Pulse Duration Detector

Objective

The goal of this project was to design, simulate, and verify an analog pulse duration detector circuit. The circuit's purpose is to detect whether an incoming digital pulse stays high longer than a specified time , and to turn ON an LED only if that condition is met.

The LED should:

- Remain **off** for short pulses
- Turn **on** when the pulse exceeds the threshold
- Turn **off immediately** when the input pulse ends
- Reset automatically for the next detection

Approach

1. Core Detection Strategy

We used an **RC charging network** combined with an **op-amp comparator** to monitor how long the input pulse remains high. If the RC voltage crosses a set reference threshold, the comparator output goes high — which then turns on a transistor driving the LED.

The key idea is:

- The capacitor voltage rises during the high pulse.
- If the pulse ends before the capacitor reaches the reference voltage, the LED remains off.
- If the capacitor crosses the threshold (indicating a long pulse), the comparator triggers the LED.
- A discharge transistor resets the capacitor immediately when the pulse ends.

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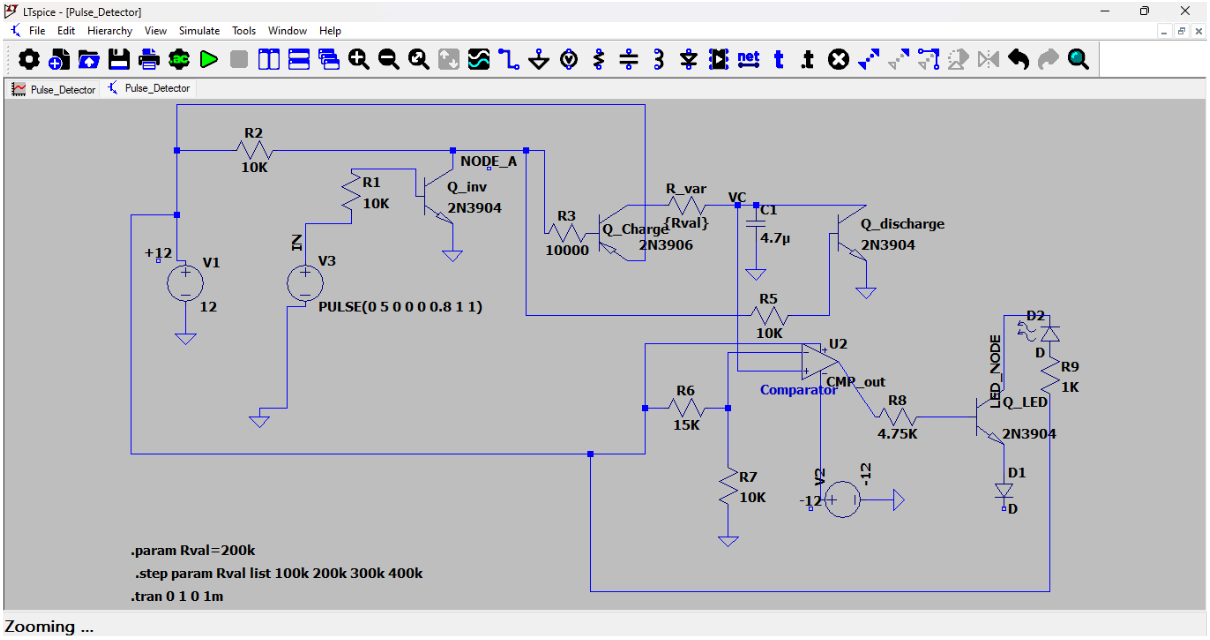
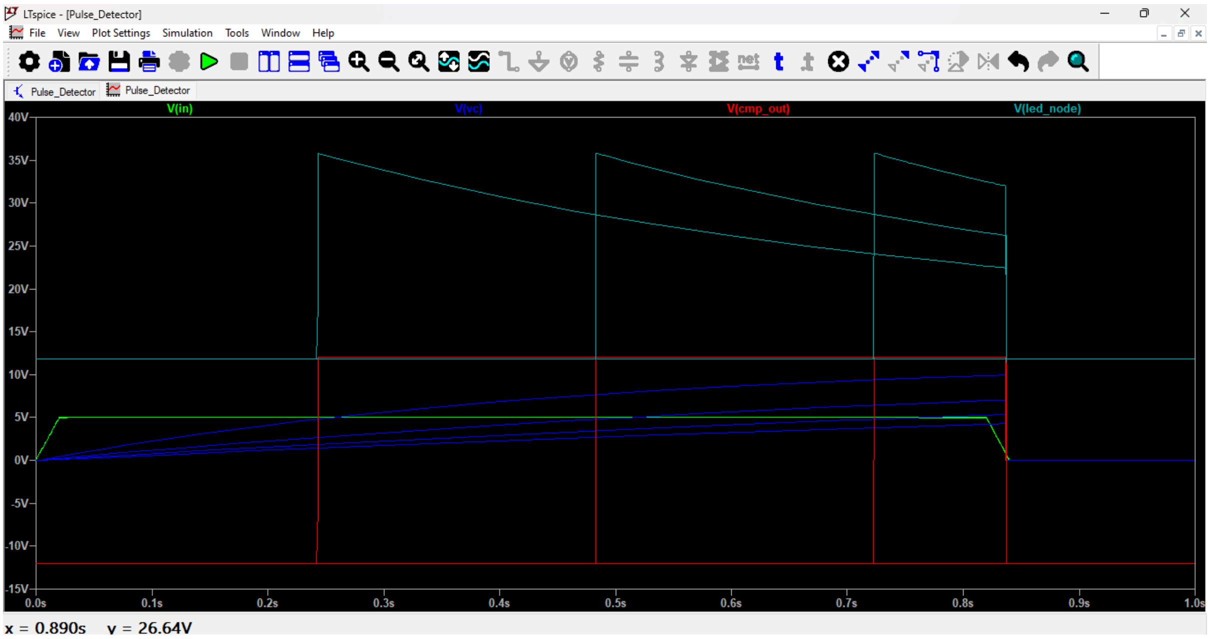
2. Transistor Roles

- **Qinv (NPN):** Inverts and buffers the input pulse, controlling other stages.
- **Qcharge (PNP):** Allows the capacitor to charge during a high input pulse.
- **Qdischarge (NPN):** Immediately discharges the capacitor when the pulse ends.
- **QLED (NPN):** Drives the LED when the comparator output is high.

Simulation Setup in LTspice





Adjustable Threshold (Bonus Implementation)

To fulfill the bonus requirement, we made the pulse duration threshold **adjustable** by replacing the fixed timing resistor with a **parameterized resistor** (`Rval`).

Steps Taken:

1. The timing resistor (R_timer) was replaced with `{Rval}`.
2. A `.param` directive defined `Rval`, e.g.:
   ```
   .param Rval = 200k
   ```
3. A `.step` directive allowed simulation across different values:
   ```
   .step param Rval list 100k 200k 300k 400k
   ```

This allowed us to **observe how the circuit responded to pulses** of fixed duration while sweeping the detection threshold.

Results

The simulation showed:

- For **short resistor values** (e.g. Rval = 100k), the LED turned on quickly → shorter threshold (~250 ms)
- For **higher values** (e.g. Rval = 300k), the LED required a longer pulse → threshold increased (~750 ms)
- The capacitor charged more slowly with higher resistance, delaying the comparator trigger point
- The LED always turned off immediately after the input pulse ended, confirming that the discharge transistor worked as intended

Sample Observations:

Rval (kΩ)	LED Turn-On Time (ms, approx)

100k	~250 ms
200k	~500 ms
300k	~750 ms
400k	~1s

Conclusion

The pulse duration detector was successfully designed and simulated using only analog components, satisfying the core requirements:

- Detect long pulses (initially 500 ms)
- Ignore short pulses
- Auto-reset after each pulse
- LED behavior confirmed via LTspice simulation

The bonus feature of an **adjustable detection threshold** was implemented by parameterizing the timing resistor using `.param` and `.step`. This allowed real-time tuning of the detection window by simulating the behavior of a potentiometer.

This project effectively demonstrated analog techniques for timing, threshold detection, and conditional output using op-amps and transistors — without any digital ICs.