Agilent
PWM Waveform Generation Using U1252A DMM

Application Note

Agilent Technologies

Introduction

Square wave is a unique function for many applications such as Pulse Width Modulation (PWM). PWM is widely used in a variety of applications in measurement and digital controls. It offers a simple method for digital control logic to create an analog equivalence.

The majority of microcontrollers today has built-in PWM capability that facilitates the implementation of the control. Using PWM in communication systems is very popular due to the fact that the digital signal is more robust and less vulnerable to noise. The feature-packed Agilent U1252A handheld digital multimeter (DMM) has a built-in programmable square wave generator.

This application note provides a brief overview of PWM and offers some ideas on how to use the U1252A handheld DMM to create pulse width modulated signals.

Concepts of Pulse Width Modulation (PWM)

PWM is a method of digitally encoding analog signal levels. The duty cycle of a square wave is modulated to encode a specific analog signal level using high-resolution counters. The PWM signal is still a digital signal because at the given instant of time, the full DC supply is either fully on or fully off.

The voltage or current source is supplied to the analog load by a repetitive series of ON and OFF pulses. The ON time is the period when the DC supply is applied to the load, and the OFF time is the period when the DC supply is switched off. If the available bandwidth is sufficient, any analog value can be encoded using PWM.

An analog signal has a continuously varying value, with infinite resolution in both time and magnitude, and it can be used to control many electronic devices directly. For example, in a simple analog radio, a knob is connected to a variable resistor. When turning the knob, the resistance goes down or up, and the current flowing through the resistor increases or decreases. Consequently, the current that drives the speaker is changed proportionally, thus increasing or decreasing the volume.

Although analog control may be considered intuitive and simple, it is not always economically attractive or practical. Analog circuits tend to drift over time and are very difficult to tune. Problems solved by precision analog circuits can be large, heavy, and expensive.

Analog circuits tend to generate heat through the power dissipation. The power dissipated is proportional to the voltage across the active elements, multiplied by the current that flows through it. Analog circuitry can also be sensitive to noise because of its infinite resolution; even minor perturbations of an analog signal can change its value.

By controlling analog circuits digitally, system costs and power consumption can be drastically reduced. Many microcontrollers and digital signal processors (DSPs) already include PWM controllers in the chip, thus making implementation easier.

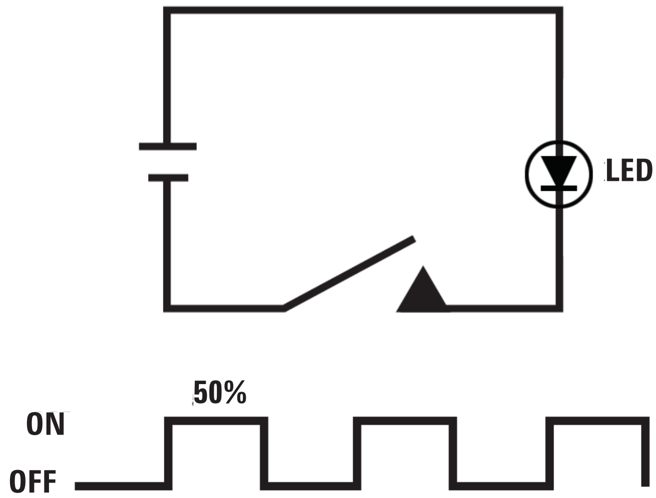

Figure 1 A simple circuit for controlling the brightness of a LED using PWM

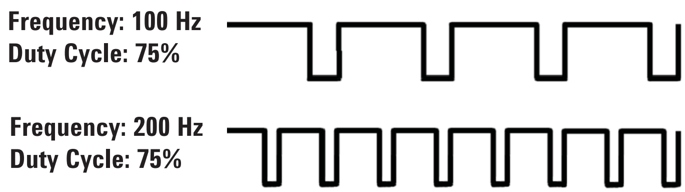

Figure 2 Two pulses with the same duty cycle

Frequency and Duty Cycle

Figure 1 illustrates a circuit established using a battery, a switch and a LED. This circuit turns on the LED for one second and then turns off the LED for one second using the switch control.

The LED is ON for 50% of the period and OFF the other 50%. The period is defined as the total time it takes to complete one cycle (from OFF to ON state and back to OFF state).

The signal can be further characterized by the duty cycle, which is the ratio of the "ON" time divided by the period. A high duty cycle generates a bright LED while a small duty cycle generates a dimmer LED. The example shown in Figure 1 provides a 50% duty cycle.

In Figure 2, two waveforms with different frequencies produce the same amount of light. Note that the amount of light is independent from the frequency, but proportional to the duty cycle.

The frequency range you can use to control a circuit is limited by the number of response time to the circuit. In the example shown in Figure 1, a low frequency can cause the LED to flash noticeably. A high frequency, in turn, can cause an inductive load to saturate.

For example, a transformer has a limited frequency range to transfer the energy efficiently. For some designs, harmonics (or beat frequencies) of the PWM frequency can get coupled into the analog circuitry, causing unwanted noise. If the right frequency is selected, the load being controlled will act as a stabilizer, a light will glow continuously and the momentum will allow a rotor to turn smoothly.

Generating PWM signals

The PWM signals are easy to generate using a comparator with a sine wave as one of the input signals. Figure 3 shows a sample block diagram of an analog PWM generator.

Figures 4 and 5 show the PWM output waveform (red line) generated by a comparator with two input signals: a sine wave (black line) and an input signal (gray line). The input signal of 0.5 VDC is the voltage reference to be compared with the sine wave to produce a PWM waveform.

With the steady-state reference voltage of 0.5 VDC, a PWM waveform with 50% duty cycle is generated. If the reference voltage decreases to 0.25 VDC, the generated PWM waveform will have a higher duty cycle, as shown in Figure 5.

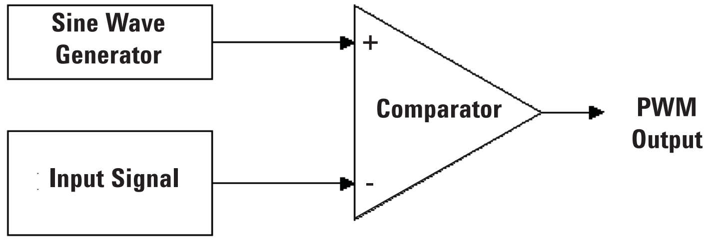

Figure 3 Block diagram of an analog PWM generator

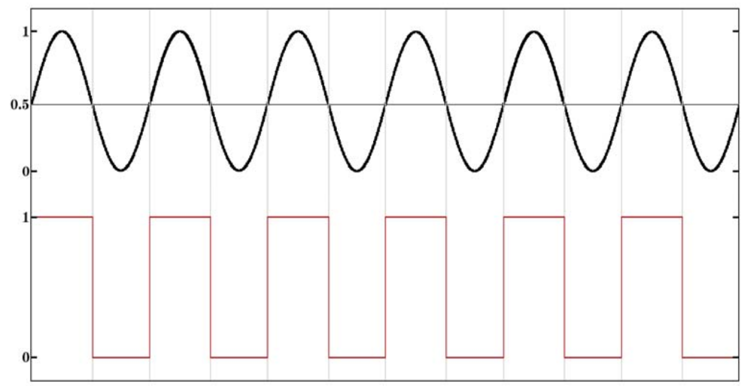

Figure 4 Comparison between a sine wave and +0.5 VDC that produces a PWM waveform

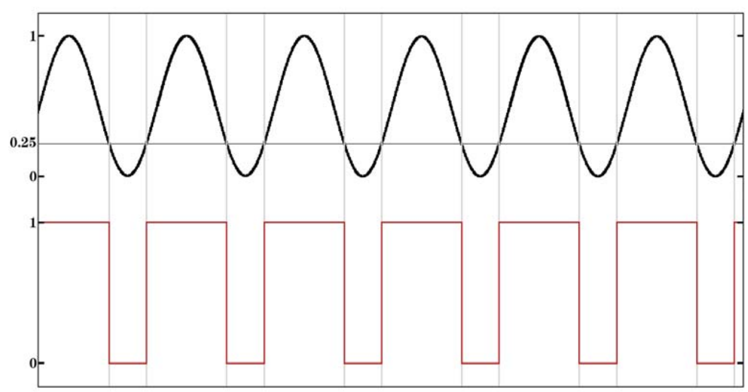

Figure 5 Comparison between a sine wave and +0.25 VDC that produces a PWM waveform

Advantages of Using PWM Application

PWM offers several advantages over an analog control. For example, using PWM to control the brightness of a lamp, the heat dissipated from the lamp is less than the heat generated from an analog control that converts the current to heat. Hence, less power is delivered to the load (light), which will prolong the life cycle of the load. With a higher frequency rate, the light (load) brightness can be controlled as smoothly as an analog control.

Rotors can operate at a lower speed if they are controlled by PWM. Some of the rotors might not function with low analog current. When an analog current controls a rotor, it will not produce significant torque at low speed. The magnetic field that is created by the small current is insufficient to turn the rotor. On the other hand, a PWM current can create short pulses of magnetic flux at full strength that enables the rotor to turn at a slow speed.

Combining ON/OFF (1/0) states with the variety voltage and the duty cycle, PWM can output at a desired voltage level. Thus, it can be used as voltage regulator for many applications. When the desired voltage level is higher than the output voltage level, the state will be ON (1). On the other hand, the state will be OFF (0) when the desired voltage level is lower than the output voltage level. For example, PWM can be applied when CPLD is used for simple voltage regulation or with a FPGA for complex control algorithms using its internal DSP blocks.

In addition, the entire control circuit can be digitized using the PWM technique. This eliminates the need to use digital-to-analog converters in control circuitries. The digital control lines generated by PWM reduce the susceptibility of your circuit to the interference.

The technology has become more pervasive as PWM controls are incorporated into low cost microcontrollers. Microcontrollers offer simple commands to vary the duty cycle and frequencies of the PWM control signal. PWM is also widely used in the communications field because the digital signals are extremely immune to noise.

Using U1252A Handheld DMM to Create PWM Signals

You can create a variety of PWM signals using a U1252A handheld DMM. With the powerful U1252A handheld DMM, you can expect more than a measuring tool; it also can improve your design of applications.

The U1252A offers the square wave function to generate PWM output and vary the duty cycle between 0.39% to 99.60%. Turn the rotary switch to the square wave output function 

position. The default settings are 600 Hz displayed on the secondary display and 50% duty cycle on the primary display. The selectable frequency ranges are within the range of 0.5 Hz to 4800 Hz with an amplitude range of 0 to 2.8 V. By varying the duty cycle, static PWM waveforms can be generated from the U1252A handheld DMM.

Conclusion

The popularity of PWM will continue to grow as the functionality becomes more popular in microcontrollers and development tools. Hence, having profound knowledge of PWM will make it easier to incorporate in your designs and works.

In addition, when working on a PWM design, a U1252A handheld DMM can be a great tool for creating a waveform.

Glossary

Duty cycle – the percentage of time of a pulse train at its higher voltage

Period – total time taken before the signal repeats

Pulse width – total time during which the pulse is in the “true state”

CPLD - Complex Programmable Logic Device, a type of integrated circuit that provides program and reprogram ability to component functions.

FPGA - Field-Programmable Gate Array, a type of integrated circuit that provides program and reprogram ability to component functions.

DSP – Digital Signal Processing, a powerful and flexible technique of processing analog (linear) signals in digital form.

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