

MICROSTEP DRIVER FOR DRIVING CAMERA LENS

DESCRIPTION

The μ PD168111 is a monolithic 2-channel H bridge driver that consists of a CMOS controller and a MOS output stage. It can reduce the current consumption and the voltage loss at the output stage compared with a conventional driver using bipolar transistors, thanks to employment of a MOS process. This product employs a P-channel MOSFET on the high side of the output stage, eliminating a charge pump. As a result, the circuit current consumption can be substantially reduced during operation.

This product is ideal for driving the motor of a digital still camera as it can switch over between two-phase excitation driving and microstep driving, using a stepper motor.

FEATURES

- Two H bridge circuits employing power MOSFET
- Current feedback 64-step microstep driving and two-phase excitation driving selectable
- Motor control by serial data (6 words of 16-bit configuration)
 - Data is input with the LSB first.
 - Pulse cycle, number of pulses, and output current value can be set.
- Input logic frequency: 6 MHz MAX.
- 3 V power supply
 - Minimum operating power supply voltage $V_{DD} = 2.7$ V
- Undervoltage lockout circuit
 - Shuts down internal circuitry at $V_{DD} = 1.7$ V TYP.
- 24-pin TSSOP

ORDERING INFORMATION

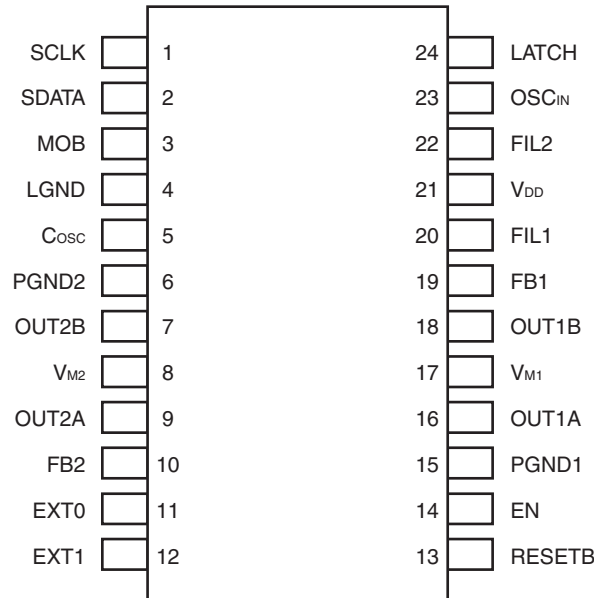
Part Number	Package
μ PD168111MA-6A5	24-pin plastic TSSOP (5.72 mm (225))

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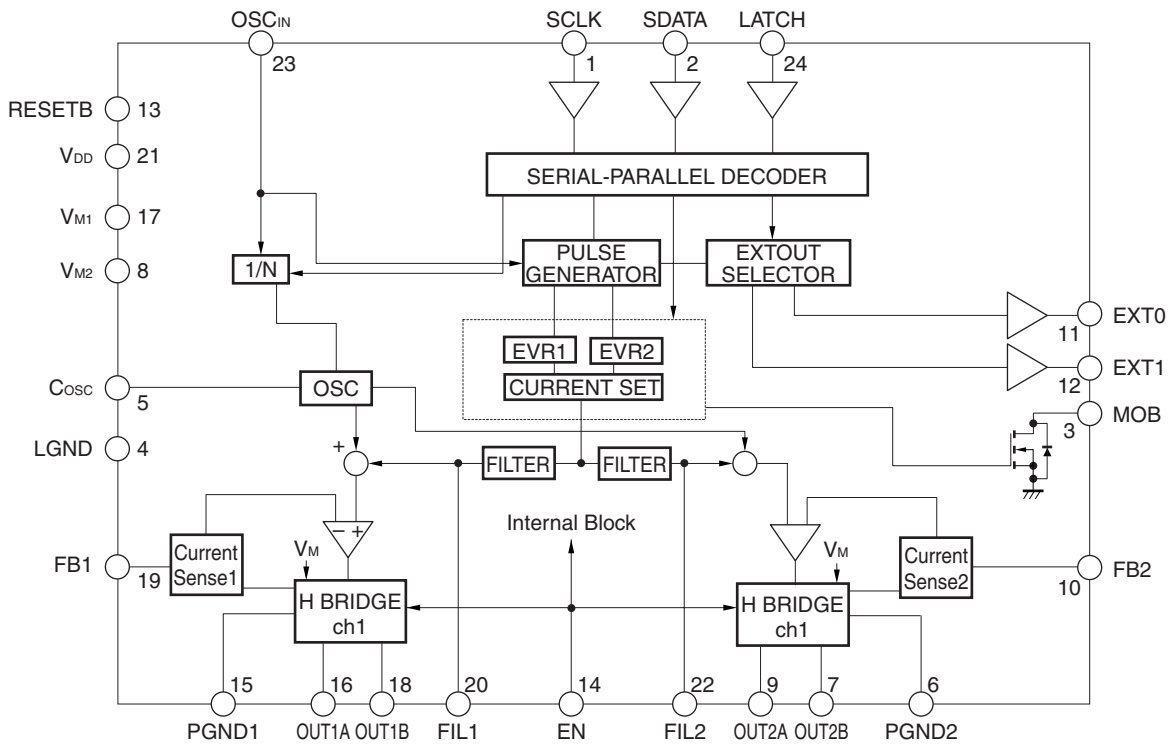
PIN FUNCTIONS

Package: 24-pin TSSOP

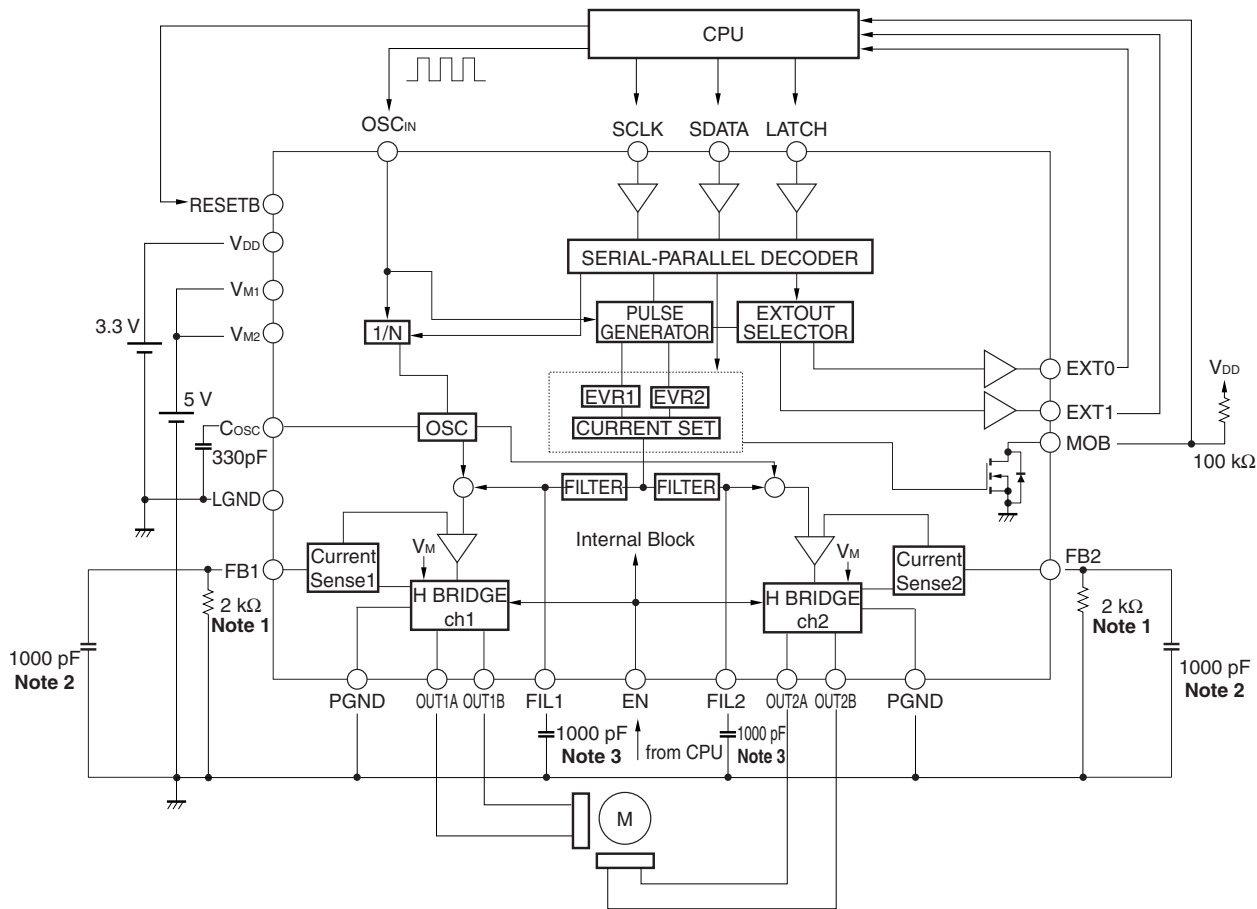


Pin No.	Pin Name	Pin Function
1	SCLK	Serial clock input pin
2	SDATA	Serial data input pin
3	MOB	Phase detection output pin
4	LGND	Control block GND pin
5	Cosc	Pin connecting capacitor for output oscillator
6	PGND2	Output block GND pin
7	OUT2B	Channel 2 output B
8	VM2	Motor power pin
9	OUT2A	Channel 2 output A
10	FB2	Channel 2 current detection resistor connecting pin
11	EXT0	Logic block monitor output pin 1
12	EXT1	Logic block monitor output pin 2
13	RESETB	Reset input pin
14	EN	Output enable pin
15	PGND1	Output block GND pin
16	OUT1A	Channel 1 output A
17	VM1	Motor power pin
18	OUT1B	Channel 1 output B
19	FB1	Channel 1 current detection resistor connecting pin
20	FIL1	Channel 1 filter capacitor connecting pin
21	VDD	Control block power pin
22	FIL2	Channel 2 filter capacitor connecting pin
23	OSCIN	Original oscillation clock input pin
24	LATCH	Serial data latch input pin

BLOCK DIAGRAM



EXAMPLE OF STANDARD CONNECTION

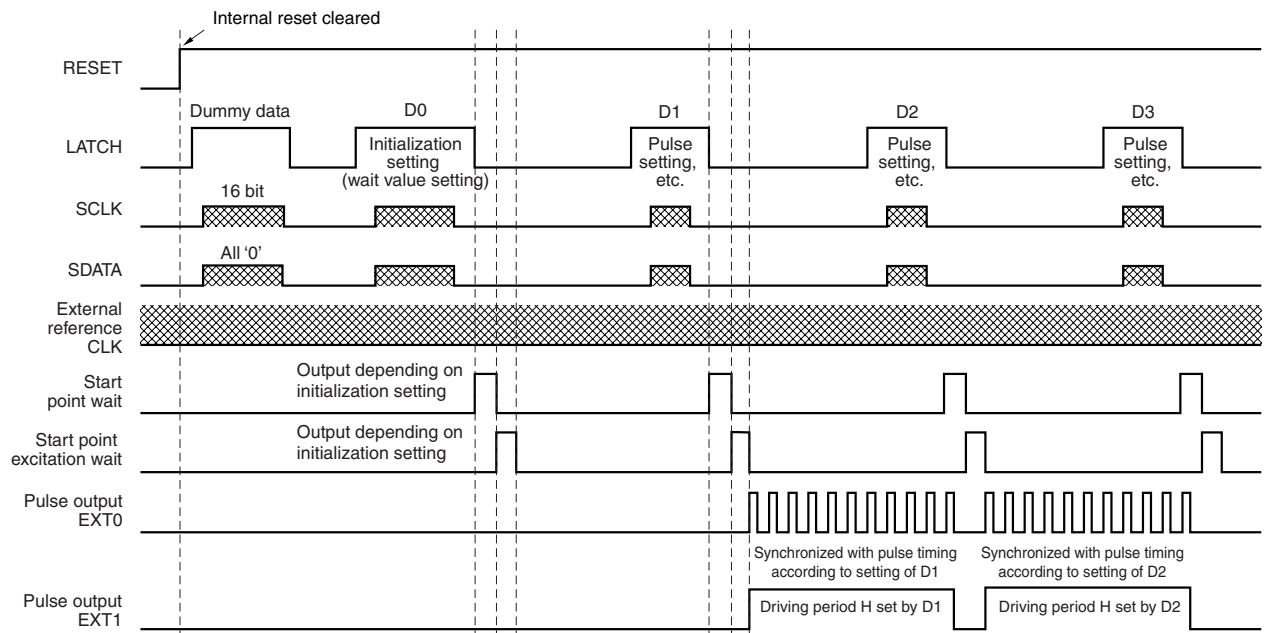


This circuit diagram is shown as an example and is not intended for mass production.
Connect a bypass capacitor between the power supply and GND pins for stabilization.

- Notes 1.** Adjust the value of the external resistor according to the output current. The relationship between the output current and external resistance is as follows.
Output current $I_{OUT} \cong EVR_{MAX} \div FB \times 1000$
- 2.** It is recommended to connect a capacitor to the FB pin for stabilization to suppress the electronic noise superimposed on the pin.
 - 3.** The capacitor connected to the FIL pin is used to suppress the voltage noise for stabilization. Adjust the capacitance of the capacitor to effectively suppress the noise.

COMMAND INPUT TIMING CHART

This IC controls the motor by transmitting serial control commands.
Here is an example of the commands.

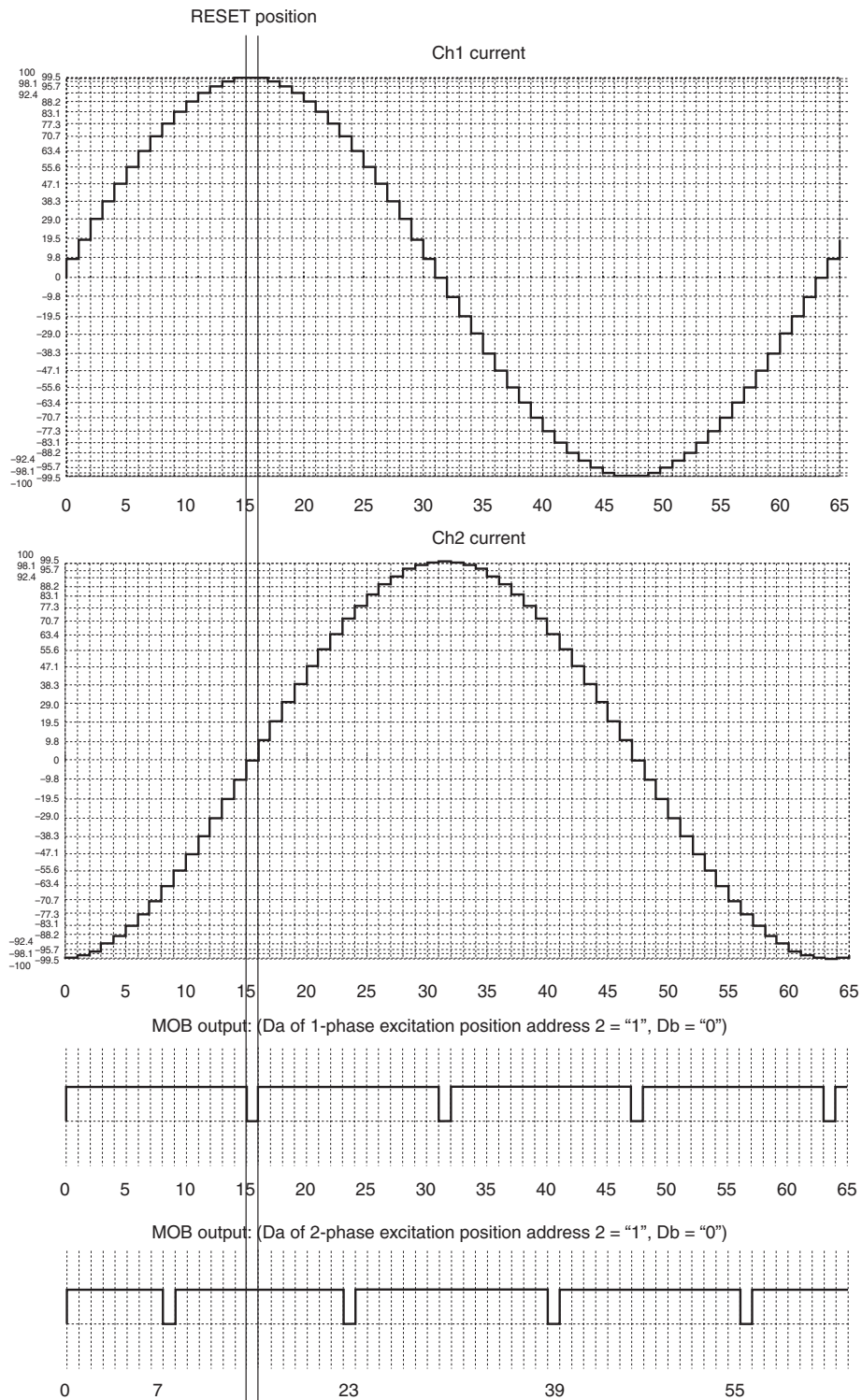


This IC can change all commands by issuing the LATCH signal once. Therefore, “initialization setting” does not have to be explicitly performed as shown in the above example.

Immediately after the reset has been cleared, dummy data must be transmitted according to the timing of the transmit data. For details, refer to SERIAL INTERFACE SPECIFICATIONS.

OUTPUT TIMING CHART

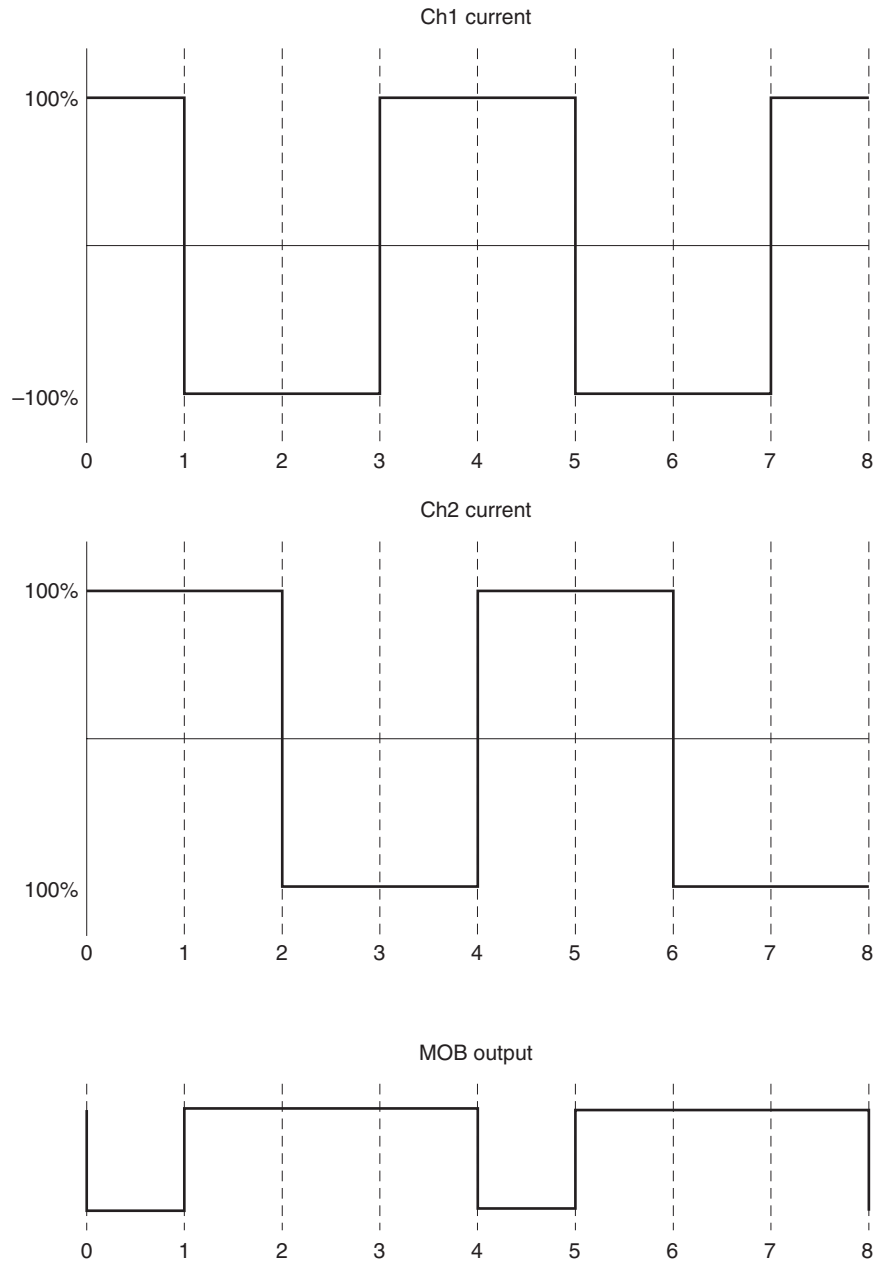
- Microstep output mode



The horizontal axis indicates the number of steps. The pulse advances in synchronization with the rising edge of CLK. The current flows into ch1 and ch2 in the positive direction when it flows from OUT1A to OUT1B, and in the negative direction when it flows from OUT1B to OUT1A (the values shown above are ideal values and do not indicate the actual values).

OUTPUT TIMING CHART

- 2-phase excitation output mode



The horizontal axis indicates the number of steps. This figure shows an example in the CW mode. The current flows into ch1 and ch2 in the positive direction when it flows from OUT1A to OUT1B, and in the negative direction when it flows from OUT1B to OUT1A.

Relationship Between Revolution Angle, Phase Current, and Vector Amount (64 microsteps)

Step	Revolution Angle	Phase A – Phase Current			Phase B – Phase Current			Vector Amount
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	TYP.
θ0	0	–	0	3.8	–	100	–	100
θ1	5.625	2.5	9.8	17.0	94.5	100	104.5	100.48
θ2	11.250	12.4	19.5	26.5	93.2	98.1	103.0	100
θ3	16.875	22.1	29.0	36.1	90.7	95.7	100.7	100.02
θ4	22.500	31.3	38.3	45.3	87.4	92.4	97.4	100.02
θ5	28.125	40.1	47.1	54.1	83.2	88.2	93.2	99.99
θ6	33.750	48.6	55.6	62.6	78.1	83.1	88.1	99.98
θ7	39.375	58.4	63.4	68.4	72.3	77.3	82.3	99.97
θ8	45	65.7	70.7	75.7	65.7	70.7	75.7	99.98
θ9	50.625	72.3	77.3	82.3	58.4	63.4	68.4	99.97
θ10	56.250	78.1	83.1	88.1	48.6	55.6	62.6	99.98
θ11	61.875	83.2	88.2	93.4	40.1	47.1	54.1	99.99
θ12	67.500	87.4	92.4	97.4	31.3	38.3	45.3	100.02
θ13	73.125	90.7	95.7	100.7	22.1	29.0	36.1	100.02
θ14	78.750	93.2	98.1	103.0	12.4	19.5	26.5	100
θ15	84.375	94.5	100	104.5	2.5	9.8	17.0	100.48
θ16	90	–	100	–	–	0	3.8	100

The above values are ideal values and do not indicate the actual values.

FUNCTION DESCRIPTION

2-phase excitation driving mode

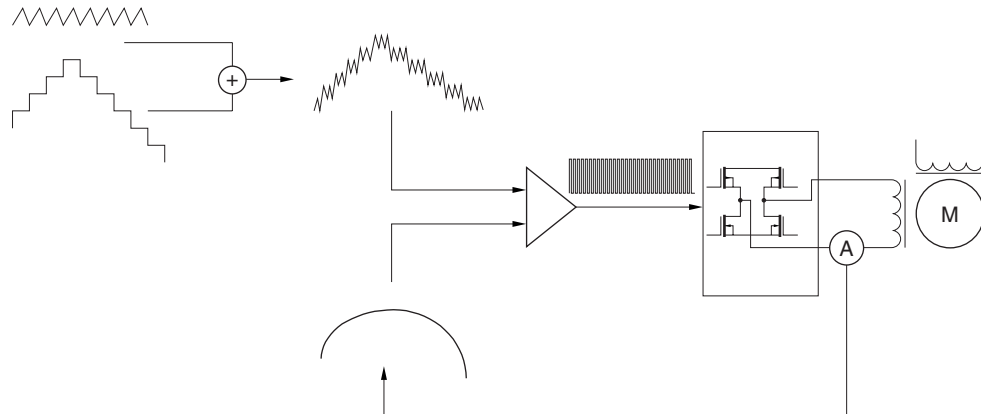
By allowing a current of ±100% to flow into output ch1 and ch2 at the same time, a motor can be driven with the larger torque. The motor can also be driven on a constant current to reduce the power consumption. The two-phase driving mode and microstep driving mode are selected by a command.

Microstep driving of stepper motor

To position a stepper motor with high accuracy, the μPD168111 has a function to hold constant the current flowing through the H bridge by a vector value and to stop one cycle in 64 steps. A 16-bit serial interface is used for controlling, so that the motor can be directly controlled by the CPU while mitigating the load of the CPU. To realize the microstep driving mode, the driver internally realizes the following functions.

- Detecting the current flowing into each channel as a voltage value by a sense resistor
- Synthesizing the dummy sine wave of the half-wave generated by the internal D/A and PWM oscillation wave for chopping operation
- The driver stage performs PWM driving based on the result of comparing the detected voltage value and synthesized waves.

The internal dummy sine wave is of 64 steps per cycle, so that the stepper motor can be driven in 64 steps. The microstep driving mode and two-phase excitation driving mode are switched by a command.



Concept of microstep driving operation

Serial control

Information necessary for microstep driving is processed by serial data from the CPU. The commands that specify the following parameters can be set.

- Start point wait and start point excitation wait
- Chopping frequency
- Motor current, motor revolution direction, and output excitation mode
- Acceleration/deceleration circuit parameters
- Pulse cycle, number of pulses, and pulse number multiplication factor

An address is allocated to each command. Each data can be updated by inputting 16-bit data. For the configuration of the data and details of the commands, refer to SERIAL INTERFACE SPECIFICATIONS.

A command is specified by specifying an address. Only the data that must be updated can be input. The previous data of the address for which no data is input is retained.

Reset function (RESET pin)

To initialize the internal registers of this IC, be sure to perform a reset operation after power application.

The registers are initialized and all the internal data are cleared to "0" when the RESETB pin is "L".

The internal circuitry is stopped. The current consumption is reduced to 1 μ A MAX. by stopping the external CLK input. The output goes into a Hi-Z state.

When the RESETB pin is "H", excitation can be started from the initial excitation position with the current of ch1 at +100% and the current of ch 2 at 0% (one-phase excitation position).

To perform two-phase excitation driving, the initial excitation position is in the status where the currents of ch1 and ch2 are +100% after the command has been set. After the RESETB pin has gone "H", the MOB pin outputs "L" until the pulse is output.

Output enable function (EN pin)

This IC generates the pulse output timing by setting a start point wait and start point excitation wait, and outputs pulses.

The output enable function (EN pin) allows an external source to forcibly stop the pulse output.

When the EN pin goes "L", the output is forcibly made to go into a Hi-Z state. Then the device enters the standby mode described below.

Be sure to input a command while the EN pin is "H".

If pulse output continues when the EN pin is "L", pulse output is started from the excitation status when the EN pin goes "H" once and then "L" again.

Standby function

The μ PD168111 can be set in the standby mode by making the EN pin "L".

In this mode, as many internal circuits as possible are stopped, so that the self current consumption can be reduced.

By stopping input of the external CLK, the current consumption can be reduced to 30 μ A MAX. It is 300 μ A MAX. when the external CLK is input.

In the standby mode, the contents of the internal registers and motor excitation position information are retained. After the standby mode is released, therefore, driving the motor can be started without having to perform an initialization operation.

To release the standby mode, input the external CLK and make the EN pin "H".

The device is set in and released from the standby mode as follows.

(1) Setting device in standby mode

External CLK off → EN pin “L”

When the external CLK is turned off, the internal logic circuit is stopped. Because the output stage operates, however, excitation continues. If the EN pin is made “L”, excitation is turned off and the device is set in the standby mode.

EN pin “L” → external CLK off

When the EN pin goes “L”, excitation is turned off and the device enters the standby mode (300 μ A MAX.). When the external CLK is later turned off, the current consumption decreases to 30 μ A MAX.

(2) Releasing device from standby mode

External CLK on → EN pin “H”

When the external CLK is input, the standby mode continues and the current consumption increases to 300 μ A. When the EN pin goes “H”, excitation is enabled.

EN pin “H” → external CLK on

When the EN pin goes “H”, excitation is enabled. Because the external CLK is turned off, however, the pulse is not output but excitation continues. When the external CLK is input later, the pulse can be output.

Acceleration/deceleration circuit

This IC can control the acceleration/deceleration output pattern of a stepper motor by commands.

By performing an acceleration/deceleration operation, step out of the stepper motor due to torque insufficiency can be prevented, and stable open loop control can be performed.

For the details of the acceleration/deceleration operation parameters, refer to SERIAL INTERFACE SPECIFICATIONS.

MOB output

The MOB pin outputs a signal as specified by a command. By monitoring the MOB output, the excitation position of the stepper motor can be checked.

In microstep output mode, the MOB pin outputs “L” when

In microstep output mode, the MOB pin outputs “L” when
“the current of ch 1 or ch 2 is $\pm 100\%$ ” (four pulses are output per cycle), or
“the current of ch 1 is $+100\%$ ” (one pulse is output per period)
as the one-phase excitation position, or
“the current of ch 1 or ch 2 is $\pm 70\%$ ” (four pulses are output per cycle), or
“the current of ch 1 is $+70\%$ ” (one pulse is output per cycle)
as the two-phase excitation position.

In the two-phase excitation output mode, the MOB pin outputs “L” when “the currents of ch 1 and ch 2 are positive and the same value”.

The MOB output indicates the stop position information of the stop mode to be described below.

The MOB output goes into a Hi-Z state when the RESETB pin is “L” and EN pin is “L” (standby mode).

When D7 of address 2 = 0 (output disabled), the MOB pin outputs a signal in accordance with the stop position.

Stop mode

When the stop mode is set by a command, pulses are automatically output until the MOB pin goes “L”. The device operates regardless of the set number of pulses and it no longer outputs pulses in the stop mode when the MOB pin goes “L”. The output retains the excitation status.

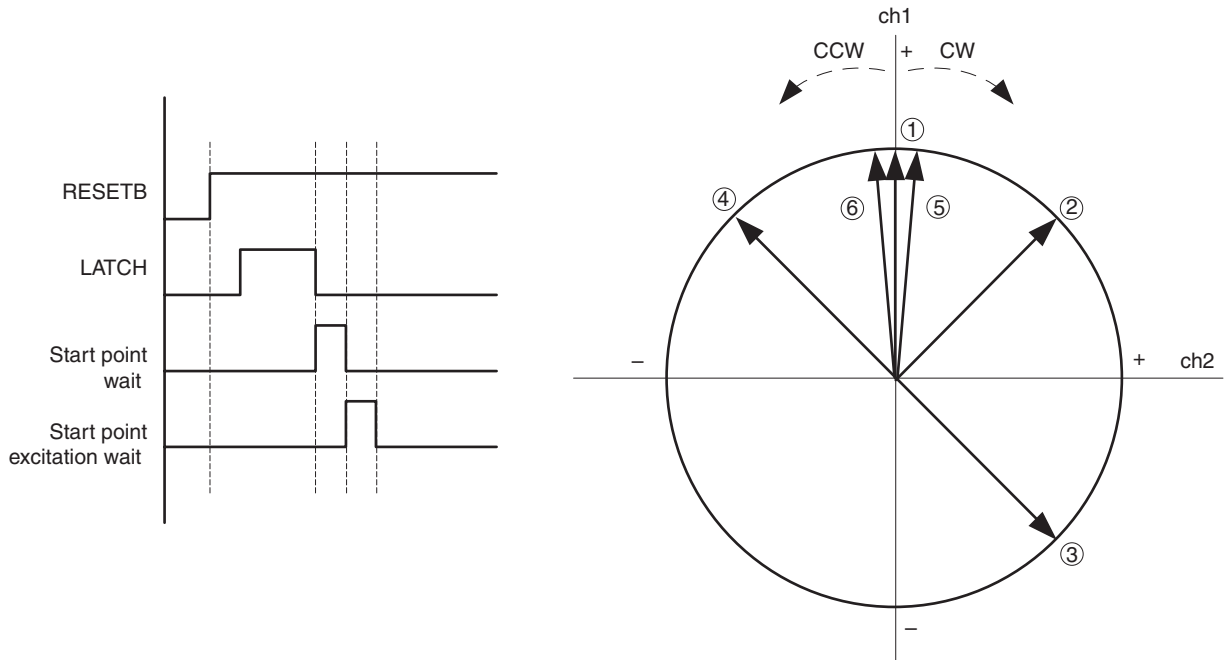
To advance the pulse again, release the stop mode and restore the normal mode by a command.

After the stop mode has been set, note that the stop position of the motor does not match the set number of pulses.

Excitation position immediately after reset

The initial excitation position immediately after reset is where the current of ch1 is +100% and the current of ch2 is 0%. The following table summarizes the operations from the initial position at each command setting.

Operation Mode		RESETB = "L" → "H" to Start Point Wait End	Start Point Wait End to Start Point Excitation Wait End	Excitation Stop Position with 0 Pulse Set	Excitation Stop Position with 1 Pulse Set
Microstep	CW mode	Output Hi-Z state	①	①	⑤
	CCW mode				⑥
2-phase excitation	CW mode		②	②	③
	CCW mode				④



Undervoltage lockout circuit (ULVO)

This circuit forcibly stops the operation of this IC to prevent malfunction of the circuitry when the V_{DD} voltage of the IC abruptly drops. This function may not operate when the V_{DD} voltage abruptly drops in the order of μs.

Power application sequence

This IC has two power supply pins: logic power supply (V_{DD}) and output power supply (V_M).
 To turn on power, turn on V_M with V_{DD} turned on.
 To turn off power, turn off V_M with V_{DD} turned on, and then turn off V_{DD}.
 (V_{DD} and V_M can also be turned on/off at the same time.)

SERIAL INTERFACE SPECIFICATIONS

The internal data is determined by inputting 16-bit serial data SDATA synchronized with serial clock SCLK and making LATCH “L”. The serial data is input from the LSB (D0) to the MSB (Df).

SDATA: Data is loaded to the internal circuitry in synchronization with the rising of SCLK when LATCH = “H”.

LATCH: Inputting SDATA is prohibited when LATCH is “L”. Inputting is enabled when it is “H”. The internal data is determined at the negative transition of LATCH (from “H” to “L”).

Because this IC generates the internal timing via the external CLK (OSCIN) its set values depend upon the frequency of OSCIN.

An example where OSCIN = 5 MHz is given below. To input a frequency other than 5 MHz to OSCIN, use the following expression. Items related to the serial register are marked ☆.

Time: Set value = Setting example x (5/OSCIN [MHz])

Frequency: Set value = Setting example x (OSCIN [MHz]/5)

Data configuration

16-bit data consists of 3 address bits and 13 data bits.

Three bits (Df, De, and Dd) are used to set an address. Five types of addresses, 0 to 5, can be used.

Thirteen bits (D0 to Dc) are used to set data.

bit	Df	De	Dd	Dc	Db	Da	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Data	Address			Data												

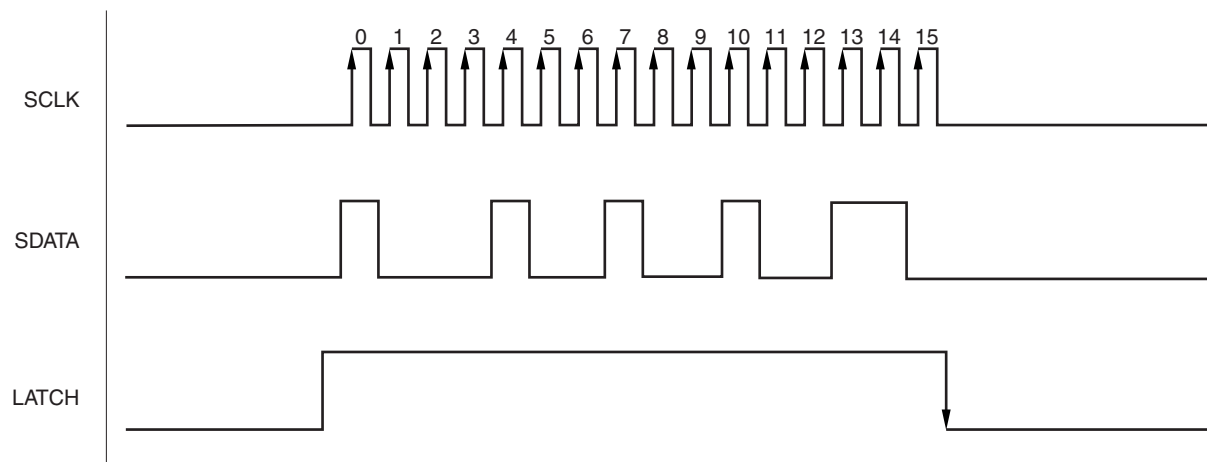
Example

Address 1: (Df, De, Dd) = (0, 0, 1)

Address 3: (Df, De, Dd) = (0, 1, 1)

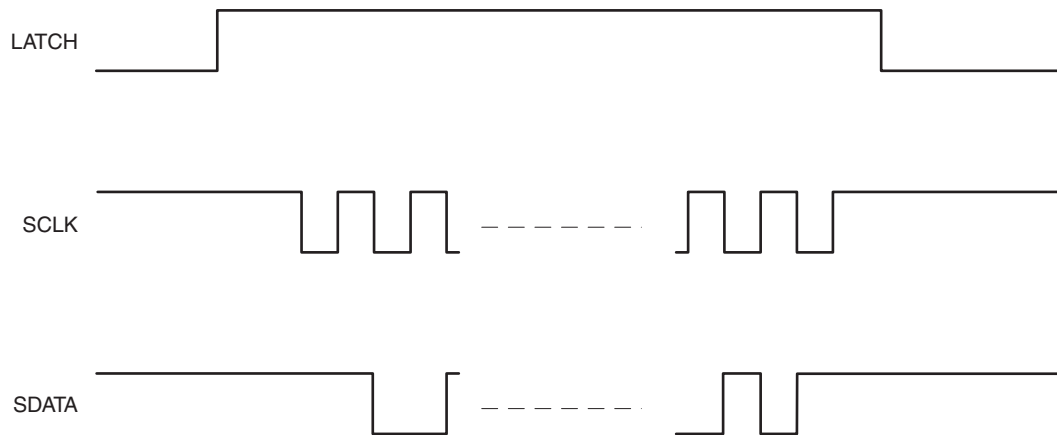
For how to set data, refer to Serial Register List and Serial Register Details.

The following chart shows an example of the serial command waveform.



NOTES ON TRANSMITTING DATA

- Basically, the input data is loaded when SCLK changes from “L” to “H” after LATCH has changed from “L” to “H”. Data is transmitted in 16-bit units, and is determined when LATCH changes from “H” to “L”. Invalid data of less than 16 bits is discarded.
- Data of different addresses can be input successively while LATCH = “H”.
- The access time can be shortened by updating only the necessary data after initialization has been performed. If an address is not input, the previous value of that address is retained as the data.
- If the same address is input more than once while LATCH is “H”, the data that is input last is valid.
- If invalid data and correct data are input while LATCH is “H”, only the correct data is valid.
- If only LATCH is input, the data is not updated, and the driver holds the current status.
- Data that is transmitted during the start point wait and start point excitation wait periods is ignored.
- Data that is transmitted when the RESETB pin is “L” and the EN pin is “L” is ignored.
- **As shown below, dummy data must be transmitted immediately after reset if SCLK = “H” while LATCH = “L”.**



The dummy data is defined to be “data of all 0 at address 0”. Transmit the dummy data before transmitting the correct data.

This operation is necessary only immediately after reset. Once the dummy data has been transmitted, it does not have to be transmitted again until the next reset operation is performed or the power is turned off and then back on again.

If SCLK = “L” while LATCH = “L”, the dummy data does not have to be transmitted immediately after reset. However, there is no problem even if the dummy data is transmitted.

Address List

Address	Item to Be Set
Address 0	Start point wait, start point excitation wait
Address 1	Chopping frequency
Address 2	Motor drive initialization, motor current
Address 3	Acceleration/deceleration parameter, pulse number multiplication factor
Address 4	Pulse cycle
Address 5	Number of pulses

Table. Serial Register List (1/2)

Bit	Address 0 (000)	
f	Address	0
e		0
d		0
c	(Reserve)	
b	Start point excitation wait 5	
a	Start point excitation wait 4	
9	Start point excitation wait 3	
8	Start point excitation wait 2	
7	Start point excitation wait 1	
6	Start point excitation wait 0	
5	Start point wait 5	
4	Start point wait 4	
3	Start point wait 3	
2	Start point wait 2	
1	Start point wait 1	
0	Start point wait 0	

Bit	Address 1 (001)	
f	Address	0
e		0
d		1
c	(Reserve)	
b	(Reserve)	
a	(Reserve)	
9	(Reserve)	
8	(Reserve)	
7	(Reserve)	
6	Pulse output function selection during EXT output	
5	Chopping frequency 5	
4	Chopping frequency 4	
3	Chopping frequency 3	
2	Chopping frequency 2	
1	Chopping frequency 1	
0	Chopping frequency 0	

Table. Serial Register List (2/2)

Bit	Address 2 (010)	
f	Address	0
e		1
d		0
c	(Reserve)	
b	MOB output position setting (for microstep driving only)	
a	MOB output selection setting (for microstep driving only)	
9	2-phase excitation current selection	
8	2-phase excitation/microstep driving selection	
7	Output enable setting	
6	Stop mode setting	
5	Revolution direction setting (CW/CCW)	
4	Motor current setting during normal operation 4	
3	Motor current setting during normal operation 3	
2	Motor current setting during normal operation 2	
1	Motor current setting during normal operation 1	
0	Motor current setting during normal operation 0	

Bit	Address 3 (011)	
f	Address	0
e		1
d		1
c	(Reserve)	
b	(Reserve)	
a	Acceleration enabled/disabled	
9	Deceleration enabled/disabled	
8	For acceleration/deceleration control	
7	For acceleration/deceleration control	
6	For acceleration/deceleration control	
5	For acceleration/deceleration control	
4	For acceleration/deceleration control	
3	For acceleration/deceleration control	
2	For acceleration/deceleration control	
1	Motor pulse multiplication factor setting 1	
0	Motor pulse multiplication factor setting 0	

Bit	Address 4 (010)	
f	Address	1
e		0
d		0
c	Motor pulse cycle setting 12	
b	Motor pulse cycle setting 11	
a	Motor pulse cycle setting 10	
9	Motor pulse cycle setting 9	
8	Motor pulse cycle setting 8	
7	Motor pulse cycle setting 7	
6	Motor pulse cycle setting 6	
5	Motor pulse cycle setting 5	
4	Motor pulse cycle setting 4	
3	Motor pulse cycle setting 3	
2	Motor pulse cycle setting 2	
1	Motor pulse cycle setting 1	
0	Motor pulse cycle setting 0	

Bit	Address 5 (011)	
f	Address	1
e		0
d		1
c	Motor pulse setting number 12	
b	Motor pulse setting number 11	
a	Motor pulse setting number 10	
9	Motor pulse setting number 9	
8	Motor pulse setting number 8	
7	Motor pulse setting number 7	
6	Motor pulse setting number 6	
5	Motor pulse setting number 5	
4	Motor pulse setting number 4	
3	Motor pulse setting number 3	
2	Motor pulse setting number 2	
1	Motor pulse setting number 1	
0	Motor pulse setting number 0	

SERIAL REGISTER DETAILS

Address 0

This register is used to set a start point wait and start point excitation wait. The data must not both be set to “0”.

	MSB				LSB				MSB				LSB			
bit	Df	De	Dd	Dc	Db	Da	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Data	0	0	0	–	Start point excitation wait						Start point wait					

☆ • Start point wait

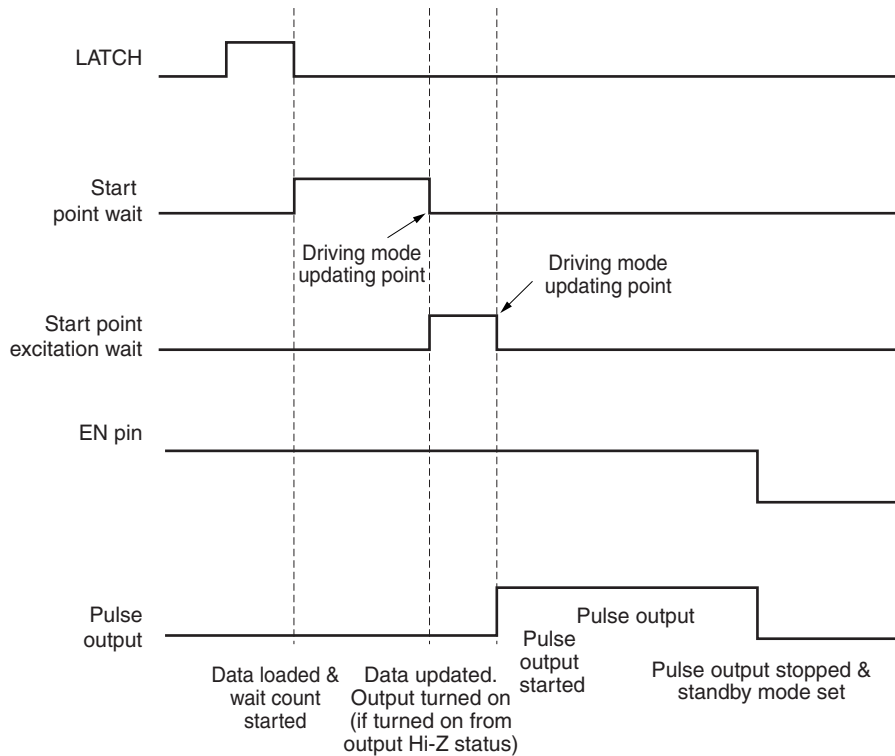
Counting is started from the falling of the LATCH signal, and the motor is excited when the count value has reached 0.

Data D0 to D5 can be used to set a count value of 32 to 2016 μs at a resolution of 32 μs.

☆ • Start point excitation wait

Counting is started after counting of the start point wait has been completed, and the output pulse is generated when the count value has reached 0.

Data D6 to Db can be used to set a count value of 32 to 2016 μs at a resolution of 32 μs.



Pulse output based on the previous data continues even during the start point wait and start point excitation wait periods. The updated data is reflected and the pulse is output after completion of the start point excitation wait.

Example of setting start point wait and start point excitation wait

D5 ... D0 and Db ... D6	Set Value (μ s)
000000	Prohibited
000001	32
000010	64
:	:
111101	1952
111110	1984
111111	2016

Caution “000000” cannot be set but the default value immediately after reset is “000000”. This default value is used only for dummy data. Be sure to set a value other than “000000”.

Address 1

This register is used to set a chopping frequency that is the basis of PWM output. This register is also used to test the internal circuitry of the IC.

bit	Df	De	Dd	Dc	Db	Da	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	
Data	0	0	1	Test function						Note	Chopping frequency						

Note Pulse output function selection during EXT output

☆ • Chopping frequency

A chopping method is employed for the output to drive the motor on a constant current. The chopping frequency that is the basis of the output can be changed with data, so that the PWM output does not interfere with the other signals.

The chopping frequency can be set in a range of 40 to 250 kHz by the data D0 to D5. Refer to the following table for the set value.

D5.....D0	Chopping Frequency (kHz)	D5.....D0	Chopping Frequency (kHz)	D5.....D0	Chopping Frequency (kHz)
000000	0 (no pulse output)	011000	120	101100	225
000001	0 (no pulse output)	011001	125	101101	
:	:	011010	130	101110	
000111	0 (no pulse output)	011011		101111	
001000	40	011100	140	110000	250
001001	45	011101	145	110001	
001010	50	011110		110010	
001011	55	011111	155	110011	
001100	60	100000		110100	
001101	65	100001		165	
001110	70	100010	110110		
001111	75	100011	180	110111	
010000	80	100100		111000	
010001	85	100101		111001	
010010	90	100110	190	111010	
010011	95	100111		111011	
010100	100	101000		111100	
010101	105	101001	210	111101	
010110	110	101010		111110	
010111	115	101011		111111	

- Pulse output function selection during EXT output

D6 is used to select a function to monitor the output of the driving pulse by using the EXT pins.

When D6 = 0, the EXT pins (EXT0 and EXT1) are fixed to “L” (output the necessary level when the test function is enabled). When D6 = 1, EXT0 is in the output pulse synchronization mode and EXT1 is fixed to “H” during output.

The duty factor of EXT0 output is 50% (TYP.), in accordance with the set pulse cycle. To count the number of pulses, count the rising edges of EXT0. Note that EXT0 and EXT1 have the following restrictions.

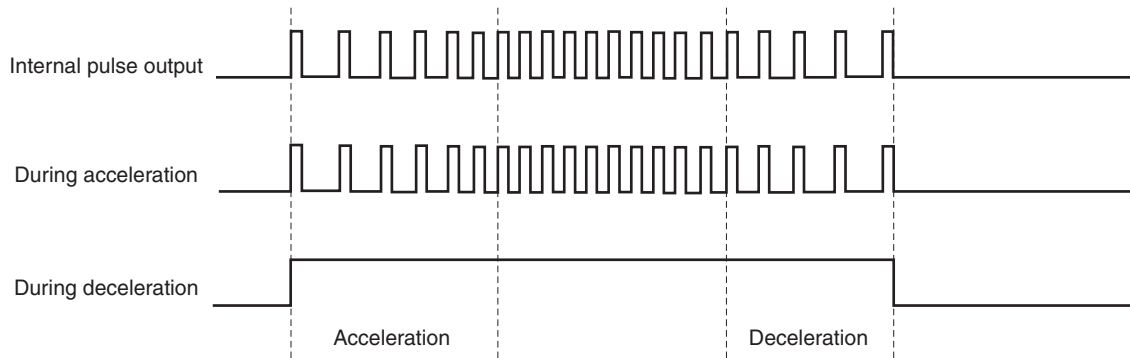
- EXT0 output restrictions

- (1) EXT0 output is not guaranteed when the pulse cycle is 1 μs (Dc to D0: 0000000000001).
- (2) EXT0 outputs a level equivalent to the H level time for normal driving (equivalent to the set pulse cycle) while an acceleration/deceleration operation is being performed.
- (3) If the pulse number multiplication factor is set to a value other than “1”, EXT0 outputs a level for the duration equivalent to the set number of pulses (address 5xm).

- EXT1 output restriction

- (1) EXT1 falls in synchronization with the falling of EXT0 at the same timing.

When the last pulse is output, therefore, it rises earlier than the period of the pulse cycle (50% of pulse cycle or less).



D6	Operation Mode	
	EXT0	EXT1
0	Not output (in accordance with test function)	
1	Output pulse synchronization mode	Output period fixed to “H” mode

Test function

The test function is used to check the internal operations of the IC. Input “0” as data D7 to Dc.

Address 2

This register is used to set the maximum current value for constant-current driving, the revolution direction of the motor (CW/CCW), and the operation mode.

bit	Df	De	Dd	Dc	Db	Da	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Data	0	1	0	(Reserve)	Note 7	Note 6	Note 5	Note 4	Note 3	Note 2	Note 1	Output current				

- Notes**
1. Motor revolution direction
 2. Stop mode
 3. Output enable setting
 4. 2-phase excitation/microstep driving selection
 5. 2-phase excitation current selection
 6. MOB output selection setting (only during microstep driving)
 7. MOB output position setting (only during microstep driving)

• Setting of output current

An internal reference voltage value (EVRMAX) for constant-current driving is set. The internal reference voltage is specified by data D0 to D4 at a resolution of 20 mV. Microstep driving can be performed with the set reference voltage as the maximum value. The ideal peak value of the drive current is $EVRMAX (V)/R_{sense} (\Omega) \times 1000$.

Set value $EVRMAX = (D4 \dots D0) \times 20 \text{ mV}$
 where, $100 \text{ mV} \leq EVRMAX \leq 500 \text{ mV}$

D4.....D0	Reference Voltage (mV)	D4.....D0	Reference Voltage (mV)
00000	100	10110	440
00001	100	10111	460
:	:	11000	480
00101	100	11001	500
00110	120	:	:
00111	140	11110	500
:	:	11111	500

If a voltage less than 100 mV is set, the reference voltage is set to 100 mV. If a voltage higher than 500 mV is set, it is set to 500 mV.

• Motor revolution direction setting

D5 is used to specify the motor revolution direction.

In the CW mode, the current of ch2 is output, 90° degrees in phase behind the current of ch1.

In the CCW mode, the current of ch2 is output, 90° degrees in phase ahead of the current of ch.

D5	Operation Mode
0	CW mode (forward revolution)
1	CCW mode (reverse revolution)

- Stop mode setting

When D6 = "1", the motor advances to the position of MOB output = "L", and the output status is held.

The set number of pulses is held even in the stop mode. Because the motor is driven regardless of the set number of pulses, however, the position information of the motor must be taken into consideration when a command is set to resume driving.

D6	Operation Mode
0	Normal mode
1	Stop mode

Caution Inputting data is prohibited while the stop mode is set (until MOB = "L"). Do not update the data. No pulse is output if the stop mode is set while MOB = "L".

- Output enable setting

When D7 = "1", the motor can be driven. To drive the motor, be sure to set this bit to "1".

When D7 = "0", the output goes into a Hi-Z state, regardless of the other settings.

Unlike the EN pin that is controlled by an external source, the standby status is not set even when D7 = "0".

If D7 is changed from "0" to "1", the internal information is held and therefore the excitation position is recorded.

Therefore, excitation is started from the position where D7 is cleared to "0".

D7	Operation Mode
0	Output Hi-Z
1	Enable mode

- Selecting two-phase excitation/microstep driving

D8 can be used to select two-phase excitation or microstep driving mode. When D8 = 0, the microstep driving mode is selected. When D8 = 1, the two-phase excitation mode (in which the currents of ch 1 and ch 2 are the same) is selected. The microstep driving mode is selected immediately after reset.

When changing the mode from the microstep driving to two-phase excitation, note the following points.

If the number of pulses is set to 0

Depending on the setting of D9 that selects the two-phase excitation current, the stop position may differ when the mode is changed.

If D9 = "0", excitation is held at an output duty of 100% at the two-phase excitation position of the quadrant of the excitation position after the start point excitation wait has been completed.

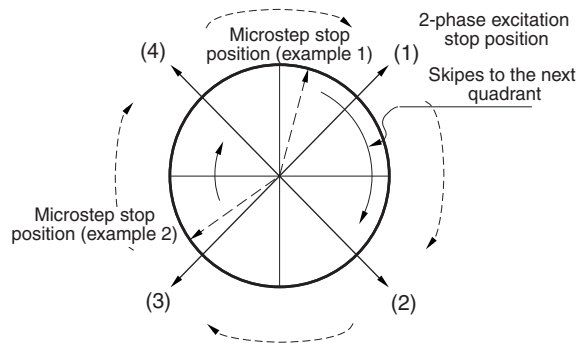
If D9 = "1", the microstep excitation position is held.

If pulse output is started by command setting to set a number of pulses of 1 or more

At the first pulse, the operation skips to the two-phase excitation position of the next quadrant and driving is started.

If the two-phase excitation mode is selected while the motor is stopped at the one-phase excitation position in the microstep driving mode, it is judged that the position is included in the quadrant in the CW direction, and the motor operates.

D8	Operation Mode
0	Microstep driving
1	2-phase excitation



Concept of switching mode from microstep driving to two-phase excitation when pulse is output

- Selecting two-phase excitation current

D9 is used to select whether the motor is driven at an output duty of 100% (maximum torque operation) or under constant-current control when the two-phase excitation mode is selected. When D9 = "0", the motor is driven at an output duty of 100%. It is excited in two phases and driven at the maximum torque regardless of the set current. When D9 = "1", the motor is excited in two phases at the set motor current. The output current value is controlled to be the same value as the driving current at the phase A = phase B position (position of step 08) in the microstep driving mode.

D9	Operation Mode
0	Driving at output duty of 100%
1	Driving with constant-current control

- Selecting MOB output (in microstep driving mode only)

The output function of MOB can be selected by Da. When Da = “0”, MOB is output once per cycle. When Da = “1”, MOB is output four times per cycle. For the output position of MOB, refer to “MOB output position” (set by Db) below.

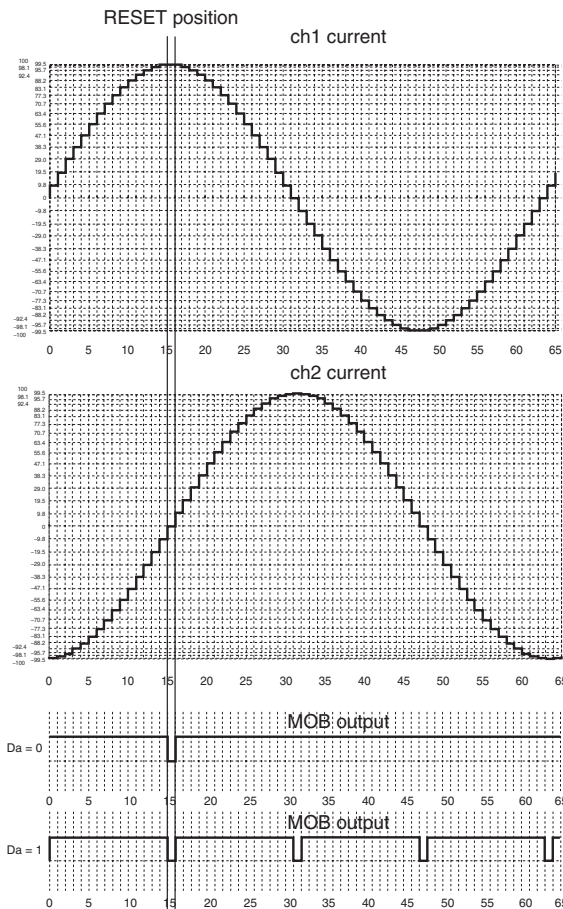
Da	MOB Output
0	1 pulse/cycle
1	4 pulses/cycle

- MOB output position (in microstep driving mode only)

The MOB output timing position can be selected by Db. When Db = “0”, MOB is output at the one-phase excitation position (where the current of ch 1 or ch 2 is 100%). When Db = “1”, MOB is output at the two-phase excitation position (where the currents of ch 1 and ch 2 are the same). Selection of MOB output (Da) is made in accordance with the setting of Db. When Db = “1”, MOB is not output at the reset position.

Db	MOB Output Position
0	1-phase excitation position
1	2-phase excitation position

The output timing of the MOB pin is shown below.



MOB Output Timing in Microstep Driving Mode

Address 3

This register is used to set parameters for acceleration/deceleration control, and the pulse multiplication factor. By setting the parameters for acceleration/deceleration control, the pulse cycle can be gradually changed while the motor is accelerated or decelerated, so that step out of the motor can be prevented.

By setting the pulse number multiplication factor to a value other than 1, the number of pulses can be extended in combination with the number of pulses set by the register at address 5. If the default value is not changed, the motor is driven without being accelerated or decelerated, and under the condition that the pulse number multiplication factor is 1.

bit	MSB							LSB									
	Df	De	Dd	Dc	Db	Da	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	
Data	0	1	1	Note 1		Note 2	Note 3	For acceleration/deceleration control								Pulse multiplication factor setting	

Notes 1. Reserved

- 2. Enables/disables acceleration.
- 3. Enables/disables deceleration.

• Pulse number multiplication factor

D1 and D0 are used to set the pulse number multiplication factor. By setting a multiplication factor, if the number of motor pulses set by the register at address 5 is insufficient, the number of pulses can be extended maintaining 64 steps/cycle.

D1	D0	Pulse Number Multiplication Factor m
0	0	m=1
0	1	
1	0	m=2
1	1	m=4

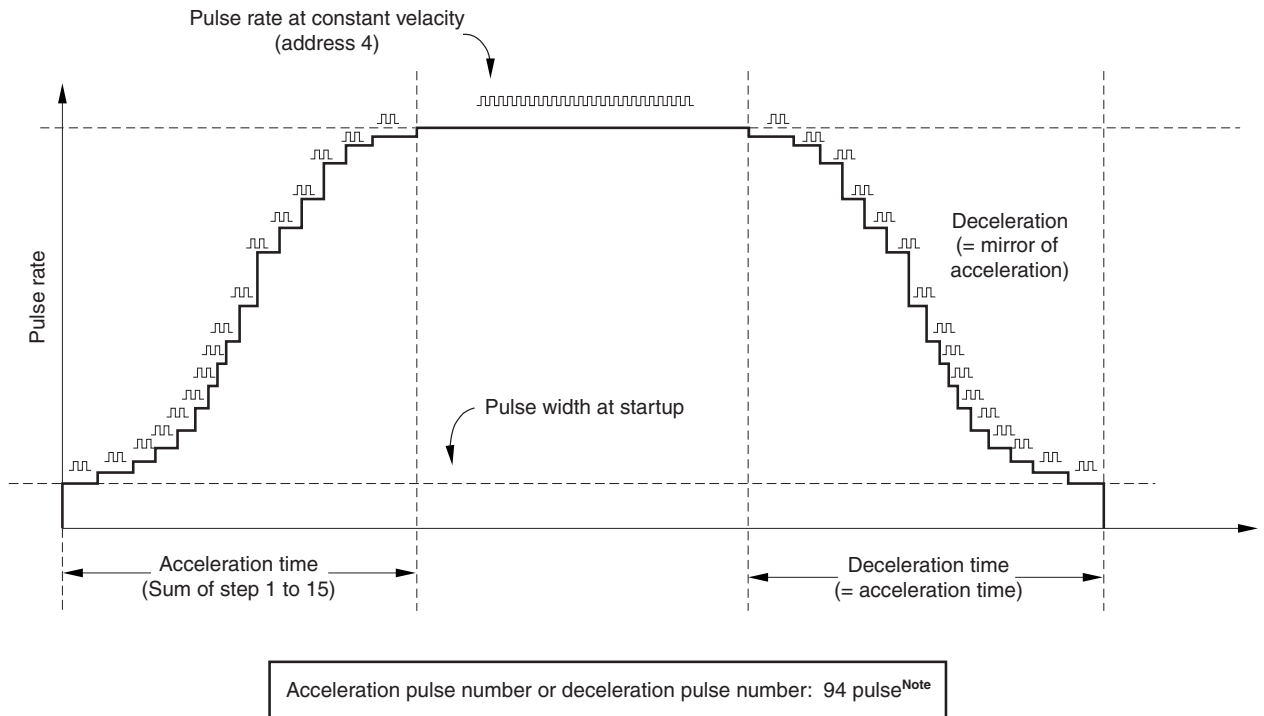
- Acceleration/deceleration control

Seven bits, D2 to D8, are used to set a driving profile for acceleration/deceleration.

The pulse rate vs. time draws an S-shaped curve. The shape of this S curve can be changed according to the values set to D2 to D7.

An example of acceleration and deceleration operations is illustrated below. 94 pulses each are necessary for acceleration and deceleration. Usually, therefore, set 188 pulses or more (acceleration pulses + deceleration pulses) to perform acceleration and deceleration.

If the set number of pulses is less than 94 during acceleration or deceleration, refer to the acceleration/deceleration operation example below.



Note An example of acceleration and deceleration operations is illustrated below. 94 pulses each are necessary for acceleration and deceleration. Usually, therefore, set 188 pulses or more (acceleration pulses + deceleration pulses) to perform acceleration and deceleration.

If the set number of pulses is less than 94 during acceleration or deceleration, refer to the acceleration/deceleration operation example below.

- Parameter for acceleration/deceleration control

Reference increment = Pulse cycle (address 4)/Set reference increment

Pulse cycle of each step = Pulse cycle (address 4) + Reference increment × Pulse cycle increment table

Time of each step = Pulse cycle of each step x Selected data table (number of pulses)

Selected Data Table List

Table	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8	STEP 9	STEP 10	STEP 11	STEP 12	STEP 13	STEP 14	STEP 15
1	2	5	2	1	1	1	1	1	1	1	2	3	11	31	31
2	1	4	4	3	2	2	2	2	2	2	4	6	12	17	31
3	1	3	3	4	3	4	3	3	3	3	5	9	13	15	22

Total: 94 pulses

Pulse Cycle Increment Table List

STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8	STEP 9	STEP 10	STEP 11	STEP 12	STEP 13	STEP 14	STEP 15
120	56	35	24	18	13	10	8	7	6	5	4	3	2	1

Example: Drive time at each step in the case of Table 1

STEP1	(Pulse cycle + Reference increment x 120)	x2
STEP2	(Pulse cycle + Reference increment x 56)	x5
STEP3	(Pulse cycle + Reference increment x 35)	x2
STEP4	(Pulse cycle + Reference increment x 24)	x1
STEP5	(Pulse cycle + Reference increment x 18)	x1
STEP6	(Pulse cycle + Reference increment x 13)	x1
STEP7	(Pulse cycle + Reference increment x 10)	x1
STEP8	(Pulse cycle + Reference increment x 8)	x1
STEP9	(Pulse cycle + Reference increment x 7)	x1
STEP10	(Pulse cycle + Reference increment x 6)	x1
STEP11	(Pulse cycle + Reference increment x 5)	x2
STEP12	(Pulse cycle + Reference increment x 4)	x3
STEP13	(Pulse cycle + Reference increment x 3)	x11
STEP14	(Pulse cycle + Reference increment x 2)	x31
STEP15	(Pulse cycle + Reference increment x 1)	x31

(The rightmost number indicates the number of pulses when table 1 is used. To use table 2 or 3, refer to Selected Data Table List.)

Acceleration time = Deceleration time = Sum of steps 1 to 15

- Reference increment setting

D2 to D4 are used to set a parameter that determines the pulse cycle at each step. The reference increment is the pulse frequency set at address 4 that is divided by the reference increment setting. So that the speed changes draw a typical S-shaped curve, it is recommended to set a value of 8 (1, 0, 0).

Reference increment = Pulse cycle (address 4)/Reference increment setting

D4	D3	D2	Reference Increment Setting
0	0	0	2
0	0	1	
0	1	0	
0	1	1	4
1	0	0	8
1	0	1	16
1	1	0	32
1	1	1	

- Table selection

This IC approximates the speed change curve during acceleration/deceleration operation to the shape S. The speed change curve can be changed by selecting an internal table.

Table 1: S curve with abrupt speed change

Table 2: S curve with gentle speed change

Table 3: S curve with linear speed change (equivalent to trapezoid waveform)

D6	D5	Table Selection
0	0	Table 1
0	1	
1	0	Table 2
1	1	Table 3

- Start time setting

D8 and D7 are used to select the operation time multiplication factor during an acceleration/deceleration operation. The number of pulses necessary for each step during acceleration/deceleration can be selected from x1, x2, and x4. For the number of pulses at each step, refer to Selected Data Table List.

D8	D7	Start Time Setting	Number of Pulses Necessary for Acceleration or Deceleration
0	0	x1	94
0	1		
1	0	x2	188
1	1	x4	376

- Enabling/disabling acceleration

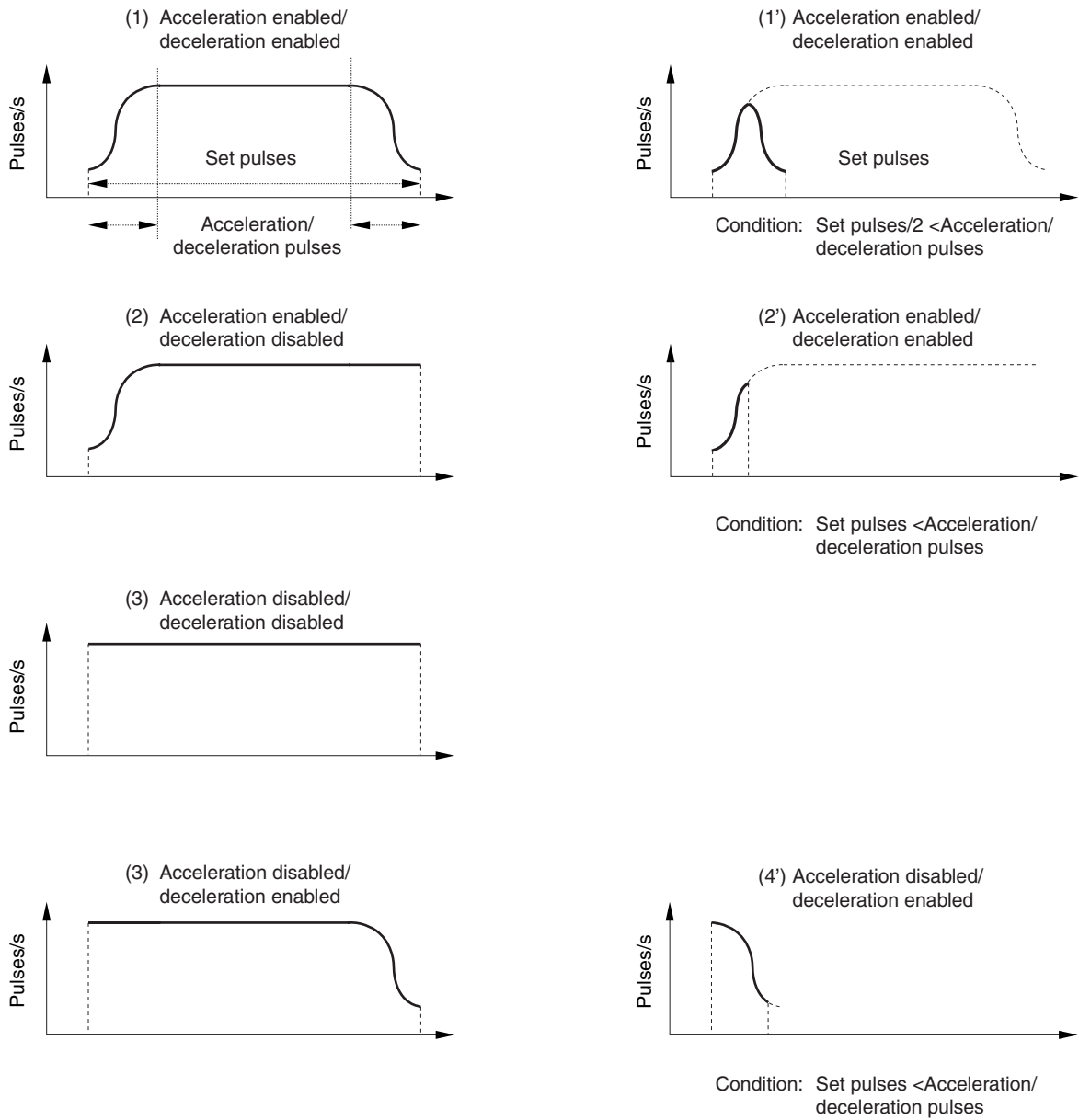
An acceleration operation can be performed in accordance with the acceleration control setting. The acceleration function can be enabled or disabled by Da.

- Enabling/disabling deceleration

A deceleration operation can be performed in accordance with the deceleration control setting. The deceleration function can be enabled or disabled by D9.

Da	D9	Operation Mode	
		Acceleration	Deceleration
0	0	Disabled	Disabled
1	0	Enabled	Disabled
0	1	Disabled	Enabled
1	1	Enabled	Enabled

Example of acceleration/deceleration operation



The uppermost left figure shows the ideal operation waveform. If the number of set pulses is less than the number of acceleration/deceleration control pulses, the operation is performed as illustrated by the figure at the uppermost right.

- (1') The deceleration operation is started when 1/2 of the set number of pulses has been reached during the acceleration operation. Therefore, acceleration and deceleration are always mirrored.
- (2') If the set number of pulses is less than the number of acceleration/deceleration control pulses during only the acceleration operation, the operation is stopped at the pulse rate in the middle of acceleration.
- (4') If the set number of pulses is less than the number of acceleration/deceleration control pulses during only the deceleration operation, the last pulse rate does not reach the target value. The set number of pulses is output in accordance with the deceleration pulse curve, and the operation is stopped.

Address 4

This register is used to set the pulse cycle per step (64 steps/cycle).

MSB													LSB			
bit	Df	De	Dd	Dc	Db	Da	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Data	1	0	0	Pulse cycle												

☆ • Pulse cycle

Thirteen bits, D0 to Dc, are used to set the pulse cycle per step.

The pulse cycle can be set in a range of 0 to 8191 μs at a resolution of 1.0 μs.

If all the 13 bits are “0”, no pulse is output and the driving status is maintained.

Example of setting pulse cycle

Dc.....D0	Set Value (μs)
0000000000000	0
0000000000001	1.0
0000000000010	2.0
:	:
1111111111101	8189
1111111111110	8190
1111111111111	8191

Address 5

This register is used to set the number of pulses. The actual number of pulses is set by the product of the pulse number multiplication factor and the number of pulses set at address 3.

	MSB													LSB		
bit	Df	De	Dd	Dc	Db	Da	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Data	1	0	1	Number of pulses												

- Number of pulses

Set the number of pulses to drive the motor. D0 to Dc are used to set pulses in a range of 0 to 8191 pulses. If the pulse number multiplication factor is set to a value other than 1 by the register at address 3, the number of pulses set here is multiplied by the set multiplication factor (m) of address 3. The number of pulses is internally multiplied by m and then counted. If it is set to output pulses to EXT0, the number of counts output is the set value itself (0 to 8191 x m).

Example of setting number of pulses

Dc.....D0	Set Value
000000000000	0
000000000001	m
000000000010	2 x m
:	:
111111111101	8189 x m
111111111110	8190 x m
111111111111	8191 x m

m indicates the set value of the pulse number multiplication factor of address 3. If the value of the 13 bits D0 to Dc is "0", the pulse is not output and the driving status is maintained.

ABSOLUTE MAXIMUM RATINGS

(T_A = 25°C: GLASS EPOXY BOARD OF 100 mm x 100 mm x 1 mm WITH COPPER FOIL AREA OF 15%)

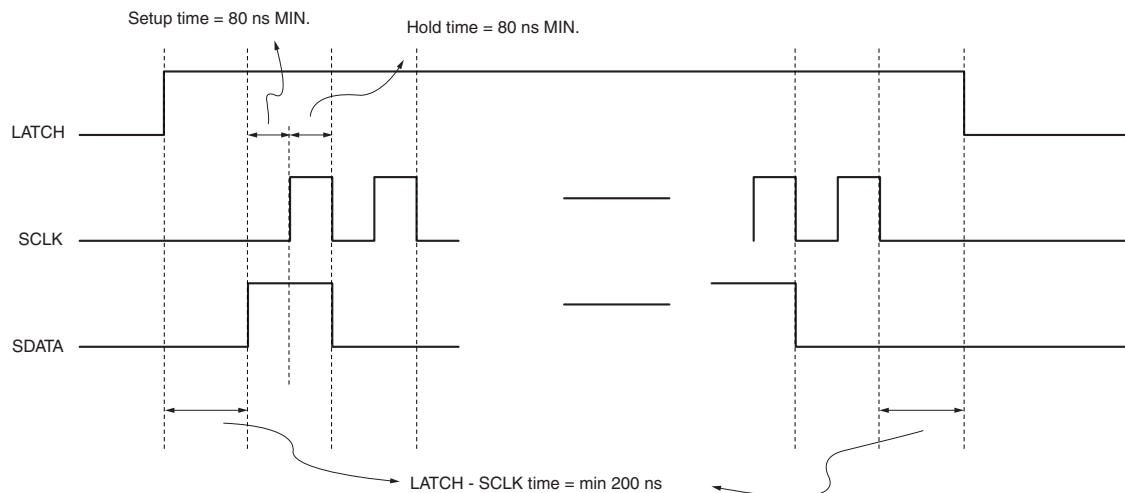
Parameter	Symbol	Conditions	Rating	Unit
Power supply voltage	V _{DD}	Control block	-0.5 to +6.0	V
	V _M	Motor block	-0.5 to +6.0	
Input voltage	V _{IN}		-0.5 to V _{DD} +0.5	V
Output pin voltage	V _{OUT}		6.2	V
DC output current	I _{D(DC)}	DC	±0.4	A/ch
Instantaneous output current	I _{D(pulse)}	PW < 10 ms, Duty ≤ 20%	±0.7	A/ch
Power consumption	P _T		0.7	W
Peak junction temperature	T _{CH(MAX)}		150	°C
Storage temperature	T _{stg}		-55 to +150	°C

RECOMMENDED OPERATING CONDITIONS

(T_A = 25°C: GLASS EPOXY BOARD OF 100 mm x 100 mm x 1 mm WITH COPPER FOIL AREA OF 15%)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Power supply voltage	V _{DD}	Control block	2.7		3.6	V
	V _M	Motor block	2.7		5.5	V
Input voltage	V _{IN}		0		V _{DD}	V
DC output current	I _{D(DC)}	DC	-0.35		+0.35	A/ch
Instantaneous output current	I _{D(pulse)}	PW < 10 ms, Duty ≤ 20%	-0.6		+0.6	A/ch
External CLK input frequency	OSC _{IN}		4	5	6.2	MHz
SCLK input frequency	f _{CLK}				6	MHz
LATCH-SCLK time	t _{L-S}		200			ns
SDATA setup time	t _{SETUP}		80			ns
SDATA hold time	t _{HOLD}		80			ns
EXT pin output drive current	I _{EXT}	Buffer output	-5		5	mA
MOB pin output sink current	I _{MOB}	Open-drain output			5	mA
Operating temperature range	T _A		-10		75	°C
Peak junction temperature	T _{CH(MAX)}				150	°C

Serial Command Timing Chart



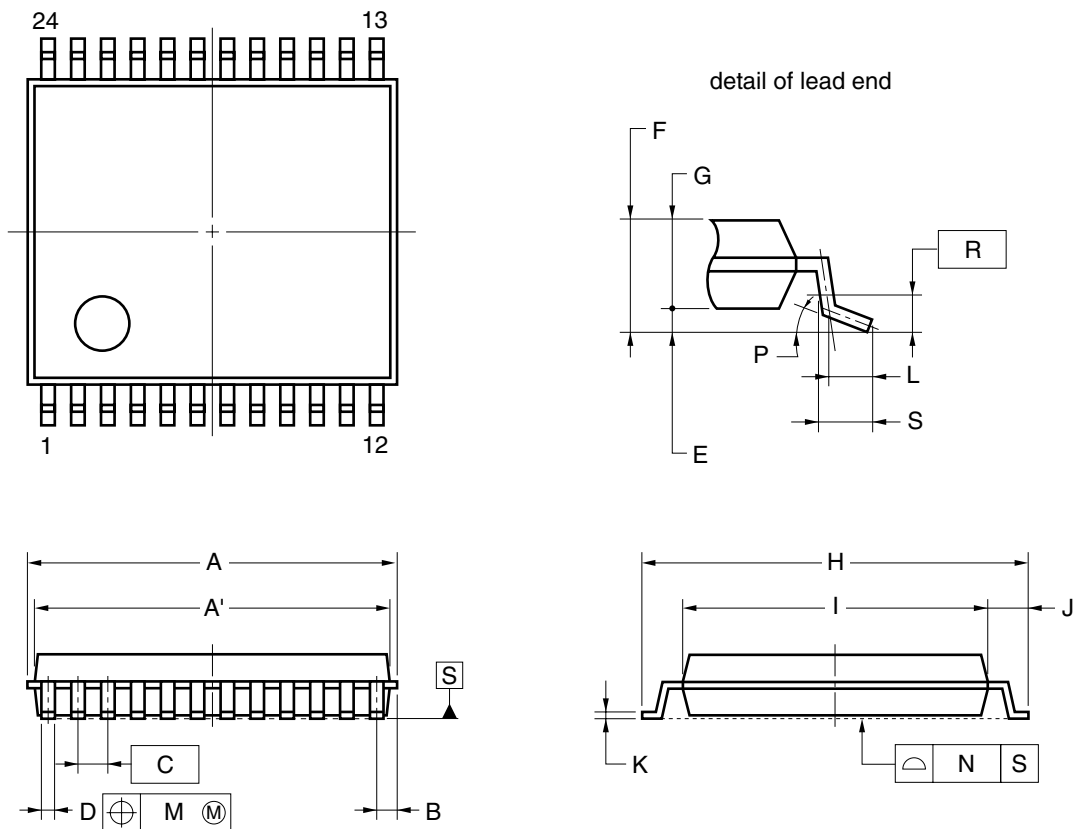
ELECTRICAL CHARACTERISTICS (UNLESS OTHERWISE SPECIFIED, $V_{DD} = V_M = 3\text{ V}$, $T_A = 25^\circ\text{C}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
V_{DD} pin current after reset	$I_{DD(STB)}$	External CLK (OSCin) stopped			1.0	μA
V_{DD} pin current in standby mode	$I_{DD(STB2)}$	External CLK (OSCin) stopped			30	μA
	$I_{DD(STB3)}$	External CLK (OSCin) input			300	μA
V_{DD} pin current during operation	$I_{DD(ACT)}$				3.0	mA
V_M leakage current	$I_{M(OFF)}$	Per V_M pin, $V_M = 5.5\text{ V}$, in standby mode			1.0	μA
High-level input current	I_{IH}	$V_{IN} = V_{DD}$			1.0	μA
Low-level input current	I_{IL}	$V_{IN} = 0$	-1.0			μA
High-level input voltage	V_{IH}	SCLK,SDATA,LATCH,RESETB, EN,OSCin pins	$0.7 \times V_{DD}$			V
Low-level input voltage	V_{IL}	SCLK,SDATA,LATCH,RESETB, EN,OSCin pins			$0.3 \times V_{DD}$	V
Input hysteresis voltage	V_{hys}	SCLK,SDATA,LATCH,RESETB, EN,OSCin pins		0.3		V
H bridge on-resistance	R_{ON}	$I_M = 0.35\text{ A}$, sum of upper and lower stages			2.0	Ω
Output turn-on time	t_{ON}	$R_M = 20\ \Omega$			0.5	μs
Output turn-off time	t_{OFF}				0.5	μs
EXT high-level output voltage	V_{extH}	$I_o = -100\ \mu\text{A}$	$0.9 \times V_{DD}$			V
EXT low-level output voltage	V_{extL}	$I_o = +100\ \mu\text{A}$			$0.1 \times V_{DD}$	V
EVRMAX voltage	EVRMAX	Address 2 (D0 to D4) = (1, 1, 1, 1, 1)	450	500	550	mV

- Cautions**
- 1. Undervoltage lockout circuit (UVLO) operates at 1.7 V TYP. and the output goes into a Hi-Z state. Internal data such as address settings is initialized. The UVLO circuit does not operate during reset.**
 - 2. The motor current accuracy varies depending on the motor actually used. With this IC, the total of the reference voltage EVRMAX error and the current sense circuit error is within ±10%.**

PACKAGE DRAWING

24-PIN PLASTIC TSSOP (5.72 mm (225))



NOTE

Each lead centerline is located within 0.10 mm of its true position (T.P.) at maximum material condition.

ITEM	MILLIMETERS
A	6.65±0.10
A'	6.5±0.1
B	0.575
C	0.5 (T.P.)
D	0.22±0.05
E	0.1±0.05
F	1.2 MAX.
G	1.0±0.05
H	6.4±0.1
I	4.4±0.1
J	1.0±0.1
K	0.17±0.025
L	0.5
M	0.10
N	0.08
P	3°+5° -3°
R	0.25
S	0.6±0.15

P24MA-50-6A5

RECOMMENDED SOLDERING CONDITIONS

The μPD168111 should be soldered and mounted under the following recommended conditions.

For soldering methods and conditions other than those recommended below, contact an NEC Electronics sales representative.

For technical information, see the following website.

Semiconductor Device Mount Manual (<http://www.necel.com/pkg/en/mount/index.html>)

Recommended Soldering Conditions for Surface Mounting Type

μPD168111MA-6A5: 24-pin plastic TSSOP (5.72 mm (225))

Soldering Method	Soldering Conditions	Recommended Condition Symbol
Infrared reflow	Package peak temperature: 260°C, Time: 60 seconds max. (at 220°C or higher), Count: Three times or less, Exposure limit: None, Flux: Rosin flux with low chlorine (0.2 Wt% or below) recommended	IR60-00-3

Caution Do not use different soldering methods together (except for partial heating).

[MEMO]

NOTES FOR CMOS DEVICES

① PRECAUTION AGAINST ESD FOR SEMICONDUCTORS

Note:

Strong electric field, when exposed to a MOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it once, when it has occurred. Environmental control must be adequate. When it is dry, humidifier should be used. It is recommended to avoid using insulators that easily build static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work bench and floor should be grounded. The operator should be grounded using wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with semiconductor devices on it.

② HANDLING OF UNUSED INPUT PINS FOR CMOS

Note:

No connection for CMOS device inputs can be cause of malfunction. If no connection is provided to the input pins, it is possible that an internal input level may be generated due to noise, etc., hence causing malfunction. CMOS devices behave differently than Bipolar or NMOS devices. Input levels of CMOS devices must be fixed high or low by using a pull-up or pull-down circuitry. Each unused pin should be connected to V_{DD} or GND with a resistor, if it is considered to have a possibility of being an output pin. All handling related to the unused pins must be judged device by device and related specifications governing the devices.

③ STATUS BEFORE INITIALIZATION OF MOS DEVICES

Note:

Power-on does not necessarily define initial status of MOS device. Production process of MOS does not define the initial operation status of the device. Immediately after the power source is turned ON, the devices with reset function have not yet been initialized. Hence, power-on does not guarantee out-pin levels, I/O settings or contents of registers. Device is not initialized until the reset signal is received. Reset operation must be executed immediately after power-on for devices having reset function.