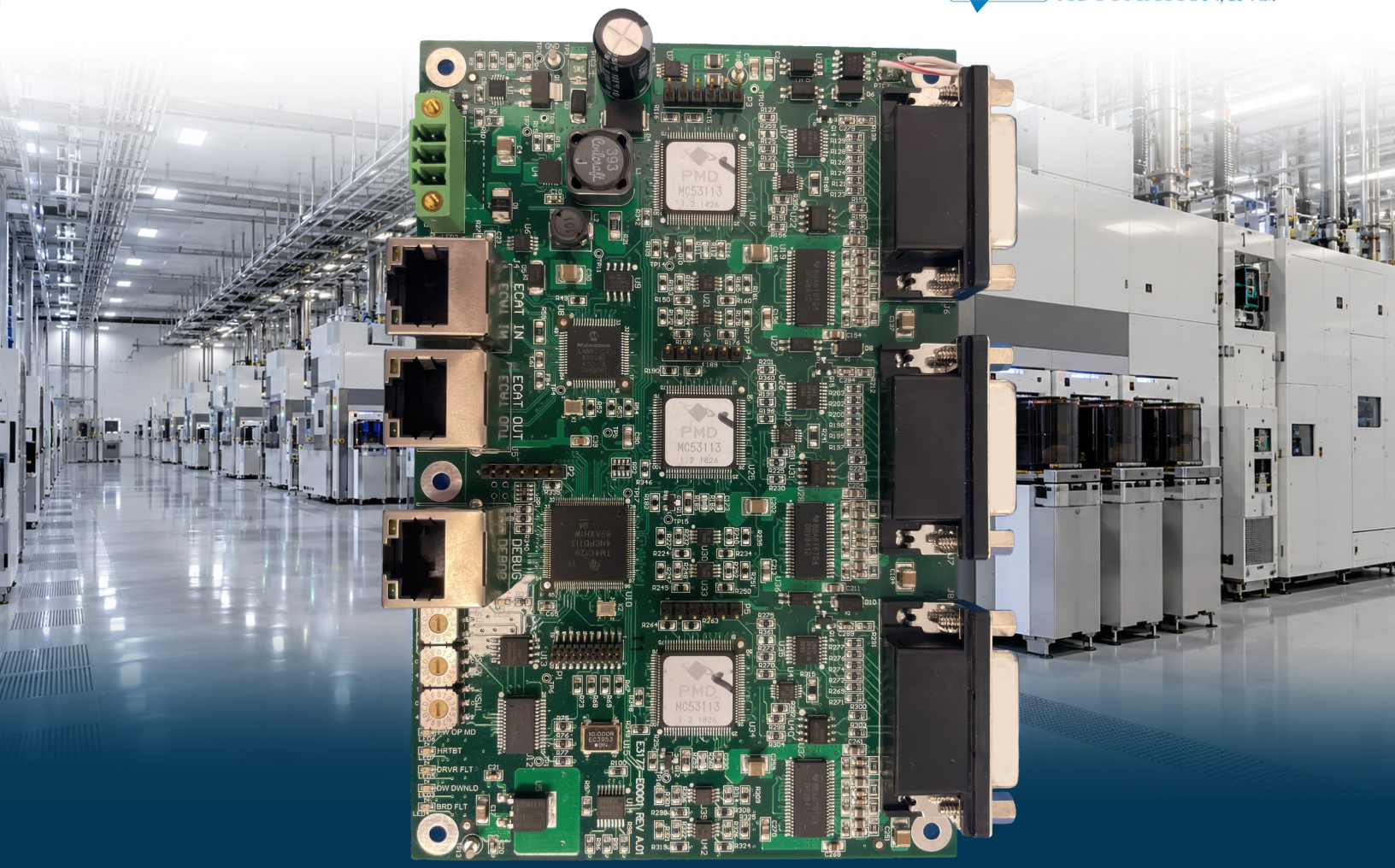
PERFORMANCE MOTION DEVICES

TRUST AUTOMATION, INC.



Closing the Loop: How Trust Automation Reached 1 Micron Repeatability with PMD Motion Control

In a submicron leveling system, repeatability matters more than accuracy. The tool doesn't need to arrive at exactly the commanded coordinate, but it does need to arrive at the same place every time, from any direction. That distinction set the constraint when Trust Automation took on the next generation of a high-precision leveling system used in wafer processing: 1 micron bidirectional repeatability across three synchronized axes, on a platform whose open-loop predecessor had no path to reach it.

Getting there meant giving up micro-stepping for closed-loop field-oriented control (FOC) on a two-phase stepper, and it meant finding a controller that could deliver FOC and dual-loop encoder feedback in the same part. Trust rebuilt the axis control around the Magellan MC58113 motion control IC from Performance Motion Devices (PMD).

Making Motion Control Disappear

Trust Automation, a PMD customer for more than two decades, builds custom-engineered motion solutions rather than general-purpose servo drives. That distinction defines its business.

“Our value that we provide to the customer is to make transparent the motion control and trajectory planning aspect of their motion application,” says Drew Bentz, senior firmware engineer at Trust Automation.

The semiconductor industry has no shortage of off-the-shelf EtherCAT servo drives, he notes, along with a broad push toward CiA 402 adoption. That’s fine for companies comfortable in the motion control field, but that’s not where Trust’s customers typically sit. “We are selling to a customer who is not wanting to deal with the complexities of motion control,” Bentz adds.

In practice, Trust Automation’s work is critical to engineering teams inside large semiconductor equipment manufacturers that lack either mechatronics expertise or the time to build it. Trust’s semiconductor portfolio splits into two long-running lines: wafer transfer robots, using theta and Z motion, and linear actuation, Bentz’s focus across his 10 years with the company. The linear work spans a wide range — from millimeter precision on a ball screw moving significant weight to submicron precision using stepper motors and ultrafine-pitch lead screws.

Where Open Loop Runs Out of Room

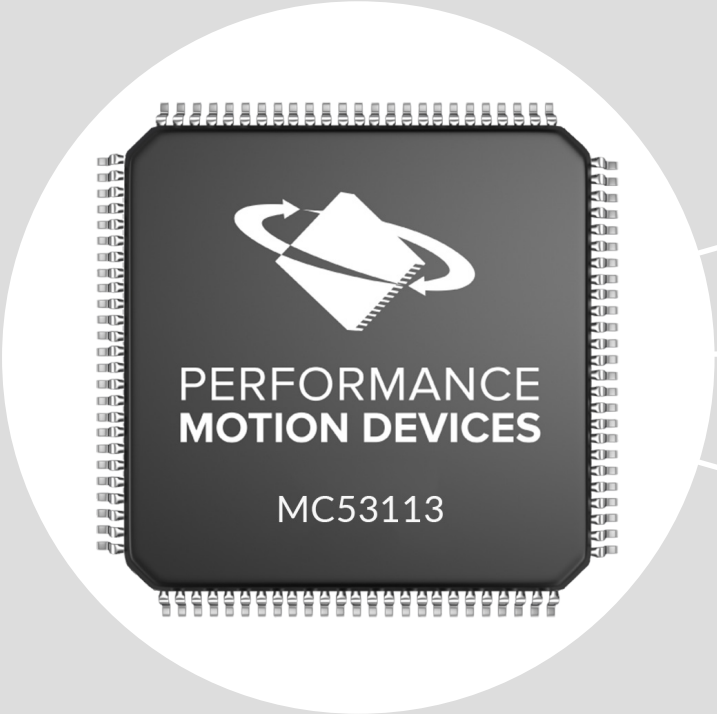
The leveling application for this particular semiconductor equipment maker sits at the precise end of that range. It is a multi-axis synchronized linear actuation system built around ultrafine-pitch lead screws.

The first-generation solution used a multi-axis open-loop stepper control. A position encoder was in the system, but only as an observer. “Effectively, the position feedback was used for reporting but not for control,” Bentz explains. If something caused the stepper to lose steps, the system could detect the error but could do nothing about it. “That basically limits the customer in what they can achieve with that positioning system.”

The next-generation tool raised the bar to 1 micron repeatability and roughly 5 to 10 micron positional accuracy.

“Repeatability is everything,” Bentz says. “It is not so much that they go to the exact accurate position. It is just that when they tell you to go to X, you go there every single time, regardless of direction, at the exact same spot.”

Micro-stepping an open-loop stepper was not going to deliver that; as a result, Trust moved to a closed-loop FOC architecture.



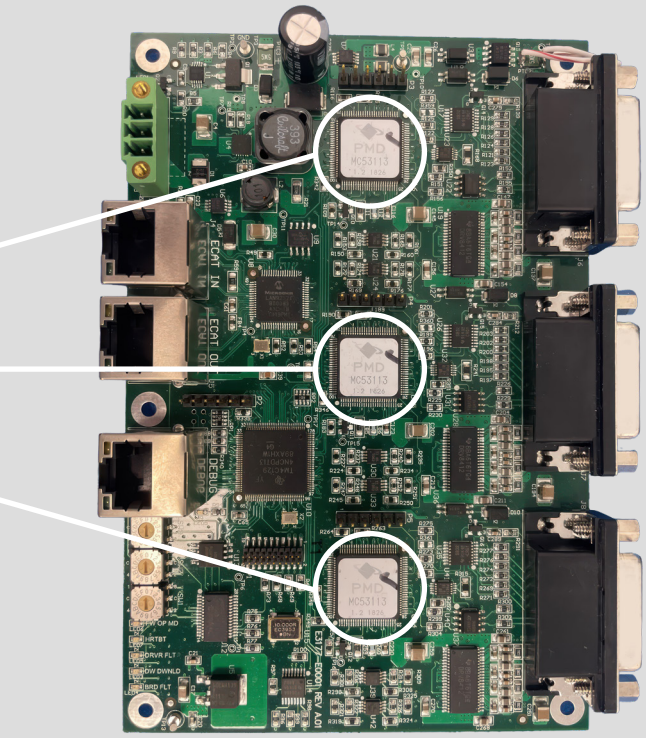
Why the MC58113?

Trust faced the usual build-versus-buy question: a custom in-house controller or a PMD solution. Two decades of accumulated PMD product knowledge and shared code weighed on one side. The chip’s feature set sealed the deal.

> “The MC58113 was selected specifically because it allows for FOC of a two-phase stepper. It also allows for dual loop, which is another reason we picked it,” Bentz says.

Notably, Trust chose single-axis MC58113s over a multi-axis Magellan precisely because the single-axis part carries the integrated FOC control loop. A host microcontroller synchronizes all axes.

The dual-loop capability supports a two-encoder design: A 14-bit rotary encoder handles motor control and FOC commutation while a linear encoder with 100nm resolution measures output position directly.



Holding Position Against Stiction

The precision target asks a great deal of the motor itself. With a 200 full-step motor and the lead screw pitch involved, holding the required accuracy works out to roughly a 512 micro-step division of a full step.

“We’re really holding tight within a full step, which is very difficult to do,” Bentz says. “Forcing a stepper motor to hold up 1/512 of a full step is about the limit of what you can reasonably do.”

Trust used FOC current-loop tuning along with gain scheduling to compensate for both the stiction and the repeatability requirement — an effort Bentz describes as considerable. PMD’s trace feature accelerated the tuning process by enabling visibility into the complex system response introduced by these mechanics.

What the Second Encoder Buys

Measuring output position directly, rather than inferring it from motor rotation, unlocked capabilities well beyond the repeatability number itself.

Because the linear encoder sees actual output position, the system can compensate for nut wear across the actuator’s life cycle, as well as for backlash and thermal effects. “When they operate these actuators at different temperatures, we don’t have to make assumptions about position,” Bentz says. “We can directly measure the position.”

Translating Between Two Worlds

Trust wrote firmware that bridges the CiA 402 drive specification to the Magellan command set for this EtherCAT platform. A ground up EtherCAT implementation allowed Trust to optimize performance using an interrupt driven implementation versus the common state machine base EtherCAT implementation. This difference improved performance and significantly increased reliability of the EtherCAT drive.

“The CiA 402 drive spec has its own set of concepts and nomenclature, and we translate that to the PMD chip, which has different concepts and nomenclature,” Bentz says. Trust also allocates RAM to buffer host set points and feeds them to the MC58113 as needed.

Early configuration and bench testing ran on PMD’s Pro-Motion software. Trust used it to communicate with and configure the motion control ICs before Trust’s own software and firmware had matured. Those capabilities proved valuable enough that Trust brought them into its own multi-axis control software rather than reinventing them. “The trace feature that Pro-Motion does is very useful,” Bentz says. “We implemented that in our firmware so that we can set up traces on three axes all at the same time.”

Custom Features — No Problem

Reaching certain specifications for Trust Automation customers has also required PMD to extend its silicon from time to time, but PMD is always ready to help. “Working with PMD has been really fantastic,” Bentz says.

> “I’ve been in direct communication with their firmware engineer multiple times. They have super-fast response.”

“I’ve sent them data dumps, CSV files, scope captures. They’ve given valuable feedback.”

The list of Trust-requested features PMD implemented is long: RS-422 serial encoder communication; support for the command set of an EEPROM embedded in that encoder, letting Trust store per-unit configuration data; and a capability PMD calls consistency ratio monitoring, which compares the relative advancement of two encoders of differing resolution.

PMD also made hardware signal routing software-controllable so that Trust could reassign signals across axes and inputs on a board layout that was already complete. “That way we didn’t have to spin a board, which is also super useful,” Bentz says.

From 90 Days to a Full Year

The payoff reached the end customer as a maintenance metric. Nut wear compensation dramatically extended actuator life, and with it the guaranteed service interval — from a 90-day minimum of operation before the tool must be taken down and opened to a full 365 days, an impressive 4X improvement.

"That's a huge selling point for them and their customers," Bentz says. Fewer interruptions mean more available production time. For a fab, that translates directly into throughput. As Bentz puts it, the benefit is "driving the sales of the next-generation tool and buildout of fabs using their new tool."

For Trust Automation, that outcome rested on a controller that could close the loop on a stepper at the edge of what's physically achievable and on a supplier willing to build what the application required. Their pick: PMD.



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