Assignment 1

SPICE Simulations, Circuit v1.0

Q1: Power supply subsystem

**Q1.1**

**Text

Description automatically generated**

Figure 1.1.1

The plot above shows the input voltage which is set at 24V DC. The output voltage will be a constant 12V DC which will be sent to the Amplifier subsystems to be used in the powering of the solenoid valves. The voltage out does have a small delay time which is negligible as it is less than 1 millisecond. This is most likely due to the internal configuration of the LTC3895 IC that will be used.

A picture containing line chart

Description automatically generated

Figure 1.1.2

The figure above shows that the switching power regulator can provide a stable 12V DC output even if the input voltage drops to15V for example. The lowest rated voltage the switching regulator can accept is 4V although this is not recommended.

A picture containing graphical user interface

Description automatically generated

Figure 1.1.2

The figure above demonstrates that the switching power regulator can provide a stable 12V DC output when the input voltage exceeds the predicted input of 12V. The plot shows an input of 48V for example. The highest rated voltage the switching regulator can accept is 140V although this is not recommended.

**Q1.2**

**Q1.3**

**Q1.3**

Q2: Amplifier

Q2.1

*Running Simulations of Amplifier subsystem of Irrigation PiHAT*

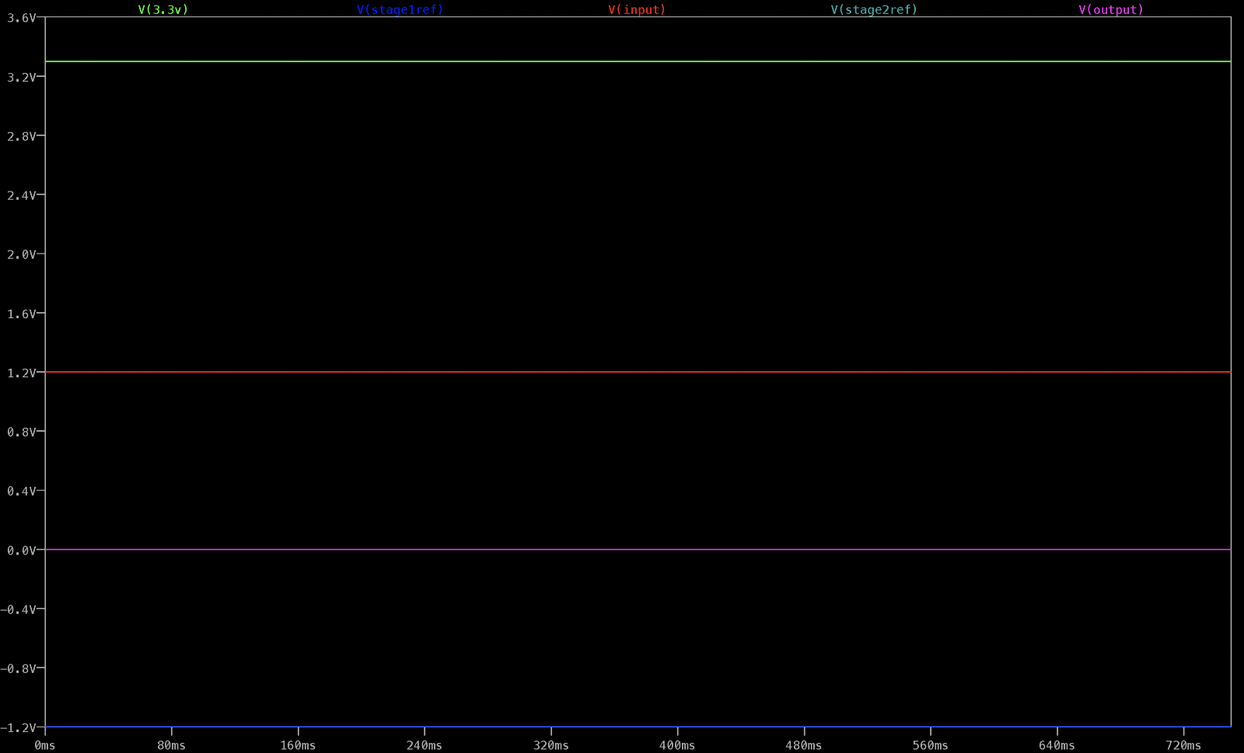
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Figure 2.1.1

Amplifier circuit simulation displaying the output Voltage of the circuit yielded from a constant 1,2 V input V(input). This input provides a means for simulating the lower bound of the input voltage received from the soil moisture level sensing circuit.

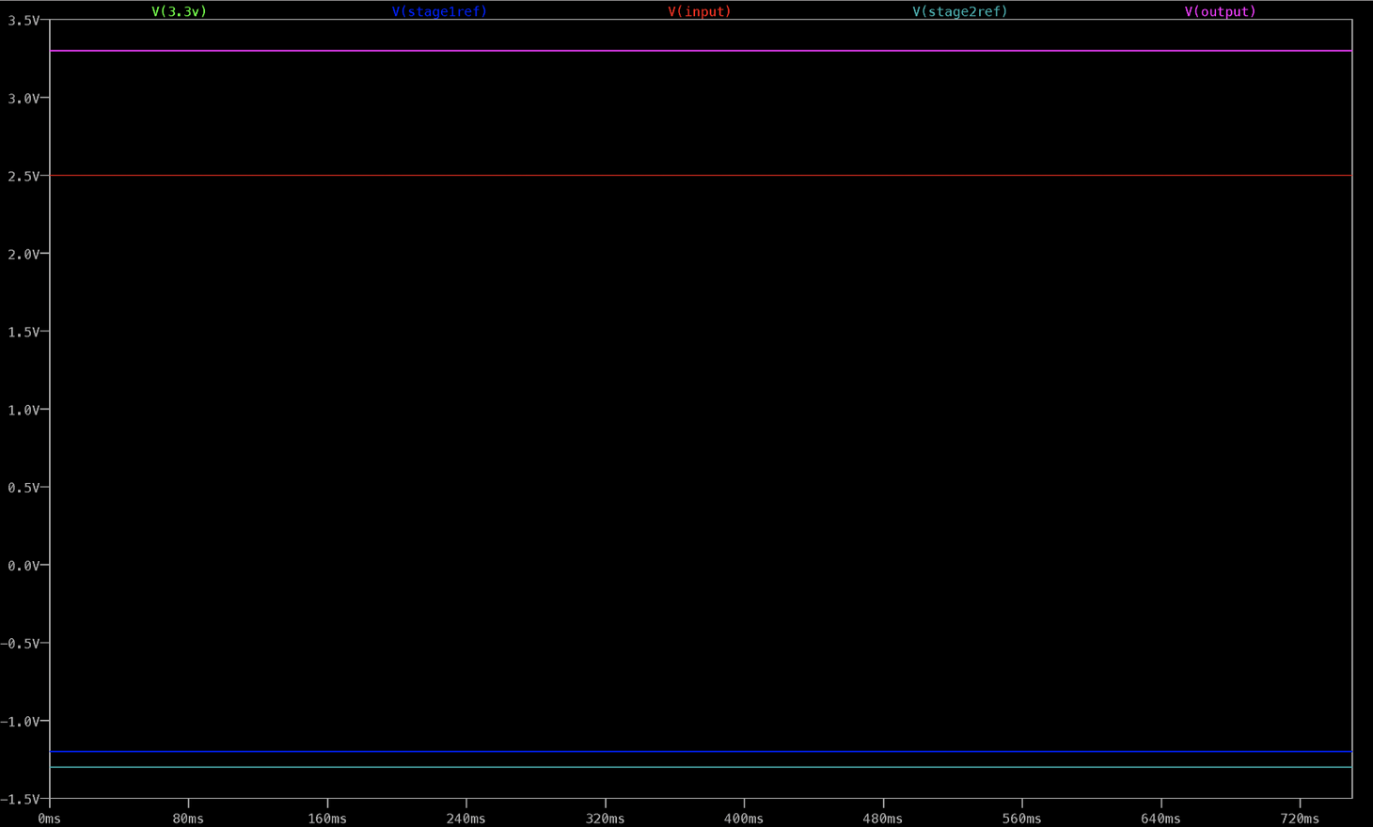


Figure 2.1.2

Amplifier circuit simulation displaying the output Voltage of the circuit yielded from a constant 2,5 V input V(input). This input provides a means for simulating the upper bound of the input voltage received from the soil moisture level sensing circuit. At this input voltage, the output of this sub-system V(out) is the maximum output of 3,3V Vout(3.3V).

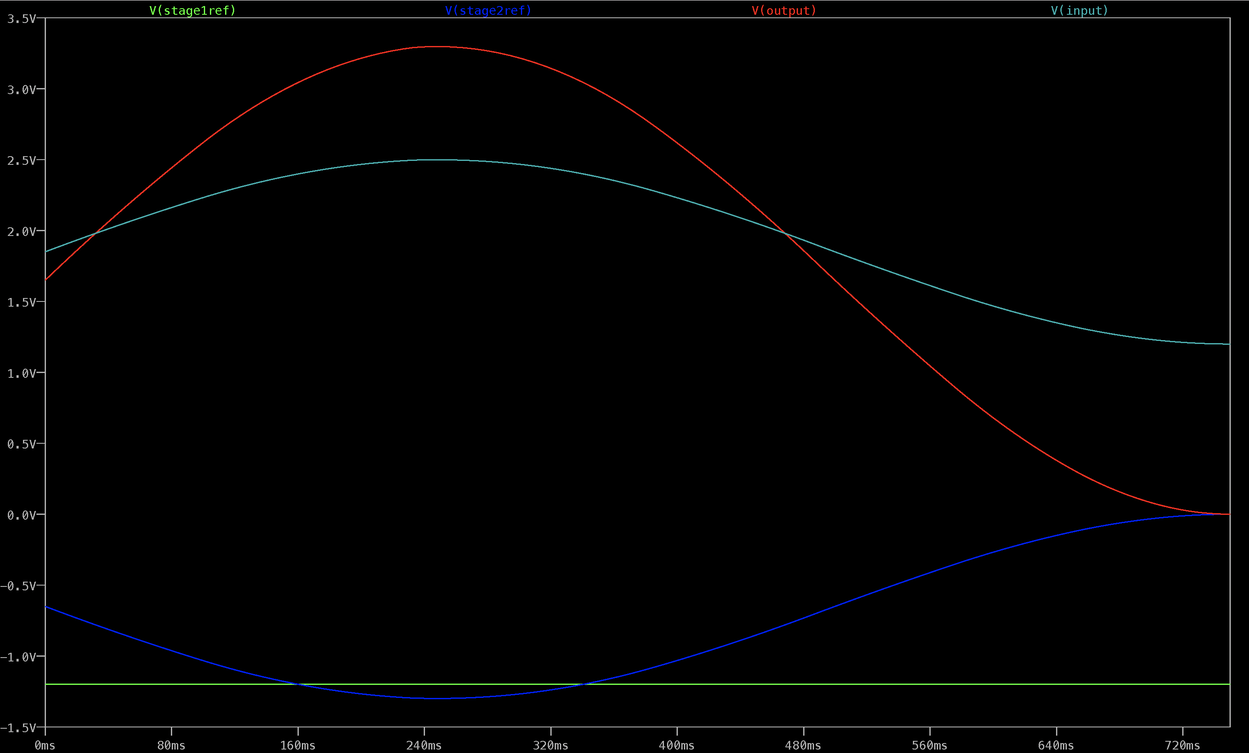


Figure 2.1.3

Amplifier circuit simulation displaying the output Voltages of the circuit yielded from a sinusoidal input V(input). This input provides a means for simulating the various voltage inputs received from the soil moisture level sensing circuit depending on the possible soil moisture levels.

Q2.2

*Circuit diagrams of Amplifier subsystem of Irrigation PiHAT*

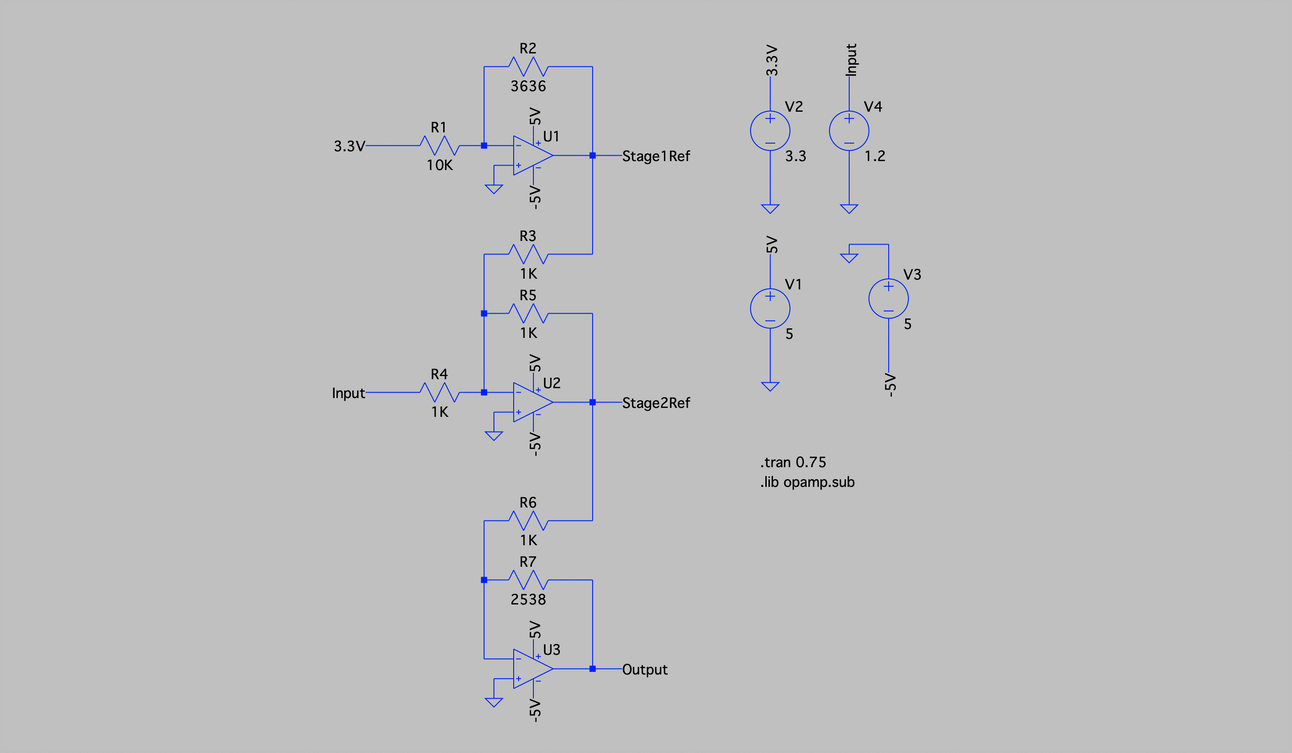


Figure 2.2.1

Amplifier circuit with an input Voltage yielded from a constant lower bound 1,2 V input V(input).

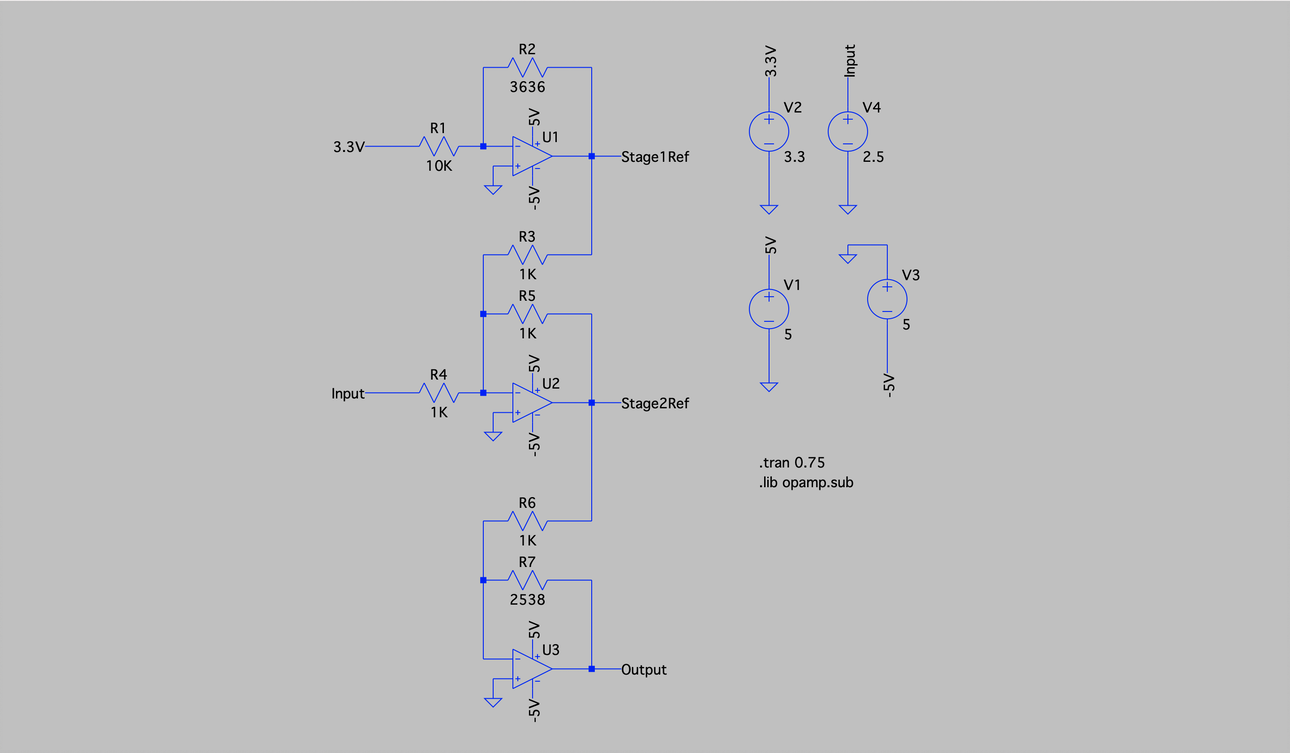


Figure 2.2.2

Amplifier circuit with an input Voltage yielded from a constant upper bound 2,5V input V(input).

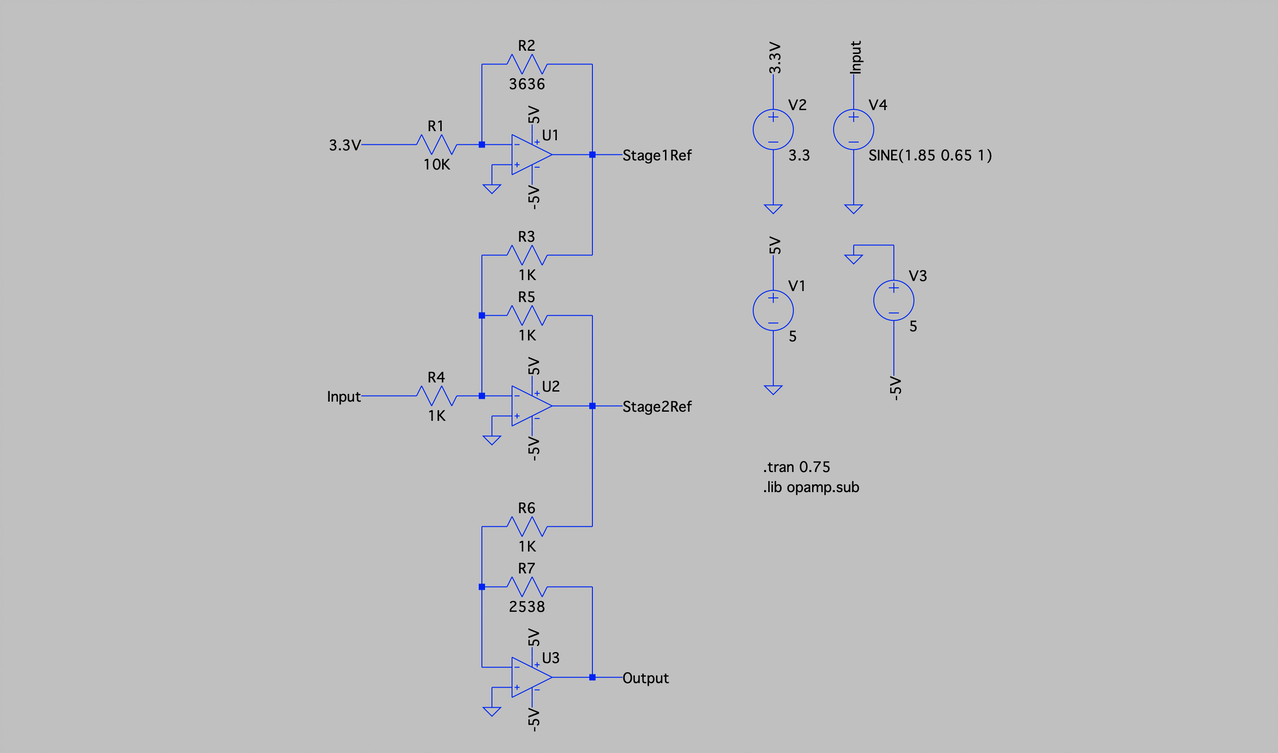


Figure 2.2.3

Amplifier circuit with an input Voltage yielded from a time-varying sinusoidal input V(input).

Q2.3

The three stages of op amps are connected to each other, with U3 providing the amplified output that will interface with the LED comparators and manual comparator subsystems. The input to the amplifier subsystem comes in the form of an analogue signal from the moisture sensors, in the range of 1.2V to 2.5V.

The output of the subsystem involves an adjusted analogue signal which is scaled to be between 0V and 3.3V to match the Raspberry Pi’s output rails.

The LM324D op amp was chosen for this circuit as it is a quad op amp, which means it is a 4-in-1 integrated circuit, and therefore is more space-efficient on a PCB. Additionally, this op amp is a Surface-Mount Device, further saving space on the PCB.

Q2.4

Yes, the circuit simulated meets the specifications for this subsystem, as follows:

***Stage 1:***

The inverting op amp U1 amplifies a 3.3V input voltage to –1.2V to be used in Stage 2.

***Stage 2:***

Consists of a summing amplifier op amp U2. The input signal of 1.2-2.5V is summed with the –1.2V to achieve a 0-1.3V output to be used in stage 3.

***Stage 3:***

The inverting op amp U3 amplifies Stage 2’s output to a value between 0V and 3.3V as required.

Q3: Status LEDs and Valve Control

Q3.1

*Running Simulations of LED and Valve Control subsystem of Irrigation PiHAT*

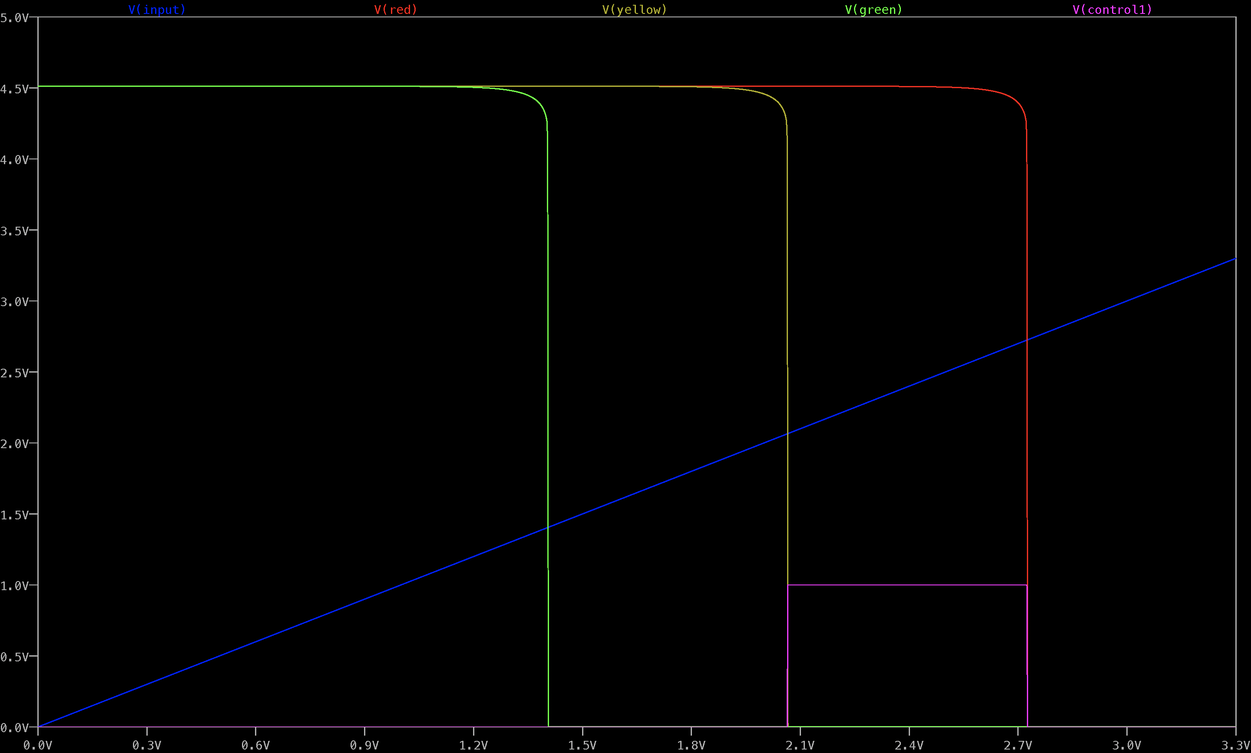


Figure 3.1.1

LED circuit simulation displaying:

1. A simulated input Voltage V(in) ranging from 0V (very moist soil) to 3,3V (very dry soil).
2. The adjustable trigger Voltages of the comparators V(red), V(yellow) and V(green) for the respective coloured LEDs, indicating at what input voltage these comparators turn on (consecutively).
3. An additional potentiometer-dependent voltage V(control) that can be adjusted by the PiHat user, to manually control the valves and bypass the soil moisture sensors.



Figure 3.1.2

Valve control circuit simulation displaying:

1. A simulated input Voltage V(in) ranging from 0V (very moist soil) to 3,3V (very dry soil).
2. The adjustable trigger Voltages of the comparators V(dry) and V(moist), in the case that the user does not want to use the LED subsystem.
3. An additional potentiometer-dependent voltage V(control2) that can be adjusted by the PiHat user, to manually control the valves and bypass the soil moisture sensors.

**Q3.2 [5]**

Circuit diagram of LED and Valve Control subsystem of Irrigation PiHAT

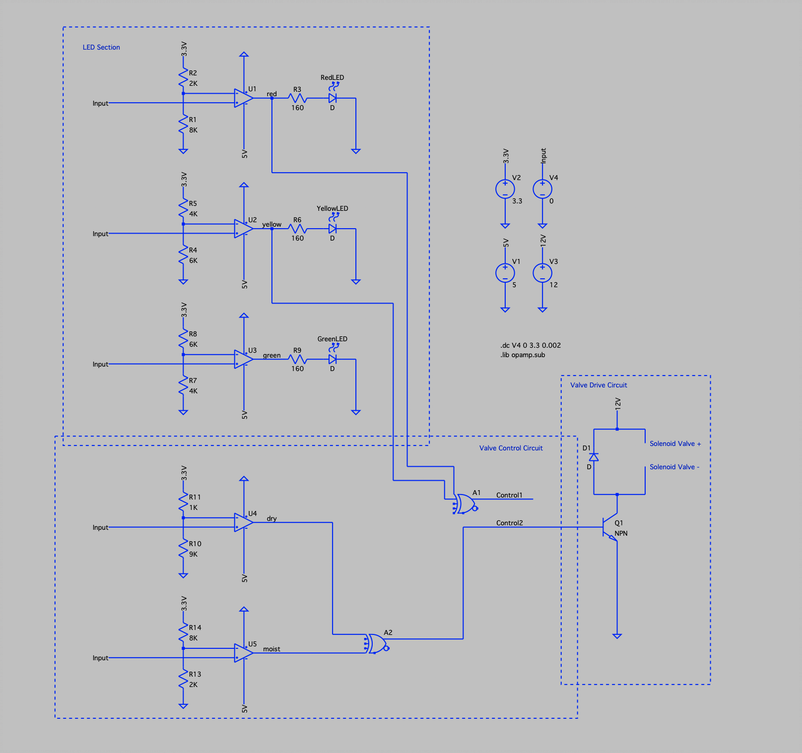


Figure 3.2.1

LED and Valve Control circuit, visually divided into the “LED Section”, “Valve Control Circuit” and “Valve Drive Circuit” circuity.

Note: Control 1 and 2 indicate the action of physical switch control, as this cannot be simulated on LTSpice. The Valve Drive Circuit demonstrates the result of triggering Control 1 and 2 (i.e. the switches).

**Q3.3 [5]**

The inputs to the comparator subsystems come in the range of 0V to 3.3V as an analogue input signal. This signal is received from the amplifier subsystem. When each comparator’s 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.

There is an override switch present between the LED and valve control circuit, 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 analogue signal and can be drawn from either the LED comparator system or by a potentiometer adjustable circuit.

The LED resistor values (160 Ohms) were determined from ( 5V-1,8V / 20mA), where 20mA is the operating current of the LED.

**Q3.4 [5]**

Yes, the circuit simulated meets the specifications for this subsystem, as follows:

1: Three comparator circuits present, with each threshold voltage controlled by a potentiometer.

2: 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.

Q4 Simulation as a design stage

The LED subsystem simulation results changed the circuitry of the comparators, which were originally designed with a 5V Vcc and 0V Vss, wherein the Vcc and Vss values had to be swopped for the simulation to correctly display the sequential triggering of the LEDs.

Other subsystems confirmed that our designs were done correctly.

Q5 Simulation Files Access