Application Note 41

Application note for the ZXBM1004 and ZXBM2004 variable speed motor controllers
- Thermal control using a thermistor

Purpose

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

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 AN42 - Speed control using an external PWM 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 single-phase motors and the ZXBM2004 is for 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.

Features described in this document are 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.
Thermistor thermal control requirements

Introduction

When speed controlling a fan using the ZXBM1004 or ZXBM2004 motor pre-driver a thermistor provides the simplest thermal feedback.

See Figure 1. The thermistor $R_{\text{therm}}$ is used with a network of 2 resistors ($R_1, R_2$) to provide the required response characteristics. This section will look at how to use the ZXBM1004 and 2004 with a thermistor.

**NTC thermistor**

The ZXBM1004 and ZXBM2004 are designed to be with an NTC type thermistor with a value of 10kΩ at 25°C. The thermistor is connected directly between the SPD pin and Ground. The thermistor can either be local i.e. part of the fan or blower itself and positioned where it can easily detect the air temperature, or it can be remote to the device, perhaps positioned on a motherboard or in an air duct.

An NTC thermistor has a non-linear characteristic. There is a larger change in resistance between 25°C and 30°C than there is between 55°C and 60°C. See Figure 2. However from Ohms law when two resistors are in parallel and one changes in a linear fashion it will produce a resultant non-linear resistance characteristic but with the opposite curve to that of the thermistor. Figure 3 illustrates the effect of having a variable resistor in parallel to a fixed 10kΩ resistor. Now when these two effects are put together the resultant characteristic seen in Figure 2 is achieved. Dependent upon the temperature range and motor type with careful selection of the $R_1$ and $R_2$, it is possible for a near linear response to be achieved.

![Figure 1 - showing resistive divider used with 10kΩ thermistor](image1)

![Figure 2 - Thermistor network characteristics](image2)

![Figure 3 - Parallel resistor characteristics](image3)
The amount of non-linearity taken out by the thermistor and parallel resistor will be dependant upon the $\beta$-value of the thermistor - the higher the $\beta$-value the more likely it is to attain a good linear overall response. The evaluation work in this document has been conducted using a thermistor with a $\beta$-value of 3977.

It is also possible to use the ZXBM series in conjunction with other lower values of NTC thermistor, and in this case a lower value of external resistive divider will be required, $R_1$ and $R_2$ as shown in Figure 1.

We now need to understand how the resistors $R_1$ and $R_2$ in Figure 1 change the temperature response characteristics. To help this Figure 4 is produced to illustrate how changing $R_1$ and $R_2$ in unison changes the slope of the characteristics.

On the ZXBM1004 and ZXBM2004 devices a change in voltage on the SPD pin changes the percentage of time the PWM circuit drives the windings. A voltage of 1V on SPD represents 100% drive, i.e. full speed, whilst a voltage of 3V represents 0% drive i.e. stop. However, it is unlikely that 2V on the SPD will produce 50% speed but would be nearer to 20% speed. This is because the winding inductance at the 25kHz PWM frequency has an influence on the current flow in the windings.

Figure 4 shows how increasing $R_1$ and $R_2$ together gives a greater range in the SPD control voltage over a lower range of temperature. Translating this into speed, let us assume that a fan reaches half speed at 70% PWM drive then the values of $R_1$ and $R_2$ in Figure 4 translates to the response characteristics in Figure 5.
It can be seen that if R1 and R2 are raised then the response slope steepens. In order to move the slope through the temperature range i.e. so as it keeps the same slope but starts at a lower temperature and reaches full speed at a corresponding lower temperature, then R1 on its own is changed as shown in Figure 6.

Under normal circumstances a fan motor will speed up when the supply voltage is increased and conversely slows down when it is reduced. With the ZXBM1004 and ZXBM2004 it is possible to nullify the effects of supply voltage variation upon the speed of the fan. To do this requires an extra external resistor, R3 as shown in Figure 7.

Under normal circumstances a fan will speed up as the supply is increased due to the higher voltage now being present across the motor windings. As previously mentioned the ZXBM series control the speed of a motor by the application of a voltage to the SPD pin, a higher voltage representing a lower speed. If we now combine these two effects it is possible, for a given temperature, to make a fan keep the same speed as the supply increases by allowing some of that supply voltage increase to be fed into the SPD pin, in effect biasing the thermistor network. R3 in Figure 7 fulfils that purpose.

It should be pointed out however, that if R3 is used then R1 will need compensating as a consequence and it could well mean a little experimentation to find the correct values for both R3 and R1.
Minimum speed setting

One of the major problems with thermal control is that a fan is generally set for operation at ambient temperatures and above. Should a fan therefore be subjected to lower than ambient temperatures the thermistor tries to set a voltage at which the fan may not run or even fail to start at switch-on.

To overcome this both the ZXB1004 and ZXB2004 have a minimum speed setting pin, SMIN, that allows the user to set a voltage, and therefore a minimum speed.

This is achieved by attaching a potential divider to the SMIN pin, as shown in Figure 8.

![Figure 8](image)

To set up the minimum speed, run the fan with SMIN open circuit. Provide a variable supply voltage to the SPD pin. There is no need to disconnect the thermistor network as this will be overdriven. 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 SMIN pin with the potential divider R4 and R5 using the following equation.

\[
V_{SMIN} = \left( \frac{3V}{R4 + R5} \right) \times R5
\]

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 R5 is set to 10kΩ and R4 calculated using the following equation.

\[
R4 = \left( \frac{3V \times R5}{V_{SMIN}} \right) - R5
\]

When the Minimum Speed function is being used the SPD pin should include a 0.1µF to Gnd. See Figure 11.

Removal of supply variation on minimum speed setting

As with the setting of the thermistor characteristics it will be apparent that the minimum speed setting is influenced by the supply voltage. Whilst you might set an ideal speed for your nominal voltage, if the fan is subjected to a lower voltage then the motor minimum speed will be slower due to the lower voltage across the windings.

This change can be removed by the same technique as used to cancel out supply voltage changes on the thermistor network. Apply a resistor from the Vcc pin to the SMIN pin as shown by R6 in Figure 9.
Kick start

If it is intended to run the fan’s minimum speed close to its lowest practical starting speed, add a 1μF capacitor to either the input network from SMIN to Gnd, or SPD to Gnd. Also increase C2 or C3 in Figure 11 to 1μF. 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 thermistor network

The complete circuit for the thermistor and minimum speed networks including the ability of the response characteristics to be immune from supply variations is shown in Figure 11.

The resultant response characteristics from a typical application circuit is shown in Figure 10. It can be seen from the graphs that the minimum speed remains the same over the 10V to 14V supply range as does the temperature characteristics up to 50°C. It is only above this temperature that any speed variation against supply voltage is seen.

Figure 10 - Typical speed characteristics
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 $C_{CLK}$ 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. Alloting 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.

Figure 11 - Complete thermistor and minimum speed network with immunity from supply voltage variations