Meeting Standby Energy Requirements in Motor Drive Applications

John Emmanuel Tan, Juan Paolo Quismundo | Power Integrations, Philippines

Abstract

Electronic devices and appliances consume electricity when plugged, even when not in use. This power draw is termed standby power consumption and represents a significant percentage of total energy consumed. In motor drive applications, conventional methods are used to reduce the standby power drawn, including the use of mechanical or solid-state relays. This paper proposes the use of integrated half-bridge modules that integrate the auxiliary supply circuit, as well as a feature to reduce standby power consumption when the device is not in use. This method reduces total part count while drastically reducing standby power consumption to 10 mW for all three half-bridge modules.

1. Introduction

According to the International Energy Agency (IEA) [1], residential standby power accounts for 9.4 percent in Japan, 10 percent in Germany and 5 percent in the United States of total residential power consumption. Standby mode is defined as the condition where equipment is connected to and requires the main AC line to work, but only provides a reactivation function, information display, or both [2]. In line with this, the European Commission (EC) of the European Union (EU) 2023/826 has limited the standby power consumption in an off-state appliance to less than 300 mW in 2025 [2][3]. These regulations are intended to reduce the total EU power consumption to 10.2 percent in 2030 alone.

Multiple methods or solutions have been proposed to reduce standby power consumption. In motor drive applications, some implementations rely on circuit disconnection to achieve a lower standby power consumption [4][5][6].

A sample implementation is shown in Fig. 1, where a main power relay is in series with the DC Bus line and is disconnected when in standby/off mode. This architecture can be implemented in household appliances, such as dishwashers and indoor / outdoor air conditioning units that drive a 3-phase high-voltage brushless DC (HV-BLDC) motor.

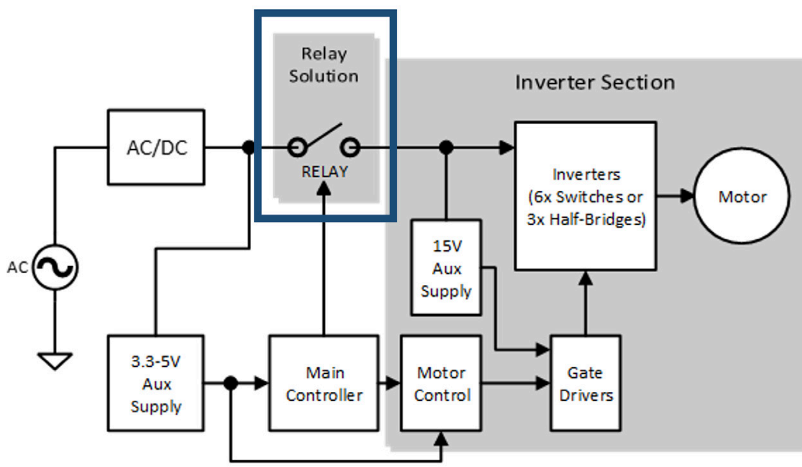

Fig. 1 Reference solution for standby power reduction in motor drives.

2. Standby Power in Conventional Motor Drives

In a high-voltage motor drive application, the system can be separated into two sections: the power section and the inverter section. The power section includes: AC input, EMI components, surge and inrush current limiting components, rectifier device/s and bulk capacitor/s. The inverter section comprises gate drivers, a dedicated power supply, a controller, and the main inverter of either 6 switches or 3 half-bridges.

This paper will focus on the standby power consumption in the inverter section of the system.

2.1 Conventional Gate Driver

In a conventional gate driver circuit, as shown in Fig. 1, a gate driver IC is used to provide the switching signals to the inverter. This requires an auxiliary supply and some external components. In the circuit shown, the gate driver takes power from the voltage at the common collector (VCC) to provide both the low-side and high-side drive signals. The gate driver IC along with the external components draw power during standby mode.

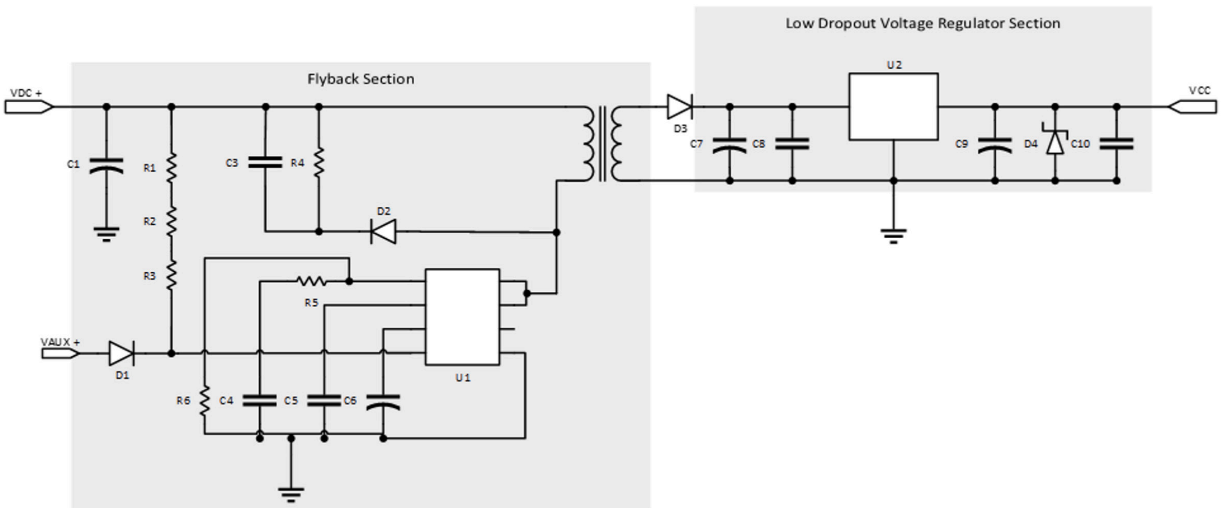

Fig. 2 Reference solution for standby power reduction in motor drives.

2.2 Auxiliary Supply

In the high-voltage inverter section, the auxiliary supply, typically a flyback converter, is used to provide power to the gate driver circuit, as shown in Fig. 2.

From the high-voltage DC bus, a flyback circuit with a controller, the transformer, and other external components are used to step down the DC voltage. The step-down circuit also employs a low dropout voltage regulator to maintain the target driver supply voltage, which in this case is 15 V. Even when the motor is not operating or is in standby mode, this circuit with the gate driver still draws power contributing to the system's standby power consumption.

3. Standby Power Reduction

The gate driver and its auxiliary supply draws power in standby mode, requiring solutions to ensure lower power consumption when the motor is not operating.

3.1 Conventional Solution

Going back to the connection between the AC/DC converter and the inverter sections of the system, a relay can be connected in series, as shown in Fig. 1. The relay is driven by a drive circuit that is enabled by the main microcontroller during normal operation. The relay is disabled when the system goes into standby mode to ensure that no power is drawn by the inverter section. The main disadvantage of a relay-based solution is the additional cost that the relay introduces, including the drive circuit. The mechanical relay also introduces reliability risk due to component fatigue.

3.2 Integrated Half-Bridge Solution

3.2.1 IHB Architecture

An integrated half-bridge (IHB) module is a single device that contains both the high-side and low-side power switches, and the gate driver circuits inside a single package.

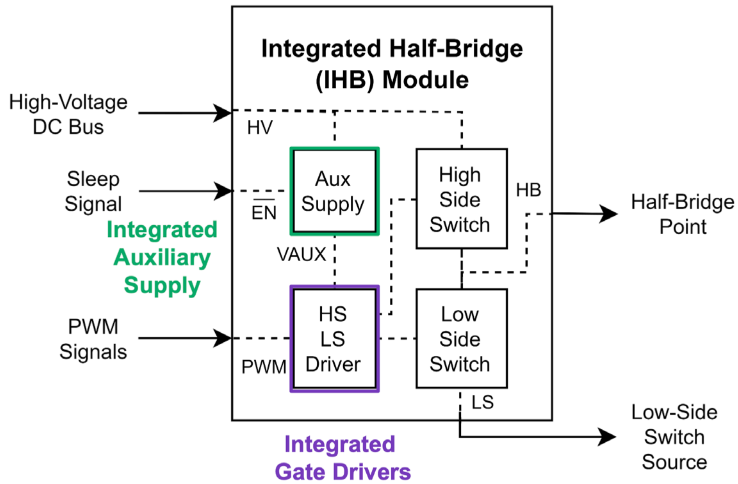

Fig. 3 Integrated half-bridge module

As shown in Fig. 3, the IHB module also incorporates an internal auxiliary supply that is directly connected to the high-voltage DC bus. This would remove the need for all the external components for the auxiliary supply, including the flyback circuit and the low-voltage dropout regulator.

The gate driver circuit is also integrated into the IHB module. Typically, the design would require an additional gate driver circuit to enable the MCU-generated control signals to drive the switching device of the half-bridge inverter section. The integrated gate driver circuit is required to drive both high-side and low-side switches of the half-bridge device. This removes the need for a separate gate driver IC, as well as the external components this requires. Due to this implementation, the output PWM signals of the MCU that are intended to drive the high-side and low-side switches of all three half-bridges can now be directly connected to the IHB without any intermediary gate drive circuit.

The high-side and low-side switches of a single-half bridge are integrated as well into the IHB module. The drain connection of the high-side switch is to the HV DC bus, and the source connection is to the half-bridge point which is connected to the motor winding. For the low-side switch, the drain is connected to the half-bridge point, while the source is connected to the ground. The integration of the switches enable additional features including internal over-current protection, over-temperature protection, as well as an Integrated Phase Current information.

3.2.2 Sleep Mode Function

Since the auxiliary supply circuit is integrated, a standby mode or sleep mode feature is made available.

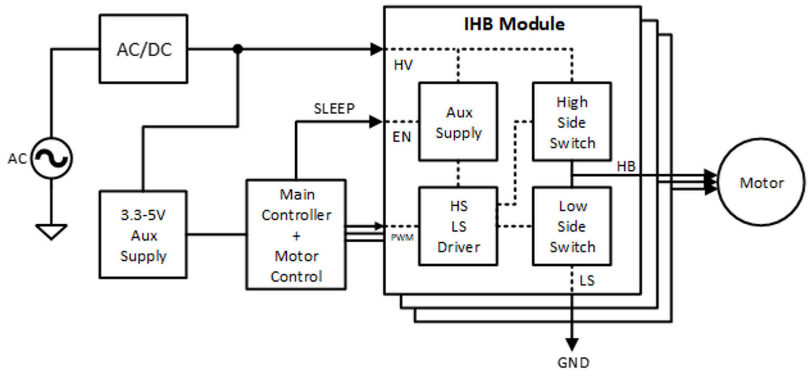

Fig. 4 Motor drive system with IHB modules

In Fig. 4, the inverter section is shown and contains the IHB modules per motor phase. The IHB supports a sleep pin that interprets a logic high signal to enable the sleep mode feature. If the system transitions from an active and operating mode into a standby (sleep) mode, the main controller simply needs to set the signal to high.

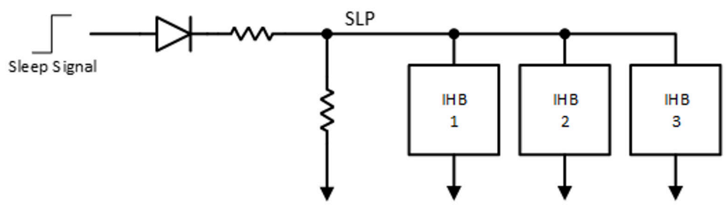

Fig. 5 IHB sleep mode function

Upon receiving the signal for sleep mode as shown in Fig. 8, the IHB module will disable the internal auxiliary supply. Once disabled, the IHB module will draw a lower amount of power during standby.

4. Standby Power Measurements

As indicated earlier, this paper is focused on the standby power for the inverter. Standby power measurements are therefore taken for the AC/DC and inverter sections.

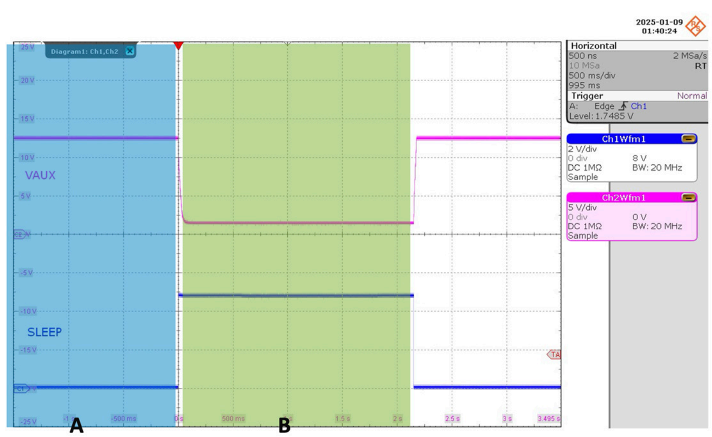

Fig. 6 Auxiliary voltage during sleep mode

The internal auxiliary voltage is regulated around 12.4 V, as shown in Fig. 6. Once the sleep mode signal is asserted, represented by channel 1 of the waveform capture, the auxiliary voltage drops down to 1.5 V, represented by channel 2 of the waveform capture. The recovery mode is also shown wherein the sleep signal is set to low, accordingly, the auxiliary voltage recovers back to around 12.4 V. This capture verifies the function-ality of disabling the internal auxiliary supply when sleep mode is enabled.

The inverter input power is measured at 305 mW during normal operation, when sleep mode is enabled, this drops down to < 4 mW for every IHB module.

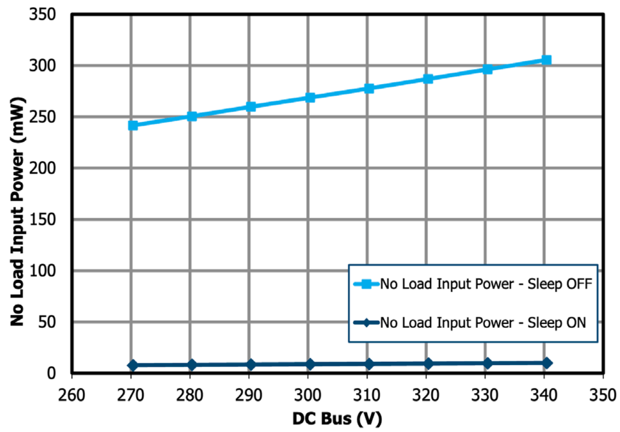

Fig. 7 No-load (standby) input power vs. DC bus voltage

The standby power consumption increases with respect to the DC bus voltage. In Fig. 7, power consumption is shown for both when the sleep mode feature is on and off. The no-load input power comparison between a disabled and enabled sleep mode feature is mapped from a DC-link bus voltage of 270 V up to 340 V. At the 340 V mark, without the proposed solution, the power drawn reaches above 300 mW at no-load or standby. This consumes most of the margin and allowance for the standby power regulations.

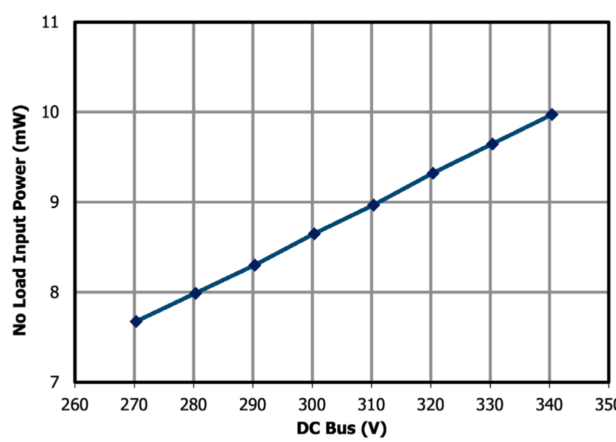

Fig. 8 No-load input power during sleep mode vs. DC bus voltage

For all three IHB modules, total no-load power drawn is reduced to <10 mW at 340 V bus voltage and < 8 mW at 270 V, as shown in Fig. 8.

Bus Voltage (VDC)	Disabled Sleep Mode Input Power (mW)	Enabled Sleep Mode Input Power (mW)
270	241.6	7.6
280	250.6	7.9
290	259.8	8.3
300	268.8	8.6
310	277.7	8.9
320	287.0	9.3
330	296.3	9.6
340	305.6	9.9

Table 1 No-load input power for disabled and enabled sleep mode

The tabulated measurements are also shown in Table 1, to highlight the significant savings in the input power drawn when using the sleep mode feature.

The half-bridge modules reduce the overall part count due to the integrations of the gate drivers and auxiliary supply, among others, having also achieved low input power during standby. This feature only requires a logic signal from the microcontroller unit to implement, simplifying the mechanism to set the entire inverter section into the standby mode.

5. Conclusion

In implementing the integrated half-bridge solution's sleep mode feature, standby energy consumption was drastically reduced to less than 10 mW without the need for additional external components. The reduction in the standby power consumption of the inverter section provides a significant contribution to meeting emerging standby power regulations and allowing increased flexibility for the design of other system blocks and components.

References

[1] International Energy Agency, "Things That Go Blip in the Night: Standby Power and How to Reduce It". 2001.

[2] European Commission. Commission Regulation (EU) 2023/826 of 17 April 2023 laying down ecodesign requirements for off mode, standby mode, and networked standby energy consumption of electrical and electronic household and office equipment pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulations (EC) No 1275/2008 and (EC) No 107/2009*. 2023.

[3] European Commission, "Commission Regulation (EU) 2019/2022 of 1 October 2019 laying down ecodesign requirements for household dishwashers pursuant to Directive 2009/125/EC of the European Parliament and of the Council amending Commission Regulation (EC) No 1275/2008 and repealing Commission Regulation (EU) No 1016/2010." 2019.

[4] C. H. Tsai, Y. W. Bai, M. B. Lin, R. J. R. Jhang, and C. Y. Chung. "Reduce the standby power consumption of a microwave oven." in IEEE Trans. Consumer Electron. vol. 59, no. 1, pp. 54-61, 2013.

[5] C. H. Tsai, Y. W. Bai, L. C. Cheng, K. S. Lin, R. J. R. Jhang, and M. B. Lin. (2012). "Reducing the standby power consumption of a PC monitor." In IEEE Global Conference on Consumer Electronics vol. 1, pp. 520-524, 2012.

[6] C. H. Tsai, Y. W. Bai, P. C. Chen, R. J. R. Jhang, and M. B. Lin. (2012). "Reduction of the standby power consumption of an automatic door system." In IEEE International Conference on Consumer Electronics (ICCE) pp. 583-584, 2016.

For more information,
visit **power.com**™

power integrations

050525