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**UNIVERSITY OF PLYMOUTH**

Department of Communication & Electronic Engineering

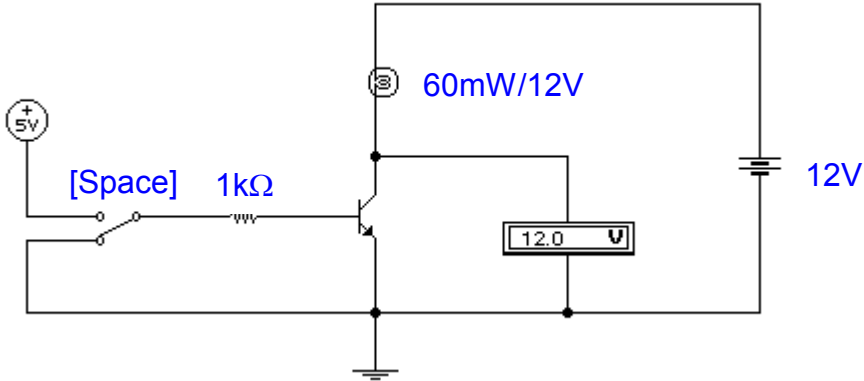
**COMPUTER SIMULATION USING ELECTRONICS WORKBENCH**

**THE TRANSISTOR SWITCH**

**PART 1. Uses of the Transistor Switch**

**a) Switching a Load On and Off**

One common use for a bipolar transistor, is to switch power (from a low-level current/ voltage input, e.g., a TTL 'computer logic' signal) to a load (e.g., switching a light bulb, on and off). In the circuit below, the physical switch, switches +5V or 0V to the input (base) of the transistor:-



Wire up the circuit. You will need to visit four EWB libraries, in the vertical tool bar:-

- |                |                    |
|----------------|--------------------|
| 5V Supply      | Passive Components |
| 12V Battery    | "                  |
| Resistor       | "                  |
| npn Transistor | Active Components  |
| Bulb           | Indicators         |
| Switch         | Control            |

For some reason, the simulation works a lot better with the circuit grounded. In real life, you would not need to connect the circuit to ground (earth) for it to work satisfactorily.

The standard light bulb is 10W, 12V, rather too hefty to be managed by a single transistor. Highlight the bulb and click left to change its value to 60 mW, 12V. In the same way, change the resistor value to 1 k $\Omega$ .

The switch is a single pole, double throw type. It is used to connect a logic level control signal (5V: logic 1, or 0V: logic 0) to the base of the transistor. The switch is operated by pressing the Space bar, with the simulation running.

Observe what happens:-

Input	Bulb (ON or OFF)	Voltage across Transistor	Voltage across Bulb
Logic 0			
Logic 1			

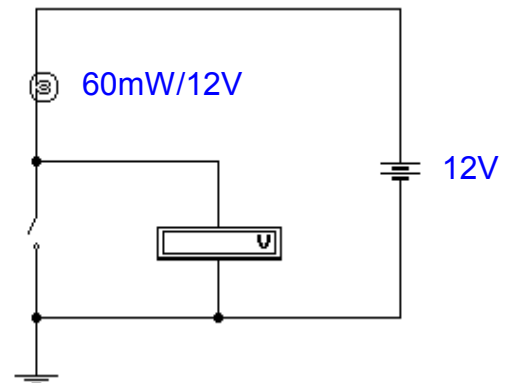
If you are unsure about the voltage across the bulb, connect a second voltmeter.

Hint: What should the two voltages add up to? .....

### Conclusion

The transistor behaves like a mechanical switch, which is either opened or closed, depending on the control input.

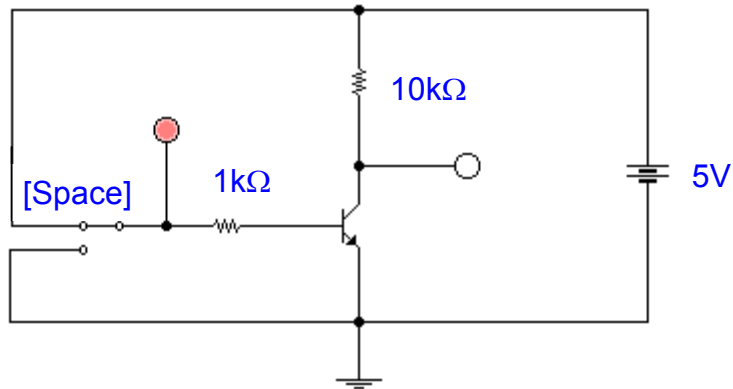
Input	Transistor
Logic 0	Switch open
Logic 1	Switch closed



Note that the transistor circuit acts as a **Current Amplifier**, in the sense that the control (input) signal by itself, could not supply the current (or the voltage), to drive the load directly.

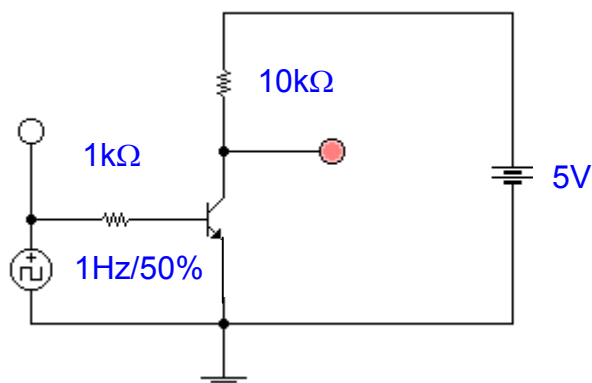
## b) The Transistor Circuit acting as a Voltage Inverter

Add a couple of logic indicators to the circuit to monitor the logic levels on the input and output. The load has been replaced by a  $10\text{ k}\Omega$  resistor, and the whole circuit is now running off a  $5\text{V}$  supply.



Note that we now think of the circuit as having a voltage input AND a voltage output. Record your observations of how the circuit works:-

For fun, you could try replacing the switch by a low speed oscillator

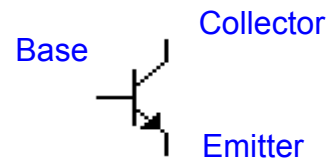


You need to reduce the frequency of the oscillator to  $1\text{ Hz}$ , as shown. What happens?

## PART 2. Investigating the Circuit Action

The three leads on the transistor are known respectively as

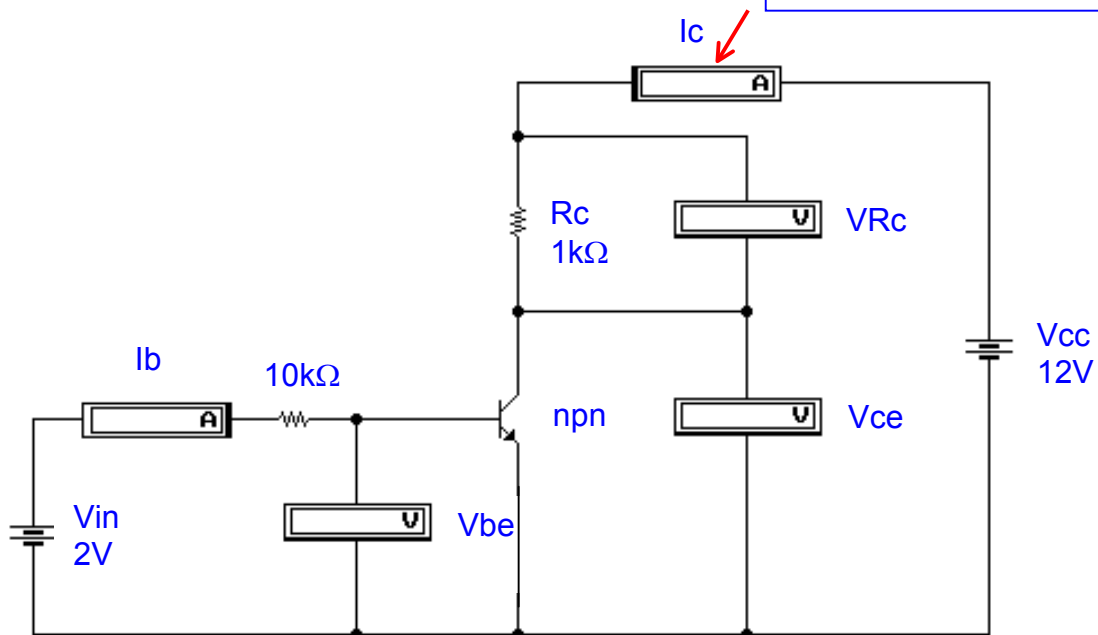
Collector  
Base  
Emitter



Wire up the following circuit, which contains a lot of meters. These enable you to look closely at the currents and voltages as the input voltage is raised progressively.

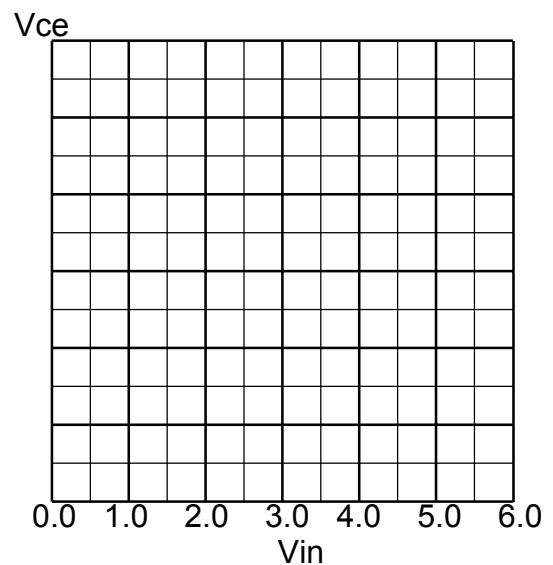
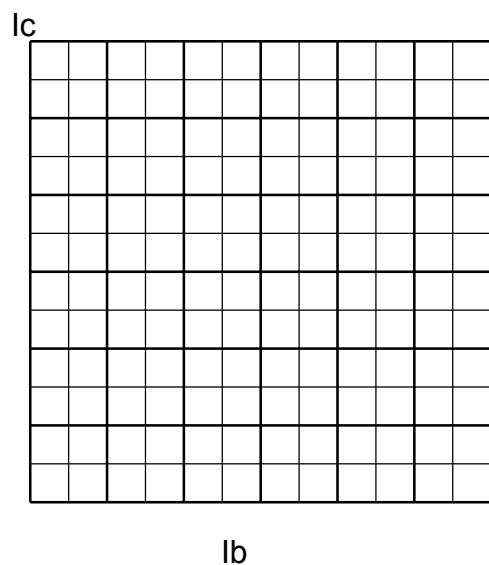
Measure the collector current, base current, base/emitter voltage, collector/emitter voltage and the voltage across the collector resistor, for the values of input voltage  $V_{in}$  shown in the table.

NB: rotate ammeter (before wiring) to give positive values of  $I_c$ .

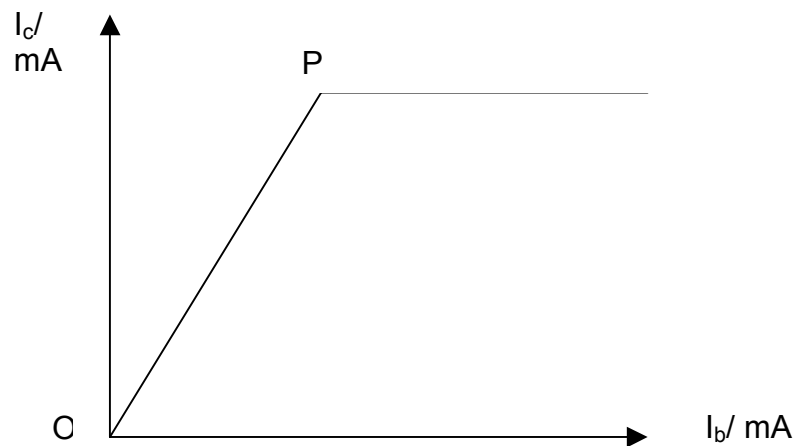


$V_{in}$ (V)	$V_{be}$ (V)	$I_b$ ( $\mu A$ )	$I_c$ (mA)	Current Gain $h_{FE} = I_c/I_b$	$V_{RC}$ (V)	$V_{ce}$ (V)
0.0						
0.5						
1.0						
1.5						
2.0						
2.5						
3.0						
4.0						
5.0						
6.0						

- (i) Plot a graph of  $I_c/I_b$ . (Convert the base current values to mA).
- (ii) Plot a graph of  $V_{ce}/V_{in}$ , ie  $V_{out}/V_{in}$



Examine the graph below:



In the first section, OP, the collector current  $I_c$  is controlled by the base current  $I_b$ .

The bipolar transistor is essentially a **Current-Controlled** device.

The slope of the section OP,  $I_c/I_b$  is the **Current Gain**. Typical values are 100 – 400.

Measure the Current Gain of this transistor.

In the second section of the graph, PQ, the input current does not control the collector current. The voltage across the transistor has dropped to nearly zero, ie the transistor is acting like a closed switch.

What limits the collector current now?

Prove this statement by applying the equation  $V = IR$  to the load resistor  $R_c$

The second graph illustrates the inverting action of the circuit. Explain this statement.

It is often useful to know how much voltage is required to switch the transistor on fully.

Read this value from the graph.

### Checking Normal Current and Voltage Rules (Kirchoff's Laws)

Insert another ammeter to measure  $I_e$ , the emitter current

For a value of  $V_{in}$  of 2.0 V, substitute values into the equation:-

$$I_e = I_c + I_b$$

Is the equation satisfied?

YES/NO

and check the relationship

$$V_{cc} = V_{Rc} + V_{ce}$$

Is the equation satisfied?

YES/NO

### Discussion

This may seem a fairly dull set of measurements. However it is of fundamental importance to the technology of digital electronics.

Why is the transistor switch circuit so important?