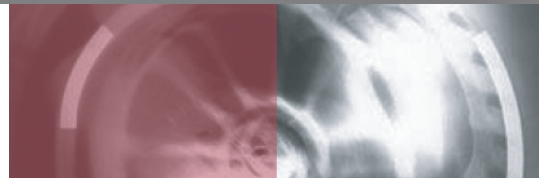


White Paper

Technical



Distributed Motion Control for Robots

Distributed Motion Control for Robotics Applications

Daryl Prince Agile Systems

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Abstract

This paper discusses the application of an intelligent power and motion control module for robotics systems. A single DSP is used to close both current and position loops for 3 axes in a compact package. By communicating commands over a serial network the user can mount the intelligent power modules close to the motors instead of in a control panel.

Summary

Agile Systems has developed an integrated power and control module that combines both the drive and motion control functions into a single compact package. The MAX™ product controls and drives 3 brushless DC motors up to 400 Watts each. With the encoders, hall sensors, and multiple user I/O and limits connected directly to the MAX™ unit, the only external requirements are for a serial network for communication purposes and a DC power source.

Embedded into the MAX™ are the current and position loops as well as an application layer for greater than 50 user commands. An S curve trajectory generation is utilized in point to point applications and a profile-streaming mode is utilized in complex trajectory applications.

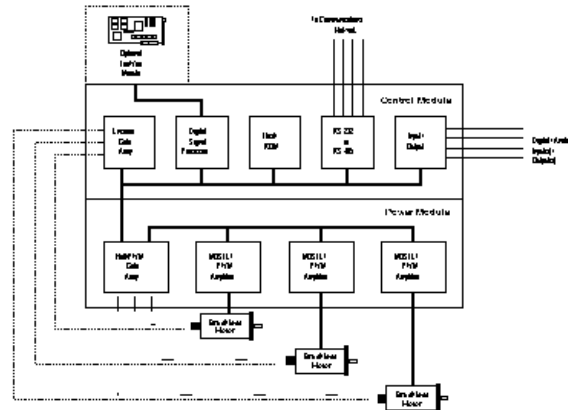
Contained within a compact 3.0" x 8.0" package, these modules are designed into robotic arms and subsystems, such as pick and place robots or XY tables. The opportunity to mount the MAX™ unit as part of the robot system instead of a traditional control panel allows the user to reduce wiring, increase reliability, decrease noise susceptibility and increase diagnostics.

Hardware Description: MAX™ is based on a basic two-module approach with a tighter coupling between power and control than the traditional analog interface as outlined in Figure 1. The digital interface from control to power section passes PWM values and returns actual current values. Trapezoidal and Sine commutation can be selected based on user requirements.

The power section can be sized for different voltage and current ratings. This paper discusses both an 85V, 12 Amp peak and 85V 3 Amp peak rating with 9 H bridges to connect to 3 - 3 phase brushless motors.

All motion processing, trajectory generation, I/O commands and network management are performed on the control module. The 3 axes control utilizes a low cost fixed point DSP and

FPGA. An expansion interface for different communications networks and additional I/O is



also available.

Figure 1: MAX Hardware Block Diagram

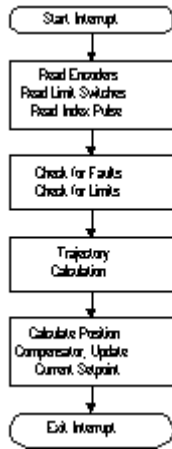
Network and Command Structure: The control module includes a 115kbaud and 1.25Mbaud RS485 communication network for transmitting command primitives to the MAX™ control modules. The command primitives are binary coded elemental commands for functions such as starting a move, configuring a move profile, reading and setting parameters, data logging, continuous profile, I/O related commands, etc. The network packet containing the command primitive totals 8 bytes. For operation with RS485 a total command time of 200ms is achieved including acknowledgement and status return.

Axis Processing: Command Primitives received over the network are put in queues for each axis for sequential execution. Commands can be executed immediately upon receipt or structured to minimize network latency by queuing and utilizing internal triggers based on user defined states, such as external inputs, absolute encoder position, completed moves. Each axis can queue up to 16 commands.

The DSP executes the loop as outlined in Figure 2 for each axis driven from a real time clock interrupt every 50ms. The current is compensated on every cycle of the interrupt. The position, acceleration, and velocity values are updated every 5 cycles. The trajectory set points are calculated based on the commanded jerk (J), Acceleration (An), Velocity (Vn) and position (Sn) as follows:

$$A_n = A_{n-1} + T_s * J$$

$$V_n = V_{n-1} + T_s * A_n$$



$$S_n = S_{n-1} + T_s \cdot V_n$$

Servo Position: The MAX™ utilizes an observer based state variable control with velocity feed forward for controlling the position. Illustrated in Figure 3 is the position loop over an inner current loop. The position loop provides better performance by controlling two state variables, namely position and velocity. Because there is no direct measurement of velocity, velocity feedback is provided by a velocity observer.

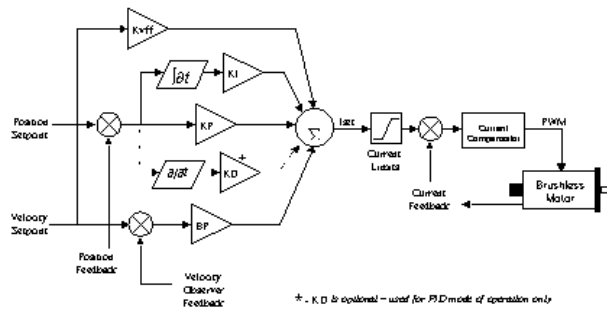


Figure 3: Position Compensator

Profile Streaming Operation: For complex trajectories the trajectory set points for acceleration, velocity and position can be provided directly from the user. It is possible to receive only the position set points and have the MAX derive the acceleration and velocity. A command primitive is utilized to transmit a set point position. Utilizing the RS485 network, position updates can occur every 600ms for 3 axis. Sub-interpolation of the data occurs on the MAX™ for the 250ms position update rate.

Robotic Arm Implementation: The robot manufacturer can create a trajectory for each axis and utilize the MAX™ in profile streaming mode. The small size of the MAX™ allows mounting inside the robot arm. The benefits of this approach include:

Wiring reduction: on a 6 axis robot with brushless DC motors and brakes with differential hall and incremental encoders with a small I/O complement, the traditional method would require upwards of 150 conductors vs. 10 for a MAX™ implementation, including HV and 24V power with communication.

Noise immunity: Two critical cable systems are reduced or eliminated with a MAX™ implementation: (1) the encoder cable is dramatically shortened, and (2) the analog current

reference is eliminated. These cables are replaced with a serial network cable that has error checking built into the network design.

Increased Diagnostics: The MAX™ DSP monitors position following errors, amplifier temperature, average current levels, voltage and current peaks and is able to respond immediately and report directly to the host any anomalies through the network.

Reliability: Reliability is improved by the reduction of flex cable and by the improved diagnostics.

Pick and Place Implementation: For electronics assembly Pick and Place the MAX™ is utilized to control and drive the z and theta axis. Using the internal S-curve generation on the MAX™ the network is used to send motion commands from the host computer. Commands are loaded into the queue for cyclic operations to minimize network latencies. Implementation of a pick cycle would be:

- Move absolute (move z spindle down),
- Wait until done (wait until move is complete),
- Discrete output on (enable vacuum),
- Wait until analog (wait for vacuum sensor threshold),
- Move absolute (move spindle up),
- Interrupt when nearly done (trigger to start XY move).
- All commands can be sent while the first command is executing, so network latency does not add delays.

Conclusions

The MAX™ architecture is ideally suited to applications that can take advantage of a distributed motion control architecture such as of robotic arms and robotic sub-systems. The advantages of sending motion commands or position set points over a serial communication network are lower systems cost, reduced wiring, better noise immunity, increased diagnostics and higher reliability.

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