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White Paper

Intel® Core™ Processors
Intel Atom® Processors
Intel® Processor N-series

Intel® architecture-based ProU NoTime Controller Enables Precise and Flexible Motion Control

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Table of Contents

"The rapid evolution of flexible and intelligent manufacturing highlights users' surging demand for next-generation motion control solutions. The ProU NoTime controller based on Intel® architecture, leveraging robust computing power and real-time performance of Intel® processors, provides superior computing power through the software control solution, significantly reduces time delay of motion control, and improves the stability and efficiency of motion control, playing a reliable role in powering the transformation and upgrading of the manufacturing industry."

- Yan Kehua
CEO
ProU Software Co., Ltd

"With the deepening of manufacturing transformation, the motion control system is evolving constantly, bringing huge demand for computing power. Through the collaboration with ProU, we are able to provide users' motion control systems with a stable, scalable, high-performance hardware platform based on Intel® architecture, helping users achieve more accurate and flexible motion control. In the future, we will continue to cooperate with ProU and Intel to bring more value to users in the manufacturing industry."

- Guo Hui
Marketing Director
Future Robot Technology Co., Ltd.

"Computing power systems featuring high performance, high stability and high scalability have become an important foundation for a new round of industrial transformation. We will continue to advance the innovation in computing power systems for industrial scenarios, and have in-depth cooperation with Chinese eco-system partners such as ProU and Future Robot, helping customers solve the challenges such as multiple complex application scenarios, diversified data, and high computing power demand, achieve more stable and safer industrial production with higher precision, and accelerate smart manufacturing transformation."

- Li Yan
Senior Director
Industrial Solutions China
Intel Network and Edge BU

1 Overview

Fine motion control plays an important role in the sorting and assembly processes of advanced equipment manufacturing, such as IC sorting and testing, die-bonding, FATP of 3C products, and 3D dispensing. Traditional motion controllers mostly interact through PCs (performing tasks such as vision and data processing) + motion control cards. In this way, the PC's information processing capability is integrated with motion control card's motion trajectory control, which meet the needs of motion control in common scenarios. However, with the continuous development of the manufacturing industry, there are increasing demands for more sophisticated control capabilities. This leads to challenges such as insufficient computational power, increased controller interaction latency, system jitter, etc for this solution.

Shenzhen ProU Software Co., Ltd. (hereinafter referred to as "ProU") launched NoTime controller based on Intel® architecture, which integrates vision and data processing and motion control capabilities on Future Robot industrial PCs carrying Intel® processors. NoTime controller also integrates machine application execution environment and motion function library based on the real-time system. Compared with traditional motion control cards and controllers, NoTime machine control application has increased its invoking efficiency of motion control function by 1,000 times[1], providing more stable and agile machine control. The controller can handle more complex algorithms, achieve finer and more complex motion planning, and meet the needs of customers in different scenarios to accelerate intelligent manufacturing revolution.

2 Market trends and challenges of motion controllers

2.1 Market trends

A motion controller is used in various scenarios for accurate control of position, speed, acceleration, and torque/force. Through processor-based logic computing, it uses actuators (generally including servo drive + motor) to convert instructions into mechanical motion, and then receives closed-loop feedback from sensors. A motion control system is a core basic component of high-end equipment, which determines the accuracy and efficiency of equipment. As an increasing number of manufacturing enterprises are switching to flexible and intelligent manufacturing, the market has put forward higher requirements for the scalability, delay and computing power of motion controllers.

According to Markets and Markets, the global motion control market is expected to reach $16.5 billion in 2024 and $21.6 billion by 2029, with a compound annual growth rate (CAGR) of 5.5%[2]. Relevant data show that the overall motion control market was RMB 42.5 billion in 2019, with motion controllers contributing RMB 8.5 billion and servo systems contributing RMB 34 billion[3].

Facing ever-changing needs of industrial application, the next-generation motion controllers are further evolving in information processing, openness, and accuracy and versatility of motion trajectory control. They can make use of multi-axis coordinated motion control and complex motion trajectory planning, as well as real-time interpolation, error compensation and servo filtering algorithms to realize closed-loop control.

Software definition is an important trend in the development of motion controllers. It helps decouple hardware from specific functions to virtualize hardware resources and make management tasks programmable, so as to obtain higher flexibility and scalability. Speaking of software-defined motion controllers, as the development platform is independent of the hardware, users can easily conduct secondary development based on motion control according to the needs of actual scenarios without changing the hardware, so as to accelerate the time-to-market of solutions.

At present, software-defined motion controllers generally adopt x86-based PCs. This solution not only makes full use of the compatibility and scalability advantages of x86 architecture, but provides an efficient operating platform for complex workloads on motion controllers with its robust computing power.

In the high-grade, high-precision and advanced manufacturing process, users have higher requirements for high-end motion controller solutions, in order to achieve lean and flexible production. High-end controller solutions improve the controller flexibility by means of software definition, and raise higher requirements for control delay, control stability, and execution efficiency, so as to provide trustworthy fine motor control capabilities for production tasks.

2.2 Challenges

Traditional motion controllers mostly interact through PCs (performing tasks such as vision and data processing) + motion control cards, which is faced with the following problems:

- Motion control cards are generally built on low-power computing platforms, which are not powerful enough to support complex control algorithms.
- All or part of the applications of the traditional motion control cards and controllers run on Windows. Therefore, the stability of the applications is affected due to the jitter of the Windows system.
- Traditional hardware controllers, control cards and PLC interact with visual applications and call functions on PCS, communicate with PCS generally through network ports or PCIs, and there is obvious delay.

[1] Internal test data of ProU as of January 2024. Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

[2] https://www.marketsandmarkets.com/Market-Reports/motion-control-market-98406125.html, visited the site in March 2024.

[3] https://www.chinabaogao.com/market/202307/639748.html, visited the site in March 2024.

3 Solution: ProU NoTime controller based on Intel® architecture

ProU NoTime controller innovatively integrates the loads of motion control and vision/data processing into Future Robot industrial PCs based on Intel® processors, and binds with different CPU cores for processing. Through high-speed shared memory communication between different loads, ProU NoTime controller has greatly improved the efficiency of data interaction between motion control and common PC applications, as well as the execution speed of functions. The solution integrates the machine application execution environment based on real-time system and motion function library to achieve more stable and agile machine control, which can meet the requirements of fine, low-delay and high-stability motion control in scenarios like die-bonding, 3C industry FATP, and 3D dispensing.

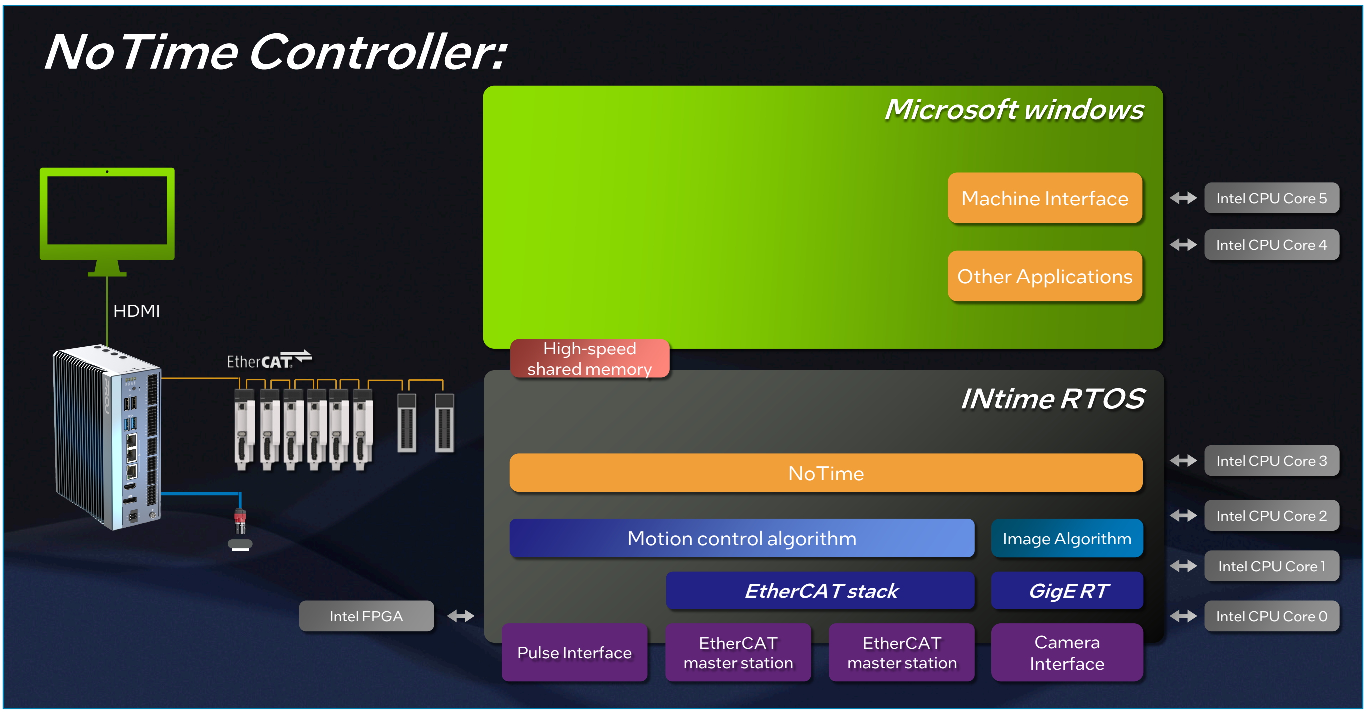


Figure 1. ProU NoTime controller design

ProU NoTime controller features rich I/O configurations, high scalability, high reliability, and structured compact design, and supports agile development and quick customization according to various application requirements.

Figure 2. E21YK (left) and Xmen (right) series controllers

3.1 Functional design of ProU NoTime controller

Thanks to Intel® processors targeting IoT, edge computing, and industrial applications, and technologies such as Intel® Resource Provisioning Technology (RDT), ProU NoTime controller delivers the following advantageous functions:

● Maintaining excellent real-time performance under heavy workloads

Thanks to the excellent hardware and software design, ProU NoTime controller achieves high real-time performance. As shown in Figure 3, ProU NoTime control platform maintains outstanding real-time performance even when CPU occupies 100% and memory occupies 94%.

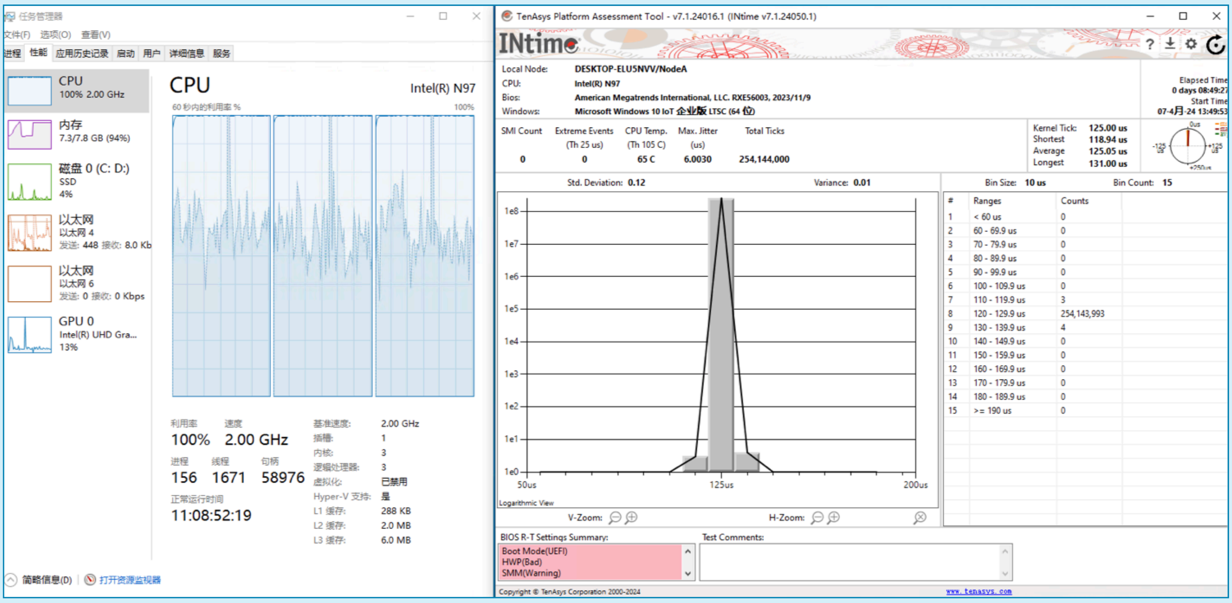


Figure 3. Real-time performance test of ProU NoTime controller under high workloads

● Significantly reducing interaction latency of motion controllers

Thanks to high-performance computing powered by the x86 system, ProU NoTime controller installs machine control application and machine vision software on the same industrial PC, and adopts high-speed shared-memory to greatly improve the efficiency of data interaction between motion control and generic PC applications, as well as the execution speed of motion functions.

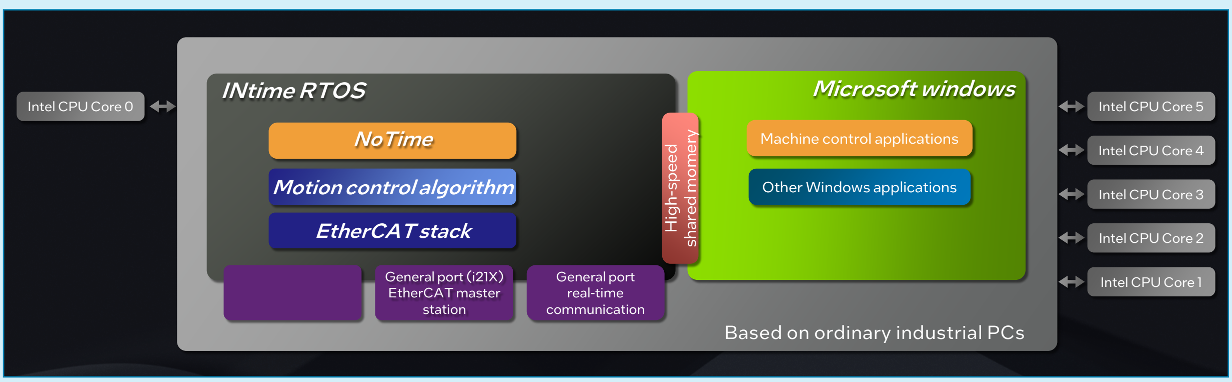


Figure 4. ProU NoTime controller integrates motion control application with machine vision software on the same hardware

In the test, ProU NoTime controller called the command of axis position read/write, ran it 20,000 times, and recorded the duration for each cycle. As shown in Figure 5, the PCI communication-based motion control card has an average read/write time of 71.74 microseconds, while ProU NoTime controller with shared memory interaction enjoys an average read/write time of only 0.06 microseconds, about 1,000 times[4] faster than the former.

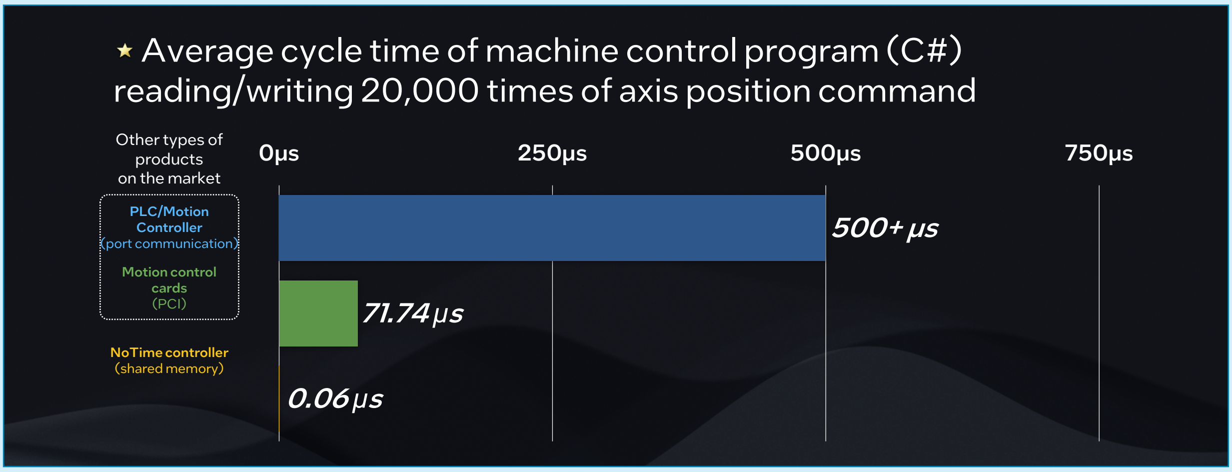


Figure 5. Time for machine control application (C#) to access motion control module (the lower, the better)

Improving execution efficiency and stability of machine control application

Traditional motion control solutions run motion control algorithms and EtherCAT stack in embedded chips, while the user machine control application runs on the Windows system. However, Windows system may encounter jitter during computing, which will lead to divergence of the speed curve and affect the execution efficiency of machine control application.

In ProU NoTime controller, the machine control applications (C#, C++) can be loaded into the INtime real-time system, freeing from the effects of Windows jitter. ProU NoTime controller adopts Intel® RDT's Cache Allocation Technology (CAT) and Memory Bandwidth Allocation (MBA) to set service levels for CPU threads and caches used in other processes, so as to set upper usage limit for memory bandwidth and CPU cache, avoid affecting critical machine control applications, and ensure real-time operation of these applications.

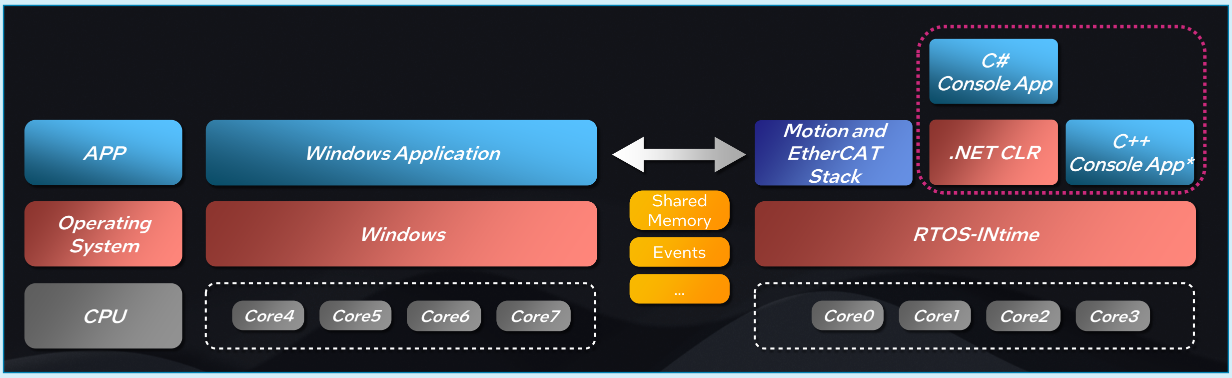


Figure 6. NoTime controller enables an application execution cycle of deterministic 125 microseconds[5]

[4] Internal test data of ProU as of January 2024. Test configurations: Intel® processor N97, total memory: 8 GB, CPU load: 40%. Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

[5] Internal test data of ProU as of January 2024. Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

ProU had a cyclic motion test. With applications running in NoTime and Windows respectively and the same hardware and servo system, the test executed IO flips and 20mm reciprocating motion 6 times from the same zero point, and read the speed curve from the drive after running 200 cycles. As shown in Figure 7, the speed curve is more divergent in the Windows system. In addition, when the CPU usage reaches 100%, it takes 63.34 seconds for the Windows solution to complete the motion cycle, while 46.02 seconds for the NoTime solution to complete the motion cycle, with overall speed up about 27%, and stability up 99.83%[6].

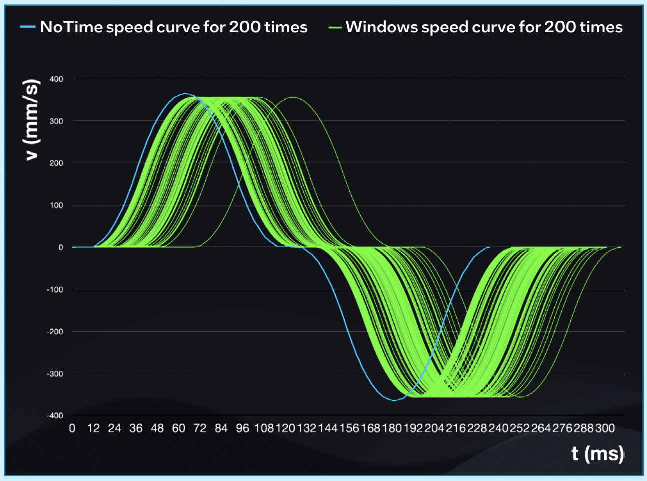


Figure 7. Comparison of NoTime/Windows speed curves

Providing powerful feedforward control function

ProU NoTime controller's feedforward control function is based on the ISG CNC algorithm library. While planning the motion, it calculates not only the position information, but the delay in speed, acceleration and variable acceleration caused by the bus cycle and the motion control system computing cycle. The compensation value is then input through EtherCAT driver's speed ring and current ring offset interfaces to reduce the axis position deviation.

The test data shows that after enabling the feedforward control function, the average path deviation decreases from 0.033mm to 0.013mm, and the setting time at 0.01mm positioning accuracy decreases from 13.2ms to 10.6ms[7].

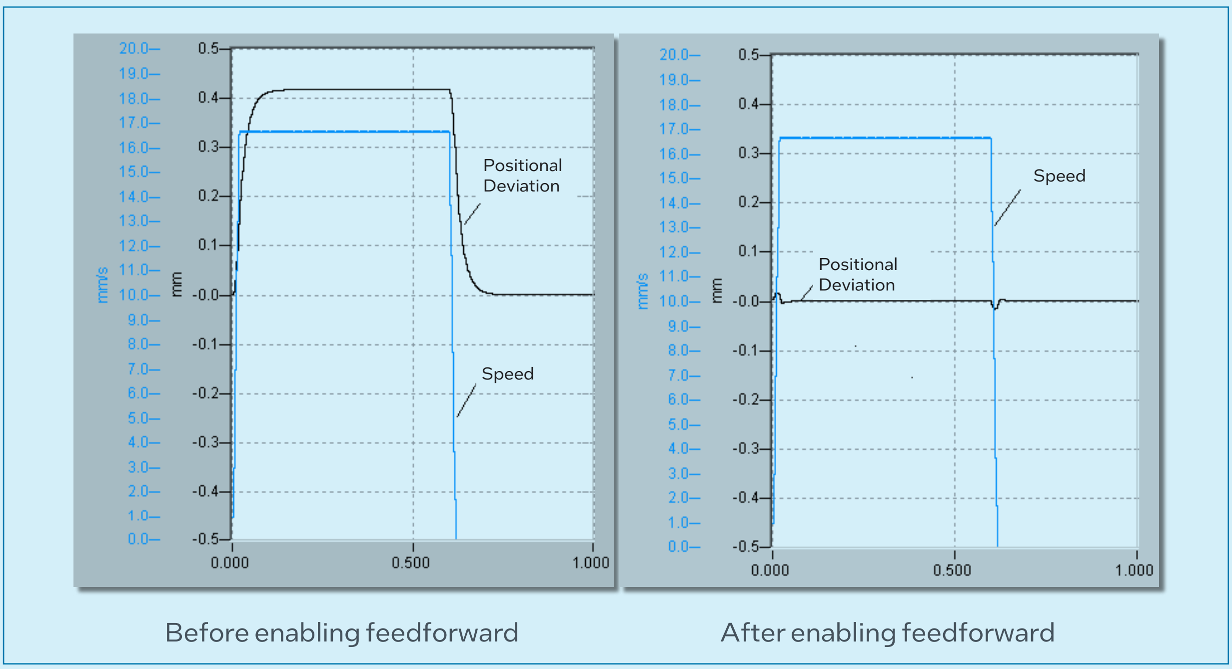


Figure 8. Comparison of position deviations before and after enabling feedforward control function

[6,7] Internal test data of ProU as of January 2024. Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

Using advanced smoothing tools for trajectory control

ProU NoTime controller integrates advanced smoothing tools such as Hyper Space Computing and ABS (Akima-spline and B-spline). Based on robust computing power of Intel® processors, Hyper Space Computing can plan for the speed and path of up to 10,000 control points[8]. It also allows path planning according to permissible error set by users, and setting more flexible dynamic parameters to reduce mechanical vibration.

As a special smoothing tool leveraging the robust computing power of Intel® processors, ABS directly generates Akima-spline or B-spline motion path, and corresponding path and speed planning through the control points. For graphics that use a lot of spline tools in CAD, the ABS tool enables high-precision track smoothing while reducing the rigidity demand of mechanical systems.

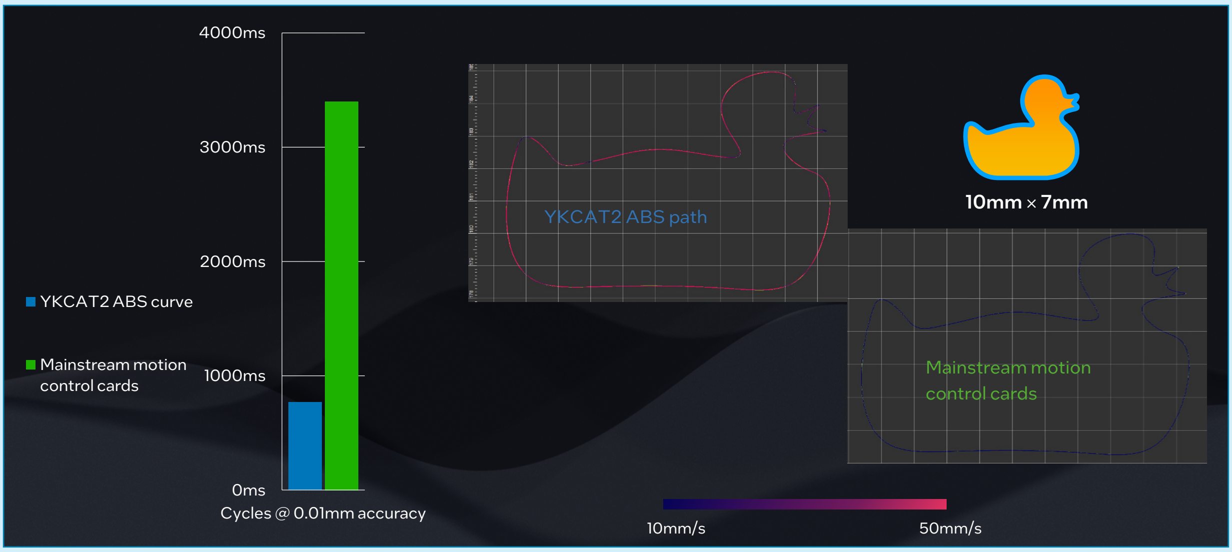


Figure 9. ABS tool improves trajectory control precision[9]

Supporting complex real-time vision algorithm

NoTime Vision's image algorithms and GigE run in real-time machine control systems, significantly reducing the time spent on image processing, guidance position computing, and motion control based on calculated results, thus improving the stability of the full cycle of vision-computing-motion.

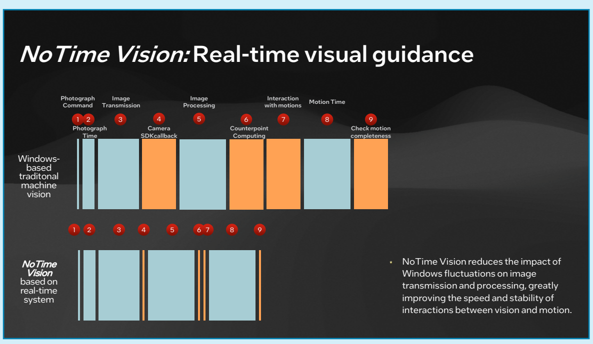
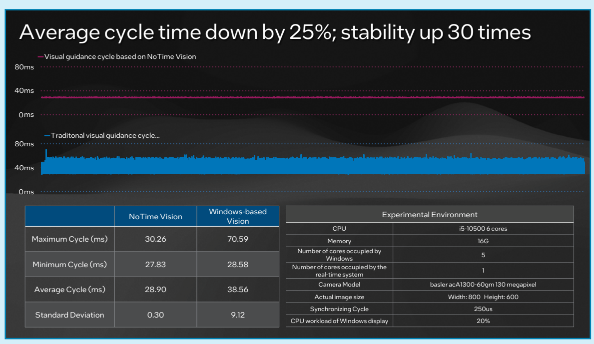


Figure 10. NoTime Vision supports real-time vision processing[10]



	NoTime Vision	Windows-based Vision
Maximum Cycle (ms)	30.26	70.59
Minimum Cycle (ms)	27.83	28.58
Average Cycle (ms)	28.90	38.56
Standard Deviation	0.30	9.12

Experimental Environment	
CPU	i5-10500 6 cores
Memory	16G
Number of cores occupied by Windows	5
Number of cores occupied by the real-time system	1
Camera Model	basler acA1300-60gm 130 megapixel
Actual image size	Width: 800 Height: 600
Synchronizing Cycle	250us
CPU workload of WIndows display	20%

Figure 11. NoTime Vision greatly shortens average cycle and improves stability[11]

[8,9,10] Internal test data of ProU as of January 2024. Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

[11] Internal test data of ProU as of January 2024. Test configurations: Intel® Core™ i5-10500G processor, total memory: 16 GB, synchronization cycle: 250 μs, CPU load: 20%. Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

3.2 Future Robot industrial PC applicable to ProU NoTime controller

ProU NoTime controller is built on Future Robot industrial PC powered by Intel® processors. Future Robot is a national high-tech enterprise focusing on industrial control, machine vision, and automation. Designed specifically for industrial controller, its industrial PC adopts embedded, compact and fanless design, and can be equipped with 12th Gen Intel® Core™ processor, Intel Atom® x7000E series processors, and Intel® Processor N-series to meet the needs of various scenarios.

Real-time computing

- Powered by Intel® processors, the product provides users with real-time and flexible high computing performance, with jitter data below 20 μs[12], responding to changes in input signals in real time, and making control decisions rapidly to ensure the continuity and synchronization of production.

Flexible communication

- Support EtherCAT, Ethernet, RS-232/485, USB, 4G/5G, and Wi-Fi, making it easy to integrate with other devices and systems, and facilitating seamless connection between informatization and automation.

High-speed counting and high-speed pulse

- Support multiple channels of 12MHz high-speed pulse input and 12MHz pulse output.

Programmability

- DI/DO interfaces are controlled based on FPGA. Users can configure them by FPGA according to actual needs.

High scalability

- The product adopts a modular cable-free design, which supports expanding functions by adding modules.

High stability

- With compact rugged structure design and leading heat dissipation solution, the product meets reliability requirements such as wide temperature range, wide pressure range, and anti-electromagnetic interference, and can work 7x24 hours continuously in harsh industrial environment.

Figure 12. Future Robot industrial PCs applicable to industrial controllers

In addition, Future Robot also provides users with agile and rapid customization services, creating products with hardware configurations and interface design that effectively meet their specific application needs. Future Robot also offers customers with development and deployment tools for rapid customization to accelerate the time to market.

Future Robot is also a partner of Intel® Premium IPC (PIPC) Program[13]. Its selected E-series industrial PC products have passed the hardware and software test of Intel® PIPC Program. Since 2023, a number of Future Robot products have passed the validation of Intel® PIPC Program.

[12] Internal test data of ProU as of January 2024. Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

[13] Intel® Premium IPC Program (PIPC) is designed for industrial users in China to test and validate a wide range of industrial PCs to meet the needs of mainstream industrial applications, such as industrial control and machine vision, and accelerate the product selection process for system integrators and end users.

3.3 Intel technologies and applications in ProU NoTime controller solution

The Intel® architecture based ProU NoTime controller offers the options of processors including 12th Gen Intel® Core™ processors, Intel Atom® x7000E series processors, and Intel® Processor N-series, which not only support efficient operation of complex machine control algorithms, but lay a solid hardware foundation for motion control with capabilities such as wide temperature range, high stability, and remote maintenance.

ProU NoTime controller also uses Intel® Resource Provisioning Technology (RDT) to improve its real-time processing capabilities, as well as Intel® Virtualization Technology for Directed I/O (VT-d) and Intel® Virtualization Technology for x86 (VT-x) to achieve hardware virtualization. The above-mentioned software and hardware technologies can meet the needs of ProU NoTime controller in computing power, delay control, and stability, etc.

Users can choose respective models of processors according to different scenarios and requirements.

Scenarios	Processors	Advantages
Pure motion control scenario Single camera guiding scenario	Intel Atom® Processors/ Intel® Processor N-series	High performance, high reliability, and high cost performance
Multi-camera guiding scenario Other complex motion control or universal computing scenarios	Intel® Core™ processors	Higher basic frequency, lower jitter, and higher computing performance

Table 1. Processor options and advantages for different scenarios

● 12th Gen Intel® Core™ processors

The 12th Gen Intel® Core™ processors, manufactured with the Intel 7 (10nm) process, are the first series of Intel processors that support a performance hybrid architecture. Designed to deliver a powerful and efficient computing experience, this series of processors adopt a hybrid architecture composed of P-cores (Performance) and E-cores (Efficiency) to balance computer resources. Both computing cores can be scheduled by Intel® Thread Director, a technology that dynamically distributes workloads to the optimal compute cores. The 12th Gen Intel® Core™ processors integrate up to 16 compute cores and 24 threads, enhanced AI capabilities, enhanced graphics capabilities, and PCIe 5.0 in a single industrial PC. In high-performance control scenarios, P-cores can perform control-related loads to achieve higher performance, while E-cores can perform common user tasks to save energy consumption. As for vision + control scenarios, the combination of P-cores and integrated graphics cards can be used to perform vision and AI workloads, while E-cores can be used to perform control tasks.

With robust computing power, ProU NoTime controllers based on 12th Gen Intel® Core™ processors can meet motion control needs of complex scenarios, such as complex planning and control models, while providing high-performance graphics processing capabilities that deliver higher real-time vision performance.

● Intel Atom® x7000E processor / Intel® Processor N-series

Intel Atom® x7000E processor and Intel® Processor N-series are designed for IoT and edge applications, providing up to four E-cores. Some processor models have key enhancements for IoT edge, including the support for hardware virtualization, virtual machine manager, and real-time workloads. These functions include hardware-level virtualization, support for multiple operating systems, and real-time computing using Intel® Time Coordinated Computing (Intel® TCC). These processors offer excellent AI acceleration capabilities with low power consumption, support Intel® Advanced Vector Extensions 2 (Intel® AVX2) and Intel® Deep Learning Boost (Intel® DL Boost), significantly accelerating compute-intensive operations and deep learning inference operations.

ProU NoTime controllers based on Intel Atom® x7000E processor or Intel® Processor N-series are more advantageous in cost and power consumption, which means they can be deployed in smaller space and become an ideal choice for lightweight or intensive motion control scenarios.

● Intel® RDT

Intel® Resource Director Technology (Intel® RDT) brings new levels of visibility and control over how shared resources such as last-level cache (LLC) and memory bandwidth are used by applications, virtual machines (VMs), and containers, helping motion controllers gain deterministic computing power and free critical processes from interference by other processes. It's the next evolutionary leap in workload consolidation density, performance consistency, and dynamic service delivery, helping to drive the real-time control capabilities of motion controllers. As software-defined infrastructure and advanced resource-aware orchestration technologies increasingly transform the industry, Intel® RDT is a key feature set to optimize application performance.

Intel® RDT provides a framework with several component features for cache and memory monitoring and allocation capabilities, including Cache Monitoring Technology (CMT), Cache Allocation Technology (CAT), Code and Data Priority (CDP), Memory Bandwidth Monitoring (MBM), and Memory Broadband Allocation (MBA). These technologies enable tracking and control of shared resources, such as the Last Level Cache (LLC) and main memory (DRAM) bandwidth, in use by many applications, containers or VMs running on the platform concurrently. RDT may aid "noisy neighbor" detection and help to reduce performance interference, ensuring the performance of key workloads in complex environments.

Cache Allocation Technology (CAT) physically isolates the cache by setting a mask on the CPU core or Pid. Each bit of the mask represents an independent cache area, and the cache areas represented by different mask bits do not overlap. Users can limit the cache usage range of processes by setting the mask. Memory Bandwidth Allocation (MBA) provides new levels of control over how memory bandwidth is distributed across running applications. MBA enables memory bandwidth management by setting priorities. A new programmable bandwidth controller has been introduced between each core and the shared high-speed interconnect which connects the cores in Intel® Xeon® processors. MBA sets service levels for CPU threads used in the process to limit maximum usage of memory bandwidth.

● Intel® VT-d

Intel® Virtualization Technology For Directed I/O (Intel® VT-d) expands Intel's virtualization technology by providing hardware support. Intel® VT-d improves system security and reliability while improving the performance of I/O devices in virtual environments. This helps developers reduce costs by shortening potential idle time and increasing throughput.

4 Application Scenarios

At present, ProU NoTime controller based on Intel® architecture has been widely used in scenarios including IC sorting and testing, die-bonding, FATP of 3C products, and 3D dispensing.

4.1 High-precision and high-stability motion control in die-bonding

In the semiconductor process, "bonding" refers to fixing the wafer chip on the substrate. Die-bonding technology enables electrical connection between the chip and external components by attaching the semiconductor chip to the Lead Frame or Printed Circuit Board (PCB). Die-bonding puts forward strict requirements for the accuracy and stability of motion control.

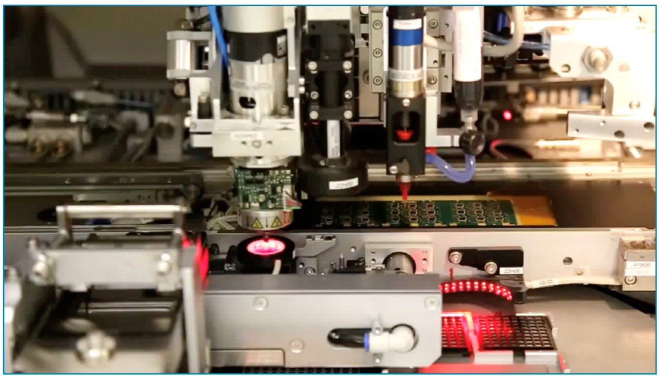


Figure 13. Die-bonding scenario

ProU NoTime controller supports the die-bonding scenario, reaching X/Y assembly precision of ±10 μm@3σ, rotation accuracy of ±0.15°@3σ, programmable bond force of 0.5N~75N, and UPH of above 6K/station[14]. It has the following advantages:

- ProU NoTime controller installs machine control application and machine vision software on the same industrial PC, and adopts high-speed shared memory to greatly improve the efficiency of data interaction between motion control and generic PC applications, as well as the execution speed of motion functions.
- Based on the high computing power of Intel® processors, each ProU NoTime controller delivers up to 64 axes of 125μs EtherCAT[15] cyclic motion control and high-performance drive management.
- In the NoTime system, the logic, motion and vision control applications of machines are completely running in the INtime real-time system, improving the stability of application execution and the machine efficiency.
- Advanced algorithms in the ISG CNC library, such as feedforward and vibration suppression, and the high computing power of Intel® processors help to improve machine stability and efficiency.

4.2 Highly flexible trajectory control in 3D dispensing

Dispensing is an important process in industrial production. It refers to applying, potting, and dropping electronic glue, oil or other liquid on products, making them adhesive, encapsulated, insulated, fixed, and have a smooth surface. Modern industrial production has higher requirements for dispensing accuracy and trajectory control, bringing more severe challenges to motion control.

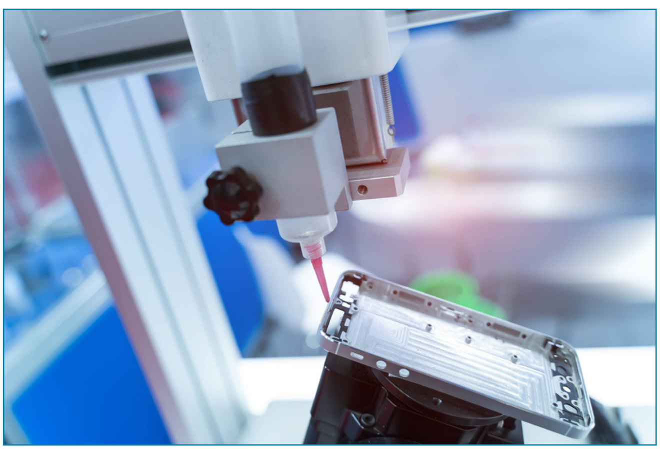


Figure 14. Dispensing process in cellphone manufacturing

The ProU NoTime controller solution offers the following advantages for the dispensing process:

- Integrated dispensing interface, supporting direct import of CAD files to generate motion instructions.
- The ISG CNC algorithm library has leading forward-looking technology, spline path, and HSC feature that meet the industry's top trajectory control needs.
- The ISG CNC algorithm library supports 5-axis RTCP and more than 50 kinematic models.
- ProU NoTime controller has built-in fast FPGA I/O, which meets special process requirements, such as advanced dispensing on/off and PWM glue valve control.

[14,15] Internal test data of ProU as of January 2024. Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

5 Outlook

ProU NoTime controller adopts the machine application execution environment and motion function library based on the real-time system, and combines Future Robot's high-performance, high-stability and high-scalability industrial PCs with Intel's hardware and software advantages, so as to support full real-time machine control. In addition, the controller's software control solution enables greater flexibility and agility, supports custom development to meet the needs of various scenarios, and runs on a wide range of optional Intel® processors with a high degree of modularity to easily extend the controller's performance.

Besides current achievements, ProU will carry out deeper collaboration with Intel and Future Robot, making further innovations on ProU NoTime controller, including releasing vibration suppression function suite and Virtuos simulation environment to meet the demand of more scenarios for complicated fine motion control, helping build flexible and intelligent industrial production lines and empowering the manufacturing upgrade.

Intel will further promote Intel® Premium IPC (PIPC) Program, leveraging its years of experience in industrial-grade chips and industrial edge software platforms to better empower the development of partners, and launch an increasing number of excellent industrial PCs with ProU and Future Robot to accelerate the industrial evolution.

About ProU

Founded in 2015, ProU is one of the few providers of x86-based machine control platforms for volume applications in Asia, and a profitable industry pioneer with rapid growth in sales and customer base. The company is dedicated to completely separating the logic, motion and visual computing and data collection/analysis from the general operating system, and achieving full real-time machine control based on X86, allowing high-performance equipment to obtain performance and stability that surpass existing motion control cards and embedded controllers.

About Future Robot

Founded in 2018, Future Robot is a national high-tech enterprise focusing on industrial control, machine vision, and automation. Based on innovative technologies with independent intellectual property rights, it has been following flexible and diversified market needs to rapidly customize solutions for customers, and focusing on the research and development, production and sales of embedded computing equipment. Future Robot is committed to the industrial automation, digitalization and intelligentization, providing customers with reliable, flexible, convenient and technologically comprehensive hardware products and system solutions, serving industrial modernization with unaffected original intentions, and joining efforts with customers to create infinite possibilities for the industry.

About Intel

Intel (Nasdaq: INTC) is an industry leader, creating world-changing technology that enables global progress and enriches lives. Inspired by Moore's Law, we continuously work to advance the design and manufacturing of semiconductors to help address our customers' greatest challenges. By embedding intelligence in the cloud, network, edge and every kind of computing device, we unleash the potential of data to transform business and society for the better. To learn more about Intel's innovations, go to newsroom.intel.com and intel.com.