So, Which PWM Technique is Best? (part 2)

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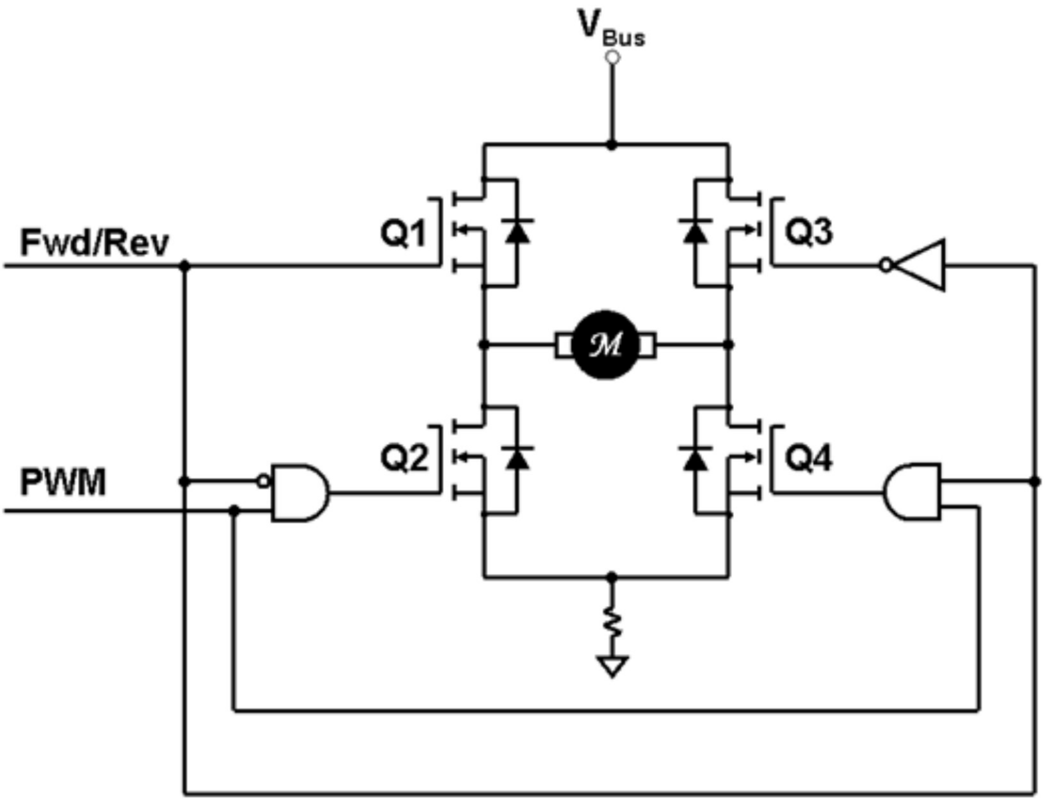
So, which PWM technique is best for your motor control application? In the previous blog, we examined the single-quadrant PWM technique, which is a good fit for extremely cost sensitive motor control applications where you want to control the motor's speed by varying the duty-cycle of a PWM signal. But the motor can only spin in one direction, and generate torque in that same direction. We also introduced the "H-Bridge" as a springboard to investigate other PWM topologies. In this blog, let's take a look at how to build a bi-directional speed control power stage by using an H-Bridge. In particular, we will construct a **2-Quadrant Drive** since it can produce forward motion with positive torque (quadrant 1), or reverse motion with negative torque (quadrant 3). Again we will choose a DC motor for this discussion, since the concepts are more easily understood with a DC motor.



For Unipolar PWM operation in quadrant 1, Q1 is turned ON continuously while we apply a

PWM signal to Q4. You can watch an animation of Unipolar PWM operation in quadrant 1 by clicking here. When Q4 is switched ON, a current path is created from V_{bus}, through Q1, through the motor, through Q4, and returning through ground. At the end of this PWM state, Q4 is switched OFF. Since the motor winding has inductance, it will fight to keep the motor current flowing in the same direction. An inductor protects its current just like a mother protects her child. It effectively says, “Don’t mess with my current! If you do, I will generate whatever voltage is necessary to keep my current flowing.” As a result, the inductor forces the back-body diode of Q3 to conduct. But since Q1 is always ON, the motor current will return through Q1, not the DC supply. When you think about it, you realize that since Q1 is ON continuously, this circuit behaves exactly like the single quadrant drive discussed earlier with one exception…if you want the motor to spin in the other direction, simply turn Q3 ON all the time and PWM Q2 instead. This results in quadrant 3 operation where the motor is running in reverse, and generating negative torque. You can see an animation of this process by clicking here.

It’s interesting to note that in both quadrant one and quadrant three operation, the bus current is either positive or zero, regardless of which direction the current is flowing in the motor! In other words, this PWM technique cannot regenerate energy. The reason for this is because the inductive flyback current is “trapped” in the top half of the H-Bridge, and never flows back into the DC bus. This can either be an advantage or a disadvantage, depending on your application. If you never have to worry about regenerated energy, then you don’t have to add expense to your design to deal with it. On the other hand, if you *want* to recover load energy, then this PWM technique is not a good choice for you.

Another advantage of this technique is that it only requires one PWM signal at any given time. This means you can potentially control more motors from one processor compared to some of the other PWM topologies. Also, there is only one transistor that is switching at any given time, so your switching losses are minimized. Finally, there is only one diode snap event per PWM cycle (when Q4 turns ON again after the Q3 back-body diode has been conducting). So this technique generates no more switching noise than the single-quadrant technique we discussed earlier.

The main disadvantage with this technique is that even though you have four transistors, you still can’t operate in all four quadrants. It’s like having a car with no brakes! If you want to slow down, you have two options; lift your foot off of the accelerator and coast (lower the PWM duty cycle), or suddenly throw the car in reverse (immediately transition from quadrant one to quadrant three!) By the way, I don’t recommend that you try this, or you will probably leave pieces of your transmission lying all over the highway! This latter scenario is called PLUGGING. Although it results in super fast deceleration of the motor, it is usually not a good idea since the resulting high currents will probably leave pieces of your drive lying all over the lab bench!

You should be aware that there is one scenario where this PWM technique (and even the single-quadrant circuit in the previous blog) *can* result in energy regeneration back into your DC power supply. When you have a load that accelerates the motor in either direction, there is nothing that will prevent it from running away since this PWM technique cannot provide any braking. The motor will continue to accelerate until its back-EMF voltage amplitude equals the DC supply voltage. If the speed increases beyond this point, the back-body diodes in the FETs will conduct, and negative current will spill into the DC bus. We will discuss ways to deal with this issue in a later blog.

In summary, this PWM technique is popular with applications where you want bi-directional motor speed control, but it's OK if the motor coasts down on its own when you want to decelerate. In the next blog, we will see that by changing just *one* signal on one of the transistors, we can use energy regeneration to decelerate the motor. In the meantime…

Keep those motors spinning! :-)

Dave

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