Device Location in a Classroom Context

Mock Design Review

TA: John Capozzo

Project Contributors:

Gregory Fabry  glfabry2
Michael Silkaitis  silkait2
Pranava Aditya  paditya2
1. Block Diagram

![Block Diagram](image)

Figure 1: Overall Block Diagram

2 Circuit Schematic

Figure 2 shows how the Li-ion battery we’ve chosen will be charged. It utilizes the MCP73831/2 regulator chip to detect if a battery is present and determine when the battery is fully charged, as well as to provide pre-programmed voltage and currents to the battery.
3. Calculation

In order for the beacons to be reliably used throughout a school day, they must be able to sustain operation for 8 hours (a typical maximum school day in United States). If the battery is depleted before this time, the hardware will be impractical to use in the classroom, as it would not be able to be used consistently. Additionally, the teacher would have to spend time charging and setting up the beacons again.

By far, the component with the greatest power draw is the transceiver, which draws up to 15mA during TX/RX operations (compared to ~50µA for the microcontroller). To accomplish power goals, four factors have to be considered: the components used and how much power they draw, the amount of time the transceiver spends in “deep sleep”/sleep/TX/RX modes, the power the signal is transmitted at and the power characteristics of the battery selected. Additionally, since low price is a significant feature of the product, the price of the battery must also considered.

Two requirements for the power system must be met: the minimum amount of time that the beacon can operate continuously, and the maximum amount of time that the beacon must be recharged before it can be used for that time period again.

We will assume that the beacon draws 1mA during continuous use. To determine this value, we assumed that, over each 25ms period allocated to ping a beacon (as per the requirements), we will be transmitting for 1ms and receiving for 1ms. The transceiver will be in a sleep state for the remaining period of that interval. Because the transceiver draws 12mA for sending/receiving, and 0.2µA when in sleep mode, the current drawn on average is:

\[
\frac{2}{25}(12mA) + \frac{23}{25}(0.2\mu A) \approx 1mA
\]

Therefore, to sustain 8 hours of operation, the battery must have a capacity of at least 8mAh.

To test these requirements we will fully charge the beacon’s battery and use it continuously for half an hour. We will then determine that there is enough charge left in the beacon to sustain 7 ½ more hours operation at the power consumption rate of the first ½ hour. To test the charging requirements, we will deplete the battery and charge it for an hour. We will then determine whether there is enough charge to last for 8 hours based on the ½ hour power consumption rate.
4. Plot

The following plot shows the expected voltages and currents delivered to the battery in a typical charge cycle, which consists of the following steps [4]:

- Check to see if the voltage across the battery is less than a preconditioned voltage ($V_{PTH}$). If so, apply a pre-programmed current $I_{PREG}$ until $V_{BAT} > V_{PTH}$.
- Once this condition occurs, apply a constant current $I_{REG} = 5I_{PREG}$ until the voltage across the battery $V_{BAT}$ is equal to the regulatory voltage, 4.2 V.
- Continue to apply 4.2 V across the battery until the current across the battery, $I_{BAT}$, falls below a predefined termination current $I_{TERM} = 0.05I_{REG}$.

As the exact times where the values switch are unknown, they are denoted as the following: $t_{PRE}$ is the time where $V_{BAT} > V_{PTH}$, $t_{VBAT}$ is the time where $V_{BAT} = 4.2$ V, and $t_{IBAT}$ is the time where $I_{BAT} = I_{TERM}$. Plotting the voltage and current gives the result shown in Figure 3.

![Current and voltage across the battery while charging](image)

Figure 3: Current and Voltage across the Battery
5. Block Description

Proximity, Timing, and Messages
Performs timing analysis, measuring the time elapsed from sending a message from the core module to receiving a message back from the beacon. The messages will be digitally generated through the AT86RF233 transceiver chip we selected, and different messages will correspond to different beacons, so each beacon only responds when it is pinged. The time-of-flight information will then be sent to the microcontroller.

Additionally, this module performs RSSI (received signal strength indicator) calculations, sending this information to the microcontroller as well. RSSI will be used as a buffer against timing errors/the potential for varying lag in the transceiver, and as a simpler way of determining when the teacher is very close to a beacon.

This module will also decode the data sent from the beacon (such as the visual aid information and other information about the group), and send this information to the microcontroller, which will send it to the tablet.

6. Requirements and Verification

<table>
<thead>
<tr>
<th>Core Module</th>
<th>Proximity, Timing, and Messages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1) Deliver messages to beacons with a 95% success rate up to 15 meters away</td>
</tr>
<tr>
<td></td>
<td>2) Deliver and receive messages with an average distance variance of 10% over 10 pingbacks at 15 meters</td>
</tr>
<tr>
<td></td>
<td>3) Address any beacon within 1ms.</td>
</tr>
</tbody>
</table>

1) Place a beacon 15 feet away from the core module. Turn the core module and the beacon on. Send 100 “pings” to the beacon. Verify that at least 95 were correctly received.

2) Turn on a beacon and the core module. Send 100 “pings” to the beacon. Record the time from sending to receiving, as well as the distance measured by the core module. Calculate the average distance variance as a percentage of the average distance. Repeat the experiment 10 times, and verify that the average distance variance is never greater than 10%.

3) Turn on a beacon and the core module. Send “pings” to the beacon for three seconds. Verify that at least 3000 pingbacks were received.
7. Safety Statement

The part of our project that could present safety hazards is the external battery that we are planning to use to power the proximity module. The battery that we are using for this purpose is a Li-ion button cell. The safety measures that should be taken that need to be taken for this battery are as follows:

- Do not charge the batteries above the maximum charging voltage (4.2V).
- Do not discharge batteries below their minimum discharging voltage (3.0V).
- Do not draw more current than the maximum discharging current (200mA).
- Do not charge with more current than the maximum charging current (100mA).
- Do not short circuit the battery by connecting the positive and negative terminals using conductive material.
- Do not immerse the battery in water or liquids.
- Make sure the battery is not installed in reverse polarity.
- Do not leave battery in a high temperature environment to prevent the battery from exploding.
- Check battery for failures before using it.

In addition to this, all the team members have completed both the general laboratory safety training and the electrical safety training.

8. References


