AN5382

Advantages of active current limitation in MC33HB2000 and MC33HB2001

Rev. 1.0 — 15 December 2016 Application note

1 Introduction

Managing thermals is the most challenging aspect of a majority of motor control applications. Higher junction temperatures increase the on resistance ($R_{DS(on)}$) of power FETs which may further increase temperature and result in reliability issues. As a result, managing the temperature at the device and system level is very important. The NXP H-Bridge motor driver product family, including MC33HB2000 and MC33HB2001, commonly referred to as the HB2000 and HB2001, provides an efficacious and effective thermal management scheme with the active current limiting feature. The active current limiting feature manages the operation of the device with minimal compromise to the current drive capability, even at elevated junction temperature. This technique allows the device to cool down by switching the MOSFETs on and off. Using this method, the device is protected against prolonged high temperature exposure which mitigates reliability issues and failures due to high temperature.

2 Active current limiting feature

Active current limiting is a feature of both the HB2000 and HB2001 incorporating four selectable current limit thresholds. The thresholds, selectable via SPI, enable the user to scale up or down the current drive capability to meet application requirements. These devices provide one of the lowest $R_{DS(on)}$ and the lowest thermal resistance from junction to case bottom ($R_{\theta JC}$). The HB2001 offers $R_{DS(on)}$ per FET of 125 mΩ (max) and the HB2000 offers 235 mΩ (max) at 150 °C junction temperature (T_J), with $R_{\theta JC} < 1$ °C / watt. The active current limit feature also provides high side recirculation during the load de-energizing part of the Pulse-Width Modulation (PWM) cycle. High side recirculation reduces the switching power dissipation for inductive loads as the energy stored in the load dissipates through the high-side FETs instead of through the body diode. Current only flows through the body diodes of the FETs during the transition time (dead-time) while switching between high side and low side FET on the same half-bridge of the device.

The industry utilizes multiple methods to limit current through the load in H-Bridge motor drivers with integrated power FETs. The majority of products in the market perform some type of thermal management incorporating a current limiting feature to protect the device and maintain part functionality at elevated ambient temperatures. Various thermal management methodologies may be used to prevent a thermal shutdown event. HB2000 and HB2001 incorporate a temperature dependent active current limiting feature that:

- limits the current through the load
- controls the junction temperature to safe limits for a given range of load
- maintains the average current to the selected threshold using the SPI register

3 Active current limiting with synchronous rectification and thermal management

HB2000 and HB2001 use the active temperature dependent current limiting algorithm with synchronous rectification. The current limit threshold (ILIM) is selectable by the SPI in four steps from 5.4 A to 10.7 A (typical) . The short circuit threshold (SC) typical value high-side FET is ILIM plus 6.5 A and low-side FET is ILIM plus 5.5 A. The current limiting circuit is activated by monitoring the current flowing through the internal FETs.

Once the active current limit is initiated, the Over Current (OC) SPI bit is set in the fault status register. A blanking time (t_B, 32 µs) is set from the point in time where the current limit exceeds the ILIM, after the 32 us, the load is de-engerized using high-side recirculation allowing the device to cool. If a short circuit shutdown is not triggered before the blanking time has expired, the H-Bridge switches to high-side recirculation mode for 2 * t_A. The t_A is determined by the time it takes for the current to decay below the current limit threshold after switching to recirculation mode. After 2 * t_A, control of the gates is released, restoring the output to the configuration set by the inputs and the cycle starts over again. If the average output FET temperature exceeds the die Over-Temperature warning threshold (OT_W), the blanking time (t_B) increases by a factor of 8 (256 µs), effectively decreasing the current limit PWM frequency. The temperature dependent blanking time does not change during the blanking interval.

Note: *The input control does not cause the output to switch ON when the current is greater than ILIM. Moreover, the input control commanding the output to switch OFF, immediately switches the output OFF and resets the ILIM circuit.*

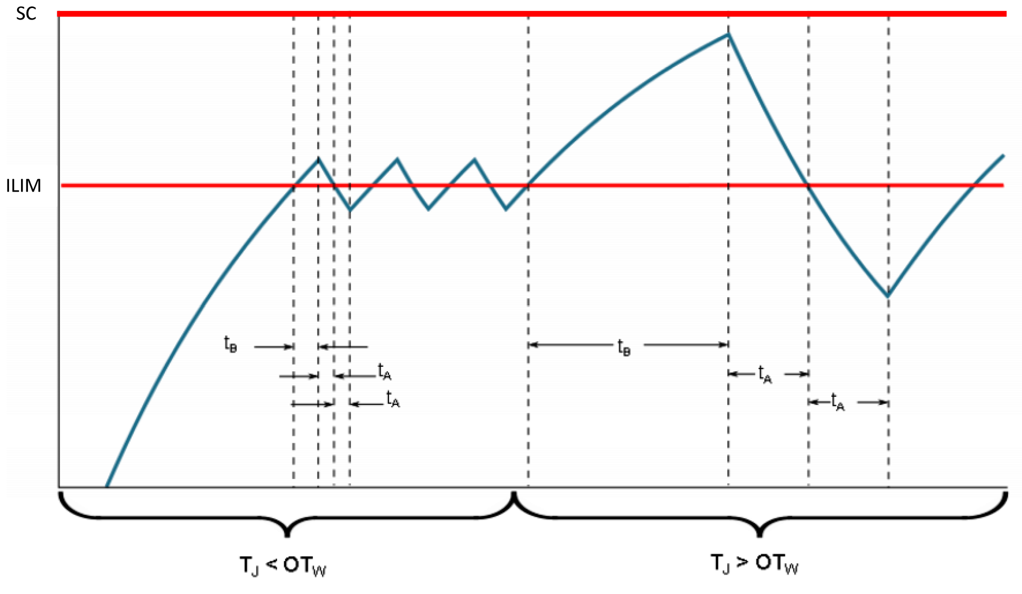

Figure 1. Active current limiting with synchronous rectification and thermal management

Figure 1 shows the current limiting algorithm used in HB2000 and HB2001. There are two parts to this algorithm.

1. $T_J < OT_W$: As long as the junction temperature (T_J) is less than 150 °C (OT_W), t_B = 32 µs and t_A, determined by the inductance discharge rate (di/dt), is kept symmetrical around the ILIM to maintain the average load current close to the ILIM selected using the SPI register. In this zone, t_B at 32 µs ensures that the motor

control remains smooth and the peak current is controlled, even while ILIM has been activated.
With t_B at 32 μs, the internal PWM frequency supplied to the brushed DC motor (load) is high enough to smooth out the mechanical impulses of each pulse generated due to a combination of mechanical inertia and motor coil inductance in the typical applications where these devices are used. It is to be noted that the optimum PWM frequency to minimize the noise and smooth out the mechanical impulses differ from motor to motor. If the PWM frequency is too low, the motor motion may be very jerky or even rattle. At the same time, the frequency cannot be too high as high PWM frequency increases switching losses that cause excess power dissipation contributing toward increased junction temperature. With target loads in mind, t_B at 32 μs provides smooth and low noise switching when in current limiting mode.

2. $T_J > OT_W$: Situations where the motor starts to stick and bind due to some external components may cause T_J to rise beyond OT_W. Once the junction temperature (T_J) exceeds 150 °C (OT_W), t_B is set to 256 μs instead of 32 μs. This method of changing the switching frequency reduces the switching losses significantly, allows the device to cool down and maintain the average current around the threshold selected via SPI register. However, by increasing t_B, the peak current and the current ripple also increase. Peak current and current ripple will increase the overall noise and the chances of short circuit threshold triggering if the peak current exceeds the short circuit threshold for the selected current limit threshold, especially with low inductance loads . Hence, the boundary limit set for the short-circuit threshold is based on the lowest load inductance for the target applications. On the other hand, by allowing higher peak currents when $T_J > OT_W$ the instantaneous current (or torque) available for the motor for that instant would be higher than the one with $T_J < OT_W$. Higher instantaneous torque provides increased chances of clearing any debris causing the motor to bind or stick.

4 Conclusion

Managing temperature resulting from internal power dissipation and elevated ambient temperatures is a very important concern regarding motor drivers in automotive applications. Both HB2000 and HB2001 have been architected and designed to operate in extreme environments within automotive and industrial applications to deliver the torque to the motor as and when required. As extremely reliable motor drivers for a wide range of automotive and industrial systems, the devices:

- offer the most thermally efficient packaging in the industry
- offer the lowest integrated $R_{DS(on)}$
- are complemented by the temperature dependent active current limiting algorithm explained in Section 3 "Active current limiting with synchronous rectification and thermal management"

The active current limiting feature, accompanied by the thermal management algorithm, helps the device maintain the average current in accordance with the selected current limit threshold, even at temperatures above 150 ˚C. The device keeps operating with the same current drive capability with $T_J > OT_W$ as long as T_J has not exceeded the overtemperature shutdown threshold (OT). This feature enables these devices to deliver torque to the motor when needed most.

5 References

Table 1. Reference table

Freescale.com Support Pages	URL
HB2000 product summary page	http://www.nxp.com/HB2000
HB2001 product summary page	http://www.nxp.com/HB2001

6 Revision history

Table 2. Revision history

Revision	Date	Description of changes
1.0	12/2016	Initial release

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