Ordering number : EN4927

Thick-Film Hybrid IC

STK672-010

Unipolar Fixed-Current Chopper (separate excitation) Type 1.7 A Output Current Stepping Motor Driver with Built-in 4-Phase Distribution Controller

Overview

The STK672-010 is a 4-phase stepping motor driver IC that adopts power MOSFET for its output stage and that uses a unipolar fixed-current chopper scheme. Since the STK672-010 includes a built-in 4-phase distribution controller, the stepping motor driver circuit and the control scheme can be simplified, and the stepping motor driver circuit structure can be standardized. The STK672-010 provides high torque, low vibration, and rapid response based on a W1-2 phase excitation drive scheme. The motor current is voluntary set from externals. Since, compared to the earlier STK6770 Series, the STK672-010 has a smaller package size and reduced drive power dissipation (reduced by 70% over previous products), it provides a wider operating power supply voltage range.

Applications

- Send/receive stepping motors in facsimile equipment
- Stepping motor drive for paper feed and optical systems in copier, and drum drive in laser beam printers
- Pen drive in X-Y plotters
- Industrial robots and other stepping motor application products

Features

- The STK672-010 can easily implement stepping motor drive applications with the provision of a DC power supply and a clock pulse oscillator.

<4-Phase Distribution Controller>

- The STK672-010 supports four excitation types selected by the excitation mode setting (M1 and M2).
  1. 4-phase 1 excitation
  2. 4-phase 1-2 excitation
  3. 4-phase 2 excitation
  4. 4-phase W1-2 excitation
- Schmitt input pins (for a high noise margin)
- Controller inputs are CMOS compatible (with built-in pull-up resistors), thus allowing direct control from I/O ports or special-purpose controller LSIs.
- An interval is set up during mutual switching of the A$\overline{A}$ and B$\overline{B}$ phase output signals in 4-phase 2 excitation mode.

<Driver Circuits>

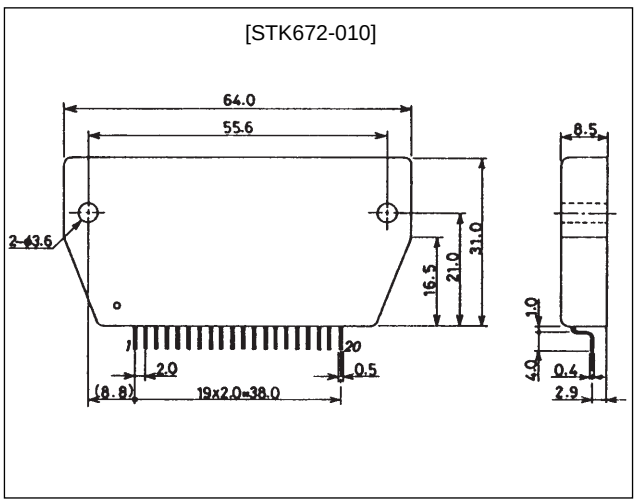
- Since the STK672-010 is a separate excitation type circuit, it supports a wide operating power supply voltage range. ($V_{CC}1$ = 5 to 42 V)
- Current detection resistors are provided within the hybrid IC.
- Drive power reduced by 70% when compared to the STK6770 Series (at 1 A drive).
- Can provide a motor drive current of up to 1.7 A without a heat sink.

Package Dimensions

unit: mm

4149

[STK672-010]



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Specifications

Absolute Maximum Ratings at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Maximum supply voltage	$V_{CC}1$ max	No signal	52	V
	$V_{CC}2$ max	No signal	7.0	V
Maximum phase output current	I_{OH} max	0.5 s, 1 pulse	2.5	A
Repeat avalanche capacity	Ear max		38	mJ
Input voltage	V_{IN} max		7.0	V
Operating substrate temperature	Tc max		105	°C
Junction temperature	Tj max		150	°C
Storage temperature range	Tstg		–40 to +125	°C

Allowable Operating Ranges at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Operating supply voltage	$V_{CC}1$	With a signal present	18 to 42	V
	$V_{CC}2$	With a signal present	5 ± 5%	V
Input voltage	V_{IH}		0 to $V_{CC}2$	V
Phase drive withstand voltage	V_{DSS}		120	V
Phase current	I_{OH} max	Duty: 50% per phase	1.7	A

Electrical Characteristics at Ta = 25°C, $V_{CC}1$ = 36 V, $V_{CC}2$ = 5 V

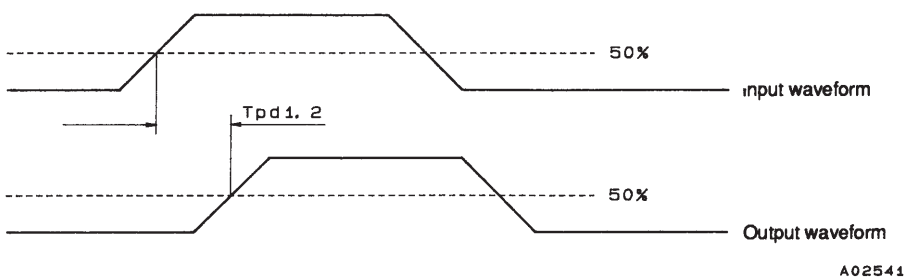
Parameter	Symbol	Conditions	min	typ	max	Unit
Output saturation voltage	Vst	R_L = 23 Ω		1.1	1.5	V
Output current (average)	Ioave	Load (each phase): R = 3.5 Ω, L = 3.8 mH	0.45	0.50	0.59	A
FET diode forward voltage	Vdf	If = 1.0 A		1.2	1.8	V
Current when stopped	Icco			36	55	mA
On input voltage	V_{IH}	Pins 14, 15, 16, 17, 18, and 19	4.0			V
Off input voltage	V_{IL}	Pins 14, 15, 16, 17, 18, and 19			1.0	V
Input leakage current	I_I	Pins 14, 15, 16, 17, 18, and 19	–600		+30	µA
C1 to C3 high level voltage	CV_{OH}	Pins 1, 2, and 3	2.4			V
C1 to C3 low level voltage	CV_{OL}	Pins 1, 2, and 3			0.4	V
Chopping frequency	fc	R/C: 2.4 kΩ/6800 pF	35	42	50	kHz

AC Characteristics at Ta = 25°C, $V_{CC}1$ = 36 V, $V_{CC}2$ = 5.0 V, C_L = 50 pF

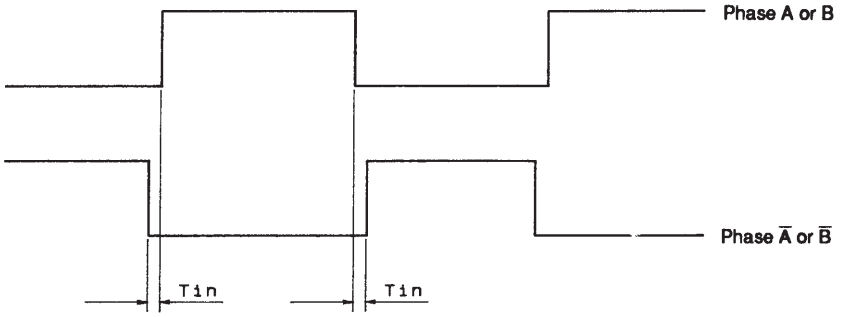
Parameter	Symbol	Conditions	min	typ	max	Unit
Delay time	Tpd1	For the clock path: CLK → A, $\overline{A}$, B, $\overline{B}$		2		µs
	Tpd2	For the clock path: CLK → C1, C2, C3			2	µs
Output signal interval	Tin	Only for 4-phase 2 excitation	20		40	µs
Maximum clock frequency	f_{CLK}				20	kHz

Note: Use a rated power supply.

Definition of the Delay Time Tpd



Definition of the Output Signal Interval Tin



Function Table

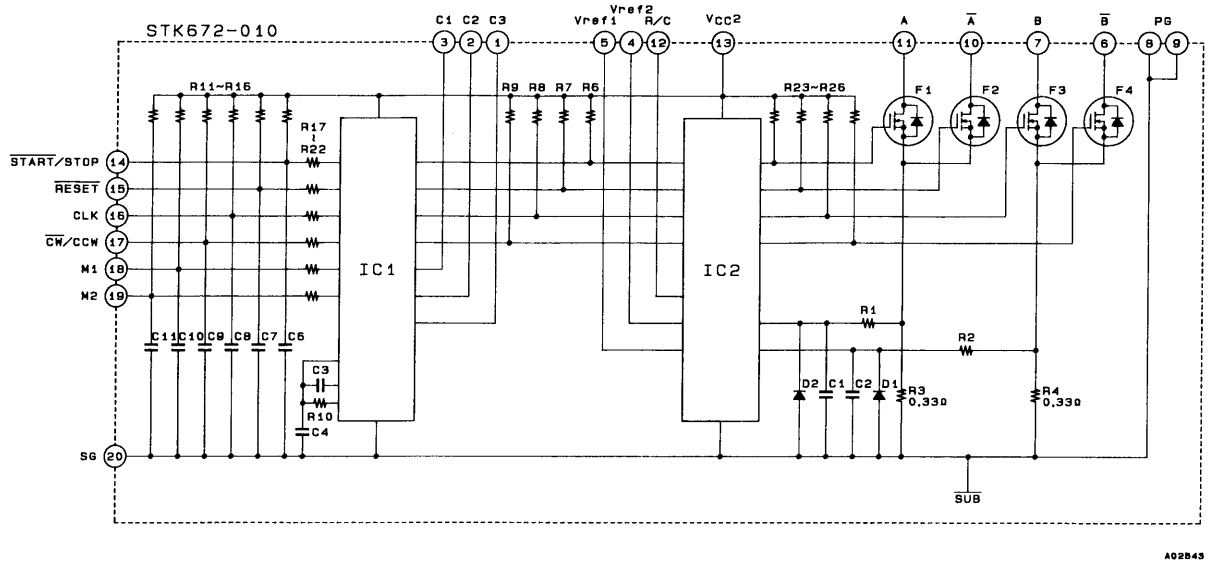
Operating Mode

	$\overline{CW}$/CCW	$\overline{START}$/STOP
CW	L	L
CCW	H	L
STOP	×	H

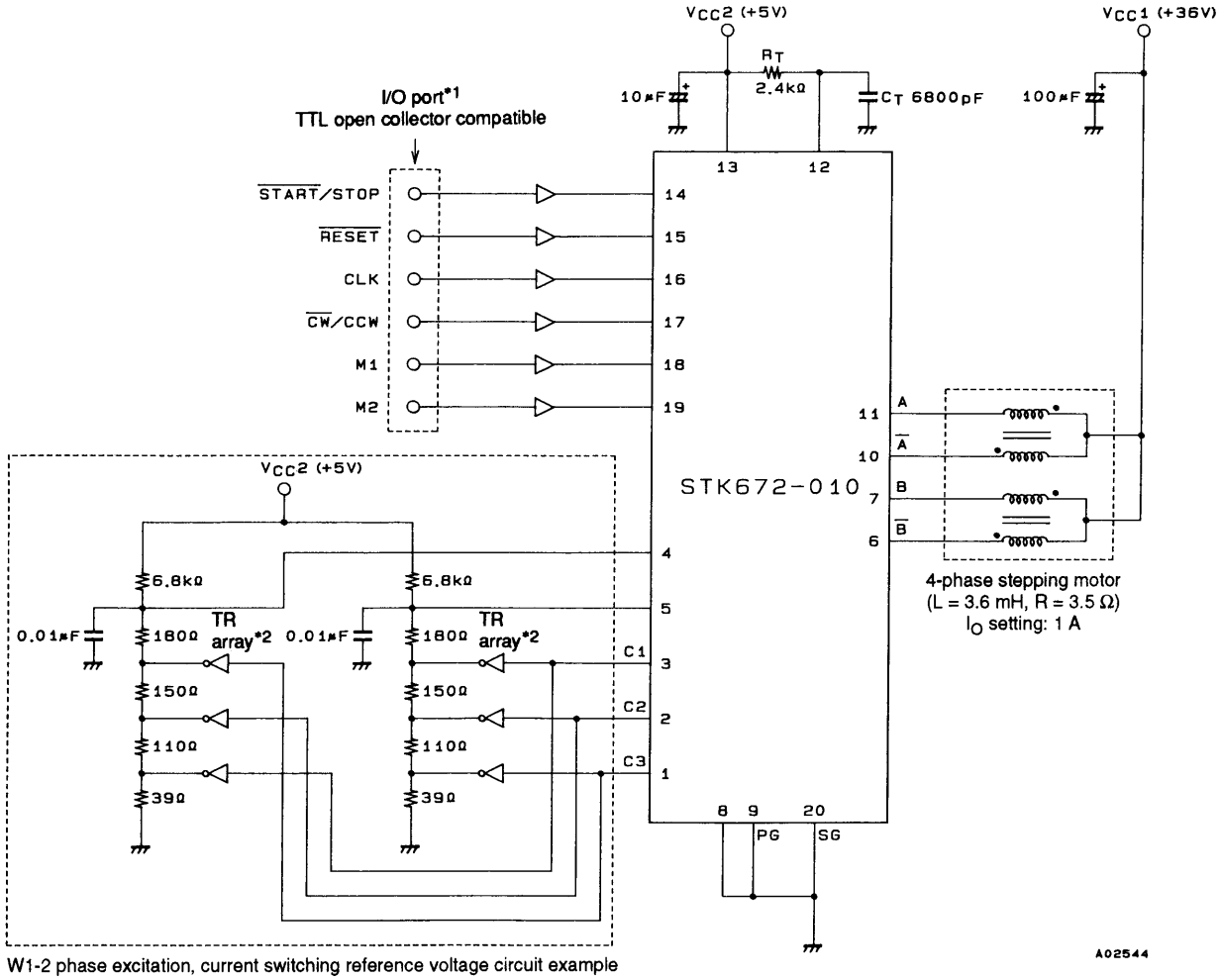
Excitation Mode

	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

Equivalent Circuit



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



W1-2 phase excitation, current switching reference voltage circuit example

Note: 1. See the function tables and the timing chart for details on the I/O port signals.
2. Use the Sanyo LB1212, LB1214, or equivalent for the TR array.
3. The $\overline{\text{RESET}}$ pin should normally be left open.

STK672-010 Operation

<Separate Excitation Chopper Driver Block Operation>

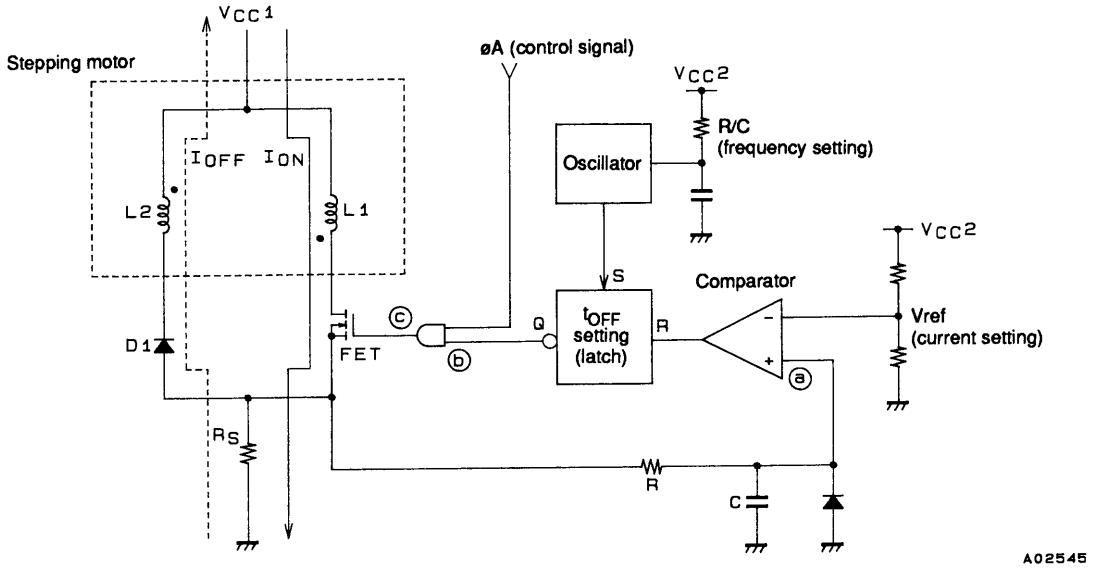


Fig. 1 STK672-010 Driver Block Basic Circuit

Figures 1 and 2 show the driver block basic circuit and the waveforms in the various blocks.
Unlike the earlier STK6710 Series, which adopted MOSFET transistors, the STK672-010 implements a fixed current drive scheme with separate excitation.

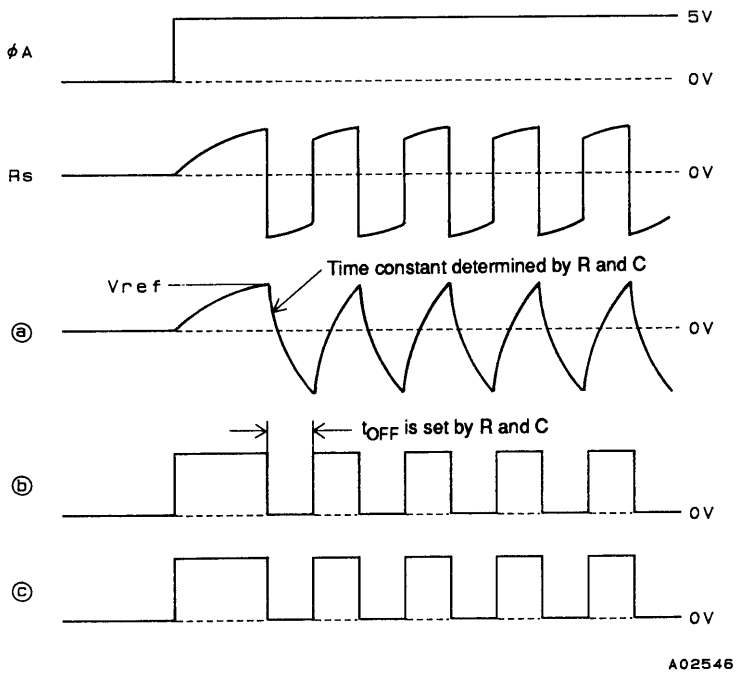


Fig. 2 Waveform Timing Chart

When the FET is turned on by a high level input on the øA signal in the driver block basic circuit, the comparator + pin goes low and the comparator output goes low. The L1 current I_{ON} that flows in the FET at this time is given by the following formula.

$$I_{ON} = \frac{V_{CC}1 - Vsat}{R}(1 - e^{-\frac{R}{L}t}) \quad \ldots\ldots (1)$$

L: Coil inductance
R: The sum of the coil resistance and Rs

Then, when the Rs voltage becomes equal to Vref, the FET turns off. At this point the energy stored in the inductor L1 induces a current in L2 and the current I_{OFF} flows. The time that the current I_{OFF} flows is proportional to the off time set at the oscillator.

Thus the chopping operation is partially fixed at the oscillator frequency by the latch function.
The STK672-010 repeats the operation of switching the motor current on and off, i.e., fixed current chopping operation, as described above.

<4-Phase Distribution Control Logic Block Operation>

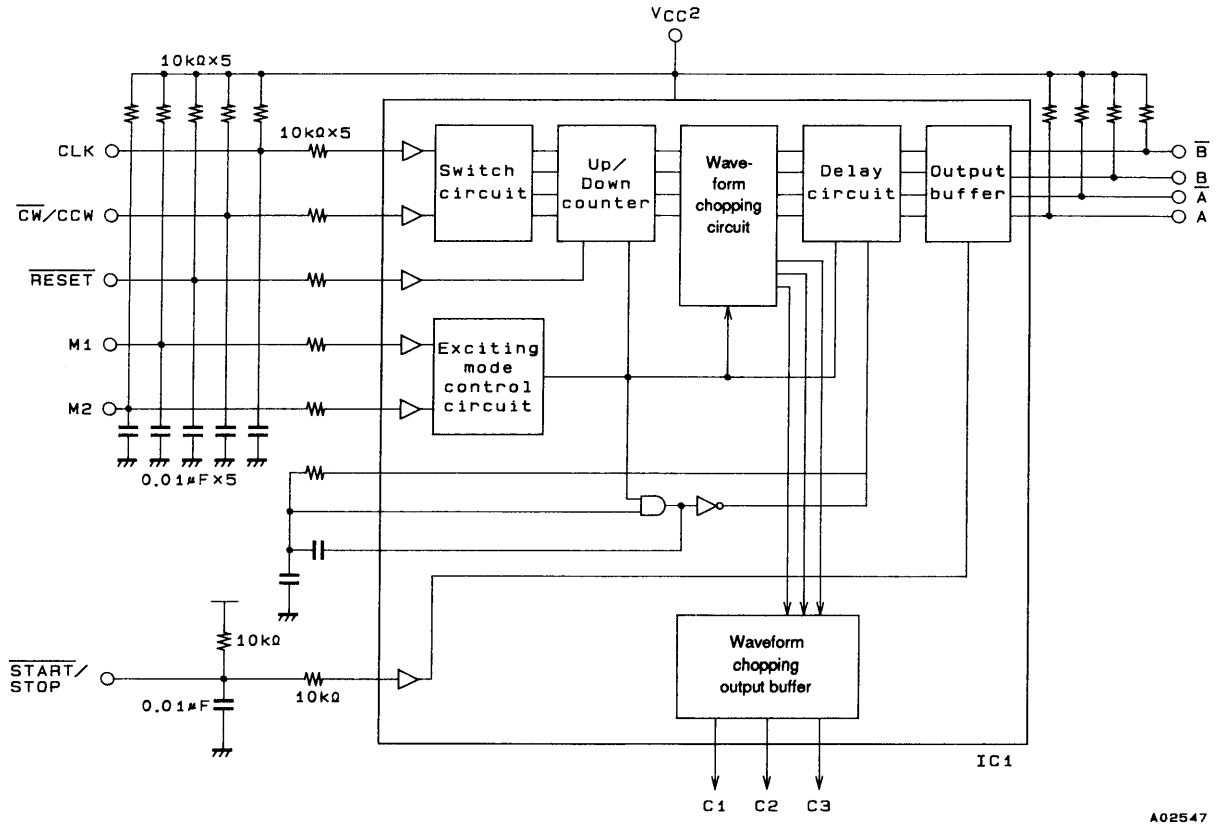


Fig. 3 Control Logic Circuit

The control logic IC built into the STK672-010 is a special-purpose IC developed to allow stepping motors to be operated more simply than was possible previously.

Features

- One of four excitation types can be selected with the excitation mode setting (M1 and M2).
  1. 4-phase 1 excitation
  2. 4-phase 1-2 excitation
  3. 4-phase 2 excitation
  4. 4-phase W1-2 excitation
- Schmitt circuits are provided on all input pins (for a high noise margin).
- Inputs have 10 kΩ pull-up resistors built in so that they are CMOS and TTL input compatible. Thus the inputs can be driven directly from I/O ports or special-purpose LSIs.
- The A$\overline{A}$ and B$\overline{B}$ phases of 4-phase control output at the 2-phase excitation set up the interval times.
- The minimum pulse width for the control logic is 25 μs. The logic operates on pulse falling edges.

The following timing charts show the logic in each excitation mode.

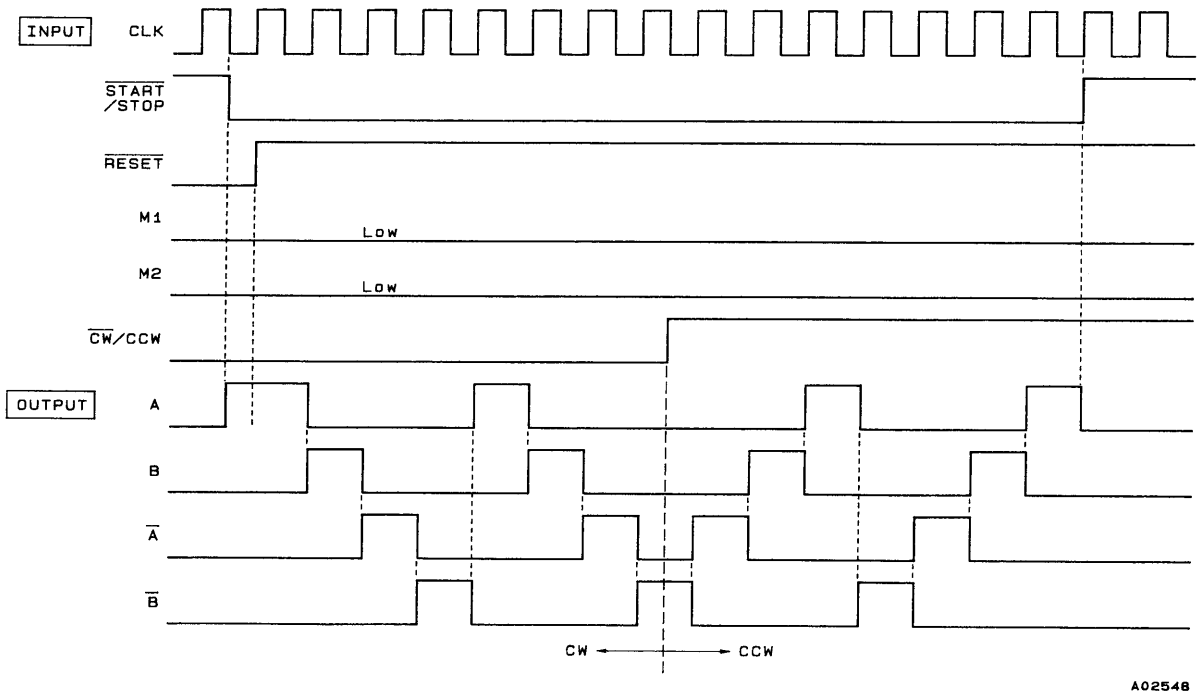


Fig. 4 4-Phase 1 Excitation Timing Chart

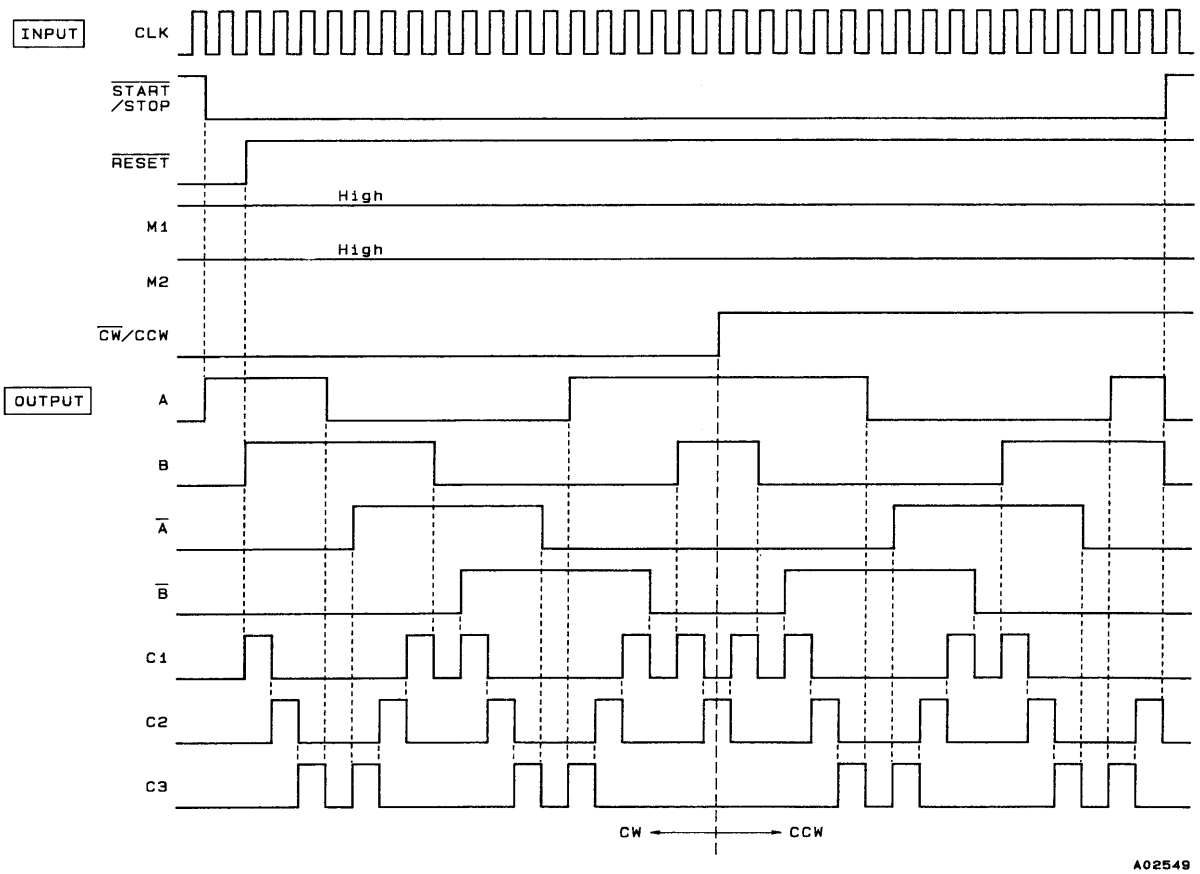


Fig. 5 4-Phase W1-2 Excitation Timing Chart

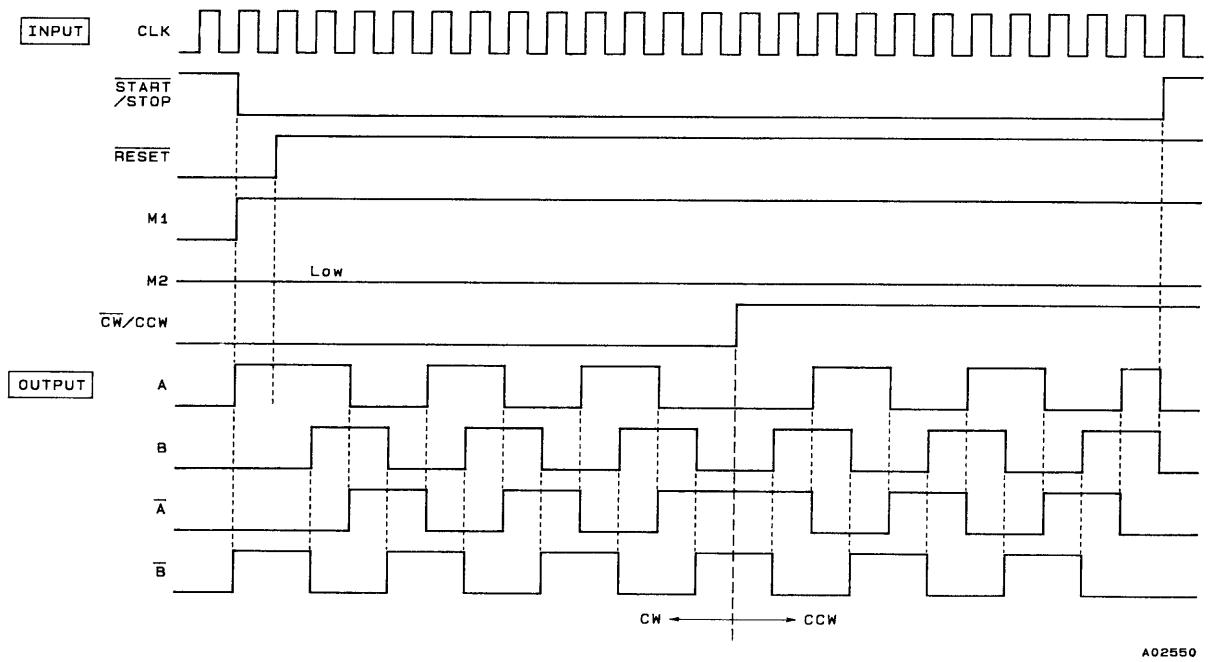


Fig. 6 4-Phase 2 Excitation Timing Chart

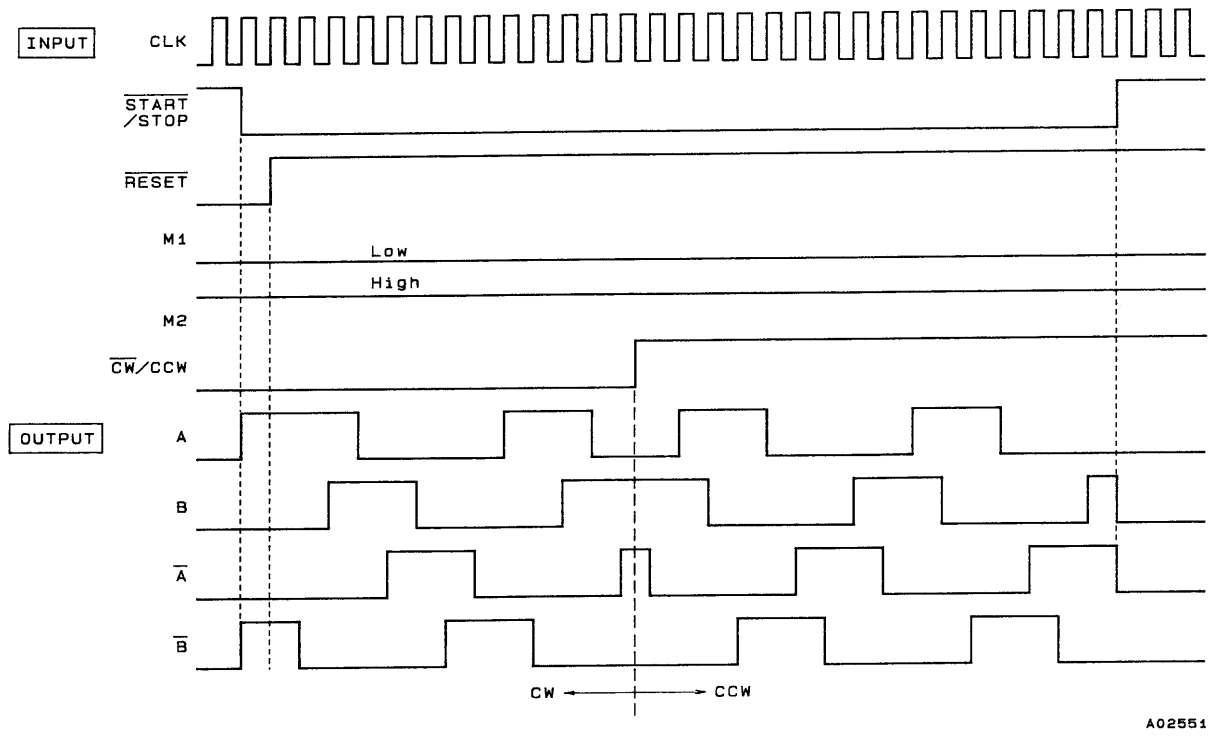


Fig. 7 4-Phase 1-2 Excitation Timing Chart

<Output Current Setting>

Figure 8 shows the motor output current waveform.
The output current I_{OH} is set by the STK672-010 pin 4 (5) voltage.
The formulas for these calculations are as follows.

$$Vref = \frac{R_O2}{R_O1 + R_O2} \times V_{CC}2 \quad \text{..... (2)}$$

$$I_{OH} = K \times \frac{Vref}{R_S} \quad \text{..... (3)}$$

R_S: The hybrid IC internal current detection resistor (0.33 ± 3%)
K: 1.1 to 1.2 (correction coefficient for differences between settings and measurements)

K is a proportionality constant that corrects for discrepancies between measurements and settings. Since the value of K is the set value in one condition, the value must be reset for each condition examined.
Sources of error include motor supply voltage and the motor electrical characteristics.

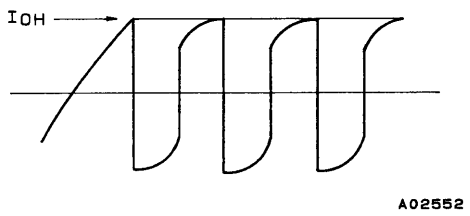


Fig. 8 Motor Output Current Waveform

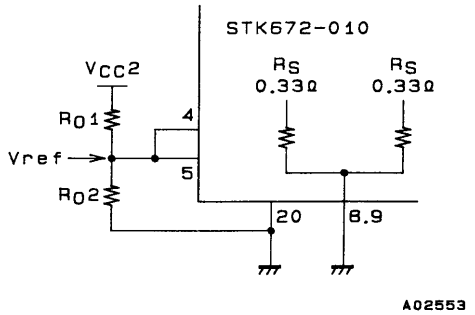


Fig. 9: Vref Peripheral Circuit

The output current range is from 0.1 A of the current caused by the t_{OFF} time in oscillator to 1.7 A of the allowable maximum current.

<Notes on W1-2 Phase Excitation Current Switching>

The STK672-010 provides the control logic circuit to allow the current to be switched over up to four levels by the C1, C2, and C3. A low saturation transistor must be used on the Vref voltage switching device in the W1-2 phase excitation circuit.
The reason for this is that when the W1-2 phase excitation current is switched over up to four levels, for switching I_O at small settings the I_O waveform will be displaced from the desired value due to variations in the V_{CE} (sat) voltage drop of the external Vref switching device. This can result in increased motor vibrations. Therefore we recommend selecting a device with a V_{CE} (sat) of about 10 mV at I_C = 100 μA for this transistor at the operating conditions used for this circuit.
Note that although we proposed using the LB1212 or LB1214, this does not necessarily apply to designs that take mass production into consideration.
The output current setting ratios for W1-2 phase excitation are 100%, 92%, 70%, and 38% for four-level switching and 100% and 70% for two-level switching. These are target values and precise adjustment should be made in the actual circuit.
A description of the W1-2 phase excitation follows.

<W1-2 Phase Excitation>

1. Overview
   W1-2 phase excitation is a technique for acquiring 1/2 the step angle of the 1-2 phase excitation by controlling the stepping motor winding currents for each phase.

2. Basic Concepts
   There are three types of W1-2 phase excitation.
   A: Fixed common current form
   B: Square form
   C: Circle form

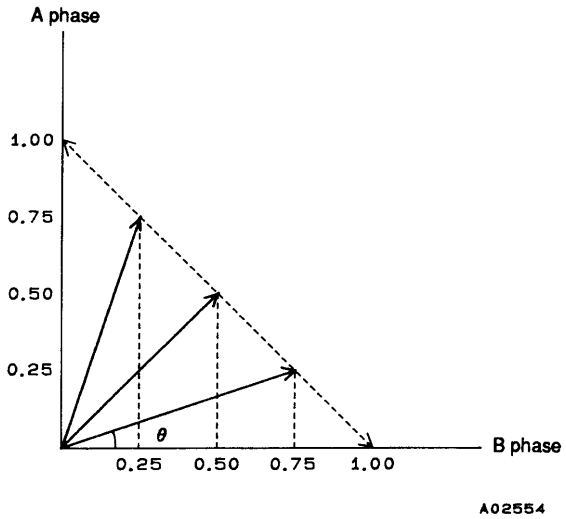
   Figure 10 shows the concepts behind these forms.
   The relation between the basic step angle θ_O of a two (or four) phase stepping motor and W1-2 phase excitation is given by the following formula.

   $$\theta = \theta_O/4$$

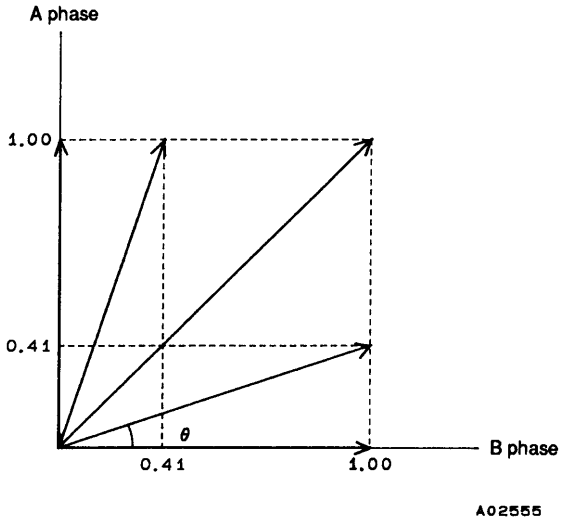
   In A, the common current is always a fixed value, and the motor vibration is even lower than for 1-2 phase excitation since the motor current in each phase increases in a stepwise manner.
   In B, the common currents is 2-times or 1.41-times, and although the motor current in each phase increases in a stepwise manner, operation is rougher than type A.
   In C, although the common current still increases, since the motor current in each phase increases in a stepwise manner and the form is circular, this type is effective at reducing vibration.

3. Application
   Figure 11 shows the timing chart for each block, i.e., the input clock, the each phase driver input, current control, and the phase currents. Based on the clock, which is the rotate command for the distributor first stage, this circuit controls the fixed current drive currents by forming each phase input as a 1-2 phase excitation sequence and forming the current control sequence as C1, C2, and C3 in the distributor.

A: Fixed Common Current Form



B: Square Form



C: Circle Form

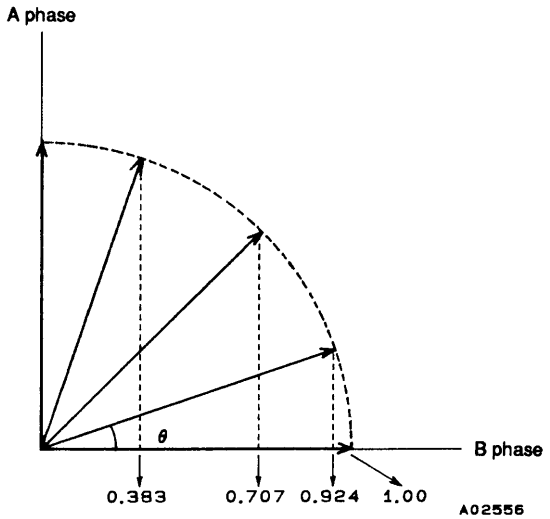
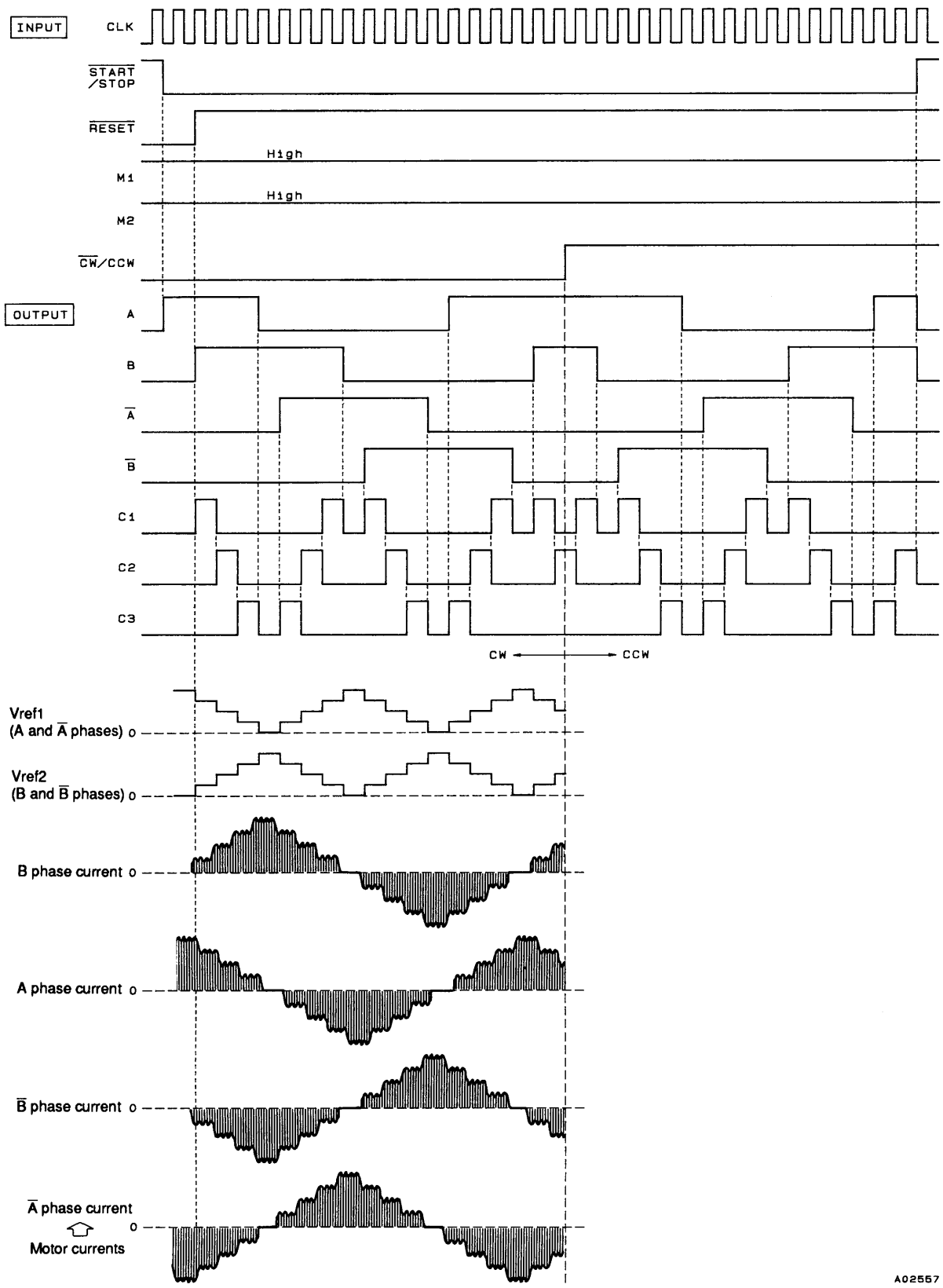


Fig. 10 W1-2 Phase Excitation Control Angle Concepts



Note: Vref1 is the A and Ā phase reference voltage.
Vref2 is the B and B̄ phase reference voltage.

Fig. 11 W1-2 Phase Excitation Timing Chart

<Oscillator Frequency Setting>

The separate excitation chopping frequency f can be derived from t_{ON} and t_{OFF} as follows.

$$t_{ON} = -CR_1 \times \ln \frac{V_L}{V_H} \quad \text{..... (4)}$$

$$t_{OFF} = -C \times \frac{Rx \times R_1}{R_1 + Rx} \times \ln \left(1 - \frac{\frac{Rx}{Rx \times R_1} \times V_{CC}2}{0.33 \times V_{CC}2} \right) \quad \text{..... (5)}$$

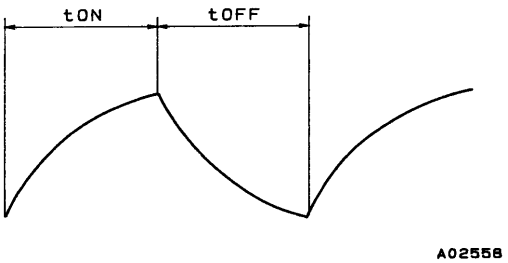


Fig. 12 R/C Waveform

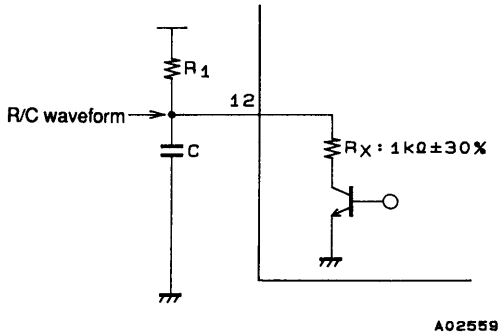


Fig. 13 R/C Pin Peripheral Circuit

Therefore, the separate excitation chopping frequency f is given by the following formula.

$$f = \frac{1}{t_{ON} + t_{OFF}} \text{ [Hz]} \quad \text{..... (6)}$$

Values of R1 = 2.4 kΩ and C = 7500 pF are appropriate to achieve the recommended time constant.

Thermal Design

The size of the heat sink required for this hybrid IC is determined by the motor output current I_{OH} (A), the motor's electrical characteristics, the excitation mode, and the clock frequency fclock (Hz) of the excitation input signal. The thermal resistance of the required heat sink can be derived from the following formula.

$$\theta c\text{-}a = \frac{Tc\ max - Ta}{Pd} \text{ [°C/W]} \quad \text{..... (7)}$$

Tc max = The hybrid IC case temperature (°C)
Ta = Set internal temperature (°C)
Pd = The hybrid IC average internal power dissipation (W)

The heat sink thermal resistance θc-a can be derived from the average power dissipation shown in Figure 14. Then the heat sink area can be derived from Figure 15. Note that the ambient temperature is influenced significantly by the air circulation conditions within the set. Therefore, the heat sink size must be determined so that back surface (the aluminum plate side) of the hybrid IC never exceeds Tc max (105°C) under any condition in the mounted state within the end product.

Fig. 14 θc-a – Pd characteristics

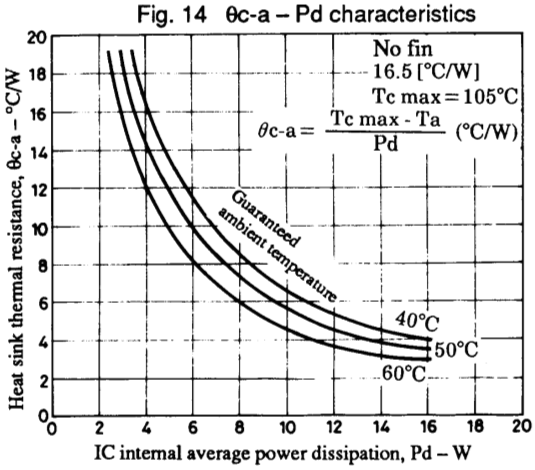
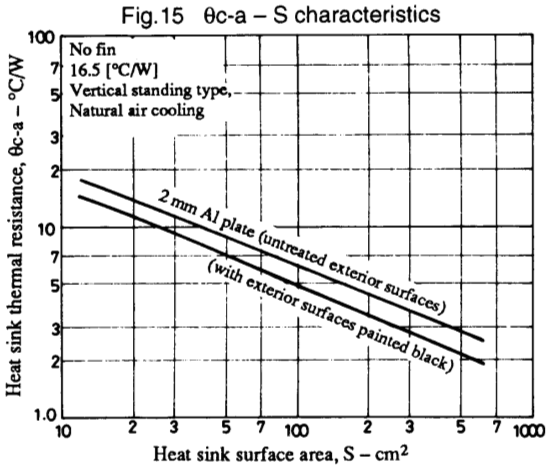


Fig.15 θc-a – S characteristics



<Hybrid IC Internal Average Power Dissipation>

The devices with the largest power dissipations within the STK672-010 are the current control devices, the regenerated current diodes, the current detection resistors, and the pre-drive circuits.
The power dissipations for each of the excitation modes are given by the following formulas.

1 phase excitation: $Pd_{1EX} = (Vst + Vdf)\frac{f\ clock}{2} I_{OH} \cdot t2 + \frac{I_{OH} \cdot f\ clock}{2}(Vst \cdot t1 + Vdf \cdot t3)$ ..... (10)

2 phase excitation: $Pd_{2EX} = (Vst + Vdf)\frac{f\ clock}{2} I_{OH} \cdot t2 + \frac{I_{OH} \cdot f\ clock}{2}(Vst \cdot t1 + Vdf \cdot t3)$ ..... (11)

1-2 phase excitation: $Pd_{1\text{-}2EX} = (Vst + Vdf)\frac{f\ clock}{4} I_{OH} \cdot t2 + \frac{I_{OH} \cdot f\ clock}{4}(Vst \cdot t1 + Vdf \cdot t3)$ ..... (12)

W1-2 phase excitation: $Pd_{W1\text{-}2EX} = (Vst + Vdf)\frac{0.64 \cdot f\ clock}{8} I_{OH} \cdot t2 + \frac{I_{OH} \cdot f\ clock}{8}(Vst \cdot t1 + Vdf \cdot t3)$ ..... (13)

Vst: The sum of the R_{ON} and R_S voltage drops
Vdf: The sum of the FET internal diode and the R_S voltage drops
f clock: Input clock

The times t1, t2, and t3 are shown in the figure below.

t1: The time for the winding current to reach the set value
t2: The time in the fixed current chopping region
t3: The time from the point where the phase input signal is cut to the point where the regenerated reverse power is dissipated.

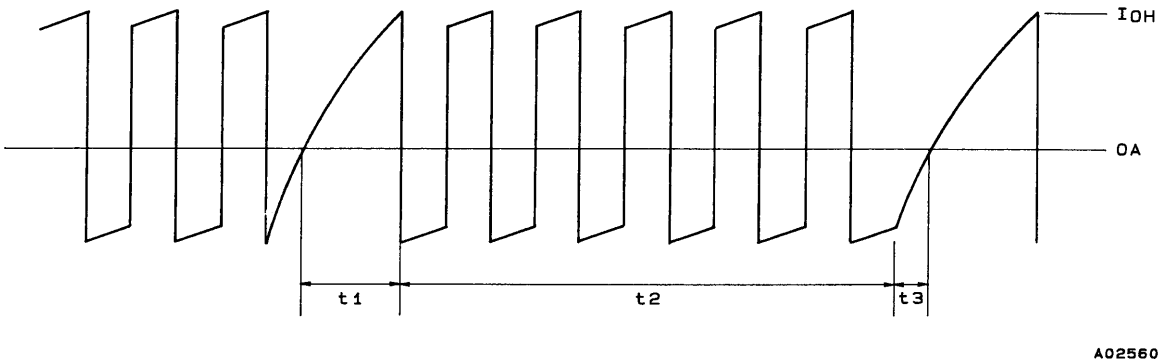


Fig. 16 Motor Output Current Waveform (idealized model)

$$t1 \approx \frac{-L}{R + 0.88} \times \ln\left(1 - \frac{R + 0.88}{V_{CC}} \times I_{OH}\right) \quad \text{..... (12)}$$

$$t1 \approx \frac{-L}{R} \times \ln\left(\frac{V_{CC} + 0.88}{I_{OH} \times R + V_{CC} + 0.88}\right) \quad \text{..... (13)}$$

V_{CC}: Motor power supply voltage (V)
L: Motor inductance (H)
R: Motor internal resistance (Ω)
I_{OH}: Motor output current peak value (A)

The t2 and excitation frequency F values for each excitation mode are given by the following formulas.

1 phase excitation: $F = f\ clock, \quad t2 = \frac{1}{F} - (t1 + t3)$ ..... (14)

2 phase excitation: $F = f\ clock/2, \quad t2 = \frac{1}{F} - (t1 + t3)$ ..... (15)

1-2 phase excitation: $F = f\ clock/3, \quad t2 = \frac{1}{F} - t1$ ..... (16)

W1-2 phase excitation: $F = f\ clock/7, \quad t2 = \frac{1}{F} - t1$ ..... (17)

<Junction Temperature>

The junction temperature Tj for each device can be derived from the power dissipation Pds for each transistor and θj-c.

$$Tj = Tc + \theta j\text{-}c \times Pds\ [°C] \quad \text{..... (18)}$$

The average power dissipation per transistor Pds can be derived by referring to the Pd calculation formula (average power dissipation: the total for four transistors) for each excitation mode.

Example: The power dissipation per transistor can be calculated as Pds = Pd/4.

Note that the thermal resistance of the power transistors has the following value.

θj-c for F1 to F4 = 13.5 °C/W

Note: When calculating the Tj for the power transistors, the power dissipation in the detection resistor is included in the Pds value. Therefore the voltage drop for the Rs must be taken into account in the calculation.

Fig. 17 I_O – Vst characteristics

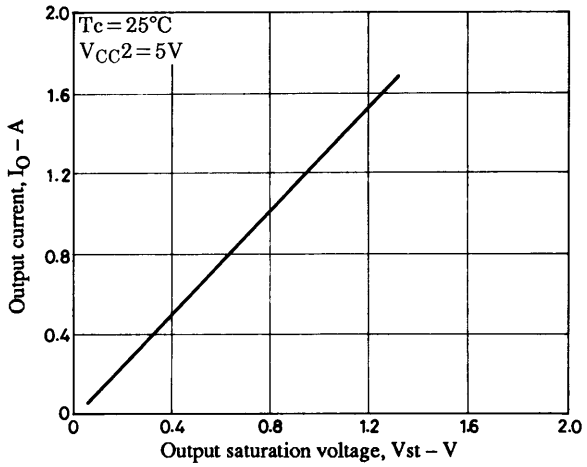
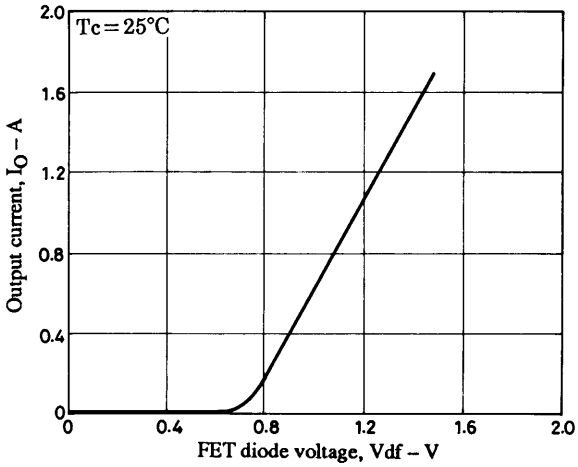


Fig. 18 I_O – Vdf characteristics



<STK672-010 No Heat Sink Region Example>

This section presents a case where the STK672-010 can be used without a heat sink.

Conditions:

- Motor power supply voltage V_{CC} = 42 V, stepping motor electrical characteristics: 3.5 mH/ø, 3.5 Ω/ø
- Excitation: 2 phase excitation
- Input clock: 500 Hz (fixed)
- Hybrid IC ambient temperature Ta = 25°C, natural convection
- Motor output current: 1.7 A

From these conditions and formulas (12), (13), and (15):

t1 ≈ 0.15 ms
t2 ≈ 3.72 ms
t3 ≈ 0.13 ms

The average power dissipation is calculated from formula (9) referencing Figure 17 and Figure 18.

$$Pd_{2EX} = (Vst + Vdf)\frac{f\ clock}{2} I_{OH} \cdot t2 + \frac{I_{OH} \cdot f\ clock}{2}(Vst \cdot t1 + Vdf \cdot t3)$$

$$\approx 4.43 + 0.16 \approx 4.6\ [W]$$

Tc is derived from formula (7) as follows:

$$Tc = Pd_{2EX} \times \theta c\text{-}a + Ta = 4.6 \times 16.5 + 25 \approx 101\ [°C] < Tc\ max = 105\ [°C]$$

(θc-a = 16.5°C/W: the thermal resistance of the hybrid IC itself with no heat sink)

Note that the typical values of the device characteristics have been used in this example. Therefore, due also to the details of the air flow around the hybrid IC, the actual values will not necessarily agree with this calculation, and must be confirmed in an actual operating circuit.

Fig. 19 I_{OH} – $V_{CC}1$ characteristics

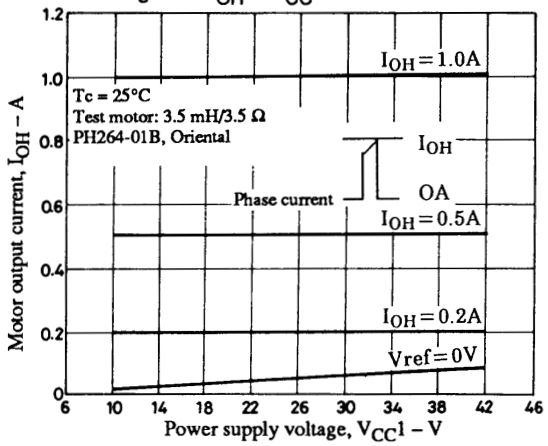


Fig. 20 I_{OH} – Tc characteristics

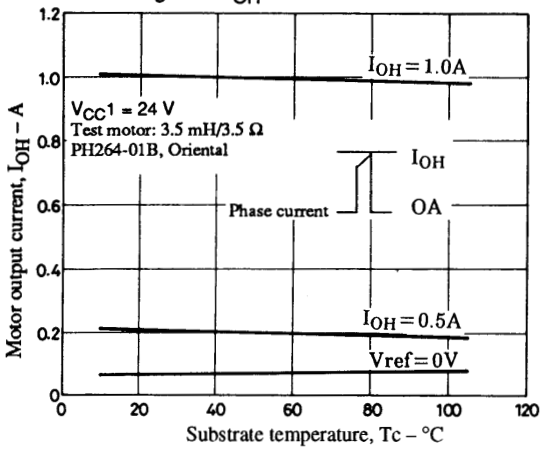


Fig. 21 I_{DD} – $V_{CC}1$ characteristics

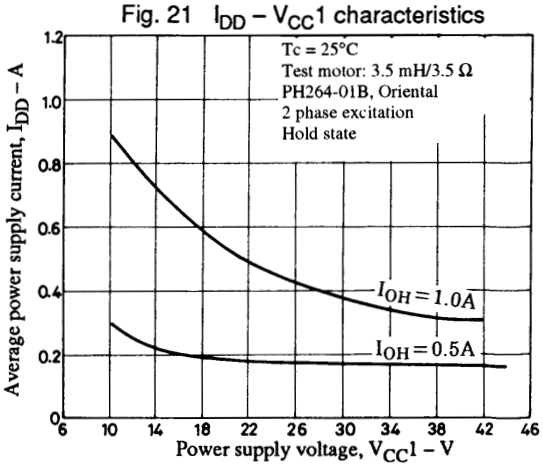


Fig. 22 fc – Tc characteristics

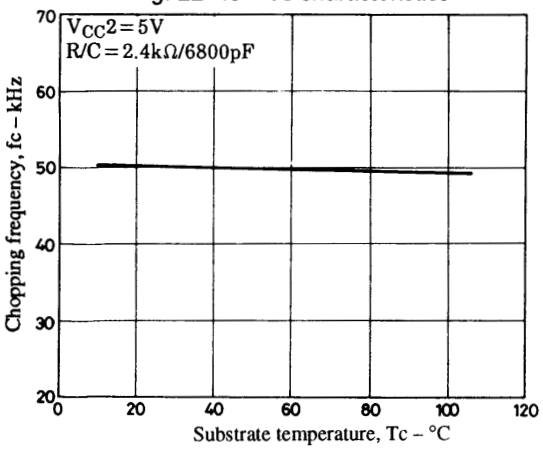


Fig. 23 fc – $V_{CC}2$ characteristics

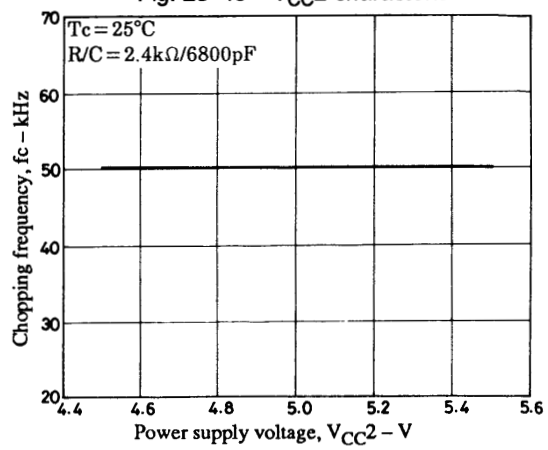


Fig. 24 fc – C1 characteristics

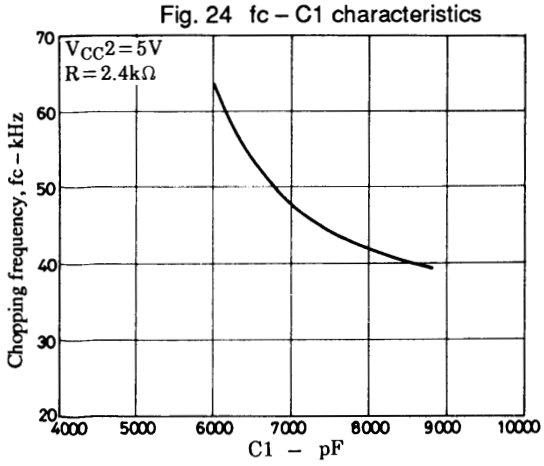


Fig. 25 ΔTc – Input pulse characteristics

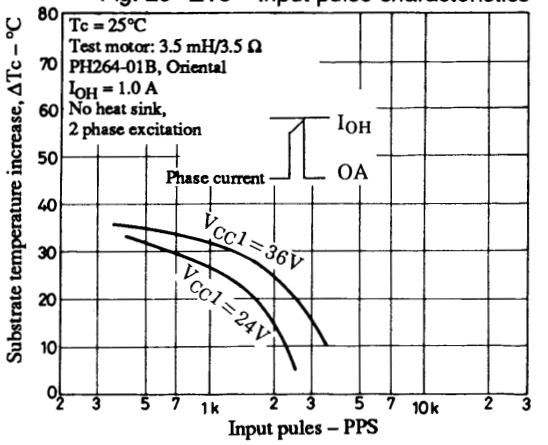


Fig. 26 τ – Input pulse characteristics