LV8771VH

Bi-CMOS LSI

PWM Constant-Current Control Stepper Motor Driver Application Note

ON Semiconductor®

http://onsemi.com

Overview

LV8771VH is a PWM current control stepper motor driver. It is ideally suited for driving stepping motors used in office equipment and entertainment applications.

Function

- 1 channel PWM current control stepping motor driver incorporated.
- IO max=1.5A
- Output on-resistance (High side: 0.6Ω; Low side: 0.4Ω; total: 1.0Ω; Ta=25°C, Io=1.5A)
- Micro-step mode can be set to Full-step, Half-step (full torque), Half-step, or Quarter-step.
- Built-in thermal shutdown circuit
- No control power supply required

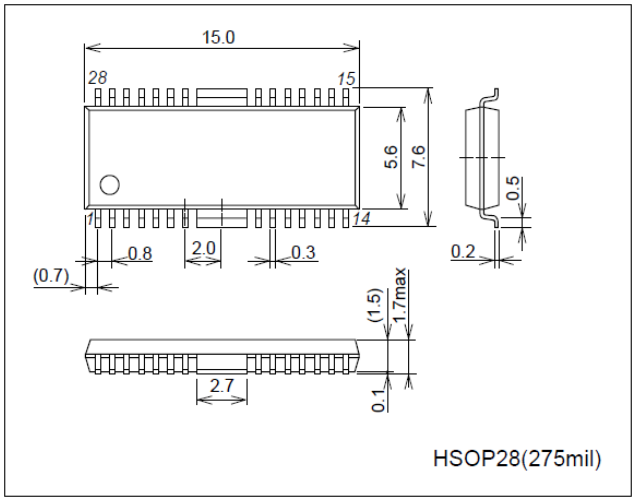
Typical Applications

- MFP (Multi Function Printer)
- PPC (Plain Paper Copier)
- LBP (Laser Beam Printer)
- Photo printer
- Scanner
- Industrial
- Cash Machine
- Entertainment
- Textile

Package Dimensions

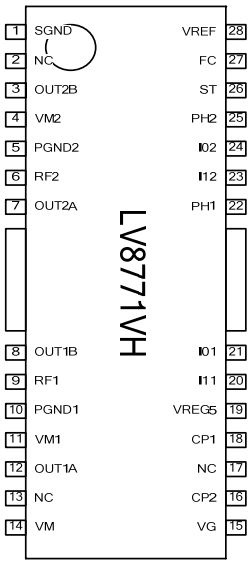
Unit: mm (typ)

3222A

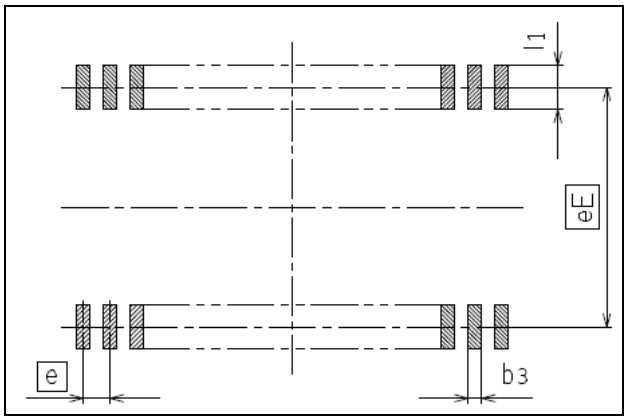


Caution: The package dimension is a reference value, which is not a guaranteed value.

Pin Assignment



Recommended Soldering Footprint

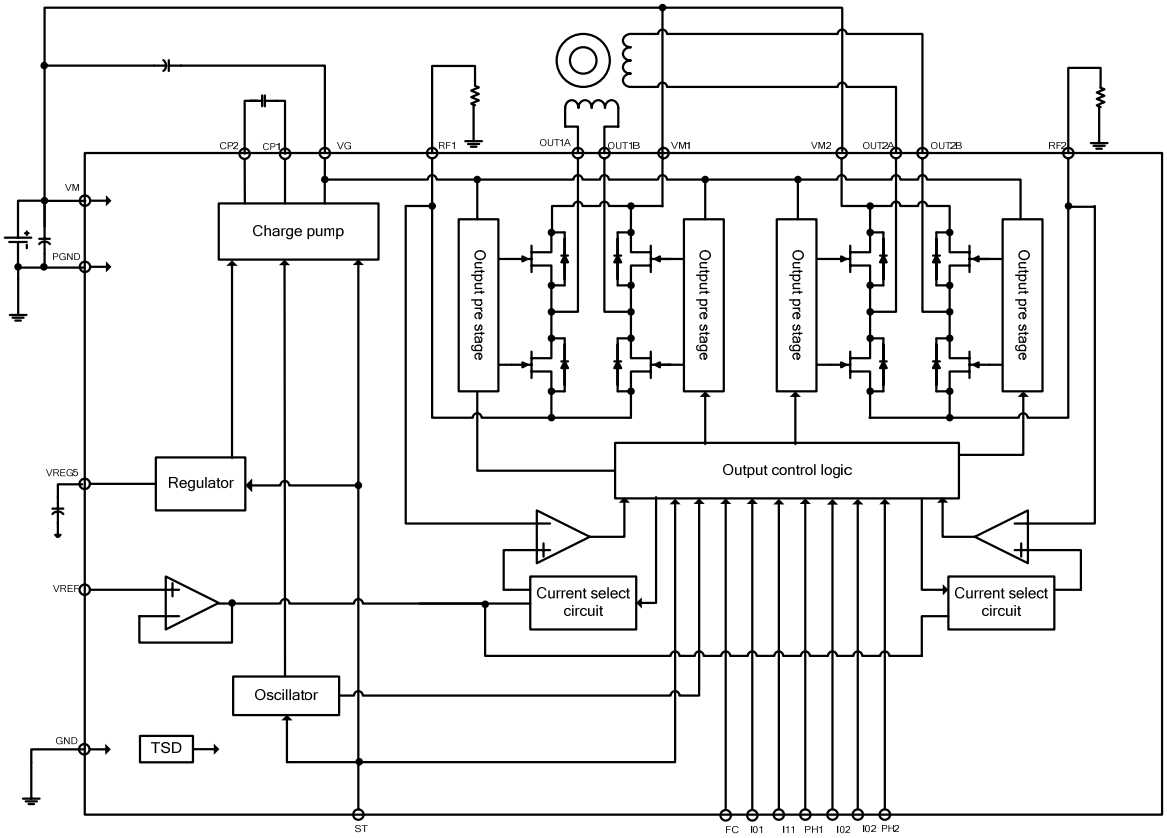


Reference symbol	HSOP28(275mil)
eE	7
e	0.8
b3	0.42
l1	1

(Unit: mm)

.

Block Diagram



Specifications

Absolute Maximum Ratings at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage	VM max		36	V
Output peak current	I_O peak	tw ≤ 10ms, duty 20%	1.75	A
Output current	I_O max		1.5	A
Logic input voltage	V_{IN} max		-0.3 to +6	V
VREF input voltage	VREF max		-0.3 to +6	V
Allowable power dissipation	Pd max	*	3.0	W
Operating temperature	Topr		-20 to +85	°C
Storage temperature	Tstg		-55 to +150	°C

* Specified circuit board: 90.0mm×90.0mm×1.6mm, glass epoxy 2-layer board.

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.

Recommended Operating Conditions at Ta = 25°C

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Supply voltage range	VM		9		32	V
Logic input voltage	V_{IN}		0		5.5	V
VREF input voltage range	VREF		0		3	V

Electrical Characteristics at Ta = 25°C, VM = 24V, VREF = 1.5V

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Standby mode current drain	IMst	ST = "L"		100	150	μA
Current drain	IM	ST = "H", I01=I11=I02=I12 = "H", with no load		2	3	mA
VREG5 output voltage	Vreg5	I_O = -1mA	4.7	5	5.3	V
Thermal shutdown temperature	TSD	Design guarantee	150	180	210	°C
Thermal hysteresis width	ΔTSD	Design guarantee		40		°C
Motor driver						
Output on resistance	Ronu	I_O = 1.5A, Upper-side on resistance		0.6	0.78	Ω
	Rond	I_O = 1.5A, Lower-side on resistance		0.4	0.52	Ω
Output leakage current	$I_O$leak	VM=36V			50	μA
Diode forward voltage	VD	ID = -1.5A		1.1	1.4	V
Logic high-level input voltage	V_{IN}H		2.0			V
Logic low-level input voltage	V_{IN}L				0.8	V
Logic pin input current	I_{IN}L	V_{IN} = 0.8V	4	8	12	μA
	I_{IN}H	V_{IN} = 5V	30	50	70	μA
Current setting comparator threshold voltage	Vtdac11	I01(02)="H", I11(12)="H"	0.29	0.30	0.31	V
	Vtdac01	I01(02)="L", I11(12)="H"	0.20	0.21	0.22	V
	Vtdac10	I01(02)="H", I11(12)="L"	0.11	0.12	0.13	V
Chopping frequency	Fchop1	FC1="L"	24.8	31.0	37.2	kHz
	Fchop2	FC1="H"	49.6	62.0	74.4	kHz
VREF pin input current	Iref	VREF = 1.5V	-0.5			μA
Charge pump						
VG output voltage	VG		28	28.7	29.8	V
Rise time	tONG	VG = 0.1μF		200	500	μS
Oscillator frequency	Fosc		100	125	150	kHz

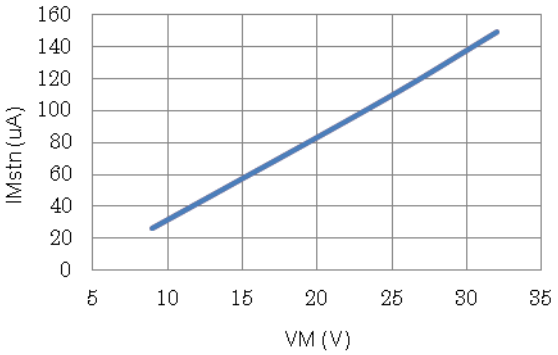


Figure 1. Standby Mode Current Drain vs VM Voltage

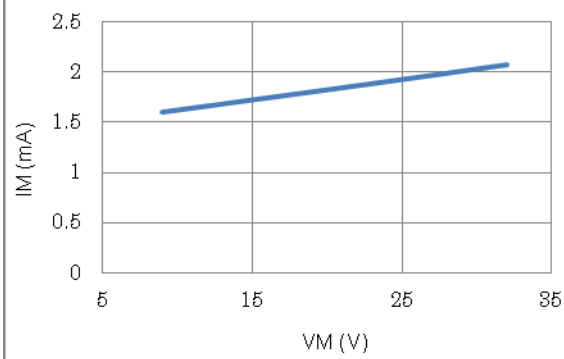


Figure 2. Current Drain vs VM Voltage

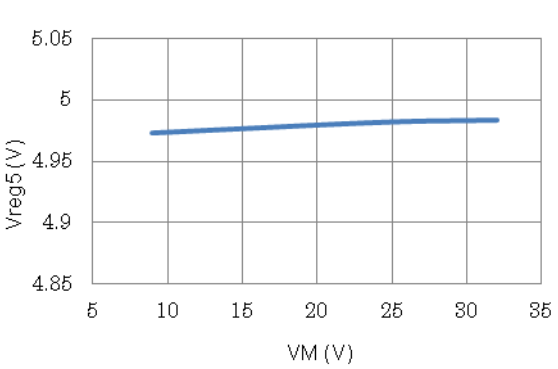


Figure 3. VREG5 Output Voltage vs VM Voltage

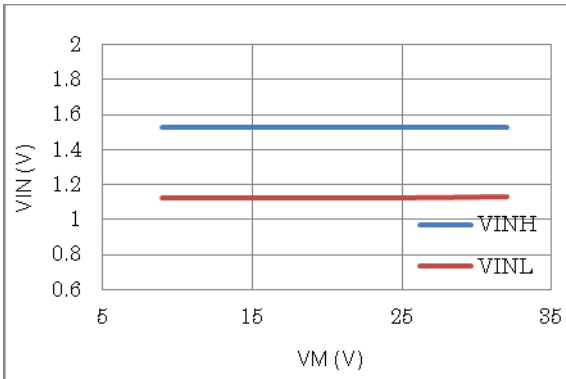


Figure 4. Logic High/Low-Level Input Voltage vs VM voltage

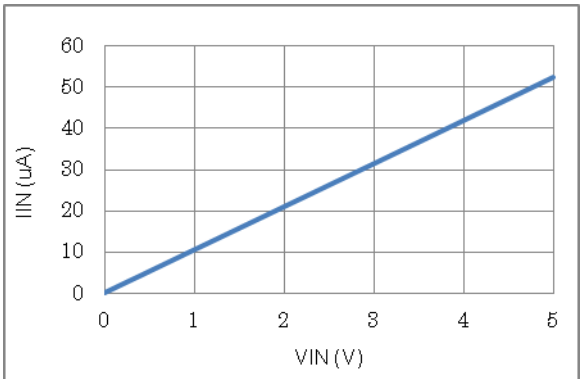


Figure 5. Logic Pin Input Current vs Input Voltage

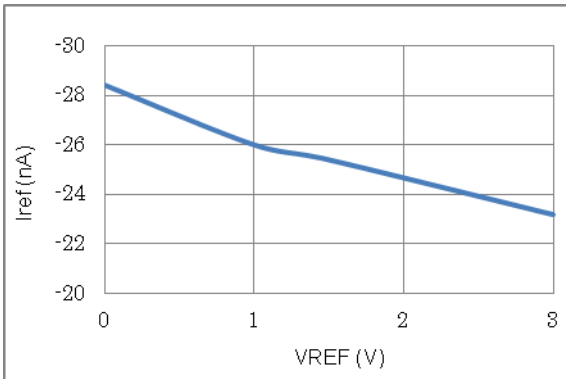


Figure 6. VREF Pin Input Current vs VREF Voltage

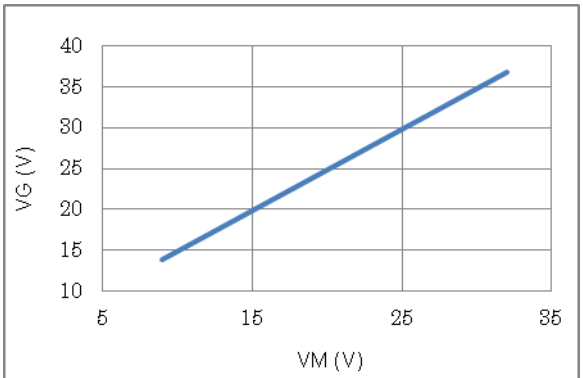


Figure 7. VG Output Voltage vs VM Voltage

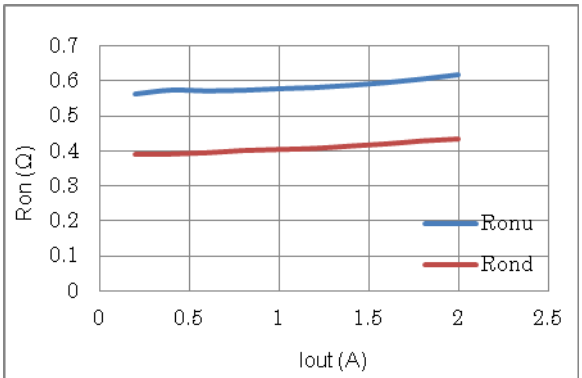


Figure 8. Output on Resistance vs Output Current

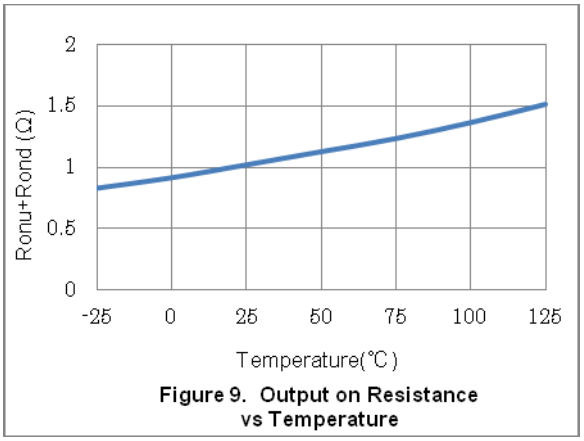


Figure 9. Output on Resistance vs Temperature

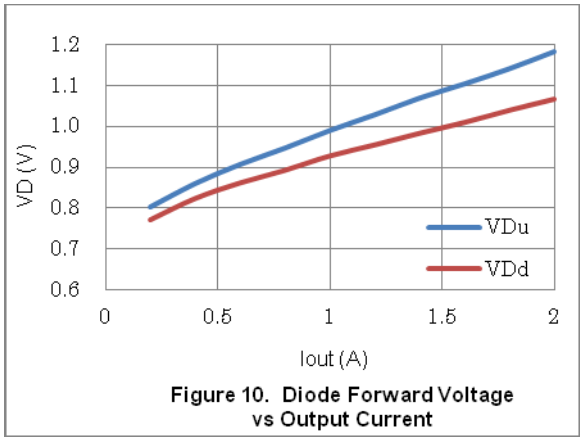
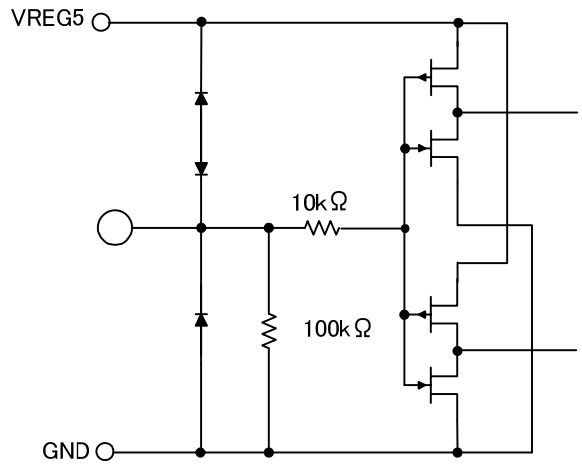
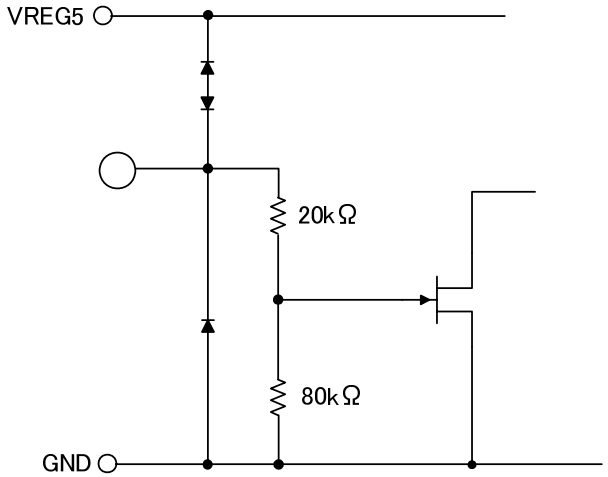
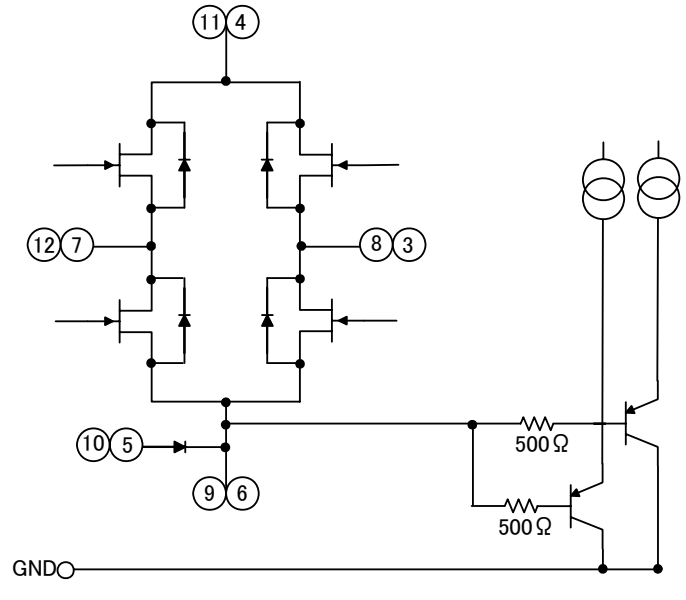


Figure 10. Diode Forward Voltage vs Output Current

Pin Functions

Pin No.	Pin Name	Pin Function	Equivalent Circuit
22 21 20 25 24 23 27	PH1 I01 I11 PH2 I02 I12 FC	Channel 1 forward/reverse rotation pin. Channel 1 output control input pin. Channel 1 output control input pin. Channel 2 forward/reverse rotation pin. Channel 2 output control input pin. Channel 2 output control input pin. Chopping frequency switching pin.	
26	ST	Chip enable pin.	
8 9 10 11 12 3 4 5 6 7	OUT1B RF1 PGND1 VM1 OUT1A OUT2B VM2 PGND2 RF2 OUT2A	Channel 1 OUTB output pin. Channel 1 current-sense resistor connection pin. Power system ground pin 1. Channel 1 motor power supply connection pin. Channel 1 OUTA output pin. Channel 2 OUTB output pin. Channel 2 motor power supply connection pin. Power system ground pin 2. Channel 2 current-sense resistor connection pin. Channel 2 OUTA output pin.	

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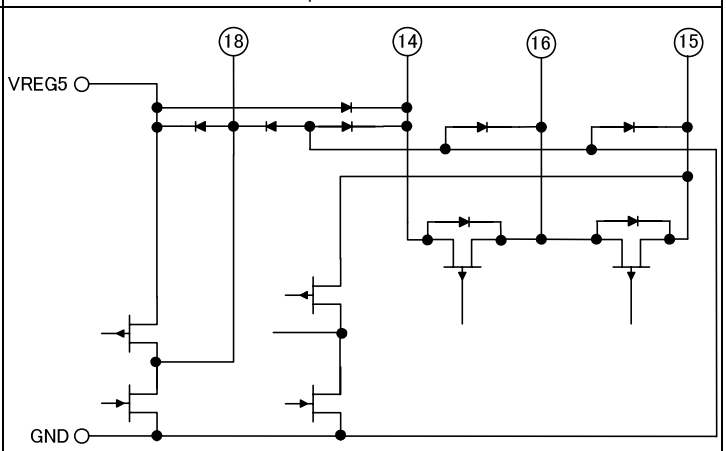
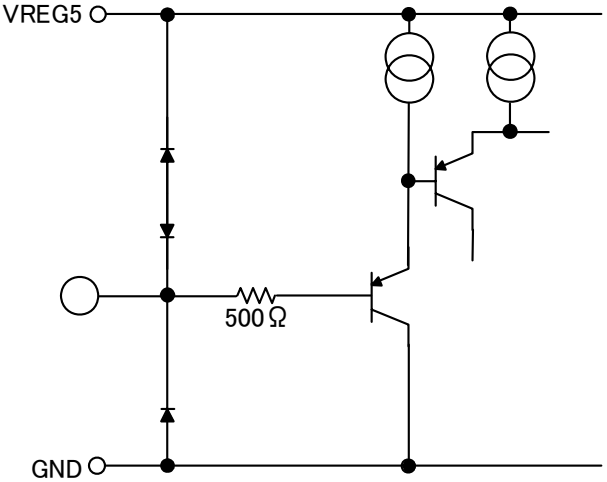
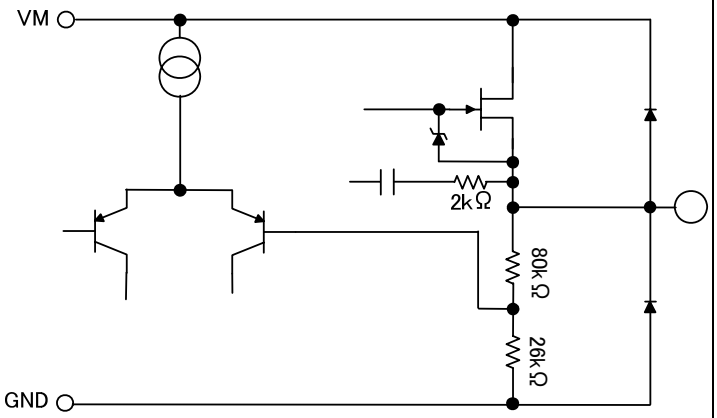
Pin No.	Pin Name	Pin Function	Equivalent Circuit
15 14 16 18	VG VM CP2 CP1	Charge pump capacitor connection pin. Motor power supply connection pin. Charge pump capacitor connection pin. Charge pump capacitor connection pin.	
28	VREF	Constant current control reference voltage input pin.	
19	VREG5	Internal power supply capacitor connection pin.	
1	GND	Ground	
2,13 17	NC	No Connection (No internal connection to the IC)	

Description of operation

Input Pin Function

Each input pin has prevention function including the prevention of current flow from input to power supply. Therefore, the current does not flow into power supply even if power supply (VM) is turned off while power is impressed to the input pin.

(1) Chip enables function

ST pin switches the IC between standby and operating mode. In standby mode, the IC is set to power-save mode and all the logic is reset. In addition, the internal regulator circuit and charge pump circuit do not operate during standby mode.

ST	Mode	Internal regulator	Charge pump
Low or Open	Standby mode	Standby	Standby
High	Operating mode	Operating	Operating

(2) Output control logic

I01(02)	I11(12)	Output current
Low	Low	0
High	Low	Io=((VREF/5)/RF)*40%
Low	High	Io=((VREF/5)/RF)*70%
High	High	Io=(VREF/5)/RF

PH1(2)	Current direction
Low	OUTB→OUTA
High	OUTA→OUTB

(3) Setting constant-current control reference current

This IC is designed to perform PWM constant-current chopping control for the motor current automatically by setting the output current. Based on the voltage input to the VREF pin and the resistance connected between RF and GND, the output current that is subject to the constant-current control is set using the calculation formula below:

I_{OUT} = (VREF/5) /RF resistance

* The above setting is the output current at I01 (02) =High, I11 (12) =High.

If VREF is open or the setting is out of the recommendation operating range, output current will increase and you cannot set constant current under normal condition. Hence, make sure that VREF is set in accordance with the specification.

However, if current control is not performed (if the IC is used by saturation drive) make sure that the setting is as follows: VREF=5V or VREF=VREG5.

Power dissipation of RF resistor is obtained as follows: $Pd=Iout^2 \times RF$. Make sure to take allowable power dissipation into consideration when you select RF resistor.

The formula used to calculate the output current when using the function for attenuating the VREF input voltage is given below.

IOUT = (VREF/5) /RF resistance × (attenuation ratio)

Example: When VREF=1.5V, I01 (02) =High, I11 (12) =Low and RF1 (2) resistance is 0.47Ω, the setting current is shown below.

I_{OUT} = (1.5V / 5) / 0.47Ω × 100% = 0.64A

(4) Chopping frequency setting

FC	Chopping frequency
Low	31kHz
High	62kHz

The higher the chopping frequency is, the greater the output switching loss becomes. As a result, heat generation issue arises. The lower the chopping frequency is, the lesser the heat generation becomes. However, current ripple occurs. Since noise increases when switching of chopping takes place, you need to adjust frequency with the influence to the other devices into consideration.

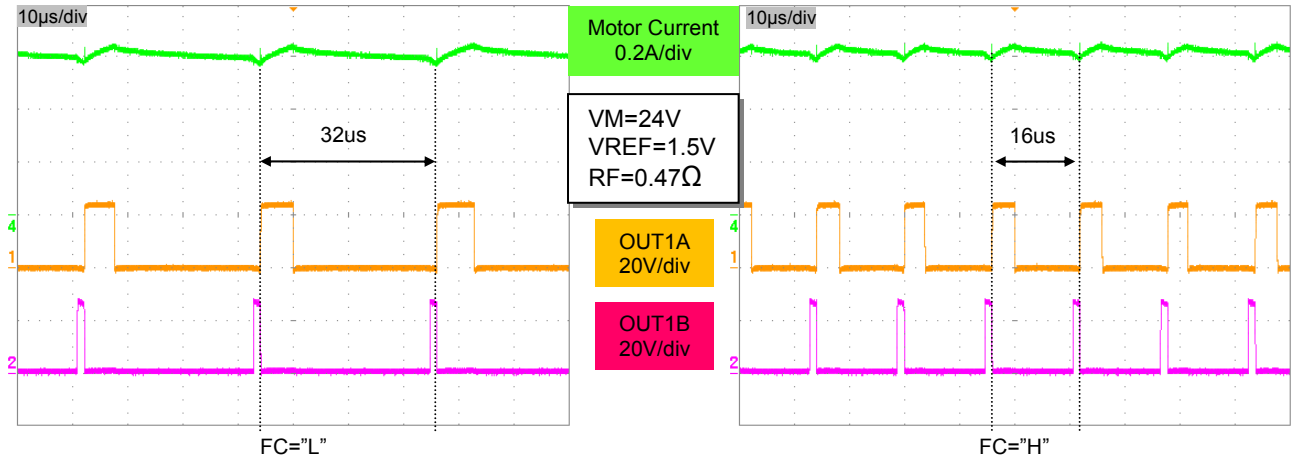


Figure 11. Chopping frequency waveform

(5) Blanking period

When performing PWM constant-current chopping control over the motor current, if the mode is switched from decay to charge, the recovery current of the parasitic diode may flow to the current sensing resistance, which causes noise to affect current sensing resistance pin. This may result in erroneous detection. To prevent such erroneous detection, a blanking period is created to prevent the reception of noise that occurs during mode switching. During this period, the mode is not switched from charge to decay even if the noise is carried to the current sensing resistance pin.

The blanking time is fixed to approximately 1µs.

(6) Typical current waveform in each micro-step mode

Full step (CW mode)

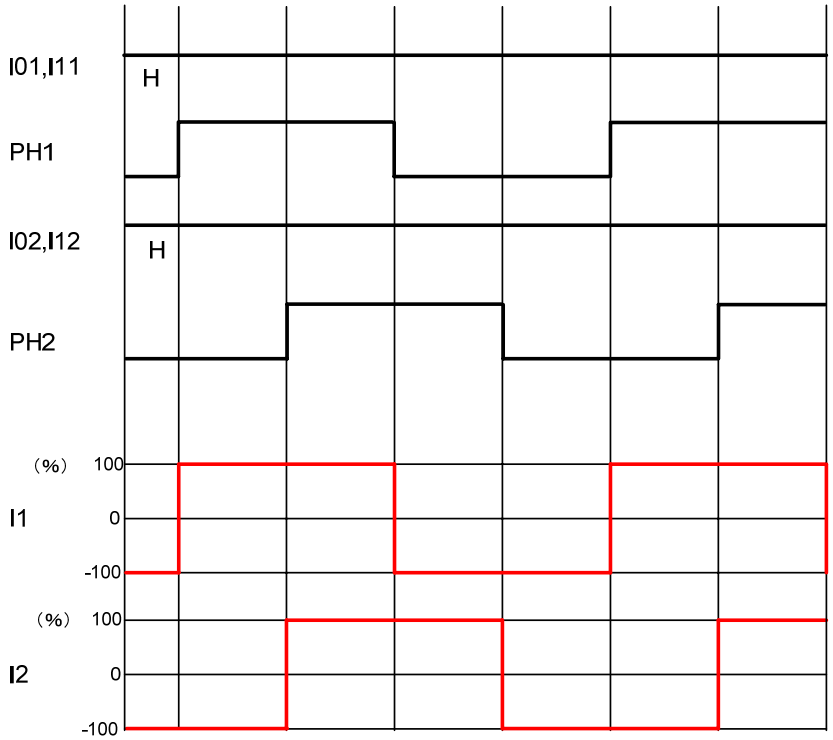


Figure 12. Current waveform of Full step

Half step full torque (CW mode)

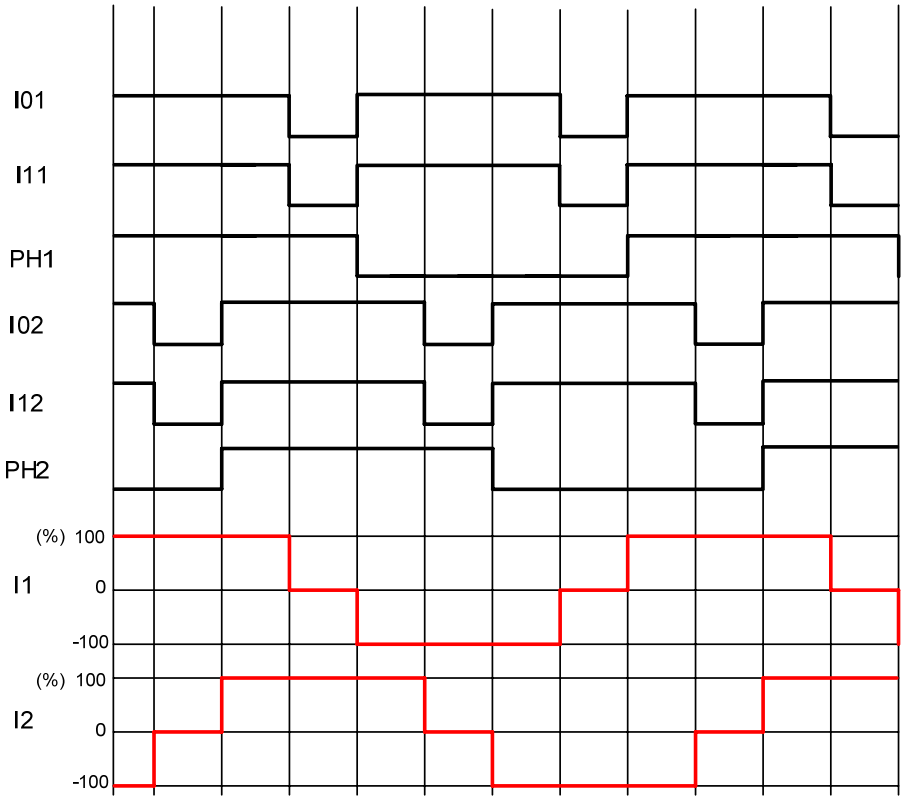


Figure 13. Current waveform of Half step full torque

Half step (CW mode)

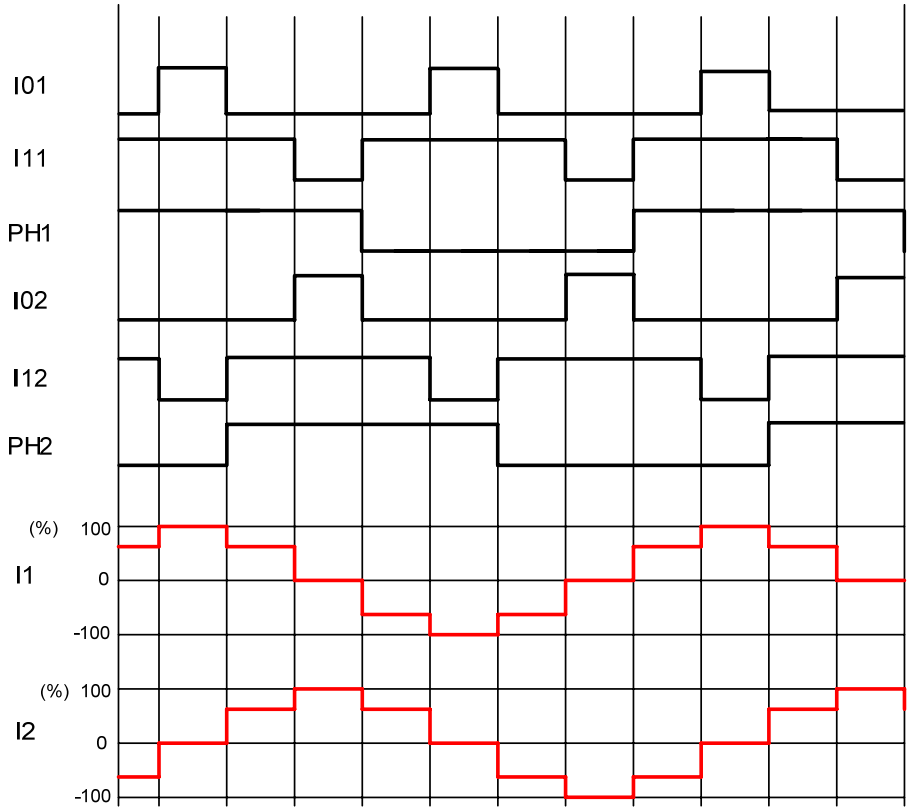


Figure 14. Current waveform of Half step

Quarter step (CW mode)

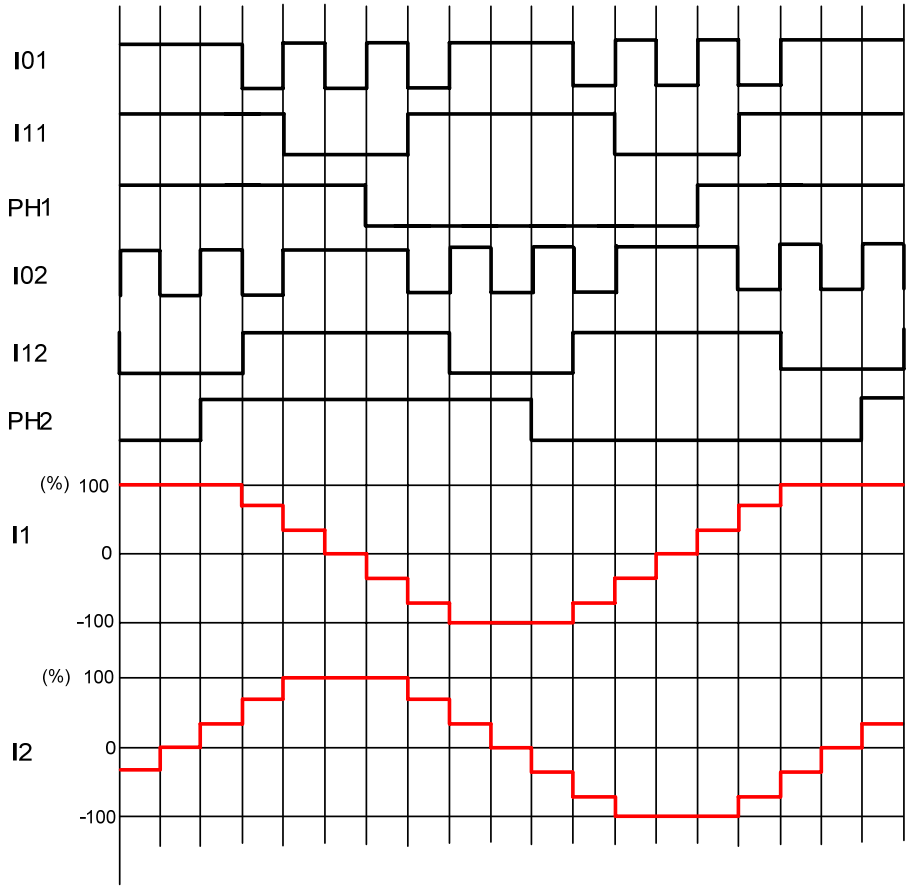
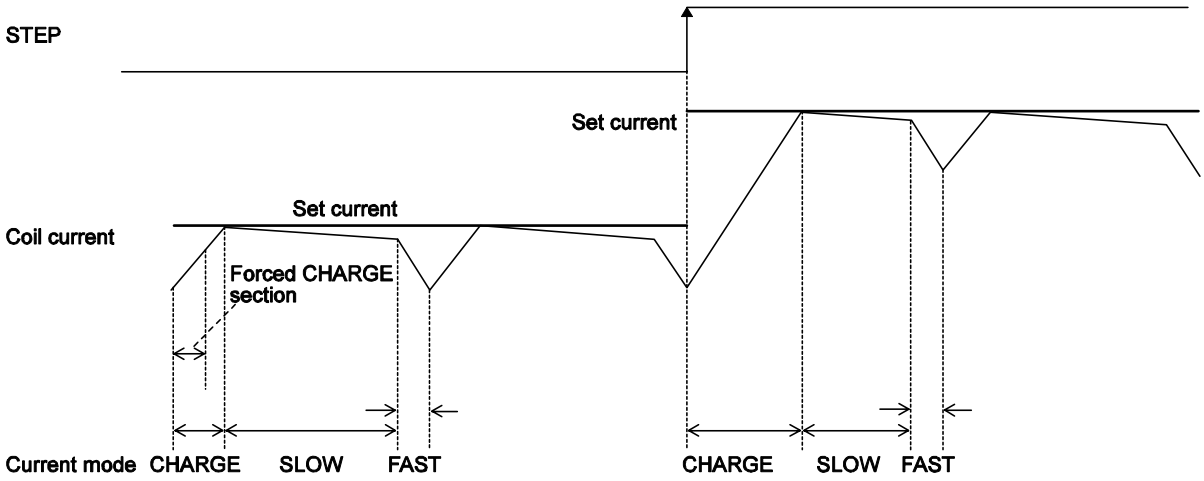


Figure 15. Current waveform of Quarter step

(7) Current control operation specification

(Sine wave increasing direction)



(Sine wave decreasing direction)

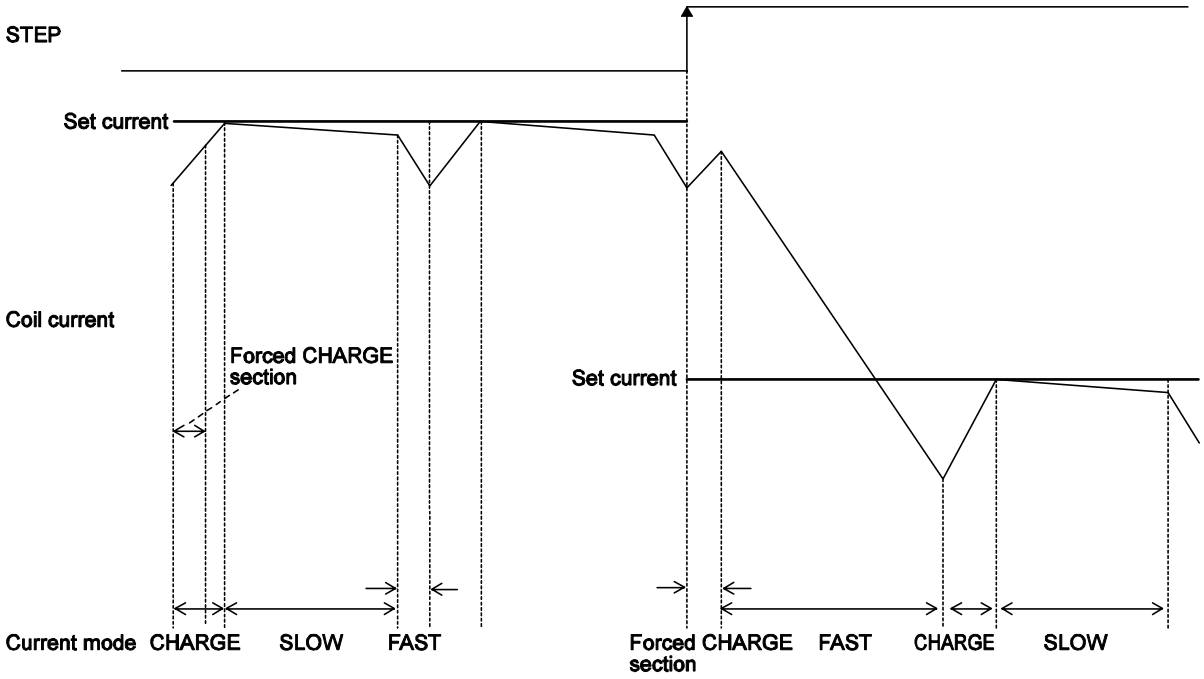


Figure 16. Current control operation

In each current mode, the operation sequence is as described below:

- At the rise of chopping frequency, the CHARGE mode begins. (In the time defined as the “blanking time,” the CHARGE mode is forced regardless of the magnitude of the coil current (ICOIL) and set current (IREF).)
- The coil current (ICOIL) and set current (IREF) are compared during this blanking time.

  Where ICOIL < IREF;

  The CHARGE mode up to ICOIL ≥ IREF, then followed by changeover to the SLOW DECAY mode, and finally by the FAST DECAY mode for approximately 1μs.

  Where ICOIL < IREF;

  The FAST DECAY mode begins. The coil current is attenuated in the FAST DECAY mode till one cycle of chopping is over.

Above operations are repeated. Normally, the SLOW (+FAST) DECAY mode continues in the Triangle wave increasing direction, then entering the FAST DECAY mode till the current is attenuated to the set level and followed by the SLOW DECAY mode.

(8) Output transistor operation mode

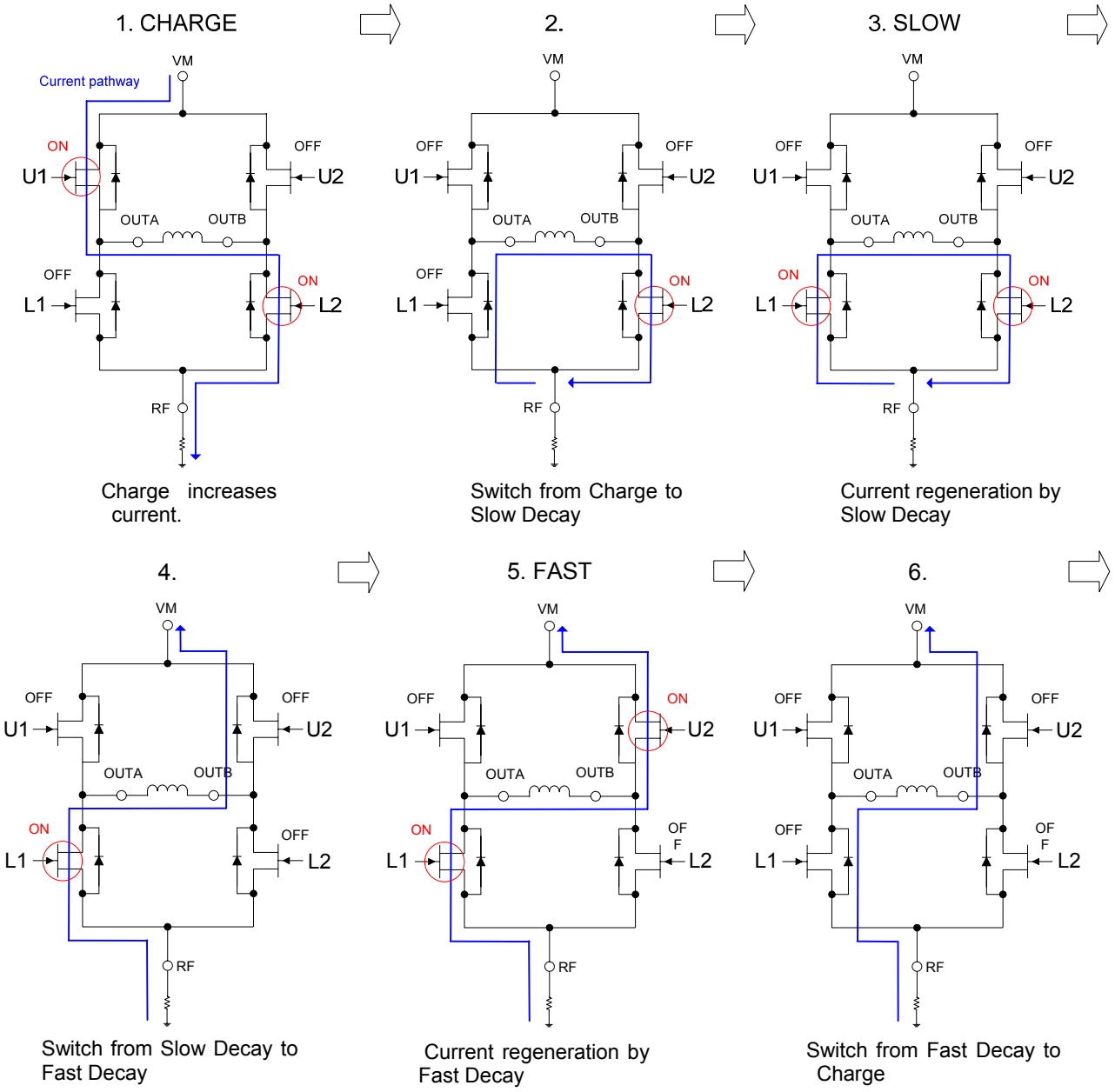


Figure 17. Switching operation

This IC controls constant current by performing chopping to output transistor.
As shown above, by repeating the process from 1 to 6, setting current is maintained.
Chopping consists of 3 modes: Charge/ Slow decay/ Fast decay. In this IC, for switching mode (No.2, 4, 6), there are “off period” in upper and lower transistor to prevent crossover current between the transistors. This off period is set to be constant (≈ 0.375μs) which is controlled by the internal logic. The diagrams show parasitic diode generated due to structure of MOS transistor. When the transistor is off, output current is regenerated through this parasitic diode.

Output Transistor Operation Function

OUTA→OUTB (CHARGE)

Output Tr	**CHARGE**	**SLOW**	**FAST**
U1	ON	OFF	OFF
U2	OFF	OFF	ON
L1	OFF	ON	ON
L2	ON	ON	OFF

OUTB→OUTA (CHARGE)

Output Tr	**CHARGE**	**SLOW**	**FAST**
U1	OFF	OFF	ON
U2	ON	OFF	OFF
L1	ON	ON	OFF
L2	OFF	ON	ON

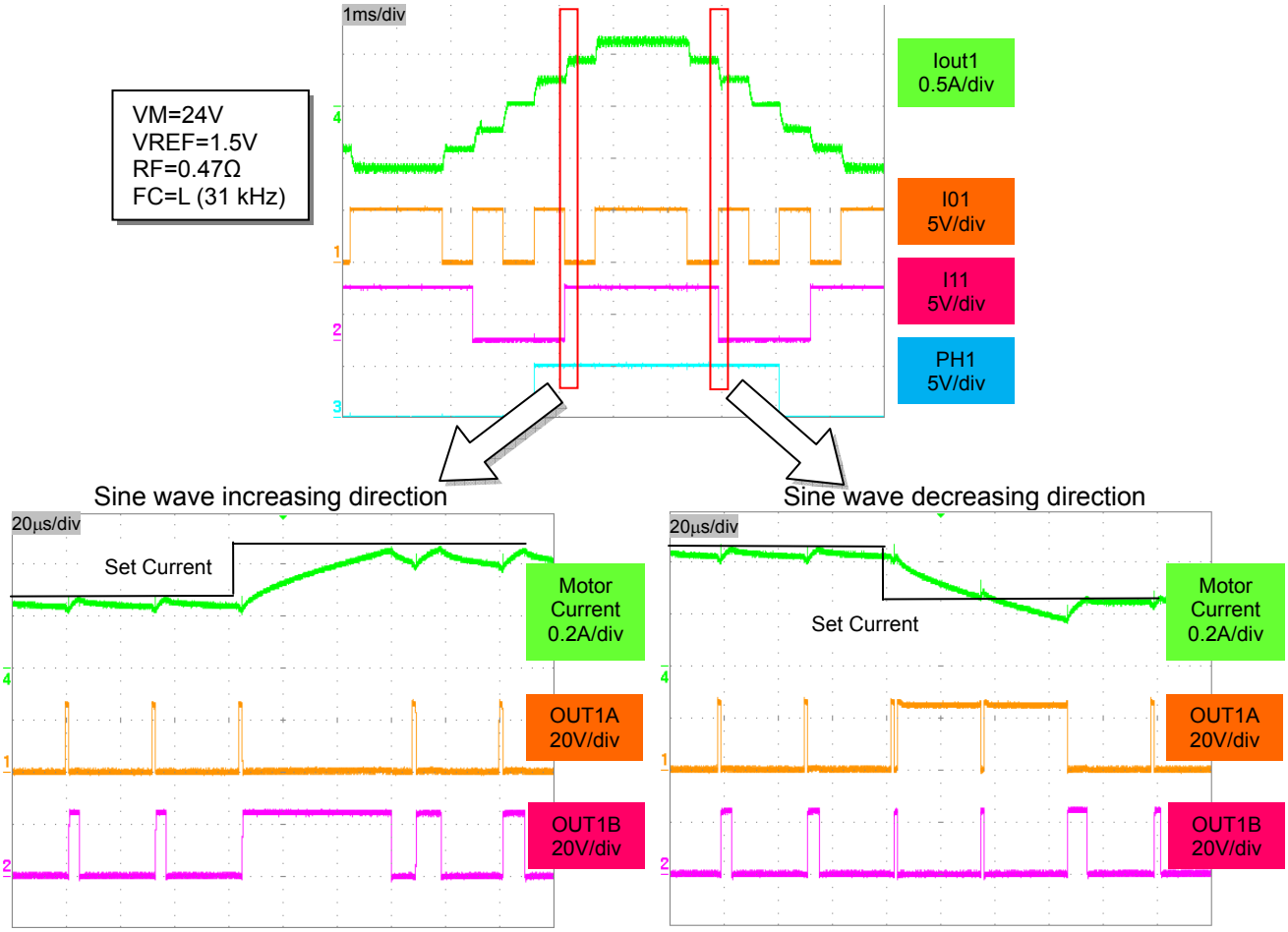


Figure 18. Current control operation waveform

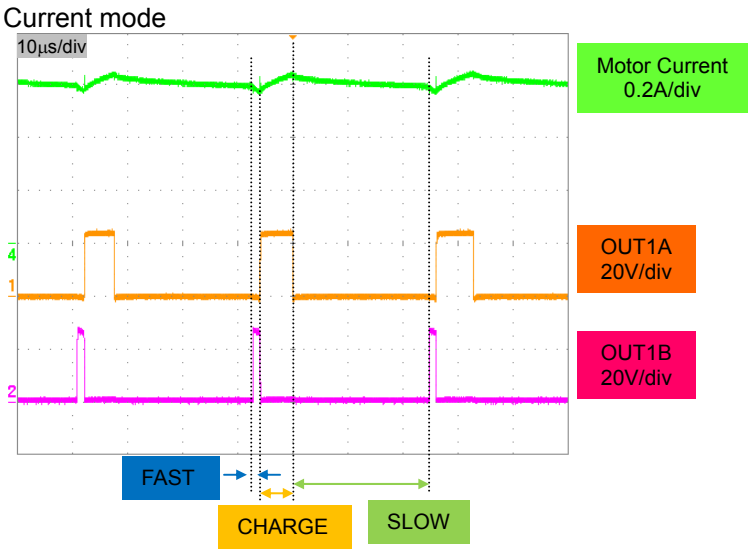


Figure 19. Current mode

When the motor current reaches to the setting current, it is switched to slow Decay mode.
Motor current switches from Slow Decay mode to Fast Decay mode for last 1us of one chopping cycle.

Charge Pump Circuit

When the ST pin is set high, the charge pump circuit operates and the VG pin voltage is boosted from the VM voltage to the VM + VREG5 voltage. Because the output is not turned on if VM+4V or more is not pressured, the voltage of the VG pin recommends the drive of the motor to put the time of t_{ONG} or more, and to begin.

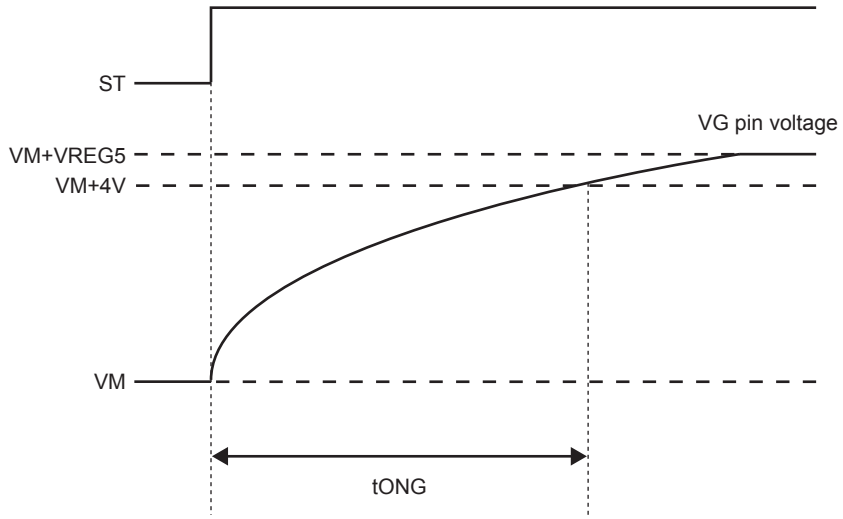


Figure 20. VG pin voltage schematic view

VG voltage is used to drive upper output FET and VREG5 voltage is used to drive lower output FET.
Since VG voltage is equivalent to the addition of VM and VREG5 voltage, VG capacitor should allow higher voltage.
The capacitor between CP1 and CP2 is used to boost charge pump. Since CP1 oscillates with 0V↔VREG5 and CP2 with VM↔VM+VREG5, make sure to allow enough capacitance between CP1 and CP2.
Since the capacitance is variable depends on motor types and driving methods, please check with your application before you define constant to avoid ripple on VG voltage.

(Recommended value) VG: 0.1µF
CP1-CP2: 0.1µF

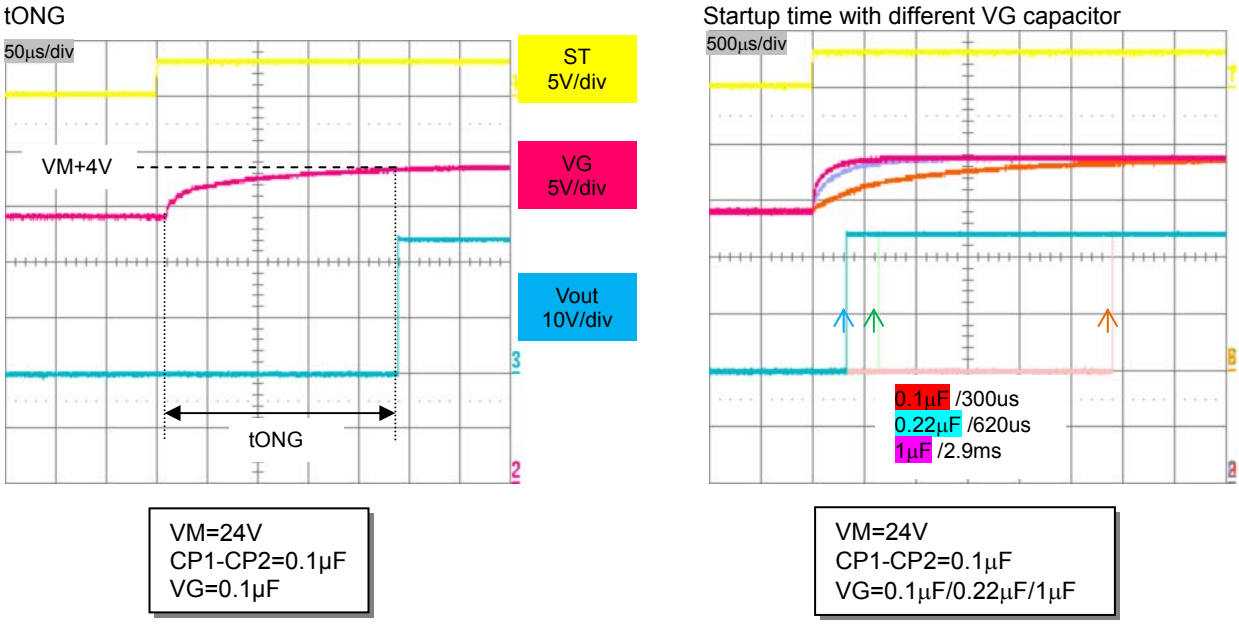


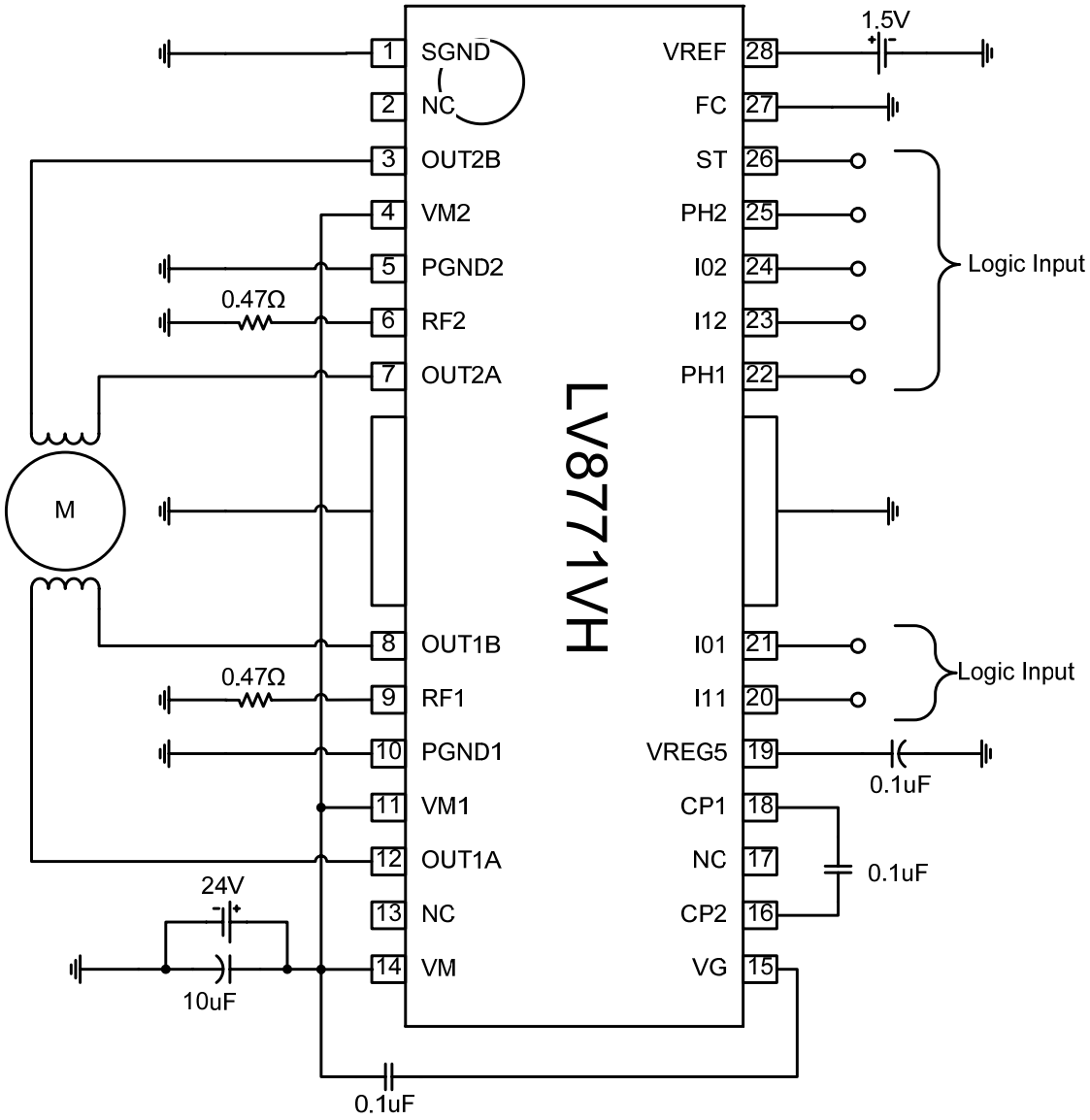
Figure 21.VG voltage pressure waveform

Thermal shutdown function

The thermal shutdown circuit is incorporated and the output is turned off when junction temperature Tj exceeds 180°C and the abnormal state warning output is turned on. 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.

TSD = 180°C (typ)
ΔTSD = 40°C (typ)

Application Circuit Example

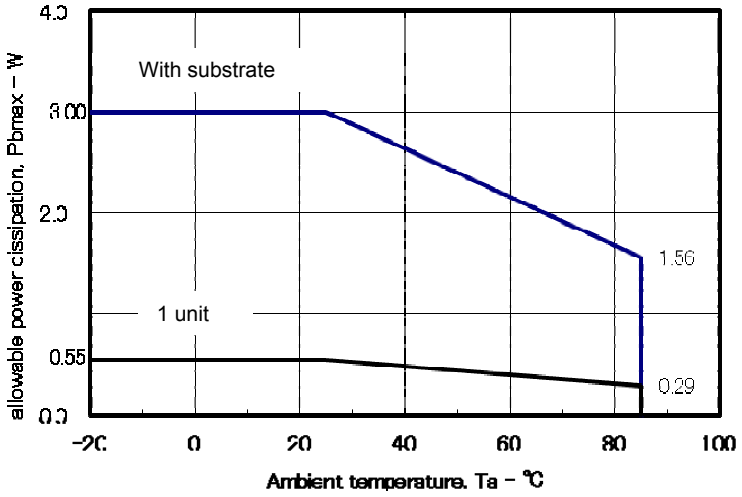


Each constant setting formula of above circuit example is as below.
Setting of chopping frequency: 31 kHz (FC=L)

Setting of constant current:
When VREF=1.5V, RF=0.47Ω,
Io = ((VREF/5)/RF
= (1.5V/5) / 0.47Ω
= 0.64A

Allowable power dissipation

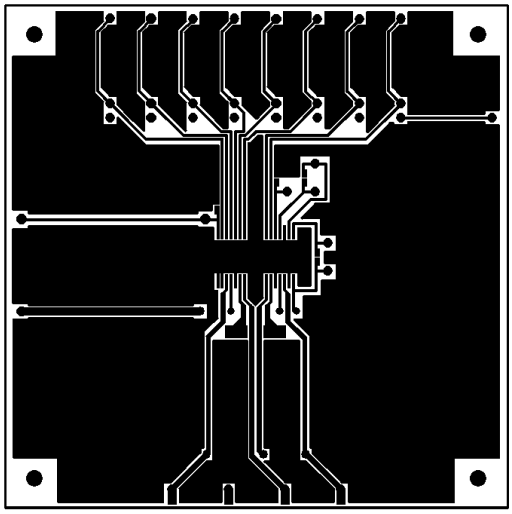
Specified circuit board: 90mm x 90mm x 1.6mm, glass epoxy **2-layer board**



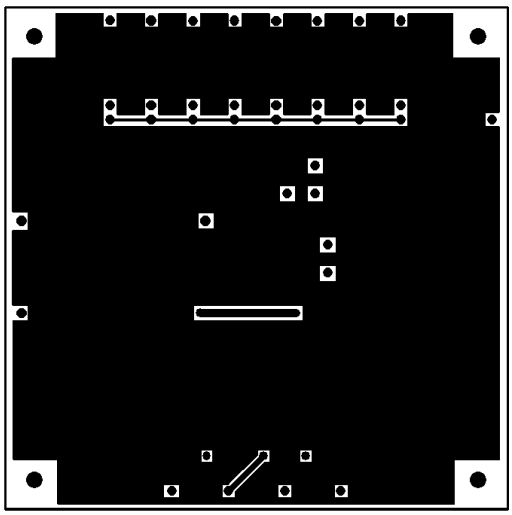
Substrate Specifications (Substrate recommended for operation of LV8771VH)

Size : 90mm × 90mm × 1.6mm (two-layer substrate [2S0P])

Material : Glass epoxy



L1: Copper wiring pattern diagram



L2: Copper wiring pattern diagram

Cautions

For the set design, employ the derating design with sufficient margin.

Stresses to be derated include the voltage, current, junction temperature, power loss, and mechanical stresses such as vibration, impact, and tension.

Accordingly, the design must ensure these stresses to be as low or small as possible.

The guideline for ordinary derating is shown below:

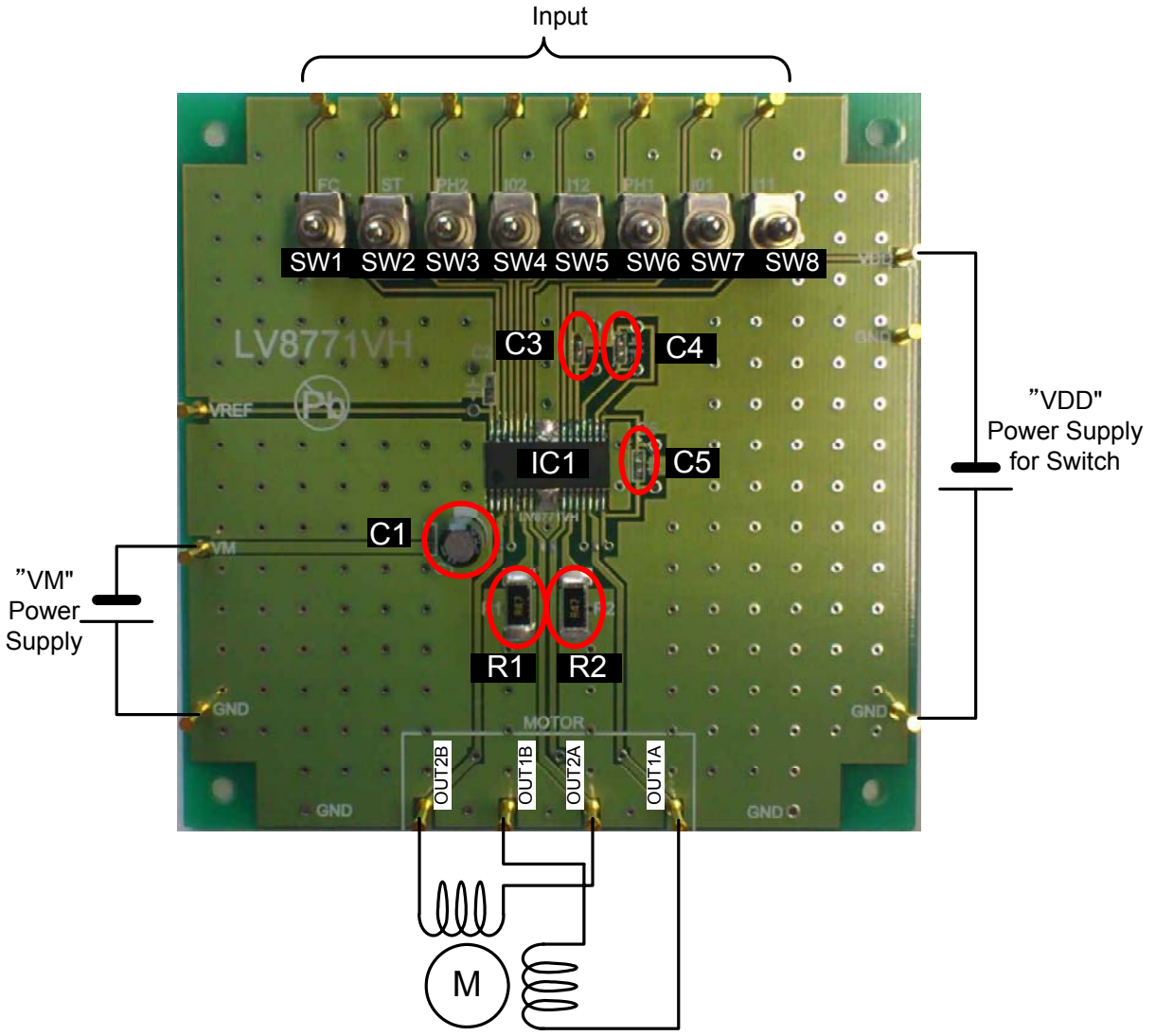
(1) Maximum value 80% or less for the voltage rating.

(2) Maximum value 80% or less for the current rating.

(3) Maximum value 80% or less for the temperature rating.

Evaluation board

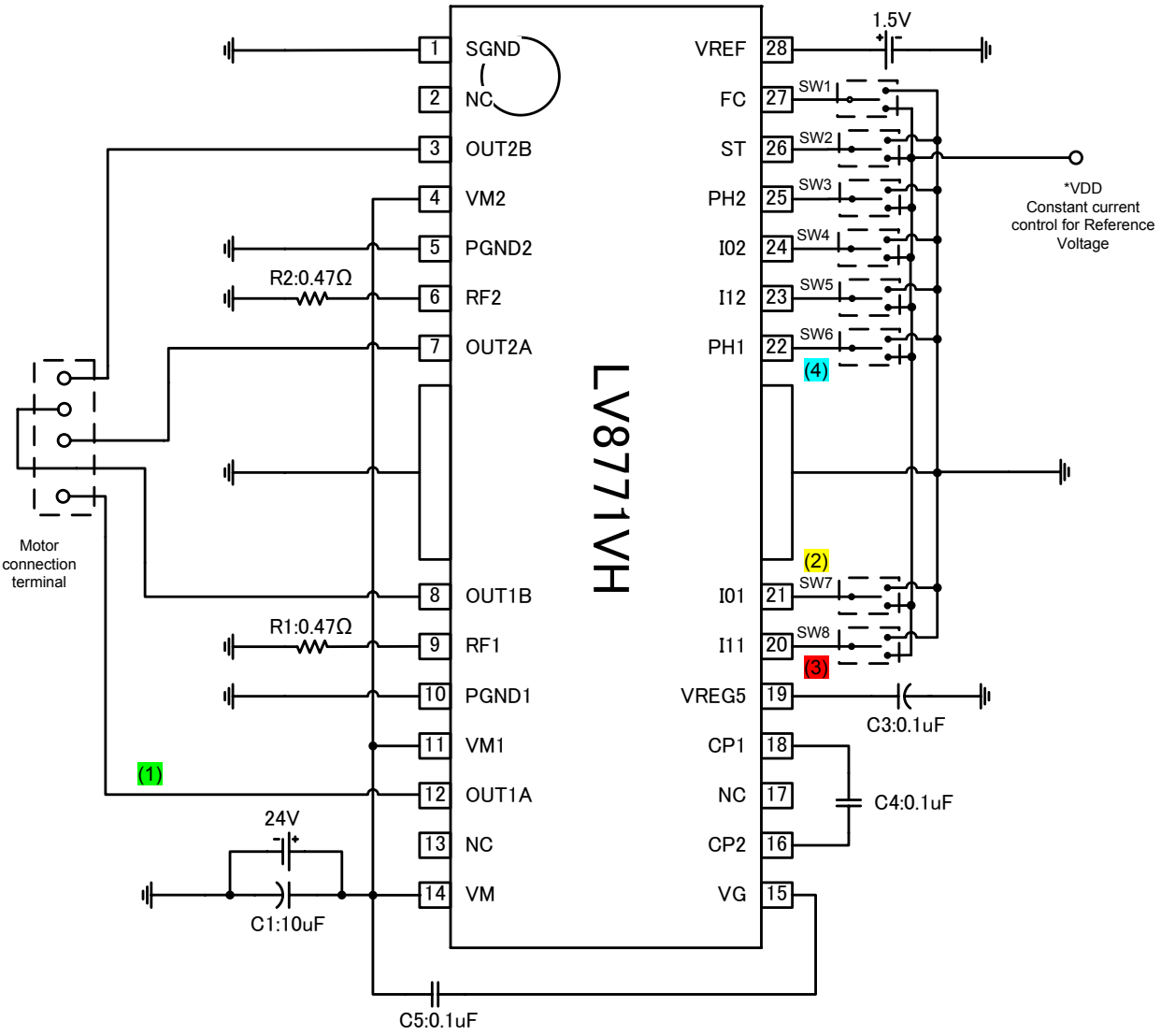
LV8771VH (90.0mm×90.0mm×1.6mm, glass epoxy 2-layer board)



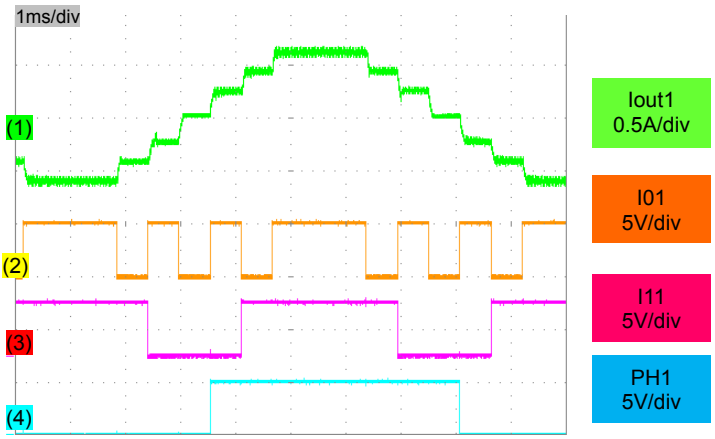
Bill of Materials for LV8771VH Evaluation Board

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
C1	1	VM Bypass Capacitor	10μF, 50V	±20%		SUN Electronic Industries	50ME10HC	Yes	Yes
C3	1	VREG5 stabilization Capacitor	0.1μF, 100V	±10%		Murata	GRM188R72A104KA35*	Yes	Yes
C4	1	Capacitor for Charge pump	0.1μF, 100V	±10%		Murata	GRM188R72A104KA35*	Yes	Yes
C5	1	Capacitor for Charge pump	0.1μF, 100V	±10%		Murata	GRM188R72A104KA35*	Yes	Yes
R1	1	Channel 1 output current detective Resistor	0.47Ω, 1W	±5%		ROHM	MCR100JZHJLR47	Yes	Yes
R2	1	Channel 2 output current detective Resistor	0.47Ω, 1W	±5%		ROHM	MCR100JZHJLR47	Yes	Yes
IC1	1	Motor Driver			HSOP28 (275mil)	ON Semiconductor	LV8771VH	No	Yes
SW1-SW8	8	Switch				MIYAMA	MS-621C-A01	Yes	Yes
TP1-TP17	17	Test Point				MAC8	ST-1-3	Yes	Yes

Evaluation board circuit



【Stepping Motor】
VM=24V, VDD=5V, VREF=1.5V
ST=H, FC=L



Evaluation Board Manual

[Supply Voltage] VM (9 to 32V): Power Supply for LSI
VREF (0 to 3V): Const. Current Control for Reference Voltage
VDD (2 to 5V): Logic “High” voltage for toggle switch

[Toggle Switch State] Upper Side: High (VDD)
Middle: Open, enable to external logic input
Lower Side: Low (GND)

[Operation Guide]

For stepping motor control

1. **Initial Condition Setting:** Set “Open or Low” all switches.
2. **Motor Connection:** Connect the Motors between OUT1A and OUT1B, between OUT2A and OUT2B.
3. **Power Supply:** Supply DC voltage to VM, VREF and VDD.
4. **Ready for Operation from Standby State:** Turn “High” the ST.
5. **Motor Operation:** Set I01, I02, PH1, I02, I12 and PH2 terminals according to the purpose.

[Setting for External Component Value]

1. Constant Current (100%)

At VREF=1.5V

Iout =VREF [V] / 5 / RF [Ω]
=1.5 [V] / 5 / 0.47 [Ω]
=0.64 [A]

Notes in design:

●Power supply connection terminal [VM, VM1, VM2]
- ✓ Make sure to short-circuit VM, VM1 and VM2.For controller supply voltage, the internal regulator voltage of VREG5 (typ 5V) is used.
- ✓ Make sure that supply voltage does not exceed the absolute MAX ratings under no circumstance. Noncompliance can be the cause of IC destruction and degradation.
- ✓ Caution is required for supply voltage because this IC performs switching.
- ✓ The bypass capacitor of the power supply should be close to the IC as much as possible to stabilize voltage. Also if you intend to use high current or back EMF is high, please augment enough capacitance.

●GND terminal [GND, PGND1, PGND2]
- ✓ Since GND is the reference of the IC internal operation, make sure to connect to stable and the lowest possible potential. Since high current flows into PGND1, PGND2, connect it to one-point GND.

●Internal power supply regulator terminal [VREG5]
- ✓ VREG5 is the power supply for logic (typ 5V).
- ✓ When VM supply is powered and ST is ”H”, VREG5 operates.
- ✓ Please connect capacitor for stabilize VREG5. The recommendation value is 0.1μF.
- ✓ Since the voltage of VREG5 fluctuates, do not use it as reference voltage that requires accuracy.

●Input terminal
- ✓ When you set input pin to low voltage, please short it to GND because the input pin is vulnerable to noise.
- ✓ The input is TTL level (H: 2V or higher, L: 0.8V or lower).
- ✓ VREF pin is high impedance.

●OUT terminal [OUT1A, OUT1B, OUT2A, OUT2B]
- ✓ During chopping operation, the output voltage becomes equivalent to VM voltage, which can be the cause of noise. Caution is required for the pattern layout of output pin.
- ✓ The layout should be low impedance because driving current of motor flows into the output pin.
- ✓ 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 [RF1, RF2]
- ✓ To perform constant current control, please connect resistor to RF pin.
- ✓ To perform saturation drive (without constant current control), please connect RF pin to GND.
- ✓ If RF pin is open, then short protector circuit operates. Therefore, please connect it to resistor or GND.
- ✓ The motor current flows into RF – GND line. Therefore, please connect it to common GND line and low impedance line.

●NC terminal
- ✓ NC pin is not connected to the IC.