

LV8728MR

Stepper Motor Driver, PWM, Constant-Current Control, 1/128 step



ON Semiconductor®

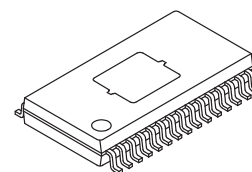
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Overview

The LV8728MR is a PWM current-controlled micro step stepper motor driver. This driver can perform eight types of excitation mode from Full step to 1/128 step and can drive simply by the CLK input.

Function

- Single-channel PWM current control stepper motor driver
- BiCDMOS process IC
- Output on-resistance (upper side: 0.3Ω ; lower side: 0.25Ω ; total of upper and lower: 0.55Ω ; $T_a = 25^\circ\text{C}$, $I_O = 2.0\text{A}$)
- Full, Half, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128 step excitation mode are selectable
- Advance the excitation step with the only step signal input
- Available forward reverse control
- $I_O \text{ max} = 2.0\text{A}$
- Over-current protection circuit
- Thermal shutdown circuit
- Input pull down resistance
- With reset pin and enable pin.



MFP30KR (375mil)

ORDERING INFORMATION

Ordering Code:
LV8728MR-AH

Package
MFP30KR
(Pb-Free / Halogen Free)

Shipping (quantity/packing)
1000 / Tape & Reel

Typical Applications

- Printer (Multi-function printer, 3D printer, etc.)
- Security camera
- Scanner
- Stage light

† For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.
http://www.onsemi.com/pub_link/Collateral/BRD8011-D.PDF

Maximum Ratings (Note 1)

Parameter	Symbol	Conditions	Ratings	Unit
Maximum supply voltage	$V_M \text{ max}$	V_M , V_{M1} , V_{M2}	36	V
Maximum output current	$I_O \text{ max}$	Per 1ch	2.0	A
Maximum logic input voltage	$V_{IN} \text{ max}$	ST, MD1, MD2, MD3, OE, RST, FR, STEP	6	V
Maximum VREF input voltage	$V_{REF} \text{ max}$		6	V
Maximum MO input voltage	$V_{MO} \text{ max}$		6	V
Maximum DOWN input voltage	$V_{DOWN} \text{ max}$		6	V
Allowable power dissipation (Note 2)	$P_d \text{ max}$		1.55	W
Operating temperature	T_{opr}		-30 to +85	$^\circ\text{C}$
Storage temperature	T_{stg}		-55 to +150	$^\circ\text{C}$

1. Stresses exceeding those listed in the Absolute Maximum Rating table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

2. Specified circuit board: 76.1mm×114.3mm×1.6mm, glass epoxy board.

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Recommended Operating Ranges (Note 3)

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage range	VM	VM, VM1, VM2	9 to 32	V
Logic input voltage	V _{IN}	ST, MD1, MD2, MD3, OE, RST, FR, STEP	0 to 5	V
VREF input voltage range	VREF		0 to 3	V

3. Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

Electrical Characteristics at Ta=25°C, VM=24V, VREF=1.5V unless otherwise noted. (Note 4)

Parameter		Symbol	Conditions	Ratings			Unit
				min	typ	max	
Standby mode current drain		I _{Mst}	ST = "L", VM+VM1+VM2		70	100	μA
Current drain		I _M	ST = "H", OE = "H", no load VM+VM1+VM2		3.3	4.6	mA
Thermal shutdown temperature		TSD	Guaranteed by design	150	180	200	°C
Thermal hysteresis width		ΔTSD	Guaranteed by design		40		°C
Logic pin input current		I _{INL}	ST, MD1, MD2, MD3, OE, RST, FR, STEP, V _{IN} = 0.8V	3	8	15	μA
		I _{INH}	ST, MD1, MD2, MD3, OE, RST, FR, STEP, V _{IN} = 5V	30	50	70	μA
Logic input voltage	High	V _{INH}	ST, MD1, MD2, MD3, OE, RST, FR, STEP	2.0		5.0	V
	Low	V _{INL}		0		0.8	V
FDT pin high level voltage		V _{fdth}		3.5			V
FDT pin middle level voltage		V _{fdtm}		1.1		3.1	V
FDT pin low level voltage		V _{fdtl}				0.8	V
Chopping frequency		F _{ch}	Cosc1 = 100pF	70	100	130	kHz
OSC1 pin charge/discharge current		I _{osc1}		7	10	13	μA
Chopping oscillation circuit threshold voltage		V _{tup1}		0.8	1	1.2	V
		V _{tdown1}		0.3	0.5	0.7	V
VREF pin input voltage		I _{ref}	VREF = 1.5V	-0.5			μA
DOWN output residual voltage		V _{OIDOWN}	I _{down} = 1mA		40	100	mV
MO pin residual voltage		V _{OIMO}	I _{mo} = 1mA		40	100	mV
Hold current switching frequency		F _{down}	Cosc2 = 1500pF	1.12	1.6	2.08	Hz
OSC1 pin charge/discharge current		I _{osc2}		7	10	13	μA
Hold current switching frequency threshold voltage		V _{tup2}		0.8	1	1.2	V
		V _{tdown2}		0.3	0.5	0.7	V
VREG1 output voltage		V _{reg1}		4.7	5	5.3	V
VREG2 output voltage		V _{reg2}		18	19	20	V
Output on-resistance		R _{onu}	I _O = 2.0A, upper side ON resistance		0.3	0.42	Ω
		R _{ond}	I _O = 2.0A, lower side ON resistance		0.25	0.35	Ω
Output leakage current		I _{Oleak}	V _M = 36V			50	μA
Diode forward voltage		V _D	I _D = -2.0A		1.1	1.4	V
Current setting reference voltage		V _{RF}	VREF = 1.5V, Current ratio 100%	0.285	0.3	0.315	V

4. Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted.
Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

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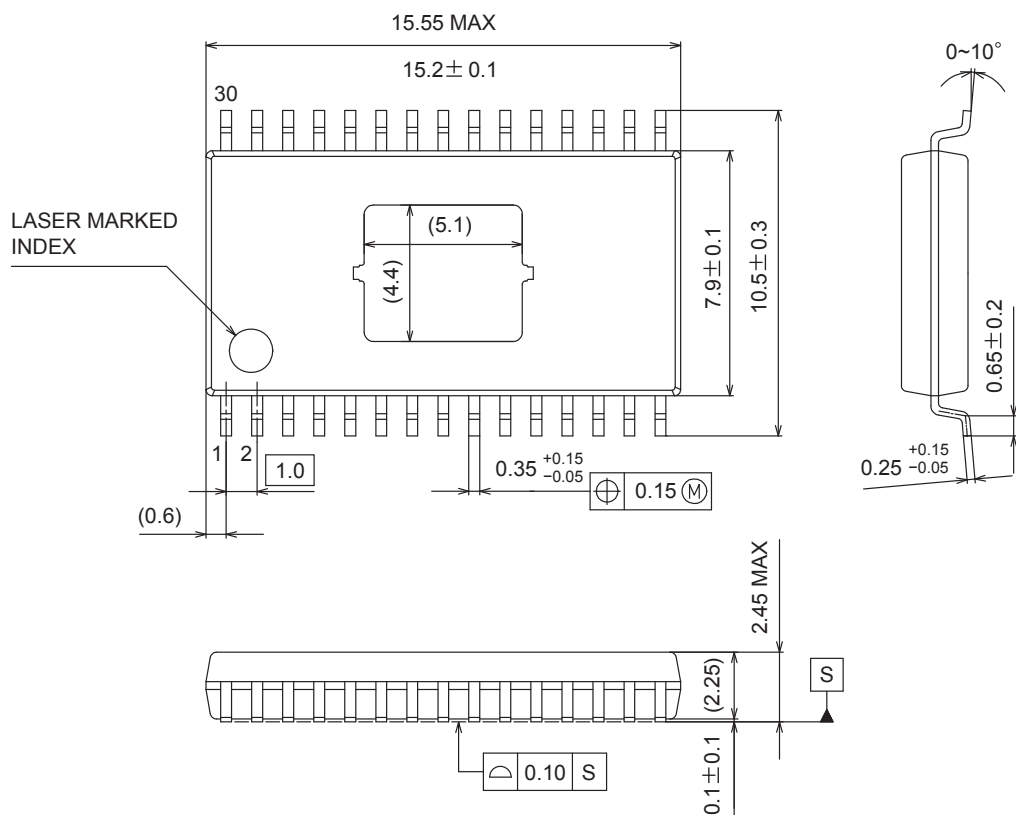
Package Dimensions

unit : mm

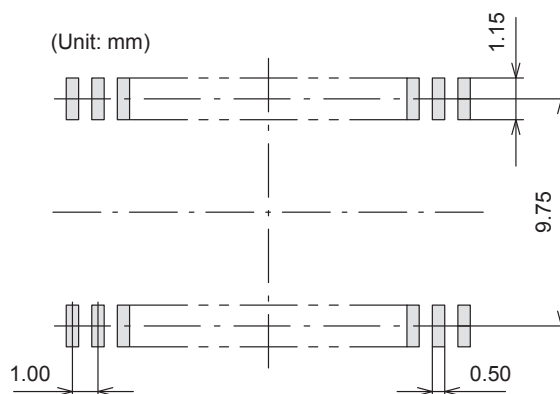
SOIC30 W / MFP30KR (375 mil)

CASE 751CH

ISSUE A



SOLDERING FOOTPRINT*

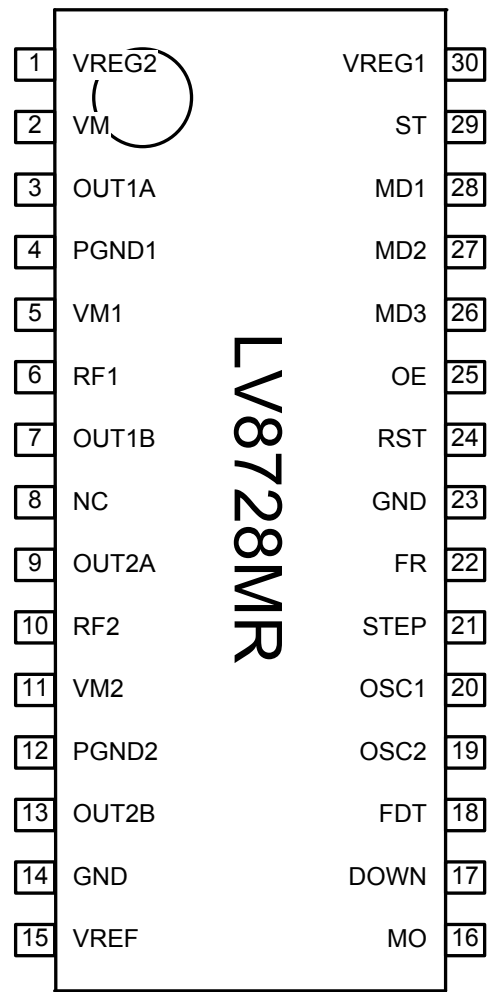


NOTE: The measurements are not to guarantee but for reference only.

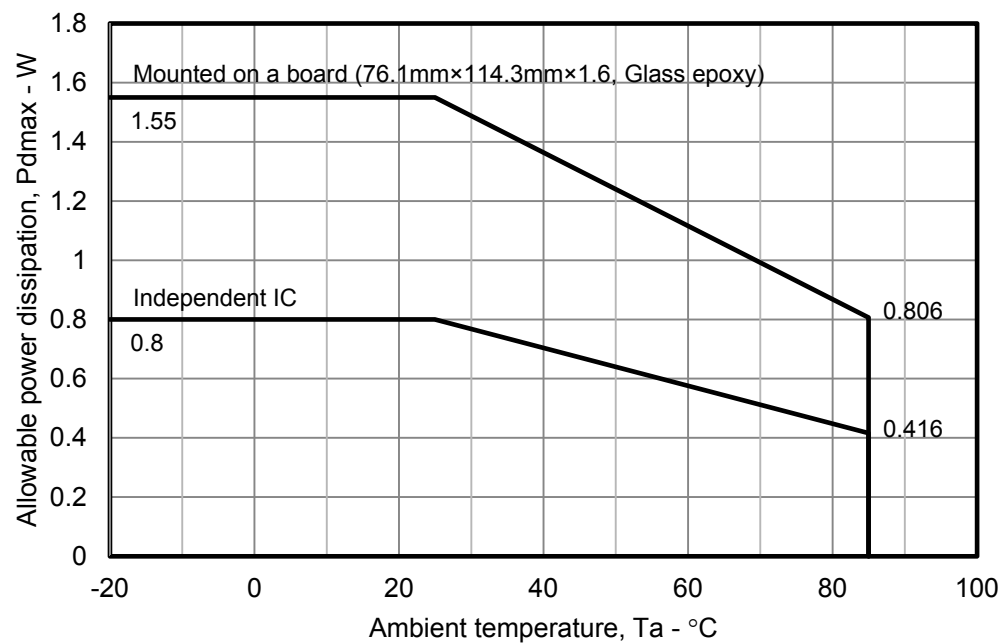
*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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Pin Assignment

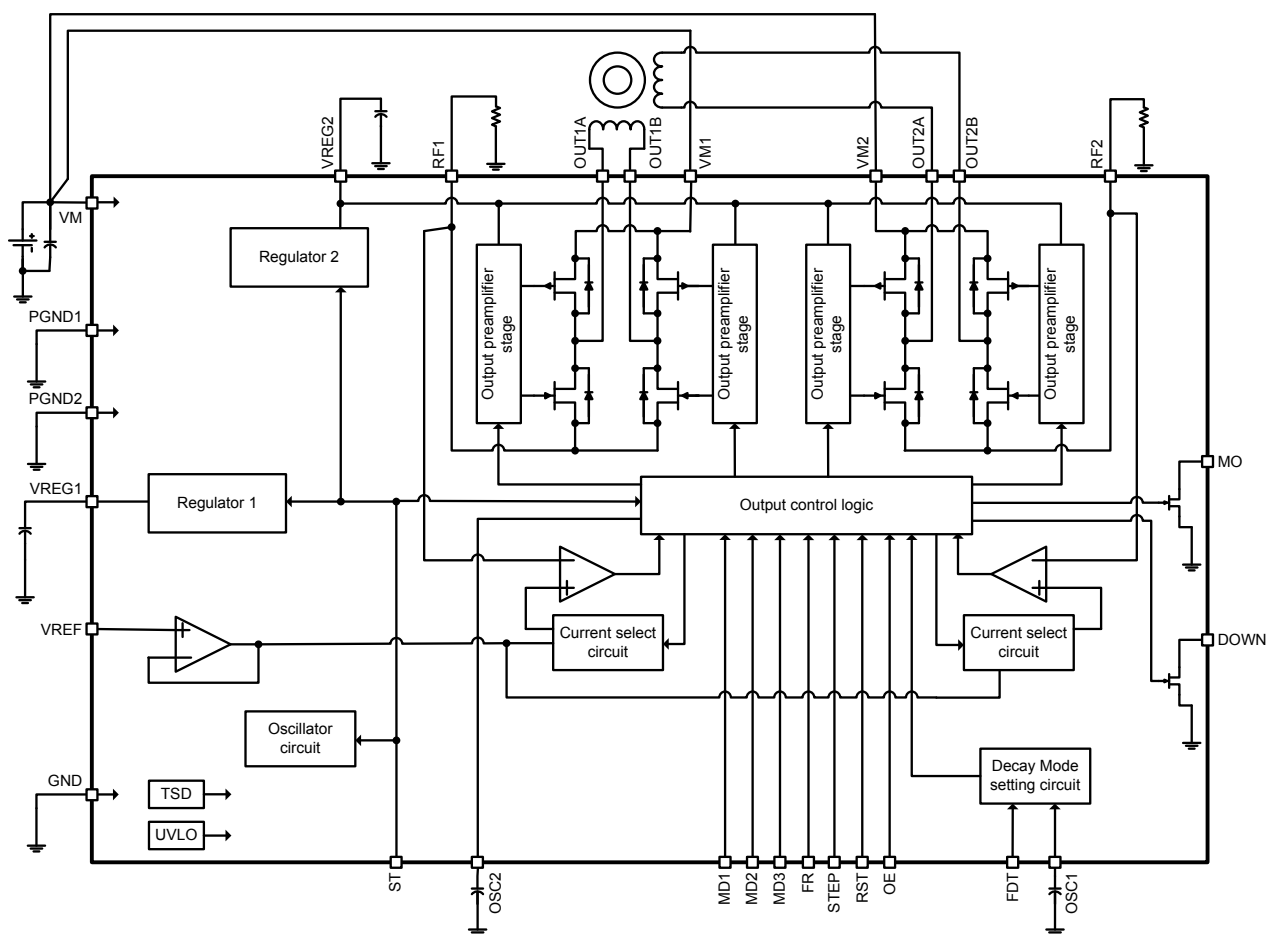


Pd max – Ta



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Block Diagram



Pin Functions

Pin No.	Pin Name	Pin Function	Equivalent Circuit
21 22 24 25 26 27 28	STEP FR RST OE MD3 MD2 MD1	Step clock pulse signal input pin Forward / Reverse signal input pin Reset signal input pin Output enable signal input pin Excitation mode switching pin Excitation mode switching pin Excitation mode switching pin	
29	ST	Chip enable pin	
3 4 5 6 7 9 10 11 12 13	OUT1A PGND1 VM1 RF1 OUT1B OUT2A RF2 VM2 PGND2 OUT2B	Channel 1 output A pin Channel 1 Power ground pin Channel 1 motor power supply pin Channel 1 current sense resistor pin Channel 1 output B pin Channel 2 output A pin Channel 2 current sense resistor pin Channel 2 motor power supply pin Channel 2 Power ground pin Channel 2 output B pin	
15	VREF	Constant-current control reference voltage input pin.	

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Pin No.	Pin Name	Pin Function	Equivalent Circuit
1	VREG2	Internal regulator capacitor connection pin.	
30	VREG1	Internal regulator capacitor connection pin.	
16 17	MO DOWN	Output pin for position detecting Output pin for holding current reduction	
19 20	OSC2 OSC1	Capacitor connection pin for STEP signal off detection time setting When not using the current reduction by DOWN pin, need to connect OSC2 pin to GND at 10kΩ (recommended value). Capacitor connection pin for chopping frequency setting.	
14 23	GND GND	Ground pin	

Functional Description

1. Input Pin Function

Each input terminal has the function to prevent the flow of the current from an input to a power supply. Therefore, Even if a power supply (VM) is turned off in the state that applied voltage to an input terminal, the electric current does not flow into the power supply.

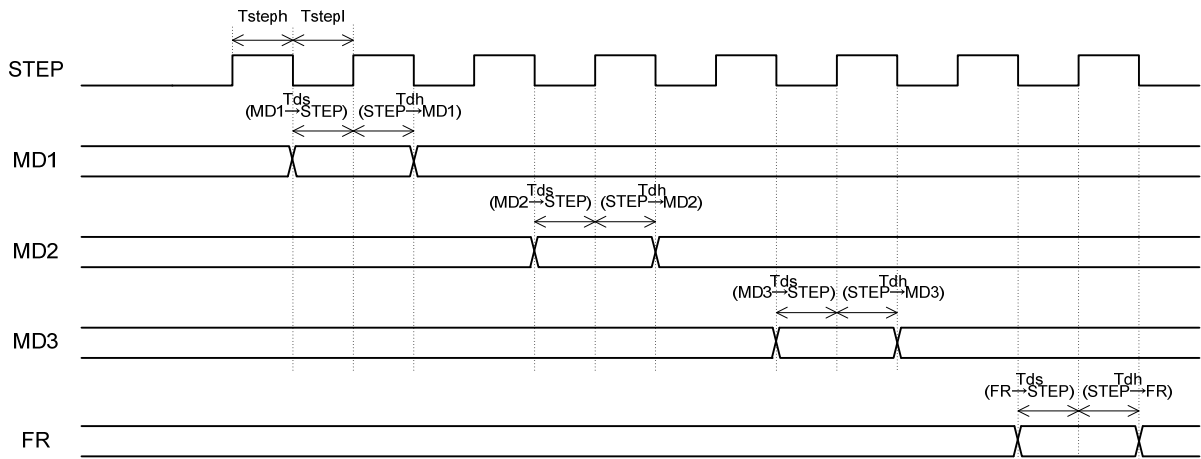
2. Stand-by function

When ST pin is at low levels, the IC enters stand-by mode, all logic is reset and output is turned OFF. When ST pin is at high levels, the stand-by mode is released.

3. STEP pin function

Input		Operating mode
ST	STEP	
Low	Don't care	Standby mode
High		Excitation step is proceeded
High		Excitation step is kept

4. Input Timing



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

5. Position detection monitor function

The MO position detection monitoring pin is an 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.")

MO	Status
ON	Initial position
OFF	Except initial position

6. Excitation mode setting function

Set the excitation setting as shown in the following

table by setting MD1 pin, MD2 pin and MD3 pin.

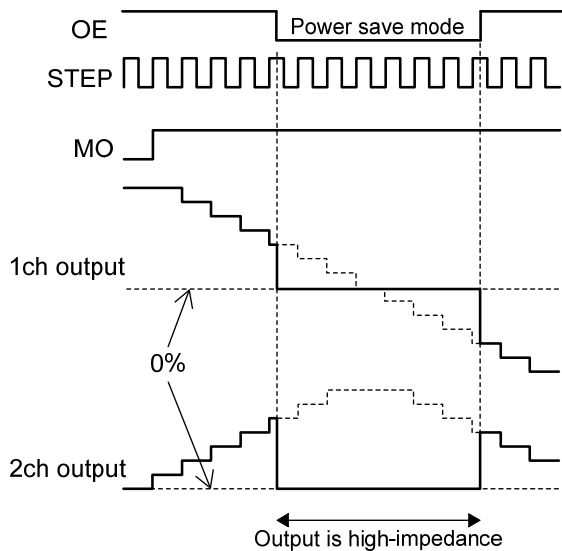
Input			Excitation mode	Initial position	
MD3	MD2	MD1		1ch current	2ch current
Low	Low	Low	Full step	100%	-100%
Low	Low	High	Half step	100%	0%
Low	High	Low	1/4 step	100%	0%
Low	High	High	1/8 step	100%	0%
High	Low	Low	1/16 step	100%	0%
High	Low	High	1/32 step	100%	0%
High	High	Low	1/64 step	100%	0%
High	High	High	1/128 step	100%	0%

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

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 that is advanced by the STEP input.

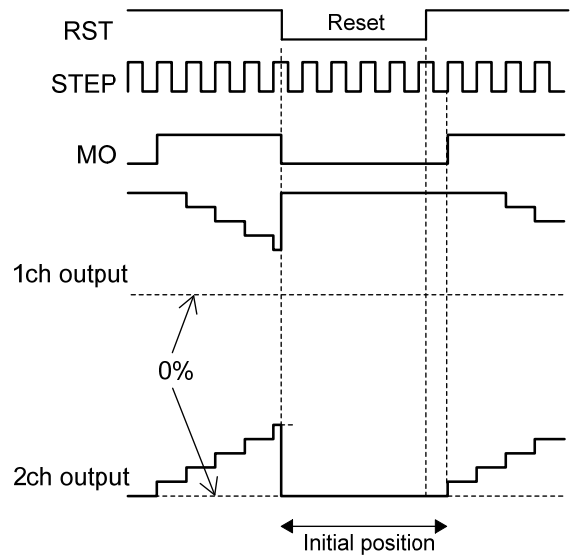
OE	Operating mode
Low	Output OFF
High	Output ON



8. Reset function

When the RST pin is set Low, the excitation position of the output is set to the initial position forcibly and MO pin output is turn ON state. And then by setting RST pin is High, the excitation position moves forward with the next step signal.

RST	Operating mode
Low	Reset status
High	Normal operation



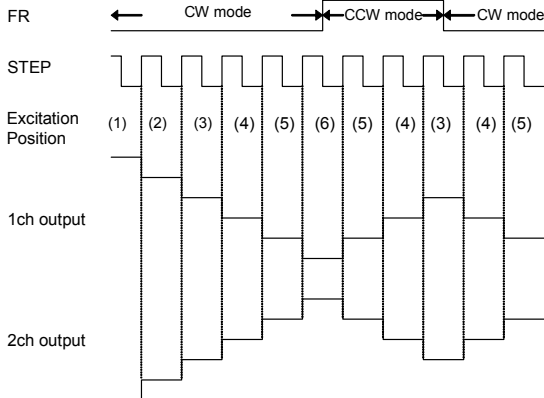
9. Forward / Reverse switching

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.

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



10. Decay mode setting

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

FDT voltage	Decay mode
3.5V to 5.0V	SLOW Decay
1.1V to 3.1V or Open	MIXED Decay
0V to 0.8V	FAST Decay

11. Output current setting

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

$$I_{OUT} = \frac{V_{REF}}{5 \cdot R_{RFx}}$$

The setting current value above is a 100% output current in each excitation mode.

Where,

I_{OUT} : Coil current [A]

R_{RFx} : Resistor between RF1 (2) and GND [Ω]

V_{REF} : Input voltage at the VREF pin [V]

For example, when $V_{REF} = 1.1V$ and RF1 (2) resistance is 0.22Ω , the setting current is shown below:

$$I_{OUT} = \frac{1.1}{5 \times 0.22} = 1.0 [A]$$

12. Chopping frequency setting

For constant-current control, LV8728 performs PWM operation at the chopping frequency determined by the capacitor (COSC1) connected between the OSC1 pin and GND.

The calculation for the value of chopping frequency is:

$$F_{ch} = \frac{I_{OSC1}}{C_{OSC1}}$$

Where,

F_{ch} : Chopping frequency [Hz]

I_{OSC1} : Charge/ Discharge current of OSC1pin [A].

I_{OSC1} is 10uA (typ) by electrical Characteristics.

C_{OSC1} : Capacitor for chopping frequency setting [F]

For example, when $C_{OSC1}=100pF$ and $I_{OSC1}=10uA$ (typ), the chopping frequency is shown below:

$$F_{ch} = \frac{10 \times 10^{-6}}{100 \times 10^{-12}} = 100 [kHz]$$

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.

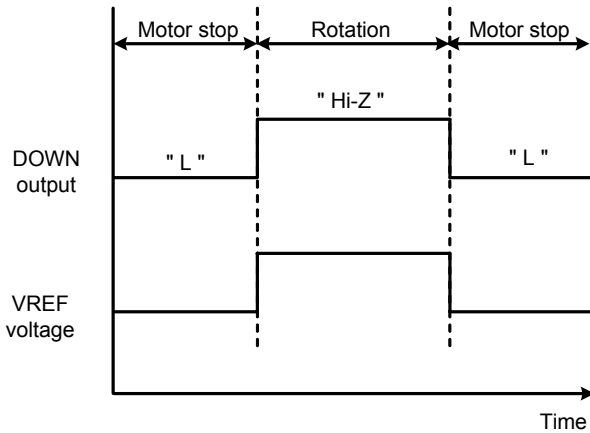
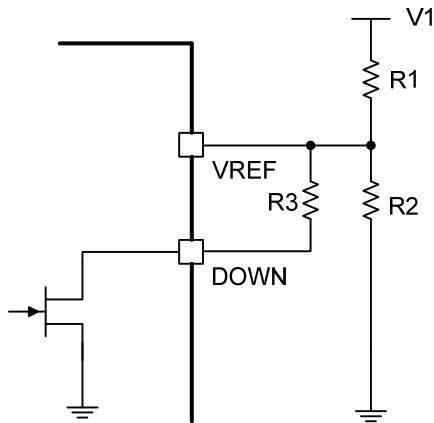
13. Blanking time

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 the blanking time, even if noise is generated in sense resistor, a mode does not switch from CHARGE to DECAY. In this IC, the blanking time is fixed to approximately $1\mu s$.

14. DOWN output pin for holding current reduction
The DOWN output pin is an open drain type. When DOWN pin is turned ON, the motor is holding current.

DOWN	Status
ON	Holding current
OFF	Normal operation

To avoid applying high current to a motor coil for long term at one position, the DOWN output may be used to reduce the reference current. The DOWN is asserted when the step clock interval is longer than TDOWN (STEP signal off detection time). With the circuit is shown in below. VREF voltage can be reduced when the DOWN is turned ON. The open-drain output in once turned ON, is turned OFF at the next rising edge of STP.



For example, when $V1=5V$, $R1=68k\Omega$, $R2=30k\Omega$, $R3=5k\Omega$, $R_{RF1(2)}=0.22\Omega$, the VREF voltage is shown below:

$R_{RF1(2)}$ is Resistor between RF1 (2) and GND [Ω]
VREF is input voltage at the VREF pin [V]

When the DOWN is turned OFF

$$V_{REF} = \frac{5 \times 30}{68 + 30} \approx 1.53 [V]$$

$$I_{OUT} = \frac{1.53}{5 \times 0.22} \approx 1.39 [A]$$

When the DOWN is turned ON, combined resistor of R2 and R3 is about 4.3k Ω .

$$V_{REF} = \frac{5 \times 4.3}{68 + 4.3} \approx 0.3 [V]$$

$$I_{OUT} = \frac{0.3}{5 \times 0.22} \approx 0.27 [A]$$

15. SETP signal off detection time setting

STEP signal off time is determined by the capacitor (COSC2) connected between the OSC2 pin and GND. When this function is unused, connect OSC2 pin to GND at 10k Ω (recommendation). The calculation for the value of STEP signal off detection time is:

$$T_{DOWN} = C_{OSC2} \times 0.4 \times 10^9$$

Where,

T_{DOWN} : STEP signal off detection time [Sec]

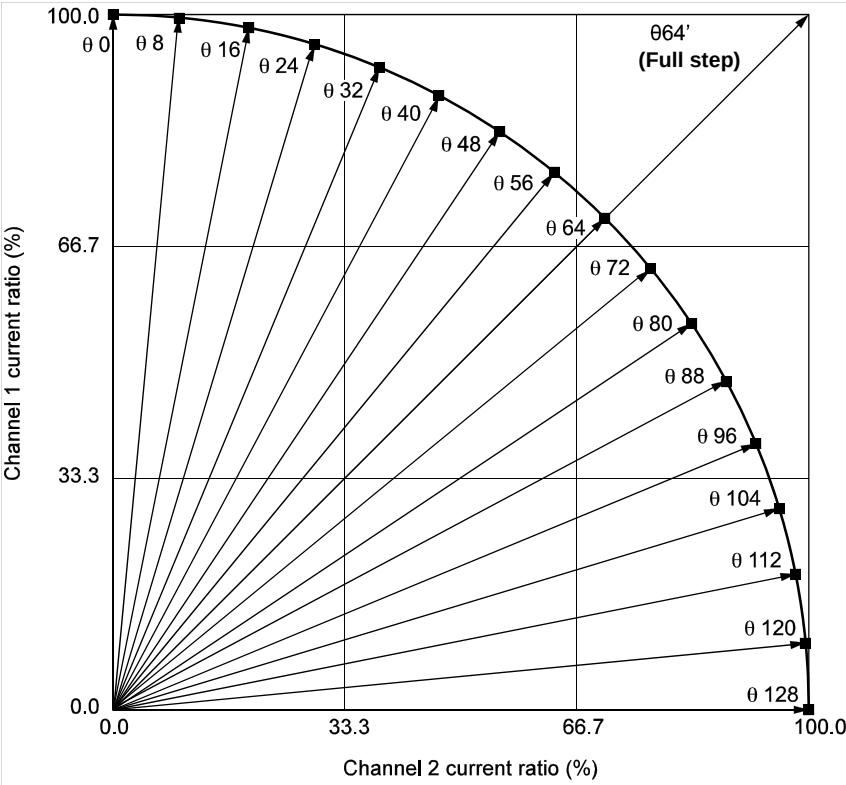
C_{OSC2} : Capacitor for STEP signal off time [F]

For example, when $COSC2=1500pF$, the STEP signal off detection time is shown below:

$$T_{DOWN} = 1500 \times 10^{-12} \times 0.4 \times 10^9 = 0.6 [Sec]$$

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



Current setting ratio in each excitation mode

STEP	1/128 step (%)		1/64 step (%)		1/32 step (%)		1/16 step (%)		1/8 step (%)		1/4 step (%)		Half step (%)		Full step (%)	
	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch
00	100	0	100	0	100	0	100	0	100	0	100	0	100	0		
01	100	1														
02	100	2	100	2												
03	100	4														
04	100	5	100	5	100	5										
05	100	6														
06	100	7	100	7												
07	100	9														
08	100	10	100	10	100	10	100	10								
09	99	11														
010	99	12	99	12												
011	99	13														
012	99	15	99	15	99	15										
013	99	16														
014	99	17	99	17												
015	98	18														
016	98	20	98	20	98	20	98	20	98	20						
017	98	21														
018	98	22	98	22												
019	97	23														
020	97	24	97	24	97	24										
021	97	25														
022	96	27	96	27												
023	96	28														
024	96	29	96	29	96	29	96	29								
025	95	30														

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STEP	1/128 step		1/64 step (%)		1/32 step (%)		1/16 step (%)		1/8 step (%)		1/4 step (%)		Half step (%)		Full step (%)	
	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch
026	95	31	95	31												
027	95	33														
028	94	34	94	34	94	34										
029	94	35														
030	93	36	93	36												
031	93	37														
032	92	38	92	38	92	38	92	38	92	38	92	38				
033	92	39														
034	91	41	91	41												
035	91	42														
036	90	43	90	43	90	43										
037	90	44														
038	89	45	89	45												
039	89	46														
040	88	47	88	47	88	47	88	47								
041	88	48														
042	87	49	87	49												
043	86	50														
044	86	51	86	51	86	51										
045	85	52														
046	84	53	84	53												
047	84	55														
048	83	56	83	56	83	56	83	56	83	56						
049	82	57														
050	82	58	82	58												
051	81	59														
052	80	60	80	60	80	60										
053	80	61														
054	79	62	79	62												
055	78	62														
056	77	63	77	63	77	63	77	63								
057	77	64														
058	76	65	76	65												
059	75	66														
060	74	67	74	67	74	67										
061	73	68														
062	72	69	72	69												
063	72	70														
064	71	71	71	71	71	71	71	71	71	71	71	71	71	71	100	100
065	70	72														
066	69	72	69	72												
067	68	73														
068	67	74	67	74	67	74										
069	66	75														
070	65	76	65	76												
071	64	77														
072	63	77	63	77	63	77	63	77								
073	62	78														
074	62	79	62	79												
075	61	80														
076	60	80	60	80	60	80										
077	59	81														
078	58	82	58	82												
079	57	82														
080	56	83	56	83	56	83	56	83	56	83						
081	55	84														
082	53	84	53	84												
083	52	85														
084	51	86	51	86	51	86										
085	50	86														
086	49	87	49	87												
087	48	88														
088	47	88	47	88	47	88	47	88								
089	46	89														
090	45	89	45	89												

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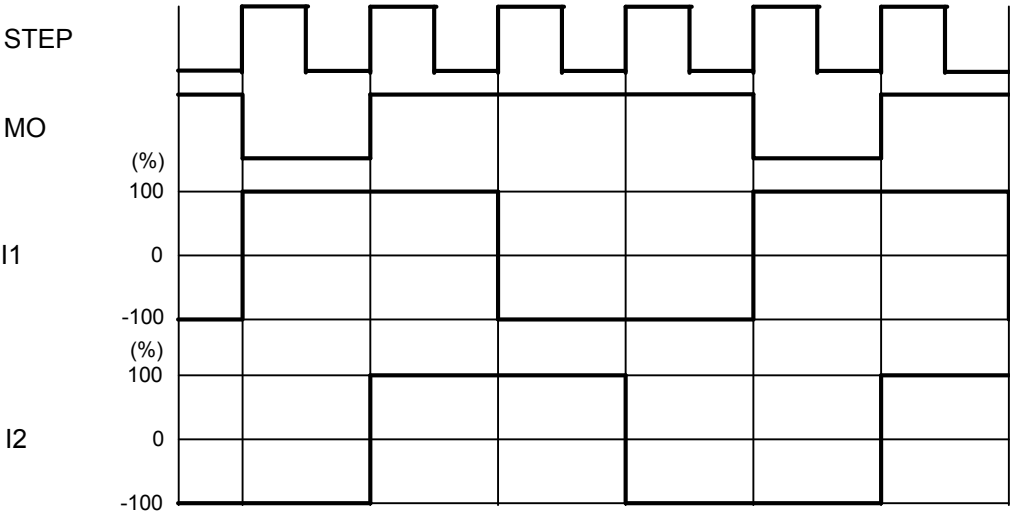
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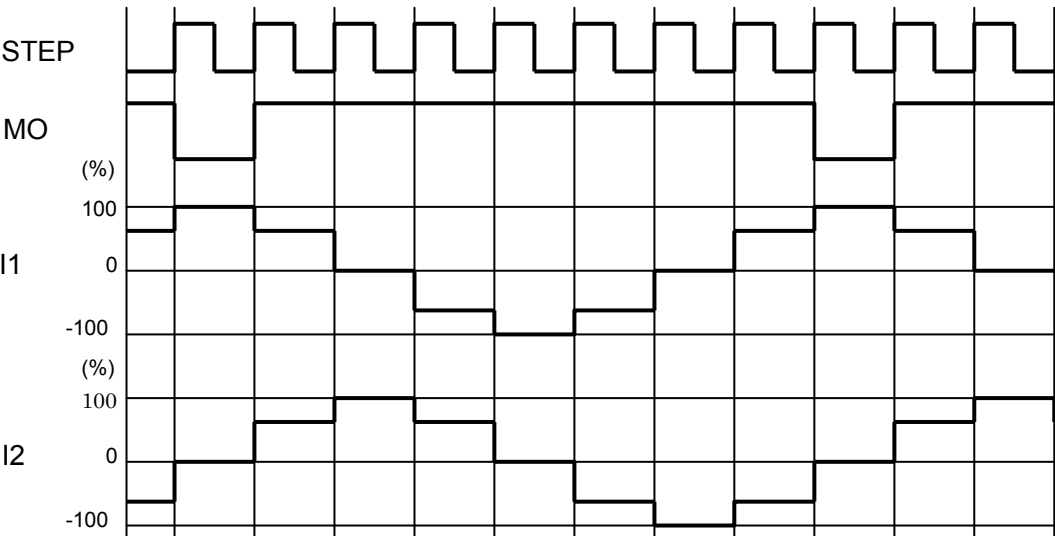
STEP	1/128 step		1/64 step (%)		1/32 step (%)		1/16 step (%)		1/8 step (%)		1/4 step (%)		Half step (%)		Full step (%)	
	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch	1ch	2ch
091	44	90														
092	43	90	43	90	43	90										
093	42	91														
094	41	91	41	91												
095	39	92														
096	38	92	38	92	38	92	38	92	38	92	38	92				
097	37	93														
098	36	93	36	93												
099	35	94														
0100	34	94	34	94	34	94										
0101	33	95														
0102	31	95	31	95												
0103	30	95														
0104	29	96	29	96	29	96	29	96								
0105	28	96														
0106	27	96	27	96												
0107	25	97														
0108	24	97	24	97	24	97										
0109	23	97														
0110	22	98	22	98												
0111	21	98														
0112	20	98	20	98	20	98	20	98	20	98						
0113	18	98														
0114	17	99	17	99												
0115	16	99														
0116	15	99	15	99	15	99										
0117	13	99														
0118	12	99	12	99												
0119	11	99														
0120	10	100	10	100	10	100	10	100								
0121	9	100														
0122	7	100	7	100												
0123	6	100														
0124	5	100	5	100	5	100										
0125	4	100														
0126	2	100	2	100												
0127	1	100														
0128	0	100	0	100	0	100	0	100	0	100	0	100	0	100		

17. Current wave example in each excitation mode (Full, Half, 1/16, 1/128 step)

Full step (CW mode)

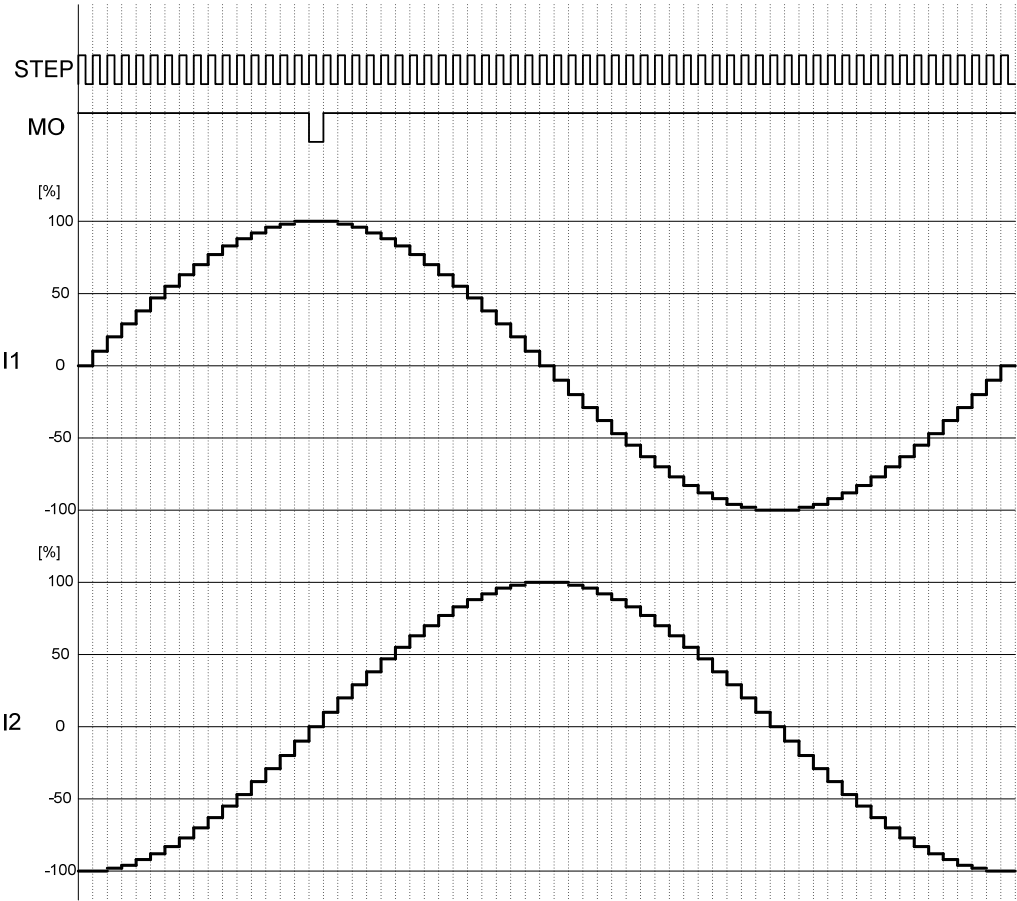


Half step (CW mode)

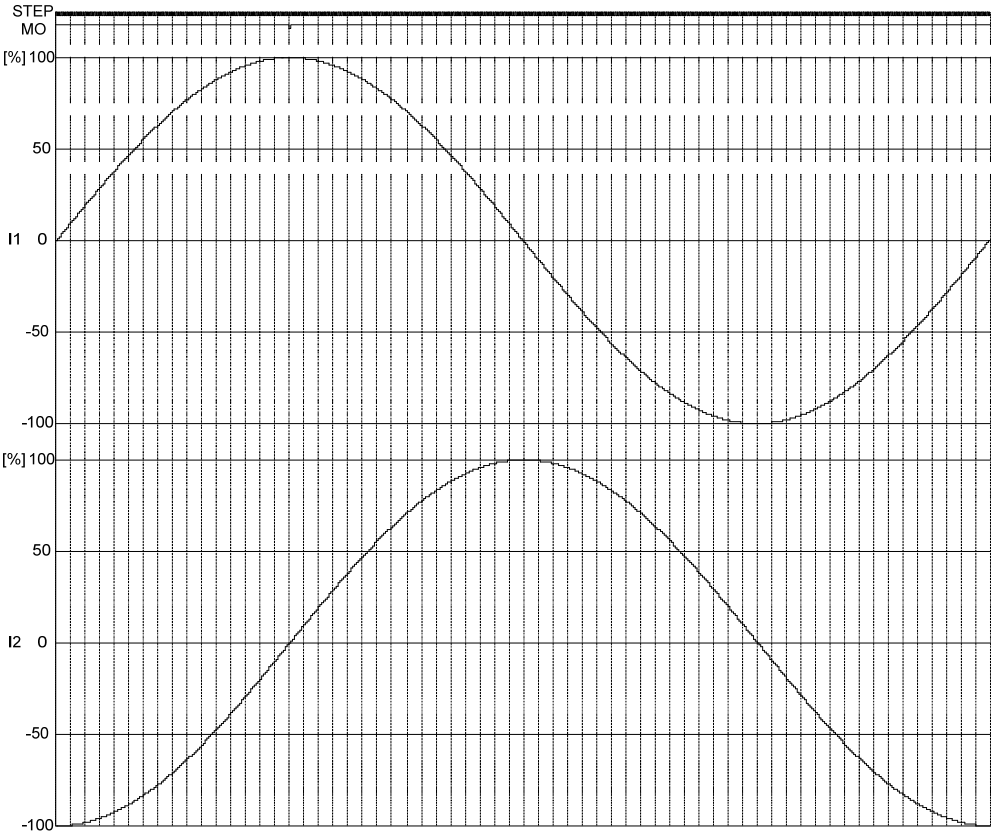


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1/16 step (CW mode)



1/128 step (CW mode)

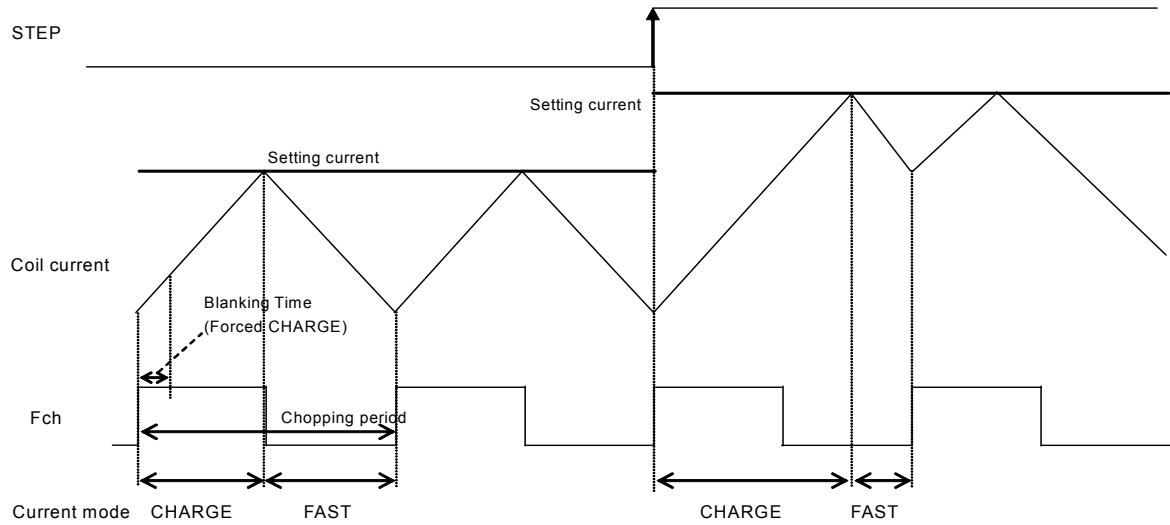


18. Current control operation

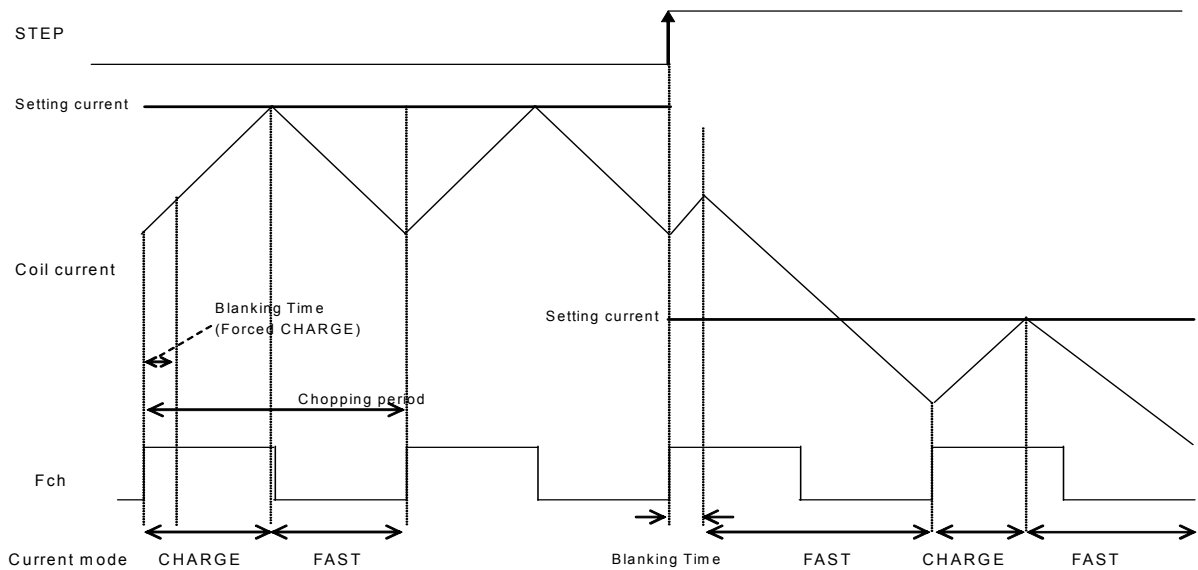
FAST Decay current control: When FDT pin voltage is 0.8V or less, the constant- current control is

operated in FAST Decay mode.

(Sine-wave increasing direction)



(Sine-wave decreasing direction)



The current control of FAST Decay operates with the follow sequence.

- The IC enters CHARGE mode at a rising edge of the chopping oscillation. The CHARGE of the blanking time is forced regardless of the magnitude of the coil current (ICOIL) and set current (IREF). The blanking time is approximately 1μs.
- After the period of the blanking time, The IC operates in CHARGE mode until $ICOIL \geq IREF$. After that, the mode switches to the FAST Decay

mode and the coil current is attenuated until the end of a chopping period.

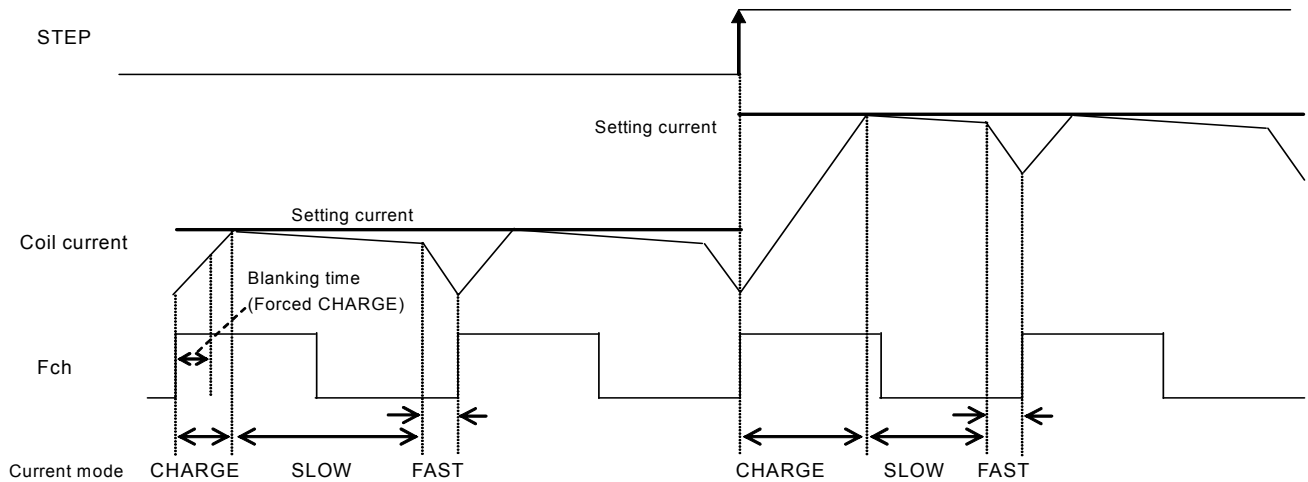
- If $ICOIL > IREF$ state exists when the end of blanking time, the coil current is attenuated by the FAST Decay mode until the end of a chopping period.

Since the attenuation of the current is fast, it is early that the coil current follows the set current. However, the current ripple value may be higher.

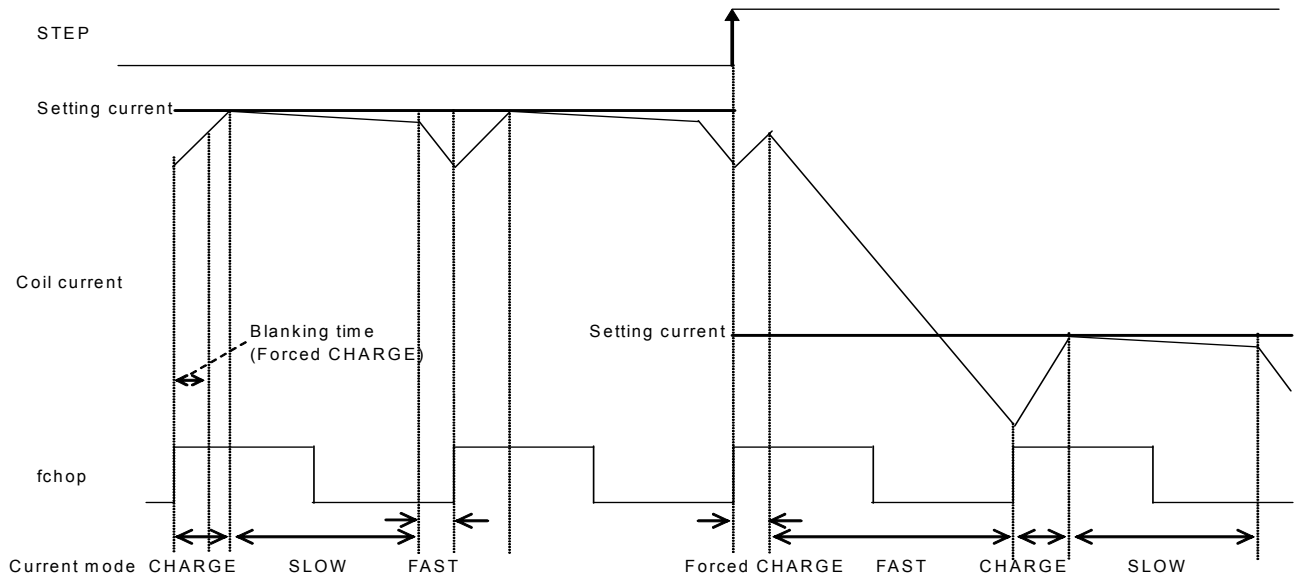
MIXED Decay current control: When FDT pin voltage is between 1.1V and 3.1V or Open, the

constant- current control is operated in MIXED Decay mode.

(Sine-wave increasing direction)



(Sine-wave decreasing direction)



The current control of MIXED Decay operates with the follow sequence.

- The IC enters CHARGE mode at a rising edge of the chopping oscillation. The CHARGE of the blanking time is forced regardless of the magnitude of the coil current (ICOIL) and set current (IREF). The blanking time is approximately 1μs.
- 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 $ICOIL \geq IREF$. 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.

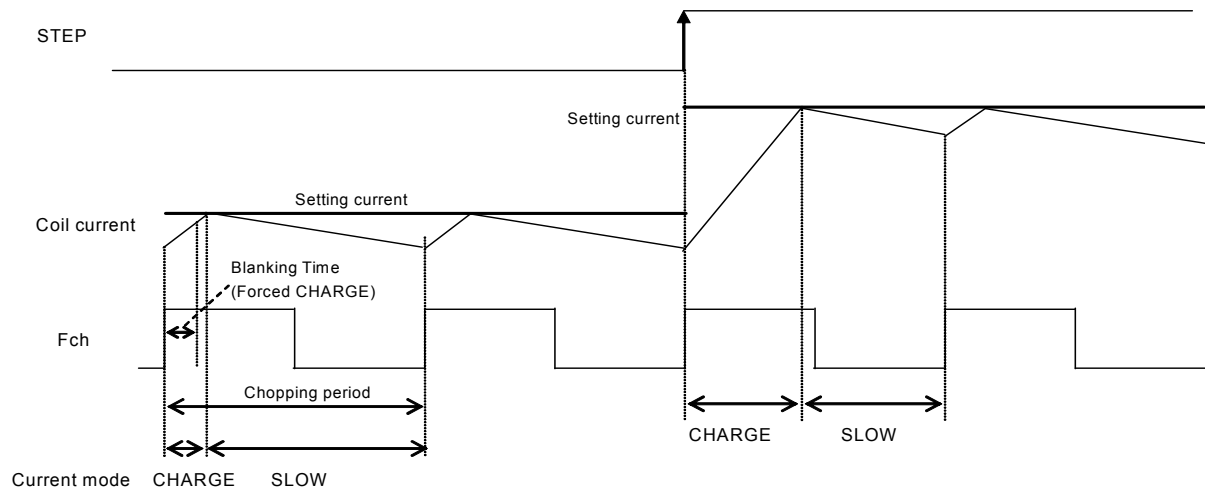
The above operation is repeated. Normally, the IC operates in SLOW (+ FAST) Decay mode at the sine wave increasing direction, and the IC operates in FAST Decay mode at the sine wave decreasing direction until the current is attenuated. And then the IC operates in SLOW Decay mode when the current reaches the set value.

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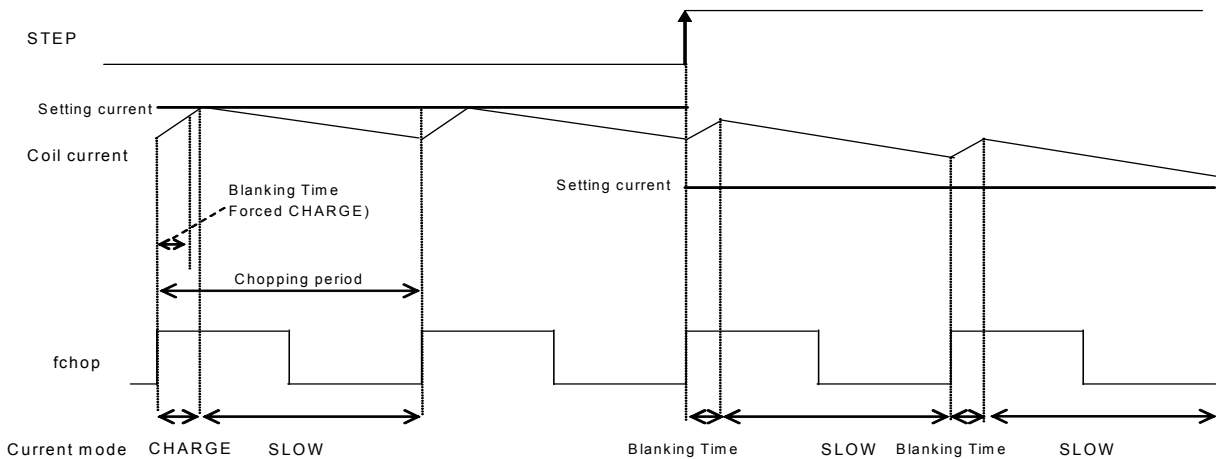
SLOW Decay current control: When FDT pin voltage is 0.8V or more, the constant- current control is

operated in SLOW Decay mode.

(Sine-wave increasing direction)



(Sine-wave decreasing direction)



The current control of SLOW Decay operates with the follow sequence.

- The IC enters CHARGE mode at a rising edge of the chopping oscillation. The CHARGE of the blanking time is forced regardless of the magnitude of the coil current (ICOIL) and set current (IREF). The blanking time is approximately 1μs.
- After the period of the blanking time, The IC operates in CHARGE mode until $ICOIL \geq IREF$. After that, the mode switches to the SLOW Decay mode and the coil current is attenuated until the end of a chopping period.

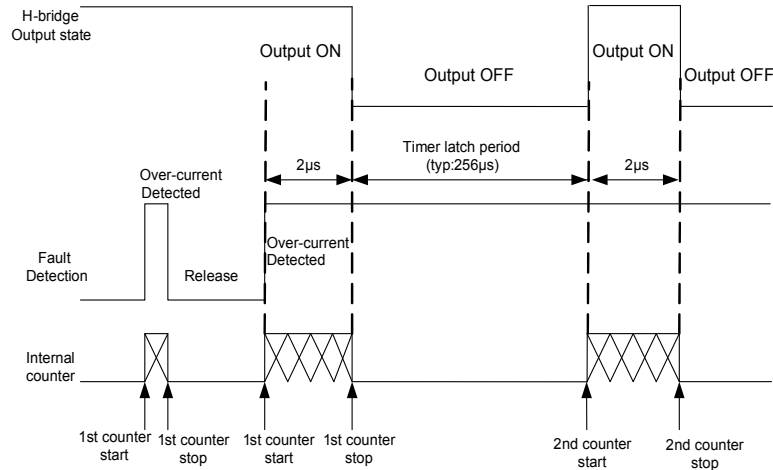
- If $ICOIL > IREF$ state exists when the end of blanking time, the coil current is attenuated by the SLOW Decay mode until the end of a chopping period.

Since the attenuation of the current is slow, it may be slow that the coil current follows the set current. Or the coil current may not follow a set current.

19. Over-current protection function

This IC incorporates an over current protection circuit that, when the output has been shorted by an event such as shorting to power, shorting to ground and shorting to other output. And it switches the output to the standby mode in order to prevent the IC from being damaged. Three over-current detection modes are shown in the next page.

When the over current is detected, the over current protection circuit operates. If the short status continues for the period of internal timer ($\approx 2\mu\text{s}$), the output of 1ch/ 2ch is turned off. If the short status exceeds the timer latch time ($\approx 256\mu\text{s}$) set in the internal timer, the output is turned on again and detects short status again. If short is detected again, all the outputs of 1ch/ 2ch are switched to standby mode and the status is kept. To cancel the standby status, set ST="L".



20. Thermal shutdown function

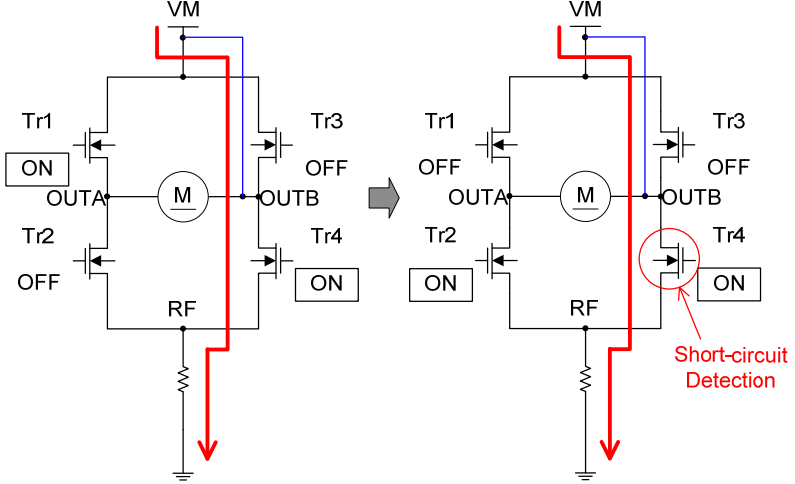
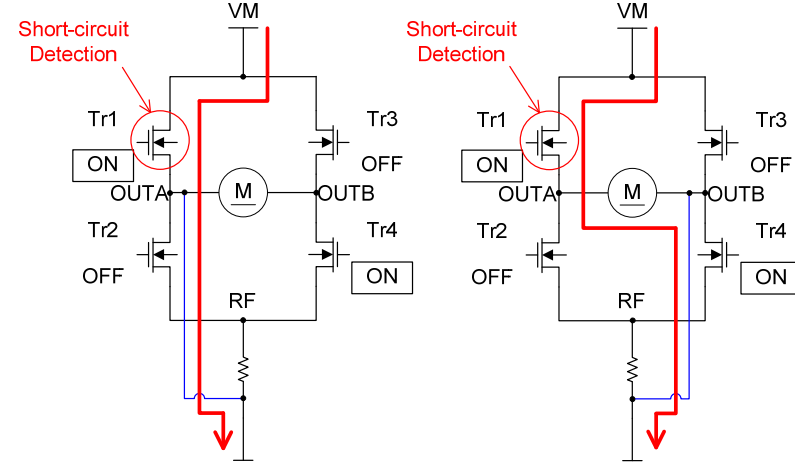
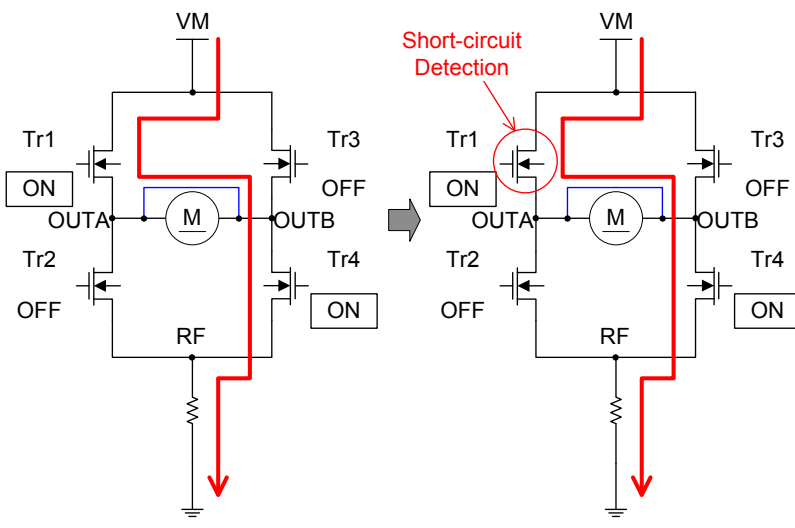
The thermal shutdown circuit is incorporated and the output is turned Off when junction temperature T_j exceeds 180°C . As the temperature falls by hysteresis, the output turned on again (automatic restoration). The thermal shutdown circuit does not guarantee the

protection of the final product because it operates when the temperature exceed the junction temperature of $T_{j\text{max}}=150^\circ\text{C}$.

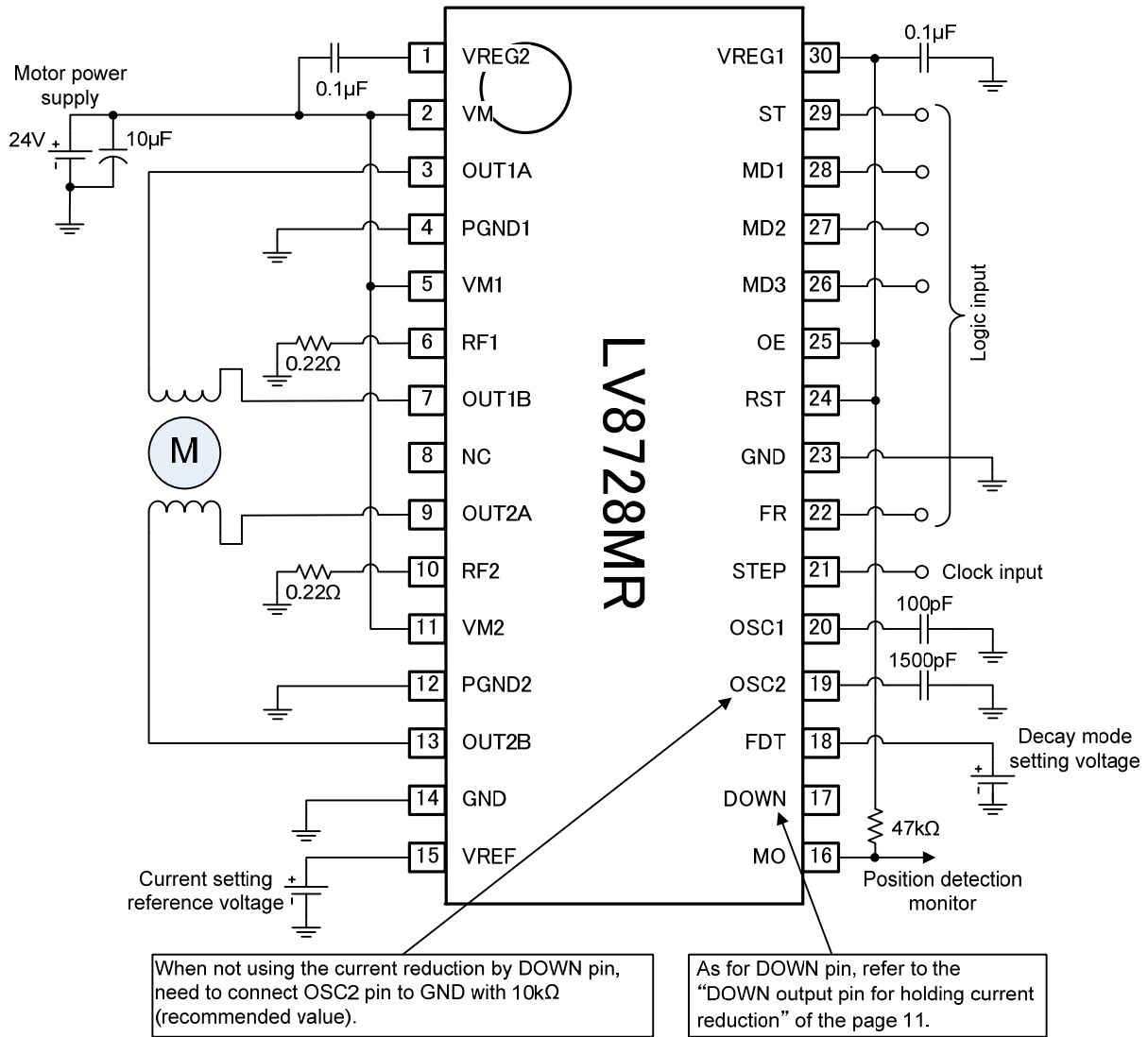
$T_{SD} = 180^\circ\text{C}$ (typ)

$\Delta T_{SD} = 40^\circ\text{C}$ (typ)

21. Over current detection mode

Short to Power 	1. High current flows if OUTB short to VM 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.
Short to GND 	(left schematic) 1. High current flows if OUTA short to GND and Tr1 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 stay 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.

Application Circuit Example



Calculation for each constant setting according to the above circuit diagram is as follows.

For example, when $V_{REF}=1.1V$, $I_{OSC1}=10\mu A$ (typ) and $C_{OSC1}=100pF$

- Coil current

$$I_{OUT} = \frac{1.1}{5 \times 0.22} \approx 1.0 [A]$$

- Chopping frequency

$$F_{ch} = \frac{10 \times 10^{-6}}{100 \times 10^{-12}} = 100 [kHz]$$

- STEP signal off detection time

$$T_{DOWN} = 1500 \times 10^{-12} \times 0.4 \times 10^9 = 0.6 [Sec]$$

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