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INTELLIGENT OPTO SENSOR **Number 39**

DESIGNER'S NOTEBOOK

TAOS TEXAS ADVANCED OPTOELECTRONIC SOLUTIONS®

Ambient Light Sensor Auto-gain Algorithm

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Description

TAOS ambient light sensors (ALS), such as the TSL2571, provide excellent sensitivity and programmability. The sensors have a dynamic range of over 1,000,000:1 allowing them to operate from dark to bright sunlight especially behind dark glass. However, the output of the sensor is constrained to a 16 bit value. To utilize the wide dynamic range of this device requires lowering the gain in bright lighting condition. This design note describes how to implement an auto-gain algorithm to take advantage of this wide dynamic range.

ALS Operations

With the versatility of programming of the integration time and gain, it can be difficult to understand the different modes of operation. The following shows a log-log plot of the LUX vs integration time/gain and no IR present. This a theoretical light source such as a green LED with no IR content. If a horizontal line is drawn at a specific LUX level the gain and integration time can be seen to control the resulting CH0 Counts value.

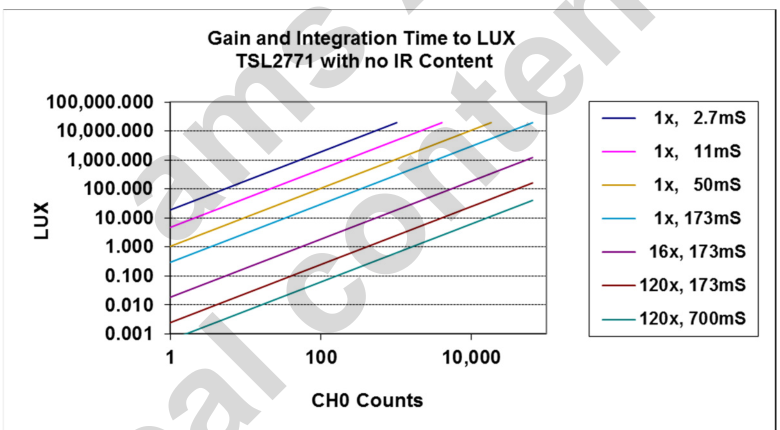

Figure 1. Gain and Integration Time to Lux

The maximum LUX the can be measured is ~19k LUX with no IR present and with no dark glass. The intercept with a CH0 counts value of 1 shows the counts per lux (CPL) of each setting. For optimal gain switching, it is recommended that the gain be switched from 1x to 16x or 8x to 120x. This will provide the best accuracy. If more range is needed, only three steps may be needed such as 1x to 8x to 120x.

The first step is to determine if auto-gain is required and adds value. If the desired lux range can be measured using a single gain setting then auto-gain is not needed. For systems without dark glass where a gain of 1x is adequate, there may be no benefit to an auto-gain algorithm. When the system is behind dark glass and the gain has been increased, a reduction of gain will extend the lux range in bright light conditions.

The next step is to understand the gain steps for the algorithm to switch between. Calculate the maximum lux required and the minimum lux accuracy and select the scale for the two. The last step is to determine the lux value at which to change the gain while providing enough hysteresis so the gain change doesn't oscillate between two values.

To understand how auto-gain works, two different examples will be given using the TSL2x71 device. For simplification, only the first segment of the lux equation will be discussed. Also, assume the goal is to cover a range from 0.5 lux to 100k lux in sunlight.

The following variables will be used in the subsequent expressions and are also found in the TSL2x71 datasheets: CPL is Counts per Lux, C0DATA and C1DATA are the 16 bit data values read from the device, ATIME_ms is the integration time (in mS), AGAINx is the ALS gain setting, DER is the digitization error and GA is the Glass Attenuation factor.

CPL = (ATIME_ms * AGAINx) / (GA * 53);
Lux1 = (C0DATA – (2 * C1DATA)) / CPL;

ALS Auto-Gain ALS Example

The first example will be of an ALS only application using the TSL2571 with a GA factor of 100 (99% transmissivity) which results in GA * 53 = 5300. Also, assume ATIME_ms is fixed at 200ms which implies a digital saturation of 65,535 counts. This gives the following:

MaxLux = 0.5 * 65,535 / CPL = 32,767 / CPL
CPL = AGAINx * 200 / 5300 = AGAINX / 26.5
MaxLux = 32,767 * 26.5 / AGAINX = 868,325 / AGAINx
DER = +/- 2 / CPL = 53 / AGAINx

With a target of +/-0.5 lux the gain must be increased to 120x. For the MaxLux requirement of 100k, the maximum AGAINx would be 8x. This requires an auto-gain algorithm which switched gain from the 8x mode to the 120 x mode.

DER = 53 / 8 = +/-7 lux	MaxLux = 868,325 / 8 = 108k lux	(8x Gain Mode)
DER = 53 / 120 = +/-0.44 lux	MaxLux = 868,325 / 120 = 7236 lux	(120x Gain Mode)

In this example, the gain must be switched from 8x to 120x which means the C0DATA will change by 16x. The algorithm will increase the gain when the C0DATA gets to a low value and will be reduced when C0DATA get to a high value. Choosing a lower threshold of 100 counts for going to a high gain and an upper threshold of 10,000 counts for moving to a lower gain produces the hysteresis shown in Figure 2.

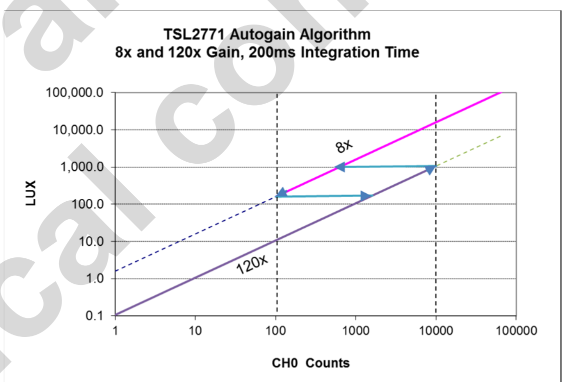

Figure 2. ALS Autogain Algorithm

The program is simple to implement this ALS auto-gain algorithm as follows:

```
if ((C0DATA > 10000) & (AGAINx == 120)
        Set_AGAINx(8);
if (C0DATA < 100) & (AGAINx == 8)
        Set_AGAINx(120);
```

Note that the Set_AGAINx routine should also change the CPL value unless it is calculated of each time the lux equation is calculated.

Proximity + ALS Auto-Gain ALS Example

The second example will be a proximity detection application using the TSL2771 with the same GA factor of 10. Since it is a proximity detection application, the device needs to sample as fast as possible so the ALS integration time will be set to the minimum of 2.7ms (averaging would be implement in software to eliminate flicker) which implies a digital saturation of 1024 counts. This gives the following:

MaxLux = 0.5 * 1024 / CPL = 512 / CPL
CPL = AGAINx * 2.7 / 530 = AGAINx / 196
MaxLux = 512 * 196 / AGAINX = 100,352 / AGAINx
DER = +/- 2 / CPL = 390 / AGAINx

For this example, the maximum lux accuracy achievable is +/- 3.25 counts with a maximum lux being right at 100k lux. This requires an auto-gain algorithm which switched gain from the 1x to 8x to 120x.

DER = 390 / 1 = +/- 390 lux	MaxLux = 100,352 / 1 = 100,354 lux	(1x Gain Mode)
DER = 390 / 8 = +/- 49 lux	MaxLux = 100,352 / 8 = 12,544lux	(8x Gain Mode)
DER = 390 / 120 = +/-3.25 lux	MaxLux = 100,352 / 120 = 836 lux	(120x Gain Mode)

For this example, the gain must be switched from 1x to 8x to 120x. Because of the low integration time and the maximum count of 1024, the gain switching points must be much lower. Switching point of 10 counts and 500 counts provide an adequate algorithm as shown in Figure 3.

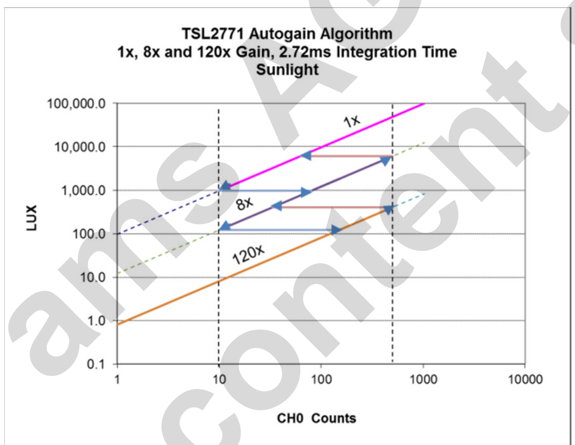

Figure 3. Proximity + ALS Autogain Algorithm

The program is simple to implement this Proximity + ALS auto-gain algorithm as follows:

```
if ((C0DATA > 500) & (AGAINx == 120)
        Set_AGAINx(8);
if ((C0DATA > 500) & (AGAINx == 8)
        Set_AGAINx(1);
if (C0DATA < 10) & (AGAINx == 8)
        Set_AGAINx(120);
if (C0DATA < 10) & (AGAINx == 1)
        Set_AGAINx(8);
```

Conclusions

Implementation of auto-gain lux algorithm will extend the range of lux measurements to a much wider and more precise range, especially under dark glass conditions. The final algorithm is very simple to implement but have great benefits.