CAD Techniques Project

Circuit for controlling soil moisture level for plants

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Contents

1. Project Topic

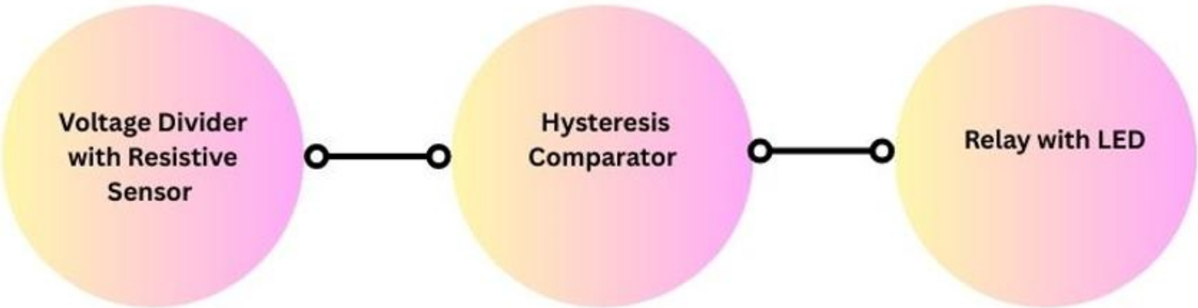
This project presents a smart irrigation system designed to automate watering based on real-time soil moisture levels. Using resistive moisture sensors, operational amplifiers (OpAmps), and a relay modeled as a resistor, the system intelligently activates a water pump when the soil becomes too dry and deactivates it once the desired humidity is reached.

2. Project Objective

The primary goal of the project is to implement an automated irrigation controller capable of maintaining soil humidity between 35% and 65%. The sensor used in this system exhibits a linear resistance change between 600 kΩ (at 20% humidity) and 60 kΩ (at 90% humidity). The circuit must translate this resistance variation into a voltage signal within the range of 2V to 13V, derived from a 15V supply. The final system should also include a visual indicator (blue LED) to show when the pump is operating.

3. Theoretical Analysis

3.1 The Block Diagram

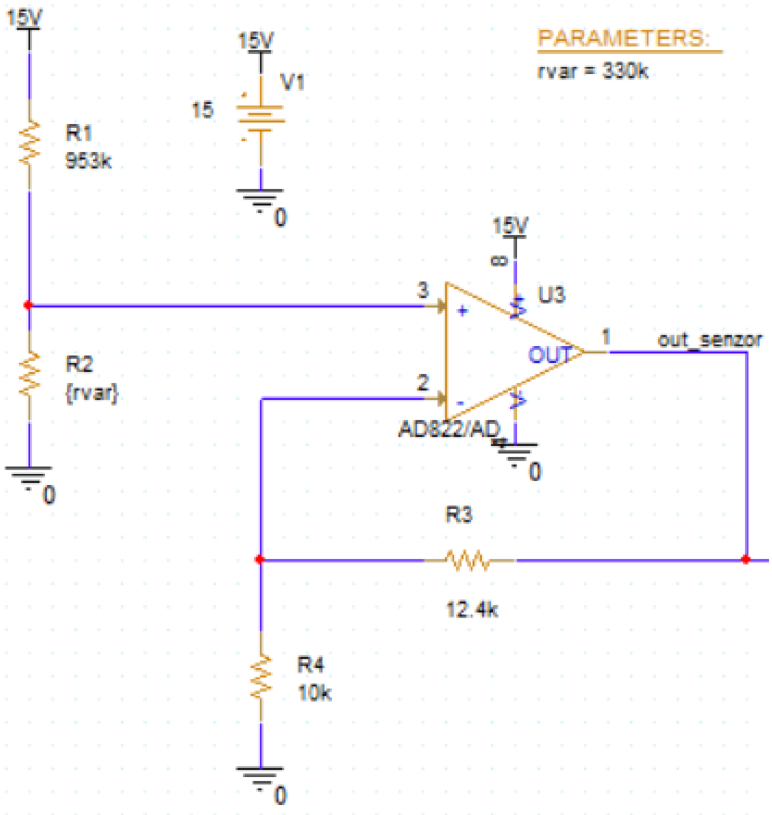


3.2 Voltage Divider with Resistive Sensor

The design begins with the moisture sensor, which is interfaced through a voltage divider to translate its resistance into a voltage level. This voltage is then compared against a hysteresis window using a comparator circuit built with an OpAmp. If the voltage indicates that the moisture is below 35%, the comparator will switch its output high, activating a relay through a transistor switch. When moisture reaches 65%, the comparator will deactivate the relay, stopping the pump. This part of the circuit represents the moisture sensor voltage conversion stage—it transforms the resistance of a moisture sensor into a corresponding voltage signal that can be processed later. R1,R3 and R4 are calculated with the following formulas:

$$V^{+} = \frac{Vsupply * R2}{R1+R2} = \frac{15V * rvar}{R1+rvar} \quad \textbf{(1)}$$

$$A(gain) = 1 + \frac{R3}{R4} \quad \textbf{(2)}$$



$$\boldsymbol{Vout = V^{+} * A} \quad \textbf{(3)}$$

Figure 1. Initial Design for the Voltage Divider with Resistive Sensor

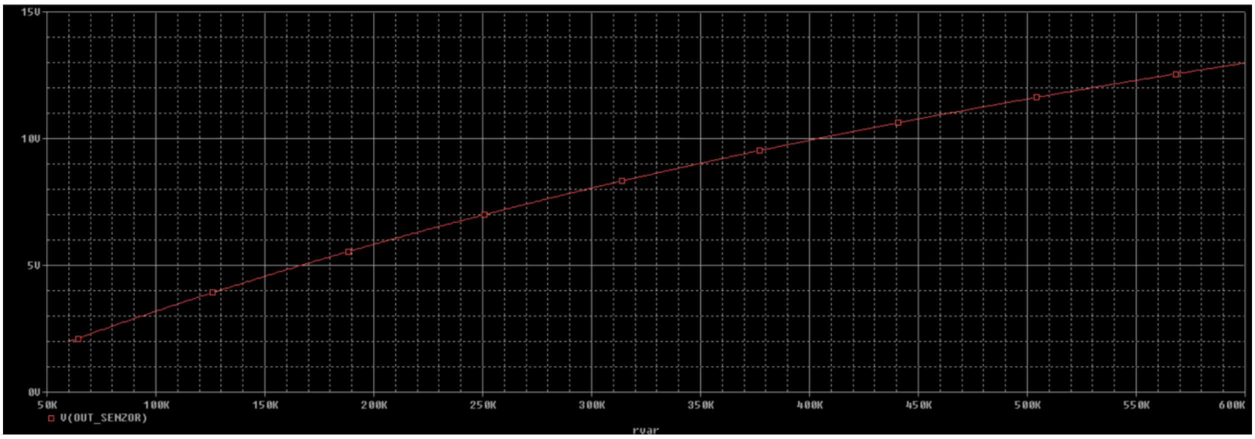


Figure 2. Simulation of the Voltage Divider with Resistive Sensor

The sensor's resistance changes with humidity in a linear fashion, which makes it ideal for use with a voltage divider. By selecting a fixed resistor of 953 kΩ and a variable resistor of 330 kΩ to represent the sensor, we achieve a voltage swing appropriate for comparison. The signal is buffered using an AD822 OpAmp (U3) configured as a voltage follower. This ensures that the following stages receive a receive a stable voltage representing the soil moisture level.

3.3 Comparator with Hysteresis

This part of the circuit is responsible for making a decision based on soil moisture — whether to turn the irrigation pump ON or OFF. It compares the amplified moisture sensor voltage against a reference threshold and applies hysteresis to prevent rapid switching.

(U4), uses a voltage divider network (R7, R8, R6) to define a reference voltage. The sensor voltage is compared to this reference, and the feedback resistor (R5) ensures that once the comparator output changes state, it requires a significant change in input voltage to switch back. This creates a clean and stable ON/OFF control signal.

The lower threshold voltage (Vth Low) corresponds to a humidity level of 35%, while the upper threshold voltage (Vth High) corresponds to 65% humidity.

We begin by calculating the total variation in humidity and voltage:

- Humidity variation: 90%−20%=70%

- Voltage variation (desired OpAmp output): 13V−2V=11V

From this, we determine how much the voltage increases per percentage of humidity:

11 V/70%=0.157 V/1%

We assume that at 20% humidity, the voltage is 2V. Using this as the base, we compute the threshold voltages for 35% and 65% humidity:

- For 35% humidity (15% above 20%):

Vth_low=2 V+15·0.157 V=4.35V

- For 65% humidity (45% above 20%):

Vth_high=2 V+45·0.157 V=9V

$$\textbf{Vout=0V => V+ =4,35V =>}\ \boldsymbol{4,35 = \frac{\frac{15V}{R8}}{\frac{1}{R8}+\frac{1}{R7}+\frac{1}{R6}}} \qquad \textbf{(4)}$$

$$\textbf{Vout=15V => V+ =9V =>}\ \boldsymbol{9V = \frac{\frac{15V}{R8}+\frac{15V}{R6}}{\frac{1}{R8}+\frac{1}{R7}+\frac{1}{R6}}} \qquad \textbf{(5)}$$

From these two equations results R7=7,75k and R8=10,68k.

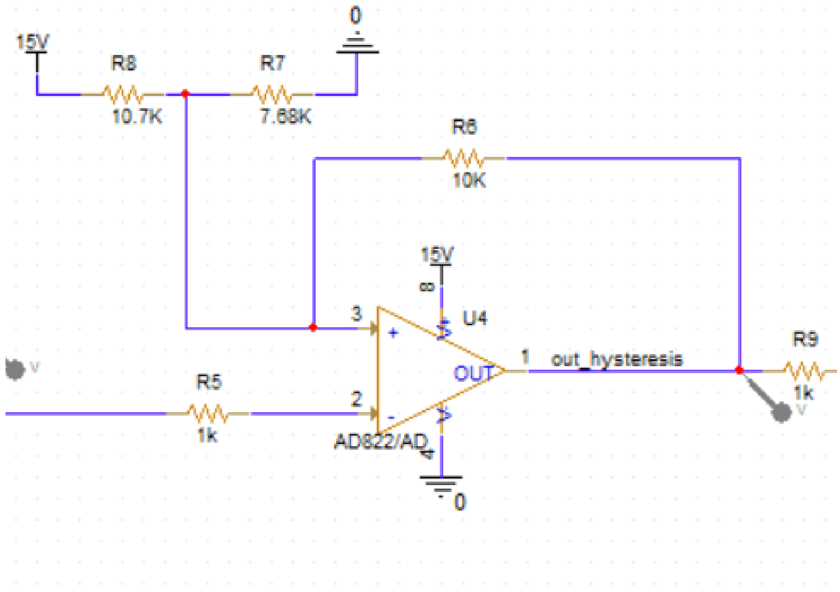


Figure 3. Design for the Hysteresis Comparator

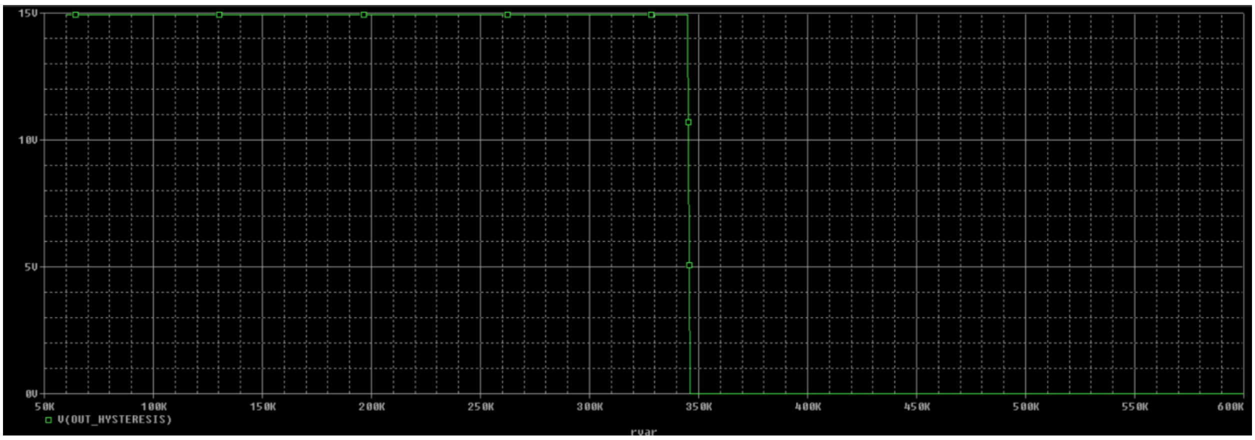


Figure 4. Simulation of the Hysteresis Comparator

3.4 Relay with LED

The output of the comparator drives an NPN transistor (2N2222A), which in turn switches the relay. The relay is modeled as a resistive load and connected in series with a blue LED (D1). The LED lights up to indicate pump activation. Resistors R10 and R11 ensure that the current through the LED is limited to safe levels, providing both protection and visual feedback.

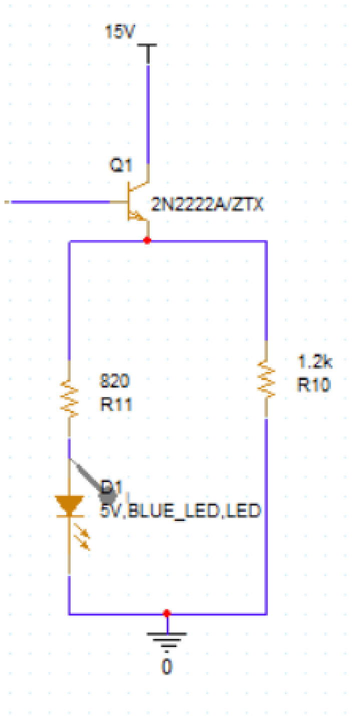


Figure 5. Design for the LED

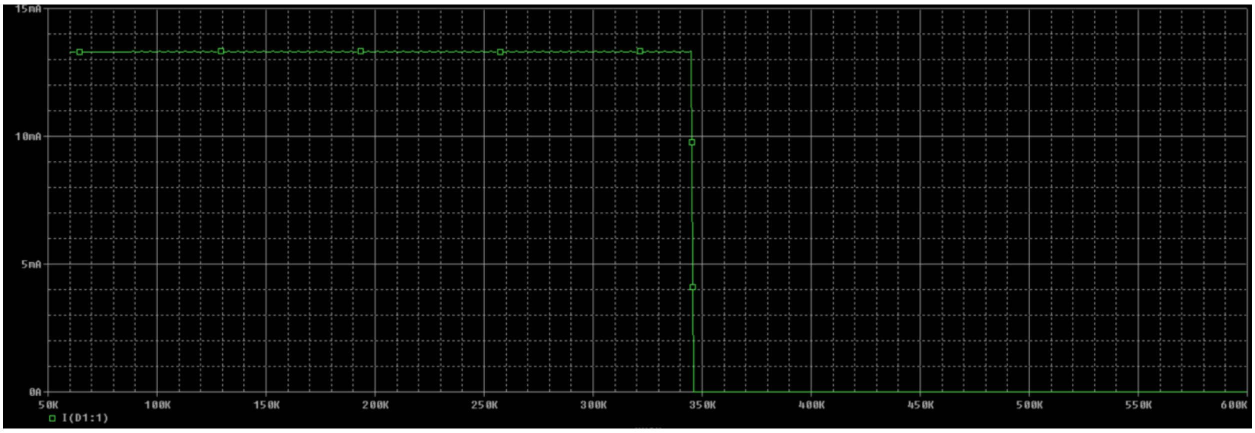


Figure 6. Simulation of the LED current

4. Final Schematic

The practical implementation of the system is shown in the figure below. The moisture sensor is modeled by a variable resistor (R2), and its voltage is read through a voltage divider. The AD822 OpAmp (U3) buffers the signal, which is then passed to the comparator stage (U4). The hysteresis comparator is built using resistors R7, R8, R6 for the reference, and R5 for positive feedback. The output of the comparator is connected to the base of the 2N2222A transistor through R9. When activated, the transistor allows current to flow through the relay and the LED, turning the pump ON and illuminating the blue LED.

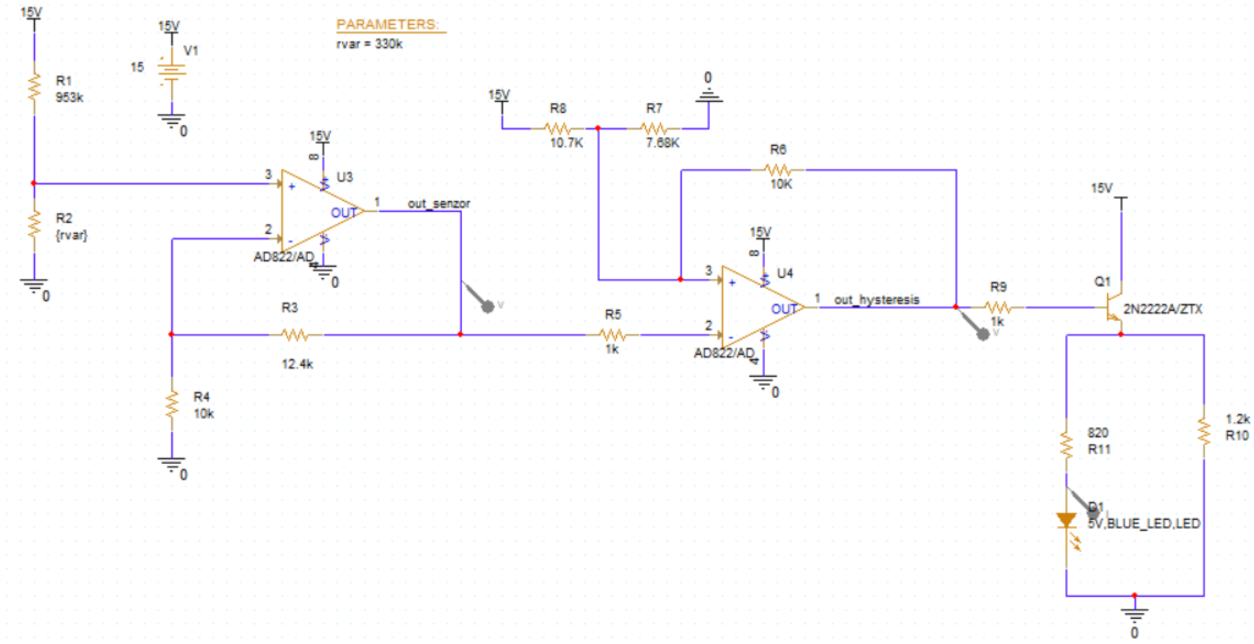


Figure 7. Initial Working Schematic

4.1 The Table of Values for the Components

For those values I used a computation software that gave me standard values for the resistors from the E96 series. I choose this series of resistors because they have a small tolerance of 1%.

Component Name	**Calculated Value**	**Standard Value**
R1	R1 = 953 kΩ	953kΩ
R2	R2 = 330 kΩ	332kΩ
R3	R3 = 12.4 kΩ	12.4kΩ
R4	R4 = 10 kΩ	10kΩ
U3	AD822 (OpAmp)	-
R5	R5 = 1 kΩ	1kΩ
R6	R6 = 10 kΩ	10kΩ
R7	R7 = 7.68 kΩ	7.68kΩ
R8	R8 = 10.7 kΩ	10.7kΩ
R9	R9 = 1 kΩ	1kΩ
Q1	2N2222A (NPN transistor)	-
R10	R10 = 1.2 kΩ	1.21kΩ
R11	R11 = 820 Ω	825Ω
D1	D1 = 5V Blue LED	-
U4	AD822 OpAmp	-

The values are the same or very close to the closest standard value that exists. The final working schematic looks like this:

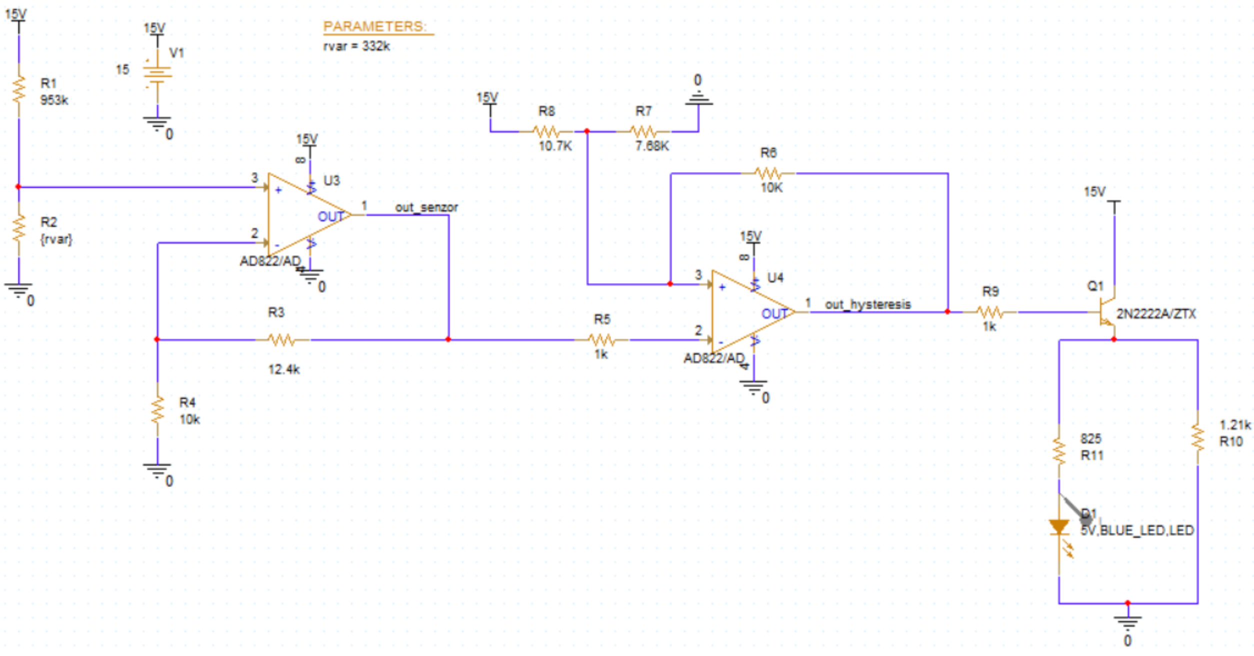


Figure 8. Final Working Schematic with Standard Values for the Components

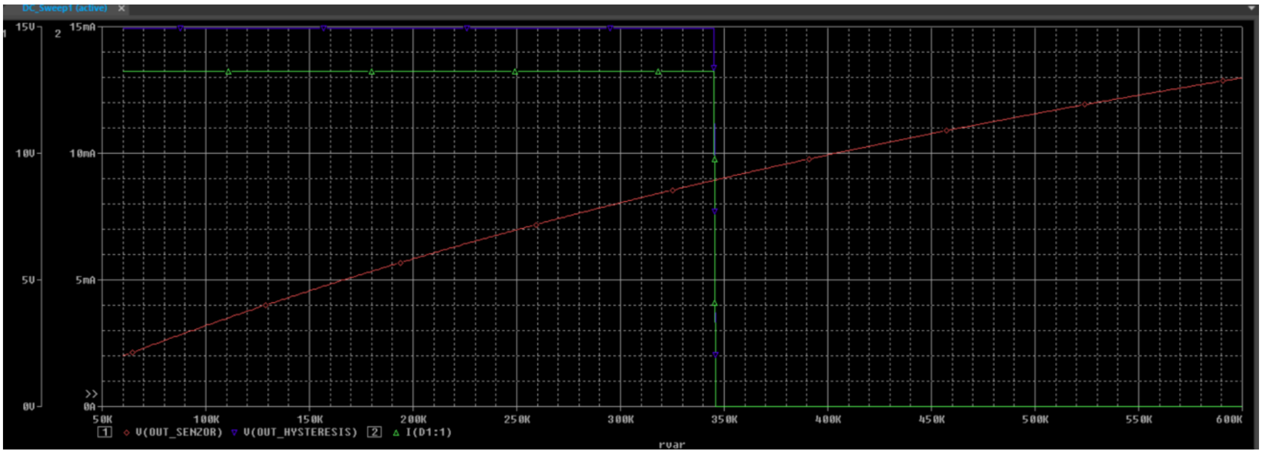


Figure 9. DC_Sweep simulation

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