

# ZXBM1016

## High efficiency variable speed single-phase fan motor controller

### Description

The ZXBM1016 is a high efficiency, low noise, single-phase, DC brushless motor pre-driver with PWM variable speed control and current control suitable for fan and blower motors. High efficiency and low noise are achieved using a novel technique (patent pending) for commutation current control.

The controllers are primarily intended to meet industry standard OEM fan specifications where external PWM control are applied, however, they can also be used with other thermal control techniques using an external voltage, PWM signal or thermistor.

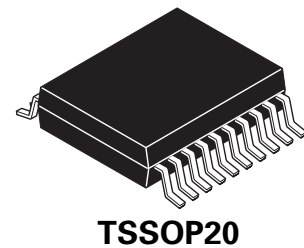
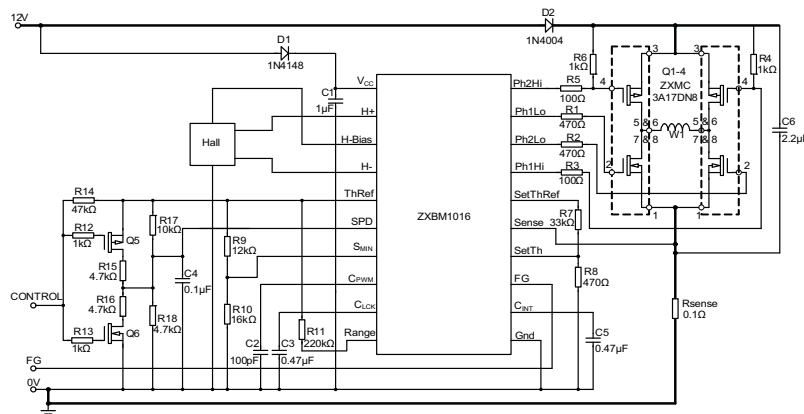
### Features

- Compliant with external PWM speed control
- Compliant with thermistor control
- Minimum speed setting
- High efficiency utilizing tail-end current control
- Low noise
- Auto restart
- Built in Hall amplifier
- Hall bias
- Speed pulse (FG) output
- Integrated current control
- Up to 18V input voltage (60V with external regulator)
- Small TSSOP20 package

### Applications

- Mainframe and personal computer fans and blowers
- Instrumentation fans
- Central heating blowers
- Automotive climate control

### Applications circuit



TSSOP20

### Ordering information - TSSOP20

Device	Reel size (inches)	Tape width (mm)	Quantity per reel
ZXBM1016ST20TA	7 (180mm)	16	1000
ZXBM1016ST20TC	13 (330mm)	16	2,500

### Device marking

ZETEX  
ZXBM1016  
Date code

## Absolute maximum ratings

Parameter	Symbol	Limits	Unit
Supply voltage	$V_{CCmax}$	-0.6 to 20	V
Input current	$I_{CCmax}$	200	mA
Maximum input voltage	$V_{Imax}$	-0.6 to $V_{CC}+0.5$	V
Maximum output voltage	$V_{Omax}$	-0.6 to $V_{CC}+0.5$	V
Power dissipation	$P_{Dmax}$	800	mW
Operating temperature	$T_{OPR}$	-40 to 85	°C
Storage temperature	$T_{STG}$	-55 to 125	°C

## Electrical characteristics (at $T_{amb} = 25^{\circ}C$ and $V_{CC} = 12V$ unless otherwise stated)

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
<b>Supply</b>						
Supply voltage	$V_{CC}$	6.7		18	V	For valid ThRef
Supply current	$I_{CC}$		15	20	mA	$V_{CC} = 12V$ , no load (*)
<b>Hall connections</b>						
Hall amp input voltage	$V_{IN}$	40			mV	diff p-p
Hall amp common mode voltage	$V_{CM}$	0.5		$V_{CC}-1.5$	V	
Hall amp input hysteresis	$V_{OFS}$	12			mV	
Hall amp input current	$I_{BS}$		700	1000	nA	
Hall bias voltage	$V_{HB}$	1.5	1.75	1.95	V	$I_{HBout} = -5mA$
Hall bias output current	$I_{HB}$			-10	mA	
<b>Reference voltage</b>						
ThRef voltage	$V_{ThRef}$	4.75	5.0	5.25	V	$I_{OThRef} = -10mA$
ThRef output current	$I_{OThRef}$			-10	mA	
<b>PWM oscillator</b>						
$C_{PWM}$ charge current	$I_{PWMC}$	-5.3	-7	-9.2	$\mu A$	
$C_{PWM}$ discharge current	$I_{PWMD}$	50	75	100	$\mu A$	
$C_{PWM}$ high threshold voltage	$V_{THH}$		3		V	
$C_{PWM}$ low threshold voltage	$V_{THL}$		1		V	
PWM frequency	$F_{PWM}$		25		kHz	$C_{PWM} = 0.1nF$
<b>Speed control</b>						
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	$\mu A$	$V_{IN} = 2V$
<b>Minimum speed setting</b>						
$S_{MIN}$ input current	$I_{ISMIN}$		-0.25	-0.5	$\mu A$	$V_{IN} = 2V$

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Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
<b>Tail-end current control</b>						
Range pin input current setting range	$I_{Range}$	4		50	$\mu A$	
Range pin input voltage	$V_{IN}$	0.50	0.65	0.75	V	Input current = $20\mu A$
$C_{LCK}$ charge current - lock	$I_{LCKCL}$	-0.75	-1.42	-1.8	$\mu A$	Lock mode, $V_{CLK} = 2.5V$
$C_{LCK}$ charge current - run	$I_{LCKCR}$		$-(4 \times I_{Range})$		$\mu A$	Run mode
$C_{LCK}$ discharge current - lock	$I_{LCKDL}$	0.8	0.8	1.25	$\mu A$	Lock mode, $V_{CLK} = 2.5V$
$C_{LCK}$ high threshold voltage	$V_{THH}$		5		V	
$C_{LCK}$ low threshold voltage	$V_{THL}$		1		V	Lock mode
$C_{INT}$ input current - lock	$I_{INTCL}$	-50		300n	nA	Lock mode, $V_{CLK} = 2.5V$
$C_{INT}$ charge current - run	$I_{INTCR}$	-1			mA	Run mode
$C_{INT}$ discharge current - run	$I_{INTDR}$		$0.8 \times I_{Range}$		$\mu A$	Run mode
<b>Current limit</b>						
SetThRef output voltage	$V_{SetThRef}$	ThRef-0.5V	ThRef-0.25V		V	$I_{SetThRef} = 200\mu A$
SetThRef output current	$I_{SetThRef}$			-200	$\mu A$	
Sense input current	$I_{Sense}$		-20	-100	nA	$V_{IN} = 1V$ , SetTh=2V
SetTh input current	$I_{SetTh}$		-20	-100	nA	$V_{IN} = 2V$ , sense=1V
<b>Output drives</b>						
Ph1Lo, Ph2Lo output high voltage	$V_{OH}$	$V_{CC} - 2.2$	$V_{CC} - 1.8$		V	$I_{OH} = 80mA$
Ph1Lo, Ph2Lo output low voltage	$V_{OLA}$		0.4	0.6	V	$I_{OL} = 16mA$ (†)
Ph1Lo, Ph2Lo output low voltage	$V_{OLB}$		0.4	0.6	V	$I_{OL} = 50\mu A$ (‡)
Ph1Lo, Ph2Lo output source current	$I_{OH}$			-80	mA	
Ph1Lo, Ph2Lo output sink current	$I_{OL}$			80	mA	
Ph1Hi, Ph2Hi output low voltage	$V_{OLA}$		0.5	0.75	V	$I_{OL} = 100mA$
Ph1Hi, Ph2Hi output sink current	$I_{OL}$			100	mA	
Ph1Hi, Ph2Hi off output leakage current	$I_{OFF}$			$\pm 100$	nA	
<b>Output flag</b>						
FG output current	$I_{OL}$			16	mA	
FG low level output voltage	$V_{OL}$			0.5	V	$I_{OL} = 16mA$

**NOTES:**

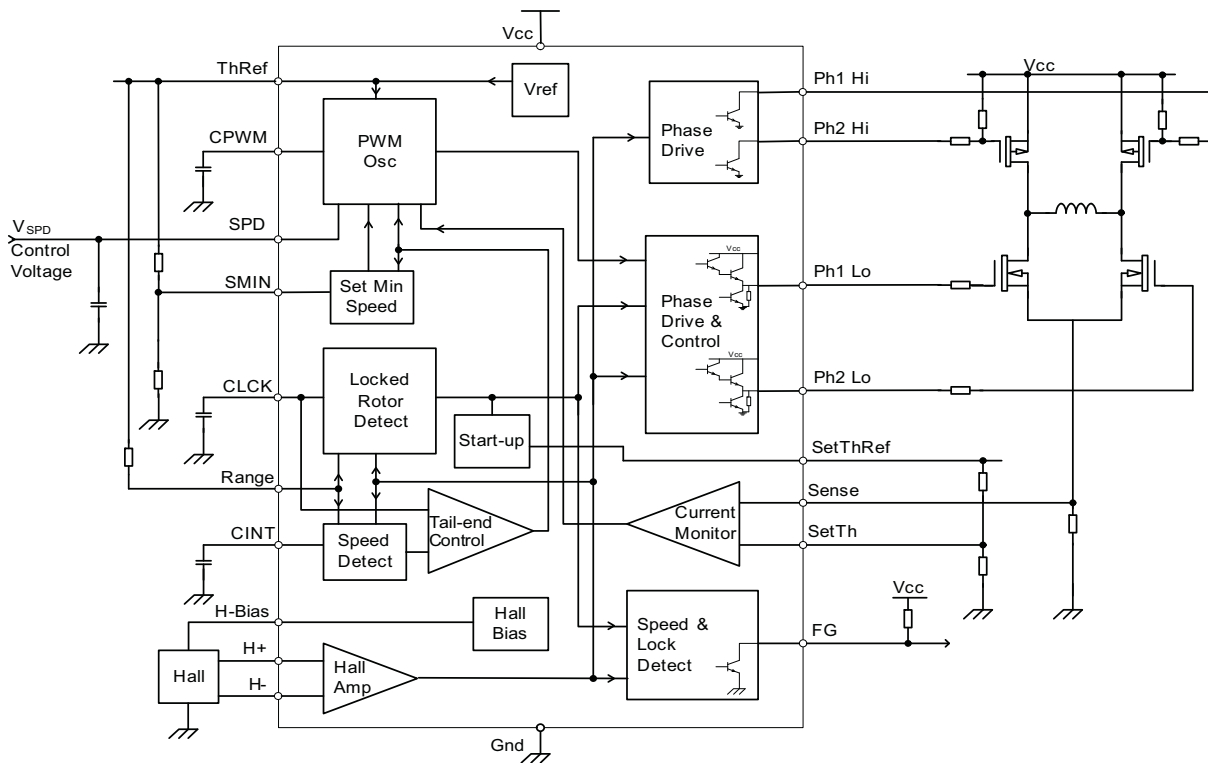
(\*) Measured with pins H+, H-,  $C_{LCK}$  and  $C_{PWM} = 0V$  and all other signal pins open circuit.

(†) Measured when opposing phase output is low.

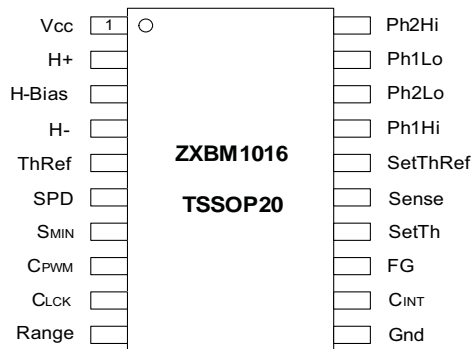
(‡) Measured when opposing phase output is high.

# ZXBM1016

## Block diagram



## Pin assignments



## Pin description table

Pin	Type	Description
V <sub>CC</sub>	Power	The positive supply pin
Gnd	Power	The negative supply pin
ThRef	Reference	A 5 volt reference for external networks
H-Bias	Reference	A nominal 1.75V reference used as the supply for naked Hall sensors
H+	Input	Hall device positive input. When high in relation to H- Ph2 is active
H-	Input	Hall device negative input
SPD	Input	Speed control input voltage, typically from a PWM integrator or thermistor. When low in relation to C <sub>PWM</sub> the phase low outputs will be turned on
S <sub>MIN</sub>	Input	Used to set a voltage that represents the minimum speed the motor is to run at
C <sub>PWM</sub>	Input	A capacitor on this pin is used to set the PWM frequency
C <sub>LCK</sub>	Input	A dual use pin used to set the lock and tail-end current control timing. This will typically be a 470nF capacitor
Range	Input	A resistor is attached between this pin and ThRef to set the device's dynamic operating range to the motor's desired speed range
C <sub>INT</sub>	Input	A capacitor is attached to this pin for use by the tail-end current control. This will normally be the same value as that on the C <sub>LCK</sub> Pin
FG	Output	Open collector buffered output from the Hall sensor
SetTh	Input	Used to set the threshold voltage that represents the maximum current to be taken by the motor
Sense	Input	Input for the signal from a sense resistor in the ground return of the H-bridge driving circuit used to represent the current taken by the motor
SetThRef	Analogue	A variable voltage source used to set the voltage on the SetTh pin
Ph1Hi	Output	Phase 1 high power output to high-side of H-bridge
Ph2Hi	Output	Phase 2 high power output to high-side of H-bridge
Ph1Lo	Output	Phase 1 high power output to low-side of H-bridge
Ph2Lo	Output	Phase 2 high power output to low-side of H-bridge

## Operational functional description

### Overview

The ZXBM1016 is a high efficiency, low noise, single-phase DC brushless motor pre-driver. It uses voltage speed control and this voltage can be derived from either a PWM or thermistor source. The device contains proprietary circuitry to control and limit the current at the end of a commutation cycle. This tail-end current control (TECC) enables the use of lower rated components thus providing for a more economic and higher efficiency solution.

The pre-driver also has the usual minimum speed setting and maximum current control functions.

## Control input

The device is controlled from a voltage applied to the SPD pin input. This control voltage can be derived from an externally generated PWM signal. This signal is converted to a voltage in a conventional integrator external to the device. Alternatively an external thermistor network can be used to generate the voltage.

## Tail-end current control

To minimize the current at the end of a commutation cycle, the tail current, a proprietary circuit technique is provided. A number of pins are used to give control over the function. The current is controlled using the internal PWM function and this acts together with the PWM speed control, the current control and the start-up function.

## Start-up function

The device has a controlled start function prior to the device going into the tail-end current control mode. This allows the motor to start up at its minimum speed before being allowed to accelerate to the speed defined by the voltage on the SPD pin.

## Device protection

Two levels of protection are provided for fault conditions. The first level of protection is the conventional lock function. If the motor is stopped or stalled for any reason the motor will enter the locked rotor condition. In this locked rotor condition the motor speed is set to minimum speed and the ZXBM1016 will attempt to restart the motor at periodic intervals.

A second level of protection is provided by a current monitor function. An external 100mΩ sense resistor is used to detect the current and this is compared with a preset voltage on the SetTh pin. If the current attempts to rise above the threshold voltage the internal PWM circuit will back-off the power being delivered to the coil to ensure the maximum is not exceeded.

## Pin functional description

### H+ - Positive Hall input

### H- - Negative Hall input

The rotor position is detected by a Hall sensor, with the output applied to the H+ and H- 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 single-ended buffered Hall sensor the Hall device output is attached to the H+ pin, with a pull-up attached if needed. The H- pin has an external potential divider attached to hold the pin at a voltage that is half of the output swing of the Hall sensor. When H+ is high in relation to H-, Ph2 is the active drive.

### H-Bias - Hall bias output voltage

This is a 1.75V nominal voltage source used to bias a differential unbuffered Hall sensor when that type is being utilized.

### ThRef - External network reference

This is a reference voltage of nominal 5V and is used by external networks to set up the SPD and S<sub>MIN</sub> pins control voltages.

It is designed for the ability to 'source' current and therefore it will not 'sink' any current from a higher voltage. The total current drawn from the pin by the minimum speed potential divider network and any other voltage setting network should not exceed 10mA.

## SPD - Speed control input

The voltage applied to the SPD pin provides control over the fan motor speed by varying the Pulse Width Modulated (PWM) drive ratio at the Ph1Lo and Ph2Lo outputs. The input voltage range for the control signal is 3V to 1V, representing 0% to 100% drive respectively.

If variable speed control is not required this pin can be left with an external potential divider to set a fixed speed or tied through a 10k $\Omega$  resistor to ground to provide full speed i.e. 100% PWM drive.

The advantage of a fixed potential divider is that the benefit of the current limit and tail-end current control can be achieved. Neither function will operate with the pin tied directly to ground. If full speed with current limit and tail-end current control is required then connect the SPD pin ground through a 10k $\Omega$  resistor with a 0.1 $\mu$ F capacitor in parallel. This capacitor is used for the tail-end current control shaping.

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

## S<sub>MIN</sub> - Minimum speed threshold voltage

A voltage can be set on this pin using a potential divider between the ThRef and Gnd. This voltage is monitored by the SPD pin such that the SPD voltage cannot rise above the S<sub>MIN</sub> voltage. As a higher voltage on the SPD pin represents a lower speed it therefore restricts the lower speed range of the motor. 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 and the minimum speed feature is required then a 10k $\Omega$  resistor should be placed in series with the external control voltage and the SPD pin.

## C<sub>LCK</sub> - Locked rotor and run mode timing capacitor

The C<sub>LCK</sub> pin will have a capacitor connected to ground. It is a dual function pin providing timing whilst running and when in the lock condition.

When a motor is running under normal conditions this pin provides a triangular waveform related to the speed of the motor. This waveform is used by the tail-end current control circuit to determine the end of the commutation cycle.

If the fan stops rotating for any reason then this pin takes on the conventional operation of a Locked Rotor monitor. In this condition and after the motor has stopped, a predetermined time (T<sub>OFF</sub>) will elapse during which the motor will not be driven. After this delay the circuitry uses a defined period (T<sub>ON</sub>) to attempt to re-enable the output drive by going through a start-up routine in an attempt to re-start the fan. This cycle of (T<sub>OFF</sub>) and (T<sub>ON</sub>) will be repeated indefinitely or until the fan re-starts.

The cycle of (T<sub>OFF</sub>) and (T<sub>ON</sub>) is also used to start the fan from power-up and so this pin forms a start-up function in conjunction with the current monitor circuit described towards the end of this section.

The time period of (T<sub>OFF</sub>) and (T<sub>ON</sub>) is determined by the value of capacitor applied to the C<sub>LCK</sub> pin. Any selection of the value will need consideration when in the run and lock modes. Typically a 0.47 $\mu$ F will provide for most applications.

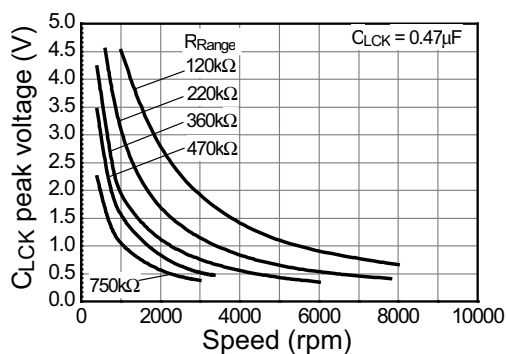
## **C<sub>INT</sub> - Integrator timing capacitor**

A capacitor is connected from this pin to ground. It is used to store a signal that is proportional to the commutation period. The stored signal is a representation of the motor speed and is used by the tail-end control circuitry. It will normally be the same value as that applied to the C<sub>LCK</sub> pin.

## **Range - Speed range setting pin**

The ZXBM1016 is designed to operate over a predefined dynamic range. This will normally be in excess of 10:1 i.e. the lowest speed will be 1/10 of the full speed. In some instance the speed range might be 200rpm to 2,000rpm yet in others it could be 1,000 to 10,000rpm. This pin allows the tail-end current control operation to be tuned to the desired speed range. To do this a resistor is attached between the range pin and the ThRef pin.

The following graph gives a range of resistor values against the speed range.



**Speed vs CLCK peak voltage**

Typically a 220kΩ resistor will cover most mid speed range motors of 600rpm to 6,000rpm, however a lower value can be used to enable the motor to be run at higher speeds. Conversely a higher value will be needed for motors running at a lower speed range.

## **CPWM - 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 25kHz.

## **FG - Frequency generator (speed)**

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.

## **Ph1Lo and Ph2Lo - Low-side external H-bridge driver**

These pair of outputs drive the low side of the external power device H-bridge that in turn drives the single phase winding. These outputs provide both the commutation and PWM waveforms. The outputs are active pull-up and active pull-down to help faster switching off when driving MOSFET devices with a high gate capacitance. When in the high state the outputs will provide up to 80mA of drive into the base or gates of external transistors as shown in the typical application circuit shown on the front page.

When in the low state the active phase drive is again capable of sinking up to 80mA to aid turn off times during PWM operation. When the phase is inactive the output is held low by a 7.5kΩ internal pull-down resistor.



## **Ph1Hi and Ph2Hi - High-side external H-bridge driver**

These are the high side outputs to the external H-bridge and are open collector outputs capable of sinking 100mA. This signal provides commutation only to the H-bridge.

## **GND - Circuitry ground return**

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

## **V<sub>CC</sub> - Circuitry applied voltage**

This provides the supply for the device's internal circuitry and for the H-bridge output stage.

## **Sense - Current control sense**

This pin is used by the current sensing circuit to monitor the current taken by the motor windings. The signal comes from a sense resistor in the low-side ground return of the external H-bridge driver.

## **SetTh - Current control threshold voltage**

This pin is used by the current sensing circuit as the reference voltage for the voltage on the sense pin to be compared against. If the voltage on the sense pin starts to exceed the voltage set on this pin the current control circuitry starts to back off the PWM voltage and thus the current being supplied to the motor coil.

## **SetThRef - SetTh and start-up reference**

This pin is derived from an internal start-up circuit and is used as the source voltage for the potential divider network attached to the SetTh pin.

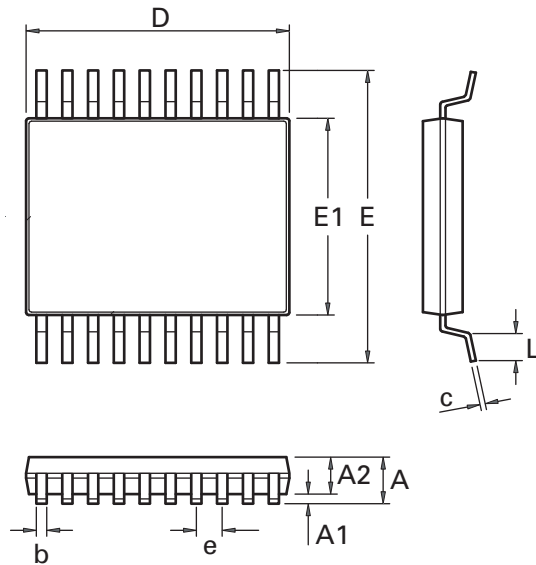
Under running conditions this will be a voltage of approximately 4.75V, however, during start up the voltage ramps up from 0V to 4.75V at a rate determined by the capacitor on the C<sub>LCK</sub> pin. Once the motor is running it will go to its steady state.

This is a low power output capable of supplying a maximum of 200 $\mu$ A. It should only be used to supply the potential divider network attached to the SetTh pin.

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# ZXBM1016

## Package outline - TSSOP20



Dim.	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	-	1.20	-	0.047
A1	0.05	0.15	0.002	0.006
A2	0.80	1.05	0.031	0.041
D	6.40	6.60	0.252	0.260
E	6.40 BSC		0.252 BSC	
L	0.45	0.75	0.018	0.030
e	0.65 BSC		0.026 BSC	
b	0.19	0.30	0.007	0.012
c	0.09	0.20	0.004	0.008

**Note:** Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

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