Assignment 2
Dew Point Generator Controller and Sensor Data Logger for Climate Modelling of Tropical Plants

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Intro

This report documents the design and implementation of an embedded system developed to serve as both a scientific data logger and a smart interface with an analogue dew point generator. The system utilizes the RP2040 microcontroller and various sensors, including SDI-12 environmental sensors and a load cell, to collect and process data for use in climate modelling applications. The project aims to provide a reliable and efficient solution for monitoring and controlling environmental parameters, particularly in the context of research on tropical plant behaviour under varying climate conditions.

The LI-610 Dew Point Generator is a precision instrument designed to produce a stable stream of gas with a precisely controlled dew point. It uses Peltier thermoelectric coolers to regulate the temperature of water reservoirs, ensuring the air stream is fully saturated with water vapor. This precise control of dew point is critical in environmental research, as it helps prevent condensation inside climate-controlled chambers, which could disrupt experimental conditions and data accuracy.

Accurate and continuous monitoring of environmental parameters is essential for tropical plant research, but traditional data collection methods are labor-intensive and prone to error. Moreover, physical presence in climate-controlled rooms can disturb experimental conditions. Commercial solutions like those from Campbell Scientific are often expensive and use closed-source technology, limiting accessibility and customization options for researchers. This project addresses these limitations by providing an open-source, cost-effective alternative that enables remote monitoring and control of environmental parameters. By integrating various sensors and offering a smart control interface for the dew point generator, the system allows researchers to simulate different climate conditions and monitor plant responses without entering the controlled environment, ensuring data integrity while maintaining flexibility and affordability.

Digital to analogue conversion and PWM Background (only a couple of sentences) Big Q did stuff on this

Overview

The system was designed around the RP2040 microcontroller, acting as the central processing unit for interfacing with a variety of sensors and control devices. The design incorporated the SF-5M sap flow sensor, LT-1T leaf temperature sensor, and MT-603 load cell to measure various environmental parameters. Each of these sensors used different communication protocols, requiring careful consideration of power requirements, signal integrity, and communication compatibility.

Hardware Design

Load Cell and ADC Integration: The MT-603 load cell required an ADC (Analog-to-Digital Converter) for signal conversion, as its output is an analog signal representing weight measurements. One of the RP2040's ADC pins was utilized to convert the load cell's voltage output into a digital signal that the microcontroller could process. This ADC integration allowed for precise scaling and calibration of the load cell to achieve accurate data representation.

SDI-12 Sensors and Communication Interface: The SDI-12 protocol was used because it is the standard communication protocol for the environmental sensors integrated into this system. However, SDI-12 differs from typical UART communication in that its bit values are inverted. To address this, the project leveraged the RP2040's UART capabilities in conjunction with an RS485 transceiver, using only the B line of the differential pair to handle the inverted logic levels. By setting the voltage reference at 2.5V, the design effectively mapped the inverted SDI-12 signals to conventional UART high and low values, allowing reliable sensor communication.

Power Supply and Voltage Regulation: Due to the diversity of communication protocols and components used in the system—such as ADC for the load cell, SDI-12 for sensors, and I2C for the DAC—multiple voltage levels were required on the PCB: 12V, 5V, and 3.3V. Each voltage level was supplied through dedicated regulators to ensure stable power delivery to each module. The careful placement of decoupling capacitors was critical to minimize voltage ripple and noise, ensuring stable operation of the entire system.

Data Logging and Storage: An SD card module was added to the schematic, utilizing the SPI interface as defined in the RP2040 datasheet. This module enabled reliable data storage and allowed easy access to logged data for further analysis.

DAC Integration: The MCP4716 DAC was integrated to provide fine-grained control of the dew point generator. Proper bypass capacitors were placed near the Vdd pin to minimize induced noise and ensure stable operation.

Software Design

Sensor Data Acquisition: Custom drivers were developed for each sensor, adhering to the SDI-12 protocol. Specific issues with the byte framing of the SDI-12 protocol were addressed by using the $uart_set_format()$ function to configure the communication format correctly, allowing the RP2040 to receive the inverted data without additional circuitry.

Data Storage: The FatFs API was integrated to enable read/write operations on the SD card, using the SPI protocol. This allowed for structured data logging and easy retrieval of information.

Control Interface: A software interface for controlling the dew point generator was implemented using the I2C protocol to communicate with the DAC. This interface allowed precise voltage adjustments to the generator, with preliminary tests confirming accurate output predictions based on command inputs.

The careful selection of communication interfaces and voltage levels, along with robust software integration, allowed the system to operate seamlessly and efficiently, providing a reliable solution for monitoring and controlling environmental parameters.

Components

Feel free to move and change the name of this subsection later

As seen in fig. 1 there were lots of blocks

Sensors

SDI-12

we used the `uart_break()` function to send the break signal, and then used the `uart_read_stuff()` function to read the response from the sensor. The response was then parsed to get the data. The timing of the SDI-12 protocol is shown in fig. 2.

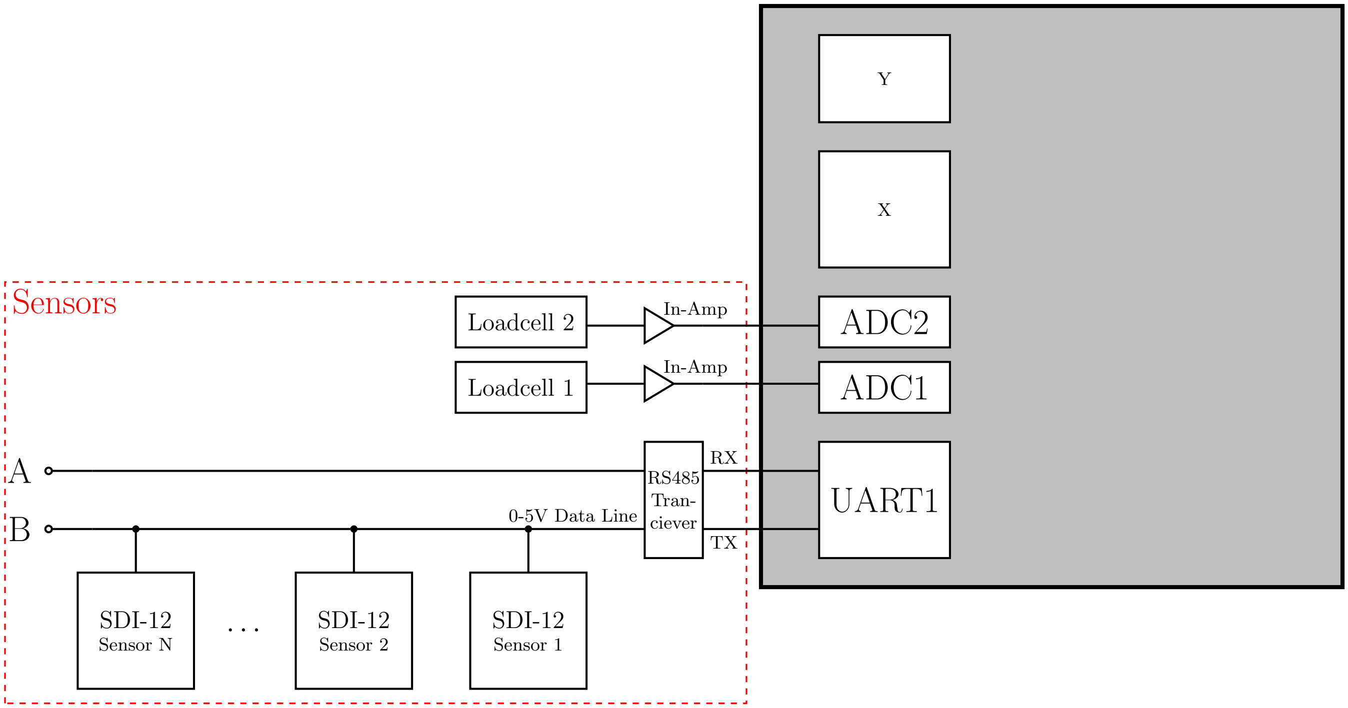

Fig. 1. Block diagram of the system

Load Cell (MT603) analogue signal, therefore requires ADC?

Sap Flow Sensor (SF5) uses SDI-12

Leaf thermistor uses SDI-12

Things to check:

- is 12V necessary?
- should we choose I2C or SPI (or both) as interface between RP2040 and DAC?
- do we want bluetooth or wifi?

- crystal like in assignment 1? - ADC for load cell?

System Design and Technical Approach

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Discussion

We discuss.

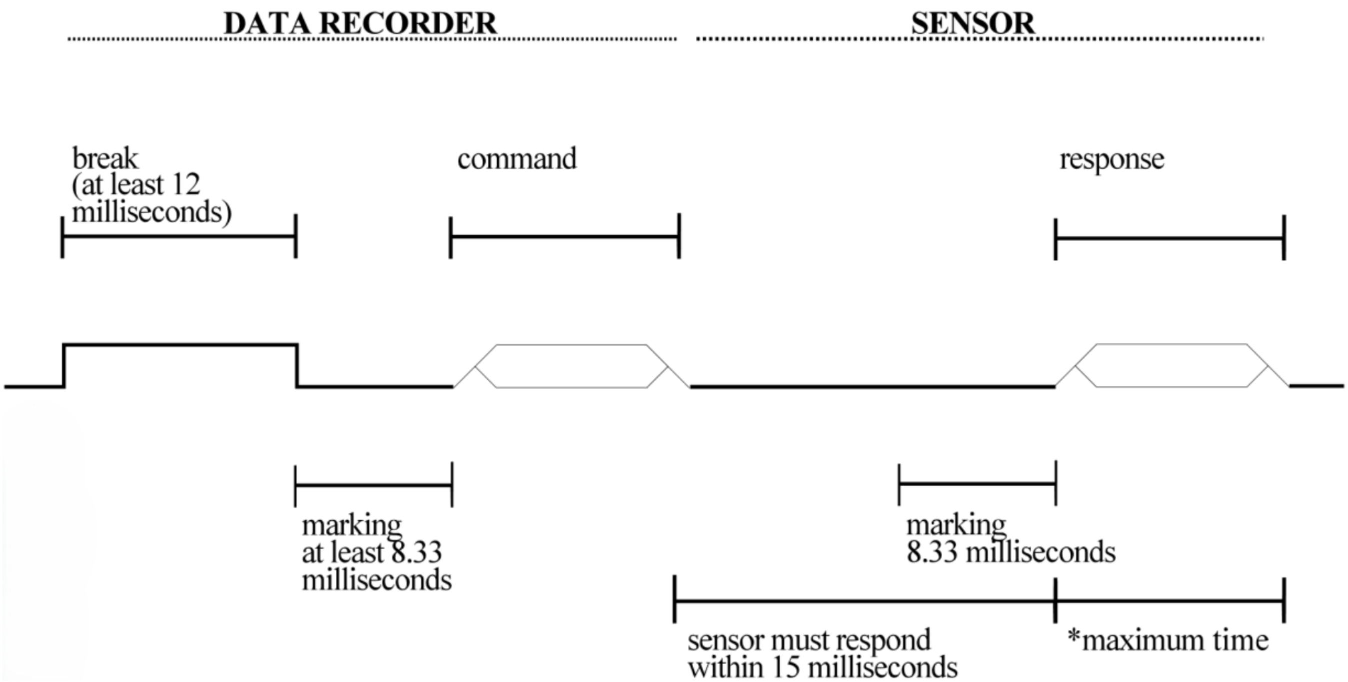

Fig. 2. SDI-12 timing from SDI-12 Support Group (2019)

Conclusion

We conclude.

Appendix

References

SDI-12 Support Group, *SDI-12: A Serial-Digital Interface Standard for Microprocessor-Based Sensors*, SDI-12 Support Group, River Heights, Utah, Jan. 2019, version 1.4. [Online]. Available: http://www.sdi-12.org