

# Pulse-Width Modulation (PWM) and digital to analog converter (DAC) Using Computer Interfacing

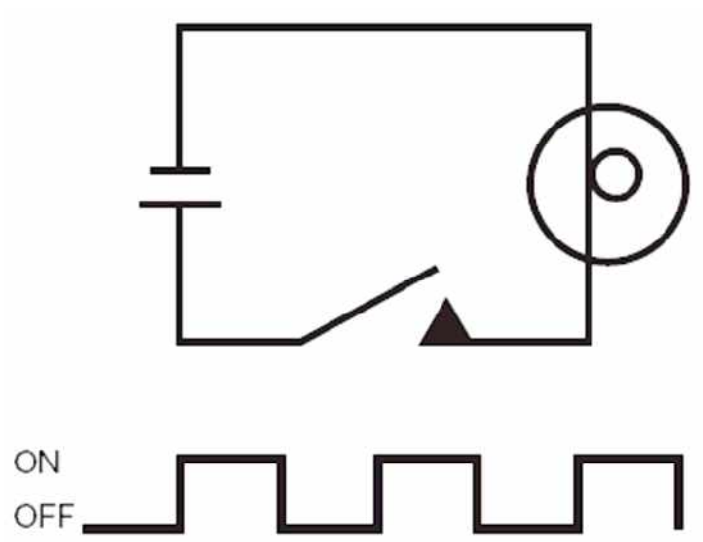
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Pulse width modulation offers a simple method for digital control logic to create an analog equivalence

## Pulse-width modulation basics

Analog signals can take on any value, and they can be used to control many electronic devices. For example, you can control a light with a dimmer switch. The dimmer switch is a simple rheostat that inserts resistance into the circuit in order to reduce the amount of current that is sent to the lamp.

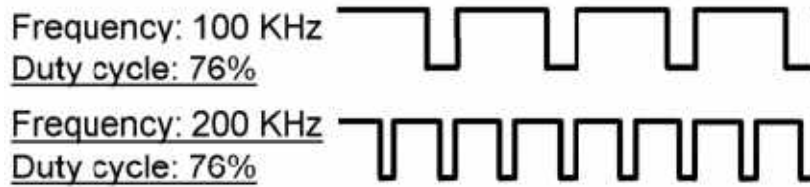
The excess current is dissipated as heat. The rheostat is a simple solution for this application. Another, approach would be to use an on/off switch shown in the diagram below



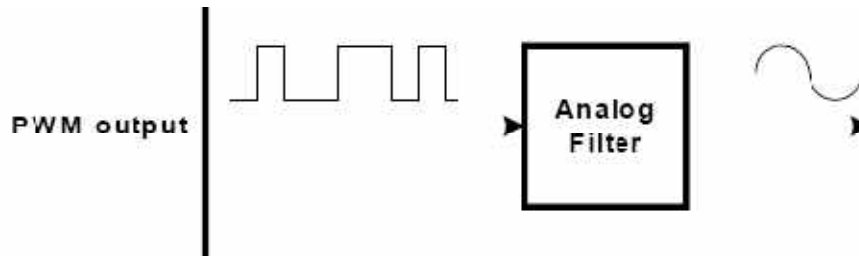
If you reduce the amount of time the switch is in the "on" position, the light will dim. In our example, the light is shown to be on 50 percent of the time and off the other 50 percent. The repetitive signal used to control the light

can be broken down into **periods**, with a single period being the time it takes to complete one cycle, from off to on and back off.

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 create a bright light, while a small duty cycle will create a dim light. The example shown in Figure 1 has a 50 percent duty cycle. It is important to understand that the light produced is independent of frequency. In Figure 2, you will see two waveforms with different frequencies; both produce the same amount of light. The amount of light is independent of the frequency, but is proportional to the duty cycle.



A PWM signal is a digital signal with **fixed frequency but varying duty cycle**. An example of a PWM signal is shown in Figure 1. If the duty cycle of the PWM signal is varied with time, and the PWM signal is filtered, the output of the filter will be an **analog signal**. The block diagram for a **PWM DAC** employing this technique is shown below.



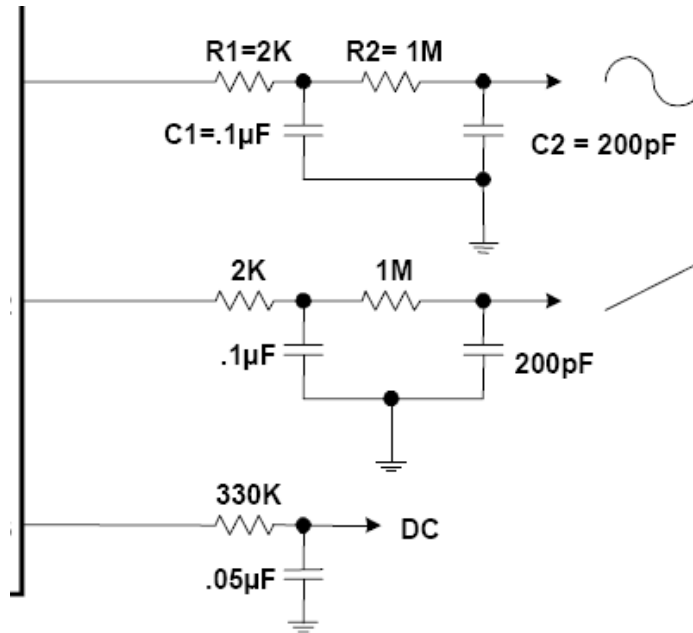
The frequency required for the PWM output signal is equivalent to the update rate of the DAC, since each change in PWM duty cycle is the equivalent of one DAC sample. The frequency required for the PWM timer will depend on the required PWM signal frequency and the desired resolution. It is shown as:

$$F_{clock} = F_{PWM} \times 2^n \text{ where:}$$

- $F_{clock}$  is the required PWM timer frequency
- $F_{PWM}$  is the PWM signal frequency, which is the DAC update rate
- $n$  is the desired resolution of the DAC in bits

It is usually best for the PWM signal frequency to be much higher than the desired sine wave frequency or the desired bandwidth of signals to be

produced. Generally, the higher the PWM frequency the lower the order of filter required and the easier it is to build a suitable filter.



PIC18F14K50 can generate a PWM signal on up to four different output pins with up to 10-bits of resolution. The PWM outputs are multiplexed with I/O pins and are designated P1A, P1B, P1C and P1D.

Each PWM channels can be enabled or disabled. For example to enable and disable PWM channel A, the appropriate commands are EA and DA. Other commands are EB, EC and ED to enable channel P1B, P1C and P1D. Similarly, the commands DB, DC and DD will disable channel P1B, P1C and P1D.

Three frequency ranges of the PWM can be set with the commands FL (low frequency, ~2.9KHz), FM (Medium frequency, ~11.7KHz) and FH (High frequency, ~46.8KHz).

The duty cycle for all the channels can be set with the command Vnnnn where nnnn is 10 bits decimal integer ranging from 0 to 1023. The duty cycle can be calculated by the equation

$$\text{Duty cycle} = \frac{nnnn}{1023} \times 100 \%$$

For example commands EA, FL and V500 will produced PWM signal on P1A output pin with duty cycle of  $\frac{500}{1023} \times 100 = 48.8\%$  at 2.9KHz.

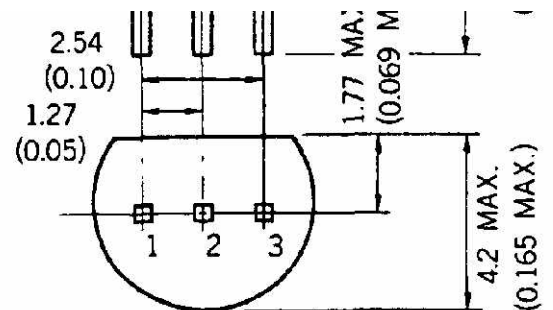
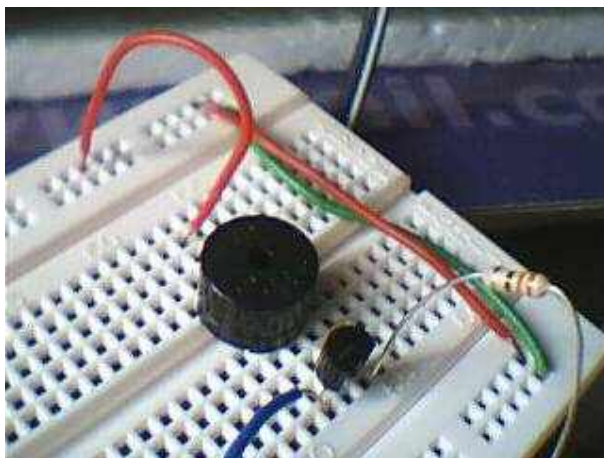
## Digital to Analogue converter (DAC)

If a low pass filter is attached to the PWM output channel, an analogue voltage ranging from 0 to 5V will be generated. The DC voltage level is set with the equation  $DC\ voltage = \frac{nnnn}{1023} \times 5V$  where *nnnn* is 10 bits decimal integer from 0 to 1023.

The resolution of the DC voltage level is  $5/1023V \sim 5\text{ mV}$ .

Exercise:

- 1) Pasang LED (Putih) sesiri dengan sebuah perintang ( $330\Omega$ ) ke salah satu port yang boleh menghasilkan output PWM, misalnya RC5 (P1A). Hantar arahan EA kemudian V1023, V512, V256, V128 dan V0. Perhatikan kecerahan LED bagi tiap arahan tersebut.
- 2) Pasang sebuah perintang  $330\Omega$  pada RC4 (P1B) dan sambung ke BASE transistor 2SC945. Sambung EMITTER 2SC945 ke GND dan COLLECTOR ke buzzer (-). Bahagian + buzzer disambung ke  $V_{CC}$ . Masukkan arahan EB kemudian V1023, V512, V256, V128 dan V0. Perhatikan keamatan bunyi yang dihasilkan.



1. EMITTER	EIAJ	: SC 43B
2. COLLECTOR	JEDEC	: TO 92
3. BASE	IEC	: PA33

2SC945 bottom view

- 3) Pasang litar low pass filter untuk menghasilkan voltan analog DC. Gunakan  $R = 10K$  (Potentiometer),  $C=1\mu F$  dan port RC3 (P1C). Jika arahan EC kemudian V800 digunakan, berapakah anggaran nilai voltan DC analog yang akan diperolehi? Ukur dengan voltmeter untuk mendapat bacaan sebenar.

