ACS Tech80
REDEFINING MOTION CONTROL

SPiiPlus Series

Advanced, High Performance Multi-Axis Motion Control Products

A complete line of motion control products and software tools

Supported Motors:
AC Servo/DC Brushless
DC Brush
P/D Stepper
Nanomotion Piezo-ceramic

The SPiiPlus products are designed to meet the requirements of the most demanding applications including semiconductors manufacturing and inspection, electronic assembly and testing, medical imaging and digital printing equipment. The SPiiPlus handles complex demands without compromising accuracy or throughput.

The SPiiPlus motion control products support up to eight axes. Advanced features and capabilities, such as a multi-tasking environment, complex motion trajectories and coordination between axes, inverse kinematics, gantry control, dynamic error compensation and built-in sin-cos encoder multipliers are optional.

The SPiiPlus series includes the following product categories:

- ***Motion Controllers:*** PC-based or stand-alone multi-axis controllers that support both direct-connected servo or stepper motors and HSSI-networked servo drives. Controllers include digital, analog, and safety I/O.
- ***Motion Control Modules (CM):*** Multi-axis controllers with up to three integrated digital drives. Control Modules support direct-connected servo motors, direct-connected stepper drives, and HSSI-networked servo drives. Control modules include digital, analog, and safety I/O.
- ***HSSI Modules:*** External modules that connect to the controller's High-Speed Synchronous Serial Interface (HSSI) channel via standard Ethernet-type cables. The HSSI modules enable distributed axis control, digital or analog I/O expansion.

SPiiPlus control products can operate stand-alone or with a host computer application, communicating via PCI bus, serial channels, and fast Ethernet channel. Multiple communication channels can operate simultaneously.

Closed-loop control can be based on high-speed quadrature encoders, sin-cos encoders (optional) with programmable x4 to x65,536 internal multipliers, analog feedback, or customized non-standard devices via the HSSI channels.

The SPiiPlus control products come with digital and analog I/O that can be used for general purpose. In addition, digital inputs can be used for hardware-based position registration and outputs can be used to trigger position-based events with sub-microsecond delays. Special high current outputs can be used to activate mechanical brakes (in control modules only).

Complex applications are easy to develop with ACSPL+, a powerful, compiled, true multitasking, high-level language that is optimized for motion control applications. Ten programs can run simultaneously, enabling multiple interacting and synchronized processes. ACSPL+ enables implementation of highly complex motion-time-event sequences with accurate positioning and timing. The program can run directly in the controller or can be implemented in a host PC application using DLL or COM libraries provided for C,C++, Visual Basic™, LabView™ (and more), operated by Windows™ 2000/ME/NT/XP. In addition, extensive C/C++DLL libraries are available for On-Time™ and Venturecom™ RTX real-time operating systems.

Powerful software tools are provided for setup, tuning, and programming. Application development is particularly easy with the integrated four-channel soft scope and multi-axis motion simulator.

The servo control algorithm executes at an uncompromising rate of 20kHz for each axis regardless of the number of axes in use, providing very large bandwidth, exceptional dynamic tracking, fast settling and excellent smoothness at low velocities.

SPiiPlus products are manufactured under an ISO 9001 certified quality management system, meeting stringent safety and EMC standards.

SPiiPlus Series Highlight

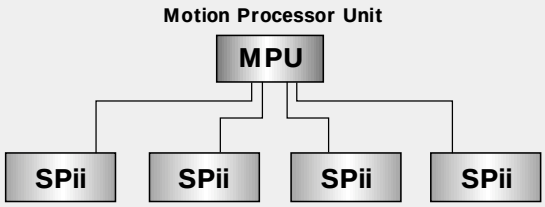
- Handles demanding applications without compromising on accuracy and throughput
- Supports a wide range of motion modes, including point-to-point, jog, segmented, master slave, and arbitrary path with PVT cubic interpolation
- Third-order profile generation with on-the-fly velocity, acceleration, jerk and target position changes
- ACSPL+: multitasking, high level, motion control programming language
- Sub-nanometer resolution with optional sin-cos encoder multiplier
- Full suite of software tools for setup, tuning, and application development
- Unique multi-axis motion simulator for rapid application development
- Extensive DLL and COM libraries for C,C++, Visual Basic™ and LabView™

For more information about each SPiiPlus product please refer to the product's data sheet.

Motion Technology

Distributed Multiprocessor Architecture

The SPiiPlus products are based on a distributed multiprocessor architecture consisting of a Motion Processor Unit (MPU) and a SPii (ACS-Tech80's second generation Servo Processor) per two axes. The MPU is a Pentium™ like PC104+ type of PC. The MPU multi-tasking real time operating system handles the profile and trajectory generation, ACSPL+ application programs, user command execution, I/O, safety and faults.

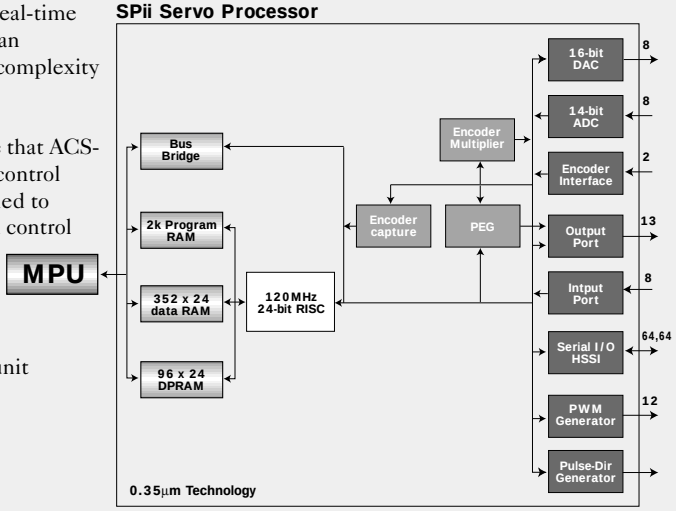


The distributed architecture with a dedicated SPii per each pair of axes guarantees 20kHz update rate for all axes.

The SPii has been design by ACS-Tech80 to provide better solutions for the growing needs of current and future machinery and industrial automation. The SPii is dedicated to the execution of the real-time control filters. It executes the filter with 48-bit accuracy at an uncompromising 20kHz-sampling rate independent of the complexity of the filters.

The SPii is an ASIC that incorporates a 120MHz RISC core that ACS-Tech80 fully designed and optimized for real time motion control algorithms, combined with all the peripherals that are needed to implement a complete high performance, all digital motion control system.

SPii Servo Processor



The SPii also provides unique capabilities such as x65,536 SIN-COS encoder multiplier, Position Event Generator (PEG), position registration and P/D stepper control.

SPii Servo Processor Highlights:

- 120MHz, 24-bit RISC with 48-bit multiply-accumulate unit
- Two high speed encoder counters
- x4 - x65,536 encoder multipliers
- 16-bit DAC interface with eight outputs
- 14-bit ADC interface with eight inputs
- Six pairs of 14-bit PWM generators
- Pulse-direction generator
- PEG - position compare outputs
- Position registration inputs
- High-speed Serial Synchronous Interface (HSSI) with 64/64 I/O

Advanced Servo Control

PIV Control and Flexible Algorithms for Enhanced Performance

PIV control is implemented with:

- Velocity loop with Proportional & Integral (PI) gains including anti-windup mechanism, a second order low-pass filter, and a notch filter
- Position loop with Proportional gain (P)
- Automatic Velocity feedforward (V) and programmable acceleration feedforward

The SPiiPlus executes the filters at an uncompromising rate of 20kHz with 48-bit accuracy, providing very high bandwidth, responsive servo loops with exceptional dynamic tracking, fast settling, and outstanding smoothness at low velocities.
If an application suffers from low frequency resonance (a common problem in belt-driven systems and high-inertia direct drive systems), performance can significantly be improved using the notch and low pass filters and dual loop feedback structure.
Special control algorithms are provided for dynamic and static friction compensation and for Nanomotion (www.nanomotion.com) piezo-ceramic motors.

Fast and Easy Tuning

With the PIV algorithm, each loop is tuned separately. Achieving a robust, stable, and optimal response is fast and easy. Special software tools provide a menu-driven, intuitive environment for setting up and tuning the system. Axis response can be monitored and analyzed in real time with the integrated four-channel soft scope.

Torque Ripple (Cogging) Compensation

The SPiiPlus torque ripple compensation significantly improves the performance of motors affected by cogging, especially at low speeds.

Customization of Control Algorithms

The standard control algorithms meet the requirements of most applications, however, if your application requires customized filters, these can be implemented for each SPii (done by ACS-Tech80). The distributed architecture of the SPiiPlus enables modifications to be made without affecting other parts of the software.

MATLAB / Simulink™ Models

Models of the filters are provided, enabling you to build complete motion control simulations.

Advanced Features of Digital Drives in Control Modules

Sophisticated Current Control for Improved Dynamic Performance

The current loop error is zeroed by controlling separately the torque-producing and field-producing current components, improving operation for a wide range of velocities.

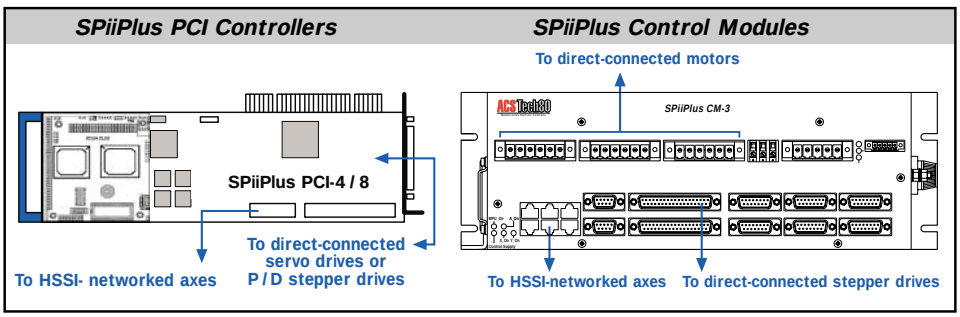
True Space Vector Modulation for Higher Yield

Space vector modulation increases the linear operation range of the digital drive by more than 15%, achieving higher velocity, lower position error, and reduced current at high velocities.

Centralized or Distributed Control Architecture

SPiiPlus products are designed for local and distributed axes. Control of an axis can be done in three options:

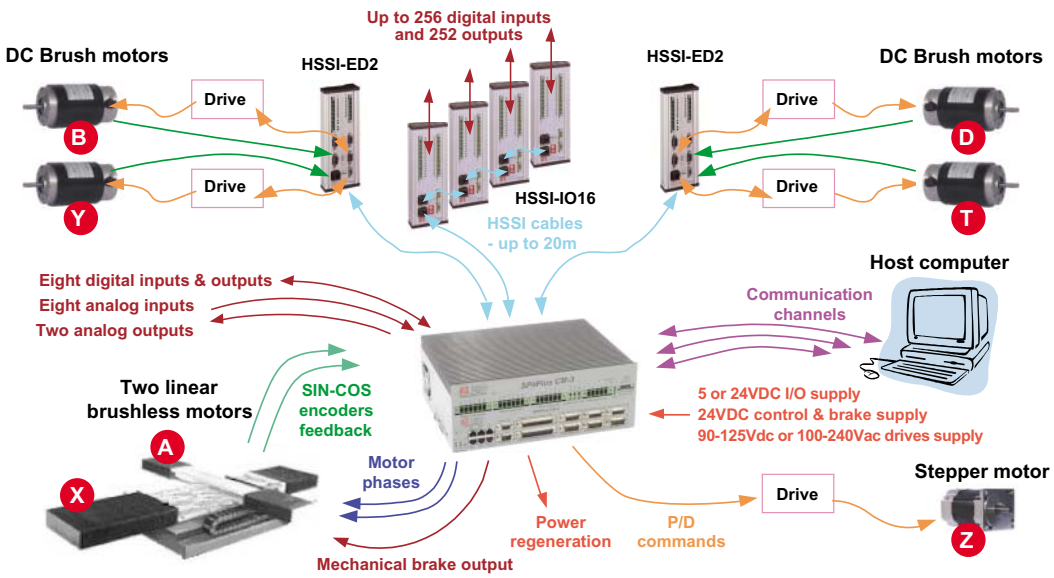
- ***Direct-connected motor (control modules only):*** This is a unique, highly cost effective full control & drive solution where the motors are powered directly from the Control Module
- ***Direct-connected drive (controllers and control modules):*** This provides control for third party drives. In SPiiPlus PCI, commands for servo drives are 16bit, differential, ±10V. In SPiiPlus PCI/CM, commands for stepper drives are differential pulse and direction (P/D)
- ***HSSI-networked axis (controllers and control modules):*** This provides control for distributed drives. All signals between the control product and a remote HSSI module are carried by a single standard Ethernet-type cable



The following HSSI expansion/distribution modules are available:

- ***HSSI-IO16:*** I/O expansion module, provides additional 16 opto-isolated digital inputs and 16 opto isolated digital outputs. Up to four HSSI-IO16 units can be daisy chained to an HSSI channel, providing a total of 64 inputs and 63 outputs per channel
- ***HSSI-ED2:*** Two brush motor drive interfaces with ±10V torque command, two 3-channel quadrature (A&B, I) encoders inputs, four limit switch inputs, and eight/eight opto-isolated general-purpose digital I/O
- ***HSSI-SA1:*** Single-axis drive module for DC brush and DC brushless motors.

The following drawing illustrates a typical distributed application with SPiiPlus CM-2:



HSSI-IO16 module

HSSI-ED2 module

HSSI-SA1 module

- Feedback signals
- Drive commands
- Motor phases
- Third party drive
- HSSI cable
- I/O
- RS-232 / RS-485/ Ethernet
- Power supply
- X - Axis name

ACSPL+ Motion Programming Language

High Level Language For Demanding Motion Applications

ACSPL+ is a fully compiled, true multitasking, high-level language for programming SPiiPlus control products. The language supports complex motion-time-event sequences with accurate positioning and timing.

Up to ten separate programs can run simultaneously, with programmable execution rate for each program. The host PC and the control product can continue to communicate while the programs are running. Programs can be stored in non-volatile memory.

General Features of ACSPL+:

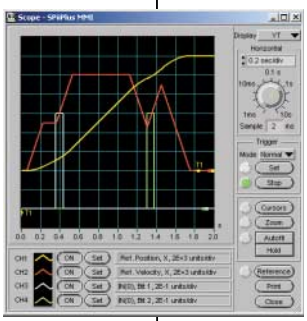
- Multitasking compiled language
- High speed PLC programming
- Parametric programming (axis can be designated as a number)
- Complex mathematical expressions
- 64-bit floating point arithmetic
- Rich set of logical, statistical, aritmetical, trigonometrical and signal processing functions (like edge, dead zone and mechanical error mapping)
- User defined local and global variables: scalar, one- and two dimensional array
- Large user defined memory (>2Mb)
- User-defined autoroutines: triggered when a predefined condition is satisfied
- Extensive safety and diagnostics
- Real-time data collection at 1kHz or 20kHz
- User-defined units for faster development and easier adaptation of different feedback devices

Advanced Motion Control Features of ACSPL+:

- Multi-axis point to point, jog, tracking and sequential multipoint motion
- Arcs and lines by segmented motion
- Arbitrary path with PVT cubic interpolation
- Third order profiles (S-curve) with jerk, acceleration and deceleration control
- On-the-fly position, velocity and acceleration change
- Inverse kinematics and axes transforms
- Master-slave with position and velocity locking (electronic gear/cam)
- Virtual master axis capability
- Open loop (torque control) motion
- Dynamic error mapping and backlash compensation
- Control of two motors as one axis (gantry) with separate feedback for each motor

Programming

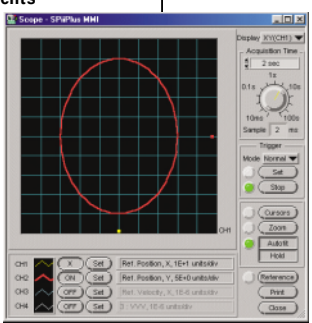
```
ENABLE X
PTP/V X,10000,5000  ! Move to 10,000 at 5000
                    ! user units per second
TILL IN0.1=1        ! Wait for input#1 (blue)
IMM X_VEL=10000     ! Change to new velocity
TILL IN0.2=1        ! Wait for input#2 (green)
BREAK X             ! Break the motion
PTP X,12000         ! Change target position
                    ! to 12,000
STOP
```



Velocity, acceleration, jerk and target position can easily be changed at any stage of the motion profile

Programming

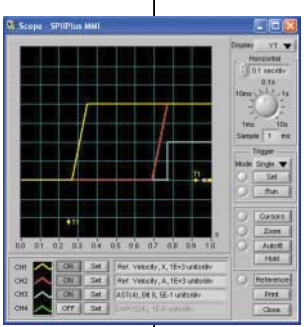
```
INT J ; REAL PI          ! Define two user variables
 J=0 ; PI=3.14159
ENABLE XY
LOOP 30
   PTP XY,20*COS(2*PI/30*J),30*SIN(2*PI/30*J)
   ! Make an ellipse by 30 line segments
   WAIT 100
   J=J+1
END
```



Complex X-Y move can easily be implemented

Programming

```
ENABLE XA
PTP X, 6000
  ! Move X axis (Yellow) to 6000
TILL X_RPOS>=2000
  ! Wait until X reference position >2000
MASTER A_MPOS=X_FPOS
  ! Define a master formula
SLAVE A
  ! Initiate A axis (red)
  ! as velocity slaved to X
PTP X,0
  ! Move X (and A) back to 0
STOP
  !---------Autoroutine ----------------------
ON A_AST.#VELLOCK
  ! Activate Output #1 (blue)
  ! when the axes are synchronized
OUT0.1=1
RET
```



Complex Master-slave with position and velocity locking (electronic gear/cam) can easily be implemented

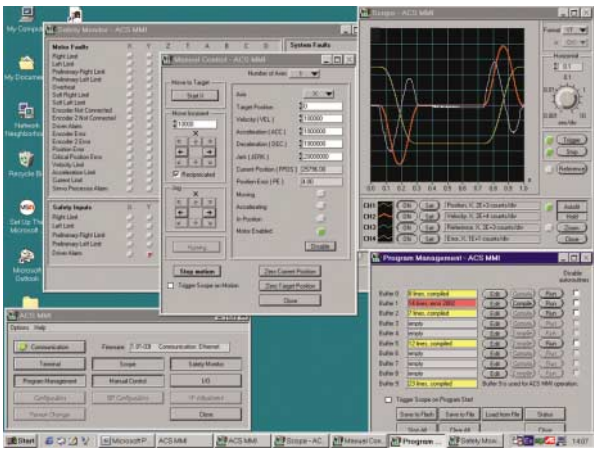
Software Tools

Easy Setup, Fast Application Development and Diagnostics with SPiiPlus Software Tools

The SPiiPlus support tools are designed to answer the needs of your system throughout its life cycle. The suite of tools allows easy setup, simple application development, fast production integration, powerful remote diagnostics and error recovery when your system is installed in the field. A well integrated solution that is designed to reduce your total cost of ownership. The tools minimize time to market while providing you with the flexibility to ensure that your special needs in motion control are answered. SPiiPlus Tools operate on Windows™ NT/2000/ME/XP and include the SPiiPlus Simulator. The tools are continuously updated to support new available platforms.

SPiiPlus MMI - A Comprehensive Motion-Machine Interface

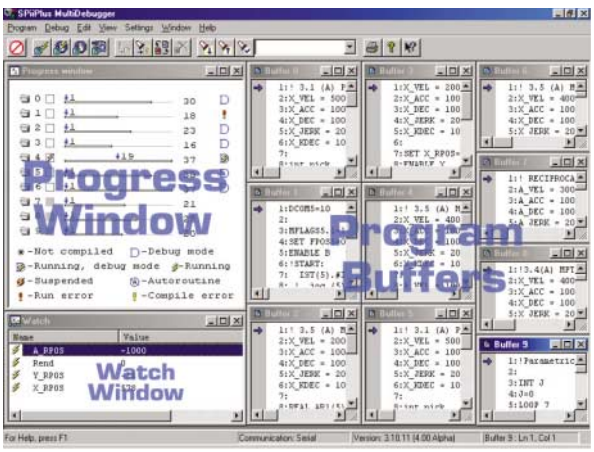
The Motion Machine Interface (MMI) offers multi-purpose interactive tools for configuration, servo tuning, programming and viewing parameters. It includes an ACSPL+ program manager, a four channel interactive oscilloscope with FFT capability, a communication terminal, an easy to operate motion manager, an I/O monitoring screen and safety monitoring features.



The SPiiPlus MMI provides software tools to run applications and analyze motion

SPiiPlus MultiDebugger - ACSPL+ Applications Development Environment

The SPiiPlus MultiDebugger is a development environment for programming the ACSPL+. It is designed to answer the development needs of sophisticated, complex and multi-tasking applications. Advanced debugging features including progress monitoring, line-by-line execution, break points and multiple variable watch. These features will help you to reduce development time and effort.



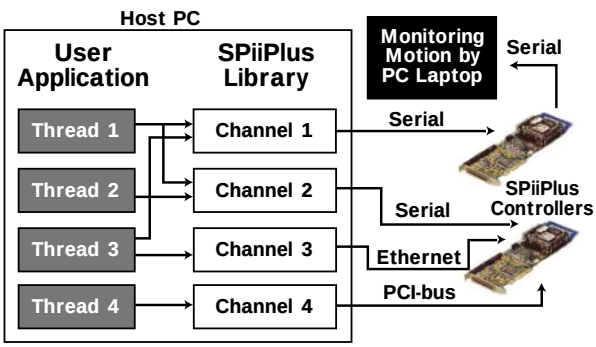
The SPiiPlus MultiDebugger provides software to develop and debug the user application

SPiiPlus Library – An Advanced API for Host Programming

A comprehensive set of dynamic link library (DLL) and drivers are available for host programming in C/C++ and Visual Basic™. The library supports simultaneous communications and multi-threaded applications (up to ten communication channels and interrupts with callback functions). Communication can be between one application and several controllers or between several applications and one controller. The communication link can be via PCI bus, two RS-232 channels, and/or Ethernet.
The following libraries are available:

- DLL/COM for Windows™ NT/2000/ME/XP
- On Time™ (RTOS)
- DLL for Windows™ NT/2000/XP with Venturecom™ RTX (RTOS)

ACS-Tech80 is continuously adding support for additional operating systems.



The SPiiPlus Library is multi-threaded and supports simultaneous communications

SPiiPlus Utilities

Utilities for upgrading firmware, recovering from errors, and managing applications.

SPiiPlus Simulator - Significantly Shortening Your System Time to Market

All SPiiPlus software tools can be provided with a unique built-in simulator of the controller which allows applications to be developed and logically debugged without attaching any hardware. Develop a virtual simulation of your whole system on your host and use ACSPL+ programs to emulate changes of inputs, outputs, safety faults, errors and more. Each controller is provided with a CD that includes the suite of software tools, including a limited version of the simulator.
SPiiPlus Simulator can be downloaded from www.acs-tech80.com.

Advanced Features

Special hardware and software features are provided to answer the needs of complex and demanding applications such as semiconductors manufacturing and inspection systems, electronic assembly, digital printing and similar high accuracy and high throughput equipment.

Software Commutation

The controller can produce a torque/current command to the drive or can commutate the AC servo motor in software - commanding the current in two of the AC servo motor phases. Commutation is done at a 20kHz update rate.

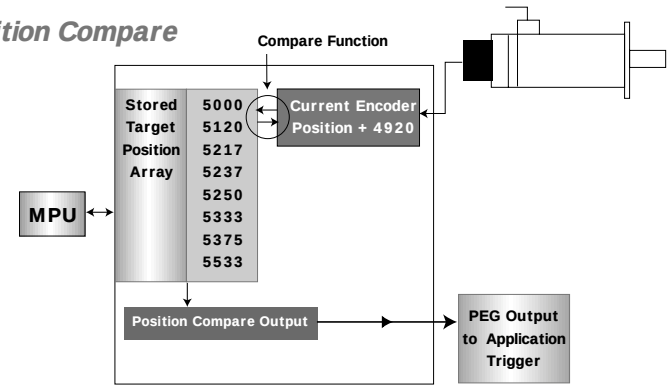
Selection of Feedback Source

For each axis, the position and the velocity feedback sources can be individually selected. They can be one of the encoder inputs, an analog input, or one of the HSSI ports. The HSSI can be used to interface to various external devices, such as absolute encoders, resolvers, laser interferometers with parallel output and more. One can dynamically switch between sources, so that high performance auto-focus system can be easily implemented. The velocity feedback can be derived from the position feedback, or from a separate sensor that is usually mounted on the motor ("dual loop").

SPiiPlus PEG - High Speed Hardware Based Position Compare

SPiiPlus controllers are provided with a hardware-based Position Event Generator (PEG). The main purpose of PEG is to trigger external events via outputs at precise positions with sub-microsecond delays. It can provide accuracy of ±1 quadrature count at up to 5,000,000 encoder quadrature counts/second. Typical applications include vision systems, automated optical inspection (AOI), scanning and laser cutting.

Two modes of operation are supported: Random and Incremental. In Random mode, pulses are generated at positions that are predefined by a position table. In addition, on both the X and Y axes Random PEG controls the state of four digital outputs. This feature provides the capability to activate up to 16 remote operations in association with each PEG event. In Incremental mode, pulses are generated at a programmable interval and start location. Both modes provide the ability to mix encoder based and time based events. This powerful feature enables the use of sin-cos encoders in applications that previously required expensive laser interferometer feedback.

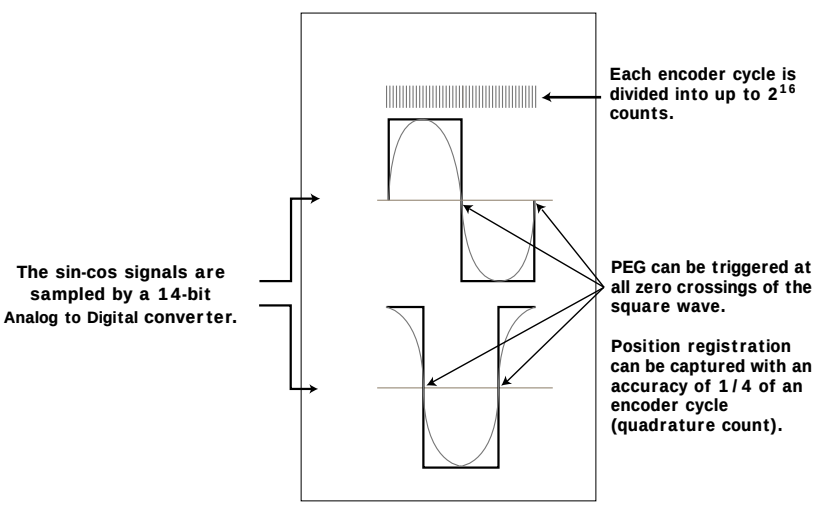


The SPiiPlus Position Event Generator (PEG)

SPiiPlus Hardware Position Registration (MARK)

SPiiPlus controllers are provided with high speed and high accuracy encoder index and application mark registration capabilities. In many applications, such as packaging, it is desirable to move an axis to a target that is relative to a registration mark. Once an axis is moving and a mark is detected, the motion profile is smoothly modified on-the-fly to reach the new target position. This feature can also be applied with high resolution sin-cos encoders.

Sin-Cos Encoder Multipliers



Analog to Digital Converter inside SPiiPlus controller

The SPiiPlus can be optionally provided with up to eight sin-cos encoder multipliers. Each sin-cos encoder multiplier accepts an analog 1 Vptp input signal.

The theoretical sin-cos encoder multiplication factor is x65,536. In field tests, a jitter of ±1 encoder count was achieved with x8,192 multiplication. Controlling a high performance XY table for wafer inspection, a jitter of 1 nanometer was achieved.

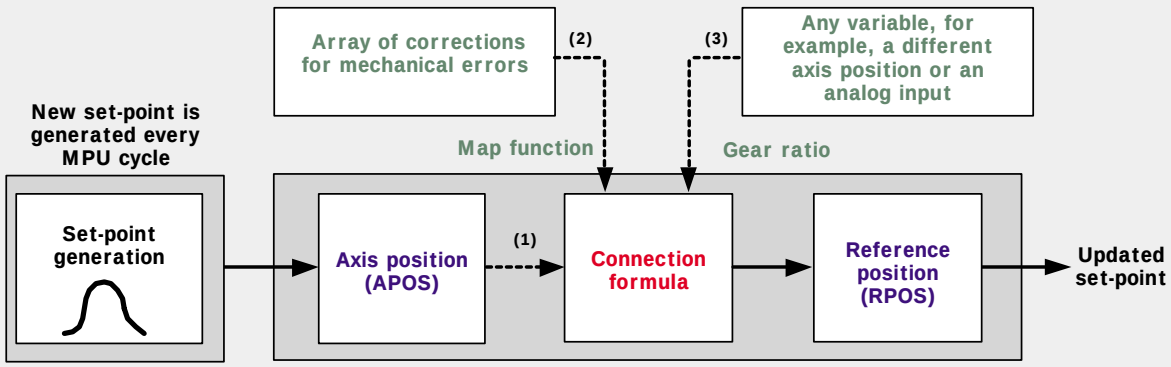
Stepper and high-resolution micro-step control

The SPiiPlus PCI supports up to eight axes, half of which can be P/D stepper motors. For example, the eight-axis controller model can control seven servos and one stepper, five servos and three steppers, etc. The controller can generate driver pulses at rates of up to 4,000,000 steps per second, which enables the use of high-resolution micro-step drives without sacrificing speed.

Powerful Capabilities

Allows and Simplifies Implementation of Complex Motion Tasks

SPiiPlus axis profile generation makes it easy to implement tasks like gantry control (two or more motors working in parallel), one- or two-dimensional dynamic error compensation (for mechanical error correction), and axis-coordinate transformations.

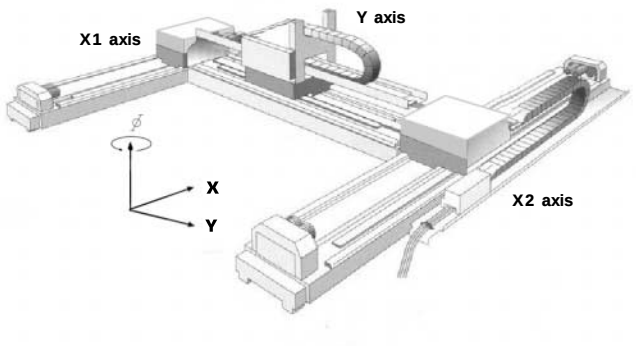


Powerful axis profile generation

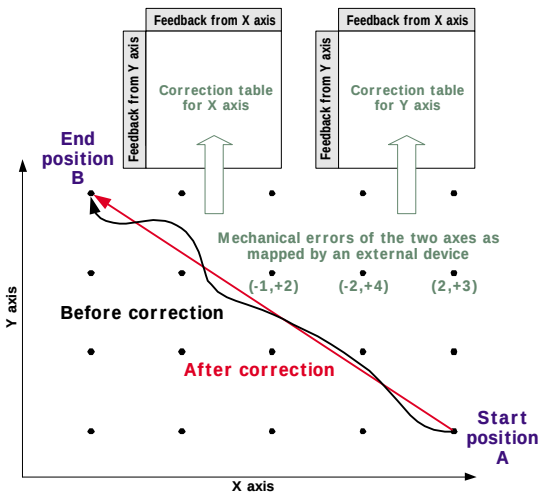
Axis profile generation is updated every MPU cycle (user-defined: 0.5, 1 or 2 msec).
The figure above illustrates three possible routes or any combination of the routes for each axis profile generation:

1. The connection formula can be modified to define any relationship between the axis virtual position (APOS) and the axis reference position (RPOS). The default formula is one to one.
2. The connection formula can be modified with a map function that reads values from a user-defined array. This route is used toimplement dynamic error compensation.
3. The axis position can be geared to one or more variables (for example, other axis position).

Built-in Functions for Ganrty and Dynamic Error Compensation



Typical gantry application with two motors working in parallel as one axis

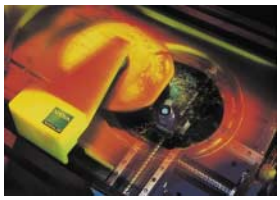


Dynamic Error Compensation for mechanical errors in X-Y stage

How To Order

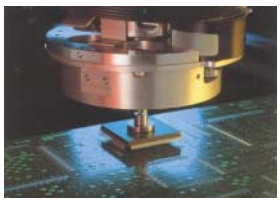
For ordering details, refer to the individual SPiiPlus product data sheets.

Applications



Semiconductor

- Sub-nanometer resolutions using the built-in sin-cos encoder multiplier for high accuracy and very low jitter
- 100 nano-second hardware position compare (PEG) for vision triggering
- 20kHz servo update rate with sophisticated PIV filter for accurate position, highly stable low velocity and quick settling times
- Software commutation for optimal ripple free operation
- Maximize machine performance in both front and back-end equipment
- Dynamic auto-focus control for wafer inspection with high magnification
- Dynamic error mapping and correction by powerful CONNECT function
- Powerful gantry control (using two motors each with its own feedback as one axis)



Electronic Assembly & Testing

- Combining very high velocities of meters per second with sub-micron resolution using sin-cos multiplier for optimal accuracy and throughput
- Third order profiles that significantly reduces settling time
- Distributed control architecture with a dedicated SPii processor for each pair of axes guaranties motion performances
- Changing motion profiles on-the-fly based on vision sensor input
- Event triggering based on profile remaining time (pre-ignition)
- Force/torque control using high resolution analog inputs that are sampled at 20kHz
- Dynamic switching between position and force control modes
- Powerful inverse kinematics using the CONNECT command

Medical Instrumentation

- Comprehensive diagnostics and safety handling
- Fail-safe operation
- High-speed hardware based position compare for X-ray activation and synchronization with patient's move
- Cost effective distributed axis and I/O control using the HSSI

General Automation

- Flexible application programming using the ACSPL+ multi-tasking language with floating point and user units support
- Short time to market - fast implementation of complex applications using powerful support tools with the unique controller simulator
- Advanced tuning tools including FFT analysis, profile and variables monitoring for optimal and fast system setup
- Dual loop control for responsive leadscrew and belt driven based systems
- Open architecture design offers a variety of communication options including PCI-bus, serial and Ethernet communications
- Remote monitoring using the Ethernet link
- A 20kHz servo update rate and a 2kHz profile update rate for tight position control and synchronization with external processes
- Up to eight axis arbitrary path generation with cubic interpolation (PVT)

Advanced Digital Printing and Laser Cutting

- Precise laser power control using an analog output proportional to actual vector velocity
- Accurate ink-jet printing control using PEG
- Two-dimensional dynamic error compensation tables
- Exact color matching in flexographic and offset printing machines

Packaging Machines

- Hardware based position registration for fast and accurate operation
- On-the-fly homing and registration correction
- Implementation of any combination of master-slave configurations with virtual axes
- Multiple masters and slaves on one controller

Applications

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