

# PWM Control Methods Increases Efficiency, Reliability and Extend Battery Lifetime

*Brushless DC motors the choice for battery-operated applications*

*PWM duty cycle control techniques enable greater efficiency and versatility of the brushless DC motor to provide flexible control and novel cyclic operation, as well as better protection schemes for the motor and control circuits.*

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There is an increasing demand for battery-operated motor applications in the market today. Traditionally, brushed DC motors have dominated this market. Until now, linear control of series and shunt wound DC motors offered simple, low cost solutions. However, due to the inherent inefficiencies of these solutions, the lifetime in which the battery is able to power the product between charging cycles can be significantly shortened. As a result, some products require additional battery capacity (weight, size, and cost) to be designed-in or suffer in the eyes of the user due to frequent trips back to the charging station.

PWM duty cycle control techniques enable greater efficiency and versatility of the brushless DC motor to provide flexible control and novel cyclic operation, as well as better protection schemes for the motor and control circuits. The high efficiency, higher power densities and reliability make brushless DC (BLDC) motors an ideal choice for battery-operated motor applications because the combination of power electronics and innovative control techniques provide a high performance, efficient, compact and low cost solution.

Typical high-volume battery-operated applications include hand-held power tools, electric garden equipment, and electric vehicles such as golf carts, and scooters.

Conventional solutions for these applications use brushed DC motors (Figure 1). The speed control is achieved by reducing the voltage applied across the motor. Typical methods used are rheostat control or linear electronic control. While both methods provide a simple solution to the speed control of the DC motor, they suffer from several disadvantages that include:

- Low efficiency at low speeds and hence low charge cycle time for the battery
- In linear electronic control circuit, the losses in the switch do not depend on the switch characteristics. The switch must be large enough to dissipate the heat generated. This method is costly for high-power motor control applications.
- Speed can be controlled only below base speed

- Speed control is possible in one direction only. Reversal of speed requires extra relays to switch polarity of the voltage across the motor.
- Battery voltage variations can not be compensated
- Limited to brushed DC motor control only

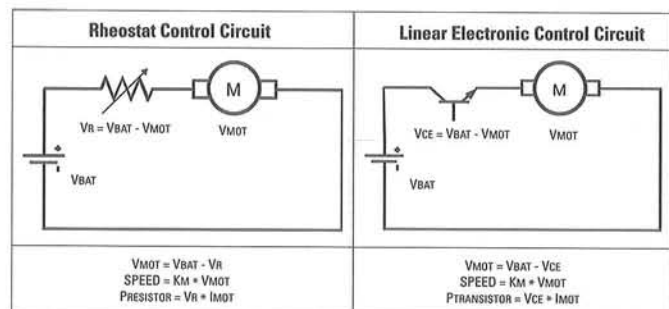


Figure 1: Typical control circuits for low power DC motors

## PWM Switching Control Methods

PWM switching control methods improve speed control and reduce the power losses in the system, which increase the mean time between charge cycles of the battery. The reduced losses also help reduce the weight of the system as smaller thermal management components are needed. These two factors are critical for portable equipment.

PWM control methods also enable novel control methods and leverage the latest silicon advancements to reduce losses in the system. With appropriate circuit and control methods, speeds above base speed can be achieved. Moreover, rugged power switches and feature-rich gate drive ICs improve the ruggedness and reliability of the system.

The losses in switching control circuits depend on the switch parameters. MOSFETs with low  $R_{DS(on)}$  and switching losses dissipate less power and hence smaller devices can be used. Therefore, using MOSFETs with the appropriate characteristics reduces the overall system losses, size and cost.

High Voltage IC gate drivers (HVICs) can be used to interface high power MOSFETs to the logic level control circuits to simplify the system design (Figure 2). International Rectifier's HVICs offer several protection features that improve system reliability. Features such as over-current shutdown and under-voltage lockout (UVLO) make the systems more robust. The power supply for the high-side MOSFET gate drive circuit is derived using bootstrapping of the VCC. The bootstrapping technique eliminates the need for multiple isolated power supplies and hence reduces the system cost and the size.

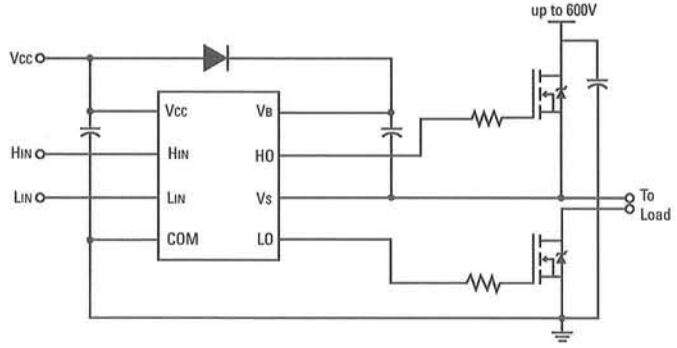


Figure 2: Typical HVIC Driver Application

A single switch chopper (Figure 3) can seamlessly control the speed through duty cycle modulation. The losses in the FWD across the motor can reduce the overall efficiency of the system. The efficiency can be improved by replacing the FWD with a MOSFET (Q2).

The MOSFET (Q2) can be switched ON during the freewheeling period to reduce the losses. The RDSON of the MOSFET is lower than the VF of the diode and hence it will reduce the over all losses in the system. This chopper configuration allows only unidirectional speed control and does not permit recovering the regeneration energy from the motor.

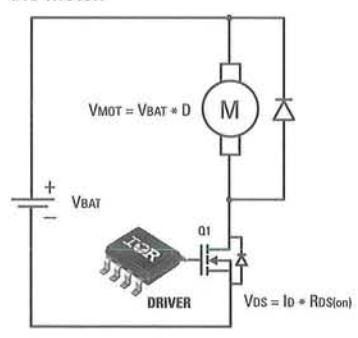


Figure 3a: Typical Single Quadrant DC Motor Control Circuits using IRS2117 Single Switch Chopper (VMOTOR = VBAT \* (TON / TOFF) , Speed = KM \* VMOTOR, PRESISTOR = VR)

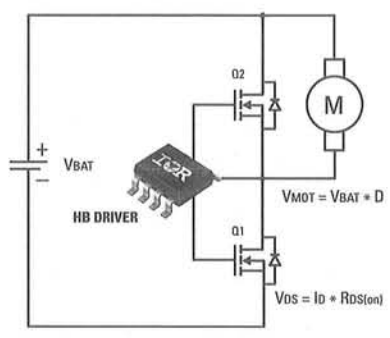


Figure 3b: Typical Single Quadrant DC Motor Control Circuits using IRS2117, Chopper with Synchronous Switching MOSFET. (VMOTOR = VBAT \* (TON / TOFF) , Speed = KM \* VMOTOR, PRESISTOR = VR \* IMOTOR )

A full bridge circuit provides greater functionality. This circuit allows four quadrant operation of the DC motor (Figure 4) and enables the battery to capture the regenerative energy from the motor. The motor can be run in both forward and reverse directions and is suitable for

electric vehicles, power tools, wheel chairs and any application requiring forward and reverse operation. The half-bridge HVIC drive simplifies the design and size of the system as shown in Figure 5,

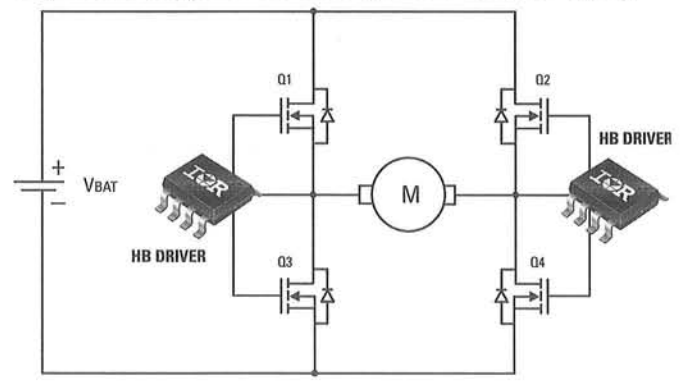


Figure 4: Typical Four Quadrant DC Motor Drive Circuit using IRS2003

The three-phase brushless motor improves the efficiency and reduces the size and weight as well as improving system reliability. BLDC motors do not have a mechanical commutator and brushes. Instead, BLDC motors depend on electronic commutating circuits. The absence of the commutator and the brushes reduce the size of the motor and improve the reliability of the system.

Typical BLDC motors have three-phase windings and hence require a three-phase inverter circuit to control the speed. Figure 5 shows the typical three-phase inverter used for controlling the BLDC motor speed. The HVIC gate drivers simplify the system design by eliminating three isolated power supplies and provide over-current protection and protect the power devices during supply under-voltage conditions.

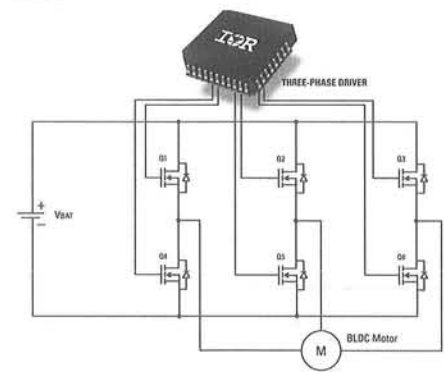


Figure 5: Typical Three Phase Inverter Circuit for BLDC Motors using IR2136

**Summary**

The PWM switching circuits and synchronous rectification improve the efficiency and increases the speed of the battery-operated motor drive system.

BLDC motor drives further improve efficiency and reliability while reducing the system size and weight. Moreover, the HVIC gate drivers simplify the system design, improve robustness and reduce the overall system size and cost.

For more information go to <http://www.irf.com/product-info/hvic/g5hvic.html>