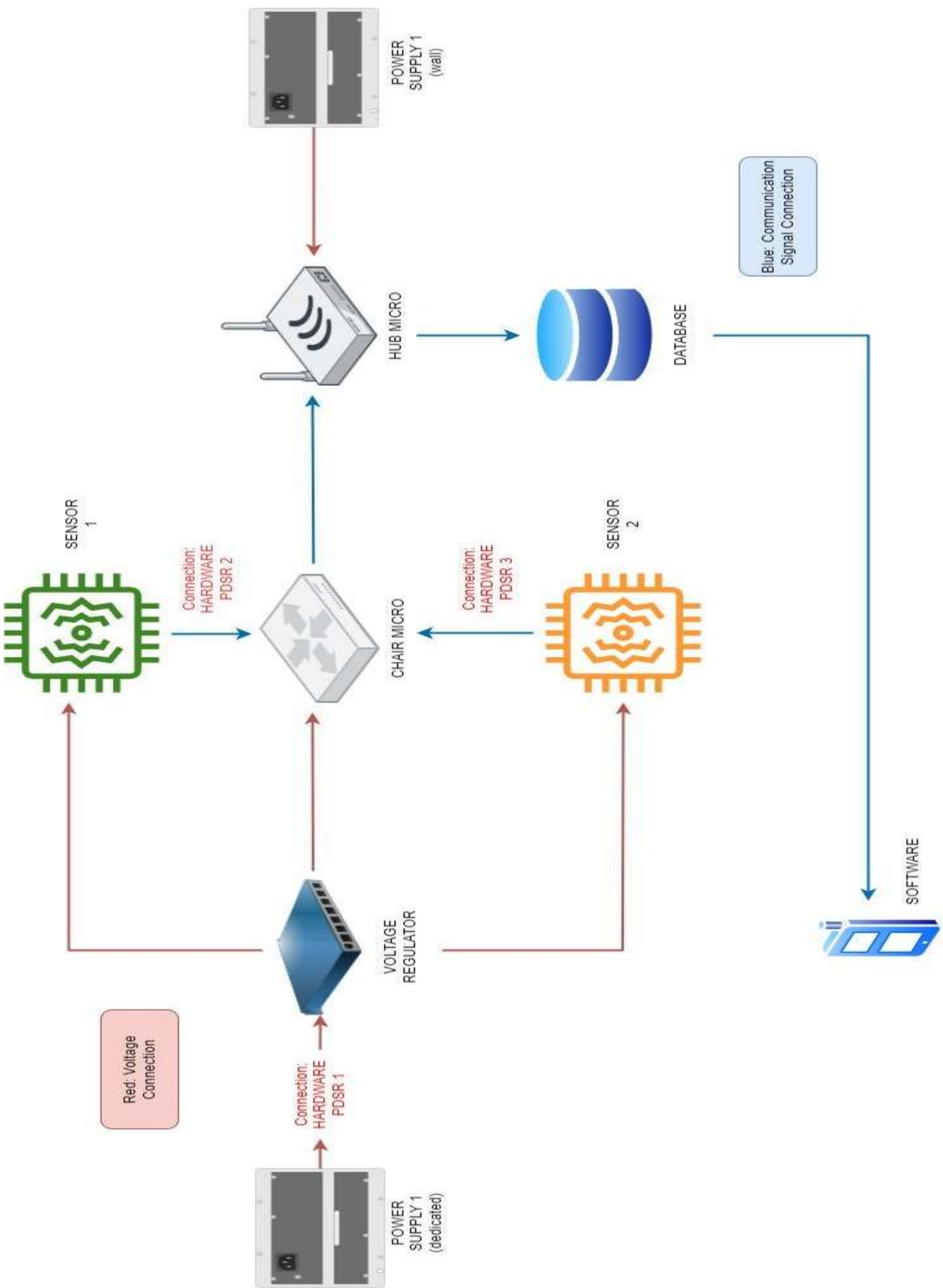
Functional Specification

Year: 2023 Semester: Fall **Team: 8** **Project: Smart Seating System**
Creation Date: **Last Modified:** August 28, 2023
Member1: Roshan Sundar **Email: rmsundar@purdue.edu**
Member2: Giang Nguyen **Email: nguye683@purdue.edu**
Member3: Gabriel Wang **Email: wang4340@purdue.edu**
Member4: Lee Dongeun **Email: ldongeun@purdue.edu**

Assignment Evaluation: See Rubric on Brightspace Assignment

1.0 Functional Description:



Functional Block Diagram (Fig.1)

List of Hardware/Software Components Contribute to System Operation and Functionality (Fig.1):

I. Power Supply:
- The Power Supply (dedicated) serves as the primary source of electrical power for the entire data collection system; consisting of Chair Microcontroller and both sensors. It ensures a stable and reliable source of electricity to keep all components operational.
- The Power Supply (wall) provides electrical power for the Hub Microcontroller solely.

II. Voltage Regulator:
- The Voltage Regulator is responsible for maintaining consistent and safe voltage levels across the system. It prevents voltage fluctuations that could potentially damage sensitive electronic components and ensures the system functions reliably over time.

III. Sensor 1 and Sensor 2:
- These sensors are strategically placed on seats or chairs within the monitored area. They are designed to detect the presence or absence of occupants. Sensor 1 and Sensor 2 are equipped with technology that can sense changes in weight, pressure, or proximity, allowing them to determine if a seat is currently occupied.

IV. Chair Microcontroller:
- The Chair Microcontroller plays a pivotal role in the system. It receives data from Sensor 1 and Sensor 2, interpreting their signals for the later determination of the occupancy status of each seat they monitor. The Chair Microcontroller processes this data and sends it to the Hub Microcontroller. It may also handle tasks such as managing sensor calibration and diagnostics.

V. Hub Microcontroller:
- The Hub Microcontroller serves as the central point for data aggregation and coordination in larger-scale implementations. It collects sensor information from multiple Chair Microcontrollers distributed across the monitored area, and then computes occupancy status for each chair. This centralized hub ensures efficient data handling, reducing the complexity of managing data from various seats. The Hub Microcontroller then forwards this aggregated data to the Database.

VI. Database:
- The Database acts as the long-term storage and retrieval system for occupancy data. It stores information about seat occupancy along with timestamps indicating when changes in occupancy occurred. The Database allows for historical data analysis, generating occupancy reports, and identifying trends over time. It also supports real-time access to the current occupancy status of seats. The Database is typically a secure and scalable solution capable of handling a growing volume of data.

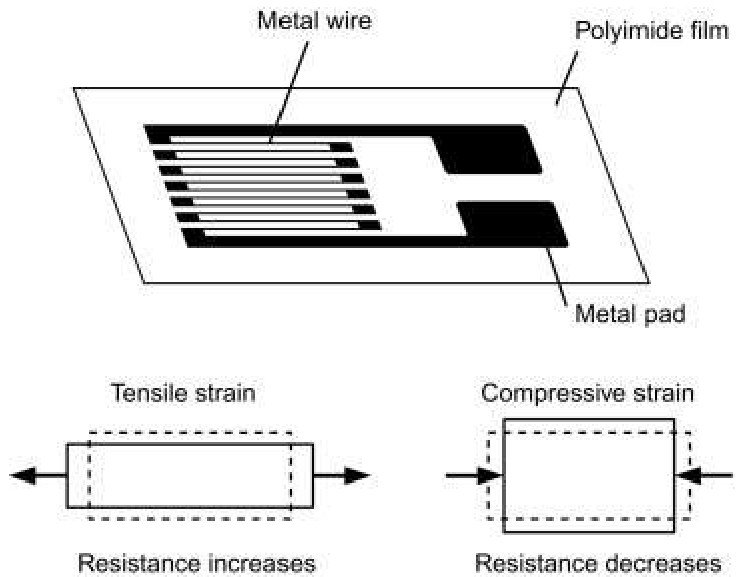
VII. Software for Users:
- The Software for Users provides the interface through which end-users, such as facility managers or individuals looking for available seats, interact with the system. This

user-friendly software retrieves occupancy data from the Database and presents it in an intuitive format. Users can access real-time information about which seats are currently occupied and which are available. They may also receive notifications or alerts based on specific occupancy conditions or preferences.

2.0 Theory of Operation

Note: We are assuming a weight sensor and IR sensor will be used for this system

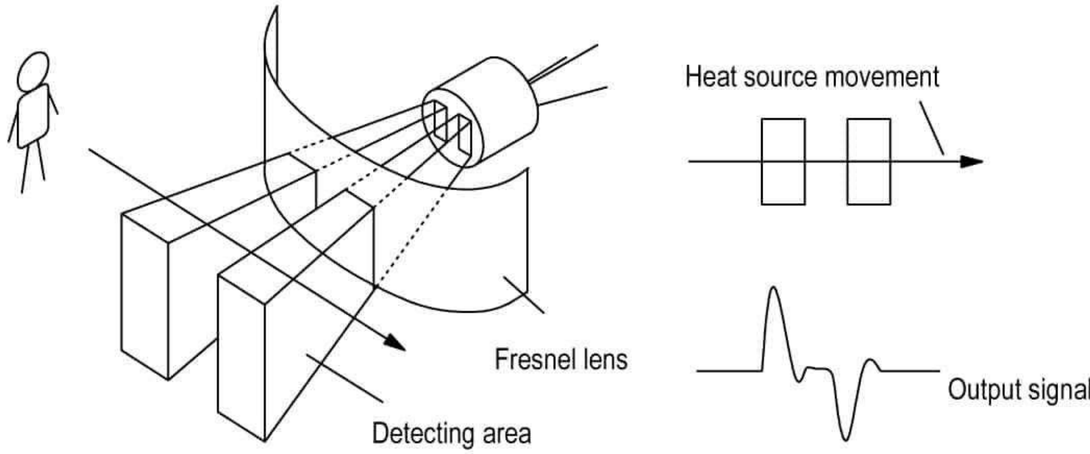
I. The Engineering Principle of Load Sensing [1]:



Strain Gauge (Fig. 2)

- The Load Sensing Principle involves the use of a force sensor, such as a strain gauge, which converts mechanical forces like load, weight, tension, or pressure into an electrical output signal. This transformation is achieved through changes in electrical resistance within the strain gauge as it deforms when subjected to force. The variation in resistance is processed using a Wheatstone Bridge circuit, generating a voltage output proportional to the applied force. This principle is fundamental in accurately measuring forces and is widely used in applications like load cells and weight sensors [1].
- When a person sits on a seat equipped with a weight or pressure sensor, their weight exerts a force on the sensor. This force causes the sensor to deform or compress slightly, leading to a measurable change in its electrical or mechanical properties. What will be obtained are responses from the sensor.
- The Chair Microcontroller, which is connected to this sensor, continuously monitors the sensor's outputs. It measures the changes in resistance or other properties.

II. The Engineering Principle of Infrared Sensing [2]:



PIR for Motion Detection (Fig. 3) [3].

- An IR sensor is an electronic device that emits light to perceive objects in its environment. It possesses the capability to both gauge an object's temperature and discern its motion. Typically, in the infrared spectrum, all objects emit some variant of thermal radiation. These emissions remain invisible to the naked eye, but IR sensors possess the ability to detect them. Unlike most types of infrared sensors, passive infrared sensors do not require their own infrared source and detector [2].
- PIR sensors detect changes in infrared radiation within their field of view. When a person approaches or sits down on a seat, their body emits heat in the form of infrared radiation. The PIR sensor can detect this change in heat signature.
- The output signal from the PIR sensor is integrated into the overall seat occupancy detection system. This data is sent to the Chair Microcontroller, which collects information from all sensors

3.0 Expected Usage Case

The system will be expected to operate in an air-conditioned, indoor, and dry area. The system will be largely stationary but some chairs may move. However, this will not add significant stress to the control units and sensors mounted on the chairs. The most physical stress it may endure is a chair falling over, or a potential liquid spill, which is more of a concern for the packaging and how the control units and sensors are mounted.

There will be two types of users for our system.

The first is the general public, the people who visit the spaces where the smart seating system will be installed (educational, restaurant, etc). They may be from any background, but the only characteristics of concern for this system is if they are able to operate a phone app. We assume that the people who visit these spaces have access to a phone and know how to use it, as most do these days. There may be an additional concern if a person is bringing a heavy object along and putting it in a chair, such as a backpack. Depending on the sensors we choose, it may not distinguish between a backpack and a person, such as with a force resistive sensor or a IR distance sensor.

The second category of user will be a system administrator of some kind, such as IT, whose responsibility would be to maintain the system. We expect this user to have greater technical knowledge compared to the average person, but nowhere near the amount of knowledge required to actually engineer the system. The administrator will need to be able to understand the setup process for the system, which will likely involve some networking, setting up bluetooth connections, changing battery + restarting a control unit, etc. Therefore, we would want the setup and maintenance of the system to be as simple as possible. However, it does not need to be so simple that a member of the general public could install and maintain the system.

4.0 Design Constraints

4.1 Computational Constraints

The processor does not need to be doing any complex calculations or mathematics, since the occupancy determination calculations will be done on the web server. There is some necessity for static memory on the Control Unit, since we want the system to store certain parameters such as server data (IP/MAC), and other parameters such as a unit ID. However, this storage does not need to be extensive, as only a few values will be stored. The processor does not have to be very quick, but it must be able to handle data transfer quickly, to send the most up-to-date sensor data through the wireless module.

4.2 Electronics Constraints

Major Components [Control Unit]	Interfaces and Constraints
Microcontroller	Interfaces to micro detailed below
Wireless (Bluetooth, WIFI, RF)	The wireless module will need to interface to the Micro. (May end up utilizing something that has wireless capabilities built-in like ESP32, in which case the interface is moot). The protocol/interface utilized will be different depending on the module. SPP may be used if bluetooth is chosen. UART may be used if WIFI is chosen.
Static Memory	The static memory module will need to interface with the Micro. The choice of what to use for static memory will greatly affect the interface. For example, if it’s an SD card, a ton of peripheral components would be

	necessary for the interface. If it is a simple EEPROM the interface may use I2C with some supporting resistors and capacitors for protection.
Sensors	The two sensors used will need to interface with the micro. Again, which sensors are used will affect the choice of interface. Most simple sensors like IR will use I2C. For more complicated sensors like RFID, UART may be used
Battery	The battery needs to interface with all the aforementioned systems, as they all require some power. The interface will likely consist of a power and voltage regulator that efficiently distributes power to all the components. It may also have an interface to the Micro in order to shut off power for specific components that are not being used, which could involve some transistor-based interface.

4.3 Thermal/Power Constraints

Our power system will need to be robust as it will have a power supply that will not be constantly monitored physically. This system will require a battery monitoring system that will perform certain functions after a certain time has passed. A feature that can be included is an auto-sleep feature that turns the system off after periods of inactivity. All sensors will need to be deactivated to save as much power as possible. The target battery life should have a minimum battery life of half a day (12 hours) before it would need to be recharged. The target charging time should not be more than an hour. Since our prototype design will include a minimum of three sensors, a predicted 9V alkaline battery should provide the minimum necessary power to our system. In terms of voltage regulation, simple DC buck converter modules that automatically lower voltages when programmed will be used. Our current power design specifications are listed below, which have numbers listed derived from battery data sheets[4].

Supply Voltage	~ 6.0 - 9.0 VDC
Consumption Rate	Sleep Mode: ~0.7µA Discharge: 20mA-30mA Idle/Off mode: < 2mA

Operating Temperature	0°F to 130°F (Alkaline Battery)
Base Resistance	1Ω - 2Ω
Weight	< 3 oz. total
Ambient Battery Temperature Range	50°F to 100°F

4.4 Mechanical Constraints

Constraints ID	Description
Dimensions and Physical Profile	We are looking for the most compact form factor since the system installed on the chair cannot be obtrusive, so that it can be discreetly integrated in various seating arrangements like benches or office furniture. Ideally, the maximum dimension should be 6x6x3 (inches) to also minimize the interference with the user's comfort and experience.
Density and Mass	The system needs to be as lightweight as possible to avoid adding significant mass to the seats. This is especially important for device installation/transport and general mobility when the seats are being occupied.
Container Specifications	Shock-resistant containers are required to ensure sensors and microcontrollers are safely housed and protected. Considerations include designs to safeguard the components from mechanical stress.
Endurance Needs	Both sensors and microcontrollers should be qualified to withstand normal wear and tear associated with daily usage in different environments. The goal is being able to achieve long-term reliability so the requirements should include the resistance to general impact such as the action of sitting down or leaning.
Environmental Considerations	The sensors and chair microcontroller may be exposed to rain, spills or sweat, hence

	weatherproof and waterproof features need to be incorporated to protect the system against moisture damage. The system should also have adequate protection against dust ingress preventing sensors and microcontrollers from being contaminated; and further delaying degradation.
Temperature Tolerance	The sensor units should be designed to operate within a specified temperature range to ensure functionality in both hot and cold environments without adverse effects on accuracy or reliability.
Mounting and Installation	Considerations should be given to the ease of mounting and installation of the sensor units onto seats or chairs. The design should allow for flexible mounting options to accommodate various seat types and materials.
Material Selection	The choice of materials for the sensor housing and components should take into account factors like durability, weight, and resistance to environmental factors.
Accessibility	Accessibility requirements need to be met, ensuring that the system installed on chairs does not obstruct or impede access to seating, especially in public spaces where accessibility regulations may apply.

4.5 Economic Constraints

Making an assumption that the sensors we use will be PIR and Weight, currently there is no commercial product (that we know of) out there that is able to take in a combination of a weight sensor and a PIR sensor which makes it currently difficult to judge our competitor's cost constraints. If we take in weight sensors and a PIR sensor in a PCB as an assumption, our price target should be around $100 (2 PIR sensors and 2 Weight Sensors) for project experimentation purposes, with a +- $20 margin of error. If we just consider the final prototype, the cost is estimated to be around $80 (50Kg load cells x 4, AK9753 x 2, an ESP32 Feather V2, 9 V battery). Also we do have to consider +- $20 for margin of error.

5.0 Sources Cited:

[1] How to measure load? | load measurement sensor | how it works - FUTEK, https://www.futek.com/load-measurement (accessed Sep. 2, 2023).

[2] Macfos, “IR sensor working principle and applications,” Robu.in | Indian Online Store | RC Hobby | Robotics, https://robu.in/ir-sensor-working/ (accessed Sep. 2, 2023).

[3] “Pir motion sensor module¶,” PIR Motion Sensor Module - SunFounder vincent_kit_for_arduino documentation, https://docs.sunfounder.com/projects/vincent-kit/en/latest/components/component_pir_module.html (accessed Sep. 2, 2023).

[4] The Eader in OW-cost, Remote Monitorin Solutions, https://monnit.blob.core.windows.net/site/documents/legacy/sensors/MDS-030-Seat-Sensor-Data-Sheet.pdf (accessed Sep. 2, 2023).