

SANYO

No.2442B

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]

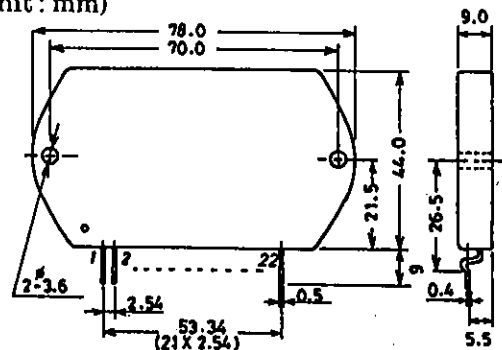
- Four settings according to excitation mode (M1,M2)

Four-phase, 1 excitation	Four-phase, 1-2 excitation
Four-phase, 2 excitation	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, \bar{A} , B, and \bar{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)



STK6772

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	V _i 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	T _{stg}		-40 to +125	°C
Junction Temperature	T _j max		150	°C
Operation Substrate Temperature	T _c 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.

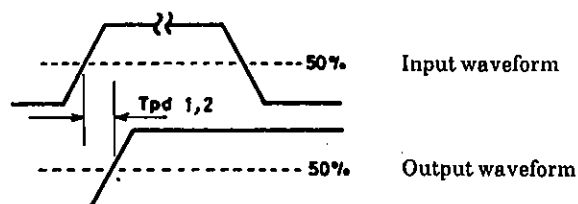
Operating Characteristics at Ta = 25°C, V_{CC}1 = 24V, V_{CC}2 = 5.0V

			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	V _{st1}	Between pins 15 and 7, pins 15 and 14, R _L = 13Ω		1.2	1.6	V
		Input V _{IH} = 4.0V				
Output Saturation Voltage2	V _{st2}	Between pins 8, 9 and 10, pins 12, 13 and 10, R _L = 13Ω,		2.5	3.0	V
		Input V _{IH} = 4.0V				
"H"-Level Output Voltage	V _{OH}	Between pins 1, 2, 3 and 11	2.4			V
"L" Level Output Voltage	V _{OL}	Between pins 1, 2, 3 and 11			0.4	V
		I _{OH} = -0.4mA I _{OL} = 2mA				
Output Current (Average)1	I _{O1}	Between pins 8, 9 and 7, pins 12, 13 and 14, R _L = 3.8mH, 3.5Ω	0.95	1.05	1.15	A
Chopping Frequency	f _c	I _{OH} = 0.3A, 270Ω: Pins 4, 5 and GND	20	24	28	kHz
Diode Forward Voltage1	V _{df1}	If = 0.3A		1.5	1.8	V
Diode Forward Voltage2	V _{df2}	If = 0.5A		1.2	1.8	V
Non-Operational Current	I _{cco}	Stop Voltage V _s at pin 22 = 2.0V		26	45	mA

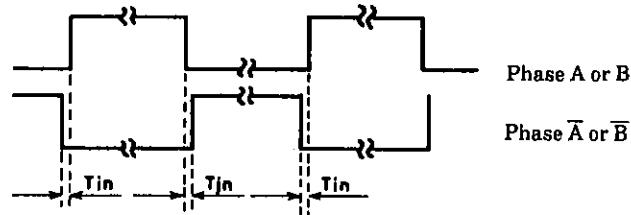
Operating Characteristics at Ta = 25°C, V_{CC}1 = 24V, V_{CC}2 = 5.0V, C_L = 50pF

			min	typ	max	unit
Delay Time1	T _{pd1}	CLK → A, \bar{A} , B, \bar{B} order		2		μs
Delay Time2	T _{pd2}	CLK → C1, C2, C3 order			2	μs
Output Signal Interval	T _{in}	4-phase 2 excitation mode only	20		40	μs
Maximum Clock Frequency	f _{CLK}				20	kHz

(1) Definition of T_{pd}



(2) Definition of T_{in}



(3) Use regulated 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 stabilizes 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

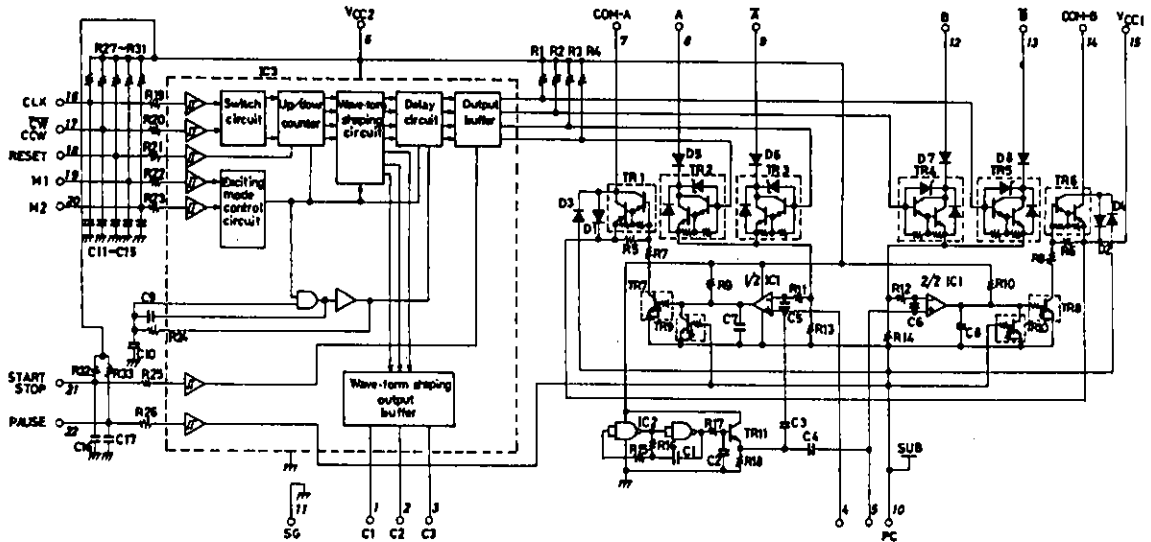
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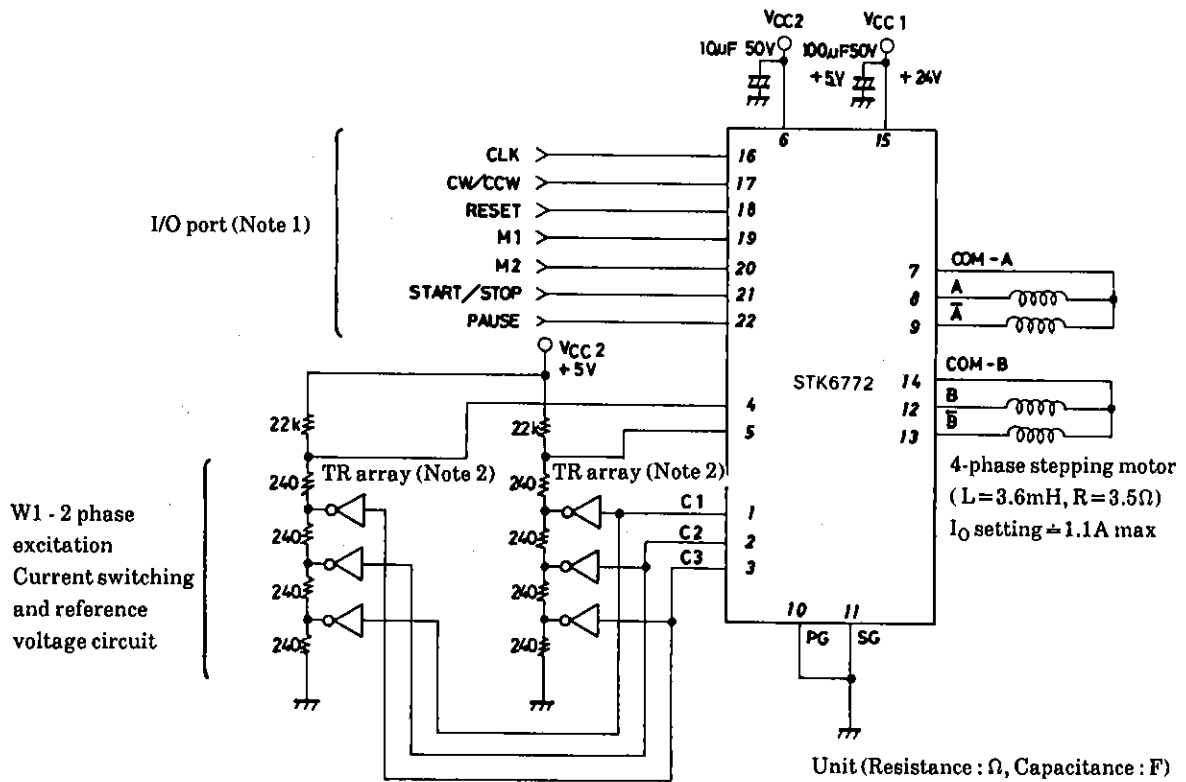
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Equivalent Circuit Diagram



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

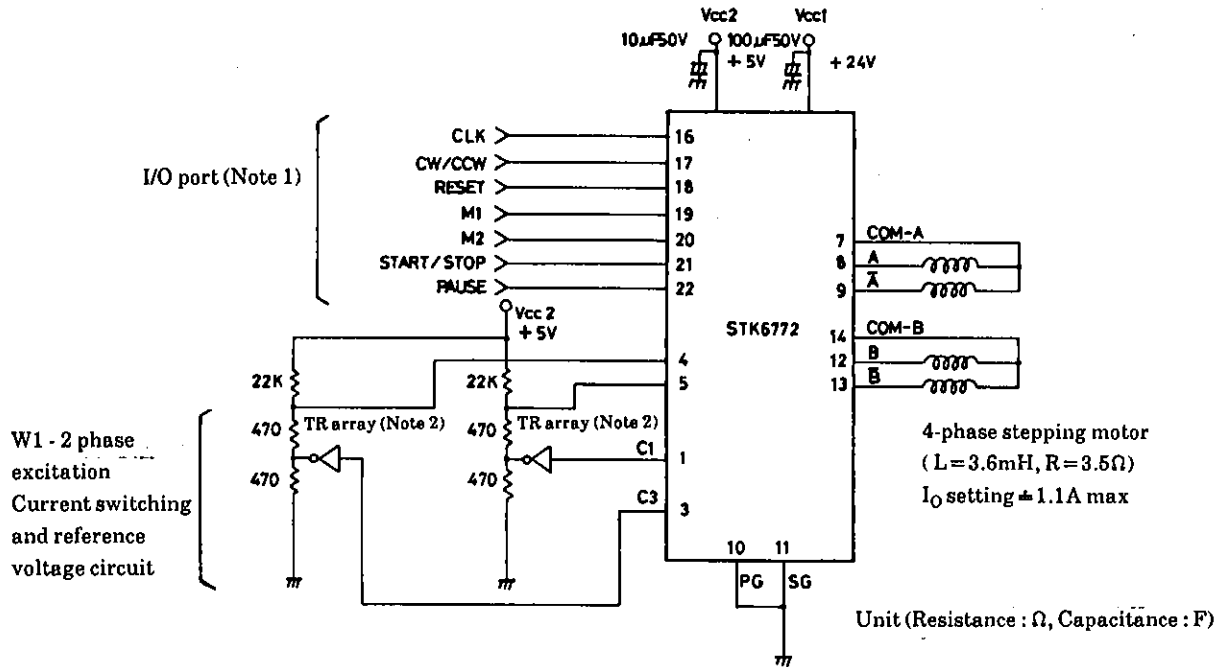


Note 1 : See Functions and Timing Charts for I/O port signals.

Note 2 : Transistor array

Sanyo LB1213 or LB1214 or equivalent are recommended.

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

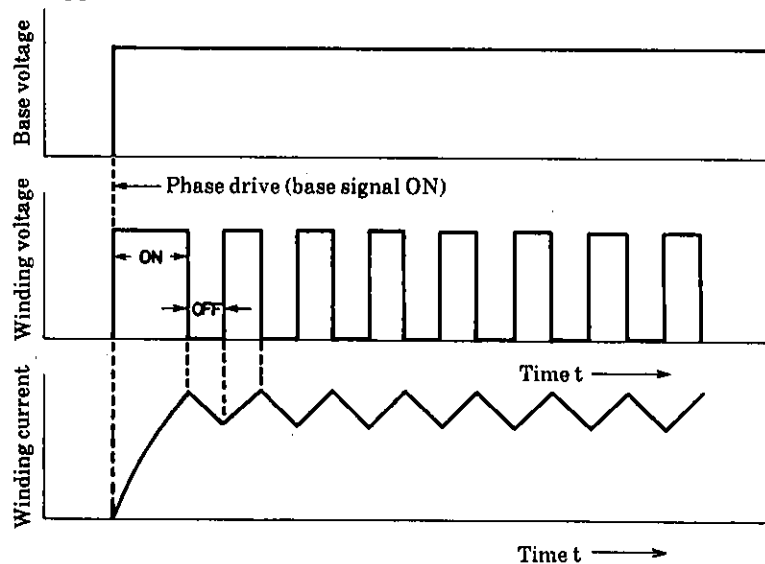


Fig. 1 Pulse Width Modulation and Winding Current

(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.

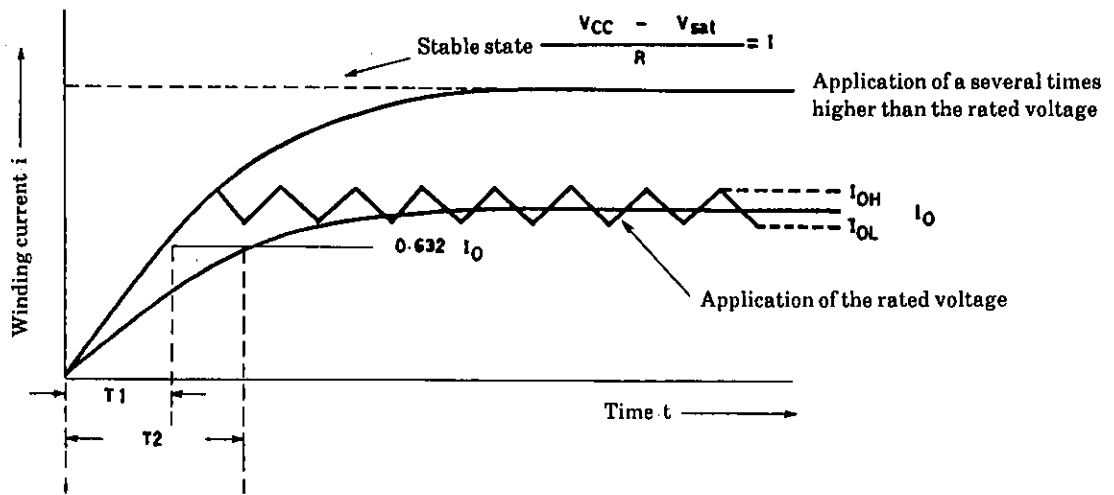


Fig.2 Constant Current Chopper Drive

- (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_0 in both cases is T_1 and T_2 , respectively, T_1 is shorter than T_2 and the rise time to the winding current is faster, giving rapid motor response characteristics. Note that T_2 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.

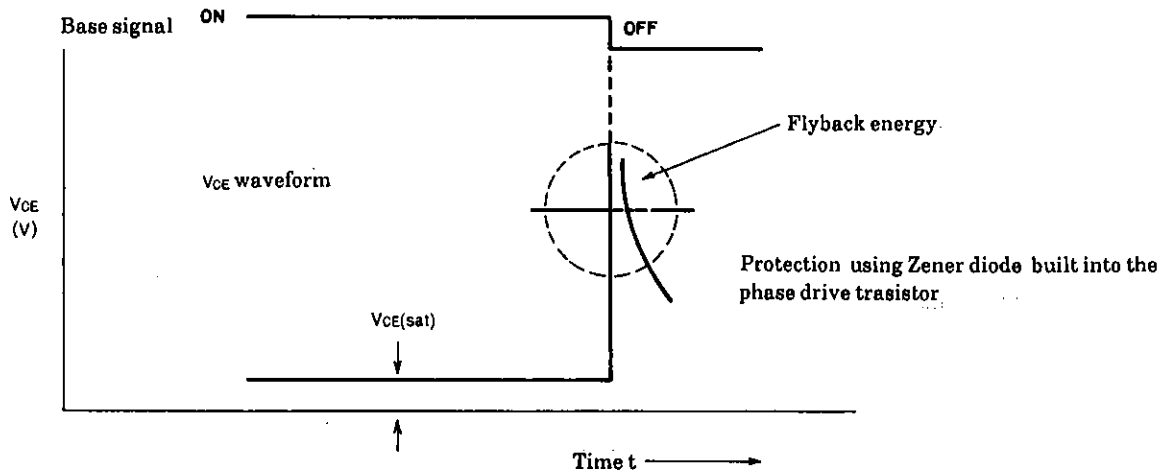
$$I_0 < \frac{V_{CC} - V_{sat}}{R} \dots\dots\dots \textcircled{1}$$

R: The winding resistance and R_E1 of one phase
 V_{sat} : $V_{st1} + V_{st2}$

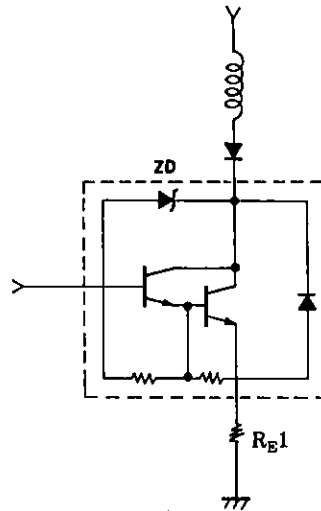
However, at a high winding inductance value, flyback energy from the motor will increase and, consequently, the loss when each phase drive transistor is turned off will be large. Thus, while taking the considerations in sections (b) and (c) above into account, a motor that meets the following specifications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

- Motor specifications (4-phase unipolar stepping motor)
 - Rated current: $1.0 \pm 0.5A/\text{phase}$
 - Winding resistance: Less than $10\Omega/\text{phase}$
 - Inductance: 1 to $10mH/\text{phase}$

- (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

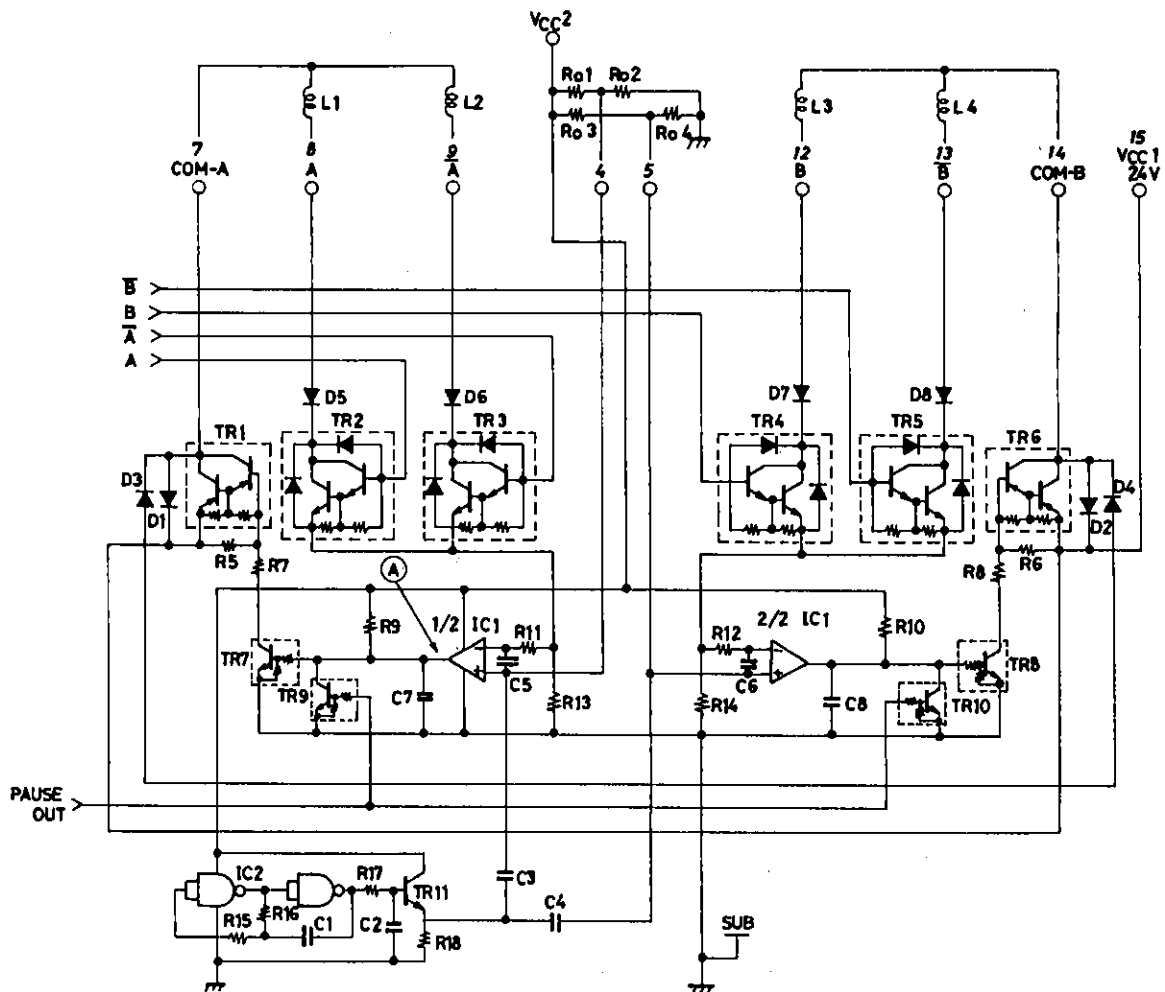


Fig.3 Driver Section Equivalent Circuit

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

$$i = \frac{V_{CC} - V_{sat}}{R} (1 - e^{-\frac{t}{\tau}}) \dots \dots \dots \textcircled{2}$$

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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 V_{df} 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 A 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.

$$V_{UTP} = k \left(\frac{R_{o2}}{R_{o1} + R_{o2}} \right) \times V_{CC2} \dots\dots\dots (4)$$

However, as K is a proportional constant, it can be thought of as approximating "1", giving the following:

$$V_{CC2} = +5V$$

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

$$i = \frac{V_{CC} - V_{sat}}{R} \times e^{-\frac{t}{\tau}} \dots\dots\dots (5)$$

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

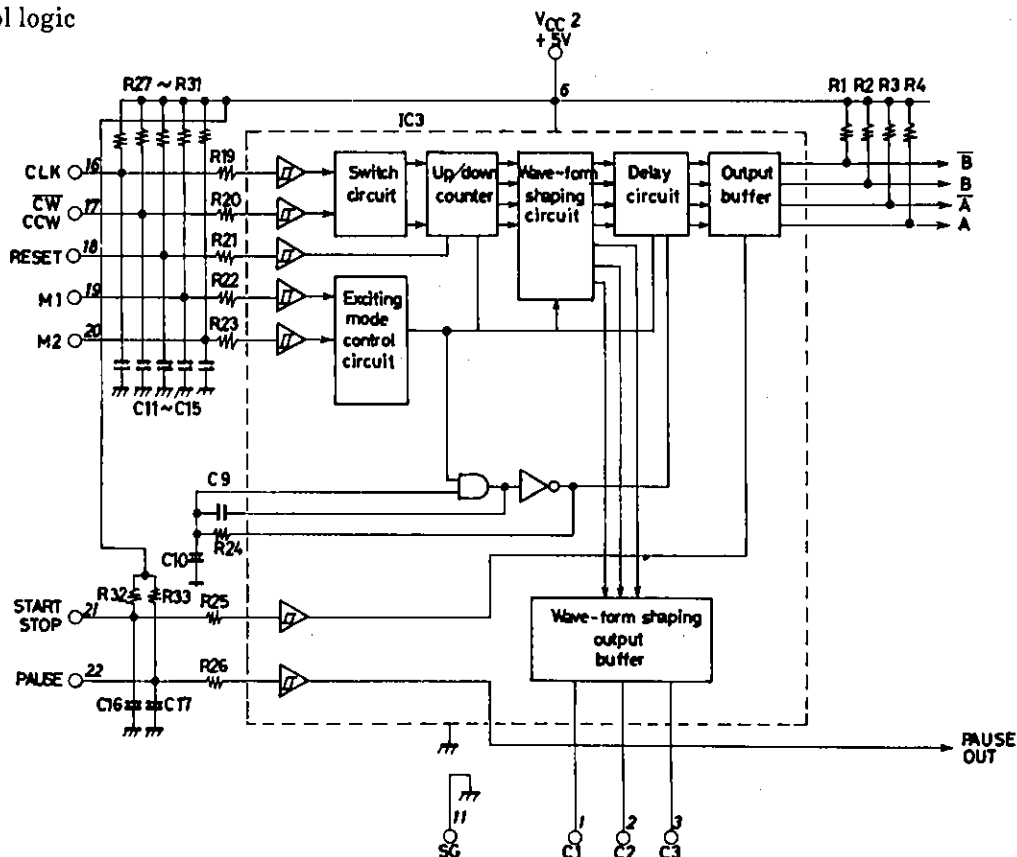
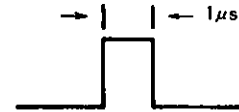


Fig.4 Block Diagram of Control Section

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, \bar{A} , B and \bar{B} output signals prevent overcurrent during phase switching.
- Control logic that operates at the falling edge of the pulses. Input pulse width is 1 μ s 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_0 can be experimentally approximated using the following equation.

$$I_0 \approx \frac{V_{ref}}{R_E} \quad (A) \dots\dots\dots ⑥$$

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

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

Note, however, that the value of I_0 will vary slightly according to the type of motor used, its inductance and other characteristics. Thus, the value of I_0 should be adjusted to the level required.

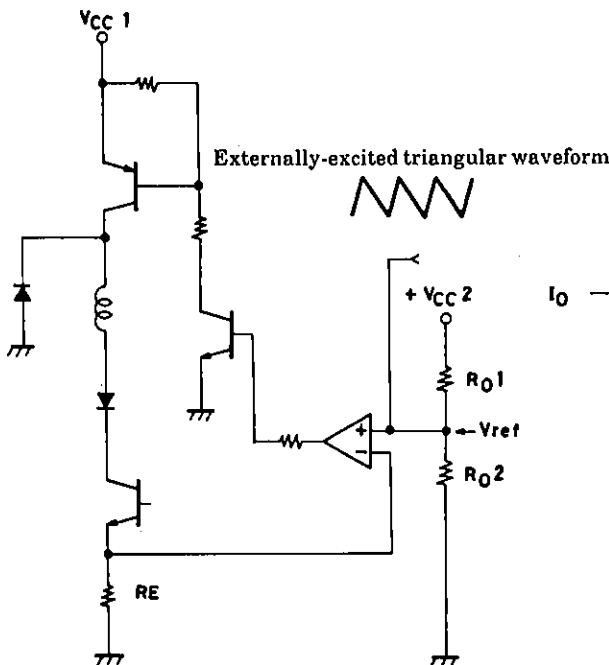


Fig.5 Internal Equivalent Circuit

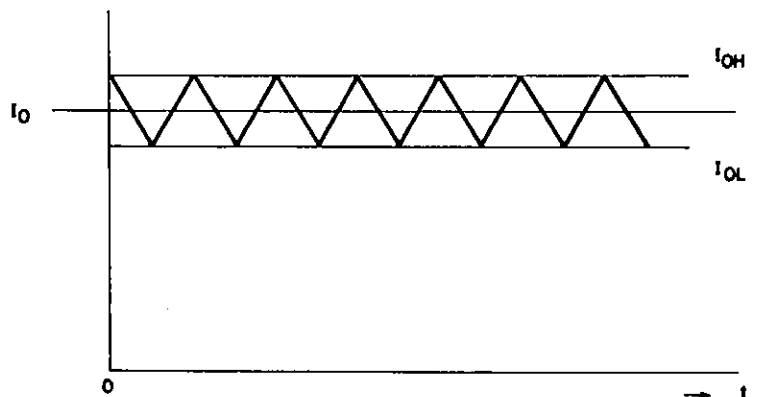


Fig.6 Current Waveform of I_0 Setting during Hold State

5. W1-2-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 approximately 10mV at I_C=100μA 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

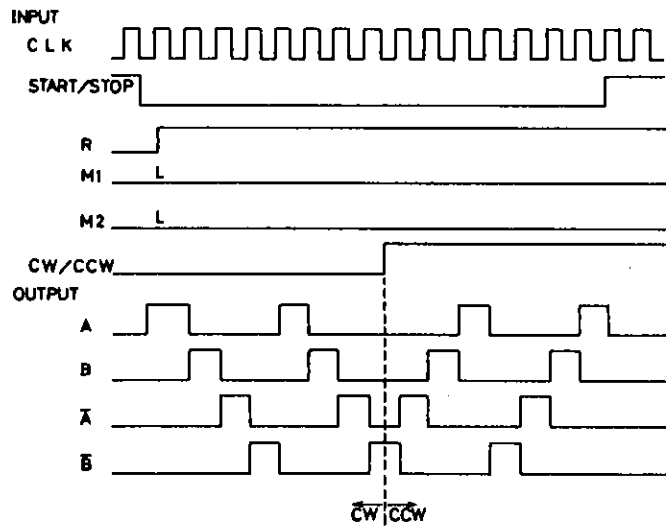


Fig.8 Timing Chart for 4-phase 2 Excitation Mode

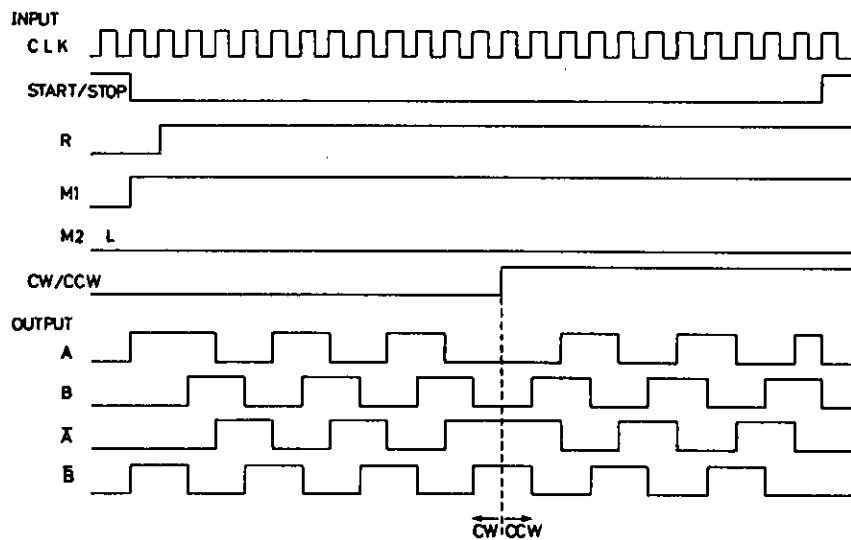


Fig.9 Timing Chart for 4-phase 1-2 Excitation Mode

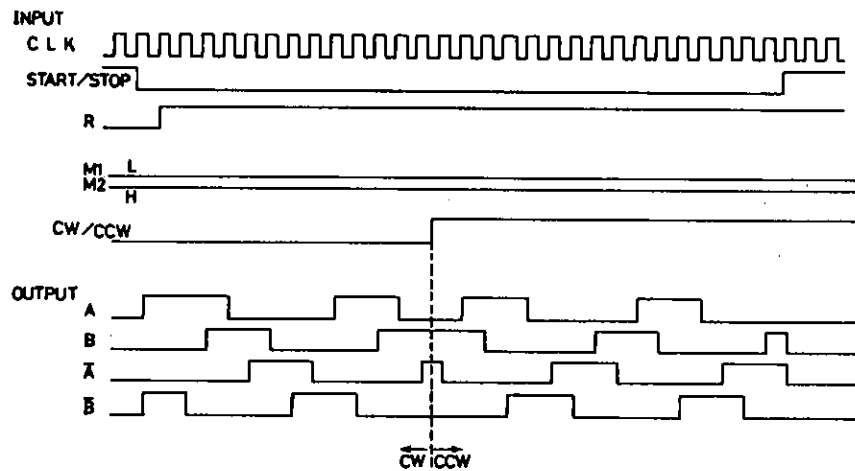
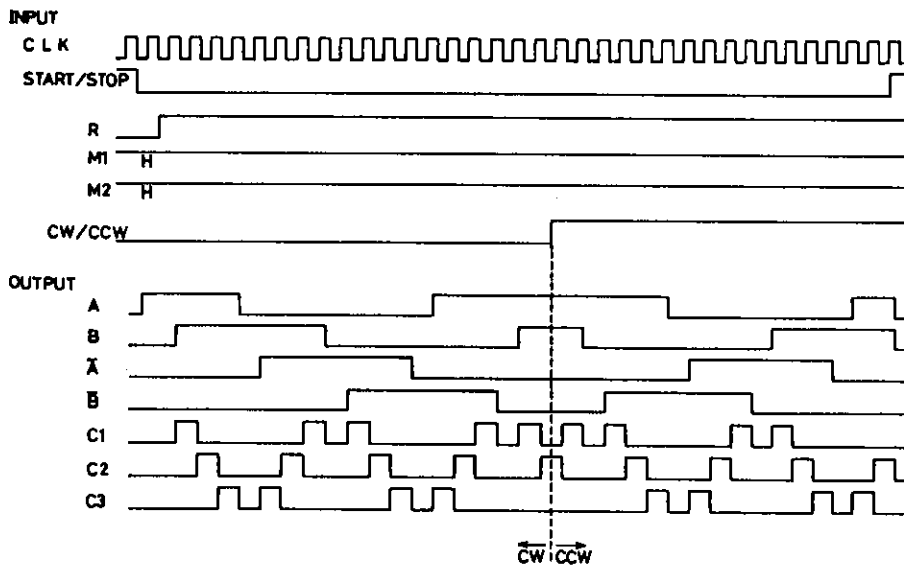


Fig.10 Timing Chart for 4-phase W1-2 Excitation Mode



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).

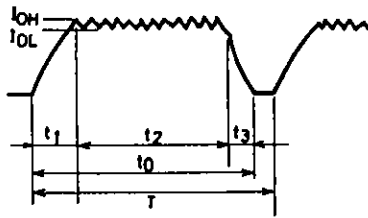
As the power dissipation of the other components is extremely small, the equation for calculating Pd within the STK6772 can be expressed as follows: H.I.C internal power dissipation (Pd) = PNP transistor switching loss + NPN transistor switching loss + output diode forward drop loss + flywheel diode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



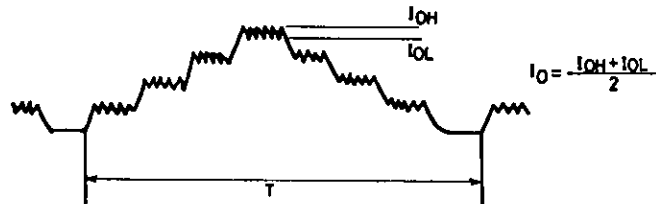
t_1 : motor coil current rise time
 t_2 : constant current chopping time
 t_3 : phase drive transistor flyback energy absorption time

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

$$I_0 = \frac{I_{OH} + I_{OL}}{2}$$

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

$$Pd(1EX) \approx \underbrace{\frac{3}{2} \cdot f_{clock} \cdot I_0 \cdot V_{st1} \cdot (0.5t_1 + 0.25t_2)}_{\text{a}} + \underbrace{f_{clock} \cdot I_0 \cdot V_{st2} \cdot (0.5t_1 + 0.5t_2)}_{\text{b}} + \underbrace{\frac{1}{4} \cdot f_{clock} \cdot I_0 \cdot V_{df2}}_{\text{c}} + \underbrace{\frac{1}{2} \cdot f_{clock} \cdot I_0 \cdot V_z \cdot t_3}_{\text{d}} \dots \text{e}$$

(b) 2 phase excitation

$$Pd(2EX) \approx \frac{3}{2} \cdot f_{clock} \cdot I_0 \cdot V_{st1} \cdot (0.5t_1 + 0.5t_2) + f_{clock} \cdot I_0 \cdot V_{st2} \cdot (0.5t_1 + t_2) + \frac{1}{2} \cdot f_{clock} \cdot I_0 \cdot V_{df2} \cdot t_2 + \frac{1}{2} \cdot f_{clock} \cdot I_0 \cdot V_z \cdot t_3 \dots \text{f}$$

(c) 1-2 phase excitation

$$Pd(1-2EX) \approx \frac{9}{32} \cdot f_{clock} \cdot I_0 \cdot V_{st1} \cdot (0.5t_1 + 0.5t_2) + \frac{3}{16} \cdot f_{clock} \cdot I_0 \cdot V_{st2} \cdot (0.5t_1 + t_2) + \frac{3}{32} \cdot f_{clock} \cdot I_0 \cdot V_{df2} \cdot t_2 + \frac{3}{64} \cdot f_{clock} \cdot I_0 \cdot V_z \cdot t_3 \dots \text{g}$$

(d) W1-2 phase excitation

$$Pd(W1-2EX) \approx \frac{21}{512} \cdot f_{clock} \cdot I_0 \cdot V_{st1} \cdot (t_1 + t_2) + \frac{7}{256} \cdot f_{clock} \cdot I_0 \cdot V_{st2} \cdot (t_1 + 2t_2) + \frac{7}{128} \cdot f_{clock} \cdot I_0 \cdot V_{df2} \cdot t_2 + \frac{7}{64} \cdot f_{clock} \cdot I_0 \cdot V_z \cdot t_3 \dots \text{h}$$

where: V_{st1} is the saturation voltage of pins 15 to 7, and 14.
 V_{st2} 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 ① is the average dissipation (for two devices) of the PNP transistors (TR1,6).
- The second term ② 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 ③ is the average dissipation (for two devices) of the flywheel diodes (D3,4).
- The fourth term ④ 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 ④ is the dissipation of the Zener diodes in the NPN transistors. As the NPN transistor dissipation is expressed by the second term ②, 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).

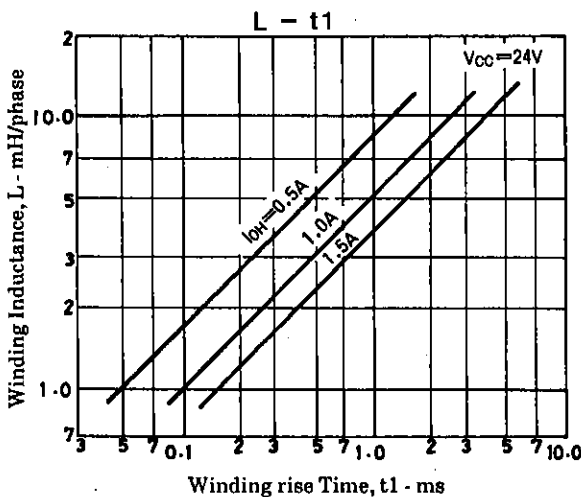


Fig. 11

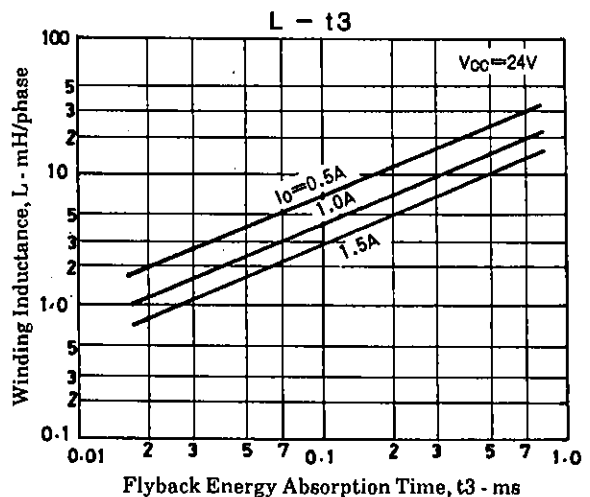


Fig. 12

3. Heat dissipation design

The average power dissipation Pd in accordance with the phase current I0 (I0H + I0L/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 θc-a is obtained using the following equation.

$$\theta_{c-a} = \frac{T_c \max - T_a}{P_d} \text{ (}^\circ\text{C/W)} \quad T_c \max = 105^\circ\text{C} \quad T_a = \text{Ambient temperature}$$

The required fin area can be obtained from θc-a by referring to Fig.14. Note, however, that the values shown in this figure are for a 2mm 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.

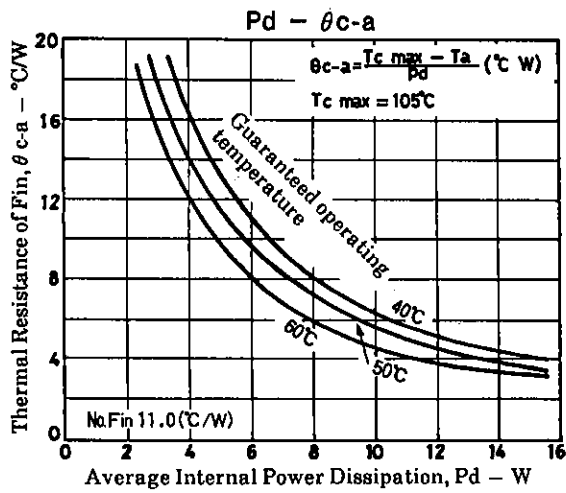


Fig-13

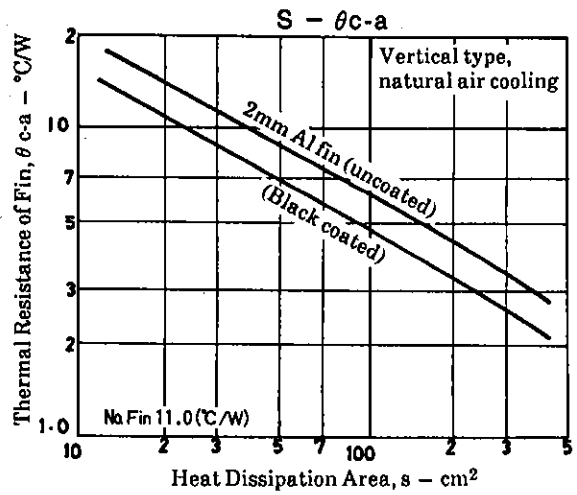


Fig-14

4. Junction temperature

The junction temperatures T_j of the various components can be obtained from the power dissipation per component P_{ds} and θ_{j-c} .

$$T_j = T_c + \theta_{j-c} \times P_{ds} \text{ (}^{\circ}\text{C)} \quad T_c = \text{fin temperature}$$

The average dissipation for each component P_{ds} is obtained by referring to the P_d values obtained using the P_d calculation equations for each excitation mode. However, caution must be exercised during calculation of T_j for each component in the case of equations including V_{st2} , as the value of V_{st2} includes three components: phase diode + phase transistor + current detection resistance (0.2 Ω).

The thermal resistance θ_{j-c} of the power transistors is as follows:

$$\text{TR1,6} \quad \theta_{j-c} = 9.0^{\circ}\text{C/W} \quad \text{TR2,3,4,5} \quad \theta_{j-c} = 9.0^{\circ}\text{C/W}$$

(Note) The each phase current I_O and fin temperature T_c of Diodes D5,6,7 and 8 should be set so that set so that T_j remains less than 150 $^{\circ}\text{C}$ during the hold state.

5. A·S·O for other power transistors

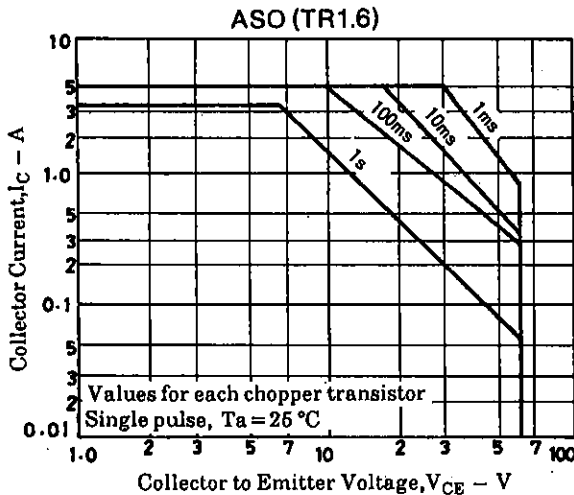


Fig-15

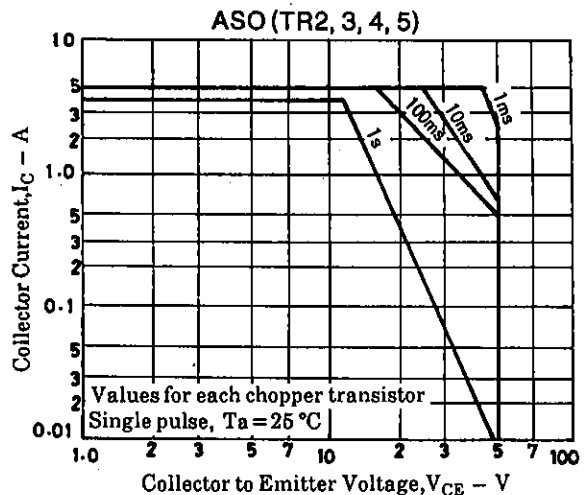


Fig-16