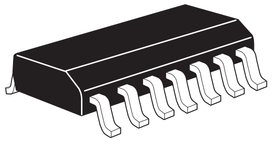
ZXBM2004

VARIABLE SPEED 2-PHASE FAN MOTOR CONTROLLER FOR THERMISTOR CONTROL

DESCRIPTION

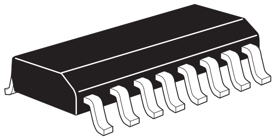
The ZXBM2004 is a 2-phase, DC brushless motor pre-driver with PWM variable speed control suitable for fan and blower motors. The controller is primarily intended for thermal control using a thermistor but can also be used for control using an external voltage or PWM signal.



SO14

FEATURES

- PWM Speed control via external thermistor
- Ability to be able to set a minimum speed
- Ability to be able to remove any speed change against supply voltage variation
- Low noise
- Built in lock detect protection, rotational speed sensing and automatic recovery
- Built in Hall amplifier allows direct connection to Hall element
- Speed (FG) pulse output
- Rotor lock (RD) output
- Up to 18V input voltage (60V with external regulator)
- SO14N and QSOP16 package options



QSOP16

APPLICATIONS

- Mainframe and Personal Computer Fans and Blowers
- Instrumentation Fans
- Central Heating Blowers
- Automotive climate control

ORDERING INFORMATION - SO14N

DEVICE	REEL SIZE	TAPE WIDTH	QUANTITY PER REEL
ZXBM2004N14TA	7" (180mm)	16mm	500
ZXBM2004N14TC	13" (330mm)	16mm	2,500

ORDERING INFORMATION - QSOP16

DEVICE	REEL SIZE	TAPE WIDTH	QUANTITY PER REEL
ZXBM2004Q16TA	7" (180mm)	12mm	500
ZXBM2004Q16TC	13" (330mm)	12mm	2,500

DEVICE MARKING

SO14: ZETEX
ZXBM2004
Date code

QSOP16: ZETEX
BM2004
Date code

ABSOLUTE MAXIMUM RATINGS

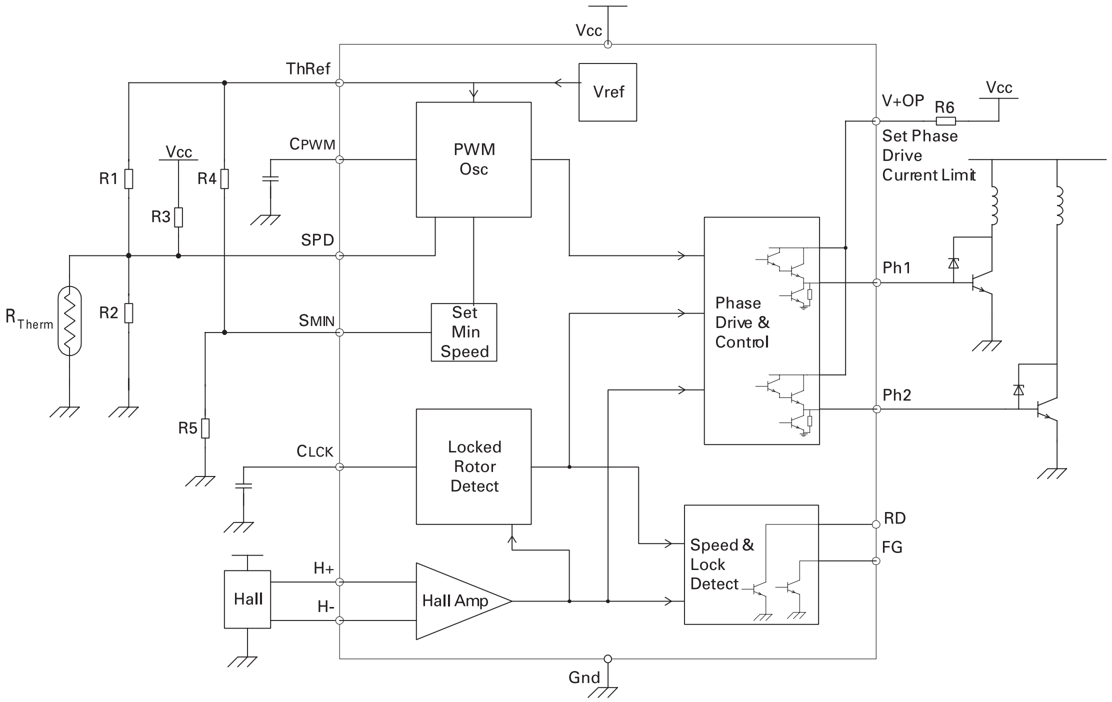
PARAMETER	SYMBOL	LIMITS	UNIT
Supply Voltage	V_{CCmax}	-0.6 to 20	V
Input Current	I_{CCmax}	200	mA
Power Dissipation	P_{Dmax}	500	mW
Operating Temp.	T_{OPR}	-55 to 110	°C
Storage Temp.	T_{STG}	-55 to 125	°C

ELECTRICAL CHARACTERISTICS (at Tamb = 25°C & Vcc = 12V)

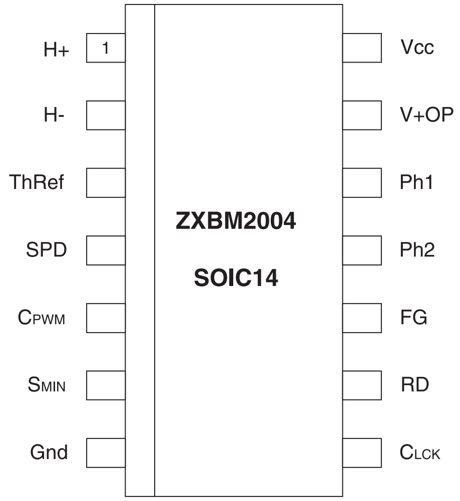
PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT	CONDITIONS
Supply Voltage	V_{CC}	4.7		18	V	
Supply Current	I_{CC}		5.5	7.5	mA	No Load [1]
Hall Amp Input Voltage	V_{IN}	40			mV	diff p-p
Hall Amp Common Mode Voltage	V_{CM}	0.5		Vcc-1.5	V	
Hall Amp Input Offset	V_{OFS}		±7		mV	
Hall Amp Bias Current	I_{BS}		400	700	nA	
PH1, PH2 Output High	V_{OH}	V_{CC} -2.2	V_{CC} -1.8		V	I_{OH} =80mA
PH1, PH2 Output Low	V_{OLA}		0.4	0.6	V	I_{OL} =16mA [2]
PH1, PH2 Output Low	V_{OLB}		0.4	0.6	V	I_{OL} =50μA [3]
PH1, PH2 Output Source Current	I_{OH}			-80	mA	
PH1, PH2 Output Sink Current	I_{OL}			16	mA	
C_{PWM} Charge Current	I_{PWMC}	-5.0	-6.0	-7.0	μA	
C_{PWM} Discharge Current	I_{PWMD}	50	62	75	μA	
C_{PWM} High Threshold Voltage	V_{THH}		3		V	
C_{PWM} Low Threshold Voltage	V_{THL}		1		V	
PWM Frequency	F_{PWM}		24		kHz	C_{PWM} = 0.1nF
ThRef Voltage	V_{ThReF}	2.94	2.96	3	V	I_{OThRef} =100μA
ThRef Output Current	I_{OThRef}			-1	mA	
S_{MIN} Input Current	I_{ISMIN}		-0.25	-0.5	μA	V_{IN} = 2V,SPD=open
SPD Voltage Minimum	V_{SPDL}		1		V	100% PWM Drive
SPD Voltage Maximum	V_{SPDH}		3		V	0% PWM Drive
SPD Input Current	I_{ISPD}		-0.8	-2	μA	V_{IN} = 2V
C_{LCK} Charge Current	I_{LCKC}	-2.8	-3.8		μA	
C_{LCK} Discharge Current	I_{LCKD}		-0.46	-0.55	μA	
C_{LCK} High Threshold Voltage	V_{THH}		3		V	
C_{LCK} Low Threshold Voltage	V_{THL}		1		V	
Lock condition On:Off ratio		1:8				
FG & RD Low Level Output Current	I_{OL}			5	mA	
FG & RD Low Level Output Voltage	V_{OL}			0.5	V	I_{OL} = 5mA

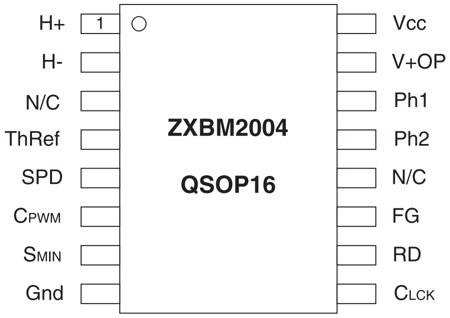
Notes:
1. Measured with pins H+, H-, C_{LCK} and C_{PWM} = 0V and all other signal pins open circuit.
2. Measured when opposing Phase Output is Low
3. Measured when opposing Phase Output is High

BLOCK DIAGRAM



PIN ASSIGNMENTS





PIN FUNCTIONAL DESCRIPTION

H+ - Hall input
H- - Hall input

The rotor position is detected by a Hall sensor whose output is applied to these pins. This sensor can be either a 4 pin 'naked' Hall device or of the 3 pin buffered switching type. For a 4 pin device the differential Hall output signal is connected to the H+ and H- pins. For a buffered Hall sensor the Hall device output is attached to the H+ pin, with a pull-up attached if needed, whilst the H- pin has an external potential divider attached to hold the pin at half Vcc. When H+ is high in relation to H-, Ph2 is the active drive.

ThRef - Thermistor network reference

This is a reference voltage of nominal 2.96V. It is designed for the ability to 'source' current into the 10kΩ Thermistor network therefore it will not 'sink' any current from a higher voltage.

The total current drawn from the pin by the minimum speed potential divider to pin S_{MIN} and by the thermistor network at maximum temperature should not exceed 1mA.

SPD - Thermistor network input

The thermistor network is attached to this pin. The resultant thermistor network voltage applied to the SPD pin provides control over the Fan Motor speed by varying the Pulse Width Modulated (PWM) drive ratio at the Ph1 and Ph2 outputs. The control signal takes the form of a voltage input of range 3V to 1V, representing 0% to 100% drive respectively.

In normal operation a 10kΩ NTC Thermistor network as shown in the Block Diagram would be attached to the SPD pin.

If variable speed control is not required this pin can be left with an external potential divider to set a fixed speed or tied to ground to provide full speed i.e. 100% PWM drive.

If required this pin can also be used as an enable pin. The application of a voltage >3.0V will to force the PWM drive fully off, in effect disabling the drive.

C_{PWM} - Sets PWM frequency

This pin has an external capacitor attached to set the PWM frequency for the Phase drive outputs. A capacitor value of 0.1nF will provide a PWM frequency of typically 24kHz.

The C_{PWM} timing period (T_{PWM}) is determined by the following equation:

$$T_{PWM} = \frac{(V_{THH} - V_{THL}) \times C}{I_{PWMC}} + \frac{(V_{THH} - V_{THL}) \times C}{I_{PWMD}}$$

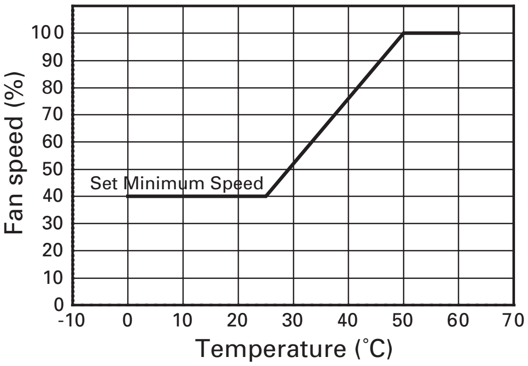
Where: $C = C_{PWM} + 15$, - (in pF)
V_{THH} and V_{THL} are the C_{PWM} pin threshold voltages
I_{PWMC} and I_{PWMD} are the charge and discharge currents (in µA).
T_{PWM} in µs

As these threshold voltages are nominally set to V_{THH} = 3V and V_{THL} = 1V the equations can be simplified as follows:

$$T_{PWM} = \frac{2C}{I_{PWMC}} + \frac{2C}{I_{PWMD}}$$

S_{MIN} - Sets Minimum Speed

When using a thermistor to control a fan's speed it is possible that at low temperatures the fan might fail to start or if already running and the temperature drops the fan might stop. This is an undesirable condition to have in thermal controlled fans so the S_{MIN} pin is used to set a minimum speed. The following graph illustrates a typical speed response characteristic for a thermally controlled fan.



Typical Temperature Response

When a potential divider is attached from this pin and between ThRef and Gnd it sets a voltage on the pin. This voltage is monitored by the SPD pin such that it cannot rise above it. As a higher voltage on the SPD pin represents a lower speed it therefore restricts the lower speed range of the fan. If this feature is not required the pin is left tied to ThRef so no minimum speed will be set.

If the fan is being controlled from an external voltage source either this feature should not be used or if it is required then a >1kΩ resistor should be placed in series with the SPD pin.

GND - Ground

This is the device supply ground return pin and will generally be the most negative supply pin to the fan.

C_{LCK} - Locked Rotor timing capacitor

Should the fan stop rotating for any reason, i.e. an obstruction in the fan blade or a seized bearing, then the device will enter a Rotor Locked condition. In this condition after a predetermined time (T_{LOCK}) the RD pin will go high and the Phase outputs will be disabled. After a further delay (T_{OFF}) the controller will re-enable the Phase drive for a defined period (T_{ON}) in an attempt to re-start the fan. This cycle of (T_{OFF}) and (T_{ON}) will be repeated indefinitely or until the fan re-starts.

The frequency at which this takes place is determined by the size of the capacitor applied to this C_{LCK} pin. For a 12V supply a value of 1uF will typically provide an 'On' (drive) period of 0.53s and an 'Off' (wait) period of 4.3s, giving an On:Off ratio of 1:8.

The C_{LCK} timing periods are determined by the following equations:

$$T_{lock} = \frac{V_{THH} \times C_{LCK}}{I_{LCKC}} \qquad T_{on} = \frac{\left(V_{THH} - V_{THL}\right) \times C_{LCK}}{I_{LCKC}}$$

$$T_{off} = \frac{\left(V_{THH} - V_{THL}\right) \times C_{LCK}}{I_{LCKD}}$$

Where: V_{THH} and V_{THL} are the C_{LCK} pin threshold voltages and I_{LCKC} and I_{LCKD} are the charge and discharge currents.

As these threshold voltages are nominally set to V_{THH} = 3V and V_{THL} = 1V the equations can be simplified as follows:

$$T_{lock} = \frac{3 \times C_{LCK}}{I_{LCKC}} \qquad T_{on} = \frac{2C_{LCK}}{I_{LCKC}} \qquad T_{off} = \frac{2C_{LCK}}{I_{LCKD}}$$

RD - Locked Rotor error output

This pin is the Locked Rotor output as referred to in the C_{LCK} timing section above. It is high when the rotor is stopped and low when running.

This is an open collector drive giving an active pull down with the high level being provided by an external pull up resistor.

FG - Frequency Generator (speed) output

This is the Frequency Generator output and is a buffered signal from the Hall sensor.

This is an open collector drive giving an active pull down with the high level being provided by an external pull up resistor.

PH1 - Phase 1 External transistor driver
PH2 - Phase 2 External transistor driver

These are the Phase drive outputs and are darlington emitter follower outputs with an active pull-down to help faster switch off when using bipolar devices. The outputs are designed to provide up to 80mA of drive when high to the base or gates of external transistors as shown in the Typical Application circuit following. The external transistors in turn drive the fan motor windings.

In addition the active Phase drive is capable of sinking up to 16mA when driving low to aid turn off times during PWM operation. When the Phase is inactive the output is held low by an internal pull-down resistor

V+OP - Phase Outputs supply voltage

This pin is the supply to the Phase outputs and will be connected differently dependant upon external transistor type.

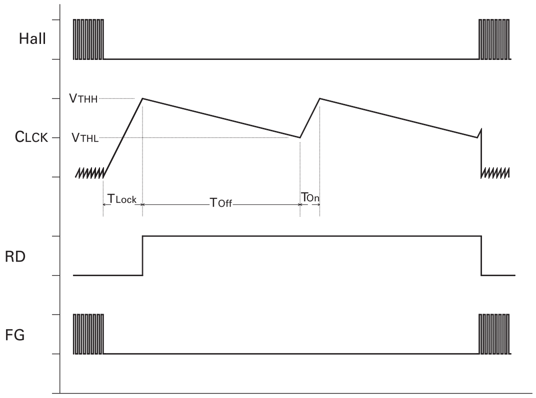
For bipolar devices this pin will be connected by a resistor to the V_{CC} pin. The resistor is used to control the current into the transistor base so its value is chosen accordingly.

For MOSFET devices the pin will connect to the V_{CC} pin

V_{CC} - Applied voltage

This is the device internal circuitry supply voltage. For 5V to 12V fans this can be supplied directly from the Fan Motor supply. For fans likely to run in excess of the 18V maximum rating for the device this will be supplied from an external regulator such as a Zener diode.

RD and FG Timing Waveform:



Lock Timing Example:

Using the equation previously described and to be found under the C_{LCK} pin description:

$$T_{lock} = \frac{3 \times C_{LCK}}{I_{LCKC}} \qquad T_{on} = \frac{2C_{LCK}}{I_{LCKC}} \qquad T_{off} = \frac{2C_{LCK}}{I_{LCKD}}$$

Using a value of C_{LCK} = 1.0uF together with the values of I_{LCKC} and I_{LCKD} to be found in the Electrical Characteristics we can derive the following timings for operation at 12V and 25°C:

$$T_{lock} = \frac{3 \times 1uF}{3.8\mu A} = 0.79s \qquad T_{on} = \frac{2 \times 1uF}{3.8\mu A} = 0.526s$$

$$T_{off} = \frac{2 \times 1uF}{0.46\ \mu A} = 4.35s$$

APPLICATIONS INFORMATION

This section is intended to give a brief insight into using the ZXBM2004. More complete data covering all applications aspects of this and other ZXBM series of fan motor pre-drivers is available from the Zetex website www.zetex.com or from your nearest Zetex office.

The ZXBM2004 device is a development of the ZXBM2001 to ZXBM2003 series of fan motor controller that has been specifically developed for use in thermistor temperature control situations. The main feature of the device is the ability to set a minimum speed at which the fan will run.

Two application circuits are illustrated here and both show slightly differing ways in which the ZXBM2004 controller can be used. For example Figure 1 is a simple solution and employs bipolar driver transistors and a naked Hall device whilst the Figure 2 employs MOSFET devices, a buffered Hall device and speed vs supply change normalisation and a kick-start feature. These differing features will be described in detail in the following sections.

The Phase Outputs

The Phase outputs on the ZXBM2004 2-phase DC brushless motor pre-driver have been designed to be capable of driving both Bipolar or MOSFET power transistors. The output stage consists of both active pull-up and active pull-down devices for optimum PWM switching. Pulling up, the output can deliver a maximum of 80mA whilst pulling down, sinking 16mA is possible. This is particularly useful for driving bipolar devices where for fast turn-off it is important to remove base stored charge as quickly as possible.

Figure 1 shows an Application Circuit for driving bipolar devices. The normal practice when driving a bipolar device would be to use a base series resistor to control and limit the current into the base. However the problem with this would be that the resistor would also restrict the removal of the base stored charge at switch-off. In order to keep turn-off times as short as possible it is therefore preferable to remove the base resistor and apply the current limiting in the supply to the output stage. This is not too dissimilar from the approach taken by conventional Totem-pole output stages in TTL devices.

In the case of the ZXBM2004 the current limiting is applied by inserting a resistor from V+OP to the V_{CC} pin. The current applied to the base of Q1 and Q2 in Figure 1 is determined by:

$$R3 = \frac{V_{CC} - (1.8 + 0.7)}{I_{Out}}$$

Where: 1.8 is the voltage drop due to the Phase Drive Output stage.
0.7 is the voltage dropped across the Base-Emitter of Q1/Q2.
I_{OUT} is the drive required by the external Phase Drive transistors Q1/Q2.

The circuit example in Figure 1 has the external drive (I_{Out}) set to approximately 30mA.

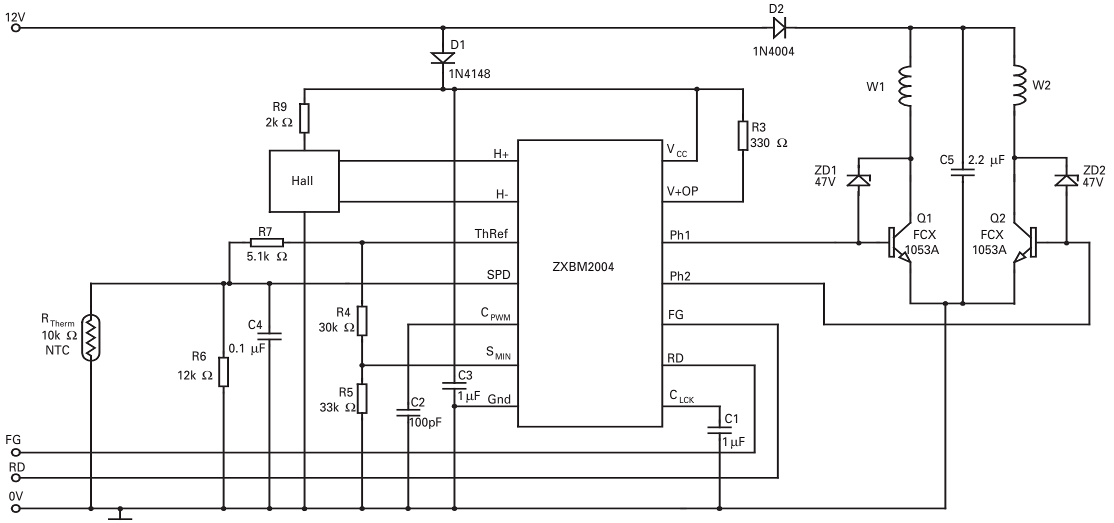


Figure 1: Typical Application Circuit utilising Bipolar power transistors and a Naked Hall device.

When driving MOSFETs a more conventional approach is employed in that each MOSFET will have a gate limiting resistor to control turn-on and turn-off. The V+OP pin will then be connected directly to the supply i.e. the Vcc pin. Figure 2 illustrates this.

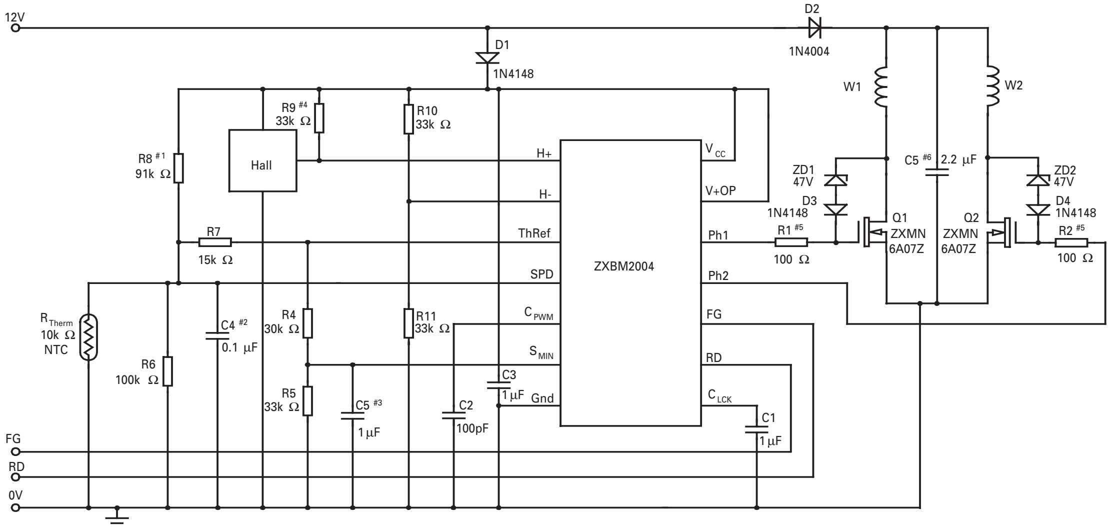


Figure 2: Typical Application Circuit utilising MOSFET power transistors and a buffered Hall device.

Notes:

Components marked # are related to specific features or fan requirements and their use is user dependent.

#1 R8 is required if the fan is being designed to give constant speed in mid range when the supply voltage varies.

#2 C4 will be required where the Thermistor is some distance from the ZXBM2004 or in high power fan or blower applications.

#3 C5 performs a kick-start to the fan if a Minimum Speed lower than or close to the fans practical starting speed is being used.

#4 R9 is only needed if it is not included in the Hall device.

#5 The normal practice with MOSFETs is to include a series resistor with the Gate to prevent oscillations, however dependent upon the characteristics of the MOSFETs being used it has been found that these can be omitted.

Thermal Control

The ZXBM2004 has been specifically designed for use in thermal control applications where a thermistor is employed for temperature sensing.

In most applications, it is expected that the user will wish to set their own temperature response characteristics. To do this a 10kΩ NTC thermistor can be employed in conjunction with a pair of resistors to set such parameters as the speed at 25°C and the slope of the response up to full speed.

R6 and R7 attached to pin SPD in both figures are used to set the temperature response. The ratio between the two resistors will enable the user to set the speed of the fan at 25°C. This is influenced by the mechanical response of the fan and also by the inductance of the stator windings so the resistor ratio needs to be adjusted by trial to take this into account.

The ratio of R6 compared to the 10kΩ of the thermistor will determine the slope. Raising the value of R6 in relation to the Thermistor will give a steeper slope, for example say 50% speed at 25°C and full speed at 40°C as is shown in Figure 2, whereas lowering the value will make the slope shallower, for example 50% speed at 25°C and full speed at 55°C as in Figure 1.

Minimum Speed

One of the main features of the ZXBM2004 is the ability to set a minimum speed that the fan will run. This will avoid the fan stopping at low temperatures and also ensures the fan will always start when cold.

R4 and R5 in both figures are used to set a voltage on the Pin S_{MIN}. This voltage represents the voltage above which the voltage of the thermistor network on the SPD pin cannot rise.

The best approach to set up a fan for this feature is to run the fan at the desired minimum speed by applying a voltage to the SPD pin with the ThRef pin Open Circuit. Measure the voltage on the SPD pin and set that voltage using the potential divider R4 and R5 between the ThRef and Ground.

If the minimum speed feature is not required the pin is left open circuit, however in noisy environments it might be better to connect it to pin ThRef. Note: it should not be connected to Ground as this will represent a minimum speed of full speed.

The addition of a capacitor on pin S_{MIN} will cause the fan to start with a higher percentage of PWM drive than when running. It is normal that a fan will run at a lower speed than that at which it can start so this feature can be useful where a fan's Minimum Speed is set very low and therefore it might not always start. It in effect gives the fan a kick to start it. The size of the capacitor required will depend upon the motor size however, it is suggested that 470µF to 1mF would be a suitable starting point.

Speed vs Supply Change Normalisation

With the ZXBM2004, and by the addition of one resistor, it is possible to set the thermistor network so as the fan’s speed remains constant when the supply voltage changes. This is very useful where a fan is to be specified over a large supply voltage range.

Figure 2 illustrates a circuit where the feature is included. In this case resistor R8 is added into the thermistor network between the supply and the SPD pin.

The value chosen for R8 will be dependent upon the fan’s characteristics but will be typically in the range 20kΩ to 100kΩ dependent upon motor winding characteristics. The precise value is best determined by trial but it should be pointed out that in order to keep the same temperature response characteristics the value of R7 will also need to be increased in compensation as the two resistors are in effect in parallel but sourced from different voltages.

External Voltage and PWM control

As an alternative to control by a thermistor it is also possible to control the speed of the fan by a signal from an external source. This signal may be either a control voltage or PWM waveform signal.

When a voltage signal is used it will be applied to the SPD pin and should vary between 1V representing full speed (100% PWM drive) and 3V representing 0% PWM drive. In practice, and dependant upon the other aspects of the motor design, low speed might be represented by 50% PWM drive. If the Minimum Speed feature is required then the signal should be applied to the ZXBM2004 SPD pin via a 2.2kΩ resistor to allow the internal minimum speed circuit to over-ride the control voltage.

Where control is required using an externally generated PWM signal the SPD pin should be left open circuit and the PWM signal applied to the C_{PWM} pin. The signal can be a conventional 5V or 3.3V TTL or CMOS compatible waveform. A potential divider of say two 47kΩ resistors should be placed between ThRef and Gnd pins and connected to the C_{LCK} pin.

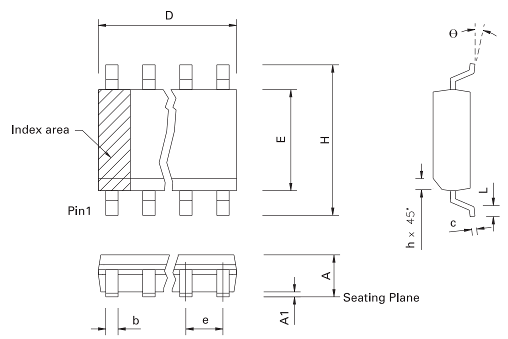
Where control is required using an externally generated PWM signal the SPD pin should have a potential divider added between G_{ND} and V_{CC}. The resistors be typically 10kΩ. The PWM signal is applied directly to the CPWM pin and can be a conventional 5V or 3.3V TTL or CMOS compatible waveform.

A Selection of Suitable Transistors and MOSFETs

Bipolar Types (NPN)	**V_{CEO} (V)**	**I_C (A)**	**Min H_{FE} @ Ic**	**$V_{CE(sat)}$ max(mV) @ IC / IB**	**Package**
FMMT619	50	2	300 @ 0.5A	220 @ 1A / 10mA	SOT23
FCX619	50	3	200 @ 1A	220 @ 1A / 10mA	SOT89
ZXT13N50DE6	50	4	300 @ 1A	100 @ 1A / 10mA	SOT23-6
FZT851	60	6	100 @ 2A	100 @ 1A / 10mA	SOT223
FCX1053A	75	4.5	300 @ 0.5A	200 @ 1A / 10mA	SOT89
FZT853	100	6	100 @ 2A	175 @ 1A / 100mA	SOT223
FZT855	150	4	100 @ 1A	65 @ 0.5A / 50mA	SOT223

MOSFET Types (N-channel)	**V_{DS} (V)**	**I_D (A)**	**I_{PEAK} (A) (Pulsed)**	**$R_{DS(on)}$ max(mΩ) @ V_{GS} = 10V**	**Package**
ZXMN3A04DN8	30	7.6	25	20	SO8 (DUAL)
ZXMN6A09DN8	60	5	17.6	45	SO8 (DUAL)
ZXMN6A07F	60	1	4	45	SOT23
ZXMN6A11Z	60	3.8	10	140	SOT89
ZXMN6A11G	60	3.8	10	140	SOT223
ZXMN6A09K	60	11.2	40	45	DPAK
ZXMN10A09K	100	7.1	25	90	DPAK
ZXMN10A11G	100	1.9	5.9	600	SOT223

PACKAGE OUTLINE SO14N

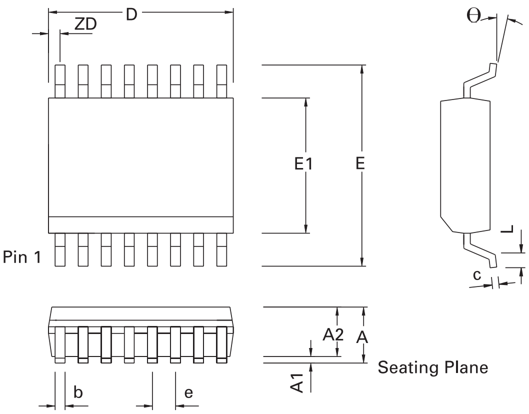


Conforms to JEDEC MS-012AB Iss.C

PACKAGE DIMENSIONS

DIM	INCHES		MILLIMETRE	
	MIN.	MAX.	MIN.	MAX.
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
D	0.337	0.344	8.55	8.75
H	0.228	0.244	5.80	6.20
E	0.150	0.157	3.80	4.00
L	0.016	0.050	0.40	1.27
e	0.050 BSC		1.27 BSC	
b	0.013	0.020	0.33	0.51
c	0.008	0.010	0.19	0.25
θ	0°	8°	0°	8°
h	0.010	0.020	0.25	0.50

PACKAGE OUTLINE QSOP16



Conforms to JEDEC MO-137AB Iss. A

PACKAGE DIMENSIONS

DIM	INCHES		MILLIMETRE	
	MIN.	MAX.	MIN.	MAX.
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
A2	0.049	0.059	1.25	1.50
D	0.189	0.197	4.80	5.00
ZD	0.009 Ref		0.23 BSC	
E	0.228	0.244	5.79	6.20
E1	0.150	0.157	3.81	3.99
L	0.016	0.050	0.41	1.27
e	0.025 BSC		0.64 BSC	
b	0.008	0.012	0.20	0.30
c	0.007	0.010	0.18	0.25
θ	0°	8°	0°	8°
h	0.010	0.020	0.25	0.50

Note: Dimensions in Inches are Control Dimensions dimensions in millimetres are approximate

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