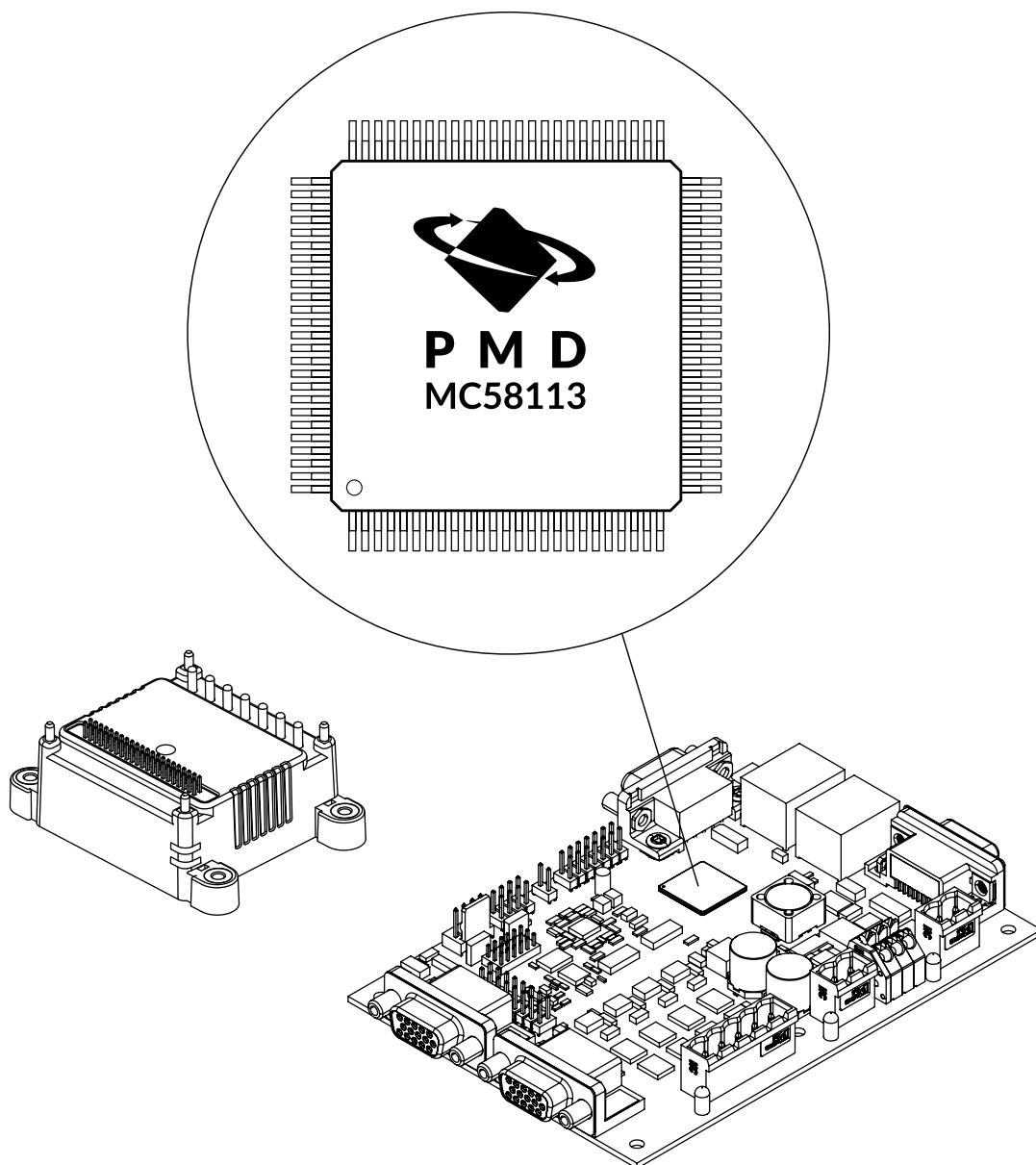




MOTION CONTROL DESIGN GUIDE:

BUILD VS. BUY DECISIONS

WITH APPLICATION CASE STUDIES



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Introduction

Choosing a motion control architecture involves more than selecting a controller. Development effort, system cost, integration requirements, performance, and long-term flexibility all influence whether an engineering team should build a custom solution, purchase an off-the-shelf controller, or combine the two approaches.

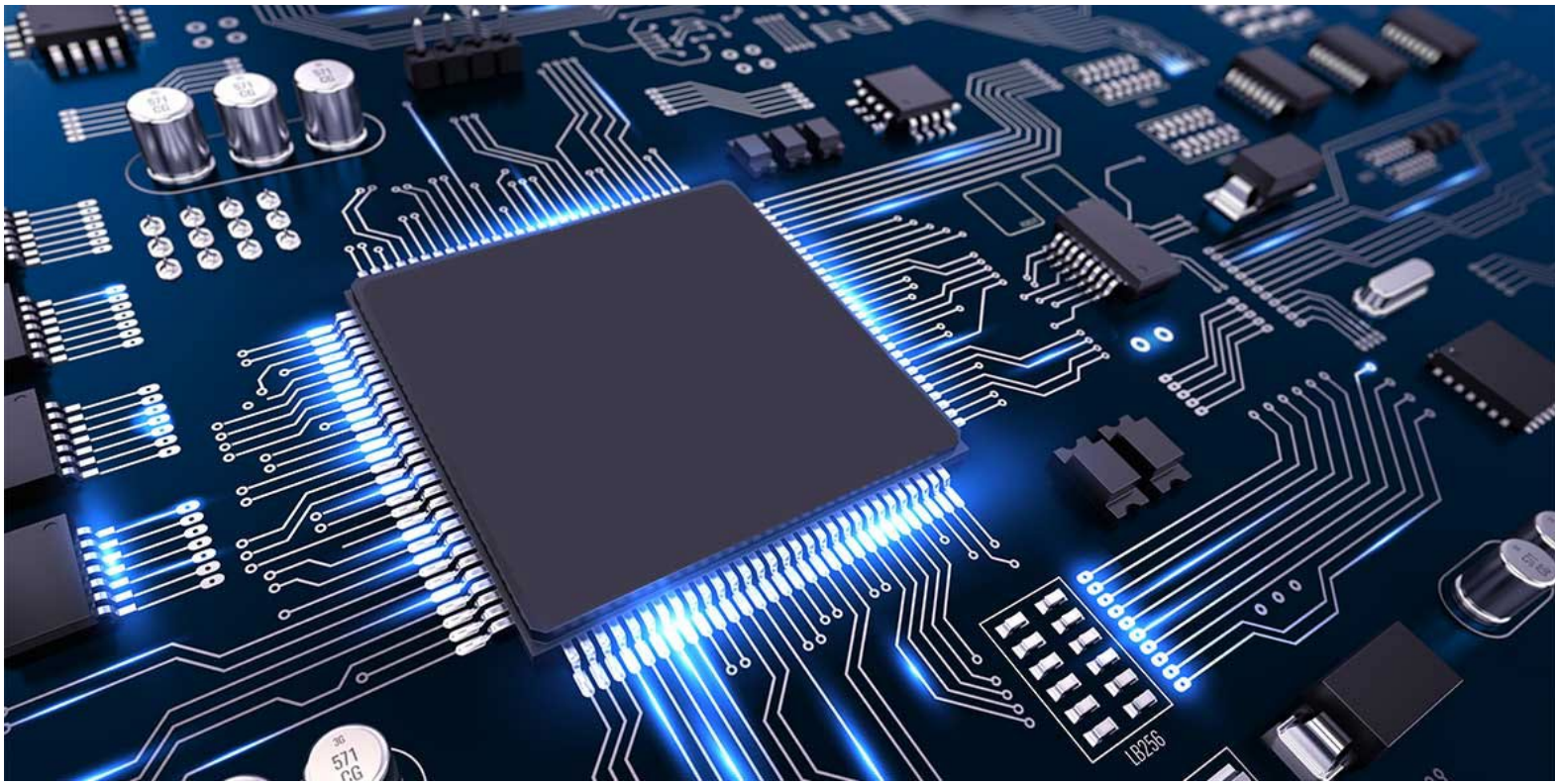
This collection begins with a technical comparison of those three options for an embedded, three-axis motion controller. It examines the engineering resources, design timelines, and cost tradeoffs associated with each approach.

Three customer case studies then show how these considerations translate into specific engineering decisions. Trust Automation addresses demanding positioning and feedback requirements in semiconductor equipment; Dusty Robotics integrates compact, configurable drives into an autonomous construction robot; and OLogic draws on reusable motion control technology across robotics designs.

Together, the paper and case studies connect architecture-level decisions with practical challenges in motion control implementation.

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Build vs. Buy of a Three-Axis Motion Controller

By PMD Engineering

In this paper we will look at building versus buying a three axis PCB-based (Printed Circuit Board) positioning motion controller. We will examine the design effort, types of resources needed, and per unit cost for each approach. In addition, we will look at a design alternative that some engineers believe represents the best of both worlds, a hybrid “blend” option that uses off-the-shelf modules to dramatically reduce the engineering needed to create a fully custom motion controller.



Introduction

In this paper we will look at three different approaches for building an embedded motion control board that can drive typical NEMA 23 or NEMA 34 sized Brushless DC motors or step motors. We will focus on a positioning motion controller used in end applications such as laboratory automation, mobile robotics, test equipment, packaging equipment, and robot arm control.

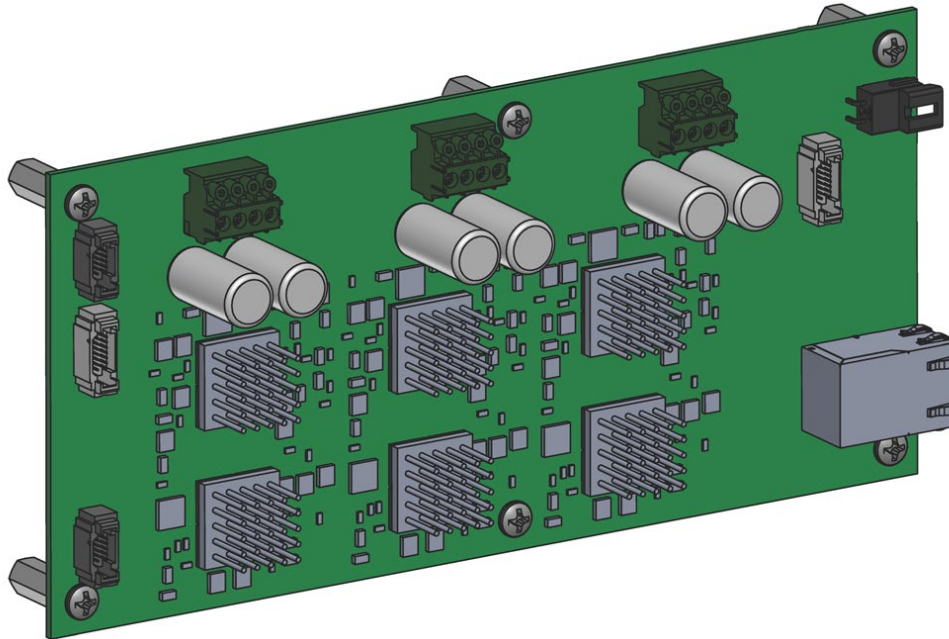


Figure 1: PCB-based positioning control board

Broadly speaking, the motion control solution we are building will look something like what is shown in Figure 1. The board is fully self contained and has all connectors and mounting hardware needed to function inside, or on, the machine being controlled. It includes an onboard microprocessor so that user-written application code can execute directly from the control board for the purpose of controlling the machine's operation.

Why Embedded Control?

Figures 2A and 2B show the two overall approaches that designers might use to construct a motion controller: a centralized controller located remotely from the controlled machine hardware, and an embedded controller located on or inside the machine.

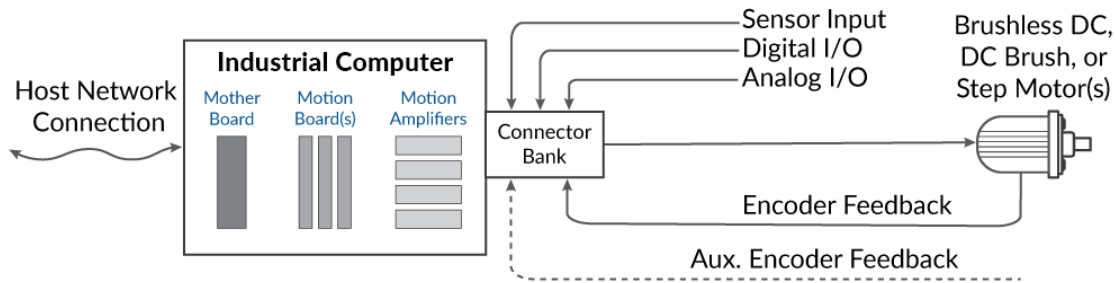


Figure 2A: Centralized motion controller architectures

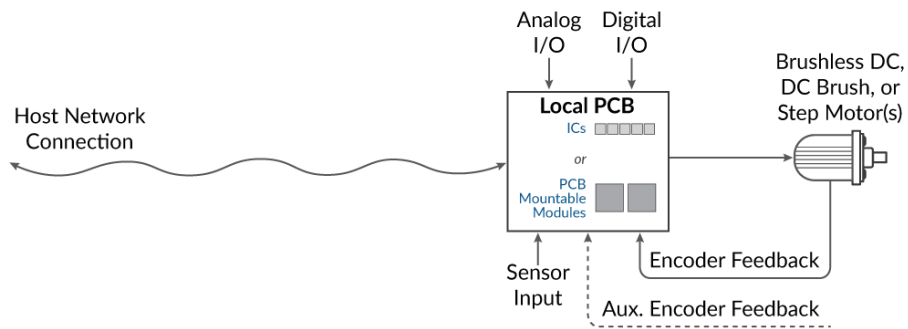


Figure 2B: Embedded motion controller architectures

Given these two different options it is reasonable to ask why build (or buy) an embedded PCB-based controller? The answer boils down to one simple principle: closer is better. Embedded controllers are closer to the sensors and motors that they will control. This means shorter cables which means less noise and faster response times. It is also less expensive because you eliminate the box/rack containing the remote controller and the thick bundle of cables to connect to the machine being controlled.



You may also be interested in: [Motion Control Goes Small](#)

Designing A PCB-Based Motion Controller...

To give our "build vs buy" comparison some specific performance metrics here are a few of the target design parameters of the desired PCB-based controller:

- Compact embedded PCB (Printed Circuit Board) designed to mount on the controlled machine hardware
- Three axis with up to 350W onboard motor amplification per axis
- Controls a mix of Brushless DC and step motors
- Provides inputs and outputs for typical motion control functions such as encoders, home sensors, limit switches, and general purpose I/O
- Powered by a single DCV input (the motor drive voltage)
- Standalone operation with onboard user-written software code execution
- Ability to communicate with an Ethernet host interface

Figure 3 shows the desired control architecture. There are three axis controllers in total but there is only one connection between the controller PCB and the Ethernet host network. The microprocessor on the controller board interfaces with the host network and parses received commands. It then coordinates the movement of the axes under its control according to this received command. Although we have labelled the axes X, Y, and Z this is arbitrary.

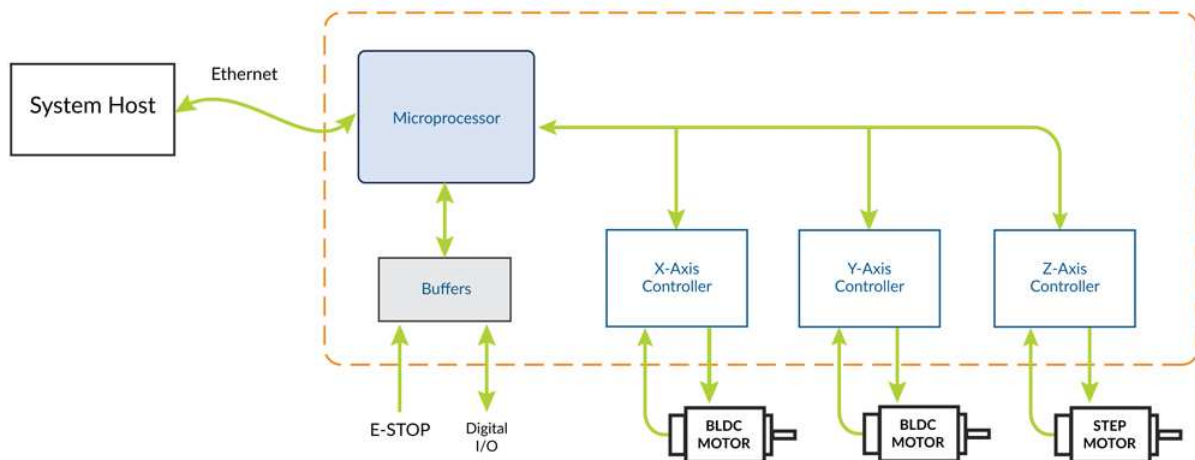


Figure 3: Overall architecture of three-axis controller

It's important to note that the commands sent on the system host are high level, such as "move to position XYZ" or "transfer the test tube from slot A1 to B7". The microprocessor contains user-written application code which knows how to convert these high-level commands into a series of low level motion commands for each axis to execute the sequence.

Alternatively, our embedded PCB-based controller can operate entirely stand-alone, taking commands from a human operator using a touch screen or buttons, and using the host network only to report results.

...Is As Easy As 1, 2, 3, (4, 5, 6)

What is entailed in the engineering design of a three axis motor controller? Every project is a bit different of course, but building our controller will broadly require the following tasks:

Select connectors and wiring scheme – This step is undertaken by an Electrical Engineer (EE) or system engineer and is a preliminary step to the step of designing the full PCB schematic.

Determine the motor amplifier scheme to use – In the embedded motion control world, a big fork in the road is what to do about the motor amplifier. A fully designed-from-the-ground up amplifier for Brushless DC or step motors that can drive 350 watts is a serious design project and will include considerations of EMI (Electro Magnetic Interference), current control, and the PCB layout. The alternative is off-the-shelf PCB-mounted amplifiers. These compact modules can drive 500W (or more) and provide high performance current control, amplification, and safety features to drive the motor's windings.

Determine whether to build, or buy, a motion control engine IC – Another big fork in the road for our embedded motion controller task list is whether to use an off-the-shelf motion control IC or instead write motion engine code for a general purpose DSP, microprocessor, or FPGA (Field Programmable Gate Array). Off-the-shelf motion control ICs cost from \$15 to \$50 per axis and provide a wealth of profiling, servo control, and amplifier control functions. If this path is chosen, the associated software writing task below can be skipped.

Design & lay out the PCB schematic – Utilizing decisions made in the previous two design tasks, this step is undertaken by one or more EEs and consists of researching and selecting IC components to achieve the various electrical functions needed and constructing the PCB's schematic.

Write the motion engine software code – If a fully custom solution for the motion engine IC is to be used it will require software to be written for profile generation, servo loop closer (often PID Proportional Integral Derivative control) and other real time management functions such as E-stop, limit switches, and more.

Write the Microprocessor system software code – This microprocessor communicates with the host network and coordinates the overall machine behavior including motion sequences, user interface, safety monitoring and other functions. This could be the same microprocessor as the motion engine IC, but using that approach adds complexity, requiring a high speed multi-tasking real time operating system. With the present day cost and size of microprocessors most three-axis motion controllers will instead separate the main PCB microprocessor from the motion control microprocessor(s).

Write the microprocessor application software code – Having a functioning operating system and software drivers for connecting to the PCB's motion and peripheral ICs is not the same as having the final machine control solution. So, we are going to break the overall microprocessor function into three parts, of which the system software code detailed above is the first, and this task is the second.

Develop the motion control profiles & parameters – This is the third and final piece of the software development process and consists of working with the actual machine hardware to optimize the motion profiles, servo settings, and other motion control settings. This effort typically involves trial and error and use of a trace facility so that trajectory overshoot and undershoot can be minimized among other optimizations.

OK, with the major project design steps detailed let's look at each of three options; Build, Buy, and Blend to see how they come out in an analysis of design cost, time to market, and per unit cost. We will start with Option 1 which is the Build option.

OPTION 1: BUILD

The table below gives very rough estimates, in engineering design man months, for each project development step listed above when choosing the build option.

	Design Effort In Man Months	Associated Additional Expenses
Connectors & wiring scheme	3	\$1,000 or less for samples, prototyping cost
Determine motor amplifiers scheme	2	\$250. May include the purchase of off-the-shelf amplifier modules or specialized ICs to benchmark performance
Determine whether to build or buy motion control engine IC	1	\$250. May include the purchase of a motion control IC engine IC development kit to benchmark performance
PCB schematic development	12-18*	\$50,000 for prototypes cost assuming three spins of the board
Motion engine IC software development	0-12**	\$5,000 for developer kits & software tools cost
Host micro system software development	6	\$5,000 for developer kits & software tools cost
Application software development	8-12	\$0
Motion parameter development	2-4	\$0
TOTAL	34 - 58 months	\$61,500

* Higher if amplifier circuit must be developed, lower if off-the-shelf amplifier is used.

** If off-the-shelf motion engine IC is used development cost for this category will be zero.

The timeframes above are estimates and should not be taken too literally. Some teams will get it done faster, and some slower based on their experience and the project complexity.

OFF-THE-SHELF COMPONENTS TO SPEED YOUR PCB DESIGN

Build Option Summary

The design effort and associated costs for building a three axis motion controller PCB are significant. You will need the right mix of engineering skills but even with this, a 2- or 3-person team will still typically take 18 months to complete the controller. Note that this can be reduced if off-the-shelf motion control ICs and amplifiers are used in the design.

The key benefits of the build approach are that the resultant controller is entirely tailored to the application in terms of connectors and form factor, and that it has the lowest cost on a per unit basis. Assuming a production run of 1,000 controllers per year, an achievable complete PCB cost is \$225 to \$450 which translates to a per axis cost of \$75 to \$150.

Motion Control ICs

Off-the-shelf motion control ICs such as the **Magellan® MC58113** from PMD provide a wealth of motion control functions including profile generation, servo loop closure, and real time signal management. They provide direct input of quadrature encoder signals and direct output control signals for amplifiers. Many even provide advanced features like FOC (Field Oriented Control).



Motion IC Developer Kits, such as the MC58113 DK, allow software developers to start writing motion control sequences and spinning motors almost immediately. So, both the electrical and the software engineers can work in parallel - greatly lowering the project development time.

PCB-mountable Amplifiers

Off-the-shelf motor control amplifiers such as the **Atlas® Digital Amplifier** from PMD provide high power levels (up to 500W) and high performance amplification for step, Brushless DC, and DC Brush motors. These compact devices accept a digital torque command and provide all the functions needed to commutate the motor and precisely control the current through each motor winding.



Atlas Digital Amplifiers provide FOC (Field Oriented Control), performance tracing, and voltage, current, and temperature safety monitoring.

OPTION 2: BUY

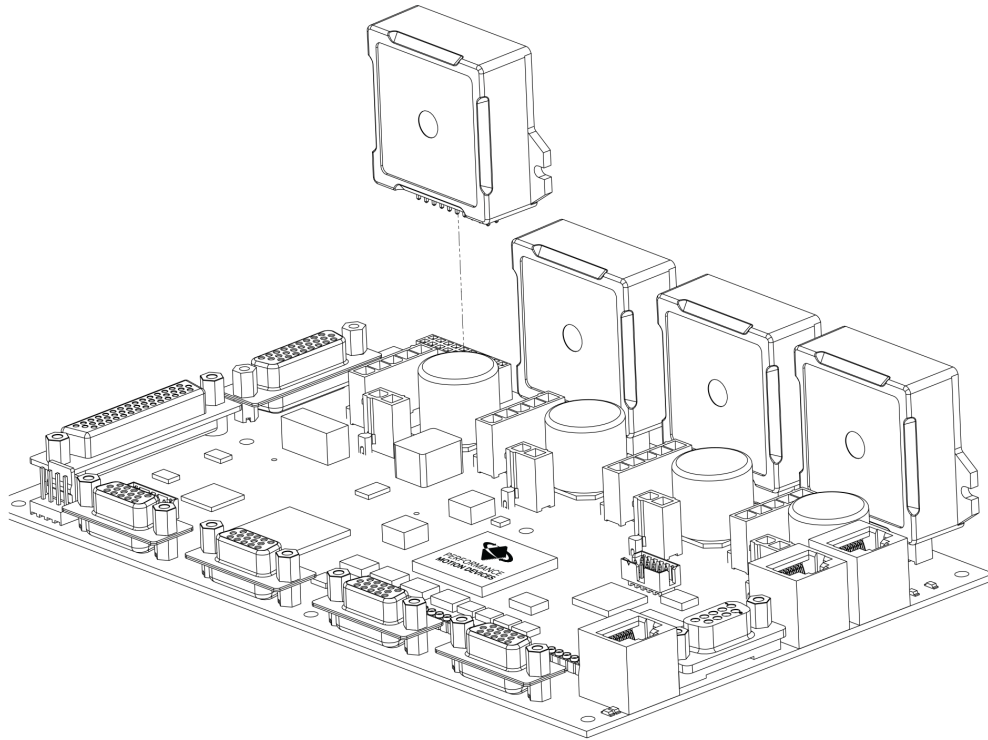


Figure 4: Prodigy®/CME Machine Controller from PMD

For this approach we will select a ready-to-go PCB-based motion controller. There are a number of board based products to choose from, but for the purposes of this analysis we'll use PMD's Prodigy/CME Machine Controller.

The configuration shown in the image above is a four axis controller but can be purchased in a three axis configuration as well. The **Prodigy®/CME Machine Controller** is a representative motion controller board that meets all of our application requirements. In addition, the usual features such as profile generation, servo position control, and encoder input, this product supports on-board amplifiers, user downloadable code written with C language libraries and provides Ethernet as well as other host connection options.

So how did the buy option affect the project timeline? The table below shows this:

	Design Effort In Man Months	Associated Additional Expenses
Connectors & wiring scheme	0	\$0
Determine motor amplifiers scheme	0	\$0
Determine whether to build or buy motion control engine IC	0	\$0
PCB schematic development	0	\$0
Motion engine IC software development	0	\$0
Host micro system software development	0	\$0
Application software development	8-12	\$0
Motion parameter development	2-4	\$0
TOTAL	10-16 man-months	\$0

Buy Option Summary

The appeal of the buy option centers around two factors. The first is that the engineering effort costs much less. The second is that the design effort takes less time which should mean the machine being controlled can get to market faster.

The tradeoffs are also two fold however. The first is that the resultant controller costs more per axis. Again assuming 1,000 controller per year, the overall controller costs \$900 - \$1,200 and each controlled axis typically costs \$300 - \$400. That's two to three times the per axis cost of the board created using the build option. The second tradeoff is that the PCB is not tailored to the application. The form factor is pre-determined, as are the connector types and pin arrangements.

OPTION 3: BLEND

There is an interesting new approach toward building fully custom motion control boards that isn't quite a build option, nor a buy option. This hybrid “blend” approach uses miniaturized motion control modules that are PCB-mounted yet contain fully functional motion controllers. These modules provide the ability to download code so that they can execute user-written application software.

These products almost always come in a single axis configuration and can drive up to a kilowatt and sometimes more of power. Figure 5 shows such a product, in this case the **ION®/CME N-Series Digital Drive** from PMD.

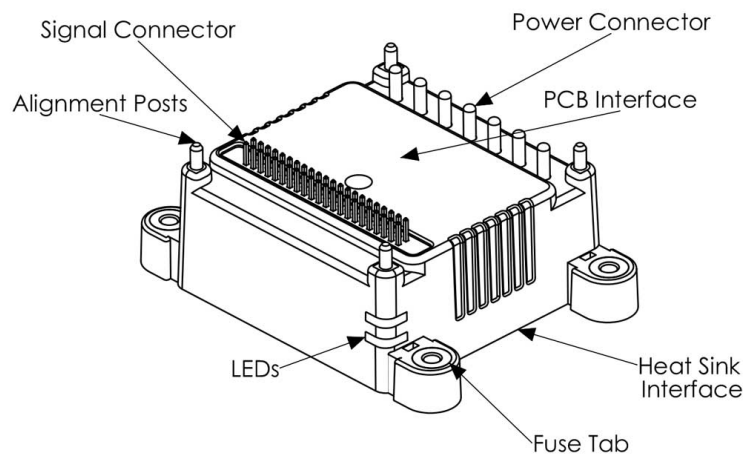


Figure 5: ION®/CME N-Series Digital Drive

Just like the 100% buy option, these modules provide a wealth of ready-to-go motion control functions such as profiling, FOC, and current monitoring safety features. But unlike the 100% buy option they are mounted on a user designed, application-specific interconnect board. An example of such a board is shown in both top view and bottom view rendering in Figure 6A and 6B. Note that in addition to the modules themselves there are just connectors and a few capacitors on the PCB.

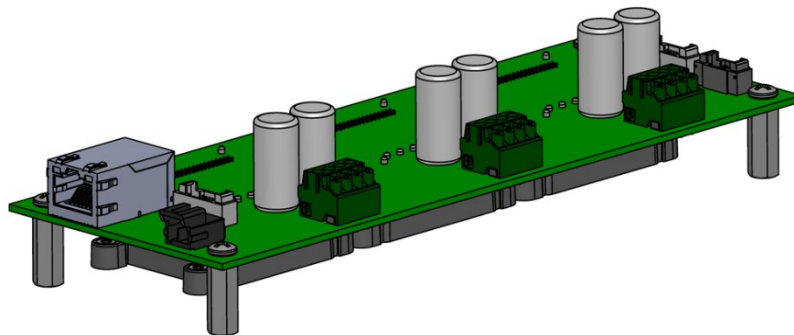


Figure 6A: ION/CME N-Series Digital Drive top view

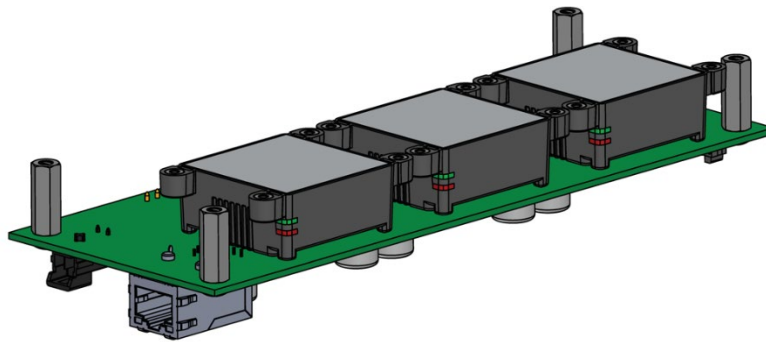


Figure 6B: ION/CME N-Series Digital Drive bottom view

The effort involved with creating a board using motion control modules is not so much creating a schematic, it's more like creating a wiring diagram. A simplified version of such a wiring diagram is shown in Figure 7. Also important is that the resulting board is not 10, 12, or 14 layers (as would be typical for the full “build” option board), but usually just 4 layers. The engineering skillset level required is therefore significantly lower because all the heavy lifting such as motor amplification and signal processing is done inside the modules.

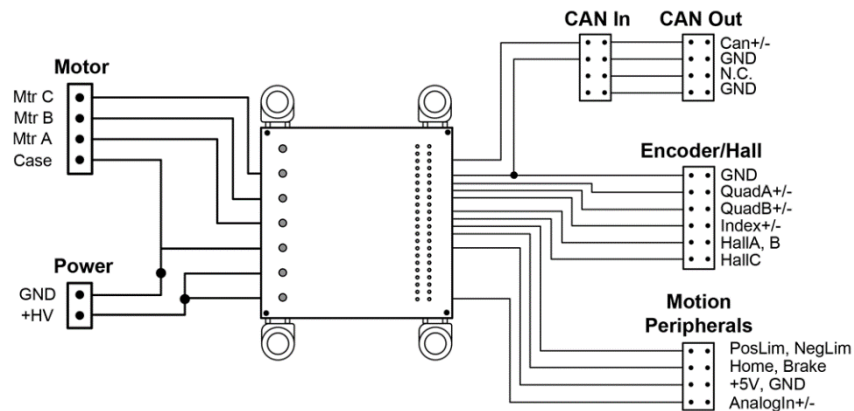


Figure 7: Simplified wiring diagram for a "blend" approach motion controller

Can these modules support the desired motion controller architecture seen at the beginning of the article? Yes, they can. Our application specification required the PCB to receive commands and provide reporting through an Ethernet connection. And we wanted to write PCB-resident application software that would interpret these commands and drive the three motor axes accordingly.

This can be accomplished using PCB-mountable modules as shown in Figure 8. One of the modules holds the user-application code as well as controlling one axis and then in turn commands the other two axis.

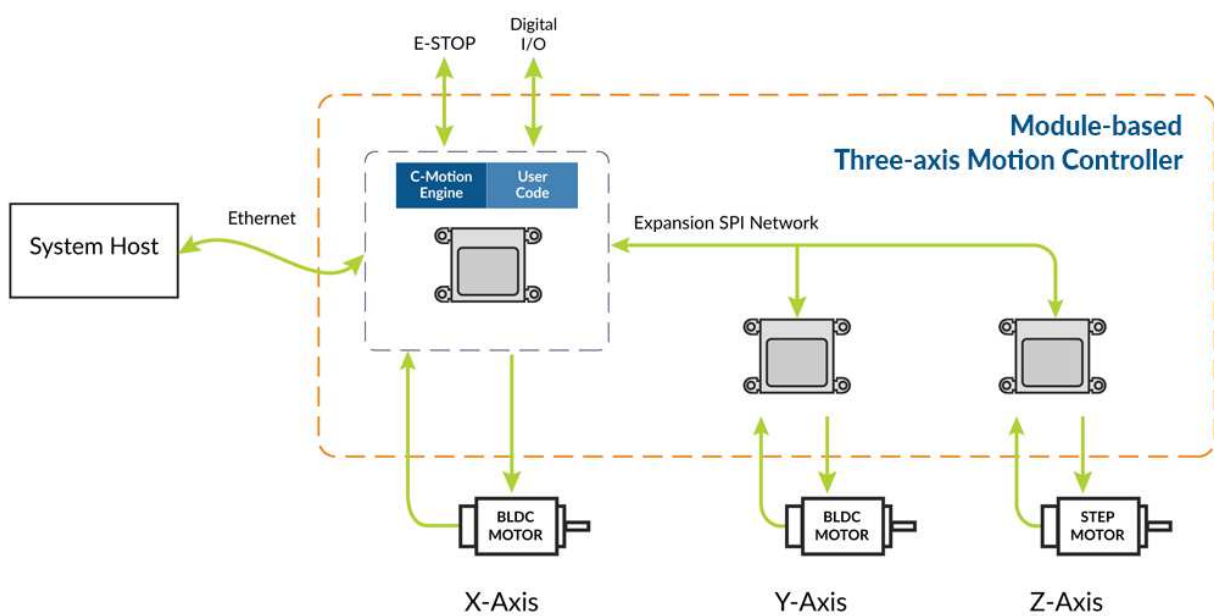


Figure 8: Control architecture for three-axis module-based controller PCB

So how does this new option affect the project timeline? The table below shows this:

	Design Effort In Man Months	Associated Additional Expenses
Connectors & wiring scheme	3	\$1,000 or less for samples, prototyping cost
Determine motor amplifiers scheme	0	\$0
Determine whether to build or buy motion control engine IC	0	\$0
PCB schematic development	3	\$5,000 for prototypes cost assuming two spins of the board
Motion engine IC software development	0	\$0
Host micro system software development	0	\$0
Application software development	8-12	\$0
Motion parameter development	2-4	\$0
TOTAL	16 - 22 man-months	\$6,000

With the blend option there are still some electrical engineering tasks but they are much, much simpler than building a full motion control board. After that the focus is on the application software development and the motion parameter development, which is unchanged from the build or buy options.

Blend Option Summary

The appeal of the blend option is that it lets you create a fully custom PCB-based controller with form factor and connectors of your own choosing, yet with only a fraction of the engineering effort needed compared to the traditional build option. This is achieved by the use of fully functional motion modules that reduce the PCB-design task to one of creating a wiring interconnect board.

Cost-wise the blend option has the same to slightly lower per unit cost than the buy option. So assuming a production rate of 1,000 three-axis controllers per year, this is \$250 - \$350 per controlled axis.

Summary

The table below summarizes the engineering effort, design out of pocket expenses, and per axis cost of our three axis motion controller PCB using the build, buy, and blend options.

Option	Engineering Time In Man Months	Additional Expenses	Per Axis Cost
Build	39-57 man-months	\$61,500	\$75-150
Buy	10-16 man-months	\$0	\$300-400
Blend	16-22 man-months	\$6,000	\$250 - \$350

The above figures are estimates for the purpose of comparison only. Actual results will depend on many factors including the experience of the design team, whether some previous design work can be leveraged for the new design, and the complexity of the machine being controlled.

We hope you found this comparison of engineering effort and per unit cost for a three-axis PCB-based controller helpful. Understanding the tradeoffs between the build, buy, and blend options will help you make the right choice in your next motion controller design.

PMD Products Featured In This Article

PMD has been producing ICs that provide advanced motion control of Brushless DC, DC Brush and step motors for more than thirty years. Since that time, we have also embedded these ICs into plug and play modules and boards. While different in packaging, all PMD products are controlled by C-Motion, our easy to use motion control language and are ideal for use in medical, laboratory, semiconductor, robotic, and industrial motion control applications.



MC58113 Motion Control IC

Performance Motion Devices' **MC58113 Motion Control IC** is ideal for controlling Brushless DC, DC Brush, and step motors, providing high-performance motion control features including field oriented control and closed loop stepper operation. In addition, the MC58113 IC provides profile generation, servo-loop closure, commutation, current control, and direct PWM (Pulse Width Modulation) motor output command to drive MOSFET switching amplifiers. It is ideally suited for a wide range of applications including scientific, mobile, medical, robotic, and automation applications.

[Learn more >>](#)



ION/CME N-Series Drives

N-Series ION Drives combine a single axis Magellan IC and a high performance digital amplifier into an ultra-compact PCB-mountable package. In addition to advanced servo and step motor control, N-Series IONs provide S-curve point to point profiling, field oriented control, downloadable user code, general purpose digital and analog I/O, and much more. With these all-in-one devices building a custom controller board is a snap, requiring you to create just a simple 2 or 4-layer interconnect board.

[Learn more >>](#)



Atlas Amplifiers

Atlas Digital Amplifiers are compact single-axis amplifiers that provide high-performance torque control for Brushless DC, DC Brush, and Step motors. Atlas amplifiers come in both a vertical and horizontal mounting configuration and are available in three power ranges: 75W, 250W, and 500W. They are used for direct control of motor torque or in conjunction with higher-level motion controllers providing position or velocity control functions.

[Learn more >>](#)



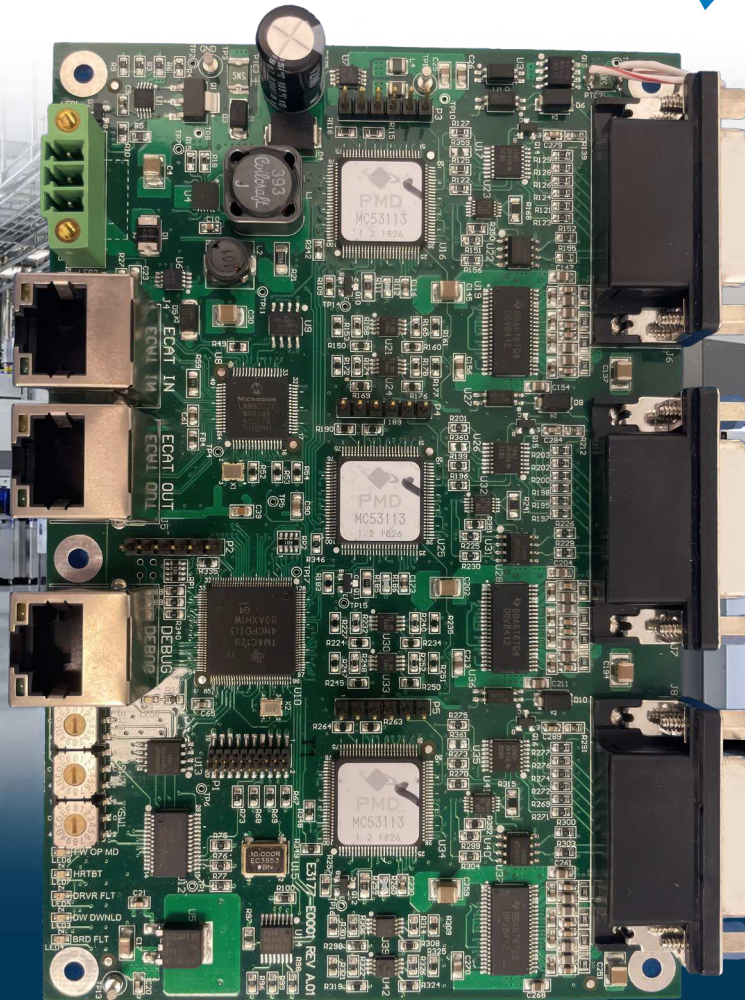
Prodigy/CME Machine Controller

PMD's Prodigy®/CME Machine-Controller boards provide high-performance motion control for medical, scientific, automation, industrial, and robotic applications. These versatile all-in-one controllers support quadrature, Sin/Cos, and SSI encoder formats, and are available in 1, 2, 3, and 4-axis configurations, with support for DC Brush, Brushless DC, and step motors. Prodigy/CME Machine-Controllers have on-board Atlas amplifiers that eliminate the need for external amplifiers.

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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

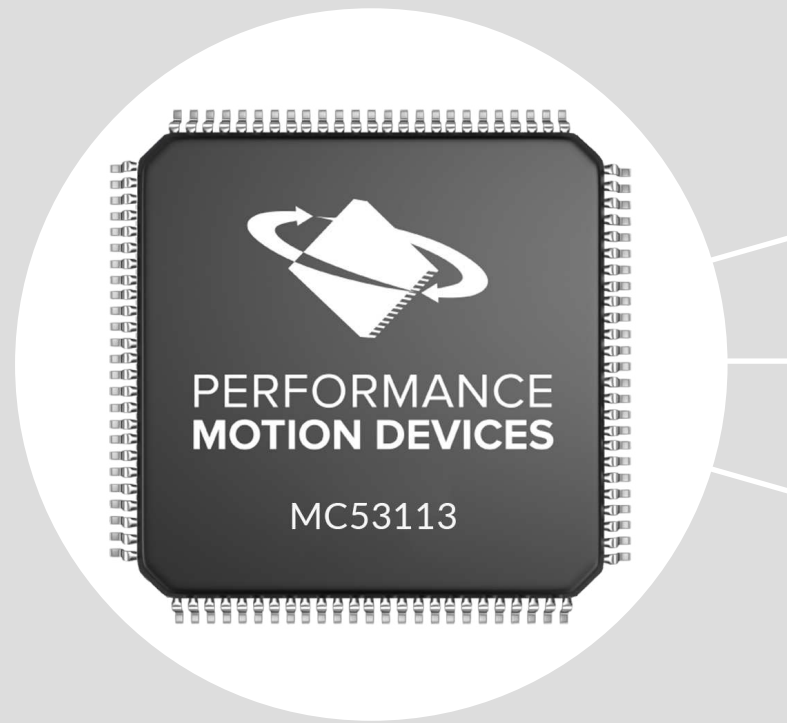
The leveling application for this particular semiconductor equipment maker sits at the precise end of that range. It is a multi-axis synchronized linear actuation system built around ultrafine-pitch lead screws.

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.



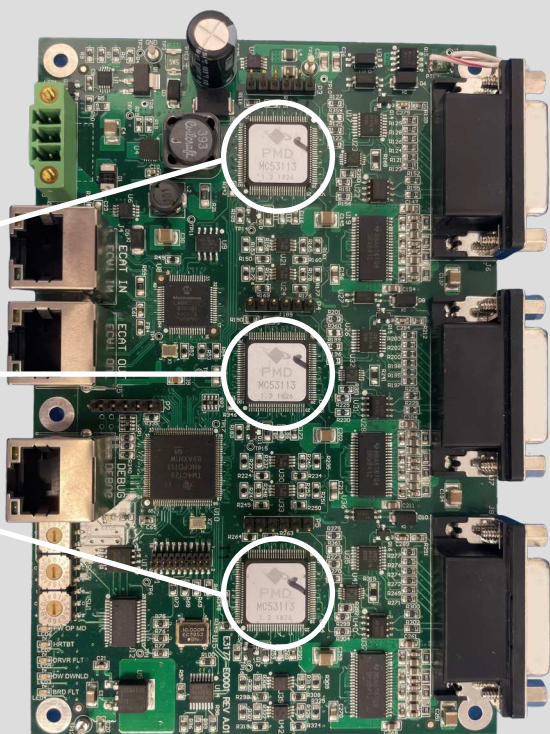
Why the MC58113?

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.



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.”

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.”

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.

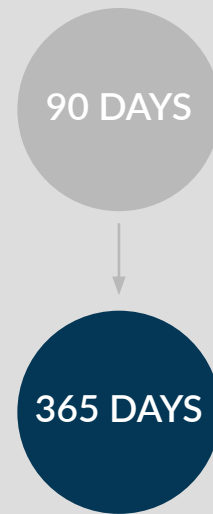
PMD also made hardware signal routing software-controllable so that Trust could reassign signals across axes and inputs on a board layout that was already complete. “That way we didn’t have to spin a board, which is also super useful,” Bentz says.

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.

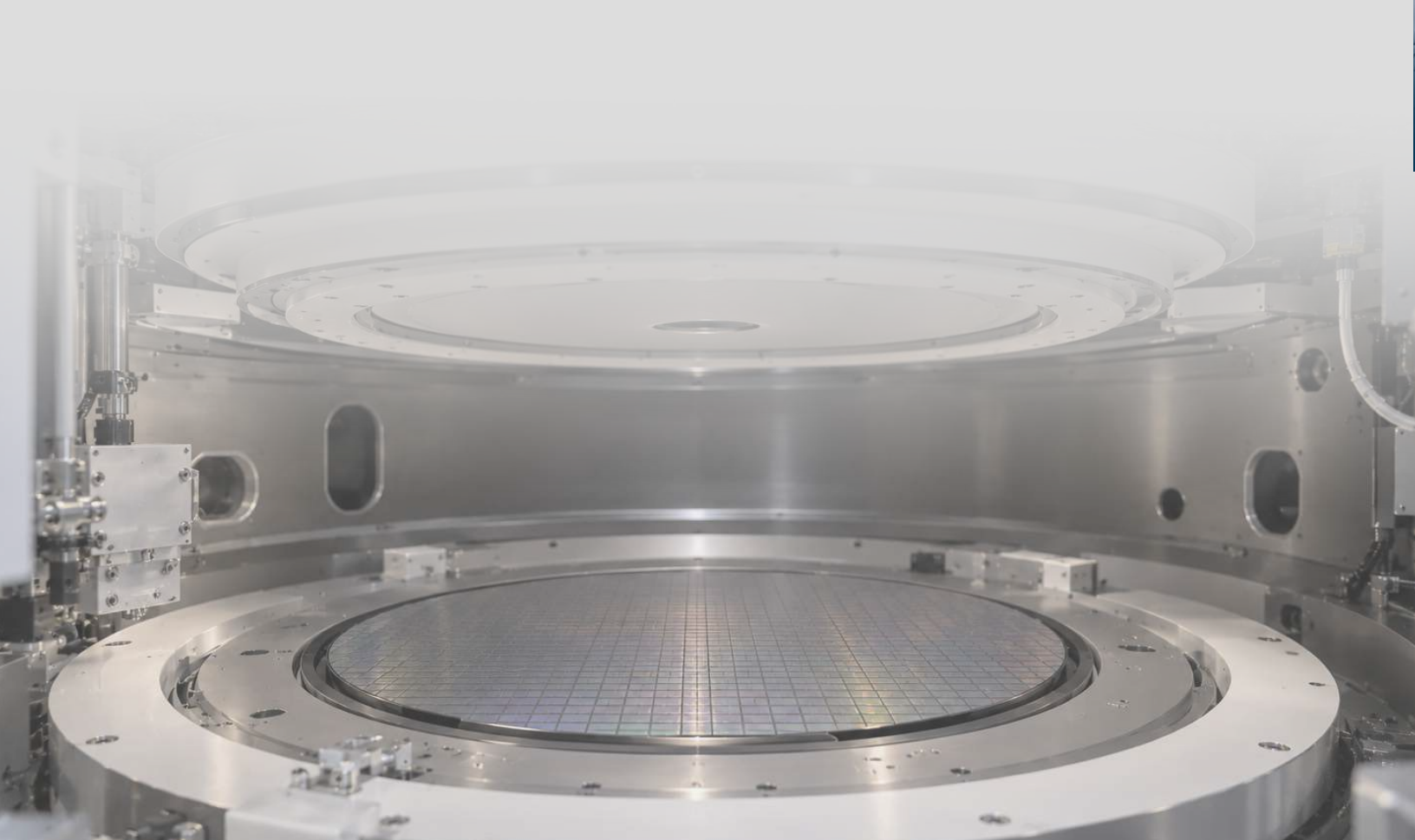
“That’s a huge selling point for them and their customers,” Bentz says. Fewer interruptions mean more available production time. For a fab, that translates directly into throughput. As Bentz puts it, the benefit is “driving the sales of the next-generation tool and buildout of fabs using their new tool.”

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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Autonomous Construction Bots Unleashed: Powered by PMD's Precision Motion

Dusty Robotics provides an essential bridge between a building's design and its construction. The ION/CME N-Series Motion Control Drive from Performance Motion Devices gives Dusty's team the control needed for precision automated operation.

As urbanization accelerates and infrastructure demands grow, the construction industry is under extreme pressure to keep pace. Labor shortages, rising material costs, and increasing demands for speed and precision are pushing builders to seek automated solutions that improve not only efficiency but safety and sustainability as well.

It's within this space that Dusty Robotics saw a particular need for a system that could automate the translation of building designs to the floor of a construction site. Too often, there is a considerable gap between a building's design and 3D model and what actually gets built. As various trades lay out their plans, mistakes and outdated information often lead to incorrect layouts, rework, and delays in production.

As the industry moves to tablets or laptops for plan information, the days of a 4-inch-thick set of blueprints covering each floor and each trade are mostly gone. But the typical process still

requires that an individual manually transfer that information onto the ground, explains Mike Thompson, principal engineer for Dusty Robotics.

"The consequences of that person getting that information wrong could be a wall being built 1 inch out of place or it could be 12 inches out of place, in which case the builder would probably have major problems," he says.

It's also a very manual process. Depending on the site, the team might have a total station (a surveying instrument integrating several measurement tools) and chalk lines or perhaps just people with tape measures and chalk lines — a technique that hasn't changed in centuries, Thompson notes. "It's a person on their knees laying down the information, writing with a grease pen," he says. "In a lot of cases, there isn't any information. They don't have the time, and it's just very labor-intensive."

- Dusty Robotics' FieldPrinter autonomous mobile robot requires precise control to enable layout accuracy for construction customers. PMD's ION/CME N-Series Motion Control Drive is instrumental to the robot's position accuracy of 1/16 of an inch.
- PMD's N-Series drives give robotics engineers essential insight and access to internal control parameters needed to customize and troubleshoot.
- The N-Series is a compact, PCB-mountable single-axis controller that provides high-performance motion control, network connectivity, and amplification in a tiny footprint.

Dusty Robotics' FieldPrinter

Dusty Robotics has pioneered a mobile robotic system that alleviates all those pain points. The company's FieldPrint Platform translates a building's 3D model into 2D drawings on the floor of the facility, preventing the miscommunications and mistakes common in the field.

"We're bridging that gap with a design field communication platform that takes all of the things you've modeled and all the things you've designed for a building and makes it physically there on a job site floor with 1/16 of an inch accuracy," says Zachary Reiss-Davis, senior director of marketing for Dusty Robotics. "The construction team no longer has to be referring back to their laptops, to their iPads, to their paper plans to know what needs to be built, where it needs to be built, and how it needs to be built. Instead, all of that information — across all of the trades, across all the stakeholders involved in a construction project — is right there under their boots and available a lot faster, a lot more accurately, and with a lot better collaboration."

Key to the robot's precise performance are two off-the-shelf compact motion controllers from Performance Motion Devices (PMD). Each ION/CME N-Series Drive provides control and power for each of the two front wheels. (The rear wheel has no active drive.) Together with a suite of onboard sensors that provide precise location information — including trackers, encoders, and IMU (inertial measurement unit) gyroscopes — the PMD drives are vital to achieving the robot's position accuracy of 1/16 of an inch.

"We want the robot to move very smoothly, and as someone would expect, so we don't want to be accelerating and decelerating a ton. We want it to be a continuous motion between all the different objects that we print," says Ryan Dimick, controls engineer for Dusty Robotics. The control system has to allow for constant profile changes as the robot switches between navigating and printing. "That is where the PMD drives come in, allowing us to transition smoothly from the different operations."

Dusty Robotics recently launched its FieldPrinter 2, improving on its previous robot with the help of the PMD controllers. The motion controllers used in the first version of the robot created some challenges for Dusty's developers, including an inability to understand and rectify errors without coming up with work-arounds.

Dusty Robotics needed to find an alternative that would provide the performance it was looking for and would also fit into its existing platform. The team found that not only was the PMD N-Series drive a good fit for Dusty's existing platform, but it also helped overcome significant challenges that the Dusty development team had been facing with its previous motion controllers.

N-Series Provides the Control

The N-Series is a compact, PCB-mountable single-axis controller in PMD's ION Drive family, providing high-performance motion control, network connectivity, and amplification in a tiny footprint measuring only 1.48 x 1.48 x 0.66 in. (37.6 x 37.6 x 16.8 mm). It is an all-in-one drive with a built-in processor, giving Dusty the ability to download and run code. The N-Series helped overcome challenges the Dusty development team had faced with its previous motion controllers.

"One of the main reasons we liked the PMD drive was that we had control over everything,"

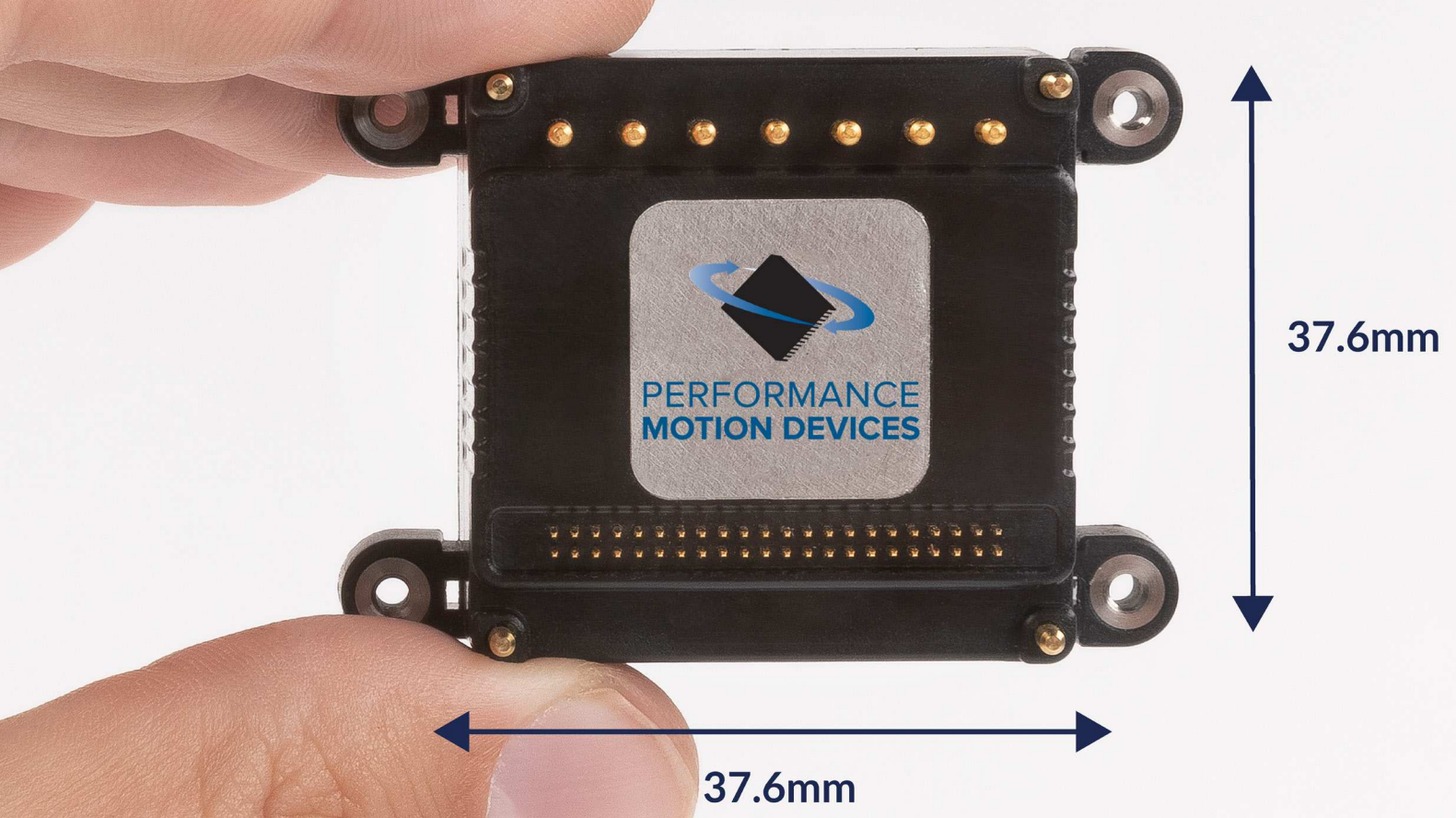
Dimick points out. "We could provide it with the parameters we wanted, and we had visibility into what was happening inside the controllers themselves."

The PMD drives gave Dusty Robotics the visibility and customizability it wanted. "And when we would run into an issue, it was always something we could fix," Dimick says. "We were able to overcome any of the latencies that we had in the past and really set our own timing characteristics for the motors and the motor control."

One of the features Dusty wanted access to was the ability to modify the control loop and the field-oriented control loop parameters, Dimick adds. "In our previous units, these were fixed parameters that we had to work with," he says. "Being able to adjust those using PMD's Pro-Motion software gave us more options to determine the optimal tuning for the robot."

As Dimick worked to perfect the electronics within the latest-generation robot, that added insight from the PMD motion controllers was invaluable. "[Dimick] is constantly pulling data into spreadsheets, graphing it, and really looking at all the inputs to the motor controller, and the outputs, and really understanding what small tweaks we need to actually achieve the goals that we want to achieve," Thompson explains. "That ability to bring those graphs into alignment with what his expectations are — that was a very big challenge before."

Dimick adds, "We're working on a millisecond-level time scale. Getting a lot of information very quickly is very important for all the tuning and the high-level controls, and we were not able to achieve that prior to PMD."



Flexibility in Communication

Throughout the development journey, Dusty Robotics has been able to collaborate closely with the PMD team to help resolve challenges. “Any time I was integrating the controller into our product and had any questions, they were always very quick to jump on a call and point me in the right direction in terms of what features of the robot or the drive I should be looking at,” Dimick says. “They even released a custom debug version for me to use temporarily to help me diagnose an issue I was having. In terms of getting them fully integrated into our process, they were really helpful along the way.”

This collaboration served Dusty well as it sorted out the ideal communication interface for its purposes. PMD’s N-Series drives come with a range of communication options, including Ethernet, CAN, RS-232, RS-485, and SPI (Serial Peripheral Interface).

Dusty had a good idea of what communication it wanted, which was coming in a slightly later version of the controller. “So we waited on it,” Dimick says. “And then I think we were one of the first people to really use it. We helped them debug some of the firmware, and they quickly turned around versions for us to be able to use it.”

Overcoming Blind Spots in the Field

That communication is important for overcoming difficulties with inevitable obstacles throughout a construction project.

A key technology for Dusty’s FieldPrinter is a very precise laser tracker that continuously reports to the robot about its position within its environment. But many times throughout a workday,

the tracker does not have a view of the robot — operating within a blind spot. The controller, and its operation with the robot’s other sensors, is vital to keeping the robot on track.

“When the robot is printing within a blind spot, not visible to the tracker, it is literally relying on the inertial measurement unit; it’s relying on the encoders that are coming through the PMD controller. It’s relying on all the other sensors that we put into the robot so it can go five, 10, 15 seconds of continuous printing,” Thompson explains. “Then, when it comes out of the blind spot, it tells the tracker exactly where it is. We need to give that tracker the accuracy so it can acquire the signal very quickly, very precisely. The precision that we can operate the robot with while it’s out of view is very critical.”

That’s where a lot of the sub-millisecond timing precision comes in, to overcome the blind spots that are not uncommon at cluttered job sites, Dimick adds. “The ability to maintain accuracy in blind spots is a tough problem, and that’s where the sub-millisecond timing is critical,” he says. “That information, combined with the smooth, predictable motion, enables the robot to accurately estimate its location and continue printing without line-of-sight to the laser tracker.”

This blind spot printing is one of Dusty’s biggest improvements in its latest robot version, according to Dimick. “The PMD drives and the information we can get out of them, and the quality of it, has really helped us achieve that performance,” he says.

“It’s a vast improvement from the previous product to this.”

Navigating Other Dangers

Construction job sites are often cluttered with obstacles, floor penetrations, and unprotected edges of the building, Dimick notes, and Dusty uses PMD's internal braking scheme to help navigate those dangers.

"We have cliff sensors mounted on all four corners of the robot looking for these ledges that could pose a threat to the robot. When we detect a ledge, the robot automatically applies the brakes and navigates away from the ledge," he explains.

Dusty is able to use the PMD drive to apply an electronic brake to the motors. "There's a pretty complicated set of actions that the robot has to do when it detects this, and a lot of it goes through the PMD interfaces," Dimick says.

A bit of Dusty's own software, running on one of the chips in the PMD controller, serves as a watchdog, Dimick adds. "If it loses communication to the robot, it powers down the motors."

As the company name implies, Dusty's robots must operate in very dusty, dirty environments, and they must be able to withstand all kinds of weather. "We have to work in the Arizona sun when it's 110 degrees out, and we also have to work on the 14th floor of a Chicago building in February, when it's minus 20," Thompson says.

Far from a controlled, sterile factory, the FieldPrinter must be more durable, more reliable, and capable of operation in those harsh environments — with unknown obstacles and unknown internet connectivity, Reiss-Davis says. Being able to deal with "those complex, dirty, dusty environments is something we know our clients expect from us, and that's something we look for in technology partners as well."

Unlike competing solutions, which leave sensitive electronics exposed to environmental hazards, the N-Series drive comes standard with an enclosed package to protect internal components.

Moving Forward

Dusty Robotics continues to look at ways to improve its platform further. Like any technology company, Thompson says, it's always interested in higher levels of integration. Developers will continue to look to PMD to help achieve their goals.

"PMD provides a pathway for us."

Not only do they provide the controllers themselves, but they can open up their controllers and give us access to the independent parts that allow us to create a highly integrated solution," Thompson says. "It's something that we haven't really pursued in any detail, but it is a pathway that allows us to preserve our investment that our engineers have made in what we have today. We can preserve that and still achieve some other engineering goals around integration to make the system faster, lighter, and even better than it is today."

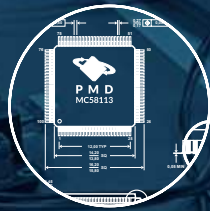
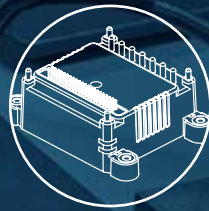
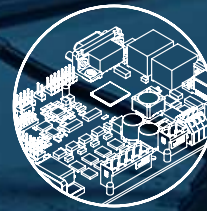
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PERFORMANCE
MOTION DEVICES
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OLogic



Leading Robotics Design Firm Returns to PMD Solutions Time and Time Again

*Helping robotics companies bring their projects to completion, **OLogic** increasingly turns to **Performance Motion Devices** for motion control technology without limits.*

Silicon Valley-based OLogic has helped robotics and consumer electronics companies — from startups to industry leaders — bring products to market. Past customers include **NVIDIA**, **Google**, **Hasbro**, **Panasonic**, **Toyota Research Institute**, and **Carnegie Mellon University**.

OLogic brings decades of experience designing DC motor systems for a wide range of applications. But when it comes to delivering advanced motion control for robotics, even OLogic benefits from having a trusted partner.

That's why the team repeatedly turns to Performance Motion Devices (PMD) — a company with the embedded motion control technologies, deep motion control expertise, and the engineering support to help bring complex designs across the finish line. As of mid-2025, OLogic has used PMD motion control solutions in at least four robotics projects.

For Ted Larson, CEO and co-founder of OLogic, the reason is clear: PMD consistently delivers great technology for commercial products, great solutions and tools for developers, and great support when it matters most.

Technology Built for Commercial Robotics

Larson draws a sharp line between hobbyist prototypes and commercial robots. Many developers start with off-the-shelf components, often adapted from industrial or academic settings, but soon find these parts inadequate. Meanwhile, robots also face unique challenges: space and power constraints, variable duty cycles, and the need to switch seamlessly between velocity and position control.

That's why OLogic relies on PMD, whose ICs and drives are designed from the ground up for commercial applications. They deliver the precision, efficiency, and reliability that OLogic's customers — from delivery robots to mobile platforms — need in the field. With PMD, OLogic can design motion systems that are robust enough for daily operation, not just one-off demonstrations.

OLogic often works with customers who have run successful trials but lack a path to volume production. The solution, Larson argues, is designing for scale from the start: "We advocate for building a highly bespoke electronic system that's specifically designed for manufacturing," he says.

That means consolidating electronics onto one or two boards for simpler assembly, troubleshooting, and cost reduction over time. PMD's product range provides a clear path to this kind of bespoke design. Customers can start with development boards, migrate to motor control modules like the ION/CME N-Series intelligent mini-drives, and eventually embed PMD ICs directly into custom designs. This progression keeps costs manageable while ensuring scalability.

OLogic has found clear advantages in using PMD's command-based motion chips rather than starting with a raw processor.

“By relying on PMD chips where the control algorithms and command set are already embedded, our engineers avoid the time-consuming process of writing and debugging low-level motor control code,”

Larson says. “This speeds up development, reduces risk, and allows our team to focus on system-level innovation instead of reinventing the basics of motion control.”

Accelerating Development in the Field

PMD's ecosystem of motion control solutions has repeatedly helped OLogic deliver under pressure. One notable example was OLogic's work with Dusty Robotics on its FieldPrinter autonomous mobile robot (AMR) for construction sites. The robot's original motion controller became unavailable during the global semiconductor shortage, jeopardizing production.

Dusty needed a replacement controller that fit within the existing footprint and integrated smoothly with the design. PMD's ION/CME N-Series Motion Control Drive proved the perfect solution. Compact and PCB-mountable, it provided both the form factor and the advanced diagnostics Dusty's engineers needed. By developing a custom carrier board, OLogic ensured seamless integration, allowing Dusty to continue production without missing a beat.

This episode highlighted two critical PMD strengths: reliable supply, even during a global shortage, and products versatile enough to fit demanding robotics applications. For Dusty, PMD technology helped transform a potential crisis into a smooth path forward.

PMD's N-Series not only fit nicely within the small footprint constraints, but it also provided Dusty's robotics engineers with essential insight and the access to internal control parameters needed to customize and troubleshoot.



Tackling Motion Control Challenges

Designing motion control comes with its fair share of challenges. Not only is PMD there to provide the support necessary to get projects off the ground — including being very able and willing to develop custom features — PMD's solutions give OLogic the flexibility and tools to address these issues.

- **Sensorless motors:** PMD chips allow engineers to add encoders and use them as sensors, creating reliable control systems without requiring dedicated motor sensors.
- **Current management:** Instead of oversizing motors and risking power drain, PMD ICs enable precise matching of motor, FETs, and H-bridges to ensure efficiency and stability.
- **Energy handling:** Large motors can generate significant energy when slowing down. PMD's Juno chip supports intelligent shunting, pulsing resistors to dissipate excess energy safely while protecting batteries and circuitry.

Larson recalls projects requiring the control of large, heavy DC motors weighing 40–50 pounds. These motors introduced complexities such as managing excess braking energy — a challenge many off-the-shelf controllers aren't designed to handle. With PMD solutions, OLogic engineers could integrate custom shunting circuits directly into designs, supported by the Juno chip's intelligent energy management features.



This capability underscores one reason OLogic continues to choose PMD: the products prove themselves in demanding real-world conditions, reducing the likelihood of costly redesigns and enabling customers to scale with confidence.

Support That Makes the Difference

Technology alone doesn't solve every challenge. For OLogic, PMD's engineering support is equally important. Larson recalls a warehouse robot project where the customer required control of four high-powered motors at an update rate of 1,000 times per second — an ambitious benchmark on an aggressive timeline.

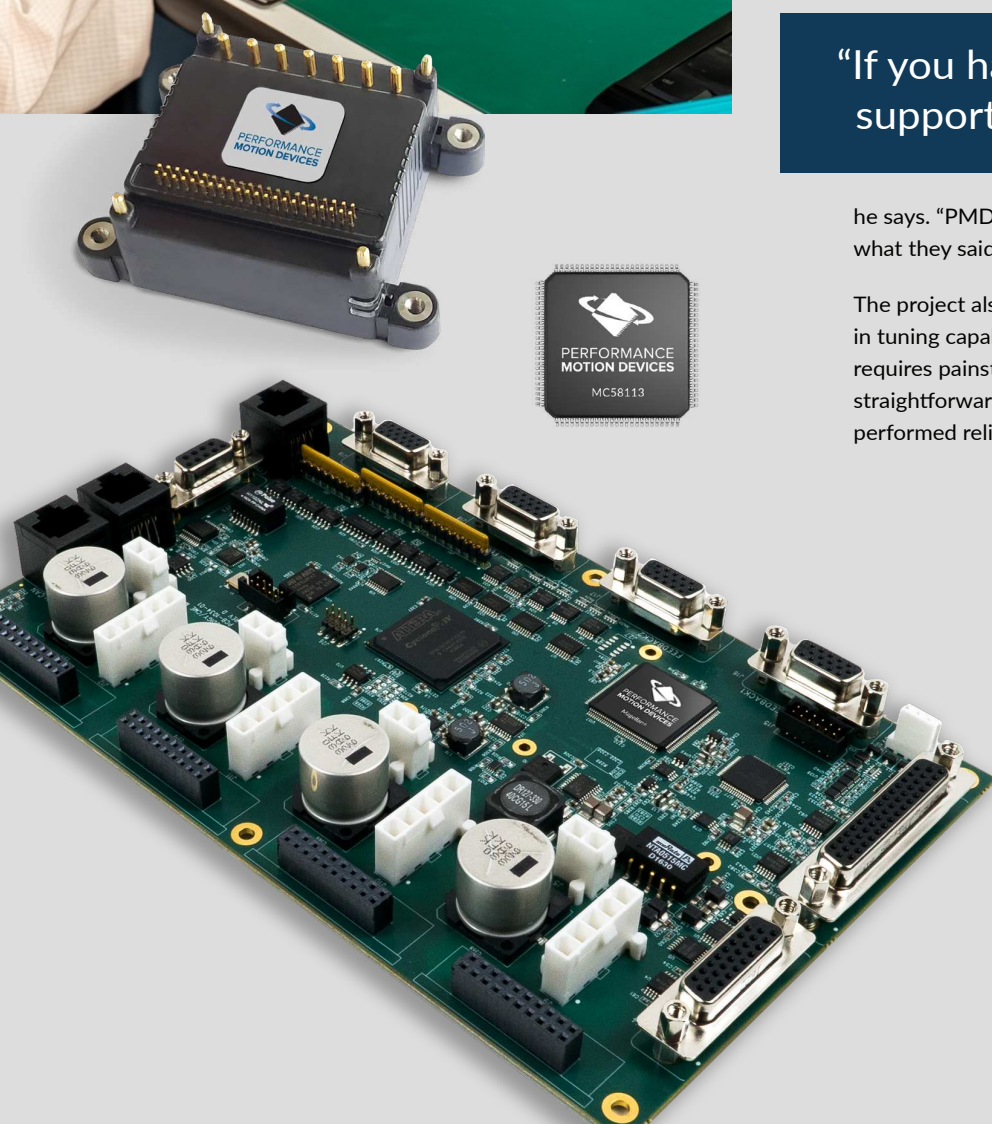
OLogic selected PMD's Juno IC for its advanced velocity and torque control at a cost-effective price. But when early testing revealed that CAN bus message limitations threatened performance, OLogic turned to PMD for help. Within two days, PMD engineers delivered a firmware update that streamlined message payloads, enabling the robot to achieve its performance target.

Not only was PMD's Juno chip easy to use and easy to control, Larson says, PMD goes the extra mile to make sure the project is a success.

"If you have a problem, PMD will support you and back it up,"

he says. "PMD as a company was awesome. They did exactly what they said they were going to do."

The project also demonstrated the advantage of PMD's built-in tuning capabilities. Traditionally, fine-tuning motor control requires painstaking adjustments. PMD's tools made the process straightforward, allowing OLogic to deliver a first revision that performed reliably under demanding conditions.



A Trusted Partner in Robotics Innovation

OLogic's ongoing collaboration with PMD reflects a relationship that goes beyond supplier and customer. PMD provides the motion control foundation for OLogic's designs, while also acting as an extension of its engineering team when challenges arise.

By partnering with PMD, OLogic helps its customers cross the gap from prototype to production — faster, more reliably, and with the confidence that their robots are built on commercial-grade motion control.

Deep motion control expertise honed over 30 years.

Product portfolio with a migration path: drives to boards to ICs.

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