CS4425, Visible Light Communication & Sensing
– Laboratory 1 –

Goal

Create a link between an LED transmitter and a photodiode receiver with On-Off-Keying Modulation (and Manchester Coding).

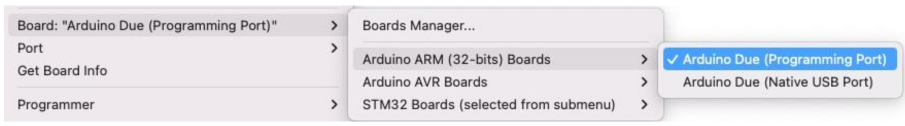
Hardware Assembling and Software Installation

Transmitter: LED + Arduino Due.
Receiver: OPT101 Photodiode + Arduino Due.

A. Assemble the Transmitter

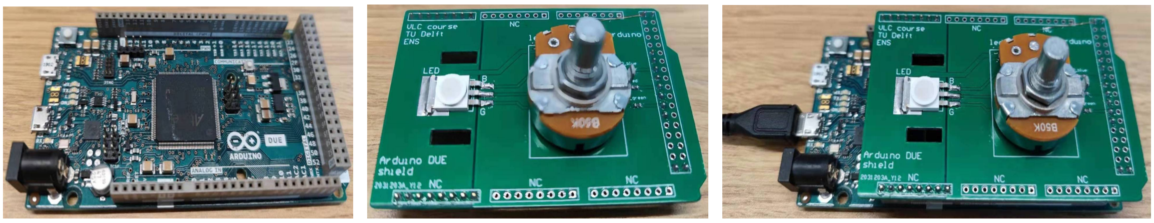
1. Install and configure the Arduino IDE on your laptop.
    a. Download the software from here: https://www.arduino.cc/en/software
    b. Install the Arduino IDE.
    c. Configure the IDE.
        i. In the IDE, under the menu "Tools", select "Board manager".
        ii. Search for "arm 32". Then install the package "Arduino SAM Boards (32-bits ARM Cortex-M3".

        iii. Under the menu "Tools" → "Boards", select the board "Arduino Due (Programming Port)".



    d. Connect the LED transmitter through a USB cable to a laptop. At the Arduino Due, use the USB port that is near the power interface (see Figure 1c for the illustration).
    e. In the Arduino IDE, under the menu "Tools" → "Port", select the serial port to connect to the Arduino Due / LED transmitter.

2. Run the testing code "test_tx.ino" to test the blinking of the LED.

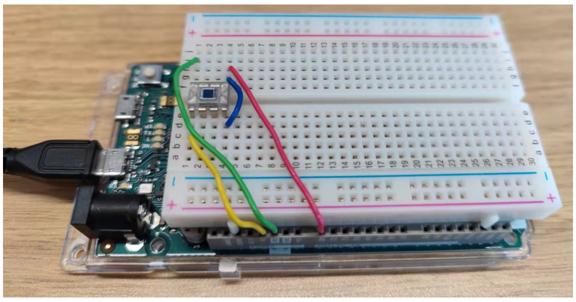


a) Arduino Due b) LED cape c) Plugging LED cape to Arduino Due

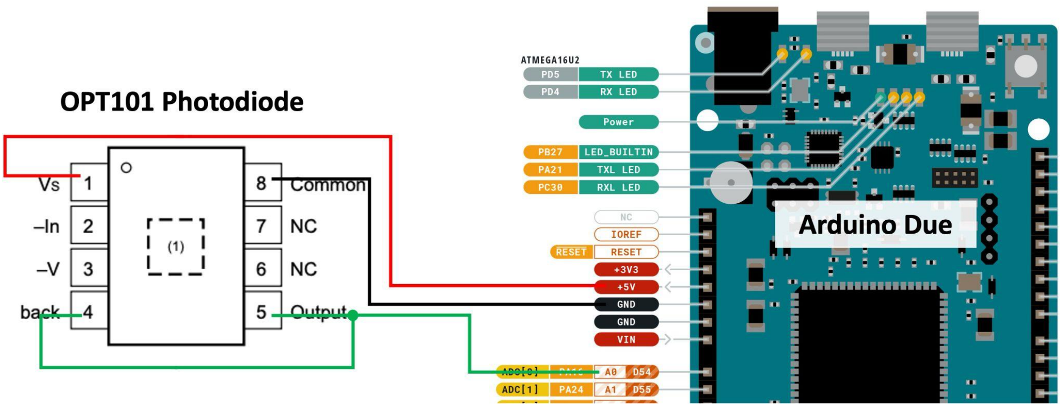
Figure 1. The hardware of the LED transmitter.

B. Assemble the Receiver

1. Connect the receiver through a USB cable to a laptop. At the Arduino Due, use the USB port that is near the power interface (see Figure 2a for the illustration).
2. Run the testing code “test_rx.ino” to test the detection of ambient light.



a) Receiver with the OPT101 connected to the Arduino board.



b) Circuit diagram of the receiver

Figure 2: The hardware of the Receiver

Sample Code

1. test_tx.ino : test blinking the LED using the RED channel.
2. test_rx.ino : test reading the light intensity from the Photodiode.
3. Cyclic Redundancy Check (CRC) is an error-detecting code commonly used in communication networks to detect wrongly received frames. In the lab, you can *call*

Arduino libraries to calculate the CRC for the frame at the transmitter and append the result to the end of that frame; at the receiver, you will need to calculate the CRC again and judge whether the frame is correctly received.

Tasks

The maximum number of points that you can get for this lab is 100. This lab accounts for 20% of the total grade for the course. The grade is divided between two tasks (80 points), a competition (10 points), and a report (10 points).

Frame transmission (80 points)

1. Place the photodiode receiver at a distance of 10 cm from the LED.
2. You can use the same frequency/rate at the TX and the RX. This does not abide by the Nyquist–Shannon sampling theorem, but it is okay because we want to simplify Lab 1.
   (Hints: if you want to work on 4c "determining the symbol period", you must assume that the receiver does not know the TX frequency in advance. In this case, a much higher RX (sampling) frequency/rate might help).
3. At the transmitter, construct the frame (refer to Table 1 for the frame format):
   a. Convert an arbitrary message (with a length between 20 to 40 bytes, such as "Hello VLC&S 2021-2022") into a binary sequence (OOK modulation + Manchester coding) [10 points]
   b. Calculate the length of the binary sequence (payload) and fill it into the length field of the frame [5 points]
   c. Calculate the CRC of the frame and append it to the frame [5 points]
   d. Blink the *Red channel* of the LED to transmit the frame [5 points]
4. At the receiver, detect the changes of light and decode the received data
   a. Detect the preamble of the frame [10 points]
   b. Determine the amplitude threshold to distinguish the symbols [5 points]
   c. Determine the symbol period (*optional;* here you MUST assume that the receiver does NOT know the TX frequency in advance) [10 points]
   d. Check the CRC of the received frame [5 points]
   e. Calculate the length of the payload [5 points]
   f. Decode the payload of the frame into meaningful data [5 points]
5. Identify the maximum data rate at a 10-cm range [5 points]
   a. Increase TX/RX frequencies until the system fails
6. Measure the effect of ambient light at a 10-cm range [5 points]
   a. Compare a dark and an illuminated scenario
7. Identify maximum range [5 points]
   a. Increase TX/RX range until the system fails

Table 1: Frame format (use 0xAAAA for the preamble)

Preamble	**Length**	**Payload**	**CRC**
2 bytes (0xAAAA)	1 byte	0-255 bytes	2 bytes

Competition [10 points]
Goodput and communication distance

The evaluation is a MUST. If your team does not participate in the evaluation, it gets zero points for Lab 1. During the evaluation, you will need to show

1. Decoded message (e.g., “Hello VLC&S 2021-2022”) at the receiver [0 points]
   a. This is to validate that the system works
2. The goodput of the system [6 points]
   a. The goodput is calculated as: M/t (bits/second), where
      M is the number of bits in the transmitted message, and
      t is the time spent on sending that whole frame (which includes the transmitted message in the payload field)
   b. The team with the maximum goodput gets 6 points
   c. The team with the minimum goodput gets 1 point
3. The communication range of the system [4 points]
   a. Increase TX/RX distance until the decoding of the message fails
   b. The team with the longest range gets 4 points
   c. The team with the shortest range gets 1 point

Report [10 points]

The report has 1-page max (excluding the figures). The template is shown on the last page.

CS4425, Visible Light Communication & Sensing
– Report Laboratory 1 –

Note: Do not modify the font size or margins of this report. Maximum 1 page. Delete this note from your final submission in pdf.

Group number: Members (Names & IDs):

Transmitted message. contents:
length (in bytes): TX frequency:
calculated CRC (2 bytes):

Decoding at a 10-cm distance. amplitude threshold:
determined symbol period:
RX frequency: maximum goodput:
maximum communication distance:

Describe the method used for the preamble detection.

What was the most challenging part of decoding the frame? What happens if there are errors in the decoded frames?

Figures on page 2:

1. Plot the time series of a received whole frame and highlight the amplitude threshold and each part of the frame (i.e., preamble, length, payload, CRC)
2. Amplitude thresholds vs distance plot.
3. Communication range vs ambient light (dark, daytime, night) plot.

General.

Describe the effect of ambient light (noise) on the frame transmissions.