Pulse-Width Modulation

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Introduction:

Pulse-width modulation (PWM) is a modulation technique that transforms the width of a pulse, based on the modulator signal information. Modulation is the process of switching an electronic device in a power electronic converter from one state to another. The aim of pulse modulation is to transfer an analog signal over an analog channel by modulating a pulse wave. A common example of using PWM is dimming the lights in a room. Dimming is controlled by the position of the switch between turning a light off and being full power.

A pulse wave is a waveform that is shaped by adjusting the duty cycle of an oscillator. A duty cycle describes the proportion of “ON” time versus “OFF” time over the period of the cycle. This is usually expressed as a percent, with 100% being fully on for the entire period.

An oscillator is a type of circuit that produces a repetitive electronic signal that converts direct current from a power supply to an alternating current signal. Oscillators are defined by the frequency of their output signal. The average value of voltage fed to the load is controlled by switching supply and load “ON” and “OFF” at a fast pace. This is because the longer the switch is “ON” versus “OFF”, the higher the power supplied to the load.

The duty cycle is an important factor for controlling a device using PWM. The manner in which the user alters the wave can communicate a different function or command to the object being controlling. When creating a periodical signal, the motor is repeatedly being turned “ON” and “OFF”, and since the motor cannot react fast enough, the signal will run at a speed that is proportional to the average time the controlling signal is “ON”. To calculate the duty cycle, it is the ratio between the pulse duration and the signal period. The user can create a set of commands based on how the duty cycle needs to be altered. Each servo motor typically has a set frequency, and defined range of motion.

These waves are generated through a circuit known as the oscillator. For something to oscillate, energy needs to move back and forth from one form of energy to another. An electronic oscillator converts direct current from an energy source to a sinusoidal wave. Due to resistance some energy is lost, so each signal of oscillation needs extra energy for the process is to continue. Oscillators are used in electronic equipment ranging from quartz watches to radios. In an electronic oscillator, a capacitor is connected to a battery which helps generate a charge which is sent it to an inductor. The capacitor and inductor transfer energy between each other until the resistance in the wires drains the energy. Resistance is the restraint that the material of the wires place on the waves. Resistance is the factor that forces the oscillation to stop until another power source replaces the energy lost. For our purposes, we can fix the oscillator signal using digital blocks.

Controlling Servo Motors on a Robotic Arm:

To generate a PWM signal to control a robotic arm, we can use two devices, a counter, and a comparator. The counter is used to convert the speed of the wave from nanoseconds to milliseconds. Many digital circuits use a counter that is directly connected to the clock of a circuit. A clock signal is a type of signal that oscillates between a high and low state to change the state of the circuit. These clock signals are produced by a clock generator and are usually in the form of a square wave with a 50% duty cycle.

A counter can be used to convert the period of the input wave from nanoseconds to milliseconds. The conversion is simple. If we are using a 50 MHz oscillator (which is the frequency of the ZedBoard), resulting in a 20 nanosecond period, we can cascade two counters to convert an input signal with a 20 nanosecond period to a 20 millisecond period (the frequency expected by the servo motors). We will refer to the first counter as the main counter. The second counter can be used to generate an enable to the main counter.

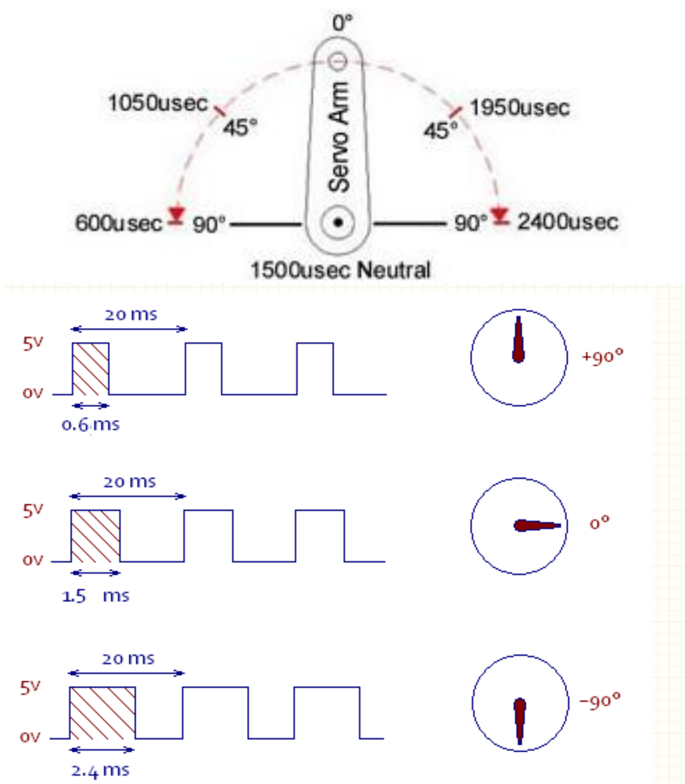

Figure 1. Servo motor operation for different PWM signal duty

A comparator is a digital circuit that compares two different input values and can output a signal indicating which one is larger. Generally, the output is a single binary digit with the values 0 or 1.

So suppose that the user needs a PWM signal with period of 100 ms and a duty cycle of 20%. Assume that the second counter counts from 1 to 100. We can compare the second counter's output value with 20, and if the number is less than 20, the comparator generates a value of "1", otherwise, it generates a value of "0". Therefore, in each period (from 1 to 100), from 1 to 20 the output is a "1", and from 21 to 100 the output is a "0". This signal can be sent to the servo motor to control the robotic arm.

On the robotic arm, our 5 servo motors can each rotate through 180°. The frequency of the PWM signal should be 50 Hz (the period should be 20 ms). The duty cycle will determine the rotational angle. The duty cycle range can vary from 3% (a 600 microsecond pulse width) to 12% (a 2400 microsecond pulse width). The rotation angle can be calculated using the following equation:

$$(\text{angle} \times 10) + 600 = \text{duty cycle}$$

For example, to rotate the servo to a 45° position, the duty cycle should be 1050 = (45 × 10) + 600.

References:

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