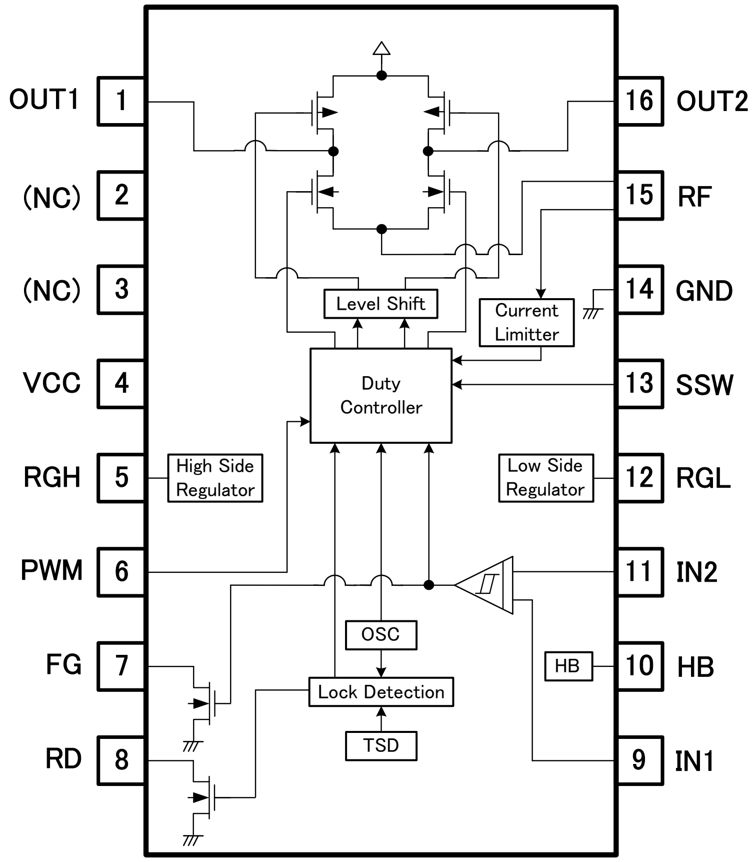
Block Diagram



Specifications

Absolute maximum rating at Ta=25°C

Parameter	Symbol	Conditions	Ratings	Unit
Maximum supply voltage	VCC max		36	V
OUT pin output current	IOUT max		0.7	A
RD/FG output pin withstand	VRD/FG max		36	V
RD/FG output maximum current	IRD/FG max		10	mA
RGL output maximum current	IRGL max		5	mA
HB output maximum current	IHB max		10	mA
PWM input pin withstand	VPWM max		6	V
Allowable power dissipation	Pd max	*On a specified board	0.8	W
Operating temperature	Topr		-40 to +95	°C
Storage temperature	Tstg		-55 to +150	°C

*Specified board: 114.3mm×76.1mm×1.6mm, fiberglass epoxy printed circuit board

Caution 1) Absolute maximum ratings represent the values 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.

Recommended Operating Conditions at Ta=25°C

Parameter	Symbol	Conditions	Ratings	Unit
Operating supply voltage range	VCC op1	Recommended supply voltage range	7 to 34	V
	VCC op2	Boot guarantee supply voltage range	6 to 34	V
Hall input common phase input voltage range	VICM		0.3 to VRGL-2.0	V
SSW pin input voltage range	SSW		1.0 to 3.0	V
Input PWM frequency range	PWMF		20 to 50	kHz

Electrical Characteristics at Ta=25°C, V_{CC}=24V

Parameter	Symbol	Conditions	Ratings min	Ratings typ	Ratings max	Unit
Circuit consumption current	ICC	Active		2.2	3.5	mA
	ICCo	Stand-by		1.7	2.7	mA
RGL pin output voltage	VRGL		4.7	5.0	5.3	V
RGH pin output voltage	VRGH		VCC-4.3	VCC-4.8	VCC-5.3	V
HB pin output voltage	VHB	IHB=5mA	1.16	1.25	1.28	V
Output ON resistance	Ron	Io=0.3A, upper and lower ON resistance		1.4	2.0	Ω
Hall input bias current	IHIN				1.0	uA
Current limiter	VRF		200	225	250	mV
PWM pin input Low level	VPWML		0		1.0	V
PWM pin input High level	VPWMH		2.5		VRGL	V
PWM input minimum pulse width	TPWM			2		uSec
RD/FG output pin Low voltage	VRD/FG	IRD/FG=3mA		0.22	0.30	V
FG output leakage current	IRDL/FGL	VRD/FG=24V			10	uA
FG comparator hysteresis width	ΔVHYS	including offset	±5	±12	±18	mV
Output ON time in Lock-detection	TACT		0.74	0.95	1.16	Sec
Output OFF time in Lock-detection	TDET		7.0	9.0	11.0	Sec
Output ON/OFF ratio in Lock-detection	TRTO	TRTO=TDET/TACT	7.5	9.0	11.0	
Thermal shutdown operating temperature	TSD	*Design guarantee		180		°C
Thermal shutdown hysteresis width	ΔTSD	*Design guarantee		40		°C

* Design guarantee value and no measurement is performed.

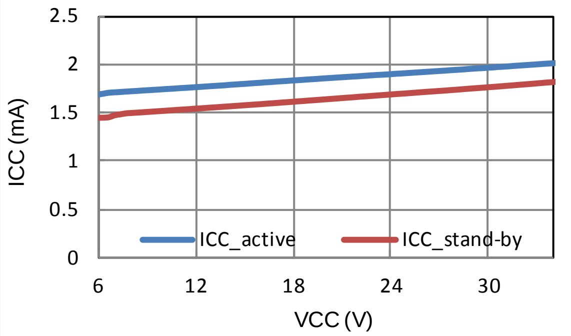


Figure 1 Curcuit consumption current vs Supply voltage

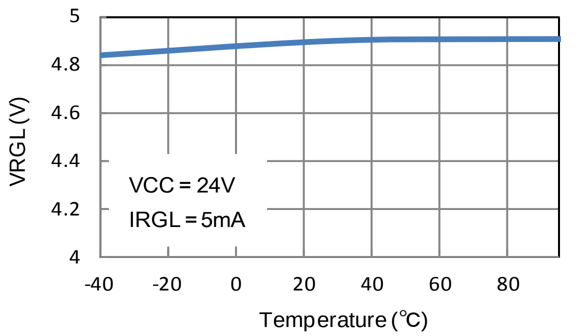


Figure 2 RGL pin output voltage vs Temperature

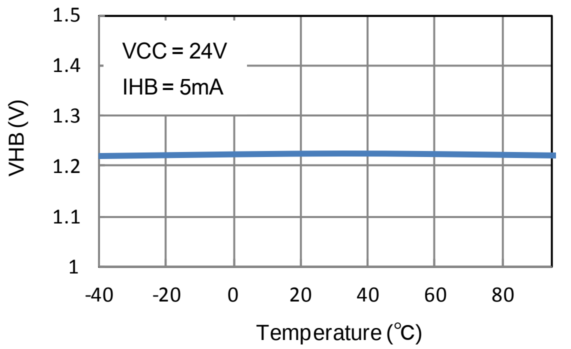


Figure 3 HB pin output voltage vs Temperature

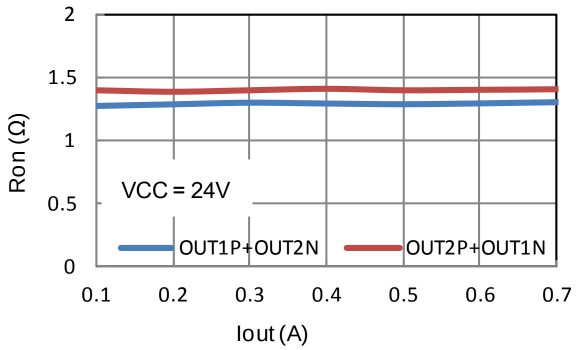


Figure 4 Output on resistance vs Output current

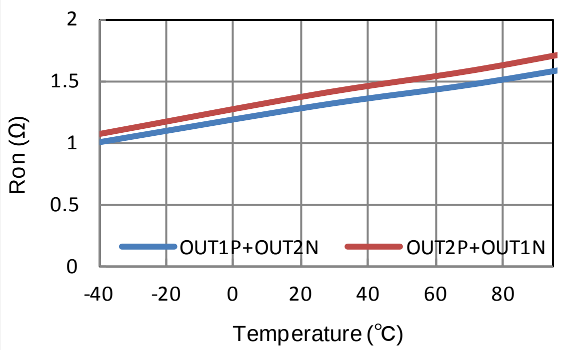


Figure 5 Output on resistance vs Temperature

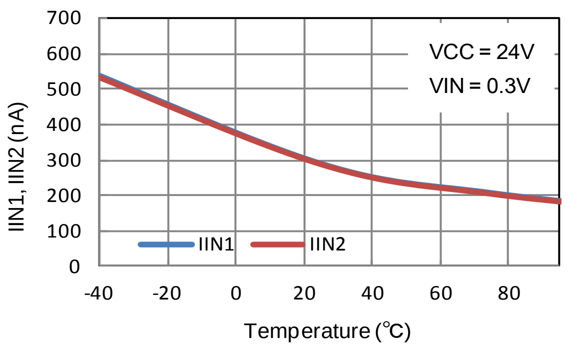


Figure 6 Hall input vias current vs Temperature

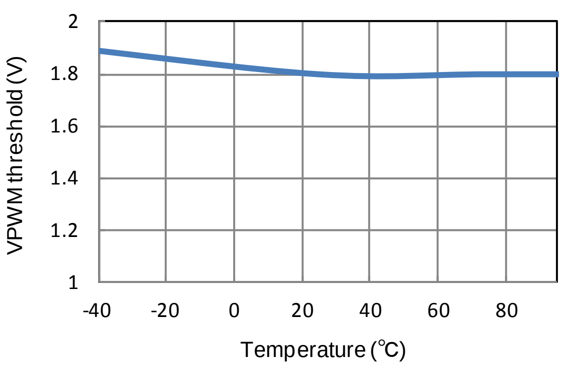


Figure 7 PWM input threshold voltage vs Temperature

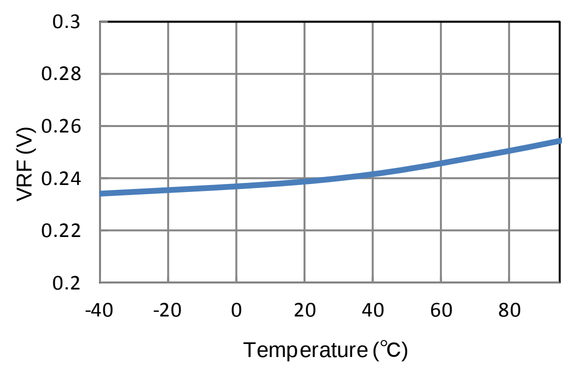


Figure 8 Current limitter voltage vs Temperature

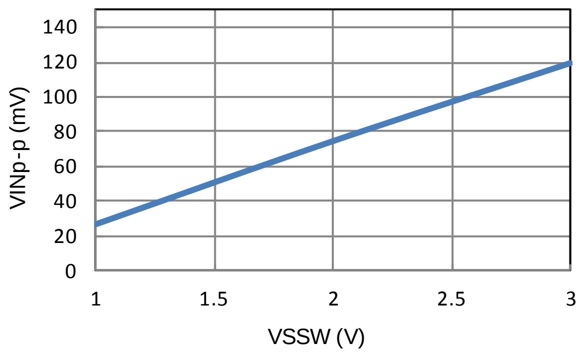


Figure 9 Voltage difference of IN1 and IN2 making Soft-SW width vs SSW voltage

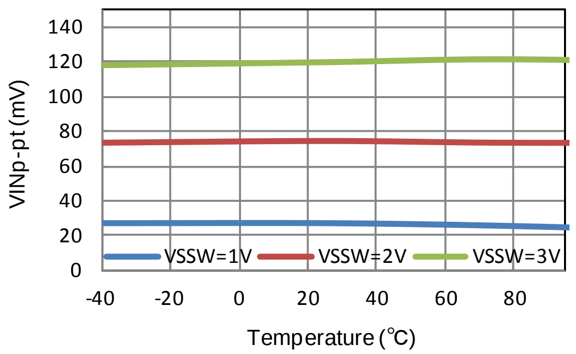


Figure 10 Voltage difference of IN1 and IN2 making Soft-SW width vs Temperature

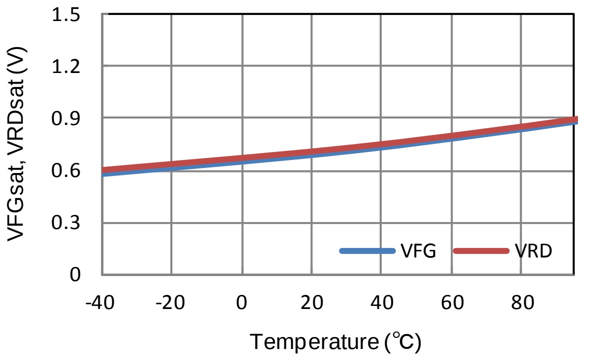


Figure 11 RD/FG output pin low voltage vs Temperature

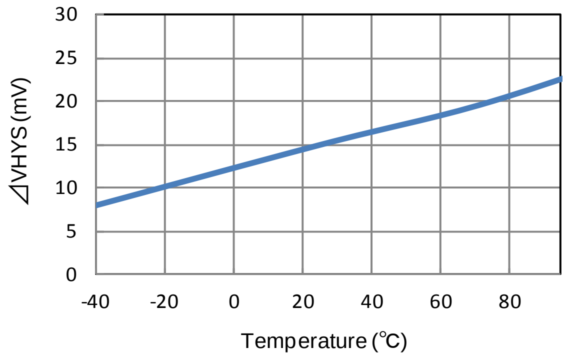
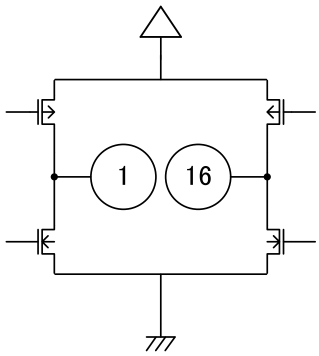
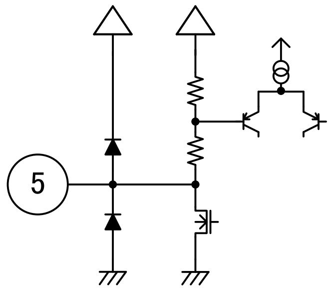
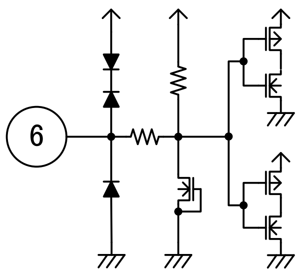
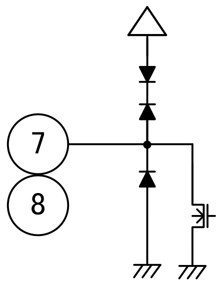


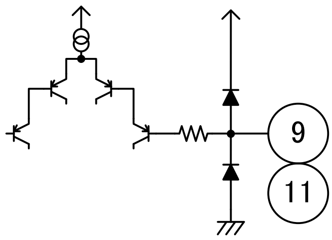
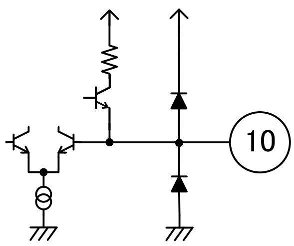
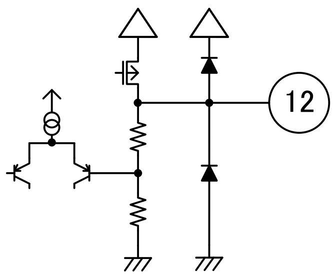
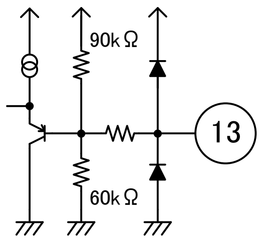
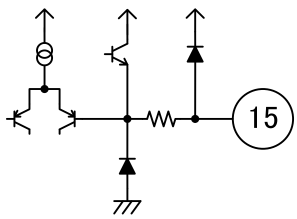
Figure 12 FG comparator hysteresis width vs Temperature

Pin Functions

*On circuit board , means VCC , means RGL.

Pin No.	Pin name	Description	Equivalent circuit
1	OUT1	Output pin for motor driver The motor coil is connected between OUT1 (pin1) and OUT2 (16pin).	
16	OUT2		
2	NC	NC pin	
3	NC	NC pin	
4	VCC	Power supply pin VCC voltage is impressed. The operation voltage range is from 7.0 to 34.0(V). The capacitor is connected to GND pin (14pin) for stabilization.	
5	RGH	Regulator voltage output pin for the upper output Tr driver The capacitor is connected to VCC pin (3pin) for stabilization.	
6	PWM	Input pin for PWM control The PWM signal is supplied for speed control. *OPEN: pull up to High * When input is High → output is High When input is Low → output is Low	
7	FG	FG(rotation detection) pulse output pin The resistor is connected to VCC pin (3pin) for detection signal.	
8	RD	RD(lock detection) signal output pin *During rotation → output is Low During lock→ output is High The resistor is connected to VCC pin (3pin) for detection signal.	

To the next page

Pin No.	Pin name	Description	Equivalent circuit
9	IN1	Hall input + pin Hall input - pin The Hall device outputs are connected. If hall signal is affected by noise, the capacitor should be connected between IN1 pin (9pin) and IN2 pin (11pin).	
11	IN2		
10	HB	Hall bias output pin The voltage supply pin of Hall device is connected.	
12	RGL	Regulator voltage output pin for internal circuit and lower output Tr driver The capacitor is connected to GND pin (14pin) for stabilization.	
13	SSW	Voltage input pin for control between soft switches The resistor is connected to for RGL or GND pin (14pin) for adjusting soft switch width. *OPEN: pin voltage is 2V *Soft switch zone is changed by connecting a resistance to RGL or GND to adjust pin voltage.	
14	GND	Ground pin	
15	RF	Resistive connection pin for current limiter The resistor is connected to GND (14pin) for detection of current value.	

Operational Description

1. Operation Overview

LV8860V is a driver with single phase full wave drive mode which outputs the voltage to a coil based on the position signal from a Hall device. By supplying power, the IC is turned on. As a result, the output voltage is impressed to the coil.
FG signal is outputted according to phase switch of the coil, and RD signal is output when a motor is locked. LV8860V incorporates speed control function with direct PWM input method. The output mode is switched according to the signal input into a PWM pin and speed control is performed.

・When PWM input duty is 100% (DC input) or PWM pin is open, a fan rotates at full speed.
・Rotation speed is controllable because when a duty signal is input to PWM input, coil is energized by the same duty.
・When PWM input duty is 0% or the PWM pin is shorted to GND, IC is set to standby mode, where power supply to coil is stopped and a fan stops.

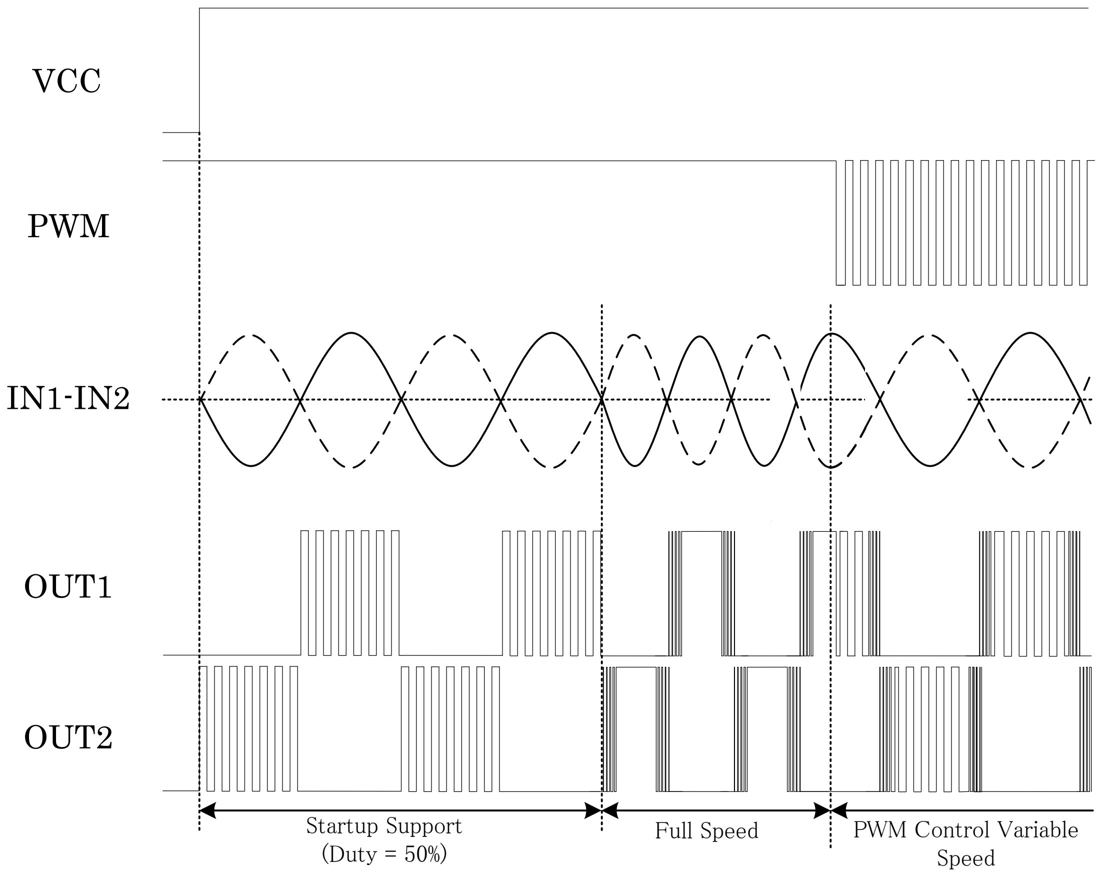


Fig.13 Operation Waveform

Input-Output Logic

Operating state	IN1	IN2	PWM	OUT1	OUT2	FG	RD
Rotation - drive mode	H	L	H	H	L	L	L
	L	H		L	H	OFF	L
Rotation – regeneration mode	H	L	L	L	L	L	L
	L	H		L	L	OFF	L
Stand-by mode	-	-	L	L	OFF	OFF	L
Lock protector	H	L	-	OFF	L	L	OFF
	L	H		L	OFF	OFF	OFF

Example Wave Form (VCC = 24V , □80 single phase fan motor is used)

Explanation of each wave
VIN1, VIN2 : input signal from Hall device
VOUT1 : output signal from OUT1 pin(1pin)
VOUT2 : output signal from OUT2 pin(16pin)
VFG : output signal from FG pin(7pin), FG pin is pulled up with VCC pin
IOUT : Coil Current

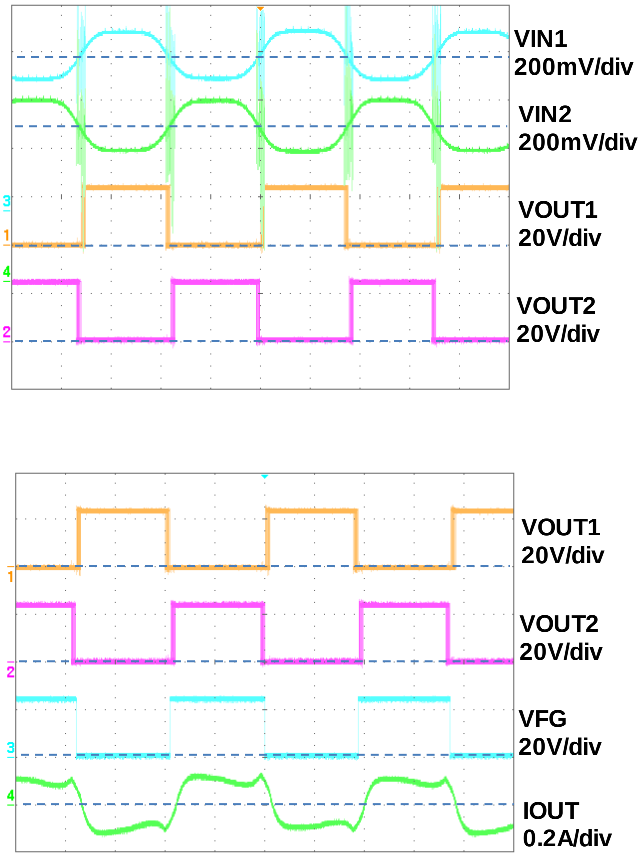


Fig.14 Operation Waveform

1-1. Full-Speed drive
When PWM pin is open or input PWM signal duty is 100%, the output of LV8860V is considered “full speed drive”.
LV8860V has adopted a new soft-switching method, with which output waveform before and after the phase switch is obtained as shown in the following figure, where the duty changes gradually.

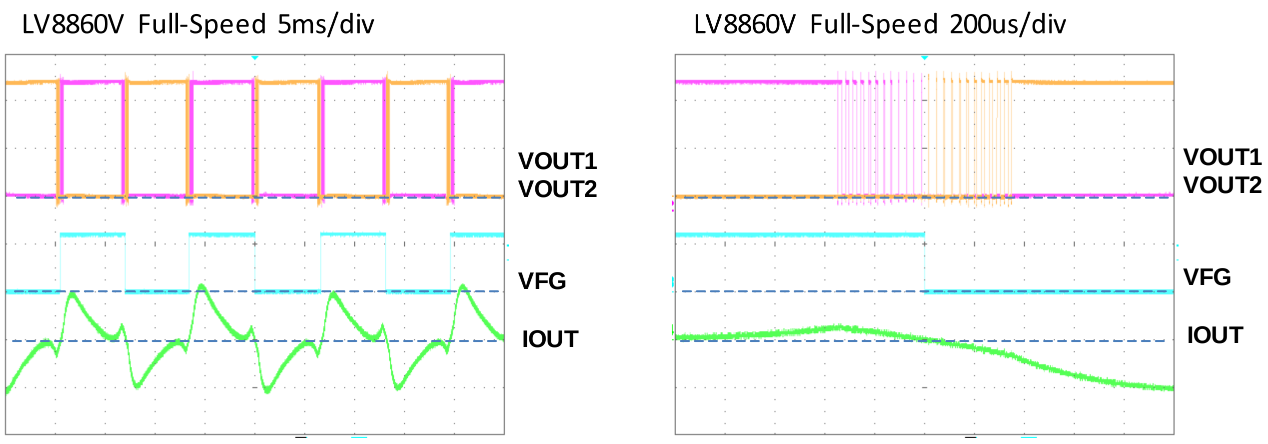


Fig.15 Waveform of full speed drive

1-2. Speed control by PWM input
The rotation speed is controllable by PWM input into PWM pin (No.6pin) .
/PWM input voltage is “ Low ” => Drive OFF
 PWM input voltage is “ High ” => Drive ON
/When PWM pin is open , IC drives Duty = 100% .
/Input PWM frequency range is 20kHz – 50kHz , and Input PWM amplitude is 0V – 5V .

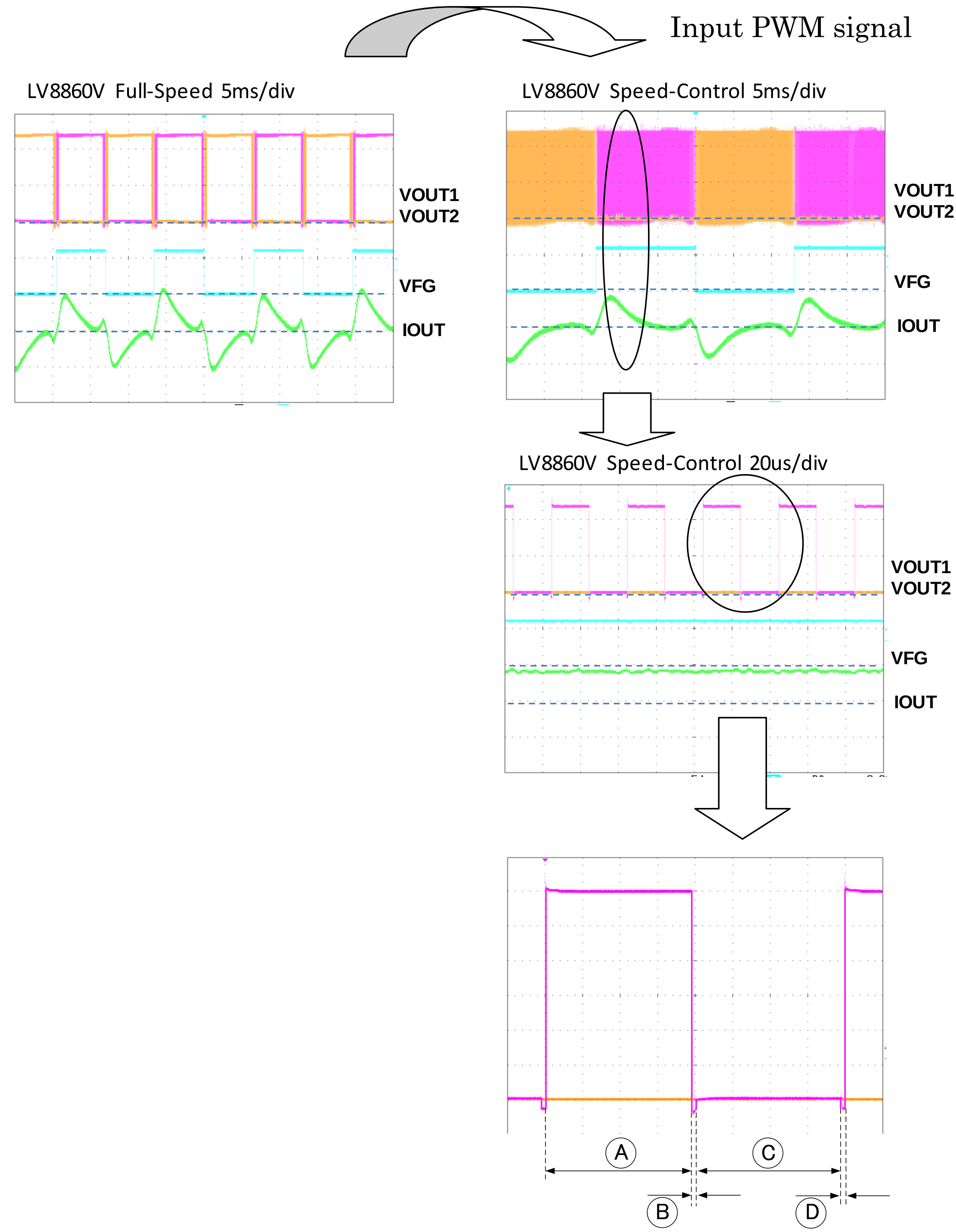
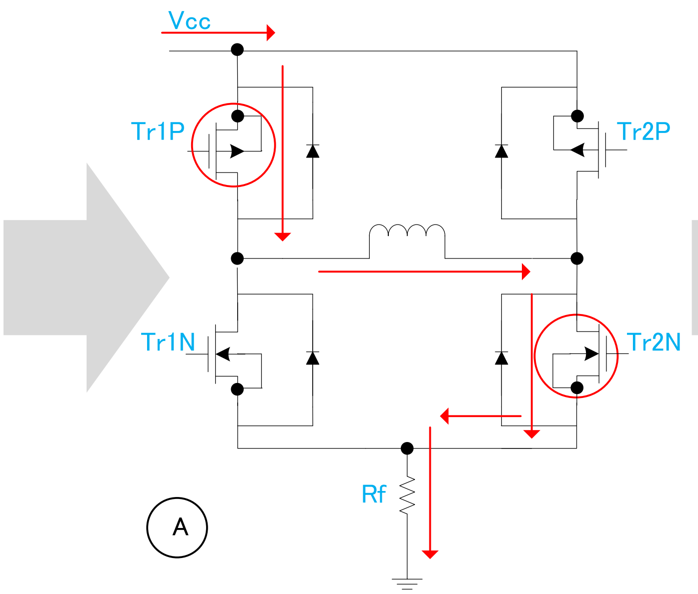
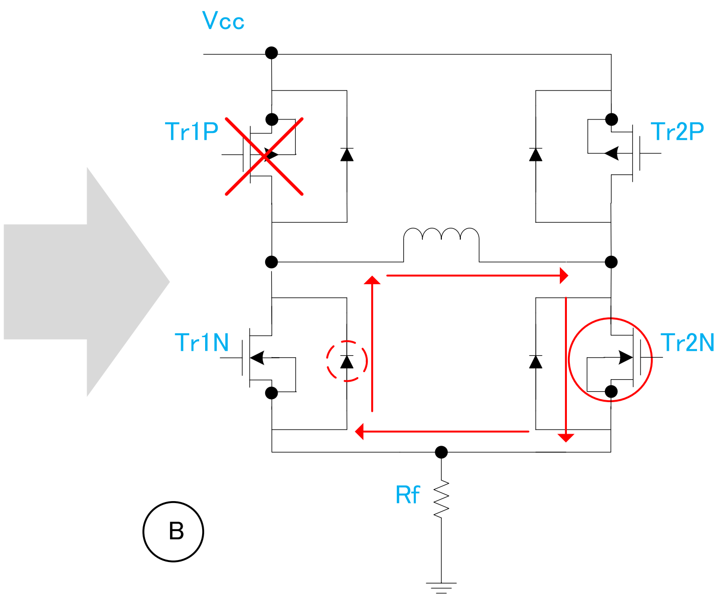


Fig.16 Waveform of speed-control drive

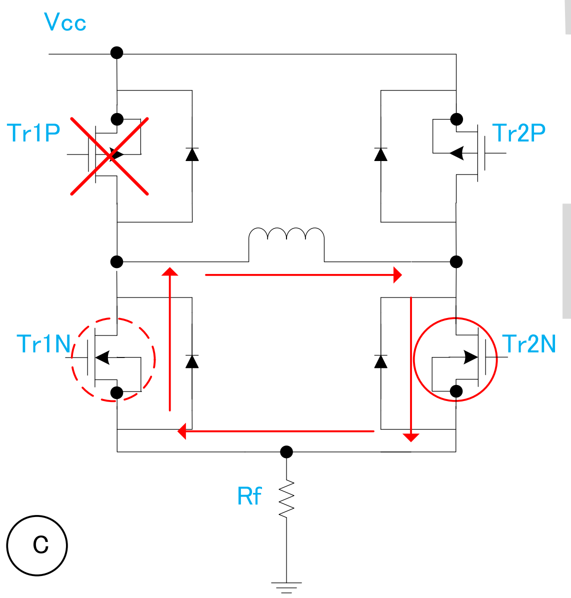
1-2-Appendix1. Description of synchronous rectification
The synchronous rectification is one method for current regeneration in PWM speed control, which realizes high efficiency and low heat generation compared to the conventional diode rectification.
The following figure explains operation of the output when synchronous rectification is performed.
The alphabet at the left lower of each figure corresponds to figure 16 of the previous section.

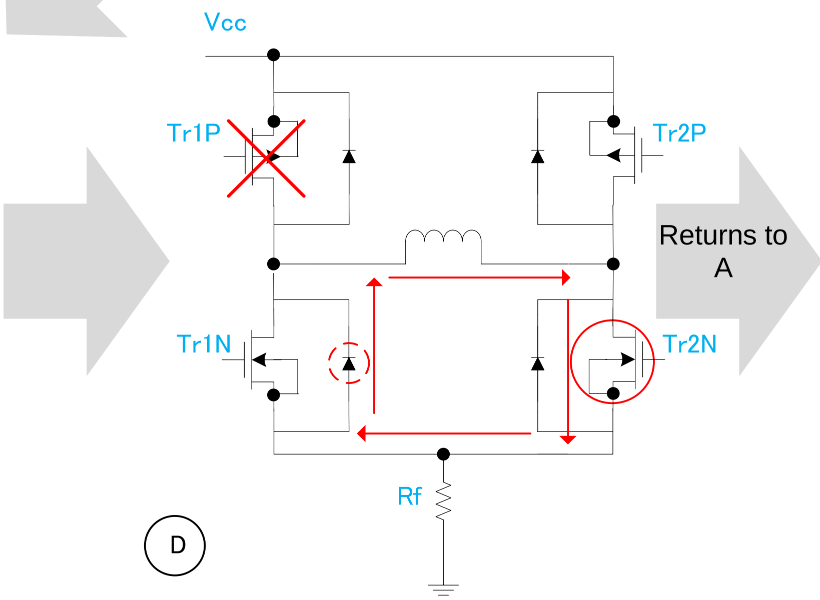




1) When 2 transistors, Tr 1P and Tr2N are ON, coil current flows through the coil.
   At that time, output voltages are
   OUT1: Vcc – Vsat1P
   OUT2: 0V + I × Rf + Vsat2N

2) When PWM signal turns to Low, Tr 1P turns OFF to prevent penetration current.
   Coil current flows through the parasite Diode of Tr1N.
   At that time, output voltages are
   OUT1: 0V – VF (negative potential)
   OUT2: 0V + Vsat2N

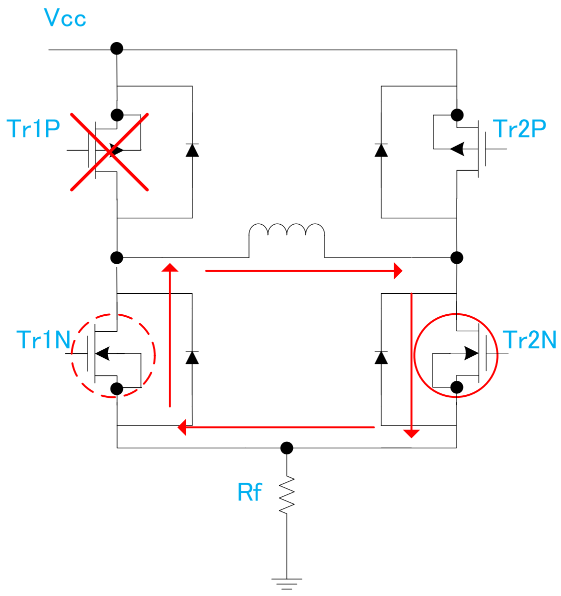


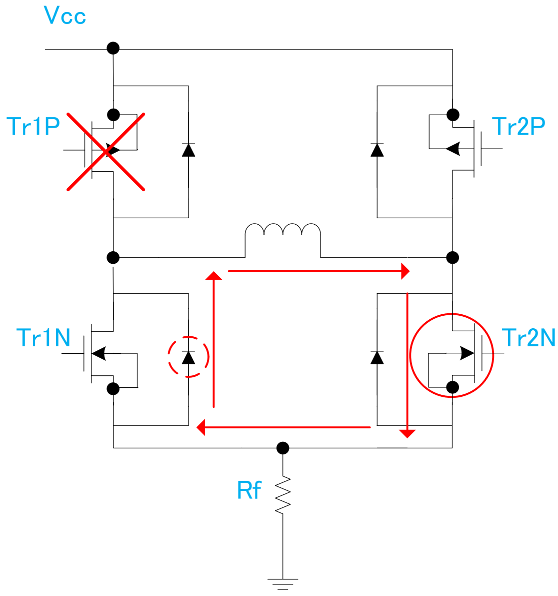


3) Next, Tr1N turns ON,
   Coil current flows through the Tr1N, coil, and Tr2N. (This method is “synchronous rectification”)
   At that time, output voltages are
   OUT1: 0V – Vsat1N (negative potential)
   OUT2: 0V + Vsat2N

4) When PWM signal turns to High, Tr1N turns OFF.
   Coil current flows through the parasite Diode of Tr1N.
   At that time, output voltages are
   OUT1: 0V – VF (negative potential)
   OUT2: 0V + Vsat2N

1-2-Appendix2.Merit of synchronous rectification compared to the conventional diode rectification.





In this case, output voltages are
OUT1: 0V – Vsat1N (negative potential)
OUT2: 0V + Vsat2N

In this case, output voltages are
OUT1: 0V – VF (negative potential)
OUT2: 0V + Vsat2N

When the ON resistance of the transistor used for regeneration (Tr1N) is low and Vsat1N (Tr1N * regenerated current) is lower than VF of the diode used for diode regeneration, the power dissipation for regeneration is small. Hence, efficiency becomes high and low heat generation is realized.
Example: Compare the power dissipation in Tr1N during regeneration where Iout = 0.3A, Ron = 0.5Ω, VF = 0.7V:

Synchronous rectification Ptr1n = Iout × Vosat1N = 0.3 × (0.3 × 0.5) = 0.045(W)
Diode regeneration Ptr1n = Iout × VF = 0.3 × 0.7 = 0.21(W)

Heat generation of synchronous rectification is about 20% of that of diode regeneration at Tr1N.

1-3. Stand-by mode

When PWM input duty is 0% or PWM pin is connected to GND, the IC runs stand-by mode.
The low signal detection time of stand-by mode is about 400us.
In stand-by mode, motor is stopped. The motor starts rotation again as soon as PWM-High signal is detected.

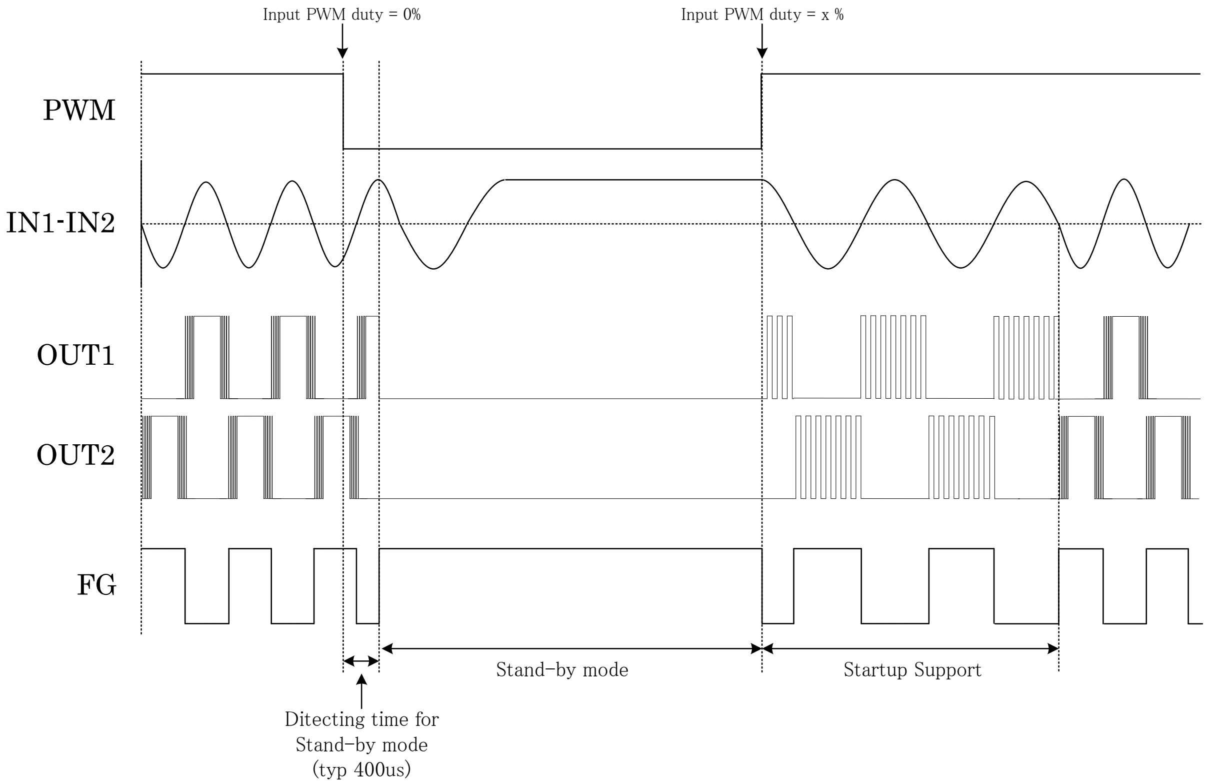


Fig.17 Operation Waveform of Stand-by mode

2. Switching method

Outline

LV8860V has silent PWM drive new switching method which realizes high efficiency and silent drive.
The characteristic waveform in silent PWM mode at phase switch is shown in figure 18.
Compared to the conventional switching method, current switch is smooth; therefore, the operation is silent and efficient.
The soft switch width before and after phase change is adjustable. As the following figure18 shows, by adjusting soft switch width, current change is optimized. As a result, we can get the following merits.

1. Small kickback waveform
2. Silent drive
3. Higher driving efficiency

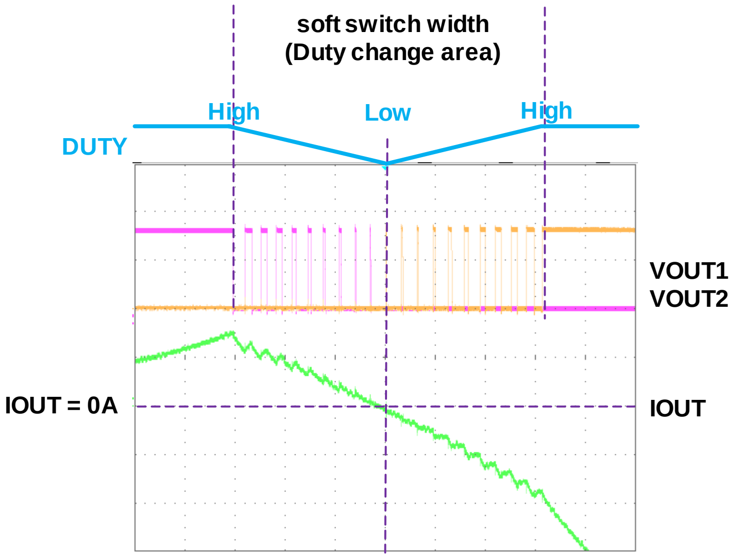


Fig.18 Waveform of OUTPUT1/2
with silent PWM drive at phase change

Comparison of silent PWM soft switching with conventional switching method

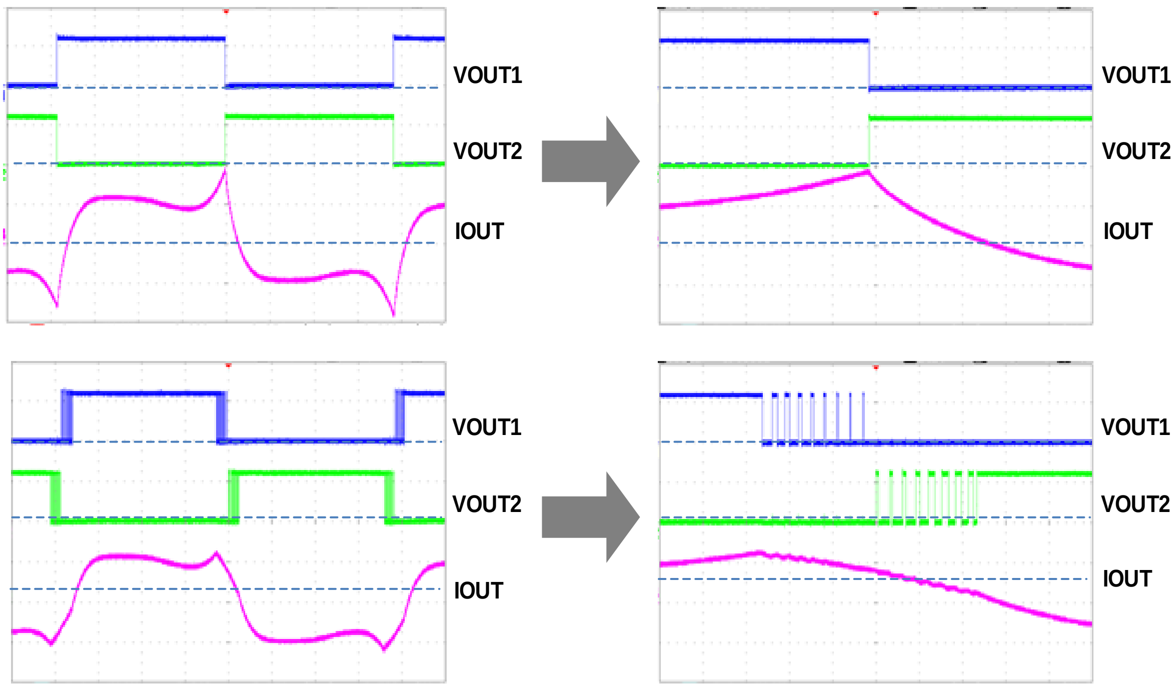


Fig.19 Operation Waveform
Upper ; conventional switching method
Lower : PWM soft switching (LV8860V)

2-1 How to set soft-switch pin

The width of soft switch before and after switching is controlled by SSW (No.13pin) voltage.
Timing of current changes at phase change is controllable by adjusting soft-switch width.
This way, reactive current is reduced and motor is driven efficiently.

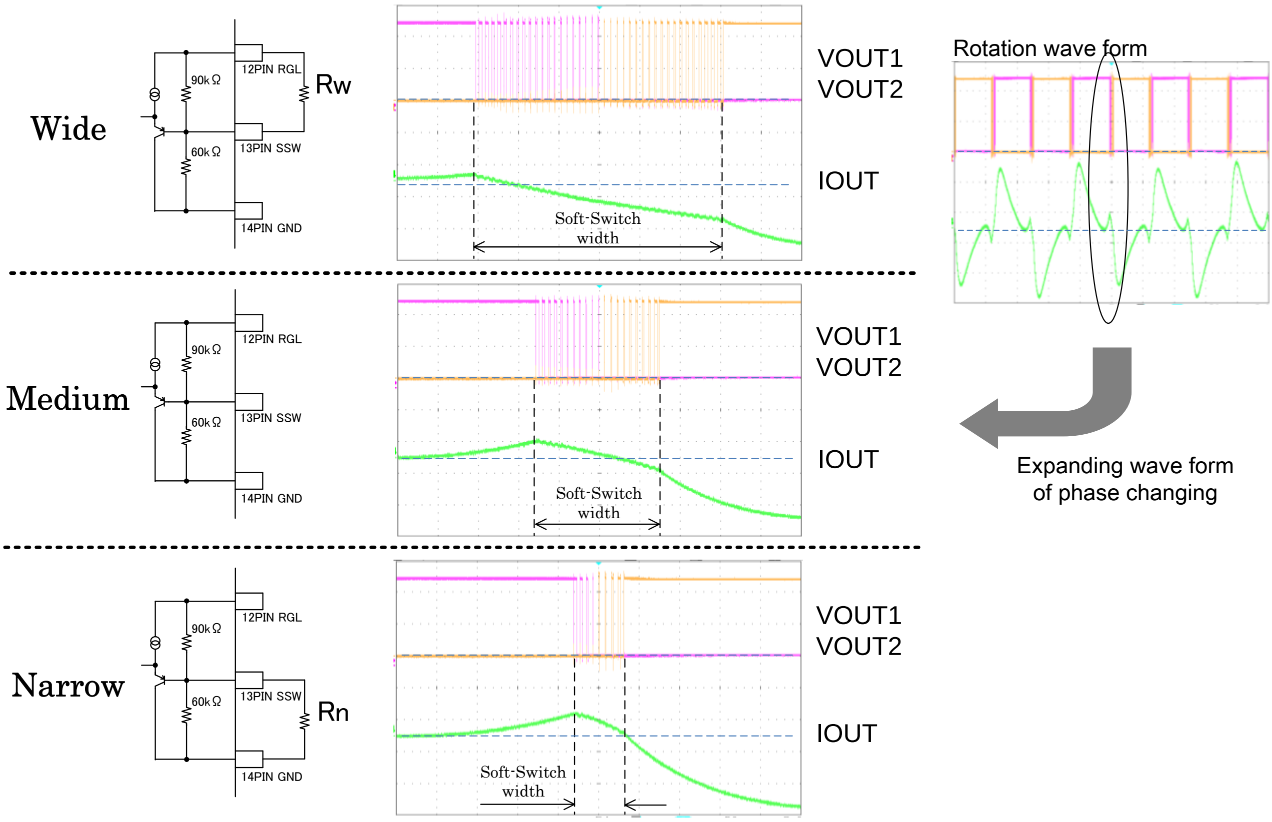


Fig.20 How to change soft-switch width

The width of soft-switch before and after switching is controlled by SSW. Therefore, it is adjustable by connecting an external resistance to SSW. Adjustable voltage range is between 1V and 3V.
Input SSW voltage range is 1V to 3V.

When SSW voltage is High, soft-switch width is wide.

When SSW voltage is Low, soft-switch width is narrow.

*The evaluation board is open .

< Configuration of SSW Voltage >

A . *Without adjustment (SSW is open * this is a reference width of soft switch) with IC's internal resistance:

VSSW = 5 × 60k / (90k + 60k) = 2V

B . *To widen width of soft switch (connect Rw (resistance) between RGL and SSW.)

VSSW = 5 × 60k / { 60k + 1 / (1/Rw + 1/90k) }

(ex.) Connect Rw = 75kΩ

VSSW = 5 × 60k / { 60k + 1 / (1/75k + 1/90k) } = 2.97V

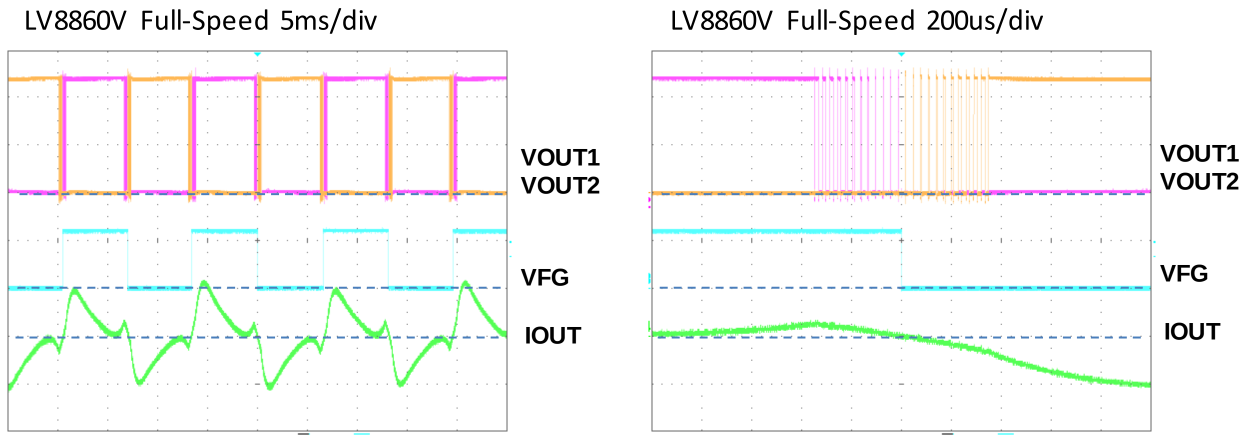
C . *To narrow soft switch width (connect Rn (resistance) between SSW and GND.)

VSSW = 5 × [{ 1 / (1/Rn + 1/60k) } / { 90k + 1 / (1/Rn + 1/60k) }]

(ex.) Connect Rn = 39kΩ

VSSW = 5 × [{ 1 / (1/39k + 1/60k)} / { 90k + 1 / (1/39k + 1/60k)}] = 1.04V

2-2. Effect of soft switching width adjustment



* Because the output current at phase switch is smooth, the operation is efficient.
If current switch is not smooth when SSW pin is open, connect a resistor to SSW pin to adjust SSW voltage for an optimum current waveform.

Example: If the direction of coil current has not been changed at phase switch

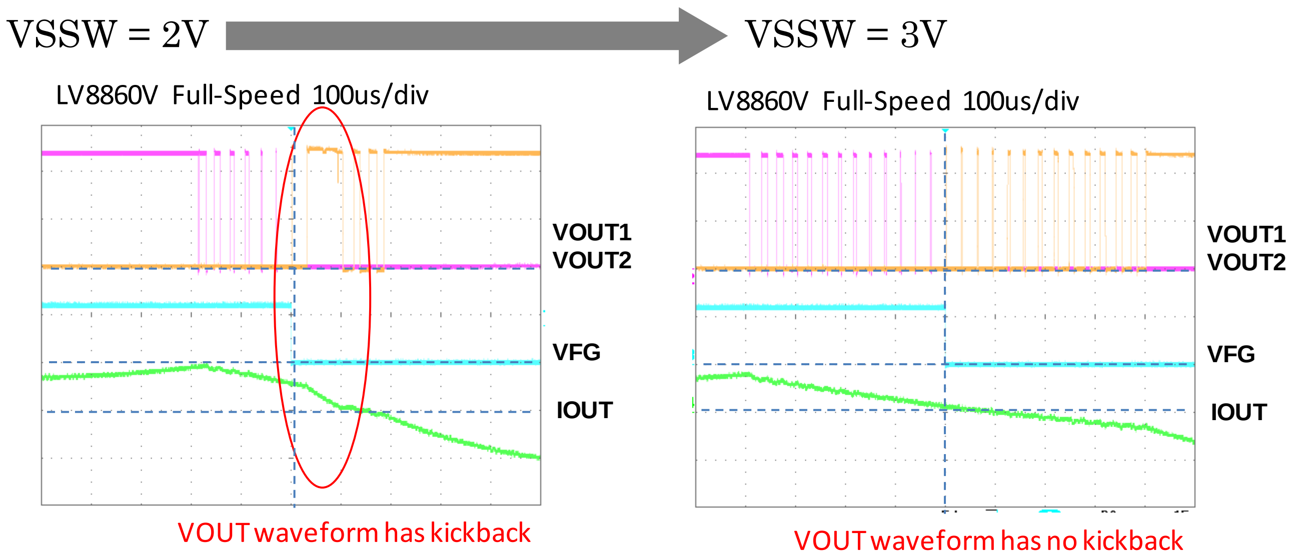


Fig.21 Efficiency of adjusting soft-switch width

2-3. Reference amplitude of input signal

The width of soft switch in LV8860V is controlled by input signal, IN1/IN2. The external SSW voltage (VSSW) adjusts the difference of input voltage (VINp-p) that creates width of soft switch. The range of SSW input voltage is between 1V and 3V.

Referential difference of input signal amplitude in VSSW range:
*When VSSW = 1V (min), VINp-p = 30 mV
--> make sure to input Hall signal with amplitude difference greater than 30mV.
*When VSSW = 2V (open), VINp-p = 90 mV
--> make sure to input Hall signal with amplitude difference greater than 90mV.
*When VSSW = 3V (max), VINp-p = 150 mV
--> make sure to input Hall signal with amplitude difference greater than 150mV.

When input signal amplitude is greater than VINp-p (as shown in Fig. A below)
Width of soft switch is defined as shown in Fig. A.

When input signal amplitude is less than VINp-p. (as shown in Fig. B below).
Since input signal is within the range of VINp-p in all rotations, the entire zone is the soft switch zone. Consequently, IC does not operate properly.

For such reason, make sure to input Hall signal with enough amplitude difference to SSW setting value so that IC operates properly.

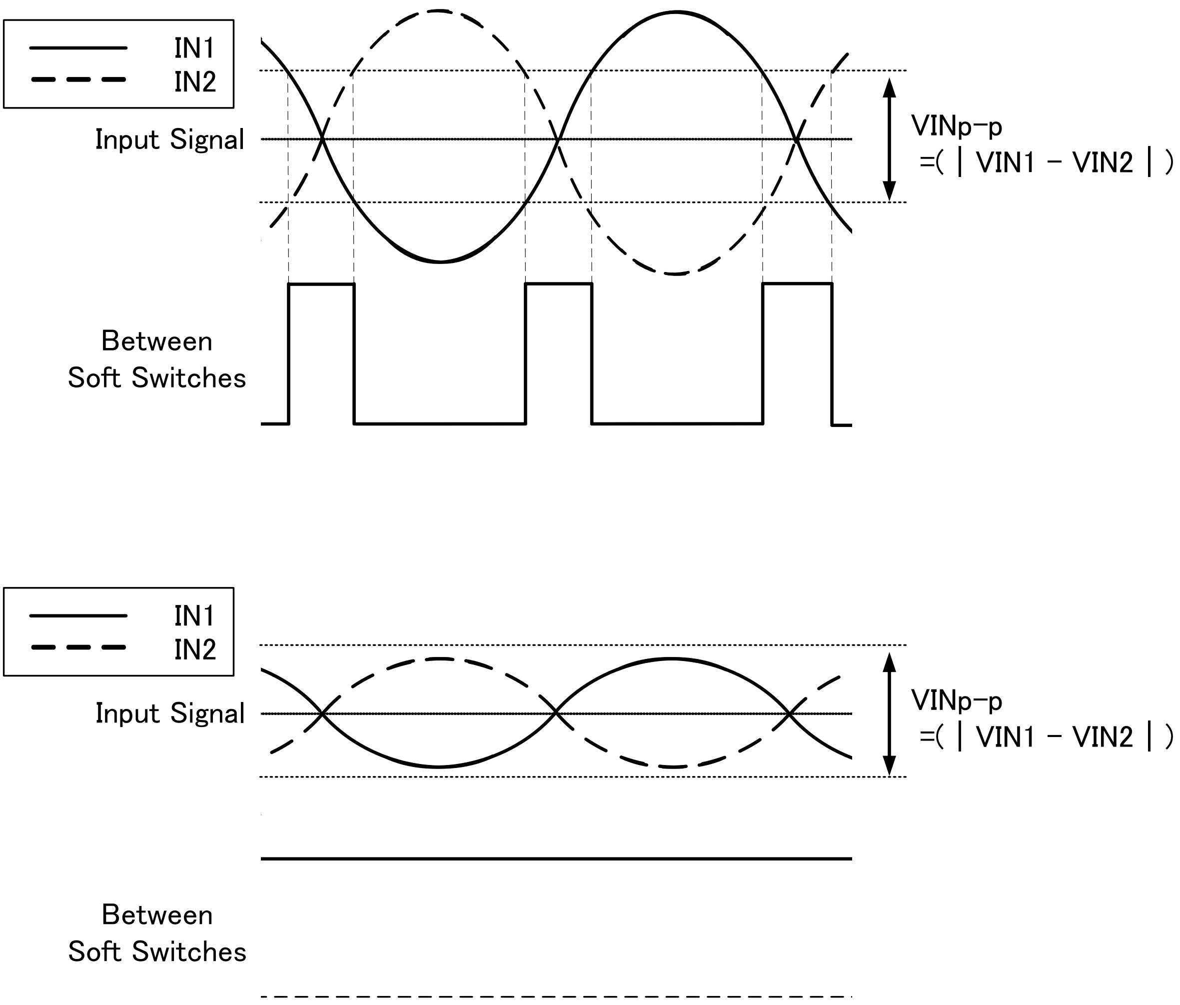


Fig.22 Reference amplitude of input signal

3. Protective Function

Outline

3-1. Current limiter

*The current limiter is activated when the current detection resistor voltage exceeds 225mV between RF (No.15pin) and GND (No.14pin).

When the current limiter is active, LV8860V turns to current regeneration mode and consumes the redundant current; hence, coil current does not flow any higher than the set value. After operating current regeneration for twice the inner clock (typ20us at normal temperature), LV8860V returns to normal operation mode.

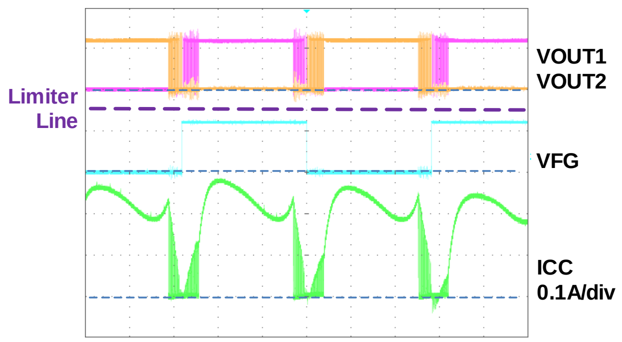
The waveform during current limiter operation is as follows. Only the Rf resistor value has been changed.

<Calculating equation>

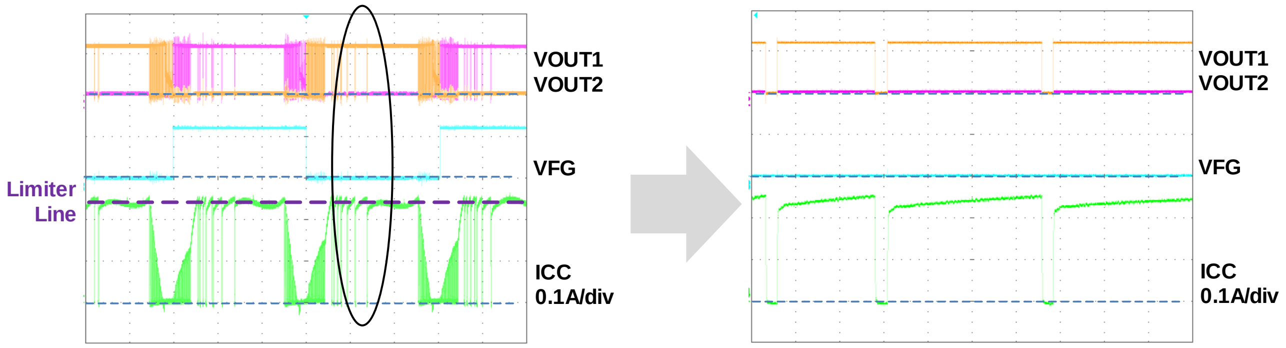
Iolim = Vlim / Rf

Iolim : setting limiter value
Vlim : setup voltage (TYP 225mV)
Rf : resistance value between RF and GND

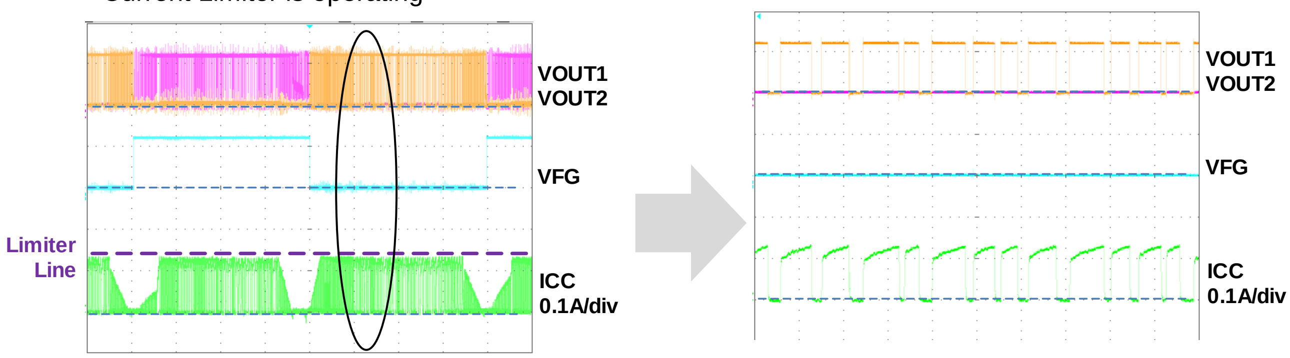
Where Rf=0.5Ω, current limiter is activated at Iolim=450mA
(Iolim = 225mV / 0.5Ω = 450mA).



Rf = 0.5Ω , Iolim = 225m / 0.5 = 450 (mA)
*Current Limiter is not operating



Rf = 1Ω , Iolim = 225m / 1 = 225 (mA)
*Current Limiter is operating



Rf = 2Ω , Iolim = 225m / 2 = 112.5 (mA)
*Current Limiter is operating

Fig.23 Current Limiter operation waveform

3-2. Lock protector circuit and automatic recovery circuit
This IC incorporates lock protector circuit and automatic recovery circuit.
If a motor is locked, lock protector function is turned on to prevent motor from destruction.
The lock protector repeats conduction mode for approximately 0.95sec and non-conduction mode for approximately 9.0sec at normal temperature.
If the lock protector is active during conduction, the IC is set to non-conduction mode again.
The above operations are repeated until lock protector is cancelled.
When the lock protector is active, RD signal level is High.

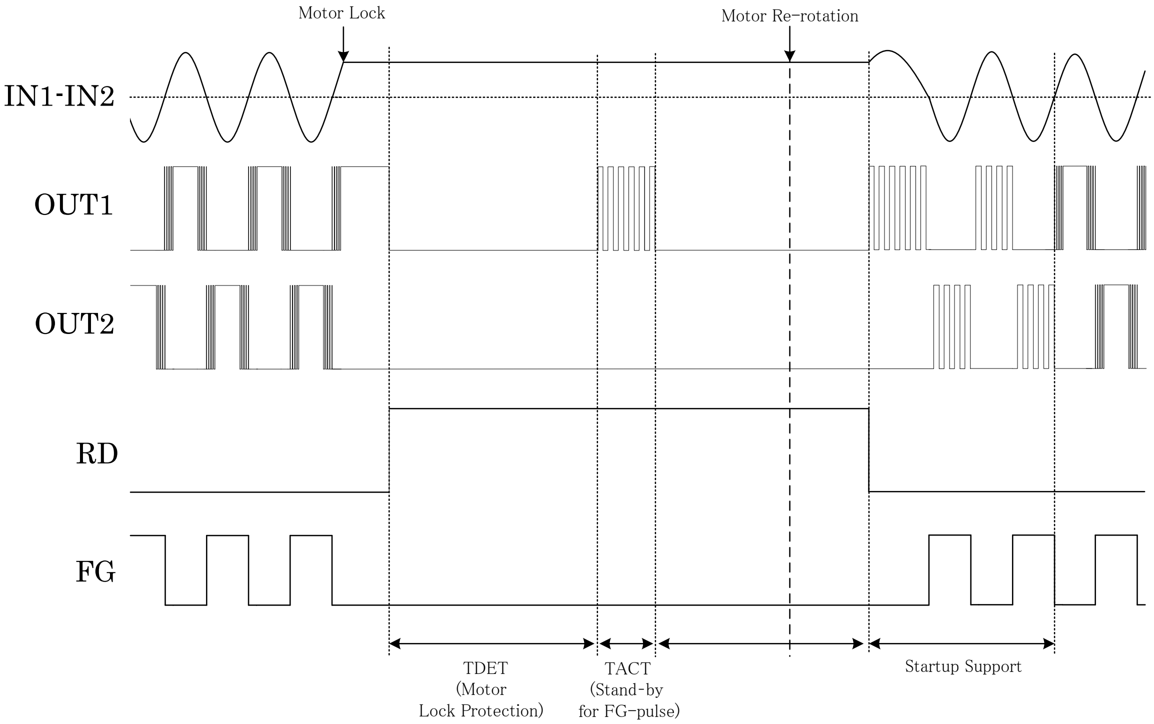


Fig.24 Lock protector operation waveform

3-3. Thermal shutdown function
This IC includes thermal shutdown circuit.
The thermal shutdown circuit is incorporated and the output is turned off when junction temperature Tj exceeds 180°C. As the temperature falls by hysteresis, the output turned on again (automatic restoration).
The thermal shutdown circuit does not guarantee the protection of the final product because it operates when the temperature exceed the junction temperature of Tjmax = 150°C.
Thermal shutdown temperature = 180°C (typ)

Application Circuit Example

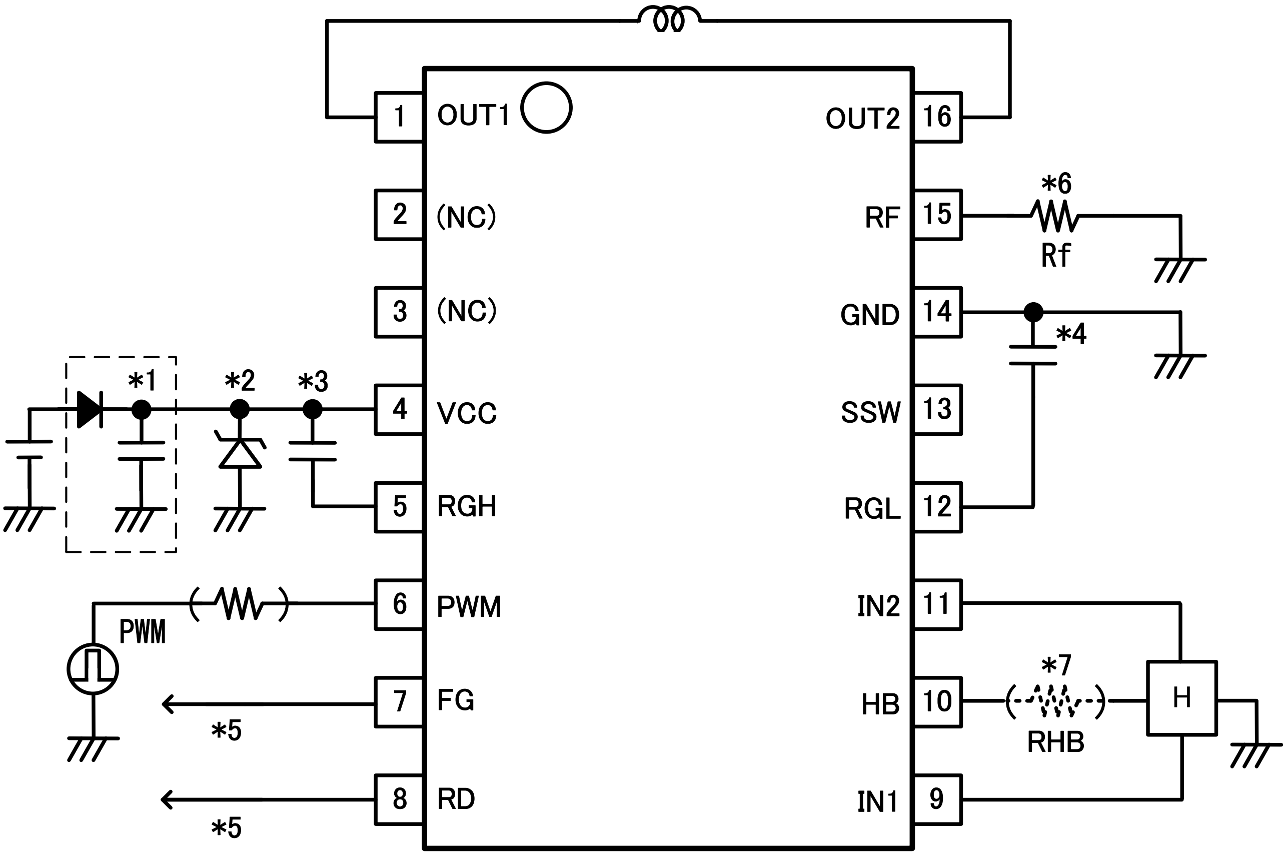


Figure 25. Sample Application Circuit

*1 When diode Di is used to prevent destruction of IC from reverse connection, make sure to implement capacitor Cr to secure regenerative current route.

*2 If kickback at a phase change is greater, insert zener diode between GND and VCC or implement the larger capacitor between GND and VCC mentioned in *1.

*3 Make sure to implement enough capacitance 0.1uF or greater between RGH pin and VCC pin for stable performance.

*4 Make sure to implement enough capacitance 0.1uF or higher between RGL pin and GND pin for stable performance.

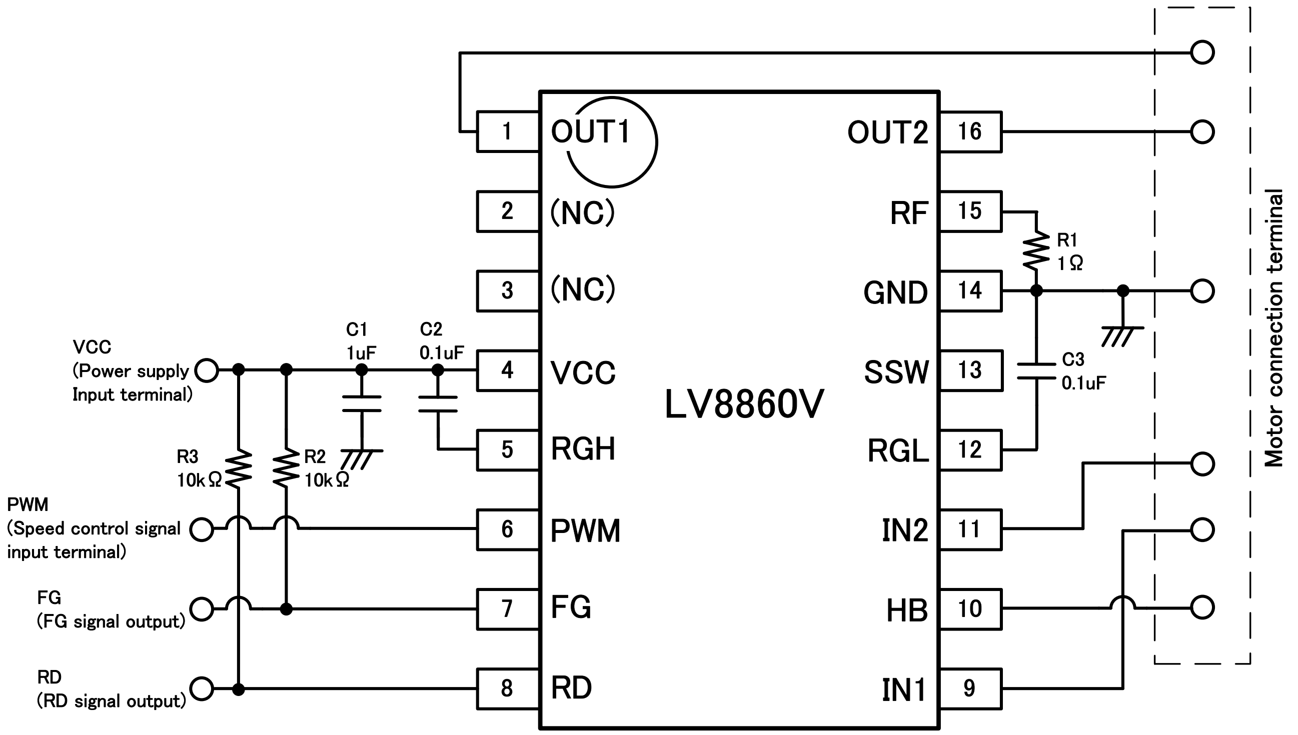
*5 FG pin and RD pin are open drain output. Keep the pins open when unused.

*6 The current limiter is activated when the current detection resistor voltage exceeds 225mV between RF and GND.
Where RL=0.5Ω, current limiter is activated at Io=450mA. Setting is made using Rf resistance.

*7 Hall element outputs stable hall signal with good temperature characteristic when it is biased with constant voltage from HB pin. If you wish to alleviate heating of IC, do not use HB pin. When you do not use this Pin (Pin HB) , pull down with resistor of around 10kΩ(recommended).

Evaluation Board Manual

1. Evaluation Board circuit diagram

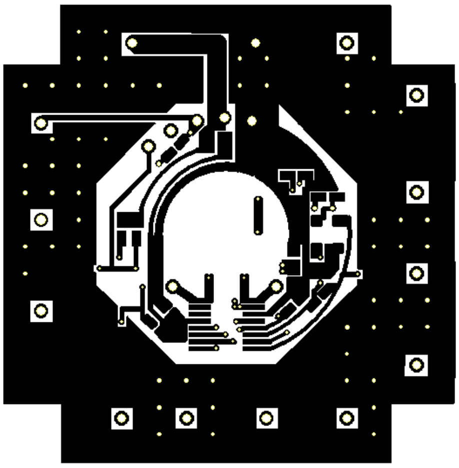


Bill of Materials for LV8860V Evaluation Board

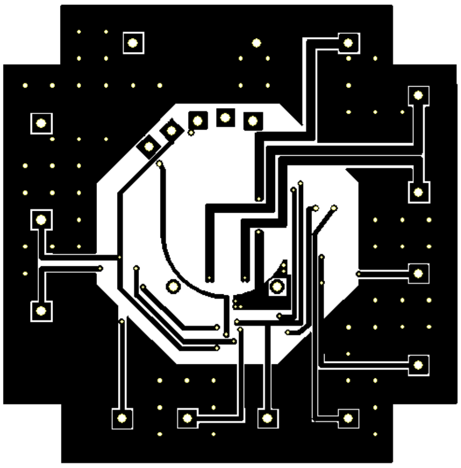
Designator	Qty	Description	Value	Tol	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
IC1	1	Motor Driver			SSOP16 (225mil)	SANYO semiconductor	LV8860V	No	Yes
C1	1	VM Bypass capacitor	1µF	±10 %	0805	Murata	GRM21BR 71H105KA	Yes	Yes
C2,C3	2	capacitor	0.1uF	±10 %	1608	Murata	GRM188B 31H104KA 92	Yes	Yes
R1	1	resistor	1Ω	±5%	0603	KOA	RK73B1JT TD1R0J	Yes	Yes
R2,R3	2	resistor	10kΩ	±5%	1608	KOA	RK73B1JT 103	Yes	Yes
TP1-TP1 2	8	Test points				MAC8	ST-1-3	Yes	Yes

Evaluation Board PCB Design

45mm 45mm



(Top side)

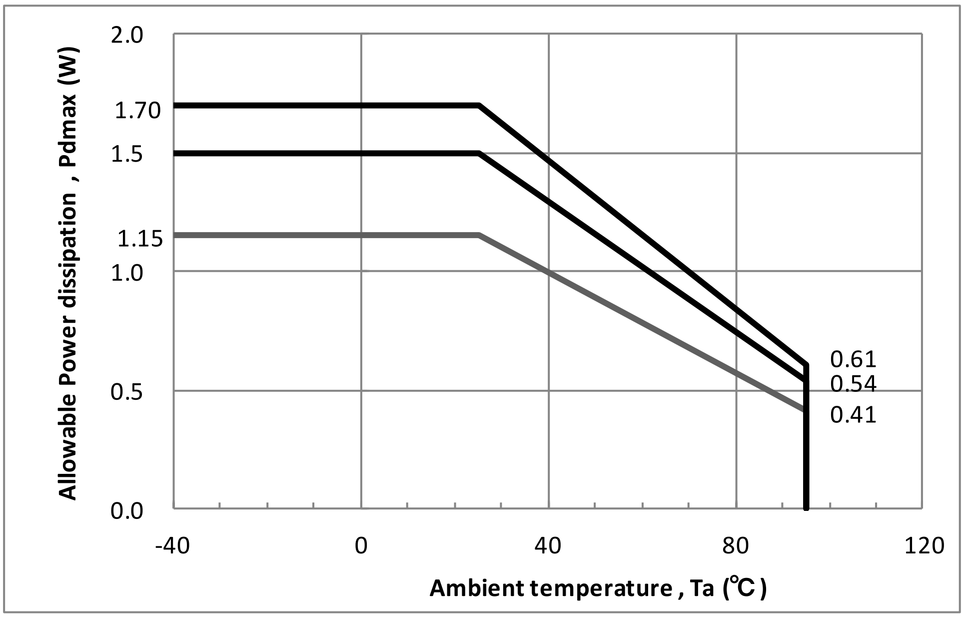


45mm

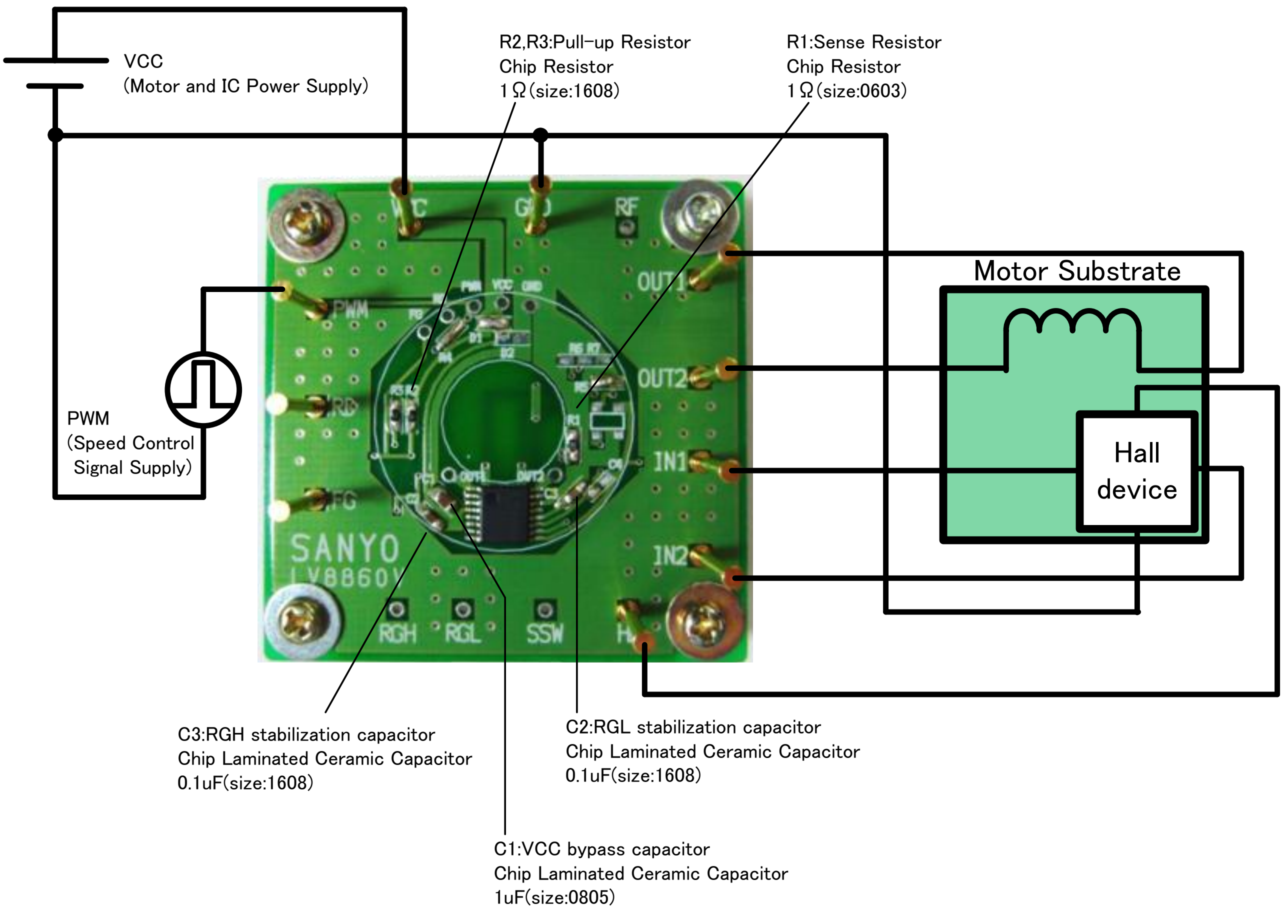
(Back side)

Allowable power dissipation

Specified circuit board : 45mm x 45mm x 1.6mm, glass epoxy 2-layer board



2. Motor drive



1. Connect a motor to OUT1, OUT2, IN1, IN2, HB and GND.

2. Connect the motor power supply to VCC, and connect the GND line to GND.

3. Connect the PWM signal supply to PWM if speed control is needed.

4. Drive motor to supply voltage to VCC.

5. Motor speed is controllable by adjusting duty of PWM signal.

Caution for layout

- Power supply connection terminal [VCC]

・VCC is the only power supply.
The regulator voltage RGL (typ 5V) is the internally generated control power supply.
・Make sure that supply voltage does not exceed the absolute maximum rating under no circumstance. Noncompliance can ve the cause of IC destruction and degradation.
・Caution is required for VCC supply voltage because this IC performs switching.
The bypass capacitor of the VCC power supply should be close to the IC as much as possible to stabilize voltage. Also if you intend to use large current or back EMF is high, please augment enough capacitance.

- GND terminal [GND]

GND terminal is 0V, hence pattern layout should be in low impedance. Since high current flows into GND, GND terminal should be connected independently.

- Internal power supply regulator terminal [RGL, RGH]

・RGL is the control power supply for logic. (typ 5V).
RGH is the gate voltage power supply for output Pch-Tr (typ VCC-4.5V).
・When VCC is energized, the voltage is impressed to RGL and RGH.
・Connect a capacitor to RGL and RGH respectively to stabilize internal power supply.
(Recommended value: 0.1uF or higher)

- PWM signal input terminal [PWM]

・PWM signal input could be the cause of noise. Hence, caution is required for pattern layout.

- OUT terminal [OUT1, OUT2]

・During PWM operation, VOUT terminal could be the cause of noise. Hence, caution is required for pattern layout.
・Since motor current flows into OUT terminals, they should be connected at low impedance.
・Output voltage may boost due to back EMF. Make sure that the voltage does not exceed the absolute MAX ratings under no circumstance. Noncompliance can be the cause of IC destruction and degradation.

- Current sense resistor connection terminal [RF]

・Since motor current flows from RF to GND line, it should be connected independently at low impedance.

- NC terminal

・NC terminal is not connected to the internal circuit of the IC.
・Use NC terminal to keep the layout for power supply line and GND line as fat and short as possible.

This catalog provides information as of June, 2011. Specifications and information herein are subject to change without notice.