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# STK672-612B-E

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**Thick-Film Hybrid IC**

## 2-phase Stepping Motor Driver

### Overview

The STK672-612B-E is a hybrid IC for use as a unipolar, 2-phase stepping motor driver with PWM current control.

### Applications

- Office photocopiers, printers, etc.

### Features

- Built-in opened motor pin detection function (output current OFF).
- Built-in overcurrent detection function (output current OFF).
- Built-in overheat detection function (output current OFF).
- If opened motor pin, over-current, or overheat detection function is activated, the FAULT1 signal (active low) is output. The FAULT2 signal is used to output the result of activation of protection circuit detection at 3 levels.
- Built-in power on reset function.
- The motor speed is controlled by the frequency of an external clock signal.
- 2 phase or 1-2 phase excitation switching function.
- Using either or both edges of the clock signal switching function.
- Phase is maintained even when the excitation mode is switched.
- Rotational direction switching function.
- Supports schmitt input for 2.5V high level input.
- Incorporating a current detection resistor ( $0.39\Omega$ : resistor tolerance  $\pm 2\%$ ), motor current can be set using two external resistors.
- The ENABLE pin can be used to cut output current while maintaining the excitation mode.
- With a wide current setting range, power consumption can be reduced during standby.
- No motor sound is generated during hold mode due to external excitation current control.

# STK672-612B-E

## Specifications

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

Parameter	Symbol	Conditions	Ratings	unit
Maximum supply voltage 1	$V_{CC}$ max	No signal	50	V
Maximum supply voltage 2	$V_{DD}$ max	No signal	-0.3 to +6.0	V
Input voltage	$V_{IN}$ max	Logic input pins	-0.3 to +6.0	V
Output current 1	$I_{OP}$ max	10 $\mu$ A, 1 pulse (resistance load)	10	A
Output current 2	$I_{OH}$ max	$V_{DD}=5\text{V}$ , $\text{CLOCK}\geq 200\text{Hz}$	1.0	A
Output current 3	$I_{OF}$ max	Pin16 output current	10	mA
Allowable power dissipation 1	$P_{dMF}$ max	With an arbitrarily large heat sink. Per MOSFET	7.3	W
Allowable power dissipation 2	$P_{dPK}$ max	No heat sink	2.8	W
Operating substrate temperature	$T_c$		-20 to +105	$^\circ\text{C}$
Junction temperature	$T_j$ max		150	$^\circ\text{C}$
Storage temperature	$T_{stg}$		-40 to +125	$^\circ\text{C}$

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

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

Parameter	Symbol	Conditions	Ratings	unit
Operating supply voltage 1	$V_{CC}$	With signals applied	10 to 46	V
Operating supply voltage 2	$V_{DD}$	With signals applied	5 $\pm$ 5%	V
Input high voltage	$V_{IH}$	Pins 10, 12, 13, 14, 15, 17 $V_{DD}=5\pm 5\%$	2.5 to $V_{DD}$	V
Input low voltage	$V_{IL}$	Pins 10, 12, 13, 14, 15, 17 $V_{DD}=5\pm 5\%$	0 to 0.8	V
Output current 1	$I_{OH1}$	$T_c=105^\circ\text{C}$ , $\text{CLOCK}\geq 200\text{Hz}$ , Continuous operation, duty=100%	0.8	A
Output current 2	$I_{OH2}$	$T_c=80^\circ\text{C}$ , $\text{CLOCK}\geq 200\text{Hz}$ , Continuous operation, duty=100%, See the motor current ( $I_{OH}$ ) derating curve	0.86	A
CLOCK frequency	$f_{CL}$	Minimum pulse width: at least 10 $\mu$ s	0 to 50	kHz
Recommended Vref range	$V_{ref}$	$T_c=105^\circ\text{C}$	0.14 to 1.53	V

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

Parameter	Symbol	Conditions	min	typ	max	unit
$V_{DD}$ supply current	$I_{CCO}$	Pin 9 current $\text{CLOCK}=\text{GND}$		5	8	mA
Output average current*	$I_{oave}$	$R/L=1\Omega/0.62\text{mH}$ in each phase	0.077	0.093	0.109	A
FET diode forward voltage	$V_{df}$	$I_f=1\text{A}$ ( $R_L=23\Omega$ )		1.16	1.7	V
Output saturation voltage	$V_{sat}$	$R_L=23\Omega$		0.61	0.80	V
Input high voltage	$V_{IH}$	Pins 10, 12, 13, 14, 15, 17	2.5			V
Input low voltage	$V_{IL}$	Pins 10, 12, 13, 14, 15, 17			0.8	V
FAULT1 low output voltage	$V_{OLF}$	Pin 16 ( $I_O=5\text{mA}$ )		0.25	0.5	V
5V level FAULT leakage current	$I_{ILF}$	Pin 16=5V			10	$\mu\text{A}$
FAULT2 opened motor pin detection output voltage	$V_{OF1}$	Pin 8 (when all protection functions have been activated)	0.00	0.01	0.20	V
FAULT2 Overcurrent detection output voltage	$V_{OF2}$		2.4	2.5	2.6	
FAULT2 Overheat detection output voltage	$V_{OF3}$		3.1	3.3	3.5	
5V level input current	$I_{ILH}$	Pins 10, 12, 13, 14, 15, 17=5V		50	75	$\mu\text{A}$
GND level input current	$I_{ILL}$	Pins 10, 12, 13, 14, 15, 17=GND			10	$\mu\text{A}$
Vref input bias current	$I_{IB}$	Pin 19=1.0V			1	$\mu\text{A}$
PWM frequency	$f_c$		29	45	61	kHz
Overheat detection temperature	$T_{SD}$	Design guarantee		144		$^\circ\text{C}$
Drain-to-Source leakage current	$I_{DSS}$	$V_{DS}=100\text{V}$ , Pins 2, 6, 9, and 18=GND			1	$\mu\text{A}$

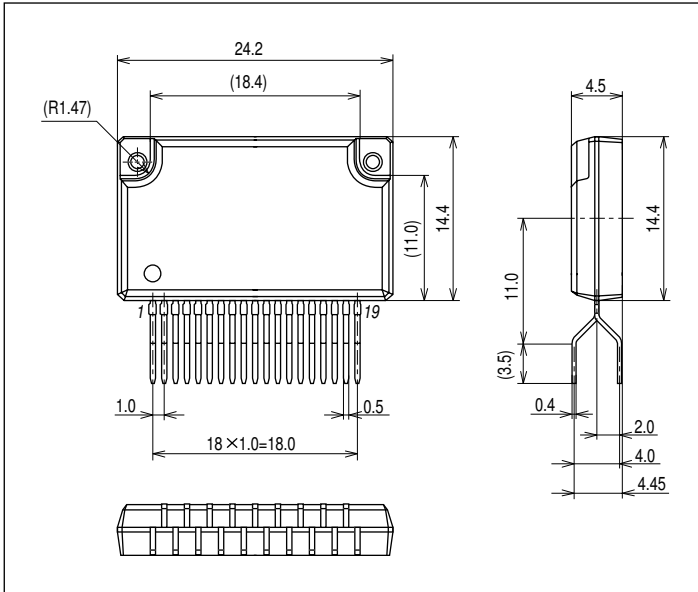
\* Maximum value of operating supply voltage 1 ( $V_{CC}$ ) can not supply to STK672-612B-E, depending on motor current value. Refer to “8. Precautions, etc” of Usage Notes.

\* $I_{oave}$  values are for when the lead frame of the product is soldered to the mounting substrate.

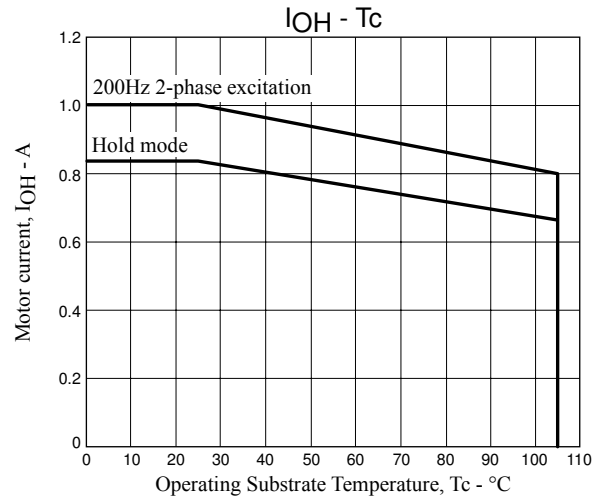
Notes: A fixed-voltage power supply must be used.

## Package Dimensions

unit:mm (typ)



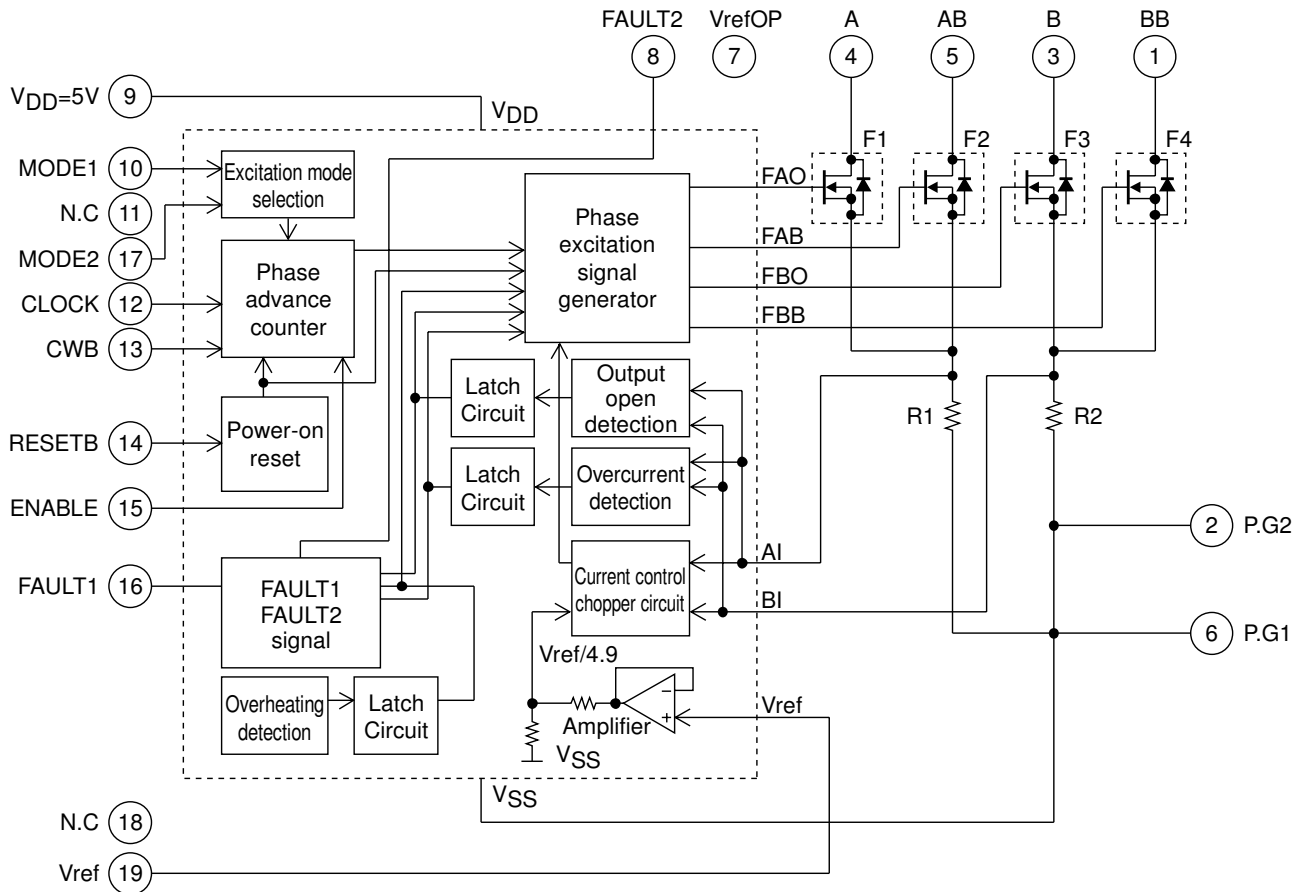
Derating curve of motor current,  $I_{OH}$ , vs. STK672-612B-E Operating substrate temperature,  $T_c$



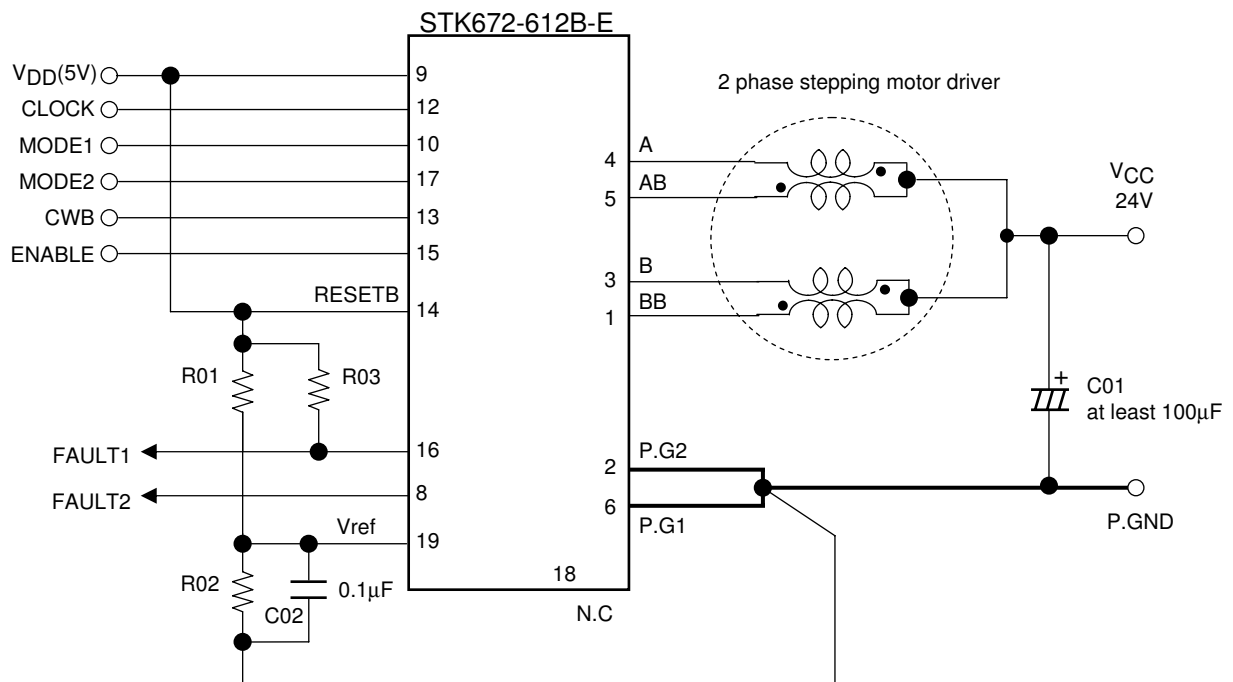
### Notes

- The current range given above represents conditions when output voltage is not in the avalanche state.
- If the output voltage is in the avalanche state, see the allowable avalanche energy for STK672-6\*\* series hybrid ICs given in a separate document.
- The operating substrate temperature,  $T_c$ , given above is measured while the motor is operating. Because  $T_c$  varies depending on the ambient temperature,  $T_a$ , the value of  $I_{OH}$ , and the continuous or intermittent operation of  $I_{OH}$ , always verify this value using an actual set.
- The  $T_c$  temperature should be checked in the center of the metal surface of the product package.

## Block Diagram



## Sample Application Circuit



## Precautions

### [GND wiring]

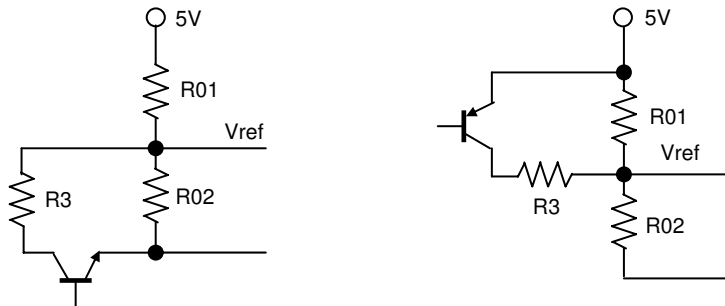
- To reduce noise on the 5V system, be sure to place the GND of C01 in the circuit given above as close as possible to Pin 2 and Pin 6 of the hybrid IC. Also, to achieve accurate current settings, be sure to connect Vref GND to the point where P.G1 and P.G2 share a connection.

### [Input pins]

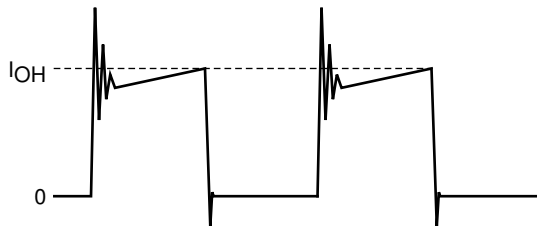
- If  $V_{DD}$  is being applied, use care that each input pin does not apply a negative voltage less than  $-0.3V$  to S.G, Pin 18, and do not apply a voltage greater than or equal to  $V_{DD}$  voltage.
- Do not wire by connecting the circuit pattern on the P.C.B side to N.C Pins. shown in the internal block diagram.
- Apply 2.5V high level input to pins 10, 12, 13, 14, 15, and 17.
- Since the input pins do not have built-in pull-up resistors, when the open-collector type pins 10, 12, 13, 14, 15, and 17 are used as inputs, a 1 to 20k $\Omega$  pull-up resistor (to  $V_{DD}$ ) must be used. At this time, use a device for the open collector driver that has output current specifications that pull the voltage down to less than 0.8V at Low level (less than 0.8V at Low level when  $I_{OL}=5mA$ ).

### [Current setting Vref]

If the motor current is temporarily reduced, the circuit given below (STK672-612B-E :  $I_{OH}>0.073A$ ) is recommended.



- Motor current peak value  $I_{OH}$  setting



$$I_{OH} = (V_{ref} \div 4.9) \div R_s$$

The value of 4.9 in Equation above represents the  $V_{ref}$  voltage as divided by a circuit inside the control IC.

$$V_{ref} = (R_{02} \div (R_{01} + R_{02})) \times 5V (\text{or } 3.3V)$$

$R_s$  is an internal current detection resistor value of the hybrid IC.

$R_s = 0.39\Omega$  when using the STK672-612B-E

## STK672-612B-E

### Input Pin Functions

Pin Name	Pin No.	Function	Input Conditions When Operating
CLOCK	12	Reference clock for motor phase current switching	Operates on the rising edge of the signal (MODE2=H)
MODE1	10	Excitation mode selection	Low: 2-phase excitation High: 1-2 phase excitation
MODE2	17		High: Rising edge Low: Rising and falling edge
CWB	13	Motor direction switching	Low: CW (forward) High: CCW (reverse)
RESETB	14	System reset Initial state of A and BB phase excitation in the timing charts is set by switching from low to high.	A reset is applied by a low level
ENABLE	15	The A, AB, B, and BB outputs are turned off, and after operation is restored by returning the ENABLE pin to the high level, operation continues with the same excitation timing as before the low-level input.	The A, AB, B, and BB outputs are turned off by a low-level input.

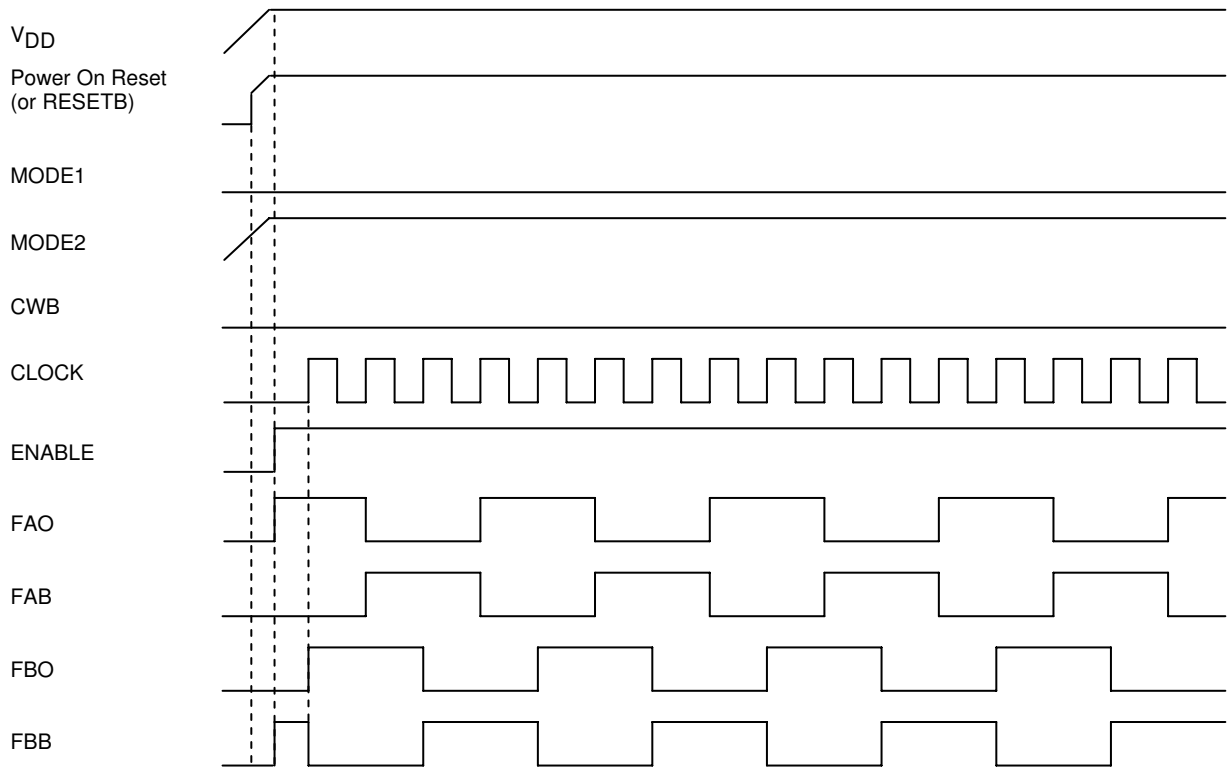
### Output Pin Functions

Pin Name	Pin No.	Function	Input Conditions When Operating
FAULT1	16	Monitor pin used when opened motor pin, over-current detection, or overheat detection function is activated.	Low level is output when detected.
FAULT2	8	The result of activation of protection circuit detection is output.	3 levels output voltage
VrefOP	7	Monitor pin of reference voltage used when opened motor pin detection.	Normal DC voltage output (typ98mV)

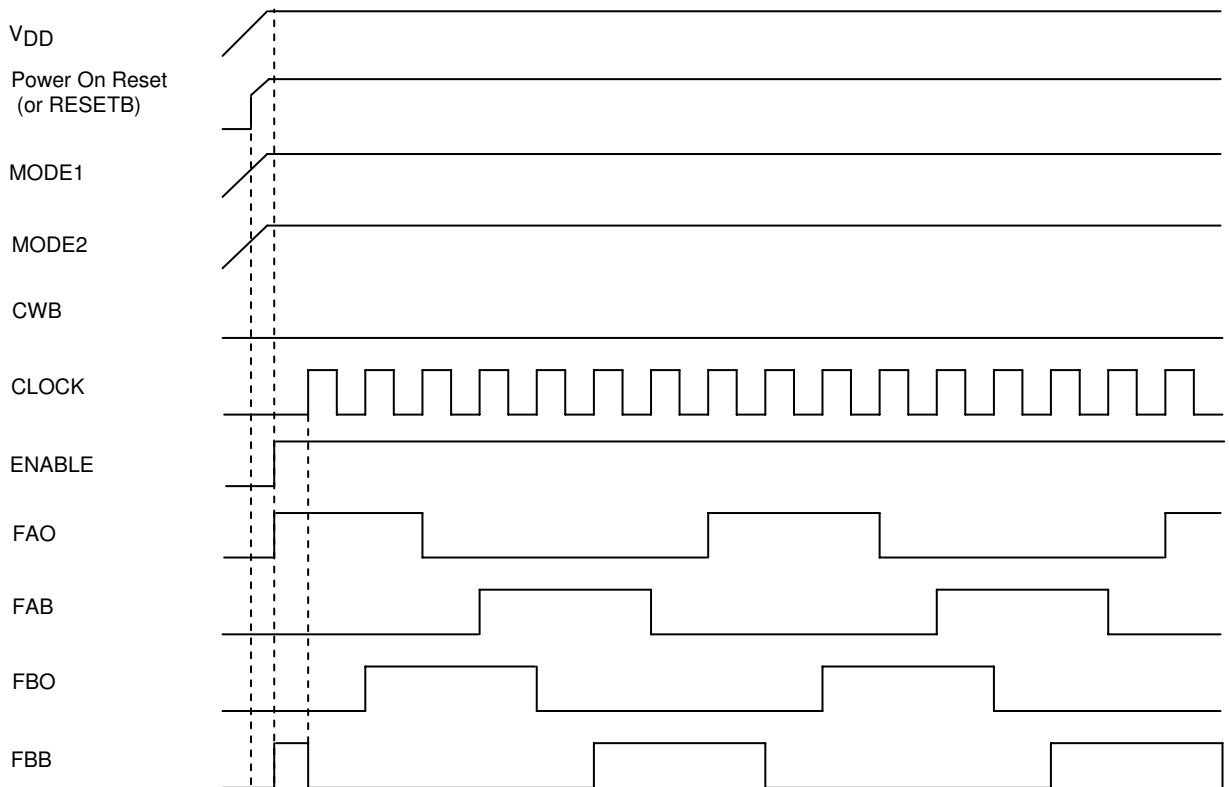
Note: See the timing chart for the concrete details on circuit operation.

## Timing Charts

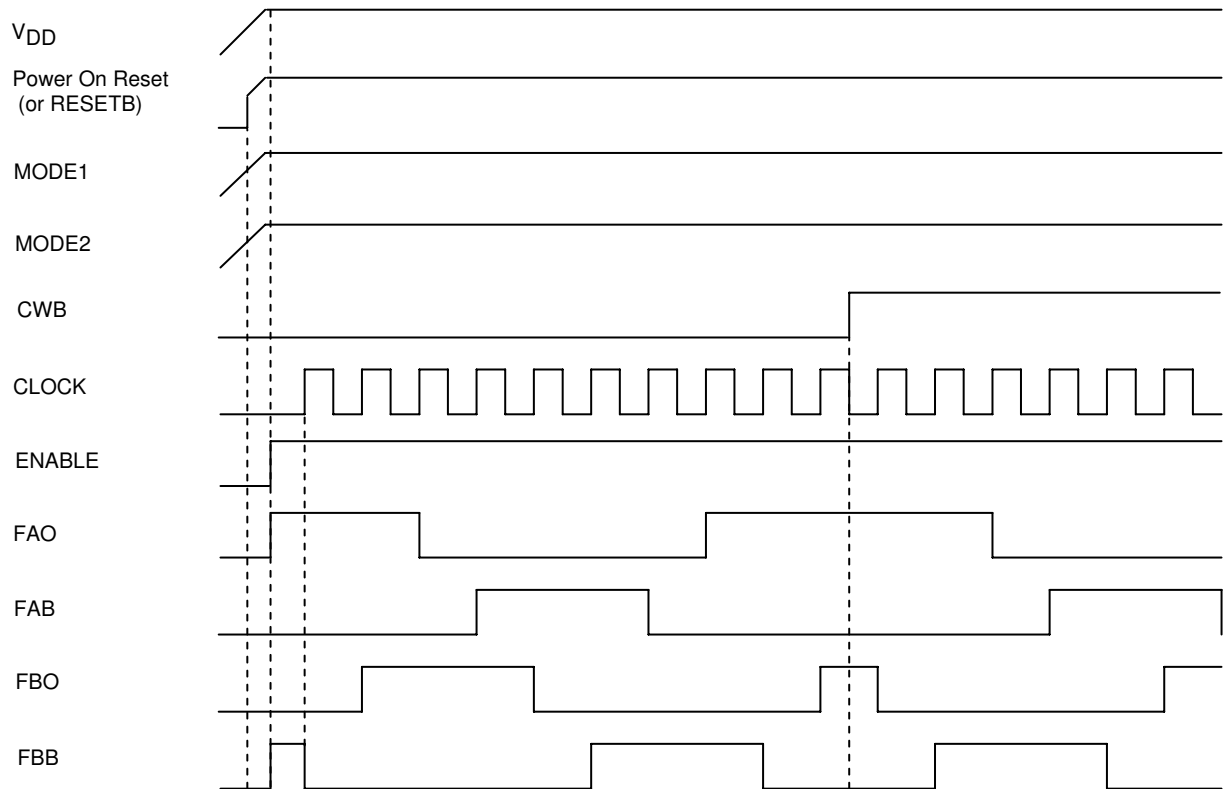
### 2-phase excitation



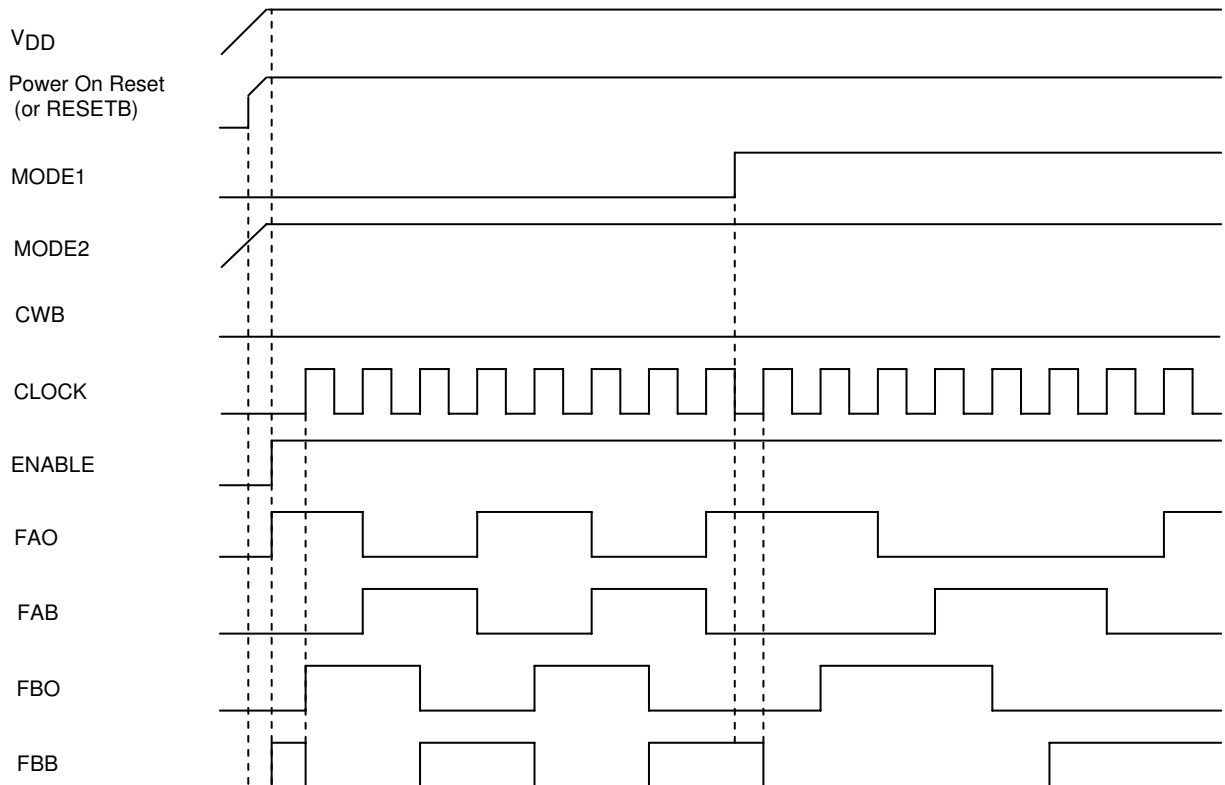
### 1-2 phase excitation



## 1-2 phase excitation (CWB)

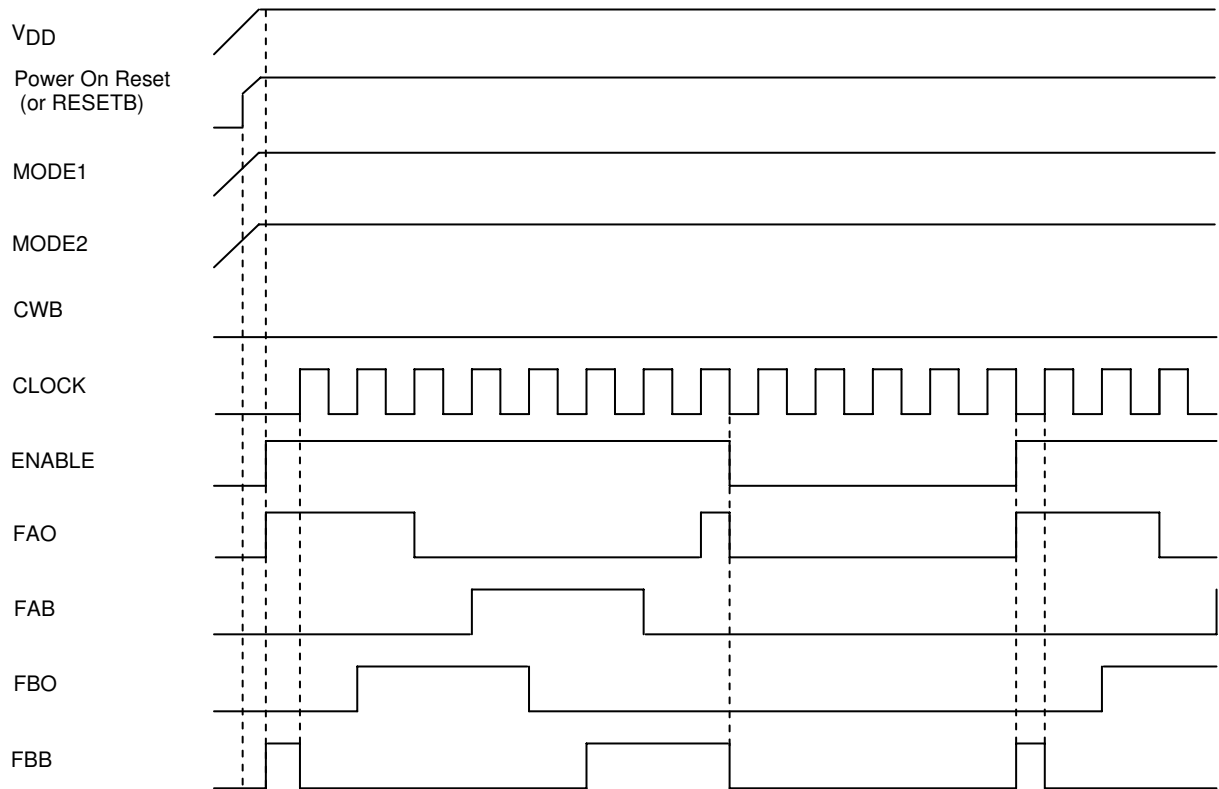


## 2 phase excitation → Switch to 1-2 phase excitation

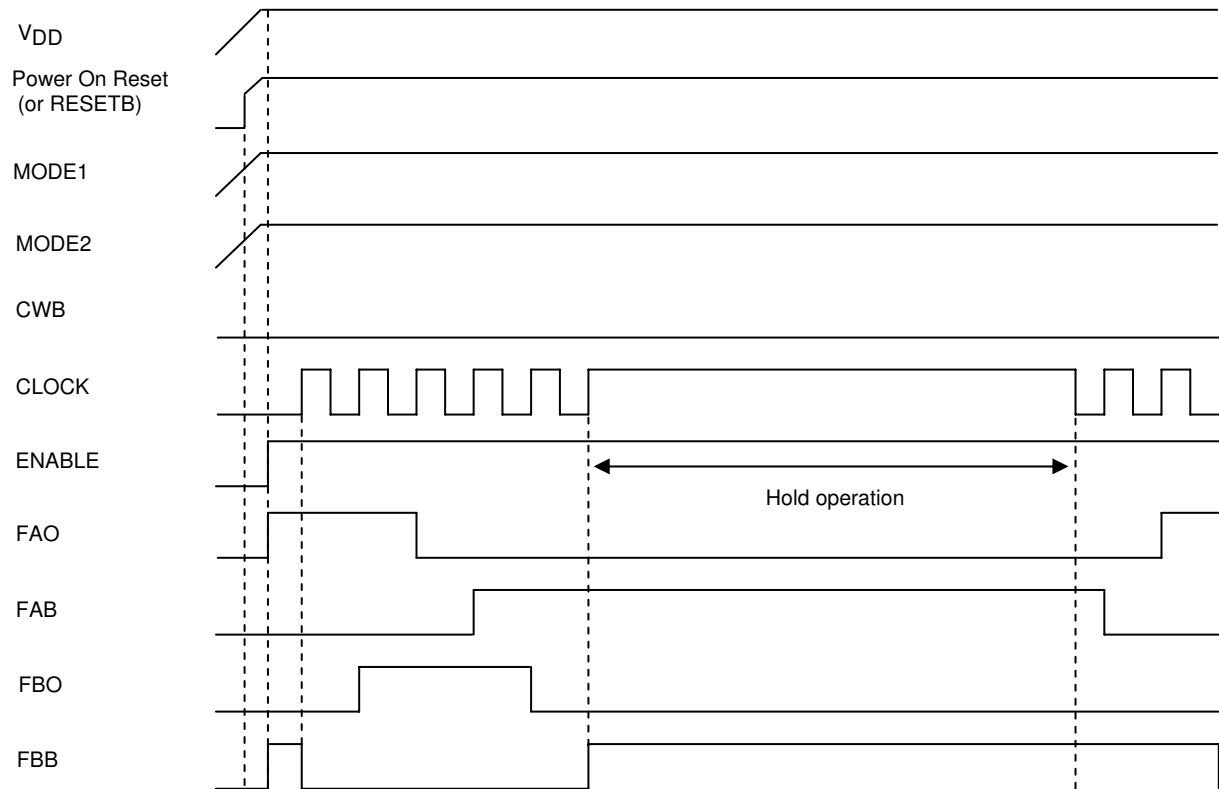




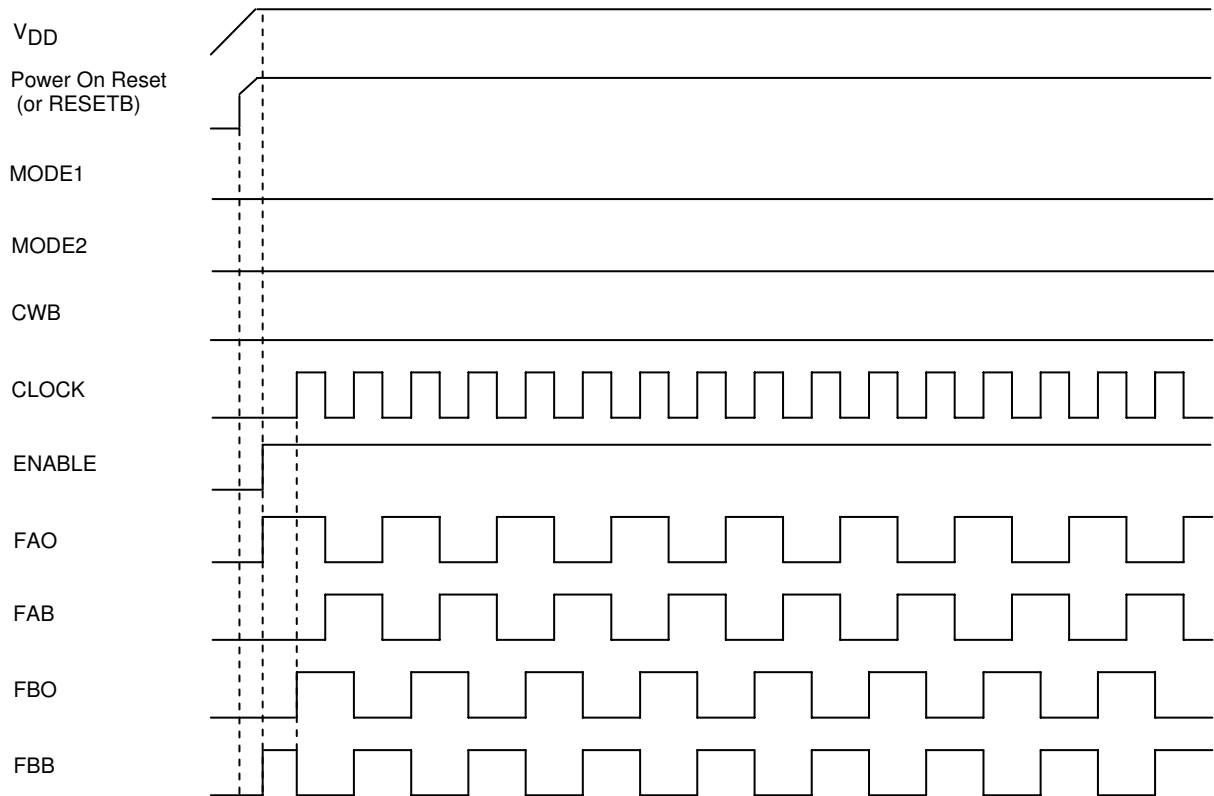
## 1-2 phase excitation (ENABLE)



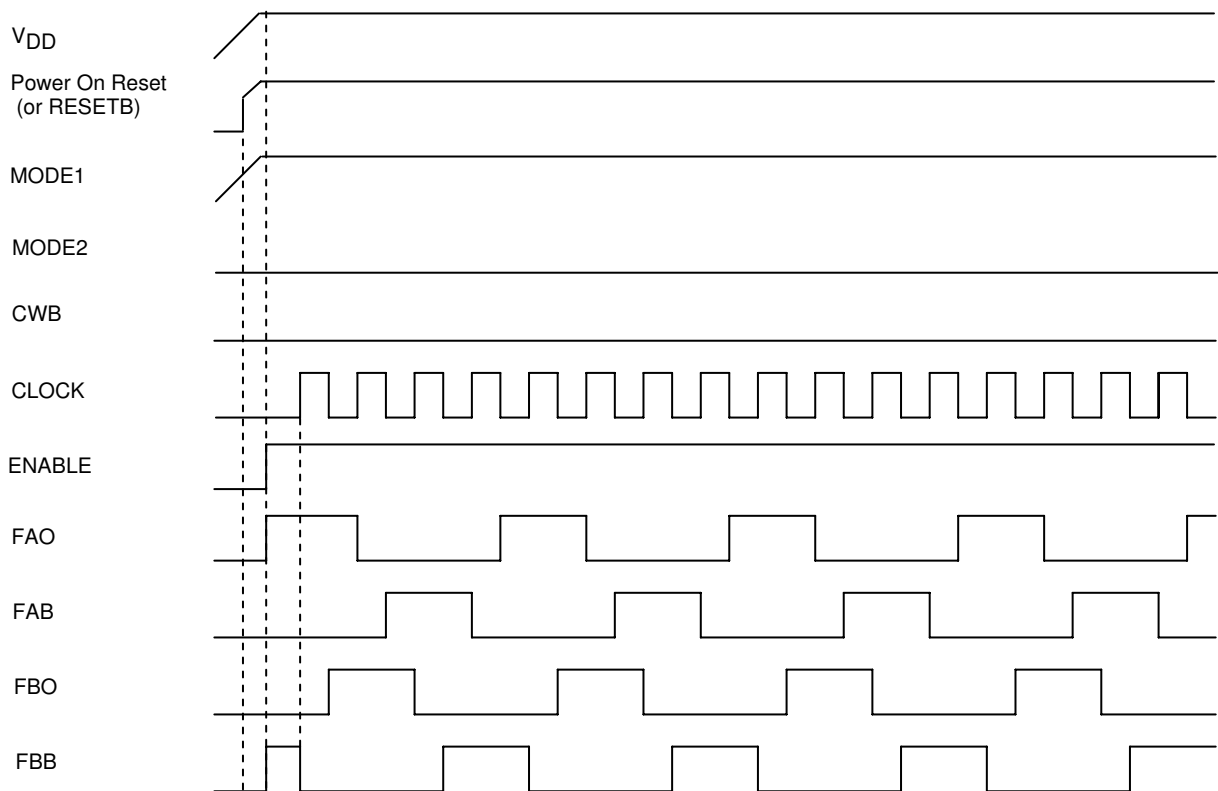
## 1-2 phase excitation (Hold operation results during fixed CLOCK)



## 2 phase excitation (MODE 2)



## 1-2 phase excitation (MODE 2)



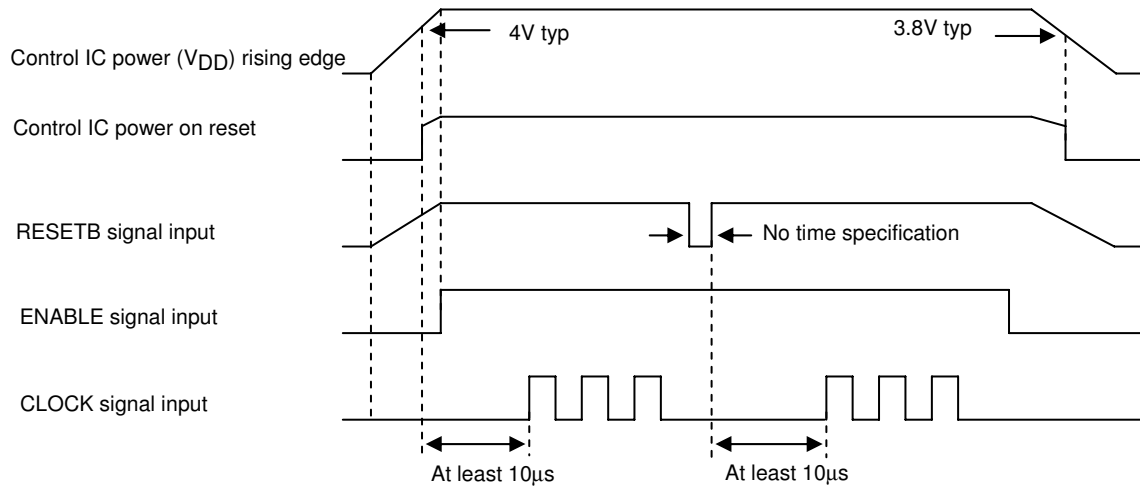
## Usage Notes

### 1. STK672-612B-E input signal functions and timing

[ENABLE, CLOCK and power on reset, RESETB (Input signal timing when power is first applied)]

The control IC of the driver is equipped with a power on reset function capable of initializing internal IC operations when power is supplied. A 4V typ setting is used for power on reset. Because the specification for the MOSFET gate voltage is  $5V \pm 5\%$ , conduction of current to output at the time of power on reset adds electromotive stress to the MOSFET due to lack of gate voltage. To prevent electromotive stress, be sure to set ENABLE=Low while  $V_{DD}$ , which is outside the operating supply voltage, is less than 4.75V.

In addition, if the RESETB terminal is used to initialize output timing, be sure to allow at least 10 $\mu$ s until CLOCK input.



ENABLE, CLOCK, and RESETB Signals Input Timing

[CLOCK (Phase switching clock)]

- Input frequency: DC to 50kHz
- Minimum pulse width: 10 $\mu$ s
- MODE2=1(High) Signals are read on the rising edge.
- MODE2=0(Low) Signals are read on the rising and falling edges.

[CWB (Motor direction setting)]

The direction of rotation is switched by setting CWB to 1 (high) or 0 (low).

See the timing charts for details on the operation of the outputs.

Note: The state of the CWB input must not be changed during the 6.25 $\mu$ s period before and after the rising edge of the CLOCK input.

[ENABLE (Forcible on/off control of the A, AB, B, and BB outputs, and hybrid IC internal operation)]

ENABLE=1: Normal operation

ENABLE=0: Outputs A, AB, B, and BB forced to the off state.

If, during the state where CLOCK signal input is provided, the ENABLE pin is set to 0 and then is later restored to the 1 state, the IC will resume operation with the excitation timing continued from before the point ENABLE was set to 0.

If sudden stop is applied to the CLOCK signal used for motor rotation, the motor axis may advance beyond the theoretical position due to inertia. To stop at the theoretical position, the SLOW DOWN setting for gradually slowing the CLOCK cycle is required.



## <FAULT1, FAULT2 output>

### FAULT1 Output

FAULT1 is an open drain output. Low is output if either overcurrent or overheating is detected.

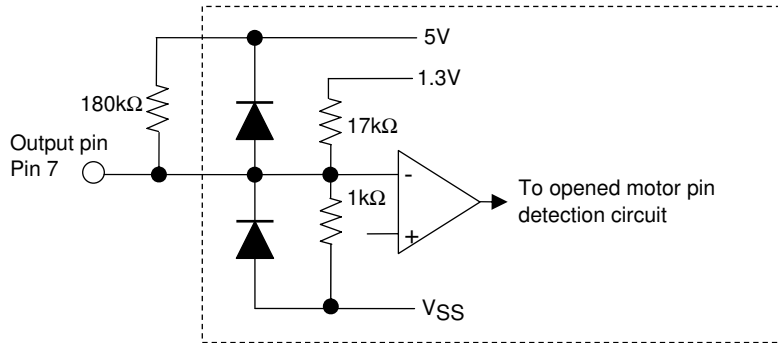
### FAULT2 output

Output is resistance divided (3 levels) and the type of abnormality detected is converted to the corresponding output voltage.

- Opened motor pin: 10mV (typ)
- Overcurrent: 2.5V (typ)
- Overheat: 3.3V (typ)

Abnormality detection can be released by a RESETB operation or turning V<sub>DD</sub> voltage on/off.

## <VrefOP output pin configuration>



## <VrefOP output>

To set the motor current detection circuit operates when pin is open, to monitor the reference voltage VrefOP terminal. It is also possible to set any detectable current by connecting an external pull-up resistor to 5V supply.

## <IOHd by setting pull-up resistor current sensing pin 7 open>

When 7 pins open, VrefOP (typ) is 98mV. In this case, detection current IOHd is expressed as follows.

$$V_{refOP} = I_{OHd} \times R_s \text{ (Rs: Current detection resistor)}$$

Detection current is 0.25A.

Now, detection current greater than 0.25A is IOHdX. Reference voltage VrefOPX is calculated as above.

Pull-up resistor Rdx by pin 7 is calculated as follows.

$$R_{dX} = (180 \times R_{TX}) \div (180 - R_{TX})$$

$$R_{TX} = (5.0V - V_{refOPX}) \div ((1.0588 \times V_{refOPX}) - 0.0765) \text{ (RdX and RTX unit is k}\Omega\text{)}$$

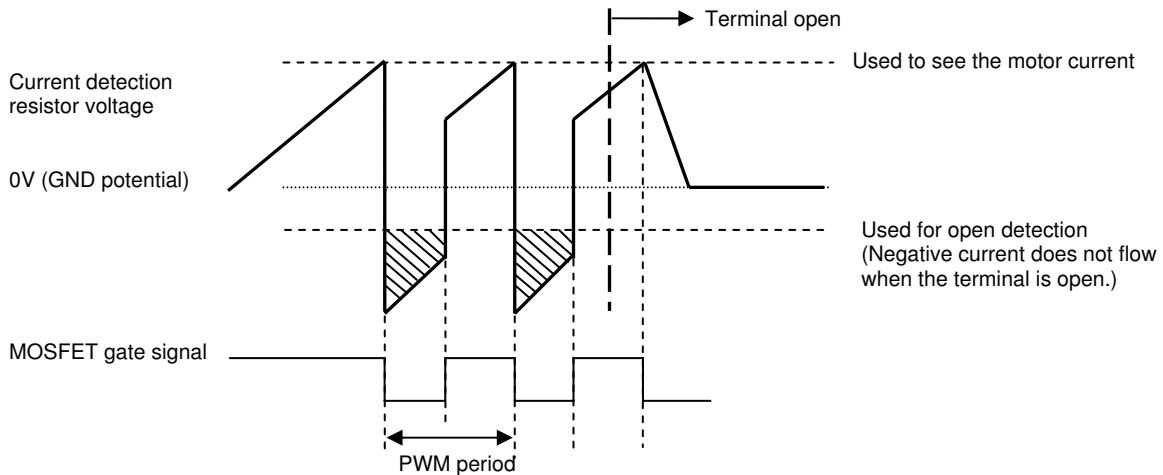
\*To disable pin open detection, please connect a 5V pull-up resistor of 10k to 15k.

## 2. STK672-612B-E overcurrent detection, overheat detection, and motor terminal open detection functions

Each detection function operates using a latch system and turns output off. Because a RESET signal is required to restore output operations, once the power supply, V<sub>DD</sub>, is turned off, you must either again apply power on reset with V<sub>DDON</sub> or apply a RESETB=High→Low→High signal.

### [Motor terminal open detection]

This hybrid IC is equipped with a function for detecting open output terminals to prevent thermal destruction of the MOSFET due to repeated avalanche operation that occurs when an output terminal connected to the motor is open. The open condition is determined by checking the presence or absence of the flyback current that flows in the motor inductance during the off period of the PWM cycle. Detection is performed by using the fact that the flyback current does not flow when a motor terminal is open.



When the current level drops, the difference with the GND potential decreases, making detection difficult. The motor current that can be detected by motor terminal open detection is 0.25A or more with the STK672-612B-E.

### <Notes on the ENABLE high edge>

When ENABLE changes from low to high and the STK672-6XXB-E performs constant-current PWM operation that flows a negative current during the 30μs period after the high edge, open detection may activate and stop the driver. The motor current setting voltage V<sub>ref</sub> must be set so that PWM operation is not performed within a period of 30μs after the high edge. If the motor current setup voltage is set for the rated motor current, PWM operation is not performed during this 30μs period after the high edge, so this is not a problem.

In addition, there is no problem with operation that lowers the current setting V<sub>ref</sub> after the motor rated current is reached as shown in the diagram on the following page. Whether constant-current PWM operation is performed during the 30μs period after the high edge can be judged by substituting the motor L and R values into the formula on the following page.

$$V_{ref} = (R02 \div (R01 + R02)) \times 5V \text{ (or } 3.3V)$$

$$I_{OH1} = (V_{ref} \div 4.9) \div R_s \quad I_{OH1}: \text{Motor current value to be set}$$

$$I_{OH2} = (V_{CC} \div R) \times (1 - e^{-t(R/L)}) \quad I_{OH2}: \text{Current value } 30\mu s \text{ after the ENABLE high edge}$$

$$\Rightarrow \text{Judgment standard: } I_{OH1} > I_{OH2}$$

R01, R02, 5V (or 3.3V): See the Sample Application Circuit documents.

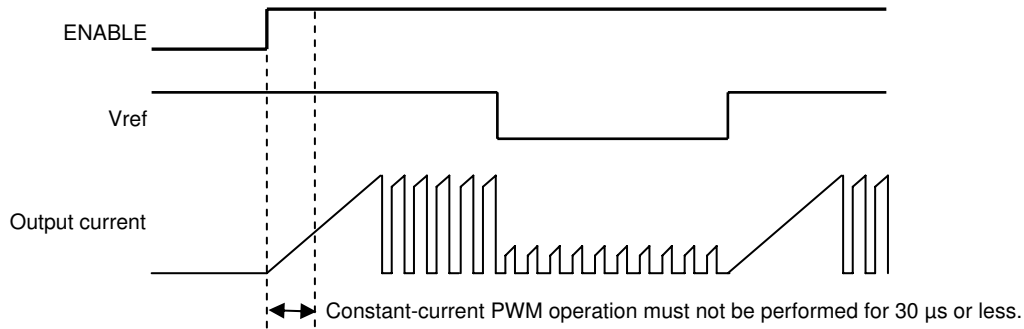
R<sub>s</sub>: Current detection resistance value (Ω)

V<sub>CC</sub>: Motor supply voltage (V)

R: Motor winding resistance (Ω)

L: Motor winding inductance (H)

⇒ There is no problem if the I<sub>OH2</sub> obtained by substituting t = 30μs and the motor L and R values is smaller than the current setting value I<sub>OH1</sub>.



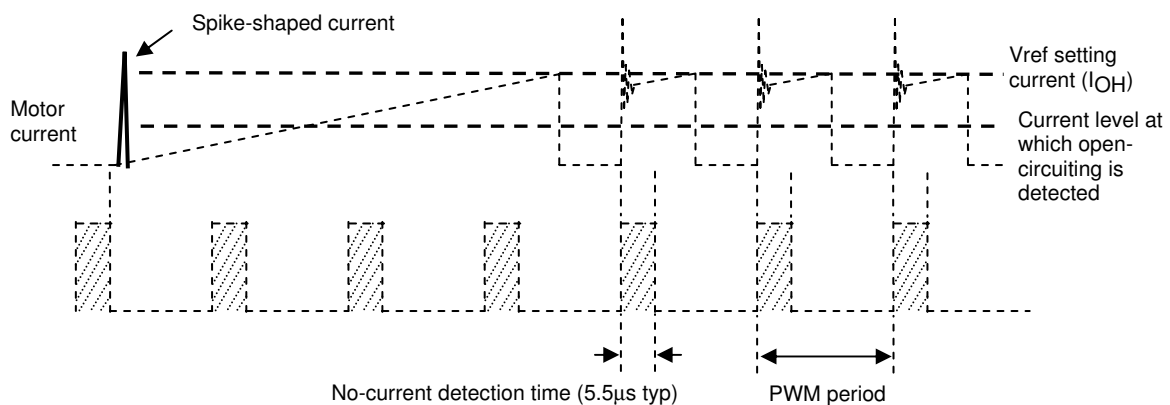
<Connection of capacitors between output pins and GND prohibited>

Capacitors must not be connected between the phase A (pin 4), phase AB (pin 5), phase B (pin 3) and phase BB (pin 1) outputs and GND. What happens if capacitors are connected is that open-circuit detection may be triggered by the discharge current of the capacitors when the internal MOSFET is set ON. This current is not an inductance current generated by the motor winding but a capacitor current so a negative current will not flow to the other phase in each pair of phases, possibly causing the driver to shut down.

<Excessive external noise>

If, when the motor current rises prior to the PWM operation, a spike-shaped current exceeding the Vref-setting current is generated by excessive external noise, for instance, before the current level (0.5A for the STK672-632B-E and 630B-E, 0.8A for the STK672-642B-E and 640B-E motor drivers) at which motor pin open-circuiting can be detected is reached, the internal MOSFET is set OFF. Since the MOSFET has been set OFF before the actual motor current reaches 0.5A (or 0.8A), the level of the negative current subsequently flowing to the other phase in each pair of phases is low, and it may be judged that no negative current is flowing, possibly causing open-circuit detection to be triggered.

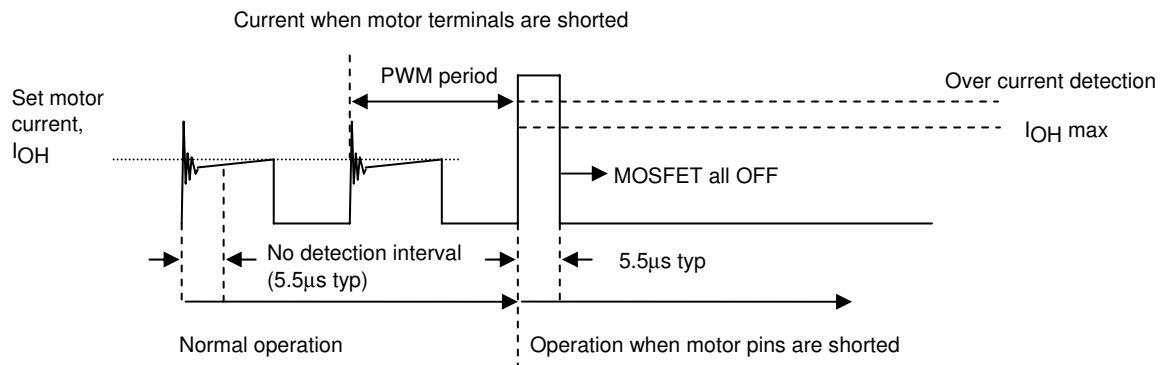
During normal constant-current PWM operation, the duration of 5.5μs, which is equivalent to 25% of the initial operation in the PWM period, corresponds to the section where the current is not detected, and this ensures that no current is detected for the linking part of the current that is generated in this section. The no-current detection section is not synchronized at the current rise prior to the PWM operation so when a spike-shaped current exceeding the Vref-setting current is generated, the MOSFET is set OFF at the stage where the level of the actual motor current is low. As a result, the level of the negative current subsequently flowing to the other phase in each pair of phases is low, and it may be judged that no negative current is flowing, possibly causing open-circuit detection to be triggered.



**[Overcurrent detection]**

This hybrid IC is equipped with a function for detecting overcurrent that arises when the motor burns out or when there is a short between the motor terminals.

Over current detection occurs at 1.2A typ with the STK672-612B-E.



Over current detection begins after an interval of no detection (a dead time of 5.5 $\mu$ s typ) during the initial ringing part during PWM operations. The no detection interval is a period of time where over current is not detected even if the current exceeds  $I_{OH}$ .

**[Overheat detection]**

Rather than directly detecting the temperature of the semiconductor device, overheat detection detects the temperature of the aluminum substrate (144 $^{\circ}$ C typ).

Within the allowed operating range recommended in the specification manual, if a heat sink attached for the purpose of reducing the operating substrate temperature,  $T_c$ , comes loose, the semiconductor can operate without breaking. However, we cannot guarantee operations without breaking in the case of operations other than those recommended, such as operations at a current exceeding  $I_{OH}$  max that occurs before overcurrent detection is activated.



## 3. Calculating STK672-612B-E HIC Internal Power Loss

The average internal power loss in each excitation mode of the STK672-612B-E can be calculated from the following formulas.

Each excitation mode

2-phase excitation mode

$$2PdAVex = 2 \times V_{sat} \times 0.5 \times CLOCK \times I_{OH} \times t_2 + 0.5 \times CLOCK \times I_{OH} \times (V_{sat} \times t_1 + V_{df} \times t_3)$$

1-2 Phase excitation mode

$$1-2PdAVex = 2 \times V_{sat} \times 0.25 \times CLOCK \times I_{OH} \times t_2 + 0.25 \times CLOCK \times I_{OH} \times (V_{sat} \times t_1 + V_{df} \times t_3)$$

Motor hold mode

$$HoldPdAVex = (V_{sat} + V_{df}) \times I_{OH}$$

$V_{sat}$ : Combined voltage of  $R_{on}$  voltage drop + current detection resistance

$V_{df}$ : Combined voltage of the FET body diode + current detection resistance

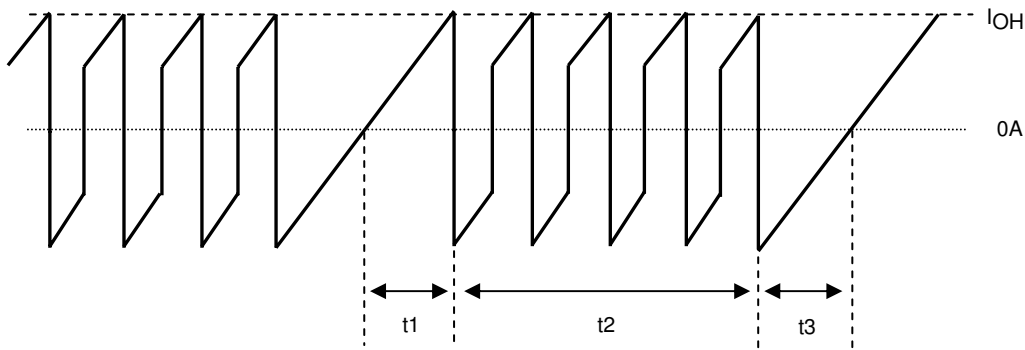
CLOCK: Input CLOCK (CLOCK pin signal frequency)

$t_1$ ,  $t_2$ , and  $t_3$  represent the waveforms shown in the figure below.

$t_1$ : Time required for the winding current to reach the set current ( $I_{OH}$ )

$t_2$ : Time in the constant current control (PWM) region

$t_3$ : Time from end of phase input signal until inverse current regeneration is complete



Motor COM Current Waveform Model

$$t_1 = (-L/(R+0.61)) \ln(1 - ((R+0.61)/V_{CC}) \times I_{OH})$$

$$t_3 = (-L/R) \ln((V_{CC}+0.61)/(I_{OH} \times R + V_{CC}+0.61))$$

$V_{CC}$ : Motor supply voltage (V)

$L$ : Motor inductance (H)

$R$ : Motor winding resistance ( $\Omega$ )

$I_{OH}$ : Motor set output current crest value (A)

Relationship of CLOCK,  $t_1$ ,  $t_2$ , and  $t_3$  in each excitation mode

2-phase excitation mode:  $t_2 = (2/CLOCK) - (t_1 + t_3)$

1-2 phase excitation mode:  $t_2 = (3/CLOCK) - t_1$

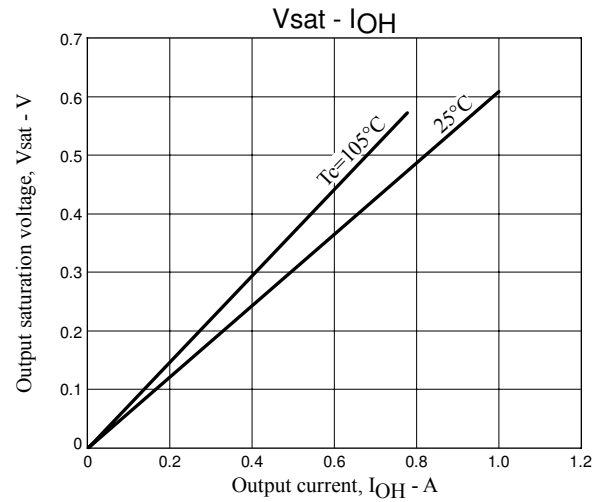
For  $V_{sat}$  and  $V_{df}$ , be sure to substitute values from the graphs of  $V_{sat}$  vs.  $I_{OH}$  and  $V_{df}$  vs.  $I_{OH}$  while the set current value is  $I_{OH}$ .

Then, determine whether a heat sink is required by comparing with the graph of  $\Delta T_c$  vs.  $P_d$  based on the average HIC power loss calculated.

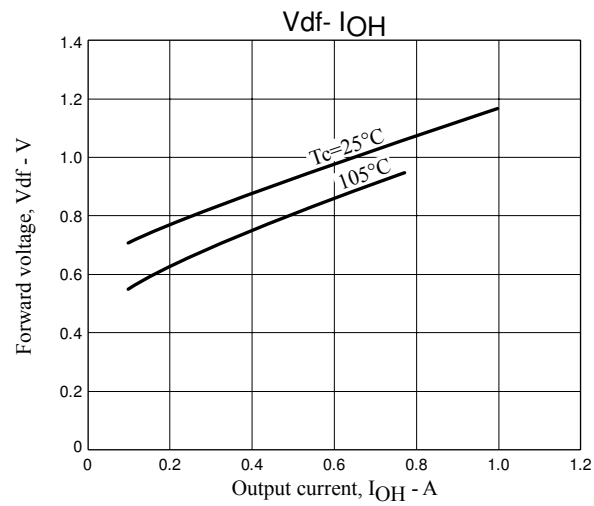
When designing a heat sink, refer to the section "Thermal design" found on the next page. The average HIC power loss,  $P_dAV$ , described above does not have the avalanche's loss. To include the avalanche's loss, be sure to add Equation (2), "STK672-6\*\* Allowable Avalanche Energy Value" to  $P_dAV$  above. When using this IC without a fin always check for temperature increases in the set, because the HIC substrate temperature,  $T_c$ , varies due to effects of convection around the HIC.

## STK672-612B-E

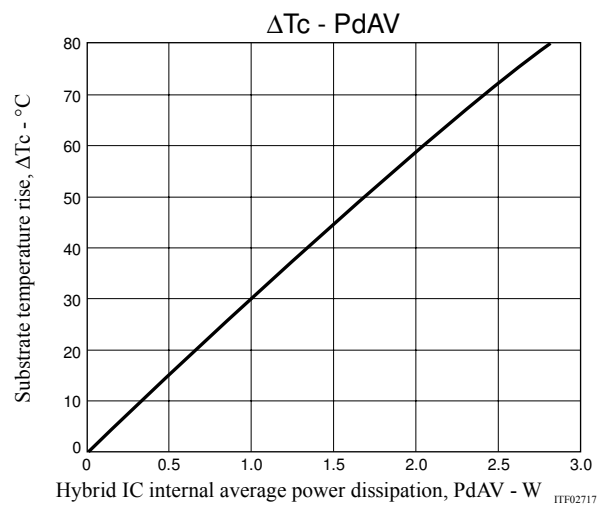
STK672-612B-E Output saturation voltage,  $V_{sat}$  - Output current,  $I_{OH}$



STK672-612B-E Forward voltage,  $V_{df}$  - Output current,  $I_{OH}$



Substrate temperature rise,  $\Delta T_c$  (no heat sink) - Internal average power dissipation,  $P_{dAV}$



ITF02717

## 4. STK672-612B-E Allowable Avalanche Energy Value

### (1) Allowable Range in Avalanche Mode

When driving a 2-phase stepping motor with constant current chopping using an STK672-6\*\* Series hybrid IC, the waveforms shown in Figure 1 below result for the output current,  $I_D$ , and voltage,  $V_{DS}$ .

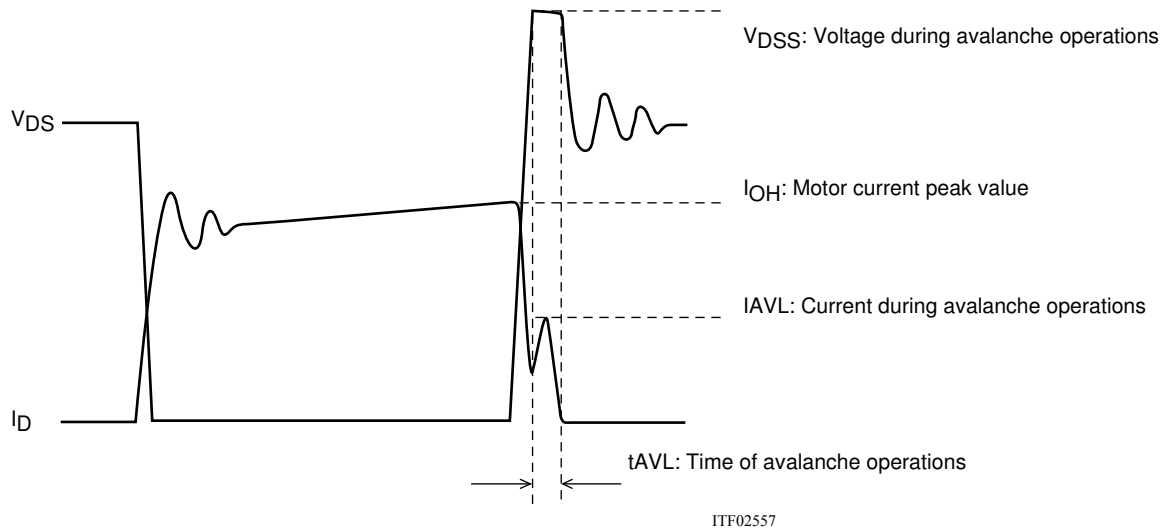


Figure 1 Output Current,  $I_D$ , and Voltage,  $V_{DS}$ , Waveforms 1 of the STK672-6\*\* Series when Driving a 2-Phase Stepping Motor with Constant Current Chopping

When operations of the MOSFET built into STK672-6\*\* Series ICs is turned off for constant current chopping, the  $I_D$  signal falls like the waveform shown in the figure above. At this time, the output voltage,  $V_{DS}$ , suddenly rises due to electromagnetic induction generated by the motor coil.

In the case of voltage that rises suddenly, voltage is restricted by the MOSFET  $V_{DSS}$ . Voltage restriction by  $V_{DSS}$  results in a MOSFET avalanche. During avalanche operations,  $I_D$  flows and the instantaneous energy at this time,  $E_{AVL1}$ , is represented by Equation (1).

$$E_{AVL1} = V_{DSS} \times I_{AVL} \times 0.5 \times t_{AVL} \text{ ----- (1)}$$

$V_{DSS}$ : V units,  $I_{AVL}$ : A units,  $t_{AVL}$ : sec units

The coefficient 0.5 in Equation (1) is a constant required to convert the  $I_{AVL}$  triangle wave to a square wave.

During STK672-6\*\* Series operations, the waveforms in the figure above repeat due to the constant current chopping operation. The allowable avalanche energy,  $E_{AVL}$ , is therefore represented by Equation (2) used to find the average power loss,  $P_{AVL}$ , during avalanche mode multiplied by the chopping frequency in Equation (1).

$$P_{AVL} = V_{DSS} \times I_{AVL} \times 0.5 \times t_{AVL} \times f_c \text{ ----- (2)}$$

$f_c$ : Hz units ( $f_c$  is set to the PWM frequency of 50kHz.)

For  $V_{DSS}$ ,  $I_{AVL}$ , and  $t_{AVL}$ , be sure to actually operate the STK672-6\*\* Series and substitute values when operations are observed using an oscilloscope.

Ex. If  $V_{DSS}=110V$ ,  $I_{AVL}=1A$ ,  $t_{AVL}=0.2\mu s$  when using a STK672-612B-E driver, the result is:

$$P_{AVL} = 110 \times 0.5 \times 0.5 \times 0.2 \times 10^{-6} \times 50 \times 10^3 = 0.28W$$

$V_{DSS}=110V$  is a value actually measured using an oscilloscope.

The allowable loss range for the allowable avalanche energy value,  $P_{AVL}$ , is shown in the graph in Figure 3. When examining the avalanche energy, be sure to actually drive a motor and observe the  $I_D$ ,  $V_{DSS}$ , and  $t_{AVL}$  waveforms during operation, and then check that the result of calculating Equation (2) falls within the allowable range for avalanche operations.

## (2) $I_D$ and $V_{DS}$ Operating Waveforms in Non-avalanche Mode

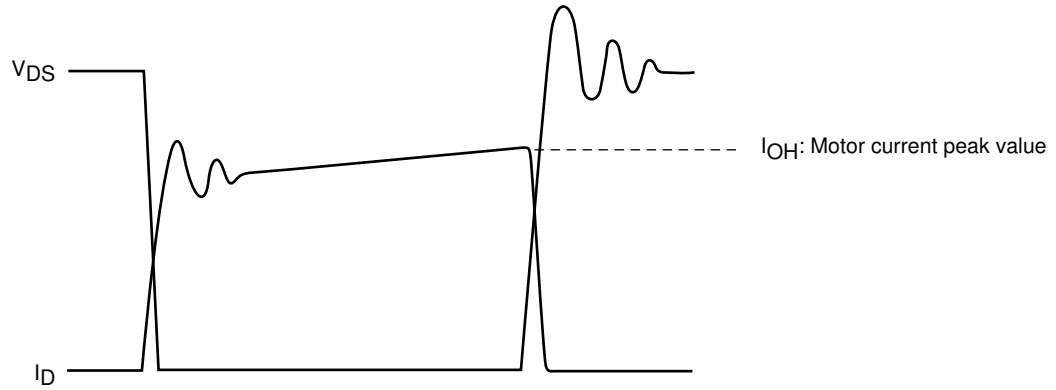
Although the waveforms during avalanche mode are given in Figure 1, sometimes an avalanche does not result during actual operations.

Factors causing avalanche are listed below.

- Poor coupling of the motor's phase coils (electromagnetic coupling of A phase and AB phase, B phase and BB phase).
- Increase in the lead inductance of the harness caused by the circuit pattern of the P.C. board and motor.
- Increases in  $V_{DS}$ ,  $t_{AVL}$ , and  $I_{AVL}$  in Figure 1 due to an increase in the supply voltage from 24V to 36V.

If the factors above are negligible, the waveforms shown in Figure 1 become waveforms without avalanche as shown in Figure 2.

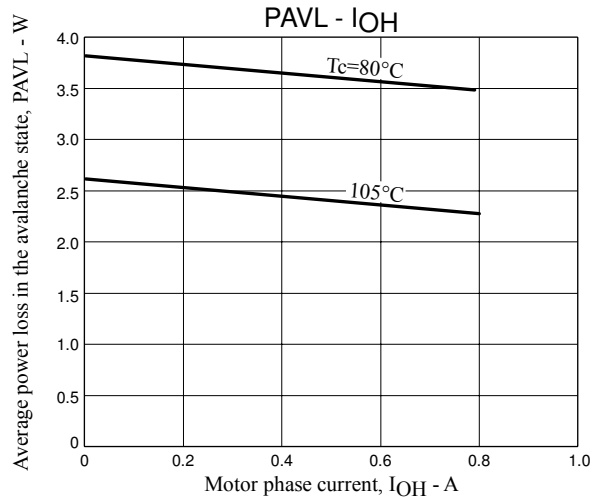
Under operations shown in Figure 2, avalanche does not occur and there is no need to consider the allowable loss range of  $PAVL$  shown in Figure 3.



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Figure 2 Output Current,  $I_D$ , and Voltage,  $V_{DS}$ , Waveforms 2 of the STK672-6\*\* Series when Driving a 2-Phase Stepping Motor with Constant Current Chopping

Figure 3 Allowable Loss Range,  $PAVL-I_{OH}$  During STK672-612B-E Avalanche Operations



Note:

The operating conditions given above represent a loss when driving a 2-phase stepping motor with constant current chopping.

Because it is possible to apply 2.6W or more at  $I_{OH}=0A$ , be sure to avoid using the MOSFET body diode that is used to drive the motor as a zener diode.

## 5. Thermal design

[Operating range in which a heat sink is not used]

Use of a heat sink to lower the operating substrate temperature of the HIC (Hybrid IC) is effective in increasing the quality of the HIC.

The size of heat sink for the HIC varies depending on the magnitude of the average power loss, PdAV, within the HIC. The value of PdAV increases as the output current increases. To calculate PdAV, refer to “Calculating Internal HIC Loss for the STK672-612B-E” in the specification document.

Calculate the internal HIC loss, PdAV, assuming repeat operation such as shown in Figure 1 below, since conduction during motor rotation and off time both exist during actual motor operations,

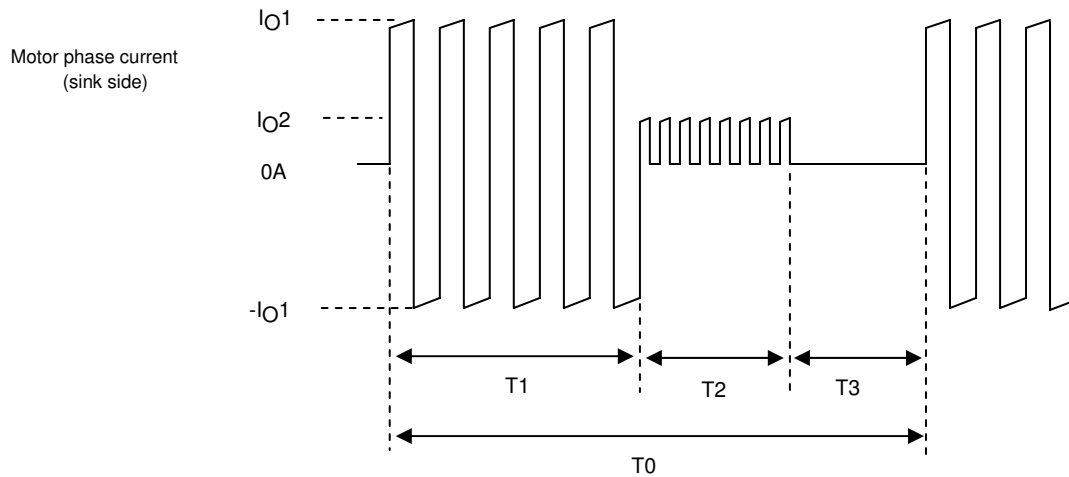


Figure 1 Motor Current Timing

T1: Motor rotation operation time

T2: Motor hold operation time

T3: Motor current off time

T2 may be reduced, depending on the application.

T0: Single repeated motor operating cycle

IO1 and IO2: Motor current peak values

Due to the structure of motor windings, the phase current is a positive and negative current with a pulse form.

Note that figure 1 presents the concepts here, and that the on/off duty of the actual signals will differ.

The hybrid IC internal average power dissipation PdAV can be calculated from the following formula.

$$PdAV = (T1 \times P1 + T2 \times P2 + T3 \times 0) \div T0 \quad \text{----- (I)}$$

(Here, P1 is the PdAV for IO1 and P2 is the PdAV for IO2)

If the value calculated using Equation (I) is 1.5W or less, and the ambient temperature, Ta, is 60°C or less, there is no need to attach a heat sink. Refer to Figure 2 for operating substrate temperature data when no heat sink is used.

[Operating range in which a heat sink is used]

Although a heat sink is attached to lower Tc if PdAV increases, the resulting size can be found using the value of θc-a in Equation (II) below and the graph depicted in Figure 3.

$$\theta_{c-a} = (T_c \text{ max} - T_a) \div PdAV \quad \text{----- (II)}$$

Tc max: Maximum operating substrate temperature = 105°C

Ta: HIC ambient temperature

Although a heat sink can be designed based on equations (I) and (II) above, be sure to mount the HIC in a set and confirm that the substrate temperature, Tc, is 105°C or less.

The average HIC power loss, PdAV, described above represents the power loss when there is no avalanche operation. To add the loss during avalanche operations, be sure to add Equation (2), “Allowable STK672-6\*\* Avalanche Energy Value”, to PdAV.

Figure 2 Substrate temperature rise,  $\Delta T_c$  (no heat sink) - Internal average power dissipation, PdAV

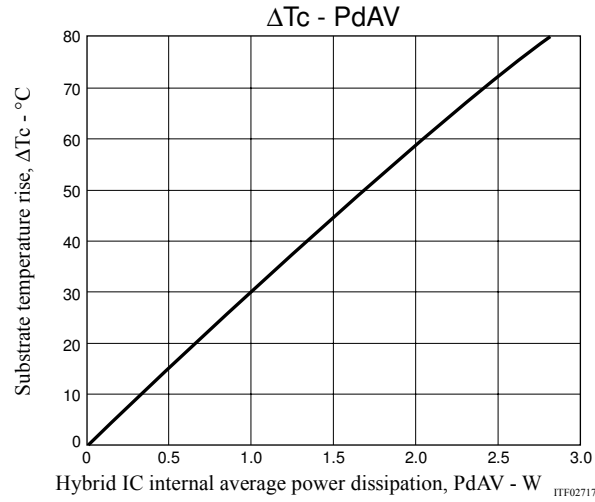
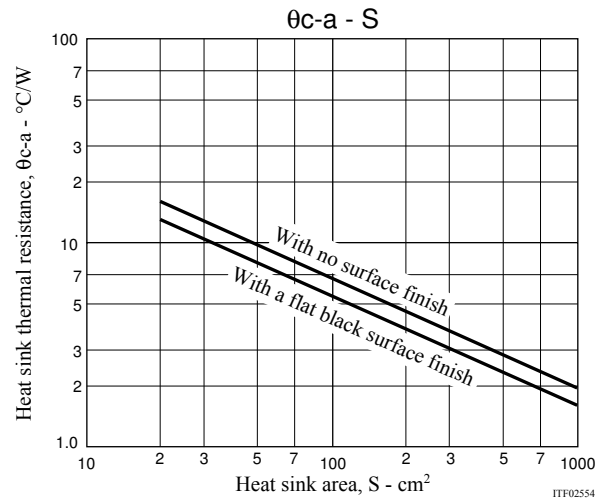


Figure 3 Heat sink area (Board thickness: 2mm) -  $\theta_{c-a}$



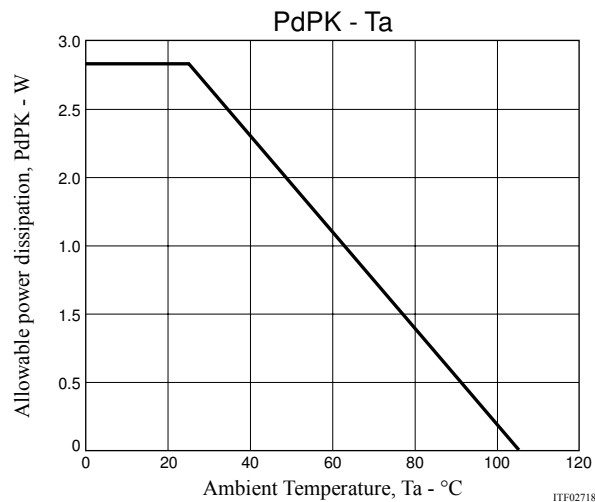
#### 6. Mitigated Curve of Package Power Loss, PdPK, vs. Ambient Temperature, Ta

Package power loss, PdPK, refers to the average internal power loss, PdAV, allowable without a heat sink.

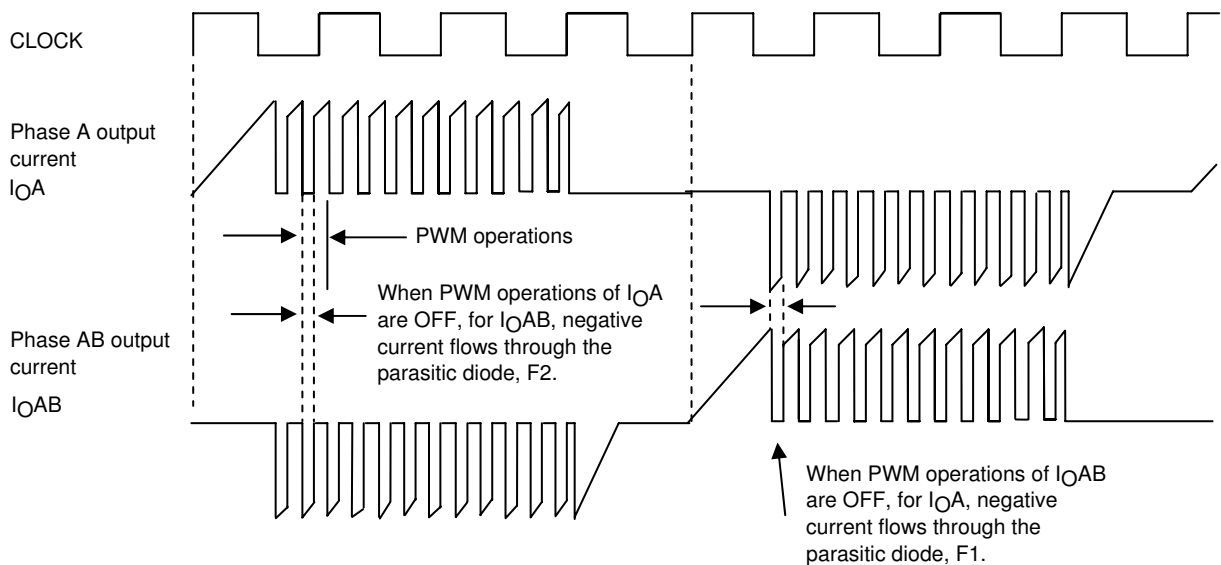
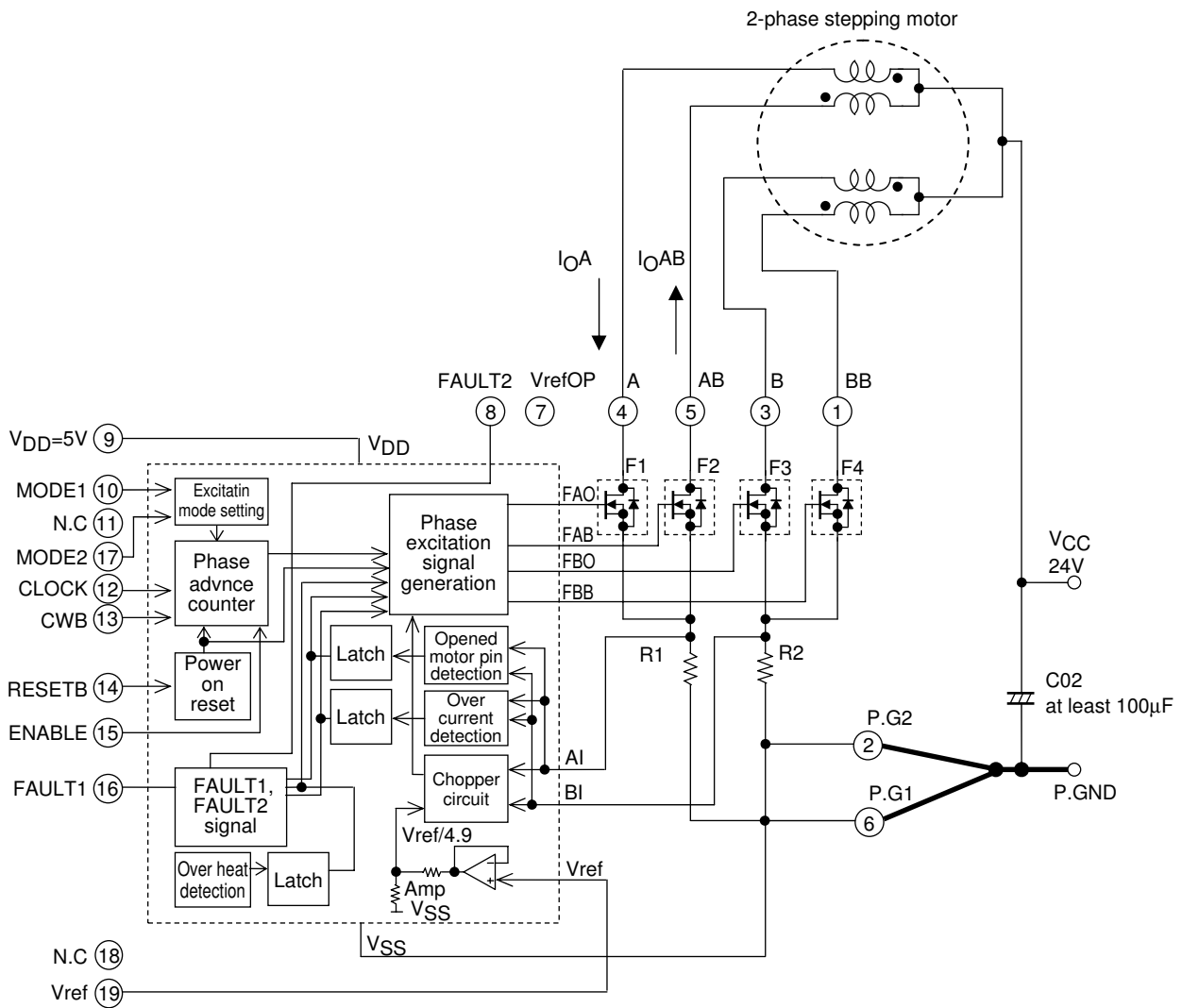
The figure below represents the allowable power loss, PdPK, vs. fluctuations in the ambient temperature, Ta.

Power loss of up to 3.1W is allowable at Ta=25°C, and of up to 1.75W at Ta=60°C.

Allowable power dissipation, PdPK(no heat sink) - Ambient temperature, Ta



## 7. Example of Stepping Motor Driver Output Current Path (1-2 phase excitation)

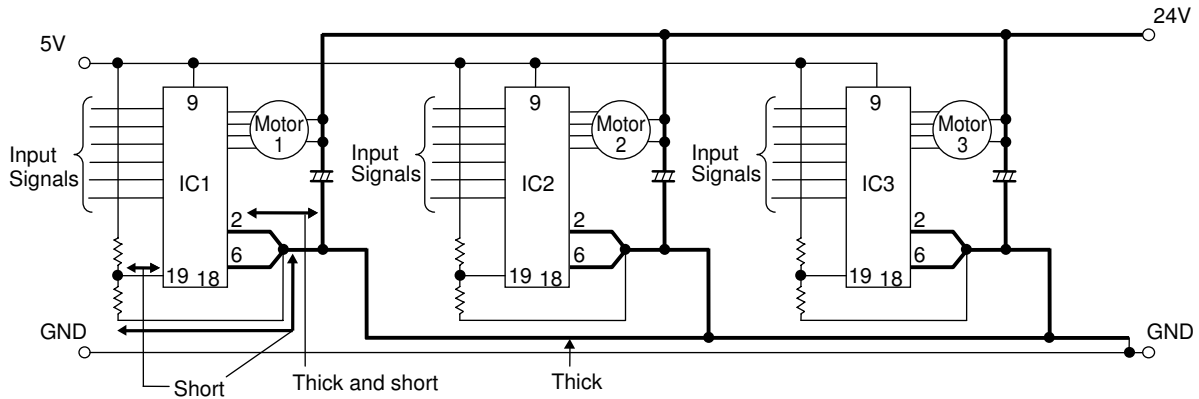






(5) When mounting multiple drivers on a single PC board

When mounting multiple drivers on a single PC board, the GND design should mount a  $V_{CC}$  decoupling capacitor, C1, for each driver to stabilize the GND potential of the other drivers. The key wiring points are as follows.



(6)  $V_{CC}$  operating limit

When the output (for example F1) of a 2-phase stepping motor driver is turned OFF, the AB phase back electromotive force  $e_{ab}$  produced by current flowing to the paired F2 parasitic diode is induced in the F1 side, causing the output voltage  $V_{FB}$  to become twice or more the  $V_{CC}$  voltage. This is expressed by the following formula.

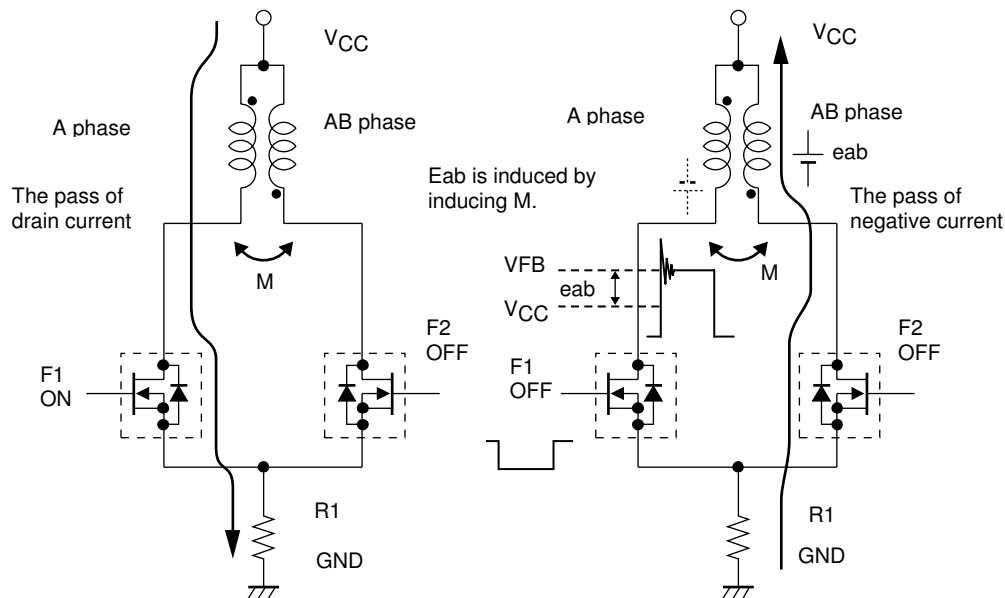
$$V_{FB} = V_{CC} + e_{ab}$$

$$= V_{CC} + V_{CC} + I_{OH} \times R_M + V_{df} (1.5 \text{ V})$$

$V_{CC}$ : Motor supply voltage,  $I_{OH}$ : Motor current set by  $V_{ref}$

$V_{df}$ : Voltage drop due to F2 parasitic diode and current detection resistor R1,  $R_M$ : Motor winding resistance value

Using the above formula, make sure that  $V_{FB}$  is always less than the MOSFET withstand voltage of 100V. This is because there is a possibility that operating limit of  $V_{CC}$  falls below the allowable operating range of 46V, due to the  $R_M$  and  $I_{OH}$  specifications.



The oscillating voltage in excess of  $V_{FB}$  is caused by LCRM (inductance, capacitor, resistor, mutual inductance) oscillation that includes micro capacitors C, not present in the circuit. Since M is affected by the motor characteristics, there is some difference in oscillating voltage according to the motor specifications. In addition, constant voltage drive without constant current drive enables motor rotation at  $V_{CC} \geq 0V$ .

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