ECE 85L Digital Logic Design Laboratory

Fresno State, Lyles College of Engineering
Electrical and Computer Engineering Department

Spring 2018

Laboratory 10 – Astable and Monostable Multivibrators

1. OBJECTIVES

- Understand the Operation of Astable and Monostable Multivibrators
- Implement an Astable Multivibrator of a Specified Frequency and Duty Cycle Utilizing the 555 Counter Timer
- Implement a Monostable Multivibrator using a Specified Time Constant using a Typical Integrated Circuit

A2. DISCUSSION – ASTABLE MULTIVIBRATORS

Multivibrators comprise a class of sequential (as opposed to combinatorial) circuits which possess two output states (1 or 0). Each member of this class is characterized by the number of stable states (that is, the number of states in which it will remain indefinitely in the absence of input). Consistent with this catagorization there are three types of Multivibrators:

- **Astable** (or free-running) possessing zero stable states
- **Monostable** (or one-shot) possessing one stable state
- **Bistable** (flip-flop or latch) possessing two stable states.

In this laboratory we shall study the first two, the Astable and Monostable Multivibrators.

A2.1 Astable Multivibrators

An Astable Multivibrator is a binary (two-state) device possessing no input (other than power of course) and no stable states. Upon the application of power the output Q toggles (moves back and forth) between the two states as shown in Figure A2.1. For each period, T_1 is the time spent in the (Boolean) HIGH state and T_2 is the time spent in the (Boolean) LOW state.

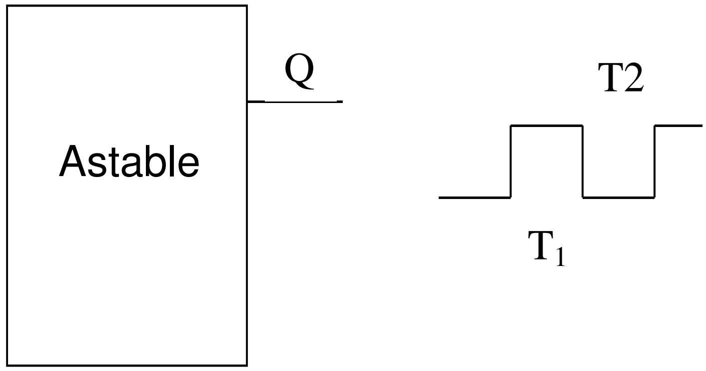

Figure A2.1: Typical output of an Astable Multivibrator

The times T_1 and T_2 are set (by the designer) via a combination of resistors and capacitors, some of which may be internal (within the chip) and some of which may be external (discrete components connected to the chip).

A2.2 Astable Multivibrator Frequency and Duty Cycle

The frequency of oscillation *f* of the Astable Multivibrator and the corresponding period *T* are given by:

$$f = 1/T, \qquad T = (T_1 + T_2)$$

The duty cycle, defined as the fraction of time the Multivibrator is in its HIGH (or 1) state, is given by:

$$\text{DUTY CYCLE} = T_1/T = T_1/(T_1 + T_2)$$

Astable Multivibrators are used as clock sources for digital circuits and systems.

A3. PRELAB – ASTABLE MULTIVIBRATORS

The 555 is a general purpose counter/timer which can be configured as an Astable Multivibrator. Although this component may be used as a digital circuit, its operation is basically analog in nature; hence it is not found in a Data Book of Digital Integrated Circuits. The data sheet of the 555 may be found on-line.

1. Study the operation of the 555 as described in the data sheet; pay particular attention to its configuration as an Astable Multivibrator.

2. Design (configure) an Astable Multivibrator using the 555 with the following characteristics:

f = 1 kHz

DUTY CYCLE = 60%

As in industry, all values of resistors and capacitors are not available for implementing your design; only a discrete set of values are manufactured, and an even smaller subset is available in your lab kit.

From the 555 Design Equations it is clear that there are two independent variables and three unknowns (two resistors and one capacitor). Hence as the designer you are allowed to arbitrarily select one of the unknowns. Since there are not as many available capacitor values as resistor values, it is common practice to select the capacitor and calculate the resistor values (the probability that a calculated resistor value is in fact available is higher than that for a calculated capacitor value). Also if a calculated resistor value is not available, combinations (series, parallel) of available resistor values may be used. And finally the selection of capacitor value is not purely arbitrary-the selected value should produce "reasonable" resistor values (for example if a selected capacitor value of 10pf produced resistor values in the 10 MΩ range, one would probably redo the design using a significantly larger capacitor value so that the resistors would be in the 10 kΩ range). Your design should be within 10% of the theoretical calculations (neglecting component tolerances).

Verify your design using Multisim.

A4. LAB ASSIGNMENT – ASTABLE MULTIVIBRATORS

1. Obtain the 555 and the resistor(s) and capacitor(s) from your lab kit. Fabricate your design.

2. Measure the Frequency and Duty Cycle of your working circuit on the Oscilloscope. If either the Frequency or Duty cycle (or both) is not precisely as specified, what would you do to the circuit to make them so (you need not actually make the circuit modifications unless the measured values are **completely** different than the calculated values)?

B2. DISCUSSION – MONOSTABLE MULTIVIBRATORS

B2.1 Monostable Multivibrators

A Monostable Multivibrator is a binary (two-state) device possessing one stable state and one input (sometimes called a trigger). In the absence of input the Monostable remains in its stable state. Upon the application of a trigger, the Monostable output Q changes state and remains in this (unstable) state for a time **t** at which point it returns to its stable state to await another trigger.

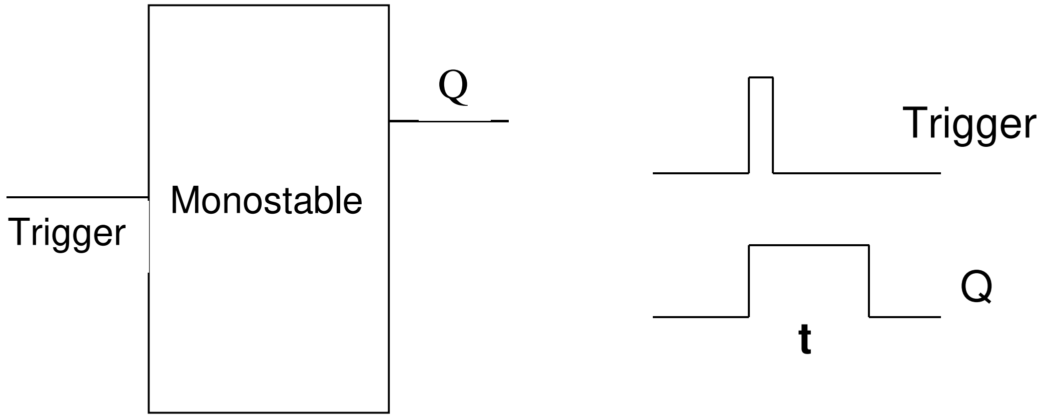

Figure B2.1: Typical Output of a Monostable Multivibrator

The time **t** is set by the designer of the circuit via a combination of internal (within the chip) and external resistors and capacitors.

In the event that a second (third, etc.) trigger occurs while the Monostable is in its unstable state, the circuit may either:

- Ignore all additional triggers while in the unstable state until such time as the Monostable returns to its stable state; or

- Reset the internal timer and begin (again) counting the time, while remaining in the unstable state.

The first method of operation results in a Non-Retriggerable Monostable Multivibrator, while the second results in a Retriggerable Monostable Multivibrator. Both Retriggerable and Non-Retriggerable Monostable Multivibrators are available as Integrated Circuits.

Monostable Multivibrators may be used for pulse-lengthening, pulse-shortening, or as part of counting circuits.

B3. PRELAB – MONOSTABLE MULTIVIBRATOR

The 121 is a general purpose Monostable Multivibrator with a Schmitt trigger input for noise immunity. Two such devices are packaged in a single DIP as the 221.

1. Study the operation of the 221 as described in the Data Sheet; pay particular attention to ranges of resistance and capacitance used to set the time constant. Is each Monostable in the chip Retriggerable or Non-Retriggerable? What is the equation for the time constant **t**?

2. Assuming that both Multivibrators in the 221 are to be driven from the Astable Multivibrator you have just constructed, select values of R and C so that, when triggered off the leading edge of the Astable output, one Monostable Multivibrator (in the 221) produces an output of 20% Duty Cycle and the other Monostable Multivibrator (in the 221) produces an output of 40% Duty Cycle. As an example (for the first) if $\mathbf{t_A}$ is the time the Monostable is in its unstable state and if $\mathbf{T\ (T_1 + T_2)}$ is the period of the Astable:

$$\mathbf{t_A/(T_1 + T_2) = 0.2 = t_A/T}$$

where **T** is the <u>theoretical</u> (calculated, not measured) period of the Astable.

As with the Astable, use only values of R and C that will be available in your lab kit and values that result in time constants within 10% of theoretical (neglecting component tolerances).

B4. LAB ASSIGNMENT – MONOSTABLE MULTIVIBRATOR

1. Obtain a 221 and the resistors and capacitors from your lab kit. Fabricate your circuit.

2. Verify the operation of your working circuit by measuring $\mathbf{t_A}$ on the Oscilloscope (for both Multivibrators). Draw the observed waveforms for the Astable output and the Monostable outputs. From the measurements compute the actual value of $\mathbf{t_A/T}$. If the Duty Cycle (for either) is not precisely as specified what would you do to the circuit to make it so (you need not make the circuit modifications unless the measured value is <u>significantly</u> different from that calculated)?

5. REVIEW QUESTIONS

1. How many stable states does an Astable Multivibrator possess? A Monostable Multivibrator?

2. Can you independently vary the Duty Cycle and the Frequency of an Astable Multivibrator?

3. How does a Retriggerable Monostable Multivibrator differ from a Non-Retriggerable Monostable Multivibrator?

4. When designing an Astable Multivibrator it is common practice to select the capacitor value and calculate the resistor value (rather than conversely). Why?