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Livestock Temperature Monitor

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1 Introduction

1.1 OBJECTIVE AND BACKGROUND

Current methods of diagnosing sick animals are insufficient. The process is largely manual. According to the Wall Street Journal, “To monitor cattle health, feedlots typically rely on cowboys to ride through pens, watching for lethargic animals that are having trouble breathing.”[1] Because the process is labor intensive and the symptoms identifiable show up days after the onset of disease, the livestock industry suffers from a great deal of both false positive and false negative sickness. This results in a great deal of animal death, over medication of animals, unnecessary vet visits, and unnecessary loss of organic certification. This problem costs the cattle industry over 2 billion dollars in losses annually. As of 2016, there are about 92.0 million heads of cattle in the United States.[2] Of these cows, digestive and respiratory illness, mastitis, and other diseases kill approximately 1.5 million of them.[3]

We aim to fix these problems by creating a cow tag that will constantly measure the temperature of the animal and send it back to a receiver. The receiver would alert the farmer of animals that are running fevers. This solution leads to less labor intensive, more accurate, and earlier diagnosis of sick animals. Because of the amount of money farmers lose to this problem, a working solution would be easily marketable -- buying our product would literally save them money.

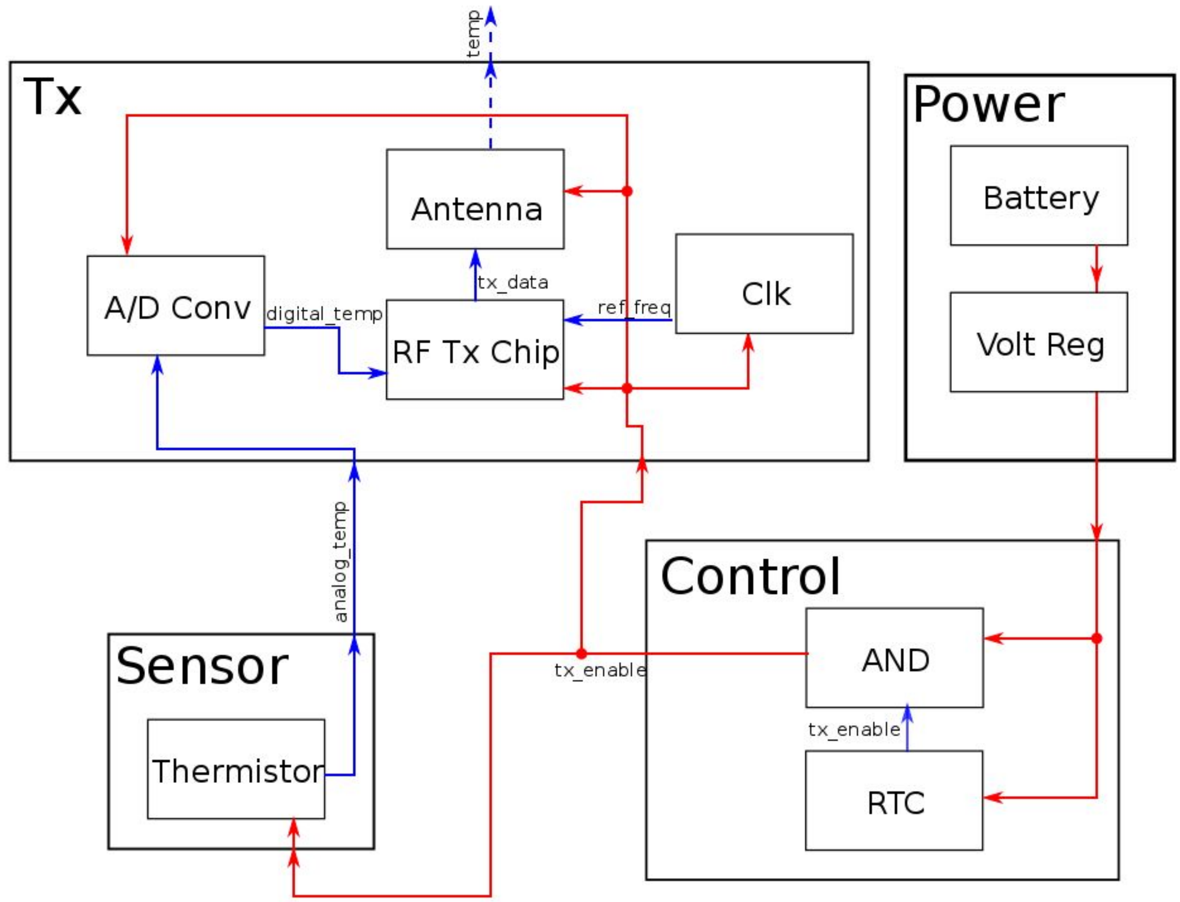
1.2 HIGH LEVEL REQUIREMENTS

- Units must be durable enough and have a battery life long enough for the unit to last the entire lifespan of a beef cow (about 18 months).
- Units must transmit temperatures frequently enough and with high enough resolution to detect a cow’s fever within 12 hours.
- Units must be as low cost as possible, ideally less than $10.

2 DESIGN

Block Diagram

The block diagram is separated into four subsystems. Blue arrows indicate where information is exchanged and red arrows indicate the flow of power.



Block Descriptions

2.1 Sensor Unit

- The sensor allows measurement of the livestock's body temperature and sends that information to the control unit. The sensor is just a thermistor in this design.

  2.1.1 Thermistor

  - This is just a thermistor designed to measure the temperature of the livestock. The resistor takes in power from the control unit and then outputs that power to the control unit again. Because the resistance varies with temperature we can measure the incoming current. Since we know the voltage already, we can send the current readings to the receiver unit's microprocessor, which can then calculate the resistance of the thermistor. The microprocessor in the receiver unit can then utilize a database to find the temperature from the resistance.

- Requirement 1: Must be able to function within 0.1 degree kelvin of accuracy for 2 years.

2.1.2 Current Reader

- The current monitor chip can read the incoming current from the thermistor so that the temperature of the livestock can be calculated later. The chip receives power from the control unit and thermistor separately, and will then output its readings to the control unit.
- Requirement 1: Must be able to read the current within 3% accuracy in a maximum of 500ms.

2.2 Control Unit

- The control logic is all done in hardware with logic gate chips and a low power RTC in order to have optimal power efficiency. It keeps track of time so that it knows when to power up the other components, and also controls how long the power and data is being sent to the other components. It contains a RTC chip, and logic gates.

2.2.1 Low Power RTC [4]

- The RTC chip provides accurate time tracking capabilities while keeping power consumption to a minimum. The RTC chip will be kept to a 1 Hz clock cycle which means that it needs to count to 1 * 60 seconds / minute * 10 = 600 in order to keep track of 10 minute intervals.
- Requirement 1: Be able to be set on a 1 Hz clock cycle.
- Requirement 2: Counter must have at least 10 bits to count up to 10 minutes.

2.3 Transmitter Unit

- This unit is in charge of signal processing and transmitting for the ear tag transmitter. It takes the thermistor reading passed by the control unit, processes it, and send it out as digital data via the antenna. For transmitted data, the tag number of the livestock as well as the current temperature reading must be transmitted. Livestock tag numbers range from three to four digit numbers [5], so there needs to be 14 bits of information for the tag number. For the temperature, the IEEE Single Precision format will be used to send the current readings, which is 32 bits. Therefore, for the complete signal, there needs to be 46 bits of information. We will also send the signal three times per transmission cycle to prevent errors.

2.3.1 Analog to Digital Converter

- This chip is in charge of transforming the analog current readings it receives from the control unit into a digital signal that it passes to the RF transmitter. This chip is only on for around a second and its power supply is controlled by the control unit.
- Requirements 1: Must convert at least 138 bits accurately per second.

2.3.2 RF Transmitter

- This chip is in charge of altering the signal to be ready for transmission. It takes the signal from the analog to digital converter, and after it is done processing it sends the altered signal to the antenna. This chip also has its power supply restricted by the control unit.
- Requirements 1: Must be able to process at least 138 bits per second.

2.3.3 Antenna

- The antenna takes the signal from the RF Transmitter chip and broadcasts it. The RF transmitter and Receiver chips both have a range of 300 to 350 MHz so we chose to use a 315 MHz antenna with 50 ohms of resistance for transmission. [6]
- Requirements 1: Must be able to transmit at least 138 bits per second at 315 MHz for 50 meters.

2.4 Power Unit

- The power unit provides the necessary power to run all the components of the ear tag transmitter. It is essentially a battery that always powers the control unit but the control unit controls the power supply to the rest of the ear tag transmitter components.

2.4.1 Battery

- This is the battery that provides power for the ear tag transmitter. It provides power to the control unit as well as the clock, and the control unit is in charge of sending power to all the other components of the transmitter.
- Requirements 1: Must have a capacity of at least 1000 mAh to power the ear tag transmitter for at least 2 years.
- Requirements 2: Must have a voltage output of 1.5 - 3 V.

2.5 Receiver Unit

- The receiver unit is in charge of collecting data from all the various ear tag transmitters and process them to be present to the customer. It includes an antenna attached to a RF Receiver chip to receive signals, a Raspberry Pi to process and store the data, and a surge protector connected to a conventional outlet for power.

2.5.1 Surge Protector

- This is the surge protector for the receiver unit. Since the power is being drawn from a wall plug, if there happens to be a current surge this will protect the rest of the receiver unit from being damaged.
- Requirements 1: Must protect the Raspberry Pi from a current surge of 700mA or greater. [7]

2.5.2 Raspberry Pi

- This is the calculating component of the receiver unit. It takes the signal readings from the RF receiver and calculates the temperature that would cause those signals. It can then store the data in its memory and later pass the data on through the built in USB adapter. Using the processed data, we can run a webserver on the Raspberry Pi and also use the Wifi capability to transmit data to a bigger central database if needed. Since the receiver unit is plugged into a wall, this is always on and ready to receive new data.
- Requirements 1: Must be able to calculate and process 55200 bits per second.

2.5.3 RF Receiver

- The RF receiver is always on and ready to receive new data from any of the ear transmitter's RF transmitters. Any data it receives will be sent to the raspberry pi unit for processing. In a 50 meter radius, assuming leaving a circle of space for the cow at the average length of 2.5908,[8] there can be a maximum of 372.5 cows packed together. So there will need to be a need to process around 400 incoming signals of 138 bits per second.
- Requirements 1: Must be able to process 55200 bits per second.

2.5.4 Antenna

- The antenna takes the signal from the RF Transmitter chip and broadcasts it. The transmitter antenna is already set at 315 MHz, so we will use the same one on the receiving end. [6]
- Requirements 1: Must be able to receive at least 138 bits per second at 315 MHz for 50 meters.

Risk Analysis

We believe that the transmission/receiving module poses the greatest risk potential in our Livestock Temperature Monitor. It has the greatest risk potential because it is the most likely to fail and if it fails it will have a big impact on its function. The transmission module is the most complex portion of our design, and, therefore, it has more components, systems, etc. that can fail than any other module. Also, when the transmission module fails it will not transmit the data correctly which jeopardizes the intended function.

To mitigate some of the risks of the transmission module, we will design the system to send multiple messages of the current value every time it is transmitting the data. Another mitigation is to have parity bits within the messages that we can check against for errors.

The tolerances of the transmission module are related to our first and second high level requirements. As for durability and battery, the module should be able to survive any temperature that a cow is expected to survive outdoors, 32-90 degrees Fahrenheit. The module should also be able to survive any forces that a normal livestock tag can survive currently. The battery must not be drained by the module before the required time. As for requirement two, the tag must be within .1 degrees Celsius of the actual temperature, transmit up to 50m and report to the receiver once an hour. Following these tolerances can mitigate the risk of a failing transmission/receiving module.

3 ETHICAL CONSIDERATIONS

Relevant IEEE Ethics Guide Provisions[9]:

[1] to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;

This ethic guideline is important to us because what we are working on is very tightly related to public health. Catching sick cows before they are used for meat or milk produce is an important part of our society.

[3] to be honest and realistic in stating claims or estimates based on available data;

It is important for us to not make any false or inaccurate claims in the design, research and testing that we do for our project. These will only hurt us and other engineers around us.

[6] to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;

This project is aimed at improving all of our technical competence and knowledge to better our understanding of our field.

[7] to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

Throughout our design process we will be asking for honest criticism of our work by peers, TAs and professors. We must be able to accept criticism of our work even if we do not agree. Looking at our project from multiple points of view will help in the growth of our technical and business skills.

[10] to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

During the duration of the design process it is very important for us to assist and support each other in our work. We are here to improve our technical and general engineering skills and we can do that better by working together as a team.

Safety Guidelines:

Though no actual construction occurred, we adhered to strict guidelines. We had all values double checked, verified that all vendors sourced their materials legally, that all planned construction and machine shop work was to be done by certified professionals. On top of this, we repeatedly accepted criticism and implemented changes. All group members contributed equally and were not subject to any form of discrimination including but not limited to on the basis of sex, orientation, age, national orientation, or religion.

IACUC POLICY [10]

- All research, teaching, and outreach activities at the University of Illinois involving vertebrate animals must be approved by the Institutional Animal Care and Use Committee (IACUC) before the activity begins.
- Once the activity begins, any proposed changes must be submitted to the IACUC as a major or minor amendment to the protocol. Changes must be reviewed and approved by the IACUC before they are implemented.
- The approval is for a 3-year period; the IACUC conducts mandatory annual reviews.
- If the approved use of animals is expected to continue beyond three years, a new Proposal for Activities Involving Animals must be submitted to the IACUC, reviewed, and approved before the active protocol expires.

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