HappyCow: A Modern, Conscientious Solution to Cow Agriculture

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Abstract

One of the biggest concerns in the agriculture industry is the lack of transparency behind the treatment and living conditions of livestock prior to the sale of their products. Utilizing sensors and a programmable microchip, we can employ technology to monitor the well-being of cows throughout their lifetime for the sake of farmers and consumers. Storing said data gives insight to both market audiences on the quality of life, and hence the quality of product, of items such as milk or beef. Moreover, constant supervision gives an opportunity to foresee critical conditions and plan accordingly, further optimizing the agriculture process.

1 Project Description

For our capstone project, we devised, designed, and built a wearable cow sensor that monitors key data such as **movement, sunlight exposure, and ambient temperature**. The express purpose of this all-in-one collar piece is twofold: it allows farmers to keep track of a large herd especially in critical situations, and gives grocery shoppers the ease of mind that their produce comes from cattle with an excellent quality of life.

There is a multitude of products and national certifications that approve the quality of livestock produce. However, the standard they indicate does not confidently indicate good ethical practices. A journal article published by Meuwissen, Velthuis, et al. [1] on agriculture and business helps to tackle this issue while discussing economic impacts of the certification business. One of the claims made is that certifications are made 'too broad' as a result of lowering cost and is simply based on whether a party has the right machinery for ethical agriculture [1, p. 6].

HappyCow, our product, aggressively provides more verbose information regarding animal treatment and quality of life. Because our product records daily from its sensors, and displays them on a user-friendly website, we give consumers the ease of mind that their food was monitored on a more intricate level.

1.1 Design and Dimensions

The design of our project went through several milestones and prototypes. **Figure** 1 below shows the schematic for our device. It features a central PSoC chip, two auxiliary sensors, and items for powering and charging the device. The corresponding PCB design, which was fabricated and soldered, is shown below too in **Figure** 2.

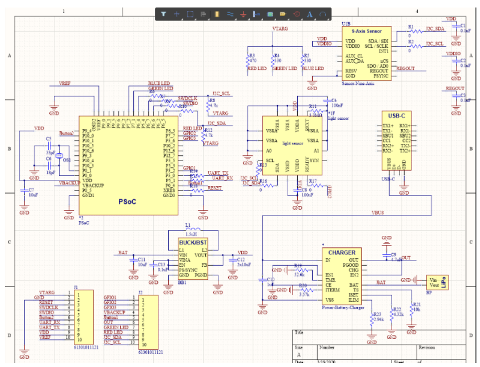

Figure 1: HappyCow Final Schematic

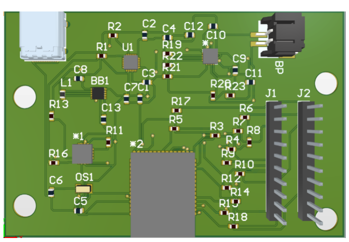

Figure 2: HappyCow Board PCB

The final dimensions of the PCB are 5x4cm. It has a small form factor making it suitable for numerous environments and unintrusive for the cows wearing it.

1.2 Mechanical Design

To complete the hardware and design stage of the HappyCow board, we also designed and 3D-printed an enclosure. This mechanical design was adapted to fit our PCB board shown above. It has the additional feature of being a translucent plastic cover, meaning the sunlight could permeate through the casing into the light sensor without allowing any dirt or water damaging the board. **Figure** 3 below shows the CAD drawing of our mechanical 3D-enclosure with the PCB shown mounted inside.

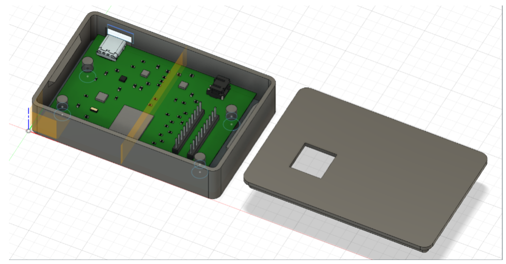

Figure 3: Mechanical Design 3D Model

2 Sensors

HappyCow is designed to collect data pertinent to cows' **overall physical health**. The main points of interest are daily exercise/movement, sleeping patterns, and sun exposure. This section breaks down the two on-board sensors and provides an in-depth analysis of both.

For both sensors, we make use of the I^2C communication protocol to read and write between the central microchip and the two sensors in a master-slave (respectively) configuration. In its fundamental sensor-reading state mode, our product continuously writes data to request measurements and then reads it from the sensors, one at a time.

2.1 Accelerometer

For movement and activity tracking, we use a two-in-one 9-axis gyroscope and accelerometer. Specifically, we use the `ICM-20948`. It specializes in being low-powered and programmable interrupts. On top of that, we also had experience using it in a previous quarter, making it an easy choice. A block view of the chip is shown below in **Figure** 4.

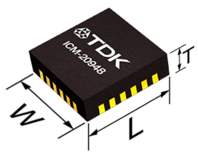

Figure 4: ICM-20948 9-Axis Sensor

We read two kinds of data from this sensor: the gyroscope shows the cow's positioning (used for sleep recognition), and the accelerometer tracks how the cow walks/roams.

2.2 Light and Temperature

We use the `AS73211` True Color sensor as a light sensor. We chose this specific light sensor because it has more than one mode for data acquisition: continuous mode for coherent measurements, and command mode for one at a time. Moreover, it doubles as a temperature sensor, which is useful. The sensor chip is shown in **Figure** 5 below.

Figure 5: AS73211 Sensor Chip

We plan on utilizing its multi-mode design to our advantage in order to make the power consumption more efficient. For example, in the product's normal *sensor mode*, we would need to continuously take measurements. Whereas, when the cow is sleeping, we want to take measurements on demand every hour or so. A visual presentation of the data acquisition cycle is show below in **Figure** 6. Reducing consumption in critical points will increase the lifespan of the HappyCow.

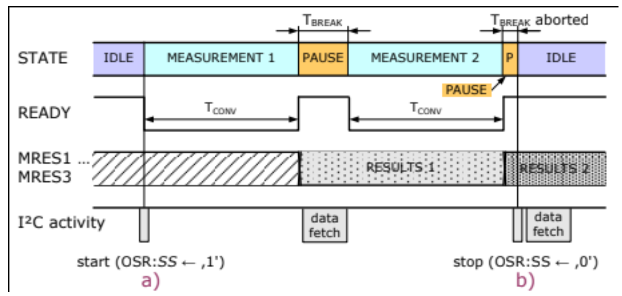

Figure 6: Measurement Sequence in CONT Mode

3 System Design

One of our goals is to have an affordable and sustainable business model while using industry standard technology. This section details the calculations and design choices made while also explaining how these choices benefit our bottom line and our target audience's needs.

3.1 Power Analysis

Arguably the biggest challenge and concern is the power consumption of the entire system. Much of our hardware and firmware structures are based on power and efficiency.

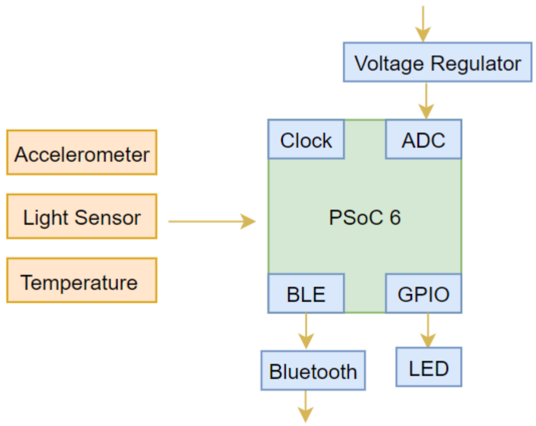

Figure 7: System Signal Diagram

In order to analyze the power in and out of the system, we use an elementary power equation relating the measured voltage and current outputs using oscilloscopes and digital multimeters (DMM).

$$P = IV \tag{1}$$

Figure 7 shows the signals roaming around the system. For power analysis, we connect the input signal from the oscilloscope to the top voltage regulator, and we probe critical areas on the board using the DMM to find power consumption by the sensors.

The overall power consumption of 23mW gives us a comfortable output pattern to deal with, and it meets our design need of having the HappyCow system awake for at least one day at a time before recharging. **Table** 1 shows the detailed power breakdown using **equation** 1.

Component	**Power (mW)**
9-Axis Sensor	5.598
Light Sensor	4.95
PSoC 6	12.54
PSoC Low Power	$2.112mW$
Total	23.1
Total Low Power	2.1417

Table 1: Power Consumption Chart

Below, we show the calculation of the battery life of the HappyCow product. It is important to note the very low power consumption from the PSoC chip. This is the case because most of the time, the device is in Deep Sleep mode conserving a lot of the power and making it more efficient.

$$\begin{aligned}\text{Battery Life} &= \frac{\text{Battery Capacity}}{\text{Load Current}} \\ &= \frac{175mAh}{\frac{2.1417mW}{3.3V}} \\ &= 269.6\,\text{Hours}\end{aligned}$$

3.2 Communication

Communication is key. Efficient communication is even more important. Instead of constantly sending signals in and out of the sensors, we have put as much effort as possible to minimize the amount of communication necessary for maximum verbose information.

Our chip and sensors communicate through the I^{2}C communication protocol – specifically in a master-slave layout. In this case, we have multiple slave sensors under the command of the master PSoC chip. All communication takes place using two wiring schemes, `SCL` clock and `SDA` data. In order to obtain data, we have to first send a signal to one of the registers to request data, and then pulling that sensor data from its respective register.

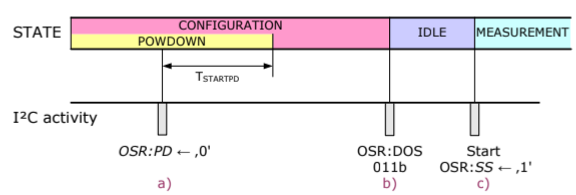

Figure 8: Sample I^{2}C Communication

Figure 8 shows a sample cycle of how we request and obtain data from a sensor after supplying the sampling rate and state mode. **Figure** 6 also shows how it specifically works for *continuous mode* in our light sensor.

Speaking of light sensor, as mentioned before we utilize the many state modes in the sensor to make sure we don't read data redundantly. For example, when the cow is sleeping, we choose to put the system in sleep mode where it won't read data until told to.

4 Firmware

The firmware is the glue that brings together all the hardware components, normalizes their communication, and decides which state the HappyCow system should be in. This section documents the state machine and diagrams related to decision making. The firmware is handled by the PSoC + BLE microchip, and is programmed and debugged using the PSoC Creator software suite.

4.1 System Diagram

The 3 main blocks interfacing with PSoC are grouped logically: The sensors are interfaced with I^2C bus and updates periodically. The software interface is handled when HappyCow is connected to a Bluetooth enabled device. Then we have some tertiary tools like GPIO pins and LED pins for debugging and monitoring.

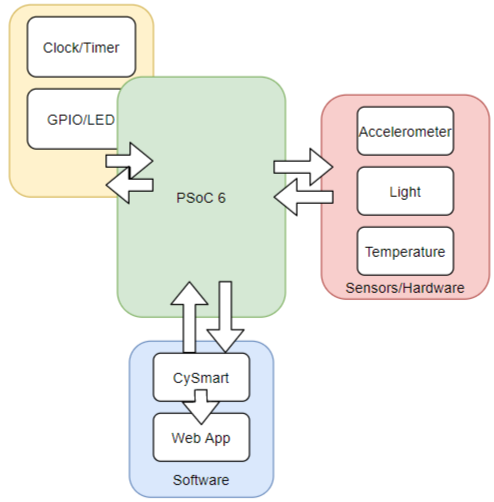

Figure 9: System Block Diagram

4.2 Finite State Machine

The block diagram in **Figure** 9 shows the logical connection between all hardware components. In order to know when and how to communicate with each module, we need a State Machine (FSF) to decide what to do.

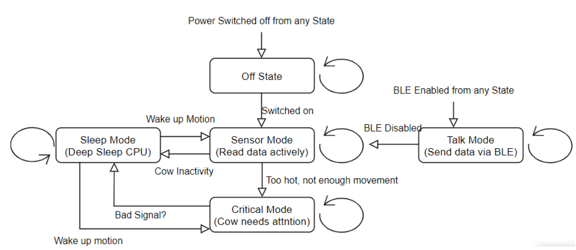

Figure 10: Finite State Machine

We have 5 main states that transition. Off mode is when the system is physically switched off. Sensor mode is the most familiar, where we continuously read data from the sensors. Sleep mode activates when the cow hasn't moved for long enough time. Critical mode is the alert state that turns on when the cow needs attention (high temperature, no activity). Lastly, talk mode activates upon Bluetooth connection; this mode stops the sensors and sends the logged data to the connected device. **Figure** 10 shows the visual scheme as well as transition prerequisites.

5 Mobile/Web Interface

As mentioned earlier, we above, we have a talk mode where the HappyCow can send data to a Bluetooth enabled device. In this case, we designed a mobile app that takes that data and uploads it directly to our web server database. From there, you can access the data in a pretty UI online.

We designed the web UI to have two layers. A detailed control room layer where the farmer can check for critical alerts as well as the detailed graph view. A second, simpler layer is there for consumers who are redirected from a barcode (on the packaging). They can see the graph view too and see averages and detailed physical health information.

6 Budget and Pricing

Our budget, consisting of passive resistors/capacitors, PSoC module, sensors, shipping and manufacturing fees, and assembly fees come out to about $68. This is a good starting point for individual units. This can be reduced even more when buying in bulk. The table below shows cost of making 1 board.

Component	**Quantity**	**Cost ($)**
Resistors	11	0.68
Crystal	1	0.187
Capacitors	12	0.062
Inductors	1	0.992
ICs	3	22.2
PCB Fab	1	20
3D Enclosure	1	24.28
Total		68.3

Table 2: Bill of Materials

For more insight on the budgeting and marketing of this product, the pie chart in **Figure** 11 shows the cost breakdown analysis to give an idea where and how we spent our budget during the quarter.

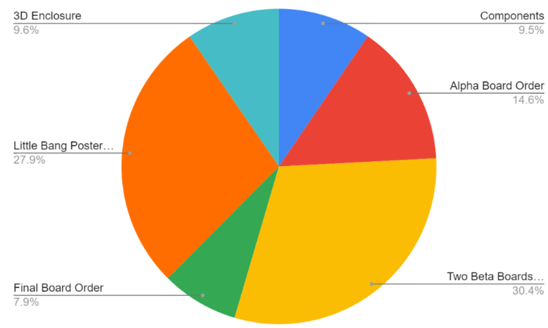

Figure 11: Budget Breakdown Analysis

7 Conclusion

In spirit of UC Davis Aggie Pride, our main design goal is to have a convenient agricultural solution that enforces ethical treatment of animals, as well as providing a maturing and conscientious generation more transparency into the process that gives them their dinner. Being affordable, reusable, and unintrusive are all qualities we believe HappyCow to possess that can help it propel in the market.

References

[1] Miranda P.M. Meuwissen et al. "TRACEABILITY AND CERTIFICATION IN MEAT SUPPLY CHAINS". In: *Journal of Agribusiness* 345-2016-15217 (2003), p. 15. DOI: 10.22004/ag.econ.14666. URL: http://ageconsearch.umn.edu/record/14666.