



# STK6103

## DC 3-phase Brushless Motor Driver (Output Current 3A)

### Overview

The STK6103 is a hybrid IC incorporating a 3-phase brushless motor controller and driver into a single package, on the Sanyo IMST (Insulated Metal Substrate Technology) substrate. Revolution speed is controlled through the DC voltage level ( $V_{ref1}$ ) external input and PWM control of motor phase winding current. The driver is MOSFET to minimize circuit loss and handle high-output current (rush current) demands.

### Applications

- PPC and LBP drum motors
- Air conditioner fan motors

### Features

- The output driver transistor is MOSFET for low power loss (half that of a bipolar transistor) and reliable handling of high-output current (rush current).
- Variation in  $V_{ref1}$  level causes the driver transistor to switch to PWM drive for high-efficiency motor speed variation.
- Normal and reverse revolution select function.
- Start/stop and brake functions.
- Current limiter function.

### Specifications

#### Maximum Ratings at $T_a = 25^\circ\text{C}$

Parameter	Symbol	Conditions	Ratings	Unit
Maximum supply voltage 1	$V_{cc1\text{ max}}$	No input signal	50	V
Maximum supply voltage 2	$V_{cc2\text{ max}}$	No input signal	7	V
Maximum output current	$I_o\text{ max}$	Position detect input signal cycle = 30 ms, PWM duty = 50%, operation time 1s	5	A
Operating substrate temperature	$T_c\text{ max}$		105	$^\circ\text{C}$
Junction temperature	$T_j\text{ max}$		150	$^\circ\text{C}$
Storage temperature	$T_{stg}$		-40 to +125	$^\circ\text{C}$

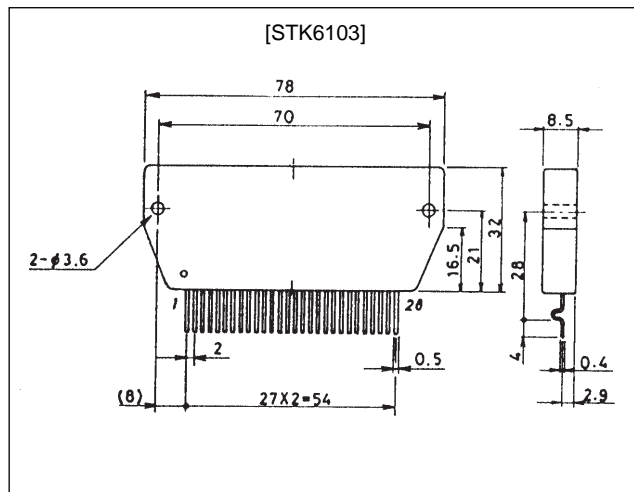
#### Allowable Operating Ranges at $T_a = 25^\circ\text{C}$

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage 1	$V_{cc1}$	With input signal	16 to 42	V
Output current	$I_o\text{ ave}$	DC phases present	3	A
Supply voltage 2	$V_{cc2}$	With input signal	4.75 to 6.0	V
Brake current	$I_{ob}$	80 Hz full sine waves (all phases). Operating time 0.1 s duty = 5% (see Note 1).	8	A

### Package Dimensions

unit: mm

4130

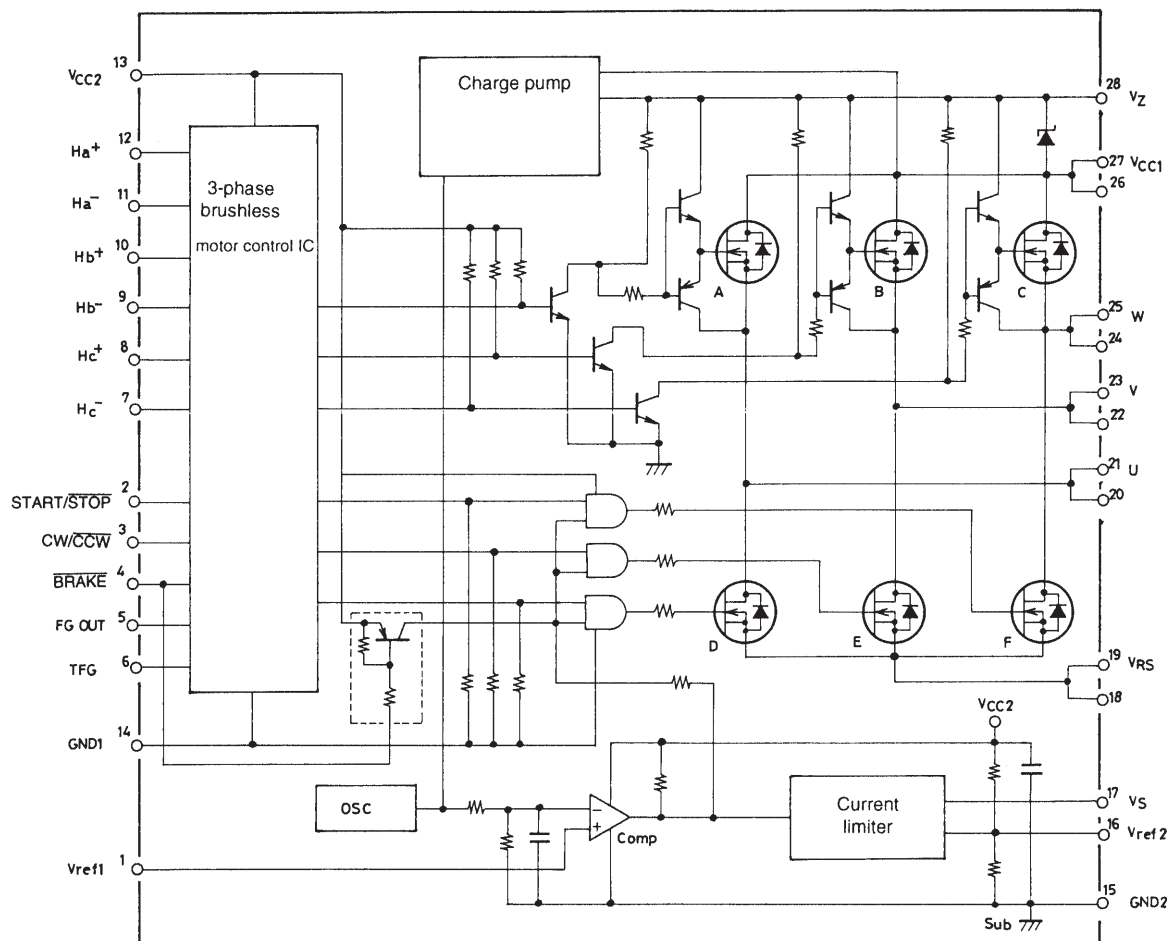


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### Electrical Characteristics at $T_c=25^\circ\text{C}$ , $V_{CC1} = 24\text{ V}$ , $V_{CC2} = 5.0\text{ V}$

Parameter	Symbol	Conditions	min	typ	max	Unit
Supply current 1 (pin 13)	$I_{CCO1}$	CW revolution		12	20	mA
Supply current 2 (pin 13)	$I_{CCO2}$	Braking		26	38	mA
Output saturation voltage 1	$V_{st1}$	$V_{CC1}$ side TR, $I_o = 3\text{ A}$		0.43	0.56	V
Output saturation voltage 2	$V_{st2}$	GND side TR, $I_o = 3\text{ A}$		0.47	0.62	V
Internal MOSFET diode forward voltage	$V_F$	$I_F = 3\text{ A}$		0.95	1.5	V
PWM oscillation frequency	$f_c$		20	25	30	kHz
Current limiter reference voltage	$V_{ref2}$		0.47	0.50	0.53	V
Position detect input sensitivity	$V_H$		20		500	mV
Position detect common mode range	CMRH		2.0		4.5	V
Input "L" current 1 (pins 2,3)	$I_{IL1}$	$V_{IL1} = \text{GND}$		130	200	$\mu\text{A}$
Input "L" voltage 1 (pins 2,3)	$V_{IL1}$				1.0	V
Input "L" current 2 (pin 4)	$I_{IL2}$	$V_{IL2} = \text{GND}$		570	910	$\mu\text{A}$
Input "L" voltage 2 (pin 4)	$V_{IL2}$				1.0	V
Vref1 "H" voltage	$V_{ref1H}$	GND side transistor not in PWM		2.82	3.2	V
Vref1 "L" voltage	$V_{ref1L}$	GND side transistor off	0.15	0.35		V
Zener voltage	$V_Z$		5.7	6.2	6.7	V
FG output current	$I_{FGH}$	$V_{FG} = 1.6\text{ V}$	80			$\mu\text{A}$
FG output "L" voltage	$V_{FGL}$	$I_{FG} = 0.3\text{ mA}$			0.4	V
FG output pulse width	$\tau_{FG}$	$C_F = 0.1\mu\text{F}$ , $R_F = 10\text{ k}\Omega$	0.9	1.0	1.1	ms

### Equivalent Circuit



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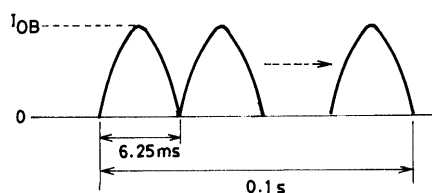
### Pin Functions

Pin No.	Symbol	Function
1	$V_{ref1}$	GND-side driver transistor PWM control pin: range 0.15 to 3.2V
2	START/ $\overline{STOP}$	"H" = START, "L" = $\overline{STOP}$ (all transistors off)
3	$CW/\overline{CCW}$	"H" = CW, "L" = $\overline{CCW}$
4	$\overline{BRAKE}$	"H" = rotate, "L" = Only GND-side transistor on
5	FG OUT	Position detect signal: output 6 pulses per cycle
6	TFG	For setting FG OUT "L" level pulse width. $R_F$ and $C_F$ pins.
7	$H_{C-}$	Motor position detect signal input pin (to Hall device)
8	$H_{C+}$	Motor position detect signal input pin (to Hall device)
9	$H_{b-}$	Motor position detect signal input pin (to Hall device)
10	$H_{b+}$	Motor position detect signal input pin (to Hall device)
11	$H_{a-}$	Motor position detect signal input pin (to Hall device)
12	$H_{a+}$	Motor position detect signal input pin (to Hall device)
13	$V_{cc2}$	Motor controller supply voltage pin
14	GND1	Motor controller IC GND pin: signal ground (SG)
15	GND2	External $R_S$ GND-side connection pin: power ground (PG)
16	$V_{ref2}$	Current limiter set pin: $0.1V_{cc2}$ when open
17	$V_S$	External $R_S$ current limiter detect pin
18, 19	$V_{RS}$	External $R_S$ connect pin
20, 21	U	Output pin (to motor winding)
22, 23	V	Output pin (to motor winding)
24, 25	W	Output pin (to motor winding)
26, 27	$V_{cc1}$	Supply voltage pin (to motor)
28	VZ	Zener voltage (6.2V typ) for $V_{cc1}$ driver transistor base source supply

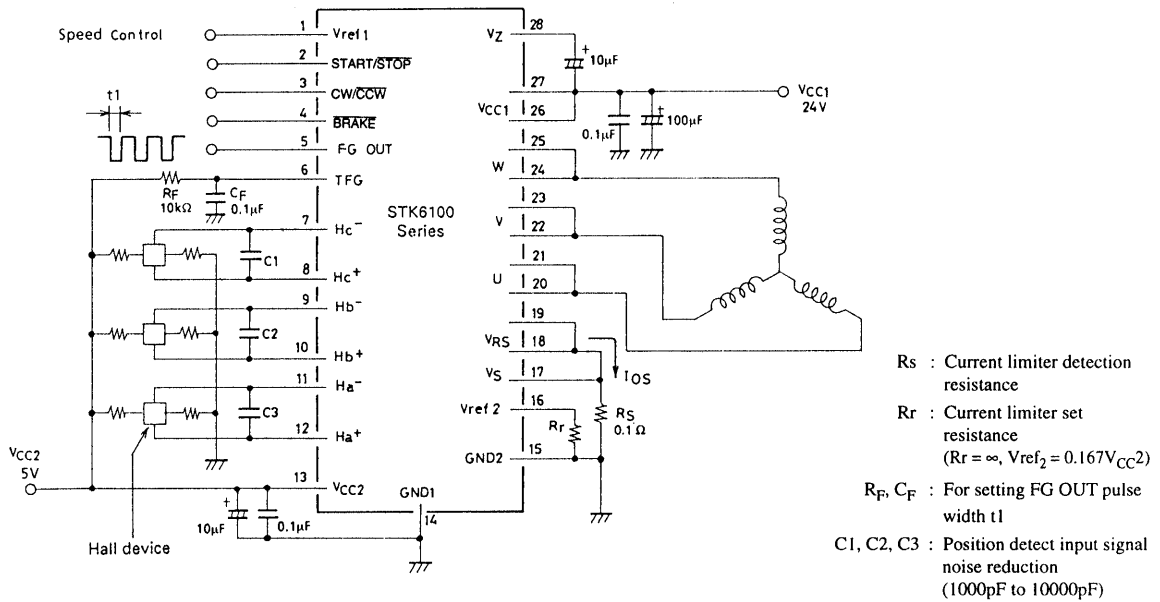
### Input Type

Input pin No.	Type
2 3	
4	

Note 1:  $I_{OB}$  indicates the operating current waveform peak as shown below.



Sample Application Circuit



Description of Operation

The DC 3-phase brushless motor generally uses a permanent magnet for the rotor and places the stator coil around it. When the rotor and stator coil are excited, magnetic force is generated between the poles, which is used for revolution torque. For efficient revolution it is necessary to know precisely where the rotor pole is in relation to the stator pole. In the brushless motor Hall devices and Hall ICs are widely used for this purpose, by detecting the electric power generated along the lines of magnetic force.

(1) Motor rotating force

The block diagram for this HIC is given in Fig. 2.

The conditions before input of V<sub>CC1</sub>, with V<sub>CC2</sub> on, are START/STOP pin H level, CW/CCW pin H level, BRAKE pin H level and Vref<sub>1</sub> pin (speed control input) H level. The position detect signal at this time, due to the effect of the rotor magnetic field, will be output signals from 1 or 2 devices (of the 3) so that H<sub>x+</sub> > H<sub>x-</sub> is input to HIC pins 7 to 12. The signals input to pins 7 to 12 are input to the motor controller and converted into signals compatible with 3-phase brushless motor revolution. When V<sub>CC1</sub> is supplied the charge pump circuit activates, generating V<sub>CC1</sub> MOSFET gate voltage V<sub>Z</sub>. This outputs excitation current to the motor phase windings as indicated in the timing chart (Fig. 3), and rotating the motor.

For revolution speed control, the Vref<sub>1</sub> pin voltage is converted and used for PWM drive to increase GND transistor efficiency, controlling the conduction of motor current I<sub>o</sub> (Fig. 1). Control of I<sub>o</sub> means control of power supplied to the motor, which controls motor rpm. In general motor rpm N is proportional to the PWM on duty (when motor load is constant). The PWM on duty is proportional to the size of Vref<sub>1</sub> (see Fig. 13), and the relation of N is as outlined below.

$$N \propto \text{PWM ON Duty} \propto V_{ref1}$$

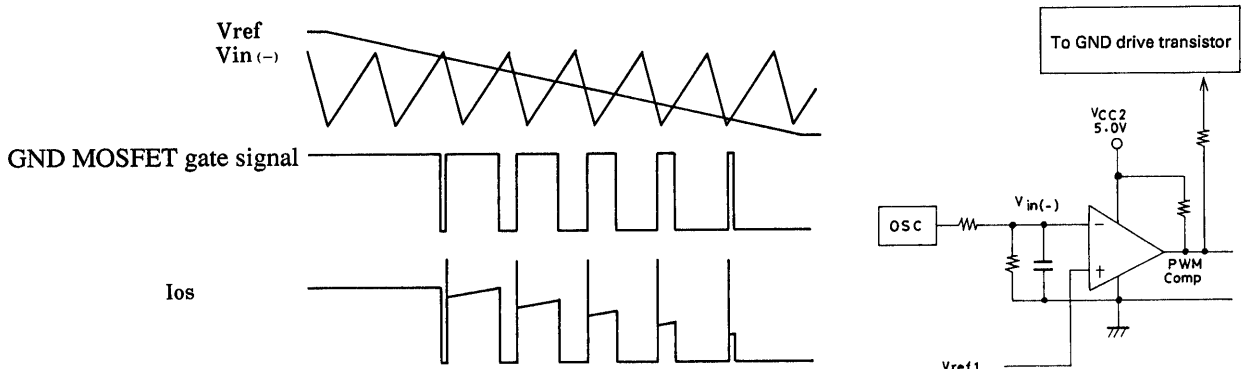
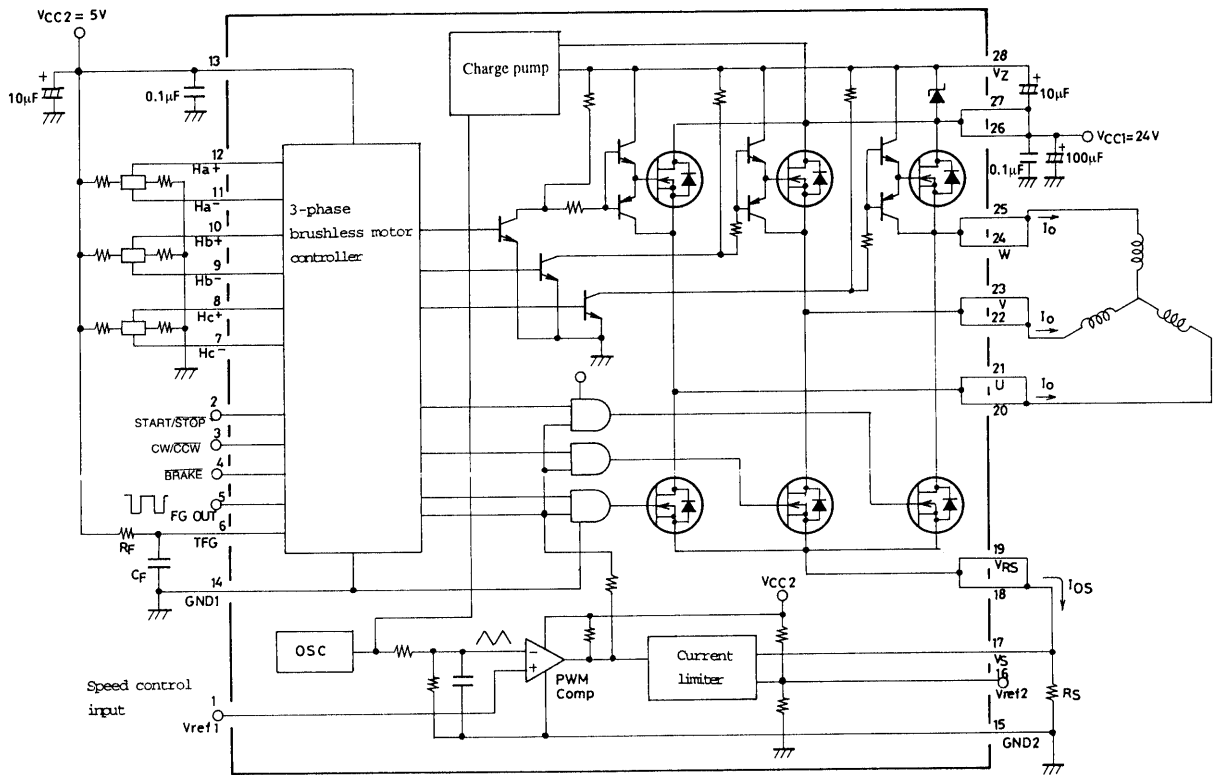


Fig.1 PWM Drive Principle

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Motor revolution is stopped by setting  $\overline{\text{START/STOP}}$  to L level to turn off all drive transistors, and cut the supply of current to the motor. Motor inertia will prevent instantaneous stopping. The brake function works to shorten the amount of time needed to come to a complete stop. In input level L the  $V_{CC1}$  driver transistor is turned off, all GND driver transistors are turned on, and the amount of power generated by the rotating motor windings reduced to reduce the rpms. This brake function has priority over all  $\overline{\text{START/STOP}}$ ,  $\overline{\text{CW/CCW}}$  and position detect input conditions.



**Fig. 2 Block Diagram**

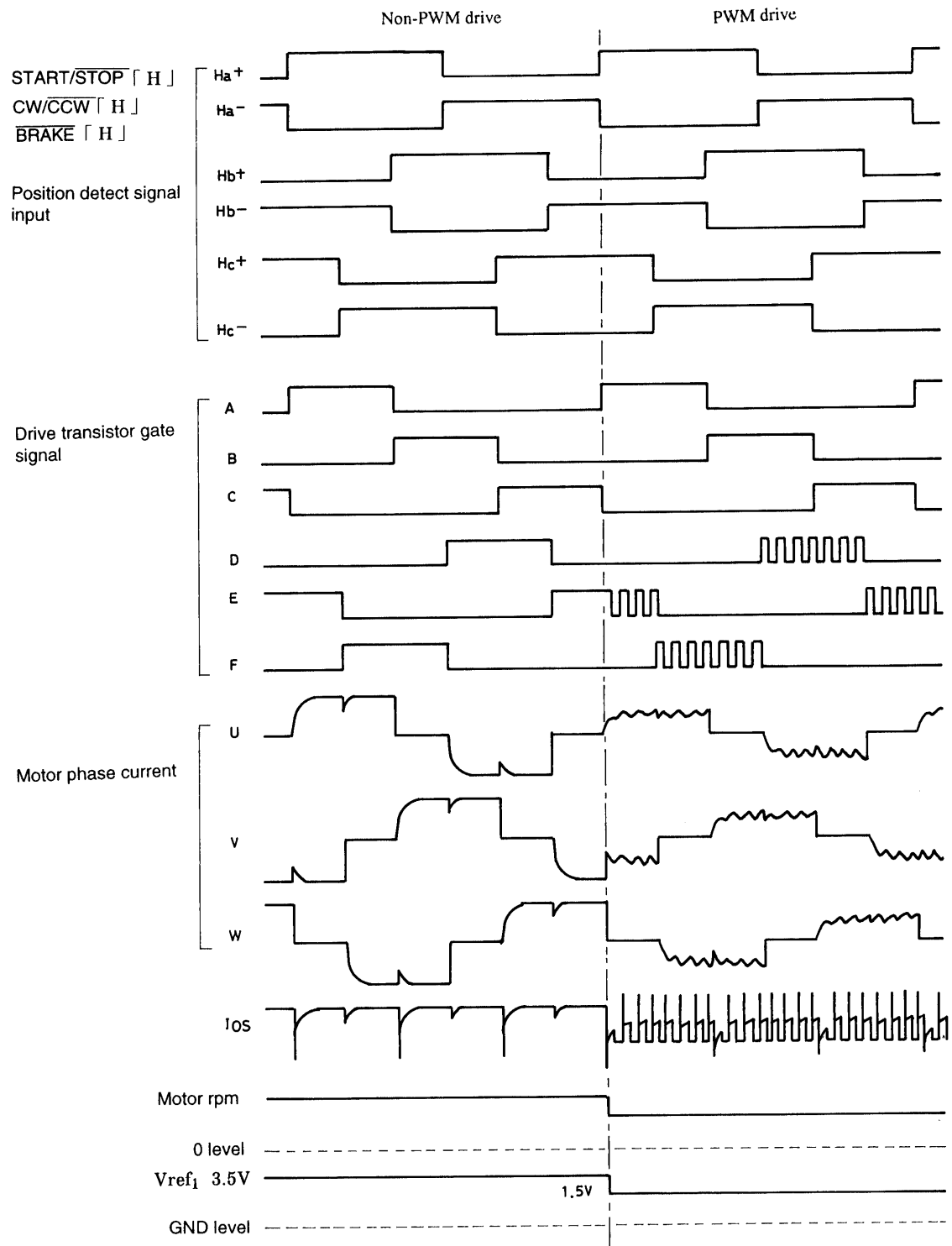


Fig. 3 I/O Timing Chart

(2) Other functions

① CW/CCW

The direction of motor revolution can be selected by setting the input level to H or L. CW is H level and CCW is L level. The CW timing chart is indicated in Fig. 3, and the CCW timing chart in Fig. 5.

② Current limiter function

The current limiter converts the GND driver transistor source current into  $V_{RS}$  through the external  $R_S$ , and controls GND driver transistor conduction based on a comparison of this voltage to  $V_{ref2}$ .  $V_{ref2}$  generates a  $0.1 V_{CC2}$  voltage in pin open state.  $V_{ref2}$  is generated by the voltage division between 27 kΩ and 3 kΩ resistances, and so the  $V_{ref2}$  level can be readily reduced by attaching an external resistor. To prevent HIC destruction in the event of motor lock, a current limiter can be enabled by setting  $V_{ref2}$  at or below  $I_o$  ave. If no such protection is required, set  $V_{ref2}$  between  $I_o$  max and  $I_o$  ave to limit rush current.

③ FG OUT

This pin outputs a square wave pulse proportional to one motor revolution, which can be used as the motor servo-control PLL IC FG input signal. The square wave L level time  $t_1$  is set by the time constant of  $C_F$  and  $R_F$  connected to the TFG pin (Fig. 4).

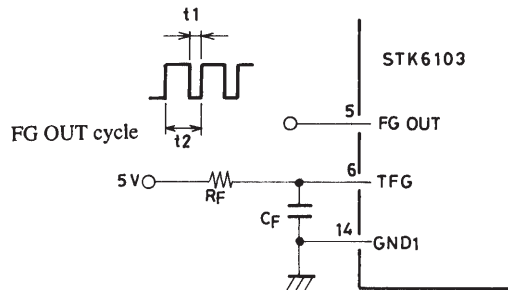


Fig. 4

In general, when the n-pole 3-phase brushless motor fixed-speed rpm is expressed as N(rpm), the setting for  $t_1$  so that  $t_1 = 0.5 t_2$  is given by expression ①.

$$t_1 = \frac{1000}{\frac{N}{60} \times 6 \times \frac{n}{2}} \times 0.5 \quad [\text{ms}] \dots\dots\dots \text{①}$$

The relation between  $C_F$ ,  $R_F$  and  $t_1$  is given by expression ②.

$$t_1 \approx a \cdot R_F \cdot C_F \dots\dots\dots \text{②}$$

$$\text{However, } a = 1 \left( \frac{s}{\Omega \cdot F} \right), R_F = 3 \text{ k}\Omega \text{ to } 30 \text{ k}\Omega, t_1 > 50 \mu s$$

Expression ① is designed to be half that of fixed speed  $t_2$ , but when an FV conversion circuit is connected to the FG OUT pin, it is necessary to reduce the duty to under 50%. In this case, adjust  $R_F$  or  $C_F$  as needed.

(3) Precautions in drive

① Start current (rush current)

The motor start  $R_s$  current waveform is shown in Fig. 6. Current peak  $I_{OH}$  must not exceed  $I_o$  max.

② Position detect signal

Because signal input sensitivity  $V_H$  is  $\pm 500$  mV max, the level of the output signal (open collector) from the Hall IC must be reduced through conversion. A sample of this circuit is shown in Fig. 7. The position detect signal must be compatible with the motor phase winding even in the time chart state shown in Fig. 3, or the motor may not revolve smoothly.

③ Motor phase winding current during braking

The motor phase winding current during braking must not exceed  $I_o$  max even during peak, although several times set current levels are input.

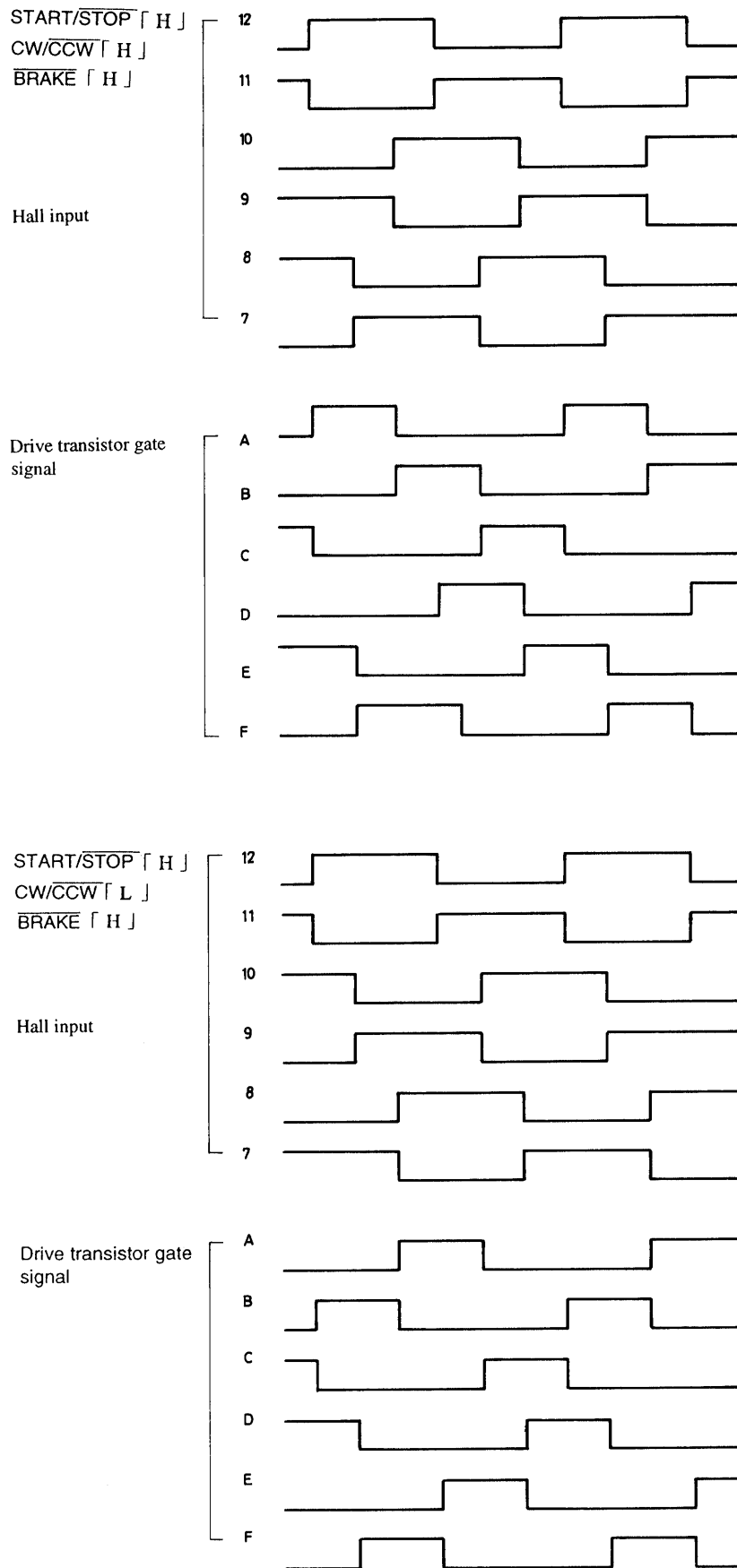


Fig. 5 CW/CCW I/O Timing Chart



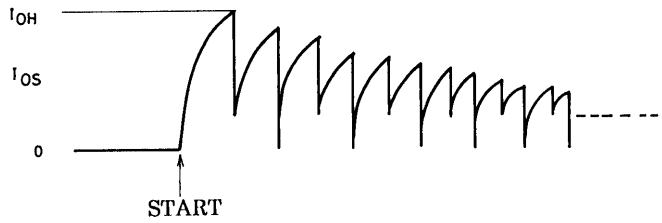


Fig.6 Starting Current

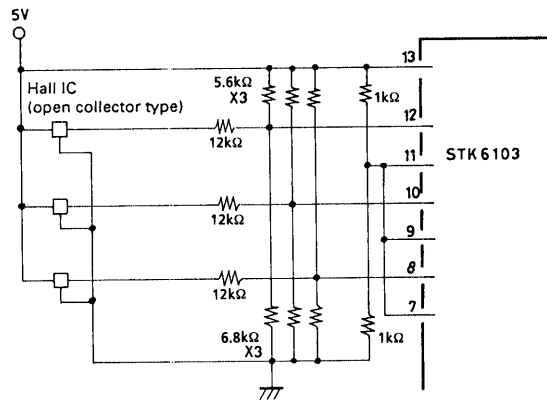


Fig.7 Conversion Circuit for Hall IC and Hall Device Signal

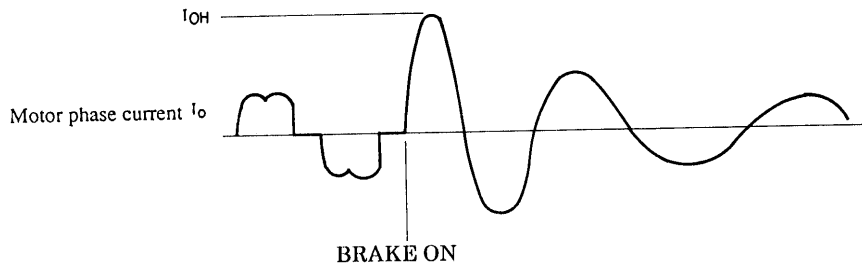


Fig.8

**Thermal Radiation Design**

(1) Internal average power dissipation Pd

The driver transistors represent the majority of the power dissipation in operation. Other losses are \$V\_{CC2}\$ and the charge pump circuit. In PWM drive in particular, the diode in the \$V\_{CC1}\$ transistor is being used as a flywheel diode, increasing \$V\_{CC1}\$ transistor loss. When these are included, internal mean power dissipation is:

$$Pd = I_o (V_{st1} + V_F d_2 + V_{st2} d_1) + Pd_A + Pd_B + Pd_C \dots\dots\dots \textcircled{1}$$

- \$I\_o\$ : Motor current
- \$V\_{st1}\$ : \$V\_{CC1}\$ transistor saturation voltage
- \$V\_{st2}\$ : GND transistor saturation voltage
- \$d\_1\$ : GND transistor PWM operation on duty
- \$d\_2\$ : GND transistor PWM operation off duty
- \$Pd\_A\$ : \$V\_{CC2}\$ loss
- \$Pd\_B\$ : Charge pump circuit loss
- \$Pd\_C\$ : GND transistor switching loss
- \$V\_F\$ : \$V\_{CC1}\$ transistor internal diode normal direction voltage

Because the driver transistor is a MOSFET, \$V\_{st1}\$ and \$V\_{st2}\$ will increase with an increase in \$I\_o\$ or substrate temperature \$T\_c\$.

\$Pd\_A\$ and \$Pd\_B\$ are generally given as:

$$Pd_A \approx V_{CC2} \times I_{CCO1} \dots\dots\dots \textcircled{2}$$

$$Pd_B \approx V_{CC1} \times (0.49V_{CC1} - 4.2) \times 0.001 \dots\dots\dots \textcircled{3}$$

where, \$V\_{CC1} = 16\$ to \$42V\$

Refer to Figs. 11 to 14 for data on \$V\_{st1}\$, \$V\_{st2}\$, \$d\_1\$ and \$V\_F\$.

(2) Thermal radiation design

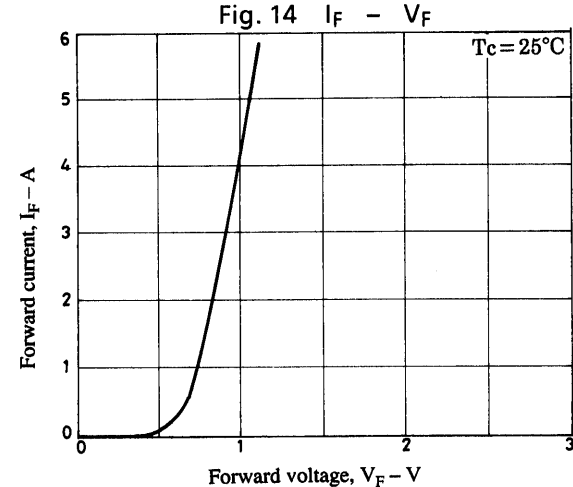
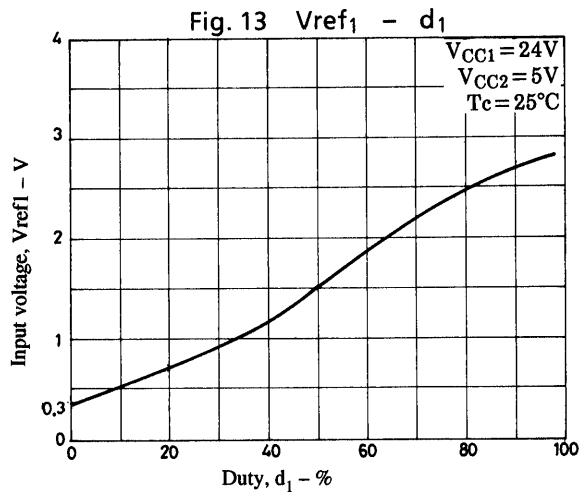
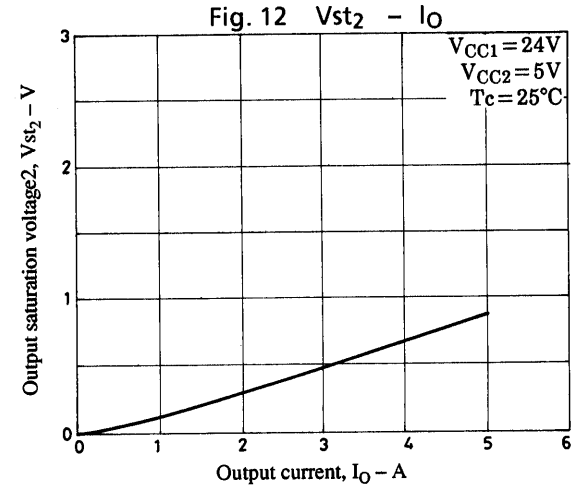
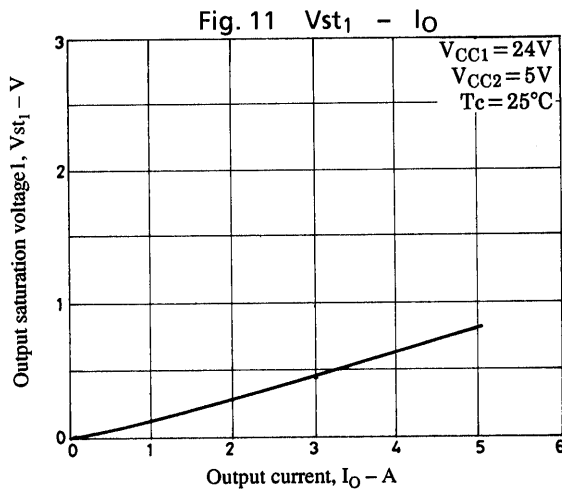
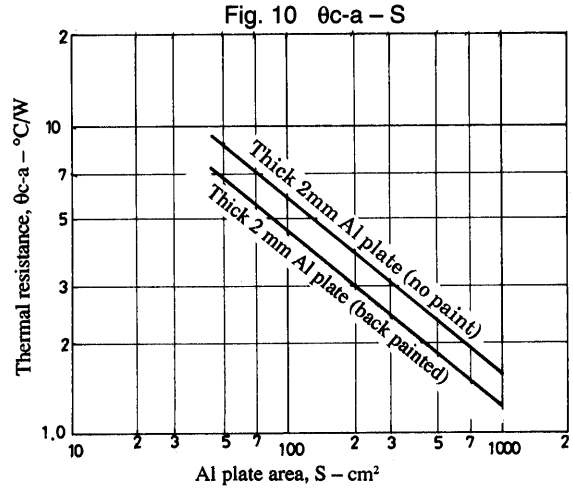
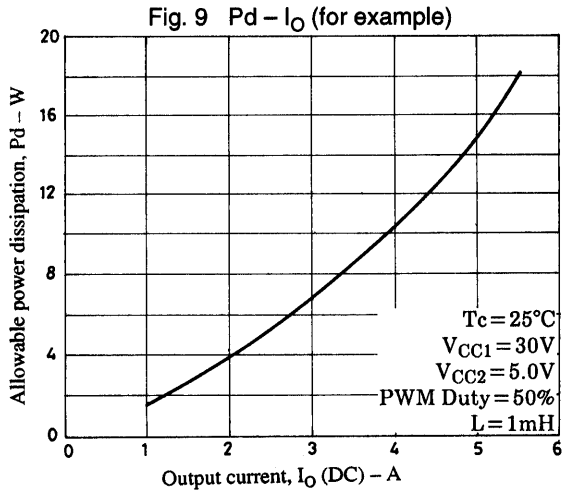
Actual thermal radiation design requires determination of the IC internal average power dissipation Pd from the motor phase current Io (Fig. 9). Pd is then used to determine the thermal resistance for the radiator from the following expression.

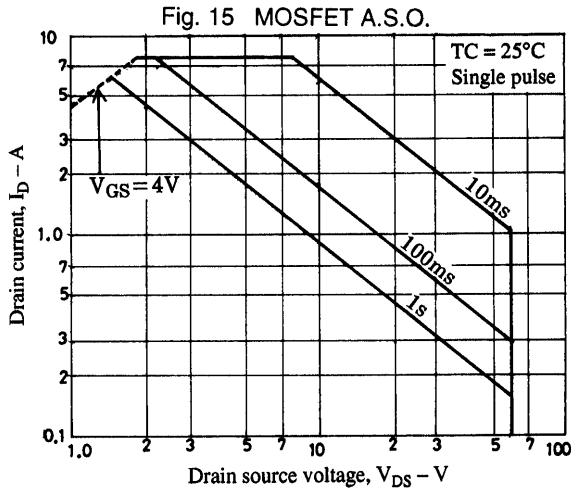
$$\theta_{c-a} = \frac{T_{c \max} - T_a}{P_d} \quad (^\circ\text{C/W})$$

where  $T_{c \max} = 105^\circ\text{C}$

$T_a$  = ambient temperature

With a 2.0 mm radiation plate, the required area can be determined from Fig. 10. Note that substrate temperature will vary widely with set internal air temperature, and  $T_c$  for the mounted state must be  $105^\circ\text{C}$  max.





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