Circuit Simulation Project

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Title of the circuit: Design and Simulation of an Op-Amp Based Soil Moisture Monitoring and Irrigation Control System Using eSim

Theory:

Efficient irrigation requires accurate sensing of soil moisture to avoid over-watering or under-watering. This project presents the design and simulation of an op-amp based soil moisture monitoring and irrigation control system using eSim. Soil moisture is modelled as a variable resistance, and based on its value, a motor (irrigation pump) and LED indicator are automatically controlled.

1. Soil Sensor and Signal Conditioning
The soil moisture sensor is modelled as a variable resistor:

- 1 kΩ for wet soil
- 50 kΩ for dry soil

This resistance forms a voltage divider whose output varies with moisture content.

2. Low-Pass Filter Stage
The amplified sensor signal is passed through an RC low-pass filter formed by R3 and C1. This stage removes high-frequency noise and fluctuations caused by soil contact irregularities and environmental interference. The filter ensures that only slow, meaningful changes in soil moisture are processed, improving reliability and preventing false triggering of the control circuit.

3. Comparator Stage
The filtered signal is applied to a second op-amp configured as a comparator. A fixed reference voltage is applied to the other input. A reference voltage of 2 volts is used for comparison.

- When dry soil (50 kΩ) is sensed, the filtered voltage exceeds the reference, and the comparator output V(o3) goes positive.
- When wet soil (1 kΩ) is sensed, the filtered voltage remains below the reference, and V(o3) goes low or negative.

This stage makes a clear decision on whether irrigation is required.

4. Motor Driver and Indicator Circuit
The comparator output drives an NPN transistor motor driver stage.

- For dry soil, V(o3) is positive, turning the transistor ON, supplying approximately 10 V to the motor, and the LED glows, indicating irrigation is active.
- For wet soil, V(o3) is low, the transistor remains OFF, only a few millivolts appear across the motor, confirming it is OFF, and the LED remains OFF, indicating irrigation is not required.

Schematic Diagram:

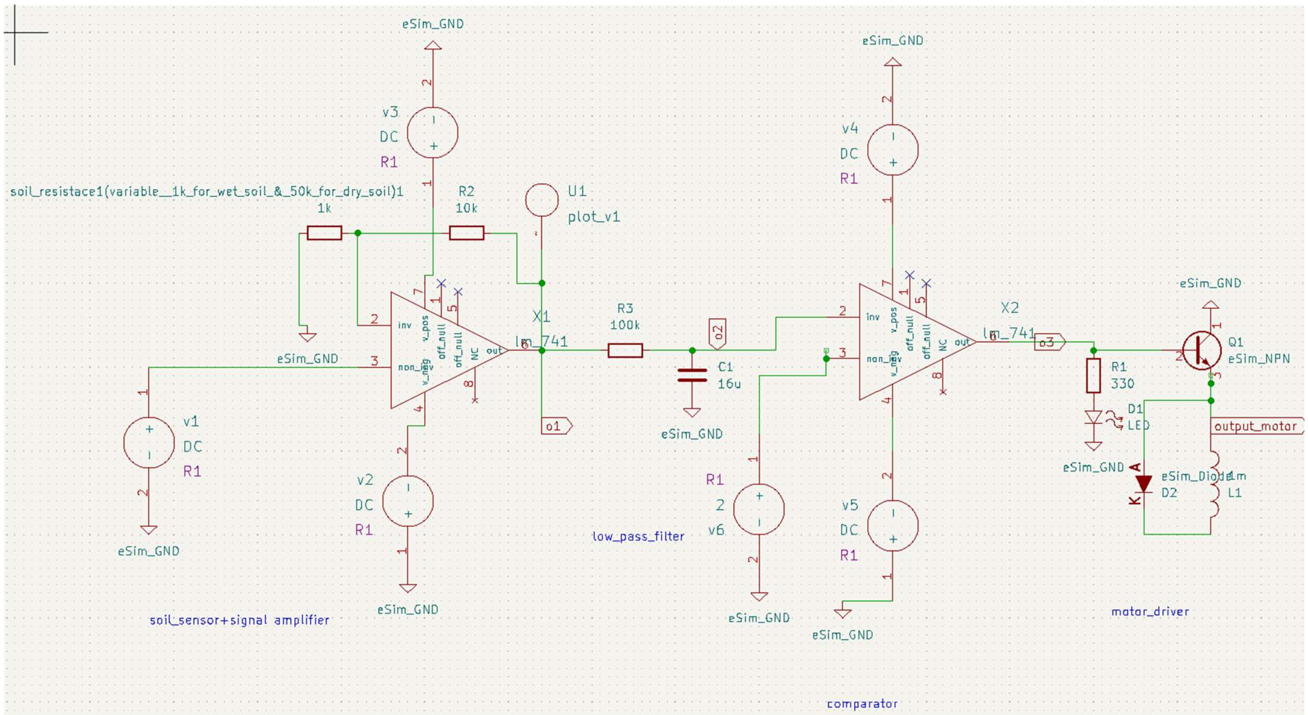

Figure 1:eSim schematic

Results (Input, Output waveforms and/or Multimeter readings):

The simulation results in eSim would show a clear change in comparator output with soil moisture variation. For **dry soil**, the comparator output goes HIGH, turning ON the LED and activating the irrigation pump. For **wet soil**, the comparator output goes LOW, switching OFF the LED and stopping the pump.

- Soil resistance=50 kΩ (for dry soil)

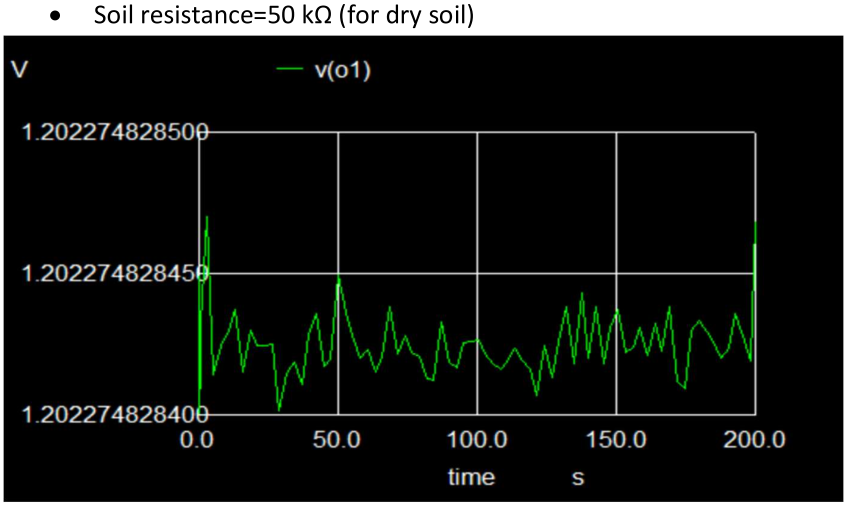

Figure 2: ngspice waveform of the sensor signal

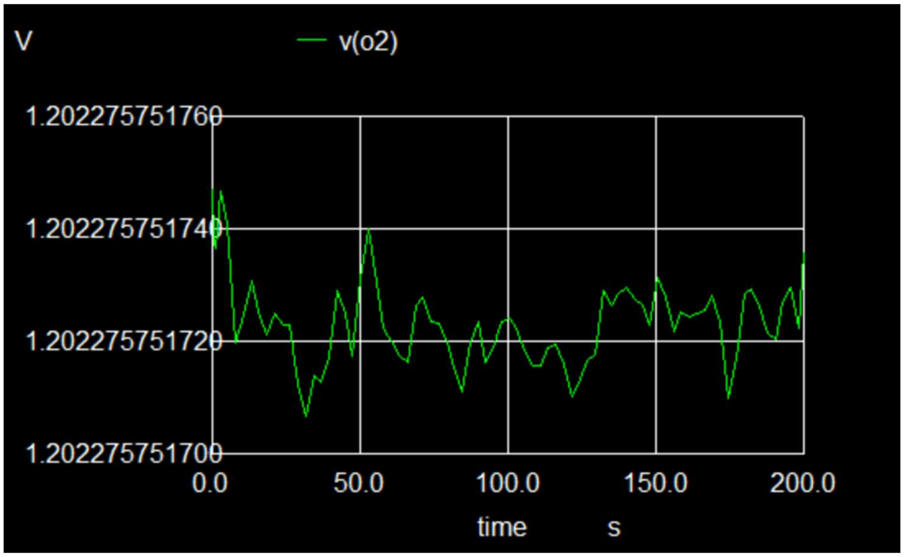

Figure 3: ngspice waveform after low pass filter

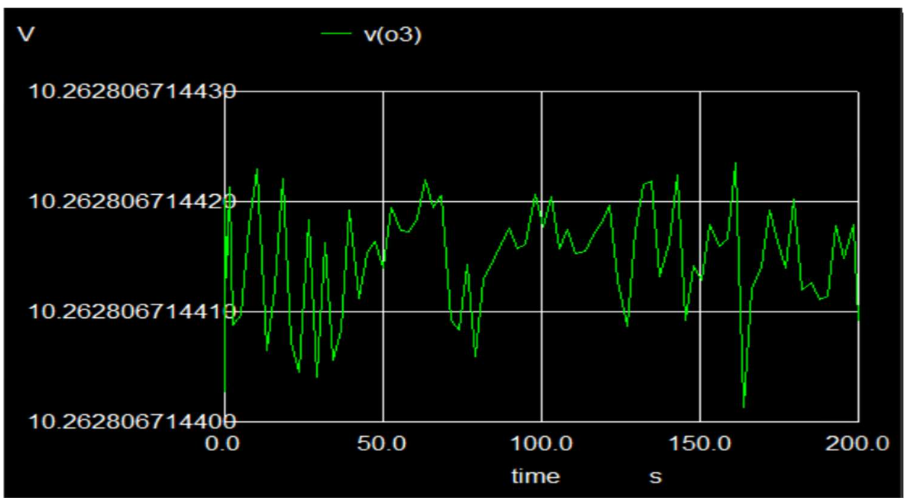

Figure 4:ngspice waveform of comparator

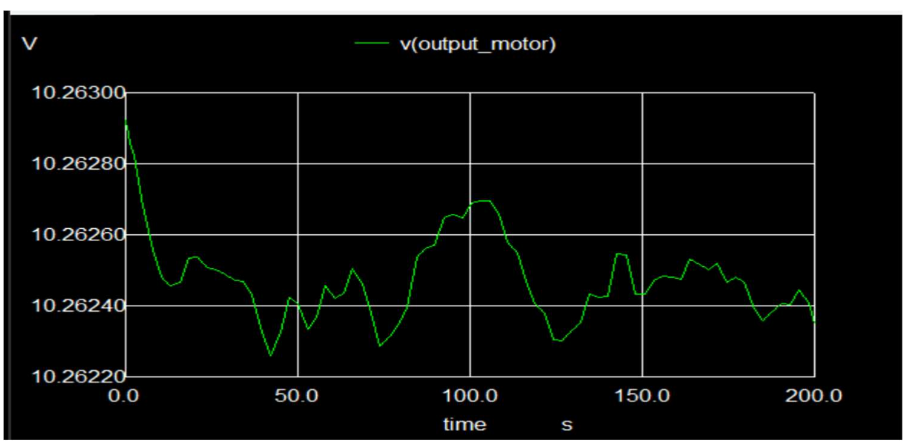

Figure 5:ngspice waveforms of motor (10 v-indicating ON)

- Soil resistance=1 kΩ (for wet soil)

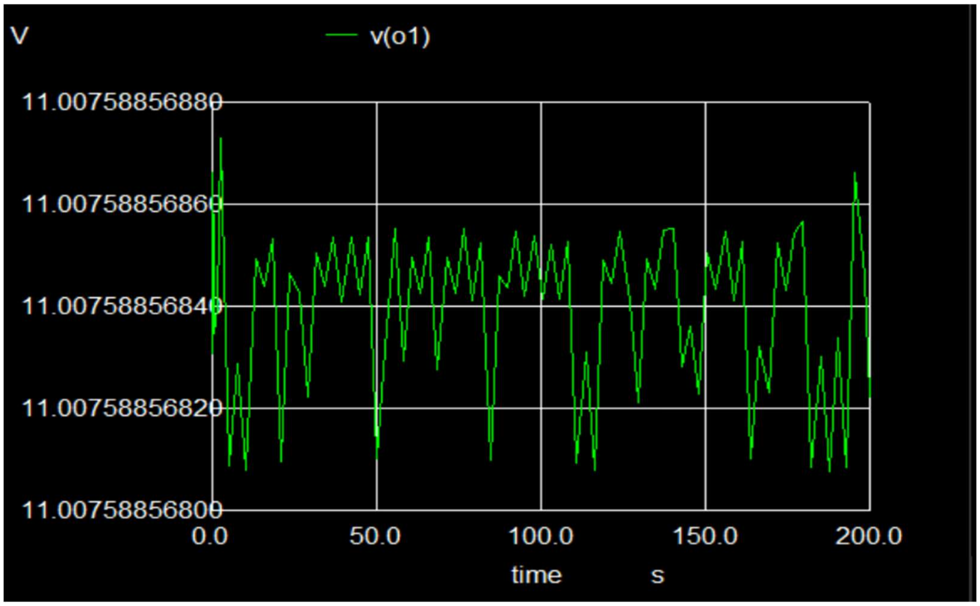

Figure 6: ngspice waveform of the sensor signal

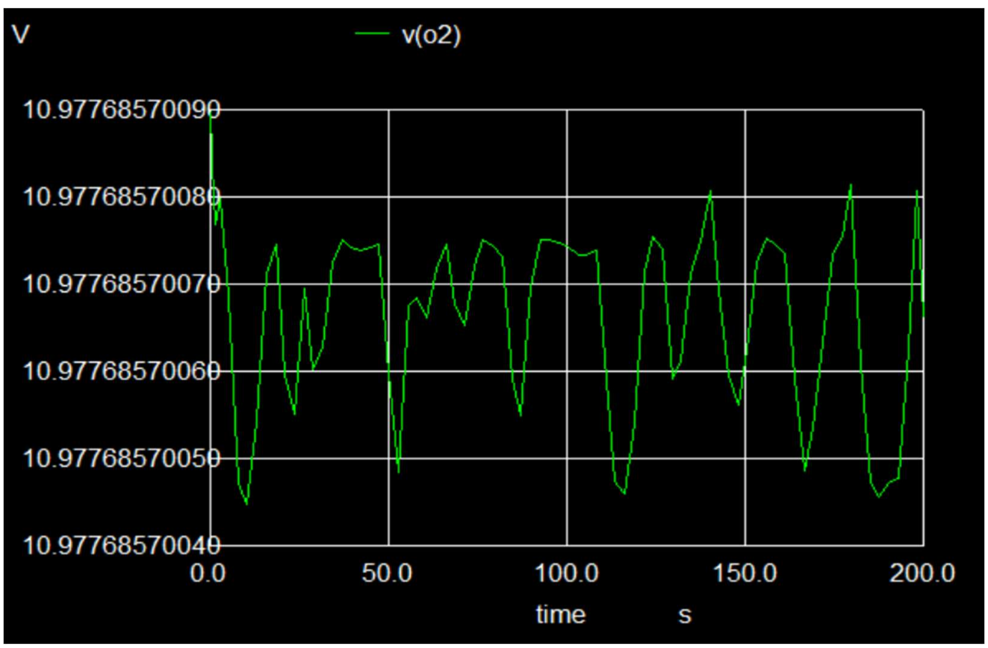

Figure 7: ngspice waveform after low pass filter

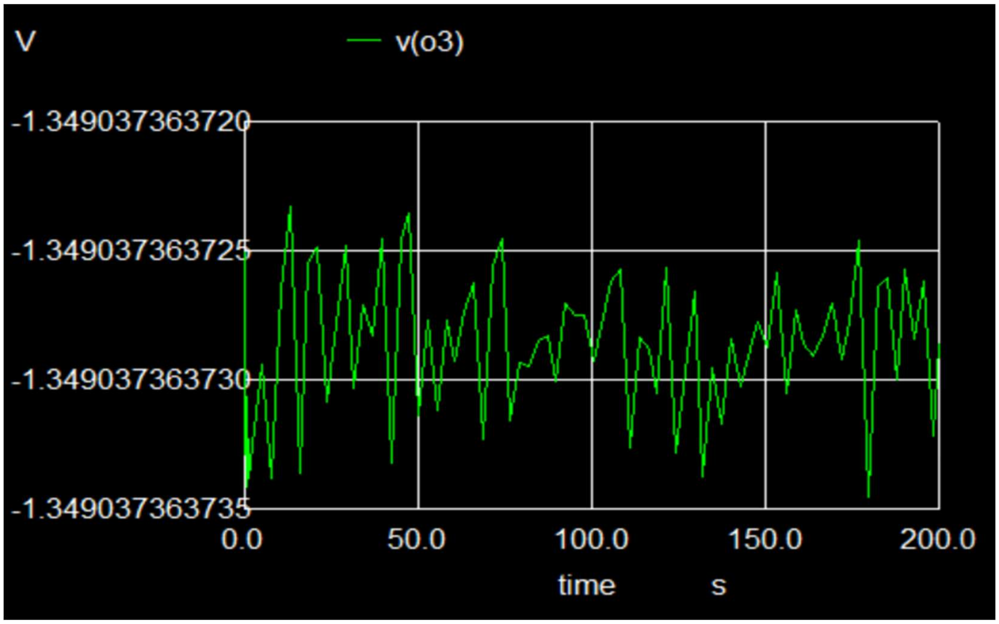

Figure 8: ngspice waveform of comparator

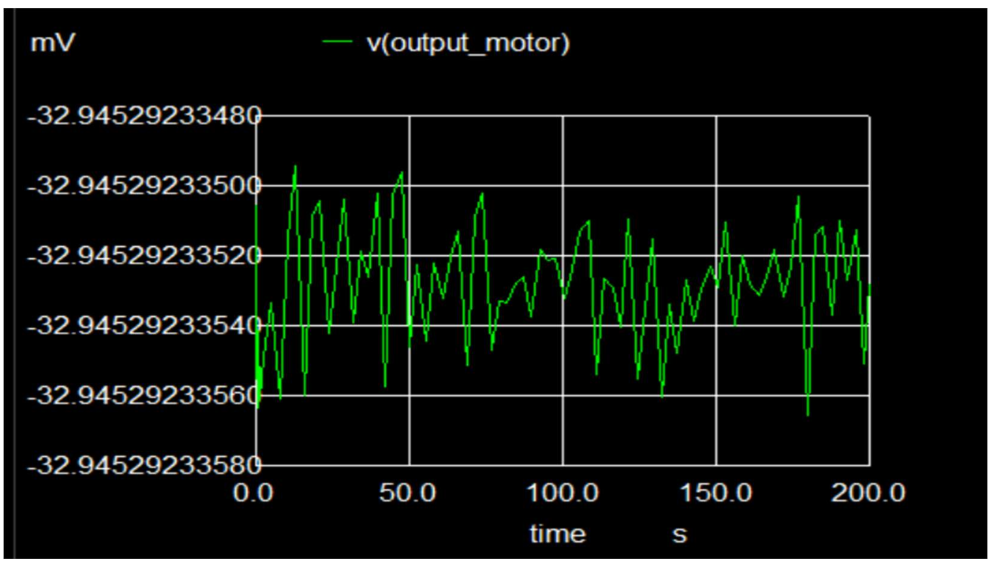

Figure 9: ngspice waveform for motor (few mv-indicating OFF)

Conclusion:
The designed circuit successfully demonstrates an automatic irrigation control system using op-amps. The system accurately distinguishes between wet and dry soil conditions using resistance variation, filters noise effectively, and makes reliable decisions using a comparator. The motor and LED outputs clearly indicate irrigation status. The project proves that low-cost analog components can be effectively used for soil moisture monitoring and control.

Source/Reference(s):

- Ramakant A. Gayakwad, *Op-Amps and Linear Integrated Circuits*, Pearson Education.
- FOSSEE Team, IIT Bombay, *eSim User Manual and Ngspice Simulation Documentation.*
- Wikipedia – Soil moisture sensor
- Using IC 741 to Make Soil Moisture Tester Circuit – Making Easy Circuits