Bluetooth Mesh Hands-On Training Lab

KEY FEATURES

Learning the basics how light control (LC) models work

Adding sensor server model and sensor setup model to the light example

Developing the smart light application

Using smartphone to provision and configure a mesh node

Using the Bluetooth Mesh App to change the LC server parameters, which reflects the behaviors on controlling the lightness

This training lab shows how to use Silicon Labs Bluetooth Mesh SDK to develop the smart lighting application, then use the smartphone app – Bluetooth Mesh from Silicon Labs to provision and configure it. You will also have a chance to tune the parameters to change the behaviors how the lightness should be controlled. You will need the following items prepared to finish the lab:

* [Simplicity Studio v4](https://www.silabs.com/products/development-tools/software/simplicity-studio) (If already installed then make sure it is updated)
* The latest Bluetooth Mesh SDK which you can install via Simplicity Studio
* An iOS or Android smartphone with Bluetooth Mesh app installed
* ThunderBoard Sense 2

# Introduction

## Light Lightness Linear State

The Light Lightness Linear state represents the lightness of a light on a linear scale. The values for the state are defined in the following table.

|  |  |
| --- | --- |
| **Value** | **Description** |
| 0x0000 | Light is not emitted by the element. |
| 0x0001–0xFFFE | The lightness of a light emitted by the element. |
| 0xFFFF | The highest lightness of a light emitted by the element. |

Table 1: Light Lightness Linear state

## Light Control Model

Automated lighting control is handled by light controllers that are defined as state machines and feedback regulators.

Light controllers have inputs for collecting data from sensors, usually by receiving sensor messages.

Outputs from light controllers are represented as states that are bound to other states within an element. In this lab, the controller that controls light level has its output state bound with the Light Lightness Linear state.

Figure 1 illustrates the principles of operation of a Light Lightness controller.

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Figure 1. Operation of a Light Lightness controller

The controller has eight phases of operation:

1. Off – the controller is turned off and does not control lighting

2. Standby – the controller is turned on and awaits an event from an occupancy sensor or a manual switch

3. Fade On – the controller has been triggered and gradually transitions to the Run phase, gradually dimming the lights up.

4. Run – the lights are on and the timer counts down (but may be retriggered by a sensor or a switch event)

5. Fade – the Run timer has expired and the controller gradually transitions to the Prolong state

6. Prolong – the lights are at a lower level and the timer counts down (but may be retriggered by a sensor or a switch event)

7. Fade Standby Auto – the controller gradually returns to the Standby state

8. Fade Standby Manual – the controller gradually returns to the Standby state after external event

# Lab Basics

As introduced in section 1.2, the LC server model takes sensor messages as input and output the lightness level. Below is the detailed information about the inputs and output.

**Inputs**:

* **Ambient light** – there is an ambient light sensor on the Thunderboard Sense 2 board, we need to sample the sensor data and send it to the LC server. The LC server regulates the light lightness output against the reported ambient lightness value to make sure that the ambient lightness equals the target level. The lightness regulating follows the formula in chapter 6.2.6 - Light LC PI Feedback Regulator of Mesh Model v1.0.1.
  + If the ambient lightness level is higher than the expected level, then the LC server will try to dim down the light lightness until the real ambient level meets the expected level or 0%.
  + If the ambient lightness level is lower than the expected level, then the LC server will try to dim up the light lightness until the real ambient level meets the expected level or 100%.
* **Occupancy state** – In this lab, we will use the People Count to represent the occupancy state. People count being 0 represents non-occupancy, while equals or greater than 1 represents occupancy. Given that there aren’t a people count sensor on ThunderBoard Sense 2, we will use the buttons instead.
  + People count increments when pressing the button 0.
  + People count decrements when pressing the button 1.
  + If occupancy is reported, which means the people count is reported as non-zero value in this case, the LC server will start the state machine to change the light from Off or Standby state to Run state if it’s not yet in run state.
  + If no occupancy is reported for a certain time, the LC server will start transitioning the light from Run state to Standby state if it’s not in Standby state.
  + If non-occupancy is reported, which means the people count is reported as zero, the LC server will transition the light from Run state to Standby state if it’s not in Standby state.

**Output:**

* **Light Lightness** – There are 4 lights on the Thunderboard Sense 2, the LC server will regulate the lightness of these 4 lights according to the sensor inputs. The value of the lightness is calculated using the formula:
* *Light LC Linear Output = max((Lightness Out)^2/65535, Regulator Output)*

Figure 2 shows the diagram of the project.

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Figure 2. Diagram of the Project

# Finish the Lab

## Import the Project

You will get a customized light example for Thunderboard Sense 2 as the starting point, which is created from Simplicity Studio based on the light example in the Bluetooth Mesh SDK. The project contains the skeleton of the LC server and the sensor models. Follow below steps to import it to your Simplicity Studio.

1. Open Simplicity Studio, then click [File] -> [Import], see below figure.

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1. Click the [More import options…] at the bottom left corner of the popup, see below figure.

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1. Then select [General] -> [Existing Projects into Workspace] and click [Next], see below figure.

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1. Finally, specify the file path to the provided project in the material folder and click [Finish].

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1. Then you could switch to the Simplicity IDE perspective and you will see the project shows up in your workspace.

## Add Sensor Models

Like mentioned in the lab basics, the LC server needs the ambient light level and the occupancy states as input, while the light example doesn’t include them natively. So, we need to add the sensor models to the project. Follow below steps to add the sensor server model and sensor setup server model to your project.

1. Navigate to the project you just imported. Find the ${PROJECT\_NAME}.isc file and double click to open it.
2. Because we are adding the sensor server model and the sensor setup server model to the primary element, so select the “Primary Element” in the element table, then click the  on the right of the “Bluetooth SIG Models” table to add the sensor server model.
3. Do exactly the same as step 2 to add the sensor setup server model.
4. Click “Generate” button on the top-right corner of the file. See below figure.

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## Complete the Project

### LC server

All LC Server state resides in and is own by the Bluetooth Mesh stack. The state update notification events to the application are informational - the application is not required to react to them. The light example saves the LC Server state in persistent storage and set the states in the LC Server following a restart. You can check the implementation in the light\_controller.c file to get all the information how to initialize and integrate the LC server into other projects.

### Sensor Server

We already added the sensor server model and the sensor server setup model to the DCD, to make it works, we still need to do more work on it, they are:

* **Initialize and configure sensor server model** - You can find the implementation from the btmesh-soc-sensor-server example. The skeleton project has already implemented it so you don’t need to work on it.
* **Data sampling** – This is not the target for the lab so all the necessary functions for sampling the sensor data including the button handling are already provided.
* **Send sensor messages to the LC server** – you need to complete the code for sending sensor messages to the LC server, you can find the places which are marked by “TO BE FINISHED - ” in the lab/models/sensor\_server.c and add your code there.
  + Line 132 of sensor\_server.c
  + Line 218 of sensor\_server.c

### Connect the Thunderboard Sense 2 to Serial Terminal

After you finish all the items listed above, you can build the project and program it into your Thunderboard Sense 2 board. Then use any serial terminal tool you are familiar with to connect the board and the terminal. It’s very important to do so because all the debugging information will be output to the terminal. If the logging works, you could see the System Boot event log to the terminal after you reset the device, see below figure.

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# Provision and Configure the Node

We will use the Bluetooth Mesh App to provision and configure the node. Before doing the following steps, make sure that you have programmed the project to your Thunderboard Sense 2 and it’s unprovisioned, this can be checked by the serial output when the device boots up. If the device is provisioned, you need to factory reset it by reset the device with button 0 or 1 holding pressed, you could release the button after you see factory reset on the terminal.

Follow below steps to provision and configure the node.

1. Open the Bluetooth Mesh app on your smartphone, grant all the permission requests if it’s the first time you use it. Switch to the “PROVISION” view and click the SCAN button on the top-right corner.
2. You will see the devices which are sending the unprovisioned beacon in the list. Identify the one to your Thunderboard Sense 2 and click the “PROVISION” button to start provisioning it.
3. You will see a popup and you can change the device name if you want, then click “ADD”. Provisioning takes time so you will need to wait a moment until it’s done, then you will automatically reach the configuration perspective.
4. In the configuration perspective, you could configure the functionalities of the device. It’s needed to add the node to a group (Demo group for example) and choose the “Functionality” as “Light LC Server”.
5. After all configuration is done, go back to the startup perspective which will disconnect from the node and click the “NETWORKS” label and switch to “DEVICES”, the smartphone will reconnect to the node. Below figures are the screenshot of the whole procedure.

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# Testing the Project

The project uses below default settings for the LC properties, which are used to control the lights.

|  |  |  |
| --- | --- | --- |
|  | Value | Description |
| Light LC Time Fade On | 2 Seconds | Time in the Fade On state |
| Light LC Time Run On | 8 Seconds | Time in the Run On state |
| Light LC Time Fade | 2 Seconds | Time in the Fade state |
| Light LC Time Prolong | 4 Seconds | Time in the Prolong state |
| Light LC Time Fade Standby Auto | 2 Seconds | Time in the Fade Standby Auto state |
| Light LC Lightness On | 100% | Represents *Lightness Out* in the lightness calculation formula |
| Light LC Lightness Prolong | 30% | Represents *Lightness Out* in the lightness calculation formula |
| Light LC Lightness Standby | 5% | Represents *Lightness Out* in the lightness calculation formula |
| Light LC Ambient LuxLevel On | 0 | Required ambient light level in Run On state |
| Light LC Ambient LuxLevel Prolong | 0 | Required ambient light level in Prolong state |
| Light LC Ambient LuxLevel Standby | 0 | Required ambient light level in Standby state |
| Light LC Regulator Kiu | 400 | Integral coefficient for Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is less than LuxLevel Out. |
| Light LC Regulator Kid | 400 | Integral coefficient for Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is greater than or equal to the value of the LuxLevel Out state. |
| Light LC Regulator Kpu | 70 | Proportional coefficient for Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is less than LuxLevel Out. |
| Light LC Regulator Kpd | 70 | Proportional coefficient for Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is greater than or equal to the value of the LuxLevel Out state. |
| Light LC Regulator Accuracy | 2% | Percentage accuracy of the Light LC PI Feedback Regulator |

## Without Ambient Sensor

The project doesn’t enable the ambient sensor to send the ambient light level to the LC server, which means the LC PI feedback regulator won’t start so that the Lightness of the lights is output from Light LC Lightness On/Prolong/Standby according to the state of the LC server.

### Occupancy VS Non-Occupancy

Once the Thunderboard Sense 2 is provisioned and configured, you could press the buttons on the board to simulate the occupancy sensor and the LC server should control the light according to its report value. Follow the below steps.

1. Press the button 0 to increase the people count to be non-zero value, which will loop the people count message back to the LC server if you have finished the lab “TO BE FINISHED -” sections. What you will see is the lightness of the lights goes up to 100% within 2 seconds (Light LC Time Fade).
2. Press the button 1 to decrease the people count to zero, then you will see:
   1. Light stays in Run On state for 8 seconds (Light LC Time Run On).
   2. Light starts to dim down to 30% (Light LC Lightness Prolong) within 2 seconds (Light LC Time Fade).
   3. Light stays in Prolong state for 4 seconds (Light LC Time Prolong).
   4. Light starts to dim down to 5% (Light LC Lightness Standby) within 2 seconds (Light LC Time Fade Standby Auto).

## Enable Ambient Sensor Feedback and LC PI Regulator

The default Light LC Ambient LuxLevel On/Prolong/Standby values are all 0, to enable the LC PI regulator, we need to set proper values to them. Follow the below steps to set the values.

1. Open the Bluetooth Mesh App on your smartphone, then click [Demo Network] -> [Devices], wait until the icon on the top-right to become green.
2. Find below place and modify the values list.
   1. Ambient LuxLevel On -> 230
   2. Ambient LuxLevel Prolong -> 5.5
   3. Ambient LuxLevel Standby -> 1.5
   4. Lightness On -> 0
   5. Lightness Prolong -> 0
   6. Lightness Standby -> 0

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### Occupancy vs Non-Occupancy

Once the Thunderboard Sense 2 is provisioned and configured, you could press the buttons on the board to simulate the occupancy sensor and the LC server should control the light according to its report value. Follow the below steps.

1. Press the button 0 to increase the people count to be non-zero value, which will loop the people count message back to the LC server if you have finished the lab “TO BE FINISHED -” sections. To observe
   1. If the light state changes? Why?
   2. Try to use your hand to other thing to slowly cover the board and see the lightness change, does it change? Why?
2. The lightness should change in the 1.b step, you could try to cover the ambient light sensor on the board immediately, then check how the lightness is regulated and how fast the regulating is. You could do the same to check when the covering is removed.

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1. Open the Bluetooth Mesh App on your smartphone and connect to the node again. Then modify below parameters.
   1. Change the Regulator Kid to 100
   2. Change the Regulator Kiu to 100
   3. Change the Regulator Kpd to 20
   4. Change the Regulator Kpu to 20

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1. Do the same test as in the 2nd step and compare the changes, you should see the regulating becomes slower than it was before the parameters are modified.