Application note for the ZXBM1004 and ZXBM2004 variable speed motor controllers - Interfacing to the motor windings

Purpose

This applications document provides details of how to drive both single-phase and 2-phase fan and blower motors using the ZXBM1004 and ZXBM2004 motor pre-drivers from Zetex. It specifically deals with the driving of both external Bipolar and MOSFET power devices.

The document will not discuss mechanical details of motor design including such aspects as the position of commutation in relationship to windings etc, for which it is assumed the user already has prior knowledge.

This applications note is one of a series with the others dealing with other aspects of using the ZXBM1004 and ZXBM2004 devices. Also available are AN41 - Thermal control using a thermistor and AN42 - Speed control from an external PWM signal.

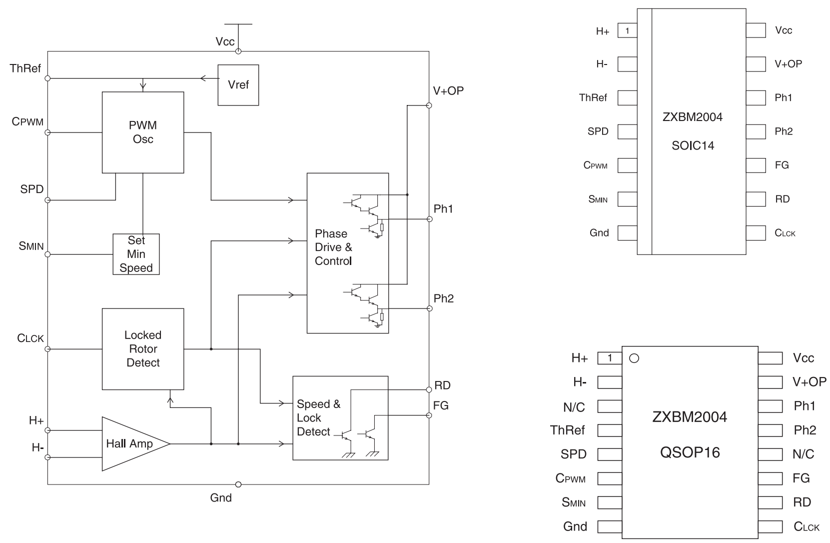
ZXBM1004 and ZXBM2004 descriptions

The ZXBM1004 and ZXBM2004 devices are both variable speed fan motor pre-drivers. The ZXBM1004 is for use with Single-Phase motors and the ZXBM2004 is for use with 2-Phase motors. Full details and Datasheets for both devices are available by logging on to **www.zetex.com/zxbm**.

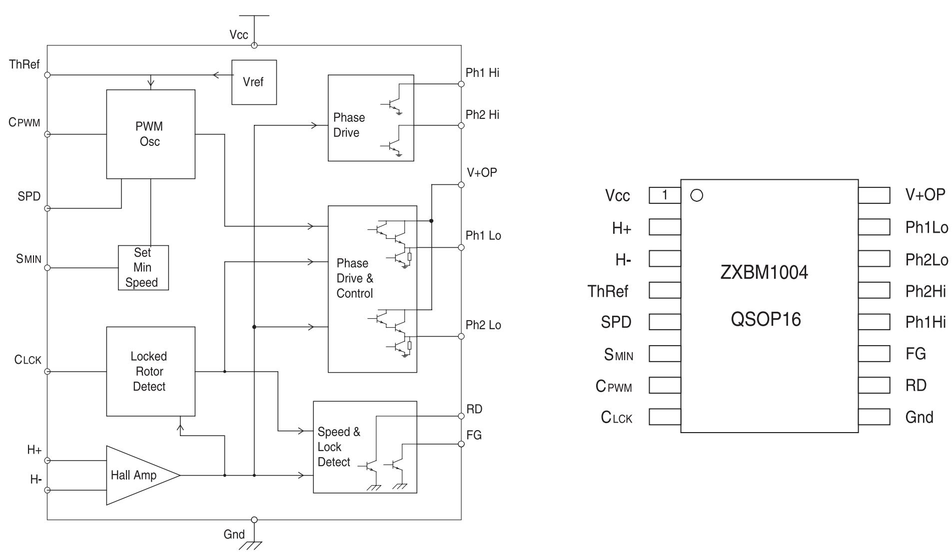
Both of these devices have the same operational and control features and in essence are identical with the exception of the output stage. The ZXBM2004 has two phase outputs capable of driving two external power devices for each phase winding. The ZXBM1004 has 4 outputs capable of driving an H-Bridge power device arrangement for a single Phase winding.

As far as the features to be described in this document are concerned they will be common to both devices and it is only the driving of the winding that will vary between the ZXBM1004 and ZXBM2004.

Block diagrams and pinouts of both these devices are included, however please refer to the ZXBM1004 and ZXBM2004 data sheets when using of this application note.



ZXBM2004 Block diagram and pinning



ZXBM1004 Block diagram and pinning

Winding Drive Requirements

Introduction

The ZXBM1004 and ZXBM2004 are motor pre-drivers and are designed to drive external power devices as a way of driving the windings of a fan motor.

The use of separate external driver transistors has been chosen so as to give the user maximum flexibility when driving fans of varying sizes. From those of small size that are capable of being driven using a SOT23 package to larger fans that need the use of the higher power handling DPAK package this Application Note discusses the various implications.

2-Phase or Single-Phase

Which ZXBM controller is chosen is dependent upon the type of fan being designed. For single-phase fans, the ZXBM1004 will be used whereas for 2-phase fans the ZXBM2004 will be used. All other aspects of the devices' control and operation are identical.

ZXBM2004 - 2-Phase Output Stage

The ZXBM2004 is designed to drive either Bipolar or MOSFET power transistors, Figure 1 and Figure 2 show the methodology of both options respectively.

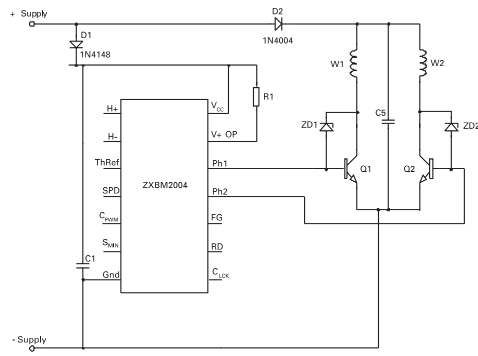


Figure 1 - ZXBM2004 with Bipolar transistor output stage

2-Phase drive using Bipolar transistors

Looking at Figure 1 first it can be seen that the phase outputs of the ZXBM2004 device directly drive the bases of the Bipolar power transistors. Resistor R1 is used to limit the current into the the bases of Q and Q2. The resistor value is determined by:

$$R1 = \frac{Vcc - PhV_{OH} - V_{BE}}{I_{OH}}$$

Where: I_{OH} is the output current from the Phase pins

PhV_{OH} is the Datasheet specified output high voltage for the Phase outputs

The phase drive outputs (Ph1 and Ph2) are push-pull outputs whereby an active transistor within the ZXBM2004 is used to turn-off the external transistor. The arrangement of having the base limiting resistor in the output stage supply as descrided above ensures there is no series resistance in the base to restrict the speedy discharge the stored charge.

ZETEX SEMICONDUCTORS

In order to control the switching voltages the active clamping arrangement using ZD1 and ZD2 is included. This restricts the voltage amplitude at the collectors of Q1 and Q2 when the devices turn-off. The advantage of active clamping is that any disipation is within the power transistors. It is possible to use non-active clamping where the Zener is attached between collector and emitter, however, it does have the disadvantage of requiring a larger zener diode to cope with the power disipation.

Bipolar transistors have been found very suitable to the smaller fan motors with both SOT23 and SOT89 having been used.

2-Phase drive using MOSFETs

When driving MOSFETs the arrangement in Figure 2 is used and here it can be seen that V+OP is driven directly from the supply and gate resistors R1 and R2 are included. These resistors are normal practice when driving MOSFETs and are included to prevent latch-up problems. It is however possible to leave these out dependant upon the type of MOSFET used. It is recommended the user establishes in his own application whether or not these resistors are required.

Voltage clamping is again achieved actively using ZD1 and ZD2, however, an extra diode is required in series with each of these otherwise the forward bias of the Zener would cause the gate voltage to be clamped at the threshold voltage when the MOSFET is turned-on.

As with the Bipolar devices the MOSFETs have also been found suitable for the smaller fan motor however they are also more suited to the higher power fan including those at 24V and above. Packaged in SOT23, SOT89, SOT223 and DPAK Zetex provide a range of MOSFET devices suited to all power ranges of fan.

ZXBM1004 - Single-phase output stage

MOSFET H-Bridge driver

When driving a Single-phase winding a different approach is required as both ends of the winding require to be switched to attain commutation. This as achieved using an H-Bridge power transistor arrangement as shown in Figure 3.

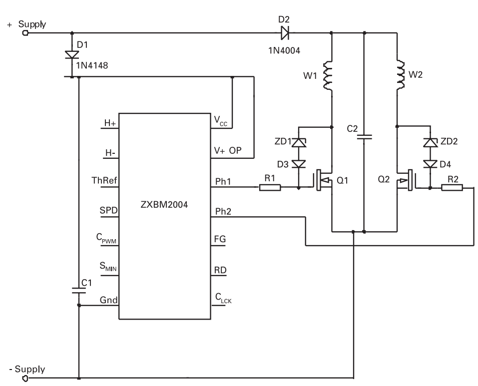


Figure 2 - ZXBM2004 with MOSFET output stage

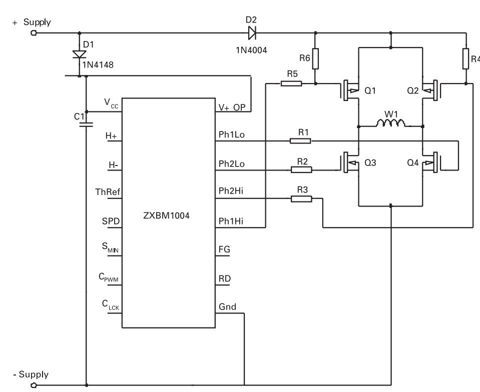


Figure 3 - ZXBM1004 driving a MOSFET H-Bridge

The basic arrangement can be built up using either Bipolar transistors, using MOSFET devices or even a combination of both such as PNP transistors on the High-side and MOSFETs on the low-side.

The switching of the H-Bridge is controlled in two halves, the high-side and the low-side. The Low-side, driven from outputs Ph1Lo and Ph2Lo of the ZXBM1004, provide the switching for commutation by deciding which of the pair is active dependent upon the state of the Hall sensor inputs H+ and H-. Superimposed on this Low-side commuatation waveform is the PWM switching used to control the speed of the fan motor. During the Lock condition, when RD goes high the Phase Low-side drive is dissabled.

The high-side switching is controlled by a pair of P-type devices driven from outputs Ph1Hi and Ph2Hi. These control the commutation only. This means that these devices are not subjected to the faster 25kHz switching and therefore only have to cope with on-resistance losses at commutation frequencies - more suited to P-Type devices.

Bipolar H-Bridge driver

As mentioned the most popular method of driving a single-phase winding is using the all MOSFET H-Bridge as shown in Figure 3. It is also possible however, to use an all Bipolar transistor H-Bridge although there is a dissadvantage of also having to provide the diode protection that is by default provided with the internal body diode when using MOSFETs. This body diode between drain and source acts as a clamp and provides a path for recirculating currents during PWM switching. This diode also prevents the excessive switching voltages to be found with 2-phase motors and therefore means that lower voltage transistors can be used.

The level of recirculating currents through the high-side protection diode is illustrated in Figure 4. It should be noted that the PWM recirculating currents can be quite excessive so the diode chosen will need a peak and average current handling specification in keeping with those currents.

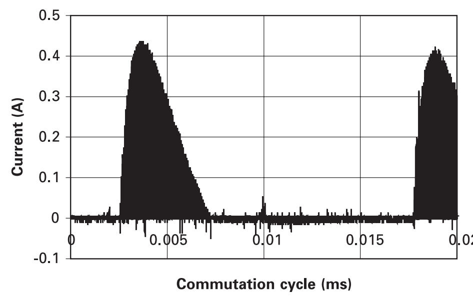


Figure 4 - High-side diode recirculating currents

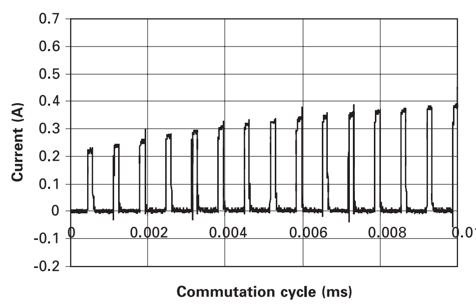


Figure 5 - Detailed High-side diode recirculating current waveform

When using Bipolar devices on the low-side the same arrangement for base drive as used in the bipolar 2-phase solution illustrated in Figure 1 is required. As described in the 2 phase section the base series resistor can be omitted and instead the drive current is controlled by inserting a resistor between the V+OP and Vcc pins. The value is calculated using the same formula as described in the bipolar 2-phase section on page 3.

Hybrid H-Bridge driver

Another arrangement worth considering is the hybrid combination as shown in Figure 6. This is proving quite suited to the higher power fan motor. Figure 6 also shows the additional diode needed when using Bipolar transistors. As with the Bipolar H-Bridge the size of diode needs to be consistant with the rating of the power transistor.

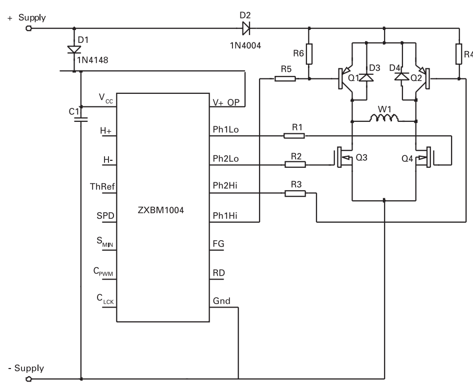


Figure 6 - MOSFET and Bipolar hybrid H-Bridge

The advantage of the hybrid H-Bridge is that it uses N-channel MOSFET devices where there is a need for 25kHz PWM switching and uses PNP devices for the slower commutation switching.

As with the 2-phase solution using the ZXBM2004 it could well be worth the user considering the omission of the low-side gate resistors, R1 and R2 in Figures 3 and 6 in order to reduce component count.

Layout considerations

Whilst it is understandable that the circuit layout is likely to be severely compromised in the restricted environment of small Single-Phase or 2-phase brushless fan and blowers a number of points are worth mentioning.

The decoupling capacitor (C3 in all the Figures) also needs to be as close to the device as possible. Also the capacitors for C_{LCK} and C_{PWM} (not discussed here) need to be positioned as close to the device as possible with the latter being the more important.

As much area as possible should be kept as copper for the tracks associated with the output stage with the technique of laying out the gaps rather than laying out the tracks being preferred. Allotting as much copper to the tab of the winding driver transistors is beneficial when using surface mount packages as they rely upon the copper of the PCB to dissipate as much of the heat as possible with the PCB itself in effect becoming the heatsink.

The power rails to the device and to the windings should be kept separate where possible. Where the power comes onto the PCB it should go in one direction to the windings and in the other direction to the controller and its associated components, in effect to form a star connection.

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