Single-Phase DC Fan Pre-Driver

Features

- **Speed Controllable by CMD (DC / PWM) Input**
- **Adjustable Speed curve (XP1 / YP1 / YMD / XP2)**
- **PWM Soft Switching**
- **Adjustable Leading Angle and Auto-off Function**
- **Adjustable current limit startup level**
- **Adjustable Soft-start time**
- **SO Speed Output (4pole / 8pole / RD)**
- **Adjustable Lock off Time and Automatic Restart**
- **Over Current Protection**
- **Low I_Q Function**
- **TQFN4X4-24 Package**

General Description

M8420 is pre-driver IC designed for single phase H-bridge motor that is composed of external MOS FET. It's suitable for cooler DC fan that needs silent drivers, and it has auto dead-zone function that can reduce power dissipation.

Applications

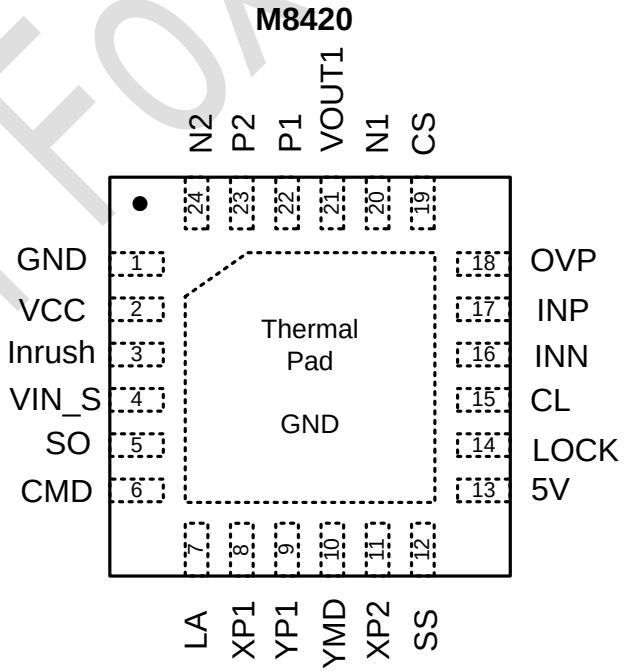
- **Cooling fan**

Ordering Information

ORDER NUMBER	MARKING	TEMP. RANGE	PACKAGE (Green)
M8420SR51U	8420	-40°C to +105°C	TQFN4X4-24

Note: R5: TQFN4X4-24
1: Bonding Code
U: Tape & Reel
Green : Lead Free / Halogen Free

Pin Configuration

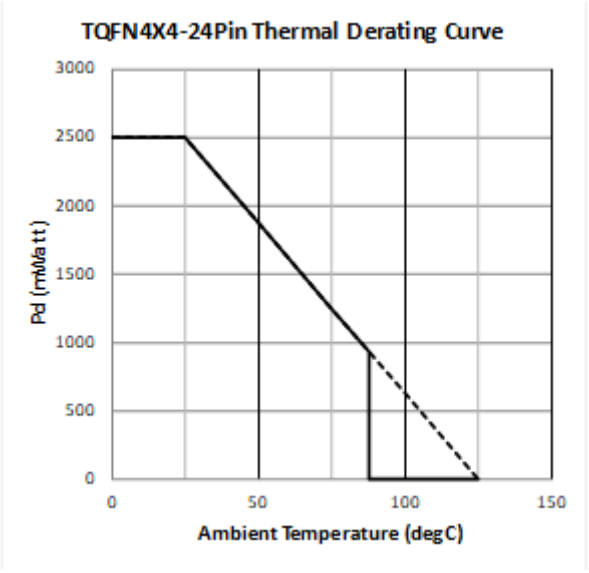


TQFN4X4-24

Note : Recommend connecting the Thermal Pad to the Ground for excellent power dissipation.

Absolute Maximum Ratings

VCC to GND . . . . . -0.3V to 18V
5VREG to GND . . . . . -0.3V to 7V
5VREG Output Source Current. 30mA
P1, P2 Output Voltage . . . . . -0.3V to VCC
N1, N2 Output Voltage . . . . . -0.3V to 7V
P1, P2 Sink Current 20mA
N1, N2 Sink and Source Current 20mA
SO Output Voltage . . . . . -0.3V to 18V
SO Output Current 10mA
CMD to GND . . . . . .-0.3V to 18V
XP1, YP1, YMD, XP2, LA, CL, SS, Lock, CS, INP, INN Pin to GND. . . . . -0.3V to 7V
VIN_S, OVP Pin to GND . . . . . -0.3V to 7V
VOUT1 Pin to GND . . . . . -0.3V to VCC
INRUSH Output Voltage . . . . . -0.3V to 7V
INRUSH Sink and Source Current 20mA
Thermal Resistance Junction to Case, (θ_{JC})
TSSOP-16 (FD) . . . . . 25°C/W
TQFN4X4-24. . . . . 20°C/W
Continuous Power Dissipation (T_A=25°C)
TSSOP-16 (FD) 1.5W
TQFN4X4-24 . . . . . .2.5W
Operating Temperature Range . . . . . -40°C to +105°C
Junction Temperature . . . . . +150°C
Storage Temperature Range . . . . . -65°C to +150°C
Reflow Temperature (soldering, 10sec) . . . . . 260°C
ESD (HBM) 4KV
ESD (MM) 200V



Note : When glass epoxy board (double layer) of 35mmx35mmX1.2mm is mounted.

Recommended Operating Conditions

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
Power Supply Voltage	V_{CC}	3.8	12	18	V
CMD PIN Input Voltage	V_{CMD}	0	---	V_{5VREG}	V
Common-Mode Hall Input Voltage Range	V_{ICM}	0.4	---	V_{5VREG}-0.4	V
XP1 PIN Input Voltage	V_{XP1}	0	---	V_{5VREG}	V
YP1 PIN Input Voltage	V_{YP1}	0	---	V_{5VREG}	V
YMD PIN Input Voltage	V_{YMD}	0	---	V_{5VREG}	V
XP2 PIN Input Voltage	V_{XP2}	0	---	V_{5VREG}	V
LA PIN Input Voltage	V_{LA}	0	---	V_{5VREG}	V
SS PIN Input Voltage	V_{SS}	0	---	V_{5VREG}	V
CL PIN Input Voltage	V_{CL}	0	---	V_{5VREG}	V
LOCK PIN Input Voltage	V_{LOCK}	0	---	V_{5VREG}	V
VIN_S PIN Input Voltage	V_{VIN}	0	---	V_{5VREG}	V
VOUT1 PIN Input Voltage	V_{VOUT1}	0	---	VCC	V
OVP PIN Input Voltage	V_{OVP}	0	---	V_{5VREG}	V
CS PIN Input Voltage	V_{CS}	0	---	V_{5VREG}	V
Operating Temperature	T_{OPR}	-40	---	100	°C

Electrical Characteristics

V_{CC}=12V; $T_A = T_J$ =25°C.

The device is not guaranteed to function outside its operating conditions. Parameters with MIN and/or MAX limits are 100% tested at +25°C, unless otherwise specified.

PARAMETER	SYMBOL	CONDITION	MIN	TYP	MAX	UNIT
Power Supply						
Operating Current	I_{VCC}		2	3	4	mA
Shutdown Current	I_Q	CMD = GND & XP1 < 2.5V	300	400	500	µA
Power on Delay						
Power ON delay Time	Ttd	VCC = 0V to 12V XP1 > 2.5V	14	20	26	ms
Power ON delay Time	Ttd	VCC = 0V to 12V XP1< 2.5V	70	100	130	ms
PWM Mode						
CMD Input Low Voltage	V_{CMDL}		0	---	0.8	V
CMD Input High Voltage	V_{CMDH}		2	---	VCC	V
CMD Pull High Voltage	V_{VPA}		3	---	5	V
CMD Pull High Current	I_{CMD}	CL < 0.15V & LOCK < 0.15V & YMD < 0.15V	15	20	30	µA
CMD Pull High Current	I_{CMD}		150	200	250	µA
CMD Input Frequency	F_{CMD}		0.1	---	50	kHz
Output Switch Frequency	F_{OUT}		55	64	75	kHz
Internal Regulator						
5V Regulator Output Voltage	V_{5VREG}	I_{5VREG} = -10mA	4.9	5	5.1	V
5V Regulator Current Limit	I_{5VOC}	V_{5VREG} = 0V	20	25	30	mA
Output Drivers						
High Side Output Low Voltage	V_{OHL}	I_{PL} = 5mA	---	0.1	0.2	V
Low Side Output High Voltage	V_{OLH}	I_{NH} = -5mA	4.7	4.8	---	V
Low Side Output Low Voltage	V_{OLL}	I_{NL} = 5mA	---	0.1	0.2	V
SO Low Voltage	V_{SOL}	I_{SO} = 5mA	---	0.2	0.3	V
SO Off Leakage Current	I_{SOL}	V_{SO} = 12V	---	2	4	µA
INRUSH High Voltage	V_{INRH}	I_{INR} = -1mA	4.1	4.5	---	V
INRUSH Low Voltage	V_{INRL}	I_{INR} = 5mA	---	0.2	0.3	V
Current Protection						
Current Limit Sense Voltage	V_{LIM}	Normal		160		mV
Over current protection Voltage	V_{OC}			180		mV
Lock Protection						
Re-start Time	T_{on}		0.5	0.75	1	Sec
Lock Mode Time	T_{off}	Lock = 5V	3.5	5	6.5	Sec
Thermal Protection						
Thermal Protection Temp.	T_{TSD}		---	165	---	°C
Thermal Protection Hysteresis	T_{HYS}		---	30	---	°C

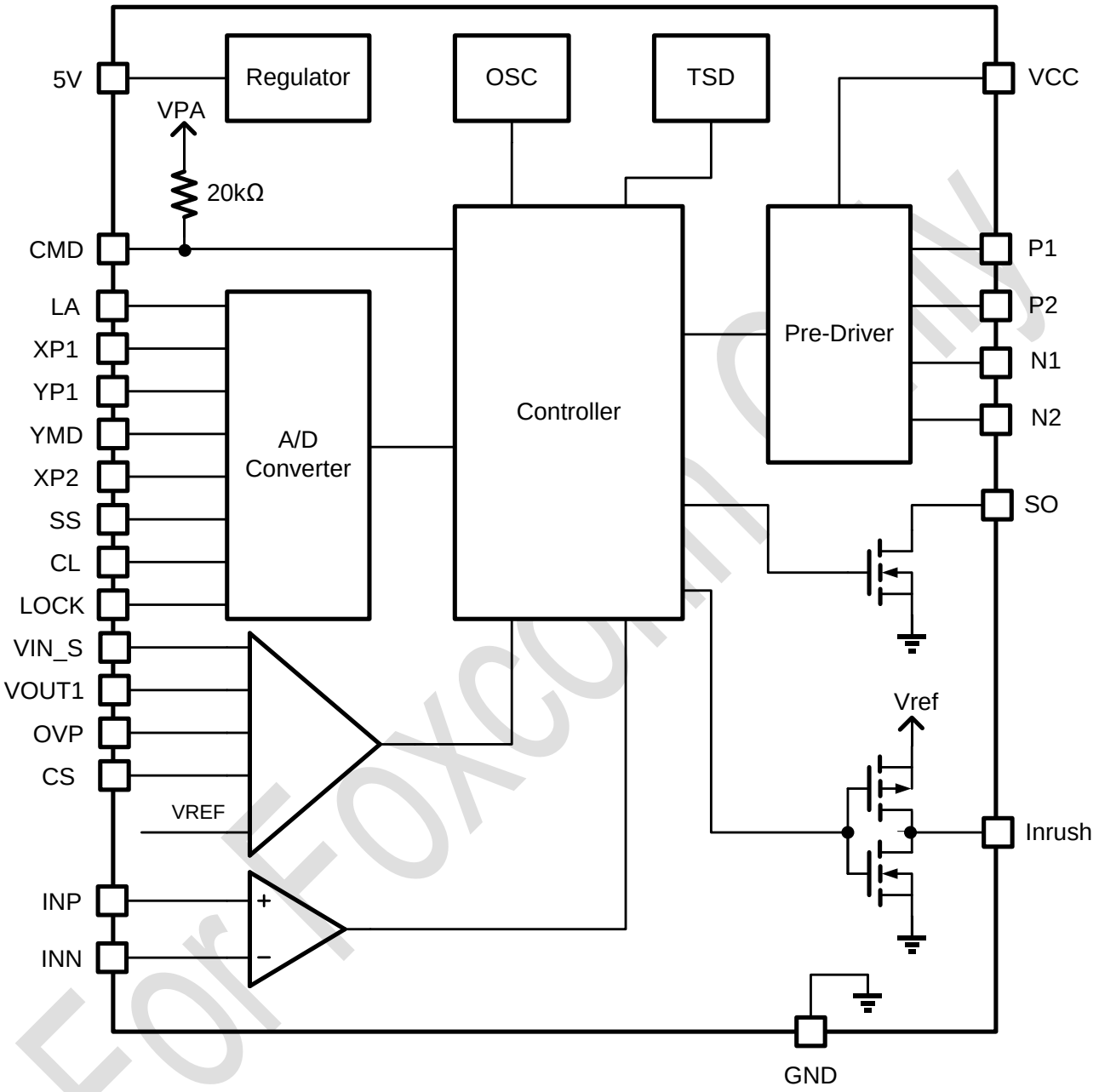
Typical Performance Curves

(TBD)

Pin Description

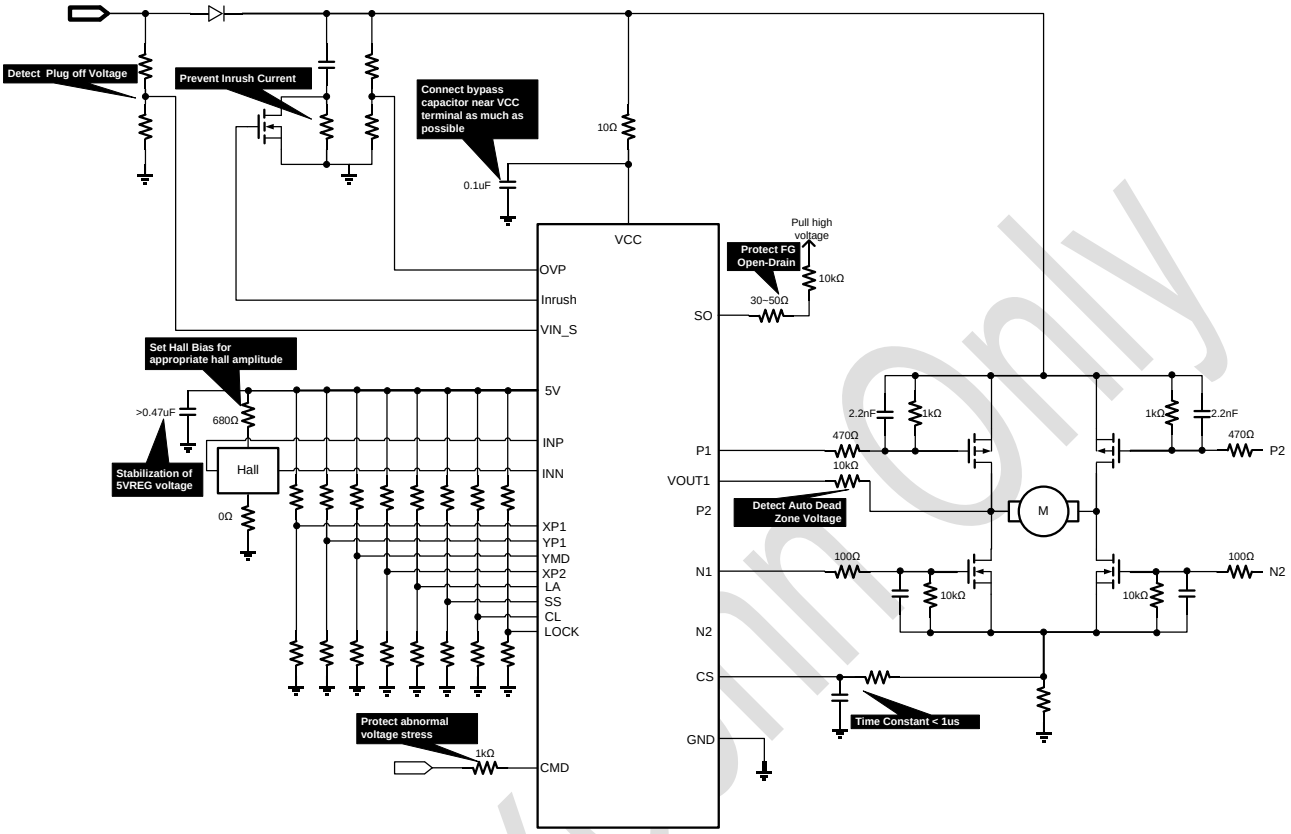
PIN NO.	SYMBOL	DESCRIPTION
1	GND	Ground
2	VCC	Power Supply
3	Inrush	Reduce Inrush Current
4	VIN_S	Detect Power Supply before Input Diode
5	SO	Rotation Speed/Detection Output
6	CMD	Speed Control (VSP mode = 1V~30V)
7	LA	Leading Angle Setting
8	XP1	Minimum Input PWM Duty Setting
9	YP1	Minimum Output PWM Duty Setting
10	YMD	Mid Output PWM Duty Setting at PWM duty=75%
11	XP2	Maximum Input PWM Duty Setting
12	SS	Duty soft start
13	5VREG	5V Regulator Output
14	LOCK	Lock Off Time
15	CL	Startup Current Limit level
16	INN	Hall – input terminal
17	INP	Hall + input terminal
18	OVP	Detect VM Power
19	CS	Current Sense Voltage
20	N1	Low Side Output1
21	VOUT1	Detect Vout1 Voltage
22	P1	High Side Output1
23	P2	High Side Output2
24	N2	Low Side Output2

Block Diagram



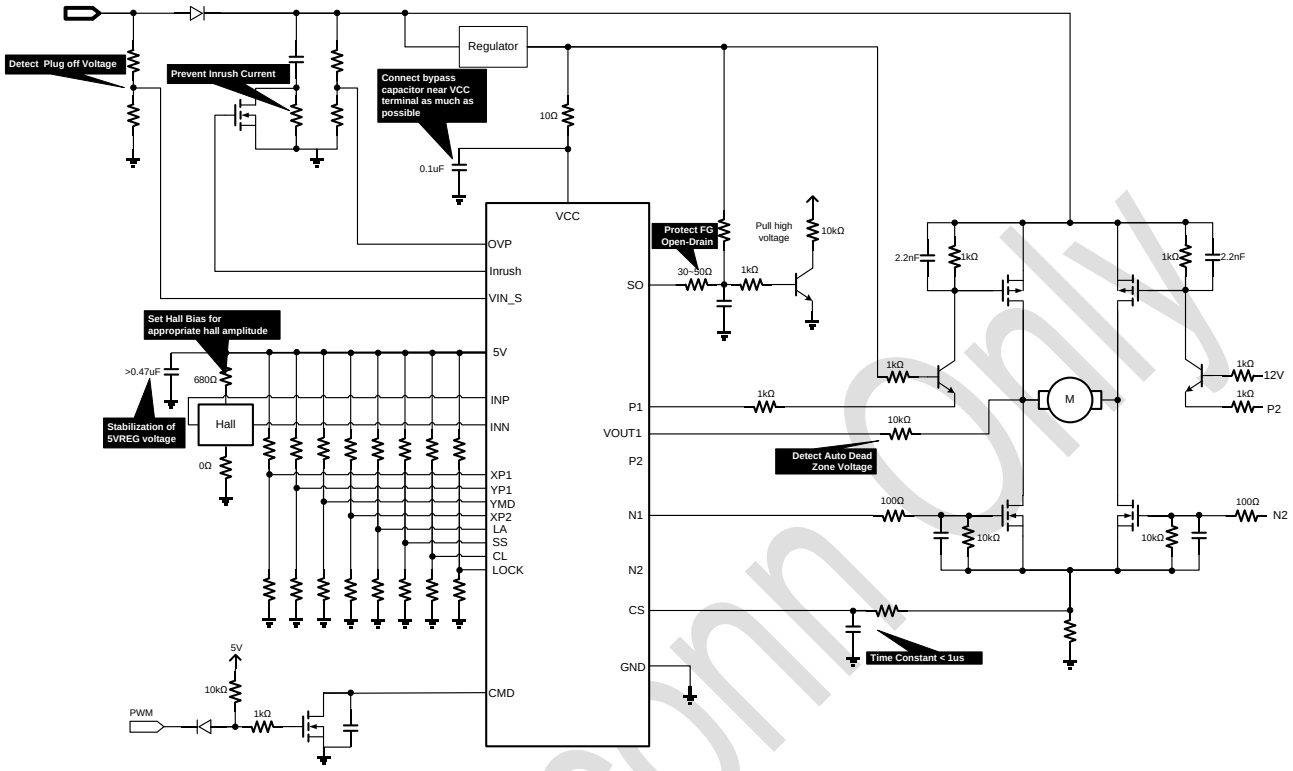
Application Circuit Examples

18V



Application Circuit Examples

48V



Function Descriptions

Speed Control Setting

The XP1 / YP1 / YMD / XP2 is detected by ADC which has 256 steps, and the resolution is 15.625mV/step. As a result, the ADC can detect voltage from 0.5V(ADC=0) to 4.5V(ADC=255).

(A) The XP1 pin is a multi function pin setting by voltage from 0V ~ 5V. The main function controls the turning point of input low duty at speed curve. The second function is to set speed curve with standby or minimum speed.

Equation :

$$D_{XP1} = \left(\frac{V_{IN}}{15.625mV} \text{ x } \frac{5}{8} + 12\right) \text{ x } \frac{50\%}{128}$$

$$V_{XP1} > 2.5V, V_{IN} = 4.5V - V_{XP1}$$

$$V_{XP1} < 2.5V, V_{IN} = V_{XP1} - 0.5V$$

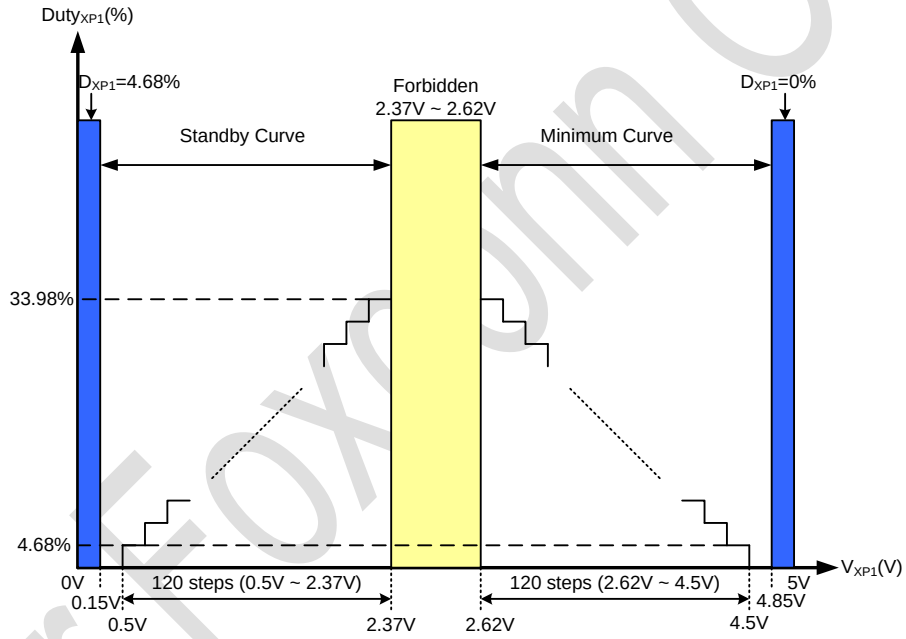


Figure : XP1 Voltage Setting Range

Table : XP1 Voltage Setting Table

Step	VXP1 (V)	Duty Input (%)	Sec. Function
	>4.85	0	Minimum
255	4.5	4.68	
136	2.62	33.98	
Forbidden			
120	2.37	33.98	Standby
0	0.5	4.68	
	<0.15	4.68	

(B) The YP1 pin is a multi function pin setting by voltage from 0V ~ 5V. The main function controls the turning point of output low duty at speed curve.

Equation :

$$D_{YP1} = \left(\frac{V_{IN}}{15.625mV} \text{ x } \frac{5}{8} + 12\right) \text{ x } \frac{50\%}{128}$$

$$V_{YP1} > 2.5V, V_{IN} = 4.5V - V_{YP1}$$

$$V_{YP1} < 2.5V, V_{IN} = V_{YP1} - 0.5V$$

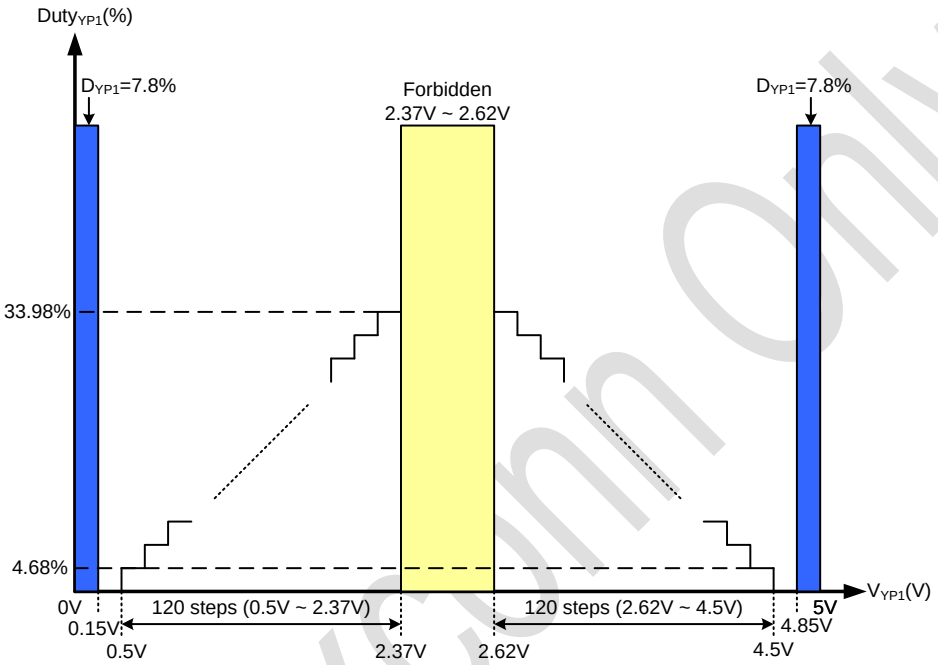


Figure : YP1 Voltage Setting Range

Table : YP1 Voltage Setting Table

Step	VYP1 (V)	Duty output (%)	Sec. Function
	>4.85	7.8	SO Select
255	4.5	4.68	
136	2.62	33.98	
Forbidden			
120	2.37	33.98	SO Select
0	0.5	4.68	
	<0.15	7.8	

(C) The YMD pin is a multi function pin setting by voltage from 0V ~ 5V. The main function controls the turning point of output mid duty (CMD = 75%) at speed curve.

Equation :

$$D_{YMD} = \left(\frac{V_{IN}}{15.625mV} \text{ x } \frac{13}{16}\right) \text{ x } \frac{50\%}{128} + 128$$

$$V_{YMD} > 2.5V, V_{IN} = V_{YMD} - 2.5V$$

$$V_{YMD} < 2.5V, V_{IN} = 2.5V - V_{YMD}$$

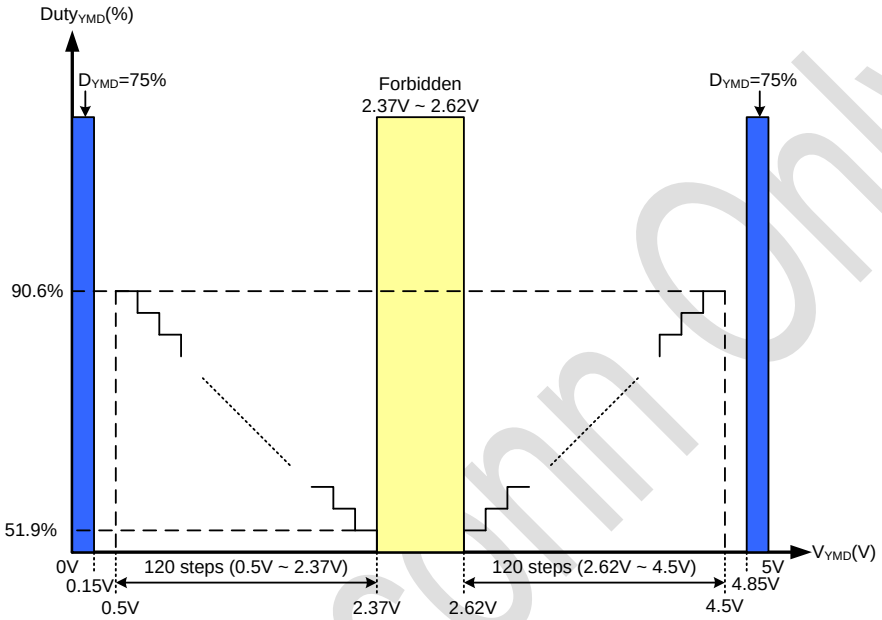


Figure : YMD Voltage Setting Range

Table : YMD Voltage Setting Table

Step	VYMD (V)	Duty output (%)	Sec. Function
	>4.85	Disable	SO Select
255	4.5	90.6	
136	2.62	52.5	
Forbidden			
120	2.37	52.5	SO Select
0	0.5	90.6	
	<0.15	Disable	

(D) The XP2 pin is a multi function pin setting by voltage from 0V ~ 5V. The main function controls the turning point of input high duty at speed curve. The second function is to set CMD PIN with clock mode (V_{XP2} = 4.356V ~ 4.5V) or set mode (V_{XP2} = 0.5V ~ 0.644V).

Equation :

$$D_{XP2} = \frac{V_{IN}}{15.625mV} \times \frac{50\%}{128} + 50\%$$

$$V_{XP2} > 2.5V, V_{IN} = V_{XP2} - 2.5V$$

$$V_{XP2} < 2.5V, V_{IN} = 2.5V - V_{XP2}$$

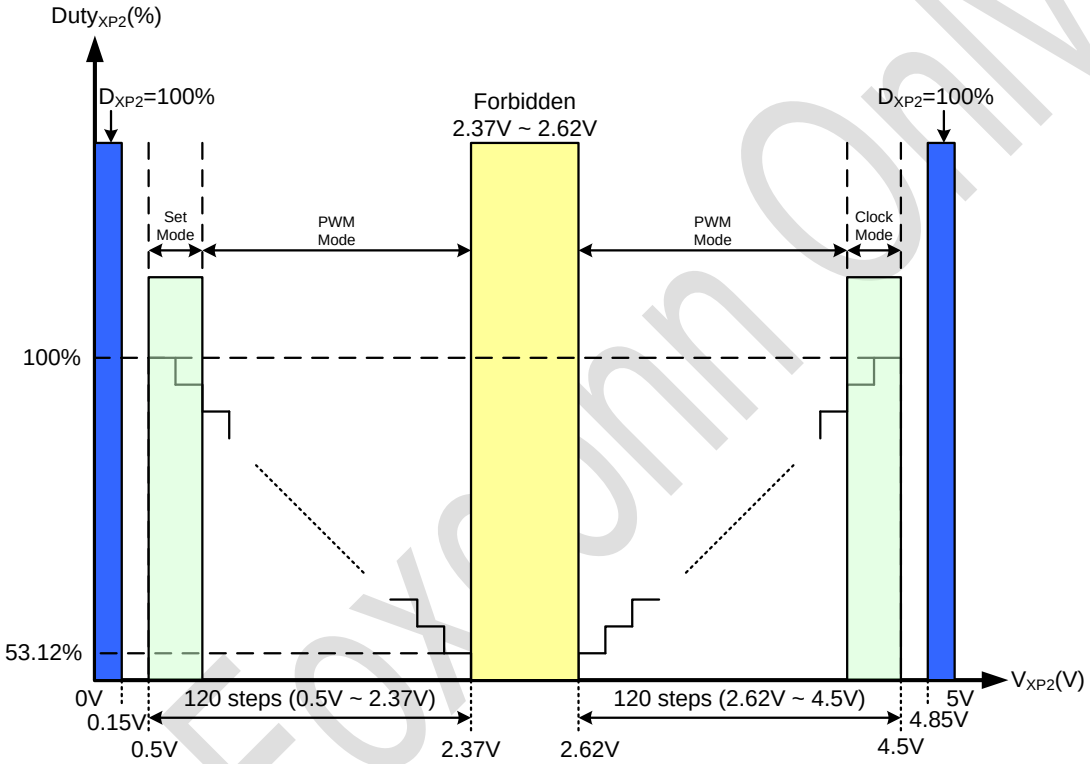


Figure : XP2 Voltage Setting Range

Table : XP2 Voltage Setting Table

Step	VXP2 (V)	Duty Input (%)	Sec. Function	Third Function
	>4.85	100	Soft Switch Type	---
255	4.5	100		Clock Mode
246	4.34	96		---
136	2.62	53.12		
Forbidden				
120	2.37	53.12	Soft Switch Type	---
10	0.65	96		
0	0.5	100		Set Mode
	<0.15	100		---

Phase Control Setting

The LA pin is a multi function pin setting by voltage from 0V ~ 5V. The main function controls the leading angle based on real hall signal. The second function is to set output signal shape with soft switch type.

Equation :

$$P_{LA} = \left(\frac{V_{IN}}{15.625mV}\right) x \frac{22.5^{\circ}}{128}$$

$$V_{LA} > 2.5V, V_{IN} = 4.5V - V_{LA}$$

$$V_{LA} < 2.5V, V_{IN} = V_{LA} - 0.5V$$

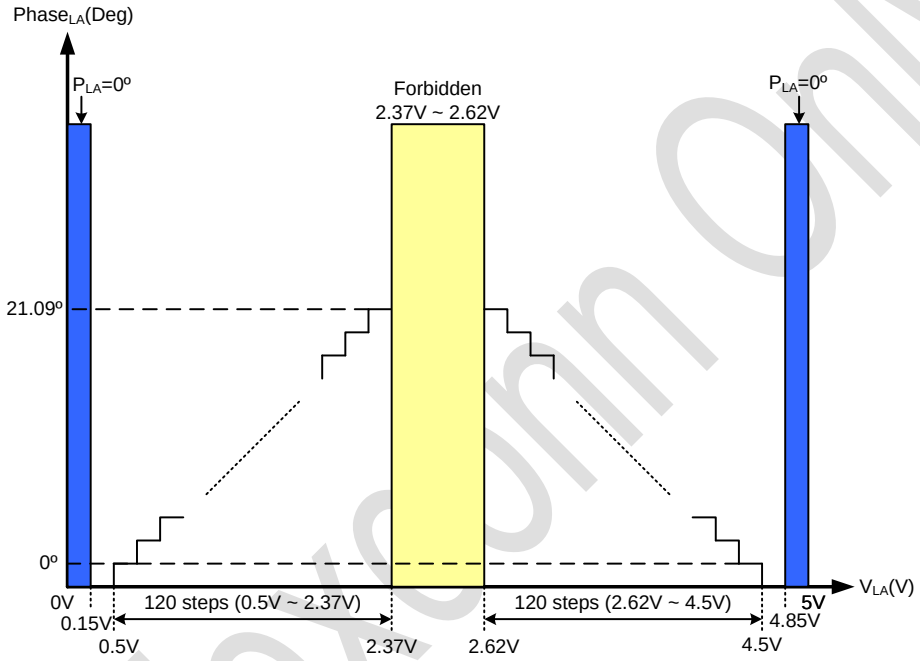


Figure : LA Voltage Setting Range

Table : LA Voltage Setting Table

Step	VLA (V)	LA (Deg)	Sec. Function
	>4.85	0	Soft Switch Type
255	4.5	0	
136	2.62	21.09	
Forbidden			
120	2.37	21.09	Soft Switch Type
0	0.5	0	
	<0.15	0	

Soft Start Setting

The SS pin is a multi function pin setting by voltage from 0V ~ 5V. The main function can use two type soft start mode :

(a) Adjustable duty soft start time + fix current limit soft start time.
(b) Fix duty soft start time + adjustable current limit soft start time.

Equation :

$$T_{duty\_SS} = \left(\left(\frac{V_{IN}}{15.625mV}\right) x \frac{3}{8} + 4\right) x \frac{256}{2000}$$

$$V_{SS} > 2.5V, V_{IN} = 4.5V - V_{SS}$$

$$T_{CL\_SS} = \left(\left(\frac{V_{IN}}{15.625mV}\right) x \frac{5}{8} + 12\right) x \frac{64}{512}$$

$$V_{SS} < 2.5V, V_{IN} = V_{SS} - 0.5V$$

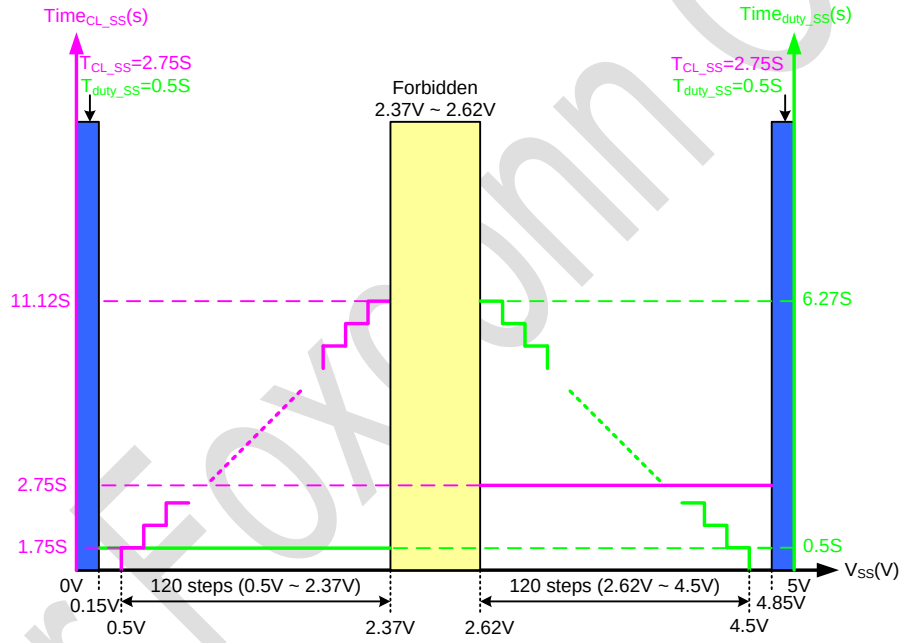


Figure : SS Voltage Setting Range

Table : SS Voltage Setting Table

Step	VSS (V)	Time Duty SS(s)	Time CL SS(s)	Sec. Function
	>4.85	0.5	0.25+2.5	
255	4.5	0.5	0.25+2.5	
136	2.62	6.27	0.25+2.5	
Forbidden				
120	2.37	0.5	0.25+10.87	
0	0.5	0.5	0.25+1.5	
	<0.15	0.5	0.25+2.5	Full Duty

Current Limit Setting

The CL pin is a multi function pin setting by voltage from 0V ~ 5V. The CL pin is set for initial current limit level (at YP1)by percentage of final current limit voltage (at 100%). The main function has two features :
(a) The current limit level is adjustable by command pin.
(b) The chip can detect overall coil current to adjust output duty.

Equation :

$$V_{CL} = \left(\frac{V_{IN}}{15.625mV}\right) x \frac{80mV}{128}$$

$$V_{CL} > 2.5V, V_{IN} = 4.5V - V_{CL}$$

$$V_{CL} < 2.5V, V_{IN} = V_{CL} - 0.5V$$

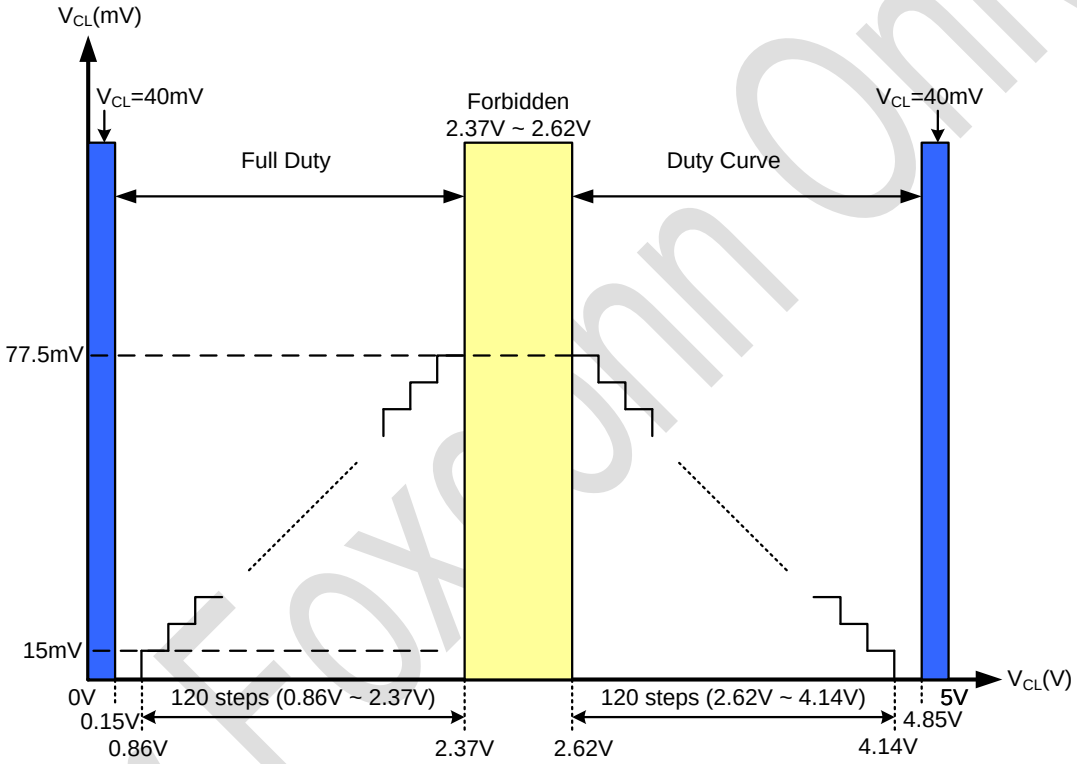


Figure : CL Voltage Setting Range

Table : CL Voltage Setting Table

Step	VCL (V)	VCL (mV)	Sec. Function
	>4.85	40	CCL Off CL Curve
>232	>4.14	15	CCL CL Curve
136	2.62	77.5	
Forbidden			
120	2.37	77.5	CCL Full Duty (CMD > 50%)
<23	<0.86	15	
	<0.15	40	CCL Off CL Curve

※CCL : Current Close Loop

Lock Off Time

The LOCK pin is a multi function pin setting by voltage from 0V ~ 5V. The main function controls the lock off time when the fan enter lock mode. The second function is to set CMD/SO PIN invert or not.

Equation :

$$T_{OFF} = \left(\frac{V_{IN}}{15.625mV}\right) x \frac{3}{8} x0.25$$

$$V_{LOCK} > 2.5V, V_{IN} = V_{LOCK} - 2.5V$$

$$V_{LOCK} < 2.5V, V_{IN} = 2.5V - V_{LOCK}$$

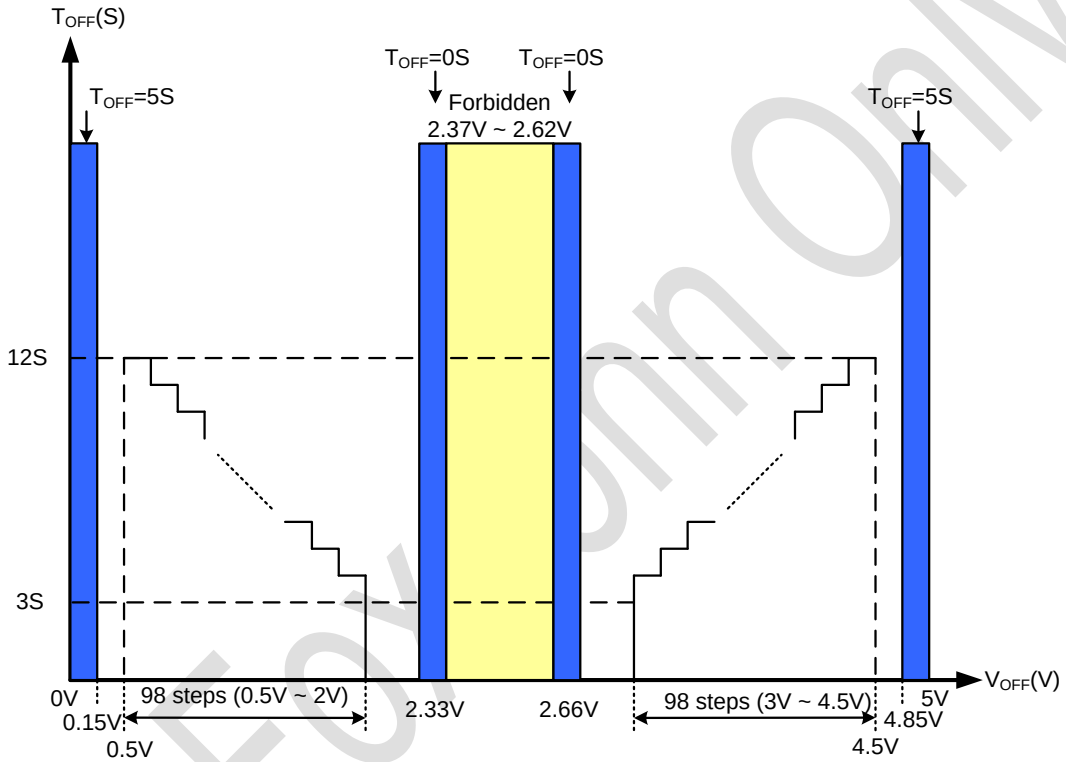


Figure : Lock Off Time Setting Range

Table : Lock Off Time Setting Table

Step	VLOCK (V)	Off Time (S)	Sec. Function
	>4.85	5	SO / CMD
255	4.5	12	
158	3	3	
138	2.66	0	
Forbidden			
117	2.33	0	SO / CMD Invert
98	2	3	
0	0.5	12	
	<0.15	5	

Truth Table

(A) Mode select

Mode	1				2
	SO = RD	SET	Normal	LOCK < 2.5V (CMD/SO INV)	CL < 0.15V LOCK < 0.15V YMD < 0.15V
CMD Pull high	200µA	NA	200µA	-200uA	20µA
5V OFF (shutdown mode)	NA	NA	Yes	NA	NA
Brake Mode	NA	NA	Yes	Yes	NA
Soft Switch Type	All	22.5° / SW 22.5°	All	All	NA

(B) Soft Switch Type

	22.5°	SW 45°	SW 22.5°	sinewave
LA	0	0	1	1
XP2	0	1	0	1

※PIN voltage > 2.5V means 1, and PIN voltage < 2.5V means 0.
※SW45° means input command <50% => soft switch front & rear 45°, input command >80% => soft switch front & rear 0°.

(C) SO Type

	FG	$\frac{4}{8}$FG	RD	TBD
YP1	1	1	0	0
YMD	1	0	1	0

※PIN voltage > 2.5V means 1, and PIN voltage < 2.5V means 0.

(D)Clock Mode

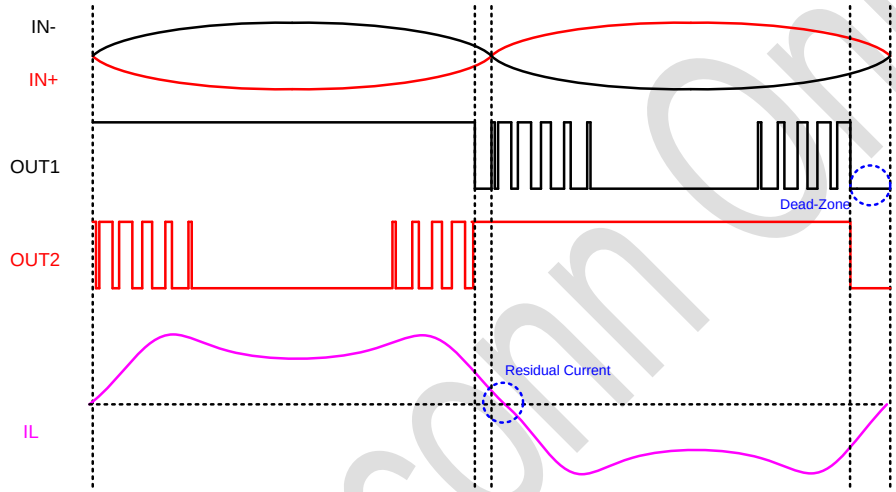
Pole	4	8
Clock cycle(Hz) / RPM	4	8
150	10	20
300	20	40
600	40	80
1200	80	160
2400	160	320
4800	320	640
9600	640	1280
19200	1280	2560

※Clock Cycle = Pole
※$\mathrm{RPM} = \frac{\mathrm{Frequency_{IN}}}{\mathrm{Clock\ Cycle}} \times 60$

Function Descriptions

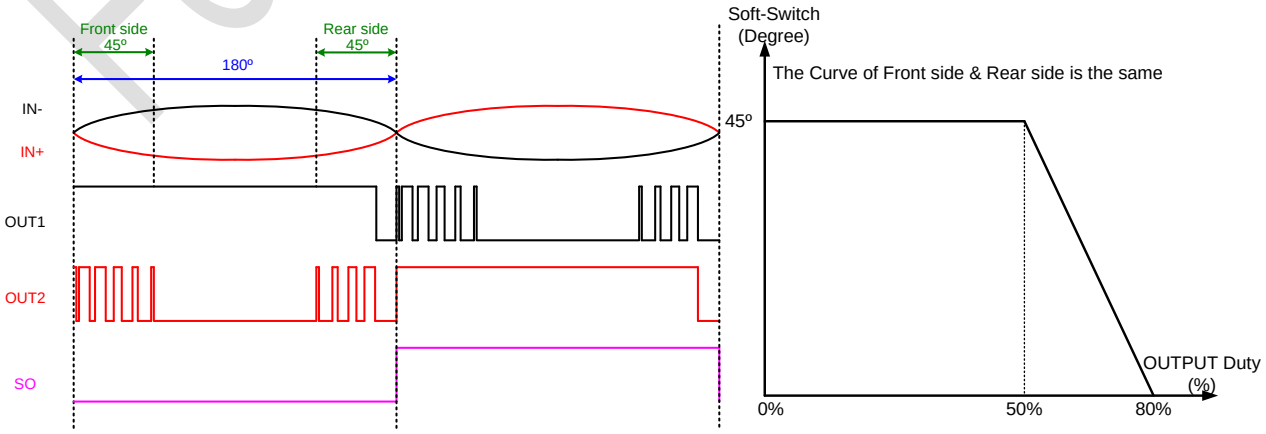
[1]Auto Dead-zone

The M8420 is a Motor pre-driver IC. When hall signal change, the coil may still have some residual current. The residual current results in MOSFETs overheat, and may cause VCC voltage peaking by residual current charging the power capacitor. The M8420 solve this problem by automatically detecting the residual current when hall signal is change. If there still have residual current, chip will increase dead-zone at the rear side of output period (180˚). The dead-zone will continue increasing until residual current is down to zero, but the dead-zone has maximum degree is 45˚. On the other hand, the coil current is decreasing to zero early before hall signal changing, and the dead-zone will decrease.

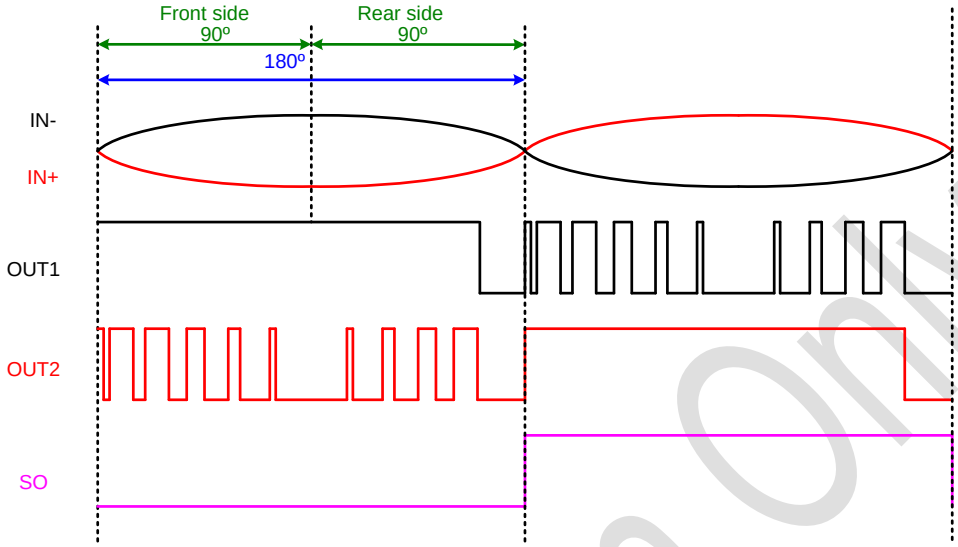


[2]Soft Switch and Sine Wave

The M8420 build-in soft-switch function to improve vibration and noise of fan motor rotation. At startup process, the M8420 drives the fan motor by square wave to force fan motor against static friction. After several rotation signal changing, the PWM soft-switch signal will be enable in output signal to improve vibration and noise of fan motor rotation. The soft-switch internal is set in the beginning (45˚) and ending (45˚) of output period (180˚) if output duty is under 50%. Along with the output duty growing up, the soft-switch internal will be decreasing. It will be down to zero when output duty over 80%.



The M8420 has multi function of soft-switch & sine-wave selected by LA PIN. Using sine-wave function, the output PWM soft-switch signal interval is all cycle of output period (180°), and the PWM signal change rate is like sine wave.

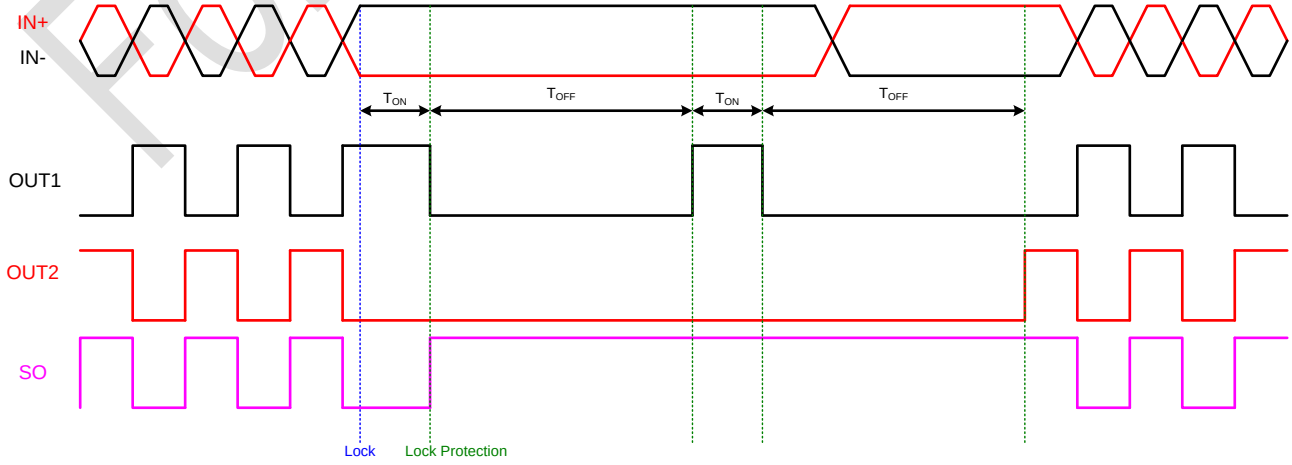


[3]Current Limit

The M8420 includes internal current limit. It will turn off low side NMOS when output driver current is over sense voltage. The low side NMOS will turn on at next PWM cycle, and reduce the output duty. The M8420 also includes over current protection (OCP). If the current sense voltage is over 180mV, all output MOS will turn off and enable lock protection. Chip will restart when lock off time is count down.

[4]Lock Protection and Automatic Restart

Motor rotation is detected by hall signal. When the fan encounters an external force, result in hall signal fixed high and low. This chip internal clock detect an on time (T_{ON} 0.5s), then all driver MOSFETs are turned off and auto restart after the recovery time (T_{OFF} 5s). It also can change the recovery time by the lock pin table setup.



[5]Standby and Shutdown

When driver off logic is setup by the control signal (CMD pin) over a fixed time (70ms), the lock protection signal will be disable. Chip all circuit still work except driver MOSFETs turned off, and wait for quick start by the control signal. This chip also has shutdown function detected by the control signal under low level (<0.5%). In the shutdown mode, it will turn off all driver MOSFETs, internal clock and SO function, and the quiescent current is under 400μA.

[6]Over Voltage Protect (OVP)、Under Voltage Lockout (UVLO)、Input Voltage Sense (VIN_S)、Hot Plug Protect (Inrush)

6.1 Over Voltage Protect (OVP)

Under the motor operating process, it may result in over voltage phenomenon because of the coil current charging input capacitor at variation condition. In order to protect IC from burning out, the M8420 can detect OVP pin voltage which is divider from VM voltage by resistor. If IC find over voltage, it will short brake. Until there are no any OVP and waiting for appropriate time, IC will return to normal driving mode.

6.2 Under Voltage Lockout (UVLO)

There are still some current storage in capacitor after disconnect input power, and it can keep the motor running for a while. At this time, in order to ensure that the IC can work correctly and not disturb by voltage, the IC can detect UVLO voltage which is divider from VCC voltage by resistor. When the VCC voltage is lower than UVLO voltage, the IC will turn off all driver MOS. Therefore it can prevent capacitor charge from decreasing too fast, and the IC still work correctly to appropriately deal with the residual current of coil. If the VCC voltage is higher than UVLO voltage again, the IC can directly enter normal driving mode because of the IC still under working state.

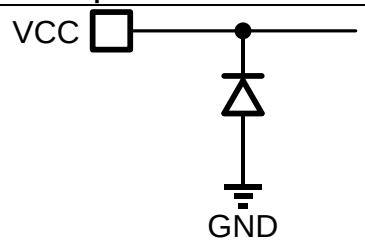
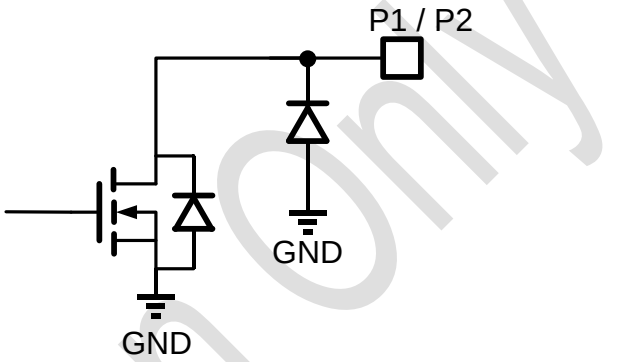
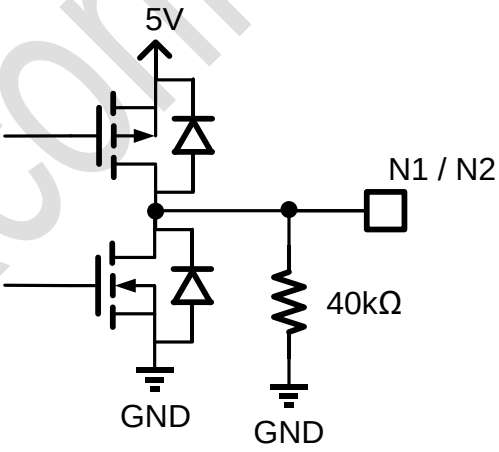
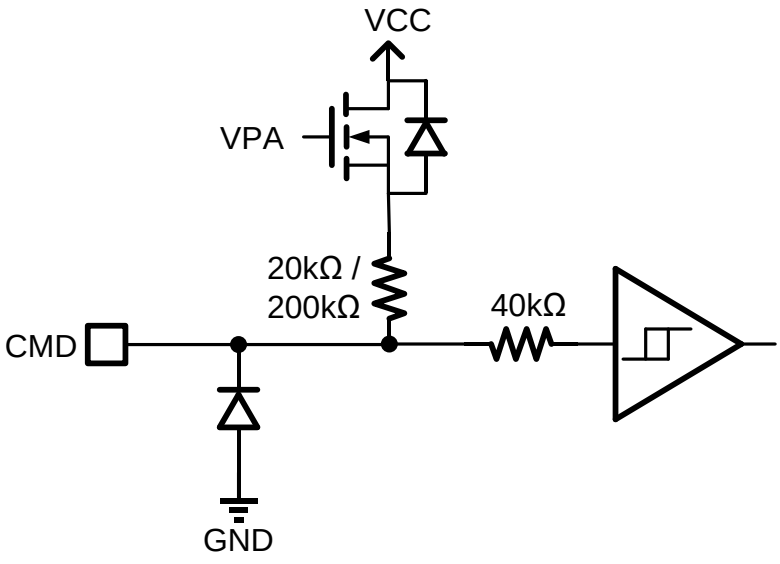
6.3 Input Voltage Sense (VIN_S)

Input diode is common using in motor driving circuit to prevent input power from reverse current of motor. The IC provide an input voltage sense circuit which is divided from input voltage (input side of diode) by resistor. The IC can turn off driving MOS by detecting input voltage, and it can work more perfectly than detecting UVLO voltage.

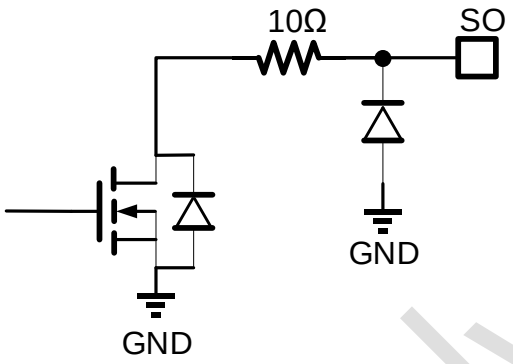
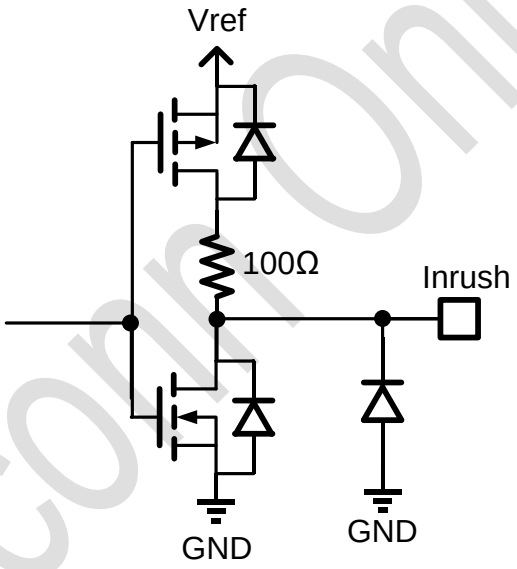
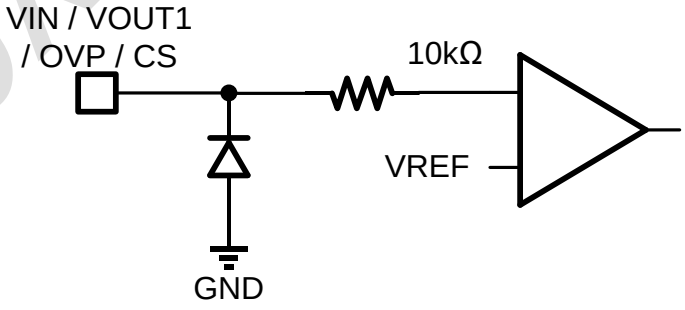
6.4 Hot Plug Protect (Inrush)

Hot Plug is very usually application condition. Due to there are input diode and input capacitor on application circuit. Input power provide current for input capacitor through power line and input diode. Because of inductance characteristic of power line, it will result in over voltage in VCC point (output side of diode). The IC uses INRUSH pin to reduce inrush current which is setup like application circuit. In the hot plug process, the inrush current is as small as possible, it will cause less over voltage phenomenon. The IC will wait for a given time before the input capacitor is really turned on.

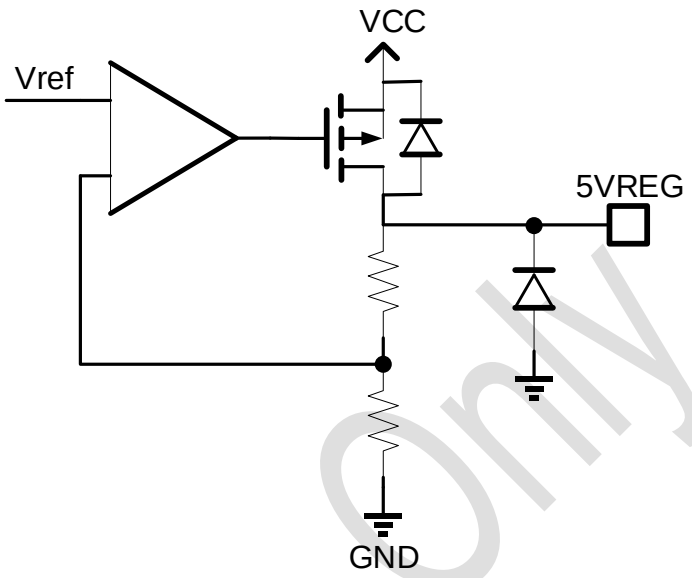
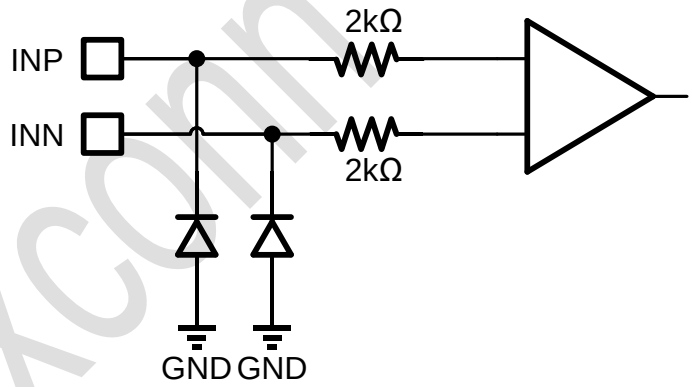
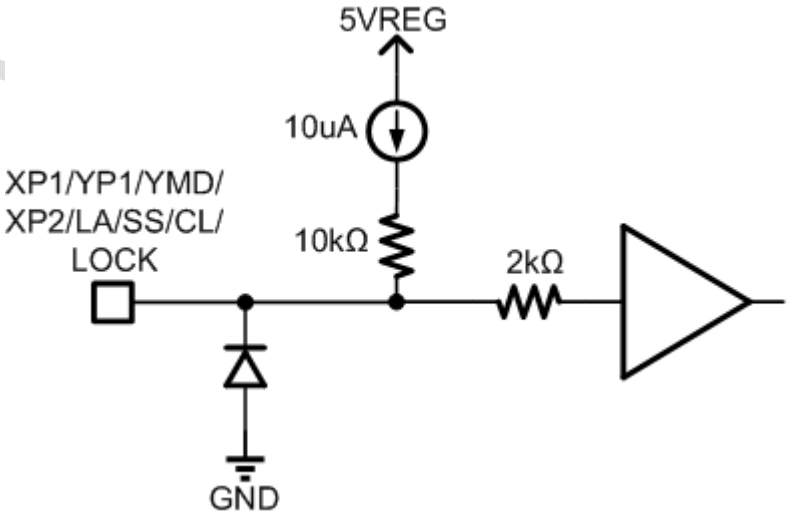
I/O Equivalence Circuit

PIN	I/O	Equivalence Circuit
Power supply (VCC / GND)	Input	
P1 / P2	Output	
N1 / N2	Output	
CMD	Input	

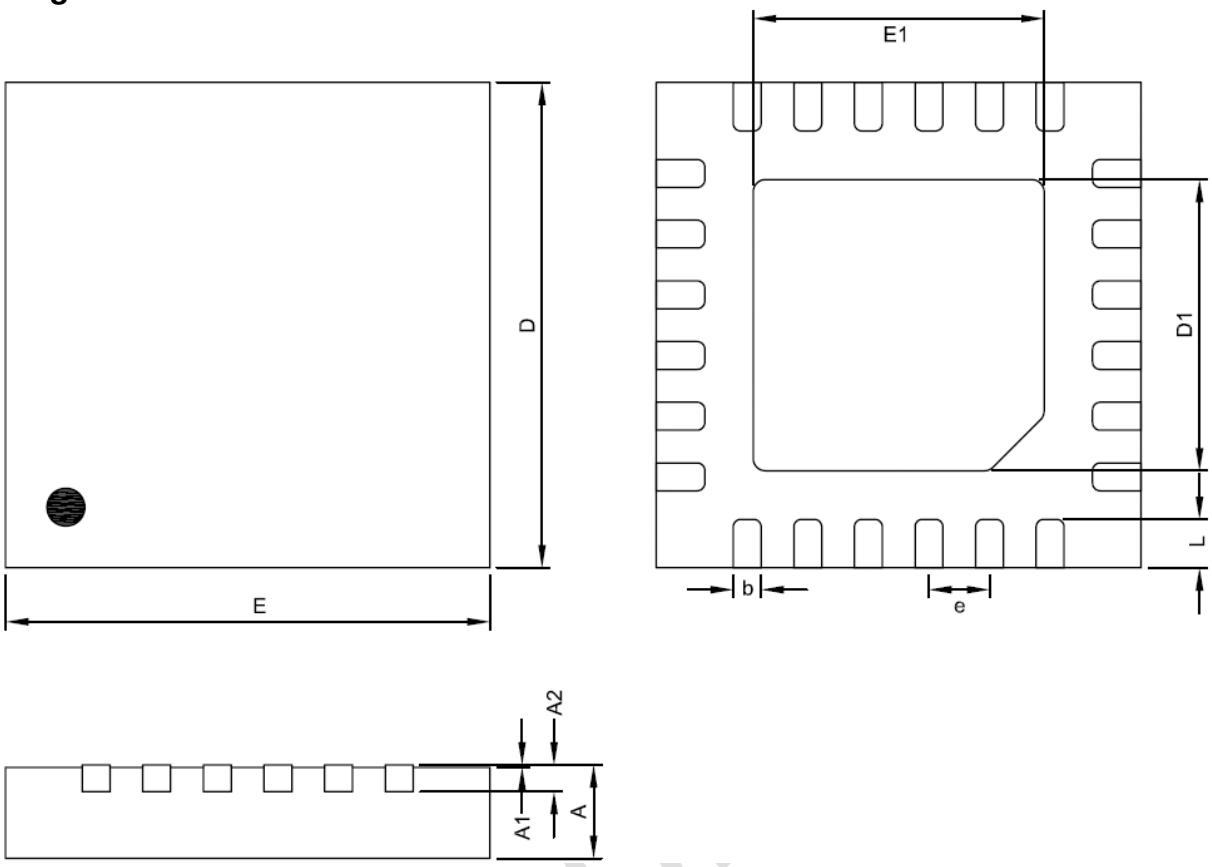
I/O Equivalence Circuit

SO	Output	
INRUSH	Output	
VIN / VOUT1 / OVP / CS	Input	

I/O Equivalence Circuit

PIN	I/O	Equivalence Circuit
Reference voltage 5VREG	Output	
Hall Signal INP / INN	Input	
XP1 / YP1 / YMD / XP2 / LA / SS / CL / LOCK	Input	

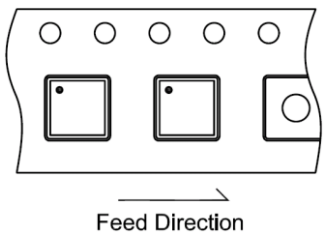
Package Information



TQFN4X4-24 Package

Symbol	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.70	0.75	0.80	0.0276	0.0295	0.0315
A1	0.00	---	0.05	0.0000	---	0.0020
A2	0.20 REF			0.0079 REF		
D	3.95	4.00	4.05	0.1555	0.1575	0.1594
E	3.95	4.00	4.05	0.1555	0.1575	0.1594
D1	2.50	2.70	2.85	0.0984	0.1063	0.1122
E1	2.50	2.70	2.85	0.0984	0.1063	0.1122
b	0.18	0.23	0.30	0.0071	0.0091	0.0118
e	0.50 BSC			0.0197 BSC		
L	0.35	0.40	0.45	0.0118	0.0138	0.0177

Taping Specification



PACKAGE	Q'TY/BY REEL
TQFN4X4-24	3,000 ea