Assignment 1

Specification, Requirements, Circuit v0.1

Q1: microHAT Concept

The irrigation PiHAT can be used for the irrigation of small gardens/vegetable patches via soil moisture level sensing and water dispensing. It may also be used in lab environments where scientists need to hold the moisture level of the soil at a constant level. An optional configuration, which shows the modular ability of the HAT, is to replace the moisture sensors with a float switch or humidity sensor to either fill up pools; ponds; or water tanks or to operate ventilation systems if an enclosed space reaches a maximum humidity level. The PiHAT will allow more advanced users to continuously perform measurements or monitor the soil moisture levels by sending its input from the sensors into the main Pi GPIO header.

The moisture sensors embedded in the soil read analogue voltage and provide this signal to the PiHAT via input pins. Watering levels are controlled by the user via a PCB mounted potentiometer. 12VDC valves (in other configurations this could be another type of device) are connected to the PiHAT for water (or fertilizer) distribution. The higher voltage power supply provides power to the PiHAT separately from the main Pi board as the valves draw far more current and voltage than the Pi can supply from its GPIO header. Each moisture sensor will have an LED level indicator (Red, Orange, Green) to show soil moisture levels, where Red indicates dry soil and all three LEDs indicate suitably dampened soil.

Q2: Requirements

Plant-based scientific experiments by scientists/ botanists/ students

- R1.1: User wants water levels to be a controlled variable in the experiment
- R1.2: Continuous measurements/ monitoring of soil moisture levels
- R1.3: Watering levels are controlled by user via potentiometer

Garden irrigation for plant parents away on holiday

- R2.1: User's plants are regularly watered
- R2.2: Needs to be fully automated
- R2.3: Must not be overwatered

Optional: Pond/ pool/ pet water bowl top up for users

- R3.1: User's pool/ pond/ water bowl needs to be regularly watered
- R3.2: Needs to be fully automated
- R3.3: Must not be overwatered
- R3.4: Needs a float switch for triggering

Q3: Specifications

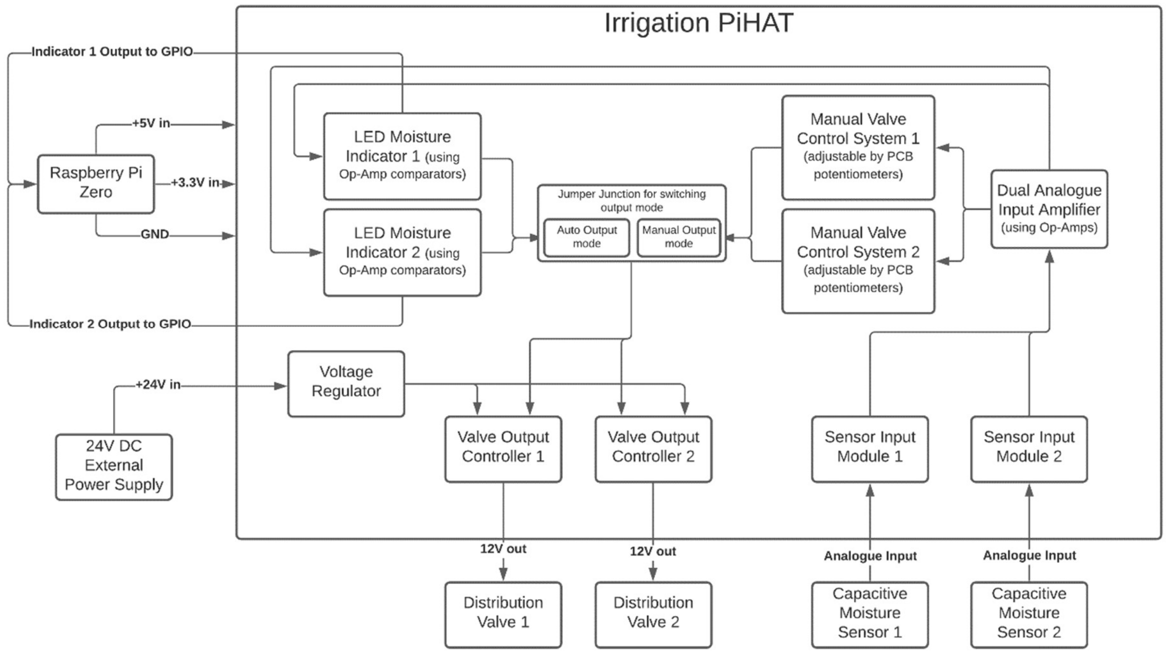
Electrical Specifications

Requirement	Specification(s)	Acceptance Test Criteria
R1 An analogue moisture sensor input signal	S1.1 Connected to and co nstrained to the 0-3.3V range of an Op-Amp comparator circuit	Ensure voltage does not exceed 3.3V or go below 0V by lab-testing comparator's practical range
R2 3 LED's indicating soil moisture levels, related to sensing/comms board	S2.1 Red LED is ON when soil moisture levels are very low and water is required to be released from valves. S2.2 Orange LED is additionally ON when moisture levels are no longer critically low S2.3 Green LED is ON when soil moisture levels are adequate and valves are closed.	LED internal bias tolerances are negligibly small
R3 Switching power supply circuitry for sensing/comms board	S3.1 Switching power regulator: 24V DC from Power Supply regulated to 12V DC for valves	12V DC does not exceed 13V or go below 12 V.

Mechanical Specifications

Requirement	Specification(s)	Acceptance Test Criteria
R1 Two valves release water as required	S1.1 Valves release water when soil moisture levels drops below a user-specified amount – when only Red LED is on. S1.2 Valves close once soil moisture levels are adequate	Valves are waterproof and functional. Amount of water released by valves is within 3 cubic centimetres of the expected amount. Sensors are suitably placed in soil.
R2 User sets soil moisture level for which watering is required	S2.1 Potentiometer and moisture sensor circuit act as voltage divider S2.2 User able to access physically adjust potentiometer to set soil moisture level requirements	Potentiometer voltage divider accuracy is within 3% of the required values.
R3 Float switch/ humidity sensor additional replacement option	S3.1 Float switch triggered when water-level drops below user-specified amount	Water level float switch is triggered by is within 3 cubic centimetres of the designated level.

Q4: Project Subsystems Block Diagram



Q5: Subsystem Specifications and Interfaces

Subsystem 1: Op-amp LED and Valve Control Subsystem

Specifications:

- Three comparator circuits present, with each threshold voltage controlled by a potentiometer.
- There are two circuits present to determine the valve control system, namely two additional comparators for when the valve turns off and on, as well as logic gates to ensure the valves turn on at the required values

Interfacing:

- The inputs to the comparator subsystems will come in the range of 0V to 3.3V as an analog signal. This signal is received from the amplifier subsystem on its input.
- When comparator input voltage exceeds the set threshold voltage, the LEDs sequentially turn on.
- The outputs of the comparators additionally enter the Raspberry Pi to provide optional data for users to read in. These outputs will vary between a high or low state as outputted by the Op-Amps. Essentially, the Raspberry Pi will read the LED state.
- Override switch present between LED and valve control circuit, controlling a BJT, as a means to manually control the valve control values.
- There is an internal subsystem which provides the user of the HAT to switch the output interface configuration using a pin jumper.
- The output is an analog signal and can be drawn from either the LED comparator system or by a potentiometer adjustable circuit.

Subsystem 2: Amplifier Subsystem

Specifications:

- The op amp U1 amplifies a 3.3V input voltage to –1.2V
- Op amp U2 is a summing amplifier. The input signal of 1.2-2.5V is summed with the –1.2V to achieve a 0-1.3V output
- Op amp U3 amplifies this output a value between 0V and 3.3V

Interfacing:

- The sets of three op amps are connected to each other, with U3 providing the amplified output that will interface with LED comparators and manual comparator subsystems
- The input to the amplifier subsystem comes in the form of an analog signal from the moisture sensors, in the range of 1.2V to 2.5V
- The output of the subsystem involves an adjusted analog signal which is scaled to be between 0V and 3.3V to match the Raspberry Pi's output rails

Subsystem 3: Power Regulator Subsystem

Specifications:

- The P78E12-1000 Switching Voltage Regulator is capable of taking in a range of voltages (16V-36V) and outputting a constant 12V DC voltage.
- P78E12-1000 Switching Voltage Regulator used to regulate the 24V input to 12V.
- P78E12-1000 Switching Voltage Regulator connected in parallel with two smoothing capacitors (10uF and 22uF) as specified by the P78E12-1000 data sheet, to smooth the input and output voltages.

Interfacing:

- The P78E12-1000 Switching Voltage Regulator takes in 24V from an external power supply and outputs a constant 12V DC voltage for powering the solenoid valves.
- The input to the voltage regulator is able to be adjusted from 16V to 36V. This regulator ensures that the solenoid valves are protected from power spikes on the input interface
- The output of the regulator is fed directly into the valves while being controlled by a small current signal from the comparator subsystem

Q6: Subsystem Draft Circuits

The following subsystem draft circuits (v0.1) have been included on the last pages in the following order:

1) Op-amp LED and Valve Control Subsystem
2) Amplifier Subsystem
3) Power Regulator Subsystem

Sources

- https://www.youtube.com/watch?v=udmJyncDvw0
- https://www.switchdoc.com/2020/06/tutorial-capacitive-moisture-sensor-grove/
- https://www.robotics.org.za/CAP-SW-12