What is PWM ?

By Del Tapparo

PWM stands for Pulse Width Modulation. PWM is a form of motor control. You may also see the term PCM used (Pulse Code Modulation); same thing, different name.

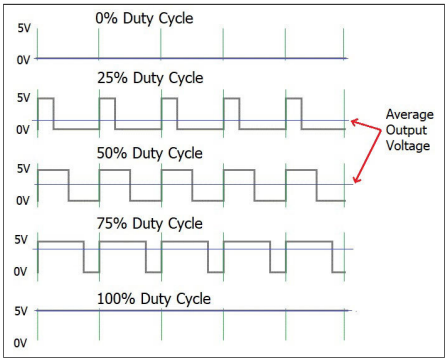
Most track powered locomotives run on DC (Direct Current) voltage. The higher the voltage the more speed you get from the motor. At full throttle, your loco is getting maximum voltage, and maximum speed. (The maximum voltage is determined by the voltage rating of your power pack or battery pack.) At half throttle it is getting half of the available voltage, and thus half the speed. This DC voltage is always a constant voltage, never varying from the throttle setting. Many train power packs put out this constant "Analog" DC voltage.

But the world is now "Digital", and so are most of our train controls. I'm sure you have heard, "In digital, everything is either a 1 or a 0". This means things are either ON or they are OFF. So in order for digital electronics to get values in between full ON and full OFF, the output switches ON and OFF for varying amounts of time. If the output is ON for 50% of the time, and OFF for the other 50% of the time, the resulting average voltage is 50% of maximum. This is called a 50% duty cycle. A 25% duty cycle will produce 25% of the maximum voltage.

PWM is also a more efficient means of controlling a DC motor. Instead of wasting much of the power in the controller, it is all (or nearly all) directed to the motor. This makes it more suitable for use with battery powered control systems.

So won't the motor be jerking around trying to start and stop all of the time?

No. The switching is very fast, usually 20KHZ; on and off 20,000 times per second. The windings of the motor smooth out the on/offs and average the voltage and current. So at 50% duty cycle the motor acts the same way as it would



with 50% of the maximum DC voltage.

Is this switching going to hurt the motor?

No, not if the frequency (on/off switching) is fast enough. Some of the older controllers used frequencies on the order of 100 to 1000 HZ. This can cause excessive heating of the motor because at the slower speeds it is actually trying to speed up and slow down at that rate. The low frequencies also cause motor hum that is audible at low speeds. Newer systems run at 20KHZ, well above audible range and they do not harm the motor.

PWM can also improve low speed operation of a motor. It takes a certain amount of voltage to break the friction of the drive train and make it start turning. At low duty cycles, the PWM provides a "dithering" action to the motor, which tends to break the friction, and allows it to start turning sooner at low throttle settings. This may give you better low speed control of your locomotive. Some power packs for track powered operation even utilize PWM at low speeds for this very reason.

So motors like PWM. What about other electronics?

Some of the older electronics that came with your locomotive from the factory have been designed to run from straight DC. If you use the PWM motor output of your controller to power these factory boards, things may not work all the time; e.g. the lights may flicker, factory sound may be messed up, or analog meters may jerk around trying to follow the PWM switching. Any kind of a DCC (Digital Command Control) board will be totally confused, because it will be trying to interpret all of the on/off voltages as a DCC signal. In this case, you may have to strip out or disconnect these parts. However, most battery powered controllers will provide a means of controlling your lights separately. And most third party sound systems work just fine from PWM.

Can I convert PWM into DC?

If you have a situation that just has to have constant DC, you can purchase PWM to DC convertors to go between the output of your controller and the track or motor. Do not try to do this with a simple capacitor, as that will actually harm the PWM motor driver.

How do I measure PWM?

This is of no real concern to most. But you may want to know what the average motor voltage is. Just use a voltmeter set on a DC voltage scale. Place the probes across the motor driver output and read the DC voltage. The PWM duty cycle can be calculated by dividing the measured value by the maximum value; i.e. (11.7V / 14.8V) * 100 = 79%. To measure PWM frequency, use the AC HZ scale (not all meters have this capability).

I measured the motor voltage at full throttle (100% duty cycle), and it is less than my battery voltage. Why is that?

PWM motor controllers, as do analog controllers, have losses. When the switch is ON, there is a very small amount of resistance. On the better controllers, this will result in losing less than 1 volt when your locomotive is drawing full current.

Why do designers use PWM?

In summary, PWM is the digital equivalent of constant analog DC. It is a digital world, and PWM is easier to implement. It is also much more efficient than DC, which makes it especially useful in battery powered systems.