# Development of Micro-Step Driver for 5-Phase Stepping Motors

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## 1. Introduction

Stepping motors are used as a generic actuator system in a wide range of applications including semiconductor fabrication systems, OA equipment, food processing machines, and embroidery machines. Particularly where semiconductor fabrication systems are concerned, there is a growing demand for the micro-division control driven by the low vibration stepping motor, and by micro-step as the wafer becomes larger and the fine processing technology advances further.

The micro-step driver has been developed to address the following issues.:

(1) Need for a control system to reduce vibration the stepping motor encounters in the mid-speed mode and during the descent of the vertical axis, both of which are the inherent characteristics of the stepping motors.

(2) Need for replacements for other actuators such as pneumatic valve or solenoid valve to reduces the number of components and size.

To satisfy these needs, we have developed a small micro-step driver for DC power supply, a hybrid IC (hereafter referred to as "HIC"), which is a micro-step, low vibration control ASIC, power bridge, current control unit, and ASIC integrated into one.

This article outlines the product and describes its features.

## 2. Product Overview

### 2.1 Development Concept

[5-phase pentagon-wired low vibration control technology]

To reduce the resonance in the mid-speed mode and vibration during the descent of vertical axis under light load, which were the drawbacks to the stepping motor.

(1) HIC ⋯ PMM5310 All-in-One type

Should incorporate main components such as ASIC, power bridge and detection resistor with fewer components used than Sanyo Denki's existing PMM530* system.

(2) ASIC ⋯ PMM7002 Micro-step control

Capable of micro-step control for 2-, 3-, and 5-phase stepping motors from microcomputer via external data bus.

### 2.2 New Products

The new products we have developed are HIC and ASIC and 2 models of 5-phase small micro-step drivers with these mounted on them. Fig. 1, and 2 are their appearance, respectively.

(1) HIC ⋯⋯⋯⋯ PMM5310          See Fig. 1
           (ASIC PMM7002 built in)

(2) ASIC ⋯⋯⋯⋯ PMM7002          See Fig. 1
           (64-pin gate array)

(3) DC power supply driver          See Fig. 2
    (a) Multi-feature type
        PMDPC1S3P01        (HIC PMM5310 installed)
    (b) Small high performance type
        PMDPD1S1P01        (ASIC PMM7002 installed)



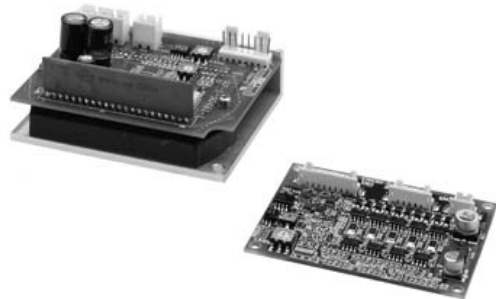Fig. 1    PMM5310 and PMM7002



Fig. 2    PM drivers

PMDPC1S3P01 (left) / PMDPD1S1P01 (right)

## 3. Features/Performance

### 3.1 Low Vibration /Micro-step Control

Motor vibration is reduced by changing from the conventional 5-phase one-batch current control method to the individual-phase current control method.

(1) Reducing the size and the number of components for excitation and regeneration current detection circuit.

(2) Circuits such as current control PWM, current command, high-speed torque control, input and pulse distribution circuits integrated on one chip

### 3.2 Toward Smaller Products with Fewer Components

(1) All-in-one type HIC
    Power bridge, detection resistor, control ASIC, oscillator integrated in one HIC

(2) Component layout and packaging density optimized

(3) Single-control power supply
    We have achieved gate drive supply voltage of 5V.

## 3.3 Performance and Features of the Products

Following is the description of performance and features of the new products.

### (1) HIC PMM5310

As mentioned above, integrating all the circuits into one HIC has eliminated the need for the external components required by existing products.

Table 1 compares the number of external components required by new and old products.

Table 1   Comparison of Number of External Components in New and Old Product

| | | New product PMM5310 | Old product PMM5301 |
|---|---|---|---|
| Power supply | Main body | PMM5310 | PMM5301 |
| | Power supply | 2-line Main, 5V | 3-line Main, 5V, 12V |
| | External components | None | Coil --- 1 Capacitor --- 1 Power diode --- 3 Detection resistor --- 2 |
| Control | Main body | None (Built-in ASIC) | PMM7001 --- 1 |
| | External component | None | Oscillator --- 1 |
| External dimensions(mm) | | 78×44×8.5 | 78×32×8.5 |
| Heat generation | | 20% reduction | |

(NOTE) 9 components eliminated

### (2) ASIC PMM7002

The input pulse distribution circuit, newly developed current detection circuit, and micro-step control circuit have been integrated to make the control circuit digital. Further more, the current command table built in for 2-, 3-, and 5- phase stepping motors and the external data bus installed provide easier access to the current command, allowing easier low vibration micro-step control of the serial interface position command type driver (such as DeviceNet, RS485 interface) as well as pulse command.

### (3) Built-in 2-, 3-, and 5-phase micro-step function

The current command table memory and memory access circuit were required for micro-step control before. These circuits have been integrated into this one ASIC. Combining the ASIC with the power circuit, allows any drive system to be built to suit the input power specifications, and required capacity for 2-, 3-, and 5-phase system.

### (4) DC power supply input type micro-step driver

Integrating HIC and ASIC, two pulse input type models have been developed.
    (a) PMDPC1S3P01
    With the newly developed HIC PMM5310 built in, this driver is built drastically smaller than any existing driver.
    * Volume ratio
    Some 50% less than the volume of the existing PMM-MD-53030
    (b) PMDPD1S1P01

With the newly developed ASIC PMM7002 built in, this is the smallest card micro-step driver, unmatched by any other Sanyo Denki product. Used in combination with 28mm × 28mm, or 42mm × 42mm sq. small motor, this driver provides a compact system.
The specifications of these drivers are given in Table 2.

Table 2   Driver Specifications

| Item | | PMDPC1S3P01 Low vibration multi-feature type | PMDPD1S1P01 Small high per-formance type |
|---|---|---|---|
| External dimen-sions (mm) | New product | 82×64×33 | 72×56×10 |
| | Existing product | 100×70×53 | No existing product |
| Power supply | | 24VDC | 24VDC/12VDC |
| Current setting | | 100 % - 55% rating | Fixed to rating |
| Number of micro-step divisions | | 10 different number of divisions 1,2,2.5, 4, 5, 8, 10, 20, 40, 80 | |
| Pulse input system | | 2-input CW, CCW 1-input CK, UD | 2-input CW, CCW |
| Input signal interface | | Photocoupler input Max. Input frequency 400Kpps | |

## 3.4 Vibration Performance

Fig. 4 and 5 show the effect of the low vibration control by the new HIC. The vibration performance using the position command type DeviceNet interface driver of the new product and existing product were compared.
.
Fig. 3 outlines the evaluation method used to evaluate the characteristics during the descent of the vertical axis (associated with ball screw load ) where vibration is likely to occur.

### (1) Reducing vibration during the descent of the ball screw load ····· See Fig. 4

The existing product experiences a negative torque during the descent, causing resonance in the mid-speed mode of the stepping motor, making it necessary to use a motor damper or to optimize the motor coil constant. In sharp contrast, it is evident that the new product's vibration is reduced significantly.

### (2) Reducing vibration through low vibration control in the low speed mode ····· See Fig. 5

Combined use of the accessibility to the external data bus and low vibration control provided by software proves to be more effective in reducing vibration at half-step drive than the existing product.

The new product not only provides a solution to the problem of vibration associated with ball screw load, which it can reduce significantly, but also realizes smooth driving in the low speed mode.
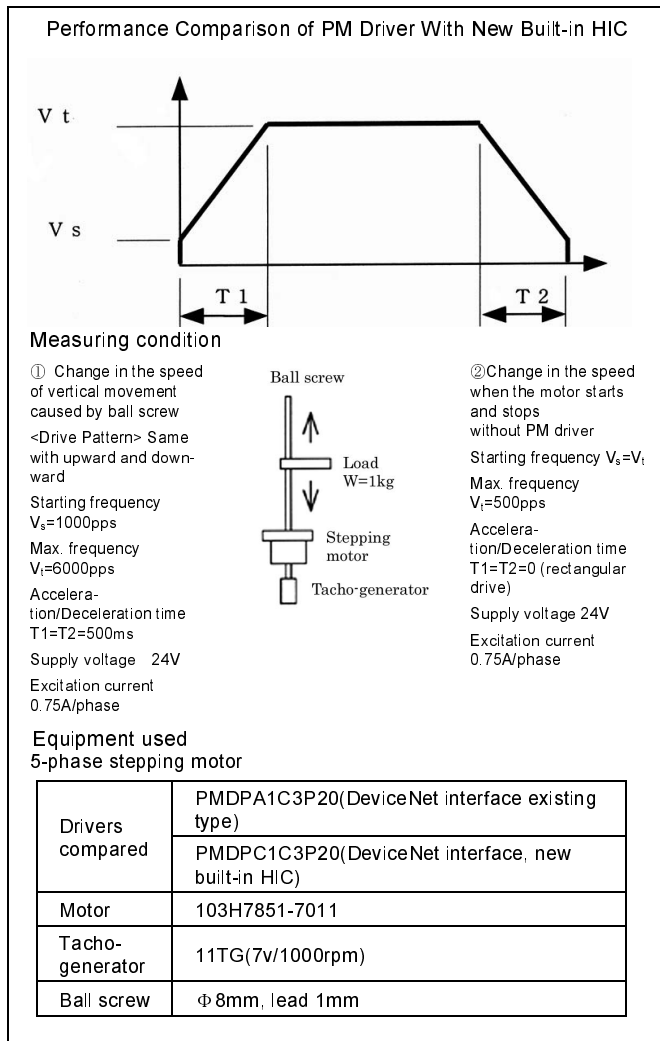
## Performance Comparison of PM Driver With New Built-in HIC



Vt

Vs

T1    T2

**Measuring condition**

① Change in the speed of vertical movement caused by ball screw

<Drive Pattern> Same with upward and downward

Starting frequency $V_s$=1000pps

Max. frequency $V_t$=6000pps

Acceleration/Deceleration time T1=T2=500ms

Supply voltage 24V

Excitation current 0.75A/phase

Ball screw

Load W=1kg

Stepping motor

Tacho-generator

②Change in the speed when the motor starts and stops without PM driver

Starting frequency $V_s$=$V_t$

Max. frequency $V_t$=500pps

Acceleration/Deceleration time T1=T2=0 (rectangular drive)

Supply voltage 24V

Excitation current 0.75A/phase

**Equipment used**
**5-phase stepping motor**

| Drivers compared | PMDPA1C3P20(DeviceNet interface existing type) |
|---|---|
| | PMDPC1C3P20(DeviceNet interface, new built-in HIC) |
| Motor | 103H7851-7011 |
| Tacho-generator | 11TG(7v/1000rpm) |
| Ball screw | Φ8mm, lead 1mm |

**Fig. 3    Vibration Comparison Measurement Condition**

Existing product          New product
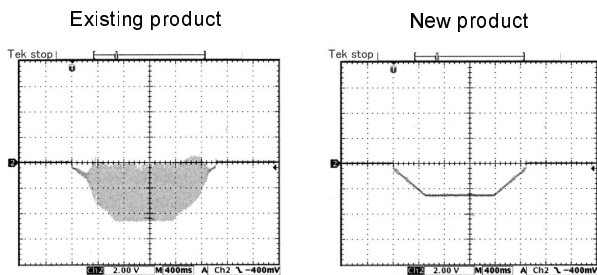


**Fig. 4    Mid-Speed mode Vibration Comparison (6000pps at half step)**
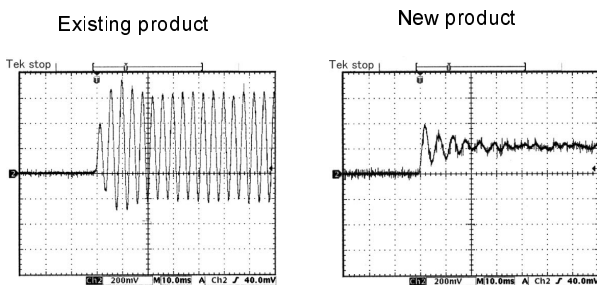
Existing product          New product



**Fig. 5 Low-Speed mode Vibration Comparison (500pps at half step)**

## 4. Conclusion

We have described the HIC, ASIC, and the drivers that incorporate them that have been developed to meet the demand for smaller stepping motors with low vibration.

We believe these new products satisfy the need for a 5-phase stepping motor with lower vibration.

(1) Future development of HIC PMM5310
   (a) With the number of external components reduced, it can support small multi-axis drivers. Working toward a product line with each product customized and value-added to reflect specific customer needs.
   (b) Exploring the markets for OA equipment such as printers and copiers.
   (c) Improving the performance of position-command type (serial interface)

(2) Future development of ASIC PMM7002
   (a) Reducing the size and cost of AC power supply driver
   (b) Strengthening the product line of 3-phase step drivers
   (c) Reducing the size of 2-phase micro-step driver

With the new DC power supply type driver, HIC, and ASIC, we will continue to be able to offer customized and high-performance drivers that satisfy the market needs.

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