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SERVO TRENDS

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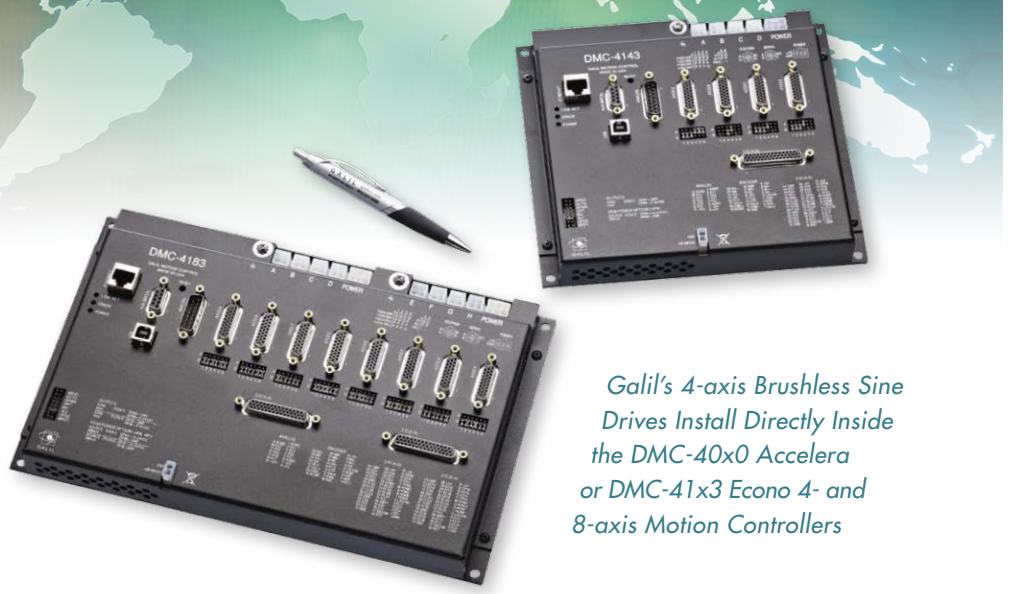
"The mission of Galil's experienced Applications Department is to provide prompt and accurate technical assistance to help OEMs successfully deliver their products to market."

GALIL SUPPORT TEAM



Galil's 4-axis Brushless Sine Drives Install Directly Inside the DMC-40x0 Accelera or DMC-41x3 Econo 4- and 8-axis Motion Controllers

Galil Introduces Servo Drives with Sinusoidal Commutation

Galil is pleased to introduce two multi-axis servo drives that perform sinusoidal commutation: the AMP-43540 which contains four 600Watt servo drives and the AMP-43640 which contains four 20Watt servo drives. Both models are sinusoidally commutated which minimizes torque ripple compared to drives using trapezoidal commutation. This is especially important for applications using low friction linear motors.

The new AMP-43540 and AMP-43640 4-axis drives are available as options for Galil's DMC-40x0 Accelera and DMC-41x3 Econo motion controllers with Ethernet. Designed to minimize space, cost and wiring, the drives reside directly inside the controller enclosure. Two 4-axis drive units can be specified inside 8-axis controller models.

The new AMP-43540 contains four 600W fully digital, transconductance amplifiers for driving brushless motors with sinusoidal commutation. Each amplifier drives motors operating at up to 8 Amps continuous, 15 Amps peak, 20-80 VDC. The gain settings of the amplifier are user-programmable at 0.4, 0.8, and 1.6 Amp/Volt. Both the switching and sampling frequencies are 33 KHz. The amplifier offers protection for over-voltage, under-voltage, over-current, short-circuit and over temperature. A shunt regulator option is available. The U.S. list price of the AMP-43540 4-axis 600W drive is $1000 in single quantity and $600 in 100 quantities.

The new AMP-43640 contains four 20W linear, transconductance amplifiers for driving brushless motors with sinusoidal commutation. Each amplifier drives motors operating at up to 1 Amp peak, 15-30 VDC with a gain setting of 0.1 Amp/Volt. The U.S. list price of the AMP-43640 4-axis 20W drive is $600 in single quantity and $350 in 100 quantities.

When using the AMP-43540 and AMP-43640 sinusoidal drives, hall sensors are not required for brushless motor commutation. Galil provides commands for initialization of the motor using the encoder feedback. ■

Brushless Sine Drives – Amplifier Technology

Drives with Trapezoidal Commutation

Trapezoidal commutation relies on feedback from Hall-effect sensors embedded within the case of a three-phase brushless motor. These sensors will report the location of the rotor to the amplifier.

Based on these inputs, the amplifier will decide how to energize the motor phases in order to produce torque. As the motor rotates, a new Hall state is sensed, forcing the amplifier to route the current to a new set of motor phases. The order of these current transitions determines the direction of rotation. For example, to generate clockwise motion on a motor with a layout shown in ***Figure 2***, the sequence would be A→B, A→C, B→C, B→A, C→A, C→B, then repeat.

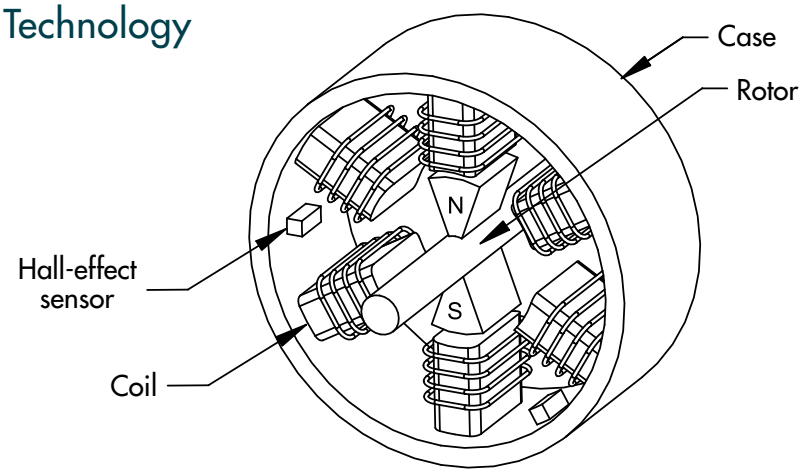


Figure 1: Basic three-phase brushless motor layout

Trapezoidally commutating amplifiers work very well when using rotary brushless motors with measurable mechanical friction, and when the Hall-effect signals are well aligned with the motor's electrical phases. The benefit of "trap drives" is that they tend to be lower cost for a given current rating, and since the Hall sensors always report the absolute position of the rotor, there is no need for any initialization routines. One possible problem with trapezoidally commutating amplifiers occurs when used with linear motors. As the stator passes over the row of magnets, an audible 'ticking' can sometimes be heard as the Hall states force a change in the current flow. Although there may be no measurable torque ripple, this audible characteristic could be considered detrimental.

Drives with Sinusoidal Commutation

Sinusoidal amplifiers vary the current being fed to the motor phases by a much more precise measurement of the rotor shaft location, defined as θ. Normally, this position data comes from an incremental quadrature encoder mounted on the back of the motor. It is important to know the number of encoder counts per electrical cycle. Based on this position data, a "Sine drive" will produce torque on the three phases using the following equations:

$$T_A = I_A * K_t * \sin\theta$$
$$T_B = I_B * K_t * \sin(\theta + 120) \quad (1)$$
$$T_C = I_C * K_t * \sin(\theta + 240)$$

Where T_A, T_B, T_C are torque outputs for motor phases A, B, C
I_A, I_B, I_C are phase currents
K_t is the motor torque constant

As can be seen in ***Figure 3***, the summing of the three torque curves will result in a smooth, ripple-free torque output on the motor shaft regardless of electrical angle. ➤(cont. pg 3)

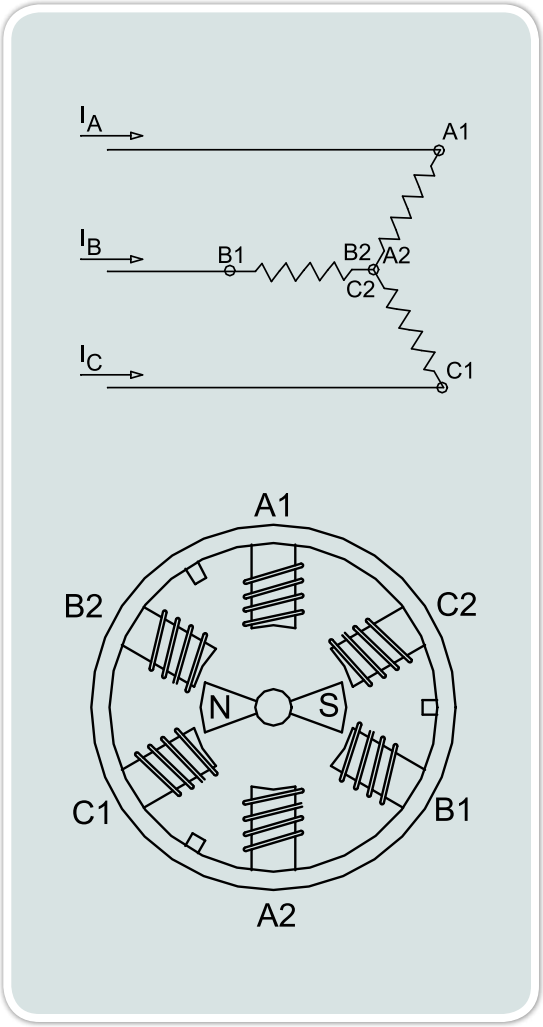


Figure 2: Motor winding schematic

The benefits of sine drives are best seen in low-friction applications, especially when using a direct-drive linear motor. Because the current on each phase is modulated to a precise degree based on a fine angular location, torque ripple is kept to an absolute minimum. Galil's sine drive has the added benefit of being a transconductance amplifier, meaning a voltage command signal to the amplifier circuit results in a specific current output. The pulse-width modulation (PWM) algorithm has been implemented in such a way that allows the Galil sine drives to use the full theoretical range of the power supply.

Galil currently offers two sine drives. The AMP-43640 is a 20W x 4 axis linear amplifier with a current loop bandwidth of up to 7 kHz. The larger 600W x 4 axis AMP-43540 is a fully digital PWM sine drive that has a 33 kHz PWM frequency, which allows for a closed-loop current bandwidth of up to 4 kHz, far higher than most commercially available sinusoidal PWM amplifiers. ■

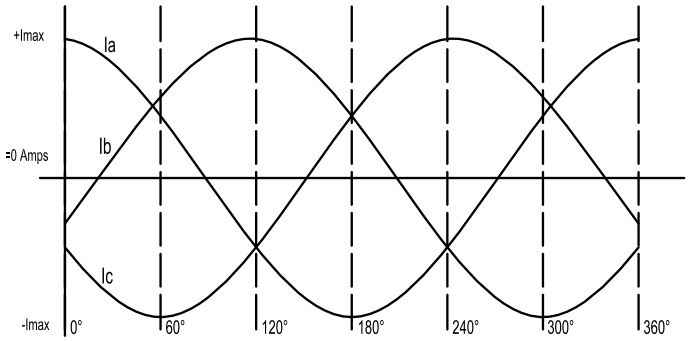


Figure 3: Sinusoidal current output based on electrical angle

Brushless Setup with a Galil AMP-43540 Sine Drive

Every sinusoidal amplifier must perform an initialization procedure to determine where in the electrical cycle the rotor is located, and set the current on the three motor phases appropriately. With past designs, the controller would force the motor to a known electrical location by energizing the motor phases in a specific way. With the electrical cycle modulo defined in encoder counts, the brushless motor is then able to sinusoidally commutate the motor. Galil's sinusoidal amplifier uses a new limited movement algorithm, that allows the electrical angle to be determined by moving the motor approximately 4 quadrature encoder counts in either direction. In most cases, this motion is invisible to the naked eye. The following is an example of setting up a Galil sinusoidal amplifier with a typical brushless motor.

Motor and Feedback Specifications

3-phase, 500W iron-core Nema 23 motor
2 electrical cycles per rev (2 pole pairs)
Equipped with 4000 count/rev quadrature encoder
Armature resistance 1.2 Ohm
Armature Inductance 2.6 mH
Peak/Continuous current 10.4A/4.9A
Supply voltage: 48VDC

Galil Configuration Commands

This motor will be connected to the A axis. The command to configure this motor for brushless operation is

```
BAA;'CONFIGURE A AXIS AS BRUSHLESS AXIS
```

Since the motor is capable of running 10A peak, the amplifier gain can be set to 1.0A/Volt:

```
AGA=2;'SET A AXIS AMP GAIN TO 1 AMP PER VOLT
```

When set to AGn=2, the user has the ability to set both a Peak and a Continuous torque limit. The 10A peak/4.9A cont. capability would be set with

```
TLA=4.9;'SET CONT TORQUE
TKA=9.998;'SET PEAK TORQUE
```

The optimal amplifier current loop is set with the AU command based on supply voltage and motor inductance. Since the motor under test has a relatively high inductance, the optimal value for AU is relatively low, determined to be '2'.

```
AUA=2;'SET CURRENT LOOP GAIN
```

For the amplifier to commutate the motor, the controller must have a value set for the encoder counts per electrical cycle. This can be determined by dividing the encoder counts/rev by the number of pole pairs. In this case, 4000 encoder counts / 2 pole pairs = 2000 counts/ electrical cycle.

```
BMA=2000;'ENCODER COUNTS PER ELEC. CYCLE
```

All these parameters can be stored to the controller's memory using the Burn Parameters (BN) command. Upon power-up, it is mandatory to perform the initialization routine as described above. The motor will be in the Motor Off state until the axis has completed this initialization.

```
BXA=1;'DETERMINE MOTOR ELECTRICAL
'LOCATION USING MAX 1 VOLT DAC OUTPUT
```

The brushless initialization routine normally takes approximately three seconds to complete, possibly up to twelve. During this time, any other commands that are sent to the controller will not respond and may cause communication timeouts. It is common to program the Galil to perform this initialization automatically on power-up using the #AUTO label. Care should be taken to ensure that this is safe to do.

Once the axis is configured for sinusoidal commutation and has been correctly initialized (_BXn reports '3'), the axis is ready to command using any Galil mode of motion. ■

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With over 500,000 controllers installed worldwide, Galil is the leading supplier of motion controllers. Galil's legacy of innovation began in 1983 with the introduction of the first microprocessor-based servo motion controller. Today, Galil continues its leadership by offering the most powerful, cost-effective and easy-to-use controllers to accommodate all your motion and I/O needs.

Galil offers a broad array of motion controllers in a variety of formats: single and multi-axis, card-level and box-level, bus-based and stand-alone. Galil's Ethernet/RS232 and PCI controllers are available in an Econo version for lowest cost and Accelera version for ultra high-speed performance. Plug-in, multi-axis drives for steppers and servos save space, cost and wiring. For intelligent I/O control, the RIO Pocket PLC is compact, low-cost and packed with analog and digital I/O.

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ACCELERA CONTROLLERS AND DRIVES

DMC-40x0	Ethernet/RS232
DMC-18x6	PCI

ECONO CONTROLLERS AND DRIVES

DMC-41x3	Ethernet/USB/RS232 — **New!**
DMC-21x3	Ethernet/RS232
DMC-18x2	PCI

SINGLE-AXIS CONTROLLERS AND DRIVES

DMC-1415	Ethernet/RS232
CDS-3310	Ethernet/RS232

POCKET PLC I/O CONTROLLER

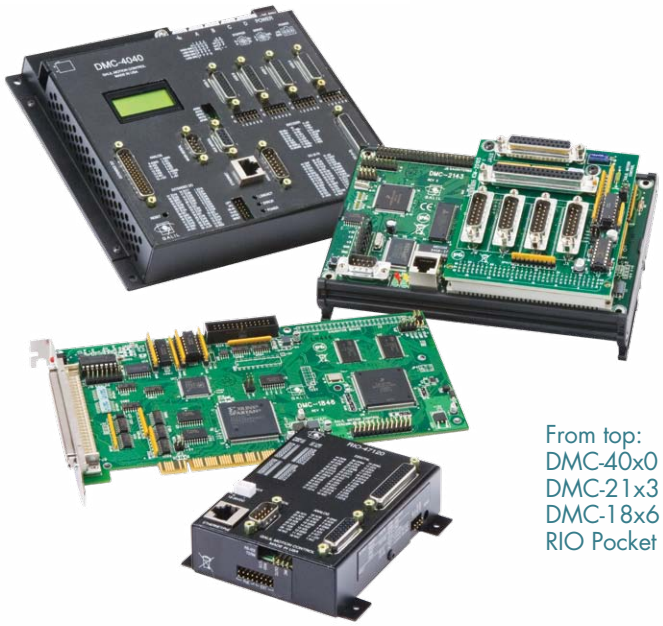
RIO-47xxx	Ethernet/RS232

SOFTWARE TOOLS

GalilTools. Servo Tuning and analysis software

Ladder Interface. Converts Ladder program into DMC code for RIO Pocket PLC.

Galil PVT. Software tool for PVT mode of motion.



From top:
DMC-40x0 Accelera Controller
DMC-21x3 Econo Controller
DMC-18x6 PCI Controller
RIO Pocket PLC

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