Electronic Metronome

Using a 555 Timer
LM 555 Timer Chip

• Used in a wide variety of circuits to generate square wave and triangular shaped single and periodic pulses.
  – High efficiency LED and fluorescence light dimmers
  – Temperature control loop for electric stoves
Multivibrators

• Monostable
  – A single pulse is outputted when an input voltage attached to the trigger pin of the 555 timer equals the voltage on the threshold pin.

• Astable
  – A periodic square wave is generated by the 555 timer.
    • The voltage for the trigger and threshold pins is the voltage across a capacitor that is charged and discharged through two different RC networks.
How a 555 Timer Works

• Astable Multivibrator Mode

http://www.williamson-labs.com/480_555.htm
Voltage Comparator

- Op Amp circuit without a feedback component.
  - Output voltage changes to force the negative input voltage to equal the positive input voltage.
  - Maximum value of the output voltage, $V_o$, is $V+$ if the negative input voltage, $v_1$, is less than the positive input voltage, $v_2$.
  - Minimum value of the output voltage, $V_o$, is $V-$ if the negative input voltage, $v_1$, is greater than the positive input voltage, $v_2$. 
Transistor

- As you will learn in ECE 2204, a transistor can be designed to act like a switch.
  - When a positive voltage is applied to the base of the transistor (B), the transistor acts like there is a very small resistor is between the collector (C) and the emitter (E).
  - When ground is applied to the base of the transistor (B), the transistor acts like there is a open circuit between the collector (C) and the emitter (E).
Metronomes

• Emits regular sounds, usually a single frequency tone, beat, or click, which instrument players and singers use to count the meter or tempo of a piece of music.

• The repetition rate of the sound from a metronome can be adjusted by the musician.
  – The typical range is from 40 to 200 beats per minute (bpm), which translates to a frequency of 0.667 to 3.33Hz.
Metronome Circuit
Equations

• Time constants of two different resistor-capacitor networks determine the length of time the timer output, $t_1$ and $t_2$, is at 5V and 0V, respectively.

$$t_1 = 0.693(R_a + R_b)C$$

$$t_2 = 0.693(R_b)C$$
Types of Capacitors

• Fixed Capacitors
  – Nonpolarized
    • May be connected into circuit with either terminal of capacitor connected to the high voltage side of the circuit.
      – Insulator: Paper, Mica, Ceramic, Polymer
  – Electrolytic
    • The negative terminal must always be at a lower voltage than the positive terminal
      – Plates or Electrodes: Aluminum, Tantalum
Nonpolarized

• Difficult to make nonpolarized capacitors that store a large amount of charge or operate at high voltages.
  – Tolerance on capacitance values is very large
    • +50%/-25% is not unusual

http://www.marvac.com/fun/ceramic_capacitor_codes.aspx
Electrolytic

Pspice Symbols

Fabrication

Electrolytic Capacitors

• The negative electrode must always be at a lower voltage than the positive electrode.
  – So in your circuit, the negative electrode must be grounded.
Frequency and Duty Cycle

\[ f = \frac{1}{t_1 + t_2} = \frac{1.44}{(R_a + 2R_b)C} \]

\[ D = \frac{t_2}{t_1 + t_2} = \frac{R_b}{R_a + 2R_b} \]

When the output of the 555 timer changes from 5V to 0V, a pulse current will flow through the speaker, causing the speaker to create a sound. You will change the frequency of the pulses to the speaker by changing the value of \( R_a \). Since \( R_a \) is usually much larger than \( R_b \), the frequency of the pulses are linearly proportional to the value of \( R_a \) and the duty cycle of the pulse waveform will be very short.
Why is there a resistor in series with the speaker?

- From the LM 555 timer datasheet:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Limits</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LM555C</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Typ</td>
</tr>
<tr>
<td>Output Voltage Drop (Low)</td>
<td>$V_{CC} = 15V$</td>
<td>0.1</td>
<td>0.25</td>
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<tr>
<td></td>
<td>$I_{SINK} = 10mA$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$I_{SINK} = 50mA$</td>
<td>0.4</td>
<td>0.75</td>
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<tr>
<td></td>
<td>$I_{SINK} = 100mA$</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>$I_{SINK} = 200mA$</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$V_{CC} = 5V$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$I_{SINK} = 8mA$</td>
<td></td>
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<tr>
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<td>$I_{SINK} = 5mA$</td>
<td>0.25</td>
<td>0.35</td>
</tr>
<tr>
<td>Output Voltage Drop (High)</td>
<td>$I_{SOURCE} = 200mA, V_{CC} = 15V$</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$I_{SOURCE} = 100mA, V_{CC} = 15V$</td>
<td>12.75</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>$V_{CC} = 5V$</td>
<td>2.75</td>
<td>3.3</td>
</tr>
<tr>
<td>Rise Time of Output</td>
<td></td>
<td>100</td>
<td>ns</td>
</tr>
<tr>
<td>Fall Time of Output</td>
<td></td>
<td>100</td>
<td>ns</td>
</tr>
</tbody>
</table>
Why won’t the sound be loud?

- Electromagnet generates a magnetic field that causes the diagram to change position based upon the magnitude of the current through the voice coil.
  - We hear sound when the diagram moves, which only occurs when the current through the voice coil has to change.
- 0.5W speaker with 8 Ω equivalent impedance.
  - $5V/8\ \Omega = 0.625\ \text{A}$

http://en.wikipedia.org/wiki/Loudspeaker