SGM42622

Low Voltage Stepper Motor Driver

GENERAL DESCRIPTION

The SGM42622 is a stepper motor driver with control logic and low $R_{DS(ON)}$ MOSFET power stages all integrated in a small TQFN package.

This device uses fixed off-time PWM current control for two independent H-bridges and is capable for fine microstepping resolution up to 1/256. Aimed for battery-powered applications, it can go to near zero-power standby mode for increased battery life.

A full set of protection features are provided including over-current, short-circuit, and thermal shutdown.

The SGM42622 is available in a Green TQFN-3×3-16L package. It operates over an ambient temperature range of -40℃ to +85℃.

FEATURES

- **Motor Power Supply Voltage Range: 1.8V to 10V**
- **1.3A Maximum RMS Output Current**
- **Low $R_{DS(ON)}$: 0.5Ω (HS + LS) at +25℃**
- **Up to 1/256 Microstepping Resolution**
- **Adaptive Mixed Current Decay Modes**
- **Current Control with Programmable Off-Time**
- **Full Set of Protections**
    - **Lossless Over-Current Protection**
    - **Short-Circuit Protection**
    - **Thermal Shutdown**
- **Less than 80nA Standby Current for Long Battery Life**
- **-40℃ to +85℃ Operating Temperature Range**
- **Available in a Green TQFN-3×3-16L Package**

APPLICATIONS

Toys

Portable Printers

Robotics

Point of Sale (POS) Devices

TYPICAL APPLICATION

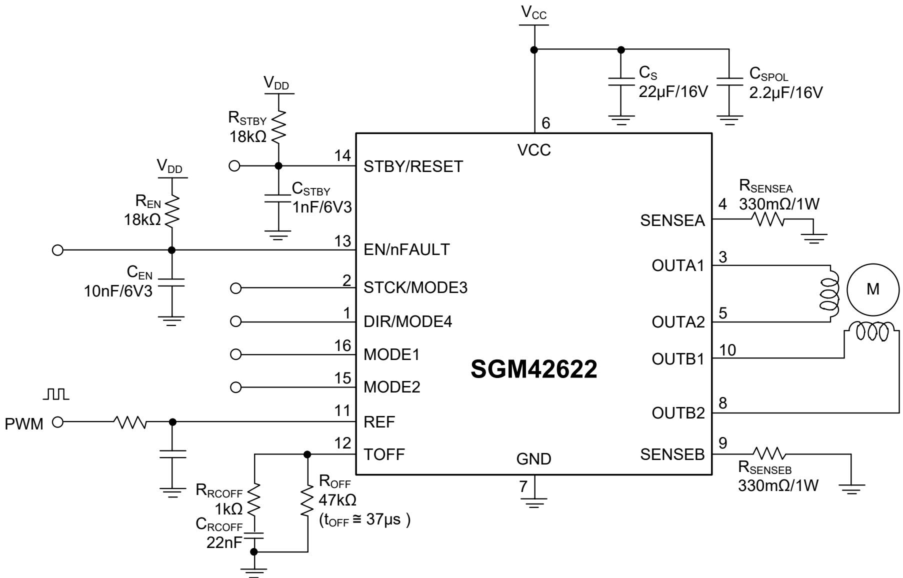


Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM42622	TQFN-3×3-16L	-40℃ to +85℃	SGM42622YTQ16G/TR	42622TQ XXXXX	Tape and Reel, 4000

MARKING INFORMATION

NOTE: XXXXX = Date Code, Trace Code and Vendor Code.

X XXX X
- Vendor Code
- Trace Code
- Date Code - Year

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

Supply Voltage, V_{CC} .... -0.3V to 11V
Logic Input Voltage .... -0.3V to 5.5V
Output-to-Sense Voltage Drop, V_{OUT} - V_{SENSE} 11V
Supply-to-Output Voltage Drop, V_{CC} - V_{OUT} 11V
Sense Pin Voltage, V_{SENSE} .... -1V to 1V
Input Reference Voltage, V_{REF} .... -0.3V to 1V
Continuous Power Stage Output Current (Each Bridge)
$I_{OUT, RMS}$ .... 1.3A_{RMS}
Power Dissipation, P_D @ T_A = +25℃
TQFN-3×3-16L 1.5W
Junction Temperature .... +150℃
Storage Temperature Range .... -65℃ to +150℃
Lead Temperature (Soldering, 10s) .... +260℃
ESD Susceptibility
HBM 4000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Supply Voltage, V_{CC} .... 1.8V to 10V
Logic Input Voltage .... 0V to 5V
Input Reference Voltage, V_{REF} .... 0.1V to 0.5V
Logic Inputs Positive/Negative Pulse Width, t_{INw} .... > 300ns
Operating Temperature Range .... -40℃ to +85℃

OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

ESD SENSITIVITY CAUTION

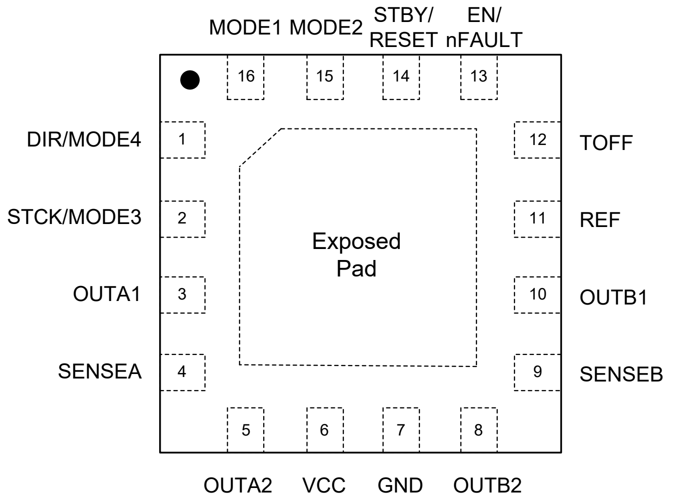
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

PIN CONFIGURATION

(TOP VIEW)



TQFN-3×3-16L

PIN DESCRIPTION

PIN	NAME	TYPE	FUNCTION
1	DIR/MODE4	Logic Input	Direction Input or Step Mode Selection Input 4.
2	STCK/MODE3	Logic Input	Step Clock Input or Step Mode Selection Input 3.
3	OUTA1	Power Output	Output Power Bridge A1.
4	SENSEA	Power Output	Sense Output of the Bridge A. Connect with a small sensing resistor to power ground.
5	OUTA2	Power Output	Output Power Bridge A2.
6	VCC	Supply	Device Supply Voltage.
7	GND	Ground	Device Ground.
8	OUTB2	Power Output	Output Power Bridge B2.
9	SENSEB	Power Output	Sense Output of the Bridge B. Connect with a small sensing resistor to power ground.
10	OUTB1	Power Output	Output Power Bridge B1.
11	REF	Analog Input	Reference Voltage Input for the PWM Current Control.
12	TOFF	Analog Input	Internal Oscillator Frequency Adjustment.
13	EN/nFAULT	Logic Input/ Open-Drain Output	5V Logic-Compliant Power Stage Enable Input or Alert Output. Power stage is turned off if it is not pulled high. This pin is also the device fault output with internal open-drain driver. If a fault occurs, it will be pulled down internally.
14	STBY/RESET	Logic Input	5V Logic-Compliant Standby Input. Device goes to low power mode if pulled low.
15	MODE2	Logic Input	Step Mode Selection Input 2.
16	MODE1	Logic Input	Step Mode Selection Input 1.
Exposed Pad	GND	Ground	Device Ground. The exposed pad must be connected to ground.

ELECTRICAL CHARACTERISTICS

(T_A = +25°C and V_{CC} = 5V, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supplies						
Power Supply Voltage	V_{CC}		1.8		10	V
V_{CC} Turn-On Voltage	V_{CCTH_ON}	V_{CC} rising from 0V	1.1	1.47	1.8	V
V_{CC} Turn-Off Voltage	V_{CCTH_OFF}	V_{CC} falling from 5V	1	1.31	1.64	V
V_{CC} Hysteresis Voltage	V_{CCTH_HYS}			180		mV
V_{CC} Supply Current	I_{CC}	No commutations, EN = low, R_{OFF} = 160kΩ		2700	3500	μA
		No commutations, EN = high, R_{OFF} = 160kΩ		2800	3650	μA
V_{CC} Standby Current	I_{CC_STBY}	V_{STBY} = 0V		10	80	nA
Standby Low Logic Level Input Voltage	V_{STBYL}				0.7	V
Standby High Logic Level Input Voltage	V_{STBYH}		2.25			V
Power Stage						
Total On-Resistance (HS + LS)	$R_{DS(ON)}$	V_{CC} = 10V, I_{OUT} = 1.3A		0.43	0.6	Ω
		V_{CC} = 3V, I_{OUT} = 0.4A		0.5	0.65	
Rise Time	t_{RISE}	V_{CC} = 10V, unloaded outputs		40		ns
Fall Time	t_{FALL}	V_{CC} = 10V, unloaded outputs		40		ns
Dead Time	t_{DT}			260		ns
Current Control						
Sensing Offset	V_{SENSE_OFFSET}	V_{REF} = 0.5V, internal reference 20% V_{REF}	-15		15	mV
Total Off-Time	t_{OFF}	R_{OFF} = 10kΩ		9		μs
		R_{OFF} = 160kΩ		106		μs
Slow Decay Time	t_{OFF_SLOW}			5/8 × t_{OFF}		μs
Fast Decay Time	t_{OFF_FAST}			3/8 × t_{OFF}		μs
Logic IOs						
High Logic Level Input Voltage	V_{IH}		1.5			V
Low Logic Level Input Voltage	V_{IL}				0.5	V
EN Low Logic Level Output Voltage	V_{OL}	I_{EN} = 4mA			0.8	V
STBY Pull-Down Resistance	R_{STBY}			72		kΩ
EN Pull-Down Current	I_{PDEN}			12		μA

ELECTRICAL CHARACTERISTICS (continued)

(T_A = +25℃ and V_{CC} = 5V, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
EN Input Propagation Delay	t_{ENd}	From EN falling edge to OUT high-impedance		2000		ns
MODEx Input Hold Time	t_{MODEho}	From STBY edge	200			μs
MODEx Input Setup Time	t_{MODEsu}	From STBY edge	2			μs
DIR Input Hold Time	t_{DIRho}	From STCK rising edge	200			ns
DIR Input Setup Time	t_{DIRsu}	From STCK rising edge	200			ns
STCK High Time	t_{STCKH}		200			ns
STCK Low Time	t_{STCKL}		200			ns
STCK Inputs Frequency	f_{STCK}				1	MHz
OCP Retry Time	t_{OCP_RETRY}			16		ms
Protections						
Thermal Shutdown Threshold	T_{TSD}			170		℃
Thermal Shutdown Hysteresis	T_{HYS}			40		℃
Over-Current Protection Threshold	I_{OCP}			2		A

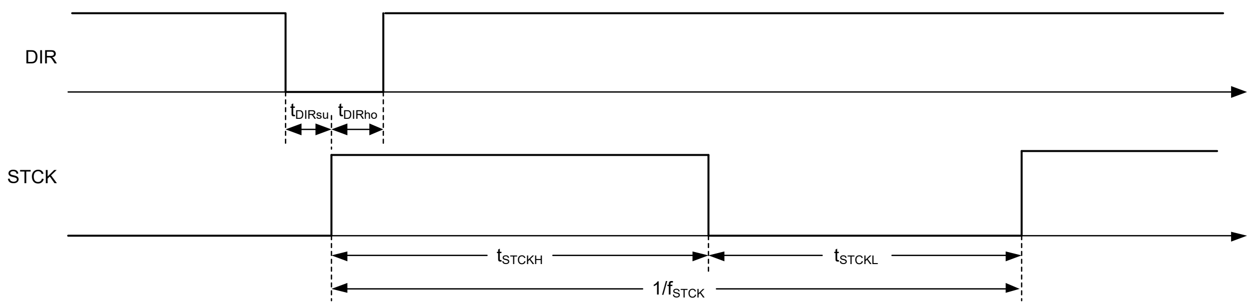
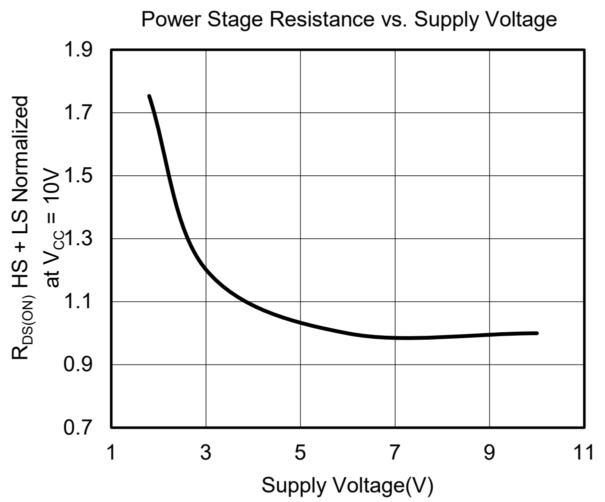
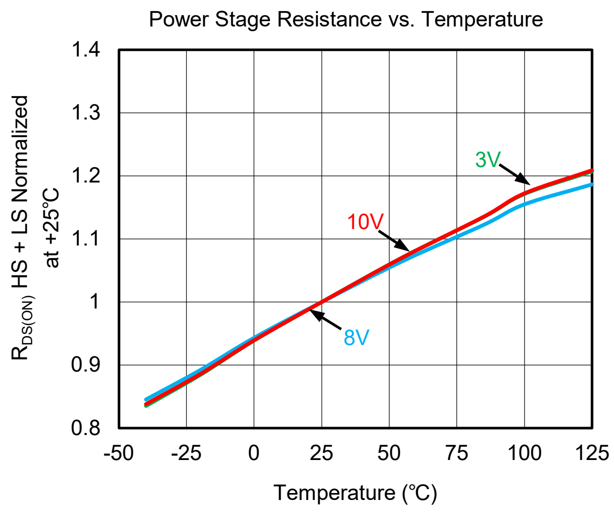
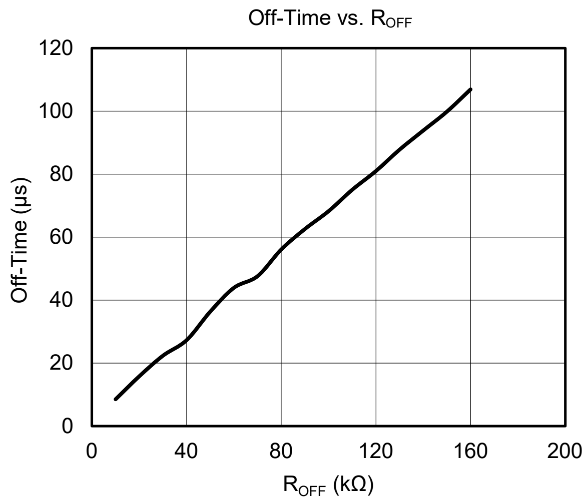


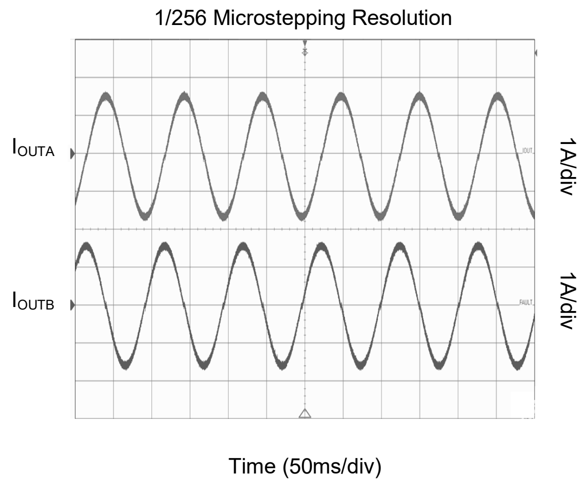
Figure 2. Direction (DIR) and Step Clock (STCK) Timing Diagram

TYPICAL PERFORMANCE CHARACTERISTICS









FUNCTIONAL BLOCK DIAGRAM

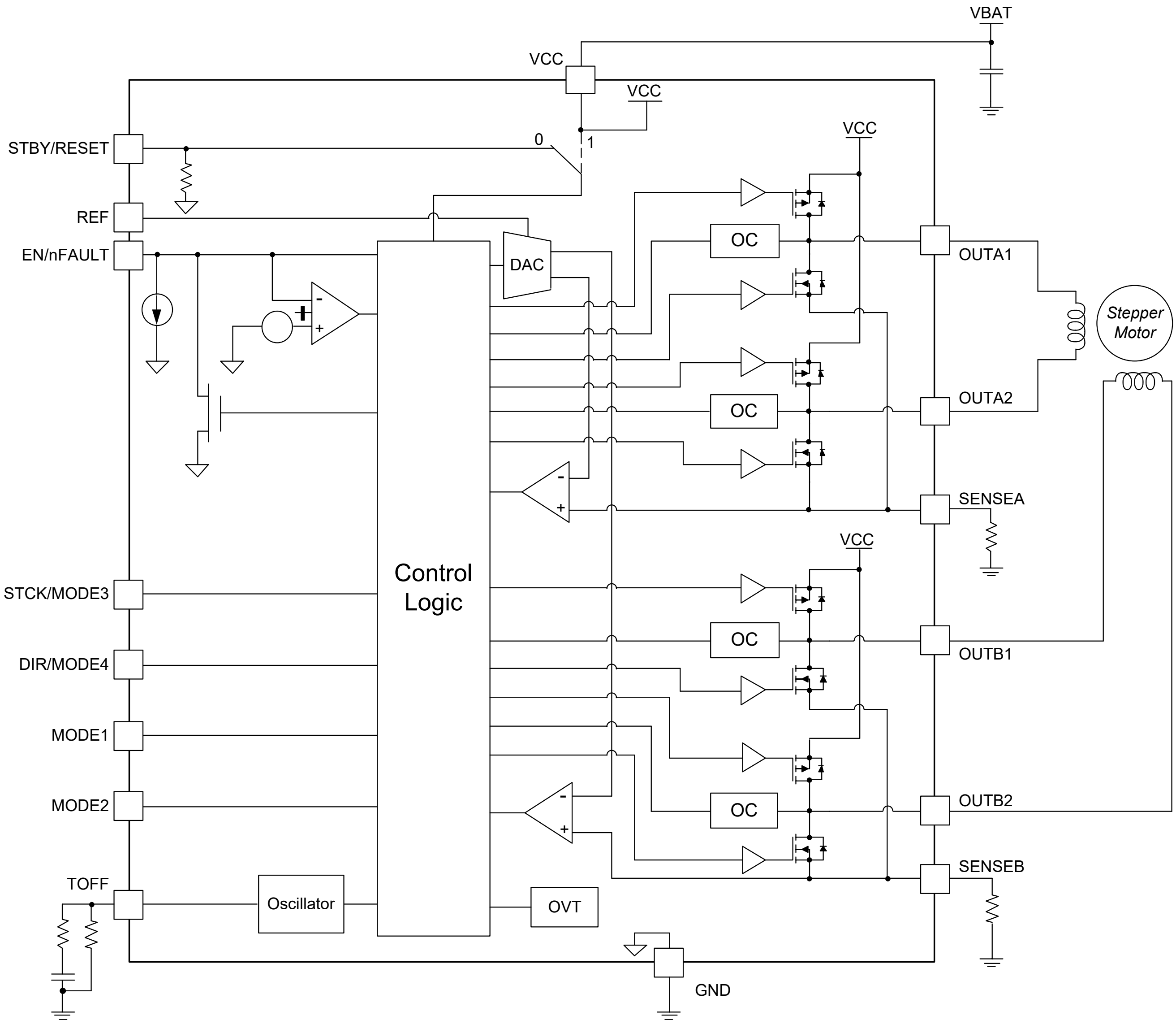


Figure 3. Block Diagram

FUNCTIONAL DESCRIPTION

The SGM42622 is a stepper motor driver that includes a 10-bit sequencer with 1/256 microstepping capability, two PWM current controllers and two protected full-bridges in power stage.

Standby and Power-Up

This device can be placed in standby mode to reduce the power consumption to near zero by pulling the STBY/RESET input pin below the V_{STBYL} threshold.

In standby mode, the supply current of the controller is significantly reduced and the power stage is turned off with outputs in a high-impedance state.

When the device exits the standby mode, the controller restarts like a power-up situation.

Microstepping Sequencer

The 4-bit binary value on the MODEx inputs is latched just after power-up or when the device exits standby mode. In normal operation, the input value is ignored and the MODE3 and MODE4 inputs act as step clock (STCK) and direction (DIR) inputs. The only exception is when MODE1 and MODE2 are both at low state. In such condition, the latched value is ignored and the device operates in full-step mode. If either MODE1 or MODE2 input returns to high state, the previous operating mode will be restored.

Table 1. Step Mode Selection through MODEx Inputs

MODE3 (STCK)	MODE4 (DIR)	MODE1	MODE2	Step Mode
0	0	0	0	**full-step** (1)
0	0	0	1	1/32 step
0	0	1	0	1/128 step
0	0	1	1	1/256 step
0	1	0	0	**full-step - 1/32 step** (1)
0	1	0	1	1/4 step
0	1	1	0	1/256 step
0	1	1	1	1/64 step
1	0	0	0	**full-step - 1/128 step** (1)
1	0	0	1	1/256 step
1	0	1	0	1/2 step
1	0	1	1	1/8 step
1	1	0	0	**full-step - 1/256 step** (1)
1	1	0	1	1/64 step
1	1	1	0	1/8 step
1	1	1	1	1/16 step

NOTE: 1. If MODE1 = MODE2 = 0 occurs, the latched value is ignored temporarily, and stepping will be in full-step mode.

Figure 4 shows how the step mode is selected for the SGM42622 with some examples.

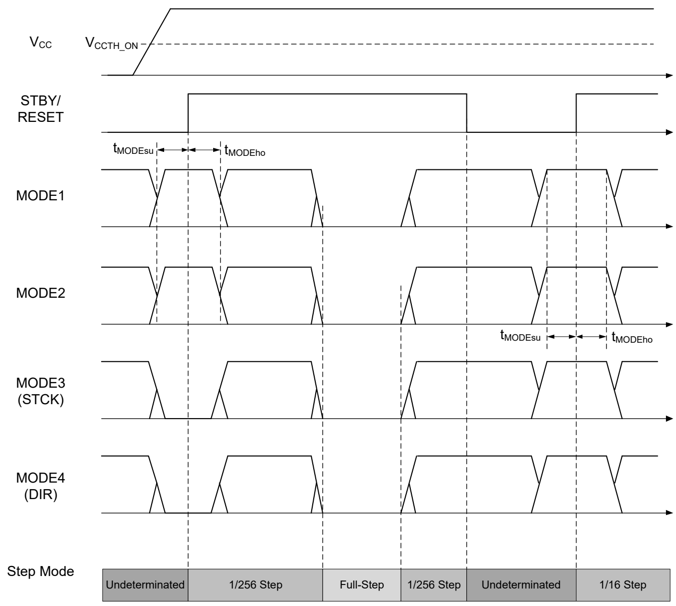


Figure 4. Mode Selection Examples

The sequencer is a 10-bit counter that sets the reference of the PWM current controllers and the current direction of the H-bridges. The counter resets to zero after power-up or standby and is counted with each rising edge of STCK. It is increased if DIR = high or decreased if DIR = low.

The current direction and references that determine the output currents of the device as listed in Table 2 for full-step mode. V_{REF} is the reference input (0.1V to 0.5V recommended) to adjust the output current magnitudes. The values for other step modes are listed in Table 3.

Table 4 lists the reference and sequencer values for 1/2, 1/4 and 1/8 step modes. For higher microstepping resolutions the same pattern is extended. Positive numbers show that the output current flows from OUTx1 to OUTx2, and negative numbers show opposite direction.

In all step modes, the home state (reset) is loaded in sequencer at power-up or after exiting the standby mode.

FUNCTIONAL DESCRIPTION (continued)

Table 2. Current Reference and Direction of the Outputs in Full-Step Modes (Determined by the Sequencer Value)

Sequencer Value										Phase A		Phase B	
										Reference Voltage	Current Direction	Reference Voltage	Current Direction
0	0	X	X	X	X	X	X	X	X	100% × V_{REF}	A1 → A2	100% × V_{REF}	B1 → B2
0	1	X	X	X	X	X	X	X	X	100% × V_{REF}	A1 → A2	100% × V_{REF}	B1 ← B2
1	0	X	X	X	X	X	X	X	X	100% × V_{REF}	A1 ← A2	100% × V_{REF}	B1 ← B2
1	1	X	X	X	X	X	X	X	X	100% × V_{REF}	A1 ← A2	100% × V_{REF}	B1 → B2

Table 3. Current Reference and Direction of the Outputs in Non-Full-Step Modes (Determined by the Sequencer Value)

Sequencer Value										Phase A		Phase B	
										Reference Voltage	Current Direction	Reference Voltage	Current Direction
0	0	0	0	0	0	0	0	0	0	Zero (bridge disabled)	-	100% × V_{REF}	B1 → B2
0	0	n								Sin(n/256 × π/2) × V_{REF}	A1 → A2	Cos(n/256 × π/2) × V_{REF}	B1 → B2
0	1	0	0	0	0	0	0	0	0	100% × V_{REF}	A1 → A2	Zero (bridge disabled)	-
0	1	n								Sin(π/2 + n/256 × π/2) × V_{REF}	A1 → A2	Cos(π/2 + n/256 × π/2) × V_{REF}	B1 ← B2
1	0	0	0	0	0	0	0	0	0	Zero (bridge disabled)	-	100% × V_{REF}	B1 ← B2
1	0	n								Sin(n/256 × π/2) × V_{REF}	A1 ← A2	Cos(n/256 × π/2) × V_{REF}	B1 ← B2
1	1	0	0	0	0	0	0	0	0	100% × V_{REF}	A1 ← A2	Zero (bridge disabled)	-
1	1	n								Sin(π/2 + n/256 × π/2) × V_{REF}	A1 ← A2	Cos(π/2 + n/256 × π/2) × V_{REF}	B1 → B2

Table 4. Reference and Sequencer Values for 1/2, 1/4 and 1/8 Step Modes

1/2 Step	1/4 Step	1/8 Step	V_{REF} Phase A	V_{REF} Phase B	Sequencer Value	1/2 Step	1/4 Step	1/8 Step	V_{REF} Phase A	V_{REF} Phase B	Sequencer Value
1	1	1	0%	100%	0000000000 **home state**	5	9	17	0%	100%	1000000000
-	-	2	19.509%	98.079%	0000100000	-	-	18	-19.509%	-98.079%	1000100000
-	2	3	38.268%	92.388%	0001000000	-	10	19	-38.268%	-92.388%	1001000000
-	-	4	55.557%	83.147%	0001100000	-	-	20	-55.557%	-83.147%	1001100000
2	3	5	70.711%	70.711%	0010000000	6	11	21	-70.711%	-70.711%	1010000000
-	-	6	83.147%	55.557%	0010100000	-	-	22	-83.147%	-55.557%	1010100000
-	4	7	92.388%	19.509%	0011100000	-	12	23	-92.388%	-38.268%	1011000000
-	-	8	98.079%	19.509%	0011100000	-	-	24	-98.079%	-19.509%	1011100000
3	5	9	100%	0%	0100000000	7	13	25	-100%	0%	1100000000
-	-	10	98.079%	-19.509%	0100100000	-	-	26	-98.079%	19.509%	1100100000
-	6	11	92.388%	-38.268%	0101000000	-	14	27	-92.388%	38.268%	1101000000
-	-	12	83.147%	-55.557%	0101100000	-	-	28	-83.147%	55.557%	1101100000
4	7	13	70.711%	-70.711%	0110000000	8	15	29	-70.711%	70.711%	1110000000
-	-	14	55.557%	-83.147%	0110100000	-	-	30	-55.557%	83.147%	1110100000
-	8	15	38.268%	-92.388%	0111000000	-	16	31	-38.268%	92.388%	1111000000
-	-	16	19.509%	-98.079%	1000100000	-	-	32	-19.509%	98.079%	1111100000

FUNCTIONAL DESCRIPTION (continued)

PWM Current Control

Figure 5 shows bridge current flow and PWM timing control. Each bridge has its own independent PWM current controller. The bridge current flows from its negative pole to ground through a sense pin and a sense resistor. The sense pin voltage (V_{SENSEA} or V_{SENSEB}) is proportional to the phase current and compared to the reference that is generated based on the sequencer value and V_{REF} (Table 2 and Table 3). As soon as V_{SENSEx} exceeds the V_{REFx} value, a comparator triggers the off-time and the decay sequence.

In off-time, the current first decays with a slow rate and then with a fast rate. In the slow decay portion, both low-side switches of the full-bridge are turned on, and output voltage is near zero. When 5/8 of the programmed off-time (t_{OFF_SLOW}) has expired, the polarity of the output voltage is reversed by current recirculating to start the fast decay.

Reverse voltage is generated by circulating the current through the high-side switch.

The reference voltage (V_{REF}) must be chosen based on the load peak current and the sense resistance:

$$V_{REF} = R_{SENSEx} \times I_{LOAD,\ PEAK} \tag{1}$$

The R_{SENSEx} must be small enough to avoid excessive power loss in the resistor and prevent large negative voltage peaks on the SENSEx pin caused by current recirculation. A few resistances can be paralleled to achieve the required power rating and resistance value. Note that if the selected R_{SENSEx} is too small, the accuracy and performance of the device will be degraded due to the low measurement sensitivity and influence of the noise and comparator offsets.

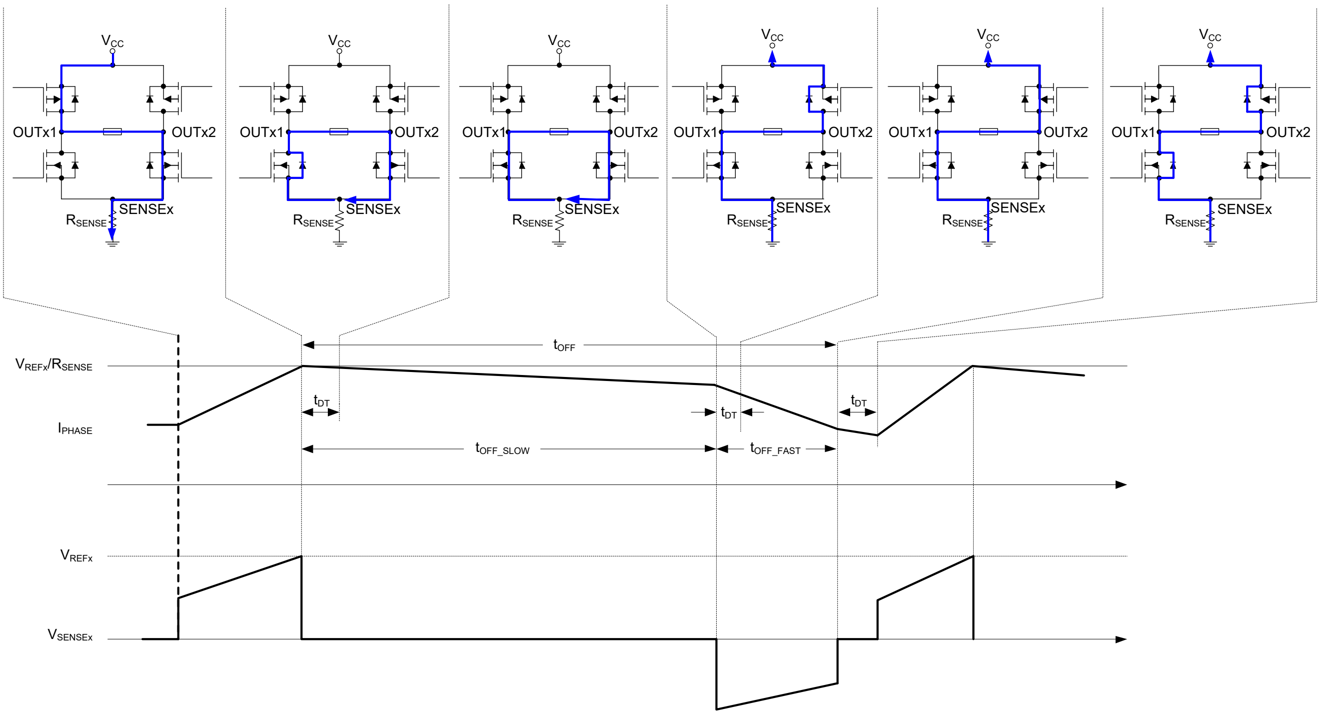


Figure 5. PWM Current Control Sequence

FUNCTIONAL DESCRIPTION (continued)

Setting PWM Off-Time

The total off-time (slow decay + fast decay) of the PWM is programmed by an external resistor (R_{OFF}) between the TOFF pin and ground, as shown in Figure 6. For stable regulation, a small series RC branch must be placed parallel to the R_{OFF} (see Table 5).

The relationship between the off-time and the external resistor value is shown in Off-Time vs. R_{OFF} curve. The value typically ranges from 10μs to 120μs.

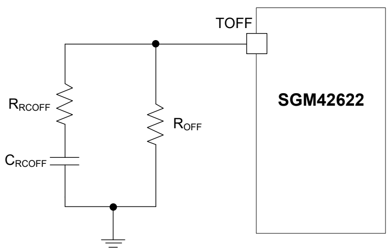


Figure 6. Programming PWM Off-Time

Table 5. Recommended R_{RCOFF} and C_{RCOFF} Values According to R_{OFF}

R_{OFF}	R_{RCOFF}	C_{RCOFF}
10kΩ ≤ R_{OFF} < 82kΩ	1kΩ	22nF
82kΩ ≤ R_{OFF} ≤ 160kΩ	2.2kΩ	22nF

Over-Current Protection (OCP)

If the current through any FET exceeds the preset over-current threshold, all FETs in the H-bridge will be disabled for a period of approximately 16ms, and the EN/nFAULT pin will be pulled low. After the period, the chip resumes operation and EN/nFAULT pin is released. Over-current conditions are sensed in both directions: that is, a short to ground, supply, or across the motor winding will all result in an over-current shutdown.

Note that over-current protection does not use the current sensing circuitry used for PWM current control and is independent of the I_{SENSE} resistor value or V_{REF} voltage.

Thermal Shutdown

If the die temperature (T_J) exceeds the maximum safe temperature threshold, a thermal shutdown event occurs. With a thermal shutdown the EN/nFAULT pin is pulled low by the internal open-drain MOSFET that disables the power stage as shown in Figure 7.

The EN/nFAULT is released when T_J returns back to the safe range ($T_J < T_{TSD} - T_{HYS}$).

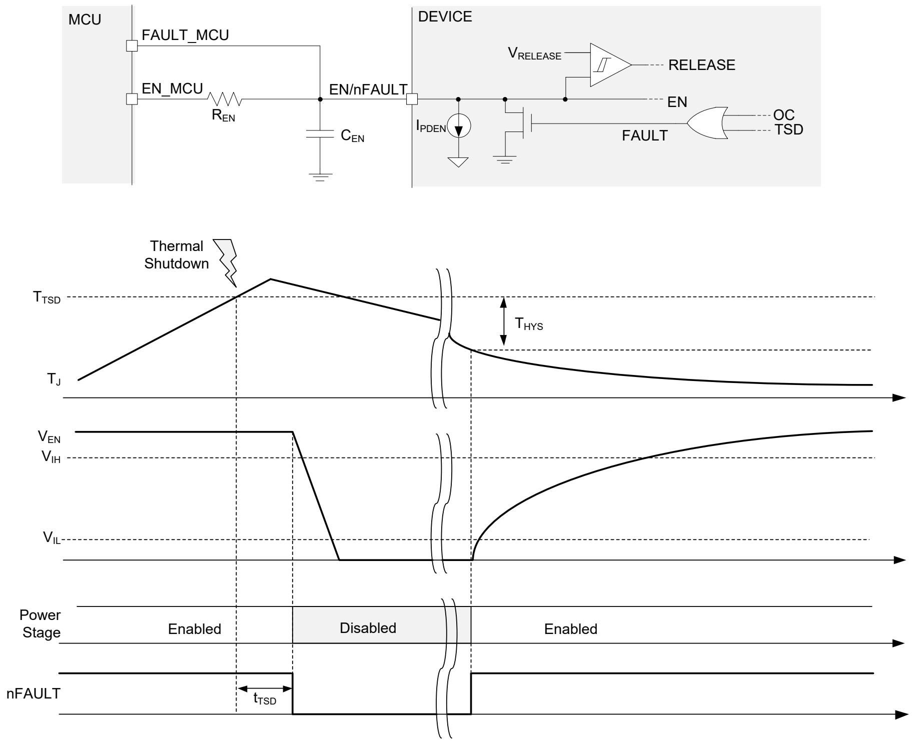


Figure 7. Thermal Shutdown in SGM42622

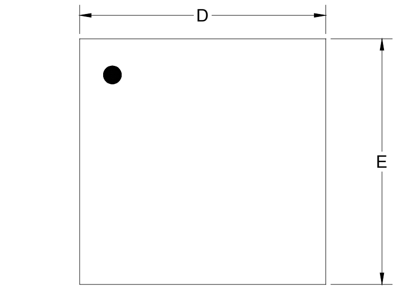
REVISION HISTORY

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

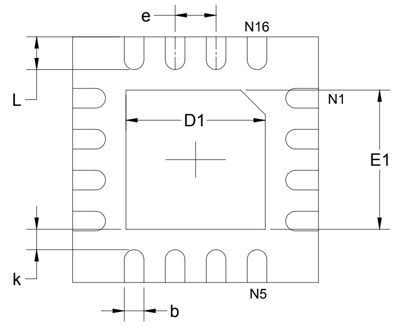
Changes from Original (DECEMBER 2020) to REV.A	Page
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

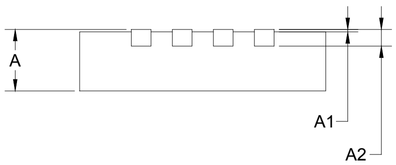
TQFN-3×3-16L



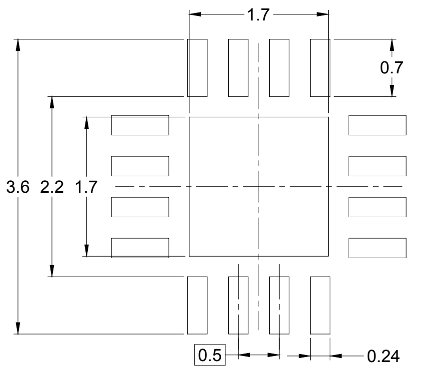
TOP VIEW



BOTTOM VIEW



SIDE VIEW

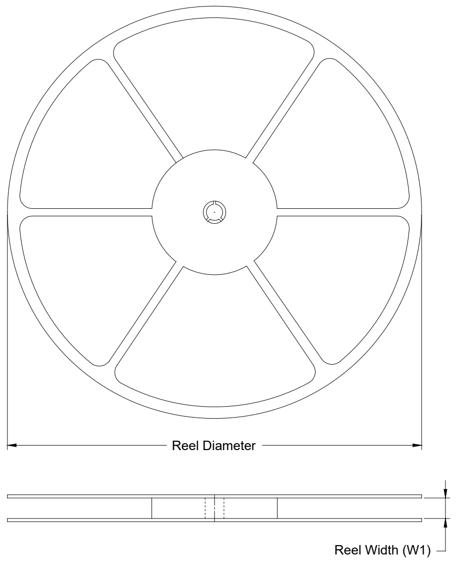


RECOMMENDED LAND PATTERN (Unit: mm)

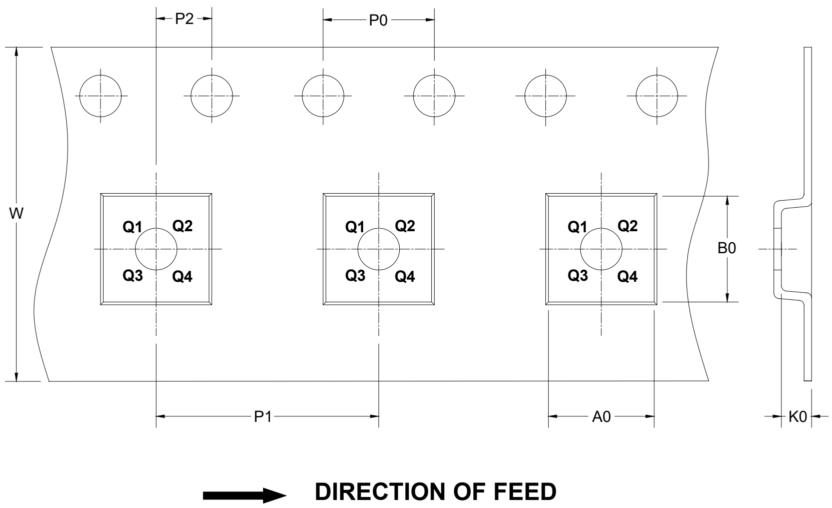
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	2.900	3.100	0.114	0.122
D1	1.600	1.800	0.063	0.071
E	2.900	3.100	0.114	0.122
E1	1.600	1.800	0.063	0.071
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.300	0.500	0.012	0.020

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



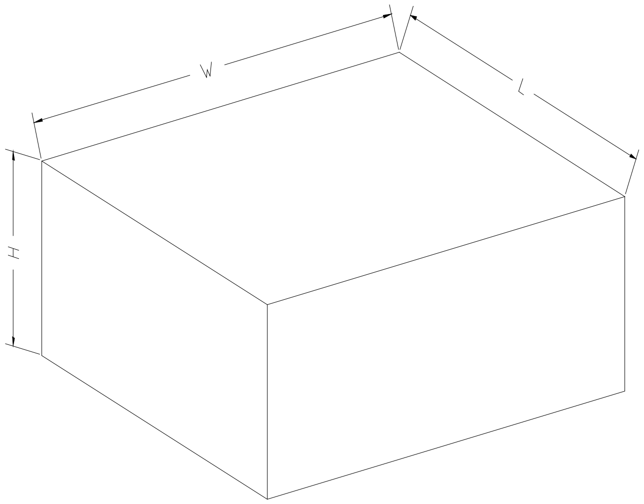
NOTE: The picture is only for reference. Please make the object as the standard.

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
TQFN-3×3-16L	13″	12.4	3.35	3.35	1.13	4.0	8.0	2.0	12.0	Q2

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