Application note for the ZXBM1004 and ZXBM2004 variable speed motor controllers - thermal control from an external PWM source

Purpose

This applications document provides details of thermally controlling the speed of both single-phase and 2-phase fan and blower motors from an external PWM source using the ZXBM1004 and ZXBM2004 motor pre-drivers from Zetex.

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 - Speed control using a thermistor signal and AN43 - Interfacing to the motor windings.

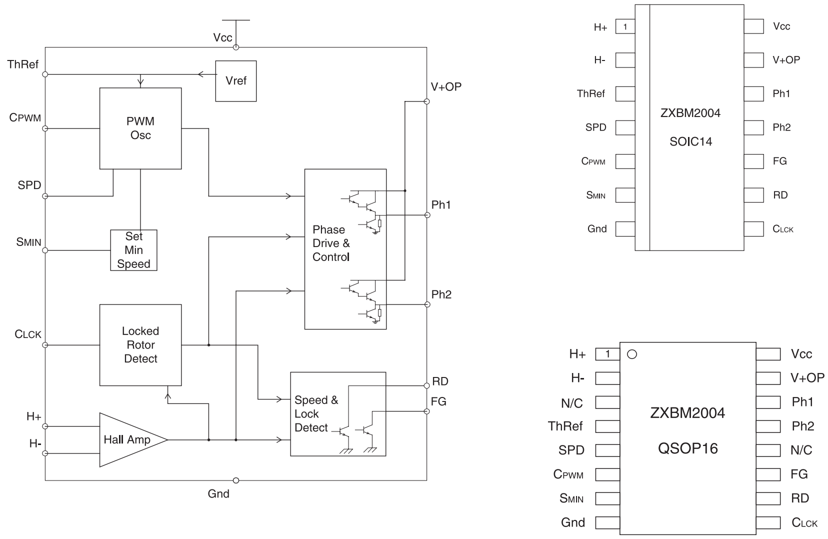
ZXBM1004 and ZXBM2004 descriptions

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**.

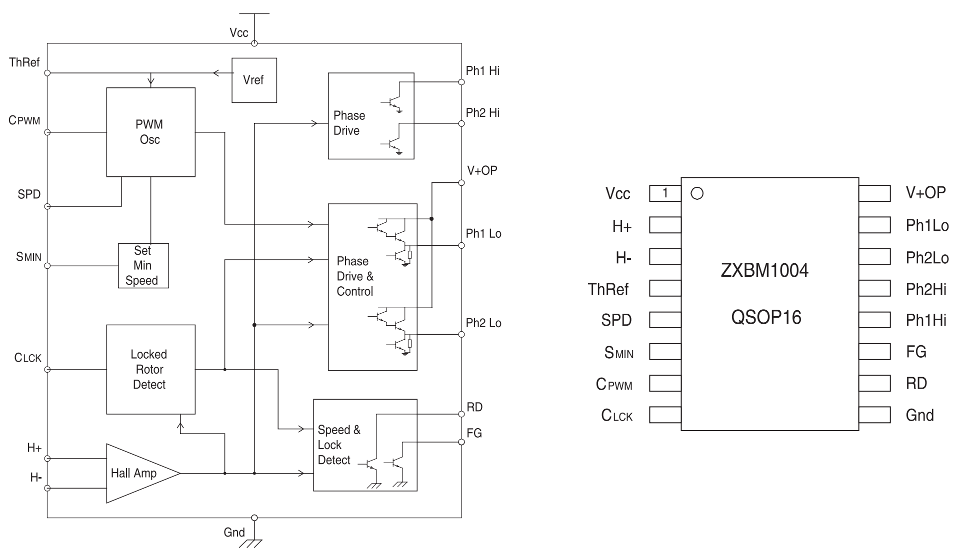
Both of these devices have the same operational and control features and in essence are identical with the exception of the output stage. Where the ZXBM2004 has two phase outputs capable of driving the two external power devices for the two phase windings, the ZXBM1004 has 4 outputs capable of driving an H-bridge power device arrangement for driving 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 datasheets when using of this application note.



ZXBM2004 Block diagram and pinning



ZXBM1004 block diagram and pinning

PWM thermal control requirements

Introduction

A popular way of controlling DC fans situated in PCs and instrumentation is to use a temperature sensing diode situated in the various processor and controller ICs within the system. This diode is interfaced to a thermal management circuit of some sort that will itself provide a signal to a DC fan to control it's speed. This control normally takes the form of a digital Pulse Width Modulation (PWM) signal.

The ZXBM1004 and ZXBM2004 motor pre-drivers are capable of taking this signal and controlling the speed of the fan through their external driver power transistors.

The methodology of driving the ZXBM1004 and ZXBM2004 with an external PWM signal is illustrated in Figure 1.

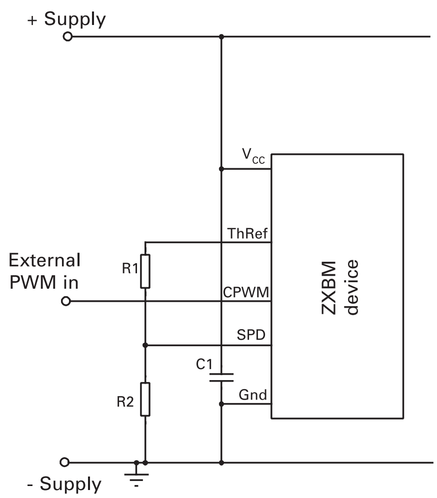


Figure 1 - methodology of driving the ZXBMn004 series by external PWM

Other aspects of using the ZXBM1004 and ZXBM2004 are discussed in their datasheet or applications notes AN41 and AN43.

External PWM control

The basic method of driving the ZXBM1004 and ZXBM2004 with a PWM signal derived from an external source is as shown in Figure 2. The PWM signal can be a standard 3.3V or 5V compatible digital signal and is applied through a diode onto the C_{PWM} pin. The purpose of the diode is to ensure the low level of the signal does not go below 200mV on the C_{PWM} pin and thus out of the operational range of the input.

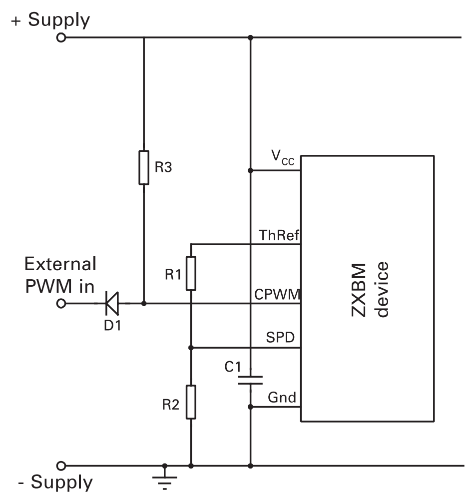


Figure 2 - External PWM drive

In order for the device to sense this signal correctly the SPD pin requires a voltage to be set on it. For 3.3V and 5V signals this would normally be set to 1.5V so 2 equal value resistors are attached as a potential divider between Gnd and ThRef. Two 10kΩ resistors will be ideal.

ZETEX SEMICONDUCTORS

If a signal of a smaller amplitude is needed to be sensed then R1 and R2 will need to be adjusted to provide a suitable threshold voltage for that signal.

The signal provided to the ZXBM device will be used to directly control the output drive transistors as shown in the waveforms in Figure 3. The top trace is the signal being applied to the CPWM pin whist the bottom trace is that to be found on either of the phase windings of the ZXBM2004.

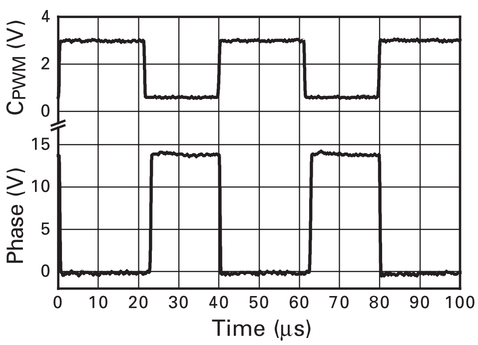


Figure 3 - PWM waveforms - normal input

The PWM signal in this circuit drives the fan with a positive pulse onto the C_{PWM} pin. This means that a continuous high level on C_{PWM} represents 100% PWM drive or full speed. Reducing the positive pulse width down to a continuous low on C_{PWM} represents a slowing of the fan until 0% drive is reached and the fan is stopped.

If it is found the opposite phase is required then the circuit in Figure 4 is recommended. In this case the external PWM is applied into the SPD pin whilst the C_{PWM} pin is used to define the threshold with the potential divider R1 and R2. The resultant waveforms are shown in Figure 5. In this waveform it can be seen that a negative going PWM pulse onto the SPD pin controls the speed. A continuous high level being 100% drive or full speed and a continuous high being 0% drive or a stopped fan.

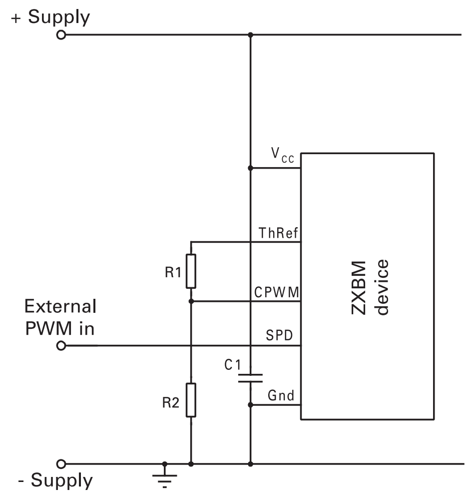


Figure 4 - External inverted PWM drive

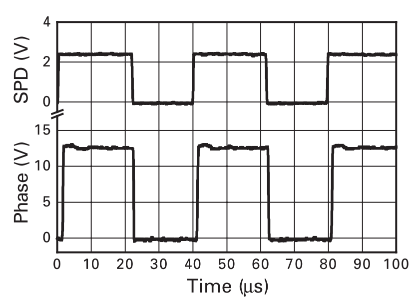


Figure 5 - PWM waveforms - inverted input

When driving with external PWM drive the response characteristics are affected by the PWM frequency and the nature of the windings.

A response graph for various frequencies is shown in Figure 6. It can be seen that at the normal 25kHz PWM frequency, whilst the response is a straight line, the fan has dropped from 2200rpm to 500 which is about 20% of the speed for 50% PWM drive. The fan would have stopped with 40% drive. Every fan will be different as it is influenced by the windings.

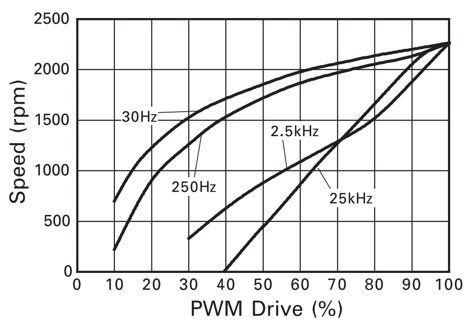


Figure 6 - Speed response vs PWM frequency

In order to overcome this and achieve the ideal response in Figure 7, the following circuit in Figure 8 can be considered. In this circuit the external PWM signal is first integrated into a voltage using Q1, R1, R2 and R3. This voltage is then used to control the fan using the PWM generator internal to the ZXBM device in the normal manner. R1, R2 and R3 are used to set the required response.

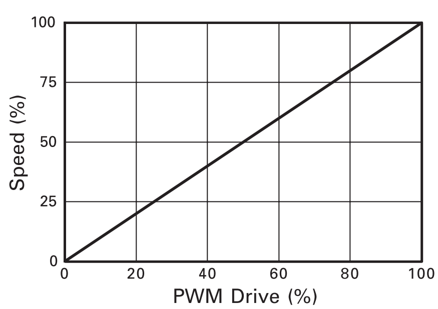


Figure 7 - Ideal speed response

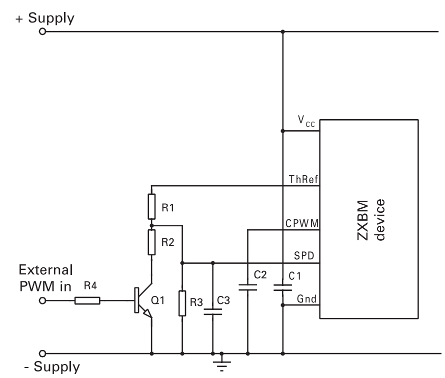


Figure 8 - External PWM drive circuit for linear response

In the circuit in Figure 8, R1 together with R2 in parallel with R3 set the full speed SPD pin voltage. The ideal values therefore would be:

R1 = 2 x R2//R3

To derive 1V from the ThRef 3V.

At 0% PWM Q1 will be off all the time so the SPD voltage required for zero speed is set by the potential divider of R1 and R3.

There will be a slight voltage error due to the saturation voltage of Q1 but this is usually insignificant. The value of C3 is PWM frequency dependant but for a 25kHz - 30kHz signal 100nF is sufficient. Lower 100Hz PWM signals will need 1µF or more.

ZETEX SEMICONDUCTORS

Minimum speed setting

One of the major problems with remote speed control of a fan is that it could be asked to run at a speed lower than it is capable of sustaining or at a speed at which it might fail to start at switch-on.

To overcome this both the ZXBM1004 and ZXBM2004 have a minimum speed setting pin, S_{MIN}, that allows the user to set a voltage, that determines the minimum speed.

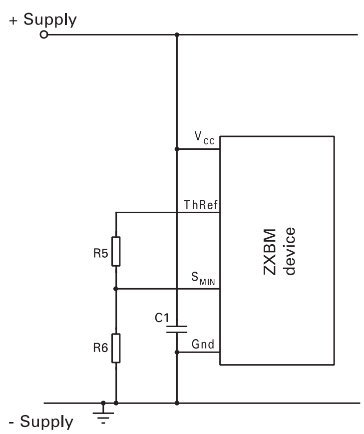


Figure 9 - Minimum speed setting

This is achieved by attaching a potential divider to the S_{MIN} pin, as shown in Figure 9.

To set up the minimum speed run the fan with S_{MIN} open circuit, supply an adjustable voltage onto the SPD pin. This can be as a PWM signal as described for Figure 8 or as a direct voltage onto the SPD pin. Adjust the voltage on the SPD pin until the desired minimum speed is attained. Note the voltage on the SPD pin. This same voltage is now set up on the S_{MIN} pin with the potential divider R5 and R6 using the following equation.

$$V_{SMIN} = \left(\frac{3V}{R5 + R6}\right) X\ R6$$

Values between 5kΩ to 33kΩ are recommended. Care should be taken so as the total load taken from the ThRef pin by the Thermistor and Minimum Speed networks does not exceed 1mA. It is suggested that R6 is set to 10kΩ and R5 calculated using the following equation.

$$R5 = \left(\frac{3V\ x\ R6}{V_{SMIN}}\right) - R6$$

The minimum speed function can only be used when the ZXBM device is being controlled by an applied voltage on the SPD pin. It cannot be used when controlling the speed directly by a PWM waveform as illustrated in Figures 2 and 4.

Removal of supply variation on minimum speed setting

When using the minimum speed function it will be apparent that the minimum speed varies with supply voltage. This is due to the variation in voltage across the motor windings. It is possible with the addition of an extra resistor to remove that variation so that the same minimum speed is maintained across the operational supply voltage.

This is achieved by applying a resistor from the Vcc pin to the S_{MIN} pin as shown by R7 in Figure 10.

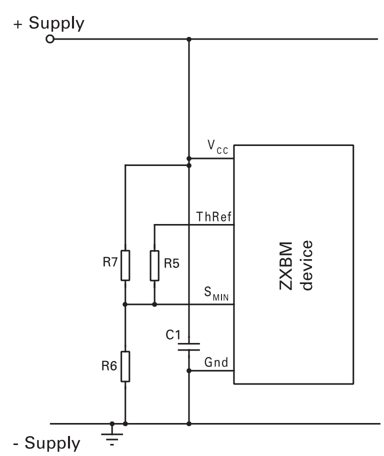


Figure 10 - Circuit for minimum speed setting with immunity from supply voltage variation

Kick start

If it is intended to run the fan's minimum speed close to it's lowest practical starting speed add a capacitor to the minimum speed network from S_{MIN} to Gnd. This ensures that the fan is given a boost to start it as the charging time of the capacitor ensures a faster minimum speed is applied at power-up. 1µF should suffice in most applications although it is left to the user to experiment with other values.

Complete solution

The circuit in Figure 11 illustrates a complete solution for a 12 volt single-phase fan to be controlled by an external PWM signal. The resultant PWM response graph is shown in Figure 12.

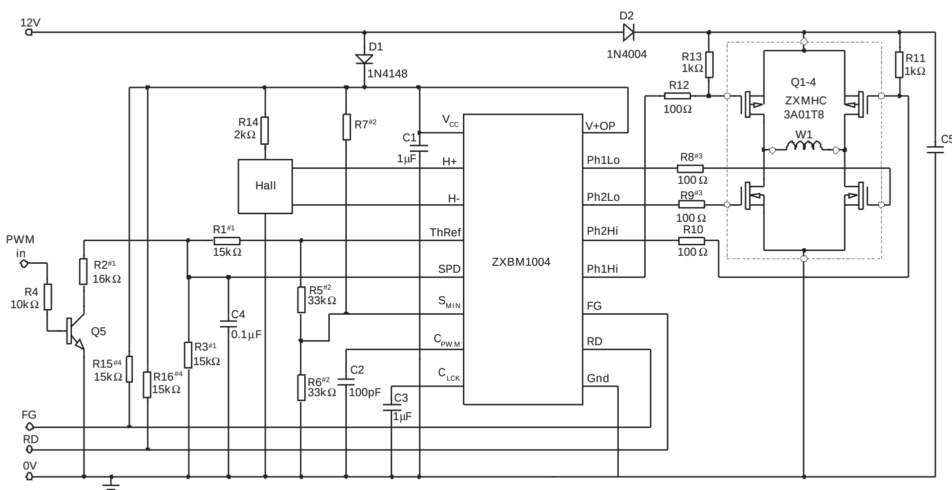


Figure 11 - Typical applications circuit incorporating PWM characteristic correction circuit

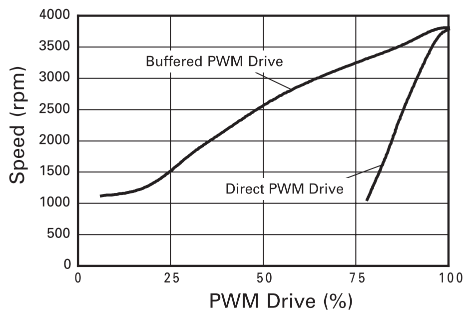


Figure 12 - External PWM drive characteristics

In this graph is shown the response of the motor to a 25kHz signal applied directly to the ZXBM1004 as described in Figure 2. In this situation the motor speed drops off quite steeply as the PWM is backed off from 100% drive.

With direct PWM control set at 75% PWM the motor is running at a speed lower than it is capable of starting at. However, with the PWM integrator buffer included it is possible to make full use of the PWM control range such that 1000rpm is reached at around 15% to 20% PWM drive. The response flattens off at this point as the minimum speed feature is included in the circuit by the inclusion of R5, R6 and R7. In this case the minimum speed was set so that anything less than 20% PWM drive results in 1000rpm.

With reference to Figure 11, as previously described, the external PWM signal is converted into a voltage using Q5, R1, R2 and R3. This voltage is applied to the SPD pin of the ZXBM1004 and controls the speed using the device's internal PWM generator. Using this method results in a slight curve to the response due to the values of the resistors chosen. For a perfect straight line it needs to be ensured that at the voltage generated on the SPD pin for 50% PWM drive. The following condition must be met:

$(I_{R1} - I_{R3}) = (I_{R2} + I_{R3} - I_{R1})$

Q5 off Q5 on

This ensures the charge and discharge of C4 is balanced.

Selection of R_1/R_2 R_3 must be selected on test iteratively.

As this will not always be possible to achieve an alternative integrator is suggested as in Figure 13. This uses an extra PNP device together with an extra resistor.

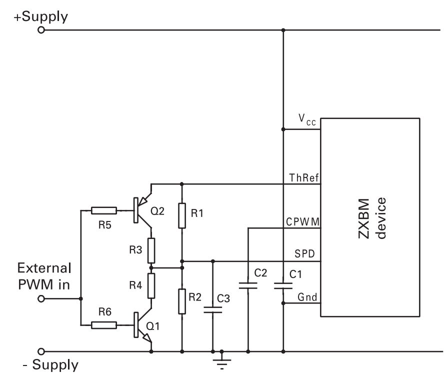


Figure 13

In this circuit to attain a perfectly linear response R3 and R4 should be the same value. Conditions for min and max speed are:

$$\text{Max. speed 100\% PWM} = V_{SPD} = \frac{V_{THREF}\; R_2 \,//\, R_4}{R_2 \,//\, R_4 + R_1}$$

$$\text{Min. speed 0\% PWM} = V_{SPD} = \frac{V_{THREF}\; R_2}{R_1 \,//\, R_3 + R_2}$$

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 (C1 in all the figures) 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.

Europe	Americas	Asia Pacific	Corporate Headquarters
Zetex GmbH Streitfeldstraße 19 D-81673 München Germany	Zetex Inc 700 Veterans Memorial Hwy Hauppauge, NY 11788 USA	Zetex (Asia) Ltd 3701-04 Metroplaza Tower 1 Hing Fong Road, Kwai Fong Hong Kong	Zetex Semiconductors plc Lansdowne Road, Chadderton Oldham, OL9 9TY United Kingdom
Telefon: (49) 89 45 49 49 0 Fax: (49) 89 45 49 49 49 europe.sales@zetex.com	Telephone: (1) 631 360 2222 Fax: (1) 631 360 8222 usa.sales@zetex.com	Telephone: (852) 26100 611 Fax: (852) 24250 494 asia.sales@zetex.com	Telephone (44) 161 622 4444 Fax: (44) 161 622 4446 hq@zetex.com

These offices are supported by agents and distributors in major countries world-wide.

ZETEX SEMICONDUCTORS