Experiment

8

Multivibrators

Objectives

To familiarize various kind of multivibrators, including bistable, monostable and unstable multivibrators.

Overview

1. Bistatble multivibrator

   Bistable multivibrator is namely FLIP-FLOP. In the experiment, the bistable multivibrator circuit use chips of 74LS00 to design a S-R FLIP-FLOP.

2. Astatble multivibrator

   By employing chips of LM555, 74LS00 or CD4098, one could implement an astable multivibrator.

3. An astable multivibrator using the Crystal oscillators

   A piezoelectric crystal, such as quartz, exhibits electromechanical-resonance characteristics that are very stable (with time and temperature) and highly selective (having very high Q factors). The circuit symbol of a crystal is shown in Fig. 1(a) and the equivalent circuit model is given in Fig. 1(b). The resonance properties are characterized by a large inductance L (as high as hundreds of henrys), a very small series capacitance C_S (as small as 0.0005 pF), a series resistance r representing a Q factor $\omega_0 L/r$ that can be as high as a few thousand, and a parallel capacitance C_P (a few picofarads). Capacitor C_P represents the electrostatic capacitance between the two parallel plates of the crystal. Note that $C_P >> C_S$.

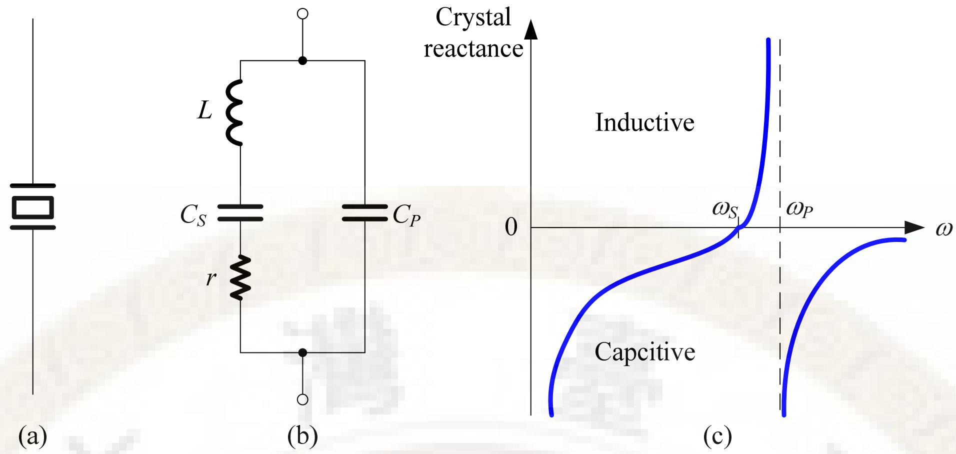


Fig. 1 A piezoelectric crystal: (a) circuit symbol; (b) equivalent circuit; (c) crystal reactance versus frequency [note that, neglecting the small resistance r, $Z_{\text{crytal}} = jX(\omega)$]

※The above content refer to section 12.3 (p.991) of text book, Microelectronic Circuits.

4. An astable multivibrator using the LM555 IC

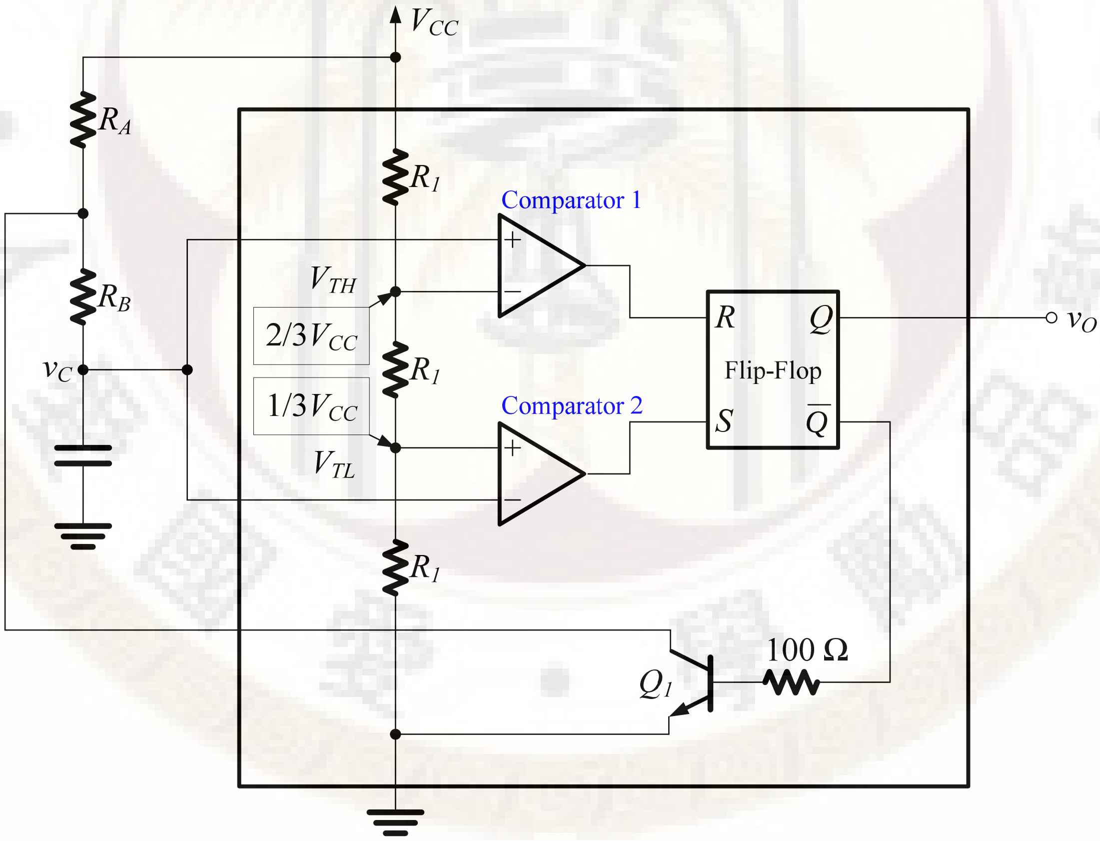


Fig. 3(a) The 555 timer connected to implement an astable multivibrator.

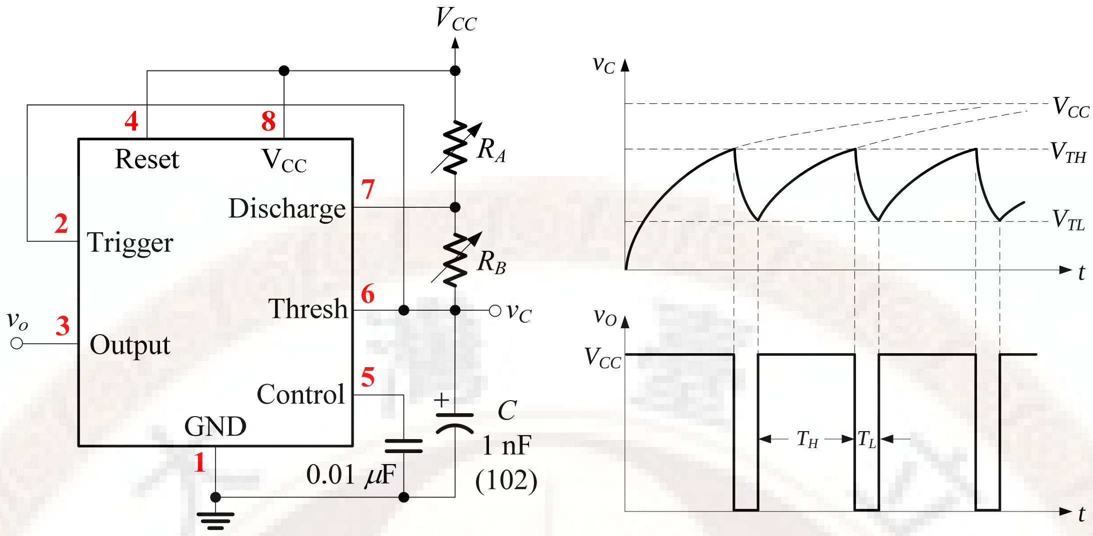


Fig. 3(b) Waveforms of the circuit in Fig. 3(a)

Fig. 3 shows the circuit of an astable multivibrator employing a 555 IC, two external resistors, R_A and R_B, and an external capacitor C. To see how the circuit operates refer to the waveforms depicted in Fig. 3(b).

The exponential rise of v_C can be described by

$$v_C(t) = v_C(\infty) + [v_C(0) - v_C(\infty)]e^{-t/RC}$$

The process of charging C cycle is analyzed as follow.

(1) $v_C(0^-) = 0$, $S = 1$, $\overline{Q} = 0$, Q_1 OFF, C is charged from V_{CC} through R_A and R_B;

(2) Until $v_C(T_H) = 2/3V_{CC}$, The output of comparator 1 transfers status to 1, R→1, S→0, Q_1→ON,

(3) $v_C(0^+) = 1/3\ V_{CC}$, $v_C(T_H) = 2/3V_{CC}$, $v_C(\infty) = V_{CC}$, $v_C(T_H) = 2/3V_{CC}$;

(4) Substituting the initial conditions shown in (3) into the above equation, we have

$$v_C(T_H) = V_{CC} - \frac{2}{3}V_{CC} \cdot e^{-T_H/C(R_A+R_B)}, v_C(T_H) = \frac{2}{3}V_{CC}$$

$$T_H = (R_A + R_B)C \cdot \ln 2$$

where $t = 0$ is the instant at which the internal T_H begins.

The process of discharging C cycle is analyzed as follow.

$$v_C(t) = v_C(\infty) + [v_C(0) - v_C(\infty)]e^{-t/RC}$$

(5) $v_C(0^-) = 2/3\ V_{CC}$, $S = 0$, $\overline{Q} = 1$, Q_1 ON, C is discharged through R_B and Q_1 to the ground;

(6) Until $v_C(T_H) = 1/3V_{CC}$, The output of comparator 2 transfers status to 1,

S→1, Q_1→OFF,

(7) $v_C(0^+) = 2/3\ V_{CC}$, $v_C(\infty) = 0$, $v_C(T_L) = 1/3V_{CC}$;

(8) Substituting the initial conditions shown in (7) into the above equation, we have

$$v_C(T_L) = \frac{2}{3}V_{CC}\cdot e^{-T_L/R_BC}, v_C(T_L) = \frac{1}{3}V_{CC}$$

$$T_L = R_BC\cdot\ln 2$$

where $t = 0$ is the instant at which the internal T_L begins.

(9) Duty cycle:

$$T = \frac{T_H}{T_H + T_L} = \frac{(R_A + R_B)C\cdot\ln 2}{(R_A + 2R_B)C\cdot\ln 2}$$

Instrument Requirement

Instrument	Quantity	Components	Quantity
Oscilloscope	1	Power supplier	2

Component Requirement

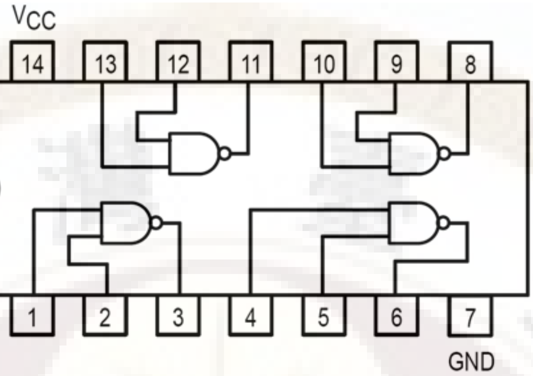
Components	Quantity	Components	Quantity
1 nF (102)	1	74LS00	1
0.01 μF (103)	1	LM555	2
0.047 μF (473)	2	2N2222 (NPN BJT)	2
0.47 μF (474)	1	Crystal oscillator 3.58MHz	1
4.7 μF	1	Diode (1N4001)	1
47 μF	2	VR (10 $k\Omega$)	4
100 μF	1	VR (100 $k\Omega$)	2
LED	3	1.2 kΩ	2
		220 Ω	4

Instrument confirmation

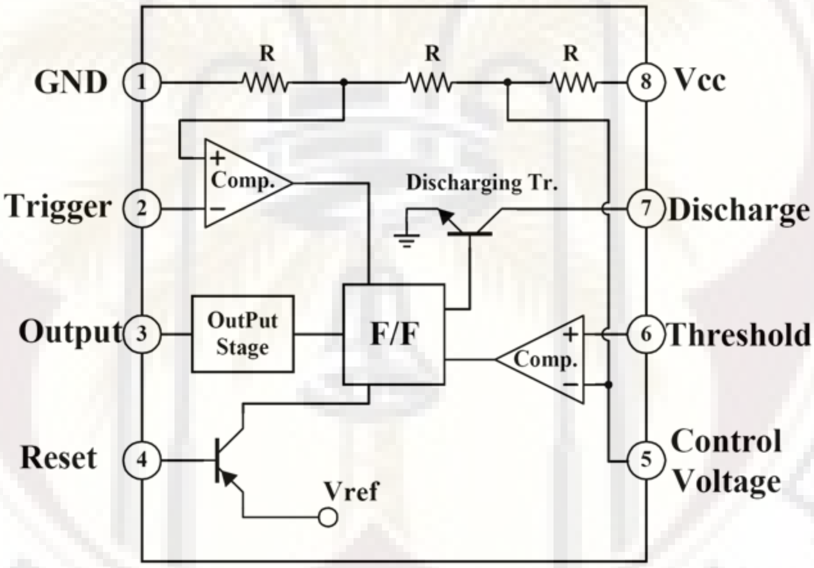
Before you proceed to any part of the experiment, please remember to do the **Instrument Examinations** to the instruments before performing any experiment. The examining procedures are shown in experiment 1.

Chip PINOUT

1. PINOUT Diagram of 74LS00

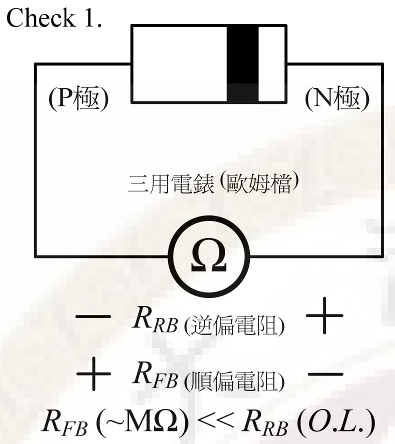


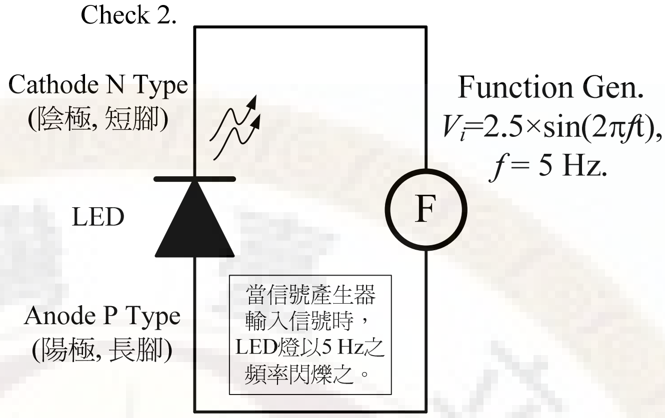
2. PINOUT Diagram of LM555

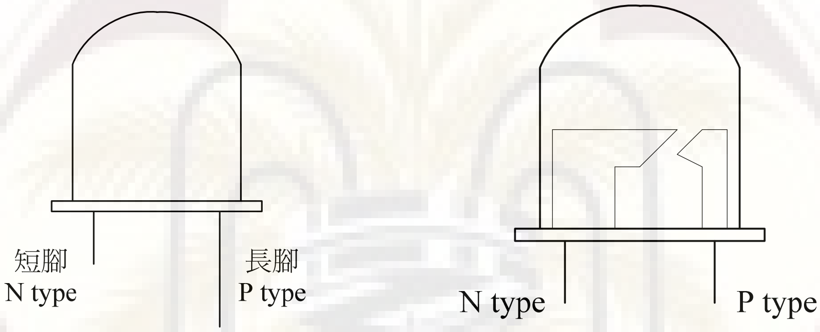


Components confirmation

1. Functional confirmation of LED







※ *Note*: Please do not directly provide DC power with LED. Otherwise it will be damaged easily.

2. 2N2222 (NPN BJT)—PINOUT

※ *Note*:

(1) The E, B, C of PN2222A terminals are as shown above.

(2) The middle lead (pin) of PN2222A is B (base) terminal.

(3) **Do not separate the terminals of 2N2222 widely apart in order to prevent from the serious injury to the transistors**.

Lab Work

1. An astable multivibrator using the Crystal oscillator

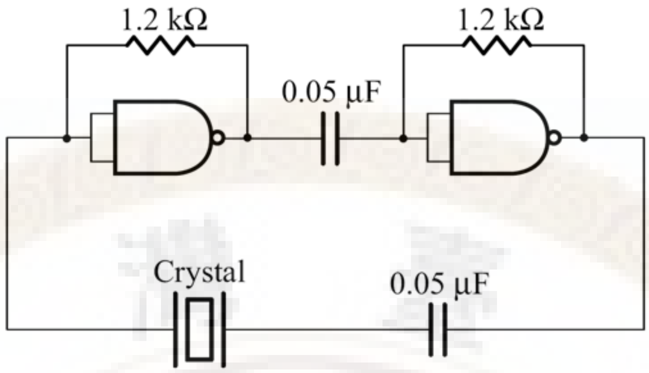


Fig. 4 Piezoelectric crystal circuit

(1) In Fig. 4, supply voltage V_{CC} = +5V to pin 14 of 74LS00 IC and short pin 7 to the ground.

(2) Attach CH1 probe of oscilloscope in the node of the output of second NAND gate.

(3) Observe whether the measured waveform in Oscilloscope is sinusoidal.

(4) Observe whether the frequency of the measured wave is almost the same as that of piezoelectric crystal (3.58 MHz).

(5) If the observations in step (3) and (4) happen to be wrong, try to change another chip of 74LS00 and crystal oscillator, respectively.

(6) Record the oscillatory frequency f_0 = _______________ Hz.

2. Circuits of Sparkling Lamp in the Vehicle (煞車燈閃爍電路)

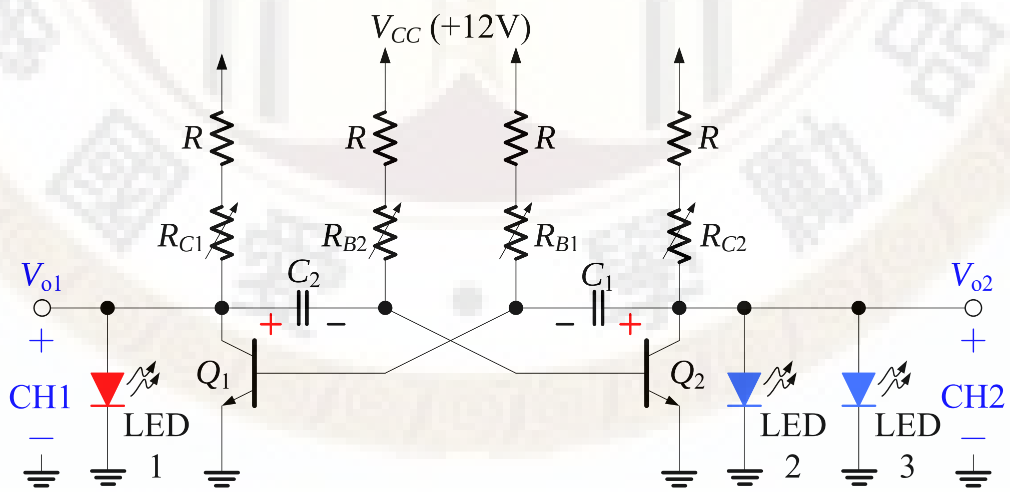


Fig. 5 An astable multivibrator using transistors

(1) **Do not separate the terminals of 2N2222 widely apart in order to prevent from the serious injury to the transistors.**

(2) In Fig. 5, supply voltage $V_{CC} = +12$V.

(3) Apply the values of R = 220 Ω, $C_1 = C_2 = 47\ \mu$F, $R_{B1} = R_{B2} = 100$ kΩ VR, $R_{C1} = R_{C2} = 10$ kΩ VR in the circuit.

(4) Adjust VR $R_{C1} = R_{C2} \approx 0.5$ kΩ.

(5) Oscilloscope ▶ Press the **CH1** and **CH2 MENU** ▶ **Coupling** ▶ **DC**.

(6) Adjust R_{B1} and R_{B2} to make the lamp be able to sparkle and make the oscillatory frequency of the lamp as ideally as you wish.

(7) Record the value of oscillatory frequency f_0 = ________Hz.

(8) Use the **Cursors** menu button to measure and record the value of T_H = ________μs, T_L = ________μs, Duty cycle = ________%,

(Hint: $Duty\ Cycle = \frac{T_H}{T_H + T_L}(\%)$)

(9) Record the value of R_{C1} = ________kΩ, and R_{C2} = ________kΩ.

(10) Record the value of R_{B1} = ________kΩ, and R_{B2} = ________kΩ.

3. An astable multivibrator using the LM555 IC

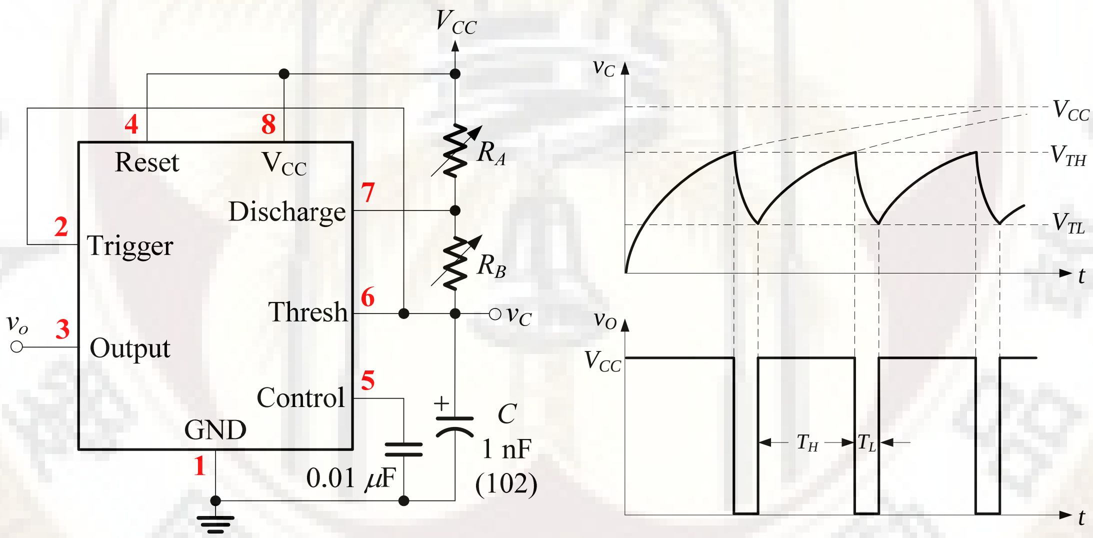


Fig. 6 An astable multivibrator using the LM555 IC

(1) In Fig. 6, supply voltage V_{CC} = +5V. Apply the values of R_A, R_B, and C designed in the Pre-Lab work to the circuit.

(2) Or you can directly use C = 1 nF, 10KΩ VR for R_A and R_B.

(3) Adjust R_A and R_B to fulfill the condition of f_0 = 100 kHz, Duty cycle = 90% and $T_L = 1\ \mu$s.

(4) Attach CH1 and CH2 probes of oscilloscope to pin 3 and pin 6, respectively, and observe the measured waveform in CH1 and CH2.

(5) Use the **Cursors** menu button to measure and record the value of T_L = ________μs, Duty cycle = ________%,

(Hint: $Duty\ Cycle = \dfrac{T_H}{T_H + T_L}(\%)$)

(6) Record the value of oscillatory frequency f_0 = ________Hz.

(7) Record the value of R_A = ________Ω, and R_B = ________Ω.

(8) Change the supply voltage V_{CC} = +10V.

(9) Record the value of T_L = ________μs, Duty cycle = ________%,

(10) Record the value of oscillatory frequency f_0 = ________Hz.

(11) Change the supply voltage V_{CC} = +15V.

(12) Record the value of T_L = ________μs, Duty cycle = ________%,

(13) Record the value of oscillatory frequency f_0 = ________Hz.

4. The series of 555 Circuits — An Alarm bell Circuit using the LM555 IC

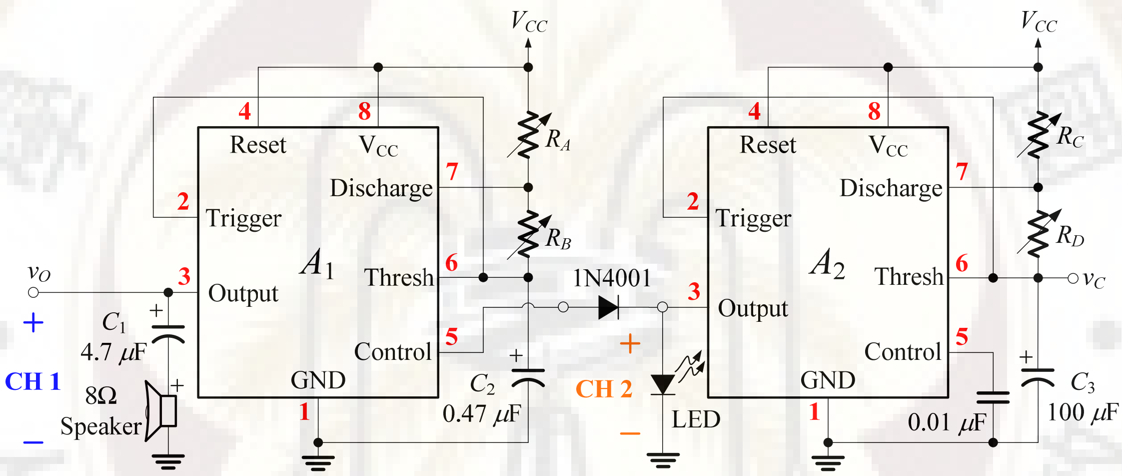


Fig. 7 An Alarm Bell Circuit using the LM555 IC

A. Circuit implementation

(1) In Fig. 7, supply voltage V_{CC} = +5V, +I_{SET} = 0.5A.

(2) Do not connect 8Ω speaker in the following steps.

(3) Use 10KΩ VR for R_A, R_B, R_C, and R_D.

(4) Attach CH1 and CH2 probes of oscilloscope to pin 3 of A_1 and A_2, respectively

(5) Observe the measured waveform in CH1 and CH2.

B. Frequency Adjustment

(6) Adjust R_A to have f_0 (CH1) = 300 ~ 700 Hz, and R_B to have Duty cycle = 50%.

(7) Adjust R_C to have f_0 (CH2) = 0.1 ~ 10 Hz, and R_D to have Duty cycle = 50%.

C. Alarm Bell Adjustment

(8) Connect 8Ω speaker. (Note: The speaker has to be acquired from TA.)

(9) Adjust R_A and R_C to have an appropriate sound similar to the alarm bell.

D. Measurement

(10) In A_1, record the value of oscillatory frequency f_0 (CH1)= ___ ~ ___Hz.

(11) In A_2, record the value of oscillatory frequency f_0 (CH2)= ___ ~ ___Hz.

(12) Record the value of R_A = ________kΩ, and R_B = ________kΩ.

(13) Record the value of R_C = ________kΩ, and R_D = ________kΩ.

E. Speaker Replacement

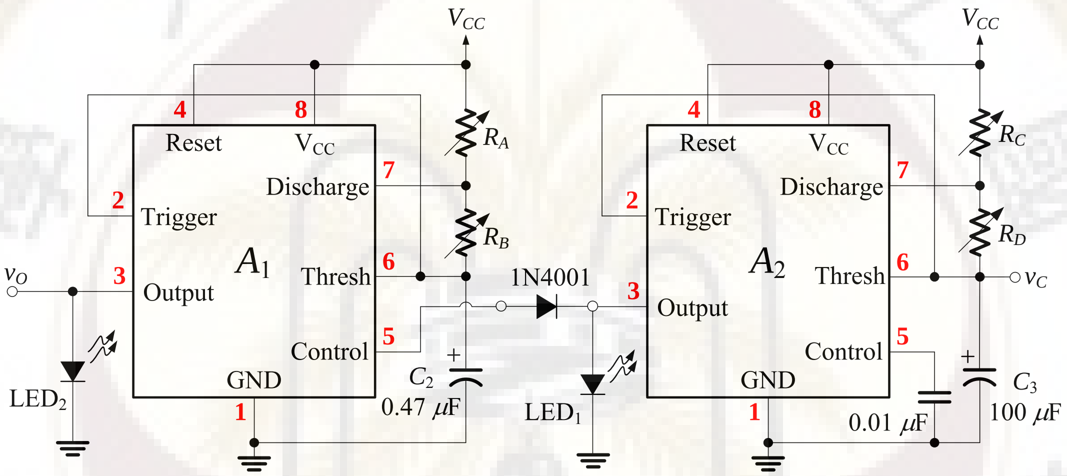


Fig. 8 An Alarm Bell Circuit using the LM555 IC

(14) In Fig. 7, replace the record the 8Ω speaker with LED (refer to Fig. 7).

(15) Observe whether the LED$_2$ twinkles in your eyes. Why?

(16) Briefly describe the answer in your homework report.

Reference

1. A.S. Sedra and K.C. Smith, *Microelectronic Circuits*, 5th ed., Oxford University Press publishing, New York, August 2007.
2. A.S. Sedra and K.C. Smith, *Laboratory Manual for Microelectronic Circuits*, 3rd ed., Oxford University Press publishing, New York, 1997.
3. Paul Horowitz, Winfield Hill, *The art of electronics*, 2nd ed., Cambridge University Press, New York, 1989.