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ENSC 387 FINAL PROJECT

LUMINOSITY SENSOR

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I – Introduction

In general, light sensors can detect current light level by providing corresponding current. Nowadays, there are many electronics can be used to do light sensing, such as 'Charge-coupled devices', 'Photo resistors', 'Photodiodes', and 'Phototransistors'.

In our project, we studied TSL2561 Luminosity Sensor, which is an advanced digital light sensor containing two photodiodes. The photodiodes have an active P-N junction when light is detected on the surface, it will produce a current flow under reverse bias (Nave, 2012). The TSL2561 luminosity sensor has both infrared and full spectrum diodes that can measure infrared, full-spectrum or human-visible light respectively (Ada, 2017).

We designed our experiments and studied TSL2561 Luminosity sensor under different conditions and collected corresponding Luminosity Reading from the sensor. We also include sensor operation and applications in this report.

II – Operation

ADAFRUIT TSL2561 DIGITAL LUMINOSITY/LUX/LIGHT SENSOR

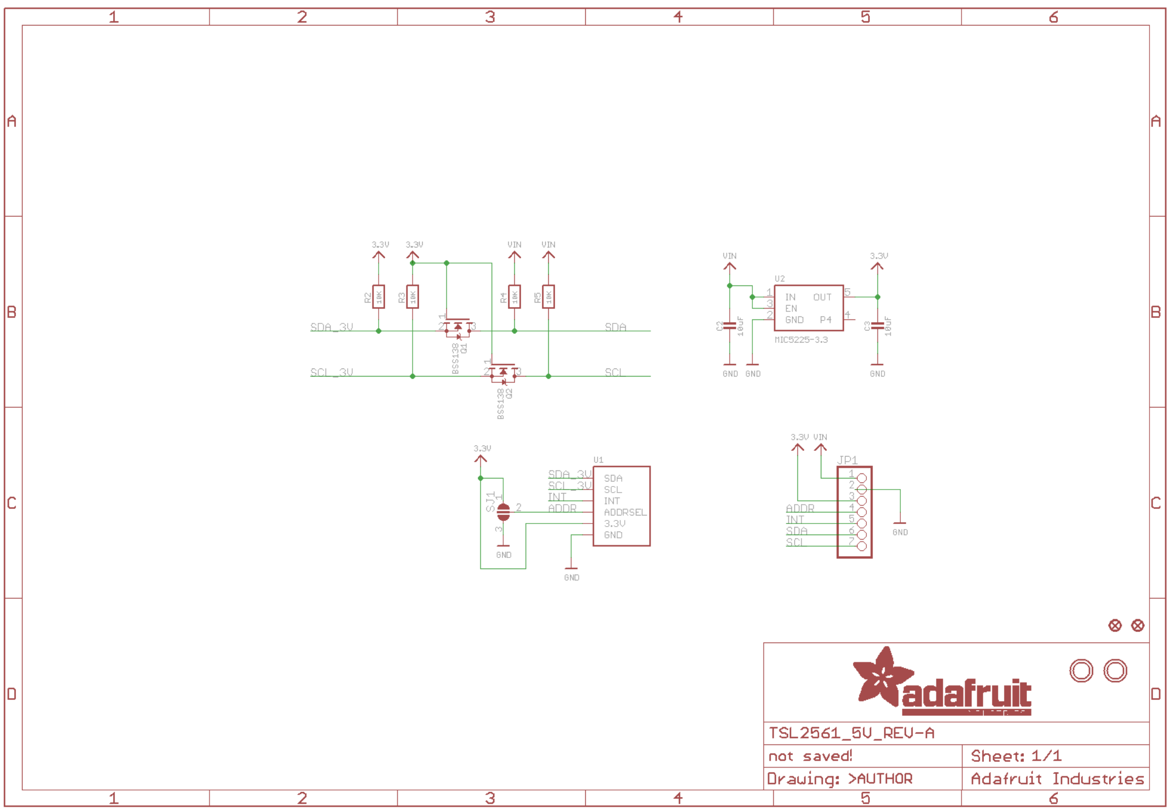

Figure 1. Board Layout

The ADAFRUIT TSL2561 digital luminosity sensor consists of two photodiodes on a CMOS integrated circuit and two integrating analog-to-digital converters. As mentioned in the introduction, the TSL2561 is a sensor used to detect and measure light intensity as perceived by the human eye. The sensor has two photodiodes, one of which is sensitive to both visible and infrared light, while the other is primarily sensitive to infrared light. The photodiode is device that converts light into current.

Since the human eye cannot see infrared light while the silicon detectors used in the photodiodes can, the second photodiode is used to compensate for this by eliminating the effect of infrared light on the output of the visible light detecting photodiode. The two integrating analog-to-digital converts the currents output from the photodiode into digital outputs.

Using empirical formulas, the digital outputs are converted to values in illuminance units of Lux, a measure of how much light hits a surface. The lux is equal to one lumen per square metre. Below are the formulas used to convert from the digital output to values in Lux (Figure 2):

CS Package

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

T, FN, and CL Package

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

The formulas shown above were obtained by optical testing with fluorescent and incandescent light sources, and apply only to open-air applications. Optical apertures (e.g. light pipes) will affect the incident light on the device.

Figure 2. Formulas for converting digital output to Lux

To operate this sensor, the recommended conditions are: a supply voltage between 2.7 to 3.6 V is required, in a temperature range of -30 to 70^{o}C.

III – Signal Conditioning

The TSL2561 sensor does not require any external circuitry for signal conditioning. The output from the sensor is digital and will be processed by a microprocessor to carry out the conversion to units of lux. Since the sensor uses two analog-to-digital converters to convert the analog current signals to digital output signals, the noise is essentially non-existent when compared to an analog signal.

IV – Applications

As we known, light sensor has a wide range of applications. We can see it has been used for automatic burglar alarms or inside garage door openers. And it is used for automatic camera exposure control.

V – Experimental Results

5.1 – Setup

The TSL2591 sensor breakout board for the high dynamic range variation contained 5 I/O connections. A 3.3 V input voltage from the Arduino board was supplied to the v_{in} pin of the sensor to provide power to the board. 3.3 V was used as it is the logic level used in the Arduino microcontroller. Sensor pin gnd was connected to the Arduino's ground port. The sensor board has two I^{2}C logic pins: SCL and SDA. SCL is the clock line, this was connected to the Arduino's I^{2}C clock line, A5. SDA is the data line, this was connected to the Arduino's I^{2}C data line, A4. A complete wiring diagram of the experimental setup is given in the figure below:

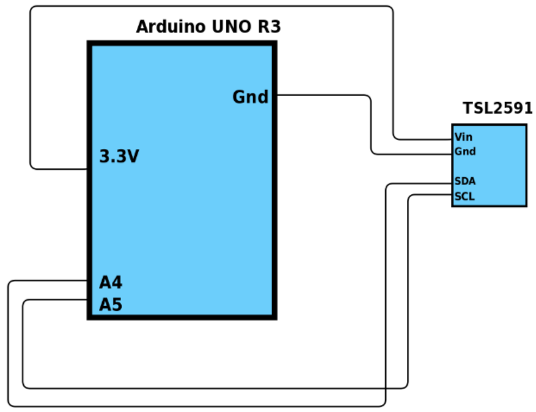

Figure 3. Wiring diagram of experimental setup connecting the TSL2591 sensor to the Arduino board.

5.2 – Coding

Programing the API for the sensor was very straight forward thanks to the Arduino system and predefined libraries for the TSL2591 sensor. We begin by first creating a sensor class with the variable name `tsl`, then obtain all relevant sensor information and assign it to `tsl` using the `getSensor()` function. Doing so allows us to print all relevant sensor information such as the sensor name, version, min and max values and resolution of sensor.

The TSL2591 sensor also gives us various settings to configure via software to alter or condition the luminosity data collected. The first configurable parameter is `setGain()`. This allows us to configure the gain of the sensor between 1x and 16x depending on light capturing environment the sensor is working with. 1x gain is better for bright light capturing to avoid sensor saturation. 16x is better for low light situations which gives a boost in sensitivity. Alternatively, the TSL2591 also an auto range function, `enableAutoRange()`, which switches automatically between 1x and 16x gain. The second configurable parameter is `setIntegrationTime()`. The TSL2591 sensor allows 3 settings for integration time: 13, 101, and 402 ms. The lower the integration time, the faster the data collection, but at the cost of lower resolution data due to the amount of time the sensor takes on processing the light source. At the slowest integration time, the sensor is capable of 16-bit data collection.

After the initial setup procedure, data collection using the TSL2591 sensor was performed inside a continuous loop with a delay of 250 ms between each collection call. The analog data from the sensor is called using the function getEvent() then printed to the Arduino's COM connection serial monitor using serial.print and event.light. Error message are also placed within our code to ensure that if the light lux level read was 0 lux, the message printed would be "Sensor overload", as the sensor is most likely to be saturated if it is reading 0 lux. Our complete code is given in the appendix of this document.

```
void loop(void)
{
    sensors_event_t event;
    tsl.getEvent(&event);

    if (event.light)
    {
        Serial.print(event.light);
        Serial.println(" lux");
    }
    else
    {
        Serial.println("Sensor overload");
    }
    delay(250);
}
```

Figure 4. Snippet of code used in acquiring light reading

5.3 – Acquired Data

Lux data from the TSL2591 sensor was acquired under various different situations/environments to test the sensor's capabilities. The average value of 10 samples for each situation is presented in the table below.

Situation	Average Luminosity Reading (lux)
Sunny day, sensor facing window	835
Room at night, ceiling lights (LED) ON	37
Room at night, ceiling lights OFF	0
Under desk lamp (40 W), 30 cm away	470.7
Under desk lamp (40 W), 10 cm away	1207.3
LED flash light, 30 cm away	1210.1
LED flash light, 10 cm away	1441.4

Table 1. Experiment data collection

References

Ada, L. (2017, 03 17). Retrieved from TSL2561 Luminosity Sensor: https://cdn-learn.adafruit.com/downloads/pdf/tsl2561.pdf

Nave, C. R. (2012). *Photodiode Light Detector*. Retrieved from HyperPhysics: http://hyperphysics.phy-astr.gsu.edu/hbase/Electronic/photdet.html