DELTA TAU
Data Systems, Inc.
NEW IDEAS IN MOTION

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Excellence in Automation

Delta Tau Motion and Machine Control Features and Benefits

- ***Standalone Capability***
- ***High Axis Count***
- ***Multiple Independent Coordinate Systems***
- ***Coordinate Rotation and Translation***
- ***High-Speed Calculations***
- ***Multiple Servo Command/Format Modes***
- ***Large Choice of Feedback Devices***
- ***Sophisticated and Powerful Servo Capabilities***
- ***Sophisticated and Flexible Trajectory Generation***
- ***Forward and Inverse Kinematic Capabilities***
- ***Special Look ahead Algorithms for Velocity and Acceleration Control***
- ***Hardware Position-Capture and Position-Compare***
- ***Move Until Trigger***
- ***Automatically Sequenced Motion Programs***
- ***Asynchronous PLC Program Execution***
- ***Broad Command Set***
- ***Open and Flexible Structure***
- ***Lead Screw Compensation***
- ***Backlash Compensation***

The Turbo PMAC (**P**rogrammable **M**ulti-**A**xis **C**ontroller) family of controllers, including the UMAC (**U**niversal **M**otion and **A**utomation **C**ontroller) 3U rack system, provides the most powerful and flexible motion and machine control capabilities in the world with an easy-to-use setup and programming scheme that permits difficult applications to done quickly and easily. The key features of the Delta Tau family of automation and control products are explained below.

Standalone Capability

The Turbo (up to 32 axis of control) PMAC is a standalone-capable controller, unlike many other controllers, which are peripheral devices. Even when under the control of a host computer or PLC, Turbo PMAC's capability to handle significant aspects of the application itself greatly reduce the computational and communications requirements for the host computer.

High Axis Count

The Turbo PMAC can control up to 32 axes simultaneously. In an application with a large axis count, the cost per axis of this top-of-the-line controller is below that of a set of low-end, low-axis-count controllers. Furthermore, it is always easier to write and debug the software coordinating events on a single controller than on multiple controllers.

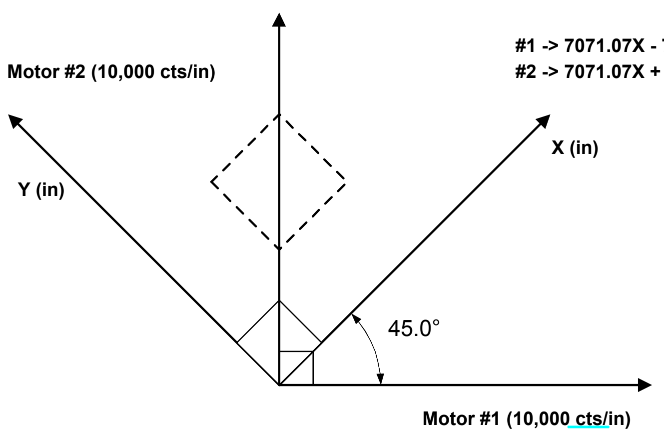
Also, significant improvements in throughput can typically be realized by tying events on a single controller together more tightly. When using multiple controllers with low axis counts, significant delays and overhead are often incurred relating the completion of events on one controller through the central computer to the start of events on another controller or I/O board.

Multiple Independent Coordinate Systems

The Turbo PMAC can support up to 16 independent "coordinate systems", providing totally independent, yet overlapping motion sequences for each system. This provides a great deal of flexibility in controlling multiple mechanisms on a machine in a manner that is very easy to program.

Coordinate Rotation and Translation

Real time coordinate rotation can be accomplished in the PMAC using the built in features supporting it. Enter the functions for the translation one time and forget about it – everything is handled transparently, in the background. This can be used in a variety of situations in which movement is in relation to a dynamic reference. One example could be placing parts on a printed circuit board. You have a set position and orientation for each part on the board. If the board is not placed identically each time you either have to have a new motion profile for each variation in position, or you have to rotate your coordinate system to account for that variation.



This example is two dimensional, but can easily be applied to three or more dimensions (for example X, Y, Z, and A, a rotary axis).

This can also be very useful when applying operations to a moving target. Robotic motion often occurs with reference to a part piece, which is in motion. Printing and cutting operations can also be applied on targets with varying location utilizing these techniques.

The same operation can be applied to scaling. So if you are producing parts of identical profile, but different scaling, the same part program can be used with different scale factors.

You can also use this for translation from one coordinate system type to another. From Cartesian coordinates to Polar, for example. This can allow you to tightly link motion of rotary axes with that of linear axes while maintaining relatively simple motion or part programs.

Summary

Coordinate rotation and translation allows you to transparently account for non-uniform motion within your motion programs without having to rewrite the programs for every possible case.

High-Speed Calculations

The Turbo PMAC uses the latest generation DSP chips to provide very high computational capabilities. DSPs are optimized for the types of calculations used most in motion control, outrunning standard microprocessors that cost ten times as much. Delta Tau's programmers write the Turbo PMAC firmware directly in assembly language, bypassing the inefficient DSP compilers that other companies use, getting around three times the performance from the DSP as compiled code would get. As a result, Turbo PMAC has unparalleled computational speed, able to close a 2 kHz servo loop, and an 8 kHz commutation and digital current loop, simultaneously on 32 axes, with half of its computational power left for other tasks.

Multiple Servo Command/Format Modes

The Turbo PMAC supports the widest variety of servo command types and formats in the industry. These include:

- Velocity commands: analog
- Torque commands: analog
- "Sine-wave" commands: dual-analog
- Direct-PWM commands: 3-phase top-and-bottom PWM
- Pulse-and-direction for stepper and stepper-replacement servo drives

In addition, the data for all of these command types can be sent over the MACRO ring to remote nodes.

In the "sine-wave" mode, Turbo PMAC is performing the commutation of the motor phases (for servo or induction motors). In the "direct-PWM" mode, Turbo PMAC is performing the commutation and closing the current-loop for the motor, yielding the highest possible performance (at the lowest price). No other controller provides all of these possibilities.

Large Choice of Feedback Devices

The Turbo PMAC can accept the widest variety of feedback devices in the industry. The choices include:

- Digital quadrature encoders (with timer-based interpolation)
- Analog sine-wave encoders (up to 4096 states per line)
- Parallel absolute encoders
- Serial absolute encoders
- Resolvers (single or geared)
- Magnetostrictive linear displacement transducers
- Analog feedback (from LVDTs, RVDTs, potentiometers, etc.)

Sophisticated and Powerful Servo Capabilities

The Turbo PMAC provides sophisticated high-speed, high-resolution servo-loop capabilities that are used on some of the highest-precision machines in the world. Because of the speed and resolution, the standard PID control law provides very tight control for a wide variety of systems. The velocity feedforward, acceleration feedforward, and friction feedforward terms, recalculated every servo cycle, provide incredibly tight tracking control. Key terms in the servo algorithm (input, integrator, output) can be limited to provide predictability, safety, and stability. An additional second-order "bi-quad" filter can be used to add a notch filter, low-pass filter, or velocity-loop integrator.

Dual motor/load feedback is very easy to implement. Likewise, cascaded servo loops provide an easy and powerful way of creating hybrid control schemes, such as force/position, with seamless transfer between the modes.

For axes with difficult dynamics, the more advanced "extended servo algorithm" can be invoked. This algorithm, with 35 separate tuning terms, provides the greatest control flexibility of any commercially available servo algorithm.

Sophisticated and Flexible Trajectory Generation

The Turbo PMAC has the widest and most powerful variety of trajectory-generation modes in the business. The user can select the mode that provides the easiest description of the desired motion. These modes include:

- Linear interpolation: straight-line paths in Cartesian space
- Circular interpolation: circle, spiral, helical arc paths in Cartesian space
- Rapid-mode interpolation: minimum-time point-to-point moves
- Cubic B-spline interpolation
- Position-velocity-time (Hermite spline) interpolation
- On-line jogging moves, both indefinite and to a specified position

In the rapid mode, Turbo PMAC provides automatic "move-until-trigger" and on-the-fly "altered destination" capabilities.

Forward and Inverse Kinematic Capabilities

The Turbo PMAC has the provision for the user to install custom forward- and inverse-kinematic routines written in high-level language so that the motion of the tool can be programmed in the desired frame of reference, regardless of the underlying geometry of the mechanism. While most commonly used for robotic arms, it can also be used for many other types of applications, such as 5-axis machining, and polar-coordinate machines.

Special Lookahead Algorithms for Velocity and Acceleration Control

Turbo PMAC's special lookahead buffers scout ahead in the motion sequence for potential violations of position, velocity, and acceleration limits, even if hundreds of moves ahead, automatically slowing the trajectory as needed not to violate any of the constraints. This permits the user to take full advantage of the machine's capabilities wherever possible, with Turbo PMAC automatically figuring out where the speeds must be limited.

Hardware Position-Capture and Position-Compare

Turbo PMAC has dedicated hardware registers to capture the position of each encoder at the instant an input trigger occurs, and to provide and output the instant the position reaches a preset value. Once set up, neither of these functions requires any software intervention, so they are accurate to the exact count at any speed. The capture function yields very accurate homing, probing, and registration capabilities without requiring any slowdown for accuracy. The compare function permits high-speed but accurate scanning and measurement capabilities.

In Position Capture you capture the exact position at which an external event occurs. In Position Compare you trigger an external event at an exact position. In PMAC this occurs in hardware, and is therefore accurate to within a microsecond.

Position Capture involves configuring the PMAC to trigger a capture on a specified input. This input will be one of the flag inputs, which is brought directly into the gate array. When the input changes state the current position is instantly copied from the position register in the gate array to a capture position register on the gate array. This happens independently of servo tasks or any logic running on the PMAC, so happens in a nanosecond time scale. This function can be used for on the fly position correction, print registration, or for any other task, which requires an extremely accurate position reference to some external event. Any 12-24 VDC input can be used to trigger the capture.

For example, on a high-speed web printing application there may be a reference mark printed at specific intervals. Using a sensor to capture the position of the rising and/or falling edges of that mark allows you to correct in real time for any deviation from the expected placement. Perhaps it can be used in conjunction with coordinate rotation to correct for misalignment of parts in a line. Finding one or more edges of a part with a proximity sensor of some sort will allow for recognizing and measuring misalignment, and coordinate rotation can correct for that.

In Position Compare you want to trigger an external event at a specific location with a high degree of accuracy. This might be used to pulse a laser on the fly without having to allow the laser to stop and settle into position. It may also be used to fire a punch, or to fire an interrupt on your computer. Basically it can be used to fire a digital output, which can be used to trigger whatever you want.

Move Until Trigger

Pmac's "move until trigger" function allows a programmed axis move to be interrupted by a trigger and the move terminated. A good example of this functions use is a probing routine. Where the trigger is an input from a probe. This function can also be used to cancel a move when a torque limit has been reached.

The "move until trigger" function has three parts. The first part is the move to position. The second part is the "move to" position relative to the trigger position after the trigger has occurred. The position of the axis is stored at the time of the trigger and can then be used for further processing. The third part is a status bit, which is set when the trigger move is started and reset to zero if a trigger has occurred. This status bit will be evaluated at the end of the move to see if a trigger has occurred.

The syntax looks like this "X8.50^-0.5" Move the X axis to 8.5". If a trigger occurs move back .5" from the rigger position.

Automatically Sequenced Motion Programs

Turbo PMAC's motion-program execution is automatically sequenced by the move, in the style of a CNC controller. Unlike standard CNC controllers, however, Turbo PMAC can also execute sophisticated, high-level math and logic functions in sequence with the motions. Compared to motion programming approaches based on standard high-level computer languages, Turbo PMAC automatically handles the sequencing of the moves and associated math, logic, and I/O in its operating system, removing this difficult sequencing requirement from the user's code.

Asynchronous PLC Program Execution

The Turbo PMAC also can execute up to 64 "PLC" programs, which all scan asynchronously to the motion sequences and handle any logic and calculations that are not appropriate for the sequenced motion programs. While very powerful for the I/O control of a traditional PLC, because they have access to all registers and variables on the Turbo PMAC, they have many other uses as well, such as safety checks, adaptive control, cross-coupled control, status monitoring, user interface, and more. Because the Turbo PMAC's operating system automatically handles the sequencing and prioritization of these and other tasks, the application programmer's task is vastly simplified.

The Pmac has the capability of up to 64 PLC programs. 32 are compiled PLC's and 32 to non-compiled. These programs are called PLC because they perform the same functions as hardware Programmable Logic Controllers. These programs in the PMAC run asynchronously and in rapid repetition. Compiled PLC's are the same as non-compiled in structure and syntax but are compiled into to processor code when downloaded to the PMAC. This allows for faster processing and more efficient code. .

The PLC programming syntax is very much like the BASIC programming language. It uses statements like "If, While, Goto" and operators like "= ,<, >, +,-" to name a few.

The PLC syntax also contains powerful math functions like "sin, cos, sqrt, abs, atan" to name a few. Common uses of PLC's are to monitor analog and digital inputs, set outputs, and starting and stopping of motion programs. By the PMAC using up to 32 PLC's the total application can be broken down into PLC's by function, (ie, spindle, tool changer).
The PLC' can be written using any ACSII text editor. Then using Delta Tau's utility software downloaded to the Pmac. Delta Tau also supplies a Marco statement substitution complier. This allows the programmer to use statements that are more readable. An example would be. "Coolant_sol" would be substituted for M900(output variable). "On would be subbed for 1 and "Off" for 0. The final code would look something like this

Coolant_sol = On
Or
Coolant_sol = Off

These Macro statement substitutions are typically created in a definition file using the #Define statement (#Define Coolant_sol M900). This Definition file is added the to the PLC using a "#Include" statement.

SUMMARY

Utilizing Pmac's built in PLC programming eliminates the need for third party PLC Hardware. The Pmac PLC syntax is easy to use and the PLC programs are easy to create, edit and document using any text editor.

Broad Command Set

The Turbo PMAC has by far the widest command set in the industry, with hundreds of different commands, both for immediate and buffered execution. This command set has been built through 20 years of motion control experience in a wide variety of markets, providing an unmatched "cross-pollenization" of capabilities at the disposal of users in every field.

Open and Flexible Structure

The Turbo PMAC provides a more open structure than any other controller, permitting the user access to all registers, including internal computational registers. This provides easy access to the information required to optimize a particular application in a way that is not possible, or at least not easy, in any other application. This gives the user the capability to go far beyond the standard feature set, limited only by the imagination.

Lead Screw Compensation

Many systems in industry today use a leadscrew with a rotary motor to implement a linear motion along a set of axes. Delta Tau controllers provide a unique ability to compensate for errors introduced in the mechanical system through the implementation of leadscrew compensation tables. By implementing this feature it is possible to get near linear encoder accuracy with a rotary encoder on the shaft of the motor. These compensation tables are stored on the controller, available for all motors, and once entered make mechanical errors unnoticeable to the user/programmer of the machine.

By using Delta Tau's leadscrew compensation you also have the ability to use cross-axis compensation tables or 2 dimensional compensation tables. Cross-axis compensation is a very unique tool helpful when a leadscrew is bowed. For example, you can make compensations in the Y direction every time the X-axis moves and vice-versa. This can also be used to implement an electronic cam operation. This is a simple easy implementation for a bi-directional electronic cam setup.

Two-dimensional compensation tables are very useful in laser marking systems or any system where the axis is defined as a combination of 2 motors. The compensation is then implemented based on the location of both motors. This is a very powerful tool that demonstrates Delta Tau's flexibility and ability to provide the most accurate control in the industry.

Backlash Compensation

Even with a comprehensive-thorough mechanical design, many systems still experience backlash in the gearing from motor shaft to end position. Backlash happens upon the reversal of motor direction. The motor changes direction and the load movement is unaffected for a period of time. Delta Tau controllers can perform sophisticated backlash compensation for all motors. The backlash compensation scheme provides the ability to provide a constant backlash parameter whenever direction is changed as well as a backlash compensation take-up rate that allows the magnitude of compensation to be implemented linearly with respect to position upon reversal. These two features can eliminate many simple backlash cases.

Other tools available to address more complex backlash situations include a backlash hysteresis term and backlash tables. The backlash hysteresis term is particularly useful in a master-slave application where the master may experience some dithering on its encoder. This hysteresis term prevents backlash from repeated compensations.

In cases where backlash varies with respect to motor position a backlash compensation table is most useful. This will allow the most flexible solution to a backlash problem.

Summary

Delta Tau Controllers provide the most flexible system solution that can compensate for many machine imperfections. Backlash and leadscrew compensation techniques in a Delta Tau controller provide the ability to realize more accurate and stable control from an inaccurate and imperfect machine.