The transistor can be configured in a unity gain situation. This is called the emitter follower or voltage follower. Vout is taken from the emitter junction and follows the input voltage Vin. In essence it is a current amplifier with unit gain.

The input impedance Rin is high and Rout is proportional to the driving source’s output impedance Rsource.

\[
V_E = V_B - 0.6V \quad \text{or} \quad \delta V_E = \delta V_B \quad \text{Vout} \sim \text{Vin} \quad (1)
\]

\[
I_E = \frac{\delta V_E}{R_E} = \frac{\delta V_B}{R_E} \quad (2)
\]

\[
I_E = I_C + I_B = \beta I_B + I_B = (1 + \beta) I_B = \frac{\delta V_B}{R_E} \quad (3)
\]

Looking in to the base \( R_{in} = \frac{\delta V_B}{I_B} = \frac{I_E R_E}{I_B} = \frac{R_E (1 + \beta)}{\beta R_E} \sim \frac{R_E}{\beta} \quad (4) \)

Looking out from the emitter \( R_{out} = R_1 + \frac{\beta}{R_{source}} + \frac{1}{R_E} \sim \frac{R_{source}}{\beta} \quad (5) \)

Construct the Voltage follower circuit. Drive it with the smallest sine wave from your generator at \( f = 1kHz \). Measure Vin (Vpp) on your oscilloscope channel-1. Measure Vout (Vpp) on channel-2 of your oscilloscope. Record these values.

\[
\text{Vin} = \quad \text{Vout} = \quad (\text{Vcc} = +15V, 2N3904, R_E = 4.7k\Omega, V_E = Vout, \text{Probe-2})
\]

\[
V_{out} = V_{in} \quad \text{Rin} = \beta R_E \quad \text{Rout} = \frac{R_{source}}{\beta}
\]
Check the frequency response of the voltage follower by sweeping the frequencies between 10Hz and 1MHz.

<table>
<thead>
<tr>
<th>$f$ (Hz)</th>
<th>10</th>
<th>100</th>
<th>1K</th>
<th>10K</th>
<th>100K</th>
<th>1M</th>
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<tbody>
<tr>
<td>Vout (V)</td>
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<tr>
<td>Vin (V)</td>
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<tr>
<td>gain</td>
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<td>$\Delta \phi$</td>
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</tbody>
</table>

**Question#1**- Does the output signal replicate the input signal? Explain why or why not in terms of transistor function.

**Question#2**- Is there a phase change between input and output signal?

**Question#3**- What is the input and output impedance of your emitter-follower?

Rin = __________  Rout= __________
TRANSISTOR SWITCH

One of the main uses of a discrete transistor is that of a switch. Often one needs to control a large current source from a small current source. We create a high impedance source by placing a a 10kΩ resistor in series with our 50Ω signal generator.

Thus a high impedance source (low current) drives a low impedance output LED. On the positive half-cycle the transistor conducts $I_C > 0$ and the LED is turned on. On the negative half-cycle the transistor cuts off and the LED goes off.

The LED takes about 1.6 volts to turn so about 10.4 V is dropped across the 470Ω $R_C$.
$R_C$ limits the current through the LED or it may burn out if the current is too high.

\[ I_B = \frac{5V}{10k\Omega} = 0.5mA \]  
\[ I_C = \frac{(12-1.6)}{470\Omega} = \frac{10.4V}{470\Omega} = 22mA \]

(1) Construct the transistor switch circuit with your 2N3904.

(2) Apply a +DC voltage to the input $V_{in} = 0$-5V nominal value to determine when the LED just turns on. Record this voltage. Then increase the voltage to ~ 5V, the LED should be ON.

$V_{ON} =$ ____________

(3) Measure the voltage drops along the Collector-Emitter-Ground path.

$V_{cc} = +12V$ \hspace{1cm} $\Delta V_{LED} =$ ____________ V \hspace{1cm} $\Delta V_{R2} =$ ____________ V

$\Delta V_{2N3904} =$ ____________ V

(4) Do the individual drops and total correspond to what you expect? Calculate $I_C$ from your measurement as in Eq (2).

$I_C =$ ____________ A

(5) Apply a 10Vpp sine wave to $V_{in}$. Explain the LED behavior.