Regenerative Braking

Recapture the energy from a vehicle's braking & downhill operation to recharge the vehicle's battery

Application Challenge

A battery powered AGV (Autonomous Guided Vehicle) using a Brushless DC permanent magnet motor must be designed to optimize power utilization. The drive must operate in all four quadrants (in particular forward deceleration and reverse deceleration) to prevent the vehicle from running away on an incline. How can the energy from braking and downhill operation be efficiently recaptured and stored in the battery?

Application Considerations

Feature/Function	Units/Description
Max Speed (flat ground)	5 mph
Acceleration (flat ground)	0-5 mph in 10 seconds
Motor	2hp 3-phase brushless with Hall Effect sensors, 20:1 gearing
4-Quadrant Drive Stage	Torque must be applied in either direction regardless of the current direction of motion
Rechargeable Supply Voltage	2 12V 22AmpHour lead acid batteries

Motion Control Solution

In this design a **MC73110 intelligent motor controller IC from PMD** will be used with PWM based hall commutation to control an IR2113 triple half bridge MOSFET drive stage. The motor's Hall Effect sensors will be used for commutation and velocity estimation. A shunt resistor and voltage comparator will be used to protect the batteries from overcharging. Figure 1 demonstrates the overall solution.

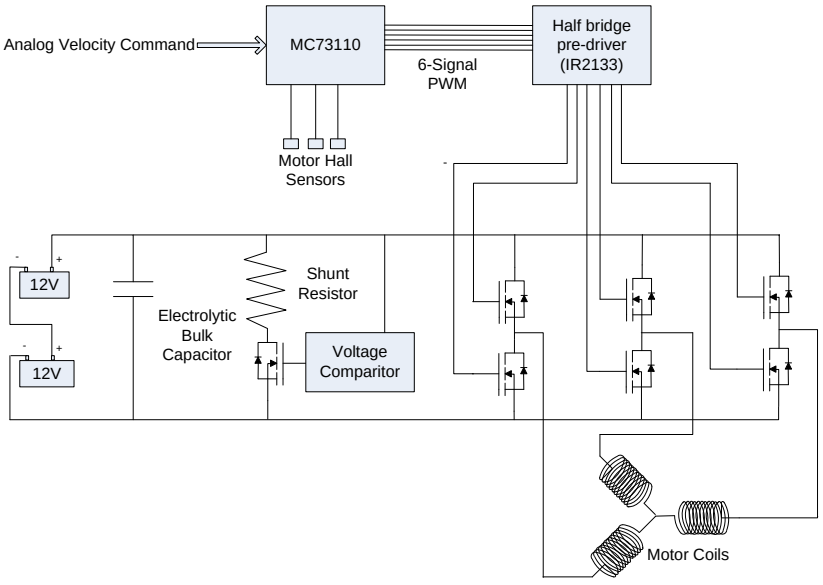

Figure 1: System Components

The implementation of "3rd leg floating" will mean the upper and lower MOSFETs of the "neutral" phase will be off. The controller will only be driving four of the six MOSFETs at any one time. Note that bi-directional MOSFETs are used in motor drive stages since the flow of current can reverse (drain to source or source to drain).

The region of regenerations can be defined by the condition where the current is flowing into the positive terminal of the battery. At steady state this means the BackEMF is greater than and has opposing polarity to the effective voltage. This condition will occur when the vehicle is going downhill and the controller is "putting the brakes on".

This is a PWM switching drive stage which means the motor windings are exposed to the 24V source "instantaneously", as defined by the controller's duty cycle output. When operating in the steady state region of regeneration there will be current flow into the positive battery terminal during a portion of this PWM cycle (one hi side MOSFET on and one low side MOSFET on). For the remainder of the PWM cycle the current is re-circulating in the motor and MOSFETs only. The power delivered to the battery is equal to the battery voltage times the average winding current times the duty cycle.

$$P = V_{batt} * I_{RMS} * DutyCycle$$

In a multi-phase PM servo motor (brushless), the BackEMF voltage on a given phase is sinusoidal (or sometimes trapezoidal on "DC Brushless" motors). However, when properly commutated, the effective voltage will be in phase with the BackEMF voltage when they have a common polarity (standard model-opposing) and 180 degrees out of phase when opposite polarity (series voltage).

The remaining components of Figure 1 exist to protect the batteries. The batteries will overheat if the recharge rate is too high (excess power flow into battery). The voltage comparator monitors the bus rail voltage and switches on the shunt resistor when the voltage is too high. When the shunt resistor is enabled, the power dissipates as thermal energy in the shunt resistor, which saves the battery from excess power flow.

Going Further

Some battery leads may not tolerate the instantaneous current flow changes that result from using a switching PWM drive stage, and will be subject to thermal failure. The solution is to add an electrolytic capacitor to the battery rail to absorb the inductive spikes on the battery leads.

To go beyond the shunt resistor design, a more sophisticated system would record the battery voltage during the regeneration PWM state and compare that to the voltage in the non-regeneration PWM state. In this case the shunt resistor is enabled when the voltage differential exceeds a set value.

The **MC73110 Motor Control IC** provides high performance digital current loop, velocity loop and commutation for brushless DC motors. This intelligent single-axis drive controller operates in internal velocity profile mode, velocity mode with an external velocity command signal, or torque mode with an external torque signal. They are designed for demanding and precise applications such as this regenerative battery solution and other automation and instrumentation challenges.

12mm x 12mm

Contact our customer support team at +1 781 674 9860 for more information including details on Developer's Kits and application support. We would like to assist you in improving your motion system.