LV8727

ON Semiconductor®

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Bi-CMOS LSI

PWM Constant-Current Control Stepper Motor Driver Application Note

Overview

The LV8727 is a micro-step stepper motor driver for bipolar stepper motors controlled by PWM.
This LV8727 supports eight micro step resolutions of Half, 1/8, 1/16, 1/32, 1/64, 1/128, 1/10 and 1/20, which is driven simply by step input.

Function

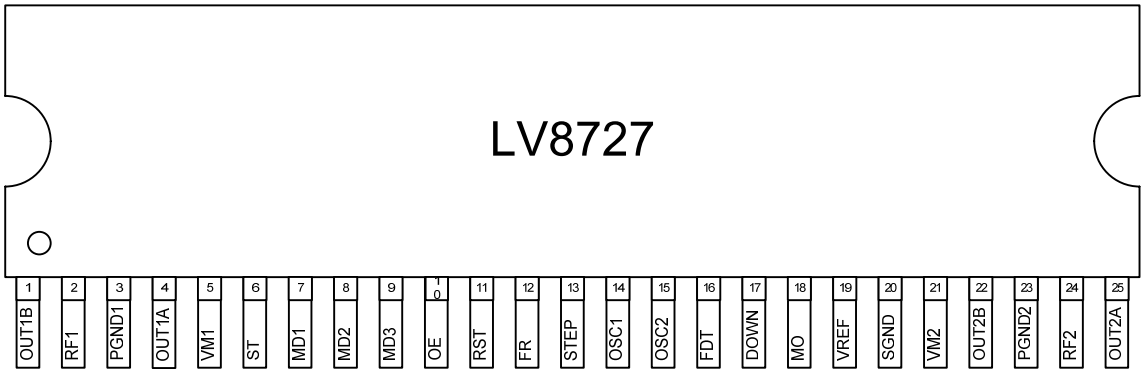
- Single-channel PWM current control stepper motor driver.
- BiCDMOS process IC.
- Output on-resistance (upper side: 0.25Ω; lower side: 0.15Ω; total of upper and lower: 0.4Ω; Ta = 25˚C, I_O = 4.0A)
- Half, 1/8, 1/16, 1/32, 1/64, 1/128, 1/10, 1/20 Step are selectable.
- Advance the excitation step with the only step signal input.
- Available forward reverse control
- Over current protection circuit
- Thermal shutdown circuit
- Input pull down resistance.
- With reset pin and enable pin.

Typical Applications

- Large format Printer
- Stage Lighting

December, 2013

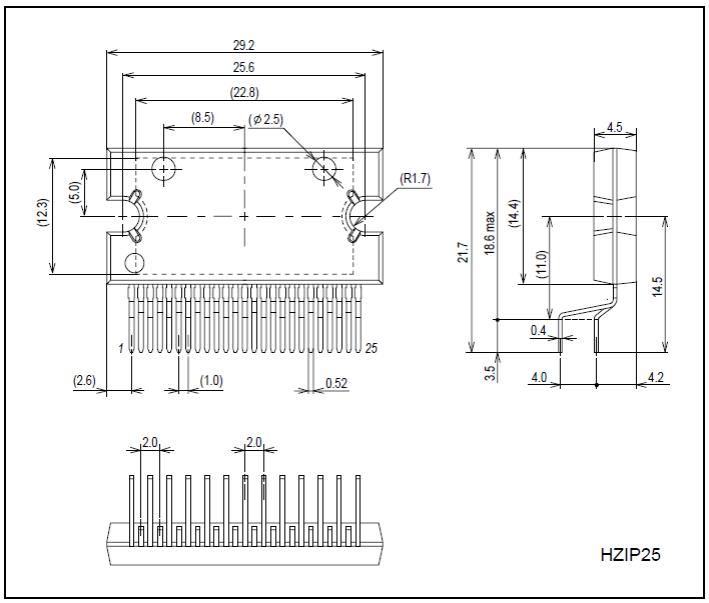
Pin Assignment



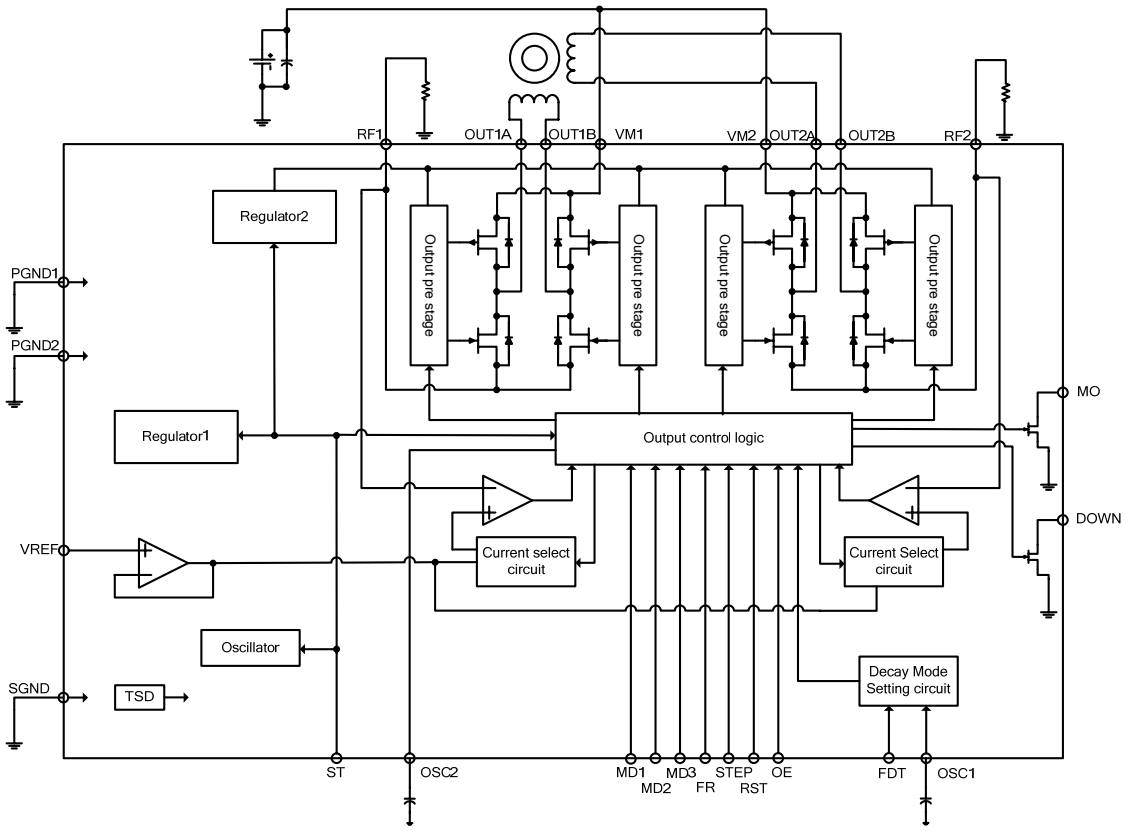
Package Dimensions

unit : mm (typ)

3236A



Block Diagram



Specifications

Absolute Maximum Ratings at Ta = 25˚C

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage	V_M max		50	V
Output current	I_O max		4	A
Output peak current	I_O peak	tw≤10ms, duty 20%	4.6	A
Logic input voltage	V_{IN} max		6	V
MO/DOWN input voltage	MO max/DOWN max		6	V
VREF input voltage	VREF max		6	V
Allowable power dissipation	Pd max	Indipendent IC	2.45	W
Operating temperature	Topr		-30 to +85	˚C
Storage temperature	Tstg		-55 to +150	˚C

Caution 1) Absolute maximum ratings represent the value which cannot be exceeded for any length of time.
Caution 2) Even when the device is used within the range of absolute maximum ratings, as a result of continuous usage under high temperature, high current, high voltage, or drastic temperature change, the reliability of the IC may be degraded. Please contact us for the further details.

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

Recommended Operating Conditions at Ta = 25°C

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Supply voltage range	VM		9		45	V
Logic input voltage	V_{IN}		0		5	V
VREF input voltage range	VREF		0		3	V

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

Parameter	Symbol	Conditions	min	Typ	max	Unit
Standby mode current drain	$I_M$stn	ST="L"		70	100	μA
current drain	I_M	ST="H", ENABLE="H", no load		3.5	4.9	mA
Thermal shutdown temperature	TSD	Design guarantee	150	180	210	˚C
Thermal hysteresis width	ΔTSD	Design guarantee		40		˚C
Logic pin input current	I_{IN}L	V_{IN}=0.8V	3	8	15	μA
	I_{IN}H	V_{IN}=5V	30	50	70	μA
Logic input high-level voltage	V_{IN}H		2.0			V
Logic input low-level voltage	V_{IN}L				0.8	V
FDT pin high-level voltage	Vfdth		3.5			V
FDT pin middle-level voltage	Vfdtm		1.1		3.1	V
FDT pin low-level voltage	Vfdtl				0.8	V
Chopping frequency	Fch	C_{OSC}1=100pF	70	100	130	kHz
OSC1 pin charge / discharge current	I_{OSC}1		7	10	13	μA
Chopping oscillator circuit	Vtup1		0.8	1	1.2	V
threshold voltage	Vtdown1		0.3	0.5	0.7	V
VREF pin input voltage	Iref	VREF=1.5V	-0.5			μA
DOWN output residual voltage	VolDO	Idown=1mA		50	200	mV
MO pin residual voltage	VolMO	Imo=1mA		50	200	mV
Hold current switching frequency	Fdo	C_{OSC}2=1500pF	1.12	1.6	2.08	Hz
OSC2 pin charge / discharge current	I_{OSC}2		7	10	13	μA
Hold current switching frequency threshold	Vtup2		0.8	1	1.2	V
voltage	Vtdown2		0.3	0.5	0.7	V
Output on-resistance	Ronu	I_O=4.0A, high-side ON resistance		0.25	0.325	Ω
	Rond	I_O=4.0A, low-side ON resistance		0.15	0.195	Ω
Output leakage current	Ioleak	V_M=50V			50	μA
Diode forward voltage	VD	ID=-4.0A		1	1.3	V
Current setting reference voltage	VRF	VREF=1.5V, Current ratio 100%	0.485	0.5	0.515	V

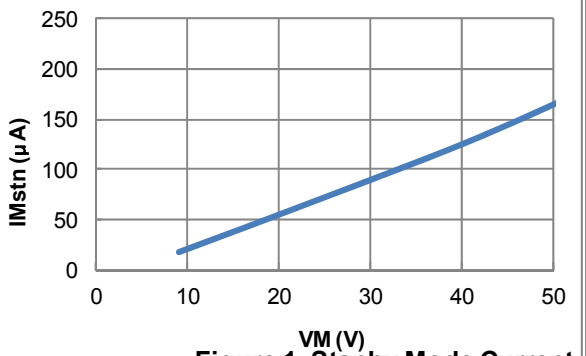


Figure 1 Stanby Mode Current Drain vs. VM Voltage

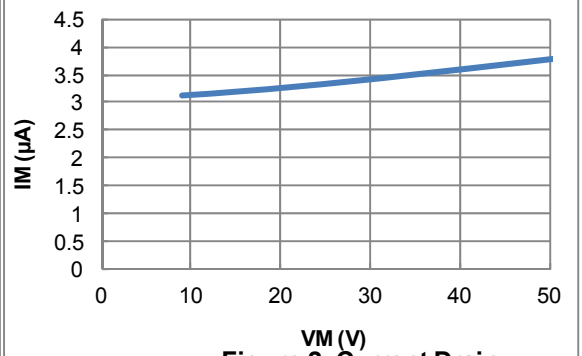


Figure 2 Current Drain vs. VM Voltage

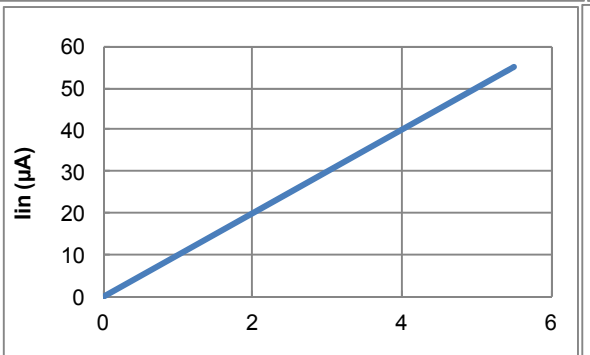


Figure 3 Logic pin input Current vs. Logic input Voltage

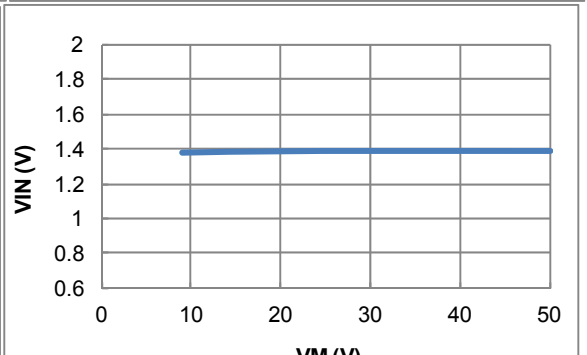


Figure 4. ST pin Threshold Voltage vs. VM Voltage

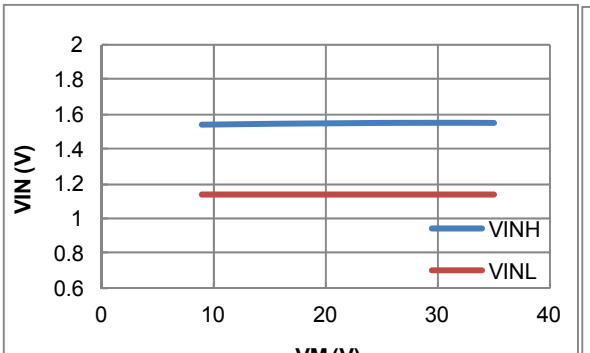


Figure 5. Logic High/Low-level input Voltage vs. VM Voltage

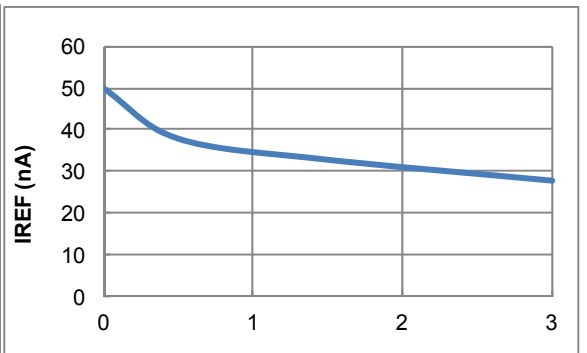


Figure 6. VREF pin input Current vs. VREF Voltage

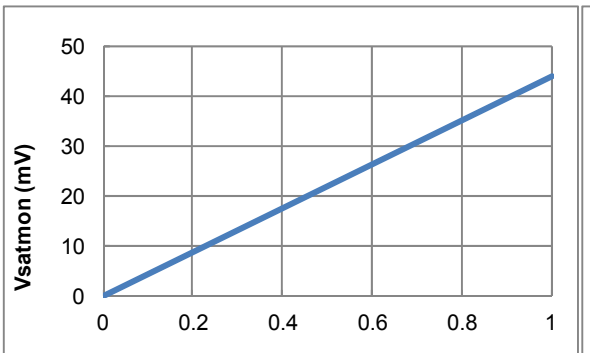


Figure 7 MO pin saturation voltage vs. MO pin input current

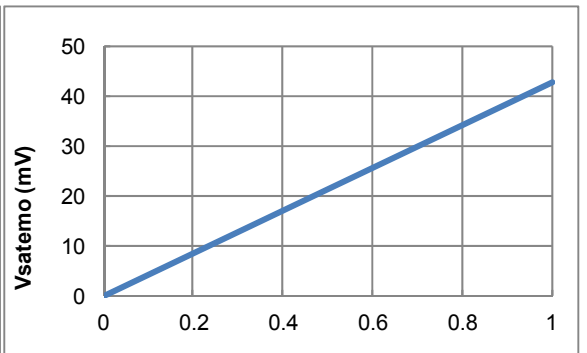


Figure 8 DOWN pin saturation voltage vs. DOWN pin input current

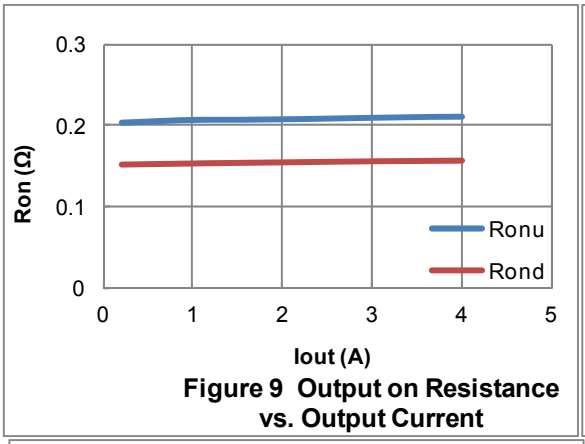


Figure 9 Output on Resistance vs. Output Current

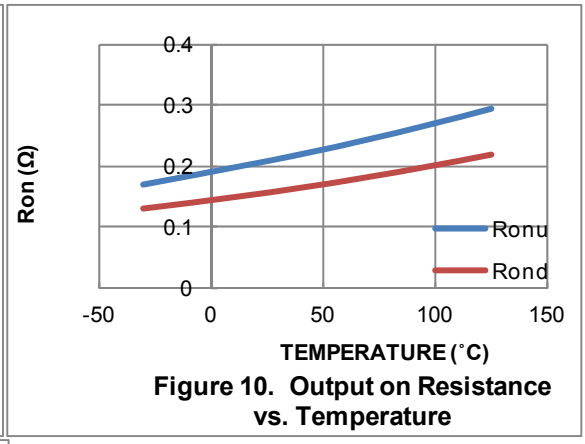


Figure 10. Output on Resistance vs. Temperature

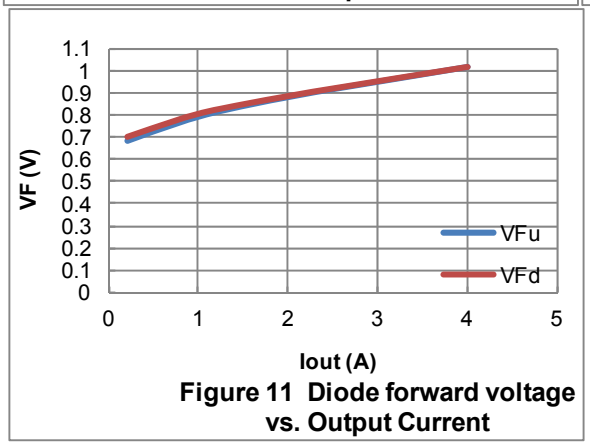
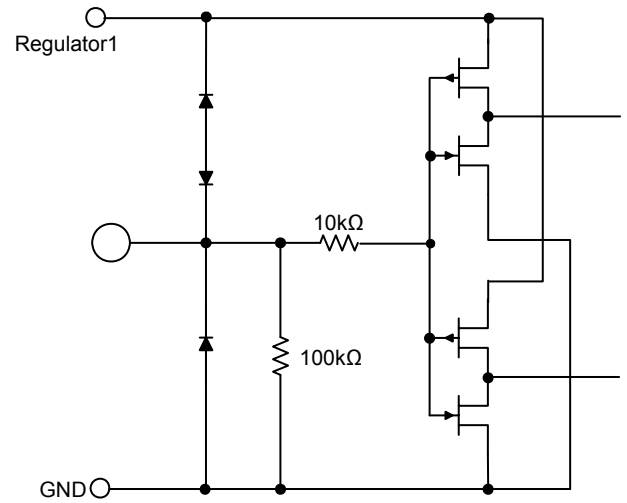
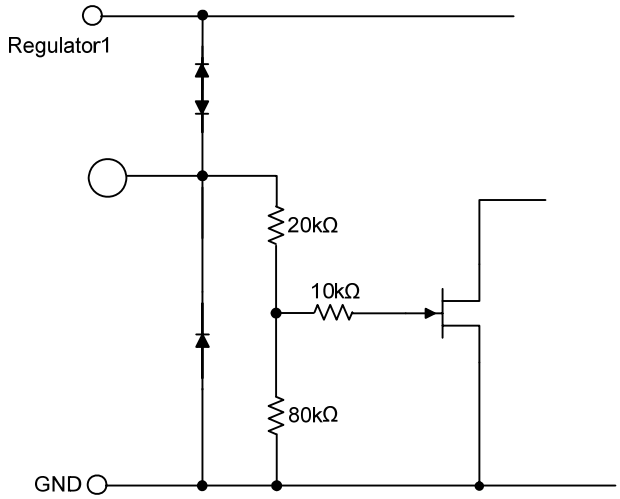
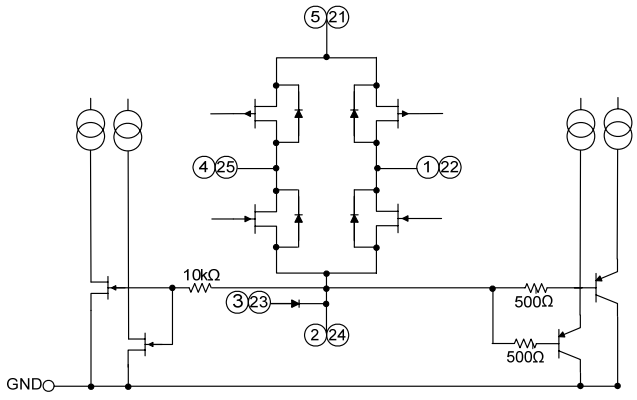


Figure 11 Diode forward voltage vs. Output Current

Pin Functions

Pin No.	Pin Name	Pin Function	Equivalent Circuit
7 8 9 10 11 12 13	MD1 MD2 MD3 OE RST FR STEP	Excitation mode switching pin Excitation mode switching pin Excitation mode switching pin Output enable signal input pin Reset signal input pin Forward / Reverse signal input pin Step clock pulse signal input pin	
6	ST	Chip enable pin.	
1 2 3 4 5 21 22 23 24 25	OUT1B RF1 PGND1 OUT1A VM1 VM2 OUT2B PGND2 RF2 OUT2A	Channel 1 OUTB output pin. Channel 1 current-sense resistor connection pin. Channel 1 Power system ground Channel 1 OUTA output pin. Channel 1 motor power supply connection pin. Channel 2 motor power supply connection pin. Channel 2 OUTB output pin. Channel 2 Power system ground Channel 2 current-sense resistor connection pin. Channel 2 OUTA output pin.	

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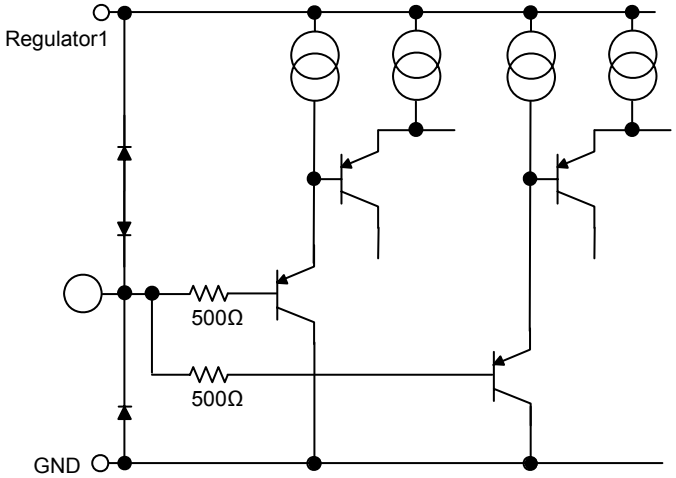
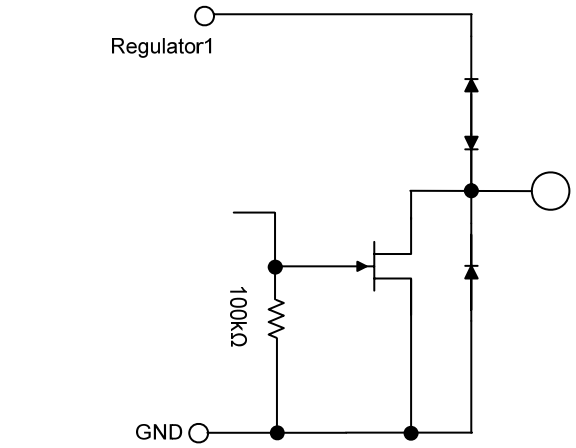
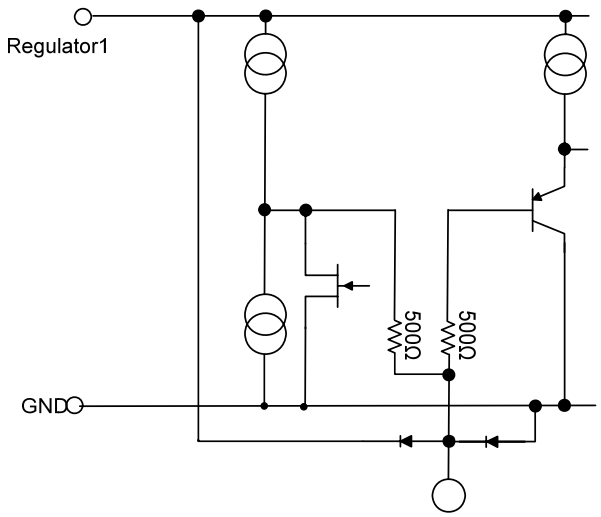
Pin No.	Pin Name	Pin Function	Equivalent Circuit
19	VREF	Constant-current control reference voltage input pin.	
17 18	DOWN MO	Holding current output pin. Position detecting monitor pin.	
14 15	OSC1 OSC2	Copping frequency setting capacitor connection pin. STEP input detection time setting capacitor connection pin.	

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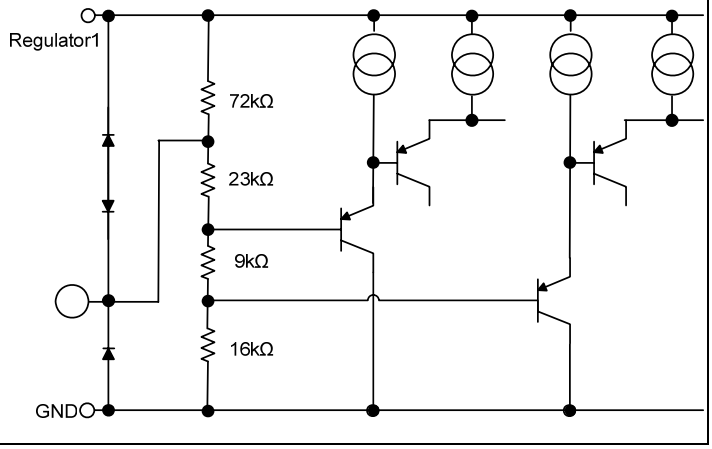
Pin No.	Pin Name	Pin Function	Equivalent Circuit
16	FDT	Constant-current control reference voltage input pin.	

Reference describing operation

(1) Stand-by function

When ST pin is at low levels, the IC enters stand-by mode, where all the logics are reset and the outputs are turned OFF.

When ST pin is at high levels, the stand-by mode is released.

(2) STEP pin function

STEP input advances electrical angle at every rising edge (advances step by step) .

Input		Operating mode
ST	STEP	
Low	*	Standby mode
High		Excitation step proceeds
High		Excitation step is kept

STEP 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 capacitor connected between OSC1 and GND. You need to perform chopping more than once per step. For this reason, for the actual STEP frequency, you need to take chopping frequency and chopping count into consideration.

For example, if chopping frequency is 50kHz (20μs) and chopping is performed twice per step, the maximum STEP frequency is obtained as follows: f＝1/(20μs×2) = 25kHz.

(3) Input timing

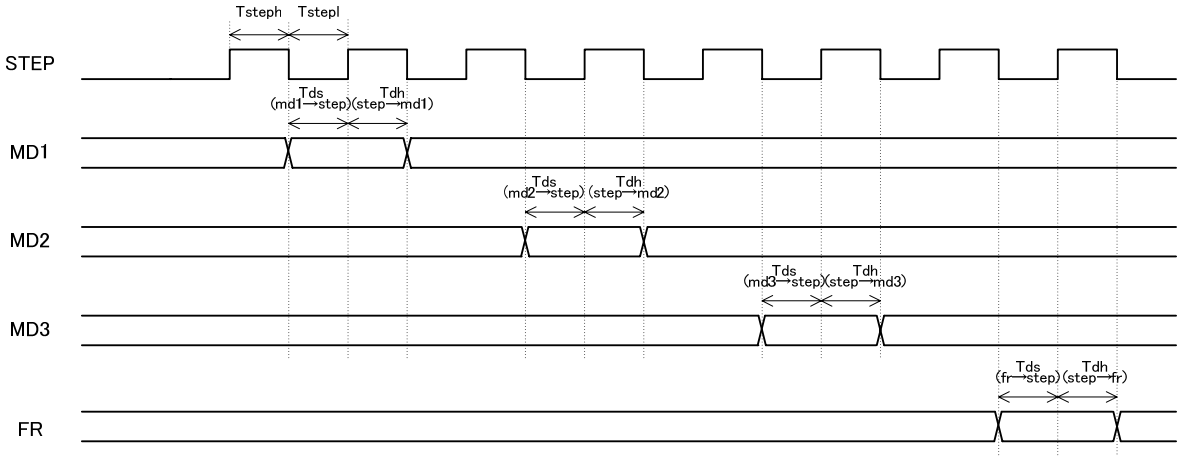


Figure 12. Input timing chart

TstepH/TstepL : Clock H/L pulse width (min 500ns)

Tds : Data set-up time (min 500ns)

Tdh : Data hold time (min 500ns)

(4) Excitation setting method

Set the micro step resolution setting as shown in the following table by setting MD1 pin, MD2 pin and MD3 pin.

Input			Micro step resolution	Excitation mode	Initial position	
MD3	MD2	MD1			1ch current	2ch current
Low	Low	Low	Half Step	1-2 phase	100%	0%
Low	Low	High	1/8 Step	2W1-2 phase	100%	0%
Low	High	Low	1/16 Step	4W1-2 phase	100%	0%
Low	High	High	1/32 Step	8W1-2 phase	100%	0%
High	Low	Low	1/64 Step	16W1-2 phase	100%	0%
High	Low	High	1/128 Step	32W1-2 phase	100%	0%
High	High	Low	1/10 Step	-	100%	0%
High	High	High	1/20 Step	-	100%	0%

The initial position is also the default state at start-up and excitation position at counter-reset in each Micro step resolution.

(5) Position detection monitoring function

The MO position detection monitoring pin is the open drain type.
When the excitation position is in the initial position, the MO output is placed in the ON state.
(Refer to "Examples of current waveforms in each of the excitation modes.")

(6) Output current setting

Output current is set shown below by the VREF pin (applied voltage) and a resistance value between RF1 (2) pin and GND.

I_{OUT} = (VREF / 3) / RF1 (2) resistance

* The setting value above is a 100% output current in each micro step resolution.

(Example) When VREF = 0.9V and RF1 (2) resistance is 0.1Ω, the setting is shown below.

I_{OUT} = (0.9V / 3) / 0.1Ω = 3.0A

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.

(7) Output enable function

When the OE pin is set Low, 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 is input. Therefore, when OE pin is returned to High, the output level conforms to the excitation position proceeded by the STP input.

OE	Operating mode
High	Output ON
Low	Output OFF

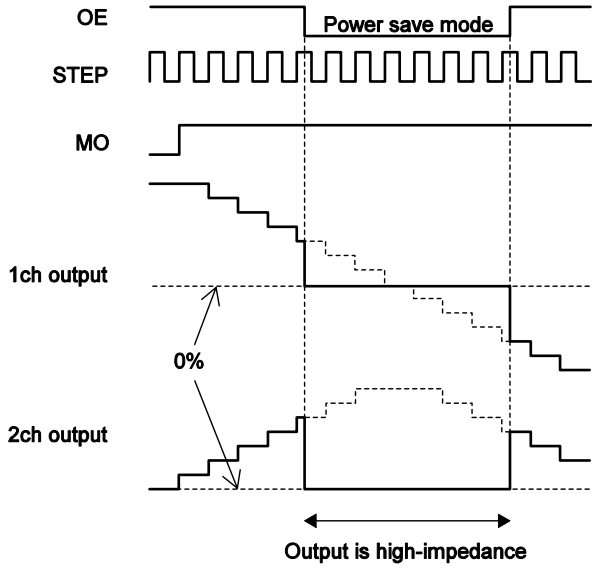


Figure 13. Output enable function timing chart

(8) Reset function

When the RST pin is set Low, the output goes to initial mode and excitation position is fixed in the initial position for STEP pin and FR pin input. MO pin outputs at low levels at the initial position. (Open drain connection)

RST	Operating mode
High	Normal operation
Low	Reset state

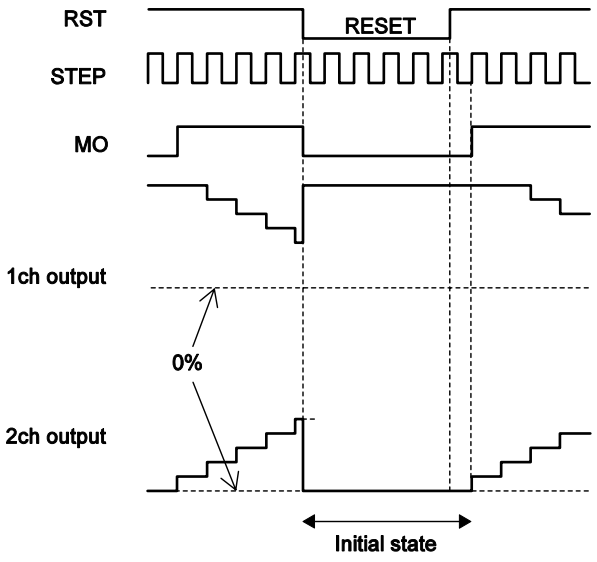


Figure 14. Reset function timing chart

(9) Forward / reverse switching function

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

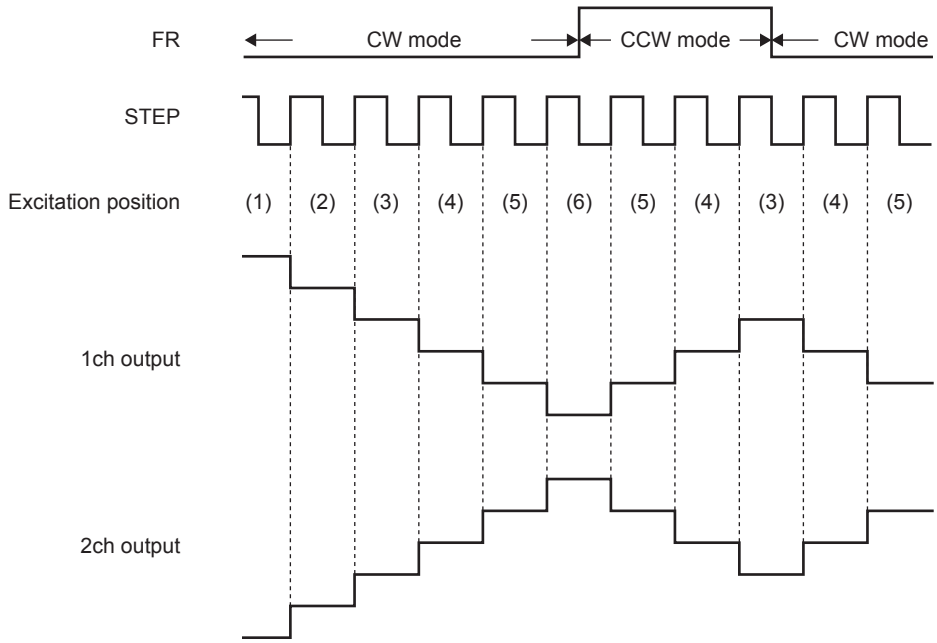


Figure 15. Forward/Reverse switching function timing chart

The internal D/A converter proceeds by a bit on the rising edge of the step signal input to the STP pin. In addition, CW and CCW mode are switched by FR pin setting.
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.

(10)Chopping frequency setting function

Chopping frequency is set as shown below by a capacitor between OSC1 pin and GND.

$Fcp = 1 / (Cosc1 / 10 \times 10^{-6})$ (Hz)

(Example) When Cosc1 = 180pF, the chopping frequency is shown below.

$Fcp = 1 / (180 \times 10^{-12} / 10 \times 10^{-6}) = 55.5$(kHz)

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. The frequency range should be between 40kHz and 125kHz.

(11)DOWN ouput pin

The DOWN output pin is open-drain output. The pin turns on and outputs Low level when STEP signal is not input for over the detection time. The open-drain output that has been turned-on is turned off by the next STEP signal.

The detection time of STEP signal (Tdown) is set as shown below by a capacitor between OSC2 pin and GND.

$$Tdown = Cosc2 \times 0.4 \times 10^{9} \text{ (s)}$$

(Example) When Cosc2 = 1500pF, the holding current switching time is as shown below.

$$Tdown = 1500pF \times 0.4 \times 10^{9} = 0.6 \text{ (s)}$$

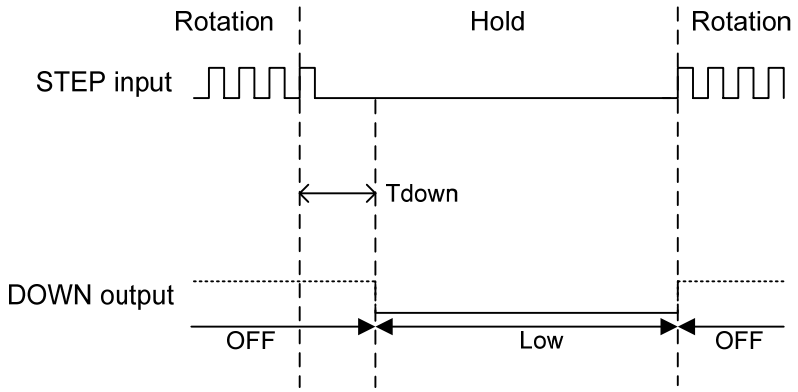


Figure 16. DOWN output function timing chart

By connecting external parts as shown in the example below using DOWN output pin, STEP signal is not input for over the detection time. In other words, while the position of the stepper motor is held with conduction, by turning on the DOWN output and lowering the VREF input voltage, the setting current lowers and power consumption is reduced.

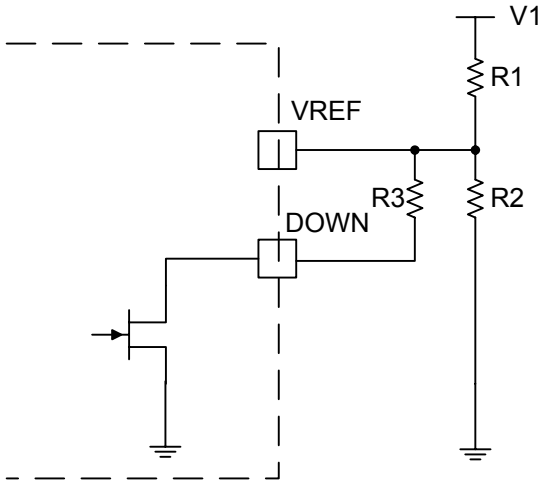


Figure 17. Example of DOWN Circuit

(Example) When V1=5V, R=27kΩ, R2=4.7kΩ, and R3=1kΩ, the setting is as shown below.

DOWN output OFF: VREF = V1 x R2 / (R1+R2) = 0.741V

DOWN output ON: VREF = V1 x (R2//R3) / (R1+ (R2//R3)) = 0.126V

(12)DECAY mode setting

Current DECAY method is selectable as shown below by applied voltage to the FDT pin.

FDT voltage	DECAY method
3.5V ≤ FDT ≤ 5.5V	SLOW DECAY
3.1V < FDT < 3.5V	Inhibited zone
1.1V ≤ FDT ≤ 3.1V or OPEN	MIXED DECAY
0.8V < FDT < 1.1V	Inhibited zone
0V ≤ FDT ≤ 0.8V	FAST DECAY

For the inhibited zone, either above or below DECAY method is selected. Ex) For the Inhibited zone where FDT voltage is 3.1V < FDT <3.5V, either SLOW DECAY or MIXED DECAY is selected. Since each threshold voltage does not have hysteresis, it is not recommended to change DECAY method during motor operation.

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

Half, 1/8, 1/16, 1/32, 1/64, 1/128 Step

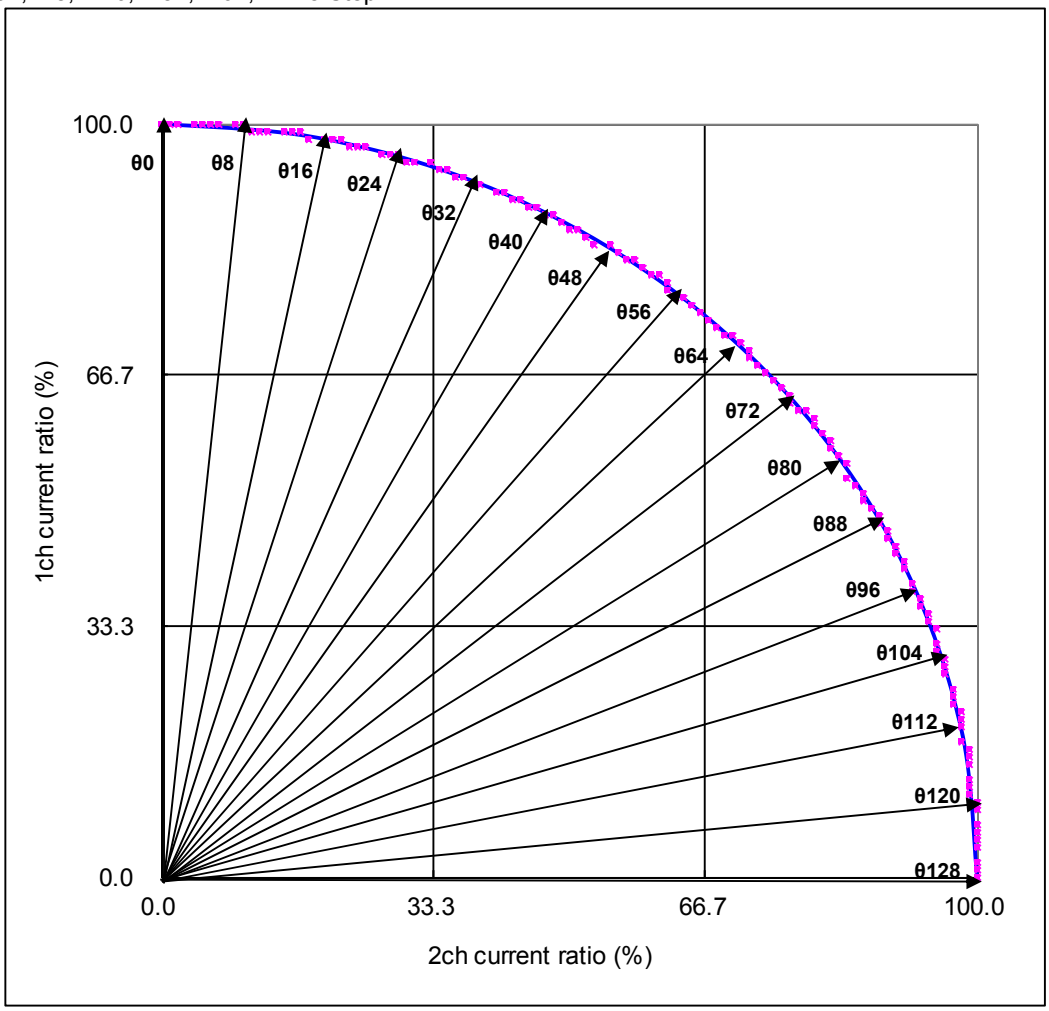


Figure 18. Output current vector

Current setting ratio in each micro step resolution

STEP	1/128 (%)		1/64 (%)		1/32 (%)		1/16 (%)		1/8 (%)		Half (%)	
	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch
θ0	100	0	100	0	100	0	100	0	100	0	100	0
θ1	100	1										
θ2	100	2	100	2								
θ3	100	4										
θ4	100	5	100	5	100	5						
θ5	100	6										
θ6	100	7	100	7								
θ7	100	9										
θ8	100	10	100	10	100	10	100	10				
θ9	99	11										
θ10	99	12	99	12								
θ11	99	13										
θ12	99	15	99	15	99	15						
θ13	99	16										
θ14	99	17	99	17								
θ15	98	18										
θ16	98	20	98	20	98	20	98	20	98	20		
θ17	98	21										
θ18	98	22	98	22								
θ19	97	23										
θ20	97	24	97	24	97	24						
θ21	97	25										
θ22	96	27	96	27								
θ23	96	28										
θ24	96	29	96	29	96	29	96	29				
θ25	95	30										

Continued on next page.

Continued from preceding page.

STEP	1/128 (%)		1/64 (%)		1/32 (%)		1/16 (%)		1/8 (%)		Half (%)	
	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch
θ26	95	31	95	31								
θ27	95	33										
θ28	94	34	94	34	94	34						
θ29	94	35										
θ30	93	36	93	36								
θ31	93	37										
θ32	92	38	92	38	92	38	92	38	92	38		
θ33	92	39										
θ34	91	41	91	41								
θ35	91	42										
θ36	90	43	90	43	90	43						
θ37	90	44										
θ38	89	45	89	45								
θ39	89	46										
θ40	88	47	88	47	88	47	88	47				
θ41	88	48										
θ42	87	49	87	49								
θ43	86	50										
θ44	86	51	86	51	86	51						
θ45	85	52										
θ46	84	53	84	53								
θ47	84	55										
θ48	83	56	83	56	83	56	83	56	83	56		
θ49	82	57										
θ50	82	58	82	58								
θ51	81	59										
θ52	80	60	80	60	80	60						
θ53	80	61										
θ54	79	62	79	62								
θ55	78	62										
θ56	77	63	77	63	77	63	77	63				
θ57	77	64										
θ58	76	65	76	65								
θ59	75	66										
θ60	74	67	74	67	74	67						
θ61	73	68										
θ62	72	69	72	69								
θ63	72	70										
θ64	71	71	71	71	71	71	71	71	71	71	71	71
θ65	70	72										
θ66	69	72	69	72								
θ67	68	73										
θ68	67	74	67	74	67	74						
θ69	66	75										
θ70	65	76	65	76								
θ71	64	77										
θ72	63	77	63	77	63	77	63	77				
θ73	62	78										
θ74	62	79	62	79								
θ75	61	80										
θ76	60	80	60	80	60	80						
θ77	59	81										
θ78	58	82	58	82								
θ79	57	82										
θ80	56	83	56	83	56	83	56	83	56	83		
θ81	55	84										
θ82	53	84	53	84								
θ83	52	85										
θ84	51	86	51	86	51	86						
θ85	50	86										
θ86	49	87	49	87								
θ87	48	88										
θ88	47	88	47	88	47	88	47	88				
θ89	46	89										
θ90	45	89	45	89								

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STEP	1/128 (%)		1/64 (%)		1/32 (%)		1/16 (%)		1/8 (%)		Half (%)	
	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch
θ91	44	90										
θ92	43	90	43	90	43	90						
θ93	42	91										
θ94	41	91	41	91								
θ95	39	92										
θ96	38	92	38	92	38	92	38	92	38	92		
θ97	37	93										
θ98	36	93	36	93								
θ99	35	94										
θ100	34	94	34	94	34	94						
θ101	33	95										
θ102	31	95	31	95								
θ103	30	95										
θ104	29	96	29	96	29	96	29	96				
θ105	28	96										
θ106	27	96	27	96								
θ107	25	97										
θ108	24	97	24	97	24	97						
θ109	23	97										
θ110	22	98	22	98								
θ111	21	98										
θ112	20	98	20	98	20	98	20	98	20	98		
θ113	18	98										
θ114	17	99	17	99								
θ115	16	99										
θ116	15	99	15	99	15	99						
θ117	13	99										
θ118	12	99	12	99								
θ119	11	99										
θ120	10	100	10	100	10	100	10	100				
θ121	9	100										
θ122	7	100	7	100								
θ123	6	100										
θ124	5	100	5	100	5	100						
θ125	4	100										
θ126	2	100	2	100								
θ127	1	100										
θ128	0	100	0	100	0	100	0	100	0	100	0	100

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

1/10, 1/20 Step

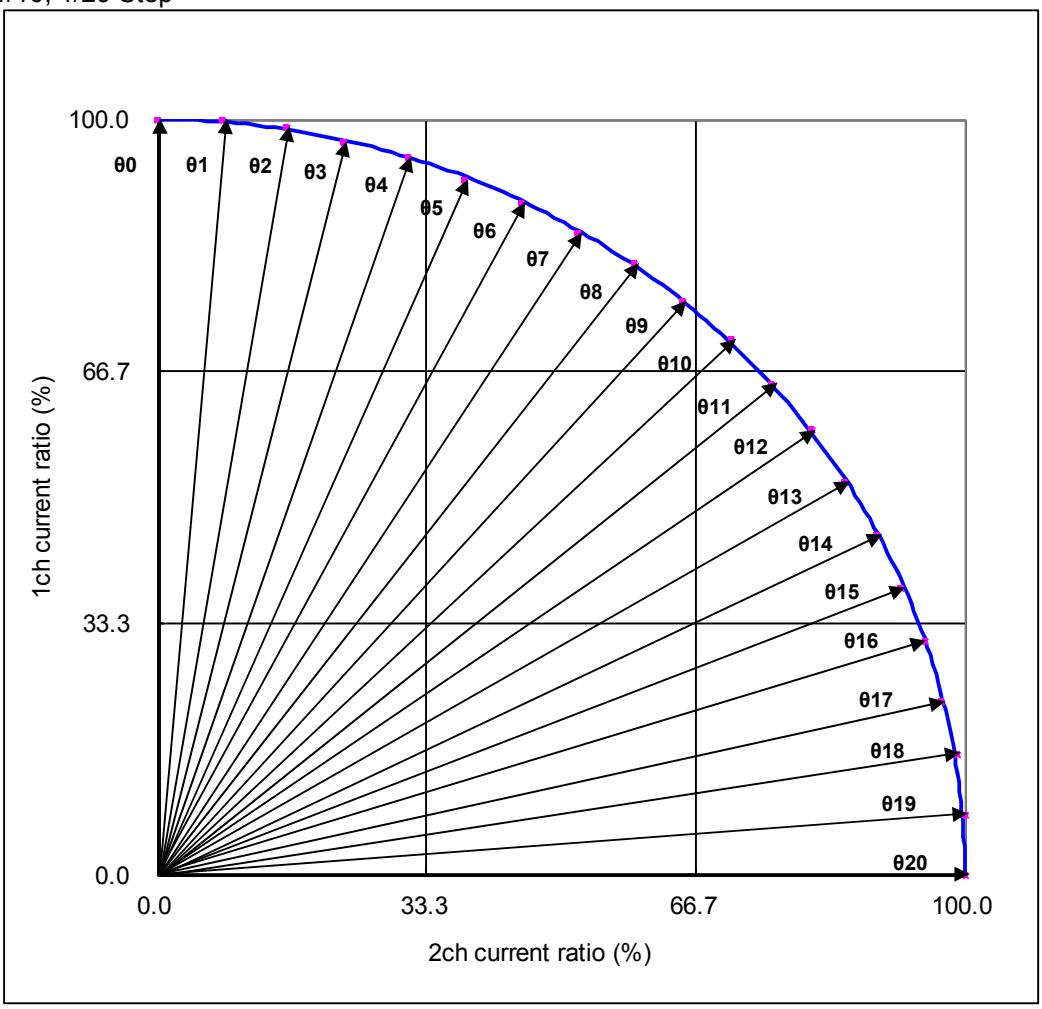


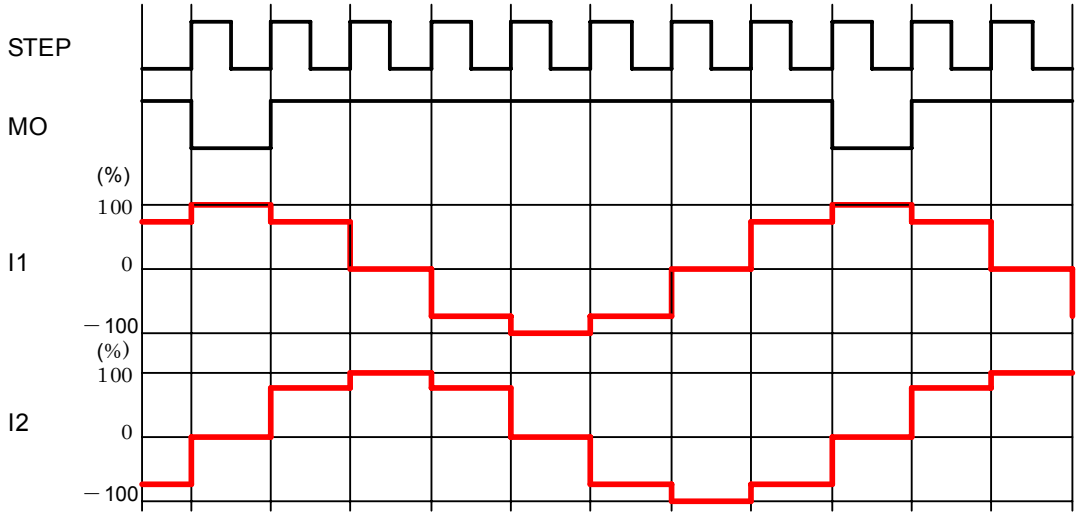
Figure 19. Output current vector

Current setting ratio in each micro step resolution

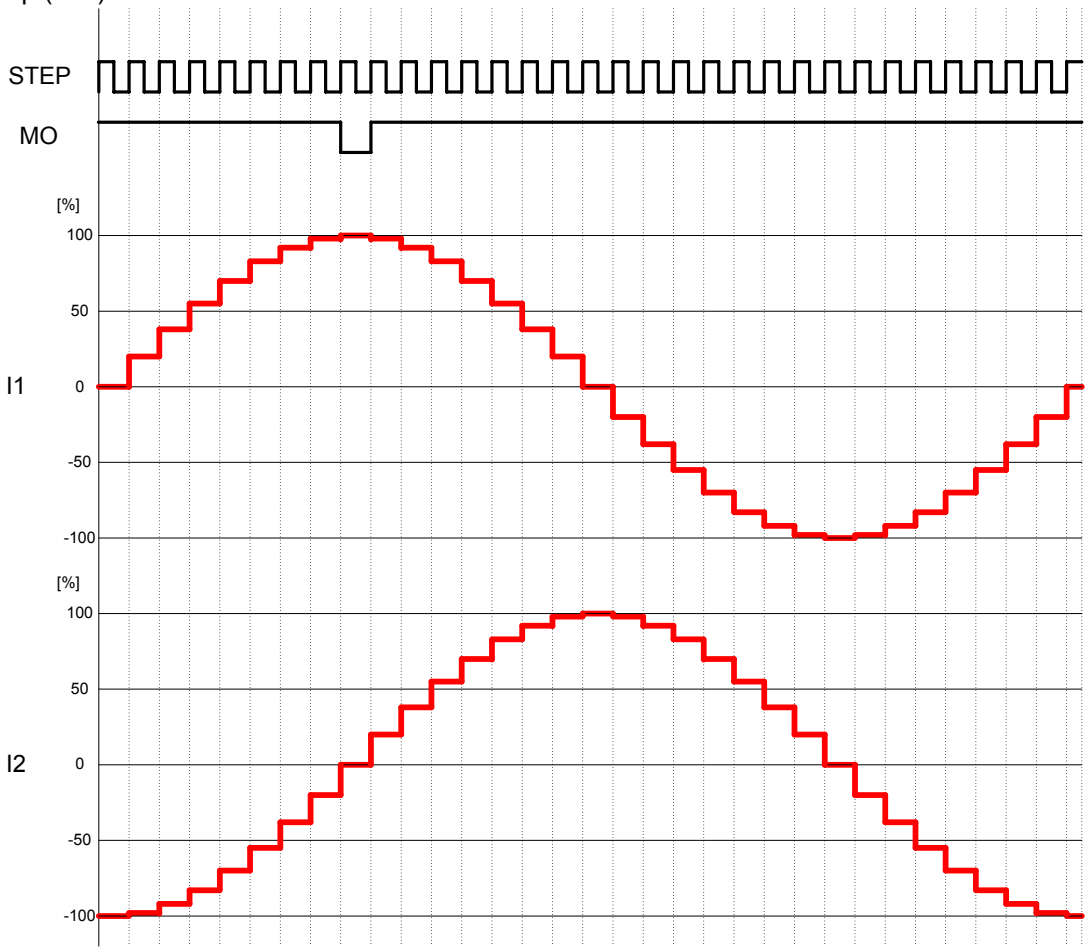
STEP	1/20 (%)		1/10 (%)	
	1ch	2ch	1ch	2ch
θ0	100	0	100	0
θ1	100	8		
θ2	99	16	99	16
θ3	97	23		
θ4	95	31	95	31
θ5	92	38		
θ6	89	45	89	45
θ7	85	52		
θ8	81	59	81	59
θ9	76	65		
θ10	71	71	71	71
θ11	65	76		
θ12	59	81	59	81
θ13	52	85		
θ14	45	89	45	89
θ15	38	92		
θ16	31	95	31	95
θ17	23	97		
θ18	16	99	16	99
θ19	8	100		
θ20	0	100	0	100

(14)Current wave example in each micro step resolution.

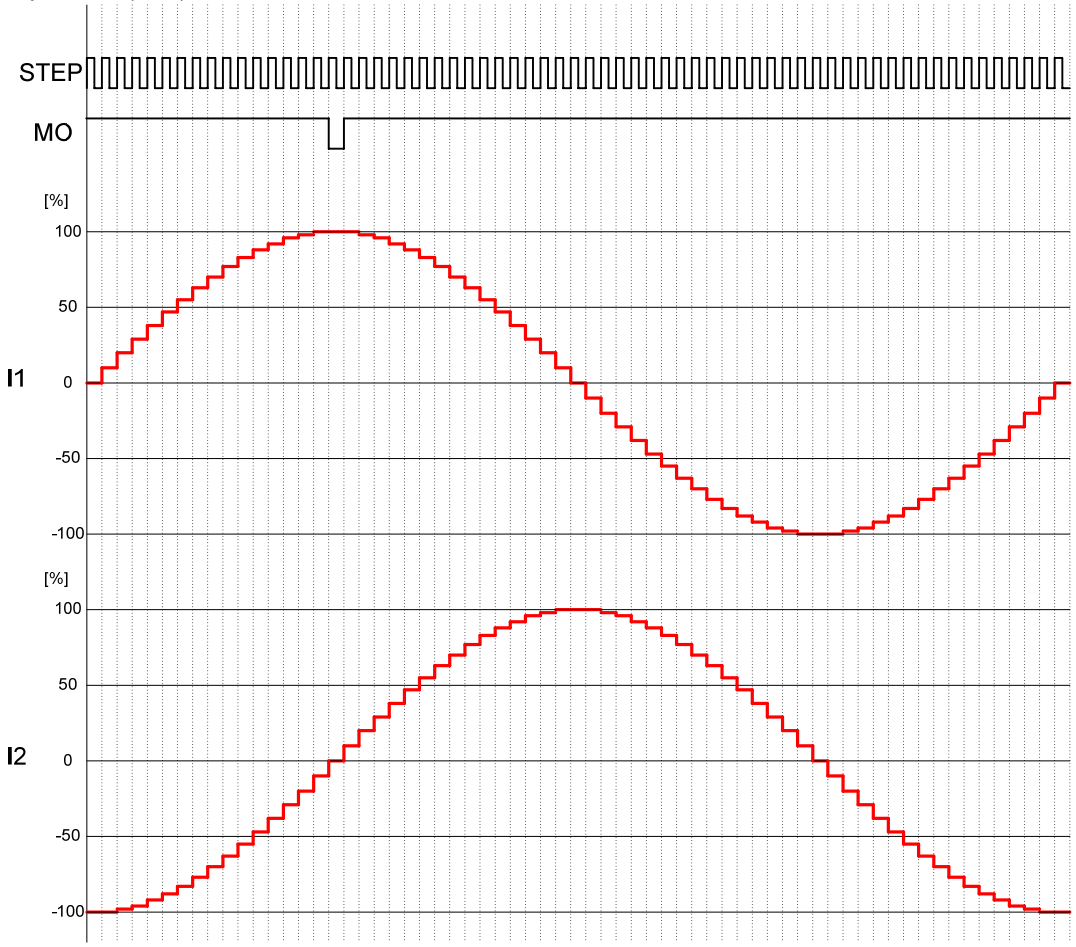
Half Step (CW)



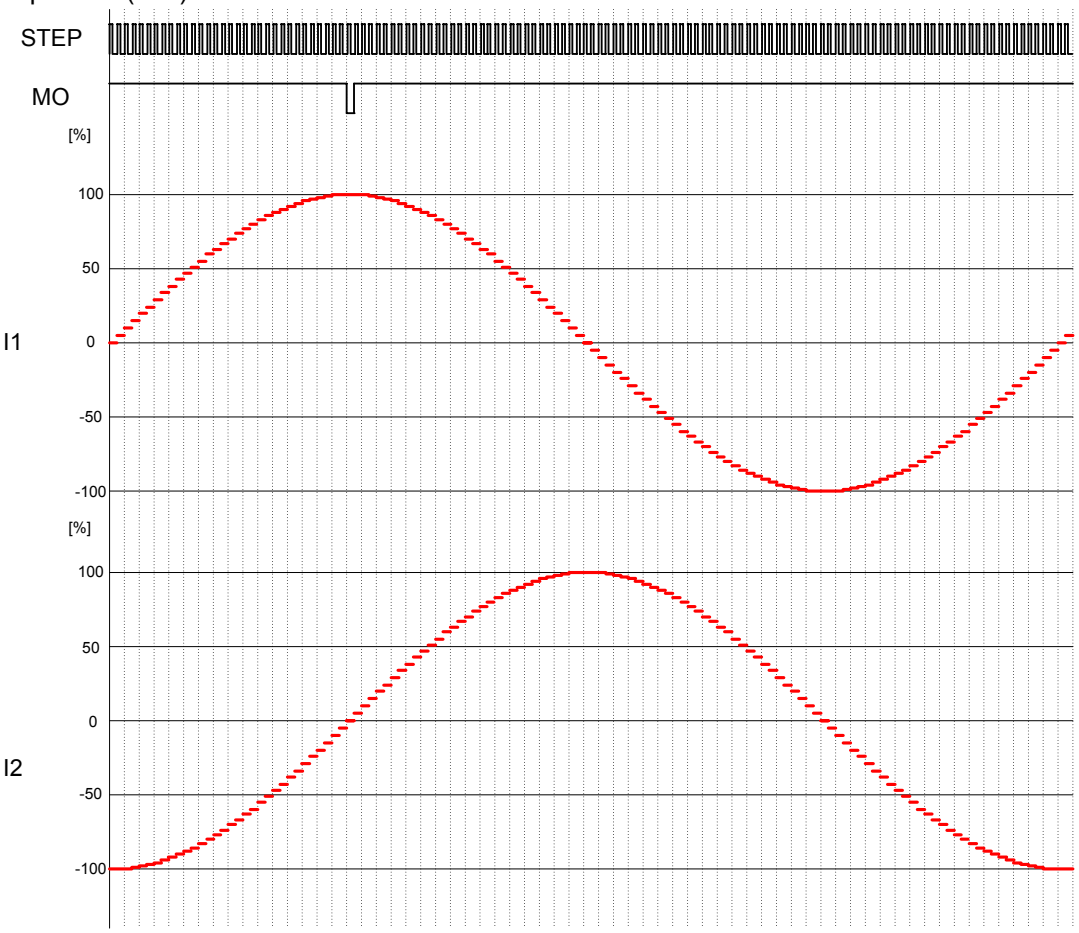
1/8 Step (CW)



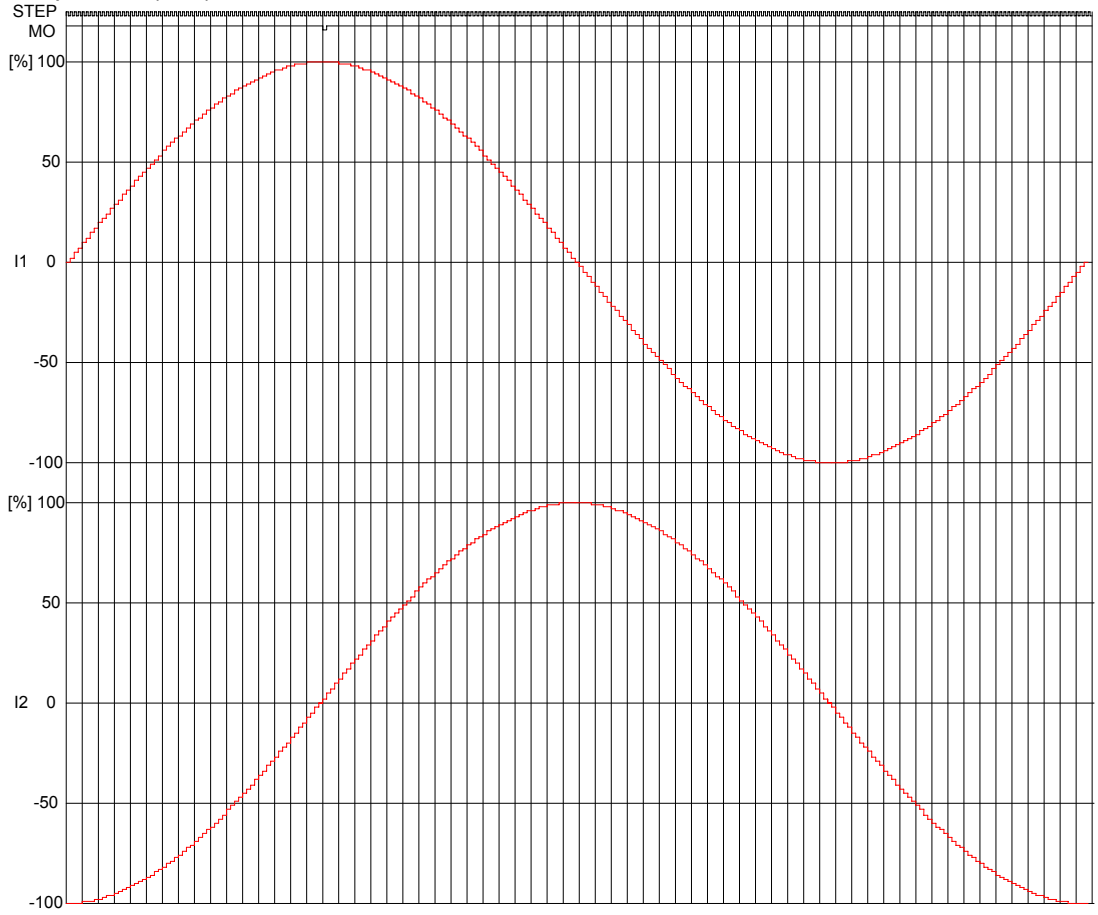
1/16 Step Mode (CW)



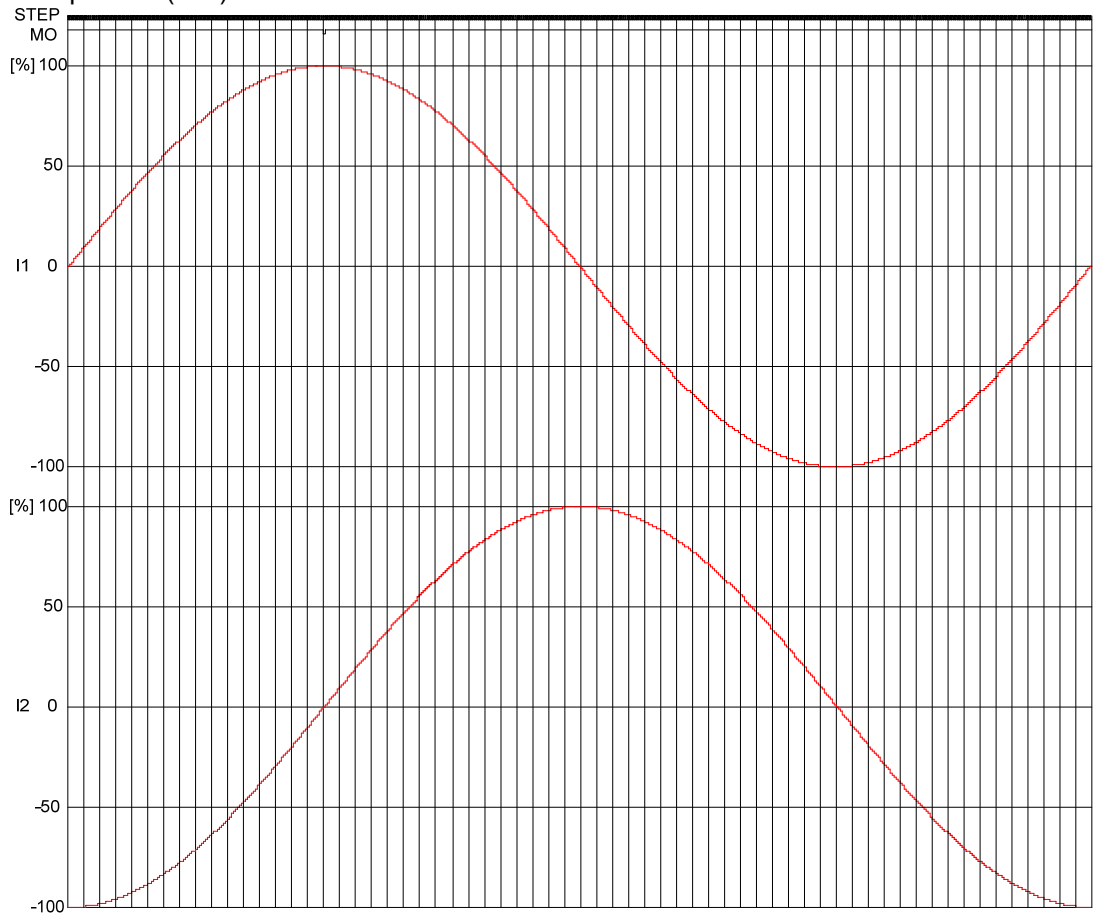
1/32 Step Mode (CW)



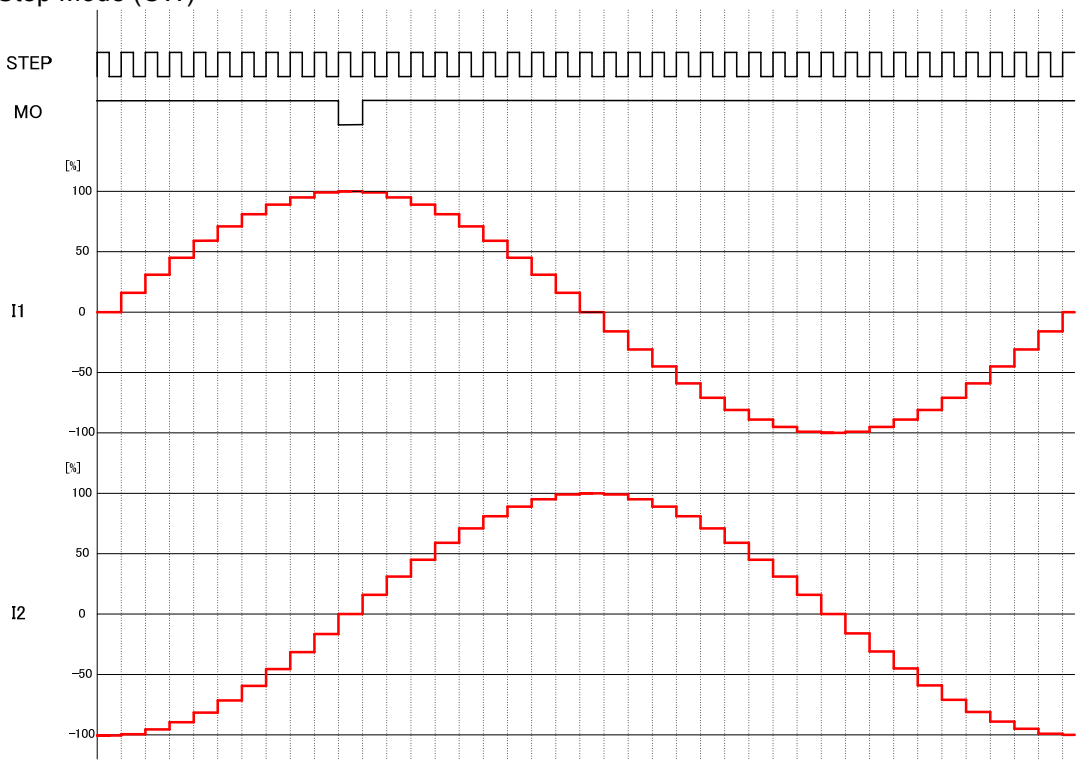
1/64 Step Mode (CW)



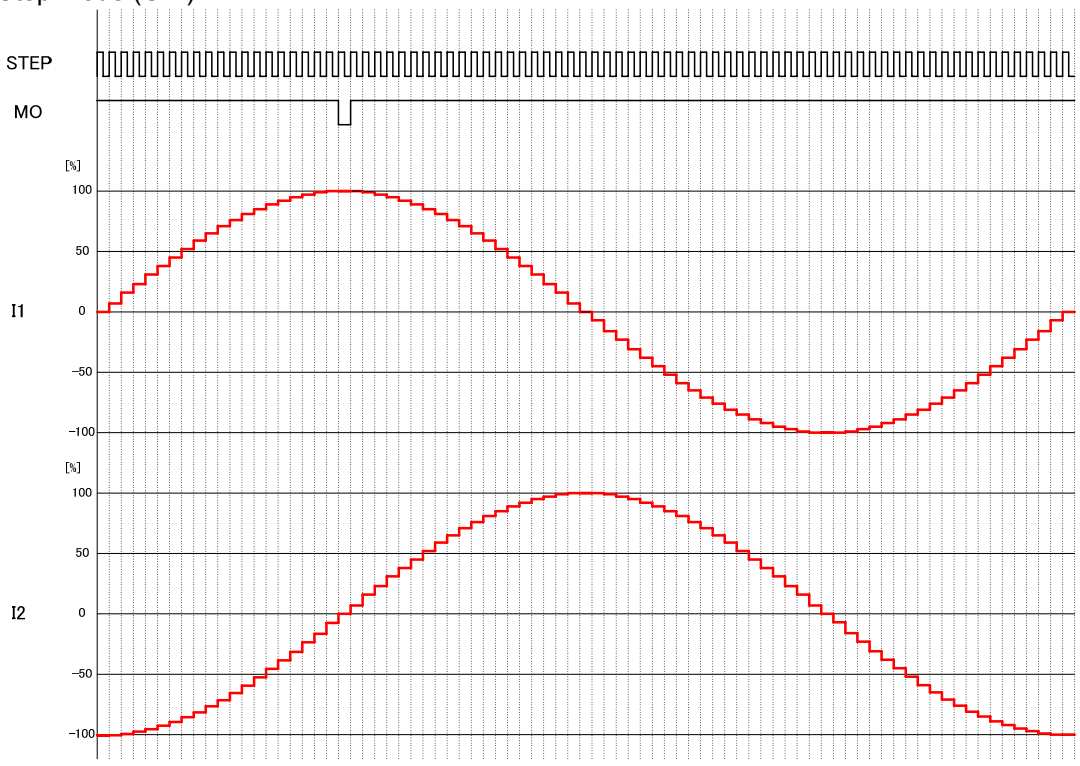
1/128 Step Mode (CW)



1/10 Step Mode (CW)



1/20 Step Mode (CW)

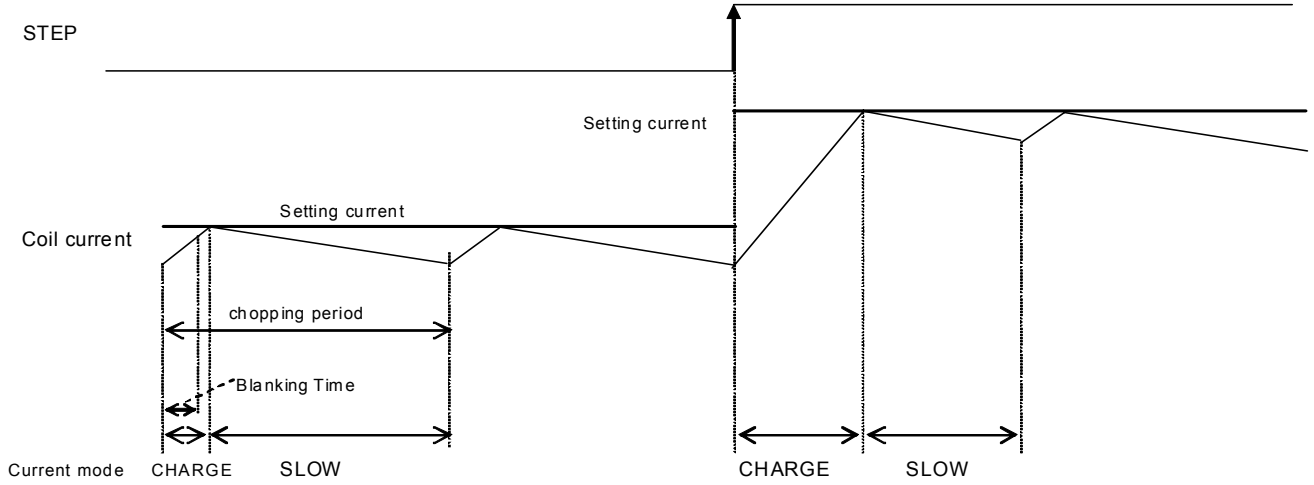


(15)Current control operation

SLOW DECAY current control operation

When FDT pin voltage is over 3.5 V, the constant-current control is operated in SLOW DECAY mode.

(Sine-wave increasing direction)



(Sine-wave decreasing direction)

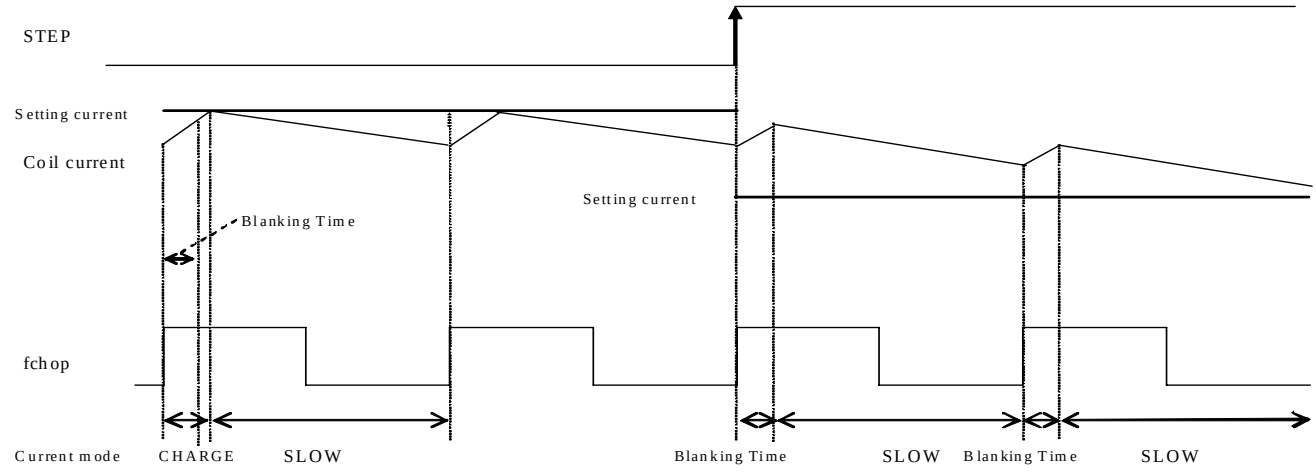


Figure 20. Constant current control timing chart

Each of current modes operates with the follow sequence.

The IC enters CHARGE mode at a rising edge of the chopping oscillation.

(A period of CHARGE mode (Blanking Time) is forcibly preset to approximately 1 μs, regardless of the current value of the coil current (ICOIL) and set current (IREF)).

After the period of the blanking time, the IC operates in CHARGE mode until ICOIL ≥ IREF. After that, the mode switches to the SLOW DECAY mode and the coil current is attenuated until the end of a chopping period.

At the constant-current control in SLOW DECAY mode, it takes time to follow up the setting current from the coil current (or may not be followed) for the current delay attenuation.

Slow DECAY output transistor operation mode

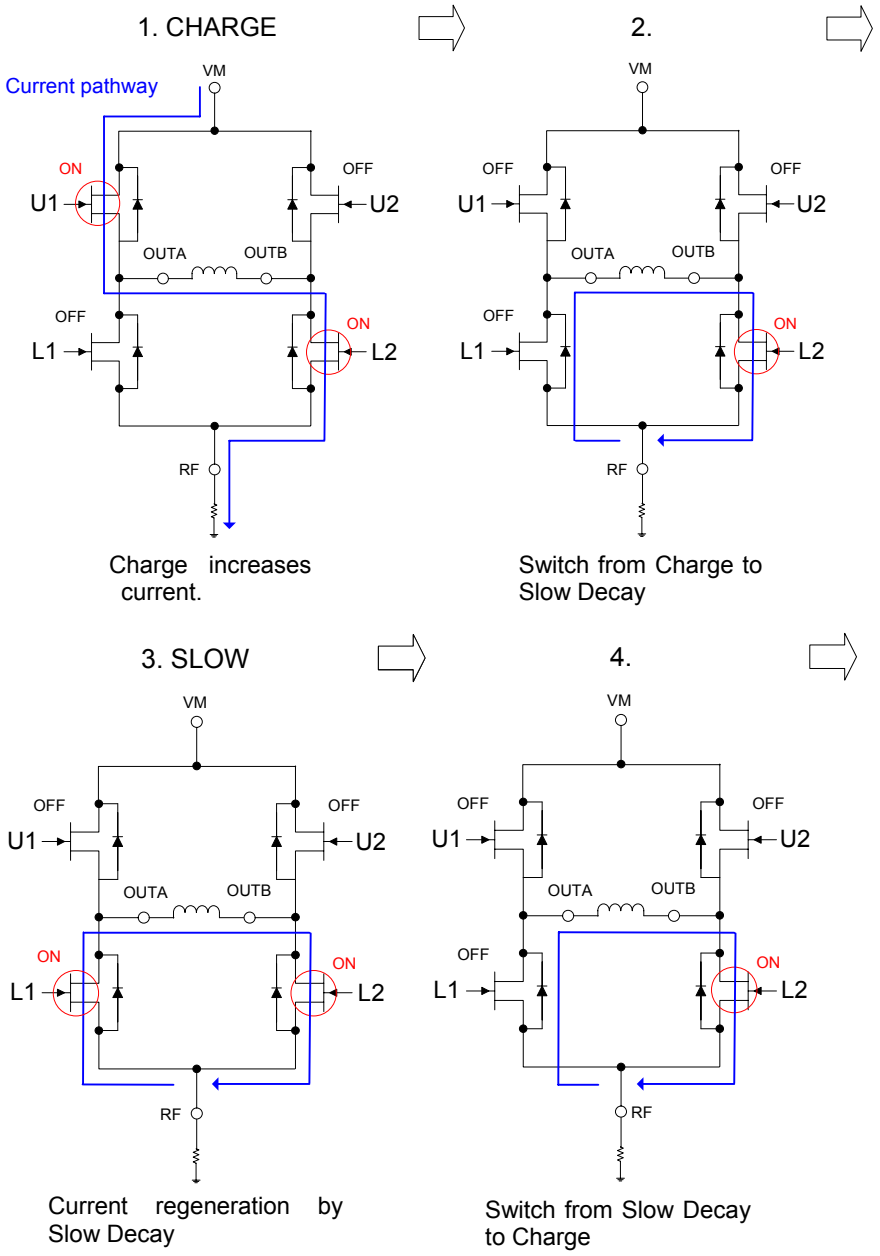


Figure 21. SLOW DECAY output transistor operation sequence

This IC controls constant current by performing chopping to output transistor.
As shown above, by repeating the process from 1 to 4, setting current is maintained.
Chopping consists of 2 modes: Charge/ Slow decay. In SLOW DECAY mode, for switching mode (No.2, 4), 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**
U1	ON	OFF
U2	OFF	OFF
L1	OFF	ON
L2	ON	ON

OUTB→OUTA (CHARGE)

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

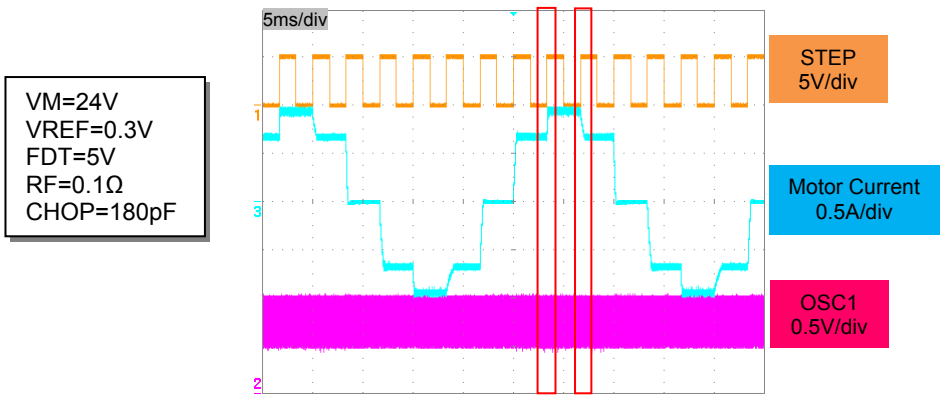


Figure 22.Constant current control waveform

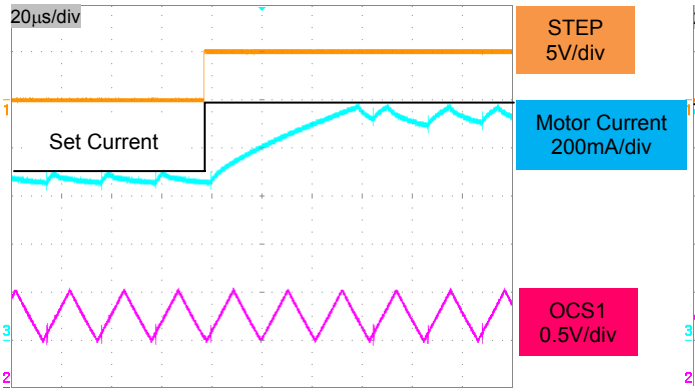


Figure 23. Sine wave increasing direction

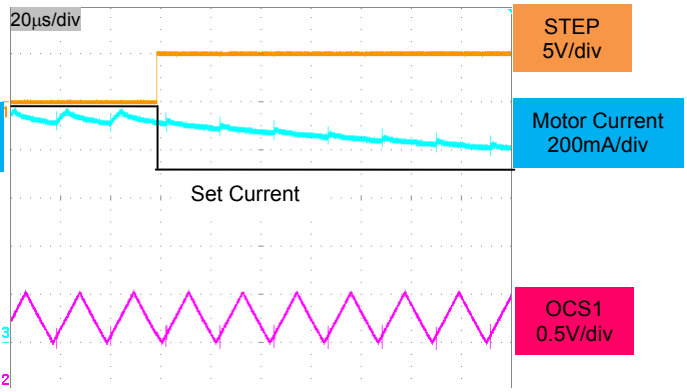


Figure 24. Sine wave decreasing direction

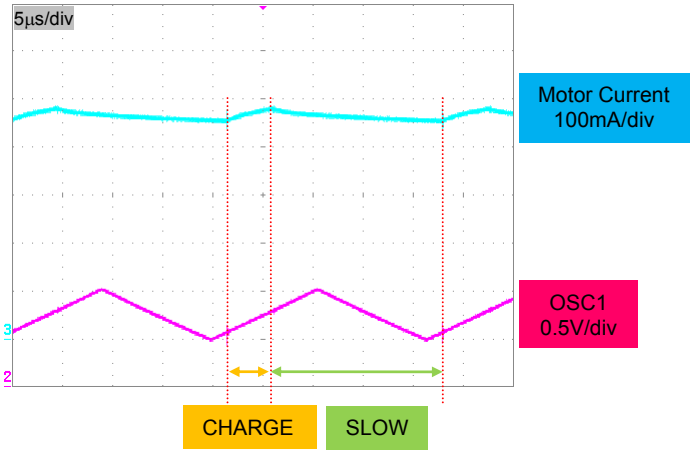


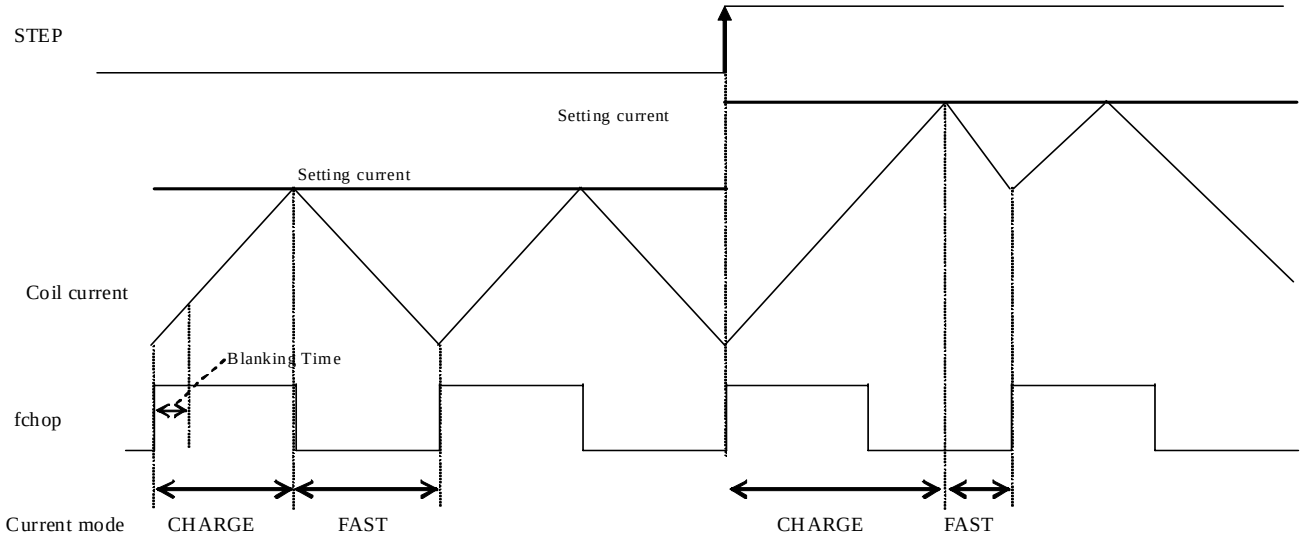
Figure 25. Constant current control waveform (Stationary state)

When the current reaches to the setting current, it is switched to Slow Decay mode which continues over the Discharge period of triangle wave.

FAST DECAY current control operation

When FDT pin voltage is a voltage under 0.8V, the constant-current control is operated in FAST DECAY mode.

(Sine-wave increasing direction)



(Sine-wave decreasing direction)

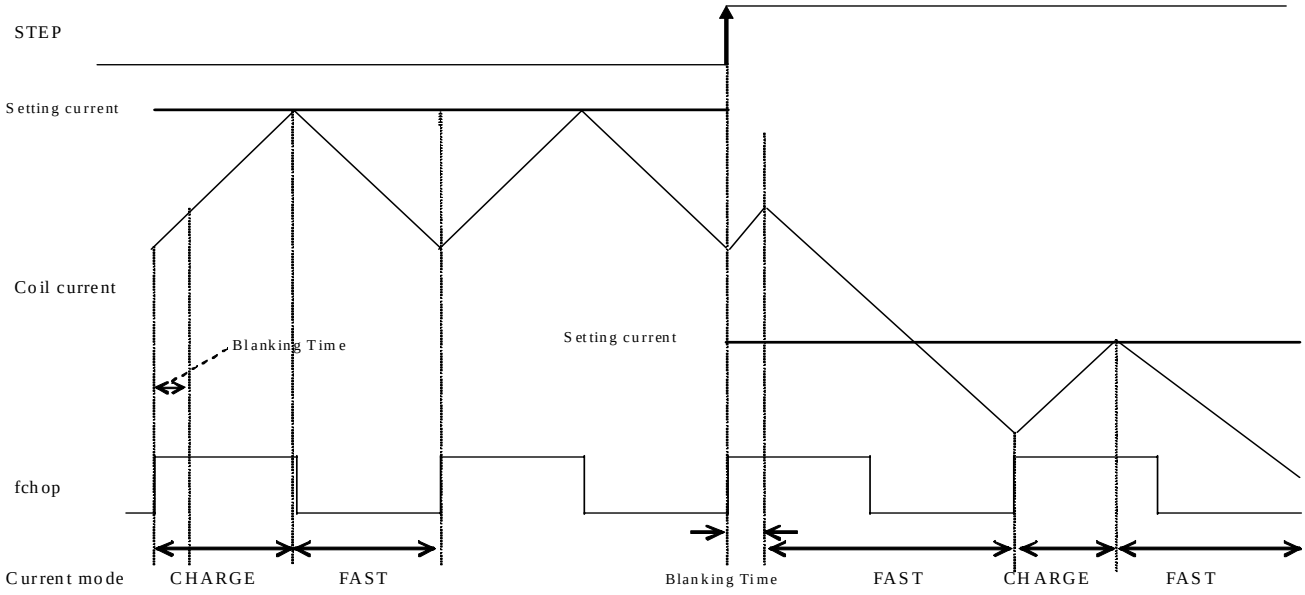


Figure 26. Constant current control timing chart

Each of current modes operates with the following sequence.
The IC enters CHARGE mode at a rising edge of the chopping oscillation.
(A period of CHARGE mode (Blanking Time) is forcibly preset to approximately 1 μs, regardless of the current value of the coil current (ICOIL) and set current (IREF)).
After the period of the blanking time, the IC operates under CHARGE mode until ICOIL ≥ IREF. After that, the mode switches to the FAST DECAY mode and the coil current is attenuated until the end of a chopping period.
At the constant-current control in FAST DECAY mode, it does not take long to follow the setting current from the coil current for the current fast attenuation. However, the current ripple value may be higher.

FAST DECAY output transistor operation mode

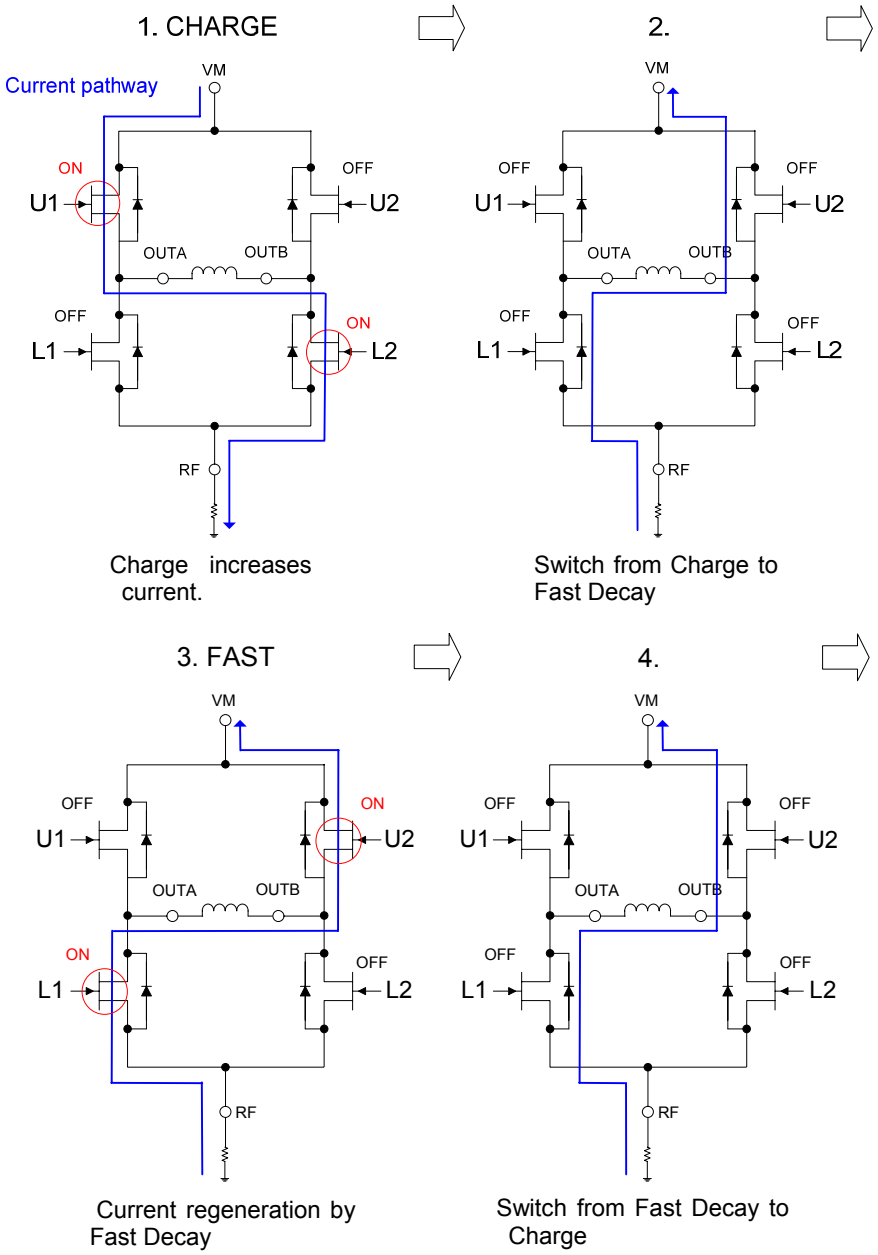


Figure 27. FAST DECAY output transistor operation sequence

This IC controls constant current by performing chopping to output transistor.
As shown above, by repeating the process from 1 to 4, setting current is maintained.
Chopping consists of 2 modes: Charge/ Fast decay. In FAST DECAY mode, for switching mode (No.2, 4), 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**	**FAST**
U1	ON	OFF
U2	OFF	ON
L1	OFF	ON
L2	ON	OFF

OUTB→OUTA (CHARGE)

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

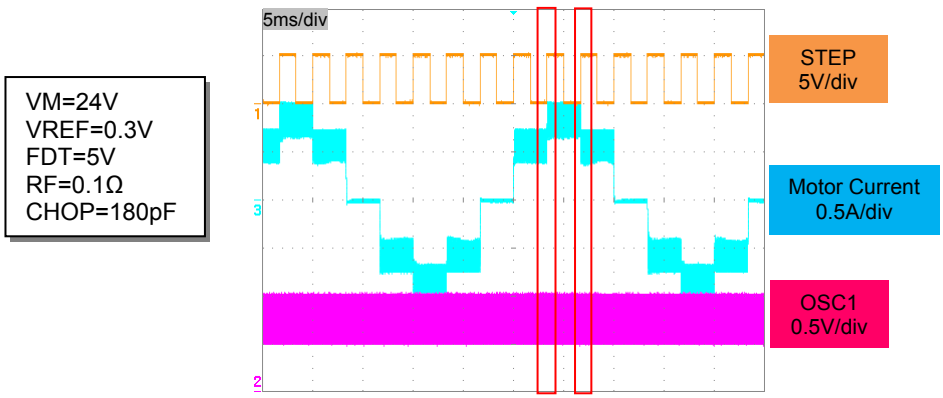


Figure 28.Constant current control waveform

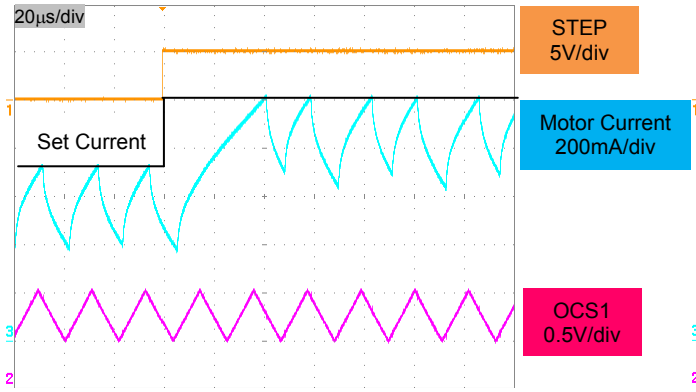


Figure 29. Sine wave increasing direction

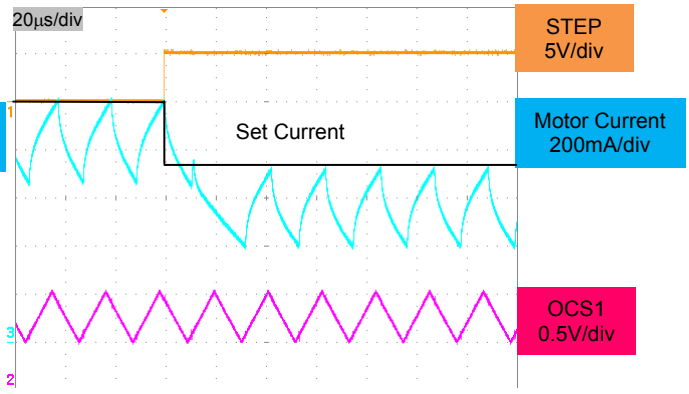


Figure 30. Sine wave decreasing direction

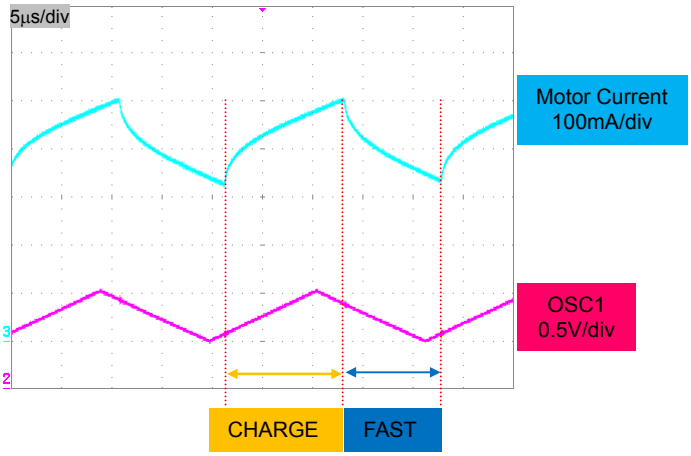


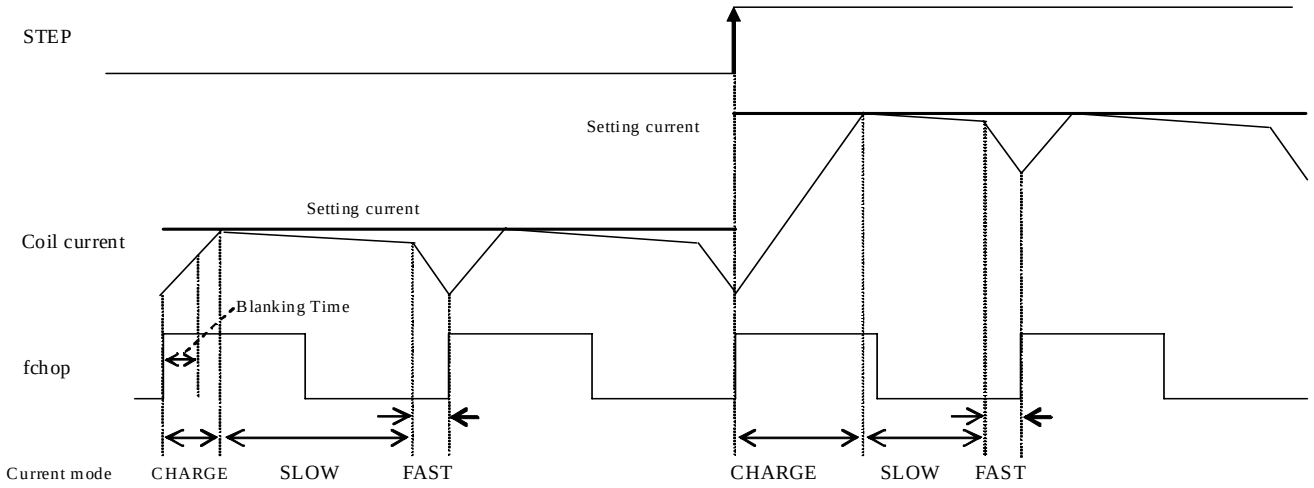
Figure 31. Constant current control waveform (Stationary state)

When the current reaches to the setting current, it is switched to Fast Decay mode which continues over the Discharge period of triangle wave.

MIXED DECAY current control operation

When FDT pin voltage is a voltage between 1.1 V to 3.1 V or OPEN, the constant-current control is operated in MIXED DECAY mode.

(Sine-wave increasing direction)



(Sine-wave decreasing direction)

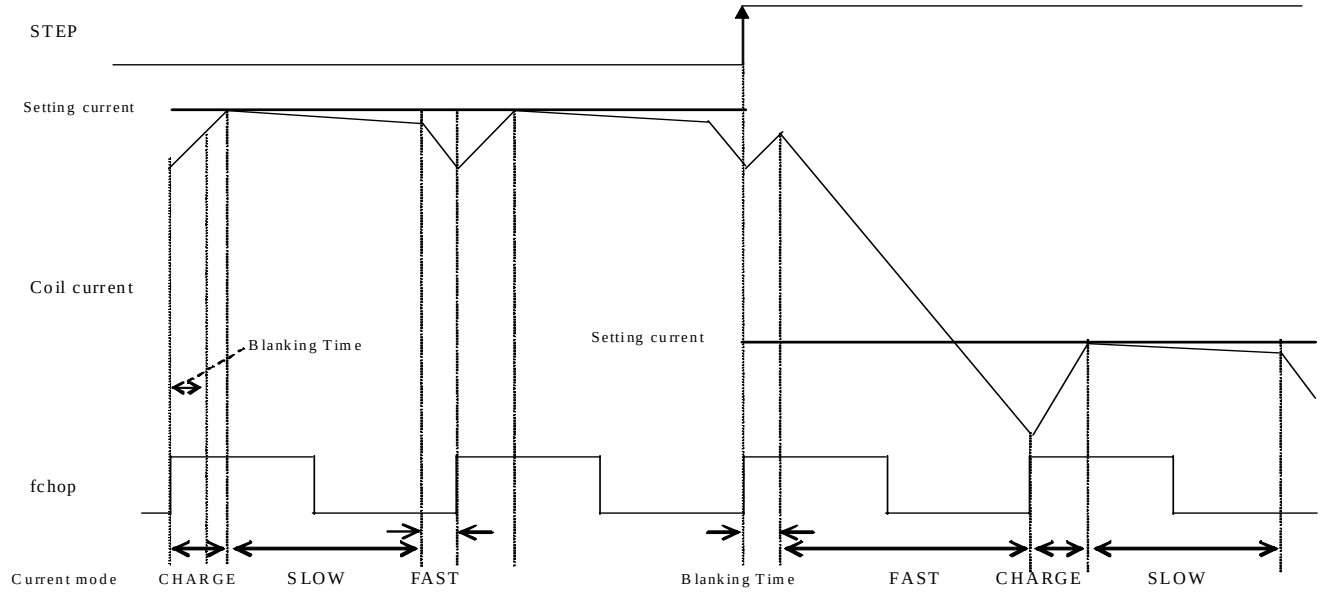


Figure 32. Constant current control timing chart

Each of current modes operates according to the following sequence.

- The IC enters CHARGE mode at a rising edge of the chopping oscillation. (A period of CHARGE mode (Blanking Time) is forcibly preset to approximately 1μs, regardless of the current value of the coil current (ICOIL) and set current (IREF)).
- In a period of Blanking Time, the coil current (ICOIL) and the setting current (IREF) are compared.
  - If an ICOIL < IREF state exists during the charge period:
    The IC operates in CHARGE mode until ICOIL ≥ IREF. After that, it switches to SLOW DECAY mode and then switches to FAST DECAY mode in the last approximately 1μs of the period.
  - If no ICOIL < IREF state exists during the charge period:
    The IC switches to FAST DECAY mode and the coil current is attenuated with the FAST DECAY operation until the end of a chopping period.

The above operation is repeated. Normally, in the sine wave when current is in increase, the IC operates in SLOW (+ FAST) DECAY mode, and when current is in decrease, the IC operates in FAST DECAY mode until the current is attenuated and reaches the set value and the IC operates in SLOW (+ FAST) DECAY mode.

(16)Output transistor operation mode

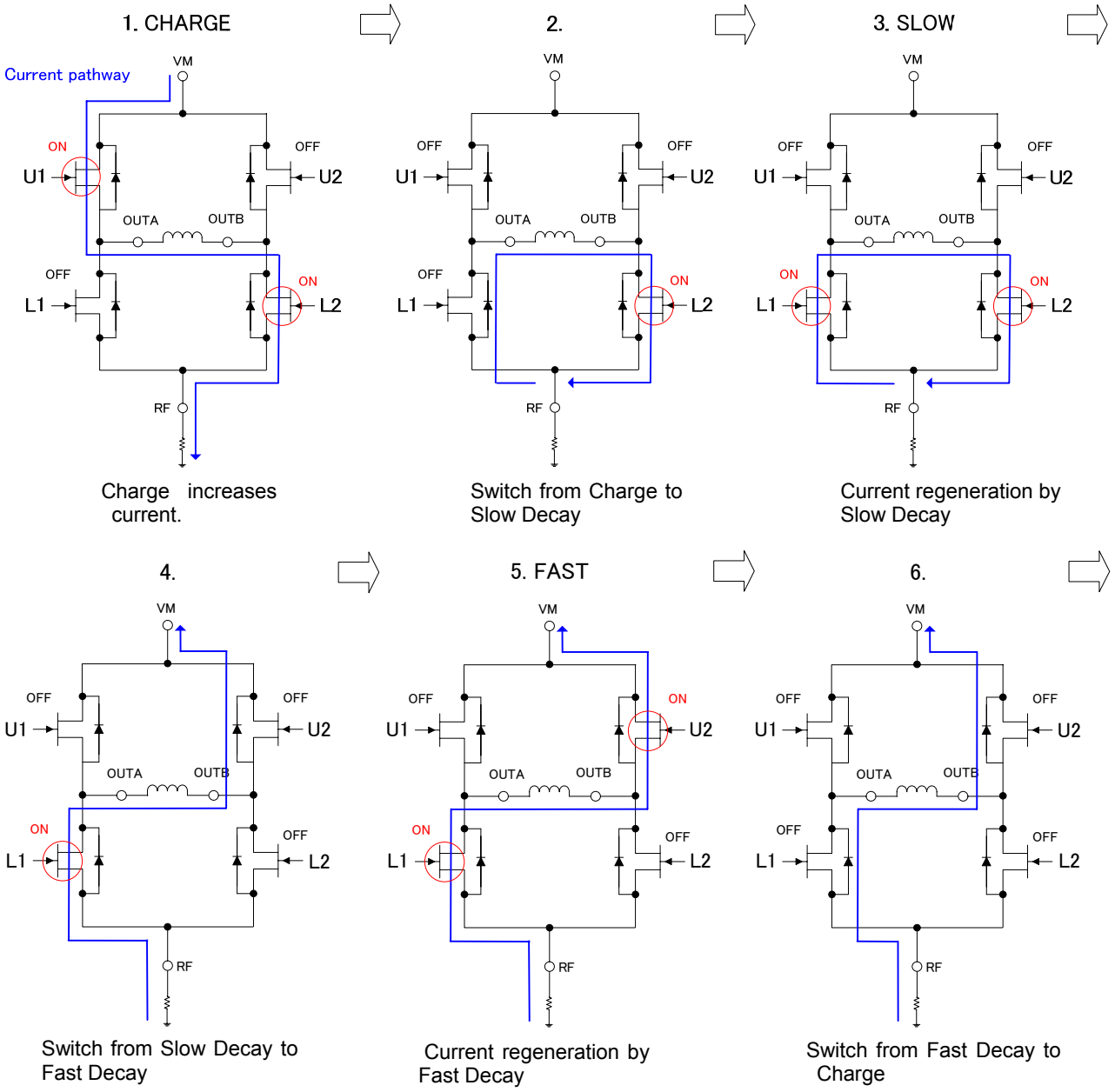


Figure 33. Output transistor operation sequence

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

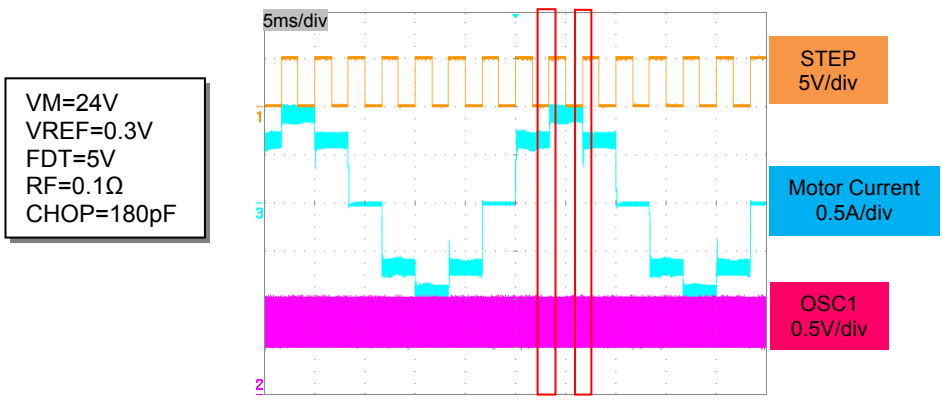


Figure 34.Constant current control waveform

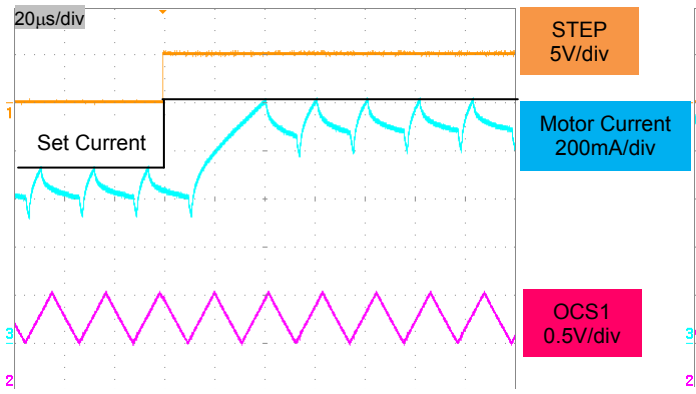


Figure 35. Sine wave increasing direction

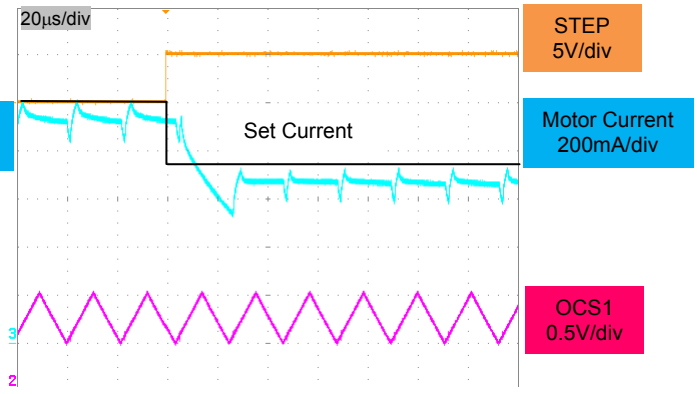


Figure 36. Sine wave decreasing direction

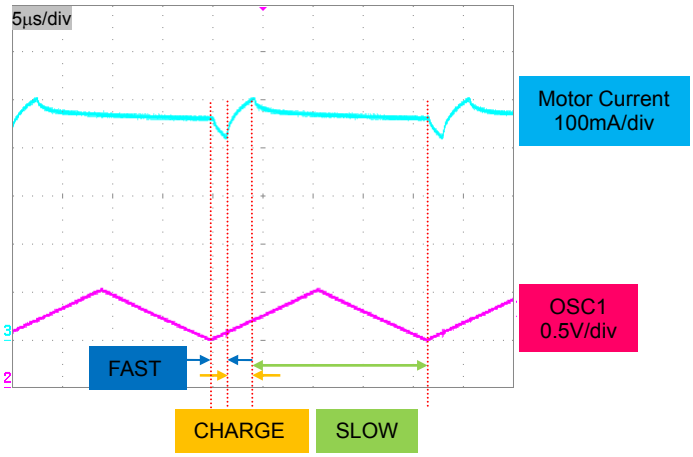


Figure 37. Constant current control waveform (Stationary state)

Motor current switches to Fast Decay mode when triangle wave (CHOP) switches from Discharge to Charge. Approximately after 1µs, the motor current switches to Charge mode. When the current reaches to the setting current, it is switched to Slow Decay mode which continues over the Discharge period of triangle wave.

(17)Blanking period

If, when performing 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 resistor, which causes noise as well as error detection. To prevent error detection, a blanking period is provided to prevent the noise during mode switching. During this period, the mode is not switched from charge to decay even if noise is carried on the current sensing resistance pin.
It is approximately 1μs in the blanking time for this IC.

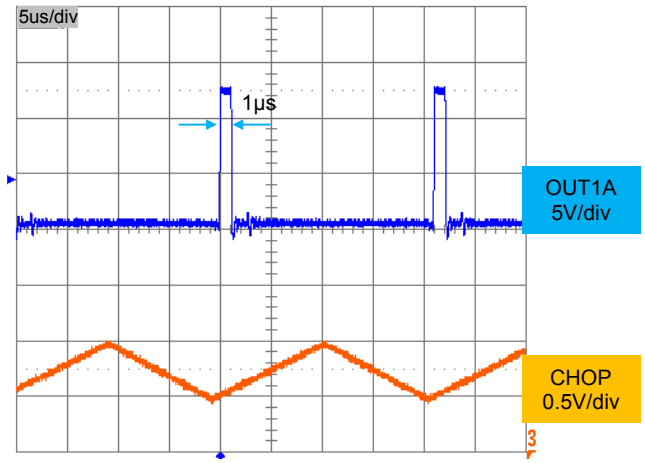


Figure 38. Blanking time waveform

(18)Micro step mode switching operation

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

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 position shown in the following.

1. Microstep (1/128-, 1/64-, 1/32-, 1/16-, 1/8-, Half-step)
   →Microstep (1/128-, 1/64-, 1/32-, 1/16-, 1/8-, Half-step),
   Microstep (1/20-, 1/10-step)
   →Microstep (1/20-, 1/10-step)

   When a microstep switches to the next microstep, the excitation position is switched to the next corresponding step angle of the next microstep mode.

   e.g.) When the rotation direction is forward at 1/8-step, and if you switch to 1/128-step (θ16 - θ47), the step angle is set to θ48 at the next step.
   When the rotation direction is forward at 1/128 step, and if you switch to 1/8-step (θ48), the step angle is set to θ49 at the next step.

2. Microstep (1/128-, 1/64-, 1/32-, 1/16-, 1/8-, Half-step)
   →Microstep (1/20-, 1/10-step),
   Microstep (1/20-, 1/10-step)
   →Microstep (1/128-, 1/64-, 1/32-, 1/16-, 1/8-, Half-step)

   When a microstep is switched to the next, the excitation position is switched to the any step angle of the next microstep mode. Therefore, swiching should be performed when the excitation position comes to the initial position.

   (Please refer to the step angle on pp.16-19 for the description on “θ*”.)

Micro step mode switching operation

Microstep (1/128-, 1/64-, 1/32-, 1/16-, 1/8-, Half-step)
→Microstep (1/128-, 1/64-, 1/32-, 1/16-, 1/8-, Half-step),

VM=24V, VDD=5V
VREF=0.45V, RNF=0.1Ω
PS=High, OE=High, RST=High, fSTEP=600Hz

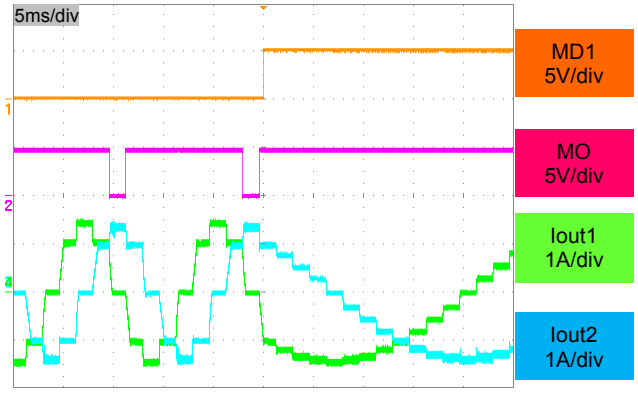


Figure39. Micro step (Half-step)
→ Micro step (1/8-step)
MD2=Low, MD3=Low

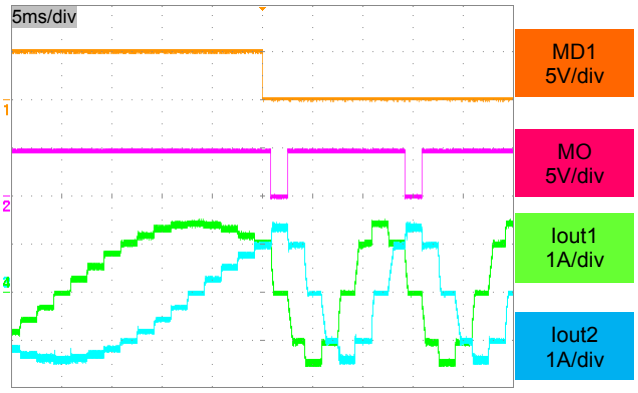


Figure40. Micro step (1/8-step)
→ Micro step (Half-step)
MD2=Low, MD3=Low

Microstep (1/20-, 1/10-step)
→Microstep (1/20-, 1/10-step)

VM=24V, VDD=5V
VREF=0.45V, RNF=0.1Ω
PS=High, OE=High, RST=High, fSTEP=1200Hz

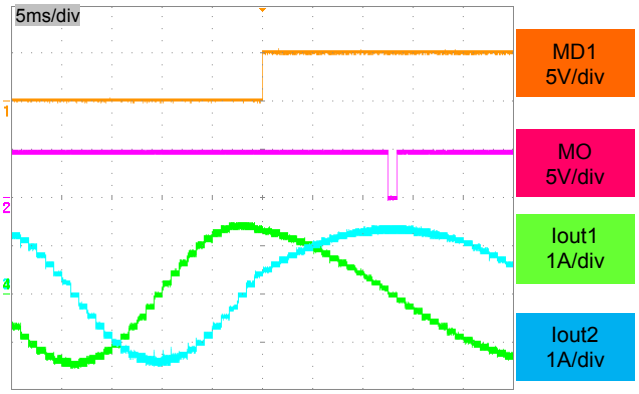


Figure.41 Micro step (1/10-step)
→ Micro step (1/20-step)
MD2=High, MD3=High

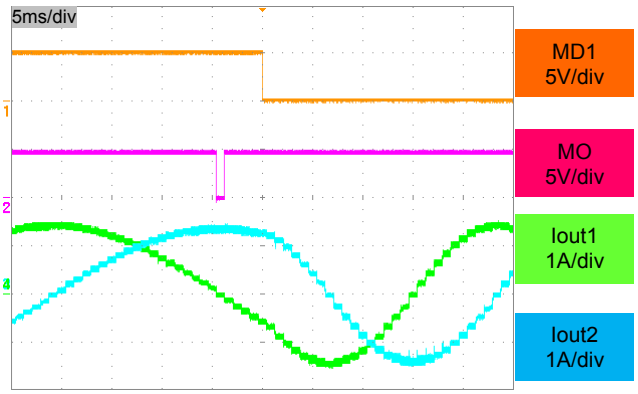
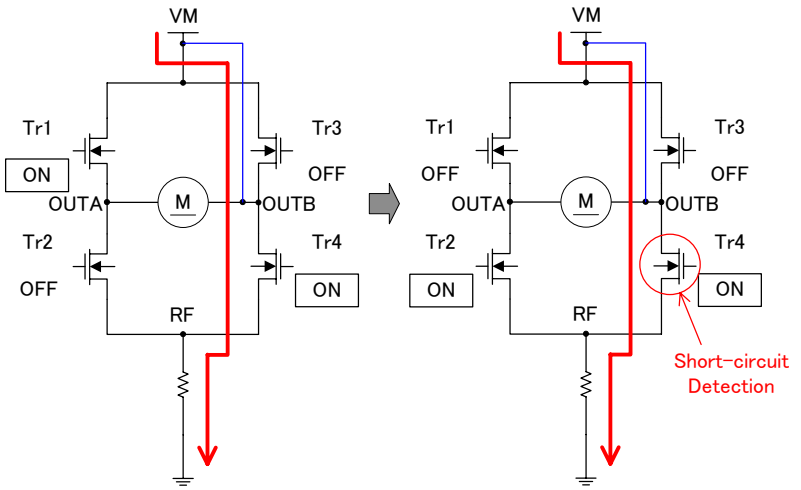
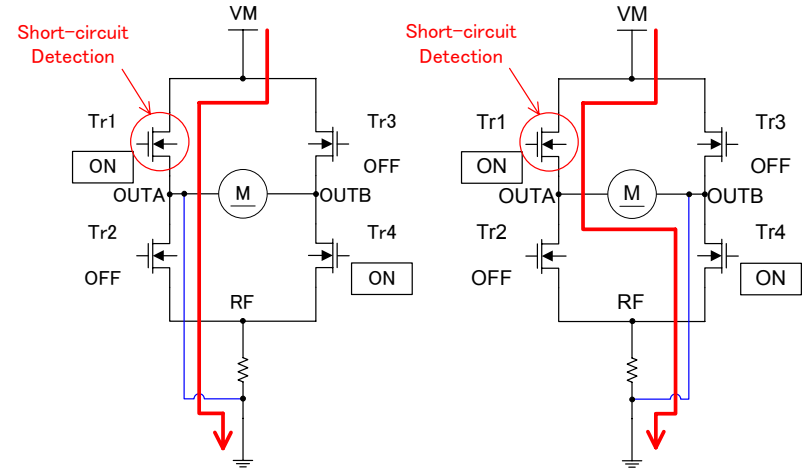
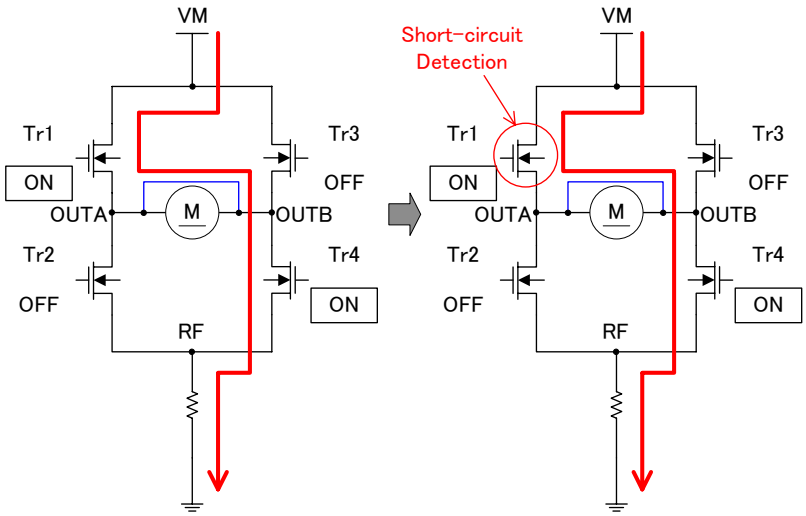


Figure42. Micro step (1/20tep)
→ Micro step (1/10-step)
MD2=High, MD3=High

Output short-circuit protection function

(1) Output short-circuit detection operation

VM short 	1.High current flows if Tr3 and Tr4 are ON. 2.If RF voltage> setting voltage, then the mode switches to SLOW decay. 3.If the voltage between drain and source of Tr4 exceeds the reference voltage for 2μs, short status is detected.
GND short 	(left schematic) 1.High current flows if Tr3 and Tr4 are ON 2. If the voltage between drain and source of Tr1 exceeds the reference voltage for 2μs, short status is detected. (right schematic) 1.Without going through RF resistor, current control does not operate and current will continue to increase in CHARGE mode. 2. If the voltage between drain and source of Tr1 exceeds the reference voltage for 2μs, short status is detected.
Load short 	1.Without L load, high current flows. 2. If RF voltage> setting voltage, then the mode switches to SLOW decay. 3.During load short state in SLOW decay mode, current does not flow and over current state is not detected. Then the mode is switched to FAST decay according to chopping cycle. 4. Since FAST state is short (≈1μs), switches to CHARGE mode before short is detected. 5.If voltage between drain and source 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 2us or so, short is detected.

(2) Output short-circuit protection detect voltage (Reference value)
Short protector operates when abnormal voltage between drain and source of output Tr exceeds the reference voltage.

Ta = 25°C (typ)

	Reference voltage
Upper-side Transistor VDS	3.2V
Lower-side Transistor VDS	0.8V

(3) Timer latch period
Built-in output short-circuit protection circuit makes output to enter in stand-by mode. This function prevents the IC from damaging when the output shorts circuit by a voltage short or a ground short, etc. When output short state is detected for 2μs, short-circuit detection circuit state the operating and output is once turned OFF. Subsequently, the output is turned ON again after the timer latch period (typ. 256μs). If the output remains in the short-circuit state, turn OFF the output, fix the output to the wait mode.
When output is fixed in stand-by mode by output short protection circuit, output is released the latch by setting ST = "L".

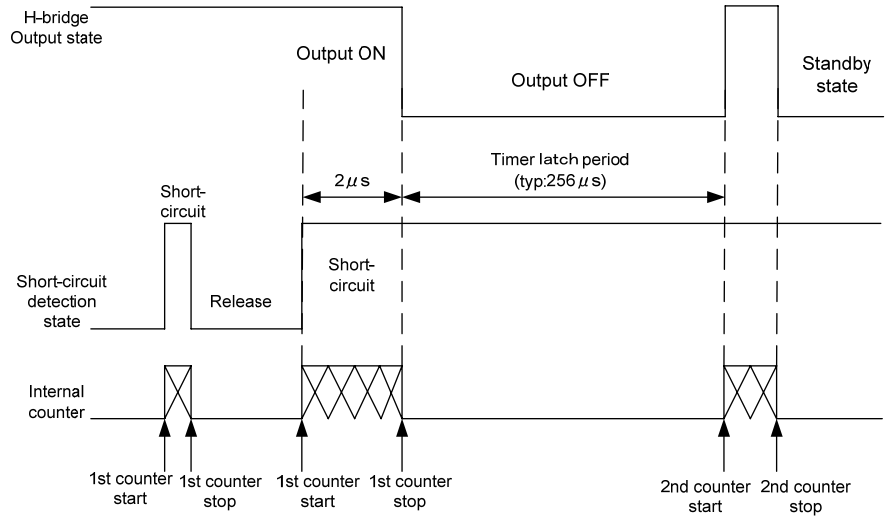


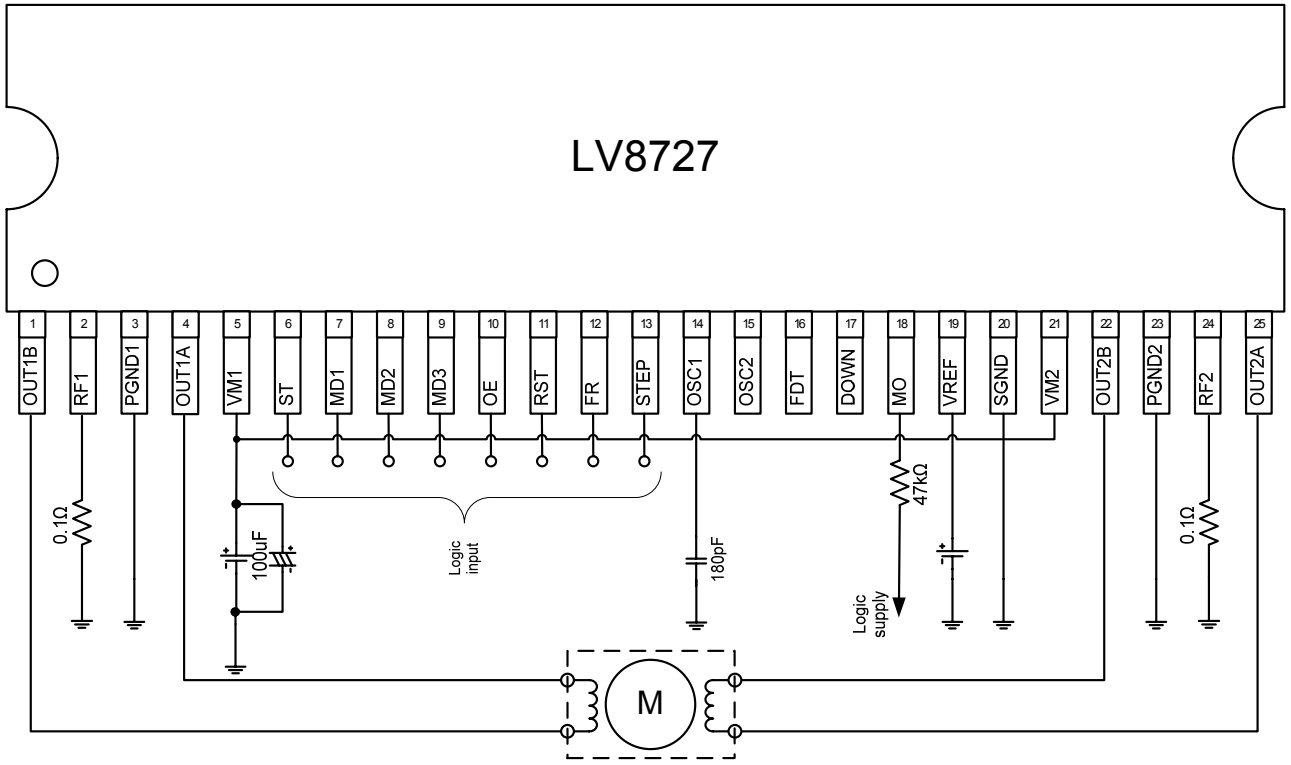
Figure 43 . short-circuit protection function timing chart

Thermal shutdown function

LV8727 incorporates thermal shutdown circuit and the output is turned off when junction temperature Tj exceeds 180°C. When the temperature is lowered to the defined hysteresis, the output is turned on again (automatic restoration).
The thermal shutdown circuit does not guarantee the protection of final products where the junction temperature of Tjmax=150°C has already been exceeded.

TSD = 180°C (typ)
ΔTSD = 40°C (typ)

Application Circuit Example

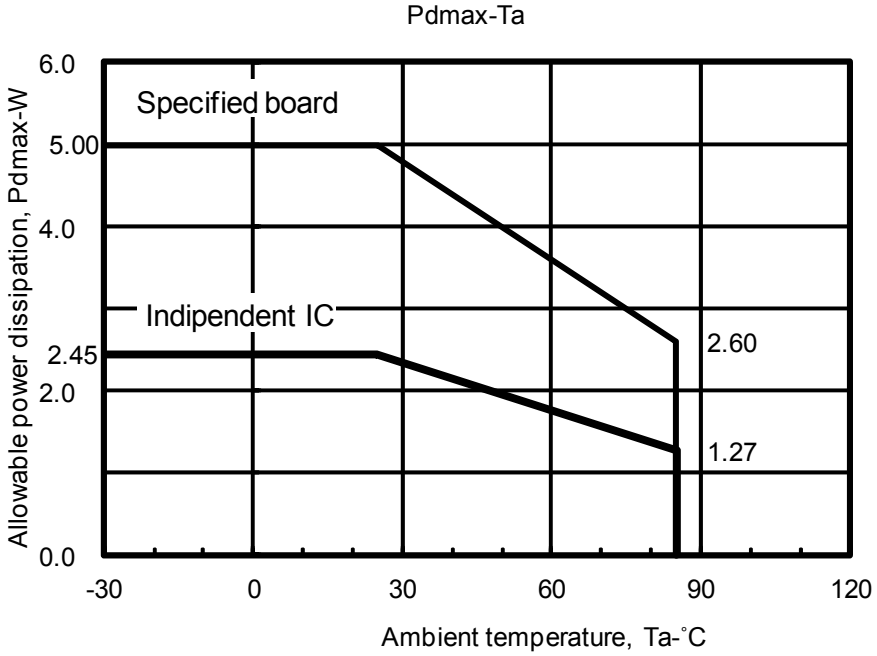


The above sample application circuit is set to the following conditions:
Chopping frequency: 55.5kHz (Cosc1 = 180pF)
Mixed DECAY mode (FDT=open)

The set current value is as follows:
I_{OUT} = (Current setting reference voltage / 3) / 0.1Ω

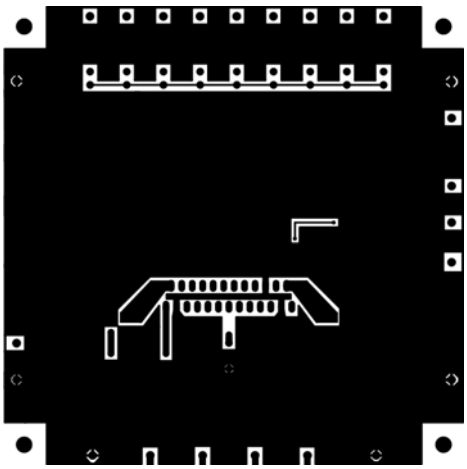
Allowable power dissipation

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

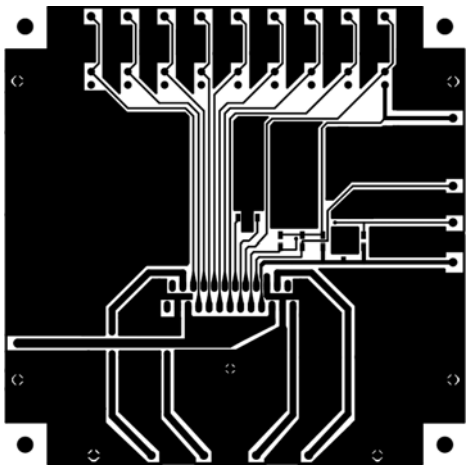


Substrate Specifications (Substrate recommended for operation of LV8727)

Size	: 90mm × 90mm × 1.6mm (two-layer substrate [2S0P])
Material	: Glass epoxy
Copper wiring density	: L1 = 90% / L2 = 80%



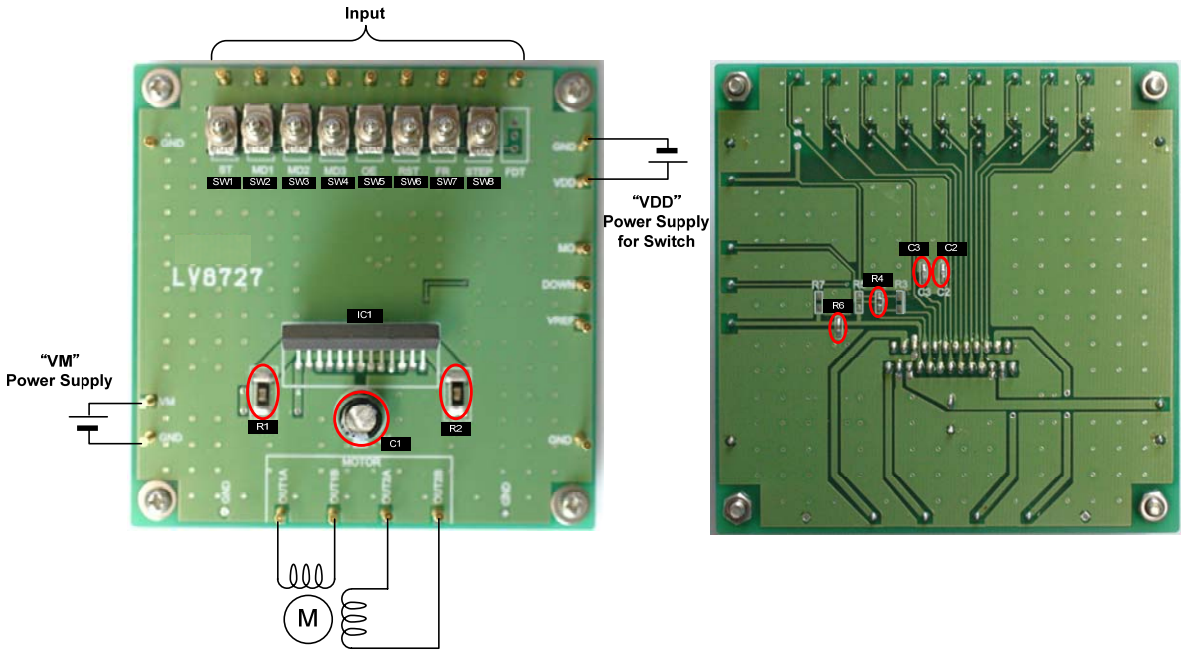
L1 : Copper wiring pattern diagram



L2 : Copper wiring pattern diagram

Evaluation board

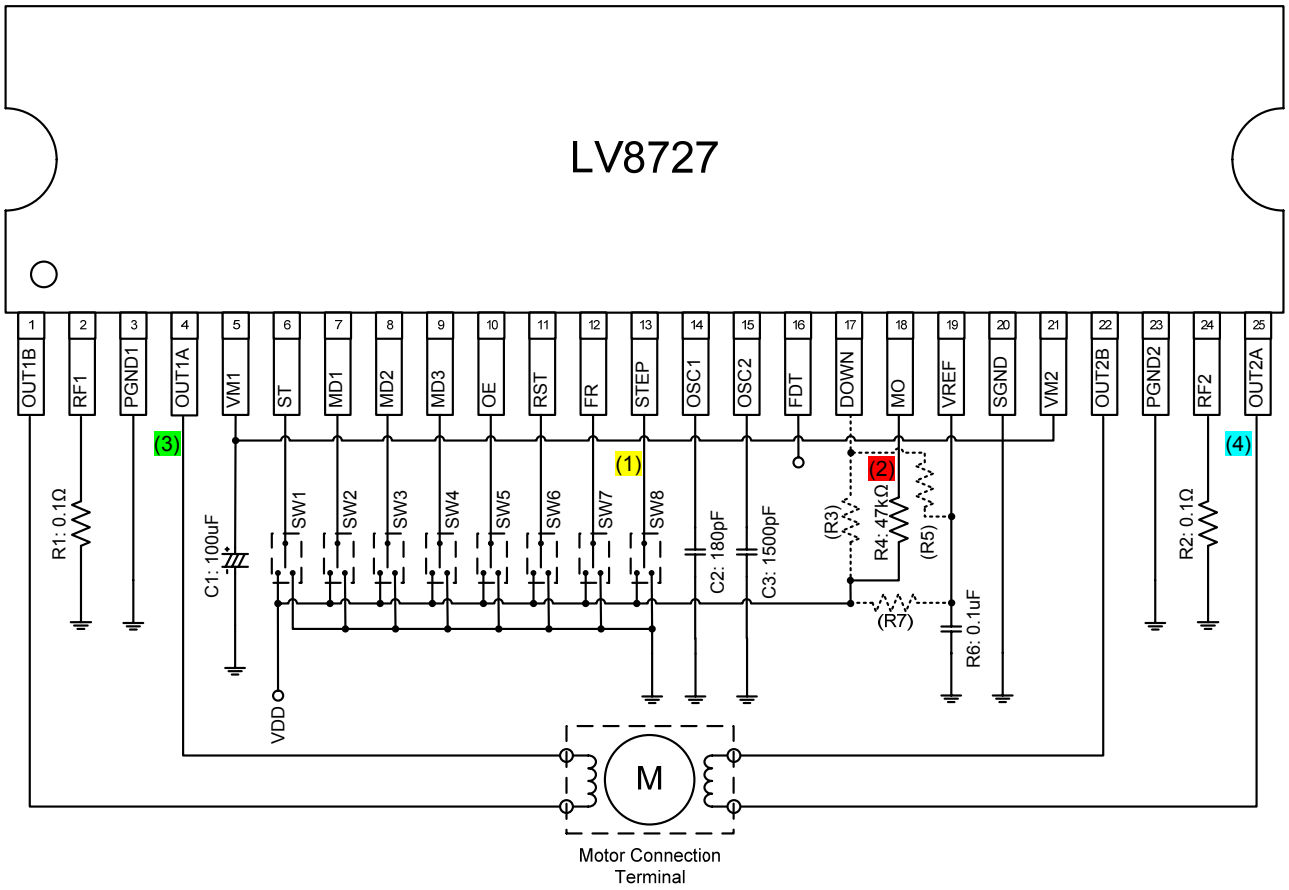
LV8727 (90mm x 90mm x 1.6mm, glass epoxy 2-layer board, with backside mounting)



Bill of Materials for LV8727 Evaluation Board

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
C1	1	VM Bypass capacitor	100µF 100V	±20%		SUN Electronic Industries	100ME100HC	yes	yes
C2	1	Capacitor to set chopping frequency	180pF, 50V	±5%		murata	GRM1882C1H181JA01	yes	yes
C3	1	Capacitor to set switching holding current	1500pF, 50V	±5%		KOA	GRM1882C1H152J	yes	yes
R1	1	Channel 1 output current detective Resistor	0.1?, 1W	±5%		ROHM	MCR100JZHJLR10	yes	yes
R2	1	Channel 2 output current detective Resistor	0.1?, 1W	±5%		ROHM	MCR100JZHJLR10	yes	yes
R4	1	Pull-up Resistor for for terminal MO	47k?, 1/10W	±5%		KOA	RK73B1JT473J	yes	yes
R6	1	VREF stabilization Capacitor	0.1µF, 100V	±10%		murata	GRM188R72A104KA35D	yes	yes
IC1	1	Motor Driver			HZIP25	ON semiconductor	LV8727	No	yes
SW1-SW8	8	Switch				MIYAMA	MS-621-A01	yes	yes
TP1-TP22	22	Test points				MAC8	ST-1-3	yes	yes

Evaluation board circuit



Evaluation Board Manual

[Supply Voltage] VM (9 to 45V): 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]

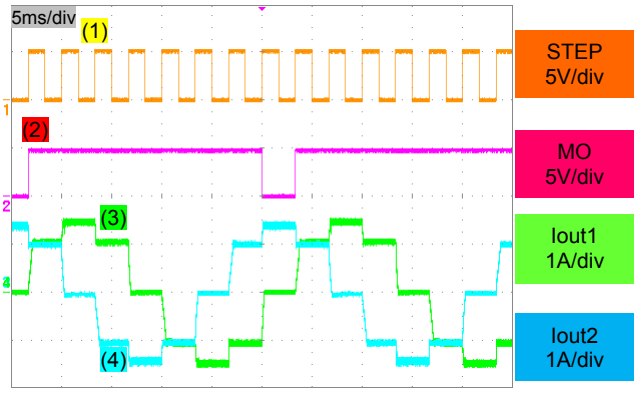
1. **Initial Condition Setting:** Set “Open” the toggle switch STEP, and “Open or Low” the other switches
2. **Motor Connection:** Connect the Motors between OUT1A and OUT1B, between OUT2A and OUT2B.
3. **Power Supply:** Supply DC voltage to VM, VREF and VDD.
4. **Ready for Operation from Standby State:** Turn “High” the following toggle switches : ST , OE, and RST. Channel 1 and 2 are into Half-Step excitement initial position (100%, 0%).
5. **Motor Operation:** Input the clock signal into the terminal STEP.
6. **Other Setting** (See Reference describing operation for detail)
   i. MD1 , MD2 , MD3 : Micro step resolution.
   ii. FR: Motor rotation direction (CW / CCW) setting.
   iii. RST : Initial Mode.
   iv. OE: Output Enable.
   v. FDT: DECAY mode.

[Setting for External Component Value]

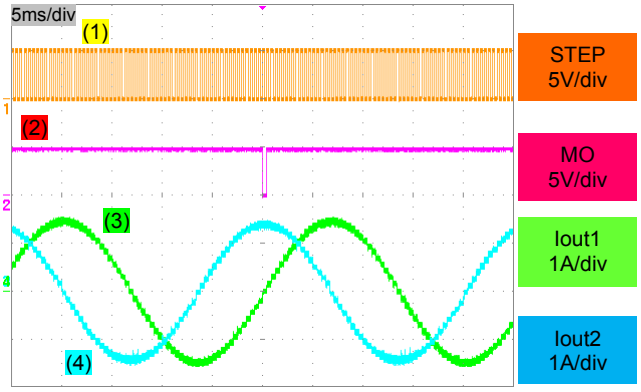
1. Constant Current (100%)
   At VREF=0.9V
   Iout =VREF [V] / 3 / RF [ohm]
   =0.9 [V] / 3 / 0.1 [ohm]
   =3 [A]
2. Chopping Frequency
   Fcp = 1 / (Cosc1 / 10 x 10^{-6}) (Hz)
   =1 / (180 [pF] / 10 x 10^{-6}) (Hz)
   =55.5 [kHz]

Waveform of LV8727 evaluation board.

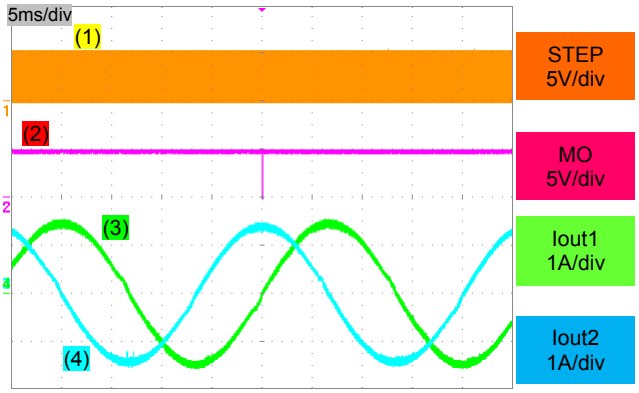
●Figure 44. Half Step
VM=24V , VREF=0.45V , VDD=5V
ST=H , OE=H , RST=H
FR=L
MD1=L , MD2=L , MD3=L
STEP=0.3kHz (Duty 50%)



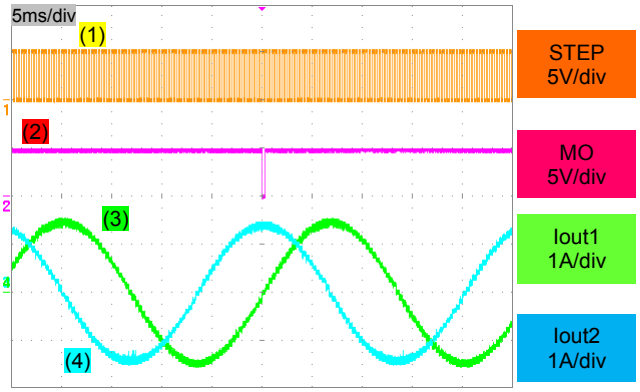
●Figure 45. Half Step
VM=24V , VREF=0.45V , VDD=5V
ST=H , OE=H , RST=H
FR=L
MD1=L , MD2=H , MD3=L
STEP=2.4kHz (Duty 50%)



●Figure 46. 1/128
VM=24V , VREF=1.5V , VDD=5V
ST=H , OE=L , RST=H
FR=L
MD1=L , MD2=L , MD3=H
STEP=19.2kHz (Duty 50%)



●Figure 47. 1/20 Step
VM=24V , VREF=1.5V , VDD=5V
ST=H , OE=H , RST=H
FR=L
MD1=H , MD2=H , MD3=H
STEP=3.0kHz (Duty 50%)



Warning:

●Power supply connection terminal [VM1, VM2]

- ✓ Make sure to short-circuit 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, PGND]

- ✓ 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.)

●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).
- ✓ FDT input is 3-state level (see pp.15).
- ✓ 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.