

SANYO

No. 4292A

STK6712BMK3**Unipolar Fixed-current Chopper-type
4-phase Stepping Motor Driver****Overview**

The STK6712BMK3 is a unipolar fixed-current chopper-type 4-phase stepping motor driver hybrid IC (HIC) which uses a MOSFET power device. The excitation sequence signal is active low.

Applications

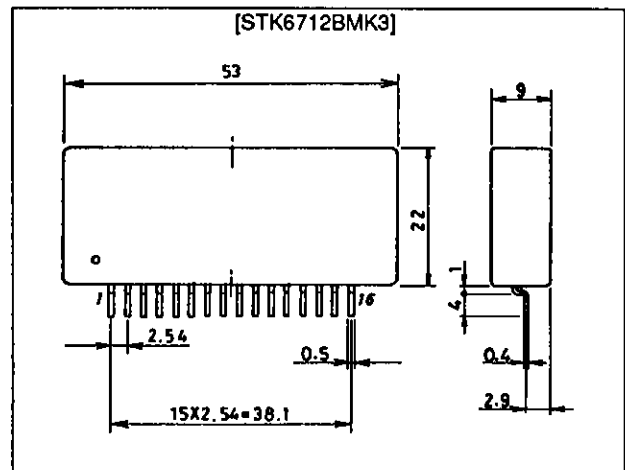
- Serial printer, line printer, and laser beam printer (LBP) paper feed and carriage motor drivers
- PPC scanner and LBP paper feed drivers
- XY plotter pen drivers
- Industrial robot applications, etc.

Features

- Uses IMST (Insulated Metal Substrate Technology) substrate.
- This IC is the same as the STK6712BMK2 without the regulator and with modifications to the MOSFET. Internal power dissipation has been cut by about 30%, and the external 2 W resistance is also unneeded.
- Self-excitation design means chopping frequency is determined by motor L and R. Supports chopping at 20 kHz or higher.
- Very low number of external components required.
- Wide operating supply voltage range ($V_{CC1} = 18$ to 42V)
- Excitation sequence signal is active low, and is TTL level for direct interfacing to the microcomputer.
- The unipolar design enables use as a driver for hybrid, PW, or VR type stepping motors.
- Supports W1-2 phase operation, with a dual Vref pin.

Package Dimensions

unit: mm

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Maximum Ratings at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Maximum supply voltage 1	V _{CC1max}	No input signal	52	V
Maximum supply voltage 1	V _{CC1max}	No input signal	52	V
Maximum supply voltage 2	V _{CC2max}	No input signal	7	V
Maximum phase current	I _{OH} max	per phase, R/L = 5Ω, 10mH, 0.5 s 1 pulse, V _{CC} input	2.5	A
Operating substrate temperature	T _c max		105	°C
Junction temperature	T _j max		150	°C
Storage temperature	T _{stg}		-40 to +125	°C
Repeated avalanche handling capability	E _{ar} max		38	mJ

Allowable Operating Ranges at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage 1	V _{CC1}	With input signal	18 to 42	V
Supply voltage 2	V _{CC2}	With input signal	4.75 to 5.25	V
Phase driver withstand voltage	V _{DSS}		(min)120	V
Phase current	I _{OH} max	Duty 50%	(max)1.7	A

Junction Thermal Resistance

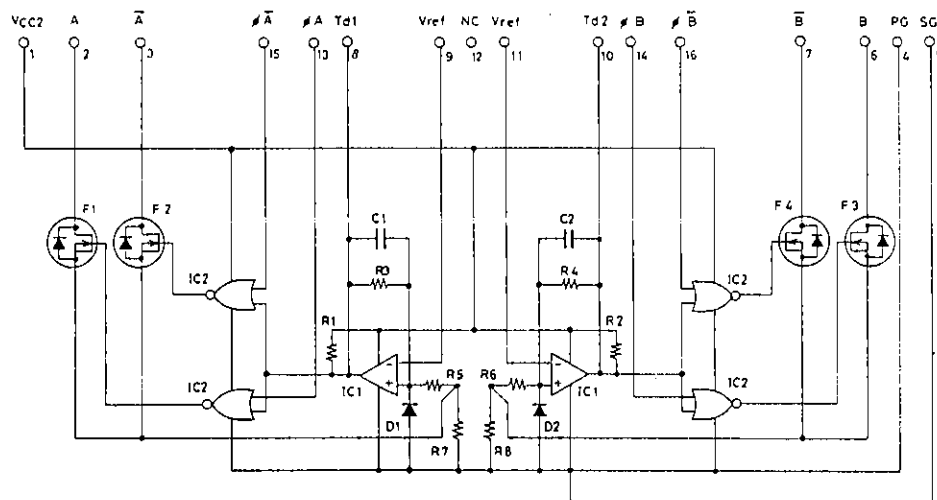
Power FET	θ _{j-c}	Unit
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Electrical Characteristics at Ta = 25°C, V_{CC1} = 36V, V_{CC2} = 5V

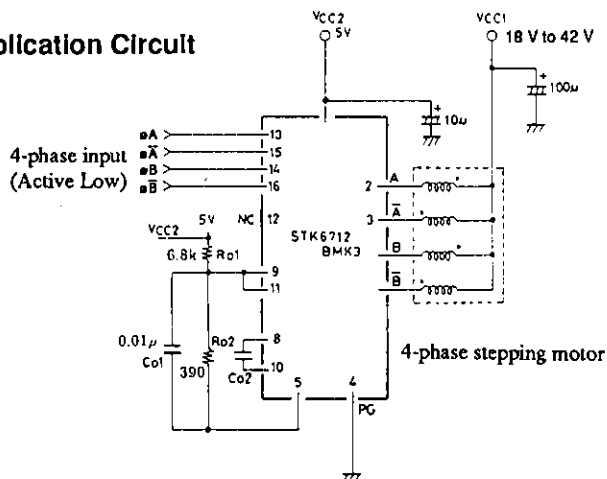
		min	typ	max	Unit
Output saturation voltage 1	V _{ST}	R _L =23Ω, V _{IN} =0.8V	1.1	1.5	V
Output current (average)	I _{o ave}	R/L=3.5Ω/3.8mH, V _{IN} =0.8V, per phase	0.52	0.58	A
Pin current consumption (average)	I _{CC2}	Load, R=3.5Ω, L=3.8mH V _{IN} = 0.8V, per phase	10	20	mA
FET diode voltage	V _{df}	I _{df} =1.0A	1.2	1.8	V
TTL input ON voltage	V _{IH}	Input voltage when F1, 2, 3, 4 OFF	2.0		V
TTL input OFF voltage	V _{IL}	Input voltage when F1, 2, 3, 4 ON		0.8	V
Switching time	t _{ON}	R _L =24Ω, V _{IN} =0.8V	95		ns
	t _{OFF}	R _L =24Ω, V _{IN} =0.8V	0.2		μs

Note: With regulated voltage power supply.

Equivalent Circuit

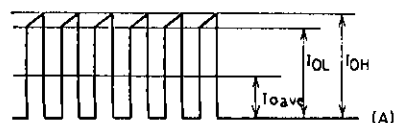


Sample Application Circuit



I_{OH} = 0.9A set constant

Output current waveform when phases held (locked)



Measure output current values in this state

Unit (resistance:Ω, capacitance:F)

Note For reference, when $I_{OH} \approx 1.1$ A, $R_{O1} = 6.8$ k Ω and $R_{O2} = 390$ Ω .

$$I_{OH} = K \times \frac{R_{O2}}{R_{O1} + R_{O2}} \times V_{CC2}/R_7$$

$$K \approx 1.3$$

$$R_7 = R_8 \approx 0.33\Omega \pm 3\%$$

To reduce noise during motor hold, it is possible to mount $C_{O1} \approx 0.01$ μ F and $C_{O2} \approx 100$ to 200 pF. Normally these are not required.

Note Both input signals cannot be L at the same time.

STK6712BMK3 Circuit Operation

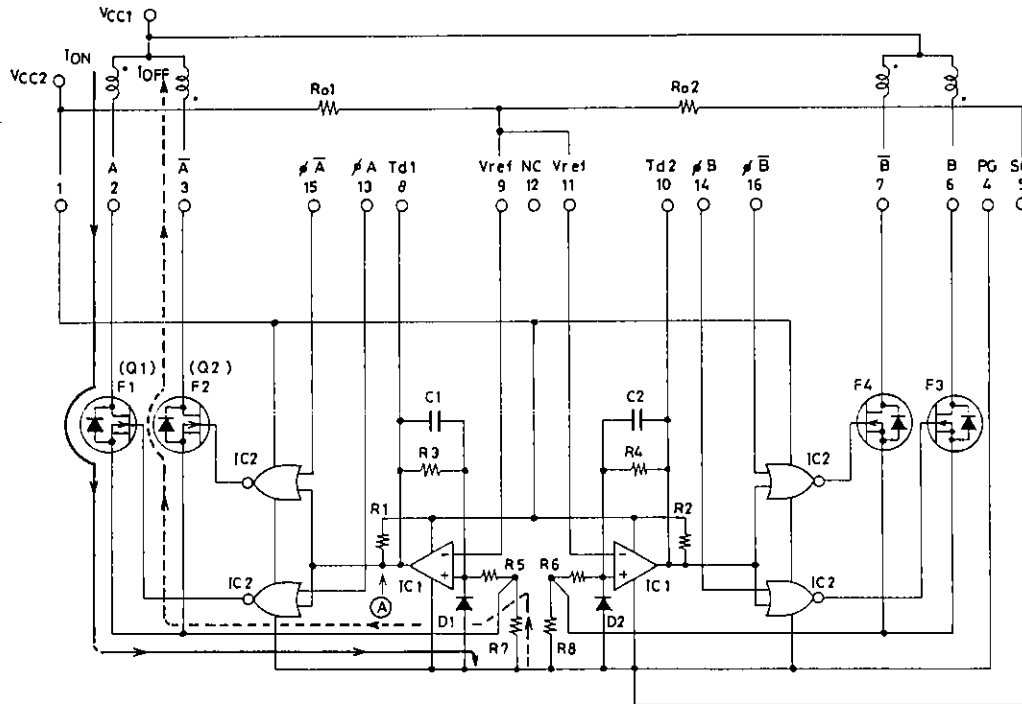


Fig. 1 STK6712BMK3 Internal Equivalent Circuit

The operation for a 4-phase dual-excitation example is described below.

The STK6712BMK3 equivalent circuit is given in Fig. 1. The circuit consists of the phase drivers, the comparator, the PWM excitation select and the current detect resistance. In Fig. 1 ϕA is input with low, and $\phi \bar{A}$ with high. When Q1 goes on, the +pin of IC1 (comparator) goes low, making IC1 output A low also. A winding current i_{ON} through Q1 increases as:

$$i_{ON} = \frac{V_{CC1} - V_{SAT}}{R} (1 - e^{-\frac{R}{L} t}) \dots \dots \dots (1)$$

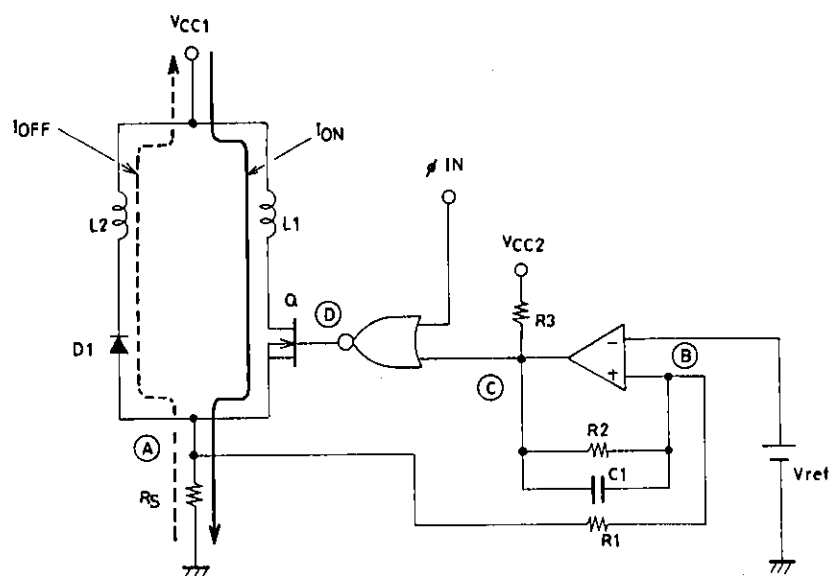
L: motor winding inductance

R: Sum of winding resistance and current detect resistance

For this reason, pin voltage VR7 at source resistor R7 increases, and when the V_{RO2} voltages of pin 8 and RO2 are equal output A goes high, and Q1 turns off. The inverse voltage VTP is as:

$$V_{TP} = V_{ref} = \frac{R_{O2}}{R_{O1} + R_{O2}} \times V_{CC2} \dots \dots \dots (2)$$

In general stepping motor coils use BIFALAR windings, so the energy stored in L1 is generated by L2, at which time the current in L2 is i_{OFF} . i_{OFF} conduction continues until the charges of capacitors C1 and C2 on R3 and R4 pins (E_C) equal V_{RO2} . When they are equal, output A inverts and becomes low. Motor winding current i_{ON} again rises to V_{RO2} level. This motor current on/off (constant current chopping) is repeated. This waveform is illustrated on the next page.



STK6712BMK3 Basic Circuit

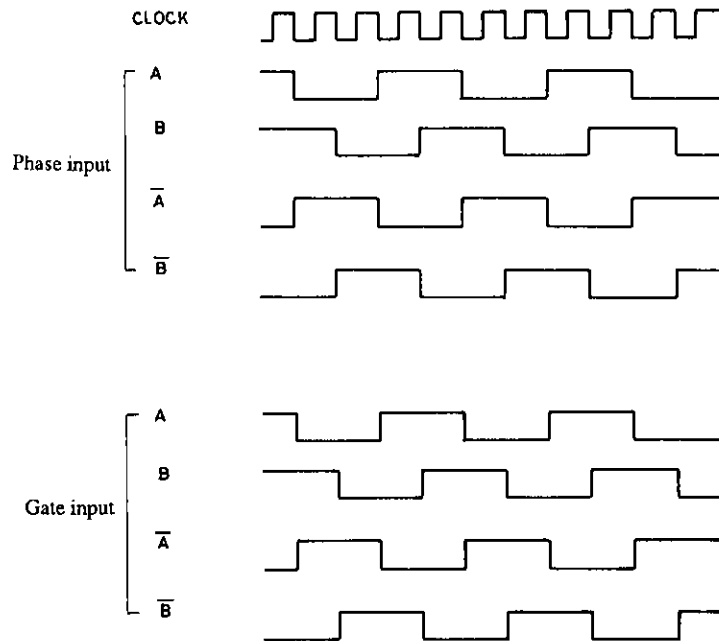
The timing diagram illustrates the electrical characteristics of the 74VHC04 inverter. It consists of several vertically stacked waveforms:

- Input (IN):** A square wave signal that transitions between logic high and low levels.
- Output (A):** The inverter's output signal, which is a square wave that is the logical complement of the input signal.
- CI discharge voltage (E_C):** A waveform showing the voltage at the internal node during the discharge phase, characterized by sharp peaks and exponential decay curves.
- Reference Voltage (V_{ref}):** A horizontal dashed line indicating the reference voltage level.
- Output Low Voltage (V_{OL}):** A horizontal dashed line indicating the maximum voltage allowed on the output when it is in the low state.
- Supply Voltage (V_{CC2}):** A square wave representing the power supply voltage, which transitions between V_{CC} and $2V_{CC}$.
- Output Current (i_{OFF}):** A waveform showing the current flowing out of the output pin when the output is in the high state.
- Output Current (i_{ON}):** A waveform showing the current flowing into the output pin when the output is in the low state.
- Gate Voltage (V_{DS}):** A square wave representing the gate voltage, which transitions between V_{CC} and $2V_{CC}$.

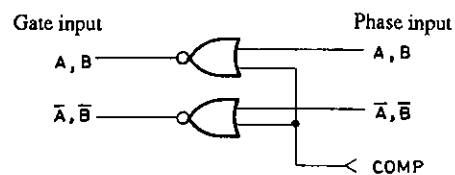
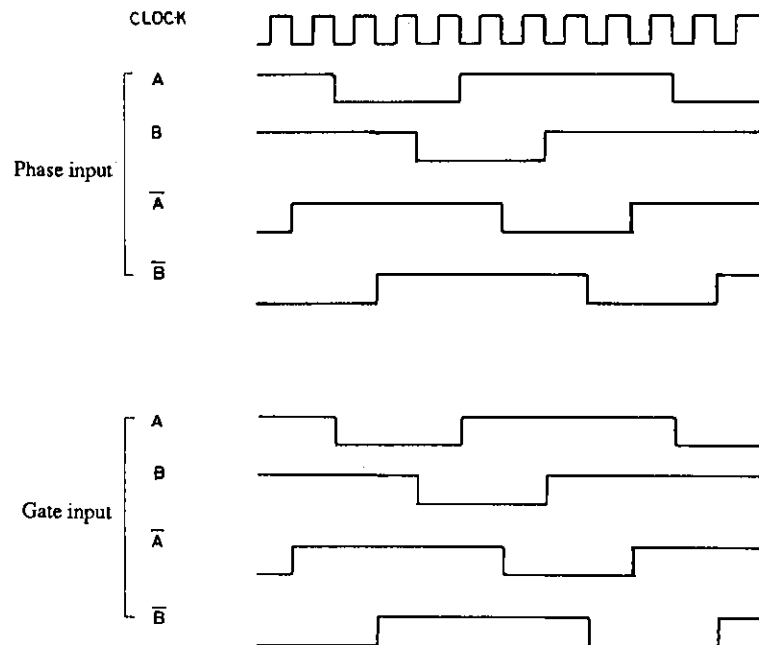
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Control Logic Timing Chart

a) 2-phase excitation



b) 1-2 phase excitation



STK6712BMK3 Excitation Circuit

Setting Output Current

The motor output current waveform is shown to the right.

Output current I_{OH} can be set by the user by adjusting the voltage of pin 9 (11).

The computation equation is indicated below.

$$V_{ref} = \frac{R_{O2}}{R_{O1} + R_{O2}} \times V_{CC2} \dots\dots\dots(3)$$

$$I_{OH} \approx K \times \frac{V_{ref}}{R_s} \dots\dots\dots(4)$$

R_s : Internal current detect resistance
(0.33±3%)

K : 1.1 to 1.2 (correction for actual measurement)

Power down can be accomplished by reducing the synthetic impedance by connecting a resistance in parallel to R_{O2} .

The motor output current variation range can be set for the range of:

$$I_{OH} = 0.2A \text{ to } 1.7A$$

but when set to $I_{OH} = 0.2 A$ or lower note that the HIC GND pattern will be one-point earth with respect to the power supply. If earth is poor, there may be no motor current when $I_{OH} = 0.2 A$. We recommend a motor inductance usage range of $L = 1 \text{ mH}$ to 10 mH .

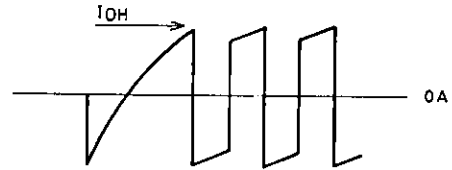


Fig. 3 Output Motor Current Waveform

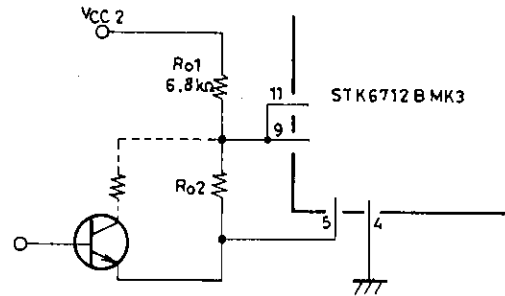


Fig. 4 Vref Peripheral Circuit

Determining Chopping Frequency

The STK6712BMK3 uses constant current for self-excitation.

The $I_{OH} t_{OFF}$ time is set to about $14 \mu s$, and the t_{ON} time can be expressed as:

$$t_{ON} \approx \frac{L}{R + 0.88} \ln \left(\frac{V_{CC} - (I_{OH} e^{-\frac{R}{L} t_{OFF}} - \frac{V_{CC} + 0.88}{R} (1 - e^{-\frac{R}{L} t_{OFF}})) (R + 0.88)}{V_{CC} - (R + 0.88) I_{OH}} \right) \dots\dots\dots(5)$$

L : Motor winding inductance

R : Motor resistance

V_{CC} : Motor supply voltage

I_{OH} : Output current

As a result, the chopping frequency is

$$F \approx \frac{1}{t_{ON} + t_{OFF}} = \frac{1}{t_{ON} + 14 \times 10^{-6}} \text{ (Hz)} \dots\dots\dots(6)$$

However, note that when the following conditions exist the value for F will change.

$$14 \times 10^{-6} \geq \frac{L}{R} \ln \left(\frac{V_{CC} + 0.88}{I_{OH} \times R + V_{CC} + 0.88} \right) = t_{OFF2} \quad (7)$$

$$t_{OFF} \approx t_{OFF1} + t_{OFF2} = 14 \times 10^{-6} + t_{OFF}$$

$$\therefore F = \frac{1}{t_{ON} + 14 \times 10^{-6} + t_{OFF2}} \text{ (Hz)} \quad (8)$$

Because the STK6712BMK3 is self-exciting there will be minor variation in motor inductance during motor revolution. Final design verification is required in an actual model.

Thermal Radiation Design

The HIC radiator plate size is dependent on the motor output current $I_{OH}(A)$, motor electrical characteristics, excitation mode, and excitation input signal clock frequency f_{clock} (Hz).

The thermal resistance for the radiator can be determined from the following expression.

$$\theta_{c-a} = \frac{T_{c \text{ max}} - T_a}{P_d} \text{ (}^\circ\text{C/W)} \quad (9)$$

$T_{c \text{ max}}$ = HIC substrate temperature ($^\circ\text{C}$)

T_a = set internal temperature ($^\circ\text{C}$)

P_d = HIC internal mean power dissipation (W)

With a 2.00 mm aluminum radiation plate, the required area can be determined from Fig. 6. Note that substrate temperature will vary widely with set internal air temperature, and therefore the rear side of the HIC (the aluminum plate side) must always be kept below the maximum temperature of 105°C .

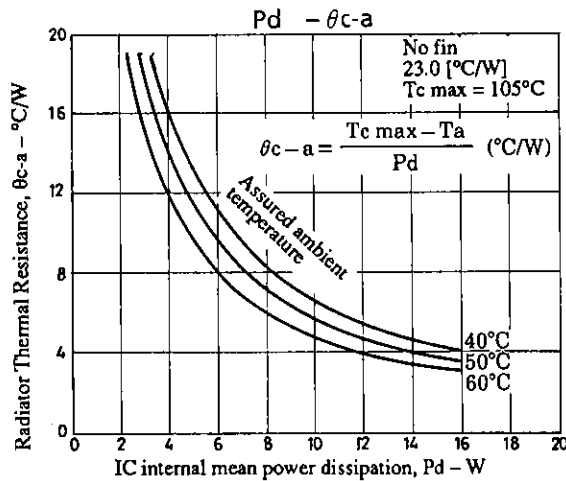


Fig-5

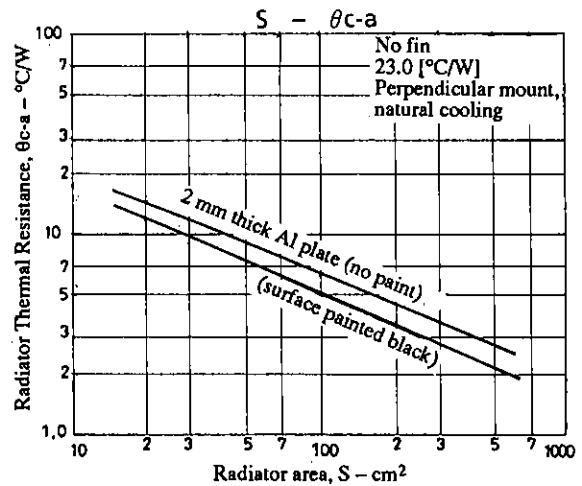


Fig-6

HIC Internal Mean Power Dissipation Pd

The internal mean power dissipation of the STK6712BMK3 is primarily due to the current control device, the regenerating current diode, the current detect resistance and the predriver circuit.

Loss in each excitation mode is:

$$2 \text{ phase excitation } Pd_{2EX} \approx (V_{st} + V_{df}) \frac{f_{clock}}{2} I_{OH} t_2 + \frac{f_{clock}}{2} I_{OH} (V_{st} \times t_1 + V_{df} \times t_3) \dots\dots\dots(10)$$

$$1-2 \text{ phase excitation } Pd_{1-2EX} \approx (V_{st} + V_{df}) \frac{3I_{OH}t_2}{8} f_{clock} + \frac{3I_{OH}}{3} f_{clock} (V_{st} \times t_1 + V_{df} \times t_3) \dots\dots\dots(11)$$

- V_{st} : R_{ON} voltage drop + R7 (R8) output voltage
- V_{df} : FET internal diode + R7 (R8) output voltage
- f_{clock} : Input clock (reference frequency before frequency divider)

t₁, t₂ and t₃ are the time modes for the waveform indicated below.

- t₁ : Time for winding current to rise to set current
- t₂ : Time for constant current chopping region
- t₃ : Time from end of phase input signal until inverse current regeneration is complete.

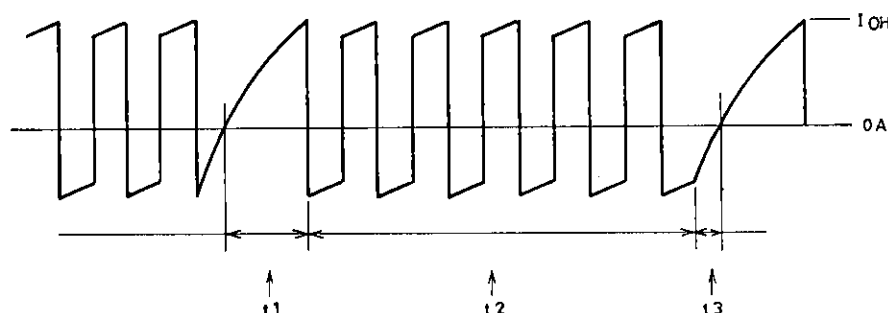


Fig. 7 Motor Output Current Waveform (model)

$$t_1 \approx \frac{-L}{R + 0.88} \ln \left(1 - \frac{R + 0.88}{V_{CC}} \times I_{OH} \right) \dots\dots\dots(12)$$

$$t_3 \approx \frac{-L}{R} \ln \left(\frac{V_{CC} + 0.88}{I_{OH} \cdot R + V_{CC} + 0.88} \right) \dots\dots\dots(13)$$

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

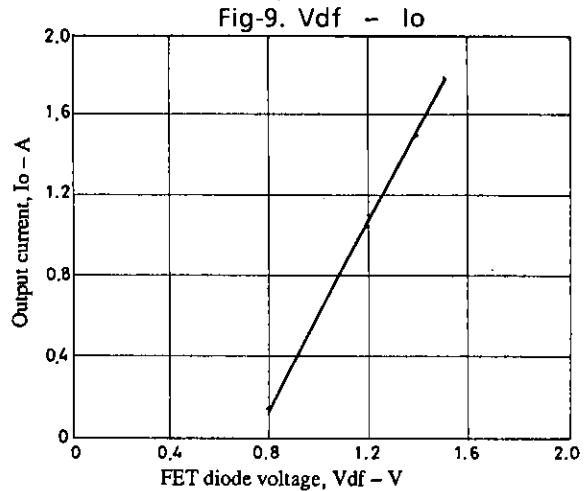
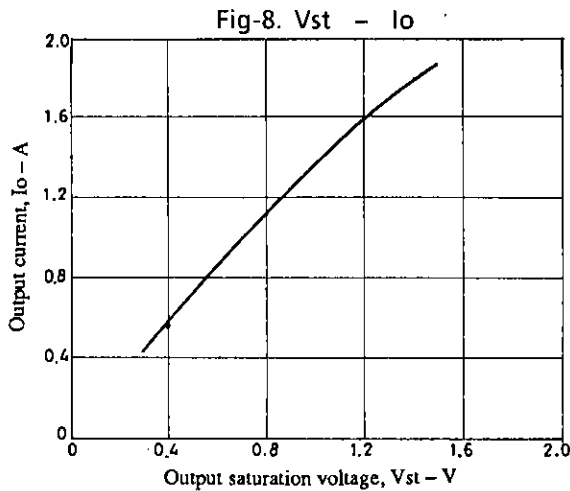
The chopping frequency F and t₂ for each excitation mode are:

$$2 \text{ phase excitation } F = f_{clock}/2, t_2 = (1/F) - (t_1 + t_3) \dots\dots\dots(14)$$

$$1-2 \text{ phase excitation } F = 3f_{clock}/8, t_2 = (1/F) - t_1 \dots\dots\dots(15)$$

f_{clock} : 4-phase divider input oscillation frequency

The characteristic diagrams (typ) for I_{OH} and V_{st}, and I_{OH} and V_{df} are given in Figs. 8 and 9.



STK6712BMK3 No Thermal Radiation Range (example)

An example of STK6712BMK3 use in the no-fin state is indicated below.

Conditions:

- Motor supply voltage $V_{CC1} = 30$ V, stepping motor: Electrical characteristics $3.5\text{mH}/\phi$, $3.5\Omega/\phi$
- Excitation: 2-phase
- Input clock frequency $500\text{Hz} = f_{\text{clock}}$
- HIC ambient temperature $T_a = 25^\circ\text{C}$, natural convection
- HIC rear substrate temperature $T_c = 105^\circ\text{C}$, saturation
- Motor output current $I_{OH} = 1.4$ A

At this time, the HIC permissible loss can be calculated as:

$$\text{Maximum loss: } P_{d \max} = \frac{T_{c \max} - T_a}{\theta_{c-a}} = \frac{105 - 25}{23} = 3.4(\text{W}) \quad (16)$$

From these conditions and expressions (12), (13) and (14):

$$t_1 = 0.183\text{ms}$$

$$t_2 = 3.670\text{ms}$$

$$t_3 = 0.147\text{ms}$$

V_{st} and V_{df} can be determined from Fig. 8, Fig. 9 and expression (10) as:

$$\begin{aligned} P_{d2EX} &= (V_{st} + V_{df}) \frac{f_{\text{clock}}}{2} I_{OH} t_2 + \frac{f_{\text{clock}}}{2} I_{OH} (V_{st} \times t_1 + V_{df} \times t_3) \quad (17) \\ &= 3.08 + 0.14 = 3.22 (\text{W}) \end{aligned}$$

From expression (9), T_c is calculated as:

$$T_c = P_{d2EX} \times \theta_{c-a} + T_a = 3.22 \times 23 + 25 \approx 99.1 (^\circ\text{C}) \quad (18)$$

This is only one example, and because convection and other air movements around the HIC will not match mathematical modelling verification with an actual model is essential.

Motor Hold Noise Countermeasures

The STK6712BMK3 executes constant current chopping outside the audible range. During motor hold the current hold is outside the range of audible frequencies, but for motors of sizes 30 to 40 mm square (when seen from the shaft direction) with inductance of about 15 mH, there are cases where the output noise is converted to low-frequency noise. In this case, addition of the following components will essentially eliminate such audible noise.

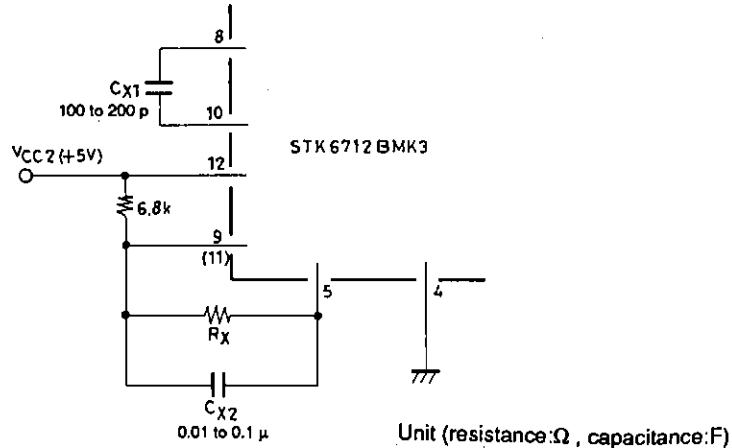


Fig. 10 Motor Hold Noise Countermeasure

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