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Versatile Microstepper Driver ICs Provide Next Generation Stepper

Improved microstepping accuracy, and lower motor audible noise and heating results from advanced techniques for current management.

Stepper motor motion systems, formerly relegated to low-speed, high audible noise environments, now pervade automation, robotics, and computer peripheral applications requiring more accurate positioning, reduced audible noise and vibration, improved efficiency, and wider speed range. Driver ICs have had the greatest advancements: from 4-transistor unipolar versions to bipolar H-bridge drivers that can use the entire motor winding for 40% greater low-speed torque. Advancements include high resolution microstepping, protection features for greater reliability, and improved efficiency for Energy Star compatibility.

The simplified stepper motor in *Fig. 1* has four stator coils and a permanent magnet rotor. Torque is generated by magnetic attraction and repulsion between the stator electromagnets and the rotor. The top row illustrates a full step "one phase on" sequence. A positive voltage across coils A to A* creates a south pole at A and a north pole at A*, attracting the rotor north pole to A and south pole to A*. Next, a positive voltage across coils B to B * creates a south pole at B and a north pole at B *, attracting the rotor north pole to B and south pole to B *. In this manner, the rotor steps and aligns at 90°. Reversing the sequence reverses direction.

Greater efficiency results by simultaneously activating the A and B phases, full-step "two phase on" driver sequencing. In the Fig. 1 middle row, a positive voltage is applied across coils A to A * and B to B,* causing south poles on A and B and north poles on A * and B *. A and B and A* and B * equally attract the rotor, aligning at 45°.

Resolution doubles by alternating "one phase on" and "two phase on." The Fig. 1 bottom row shows rotor half stepping at 45°. Easily implemented, current levels are the same in each winding.

Advanced driver ICs divide full steps into "microsteps" by precisely adjusting the current and thereby the torque contribution of each phase:

$$T_A \propto I_{phaseA} = I_{max} \sin\theta \quad (1)$$

$$T_B \propto I_{phaseB} = I_{max} \cos\theta \quad (2)$$

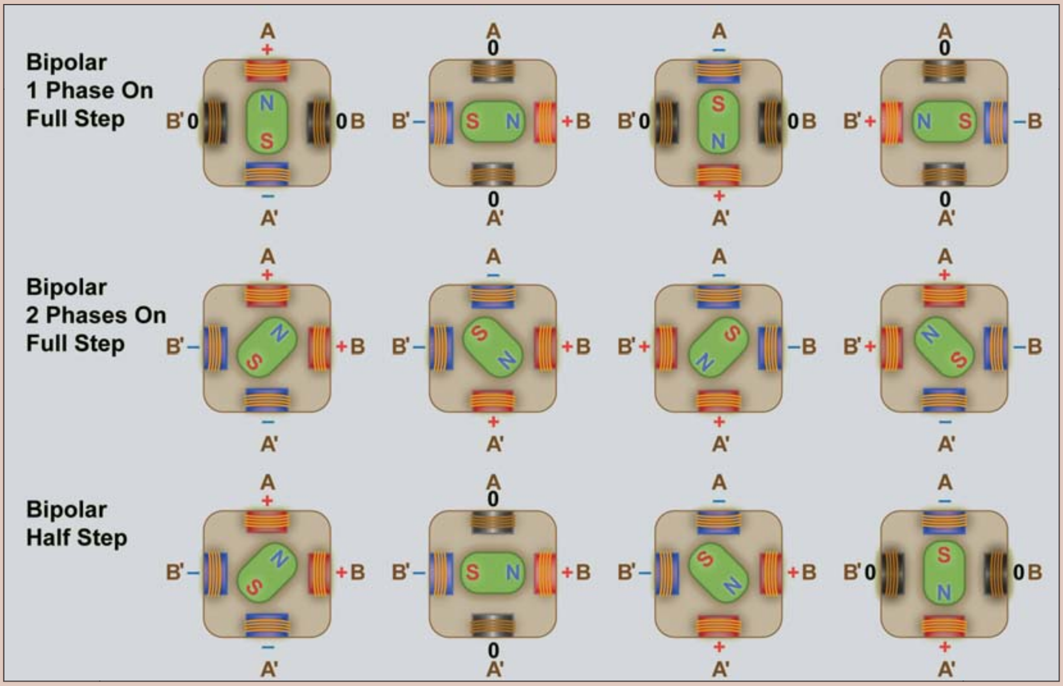

Fig. 1. The simplified stepper motor in has four stator coils and a permanent magnet rotor.

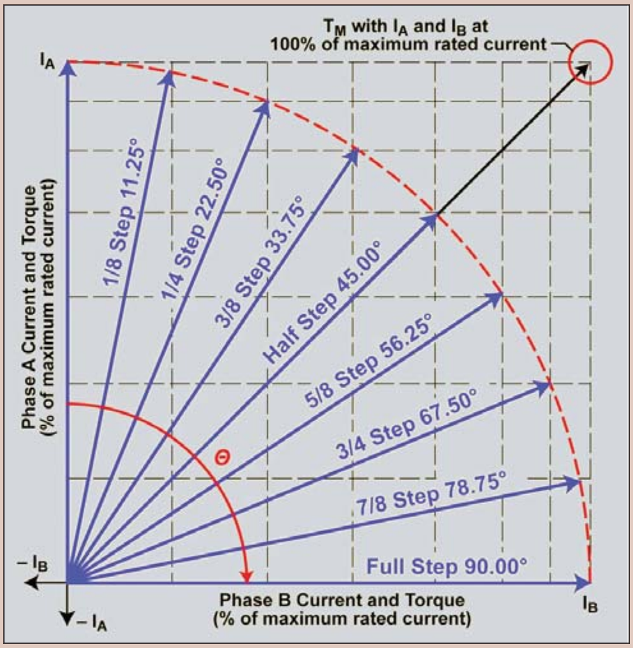

Fig. 2. One quadrant of phase current and torque for full-, quarter-, and eighth-step microstepping.

$$T_M = \sqrt{\left(T_A^{\,2} + T_B^{\,2}\right)} \qquad (3)$$

Where:
Imax = Motor rated current,
Θ = Electrical angle of the rotor (each full step is 90 electrical degrees),
T(A or B) = Torque due to phase A or phase B, and
TM = Motor output torque.
Fig. 2 plots one quadrant of phase current and torque for full-, quarter-, and eighth-step microstepping.

ADVANCED CURRENT CONTROL

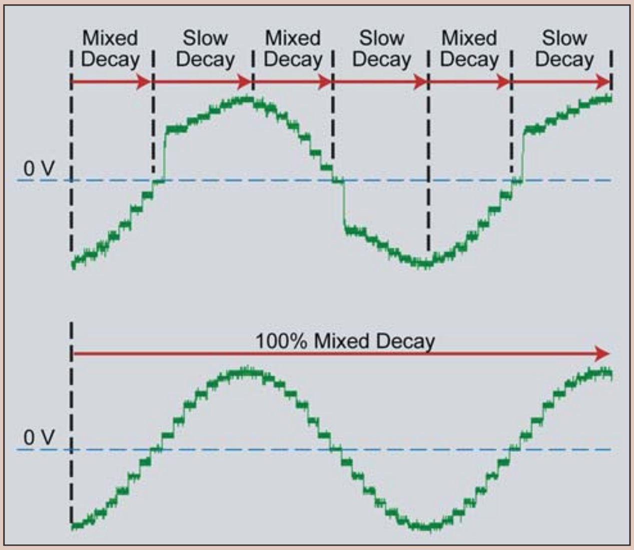

Fig. 3. Use of 100% mixed decay to reduce current overshoot

Microstepping drivers typically use PWM current control to increase supply voltage. This overcomes motor BEMF effects and current rise time, while producing greater torque at high speed.

Most microstepping drivers use fixed off-time PWMing to regulate winding currents to slow, fast, or mixed decay modes. Slow decay is preferred for low current ripple and small dI/dt resulting in lower motor heating, but distortions arise from motor BEMF. Fast decay overcomes BEMF problem but results in higher ripple current and increased motor heating. The solution is mixed decay, which combines fast and slow decay. Fast decay allows the current to track the ideal sinusoidal pattern, without increasing current ripple.

Driving a stepper motor that has a very short electrical time constant from a high voltage supply can result in current distortion as shown in *Fig. 3* upper panel. The overshoot results from extremely fast current rise time and minimum driver on-time. When the driver shuts-off in slow decay, the current cannot fall enough to compensate for the overshoot. 100% mixed decay, as in the Allegro MicroSystems A4984, compensates for this, as shown in the lower panel.

SIMPLIFIED CONTROL INTERFACES

Most bipolar drivers use either the Phase I0 I1 or the Step and Direction interfaces, and stepper motor system designers usually apply one or both in their microprocessor controllers. Phase I0 I1 uses three control lines for each motor phase. The Phase line controls the winding current direction, and the I0 and I1 inputs control a 2-bit nonlinear DAC. This allows the motor to be run in full-, half-, and quarter-step modes. Many pioneering driver ICs, such as the Allegro MicroSystems UDN2916, used this interface, and system designers often prefer to reuse their proven control code. However, most new stepper system designs use the Step and Direction interface. It requires fewer (only two) control lines and no controller memory is consumed storing phase sequence tables to commutate the motor. Direction is a simple logic input, and Step input uses a translator to convert step pulse signal to the correct DAC outputs. This input control scheme is used in the Allegro MicroSystems A4982, A4984. ICs such as the A4985 with the same control scheme are offered in the same packages and pinouts, but at half the output current, giving system designers a scalable solution using the same board layout. The A4988 also offers half-, quarter-, eighth-, and sixteenth-step resolutions.

ADVANCED PROTECTION FEATURES

The newest driver ICs provide short-to-load and short-to-ground, overcurrent protection along with thermal shutdown, and shoot-through protection. No smoke no fire requirements are met with the A4982, A4984, and A4985 by adding no-connect pins between supply pins and high-current motor outputs.