Ordering number: EN2442B

SANYO

No.2442B

Thick Film Hybrid IC

STK6772

Unipolar Constant-Current Driver/Separate excitation type chopper regulator

Four-Phase Stepping Motor Driver
(with Built-in Four-Phase Distributed Controller)

Applications

- Copy machines
- Facsimile carriage
- Pen drivers for X-Y plotters
- Industrial robots, X-Y tables

Features

- Easy driver configuration using DC power supply and clock pulse oscillator
- Built-in four-phased distributed controller simplifies motor driver circuit and control method for single stepper motor drive circuits.
- High torque, low vibration and rapid response characteristics using four-phase, W1-2 excitation drive. (Current value can be set externally.)

[Four-phase distributed controller]

- Four settings according to excitation mode (M1,M2)

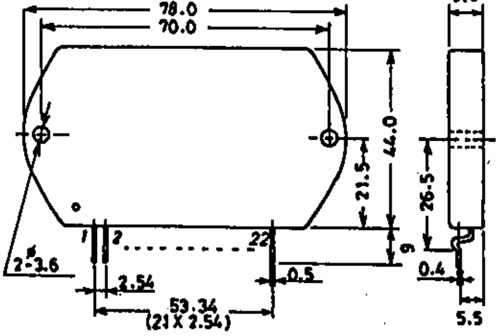
Four-phase, 1 excitaiton	Four-phase, 1-2 excitation
Four-phase, 2 excitaiton	Four-phase, W1-2 excitation

- All input terminals have built-in Schmidt circuits. (High noise margin)
- CMOS and TTL-compatible inputs allow direct control from stepper motor control LSI and I/O ports.
- Intervals in the four-phase 2 excitation A, $\overline{A}$, B, and $\overline{B}$ output signals prevent overcurrent during phase switching.

[Driver circuit]

- Unipolar drive compatible with hybrid, PM and VR-type stepper motors
- Built-in protection from flyback voltage
- Chopping provides excellent motor current rise characteristics and reduces heat dissipation at constant current.
- Built-in current detection resistors
- Built-in pause function

Package Dimensions 4086
(unit : mm)



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TOKYO OFFICE Tokyo Bldg., 1-10, 1 Chome, Ueno, Taito-ku, TOKYO, 110 JAPAN

Maximum Ratings at Ta = 25°C

				unit
Maximum Supply Voltage1	V_{CC} max1	No Signal	30	V
Maximum Supply Voltage2	V_{CC} max2		−0.3 to +7.0	V
Input Voltage	Vi max	For logic input section	−0.3 to +7.0	V
Phase Output Current	I_{OH} max	0.5s, 1 pulse/phase, W = 30mJ	2.5	A
Storage Temperature	Tstg		−40 to +125	°C
Junction Temperature	Tj max		150	°C
Operation Substrate Temperature	Tc max		105	°C

Recommended Operating Conditions at Ta = 25°C

				unit
Supply Voltage1	$V_{CC}1$	Operating mode	18 to 28	V
Supply Voltage2	$V_{CC}2$		5.0±10%	V
Input Voltage	V_{IH}		0 to $V_{CC}2$	V
Phase Current	I_{OH}	Duty 50% max	max 1.7	A

Notes:

- Unused input pins must be connected to GND or V_{DD}.
- Hold current level must be set.
- Permissible flyback energy from system motor, clock and phase current must be set.

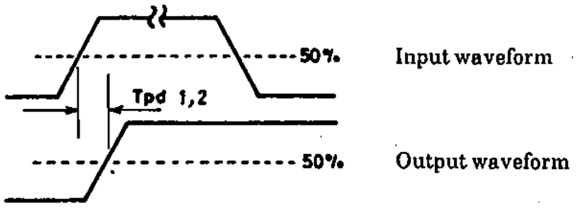
Operating Characteristics at Ta = 25°C, $V_{CC}1$ = 24V, $V_{CC}2$ = 5.0V

			min	typ	max	unit
Input ON-State Voltage	V_{IH}		4.0			V
Input OFF-State Voltage	V_{IL}				1.0	V
Input Leakage Current	I_{IL}		−30		+30	μA
Output Saturation Voltage1	Vst1	Between pins 15 and 7, pins 15 and 14, $R_L = 13\Omega$ Input $V_{IH} = 4.0V$		1.2	1.6	V
Output Saturation Voltage2	Vst2	Between pins 8, 9 and 10, pins 12, 13 and 10, $R_L = 13\Omega$, Input $V_{IH} = 4.0V$		2.5	3.0	V
"H"-Level Output Voltage	V_{OH}	Between pins 1, 2, 3 and 11 $I_{OH} = -0.4mA$	2.4			V
"L" Level Output Voltage	V_{OL}	Between pins 1, 2, 3 and 11 $I_{OL} = 2mA$			0.4	V
Output Current (Average)1	I_O1	Between pins 8, 9 and 7, pins 12, 13 and 14, $R_L = 3.8mH, 3.5\Omega$	0.95	1.05	1.15	A
Chopping Frequency	fc	$I_{OH} = 0.3A$, 270Ω:Pins 4, 5 and GND	20	24	28	kHz
Diode Forward Voltage1	Vdf1	If = 0.3A		1.5	1.8	V
Diode Forward Voltage2	Vdf2	If = 0.5A		1.2	1.8	V
Non-Operational Current	Icco	Stop Voltage Vs at pin 22 = 2.0V		26	45	mA

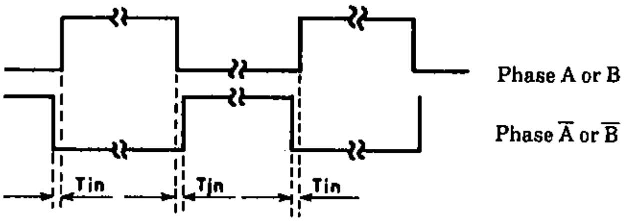
Operating Characteristics at Ta = 25°C, $V_{CC}1$ = 24V, $V_{CC}2$ = 5.0V, C_L = 50pF

			min	typ	max	unit
Delay Time1	Tpd1	CLK→ A, $\overline{A}$, B, $\overline{B}$ order		2		μs
Delay Time2	Tpd2	CLK→ C1, C2, C3 order			2	μs
Output Signal Interval	Tin	4-phase 2 excitation mode only	20		40	μs
Maximum Clock Frequency	f_{CLK}				20	kHz

(1) Definition of Tpd



(2) Definition of Tin



(3) Use regurated power supply only.
(4) During operation, the 5V power supply should be stabilized before 24V power system rises. Otherwise, a protective circuit which prevents circuit operation until 5V power system stabililizes should be provided.

Functions

(1) Operation mode

Item	CW/CCW	START/STOP
CW	L	L
CCW	H	L
STOP	X	H

X : Don't care

(2) Excitation mode

Item	M1	M2
4-phase 1 excitation	L	L
4-phase 2 excitation	H	L
4-phase 1 -2 excitation	L	H
4-phase W1 -2 excitation	H	H

(3) Timing charts for excitation mode

4-phase 1 excitation	···Fig.7
4-phase 2 excitation	···Fig.8
4-phase 1-2 excitation	···Fig.9
4-phase W1-2 excitation	···Fig.10

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② Not impose any responsibility for any fault or negligence which may be cited in any such claim or litigation on SANYO ELECTRIC CO., LTD., its affiliates, subsidiaries and distributors or any of their officers and employees jointly or severally.

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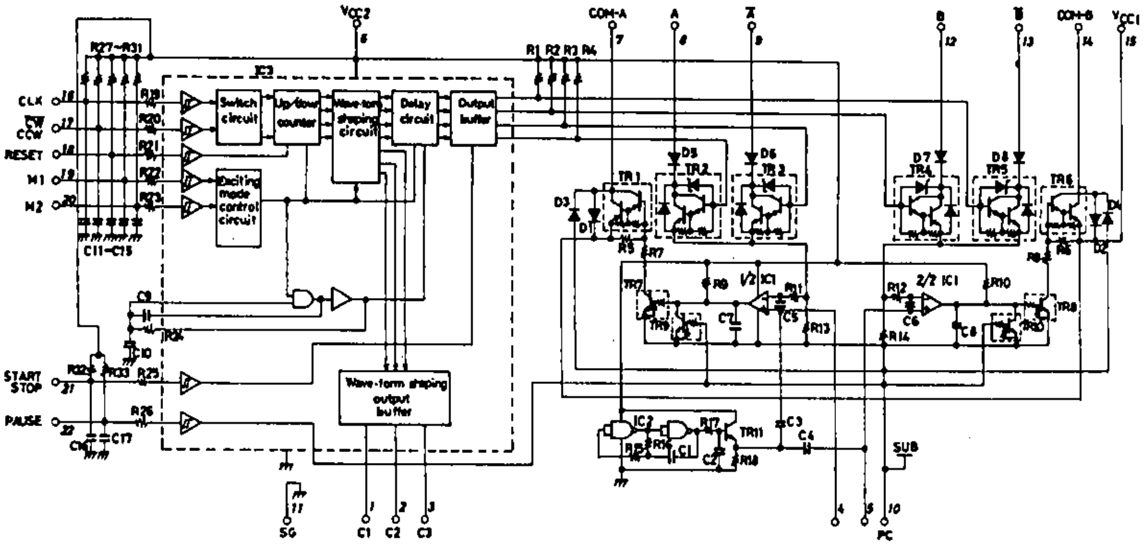
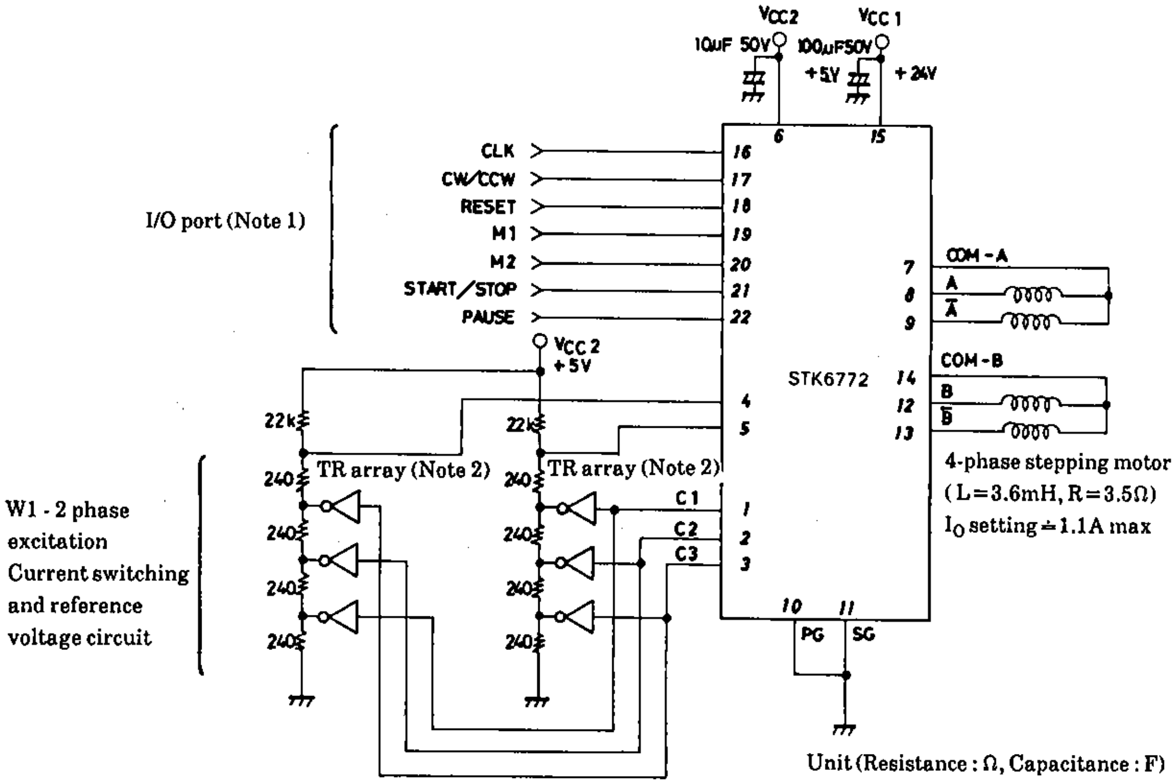
Equivalent Circuit Diagram



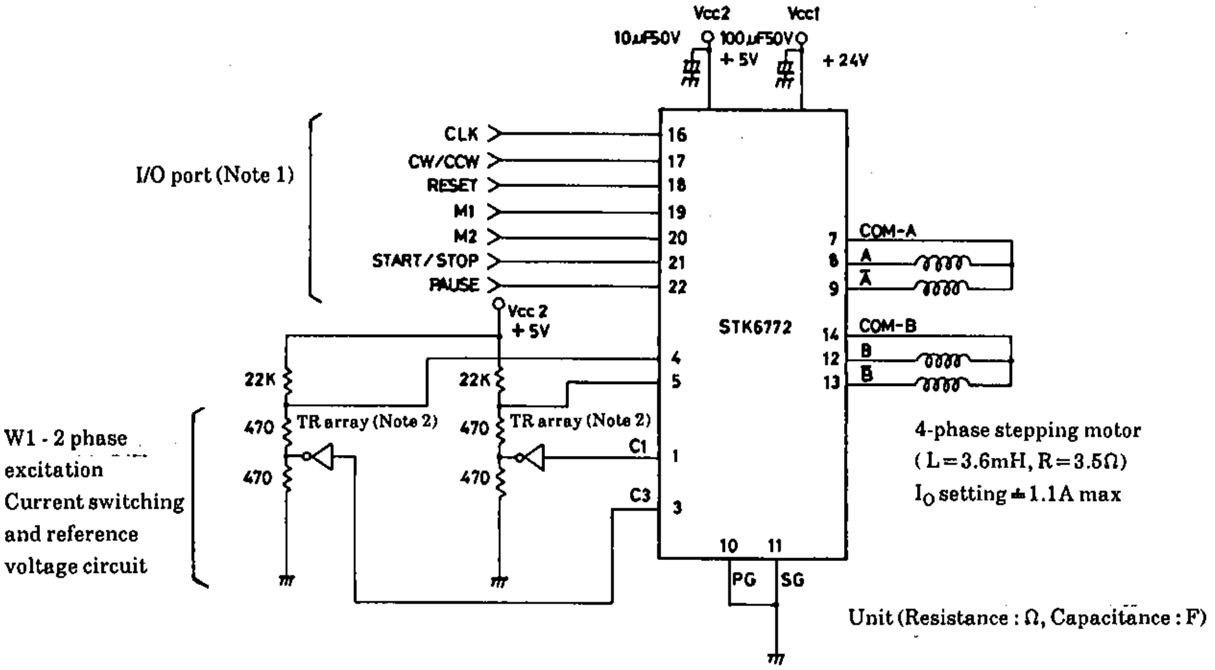
Sample Application Circuit 1 (4-stage current switching, W1-2 phase excitation)



Unit (Resistance : Ω, Capacitance : F)

Note 1 : See Functions and Timing Charts for I/O port signals.
Note 2 : Transistor array
Sanyo LB1213 or LB1214 or equivalent are recommended.

Sample Application Circuit 2 (2-stage current switching, W1-2 phase excitation)



Note 1 : See Functions and Timing Charts for I/O port signals.
Note 2 : Transistor array
Sanyo LB1213 or LB1214 or equivalent are recommended.

Operation Description

1. Constant current chopper drive

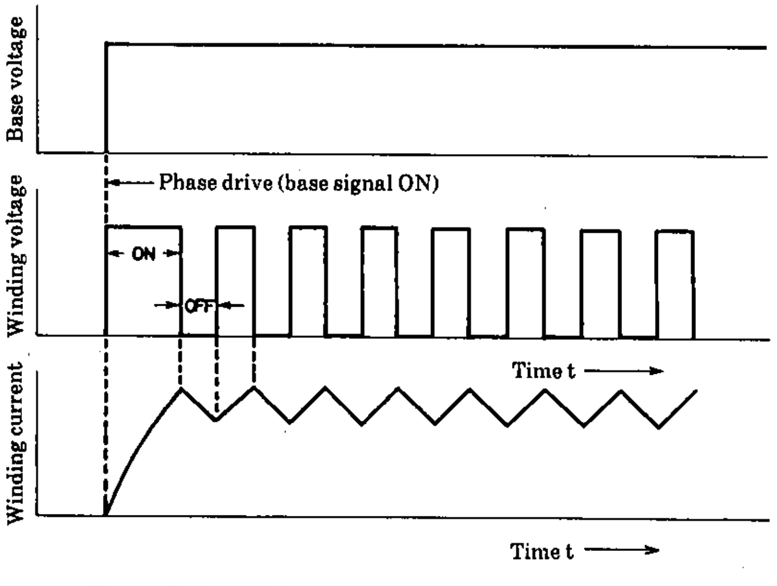


Fig. 1 Pulse Width Modulation and Winding Current

(a) Fig.1 shows constant current chopper driving using PWM (pulse width modulation). When phase drive is ON, the winding current slowly increases as the result of the winding resistance and inductance of the motor. At the point where the set current (that is the motor's rated current) is reached, the voltage applied to the windings is switched on and off, stabilizing the winding current increase. (See section 1-2 for further details.)

Although chopper driving is more efficient than constant voltage driving using serial resistors (approximately 30% better under certain conditions), noise is generated as the result of the switching operation. Two PWM methods are in use: self-excited PWM and externally-excited PWM.Externally-excited PWM requires an oscillator and other circuit. Self-excited PWM, however, makes use of the motor's winding resistance and inductance. This obviates the need for an oscillator and results in a simpler circuit.

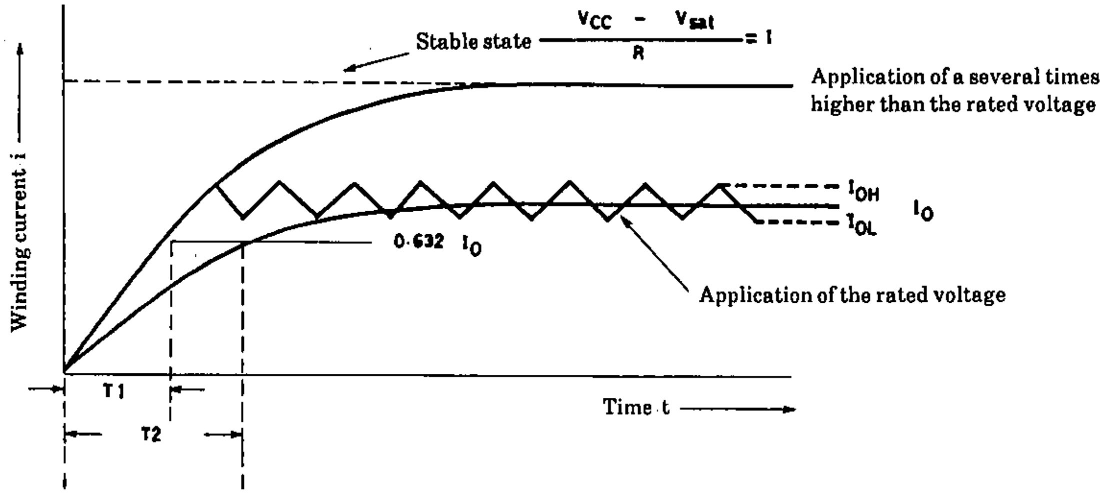


Fig.2 Constant Current Chopper Drive

(b) Fig.2 shows the winding current when the rated voltage is applied and also at several times higher than the rated voltage. For example, if the time to reach 63.2% of the rated current I_O in both cases is T1 and T2, respectively, T1 is shorter than T2 and the rise time to the winding current is faster, giving rapid motor response characteristics. Note that T2 represents the time constant of the L/R series circuit when the rated current is applied.

(c) As stated above, rapid response characteristics can be obtained by applying voltage higher than the rated voltage of the motor. However, this results in over-current until the stable state as shown in Fig.2 is reached, unless a constant current circuit is provided. In order to generate the chopper action at a value lower than the stable state shown in Fig.2, a winding resistance and rated current satisfying the following conditions should be selected.

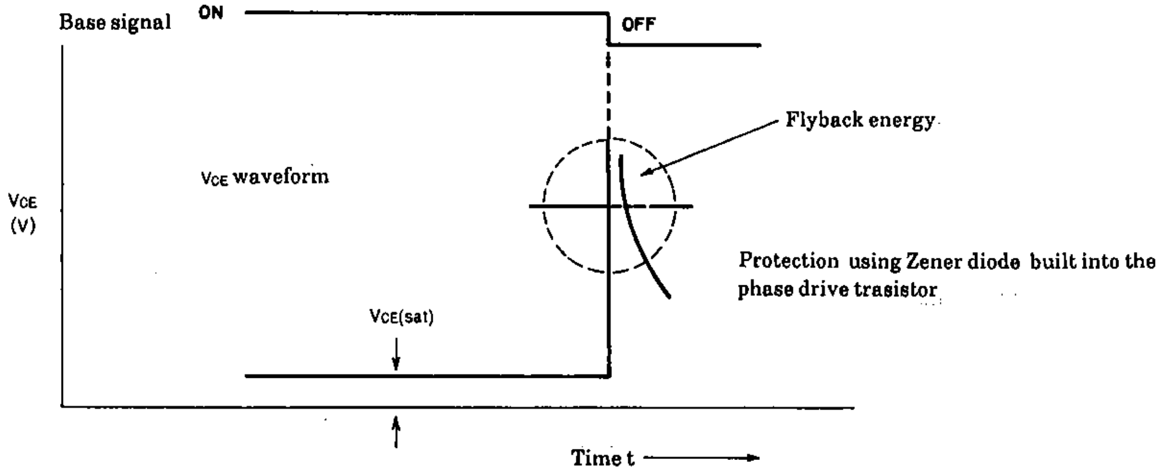
$$I_O < \frac{V_{CC} - V_{sat}}{R} \quad \cdots\cdots\cdots\cdots ①$$

R: The winding resistance and R_E1 of one phase
Vsat: Vst1 + Vst2

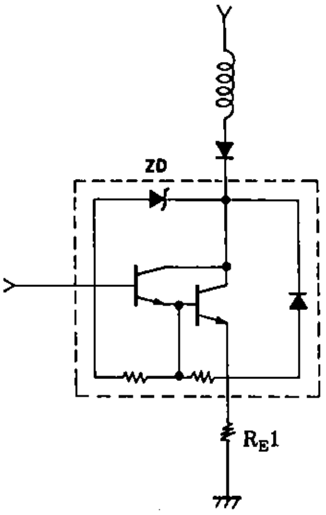
However, at a high winding inductance value, flyback energy from the motor will increase and, consequently, the loss when each phase drive transistor is turned off will be large. Thus, while taking the considerations in sections (b) and (c) above into account, a motor that meets the following specifications is recommended.

Motor specifications (4-phase unipolar stepping motor)
  Rated current: 1.0 ± 0.5A/phase
  Winding resistance: Less than 10Ω/phase
  Inductance: 1 to 10mH/phase

(d) Protection of phase drive transistors
The V_{CE} waveform of the phase drive transistors are shown below.



Phase drive transistor



The phase drive transistors protect themselves by absorbing the energy cut off by the Zener diode.

2. Externally-excited chopper drive section

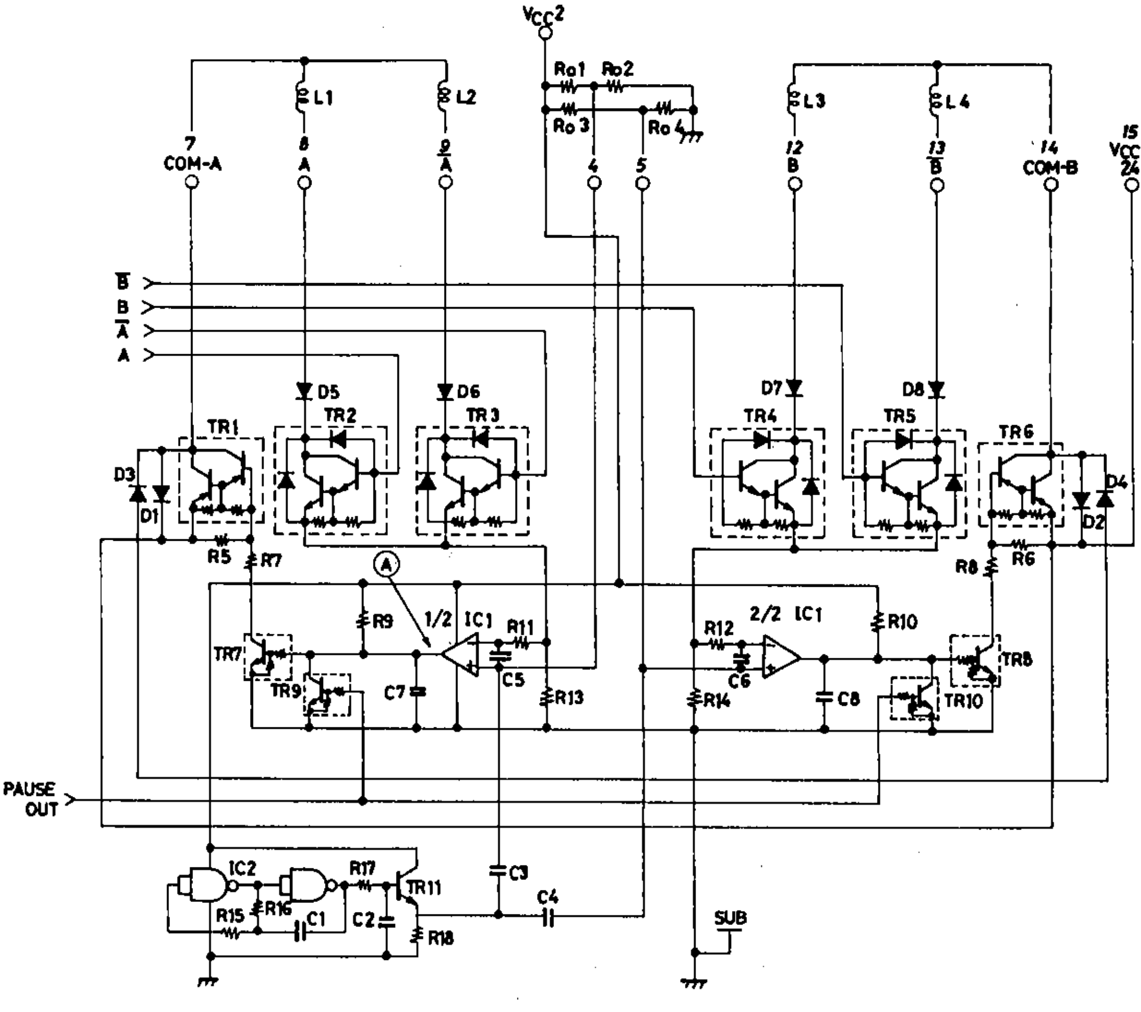


Fig.3 Driver Section Equivalent Circuit

High- and Low-level inputs are each applied to the bases of TR2 and TR3, respectively, for the A and $\overline{A}$ phases. TR2 turns on. However, as the negative terminal of the comparator (1/2 IC1) is at ground potential, its output (point Ⓐ) goes HIGH and TR7 turns on. This activates TR1 and the A winding current increasas according to the following equation.

$$i = \frac{VCC - Vsat}{R} \left(1 - \varepsilon^{-\frac{t}{\tau}}\right) \cdots\cdots\cdots\cdots\cdots\cdots ②$$

Continued on next page.

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In this equation, τ is equal to the time constant L/R.
L: The winding inductance of the first phase of the motor
R: The winding resistance and emitter resistance of the first phase of the motor

$V_{sat} = V_{sat}(1) + V_{sat}(2)$
$V_{sat}(1)$: $V_{CE\,(sat)}$ of chopper TR (TR1, 6)
$V_{sat}(2)$: $V_{CE\,(sat)}$ of phase driver TR (TR2, 3, 4, 5) and the Vdf of output diodes (D5, 6, 7, 8)
V_{CC}: Power supply voltage

The voltage at both sides of emitter resistor R13 increases, and when this approximates the triangular waveform of the set voltage, point Ⓐ goes LOW. TR7 turns off, deactivating TR1.
The point where this comparator output goes from HIGH to LOW is called the upper trip point, and this voltage is represented as V_{UTP}. V_{UTP} can be expressed by the following experimental equation.

$$V_{UTP} = k\left(\frac{Ro2}{Ro1 + Ro2}\right) \times V_{CC}2 \cdots\cdots④$$

However, as K is a proportional constant, it can be thought of as approximating "1", giving the following:
$V_{CC}2 = +5V$

Next, the comparator output goes LOW and TR1 turns off, causing the winding current to decrease according to the following equation.

$$i = \frac{V_{CC} - V_{sat}}{R} \times \varepsilon^{-\frac{t}{\tau}} \cdots\cdots⑤$$

Then, when the voltage at pin ④ reaches a certain value, the comparator output again goes HIGH, TR turns on, and the current begins to increase again. This operation is then repeated.
The point at which the comparator output goes from LOW to HIGH is called the low trip point, and this voltage is represented by V_{LTP}. Thus, in externally-excited PWM operation, the triangular wave level is slid to the reference voltage pins ④ and ⑤, and the level is compared with the arbitrary voltage occurring at the current detection resistance. The comparator output is reversed repeatedly between the V_{UTP} and V_{LTP} voltages of the triangular wave level according to the hysteresis voltage width input to pins ④ and ⑤, and constant current operation is obtained by switching TR1 on and off.

3. Control logic

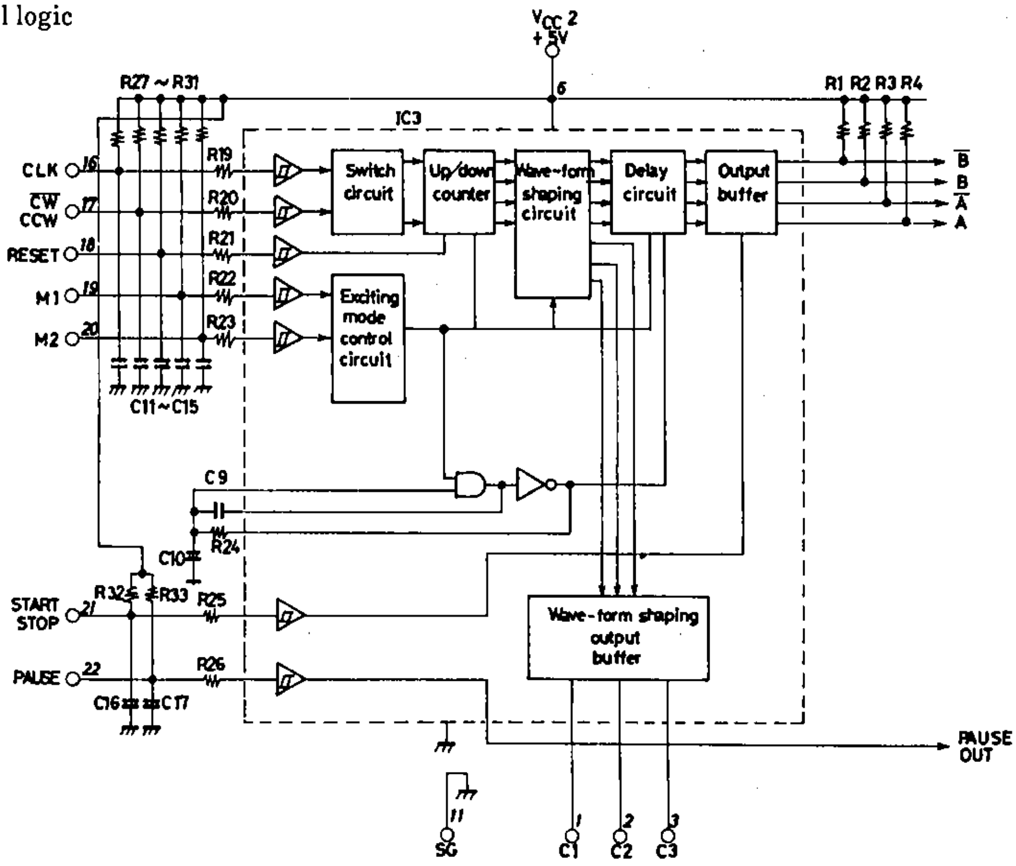


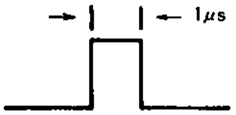
Fig.4 Block Diagram of Control Section

The control logic section built into the STK6772 is a dedicated IC incorporating a number of features designed to simplify stepper motor operation.

Features of control logic section

- These include the selection of four settings according to excitation mode (M1, M2)

  4-phase 1 excitation, 4-phase 1-2 excitation
  4-phase 2 excitation, 4-phase W1-2 excitation
- Schmidt circuit on all input terminals (High noise margin)
- CMOS and TTL-compatible inputs allow direct control from stepper motor control LSI and I/O ports.
- Intervals in the four-phase 2 excitation A, $\overline{A}$, B and $\overline{B}$ output signals prevent overcurrent during phase switching.
- Control logic that operates at the falling edge of the pulses. Input pulse width is 1μs or greater.



The logic timing charts for each of the excitation modes are shown in Fig.7 through 10, and the functions of each of the input terminals are shown in Functions.

4. Current setting equations

The STK6772 provides a triangular wave constant current chopper drive using externally-excited PWM. The average output current I_O can be experimentally approximated using the following equation.

$$I_O \doteqdot \frac{V_{ref}}{R_E} \quad (A) \cdots\cdots ⑥$$

where $$V_{ref} = \frac{R_{O2}}{R_{O1} + R_{O2}} \times V_{CC2} \ (V) \cdots\cdots ⑦$$

$$R_E = 0.2\Omega \pm 5\%$$

Note, however, that the value of I_O will vary slightly according to the type of motor used, its inductance and other characteristics. Thus, the value of I_O should be adjusted to the level required.

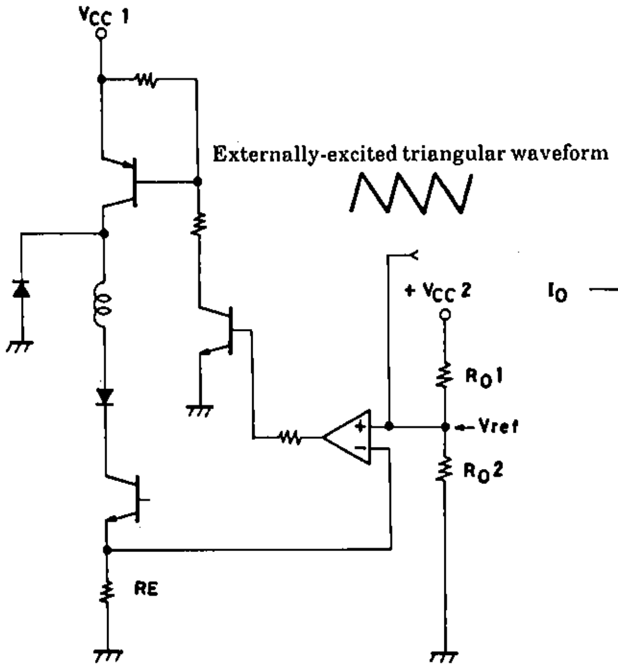


Fig.5 Internal Equivalent Circuit

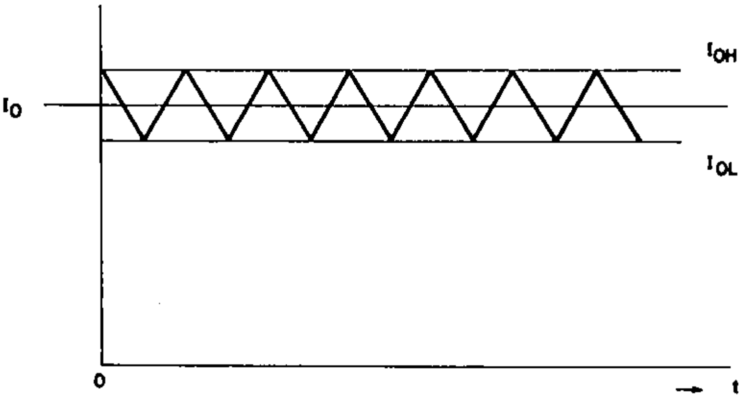


Fig.6 Current Waveform of I_O Settting during Hold State

5. W 1-2-phase excitation current switching
   The STK6772 uses control logic section outputs C1, C2 and C3 to allow current switching of four stages. When the circuit is used with W1-2 phase excitation mode, a low-saturation transistor array must be used for the components which switch the Vref voltage. Sanyo LB1213 and LB1214 are recommended, and are used in the Sample Application Circuit. Further, the use of a V_{CE} saturation transistor array rated at approximmately 10mV at $I_C = 100\mu A$ between the transistor array OUT terminal and GND is recommended under certain operating conditions. When I_O can be switched at a low setting current using the four-stage current switching of the W1-2 phase excitation mode, extreme caution must be taken regarding setting as the I_O waveform is liable to change according to saturation of the externally-mounted Vref switching element.

Fig.7 Timing Chart for 4-phase 1 Excitation Mode

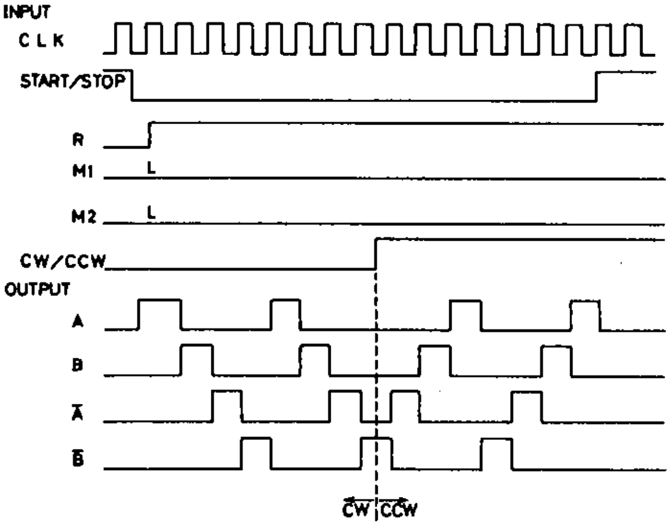


Fig.8 Timing Chart for 4-phase 2 Excitation Mode

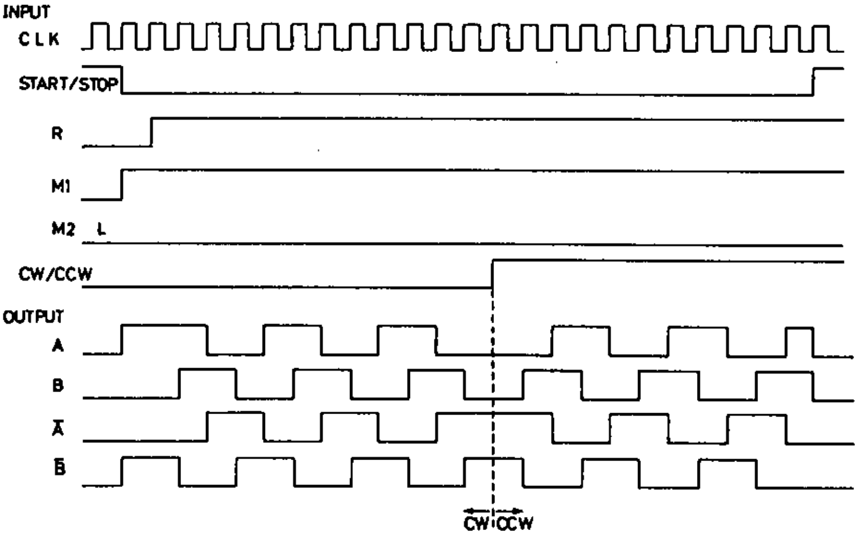


Fig.9 Timing Chart for 4-phase 1-2 Excitation Mode

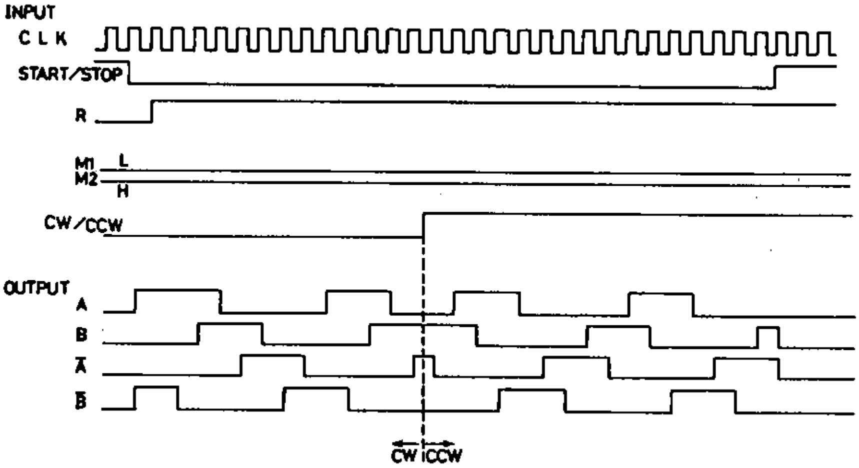
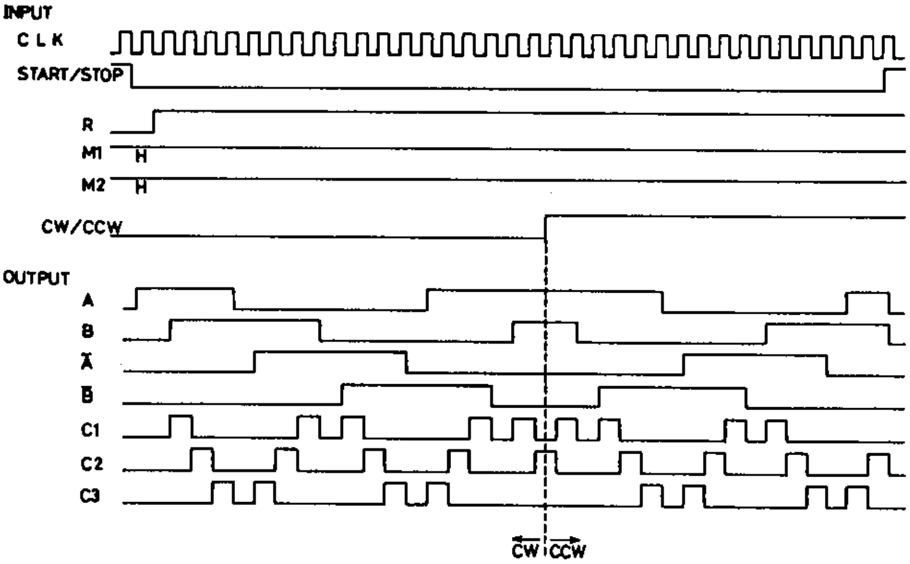


Fig.10 Timing Chart for 4-phase W1-2 Excitation Mode



Heat Dissipation

1. Internal average power dissipation Pd

   Internal components which have a high average power dissipation are the following devices: PNP transistors (TR1, 6), phase driver NPN transistors (TR2, 3, 4, 5), diodes (D5, 6, 7, 8) connected in parallel to the phase drive transistors, and flywheel diodes (D3,4) and current detection resistors (R13, 14).

   As the power dissipation of the other components is extremely small, the equation for calculating Pd within the STK6772 can be expressed as follows:H.I.C internal power dissipation (Pd) = PNP transistor switching loss + NPN transistor switching loss + output diode forward drop loss + flywheel diode loss + flyback energy protection loss + current detection resistor loss.

   The value of Pd should be obtained for each excitation mode. In the case of 2 phase excitation, 1-2 phase excitation, and 1 phase excitation modes, this can be done by assuming the current waveform shown in the figure at next page.

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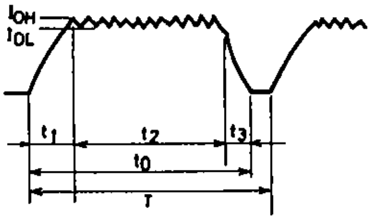
Motor COM Current Waveform at Terminal



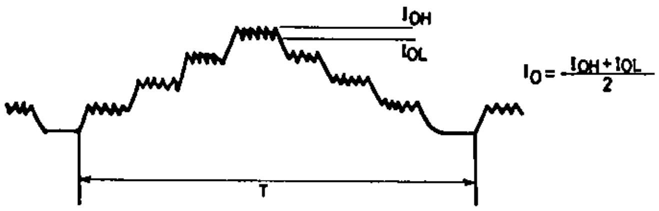
t_1 : motor coil current rise time
t_2 : constant current chopping time
t_3 :phase drive transistor flyback energy absorption time

External input $CLK=\frac{1}{T}$: fclock (Hz)

$$Io=\frac{IOH+IOL}{2}$$

The current waveform for the W1-2 excitation mode can be obtained by assuming the staged waveform shown below.

W1-2 Phase Motor COM Current Waveform
(motor current of 4 step switching)



2. Internal average dissipation equations for each excitation mode

(a) 1 phase excitation

$$Pd(1EX)\fallingdotseq\underbrace{\frac{3}{2}\cdot fclock\cdot Io\cdot Vst1\cdot(0.5t1+0.25t2)}_{\text{ⓐ}}+\underbrace{fclock\cdot Io\cdot Vst2\cdot(0.5t1+0.5t2)}_{\text{ⓑ}}$$
$$+\underbrace{\frac{1}{4}\cdot fclock\cdot Io\cdot Vdf2}_{\text{ⓒ}}+\underbrace{\frac{1}{2}\cdot fclock\cdot Io\cdot Vz\cdot t3}_{\text{ⓓ}}\cdots\cdots\text{⑧}$$

(b) 2 phase excitation

$$Pd(2EX)\fallingdotseq\frac{3}{2}\cdot fclock\cdot Io\cdot Vst1\cdot(0.5t1+0.5t2)+fclock\cdot Io\cdot Vst2\cdot(0.5t1+t2)$$
$$+\frac{1}{2}\cdot fclock\cdot Io\cdot Vdf2\cdot t2+\frac{1}{2}\cdot fclock\cdot Io\cdot Vz\cdot t3\cdots\cdots\text{⑨}$$

(c) 1-2 phase excitation

$$Pd(1\text{-}2EX)\fallingdotseq\frac{9}{32}\cdot fclock\cdot Io\cdot Vst1\cdot(0.5t1+0.5t2)+\frac{3}{16}\cdot fclock\cdot Io\cdot Vst2\cdot(0.5t1+t2)$$
$$+\frac{3}{32}\cdot fclock\cdot Io\cdot Vdf2\cdot t2+\frac{3}{64}\cdot fclock\cdot Io\cdot Vz\cdot t3\cdots\cdots\text{⑩}$$

(d) W1-2 phase excitation

$$Pd(W1\text{-}2EX)\fallingdotseq\frac{21}{512}\cdot fclock\cdot Io\cdot Vst1\cdot(t1+t2)+\frac{7}{256}\cdot fclock\cdot Io\cdot Vst2\cdot(t1+2t2)$$
$$+\frac{7}{128}\cdot fclock\cdot Io\cdot Vdf2\cdot t2+\frac{7}{64}\cdot fclock\cdot Io\cdot Vz\cdot t3\cdots\cdots\text{⑪}$$

where: Vst 1 is the saturation voltage of pins 15 to 7, and 14.
Vst 2 is the saturation voltage of pins 10 to 8, 9, 12, and 13.
f_{clock} is the input signal frequency to pin 16

Notes:

(1) Definition of t2 for each excitation mode

Excitation Mode	Equation for Calculating t2
1 phase excitation	$t2 = \frac{2}{f_{clock}} - t3 - t1$
2 phase excitation	〃
1-2 phase excitation	$t2 = \frac{8}{f_{clock}} - t1$
W1-2 phase excitation	$t2 = \frac{16}{f_{clock}} - t1$

(2) The internal average dissipation for each excitation mode consists of a four term equation. The following is an example of equation ⑧ :

The first term ⓐ is the average dissipation (for two devices) of the PNP transistors (TR1,6).

The second term ⓑ is the average dissipation of NPN transistors (TR2,3,4,5) + phase diodes (D5,6,7,8) + current detection resistance (four pairs for each transistor/diode).

The third term ⓒ is the average dissipation (for two devices) of the flywheel diodes (D3,4).

The fourth term ⓓ is the average dissipation (for four devices) of the protective Zener diodes built into the NPN transistors.

The Pd calculation equations ⑨ through ⑪ for the various excitation modes are expressed in this order.

Note that as the dissipation of the fourth term ⓓ is the dissipation of the Zener diodes in the NPN transistors. As the NPN transistor dissipation is expressed by the second term ⓑ , care should be taken when calculating Tj, as the overall (four devices) average NPN transistor dissipation is equivalent to the dissipation of the NPN transistors + dissipation of the Zener diode for NPN transistor protection.

(3) t1 and t3

As t1 and t3 vary according to the motor winding inductance, winding resistance, and the voltage applied to motor coil, the motor current should be monitored to confirm these values. The following graphs show examples of the relationship between the motor winding inductance (mH/phase) and rise time t1 (ms), and flyback energy absorption time t3 (ms).

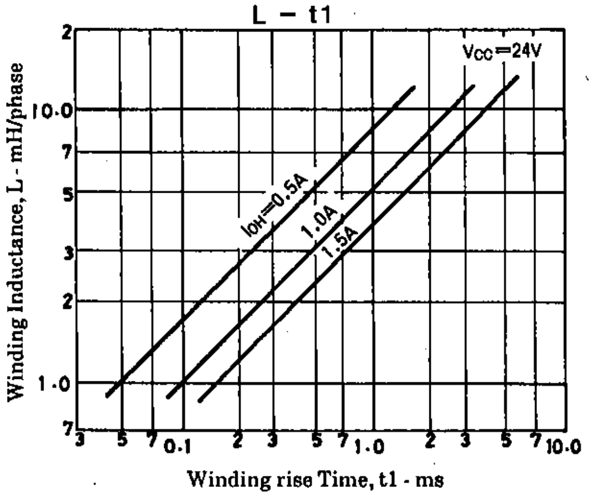


Fig. 11

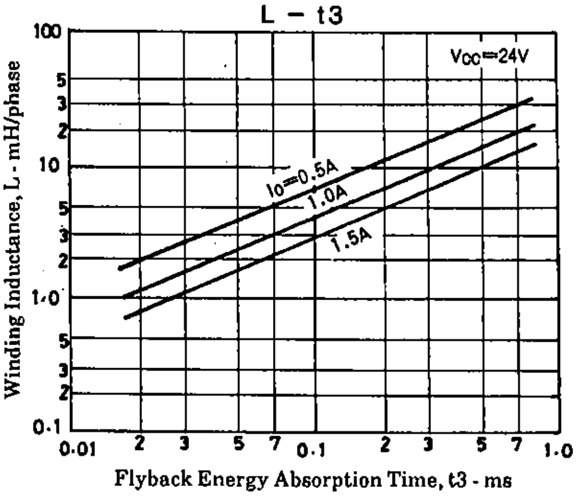


Fig. 12

3. Heat dissipation design

The average power dissipation Pd in accordance with the phase current I_O ($I_{OH} + I_{OL}/2$), the rise time of the winding current, the flyback time, and clock frequency is obtained using the Pd calculation equations. The thermal resistance of fin $\theta_{c\text{-}a}$ is obtained using the following equation.

$$\theta\,c\text{−}a = \frac{Tc\ max - Ta}{Pd}\ (℃/W) \qquad Tc\ max = 105℃ \quad Ta = \text{Ambient temperature}$$

The required fin area can be obtained from $\theta_{c\text{-}a}$ by referring to Fig.14. Note, however, that the values shown in this figure are for a 2mmt aluminum fin. As the ambient temperature can vary considerably in accordance with the air convections within the installation unit, the Tc value should be confirmed under the actual installation conditions to ensure that this value is less than 105°C.

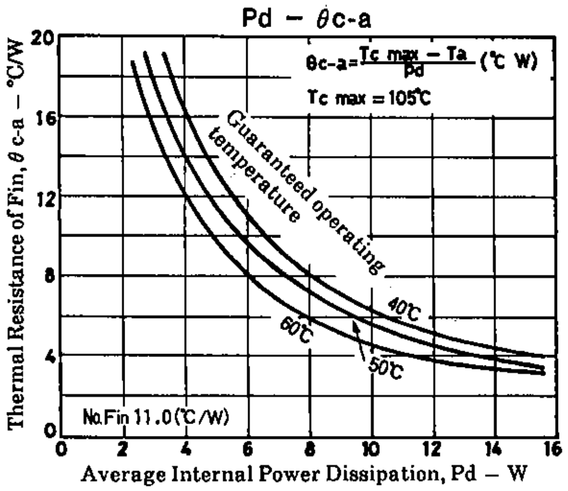


Fig-13

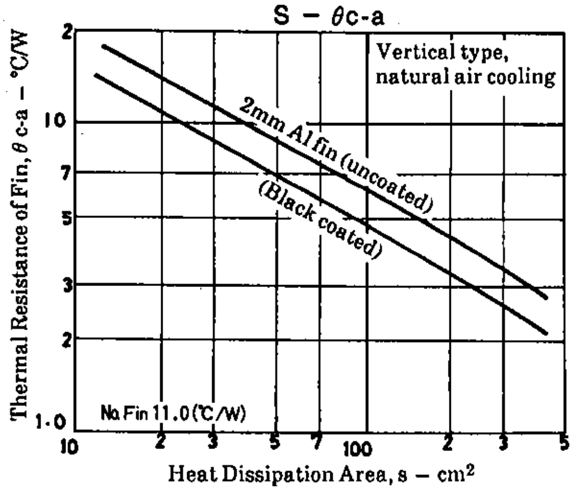


Fig-14

4. Junction temperature

The junction temperatures Tj of the various components can be obtained from the power dissipation per component Pds and θj-c.

Tj = Tc + θj-c × Pds (°C)   Tc = fin temperature

The average dissipation for each component Pds is obtained by referring to the Pd values obtained using the Pd calculation equations for each excitation mode. However, caution must be exercised during calculation of Tj for each component in the case of equations including Vst 2, as the value of Vst 2 includes three components: phase diode + phase transistor + current detection resistance (0.2Ω).

The thermal resistance θj-c of the power transistors is as follows:

TR1 ,6   θj-c = 9.0°C/W   TR2 ,3, 4, 5   θj-c = 9.0°C/W

(Note) The each phase current I_O and fin temperature Tc of Diodes D5,6,7 and 8 should be set so that set so that Tj remains less than 150°C during the hold state.

5. A·S·O for other power transistors

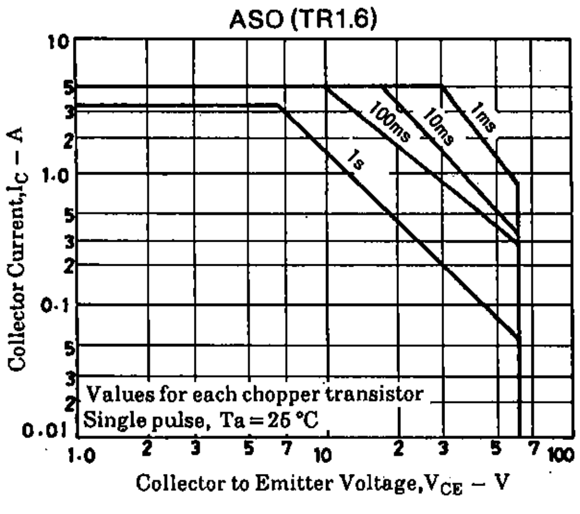


Fig-15

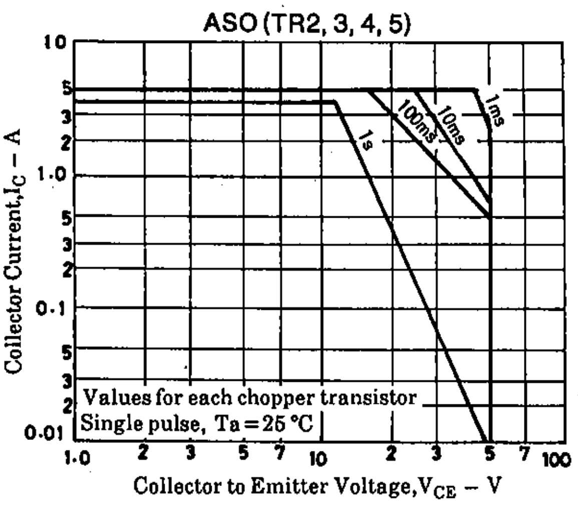


Fig-16