What is PWM?

by Del Tapparo

PWM is a form of motor control. Before you gasp and move on to something else, **this is intended to be a simplified explanation of PWM** for the vast majority of model railroaders that don't understand all of this electronics "mumbo-jumbo". 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. The locomotives' motor current is determined by the load; i.e. how much weight it is trying to pull and/or the grade it is running on at the time. When you set your power pack to maximum voltage, your loco is likely running like a slot-train, so let's say you decrease it to half that setting. Now the motor only gets half the voltage, and thus half the speed. The other half of the maximum available voltage is now literally wasted inside of your power pack in the form of heat. So what? Well what if you want to run on battery power? This same kind of system can be used to run the motor from straight DC by using a rheostat or a linear voltage regulator. But the same thing happens, except now you are wasting battery power, which means less run time between charges!

PWM, or pulse width modulation is 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. PWM controls the voltage to the motor using a "duty cycle"; i.e. it is always either full ON (maximum battery voltage) or full OFF (zero battery voltage). A duty cycle of 100% (always ON) provides max voltage to the motor. 50% duty cycle provides the max voltage, but only half of the time; on for 50%, off for 50%. 20% duty cycle is on for 20% of the time, and off for 80% of the time, resulting in an average of 20% of the battery voltage to the motor.

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 DC battery 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 very easy to hear 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 motor 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 allow it to turn more easily at low speeds. 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?

Most of the electronics that come 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, thing may not work all the time; e.g. the lights may dim or flash and the factory sound may be messed up. Any kind of a DCC (Digital Command Control) board (perhaps used for sound) 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 anyway. And most third party sound systems do work just fine from PWM.

How do I measure PWM?

This is of no real concern to most. But you may want to know what the 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 will be the measured motor output voltage divided by the battery voltage; i.e. (11.7V / 14.8V) * 100 = 79%. To measure PWM frequency, use the AC HZ scale (not all meters have this capability).

So 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 still have some 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. This loss in the controller is an important specification. For each 1.2 volts you lose in the controller that is one more 1.2 volt battery cell you will need to have in your battery pack that will just take up space and add cost!

In summary, the primary advantage of PWM is to save power in battery powered motor control systems. Any time the duty cycle is less than 100%, you will be saving battery run time, compared to using a rheostat or linear voltage regulator. PWM runs cooler, so less heat in your electronics compartment. And, you may also see improved low speed response from your locomotive.