# NEC

## MOS INTEGRATED CIRCUIT
# µPD168110

## MICROSTEP DRIVER FOR DRIVING CAMERA LENS

### DESCRIPTION

The µPD168110 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

O Two H bridge circuits employing power MOSFET

O Current feedback 64-step microstep driving and two-phase excitation driving selectable

O Low on-resistance: 2 Ω MAX.

O 3 V power supply

   Minimum operating power supply voltage $V_{DD}$ = 2.7 V

O Under voltage lockout circuit

   Shuts down internal circuitry at $V_{DD}$ = 1.7 V TYP.

O 24-pin TSSOP
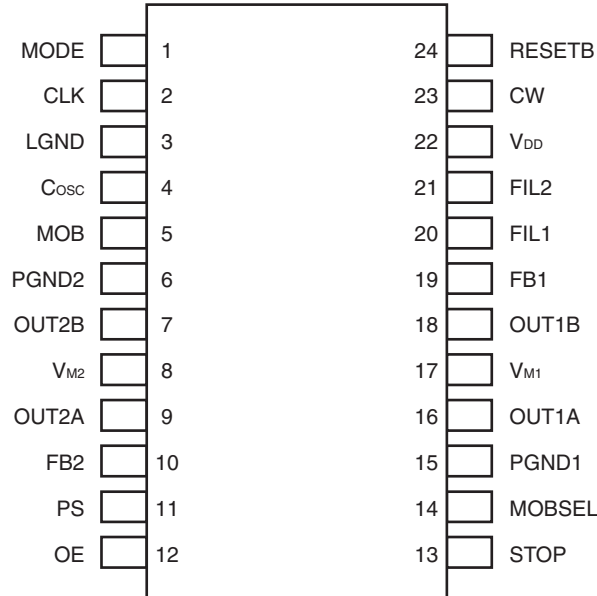
### ORDERING INFORMATION

| Part Number | Package |
|---|---|
| µPD168110MA-6A5 | 24-pin plastic TSSOP (5.72 mm (225)) |

## PIN  FUNCTIONS

Package: 24-pin TSSOP

```
           ┌─────────────┐
   MODE ──┤ 1        24 ├── RESETB
    CLK ──┤ 2        23 ├── CW
   LGND ──┤ 3        22 ├── VDD
   COSC ──┤ 4        21 ├── FIL2
    MOB ──┤ 5        20 ├── FIL1
  PGND2 ──┤ 6        19 ├── FB1
  OUT2B ──┤ 7        18 ├── OUT1B
    VM2 ──┤ 8        17 ├── VM1
  OUT2A ──┤ 9        16 ├── OUT1A
    FB2 ──┤ 10       15 ├── PGND1
     PS ──┤ 11       14 ├── MOBSEL
     OE ──┤ 12       13 ├── STOP
           └─────────────┘
```

| Pin No. | Pin Name | Pin Function |
|---------|----------|--------------|
| 1 | MODE | Microstep/2-phase excitation switch pin |
| 2 | CLK | Pulse input pin |
| 3 | LGND | Control block GND pin |
| 4 | $C_{OSC}$ | Pin connecting capacitor for output oscillator |
| 5 | MOB | Phase detection output pin |
| 6 | PGND2 | Output block GND pin |
| 7 | OUT2B | Channel 2 output B |
| 8 | $V_{M2}$ | Motor power pin |
| 9 | OUT2A | Channel 2 output A |
| 10 | FB2 | Channel 2 current detection resistor connecting pin |
| 11 | PS | Power save mode pin |
| 12 | OE | Output enable pin |
| 13 | STOP | Stop mode pin |
| 14 | MOBSEL | MOB output select pin |
| 15 | PGND1 | Output block GND pin |
| 16 | OUT1A | Channel 1 output A |
| 17 | $V_{M1}$ | 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 | FIL2 | Channel 2 filter capacitor connecting pin |
| 22 | $V_{DD}$ | Control block power pin |
| 23 | CW | Revolution direction setting pin |
| 24 | RESETB | Reset input pin |

## BLOCK DIAGRAM
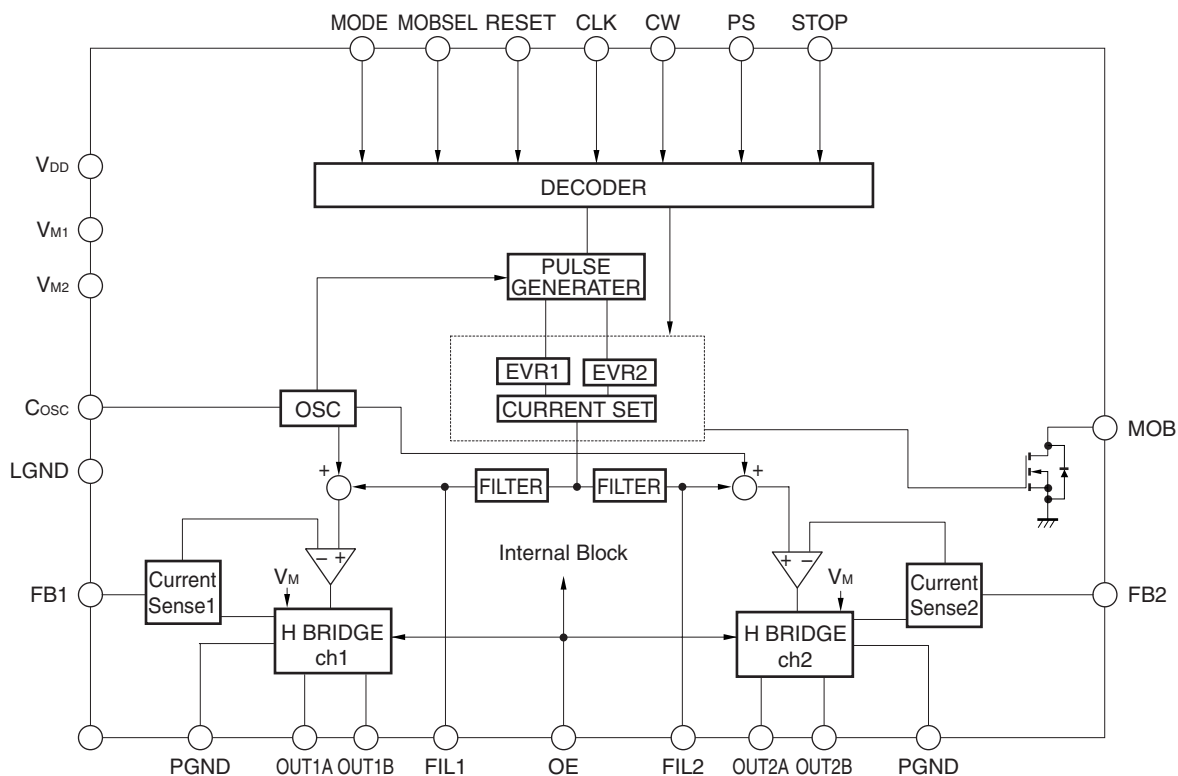


### Truth Table

| RESET | CLK | CW | OE | PS | STOP | MODE | MOBSEL | Operation Mode |
|-------|-----|----|----|----|------|------|--------|----------------|
| H | ⌐ | L | H | L | L | H | L | Microstep CW mode<br>MOB: 1 pulse/cycle |
| H | ⌐ | H | H | L | L | H | L | Microstep CCW mode<br>MOB: 1 pulse/cycle |
| H | ⌐ | L | H | L | L | H | H | Microstep CW mode<br>MOB: 4 pulses/cycle |
| H | ⌐ | H | H | L | L | H | H | Microstep CCW mode<br>MOB: 4 pulses/cycle |
| H | ⌐ | L | H | L | L | L | X | 2-phase CW mode |
| H | ⌐ | H | H | L | L | L | X | 2-phase CCW mode |
| H | X | X | L | X | X | X | X | Output Hi-Z |
| H | X | X | H | L | H | H | X | STOP mode after MOB = L<br>(CLK must be input until MOB = L) |
| H | X | X | H | H | H | H | X | PS mode after MOB = L<br>(CLK must be input until MOB = L) |
| H | X | X | H | H | L | H | X | Setting prohibited |
| L | X | X | X | X | X | X | X | Reset mode |

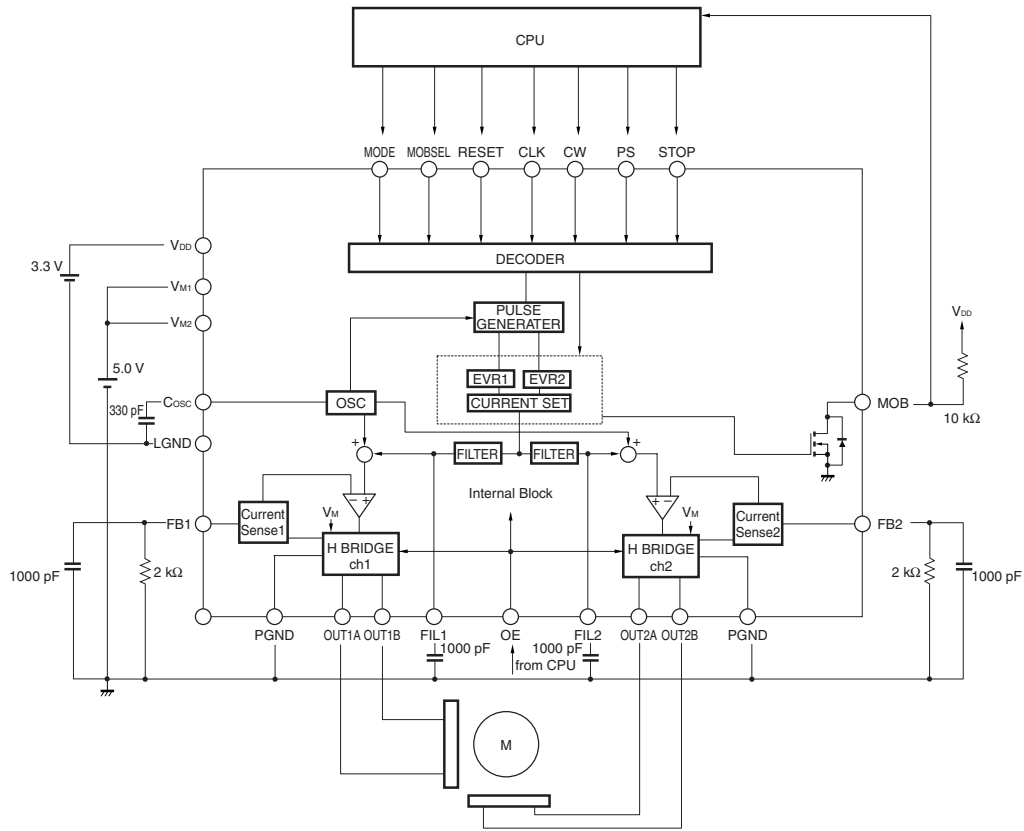H:  High level, L:  Low level, X:  High level or low level
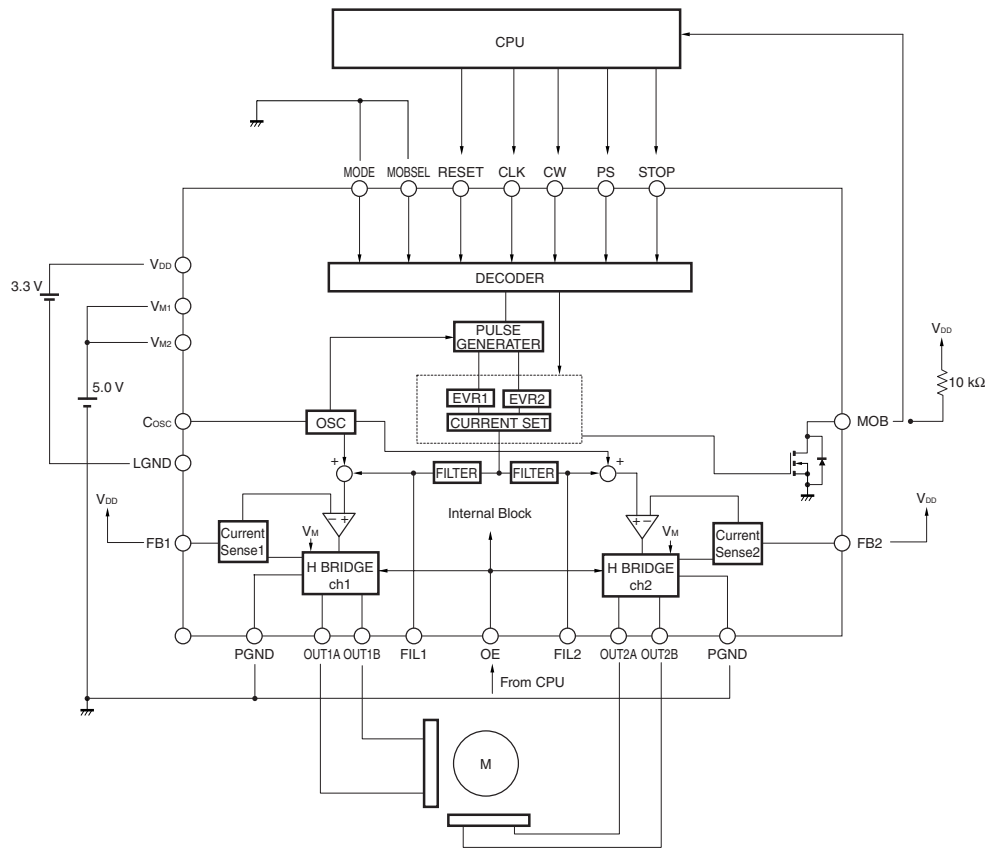
## Command Input Timing Chart

In microstep mode
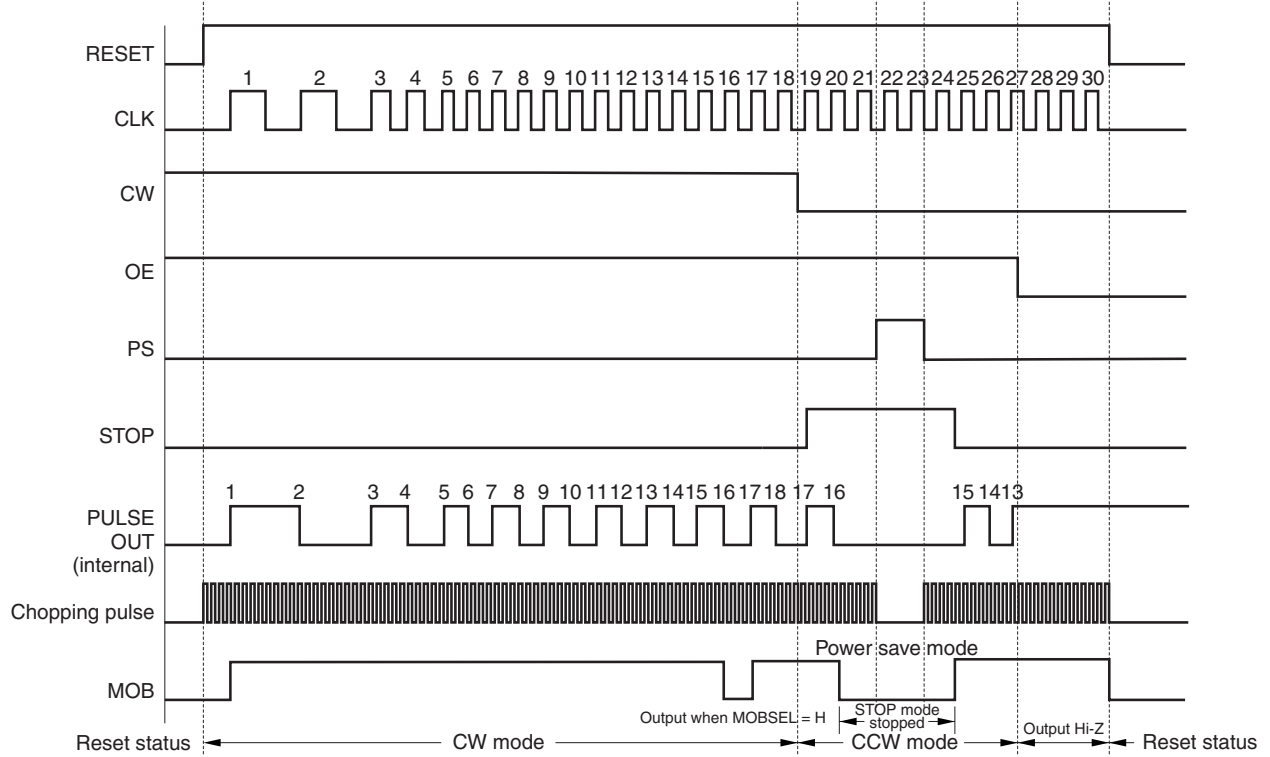
## Standard Connection Diagram
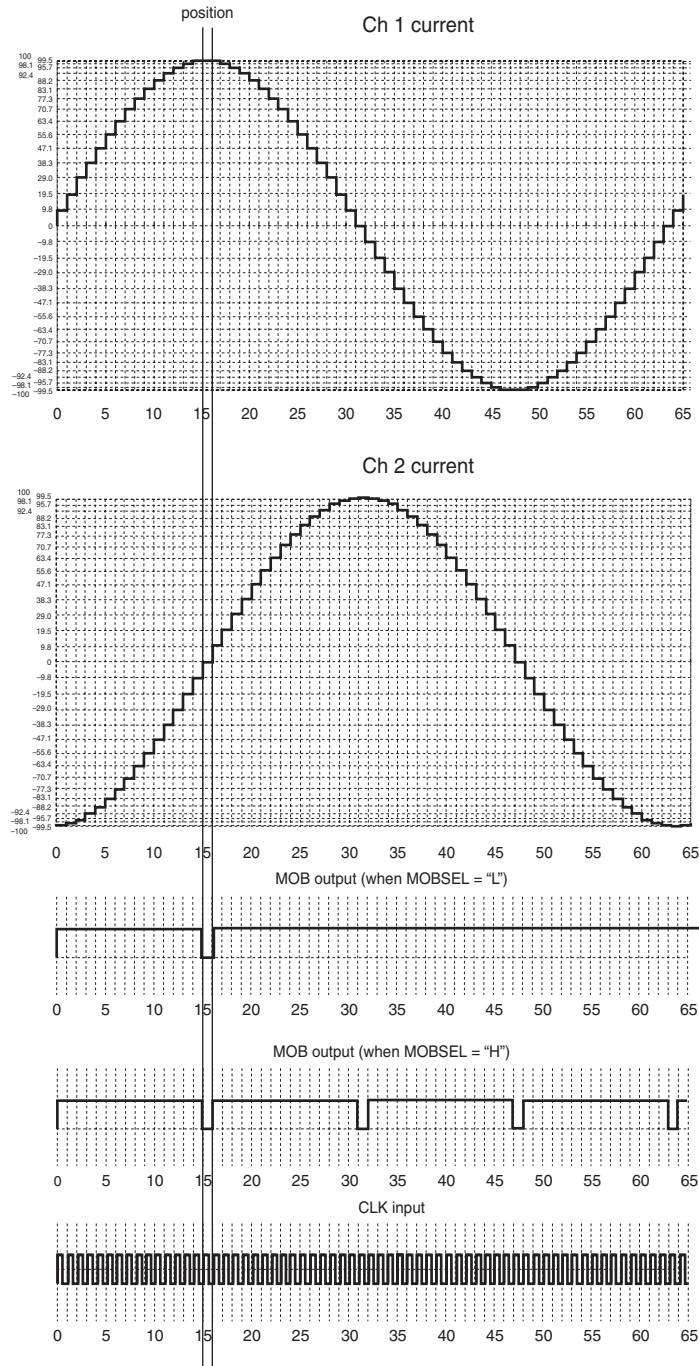
Microstep/2-phase excitation driving



Only 2-phase excitation driving

**Output Timing Chart**

● **Microstep output mode**

position

Ch 1 current

Ch 2 current

MOB output (when MOBSEL = "L")

MOB output (when MOBSEL = "H")

CLK input

The horizontal axis indicates the number of steps. This figure shows an example in the CW mode. The pulse advances in synchronization with the rising edge of CLK. The current flows into ch 1 and ch 2 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
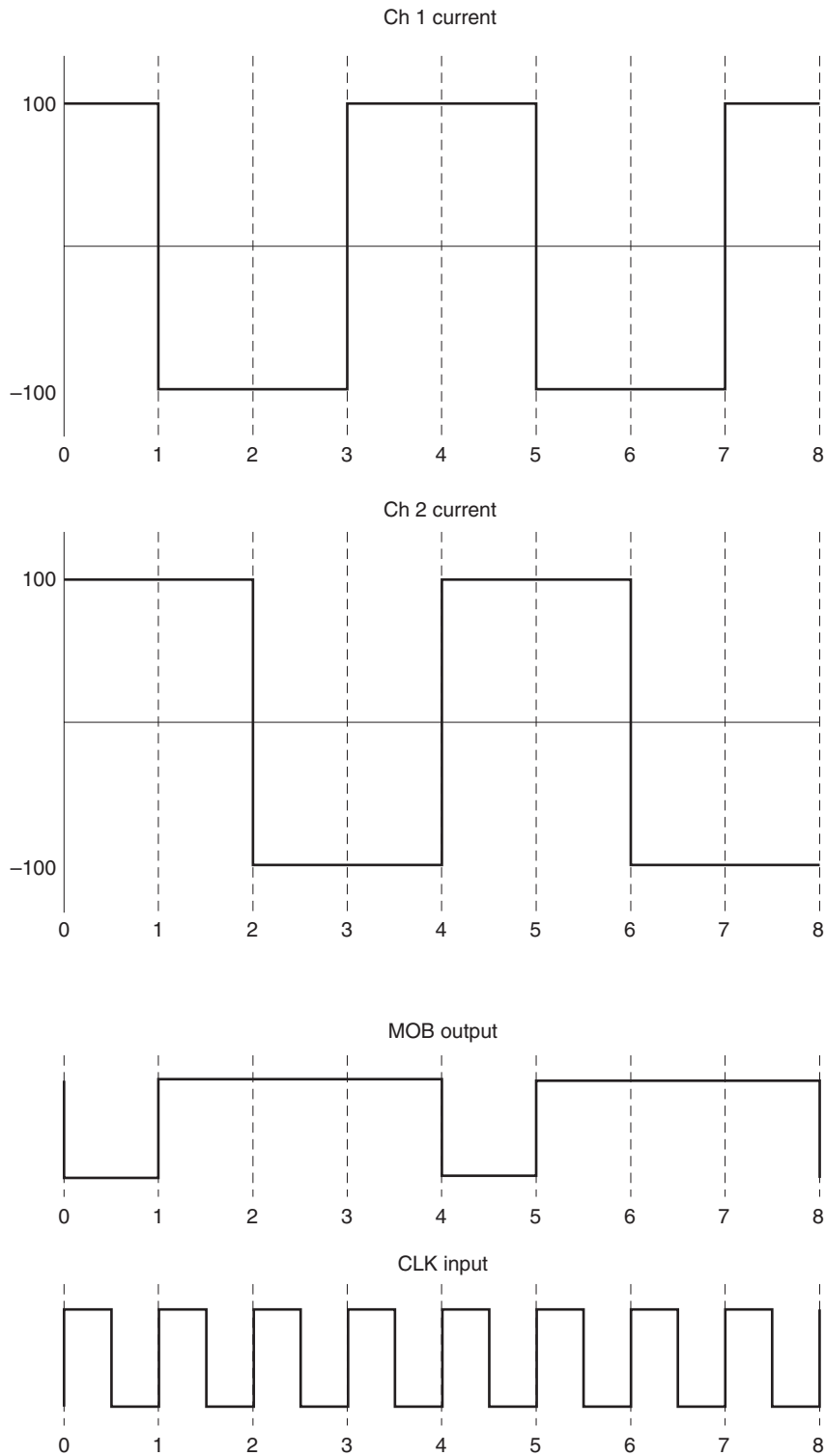
Ch 1 current



Ch 2 current



MOB output



CLK input



The horizontal axis indicates the number of steps. This figure shows an example in the CW mode. The current flows into ch 1 and ch 2 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. |
| $\theta$ 0 | 0 | – | 0 | 3.8 | – | 100 | – | 100 |
| $\theta$ 1 | 5.625 | 2.5 | 9.8 | 17.0 | 94.5 | 100 | 104.5 | 100.48 |
| $\theta$ 2 | 11.250 | 12.4 | 19.5 | 26.5 | 93.2 | 98.1 | 103.0 | 100 |
| $\theta$ 3 | 16.875 | 22.1 | 29.0 | 36.1 | 90.7 | 95.7 | 100.7 | 100.02 |
| $\theta$ 4 | 22.500 | 31.3 | 38.3 | 45.3 | 87.4 | 92.4 | 97.4 | 100.02 |
| $\theta$ 5 | 28.125 | 40.1 | 47.1 | 54.1 | 83.2 | 88.2 | 93.2 | 99.99 |
| $\theta$ 6 | 33.750 | 48.6 | 55.6 | 62.6 | 78.1 | 83.1 | 88.1 | 99.98 |
| $\theta$ 7 | 39.375 | 58.4 | 63.4 | 68.4 | 72.3 | 77.3 | 82.3 | 99.97 |
| $\theta$ 8 | 45 | 65.7 | 70.7 | 75.7 | 65.7 | 70.7 | 75.7 | 99.98 |
| $\theta$ 9 | 50.625 | 72.3 | 77.3 | 82.3 | 58.4 | 63.4 | 68.4 | 99.97 |
| $\theta$ 10 | 56.250 | 78.1 | 83.1 | 88.1 | 48.6 | 55.6 | 62.6 | 99.98 |
| $\theta$ 11 | 61.875 | 83.2 | 88.2 | 93.4 | 40.1 | 47.1 | 54.1 | 99.99 |
| $\theta$ 12 | 67.500 | 87.4 | 92.4 | 97.4 | 31.3 | 38.3 | 45.3 | 100.02 |
| $\theta$ 13 | 73.125 | 90.7 | 95.7 | 100.7 | 22.1 | 29.0 | 36.1 | 100.02 |
| $\theta$ 14 | 78.750 | 93.2 | 98.1 | 103.0 | 12.4 | 19.5 | 26.5 | 100 |
| $\theta$ 15 | 84.375 | 94.5 | 100 | 104.5 | 2.5 | 9.8 | 17.0 | 100.48 |
| $\theta$ 16 | 90 | – | 100 | – | – | 0 | 3.8 | 100 |

The above values are ideal values and are not guaranteed 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.
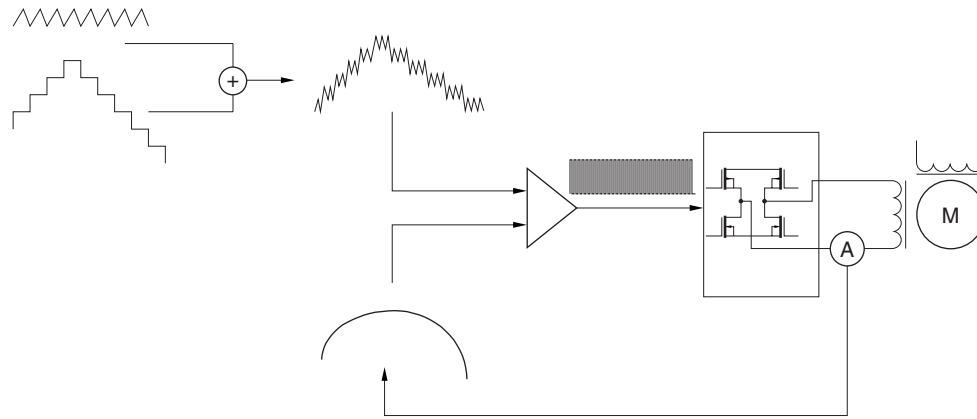
The two-phase excitation driving mode and microstep driving mode are switched by the MODE pin. In the two-phase excitation driving mode, the chopping pulse circuit does not operate.

**Microstep driving of stepper motor**

To position a stepper motor with high accuracy, the μPD168110 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. 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 an external pin.



Concept of microstep driving operation

**MOB output**

The MOB output pin outputs "L" if the current of ch1 or ch2 reaches ±100% in the microstep output mode, or if the current of ch 1 reaches +100%. In the two-phase excitation output mode, the MOB pin outputs "L" when the current of ch1 and ch2 reaches +100%. The excitation position of the stepper motor can be checked by monitoring the MOB output. The MOB output also indicates the stop position information in the stop mode to be explained below.

The MOB output goes into a Hi-Z state (output H level if pulled up) when OE = "L".

**Stop mode**

If the stop mode is set by the STOP pin, the pulse is automatically output until MOB = "L" when CLK is input. If MOB = "L" in the stop mode, the pulse is not output even when CLK is input, and the output holds the excitation status.

To advance the pulse, release the stop mode and restore the normal mode.

**Reset function**

When RESET = "L", initialization is executed and the output goes into a Hi-Z state. When RESET = "H", excitation is started with the current of ch1 at +100% and the current of ch2 at 0% (one-phase excitation position). To perform two-phase excitation driving, excitation is started with the currents of ch1 and ch2 at +100% after the mode has been set. Be sure to execute a reset operation after power application. MOB outputs "L" until the pulse is output when RESET goes "L".

**Output enable (OE) pin**

The pulse output can be forcibly stopped from an external source by using the OE pin. When OE = "L", the output is forcibly made to go into a Hi-Z state.

**Standby function**

The $\mu$PD168110 can enter the standby mode when the pulse is not output and when PS = "H" and

STOP = "H". In the standby mode, as many internal circuits as possible are stopped so that the self current consumption can be reduced. In the standby mode, the current consumption is 1 $\mu$A MAX. when external CLK input is stopped. While CLK is being input, the current consumption is reduced to 300 $\mu$A MAX. by the current flowing into the input buffer. The standby mode is released when PS = "L" and STOP = "L".

**Under voltage lockout circuit (UVLO)**

This function is used to forcibly stop the operation of the IC to prevent malfunction of the circuits if $V_{DD}$ of the IC drops during operation. Note that if the $V_{DD}$ voltage abruptly drops in the order of $\mu$s, this function may not operate.

**$V_M$ pin current shutdown circuit**

A circuit that prevents a current from flowing into the VM pin when $V_{DD}$ = 0 V is provided. Therefore, the current flowing into the VM pin is cut off when $V_{DD}$ = 0 V.

A current of up to 3 $\mu$A flows into the $V_M$ pin when $V_{DD}$ is applied so that the voltages on the $V_{DD}$ and $V_M$ pins can be monitored.

### OPERATION  DESCRIPTION

- Setting output current

  The peak value of the output current (when current of ch 1 or ch 2 is 100%) is determined by the resistor $R_{FB}$ that is connected to FB1 and FB2.  This IC has an internal reference power supply $V_{REF}$ (500 mV TYP.) for comparing current, and drives the stepper motor with the current value calculated by $R_{FB}$ and $V_{REF}$ as the peak output current value.

  Peak output current value $I_{MAX}$ (A) $\cong$ $V_{REF}$ (V) $\div$ $R_{FB}$ ($\Omega$) x 1000

- Pulse output

  The motor is driven by inputting a pulse to the CLK pin.  The motor advances by one pulse at the rising edge of the CLK signal.  When MODE = "H", the motor is driven in the 64-microstep driving mode, and the driving current of each step is determined based on the internal motor excitation position information and revolution direction. When MODE = "L", the two-phase excitation mode is selected, and the current direction (100% drive) of ch 1 and ch 2 are switched each time a pulse has been input.

- Setting motor revolution direction

  The revolution direction of the motor is set by CW. In the CW mode (CW = "L"), the current of ch2 is output, 90° degrees in phase behind the current of ch1. In the CCW mode (CW = "H"), the current of ch2 is output, 90° degrees in phase ahead of the current of ch1.

  | CW Pin | Operation Mode |
  |---|---|
  | L | CW mode (forward revolution) |
  | H | CCW mode (reverse revolution) |

- Setting stop mode (valid only in microstep driving mode)

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

  The excitation status is not changed even when a pulse is input to CLK while MOB = "L" when STOP = "H".  The pulse can be advanced when STOP = "L".

  | STOP | Operation Mode |
  |---|---|
  | L | Normal mode |
  | H | Stop mode |

**Caution   If STOP = "L" before the stop mode is set (until MOB = "L"), the operation is performed in the same manner as in the normal mode.**

- **Power save mode (valid only in microstep driving mode)**

  When PS = "H" and STOP = "H", the motor advances to the position of MOB output = "L" and then the output goes to a Hi-Z state.

  The internal circuitry is stopped as much as possible and the standby mode is set.  The power save mode is released when PS = "L" and STOP = "L".

| STOP | Operation Mode |
|---|---|
| L | Normal mode |
| H | Power save mode (only when STOP = "H") |

**Caution   Inputting PS = "H" and STOP = "L" is prohibited.**

- Setting output enable

  When OE = "H", the motor is driven (output excitation status).  Be sure to set OE to "H" to drive the motor.

| STOP | Operation Mode |
|---|---|
| L | Output Hi-Z |
| H | Enable mode |

- Selecting two-phase excitation/microstep driving mode

  The MODE pin can be used to select the two-phase excitation or microstep driving mode.  When MODE = "H", the microstep driving mode is selected.  When MODE = "L", the two-phase excitation mode (both ch 1 and ch 2 are driven at +100% or –100%) is selected.  The $\mu$PD168110 is initialized immediately after a RESET operation, so excitation is started from the position at which the output current of ch 1 is 100% and the output current of ch 2 is 0% in the microstep driving mode, and from the position at which the output currents of both ch 1 and ch 2 are +100% in the two-phase excitation driving mode.

  If the mode is changed from the microstep to the two-phase, the position of the microstep mode is retained until CLK is input.  When the first CLK is input, pulse output is started, the operation skips to the two-phase position of the next quadrant, and driving is started.

| MODE | Operation Mode |
|---|---|
| L | 2-phase excitation |
| H | Microstep driving |
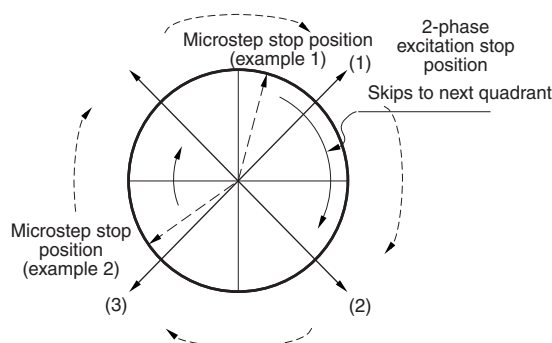


Concept of switching operation mode
from microstep to 2-phase excitation

- Selecting MOB output (in microstep driving mode only)

  The output function of MOB can be selected by MOBSEL. When MOBSEL = "L", MOB is output at the position where the current of ch1 is +100% and the current of ch2 is 0%. When MOBSEL = "H", MOB is output at the position where the current of ch1 or ch2 is ±100%.

| MOBSEL | MOB Output |
|---|---|
| L | Current of ch1 is +100% and current of ch2 is 0% (1 pulse/cycle). |
| H | Current of ch1 or ch2 is ±100% (4 pulses/cycle). |
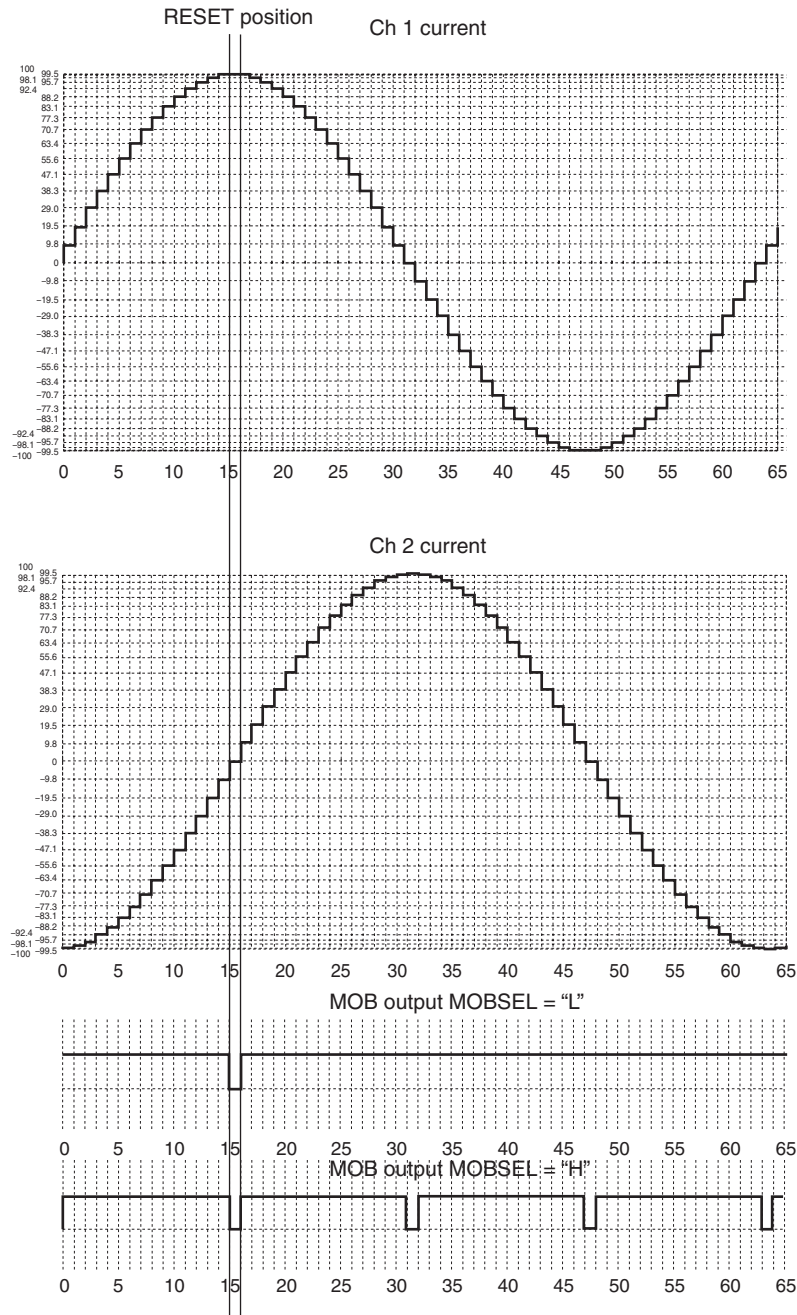
## ABSOLUTE  MAXIMUM RATINGS
## (T$_A$ = 25°C: GLASS EPOXY BOARD OF 100 mm × 100 mm × 1 mm WITH C OPPER  FOIL OF 15%)

| 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 × 100 mm × 1 mm WITH COPPER FOIL 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 |
| MOB pin output sink current | I$_{MOB}$ | Open-drain output | | | 5 | mA |
| Operating temperature range | T$_A$ | | −10 | | 75 | °C |

**ELECTRICAL  CHARACTERISTICS (UNLESS  OTHERWISE  SPECIFIED, $V_{DD}$ = $V_M$ = 3 V, $T_A$ = 25°C)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| $V_{DD}$ pin current after reset | $I_{DD(STB)}$ | External CLK stopped | | | 1.0 | $\mu$A |
| $V_{DD}$ pin current in standby mode | $I_{DD(STB2)}$ | External CLK stopped | | | 30 | $\mu$A |
| | $I_{DD(STB3)}$ | External CLK is input | | | 300 | $\mu$A |
| $V_{DD}$ pin current during operation | $I_{DD(ACT)}$ | | | | 3.0 | mA |
| VM pin current | $I_{M(OFF)}$ | $V_M$ = 5.5 V per $V_M$ pin, after reset and in standby mode | | | 3.0 | $\mu$A |
| High-level input current | $I_{IH}$ | $V_{IN}$ = $V_{DD}$ | | | 1.0 | $\mu$A |
| Low-level input current | $I_{IL}$ | $V_{IN}$ = 0 V | −1.0 | | | $\mu$A |
| High-level input voltage | $V_{IH}$ | 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | 0.7 x $V_{DD}$ | | | V |
| Low-level input voltage | $V_{IL}$ | 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | | | 0.3 x $V_{DD}$ | V |
| Input hysteresis voltage | $V_{hys}$ | | | 0.3 | | V |
| H bridge on-resistance | $R_{ON}$ | $I_M$ = 0.35 A, sum of upper and lower stages, FB1 = FB2 = 0 V | | | 2.0 | $\Omega$ |
| Output turn-on time | $t_{ON}$ | $R_M$ = 20 $\Omega$ OE pin ↑ → output SW time | 0.02 | | 0.5 | $\mu$s |
| Output turn-off time | $t_{OFF}$ | | 0.02 | | 0.5 | $\mu$s |
| Internal reference voltage | $V_{REF}$ | | 450 | 500 | 550 | mV |
| Output detection ratio | | $I_M$ = 0.1 A, with 2.5 k$\Omega$ sense resistor connected | 950 | 1050 | 1150 | |

**Cautions 1.** The undervoltage lockout detection circuit (UVLO) operates at 1.7 V TYP. whereupon the output goes into a Hi-Z state. Internal data such as the excitation position information is reset. The UVLO circuit does not operate after reset.

**2.** A shutdown circuit that prevents a current from flowing into the $V_M$ pin when $V_{DD}$ = 0 V is provided.

**PACKAGE DRAWING**

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

detail of lead end
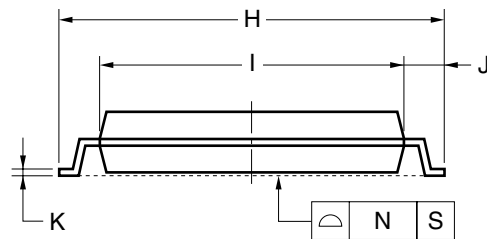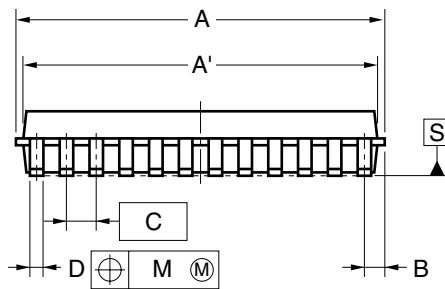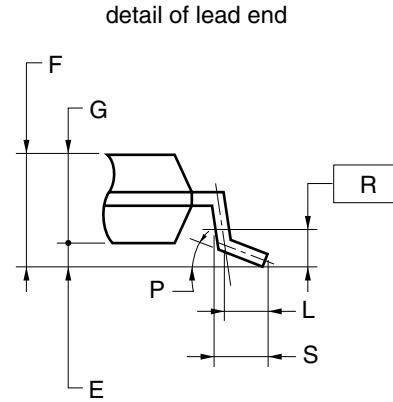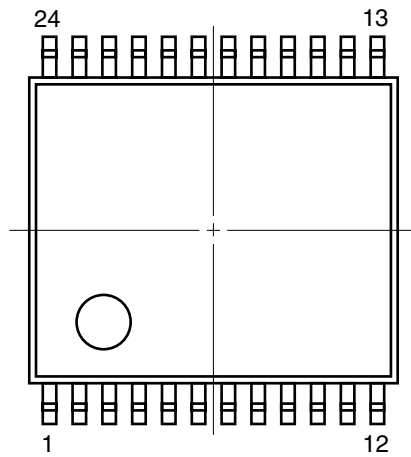
**NOTE**

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 μPD168110 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**
**μPD168110MA-6A5   24pin TSSOP**

| 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.