The transistor as a function generator

Experiment Objectives

- Constructing and learning about an astable multivibrator
- Setting circuit times by modifying the resistors and capacitors
- Observing a square wave with an oscilloscope and determining circuit times and duty cycle

Basic Information

Function generators are devices that produce electric oscillations of different time progressions (functions), in particular a square wave. The electronic basic circuit is thereby an astable multivibrator. It is essentially composed of two transistors, which are alternately disabled and connected, so that a voltage drops or no voltage drops on the particular collector-emitter path. The circuit then has two states that remain stable for a period of time until the circuit jumps back to the other state. The states' lengths of time are determined by the resistors and capacitors used. So a symmetrical or an asymmetrical square wave can be produced with different switching times.

In these experiments, lamps indicate the states. By varying the resistors and capacitors, their influence on the switching times or the oscillation frequency is observed. An oscilloscope is used to determine the switching times (switch-on times).

The switching times depend on the time constants τ of the corresponding RC elements:

$$\tau = R \cdot C \quad (1)$$

For the switch-on time T_{ED}, we have, for a supply voltage that is large compared to the base-emitter path's forward voltage,

$$T_{ED} = \ln 2 \cdot R \cdot C \quad (2)$$

The relative switch-on time or duty cycle of the square wave at the particular transistor is denoted by the value

$$\frac{T_{ED}}{T_S} \quad (3)$$

where the oscillation period T_S is the sum of the two switch-on times.

Apparatus

1 Plug-in board DIN A4	576 74
1 Set of 10 bridging plugs	501 48
1 STE Transistor BC 140, NPN, emitter bottom	578 76
1 STE Transistor BC 140, NPN, emitter top	578 762
2 STE Resistors 1.5 kΩ, 1.4 W	577 46
2 STE Resistors 15 kΩ, 0.5 W	577 58
1 STE Capacitor 0.22 µF, 250 V, 5 %	578 13
1 STE Capacitor 0.47 µF, 100 V, 20 %	578 33
1 STE Capacitor 220 µF, 35 V, 20 %	578 41
1 STE Capacitor 470 µF, 16 V, 20 %	578 40
2 STE Si-diode 1N 4007	578 51
2 STE Lamp holders E 10, top	579 06
2 Incandescent lamps E10; 15 V/2 W	505 19
1 DC power supply 0 ... ± 15 V	521 45
1 Two-channel oscilloscope 303	575 211
2 Screened cables BNC/4 mm	575 24
3 Connecting leads, Ø 2,5 mm², 50 cm, black	501 28

Setup

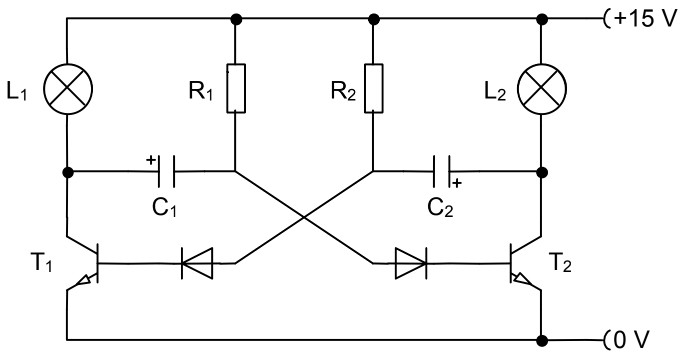


Illustration 1: Astable multivibrator
The two diodes have a protective function for the transistors, since voltage applied to the base-emitter path can be greater than the reverse voltage.

KEM/JN 0407

Procedure

a) Setup of an astable multivibrator

– Setup according to the illustration. (The transistors' emitters are connected by a cable.)

	$\frac{R_1}{k\Omega}$	$\frac{C_1}{\mu F}$	$\frac{R_2}{k\Omega}$	$\frac{C_2}{\mu F}$
a1	15	470	15	220

– Turn on the power supply and set the operating voltage to 15 V.

– Observe lamps L_1 and L_2.

b) Modifying the resistors

– Switch the resistors according to the table and observe the lamps L_1 and L_2 in each case.

	$\frac{R_1}{k\Omega}$	$\frac{C_1}{\mu F}$	$\frac{R_2}{k\Omega}$	$\frac{C_2}{\mu F}$
b1	1.5	470	15	220
b2	15	470	1.5	220
b3	1.5	470	1.5	220

– Compare each oscillation period with the period when both 15 kΩ resistors were used (a1).

c) Modifying the capacitors

– Switch the capacitors according to the table and observe the lamps L_1 and L_2 in each case.

	$\frac{R_1}{k\Omega}$	$\frac{C_1}{\mu F}$	$\frac{R_2}{k\Omega}$	$\frac{C_2}{\mu F}$
c1	15	0.47	15	220
c2	15	470	15	0.22

d) Investigation of the voltage curve

	$\frac{R_1}{k\Omega}$	$\frac{C_1}{\mu F}$	$\frac{R_2}{k\Omega}$	$\frac{C_2}{\mu F}$
d1	1.5	0.47	1.5	0.22

– Observe lamps L_1 and L_2.

– Measure with the oscilloscope the voltages U_{CE} at the transistors T1 and T2, determine the switch-on times.

– Calculate switch-on times according to (2) and the duty cycle according to (3).

– Measure with the oscilloscope the voltages (U_{BE} and U_{CE}) at a transistor (e.g. T_1).

Observations and Analysis

a) Setup of an astable multivibrator

a1 The lamps flash alternately. The switch-on time of the lamp L_1 is greater than that of the lamp L_2.

b) Modifying the resistors

b1 The lamp L_1 flashes only briefly, i.e. the resistor R_1 determines the switch-on time, resp. the switching time, of the transistor T_1.

b2 The lamp L_2 flashes only briefly, i.e. the resistor R_2 determines the switch-on time, resp. the switching time, of the transistor T_2.

b3 The lamps flash alternately. When using the smaller resistors, the oscillation period is shorter, i.e. the flash frequency is greater.

c) Modifying the capacitors

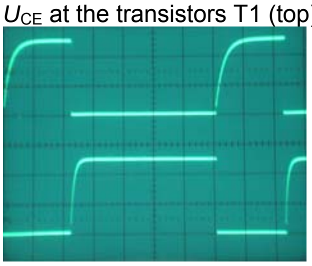
c1 The lamp L_1 flashes only very briefly (and weakly), i.e. the capacitor C_1 determines the switch-on time, resp. the switching time, of the transistor T_1.

c2 The lamp L_2 flashes only very briefly (and weakly), i.e. the capacitor C_2 determines the switch-on time, resp. the switching time, of the transistor T_2.

d) Investigation of the voltage curve

*d*1 Both lamps are shining. The oscillation can no longer be observed with the naked eye.

U_{CE} at the transistors T1 (top) and T2 (bottom)



(T1) Y I: 5 V/div DC
(T2) Y II: 5 V/div DC
Sweep: 0.1 msec/div

Switch-on times			
measured		calculated with (2)	
$\frac{T_{ED,1}}{ms}$	$\frac{T_{ED,2}}{ms}$	$\frac{\ln 2 \cdot R_1 \cdot C_1}{ms}$	$\frac{\ln 2 \cdot R_2 \cdot C_2}{ms}$
0.46	0.24	0.49	0.23

– Therefore the oscillation period is

$$T_S = 0.46\,\text{ms} + 0.24\,\text{ms} = 0.70\,\text{ms}$$

– According to (3), we get for the duty cycle

T1: $$\frac{T_{ED,1}}{T_S} = \frac{0.46\,\text{ms}}{0.70\,\text{ms}} \approx 0.66$$

T2: $$\frac{T_{ED,2}}{T_S} = \frac{0.24\,\text{ms}}{0.70\,\text{ms}} \approx 0.34$$

U_{CE} (top) and U_{BE} (bottom) at the transistor T_1

(U_{CE}) Y I: 5 V/div DC
(U_{BE}) Y II: 2 V/div DC
Sweep: 0.1 msec/div

– As soon as U_{BE} becomes greater than the base-emitter path's forward voltage ($U_{BE} \approx 0.8$ V), the transistor becomes conductive, i.e. the voltage U_{CE} falls to 0 V.