Keysight Technologies
PWM Waveform Generation Using U1252B DMM

Application Note

KEYSIGHT
TECHNOLOGIES

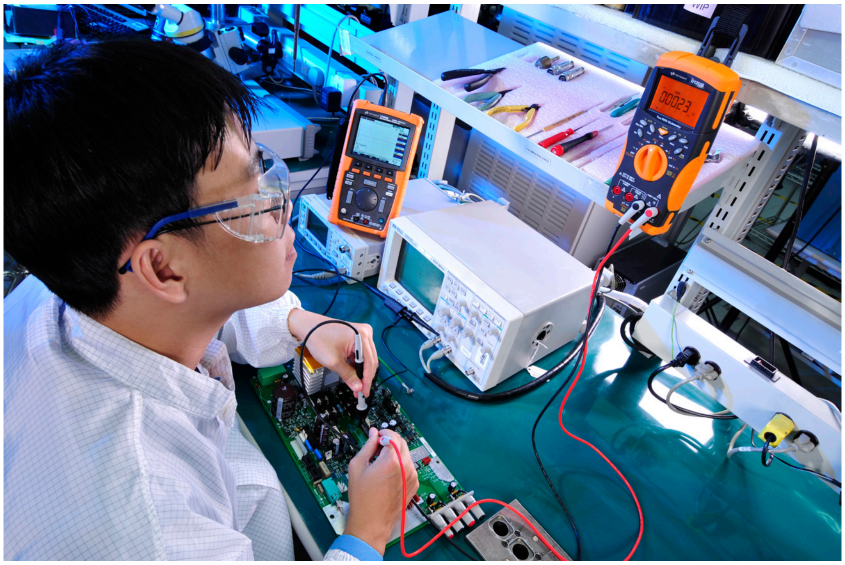
Introduction

Square wave is a unique function for many applications such as pulse width modulation (PWM). PWM is widely used in a variety of measurement and digital control applications. It offers a simple method for digital control logic to create an analog equivalent. Most of today's microcontrollers have built-in PWM capability that simplifies the control's implementation. PWM is widely-used in communication systems because the digital signals are more robust and less vulnerable to noise.

This application note provides an overview of PWM and shows how the feature-packed Keysight Technologies, Inc. U1252B handheld digital multimeter (DMM), with a built-in programmable square wave generator, can be used to create PWM signals.

What is Pulse Width Modulations

PWM is a method of digitally encoding analog signal levels. By digitally controlling analog circuits, system cost and power consumption can be drastically reduced. Many microcontrollers and digital signal processors (DSPs) already include the PWM controller chip, thus making implementation easier.



Frequency and Duty Cycle

Figure 1 shows a circuit with a battery, switch, and 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 taken to complete one cycle (from OFF to ON state and back to OFF state).

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

The duty cycle of a square wave is modulated to encode a specific analog signal level using high-resolution counters. The PWM signal remains a digital signal because the DC supply is either ON or OFF. The voltage or current source is supplied to the analog load by repeating a series of ON and OFF pulses. When On, the DC supply is applied to the load and when OFF, the DC supply is switched off.

Referring to 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 used to control a circuit is limited by the response time to the circuit. From the example shown in Figure 1, a low frequency can cause the LED to flash noticeably. Whereby, a high frequency 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.

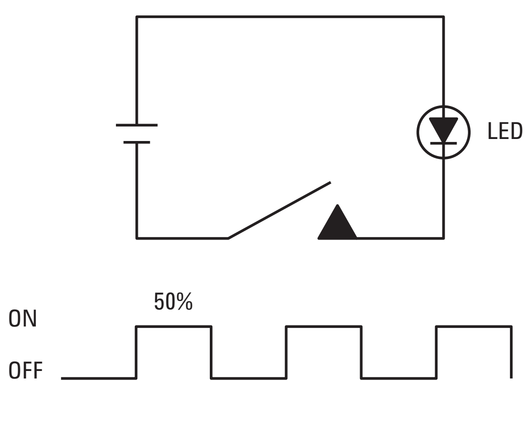


Figure 1. A simple circuit for controlling the brightness of a LED using PWM

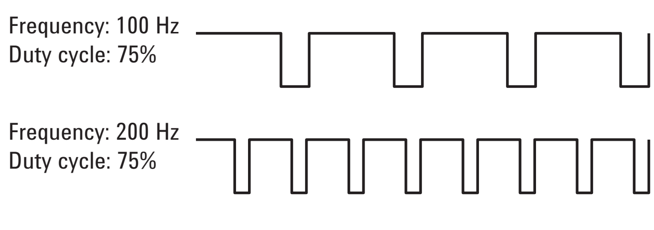


Figure 2. Two pulses with the same duty cycle

Generating PWM Signals

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

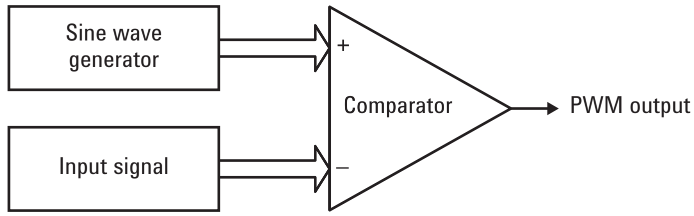


Figure 3. Block diagram of an analog PWM generator

Figure 4 shows 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.

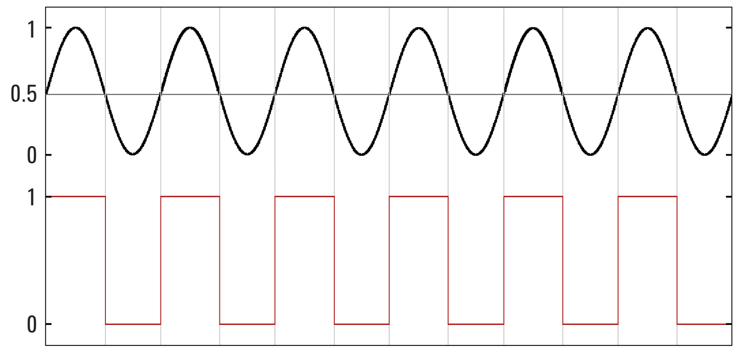


Figure 4. Comparison between a sine wave and +0.5 VDC that produces a PWM waveform

If the reference voltage decreases to 0.25 VDC, the generated PWM waveform has a higher duty cycle, as shown in Figure 5.

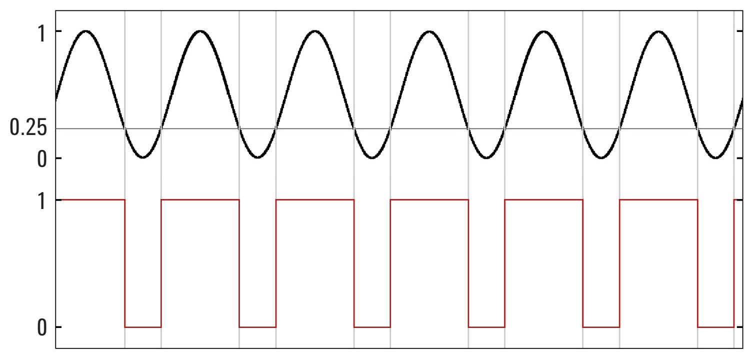


Figure 5. Comparison between a sine wave and +0.25 VDC that produces a PWM waveform

Using U1252B Handheld DMM to Create PWM Signals

You can create variety PWM signals using a U1252B handheld DMM. The U1252B handheld DMM is more than a measuring tool; it can improve your design of applications. The U1252B 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 OUT position. The default settings is 600 Hz displayed on secondary display and 50% duty cycle on primary display. The selectable frequency ranges are within the range of 0.5 Hz to 4,800 Hz with amplitude range of 0 to 2.8 V. By varying the duty cycle, static PWM waveforms can be generated from U1252B handheld DMM.

Advantages of PWM Application

PWM offers several advantages over 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, which converts the current to heat. Hence, less power is delivered to load (light), prolonging the life cycle of the load. With a higher frequency rate, the light (load) brightness can be controlled as smooth as analog control.

Rotors can be operated at a lower speed if they are controlled by PWM. When an analog current controls a rotor, not enough torque is produced at low speeds. 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 enabling the rotor to turn at a slow speed.

By combining ON/OFF (1/0) states with a variety of voltages and duty cycles, PWM can output a desired-level voltage and 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 complex programmable logic devices (CPLDs) are used for simple voltage regulation or with a field-programmable gate array (FPGA) for complex control algorithms using its internal digital signal processing (DSP) blocks.

In addition, the entire control circuit can be digitized using PWM. 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 interference.

The use of PWM has become more pervasive as the deployment of PWM controls in the number of low cost microcontrollers continues to climb. Microcontrollers offer simple commands to vary the duty cycle and frequencies of the PWM control signal. PWM is also widely used in communications field because the digital signals provide high immune capability towards noise.

Conclusion

The popularity of PWM will continue to grow as its functionality becomes more popular in microcontrollers and development tools. Having a good understanding of PWM will make it easier to incorporate it into your designs.

In addition, when working on a PWM design, a U1252B handheld DMM can be a great tool for creating a waveform.

Glossary

CPLD — complex programmable logic device, a programmable logic device with complexity between that of PALs and FPGAs

DSP — digital signal processing, a powerful and flexible technique of processing analog (linear) signals in digital form

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

FPGA — field-programmable gate array, a type of integrated circuit that provides program and reprogram ability to component function

Period — total time taken before the signal repeats

Pulse width — total time of the pulse is in the “true state” myKeysight

www.keysight.com/find/mykeysight
A personalized view into the information most relevant to you.

www.axiestandard.org
AdvancedTCA® Extensions for Instrumentation and Test (AXIe) is an open standard that extends the AdvancedTCA for general purpose and semiconductor test. Keysight is a founding member of the AXIe consortium. ATCA®, AdvancedTCA®, and the ATCA logo are registered US trademarks of the PCI Industrial Computer Manufacturers Group.

www.lxistandard.org
LAN eXtensions for Instruments puts the power of Ethernet and the Web inside your test systems. Keysight is a founding member of the LXI consortium.

www.pxisa.org
PCI eXtensions for Instrumentation (PXI) modular instrumentation delivers a rugged, PC-based high-performance measurement and automation system.

Three-Year Warranty
www.keysight.com/find/ThreeYearWarranty
Keysight's commitment to superior product quality and lower total cost of ownership. The only test and measurement company with three-year warranty standard on all instruments, worldwide.

Keysight Assurance Plans
www.keysight.com/find/AssurancePlans
Up to five years of protection and no budgetary surprises to ensure your instruments are operating to specification so you can rely on accurate measurements.

www.keysight.com/quality
Keysight Technologies, Inc.
DEKRA Certified ISO 9001:2008
Quality Management System

Keysight Channel Partners
www.keysight.com/find/channelpartners
Get the best of both worlds: Keysight's measurement expertise and product breadth, combined with channel partner convenience.

www.keysight.com/find/dmm

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
www.keysight.com/find/contactus

Americas

Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100

Europe & Middle East

Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	0800 000154
Sweden	0200 882255
Switzerland	0800 805353
	Opt. 1 (DE)
	Opt. 2 (FR)
	Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries:
www.keysight.com/find/contactus
(BP-07-10-14)

KEYSIGHT TECHNOLOGIES

Published in USA, August 1, 2014
5989-6673EN
www.keysight.com