# LV8740V

**Bi-CMOS LSI**

# PWM Current Control Stepper Motor Driver Application Note

**ON Semiconductor®**

http://onsemi.com

## Overview

The LV8740V is a 2-channel H-bridge driver IC that can switch a stepper motor driver, which is capable of micro-step drive and supports Full-step, Half-step (full torque), Half-step, and Quarter-step resolution, and two channels of a brushed motor driver, which supports forward, reverse, brake, and standby of a motor.

## Function

- Single-channel PWM current control stepper motor driver (selectable with DC motor driver channel 2) incorporated.
- BiCDMOS process IC
- On resistance (upper side: 0.3Ω; lower side: 0.2Ω; total of upper and lower: 0.5Ω; Ta = 25°C, $I_O$ = 2.5A)
- Micro step mode can be set to Full-step, Half-step (full torque), Half-step, or Quarter-step mode
- Excitation step proceeds only by step signal input
- Motor current selectable in four steps
- Output short-circuit protection circuit (selectable from latch-type or auto reset-type) incorporated
- Unusual condition warning output pins
- Built-in thermal shutdown circuit
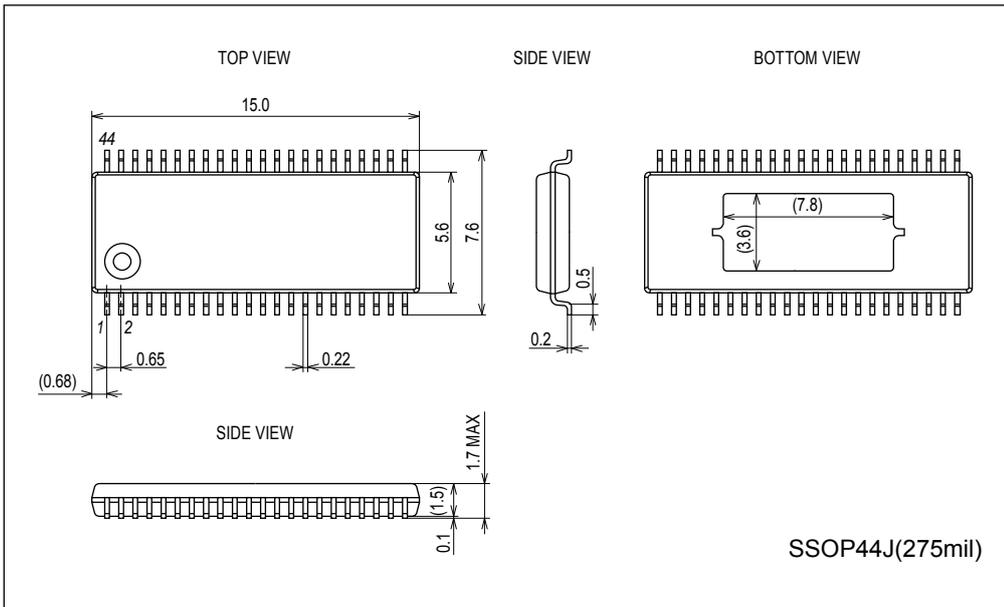- No control power supply required

## Typical Applications

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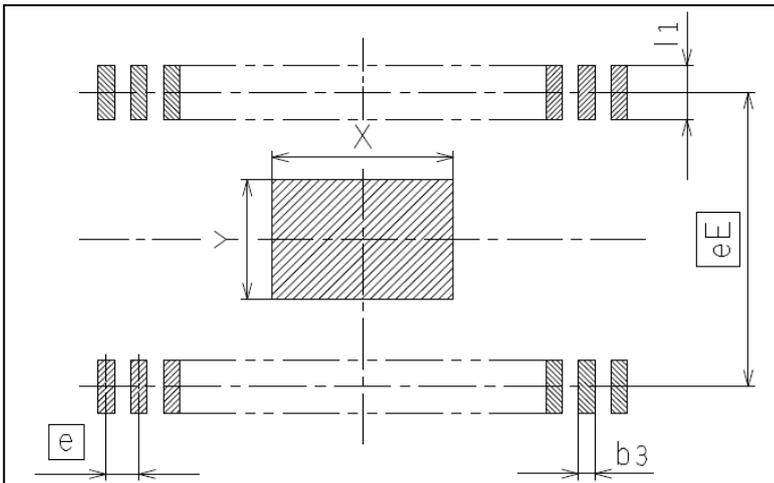- Industrial
- Cash Machine
- Amusement
- Textile

## Package Dimensions

unit : mm (typ)

TOP VIEW     SIDE VIEW     BOTTOM VIEW

15.0

44

5.6

7.6

(7.8)

(3.6)

1  2

0.65

0.22

(0.68)

0.5

0.2

SIDE VIEW

1.7 MAX

(1.5)

0.1

SSOP44J(275mil)

Caution: The package dimension is a reference value, which is not a guaranteed value.
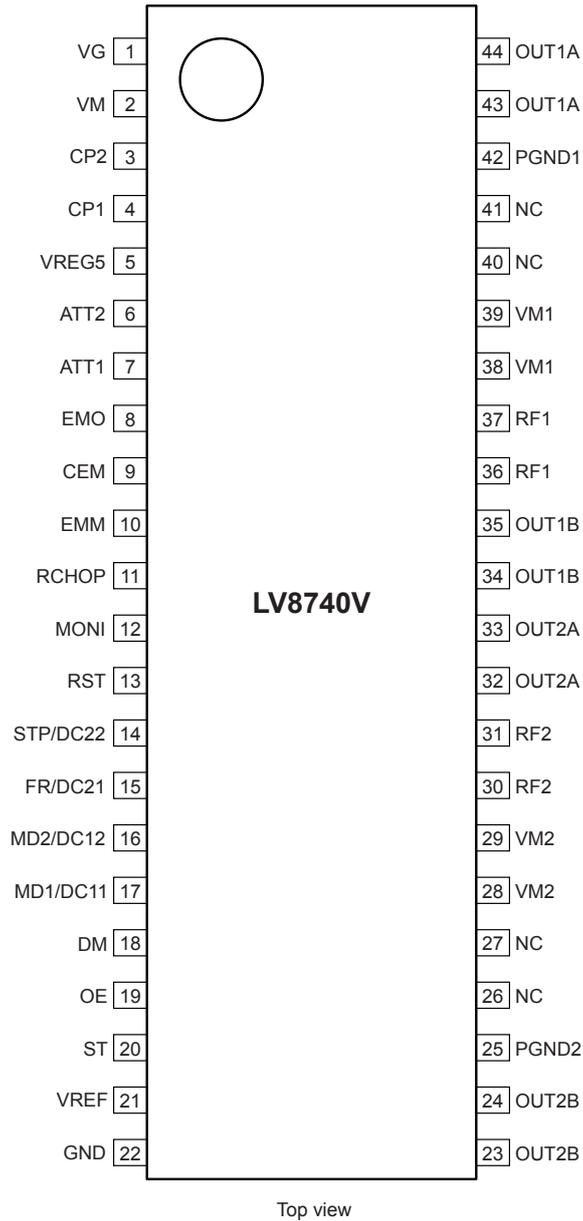
## Recommended Soldering Footprint

l1

X

Y

eE

e

b3

(Unit: mm)

| Reference symbol | SSOP44J(275mil) |
|---|---|
| eE | 7.00 |
| e | 0.65 |
| b3 | 0.32 |
| l1 | 1.00 |
| X | (7.8) |
| Y | (3.5) |

## Pin Assignment

| | | | |
|---|---|---|---|
| VG | 1 | 44 | OUT1A |
| VM | 2 | 43 | OUT1A |
| CP2 | 3 | 42 | PGND1 |
| CP1 | 4 | 41 | NC |
| VREG5 | 5 | 40 | NC |
| ATT2 | 6 | 39 | VM1 |
| ATT1 | 7 | 38 | VM1 |
| EMO | 8 | 37 | RF1 |
| CEM | 9 | 36 | RF1 |
| EMM | 10 | 35 | OUT1B |
| RCHOP | 11 | 34 | OUT1B |
| MONI | 12 | 33 | OUT2A |
| RST | 13 | 32 | OUT2A |
| STP/DC22 | 14 | 31 | RF2 |
| FR/DC21 | 15 | 30 | RF2 |
| MD2/DC12 | 16 | 29 | VM2 |
| MD1/DC11 | 17 | 28 | VM2 |
| DM | 18 | 27 | NC |
| OE | 19 | 26 | NC |
| ST | 20 | 25 | PGND2 |
| VREF | 21 | 24 | OUT2B |
| GND | 22 | 23 | OUT2B |

**LV8740V**

Top view

It is short-circuited in IC though there are VM1, VM2, OUT1A, OUT1B, OUT2A, OUT2B, RF1 and RF2 of each of two pins.

## Block Diagram
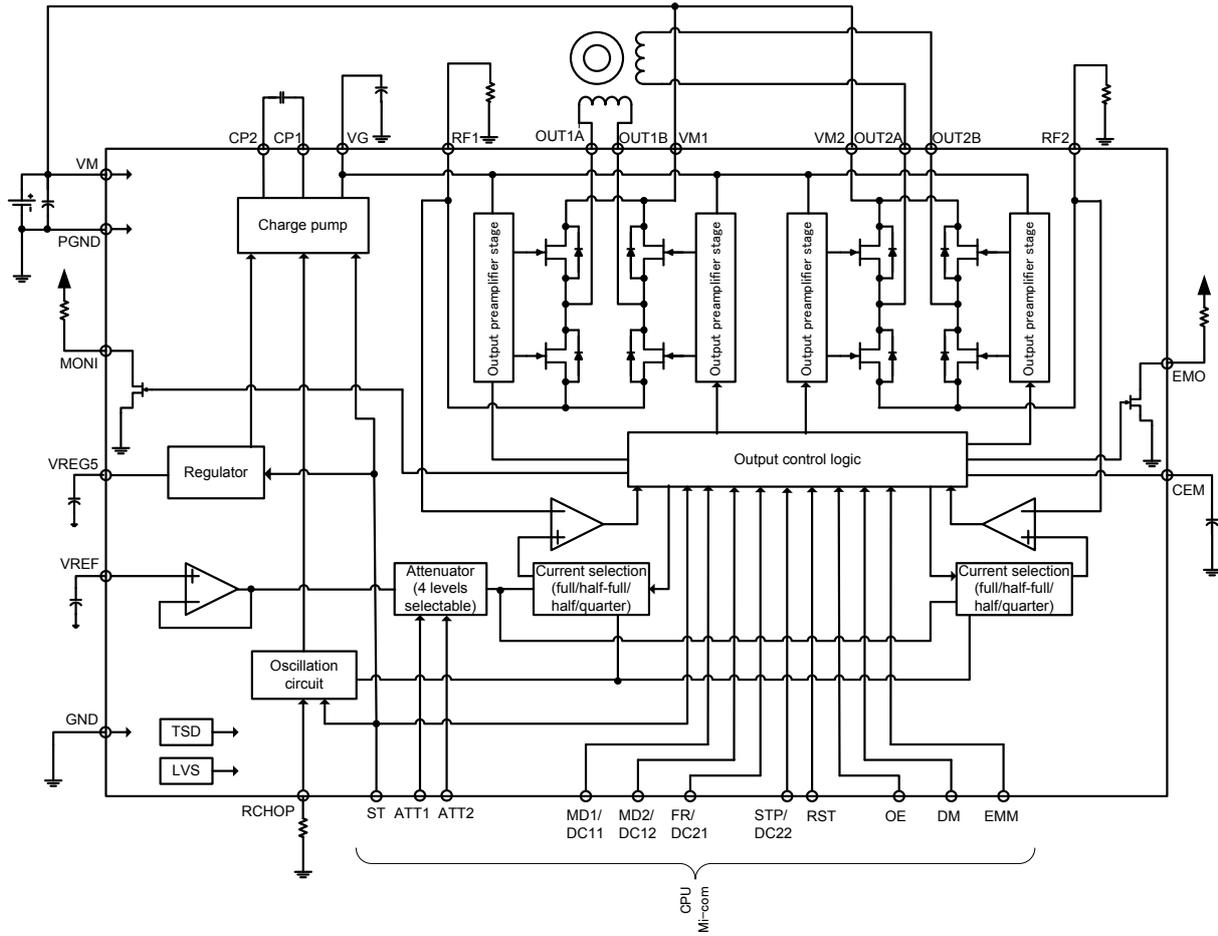
## Specifications

### Absolute Maximum Ratings at Ta = 25°C

| Parameter | Symbol | Conditions | Ratings | Unit |
|---|---|---|---|---|
| Supply voltage 1 | $V_M$ max | | 38 | V |
| Output peak current | $I_O$ peak | tw ≤ 10ms, duty 20%, Each 1ch | 3.0 | A |
| Output current | $I_O$ max | Each 1ch | 2.5 | A |
| Logic input voltage | $V_{IN}$ | | -0.3 to +6.0 | V |
| MONI/EMO input voltage | $V_{MONI}/V_{EMO}$ | | -0.3 to +6.0 | V |
| Allowable power dissipation | Pd max | * | 3.45 | W |
| Operating temperature | Topr | | -30 to +85 | °C |
| Storage temperature | Tstg | | -55 to +150 | °C |

* Specified circuit board : 90×90×1.6mm$^3$ : 2-Layer glass epoxy printed circuit board with back mounting.

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 | $V_M$ | | 9 | | 35 | V |
| Logic input voltage | $V_{IN}$ | | 0 | | 5.5 | V |
| VREF input voltage range | VREF | | 0 | | 3.0 | V |

### Electrical Characteristics at Ta = 25°C, $V_M$ = 24V, VREF = 1.5V

| Parameter | | Symbol | Conditions | Ratings | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | min | typ | max | |
| Standby mode current drain 1 | | IMstn | ST = "L" | | 180 | 250 | μA |
| Current drain | | IM | ST = "H", OE = "L", no load | | 3 | 5 | mA |
| VREG5 output voltage | | Vreg5 | $I_O$=-1mA | 4.7 | 5.0 | 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 | $I_O$ = 2.5A, Upper-side on resistance | | 0.3 | 0.4 | Ω |
| | | Rond | $I_O$ = 2.5A, Lower-side on resistance | | 0.2 | 0.25 | Ω |
| Output leakage current | | $I_O$leak | | | | 50 | μA |
| Diode forward voltage | | VD | ID = -2.5A | | 1.1 | 1.3 | V |
| ST pin input current | | $I_{ST}L$ | $V_{IN}$ = 0.8V | 3 | 8 | 15 | μA |
| | | $I_{ST}H$ | $V_{IN}$ = 5V | 48 | 80 | 112 | μA |
| Logic pin input current (other ST pin) | | $I_{IN}L$ | $V_{IN}$ = 0.8V | 3 | 8 | 15 | μA |
| | | $I_{IN}H$ | $V_{IN}$ = 5V | 30 | 50 | 70 | μA |
| Logic high-level input voltage | | $V_{IN}H$ | | 2.0 | | | V |
| Logic low-level input voltage | | $V_{IN}L$ | | | | 0.8 | V |
| Current selection comparator threshold voltage (Current step switch) | Quarter-step drive | Vtdac0_W | Step 0(When initialized : channel 1 comparator level) | 0.290 | 0.300 | 0.310 | V |
| | | Vtdac1_W | Step 1 (Initial state+1) | 0.260 | 0.270 | 0.280 | V |
| | | Vtdac2_W | Step 2 (Initial state+2) | 0.200 | 0.210 | 0.220 | V |
| | | Vtdac3_W | Step 3 (Initial state+3) | 0.095 | 0.105 | 0.115 | V |
| | Half-step drive | Vtdac0_H | Step 0 (When initialized: channel 1 comparator level) | 0.290 | 0.300 | 0.310 | V |
| | | Vtdac2_H | Step 2 (Initial state+1) | 0.200 | 0.210 | 0.220 | V |
| | Half-step (full torque) drive | Vtdac0_HF | Step 0 (Initial state, channel 1 comparator level) | 0.290 | 0.300 | 0.310 | V |
| | | Vtdac2_HF | Step 2 (Initial state+1) | 0.290 | 0.300 | 0.310 | V |
| | Full-step drive | Vtdac2_F | Step 2 | 0.290 | 0.300 | 0.310 | V |
| Current selection comparator threshold voltage (Current attenuation rate switch) | | Vtatt00 | ATT1=L, ATT2=L | 0.290 | 0.300 | 0.310 | V |
| | | Vtatt01 | ATT1=H, ATT2=L | 0.190 | 0.200 | 0.210 | V |
| | | Vtatt10 | ATT1=L, ATT2=H | 0.140 | 0.150 | 0.160 | V |
| | | Vtatt11 | ATT1=H, ATT2=H | 0.090 | 0.100 | 0.110 | V |

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| Parameter | Symbol | Conditions | Ratings | | | Unit |
|---|---|---|---|---|---|---|
| | | | min | typ | max | |
| Chopping frequency | Fchop | RCHOP = 20kΩ | 45 | 62.5 | 75 | kHz |
| VREF pin input current | Iref | VREF = 1.5V | -0.5 | | | μA |
| MONI pin saturation voltage | Vsatmon | $I_{MONI}$=1mA | | 50 | 100 | mV |
| **Charge pump** | | | | | | |
| VG output voltage | VG | | 28 | 28.7 | 29.8 | V |
| Rise time | tONG | VG = 0.1μF | | | 0.5 | ms |
| Oscillator frequency | Fosc | RCHOP = 20kΩ | 90 | 125 | 150 | kHz |
| **Output short-circuit protection** | | | | | | |
| EMO pin saturation voltage | Vsatemo | Iemo = 1mA | | 50 | 100 | mV |
| CEM pin charge current | Icem | Vcem=0V | 7 | 10 | 13 | μA |
| CEM pin threshold voltage | Vtcem | | 0.8 | 1.0 | 1.2 | V |

Figure 1.  Stanby Mode Current Drain vs. VM Voltage

Figure 2.  Current Drain vs. VM Voltage

Figure 3.  VREG5 Output Voltage vs. VM Voltage

Figure 4.  ST pin Threshold Voltage vs. VM Voltage

Figure 5.  Logic High/Low-level input Voltage vs. VM Voltage

Figure 6.  ST pin input Current vs. Logic input Voltage

Figure 7.  Logic pin input Current vs. Logic input Voltage

Figure 8.  VREF pin input Current vs. VREF Voltage

**Figure 9. MONI pin saturation voltage vs. MONI pin input current**



**Figure 10. EMO pin saturation voltage vs. EMO pin input current**



**Figure 11. VG Output Voltage vs. VM Voltage**



**Figure 12. Output on Resistance vs. Output Current**



**Figure 13. Output on Resistance vs. Temperature**



**Figure 14. Diode forward voltage vs. Output Current**

# LV8740V Application Note

## Pin Functions

| Pin No. | Pin Name | Pin Function | Equivalent Circuit |
|---|---|---|---|
| 6 | ATT2 | Motor holding current switching pin. | |
| 7 | ATT1 | Motor holding current switching pin. | |
| 10 | EMM | Output short-circuit protection mode switching pin. | |
| 13 | RST | RESET signal input pin | |
| 14 | STP/DC22 | STEP signal input pin (STM) / Channel 2 output control input pin 2 (DCM). | |
| 15 | FR/DC21 | CW / CCW signal input pin (STM) / Channel 2 output control input pin 1 (DCM). | |
| 16 | MD2/DC12 | Excitation mode switching pin 2 (STM) / Channel 1 output control input pin 2 (DCM). | |
| 17 | MD1/DC11 | Excitation mode switching pin 1 (STM) / Channel 1 output control input pin 1 (DCM). | |
| 18 | DM | Drive mode (STM/DCM) switching pin. | |
| 19 | OE | Output enable signal input pin. | |
| 20 | ST | Chip enable pin. | |
| 23, 24 | OUT2B | Channel 2 OUTB output pin. | |
| 25, 42 | PGND | Power system ground. | |
| 28, 29 | VM2 | Channel 2 motor power supply connection pin | |
| 30, 31 | RF2 | Channel 2 current-sense resistor connection pin. | |
| 32, 33 | OUT2A | Channel 2 OUTA output pin. | |
| 34, 35 | OUT1B | Channel 1 OUTB output pin. | |
| 36, 37 | RF1 | Channel 1 current-sense resistor connection pin. | |
| 38, 39 | VM1 | Channel 1 motor power supply pin. | |
| 43, 44 | OUT1A | Channel 1 OUTA output pin. | |

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| Pin No. | Pin Name | Pin Function | Equivalent Circuit |
|---|---|---|---|
| 1 | VG | Charge pump capacitor connection pin. | |
| 2 | VM | Motor power supply connection pin. | |
| 3 | CP2 | Charge pump capacitor connection pin. | |
| 4 | CP1 | Charge pump capacitor connection pin. | |
| 21 | VREF | Constant current control reference voltage input pin. | |
| 5 | VREG5 | Internal power supply capacitor connection pin. | |
| 8 | EMO | Output short-circuit state warning output pin. | |
| 12 | MONI | Position detection monitor pin. | |

# LV8740V Application Note

| Pin No. | Pin Name | Pin Function | Equivalent Circuit |
|---------|----------|--------------|--------------------|
| 9 | CEM | Pin to connect the output short-circuit state detection time setting capacitor. |  |
| 11 | RCHOP | Chopping frequency setting capacitor connection pin. |  |
| 22 | GND | Ground. | |
| 26, 27 40, 41 | NC | No Connection (No internal connection to the IC) | |

## Description of operation

### Input Pin Function

The function to prevent including the turn from the input to the power supply is built into each input pin. Therefore, the current turns to the power supply even if power supply (VM) is turned off with the voltage impressed to the input pin and there is not crowding.

### (1) Chip enable function

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

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

### (2) Drive mode switching pin function

The IC drive mode is switched by setting the DM pin. In STM mode, stepping motor channel 1 can be controlled by the CLK-IN input. In DCM mode, DC motor channel 2 or stepping motor channel 1 can be controlled by parallel input. Stepping motor control using parallel input is full-step or half-step full torque.

| DM | Drive mode | Application |
|----|-----------|-------------|
| Low or Open | STM mode | Stepping motor channel 1 (CLK-IN) |
| High | DCM mode | DC motor channel 2 or stepping motor channel 1 (parallel) |

STM mode (DM = Low or Open)

### (1) STP pin function

The excitation step progresses by inputting the step signal to the STP pin.

| Input | | Operating mode |
|-------|-----|----------------|
| ST | STP | |
| Low | * | Standby mode |
| High | ⤒ | Excitation step proceeds |
| High | ⤓ | Excitation step is kept |
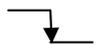
STP input MIN pulse width (common in H/L):  500ns (MAX input frequency: 1MHz)
However, constant current control is performed by PWM during chopping period, which is set by the resistor connected between RCHOP and GND. You need to perform chopping more than once per step. For this reason, for the actual STP frequency, you need to take chopping frequency and chopping count into consideration.
For example, if chopping frequency is 62.5kHz (16µs) and chopping is performed twice per step, the maximum STP frequency is obtained as follows: f=1/(16µs × 2) = 31kHz.

### (2) Input timing
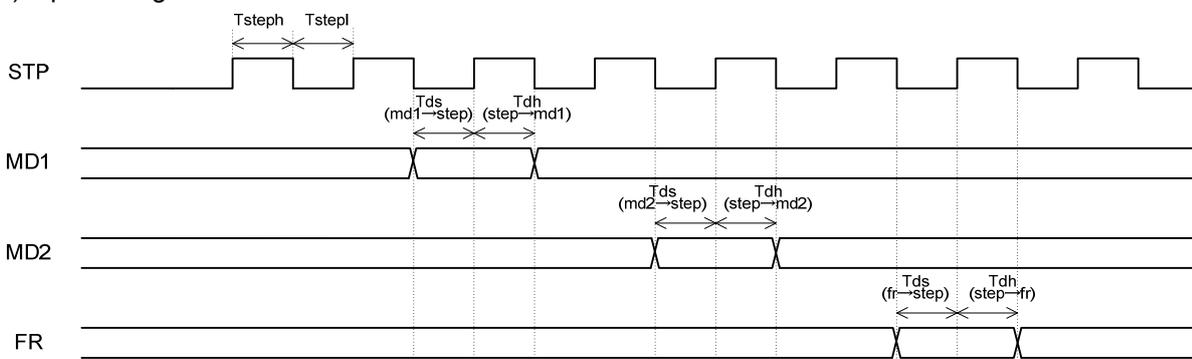


TstepH/TstepL : Clock H/L pulse width (min 500ns)
Tds : Data set-up time (min 500ns)
Tdh : Data hold time (min 500ns)

(3) Positional detection monitor function

Positional detection monitor MONI pin is an open drain output. When the excitation position is an initial position, the MONI output becomes ON.
Please refer to (example of current wave type in each excitation mode).

(4) Setting constant-current control reference current

This IC is designed to automatically exercise PWM constant-current chopping control for the motor current 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:

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

\* The above setting is the output current at 100% of each microstep mode.

If VREF is open or the setting is out of the recommendation operating range, VREF is set around 5V. As a result, 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 without saturation drive or current limit) make sure that the setting is as follows: VREF=5V or VREF=VREG5

The voltage input to the VREF pin can be switched to four-step settings depending on the statuses of the two inputs, ATT1 and ATT2. This is effective for reducing power consumption when motor holding current is supplied.

Attenuation function for VREF input voltage

| ATT1 | ATT2 | Current setting reference voltage attenuation ratio |
|------|------|-----------------------------------------------------|
| Low  | Low  | 100%   |
| High | Low  | 66.7%  |
| Low  | High | 50%    |
| High | High | 33.3%  |
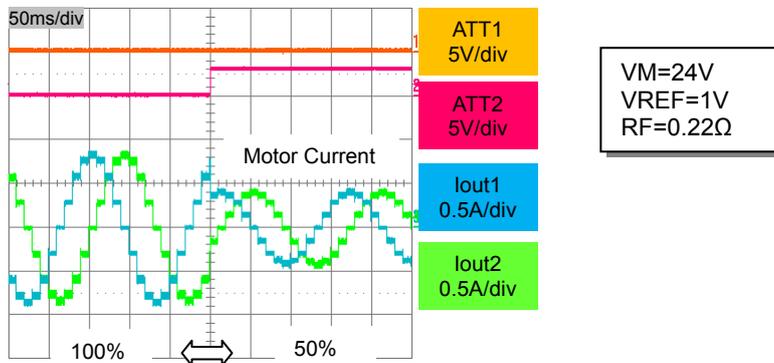


The formula used to calculate the output current when using the function for attenuating the VREF input voltage is given below.
$$I_{OUT} = (VREF/5) \times (\text{attenuation ratio})/RF \text{ resistance}$$

Example : At VREF of 1.65V, a reference voltage setting of 100% [(ATT1, ATT2) = (L, L)] and an RF resistance of 0.22Ω, the output current is set as shown below.
$$I_{OUT} = 1.65V/5 \times 100\%/0.22Ω = 1.5A$$

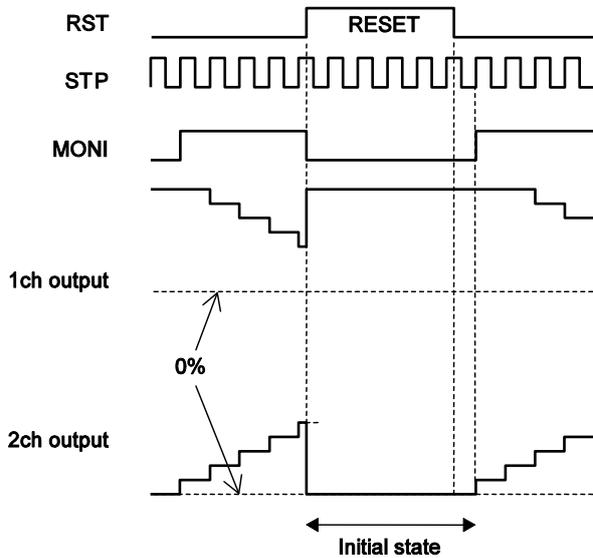If, in this state, (ATT1, ATT2) is set to (H, H), IOUT will be as follows :
$$I_{OUT} = 1.5A \times 33.3\% = 0.5A$$

In this way, the output current is attenuated when the motor holding current is supplied so that power can be conserved.

(5) Reset function

| RST | Operating mode |
|------|------------------|
| Low | Normal operation |
| High | Reset state |

When the RST pin is set to High, the excitation position of the output is forcibly set to the initial state, and the MONI output is placed in the ON state. When RST is then set to Low, the excitation position is advanced by the next STEP input.

(6) Output enable function

| OE | Operating mode |
|------|------------------|
| High | Output OFF |
| Low | Output ON |
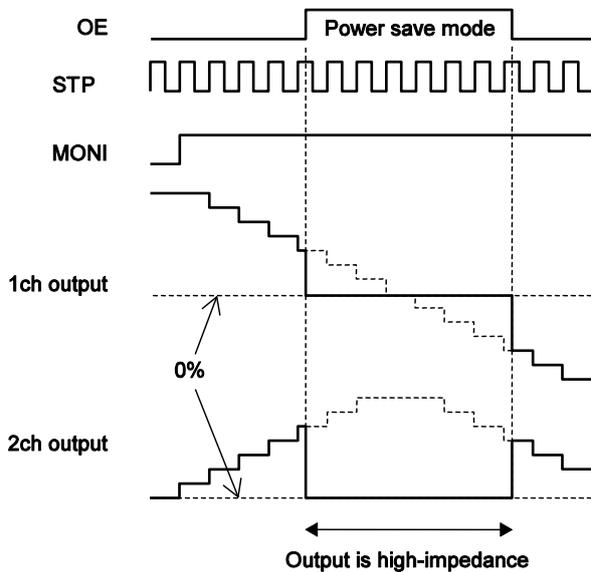
When the OE pin is set High, the output is forced OFF and goes to high impedance.
However, the internal logic circuits are operating, so the excitation position proceeds when the STEP signal is input to the STP pin. Therefore, when OE is returned to Low, the output level conforms to the excitation position proceeded by the STEP input.

(7) Forward/reverse switching function

| FR | Operating mode |
|---|---|
| Low | Clockwise (CW) |
| High | Counter-clockwise (CCW) |
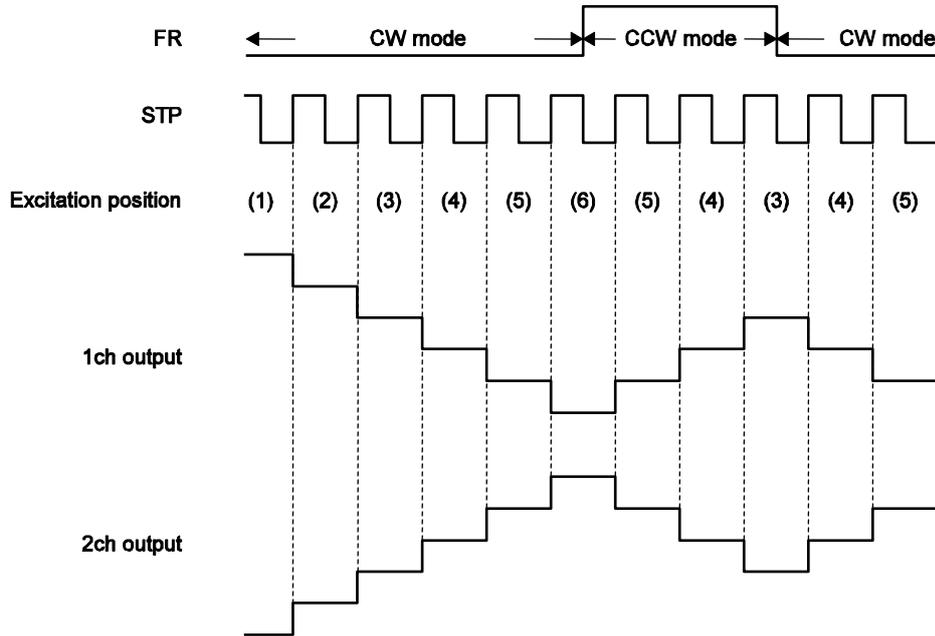


The internal D/A converter proceeds by one bit at the rising edge of the input STEP pulse.
In addition, CW and CCW mode are switched by setting the FR pin.
In CW mode, the channel 2 current phase is delayed by 90° relative to the channel 1 current.
In CCW mode, the channel 2 current phase is advanced by 90° relative to the channel 1 current.

(8) Setting the chopping frequency
For constant-current control, chopping operation is made with the frequency determined by the external resistor (connected to the RCHOP pin).
The chopping frequency to be set with the resistance connected to the RCHOP pin (pin 11) is as shown below.

Chopping frequency settings (reference data)
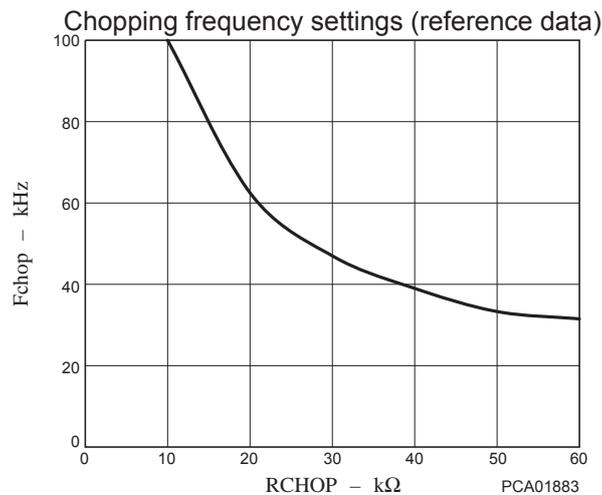
(9) Blanking period

If, when exercising PWM constant-current chopping control over the motor current, the mode is switched from decay to charge, the recovery current of the parasitic diode may flow to the current sensing resistance, causing noise to be carried on the current sensing resistance pin, and this may result in erroneous detection. To prevent this erroneous detection, a blanking period is provided to prevent the noise occurring during mode switching from being received. During this period, the mode is not switched from charge to decay even if noise is carried on the current sensing resistance pin.

In this IC, the blanking time is fixed at 1/16 of one chopping cycle.

(10) Output current vector locus (one step is normalized to 90 degrees)
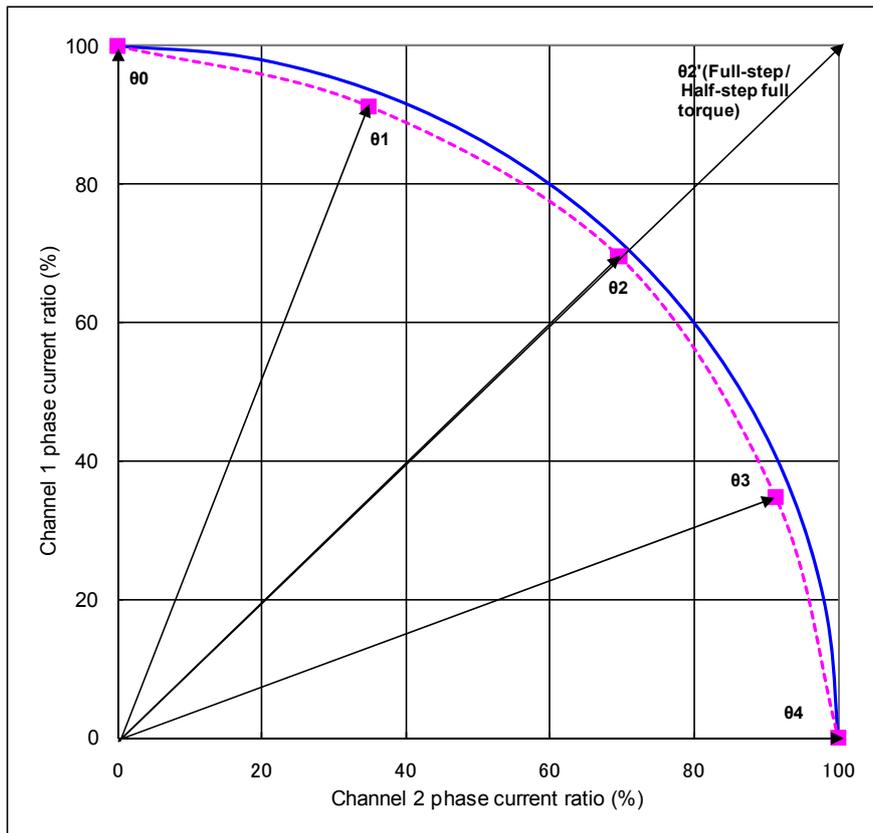


Setting current ration in each microstep resolution

| STEP | Quarter Step (%) | | Half Step (%) | | Half Step (full torque) (%) | | Full Step (%) | |
|------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | Channel 1 | Channel 2 | Channel 1 | Channel 2 | Channel 1 | Channel 2 | Channel 1 | Channel 2 |
| θ0 | 100 | 0 | 100 | 0 | 100 | 0 | | |
| θ1 | 90 | 35 | | | | | | |
| θ2 | 70 | 70 | 70 | 70 | 100 | 100 | 100 | 100 |
| θ3 | 35 | 90 | | | | | | |
| θ4 | 0 | 100 | 0 | 100 | 0 | 100 | | |

(11) Excitation mode setting function

The excitation mode of the stepping motor can be set as follows by setting the MD1 pin and the MD2 pin.

| MD1 | MD2 | Microstep Resolution | Excitation mode | Initial position | |
|---|---|---|---|---|---|
| | | | | Channel 1 | Channel 2 |
| Low | Low | Full Step | 2 phase | 100% | -100% |
| High | Low | Half Step (full torque) | 1-2 phase (full torque) | 100% | 0% |
| Low | High | Half Step | 1-2 phase | 100% | 0% |
| High | High | Quarter Step | W1-2 phase | 100% | 0% |

This is the initial position of each excitation mode in the initial state after power-on and when the counter is reset.

(12) Excitation mode switching operation

When excitation mode is switched while the motor is rotating, each drive mode operates with the following sequence.

Clockwise mode

| Before the Microstep Resolution changes | | Position after the Microstep Resolution is changed | | | |
|---|---|---|---|---|---|
| Microstep mode | Position | Quarter Step | Half Step | Half Step (full torque) | Full Step |
| Quarter Step | θ0 | | θ2 | θ2' | θ2' |
| | θ1 | | θ2 | θ2' | θ2' |
| | θ2 | | θ4 | θ4 | θ2' |
| | θ3 | | θ2 | θ2' | θ2' |
| | θ4 | | -θ2 | -θ2' | -θ2' |
| Half Step | θ0 | θ1 | | θ2' | θ2' |
| | θ2 | θ3 | | θ2' | θ2' |
| | θ4 | -θ3 | | -θ2' | -θ2' |
| Half Step (full torque) | θ0 | θ1 | θ2' | | θ2' |
| | θ2' | θ3 | θ4 | | θ2' |
| | θ4 | -θ3 | -θ2 | | -θ2' |
| Full Step | θ2' | θ3 | θ4 | θ4 | |

*As for θ0 to θ4, please refer to the step position of current ratio setting.

If you switch microstep mode while the motor is driving, the mode setting will be reflected from the next STEP and the motor advances to the closest excitation position at switching operation.

(13) Typical current waveform in each Microstep mode

Full Step (CW mode)
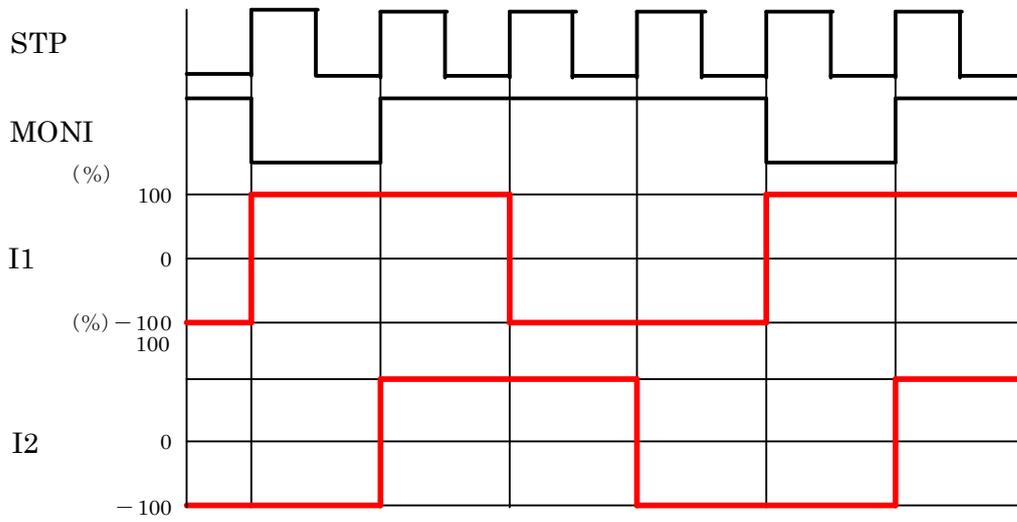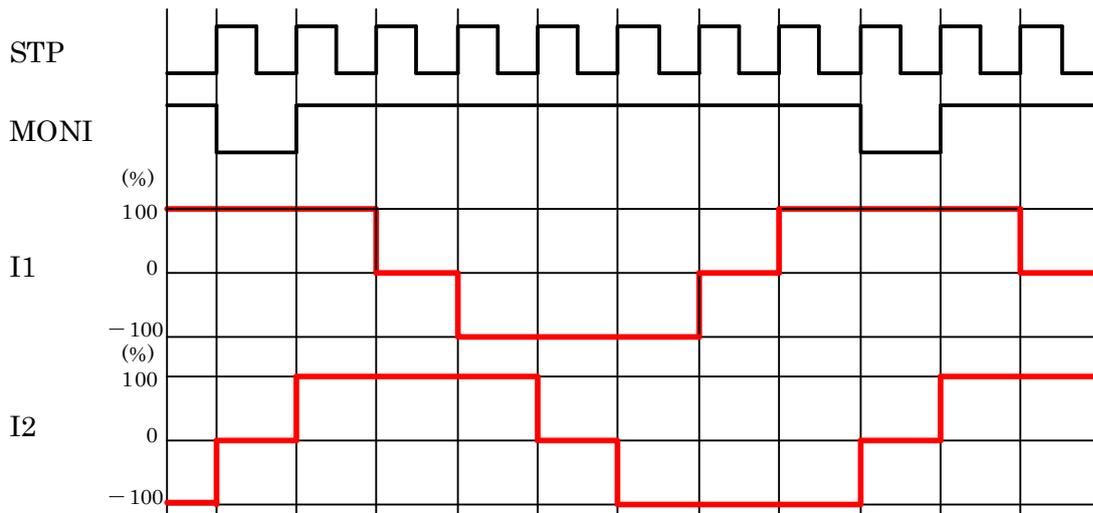


Half Step (full torque) (CW mode)
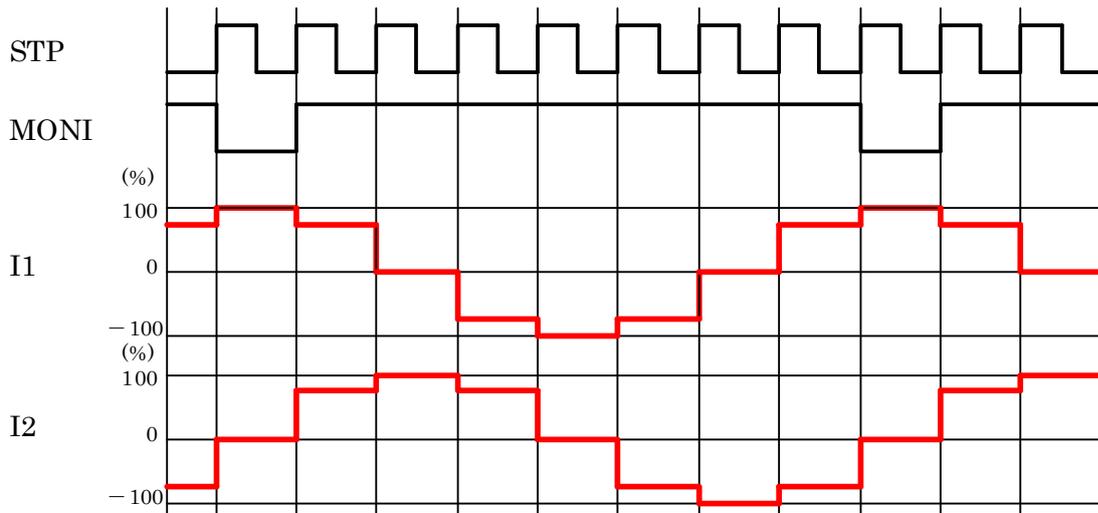
Half step (CW mode)



Quarter Step (CW mode)
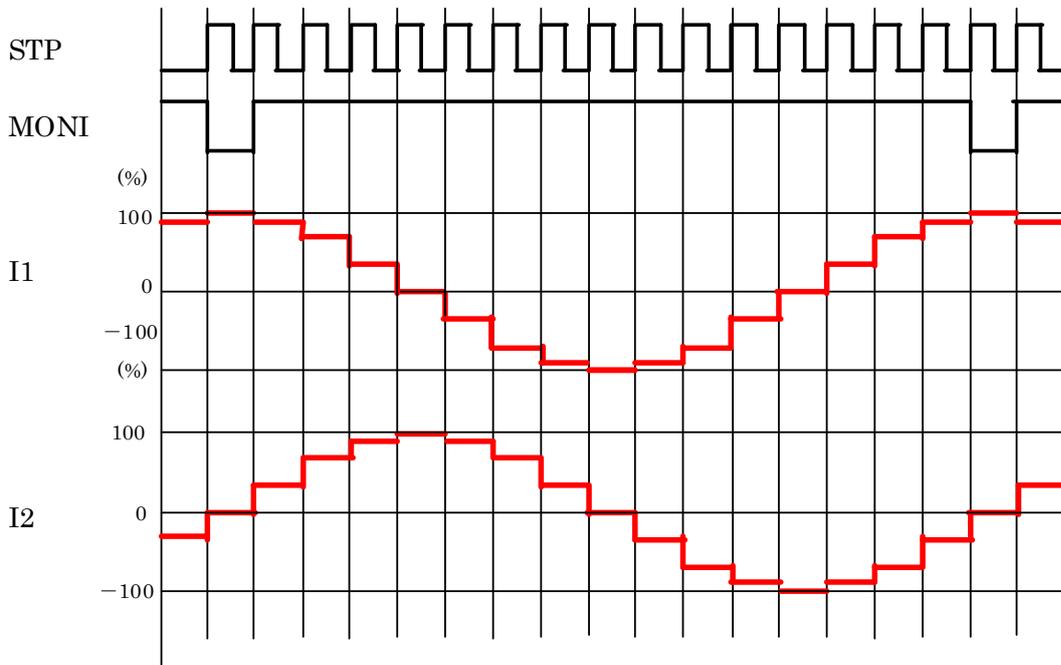
(14) Current control operation specification
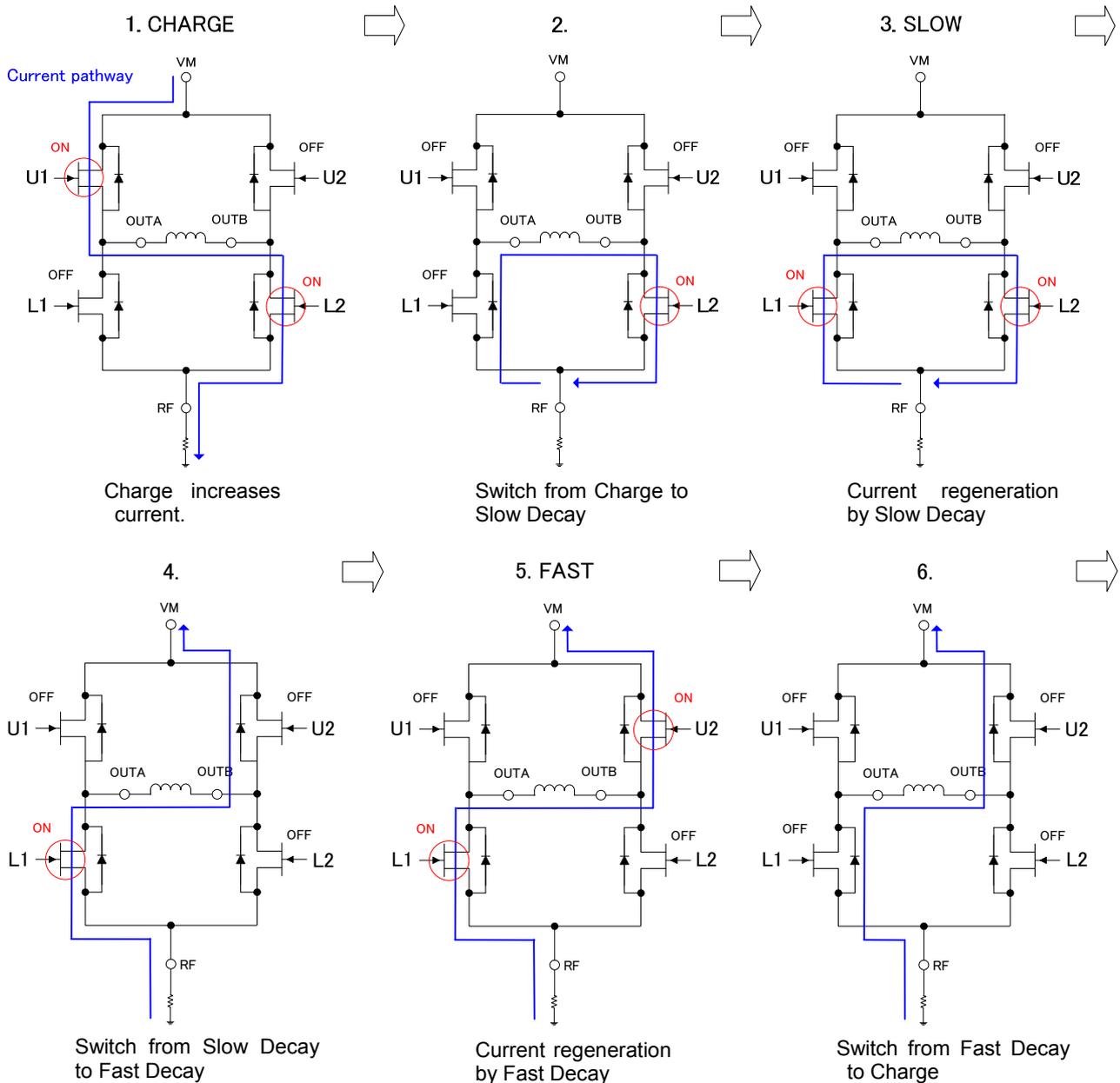(Sine wave increasing direction)
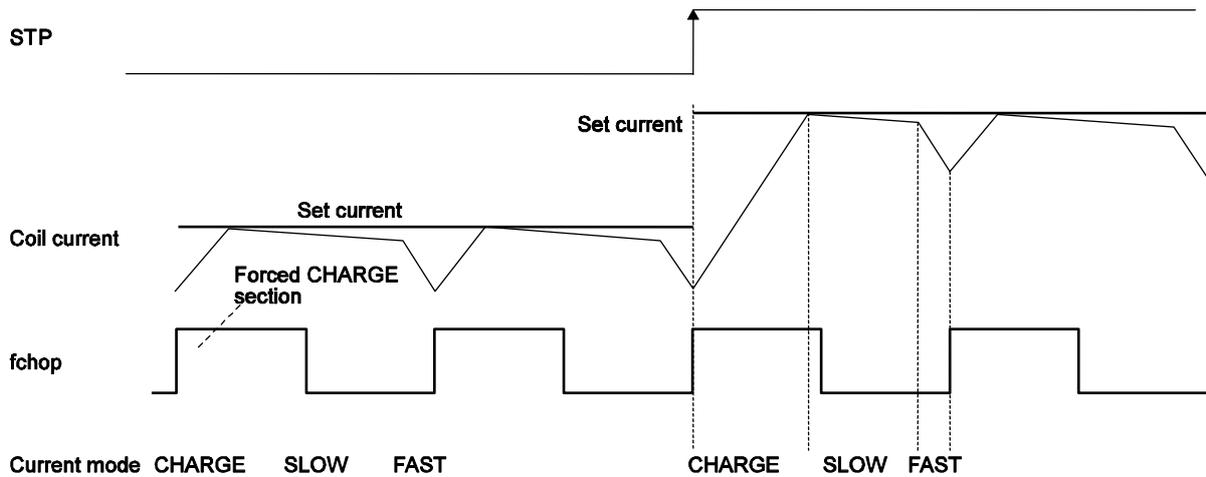


(Sine wave decreasing direction)
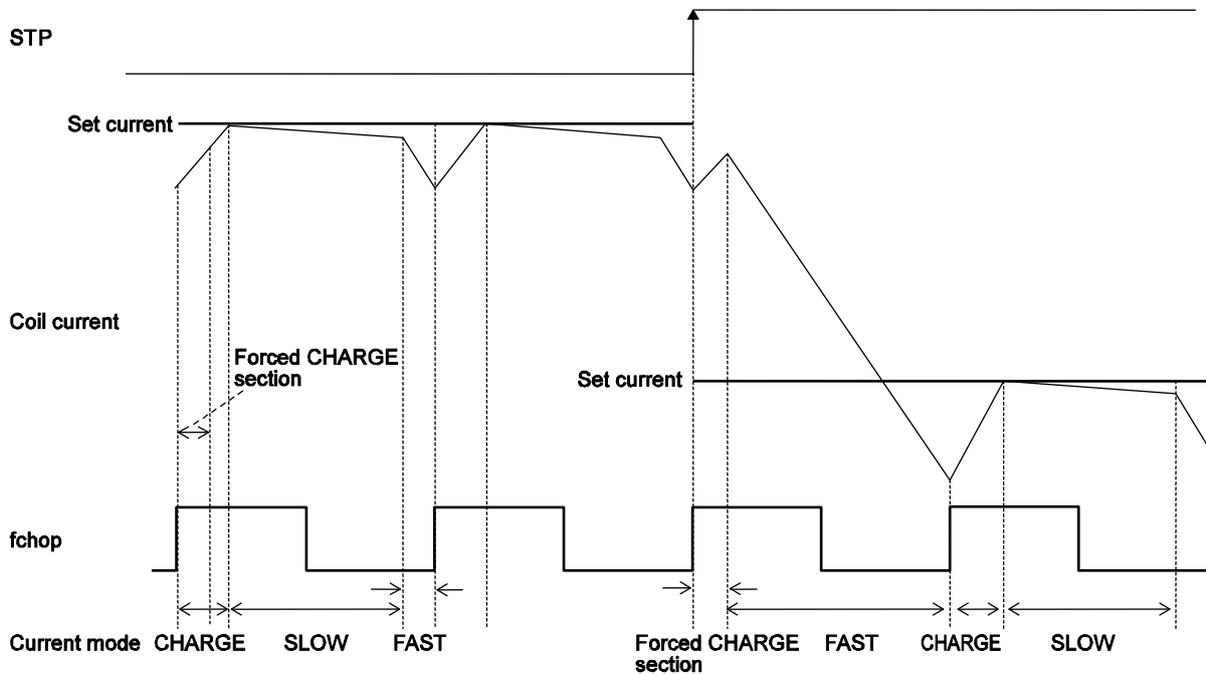


In each current mode, the operation sequence is as described below :
- At rise of chopping frequency, the CHARGE mode begins.(The section in which the CHARGE mode is forced regardless of the magnitude of the coil current (ICOIL) and set current (IREF) exists for 1/16 of one chopping cycle.)
- The coil current (ICOIL) and set current (IREF) are compared in this forced CHARGE section.
    When (ICOIL<IREF) state exists in the forced CHARGE section ;
        CHARGE mode up to ICOIL $\geq$ IREF, then followed by changeover to the SLOW DECAY mode, and finally by the FAST DECAY mode for the 1/16 portion of one chopping cycle.
    When (ICOIL<IREF) state does not exist in the forced CHARGE section;
        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 sine 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.

(15)Output transistor operation mode



1. CHARGE — Charge increases current.

2. — Switch from Charge to Slow Decay

3. SLOW — Current regeneration by Slow Decay

4. — Switch from Slow Decay to Fast Decay

5. FAST — Current regeneration by Fast Decay

6. — Switch from Fast Decay to Charge

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 between the transistors. This off period is set to be constant (≈ 0.5µs) 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 |

VM=24V
VREF=1V
RF=0.22Ω
RCHOP=20kΩ

STEP 5V/div

Motor Current 0.5A/div

STEP 5V/div

Set Current

Motor Current 0.5A/div

OUTA 20V/div

OUTB 20V/div

Sine wave increasing direction

STEP 5V/div

Set Current

Motor Current 0.5A/div

OUTA 20V/div

OUTB 20V/div

Sine wave decreasing direction

Current mode

Motor Current 200mA/div

OUTA 20V/div

OUTB 20V/div

FAST

CHARGE    SLOW
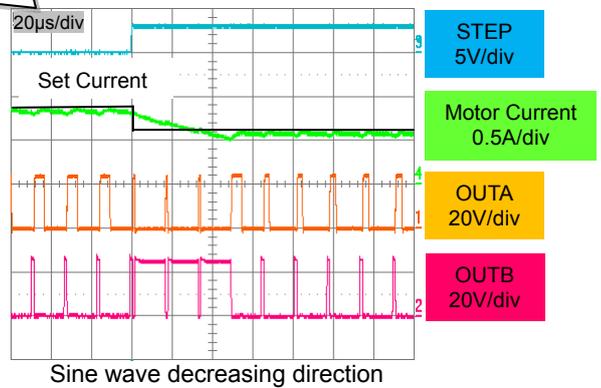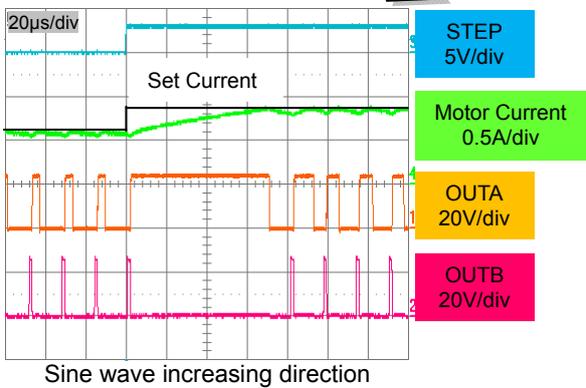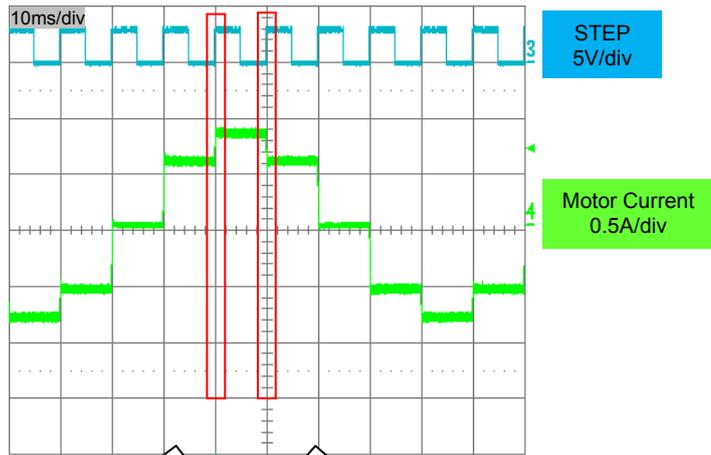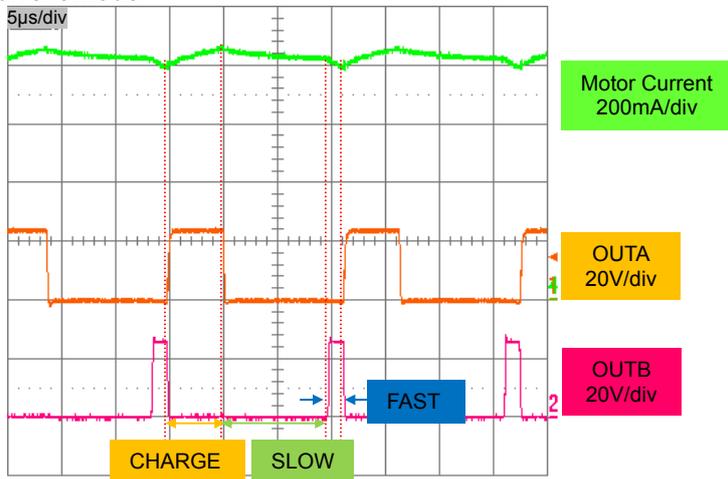
When the motor current reaches to the setting current, it is switched to Slow Decay mode.
Motor current switches from Slow Decay mode to Fast Decay mode for 1/16 of one chopping cycle.

## DCM Mode (DM-High)

(1) DCM mode output control logic

| Parallel input | | Output | | Mode |
|---|---|---|---|---|
| DC11 (21) | DC12 (22) | OUT1 (2) A | OUT1 (2) B | |
| Low | Low | OFF | OFF | Standby |
| High | Low | High | Low | CW (Forward) |
| Low | High | Low | High | CCW (Reverse) |
| High | High | Low | Low | Brake |

When the control input switched from CW mode or CCW mode to standby mode, the current is pulled out with FAST DECAY. Afterwards, when the current becomes 0, the output is forcibly turned off. This forced OFF is released on the following condition.
1) Switched to CW mode or CCW mode.
2) Setting ST to low.

Therefore, forced OFF might not be released, If the input signal is followed in order by CW (CCW) mode, standby mode, and brake mode. When the standby mode enters the above-mentioned timing, set the input time of the standby mode less than 0.5µs.

(2) Reset function

| RST | Operating mode | MONI |
|---|---|---|
| High or Low | Reset operation not performed | High output |

The reset function does not operate in DCM mode. In addition, the MONI output is High, regardless of the RST pin state.

(3) Output enable function

| OE | Operating mode |
|---|---|
| High | Output OFF |
| Low | Output ON |

When the OE pin is set High, the output is forced OFF and goes to high impedance. When the OE pin is set Low, output conforms to the control logic.

(4)PWM control

You can perform H-Bridge direct PWM control to DC11, DC12, DC21, and DC22 by inputting PWM signal. The maximum frequency of PWM signal is 200kHz. However, dead zone is generated when On-Duty is around 0%. Make sure to select optimum PWM frequency according to the target control range.

Input-Output Characteristics of H-Bridge(Reference data)
VM=24V,VREF=1.5V
Forward/Reverse↔Brake
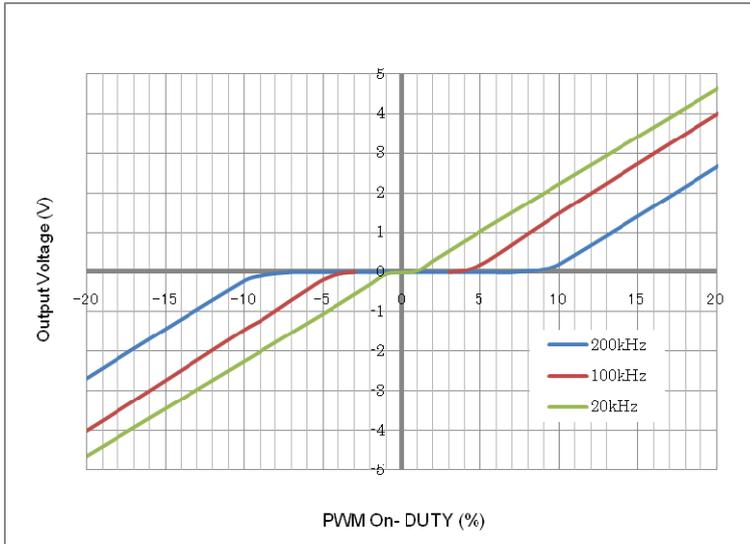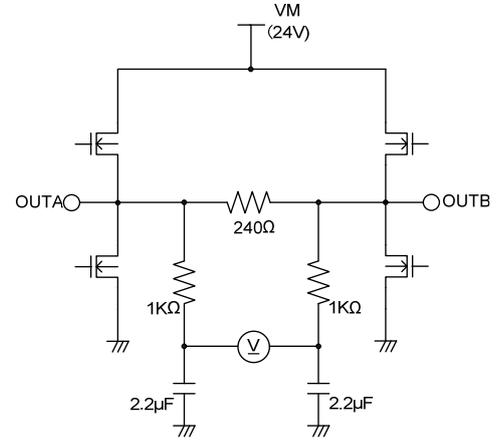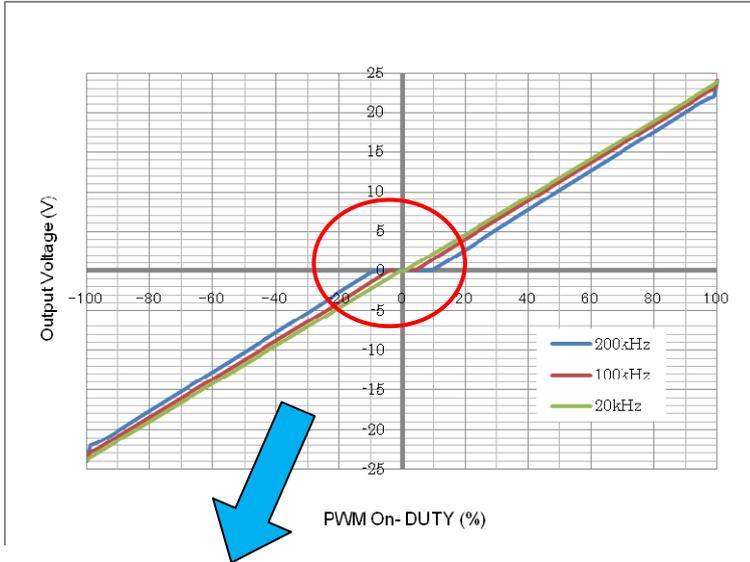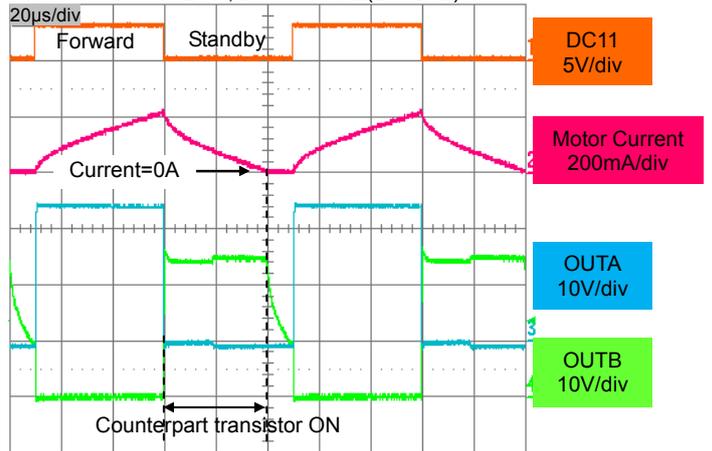
Forward↔Brake
No load , VM=24V , DC12=10kHz(DC11=H)

20µs/div

| | High | High | DC11 5V/div |
| | Low | High | DC12 5V/div |
| | | | OUTA 10V/div |
| | | | OUTB 10V/div |

Forward | Brake
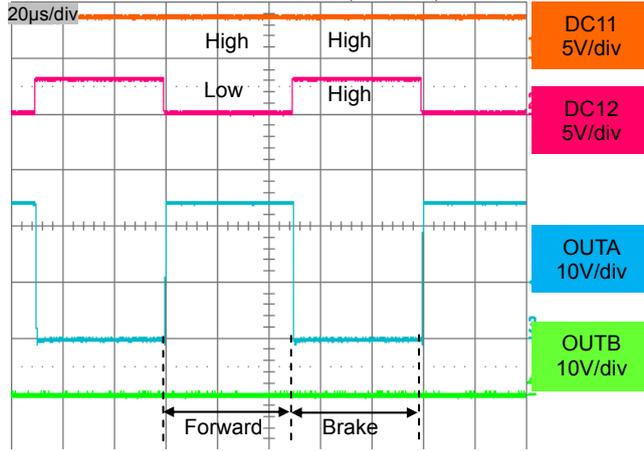
Forward↔Standby
No load   VM=24V , DC11=10kHz(DC12=L)

20µs/div

| | High | Low | DC11 5V/div |
| | Low | Low | DC12 5V/div |
| | | | OUTA 10V/div |
| | | | OUTB 10V/div |

Forward | Standby

0.5µs/div

w/out load (no currnet), even if the counterpart transistor is on, output turns off at a MIN time (≈0.5µs)

Counterpart transistor ON

Motor load   VM=24V , DC11=10kHz(DC12=L)

20µs/div

| Forward | Standby | DC11 5V/div |
| | | Motor Current 200mA/div |
| Current=0A | | OUTA 10V/div |
| | | OUTB 10V/div |
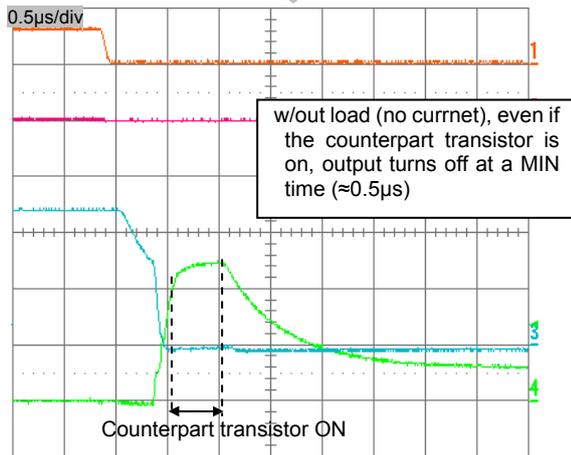
Counterpart transistor ON

Standby mode turns on the counterpart transistor
(synchronous rectification) . After motor current fades off, output turns off.
Synchronous rectification reduces heat generation compared to diode
regeneration.

(5) Current limit reference voltage setting function

By setting a current limit, this IC automatically exercises short braking control to ensure that when the motor current has reached this limit, the current will not exceed it.

(Current limit control time chart)





VM=24V
VREF=1V
RF=0.22Ω
ATT1=ATT2=L
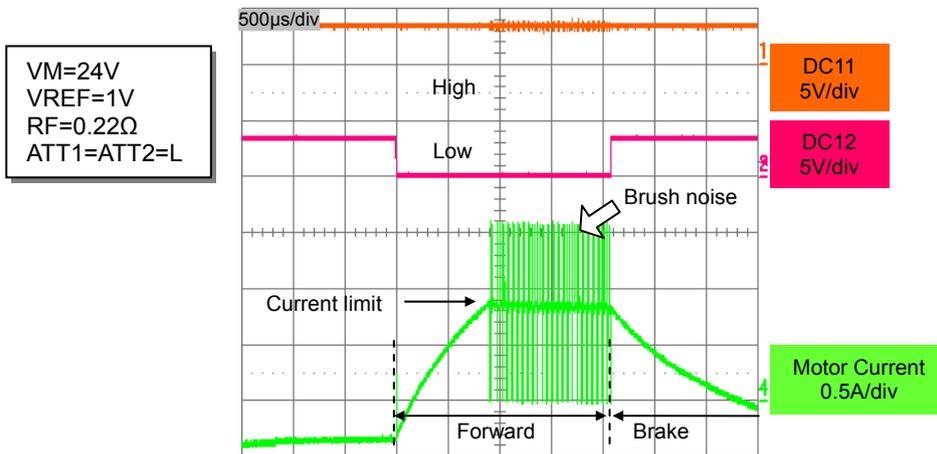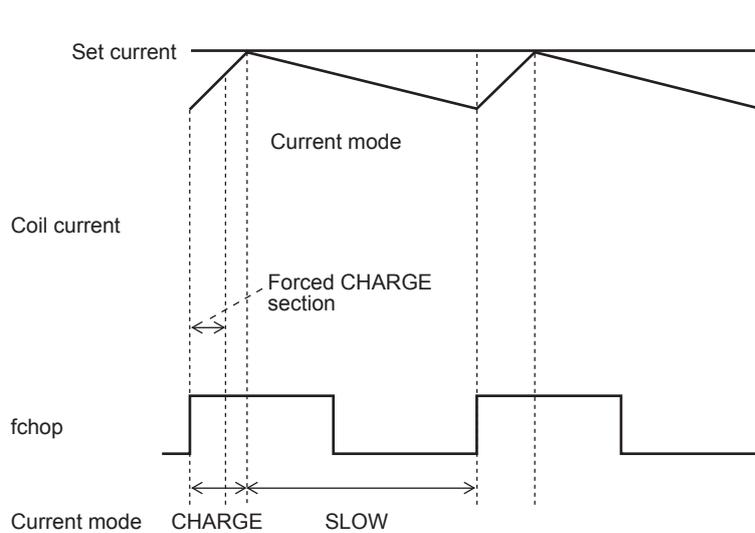
The limit current is set as calculated on the basis of the voltage input to the VREF pin and the resistance between the RF pin and GND using the formula given below.

$$Ilimit = (VREF/5) / RF\ resistance$$

The voltage applied to the VREF pin can be switched to any of the four setting levels depending on the statuses of the two inputs, ATT1 and ATT2.

Function for attenuating VREF input voltage

| ATT1 | ATT2 | Current setting reference voltage attenuation ratio |
|------|------|-----------------------------------------------------|
| Low  | Low  | 100% |
| High | Low  | 66.7% |
| Low  | High | 50% |
| High | High | 33.3% |

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

$$Ilimit = (VREF/5) \times (attenuation\ ratio) / RF\ resistance$$

Example : At VREF of 1.65V, a reference voltage setting of 100% [(ATT1, ATT2) = (L, L)] and an RF resistance of 0.22Ω, the output current is set as shown below.

$$Ilimit = 1.65V/5 \times 100\%/0.22Ω = 1.5A$$

If, in this state, (ATT1, ATT2) has been set to (H, H), Ilimit will be as follows :

$$Ilimit = 1.5A \times 33.3\% = 0.5A$$

(6) Blanking period
    In this IC, the blanking time is fixed at 1/8 of one chopping cycle.
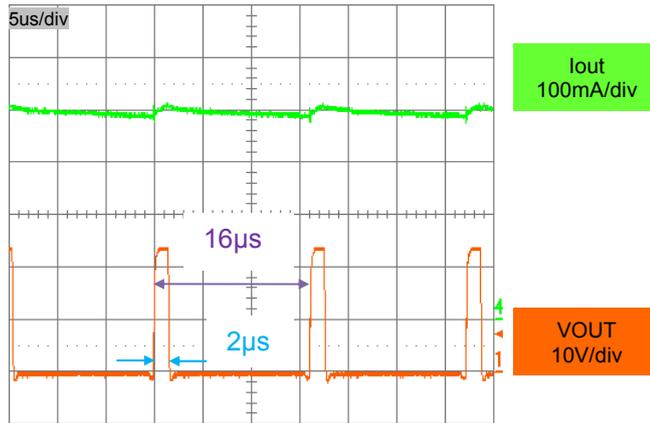
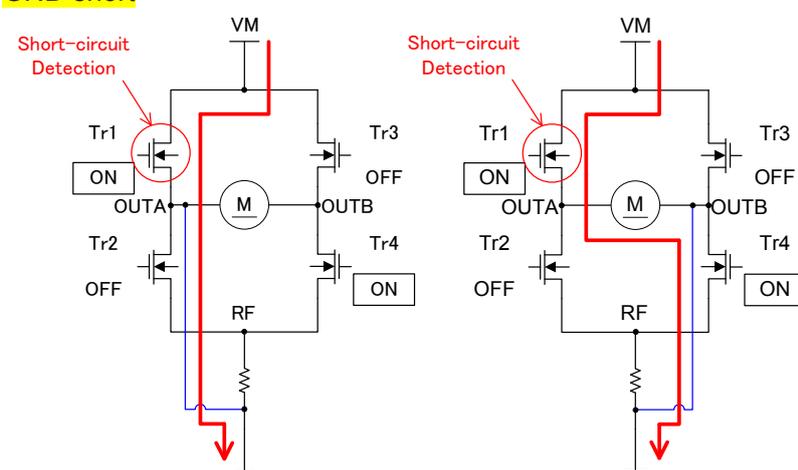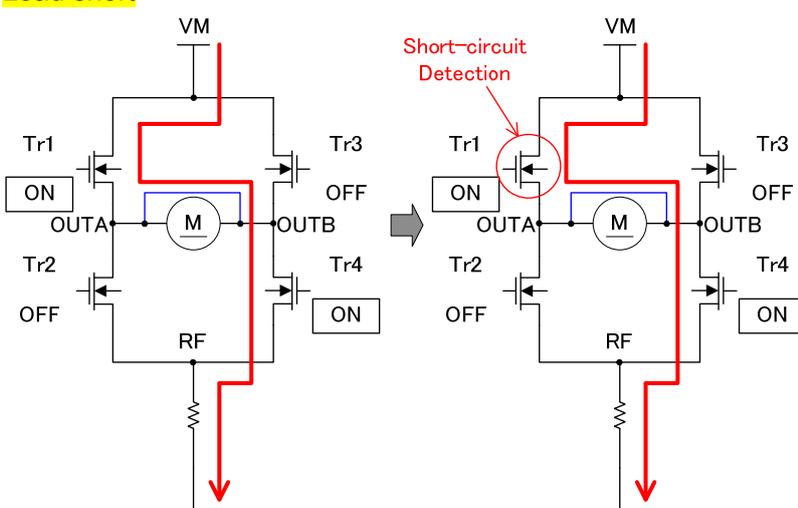(7) Typical current waveform in each excitation mode when stepping motor parallel input control

Full Step (CW mode)
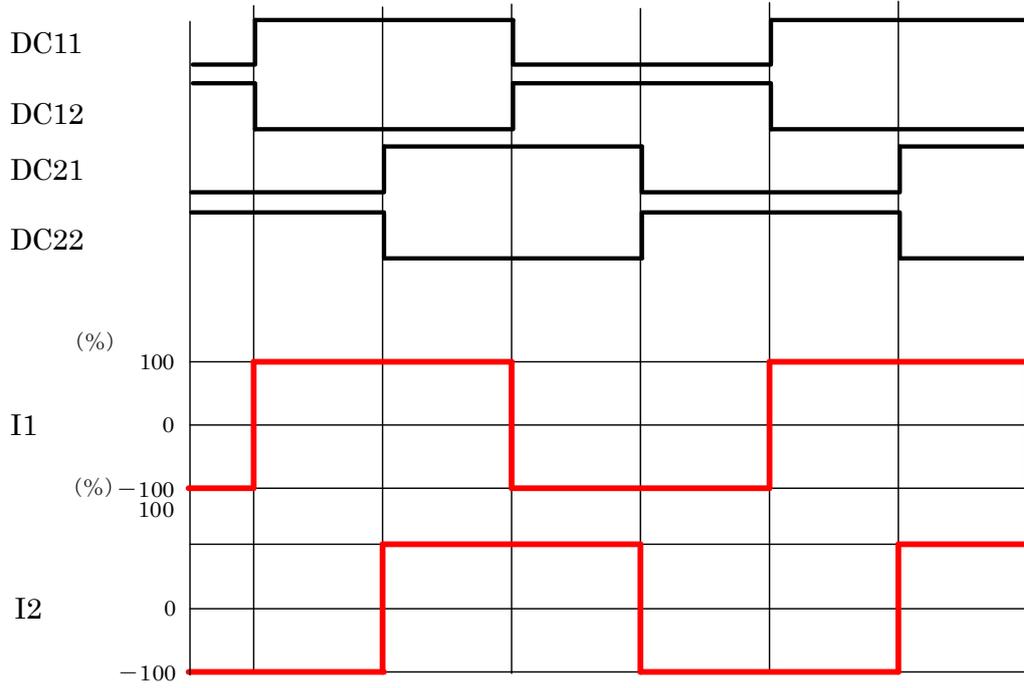


Half Step (full torque) (CW mode)
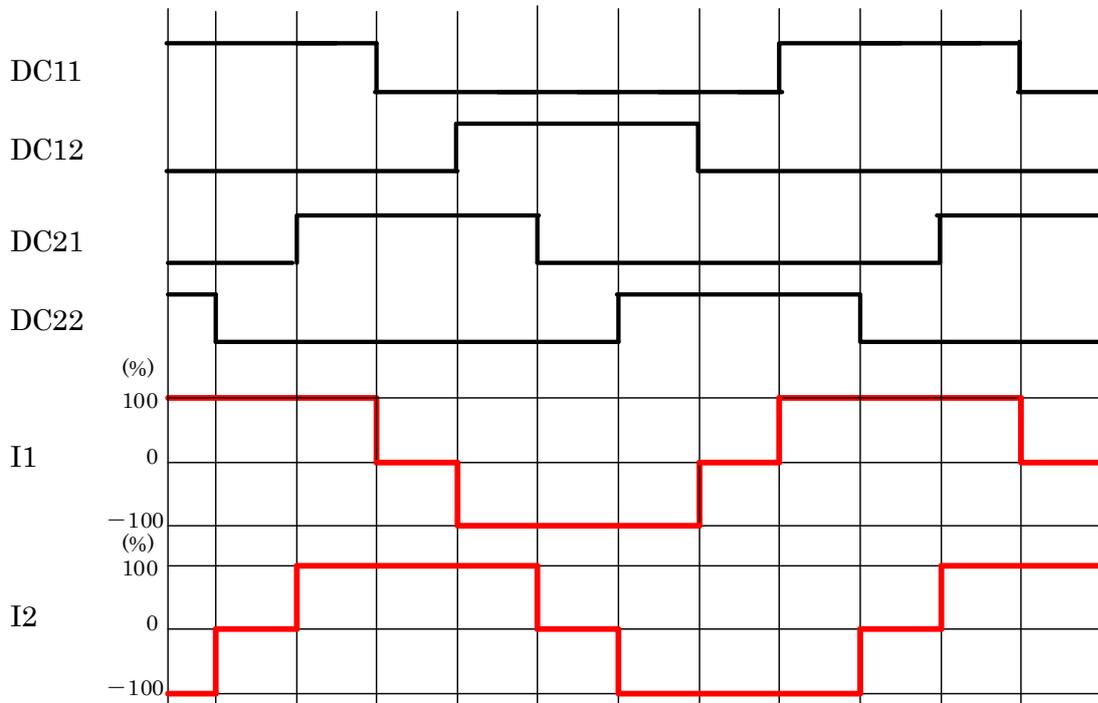
Output short-circuit protection function

This output short protection circuit that makes the output a standby mode to prevent the thing that IC destroys when the output is short-circuited by a voltage short and the earth fault, etc. , and turns on the warning output to IC is built into.

| | |
|---|---|
| **VM short**<br><br>Short-circuit Detection | 1. High current flows if Tr1 and Tr4 are ON.<br>2. If RF voltage> setting voltage, then the mode switches to SLOW decay.<br>3. If the voltage between D and S of Tr4 exceeds the reference voltage for 4µs, short status is detected. |
| **GND short**<br>Short-circuit Detection<br><br>Short-circuit Detection | (left schematic)<br>1. High current flows if Tr1 and Tr4 are ON<br>2. If the voltage between D and S of Tr1 exceeds the reference voltage for 4µs, short status is detected.<br><br>(right schematic)<br>1. Without going through RF resistor, current control does not operate and current will continue to increase in CHARGE mode.<br>2. If the voltage between D and S of Tr1 exceeds the reference voltage for 4µs, short status is detected. |
| **Load short**<br><br>Short-circuit Detection | 1. Without L load, high current flows.<br>2. If RF voltage> setting voltage, then the mode switches to SLOW decay.<br>3. During load short status in SLOW decay mode, current does not flow and overcurrent state is not detected. Then the mode is switched to FAST decay according to chopping cycle.<br>4. Since FAST state is short (≈1µs), switches to CHARGE mode before short is detected.<br>5. If voltage between D and S exceeds the reference voltage continuously during blanking time at the start of CHARGE mode (Tr1), CHARGE state is fixed (even if RF voltage exceeds the setting voltage, the mode is not switched to SLOW decay). After 4µs or so, short is detected. |

(1) Detect current



**Figure 15  Over Current vs. Temperature**
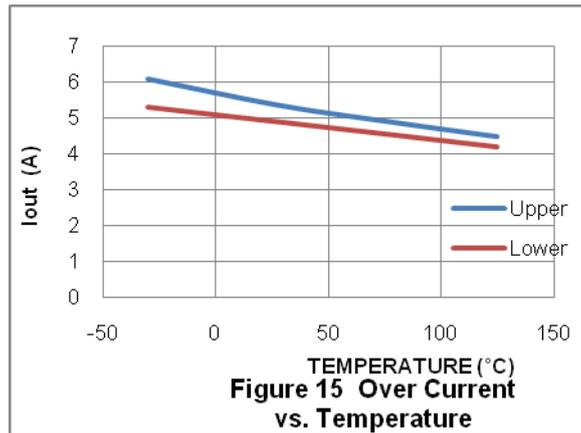
(2) Output short-circuit protection operation changeover function

Changeover to the output short-circuit protection of IC is made by the setting of EMM pin.

| EMM | State |
|---|---|
| Low or Open | Latch method |
| High | Auto reset method |

(3) Latch method

In the latch mode, the output is turned off when the output current exceeds the detection current, and the state is maintained.

The output short protection circuit starts operating so that IC may detect a short output. When the short-circuit is the consecutive between internal timers (≈4μs), the output where the short-circuit is first detected is turned off. Even if the following time (Tcem) of the timer latch is exceeded, the output is turned ON again, and afterwards, when the short-circuit is detected, all the outputs of correspondence ch side are still switched to the standby mode, and the state is maintained. This state is released by making it to ST ="L".
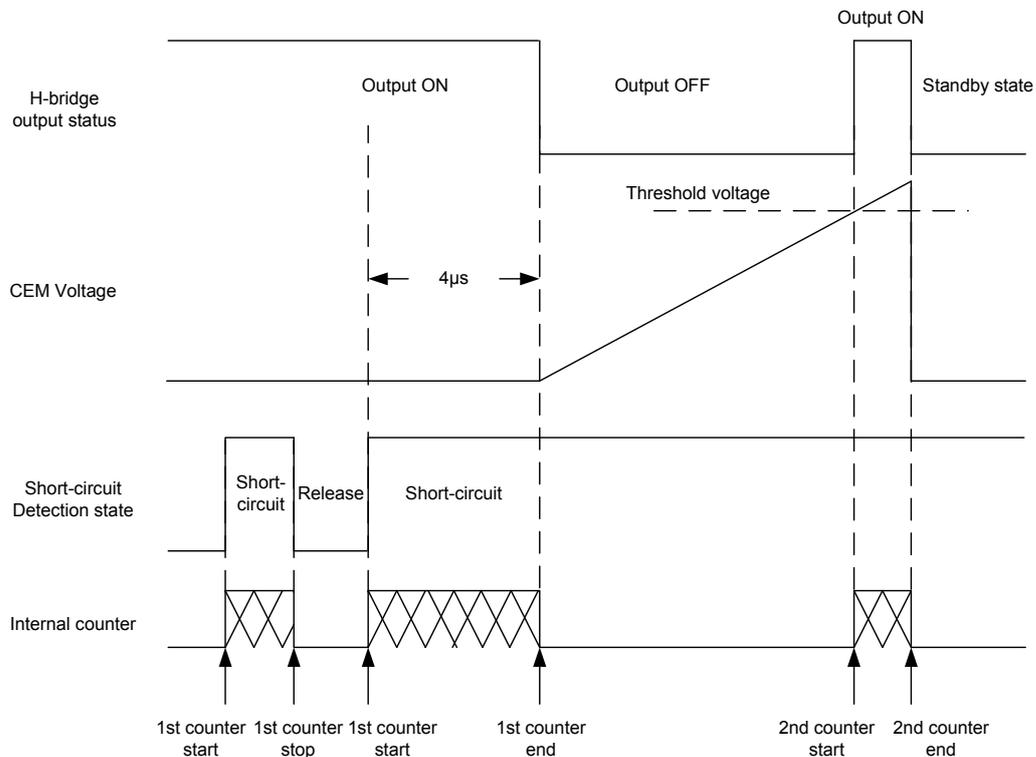
(4) Automatic return method

In the automatic return mode, the output wave type changes into the switching wave type when the output current exceeds the detection current.

The short-circuit detection circuit operates when a short output is detected as well as the latch method. The output is switched to the standby mode when the operation of the short-circuit detection circuit exceeds the following time (Tcem) of the timer latch, and it returns to the turning on mode again after 2ms (TYP). At this time, the above-mentioned switching mode is repeated when is still in the overcurrent mode until the overcurrent mode is made clear.

(5) Abnormal state warning output pin

When IC operates the protection circuit detecting abnormality, the EMO pin has been installed as a terminal that outputs this abnormality to CPU side. This pin is an open drain output, and if abnormality is detected, the EMO output becomes (EMO="L") of ON.

EMO pin enters on a state in the following.

- When a voltage short, the earth fault or the load is short-circuited and the output short-circuit protection circuit operates, the output pin
- When the junction temperature of IC rises, and the overheating protection circuit operates

| Unusual condition | EMO | Channel 1 Output | Channel 2 Output |
|---|---|---|---|
| Channel 1 short-circuit detected | ON | OFF | - |
| Channel 2 short-circuit detected | ON | - | OFF |
| Overheating condition detected | ON | OFF | OFF |

(6) Timer latch time (Tcem)

The time to output OFF when an output short-circuit occurs can be set by the capacitor connected between the CEM pin and GND. The capacitor (Ccem) value can be determined as follows:

Timer latch: Tcem $\qquad$ Tcem $\approx$ C $\times$ V/I [sec]

V : Threshold voltage of comparator TYP 1V

I : CEM charge current TYP 10µA

Latch type

Auto reset type

5us/div

OUT
10V/div

OUT-GND short

1V

1st counter
4µs

2nd counter

CEM
0.5V/div

CEM charge

EMO
5V/div

1ms/div

2ms
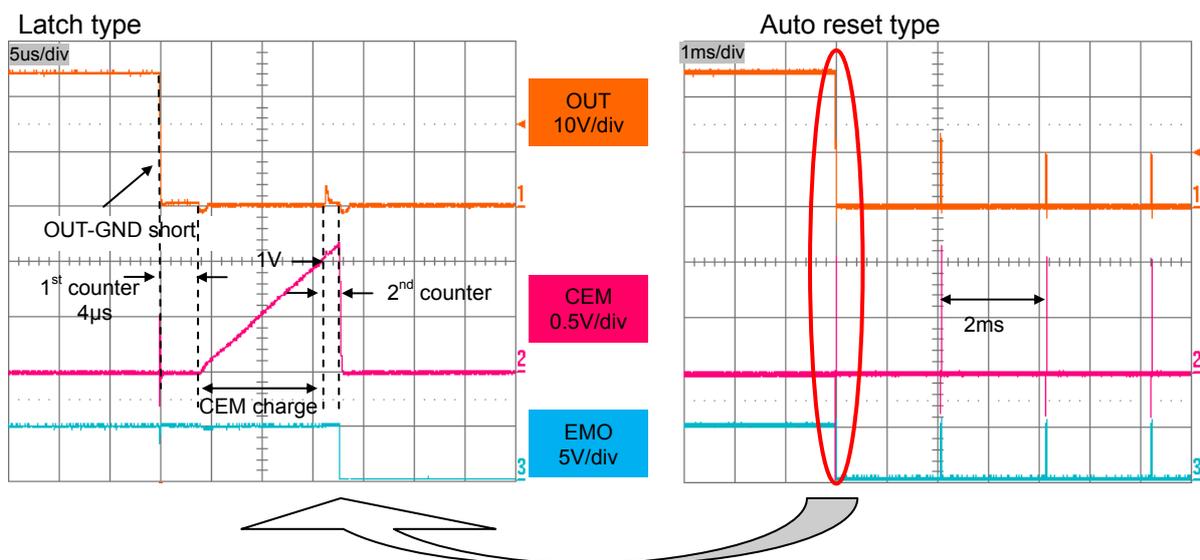
## Thermal shutdown function

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).
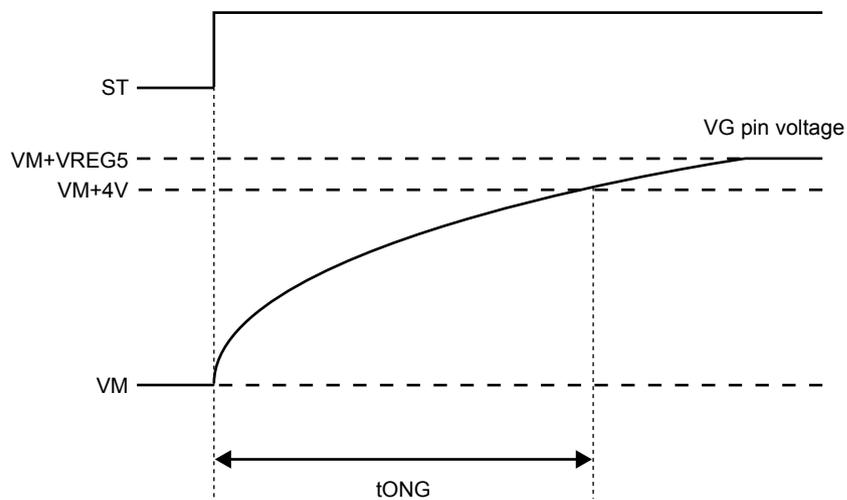The thermal shutdown circuit does not guarantee the protection of the final product because it operates when the temperature exceed the junction temperature of Tjmax=150°C.

$$TSD = 180°C \text{ (typ)}$$
$$\Delta TSD = 40°C \text{ (typ)}$$

## 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. I will recommend the drive of the motor to put the time of tONG or more after the ST pin is made "H", and to begin because I cannot control the output if there is no pressure voltage of the voltage of the VG pin enough.

VG Pin Voltage Schematic View
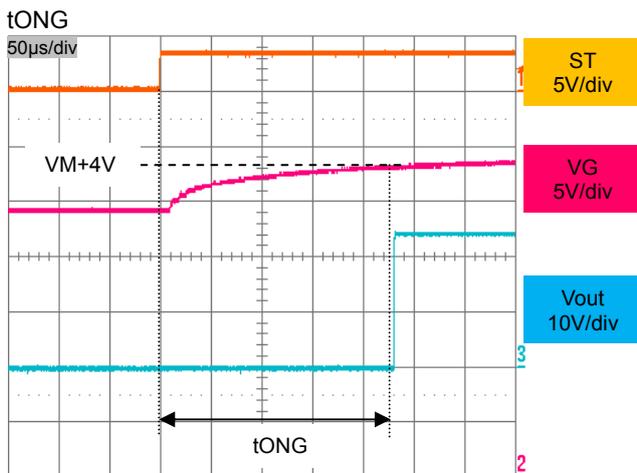
tONG

ST
5V/div

VG
5V/div

Vout
10V/div

VM+4V

tONG

VM=24V
CP1-CP2=0.1µF
VG=0.1µF

Startup time with different VG capacitor

500µs/div

0.1µF/220µs
0.22µF/500µs
1µF/2.4ms
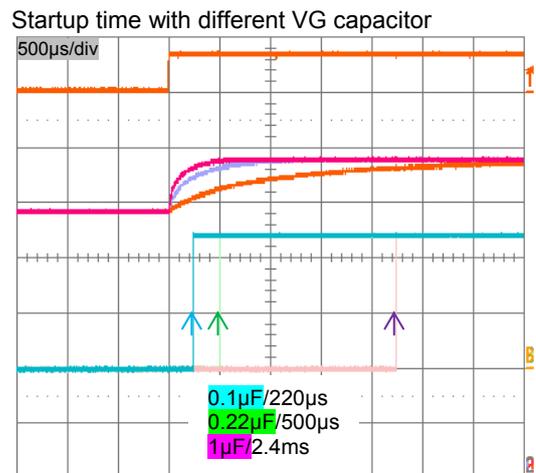
VM=24V
CP1-CP2=0.1µF
VG=0.1µF/0.22µF/1µF

## Application Circuits

• Stepping motor driver application circuit example (DM="L")
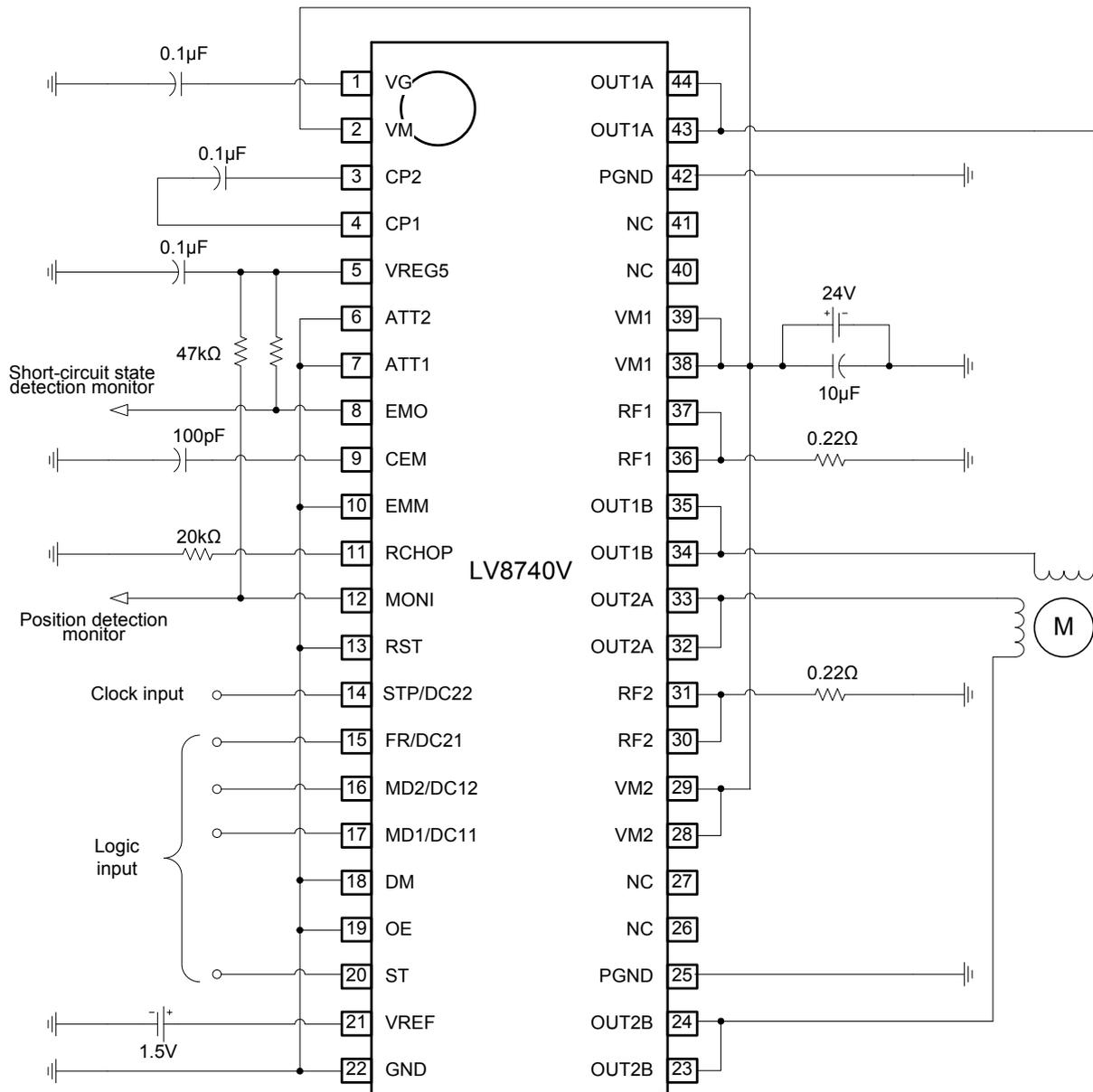


Each constant setting type in the example of the above-mentioned circuit is as follows.
When setting current ratio = 100%, VREF = 1.5V, the following output current flows :

$I_{OUT}$ = VREF/5/RF resistance

= 1.5V/5 × 100%/0.22Ω=1.36A
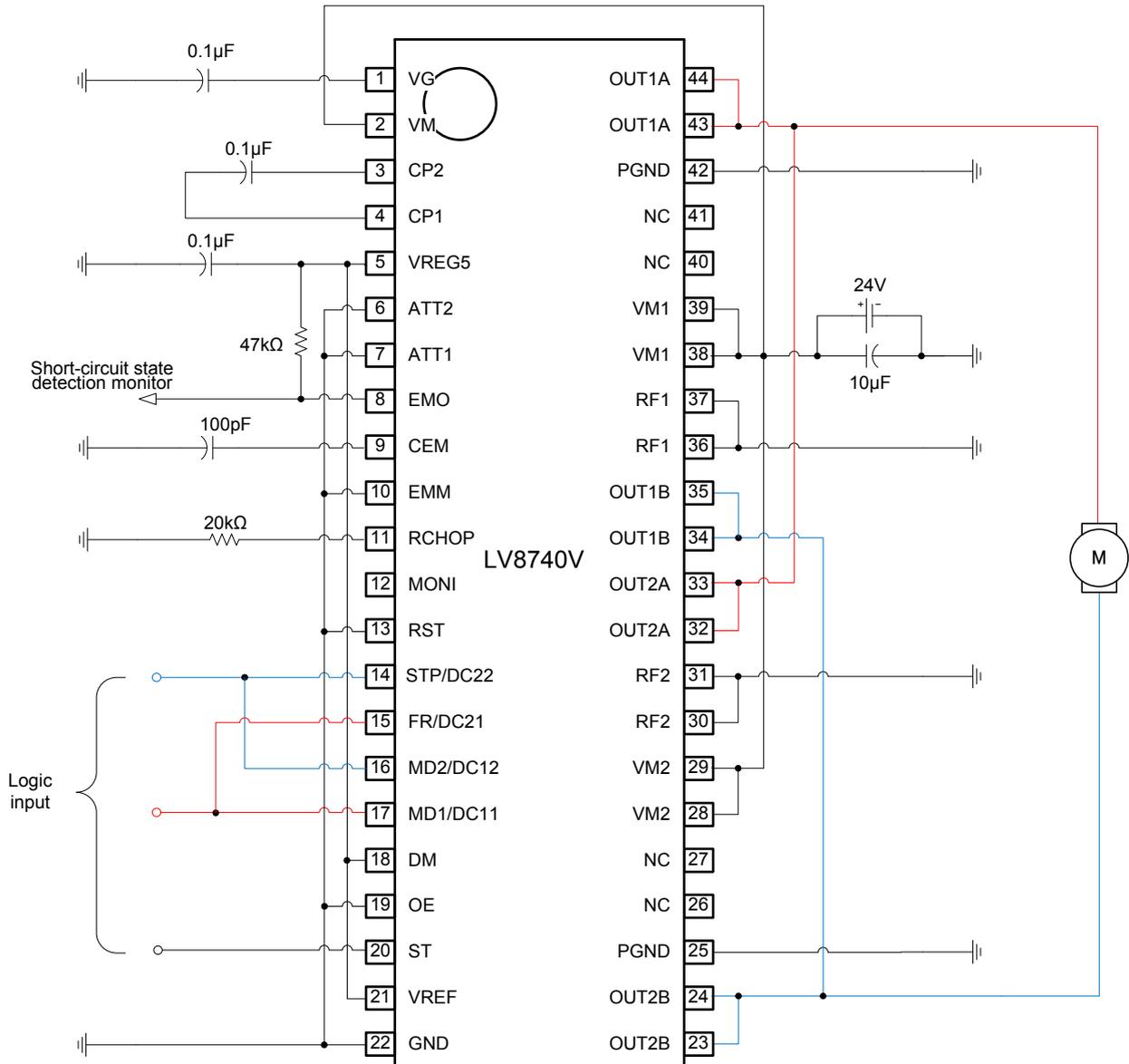
Chopping frequency setting.

62.5kHz (RCHOP=20kΩ)

Time of timer latch when output is short-circuited

Tcem = CcemV × tcem/Icem

= 100pF × 1V/10µA = 10µs

• DC motor driver application circuit example
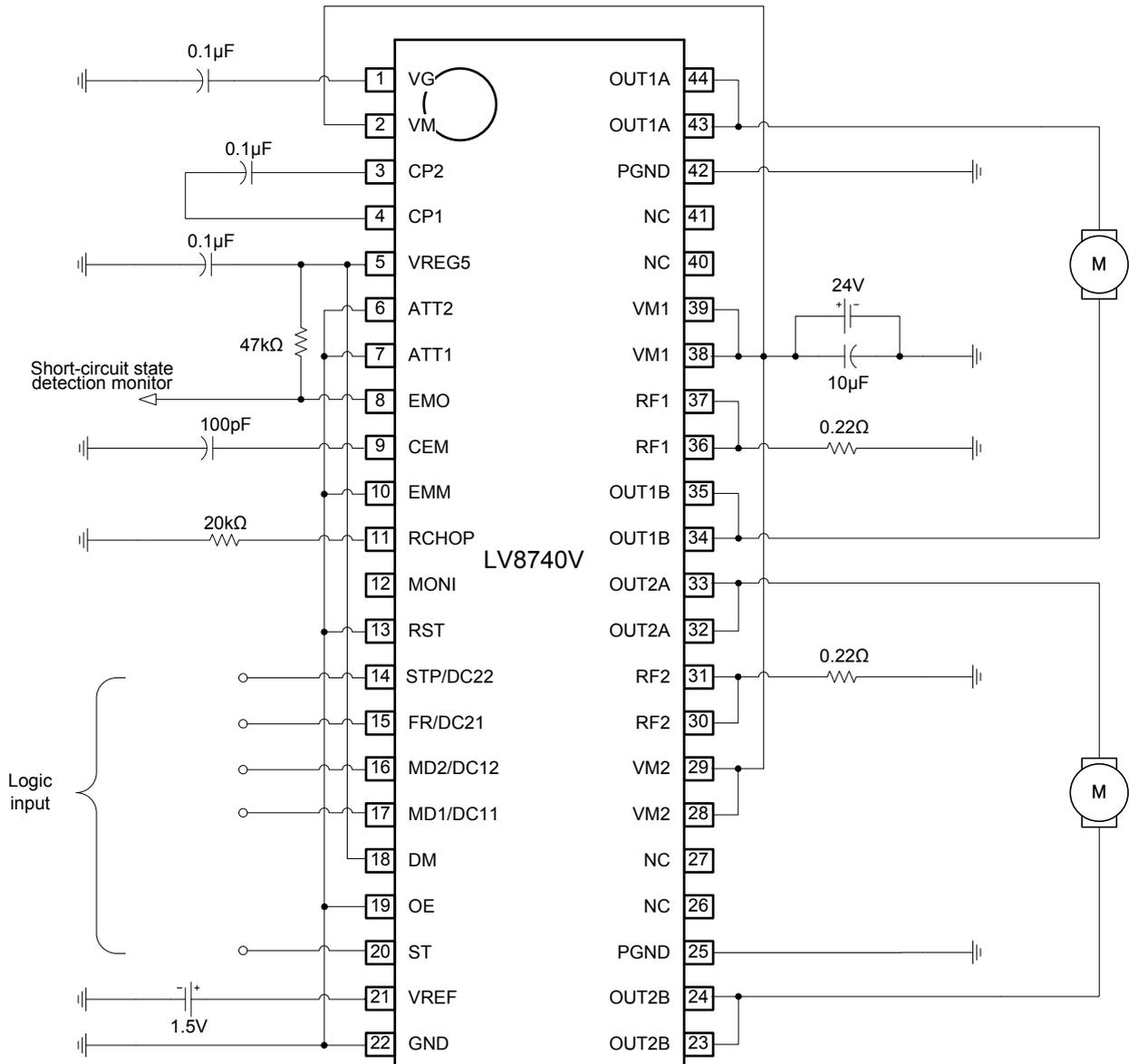


Each constant setting type in the example of the above-mentioned circuit is as follows.

When setting current LIMIT = 100%, VREF = 1.5V, the following output current flows :

Ilimit = VREF/5/RF resistance

= 1.5V/5 × 100%/0.22Ω=1.36A

Chopping frequency setting.

62.5kHz (RCHOP=20kΩ)

Time of timer latch when output is short-circuited

Tcem = Ccem × Vtcem/Icem

= 100pF × 1V/10μA = 10μs

# LV8740V Application Note

- DC motor driver parallel connection application circuit example

    By connecting OUT1A and OUT2A as well as OUT2A and OUT2B, you can double the current capability. However, you cannot use current limit function. (RF=GND)



Each constant setting type in the example of the above-mentioned circuit is as follows.

Chopping frequency setting.

62.5kHz (RCHOP=20kΩ)

Time of timer latch when output is short-circuited

Tcem = Ccem ×Vtcem/Icem

= 100pF×1V/10μA  = 10μs

## Allowable power dissipation
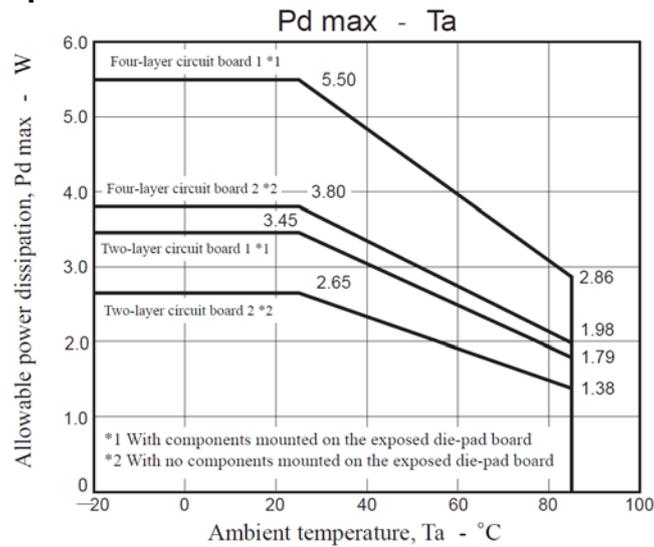


**Substrate Specifications** (Substrate recommended for operation of LV8740V)

Size : 90mm × 90mm × 1.6mm
Material : Glass epoxy
Copper wiring density : L1 = 85% / L2 = 90%
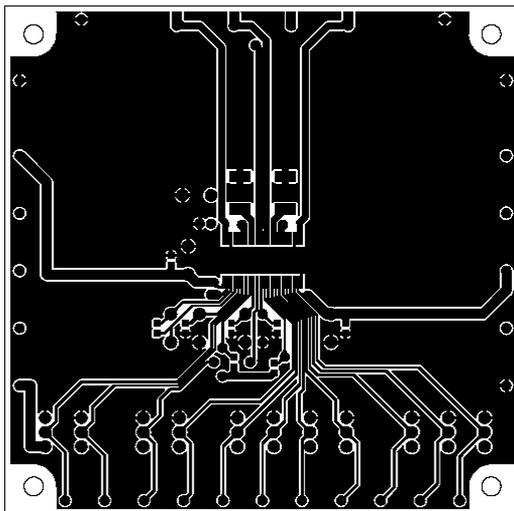


L1 : Copper wiring pattern diagram
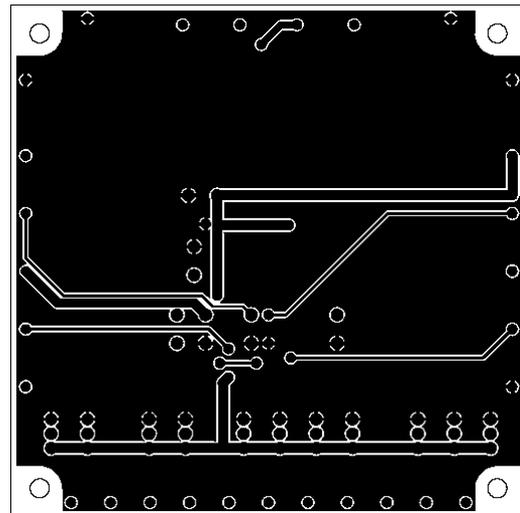


L2 : Copper wiring pattern diagram

### Cautions

1) The data for the case with the Exposed Die-Pad substrate mounted shows the values when 90% or more of the Exposed Die-Pad is wet.

2) 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

3) After the set design, be sure to verify the design with the actual product.
   Confirm the solder joint state and verify also the reliability Tf solder joint for the Exposed Die-Pad, etc.
   Any void or deterioration, if observed in the solder joint of these parts, causes deteriorated thermal conduction, possibly resulting in thermal destruction of IC.

# LV8740V Application Note

## Evaluation board

LV8740V    (90.0mm×90.0mm×1.6mm, glass epoxy 2-layer board, with backside mounting)
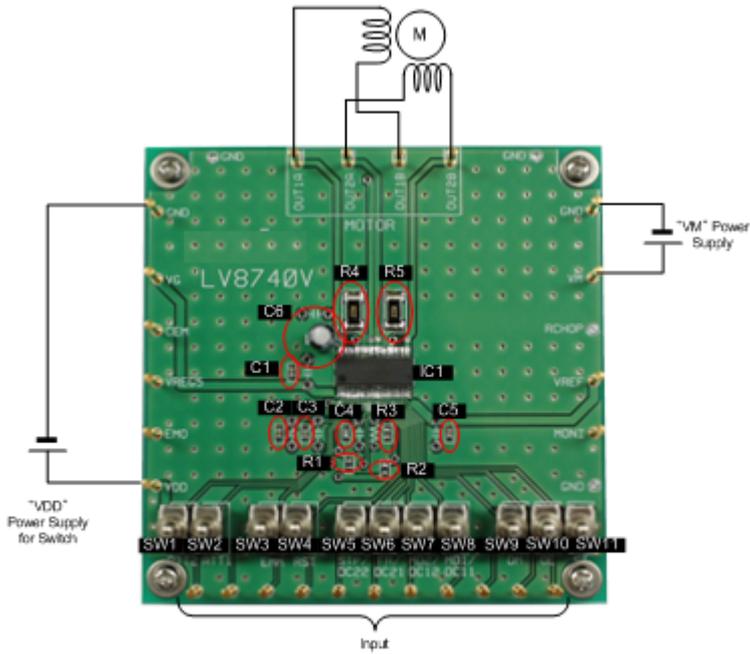


## Bill of Materials for LV8740V Evaluation Board

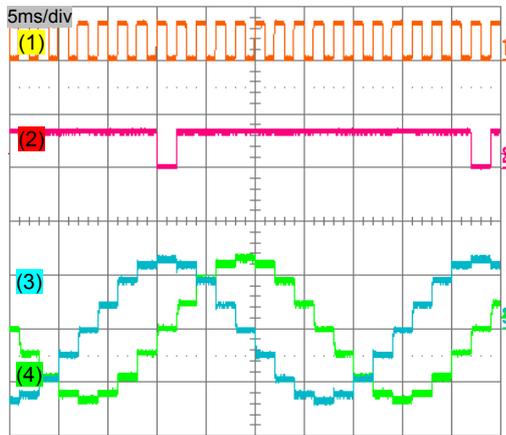| Designator | Quantity | Description | Value | Tolerance | Footprint | Manufacturer | Manufacturer Part Number | Substitution Allowed | Lead Free |
|---|---|---|---|---|---|---|---|---|---|
| C1 | 1 | Capacitor for Charge pump | 0.1μF, 100V | ±10% | | Murata | GRM188R72A104KA35* | Yes | Yes |
| C2 | 1 | Capacitor for Charge pump | 0.1μF, 100V | ±10% | | Murata | GRM188R72A104KA35* | Yes | Yes |
| C3 | 1 | 5VREG stabilization Capacitor | 0.1μF, 100V | ±10% | | Murata | GRM188R72A104KA35* | Yes | Yes |
| C4 | 1 | Capacitor to set CEM timer | 100pF, 50V | ±5% | | Murata | GRM1882C1H101JA01* | Yes | Yes |
| C5 | 1 | VREF stabilization Capacitor | 0.1μF, 100V | ±10% | | Murata | GRM188R72A104KA35* | Yes | Yes |
| C6 | 1 | VM Bypass Capasitor | 10μF, 50V | ±20% | | SUN Electronic Industries | 50ME10HC | Yes | Yes |
| R1 | 1 | Pull-up Resistor for for terminal EMO | 47kΩ, 1/10W | ±5% | | KOA | RK73B1JT**473J | Yes | Yes |
| R2 | 1 | Pull-up Resistor for for terminal MONI | 47kΩ, 1/10W | ±5% | | KOA | RK73B1JT**473J | Yes | Yes |
| R3 | 1 | Resistor to set chopping frequency | 20kΩ, 1/10W | ±5% | | KOA | RK73B1JT**203J | Yes | Yes |
| R4 | 1 | Channel 1 output current detective Resistor | 0.22Ω, 1W | ±5% | | ROHM | MCR100JZHJLR22 | Yes | Yes |
| R5 | 1 | Channel 2 output current detective Resistor | 0.22Ω, 1W | ±5% | | ROHM | MCR100JZHJLR22 | Yes | Yes |
| IC1 | 1 | Motor Driver | | | SSOP44J (275mil) | ON Semiconductor | LV8740V | No | Yes |
| SW1-SW11 | 11 | Switch | | | | MIYAMA | MS-621C-A01 | Yes | Yes |
| TP1-TP25 | 25 | Test Point | | | | MAC8 | ST-1-3 | Yes | Yes |

Evaluation board circuit
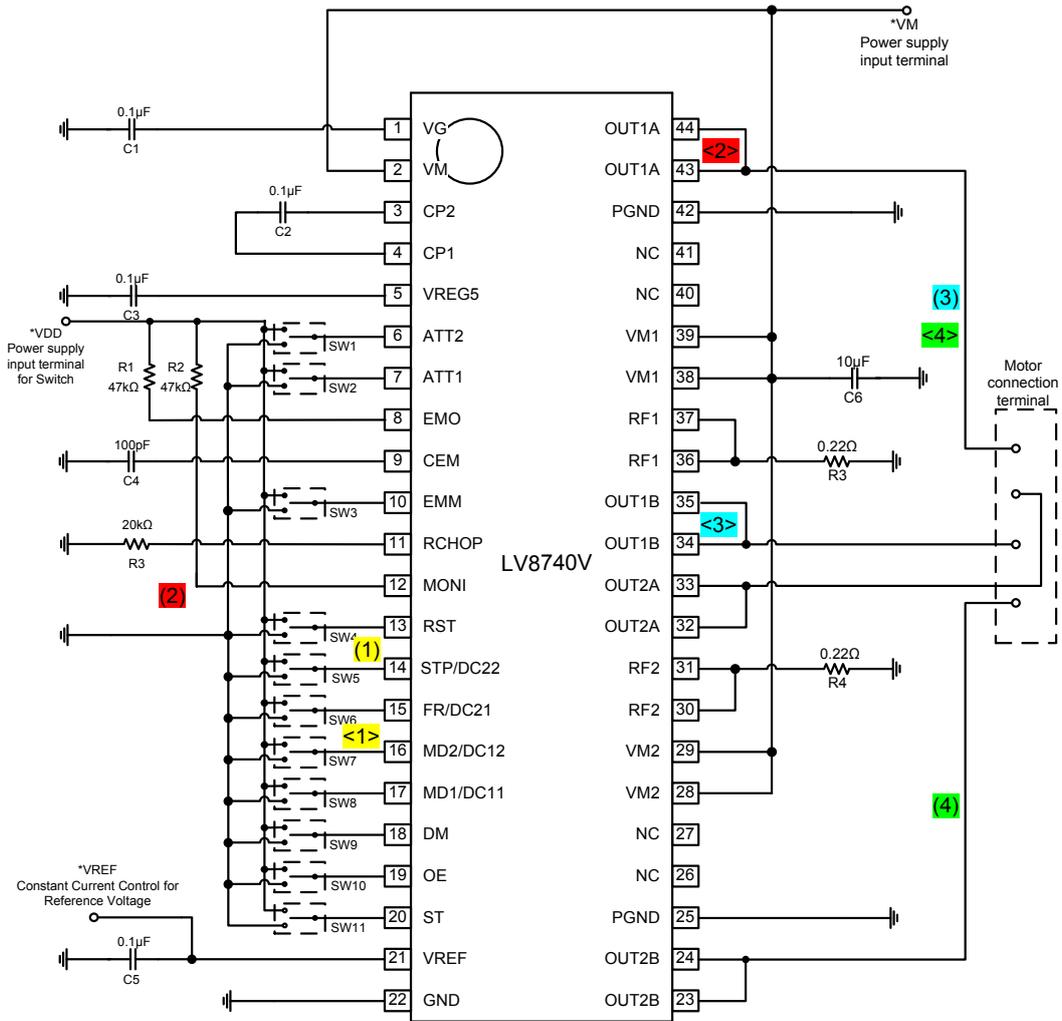


【Stepping Motor】
VM=24V,VDD=3.3V,VREF=1.5V
ST=H,DM=L
EMM=L,RST=L,OE=L
ATT1=ATT2=L,
FR/DC21=L
MD1/DC11=MD2/DC12=H
STP/DC22=500Hz(Duty50%)

【DC Motor(OUT1A-OUT1B)】
VM=24V,VDD=3.3V,VREF=1.5V
ST=H,DM=H
EMM=L,RST=L,OE=L
ATT1=ATT2=L,
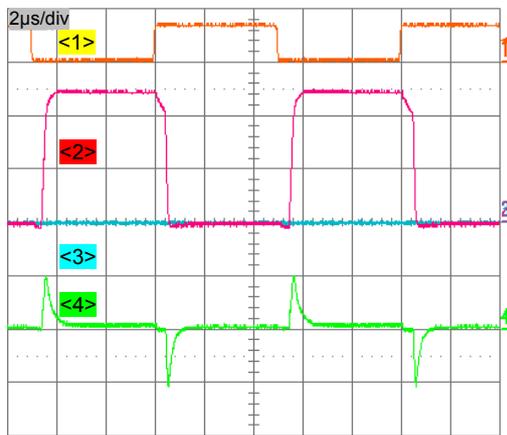FR/DC21=STP/DC22=L
MD1/DC11=H
MD2/DC12=100kHz(Duty50%)

**Evaluation Board Manual**

[Supply Voltage]  VM (9 to 35V): 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" the toggle switch STP/D22, and "Open or Low" the other 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 terminal toggle switch. Channel 1 and 2 are into full-step initial position (100%, -100%).
5. **Motor Operation:** Input the clock signal into the terminal STP/DC22.
6. **Other Setting** (See Application Note for detail)
    i. ATT1, ATT2: Motor current attenuation.
    ii. EMM: Short circuit protection mode change.
    iii. RST: Initial Mode.
    iv. FR/DC21: Motor rotation direction (CW / CCW) setting.
    v. MD1/DC11, MD2/DC12: Excitation mode.
    vi. OE: Output Enable.

For DC motor control

1. **Initial Condition Setting:** Set "Open" the toggle switch DM, and "Open or Low" the other switches
2. **Motor Connection:** Connect the Motor(s) 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 and DM terminal toggle switch.
5. **Motor Operation:** Set MD1/DC11, MD2/DC12 and STP/DC22 terminals according to the purpose.
6. **Other Setting** (See Application Note for detail)
    i. ATT1, ATT2: Motor current attenuation.
    ii. EMM: Short circuit protection mode change.
    iii. RST: Not performed
    iv. OE: Output enable.

[Setting for External Component Value]

1. Constant Current (100%)
    At VREF=1.5V
    $I_{out}$ =VREF [V] / 5 / RF [Ω]
    =1.5 [V] / 5 / 0.22 [Ω]
    =1.36 [A]
2. Chopping frequency setting.
    62.5kHz (RCHOP=20kΩ)
3. Short Protection Latch Time
    Tscp =CEM [pF] × Vt[V] / Ichg [μA]
    =100 [pF] × 1 [V] / 10 [μA]
    =10 [μS]

# LV8740V Application Note

**Warning:**

●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, Exposed Die-Pad]
- ✓ 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 PGND, connect it to one-point GND.
- ✓ The exposed die-pad is connected to the board frame of the IC. Therefore, do not connect it other than GND. Independent layout is preferable. If such layout is not feasible, please connect it to signal GND. Or if the area of GND and PGND is larger, you may connect the exposed die pad to the GND.
  (The independent connection of exposed die pad to PGND is not recommended.)

●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 0.1uF.
- ✓ Since the voltage of VREG5 fluctuates, do not use it as reference voltage that requires accuracy.

●Input terminal
- ✓ The logic input pin incorporates pull-down resistor (100kΩ).
- ✓ 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.
- ✓ If VM line and output line are wide enough in your layout, please use NC