Bulletin No
I02 EB0
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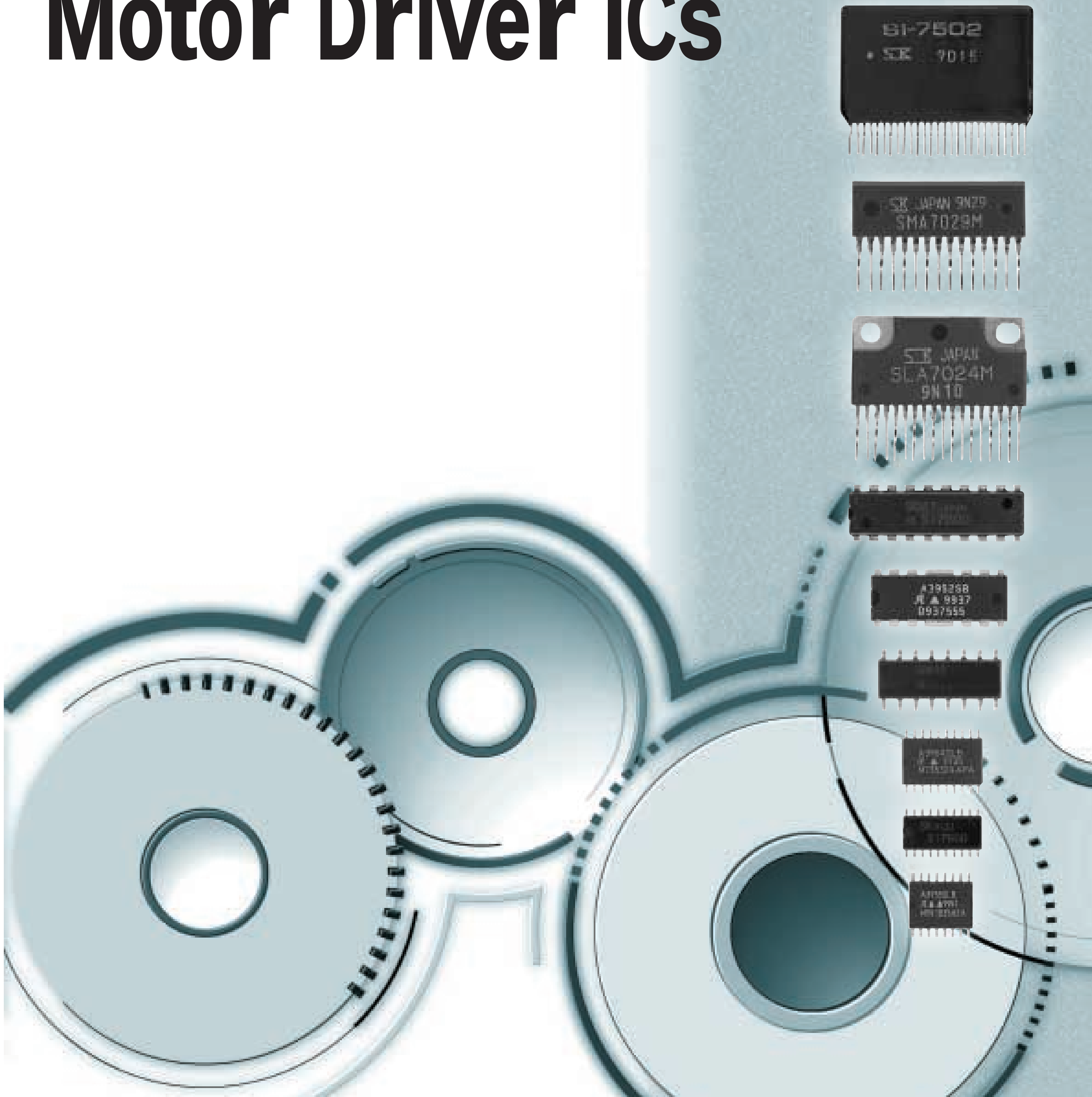
Sanken

Motor Driver ICs



SANKEN ELECTRIC CO.,LTD.

Contents

Selection Guide

■2-Phase Stepper Motor Unipolar Driver ICs

Excitation method	Output current (A)					Motor supply voltage (V)	Package	Remarks	Page
	1	1.2	1.25	1.5	3				
2-phase excitation	SLA7022MU					to 46	ZIP15Pin		5
	SMA7022MU					to 46	ZIP15Pin		5
				SLA7029M		to 46	ZIP15Pin		5
				SMA7029M		to 46	ZIP15Pin		5
				SMA7036M		to 46	ZIP15Pin		12
2-phase/ 1-2 phase excitation	SDK03M					to 46	SMD16Pin	1 motor driven by 2 packages	36
	SLA7027MU					to 46	ZIP18Pin		20
			UCN5804B			to 35	DIP16Pin	Internal sequencer, constant voltage driver	42
				SLA7024M		to 46	ZIP18Pin		20
				SLA7032M		to 46	ZIP18Pin		28
					SLA7026M	to 46	ZIP18Pin		20
					SLA7033M	to 46	ZIP18Pin		28
2W1-2 phase Micro-step support		SLA7042M				to 46	ZIP18Pin		44
					SLA7044M	to 46	ZIP18Pin		44

■Serial Signal Generator IC for SLA704xM

	Supply voltage (V)	Package	page
PG001M	4.5 to 5.5	DIP16Pin	48

■2-Phase Stepper Motor Bipolar Driver ICs

Excitation method	Output current (A)						Motor supply voltage (V)	Package	Remarks	Page
	0.65	0.75	0.8	1.3	1.5	2				
2-phase/ 1-2 phase excitation	A3966SA						Vcc to 30	DIP16Pin		54
	A3966SLB						Vcc to 30	SOP16Pin		54
			A3964SLB				Vcc to 30	SOP20Pin		58
				A3953SB			Vcc to 50	DIP16Pin	One motor driven by 2 ICs	60
				A3953SLB			Vcc to 50	SOP16Pin	One motor driven by 2 ICs	60
					A2918SW		10 to 45	ZIP18Pin		68
						A3952SB	Vcc to 50	DIP16Pin	One motor driven by 2 ICs	70
						A3952SLB	Vcc to 50	SOP16Pin	One motor driven by 2 ICs	70
						A3952SW	Vcc to 50	SIP12Pin	One motor driven by 2 ICs	70
2-phase/1-2 phase/W1-2 phase excitation		UDN2916B					10 to 45	DIP24Pin		78
		UDN2916LB					10 to 45	SOP24Pin		78
					UDN2917EB		10 to 45	PLCC44Pin		84
2W1-2 phase excitation/ micro-step support					A3955SB		Vcc to 50	DIP16Pin	One motor driven by 2 ICs	88
					A3955SLB		Vcc to 50	SOP16Pin	One motor driven by 2 ICs	88
4W1-2 phase excitation/micro-step support					A3957SLB		Vcc to 50	SOP24Pin	One motor driven by 2 ICs	94

■3-Phase Stepper Motor Driver Control ICs

Excitation method	Part No.	Motor supply voltage (V)	Package	Remarks	Page
2-phase/ 2-3 phase excitation	SI-7600	15 to 45	SOP20Pin	Use with SLA5017 or others	98
	SI-7600D		DIP20Pin		

■5-Phase Stepper Motor Driver Control ICs

Drive method	Part No.	Motor supply voltage (V)	Package	Remarks	Page
Pentagon connection	SI-7502	15 to 42	Powder coating 27 pin	Use with SLA6503 and SLA5011	104

Product Index by Part Number

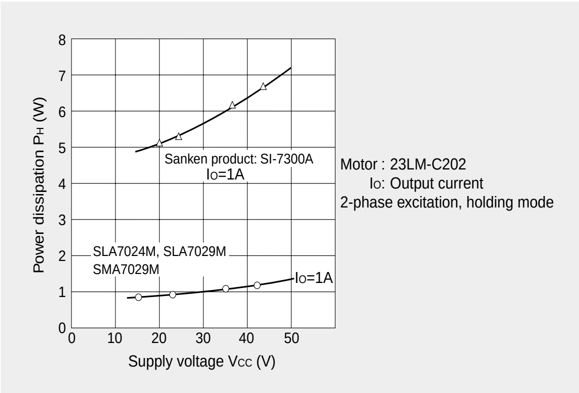
Part No.	Output current (A)	Supply voltage (V)	Drive method	Excitation method	Package	Remarks	Page
A2918SW	1.5	10 to 45	Bipolar	2-phase/1-2 phase excitation	ZIP18pin		68
A3952SB	2	V_{CC} to 50	Bipolar	2-phase/1-2 phase excitation	DIP16pin	One motor driven by 2 ICs	70
A3952SLB	2	V_{CC} to 50	Bipolar	2-phase/1-2 phase excitation	SOP16pin	One motor driven by 2 ICs	70
A3952SW	2	V_{CC} to 50	Bipolar	2-phase/1-2 phase excitation	SIP12pin	One motor driven by 2 ICs	70
A3953SB	1.3	V_{CC} to 50	Bipolar	2-phase/1-2 phase excitation	DIP16pin	One motor driven by 2 ICs	60
A3953SLB	1.3	V_{CC} to 50	Bipolar	2-phase/1-2 phase excitation	SOP16pin	One motor driven by 2 ICs	60
A3955SB	1.5	V_{CC} to 50	Bipolar	2W/1-2 phase micro-step support	DIP16pin	One motor driven by 2 ICs	88
A3955SLB	1.5	V_{CC} to 50	Bipolar	2W/1-2 phase micro-step support	SOP16pin	One motor driven by 2 ICs	88
A3957SLB	1.5	V_{CC} to 50	Bipolar	4W/1-2 phase micro-step support	SOP24pin	One motor driven by 2 ICs	94
A3964SLB	0.8	V_{CC} to 30	Bipolar	2-phase/1-2 phase excitation	SOP20pin		58
A3966SA	0.65	V_{CC} to 30	Bipolar	2-phase/1-2 phase excitation	DIP16pin		54
A3966SLB	0.65	V_{CC} to 30	Bipolar	2-phase/1-2 phase excitation	SOP16pin		54
PG001M	–	4.5 to 5.5	–	–	DIP16pin	Serial signal generator IC for SLA704xM	48
SDK03M	1	to 46	Unipolar	2-phase/1-2 phase excitation	SMD16pin	One motor driven by 2 ICs	36
SI-7502	–	15 to 42	Pentagon connection	5-phase excitation	Powder coat 27pin	Control IC	104
SI-7600	–	15 to 45	Star connection/ delta connection	2-phase/2-3 phase excitation	SOP20pin	Control IC	98
SI-7600D	–	15 to 45	Star connection/ delta connection	2-phase/2-3 phase excitation	DIP20pin	Control IC	98
SLA7022MU	1	to 46	Unipolar	2-phase excitation	ZIP15pin		5
SLA7024M	1.5	to 46	Unipolar	2-phase/1-2 phase excitation	ZIP18pin		20
SLA7026M	3	to 46	Unipolar	2-phase/1-2 phase excitation	ZIP18pin		20
SLA7027MU	1	to 46	Unipolar	2-phase/1-2 phase excitation	ZIP18pin		20
SLA7029M	1.5	to 46	Unipolar	2-phase excitation	ZIP15pin		5
SLA7032M	1.5	to 46	Unipolar	2-phase/1-2 phase excitation	ZIP18pin	SLA7024M equivalent	28
SLA7033M	3	to 46	Unipolar	2-phase/1-2 phase excitation	ZIP18pin	SLA7026M equivalent	28
SLA7042M	1.2	to 46	Unipolar	2W/1-2 phase micro-step support	ZIP18pin		44
SLA7044M	3	to 46	Unipolar	2W/1-2 phase micro-step support	ZIP18pin		44
SMA7022MU	1	to 46	Unipolar	2-phase excitation	ZIP15pin		5
SMA7029M	1.5	to 46	Unipolar	2-phase excitation	ZIP15pin		5
SMA7036M	1.5	to 46	Unipolar	2-phase excitation	ZIP15pin	SMA7029M equivalent	12
UCN5804B	1.25	to 35	Unipolar	2-phase/1-2 phase excitation	DIP16pin	Internal sequencer, constant voltage driver	42
UDN2916B	0.75	10 to 45	Bipolar	2-phase/1-2 phase/W1-2 phase excitation	DIP24pin		78
UDN2916LB	0.75	10 to 45	Bipolar	2-phase/1-2 phase/W1-2 phase excitation	SOP24pin		78
UDN2917EB	1.5	10 to 45	Bipolar	2-phase/1-2 phase/W1-2 phase excitation	PLCC44pin		84

Notes on SLA7000/SMA7000 Series

■Features

- Employs a constant-current chopper control method.
- Integrates power MOSFETs and monolithic chip control circuitry in a single package.
- One-fifth the size and one-fourth the power dissipation compared with conventional SANKEN ICs

Comparison of power dissipation.



- Eliminates the need for heatsink thereby decreasing part-insertion workload and increasing flexibility in mounting.
- Reduces the size of power supplies required.
- Lineup: 2-phase excitation, 2-phase/1-2 phase excitation, 2W1-2 phase micro-step support ICs

■Applications

The SLA7000 and SMA7000 series are ideal for the following applications.

- Sheet feeders and carriage drivers in printers.
- Sheet feeders for PPC and facsimile machines.
- Numeric control equipment.
- Industrial robots.

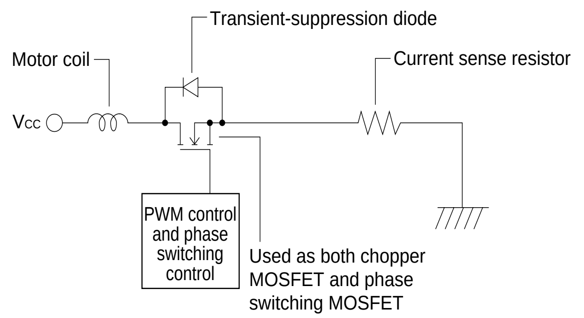
■Handling Precautions

- Recommended screw torque
  0.588 to 0.784 [N•m](6.0 to 8.0 [kgf•cm])
- Recommended silicon grease
  Shin-Etsu Chemical Co., Ltd.: G746
  GE Toshiba Silicone Co., Ltd.: YG-6260
  Dow Corning Toray Silicone Co., Ltd.: SC102
  Please be careful when selecting silicone grease since the oil in some grease may penetrate the product, which will result in an extremely short product life.

■Constant Current Chopper Method

In the constant current chopper method, a voltage higher than the rated voltage of the motor is applied and when the current rises, the chopper transistor is switched on thereby shortening the current rise time. After the current rises, the coil current is held by the PWM chopper to a constant current level determined by the current sense resistor. This method has the advantage of improving the motor's high frequency response and the efficiency response and efficiency of the driver circuitry.

Basic constant current chopper circuitry



2-Phase Stepper Motor Unipolar Driver ICs

■Absolute Maximum Ratings

(T_a=25°C)

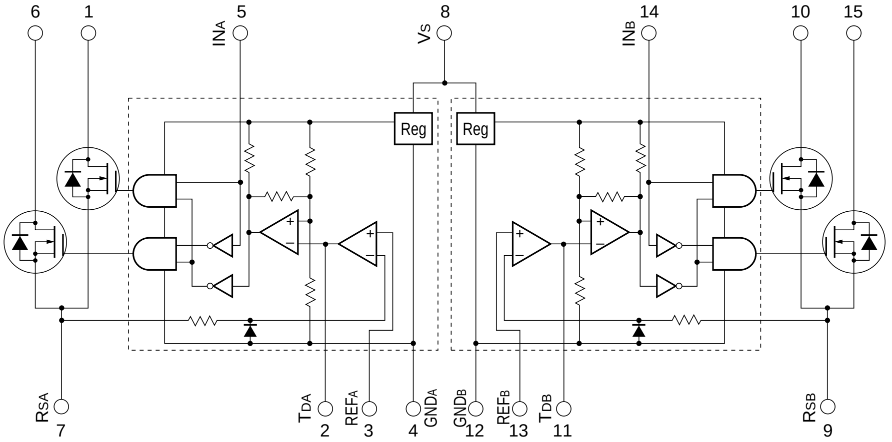
Parameter	Symbol	Ratings				Units
		SLA7022MU	SLA7029M	SMA7022MU	SMA7029M	
Motor supply voltage	V_{CC}	46				V
FET Drain-Source voltage	V_{DSS}	100				V
Control supply voltage	V_S	46				V
TTL input voltage	V_{IN}	7				V
Reference voltage	V_{REF}	2				V
Output current	I_O	1	1.5	1	1.5	A
Power dissipation	P_{D1}	4.5 (Without Heatsink)		4.0 (Without Heatsink)		W
	P_{D2}	35 (T_C=25°C)		28(T_C=25°C)		W
Channel temperature	T_{ch}	+150				°C
Storage temperature	T_{stg}	–40 to +150				°C

■Electrical Characteristics

(T_a=25°C)

	Parameter	Symbol	SLA7022MU			SLA7029M			SMA7022MU			SMA7029M			Units
			min	typ	max	min	typ	max	min	typ	max	min	typ	max	
DC characteristics	Control supply current	I_S		10	15		10	15		10	15		10	15	mA
		Condition	V_S=44V			V_S=44V			V_S=44V			V_S=44V			
	Control supply voltage	V_S	10	24	44	10	24	44	10	24	44	10	24	44	V
	FET Drain-Source voltage	V_{DSS}	100			100			100			100			V
		Condition	V_S=44V, I_{DSS}=250 μA			V_S=44V, I_{DSS}=250 μA			V_S=44V, I_{DSS}=250 μA			V_S=44V, I_{DSS}=250 μA			
	FET ON voltage	V_{DS}			0.85			0.6			0.85			0.6	V
		Condition	I_D=1A, V_S=14V			I_D=1A, V_S=14V			I_D=1A, V_S=14V			I_D=1A, V_S=14V			
	FET drain leakage current	I_{DSS}			4			4			4			4	mA
		Condition	V_{DSS}=100V, V_S=44V			V_{DSS}=100V, V_S=44V			V_{DSS}=100V, V_S=44V			V_{DSS}=100V, V_S=44V			
	FET diode forward voltage	V_{SD}			1.2			1.1			1.2			1.1	V
		Condition	I_D=1A			I_D=1A			I_D=1A			I_D=1A			
	TTL input current	I_{IH}			40			40			40			40	μA
		Condition	V_{IH}=2.4V, V_S=44V			V_{IH}=2.4V, V_S=44V			V_{IH}=2.4V, V_S=44V			V_{IH}=2.4V, V_S=44V			
		I_{IL}			–0.8			–0.8			–0.8			–0.8	mA
		Condition	V_{IL}=0.4V, V_S=44V			V_{IL}=0.4V, V_S=44V			V_{IL}=0.4V, V_S=44V			V_{IL}=0.4V, V_S=44V			
	TTL input voltage (Active High)	V_{IH}	2			2			2			2			V
		Condition	I_D=1A			I_D=1A			I_D=1A			I_D=1A			
		V_{IL}			0.8			0.8			0.8			0.8	
		Condition	V_{DSS}=100V			V_{DSS}=100V			V_{DSS}=100V			V_{DSS}=100V			
	TTL input voltage (Active Low)	V_{IH}	2			2			2			2			V
		Condition	V_{DSS}=100V			V_{DSS}=100V			V_{DSS}=100V			V_{DSS}=100V			
		V_{IL}			0.8			0.8			0.8			0.8	
		Condition	I_D=1A			I_D=1A			I_D=1A			I_D=1A			
AC characteristics	Switching time	T_r		0.5			0.5			0.5			0.5		μs
		Condition	V_S=24V, I_D=0.8A			V_S=24V, I_D=1A			V_S=24V, I_D=0.8A			V_S=24V, I_D=1A			
		T_{stg}		0.7			0.7			0.7			0.7		
		Condition	V_S=24V, I_D=0.8A			V_S=24V, I_D=1A			V_S=24V, I_D=0.8A			V_S=24V, I_D=1A			
		T_f		0.1			0.1			0.1			0.1		
		Condition	V_S=24V, I_D=0.8A			V_S=24V, I_D=1A			V_S=24V, I_D=0.8A			V_S=24V, I_D=1A			

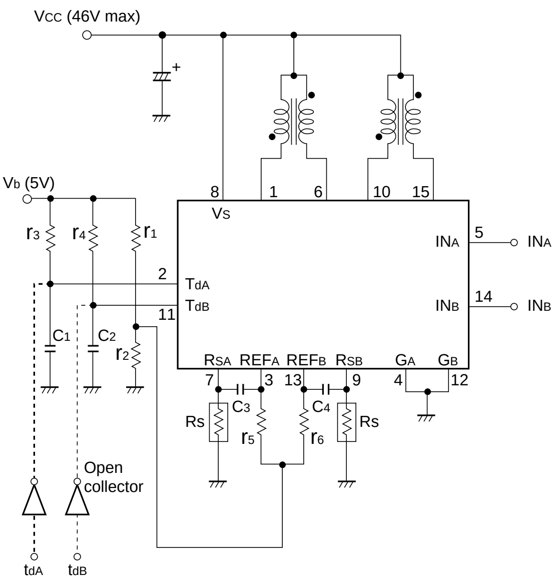
■Internal Block Diagram



1, 6, 10, 15pin
Description of pins

	Excitation input	
	Active H	Active L
1pin	OUT A	OUT $\overline{A}$
6pin	OUT $\overline{A}$	OUT A
10pin	OUT B	OUT $\overline{B}$
15pin	OUT $\overline{B}$	OUT B

■Diagram of Standard External Circuit (Recommended Circuit Constants)



Excitation signal time chart
2-phase excitation

clock	0	1	2	3	0	1
INA	H	H	L	L	H	H
INB	L	H	H	L	L	H

1-2 phase excitation

clock	0	1	2	3	4	5	6	7	0	1	2	3
INA	H	H	H	H	L	L	L	L	H	H	H	H
tdA	L	L	L	H	L	L	L	H	L	L	L	H
INB	L	L	H	H	H	H	L	L	L	L	H	H
tdB	L	H	L	L	L	H	L	L	L	H	L	L

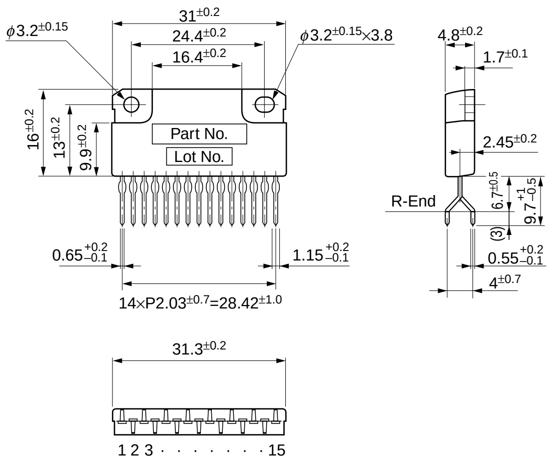
● tdA and tdB are signals before the inverter stage.

r_1 : 510Ω
r_2 : 100Ω (VR)
r_3 : 47kΩ
r_4 : 47kΩ
r_5 : 2.4kΩ
r_6 : 2.4kΩ
C_1 : 330 to 500pF
C_2 : 330 to 500pF
C_3 : 2200pF
C_4 : 2200pF
R_S (1 to 2W) : 1.8Ω typ(7022MU)
1Ω typ(7029M)

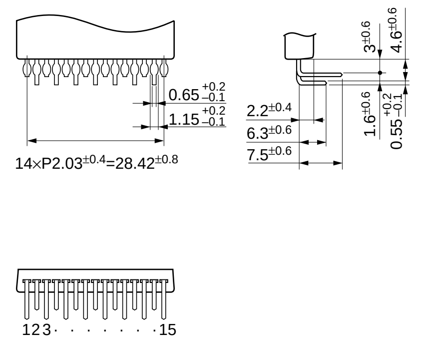
■External Dimensions SLA7022MU/SLA7029M

(Unit: mm)

Epoxy resin package



Forming No. No.853

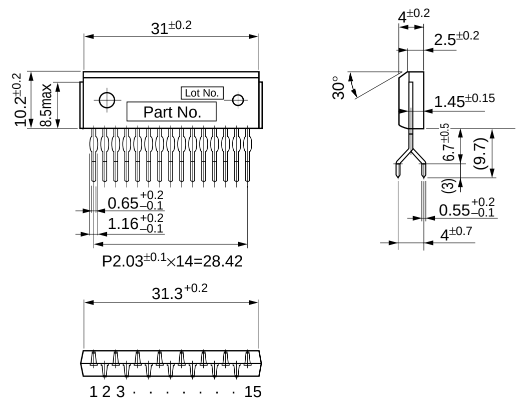


Forming No. No.855

■External Dimensions SMA7022MU/SMA7029MA

(Unit: mm)

Epoxy resin package



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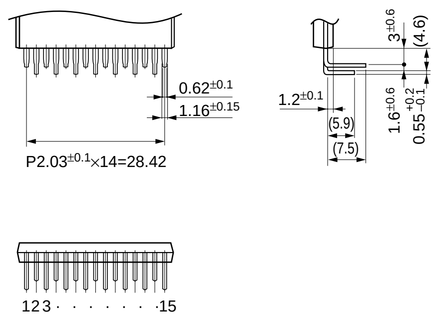


Forming No. No.1055

Application Notes

■Determining the Output Current

Fig. 1 shows the waveform of the output current (motor coil current). The method of determining the peak value of the output current (I_O) based on this waveform is shown below.

(Parameters for determining the output current I_O)

V_b: Reference supply voltage

r_1,r_2: Voltage-divider resistors for the reference supply voltage

R_S: Current sense resistor

(1) Normal rotation mode

I_O is determined as follows when current flows at the maximum level during motor rotation. (See Fig.2.)

$$I_O \cong \frac{r_2}{r_1+r_2} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (1)$$

(2) Power down mode

The circuit in Fig.3 (r_X and Tr) is added in order to decrease the coil current. I_O is then determined as follows.

$$I_{OPD} \cong \frac{1}{1+\dfrac{r_1(r_2+r_X)}{r_2 \bullet r_X}} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (2)$$

Equation (2) can be modified to obtain equation to determine r_X.

$$r_X = \frac{1}{\dfrac{1}{r_1}\left(\dfrac{V_b}{R_S \bullet I_{OPD}} - 1\right) - \dfrac{1}{r_2}}$$

Fig. 4 and 5 show the graphs of equations (1) and (2) respectively.

Fig. 1 Waveform of coil current (Phase A excitation ON)

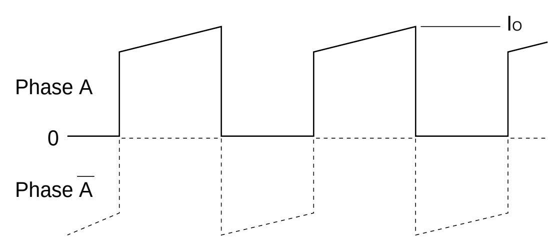


Fig. 2 Normal mode

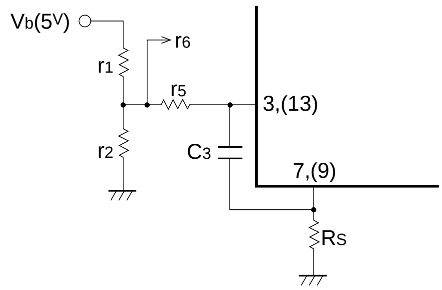


Fig. 3 Power down mode

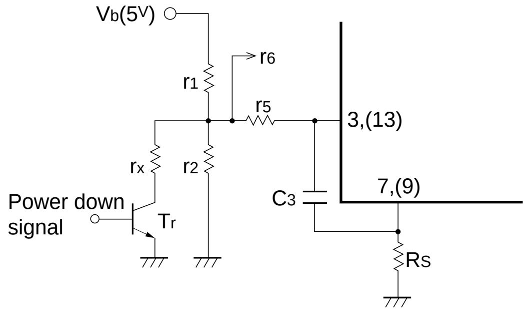


Fig. 4 Output current I_O vs. Current sense resistor R_S

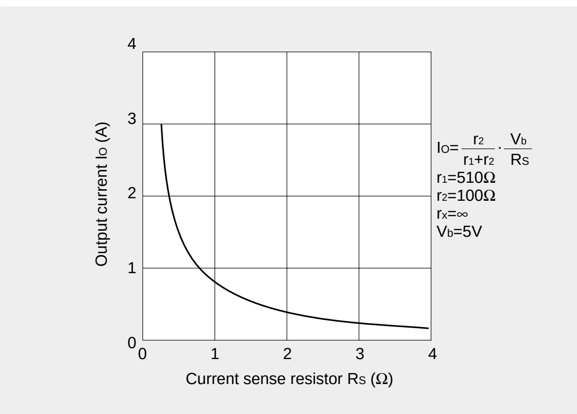
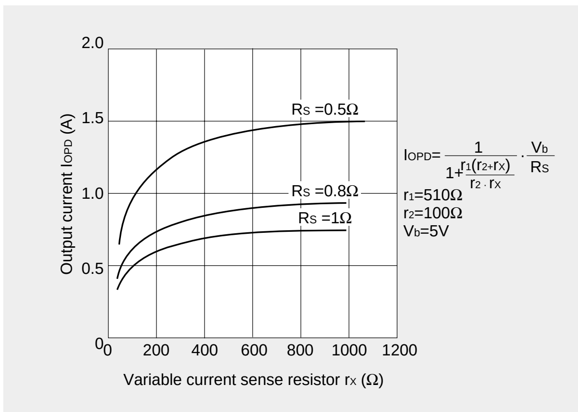


Fig. 5 Output current I_{OPD} vs. Variable current sense resistor r_X



(NOTE)

Ringing noise is produced in the current sense resistor R_S when the MOSFET is switched ON and OFF by chopping. This noise is also generated in feedback signals from R_S which may therefore cause the comparator to malfunction. To prevent chopping malfunctions, $r_5(r_6)$ and $C_3(C_4)$ are added to act as a noise filter. However, when the values of these constants are increased, the response from R_S to the comparator becomes slow. Hence the value of the output current I_O is somewhat higher than the calculated value.

■Determining the chopper frequency

Determining T_{OFF}

The SLA7000M and SMA7000M series are self-excited choppers. The chopping OFF time T_{OFF} is fixed by r_3/C_1 and r_4/C_2 connected to terminal Td.

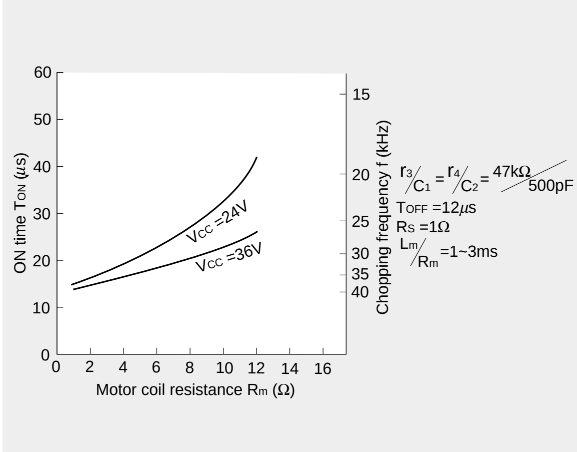
T_{OFF} can be calculated using the following formula:

$$T_{OFF} \cong -r_3 \bullet C_1 \ell n (1-\frac{2}{V_b}) = -r_4 \bullet C_2 \ell n (1-\frac{2}{V_b})$$

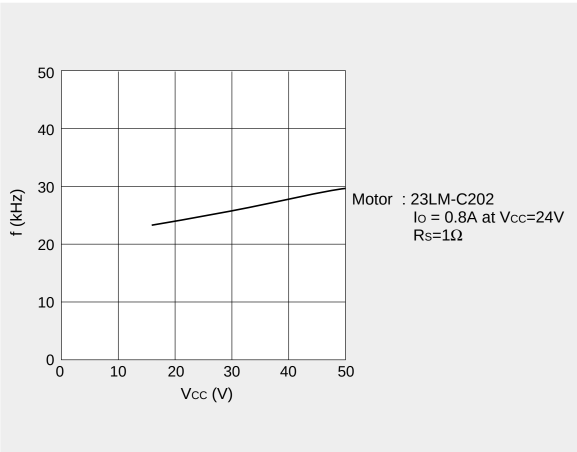
The circuit constants and the T_{OFF} value shown below are recommended.

$T_{OFF} = 12\mu s$ at r_3=47kΩ, C_1=500pF, V_b=5V

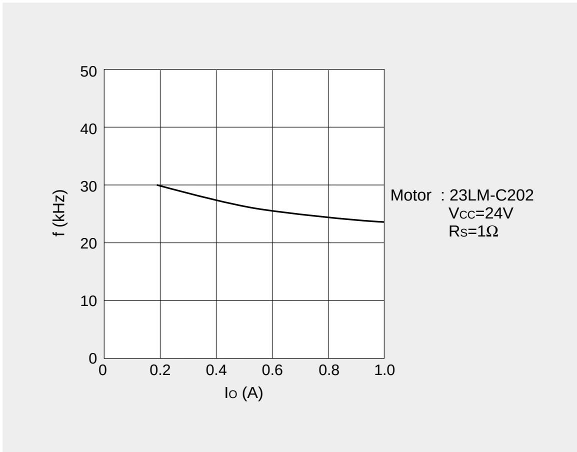
Fig. 6 Chopper frequency vs. Motor coil resistance



■Chopper frequency vs. Supply voltage



■Chopper frequency vs. Output current



■Thermal Design

An outline of the method for calculating heat dissipation is shown below.

(1) Obtain the value of P_H that corresponds to the motor coil current I_O from Fig. 7 "Heat dissipation per phase P_H vs. Output current I_O."

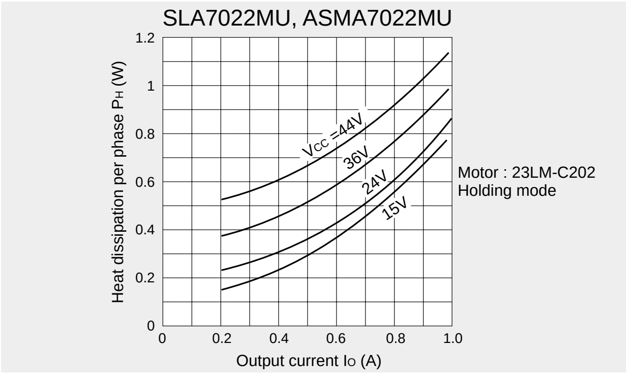
(2) The power dissipation P_{diss} is obtained using the following formula.

2-phase excitation: $P_{diss} \cong 2P_H + 0.015 \times V_S$ (W)

1-2 phase excitation: $P_{diss} \cong \frac{3}{2} P_H + 0.015 \times V_S$ (W)

(3) Obtain the temperature rise that corresponds to the calculated value of P_{diss} from Fig. 8 "Temperature rise."

Fig. 7 Heat dissipation per phase P_H vs. Output current I_O



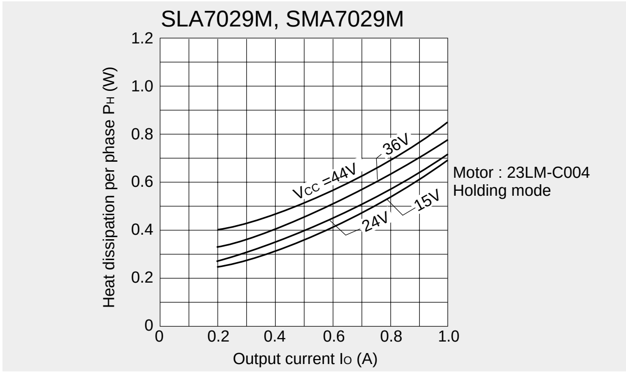
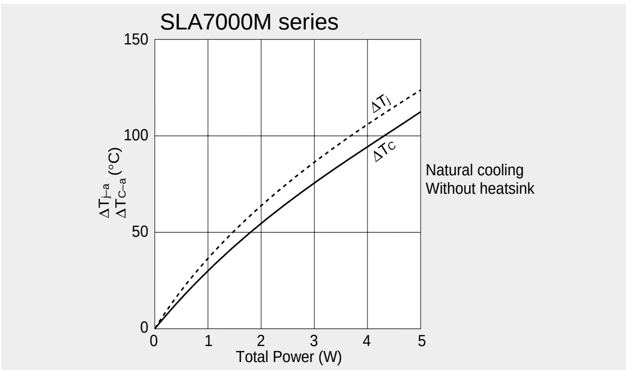
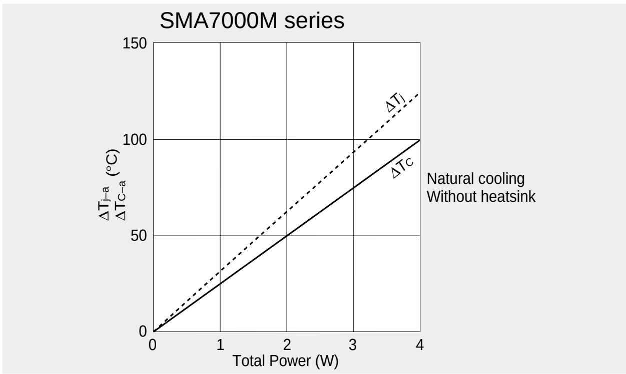
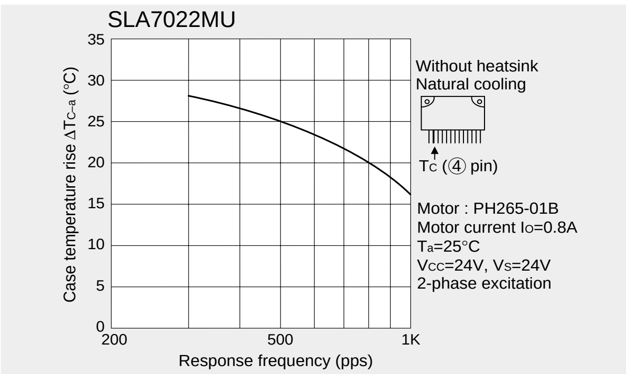


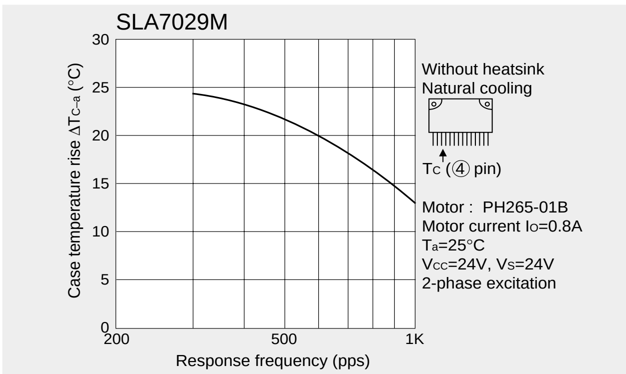
Fig. 8 Temperature rise

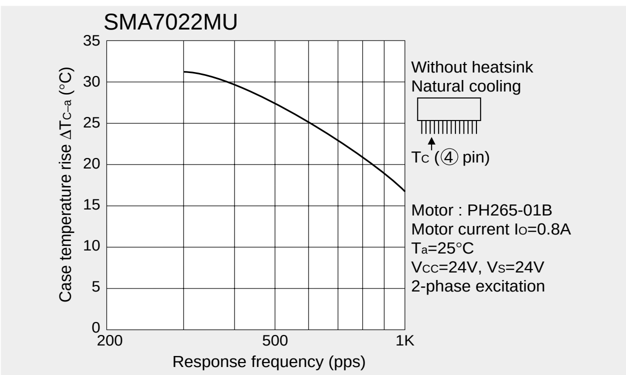


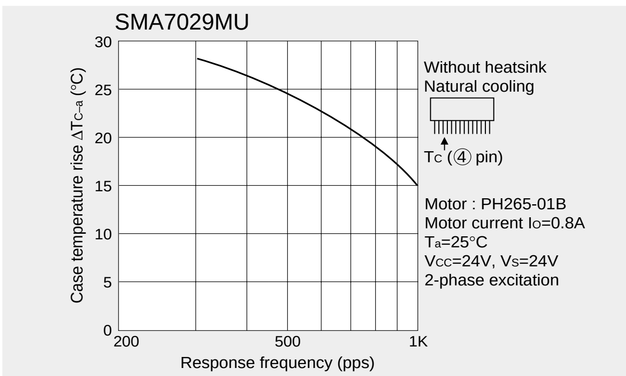


Thermal characteristics



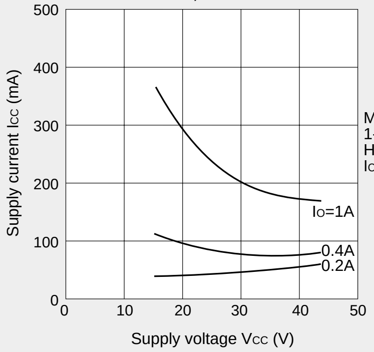






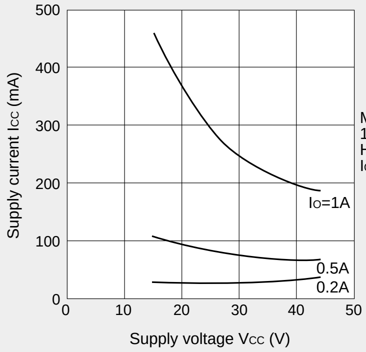
■Supply Voltage V_{CC} vs. Supply Current I_{CC}

SLA7022MU, SMA7022MU



Motor : 23LM-C202
1-phase excitation
Holding mode
I_O : Output current

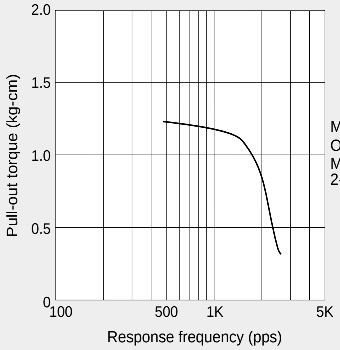
SLA7029M, SMA7029M



Motor : 23LM-C004
1-phase excitation
Holding mode
I_O : Output current

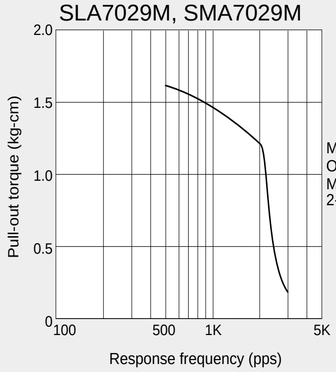
■Torque Characteristics

SLA7022MU, SMA7022MU



Motor : PX244-02
Output current I_O =0.6A
Motor supply voltage V_{CC} =24V
2-phase excitation

SLA7029M, SMA7029M



Motor : 23LM-C202
Output current I_O =0.8A
Motor supply voltage V_{CC} =24V
2-phase excitation

2-Phase Stepper Motor Unipolar Driver IC

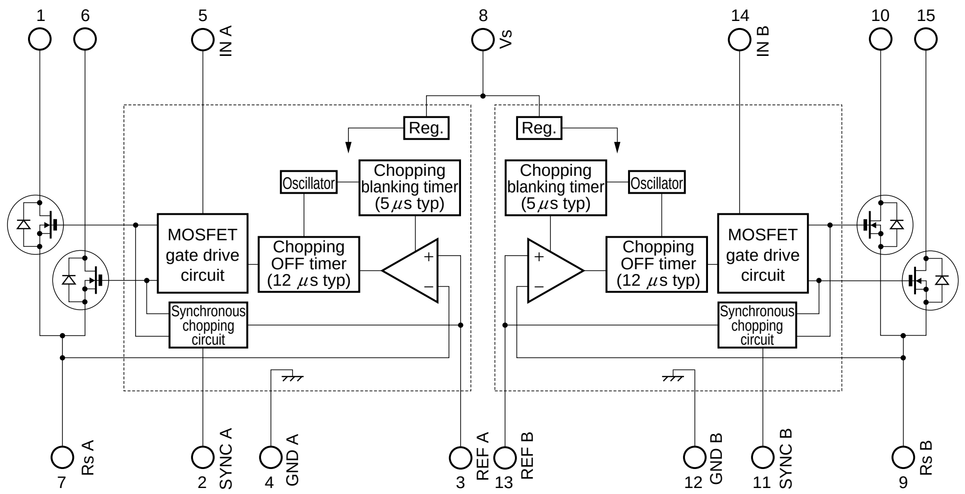
■Absolute Maximum Ratings

Parameter		Symbol	Ratings	Units
Motor supply voltage		V_{CC}	46	V
Control supply voltage		V_S	46	V
FET Drain-Source voltage		V_{DSS}	100	V
TTL input voltage		V_{IN}	−0.3 to +7	V
SYNC terminal voltage		V_{SYNC}	−0.3 to +7	V
Reference voltage		V_{REF}	−0.3 to +7	V
Sense voltage		V_{RS}	−5 to +7	V
Output current		I_O	1.5	A
Power dissipation		P_{D1}	4.0 (T_a=25°C)	W
		P_{D2}	28 (T_c=25°C)	W
Channel temperature		T_{ch}	150	°C
Storage temperature		T_{stg}	−40 to +150	°C
Ambient operating temperature		T_a	−20 to +85	°C

■Electrical Characteristics

	Parameter		Symbol	Ratings min	Ratings typ	Ratings max	Units
DC characteristics	Control supply current		I_S		10	15	mA
			Condition		V_S=44V		
	Control supply voltage		V_S	10	24	44	V
	FET Drain-Source voltage		V_{DSS}	100			V
			Condition		V_S=44V, I_{DSS}=250 μA		
	FET ON voltage		V_{DS}			0.6	V
			Condition		I_D=1A, V_S=10V		
	FET diode forward voltage		V_{SD}			1.1	V
			Condition		I_{SD}=1A		
	FET drain leakage current		I_{DSS}			250	μA
			Condition		V_{DSS}=100V, V_S=44V		
	IN terminal	Active H	V_{IH}	2			V
			Condition		I_D=1A		
			V_{IL}			0.8	
			Condition		V_{DSS}=100V		
		Active L	V_{IH}	2			V
			Condition		V_{DSS}=100V		
			V_{IL}			0.8	
			Condition		I_D=1A		
		Input current	I_I			±1	μA
			Condition		V_S=44V, V_I=0 or 5V		
	SYNC terminal	Input voltage	V_{SYNC}H	4.0			V
			Condition		Synchronous chopping mode		
			V_{SYNC}L			0.8	
			Condition		Asynchronous chopping mode		
		Input current	I_{SYNC}H			0.1	mA
			Condition		V_S=44V, V_{YS}=5V		
			I_{SYNC}L			−0.1	
			Condition		V_S=44V, V_{YS}=0V		
	REF terminal	Input voltage	V_{REF}	0		2.0	V
			Condition		Reference voltage input		
			V_{REF}	4.0		5.5	
			Condition		Output FET OFF		
		Input current	I_{REF}			±1	μA
			Condition		No synchronous trigger		
		Internal resistance	R_{REF}		40		Ω
			Condition		Resistance between GND and REF terminal at synchronous trigger		
AC characteristics	Switching time		T_{on}		1.5		μs
			Condition		V_S=24V, I_D=1A		
			T_r		0.5		
			Condition		V_S=24V, I_D=1A		
			T_{stg}		0.9		
			Condition		V_S=24V, I_D=1A		
			T_f		0.1		
			Condition		V_S=24V, I_D=1A		
	Chopping OFF time		T_{OFF}		12		μs
			Condition		V_S=24V		

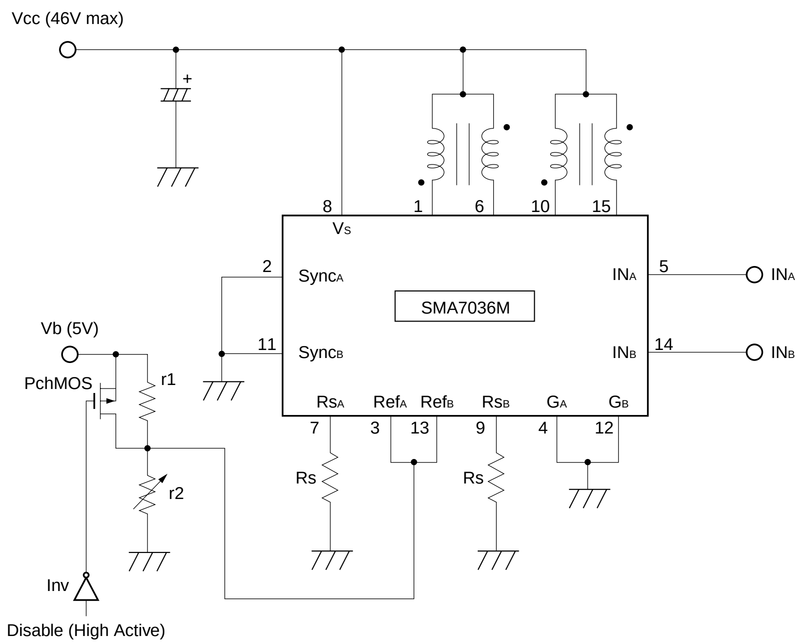
■Internal Block Diagram



1, 6, 10, 15pin
Description of pins

	Excitation input	
	Active H	Active L
1pin	OUT A	OUT $\overline{A}$
6pin	OUT $\overline{A}$	OUT A
10pin	OUT B	OUT $\overline{B}$
15pin	OUT $\overline{B}$	OUT B

■Diagram of Standard External Circuit (Recommended Circuit Constants)



Excitation signal time chart

2-phase excitation

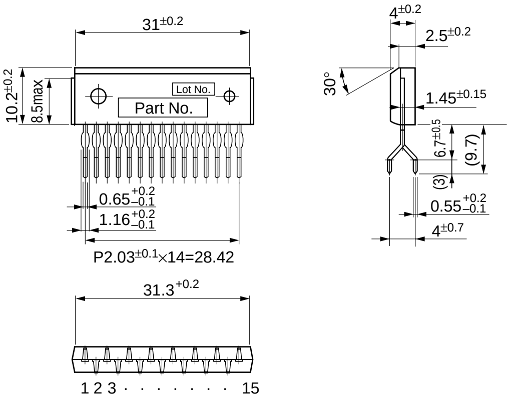
clock	0	1	2	3	0	1
IN_A	H	H	L	L	H	H
IN_B	L	H	H	L	L	H

r_1 : 8kΩ
r_2 : 2kΩ (VR)
R_s (1 to 2W) : 1Ω typ
PchMOS : HN1J02FU (Toshiba)
Inv : 7404

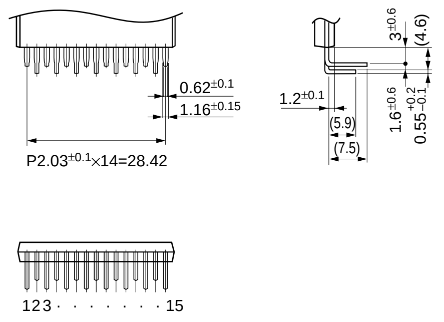
■External Dimensions

(Unit: mm)

Epoxy resin package



Forming No. No.1054



Forming No. No.1055

Application Notes

■Outline

SMA7036M is a stepper motor driver IC developed to reduce the number of external parts required by the conventional SMA7029M. This IC successfully eliminates the need for some external parts without sacrificing the features of SMA7029M. The basic function pins are compatible with those of SMA7029M.

■Notes on Replacing SMA7029M

SMA7036M is pin-compatible with SMA7029M. When using the IC on an existing board, the following preparations are necessary:

(1) Remove the resistors and capacitors attached for setting the chopping OFF time. (r_3, r_4, C_1, and C_2 in the catalog)

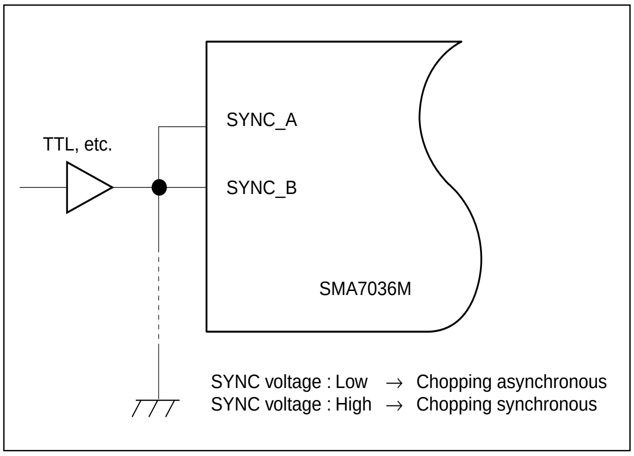
(2) Remove the resistors and capacitors attached for preventing noise in the detection voltage V_{RS} from causing malfunctioning and short the sections from which the resistors were removed using jumper wires. (r_5, r_6, C_3, and C_4 in the catalog)

(3) Normally, keep pins 2 and 11 grounded because their functions have changed to synchronous and asynchronous switching (SYNC terminals). For details, see "Circuit for Preventing Abnormal Noise When the Motor Is Not Running (Synchronous circuit)." (Low: asynchronous, High: synchronous)

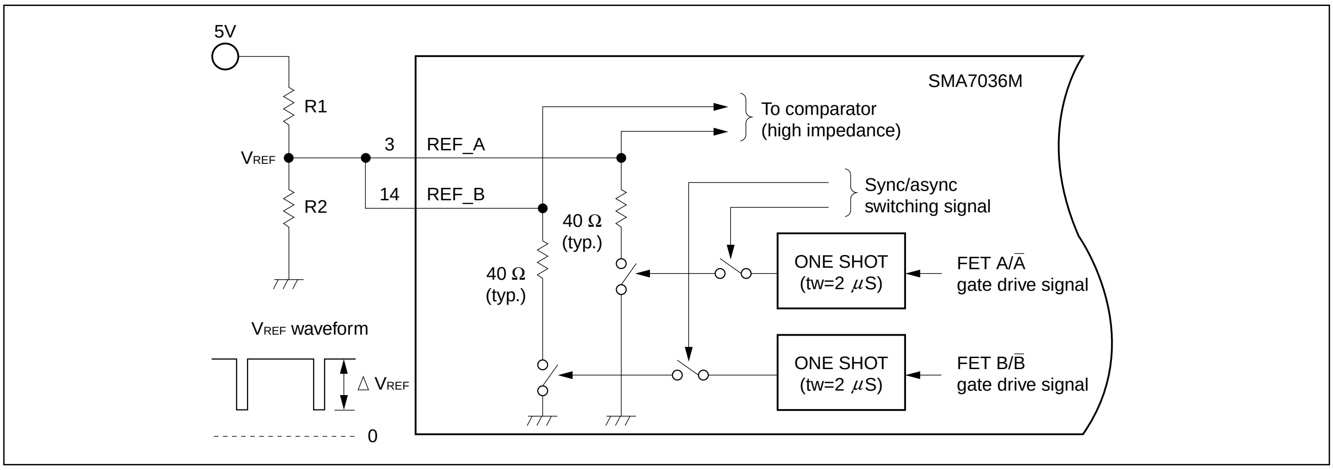
■Circuit for Preventing Abnormal Noise When the Motor Is Not Running (Synchronous Circuit)

A motor may generate abnormal noise when it is not running. This phenomenon is attributable to asynchronous chopping between phases A and B. To prevent the phenomenon, SMA7036M contains a synchronous chopping circuit. Do not leave the SYNC terminals open because they are for CMOS input.

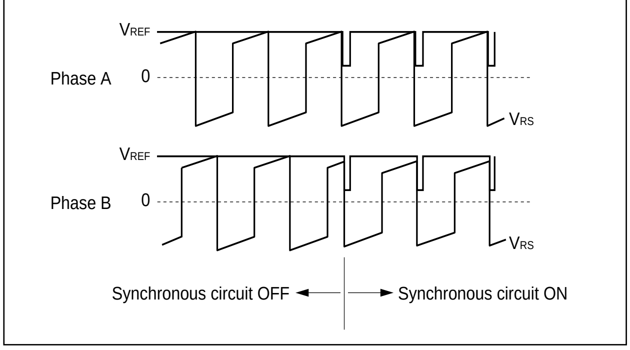
Connect TTL or similar to the SYNC terminals and switch the SYNC terminal level high or low.
When the motor is not running, set the TTL signal high (SYNC terminal voltage: 4 V or more) to make chopping synchronous. When the motor is running, set the TTL signal low (SYNC terminal voltage: 0.8 V or less) to make chopping asynchronous. If chopping is set to synchronous when the motor is running, the motor torque deteriorates before the coil current reaches the set value.
If no abnormal noise occurs when the motor is not running, ground the SYNC terminals (TTL not necessary).



The built-in synchronous chopping circuit superimposes a trigger signal on the REF terminal for synchronization between the two phases. The figure below shows the internal circuit of the REF terminal. Since the ΔV_{REF} varies depending on the values of R1 and R2, determine these values for when the motor is not running within the range where the two phases are synchronized.



■Synchronous circuit operating waveform



■Determining the Output Current

Fig. 1 shows the waveform of the output current (motor coil current). The method of determining the peak value of the output current (I_O) based on this waveform is shown below.

(Parameters for determining the output current I_O)

V_b: Reference supply voltage

r_1,r_2: Voltage-divider resistors for the reference supply voltage

R_S: Current sense resistor

(1) Normal rotation mode

I_O is determined as follows when current flows at the maximum level during motor rotation. (See Fig.2.)

$$I_O \cong \frac{r_2}{r_1+r_2} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (1)$$

(2) Power down mode

The circuit in Fig.3 (r_x and T_r) is added in order to decrease the coil current. I_O is then determined as follows.

$$I_{OPD} \cong \frac{1}{1+\frac{r_1(r_2+r_x)}{r_2 \bullet r_x}} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (2)$$

Equation (2) can be modified to obtain equation to determine rx.

$$r_x = \frac{1}{\frac{1}{r_1}\left(\frac{V_b}{R_s \bullet I_{OPD}}-1\right)-\frac{1}{r_2}}$$

Fig. 4 and 5 show the graphs of equations (1) and (2) respectively.

Fig. 1 Waveform of coil current (Phase A excitation ON)

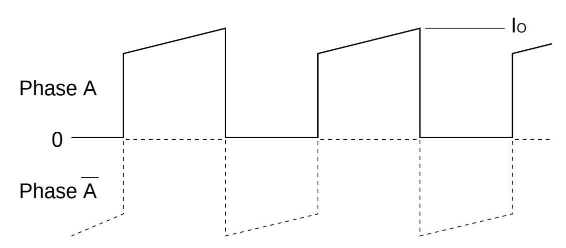


Fig. 2 Normal mode

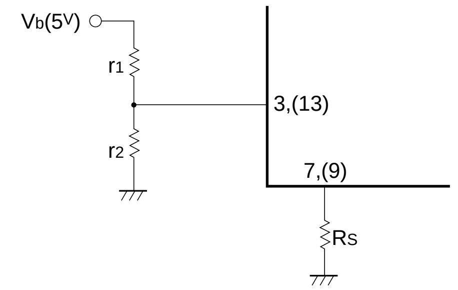


Fig. 3 Power down mode

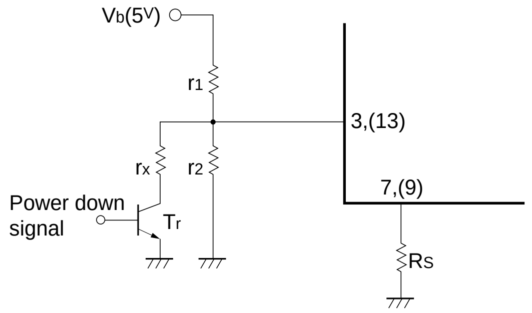


Fig. 4 Output current I_O vs. Current sense resistor R_S

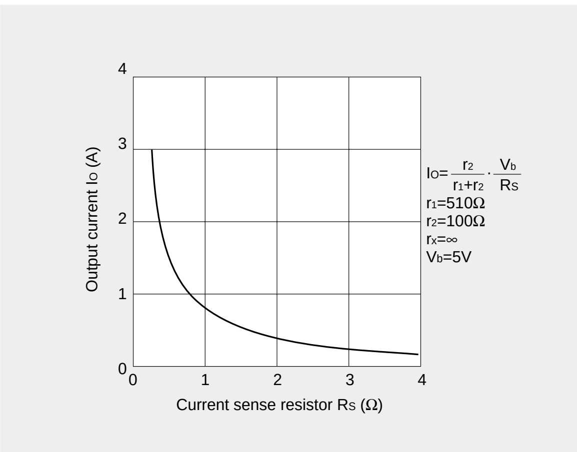
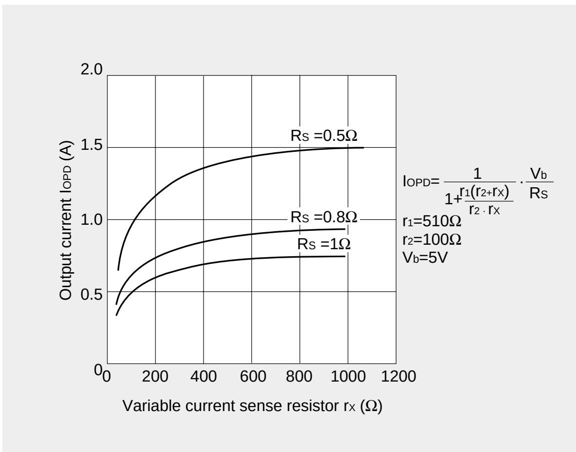


Fig. 5 Output current I_{OPD} vs. Variable current sense resistor rx



■Thermal Design

An outline of the method for calculating heat dissipation is shown below.

(1) Obtain the value of P_H that corresponds to the motor coil current I_O from Fig. 6 "Heat dissipation per phase P_H vs. Output current I_O."

(2) The power dissipation P_{diss} is obtained using the following formula.

2-phase excitation: $P_{diss} \cong 2P_H + 0.015 \times V_S$ (W)

1-2 phase excitation: $P_{diss} \cong \frac{3}{2} P_H + 0.015 \times V_S$ (W)

(3) Obtain the temperature rise that corresponds to the calculated value of P_{diss} from Fig. 7 "Temperature rise."

Fig. 6 Heat dissipation per phase P_H vs. Output current I_O

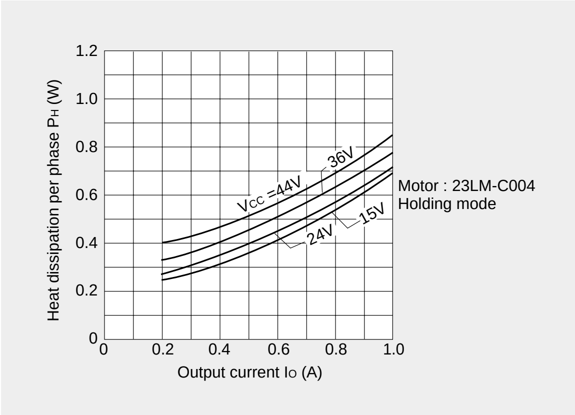
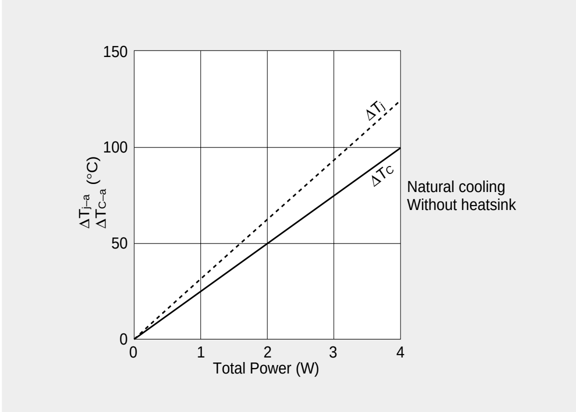
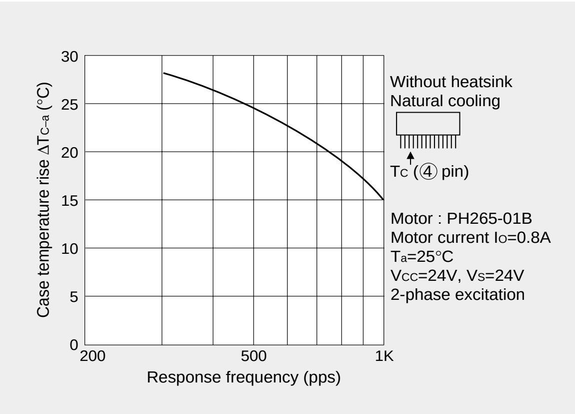


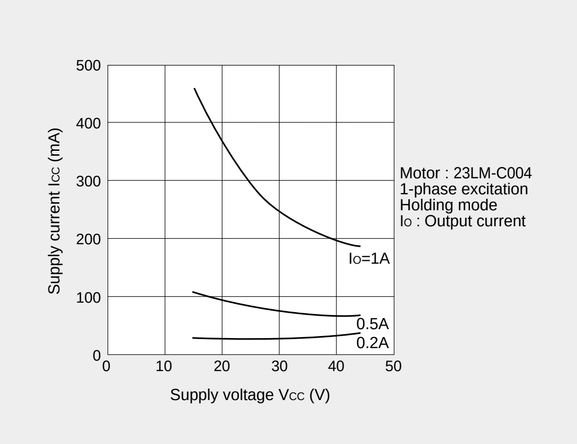
Fig. 7 Temperature rise



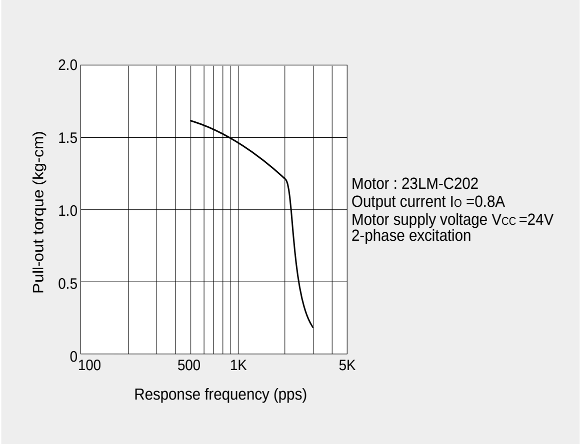
Thermal characteristics



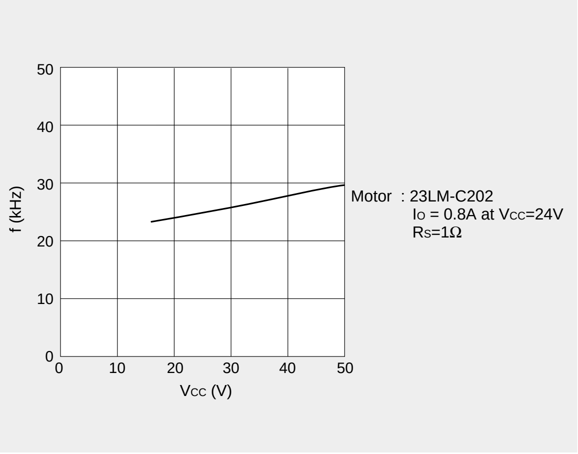
■Supply Voltage Vcc vs. Supply Current Icc



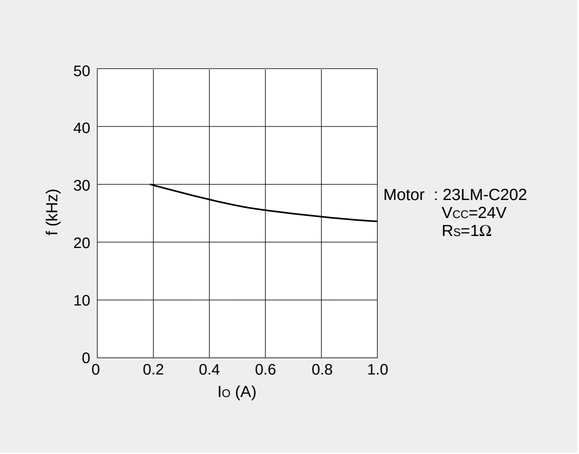
■Torque Characteristics



■Chopper frequency vs. Supply voltage



■Chopper frequency vs. Output current



■Handling Precautions

The input terminals of this product use C-MOS circuits. Observe the following precautions.

- Carefully control the humidity of the room to prevent the buildup of static electricity. Since static electricity is particularly a problem during the winter, be sure to take sufficient precautions.
- Take care to make sure that static electricity is not applied to the IC during wiring and assembly. Take precautions such as shorting the terminals of the printed wiring board to ensure that they are at the same electrical potential.

2-Phase Stepper Motor Unipolar Driver ICs

■Absolute Maximum Ratings

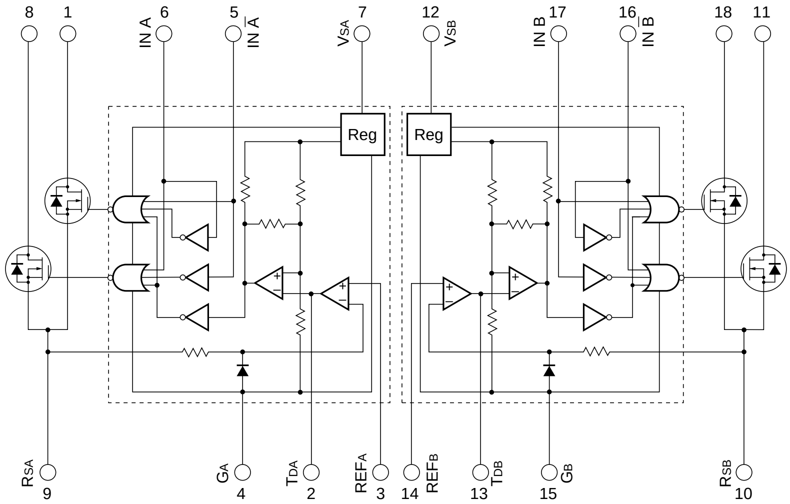
(Ta=25°C)

Parameter	Symbol	Ratings SLA7027MU	Ratings SLA7024M	Ratings SLA7026M	Units
Motor supply voltage	V_{CC}		46		V
FET Drain-Source voltage	V_{DSS}		100		V
Control supply voltage	V_S		46		V
TTL input voltage	V_{IN}		7		V
Reference voltage	V_{REF}		2		V
Output current	I_O	1	1.5	3	A
Power dissipation	P_{D1}		4.5 (Without Heatsink)		W
	P_{D2}		35 (T_C=25°C)		W
Channel temperature	T_{ch}		+150		°C
Storage temperature	T_{stg}		–40 to +150		°C

■Electrical Characteristics

	Parameter	Symbol	SLA7027MU min	SLA7027MU typ	SLA7027MU max	SLA7024M min	SLA7024M typ	SLA7024M max	SLA7026M min	SLA7026M typ	SLA7026M max	Units
DC characteristics	Control supply current	I_S		10	15		10	15		10	15	mA
		Condition	V_S=44V			V_S=44V			V_S=44V			
	Control supply voltage	V_S	10	24	44	10	24	44	10	24	44	V
	FET Drain-Source voltage	V_{DSS}	100			100			100			V
		Condition	V_S=44V, I_{DSS}=250μA			V_S=44V, I_{DSS}=250μA			V_S=44V, I_{DSS}=250μA			
	FET ON voltage	V_{DS}			0.85			0.6			0.85	V
		Condition	I_D=1A, AV_S=14V			I_D=1A, V_S=14V			I_D=3A, V_S=14V			
	FET drain leakage current	I_{DSS}			4			4			4	mA
		Condition	V_{DSS}=100V, V_S=44V			V_{DSS}=100V, V_S=44V			V_{DSS}=100V, V_S=44V			
	FET diode forward voltage	V_{SD}			1.2			1.1			2.3	V
		Condition	I_D=1A			I_D=1A			I_D=3A			
	TTL input current	I_{IH}			40			40			40	μA
		Condition	V_{IH}=2.4V, V_S=44V			V_{IH}=2.4V, V_S=44V			V_{IH}=2.4V, V_S=44V			
		I_{IL}			–0.8			–0.8			–0.8	mA
		Condition	V_{IL}=0.4V, V_S=44V			V_{IL}=0.4V, V_S=44V			V_{IL}=0.4V, V_S=44V			
	TTL input voltage (Active High)	V_{IH}	2			2			2			V
		Condition	I_D=1A			I_D=1A			I_D=3A			
		V_{IL}			0.8			0.8			0.8	
		Condition	V_{DSS}=100V			V_{DSS}=100V			V_{DSS}=100V			
	TTL input voltage (Active Low)	V_{IH}	2			2			2			V
		Condition	V_{DSS}=100V			V_{DSS}=100V			V_{DSS}=100V			
		V_{IL}			0.8			0.8			0.8	
		Condition	I_D=1A			I_D=1A			I_D=3A			
AC characteristics	Switching time	T_r		0.5			0.5			0.5		μs
		Condition	V_S=24V, I_D=0.8A			V_S=24V, I_D=1A			V_S=24V, I_D=1A			
		T_{stg}		0.7			0.7			0.7		
		Condition	V_S=24V, I_D=0.8A			V_S=24V, I_D=1A			V_S=24V, I_D=1A			
		T_f		0.1			0.1			0.1		
		Condition	V_S=24V, I_D=0.8A			V_S=24V, I_D=1A			V_S=24V, I_D=1A			

■Internal Block Diagram



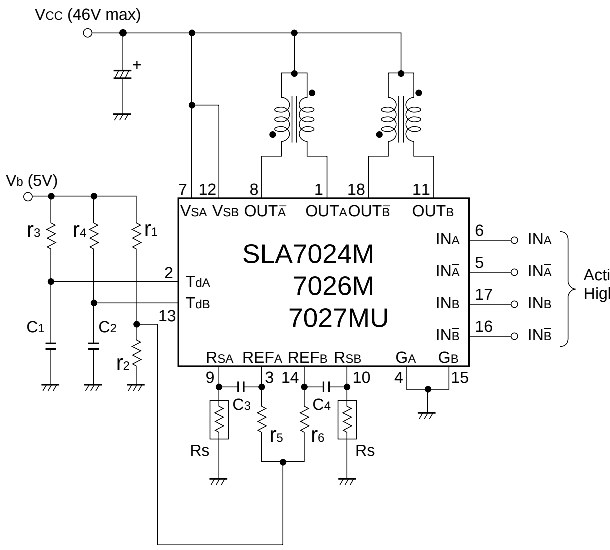
1, 8, 11, 18pin

Description of pins

	Excitation input	
	Active H	Active L
Pin 1	OUTA	OUTĀ
Pin 8	OUTĀ	OUTA
Pin 11	OUTB	OUTB̄
Pin 18	OUTB̄	OUTB

■Diagram of Standard External Circuit(Recommended Circuit Constants)

Active High



Excitation signal time chart

2-phase excitation

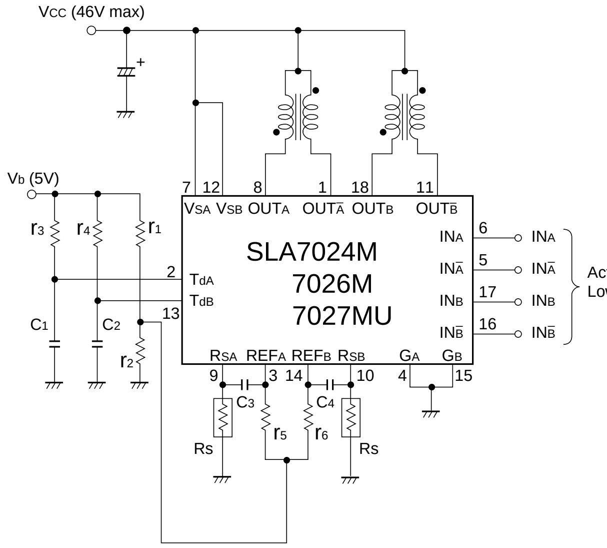
clock	0	1	2	3	0	1
INA	H	L	L	H	H	L
INĀ	L	H	H	L	L	H
INB	H	H	L	L	H	H
INB̄	L	L	H	H	L	L

r_1 : 510Ω
r_2 : 100Ω (VR)
r_3 : 47kΩ
r_4 : 47kΩ
r_5 : 2.4kΩ
r_6 : 2.4kΩ
C_1 : 470pF
C_2 : 470pF
C_3 : 2200pF
C_4 : 2200pF
R_s : 1Ω typ(7024M)
(1 to 2W) 0.68Ω typ(7026M)
1.8Ω typ(7027MU)

1-2 phase excitation

clock	0	1	2	3	4	5	6	7	0	1	2	3
INA	H	H	L	L	L	L	L	H	H	H	L	L
INĀ	L	L	L	H	H	H	L	L	L	L	L	H
INB	L	H	H	H	L	L	L	L	L	H	H	H
INB̄	L	L	L	L	L	H	H	H	L	L	L	L

Active Low



Excitation signal time chart

2-phase excitation

clock	0	1	2	3	0	1
INA	L	H	H	L	L	H
INĀ	H	L	L	H	H	L
INB	L	L	H	H	L	L
INB̄	H	H	L	L	H	H

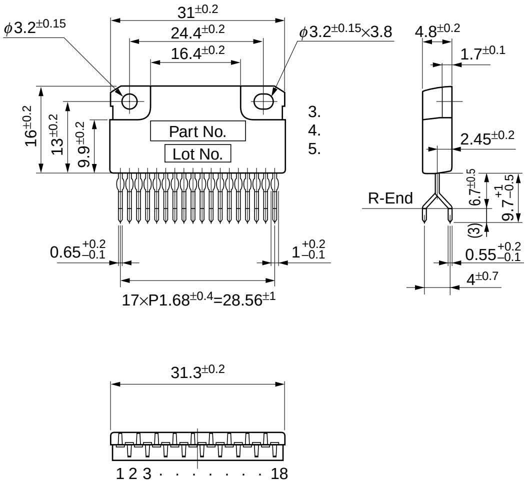
r_1 : 510Ω
r_2 : 100Ω(VR)
r_3 : 47kΩ
r_4 : 47kΩ
r_5 : 2.4kΩ
r_6 : 2.4kΩ
C_1 : 470pF
C_2 : 470pF
C_3 : 2200pF
C_4 : 2200pF
R_s : 1Ω typ(7024M)
(1 to 2W) 0.68Ω typ(7026M)
1.8Ω typ(7027MU)

1-2 phase excitation

clock	0	1	2	3	4	5	6	7	0	1	2	3
INA	L	L	H	H	H	H	H	L	L	L	H	H
INĀ	H	H	H	L	L	L	H	H	H	H	H	L
INB	H	L	L	L	H	H	H	H	H	L	L	L
INB̄	H	H	H	H	H	L	L	L	H	H	H	H

■External Dimensions

(Unit: mm)



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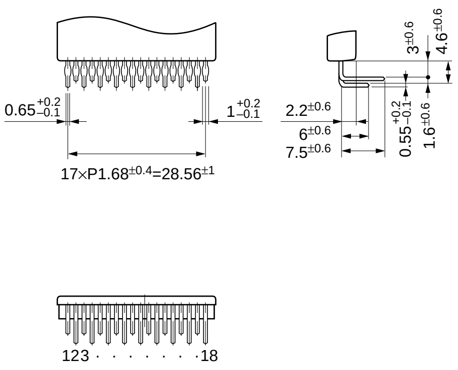

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Application Notes

■Determining the Output Current

Fig. 1 shows the waveform of the output current (motor coil current). The method of determining the peak value of the output current (I_O) based on this waveform is shown below.

(Parameters for determining the output current I_O)

V_b: Reference supply voltage

r_1,r_2: Voltage-divider resistors for the reference supply voltage

R_S: Current sense resistor

(1) Normal rotation mode

I_O is determined as follows when current flows at the maximum level during motor rotation. (See Fig.2.)

$$I_O \cong \frac{r_2}{r_1+r_2} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (1)$$

(2) Power down mode

The circuit in Fig.3 (r_X and Tr) is added in order to decrease the coil current. I_O is then determined as follows.

$$I_{OPD} \cong \frac{1}{1+\dfrac{r_1(r_2+r_X)}{r_2 \bullet r_X}} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (2)$$

Equation (2) can be modified to obtain equation to determine rx.

$$r_X = \frac{1}{\dfrac{1}{r_1}\left(\dfrac{V_b}{R_S \bullet I_{OPD}} - 1\right) - \dfrac{1}{r_2}}$$

Fig. 4 and 5 show the graphs of equations (1) and (2) respectively.

Fig. 1 Waveform of coil current (Phase A excitation ON)

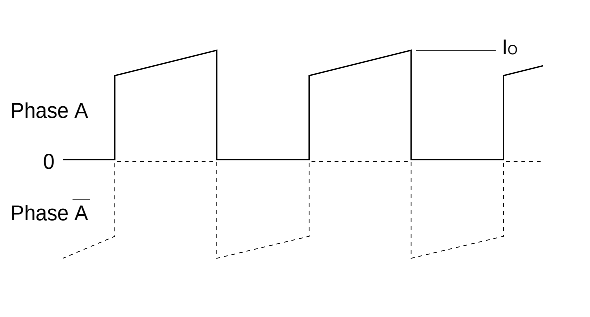


Fig. 2 Normal mode

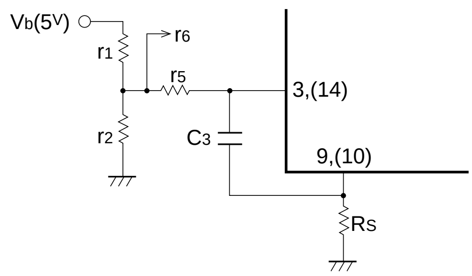


Fig. 3 Power down mode

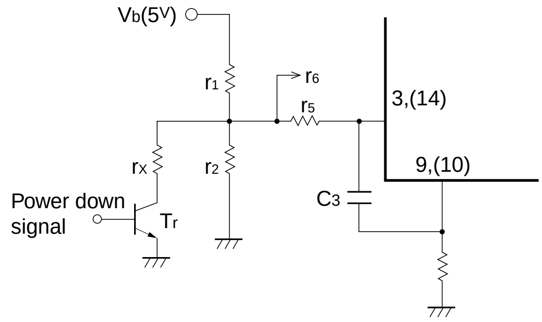


Fig. 4 Output current I_O vs. Current sense resistor R_S

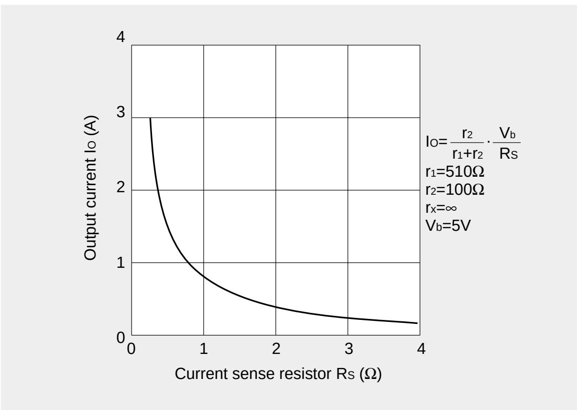
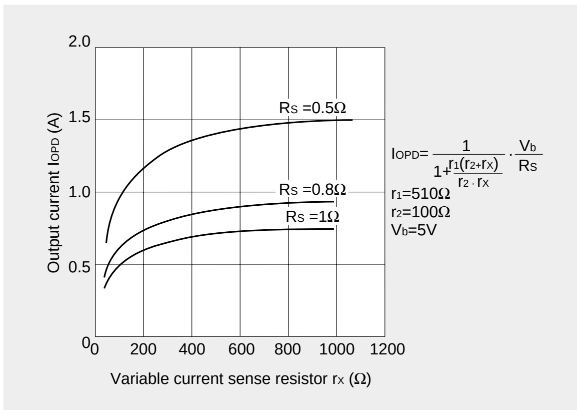


Fig. 5 Output current I_{OPD} vs. Variable current sense resistor r_X



(NOTE)

Ringing noise is produced in the current sense resistor R_S when the MOSFET is switched ON and OFF by chopping. This noise is also generated in feedback signals from R_S which may therefore cause the comparator to malfunction. To prevent chopping malfunctions, r_5(r_6) and C_3(C_4) are added to act as a noise filter.

However, when the values of these constants are increased, the response from R_S to the comparator becomes slow. Hence the value of the output current I_O is somewhat higher than the calculated value.

■Determining the chopper frequency

Determining T_{OFF}

The SLA7000M series are self-excited choppers. The chopping OFF time T_{OFF} is fixed by r_3/C_1 and r_4/C_2 connected to terminal Td.

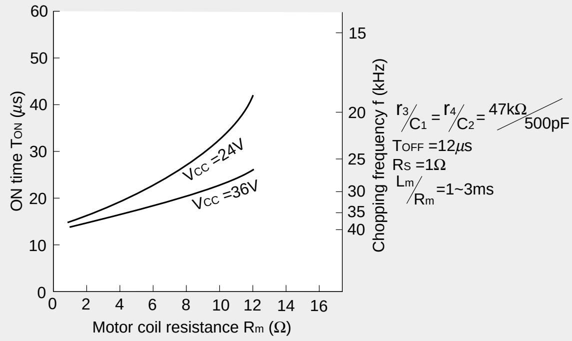
T_{OFF} can be calculated using the following formula:

$$T_{OFF} \cong -r_3 \bullet C_1 \ell n\left(1-\frac{2}{V_b}\right) = -r_4 \bullet C_2 \ell n\left(1-\frac{2}{V_b}\right)$$

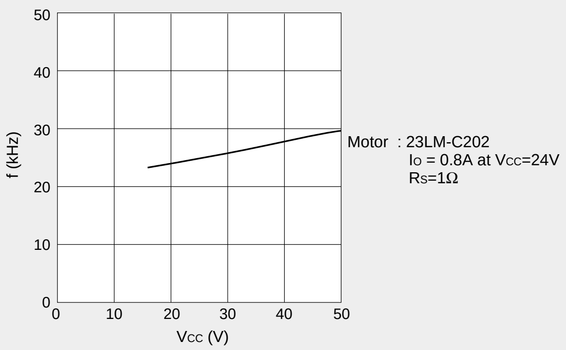
The circuit constants and the T_{OFF} value shown below are recommended.

T_{OFF} = 12μs at r_3=47kΩ, C_1=500pF, V_b=5V

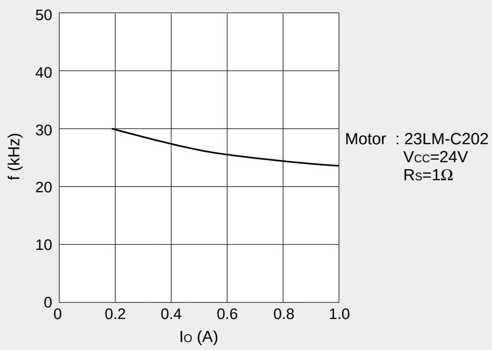
Fig. 6 Chopper frequency vs. Motor coil resistance



■Chopper frequency vs. Supply voltage



■Chopper frequency vs. Output current



■Thermal Design

An outline of the method for calculating heat dissipation is shown below.

(1) Obtain the value of P_H that corresponds to the motor coil current I_O from Fig. 7 "Heat dissipation per phase P_H vs. Output current I_O."

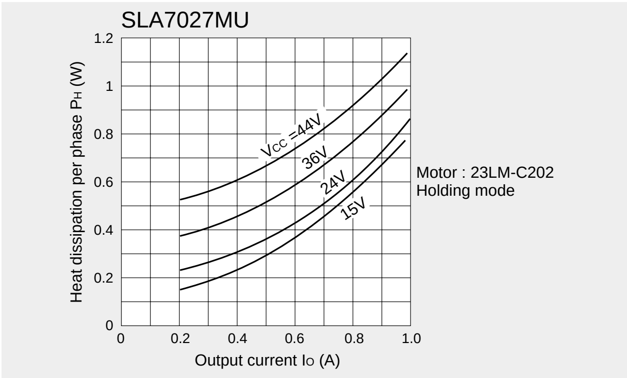
(2) The power dissipation Pdiss is obtained using the following formula.

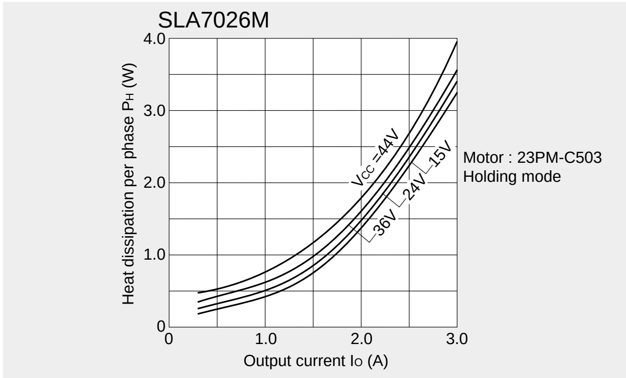
2-phase excitation: $P_{diss} \cong 2P_H + 0.015 \times V_S$ (W)

1-2 phase excitation: $P_{diss} \cong \frac{3}{2} P_H + 0.015 \times V_S$ (W)

(3) Obtain the temperature rise that corresponds to the calculated value of Pdiss from Fig. 8 "Temperature rise."

Fig. 7 Heat dissipation per phase P_H vs. Output current I_O





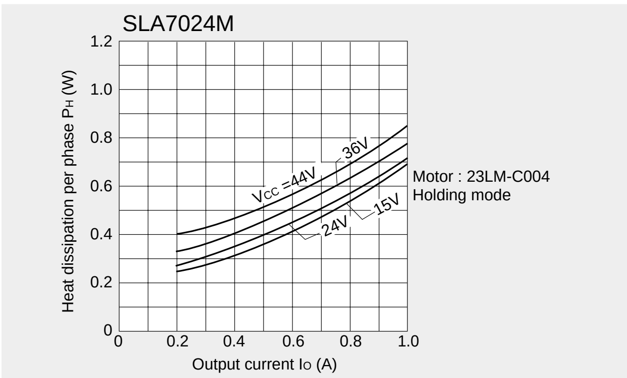
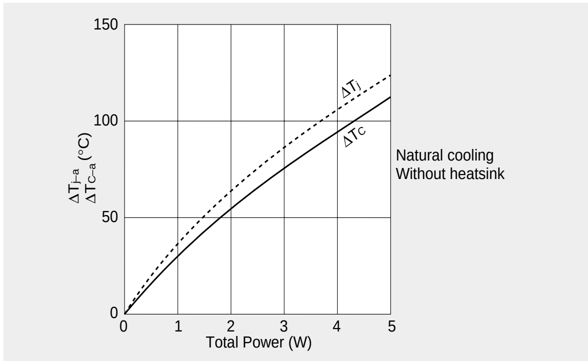
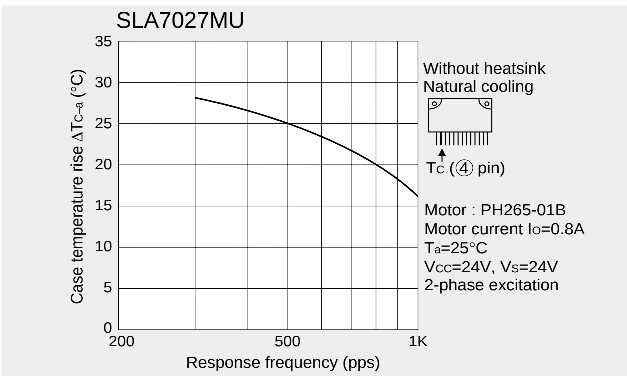
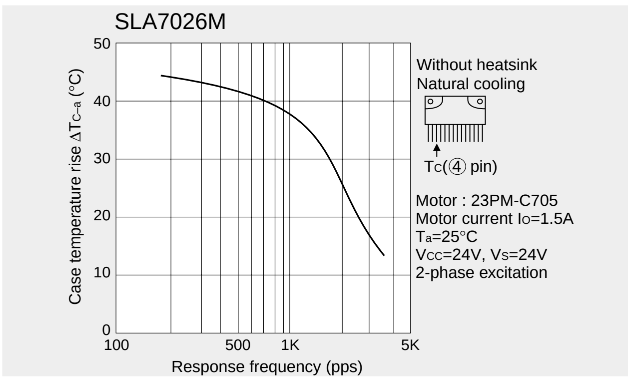


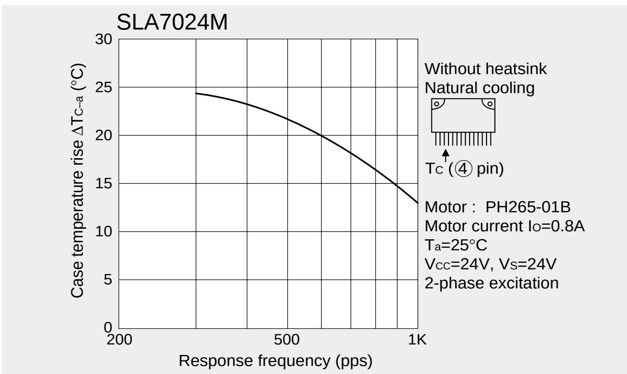
Fig. 8 Temperature rise



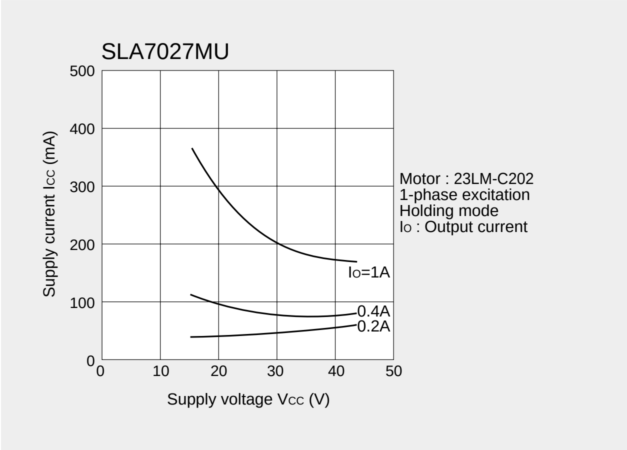
Thermal characteristics

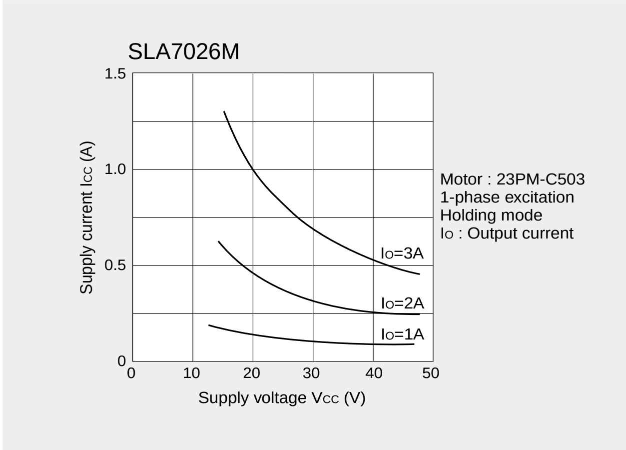


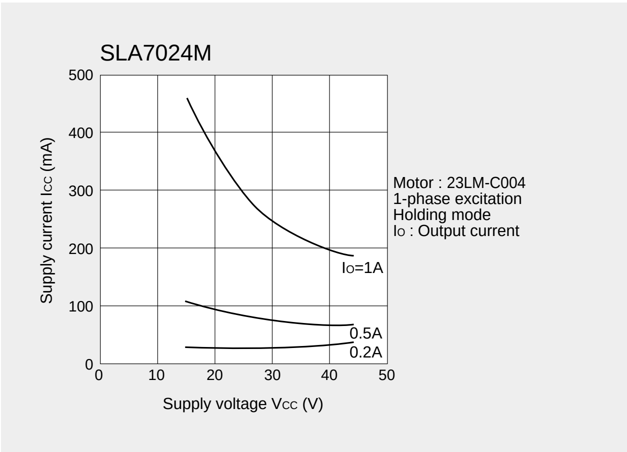




■Supply Voltage V_{CC} vs. Supply Current I_{CC}







■Note

The excitation input signals of the SLA7027MU, SLA7024M and SLA7026M can be used as either Active High or Active Low. Note, however, that the corresponding output (OUT) changes depending on the input (IN).

Active High

Input	Corresponding output
IN_A (pin6)	OUT_A (pin1)
$IN_{\overline{A}}$ (pin5)	$OUT_{\overline{A}}$ (pin8)
IN_B (pin17)	OUT_B (pin11)
$IN_{\overline{B}}$ (pin16)	$OUT_{\overline{B}}$ (pin18)

Active Low

Input	Corresponding output
IN_A (pin6)	OUT_A (pin8)
$IN_{\overline{A}}$ (pin5)	$OUT_{\overline{A}}$ (pin1)
IN_B (pin17)	OUT_B (pin18)
$IN_{\overline{B}}$ (pin16)	$OUT_{\overline{B}}$ (pin11)

2-Phase Stepper Motor Unipolar Driver ICs

■Absolute Maximum Ratings

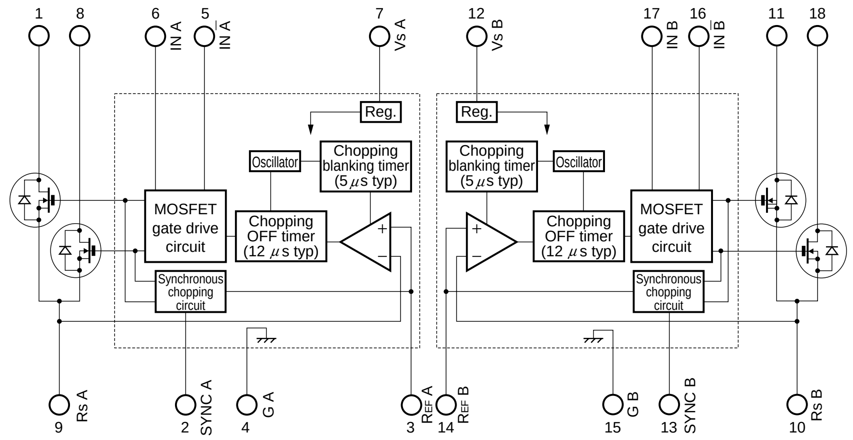
(Ta=25°C)

Parameter	Symbol	Ratings SLA7032M	Ratings SLA7033M	Units
Motor supply voltage	V_{CC}	46		V
Control supply voltage	V_S	46		V
FET Drain-Source voltage	V_{DSS}	100		V
TTL input voltage	V_{IN}	−0.3 to +7		V
SYNC terminal voltage	V_{SYNC}	−0.3 to +7		
Reference voltage	V_{REF}	−0.3 to +7		V
Sense voltage	V_{RS}	−5 to +7		V
Output current	I_O	1.5	3	A
Power dissipation	P_{D1}	4.5 (Without Heatsink)		W
	P_{D2}	35 (T_c = 25°C)		W
Channel temperature	T_{ch}	+150		°C
Storage temperature	T_{stg}	−40 to +150		°C

■Electrical Characteristics

	Parameter		Symbol	SLA7032M min	SLA7032M typ	SLA7032M max	SLA7033M min	SLA7033M typ	SLA7033M max	Units
DC characteristics	Control supply current		I_S		10	15		10	15	mA
			Condition	V_S=44V			V_S=44V			
	Control supply voltage		V_S	10	24	44	10	24	44	V
	FET Drain-Source voltage		V_{DSS}	100			100			V
			Condition	V_S=44V, I_{DSS}=250μA			V_S=44V, I_{DSS}=250μA			
	FET ON voltage		V_{DS}			0.6			0.85	V
			Condition	I_D=1A, V_S=14V			I_D=3A, V_S=14V			
	FET diode forward voltage		V_{SD}			1.1			2.3	V
			Condition	I_{SD}=1A			I_{SD}=3A			
	FET drain leakage current		I_{DSS}			250			250	μA
			Condition	V_{DSS}=100V, V_S=44V			V_{DSS}=100V, V_S=44V			
	IN terminal	OUT	V_{IH}	2.0			2.0			V
			Condition	I_D=1A			I_D=3A			
			V_{IL}			0.8			0.8	
			Condition	V_{DSS}=100V			V_{DSS}=100V			
		$\overline{OUT}$	V_{IH}	2.0			2.0			V
			Condition	V_{DSS}=100V			V_{DSS}=100V			
			V_{IL}			0.8			0.8	
			Condition	I_D=1A			I_D=3A			
		Input current	I_I			±1			±1	μA
			Condition	V_S=44V, V_I=0 or 5V			V_S=44V, V_I=0 or 5V			
	SYNC terminal	Input voltage	V_{SYNC}	4.0			4.0			V
			Condition	Synchronous chopping mode			Synchronous chopping mode			
			V_{SYNC}			0.8			0.8	
			Condition	Asynchronous chopping mode			Asynchronous chopping mode			
		Input current¨	I_{SYNC}			0.1			0.1	mA
			Condition	V_S=44V, V_{YS}=5V			V_S=44V, V_{YS}=5V			
			I_{SYNC}			−0.1			−0.1	
			Condition	V_S=44V, V_{YS}=0V			V_S=44V, V_{YS}=0V			
	REF terminal	Input current	V_{REF}	0		2.0	0		2.0	V
			Condition	Reference voltage input			Reference voltage input			
			V_{REF}	4.0		5.5	4.0		5.5	
			Condition	Output FET OFF			Output FET OFF			
		Input current	I_{REF}			±1			±1	μA
			Condition	No synchronous trigger			No synchronous trigger			
		Internal resistance	R_{REF}		40			40		Ω
			Condition	Resistance between GND and REF terminal at synchronous trigger			Resistance between GND and REF terminal at synchronous trigger			
AC characteristics	Switching time		T_r		0.5			0.5		μs
			Condition	V_S=24V, I_D=1A			V_S=24V, I_D=1A			
			T_{stg}		0.7			0.7		
			Condition	V_S=24V, I_D=1A			V_S=24V, I_D=1A			
			T_f		0.1			0.1		
			Condition	V_S=24V, I_D=1A			V_S=24V, I_D=1A			
	Chopping OFF time		T_{OFF}		12			12		μs
			Condition	V_S=24V			V_S=24V			

■Internal Block Diagram

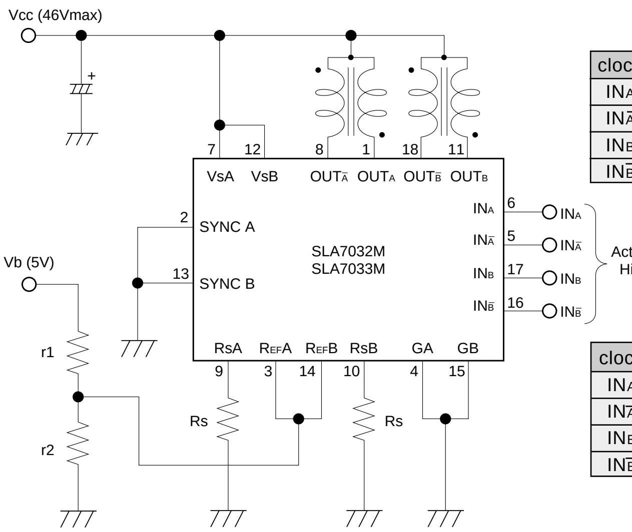


1, 8, 11, 18pin
Description of pins

	Excitation input	
	Active H	Active L
1pin	OUT A	OUT Ā
8pin	OUT Ā	OUT A
11pin	OUT B	OUT B̄
18pin	OUT B̄	OUT B

■Diagram of Standard External Circuit (Recommended Circuit Constants)

Active High



Excitation signal time chart
2-phase excitation

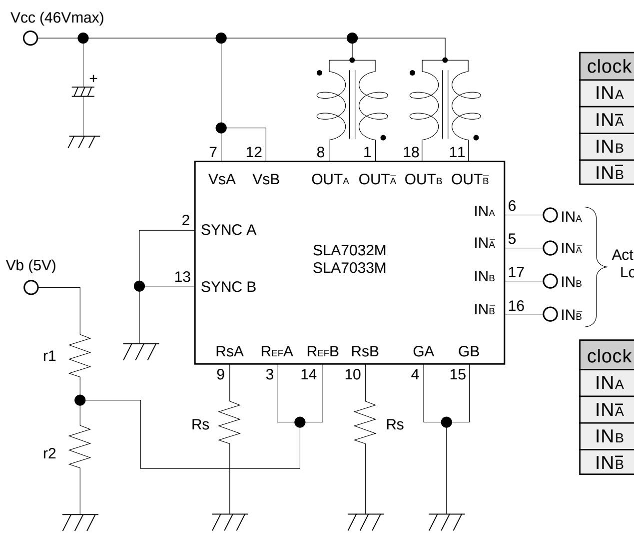
clock	0	1	2	3	0	1
IN_A	H	L	L	H	H	L
$IN_{\bar{A}}$	L	H	H	L	L	H
IN_B	H	H	L	L	H	H
$IN_{\bar{B}}$	L	L	H	H	L	L

r_1 : 4kΩ
r_2 : 1kΩ(VR)
R_s : 1Ω typ(7032M)
(1 to 2W) 0.68Ω typ(7033M)

1-2 phase excitation

clock	0	1	2	3	4	5	6	7	0	1	2	3
IN_A	H	H	L	L	L	L	L	H	H	H	L	L
$IN_{\bar{A}}$	L	L	L	H	H	H	L	L	L	L	L	H
IN_B	L	H	H	H	L	L	L	L	L	H	H	H
$IN_{\bar{B}}$	L	L	L	L	L	H	H	H	L	L	L	L

Active Low



Excitation signal time chart
2-phase excitation

clock	0	1	2	3	0	1
IN_A	L	H	H	L	L	H
$IN_{\bar{A}}$	H	L	L	H	H	L
IN_B	L	L	H	H	L	L
$IN_{\bar{B}}$	H	H	L	L	H	H

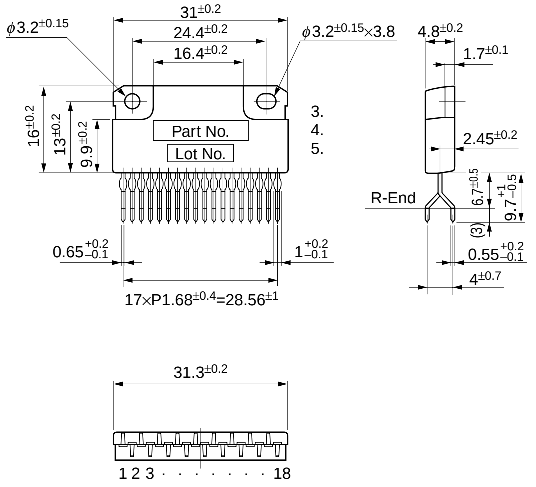
r_1 : 4kΩ
r_2 : 1kΩ(VR)
R_s : 1Ω typ(7032M)
(1 to 2W) 0.68Ω typ(7033M)

1-2 phase excitation

clock	0	1	2	3	4	5	6	7	0	1	2	3
IN_A	L	L	H	H	H	H	H	L	L	L	H	H
$IN_{\bar{A}}$	H	H	H	L	L	L	H	H	H	H	H	L
IN_B	H	L	L	L	H	H	H	H	H	L	L	L
$IN_{\bar{B}}$	H	H	H	H	H	L	L	L	H	H	H	H

■External Dimensions

(Unit: mm)



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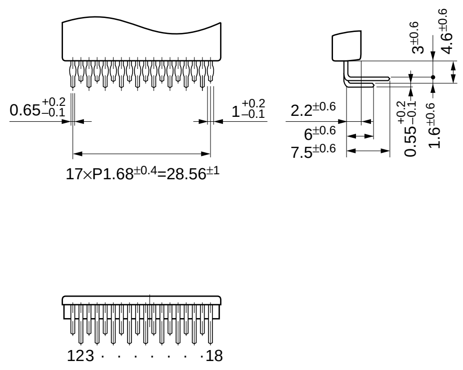


Forming No. No.872

Application Notes

■Outline

SLA7032M (SLA7033M) is a stepper motor driver IC developed to reduce the number of external parts required by the conventional SLA7024M (SLA7026M). This IC successfully eliminates the need for some external parts without sacrificing the features of SLA7024M (SLA7026M). The basic function pins are compatible with those of SLA7024M (SLA7026M).

■Notes on Replacing SLA7024M (SLA7026M)

SLA7032M (SLA7033M) is pin-compatible with SLA7024M (SLA7026M). When using the IC on an existing board, the following preparations are necessary:

(1) Remove the resistors and capacitors attached for setting the chopping OFF time. (r_3, r_4, C_1, and C_2 in the catalog)

(2) Remove the resistors and capacitors attached for preventing noise in the detection voltage V_{RS} from causing malfunctioning and short the sections from which the resistors were removed using jumper wires. (r_5, r_6, C_3, and C_4 in the catalog)

(3) Normally, keep pins 2 and 13 grounded because their functions have changed to synchronous and asynchronous switching (SYNC terminals). For details, see "Circuit for Preventing Abnormal Noise When the Motor Is Not Running (Synchronous circuit)." (Low: asynchronous, High: synchronous)

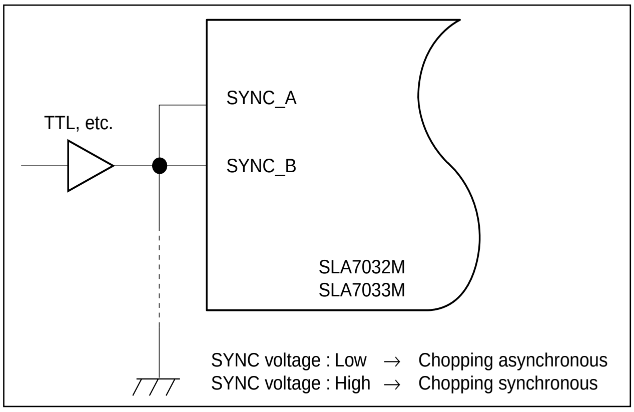
■Circuit for Preventing Abnormal Noise When the Motor Is Not Running (Synchronous Circuit)

A motor may generate abnormal noise when it is not running. This phenomenon is attributable to asynchronous chopping between phases A and B. To prevent the phenomenon, SLA7032M (SLA7033M) contains a synchronous chopping circuit. Do not leave the SYNC terminals open because they are for CMOS input.

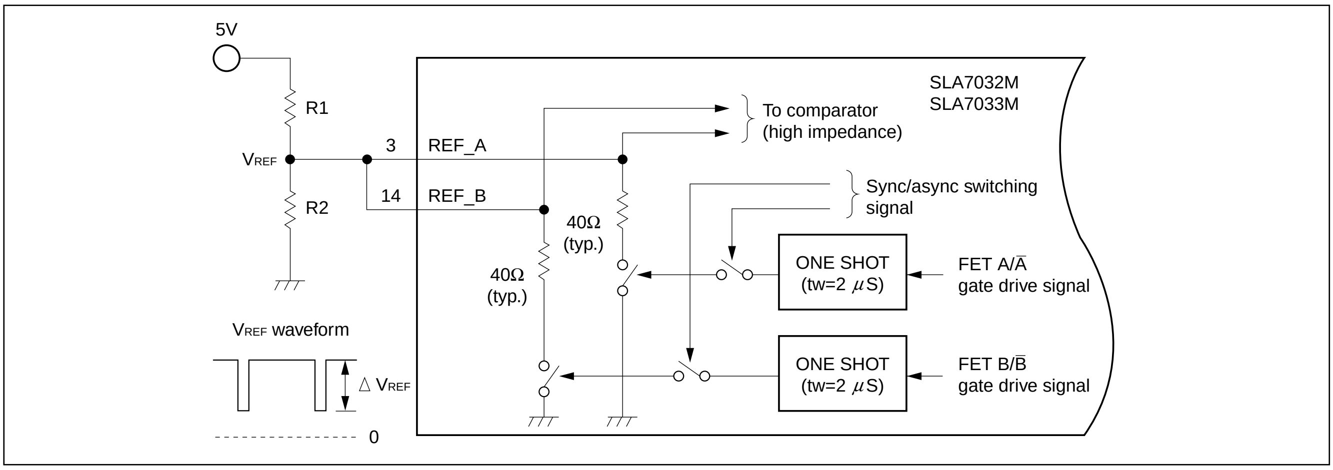
Connect TTL or similar to the SYNC terminals and switch the SYNC terminal level high or low.

When the motor is not running, set the TTL signal high (SYNC terminal voltage: 4 V or more) to make chopping synchronous. When the motor is running, set the TTL signal low (SYNC terminal voltage: 0.8 V or less) to make chopping asynchronous. If chopping is set to synchronous at when the motor is running, the motor torque deteriorates before the coil current reaches the set value.

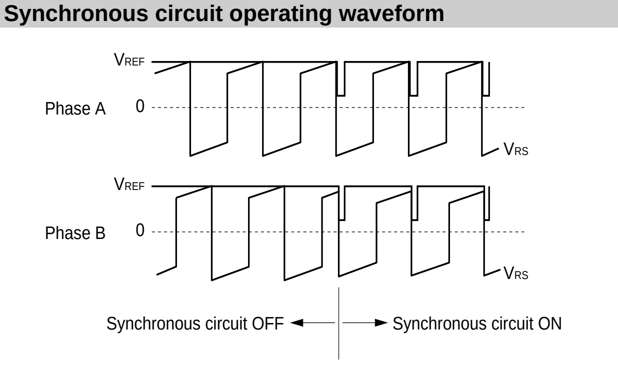
If no abnormal noise occurs when the motor is not running, ground the SYNC terminals (TTL not necessary).



The built-in synchronous chopping circuit superimposes a trigger signal on the REF terminal for synchronization between the two phases. The figure below shows the internal circuit of the REF terminal. Since the ΔV_{REF} varies depending on the values of R1 and R2, determine these values for when the motor is not running within the range where the two phases are synchronized.



Synchronous circuit operating waveform



■Determining the Output Current

Fig. 1 shows the waveform of the output current (motor coil current). The method of determining the peak value of the output current (I_O) based on this waveform is shown below.

(Parameters for determining the output current I_O)

V_b: Reference supply voltage

r_1,r_2: Voltage-divider resistors for the reference supply voltage

R_S: Current sense resistor

(1) Normal rotation mode

I_O is determined as follows when current flows at the maximum level during motor rotation. (See Fig.2.)

$$I_O \cong \frac{r_2}{r_1+r_2} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (1)$$

(2) Power down mode

The circuit in Fig.3 (r_x and T_r) is added in order to decrease the coil current. I_O is then determined as follows.

$$I_{OPD} \cong \frac{1}{1+\dfrac{r_1(r_2+r_x)}{r_2 \bullet r_x}} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (2)$$

Equation (2) can be modified to obtain equation to determine r_x.

$$r_x = \frac{1}{\dfrac{1}{r_1}\left(\dfrac{V_b}{R_s \bullet I_{OPD}} - 1\right) - \dfrac{1}{r_2}}$$

Fig. 4 and 5 show th e graphs of equations (1) and (2) respectively.

Fig. 1 Waveform of coil current (Phase A excitation ON)

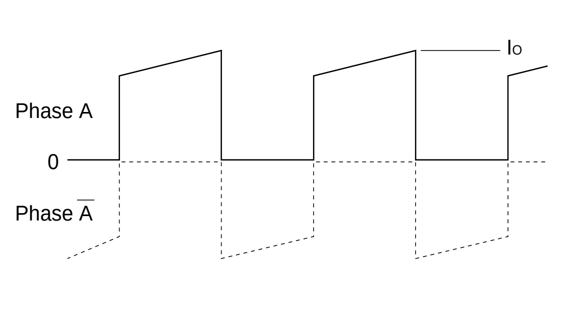


Fig. 2 Normal mode

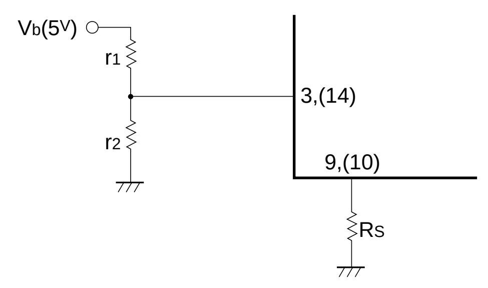


Fig. 3 Power down mode

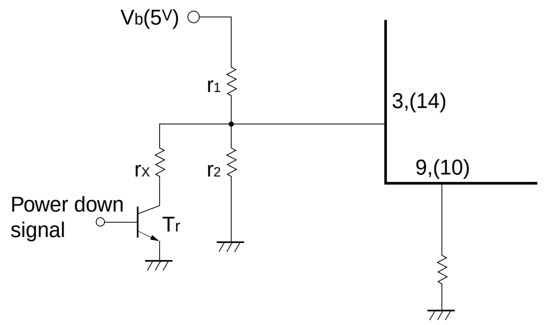


Fig. 4 Output current I_O vs. Current sense resistor R_S

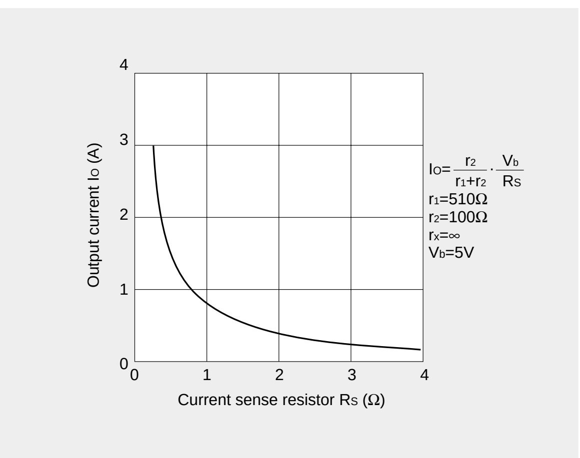
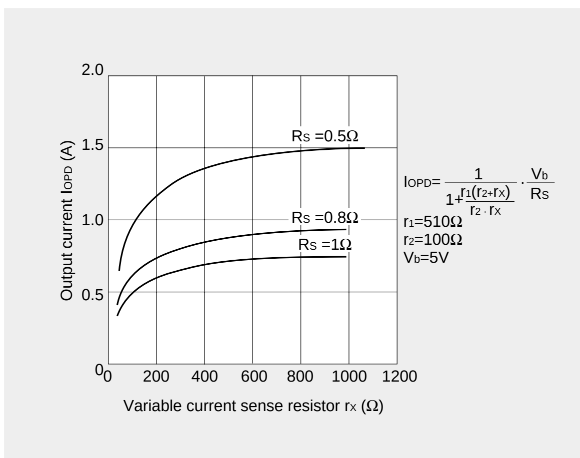


Fig. 5 Output current I_{OPD} vs. Variable current sense resistor r_x



■Thermal Design

An outline of the method for calculated heat dissipation is shown below.

(1) Obtain the value of P_H that corresponds to the motor coil current I_O from Fig. 6 "Heat dissipation per phase P_H vs. Output current I_O."

(2) The power dissipation P_{diss} is obtained using the following formula.

2-phase excitation: $P_{diss} \cong 2P_H + 0.015 \times V_S$ (W)

1-2 phase excitation: $P_{diss} \cong \frac{3}{2} P_H + 0.015 \times V_S$ (W)

(3) Obtain the temperature rise that corresponds to the computed value of P_{diss} from Fig. 7 "Temperature rise."

Fig. 6 Heat dissipation per phase P_H vs. Output current I_O

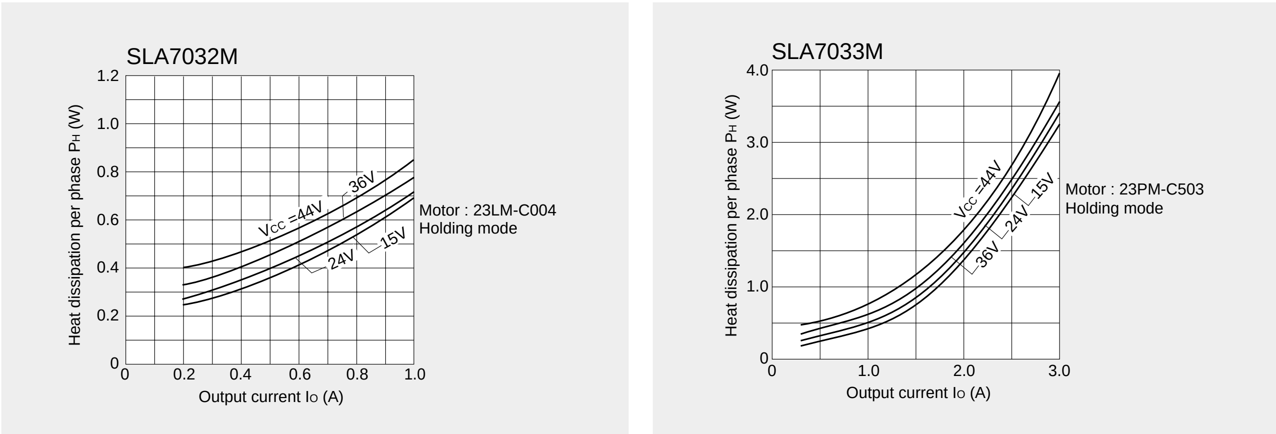
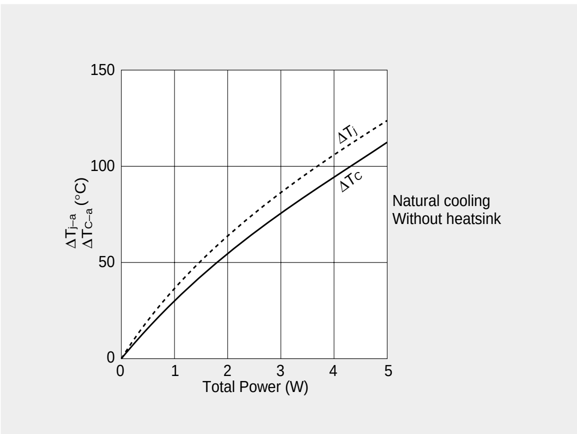
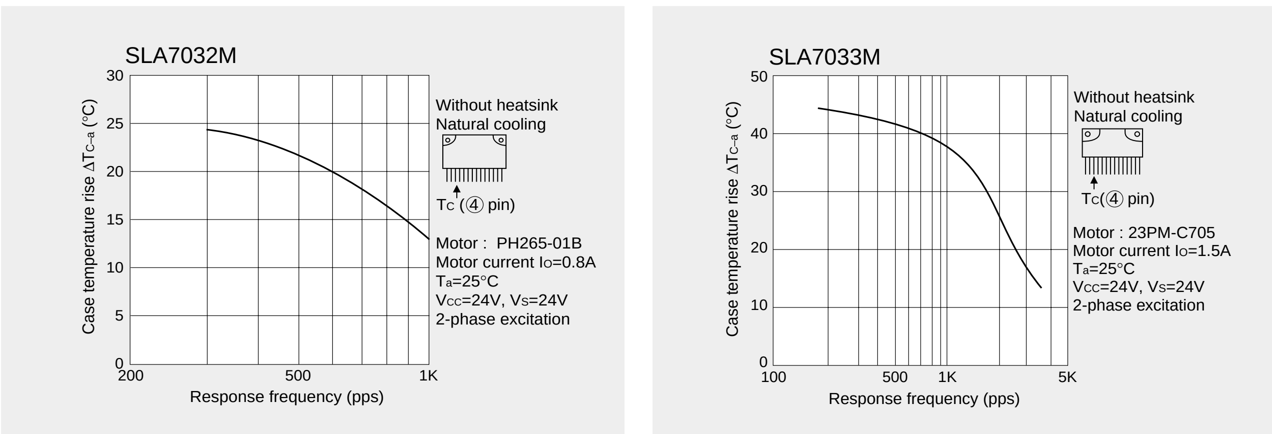


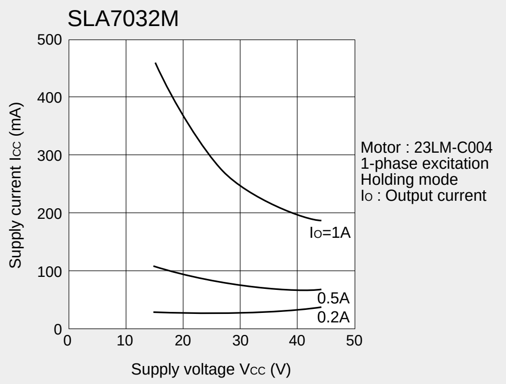
Fig. 7 Temperature rise

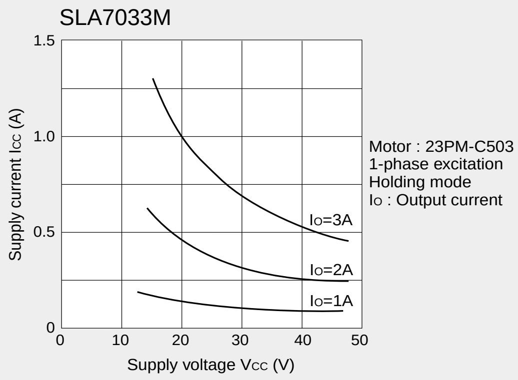


Thermal characteristics

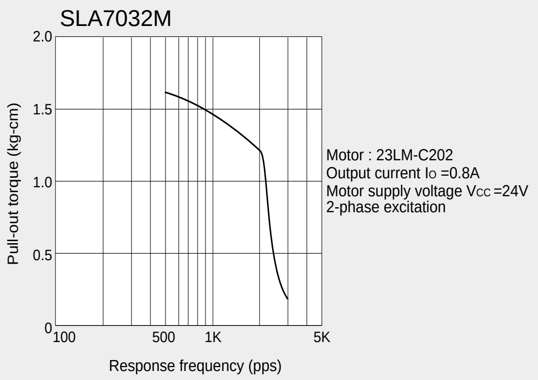


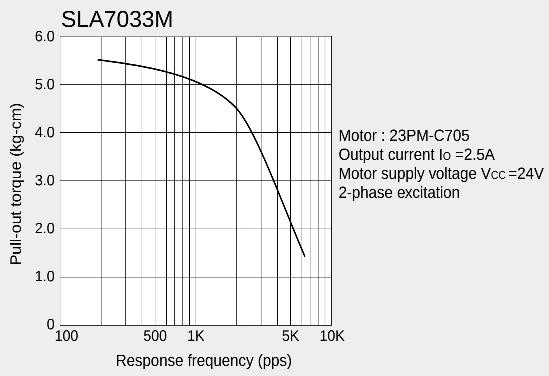
■Supply Voltage V_{CC} vs. Supply Current I_{CC}



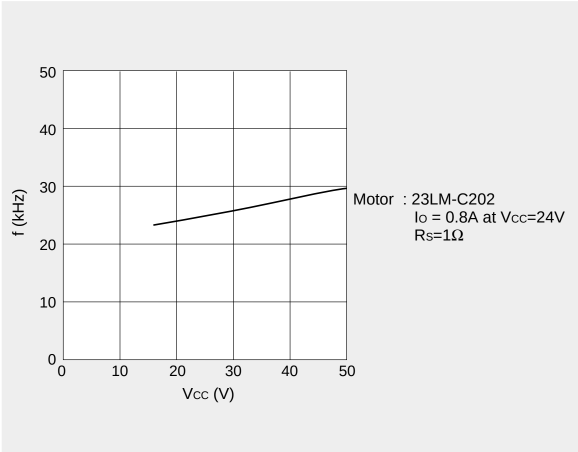


■Torque Characteristics

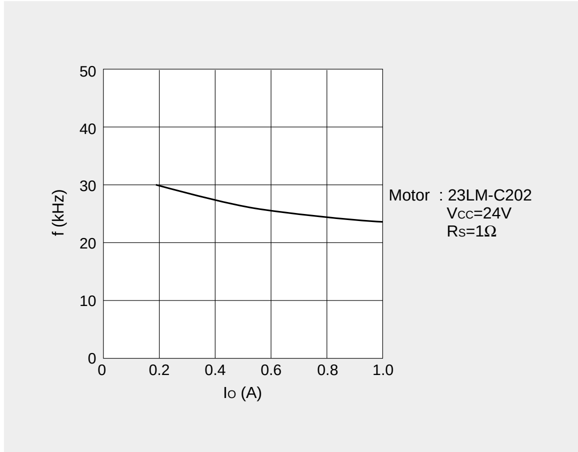




■Chopper frequency vs. Supply voltage



■Chopper frequency vs. Output current



■Note

The excitation input signals of the SLA7032M, SLA7033M can be used as either Active High or Active Low. Note, however, that the corresponding output (OUT) changes depending on the input (IN).

Active High

Input	Corresponding output
IN_A (pin6)	OUT_A (pin1)
$IN_{\bar{A}}$ (pin5)	$OUT_{\bar{A}}$ (pin8)
IN_B (pin17)	OUT_B (pin11)
$IN_{\bar{B}}$ (pin16)	$OUT_{\bar{B}}$ (pin18)

Active Low

Input	Corresponding output
IN_A (pin6)	OUT_A (pin8)
$IN_{\bar{A}}$ (pin5)	$OUT_{\bar{A}}$ (pin1)
IN_B (pin17)	OUT_B (pin18)
$IN_{\bar{B}}$ (pin16)	$OUT_{\bar{B}}$ (pin11)

■Handling Precautions

The input terminals of this product use C-MOS circuits. Observe the following precautions.

- Carefully control the humidity of the room to prevent the buildup of static electricity. Since static electricity is particularly a problem during the winter, be sure to take sufficient precautions.
- Take care to make sure that static electricity is not applied to the IC during wiring and assembly. Take precautions such as shorting the terminals of the printed wiring board to ensure that they are at the same electrical potential.

2-Phase Stepper Motor Unipolar Driver ICs

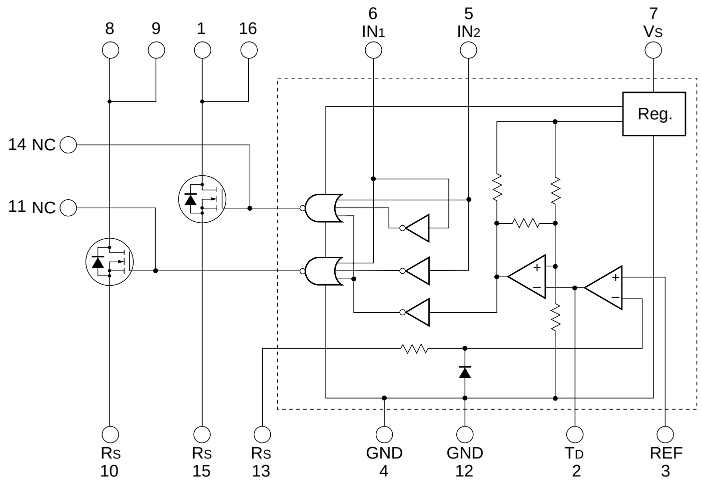
■Absolute Maximum Ratings

Parameter	Symbol	Ratings	Units
Motor supply voltage	V_{CC}	46	V
FET Drain-Source voltage	V_{DSS}	100	V
Control supply voltage	V_S	46	V
TTL input voltage	V_{IN}	7	V
Reference voltage	V_{REF}	2	V
Output current	I_O	1	A
Power dissipation	P_D	2.5 (Without Heatsink)	W
Channel temperature	T_{ch}	+150	°C
Storage temperature	T_{stg}	−40 to +150	°C

■Electrical Characteristics

	Parameter	Symbol	Ratings			Units
			min	typ	max	
DC characteristics	Control supply current	I_S		5	7.5	mA
		Condition	V_S=44V			
	Control supply voltage	V_S	10	24	44	V
	FET Drain-Source voltage	V_{DSS}	100			V
		Condition	V_S=44V, I_{DSS}=250μA			
	FET ON voltage	V_{DS}			0.85	V
		Condition	I_D=1A, V_S=14V			
	FET drain leakage current	I_{DSS}			4	mA
		Condition	V_{DSS}=100V, V_S=44V			
	FET diode forward voltage	V_{SD}			1.2	V
		Condition	I_D=1A			
	TTL input current	I_{IH}			40	μA
		Condition	V_{IH}=2.4V, V_S=44V			
		I_{IL}			−0.8	mA
		Condition	V_{IL}=0.4V, V_S=44V			
	TTL input voltage (Active High)	V_{IH}	2			V
		Condition	I_D=1A			
		V_{IL}			0.8	
		Condition	V_{DSS}=100V			
	TTL input voltage (Active Low)	V_{IH}	2			V
		Condition	V_{DSS}=100V			
		V_{IL}			0.8	
		Condition	I_D=1A			
AC characteristics	Switching time	T_r		0.5		μs
		Condition	V_S=24V, I_D=0.8A			
		T_{stg}		0.7		
		Condition	V_S=24V, I_D=0.8A			
		T_f		0.1		
		Condition	V_S=24V, I_D=0.8A			

■Internal Block Diagram

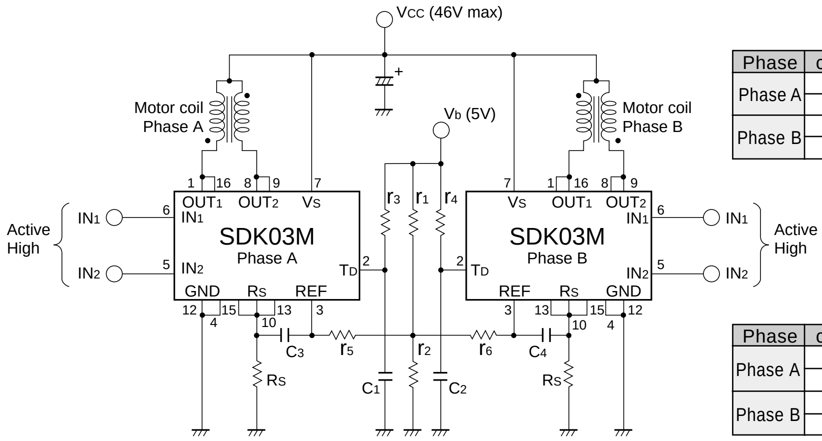


1, 8, 9, 16pin Description of pins

	Excitation input	
	Active H	Active L
Pin 1 / Pin 16	OUT1	OUT2
Pin 8 / Pin 9	OUT2	OUT1

■Diagram of Standard External Circuit (Recommended Circuit Constants)

Active High



Excitation signal time chart

2-phase excitation

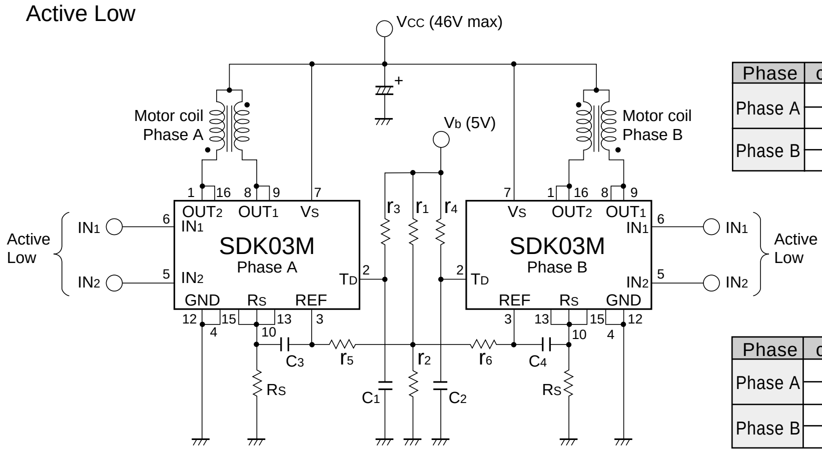
Phase	clock	0	1	2	3	0	1
Phase A	IN1	H	L	L	H	H	L
	IN2	L	H	H	L	L	H
Phase B	IN1	H	H	L	L	H	H
	IN2	L	L	H	H	L	L

- r_1 : 510Ω
- r_2 : 100Ω (VR)
- r_3 : 47kΩ
- r_4 : 47kΩ
- r_5 : 2.4kΩ
- r_6 : 2.4kΩ
- C_1 : 470pF
- C_2 : 470pF
- C_3 : 2200pF
- C_4 : 2200pF
- R_S : 1.8Ω typ (1 to 2W)

1-2-phase excitation

Phase	clock	0	1	2	3	4	5	6	7	0	1	2	3
Phase A	IN1	H	H	L	L	L	L	L	H	H	H	L	L
	IN2	L	L	L	H	H	H	L	L	L	L	L	H
Phase B	IN1	L	H	H	H	L	L	L	L	L	H	H	H
	IN2	L	L	L	L	L	H	H	H	L	L	L	L

Active Low



Excitation signal time chart

2-phase excitation

Phase	clock	0	1	2	3	0	1
Phase A	IN1	L	H	H	L	L	H
	IN2	H	L	L	H	H	L
Phase B	IN1	L	L	H	H	L	L
	IN2	H	H	L	L	H	H

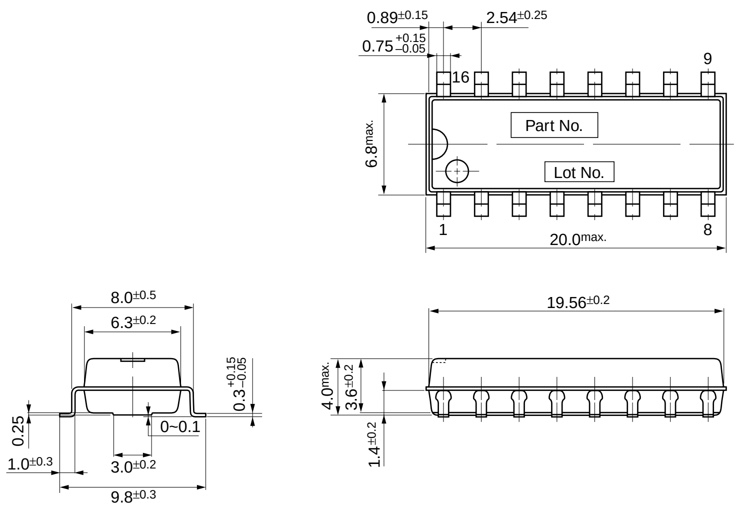
- r_1 : 510Ω
- r_2 : 100Ω (VR)
- r_3 : 47kΩ
- r_4 : 47kΩ
- r_5 : 2.4kΩ
- r_6 : 2.4kΩ
- C_1 : 470pF
- C_2 : 470pF
- C_3 : 2200pF
- C_4 : 2200pF
- R_S : 1.8Ω typ (1 to 2W)

1-2-phase excitation

Phase	clock	0	1	2	3	4	5	6	7	0	1	2	3
Phase A	IN1	L	L	H	H	H	H	H	L	L	L	H	H
	IN2	H	H	H	L	L	L	H	H	H	H	H	L
Phase B	IN1	H	L	L	L	H	H	H	H	H	L	L	L
	IN2	H	H	H	H	H	L	L	L	H	H	H	H

■External Dimensions

(Unit: mm)



Application Notes

■Determining the Output Current

Fig. 1 shows the waveform of the output current (motor coil current). The method of determining the peak value of the output current (I_O) based on this waveform is shown below.

(Parameters for determining the output current I_O)

V_b: Reference supply voltage

r_1,r_2: Voltage-divider resistors for the reference supply voltage

R_S: Current sense resistor

(1) Normal rotation mode

I_O is determined as follows when current flows at the maximum level during motor rotation. (See Fig.2.)

$$I_O \cong \frac{r_2}{r_1+r_2} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (1)$$

(2) Power down mode

The circuit in Fig.3 (r_x and T_r) is added in order to decrease the coil current. I_O is then determined as follows.

$$I_{OPD} \cong \frac{1}{1+\dfrac{r_1(r_2+r_x)}{r_2 \bullet r_x}} \bullet \frac{V_b}{R_S} \quad \cdots\cdots (2)$$

Equation (2) can be modified to obtain equation to determine r_x.

$$r_x = \frac{1}{\dfrac{1}{r_1}\left(\dfrac{V_b}{R_s \bullet I_{OPD}}-1\right)-\dfrac{1}{r_2}}$$

Fig. 4 and 5 show the graphs of equations (1) and (2) respectively.

Fig. 1 Waveform of coil current (Phase A excitation ON)

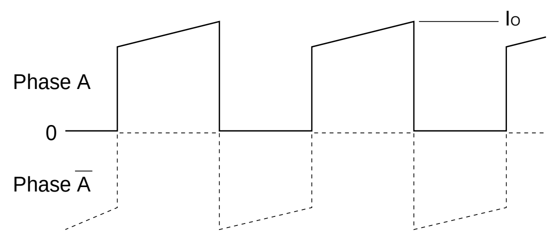


Fig. 2 Normal mode

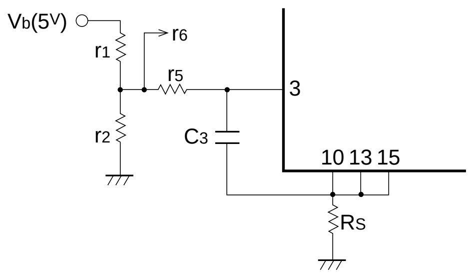


Fig. 3 Power down mode

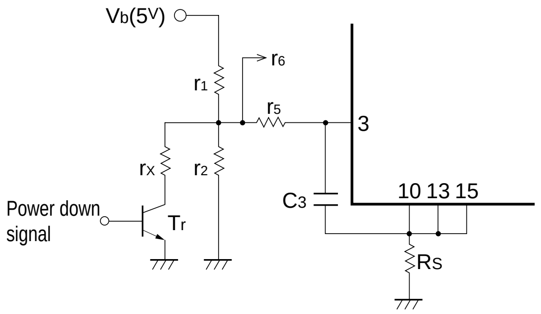


Fig. 4 Output current I_O vs. Current sense resistor R_S

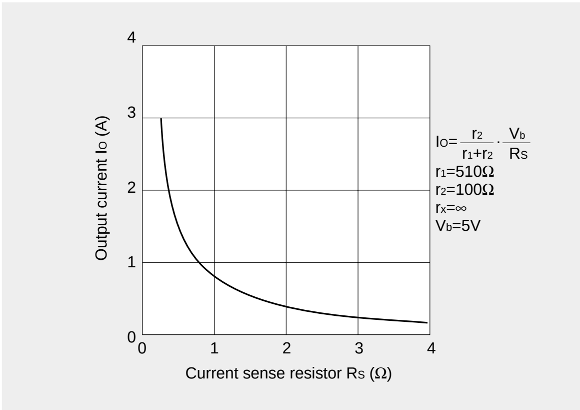
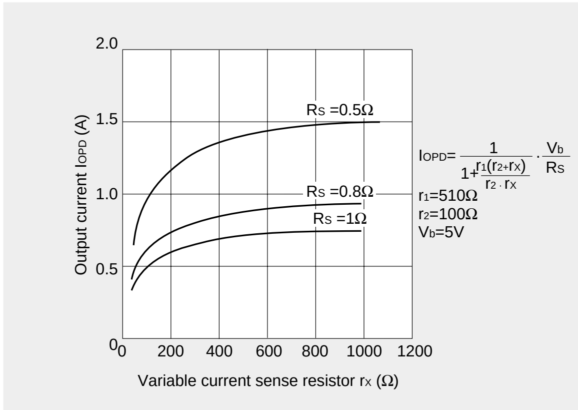


Fig. 5 Output current I_{OPD} vs. Variable current sense resistor r_x



(NOTE)

Ringing noise is produced in the current sense resistor R_S when the MOSFET is switched ON and OFF by chopping. This noise is also generated in feedback signals from R_S which may therefore cause the comparator to malfunction. To prevent chopping malfunctions, r_5(r_6) and C_3(C_4) are added to act as a noise filter.

However, when the values of these constants are increased, the response from R_S to the comparator becomes slow. Hence the value of the output current I_O is somewhat higher than the calculated value.

■Determining the chopper frequency

Determining T_{OFF}

SDK03M is self-excited choppers. The chopping OFF time T_{OFF} is fixed by r_3/C_1 and r_4/C_2 connected to terminal T_d.

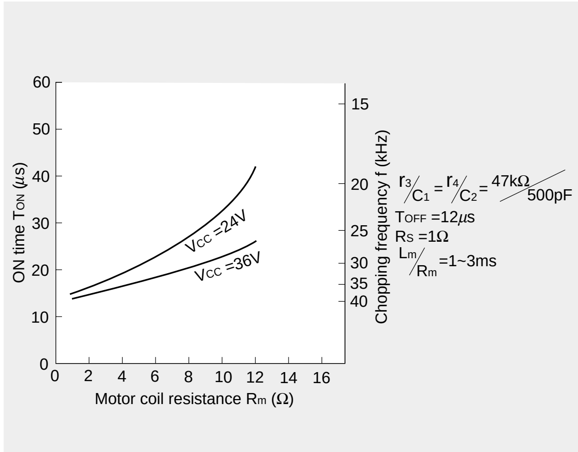
T_{OFF} can be calculated using the following formula:

$$T_{OFF} \cong -r_3 \bullet C_1 \ell n (1-\frac{2}{V_b} = -r_4 \bullet C_2 \ell n (1-\frac{2}{V_b})$$

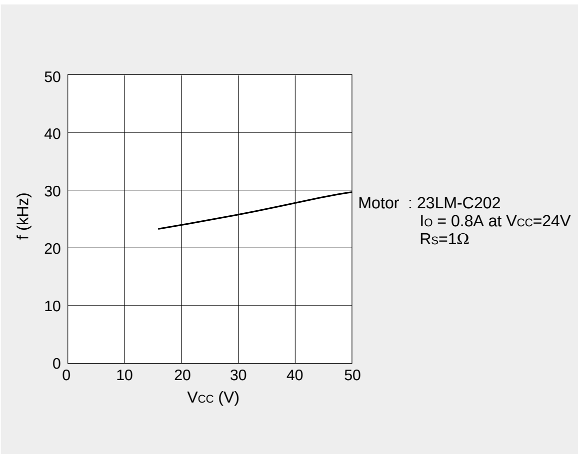
The circuit constants and the T_{OFF} value shown below are recommended.

T_{OFF} = 12μs at r_3=47kΩ, C_1=500pF, V_b=5V

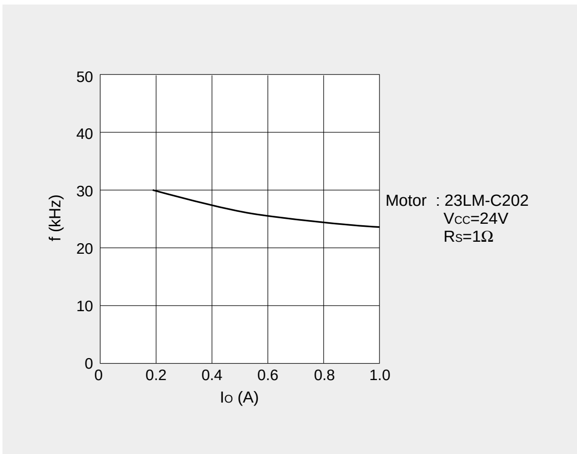
Fig. 6 Chopper frequency vs. Motor coil resistance



■Chopper frequency vs. Supply voltage



■Chopper frequency vs. Output current



■Thermal Design

An outline of the method for computing heat dissipation is shown below.

(1) Obtain the value of P_H that corresponds to the motor coil current I_O from Fig. 7 "Heat dissipation per phase P_H vs. Output current I_O."

(2) The power dissipation Pdiss is obtained using the following formula.

2-phase excitation: $P_{diss} \cong P_H + 0.0075 \times V_S$ (W)

1-2 phase excitation: $P_{diss} \cong \frac{3}{4} P_H + 0.0075 \times V_S$ (W)

(3) Obtain the temperature rise that corresponds to the calculated value of P_{diss} from Fig. 8 "Temperature rise."

Fig. 7 Heat dissipation per phase P_H vs. Output current I_O

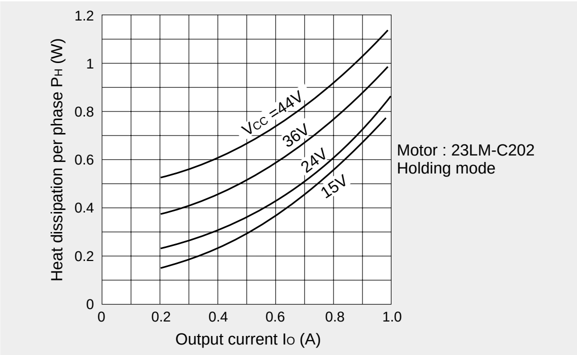
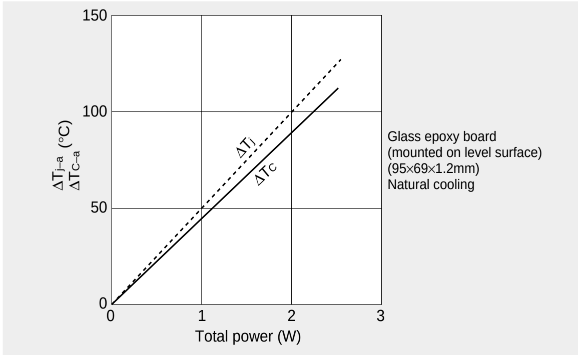
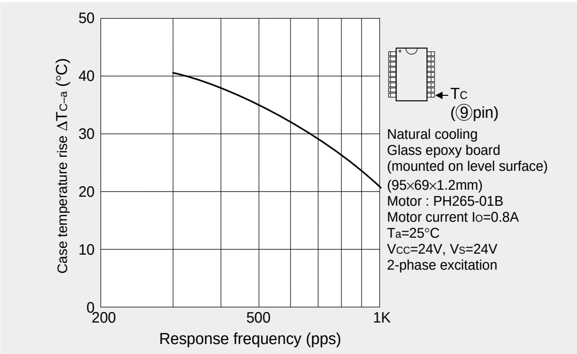


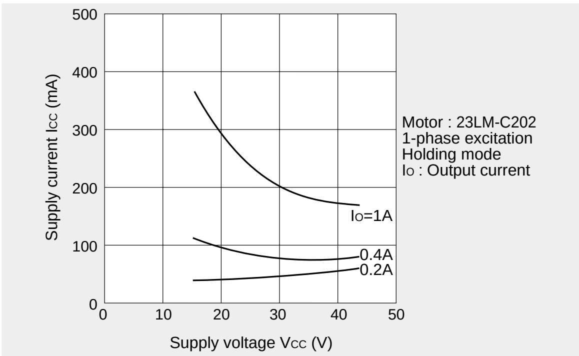
Fig. 8 Temperature rise



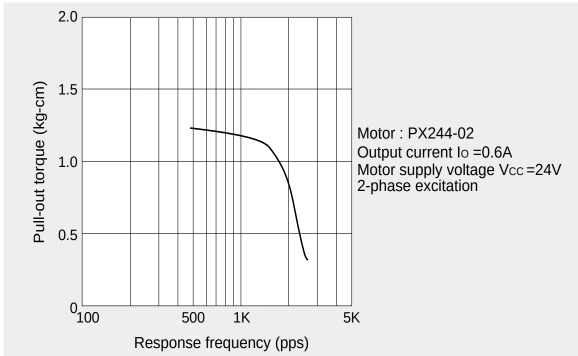
Thermal characteristics



■Supply Voltage V_{CC} vs. Supply Current I_{CC}



■Torque Characteristics



■Note

The excitation input signals of the SDK03M can be used as either Active High or Active Low. Note, However, that the corresponding output (OUT) changes depending on the input (IN).

Active High

Input	Corresponding output
IN_1 (pin6)	OUT_1 (pin1, 16)
IN_2 (pin5)	OUT_2 (pin8, 9)

Active Low

Input	Corresponding output
IN_1 (pin6)	OUT_1 (pin8, 9)
IN_2 (pin5)	OUT_2 (pin1, 16)

2-Phase Stepper Motor Unipolar Driver IC

Allegro MicroSystems product

■Features

- Internal 1-phase/1-2 phase/2-phase excitation pattern generator
- Output enable and direction control
- Power-on reset
- Internal thermal shutdown circuitry
- Internal transient-suppression diodes
- Low thermal resistance 16-pin DIP

Absolute Maximum Ratings

(T_a=+25°C)

Parameter	Symbol	Ratings	Units
Output voltage	V_{CE}	50	V
Output sustaining voltage	$V_{CE\ (SUS)}$	35	V
Output current (1 circuit)	I_O	1.5	A/unit
Logic supply voltage	V_{DD}	7.0	V
Input voltage	V_{IN}	7.0	V
Package power dissipation	P_D (Note1)	2.90	W/pkg
Operating temperature	T_a	−20 to +85	°C
Junction temperature	T_j (Note2)	+150	°C
Storage temperature	T_{stg}	−55 to +150	°C

Note 1: When ambient temperature is 25°C or over, derate using −23.3mW/°C.
Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

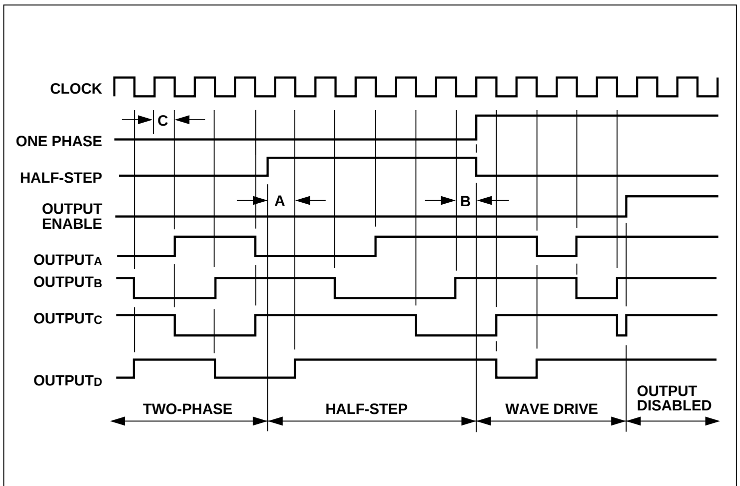
■Electrical Characteristics

(Unless specified otherwise, T_a=25°C, V_{DD}=4.5V to 5.5V)

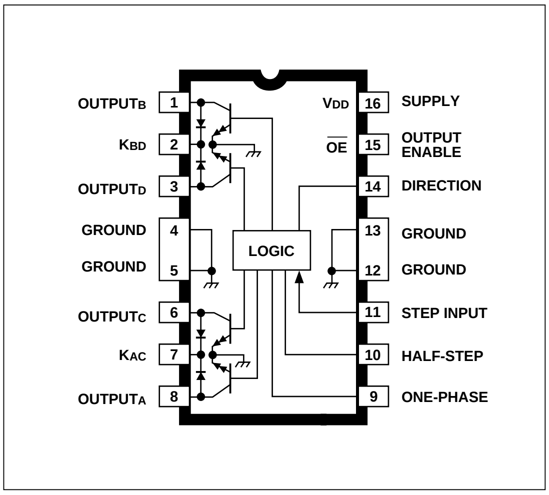
Parameter	Symbol	Conditions	Limits min	Limits typ	Limits max	Units
Output drivers						
Output leakage current	I_{CEX}	V_O=50V		10	50	μA
Output sustaining voltage	$V_{CE\ (SUS)}$	I_O=1.25A, L=3mH	3.5			V
Output saturation voltage	$V_{CE\ (SAT)}$	I_O=700mA		1.0	1.2	V
		I_O=1A		1.1	1.4	V
		I_O=1.25A		1.2	1.5	V
Clamp diode leakage current	I_R	V_R=50V		10	50	μA
Clamp diode forward voltage	V_F	I_F=1.25A		1.5	3.0	V
Turn-on delay	t_{ON}	50% step inputs to 50% output			10	μs
Turn-off delay	t_{OFF}	50% step inputs to 50% output			10	μs
Thermal shutdown temperature	T_j			165		°C
Control logic		(Unless specified otherwise, V_{IN}=V_{DD} or GND)				
Input current	I_{IH}	V_{IN}=V_{DD}		0.5	5.0	μA
	I_{IL}	V_{IN}=0.8V		−0.5	−5.0	μA
Input voltage	V_{IH}	V_{DD}=5V	3.5		5.3	V
	V_{IL}		−0.3		0.8	V
Supply current	I_{DD}	2 outputs ON		20	30	mA
Data setup time	$t_{s\ DAT\ (A)}$	Inter-clock	100			ns
Data hold time	$t_{h\ DAT\ (B)}$	Inter-clock	100			ns
Clock pulse width	$t_{w\ CLK\ (C)}$		500			ns

- "typ" values are for reference.

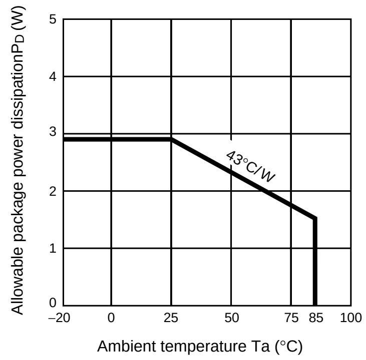
■Timing Conditions



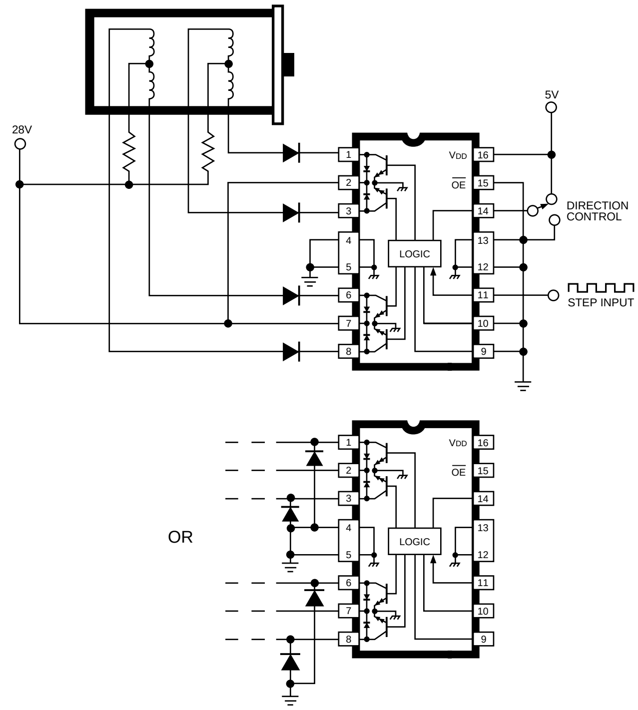
■Terminal Connection Diagram



■Derating



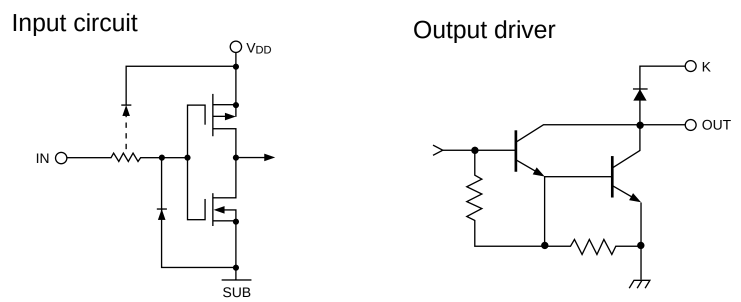
■Application Circuit



■Truth Table

Drive Format	Pin 9	Pin 10
Two-Phase	L	L
One-Phase	H	L
Half-Step	L	H
Step-Inhibit	H	H

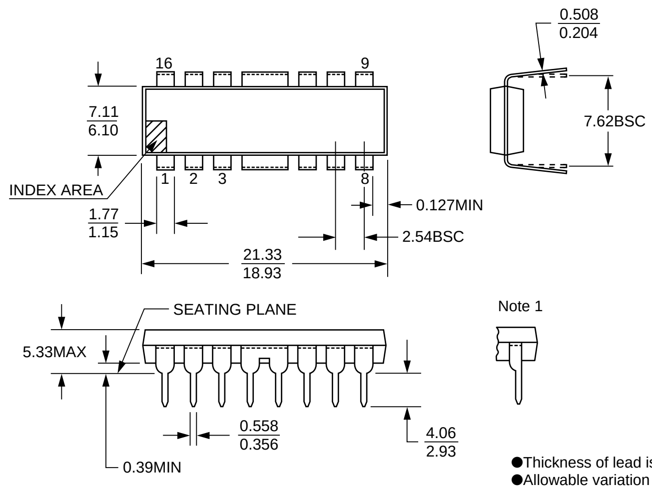
■I/O Equivalent Circuit



■External Dimensions

(Unit: mm)

ICs per stick	25



●Thickness of lead is measured below seating plane.
●Allowable variation in distance between leads is not cumulative.
Note 1: Lead width of pin 1,8, 9, 16 may be half the value shown here.

2-Phase Stepper Motor Unipolar Driver ICs

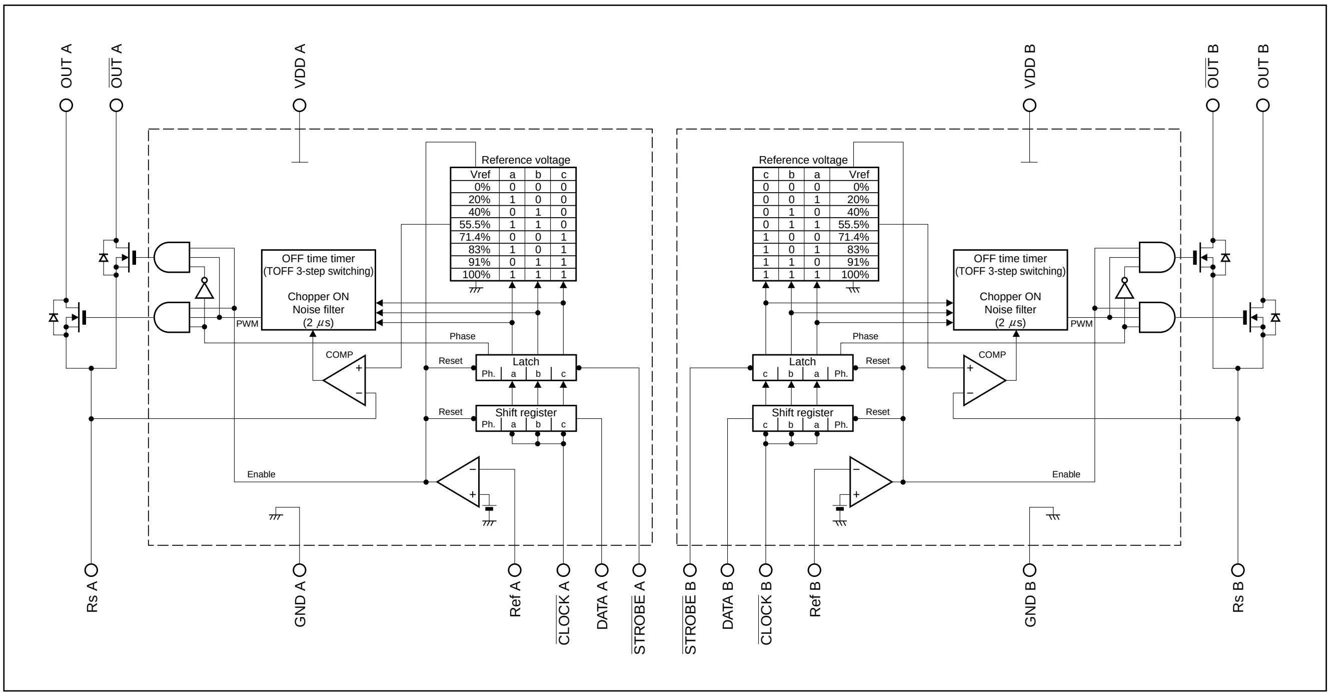
■Absolute Maximum Ratings

Parameter	Symbol	Ratings		Units
		SLA7042M	SLA7044M	
Motor supply voltage	V_{CC}	46		V
FET Drain-Source voltage	V_{DSS}	100		V
Control supply voltage	V_{DD}	7		V
Input voltage	V_{IN}	−0.5 to V_{DD}+0.5		V
Output current	I_O	1.2	3	A
Power dissipation	P_D	4.5 (Without Heatsink)		W
Channel temperature	T_{ch}	+150		°C
Storage temperature	T_{stg}	−40 to +150		°C

■Electrical Characteristics

	Parameter		Symbol	Ratings						Units
				SLA7042M			SLA7044M			
				min	typ	max	min	typ	max	
DC characteristics	Control supply current		I_{DD}			7			7	mA
			Conditions		V_{DD}=5.5V			V_{DD}=5.5V		
	Control supply voltage		V_{DD}	4.5	5	5.5	4.5	5	5.5	V
	Terminals DATA, CLOCK and STROBE	Input voltage	V_{IH}	3.5		5	3.5		5	V
			Conditions		V_{DD}=5V			V_{DD}=5V		
			V_{IL}	0		1.5	0		1.5	
			Conditions		V_{DD}=5V			V_{DD}=5V		
		Input hysteresis voltage	V_H		1			1		V
			Conditions		V_{DD}=5V			V_{DD}=5V		
		Input current	I_I			±1			±1	μA
			Conditions		V_{DD}=5V, V_I=0 or 5V			V_{DD}=5V, V_I=0 or 5V		
	REF terminal	Input voltage	V_{REF}	0.4		2.5	0.4		2.5	V
			Conditions		V_{DD}=5V			V_{DD}=5V		
			$V_{DISABLE}$	V_{DD}−1		V_{DD}	V_{DD}−1		V_{DD}	
			Conditions		V_{DD}=5V			V_{DD}=5V		
		Input current	I_{REF}			±1			±1	μA
			Conditions		V_{DD}=5V, V_I=0 or 5V			V_{DD}=5V, V_I=0 or 5V		
	Reference voltage selection output voltage		V_{ref}		0			0		%
			Conditions		MODE 0			MODE 0		
			V_{ref}		20			20		
			Conditions		MODE 1			MODE 1		
			V_{ref}		40			40		
			Conditions		MODE 2			MODE 2		
			V_{ref}		55.5			55.5		
			Conditions		MODE 3			MODE 3		
			V_{ref}		71.4			71.4		
			Conditions		MODE 4			MODE 4		
			V_{ref}		83			83		
			Conditions		MODE 5			MODE 5		
			V_{ref}		91			91		
			Conditions		MODE 6			MODE 6		
			V_{ref}		100			100		
			Conditions		MODE 7			MODE 7		
	FET ON voltage		V_{DS}			0.8			1.4	V
			Conditions		I_D=1.2A, V_{DD}=4.75V			I_D=3A, V_{DD}=4.75V		
	FET Drain-Source voltage		V_{DSS}	100			100			V
			Conditions		I_{DSS}=4mA, V_{DD}=5V			I_{DSS}=4mA, V_{DD}=5V		
	FET drain leakage current		I_{DSS}			4			4	mA
			Conditions		V_{DSS}=100V, V_{DD}=5V			V_{DSS}=100V, V_{DD}=5V		
	FET diode forward voltage		V_{SD}			1.2			2.3	V
			Conditions		I_D=1.2A			I_D=3A		
AC characteristics	Chopper off time		T_{OFF}		7			7		μs
			Conditions		MODE 1, 2			MODE 1, 2		
			T_{OFF}		9			9		
			Conditions		MODE 3, 4, 5			MODE 3, 4, 5		
			T_{OFF}		11			11		
			Conditions		MODE 6, 7			MODE 6, 7		
	Switching time		T_r		0.5			0.5		μs
			Conditions		V_{DD}=5V, I_D=1A			V_{DD}=5V, I_D=1A		
			T_{stg}		0.7			0.7		
			Conditions		V_{DD}=5V, I_D=1A			V_{DD}=5V, I_D=1A		
			T_f		0.1			0.1		
			Conditions		V_{DD}=5V, I_D=1A			V_{DD}=5V, I_D=1A		
	Data setup time "A"		$_{ts}$DAT	75			75			ns
			Conditions		Inter-clock			Inter-clock		
	Data hold time "B"		$_{th}$DAT	75			75			
			Conditions		Inter-clock			Inter-clock		
	Data pulse time "C"		$_{tw}$DAT	150			150			
			Conditions							
	Clock pulse width "D"		$_{twh}$CLK	100			100			
			Conditions							
	Stabilization time before strobe "E"		$_{tps}$STB	100			100			
			Conditions		Strobe=L from clock			Strobe=L from clock		
	Strobe pulse H width "F"		$_{twh}$STB	100			100			
			Conditions							

■Internal Block Diagram

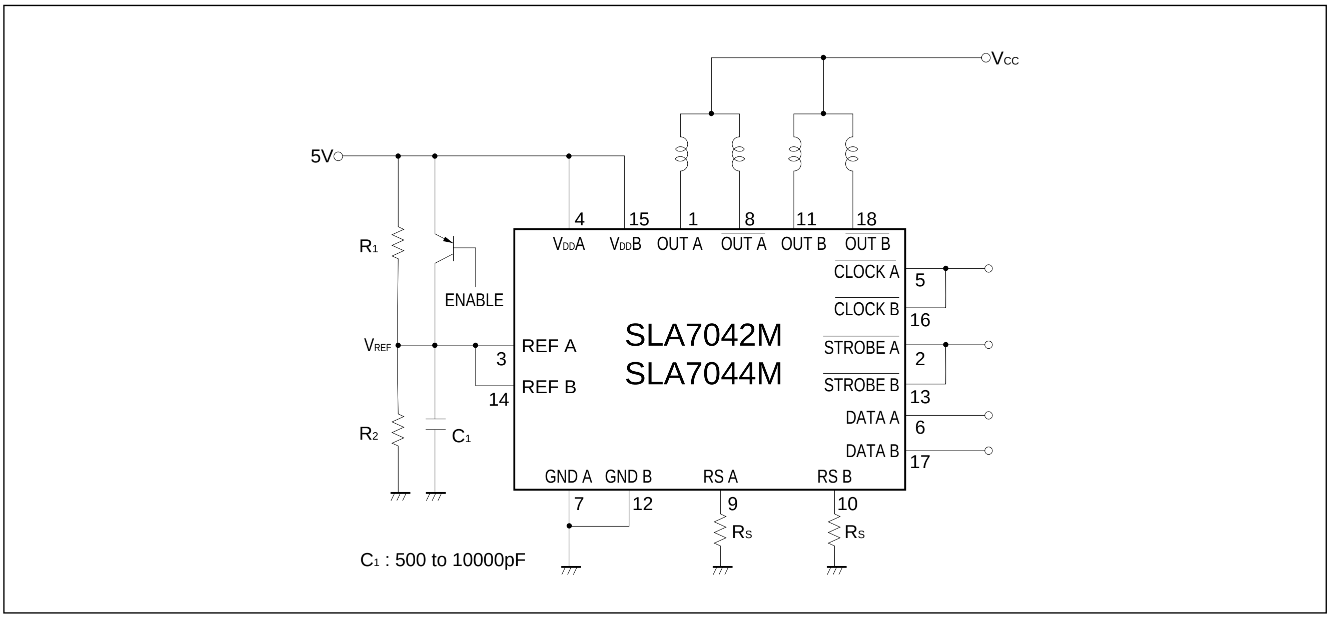


■Output Current Formula

$$I_O = \frac{K}{3} \cdot \frac{V_{REF}}{R_S}$$

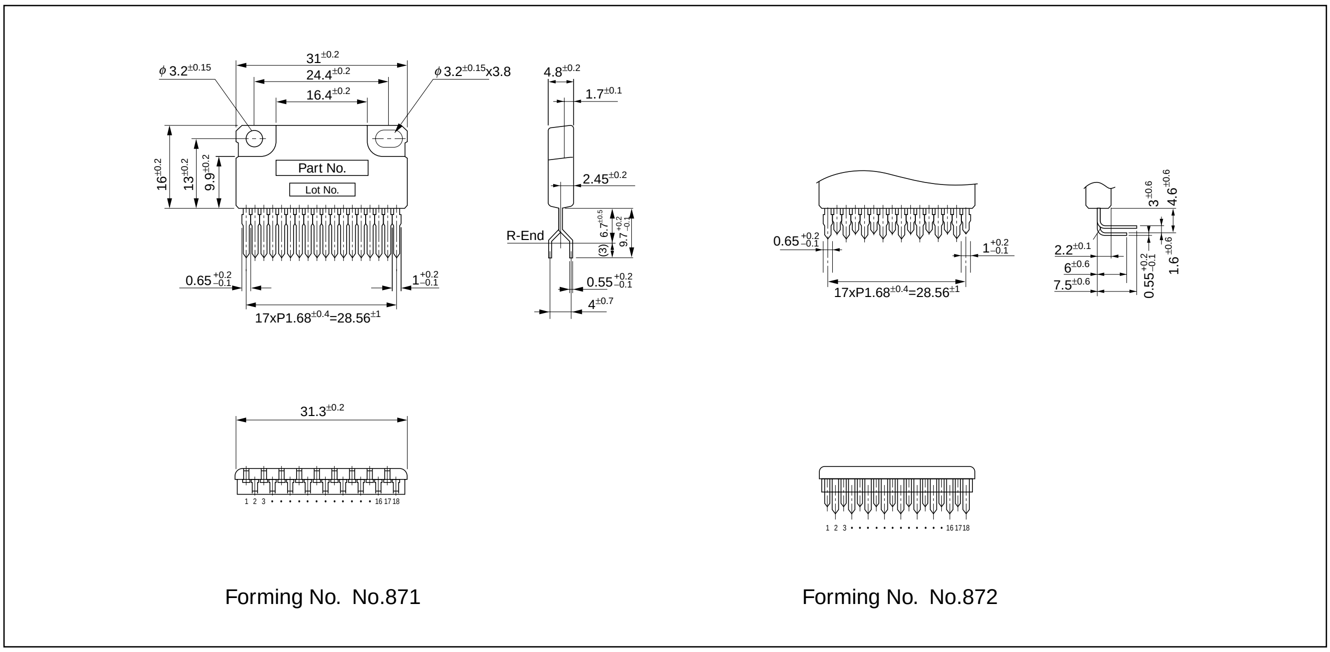
K: Reference voltage setting rate by serial signal
(See the internal block diagram)

■Diagram of Standard External Circuit

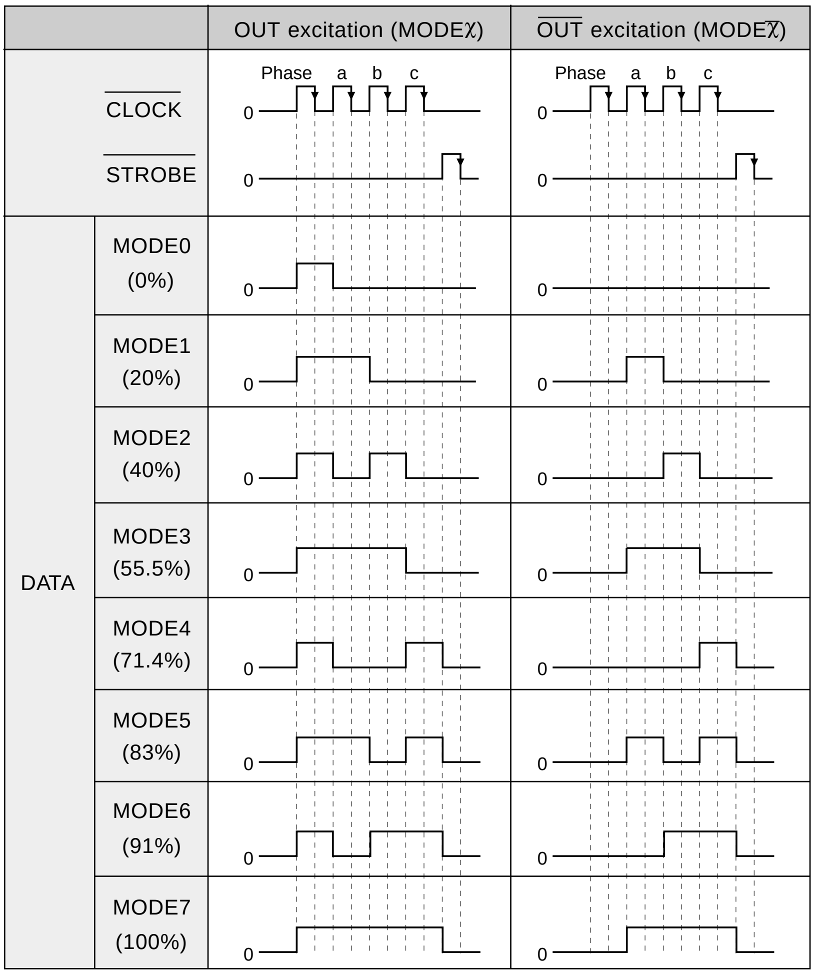


■External Dimensions

(Unit: mm)



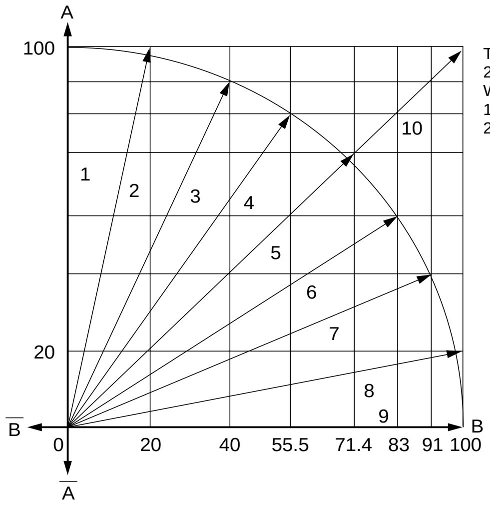
■Serial Data Pattern



Successively output this serial data and set any current. Then, determine the step time of the reference voltage V_{ref} at $\overline{\text{STROBE}}$ signal intervals.

See page 48 for details of PG001M serial signal generator IC for SLA7042M and SLA7044M.

■Current Vector Locus (One step of stepper motor normalized to 90 degrees)



To rotate the motor, enter serial data as follows:
2W1-2 phase excitation : Vector 1→2→3→4→5→6→7→8→9 ...
W1-2 phase excitation : Vector 1→3→5→7→9→....
1-2 phase excitation : Vector 1→5→9
2-2 phase excitation : Vector 5 or 10

Combined vector	Current A	Current B
1	100%	0%
2	100%	20%
3	91%	40%
4	83%	55.5%
5	71.4%	71.4%
6	55.5%	83%
7	40%	91%
8	20%	100%
9	0%	100%
10	100%	100%

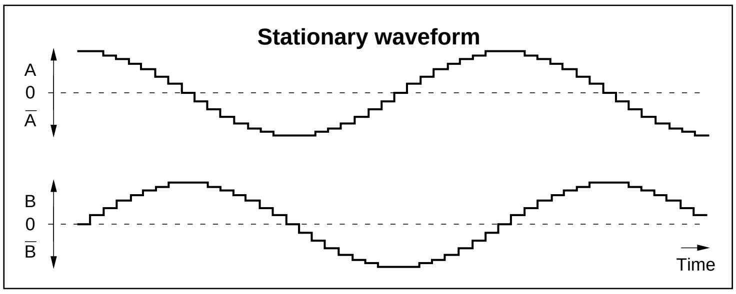
■Serial Data Sequence Example (2W 1-2 Phase Excitation for CW)

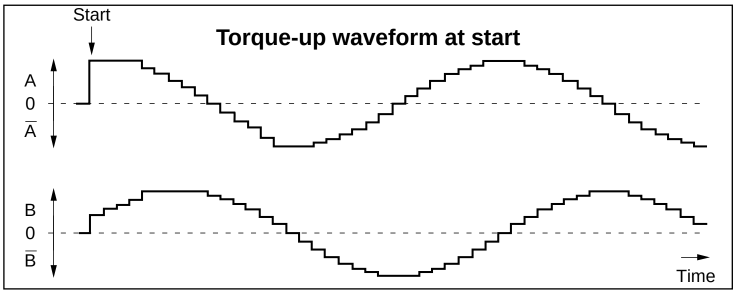
Sequence	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DATA-A MODE	4	3	2	1	0	$\overline{1}$	$\overline{2}$	$\overline{3}$	$\overline{4}$	$\overline{5}$	$\overline{6}$	$\overline{7}$	$\overline{7}$	$\overline{7}$	$\overline{6}$	$\overline{5}$	$\overline{4}$
DATA-B MODE	4	5	6	7	7	7	6	5	4	3	2	1	0	$\overline{1}$	$\overline{2}$	$\overline{3}$	$\overline{4}$

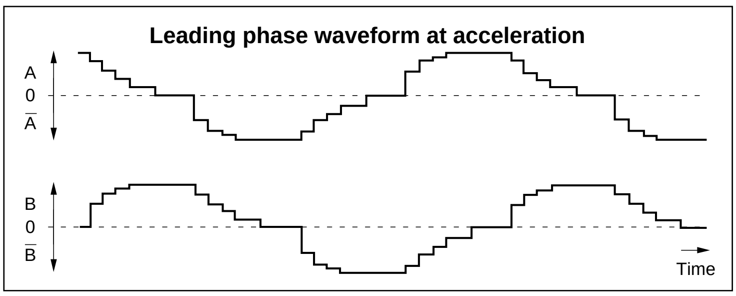
Sequence	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	0
DATA-A MODE	$\overline{3}$	$\overline{2}$	$\overline{1}$	$\overline{0}$	1	2	3	4	5	6	7	7	7	6	5	4
DATA-B MODE	$\overline{5}$	$\overline{6}$	$\overline{7}$	$\overline{7}$	$\overline{7}$	$\overline{6}$	$\overline{5}$	$\overline{4}$	$\overline{3}$	$\overline{2}$	$\overline{1}$	0	1	2	3	4

A malfunction may occur just after the power (V_{DD}) is turned on because the internal logic is unstable. Therefore, set the RESET state (REF terminal voltage: V_{DD}–1V to V_{DD}) after the power is turned on.)

■Operation Current Waveform Examples







These three types of waveforms can all be set with a serial signal.

Serial Signal Generator IC for SLA7042M and SLA7044M

■Absolute Maximum Ratings

(T_a=25°C)

Parameter	Symbol	Ratings	Units
Supply voltage	V_{DD}	−0.5 to 7	V
Input voltage	V_I	−0.5 to V_{DD}+0.5	V
Input current	I_I	±10	mA
Output voltage	V_O	−0.5 to V_{DD}+0.5	V
Output current	I_O	±15	mA
Power dissipation	P_D	200	mW
Operating temperature	T_{OP}	−20 to +85	°C
Storage temperature	T_{stg}	−40 to +150	°C

■Electrical Characteristics

(T_a=25°C)

	Parameter	Symbol	Conditions	Ratings min	Ratings typ	Ratings max	Units
DC characteristics	Supply voltage	V_{DD}		4.5		5.5	V
	Supply current	I_{DD}	V_{DD}=5.5V		0.35	0.45	mA
	Output voltage	V_{OH}	V_{DD}=5V, I_O=±3mA	4.5			V
		V_{OL}				0.4	
	Input current	I_I	V_{DD}=5V, V_I=0 or 5V			±1	μA
	Input voltage	V_{IH}	V_{DD}=5V	3.5		5	V
		V_{IL}		−0.3		1.5	
	Input hysteresis voltage	V_H	V_{DD}=5V		1		V
	Input capacity	C_I	V_{DD}=5V		5	10	pF
AC characteristics	Internal oscillation frequency	F	V_{DD}=5V See Fig. 1.		1.5		MHz
	Propagation delay time	T_{CS}			50	100	ns
		T_{CC}			430	550	
	Output voltage Rise and fall time	T_r	V_{DD}=5V, C_L=15pF See Fig. 2.		20		ns
		T_f			20		
	CLOCK IN terminal Input clock time	V_{CIH}	H level time, V_{DD}=5V	4.5			μs
		V_{CIL}	L level time, V_{DD}=5V	0.5			
	Reset setting time (A)	$_{ts}R$	Inter-clock See Fig. 3.	100			ns
	Stabilization time after reset (B)	$_{tps}R$					
	Signal setting time (C)	$_{ts}S$	Inter-clock See Fig. 3.	100			ns
	Stabilization time after signal input (D)	$_{tps}S$					

Fig. 1

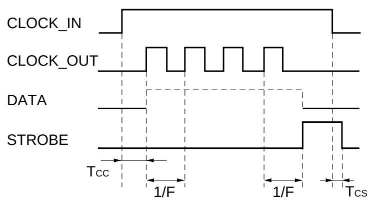


Fig.2

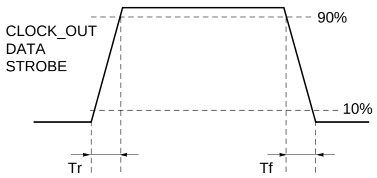
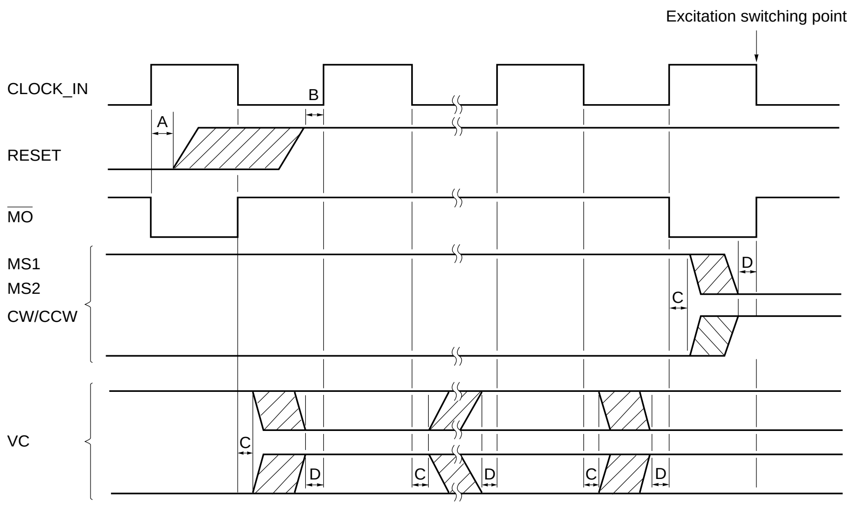
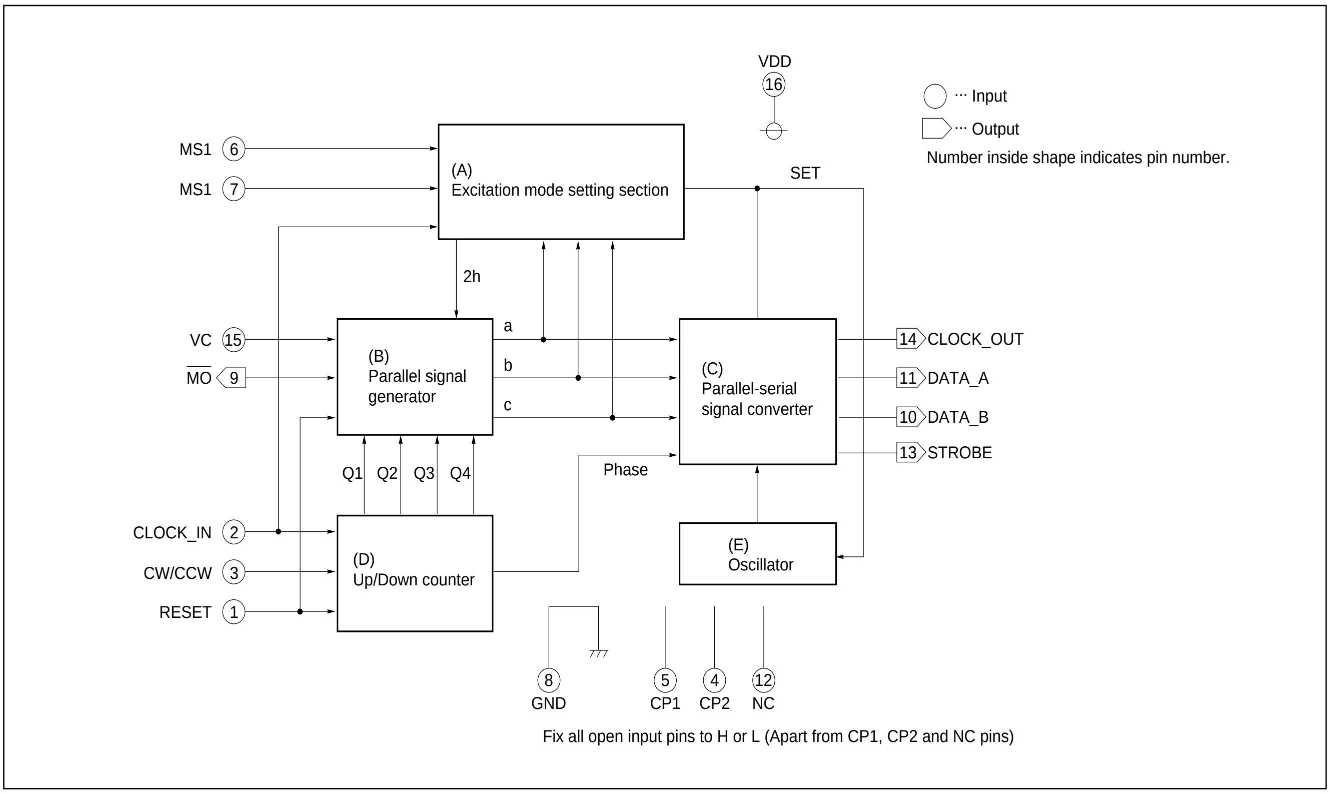


Fig. 3 Timing conditions

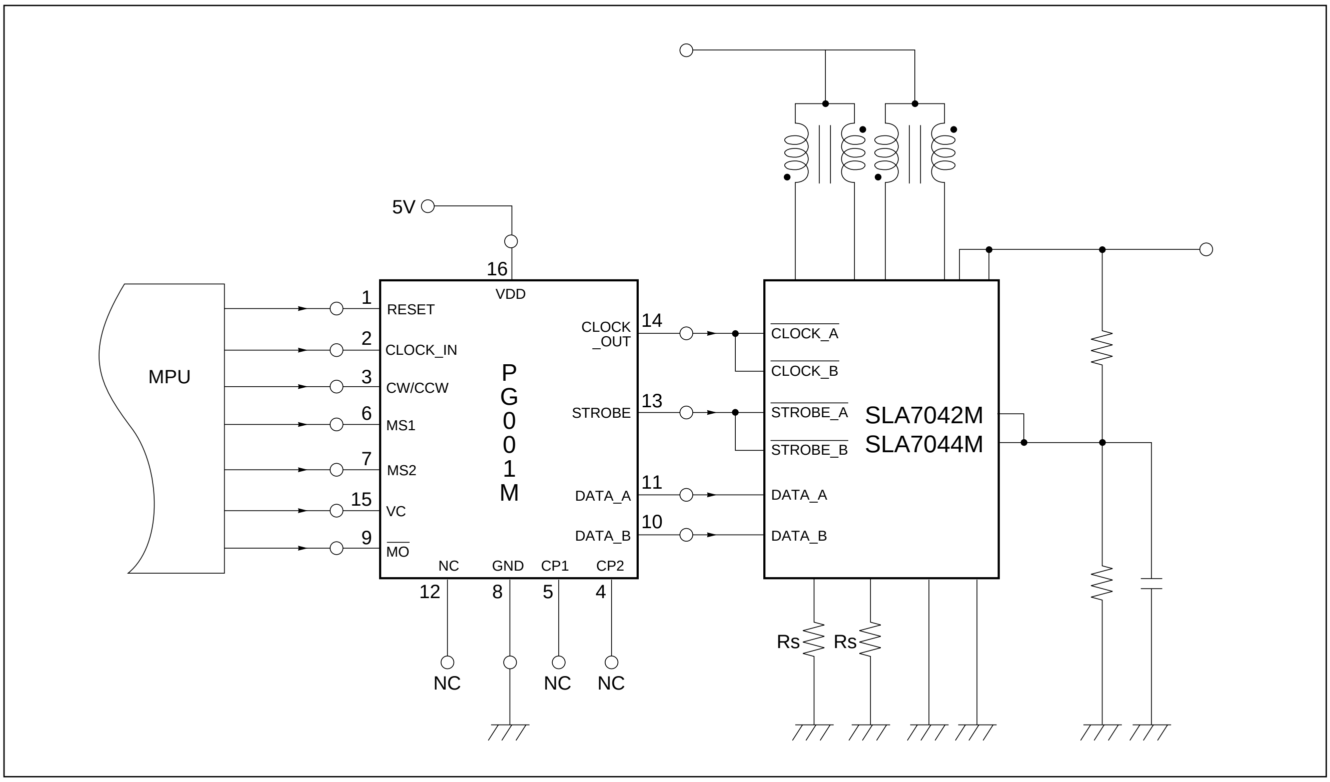


VC switching occurs only while CLOCK-IN level is L.

■Internal Block Diagram

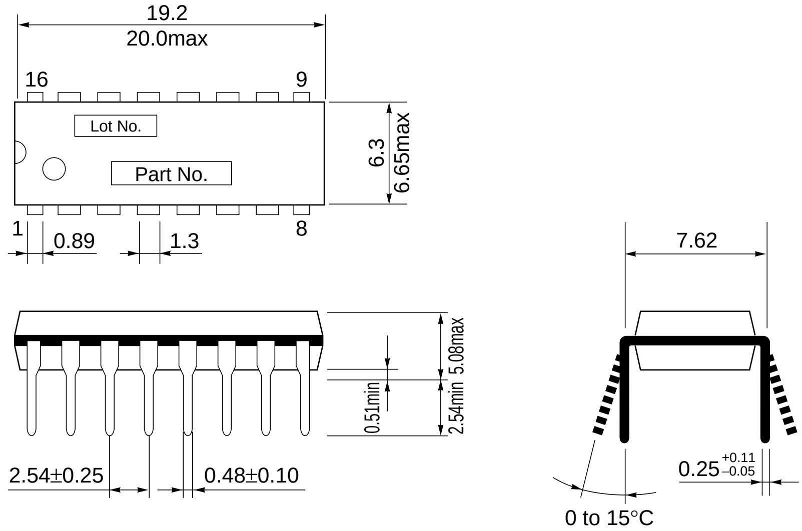


■Diagram of Standard External Circuit

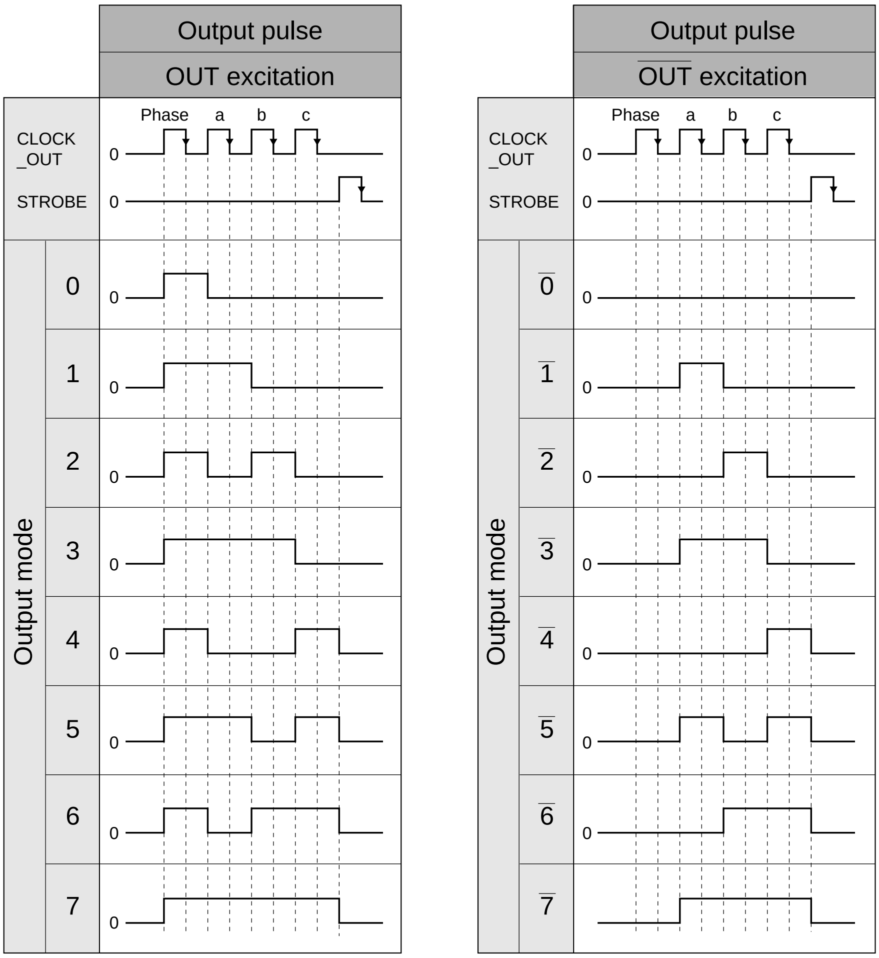


■External Dimensions

(Unit: mm)



■Output Mode Vs Output Pulse



■Input and Output Function Correlation Table

Input				Output				
Mode	CLOCK_IN	CW/CCW	RESET	$\overline{MO}$	CLOCK_OUT	STROBE	DATA-A	DATA-B
CW	↑	L	H	↓	⊓⊓⊓⊓	↑	CW	CW
	↓	L	H	↑	—	↓		
CCW	↑	H	H	↓	⊓⊓⊓⊓	↑	CCW	CCW
	↓	H	H	↑	—	↓		
RESET	↑	×	L	↓	⊓⊓⊓⊓	↑	Output Mode 4 or 7 Output Mode	Input Mode 4 or 7 Output Mode
	↓	×	L	↑	—	↓		

×: Don't care

∗: $\overline{MO}$ outputs L level while CLOCK_IN is H level when output mode is 4:4 (7:7), $\bar{4}$:4 ($\bar{7}$:7), 4:$\bar{4}$ (7:$\bar{7}$),or $\bar{4}$:$\bar{4}$ ($\bar{7}$:$\bar{7}$). Modes in brackets ( ) are for 2-2 phase VC: H.

■Excitation Selection Table

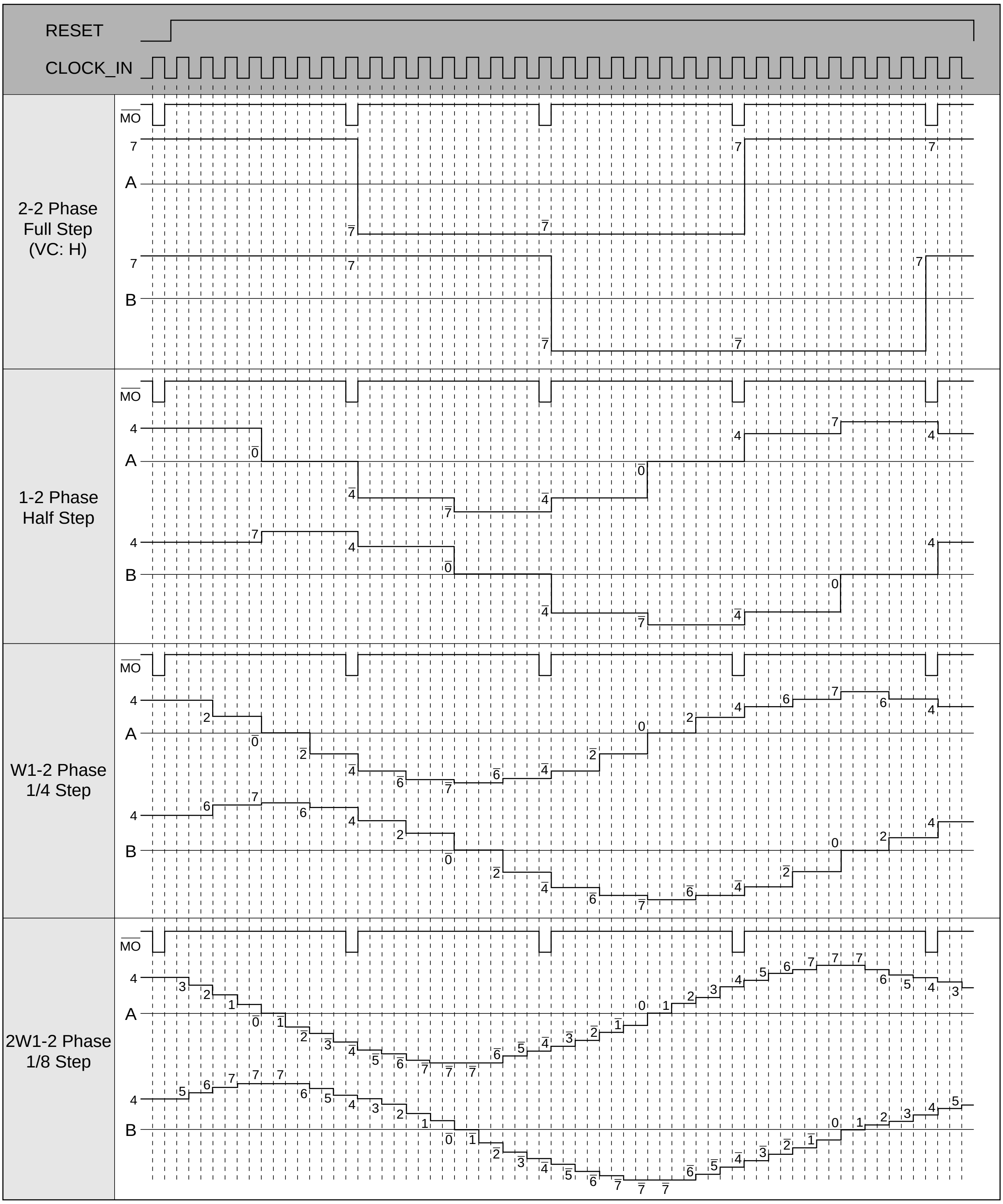
Excitation method	Input			Output current mode of SLA7042M/7044M								Torque vector
	Excitation mode selection			0	1	2	3	4	5	6	7	
	VC	MS1	MS2	0%	20%	40%	55.5%	71.4%	83%	91%	100%	
2-2 Phase Full Step	H	L	L	–	–	–	–	–	–	–	○	141%
	L	L	L	–	–	–	–	○	–	–	–	100%
1-2 Phase Half Step	×	H	L	○	–	–	–	○	–	–	○	100%
W1-2 Phase 1/4 Step	×	L	H	○	–	○	–	○	–	○	○	100%
2W1-2 Phase 1/8 Step	×	H	H	○	○	○	○	○	○	○	○	100%

■Output Mode Sequence

Excitation method	CW/CCW	CLOCK	RESET ↑	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
		$\overline{MO}$	L	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H	L	H	H	H	H	H	H	H	L
2-2 Phase Full Step (1) (VC: H)	CW	DATA_A	7	=	=	=	=	=	=	=	$\bar{7}$	=	=	=	=	=	=	=	$\bar{7}$	=	=	=	=	=	=	=	7	=	=	=	=	=	=	=	7
		DATA_B	7	=	=	=	=	=	=	=	7	=	=	=	=	=	=	=	$\bar{7}$	=	=	=	=	=	=	=	$\bar{7}$	=	=	=	=	=	=	=	7
	CCW	DATA_A	7	=	=	=	=	=	=	=	7	=	=	=	=	=	=	=	$\bar{7}$	=	=	=	=	=	=	=	$\bar{7}$	=	=	=	=	=	=	=	7
		DATA_B	7	=	=	=	=	=	=	=	$\bar{7}$	=	=	=	=	=	=	=	$\bar{7}$	=	=	=	=	=	=	=	7	=	=	=	=	=	=	=	7
2-2 Phase Full Step (2) (VC: L)	CW	DATA_A	4	=	=	=	=	=	=	=	$\bar{4}$	=	=	=	=	=	=	=	$\bar{4}$	=	=	=	=	=	=	=	4	=	=	=	=	=	=	=	4
		DATA_B	4	=	=	=	=	=	=	=	4	=	=	=	=	=	=	=	$\bar{4}$	=	=	=	=	=	=	=	$\bar{4}$	=	=	=	=	=	=	=	4
	CCW	DATA_A	4	=	=	=	=	=	=	=	4	=	=	=	=	=	=	=	$\bar{4}$	=	=	=	=	=	=	=	$\bar{4}$	=	=	=	=	=	=	=	4
		DATA_B	4	=	=	=	=	=	=	=	$\bar{4}$	=	=	=	=	=	=	=	$\bar{4}$	=	=	=	=	=	=	=	4	=	=	=	=	=	=	=	4
1-2 Phase Half Step	CW	DATA_A	4	=	=	=	$\bar{0}$	=	=	=	$\bar{4}$	=	=	=	$\bar{7}$	=	=	=	$\bar{4}$	=	=	=	0	=	=	=	4	=	=	=	7	=	=	=	4
		DATA_B	4	=	=	=	7	=	=	=	4	=	=	=	$\bar{0}$	=	=	=	$\bar{4}$	=	=	=	$\bar{7}$	=	=	=	$\bar{4}$	=	=	=	0	=	=	=	4
	CCW	DATA_A	4	=	=	=	7	=	=	=	4	=	=	=	0	=	=	=	$\bar{4}$	=	=	=	$\bar{7}$	=	=	=	$\bar{4}$	=	=	=	$\bar{0}$	=	=	=	4
		DATA_B	4	=	=	=	0	=	=	=	$\bar{4}$	=	=	=	$\bar{7}$	=	=	=	$\bar{4}$	=	=	=	$\bar{0}$	=	=	=	4	=	=	=	7	=	=	=	4
W1-2 Phase 1/4 Step	CW	DATA_A	4	=	2	=	$\bar{0}$	=	$\bar{2}$	=	$\bar{4}$	=	$\bar{6}$	=	$\bar{7}$	=	$\bar{6}$	=	$\bar{4}$	=	$\bar{2}$	=	0	=	2	=	4	=	6	=	7	=	6	=	4
		DATA_B	4	=	6	=	7	=	6	=	4	=	2	=	$\bar{0}$	=	$\bar{2}$	=	$\bar{4}$	=	$\bar{6}$	=	$\bar{7}$	=	$\bar{6}$	=	$\bar{4}$	=	$\bar{2}$	=	0	=	2	=	4
	CCW	DATA_A	4	=	6	=	7	=	6	=	4	=	2	=	0	=	$\bar{2}$	=	$\bar{4}$	=	$\bar{6}$	=	$\bar{7}$	=	$\bar{6}$	=	$\bar{4}$	=	$\bar{2}$	=	$\bar{0}$	=	2	=	4
		DATA_B	4	=	2	=	0	=	$\bar{2}$	=	$\bar{4}$	=	$\bar{6}$	=	$\bar{7}$	=	$\bar{6}$	=	$\bar{4}$	=	$\bar{2}$	=	$\bar{0}$	=	2	=	4	=	6	=	7	=	6	=	4
2W1-2 Phase 1/8 Step	CW	DATA_A	4	3	2	1	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$	$\bar{5}$	$\bar{6}$	$\bar{7}$	$\bar{7}$	$\bar{7}$	$\bar{6}$	$\bar{5}$	$\bar{4}$	$\bar{3}$	$\bar{2}$	$\bar{1}$	0	1	2	3	4	5	6	7	7	7	6	5	4
		DATA_B	4	5	6	7	7	7	6	5	4	3	2	1	$\bar{0}$	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$	$\bar{5}$	$\bar{6}$	$\bar{7}$	$\bar{7}$	$\bar{7}$	$\bar{6}$	$\bar{5}$	$\bar{4}$	$\bar{3}$	$\bar{2}$	$\bar{1}$	0	1	2	3	4
	CCW	DATA_A	4	5	6	7	7	7	6	5	4	3	2	1	0	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$	$\bar{5}$	$\bar{6}$	$\bar{7}$	$\bar{7}$	$\bar{7}$	$\bar{6}$	$\bar{5}$	$\bar{4}$	$\bar{3}$	$\bar{2}$	$\bar{1}$	$\bar{0}$	1	2	3	4
		DATA_B	4	3	2	1	0	$\bar{1}$	$\bar{2}$	$\bar{3}$	$\bar{4}$	$\bar{5}$	$\bar{6}$	$\bar{7}$	$\bar{7}$	$\bar{7}$	$\bar{6}$	$\bar{5}$	$\bar{4}$	$\bar{3}$	$\bar{2}$	$\bar{1}$	$\bar{0}$	1	2	3	4	5	6	7	7	7	6	5	4

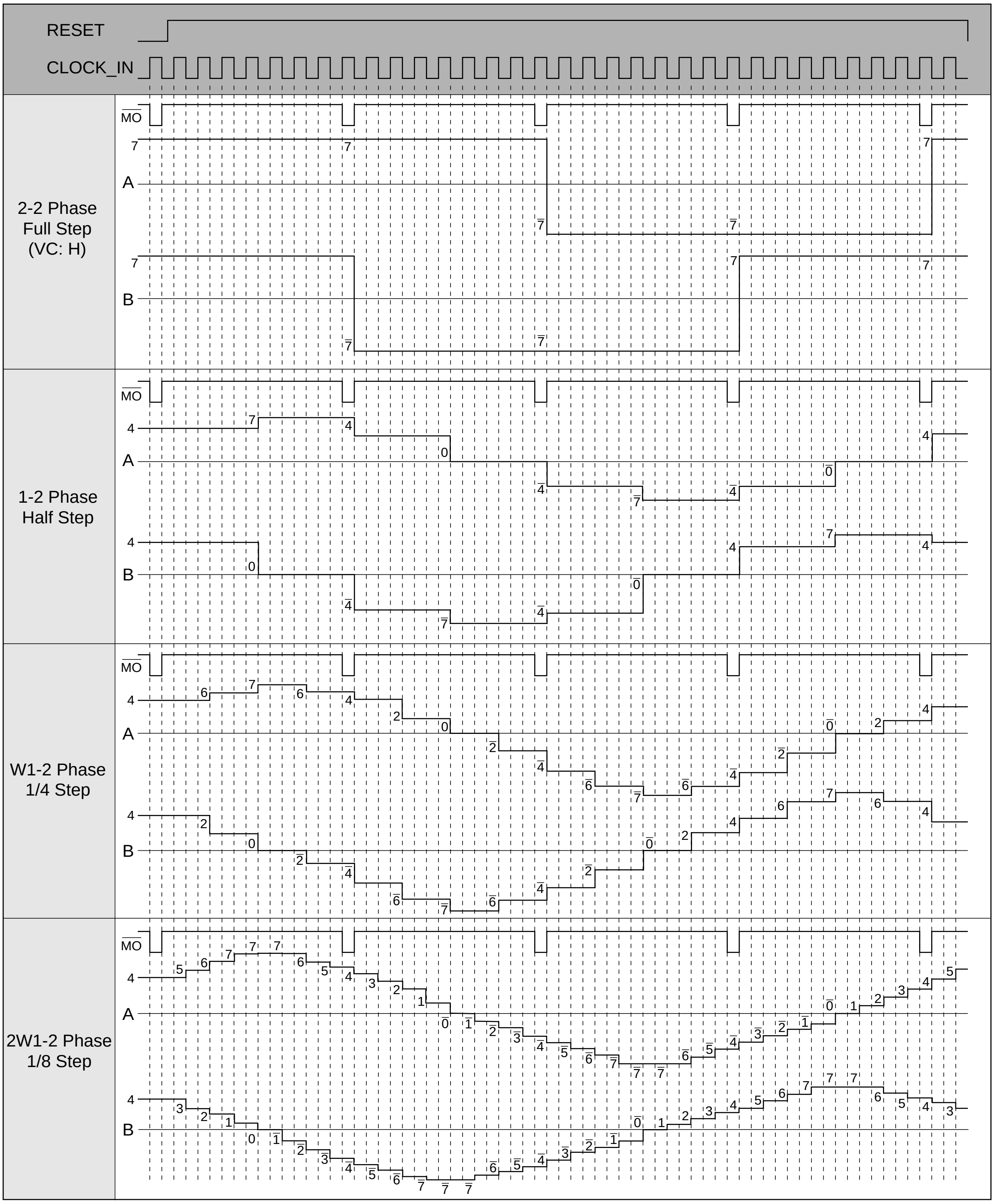
= : No output

■Output Timing Chart (CW) ··· Excitation Current of SLA7042M/7044M



For 2-2 phase VC : L, output mode is 7→4.

■Output Timing Chart (CCW) ··· Excitation Current of SLA7042M/7044M



For 2-2 phase VC:L, output mode is 7→4.

2-Phase Stepper Motor Bipolar Driver IC

Allegro MicroSystems product

■Features

- Maximum output ratings: 30V, ±650mA
- Internal fixed-frequency PWM current control
- Internal ground-clamp & flyback diodes
- Internal thermal shutdown, crossover-current protection and UVLO protection circuitry
- Employs copper batwing lead frame with low thermal resistance

■Absolute Maximum Ratings

Parameter	Symbol	Ratings		Units
		A3966SA	A3966SLB	
Load supply voltage	V_{BB}	30		V
Output current (peak)	I_O (Peak)	±750		mA
Output current (continuous)	I_O	±650		mA
Logic supply voltage	V_{CC}	7.0		V
Logic input voltage range	V_{IN}	–0.3 to V_{CC}+0.3		V
Sense voltage	V_S	1.0		V
Package power dissipation	P_D (Note1)	2.08	1.86	W
Ambient operating temperature	T_a	–20 to +85		°C
Junction temperature	T_j (Note2)	+150		°C
Storage temperature	T_{stg}	–55 to +150		°C

●Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of 150°C.

Note 1: When ambient temperature is 25°C or over, derate using –16.67mW/°C (SA), –14.93mW/°C (SLB).

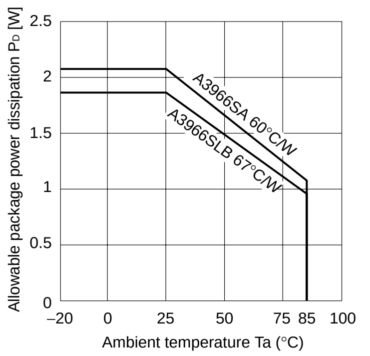
Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

■Electrical Characteristics (Unless specified otherwise, T_a=25°C, V_{BB}=30V, V_{CC}=4.75V to 5.5V, V_{REF}=2V, V_S= 0V, 56kΩ & 680pF RC to ground)

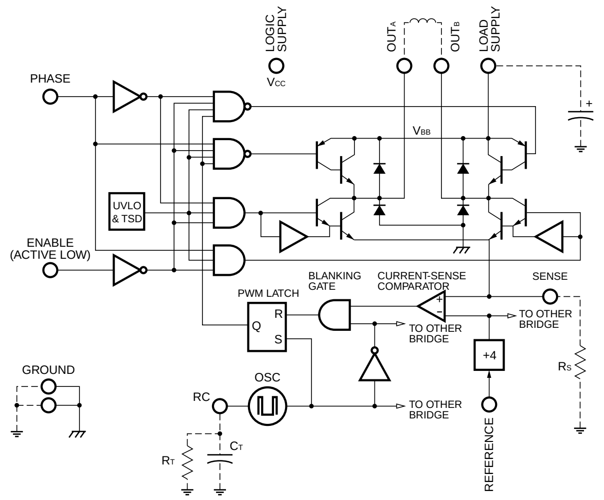
Parameter	Symbol	Conditions	Ratings			Units
			min	typ	max	
Power outputs (OUT_A or OUT_B)						
Load supply voltage range	V_{BB}	Operating, I_O=±650mA, L=3mH	V_{CC}		30	V
Output leakage current	I_{CEX}	V_O=30V		< 1.0	50	μA
		V_O=0V		< –1.0	–50	μA
Output saturation voltage	V_{CE} (sat)	Source Driver, I_O=–400mA		1.7	2.0	V
		Source Driver, I_O=–650mA		1.8	2.1	V
		Sink Driver, I_O=+400mA, V_{SENSE}=0.5V		0.3	0.5	V
		Sink Driver, I_O=+650mA, V_{SENSE}=0.5V		0.4	1.3	V
Sense-current offset	I_{SO}	I_S–I_O, I_O=50~650mA	12	18	24	mA
Clamp diode forward voltage	V_F	I_F=400mA		1.1	1.4	V
		I_F=650mA		1.4	1.6	V
Motor supply current (No load)	I_{BB} (ON)	$V_{ENABLE1}$=$V_{ENABLE2}$=0.8V		3.0	5.0	mA
	I_{BB} (OFF)	$V_{ENABLE1}$=$V_{ENABLE2}$=2.4V		< 1.0	200	μA
Control logic						
Logic supply voltage range	V_{CC}	Operating	4.75		5.50	V
Logic input voltage	V_{IH}		2.4			V
	V_{IL}				0.8	V
Logic input current	I_{IH}	V_{IN}=2.4V		< 1.0	20	μA
	I_{IL}	V_{IN}=0.8V		< –20	–200	μA
Reference input voltage range	V_{REF}	Operating	0.1		2.0	V
Reference input current	I_{REF}		–2.5	0	1.0	μA
Reference divider ratio	V_{REF}/V_{TRIP}		3.8	4.0	4.2	
Current-sense comparator input offset voltage	V_{IO}	V_{REF}=0V	–6.0	0	6.0	mV
Current-sense comparator input voltage range	V_S	Operating	–0.3		1.0	V
PWM RC frequency	f_{OSC}	C_T=680pF, R_T=56kΩ	22.9	25.4	27.9	kHz
PWM propagation delay time	t_{PWM}	Comparator Trip to Source OFF		1.0	1.4	μS
		Cycle Reset to Source ON		0.8	1.2	μS
Cross-over dead time	t_{codt}	1kΩ Load to 25V	0.2	1.8	3.0	μS
Propagation delay time	t_{pd}	I_O=±650mA, 50% to 90% : ENABLE ON to Source ON		100		ns
		I_O=±650mA, 50% to 90% : ENABLE OFF to Source OFF		500		ns
		I_O=±650mA, 50% to 90% : ENABLE ON to Sink ON		200		ns
		I_O=±650mA, 50% to 90% : ENABLE OFF to Sink OFF		200		ns
		I_O=±650mA, 50% to 90% : PHASE Change to Sink ON		2200		ns
		I_O=±650mA, 50% to 90% : PHASE Change to Sink OFF		200		ns
		I_O=±650mA, 50% to 90% : PHASE Change to Source ON		2200		ns
		I_O=±650mA, 50% to 90% : PHASE Change to Source OFF		200		ns
Thermal shutdown temperature	T_j			165		°C
Thermal shutdown hysteresis	ΔT_j			15		°C
UVLO enable threshold	$V_{UVLO\ en}$	Increasing V_{CC}		4.1	4.6	V
UVLO hysteresis	$V_{UVLO\ hys}$		0.1	0.6		V
Logic supply current	I_{CC} (ON)	$V_{ENABLE1}$=$V_{ENABLE2}$=0.8V			50	mA
	I_{CC} (OFF)	$V_{ENABLE1}$=$V_{ENABLE2}$=2.4V			9	mA

● "typ" values are for reference.

■Derating



■Internal Block Diagram (1/2 circuit)



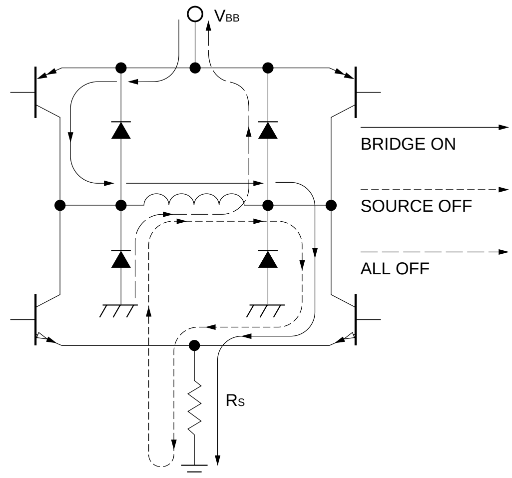
■Truth Table

PHASE	ENABLE	OUTA	OUTB
X	H	Z	Z
H	L	H	L
L	L	L	H

X: Don't care (either L or H)

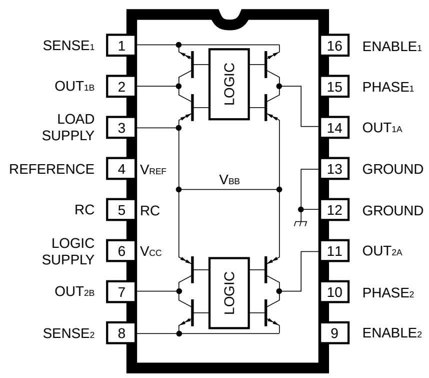
Z: High impedance (source and sink both OFF)

■Load-Current Paths

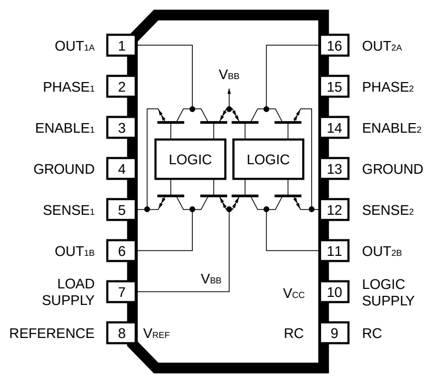


■Terminal Connection Diagram

A3966SA



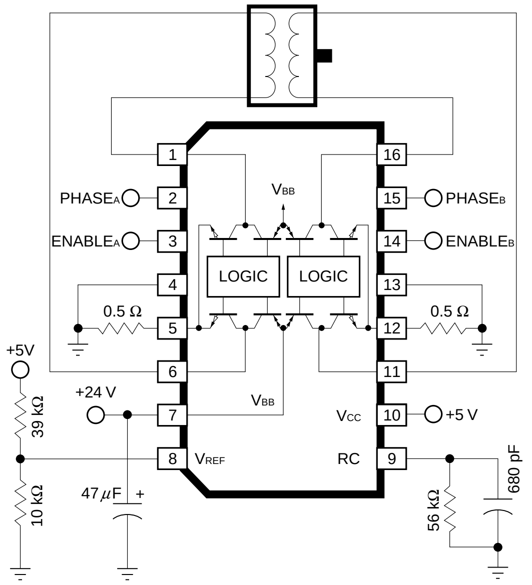
A3966SLB



■Typical Application

(A3966SLB)

Example of stepper motor drive



$I_{TRIP} \cong I_{OUT} + I_{SO} \cong V_{REF}/(4 \cdot R_S)$

$t_{blank} \cong 1{,}900 \cdot C_T$

$f_{OSC} \cong 1/(R_T \cdot C_T + t_{blank})$

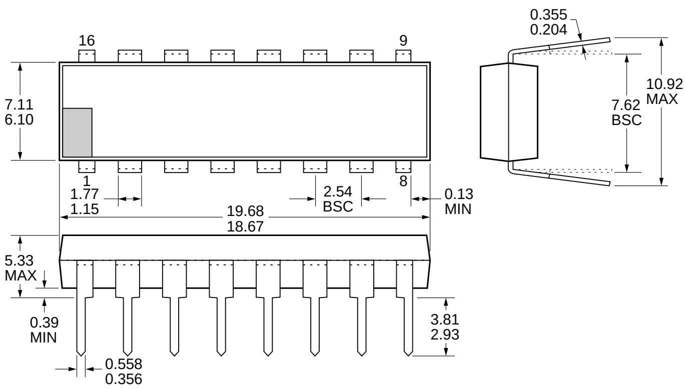
R_T=56kΩ (20kΩ to 100kΩ)

C_T=680pF(470pF to 1,000pF)

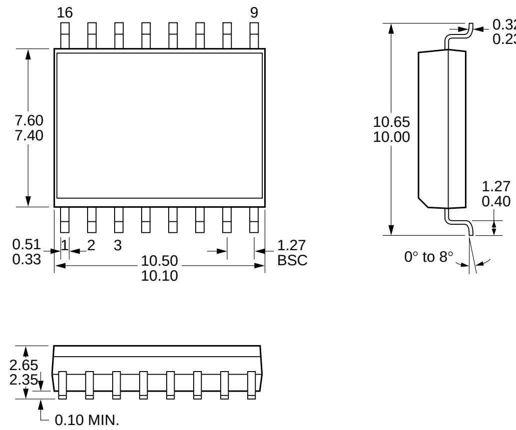
■External Dimensions

(Unit: mm)

A3966SA



A3966SLB



2-Phase Stepper Motor Bipolar Driver IC

Allegro MicroSystems product

■Features

- Fixed off-time PWM current control
- Internally generated, precision 2.5V reference
- External filter for sense terminal not required
- Internal thermal shutdown circuitry
- Internal crossover-current protection circuity
- Internal UVLO protection
- Internal transient-suppression diodes
- Low thermal resistance 20-pin SOP

■Absolute Maximum Ratings

Parameter	Symbol	Ratings	Units
Load supply voltage	V_{BB}	30	V
Output current (continuous)	I_O	±0.80	A
Logic supply voltage	V_{CC}	7.0	V
Logic input voltage range	V_{IN}	–0.3 to V_{CC}+0.3	V
Continuous output emitter voltage	V_E	1.0	V
Reference output current	$I_{REF\text{-}OUT}$	1.0	mA
Package power dissipation	P_D (Note1)	2.08	W
Operating temperature	T_a	–20 to +85	°C
Junction temperature	T_j (Note2)	+150	°C
Storage temperature	T_{stg}	–55 to +150	°C

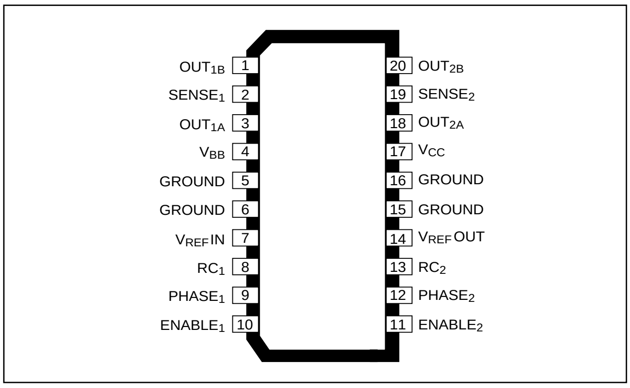
●Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of 150°C.
Note 1: When ambient temperature is 25°C or over, derate using –16.7mW/°C.
Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

■Electrical Characteristics (Unless specified otherwise, T_a=25°C, V_{BB}=30V, V_{CC}=4.75V to 5.25V, V_{REF}=2V, V_{SENSE}= 0V)

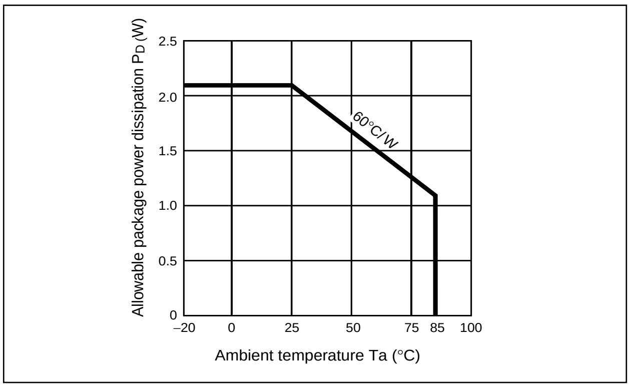
Parameter	Symbol	Conditions	Ratings			Units
			min	typ	max	
Power outputs (OUT_A or OUT_B)						
Load supply voltage range	V_{BB}	Operating	5		30	V
Output leakage current	I_{CEX}	Sink driver, V_O=V_{BB}		< 1.0	50	μA
		Source driver, V_O=0V		<– 1.0	–50	μA
Output saturation voltage	$V_{CE\,(SAT)}$	Sink driver, I_O=+500mA		0.3	0.6	V
		Sink driver, I_O=+750mA		0.5	1.2	V
		Sink driver, I_O=+800mA			1.5	V
		Source driver, I_O=–500mA		1.0	1.2	V
		Source driver, I_O=–750mA		1.1	1.5	V
		Source driver, I_O=–800mA			1.7	V
Output sustaining voltage	$V_{CE\,(SUS)}$	I_O=±800mA, L=3mH	30			V
Clamp diode leakage current	I_R	V_R=30V		< 1.0	50	μA
Clamp diode forward voltage	V_F	I_F=800mA		1.6	2.0	V
Motor supply current	$I_{BB\,(ON)}$	V_{EN1}=V_{EN2}=0.8V, no load			10	mA
	$I_{BB\,(OFF)}$	V_{EN1}=V_{EN2}=2.4V, no load			10	mA
Control logic		(Unless specified otherwise, V_{IN}=V_{DD} or GND)				
Logic input voltage	V_{IH}		2.4			V
	V_{IL}				0.8	V
Logic input current	I_{IH}	V_{IN}=2.4V		< –1.0	20	μA
	I_{IL}	V_{IN}=0.8V		< –20	–200	μA
Reference output voltage	$V_{REF\bullet OUT1}$	V_{CC}=5.0V, $I_{REF\bullet OUT}$=90~900μA	2.45	2.50	2.55	V
Current-sense comparator input current	$I_{REF\bullet IN}$	$V_{REF\bullet IN}$=1V	–5.0		5.0	μA
Current-sense comparator input voltage range	$V_{REF\bullet IN}$	Operating	–0.3		1.0	V
Current-sense comparator input offset voltage	V_{TH}	$V_{REF\bullet IN}$=0V	–6		6	mV
Timer blanking charge current (RC off)	I_{RC}	V_{RC}=2.0V		1.0		mA
Timer blanking threshold (RC off)	$V_{BLTH(1)}$			3.0		V
	$V_{BLTH(0)}$			1.0		V
Timer blanking OFF voltage (RC off)	V_{RCOFF}	R_T=20kΩ		3.0		V
Thermal shutdown temperature	T_j			165		°C
Thermal shutdown hysteresis	ΔT_j			15		°C
Logic supply current	$I_{CC\,(ON)}$	V_{EN1}=V_{EN2}=0.8V, no load		65	85	mA
	$I_{CC\,(OFF)}$	V_{EN1}=V_{EN2}=2.4V, no load			17	mA
Logic supply current/temperature coefficient	$\Delta I_{CC\,(ON)}$	V_{EN1}=V_{EN2}=0.8V, no load		0.18		mA/°C

● "typ" values are for reference.
Note) Logic input: En1, En2, Ph1, Ph2

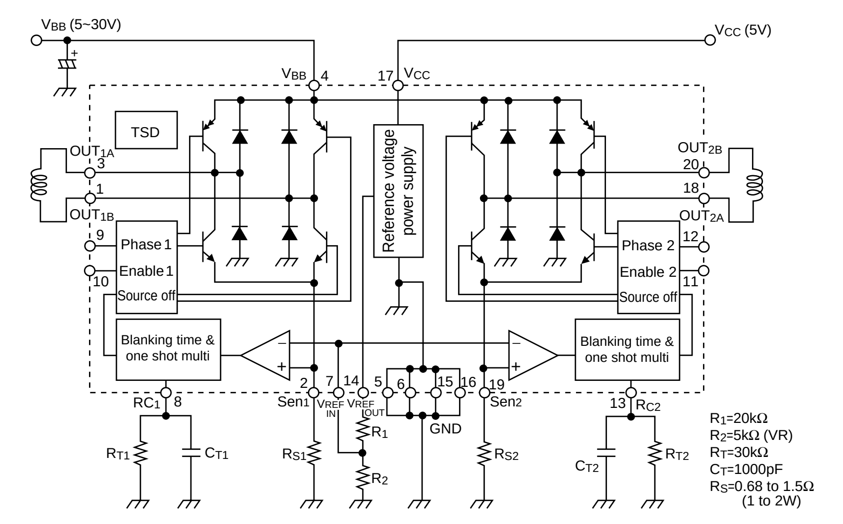
■Terminal Connection Diagram



■Derating



■Internal Block Diagram(Dotted Line)/ Diagram of Standard External Circuit (Recommended Circuit Constants)



■Truth Table

Phase	Enable	Out A	Out B
H	L	H	L
L	L	L	H
X	H	Z	Z

X = Don't care, Z = High impedance

■Excitation Sequence

[2-phase excitation]

	0	1	2	3	0
Phase 1	H	L	L	H	H
Enable 1	L	L	L	L	L
Phase 2	H	H	L	L	H
Enable 2	L	L	L	L	L

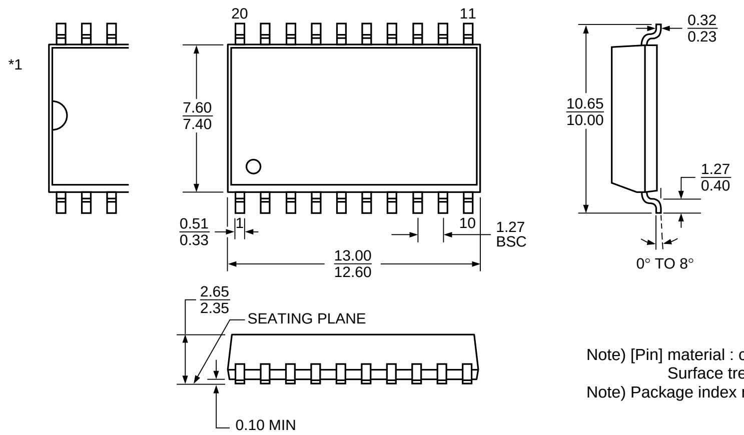
[1-2 phase excitation]

	0	1	2	3	4	5	6	7	0
Phase 1	H	H	X	L	L	L	X	H	H
Enable 1	L	L	H	L	L	L	H	L	L
Phase 2	X	H	H	H	X	L	L	L	X
Enable 2	H	L	L	L	H	L	L	L	H

■External Dimensions Wide body plastic SOP (300mil)

(Unit: mm)

ICs per stick	37



Note) [Pin] material : copper
Surface treatment : solder plating
Note) Package index may be *1.

2-Phase Stepper Motor Bipolar Driver ICs

Allegro MicroSystems product

■Features

- Fixed off-time PWM current control
- Switching between power supply regeneration mode and loop regeneration mode in order to improve motor current response in microstepping
- External filter for sense terminal not required
- 3.3V and 5V logic supply voltage
- Sleep (low current consumption) mode
- Brake operation with PWM current limiting
- Internal thermal shutdown circuitry
- Internal crossover-current protection circuitry
- Internal UVLO protection
- Internal transient-suppression diodes
- Low thermal resistance package

■Absolute Maximum Ratings

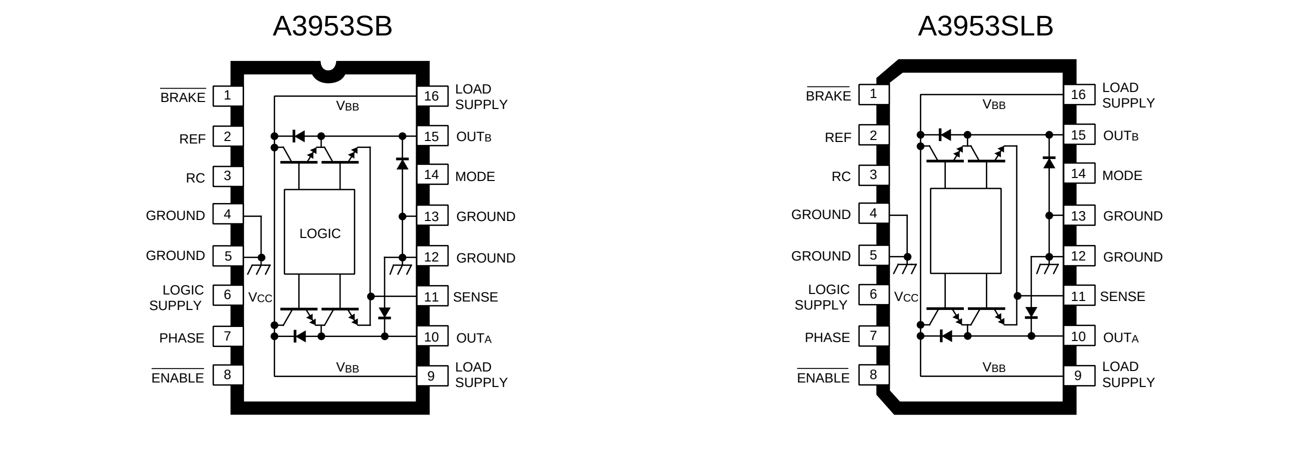
Parameter	Symbol	Ratings A3953SB	Ratings A3953SLB	Units
Load supply voltage	V_{BB}	50		V
Output current (continuous)	I_O	±1.3		A/unit
Logic supply voltage	V_{CC}	7.0		V
Logic/reference input voltage range	V_{IN}	–0.3 to V_{CC}+0.3		V
Sense voltage	V_{SENSE} D.C.	1.0 (V_{CC}=5.0V) 0.4 (V_{CC}=3.3V)		V
Package power dissipation	P_D (Note1)	2.90	1.86	W/pkg
Operating temperature	T_a	–20 to +85		°C
Junction temperature	T_j (Note2)	+150		°C
Storage temperature	T_{stg}	–55 to +150		°C

●Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of 150°C.

Note 1: When ambient temperature is 25°C or over, derate using –23.26mW/°C(SB) or –14.93mW/°C(SLB).

Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

■Terminal Connection Diagram



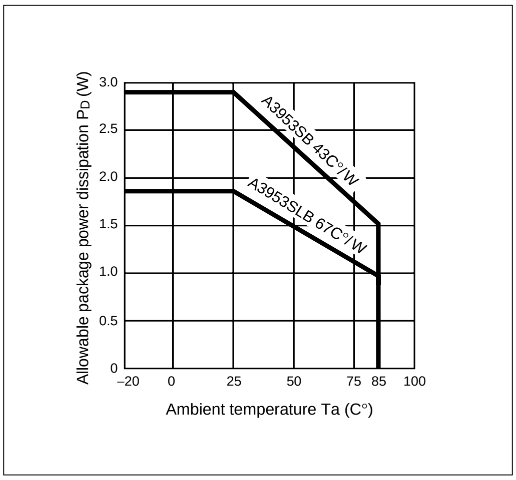
■Electrical Characteristics

(Unless specified otherwise, T_a=25°C, V_{BB}=5V to 50V, V_{CC}=3.0V to 5.5V)

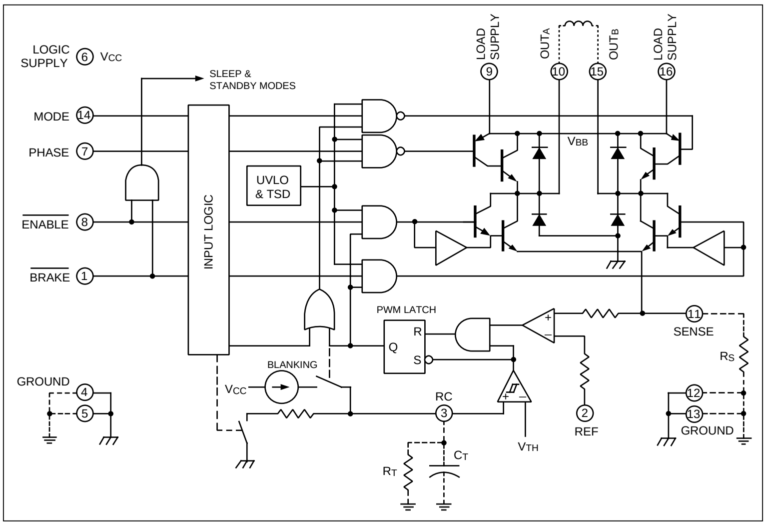
Parameter	Symbol	Conditions	Limits			Units
			min	typ	max	
Power outputs (OUT_A or OUT_B)						
Load supply voltage range	V_{BB}	Operating, I_O=±1.3A, L=3mH	V_{CC}		50	V
Output leakage current	I_{CEX}	V_O=V_{BB}		<1.0	50	μA
		V_O=0V		<–1.0	–50	μA
Sense current offset	I_{SO}	I_{SENSE}–I_O, I_O=850mA, V_{SENSE}=0V, V_{CC}=5V	18	33	50	mA
Output saturation voltage (Forward/reverse mode)	$V_{CE\ (SAT)}$	V_{SENSE}=0.4V, V_{CC}=3.0V, $\overline{BRAKE}$=H:Source driver, I_O=–0.85A		1.0	1.1	V
		V_{SENSE}=0.4V, V_{CC}=3.0V, $\overline{BRAKE}$=H:Source driver, I_O=–1.3A		1.7	1.9	V
		V_{SENSE}=0.4V, V_{CC}=3.0V, $\overline{BRAKE}$=H:Sink driver, I_O=0.85A		0.4	0.9	V
		V_{SENSE}=0.4V, V_{CC}=3.0V, $\overline{BRAKE}$=H:Sink driver, I_O=1.3A		1.1	1.3	V
Output saturation voltage (Brake mode)	$V_{CE\ (SAT)}$	V_{SENSE}=0.4V, V_{CC}=3.0V, $\overline{BRAKE}$=L:Sink driver, I_O=0.85A		1.2	1.4	V
		V_{SENSE}=0.4V, V_{CC}=3.0V, $\overline{BRAKE}$=L:Sink driver, I_O=1.3A		1.4	1.8	V
Clamp diode forward voltage	V_F	I_F=0.85A		1.2	1.4	V
		I_F=1.3A		1.4	1.8	V
Motor supply current (No load)	$I_{BB\ (ON)}$	$V_{\overline{ENABLE}}$=0.8V, $V_{\overline{BRAKE}}$=2.0V		2.5	4.0	mA
	$I_{BB\ (OFF)}$	$V_{\overline{ENABLE}}$=$V_{\overline{BRAKE}}$=2.0V, V_{MODE}=0.8V		1.0	50	μA
	$I_{BB\ (BRAKE)}$	$V_{\overline{BRAKE}}$=0.8V		1.0	50	μA
	$I_{BB\ (SLEEP)}$	$V_{\overline{ENABLE}}$=$V_{\overline{BRAKE}}$=V_{MODE}=2.0V		1.0	50	μA
Control logic						
Thermal shutdown temperature	T_j			165		°C
Thermal shutdown hysteresis	ΔT_j			8		°C
UVLO enable threshold	V_{UVLO}		2.5	2.75	3.0	V
UVLO hysteresis	ΔV_{UVLO}		0.12	0.17	0.25	V
Logic supply current	$I_{CC\ (ON)}$	$V_{\overline{ENABLE}}$=0.8V, $V_{\overline{BRAKE}}$=2.0V		42	50	mA
	$I_{CC\ (OFF)}$	$V_{\overline{ENABLE}}$=$V_{\overline{BRAKE}}$=2.0V, V_{MODE}=0.8V		12	15	mA
	$I_{CC\ (BRAKE)}$	$V_{\overline{BRAKE}}$=0.8V		42	50	mA
	$I_{CC\ (SLEEP)}$	$V_{\overline{ENABLE}}$=$V_{\overline{BRAKE}}$=V_{MODE}=2.0V		500	800	μA
Logic supply voltage range	V_{CC}	Operating	3.0	3.3		V
				5.0	5.5	
Logic input voltage	V_{IH}		2.0			V
	V_{IL}				0.8	V
Logic input current	I_{IH}	V_{IN}=2.0V		<1.0	20	μA
	I_{IL}	V_{IN}=0.8V		<–2.0	–200	μA
Sense voltage range	$V_{SENSE\ (3.3)}$	V_{CC}=3.0V to 3.6V	0		0.4	V
	$V_{SENSE\ (5.0)}$	V_{CC}=4.5V to 5.5V	0		1.0	V
Reference input current	I_{REF}	V_{REF}=0V to 1V			±5.0	μA
Comparator input offset voltage	V_{IO}	V_{REF}=0V		±2.0	±5.0	mV
AC timing						
PWM RC fixed off-time	$t_{OFF\ RC}$	C_T=680pF, R_T=30kΩ, V_{CC}=3.3V	18.3	20.4	22.5	μs
PWM turn-off time	$t_{PWM\ (OFF)}$	Comparator Trip to Source OFF, Io=25mA		1.0	1.5	μs
		Comparator Trip to Source OFF, Io=1.3A		1.8	2.6	μs
PWM turn-on time	$t_{PWM\ (ON)}$	I_{RC} Charge ON to Source ON, Io=25mA		0.4	0.7	μs
		I_{RC} Charge ON to Source ON, Io=1.3A		0.55	0.85	μs
PWM minimum on-time	$t_{PWM\ (ON)}$	V_{CC}=3.3V, R_T≥12kΩ, C_T=680pF	0.8	1.4	1.9	μs
		V_{CC}=5.0V, R_T≥12kΩ, C_T=470pF	0.8	1.6	2.0	μs
Propagation delay time	t_{pd}	I_O=±1.3A, 50% to 90% $\overline{ENABLE}$ ON to Source ON		1.0		μs
		I_O=±1.3A, 50% to 90% $\overline{ENABLE}$ OFF to Source OFF		1.0		μs
		I_O=±1.3A, 50% to 90% $\overline{ENABLE}$ ON to Sink ON		1.0		μs
		I_O=±1.3A, 50% to 90% $\overline{ENABLE}$ OFF to Sink OFF (MODE=L)		0.8		μs
		I_O=±1.3A, 50% to 90% PHASE Change to Sink ON		2.4		μs
		I_O=±1.3A, 50% to 90% PHASE Change to Sink OFF		0.8		μs
		I_O=±1.3A, 50% to 90% PHASE Change to Source ON		2.0		μs
		I_O=±1.3A, 50% to 90% PHASE Change to Source OFF		1.7		μs
Crossover dead time	t_{CODT}	1kΩ Load to 25V, V_{BB}=50V	0.3	1.5	3.0	μs

●"typ" values are for reference.

■Derating



■Internal Block Diagram



■Truth Table

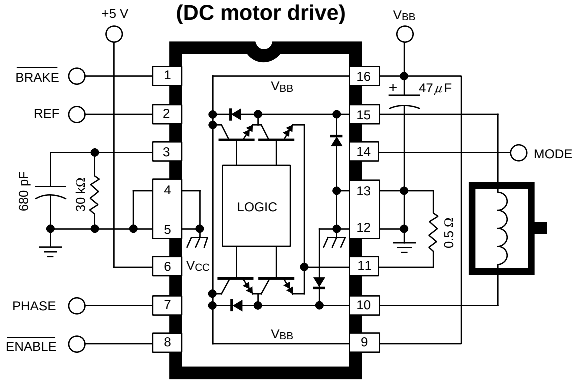
BRAKE	ENABLE	PHASE	MODE	OUT_A	OUT_B	Operating Mode
H	H	X	H	Z	Z	Sleep mode
H	H	X	L	Z	Z	Standby
H	L	H	H	H	L	Forward, fast current-decay mode
H	L	H	L	H	L	Forward, slow current-decay mode
H	L	L	H	L	H	Reverse, fast current-decay mode
H	L	L	L	L	H	Reverse, slow current-decay mode
L	X	X	H	L	L	Brake, fast current-decay mode
L	X	X	L	L	L	Brake, no current control

X : Don't Care
Z : High impedance

■Application Circuit

(A3953SB)

(DC motor drive)



Off-time setting
$t_{OFF} \fallingdotseq R_T \cdot C_T$
R_T=12k to 100kΩ
C_T=470 to 1500pF (Operating at V_{CC}=5V)
C_T=680 to 1500pF (Operating at V_{CC}=3.3V)

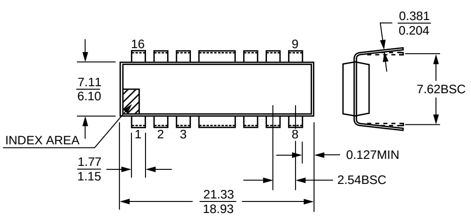
■External Dimensions

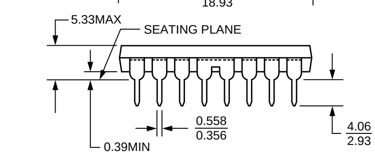
(Unit: mm)

A3953SB

Plastic DIP (300mil)

ICs per stick	25





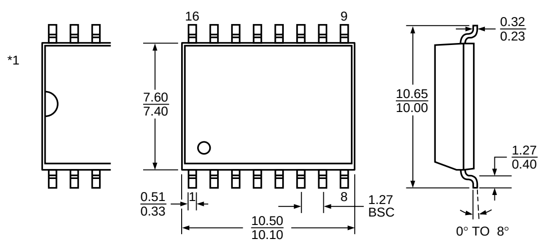
- Thickness of lead is measured below seating plane.
- Allowable variation in distance between leads is not cumulative.

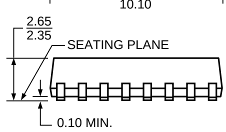
Note 1: Lead width of pin 1, 8, 9, 16 may be
2: half the value shown here.
Maximum thickness of lead is 0.508mm.

A3953SLB

(16-pin wide SOIC)

ICs per stick	47





- Pin material: copper, pin surface treatment: solder plating
- Package index may be *1.
- Allowable variation in distance between leads is not cumulative.
- Web (batwing) type lead frames are used for pin 4, 5, 12, 13. The pins are connected to GND.

Application Notes

■Outline

Designed for bidirectional pulse-width modulated (PWM) current control of inductive loads, the A3953S- is capable of continuous output currents to ±1.3A and operating voltages to 50V. Internal fixed off-time PWM current-control circuitry can be used to regulate the mximum load current to a desired value. The peak load current limit is set by the user's selection of an input reference voltage and external sensing resistor. The fixed off-time pulse duration is set by a userselected external RC timing network. Internal circuit protection includes thermal shutdown with hysteresis, transient-suppression diodes, and crossover current protection. Special power-up sequencing is not required.

With the ENABLE input held low, the PHASE input controls load current polarity by selecting the appropriate source and sink driver pair. The MODE input determines whether the PWM current-control circuitry operates in a slow current-decay mode (only the selected source driver switching) or in a fast current-decay mode (selected source and sink switching). A user-selectable blanking window prevents false triggering of the PWM current-control circuitry. With the ENABLE input held high, all output drivers are disabled. A sleep mode is provided to reduce power consumption.

When a logic low is applied to the Brake input, the braking function is enabled. This overrides ENABLE and PHASE to turn OFF both source drivers and turn ON both sink drivers. The brake function can be used to dynamically brake brush dc motors.

■FUNCTIONAL DESCRIPTION

(A) Internal PWM Current Control During Forward and Reverse Operation.

The A3953S-contains a fixed off-time pulse-width modulated (PWM) current-control circuit that can be used to limit the load current to a desired value. The peak value of the current limiting (I_{TRIP}) is set by the selection of an external current sensing resistor (R_S) and reference input voltage (V_{REF}). The internal circuitry compares the voltage across the external sense resistor to the voltage on the reference input terminal (REF) resulting in a transconductance function approximated by:

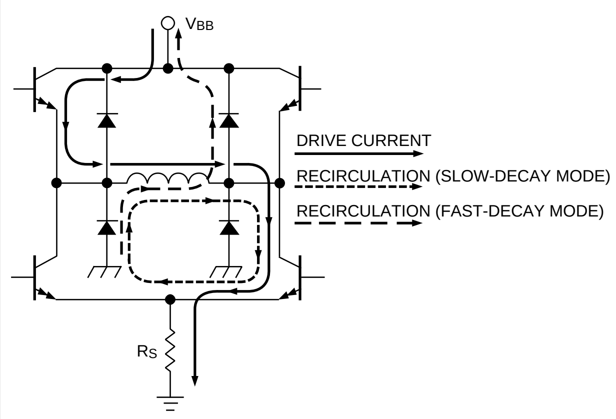
$$I_{TRIP} \approx \frac{V_{REF}}{R_{SENSE}} - I_{SO}$$

where I_{SO} is the offset due to base drive current.

In forward or reverse mode the current-control circuitry limits the load current as follows: when the load current reaches I_{TRIP}, the comparator resets a latch that turns off the selected source driver or selected sink and source driver pair depending on whether the device is operating in slow or fast current-decay mode, respectively.

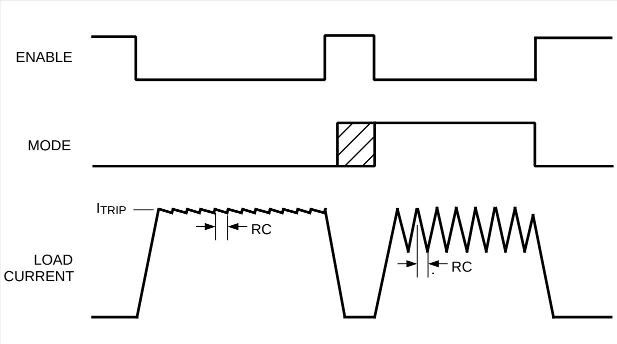
In slow current-decay mode, the selected source driver is disabled; the load inductance causes the current to recirculate through the sink driver and ground clamp diode. In fast current-decay mode, the selected sink and source driver pair are disabled; the load inductance causes the current to flow from ground to the load supply via the ground clamp and flyback diodes.

Fig. 1 Load-current Paths



The user selects an external resistor (R_T) and capacitor (C_T) to determine the time period ($t_{OFF}=R_T \bullet C_T$) during which the drivers remain disabled (see "RC Fixed Off-time" below). At the end of the RC interval, the drivers are enabled allowing the load current to increase again. The PWM cycle repeats, maintaing the peak load current at the desired value (see figure 2).

Fig. 2 Fast and Slow Current-Decay Waveforms



(B) INTERNAL PWM CURRENT CONTROL DURING BRAKE-MODE OPERATION

(1) Brake Operation-MODE Input High.

The brake circuit turns OFF both source drivers and turns ON both sink drivers. For dc motor applications, this has the effect of shoring the motor's back-EMF voltage resulting in current flow that dynamically brakes the motor. If the back-EMF voltage is large, and there is no PWM current limiting, the load current can increase to a value that approaches that of a locked rotor condition. To limit the current, when the I_{TRIP} level is reaced, the PWM circuit disables the conducting sink drivers. The energy stored in the motor's inductance is discharged into the load supply causing the motor current to decay.

As in the case of forward/reverse operation, the drivers are enabled after a time given by $t_{OFF}=R_T \bullet C_T$ (see "RC Fixed Off-time" below). Depending on the back-EMF voltage (proportional to the motor's decreasing speed), the load current again may increase to I_{TRIP}. If so, the PWM cycle will repeat, limiting the peak load current to the desired value.

During braking, when the MODE input is high, the peak current limit can be approximated by:

$$I_{TRIP\ BRAKE\ MH} \approx \frac{V_{REF}}{R_{SENSE}}$$

CAUTION: Because the kinetic energy stored in the motor and load inertia is being converted into current, which charges the V_{BB} supply bulk capacitance (power supply output and decoupling capacitance), care must be taken to ensure the capacitance is sufficient to absorb the energy without exceeding the voltage rating of any devices connected to the motor supply.

(2) Brake Operation-MODE Input Low.

During braking, with the MODE input low, the internal current-control circuitry is disabled. Therefore, care should be taken to ensure that the motor's current does not exceed the ratings of the device. The braking current can be measured by using an oscilloscope with a current probe connected to one of the motor's leads, or if the back-EMF voltage of the motor is known, approximated by:

$$I_{PEAK\ BRAKE\ ML} \approx \frac{V_{BEMF}-1V}{R_{LOAD}}$$

(C) RC Fixed Off-Time.

The internal PWM current-control circuitry uses a one shot to control the time the driver (s) remain (s) off. The one-shot time, t_{OFF} (fixed off-time), is determined by the selection of an external resistor (R_T) and capacitor (C_T) connected in parallel from the RC timing terminal to ground. The fixed off-time, over a range of values of C_T=470pF to 1500pF and R_T=12kΩ to 100kΩ, is approximated by:

$$t_{off} \approx R_T \cdot C_T$$

The operation of the circuit is as follows: when the PWM latch is reset by the current comparator, the voltage on the RC terminal will begin to decay from approximately 0.60V_{CC}. When the voltage on the RC terminal reaches approximately 0.22 V_{CC}, the PWM latch is set, thereby enabling the driver (s).

(D) RC Blanking.

In addition to determining the fixed off-time of the PWM control circuit, the C_T component sets the comparator blanking time. This function blanks the output of the comparator when the outputs are switched by the internal current-control circuitry (or by the PHASE, BRAKE, or ENABLE inputs). The comparator output is blanked to prevent false over-current detections due to reverse recovery currents of the clamp diodes, and/or switching transients related to distributed capacitance in the load.

During internal PWM operation, at the end of the t_{OFF} time, the comparator's output is blanked and C_T begins to be charged from approximately 0.22 V_{CC} by an internal current source of approximately 1 mA. The comparator output remains blanked until the voltage on C_T reaches approximately 0.60 V_{CC}.

When a transition of the PHASE input occurs, C_T is discharged to near ground during the crossover delay time (the crossover delay time is present to prevent simultaneous conduction of the source and sink drivers). After the crossover delay, C_T is charged by an internal current source of approximately 1 mA. The comparator output remains blanked until the voltage on C_T reaches approximately 0.60V_{CC}.

When the device is disabled, via the ENABLE input, C_T is discharged to near ground. When the device is reenabled, C_T is charged by an internal current source of approximately 1 mA. The comparator output remains blanked until the voltage on C_T reaches approximately 0.60 V_{CC}.

For 3.3 V operation,

the minimum recommended value for C_T is 680pF±5%.

For 5.0V operation,

the minimum recommended value for C_T is 470pF±5%.

These values ensure that the blanking time is sufficient to avoid false trips of the comparator under normal operating conditions. For optimal regulation of the load current, the ablove values for C_T are recommended and the value of R_T can be sized to determine t_{OFF}. For more information regarding load current regulation, see below.

(E) LOAD CURRENT REGULATION WITH INTERNAL PWM CURRENT-CONTROL CIRCUITRY

When the device is operating in slow current-decay mode, there is a limit to the lowest level that the PWM current-control circuitry can regulate load current. The limitation is the minimum duty cycle, which is a function of the user-selected value of t_{OFF} and the minimum on-time pulse $t_{ON\ (min)}$ max that occurs each time the PWM latch is reset. If the motor is not rotating (as in the case of a stepper motor in hold/detent mode, a brush dc motor when stalled, or at startup), the worst case value of current regulation can be approximated by:

$$I_{AVE} \cong \frac{[(V_{BB}-V_{SAT\ (source\ +\ sink)}) \cdot t_{on\ (min)}\ max]-[1.05 \cdot (V_{SAT\ (sink)} + V_F) \cdot t_{off}]}{1.05 \cdot (t_{on\ (min)}\ max + t_{off}) \cdot R_{LOAD}}$$

where t_{OFF}=R_T•C_T, R_{LOAD} is the series resistance of the load, V_{BB} is the motor supply voltage and $t_{ON\ (min)}$ max is specified in the electrical characteristics table. When the motor is rotating, the back EMF generated will influence the above relationship. For brush dc motor applications, the current regulation is improved. For stepper motor applications, when the motor is rotating, the effect is more complex. A discussion of this subject is included in the section on stepper motors below.

The following procedure can be used to evaluate the worst-case slow current-decay internal PWM load current regulation in the system:

Set V_{REF} to 0 volts. With the load connected and the PWM current control operating in slow current-decay mode, use and oscilloscope to measure the time the output is low (sink ON) for the output that is chopping. This is the typical minimum ON time ($t_{ON\ (min)}$ typ) for the device.

The C_T then should be increased until the measured value of $t_{ON\ (min)}$ is equal to $t_{ON\ (min)}$ max as specified in the electrical characteristics table. When the new value of C_T has been set, the value of R_T should be decreased so the value for $t_{OFF}=R_T \bullet C_T$ (with the artificially increased value of C_T) is equal to the nominal design value. The worst-case load-current regulation then can be measured in the system under operating conditions.

(F) PWM of the PHASE and ENABLE Inputs.

The PHASE and ENABLE inputs can be pulse-width modulated to regulate load current. Typical propagation delays from the PHASE and ENABLE inputs to transitions of the power outputs are specified in the electrical characteristics table. If the internal PWM current control is used, the comparator blanking function is active during phase and enable transitions. This eliminates false tripping of the over-current comparator caused by switching transients (see “RC Blanking” above).

(1) Enable PWM.

With the MODE input low, toggling the ENABLE input turns ON and OFF the selected source and sink drivers. The corresponding pair of flyback and ground-clamp diodes conduct after the drivers are disabled, resulting in fast current decay. When the device is enabled the internal current-control curcuitry will be active and can be used to limit the load current in a slow current-decay mode.

For applications that PWM the ENABLE input and desire the internal current-limiting circuit to function in the fast decay mode, the ENABLE input signal should be inverted and connected to the MODE input. This prevents the device from being switched into sleep mode when the ENABLE input is low.

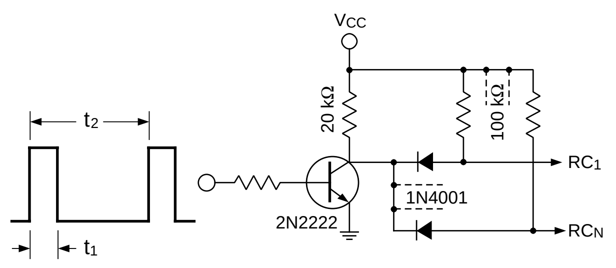
(2) Phase PWM.

Toggling the PHASE terminal selects which sink/source pair is enabled, producing a load current that varies with the duty cycle and remains continuous at all times. This can have added benefits in bidirectional brush dc servo motor applications as the transfer function between the duty cycle on the PHASE input and the average voltage applied to the motor is more linear than in the case of ENABLE PWM control (withch produces a discontinuous current at low current levels). For more information see “DC Motor Applications” below.

(3) Synchronous Fixed-Frequency PWM.

The internal PWM current-control circuitry of multiple A3953S- devices can be synchronized by using the simple circuit shown in figure 3. A 555IC can be used to generate the reset pulse/ blanking signal (t_1) for the device and the period of the PWM cycle (t_2). The value of t_1 should be a minimum of 1.5ms. When used in this configuration, the R_T and C_T components should be omitted. The PHASE and ENABLE inputs should not be PWM with this circuit configuration due to the absence of a blanking function synchronous with their transitions.

Fig. 3 Synchronous Fixed-Frequency Control Circuit



(G) Miscellaneous Information.

A logic high applied to both the ENABLE and MODE terminals puts the device into a sleep mode to minimize current consumption when not in use.

An internally generated dead time prevents crossover currents that can occur when switching phase or braking.

Thermal protection circuitry turns OFF all drivers should the junction termperature reach 165°C (typical). This is intended only to protect the device from failures due to excessive junction temperatures and should not imply that output short circuits are permitted. The hysteresis of the thermal shutdown circuit is approximately 8°C.

■APPLICATION NOTES

(A) Current Sensing.

The actual peak load current (I_{PEAK}) will be above the calculated value of I_{TRIP} due to delays in the turn off of the drivers. The amount of overshoot can be approximated by:

$$I_{OS} \approx \frac{(V_{BB}-[(I_{TRIP} \bullet R_{LOAD}) + V_{BEMF}]) \bullet t_{PWM\ (OFF)}}{L_{LOAD}}$$

where V_{BB} is the motor supply voltage, V_{BEMF} is the back-EMF voltage of the load, R_{LOAD} and L_{LOAD} are the resistance and inductance of the load respectively, and $t_{PWM\ (OFF)}$ is specified in the electrical characteristics table.

The reference terminal has a maximum input bias current of ±5μA. This current should be taken into account when determining the impedance of the external circuit that sets the reference voltage value.

To minimize current-sensing inaccuracies caused by ground trace I•R drops, the current-sensing resistor should have a separate return to the ground terminal of the device. For low-value sense resistors, the I•R drops in the printed wiring board can be significant and should be taken into account. The use of sockets should be avoided as their contact resistance can cause variations in the effective value of R_S.

Generally, larger values of R_S reduce the aforementioned effects but can result in excessive heating and power loss in the

sense resistor. The selected value of R_S should not cause the absolute maximum voltage rating of 1.0V (0.4V for V_{CC}=3.3Voperation), for the SENSE terminal, to be exceeded.
The current-sensing comparator functions down to ground allowing the device to be used in microstepping, sinusoidal, and other varying current-profile applications.

(B) Thermal Considerations.

For reliable operation it is recommended that the maximum junction termperature be kept below 110°C to 125°C. The junction termperature can be measured best by attaching a thermocouple to the power tab/batwing of the device and measuring the tab temperature, T_{TAB}. Tthe junction temperature can then be approximated by using the formula:

$$T_J \approx T_{TAB} + (I_{LOAD} \cdot 2 \cdot V_F \cdot R_{\theta JT})$$

where V_F may be chosen from the electrical specification table for the given level of I_{LOAD}. The value for $R_{\theta JT}$ is given in the package thermal resistance table for the appropriate package.
The power dissipation of the batwing packages can be improved by 20% to 30% by adding a section of printed circuit board copper (typically 6 to 18 square centimeters) connected to the batwing terminals of the device.
The thermal performance in applications that run at high load currents and/or high duty cycles can be improved by adding external diodes in parallel with the internal diodes. In internal PWM slow-decay applications, only the two ground clamp diodes need be added. For internal fast-decay PWM, or external PHASE or ENABLE input PWM applications, all four external diodes should be added for maximum junction temperature reduction.

(C) PCB Layout.

The load supply terminal, V_{BB} should be decoupled with an electrolytic capacitor (>47μF is recommeded) placed as close to the device as is physically practical. To minimize the elffect of system ground I•R drops on the logic and reference input signals, the system ground should have a low-resistance return to the motor supply voltage.
See also "Current Sensing" and "Thermal Considerations" above.

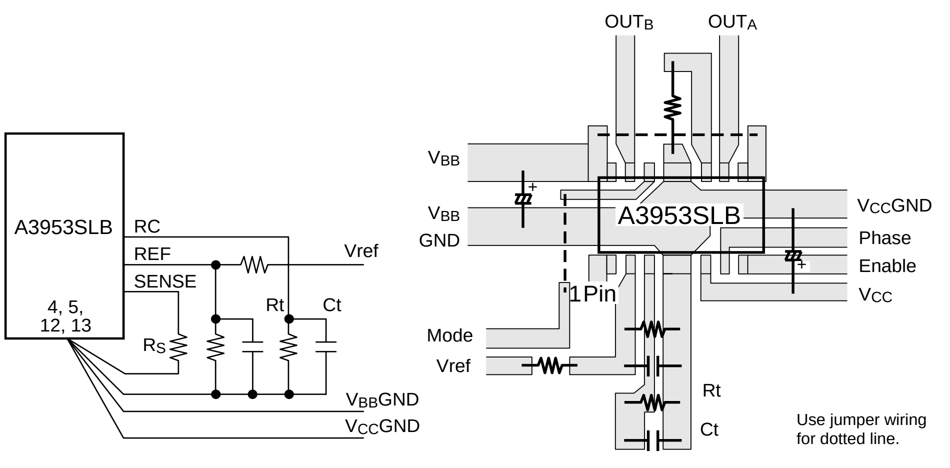
(D) Fixed Off-Time Selection.

With increasing values of t_{OFF}, switching losses will decrease, low-level load-current regulation will improve, EMI will be reduced, the PWM frequency will decrease, and ripple current will increase. The value of t_{OFF} can be chosen for optimization of these parameters. For applications where audible noise is a concern, typical values of t_{OFF} are chosen to be in the range of 15 ms to 35 ms.

(E) Stepper Motor Applications.

The MODE terminal can be used to optimize the performance of the device in microstepping/sinusoidal stepper-motor drive applications. When the load current is increasing, slow decay mode is used to limit the switching losses in the device and iron losses in the motor. This also improves the maximum rate at which the load current can increase (as compared to fast decay) due to the slow rate of decay during t_{OFF}.
When the load current is decreasing, fast-decay mode is used to regulate the load current to the desired level. This prevents tailing of the current profile caused by the back-EMF voltage of the stepper motor.

Fig. 4 Example of Circuit (including GND) and GND Wiring Pattern



In stepper-motor applications applying a constant current to the load, slow-decay mode PWM is typically used to limit the switching lossess in the device and iron losses in the motor.

(F) DC Motor Applications.

In closed-loop systems, the speed of a dc motor can be controlled by PWM of the PHASE or ENABLE inputs, or by varying the reference input voltage (REF). In digital systems (microprocessor controlled), PWM of the PHASE or ENABLE input is used typically thus avoiding the need to generate a variable analog voltage reference. In this case, a dc voltage on the REF input is used typically to limit the maximum load current.

In dc servo applications, which require accurate positioning at low or zero speed, PWM of the PHASE input is selected typically. This simplifies the servo control loop because the transfer function between the duty cycle on the PHASE input and the average voltage applied to the motor is more linear than in the case of ENABLE PWM comtrol (which produces a discontinuous current at low current levels).

With bidirectional dc servo motors, the PHASE terminal can be used for mechanical direction control. Similar to when branking the motor dynamically, abrupt changes in the direction of a rotating motor produces a current generated by the back-EMF. The current generated will depend on the mode of operation. If the internal current control circuitry is not being used, then the maximum load current generated can be approximated by $I_{LOAD}=(V_{BEMF}+V_{BB})/R_{LOAD}$ where V_{BEMF} is proportional to the motor's speed. If the internal slow current-decay control circuitry is used, then the maximum load current generated can be approximated by $I_{LOAD}=V_{BEMF}/R_{LOAD}$. For both cases care must be taken to ensure that the maximum ratings of the device are not exceeded. If the internal fast current-decay control circuitry is used, then the load current will regulate to a value given by:

$$I_{LOAD} \approx \frac{V_{REF}}{R_S}$$

CAUTION: In fast current-decay mode, when the direction of the motor is changed abruptly, the kinetic energy stored in the motor and load inertia will be converted into current that charges the V_{BB} supply bulk capacitance (power supply output and decoupling capacitance). Care must be taken to ensure that the capacitance is sufficient to absorb the energy without exceeding the voltage rating of any devices connected to the motor supply.

See also "Brake Operation" above.

2-Phase Stepper Motor Bipolar Driver IC

Allegro MicroSystems product

■Features

- ● Fixed off-time PWM current control
- ● Low saturation voltage (Sink transistor)
- ● Internal thermal shutdown circuitry
- ● Internal crossover-current protection circuitry
- ● Internal UVLO protection
- ● Internal transient-suppression diodes
- ● Low thermal resistance 18-pin SIP

■Absolute Maximum Ratings

Parameter	Symbol	Conditions	Ratings	Units
Motor supply voltage	V_{BB}		45	V
Output current (peak)	$I_{O\ (peak)}$	tw≤20μs	±1.75	A
Output current (continuous)	I_O		±1.5	A
Logic supply voltage	V_{CC}		7.0	V
Logic input voltage range	V_{IN}		–0.3 to +7.0	V
Output emitter voltage	V_E		1.5	V
Package power dissipation	P_D (Note1)		4.0	W
Operating temperature	T_a		–20 to +85	°C
Junction temperature	T_j (Note2)		+150	°C
Storage temperature	T_{stg}		–55 to +150	°C

●Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of 150°C.
Note 1: When ambient temperature is 25°C or over, derate using –32.0mW/°C.
Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

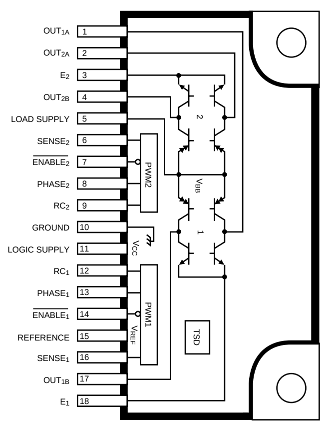
■Electrical Characteristics

(Unless specified otherwise, T_a=25°C, V_{BB}=45V, V_{CC}=4.75V to 5.25V, V_{REF}=5V)

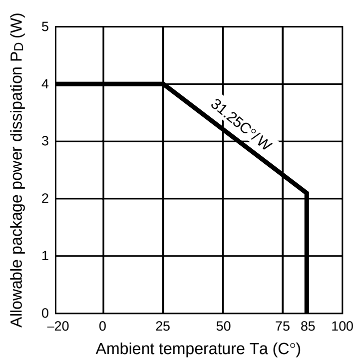
Parameter	Symbol	Conditions	Limits			Units
			min	typ	max	
Power outputs (OUT_A or OUT_B)						
Motor supply voltage range	V_{BB}		10		45	V
Output leakage current	I_{CEX}	V_O=V_{BB}			50	μA
		V_O=0V			–50	μA
Output saturation voltage	$V_{CE\ (SUS)}$	I_O=±1.5A, L=3.5mH	45			V
Output sustaining voltage	$V_{CE\ (SAT)}$	Sink driver, I_O=+1.0A			0.8	V
		Sink driver, I_O=+1.5A			1.1	V
		Source driver, I_O=–1.0A			2.0	V
		Source driver, I_O=–1.5A			2.2	V
Clamp diode leakage current	I_R	V_R=45V			50	μA
Clamp diode forward voltage	V_F	I_F=1.5A			2.0	V
Motor supply current	$I_{BB\ (ON)}$	Both bridges ON, no load			15	mA
	$I_{BB\ (OFF)}$	Both bridges OFF			10	mA
Control logic						
Input voltage	V_{IH}	All inputs	2.4			V
	V_{IL}	All inputs			0.8	V
Input current	I_{IH}	V_{IN}=2.4V			20	μA
	I_{IL}	V_{IN}=0.8V			–200	μA
Reference voltage range	V_{REF}	Operating	1.5		V_{CC}	V
Current control threshold	V_{REF}/V_{SENSE}	V_{REF}=5V	9.5	10	10.5	
Thermal shutdown temperature	T_j			170		°C
Logic supply current	I_{CC}	V_{EN}=0.8V, no load			140	mA

●"typ" values are for reference.

■Terminal Connection Diagram



■Derating

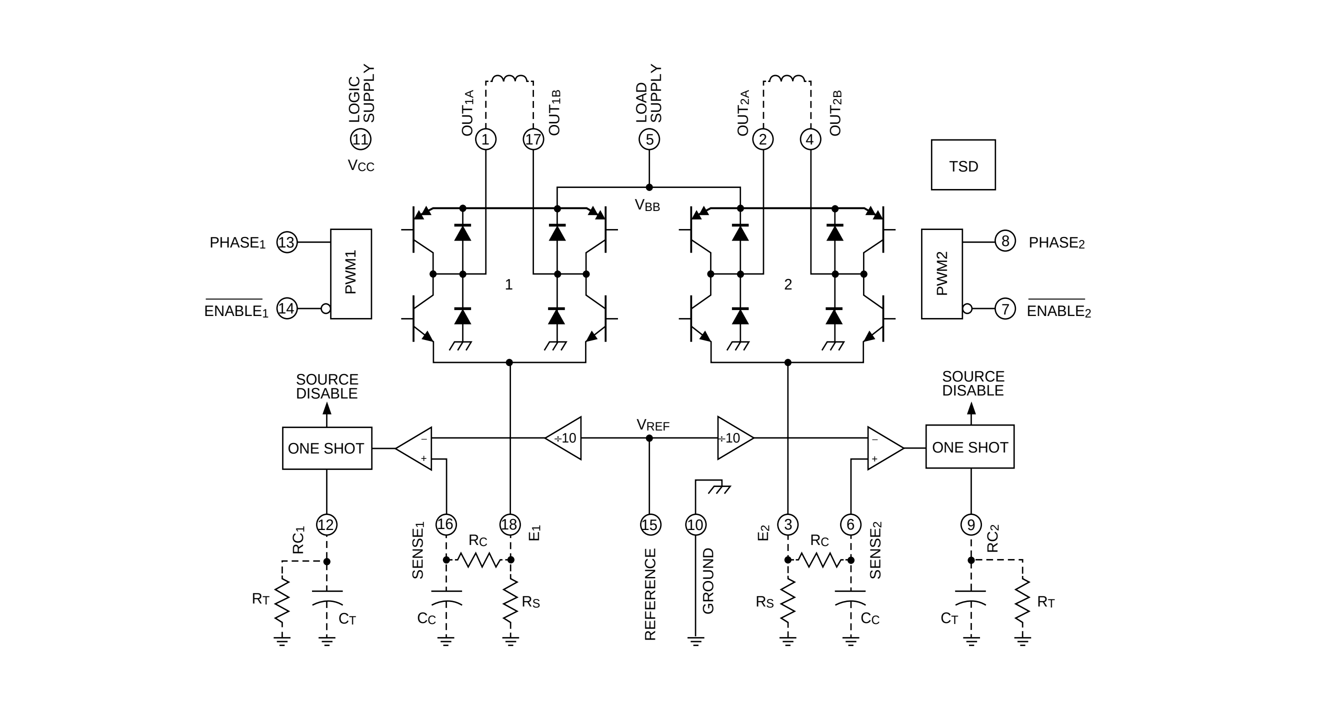


■Truth Table

ENABLE	PHASE	OUT_A	OUT_B
L	H	H	L
L	L	L	H
H	X	Z	Z

X=Don't Care Z=High impedance

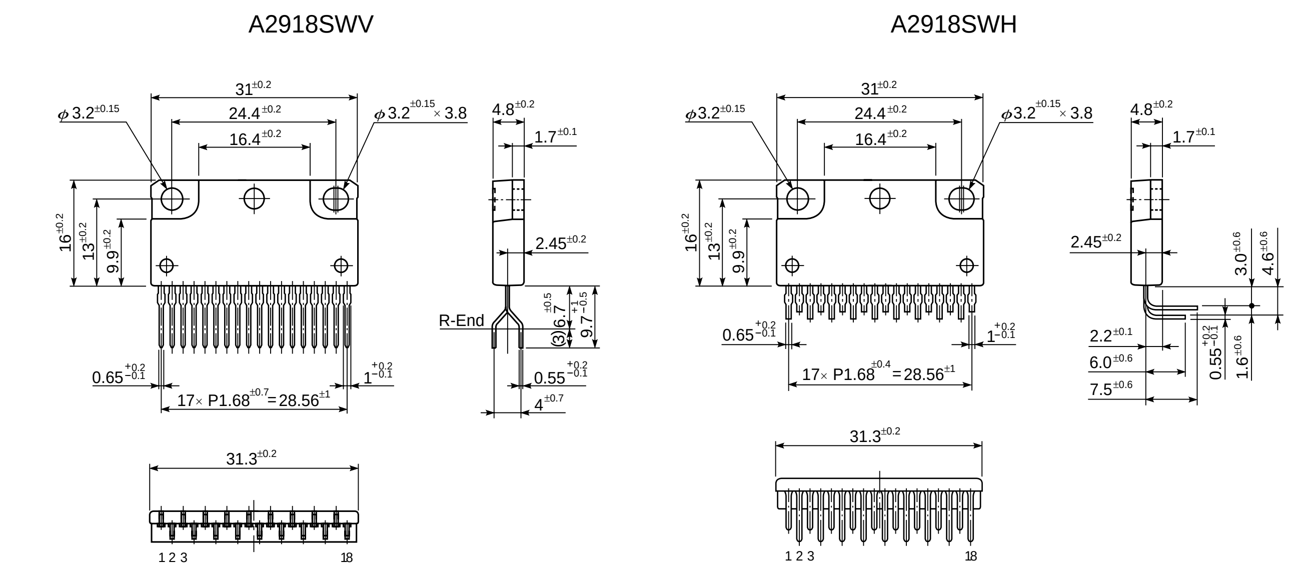
■Internal Block Diagram



■External Dimensions Plastic SIP

(Unit: mm)

ICs per stick	18



2-Phase Stepper Motor Bipolar Driver ICs

Allegro MicroSystems product

■Features

- Fixed off-time PWM current control
- Switching between power supply regeneration mode and loop regeneration mode in order to improve motor current response in microstepping
- External filter for sense terminal not required
- Sleep (low current consumption) mode
- Brake operation with PWM current limiting
- Internal thermal shutdown circuitry
- Internal crossover-current protection circuitry
- Internal UVLO protection
- Internal transient-suppression diodes
- Low thermal resistance package

■Absolute Maximum Ratings

Parameter	Symbol	Conditions	Ratings			Units
			A3952SB	A3952SLB	A3952SW	
Load supply voltage	V_{BB}		50			V
Output current (peak)	$I_{O\,(Peak)}$	tw≤20μ s	±3.5			A
Output current (continuous)	I_O		±2.0			A
Logic supply voltage	V_{CC}		7.0			V
Logic input voltage	V_{IN}		–0.3 to V_{CC}+0.3			V
Sense voltage	V_{SENSE}		1.5			V
Reference voltage	V_{REF}		15			V
Package power dissipation	P_D (Note1)		2.90	1.86	3.47	W
Operating temperature	T_a		–20 to +85			°C
Junction temperature	T_j (Note2)		+150			°C
Storage temperature	T_{stg}		–55 to +150			°C

●Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of 150°C.
Note 1: When ambient temperature is 25°C or over, derate using –23.26mW/°C(SB), –14.93mW/°C(SLB) or –27.78mW/°C(SW).
Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

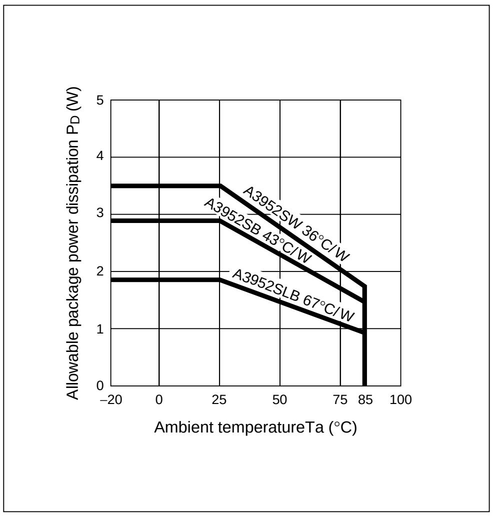
■Electrical Characteristics

(Unless specified otherwise, T_a=25°C, V_{BB}=50V, V_{CC}=5.0V, V_{BRAKE}=2.0V, V_{SENSE}= 0V, 20kΩ & 1000pF RC to ground)

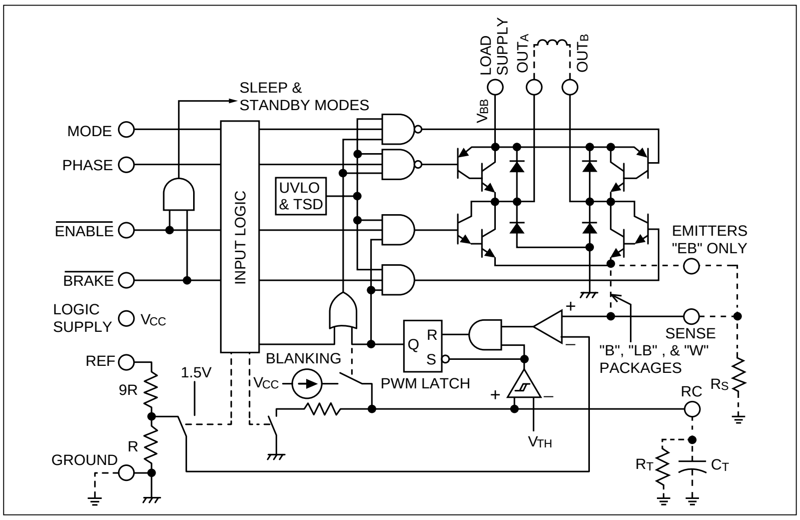
Parameter	Symbol	Conditions	Limits min	Limits typ	Limits max	Units
Power outputs						
Load supply voltage range	V_{BB}	Operating, I_O=±2.0A, L=3mH	V_{CC}		50	V
Output leakage current	I_{CEX}	V_O=V_{BB}		<1.0	50	μ A
		V_O=0V		< –1.0	–50	μ A
Output saturation voltage	$V_{CE\,(SAT)}$	Source driver, I_O=–0.5A		0.9	1.2	V
		Source driver, I_O=–1.0A		1.0	1.4	V
		Source driver, I_O=–2.0A		1.2	1.8	V
		Sink driver, I_O=+0.5A		0.9	1.2	V
		Sink driver, I_O=+1.0A		1.0	1.4	V
		Sink driver, I_O=+2.0A		1.3	1.8	V
Clamp diode forward voltage (Source or sink)	V_F	I_F=0.5A		1.0	1.4	V
		I_F=1.0A		1.1	1.6	V
		I_F=2.0A		1.4	2.0	V
Load supply current (No load)	$I_{BB\,(ON)}$	$V_{\overline{ENABLE}}$=0.8V, $V_{\overline{BRAKE}}$=2.0V		2.9	6.0	mA
	$I_{BB\,(OFF)}$	$V_{\overline{ENABLE}}$=2.0V, V_{MODE}=0.8V, $V_{\overline{BRAKE}}$=2.0V		3.1	6.5	mA
	$I_{BB\,(BRAKE)}$	$V_{\overline{BRAKE}}$=2.0V		3.1	6.5	mA
	$I_{BB\,(SLEEP)}$	$V_{\overline{ENABLE}}$=V_{MODE}=$V_{\overline{BRAKE}}$=2.0V		<1.0	50	μ A
Control logic						
Logic supply voltage range	V_{CC}	Operating	4.5	5.0	5.5	V
Logic input voltage	V_{IH}		2.0			V
	V_{IL}				0.8	V
Logic input current	I_{IH}	V_{IH}=2.0V		<1.0	20	μ A
	I_{IL}	V_{IL}=0.8V		< –2.0	–200	μ A
Reference voltage range	V_{REF}	Operating	0		15	V
Reference input current	I_{REF}	V_{REF}=2.0V	25	40	55	μ A
Reference voltage divider ratio		V_{REF}=15V	9.5	10.0	10.5	
Comparator input offset voltage	V_{IO}	V_{REF}=0V		±1.0	±10	mV
PWM RC fixed off-time	t_{off}	C_T=1000pF, R_T=20kΩ	18	20	22	μ s
PWM minimum on-time	$t_{on\,(min)}$	C_T=820pF, R_T≥12kΩ		1.7	3.0	μ s
		C_T=1200pF, R_T≥12kΩ		2.5	3.8	μ s
Propagation delay time	t_{pd}	I_{OUT}=±2.0A, 50% E_{IN} to 90% E_{out} Transition:				
		$\overline{\text{ENABLE}}$ ON to SOURCE ON		2.9		μ s
		$\overline{\text{ENABLE}}$ OFF to SOURCE OFF		0.7		μ s
		$\overline{\text{ENABLE}}$ ON to SINK ON		2.4		μ s
		$\overline{\text{ENABLE}}$ OFF to SINK OFF		0.7		μ s
		PHASE CHANGE to SOURCE ON		2.9		μ s
		PHASE CHANGE to SOURCE OFF		0.7		μ s
		PHASE CHANGE to SINK ON		2.4		μ s
		PHASE CHANGE to SINK OFF		0.7		μ s
	$t_{pd\,(PWM)}$	Comparator Trip to SINK OFF		0.8	1.5	μ s
Thermal shutdown temperature	T_j			165		°C
Thermal shutdown hysteresis	ΔT_j			15		°C
UVLO enable threshold	$V_{CC\,(UVLO)}$		3.15	3.50	3.85	V
UVLO hysteresis	$\Delta V_{CC\,(UVLO)}$		300	400	500	mV
Logic supply current (No load)	$I_{CC\,(ON)}$	$V_{\overline{ENABLE}}$=0.8V, $V_{\overline{BRAKE}}$=2.0V		20	30	mA
	$I_{CC\,(OFF)}$	$V_{\overline{ENABLE}}$=2.0V, V_{MODE}=0.8V, $V_{\overline{BRAKE}}$=2.0V		12	18	mA
	$I_{CC\,(BRAKE)}$	$V_{\overline{BRAKE}}$=0.8V		26	40	mA
	$I_{CC\,(SLEEP)}$	$V_{\overline{ENABLE}}$=V_{MODE}=$V_{\overline{BRAKE}}$=2.0V		3.0	5.0	mA

●"typ" values are for reference.

■Derating



■Internal Block Diagram

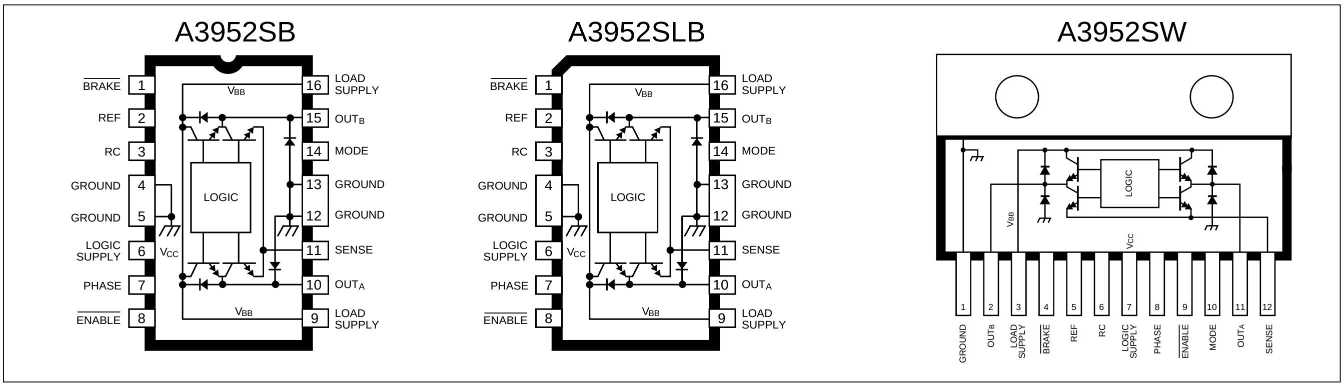


■Truth Table

BRAKE	ENABLE	PHASE	MODE	OUTA	OUTB	Operating Mode
H	H	X	H	Z	Z	Sleep mode
H	H	X	L	Z	Z	Standby (Note 1)
H	L	H	H	H	L	Forward, fast current-decay mode
H	L	H	L	H	L	Forward, slow current-decay mode
H	L	L	H	L	H	Reverse, fast current-decay mode
H	L	L	L	L	H	Reverse, slow current-decay mode
L	X	X	H	L	L	Brake, fast current-decay mode
L	X	X	L	L	L	Brake, no current control (Note 2)

X : Don't Care
Z : High impedance
Note 1: Includes active pull-offs for power outputs
Note 2: Includes internal default V_{SENSE} level for overcurrent protection

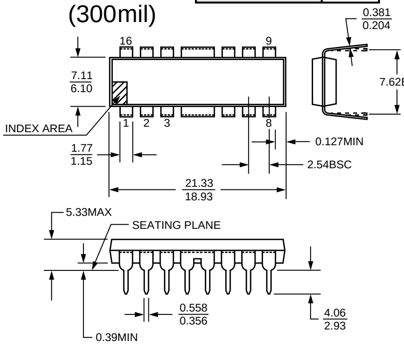
■Terminal Connection Diagram

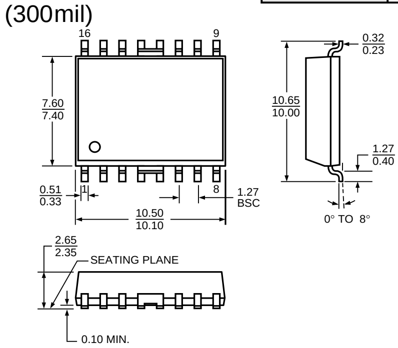


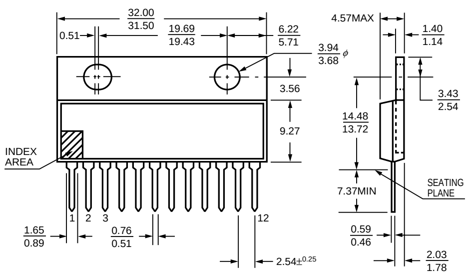
■External Dimensions

(Unit: mm)

A3952SB	A3952SLB	A3952SW
Plastic DIP (300mil) — ICs per stick 25	Wide body plastic SOP (300mil) — ICs per stick 47	Plastic power SIP — ICs per stick 15







●Thickness of lead is measured below seating plane.
●Allowable variation in distance between leads is not cumulative.
Note 1: Lead width of pin 1, 8, 9, 16 may be half the value shown here.
2: Maximum thickness of lead is 0.508mm.

●Thickness of lead is measured below seating plane.
●Allowable variation in distance between leads is not cumulative.
●Lead is measured 0.762mm below seating plane.

Application Notes

■Outline

Designed for bidirectional pulse-width modulated current control of inductive loads, the A3952S- is capable of continuous output currents to ±2A and operating voltages to 50V. Internal fixed off-time PWM current-control circuitry can be used to regulate the maximum load current to a desired value. The peak load current limit is set by the user's selection of an input reference voltage and external sensing resistor. The fixed OFF-time pulse duration is set by a user-selected external RC timing network. Internal circuit protection includes thermal shutdown with hysteresis, transient suppression diodes, and crossover-current protection. Special power-up sequencing is not required.

With the ENABLE input held low, the PHASE input controls load current polarity by selecting the appropriate source and sink driver pair. The MODE input determines whether the PWM current-control circuitry operates in a slow current-decay mode (only the selected sink driver switching) or in a fast current-decay mode (selected source and sink switching). A user-selectable blanking window prevents false triggering of the PWM current control circuitry. With the ENABLE input held high, all output drivers are disabled. A sleep mode is provided to reduce power consumption when inactive.

When a logic low is applied to the BRAKE input, the braking function is enabled. This overrides ENABLE and PHASE to turn OFF both source drivers and turn ON both sink drivers. The brake function can be safely used to dynamically brake brush dc motors.

■FUNCTIONAL DESCRIPTION

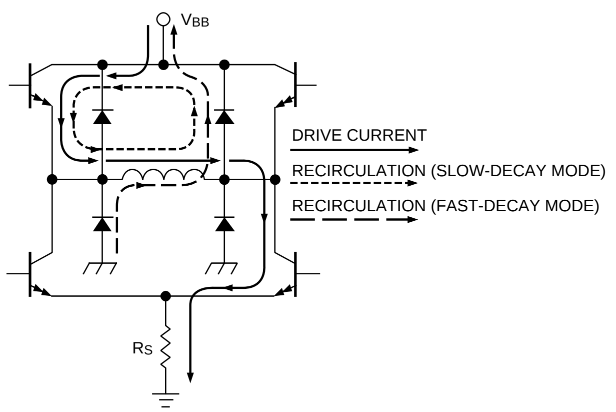
(A) INTERNAL PWM CURRENT CONTROL DURING FORWARD AND REVERSE OPERATION

The A3952S- contains a fixed OFF-time pulse-width modulated (PWM) current-control circuit that can be used to limit the load current to a desired value. The value of the current limiting (I_{TRIP}) is set by the selection of an external current sensing resistor (R_S) and reference input voltage (V_{REF}). The internal circuitry compares the voltage across the external sense resistor to one tenth the voltage on the REF input terminal, resulting in a function approximated by

$$I_{TRIP} \approx \frac{V_{REF}}{10 \cdot R_S}$$

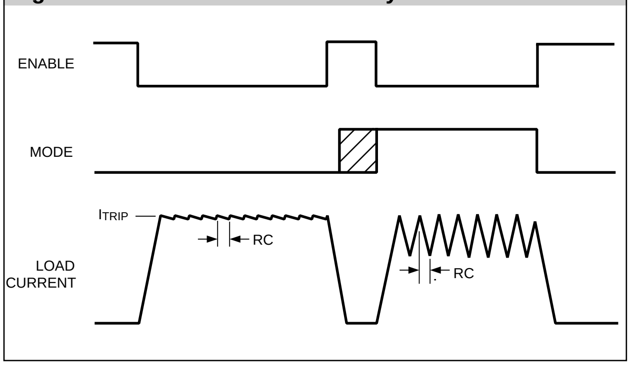
In forward or reverse mode the current-control circuitry limits the load current. When the load current reaches I_{TRIP}, the comparator resets a latch to turn OFF the selected sink driver (in the slow-decay mode) or selected sink and source driver pair (in the fast-decay mode). In slow-decay mode, the selected sink driver is disabled; the load inductance causes the current to recirculate through the source driver and flyback diode (see figure 1). In fast-decay mode, the selected sink and source driver pair are disabled; the load inductance causes the current to flow from ground to the load supply via the ground clamp and flyback diodes.

Fig. 1 Load-Current Paths



The user selects an external resistor (R_T) and capacitor (C_T) to determine the time period ($t_{off}=R_TC_T$) during which the drivers remain disabled (see "RC Fixed OFF Time" below). At the end of the R_TC_T interval, the drivers are re-enabled allowing the load current to increase again. The PWM cycle repeats, maintaining the load current at the desired value (see figure 2).

Fig. 2 Fast and Slow Current-Decay Waveforms



(B) INTERNAL PWM CURRENT CONTROL DURING BRAKE MODE OPERATION

The brake circuit turns OFF both source drivers and turns ON both sink drivers. For dc motor applications, this has the effect of shorting the motor's back-EMF voltage, resulting in current flow that brakes the motor dynamically. However, if the back-EMF voltage is large, and there is no PWM current limiting, then the load current can increase to a value that approaches a locked rotor condition. To limit the current, when the I_{TRIP} level is reached, the PWM circuit disables the conducting sink driver. The energy stored in the motor's inductance is then discharged into the load supply causing the motor current to decay.

As in the case of forward/reverse operation, the drivers are re-enabled after a time given by $t_{off}=R_T \bullet C_T$ (see"RC Fixed OFF Time" below). Depending on the back-EMF voltage (proportional to the motor's decreasing speed), the load current again may increase to I_{TRIP}. If so, the PWM cycle will repeat, limiting the load current to the desired value.

(1) Brake Operation-MODE Input High

During braking, when the MODE input is high, the current limit can be approximated by

$$I_{TRIP} \approx \frac{V_{REF}}{10 \cdot R_S}$$

CAUTION: Because the kinetic energy stored in the motor and load inertia is being converted into current, which charges the V_{BB} supply bulk capacitance (power supply output and decoupling capacitance), care must be taken to ensure the capacitance is sufficient to absorb the energy without exceeding the voltage rating of any devices connected to the motor supply.

(2) Brake Operation-MODE Input Low

During braking,with the MODE input low, the peak current limit defaults internally to a value approximated by

$$I_{TRIP} \approx \frac{1.5V}{R_S}$$

In this mode, the value of R_S determines the I_{TRIP} value independent of V_{REF}. This is useful in applicaions with differing run and brake currents and no practical method of varying V_{REF}.
Choosing a small value for R_S essentially disables the current limiting during braking. Therefore, care should be taken to ensure that the motor's current does not exceed the absolute maximum ratings of the device. The braking current can be measured by using an oscilloscope with a current probe connected to one of the motor's leads.

(C) RC Fixed OFF Time

The internal PWM current control circuitry uses a one shot to control the time the driver (s) remain (s) OFF. The one shot time, t_{off} (fixed OFF time), is determined by the selection of an external resistor (R_T) and capacitor (C_T) connected in parallel from the RC terminal to ground. The fixed OFF time, over a range of values of C_T=820pF to 1500pF and R_T=12kΩ to 100kΩ, is approximated by

$$t_{OFF} \approx R_T \cdot C_T$$

When the PWM latch is reset by the current comparator, the voltage on the RC terminal will begin to decay from approximately 3 volts. When the voltage on the RC terminal reaches approximately 1.1 volt, the PWM latch is set, thereby re-enabling the driver (s).

(D) RC Blanking

In addition to determining the fixed OFF-time of the PWM control circuit, the C_T component sets the comparator blanking time. This function blanks the output of the comparator when the outputs are switched by the internal current control circuitry (or by the PHASE, BRAKE, or ENABLE inputs). The comparator output is blanked to prevent false over-current detections due to reverse recovery currents of the clamp diodes, and/or switching transients related to distributed capacitance in the load.
During internal PWM operation, at the end of the t_{off} time, the comparator's output is blanked and C_T begins to be charged from approximately 1.1V by an internal current source of approximately 1mA. The comparator output remains blanked until the voltage on C_T reaches approximately 3.0 volts.
Similarly, when a transition of the PHASE input occurs, C_T is discharged to near ground during the crossover delay time (the crossover delay time is present to prevent simultaneous conduction of the source and sink drivers). After the crossover delay, C_T is charged by an internal current source of approximately 1mA. The comparator output remains blanked until the voltage on C_T reaches approximately 3.0 volts.
Similarly, when the device is disabled via the ENABLE input, C_T is discharged to near ground. When the device is re-enabled, C_T is charged by the internal current source. The comparator output remains blanked until the voltage on C_T reaches approximately 3.0V.
For applications that use the internal fast-decay mode PWM operation, the minimum recommended value is C_T=1200pF±5%. For all other applications, the minimum recommended value is C_T=820pF±5%. These values ensure that the blanking time is sufficient to avoid false trips of the comparator under normal operating conditions. For optimal regulation of the load current, the above values for C_T are recommended and the value of R_T can be sized to determine t_{off}. For more information regarding load current regulation, see below.

(E) LOAD CURRENT REGULATION WITH THE INTERNAL PWM CURRENT-CONTROL CIRCUITRY

When the device is operating in slow-decay mode, there is a limit to the lowest level that the PWM current-control circuitry can regulate load current. The limitation is the minimum duty cycle, which is a function of the user-selected value of t_{off} and the maxuimum value of the minimum ON-time pulse, $t_{on\,(min)}$, that occurs each time the PWM latch is reset. If the motor is not rotating, as in the case of a stepper motor in hold/detent mode, or a brush dc motor when stalled or at startup, the worst-case value of current regulation can be approximated by

$$I_{(AV)} \cong \frac{[(V_{BB} - V_{SAT\,(source\,+\,sink)}) \cdot t_{on\,(min)}\,max] - [1.05 \cdot (V_{SAT\,(sink)} + V_D) \cdot t_{off}]}{1.05 \cdot (t_{on\,(min)}\,max + t_{off}) \cdot R_{LOAD}}$$

where $t_{off}=R_T \cdot C_T$, R_{LOAD} is the series resistance of the load, V_{BB} is the load/motor supply voltage, and $t_{on\,(min)}$ max is specified in the electrical characteristics table. When the motor is rotating, the back EMF generated will influence the above relationship. For brush dc motor applications, the current regulation is improved. For stepper motor applications when the motor is rotating, the effect is more complex. A discussion of this subject is included in the section on stepper motors under "Applications".
The following procedure can be used to evaluate the worst-case slow-decay internal PWM load current regulation in the system:
Set V_{REF} to 0 volts. With the load connected and the PWM current control operating in slow-decay mode, use an oscilloscope to measure the time the output is low (sink ON) for the output that is chopping. This is the typical minimum ON time ($t_{on\,(min)}$ typ) for the

device. C_T then should be increased until the measured value of $t_{on\,(min)}$ is equal to $t_{on\,(min)}$ max)=3.0μs as specified in the electrical characteristics table. When the new value of C_T has been set, the value of R_T should be decreased so the value for $t_{off}=R_T \cdot C_T$ (with the artificially increased value of C_T) is equal to 105% of the nominal design value. The worst-case load current regulation then can be measured in the system under operating conditions.

In applications utilizing both fast-and slow-decay internal PWM modes, the performance of the slow-decay current regulation should be evaluated per the above procedure and a $t_{on\,(min)}$ max of 3.8μs. This corresponds to a C_T value of 1200pF, which is required to ensure sufficient blanking during fast-decay internal PWM.

(F) LOAD CURRENT REGULATION WITH EXTERNAL PWM OF THE PHASE AND ENABLE INPUTS

The PHASE and ENABLE inputs can be pulse-width modulated to regulate load current. Typical propagation delays from the PHASE and ENABLE inputs to transitions of the power outputs are specified in the electrical characteristics table. If the internal PWM current control is used, then the comparator blanking function is active during phase and enable transitions. This eliminates false tripping of the over-current comparator caused by switching transients (see "RC Blanking" above).

(1) ENABLE Pulse-Width Modulation

With the MODE input low, toggling the ENABLE input turns ON and OFF the selected source and sink drivers. The corresponding pair of flyback and ground clamp diodes conduct after the drivers are disabled, resulting in fast current decay. When the device is enabled, the internal current control circuitry will be active and can be used to limit the load current in a slow-decay mode.

For applications that PWM the ENABLE input, and desire that the internal current limiting circuit function in the fast-decay mode, the ENABLE input signal should be inverted and connected to the MODE input. This prevents the device from being switched into sleep mode when the ENABLE input is low.

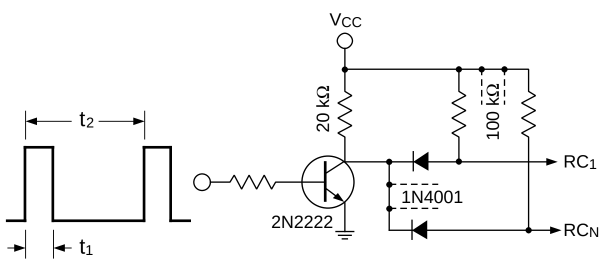
(2) PHASE Pulse-Width Modulation

Toggling the PHASE terminal determines/controls which sink/source pair is enabled, producing a load current that varies with the duty cycle and remains continuous at all times. This can have added benefits in bidirectional brush dc servo motor applications as the transfer function between the duty cycle on the phase input and the average voltage applied to the motor is more linear than in the case of ENABLE PWM control (which produces a discontinuous current at low current levels). See also, "DC Motor Applications" below.

(3) SYNCHRONOUS FIXED-FREQUENCY PWM

The internal PWM current-control circuitry of multiple A3952S- devices can be synchronized by using the simple circuit shown in figure 3. A555IC can be used to generate the reset pulse/blanking signal (t_1) and the period of the PWM cycle (t_2). The value of t_1 should be a minimum of 1.5μs in slow-decay mode and 2μs in fast-decay mode. When used in this configuration, the R_T and C_T components should be omitted. The PHASE and ENABLE inputs should not be PWMed with this circuit configuration due to the absence of a blanking function synchronous with their transitions.

Fig. 3 Synchronous Fixed-Frequency Control Circuit



(G) MISCELLANEOUS INFORMATION

A logic high applied to both the ENABLE and MODE terminals puts the device into a sleep mode to minimize current consumption when not in use.

An internally generated dead time prevents crossover currents that can occur when switching phase or braking.

Thermal protection circuitry turns OFF all drivers should the junction temperature reach 165°C (typical). This is intended only to protect the device from failures due to excessive junction temperatures and should not imply that output short circuits are permitted. The hysteresis of the thermal shutdown circuit is approximately 15°C.

If the internal current-control circuitry is not used; the V_{REF} terminal should be connected to V_{CC}, the SENSE terminal should be connected to ground, and the RC terminal should be left floating (no connection).

An internal under-voltage lockout circuit prevents simultaneous conduction of the outputs when the device is powered up or powered down.

■APPLICATION NOTES

(A) Current Sensing

The actual peak load current (I_{OUTP}) will be greater than the calculated value of I_{TRIP} due to delays in the turn OFF of the drivers. The amount of overshoot can be approximated as

$$I_{OUTP} \approx \frac{(V_{BB} - [(I_{TRIP} \bullet R_{LOAD}) + V_{BEMF}]) \bullet t_{pd\ (pwm)}}{L_{LOAD}}$$

where V_{BB} is the load/motor supply voltage, V_{BEMF} is the back-EMF voltage of the load, R_{LOAD} and L_{LOAD} are the resistance and inductance of the load respectively, and $t_{pd\ (pwm)}$ is the propagation delay as specified in the electrical characteristics table.

The reference terminal has an equivalent input resistance of 50kΩ±30%. This should be taken into account when determining the impedance of the external circuit that sets the reference voltage value.

To minimize current-sensing inaccuracies caused by ground trace IR drops, the current-sensing resistor should have a separate return to the ground terminal of the device. For low-value sense resistors, the IR drops in the PCB can be significant and should be taken into account. The use of sockets should be avoided as their contact resistance can cause variations in the effective value of R_S.

Larger values of R_S reduce the aforementioned effects but can result in excessive heating and power loss in the sense resistor. The selected value of R_S must not cause the SENSE terminal absolute maximum voltage rating to be exceeded. The recommended value of R_S is in the range of

$$R_S \approx \frac{(0.375 \text{ to } 1.125)}{I_{TRIP}}$$

The current-sensing comparator functions down to ground allowing the device to be used in microstepping, sinusoidal, and other varying current profile applications.

(B) Thermal Considerations

For reliable operation, it is recommended that the maximum junction temperature be kept as low as possible, typically 90°C to 125°C. The junction temperature can be measured by attaching a thermocouple to the power tab/batwing of the device and measuring the tab temperature, T_T. The junction temperature can then be approximated by using the formula

$$T_J \approx T_T + (2V_F\ I_{OUT}\ R_{\theta JT})$$

where V_F is the clamp diode forward voltage and can be determined from the electrical specification table for the given level of I_{OUT}. The value for $R_{\theta JT}$ is given in the package thermal resistance table for the appropriate package.

The power dissipation of the batwing packages can be improved by 20 to 30% by adding a section of printed circuit board copper (typically 6 to 18 square centimeters) connected to the batwing terminals of the device.

The thermal performance in applications with high load currents and/or high duty cycles can be improved by adding external diodes in parallel with the internal diodes. In internal PWM slow-decay applications, only the tow top-side (flyback) diodes need be added. For internal fast-decay PWM, or external PHASE or ENABLE input PWM applications, all four external diodes should be added for maximum junction temperature reduction.

(C) PCB Layout

The load supply terminal, V_{BB}, should be decoupled (>47μF electrolytic and 0.1μF ceramic capacitors are recommended) as close to the device as is physically practical. To minimize the effect of system ground I•R drops on the logic and reference input signals, the system ground should have a low-resistance return to the load supply voltage.

See also “Current Sensing” and “Thermal Considerations” above.

(D) Fixed Off-Time Selection

With increasing values of t_{off}, switching losses decrease, low-level load-current regulation improves, EMI is reduced, the PWM frequency will decrease, and ripple current will increase. The value of t_{off} can be chosen for optimization of these parameters. For applications where audible noise is a concern, typical values of t_{off} are chosen to be in the range of 15 to 35μs.

(E) Stepper Motor Applications

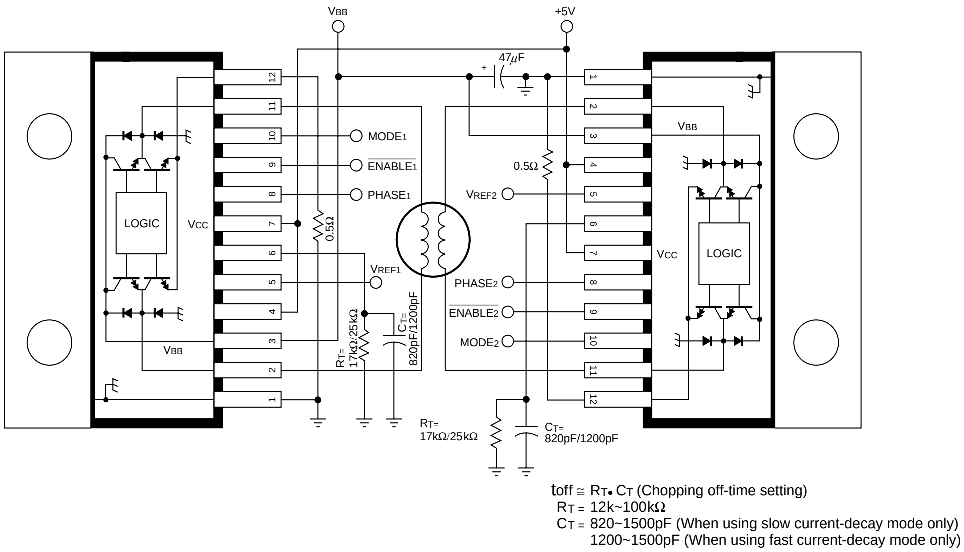
The MODE terminal can be used to optimize the performance of the device in microstepping/sinusoidal stepper motor drive applications. When the average load current is increasing, slow-decay mode is used to limit the switching losses in the device and iron losses in the motor.

This also improves the maximum rate at which the load current can increase (as compared to fast decay) due to the slow rate of decay during t_{off}. When the average load current is decreasing, fast-decay mode is used to regulate the load current to the desired level. This prevents tailing of the current profile caused by the back-EMF voltage of the stepper motor.

In stepper motor applications applying a constant current to the load, slow-decay mode PWM is used typically to limit the switching losses in the device and iron losses in the motor.

(F) Application circuit (Bipolar stepper motor drive)

Fig. 4 Example of stepper motor drive



(G) DC Motor Applications

In closed-loop systems, the speed of a dc motor can be controlled by PWM of the PHASE or ENABLE inputs, or by varying the REF input voltage (V_{REF}). In digital systems (microprocessor controlled), PWM of the PHASE or ENABLE input is used typically thus avoiding the need to generate a variable analog voltage reference. In this case, a dc voltage on the REF input is used typically to limit the maximum load current.

In dc servo applications that require accurate positioning at low or zero speed, PWM of the PHASE input is selected typically. This simplifies the servo-control loop because the transfer function between the duty cycle on the PHASE input and the average voltage applied to the motor is more linear than in the case of ENABLE PWM control (which produces a discontinuous current at low-current levels).

With bidirectional dc servo motors, the PHASE terminal can be used for mechanical direction control. Similar to when braking the motor dynamically, abrupt changes in the direction of a rotating motor produce a currrent generated by the back EMF. The current generated will depend on the mode of operation. If the internal current-control circuitry is not being used, then the maximum load current generated can be approximated by

$$I_{LOAD} \approx \frac{(V_{BEMF} + V_{BB})}{R_{LOAD}}$$

where V_{BEMF} is proportional to the motor's speed. If the internal slow-decay current-control circuitry is used, then the maximum load current generated can be approximated by $I_{LOAD}=V_{BEMF}/R_{LOAD}$. For both cases, care must be taken to ensure the maximum ratings of the device are not exceeded. If the internal fast-decay current-control circuitry is used, then the load current will regulate to a value given by

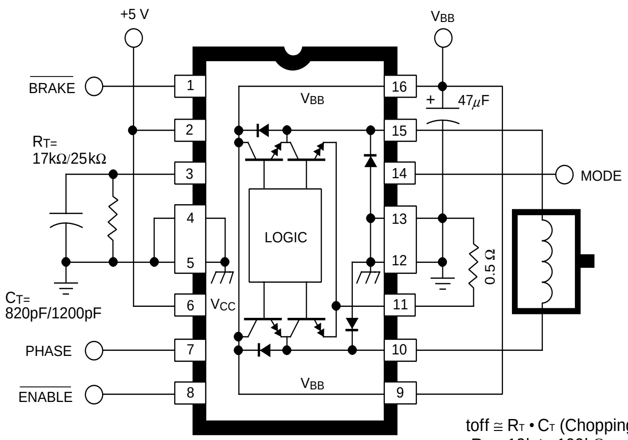
$$I_{LOAD} \approx \frac{V_{REF}}{(10 \cdot R_S)}$$

CAUTION: In fast-decay mode, when the direction of the motor is changed abruptly, the kinetic energy stored in the motor and load inertia will be converted into current that charges the V_{BB} supply bulk capacitance (power supply output and decoupling capacitance). Care must be taken to ensure the capacitance is sufficient to absorb the energy without exceeding the voltage rating of any devices connected to the motor supply.

See also, the sections on brake operation under "Functional Description," above.

(H) Application circuit (DC motor drive)

Fig. 5 Example of DC motor drive



toff ≅ $R_T \cdot C_T$ (Chopping off-time setting)
R_T = 12k to 100kΩ
C_T = 820 to 1500pF (When using slow current-decay mode only)
1200 to 1500pF (When using fast current-decay mode only)

2-Phase Stepper Motor Bipolar Driver ICs

Allegro MicroSystems product

■Features

- Fixed off-time PWM current control
- Internal 1/3 and 2/3 reference divider
- 1-phase/2-phase/W1-2 phase excitation mode with digital input
- Microstepping with reference input
- Low saturation voltage (Sink transistor)
- Internal thermal shutdown circuitry
- Internal crossover-current protection circuitry
- Internal UVLO protection
- Internal transient-suppression diodes
- Low thermal resistance package

■Absolute Maximum Ratings

Parameter	Symbol	Conditions	Ratings		Units
			UDN2916B	UDN2916LB	
Motor supply voltage	V_{BB}		45		V
Output current (peak)	$I_{O\,(peak)}$	tw≤20μs	±1.0		A
Output current (continuous)	I_O		±0.75		A
Logic supply voltage	V_{CC}		7.0		V
Logic input voltage range	V_{IN}		–0.3 to +7.0		V
Output emitter voltage	V_E		1.5		V
Package power dissipation	P_D (Note1)		3.12	2.27	W
Operating temperature	T_a		–20 to +85		°C
Junction temperature	T_j (Note2)		+150		°C
Storage temperature	T_{stg}		–55 to +150		°C

●Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of 150°C.

Note 1: When ambient temperature is 25°C or over, derate using –25mW/°C (UDN2916B) or –18.2mW/°C (UDN2916LB).

Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

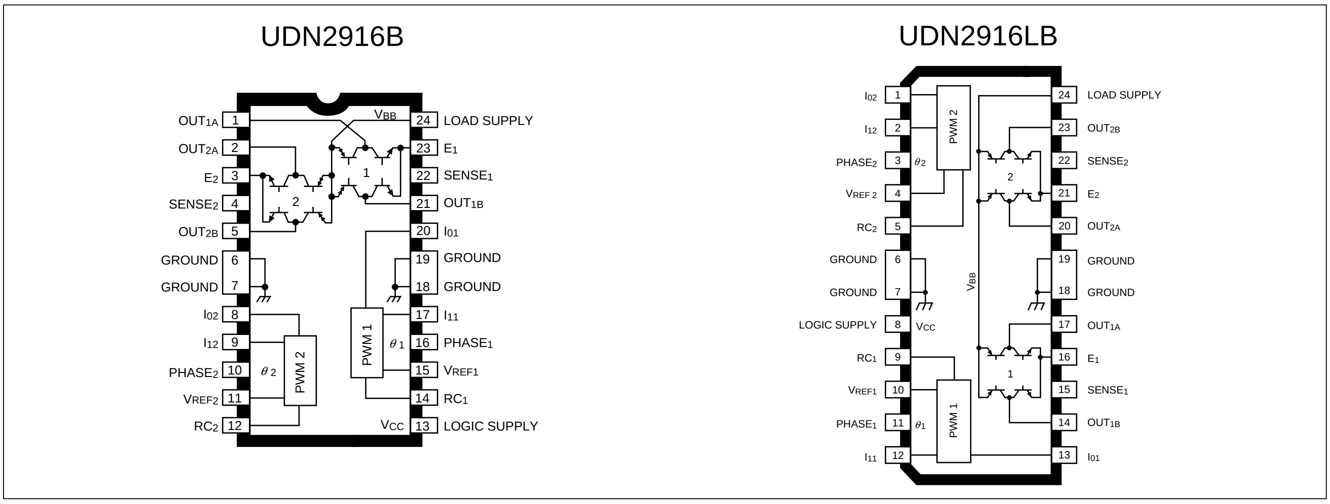
■Electrical Characteristics

(Unless specified otherwise, T_a=25°C, V_{BB}=45V, V_{CC}=4.75V to 5.25V, V_{REF}=5.0V)

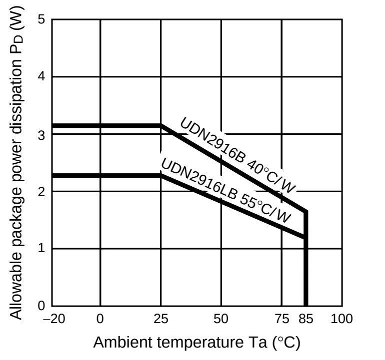
Parameter	Symbol	Conditions	Limits			Units
			min	typ	max	
Power outputs (OUT_A or OUT_B)						
Motor supply voltage range	V_{BB}		10		45	V
Output leakage current	I_{CEX}	Sink driver, V_O=V_{BB}		<1.0	50	μA
		Source driver, V_O=0V		<–1.0	–50	μA
Output sustaining voltage	$V_{CE\,(SUS)}$	I_O=±750mA, L=3.0mH	45			V
Output saturation voltage	$V_{CE\,(SAT)}$	Sink driver, I_O=+500mA		0.4	0.6	V
		Sink driver, I_O=+750mA		1.0	1.2	V
		Source driver, I_O=–500mA		1.0	1.2	V
		Source driver, I_O=–750mA		1.3	1.5	V
Clamp diode leakage current	I_R	V_R=45V		<1.0	50	μA
Clamp diode forward voltage	V_F	I_F=750mA		1.6	2.0	V
Motor supply current	$I_{BB\,(ON)}$	Both bridges ON, no load		20	25	mA
	$I_{BB\,(OFF)}$	Both bridges OFF		5.0	10	mA
Control logic						
Input voltage	V_{IH}	All inputs	2.4			V
	V_{IL}	All inputs			0.8	V
Input current	I_{IH}	V_{IH}=2.4V		<1.0	20	μA
	I_{IL}	V_{IL}=0.8V		–3.0	–200	μA
Reference voltage range	V_{REF}	Operating	1.5		7.5	V
Current control threshold	V_{REF}/V_{SENSE}	I_0=I_1=0.8V	9.5	10.0	10.5	
		I_0=2.4V, I_1=0.8V	13.5	15.0	16.5	
		I_0=0.8V, I_1=2.4V	25.5	30.0	34.5	
Thermal shutdown temperature	T_j			170		°C
Logic supply current	$I_{CC\,(ON)}$	I_0=I_1=0.8V, no load		40	50	mA
	$I_{CC\,(OFF)}$	I_0=I_1=2.4V, no load		10	12	mA

●"typ" values are for reference.

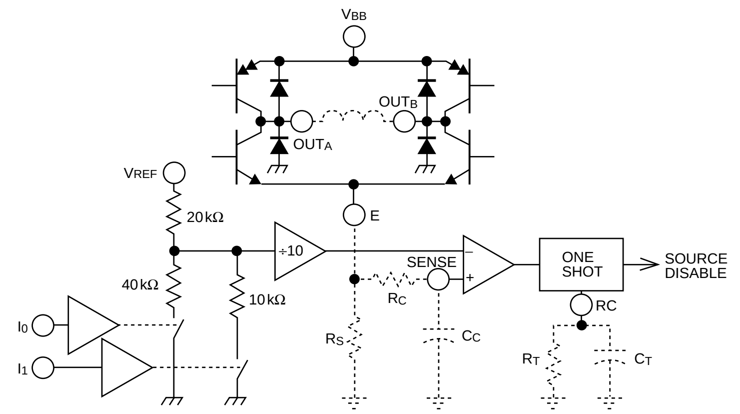
■Terminal Connection Diagram



■Derating



■Internal Block Diagram (1/2 Circuit)

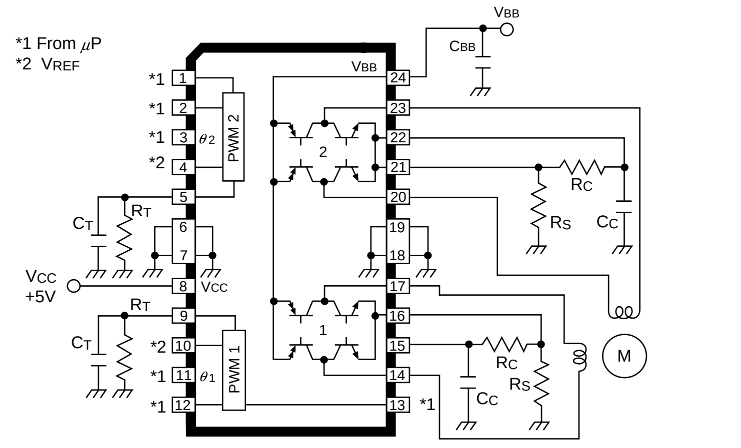


■Truth Table

PHASE	OUT_A	OUT_B
H	H	L
L	L	H

I_0	I_1	Output Current
L	L	$V_{REF}/(10 \times R_S) = I_{TRIP}$
H	L	$V_{REF}/(15 \times R_S) = I_{TRIP} \times 2/3$
L	H	$V_{REF}/(30 \times R_S) = I_{TRIP} \times 1/3$
H	H	0

■Application Circuit (UDN2916LB)



●Off-time setting
$t_{off} \cong C_T R_T$

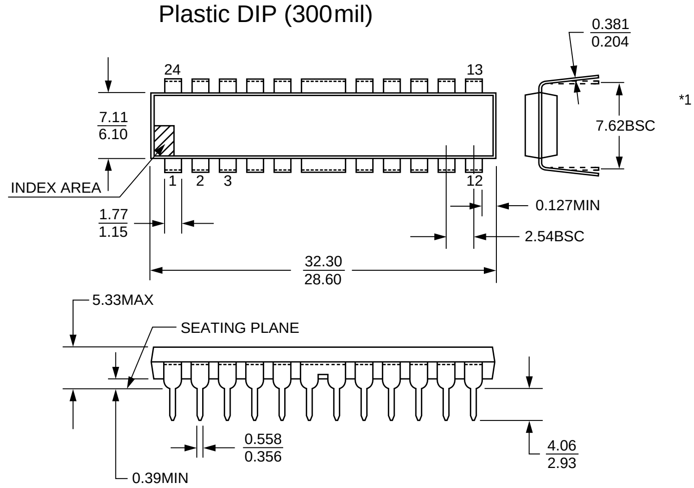
- R_S : 1.5Ω, 1/2W (1.0 to 2.0Ω, 1 to 1/2W)
- V_{REF}: 5.0V (1.5 to 7.5V)
- R_T : 56kΩ (20k to 100kΩ)
- C_T : 470pF (100 to 1,000pF)
- R_C : 1kΩ
- C_C : 4,700pF (470 to 10,000pF)
- C_{BB} : 100μF

■External Dimensions

(Unit: mm)

UDN2916B | ICs per stick | 15

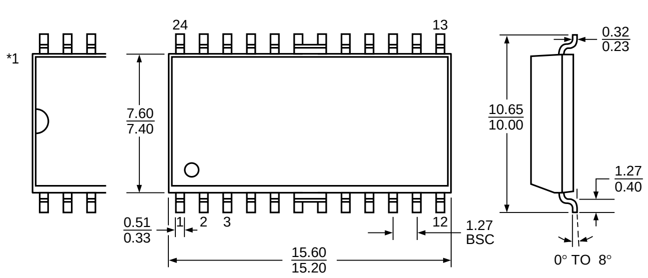
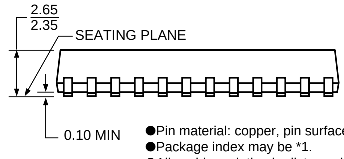
Plastic DIP (300mil)



●Thickness of lead is measured below seating plane.
●Allowable variation in distance between leads is not cumulative.

UDN2916LB | ICs per stick | 31

Wide body plastic SOP (300mil)

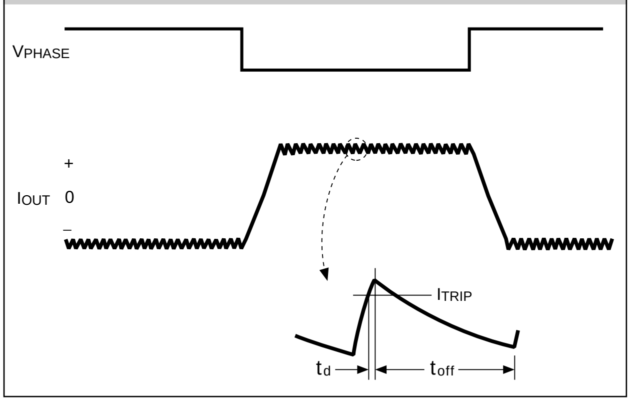
●Pin material: copper, pin surface treatment: solder plating
●Package index may be *1.
●Allowable variation in distance between leads is not cumulative.
●Web (batwing) type lead frames are used for pin 6, 7, 18, 19. The pins are connected to GND.

Application Notes

●PWM CURRENT CONTROL

The UDN2916B/LB dual bridges are designed to drive both windings of a bipolar stepper motor. Output current is sensed and controlled independently in each bridge by an external sense resistor (R_S), internal comparator, and monostable multivibrator.

PWM OUTPUT CURRENT WAVE FORM



When the bridge is turned ON, current increases in the motor winding and it is sensed by the external sense resistor until the sense voltage (V_{SENSE}) reaches the level set at the comparator's input:

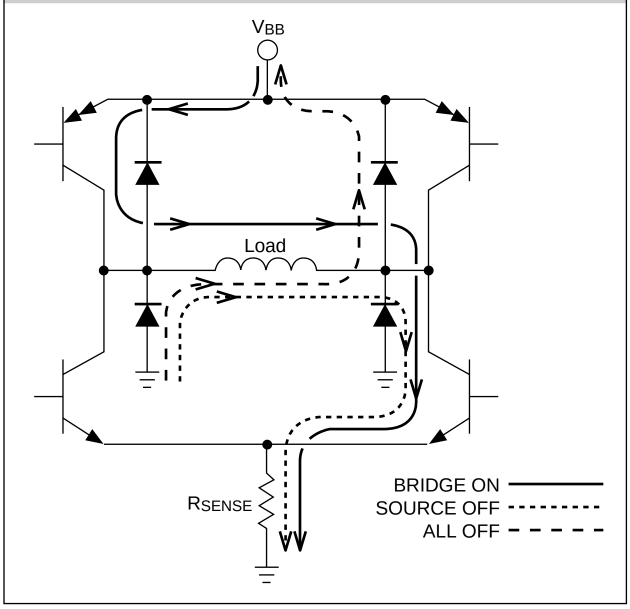
$$I_{TRIP}=V_{REF}/\ 10R_S$$

The comparator then triggers the monostable which turns OFF the source driver of the bridge. The actual load current peak will be slightly higher than the trip point (especially for low-inductance loads) because of the internal logic and switching delays. This delay (t_d) is typically 2μs. After turn-off, the motor current decays, circulating through the ground-clamp diode and sink transistor. The source driver's OFF time (and therefore the magnitude of the current decrease) is determined by the monostable's external RC timing components, where $t_{off}=R_TC_T$ wihtin the range of 20kΩ to 100kΩ and 100pF to 1000 pF.

When the source driver is re-enabled, the winding current (the sense voltage) is again allowed to rise to the comparator's threshold. This cycle repeats itself, maintaining the average motor winding current at the desired level.

Loads with high distributed capacitances may result in high turn-ON current peaks. This peak (appearing across R_S) will attempt to trip the comparator, resulting in erroneous current control or high-frequency oscillations. An external R_CC_C time delay should be used to further delay the action of the comparator. Depending on load type, many applications will not require these external components (SENSE connected to E.)

Load-Current Paths



●LOGIC CONTROL OF OUTPUT CURRENT

Two logic level inptus (I_0 and I_1) allow digital selection of the motor winding current at 100%, 67%, 33%, or 0% of the maximum level per the table. The 0% output current condition turns OFF all drivers in the bridge and can be used as an OUTPUT ENABLE function.

These logic level inputs greatly enhance the implementation of μP-controlled drive formats.

During half-step operations, the I_0 and I_1 allow the μP to control the motor at a constant torque between all positions in an eight-step sequence. This is accomplished by digitally selecting 100% drive current when only one phase is ON and 67% drive current when two phases are ON. Logic highs on both I_0 and I_1 turn OFF all drivers to allow rapid current decay when switching phases. This helps to ensure proper motor operation at high step rates.

The logic control inputs can also be used to select a reduced current level (and reduced power dissipation) for 'hold' conditions and/or increased current (and available torque) for start-up conditions.

●SWITCHING THE EXCITATION CURRENT DIRECTION

The PHASE input to each bridge determines the direction moter winding current flows. An internally generated deadtime (approximately 2μs) prevents crossover currents that can occur when switching the PHASE input.

●REDUCTION AND DISPERSION OF POWER LOSS

The thermal performance can be improved by adding four external Schottky barrier diodes (AK03 or other) between each output terminal and ground. In most applications, the chopping ON time is shorter than the chopping OFF time (small ON duty). Therefore, a great part of the power loss of the driver IC is attributable to the motor regenerative current during the chopping OFF period. The regenerative current from the motor flows through the current sensing resistor and ground clamp diode and returns to the motor. The voltage drop across this path causes the power loss. On this path, the forward voltage VF of ground clamp diode shows the greatest drop. This means that adding Schottky barrier diodes will improve the thermal performance if their V_F characteristic is smaller than that of the internal ground clamp diode.

The external diodes also disperse the loss (a source of heat) and reduce the package power dissipation P_D of the driver IC. Consequently, a greater output current can be obtained.

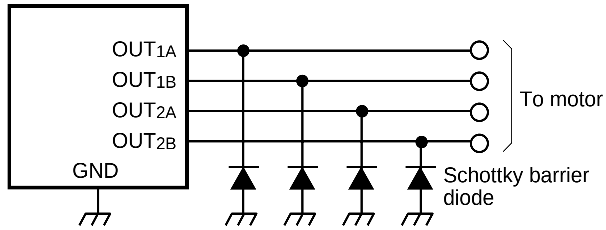
●CONTROL SEQUENCE OF 1-2 OR W1-2 PHASE EXCITATION

To reduce vibration when the stepper motor is rotating, the UDN2916B/LB can provide 1-2 or W1-2 phase excitation for the control sequence without varying the V_{REF} terminal voltage. The step angle is

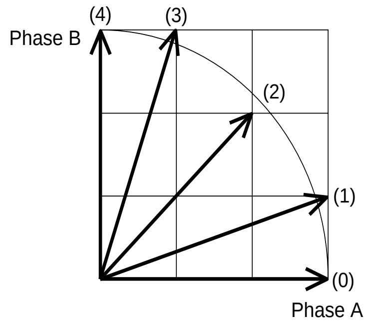
1/2 step : 1-2 excitation

About 1/4 step : W1-2 excitation

The control sequence is as shown below. (This sequence uses threshold signal terminals Io and I_1 for PWM current control.)



Combined vector (1/4 cycle)



Control sequence (1-2/W1-2 phase)

(NABLE1= ENABLE2= 0)

Sequence No.	Phase A				Phase B				1-2 phase excitation	W1-2 phase excitation
	PH_1	I_{11}	I_{01}	Current ratio	PH_2	I_{12}	I_{02}	Current ratio		
0	0	0	0	1	X	1	1	0	*	*
1	0	0	0	1	0	1	0	1/3		*
2	0	0	1	2/3	0	0	1	2/3	*	*
3	0	1	0	1/3	0	0	0	1		*
4	X	1	1	0	0	0	0	1	*	*
5	1	1	0	1/3	0	0	0	1		*
6	1	0	1	2/3	0	0	1	2/3	*	*
7	1	0	0	1	0	1	0	1/3		*
8	1	0	0	1	X	1	1	0	*	*
9	1	0	0	1	1	1	0	1/3		*
10	1	0	1	2/3	1	0	1	2/3	*	*
11	1	1	0	1/3	1	0	0	1		*
12	X	1	1	0	1	0	0	1	*	*
13	0	1	0	1/3	1	0	0	1		*
14	0	0	1	2/3	1	0	1	2/3	*	*
15	0	0	0	0	1	1	0	1/3		*

Note: When the sequence no. is 0, 4, 8, or 12, power-down can be set as follows
I_{11}=1, I_{01}=0: Sequence No. 0 or 8
I_{12}=1, I_{02}=0: Sequence No. 4 or 12
If power-down is necessary for a sequence other than 0, 4, 8, or 12, lower the V_{REF} terminal voltage. However, do not set the voltage lower than the lower limit of the setting range.

●MICROSTEPPING (1/8 STEP) CONTROL SEQUENCE

Varying the V_{REF} terminal voltage in steps provides 1/8 microstepping and reduces motor vibration greatly. The microstepping control sequence is as follows:

Control sequence (microstepping)

Sequence No.	Phase A					Phase B				
	PH_1	V_{REF1} (V)	I_{11}	I_{01}	Current ratio (%)	PH_2	V_{REF2} (V)	I_{12}	I_{02}	Current ratio (%)
0	0	7.5	0	0	100	X	1.5	1	1	0
1	0	7.4	0	0	98	0	1.5	0	0	20
2	0	6.9	0	0	92	0	2.9	0	0	38
3	0	6.2	0	0	83	0	4.2	0	0	56
4	0	5.3	0	0	71	0	5.3	0	0	71
5	0	4.2	0	0	56	0	6.2	0	0	83
6	0	2.9	0	0	38	0	6.9	0	0	92
7	0	1.5	0	0	20	0	7.4	0	0	98
8	X	1.5	1	1	0	0	7.5	0	0	100
9	1	1.5	0	0	20	0	7.4	0	0	98
10	1	2.9	0	0	38	0	6.9	0	0	92
11	1	4.2	0	0	56	0	6.2	0	0	83
12	1	5.3	0	0	71	0	5.3	0	0	71
13	1	6.2	0	0	83	0	4.2	0	0	56
14	1	6.9	0	0	92	0	2.9	0	0	38
15	1	7.4	0	0	98	0	1.5	0	0	20
16	1	7.5	0	0	100	X	1.5	1	1	0
17	1	7.4	0	0	98	1	1.5	0	0	20
18	1	6.9	0	0	92	1	2.9	0	0	38
19	1	6.2	0	0	83	1	4.2	0	0	56
20	1	5.3	0	0	71	1	5.3	0	0	71
21	1	4.2	0	0	56	1	6.2	0	0	83
22	1	2.9	0	0	38	1	6.9	0	0	92
23	1	1.5	0	0	20	1	7.4	0	0	98
24	X	1.5	1	1	0	1	7.5	0	0	100
25	0	1.5	0	0	20	1	7.4	0	0	98
26	0	2.9	0	0	38	1	6.9	0	0	92
27	0	4.2	0	0	56	1	6.2	0	0	83
28	0	5.3	0	0	71	1	5.3	0	0	71
29	0	6.2	0	0	83	1	4.2	0	0	56
30	0	6.9	0	0	92	1	2.9	0	0	38
31	0	7.4	0	0	98	1	1.5	0	0	20

Note: The V_{REF} terminal voltage cannot be set to 0 V. To make the output current ratio 0%, set $I_{0X}=I_{1X}=1$.
When the sequence is 0, 8, 16, or 24, power-down can be set as follows:
$I_{11}=1$, $I_{01}=0$: Sequence No. 0 or 16
$I_{12}=1$, $I_{02}=0$: Sequence No. 8 or 24

●V_{REF} terminal

V_{REF} is the reference voltage input terminal for PWM constant current control. To realize stable ensure a stable signal, make sure noise is not applied to the terminal.

●V_{BB} terminal

To prevent voltage spikes on the load power supply terminal (V_{BB}), connect a large capacitor (≥22μF) between the V_{BB} terminal and ground as close to the device as possible. Make sure the load supply voltage does not exceed 45 V.

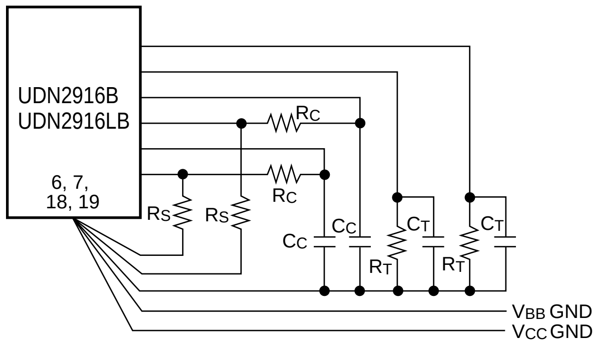
●Thermal protection

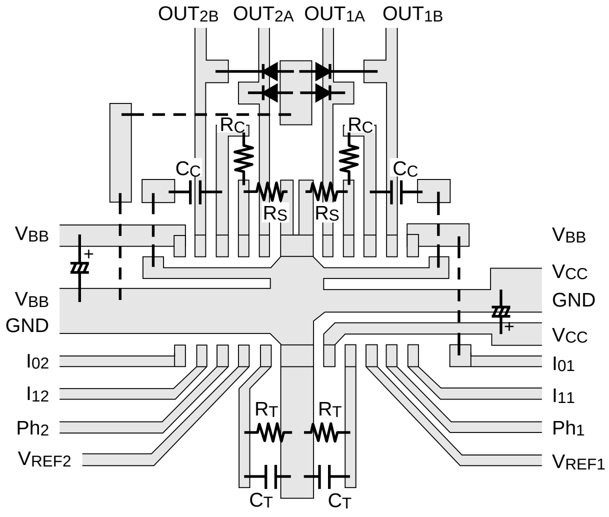
Thermal protection circuitry turns OFF all drivers when the junction temperature reaches +170°C. It is only intended to protect the device from failures due to excessive junction temperature and should not imply that output short circuits are permitted. The output drivers are re-enabled when the junction temperature cools to +145°C.

●Around the ground

Since the UDN2916B/LB is a chopping type power driver IC, take great care around the ground when mounting. Separate the power system and the small signal (analog) system. Provide a single-point connection to the GND terminal or a solid pattern of low enough impedance.

Example of Circuit (including GND) and GND Wiring Pattern (UDN2916LB)





2-Phase Stepper Motor Bipolar Driver IC

Allegro MicroSystems product

■Features

- Fixed off-time PWM current control
- Internal 1/3 and 2/3 reference divider
- 1-phase/2-phase/W1-2 phase excitation mode with digital input
- Microstepping with reference input
- Low saturation voltage (Sink transistor)
- Internal thermal shutdown circuitry
- Internal crossover-current protection circuitry
- Internal UVLO protection
- Internal transient-suppression diodes
- Low thermal resistance 44-pin PLCC

■Absolute Maximum Ratings

Parameter	Symbol	Conditions	Ratings	Units
Motor supply voltage	V_{BB}		45	V
Output current (peak)	$I_{O\ (peak)}$	tw≤20μ s	±1.75	A
Output current (continuous)	I_O		±1.5	A
Logic supply voltage	V_{CC}		7.0	V
Logic input voltage range	V_{IN}		–0.3 to +7.0	V
Output emitter voltage	V_E		1.0	V
Package power dissipation	P_D (Note1)		4.16	W
Operating temperature	T_a		–20 to +85	°C
Junction temperature	T_j (Note2)		+150	°C
Storage temperature	T_{stg}		–55 to +150	°C

●Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of 150°C.
Note 1: When ambient temperature is 25°C or over, derate using –33.3mW/°C.
Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

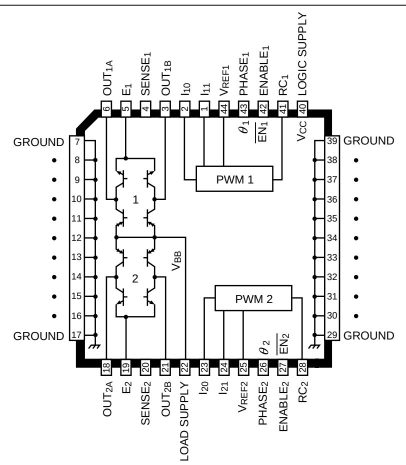
■Electrical Characteristics

(Unless specified otherwise, T_a=25°C, V_{BB}=45V, V_{CC}=5.0V, V_{REF}=5.0V)

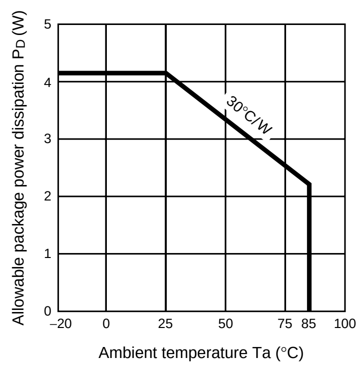
Parameter	Symbol	Conditions	Limits min	Limits typ	Limits max	Units
Power outputs (OUT_A or OUT_B)						
Motor supply voltage range	V_{BB}		10		45	V
Output leakage current	I_{CEX}	Sink driver, V_O=V_{BB}		<1.0	50	μA
		Source driver, V_O=0V		< –1.0	–50	μA
Output sustaining voltage	$V_{CE\ (SUS)}$	I_O=±1.5A, L=3.5mH	45			V
Output saturation voltage	$V_{CE\ (SAT)}$	Sink driver, I_O=+1.0A		0.5	0.7	V
		Sink driver, I_O=+1.5A		0.8	1.0	V
		Source driver, I_O=–1.0A		1.8	1.9	V
		Source driver, I_O=–1.5A		1.9	2.1	V
Clamp diode leakage current	I_R	V_R=45V		<1.0	50	μA
Clamp diode forward voltage	V_F	I_F=1.5A		1.6	2.0	V
Motor supply current	$I_{BB\ (ON)}$	Both bridges ON, no load		9.0	12	mA
	$I_{BB\ (OFF)}$	Both bridges OFF		4.0	6.0	mA
Control logic						
Logic supply voltage	V_{CC}	Operating	4.75	5.0	5.25	V
Input voltage	V_{IH}	All inputs	2.4			V
	V_{IL}	All inputs			0.8	V
Input current	I_{IH}	V_{IH}=2.4V		<1.0	20	μA
	I_{IL}	V_{IL}=0.8V		–3.0	–200	μA
Reference voltage range	V_{REF}	Operating	1.5		7.5	V
Current control threshold	V_{REF}/V_{SENSE}	I_0=I_1=0.8V	9.5	10.0	10.5	
		I_0=2.4V, I_1=0.8V	13.5	15.0	16.5	
		I_0=0.8V, I_1=2.4V	25.5	30.0	34.5	
Thermal shutdown temperature	T_j			170		°C
Logic supply current	$I_{CC\ (ON)}$	I_0=I_1=V_{EN}=0.8V, no load		90	105	mA
	$I_{CC\ (OFF)}$	I_0=I_1=2.4V, no load		10	12	mA

●"typ" values are for reference.

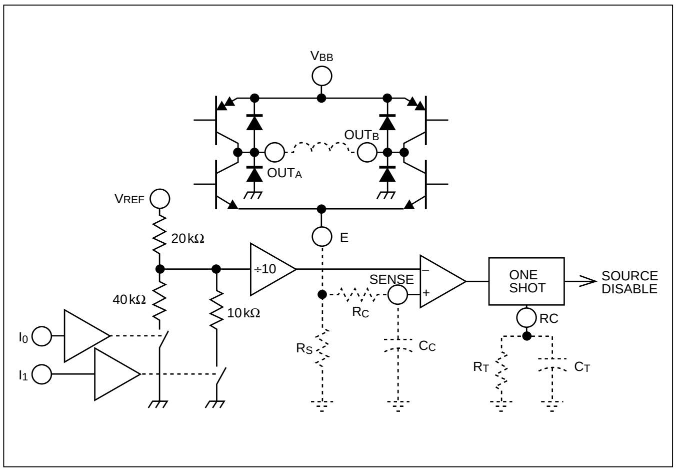
■Terminal Connection Diagram



■Derating



■Internal Block Diagram (1/2 Circuit)



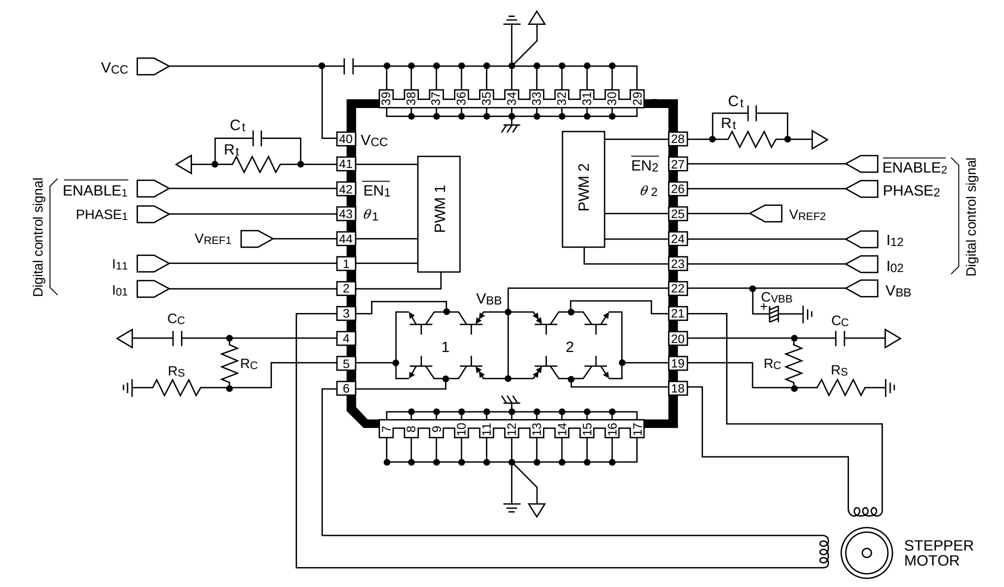
■Truth Table

ENABLE	PHASE	OUTA	OUTB
L	H	H	L
L	L	L	H
H	X	Z	Z

X=Don't Care Z=High impedance

I_0	I_1	Output Current
L	L	V_{REF} / ($10 \times R_S$)=I_{TRIP}
H	L	V_{REF} / ($15 \times R_S$)=$I_{TRIP} \times 2/3$
L	H	V_{REF} / ($30 \times R_S$)=$I_{TRIP} \times 1/3$
H	H	0

■Application Circuit



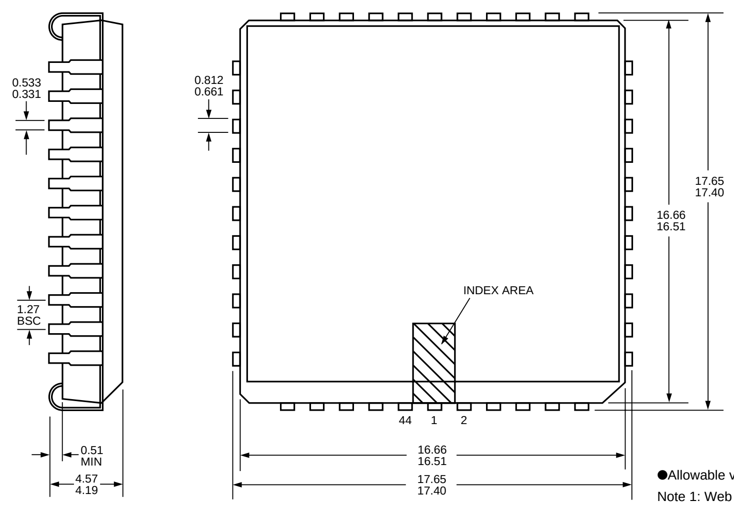
●Off-time setting $t_{off} \cong C_T R_T$

R_S : 0.82Ω, 1W (0.5 to 1.0Ω, 2 to 1W)
V_{REF}: 5.0V (1.5 to 7.5V)
R_T : 56kΩ (20k to 100kΩ)
C_T : 470pF (200 to 500pF)
R_C : 1kΩ
C_C : 3,300pF (470 to 10,000pF)
C_{VBB}: 100μF

■External Dimensions Plastic PLCC

(Unit: mm)

ICs per stick	27



●Allowable variation in distance between leads is not cumulative.
Note 1: Web type leads are internally connected together.

Application Notes

●REDUCTION AND DISPERSION OF POWER LOSS

The thermal performance can be improved by adding four external Schottky barrier diodes (EK13 or other) between each output terminal and ground. In most applications, the chopping ON time is shorter than the chopping OFF time (small ON duty). Therefore, a great part of the power loss of the driver IC is attributable to the motor regenerative current during the chopping OFF period. The regenerative current from the motor flows through the current sensing resistor and ground clamp diode and returns to the motor. The voltage drop across this path causes the power loss. On this path, the forward voltage V_F of ground clamp diode shows the greatest drop. This means that adding Schottky barrier diodes will improve the thermal performance if their V_F characteristic is smaller than that of the internal ground clamp diode.

The external diodes also disperse the loss (a source of heat) and reduce the package power dissipation P_D of the driver IC. Consequently, a greater output current can be obtained.

●CONTROL SEQUENCE OF 1-2 OR W1-2 PHASE EXCITATION

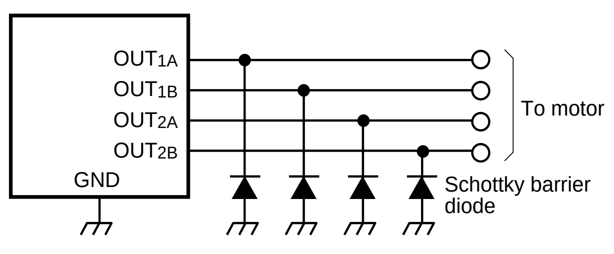
To reduce vibration when the stepper motor is rotating, the UDN2917EB can provide 1-2 or W1-2 phase excitation for the control sequence without varying the V_{REF} terminal voltage.

The step angle is

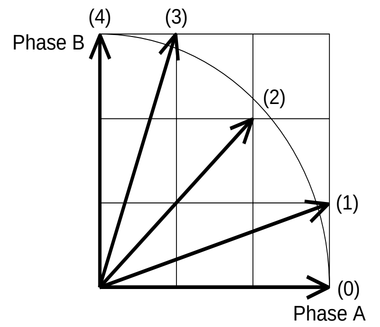
1/2 step : 1-2 excitation

About 1/4 step : W1-2 excitation

The control sequence is as shown below. (This sequence uses threshold signal terminals Io and I_1 for PWM current control.)



Combined vector (1/4 cycle)



Control sequence (1-2/W1-2 phase)

($\overline{ENABLE}$1= $\overline{ENABLE}$2=0)

Sequence No.	Phase A				Phase B				1-2 phase excitation	W1-2 phase excitation
	PH1	I11	I01	Current ratio	PH2	I12	I02	Current ratio		
0	0	0	0	1	X	1	1	0	*	*
1	0	0	0	1	0	1	0	1/3		*
2	0	0	1	2/3	0	0	1	2/3	*	*
3	0	1	0	1/3	0	0	0	1		*
4	X	1	1	0	0	0	0	1	*	*
5	1	1	0	1/3	0	0	0	1		*
6	1	0	1	2/3	0	0	1	2/3	*	*
7	1	0	0	1	0	1	0	1/3		*
8	1	0	0	1	X	1	1	0	*	*
9	1	0	0	1	1	1	0	1/3		*
10	1	0	1	2/3	1	0	1	2/3	*	*
11	1	1	0	1/3	1	0	0	1		*
12	X	1	1	0	1	0	0	1	*	*
13	0	1	0	1/3	1	0	0	1		*
14	0	0	1	2/3	1	0	1	2/3	*	*
15	0	0	0	0	1	1	0	1/3		*

Note: When the sequence no. is 0, 4, 8, or 12, power-down can be set as follows

I_{11}=1, I_{01}=0: Sequence No. 0 or 8

I_{12}=1, I_{02}=0: Sequence No. 4 or 12

If power-down is necessary for a sequence other than 0, 4, 8, or 12, lower the V_{REF} terminal voltage. However, do not set the voltage lower than the lower limit of the setting range.

●MICROSTEPPING (1/8 STEP) CONTROL SEQUENCE

Varying the V_{REF} terminal voltage in steps provides 1/8 microstepping and reduces motor vibration greatly. The microstepping control sequence is as follows:

Control sequence (microstepping)

($\overline{ENABLE1}$= $\overline{ENABLE2}$=0)

Sequence No.	Phase A					Phase B				
	PH1	VREF1 (V)	I11	I01	Current ratio (%)	PH2	VREF2 (V)	I12	I02	Current ratio (%)
0	0	7.5	0	0	100	X	1.5	1	1	0
1	0	7.4	0	0	98	0	1.5	0	0	20
2	0	6.9	0	0	92	0	2.9	0	0	38
3	0	6.2	0	0	83	0	4.2	0	0	56
4	0	5.3	0	0	71	0	5.3	0	0	71
5	0	4.2	0	0	56	0	6.2	0	0	83
6	0	2.9	0	0	38	0	6.9	0	0	92
7	0	1.5	0	0	20	0	7.4	0	0	98
8	X	1.5	1	1	0	0	7.5	0	0	100
9	1	1.5	0	0	20	0	7.4	0	0	98
10	1	2.9	0	0	38	0	6.9	0	0	92
11	1	4.2	0	0	56	0	6.2	0	0	83
12	1	5.3	0	0	71	0	5.3	0	0	71
13	1	6.2	0	0	83	0	4.2	0	0	56
14	1	6.9	0	0	92	0	2.9	0	0	38
15	1	7.4	0	0	98	0	1.5	0	0	20
16	1	7.5	0	0	100	X	1.5	1	1	0
17	1	7.4	0	0	98	1	1.5	0	0	20
18	1	6.9	0	0	92	1	2.9	0	0	38
19	1	6.2	0	0	83	1	4.2	0	0	56
20	1	5.3	0	0	71	1	5.3	0	0	71
21	1	4.2	0	0	56	1	6.2	0	0	83
22	1	2.9	0	0	38	1	6.9	0	0	92
23	1	1.5	0	0	20	1	7.4	0	0	98
24	X	1.5	1	1	0	1	7.5	0	0	100
25	0	1.5	0	0	20	1	7.4	0	0	98
26	0	2.9	0	0	38	1	6.9	0	0	92
27	0	4.2	0	0	56	1	6.2	0	0	83
28	0	5.3	0	0	71	1	5.3	0	0	71
29	0	6.2	0	0	83	1	4.2	0	0	56
30	0	6.9	0	0	92	1	2.9	0	0	38
31	0	7.4	0	0	98	1	1.5	0	0	20

Note: The V_{REF} terminal voltage cannot be set to 0 V. To make the output current ratio 0%, set $I_{0X}=I_{1X}=1$.
When the sequence is 0, 8, 16, or 24, power-down can be set as follows:
$I_{11}=1$, $I_{01}=0$: Sequence No. 0 or 16
$I_{12}=1$, $I_{02}=0$: Sequence No. 8 or 24

●V_{REF} terminal

V_{REF} is the reference voltage input terminal for PWM constant current control. To realize stable ensure a stable signal, make sure noise is not applied to the terminal.

●V_{BB} terminal

To prevent voltage spikes on the load power supply terminal (V_{BB}), connect a large capacitor (≥47μF) between the V_{BB} terminal and ground as close to the device as possible. Make sure the load supply voltage does not exceed 45V.

●Thermal protection

Thermal protection circuitry turns OFF all drivers when the junction temperature reaches +170°C. It is only intended to protect the device from failures due to excessive junction temperature and should not imply that output short circuits are permitted. The output drivers are re-enabled when the junction temperature cools to +145°C.

●Around the ground

Since the UDN2917EB is a chopping type power driver IC, take great care around the ground when mounting. Separate the power system and the small signal (analog) system. Provide a single-point connection to the GND terminal or a solid pattern of low enough impedance.

2-Phase Stepper Motor Bipolar Driver ICs

Allegro MicroSystems product

■Features

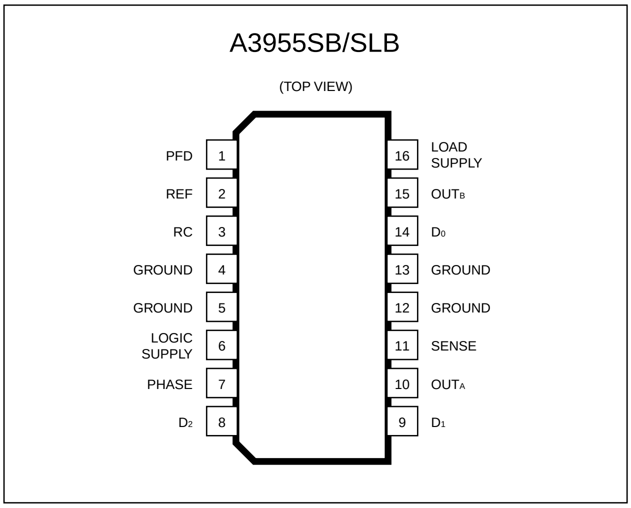
- Maximum output ratings: 50V, ±1.5A
- Internal 3-bit non-linear DAC for 8-division microstepping enables 2W1-2,W1-2, 1-2, 2-phase excitation drive without external sine wave generator
- Internal PWM current control in Mixed Decay mode (can also be used in Fast Decay and Slow Decay mode), which improves motor current response and stability without deterioration of motor iron loss
- External RC filter for sense terminal not required thanks to internal blanking circuitry
- Internal thermal shutdown, crossover-current protection and transient-suppression diodes
- Special power-up and power-down sequencing for motor supply and logic supply not required
- Employs copper batwing lead frame with low thermal resistance

■Absolute Maximum Ratings

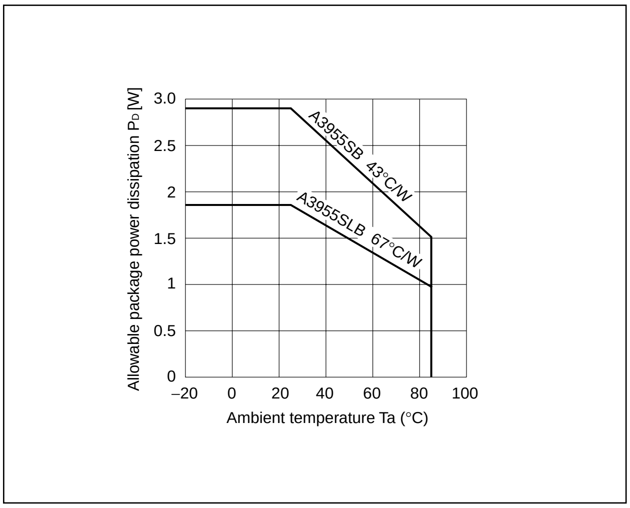
Parameter	Symbol	Ratings		Units
		A3955SB	A3955SLB	
Load supply voltage	V_{BB}	50		V
Output current (continuous)	I_O	±1.5		A
Logic supply voltage	V_{CC}	7.0		V
Logic/reference input voltage range	V_{IN}	–0.3 to V_{CC}+0.3		V
Sense voltage	V_S	1.0		V
Package power dissipation	P_D (Note1)	2.90	1.86	W
Operating temperature	T_a	–20 to +85		°C
Junction temperature	T_j (Note2)	+150		°C
Storage temperature	T_{stg}	–55 to +150		°C

●Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of 150°C.
Note 1: When ambient temperature is 25°C or over, derate using –23.26mW/°C(SB) or –14.93mW/°C(SLB).
Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

■Terminal Connection Diagram



■Derating



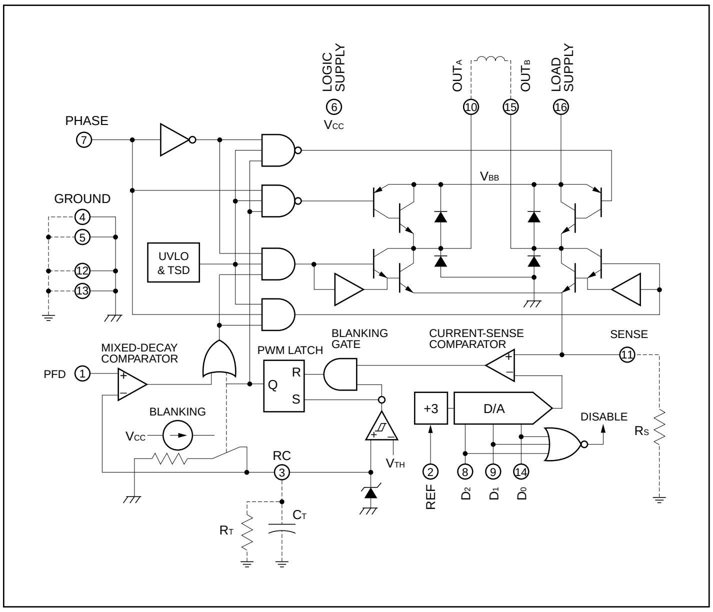
■Electrical Characteristics

(Unless specified otherwise, T_a=25°C, V_{BB}=5V to 50V, V_{CC}=4.5V to 5.5V)

Parameter	Symbol	Conditions	Limits			Units
			min	typ	max	
Power outputs (OUT_A or OUT_B)						
Load supply voltage range	V_{BB}	Operating, I_O=±1.5A, L=3mH	Vcc		50	V
Output leakage current	I_{CEX}	V_O=V_{BB}		<1.0	50	μA
		V_O=0V		< –1.0	–50	μA
Output saturation voltage	$V_{CE (sat)}$	V_{SENSE}=1.0V : Source Driver, I_O=–0.85A		1.0	1.2	V
		V_{SENSE}=1.0V : Source Driver, I_O=–1.5A		1.3	1.5	V
		V_{SENSE}=1.0V : Sink Driver, I_O=0.85A		0.5	0.6	V
		V_{SENSE}=1.0V : Sink Driver, I_O=1.5A		1.3	1.5	V
Sense current offset	I_{SO}	I_S-I_O, I_O=0.85A, V_S=0V, V_{CC}=5V	20	33	40	mA
Clamp diode forward voltage	V_F	I_F=0.85A		1.2	1.4	V
		I_F=1.5A		1.4	1.7	V
Motor supply current (No load)	$I_{BB (ON)}$			2.0	4.0	mA
	$I_{BB (OFF)}$	D_0=D_1=D_2=0.8V		1.0	50	μA
Control logic						
Logic supply voltage range	V_{CC}	Operating	4.5	5.0	5.5	V
Reference voltage range	V_{REF}	Operating	0.5		2.5	V
UVLO enable threshold	V_{UVLOen}	V_{CC}=0→5V	3.35	3.70	4.05	V
UVLO hysteresis	$V_{UVLOhys}$		0.30	0.45	0.60	V
Logic supply current	$I_{CC (ON)}$			42	50	mA
	$I_{CC (OFF)}$	D_0=D_1=D_2=0.8V		12	16	mA
Logic input voltage	V_{IH}		2.0			V
	V_{IL}				0.8	V
Logic input current	I_{IH}	V_{IN}=2.0V		<1.0	20	μA
	I_{IL}	V_{IN}=0.8V		< –2.0	–200	μA
Mixed Decay comparator trip points	V_{PFD}	Slow Decay Mode	3.5			V
		Mixed Decay Mode	1.1		3.1	V
		Fast Decay Mode			0.8	V
Mixed Decay comparator input offset voltage	$V_{IO (PFD)}$			0	±20	mV
Mixed Decay compartor hysteresis	$\Delta V_{IO (PFD)}$		5	25	55	mV
Reference input current	I_{REF}	V_{REF}=0V~2.5V			±5.0	μA
Reference divider ratio	V_{REF}/V_S	at trip, D_0=D_1=D_2=2V		3.0		
DAC accuracy *1	DAC_{ERR}	V_{REF}=1.0V~2.5V			±3.0	%
		V_{REF}=0.5V~1.0V			±4.0	%
Current-sense comparator input offset voltage *1	$V_{IO (S)}$	V_{REF}=0V			±5.0	mV
Step reference current ratio	SRCR	D_0=D_1=D_2=0.8V		0		%
		D_0=2.0V, D_1=D_2=0.8V		19.5		%
		D_0=0.8V, D_1=2V, D_2=0.8V		38.2		%
		D_0=D_1=2V, D_2=0.8V		55.5		%
		D_0=D_1=0.8V, D_2=2V		70.7		%
		D_0=2V, D_1=0.8V, D_2=2V		83.1		%
		D_0=0.8V, D_1=D_2=2V		92.4		%
		D_0=D_1=D_2=2V		100		%
Thermal shutdown temperature	T_j			165		°C
Thermal shutdown hysteresis	ΔT_j			15		°C
AC timing						
PWM RC fixed off-time	t_{OFFRC}	C_T=470pF, R_T=43kΩ	18.2	20.2	22.3	μS
PWM turn-off time	$t_{PWM (OFF)}$	Current-Sense Comparator Trip to Source OFF, I_O=0.1A		1.0	1.5	μS
		Current-Sense Comparator Trip to Source OFF, I_O=1.5A		1.4	2.5	μS
PWM turn-on time	$t_{PWM (ON)}$	I_{RC} Charge ON to Source ON, I_O=0.1A		0.4	0.7	μS
		I_{RC} Charge ON to Source ON, I_O=1.5A		0.55	0.85	μS
PWM minimum on-time	$t_{ON (min)}$	V_{CC}=5.0V, R_T≥43kΩ, C_T=470pF, I_O=0.1A	1.0	1.6	2.2	μS
Crossover dead time	t_{CODT}	1kΩ Load to 25V	0.3	1.5	3.0	μS

*1: The total error for the V_{REF}/V_{SENSE} function is the sum of the D/A error and the current-sense comparator input offset voltage.
●"typ" values are for reference.

■Internal Block Diagram



■Truth Table

PHASE

PHASE	OUT_A	OUT_B
H	H	L
L	L	H

PFD

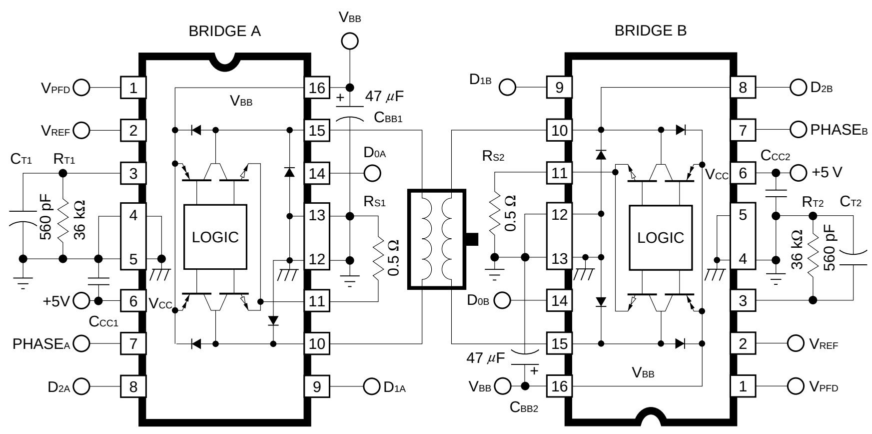
V_{PFD}	Operating Mode
≥3.5V	Slow current-decay mode
1.1V to 3.1V	Mixed current-decay mode
≤0.8V	Fast current-decay mode

DAC

DAC DATA			DAC [%]	V_{REF}/V_S
D_2	D_1	D_0		
H	H	H	100	3.00
H	H	L	92.4	3.25
H	L	H	83.1	3.61
H	L	L	70.7	4.24
L	H	H	55.5	5.41
L	H	L	38.2	7.85
L	L	H	19.5	15.38
L	L	L	All Outputs Disabled	

where $V_S \cong I_{TRIP} * R_S$

■Application Circuit



●Off-time setting : $t_{OFF} \cong R_T \bullet C_T$

R_T=12kΩ to 100kΩ

C_T=470pF to 1500pF

R_S=0.39Ω to 0.62Ω

C_{BB}=47μ F+0.1μ F

C_{CC}=0.1μ F

V_{REF}=0.5V to 2.5V

V_{PFD}=1.1V to 3.1V (Mixed current-decay mode)

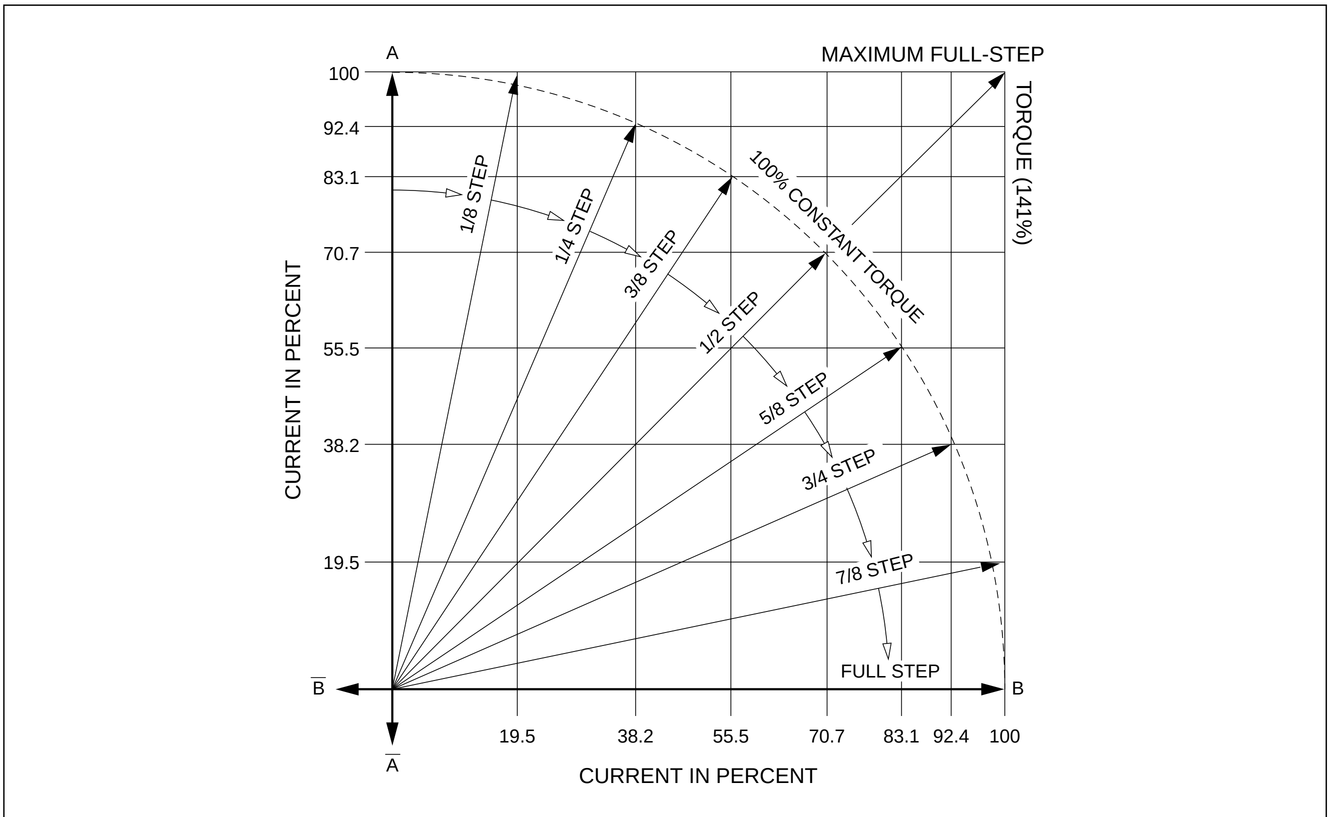
≥3.5V (Slow current-decay mode)

≤0.8V (Fast current-decay mode)

■Step Sequence

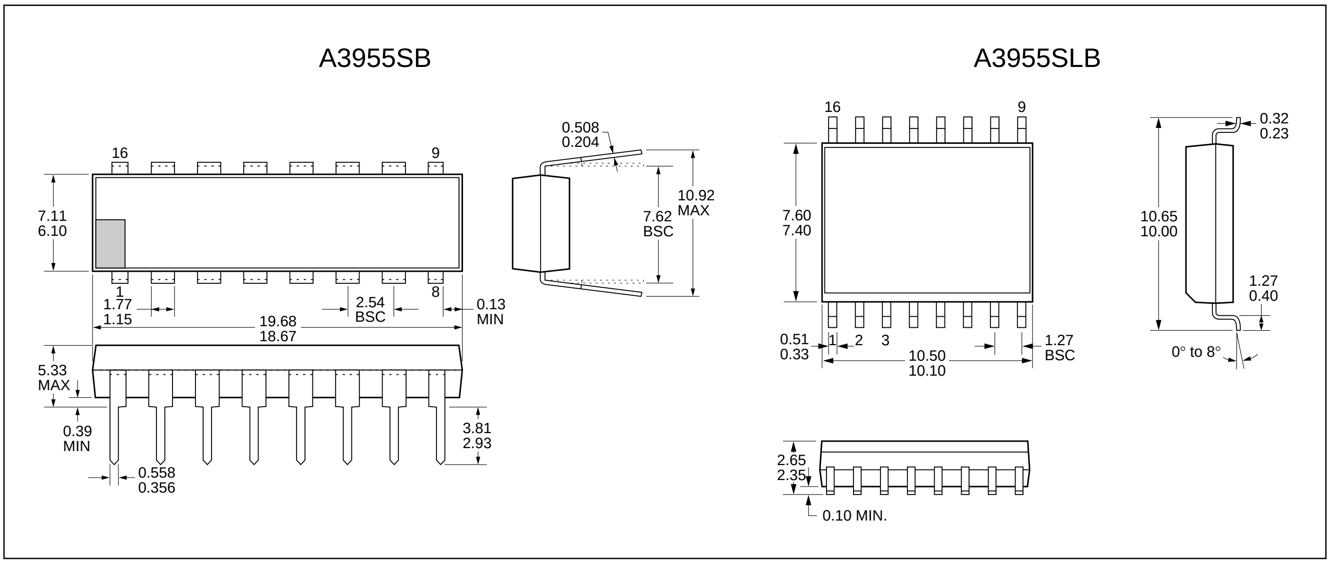
				Bridge A					Bridge B				
Full Step	Half Step	Quarter Step	Eigth Step	PHASE$_A$	D_{2A}	D_{1A}	D_{0A}	I_{LOADA}	PHASE$_B$	D_{2B}	D_{1B}	D_{0B}	I_{LOADB}
1	1	1	1	H	H	L	L	70.7%	H	H	L	L	70.7%
			2	H	L	H	H	55.5%	H	H	L	H	83.1%
		2	3	H	L	H	L	38.2%	H	H	H	L	92.4%
			4	H	L	L	H	19.5%	H	H	H	H	100%
	2	3	5	X	L	L	L	0%	H	H	H	H	100%
			6	L	L	L	H	–19.5%	H	H	H	H	100%
		4	7	L	L	H	L	–38.2%	H	H	H	L	92.4%
			8	L	L	H	H	–55.5%	H	H	L	H	83.1%
2	3	5	9	L	H	L	L	–70.7%	H	H	L	L	70.7%
			10	L	H	L	H	–83.1%	H	L	H	H	55.5%
		6	11	L	H	H	L	–92.4%	H	L	H	L	38.2%
			12	L	H	H	H	–100%	H	L	L	H	19.5%
	4	7	13	L	H	H	H	–100%	X	L	L	L	0%
			14	L	H	H	H	–100%	L	L	L	H	–19.5%
		8	15	L	H	H	L	–92.4%	L	L	H	L	–38.2%
			16	L	H	L	H	–83.1%	L	L	H	H	–55.5%
3	5	9	17	L	H	L	L	–70.7%	L	H	L	L	–70.7%
			18	L	L	H	H	–55.5%	L	H	L	H	–83.1%
		10	19	L	L	H	L	–38.2%	L	H	H	L	–92.4%
			20	L	L	L	H	–19.5%	L	H	H	H	–100%
	6	11	21	X	L	L	L	0%	L	H	H	H	–100%
			22	H	L	L	H	19.5%	L	H	H	H	–100%
		12	23	H	L	H	L	38.2%	L	H	H	L	–92.4%
			24	H	L	H	H	55.5%	L	H	L	H	–83.1%
4	7	13	25	H	H	L	L	70.7%	L	H	L	L	–70.7%
			26	H	H	L	H	83.1%	L	L	H	H	–55.5%
		14	27	H	H	H	L	92.4%	L	L	H	L	–38.2%
			28	H	H	H	H	100%	L	L	L	H	–19.5%
	8	15	29	H	H	H	H	100%	X	L	L	L	0%
			30	H	H	H	H	100%	H	L	L	H	19.5%
		16	31	H	H	H	L	92.4%	H	L	H	L	38.2%
			32	H	H	L	H	83.1%	H	L	H	H	55.5%

■Current Vector Locus



■External Dimensions

(Unit: mm)



2-Phase Stepper Motor Bipolar Driver IC

Allegro MicroSystems product

■Features

- Maximum output ratings: 50V, ±1.5A
- Internal 4-bit non-linear DAC for 16-division microstepping enables 4W1-2, 2W1-2, W1-2, 2-phase excitation drive without external sine wave generator
- Internal PWM current control in Mixed Decay mode (can also be used in Fast Decay and Slow Decay mode), which improves motor current response and stability without deterioration of motor iron loss
- External RC filter for sense terminal not required thanks to internal blanking circuitry
- Internal thermal shutdown, crossover-current protection and transient-suppression diodes
- Special power-up and power-down sequencing for motor supply and logic supply not required
- Employs copper batwing lead frame with low thermal resistance

■Absolute Maximum Ratings

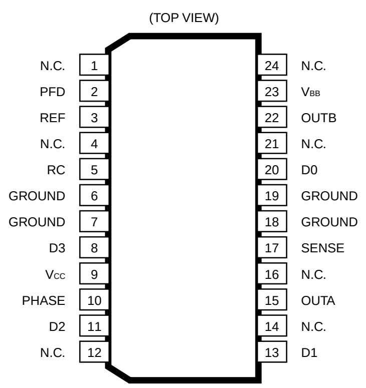
Parameter	Symbol	Ratings	Units
Load supply voltage	V_{BB}	50	V
Output current (continuous)	I_O	±1.5	A
Logic supply voltage	V_{CC}	7.0	V
Logic/reference input voltage range	V_{IN}	–0.3 to V_{CC}+0.3	V
Sense voltage	V_S	1.0	V
Package power dissipation	P_D (Note1)	2.23	W
Operating temperature	T_a	–20 to +85	°C
Junction temperature	T_j (Note2)	+150	°C
Storage temperature	T_{stg}	–55 to +150	°C

●Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current rating or a junction temperature of 150°C.

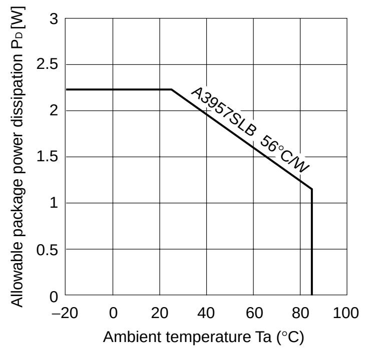
Note 1: When ambient temperature is 25°C or over, derate using –17.86mW/°C.

Note 2: Fault conditions where junction temperature (T_j) exceeds 150°C will activate the device's thermal shutdown circuitry. These conditions can be tolerated but should be avoided.

■Terminal Connection Diagram



■Derating



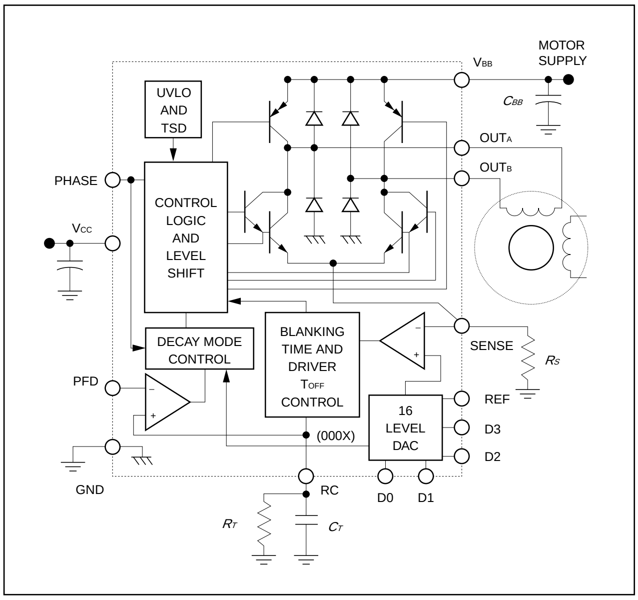
■Electrical Characteristics

(Unless specified otherwise, T_a=25°C, V_{BB}=5V to 50V, V_{CC}=4.5V to 5.5V)

Parameter	Symbol	Conditions	Limits			Units
			min	typ	max	
Power outputs (OUT_A or OUT_B)						
Load supply voltage range	V_{BB}	Operating, I_O=±1.5A, L=3mH	Vcc		50	V
Output leakage current	I_{CEX}	V_O=V_{BB}		<1.0	50	μA
		V_O=0V		< –1.0	–50	μA
Output saturation voltage	$V_{CE (sat)}$	V_{SENSE}=1.0V : Source Driver, I_O=–0.85A		1.0	1.2	V
		V_{SENSE}=1.0V : Source Driver, I_O=–1.5A		1.4	1.5	V
		V_{SENSE}=1.0V : Sink Driver, I_O=0.85A		0.5	0.7	V
		V_{SENSE}=1.0V : Sink Driver, I_O=1.5A		1.2	1.5	V
Sense current offset	I_{SO}	I_S–I_O, I_O=0.85A, V_S=0V, V_{CC}=5V	20	30	40	mA
Clamp diode forward voltage	V_F	I_F=0.85A		1.2	1.4	V
		I_F=1.5A		1.5	1.7	V
Motor supply current (No load)	$I_{BB (ON)}$			2.0	4.0	mA
	$I_{BB (OFF)}$	D_0=D_1=D_2=D_3=0.8V		1.0	50	μA
Control logic						
Logic supply voltage range	V_{CC}	Operating	4.5	5.0	5.5	V
Reference voltage range	V_{REF}	Operating	0.5		2.5	V
UVLO enable threshold	V_{UVLOen}	V_{CC}=0→5V	3.35	3.70	4.05	V
UVLO hysteresis	$V_{UVLOhys}$		0.25	0.40	0.55	V
Logic supply current	$I_{CC (ON)}$			42	50	mA
	$I_{CC (OFF)}$	D_0=D_1=D_2=D_3=0.8V		14	17	mA
Logic input voltage	V_{IH}		2.0			V
	V_{IL}				0.8	V
Logic input current	I_{IH}	V_{IN}=2.0V		<1.0	20	μA
	I_{IL}	V_{IN}=0.8V		< –2.0	–200	μA
Mixed Decay comparator trip point	V_{PFD}	Slow Decay Mode	3.5			V
		Mixed Decay Mode	1.2		2.9	V
		Fast Decay Mode			0.8	V
Mixed Decay comparator input offset voltage	$V_{IO (PFD)}$			0	±20	mV
Mixed Decay compartor hysteresis	$\Delta V_{IO (PFD)}$		5	25	55	mV
Reference input current	I_{REF}	V_{REF}=0V to 2.5V			±5.0	μA
Reference divider ratio	V_{REF}/V_S	at trip, D_0=D_1=D_2=D_3=2V		3.0		
DAC accuracy *1	DAC_{ERR}	V_{REF}=1.0V to 2.5V			±3.0	%
		V_{REF}=0.5V to 1.0V			±4.0	%
Current-sense comparator input offset voltage *1	$V_{IO (S)}$	V_{REF}=0V		–16		mV
Step reference current ratio	SRCR	D_1=D_2=D_3=0.8V		0		%
		D_0=0.8V, D_1=2.0V, D_2=D_3=0.8V		17.4		%
		D_0=D_1=2.0V, D_2=D_3=0.8V		26.1		%
		D_0=D_1=0.8V, D_2=2V, D_3=0.8V		34.8		%
		D_0=2.0V, D_1=0.8V, D_2=2.0V, D_3=0.8V		43.5		%
		D_0=0.8V, D_1=D_2=2.0V, D_3=0.8V		52.2		%
		D_0=D_1=D_2=2.0V, D_3=0.8V		60.9		%
		D_0=D_1=D_2=0.8V, D_3=2.0V		69.6		%
		D_0=2.0V, D_1=D_2=0.8V, D_3=2.0V		73.9		%
		D_0=0.8V ,D_1=2.0V, D_2=0.8V, D_3=2.0V		78.3		%
		D_0=D_1=2.0V, D_2=0.8V, D_3=2.0V		82.6		%
		D_0=D_1=0.8V, D_2=D_3=2.0V		87.0		%
		D_0=2.0V, D_1=0.8V, D_2=D_3=2.0V		91.3		%
		D_0=0.8V, D_1=D_2=D_3=2.0V		95.7		%
		D_0=D_1=D_2=D_3=2.0V		100		%
Thermal shutdown temperature	T_j			165		°C
Thermal shutdown hysteresis	ΔT_j			15		°C
AC timing						
PWM RC fixed off-time	t_{OFFRC}	C_T=470pF, R_T=43kΩ	18.2	20.2	22.3	μS
PWM turn-off time	$t_{PWM (OFF)}$	Current-Sense Comparator Trip to Source OFF, I_O=0.1A		1.0	1.5	μS
		Current-Sense Comparator Trip to Source OFF, I_O=1.5A		1.4	2.5	μS
PWM turn-on time	$t_{PWM (ON)}$	I_{RC} Charge ON to Source ON, I_O=0.1A		0.4	0.7	μS
		I_{RC} Charge ON to Source ON, I_O=1.5A		0.55	0.85	μS
PWM minimum on-time	$t_{ON (min)}$	V_{CC}=5.0V, R_T≥43kΩ, C_T=470pF, I_O=0.1A	1.0	1.6	2.2	μS
Crossover dead time	t_{CODT}	1kΩ Load to 25V	0.3	1.5	3.0	μS

*1: The total error for the V_{REF}/V_{SENSE} function is the sum of the D/A error and the current-sense comparator input offset voltage.
●"typ" values are for reference.

■Internal Block Diagram



■Truth Table

Power Outputs

D3, D2, D1, D0	PHASE	OUTA	OUTB	PFD	Power Output Operating Mode
0000 or 0001	X	Z	Z	X	Disable
1XXX or X1XX or XX1X	H	H	L	≥3.5V	Forward, slow current-decay mode
				1.2V to 2.9V	Forward, mixed current-decay mode
				≤0.8V	Forward, fast current-decay mode
	L	L	H	≥3.5V	Reverse, slow current-decay mode
				1.2V to 2.9V	Reverse, mixed current-decay mode
				≤0.8V	Reverse, fast current-decay mode

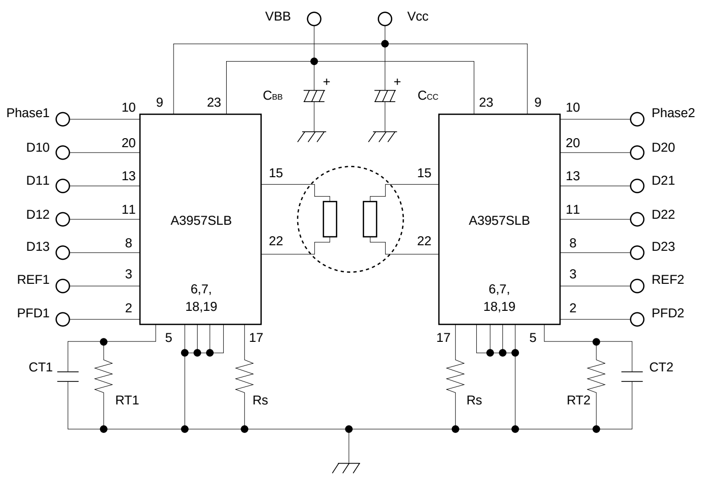
X: Don't care
High impedance (source and sink both OFF)

DAC

D3	D2	D1	D0	DAC [%]
1	1	1	1	100
1	1	1	0	95.7
1	1	0	1	91.3
1	1	0	0	87.0
1	0	1	1	82.6
1	0	1	0	78.3
1	0	0	1	73.9
1	0	0	0	69.6

D3	D2	D1	D0	DAC [%]
0	1	1	1	60.9
0	1	1	0	52.2
0	1	0	1	43.5
0	1	0	0	34.8
0	0	1	1	26.1
0	0	1	0	17.4
0	0	0	1	0
0	0	0	0	0

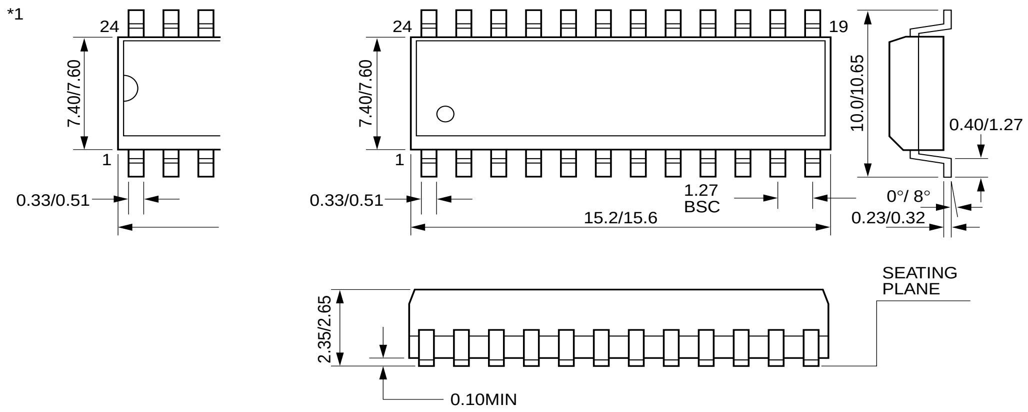
■Application Circuit



●Off-time setting : $t_{OFF} \cong R_T \cdot C_T$
R_T=36Ω (12kΩ to 100kΩ)
C_T=560pF (470pF to 1500pF)
R_S=0.51Ω (0.39Ω to 0.62Ω)
C_{BB}=100μF+0.1μF
C_{CC}=0.1μF
V_{REF}=0.5V to 2.5V
V_{PFD}=1.2V to 2.9V (Mixed current-decay mode)
≥3.5V (Slow current-decay mode)
≤0.8V (Fast current-decay mode)

■External Dimensions

(Unit: mm)



- Pin material: copper, pin surface treatment: solder plating
- Package index may be *1.
- Allowable variation in distance between leads is not cumulative.
- Web (batwing) type lead frames are used for pin 6, 7, 18, 19. The pins are connected to GND.

3-Phase Stepper Motor Driver ICs

■Absolute Maximum Ratings

Parameter	Symbol	Ratings	Units
Load supply voltage	V_{BB}	50	V
Logic supply voltage	V_{CC}	7	V
Input voltage	V_{IN}	–0.3 to V_{CC}	V
Reference input voltage	V_{REF}	–0.3 to V_{CC}	V
Sense voltage	V_{sense}	1.5	V
Package power dissipation	P_D	1	W
Junction temperature	T_j	–20 to +85	°C
Operating temperature	T_{op}	+125	°C
Storage temperature	T_{stg}	–55 to +125	°C

■Recommended Operating Voltage Ranges

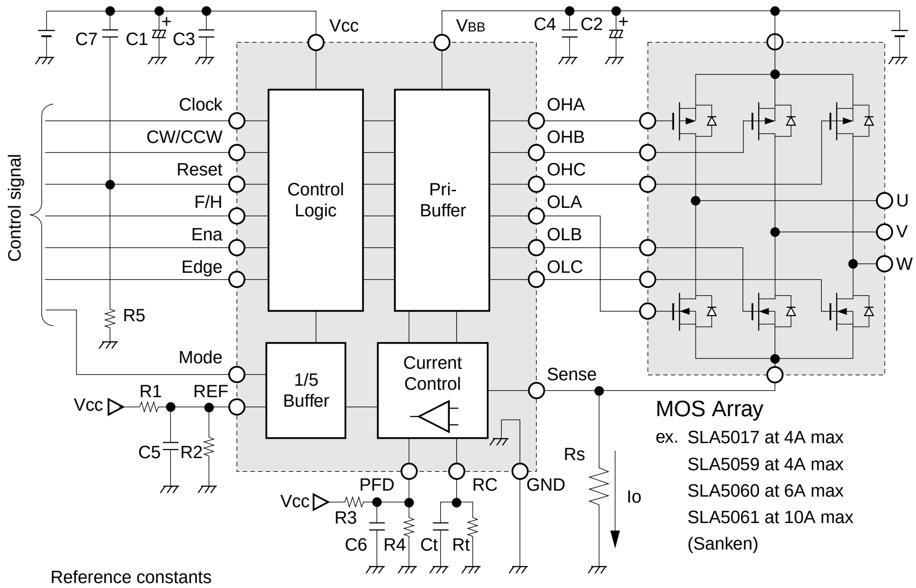
(Ta=25°C)

Parameter	Symbol	Ratings	Units
Load supply voltage	V_{BB}	15 to 45	V
Logic supply voltage	V_{CC}	3 to 5.5	V
Reference input voltage	V_{REF}	0.2 to Vcc–2	V

■Electrical Characteristics

Parameter	Symbol	Ratings			Units	Conditions
		min	typ	max		
Load supply voltage	V_{BB}	15		45	V	
Logic supply voltage	V_{CC}	3.0		5.5	V	
Output voltage	V_{OL1}	8		15	V	
	V_{OL2}	0		1	V	
	V_{OH1}	V_{BB}–15		V_{BB}–8	V	
	V_{OH2}	V_{BB}–1		V_{BB}	V	
Load supply current	I_{BB}			25	mA	V_{CC}=5.5V
Logic supply current	I_{CC}			10	mA	V_{CC}=5.5V
Logic input voltage	V_{IH}	3.75			V	
	V_{IL}			1.25	V	
Logic input current	I_{IH}			20	μA	V_{IN}=V_{CC}×0.75
	I_{IL}	–20			μA	V_{IN}=V_{CC}×0.25
Maximum clock frequency	F	200			kHz	Edge=0V
		100				Edge=V_{CC}
PFD input voltage	V_{Slow}	1.7		V_{CC}	V	
	V_{Mix}	0.7		1.3	V	
	V_{Fast}			0.3	V	
PFD input current	I_{PFD}		±50		μA	
Reference input voltage	V_{REF}	0		V_{CC}–2	V	
Reference input current	I_{REF}		±10		μA	V_{REF}=0~Vcc–2V
Sense voltage	V_{S1}		V_{REF}×0.2		V	Mode=V_{CC}, V_{REF}=0~V_{CC}–2V
	V_{S2}		V_{REF}×0.17		V	Mode=0V, AV_{REF}=0~V_{CC}–2V
RC source current	I_{RC}		220		μA	
Off time	T_{off}		1.1×R_t×C_t		Sec.	

■Internal Block Diagram/Diagram of Standard External Circuit

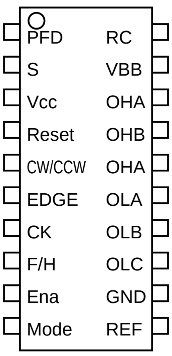


Reference constants

Rs:0.1 to 1Ω (1 to 5W)	C1:10 µF/10V	R1+R2≤10kΩ	R5:10kΩ
	C2:100 µF/63V	(V_{REF}:0.2 to V_{CC}2-2V)	
Rt:15k to 75kΩ	C3 to C6:0.01 to 1 µF	R3+R4≤10kΩ	
Ct:420p to 1100pF	C7:1000pF	(V_{PFD}:0 to V_{CC}2)	

■Terminal Connection

The package shapes of SI-7600 and SI-7600D are different, however the terminal connection is the same.

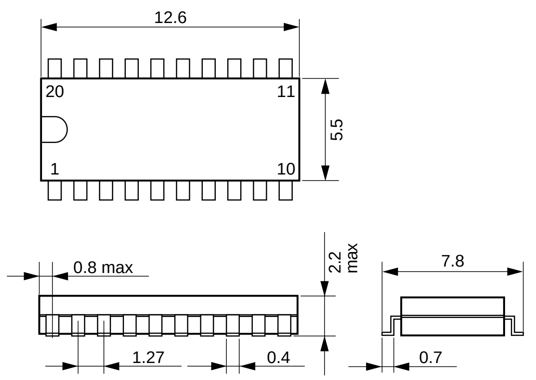


Pin No.	Name	Pin No.	Name	Pin No.	Name
Pin1	PFD	Pin8	Full/Half	Pin15	OLA
Pin2	Sense	Pin9	Enable	Pin16	OHC
Pin3	Vcc	Pin10	Mode	Pin17	OHB
Pin4	Reset	Pin11	REF	Pin18	OHA
Pin5	CW/CCW	Pin12	GND	Pin19	V_{BB}
Pin6	Edge	Pin13	OLC	Pin20	RC
Pin7	Clock	Pin14	OLB		

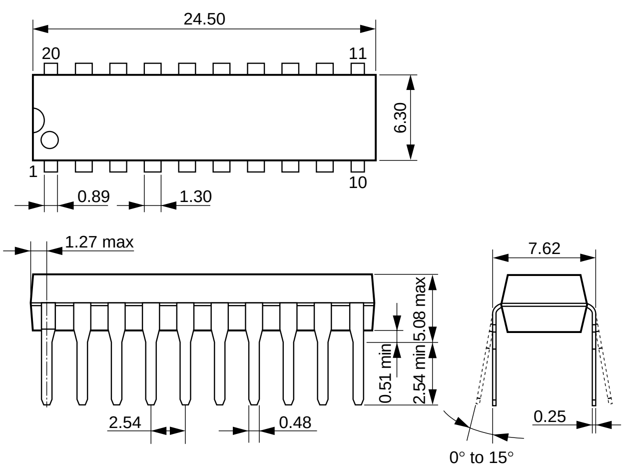
■External Dimensions (Unless specified otherwise, all values are typical)

(Units: mm)

SI-7600



SI-7600D



Application Notes

1. Outline

The SI-7600/SI-7600D is a control IC used with a power MOS FET array to drive a 3-phase stepper motor. Select the output-stage MOS FET according to the rated current of the motor. The full step is 2-phase excitation when this IC is in a star connection but 3-phase excitation when it is in a delta connection.

2. Features

- Suitable for both star connection drive and delta connection drive
- Maximum load supply voltage V_{BB}=45V
- Control logic supply voltage Vcc=3 to 5.5V
- Supports star connection (2/2-3phase excitation) and delta connection (3/2-3phase excitation)
- Step switching timing by clock signal input
- Forward/reverse, hold, and motor-free control
- Step switching at the positive edge or positive/negative edge of the clock signal
- Control current automatic switching function for 2-3phase excitation (effective for star connection)
  (Current control: 86% for 2-phase excitation, 100% for 3-phase excitation)
- Self-excitation constant-current chopping by external C/R
- Slow Decay, Mixed Decay, or Fast Decay selectable
- Two package lineup: SOP (surface mounting) and DIP (lead insertion)
  SOP···SI-7600, DIP···SI-7600D
- Maximum output current depends on the ratings of the MOS FET array used

3. Input Logic Truth Table

Input terminal	Low level	High level
CW/CCW	CW	CCW
Full/Half	2-3phase excitation	2-phase excitation
Enable	Disable	Enable
Mode (Note 1)	Always 100%	2-phase excitation: 85% 3-phase excitation: 100%
Edge (Note 2)	Positive	Positive/negative
Reset (Note 3)	Enable	Internal logic reset output disable

Select CW/CCW, Full/Half, or Edge when the clock level is low.

Note 1: The control current is always 85% for the full step (2-phase excitation) when the Mode terminal level is high. The value of 100% control current is calculated at the $V_{REF}/(5\times Rs)$ terminal because a 1/5 buffer is built into the reference section.

Note 2: When the Edge terminal level is set high, the internal counter increments both at the rising and falling edges. Therefore, the duty ratio of the input clock should be set at 50%.

Note 3: When the Reset terminal level is set high, the internal counter is reset. Output remains disabled as long as the Reset terminal level is high.

4. Determining the control current

The control current Io can be calculated as follows:

When the Mode terminal level is low

$I_O \cong V_{REF}/(5\times R_S)$

When the Mode terminal level is high

$I_O \cong V_{REF}/(5\times R_S) \rightarrow$ 3-phase excitation

$I_O \cong V_{REF}/(5.88\times R_S) \rightarrow$ 2-phase excitation

The reference voltage can be set within the range of 0.2V to Vcc –2V. (When the voltage is less than 0.2V, the accuracy of the reference voltage divider ratio deteriorates.)

5. About the Current Control System (Setting the Constant Ct/Rt)

The SI-7600 uses a current control system of the self-excitation type with a fixed chopping OFF time.

The chopping OFF time is determined by the constant Ct/Rt.

The constant Ct/Rt is calculated by the formula

$T_{OFF} \cong 1.1\times Ct\times Rt$ ······ (1)

The recommended range of constant Ct/Rt is as follows:

Ct: 420 to 1100pF

Rt: 15 to 75kΩ

(Slow Decay or Mixed Decay →560pF/47kΩ, Fast Decay → 470pF/20kΩ)

Usually, set T_{OFF} to a value where the chopping frequency becomes about 30 to 40kHz.

The mode can be set to Slow Decay, Fast Decay, or Mixed Decay depending on the PFD terminal input potential.

PFD applied voltage and decay mode

PFD applied voltage	Decay mode
0 to 0.3V	Fast Decay
0.7V to 1.3V	Mixed Decay
1.7V to Vcc	Slow Decay

In Mixed Decay mode, the Fast/Slow time ratio can be set using the voltage applied to the PFD terminal. The calculated values are summarized below.

In this mode, the point of switching from Fast Decay to Slow Decay is determined by the RC terminal voltage that determines the chopping OFF time and by the PFD input voltage V_{PFD}.

Formula (1) is used to determine the chopping OFF time.

The Fast Decay time is then determined by the RC discharge time from the RC voltage (about 1.5V) to the PFD input voltage (V_{PFD}) when chopping is turned from ON to OFF.

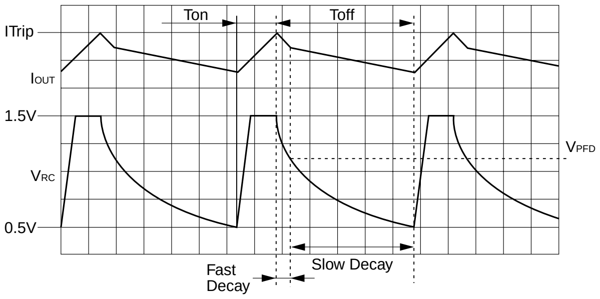
The Fast Decay time is

$$t_{OFFf} \cong -R_T\times C_T\times \ln\left(\frac{V_{PFD}}{1.5}\right) \quad \cdots\cdots(2)$$

The Slow Decay time (t_{OFFs}) is calculated by subtracting the value of (2) from that of (1).

$t_{OFFs} \cong T_{OFF} - t_{OFFf}$ ······(3)

Relationship between RC terminal voltage and output current



6. Method of Calculating Power Loss of Output MOS FET

The SI-7600 uses a MOS-FET array for output. The power loss of this MOS FET array can be calculated as summarized below. This is an approximate value that does not reflect parameter variations or other factors during use in the actual application. Therefore, heat from the MOS FET array should actually be measured.

● **Parameters for calculating power loss**

To calculate the power loss of the MOS FET array, the following parameters are needed:

(1) Control current Io (max)

(2) Excitation method

(3) Chopping ON-OFF time at current control: T_{ON}, T_{OFF}, t_{OFFf}

(T_{ON}: ON time, T_{OFF}: OFF time, t_{OFFf}: Fast Decay time at OFF)

(4) ON resistance of MOS FET: $R_{DS (ON)}$

(5) Forward voltage of MOS FET body diode: V_{SD}

For (4) and (5), use the maximum values of the MOS FET specifications.

(3) should be confirmed on the actual application.

● **Power loss of Pch MOS FETs**

The power loss of Pch MOS FETs is caused by the ON resistance and by the chopping-OFF regenerative current flowing through the body diodes in Fast Decay mode.

(In Slow Decay mode, the chopping-OFF regenerative current does not flow the body diodes.)

The losses are

ON resistance loss P1: $P1=I_M^2 \times R_{DS (ON)}$

Body diode loss P2: $P2=I_M \times V_{SD}$

With these parameters, the loss Pp per MOS FET is calculated depending on the actual excitation method as follows:

a) 2-phase excitation ($T=T_{ON}+T_{OFF}$)

$P_P= (P1 \times T_{ON}/T+P2 \times t_{OFFf}/T) \times (1/3)$

b) 2-3 phase excitation ($T=T_{ON}+T_{OFF}$)

$P_P= (P1 \times T_{ON}/T+P2 \times t_{OFFf}/T) \times (1/4)+(0.5 \times P1 \times T_{ON}/T+P2 \times t_{OFFf}/T) \times (1/12)$

● **Power loss of Nch MOS FETs**

The power loss of Nch MOS FETs is caused by the ON resistance or by the chopping-OFF regenerative current flowing through the body diodes.

(This loss is not related to the current control method, Slow, Mixed, or Fast Decay.)

The losses are

ON resistance loss N1: $N1=I_M^2 \times R_{DS(ON)}$

Body diode loss N2: $N2=I_M \times V_{SD}$

With these parameters, the loss P_N per MOS FET is calculated depending on the actual excitation method as follows:

a) 2-phase excitation ($T=T_{ON}+T_{OFF}$)

$P_N=(N1+N2 \times T_{OFF}/T) \times (1/3)$

b) 2-3 phase excitation ($T=T_{ON}+T_{OFF}$)

$P_N=(N1+N2 \times T_{OFF}/T) \times (1/4)+(0.5N1+N2 \times T_{OFF}/T) \times (1/12)$

● **Determining power loss and heatsink when SLA5017 is used**

If the SLA5017 is used in an output section, the power losses of a Pch MOS FET and an Nch MOS FET should be multiplied by three and added to determine the total loss P of SLA5017.

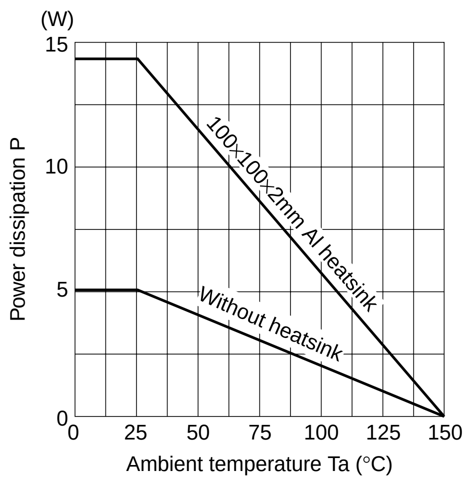
In other words, $P=3 \times P_P+3 \times P_N$

The allowable losses of SLA5017 are

Without heatsink: 5W θj-a=25°C/W

Infinite heatsink: 35W θj-c=3.57°C/W

Select a heatsink by considering the calculated losses, allowable losses, and following ratings:

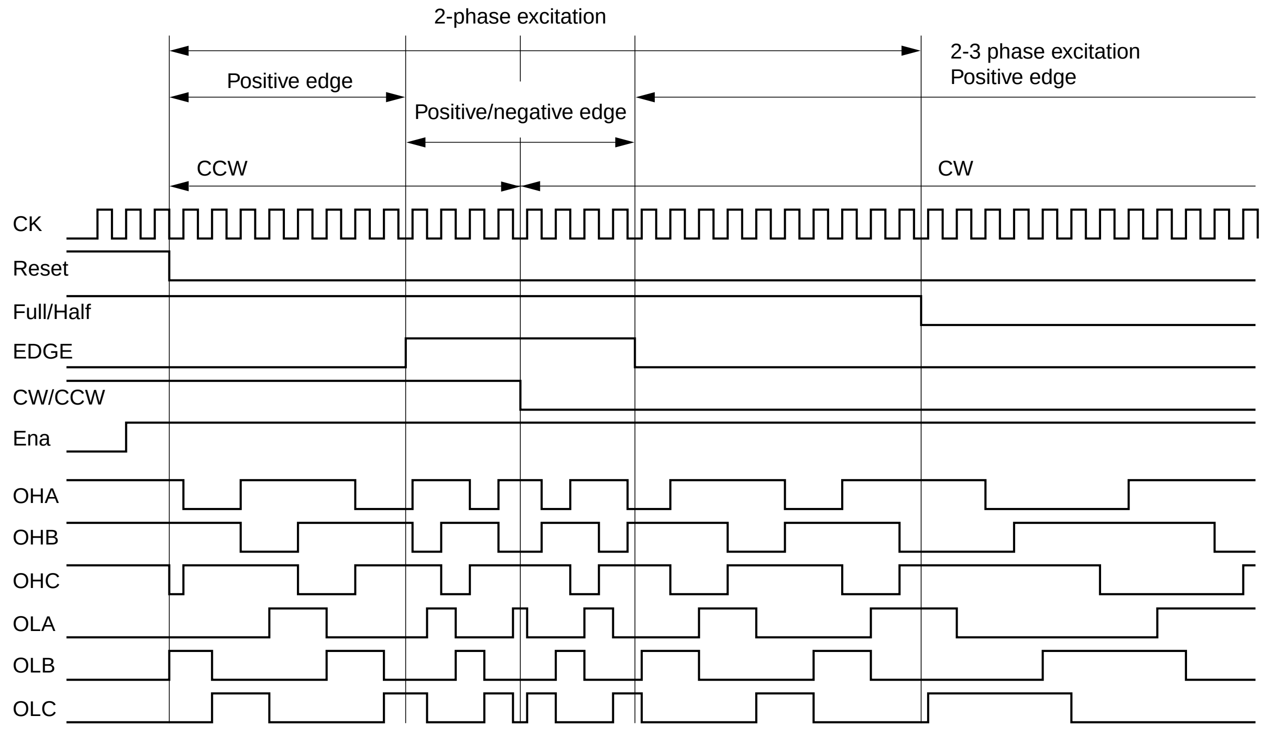


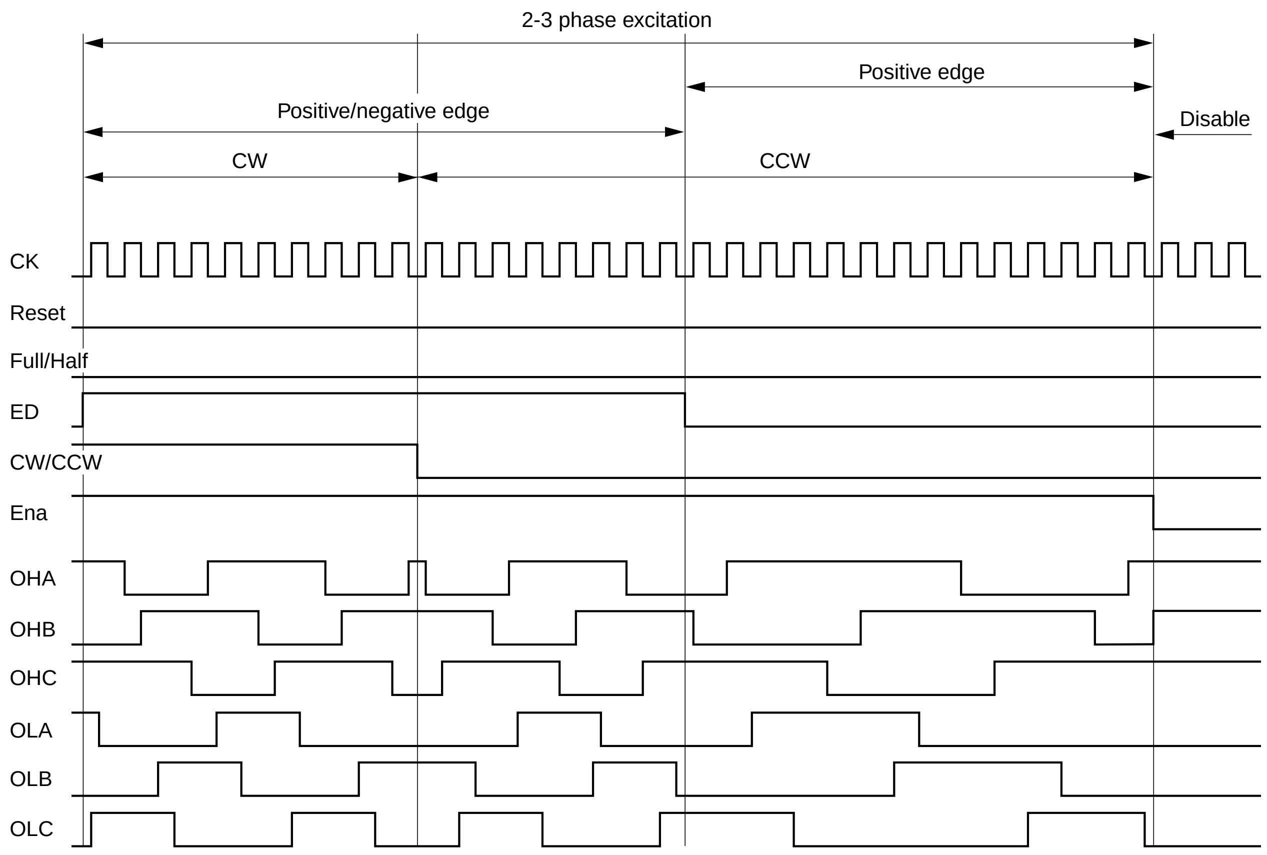
When selecting a heatsink for SLA5017, be sure to check the product temperature when in use in an actual applicaiton.

The calculated loss is an approximate value and therefore contains a degree of error.

Select a heatsink so that the surface Al fin temperature of SLA5017 will not exceed 100°C under the worst conditions.

7. I/O Timing Chart





5-Phase Stepper Motor Driver ICs

■Absolute Maximum Ratings

(T_a=25°C)

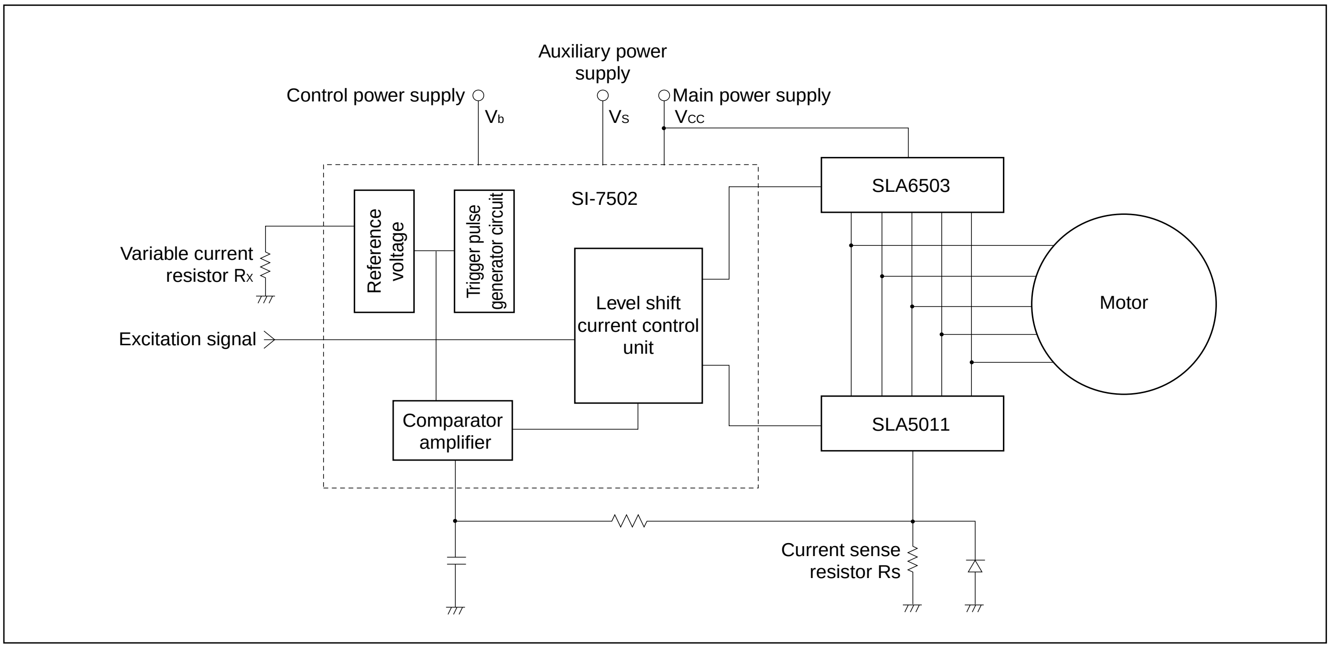
Part No.	Parameter	Symbol	Ratings	Units
SI-7502	Motor supply voltage	V_{CC}	44	V
	Auxiliary supply voltage	V_S	15	V
	Control voltage	V_b	7	V
	Reference voltage	V_{ref}	1.5	V
	Detection voltage	V_{RS}	5	V
	Power dissipation	P_D	1	W
	Ambient operating temperature	T_{OP}	0 to +65	°C
SLA5011	Drain -Source voltage	V_{DSS}	60	V
	Drain current	I_D	±5	A
	Avalanche energy capability (Single pulse)	E_{AS}	2	mJ
	Power dissipation	P_T	35	W
	Channel temperature	T_{ch}	150	°C
	Storage temperature	T_{stg}	–40 to +150	°C
SLA6503	Collector-Base voltage	V_{CBO}	–60	V
	Collector-Emitter voltage	V_{CEO}	–60	V
	Emitter-Base voltage	V_{EBO}	–6	V
	Collector current	I_C	–3	A
	Collector current (Pulse)	$I_{C\ (pulse)}$	–6	A
	Base current	I_B	–1	A
	Power dissipation	P_T	35	W
	Junction temperature	T_j	150	°C
	Storage temperature	T_{stg}	–40 to +150	°C

■Electrical Characteristics

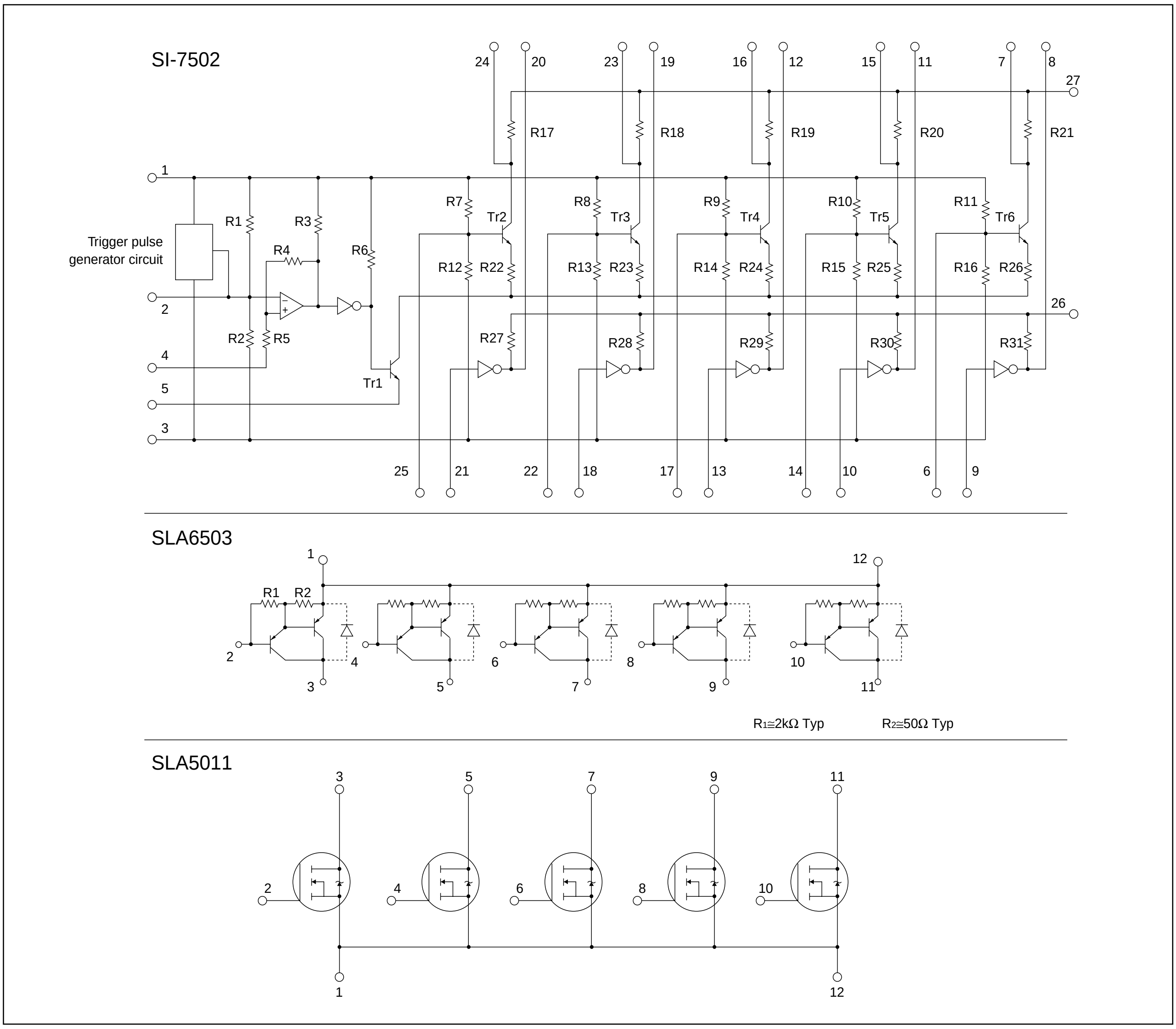
(T_a=25°C)

Part No.	Parameter	Symbol	Limits			Units	Conditions
			min	typ	max		
SI-7502	Supply current	I_{CC}			40	mA	V_{CC}=42V, V_b=5.5V
		I_S			12.5	mA	V_S=12.5V
		I_b			50	mA	V_b=5.5V
	Input current	$I_{IU\text{-}L}$, $I_{IL\text{-}L}$			1.6	mA	V_{IU}=V_{IL}=0.4V
	Upper drive circuit drive current	I_{OU}-on	8		11	mA	V_b=5V, AIU to EIU pin open
		I_{OU}-off			10	μA	V_b=5V
	Lower drive circuit voltage	V_{OL}-on	V_S–1.5			V	V_b=5V, AIL to EIL pin open
		V_{OL}-off			1.5	V	V_b=5V
	Oscillation frequency	F	20		30	kHz	V_b=5V
	Detection voltage	V_{RS}	0.8		1.05	V	V_b=5V, V_{REF} pin open
SLA5011	Gate threshold voltage	V_{TH}	2.0		4.0	V	V_{DS}=10V, I_D=250μA
	Forward Transconductance	$R_{e\ (yts)}$	2.2	3.3		S	V_{DS}=10V, I_D=5A
	DC ON-resistance	$R_{DS\ (ON)}$		0.17	0.22	Ω	V_{GS}=10V, I_D=5A
	Input capacitance	C_{ISS}		300		pF	V_{DS}=25V, f=1.0MHz, V_{GS}=0V
	Output capacitance	C_{OSS}		160		pF	
	Di forward voltage between source and drain	V_{SD}		1.1	1.5	V	I_{SD}=5A
	Di reverse recovery time between source and drain	t_{rr}		150		ns	I_{SD}=±100mA
SLA6503	Collector cut-off current	I_{CBO}			–10	μA	V_{CB}=–60V
	Collector-emitter voltage	V_{CEO}	–60			V	I_C=–10mA
	DC current gain	h_{FE}	2000				V_{CE}=–4V, I_C=–3A
	Collector emitter saturation voltage	$V_{CE\ (sat)}$			1.5	V	I_C=–3A, I_B=–6mA

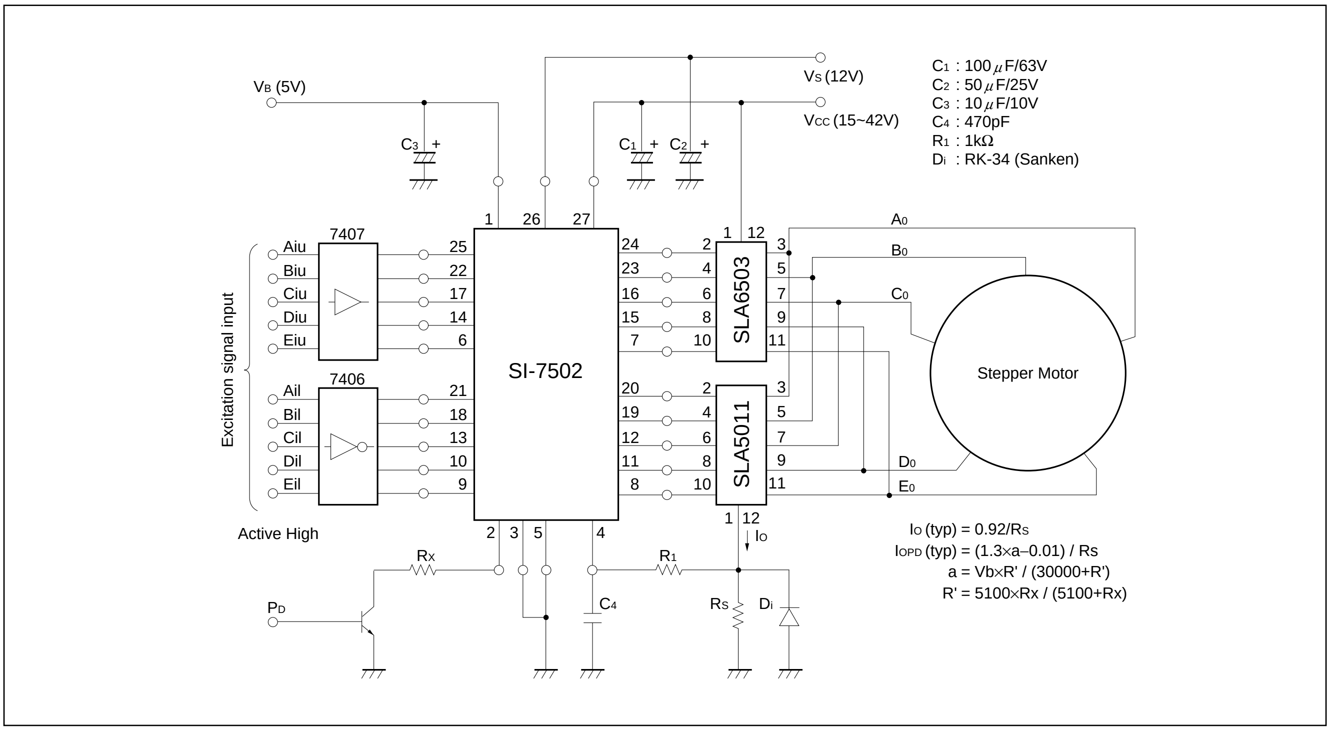
■Internal Block Diagram (Dotted Line)



■Equivalent Circuit Diagram



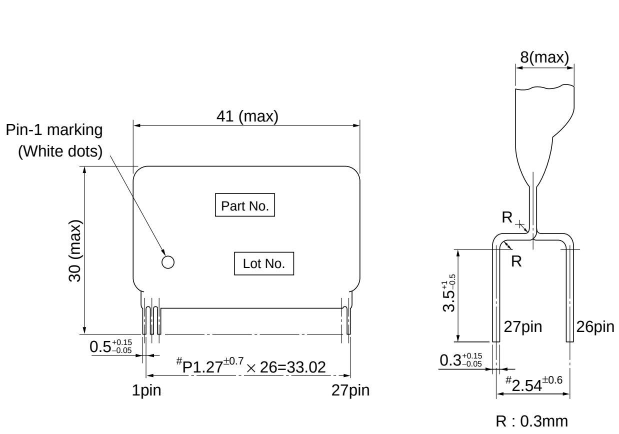
■Diagram of Standard External Circuit



■External Dimensions

(Unit: mm)

SI-7502

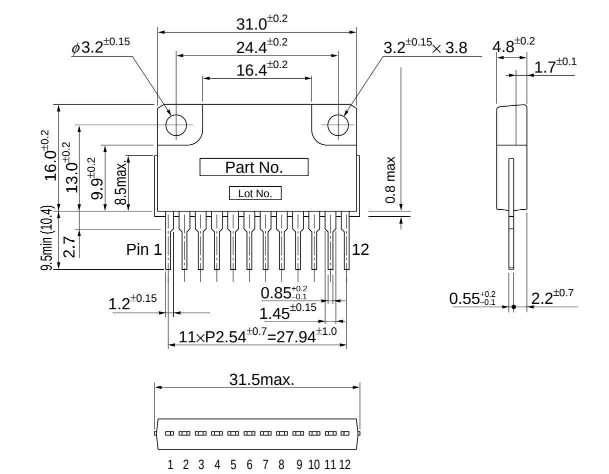


(Note) Dimensions marked with a # indicate dimensions of lead tip.

■External Dimensions

(Unit: mm)

SLA6503/SLA5011



Application Notes

■Determining the Output Current I_O (Control Current)

The main factors that determine the output current are current sense resistor R_S, supply voltage V_b, and variable current resistor R_X.

(1) Normal mode

To operate a motor at the maximum current level, set R_X to infinity (open).

From Fig. A, when the maximum current ripple is designated as I_{OH}, its value will be,

$$I_{OH}=\frac{V_{RSH}}{R_S} \quad \cdots\cdots (1)$$

V_{RSH} can be calculated as follows:

$$V_{RSH}=0.19\times V_b-0.03 \text{ (center value)} \quad \cdots\cdots (2)$$

From equations (1) and (2), the output current I_{OH} can be calculated as follows:

$$I_{OH}=\frac{1}{R_S}(0.19\times V_b\times\text{-}0.03)$$

The relationship between I_{OH} and R_S is shown in Fig. B.

(2) Power down mode

When an external resistor R_X is connected, V_{RSH} changes as shown in Fig. C even when R_S is retained. Obtain a power down output current I_{OHPD} from Fig. C and equation (1).

■Relation between Output Current I_O (Control Current) and Motor Winding Current I_{OM}

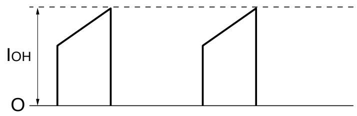
The SI-7502 uses the total current control system; therefore, the output current I_O is different from the motor winding current. In a general pentagonal driving system, the current flows as shown in Figure D. The relation between I_O and I_{OM} is as follows:

$I_O=4\times I_{OM}$

With some driving systems, the relation can also be as follows:

$I_O=2\times I_{OM}$

Fig. A



Waveform of output current

Fig. B Output current vs. Current sense resistor

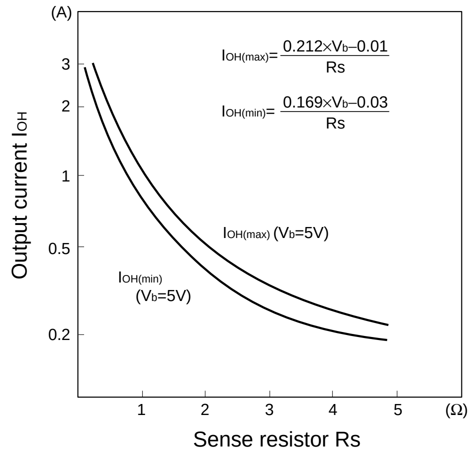


Fig. C Sense voltage vs. Variable current resistor

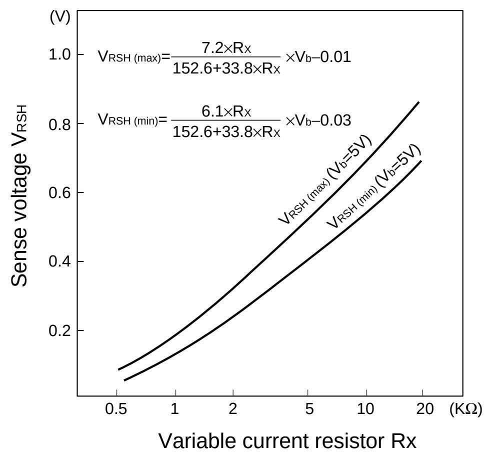
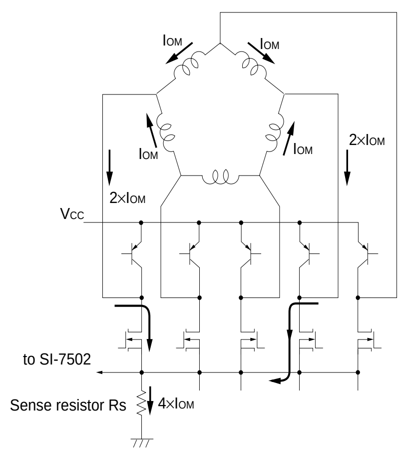


Fig. D Coil current flow at pentagonal driving



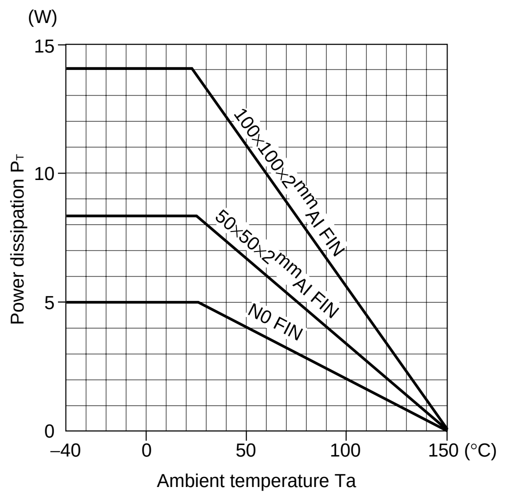
■Motor Connection

The 5-phase stepper motor supports various driving systems and the motor connection varies depending on the driving system used.
Use of the motor with some driving systems may be restricted by patents. Therefore, be sure to ask the motor manufacturer about the motor connection and driving system to be used.

■Thermal design

The driver (SLA5011/SLA6503) dissipation varies depending on a driving system used even if the output currents (control current) are the same. Therefore, measure the temperature rise of the driver under the actual operating conditions to determine the size of the heatsink.
Figure E shows an SLA5011/SLA6503 derating curve. This derating curve indicates T_j=150°C; however, when using this device, allow sufficient margin when selecting a heatsink so that T_C≤100°C (Al FIN temperature on the back of the SLA) is obtained.

Fig. E SLA5011/SLA6503 Derating curve



SI-7502

■Handling Precautions

Refer to the product specifications.
Solvents- Do not use the following solvents:

Substances that can dissolve the package	Chlorine-based solvents: Trichloroethylene, Trichloroethane, etc. Aromatic hydrogen compounds: Benzene, Toluene, Xylene, etc. Keton and Acetone group solvents
Substances that can weaken the package	Gasoline, Benzine, Kerosene, etc.

List of Discontinued Products

■Discontinued Products

Part No.	Substitute
SI-7200E	–
SI-7201A	–
SI-7202A	–
SI-7230E	–
SI-7235E	–
SDK01M	SDK03M
SMA7022M	SMA7022MU
SLA7022M	SLA7022MU
SLA7027M	SLA7027MU

■Not for new design

Part No.	Substitute
SI-7115B	SLA7032M
SI-7300A	SLA7032M
SI-7330A	SLA7033M
SI-7200M	A2918SW
SI-7230M	–
SI-7500A	–

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