DESIGN AND SIMULATION
OF AN FSR-BASED GRIP STRENGTH MONITORING SYSTEM USING ESIM

FOSSEE ESIM SEMESTER LONG INTERNSHIP AUTUMN 2026

ABSTRACT & SIMULATION REPORT

TASK 3

REPORT BY

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ABSTRACT:

Grip strength is an important parameter used to assess hand function during physiotherapy, rehabilitation, post-operative recovery, and muscle strength evaluation. This project presents the design and simulation of an FSR-Based Grip Strength Monitoring System using Analog electronic circuits. The proposed system employs a **Force Sensitive Resistor (FSR)** as the sensing element, where the resistance varies according to the applied grip force. The sensor resistance is converted into a corresponding voltage using a voltage divider circuit, providing an electrical representation of the applied grip. Since the generated voltage is relatively small, it is amplified using an **LM741 operational amplifier** to obtain a suitable signal level for further processing while preserving the relationship between the sensor output and the applied force.

The amplified signal is processed using **LM393 voltage comparators**, where it is compared with predefined reference voltages to classify the grip strength into three categories: **low**, **medium**, and **high**. The comparator outputs are interfaced with transistor switching circuits that drive three LED indicators corresponding to each grip level. The LEDs provide a simple visual indication of the comparator output, while the performance of the proposed circuit is primarily evaluated through waveform analysis obtained from circuit simulation.

The complete system has been designed and analysed by dividing the circuit into four functional stages: voltage divider, signal amplification, voltage comparison, and transistor switching with LED indication. Each stage has been simulated independently to verify its operation before integrating the complete circuit. For simulation and verification, a representative **FSR resistance value** was considered to emulate a **fixed** grip condition, while **predefined reference voltages** were selected to demonstrate the threshold-based classification process. The operation of each stage was verified by observing the corresponding voltage waveforms, confirming the expected behaviour of the Analog signal processing chain.

The simulation results demonstrate that the voltage divider converts the sensor resistance into a measurable voltage, the amplifier provides the required signal amplification, the comparator stages switch accurately at the selected threshold voltages, and the transistor circuits successfully drive the corresponding output indicators. The stage-wise waveform analysis verifies the correct operation of the complete circuit and confirms the feasibility of the proposed Analog design.

COMPLETE SCHEMATIC DIAGRAM:

The complete schematic diagram of the proposed FSR-Based Grip Strength Monitoring System is shown in Figure. The circuit integrates the voltage divider, signal amplification, voltage comparison, and transistor switching stages into a single analog system.

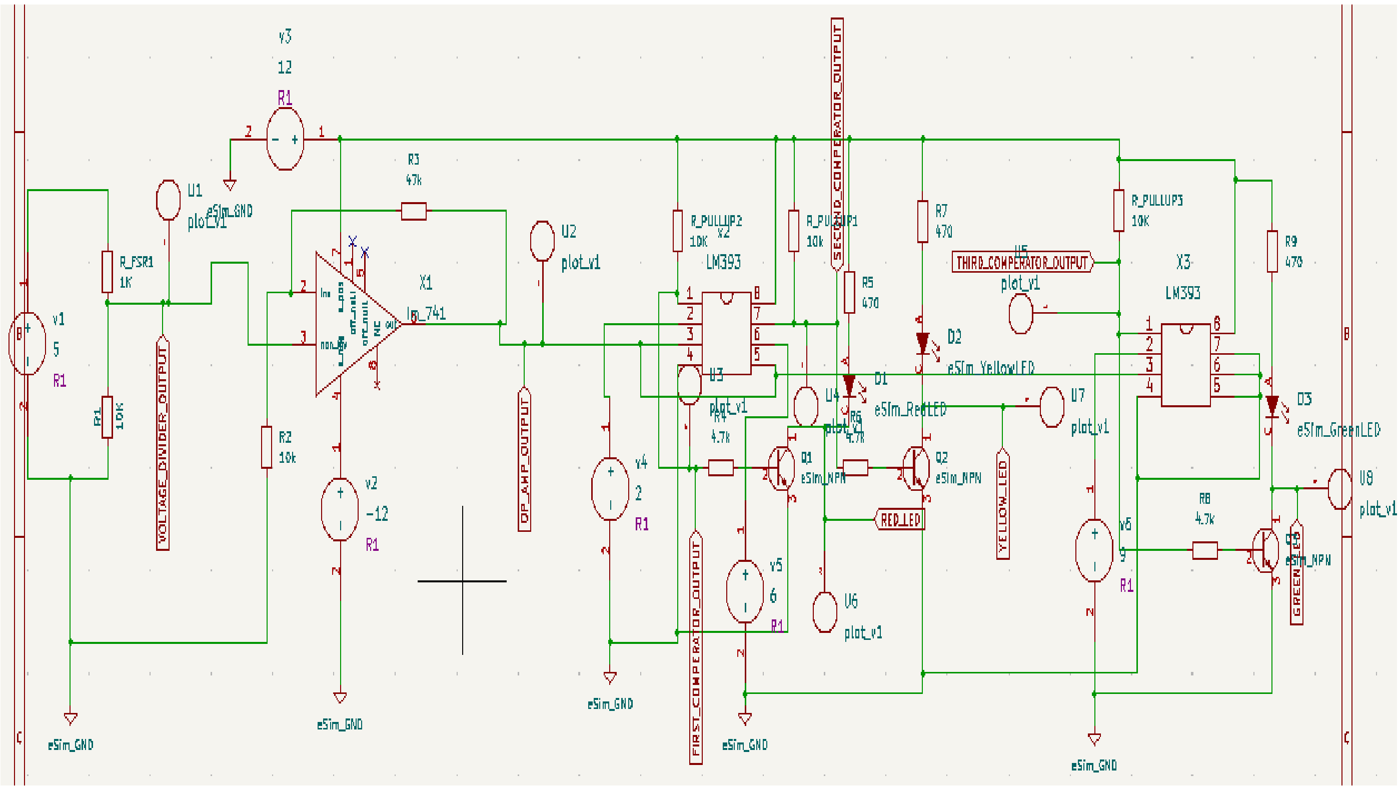

Figure: Complete schematic diagram of the proposed FSR-Based Grip Strength Monitoring System.

CIRCUIT DESIGN STAGES:

- VOLTAGE DIVIDER STAGE.
- LM741 OPERATIONAL AMPLIFIER STAGE.
- LM393 VOLTAGE COMPARATOR STAGE.
- TRANSISTOR SWITCHING STAGE.

VOLTAGE DIVIDER STAGE:

1.OBJECTIVE:

To convert the resistance variation of the Force Sensitive Resistor (FSR) into a corresponding voltage for further signal processing.

2.COMPONENTS LIST:

SI NO	COMPONENT NAME	VALUE	QUANTITY
1	FSR RESISTOR (VALUE FIXED)	1 Kohm	1
2	RESISTOR(FIXED)	10 Kohm	1
3	DC VOLTAGE SOURCE	5 volts	1
4	GROUND	----	1

3.DESIGN EQUATION:

$$V_{OUT} = VCC \times R(FIXED)/(R(FSR)+R(FIXED)).$$

4.SIMULATED WAVE FORM:

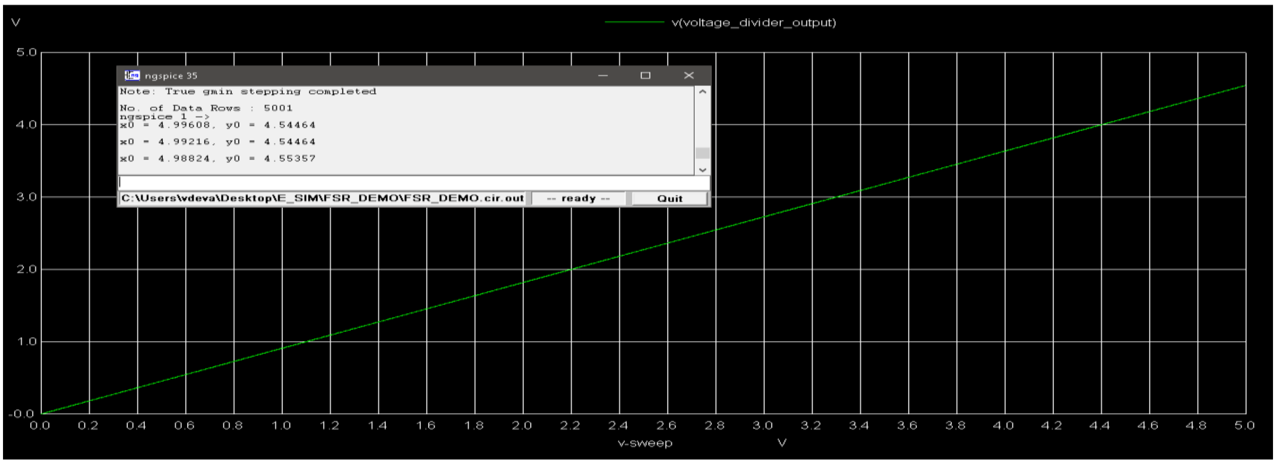

Figure 1:Voltage across the R(fixed)Resistor

5.ANALYSIS:

The voltage divider converts the selected FSR resistance into a corresponding output voltage. The simulation waveform verifies the expected output voltage, confirming the correct operation of the sensing stage.

6.RESULT:

- THEORETICAL OUTPUT= **4.545** v(calculated).
- SIMULATED OUTPUT=**4.5 v** (approximately).

LM741 OPERATIONAL AMPILIFER STAGE:

1.OBJECTIVE:

To amplify the voltage obtained from the voltage divider stage to a suitable level for threshold comparison.

2.COMPONENTS LIST:

SI NO	COMPONENT NAME	VALUE	QUANTITY
1	LM741 OPERATIONAL AMPIFIER	IC	1
2	INPUT RESISTOR (R1)	10 Kohm	1
3	FEEDBACK RESISTOR (R2)	47 Kohm	1
4	DC SUPPLY	12 volts	1
5	GROUND	----	1

3.DESIGN EQUATION:

- For the non-inverting amplifier, A_v (Gain) = 1 + (R2/R1).
- The output voltage is given by, V(out)=A_V x v(input).

4.SIMULATED WAVEFORM:

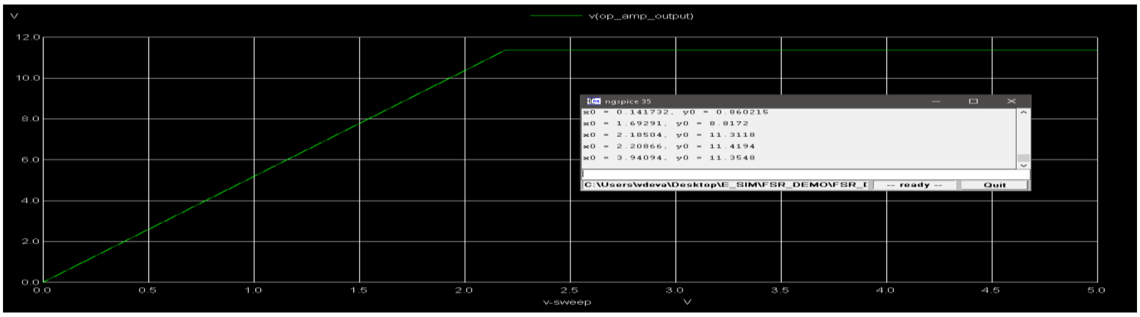

Figure 2:Output of LM741 Amplifier

5.ANALYSIS:

The LM741 operational amplifier amplifies the voltage obtained from the voltage divider stage according to the designed gain.

6.RESULT:

- THEORETICAL OUTPUT= gain x vin=> 5.7*vin=5.7*4.5=25.91V.
- PRACTICAL OUTPUT => LM741 saturates near **11.35V(since our supply is 12v).**
- **NOTE**: The LM741 output increases according to the calculated gain and saturates at approximately **11.35 V** due to the +12 V supply limitation, matching the simulation results.

LM393 VOLTAGE COMPARATOR STAGE:

1.OBJECTIVE:

To compare the amplified sensor voltage with predefined threshold voltages and classify the grip strength into different levels.

2.COMPONENTS LIST:

SI NO	COMPONENT NAME	VALUE	QUANTITY
1	LM393 VOLTAGE COMPARATOR	IC	2
2	PULL UP RESISTOR	10 Kohm	3
3	DC SUPPLY	12 volts	1
4	THRESHOLD VOLTAGES	(2v,6v,9v)	1(each)
5	GROUND	-----	1

3.DESIGN EQUATION:

The comparator output is determined by comparing the input voltage with the threshold voltage:

$$V(output) = HIGH, \{V(input)>V(threshold)\}$$

$$=LOW, \{V(input)<V(threshold)\}$$

where:

- V(input)= Amplified sensor voltage
- V(threshold)= threshold(reference) voltage

4.SIMULATED WAVEFORMS:

FIRST VOLTAGE COMPARATOR:

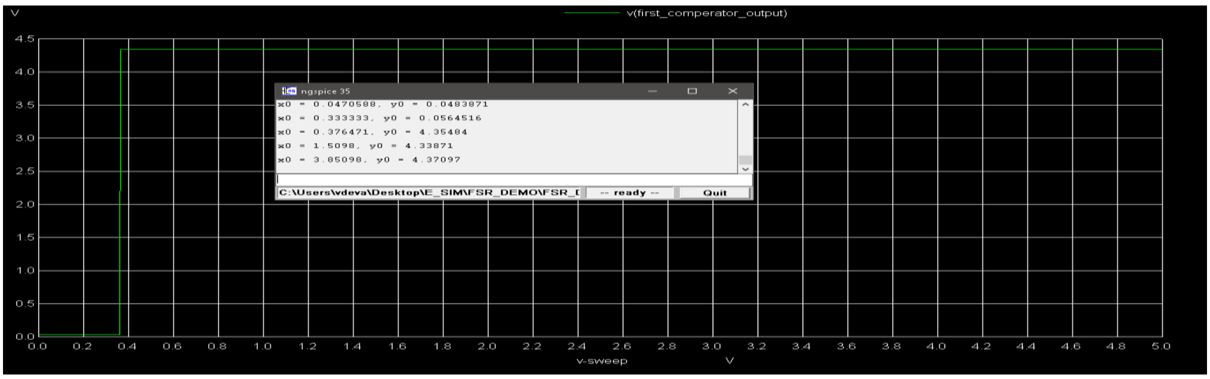

Figure 3:First Voltage Comparator

SECOND VOLTAGE COMPARATOR:

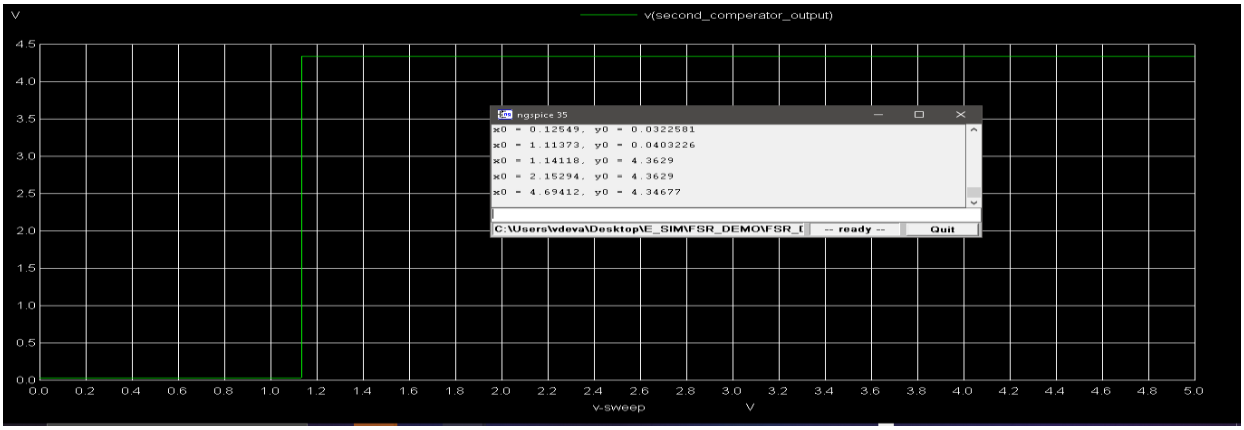

Figure 4:Second Voltage Comparator

THIRD VOLTAGE COMPARATOR:

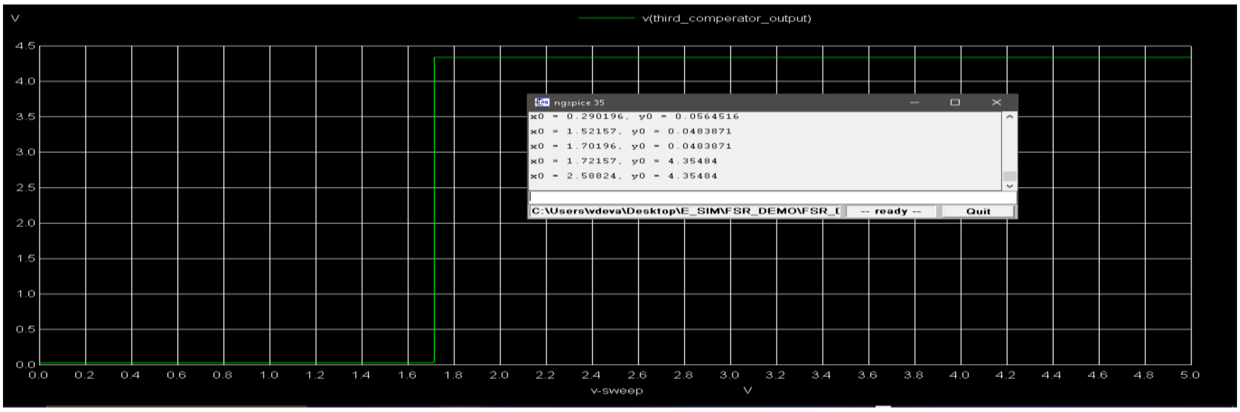

Figure 5:Third Voltage Comparator

5.ANALYSIS:

The LM393 voltage comparator switches its output when the amplified input voltage crosses the predefined reference voltage. The simulation waveforms verify the threshold-based switching operation, confirming the correct functioning of the comparator stage.

6.RESULT:

Simulated output voltages of all comparators ≈ 4.35 V, due to the loading effect of the 4.7kohm base resistor connected to the transistor input.

- Comparator 1 switches around **0.35 V** (since threshold voltage is 2v).
- Comparator 2 switches around **1.15 V** (since threshold voltage is 6v).
- Comparator 3 switches around **1.72 V** (since threshold voltage is 9v).

NOTE: Although the pull-up supply is 12 V, the simulated output is approximately 4.35 V due to the loading of the 4.7kohm transistor base resistor connected to the comparator output.

TRANSISTOR SWITCHING STAGE:

1.OBJECTIVE:

To verify the transistor switching operation using the output of the LM393 voltage comparator and analyse the corresponding simulation waveform.

2.COMPONENT LIST:

SI NO	COMPONENT NAME	VALUE	QUANTITY
1	NPN TRANSISTOR	----	3
2	LED (RED, YELLOW, GREEN)	----	3
3	CURRENT LIMITING RESISTOR	470 ohm	3
4	BASE RESISTOR	4.7 Kohm	3
5	DC SUPPLY	12volts	1
6	GROUND	---	1

3.OPERATION PRINCIPLE:

The transistor receives the output signal from the LM393 voltage comparator through a base resistor. Based on the comparator output, the transistor operates as a switching element, allowing the corresponding output indication circuit to respond.

4.SIMULATED WAVEFORMS:

NOTE: "LEDS WILL TURN ON WHEN COLLECTOR VOLTAGES IS ZERO SINCE THE CATHODE OF LEDS ARE CONNECTED TO COLLECTOR TERMINALS ".

RED LED:

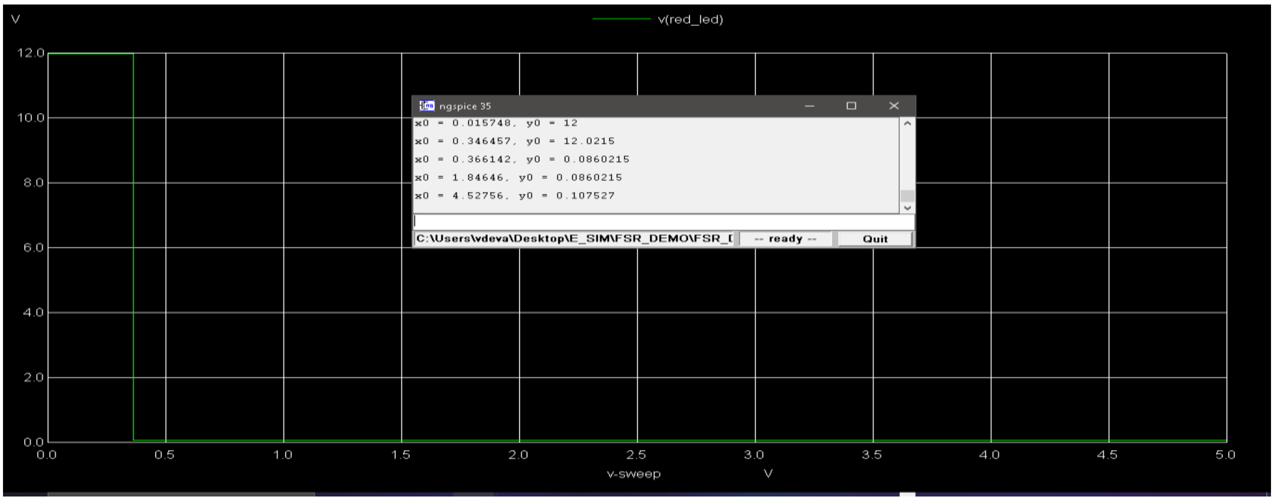

Figure 6: Collector Voltage of 1st Transistor

YELLOW LED:

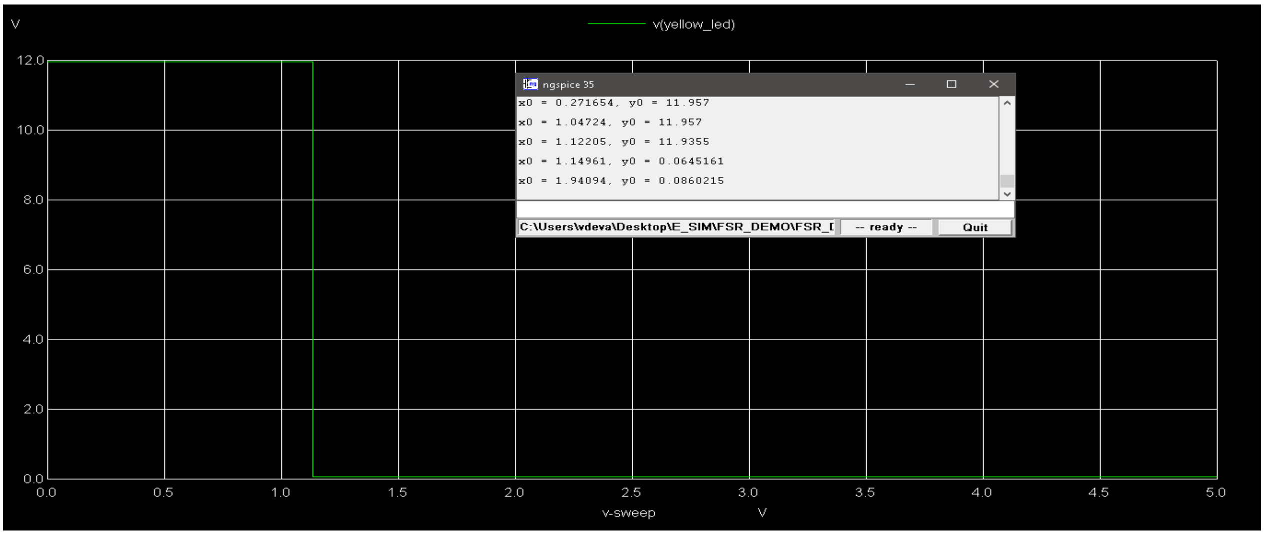

Figure 7:Collector voltage of 2nd Transistor

GREEN LED:

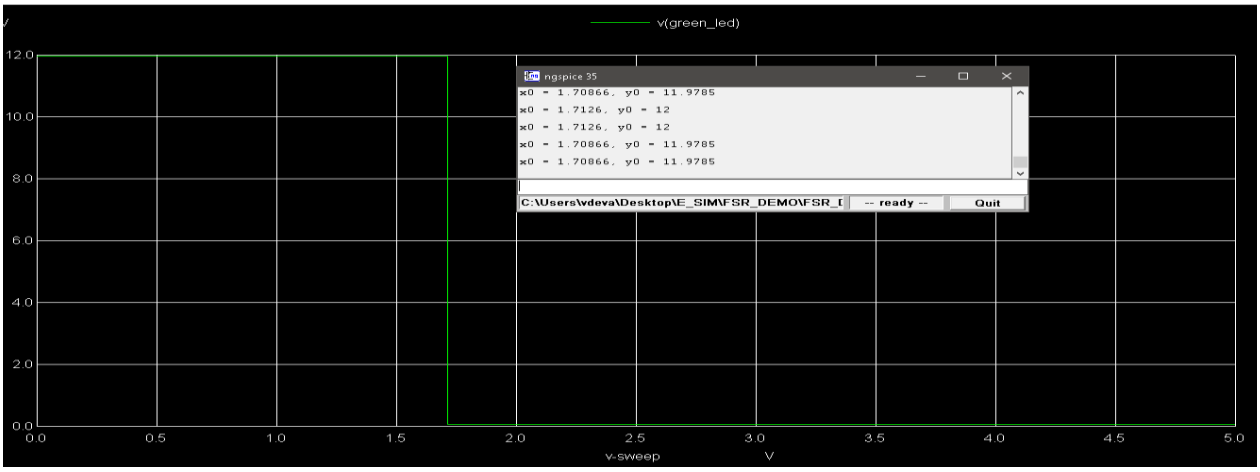

Figure 8:Collector Voltage of 3rd Transistor

5.ANALYSIS:

The simulated collector voltage transitions closely match the theoretical switching behaviour of the transistor, confirming the correct operation of the final output stage.

6.RESULT:

- RED LED TURN ON WHEN INPUT VOLTAGE(V-SWEEP) = 0.36v
- YELLOW LED TURN ON WHEN INPUT VOLTAGE(V-SWEEP) = 1.15 V
- GREEN LED TURN ON WHEN INPUT VOLTAGE(V-SWEEP) = 1.71 V
- **NOTE**: “LEDS WILL TURN ON WHEN COLLECTOR VOLTAGES IS ZERO SINCE THE CATHODE OF LEDS ARE CONNECTED TO COLLECTOR TERMINALS “.

FINAL RESULT:

SI NO	STAGE	RESULTS
1	VOLTAGE DIVIDER	V(OUT)=4.5V FOR R(FSR)=1Kohm, R(FIXED)=10kohm
2	LM741 AMPLIFIER	Gain=5.7, Output Saturates at 11.35v
3	LM393 COMPARATOR	Output switches according to threshold values
4	TRANSISTOR SWITCHING	Collector voltage switches from 12v to 0v

Under the selected simulation conditions, a representative FSR resistance and predefined threshold voltages were used, the complete circuit demonstrated the expected operation of the voltage divider, LM741 amplifier, LM393 comparator, and transistor switching stages. The theoretical calculations and simulated results showed close agreement under the selected simulation conditions, confirming the correct operation of each stage of the proposed circuit.

CONCLUSION:

The proposed **FSR-Based Grip Strength Monitoring System** provides a simple analog approach for representing grip force through electrical signal processing and threshold-based classification. The design combines sensor interfacing, signal amplification, voltage comparison, and transistor switching to form a complete circuit-level monitoring system.

The project demonstrates how fundamental analog electronic circuits can be integrated to develop a sensor-based application using eSim. It also provides a practical understanding of the relationship between sensor characteristics, signal conditioning, threshold selection, monitoring systems.

REFERENCES:

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[4] Texas Instruments, *LM393 Dual Differential Comparator Datasheet*, Texas Instruments. LM393 Product and Datasheet Page.