

DESIGN AND SIMULATION OF A SMART IOT BASED RAILWAY LEVEL CROSSING SAFETY AND CONTROL SYSTEM USING ESIM

FOSSEE ESIM SEMESTER LONG INTERNSHIP AUTUMN 2026
ABSTRACT & SIMULATION REPORT
TASK 3

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ABSTRACT:

Railway level crossings require reliable detection and control mechanisms to reduce the risk of accidents caused by trains approaching while road users are crossing the railway track. This project proposes a circuit-level simulation of an automatic railway level-crossing safety system using FOSSEE eSim. The system is developed in multiple functional circuit blocks and verified using SPICE transient simulations.

Circuit 1 generates a train-detection signal using a VPULSE source to represent the output of a train-detection sensor. The signal is labelled TRAIN_DETECTION and is used as the primary input to the control system. The simulated waveform is observed to verify the train-detection signal.

Circuit 2 receives the TRAIN_DETECTION signal and provides signal conditioning and transistor-based control. A BC547 transistor and LED driver stages are used to demonstrate the response of the control circuit when a train is detected. The circuit is powered using a 5 V supply and includes appropriate resistors for current limiting and transistor operation.

Circuit 3 extends the detection/control section toward the railway-crossing warning function. The detected-train condition is used to activate visual warning indicators, allowing the system response to be observed through SPICE simulation.

Circuit 4 represents the automatic crossing-control stage. The conditioned train-detection signal is used to control the corresponding output/indicator stage, demonstrating how the crossing can respond automatically when a train approaches. The different circuit stages are interconnected using labelled SPICE nets so that their behaviour can be verified without unnecessarily duplicating signal sources.

The complete system is evaluated using transient SPICE simulations under different input conditions. The simulation waveforms are used to verify train detection, signal propagation, transistor switching, warning indication, and the response of the control stage. The project demonstrates how a railway level-crossing safety concept can be modelled and verified at circuit level using FOSSEE eSim and its SPICE simulation environment.

Keywords: Railway Level Crossing, Train Detection, Automatic Warning System, Transistor Switching, BC547, LED Indicator, SPICE, eSim, FOSSEE.

COMPLETE SCHEMATIC DIAGRAM:

The complete schematic diagram of the proposed Smart IoT Based Railway Level Crossing Safety and Control System is shown in the figure below. The circuit integrates the train-detection stage, signal conditioning and transistor driver stage, warning indication stage, and crossing control/output stage into a single interconnected system.

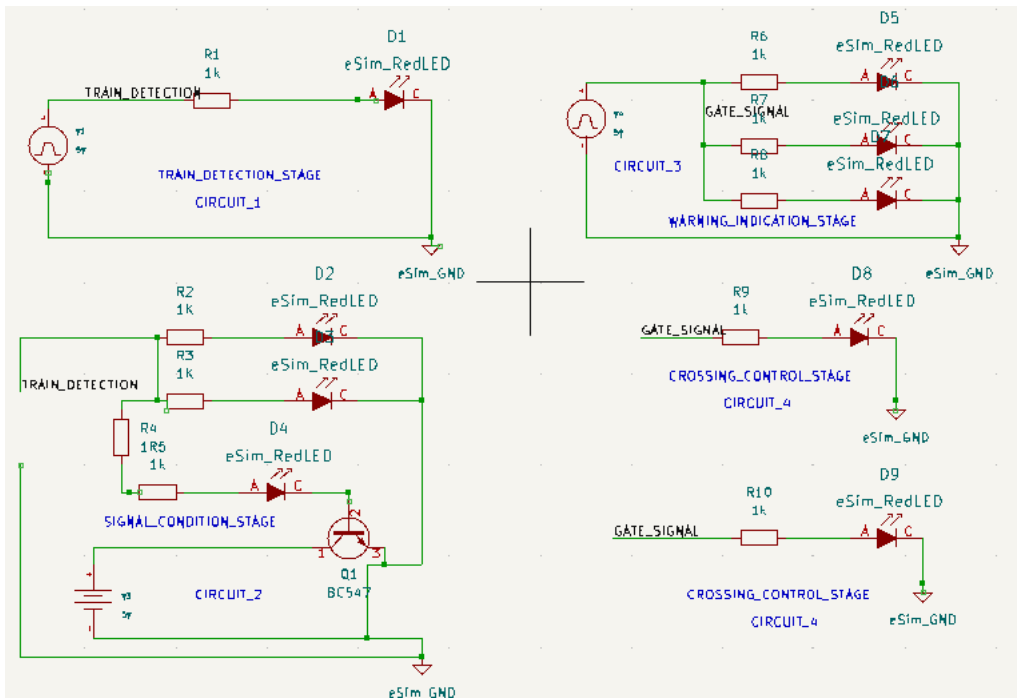


Figure: Complete schematic diagram of the proposed Railway Level Crossing Safety System.

CIRCUIT DESIGN STAGES:

STAGE	NAME	PURPOSE
Circuit 1	Train Detection (Sensor) Stage	Represents the sensor output using a VPULSE source and generates the TRAIN_DETECTION signal.
Circuit 2	Signal Conditioning & Transistor Driver Stage	Conditions the detection signal and uses a BC547 transistor to drive the LED indicators.
Circuit 3	Warning Indicator Stage	Activates visual warning indicators (red LEDs) when the GATE_SIGNAL is active.
Circuit 4	Crossing Control / Output Stage	Uses the GATE_SIGNAL condition to produce the final crossing-control output indication.

CIRCUIT 1 — TRAIN DETECTION (SENSOR) STAGE:

1. OBJECTIVE:

To generate a sensor-equivalent signal representing an approaching train and produce the TRAIN_DETECTION signal for the next stage.

2. COMPONENTS LIST:

SI NO	COMPONENT NAME	VALUE / MODEL	QUANTITY
1	VPULSE Source	0 – 5 V, Period = 2 s, PW = 1 s	1
2	Resistor (R1)	1 k Ω	1
3	Red LED (D1)	eSim_RedLED	1
4	Ground	----	1

3. OPERATION PRINCIPLE:

A VPULSE source (0 V $\rightarrow$ 5 V, rise/fall time 10 ms, pulse width 1 s, period 2 s) is used to emulate the sensor output. When the pulse goes HIGH, the TRAIN_DETECTION node becomes active and the corresponding LED (D1) indicates detection through the current-limiting resistor R1.

4. SIMULATED WAVEFORM:

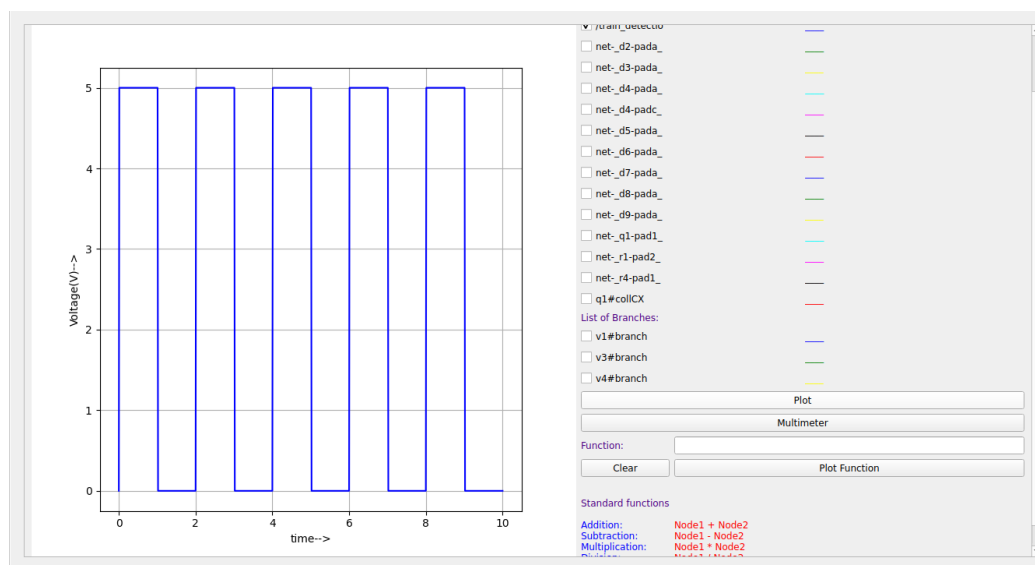


Figure 1: TRAIN_DETECTION signal waveform (VPULSE output).

5. ANALYSIS:

The waveform confirms that the VPULSE source correctly generates a repeating 0 V to 5 V pulse train with a period of 2 seconds and a pulse width of 1 second, matching the configured source parameters. This verifies the correct operation of the train-detection sensor stage.

6. RESULT:

- TRAIN_DETECTION signal amplitude = 0 V to 5 V (as configured).
- Pulse period = 2 s, Pulse width = 1 s, Rise/Fall time = 10 ms.
- LED D1 switches ON whenever TRAIN_DETECTION goes HIGH, confirming correct sensor-stage behaviour.

CIRCUIT 2 — SIGNAL CONDITIONING & TRANSISTOR DRIVER STAGE:

1. OBJECTIVE:

To receive the TRAIN_DETECTION signal, condition it, and use a BC547 transistor driver to control the LED indicator section (D2 and D4).

2. COMPONENTS LIST:

SI NO	COMPONENT NAME	VALUE / MODEL	QUANTITY
1	Resistor (R2, R3, R4)	1 k Ω each	3
2	Red LED (D2, D4)	eSim_RedLED	2
3	NPN Transistor (Q1)	BC547	1
4	DC Voltage Source	5 V	1
5	Ground	----	1

Resistor usage: R2 – D2 current limiting; R3 – D3 current limiting; R4 – BC547 base-current limiting.

3. OPERATION PRINCIPLE:

The TRAIN_DETECTION signal is applied through R4 to the base of BC547 (Q1). When TRAIN_DETECTION goes HIGH, Q1 switches ON, providing a conduction path that drives the LED nodes D2 and D4. The resulting node voltages follow the TRAIN_DETECTION pulse pattern.

4. SIMULATED WAVEFORM:

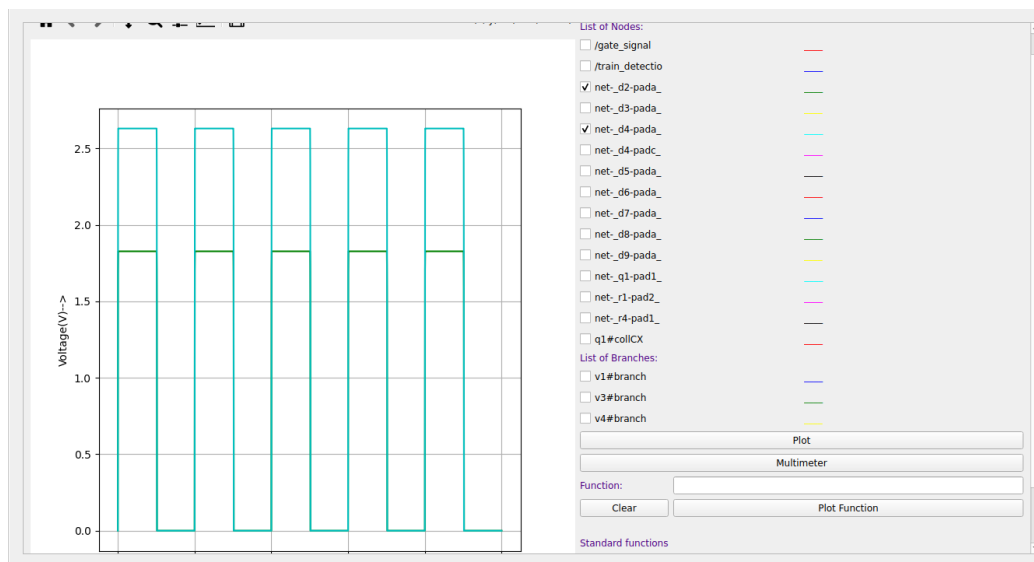


Figure 2: Waveform of D2 node (~2.85 V) and D4 node (~1.85 V), switching in synchronism with TRAIN_DETECTION.

5. ANALYSIS:

The D2 and D4 node waveforms switch HIGH and LOW in step with the TRAIN_DETECTION pulse, confirming that the BC547 transistor correctly conditions and switches the signal to drive the indicator LEDs. The two nodes settle at different peak voltages (~2.85 V for D2 and ~1.85 V for D4) due to the different resistor paths (R2 and R4) feeding each node.

6. RESULT:

- D2 node switches between 0 V and approximately 2.85 V.
- D4 node switches between 0 V and approximately 1.85 V.
- Both nodes switch synchronously with TRAIN_DETECTION, confirming correct BC547 switching action.

CIRCUIT 3 — WARNING INDICATOR STAGE:

1. OBJECTIVE:

To provide a clear visual warning through red LED indicators (D5, D6, D7) when the GATE_SIGNAL is active.

2. COMPONENTS LIST:

SI NO	COMPONENT NAME	VALUE / MODEL	QUANTITY
1	VPULSE Source (GATE_SIGNAL)	0 – 5 V pulse	1
2	Resistor (R6, R7, R8)	1 k Ω each	3
3	Red LED (D5, D6, D7)	eSim_RedLED	3
4	Ground	----	1

3. OPERATION PRINCIPLE:

The GATE_SIGNAL source drives three parallel LED branches (D5, D6, D7) through individual current-limiting resistors (R6, R7, R8). When GATE_SIGNAL is HIGH, all three warning LEDs switch ON together, providing a clear multi-point visual warning.

4. SIMULATED WAVEFORM:

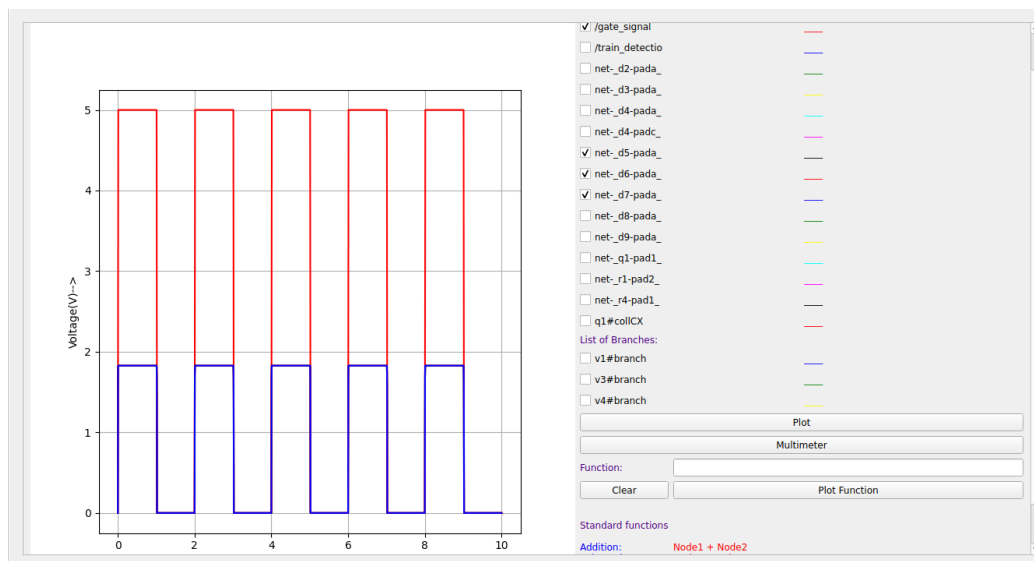


Figure 3: GATE_SIGNAL waveform (0–5 V, red trace) and the corresponding LED node response D5/D6/D7 (~1.8 V, overlapping traces).

5. ANALYSIS:

The LED nodes D5, D6 and D7 switch HIGH and LOW in direct synchronism with GATE_SIGNAL, confirming that the warning indicator stage responds correctly to the gate condition. The three LED branches behave identically since they are symmetric in resistor value and loading.

6. RESULT:

- GATE_SIGNAL switches between 0 V and 5 V, matching the configured VPULSE source.
- D5, D6 and D7 nodes switch to approximately 1.8 V whenever GATE_SIGNAL is HIGH.
- All three warning LEDs respond identically, confirming symmetric operation of the stage.

CIRCUIT 4 — CROSSING CONTROL / OUTPUT STAGE:

1. OBJECTIVE:

To convert the GATE_SIGNAL condition into the final railway-crossing control indication, representing the command to place the crossing in a safe (closed) state, using two parallel output blocks (D8 and D9).

2. COMPONENTS LIST:

SI NO	COMPONENT NAME	VALUE / MODEL	QUANTITY
1	Resistor (R9, R10)	1 k Ω each	2
2	Red LED (D8, D9)	eSim_RedLED	2
3	Ground	----	1

Input: GATE_SIGNAL Outputs: D8 node (GATE_CLOSE), D9 node (SAFE_OUTPUT)

3. OPERATION PRINCIPLE:

The GATE_SIGNAL is applied through R9 and R10 to two independent LED output branches, D8 and D9. When GATE_SIGNAL goes HIGH, both output LEDs switch ON simultaneously, representing the crossing-control output that commands the barrier/indicator to the safe (closed) state.

4. SIMULATED WAVEFORMS:

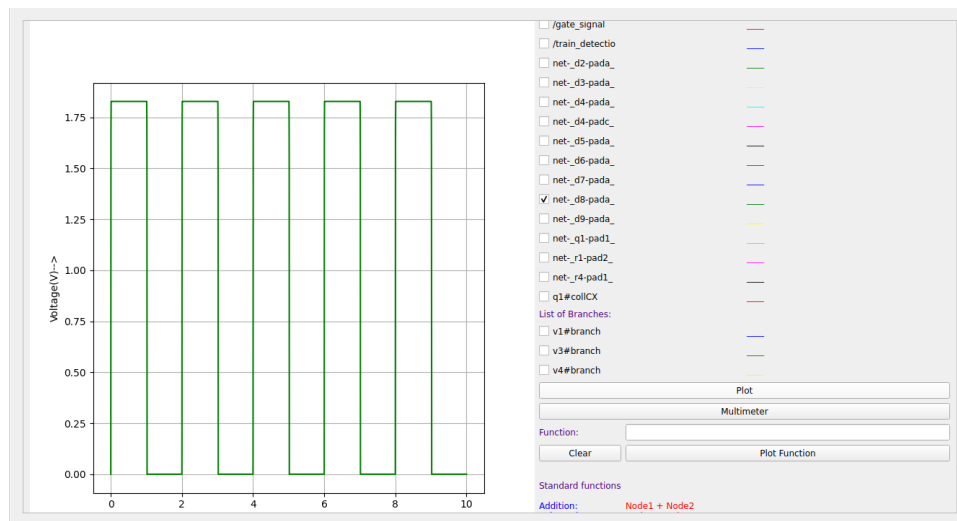


Figure 4: D8 node waveform (~1.85 V), switching with GATE_SIGNAL.

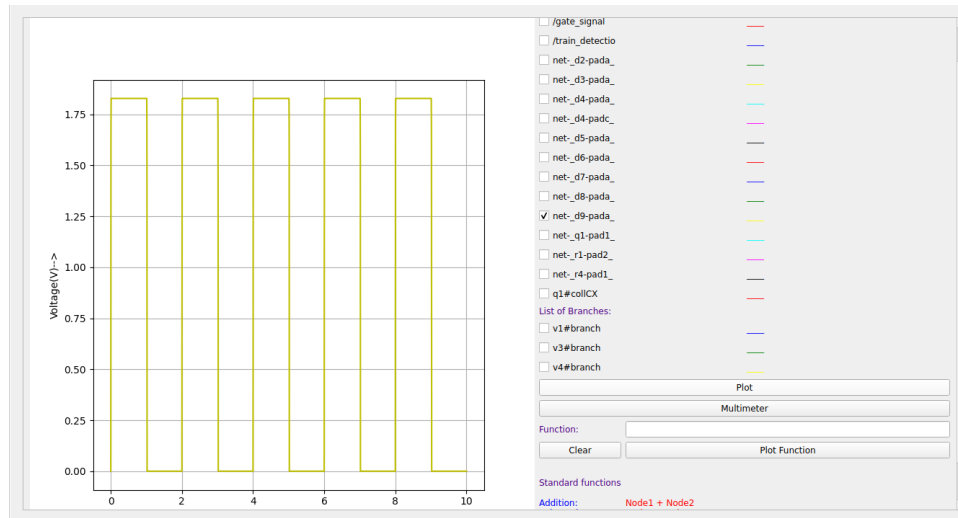


Figure 5: D9 node waveform (~1.85 V), switching with GATE_SIGNAL.

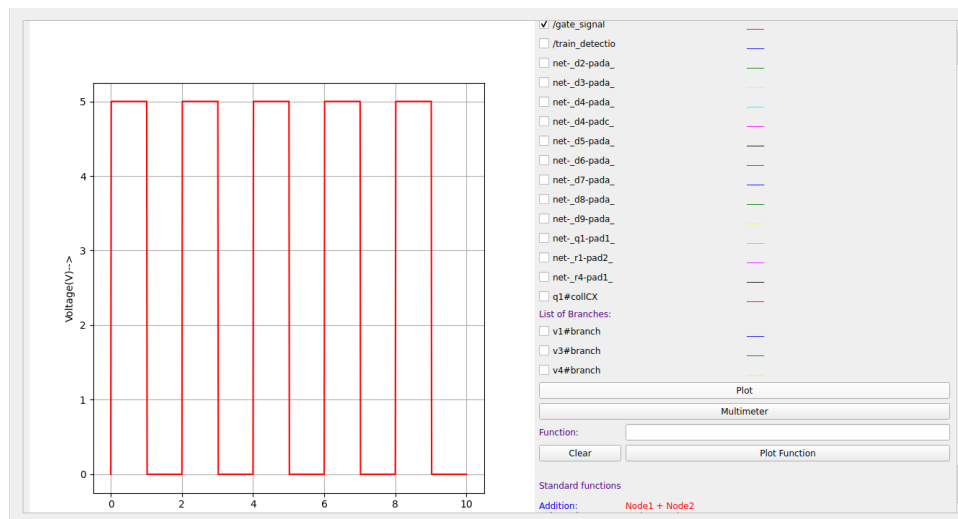


Figure 6: GATE_SIGNAL source waveform (0–5 V) driving Circuit 4.

5. ANALYSIS:

Both D8 and D9 node waveforms switch between 0 V and approximately 1.85 V in exact synchronism with GATE_SIGNAL, confirming that the crossing-control output stage correctly reflects the detected-train condition. The two output branches operate identically, verifying consistent switching behaviour across the final output stage.

6. RESULT:

- D8 node switches between 0 V and approximately 1.85 V, synchronised with GATE_SIGNAL.
- D9 node switches between 0 V and approximately 1.85 V, synchronised with GATE_SIGNAL.
- Both crossing-control outputs respond correctly and simultaneously to the detected-train condition.

FINAL RESULT:

Under the selected simulation conditions, representative VPULSE input signals were used to emulate the train-detection sensor and the gate-control trigger. The complete circuit demonstrated the expected operation of the train-detection stage, the signal-conditioning and transistor driver stage, the warning-indicator stage, and the crossing control/output stage. The simulated waveforms showed consistent and synchronized switching across all stages, confirming the correct operation of the proposed Smart IoT Based Railway Level Crossing Safety and Control System.

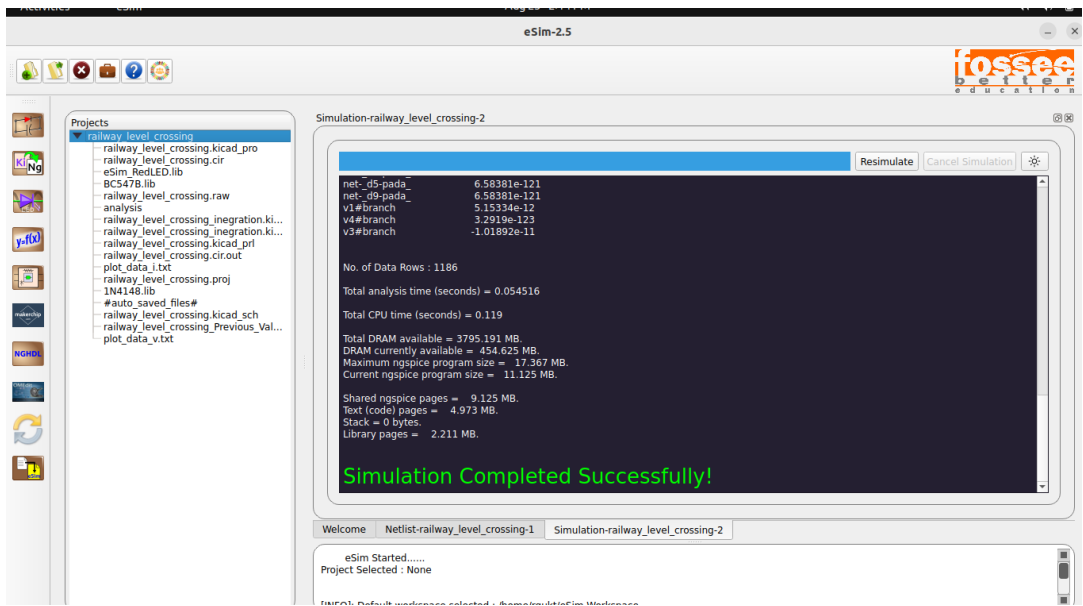


Figure 7: eSim/ngspice transient simulation log confirming successful completion of the complete railway level-crossing circuit simulation.

SI NO	STAGE	RESULTS
1	Train Detection Stage	TRAIN_DETECTION pulse: 0–5 V, Period = 2 s, PW = 1 s
2	Signal Conditioning & Driver Stage	D2 ≈ 2.85 V, D4 ≈ 1.85 V; BC547 switches in sync with TRAIN_DETECTION
3	Warning Indicator Stage	D5/D6/D7 nodes ≈ 1.8 V, switching in sync with GATE_SIGNAL
4	Crossing Control / Output Stage	D8 ≈ 1.85 V, D9 ≈ 1.85 V, both synchronised with GATE_SIGNAL

CONCLUSION:

The proposed Smart IoT Based Railway Level Crossing Safety and Control System demonstrates a simple circuit-level approach to train detection, signal conditioning, warning indication, and crossing control using analog and switching elements simulated in FOSSEE eSim. The design combines a sensor-equivalent VPULSE source, BC547 transistor-based signal conditioning, LED-based warning indication, and a dual-branch output/control stage to form a complete circuit-level safety-monitoring concept.

The project demonstrates how fundamental analog and switching circuits can be integrated to model a sensor-based railway safety application using eSim. It also provides a practical understanding of signal propagation, transistor switching, and threshold-based indication in a multi-stage circuit system.

REFERENCES:

- [1] FOSSEE, IIT Bombay, eSim: Open Source EDA Tool, FOSSEE, IIT Bombay – eSim Official Website and Documentation.
- [2] Texas Instruments / STMicroelectronics, BC547 NPN Transistor Datasheet.
- [3] ngspice – Open Source Mixed-Level/Mixed-Signal Circuit Simulator, User Manual.

BILL OF MATERIALS (COMPLETE COMPONENT SUMMARY):

COMPONENT	VALUE / MODEL	TOTAL QTY.
VPULSE Source	0–5 V	2
DC Voltage Source	5 V	1
Resistor	1 k Ω	9
Red LED	eSim_RedLED	7
NPN Transistor	BC547	1
Ground	eSim_GND	4+