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New Stepper Position Maintenance Mode for Galil Controllers

By Glen Garrettson, Galil Application Engineer

Stepper motors are designed to offer an economical method of open-loop motion control. While easy-to-use, they are prone to skipping or stalling, which results in position loss. This article discusses various options for handling stepper motor position error and presents new commands available in Galil controllers to implement these options.

In an attempt to "close-the-loop" and obtain actual position information, a feedback sensor is often added to a stepper motor. This position information is used to determine if there is any significant difference between the commanded and the actual motor positions. If such an error is detected, the designer has several options for dealing with it, including halting the motion, executing a correction move, or continuing motion with error.

Galil has added several commands to its controllers for the new Stepper Position Maintenance Mode (SPM), allowing the user to actively handle stepper position error.

New Commands

SPM mode is configured, executed and managed with six new commands and one existing command. This mode also utilizes the #POSERR automatic subroutine allowing for automatic user-defined handling of an error event. These new commands are as follows:

Internal Controller Commands (user can query):

QS	*Error Magnitude (pulses)*

User Configurable Commands (user can query & change):

OE	*Profiler Off-On Error*
YA	*Step Drive Resolution (pulses/full motor step)*
YB	*Step Motor Resolution (full motor steps/revolution)*
YC	*Encoder Resolution (counts/revolution)*
YR	*Error Correction (pulses)*
YS	*Stepper Position Maintenance enable, status*

A step pulse is defined by the resolution of the step drive being used. Therefore, one pulse could be a full step, a half step or a microstep.

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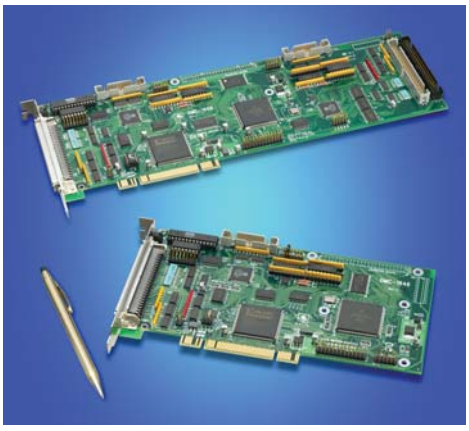
Galil Offers Instruction Set Enhancement for DMC-18x6 Accelera Controllers

In July 2005, Galil introduced the DMC-18x6 PCI bus controllers, which are Galil's newest generation of motion controllers: the Accelera Series. Incorporating a 32-bit RISC-based microcomputer, the Accelera controllers offer ultra high-speed performance and processing power.

Speed improvements include the acceptance of encoder inputs up to 22 MHz, servo update rates as low as 24 microseconds/axis, and command execution speeds as low as 40 microseconds. In addition, the DMC-18x6 has larger RAM and FLASH, which results in increased program space with 2,000 lines (x80 characters/line), 16,000 array elements and 510 user-defined variables. While the command set of the prior generation Optima series is basically the same in the Accelera Series, the increased processing power has allowed for the enhancement of many instructions as well as the addition of several new commands. This article discusses program modifications that must be considered to convert a program from an Optima DMC-18x0 controller to a DMC-18x6 Accelera controller.



DMC-1846 and DMC-1886 Accelera Controllers

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New Stepper Position Maintenance Mode for Galil Controllers *By Glen Garrettson, Galil Application Engineer*

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When a Galil controller is configured for step motor operation, the step pulses output by the controller are internally fed back into the auxiliary encoder register. The feedback encoder on the stepper is connected to the main encoder port. Enabling the SPM mode on a controller with YS=1 executes an internal monitoring of the auxiliary and main encoder registers for that axis or axes. Position error is then tracked in step pulses between these two registers (QS command).

$$QS = TD - \frac{TP \times YA \times YB}{YC}$$

Where TD is the auxiliary encoder register (step pulses), TP is the main encoder register (feedback encoder), and YA=1 for full stepping, YA=2 for half stepping or YA=64 for microstepping with the SDM-20640 microstepping drive.

Error Limit

Typically, if a stepper falls behind by more than two full steps, the error is unrecoverable. Thus, the value of QS is internally monitored to determine if it exceeds a preset limit of three full motor steps. Once the value of QS exceeds this limit, the controller then performs the following actions:

1. The motion is maintained or is stopped, depending on the setting of the OE command. If OE has been set to 1, the axis is stopped.
2. YS is set to 2, which causes the automatic subroutine labeled #POSERR to be executed.

Correction

A correction move can be easily commanded by assigning the value of QS to the YR correction commnd. The correction move is issued after the axis has been stopped. After an error correction move has completed and QS is less than three full motor steps, the YS error status bit is automatically reset back to 1 indicating a cleared error.

Example

Consider a DMC-2113 motion controller with a Galil SDM-20240 half-stepping drive, 1.8˚ step motor and 4000 count/rev encoder. The following code demonstrates what is necessary to set up SPM mode, detect error, stop the motor, correct the error, and return to the main code.

```
#SETUP
OE1;              'SET THE PROFILER TO
                   STOP AXIS UPON ERROR
KS16;             'SET STEP SMOOTHING
MT-2;             'MOTOR TYPE SET TO STEPPER
YA2;              'STEP RESOLUTION OF THE
                   SDM-20240(HALF-STEP)
YB200;            'MOTOR RESOLUTION (FULL STEPS)
YC4000;           'ENCODER RESOLUTION (COUNTS
                   PER REVOLUTION)
SHX;              'ENABLE AXIS
WT100;            'ALLOW SLIGHT SETTLE TIME
YS1;              'ENABLE SPM MODE

#MOTION           'PERFORM MOTION
SP512;            'SET THE SPEED
PR1000;           'SET POSITION COMMAND
BGX;              'BEGIN MOTION
#LOOP;JP#LOOP;    'KEEP THREAD ZERO ALIVE FOR
                   #POSERR TO RUN IN

#POSERR           'AUTOMATIC SUBROUTINE IS
                   CALLED WHEN YS=2
WT250;            'WAIT HELPS USER SEE THE
                   CORRECTION
spsave=_SPX;      'SAVE CURRENT SPEED SETTING
JP#RETURN,_YSX<>2; 'RETURN TO THREAD ZERO IF
                   INVALID ERROR
SP64;             'SET SLOW SPEED SETTING FOR
                   CORRECTION
MG"ERROR= ",_QSX
YRX=_QSX;         'ELSE, ERROR IS VALID, USE
                   QS TO CORRECT
MCX;              'WAIT FOR MOTION TO COMPLETE
MG"CORRECTED, ERROR NOW= ",_QSX
WT250;            'WAIT HELPS USER SEE THE
                   CORRECTION

#RETURN
SPX=spsave;       'RETURN THE SPEED TO PREVIOUS
                   SETTING
RE0;              'RETURN FROM #POSERR
```

In addition to correcting for error due to stalling or skipping, the SPM mode can be used as a method to correct for friction at the end of a microstepping move. This capability provides closed-loop control at the application program level.

For more information on Stepper Position Maintenance, please contact a Galil Applications Engineer at **800-377-6329**. New firmware containing the SPM mode can be downloaded at ***http://www.galilmc.com/support/download.html*** (available for Accelera, Optima, DMC-18x2 and DMC-21x3 controllers).

Galil Offers Instruction Set Enhancement for DMC-18x6 Accelera Controllers (Continued from Page 1)

PID Changes

When using PID control parameters for an Optima controller on a new Accelera controller, the values for KP, KD, and KI must be scaled. KP and KD must be increased by a factor of 4 compared to what would have been used on an Optima controller. On the other hand, KI must be divided by 2 in order to have an equivalent Integral Loop. The resolution of KI is 1/128 for Optima controllers, and is 1/1024 for Accelera controllers. The effective resolution of KP and KD has been increased by 4, but the command resolution remains at 0.125.

Therefore, to convert PID parameters from a DMC-18x0 to their equivalent DMC-18x6 parameters, multiply KP and KD by 4, and divide KI by 2.

Example: If the DMC-18x0 PID parameters are KP=10, KD=100, and KI=4, then the DMC-18x6 new PID parameters will be KP=40, KD=400 and KI=1.

Other Considerations

Hardware Latch for Find Home and Find Index

With the DMC-18x6 controller, both the Homing Routine and Find Index Routine now use a hardware latch to define the index position. This latched position is returned to and defined as 0. In prior generation controllers, the index was not latched.

Programmable Homing and Find Index Speed

The slew speed for the final 2 stages of the homing routine, and the last stage of the Find Index Routine, are set by the new HV (Homing Velocity) command. The default for HV is 256 counts/second.

Replacement of VT command by IT

With the VT command removed from the DMC-18x6 command set, the functionality of the IT command has been expanded to operate over the entire sequence of a vector or linear interpolated sequence of moves. The IT command is now, effectively, a first order low pass filter which smoothes out basic movements, coordinated motion and contoured mode motion. While in coordinated vector motion, the IT command will act on the individual vector components. This differs from the VT command, which acted over the resultant vector movement. Because of the expanded functionality of the IT command, the VT command is no longer needed.

Removal of WC command in Contour Mode

The architecture of the contour mode has changed with the DMC-18x6 so that the moves are now buffered in similar fashion to that of Vector and Linear Interpolation moves. As a result, WC has been removed from the new command set and CD has been modified to operate without the need of WC.

Removal of Stepper Motor Jumpers

The Stepper Motor Jumpers have been removed from the DMC-18x6 controller. For operating in Stepper mode, MT must be set to the correct setting. The hardware does not need to be changed. Servo drives that accept a PWM signal for their motor command will now use MT 1.5 rather than having the SM jumpers installed and an MT of 1.

Command Summary

The table below contains three sections in which the new, modified and removed commands are overviewed. For additional information, please refer to Galil application note #2501- ***http://www.galilmc.com/support/appnotes/accelera/note2501.pdf***

New Commands for the DMC 18x6

%	*Math Operand that returns integer remainder of a division*
EY	***CAM Cycle Count.*** *Returns number of ECAM cycles.*
HV	***Homing Velocity.*** *Sets slew speed in FI and HM routines*
LD	***Limit Disable.*** *Ignores when limit switch has been reached*
^L^K	***Lock Program.*** *Locks user access to application program*
OA	***Off on Encoder Error Failure.*** *Toggles the encoder failure feature*
OT	***Off on Encoder Failure Time.*** *Sets time prior to issuing encoder error*
OV	***Off on Encoder Failure Voltage.*** *Sets torque output voltage for encoder error*
PW	***Password.*** *Sets the password for the ^L^K lock setting.*
SD	***Limit Switch Deceleration.*** *Sets the deceleration rate for limit*
ZA	***User Data Record Variables.*** *Allows user to write data to part of the data record. There are 4 bytes of memory available per axis*

(Continued On Page 4)

Galil Offers Instruction Set Enhancement for DMC-18x6 Accelera Controllers (Continued from Page 3)

Modified Commands for the DMC 18x6

AC/DC — ***Acceleration and Deceleration Rates.*** *The ranges of AC and DC commands have been expanded to 1024 to 1,073,740,800 counts/sec^2*

Automatic Subroutines — *Except for #CMDERR, all automatic subroutines no longer require thread 0 to be running in order for them to operate*

AL — ***Arm Latch.*** *This command has been expanded so that a high-speed capture of the encoder position can be latched to the index pulse*

CD — ***Contour Data.*** *CD command has been modified for use without WC command*

ER — ***Error Limit.*** *The range of the Error Limit command has been expanded to 1 to 2,147,483,647 counts*

Homing — ***Homing Routine.*** *The homing routine now uses a hardware latch to mark the position of the index, and will return to that position on the final move of the routine with a speed specified by the HV command*

IT — ***Independent Time Constant.*** *The IT command has been expanded to operate over the entire sequence of a vector or linear interpolated sequence of moves*

JG/SP — ***Jog and Speed.*** *The range of the SP and JG has been expanded to 0 to 22,000,000 counts/sec for servos and 0 to 6,000,000 steps/sec for steppers*

KP/KD/KI — ***PID Filter Parameters.*** *KP and KD must be increased by a factor of 4 compared to what would have been used on an Optima controller. KI on the other hand, must be divided by 2 in order to have an equivalent Integral Loop. The resolution of KI is 1/128 for Optima controllers, and is 1/1024 for Accelera controllers. The effective resolution of KP and KD has been increased by 4, but the command resolution remains at 0.125*

LC — ***Low Current Stepper Mode.*** *Represents the number of samples after the motion is complete in which the controller will wait until Low Current Stepper Mode is activated*

M-Axis — ***M Virtual Axis.*** *A second virtual axis has been added to the Accelera series controllers*

MT1.5 — ***Motor Type.*** *Setting MT to 1.5 specifies PWM/Sign mode for an axis*

_NO — ***No Operation.*** *_NO is an operand that returns number of threads running on the controller*

OE2 — ***Off On Error.*** *This command can now automatically shut off the motor command signal when a limit switch is triggered*

TM — ***Update Time.*** *Most functions that were previously affected by changes to the Update Time are now automatically scaled by the controller*

*The three functions that are not scaled with the new controller are KD, KI and PL. True Dampening = KD*TM; True Integral = KI/TM*

TRn,m — ***Trace.*** *The trace function can now specify which threads to trace and send their commands down the communications port prior to execution*

VA/VD — ***Vector Acceleration and Deceleration Rates.*** *The ranges of VA and VD have been expanded to 1024 to 1,073,740,800 counts/sec^2*

VS — ***Vector Speed.*** *The range of VS has been expanded to 2 to 22,000,000 counts/sec for servos and 2 to 6,000,000 steps/sec for steppers*

Removed Commands and Hardware for DMC-18x6

DU — ***Dual Port RAM Access.*** *This command was used to set the controller in Dual Port RAM (DPRAM) mode on the later versions of the DMC 18x0 series controllers that were retrofitted with DPRAM hardware. The DMC 18x6 controllers are all equipped with DPRAM hardware and no longer use secondary FIFO hardware interface for secondary communications*

QR — ***Data Record.*** *Bus-based controllers with DMA, secondary FIFO or DPRAM do not accept the QR command*

SM Jmprs — ***Stepper Motor Jumpers.*** *The stepper motor jumpers have been removed for the DMC 18x6 controller*

VT — ***Vector Smoothing.*** *The IT command has been expanded to handle vector smoothing*

WC — ***Wait for Contour Data.*** *Contoured mode motion is now buffered similar to LM and VM commands, eliminating the need for the WC command*

Enhanced Firmware for Cam Tables with Linear Sections

By Chris Cortopassi, Galil Application Engineer

The advent of digital motion control has brought about electronic replacements for both mechanical gears and cams. In electronic gearing, a gear ratio is established between two servo motors: a master and a slave. Once engaged, the slave follows the master through a pre-programmed ratio and the two motors behave as though they are linked by mechanical gears.

Where electronic gearing provides a simple linear relationship, electronic cam is a more general extension of electronic gearing in which a nonlinear relationship is established between the master and slave motors. The slave position is a function of the master position, and this relationship could be specified by a continuous equation or by a table of discrete points.

When a table is used, interpolation (e.g. linear or cubic) must be performed between the points to determine the slave positions at points other than those provided in the table. With linear interpolation, more points result in smoother motion, which is especially important in curved sections of the table.

For example, electronic cam is often used in winding applications to control how fiber is wound around a rotating spool. Because the distributor repeatedly moves back and forth across the spool as it lays fiber, the cam table for the distributor (slave) position versus spool (master) position is triangle-shaped, often with rounded corners (*Figure 1*)

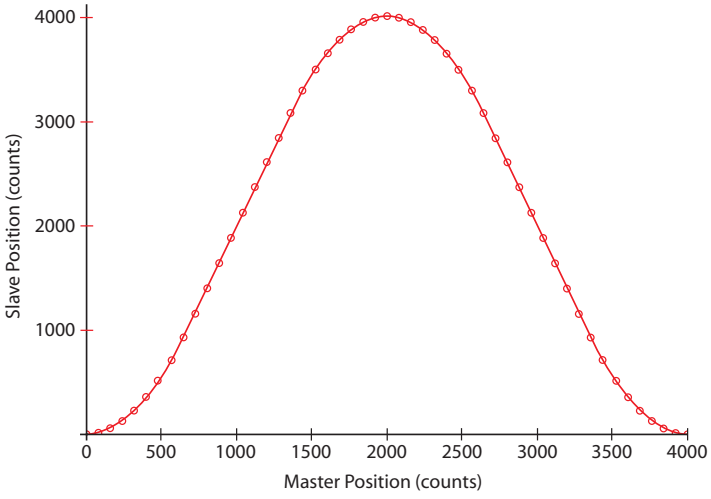

Figure 1. A cam table using linear interpolation in which all points are equally spaced

Figure 1 uses evenly spaced points, but since the graph can be divided into three curved sections and two linear sections, it is better specified with unevenly spaced points (*Figure 2*). Given a finite number of points, it is desirable to distribute the points more densely in the curved sections since the linear sections only need two points to define them.

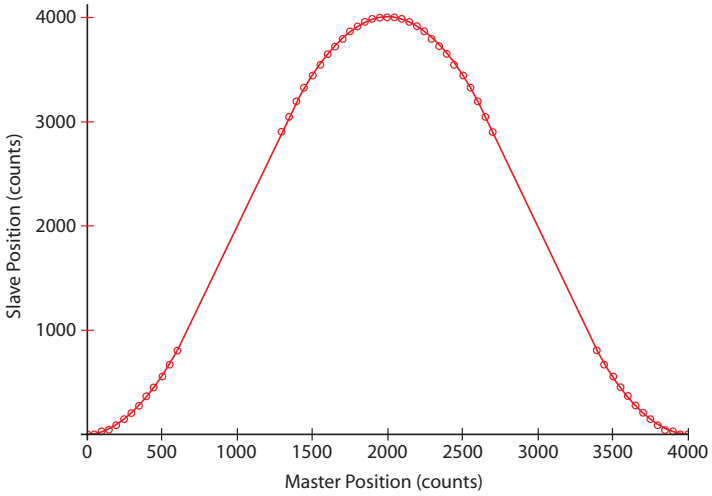

Figure 2. Smoother cam table in which the curved sections have more points. Both figure 1 and figure 2 have the same number of points.

In Galil controllers, the ECAM (electronic cam) table is constructed by specifying the interval between master positions (EP command) and the table of corresponding slave positions at each master position (ET). The master interval EP is nominally constant and linear interpolation is used between table entries.

Galil recently enhanced the ECAM mode by adding the EW (ECAM widen) command, which allows one or two of the master intervals to be longer than the specified EP interval. EW optimizes the table entries by requiring fewer entries for linear sections, which allows for more entries during curved sections (*Figure 2*). Without EW, all segments must be of equal length and thus points are "wasted" on the linear sections (*Figure 1*). Cam tables composed of only curves do not benefit from EW.

Example

This section details a simple example that uses the EW command to implement the cam table in *Figure 3*. Although this table could be implemented with only three points and without the EW command, its simplicity makes it easier to understand how to use EW to create a cam table such as that in *Figure 2*.

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Enhanced Firmware for Cam Tables with Linear Sections *By Chris Cortopassi, Galil Application Engineer*

(Continued from Page 5)

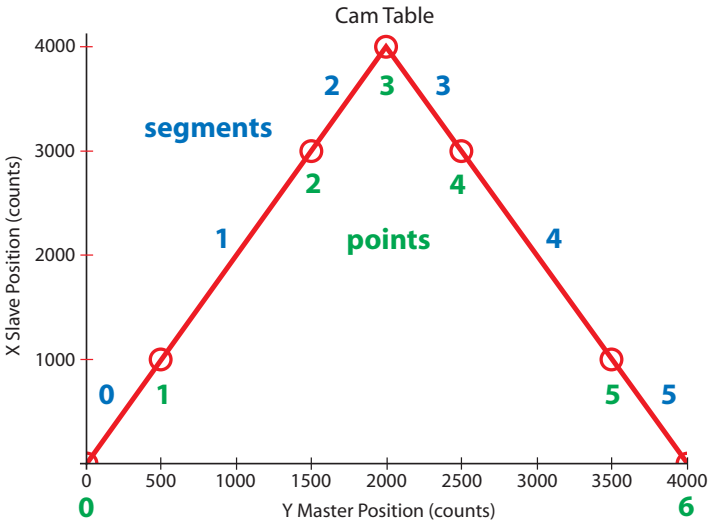


Figure 3. Cam table generated using EW to widen segments 1 and 4 (see code)

The table in *Figure 3* is made up of seven points (labeled 0 to 6 in green) and six segments (labeled 0 to 5 in blue). The segment associated with each point is the segment just to the right of the point (with the exception of point 6, which has no associated segment). Use point numbers for ET (ECAM table) and segment numbers for EW. Segments 0, 2, 3, and 5 are of equal length (500 counts), specified with EP 500. Segments 1 and 4 are widened to 1000 counts with the command EW 1=1000, 4=1000.

The code to generate the cam table in *Figure 3* is below:

```
EB0         ;'turn cam off
EAY         ;'y axis is the master
EM 0,4000 ;'x slave change, y master change
EP 500,0  ;'interval width,starting position

ET[0]=0
ET[1]=1000

ET[2]=3000
ET[3]=4000
ET[4]=3000

ET[5]=1000
ET[6]=0

EW 1=1000, 4=1000 ;'widen segments 1 and 4
                   to 1000 master counts

EB1         ;'turn cam on
EG0         ;'engage slave immediately
JGY=1000  ;'jog the master
BGY         ;'begin motion
AMY         ;'wait for motion complete
EN          ;'end program
```

New Firmware Available for Galil Controllers

Galil has recently made several firmware enhancements to its Accelera, Optima, DMC-18x2 and DMC-21x3 motion controllers. The revised firmware provides new commands for Stepper Position Maintenance and for the Electronic Cam mode (see articles in this issue of *ServoTrends* for detailed information about these enhancements). New firmware revisions for each product are listed in the following chart. Download firmware at no cost at: ***http://www.galilmc.com/support/download.html***

Controller Series	Firmware Revision
DMC-12xx	1.0p
DMC-16xx	1.0p
DMC-17xx	2.2p
DMC-18x0	2.0p
DMC-18x2	1.0p
DMC-18x6	1.0
DMC-2xx0	1.0o
DMC-21x3/21x2	1.0o
DMC-31x3/31x2	1.0e

EXOR Provides Simple Interface For Connecting Galil Controllers to PLCs and Other Devices

While many machines incorporate Galil motion controllers along with other devices such as programmable logic controllers (PLCs), it is often challenging to get the various devices to communicate with each other. This is especially the case when each device has a different communications protocol and command language. To simplify the communications between such devices, EXOR Electronics, a worldwide supplier of HMIs, has developed a line of dual-protocol converters designed to sit between the differing devices, as well as easily bridge the communication gap between motion controllers and PLCs.

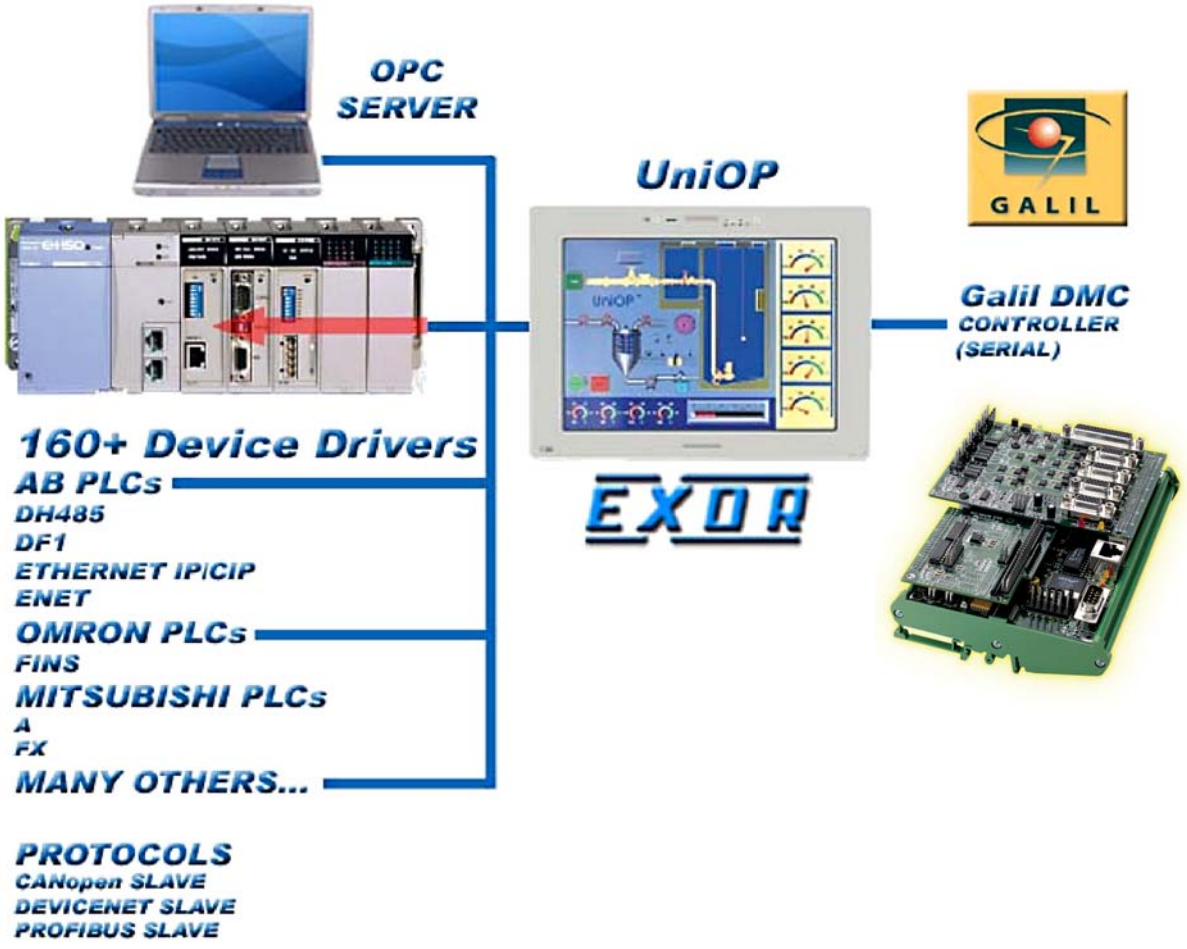
Many of EXOR's HMI products include protocol converters that communicate with DeviceNet, Profibus, CANopen, Ethernet/IP, Modbus/TCP and other such devices. To accommodate easy set-up for the most commonly used devices and protocols, EXOR's menu-driven software enables the designer to merely select the two devices that are communicating from a drop-down list, and then assign protocol conversion parameters.

Galil controllers, which are included in EXOR's vast library of supported devices, easily communicate with other devices by using these dual-protocol conversion products. For example, a Galil DMC-21x3 controller will be able to communicate with an Allen Bradley MicroLogix 1000 PLC using an EXOR UniOP eTOP10. To do so, the EXOR unit connects to the Galil serial port on one end and to the Allen Bradley serial port on the other. The EXOR Uni-OP seamlessly does the translation between the Galil language and Allen Bradley DF1 protocol.

In addition to its wide selection of HMIs with dual-protocol conversion, EXOR can create custom protocol converters for those applications that do not need an HMI front end.

For more information please call Galil at 800-377-6329. For additional details, please refer to Galil application note #5469 *"Using an EXOR HMI as a Protocol Converter"* ***http://www.galilmc.com/support/appnotes/miscellaneous/note5469.pdf***

EXOR products can be viewed at ***www.exor-rd.com***



Galil. We Move the World.

With over 350,000 controllers installed worldwide, Galil is the #1 leading supplier of motion controllers. Galil's legacy of innovation began in 1983 when they introduced the first microprocessor-based servo motion controller. Today, Galil continues its leadership by offering the most powerful, cost-effective and easy-to-use motion controllers to accommodate all your motion needs.

Galil provides you with the widest choice of single or multi-axis, bus-based or stand-alone, and box-level or card-level controllers. Interface options include PCI, ISA, PC/104, VME, cPCI, USB, RS232 and Ethernet. Select from 1-, 2-, 3-, 4-, 5-, 6-, 7- and 8-axis controllers, and configure them to run stepper or servo motors on any combination of axes.

Additionally, Galil provides various accessories that enable you to complete your project quickly. These include servo motors, amplifiers and software tools for quick set-up and "one-button" servo tuning.

Motion Controllers – PCI

DMC-18x6. *PCI, 1-8 axes. Accelera*
DMC-18x0. *PCI, 1-8 axes*
DMC-18x2. *PCI, 1-4 axes*
DMC-1417. *PCI, 1 axis*

Motion Controllers – Ethernet/RS232

DMC-20x0. *USB/RS232, 1-8 axes*
DMC-22x0. *Ethernet/RS232, 1-8 axes*
DMC-21x2/x3. *Ethernet/RS232, 1-8 axes*
CDS-3310. *Ethernet/RS232, 1 axis controller and servo drive unit*
DMC-14x5. *Ethernet/RS232, 1-2 axes*
IOC-7007. *Ethernet I/O controller*

Motion Controllers – Other

DMC-12x0. *PC-104, 1-8 axes*
DMC-13x8. *VME, 1-4 axes*
DMC-16x0. *cPCI, 1-4 axes*
DMC-17x0. *ISA, 1-8 axes*
DMC-1410. *ISA, 1 axis*
DMC-1411. *PC/104, 1 axis*
DMC-1412. *RS232, 1 axis*

Plug-In, Multi-axis Drives

AMP-20341. *4 axis, 20W servo drives*
AMP-204x0. *2 & 4 axis, 200W servo drives*
AMP-205x0. *2 & 4 axis, 500W servo drives*
SDM-20240. *4 axis, full/half stepper drives*
SDM-206x0. *2 & 4 axis, microstep drives*

Software Tools

Communication Drivers. For DOS, QNX, Linux and all current versions of Windows

SmartTerm. Provides a friendly interface to all Galil controllers

WSDK. Servo Tuning and analysis software

ActiveX Toolkit. Custom controls for Visual Basic or other ActiveX software

CAD-to-DMC. Translates AutoCAD DXF files into DMC controller files

For complete specifications and pricing on all Galil products, please go to *www.galilmc.com*. Request a free catalog at ***http://www.galilmc.com/products/catalog.html***.

Rely on Galil for Unmatched Support and Service

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FREE	ONLINE SUPPORT TOOLS
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✓	Over 20 tutorials about servo tuning, motion programming, & motors and drives *http://www.galilmc.com/training/webconf.html*
✓	MotionCode™ Toolkit, step-by-step solutions with downloadable code *http://www.galilmc.com/support/motioncode/index.html*
✓	MotorSizer™ Tool for quick sizing of stepper and servo motion systems *http://www.galilmc.com/support/motorsizer/index.html*
✓	Interactive bulletin board with knowledge base for fast answers to your questions *http://www.galilmc.com/cgi-bin/ubb/ultimatebb.cgi*
✓	Extensive motion controller and drive product catalog with specs and prices *http://www.galilmc.com/products/catalog.html*

"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"