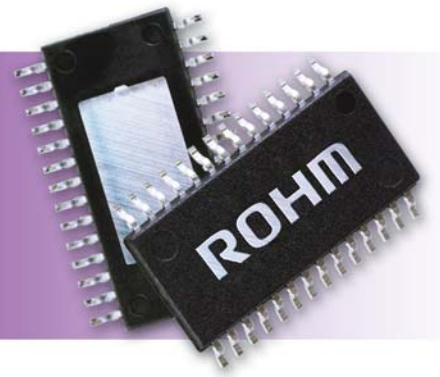




*Innovations Embedded*

## Selecting Stepper Motor Drivers for Optimum Performance



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## Introduction

By rotating in discrete angular increments, stepping, stepper or simply step motors provide a more precise solution for many motion control and measurement applications, especially when the appropriate driver technology is used. In addition to forward, reverse, braking and speed control functions, stepper motors have the ability to implement motion control in very fine increments for high precision. According to recent estimates, stepper motors represent about 17% of the total worldwide market for motor drivers.

As a special class of brushless DC motors or AC synchronous machines, stepper motors have advantages of long life and precise control. Stepper motors include permanent magnet and variable reluctance classes of brushless motors, as well as a hybrid classification with operating principles of both permanent magnet and variable reluctance designs. The hybrid has the ability to achieve very high resolution.

In addition to their ability to respond to digital input pulses, stepper motors' typical advantages over other motor designs include:

- A rotational angle directly proportional to the input pulses;
- Full torque at standstill when the windings are energized;
- Precise positioning;
- Repeatability;
- Excellent response to starting, stopping and reverse commands and more

Popular applications for stepper motors include: printers, copiers, scanners and other office machines that require precise motor movement as well as security cameras, sewing machines, factory automation and robotics.

## Basic Operational Principles of Stepper Motors

Unlike servo motors, stepper motors can be accurately controlled with open-loop operation eliminating the need for position sensing and an error amplifier. Major design differences for stepper motors include the number of phases and poles as well as stepping angle. Common design classifications include unipolar, bipolar and bifilar to identify different winding per phase combinations. For example, a unipolar motor has one winding per phase with a center tap for each phase. In contrast, a bipolar motor with two phases has one winding per phase. Figure 1 shows the differences.

Stepper motors with bifilar windings have rotor and stator designs similar to bipolar motors except that each winding consists of two wires wound parallel to each other – wound in parallel but wired in series. A common bifilar motor has eight wires and can be driven as either a bipolar or unipolar motor.

To reduce ripple torque, additional phases are added to stepper motors. In addition to the most common two-phase motors, three and five-phase designs are also available. (Note: a unipolar stepper motor is sometimes referred to as a four-phase motor.) For an example of the design impact, typical two-phase, 0.9-degree step-motor designs use eight or 16 stator poles and typical five-phase motors use 10 stator poles.

The increased number of power drivers—10 transistors for the five-phase driver versus eight power transistors to switch the phases of the two-phase driver—increases the driver cost and generates additional heat. Newer stepper driver techniques allow two-phase motors to be used in applications that previously required a five-phase design.

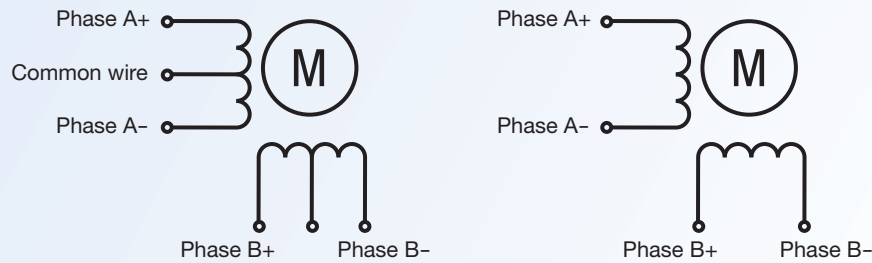


Figure 1. In contrast to the bipolar design (right), the unipolar stepper motor (left) has a center tapped winding.

The number of rotor and stator poles create teeth that determine the resolution of the stepper motor. The step angle for a stepper motor with an equal rotor and stator tooth pitch is given by:

$$\text{Step angle} = 360 \div (N_{\text{Pn}} \times \text{Ph}) = 360/N$$

Where:

$N_{\text{Pn}}$  = Number of equivalent poles per phase = number of rotor poles;

Ph = Number of phases;

N = Total number of poles

A permanent magnet design with 12 poles and two phases (a total of 24 poles) has a full step angle of 15 degrees.

## Stepper Motor Driver Considerations

Popular operating modes for stepper motors include wave drive, full stepping, fractional stepping and microstepping. Unlike wave drive, where one phase is on, full-step drive where two phases are on, or half-step drive where one and two phases are on, a quarter-step drive uses special sequencing for stator phases in hybrid stepper motor designs with poles that are offset by one-quarter of a tooth.

Microstepping employs continuously varying motor currents. One eighth, one tenth, one twelfth and one sixteenth are common microstepping classifications. In addition to increased resolution, microstepping helps suppress low-speed resonance.

With four windings, stepper motors can have four, six or eight connections. Four-wire connections have two windings in series. Six-wire connections add a common connection between the windings. This allows the motor to be connected either half-winding (center tap to one winding of each section or full-winding, similar to the four wire connection). Half-winding uses half of the normal current. Eight-wire motors can be connected either in series or parallel. The series connection makes the motor similar to the full winding, six-wire design. The parallel connected eight-wire motor is about 3% more efficient than a half-winding connected six-wire motor.

Key operating characteristics for stepper motors include:

- Speed
- Torque and torque ripple
- Precision (resolution)
- Vibration/noise/resonance
- Drive voltage
- Drive current
- Position accuracy

The addition of an encoder or resolver to a stepper motor creates a so-called pseudo-servo. The stepper motor can still operate open loop, but has the capability to function in closed loop and avoid getting out of step. This type of stepper motor design solves the oscillating problem commonly found in servo motors.

## Design Considerations for Selecting a Stepper Motor Driver: ROHM Semiconductor Solutions

Stepper motor drivers ultimately are just special power management solutions, similar to the way the LED driver is to solid state lighting. As such, stepper motor drivers are an important part of ROHM's power management IC portfolio. Microsteppers are the newest approach to increased performance and the focus of ROHM's and industry R&D efforts. As shown in Figure 2, ROHM's stepper motor drivers address three critical design areas: technology, safety and care. The highlighted text indicates areas where ROHM has demonstrated leadership and product differentiation in stepper motor drivers. ROHM's technology roadmap for stepper motor drivers calls for continued refinement of its established high-density bipolar+CMOS+DMOS (BCD) processing technology using high-voltage BCD for some of the newest stepper motor drivers. These mixed-signal processes combined with efficient DMOS power technology provide the capability for logic interface and efficient power control for advanced topologies in a monolithic design. Improvements in process technology

achieve increasingly lower on-resistance for a given area and reduced saturation voltage levels for increasingly more efficient silicon designs for each successive generation.

As in many other areas of the ROHM product line, packaging is one its strengths. Significant attention is being given to product development with backwards compatibility in mind. Packaging with common form factors and pin-outs within a particular series simplifies the transition from one driver to another in the same series and avoids expensive and time-consuming board level changes.

The use of a backside metal slug located directly under the silicon chip combined with more efficient silicon design and pulse-width modulated (PWM) drive makes the amount of heat generated and its removal much easier. An example of packaging advancement is the transition from a HSOP-M28 package that is 9.9 x 18.5 x 2.2 mm and dissipates 2.2W shown in Figure 3. This package can be replaced with the much smaller HTSSOP-B24, a 7.8 x 7.8 x 1.0 mm design that can handle 4.0W when used with the appropriate board layout.

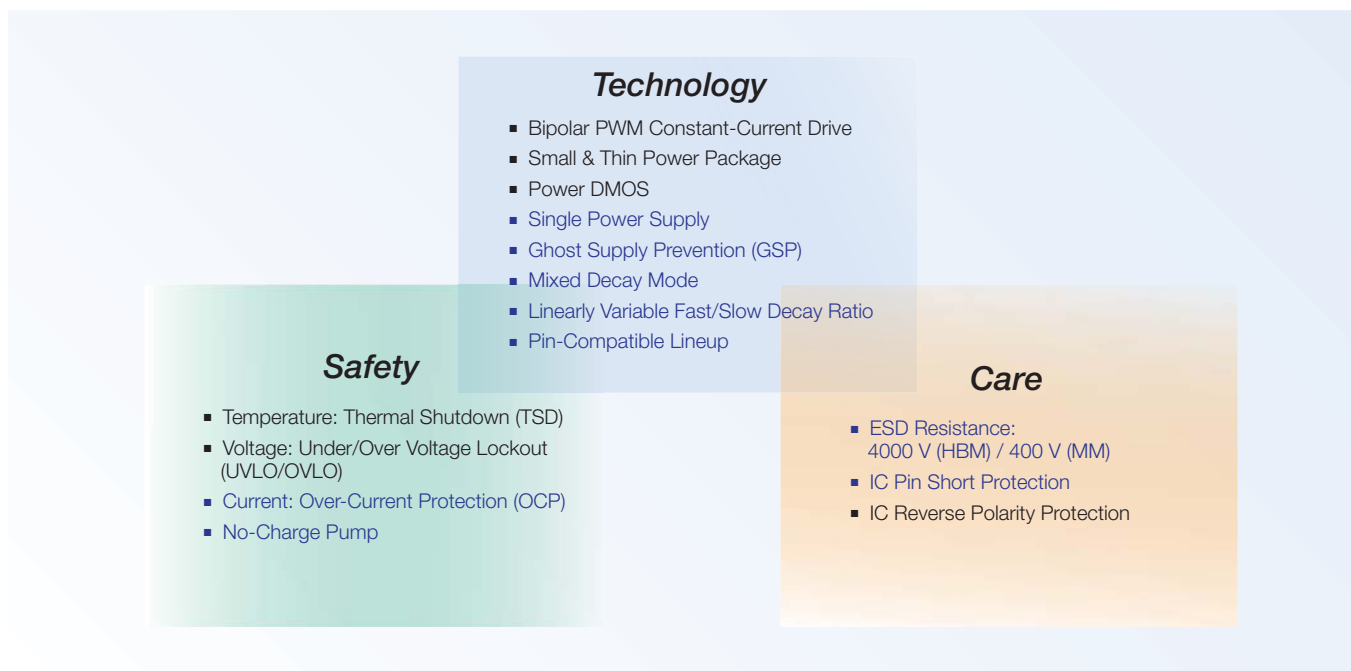


Figure 2. Technology, safety and care form a three-legged stool for ROHM Semiconductor's stepping motor drivers. The blue-colored items are ROHM firsts for stepper motor drivers.

## Additional ROHM Stepper Motor Capabilities

Several other stepper motor driver design features deserve additional consideration, including: added protection and safety circuitry, single power supply, ghost supply prevention (GSP), mixed decay mode and the use of P-channel DMOS high-side switches.

ROHM's ongoing evaluation of failures that occurred in customers' applications has led to the integration of additional protection in the output stage and a high level of ESD protection for circuitry inside the stepper motor driver. These more robust design features reduce or eliminate the most common causes of failure.

ROHM stepper motor drivers are designed to achieve high ESD resistance levels—4000V human body model (HBM) with some products at 8000V capability / 400V machine model (MM)—typically well beyond the requirements of most applications. Overcurrent protection (OCP), rather common in standard power management solutions such as switched mode power supplies and linear regulators, has now been made standard in all of ROHM's stepper motor drivers. IC pin short protection which provides the added benefit of preventing

problems that can occur as a result of adjacent pins shorting out, is also a standard feature on many of ROHM's stepper motor drivers.

ROHM's latch type overcurrent protection provides instantaneous, more reliable protection than a fuse, since it avoids the delay time associated with the I<sup>2</sup>t. An overcurrent situation that is allowed to persist can eventually lead to device failure and motor damage as well. Removing the source of overcurrent and restarting can restore normal operation. In some applications, the OCP feature can eliminate the need for fusing altogether.

Instead of requiring two power supplies, one for logic and one for driver circuitry, most of ROHM's newest stepper motor drivers have an integrated regulator that requires a single source. The single supply reduces the number of external capacitors reducing system cost and simplifying the PCB layout and routing. In addition, this design approach eliminates the need for power-up and power-down sequencing.

Mixed-decay mode and ghost supply prevention (GSP) features address operating characteristics of a circuit that is electrically connected to a motor in a motion control system.

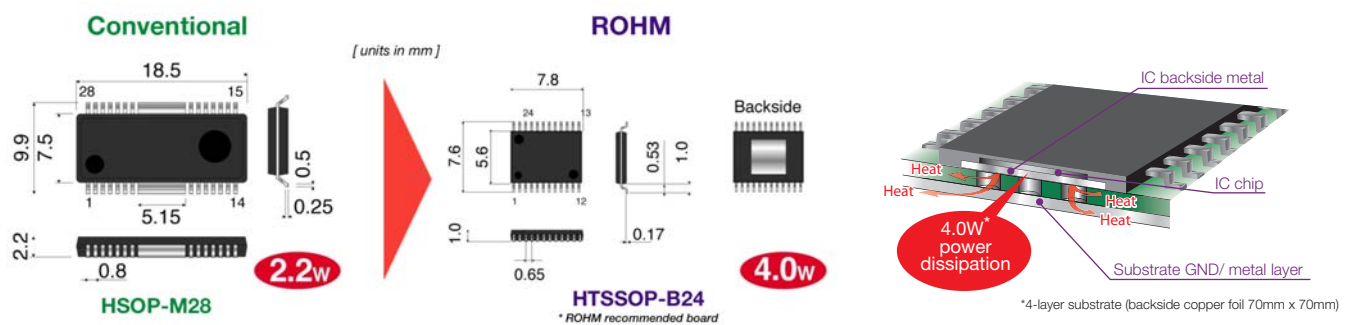


Figure 3. Efficient silicon design combined with advanced power packaging enable smaller footprints that can handle higher power levels.

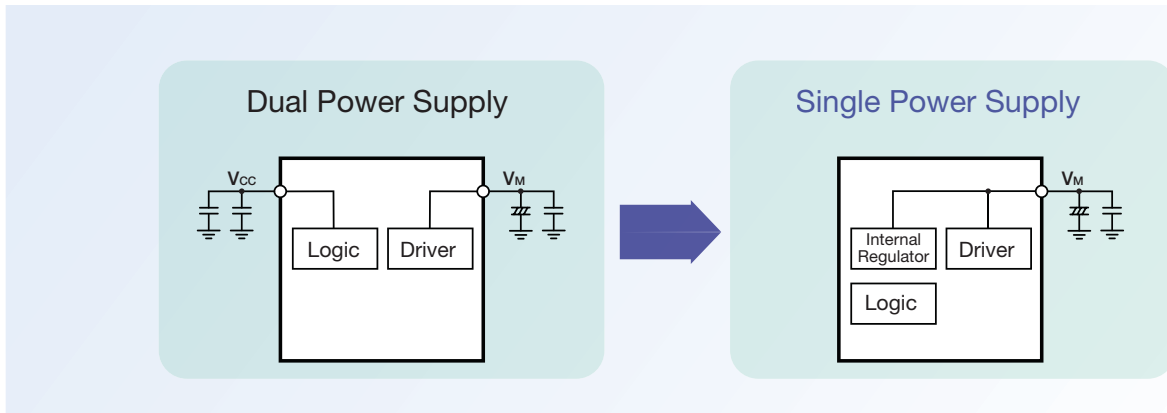


Figure 4. The advantages of a single supply with an internal regulator for the logic circuitry includes fewer additional components. Note: the single supply does not apply to low voltage series products.

External connections can cause inadvertent sourcing or sinking of current that could actuate the stepper motor and cause positioning inaccuracies. ROHM's ghost supply prevention design eliminates erroneous operation the motor driver IC or any other IC connected to the same  $V_{cc}$  supply line. With GSP, the designer can trust that when the circuit is commanded to be off, it truly is off. Residual charge on a capacitor or other extraneous input will not cause an incremental step or erratic/unexpected behavior.

Mixed-decay mode in the driver improves the ability to control the stepper motor. A linearly variable decay (FAST/SLOW) ratio feature avoids a distorted output current during ramp down that can generate noise and cause vibration. As shown in Figure 6, with a slow decay, the step is distorted but V.D.S. (variable decay setting) adjustments can improve the step to a very distinct level. The MTH terminal (on parts possessing this feature) allows the selection of FAST/SLOW/MIX DECAY modes.

With stepper motor drivers, a slow decay in output current is desirable for smooth torque. However, a fast decay output current is required for high-pulse rates and high-speed operation. The mix decay capability allows designers to vary the rate and optimize control based on the motor's characteristics and application requirements.

Reducing vibration created by a noisy waveform can be critically important in sensitive applications such as scanning, where the scanner head needs to move

uniformly across an object or surface without incurring the distortion that can result from jerky motor movement.

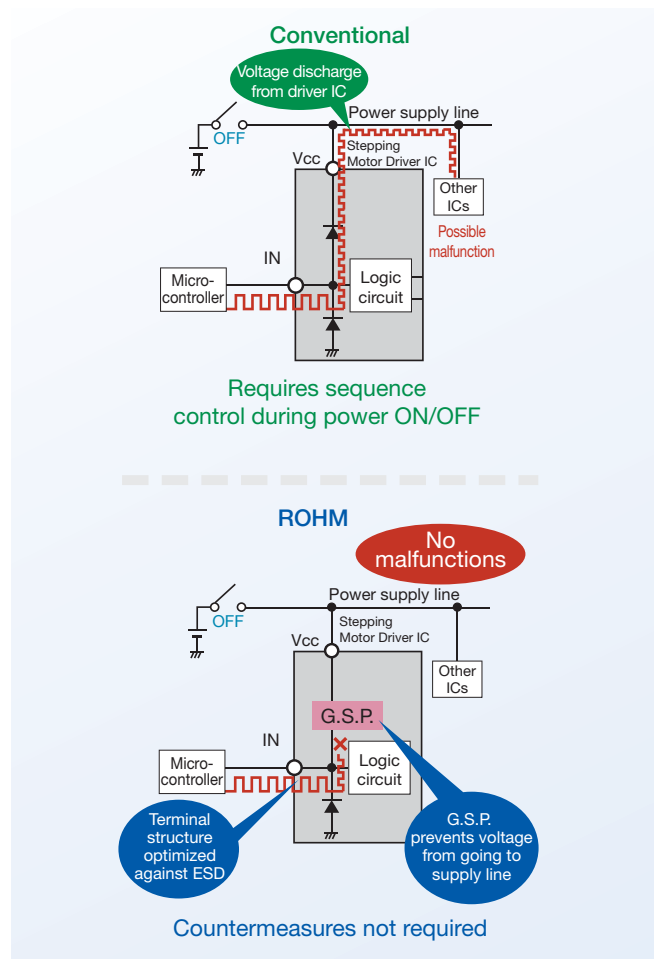


Figure 5. Ghost supply prevention avoids the inadvertent application of power to the stepper motor driver's  $V_{cc}$  supply line that could produce unexpected stepper motor behavior.

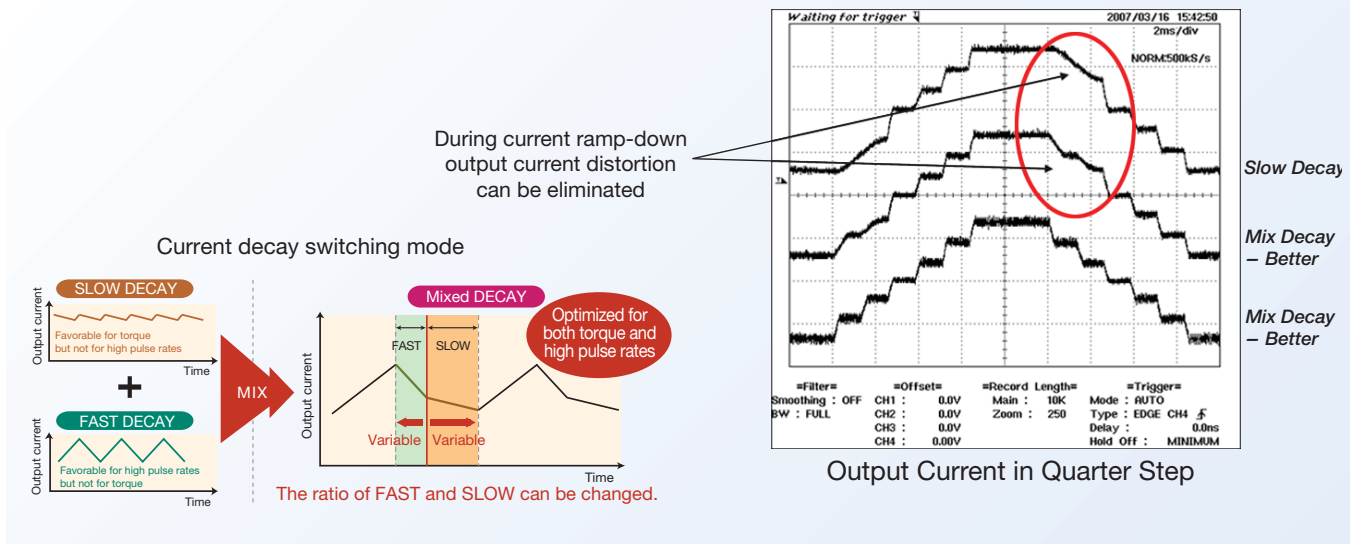


Figure 6. Current decay switching mode can solve noise and vibration problems by optimizing the current ramp down.

With high-side switching, circuit designers have the choice of using N-channel power MOSFETs that require a charge pump with two additional high-voltage electrolytic capacitors to enhance the gate or P-channel MOSFETs. ROHM stepper motor drivers use P-channel high-side switches to eliminate the need for external components and reduce the EMI and efficiency loss associated with charge pump switching.

To summarize, ROHM's stepper motor solutions implement a synchronous rectification / current mode power conversion scheme that is both more efficient than a charge pump and reduces the external component count.

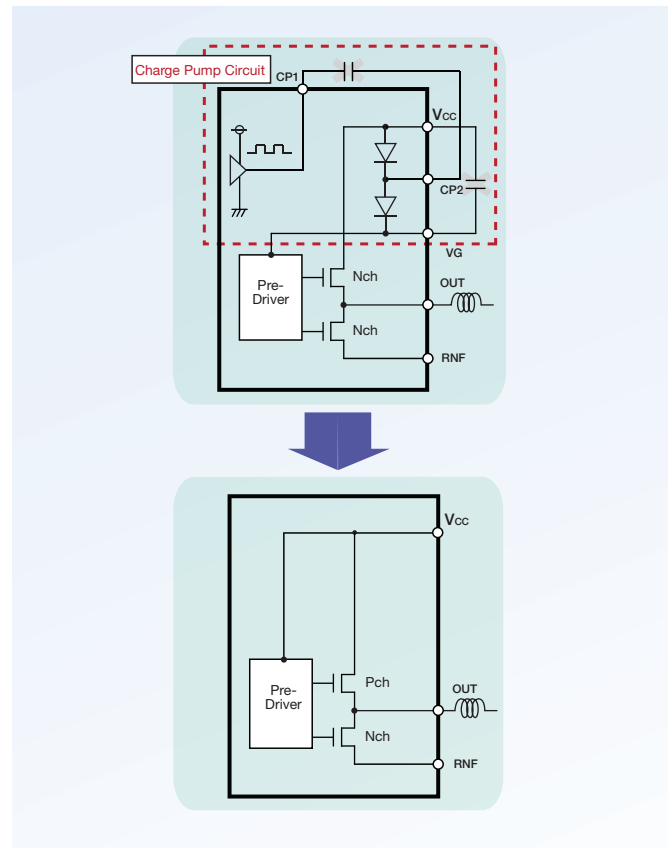


Figure 7. ROHM's use of P-channel DMOS technology in the high-side switches avoids the need for additional charge pump capacitors.

## ROHM Design Examples

ROHM pin-compatible stepper motor drivers provide users both cost savings and design flexibility. Instead of using the highest rated part to cover all applications, when users can accept a lower current solution, they can select a more economical part. Higher current ratings are often available when required and within the same series, they are package and pin compatible. This can provide an alternative when a motor supplier increases the current capability of a motor, or a supplier change occurs and the replacement motor requires more current than the one it replaced, or simply if more horsepower is required in a new design.

ROHM stepper motor driver series include standard, microstep, low voltage and high voltage families with CLK-IN (clock input) or PARA-IN (parallel input) control. For drivers with the CLK-IN feature, a built-in translator allows IC control using a clock signal, which simplifies system design by reducing the number of port connections to an MCU and pc board traces. Figure 8 shows the design simplification that results from the simplified control scheme.

The amount of resolution that a specific application requires is addressed by using full-step (F), half-step (H) or quarter-step (Q) drivers. Microstepping in 1/8th and 1/16th steps can provide even higher resolution. Figure

9 shows the block diagram of ROHM's BD63847EFV 1/16th-step microstepper. This design incorporates all of ROHM's stepper motor driver features including:

- Single 36V supply voltage (Internal Voltage Regulator)
- DMOS Output (Pchannel + Nchannel)
- $I_o$  (max): 2.0 A
- Constant Current PWM Driver
- Serial / CLK-IN with Built-In Translator
- No Charge Pump Required
- Full / Half / Eighth / Sixteenth-Step
- Mixed Decay Mode
- Linearly Variable Fast/Slow Decay Ratio
- Integrated 4-bit DAC
- Ghost Supply Prevention
- Protection Features
- HTSSOP-B28 Package

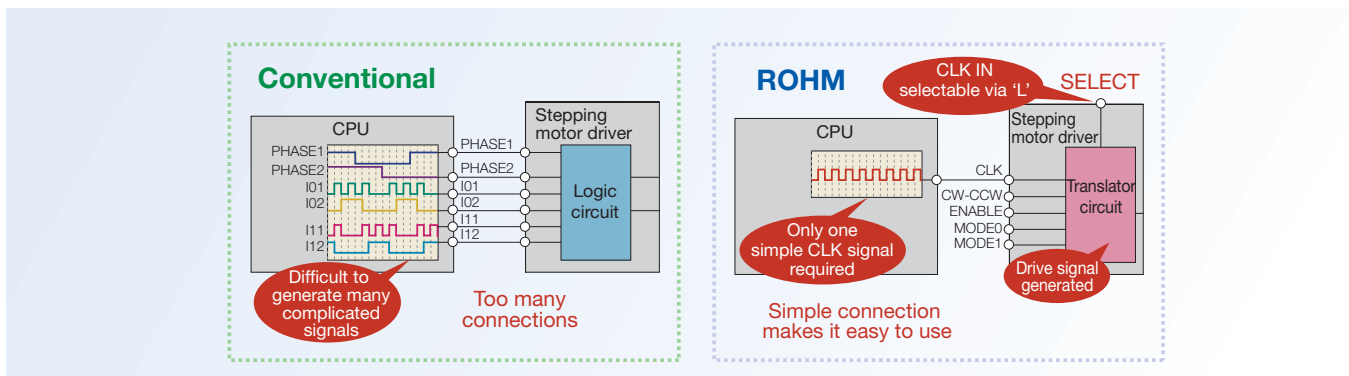


Figure 8. Compared to conventional parallel inputs, CLK-IN circuitry reduces the number of connections required to control the stepper motor.



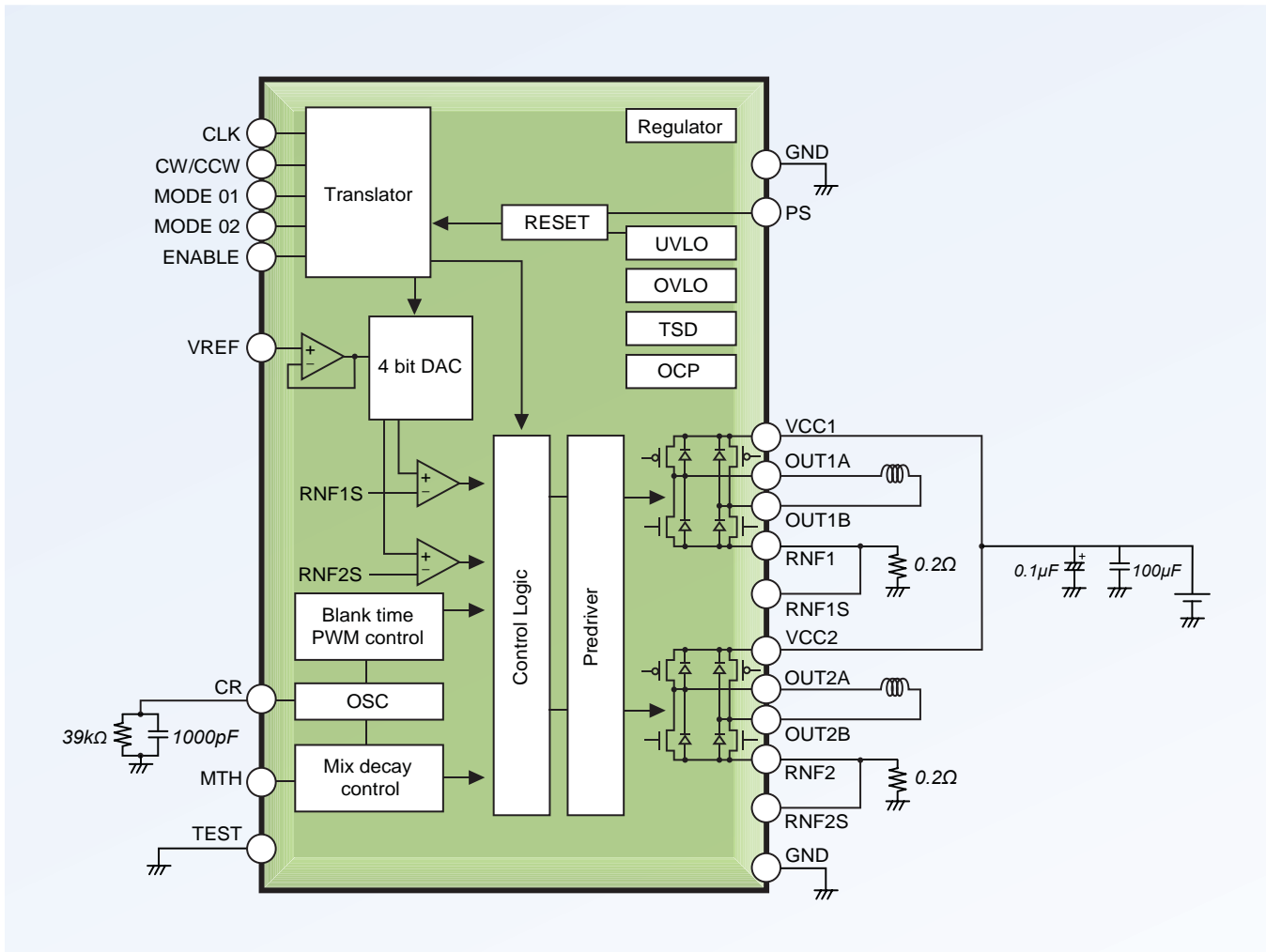


Figure 9. The block diagram of the BD63847EFV demonstrates all of the capabilities of ROHM stepper motor drivers in a microstepping design including CLK-In control.

## Conclusion

ROHM has demonstrated its leadership in stepper motors by offering:

- Pin-compatible designs that accommodate different current requirements
- Built-in over-current protection circuitry
- Designs that do not require additional charge pump capacitors
- Built-in 4kV+ ESD Resistance (HBM)

In addition, ROHM differentiators include wide operating temperature from -25 to 85°C instead of -20 to 85°C, higher output current rating (up to 2.5A), wider supply voltage rating (from -0.2 to 36V) and additional protection features (OVLO and OCP).

Stepper motor drivers are frequently used in applications such as printers and scanners, where ROHM Semiconductor's design and applications experience in other products, such as contact image sensors or thermal print heads, provides customers additional system-level support. For more information on ROHM stepper motor drivers including the newest products, please see <http://www.rohmsemiconductor.com/Stepper-Motor-Drivers.html> or the [Stepper Motor Driver Selector Guide](#).



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