

System Requirements: Notebook or Desktop PC running Windows 98, 2000, NT4.0, XP
Host Connection: USB v2.0 using A-type connector
EVM Connection: Mini B-type connector
Software Installation: CD-ROM

After the mini-B connector is attached to the EVM using the enclosed USB cable, and subsequently plugged into the USB port of the computer, a Wizard should appear instructing the user to load a USB driver. The USB INF driver file is located in the FTDI directory on the CD-ROM and can be selected using the 'Browse' button. Please note that if the FTDI USB driver installs automatically without prompting the user to load the driver, then the FTDI USB driver will likely need to be updated. After the software is executed, if an error message appears indicating that the "FTD2XX.DLL" could not be found, then the USB driver will need to be updated. To update the driver with the proper file,

- Click 'Control Panel -> System -> Hardware -> Device Manager -> Universal Serial bus controllers'
- Highlight the appropriate FTDI driver in the list
- Right mouse on the highlighted driver and select "Update". **Note**: The driver can found in the FTDI directory on the CD-ROM

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GETTING STARTED

IMPORTANT: Before getting started, please review the "USB EVM Hardware and Driver Description" section which contains information to insure that the proper USB driver is loaded.

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.

Two applications are loaded: "Automatic Brightness Control Demo" and "Device Utility". Both applications are discussed in the following pages.

AUTOMATIC BRIGHTNESS CONTROL DEMO

Software Description

To start the Automatic Brightness Control Demo application, click:
Start -> Programs -> TSL2560 USB EVM -> Automatic Brightness Control Demo

After the demo is executed, a "Monitor" dialog window (see below) will appear on top and an application icon will appear in the system tray. The demo will continue to run until the monitor application is closed.

The TSL2560/61 device can measure light levels ranging from approximately 0.1 lux to 40,000 lux. No external circuitry is required for signal conditioning, and the integrating conversion technique used in the ALS device eliminates the effect of fluorescent flicker, thereby increasing the stability of the measurement.

The EVM application constantly monitors the ambient light level through the use of two photodiodes on the TSL2560. 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.

Graphical User Interface (GUI)

The TSL2560 GUI is composed of three dialogs: **Automatic Brightness Control Configuration**, **Advanced**, and **Monitor**. A fourth dialog (Main) is hidden and manages the ALS' system tray icon, menu, and profile selection.
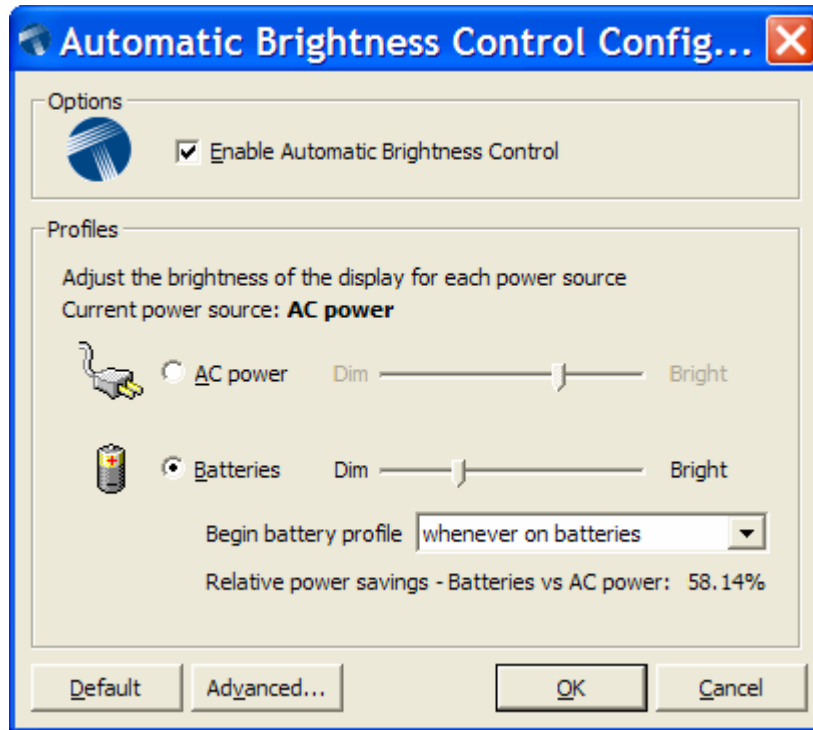
Figure 2. Automatic Brightness Control Configuration Dialog

The **Automatic Brightness Control Configuration** dialog (see Figure 2) is the user's primary interface to configure the ALS environment. The dialog provides the capability to enable/disable automatic brightness control, set two display brightness profiles, and open the Advanced Configuration dialog. A default button is provided to reset the dialog back to the original settings.

The Configuration interface defines two display brightness profiles (i.e. two response curves) to independently manage the lux-to-nits relationship between the current ambient light and display panel luminance. The software provides the *AC* (for external power) and the *Batteries* display brightness profiles to be configured. The *AC* Profile provides optimal viewing for varying ambient light conditions. The purpose of the *Batteries* Profile is to extend the battery life by automatically dimming (i.e. minimizing) the display luminance under equivalent ambient light conditions. Since it is anticipated that the user will likely prefer optimal display aesthetics for some period of time when the system is running on batteries, a pull-down menu is provide to allow the user to set the parameters of the Batteries Profile to change from *AC* to *Batteries* profile when the power level is below a specified percentage. Effectively, the profile becomes more aggressive (i.e. by minimizing the display brightness) as battery life becomes more "critical".

> **Note:** The brightness range of the AC and Batteries Profile is bounded by the EVM software. Since a "picture view" (see Automatic Brightness Control Monitor) is used to simulate the display for a wide-range of platforms (e.g. notebooks, tablets, LCD monitors, etc.), an approximate range of 20-140 nits was chosen to best simulate the dynamic range of the display panel.

The Relative Power Savings is displayed on the Configuration dialog and is simply the relative power savings between the *AC* and *Batteries* profiles at which the nit level of the LCD panel is set for each profile.
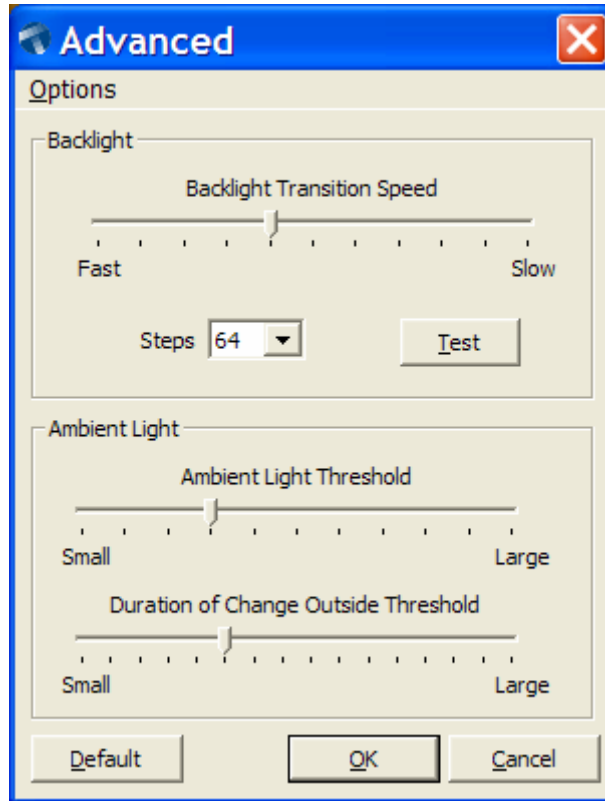

Figure 3. Advanced Dialog

The **Advanced** dialog (see Figure 3) displays three key TSL2560 options that directly affect how and when the display backlight is adjusted when ambient light conditions change. The ALS software automatically manages the LCD's brightness using one of the two aforementioned brightness profiles. A default button is provided to reset the dialog back to the original settings.

The three options that are exposed on the dialog include (1) Backlight Transition Speed, (2) Ambient Light Threshold, and (3) Duration of Change Outside Threshold:

1. The **Backlight Transition Speed** specifically addresses the question of "How fast should the backlight change?" The Backlight Transition Speed determines how fast (or slow) to increment/decrement the display brightness steps from the current brightness step to the target brightness step (according to the lux-to-nits response curve). This feature also provides the capability of simulating the number of backlight steps to closely model the ODM/OEM's display brightness implementation. Up to 256 steps are supported.
2. **Ambient Light Threshold** describes the percentage change in ambient light condition to detect. For example, small changes in ambient light can be filtered out while only "significant" changes are detected.

3. The **Duration of Change Outside Threshold** is related to the Ambient Light Threshold. Once an ambient light change exceeds the threshold, the change must persist for a certain period of time. This feature filters large changes in light such as a shadow moving across the light sensor and prevents display "bouncing."

TAOS suggests exposing Backlight Transition Speed, Ambient Light Threshold, and Duration of Change Outside Threshold on a user interface in order to provide some level of end-user customization. Alternatively, the designer can hard-code these values to best fit their application.

The **Advanced** dialog also includes an 'Option' menu item which allows the user to select which package type (TMB or chipscale) is being evaluated and whether to turn on/off the LEDs on the EVM. When deriving lux, the lux equation is similar for both TMB and chipscale packages, but two distinct equations are provided to optimize the illuminance value for the different package types. The LED(s) on/off item is provided to eliminate the interference of the LED reflections at low light levels when the EVM is covered. The green LED indicates power, and the red LED indicates if an interrupt event has occurred. The LEDs will always be disabled at the start of the demo application and must be manually selected in order to turn on the LEDs.
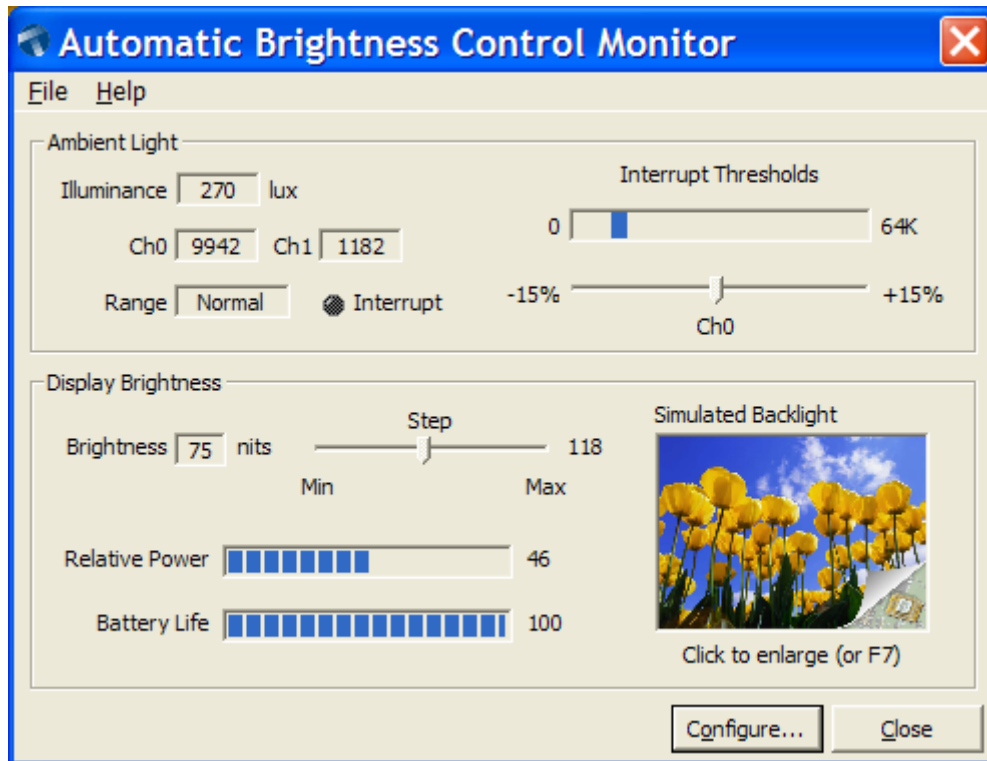

Figure 4. Automatic Brightness Control Monitor Dialog

The TSL2560 application also supports a **Monitor** dialog (see Figure 4) that displays the illuminance, channel 0 and channel 1 values, interrupt threshold, auto-range, and the display brightness setting of a "simulated panel". The remaining battery life and relative power (relative to maximum backlight brightness) are also displayed.

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The **Monitor** simulates display backlight control in a small panel box on the form. If the image is clicked, the image will snap to the entire size of the display ("picture view") to simulate the full screen.

> **Note:** The EVM software performs a "picture view" update manually by manipulating the picture image. Performance (i.e. image refreshing) will be directly impacted by the processor speed since the USB EVM does not directly control the inverter, LCD monitor controller, nor display graphic stack.

The **Monitor** receives notifications of changes from the Automatic Brightness Control object whenever there is a change in the display brightness or whenever there is a change in the ambient light condition. A change in the "simulated display brightness" directly updates the nits, backlight step, relative power savings, and battery life. A change in the ambient light condition updates the illuminance.

The **Monitor** dialog also includes a 'Config' menu item which allows the user to go directly to the **Automatic Brightness Control Configuration** dialog (see Figure 2) and also close the demo application.

Interrupt

The TSL2560 permits an SMB-Alert style interrupt and the TSL2561 supports a traditional style interrupt that remains asserted until the firmware clears it. Channel 0 is used to trigger an interrupt based upon a relative change in ambient light. When channel 0 crosses either the upper or lower threshold as configured on the **Advanced** dialog, the Interrupt indicator will turn "red." When an interrupt is triggered, the EVM software will display the current state (i.e. threshold crossing), show the new state (i.e. new ambient light reference point), clear the interrupt, and update the simulated backlight accordingly.

Auto-Range

The TSL2560/61 EVM software supports two nominal integration times (402 ms and 101 ms) and both the low gain (1x) and high gain (16x) modes as outlined in the datasheet. The EVM software auto-ranges between the integration times and gain modes (see Timing Register in datasheet) to optimize the setting under any given ambient light condition.

The software defaults to 402 ms and 16x gain (**Normal Mode**) to provide maximum resolution in most artificial lighting conditions. If either photodiode channel saturates in this configuration, the software will auto-range to 402 ms and 1x gain (**Extended Mode**). If the device saturates in this subsequent configuration, the software will auto-range to 100 ms and 1x gain (**Expanded Mode**). In general, these three configurations provide the best overall balance between resolution and dynamic range under most ambient light conditions.

Illuminance (Lux) Derivation

Conventional silicon detectors respond strongly to infrared light, which the human eye does not see. This can lead to significant error when the infrared content of the ambient light is high, such as with incandescent lighting, due to the difference between the silicon detector response and the brightness perceived by the human eye.

This problem is overcome in the TSL256x through the use of two photodiodes. 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 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. The ADC digital outputs from the two channels are used in the formula below to obtain a value that approximates the human eye response in the commonly used illuminance unit of Lux:

Chipscale Package

For $0 < CH1/CH0 <= 0.52$ $Lux = 0.0315 \times CH0 - 0.0593 \times CH0 \times ((CH1/CH0)^{1.4})$
For $0.52 < CH1/CH0 <= 0.65$ $Lux = 0.0229 \times CH0 - 0.0291 \times CH1$
For $0.65 < CH1/CH0 <= 0.80$ $Lux = 0.0157 \times CH0 - 0.0180 \times CH1$
For $0.80 < CH1/CH0 <= 1.30$ $Lux = 0.00338 \times CH0 - 0.00260 \times CH1$
For $CH1/CH0 > 1.30$ $Lux = 0$

TMB Package

For $0 < CH1/CH0 <= 0.50$ $Lux = 0.0304 \times CH0 - 0.062 \times CH0 \times ((CH1/CH0)^{1.4})$
For $0.50 < CH1/CH0 <= 0.61$ $Lux = 0.0224 \times CH0 - 0.031 \times CH1$
For $0.61 < CH1/CH0 <= 0.80$ $Lux = 0.0128 \times CH0 - 0.0153 \times CH1$
For $0.80 < CH1/CH0 <= 1.30$ $Lux = 0.00146 \times CH0 - 0.00112 \times CH1$
For $CH1/CH0 > 1.30$ $Lux = 0$

DEVICE UTILITY

Software Description

To start the Device Utility application, click:

        Start -> Programs -> TSL2560 USB EVM -> Device Utility

The Device Utility program is included as a part of the EVM and is a separate application which exposes key registers and control functions described in the TSL2560/61 datasheet. This utility provides a knowledge of the low-level functionality of the TSL2560/61 device.
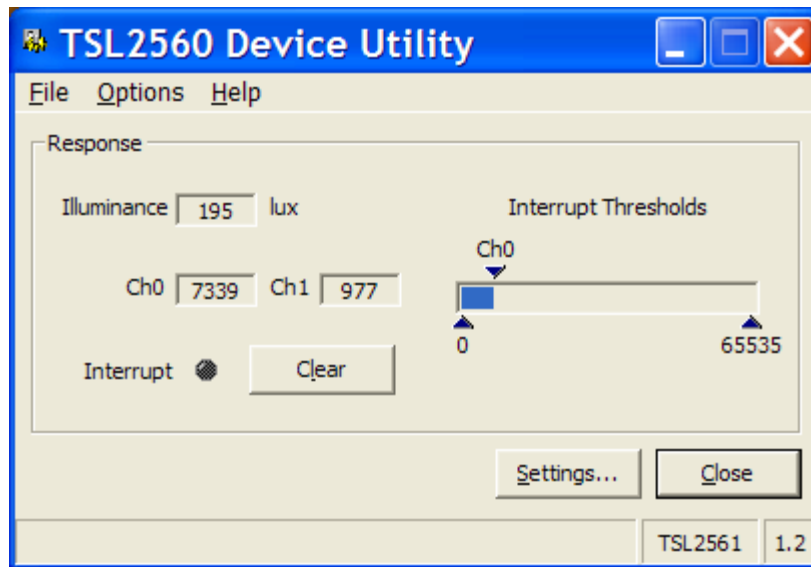
Figure 5. TAOS TSL2560/61 Device Utility Dialog

Graphical User Interface (GUI)

The **Main** dialog of the Device Utility application displays the illuminance (lux), raw channel values, and relative position of the channel 0 value. The raw values are read from the **ADC Channel Data Registers (Ch-Fh)** described in the TSL2560/61 datasheet. Since the TSL2560 has interrupt capability, the upper and lower interrupt threshold values are also displayed along with the relative position of the channel 0 value. Channel 0 is used to trigger an interrupt based upon a relative change in ambient light.

When channel 0 crosses either the upper or lower threshold, the Interrupt indicator will turn "red." The interrupt will continue to be visible until it is reset using the adjacent 'Clear' button.

The **Main** dialog also includes an 'Option' menu item which allows the user to select which package type (TMB or chipscale) is being evaluated and whether to turn on/off the LEDs on the EVM. When deriving lux, the lux equation is similar for both TMB and chipscale packages, but two distinct equations are provided to optimize the illuminance value for the different package types. The LED(s) on/off item is provided to eliminate the interference of the LED reflections at low light levels when the

EVM is covered. The green LED on the EVM hardware indicates power, and the red LED indicates if an interrupt event has occurred. The LEDs will be enabled at the start of the utility and can be turned on/off as an application preference from this menu item.

The **Main** form also supports the capability of logging the current state to a file from the 'File' menu item. This feature is useful for studying the lux-to-nits relationship for a particular LCD panel. This feature can be accessed from the menu. Simply enable logging and select the interval at which to log the data.
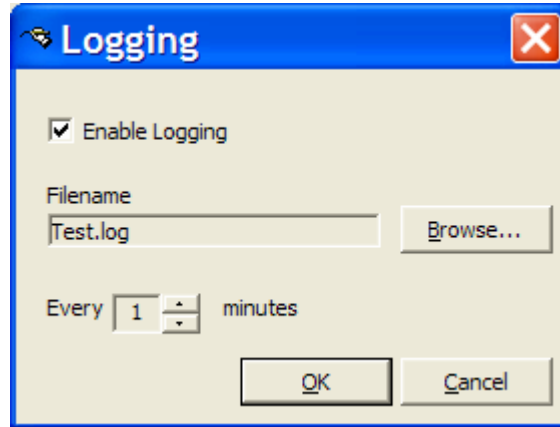

Figure 6. Device Utility Logging Dialog

The firmware version of the EVM is noted in the lower right hand corner on the status bar.

The **Settings** form exposes the following key TSL2560/61 device registers:

1. **Control Register (0h)**: Primarily used to power up/down the TSL2560/61 device
2. **Timing Register (1h)**: Controls the integration time and gain of the ADC channels
3. **Interrupt Control Register (6h):** Controls the interrupt capabilities of the device
4. **Interrupt Threshold Registers (2h-5h):** Stores the high and low trigger points for the comparison function for interrupt generation
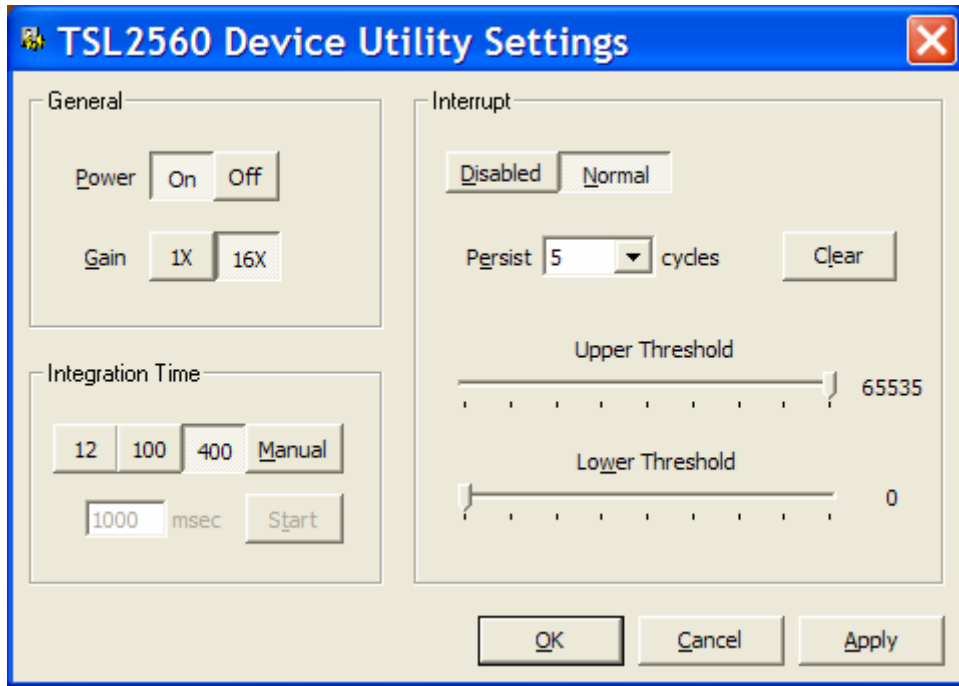
Figure 7. Device Utility Settings Dialog