HACETTEPE UNIVERSITY
COMPUTER ENGINEERING DEPARTMENT

BBM 434 – Embedded Systems Laboratory
Project Report

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1 Introduction

1.1 Overview of Visible Light Communication

Visible light is a small portion portion of electromagnetic spectrum, it has frequencies of about 400 THz[1] to 800 THz and wavelength of about 780 nm[2] to 375 nm. Figure 1.1 shows the position of the visible light in electromagnetic spectrum.

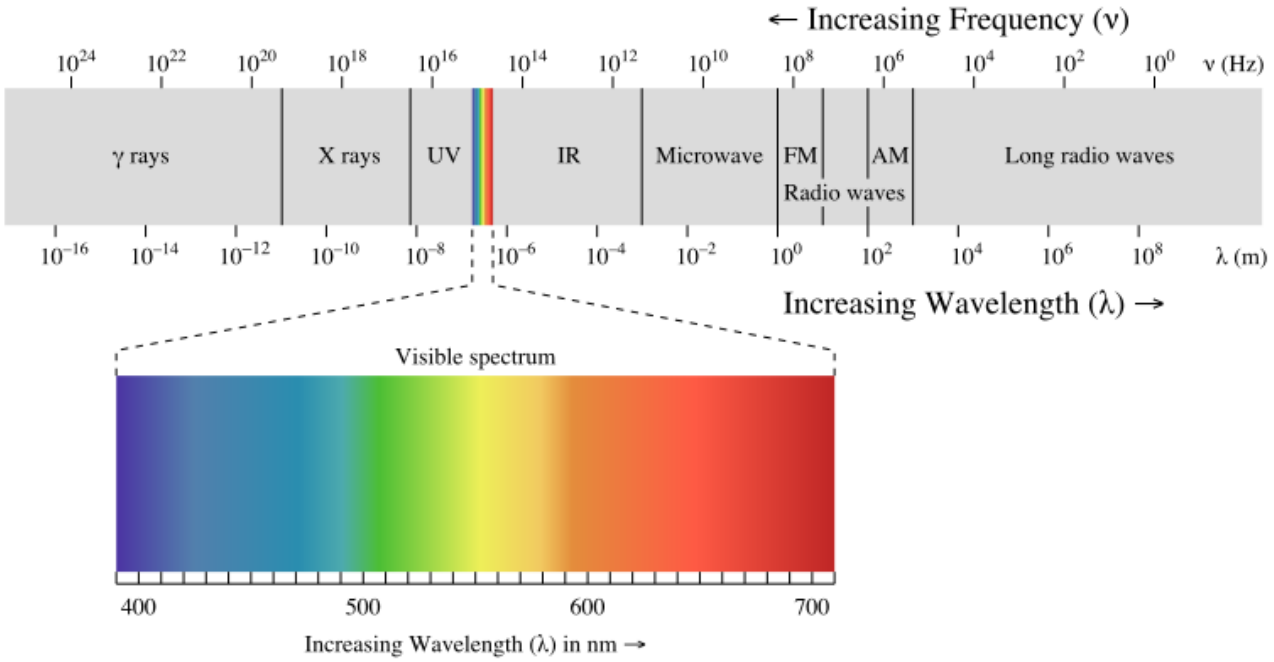

Figure 1.1: *Visible light in electromagnetic spectrum.*

Visible Light Communication can be used as a communications medium for ubiquitous computing, because light-producing devices such as indoor/outdoor lamps, TVs, traffic signs, commercial displays and car headlights/taillights are used everywhere.

Also, using visible light is also less dangerous for high-power applications because humans can perceive it.

Visible Light Communication allows sending data from a microcontroller to another one using the VLC library with a LED and a photodiode. Figure 1.2 illustrates the general structure.

1 1 THz (terahertz) equals to 10^{12} Hz.

2 1 nm (nanometer) equals to 10^{-9} m.

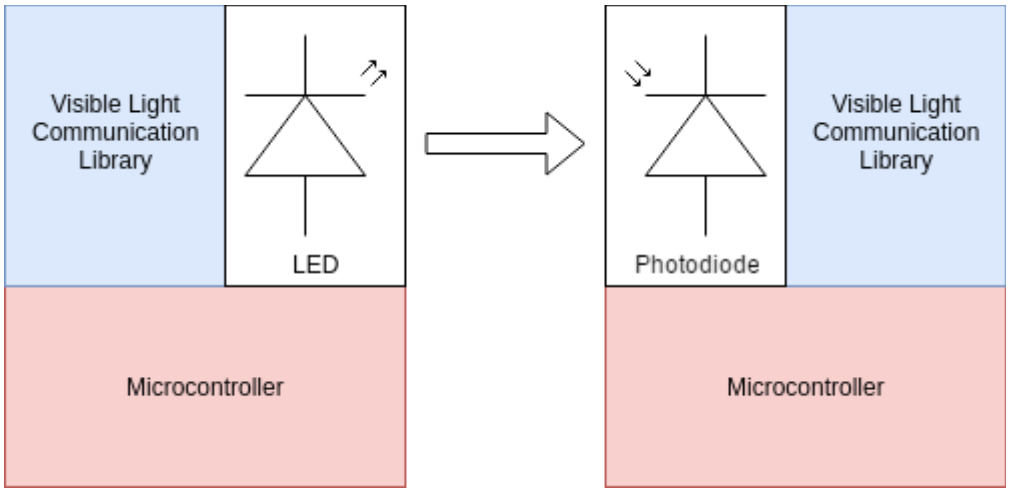

Figure 1.2: *General structure*

1.2 Report Outline

The following chapter, “Design Considerations”, shall detail the design considerations, example application and performance results. The next chapter, “Photo Documencation”, includes the example application setup. The hardware schematics shall be listed in the final chapter.

2 Design Considerations

2.1 Transmitter

In the Visible Light Communication library, the data to send is encoded with Manchester coding. Because in Manchester coding, each data bit is either low then high, or high then low, of equal time. So, it does not affect the perceived lighting and the LED appears to be high all the time for the user. Figure 2.1 shows an example of Manchester encoding.

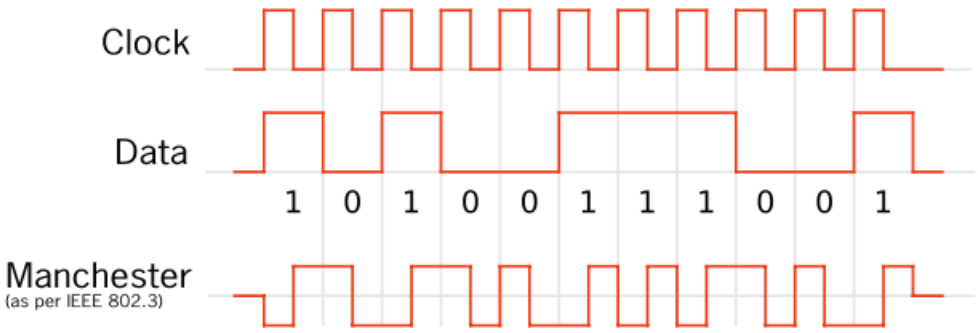

Figure 2.1: *An example of Manchester encoding. The logic 0 is represented by a high-low signal sequence and the logic 1 represented by a low-high signal sequence.*

On the transmitter side, STX (start of text from the ASCII table) is added at the beginning of the message and ETX (end of text from the ASCII table) is added at the end of the message. (Figure 2.2) Then, the message is encoded using Manchester encoding and is transmitted using a LED.

Figure 2.2: *Frame format*

Please refer Figure 4.1 and Figure 4.2 for Hardware schematics of transmitter components.

2.2 Receiver

A finite-state machine was used to simply the code and make the code maintainable. Figure 2.3 shows the state diagram of the logic of the receiver side.

In "Take Sample" state, the receiver takes samples to determine the threshold. The amount of the samples is dependent on the baud rate. For example, it takes 400 samples at 2000 bauds.

One bit is represented by two signals, either high-low or low-high, in Manchester coding. The receiver determines bit position in "Bit Synchronization" state with waiting for two identical signals (low-low or high-high).

After "Bit Synchronization" state, the receiver waits for STX byte, which is 0x02 in ASCII table, in "Word Synchronization" state. After that, it reads the data byte by byte until reading ETX byte which is 0x03 in ASCII table.

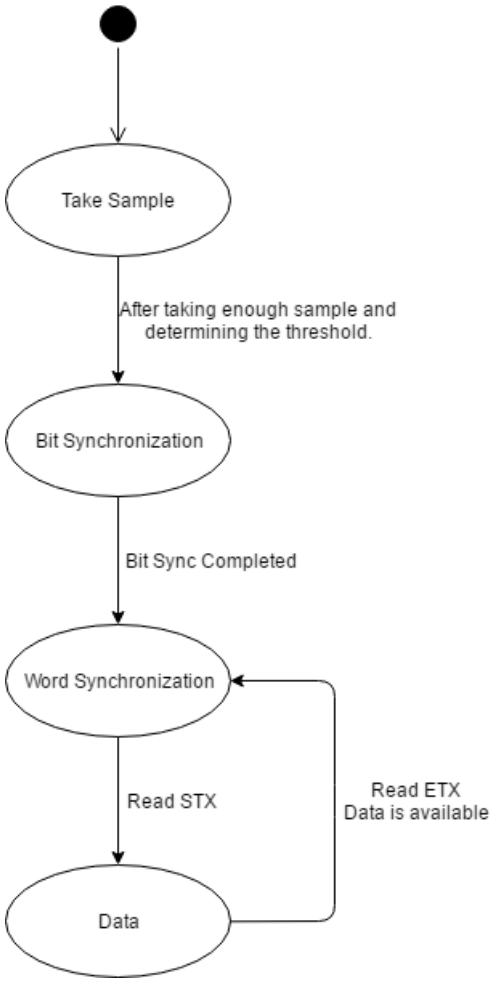

Figure 2.3: *State diagram of the receiver logic*

Please refer Figure 4.3 for Hardware schematics of receiver components.

2.3 Example Application

An example application was developed to demonstrate the Visible Light Communication library. On the transmitter side, an Arduino Duo was used by transforming the transmitter code of the library. And TI Tiva TM4C123 was used as the receiver.

The transmitter send a text using a LED and the receiver reads it using a photodiode and displays it on the Nokia 5110 LCD screen. Figure 2.4 shows the hardware layout of the example application.

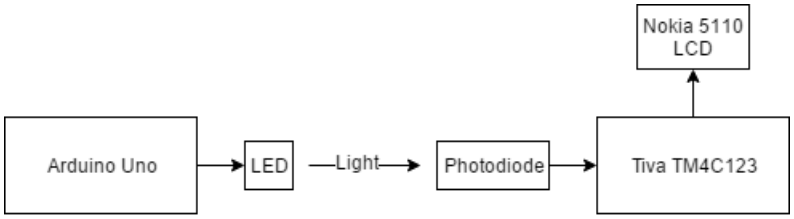

Figure 2.4: *Hardware layout of the example application*

Also, please refer Section 4 for the hardware schematics.

2.4 Performance

In Visible Light Communication, there is a trade-off between speed, distance and consistency. For example, if consistency is not much important, speed and distance can be increased.

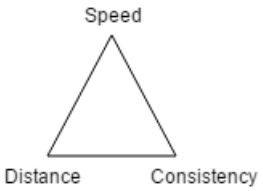

Figure 2.5: *Speed, Distance, Consistency Triangle. You can pick up to two.*

In our approach, consistency was tried to be maximized. The results for a standard LED and a 1W LED are following:

- Standard LED
  - speed ~1 kbit/sec, distance ~5 cm
  - speed ~10 kbit/sec, distance ~2 cm
- 1W Power LED:
  - speed ~1 kbit/sec, distance ~10 cm
  - speed ~2 kbit/sec, distance ~6 cm

3 Photo Documentation

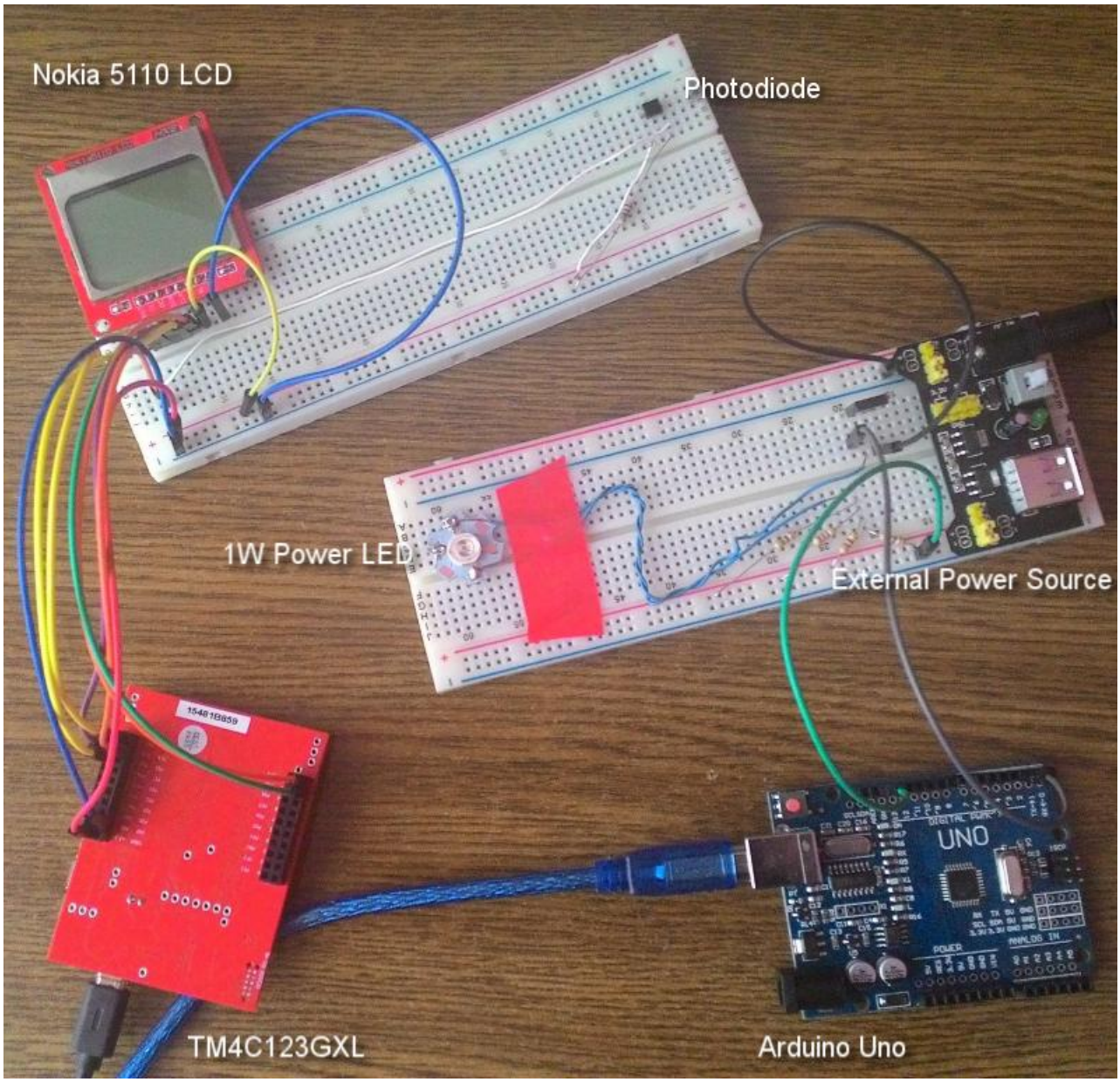

Figure 3.1: *Visible Light Communication example application setup*

4 Hardware Schematics

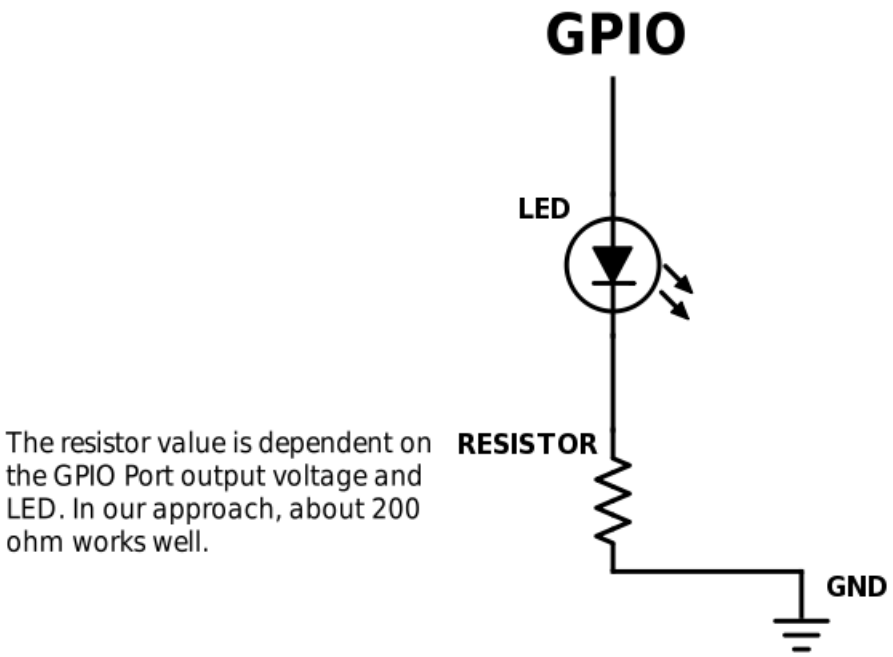

Figure 4.1: *Standard LED hardware schematic*

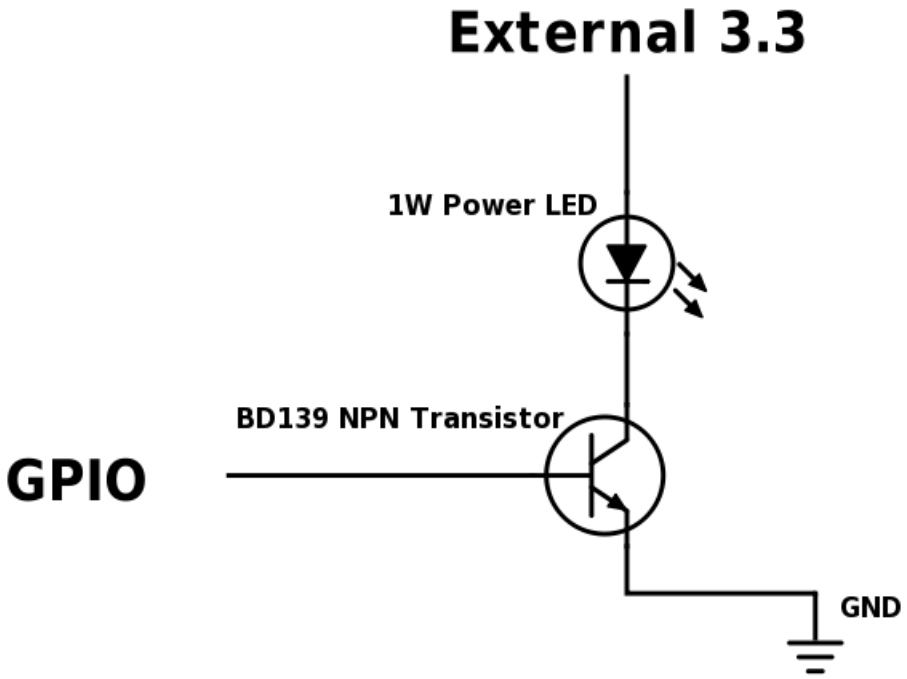

Figure 4.2: *1W Power LED hardware schematic*

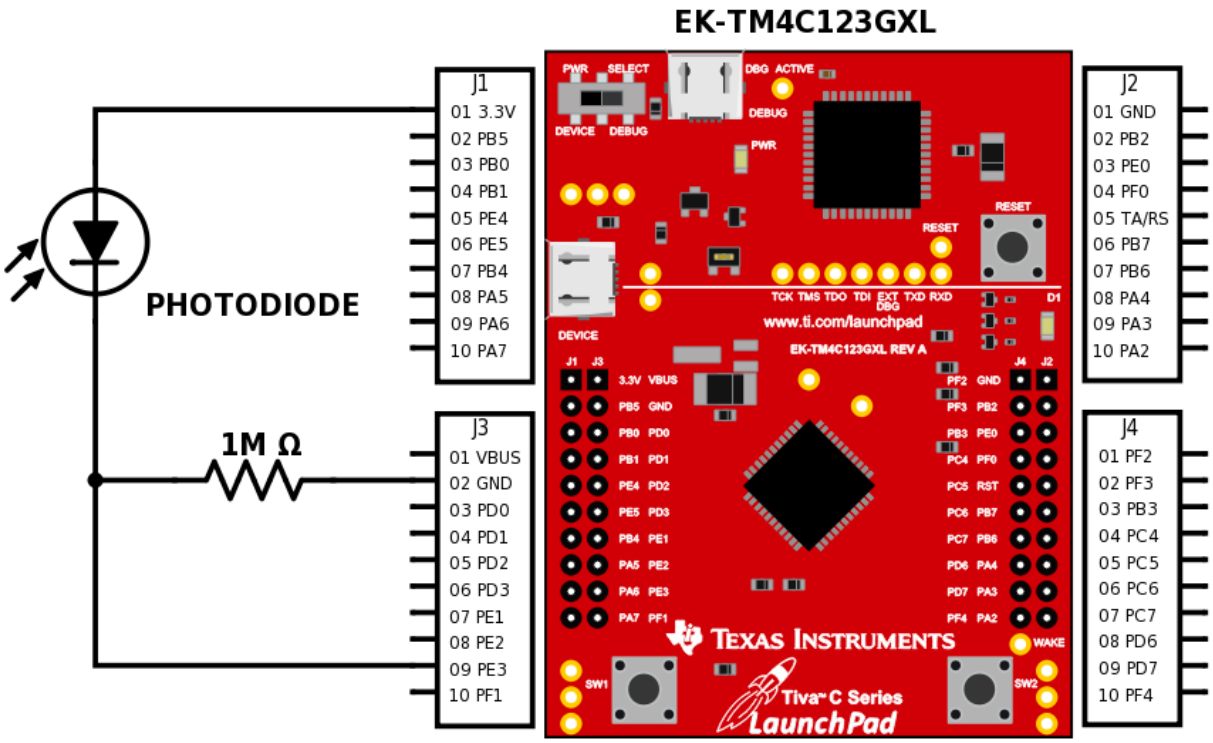

Figure 4.3: *Photodiode hardware schematic*