SGM42609
Single H-Bridge Motor Driver

GENERAL DESCRIPTION

The SGM42609 provides a single bridge motor driver solution for battery-powered toys, toothbrushes and other low-voltage or battery-powered motion control applications. The device has one H-bridge driver, and can drive one DC brush motor, solenoid, or other inductive load.

The output driver block of H-bridge consists of N-channel power MOSFETs configured as an H-bridge to drive the motor windings. H-bridge includes circuitry to regulate or limit the winding current.

With proper PCB design, H-bridge of the SGM42609 is capable of driving up to 1.5A RMS (or DC) continuously, at +25℃ with a V_{CC} supply of 5V. It can support peak current of up to 2A. Current capability is reduced slightly at lower V_{CC} voltage.

Internal shutdown functions with a fault output pin are provided for H-bridge over-current protection, power supply under-voltage lockout, charge pump under-voltage lockout and over-temperature protection. If one of fault conditions happens, the SGM42609 would prevent each input PWM signal from driving H-bridge and H-bridge is in high impedance status.

A low-power sleep mode is also provided to save power dissipation. If both IN1 and IN2 are low for more than t_{sleep}, the SGM42609 will enter into sleep state automatically.

The SGM42609 is available in Green MSOP-10 and TDFN-3×3-10L packages. It operates over an ambient temperature range of -40℃ to +125℃.

FEATURES

- **Single H-Bridge Motor Driver can Drive One DC Brush Motor**
- **Low MOSFET On-Resistance: HS + LS 480mΩ**
- **Output Current 1.5A RMS, 2A Peak Current (at V_{CC} = 5V, +25℃)**
- **2.7V to 24V Wide Power Supply Voltage Range**
- **PWM Winding Current Regulation/Limiting**
- **Fault Indication Output**
- **Available in Green MSOP-10 and TDFN-3×3-10L Packages**

APPLICATIONS

Battery-Powered Toys
Toothbrushes
Video Security Cameras
Office Automation Machines
Gaming Machines
Robotics

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM42609	MSOP-10	-40℃ to +125℃	SGM42609XMS10G/TR	SGM42609 XMS10 XXXXX	Tape and Reel, 4000
	TDFN-3×3-10L	-40℃ to +125℃	SGM42609XTD10G/TR	SGM 42609D XXXXX	Tape and Reel, 4000

NOTE: XXXXX = Date Code and Vendor Code.

Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

Power Supply Voltage Range, V_{CC} .... -0.3V to 26.5V
Digital Input Pin Voltage Range .... -0.3V to 6V
ISEN Pin Voltage Range.................................. -0.3V to 0.5V
Peak Motor Drive Output Current .... Internally Limited
Package Thermal Resistance
MSOP-10, $θ_{JA}$ .... 175℃/W
TDFN-3×3-10L, $θ_{JA}$ .... 80℃/W
Junction Temperature...+150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering, 10sec) ....+260℃
ESD Susceptibility
HBM...5000V
MM...300V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Power Supply Voltage Range, V_{CC} ....2.7V to 24V
Digital Input Pin Voltage Range ....0V to 5.5V
Continuous DC/RMS Output Current.............................. 1.5A
Operating Temperature Range ....-40℃ to +125℃

OVERSTRESS CAUTION

Stresses beyond those listed may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational section of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

ESD SENSITIVITY CAUTION

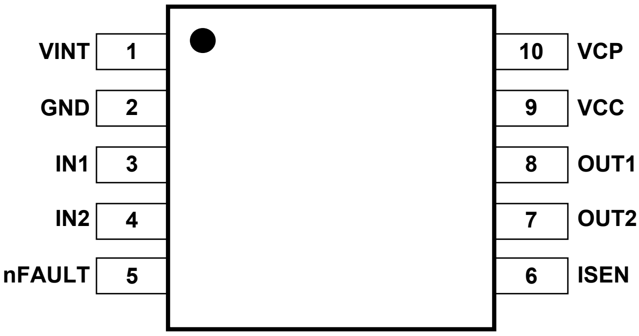
This integrated circuit can be damaged by ESD if you don't pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time.

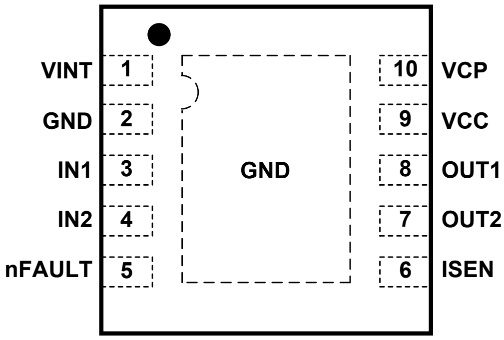
PIN CONFIGURATIONS

SGM42609 (TOP VIEW)



MSOP-10

SGM42609 (TOP VIEW)



TDFN-3×3-10L

PIN DESCRIPTION

PIN		NAME	I/O	FUNCTION
MSOP-10	TDFN-3×3-10L			
1	1	VINT	–	Internal Supply Bypass. Bypass to GND with 2.2μF, 6.3V capacitor.
2	2	GND	G	Ground. Both the GND pin and device exposed pad must be connected to ground.
3	3	IN1	I	Bridge Input 1. Logic input controls state of OUT1. Internal pull-down.
4	4	IN2	I	Bridge Input 2. Logic input controls state of OUT2. Internal pull-down.
5	5	nFAULT	OD	Fault Output. Logic low when in fault condition (over-temperature, over-current, power supply under-voltage, charge pump under-voltage).
6	6	ISEN	IO	Bridge Ground or I_{SENSE}. Connect to current sense resistor for bridge, or GND if current control not needed.
7	7	OUT2	O	Bridge Output 2. Connect to motor winding.
8	8	OUT1	O	Bridge Output 1. Connect to motor winding.
9	9	VCC	P	Device Power Supply. Connect to motor supply. A 10μF (MIN) ceramic bypass capacitor to GND is recommended.
10	10	VCP	IO	High-side Gate Drive Voltage. Connect a 0.01μF, 30V (MIN) ceramic capacitor to VCC.
—	Exposed Pad	GND	G	Exposed Pad. Exposed pad is internally connected to GND. Connect it to a large ground plane to maximize thermal performance; not intended as an electrical connection point.

NOTE: I = input; O = output; IO = input or output; OD = open-drain output; G: ground; P: power for the circuit.

ELECTRICAL CHARACTERISTICS

(V_{CC} = 5V, Full = -40℃ to +125℃. Typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
POWER SUPPLIES							
VCC Operating Supply Voltage	V_{CC}		Full	2.7		24	V
VCC Operating Supply Current	I_{VCC}	IN1 = 0V, IN2 = 0V (less than t_{sleep})	+25℃		1.5	2	mA
VCC Sleep Mode Supply Current	I_{VCCQ}	IN1 = 0V, IN2 = 0V (more than t_{sleep})	+25℃		0.9	2.5	μA
Enter Sleep Mode Time	t_{sleep}	IN1 = 0V, IN2 = 0V	+25℃	5.2	6.2	7.4	s
VCC Under-Voltage Lockout Voltage	V_{UVLO}		+25℃		2.3	2.4	V
VCC Under-Voltage Lockout Voltage Hysteresis	V_{HYS}		+25℃		100		mV
LOGIC LEVEL INPUTS							
Input Low Voltage	V_{IL}	V_{CC} = 2.7V to 24V	Full			0.7	V
Input High Voltage	V_{IH}	V_{CC} = 2.7V to 24V	Full	2.3			V
Input Hysteresis	V_{HYS}		+25℃		200		mV
Input Pull-Down Resistance	R_{PD}		+25℃		160		kΩ
Input Low Current	I_{IL}	V_{IN} = 0V	Full	-1		1	μA
Input High Current	I_{IH}	V_{IN} = 5V	Full		35	48	μA
Input Deglitch Time	t_{DEG}	V_{IN} = 5V	+25℃		460		ns
nFAULT OUTPUT (OPEN-DRAIN OUTPUT)							
Output Low Voltage	V_{OL}	V_{IN} = 2V, I_O = -5mA	+25℃			0.52	V
Output High-Impedance Leakage Current	I_{OH}		+25℃			1	μA
H-BRIDGE FETS							
HS FET On-Resistance	$R_{DS(ON)}$	V_{CC} = 5V, I_O = 200mA	+25℃		260		mΩ
		V_{CC} = 5V, I_O = 200mA	Full			545	
		V_{CC} = 2.7V, I_O = 200mA	+25℃		320		
		V_{CC} = 2.7V, I_O = 200mA	Full			635	
LS FET On-Resistance	$R_{DS(ON)}$	V_{CC} = 5V, I_O = -200mA	+25℃		220		mΩ
		V_{CC} = 5V, I_O = -200mA	Full			510	
		V_{CC} = 2.7V, I_O = -200mA	+25℃		260		
		V_{CC} = 2.7V, I_O = -200mA	Full			590	
Off-State Leakage Current	I_{OFF}	V_{CC} = 26.5V, V_{OUT} = 0V	+25℃	-1.5		1.5	μA
MOTOR DRIVER							
Current Control PWM Frequency	f_{PWM}	Internal PWM Frequency	+25℃		45		kHz
Rise Time	t_R	R_L = 16Ω to GND, 10% to 90% V_{CC}	+25℃		130		ns
Fall Time	t_F	R_L = 16Ω to V_{CC}, 90% to 10% V_{CC}	+25℃		120		ns
Propagation Delay INx to OUTx	t_{PROP}		+25℃		1.2		μs
Dead Time [1]	t_{DEAD}		+25℃		550		ns

ELECTRICAL CHARACTERISTICS

(V_{CC} = 5V, Full = -40℃ to +125℃. Typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
PROTECTION CIRCUITS							
Over-Current Protection Trip Level	I_{OCP}		+25℃	2.5	3.3		A
OCP Deglitch Time	t_{DEG}		+25℃		4		μs
Over-Current Protection Period	t_{OCP}		+25℃		1.4		ms
Thermal Shutdown Temperature	T_{TSD}	Die Temperature			160		℃
Thermal Shutdown Temperature Hysteresis	T_{HYS}				30		℃
CURRENT CONTROL							
ISEN Trip Voltage	V_{TRIP}		+25℃	150	200	260	mV
Current Sense Blanking Time	t_{BLANK}		+25℃		4		μs
SLEEP MODE							
Start-Up Time	t_{WAKE}	nSleep inactive high to H-bridge on	+25℃			1.4	ms

NOTE: 1. Internal dead time. External implementation is not necessary.

FUNCTIONAL BLOCK DIAGRAM

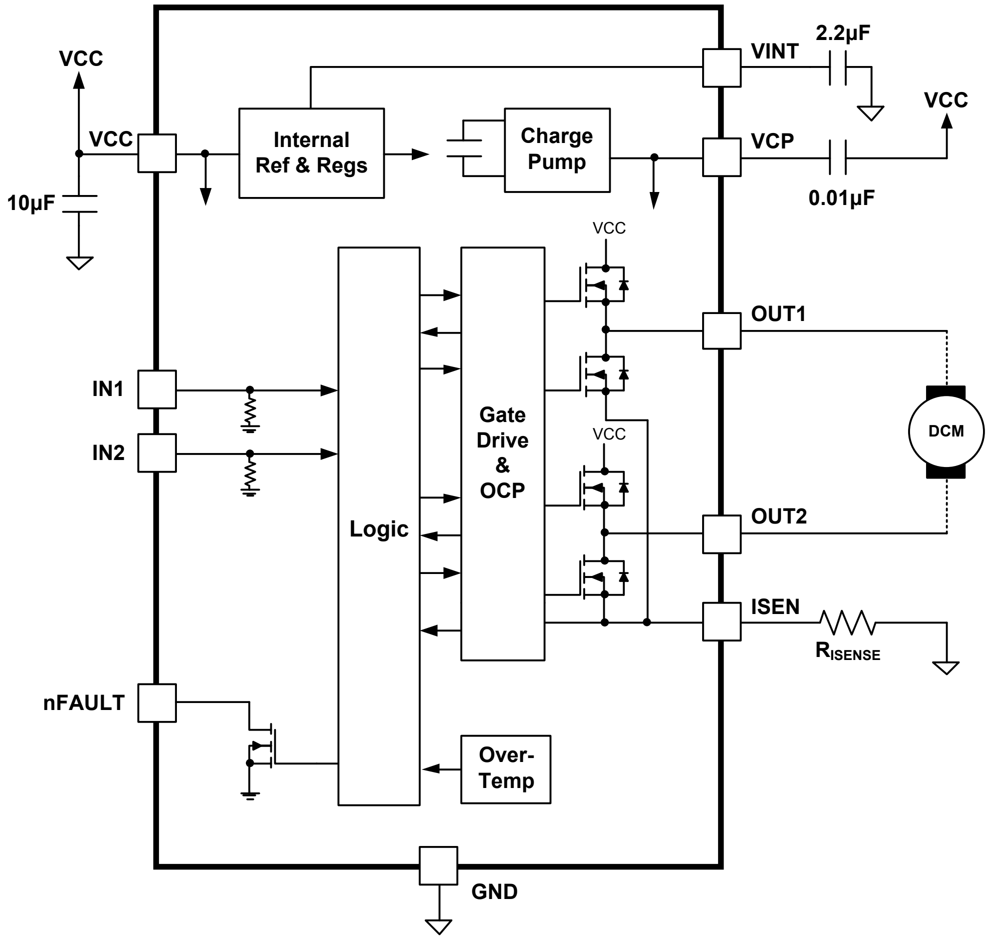


Figure 1. SGM42609 Block Diagram

DETAILED DESCRIPTION

PWM Motor Drivers

The SGM42609 contains one H-bridge motor driver with current-control PWM circuitry. A block diagram of the circuitry is shown below:

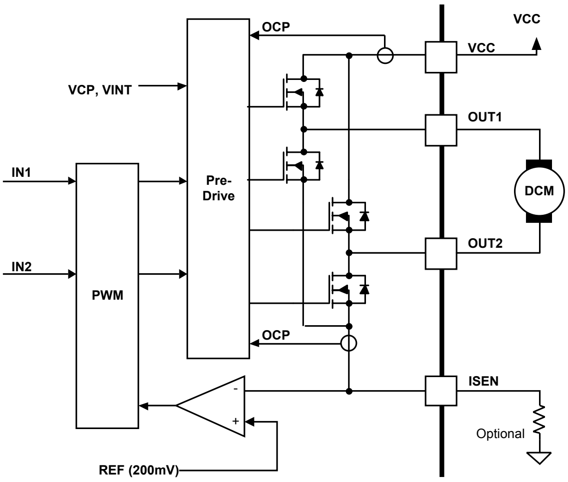


Figure 2. Motor Control Circuitry

Bridge Control and Decay Modes

The IN1 and IN2 input pins control the state of the OUT1 and OUT2 outputs. Table 1 shows the logic.

Table 1. H-Bridge Logic

IN1	IN2	OUT1	OUT2	FUNCTION	NOTES
0	0	Z	Z	Sleep	Both IN1 & IN2 are low more than t_{sleep}.
0	0	Z	Z	Coast	Both IN1 & IN2 are low less than t_{sleep}.
0	1	L	H	Reverse	
1	0	H	L	Forward	
1	1	L	L	Brake/Slow Decay	

When both IN1 and IN2 are low more than t_{sleep}, the device will into a low-power sleep state. When both IN1 and IN2 are low less than t_{sleep}, the device will be at coast state. The inputs can also be used for PWM control of the motor speed. When controlling a winding with PWM, when the drive current is interrupted, the inductive nature of the motor requires that the current must continue to flow. This is called recirculation current. To handle this recirculation current, the H-bridge can operate in two different states, fast decay or slow decay. In fast decay mode, the H-bridge is disabled and recirculation current flows through the body diodes; in slow decay, the motor winding is shorted.

To PWM using fast decay, the PWM signal is applied to one IN pin while the other is held low; to use slow decay, one IN pin is held high.

Table 2. PWM Control of Motor Speed

IN1	IN2	FUNCTION
PWM	0	Forward PWM, Fast Decay
1	PWM	Forward PWM, Slow Decay
0	PWM	Reverse PWM, Fast Decay
PWM	1	Reverse PWM, Slow Decay

Figure 3 shows the current paths in different drive and decay modes.

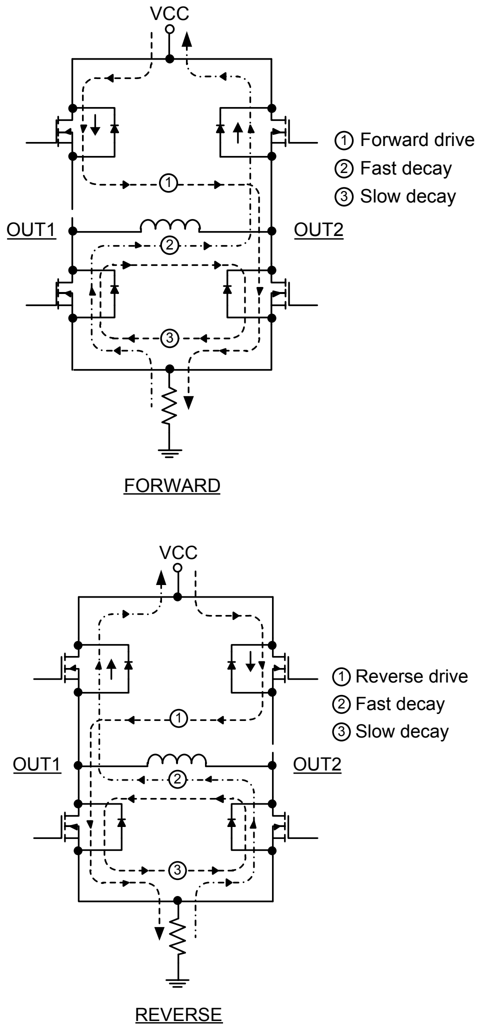


Figure 3. Decay Modes

DETAILED DESCRIPTION (continued)

Current Control

The current through the motor windings may be limited, or controlled, by a fixed-frequency PWM current regulation, or current chopping. For DC motors, current control is used to limit the start-up and stall current of the motor.

When an H-bridge is enabled, current rises through the winding at a rate dependent on the DC voltage and inductance of the winding. If the current reaches the current chopping threshold, the bridge disables the current until the beginning of the next PWM cycle. Note that immediately after the current is enabled, the voltage on the ISEN pin is ignored for a fixed period of time before enabling the current sense circuitry. This blanking time is fixed at 4μs. This blanking time also sets the minimum on time of the PWM when operating in current chopping mode.

The PWM chopping current is set by a comparator which compares the voltage across a current sense resistor connected to the ISEN pin with a reference voltage. The reference voltage is fixed at 200mV. The chopping current is calculated in Equation 1.

$$I_{CHOP} = \frac{200mV}{R_{ISENSE}} \qquad (1)$$

For example:
If a 1Ω sense resistor is used, the chopping current will be 200mV/1Ω = 200mA. Once the chopping current threshold is reached, the H-bridge switches to slow decay mode. Winding current is re-circulated by enabling both of the low-side FETs in the bridge. This state is held until the beginning of the next fixed-frequency PWM cycle.

Note that if current control is not needed, the ISEN pin should be connected directly to ground.

Sleep Operation

After both IN1 and IN2 are low more than t_{sleep}, the output drivers are disabled and the device is placed into a low-power sleep state. In this state, the H-bridge is disabled, the gate drive charge pump is stopped, all internal logic is reset, and all internal clocks are stopped. When returning from sleep mode, some time (up to 1.4ms) needs to pass before the motor driver becomes fully operational.

Over-Current Protection (OCP)

An analog current limit circuit on each FET limits the current through the FET by limiting the gate drive. If this analog current limit persists for longer than the OCP deglitch time, all FETs in the H-bridge will be disabled and the nFAULT pin will be driven low. The driver will be re-enabled after the OCP retry period (t_{OCP}) has passed. nFAULT becomes high again at this time. If the fault condition is still present, the cycle repeats. If the fault is no longer present, normal operation resumes and nFAULT remains deasserted.

Over-current conditions are detected independently on both high and low side devices; i.e., a short across the motor winding will all result in an over-current shutdown. Note that over-current protection does not use the current sense circuitry used for PWM current control, so functions even without presence of the ISEN resistors.

Thermal Shutdown (TSD)

If the die temperature exceeds safe limits, all FETs in the H-bridge will be disabled and the nFAULT pin will be driven low. Once the die temperature has fallen to a safe level operation will automatically resume.

Under-Voltage Lockout (UVLO)

If at any time the voltage on the VCC pin falls below the under-voltage lockout threshold voltage, all circuitry in the device will be disabled, and all internal logic will be reset. Operation will resume when V_{CC} rises above the UVLO threshold. nFAULT is driven low in the event of an under-voltage condition.

APPLICATION INFORMATION

Maximum Output Current

In actual operation, the maximum output current achievable with a motor driver is a function of die temperature.

This in turn is greatly affected by ambient temperature and PCB design. Basically, the maximum motor current will be the amount of current that results in a power dissipation level that, along with the thermal resistance of the package and PCB, keeps the die at a low enough temperature to stay out of thermal shutdown.

The dissipation ratings given in the datasheet can be used as a guide to calculate the approximate maximum power dissipation that can be expected to be possible without entering thermal shutdown for several different PCB constructions. However, for accurate data, the actual PCB design must be analyzed via measurement or thermal simulation.

Power Dissipation

Power dissipation in the SGM42609 is dominated by the DC power dissipated in the output FET resistance. There is additional power dissipated due to PWM switching losses, which are dependent on PWM frequency, rise and fall times, and VCC power supply voltage. These switching losses are typically on the order of 10% to 30% of the DC power dissipation.

The DC power dissipation of H-bridge can be roughly estimated by Equation 2.

$$P_{TOT} = (HS - R_{DS(ON)} \times I_{OUT(RMS)}{}^{2}) + (LS - R_{DS(ON)} \times I_{OUT(RMS)}{}^{2})$$

where P_{TOT} is the total power dissipation, HS - $R_{DS(ON)}$ is the resistance of the high side FET, LS - $R_{DS(ON)}$ is the resistance of the low side FET, and $I_{OUT(RMS)}$ is the RMS output current being applied to the motor.

Note that $R_{DS(ON)}$ increases with temperature, so as the device heats, the power dissipation increases. This must be taken into consideration when sizing the heatsink.

Thermal Protection

Any tendency of the device to enter TSD is an indication of either excessive power dissipation, insufficient heatsinking, or too high an ambient temperature.

Heatsinking

The TDFN-3×3-10L package uses an exposed pad to remove heat from the device. For proper operation, this pad must be thermally connected to copper on the PCB to dissipate heat. On a multi-layer PCB with a ground plane, this can be accomplished by adding a number of vias to connect the thermal pad to the ground plane. On PCBs without internal planes, copper area can be added on either side of the PCB to dissipate heat. If the copper area is on the opposite side of the PCB from the device, thermal vias are used to transfer the heat between top and bottom layers.

REVISION HISTORY

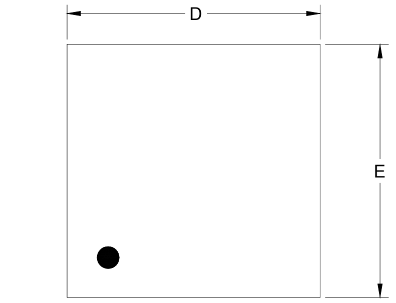
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (JUNE 2017) to REV.A

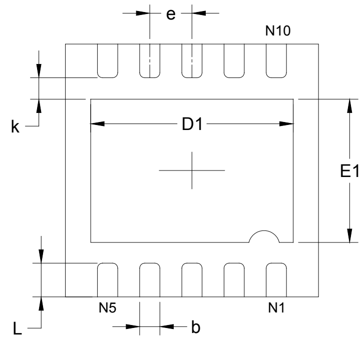
Changed from product preview to production data..All

PACKAGE OUTLINE DIMENSIONS

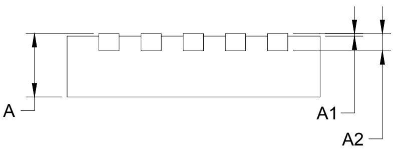
TDFN-3×3-10L



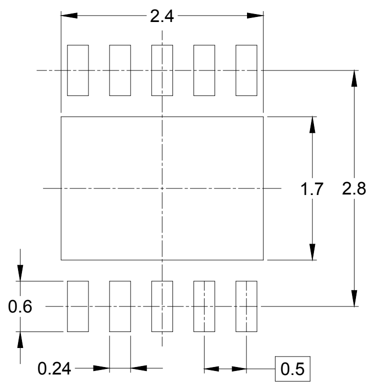
TOP VIEW



BOTTOM VIEW



SIDE VIEW

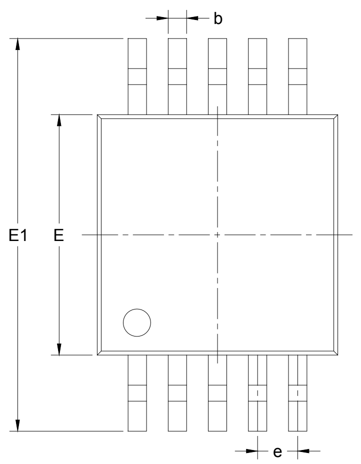


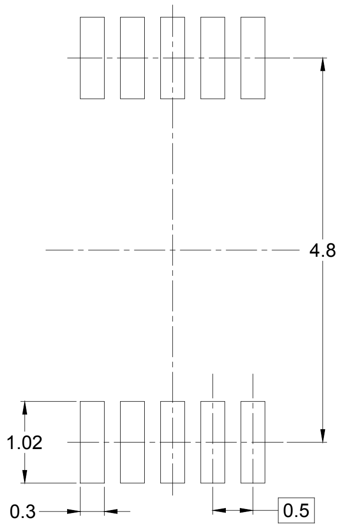
RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	2.900	3.100	0.114	0.122
D1	2.300	2.600	0.091	0.103
E	2.900	3.100	0.114	0.122
E1	1.500	1.800	0.059	0.071
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.300	0.500	0.012	0.020

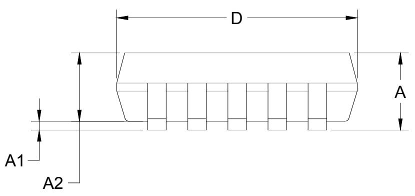
PACKAGE OUTLINE DIMENSIONS

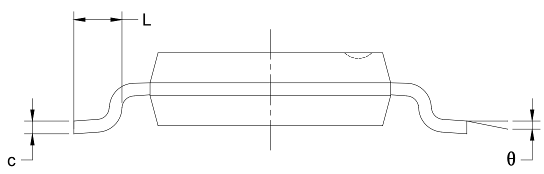
MSOP-10





RECOMMENDED LAND PATTERN (Unit: mm)

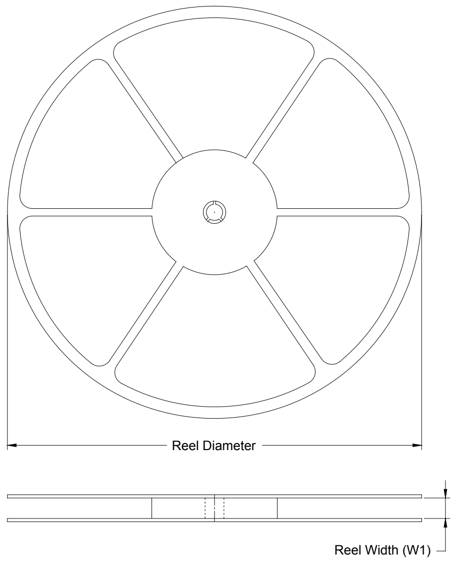




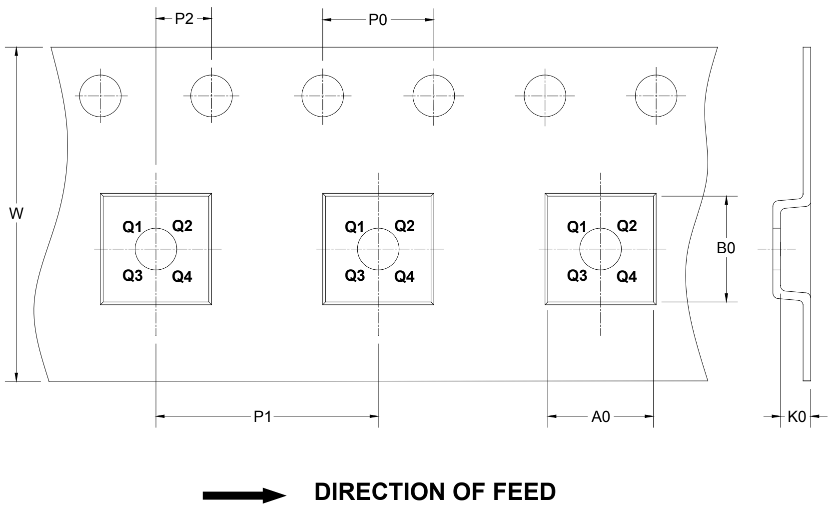
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.180	0.280	0.007	0.011
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
e	0.500 BSC		0.020 BSC	
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



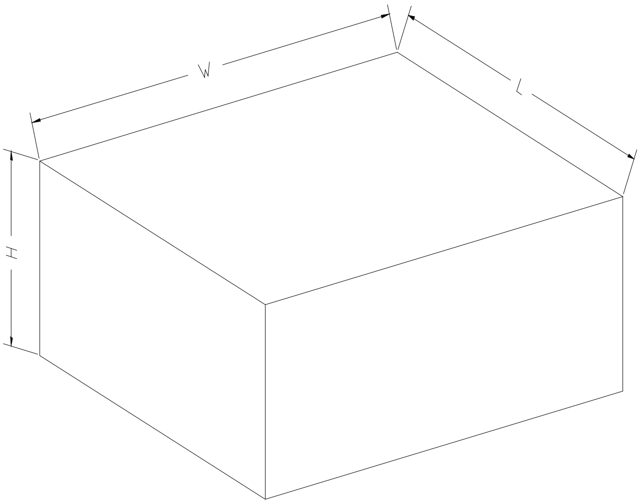
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
MSOP-10	13″	12.4	5.20	3.30	1.20	4.0	8.0	2.0	12.0	Q1
TDFN-3×3-10L	13″	12.4	3.35	3.35	1.13	4.0	8.0	2.0	12.0	Q1

DD0001

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13″	386	280	370	5

DD0002