Embedded systems 2

Report Cosy Cafeteria

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Contents

1 Intro

To improve the experience of the students in the cafeteria, an embedded system will be developed to gather a variety of data. This data will then be display to the students through an online medium such as a website. The main focus will be to gather information about the amount off people that are in the cafeteria. There are two main goals. The first goal is to display the estimated waiting time to get a meal to the students. Secondly the amount of available seats will be tracked and displayed to the students. Next to this some additional information will be gathered. The temperature, air-quality and sound level will be monitored to give the student a general idea about the conditions in the cafeteria. This way the student can gauge if the cafeteria is suitable to study in at a certain moment. An overview of the envisioned system is displayed in figure 1. All the developed hardware and software is displayed at: `https://github.com/thomasf10/cosy_cafeteria`.
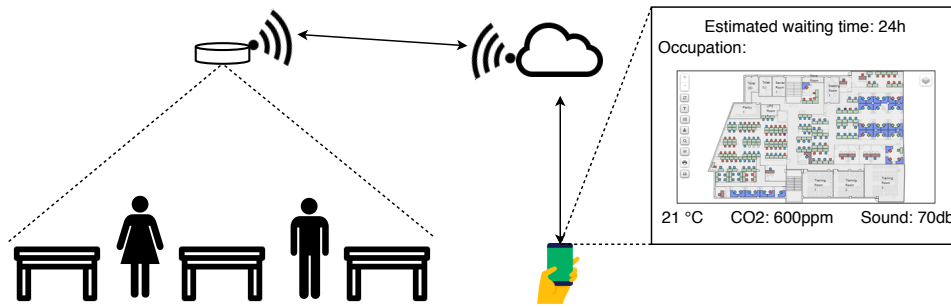
Figure 1: Situation sketch

2 Functionality

The developed system uses three sensors:

- AMG8833: IR grid sensor

- CSS811: air quality sensors

- Sparkfun sound detector: microphone

By incorporating these sensors in to the system, a variety of sensor data is gathered, namely: ambient temperature [°C], CO_2-level [ppm], TVOC-level (total volatile organic compounds) [ppb] and sound level [db]. Next to this the AMG8833 captures the temperature af a two dimensional area in 8 by 8 pixels.

The 'brain' of the system is an ESP32, this microcontroller has an integrated Wi-Fi module, which will be used to transmit the data. The gathered data is sent to a server, which stores the received data in a database.

Alongside the reception of data from the ESP32, the server hosts a website which is used to display the data to the students. The website uses the pixel data to generate a heatmap of the cafeteria, this allows the students to see how many people are present in the cafeteria. Unfortunately one module cannot cover the entire cafeteria, to generate the heatmap. In order to do this, several modules have to be deployed in the cafeteria. In this project only one module will be constructed as a proof of concept. Next to the heatmap, the other sensor data is displayed on the website this includes: ambient temperature, CO_2-level, TVOC-level and the sound-level. Based on these parameters the students can gauge if the cafeteria is currently suitable as a study-location.

3   System architecture

systeem wat uitleggen ...**EENS CHECKEN OF DE ARCHITEC-TUUR IN GROTE LIJNEN KLOPT** An overview of the full system is displayed in figure 2.
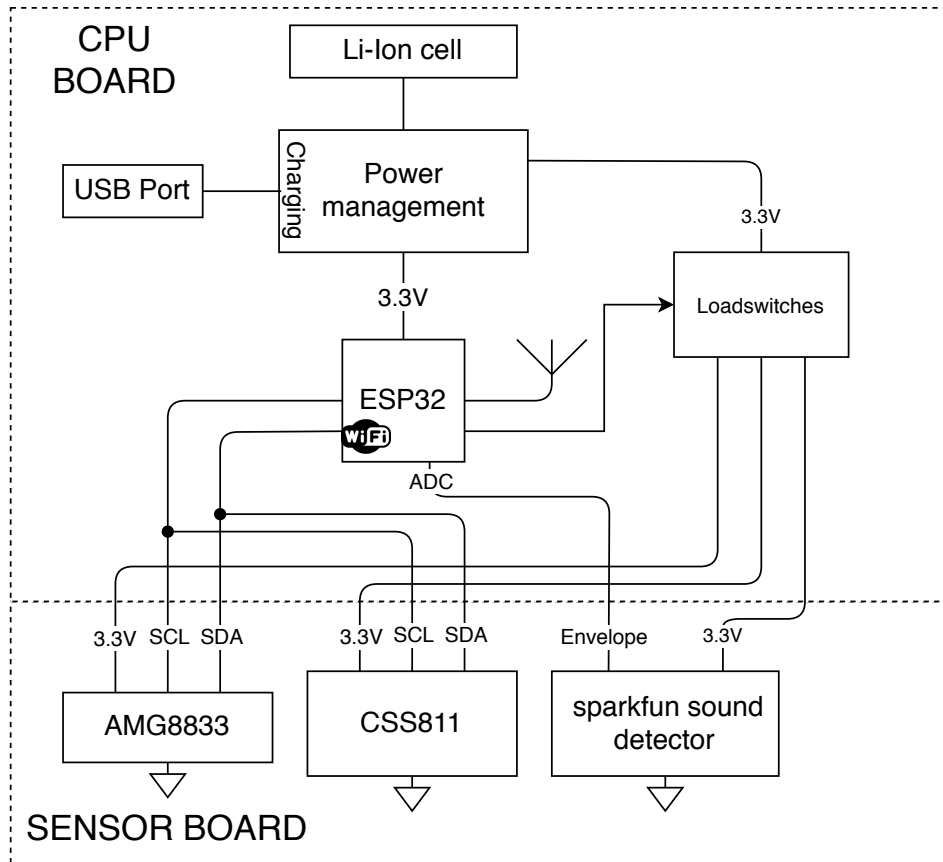
Figure 2: System architecture

4 Design power management

This section explains the different trade-off's which were made in designing the power management part of the system. The first part in designing the power management is choosing a way to supply the circuit. In our case, the device needs to be deployed at the ceiling of a cafeteria. You can't just tap off the electricity cable at any point here, so our device will need a battery to supply the power. Our first aim was to supply the device as long as one semester. Another aspect was the ability to recharge the battery for environmental reasons. This excludes standard cell batteries that have a much lower energy density and are not rechargeable. Our choice was quickly made for the type of battery, namely a Lithium-Ion (Li-Ion) battery which will be discussed in section 4.1.

4.1 Lithium-Ion battery

Lithium-Ion batteries are now a commonly used battery in consumer electronics. Li-Ion batteries is the most commonly used battery in phones, MP3 players and other portable equipment. The voltage of a single Li-Ion battery cell is usually fixed at 3.6 V or 3.7 V. We call this the nominal voltage. However, the actual voltage during use can vary from 2.4 V to 4.2 V. When the voltage drops below 2.4 V, the cell is discharged too deeply and damaged beyond repair. Therefore, a safety voltage of 3 V is often maintained. If the cell is discharged to this voltage, nothing is wrong. Charging a Li-Ion battery usually takes 3 hours. Don't be blinded by fast chargers for these batteries, practical tests have shown that it takes 3 hours until a battery is fully charged [1]. A few benefits of a Li-Ion battery are:

- Very high energy density

- Minor self-discharge

- No memory effect

- High power, long service life

Some disadvantages are:

- Relatively expensive to purchase

- Dangerous if used incorrectly, can explode/combust

- Need a protection circuit to not drop below the 2.4 V threshold value

- Charging and discharging process needed

The most common Li-Ion battery is the 18650 cylindrical cell which is 18mm wide, 65mm long and the '0' stands for its cylindrical shape. Another common type of Lithium-Ion battery is the Lithium-Ion Polymer Battery (LiPo). LiPo's are preferred over standard Li-Ion batteries in application where weight reduction is important, fast charge opportunity is needed and which need a very high current during discharge time. LiPo's are more used for drones (where lightweight is a requirement) and electric cars (fast charging requirement). LiPo's are also less likely to combust or explode and are more expensive. Therefor a LiPo would be overkill in our application [2, 3, 4].

4.1.1 Requirements

The reason we chose a Li-Ion battery was:

- Voltage range: our microcontroller needs 3.3 V supply voltage, which is only a low dropout voltage of 0.4 V in comparison with the 3.7 V nominal voltage of a single cell Li-Ion battery. This results in less power dissipation in the voltage regulator.

- Rechargeable: for environmental aspects

- High capacity: around 3000 mAh, to last a semester

4.1.2 Selected battery

Specifications:

- Size/package: 18650

- Rated capacity: 3200 mAh

- Nominal voltage: 3.6 V

- Maximum voltage: 4.2 V

- Maximum charge current: 1625 mA

- Maximum discharge current: 6400 mA[1]

- Maximum discharge voltage: 2.5 V

- Charge time: 4 hours

- No protection circuit

4.2 Battery charging circuit

4.3 Battry protection circuit

4.4 Polarity protection

5 Microcontroller

6 Sensorboard

7 Selection battery charger components

There are many manufacturers who produce charging IC's bla bla bla ...

We considerd many chips from different kind of manufacturers. Eventualy we went with the BQ24075 IC from Texas Instruments. It's a great

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[1]Maximum discharge rate is 2C. This means discharging the battery capacity in 0.5 hours $\frac{3200mAh}{0.5h} = 6400mA$.

chose because it's made to charge a single cell Li-Ion battery (that's all we need), and it's perfectly fit to charge using a USB port because the IC has a selectable 100 mA and 500 mA maximum input current **TO DO: VERWIJZEN NAAR USB TABEL**. **OOK NOG ZEGGEN DAT DE OPLAADSTROOM OVEREENKOMT MET DIE VAN DE BATTERY**. In the subsections below you'll find the calculations.

7.1 Charging

Set $\overline{CE}$ low to initiate battery charging. The battery is charged in three phases:

1. Conditioning pre-charge

2. Constant current fast charge (current regulation)

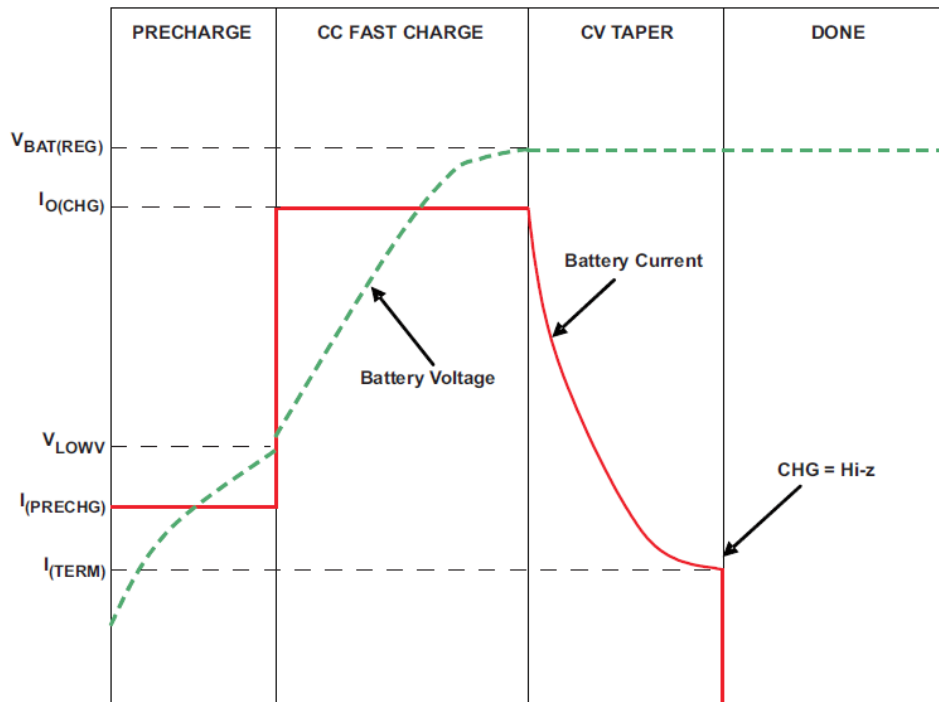3. Constant voltage tapering (voltage regulation)

Figure 3: Charge cycle

In the pre-charge phase, the battery is charged at with the pre-charge current I_{PRECHG}. Once the battery voltage crosses the V_{LOWV} threshold, the battery is charged with the fast-charge current I_{CHG}. As the battery voltage

reaches $V_{BAT(REG)}$, the battery is held at a constant voltage of $V_{BAT(REG)}$ and the charge current tapers off as the battery approaches full charge. When the battery current reaches I_{TERM}, the CHG pin indicates charging done by going high-impedance.

The value of the fast-charge current is set by the resistor connected from the ISET pin to VSS, and is given by the equation:

$$I_{CHG} = \frac{K_{ISET}}{R_{ISET}}$$

The charge current limit is adjustable up to 1.5 A. The valid resistor range is 590 Ω to 8.9 kΩ. If I_{CHG} is programmed as greater than the input current limit, the battery will not charge at the rate of I_{CHG}, but at the slower rate of $I_{IN(MAX)}$ (minus the load current on the OUT pin, if any). In this case, the charger timers will be proportionately slowed down.

7.1.1 Charge Current Translator

When the charger is enabled, internal circuits generate a current proportional to the charge current at the ISET input. The current out of I_{SET} is 1/400 ($\pm 10\%$) of the charge current. This current, when applied to the external charge current programming resistor, R_{ISET}, generates an analog voltage that can be monitored by an external host to calculate the current sourced from BAT.

$$V_{ISET} = \frac{I_{CHG}}{400} R_{ISET}$$

7.2 System enable input

Connect SYSOFF high to turn off the FET connecting the battery to the system output. When an adapter is connected, charging is also disabled. Connect SYSOFF low for normal operation. SYSOFF is internally pulled up to VBAT through a large resistor (approximately 5 MΩ). Do not leave SYSOFF unconnected to ensure proper operation.

7.3 Calculations

7.3.1 Program the Fast Charge Current I_{CHG}

$$R_{ISET} = \frac{K_{ISET}}{I_{CHG}}$$

From the electrical table we can find:

$$K_{ISET} = 890 A\Omega$$

The charge current limit is adjustable up to 1.5 A. The maximum charge current for the Panasonic NCR18650B battery is 1625 mA. Set the charge

current to 1.3 A to have some margin for the battery lifetime.

$$R_{ILIM} = \frac{890A\Omega}{1.3A} = 684.62\Omega \approx 680\Omega$$

The valid resistor range is 590 Ω to 8.9 kΩ. Select the closest standard value, which for this case is 680 Ω. Connect this resistor between ISET (pin 16) and VSS.

$$I_{CHG} = \frac{890A\Omega}{680\Omega} = 1.31A$$

7.3.2 Program the Input Current Limit I_{LIM}

$$R_{ILIM} = \frac{K_{ILIM}}{I_{IN(MAX)}}$$

From the electrical table we can find:

$$K_{ILIM} = 1610A\Omega$$

The input current limit is adjustable up to 1.5 A. Set the input current limit higher than the charge current of 1.3 A.

$$R_{ILIM} = \frac{1610A\Omega}{1.5A} = 1.073k\Omega \approx 1.1k\Omega$$

The valid resistor range is 1.1 kΩ to 8 kΩ. Select the closest standard value, which for this case is 1.1 kΩ. Connect this resistor between ILIM (pin 12) and VSS.

$$I_{ILIM} = \frac{1610A\Omega}{1.1k\Omega} = 1.46A$$

7.3.3 Fast-Charge Safety Timer (TMR)

Leave TMR open to set to default safety timers. Connect to VSS to disable safety timers.

7.3.4 TS function

Connect a 10 kΩ resistor from TS to VSS to set the TS voltage at a valid level and maintain charging.

7.3.5 Selecting IN, OUT, and BAT Pin Capacitors

In most applications, all that is needed is a high-frequency decoupling capacitor (ceramic) on the power pin, input, output and battery pins. Using the values shown on the application diagram, is recommended. After evaluation of these voltage signals with real system operational conditions, one can determine if capacitance values can be adjusted toward the minimum recommended values (DC load application) or higher values for fast high

amplitude pulsed load applications. Note if designed high input voltage sources (bad adaptors or wrong adaptors), the capacitor needs to be rated appropriately. Ceramic capacitors are tested to 2x their rated values so a 16-V capacitor may be adequate for a 30-V transient (verify tested rating with capacitor manufacturer).

7.3.6 Selecting MOSFETs

Discharge Overcurrent Detection (OCD) voltage = 100 mV. $R_{DSON} = 30m\Omega@V_{GS} = 4.5V$ Maximum operating discharge current = $\frac{100mV}{2*30m\Omega} = 1.67A$

8 Wireless connectivity

8.1 Wi-Fi connection

In order to transmit the sensor data to the server, the Wi-Fi connectivity of the ESP32 is used. The transmission is provided by a TCP connection that is established between the ESP32 and the python server. At the initialisation of the python server, a socket is opened, this socket is used to receive the data. In this manner, the server is always listening on the socket, until a message is received. The ESP32 sends the data in the following order: pixeldata (64 floats), temperature (1 float), audio level (1 float), CO_2-level (1 unint16) and TVOC-level (1 unint64). The received data is processed by order to determine which data is represented by the received values. The data is parsed into different variable, these variables are then used to update the values in the database.

8.2 Power consumption

To determine the power that is consumed when the sensor data is transmitted once, a measurement is performed. The current consumption is measured, the result is displayed in figure 4.
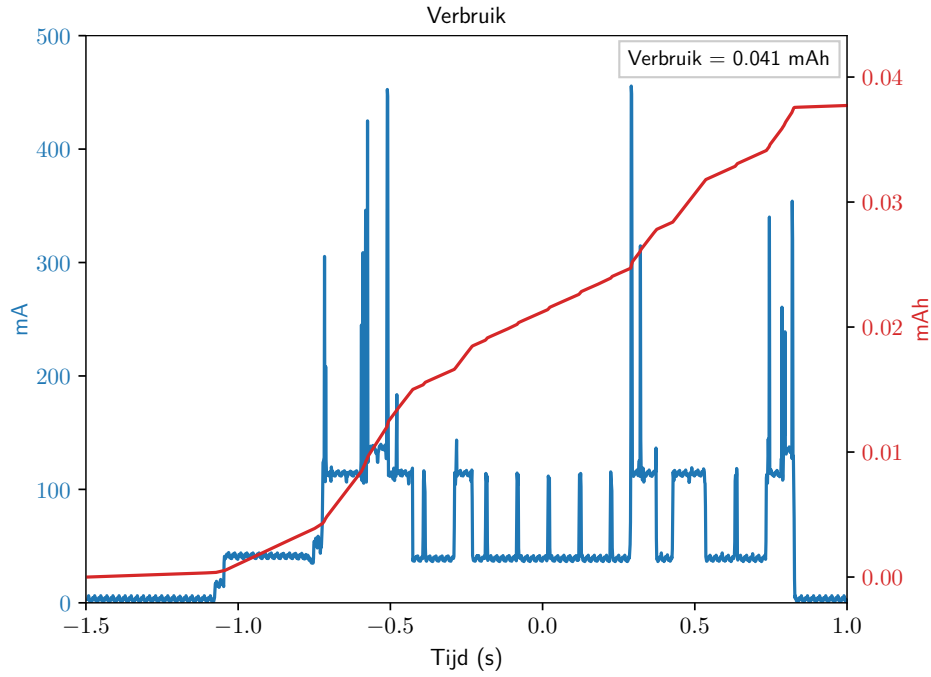
Figure 4: Power consumption of one Wi-Fi transmission

In order to interpret the current consumption, the used capacity is displayed in [mAh]. This results in 0.041 mAh of capacity that is used in order to transmit the sensor data once. With this knowledge, we can calculate the amount of Wi-Fi transmissions that are possible with the 6400 mAh battery:

$$\frac{6400}{0.041} \approx 156097$$

156097 transmissions are possible, if there are 6 transmissions per hour and the system is active for 7 hours a day, this leads to a battery life off 3716 days. However, this calculation only accounts for the Wi-Fi transmission other power consumption such as stand-by power, CPU power and sensor power are not accounted for in the calculation.
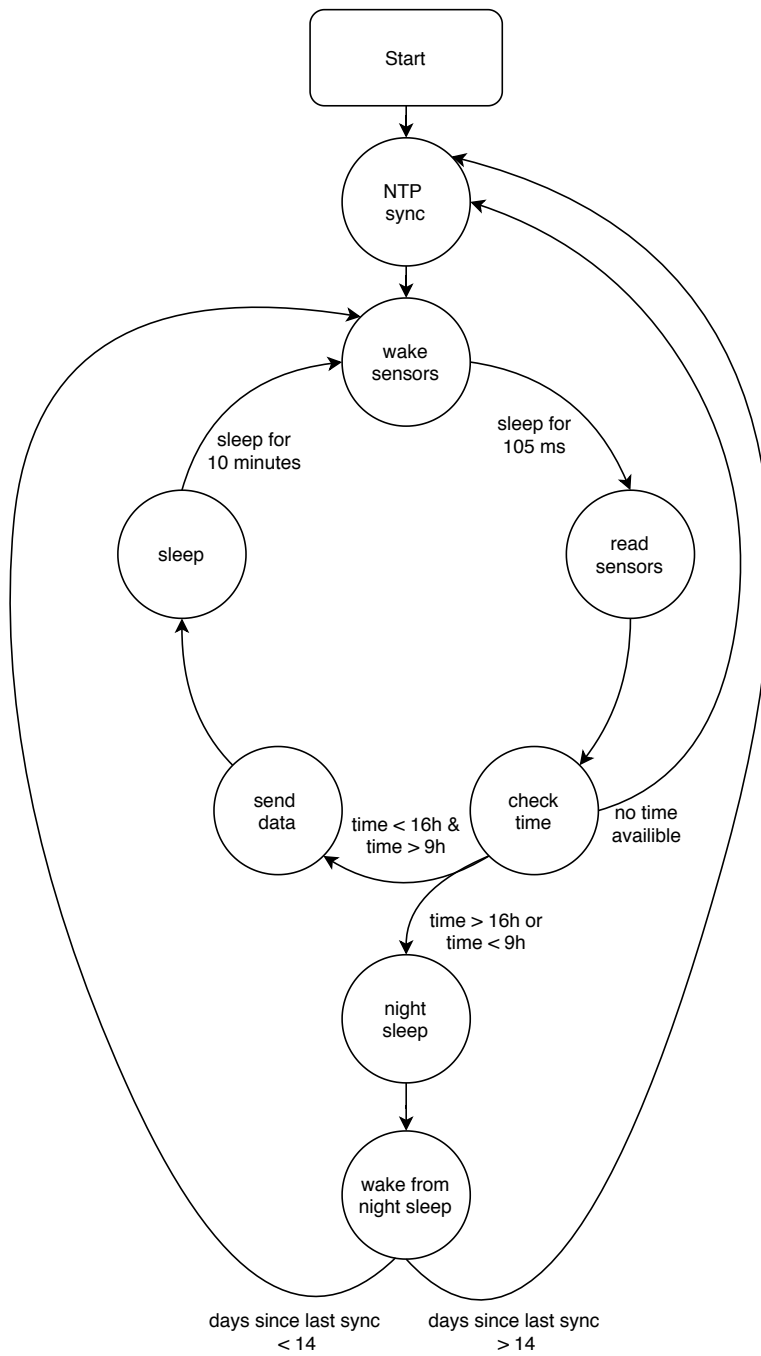
9 Software design

todo

Figure 5: State diagram

10   Autonomy

Calculations for lifetime.

11 Website

12 Financial estimate

Kostprijs van het project opstellen.

13 Validation and measurements

Hier moeten we aantonen of dat alles werkt. Of eventuele fouten verklaren.

References

[1] "Wat je moet weten over lithium ion accu's," https://www.ledscherp.nl/blog/blog/wat-je-moet-weten-over-lithium-ion-accus.

[2] "Li-po vs li-ion battery,what are the difference between them?" https://www.ovonicshop.com/blogs/how-to/li-po-vs-li-ion-battery-what-are-the-difference-between-them.

[3] Wikipedia, "Lithium-ion battery," https://en.wikipedia.org/wiki/Lithium-ion_battery.

[4] ——, "Lithium polymer battery," https://en.wikipedia.org/wiki/Lithium_polymer_battery.