LV8806QA

ON Semiconductor®
http://onsemi.com

Three-phase Sensor-less Motor Driver IC
Application Note

Overview

LV8806QA is a 3-phase sensor-less motor driver IC.
3-phase driver has inherently low power consumption and low vibration.
Sensor-less drive allows reduction of the complexity and size of the motor and control system.
This IC is suitable for use in products which require high reliability and long life such as note PC fans.

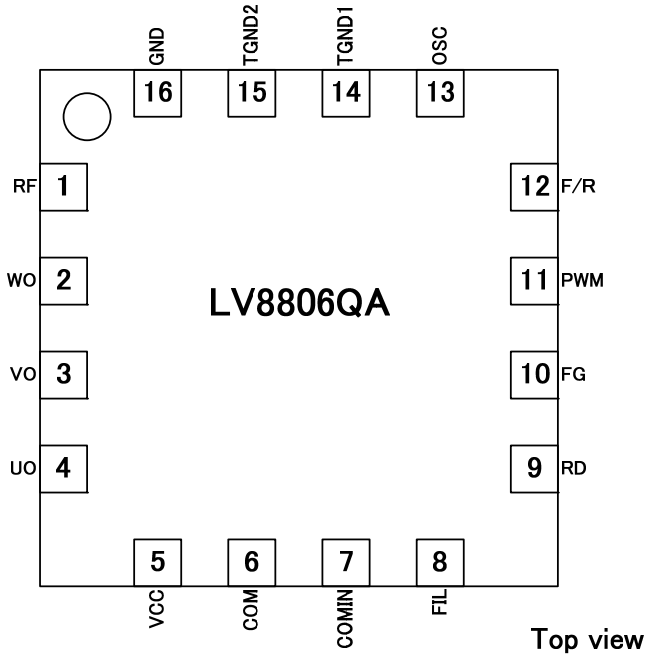
Functions

- Built-in current limit circuit utilizing a single external sense resistor.
- 3-phase full-wave sensor-less driver
- FG – tachometer output signal pin
- Built-in lock protection and auto-recovery circuit
- Direct PWM input
- RD - rotor lock detection output signal pin
- Built-in TSD - thermal shutdown circuit

Application

- laptop
- LED cooling fan

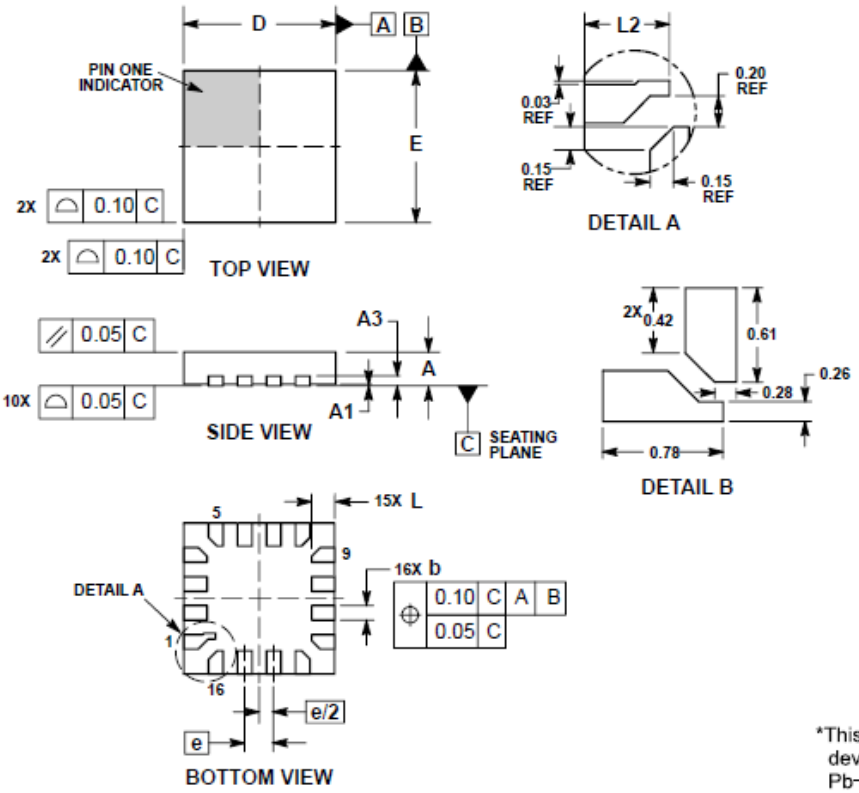
Pin Assignment



Top view

Package Dimensions

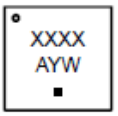
UQFN16 2.6x2.6, 0.5P
CASE 523AU
ISSUE A



NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.25mm FROM THE TERMINAL TIP.

DIM	MILLIMETERS MIN	MAX
A	0.45	0.55
A1	0.00	0.05
A3	0.13 REF	
b	0.20	0.30
D	2.60 BSC	
E	2.60 BSC	
e	0.50 BSC	
L	0.30	0.50
L1	---	0.15
L2	0.40	0.70

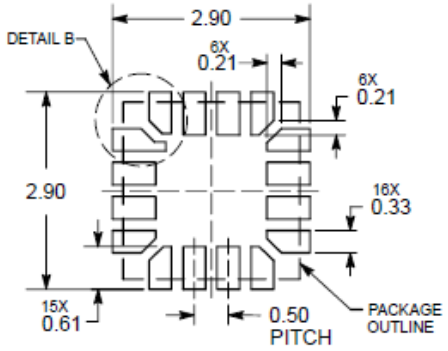
GENERIC MARKING DIAGRAM*



XXXX = Specific Device Code
A = Assembly Location
Y = Year
W = Work Week
▪ = Pb-Free Package

*This information is generic, Please refer to device data sheet for actual part marking. Pb−Free indicator, "G" or microdot " ▪", may or may not be present.

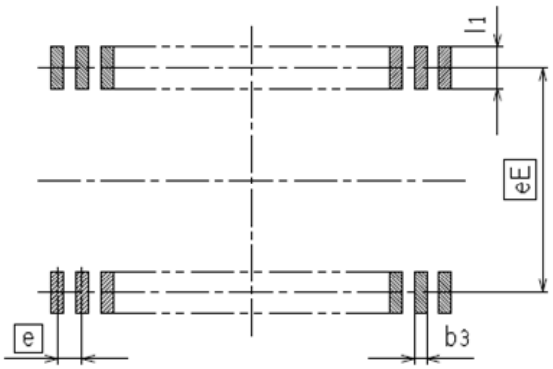
RECOMMENDED SOLDERING FOOTPRINT*



DIMENSIONS: MILLIMETERS

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

Mounting pad sketch

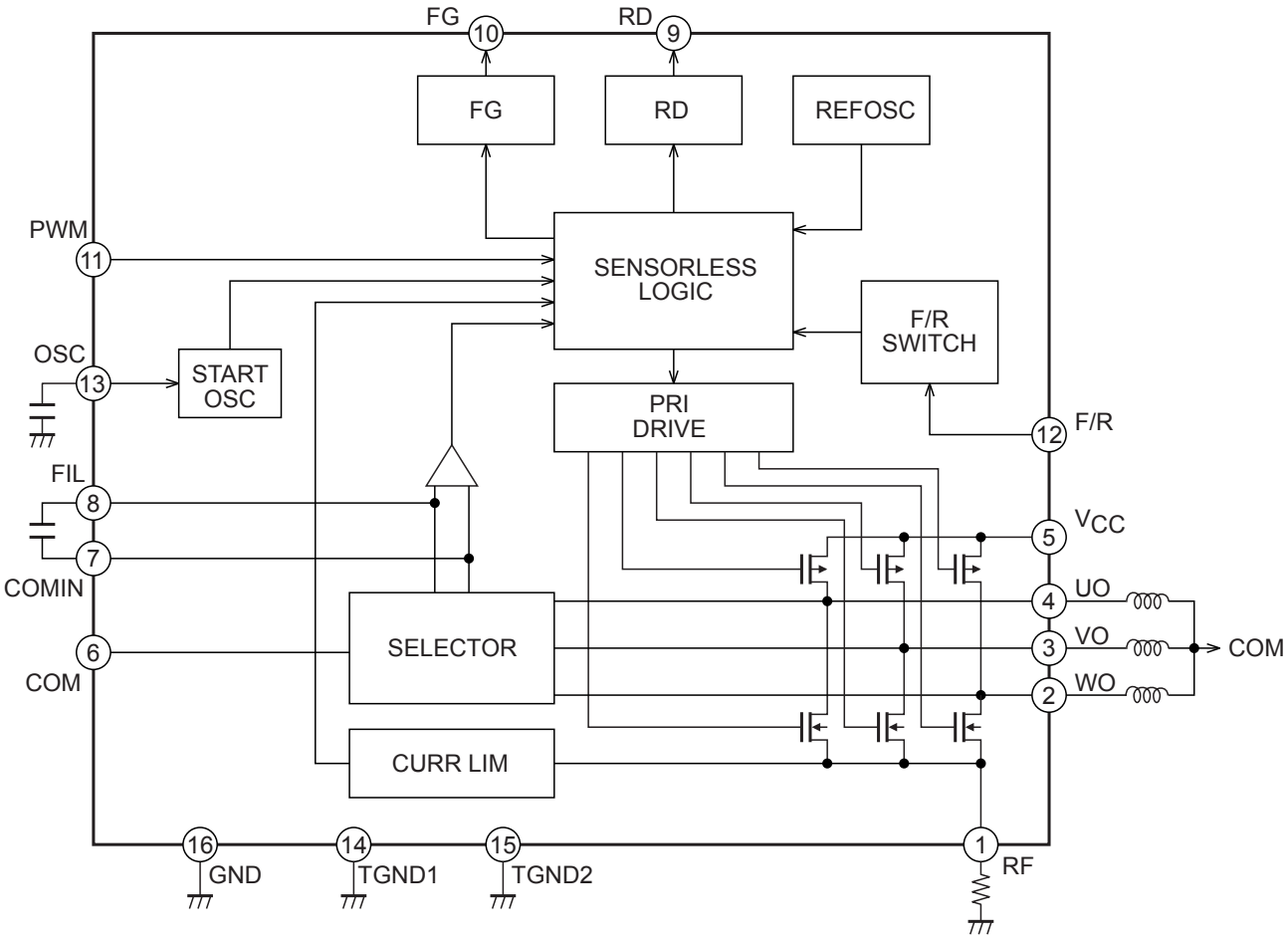


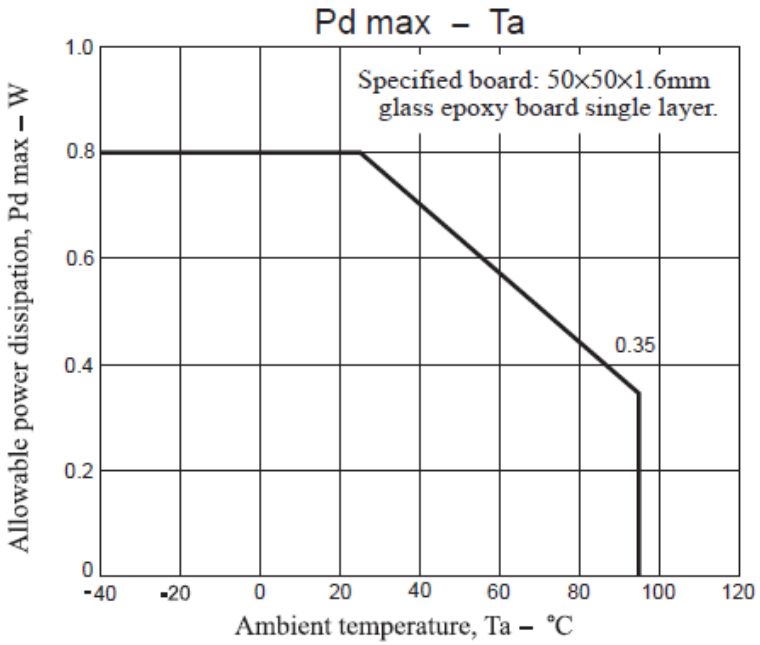
(Unit:mm)

Reference Symbol	SSOP20J (225mil)
eE	
e	
b3	
l1	

Caution: The package dimension is a reference value, which is not a guaranteed value.

Block diagram





Specifications

Absolute Maximum Ratings at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
V_{CC} maximum supply voltage	V_{CC} max		7	V
OUT pin maximum output current	I_{OUT} max		0.7	A
OUT(VO, VO, WO) pin withstand voltage	V_{OUT} max		7	V
FG output pin maximum sink current	I_{FG} max		5	mA
FG output pin withstand voltage	V_{FG} max		7	V
RD output pin maximum sink current	I_{RD} max		5	mA
RD output pin withstand voltage	V_{RD} max		7	V
Allowable power dissipation	Pd max	With specified board *1	800	mW
Operating temperature	Topr	*2	-40 to 95	°C
Storage temperature	Tstg		-55 to 150	°C

*1: With specified board: 50mm×50mm×1.6mm, grass epoxy board / single layer.

*2: Tjmax must not exceed 150°C

Caution 1) Absolute maximum ratings represent the value which cannot be exceeded for any length of time.

Caution 2) Even when the device is used within the range of absolute maximum ratings, as a result of continuous usage under high temperature, high current, high voltage, or drastic temperature change, the reliability of the IC may be degraded. Please contact us for the further details.

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

Specifications

Recommended Operating Conditions at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
V_{CC} supply voltage	V_{CC}		5.0	V
Operating V_{CC} supply voltage range	V_{CC} op		2.0 to 6.0	V
PWM input frequency range	f_{PWM}		20 to 50	kHz

Electrical Characteristics at Ta = 25°C, V_{CC} = 5.0V

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Circuit current	$I_{CC}1$	PWM=5V		1.5	2.5	mA
	$I_{CC}2$	PWM=0V		10	50	μA
Output circuit						
ON-resistance of high-side output transistor	$R_{ON}(H)$	I_O=500mA		0.5	0.9	Ω
ON-resistance of low-side output transistor	$R_{ON}(L)$	I_O=500mA		0.5	0.9	Ω
Sum of the ON-resistance of high/low-side output transistor	$R_{ON}(H+L)$	I_O=500mA		1.0	1.8	Ω
Startup oscillation (OSC) pin						
OSC pin charge current	$I_{OSC}C$	OSC=0V	-3.25	-2.50	-1.75	μA
OSC pin discharge current	$I_{OSC}D$	OSC=1.2V	1.75	2.50	3.25	μA
OSC pin High level threshold voltage	$V_{OSC}THH$		1.0	1.1	1.2	V
OSC pin Low level threshold voltage	$V_{OSC}THL$		0.5	0.6	0.7	V
PWM input (PWM) pin						
PWM pin High level input voltage	$V_{PWM}H$		2.5		V_{CC}	V
PWM pin Low level input voltage	$V_{PWM}L$		0		1.0	V
PWM pin current	I_{PWM}	PWM pin=0V	-50	-10		μA
Forward/reverse switching (F/R) pin						
F/R pin High level input voltage	V_FRH		2.5		V_{CC}	V
F/R pin Low level input voltage	$V_{FR}L$		0		1.0	V
F/R pin current	I_{FR}	FR pin=5V		10	50	μA
FG, RD output pin						
FG pin Low level voltage	V_{FG}	I_{FG}=3mA		0.2	0.3	V
FG pin leakage current	I_{FG}	V_{FG}=7V			10	μA
RD pin Low level voltage	V_RD	I_{RD}=3mA		0.2	0.3	V
RD pin leakage current	I_{RD}	V_{RD}=7V			10	μA
Current limiter circuit						
Limiter voltage	V_{RF}	Operating when RF=0.5Ω, I_O=0.53A	0.238	0.265	0.291	V
Lock protection circuit						
Output ON-time	LT1		0.35	0.50	0.65	S
Output OFF-time	LT2		3.2	4.5	5.9	S
Output ON/OFF ratio	LRTO	LRTO=LT2/LT1	4.9	9.0	16.8	
Thermal shutdown circuit						
Operating temperature	TSD	*Design guarantee	150	180		°C
Hysteresis width	ΔTSD	*Design guarantee		30		°C

*Design guarantee: This is a design target value, which will not be measured independently.

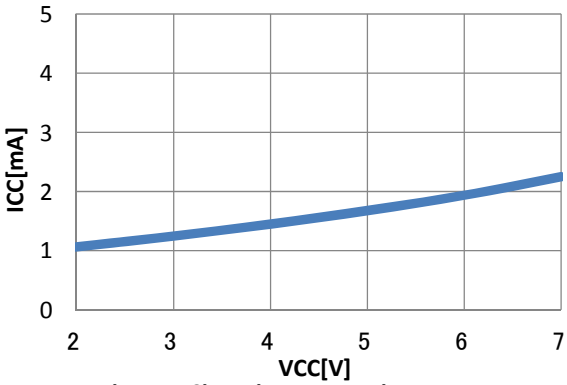


Figure 1 Ciurcuit consumption cueernt vs VCC

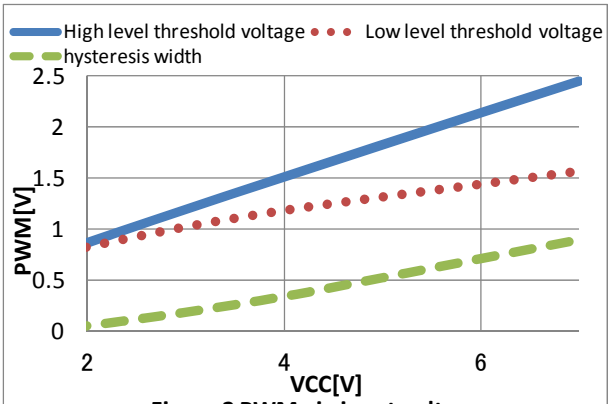


Figure 2 PWM pin input voltage vs VCC

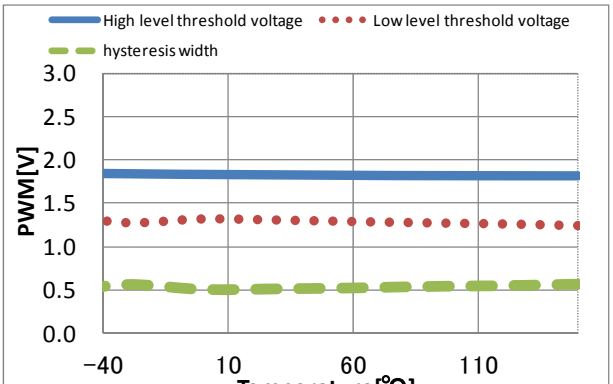


Figure 3 PWM pin input voltage vs Temperature

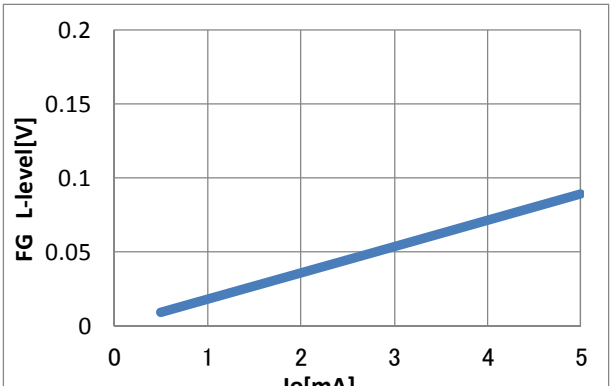


Figure 4 FG Low level voltage vs FG current

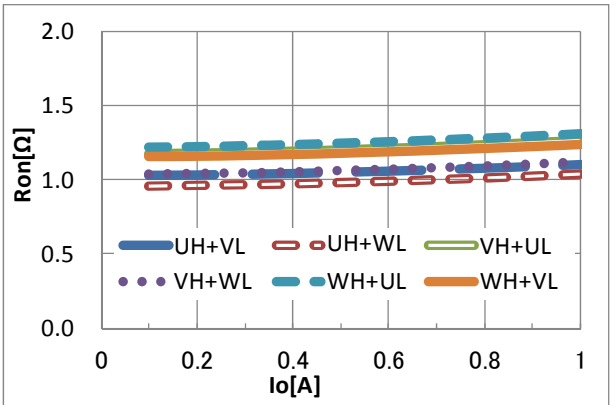


Figure 5 OUTFET on resistance vs output current (Io)

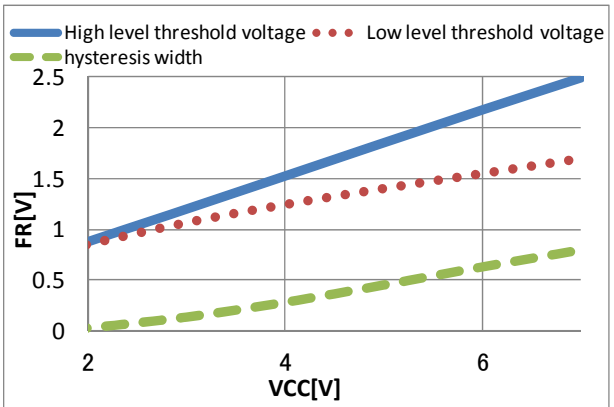


Figure 6 FR pin Hi-Lo level threshold voltage vs VCC

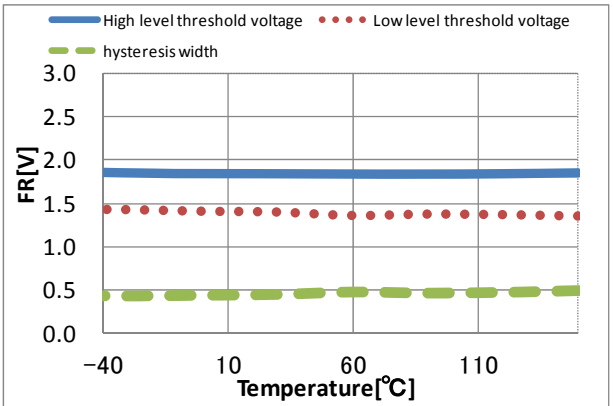


Figure 7 FR pin threshold voltage vs Temperature

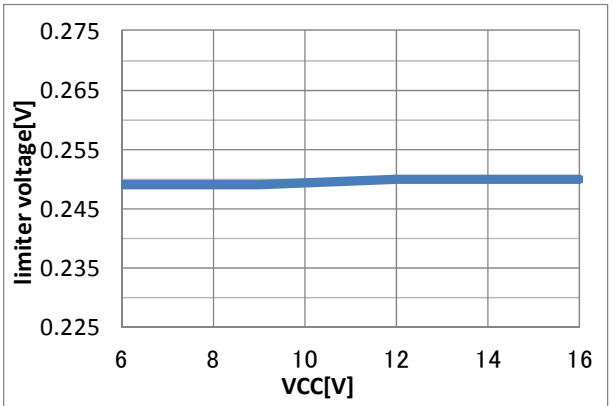
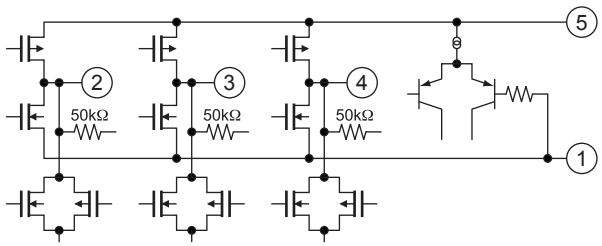
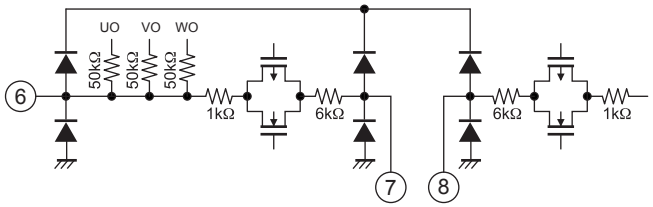
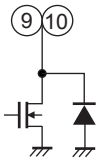
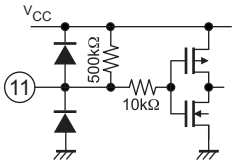
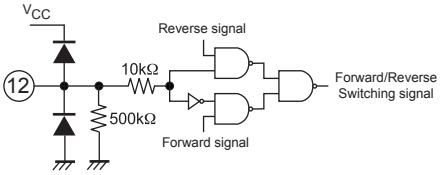
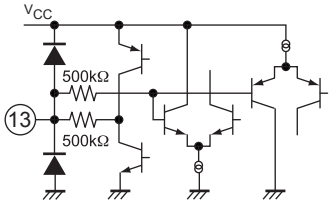


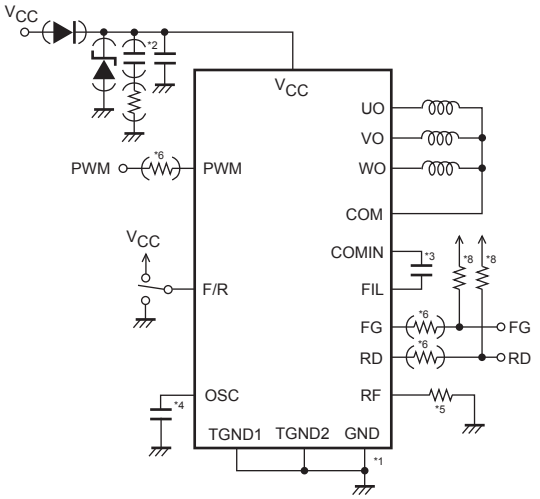
Figure 8 RF pin limiter voltage vs VCC

Pin function

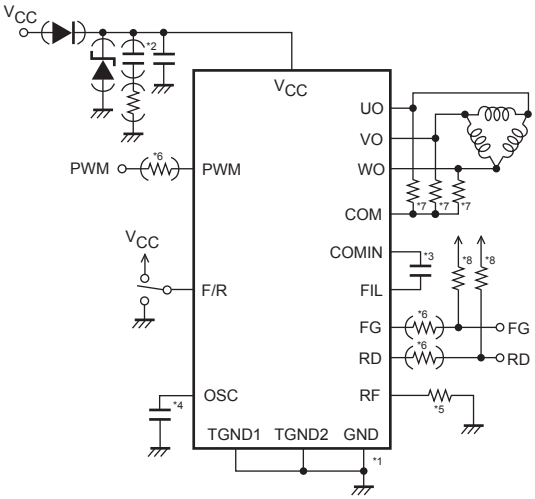
Pin No.	Symbol	Function	Equivalent circuit
1	RF	Output current detection pin. Drive current is detectable with sense resistors connected to GND.	
2 3 4	UO VO WO	Output pin. Connected to motor coil.	
5	V_{CC}	IC power supply pin and motor power supply pin. A capacitor is connected between GND and this pin.	
6	COM	Connected to the neutral of the motor.	
7	COMIN	Motor position detection comparator filter pin. A capacitor is connected between FIL (PIN8) and this pin.	
8	FIL	Motor position detection comparator filter pin. A capacitor is connected between COMIN (PIN7) and this pin.	
9	RD	Motor lock detection output pin. Outputs High when motor is locked.	
10	FG	FG pulse output pin. This pin outputs pulse equivalent to one Hall sensor system pulse output.	
11	PWM	PWM signal input pin. The output transistor array is enabled/disabled by this pin. The speed of the motor is proportional to the Duty Cycle of this pin. Pin has internal pull-ups and constantly enables the output array at 100% duty cycle if open.	
12	F/R	Switches motor rotation direction. High level voltage input: U→W→V, Low level voltage input: U→V→W. Current flow into the motor according to the above order. Motor rotates reversely when the order of energization is changed.	
13	OSC	Motor start-up frequency setting pin. A capacitor is connected between this pin and GND. The start-up frequency is adjustable with a capacitor and charge/discharge current (2.5μA).	
14 15 16	TGND2 TGND1 GND	GND pin of the IC	

Application Circuit Example

(1)Application to Y-Connector Motor



(2)Application to Delta-Connector Motor



*1. [Connection of power supply and GND]

GND is connected to the power supply line of control circuit.

*2. [Power supply stabilizer capacitor]

The power supply stabilizer capacitor needs to be 4.7μA or higher. Connect V_{CC} and GND as wide and short as possible. If the supply voltage increases due to the kickback of coil as a result of using reverse connection protector diode, make sure to connect Zener diode between the power supply and GND.

LV8806QA uses synchronous rectification for high efficiency drive. Synchronous rectification is effective for heat reduction and higher efficiency. However, it may increase supply voltage under the following conditions:

*When output duty is reduced rapidly.

*PWM input frequency is low.

If the supply voltage shall increase, make sure that it does not exceed the maximum ratings with the following measures:

*Select an optimal capacitor between power supply and GND.

*Insert a zener diode between power supply and GND.

*3. [COMIN and FIL]

COMIN and FIL are the filter capacitor connection pins. LV8806QA detects the position of rotor using BEMF signal generated during motor rotation. Based on the information, current-carrying timing of the output is determined. By inserting a filter capacitor of about 1000 to 10000pF (recommendation) between COMIN and FIL, start-up failure caused by noise is alleviated. However, if the capacitance is too high, timing of current-carrying for output may be delayed during high-speed rotation and efficiency may be degraded.

Make sure that the filter capacitor is connected between COMIN and FIL as short as possible to avoid influence of noise.

*4. [OSC]

Capacitor connection pin for setting boot frequency.

Make sure to connect a capacitor of 500pF to 2200pF (recommendation) between this pin and GND. The capacitor is required to determine boot frequency to start motor.

How to define capacitance:

The capacitance should allow the shortest boot time for the target rotation count and less variation. The higher the capacitance is, the more likely the variation occurs in boot time. On the other hand, the lower the capacitance is, the more likely an idling occurs. Since an optimum value for OSC pin constant varies depends on motor characteristics and boot current, make sure to confirm the constant when motor or circuit specification are changed.

*5. [RF]

Current limit setting pin.
When a pin voltage exceeds 0.265V, current limiter operates and the mode shifts to regeneration mode.
The calculation formula is as follows.
RF resistance value = 0.265V / desired current limit value

*6. [Pin protection resistor]

It is recommended that resistors higher than 1kΩ are connected serially to protect pins against misconnection such as GND open and reverse connection.

*7. [Resistor for pseudo midpoint]

Delta connector motor does not have midpoint. Therefore, we need to create a pseudo midpoint by external resistor. Please note that the amplitude of BEMF signal generated during motor rotation varies depends on motor types. Some motors require the external pseudo midpoint and others do not.

*8. [FG, RD pull-up resistor]

Since FG and RD are open-drain output, make sure to use pull-up resistors.
It is recommended that the pull-up resistor is approximately 10kΩ.

1. Operation overview

LV8806 is a PWM three-phase sensorless motor driver.
In the sensorless drive, the timing of motor commutation switch is determined by comparing the back EMF (BEMF) generated by the motor and the voltage of CON pin or Motor Neutral.
After power activation, supplying a PWM signal to the PWMIN pin will enable output voltage to the motor coil.

・The FG signal is proportional to motor rotation and can be used for velocity control.
・RD Output is fixed high when motor is locked up and it is fixed low while motor is rotating.
・Speed of motor rotation is controlled by changing PWM signal frequency on the PWMIN pin.

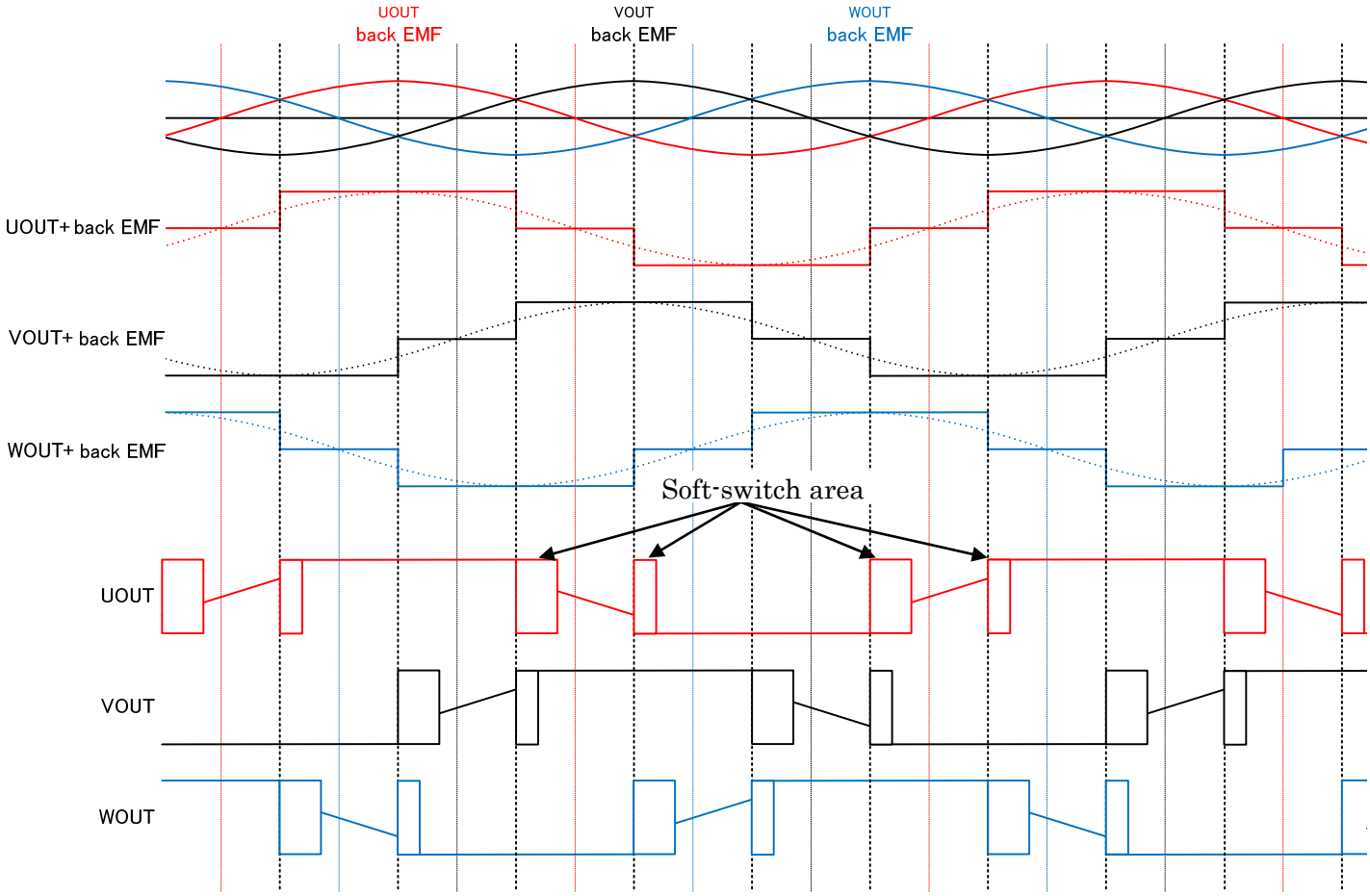
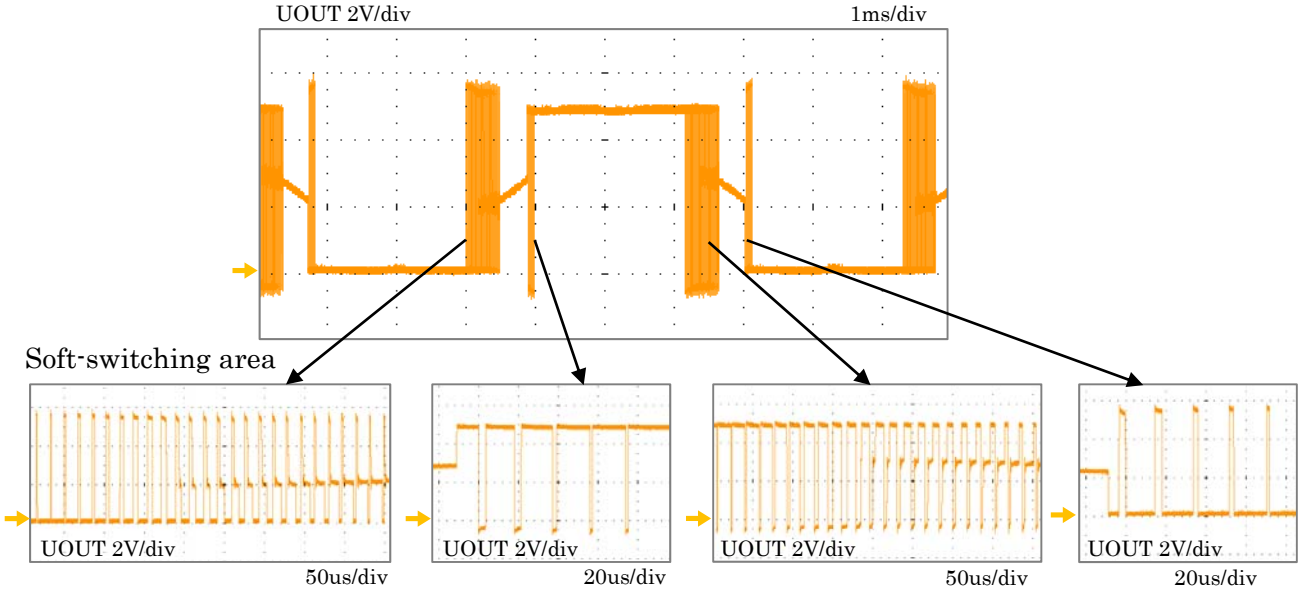


Fig. OUT pin wave patterns image.

Output waveform

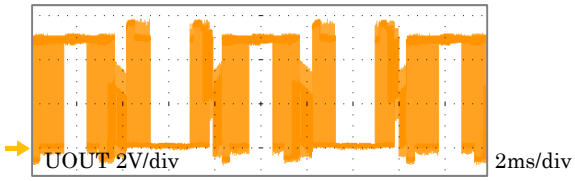
Full speed drive（PWM100％）

The waveform of output voltage of UOUT pin and FG pin are as follows. This graph shows the waveform when motor is driven at full speed.
The waveforms of output voltages for UOUT, VOUT and WOUT are the same.

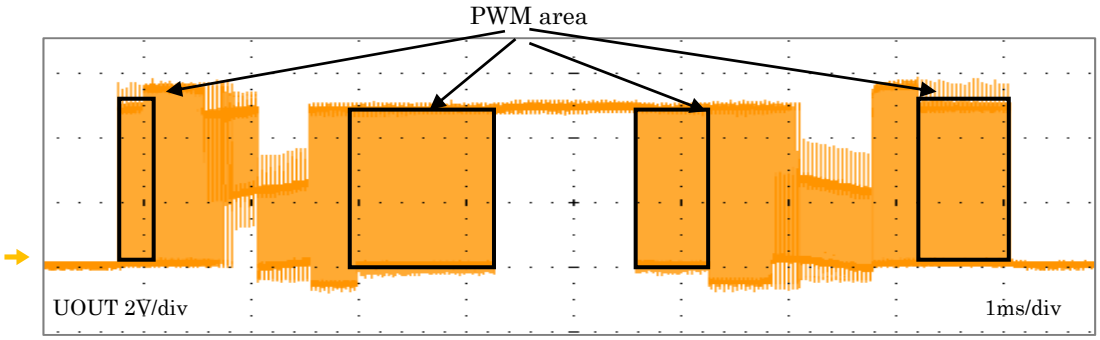


There are soft switching zone in UOUT signal that help smooth out the motor coil current and reduces physical noise in the motor.

PWM drive



The waveform of output voltage of UOUT pin and FG pin are as shown above.



There are soft switching zones and PWM zones in UOUT signal.

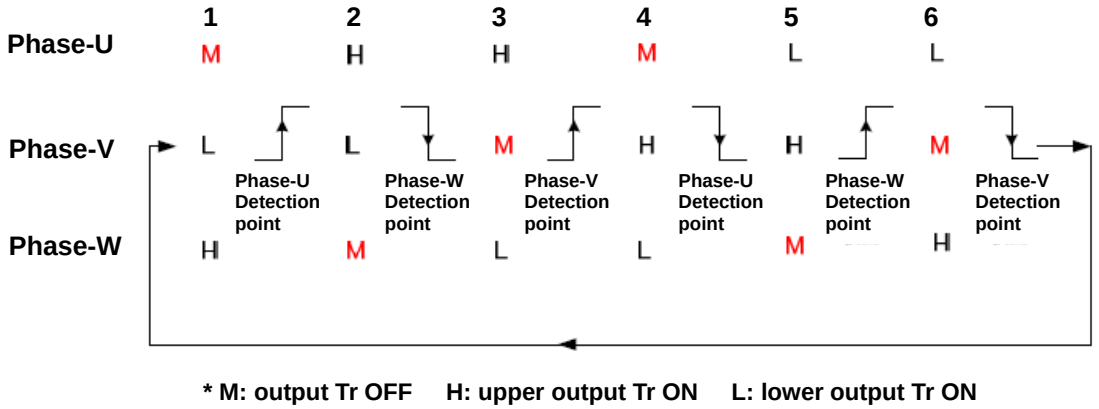
2. Sensor less control

LV8806 is a sensorless motor driver which detects the back EMF (BEMF) signal during motor rotation to detect rotor position. According to the detected rotor position, a specified output transistor turns on or off, which enables motor rotation.

When starting up a motor, it is impossible to detect the rotor position at very low RPM as the BEMF signal amplitude is too low. Therefore the motor starts by cycling the output with a fixed frequency determined by a capacitor between the OSC pin and GND in startup mode. After startup, a rotor position is detected by the back EMF signal and the controller will transition into a drive mode.

Principle for Motor starting operation

Switching pattern of output transistor during motor start up



*** M: output Tr OFF H: upper output Tr ON L: lower output Tr ON**

The transition timing varies depending on specific motor types so it is necessary to set up an optimum OSC capacitor for the motor. (Refer to “Start up pin setting”)

3. Startup pin setup

In order to adjust startup characteristics of the motor, it is necessary to set OSC pin (OSC-GND capacitor) and COMIN pin FIL pin (COMIN-FIL capacitor) with optimal capacitances.
The best capacitance depends on motor type and condition (power supply, coil current, number of rotation). Hence be sure to make an adjustment for each motor type.

3.1 OSC-GND capacitance setup

(Recommendation value 470pF - 2200pF)
Startup frequency is defined by OSC capacitance.
The formula for obtaining OSC frequency is as follows.

$$Fosc = \frac{1}{Toscc+Toscd}$$

$$Toscc = \frac{(Vosch-Voscl)\times Cosc}{Ioscc}$$

$$Toscd = \frac{(Vosch-Voscl)\times Cosc}{Ioscd}$$

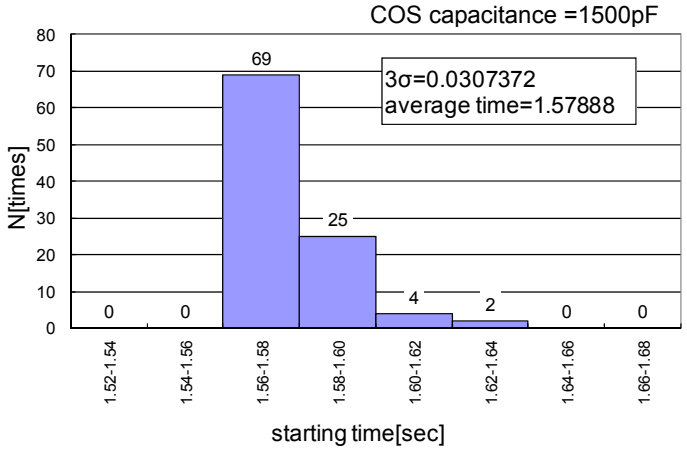
OSC pin frequency : Fosc
OSC capacitor charge time : Toscc
OSC capacitor discharge time : Toscd
OSC capacitance : Cosc
OSC pin high-level voltage : Vosch=1.1V(TYP)
OSC pin low-level voltage : Voscl=0.6V(TYP)
OSC pin charge current : Ioscc
OSC pin discharge current : Ioscd

I In general a low capacitance tends to be used if the motor runs at a high speed and a higher capacitance is used if the motor runs at lower speeds.

Use a lower capacitance when:
・Startup is slow and fails.
・Startup time varies widely.

Example) fan motor startup test of LV8805
Condition: Vcc＝12V
OSC capacitance=1500 pF/3300 pF
Goal number of revolutions=4500 rpm
COMIN-FIL capacitance =2200 pF
Test count=100 times

When a capacitance of COS is optimum:



When a capacitance of COS is not optimum:

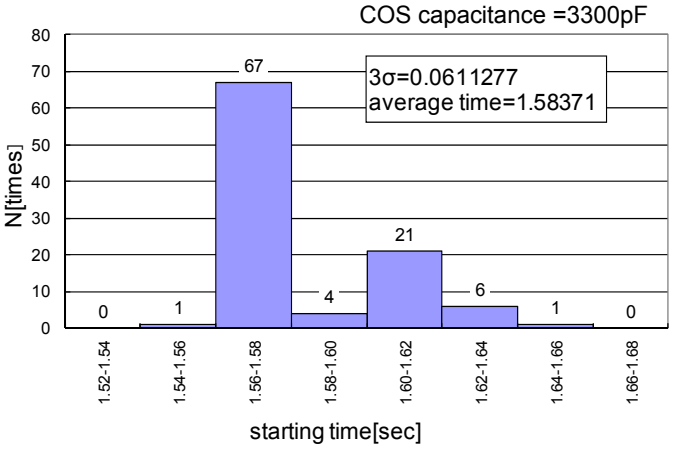


Fig. Startup test of a fan motor using LV8805

Use a higher capacitance if:
・Startup fails a Beat lock* occurs.

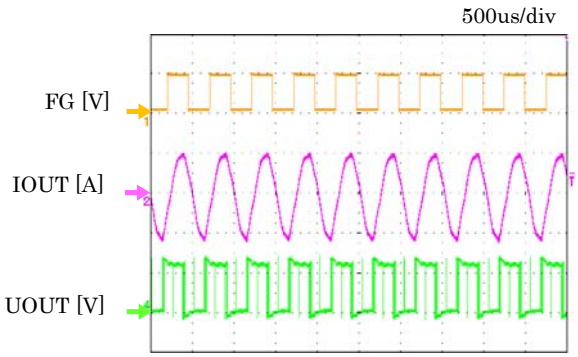


Fig. The output waveform with beat lock

Select a capacitance value that allows the shortest possible startup time to achieve target speed and minimal variations in startup time.
The optimum OSC constant depends on the motor characteristics and startup current, so be sure to recheck them when either motor or circuit specifications are changed.
(* Refer to "**3 Beat lock**")

3.2 COMIN-FIL capacitance setup

(Recommendation value: 1000pF ~ 10nF)
Compare the back EMF signal from motor and the voltage of CON pin (motor neutral) to detect the rotor position. The timing of motor commutation is determined by the detected rotor position.
Insert a filter capacitor between the COMIN pin and FIL pin to prevent startup failure caused by noise.

●When a capacitance is high and:
・The commutation time is slow during motor rotation. → Driving efficiency falls.

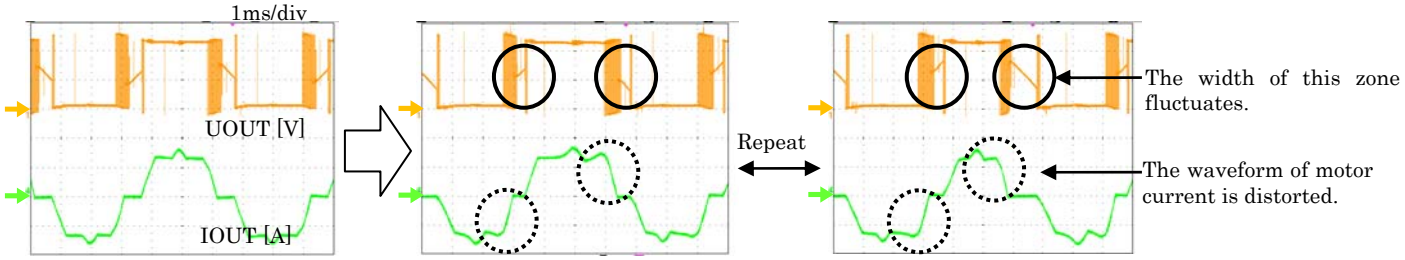


Fig. normal waveform

Fig. waveform when FIL-COMIN capacitance is too large.

◎If such behavior is witnessed, use a lower capacitor.

●When a capacitance is low and:
・Beat lock* occurs.

◎If such behavior is witnessed, use a higher capacitor.

A capacitor is selected by checking the intended motor type. Run the motor to see whether there is any issue with startup.
(* Refer to **3.3 Beat lock on next page.**)

3.3 Beat lock

Beat lock may occur when a motor is stopped abruptly during motor operation or OSC capacitor is too low.
Output waveform under the influence of beat lock is as shown below.

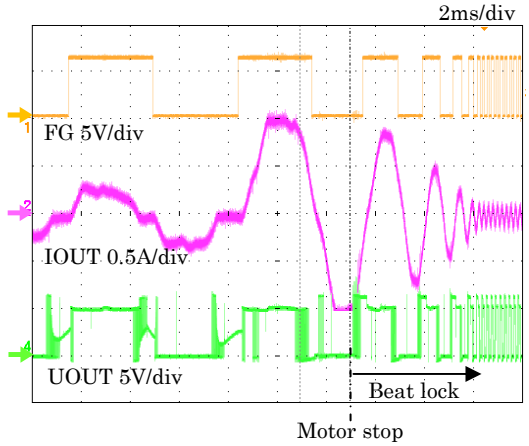


Fig. The beat lock caused by a motor quick stop

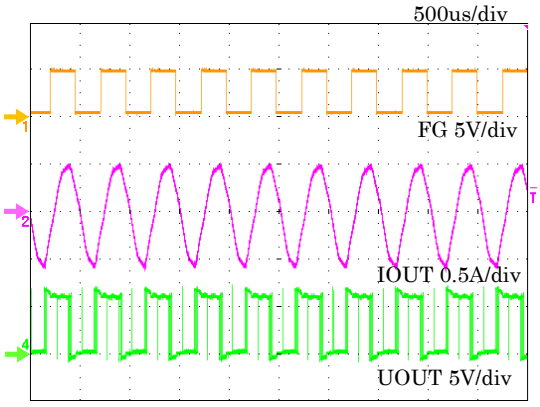


Fig. The beat lock weave form.

{Behavior}

- There is intense switching sound from transistor and then the motor stops.
- Waveform of OUT pin and FG pin shows the influence of noise.
- Motor cannot restart automatically after motor rotation stops.

Countermeasures:

1) False detection of the internal comparator is prevented by adjusting a capacitor between COMIN and FIL. Basically, the number of false detections by the internal comparator decreases with a higher capacitor between COMIN and FIL.
However, care must be taken since excessively high capacitance will give rise to deterioration in efficiency and delays in the output power-on timing when the motor is intended to run at high speed.

2) Increase the OSC capacitance. By doing so, OSC frequency decreases, which prevents false detection by the internal comparator due to delay in the output power-on timing. Consequently, beat lock is prevented.

If motor type is changed, test the motor startup behavior again.

4. input signal condition of PWM pin

LV8806 is a direct PWM signal input system for speed control.
Recommendation Condition

High-level input voltage :	5 [V]
Low-level input voltage :	0 [V]
PWM frequency range :	20k-50k [Hz]

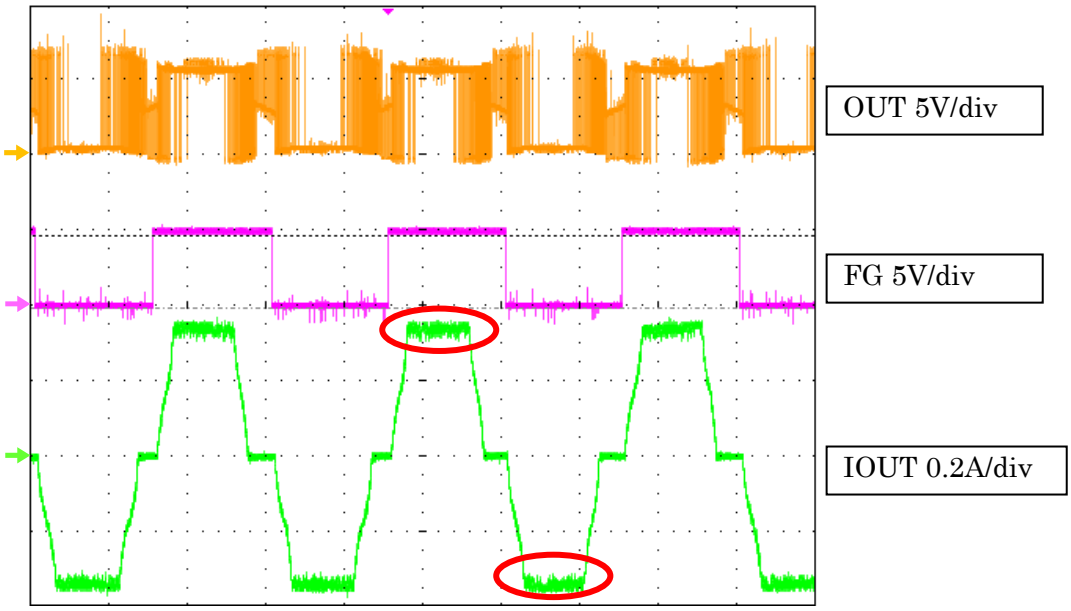
*Caution: The minimum pulse width of PWM signal is 0.2u [sec](= duty of 1% at 50k [Hz])

5. Other protection circuits

5.1 Current limier

Current limiter is configured by adjusting the resistance between RF and GND.
When the pin voltage exceeds 0.265V, the current is limited, and regeneration mode is set. In the application circuit, the current limit setting voltage is 0.265V; therefore the current limit operates at 1A.
The calculation formula is given below.
(RF resistance) = 0.265V / (target current limit value)

Current limit driving



Red-circled IOUT is the current limited area.

5.2 Thermal protection circuit

LV8806 integrates thermal protection circuit. When Junction temperature, Tj exceeds 180°C, output transistor turns off.

6. Evaluation board manual

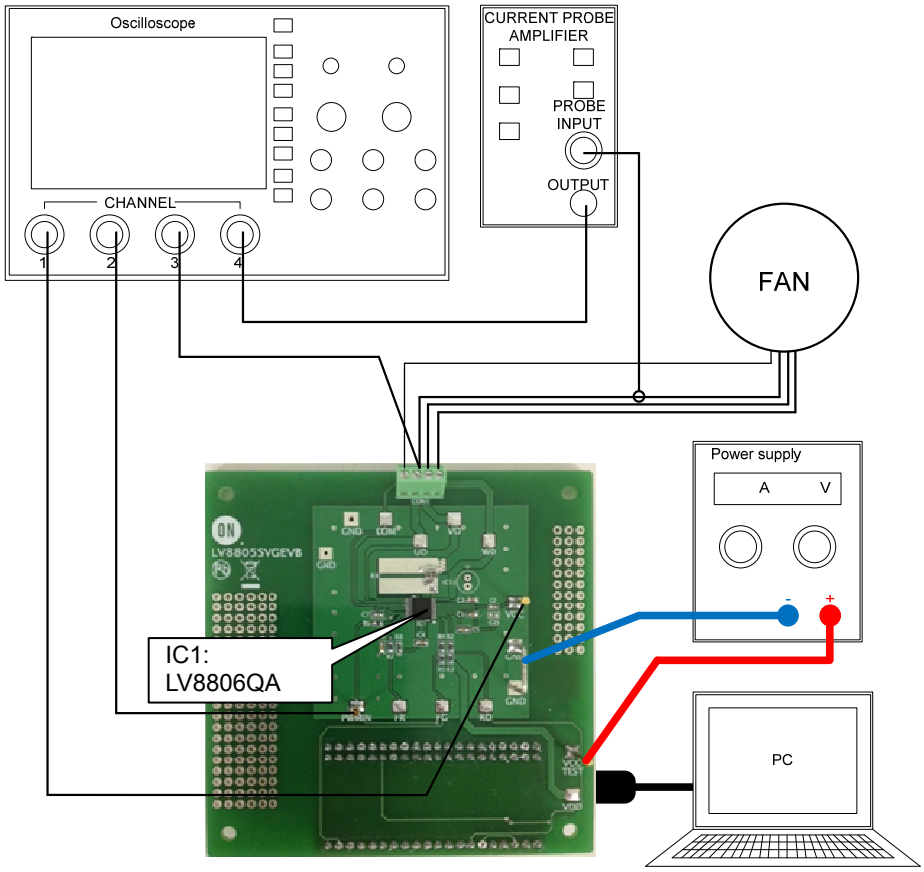
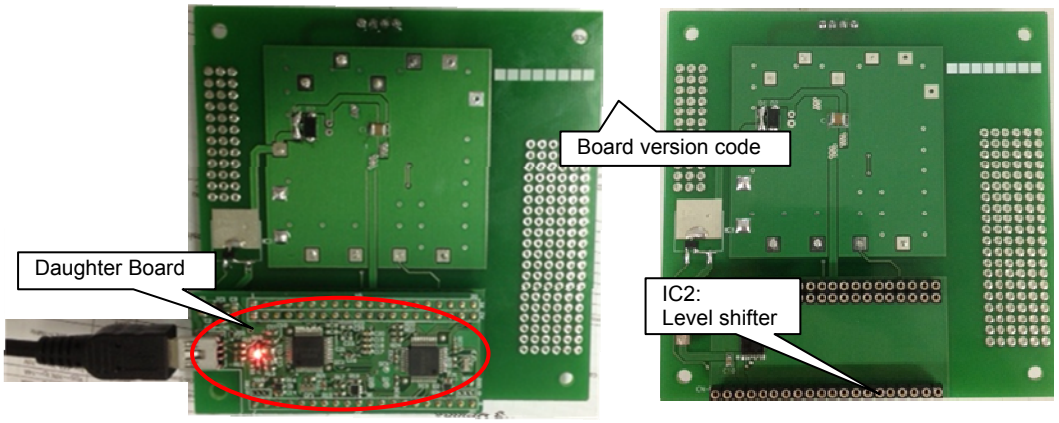


Figure 1. Setup for motor control



With the Daughter Board plugged into USB Without the Daughter Board

Figure 2. Bottom view of the Evaluation Board

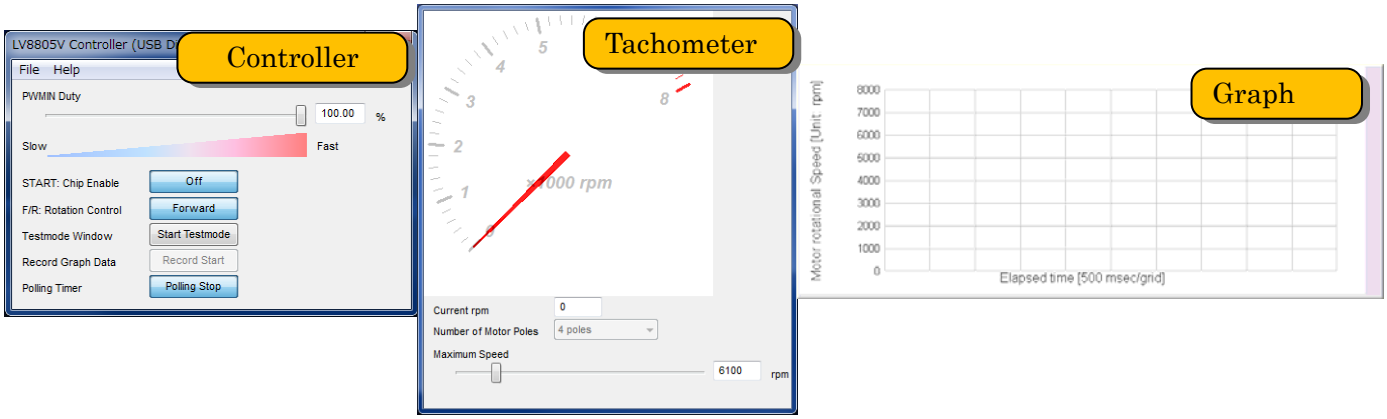


Figure3. Images of GUI

Bill of Materials for LV8806QA Evaluation Board

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
IC1	1	Motor Driver			UQFN16(2.6*2.6)	ON semiconductor	LV8806QA	No	Yes
IC2	1	Level Shifter			TSSOP16	ON semiconductor	MC14504B	No	Yes
IC3	1	MOSFET			CPH3	ON semiconductor	CPH3350	No	Yes
R1	2	Thick film Resistor	1Ω, 0.25W	±5%	2012(0805Inch)	Rohm	MCR10EZHFL1R00	Yes	Yes
R2,4,6,7	4	Thick film Resistor	100Ω, 0.1W	±5%	1608(0603Inch)	Koa	RK73B1JT101J	Yes	Yes
R3,5	2	Thick film Resistor	10kΩ, 0.1W	±5%	1608(0603Inch)	Koa	RK73B1JT103J	Yes	Yes
C1	1	Ceramic multilayer Capacitor	4.7μF, 25V	±10%	3216(1206Inch)	Murata	GRM319B31E475KA75	Yes	Yes
C2	1	Ceramic multilayer Capacitor	2200pF, 50V	±10%	1608(0603Inch)	Murata	GRM188B11H222KA01	Yes	Yes
C3	1	Ceramic multilayer Capacitor	1000pF, 50V	±10%	1608(0603Inch)	Murata	GRM1882C1H102JA01	Yes	Yes
C4,5	2	Ceramic multilayer Capacitor	1μF, 25V	±10%	1608(0603Inch)	Murata	GRM188B31E105KA75	Yes	Yes
Daughter Board	1	Interface board				ON semiconductor		No	Yes
CN-A1,A2,B	3	Female Socket				MAC8	PM-61	Yes	Yes
CON_M	1	Socket to Motor				JST	MPT 0.5/4-2.54	No	Yes
P1-9	1	Test Point				MAC8	ST-1-3		

Evaluation board circuit diagram

LV8806QAGEVB Schematic