Overview

The STK672-080 is a stepping motor driver hybrid IC that uses power MOSFETs in the output stage. It includes a built-in microstepping controller and is based on a unipolar constant-current PWM system. The STK672-080 supports application simplification and standardization by providing a built-in 4 phase distribution stepping motor controller. It supports five excitation methods: 2 phase, 1-2 phase, W1-2 phase, 2W1-2 phase, and 4W1-2 phase excitations, and can provide control of the basic stepping angle of the stepping motor divided into 1/16 step units. It also allows the motor speed to be controlled with only a clock signal.

The use of this hybrid IC allows designers to implement systems that provide high motor torques, low vibration levels, low noise, fast response, and high-efficiency drive. Compared to the earlier SANYO STK672-050, the STK672-080 features a significantly smaller package for easier mounting in end products.

Applications

- Facsimile stepping motor drive (send and receive)
- Paper feed and optical system stepping motor drive in copiers
- Laser printer drum drive
- Printer carriage stepping motor drive
- X-Y plotter pen drive
- Industrial robots and other stepping motor applications

Features

- Can implement stepping motor drive systems simply by providing a DC power supply and a clock pulse generator.

<Control Block Features>

- One of five drive types can be selected with the drive mode settings (M1, M2, and M3)
  - 2 phase excitation drive
  - 1-2 phase excitation drive
  - W1-2 phase excitation drive
  - 2W1-2 phase excitation drive
  - 4W1-2 phase excitation drive
- Phase retention even if excitation is switched.
- The MOI phase origin monitor pin is provided.
- The CLK input counter block can be selected to be one of the following by the high/low setting of the M3 input pin.
  - Rising edge only
  - Both rising and falling edges

Note*: Conditions: VCC1 = 24 V, IOH = 2.0 A, 2W1-2 drive used. Continued on next page.

Package Dimensions

unit: mm

4186

[STK672-080]

Any and all SANYO products described or contained herein do not have specifications that can handle applications that require extremely high levels of reliability, such as life-support systems, aircraft’s control systems, or other applications whose failure can be reasonably expected to result in serious physical and/or material damage. Consult with your SANYO representative nearest you before using any SANYO products described or contained herein in such applications.

SANYO assumes no responsibility for equipment failures that result from using products at values that exceed, even momentarily, rated values (such as maximum ratings, operating condition ranges, or other parameters) listed in products specifications of any and all SANYO products described or contained herein.
The CLK input pin include built-in malfunction prevention circuits for external pulse noise. ENABLE and RESET pins provided. These are Schmitt trigger inputs with built-in 20 kΩ (typical) pull-up resistors. No noise generation due to the difference between the A and B phase time constants during motor hold since external excitation is used. Microstepping operation supported even for small motor currents, since the reference voltage Vref can be set to any value between 0 V and 1/2 VCC2.

<Driver Block>
External excitation PWM drive allows a wide operating supply voltage range (VCC1 = 10 to 45 V) to be used. Current detection resistor (0.15 Ω) built into the hybrid IC. Power MOSFETs for minimal driver loss. Motor output drive currents IOH up to 2.8 A (When Tc = 105°C).

Specifications
Absolute Maximum Ratings at Tc = 25°C

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum supply voltage1</td>
<td>VCC1 max</td>
<td>No signal</td>
<td>52</td>
<td>V</td>
</tr>
<tr>
<td>Maximum supply voltage2</td>
<td>VCC2 max</td>
<td>No signal</td>
<td>–0.3 to +7.0</td>
<td>V</td>
</tr>
<tr>
<td>Input voltage</td>
<td>VN max</td>
<td>Logic input pins</td>
<td>–0.3 to +7.0</td>
<td>V</td>
</tr>
<tr>
<td>Phase output current</td>
<td>IOH max</td>
<td>0.5 seconds, single pulse, with VCC1 applied.</td>
<td>3.3</td>
<td>A</td>
</tr>
<tr>
<td>Power loss</td>
<td>PD max</td>
<td>P&lt;sub&gt;c-a&lt;/sub&gt; = 0</td>
<td>8</td>
<td>W</td>
</tr>
<tr>
<td>Operating substrate temperature</td>
<td>TC max</td>
<td></td>
<td>105</td>
<td>°C</td>
</tr>
<tr>
<td>Junction temperature</td>
<td>TJ max</td>
<td></td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>Tstg</td>
<td></td>
<td>–40 to +125</td>
<td>°C</td>
</tr>
</tbody>
</table>

Allowable Operating Ranges at Ta = 25°C

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage1</td>
<td>VCC1</td>
<td>With input signals present</td>
<td>10 to 45</td>
<td>V</td>
</tr>
<tr>
<td>Supply voltage2</td>
<td>VCC2</td>
<td>With input signals present</td>
<td>5 ±5%</td>
<td>V</td>
</tr>
<tr>
<td>Input voltage</td>
<td>VI</td>
<td></td>
<td>0 to VCC2</td>
<td>V</td>
</tr>
<tr>
<td>Phase driver voltage handling</td>
<td>VDISS</td>
<td>Tr1, 2, 3, and 4 (the A, A, B, and B outputs)</td>
<td>100 (min)</td>
<td>V</td>
</tr>
<tr>
<td>Phase current 1</td>
<td>IOH 1</td>
<td>Tc = 105°C, CLK ≥ 200 Hz</td>
<td>2.8</td>
<td>A</td>
</tr>
<tr>
<td>Phase current 2</td>
<td>IOH 2</td>
<td>Tc = 80°C, CLK ≥ 200 Hz</td>
<td>3</td>
<td>A</td>
</tr>
</tbody>
</table>

Electrical Characteristics at Tc = 25°C, VCC1 = 24 V, VCC2 = 5 V

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control supply current</td>
<td>ICC</td>
<td>Pin 6 input, with ENABLE pin held low.</td>
<td>2.1</td>
<td>mA</td>
</tr>
<tr>
<td>Output saturation voltage</td>
<td>Vsat</td>
<td></td>
<td>0.65</td>
<td>V</td>
</tr>
<tr>
<td>Average output current</td>
<td>Io ave</td>
<td>Load: R = 3.5 W/L = 3.8 mH per phase</td>
<td>0.445</td>
<td>A</td>
</tr>
<tr>
<td>FET diode Forward voltage</td>
<td>Vdf</td>
<td></td>
<td>1</td>
<td>V</td>
</tr>
</tbody>
</table>

[Control Inputs]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage</td>
<td>VI</td>
<td>Except for the Vref pin</td>
<td>4</td>
<td>V</td>
</tr>
<tr>
<td>Input current</td>
<td>Ii</td>
<td>Except for the Vref pin</td>
<td>0</td>
<td>μA</td>
</tr>
</tbody>
</table>

[Vref Input Pin]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage</td>
<td>Vi</td>
<td>Pin 7</td>
<td>0</td>
<td>V</td>
</tr>
<tr>
<td>Input current</td>
<td>II</td>
<td>Pin 7, 2.5-V input</td>
<td>330</td>
<td>μA</td>
</tr>
</tbody>
</table>

[Control Outputs]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output voltage</td>
<td>VOH</td>
<td>I = –3 mA, pin MOI</td>
<td>2.4</td>
<td>V</td>
</tr>
<tr>
<td>Output voltage</td>
<td>VOL</td>
<td>I = +3 mA, pin MOI</td>
<td>0.4</td>
<td>V</td>
</tr>
</tbody>
</table>

Continued on next page.
Continued from preceding page.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Current Distribution Ratio (A-B)]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2W1-2, W1-2, 1-2</td>
<td>Vref</td>
<td>0 = 1/8</td>
<td>100</td>
<td>%</td>
</tr>
<tr>
<td>2W1-2, W1-2</td>
<td>Vref</td>
<td>0 = 2/8</td>
<td>92</td>
<td>%</td>
</tr>
<tr>
<td>2W1-2</td>
<td>Vref</td>
<td>0 = 3/8</td>
<td>83</td>
<td>%</td>
</tr>
<tr>
<td>2W1-2, W1-2, 1-2</td>
<td>Vref</td>
<td>0 = 4/8</td>
<td>71</td>
<td>%</td>
</tr>
<tr>
<td>2W1-2</td>
<td>Vref</td>
<td>0 = 5/8</td>
<td>55</td>
<td>%</td>
</tr>
<tr>
<td>2W1-2, W1-2</td>
<td>Vref</td>
<td>0 = 6/8</td>
<td>40</td>
<td>%</td>
</tr>
<tr>
<td>2W1-2</td>
<td>Vref</td>
<td>0 = 7/8</td>
<td>21</td>
<td>%</td>
</tr>
<tr>
<td>2</td>
<td>Vref</td>
<td></td>
<td>100</td>
<td>%</td>
</tr>
<tr>
<td>PWM frequency</td>
<td>fc</td>
<td></td>
<td>37</td>
<td>47</td>
</tr>
</tbody>
</table>

Note: A constant-voltage power supply must be used.
The design target value is shown for the current distribution ratio.
To measuring $I_{ave}$: With SW1 set to the b position, input Vref and switch SW2.
To measuring $f_c$: With SW1 set to the a position, set Vref to 0 V, and switch SW3.
To measuring $I_{cc}$: Set the ENABLE pin low.
Functional Description
2W1-2 Phase Excitation Drive (microstepping operation)

Setting the Motor Current
The motor current \( I_{OH} \) is set by the Vref voltage on the hybrid IC pin 7. The following formula gives the relationship between \( I_{OH} \) and Vref.

\[
R_{OX} = \frac{R_{O2} \times 6 \, \Omega}{R_{O2} + 6 \, \Omega} \quad (1)
\]

\[
V_{ref} = \frac{V_{CC2} \times R_{Ox}}{R_{O1} + R_{Ox}} \quad (2)
\]

\[
I_{OH} = \frac{1}{K} \times \frac{V_{ref}}{R_{S}} \quad (3)
\]

K: 4.7 (Voltage division ratio), \( R_{S} \): 0.15 \( \Omega \) (The hybrid IC’s internal current detection resistor (precision: ±3%))

Applications can use motor currents from the current (0.05 to 0.1 A) set by the duty of the frequency set by the oscillator up to the limit of the allowable operating range, \( I_{OH} = 2.8 \, A \)

<table>
<thead>
<tr>
<th>M2</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>M3</td>
<td>1</td>
<td>2 phase excitation</td>
<td>1-2 phase excitation</td>
<td>W1-2 phase excitation</td>
</tr>
<tr>
<td>0</td>
<td>1-2 phase excitation</td>
<td>W1-2 phase excitation</td>
<td>2W1-2 phase excitation</td>
<td>4W1-2 phase excitation</td>
</tr>
</tbody>
</table>

Motor current waveform

[Function Table]
**Functional Description**

External Excitation Chopper Drive Block Description

Since this hybrid IC adopts an external excitation method, no external oscillator circuit is required. When a high level is input to ØA in the basic driver block circuit shown in the figure and the MOSFET is turned on, the comparator + input will go low and the comparator output will go low. Since a set signal with the PWM period will be input, the Q output will go high, and the MOSFET will be turned on as its initial value. The current ION flowing in the MOSFET passes through L1 and generates a potential difference in Rs. Then, when the Rs potential and the Vref potential become the same, the comparator output will invert, and the reset signal Q output will invert to the low level. Then, the MOSFET will be turned off and the energy stored in L1 will be induced in L2 and the current IOFF will be regenerated to the power supply. This state will be maintained until the time when an input to the latch circuit set pin occurs.

In this manner, the Q output is turned off and on repeatedly by the reset and set signals, thus implementing constant current control. The resistor and capacitor on the comparator input are spike removal circuit elements and synchronize with the PWM frequency. Since this hybrid IC uses a fixed frequency due to the external excitation method and at the same time also adopts a synchronized PWM technique, it can suppress the noise associated with holding a position when the motor is locked.

**Input Pin Functions**

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Symbol</th>
<th>Function</th>
<th>Pin circuit type</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>CLK</td>
<td>Phase switching clock</td>
<td>Built-in pull-up resistor CMOS Schmitt trigger input</td>
</tr>
<tr>
<td>10</td>
<td>CWB</td>
<td>Rotation direction setting (CW/CCW)</td>
<td>Built-in pull-up resistor CMOS Schmitt trigger input</td>
</tr>
<tr>
<td>15</td>
<td>ENABLE</td>
<td>Output cutoff</td>
<td>Built-in pull-up resistor CMOS Schmitt trigger input</td>
</tr>
<tr>
<td>8, 9, 12</td>
<td>M1, M2, M3</td>
<td>Excitation mode setting</td>
<td>Built-in pull-up resistor CMOS Schmitt trigger input</td>
</tr>
<tr>
<td>13</td>
<td>RESET</td>
<td>System reset</td>
<td>Built-in pull-up resistor CMOS Schmitt trigger input</td>
</tr>
<tr>
<td>7</td>
<td>Vref</td>
<td>Current setting</td>
<td>Input impedance 6 kΩ (typ.) ±30%</td>
</tr>
</tbody>
</table>
Input Signal Functions and Timing

- **CLK (phase switching clock)**
  
  Input frequency range: DC to 50 kHz  
  Minimum pulse width: 10 µs  
  Duty: 40 to 60% (However, the minimum pulse width takes precedence when M3 is high.)
  
  Pin circuit type: Built-in pull-up resistor (20 kΩ, typical) CMOS Schmitt trigger structure
  
  Built-in multi-stage noise rejection circuit
  
  Function
  
  — When M3 is high or open: The phase excited (driven) is advanced one step on each CLK rising edge.
  
  — When M3 is low: The phase moves on both the rising and falling edges of the CLK signal, for a total of two steps per cycle.

- **CWB (Method for setting the rotation direction)**
  
  Pin circuit type: Built-in pull-up resistor (20 kΩ, typical) CMOS Schmitt trigger structure
  
  Function
  
  — When CWB is high: The motor turns in the clockwise direction.
  
  — When CWB is low: The motor turns in the counterclockwise direction.

  Notes: When M3 is low, the CWB input must not be changed for about 6.25 µs before or after a rising or falling edge on the CLK input.

- **ENABLE (Controls the on/off state of the A, A, B, and B excitation drive outputs and selects either operating or hold as the internal state of this hybrid IC.)**
  
  Pin circuit type: Built-in pull-up resistor (20 kΩ, typical) CMOS Schmitt trigger structure
  
  Function
  
  — When ENABLE is high or open: Normal operating state
  
  — When ENABLE is low: This hybrid IC goes to the hold state and excitation drive output (motor current) is forcibly turned off. In this mode, the hybrid IC system clock is stopped and no inputs other than the reset input have any effect on the hybrid IC state.
• M1, M2, and M3 (Excitation mode and CLK input edge timing selection)
  Pin circuit type: Built-in pull-up resistor (20 kΩ, typical) CMOS Schmitt trigger structure

Function:

<table>
<thead>
<tr>
<th></th>
<th>M2</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>M3</td>
<td>1</td>
<td>2 phase excitation</td>
<td>1-2 phase excitation</td>
<td>W1-2 phase excitation</td>
<td>2W1-2 phase excitation</td>
</tr>
</tbody>
</table>

Valid mode setting timing: Applications must not change the mode in the period 5 µs before or after a CLK signal rising or falling edge.

**Mode Setting Acquisition Timing**

<table>
<thead>
<tr>
<th></th>
<th>CLK input</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>System clock</td>
</tr>
<tr>
<td></td>
<td>Mode setting</td>
</tr>
<tr>
<td></td>
<td>Mode switching clock</td>
</tr>
<tr>
<td></td>
<td>Hybrid IC internal setting state</td>
</tr>
<tr>
<td></td>
<td>Phase excitation clock</td>
</tr>
</tbody>
</table>

**RESET (Resets all parts of the system.)**

Pin circuit type: Built-in pull-up resistor (20 kΩ, typical) CMOS Schmitt trigger structure

Function

—All circuit states are set to their initial values by setting the **RESET** pin low. (Note that the pulse width must be at least 10 µs.)

At this time, the A and B phases are set to their origin, regardless of the excitation mode. The output current goes to about 71% after the reset is released.

Notes: When power is first applied to this hybrid IC, Vref must be established by applying a reset. Applications must apply a power on reset when the VCC2 power supply is first applied.

• Vref (Sets the current level used as the reference for constant-current detection.)

Pin circuit type: Analog input structure

Function

—Constant-current control can be applied to the motor excitation current at 100% of the rated current by applying a voltage less than the control system power supply voltage VCC2 minus 2.5 V.

—Applications can apply constant-current control proportional to the Vref voltage, with this value of 2.5 V as the upper limit.

Output Pin Functions

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Symbol</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>MoI</td>
<td>Phase excitation monitor</td>
</tr>
</tbody>
</table>

Output Signal Functions and Timing

• A, X, B, and B (Motor phase excitation outputs)

Function

—In the 4 phase and 2 phase excitation modes, a 3.75 µs (typical) interval is set up between the A and X and B and B output signal transition times.
Phase States During Excitation Switching

- Excitation phases before and after excitation mode switching (clockwise direction)

2W1-2 phase → 2 phase

W1-2 phase → 2 phase

1-2 phase → 2 phase

2 phase → 1-2 phase

2W1-2 phase → 2W1-2 phase

W1-2 phase → W1-2 phase

1-2 phase → W1-2 phase

2 phase → W1-2 phase

2W1-2 phase → W1-2 phase

Excitation phase according to the first clock input pulse after changing the excitation mode setting (M1 to M2)

Excitation phase immediately before setting the excitation mode
• Excitation phases before and after excitation mode switching (counterclockwise direction)
Excitation Time and Timing Charts

- CLK rising edge operation
- CLK rising and falling edge operation

1-2 Phase Excitation Timing Chart (M3=0)

<table>
<thead>
<tr>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>RESET</th>
<th>CWB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>-------</td>
<td>-----</td>
</tr>
</tbody>
</table>

CLK

Comparator Reference Voltage

Vref A

Vref B

2W1-2 Phase Excitation Timing Chart (M3=0)

<table>
<thead>
<tr>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>RESET</th>
<th>CWB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>-------</td>
<td>-----</td>
</tr>
</tbody>
</table>

CLK

Comparator Reference Voltage

Vref A

Vref B

4W1-2 Phase Excitation Timing Chart (M3=0)

<table>
<thead>
<tr>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>RESET</th>
<th>CWB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>-------</td>
<td>-----</td>
</tr>
</tbody>
</table>

CLK

Comparator Reference Voltage

Vref A

Vref B
**Thermal Design**

<Hybrid IC Average Internal Power Loss Pd>

The main elements internal to this hybrid IC with large average power losses are the current control devices, the regenerative current diodes, and the current detection resistor. Since sine wave drive is used, the average power loss during microstepping drive can be approximated by applying a waveform factor of 0.64 to the square wave loss during 2 phase excitation.

The losses in the various excitation modes are as follows.

1. **2 phase excitation**
   \[ P_{d_{2EX}} = \frac{f_{clock}}{2} \cdot I_{OH} \cdot t_2 + \frac{f_{clock}}{4} \cdot I_{OH} \cdot t_2 + \frac{f_{clock}}{8} \cdot I_{OH} \cdot t_2 + (V_{sat} \cdot t_1 + V_{df} \cdot t_3) \]

2. **1-2 phase excitation**
   \[ P_{d_{1-2EX}} = 0.64 \cdot \{ (V_{sat} + V_{df}) \cdot \frac{f_{clock}}{4} \cdot I_{OH} \cdot t_2 + \frac{f_{clock}}{4} \cdot (V_{sat} \cdot t_1 + V_{df} \cdot t_3) \} \]

3. **W1-2 phase excitation**
   \[ P_{d_{W1-2EX}} = 0.64 \cdot \{ (V_{sat} + V_{df}) \cdot \frac{f_{clock}}{16} \cdot I_{OH} \cdot t_2 + \frac{f_{clock}}{8} \cdot (V_{sat} \cdot t_1 + V_{df} \cdot t_3) \} \]

4. **2W1-2 phase excitation**
   \[ P_{d_{2W1-2EX}} = 0.64 \cdot \{ (V_{sat} + V_{df}) \cdot \frac{f_{clock}}{16} \cdot I_{OH} \cdot t_2 + \frac{f_{clock}}{16} \cdot (V_{sat} \cdot t_1 + V_{df} \cdot t_3) \} \]

5. **4W1-2 phase excitation**
   \[ P_{d_{4W1-2EX}} = 0.64 \cdot \{ (V_{sat} + V_{df}) \cdot \frac{f_{clock}}{16} \cdot I_{OH} \cdot t_2 + \frac{f_{clock}}{16} \cdot (V_{sat} \cdot t_1 + V_{df} \cdot t_3) \} \]

Here, \( t_1 \) and \( t_3 \) can be determined from the same formulas for all excitation methods.

\[ t_1 = \frac{-L}{R + 0.35} \cdot \frac{1}{V_{CC1}} \cdot (1 - \frac{R + 0.35}{V_{CC1}}) \cdot I_{OH} \]

\[ t_3 = \frac{-L}{R} \cdot \frac{1}{V_{CC1}} \cdot (\frac{V_{CC1} + 0.35}{I_{OH} \cdot R + V_{CC1} + 0.35}) \]

However, the formula for \( t_2 \) differs with the excitation method.

- **2 phase excitation**
  \[ t_2 = \frac{2}{f_{clock}} - (t_1 + t_3) \]

- **1-2 phase excitation**
  \[ t_2 = \frac{3}{f_{clock}} - t_1 \]

- **W1-2 phase excitation**
  \[ t_2 = \frac{7}{f_{clock}} - t_1 \]

- **2W1-2 phase excitation**
  \[ t_2 = \frac{15}{f_{clock}} - t_1 \]

- **4W1-2 phase excitation**
  \[ t_2 = \frac{15}{f_{clock}} - t_1 \]

---

*fclock*: CLK input frequency (Hz)

*V_{sat}*: The voltage drop of the power MOSFET and the current detection resistor (V)

*V_{df}*: The voltage drop of the body diode and the current detection resistor (V)

*I_{OH}* : Phase current peak value (A)

*t_1*: Phase current rise time (s)

*t_2*: Phase current operating time (s)

*t_3*: Phase switching current regeneration time (s)

*V_{CC1}* : Supply voltage applied to the motor (V)

*L*: Motor inductance (H)

*R*: Motor winding resistance (W)
Next we determine the usage conditions with no heat sink by determining the allowable hybrid IC internal average loss from the thermal resistance of the hybrid IC substrate, namely 25.5 °C/W.

\[
P_{d_{EX}} = \frac{105 - 50}{25.5} = 2.15 \text{ W}
\]

\[
P_{d_{EX}} = \frac{105 - 40}{25.5} = 2.54 \text{ W}
\]

This hybrid IC can be used with no heat sink as long as it is used at operating conditions below the losses listed above. (See \(\Delta T_c - P_d\) curve in the graph on page 17.)

<Hybrid IC internal power element (MOSFET) junction temperature calculation>

The junction temperature, \(T_j\), of each device can be determined from the loss \(P_{ds}\) in each transistor and the thermal resistance \(\theta_{J-C}\).

\[
T_j = T_c + \theta_{J-C} \times P_{ds} \ (\text{°C})
\]

Here, we determine \(P_{ds}\), the loss for each transistor, by determining \(P_{d_{EX}}\) in each excitation mode.

\[P_{ds} = P_d/4\]

Since the average loss includes the loss of the current detection resistor, we take that voltage drop into consideration in the calculation.

\[
V_{\text{sat}} = I_{OH} \cdot R_{on} + I_{OH} \cdot R_s
\]

\[
V_{df} = V_{df} + I_{OH} \cdot R_s
\]

The steady-state thermal resistance of a power MOSFET is 15.6 °C/W.
This catalog provides information as of February, 2002. Specifications and information herein are subject to change without notice.