Unipolar 2-Phase Stepper Motor Driver ICs

STA7120MC Series

Datasheet

June, 2016 Rev.4.1

Table of Contents

1. General Description

Thank you for your long years of patronage for each series of our unipolar 2-phase stepping motor driver ICs. **The STA7120MC series** is our latest release.

This document describes summaries of our latest products.

2. Features and Benefits

(1) Load (motor supply) voltages, V_M: 35 V (max.), 0 to 33 V normal operating range
(2) Main power supply voltages, V_{BB}: 46 V (max.), 10 to 44 V normal operating range
(3) Maximum output currents, $I_{O(max)}$: 2.0 A, 3.0 A
(4) Stepping control for phase input
(5) Built-in "sense resistor" detects motor current
(6) All variants are pin-compatible for enhanced design flexibility
(7) ZIP type 18-pin molded package (STA package)
(8) Self-excitation PWM current control with fixed OFF-time: t_{OFF} = 12 μs (typ.)
(9) Built-in synchronous rectifying circuit reduces power dissipation at PWM-OFF
(10) Synchronous PWM chopping function prevents motor noise in the Hold mode
(11) The Standby mode to reduce IC input current in stand-by state
(12) Built-in protection circuitry against motor coil opens/shorts and thermal shutdown protection
(13) Externally-adjustable blanking time (Minimum ON-time): 3.0 μs, 5.0 μs

3. Part Numbers and Rated Currents

Table 3-1 shows each part number and its rated current for the STA7120MC series.

Table 3-1. Part Numbers and Rated Currents

Part Number	Rated Current (Maximum Setting Value)
STA7122MC	2.0 A
STA7123MC	3.0 A

4. Specifications

Table 4-1. Absolute Maximum Ratings

Unless specifically noted, T_A = 25 °C

Characteristic	Symbol	Rating	Unit	Remarks	
Load (Motor Supply) Voltage	V_M	35	V		
Main Power Supply Voltage	V_{BB}	46	V		
Output Current	I_O	2.0	A	STA7122MC	Control current value
		3.0	A	STA7123MC	
Logic Input Voltage	V_{LI}	−0.3 to 5.5	V		
Logic Output Voltage	V_{LO}	5.5	V	FLAG pin	
REF Input Voltage	V_{REF}	−0.3 to 5.5	V		
Detection Voltage	V_{RS}	±1	V		
Power Dissipation	P_D	3.5	W	Without heatsink	
Junction Temperature	T_J	150	°C		
Ambient Temperature	T_A	−20 to 80	°C		
Storage Temperature	T_{stg}	−30 to 150	°C		

NOTE: Output current ratings may be limited by duty cycles, ambient temperatures, and heat sinking conditions. Do not exceed the maximum output current and maximum junction temperature (T_J) given above, under any conditions of use.

Table 4-2. Recommended Operating Conditions

Unless specifically noted, T_A = 25 °C

Characteristic	Symbol	Standard Value		Unit	Remarks
		Min.	Max.		
Load (Motor Supply) Voltage	V_M		33	V	
Main Power Supply Voltage	V_{BB}	10	44	V	
Logic Input Voltage	$V_{IN(Logic)}$	0	5.5	V	
REF Input Voltage	V_{REF}	0.1	0.9	V	Control current accuracy degrades at a voltage of 0.1 V or less
Case Temperature	T_C		85	°C	Measured at Pin 10 (lead portion), without heatsink

NOTE: As the motor supply voltage, V_M, becomes higher, it also approaches the breakdown voltage of the OUTx pins (75 V min.); and breakdown will be more likely to happen. Even if one of the OUTx pins breaks down (due to surge noise or other factors), the STA7120MC series will recognize it as abnormality (coil open) and will run appropriate protection functions. Therefore, a thorough evaluation is recommended.

Table 4-3. Electrical Characteristics

Unless specifically noted, T_A = 25 °C, V_{BB} = 24 V

Characteristic	Symbol	Rating			Unit	Conditions
		Min.	Typ.	Max.		
Main Power Supply Current	I_{BB}			15	mA	Normal mode
	I_{BBS}			3	mA	Standby mode
MOSFET Breakdown Voltage	V_{DSS}	75			V	I_D = 1 mA
MOSFET On-Resistance	$R_{DS(on)}$		0.18	0.24	Ω	STA7122MC
			0.12	0.18		STA7123MC
MOSFET Body Diode Forward Voltage	V_F		0.85	1.2	V	STA7122MC
			0.9	1.3		STA7123MC
Maximum Response Frequency	f_{CLK}	250			kHz	Clock duty cycle = 50%
Logic Input Voltage	V_{LIL}	0		0.7	V	
	V_{LIH}	2.3		5.5	V	
Logic Input Current	I_{LIL}		±1		μA	V_{LIL} = 0 V
	I_{LIH}		±1		μA	V_{LIH} = 5 V
Logic Output Voltage	V_{LOL}			0.5	V	I_{LOL} = 3 mA
Logic Output Current	I_{LOL}			3	mA	V_{LOL} = 0.5 V
REF Input Voltage	V_{REF}	0.1		0.9	V	
	V_{REFS}	2.0		5.5	V	Standby1[1)]
REF Input Current	I_{REF}		±10		μA	V_{REF} = 0.1 to 5 V
SENSE Detection Voltage	V_{SENSE}	V_{REF} × 1/3 − 0.03	V_{REF} × 1/3	V_{REF} × 1/3 + 0.03	V	V_{REF} = 0.6 V
Sense Resistor[2)]	R_S		0.15		Ω	STA7122MC
			0.1			STA7123MC
PWM Minimum ON-Time	$t_{ON(min)}$		3.0		μs	B_SEL=L
			5.0		μs	B_SEL=H
PWM OFF-Time	t_{OFF}		12		μs	
Standby-Enable Recovery Time	t_{SE}	100			μs	Standby1[1)], Standby2[2)]
Switching Time	t_{PDON}		1.6		μs	Phase IN → Output ON
	t_{PDOFF}		0.9		μs	Phase IN → Output OFF
Overcurrent Detection Voltage[3)]	V_{SOC}		0.45		V	SENSE Terminal Voltage
Overcurrent Detection Current (V_{SOC} / Rs)	I_{OCP}		3		A	STA7122MC
			4.5		A	STA7123MC
Load Disconnection Undetected Time	t_{OPP}		2		μs	From PWM-OFF
Overheat Protection Temperature	T_{TSD}		125		°C	Measured at back of device case (after heat has saturated)

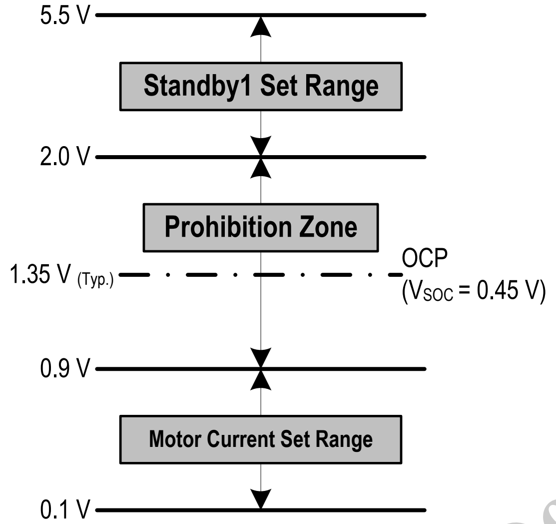
NOTE: Unless specifically noted, negative current is defined as output current flow from a specified pin.

1) In a state of: I_{BBS}, and output OFF.

2) In a state of: I_{BBS}, output OFF, and Protection Release.

3) The protection circuit operates when $V_{SENSE} > V_{SOC}$.

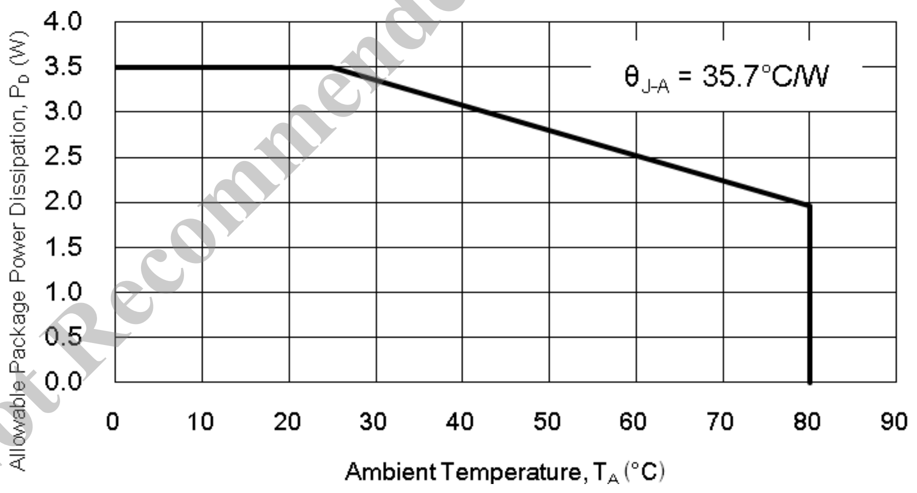
Figure 4-1. Setting Range of Reference Voltage, V_{REF}



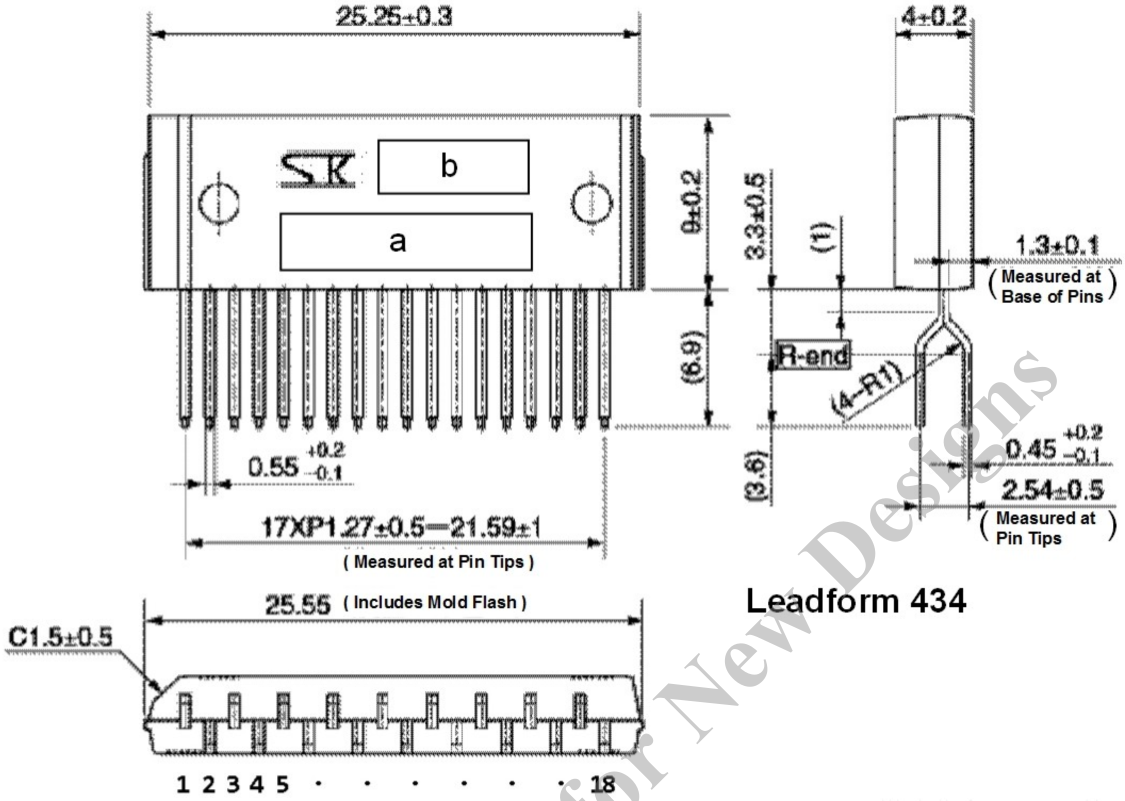
NOTE: Extra attentions should be paid to the changeover between the motor current specification range and the Standby1 set range. If the changeover takes too long, OCP operation will start when $V_{SENSE} > V_{SOC}$.

5. Power Derating Chart

Figure 5-1. Power Derating Chart



6. Package Outline Drawing

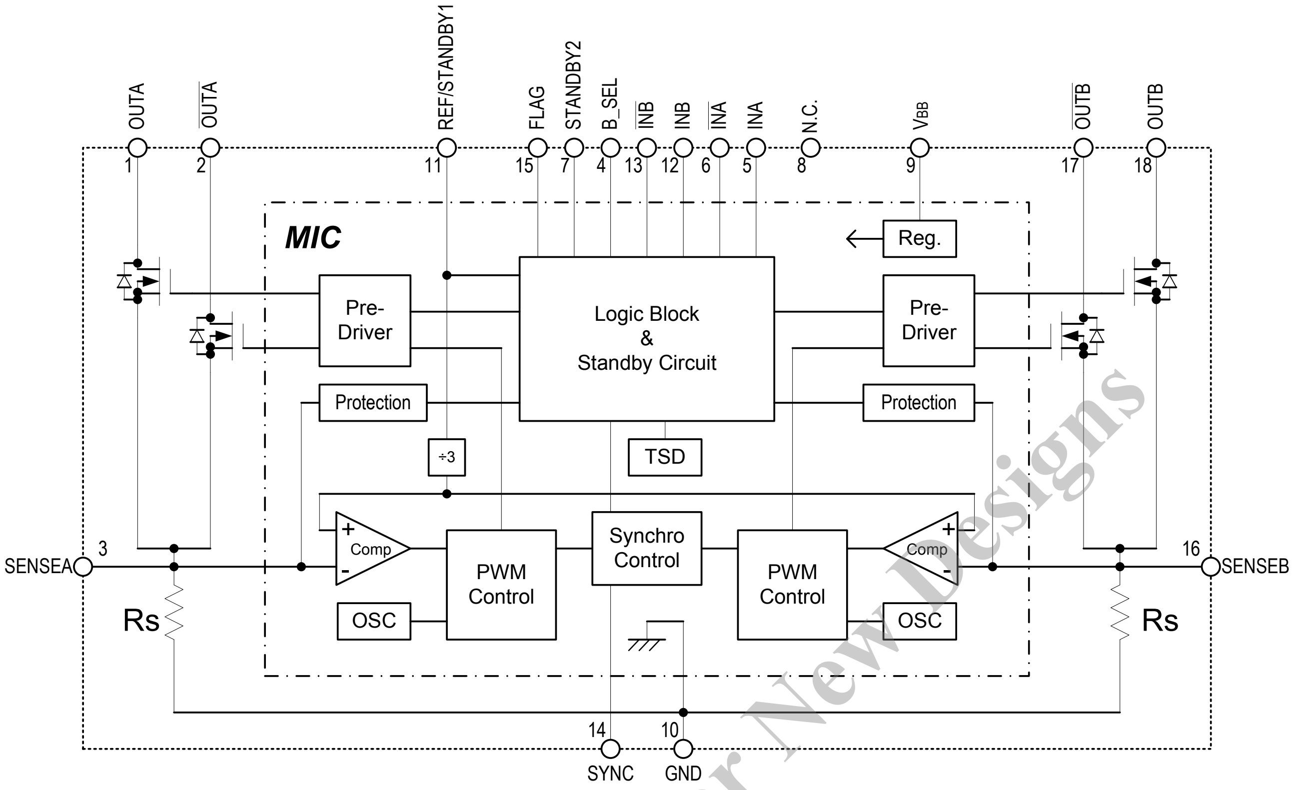


NOTES:

- Dimensions in millimeters
- Pin material: Cu
- Pin plating: Solder plating (Pb-free)
- Branding codes:
  - a Part number: *STA712xMC*
    - The lowercase letter *x* represents a number of either of *2* or *3*, according to rated current. See also Table 3-1.
  - b Lot number: *YMDD*
    - *Y* is the last digit of the year of manufacture
    - *M* is the month of the year (1 to 9, O, N, or D)
    - *DD* is the day of the month (01 to 31)

7. Functional Block Diagram and Pin Assignment

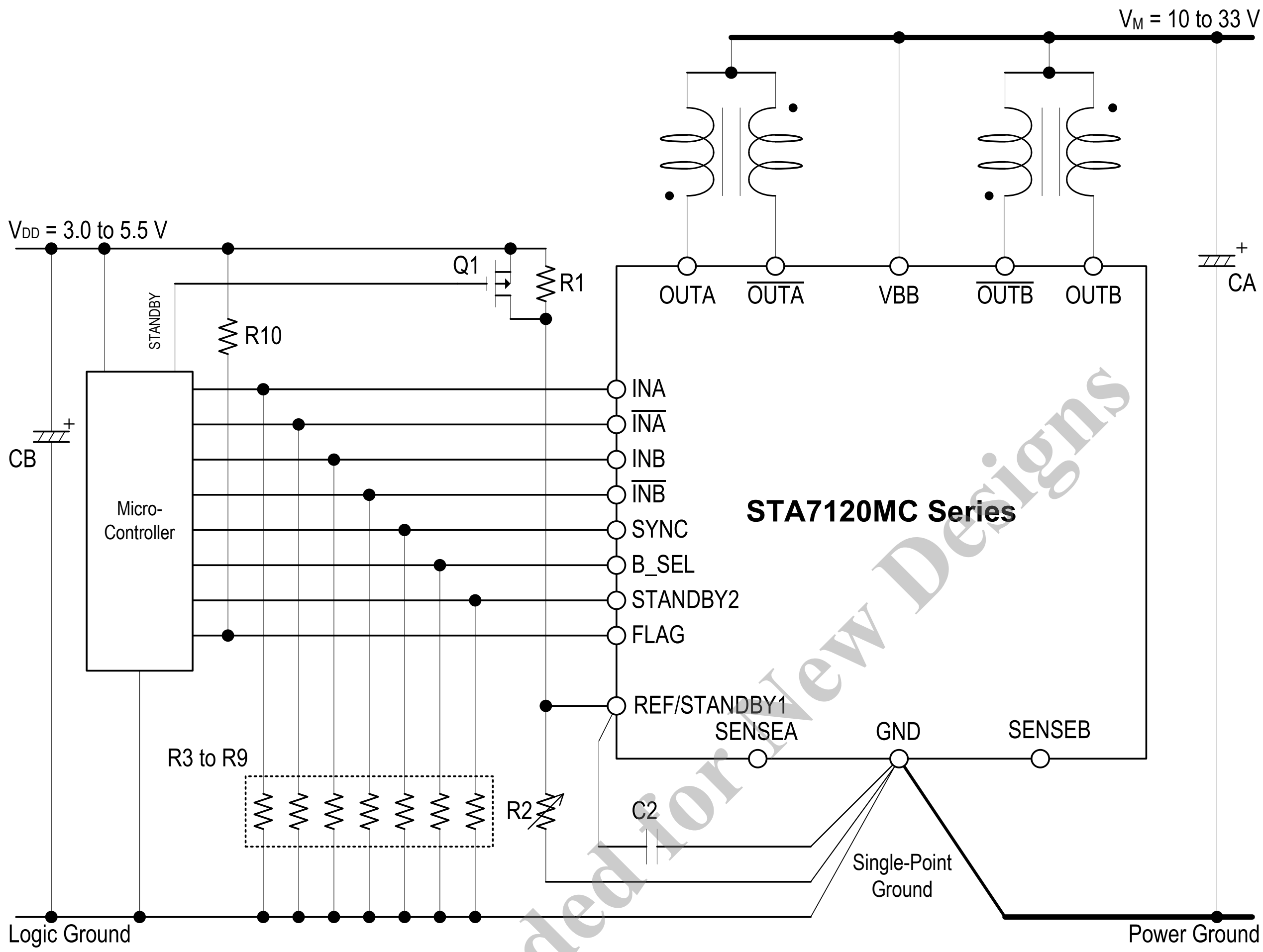
Figure 7-1. Functional Block Diagram



Pin No.	Symbol	Function
1	OUTA	Phase A output
2	$\overline{\text{OUTA}}$	Phase $\overline{\text{A}}$ output
3	SENSEA	Phase A current sensing
4	B_SEL	Blanking time switching input
5	INA	Switching input for Phase A
6	$\overline{\text{INA}}$	
7	STANDBY2	Input for Standby2 setting
8	N.C.	No connection
9	V_{BB}	Main power supply (for motor)
10	GND	Device ground
11	REF/STANDBY1	Input for control current / Standby1 setting
12	INB	Switching input for Phase B
13	$\overline{\text{INB}}$	
14	SYNC	Synchronous PMW control switch input
15	FLAG	Output from protection circuit monitor
16	SENSEB	Phase B current sensing
17	$\overline{\text{OUTB}}$	Phase $\overline{\text{B}}$ output
18	OUTB	Phase B output

8. Application Example

Figure 8-1. Application Example



Constants, for reference use only:

R1 = 10 kΩ
R2 = 1 kΩ (VR)
R3 to R9 = 1 to 10 kΩ (Not required if input state does not reach indefinite.)
R10 = 5.1 to 10 kΩ

NOTES:

- Take precautions to avoid noise on the V_{DD} line; noise levels greater than 0.5 V on the V_{DD} line may cause device malfunction. Noise can be reduced by separating the logic ground and the power ground on a PCB from the GND pin (Pin 10).
- Unused logic input pins (INA, $\overline{\text{INA}}$, INB, $\overline{\text{INB}}$, B_SEL, STANDBY2, and SYNC) **must be pulled up or down to VDD or ground**. If those unused pins are left open, the device may malfunction.
- Unused logic output pin (FLAG) **must be kept open**.

9. Truth Tables

(1) Dual Phase Inputs and Outputs

Table 9-1. Truth Table for Phase-Switching Input Pins

	INA (Pin 5)	$\overline{\text{INA}}$ (Pin 6)	OUTA (Pin 1)	$\overline{\text{OUTA}}$ (Pin 2)
Phase A	Low	Low	OFF	OFF
	High	Low	**ON**	OFF
	Low	High	OFF	**ON**
	High	High	OFF	OFF
	INB (Pin 12)	$\overline{\text{INB}}$ (Pin 13)	OUTB (Pin 18)	$\overline{\text{OUTB}}$ (Pin 17)
Phase B	Low	Low	OFF	OFF
	High	Low	**ON**	OFF
	Low	High	OFF	**ON**
	High	High	OFF	OFF

NOTE: OUTx indicates power MOSFET drain state (does not indicate PWM operation).

(2) Logic Inputs

Table 9-2. Truth Table for Logic Input Pins

Pin Name	Low Level	High Level
SYNC	Non-sync PWM control	Synchronous PWM control
B_SEL	Blanking time: 3.0 μs	Blanking time: 5.0 μs
STANDBY2	Enable	Standby2 (Protection Release)

(3) Output Pin

Table 9-3. Truth Table for Monitor Output Pin

Pin Name	Low Level	High Level (Hi-Z)
FLAG	Normal operation	Protection circuit operation

NOTES:

- The monitor pin is <u>an open-drain output</u>. In an actual application, add a pull-up resistor (approximately 5.1 to 10 kΩ).
- The output turns off at the point where the protection circuit starts operating. To release the protection state, re-input the main power supply voltage (V_{BB}) or put the IC into the Standby2 mode.

10. Logic Input Pins

The low pass filter (LPF) incorporated with the logic input pins (INA, $\overline{\text{INA}}$, INB, $\overline{\text{INB}}$, B_SEL, STANDBY2, and SYNC) improves noise rejection.

The logic inputs are MOS input compatible; therefore, they are in a high impedance state. <u>Note that the IC should be used at a fixed input level, either low or high</u>.

If there is a possibility that signals from the microcontroller are in high impedance, add a pull-up/-down resistor. Since outputs from the logic input pins, which function as output ON/OFF controllers, may result in abnormal oscillation, leading to MOSFET breakdown as the worst-case scenario.

11. Individual Circuit Descriptions

(1) Monolithic IC (MIC)

・Logic Block

A circuit block that transmits signals to each circuit in accordance with logic input signals.

・PWM Control

Circuits that allow self-excitation PWM current controlling with a fixed OFF-time are used in this series. Each built-in oscillator (OSC) determines an OFF-time and a blanking time for proper PWM operation. The operation mechanism of the PWM control circuitry is identical to that of the SLA7080MPR family. For more detailed functional descriptions, see Section 12.

・Synchronous Control

A synchronous chopping circuit that prevents occasional motor noise during a hold state which normally results from the asynchronous PWM operation of both motor phases. When the SYNC input pin is set to logic high, the circuit sends a timing signal that simultaneously turns off the chopping of phases A and B.

This function adopts the same operation mechanism applied to the SLA7080MPR series. The use of the synchronous control during normal stepping is not recommended, because it produces less motor torque or may cause motor vibration due to staircase current.

・Regulator Circuit

An integrated regulator circuit is used for powering the output MOSFET gate drive circuit (pre-driver) and other internal linear circuits.

・Protection Circuit

Built-in protection circuits against motor coil opens or shorts are provided. This protection is activated by sensing the voltage across internal sense resistors, R_S. Therefore, an overcurrent condition cannot be detected which results from the OUTx pins or SENSEx pins, or both, shorting to GND. The protection against motor coil opens is available only during PWM operation; therefore, it does not work at constant voltage driving, when the motor is rotating at a high speed.

The operation of the protection circuit disables all outputs and reduces the circuit current to approximately one-third. To return from the Protection mode, perform the following steps:

1) Cycle the main power supply, V_{BB}.
2) Release the protection state by setting the STANDBY2 pin logic high to change into the Standby2 mode.

・TSD Circuit

A TSD circuit that protects a driver by shifting an output to the Disable mode is incorporated. When the temperature of the product control IC (MIC) rises and becomes higher than its threshold, the circuit starts operating.

To reset the function, perform the same steps as described in the Protection Circuit description.

(2) Output MOSFET Chip

The type of MOSFET chips to be mounted varies according to which of the two different output current ratings has been selected. For specifications, see Table 4-3.

(3) Sense Resistor

Sense resistors are incorporated in this series to detect motor current. The resistance of these varies according to which of the two different output current ratings has been selected. For specifications, see Table 4-3.

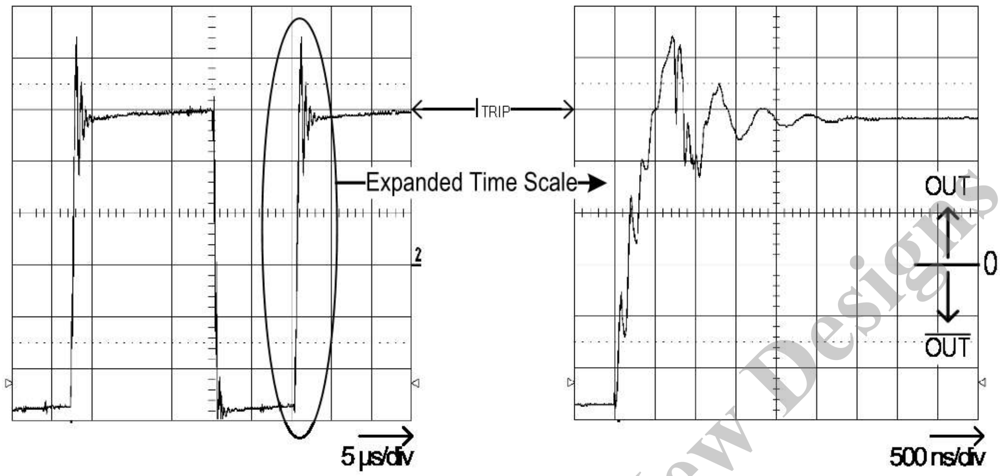
12. Functional Descriptions

(1) PWM Current Control

[1] Blanking Time

An actual operating waveform on the SENSEx pin when driving a motor is shown in Figure 12-1.

Figure 12-1. Operating Waveform on SENSEx Pin during PWM Chopping
(Circled area of the left panel is shown in expanded scale in the right panel)



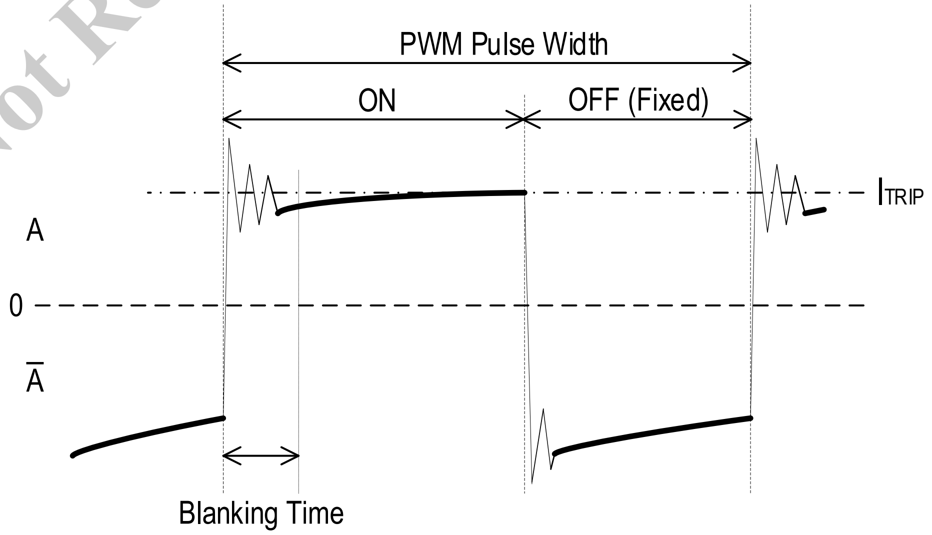
Immediately after a PWM turns off, ringing (or spike) noise on the SENSEx pin is observed for a period of a few microseconds. Ringing noise can be generated by various causes, such as capacitance between motor coils or inappropriate motor wiring.

Each pair of outputs is controlled by a fixed OFF-time PWM current-control circuit that limits the load current to a target value, I_{TRIP}. Initially, an output is enabled and then currents flow through the motor winding and the current sense resistors.

When the voltage across the current sense resistors equals one-third of the REF pin voltage, V_{TRIP}, the current sense comparator resets a PWM latch. This turns off the driver for the fixed OFF-time, during which the load inductance causes the current to recirculate for the OFF-time period. Therefore, if the ringing noise on the current sense resistor(s) equals and surpasses V_{TRIP}, the PWM turns off (i.e., a hunting phenomenon).

To prevent this phenomenon, a blanking time is set to override signals from the current sense comparator for a certain period immediately after the PWM turns on (Figure 12-2).

Figure 12-2. SENSEx Pin Waveform Pattern during PMW Control



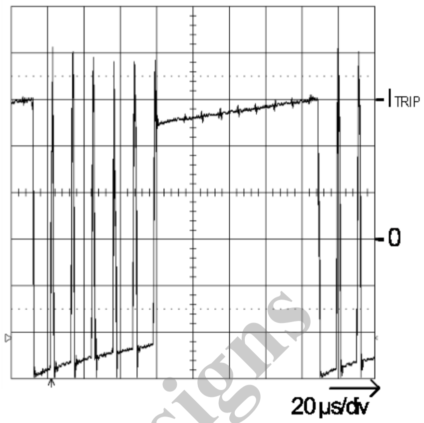
[2] Blanking Time and Hunting Phenomenon

Although current control can be improved by shortening a blanking time, the degree of margin to a ringing noise decreases simultaneously. For this reason, when a motor is driven by the device, a hunting phenomenon may occur. Figure 12-3 shows an example of the waveform pattern when the phenomenon occurs.

In order to overcome this problem, the STA7120MC series is designed to have the B_SEL pin, allowing the dynamic selection of blanking time duration.

In the event that the seeking behavior occurs with a shorter blanking time of 3.0 μs, it may be eased by selecting a longer blanking time of 5.0 μs.

Figure 12-3. Example of SENSEx Pin Waveform during Hunting Phenomenon



[3] Blanking Time Difference

Table 12-1 shows characteristic differences between two blanking times, shorter and longer blanking periods.

This comparison is based on the case where drive conditions, such as a motor, motor power supply voltage, REF input voltage, and circuit constant were kept the same while only the indicated parameters were changed.

Table 12-1. Characteristic Comparison of Difference in Blanking Time

Parameter	Better Performance	
Internal blanking time	Short	Long
Minimum PWM ON-time	Small ←	
Ringing noise suppression	→	Large
Minimum coil current	Small ←	

The following are the brief descriptions of the parameters in Table 12-1:

- Minimum PWM ON-time, $t_{ON(min)}$

  This series has a blanking time that is effectively selected and fixed by the PWM control. Therefore, even if an application attempts to shorten its ON-time for limiting currents, it would not go below the fixed blanking time. Minimum PWM ON-time refers to the time when an output is on during this blanking time period, that is, when an output MOSFET is actually turned on. In other words, a blanking time determines a minimum ON-time ("Small" in Table 12-1).

- Minimum Coil Current

  This refers to the coil current when the PWM control is performed during a minimum PWM ON-time. In other words, the device with a shorter blanking time can reduce more coil current.

[4] PWM OFF-time

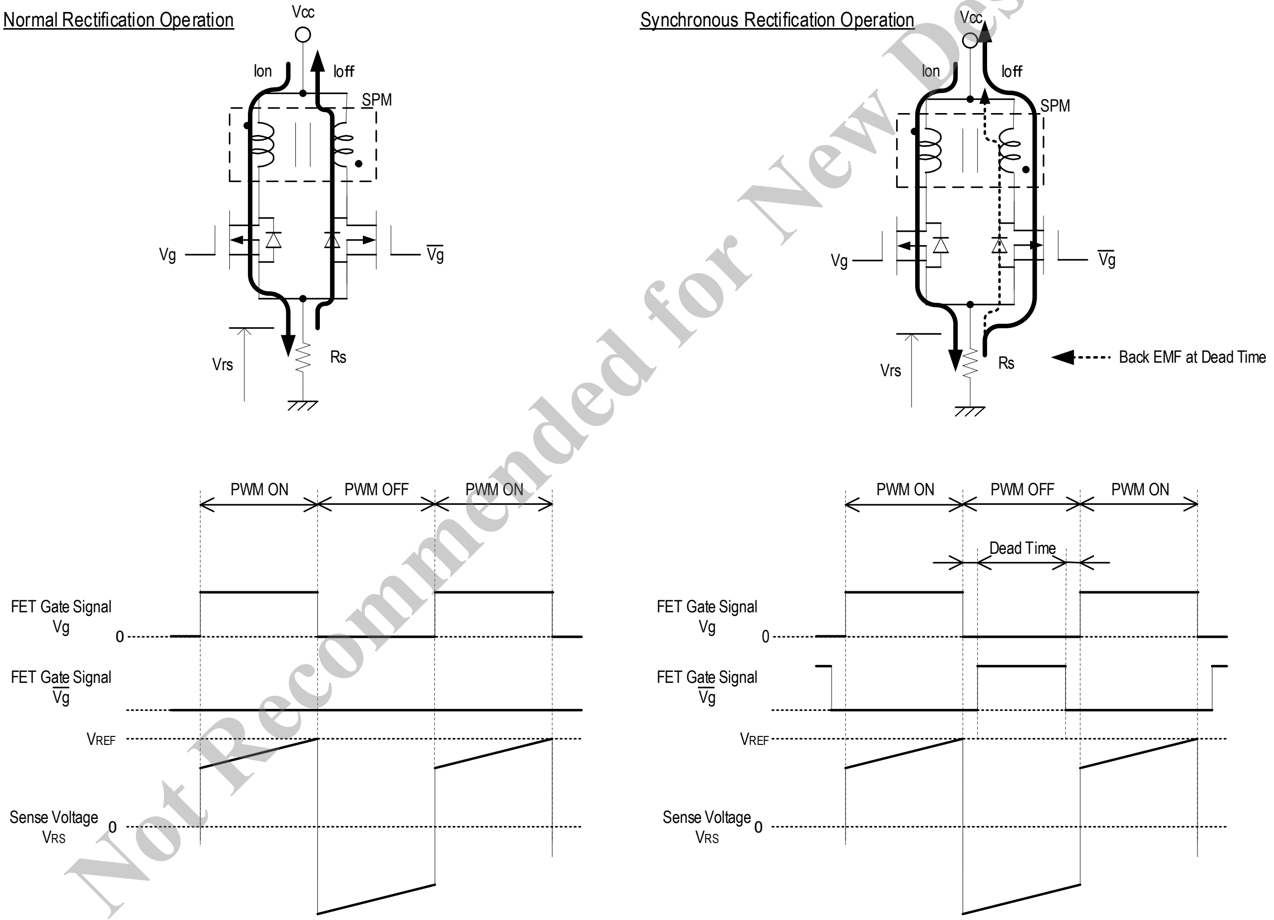
PWM OFF-time for the STA7120MC series is controlled at a fixed time generated by the corresponding internal oscillator.

In addition, the STA7120MC series provides a function that decreases power losses occurring when the PWM turns off. This function dissipates the back EMF stored in the motor coil at MOSFET turn-on, as well as at PWM turn-on (synchronous rectification operation).

Figure 12-4 explains differences between two back EMF generation mechanisms. Whereas the older version of our product series only performs ON/OFF operations using a MOSFET on the PWM-ON side, the STA7120MC series can perform ON/OFF operations using a MOSFET on the PWM-OFF side.

To prevent simultaneous switching of the output MOSFETs at the synchronous rectification operation, the IC has a dead time of approximately 0.5 µs. During the dead time, the back EMF flows through the body diodes of the MOSFETs.

Figure 12-4. Difference in Back EMF Generation



Back EMF flows through the body diode of MOFSET during dead time.

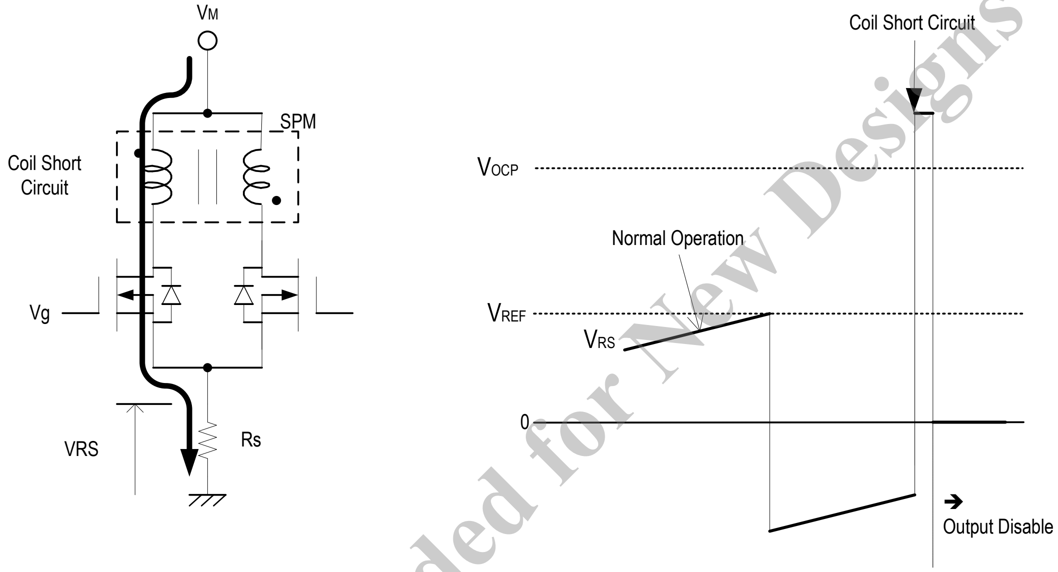
(2) Protection Functions

The STA7120MC series includes a motor coil short protection circuit, a motor coil open protection circuit, and an overheat protection circuit. Detailed explanations of each protection circuit are provided below.

[1] Motor Coil Short Protection (Load Short) Circuit

This protection circuit, embedded in the STA7120MC series, begins to operate when the device detects an increase in the sense resistor voltage level, V_{RS}. The threshold voltage of this protection circuit, V_{SOC}, is set to approximately 0.45 V. Outputs are disabled at the time the protection circuit starts, **where V_{RS} exceeds V_{SOC}.**

Figure 12-5. Motor Coil Short Protection Circuit Operation



NOTE: Overcurrent that flows without passing the sense resister is undetectable.

[2] Motor Coil Open Protection Circuit *(Patent acquired)*

Driver destruction can occur when one output pin (motor coil) is disconnected in unipolar drive operation. This is because a MOSFET connected after disconnection will be in an avalanche breakdown state, where very high energy is added with back EMF when PWM is off. With the avalanche state, an output cancels the energy stored in the motor coil where the resisting pressure between the drain and source of the MOSFET is reached (i.e., the condition in which the breakdown occurred).

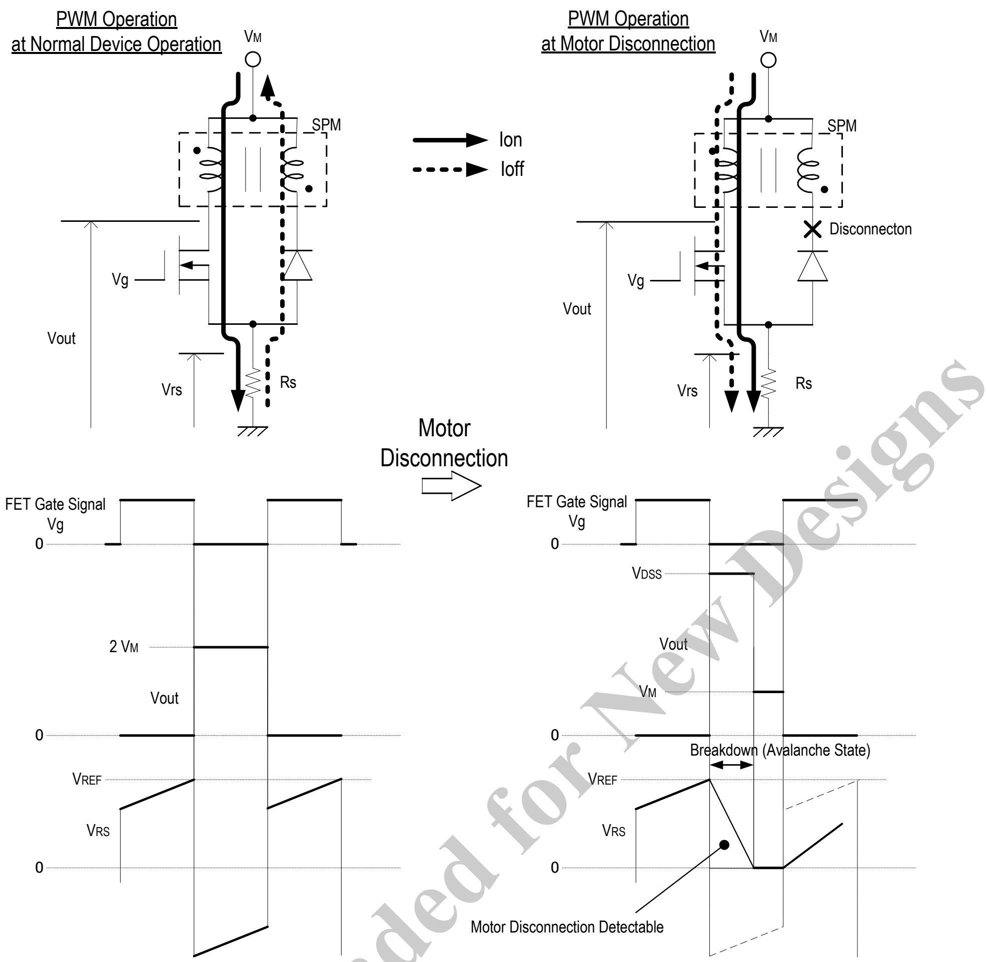
Although MOSFETs with a certain amount of an avalanche energy tolerance rating are used in the STA7120MC series, the avalanche energy tolerance falls as a temperature increases.

Because high energy is added repeatedly whenever PWM operation disconnects the MOSFET, the temperature of the MOSFET rises; and when the applied energy exceeds the tolerance, the driver will be destroyed. Therefore, a circuit which detects this avalanche state and protects the driver is added in the STA7120MC series.

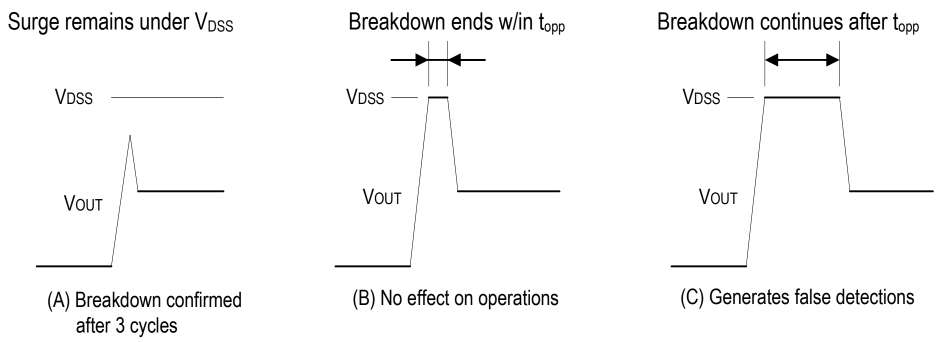
As explained above, when the motor coil is disconnected, accumulated voltage in the MOSFET causes a reverse current to flow during a PWM OFF-time. For this reason, V_{RS} that is negative during a PWM OFF-time in a normal operation becomes positive when the motor coil is disconnected. Thus, the disconnected motor is detectable by sensing that V_{RS} in the PWM OFF-time is positive.

In order to avoid detection malfunctions, the STA7120MC series actuates a dedicated protection function, the motor coil open protection circuit, when the motor disconnection state is detected three times continuously (see Figure 12-6).

Figure 12-6. Coil Open Protection Operation



NOTE: In addition to requiring three breakdown cycles to confirm the open circuit condition, the STA7120MC series provides a fixed delay, an overload disconnection undetected time (t_{opp}), before the protection is activated. This is to avoid false detections, which can be occurred by surge noise after PWM turn-off, causing an unwanted operation of the function even when the load is not actually disconnected. The figure below describes alternative t_{opp} scenarios. If a total period of breakdown time exceeds t_{opp}, the device shuts down the output. If this is the case, check the motor and wiring layout to reduce surge noise. Shortening the breakdown time will allow the protection circuit to function properly. (Variation among device variants and applications should be taken into consideration.) When there is no actual breakdown, normal operations will continue. One possible solution is adding a capacitor between the OUTx and GND pins, which could damp the surge noise sufficiently.



[3] Overheat Protection Circuit

When a product temperature rises and exceeds T_{tsd}, this protection circuit starts operating and sets all outputs to be disabled.

NOTE: This product series has multichip composition (one IC for control, four MOSFETs, and two chip resistors). Although main heat sources are the MOSFETs and chip resisters, the location which actually detects temperature is the control IC (MIC). Separated from these main heat sources, the control IC cannot detect a rapid temperature change. Accordingly, perform worst-case thermal evaluations, in which junction temperatures must not exceed a guaranteed value of 150 °C, in your application design phase.

13. Application Information

(1) Motor Current Ratio Setting

The motor current, I_O, for the STA7120MC series is determined by the values chosen for the external components, R1 and R2, and the current sense resistors, R_S, in the case of the sample application circuit shown in Figure 8-1. The formula to calculate I_O is shown below:

$$Io = \underline{\underline{\frac{R2}{R1+R2} \times V_{DD}}} \times \frac{1}{3} \; / \; Rs. \qquad (1)$$

The double-underlined term represents the reference voltage, V_{REF}.

If V_{REF} is set below 0.1 V, the accuracy of I_O setting is more likely to be degraded due to the variation between individual devices and/or the impedance of application trace layout.

(2) Lower Limit of Control Current

The STA7120MC series uses a self-oscillating PWM current control topology in which an OFF-time is fixed. As energy stored in a motor coil is eliminated within the fixed PWM OFF-time, coil current flows intermittently, as shown in Figure 13-1. Thus, average current decreases as well as motor torque decreases. The point at which current starts flowing to the coil is considered as the lower limit of the control current, $I_{O(min)}$, where I_{OUT} is a target current level.

The lower limit of control current differs by application conditions of the motor or other factors, but it can be calculated from the following formula:

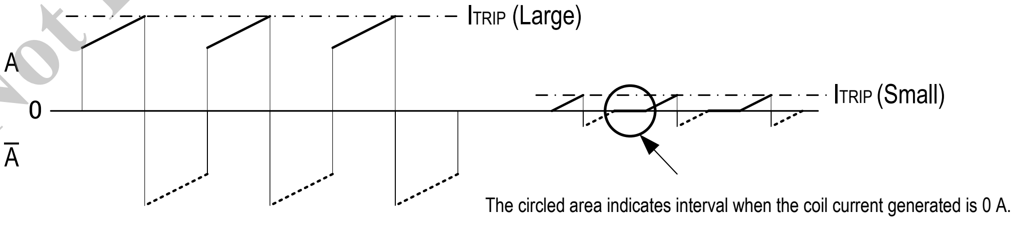
$$I_{O(\min)} = \frac{V_M}{R}\left(\frac{1}{\exp\left(-t_{OFF}/t_C\right)} - 1\right), \quad \text{with } t_C = \frac{L_m}{R}, \text{ and } R = R_m + R_{DS(on)} + R_S. \qquad (2)$$

Where:

V_M is the motor supply voltage,
$R_{DS(on)}$ is the MOS FET on-resistance,
R_m is the motor winding resistance,
L_m is the motor winding inductance,
t_{OFF} is the PWM OFF-time, and
R_S is the current sense resistor.

Even if the control current value is set at less than its lower limit, there is no setting at which the IC fails to operate. However, the control current will worsen against its target current.

Figure 13-1. Model Waveform of Control Current Lower Limit



(3) Avalanche Energy

In the unipolar topology of the STA7120MC series, a surge voltage (ringing noise) that exceeds the MOSFET capacity to withstand might be applied to the IC. To prevent damage, the STA7120MC series is designed with built-in MOSFETs having sufficient avalanche resistance to withstand this surge voltage. Therefore, even if surge voltages occur, users will be able to use the IC without any problems.

However, in case the motor harness used is too long or the IC is used above its rated current or voltage, there is a possibility that an avalanche energy could be applied that exceeds Sanken design expectations. Thus, users must test the avalanche energy applied to the IC under actual application conditions.

The following procedure can be used to check the avalanche energy in an application. Figure 13-2 and Figure 13-3 show test points and waveform characteristics resultant, respectively.

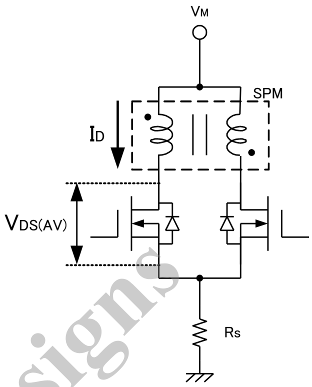


Figure 13-2. Test Points

From the waveform test result shown in Figure 13-3:

$V_{DS(AV)} = 80$ V,
$I_D = 1$ A, and
$t = 0.5$ µs.

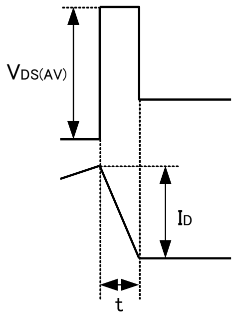


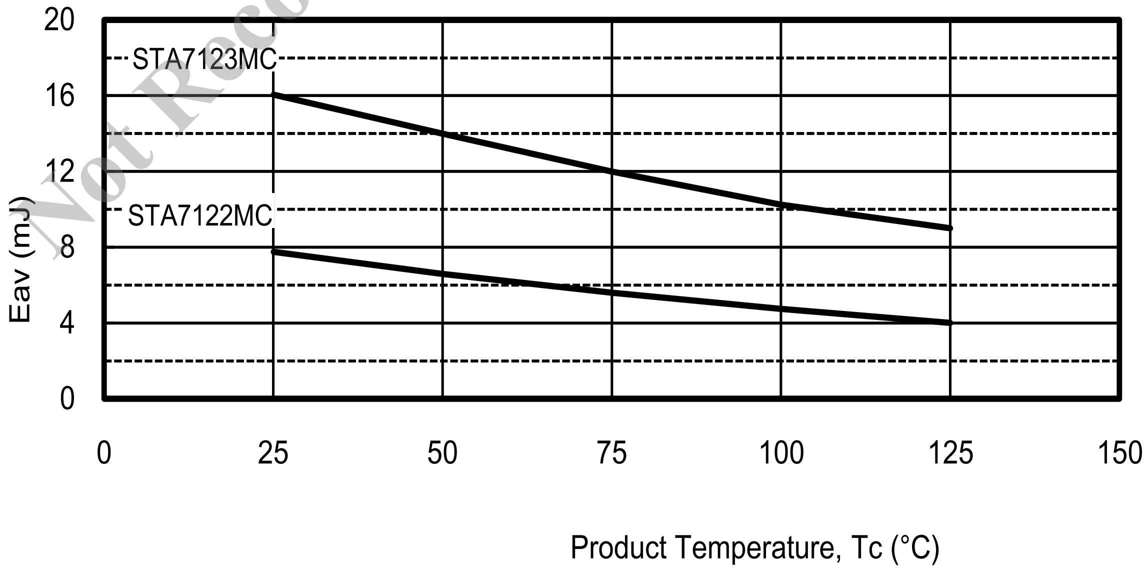
Figure 13-3. Waveform at Avalanche Breakdown

The avalanche energy, E_{AV}, then can be calculated using the following formula:

$$E_{AV} \approx V_{DS(AV)} \times 1/2 \times I_D \times t \quad (3)$$
$$= 80\ (\mathrm{V}) \times 1/2 \times 1\ (\mathrm{A}) \times 0.5 \times 10^{-6}\ (\mu\mathrm{s})$$
$$= 0.02\ (\mathrm{mJ}).$$

By comparing the calculated E_{AV} values with the graph shown in Figure 13-4, the application can be evaluated if it is safe for the IC by being within the avalanche energy-tolerated dose range of the MOFSETs.

Figure 13-4. Iterated Avalanche Energy Tolerated Level, E_{AV}



(4) Motor Supply Voltage (V_M) and Main Power Supply Voltage (V_{BB})

Because the STA7120MC series has a structure that separates the control IC (MIC) and the power MOSFETs as shown in Figure 7-1, the motor supply and main power supply are electrically separated. Therefore, it is possible to drive the IC with using different power supplies and different voltages for the motor supply and the main power supply. Note that the power supplies have different voltage ranges.

(5) Internal Logic Circuits

a. Chopping Synchronous Circuit

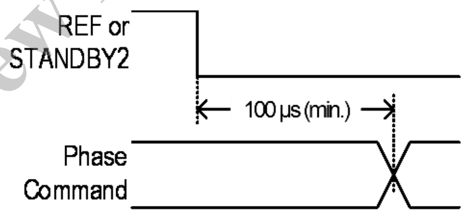
The STA7120MC series has a chopping synchronous function to protect from abnormal noises that may occasionally occur during the motor Hold mode. This function can be operated by setting the SYNC pin at high level. However, if this function is used during motor rotation, control current does not stabilize; and that may result in reduced motor torque and/or increased vibration.

b. Output Disable Circuits (Standby1 and Standby2)

There are two methods to set the IC to a motor free state (coast, with outputs disabled). One is to set the REF pin to more than 2 V (Standby1). And the other is to set the STANDBY2 pin to high (Standby2). In either way, the IC is put into the Standby mode, which stops the main power supply and reduces circuit current.

The difference between the two methods is that the Standby2 also works as a function to return from the state in which the protection function is activated.

Figure 13-5. Timing Delay between Disable Mode Cancellation and the Next Phase Input



When awaking to the normal operation mode (motor rotation) from the Disable (Standby1 or Standby2) mode, set an appropriate delay time, i.e., a time period from cancellation of the Disable mode to the next motor phase input command. In doing so, consider not only a rise time for the IC, but also a rise time for the motor excitation current (Figure 13-5).

c. REF/STANDBY1 Pin

The REF pin provides access to the following functions:

[1] Reference voltage setting for output current setting: Low level ($V_{REF} \leq 0.9$ V)

[2] Output Enable-Disable control input: High level ($V_{REF} \geq 2.0$ V)

These functions are further described in Section 9, and in the discussion of output disabling, above. Moreover, the threshold voltage to switch the output enable-disable signals is set to approximately 1.75 V.

To control the REF voltage, pay attention to the following points:

Range A – Control current value varies in accordance with V_{REF}, not only within the range specified in [1], but also within the range from [1] to the threshold voltage (typically 1.75 V). Therefore, power dissipation in the IC and the sense resistors must be given extra consideration. In addition, note that OCP operation may start if the control current value goes beyond the OCP operation threshold due to poorly-regulated REF voltage.

Range B – In this range, the voltage that switches output enable and disable exists. At enable, the same cautions apply as in *Range A*. For some cases, there are possibilities that an output status will become unstable as a result of iterations between enable and disable states.

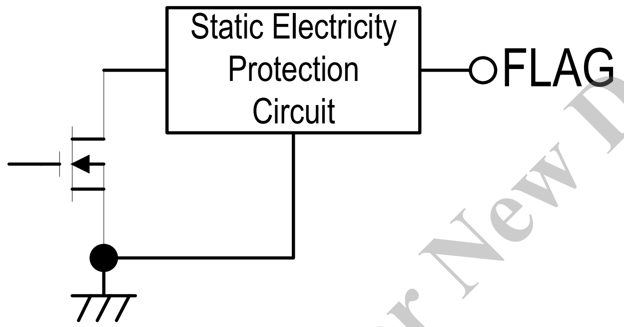
d. Logic Input Pins (INA, $\overline{\text{INA}}$, INB, $\overline{\text{INB}}$, B_SEL, STANDBY2, and SYNC)

When a logic input pin (INA, $\overline{\text{INA}}$, INB, $\overline{\text{INB}}$, B_SEL, STANDBY2, or SYNC) is not used, the pin must be tied to VDD or GND. Do not leave any of these pins floating, because there is possibility of undefined effects on IC performance if they are left open.

e. Monitor Output Pin (FLAG)

The FLAG pin is designed as a monitor output. Moreover, the IC consists of **an open-drain output** configuration, as shown in Figure 13-6. When using the monitor output pin, add a pull-up resistor of approximately 5.1 to 10 kΩ. Therefore, let the pin open when it is not used.

Figure 13-6. FLAG Pin General Internal Circuit Layout



14. Thermal Design Information

It is not practical to calculate the power dissipation of the STA7120MC series accurately, because that would require factors that are variable during operation, such as time periods and excitation modes during motor rotation, input frequencies and sequences, and so forth.

Given this situation, it is preferable to perform approximate calculations at worst conditions. The following is a simplified formula for the calculation of power dissipation using extracted minimum necessary parameters:

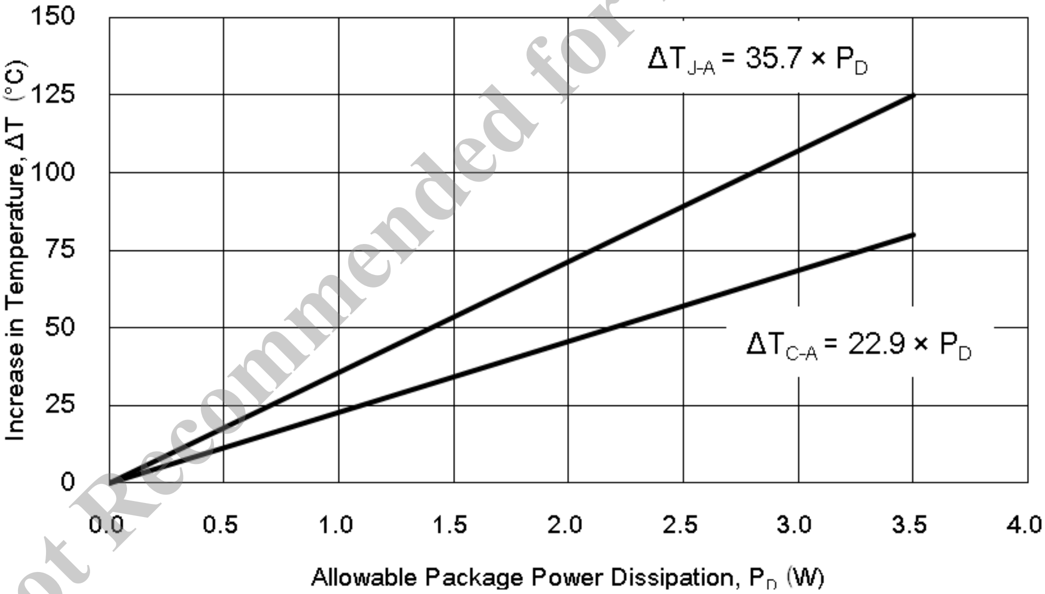
$$P = I^2 \times (R_{DS(on)} + Rs) \times 2,$$

where:

P is the power dissipation in the IC,
I is the operation current ($\approx I_O$),
$R_{DS(on)}$ is the on-resistance of the output MOSFET, and
Rs is the current sense resistance.

Based on the power dissipation in the IC calculated using the above formula, the expected increase in operating junction temperature, ΔT_J, of the IC can be estimated using Figure 14-1. This result should be added to the worst-case ambient temperature when operating, $T_{A(max)}$. Based on the calculation, there is no problem unless $T_{A(max)} + \Delta T_J > 150$ °C. However, final confirmation should be made by measuring the IC temperature during operation and then verifying power dissipation and junction temperature in the corresponding graph in Figure 14-1.

Figure 14-1. Temperature Increase



When the IC is used with a heatsink mounted, product package thermal resistance, $\theta_{J\text{-}A}$, is a variable used in calculating $\Delta T_{J\text{-}A}$. The value of $\theta_{J\text{-}A}$ is calculated from the following formula:

$$\theta_{J\text{-}A} \approx \theta_{J\text{-}C} + \theta_{FIN} = (\theta_{J\text{-}A} - \theta_{C\text{-}A}) + \theta_{FIN},$$

where θ_{FIN} is the thermal resistance of the heatsink. Then, $\Delta T_{J\text{-}A}$ can be calculated with using the value of $\theta_{J\text{-}A}$.

The following procedure should be used to measure product temperature and to estimate junction temperature in actual operation.

First, measure a temperature rise in the center of backside of mold resin used for the device ($\Delta T_{C\text{-}A}$).

Second, estimate power dissipation (P) and junction temperature (T_J) from the temperature rise with reference to Figure 14-1, the Temperature Increase graph. At this point, the device temperature rise ($\Delta T_{C\text{-}A}$) and the junction temperature rise (T_J) become almost equivalent in the following formula:

$$\Delta T_J \approx \Delta T_{C\text{-}A} + P \times \theta_{J\text{-}C}\,.$$

CAUTION

The STA7120MC series is designed as a multichip, consisting of four separate power elements (MOSFETs), one control IC (MIC), and two sense resistors. Moreover, because the control IC cannot accurately detect the temperature of the built-in power elements, which are the primary sources of heat, the STA7120MC series does not provide a protection function against overheating. For thermal protection, users must conduct sufficient thermal evaluations to ensure that the junction temperature of the IC does not exceed a guaranteed level of 150 °C.

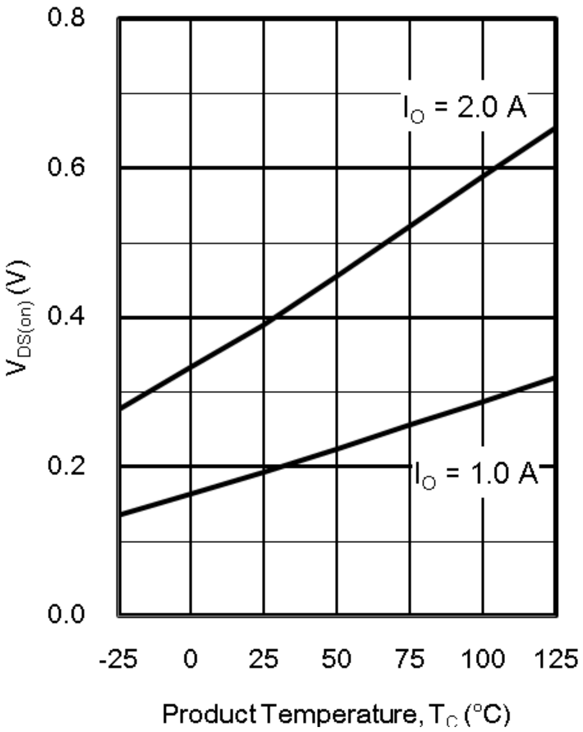
This thermal design information is provided for preliminary design estimations only. Before operating the IC in an application, users must experimentally determine its actual thermal performance (the case temperature of Pin 10). The maximum recommended case temperatures (Pin 10) for the IC are:

- With no external heatsink connection: 85 °C
- With external heatsink connection: 75 °C

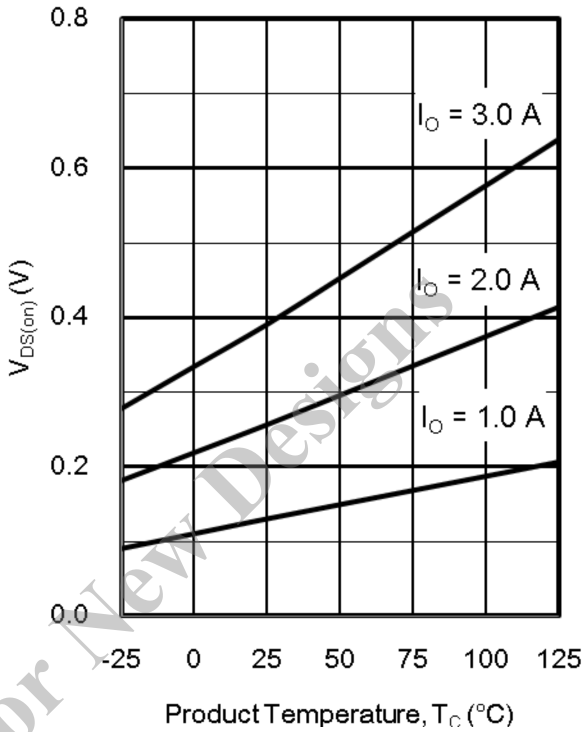
15. Characteristics Data

(1) Output MOSFET On-Voltage, $V_{DS(on)}$

STA7122MC

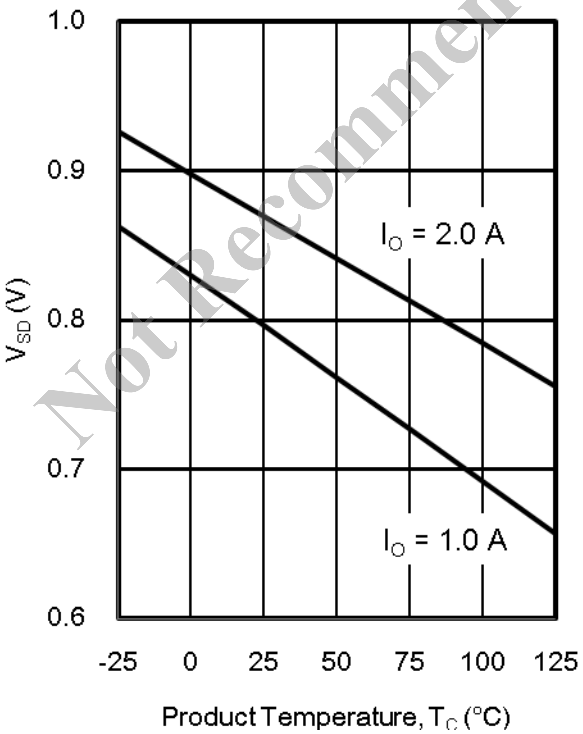


STA7123MC

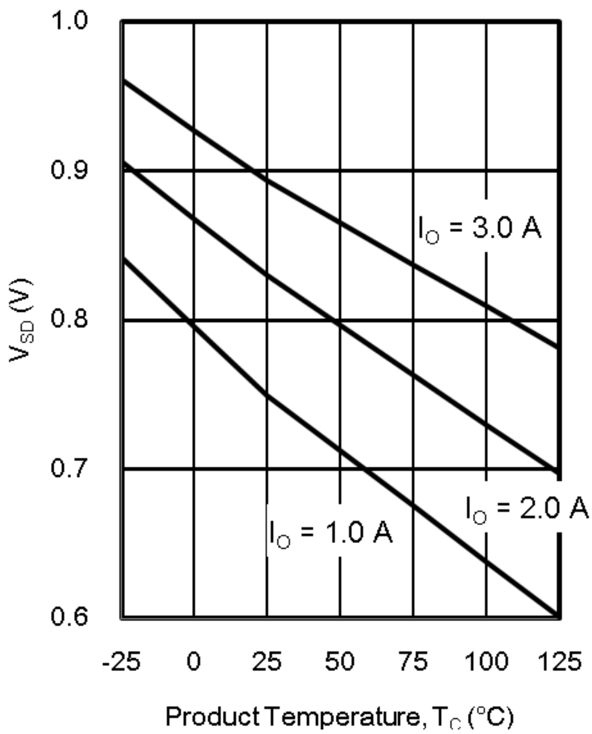


(2) Output MOSFET Body Diodes Forward Voltage, V_F

STA7122MC



STA7123MC



Important Notes

- All data, illustrations, graphs, tables and any other information included in this document as to Sanken's products listed herein (the "Sanken Products") are current as of the date this document is issued. All contents in this document are subject to any change without notice due to improvement of the Sanken Products, etc. Please make sure to confirm with a Sanken sales representative that the contents set forth in this document reflect the latest revisions before use.
- The Sanken Products are intended for use as components of general purpose electronic equipment or apparatus (such as home appliances, office equipment, telecommunication equipment, measuring equipment, etc.). Prior to use of the Sanken Products, please put your signature, or affix your name and seal, on the specification documents of the Sanken Products and return them to Sanken. When considering use of the Sanken Products for any applications that require higher reliability (such as transportation equipment and its control systems, traffic signal control systems or equipment, disaster/crime alarm systems, various safety devices, etc.), you must contact a Sanken sales representative to discuss the suitability of such use and put your signature, or affix your name and seal, on the specification documents of the Sanken Products and return them to Sanken, prior to the use of the Sanken Products. The Sanken Products are not intended for use in any applications that require extremely high reliability such as: aerospace equipment; nuclear power control systems; and medical equipment or systems, whose failure or malfunction may result in death or serious injury to people, i.e., medical devices in Class III or a higher class as defined by relevant laws of Japan (collectively, the "Specific Applications"). Sanken assumes no liability or responsibility whatsoever for any and all damages and losses that may be suffered by you, users or any third party, resulting from the use of the Sanken Products in the Specific Applications or in manner not in compliance with the instructions set forth herein.
- In the event of using the Sanken Products by either (i) combining other products or materials therewith or (ii) physically, chemically or otherwise processing or treating the same, you must duly consider all possible risks that may result from all such uses in advance and proceed therewith at your own responsibility.
- Although Sanken is making efforts to enhance the quality and reliability of its products, it is impossible to completely avoid the occurrence of any failure or defect in semiconductor products at a certain rate. You must take, at your own responsibility, preventative measures including using a sufficient safety design and confirming safety of any equipment or systems in/for which the Sanken Products are used, upon due consideration of a failure occurrence rate or derating, etc., in order not to cause any human injury or death, fire accident or social harm which may result from any failure or malfunction of the Sanken Products. Please refer to the relevant specification documents and Sanken's official website in relation to derating.
- No anti-radioactive ray design has been adopted for the Sanken Products.
- No contents in this document can be transcribed or copied without Sanken's prior written consent.
- The circuit constant, operation examples, circuit examples, pattern layout examples, design examples, recommended examples, all information and evaluation results based thereon, etc., described in this document are presented for the sole purpose of reference of use of the Sanken Products and Sanken assumes no responsibility whatsoever for any and all damages and losses that may be suffered by you, users or any third party, or any possible infringement of any and all property rights including intellectual property rights and any other rights of you, users or any third party, resulting from the foregoing.
- All technical information described in this document (the "Technical Information") is presented for the sole purpose of reference of use of the Sanken Products and no license, express, implied or otherwise, is granted hereby under any intellectual property rights or any other rights of Sanken.
- Unless otherwise agreed in writing between Sanken and you, Sanken makes no warranty of any kind, whether express or implied, including, without limitation, any warranty (i) as to the quality or performance of the Sanken Products (such as implied warranty of merchantability, or implied warranty of fitness for a particular purpose or special environment), (ii) that any Sanken Product is delivered free of claims of third parties by way of infringement or the like, (iii) that may arise from course of performance, course of dealing or usage of trade, and (iv) as to any information contained in this document (including its accuracy, usefulness, or reliability).
- In the event of using the Sanken Products, you must use the same after carefully examining all applicable environmental laws and regulations that regulate the inclusion or use of any particular controlled substances, including, but not limited to, the EU RoHS Directive, so as to be in strict compliance with such applicable laws and regulations.
- You must not use the Sanken Products or the Technical Information for the purpose of any military applications or use, including but not limited to the development of weapons of mass destruction. In the event of exporting the Sanken Products or the Technical Information, or providing them for non-residents, you must comply with all applicable export control laws and regulations in each country including the U.S. Export Administration Regulations (EAR) and the Foreign Exchange and Foreign Trade Act of Japan, and follow the procedures required by such applicable laws and regulations.

- Sanken assumes no responsibility for any troubles, which may occur during the transportation of the Sanken Products including the falling thereof, out of Sanken's distribution network.
- Although Sanken has prepared this document with its due care to pursue the accuracy thereof, Sanken does not warrant that it is error free and Sanken assumes no liability whatsoever for any and all damages and losses which may be suffered by you resulting from any possible errors or omissions in connection with the contents included herein.
- Please refer to the relevant specification documents in relation to particular precautions when using the Sanken Products, and refer to our official website in relation to general instructions and directions for using the Sanken Products.

DSGN-CEZ-16001