Energy Efficiency Control & Optimization System

Personal Project

[#2]

Adam Michelin
Gothenburg, 2024

Abstract

This project focuses on the design and implementation of an advanced ventilation system for a multifunctional facility in Stockholm, which includes multiple office spaces and a church. The existing ventilation system has led to significant energy costs due to its inability to monitor supply air conditions or manage airflow effectively across various rooms. The new system is designed to integrate with the current setup, either by overlapping or running parallel to it.

The goal is to create a smarter, more controlled ventilation solution that optimises air distribution, reduces energy consumption, and lowers operational costs. By leveraging advanced sensors and control algorithms, the new system will provide precise airflow and ultimately lower the total energy consumption

Currently, this project is in the proof-of-concept phase and has not yet been scaled across the entire facility. Testing is being conducted in a single room (Vitsippan) to evaluate the performance and effectiveness of the new system. All components of the project, including electronics and software, are homemade, ensuring full control over the system's functionality and allowing for future customization.

The results of this initial testing phase will inform the potential expansion of the system to the rest of the facility. management tailored to the unique needs of different spaces within the facility. This will result in improved energy efficiency, a more comfortable indoor environment, and substantial cost savings for the facility's operations

1. Introduction

Vaxthus1 is a facility located in Stockholm, Patron Pehrs väg 3, 141 35 Huddinge, it houses Svensk Fastighetsförmedling, Södertörnkyrkan, a sports hall, and several smaller office spaces.

The facility's energy consumption is significant, with monthly electricity bills equivalent to the annual energy costs of a typical household. Therefore the need to reduce energy demand is a high priority

The current ventilation system worsen this issue due to its lack of room-specific controls, absence of temperature feedback for supply air, and no presence sensors. As a result, the system frequently attempts to cool rooms using supply air that is warmer than the desired room temperature, causing the central fan to operate at full capacity continuously.

I eagerly took on this project because of its direct relevance to my electrical engineering studies at Chalmers. It provided an excellent opportunity to apply and deepen my theoretical knowledge in a practical setting.

Additionally, the hands-on experience was invaluable for enhancing my understanding of the concepts learned in class. Beyond the educational benefits, I found the project genuinely enjoyable, making it both a rewarding and fulfilling experience.

Fig 1. Vaxthus1 main entrance

2. Methodology

This section details the approach taken to design, implement, and test the advanced ventilation system at Vaxthus1.

2.1 Needs Assessment

The first step in the project was to conduct a thorough needs assessment to understand the limitations of the existing ventilation system and the specific requirement of the facility. This involved a detailed overview with the facility managers focusing on consumption patterns and areas of inefficiency.

This led to the findings that the existing lacked room specific controls, temperature feedback mechanisms, and smart presence sensors.

2.2 System Design

Based on the needs assessment, the new ventilation system was designed to address the identified inefficiencies. I set on the idea to have a system controlled “over-the-air” which lets me to trim and update parameters and software without having to travel to stockholm.

The systems needs a central UI that can be accessed by the facility manager that can override the new automated feature for safety.

2.3 Hardware Development

The hardware involved the design and production of custom electronics to control and monitor the ventilation system. This is partly to lower the development cost of the overall system and partly because the needed electronics for the needs assessment is not exactly on the consumer market yet. By creating custom components, we were able to tailor the system precisely to the facility's requirements, ensuring that the sensors, controllers, and communication modules met the unique demands of the project while maintaining cost-effectiveness.

The main components used for the room-unit:

- ESP32 D1 mini microcontroller.
- LD2410C mmWave Human Presence sensor.
- SenseAir aSENSE, Co2 and Temp sensor.
- LM358AN op-amp for motor control.
- Dallas 1-wire ds18b20 temp sensors.
- Belimo Damper Actuator.

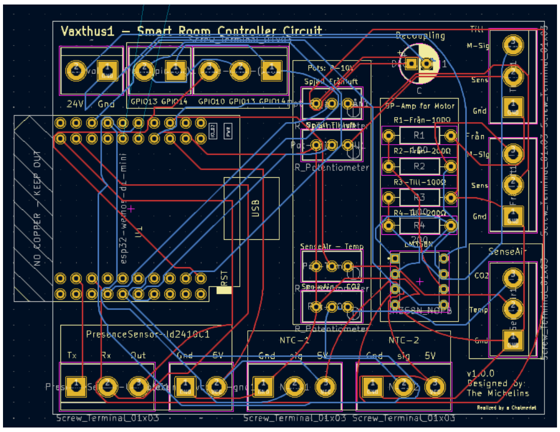


Fig 2, PCB design in KiCad 7.0,

2.4 Software Development

Parallel to the hardware development, the software that would control the ventilation system was developed. This included Control Algorithms, Microcontroller Programming and UI development. To gather data from the sensors connected to the controller units in each room, Home Assistant - an open-source home automation software - was flashed on a Linux-run laptop. This setup allows for seamless integration and real-time data collection from the various sensors.

NodeRed is running on HA (Home Assistant) to program the logic for the different rooms, this makes the project expandable and easy to run.

ZeroTier is also running on HA in which it creates a virtual network so local access can be made anywhere.

3. Discussion

This chapter presents the ongoing test in Vitsippan, future plans, limitations and a general overview of the

3.1 General Overview

Since only one room is installed and active at the moment, more data will be needed to determine the stability and effectiveness of the system. Fig 3 shows a general overview of the connections made for one room.

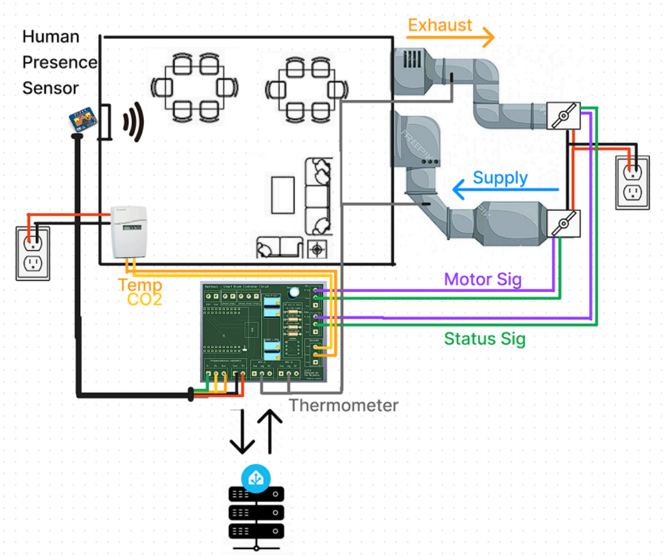


Fig 3, Simple overview of Vitsippans connections

3.2 Limitations

The project focuses on "smartifying" existing rooms that are rarely used to significantly reduce their energy consumption. Rather than opting for expensive electronics like regulators, high-end presence detectors, or PLCs, the goal was to test whether a cost-effective, homemade system could match or exceed the performance of these more expensive solutions.

3.3 Future Plans / Improvements

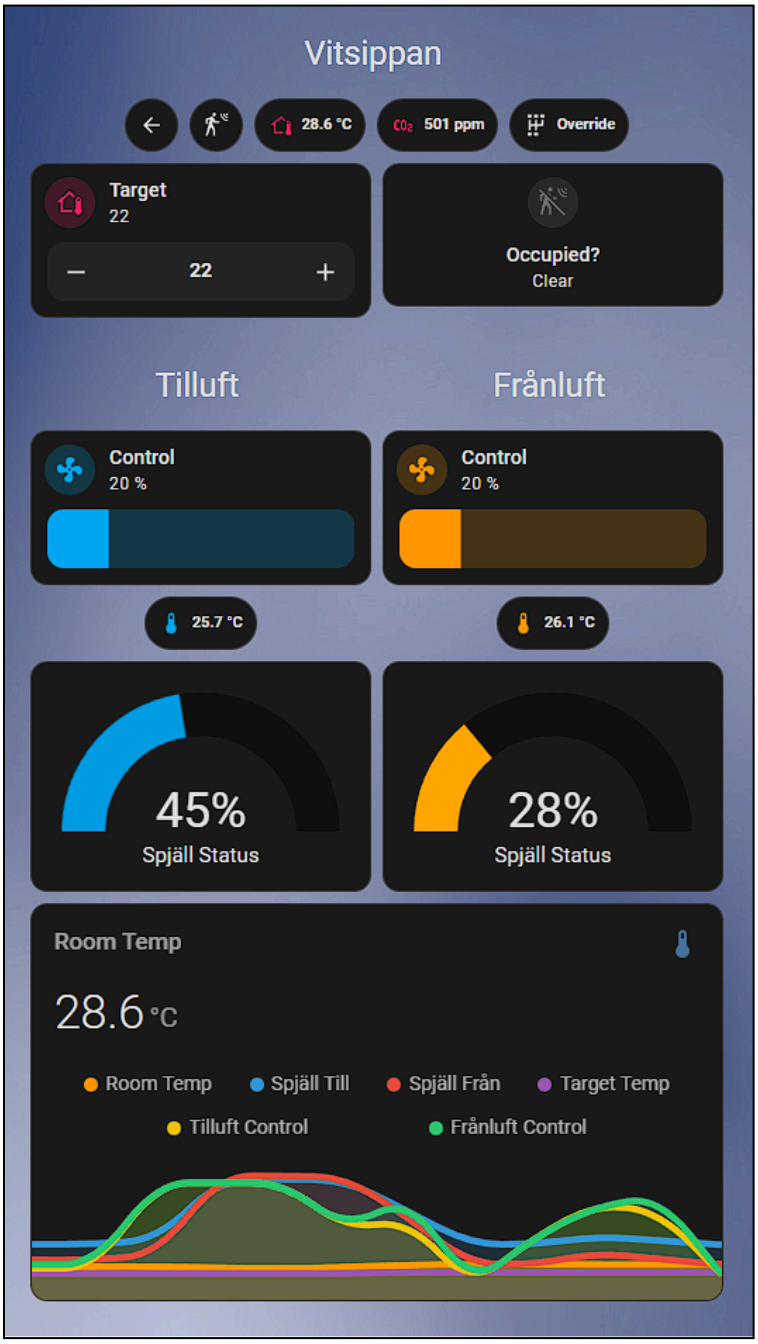
In the near future, the project will extend its scope to include additional rooms within the facility. This expansion will enable the creation of detailed heatmaps and the application of advanced algorithms to optimize air distribution and manage the varying heating and cooling needs of different spaces. By analyzing these heatmaps, the system can more effectively determine the optimal transfer and supply of air, as well as accurately assess the demand distribution across the facility.

One key goal is to implement electronic valves for each heating element, allowing for even more precise control over individual room temperatures. This setup will enable the system to preemptively adjust heating or cooling levels in anticipation of temperature fluctuations or energy price changes. By scheduling these adjustments based on real-time electricity prices, the facility can take advantage of lower rates typically available during off-peak hours, such as nighttime.

This approach could significantly reduce energy costs by leveraging the generally lower electricity prices during these periods. The system will be programmed to "prime" the facility in advance of anticipated heat or cold spikes, ensuring that the building remains comfortable while minimizing energy expenses. Overall, these enhancements are expected to improve both energy efficiency and cost-effectiveness, providing a scalable solution for managing energy use across the entire facility.

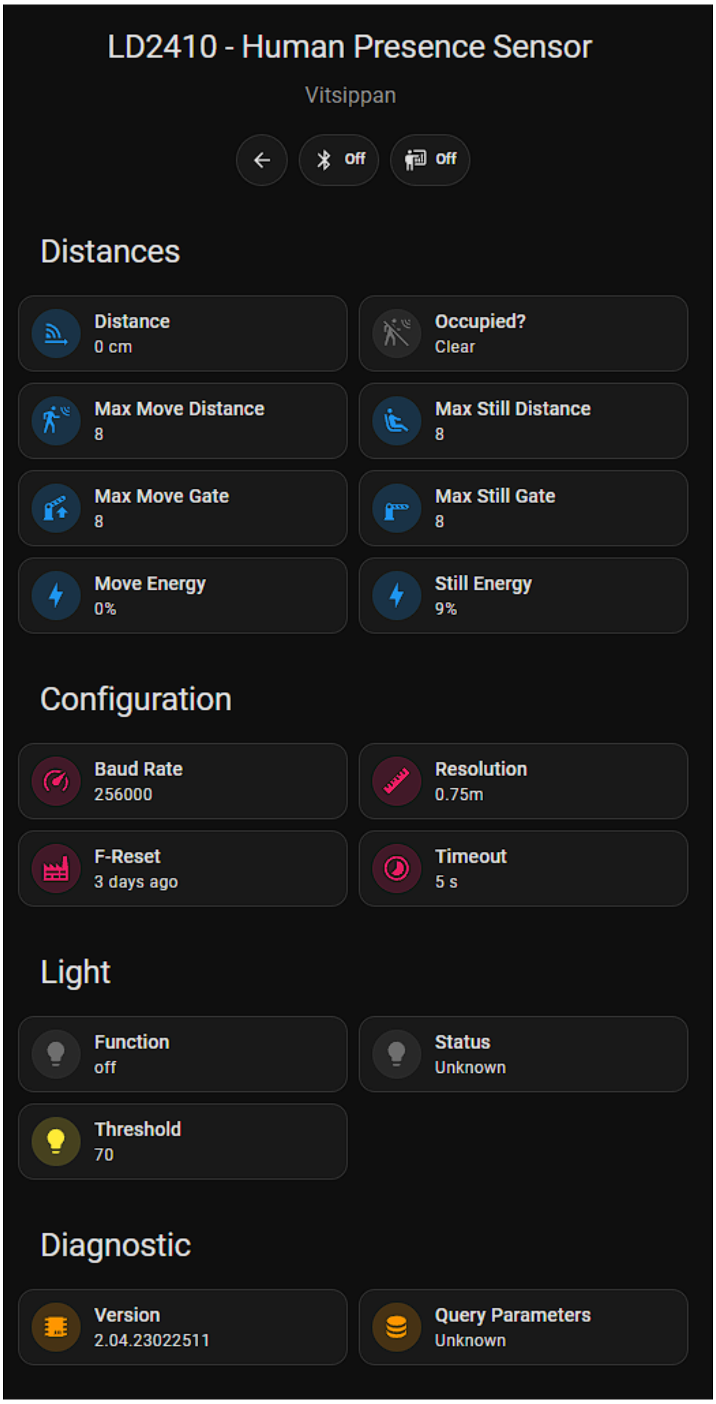
4. Appendix

4.1 Vitsippan UI



UI - Code for Vitsippan (YAML)

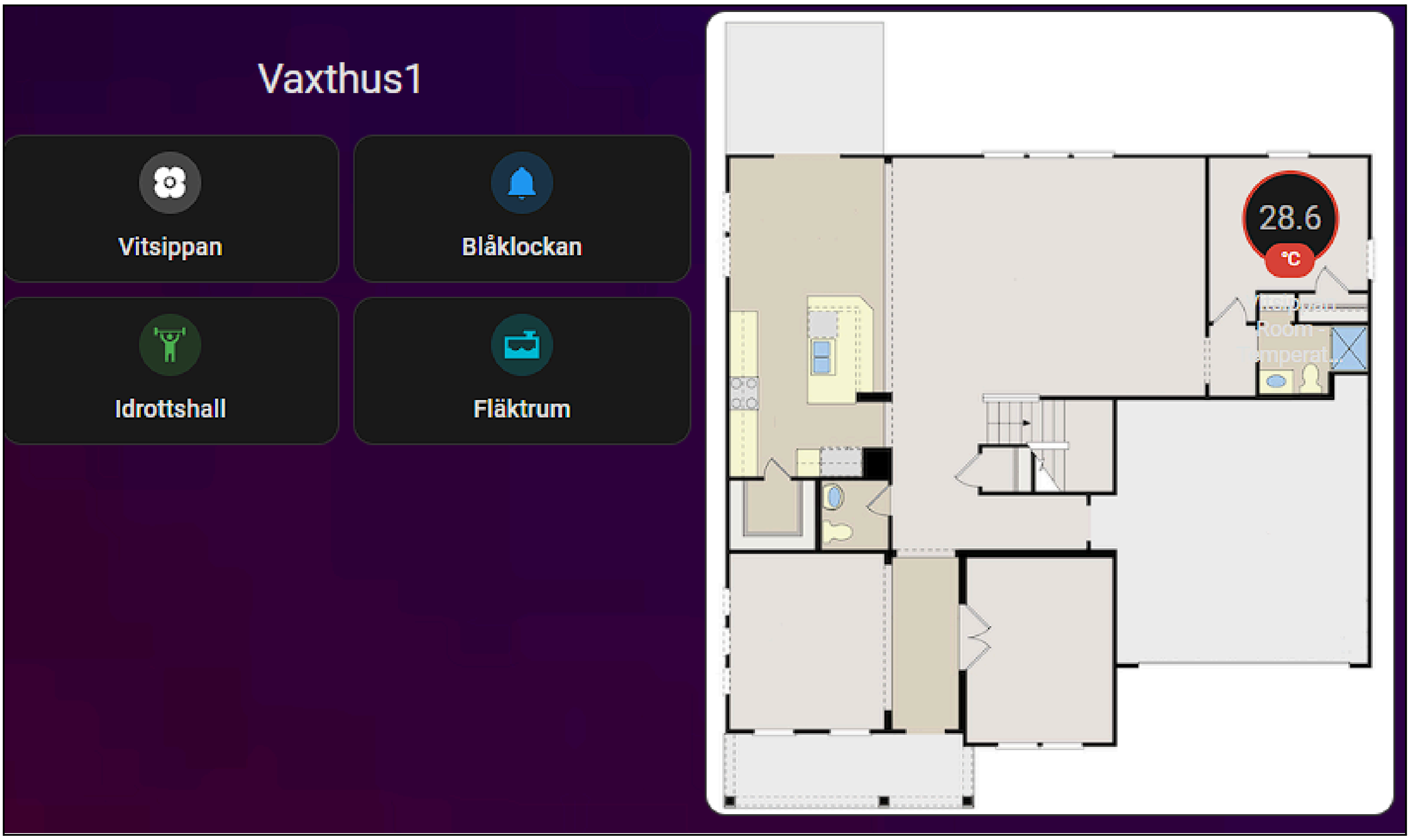
```yaml
square: false
type: grid
cards:
  - type: custom:mushroom-title-card
    title: Vitsippan
    subtitle: ''
    alignment: center
  - type: custom:mushroom-chips-card
    chips:
      - type: back
      - type: action
        tap_action:
          action: navigate
          navigation_path: /dashboard-radar/0
        icon: mdi:motion-sensor
      - type: entity
        entity: sensor.vitsippan_room_temperature
        icon: mdi:home-thermometer-outline
        icon_color: pink
      - type: entity
        entity: sensor.vitsippan_room_co2
        icon: mdi:molecule-co2
        icon_color: pink
      - type: entity
        entity: input_boolean.vitsippan_manual_overide
        icon_color: pink
        name: Override
        icon: mdi:car-shift-pattern
        content_info: name
    alignment: center
  - square: false
    type: grid
    cards:
      - type: custom:mushroom-number-card
        name: Target
        icon: mdi:home-thermometer-outline
        icon_color: pink
        display_mode: buttons
        entity: input_number.vitsippan_target_temp
      - type: vertical-stack
        cards:
          - type: custom:mushroom-entity-card
            entity: binary_sensor.vitsippan_occupied
            name: Occupied?
            icon_color: red
            fill_container: false
            layout: vertical
    columns: 2
  - square: false
    type: grid
    cards:
      - type: vertical-stack
        cards:
          - type: custom:mushroom-title-card
            title: Tilluft
            alignment: center
            subtitle: ''
          - type: custom:mushroom-number-card
            entity: number.vitsippan_spj_ll_tilluft
            icon: mdi:fan
            icon_color: primary
            fill_container: false
            primary_info: name
            display_mode: slider
            name: Control
          - type: custom:mushroom-chips-card
            chips:
              - type: entity
                entity: sensor.vitsippan_temperature_tilluft
                icon: mdi:thermometer
                icon_color: primary
                name: Temp
                content_info: state
                use_entity_picture: false
            alignment: center
          - type: gauge
            entity: sensor.vitsippan_sensor_spj_ll_tilluft
            unit: '%'
            name: Spjäll Status
      - type: vertical-stack
        cards:
          - type: custom:mushroom-title-card
            title: Frånluft
            alignment: center
            subtitle: ''
          - type: custom:mushroom-number-card
            entity: number.vitsippan_spj_ll_fr_nluft
            icon: mdi:fan
            icon_color: accent
            fill_container: false
            primary_info: name
            display_mode: slider
            name: ' Control'
          - type: custom:mushroom-chips-card
            chips:
              - type: entity
                entity: sensor.vitsippan_temperature_fr_nluft
                icon: mdi:thermometer
                icon_color: accent
                name: Temp
                content_info: state
                use_entity_picture: false
            alignment: center
          - type: gauge
            entity: sensor.vitsippan_sensor_spj_ll_fr_nluft
            theme: Mushroom Shadow
            unit: '%'
            name: Spjäll Status
            severity:
              green: 0
              yellow: 0
              red: 110
    columns: 2
  - type: custom:mini-graph-card
    entities:
      - entity: sensor.vitsippan_room_temperature
        name: Room Temp
      - entity: sensor.vitsippan_sensor_spj_ll_tilluft
        name: Spjäll Till
      - entity: sensor.vitsippan_sensor_spj_ll_fr_nluft
        name: Spjäll Från
      - entity: input_number.vitsippan_target_temp
        name: Target Temp
      - entity: number.vitsippan_spj_ll_tilluft
        name: Tilluft Control
      - entity: number.vitsippan_spj_ll_fr_nluft
        name: Frånluft Control
    hours_to_show: 12
    points_per_hour: 1
columns: 1
```



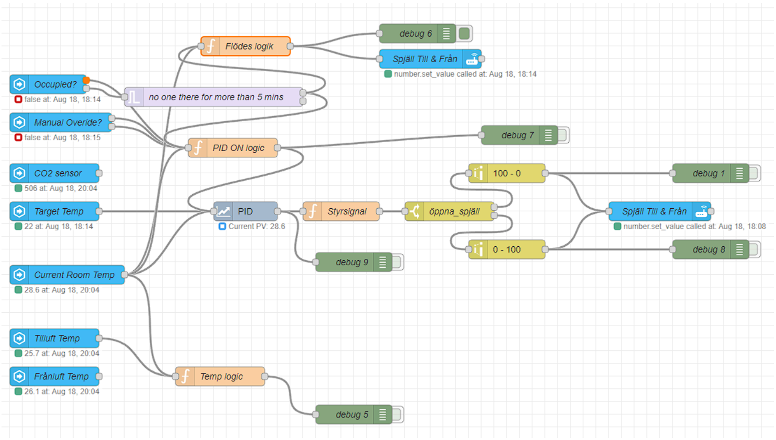
Human Precense Sensor - Parameters UI - Code (YAML)

```yaml
square: false
type: grid
cards:
  - type: custom:mushroom-title-card
    title: LD2410 - Human Presence Sensor
    alignment: center
    subtitle: Vitsippan
  - type: horizontal-stack
    cards:
      - type: custom:mushroom-chips-card
        chips:
          - type: back
          - type: entity
            entity: switch.vitsippan_control_bluetooth
            name: Bluetooth
            icon_color: primary
          - type: entity
            entity: switch.vitsippan_engineering_mode
            icon_color: yellow
            icon: mdi:human-male-board-poll
            name: Engineering Mode
        alignment: center
  - square: false
    type: grid
    cards:
      - type: custom:mushroom-entity-card
        entity: sensor.vitsippan_detection_distance
        name: Distance
        icon: mdi:signal-distance-variant
      - type: custom:mushroom-entity-card
        entity: binary_sensor.vitsippan_occupied
        name: Occupied?
      - type: custom:mushroom-entity-card
        entity: number.vitsippan_max_move_distance_gate
        name: Max Move Distance
      - type: custom:mushroom-entity-card
        entity: number.vitsippan_max_still_distance_gate
        name: Max Still Distance
        icon: mdi:seat-recline-extra
      - type: custom:mushroom-entity-card
        entity: number.vitsippan_max_move_distance_gate
        name: Max Move Gate
        icon: mdi:boom-gate-arrow-up
      - type: custom:mushroom-entity-card
        entity: number.vitsippan_max_still_distance_gate
        name: Max Still Gate
        icon: mdi:boom-gate
      - type: custom:mushroom-entity-card
        entity: sensor.vitsippan_move_energy
        icon: mdi:lightning-bolt
        name: Move Energy
      - type: custom:mushroom-entity-card
        entity: sensor.vitsippan_still_energy
        icon: mdi:lightning-bolt
        name: Still Energy
    columns: 2
    title: Distances
  - square: false
    type: grid
    cards:
      - type: custom:mushroom-entity-card
        entity: select.vitsippan_baud_rate
        name: Baud Rate
        icon: mdi:speedometer
        icon_color: pink
      - type: custom:mushroom-entity-card
        entity: select.vitsippan_distance_resolution
        icon: mdi:ruler
        name: Resolution
        icon_color: pink
      - type: custom:mushroom-entity-card
        entity: button.vitsippan_factory_reset
        icon: mdi:factory
        name: F-Reset
        icon_color: pink
      - type: custom:mushroom-entity-card
        entity: number.vitsippan_timeout
        name: Timeout
        icon_color: pink
    columns: 2
    title: Configuration
  - square: false
    type: grid
    cards:
      - type: custom:mushroom-entity-card
        entity: select.vitsippan_light_function
        name: Function
        icon_color: yellow
      - type: custom:mushroom-entity-card
        entity: sensor.vitsippan_light
        name: Status
        icon_color: yellow
      - type: custom:mushroom-entity-card
        entity: number.vitsippan_light_threshold
        name: Threshold
        icon_color: yellow
    title: Light
    columns: 2
  - square: false
    type: grid
    cards:
      - type: custom:mushroom-entity-card
        entity: sensor.vitsippan_firmware_version
        name: Version
        icon_color: accent
      - type: custom:mushroom-entity-card
        entity: button.vitsippan_query_params
        name: Query Parameters
        icon_color: accent
    title: Diagnostic
    columns: 2
columns: 1
```

4.2 Main Tab


Vaxthus1
Vitsippan
Blåklockan
Idrottshall
Fläktrum
28.6
°C

4.3 NodeRed Code




```
[{"id":"d00c2fbf9ec35b5c","type":"tab","label":"Vitsippan","disabled":false,"info":"","env":[]},{"id":"6c8983ef0b5403e9","type":"tab","label":"Blåklockan","disabled":false,"info":"","env":[]},{"id":"424ef5418fa8278b","type":"tab","label":"Idrottshall","disabled":false,"info":"","env":[]},{"id":"0cd4e64f206e4785","type":"tab","label":"Get Weather","disabled":false,"info":"","env":[]},{"id":"a3684dc9.1cf72","type":"server","name":"Home Assistant","addon":true,"rejectUnauthorizedCerts":true,"ha_boolean":"","connectionDelay":false,"cacheJson":false,"heartbeat":false,"heartbeatInterval":"","statusSeparator":"","enableGlobalContextStore":false},{"id":"e1f0ffb233a6e40e","type":"server-state-changed","z":"d00c2fbf9ec35b5c","name":"Target Temp","server":"a3684dc9.1cf72","version":5,"outputs":1,"exposeAsEntityConfig":"","entityId":"input_number.vitsippan_target_temp","entityIdType":"exact","outputInitially":true,"stateType":"num","ifState":"","ifStateType":"str","ifStateOperator":"is","outputOnlyOnStateChange":true,"for":"0","forType":"num","forUnits":"minutes","ignorePrevStateNull":false,"ignorePrevStateUnknown":false,"ignorePrevStateUnavailable":false,"ignoreCurrentStateUnknown":false,"ignoreCurrentStateUnavailable":false,"outputProperties":[{"property":"payload","propertyType":"msg","value":"","valueType":"entityState"},{"property":"data","propertyType":"msg","value":"","valueType":"eventData"},{"property":"topic","propertyType":"msg","value":"SV","valueType":"str"},{"property":"target_temp","propertyType":"flow","value":"msg.payload","valueType":"jsonata"}],"x":90,"y":340,"wires":[["c638d62db7a2a22a"]]},{"id":"a4b43060e4c13b7c","type":"server-state-changed","z":"d00c2fbf9ec35b5c","name":"Occupied?","server":"a3684dc9.1cf72","version":5,"outputs":2,"exposeAsEntityConfig":"","entityId":"binary_sensor.vitsippan_occupied","entityIdType":"exact","outputInitially":true,"stateType":"habool","ifState":"true","ifStateType":"bool","ifStateOperator":"is","outputOnlyOnStateChange":false,"for":"","forType":"num","forUnits":"seconds","ignorePrevStateNull":false,"ignorePrevStateUnknown":false,"ignorePrevStateUnavailable":false,"ignoreCurrentStateUnknown":false,"ignoreCurrentStateUnavailable":false,"outputProperties":[{"property":"payload","propertyType":"msg","value":"","valueType":"entityState"},{"property":"data","propertyType":"msg","value":"","valueType":"eventData"},{"property":"topic","propertyType":"msg","value":"occupied","valueType":"str"},{"property":"occupied","propertyType":"flow","value":"","valueType":"entityState"}],"x":80,"y":140,"wires":[["e461e4453717f354"],["1a8576ddacbb3326"]]},{"id":"b249069a7e2e3cdd","type":"server-state-changed","z":"d00c2fbf9ec35b5c","name":"Current Room Temp","server":"a3684dc9.1cf72","version":5,"outputs":1,"exposeAsEntityConfig":"","entityId":"sensor.vitsippan_room_temperature","entityIdType":"exact","outputInitially":true,"stateType":"num","ifState":"","ifStateType":"str","ifStateOperator":"is","outputOnlyOnStateChange":true,"for":"0","forType":"num","forUnits":"minutes","ignorePrevStateNull":false,"ignorePrevStateUnknown":false,"ignorePrevStateUnavailable":false,"ignoreCurrentStateUnknown":false,"ignoreCurrentStateUnavailable":false,"outputProperties":[{"property":"payload","propertyType":"msg","value":"","valueType":"entityState"},{"property":"data","propertyType":"msg","value":"","valueType":"eventData"},{"property":"topic","propertyType":"msg","value":"PV","valueType":"str"},{"property":"room_temp","propertyType":"flow","value":"msg.payload","valueType":"jsonata"},{"property":"room_temm","propertyType":"flow","value":"30","valueType":"num"}],"x":110,"y":440,"wires":[["c638d62db7a2a22a","9700bb7d83bd7b3e","e461e4453717f354","0765d24eef1b882f"]]},{"id":"b659cb3266656b56","type":"function","z":"d00c2fbf9ec35b5c","name":"Styrsignal","func":"var op = msg.payload.Value;\n\nmsg.payload = op;\n\nreturn msg;","outputs":1,"timeout":"","noerr":0,"initialize":"","finalize":"","libs":[],"x":540,"y":340,"wires":[["5cbe276a257ae7e5"]]},{"id":"da7ab3b2c00c8f50","type":"range","z":"d00c2fbf9ec35b5c","minin":"0","maxin":"10","minout":"0","maxout":"100","action":"scale","round":false,"property":"payload","name":"","x":800,"y":400,"wires":[["aff26ab04164368b","94b1b68a3c369751"]]},{"id":"c638d62db7a2a22a","type":"easy-pid-controller","z":"d00c2fbf9ec35b5c","name":"PID","k_p":"3","k_i":"1","k_d":"0.1","sensor_type":"0-10V","dt":"1","range_min":"0","range_max":"50","x":390,"y":340,"wires":[["b659cb3266656b56","0346fd4cceb91de9"]]},{"id":"b88fead8875127a7","type":"server-state-changed","z":"d00c2fbf9ec35b5c","name":"Manual Overide?","server":"a3684dc9.1cf72","version":5,"outputs":2,"exposeAsEntityConfig":"","entityId":"input_boolean.vitsippan_manual_overide","entityIdType":"exact","outputInitially":true,"stateType":"habool","ifState":"true","ifStateType":"bool","ifStateOperator":"is","outputOnlyOnStateChange":true,"for":"0","forType":"num","forUnits":"minutes","ignorePrevStateNull":false,"ignorePrevStateUnknown":false,"ignorePrevStateUnavailable":false,"ignoreCurrentStateUnknown":false,"ignoreCurrentStateUnavailable":false,"outputProperties":[{"property":"payload","propertyType":"msg","value":"","valueType":"entityState"},{"property":"data","propertyType":"msg","value":"","valueType":"eventData"},{"property":"topic","propertyType":"msg","value":"overide","valueType":"str"},{"property":"overide","propertyType":"flow","value":"msg.payload","valueType":"jsonata"}],"x":100,"y":200,"wires":[["e461e4453717f354"],["e461e4453717f354"]]},{"id":"3124bb90eada63b4","type":"debug","z":"d00c2fbf9ec35b5c","name":"debug 1","active":false,"tosidebar":true,"console":false,"tostatus":false,"complete":"true","targetType":"full","statusVal":"","statusType":"auto","x":1120,"y":280,"wires":[]},{"id":"daac18ab045b229c","type":"server-state-changed","z":"d00c2fbf9ec35b5c","name":"Tilluft Temp","server":"a3684dc9.1cf72","version":5,"outputs":1,"exposeAsEntityConfig":"","entityId":"sensor.vitsippan_temperature_tilluft","entityIdType":"exact","outputInitially":true,"stateType":"num","ifState":"","ifStateType":"num","ifStateOperator":"is","outputOnlyOnStateChange":true,"for":"0","forType":"num","forUnits":"minutes","ignorePrevStateNull":false,"ignorePrevStateUnknown":false,"ignorePrevStateUnavailable":false,"ignoreCurrentStateUnknown":false,"ignoreCurrentStateUnavailable":false,"outputProperties":[{"property":"payload","propertyType":"msg","value":"","valueType":"entityState"},{"property":"data","propertyType":"msg","value":"","valueType":"eventData"},{"property":"topic","propertyType":"msg","value":"tilluft_temp","valueType":"str"},{"property":"tilluft_temp","propertyType":"flow","value":"msg.payload","valueType":"jsonata"}],"x":90,"y":540,"wires":[["0765d24eef1b882f"]]},{"id":"dcdf904102ab4dea","type":"server-state-changed","z":"d00c2fbf9ec35b5c","name":"Frånluft Temp","server":"a3684dc9.1cf72","version":5,"outputs":1,"exposeAsEntityConfig":"","entityId":"sensor.vitsippan_temperature_fr_nluft","entityIdType":"exact","outputInitially":true,"stateType":"num","ifState":"","ifStateType":"num","ifStateOperator":"is","outputOnlyOnStateChange":true,"for":"0","forType":"num","forUnits":"minutes","ignorePrevStateNull":false,"ignorePrevStateUnknown":false,"ignorePrevStateUnavailable":false,"ignoreCurrentStateUnknown":false,"ignoreCurrentStateUnavailable":false,"outputProperties":[{"property":"payload","propertyType":"msg","value":"","valueType":"entityState"},{"property":"data","propertyType":"msg","value":"","valueType":"eventData"},{"property":"topic","propertyType":"msg","value":"frånluft_temp","valueType":"str"},{"property":"franluft_temp","propertyType":"flow","value":"msg.payload","valueType":"jsonata"}],"x":90,"y":600,"wires":[[]]},{"id":"e461e4453717f354","type":"function","z":"d00c2fbf9ec35b5c","name":"PID ON logic","func":"var threshold = 1000;\n//var co2_val = context.get('co2_val');\nvar co2_val = flow.get('co2_value');\n\n\n// if the message is from the Manual overide button and low enought co2 value\nif(co2_val < threshold  &&  flow.get('overide') == true){  \n    msg.topic =\"auto\"; // need to be auto to control the PID\n    msg.payload = false; //turn of the PID for manual adjustment\n    return msg;\n}\n\n// if the co2 is too high then dont start the PID\nelse if (co2_val >= threshold){\n    msg.topic = \"auto\";\n    msg.payload = false; // highest value to lower the co2 value\n    return msg;\n} \n\n\n// is the signal from occupied true, then turn on the PID\nif (flow.get('occupied') == true) {\n    msg.topic = \"auto\"; // PID ON\n    msg.payload = true;\n    return msg;\n}\n\nelse {\n    msg.topic = \"auto\"; // PID OFF\n    msg.payload = false;\n    return msg;\n}\n\nreturn msg;","outputs":1,"timeout":0,"noerr":0,"initialize":"","finalize":"","libs":[],"x":370,"y":240,"wires":[["c638d62db7a2a22a","51ac302d84f8e954"]]},{"id":"0765d24eef1b882f","type":"function","z":"d00c2fbf9ec35b5c","name":"Temp logic","func":"// Retrieve the previously stored room temperature\nvar room_temp = flow.get('room_temp');\nvar tilluft_temp = flow.get('tilluft_temp');\nvar franluft_temp = flow.get('franluft_temp');\nvar target_temp = flow.get('target_temp');\n\n\n// Ensure both temperatures have values before making a comparison\nif (tilluft_temp !== undefined && room_temp !== undefined) {\n    \n    //Tilluft is cooler than room\n    if (tilluft_temp <= room_temp) {\n        msg.payload = \"tilluft_kallare\";\n        flow.set(\"tilluft_kallare\", true);\n        flow.set(\"tilluft_varmare\", false);\n    }\n    //Tilluft is warmer than room\n    else{ \n        flow.set(\"tilluft_kallare\", false);\n        flow.set(\"tilluft_varmare\", true);  \n    }\n\n    // Frånluft is cooler than room\n    if (franluft_temp <= room_temp){\n        flow.set(\"franluft_kallare\", true);\n        flow.set(\"franluft_varmare\", false);\n    }\n    // Frånluft is warmer than room\n    else{ \n        flow.set(\"franluft_kallare\", false);\n        flow.set(\"franluft_varmare\", true);\n    }\n\n}\n\n\n // om vi vill kyla rummet & tilluft är kallt\n // --> måste vi öppna spjällen\nif (target_temp < room_temp && flow.get('tilluft_kallare') == true) {\n    flow.set('oppna_spjall', true);\n}\n\n\n // om vi vill kyla rummet & tilluft är varmt\n // --> måste vi stänga spjällen\nelse if (target_temp < room_temp && flow.get('tilluft_varmare') == true) {\n    flow.set('oppna_spjall', false);\n}\n\n\n// om vi vill värma rummet & tilluft är kallt\n// --> måste vi stänga spjällen\nelse if (target_temp > room_temp && flow.get('tilluft_kallare') == true) {\n    flow.set('oppna_spjall', false);\n}\n\n// om vi vill värma rummet & tilluft är varmt\n// --> måste vi öppna spjällen\nelse if (target_temp > room_temp && flow.get('tilluft_varmare') == true) {\n    flow.set('oppna_spjall', true);\n}\n\nreturn msg;\n","outputs":1,"timeout":0,"noerr":0,"initialize":"","finalize":"","libs":[],"x":350,"y":600,"wires":[["0390d7f54258227b"]]},{"id":"0390d7f54258227b","type":"debug","z":"d00c2fbf9ec35b5c","name":"debug 5","active":false,"tosidebar":true,"console":false,"tostatus":false,"complete":"true","targetType":"full","statusVal":"","statusType":"auto","x":560,"y":660,"wires":[]},{"id":"aff26ab04164368b","type":"api-call-service","z":"d00c2fbf9ec35b5c","name":"Spjäll Till & Från","server":"a3684dc9.1cf72","version":5,"debugenabled":false,"domain":"number","service":"set_value","areaId":[],"deviceId":[],"entityId":["number.vitsippan_spj_ll_fr_nluft","number.vitsippan_spj_ll_tilluft"],"data":"{ \"value\": msg.payload}","dataType":"jsonata","mergeContext":"","mustacheAltTags":false,"outputProperties":[],"queue":"none","x":1040,"y":340,"wires":[[]]},{"id":"823c728ce6d902ec","type":"api-call-service","z":"d00c2fbf9ec35b5c","name":"Spjäll Till & Från","server":"a3684dc9.1cf72","version":5,"debugenabled":false,"domain":"number","service":"set_value","areaId":[],"deviceId":[],"entityId":["number.vitsippan_spj_ll_fr_nluft","number.vitsippan_spj_ll_tilluft"],"data":"{ \"value\": msg.payload}","dataType":"jsonata","mergeContext":"","mustacheAltTags":false,"outputProperties":[],"queue":"none","x":680,"y":100,"wires":[[]]},{"id":"9700bb7d83bd7b3e","type":"function","z":"d00c2fbf9ec35b5c","name":"Flödes logik","func":"var threshold = 1000;\n\n// overide button is enabled\nif(flow.get('overide') == true){\n    msg.payload = null;\n    return msg;\n}\n\nif(flow.get('co2_value') >= threshold){\n    msg.payload = 100; //blast the air to lower the co2 value\n    return msg;\n}\n\n\n// no one is there, turn on grundflöde\nif (msg.topic == \"occupied\" && msg.payload == false){\n    msg.payload = 20; // 20% open is grundflöde\n    return msg;\n}","outputs":1,"timeout":0,"noerr":0,"initialize":"","finalize":"","libs":[],"x":390,"y":80,"wires":[["823c728ce6d902ec","cd484df13103fd1e"]]},{"id":"cd484df13103fd1e","type":"debug","z":"d00c2fbf9ec35b5c","name":"debug 6","active":true,"tosidebar":true,"console":false,"tostatus":false,"complete":"true","targetType":"full","statusVal":"","statusType":"auto","x":660,"y":60,"wires":[]},{"id":"ef44db989d2eb0f4","type":"server-state-changed","z":"d00c2fbf9ec35b5c","name":"CO2 sensor","server":"a3684dc9.1cf72","version":5,"outputs":1,"exposeAsEntityConfig":"","entityId":"sensor.vitsippan_room_co2","entityIdType":"exact","outputInitially":true,"stateType":"num","ifState":"","ifStateType":"num","ifStateOperator":"is","outputOnlyOnStateChange":true,"for":"0","forType":"num","forUnits":"minutes","ignorePrevStateNull":false,"ignorePrevStateUnknown":false,"ignorePrevStateUnavailable":false,"ignoreCurrentStateUnknown":false,"ignoreCurrentStateUnavailable":false,"outputProperties":[{"property":"payload","propertyType":"msg","value":"","valueType":"entityState"},{"property":"data","propertyType":"msg","value":"","valueType":"eventData"},{"property":"topic","propertyType":"msg","value":"co2","valueType":"str"},{"property":"co2_value","propertyType":"flow","value":"msg.payload","valueType":"jsonata"}],"x":90,"y":280,"wires":[[]]},{"id":"51ac302d84f8e954","type":"debug","z":"d00c2fbf9ec35b5c","name":"debug 7","active":false,"tosidebar":true,"console":false,"tostatus":false,"complete":"true","targetType":"full","statusVal":"","statusType":"auto","x":820,"y":220,"wires":[]},{"id":"bef835806be24da6","type":"range","z":"d00c2fbf9ec35b5c","minin":"0","maxin":"100","minout":"100","maxout":"0","action":"scale","round":false,"property":"payload","name":"","x":800,"y":280,"wires":[["aff26ab04164368b","3124bb90eada63b4"]]},{"id":"94b1b68a3c369751","type":"debug","z":"d00c2fbf9ec35b5c","name":"debug 8","active":false,"tosidebar":true,"console":false,"tostatus":false,"complete":"true","targetType":"full","statusVal":"","statusType":"auto","x":1120,"y":400,"wires":[]},{"id":"5cbe276a257ae7e5","type":"switch","z":"d00c2fbf9ec35b5c","name":"öppna_spjäll","property":"oppna_spjall","propertyType":"flow","rules":[{"t":"true"},{"t":"false"}],"checkall":"true","repair":false,"outputs":2,"x":710,"y":340,"wires":[["bef835806be24da6"],["da7ab3b2c00c8f50"]]},{"id":"0346fd4cceb91de9","type":"debug","z":"d00c2fbf9ec35b5c","name":"debug 9","active":false,"tosidebar":true,"console":false,"tostatus":false,"complete":"true","targetType":"full","statusVal":"","statusType":"auto","x":560,"y":420,"wires":[]},{"id":"1a8576ddacbb3326","type":"trigger","z":"d00c2fbf9ec35b5c","name":"no one there for more than 5 mins","op1":"false","op2":"0","op1type":"bool","op2type":"str","duration":"5","extend":false,"overrideDelay":false,"units":"min","reset":"","bytopic":"all","topic":"topic","outputs":2,"x":340,"y":160,"wires":[["e461e4453717f354","9700bb7d83bd7b3e"],[]]},{"id":"d8f083a7c8192c26","type":"debug","z":"0cd4e64f206e4785","name":"debug 3","active":false,"tosidebar":true,"console":false,"tostatus":false,"complete":"true","targetType":"full","statusVal":"","statusType":"auto","x":620,"y":140,"wires":[]},{"id":"95f6425fa28d5642","type":"function","z":"0cd4e64f206e4785","name":"Outside Temp","func":"msg.payload = msg.payload.tempc;\nreturn msg;","outputs":1,"timeout":0,"noerr":0,"initialize":"","finalize":"","libs":[],"x":440,"y":160,"wires":[["d8f083a7c8192c26","53ddaf7ed574c0a7"]]},{"id":"53ddaf7ed574c0a7","type":"link out","z":"0cd4e64f206e4785","name":"Weather data - out","mode":"link","links":["0d0d0217dddd76a8"],"x":585,"y":180,"wires":[]},{"id":"fb073121f1de93ae","type":"openweathermap in","z":"0cd4e64f206e4785","name":"5dags prognos - Vaxthuset Huddinge","wtype":"current","lon":"","lat":"","city":"Huddinge","country":"Sweden","language":"sv","x":180,"y":180,"wires":[["95f6425fa28d5642","67d78e84c1a244e3"]]},{"id":"67d78e84c1a244e3","type":"debug","z":"0cd4e64f206e4785","name":"debug 4","active":false,"tosidebar":true,"console":false,"tostatus":false,"complete":"true","targetType":"full","statusVal":"","statusType":"auto","x":440,"y":280,"wires":[]}]
```

4.4 ESP code

Code for the esp32 flashed with the esphome software

```yaml
esphome:
  name: vitsippan
  friendly_name: Vitsippan

esp32:
  board: esp32dev
  framework:
    type: arduino

# Enable logging
logger:
  baud_rate: 0
# Enable Home Assistant API
api:
  encryption:
    key: "6co5PgKMpFRbOKTqdzl1igLsK3LU+wO/dhlrUlX9Kbw="

ota:
  - platform: esphome
    password: "0a1320e54fd86d5a58ac6741fe33f5af"

wifi:
  ssid: !secret wifi_ssid
  password: !secret wifi_password
  use_address: 10.100.4.48


  # Enable fallback hotspot (captive portal) in case wifi connection fails
  ap:
    ssid: "Vitsippan Fallback Hotspot"
    password: "On742JWxO67Q"

captive_portal:


ld2410:
  id: ld2410_radar


uart:
  id: ld2410_uart
  tx_pin: GPIO1
  rx_pin: GPIO3
  baud_rate: 256000
  parity: NONE
  stop_bits: 1


# DAC output configuration
output:
  - platform: esp32_dac
    id: dac_output_franluft
    pin: GPIO25

  - platform: esp32_dac
    id: dac_output_tilluft
    pin: GPIO26


# Numbers For Configuration
number:

 # DAC Spjäll motor Frånluft
  - platform: template
    name: "Spjäll - Frånluft"
    min_value: 0
    max_value: 100
    unit_of_measurement: "%"
    mode: SLIDER
    step: 0.5
    optimistic: true
    set_action:
      - output.set_level:
          id: dac_output_franluft
          level: !lambda 'return x / 100.0;'

  - platform: template
    name: "Spjäll - Tilluft"
    min_value: 0
    max_value: 100
    unit_of_measurement: "%"
    mode: SLIDER
    step: 0.5
    optimistic: true
    set_action:
      - output.set_level:
          id: dac_output_tilluft
          level: !lambda 'return x / 100.0;'

  - platform: ld2410
    timeout:
      name: timeout
    light_threshold:
      name: light threshold
    max_move_distance_gate:
      name: max move distance gate
    max_still_distance_gate:
      name: max still distance gate


external_components:
  - source: github://nrandell/dallasng

# Spjäll temperature


one_wire:
    platform: gpio
    pin: GPIO32


sensor:
# Spjäll sensor reading
  - platform: adc
    pin: GPIO35
    attenuation: 12db
    accuracy_decimals: 0
    unit_of_measurement: "%"
    filters:
      - offset: -0.70
      - multiply: 42.5  # Skala upp värdet till att representera 0-100%
      - exponential_moving_average:
          alpha: 0.3
          send_every: 2
    name: "Sensor-Spjäll-Frånluft"
    update_interval: 2s

  - platform: adc
    pin: GPIO34
    attenuation: 12db
    accuracy_decimals: 0
    unit_of_measurement: "%"
    filters:
      - offset: -0.10
      - multiply: 33.3  # Skala upp värdet till att representera 0-100%
      - exponential_moving_average:
          alpha: 0.3
          send_every: 2
    name: "Sensor-Spjäll-Tilluft"
    update_interval: 2s

# CO2 sensor reading
  - platform: adc
    pin: GPIO39
    unit_of_measurement: "ppm"
    attenuation: 12db
    filters:
      - multiply: 606.06 #  2000/3.33 --> Skala upp värdet till att representera ppm
    name: "Room - CO2"
    update_interval: 10s
    accuracy_decimals: 0

# Temperature sensor reading
  - platform: adc
    pin: GPIO36
    unit_of_measurement: "°C"
    attenuation: 12db
    filters:
      - multiply: 15.15 # 50/3.33 --> Skala upp värdet till att representera Celcius
    name: "Room - Temperature"
    update_interval: 10s
    accuracy_decimals: 1

# Temperature sensor reading - DS18B20
  - platform: dallas_temp
    address: 0xcc3c01e076c6f828
    update_interval: 5sec
    unit_of_measurement: "°C"
    name: "Temperature - Tilluft"

  - platform: dallas_temp
    address: 0x1f3c01e076caac28
    update_interval: 5sec
    unit_of_measurement: "°C"
    name: "Temperature - Frånluft"




  # - platform: adc
  #   pin: GPIO33
  #   attenuation: 12db
  #   filters:
  #     - multiply: 15.15 # Skala upp värdet till att representera Celcius
  #   name: "Temperature - Tilluft"
  #   update_interval: 1s


  - platform: ld2410
    light:
      name: light
    moving_distance:
      name : Moving Distance
    still_distance:
      name: Still Distance
    moving_energy:
      name: Move Energy
    still_energy:
      name: Still Energy
    detection_distance:
      name: Detection Distance


button:
  - platform: ld2410
    factory_reset:
      name: "factory reset"
    restart:
      name: "restart"
    query_params:
      name: query params

switch:
  - platform: ld2410
    engineering_mode:
      name: Engineering Mode
    bluetooth:
      name: Control Bluetooth


select:
  - platform: ld2410
    distance_resolution:
      name: "distance resolution"
    baud_rate:
      name: "baud rate"
    light_function:
      name: light function


text_sensor:
  - platform: ld2410
    version:
      name: "firmware version"

binary_sensor:
  - platform: gpio
    pin: GPIO13
    name: "Occupied"
    device_class: motion
```

4.5 KiCad smart control room-unit