Design and Implementation of a Pentatonic Tone Generator Circuit

Fall 2024

College of Engineering and Computing

Department of Electrical and Computer Engineering

ECE 304: Electronics

Professor - Mark Scott, PhD

Professor – James Leonard

Logan Liu

Step-by-Step Guide to Build and Understand the Pentatonic Tone Generator Circuit

This guide explains the construction and operation of the Pentatonic Tone Generator Circuit, utilizing two NE555 timers (IC1 and IC3) and a CD4017 decade counter (IC2). It incorporates detailed explanations to ensure a comprehensive understanding of the circuit's functionality.

1. Components Required

Table 1: Bill of Materials for the Pentatonic Tone Generator Circuit

Component	Value	Quantity	Description
IC1	NE555 Timer	1	Astable multivibrator for clock generation.
IC2	4017 Decade Counter	1	Sequential output generator.
IC3	NE555 Timer	1	Monostable multivibrator for tone generation.
Resistor (R1)	2kΩ	1	Sets IC1 frequency along with RP1 and C1.
Resistor (R2)	27kΩ	1	Determines tone frequency in IC3.
Resistors (R3–R7)	10kΩ, 27kΩ, 47kΩ, 100kΩ, 200kΩ	5	Sets voltage division and adjusts tone parameters.
Variable Resistor (RP1)	200kΩ	1	Adjusts IC1 oscillation frequency (tone speed).
Capacitor (C1)	4.7µF	1	Determines IC1 oscillation frequency.
Capacitor (C2)	0.01µF (103)	1	Timing or decoupling capacitor for IC1.
Capacitor (C3)	0.01µF (103)	1	Determines timing for IC3.
Capacitor (C4)	0.01µF (103)	1	Decoupling capacitor for IC3.
Capacitor (C5)	10µF	1	Filtering capacitor for the speaker output.
Capacitor (C6)	100µF	1	Power supply smoothing capacitor.
Diodes (VD1–VD5)	1N4148	5	Signal routing for sequential outputs.
Speaker (BP)	8Ω, 0.5W	1	Outputs sound.
Battery (BT)	6V	1	Powers the circuit.
Breadboard	-	1	For assembling the circuit.
Connecting Wires	-	As Needed	For connecting components.

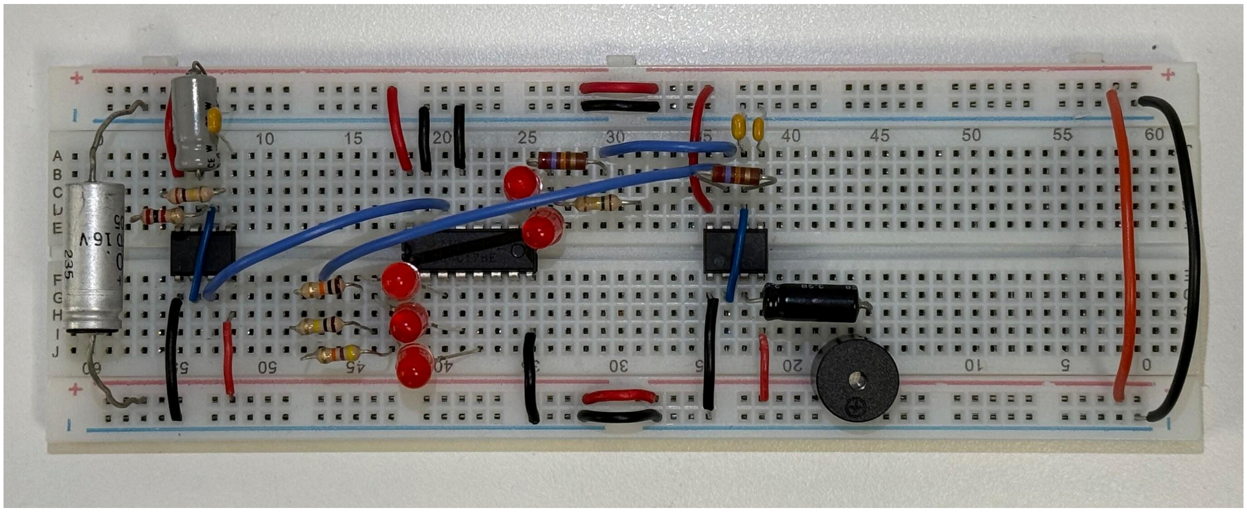

Figure 1: Breadboard Circuit Layout for the Pentatonic Tone Generator Circuit

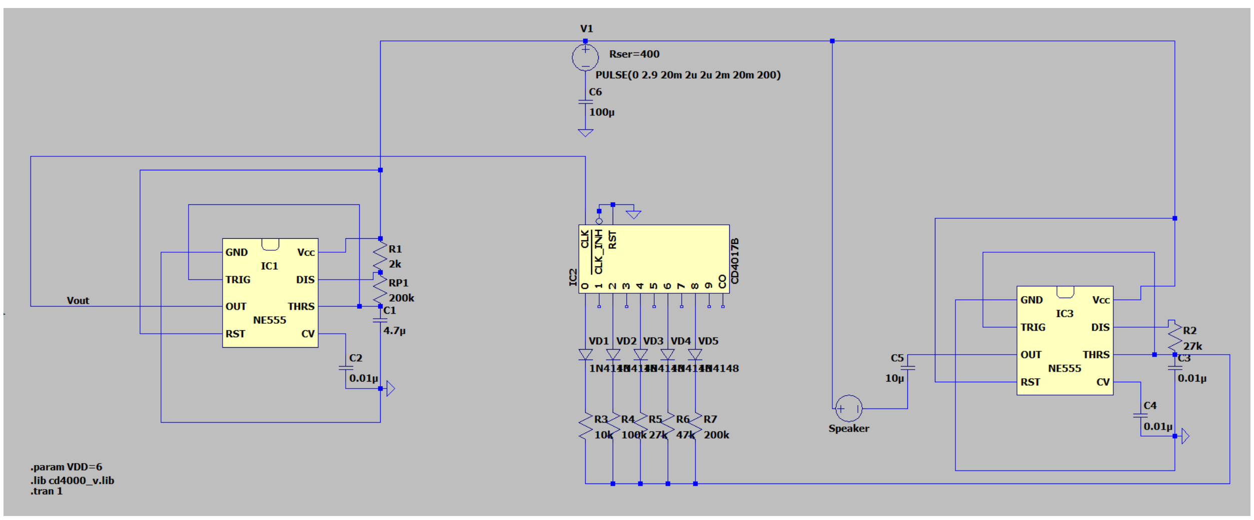

Figure 2: Schematic Diagram for the Pentatonic Tone Generator Circuit

2. Circuit Overview

This circuit generates sequential tones using a clock signal (IC1), a sequential counter (IC2), and a tone generator (IC3). The key working principle is:

1. IC1: Generates a square wave to clock IC2.
2. IC2: Activates outputs (Q0, Q2, etc.) sequentially, triggering IC3.
3. IC3: Generates high-frequency sound signals, passed to the speaker.

3. Circuit Assembly

(a) IC1 (555 Timer) - Astable Oscillator

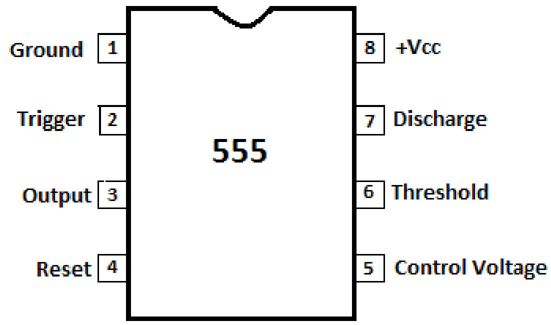

Figure 3: NE555 Timer Pinout Diagram

- Purpose: Generates a clock signal for IC2.
- Steps:
    1. Place IC1 (555 Timer) on the breadboard.
    2. Connect:
        - Pin 8 to +6V and Pin 1 to GND.
        - Pin 4 (RESET) to +6V to enable the timer.
        - Pin 2 (TRIGGER) and Pin 6 (THRESHOLD) together.
        - R1 (2kΩ) between Pin 7 (DISCHARGE) and +6V.
        - RP1 (200kΩ) between Pin 7 and Pin 6.
        - C1 (4.7μF) between Pin 6 and GND.
    3. Connect Pin 3 (OUTPUT) to Pin 14 (CLK) of IC2.
- Key Adjustment: RP1 controls the clock frequency of IC1, affecting the speed at which IC2 switches outputs.

(b) IC2 - 4017 Decade Counter

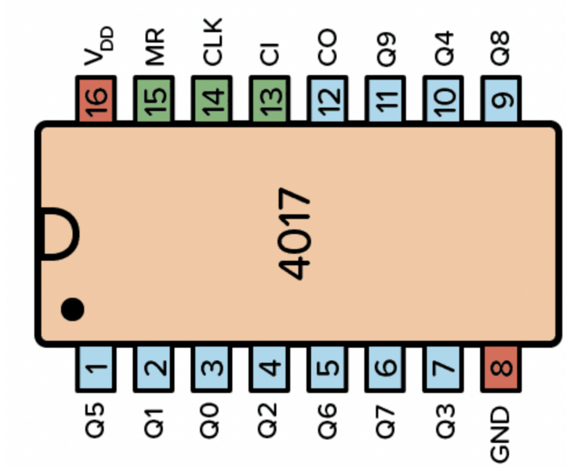

Figure 4: CD4017 Decade Counter Pinout Diagram

- Purpose: Sequentially activates outputs to control the tones.

- Steps:
    1. Place IC2 (4017) on the breadboard.
    2. Connect:
        - Pin 16 to +6V and Pin 8 to GND.
        - Pin 15 (MR) to GND.
        - Pin 13 (CI) to GND.
        - Pin 14 (CLK) to Pin 3 of IC1.
    3. Connect outputs Q0, Q2, Q4, Q6, and Q8 (Pins 3, 4, 10, 5, and 9) to the diode-resistor network.
- Explanation: Each activated output triggers IC3 via the network, allowing sequential tones.

(c) Diode-Resistor Network

- Purpose: Directs IC2 outputs to IC3 while adjusting the tone characteristics.
- Steps refer to Figure 4:
    1. Connect diodes VD1–VD5 (1N4148) to IC2 outputs (Q0, Q2, Q4, Q6, and Q8).
    2. Attach resistors R3–R7 (10kΩ, 100kΩ, 27kΩ, 47kΩ, 200kΩ) in series with each diode.
    3. Connect the free ends of the resistors together and route them to Pin 2 (TRIGGER) of IC3.
- Note: Changing the values of R3–R7 can modify the tone frequency by altering the voltage level triggering IC3.

(d) IC3 - Monostable Oscillator

- Purpose: Produces high-frequency tones for the speaker.
- Steps:
    1. Place IC3 (555 Timer) on the breadboard.
    2. Refer to Figure 3, Connect:
        - Pin 8 to +6V and Pin 1 to GND.
        - Pin 4 (RESET) to +6V.
        - Pin 2 (TRIGGER) to the output of the diode-resistor network.
        - R2 (27kΩ) between Pin 7 (DISCHARGE) and +6V.
        - C3 (0.01μF) between Pin 6 (THRESHOLD) and GND.
    3. Connect Pin 3 (OUTPUT) to the negative terminal of the speaker via C5 (10μF). The positive terminal of the speaker goes to +6V.
- Alert: Ensure R2 and C3 values keep IC3's frequency in the audible range (20 Hz to 20 kHz) for clear and distinct sound output.

(e) Speaker and Power Supply

- Speaker (BP):
    - Converts the high-frequency signals from IC3 into sound.
- Power Decoupling:

- Place C6 (100μF) across +6V and GND near IC1 to stabilize the power supply.

4. Circuit Functionality

(a) IC1 (Clock Generator)

- Produces a square wave clock signal at a frequency determined by:

$$f = \frac{1.44}{(R1 + 2RP1) \cdot C1} \quad (1)$$

- Adjusting RP1 changes the clock frequency, affecting the speed of tone sequencing.

(b) IC2 (Sequential Activation)

- Sequentially activates its outputs (Q0, Q2, Q4, Q6, Q8) with each clock pulse from IC1.
- Outputs pass through the diode-resistor network to trigger IC3.

(c) IC3 (Tone Generator)

- Generates high-frequency tones determined by:

$$f_{\text{tone}} = \frac{1.44}{R2 \cdot C3} \quad (2)$$

- R2 (27kΩ) and C3 (0.01μF) ensure IC3 operates at a frequency significantly higher than IC1, remaining in the audio range for sound production.
- The generated signal is passed to the speaker through C5 (10μF) for filtering.

(d) Speaker (BP)

- Converts electrical signals into audible tones.
- Each IC2 output generates a distinct tone, with the sequence speed controlled by RP1.

5. Key Notes and Adjustments

1. Frequency Tuning:
   - Adjust RP1 to change the tone sequence speed.
   - Changing R3–R7 values modifies tone frequency by adjusting the voltage level triggering IC3, affecting pitch and tone distinction.

    - Ensure R2 and C3 values are appropriate to keep IC3's frequency in the audible range.
2. Component Values:
    - Verify resistor and capacitor values are as specified to ensure proper operation.
3. Power Stability:
    - Use C6 (100µF) to stabilize the power supply and reduce noise.

6. Warnings

1. Use correct polarities for capacitors (C1, C5, C6) and diodes (VD1–VD5).
2. Ensure connections match the schematic to avoid circuit failure.
3. Test IC1 and IC3 outputs independently if the circuit doesn't work as expected.

7. Reference

This project was completed with the assistance of ChatGPT, which used the detailed knowledge I provided on how the circuit works, including adjustments like RP1 for sequence speed and R2, C3, and R3–R7 for tone and frequency control. Based on this input, ChatGPT developed the schematic, component list, and step-by-step instructions, clarified component roles, and assisted in troubleshooting and optimizing the circuit. It also supported the creation of a professional project instruction with integrated visuals and clear explanations.