



AP1013DEN

18V 1ch H-Bridge Motor Driver IC

1. General Description

The AP1013DEN realizes four drive mode of forward, reverse, break and standby by 1 channel H-bridge motor driver corresponding to operating voltage 18V. The AP1013DEN layouts N-channel LDMOSFET in high side and low side in output circuit and realizes a small package. Also it has under voltage detection and thermal shut down circuits. It is suitable for driving various small motor.

2. Features

- Control Power Supply Voltage (VC) 2.7V to 5.5V
- Logic Terminal Supply Voltage 1.62V to VC
- Wide Motor Driver Operating Voltage 2V to 18V
(N-channel MOSFET high side and Low side architecture)
- Maximum Output Current (DC) 1.3A
- Maximum Output Current (Peak) 2.2A (Ta=25°C, within 10ms in 200ms)
- Maximum Output Current (Peak) 3.3A (Ta=25°C, within 5ms in 200ms)
- Maximum Output Current (Peak) 5.0A (Ta=25°C, within 2ms in 200ms)
- H-Bridge On Resistance RON(TOP+BOT)=0.38Ω@25°C
- Power-Save Mode Quiescent current is under 1uA (Ta=25°C)
- Built-in Under Voltage Detection Circuit Detect V_{VC} under 2.2V
- Built-in Thermal Shut Down Circuit (Tj) 175°C
- Junction Temperature 150°C
- Package 16-pin QFN (3mm×3mm)

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4. Block Diagram

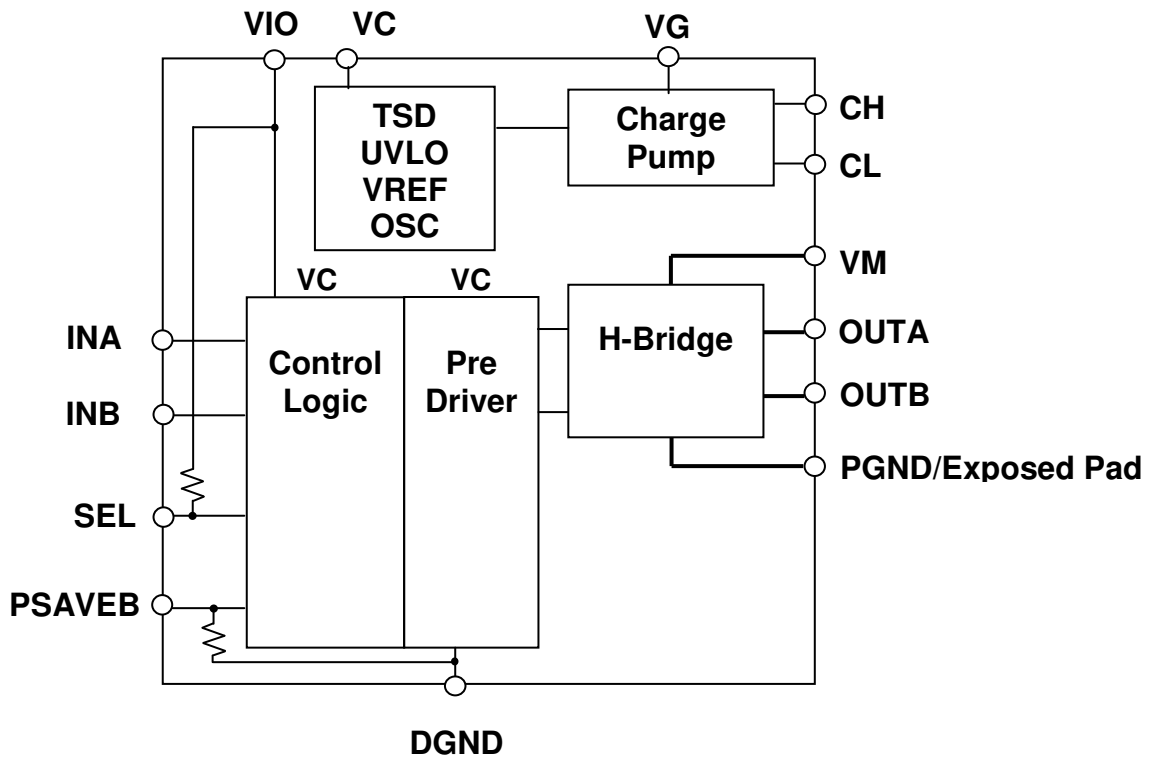


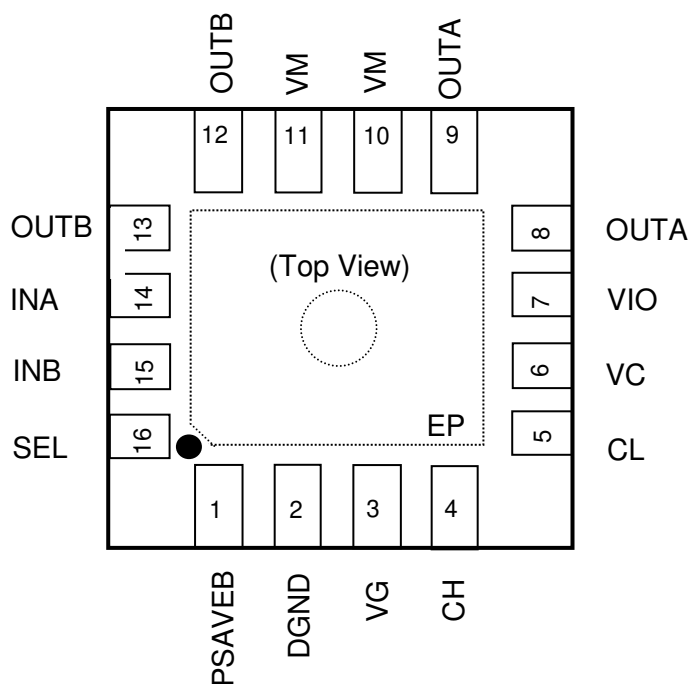
Figure 1. Block Diagram

5. Ordering Guide

| | | |
|-----------|----------|------------|
| AP1013DEN | -30~85°C | 16-pin QFN |
|-----------|----------|------------|

6. Pin Configurations and Functions

■ Pin Configurations



Note) EP(Exposed Pad) is Power Ground.
The Exposed Pad is necessary soldered to PCB.

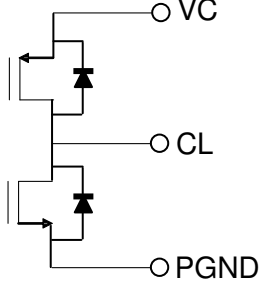
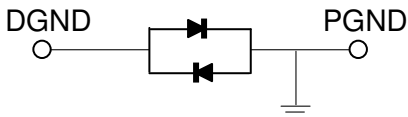
■ Functions

| No | Pin Name | I/O | Description | Note |
|-------|----------|-----|--|-----------------|
| 1 | PSAVEB | I | Power save input terminal | 100kΩ Pull-down |
| 2 | DGND | P | Ground terminal | |
| 3 | VG | O | Connect terminal of charge pump output capacitor | |
| 4 | CH | O | Connect terminal of charge pump capacitor | |
| 5 | CL | O | Connect terminal of charge pump capacitor | |
| 6 | VC | P | Control power supply terminal | |
| 7 | VIO | P | Power supply terminal for logic input | |
| 8,9 | OUTA | O | Motor driver output terminal | |
| 10,11 | VM | P | Motor driver power supply | |
| 12,13 | OUTB | O | Motor driver output terminal | |
| 14 | INA | I | Control signal input terminal | |
| 15 | INB | I | Control signal input terminal | |
| 16 | SEL | I | Select signal input terminal | 100kΩ Pull-up |
| EP | PGND | P | Power ground terminal | Exposed Pad |

Note 1. I (Input terminal), O(Output terminal) and P (Power terminal)

■ Terminal Equivalent Circuit

| Pin name | Name | Functions | Equivalent Circuits |
|--------------|--------------|---|---------------------|
| 6 | VC | Control power supply | |
| 7 | VIO | Power supply for logic input | |
| 10,11 | VM | Motor driver power supply | |
| 1 | PSAVEB | Logic input (Built-in pull-down resistor) | |
| 16 | SEL | Logic input (Built-in pull-up resistor) | |
| 14 15 | INA INB | Control signal input | |
| 8,9 12,13 | OUTA OUTB | Motor driver output | |
| 3 4 | VG CH | Connect terminal of charge pump output capacitor Connect terminal of charge pump capacitor | |

| Pin name | Name | Functions | Equivalent Circuits |
|----------|--------------|---|---|
| 5 | CL | Connect terminal of charge pump capacitor |  |
| 2 EP | DGND PGND | Ground terminal Power ground terminal |  |

7. Absolute Maximum Ratings

| Parameter | Symbol | min | max | Unit | Note |
|--|-------------|------|-------------------|------|---|
| Control power supply voltage | VC | -0.5 | 6 | V | |
| Logic terminal supply voltage | VIO | -0.5 | 6 | V | |
| Motor driver power supply voltage | VM | -0.5 | 19 | V | |
| VC, VIO level terminal voltage (PSAVEB, SEL, INA, INB, CL) | Vterminal1 | -0.5 | 5.5 | V | |
| VM level terminal voltage (OUTA, and OUTB) | Vterminal2 | -0.5 | 19 | V | |
| VG, CH terminal voltage | Vterminal3 | -0.5 | 25 | V | |
| Maximum DC output current | IloadcMD | - | 1.3 | A | OUTA and OUTB terminal |
| Maximum peak output current | IloadpeakMD | - | 2.2 3.3 5.0 | A | OUTA and OUTB terminal Under 10ms in 200ms Under 5ms in 200ms Under 2ms in 200ms |
| Power dissipation | PD | - | 2083 | mW | (Note 4) Ta=25°C |
| | | - | 1083 | mW | (Note 4) Ta=85°C |
| Operating Temperature range | Ta | -30 | 85 | °C | |
| Junction temperature | Tj | - | 150 | °C | |
| Storage temperature | Tstg | -65 | 150 | °C | |

Note 2. All above voltage is defined to VSS (DGND/PGND terminal voltage)

Note 3. Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the products on the verge of suffering physical damages, and therefore products must be used under conditions that ensure that the absolute maximum ratings are not exceeded.

Note 4. When 2-layer board is used, this is calculated RθJ=60°C/W. EP terminal should be connected to ground.

Note 5. Input terminal does not work until input logic terminal power supplies VIO, and is handled as “L” fixation.

Note 6. The each power supply of VM, VC and VIO is sequence-free.

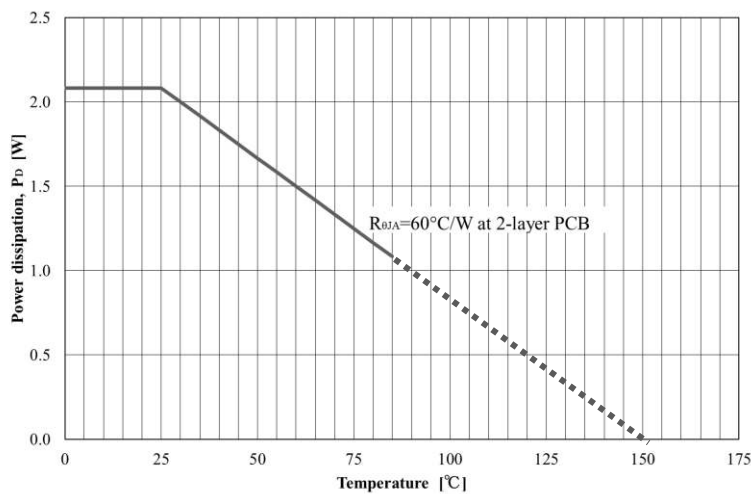


Figure 2. Power Dissipation

8. Recommended Operating Conditions

| Parameter | Symbol | min | typ | max | Unit |
|-----------------------------------|--------|------|---------|-----|------|
| Control power supply voltage | VC | 2.7 | 3.3 | 5.5 | V |
| Logic terminal supply voltage | VIO | 1.62 | 1.8/3.3 | VC | V |
| Motor driver power supply voltage | VM | 2.0 | - | 18 | V |
| Input frequency range | Fin | - | - | 200 | kHz |

9. Electrical Characteristics

(Ta=25°C, VM=15V, VC=3.3V and VIO= 3.3V, unless otherwise specified.)

| Parameter | Symbol | Test conditions | min | typ | max | Unit |
|--|---|---|------|------|------|------|
| Charge pump | | | | | | |
| Charge pump voltage | VG | VG=VC+VM | 18.0 | 18.2 | 18.3 | V |
| Charge pump wake up time | t _{VG} | VG=VC+VM-0.3V | 0.1 | 0.36 | 3 | ms |
| VDET1 | | | | | | |
| VC under voltage detect voltage | VC _{DETLV} | | 1.9 | 2.2 | 2.5 | V |
| TSD | | | | | | |
| Thermal shut down temperature (Note 7) | T _{DET} | | 150 | 175 | 200 | °C |
| Temperature hysteresis (Note 7) | T _{DETHYS} | | 20 | 30 | 40 | °C |
| Quiescent current | | | | | | |
| VM quiescent current at no power | I _{VMNOPOW} | VC=0V | - | - | 1 | μA |
| VM quiescent current at standby | I _{VMSTBY} | PSAVEB="H", SEL="H", No load | - | 16 | 50 | μA |
| VC quiescent current at standby | I _{VCSTBY} | PSAVEB="H", SEL="H", No load | - | 150 | 400 | μA |
| VC quiescent current at power save | I _{VMPSAVE} | PSAVEB="L", SEL="H" | - | - | 1 | μA |
| VC quiescent current at PWM operation | I _{VCPWM} | f _{pwm} =200kHz | - | 0.5 | 0.8 | mA |
| Motor Driver | | | | | | |
| Driver on resistance (High side or Low side) | R _{ON1} | VC=3.3V, Iload=100mA Ta=25°C | - | 0.19 | 0.27 | Ω |
| Driver on resistance (High side or Low side) (Note 7) | R _{ON2} Design certification | VC=3.3V, Iload=1.0A Ta=25°C (Equivalent Tj=50°C) | - | 0.21 | 0.29 | Ω |
| Driver on resistance (High side or Low side) (Note 7) | R _{ON3} Design certification | VC=3.3V, Iload=1.0A Ta=85°C (Equivalent Tj=115°C) | - | 0.25 | 0.35 | Ω |

| Parameter | Symbol | Test conditions | min | typ | max | Unit |
|--|--------------|--|-------------|------|-------------|------------|
| Body diode forward voltage | V_{FMD} | $I_F=100mA$ | - | 0.8 | 1.2 | V |
| H-Bridge propagation delay time ("L"→"L") (Note 8) | t_{PDLHB} | SEL="L", tr=tf=10ns | - | 0.10 | 0.5 | μs |
| H-Bridge propagation delay time ("H"→"H") (Note 8) | t_{PDHHB} | | - | 0.35 | 1.0 | μs |
| H-Bridge propagation delay time (HiZ→"H") | t_{PDZHHB} | | - | 0.15 | 0.5 | μs |
| H-Bridge propagation delay time ("H"→HiZ) | t_{PDHZHB} | | - | 0.15 | 1.0 | μs |
| H-Bridge propagation delay time ("H"→"L") (Note 8) | t_{PDHLHB} | SEL="H", tr=tf=10ns | - | - | 1.0 | μs |
| H-Bridge propagation delay time ("L"→"H") (Note 8) | t_{PDLHHB} | | - | - | 1.0 | μs |
| H-bridge output puls width | t_{PWOHB} | PWL=1.0us, tr=tf=10ns | 0.6 | 0.9 | - | μs |
| Control logic | | | | | | |
| Input "H" level voltage (INA, INB, SEL, PSAVEB) | V_{IH} | VIO=1.6V~5.5V | 0.7× VIO | - | - | V |
| Input "L" level voltage (INA, INB, SEL, PSAVEB) | V_{IL} | | - | - | 0.3× VIO | V |
| Input "H" level current (INA, INB, SEL) | I_{IH} | VIO=1.6V~5.5V | - | - | 1 | μs |
| Input "L" level current (INA, INB, PSAVEB) | I_{IL} | | -1 | - | - | μs |
| Input terminal pullup register (SEL) | R_{PU} | | 50 | 100 | 200 | k Ω |
| Input terminal pulldown register (PSAVEB) | R_{PD} | | 50 | 100 | 200 | k Ω |
| VIO input "H" level voltage (VIO) | VIO_H | VC=3.3V, VM=15V, INA="H", INB="L", VIO: 0V => 1.1V | 1.1 | - | - | V |
| VIO input "L" level voltage (VIO) | VIO_L | VC=3.3V, VM=15V, INA="H", INB="L", VIO: 3.3V => 0.3V | - | - | 0.3 | V |

Note 7. Not tested under mass-production.

Note 8. Refer [Figure 3](#).

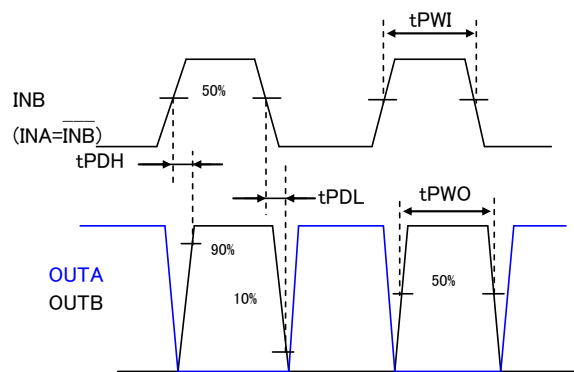


Figure 3. Time chart of propagation of delay time and pulse width (CL=100pF, RL=1kΩ)

10. Descriptions

10.1. Control Logic

The relations of the input and output of each mode are as follows.

Table 1. Input and Output relations

| PSAVEB | SEL | Input | | Output | | Motion |
|--------|-----|-------|-----|--------|------|---------------------|
| | | INA | INB | OUTA | OUTB | |
| H | L | L | L | Hi-Z | Hi-Z | Standby (Idling) |
| H | L | L | H | L | H | Reverse |
| H | L | H | L | H | L | Forward |
| H | L | H | H | L | L | Break (Stop) |
| H | H | L | X | L | L | Break (Stop) |
| H | H | H | L | H | L | Forward |
| H | H | H | H | L | H | Reverse |
| L | X | X | X | Hi-Z | Hi-Z | Power save (Note 9) |

Note 9. TSD/UVLO/VREF/OSC/Charge pump are shut down.

Note 10. Input terminal is handled as Low fixation when VIO is not input power, OUTA/OUTB are Hi-Z condition.

10.2. Basic Architecture of the Motor Driver

The AP1013DEN places N-channel LD MOSFET on both sides of high side and low side in the output circuit and realize small package. High side MOSFET is driven by VG. $VG=VM+VC$ is generated with a charge pump. VG reaches the targeted level at the time of the charge pump setup within 0.36ms (typ). Low side MOSFET is driven by VC.

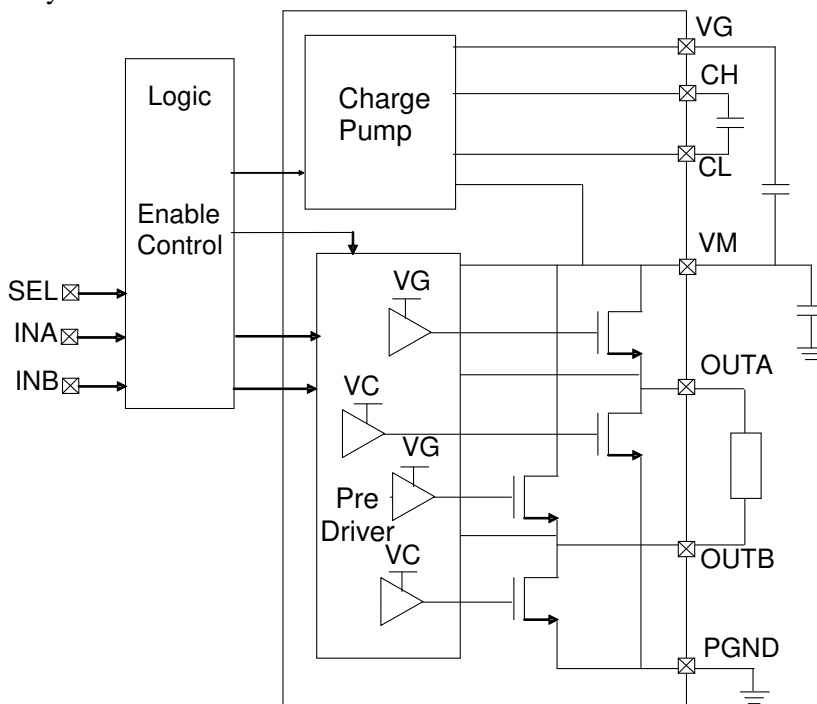


Figure 4. Motor driver part equivalent circuit

The OSC block supplies a drive pulse to a charge pump. The logic of input interface is operated by logic power supply VIO. The input interface does not work until VIO is input, and handled as “L” fixation.

10.3. Protection Circuits

The AP1013DEN has penetration current prevention, thermal shut down and under voltage detection circuits.

- Penetration current prevention circuit

MOSFET turns off both of high side and low side during the dead time period when penetration current prevention circuit operates. During this period, either body diode is turn on depends on the direction of the current. Figure 5 shows an example when the AP1013DEN drives the output from “L” to “H” in. (a) shows the case that current flows from external load to the AP1013DEN, (b) shows the case that current flows from the AP1013DEN to external load

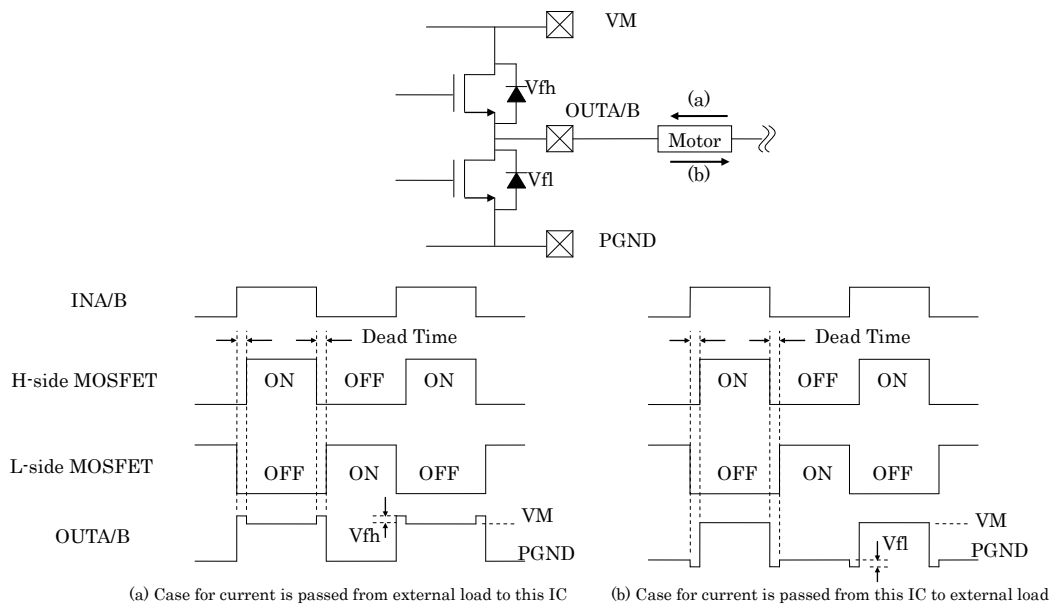


Figure 5. Difference in output terminal by load current direction

- Thermal Shut Down

The AP1013DEN prevents destruction due to the self-heat up by making OUTA and OUTB output Hi-Z as soon as abnormal high temperature is detected. The AP1013DEN restarts as soon as temperature becomes lower than the bottom detection threshold.

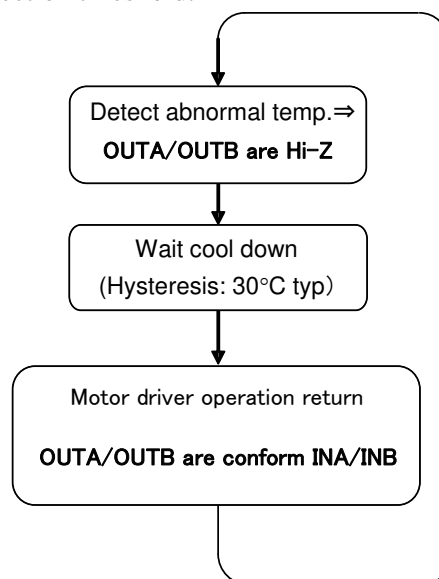


Figure 6. Detection of abnormal heat up and return operation

11.Recommended External Circuits

■ Recommended External Circuit

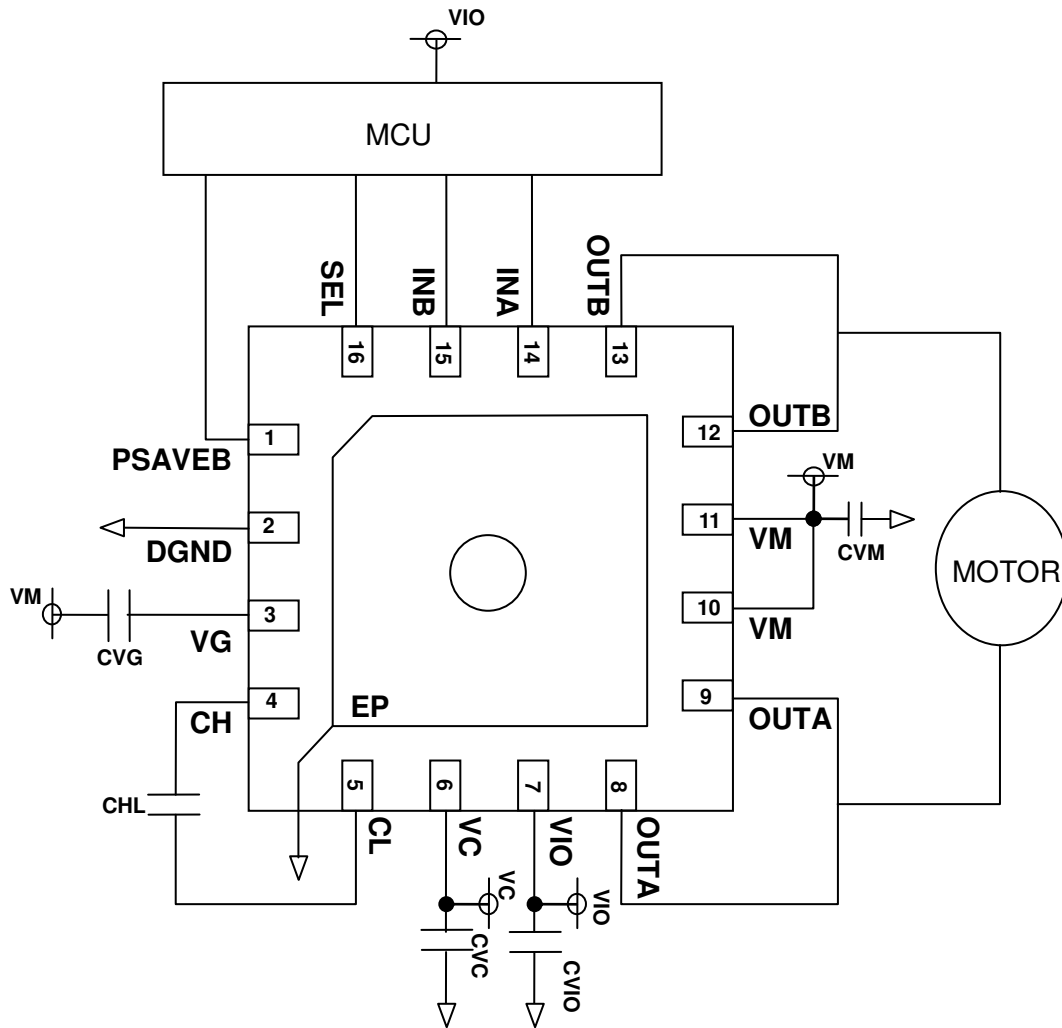


Figure 7. Recommended External Circuit

■ Parts List

Table 2. Recommended external components

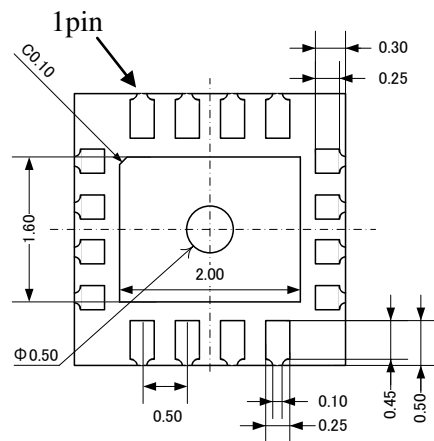
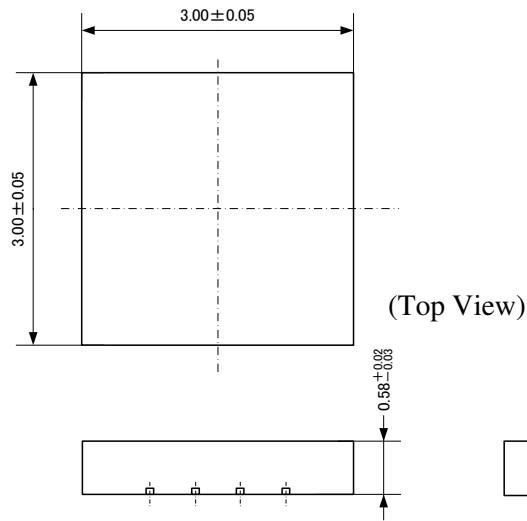
| Items | Symbol | min | typ | max | Unit | Note |
|---|--------|-------|-----|------|------|-----------|
| Motor driver power supply connection decoupling capacitor | CVM | 1.0 | - | - | uF | (Note 11) |
| Control power supply connection bypass capacitor | CVC | 0.1 | 1.0 | - | uF | (Note 11) |
| Logic input terminal power supply connection bypass capacitor | CVIO | 0.1 | 1.0 | - | uF | (Note 11) |
| Charge pump capacitor1 | CVG | 0.047 | 0.1 | 0.22 | uF | |
| Charge pump capacitor2 | CHL | 0.047 | 0.1 | 0.22 | uF | |

Note 11. Please adjust the connecting capacitor of CVM, CVC and CVIO depending on the load current profile, the load capacitance, the line resistance and etc. with each application boards.

12. Package

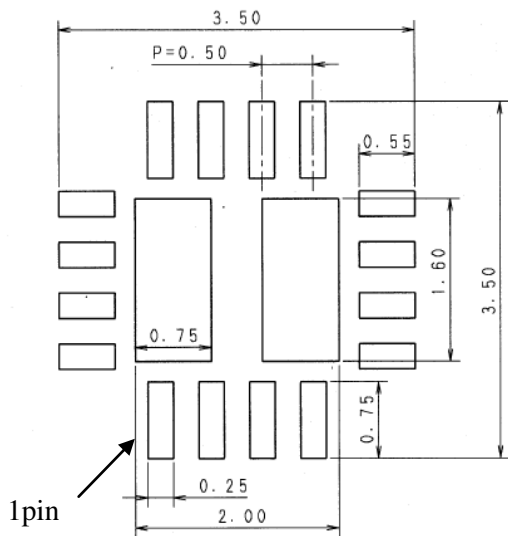
■ **Outline Dimensions**

• 16-pin QFN(Unit: mm)



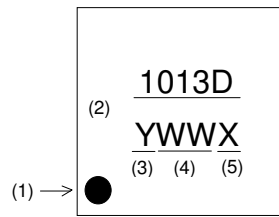
Note) The Exposed Pad is Power Ground.
The Exposed Pad is necessary soldered to PCB.

■ **Reference Foot Pattern**



Note) Please layout the foot pattern of Exposed Pad not to surround the steam beer of AP1013DEN. Please locate thermal via more than four for improve radiation.

■ **Marking**



- (1) Ipin Indication
- (2) Market No.
- (3) Year code (last 1 digit)
- (4) Week code
- (5) Management code

13. Revise History

| Date (YY/MM/DD) | Revision | Page | Contents |
|--------------------|----------|------|---------------|
| 14/11/27 | 00 | - | First edition |

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