Pulse Width Modulation (PWM) Basics

There are many forms of modulation used for communicating information. When a high frequency signal has an amplitude varied in response to a lower frequecny signal we have AM (amplitude modulation). When the signal frequency is varied in response to the modulating signal we have FM (frequency modulation. These signals are used for radio modulation because the high frequncy carrier signal is needs for efficient radiation of the signal. When communication by pulses was introduced, the amplitude, frequency and pulse width become possible modulation options. In many power electronic converters where the output voltage can be one of two values the only option is modulation of average conduction time.

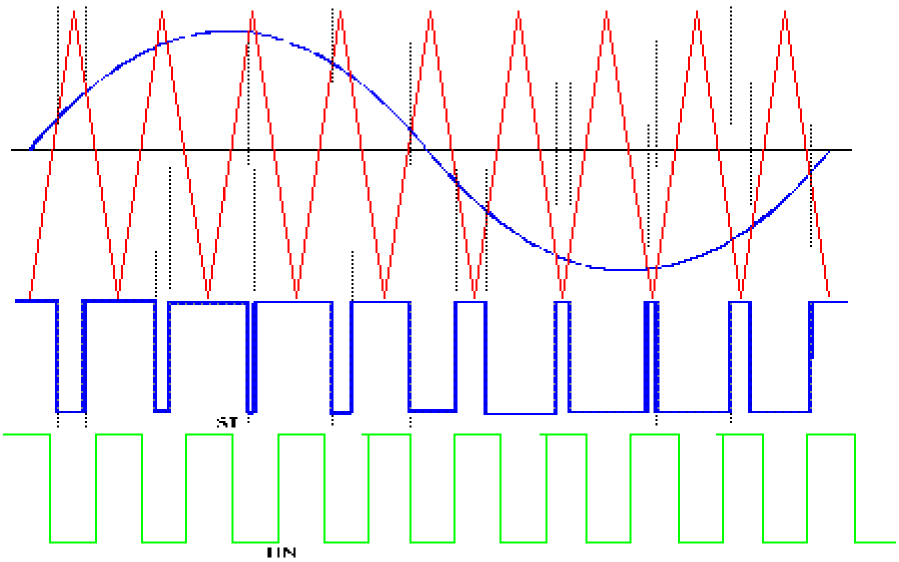

Fig. 1: Unmodulated, sine modulated pulses

1. Linear Modulation

The simplest modulation to interpret is where the average ON time of the pulses varies proportionally with the modulating signal. The advantage of linear processing for this application lies in the ease of de-modulation. The modulating signal can be recovered from the PWM by low pass filtering. For a single low frequency sine wave as modulating signal modulating the width of a fixed frequency (fs) pulse train the spectra is as shown in Fig 2. Clearly a low pass filter can extract the modulating component fm.

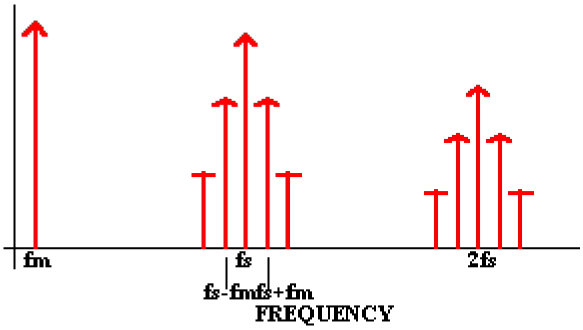

Fig. 2: Spectra of PWM

2. Sawtooth PWM

The simplest analog form of generating fixed frequency PWM is by comparison with a linear slope waveform such as a sawtooth. As seen in Fig 2 the output signal goes high when the sine wave is higher than the sawtooth. This is implemented using a comparitor whose outputvoltage goes to a logic HIGH when ne input is greater than the other.

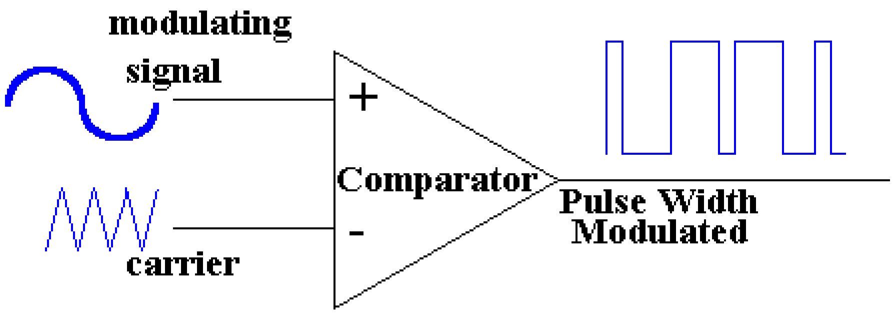

Fig. 3: Sine Sawtooth PWM

Other signals with straight edges can be used for modulation a rising ramp carrier will generate PWM with Trailing Edge Modulation.

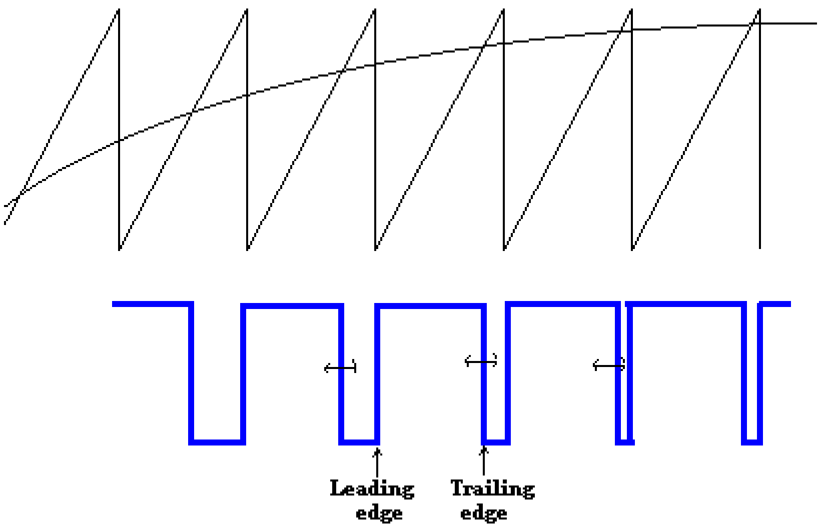

Fig. 4: Trailing Edge Modulation

It is easier to have an integrator with a reset to generate the ramp in Fig 4 but the modulation is inferior to double edge modulation.

3. Regular Sampled PWM

The scheme illustrated above generates a switching edge at the instant of crossing of the sine wave and the triangle. This is an easy scheme to implement using analog electronics but suffers the imprecision and drift of all analog computation as well as having difficulties of generating multiple edges when the signal has even a small added noise. Many modulators are now implemented digitally but there is difficulty is computing the precise intercept of the modulating wave and the carrier. Regular sampled PWM makes the width of the pulse proportional to the value of the modulating signal at the beginning of the carrier period. In Fig 5 the intercept of the sample values with the traingle determine the edges of the Pulses. For a sawtooth wave of frequency fs the samples are at 2fs.

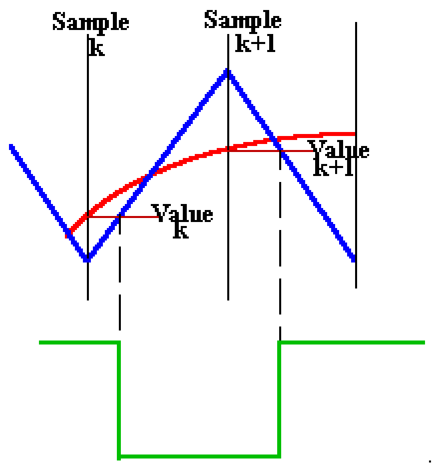

Fig. 5: Regular Sampled PWM

There are many ways to generate a Pulse Width Modulated signal other than fixed frquency sine sawtooth. For three phase systems the modulation of a Voltage Source Inverter can generate a PWM signal for each phase leg by comparison of the desired output voltage waveform for each phase with the same sawtooth. One alternative which is easier to implement in a computer and gives a larger MODULATION DEPTH is using SPACE VECTOR MODULATION.

4. Modulation Depth

For a single phase inverter modulated by a sine-sawtooth comparison, if we compare a sine wave of magnitude from -2 to +2 with a traingle from -1 to +1 the linear relation between the input signal and the average output signal will be lost. Once the sine wave reaches the peak of the transgle the pulses will be of maximum width and the modulation will then saturate. The Modulation depth is the ratio of the current signal to the case when saturation is just starting. Thus sine wave of peak 1.2 compared with a triangle with peak 2.0 will have a modulation depth of m=0.6.

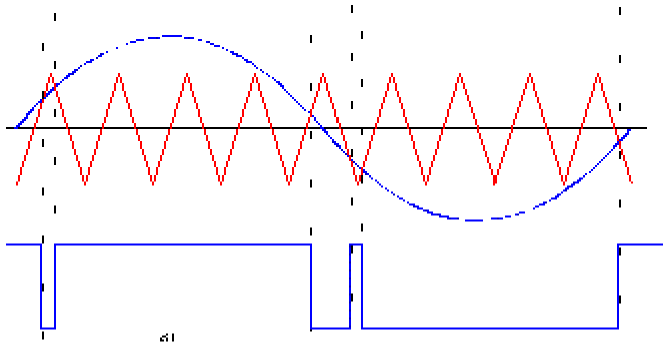

Fig. 6: Saturated Pulse Width Modulation