Experiment No. (5)

Transistor as a Switch & Device Driver

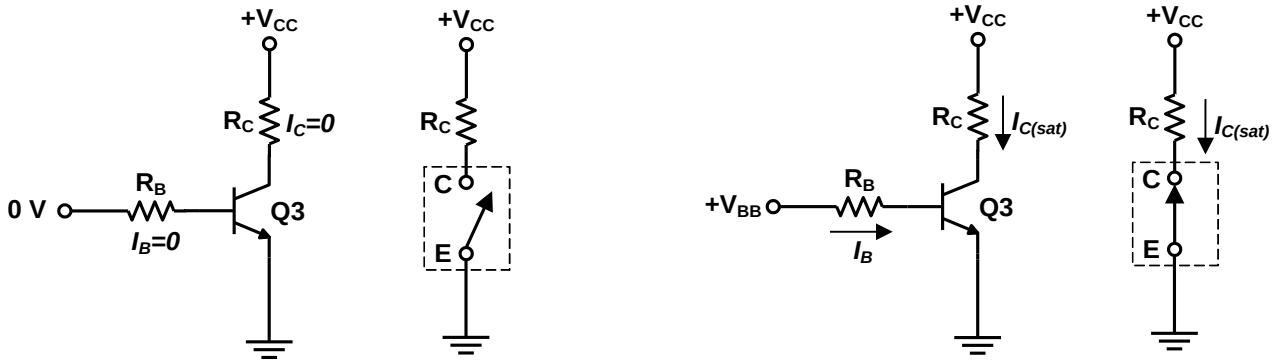
STUDY OBJECTIVE:

(1) Understanding the characteristic transistors in cut-off and saturation.
(2) Understanding how the transistor to be act as a device driver circuit.
(3) Learning the transistor application in switching and driving.

INTRODUCTION:

1. Transistor as a Switch

Fig. 1 illustrates the basic operation of the transistor as a switching device. In Fig. 1a, the transistor is in the cutoff region because the base-emitter junction is reversed-biased. In this condition, there is, ideally, an open circuit between collector and emitter, as indicated by the switch equivalent. In Fig. 1b, the transistor is in the saturation region because the base-emitter junction and the base-collector junction are forward-biased. In this case base current is made large enough to cause the collector current to reach its saturation value. In this condition, there is, ideally, a short circuit between collector and emitter and the equivalent switch is closed as shown in Fig. 1b.



(a) Cutoff-open switch **(b) Saturation-closed switch**

Fig. 1: Ideal switching action of a transistor

Condition in cutoff:

A transistor is in the cutoff region when the base-emitter junction in reversed-bias. neglecting leakage current, all of the currents are zero, and $\mathbf{V_{CE}}$ is equal to $\mathbf{V_{CC}}$ (Fig. 2).

$$V_{CE}(\text{cutoff}) = V_{CC}$$

Condition in saturation:

when the base-emitter junction is forward-biased and there is enough base current to produce a maximum collector current, the transistor is saturated. The formula for collector saturation current is:

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C}$$

The minimum value of base current needed to produce saturation is:

$$I_{B(\min)} = \frac{I_{C(sat)}}{\beta}$$

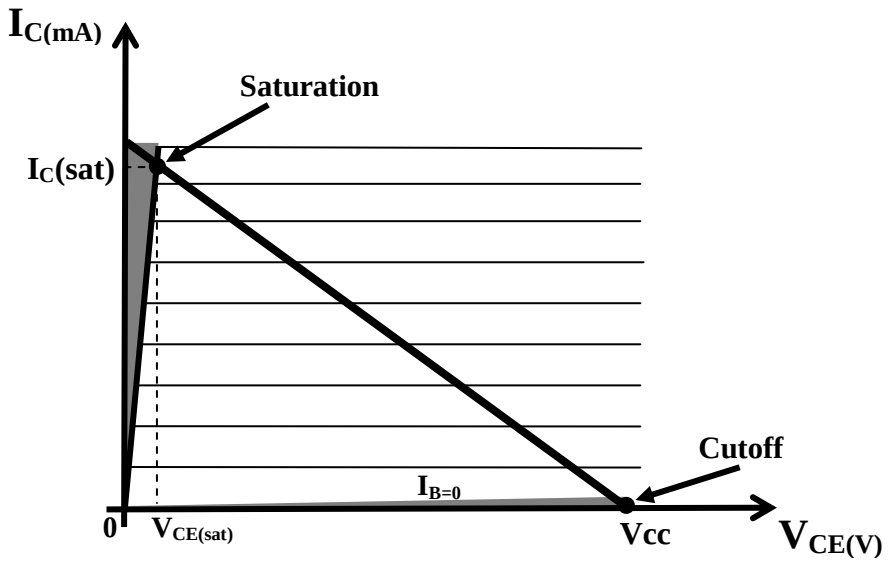


Fig. 2: Output characteristic curves illustrating the cutoff and saturation conditions

2. Use transistor to drive inductive device such as relay, motor

When the transistor is used to drive inductive device, you shall consider if the current flowing through Collector during saturation of transistor conforms to the specified requirements, and you shall also consider if the voltage applied to Collector during cutoff of transistor will exceed $\mathbf{V_{CEO}}$ that the transistor can sustain ($\mathbf{V_{CEO}}$: the voltage that **CE** can sustain during **CE** open status of transistor) As shown in Fig. 3, because a reverse electromotive force will be generated during cutoff of transistor with polarity indicated in this figure, $\mathbf{V_{CE}}$ will be two times of $\mathbf{V_{CC}}$.

$$V_{CEO} = V_{RELAY} + V_{CC} \cong 2V_{CC}$$

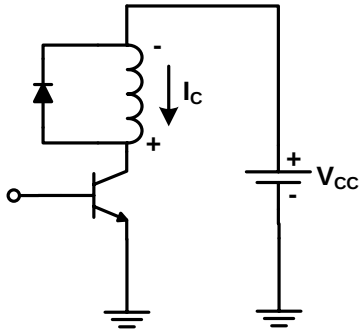


Fig. 3

In order to eliminate the reverse electromotive force generated by inductive device during cutoff of transistor, a diode can be connected in parallel across two terminals of the coil, shown in Fig .2. as the discharge circuit for the reverse electromotive force. V_{CEO} can thus be decreased, and achieve the function for protection of transistor.

3. Relays

A relay is an electro-mechanical switch. It consists of a coil and moveable iron lever (Fig. 4). when current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contact. The coil current can be on or off so relays have two switch positions and they are double throw switches.

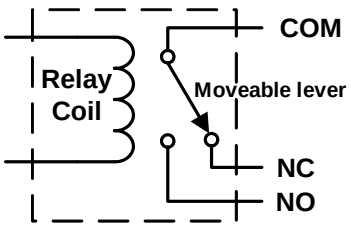


Fig. 4: A relay

The relay's switch connections are usually labeled **COM**, **NC** and **NO**:

- **COM** = **Com**mon, this is the fixed side of the moving lever.
- **NC** = **N**ormally **C**losed, point **COM** is connected to this point when the relay coil is off.
- **NO** = **N**ormally **O**pen, point **COM** is connected to this point when the relay coil is on.

Relays allow one circuit to switch a second circuit (AC or DC) which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 220V AC mains circuit as shown in Fig. 5. There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical.

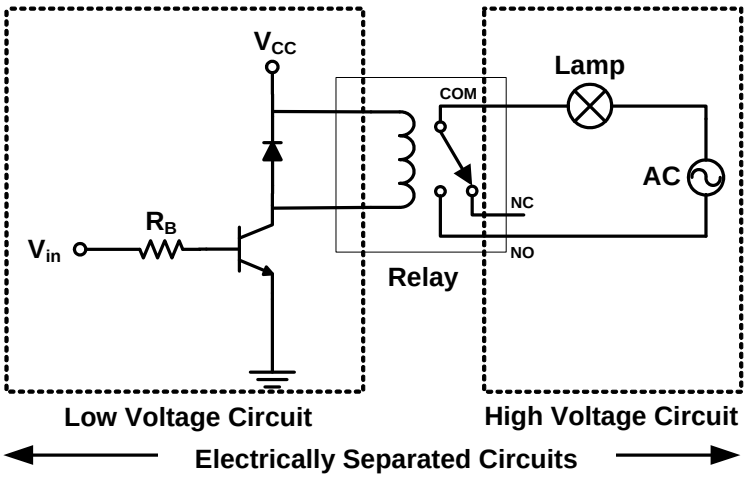


Fig. 5: A transistor drives an AC circuit

Like relays, transistors can be used as an electrically operated switch. for switching a small DC currents (< 1A) at low voltage they are usually a better choice than a relay. However transistors cannot switch AC or high voltages (such as mains electricity) and they are not usually a good choice for switching large currents (> 5A). In these cases a relay will be needed, but note that a low power transistor may still be needed to switch the current for the relay's coil. The main advantages and disadvantages of relays are listed below:

Advantages of relays:

- Relays can switch AC and DC, transistors can only switch DC.
- Relays can switch high voltages, transistors cannot.
- Relays are a better choice for switching large currents (> 5A).
- Relays can switch many contacts at once.

Disadvantages of relays:

- Relays are bulkier than transistors for switching small currents.
- Relays cannot switch rapidly, transistors can switch many times per second.
- Relays use more power due to the current flowing through their coil.
- Relays require more current than many ICs can provide, so a low power transistor may be needed to switch the current for the relay's coil.

Experiment Equipments:

(1) KL-200 Linear Circuit Lab.
(2) Experiment Module: KL-23003.
(3) Experiment Instrument: 1. Multimeter or digital multimeter.
2. Oscilloscope.
(4) Tools: Basic hand tools.
(5) Materials: As indicated in the KL-23003.

Experiment Items:

Item One (1): Experiment for ON (saturation) and OFF (cutoff) currents of transistor.

1-1 Experiment Procedures:

(1) Insert the short-circuit clip by referring to Fig. 6.
(2) Connect ammeter to measure $\mathbf{I_B}$ and $\mathbf{I_C}$.
(3) Feed 5V voltage to the input terminal, then view $\mathbf{I_B}$, $\mathbf{I_C}$ and $\mathbf{V_{CE}}$, and make records in table -1.
(4) Disconnect voltage from the input terminal, then view $\mathbf{I_B}$, $\mathbf{I_C}$ and $\mathbf{V_{CE}}$, and make records in table -1.

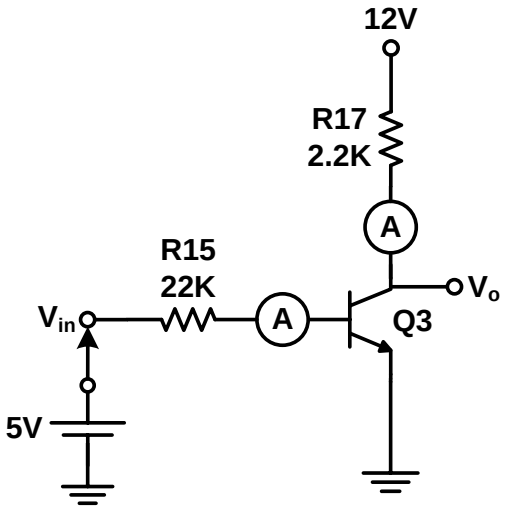


Fig .6

1-2 Experiment Result:

Record in Table -1.

Table -1

Operating Region of Transistor	V_{in}	I_B	I_C	V_{CE}
Saturation				
Cut-off				

Item Two (2): Use transistor to drive a relay (Using Multi-Sim)

2-1 Experiment Procedures:

(1) Connect the circuit shown in Fig. 7 using Multi-Sim Program. you can find the main devices of this circuit in the following Multi-sim libraries:

- Relay from (Basic library/Relay/EDR201A05).
- 120V 60Hz AC Source from (sources library).
- 120V_100Watt Lamp from (indicators library/Lamp).
- Switch from (Basic library/switch/SPDT).

(2) a. By using the switch (in the input of the circuit), feed 5V voltage to the input terminal, then view if the lamp is illuminated (this means that the relay has been turned on (magnetized)), use voltmeter to measure $\mathbf{V_{CE}}$ and $\mathbf{V_{BE}}$.

b. Disconnect voltage from the input terminal, and then view if the lamp is turned off (this means that the relay returns to OFF))), use voltmeter to measure $\mathbf{V_{CE}}$ and $\mathbf{V_{BE}}$.

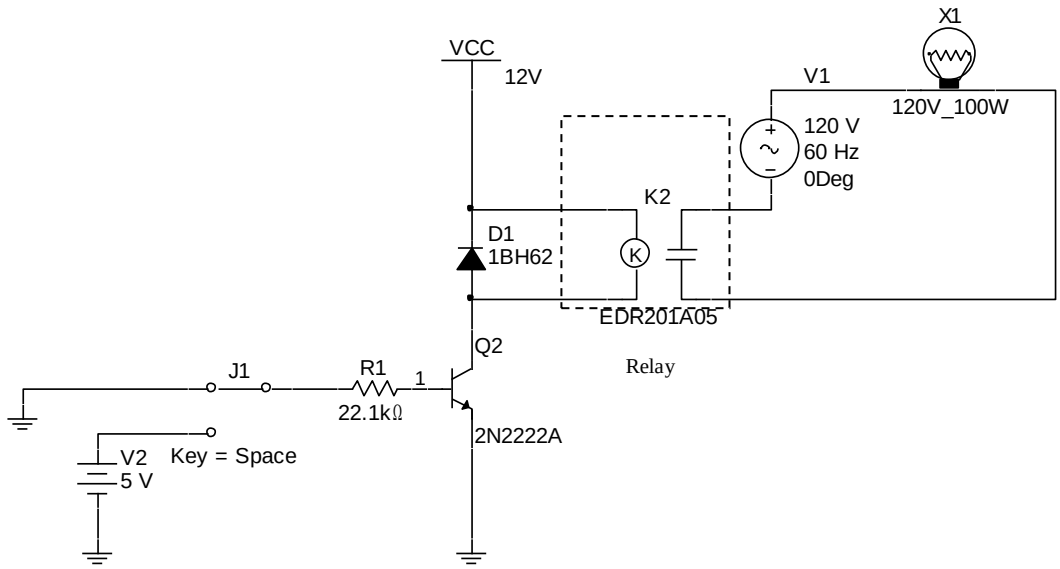


Fig. 7

2-2 Experiment Result:

Record in Table -3.

Table -2

Relay	V_{BE}	V_{CE}
ON		
OFF		

CONCLUTION:(الاستنتاج)

DISCUSSIONS:

(1) Explain at what conditions the transistor operate as a switch and as a driver.

(2) When the transistor drives a coil, why we must connect a diode in parallel with the coil?

(3) choose the correct answer:

a) When the transistor works as a switch, it represents:
   1. Amplifier
   2. NOT Gate
   3. Buffer

b) In saturation, the transistor ideally behaves like an closed switch between:
   1. Base and Emitter
   2. Base and Collector
   3. Collector and Emitter

c) In cutoff, the parameter that will be in its maximum value is:
   1. V_{CE}
   2. I_C
   3. I_B

d) To saturate a BJT,
   1. $I_B = I_{C(SAT)}$
   2. $I_B > I_{C(SAT)}/\beta$
   3. $I_B = 0$

e) If base-emitter junction is open, the collector voltage is:
   1. V_{CC}
   2. 0V
   3. Floating