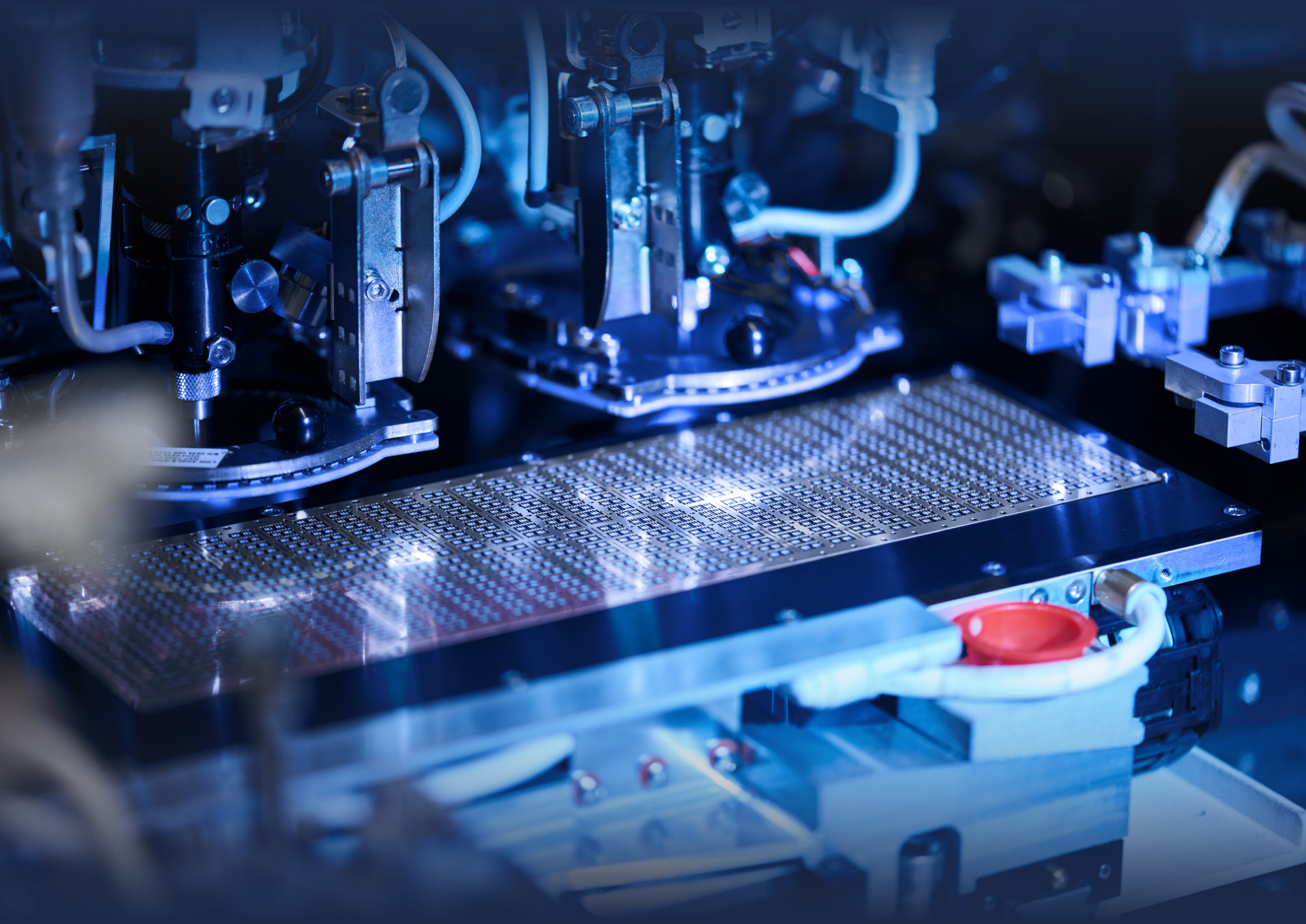
AdaCore CASE STUDY

Ada at ITEC: Real-Time Control over Complex Semiconductor Manufacturing Processes



adacore.com

Summary

Semiconductor manufacturing has some of the most exacting needs when it comes to performance and reliability, requiring millisecond-level precision and the ability to cost-effectively produce billions of smaller and smaller devices every year. That's why ITEC, one of the major semiconductor manufacturing equipment and automation providers, chose Ada as its programming language to develop its critical control software.

The challenge of real-time semiconductor manufacturing

Successfully manufacturing high-volume semiconductors requires advanced production equipment that is continually evolving to deliver greater throughput, better efficiency, consistently higher quality, and increased functionality in smaller footprint devices.

For over 30 years, Netherlands-based ITEC has met these complex needs through its technical expertise and manufacturing insight. It was formed in 1991 as a division of the electronics company Philips that subsequently became NXP and then Nexperia, to provide semiconductor, RFID, and miniLED manufacturing equipment and systems. ITEC's machines target backend semiconductor manufacturing processes with a special focus on small discrete devices, machine cover die bonding, wire bonding, die sorting, molding, and testing. They are used to cost-effectively produce billions of small semiconductors every year, with machines operating at high speed to assemble and test devices, and delivering low production costs combined with quality and reliability.

Software to deliver millisecond-level control

"The software that controls ITEC's equipment must meet stringent requirements around performance, speed, and ease of maintenance," explains ITEC software engineer Felix Patschkowski.

"Our equipment has to be efficient enough to assemble and test high-volume, high-quality semiconductors at low cost, while constantly evolving to meet changing customer needs. This is a challenge we've been successfully meeting for more than three decades. High-performance code is central to this – our software has to control machine cycles that last just a few milliseconds."

Not only does ITEC's control software have to deliver high-performance, but the code base must be easy to maintain by a small team, some of whom are mechatronic engineers rather than trained software developers.

Customer:
ITEC - a leading semiconductor manufacturing equipment and automation provider

Challenge:
To find a programming language capable of driving ITEC's mission-critical manufacturing equipment, which must meet the highest levels of real-time performance and reliability and be capable of producing billions of semiconductors every year.

Solution:
The Ada programming language, AdaCore's GNAT Pro Ada development environment, and AdaCore technical support.

Result:
Ada currently makes up over 95% of the company's code base which has grown to over 2 million lines of code. The language's design makes it easy to maintain over the long term and simple for new developers to quickly learn and trust.

Choosing the right language for real-time, mission-critical software

All of these challenges meant ITEC required a high performance, secure programming language to develop its control software, which runs on standard x86 Windows systems and controls both the physical semiconductor production and its testing.

ITEC originally used a dialect of Pascal when development began, but soon realized that the language would not meet its long-term needs and started evaluating alternatives in the late 1990s. According to Patschkowski, the right choice quickly became clear.

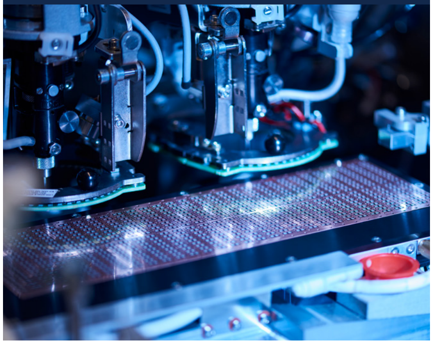
“Speed is everything to us, meaning we needed a programming language that could natively compile to machine code and was deterministic, to enable us to meet real-time requirements. That quickly ruled out languages that run on virtual environments such as Java. At the time that left us with three choices – Ada, C, and C++.”

Many of ITEC’s developers responsible for writing high-performance code are engineers rather than trained programmers, so the team discounted C due to its lack of in-built error checking, lack of concurrency awareness, and fundamental issues with memory safety. Essentially, the concern was that any errors made by non-C experts would not be caught until much later in the development process, delaying projects and adding to costs while bugs were fixed. C++ was also ruled out for these factors, as well as for its lack of contract-based programming (Pre/Post Conditions and Asserts).

The team therefore chose Ada for its combination of high performance (on a par with C/C++), ease of learning and use, and strong typing features that inherently reduce errors and delays and prevent mistakes from creeping into the development process.

Other Ada features that supported ITEC’s choice included packages, which make it simple to modularize code; generics, which allow common data structures and other constructs to be reused in multiple contexts; and tasking, which offers a reliable and high-level abstraction for concurrent programming.

> **“We have a great deal of trust in Ada because it has well-defined semantics and no surprises compared to using C”**
>
> **- Felix Patschkowski,**
> **ITEC software engineer**



“We have a great deal of trust in Ada because it has well-defined semantics and no surprises compared to using C,” says Patschkowski. And with Ada, you can focus more on the application requirements, rather than having to deal with any issues in the programming language. This was a huge time saver, particularly for our team of developers without specific Ada programming expertise.”

Why ITEC chose AdaCore

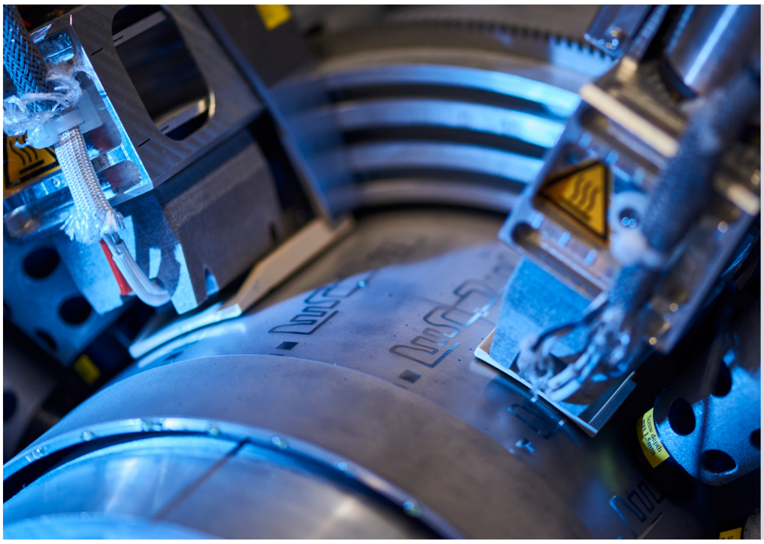
Alongside Ada, ITEC chose AdaCore’s GNAT Pro development environment. A complete solution for producing critical software systems where reliability, efficiency, and maintainability are essential, GNAT Pro provides an integrated development environment for Ada. It offers a suite of tools and libraries for developing large, mission-critical applications, as well as providing support for integration with C and C++.

To meet its needs for running both Windows and embedded code, ITEC is using two compilers with GNAT Pro - one targeting x86 Windows, and a cross-compiler that runs under Windows and targets ARM’s AARCH64 Linux.

GNAT Pro is backed by AdaCore’s comprehensive support. Patschkowski is delighted that most support tickets raised with AdaCore are answered within the same business day, including quick fixes to compiler shortcomings and library issues. ITEC always has access to top Ada experts within AdaCore, ensuring a continually high pace of development. Developers can contribute code to AdaCore libraries such as AWS via Github, as well as receive priority on pull-requests via AdaCore’s GNAT Tracker ticket system. He also appreciates the quality of AdaCore’s training services, which has helped get new Ada programmers up to speed.

Adopting Ada as the standard for mission-critical systems

Ada is now the standard language within ITEC, used for over 95% of all code within the company. It is used for high-performance applications running on Windows 10 on each piece of production equipment, connecting via firmware to FPGA boards running



> In our experience, programmers can learn Ada and get up to speed within just two weeks. They learn quickly that Ada is a language that they can trust, building confidence, saving time, and allowing them to focus on other parts of their role.
>
> **- Felix Patschkowski, ITEC software engineer**

VHDL code that controls physical production. Libraries such as OpenCV, integrated with Ada, are used to run image analysis on visual test inspections.

Ada is also used for web servers and user interface developments, showing its breadth of applicability across the company. As development increases, Ada is increasingly at the heart of multi-language projects, with C++ and Python solutions created and integrated where applicable.

ITEC has recently adopted Ada 2022 as part of its commitment to deploy the latest compilers and language versions. Overall, the company's Ada code base has grown to over 2 million source lines of code, including half a million lines of code added just in the past year. While a large portion of this code is still based on procedural programming, object-oriented programming (interfaces and class hierarchies) is seeing increasing usage to ensure greater code disentanglement and extensibility.

Training a new generation of Ada programmers

Until recently, ITEC's code base was maintained by a small team of just 15 programmers.

As it expands, ITEC is growing its development team. Bringing on new programmers who have not previously used Ada is a potential challenge, but Patschkowski sees them quickly understand and appreciate the benefits of Ada's features.

"In our experience, programmers can learn Ada and get up to speed within just two weeks, helped by the training and support that AdaCore provides. While some may initially be wary of Ada, their opinion soon becomes very positive. They learn quickly that Ada is a language that they can trust and that the kind of low-level language mistakes that easily happen in C and C++ simply cannot happen in Ada. This directly benefits programmers, building confidence, saving time, and allowing them to focus on other parts of their role."

Delivering high-performance over the long term

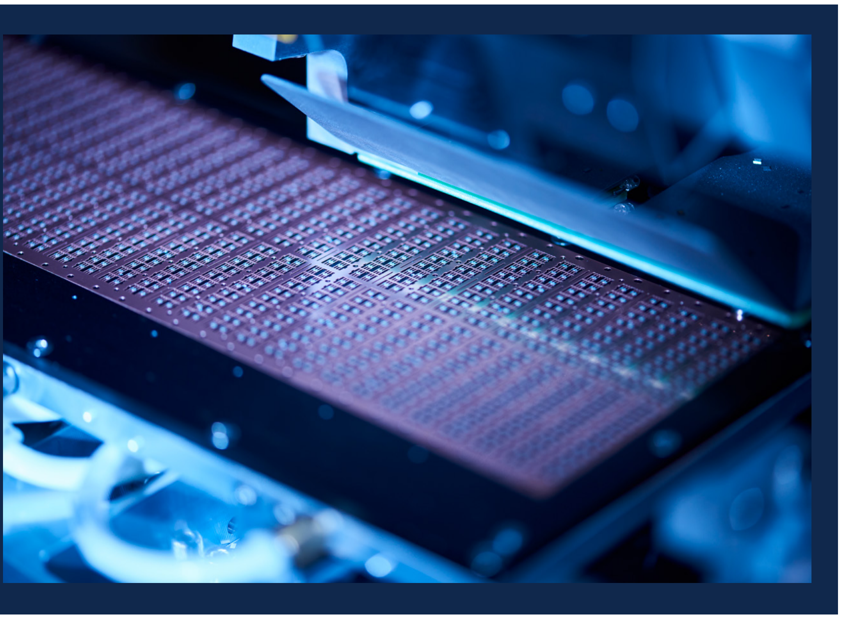
Using Ada has helped ITEC successfully produce advanced semiconductor manufacturing equipment over the last 20 years. It delivers real benefits when it comes to enabling innovation, creating mission-critical code, and enabling high performance, easy maintenance, and ease of learning.

In a fast-moving industry, Ada provides the ability to innovate at speed, as Patschkowski explains. "In general, we can deliver new features quickly because of Ada – it helps with our rapid development cycles and ensures our projects are developed on-time and are cost-efficient."

The systems supplied by ITEC are mission-critical, meaning the reliability of code is crucial. This all starts by minimizing programming errors – and spotting any issues early in the process when they are easier to correct. Developing in Ada encourages programmers to take a higher-level approach than in languages such as C or C++. This means their code is better planned, and they have a clear idea of their objectives before they start writing code, reducing the potential for issues.

ITEC's control systems operate at millisecond levels of precision, demanding consistently high performance. Ada delivers this speed and reliability, matching the performance provided by languages such as C/C++. It also has the openness to easily integrate with systems written in a range of languages, from embedded board-level solutions to those running visual inspections of semiconductors.

> If you intend to use C++ or especially C you should take a look at Ada. It will support your mission-critical development, now and in the future.
>
> - Felix Patschkowski,
> ITEC software engineer



Efficiently maintaining a growing code base

ITEC's code base has been developed over a 20-year span, and many of the original programmers have either left the company or moved to new roles. Being able to understand, maintain and refactor this code is essential.

"Reading and understanding existing code is very easy with Ada," says Patschkowski. "This helps immensely as we need to maintain the code base while meeting ever-changing requirements with new engineers coming on board. I see other companies that have lots of legacy code struggle with refactoring – with Ada this is super-smooth. As many potential issues are caught by the compiler early in the process you can refactor with confidence."

Supporting a growing customer base with Ada

ITEC is now poised at a key stage in its development. In 2021, ITEC became an independent company within the Nexperia group of companies to address semiconductor shortages by offering high-productivity chip-assembly systems to third-party markets. It is clear that ITEC's control software has played a vital role in the success of this initiative to accelerate new market opportunities, and drive major expansion across the company.

The company is currently growing at a rate of 12% per year, and its original software development team has doubled to around 30 members. As ITEC scales its operations, Ada will continue to power its innovation and success. The fact that the language is easy to learn ensures that new programmers are up and running quickly. And the structure of the language means that the sort of low-level errors that occur in C and C++ cannot happen in Ada, building the confidence of developers while increasing their productivity.

"Ada is central to ITEC's exciting journey," concludes Patschkowski. "Our experience shows that any organization developing long-term software projects that will evolve over time with high-performance requirements should consider using Ada. If you intend to use C++ or especially C you should take a look at Ada. It will support your mission-critical development, now and in the future."

AdaCore

adacore.com