Transistor as a switch

Task 1:

nPn

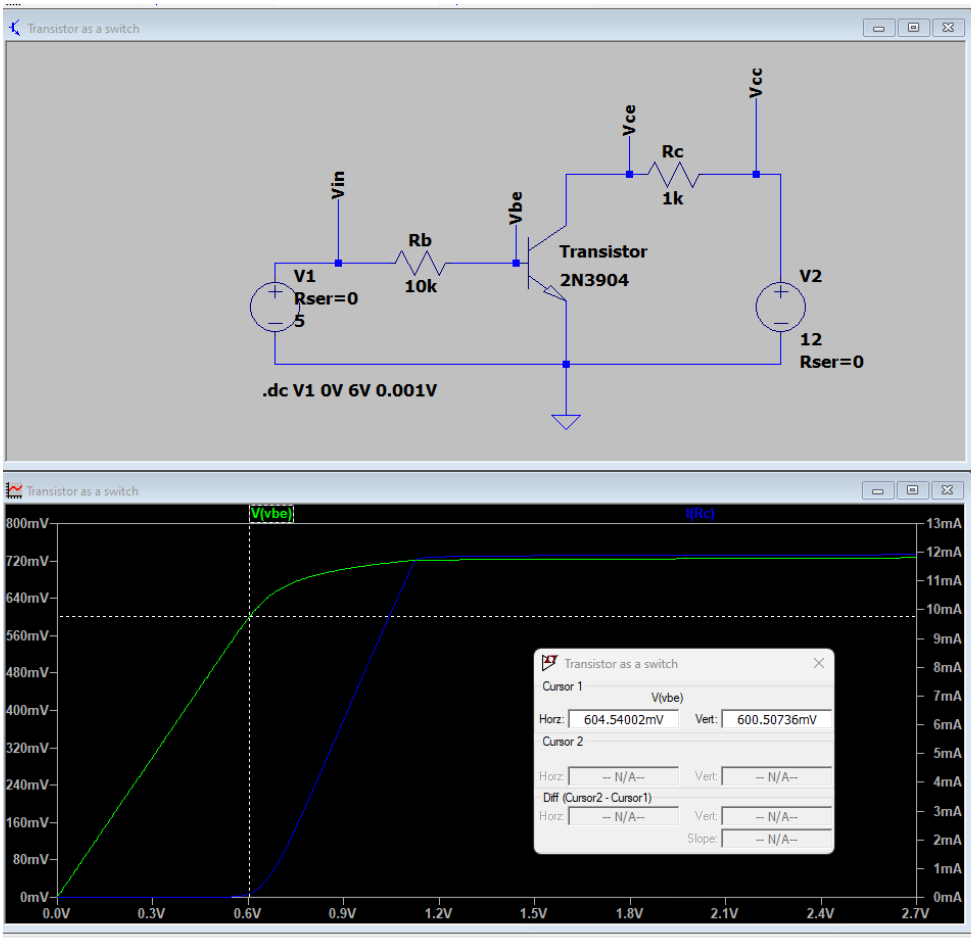
DC sweep:

- Type of sweep 'Linear'
- Start value 0 V
- End value 11 V
- increments 0.001 V

Components:

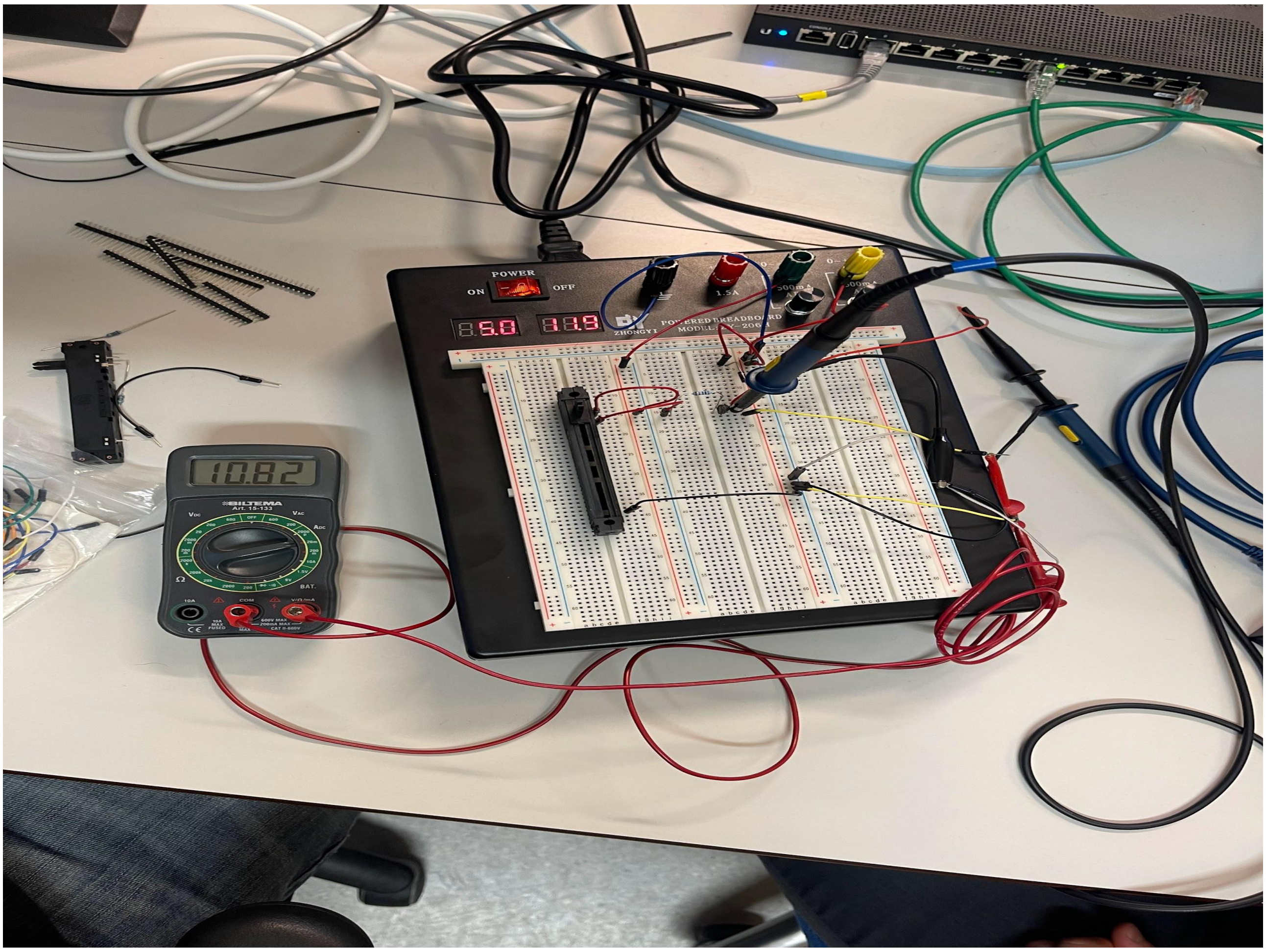
- V1 +12 VDC
- Rc 1k ohm
- nPn 2N3904
- Rb 10k ohm
- V2 +5 VDC

Circuit:



Calculations:

- Let’s use 700mV to calculate current and compare with simulation data
- Ic = (Vin – Vout) /R1 = (12V-0.7V) /1k ohm = 11,3mA
- Ib = (Vin-Vout) /R2 = (12V-0.7V) /10k ohm = 1,13mA



<u>Conclusion:</u>

The analysis of collector current (Ic) and base current (Ib) strongly suggests the transistor operates in the active region, signifying it's in the "on" state.

LTspice simulation confirms this, showing a clear transition from cutoff to active operation as voltage increases.

This transition point serves as a reliable indicator of the transistor's cutoff level.

In summary, Ic and Ib values, along with simulation data, confirm the transistor's expected behavior and provide a reliable cutoff level determination, crucial for circuit design and analysis.

Task 2:

PNP

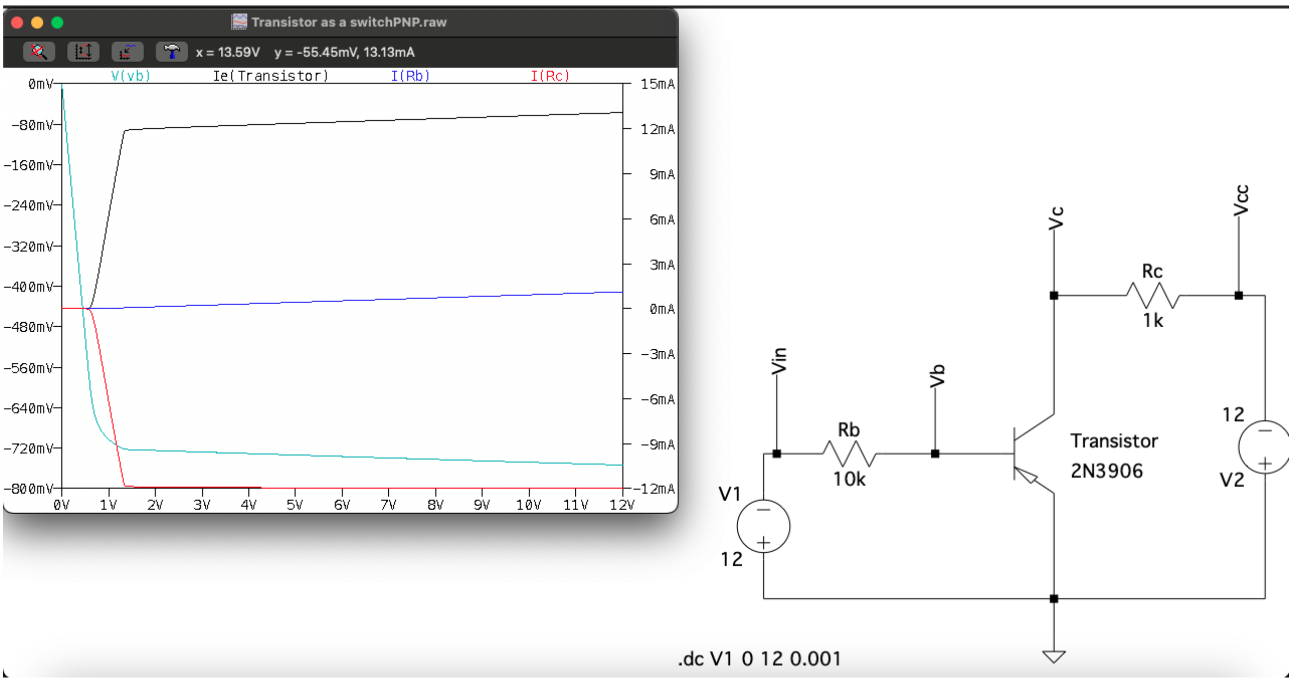
DC sweep:

- Type of sweep 'Linear'
- Start value 0 V
- End value 11 V
- increments 0.001 V

Components:

- V1 -12 VDC
- Rc 1k ohm
- PNP 2N3906
- Rb 10k ohm
- V2 -12 VDC

Circuit:



Note: explain why the voltge and current is – polarity. *Uras – I couldn't figure out why Ib shows positive where Ic shows negative. I believe their signs should be the same. There is sth off here. I will try to figure it out.

Calculations:

Calculating the base current:
$V_b = I_b * R_b + V_{be}$

where V_b is voltage of the dc source connected to the base; and V_{be} is the base emitter voltage

$12V = I_b * 10kohms + (-0.7V)$

$I_b = (12 + 0.7) / 10kohms$ □ $I_b = 1.27mA$

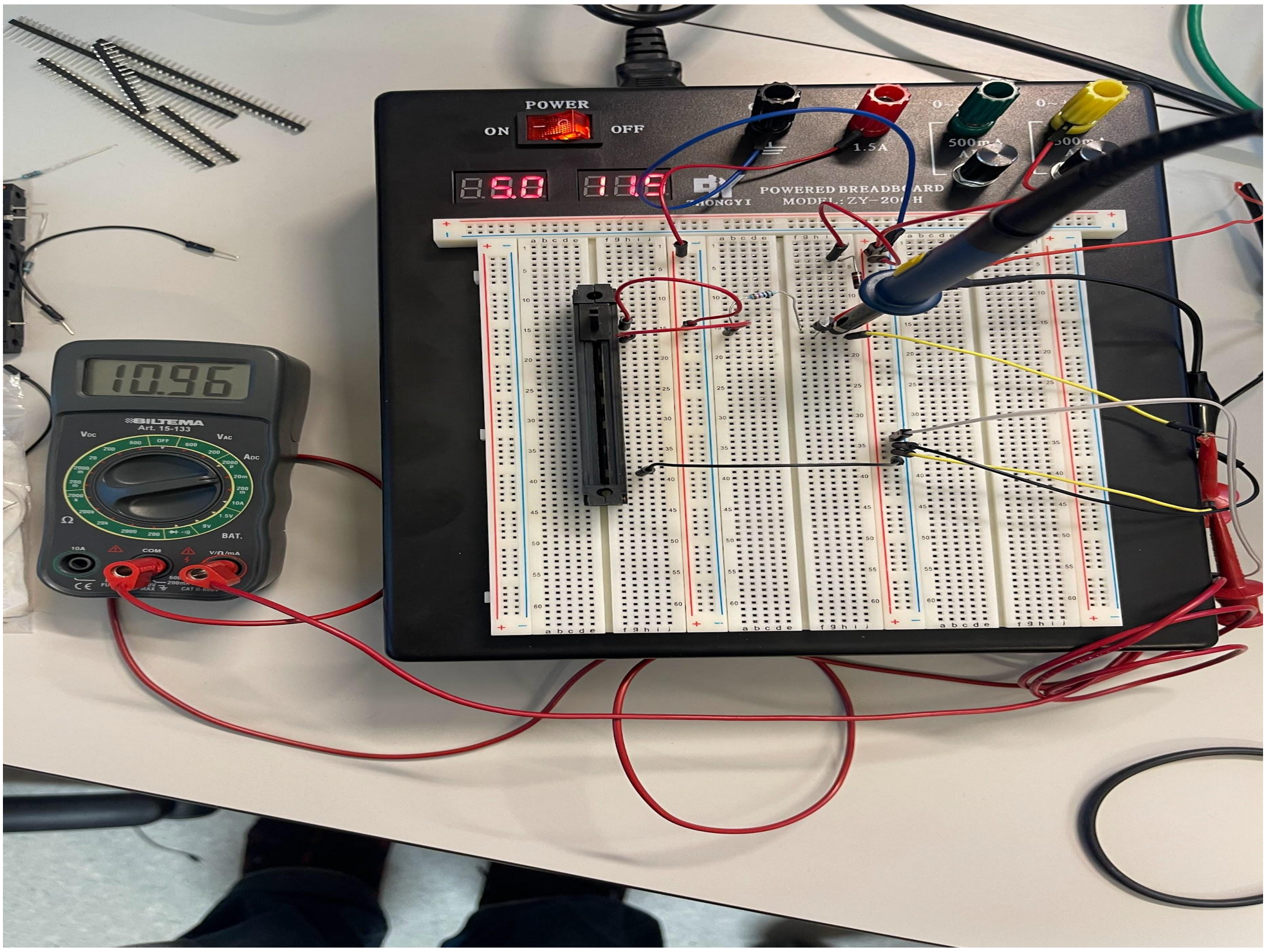
Calculating collector current:

$V_{cc} = I_c * R_c + V_{ce}$

Where V_{cc} is the voltage of the DC source connected to the collector, and V_{ce} is the collector emitter voltage

$Ic = V_{cc} / R_c$ 12V / 1kohms □ 12mA

IE = Ib + Ic □ 12mA + 1.27mA = 13.27mA



Task 3:

nPn circuit 15mA Led

DC sweep:

- Type of sweep 'Linear'
- Start value 0 V
- End value 6 V
- increments 1 V

Transient Analysis:

- Stop time 25 ms
- Starting saving data time 1 ms
- maximum time step 20

Components:

- V1 +12 VDC
- Rc 800 ohm
- nPn 2N3904
- Rb 8k ohm
- V2 +5 V Pulse
    - Tinitial = 0V
    - Ton = 5V
    - Tdelay, Trise, Tfall = 0V
    - Ton = 1e-3 s
    - Tperiod = 2e-3 s
- LED 1N914

Circuit:

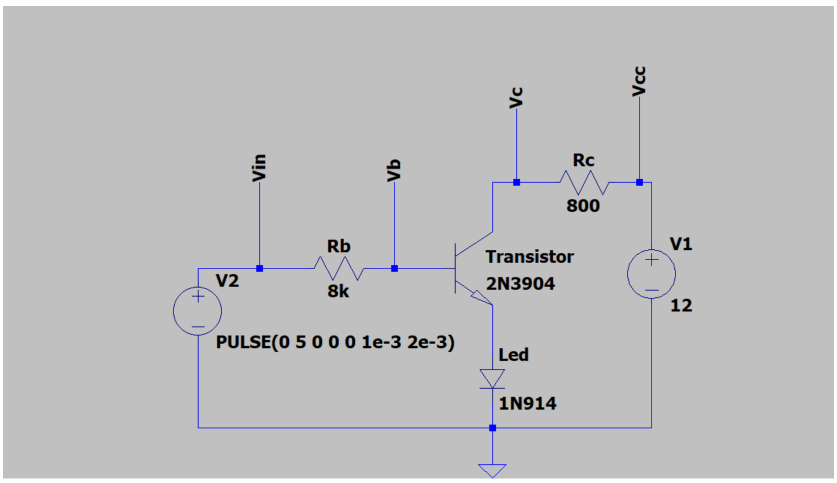


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Diagram 1. How the 2N3904 transistor behaves with a 5V logic control signal. Green = Vin, Red = Vb, Blue = Vc.:

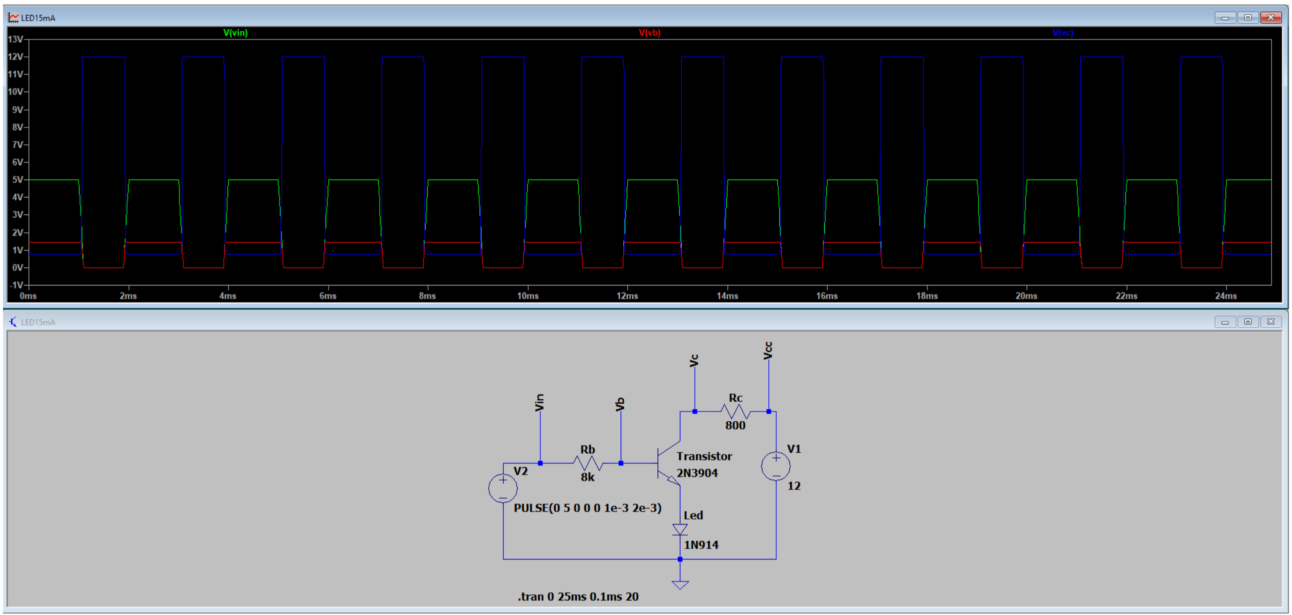
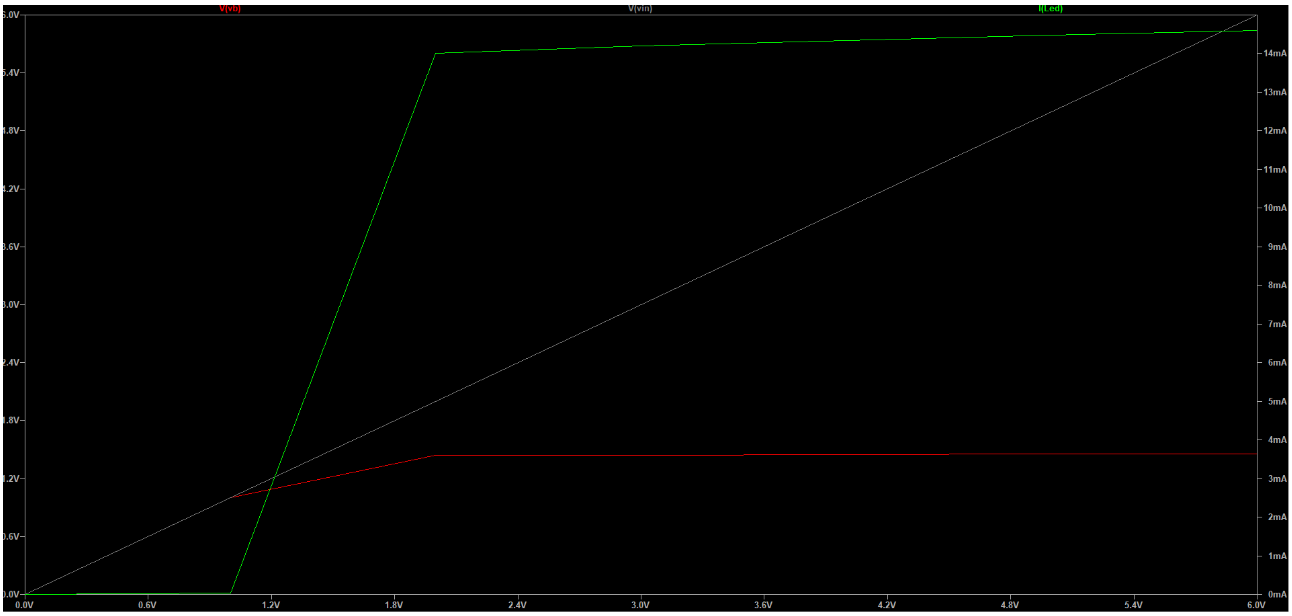


Diagram 2. Let’s determine current flow through current diagram:



Conclusion:

The analysis of the NPN transistor circuit, controlled by a 5V logic pulse, provides valuable insights into its switching behavior. Key observations from the circuit's response include:

The LED's current begins to flow when the input voltage (Vin) reaches approximately 0.7–0.9 Volts, indicating the forward voltage drop of the LED.

As Vin continues to rise linearly, it eventually reaches approximately 5 Volts.

When the base voltage surpasses the 0.7 Volt threshold, a significant and rapid increase in LED current occurs.

These observations reveal that the transistor effectively functions as an amplifier, allowing the LED to be controlled by a low-voltage logic signal. The distinct threshold behavior at both the LED and base terminals highlights the transistor's switching capability, making it a fundamental component in electronic circuits for signal amplification and control applications.

TASK 3 – Physical Implementation – VIDEO (click to watch)

Task 4:

DC sweep:

- Type of sweep 'Linear'
- Start value 0 V
- End value 50 V
- increments 5 V

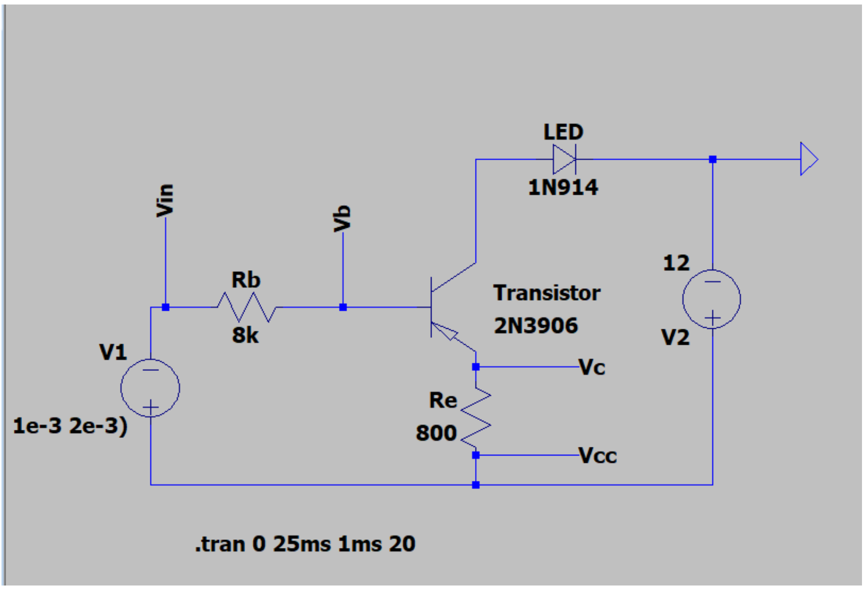
Transient Analysis:

- Stop time 25 ms
- Starting saving data time 1 ms
- maximum time step 20

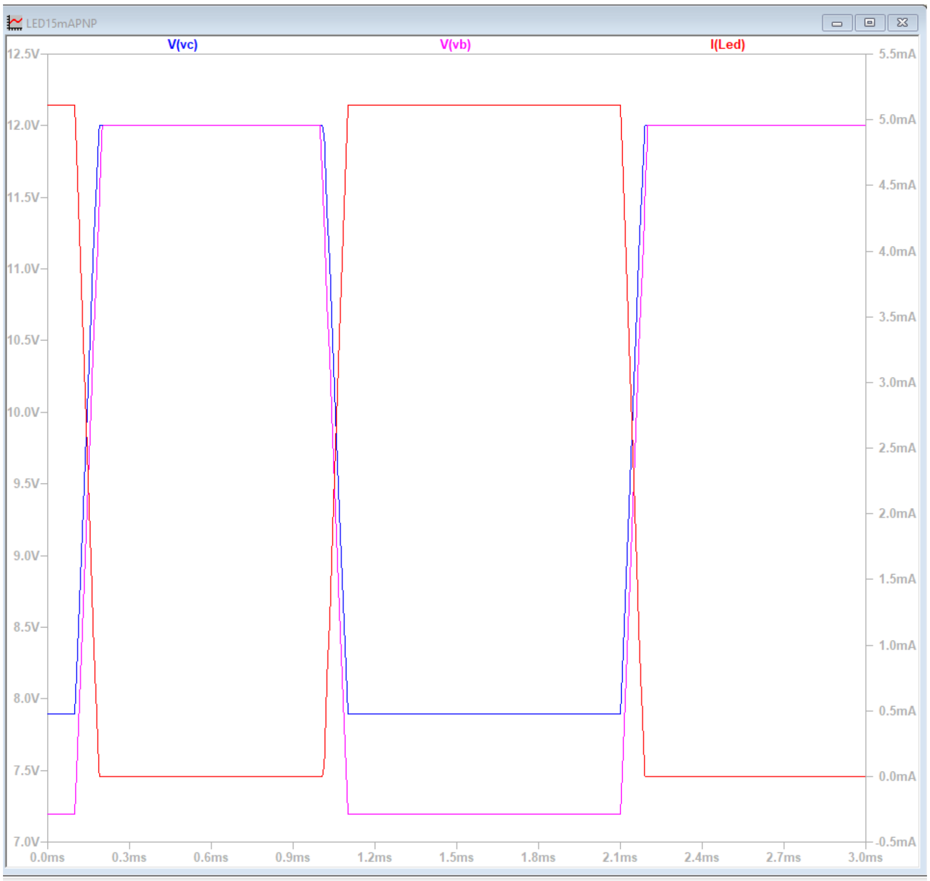
Components:

- V1 +12 VDC
- Rc 800 ohm
- PNP 2N3906
- Rb 8k ohm
- V2 +5 V Pulse
    - Tinitial = 0V
    - Ton = 5V
    - Tdelay, Trise, Tfall = 0V
    - Ton = 1e-3 s
    - Tperiod = 2e-3 s
- LED 1N914

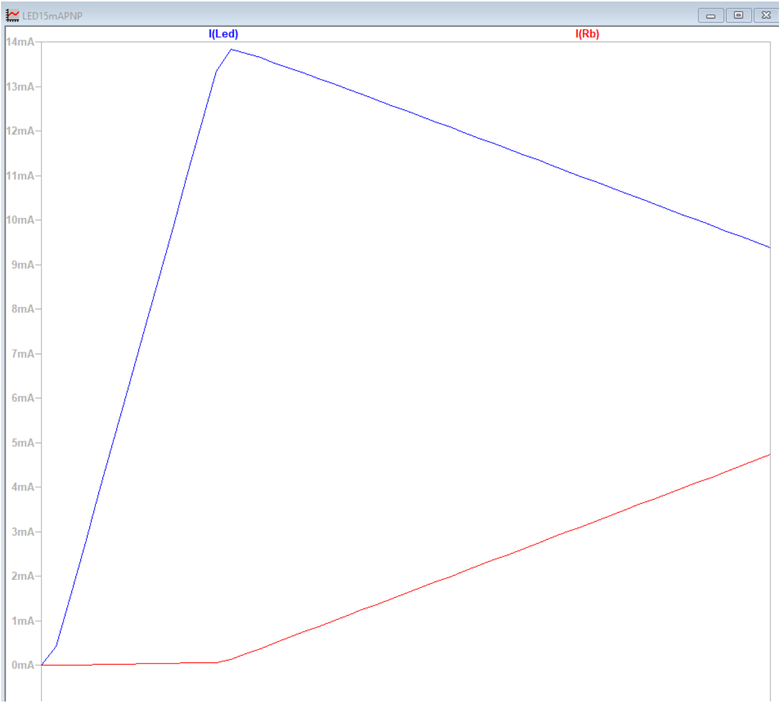
Circuit:



Let's determine that 2N3906 transistor behaves correctly:



Let's determine current flow through current diagram:



Conclusion:

The behavior of the LED current in this circuit is notable for its response to the voltage difference (Vb – Ve) across the base-emitter junction of the transistor:

When the voltage difference (Vb – Ve) falls below approximately 0.7 Volts, the LED current decreases. This behavior aligns with the desired functionality.

Conversely, as Vb decreases sufficiently compared to Ve, the LED current starts to rise again.

The simulation results confirms the success of the circuit in achieving the intended functionality. This behavior is essential for efficient signal control and amplification applications. And simulation correctly describes PNP transistor functionality.

[LAB4 - TASK4 Physical Implementation]() - VIDEO - (Click to Watch)