PHYWE	**How can the switching process of a transistor be delayed?**	EEP 13.3	S

Problem

Investigate the factors responsible for delaying switching of a transistor.

Equipment

Plug-in board	06033.00	1
Changeover switch	39169.00	1
Lamp holder E10	17049.00	1
Filament lamp, 4 V/0.04 A, E10, 1 pc.	06154.03	(1)
Resistor, 100 Ω	39104.63	1
Resistor, 4.7 kΩ	39104.27	1
Resistor, 10 kΩ	39104.30	1
Electrolytic capacitor, 470 μF, bipolar	39105.47	2
Transistor BC337	39127.20	1
Wire building block	39120.00	6
Connecting cables, 25 cm, red	07360.01	1
Connecting cables, 25 cm, blue	07360.04	1
Connecting cables, 50 cm, red	07361.01	1
Connecting cables, 50 cm, blue	07361.04	1
Multi-range meter	07028.01	1
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1
Stopwatch	03071.01	1

Set-Up and Procedure

— Set up experiment as shown in Fig. 1 with R_E = 100 Ω and R = 10 kΩ. Do not include capacitor in circuit initially.

— Switch on power supply unit and set direct voltage to 12 V.

— Toggle changeover switch back and forth several times and observe when the filament lamp lights up and goes out. Note observation under (1).

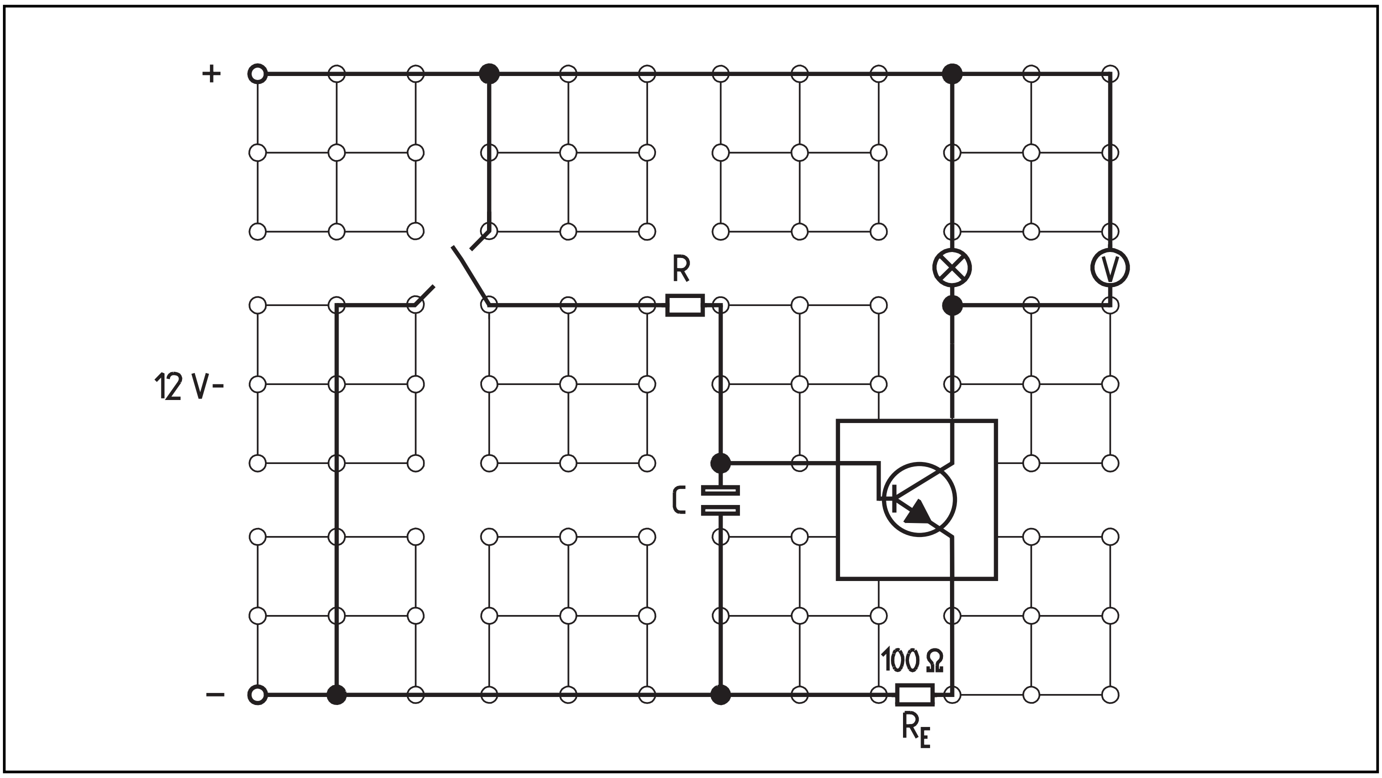
— Add 470 μF capacitor to circuit as shown in Fig. 1. Toggle changeover switch repeatedly and observe once again when the filament lamp lights up and goes out. Note observation under (2).

— Flip changeover switch again and determine the time t_{On} und t_{Off} it takes to attain maximum voltage and/or for the voltage to reach 0 V from the time the switch is flipped. Enter measurements in Table 1.

— Carry out the time measurements for all combinations of resistors R and capacitor listed in Table 1. Note measurements.

Note:
When two capacitors are called for, connect the two capacitors in parallel to each other.

Fig. 1



How can the switching process of a transistor be delayed?

Observations and Measurements

(1) Circuit without capacitor:

(2) Circuit with capacitor:

Table 1

Capacitor C /μF	Resistance R /kΩ	Turn-on delay t_{On}/s	Turn-off delay t_{Off}/s
470	10		
2 x 470	10		
2 x 470	4.7		
470	4.7		

Evaluation

1. Explain the processes for both switching positions on the basis of the circuit diagram (Fig. 1).

2. Why does the filament lamp not light up immediately when the switch establishes the connection to the positive pole of the current source?

3. Why does the filament lamp not go out immediately when the switch establishes the connection to the negative pole?

4. What do the delay times depend on?

5. List some possible applications for a delay circuit

6. What disadvantage of this simple circuit is apparent from the behavior of the filament lamp?

(How can the switching process of a transistor be delayed?)

Delay circuits are presently used widely for turn-on delay in alarm system. The basic principle behind them is based on the time involved in the charging and discharging process of capacitors, which the students are already aware of. The increase or decrease in capacitor voltage triggers the transistor into a conductive or blocked switching state as soon as the base-emitter voltage attains the necessary threshold value or falls below this value, respectively.

Notes on Set-Up and Procedure
Since the input resistance of a transistor in the emitter circuit is very minimal, it would accelerate the charging process noticeably because it is connected in parallel to the capacitor. Therefore, this experiment calls for an emitter resistance of R_E = 100 Ω which counteracts a negative coupling and leads to a considerable increase in the input resistance and, consequently, in the delay time.

Observations and Measurement Results
(1) When there is no capacitor in the circuit, the filament lamp lights up and/or goes out at the same time as the switch is flipped.
(2) When the changeover switch is flipped, there is a delay before the filament lamp lights up in the one switching position, and a delay before it goes out in the other switching position.

Evaluation
1. When the connection to the positive pole of the current source is established by the changeover switch, the capacitor is charged via the resistor and the capacitor voltage increases. This also results in an increases in base-emitter voltage.
   When the connection to the negative pole is established by the changeover switch, then the capacitor discharges via the same resistor. The capacitor voltage and, consequently, the base-emitter voltage decrease.
2. The filament lamp does not light up until the base-emitter voltage has increased far enough to put the transistor into a conductive state.
3. The transistor does not block the current and the filament lamp does not go out until the base-emitter voltage falls below 0.7 V.
4. The delay times are (principally) determined by the values for capacity and charge/discharge resistance. The greater the capacity and resistance, the longer it takes to charge/discharge and the longer the turn-on and turn-off delay.
5. Delay circuits can be used in alarm systems, for time-delay light switches, and as a safety device on machines for preventing accidents.
6. The simple circuit does not actually carry out a switching function because the transition from the non-conductive to conductive state is gradual and the filament lamp does not light up/go out immediately.

Notes
This experiment represents an extremely simplified principle of delay circuits since the transistor goes from one state to the other gradually. Furthermore, the experiment is only good for a semi-quantitative analysis of delay time as a function of capacity and resistance because the exact final moment of delay can only be determined approximately due to the exponential nature of the voltage-time curve.
There is a long lag in reaction time for the measuring system used in this experiment (its setting time is 3 second). Because of this, the smaller the delay times measured, the more prone to errors they are and the more they deviate from the values that would normally be expected. Multivibrators with a positive feedback are used for delay circuits with real switching characteristics. They contain at least two active components.

Table 1

Capacitor C /μF	Resistance R /kΩ	Turn-on delay t_{On}/s	Turn-off delay t_{Off}/s
470	10	5	10
2 x 470	10	10	18
2 x 470	4.7	5	10
470	4.7	4	5

(How can the switching process of a transistor be delayed?)

Room for notes