Dual H-Bridge Stepper Motor Driver

1 Features

- Dual H-Bridge Current Control Motor Driver
  - One Stepper Motor
  - Low MOSFET ON-Resistance:
    HS + LS 1.0Ω(Typical, 25°C)
- Output Current Capability (at V_M = 5V, 25°C)
  - eTSSOP Package:
    1.0A RMS, 1.2A Peak per H-Bridge
  - QFN Package:
    0.9A RMS, 1.2A Peak per H-Bridge
- Wide Power Supply Voltage: 2.5V to 10.8V
- Integrated Current Regulation
- Easy Pulse-Width-Modulation (PWM) Interface
- Protection Features
  - VM Undervoltage Lockout (UVLO)
  - Overcurrent Protection (OCP)
  - Thermal Shutdown (TSD)
  - Fault Indication Pin(nFAULT)

2 Applications

- Point-of-Sale Printers
- Video Security Cameras
- Office Automation Machines
- Gaming Machines
- Robotics
- Battery-Powered Toys

3 Description

The GD30DR3820 provides a dual-bridge stepper motor driver solution for cameras, printers, toys, robotics and other mechatronic applications.

The device has two H-bridge drivers, drive a bipolar stepper motor. The output driver block consists of N-channel power MOSFETs configured as an H-bridge to drive the motor winding. An internal charge pump generates gate drive voltages.

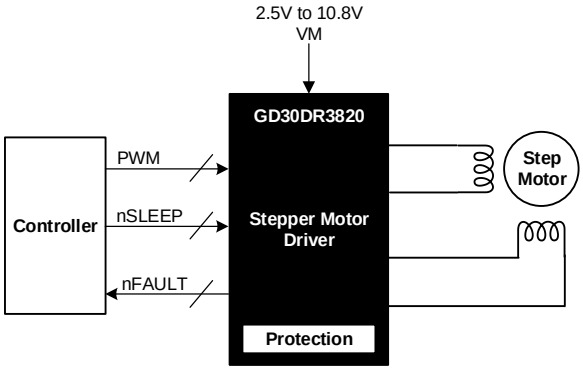
The GD30DR3820 device has two PWM(IN/IN) input interface. Internal shutdown functions with a fault output pin are provided for overcurrent protection, short circuit protection, undervoltage lockout, and overtemperature. In addition, GD30DR3820 also supports low-power sleep mode.

The GD30DR3820 is packaged in a 16-pin eTSSOP and 16-pin QFN package.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
GD30DR3820	eTSSOP (16)	5.00 mm × 6.40 mm
	QFN (16)	3.00 mm × 3.00 mm

1. For packaging details, see *Package Information* section.



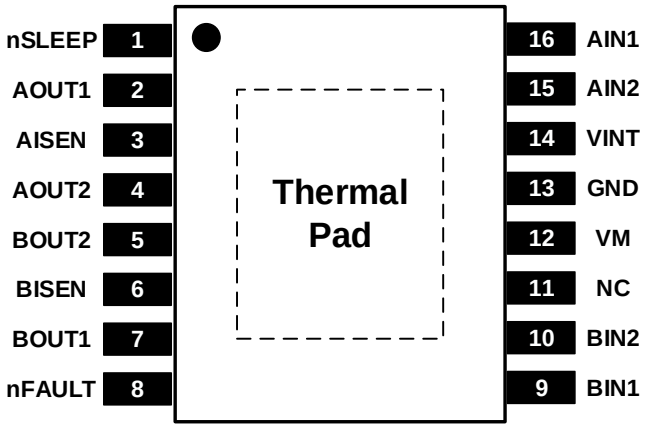
Simplified Application Schematic

Table of Contents

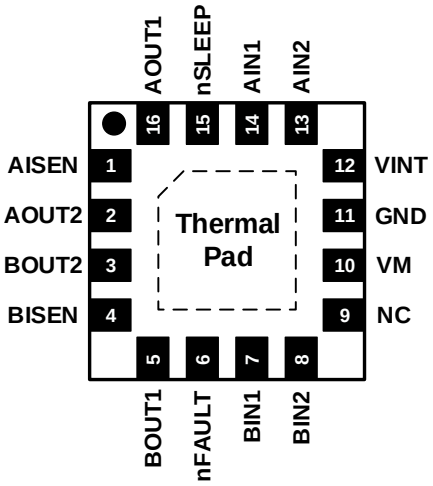
4 Device Overview

4.1 Pinout and Pin Assignment

eTSSOP
(Top View)



QFN 16
(Top View)



4.2 Pin Description

PIN NUMBER			PIN TYPE[1]	FUNCTION
NAME	eTSSOP	QFN		
nSLEEP	1	15	I	Sleep mode input. Logic high to enable device; Logic low to enter low-power sleep mode and reset all internal logic; Internal pulldown.
AOUT1	2	16	O	Bridge A output 1. Connect to motor winding A.
AISEN	3	1	I/O	Bridge A ground or Isense. Connect to current sense resistor for bridge A or GND if current control not needed.
AOUT2	4	2	O	Bridge A output 2. Connect to motor winding A.
BOUT2	5	3	O	Bridge B output 2. Connect to motor winding B.
BISEN	6	4	I/O	Bridge B ground or Isense. Connect to current sense resistor for bridge B or GND if current control not needed.
BOUT1	7	5	O	Bridge B output 1. Connect to motor winding B.
nFAULT	8	6	OD	Fault output. Logic low when in fault condition (overtemperature, overcurrent,undervoltage lockout).
BIN1	9	7	I	Bridge B input 1. Controls the state of BOUT1. Internal pulldown.
BIN2	10	8	I	Bridge B input 2. Controls the state of BOUT2. Internal pulldown.
NC	11	9		No connection pin.
VM	12	10	P	Power supply. Connect to motor supply. A 10μF(minimum) ceramic bypass capacitor to GND is recommended.
GND	13	11	P	Device ground. This pin must be connected to the PCB ground.

PIN NUMBER			PIN TYPE[1]	FUNCTION
NAME	eTSSOP	QFN		
VINT	14	12	P	Internal regulator. Bypass to GND with a 2.2μF, 6.3V capacitor.
AIN2	15	13	I	Bridge A input 2. Controls the state of AOUT2. Internal pulldown.
AIN1	16	14	I	Bridge A input 1. Controls the state of AOUT1. Internal pulldown.
GND	Thermal	Thermal	P	Power ground, connect to board ground, use large ground plane for good thermal dissipation, and multiple nearby vias connecting those planes.

1. I = input, O = output, I/O= input/output, OD =open drain, P = power.

5 Parameter Information

5.1 Absolute Maximum Ratings

Exceeding the operating temperature range (unless otherwise noted)[1,2]

SYMBOL	PARAMETER	MIN	MAX	UNIT
VM	Power supply voltage	−0.3	12	V
VINT	Internal regulator	−0.3	3.8	V
	Logic input pin voltage	−0.5	7.0	V
	Peak motor drive output current	Internally limited		A
T_J	Operating junction temperature	−40	150	°C
T_{stg}	Storage temperature	−60	150	°C

1. Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
2. All voltage values are with respect to network ground terminal.

5.2 Recommended Operation Conditions

SYMBOL[1,2]	PARAMETER		MIN	TYP	MAX	UNIT
VM	Motor power supply voltage[3]		2.5		10.8	V
V_{LOGIC}	Logic level input voltage		0		5.5	V
I_{RMS}	Motor RMS current[4]	eTSSOP16 Package	0		1.0	A
		QFN16 Package	0		0.9	A
f_{pwm}	Externally applied PWM frequency		0		200	kHz
T_A	Operating ambient temperature[4]		−40		85	°C

1. The device is not guaranteed to function outside of its operating conditions.
2. Refer to the *Application Information* section for further information.
3. Note that when VM is below 5 V, $R_{DS(ON)}$ increases and maximum output current is reduced.
4. Power dissipation and thermal limits must be observed.

5.3 Electrical Sensitivity

SYMBOL	CONDITIONS	VALUE	UNIT
$V_{ESD(HBM)}$	Human-body model (HBM), ANSI/ESDA/JEDEC JS-001-2017[1]	±3000	V
$V_{ESD(CDM)}$	Charge-device model (CDM), ANSI/ESDA/JEDEC JS-002-2022[2]	±1500	V

1. JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
2. JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

5.4 Electrical Characteristics

T_A = 25°C, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLY (VM, VINT)						
VM	VM operating voltage		2.5		10.8	V
I_{VM}	VM operating supply current	V_M=5V, xINx low, nSLEEP high		0.6	1.0	mA
I_{VMQ}	VM sleep mode supply current	V_M=5V, nSLEEP low		30	95	nA
t_{sleep}	Sleep time	nSLEEP low to sleep mode		10		μs
t_{wake}	Wake-up time	nSLEEP high to output transition		155		μs
t_{on}	Turn-on time	V_M> V_{UVLO} to output transition		25		μs
VINT	Internal regulator voltage	V_M = 5V	3.2	3.5	3.8	V
V_{UVLO}	VM undervoltage lockout voltage	V_M rising			2.5	V
		V_M falling			2.4	V
LOGIC-LEVEL INPUTS (AIN1, AIN2, BIN1, BIN2, nSLEEP)						
V_{IL}	Input low voltage	xINx	0		0.7	V
		nSLEEP	0		0.5	V
V_{EN_FALL}	Input high voltage	xINx	1.8		5.5	V
		nSLEEP	2.3		5.5	V
V_{HYS}	Input logic hysteresis		200	300	500	mV
I_{IL}	Input low current	VIN = 0	−5		5	μA
I_{IH}	Input high current	VIN = 5V			50	μA
R_{PD}	Pulldown resistance			100		KΩ
t_{DEG}	Input deglitch time				600	ns
T_{PROP}	Propagation delay INx to OUTx	V_M = 5V			1.2	μs
CONTROL OUTPUT (nFAULT)						
V_{OL}	Output logic low voltage	I_O = 5mA			0.1	V
I_{OH}	Output logic high leakage	V_O = 3.3V	−1		1	μA
MOTOR DRIVER OUTPUTS(AOUT1, AOUT2, BOUT1, BOUT2)						
$R_{DS(ON)}$	High-side FET on resistance	V_M = 5V, I_O = 0.2A, T_J = -40°C[1]		400		mΩ
		V_M = 5V, I_O = 0.2A, T_J = 20°C		550		mΩ
		V_M = 5V, I_O = 0.2A, T_J = 85°C[1]		650		mΩ
		V_M = 2.7V, I_O = 0.2A, T_J = -40°C[1]		650		mΩ
		V_M = 2.7V, I_O = 0.2A, T_J =25°C		800		mΩ
		V_M = 2.7V, I_O = 0.2A, T_J = 85°C[1]		900		mΩ
	Low-side FET on resistance	V_M = 5V, I_O = 0.2A, T_J = -40°C[1]		350		mΩ
		V_M = 5V, I_O = 0.2A, T_J = 20°C		450		mΩ
		V_M = 5V, I_O = 0.2A, T_J = 85°C[1]		550		mΩ
		V_M = 2.7V, I_O = 0.2A, T_J = -40°C[1]		650		mΩ

Electrical Characteristics(continued)

T_A = 25°C (unless otherwise noted).

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
$R_{DS(ON)}$	Low-side FET on resistance	V_M = 2.7V, I_O = 0.2A, T_J =25°C		800		mΩ
		V_M = 2.7V, I_O = 0.2A, T_J = 85°C[1]		900		mΩ
I_{OFF}	OFF-state leakage current	V_M = 5V	−1		1	μA
t_{RISE}	Output rise time	V_M = 5V, 16Ω to GND, 10% to 90%VM		70		ns
t_{FALL}	Output fall time	V_M = 5V, 16Ω to GND, 10% to 90%VM		80		ns
T_{DEAD}	Dead time[2]	V_M = 5V		450		ns
PWM CURRENT CONTROL (AISEN, BISEN)						
V_{TRIP}	xISEN trip voltage		160	200	240	mV
t_{OFF}	Current control constant off time	Internal PWM constant off time		23		μs
PROTECTION CIRCUITS						
I_{OCP}	Overcurrent protection trip level		1.2			A
t_{DEG}	Overcurrent de-glitch time			1		μs
t_{OCR}	Overcurrent protection retry time			1.4		ms
T_{TSD}[1]	Thermal shutdown temperature		150			°C
T_{HYS}	Thermal shutdown hysteresis			20		°C

1. Not tested in production; based on design and characterization data.
2. Internal dead time. External implementation is not necessary.

6 Functional Description

6.1 Block Diagram

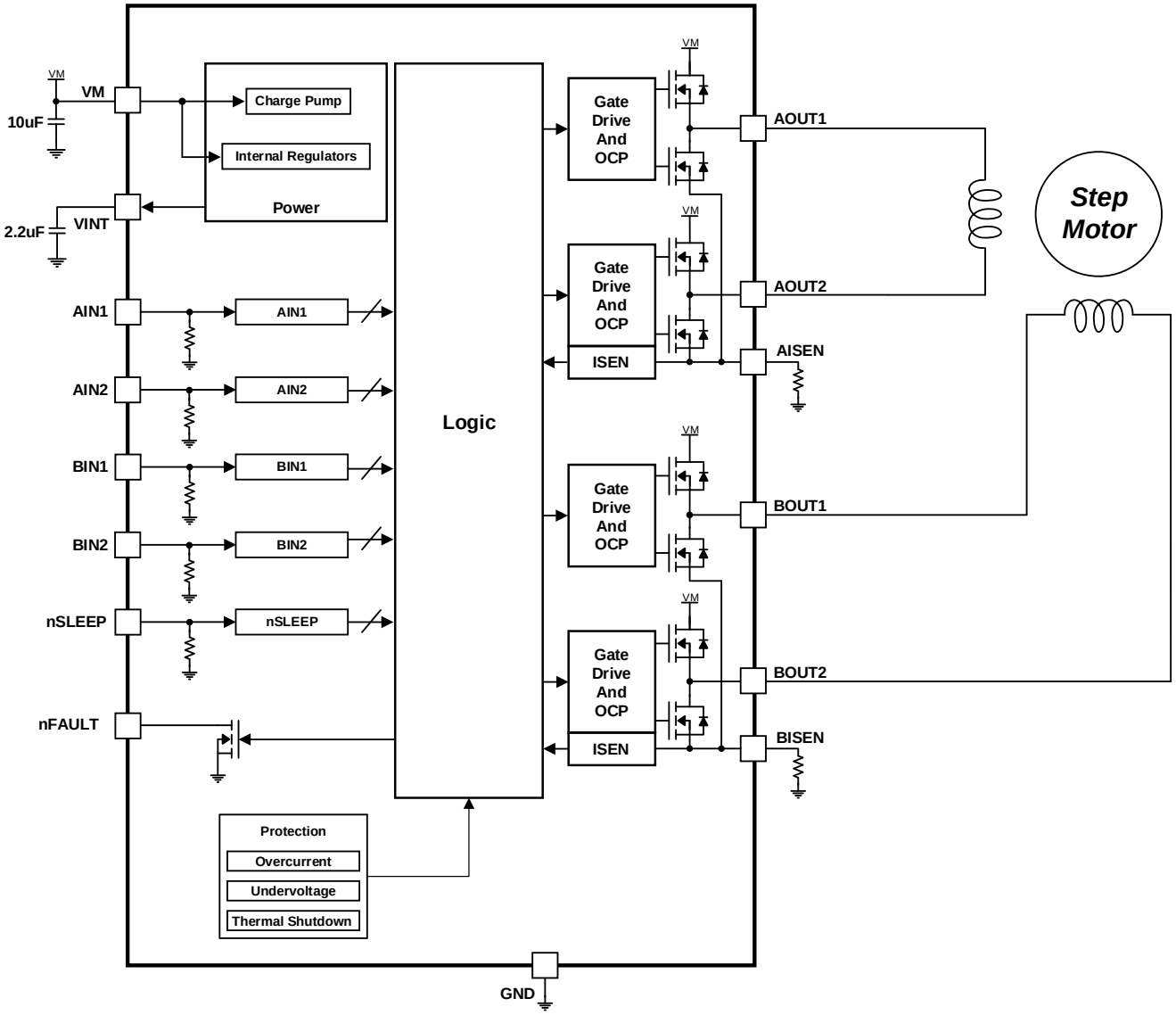


Figure 1. GD30DR3820 Functional Block Diagram

6.2 Operation

The GD30DR3820 device is an integrated motor driver solution for bipolar stepper motors. The device integrates two NMOS + NMOS H-bridges and current regulation circuitry. The GD30DR3820 can be powered with a supply voltage from 2.5V to 10.8V and can provide an output current up to 1.0A RMS.

A simple PWM interface allows easy interfacing to the controller circuit. The current regulation is a 23μs fixed off-time slow decay. The device includes a low-power sleep mode, which lets the system save power when not driving the motor.

6.2.1 PWM Motor Drivers

The GD30DR3820 contains drivers for two full H-bridges. The circuit block diagram is shown in Figure 2.

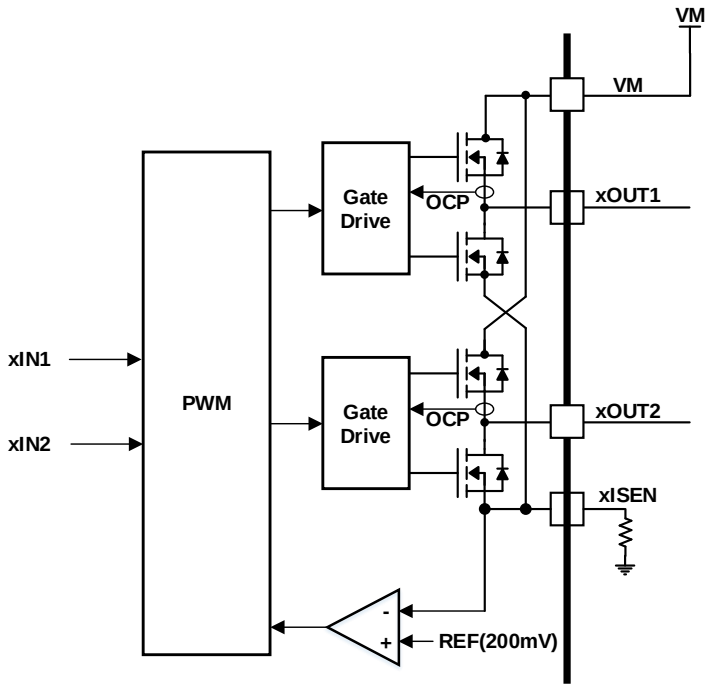


Figure 2. Motor Contorl Circuitry

6.2.2 Bridge Control and Decay Modes

Each H-Bridge has independent control pins and output pins, where AIN1 and AIN2 control the outputs of AOUT1 and AOUT2. Similarly, the BIN1 and BIN2 control the outputs of BOUT1 and BOUT2. The control logic is shown in Table 1.

Table 1. H-Bridge Control

xIN1	xIN2	xOUT1	xOUT2	FUNCTION
0	0	Z	Z	Coast/fast decay
0	1	L	H	Reverse
1	0	H	L	Forward
1	1	L	L	Brake/slow decay

When the input signal is PWM, the speed of the motor can be justed. Since there is inductance in the motor winding, and the inductance has the characteristic that the current cannot mutate, when the drive current is interrupted, the current will find a way to continue flowing. The H-bridge provides two paths for current freewheeling. One is to disable the H-bridge and allow the current to flow through the body diode of the FET. This method is called fast decay mode. The other is to short-circuit the motor windings, which is called slow decay mode.

In summary, when one input pin is a PWM signal and the other pin is a low-level signal, it is fast decay mode. When the other pin is high-level signal, it is slow decay mode. See Table 2 for more information.

Table 2. H-Bridge PWM Control

xIN1	xIN2	FUNCTION
PWM	0	Forward PWM, fast decay
1	PWM	Forward PWM, low decay
0	PWM	Reverse PWM, fast decay
PWM	1	Reverse PWM, low decay

When disabling current control, the xISEN pin should be connected directly to ground.

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

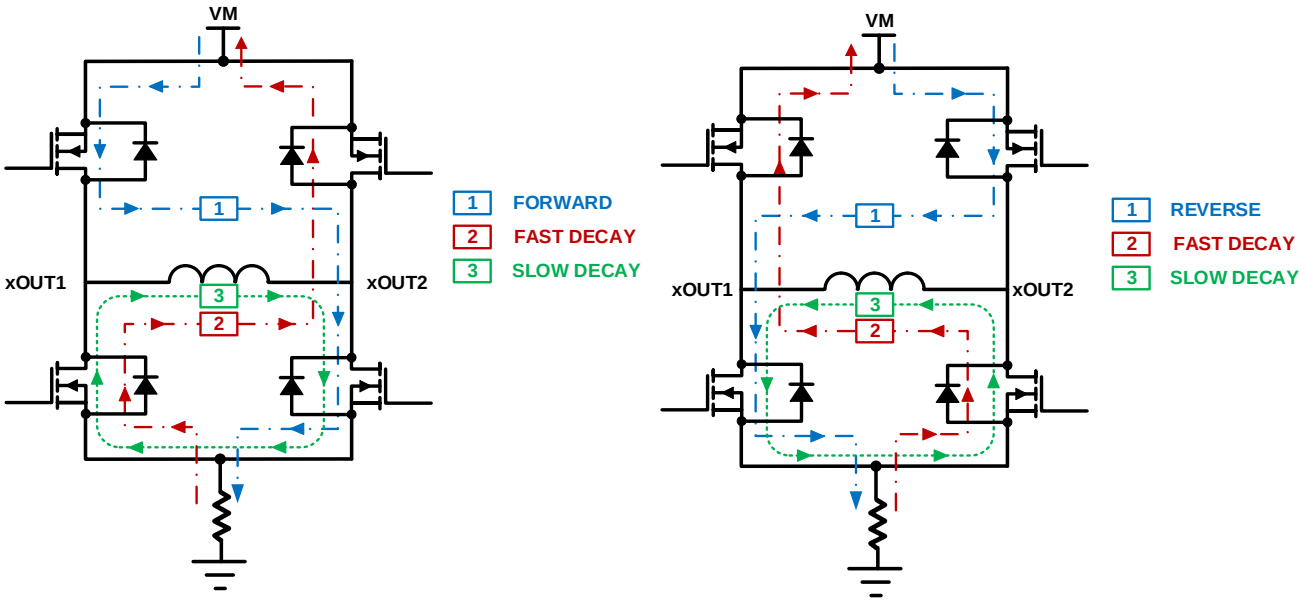


Figure 3. The driver outputs and current path

6.2.3 Current Control

The current on the motor winding can be adjusted by PWM with a certain frequency. This function can prevent excessive current from causing permanent damage to the device when the stepper motor is started or blocked.

The speed of the motor current climb depends on the voltage and winding inductance across the winding. When the device is operated with a motor, if the motor current reaches the set threshold, the H-bridge will be disabled before the next drive cycle starts. After the current is enabled, the voltage monitoring function on the xISEN pin is

enabled after a fixed blanking time.

The trip current threshold is set by a comparator that compares the voltage on the xISEN pin to an internal reference voltage(fixed at 200mv).

The tripping current is calculated as in Equation(1):

$$I_{TRIP} = \frac{200mV}{R_{xISEN}} \quad (1)$$

where: If the xISEN pin is connected to GND through a 400mΩ resistor, then the trip current will be 200mV / 400mΩ = 500mA.

NOTE: If current control is not needed, the xISEN pins should be connected directly to ground.

6.2.4 Decay Mode

When the motor current reaches the set threshold current, the H-bridge will enter the slow decay mode and re-enable the H-bridge according to the status of the input signal after a fixed period of time(23us).

6.2.5 Slow Decay

In slow-decay mode, the high-side MOSFETs are turned off, while both of the low-side MOSFETs are turned on. The motor current flowing in the two-side MOSFETs will be decreased until the fixed off time is reached (typically 23μs). Afterwards, in order to increase the winding current again, the MOSFETs on the high-side are enabled.

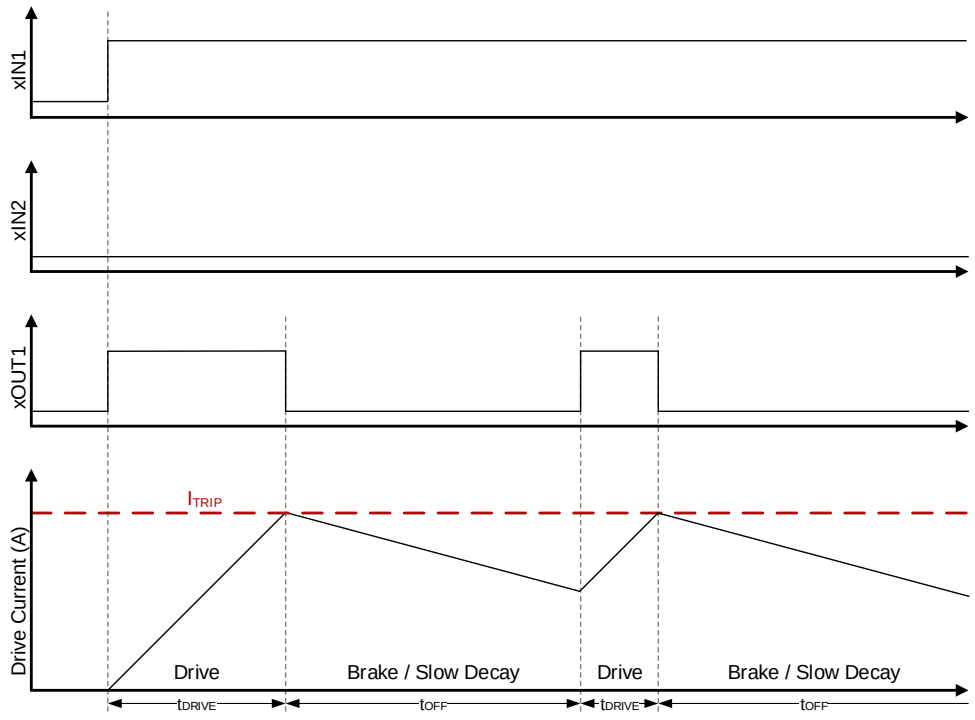


Figure 4. Slow Current Decay

6.2.6 Sleep Mode

Pulling down the nSLEEP puts the device into a low-power sleep state. In this state, the H-bridges are disabled, all internal logic is reset, all internal clocks stop working, and all inputs fail until nSLEEP is pulled up and activated. It takes some time, t_{WAKE}(typically 155μs), from exit sleep mode to the motor driver becomes fully operational.

6.2.7 Protection Circuits

The GD30DR3820 is provided with overcurrent protection, overtemperature protection, and undervoltage protection functions.

6.2.7.1 VM undervoltage lockout(UVLO)

When the voltage of the VM pin is below the threshold voltage (V_{UVLO}), all circuits fail and all internal logic resets. The device returns to normal when the voltage of the VM pin rises above the threshold voltage (V_{UVLO}).

6.2.7.2 Thermal shutdown (TSD)

Once the die temperature exceeds the safe limits, all MOSFETs in the H-bridge will be disabled, and the nFAULT pin will also be driven low until the die temperature drops below the specified hysteresis (T_{HYS}). When the operation resumes, the nFAULT pin will be released.

6.2.7.3 Overcurrent protection (OCP)

Each FET has an analog current limit (I_{OCP}) circuit to limit the current through the FET, which will be realized by limiting the gate drive. All FETs in the H-bridge will be disabled and the nFAULT pin will be driven low if the analog current limiting duration exceeds the OCP deglitch time (t_{DEG}). After the OCP retry period (t_{OCP}), the driver will be re-enabled, and after the retry time, the nFAULT pin will be driven high. If the fault still exists, repeat the above operation. If the fault is eliminated, the normal operation will resum, and the nFAULT pin will remain deserted. Note that only the H-bridge that detect OCP will be disabled while other bridges work properly.

Short circuit to ground, supply, or across the motor winding will cause overcurrent shutdown, and overcurrent conditions are independently detected on both high-side and low-side devices. Please note that overcurrent protection does not use current detections circuit for PWM current control, so it can work even without xISEN resistors.

Table 3. Fault Conditions Summary

FAULT	CONDITION	ERROR REPORT	H-BRIDGE	INTERNAL CIRCUIT	RECOVERY
VM undervoltage (UVLO)	V_M < 2.4V	None	Disabled	Disabled	V_M > 2.5V
Overcurrent(OCP)	I_{OUT} > I_{OCP}	FAULTn	Disabled	Operating	OCP
Thermal Shutdown (TSD)	T_J > T_{TSD}	FAULTn	Disabled	Operating	T_J < T_{TSD} – T_{HYS}

6.3 Device Functional Modes

6.3.1 Device Enable

When the nSLEEP pin switches from high level to low level, after a period of time(t_{SLEEP}=10μs), GD30DR3820 will enter sleep mode, and in this mode, the H-bridge will be in a disabled state(Hi-Z).

When the nSLEEP pin switches from low level to high level, The GD30DR3820 will automatically exit the sleep mode and enter the active mode after t_{WAKE}(155μs).

Table 4. Modes of Operation

OPERATING MODE	CONDITION	H-BRIDGE	INTERNAL CIRCUIT
Operating	nSLEEP high	Operating	Operating
Sleep mode	nSLEEP low	Disabled	Disabled
Fault encountered	Any fault condition met	Disabled	See Table 3

7 Application Information

The GD30DR3820 is typically used to drive a bipolar stepper motor.

7.1 Typical Application Circuit

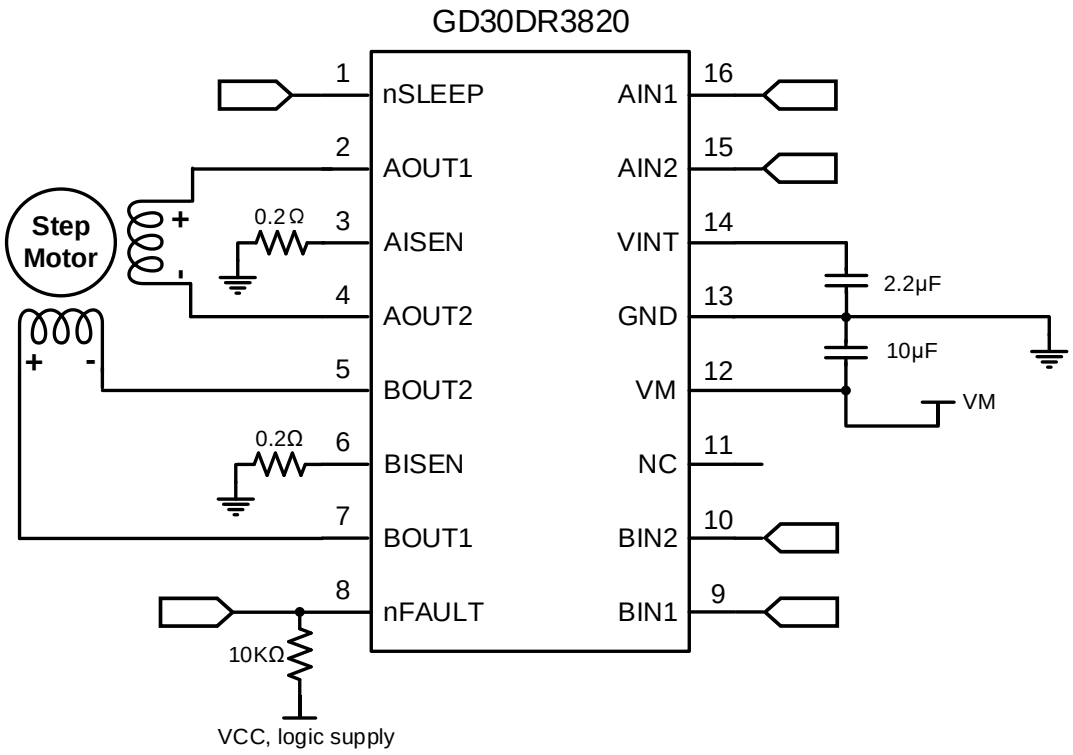


Figure 5. Schematic of GD30DR3820 Application

7.2 Design Example

For this design example, use the parameters in Table 5.

Table 5. Design Parameters

PARAMETER	EXAMPLE VALUE
Motor Supply Voltage	5V
Logic Supply Voltage	3.3V
Target RMS Current	0.5A

7.3 Detailed Design Description

7.3.1 Motor Voltage

The motor voltage to use will depend on the ratings of the motor selected and the desired RPM. A higher voltage spins a bipolar stepper motor faster with the same PWM duty cycle applied to the power FETs. A higher voltage also increases the rate of current change through the inductive motor windings.

7.3.2 Motor Current Trip Point

When the voltage on pin xISEN exceeds V_{REF} (0.2V), current regulation is activated. The R_{SENSE} resistor connected from xISEN to ground, according to the Equation(1) to set the desired I_{TRIP} level.

7.3.3 Sense Resistor

To ensure optimal performance, it is important for the sense resistor to be:

- Surface-mount
- Rated power meets the requirements
- Low Inductance
- Placed as close as to the motor driver pin

The power dissipated by the sense resistor can be calculated using $(I_{RMS})^2 \times R$. For example, if peak motor current is 0.8A, RMS motor current is 0.5A, and a 0.2Ω sense resistor is used, the resistor dissipates $0.5A^2 \times 0.2\Omega$ = 0.05W. The power rapidly increases with higher current levels.

Resistors generally have a rated power within a specific range of ambient temperature and a reduced power curve at high ambient temperatures. When the PCB is shared with other components generating heat, the system designer should increase the margin. It is always best to measure the actual sense resistor temperature in a final system.

Power resistors are larger and more expensive than standard resistors, and it is common to use multiple standard resistors in parallel between the sense node and ground to distributes the current and heat dissipation.

7.4 Power Dissipation

Power dissipation in the GD30DR3820 is dominated by the power dissipated in the output FET resistance, or $R_{DS(on)}$. The DC power dissipation of one H-bridge can be roughly estimated by Equation(2).

$$P_D \approx I_{RMS}^{\ 2} \times \left(R_{HS\_DS(ON)} + R_{LS\_DS(ON)}\right) \quad (2)$$

where

- P_D is the device power dissipation
- $R_{HS\_DS(ON)}$ is the resistance of the high-side FET
- $R_{LS\_DS(ON)}$ is the resistance of the low-side FET
- I_{RMS} is the RMS or DC output current being supplied to the load

The maximum amount of power that can be dissipated in the device is dependent on ambient temperature and heatsinking.

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

7.5 Typical Application Curves

T_A = 25°C, unless otherwise noted.

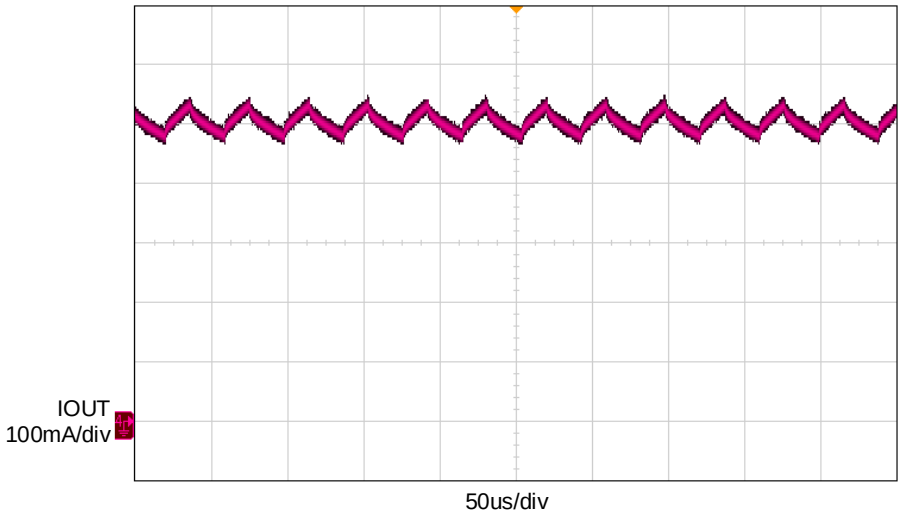


Figure 6. Current Regulation

8 Layout Guidelines and Example

8.1 Layout Guidelines

Low ESR ceramic capacitors should be utilized for the VM to GND bypass capacitors. 10μF X5R or X7R types are recommended. These capacitors should be placed as close to the VM pins as possible with a thick trace or ground plane connection to the device GND pin.

In addition, bulk capacitor is required on the VM pin. This bulk capacitor can be ceramic or electrolytic type, but should also be placed as close as possible to the VM pin to minimize the loop inductance.

The high-current device outputs should use wide metal trace, and numerous vias should be used when connecting PCB layers.

Bypass VINT to ground with a 2.2μF ceramic capacitor rated 6.3V. Place this bypass capacitor as close to the pin as possible.

8.2 Layout Example

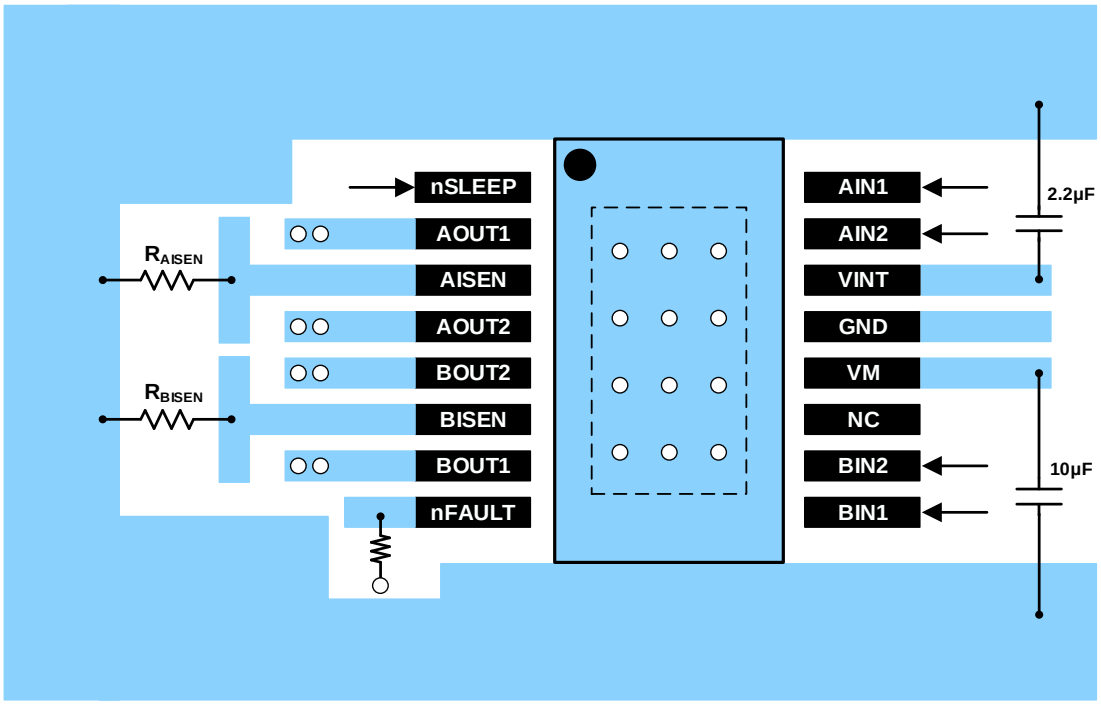
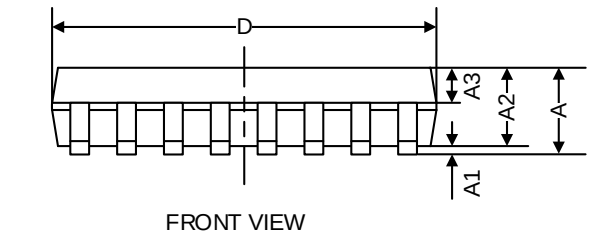


Figure 7. Typical Layout Example

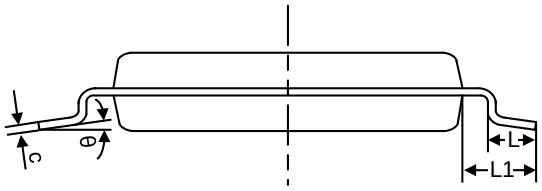
9 Package Information

9.1 Outline Dimensions

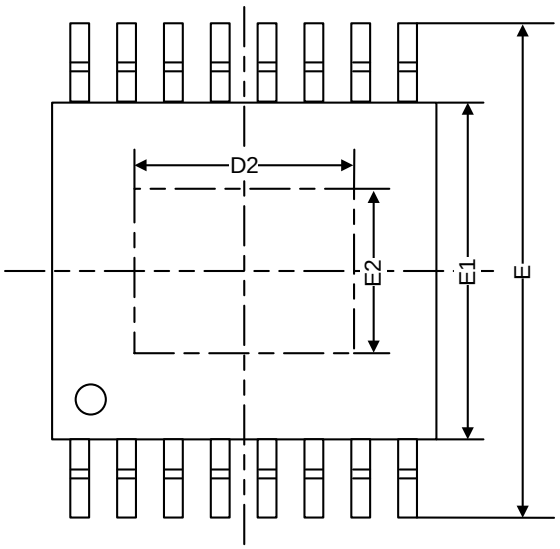
eTSSOP16 Package Outline



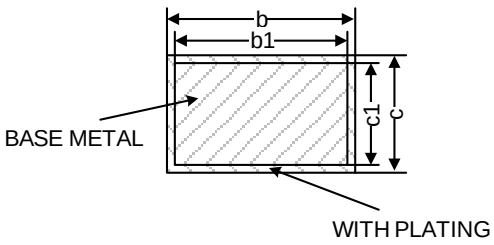
FRONT VIEW



SIDE VIEW



TOP VIEW



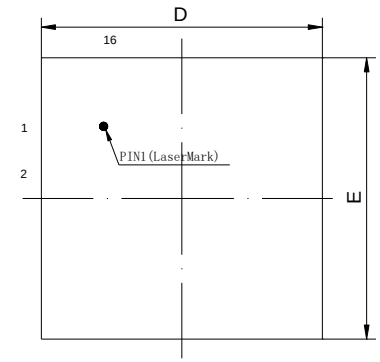
NOTES:

1. All dimensions are in millimeters.
2. Package dimensions does not include mold flash, protrusions, or gate burrs.
3. Refer to the Table 6 *eTSSOP16 dimensions(mm)*.

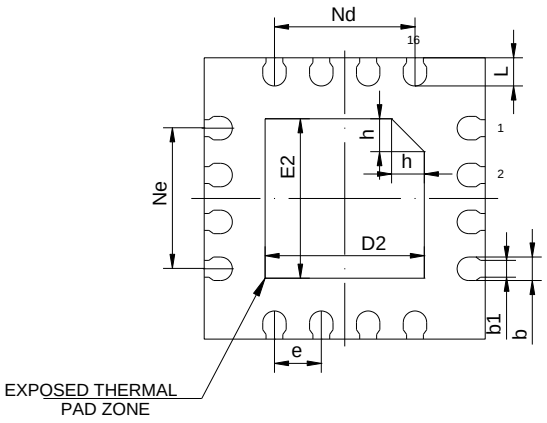
Table 6. eTSSOP16 dimensions(mm)

SYMBOL	MIN	NOM	MAX
A			1.2
A1	0.05		0.15
A2	0.90	1.00	1.05
A3	0.39	0.44	0.49
b	0.20		0.28
b1	0.19	0.22	0.25
c	0.13		0.17
c1	0.12	0.13	0.14
D	4.90	5.00	5.10
E	6.20	6.40	6.60
E1	4.30	4.40	4.50
e	0.65 BSC		
L	0.45		0.75
L1	1.00 BSC		
θ	0°		8°
D2	2.80 REF (L/F Size = 91 * 118)		
E2	2.10 REF (L/F Size = 91 * 118)		

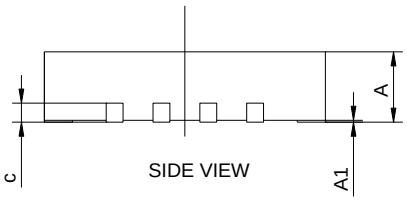
QFN16 Package Outline



TOP VIEW



BOTTOM VIEW



SIDE VIEW

NOTES: (continued)

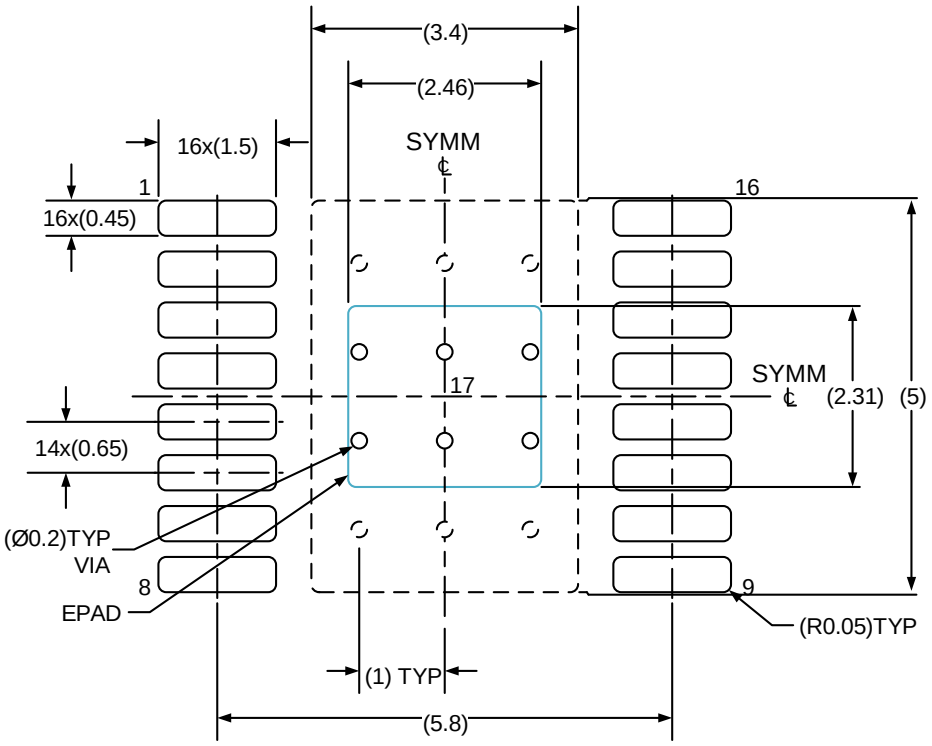
1. Refer to the Table 7 *QFN16 dimensions(mm).*

Table 7. QFN16 dimensions(mm)

SYMBOL	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	0	0.02	0.05
b	0.18	0.25	0.30
b1	0.18 REF		
c	0.18 REF		
D	2.90	3.00	3.10
D2	1.60	1.70	1.80
e	0.50 BSC		
Ne	1.50 BSC		
Nd	1.50 BSC		
E	2.90	3.00	3.10
E2	1.60	1.70	1.80
L	0.25	0.30	0.35
h	0.30	0.35	0.40

9.2 Recommended Land Pattern

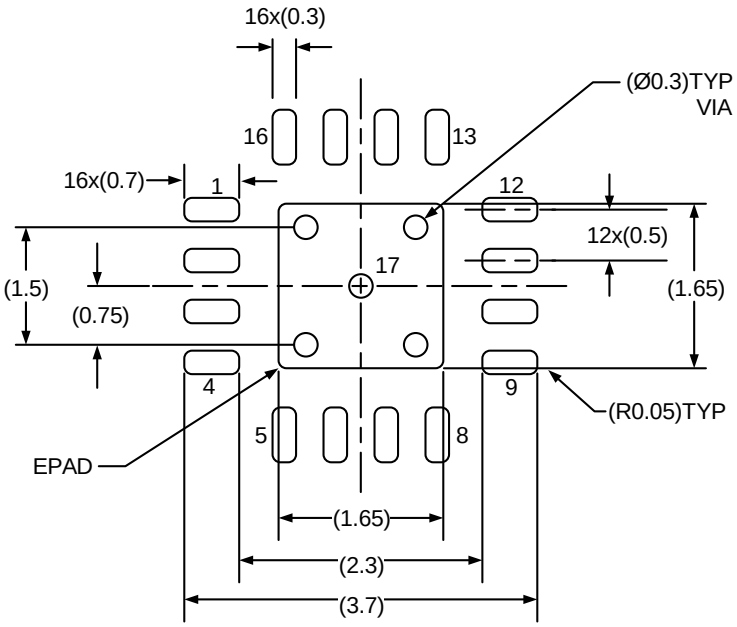
eTSSOP16 Land Pattern Example



NOTES: (continued)

1. Refer to the IPC-7351 can also help you complete the designs.
2. Explosed metal shown.
3. Drawing is 10X scale.

QFN16 Land Pattern Example



NOTES: (continued)

1. Refer to the IPC-7351 can also help you complete the designs.
2. Exposed metal shown.
3. Drawing is 10X scale.

10 Ordering Information

Ordering Code	Package Type	ECO Plan	Packing Type	MOQ	OP Temp(°C)
GD30DR3820LPTR-K	eTSSOP16	Green	Tape & Reel	3000	−40°C to +85°C
GD30DR3820LUTR-K	QFN16	Green	Tape & Reel	3000	−40°C to +85°C

11 Revision History

REVISION NUMBER	DESCRIPTION	DATE
1.0	Initial release and device details	October 26, 2023
1.1	Delete parallel mode, only supports stepper motor.	January 30, 2024
1.2	Modify QFN16 recommended land pattern.	July 2, 2025

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