Oscillators and Timers

• Oscillators & Timers
  – Produce timing signals to initiate measurement
    • Periodic or single pulse
    • Periodic output at known (controlled) frequency
    • Shape is also known (controllable)
      – Sinusoid, square, triangle, etc.
  – Part of nearly every electronic device
Relaxation oscillators

- Use a simple RC decay to generate a sustained oscillation
- Example using an op amp as a “comparator”
  - Flips between states at a given frequency \(1/RC\)
Sine Wave Generator

- Wien Bridge oscillator
  - 1/3 gain amplifier with phase shift cancellation
- Other techniques
  - RC phase shift
  - quadrature
Resonators

• Use “piezoelectric” effect
  – Voltage generates a strain
  – Quartz crystal vibrates at a specific frequency
    • Depends on thickness of crystal
  – Can cat like a very sharply tuned RLC circuit element
    • Q is $10^{4-5}$
  – Very stable and useful!
The 555 Timer

- The 555 Timer is one of the most popular and versatile integrated circuits ever produced!
- It is 30 years old and still being used!
- It is a combination of digital and analog circuits.
- It is known as the “time machine” as it performs a wide variety of timing tasks.
- **Applications for the 555 Timer include:**
  - Bounce-free switches and Cascaded timers
  - Frequency dividers
  - Voltage-controlled oscillators
  - Pulse generators and LED flashers
555 Timer

- Each pin has a function
- Note some familiar components inside
Inside the 555 Timer

– The voltage divider (blue) has three equal 5K resistors. It divides the input voltage (Vcc) into three equal parts.

– The two comparators (red) are op-amps that compare the voltages at their inputs and saturate depending upon which is greater.
  • The Threshold Comparator saturates when the voltage at the Threshold pin (pin 6) is greater than \((2/3)Vcc\).
  • The Trigger Comparator saturates when the voltage at the Trigger pin (pin 2) is less than \((1/3)Vcc\).
– The flip-flop (green) is a bi-stable device. It generates two values, a “high” value equal to Vcc and a “low” value equal to 0V.
  • When the Threshold comparator saturates, the flip flop is Reset (R) and it outputs a low signal at pin 3.
  • When the Trigger comparator saturates, the flip flop is Set (S) and it outputs a high signal at pin 3.

– The transistor (purple) is being used as a switch, it connects pin 7 (discharge) to ground when it is closed.
  • When Q is low, Qbar is high. This closes the transistor switch and attaches pin 7 to ground.
  • When Q is high, Qbar is low. This open the switch and pin 7 is no longer grounded
Types of 555-Timer Circuits

- **Astable Multivibrator** puts out a continuous sequence of pulses
- **Monostable Multivibrator** (or one-shot) puts out one pulse each time the switch is connected
Monostable Multivibrator (One Shot)
Behavior of the Monostable Multivibrator

- The monostable multivibrator is constructed by adding an external capacitor and resistor to a 555 timer.
- The circuit generates a single pulse of desired duration when it receives a trigger signal, hence it is also called a one-shot.
- The time constant of the resistor-capacitor combination determines the length of the pulse.
Uses of the Monostable Multivibrator

– Used to generate a clean pulse of the correct height and duration for a digital system
– Used to turn circuits or external components on or off for a specific length of time.
– Used to generate delays.
– Can be cascaded to create a variety of sequential timing pulses. These pulses can allow you to time and sequence a number of related operations.
Astable Pulse-Train Generator (Multivibrator)

- $V_{cc}$
- $R_1$
- $R_2$
- $C$
- Trigger Comparator
- Threshold Comparator
- Control Flip-Flop
- Output

Astable Pulse-Train Generator
Behavior of the Astable Multivibrator

- The astable multivibrator is simply an oscillator. The astable multivibrator generates a continuous stream of rectangular off-on pulses that switch between two voltage levels.
- The frequency of the pulses and their duty cycle are dependent upon the RC network values.
- The capacitor C charges through the series resistors $R_1$ and $R_2$ with a time constant $(R_1 + R_2)C$.
- The capacitor discharges through $R_2$ with a time constant of $R_2C$. 
Uses of the Astable Multivibrator

– Flashing LED’s
– Pulse Width Modulation
– Pulse Position Modulation
– Periodic Timers
• 40 LED bicycle light with 20 LEDs flashing alternately at 4.7Hz
Understanding the Astable Mode Circuit

- 555-Timers, like op-amps can be configured in different ways to create different circuits. This one creates a train of equal pulses, as shown at the output.
• Capacitor C1 is charged up by current flowing through R1

\[ I = \frac{V1 - V_{\text{CAPACITOR}}}{R1} = \frac{10 - V_{\text{CAPACITOR}}}{1k} \]

• As the capacitor charges up, its voltage increases and the current charging it decreases
• Capacitor Current

\[ I = I_0 e^{-t/\tau} \]

• Capacitor Voltage

\[ V = V_o \left( 1 - e^{-t/\tau} \right) \]

• Where the time constant

\[ \tau = RC = R1 \cdot C1 = 1ms \]
• Note that the voltage rises to a little above 6V in 1ms.

\[(1 - e^{-1}) = 0.632\]
555 Timer

- At the beginning of the cycle, C1 is charged through resistors R1 and R2. The charging time constant is

\[ \tau_{charge} = (R1 + R2)C1 \]

- The voltage reaches \((2/3)Vcc\) in a time \(t_{charge} = T1 = 0.693(R1 + R2)C1\)
555 Timer

- When the voltage on the capacitor reaches \((2/3)V_{cc}\), a switch (the transistor) is closed (grounded) at pin 7.
- The capacitor is discharged to \((1/3)V_{cc}\) through R2 to ground, at which time the switch is opened and the cycle starts over.

\[
\tau_{\text{discharge}} = (R2)C1
\]

\[
t_{\text{discharge}} = T2 = 0.693(R2)C1
\]
The frequency is then given by

\[ f = \frac{1}{0.693(R1 + 2 \cdot R2)C1} = \frac{1.44}{(R1 + 2 \cdot R2)C1} \]
PWM: Pulse Width Modulation

- Signal is compared to a sawtooth wave producing a pulse width proportional to amplitude
What Can Be Done With PWM?

- **Low Duty Cycle**

- **Medium Duty Cycle**

- **High Duty Cycle**

**Question:** What happens if voltages like the ones above are connected to a light bulb? **Answer:** The longer the duty cycle, the longer the light bulb is on and the brighter the light.
What Can Be Done With PWM?

- Average power can be controlled
- Average flows can also be controlled by fully opening and closing a valve with some duty cycle