



Analog Devices: Trinamics – Ideal control for solenoids to motors.

BP&M / ADI – Juliano K. Cioffi (FAE)

WE Tour 2026

analog.com

Trinamics - Agenda

- Trinamics Overview
 - History and Concept
 - Wide view Portfolio
- Motor control solutions (HW)
 - Advantages and unique features
 - Ecosystem Picture
 - Highlighted Part Numbers
- Solenoid and contactors control solutions (HW)
 - Advantages and unique features
 - BDC control feature
 - Highlighted Part Numbers
- Software Platform
 - SW tool overview (MAX22216)
 - SW tool overview (BLDC)
 - Useful links

Trinamics Overview

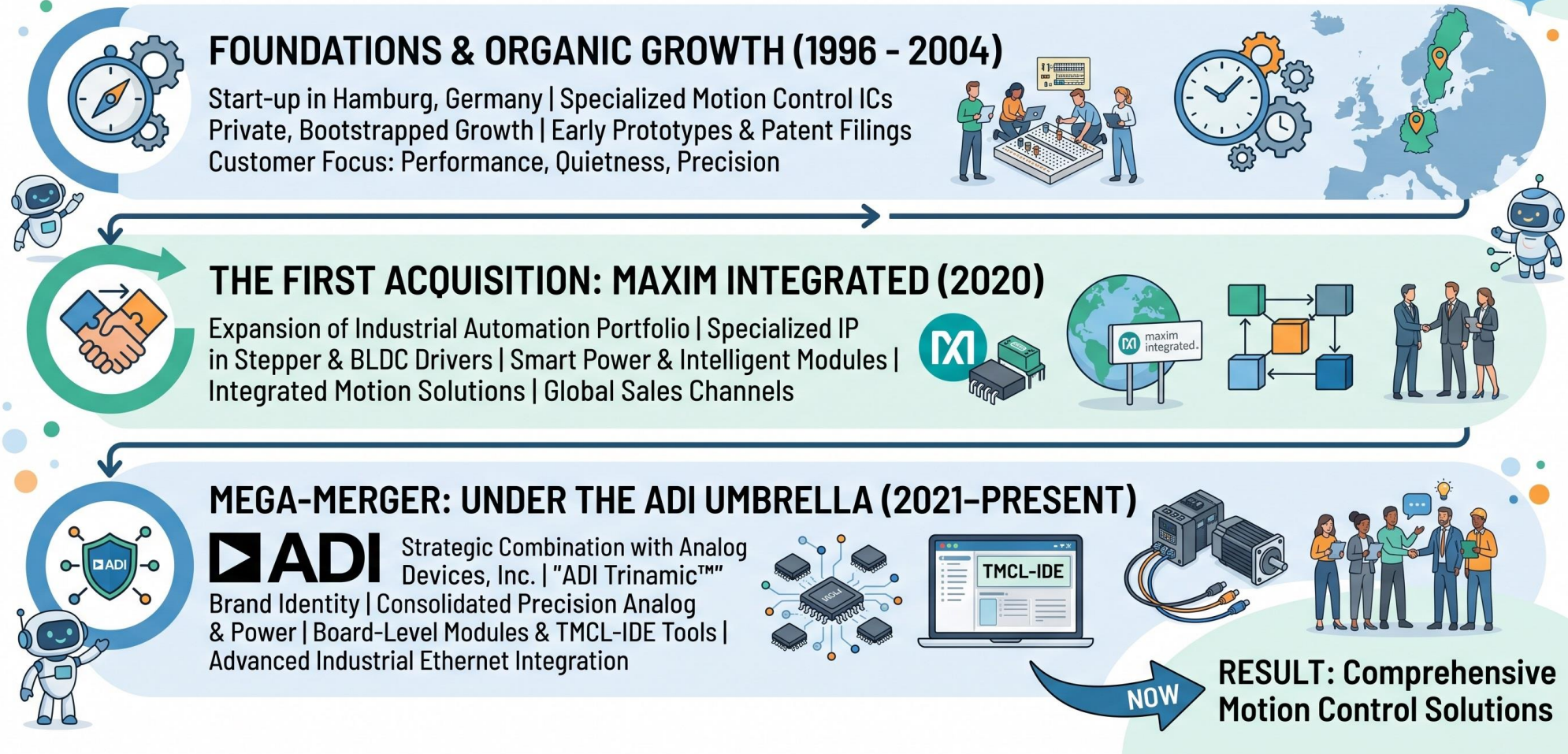
Trinamics Overview – History and Concept

1101000011100010101001
0011101000011100010101
0100100100011101000011
0101000100100100100011



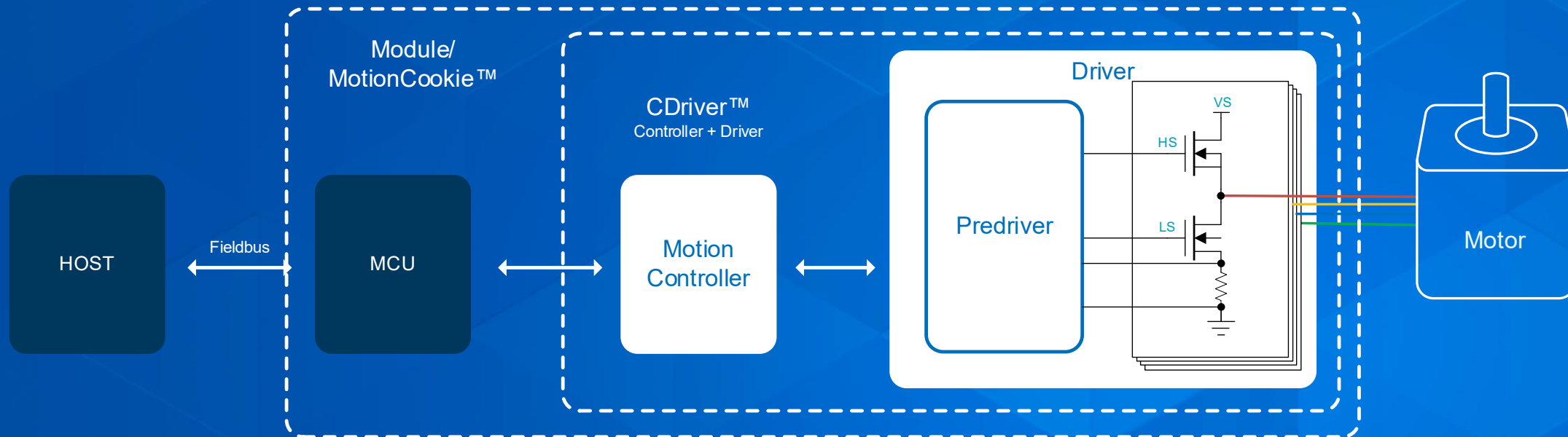
We Transform
Digital Information
Into **Physical Motion.**

ADI TRINAMIC™ PRODUCT PORTFOLIO: A FOCUSED HISTORY



Trinamics Overview – History and Concept

- How does a typical System look like?



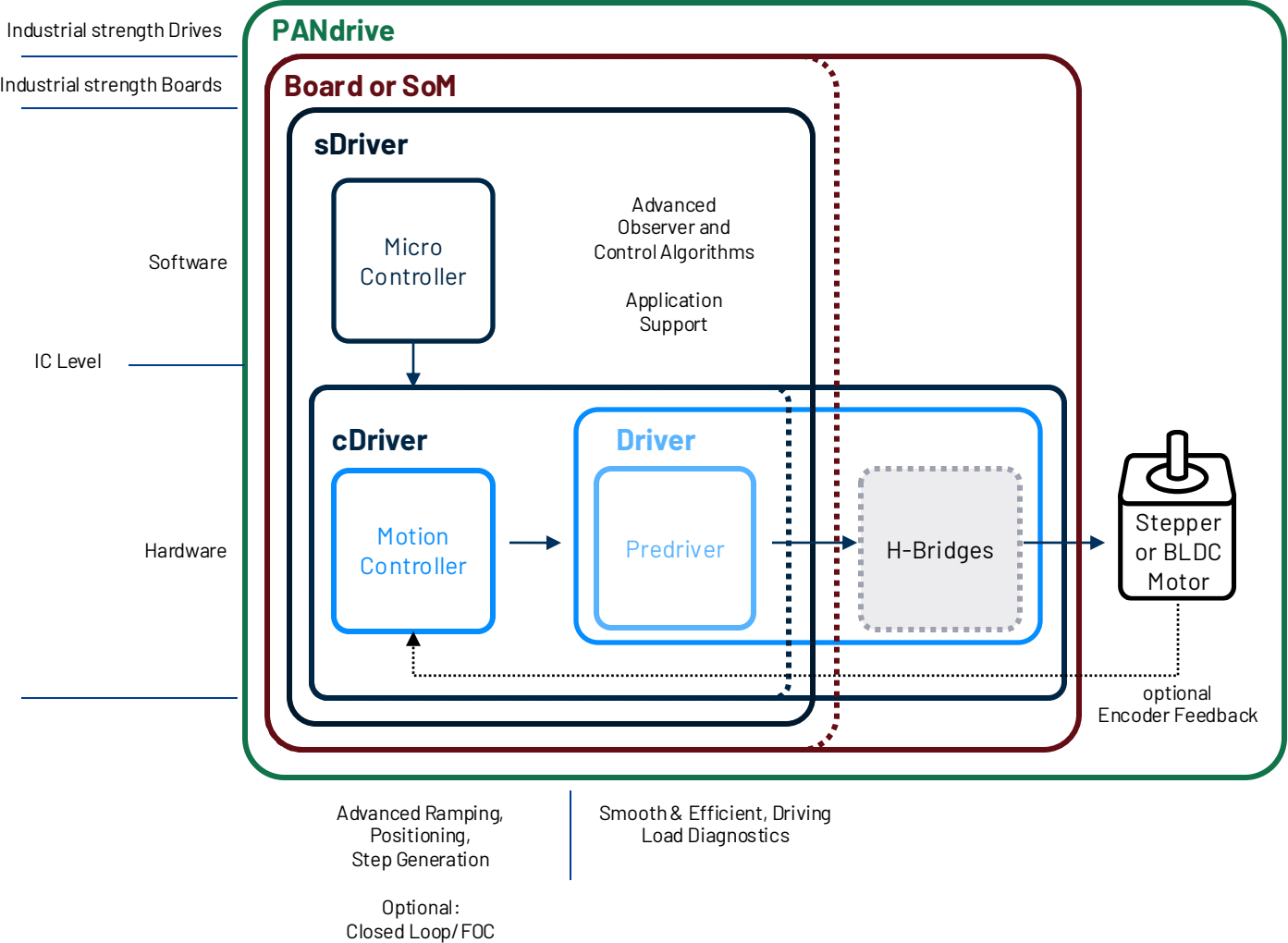
- Motor Types: Stepper, BLDC, Brushed DC
- Motor Sizes: mW ... 1kW / 0.1A ... 100A
- Voltage Range: 1.8...80V



Trinamics Overview – History and Concept



Solution	Description
PANdrive	Ready to go smart motor with ADI Trinamic motor driver & controller solutions, advanced software algorithms and industrial bus stacks, e.g. CANopen, CoE, TMCL for smallest time-to-market.
Board	Ready to go ADI Trinamic board-level single or multi-axes product with ready to go ADI Trinamic motor driver & controller solutions, advanced software algorithms and industrial bus stacks, e.g. CANopen, CoE, TMCL for smallest time-to-market.
SoM	System On a Module with ready to go ADI Trinamic motor driver & controller solutions, advanced software algorithms and industrial bus stacks, e.g. CANopen, CoE, TMCL for smallest time-to-market.
sDriver	Dedicated IC that integrates ADI Trinamic motor driver and controller hardware IP building blocks and a microcontroller for software algorithm and application support.
cDriver	Dedicated single IC that integrates ADI Trinamic motion control and driver hardware IP for smooth, reliable, efficient and fast positioning, ramping, as well as closed loop/FOC control.
Motion Controller	Dedicated single IC that integrates ADI Trinamic motion control IP to be used with ADI Trinamic or standard drivers, e.g. for positioning, ramp generation, FOC
Driver	Dedicated single IC that integrates ADI Trinamic driver IP and H-bridges for smoothest and most efficient motor control.
Pre-Driver	Dedicated single IC that integrates ADI Trinamic driver IP, with or without current controller and sequencer for smoothest and most efficient motor control to use with external MOSFETS.



Trinamics Overview – History and Concept

- Product Families – 3 Levels of Integration

Solution proposition, up the stack ↑

PANdrive™



ASP

\$125 to \$600

1 – 1k+ pcs/Project

Boards

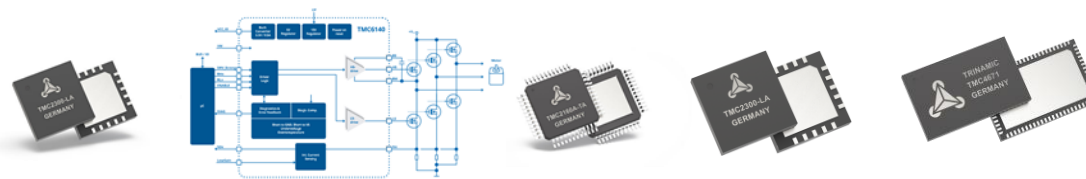


ASP

\$50 to \$400

1 – 5k+ pcs/Project

ICs



ASP

\$1 to \$10

10k – 1M+
pcs/Project

Trinamics Overview – History and Concept

- TMCL-IDE

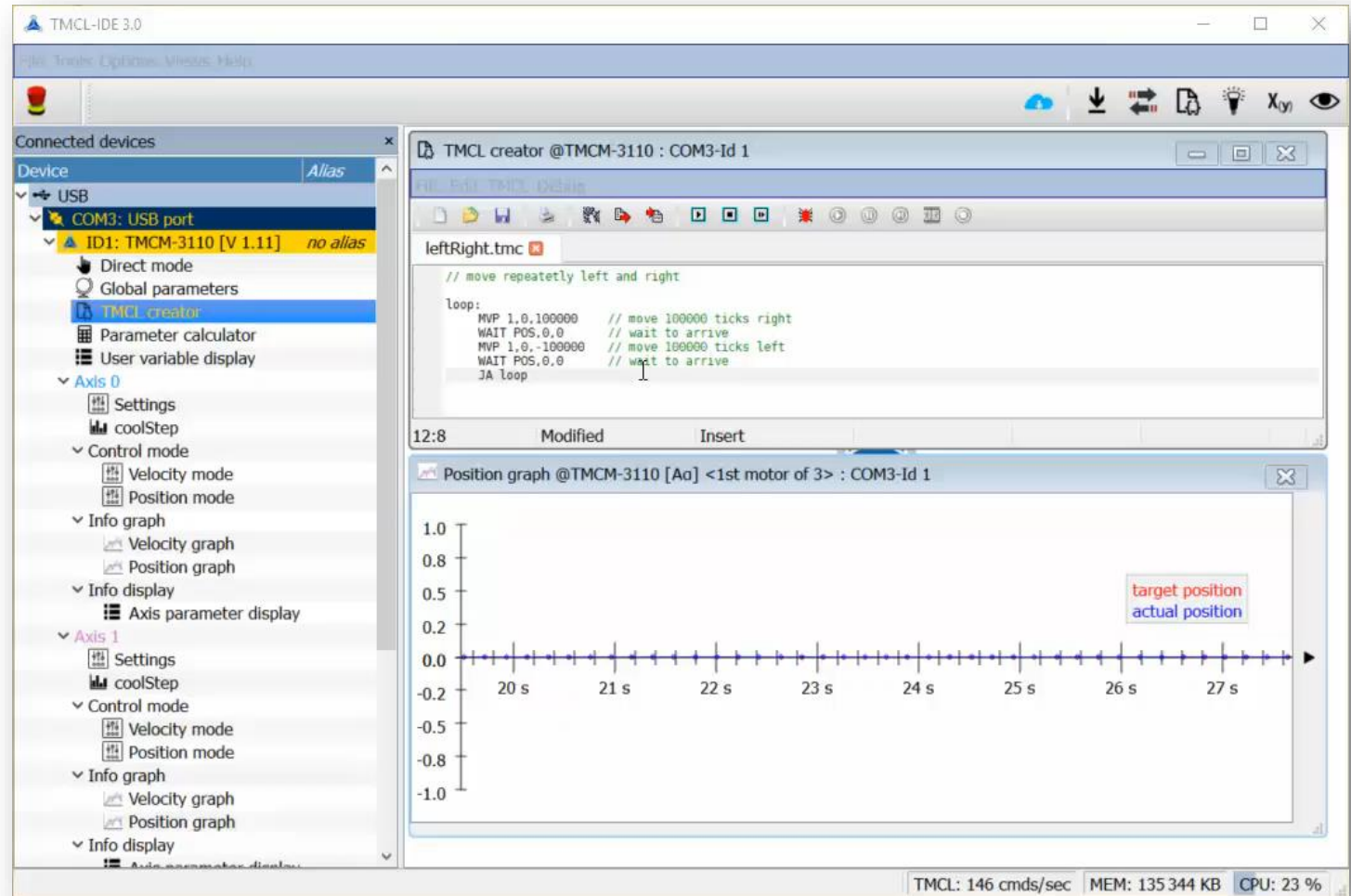
Connect & get Started

Parametrize & Program

Analyze & Debug

Intuitive

It's free to download & use!

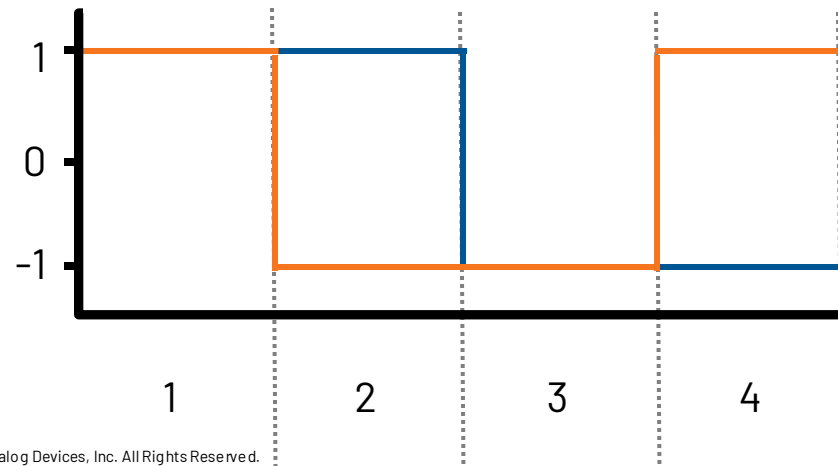
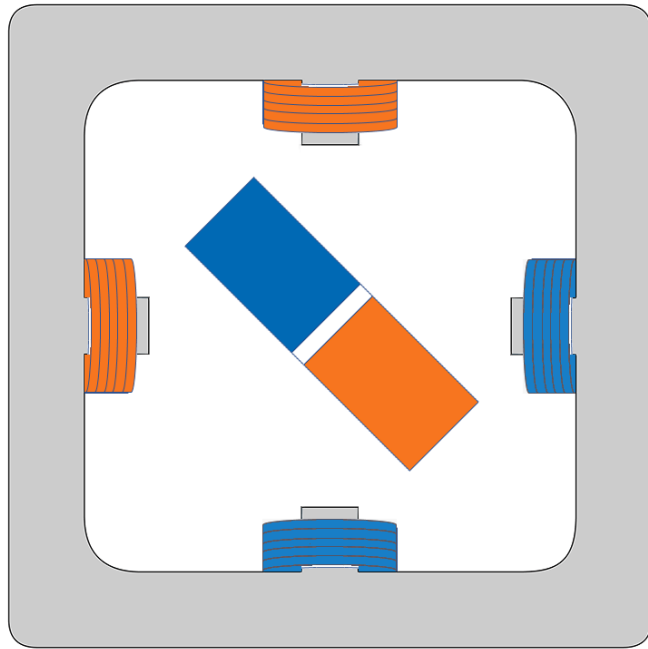


Motor Control solutions (HW)

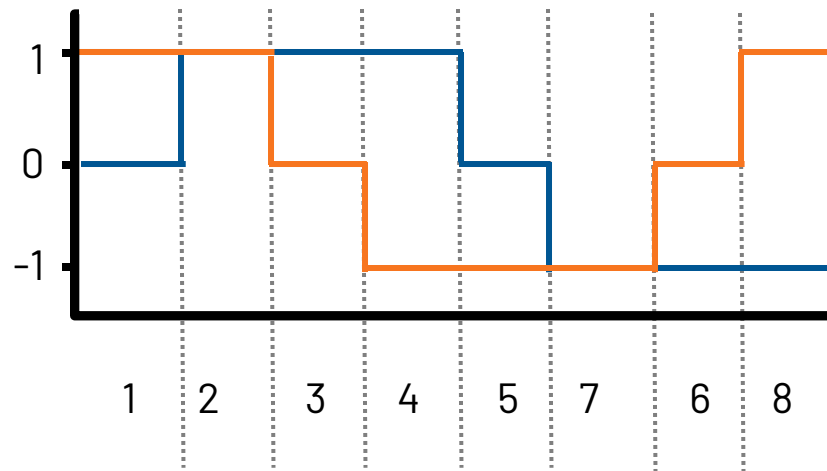
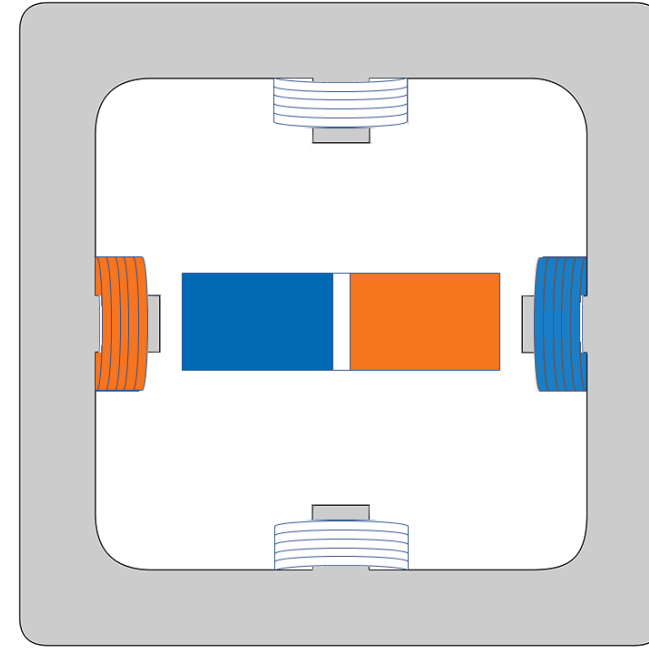
Seamless Movement

- Microstepping

Fullstep

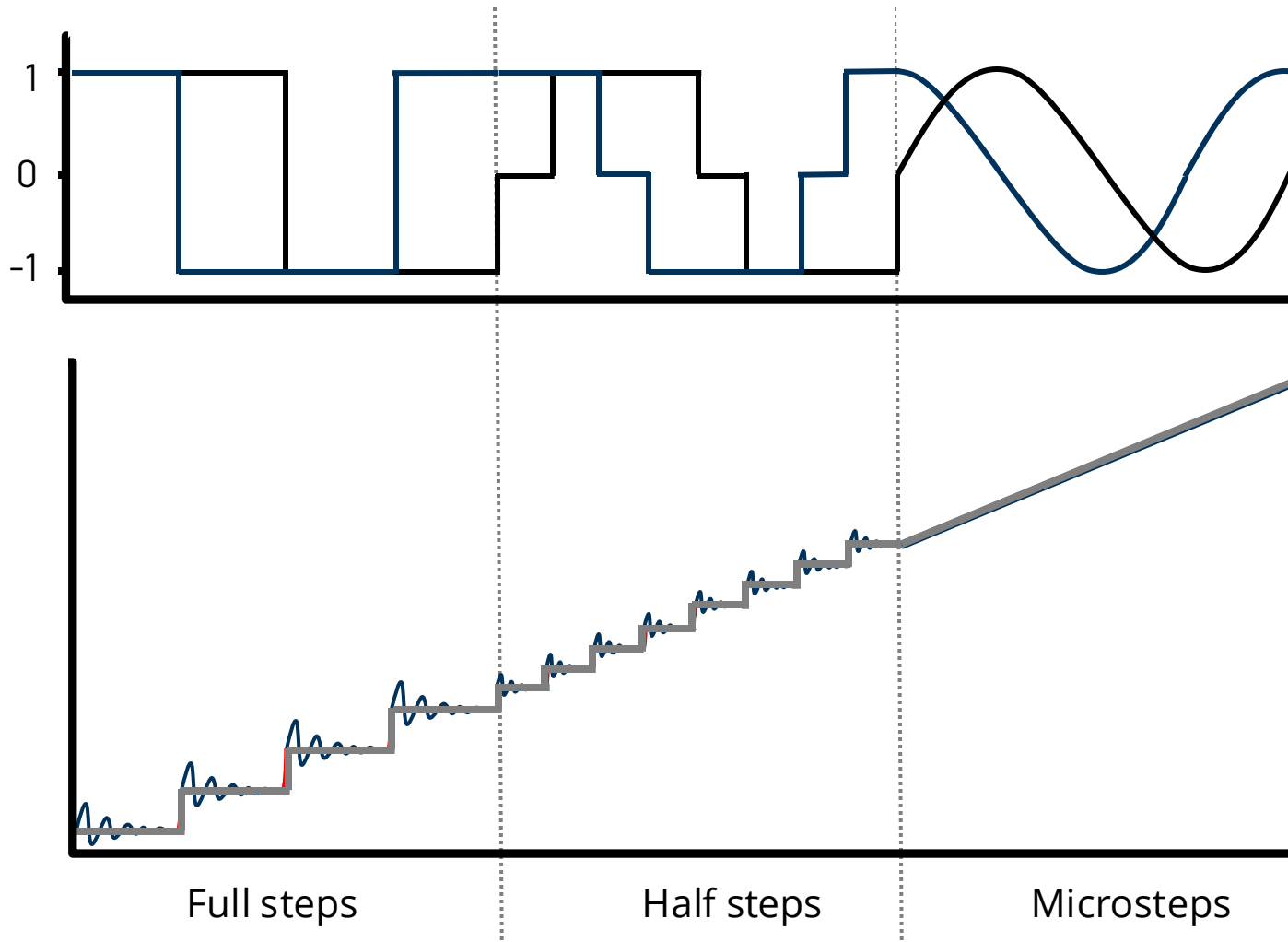


Halfstep



Seamless Movement

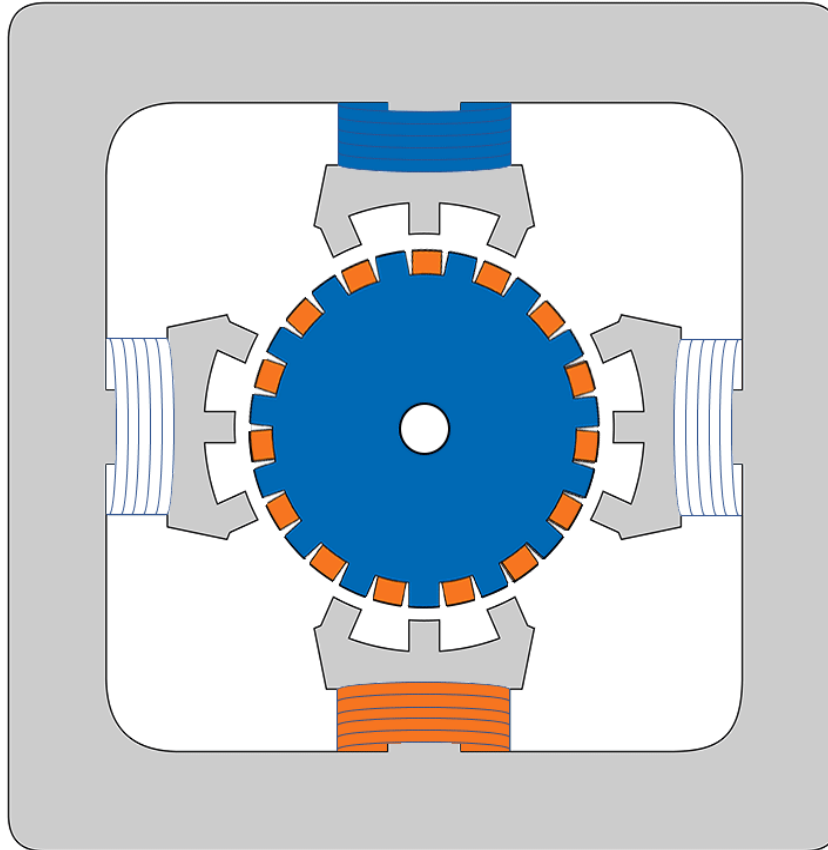
- Microstepping



A Motion Controller generates pulses to move the motor forward.

256 times micro-stepping enables a sinusoidal current wave form.

Trinamic Motion Controllers can take care of the step pulse generation as well as advanced ramping of the step frequency.



Hybrid Stepper Motor

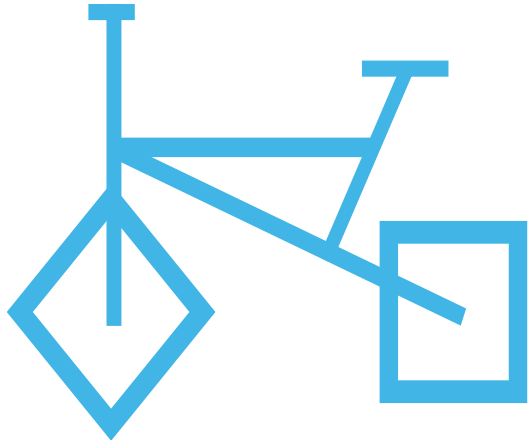
MicroPlyer™ adds equidistant steps between micro steps to interpolate to 256 micro steps on the motor.

MicroPlyer™ reduces required processing power for smooth motion.

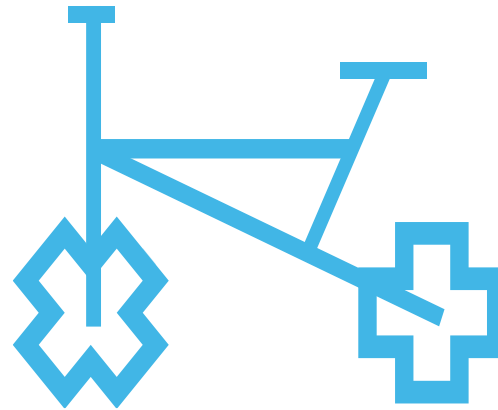
MicroPlyer™ works seamlessly. There are no software adaptations required

Microstepping

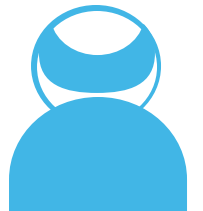
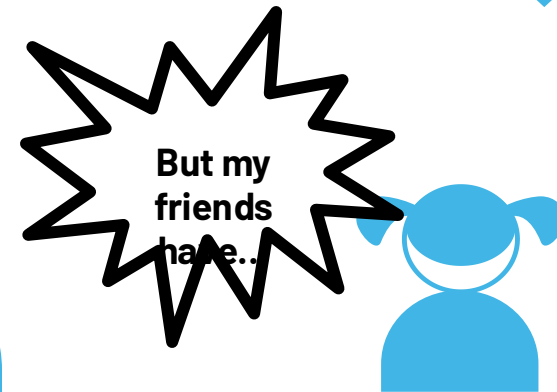
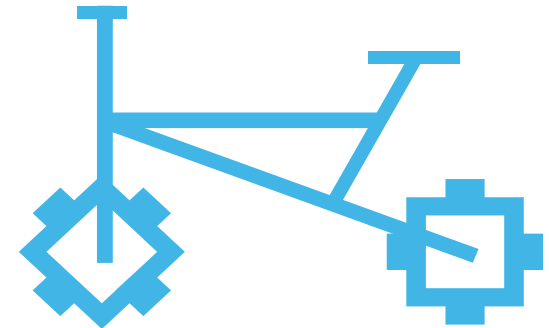
Fullstep



Halfstep

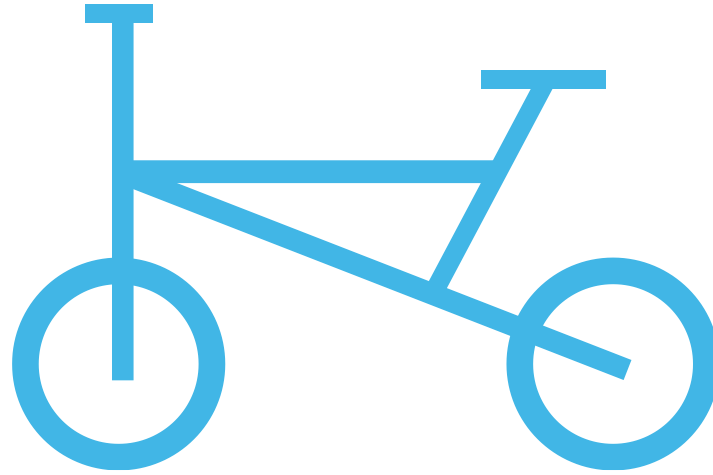


Quarterstep



Microstepping

256 Microstep

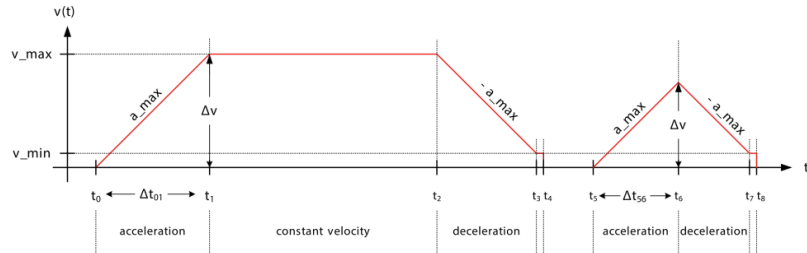


Micro-stepping adds equidistant steps between each native full step of a stepper motor.

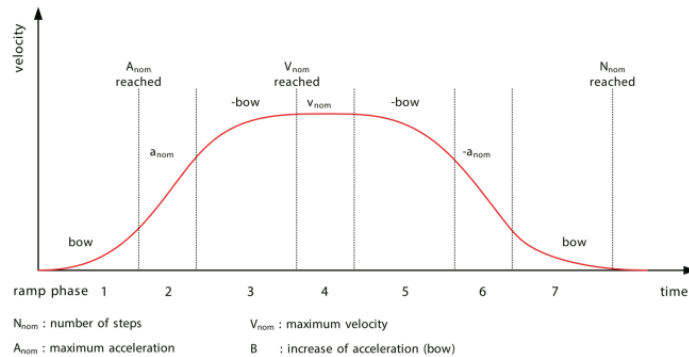
This enables a way smoother motor run and higher torque output at low speed.



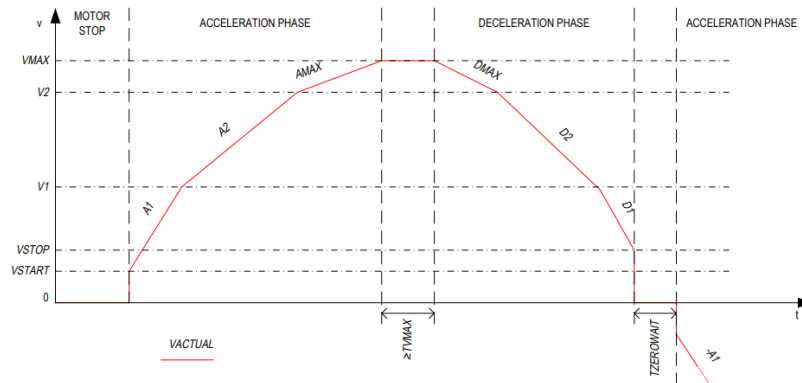
Advanced Ramping



► 1st generation Motion Controller – TMC429 / TMC4210



► 2nd generation motion controller – TMC457 / TMC4361



- 3rd gen. motion controller – multi point
- TMC5240, TMC5130 ... all cDrivers

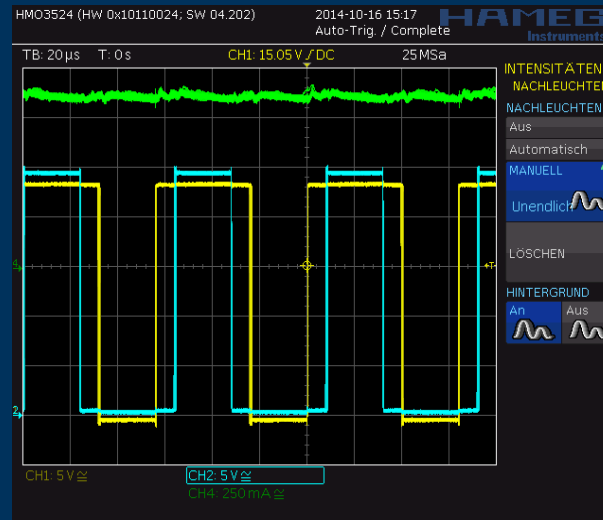
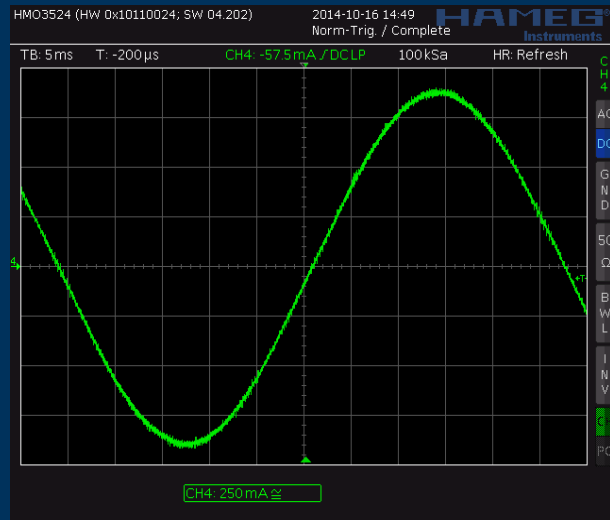


Advantages:

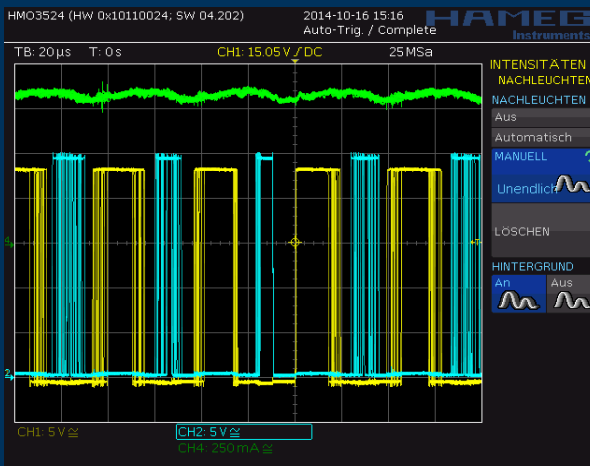
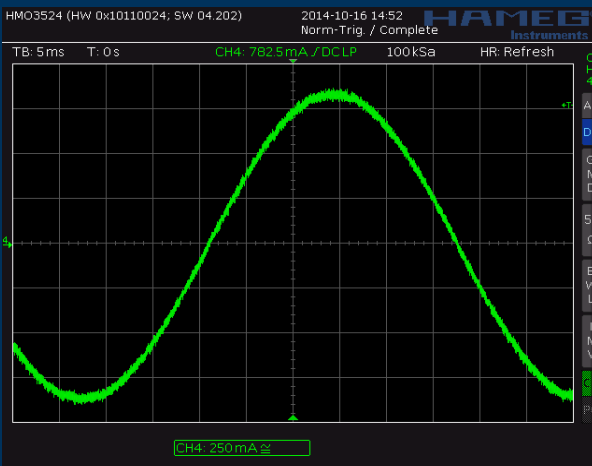
- Proven Hardware Blocks
- Offloading the Processor
- Parameter Change on the Fly
- Reference Switch input (Hard- /Soft-Stop)

Current Control

- Current Controller – SpreadCycle™ vs. StealthChop™
 - StealthChop™ = Silent, smooth motion at lower/medium speeds.
 - SpreadCycle™ = High torque, dynamic responsiveness, and fast acceleration at higher speeds.



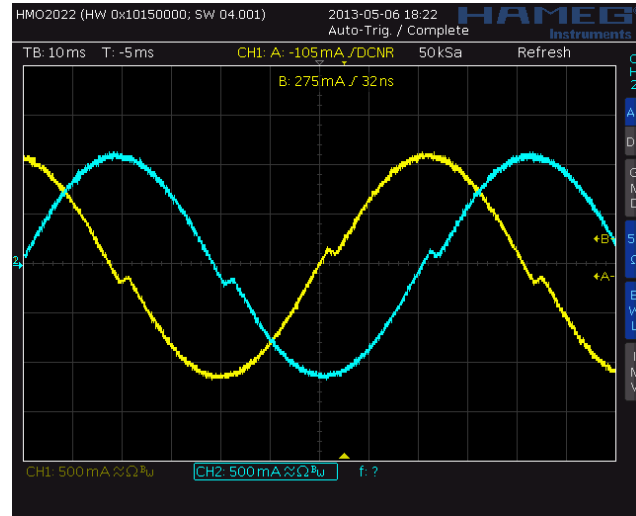
StealthChop™



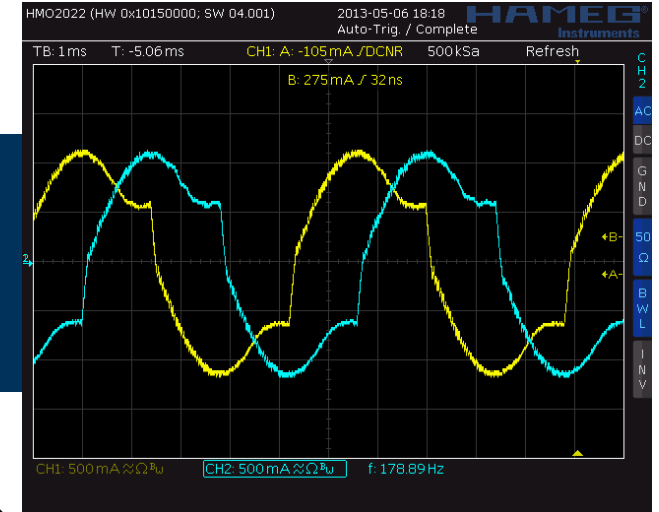
SpreadCycle

Current Control

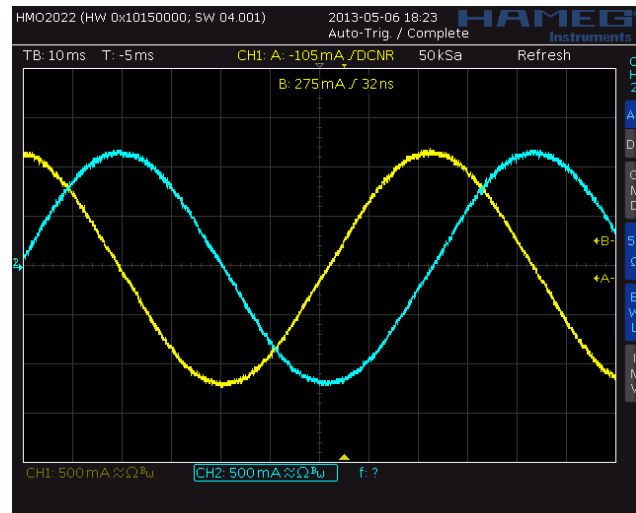
- Current Controller – SpreadCycle™ vs. StealthChop™
 - StealthChop™ = Silent, smooth motion at lower/medium speeds.
 - SpreadCycle™ = High torque, dynamic responsiveness, and fast acceleration at higher speeds.



← Low Speed

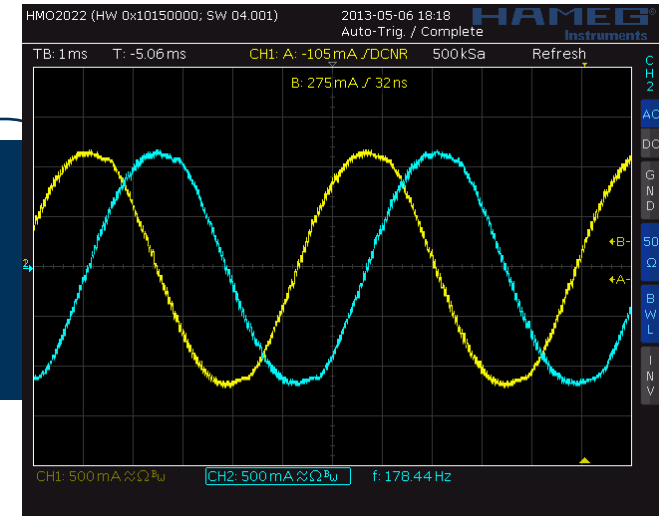


High Speed →



TRINAMIC SpreadCycle™

Sinusoidal current waveform enables maximum torque and smooth motor run



Referencing

- Real World Position
 - ▶ After the system is powered off, there is no information of the motor position.
 - ▶ The motor position might be manipulated.
 - ▶ The absolute maximum travel distance might differ due to mechanical tolerances.

Trinamic offers StallGuard
for sensor-free load
detection.

**Reference search algorithms aligns motor step
positions to real world positions.**

Using StallGuard...

...for sensorless homing

Instead of using limit switches, the mechanical hard stops can be used.

By adjusting the StallGuard values, it only kicks in when the normal load is exceeded.

If the load angle value is exceeded, the system knows it reached the end of the axis.



Bonus

Unexpected hard stops will make the system stop as well, adding a level of security.

Using CoolStep...



...for cooler motors

Originally designed for medical and lab automation, CoolStep keeps the motor cool using only the minimum current needed.

This safeguards sensitive tissue samples leading to more reliable test results.

Running the motor at a lower temperature allows for temporary boosts.

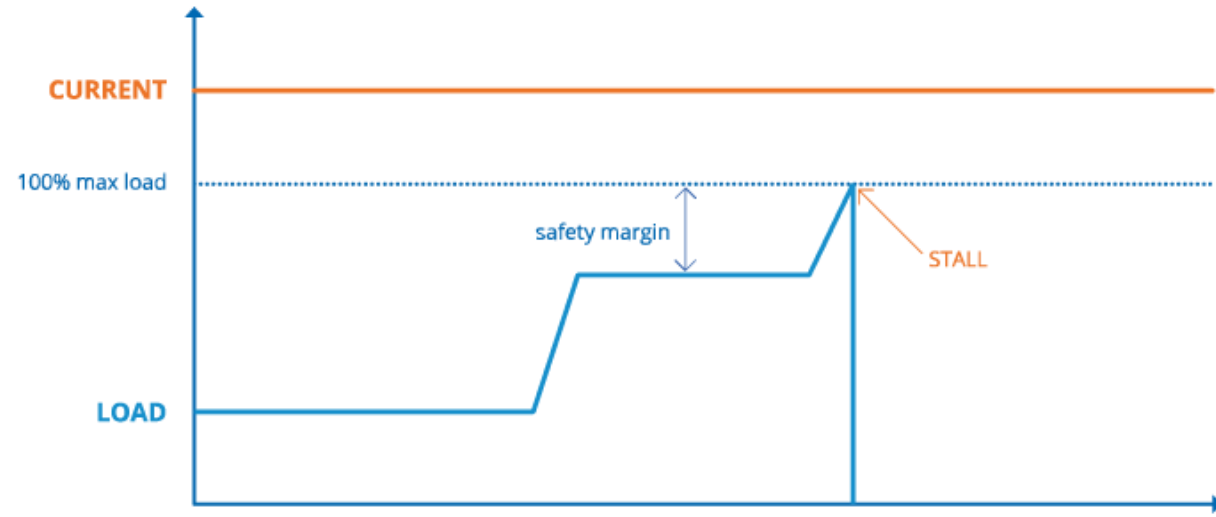


Bonus

It also saves up to 75% energy.

Enables smaller motors.

StallGuard & CoolStep



StallGuard™

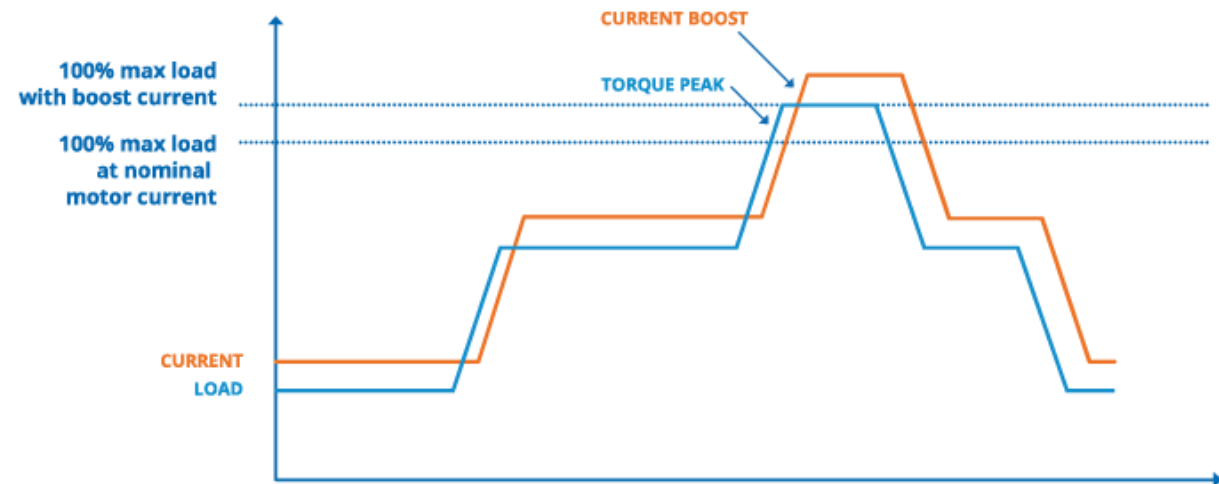
Sensorless Load Angle Detection

- Blocking Detection
- Referencing
- System Check

CoolStep™

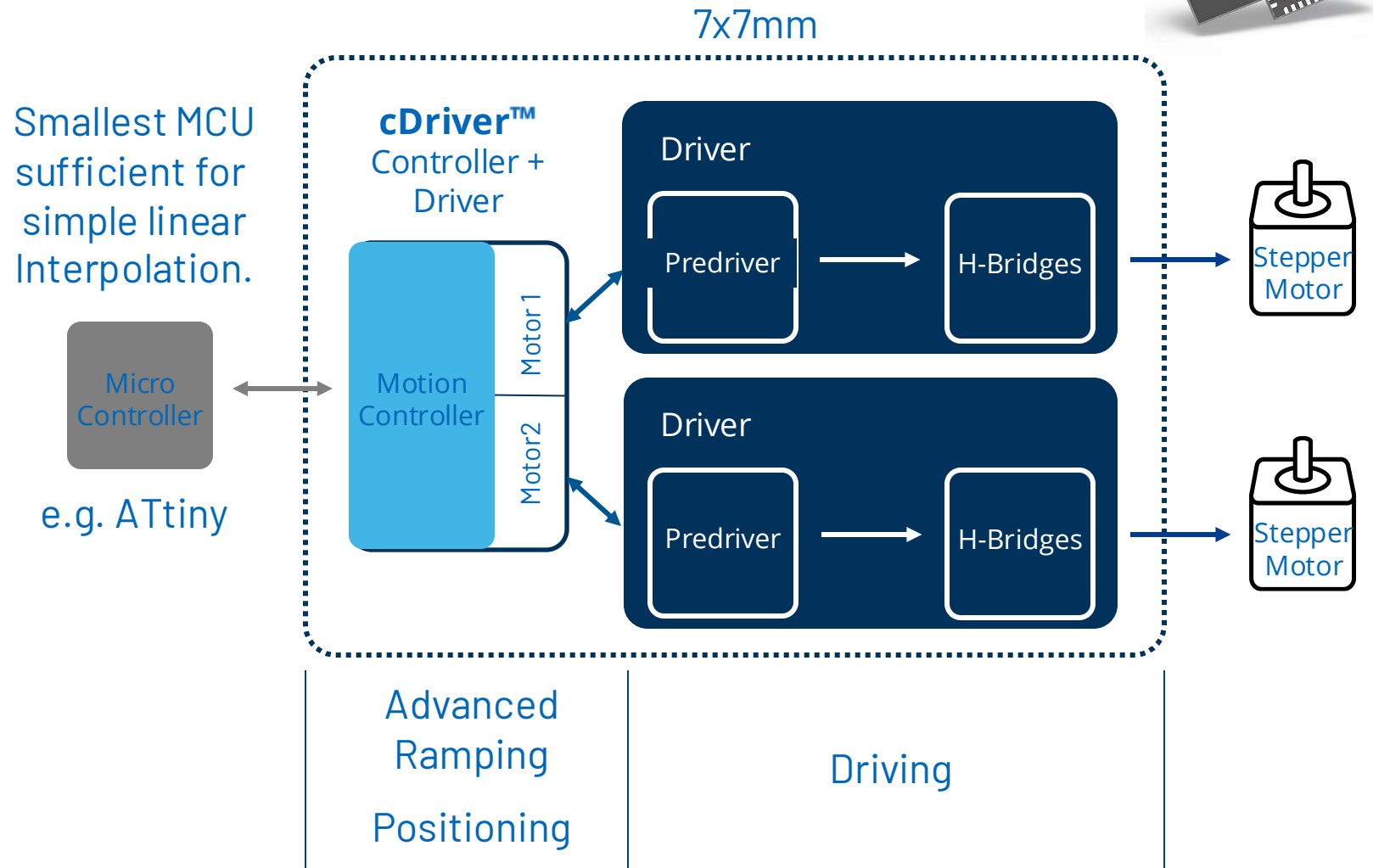
Load dependent Current Control

Saves up to 75% Energy



Development Time

- Solutions in Silicon



Why?

Reduce time to market through integrated Motion Controller

Reduce size & part count

Meet expected quality on motor and motion control



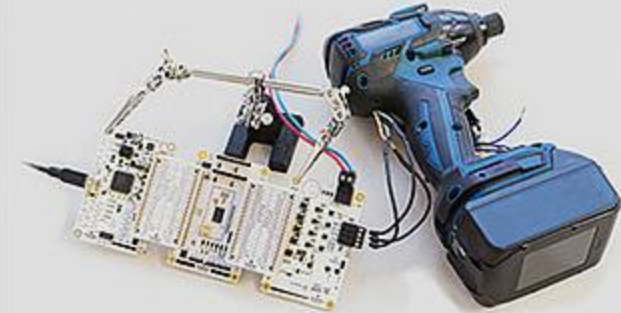
Start with the Landungsbrücke

Depending on your Evaluation Kit, the Landungsbrücke or Startrampe interface board forms the bridge between your PC and Trinamic's powerful ICs.



Connect the evaluation board

Connect the preferred eval board with the interface board using the Eselsbrücke connector board. You can even link a few together.



Discover powerful technologies

Explore the full potential of Trinamic's solutions using the free TMCL-IDE software. This allows for easy programming with ready-to-use code libraries.

Driver Eco System

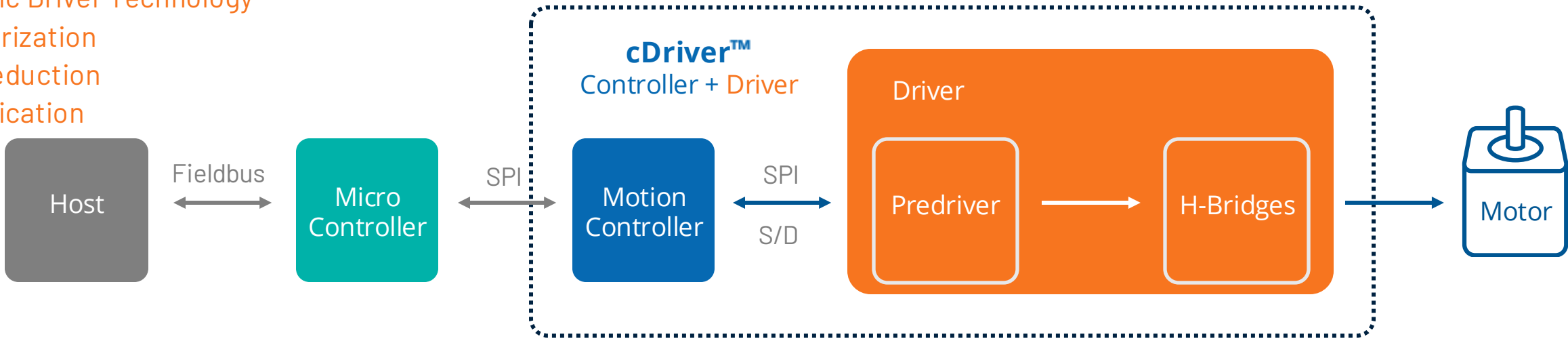


- ▶ **Pumps**
- ▶ **Medical equipment**
- ▶ **POS Printer**
- ▶ **White goods**
- ▶ **3D Printer**

Product	Motor Type	Interface	Product Type	Motor Supply	Phase Current (RMS)	Package
TMC2240	2-Phase Stepper Motor	S/D, SPI	Smart Driver	4,75 – 36 V	2.1A (int I sense)	TQFN32
TMC2130	2-Phase Stepper Motor	S/D, SPI	Smart Driver	4.75 – 46 V	1.4A	eTQFP48
TMC2209	2-Phase Stepper Motor	S/D, SPI / Pin	Smart Driver	4.75 – 29 V	2A	QFN28
TMC2300	2-Phase Stepper Motor	S/D, SPI / Pin	Smart Driver	1.8 – 11 V	1.2A	QFN20
TMC2160	2-Phase Stepper Motor	S/D, SPI / Pin	Smart Gate Driver	8 – 60 V	Ext. MOSFETs	eTQFP48

TMC2209: Stepper Driver IC

- ▶ Trinamic Driver Technology
- ▶ Miniaturization
- ▶ BOM Reduction
- ▶ Simplification



Predriver Eco System

- ▶ Pumps
- ▶ Medical equipment
- ▶ POS Printer
- ▶ White goods
- ▶ 3D Printer



- ▶ **Packing machines**
- ▶ **Small industrial robots**
- ▶ **Semiconductor equipment**
- ▶ **Analyzers (Gas / Liquid)**

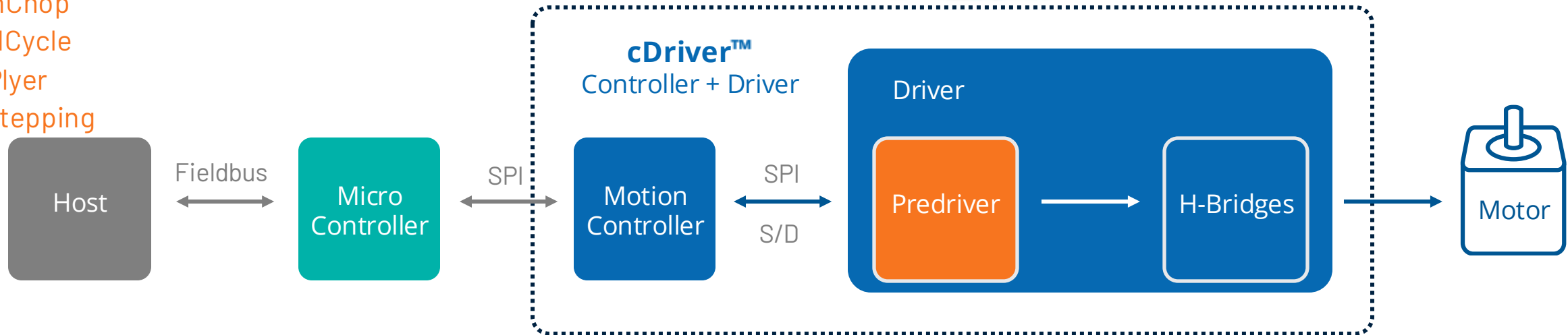


- ▶ Medical equipment
- ▶ CCTV/ conference cameras
- ▶ Textile machinery
- ▶ Dental milling



TMC2160: Predriver IC

- ▶ StallGuard
- ▶ CoolStep
- ▶ StealthChop
- ▶ SpreadCycle
- ▶ MicroPlyer
- ▶ Microstepping



cPredriver Eco System

- ▶ Pumps
- ▶ Medical equipment
- ▶ POS Printer
- ▶ White goods
- ▶ 3D Printer



- ▶ **Packing machines**
- ▶ **Small industrial robots**
- ▶ **Semiconductor equipment**
- ▶ **Analyzers (Gas / Liquid)**

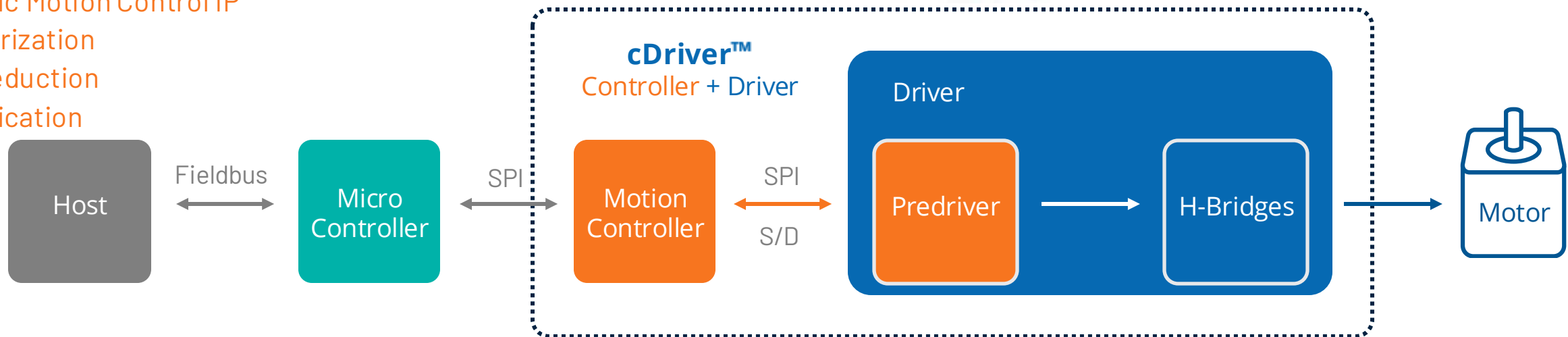


- ▶ Medical equipment
- ▶ CCTV/ conference cameras
- ▶ Textile machinery
- ▶ Dental milling



TMC5160: cPredriver IC

- ▶ Trinamic Driver Technology
- ▶ Trinamic Motion Control IP
- ▶ Miniaturization
- ▶ BOM Reduction
- ▶ Simplification



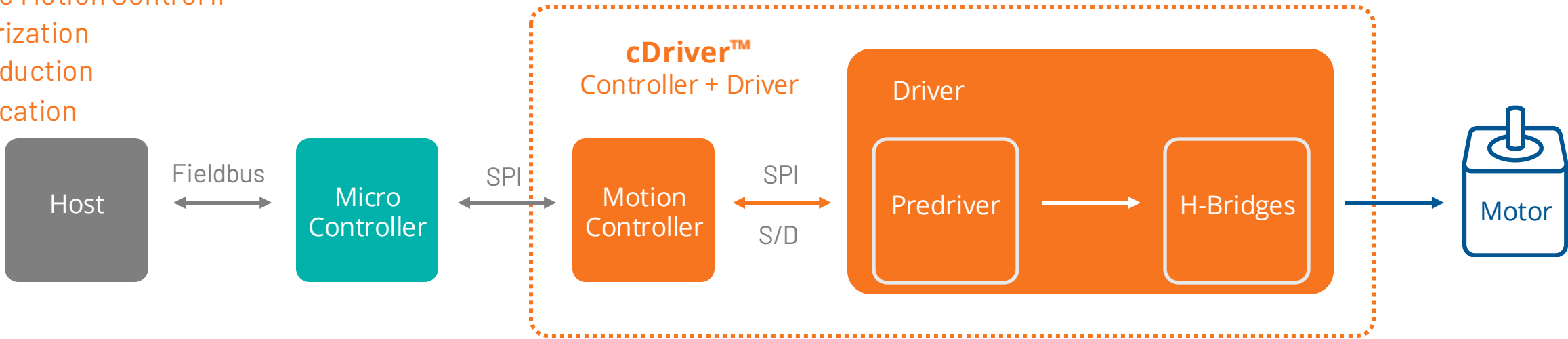
Product	Motor Type / Feature	Product Type	Motor Supply	Phase Current (RMS)	Package
TMC5240	2-Phase Stepper Motor	cDriver™	4,75 – 36 V	2.1 A	TQFN32
TMC5130A	2-Phase Stepper Motor	cDriver™	4.75 – 46 V	1.4 A	eTQFP48
TMC5160	2-Phase Stepper Motor	cDriver™	8 – 60 V	Ext. MOSFETs	eTQFP48 / QFN56
TMC4361	S-Shaped Ramping / Closed loop	Motion Controller	digital	-	QFN40

- ▶ Medical equipment
- ▶ CCTV/ conference camera
- ▶ Textile machinery
- ▶ Dental milling



TMC5130: cDriver IC

- ▶ Trinamic Driver Technology
- ▶ Trinamic Motion Control IP
- ▶ Miniaturization
- ▶ BOM Reduction
- ▶ Simplification



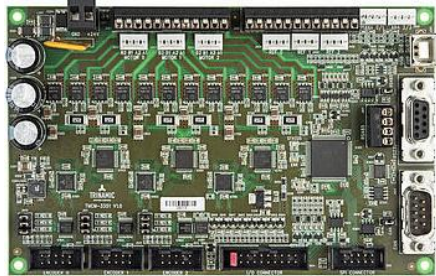
Board Level Turnkey Solutions



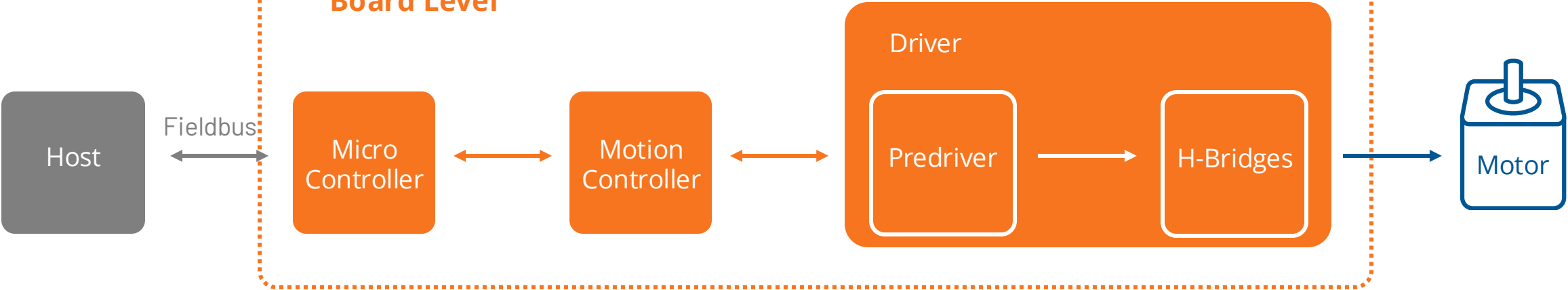
Product	Motor Type	Product Type	Motor Supply	Phase Current (RMS)	Size	Interface
TMCM-1260	2-Phase Stepper Motor	Single Axis Open Loop	12 – 48V	6A	60mm x 60mm 2.36" x 2.36"	CAN, RS485, USB, GPIO, Encoder
TMCM-3351	2-Phase Stepper Motor	3 Axis S-Ramps Closed loop	12V – 24V max 28V	3A	160mm x 100mm 6.2" x 3.9"	CAN, RS485, RS232, USB, GPIO, Encoder
TMCM-1640	3-Phase BLDC / EC	Single Axis Board	12V – 24V	5A	42mm x 42mm 1.7" x 1.7"	RS485, USB, HALL, Encoder
TMCM-1636	3-Phase BLDC / EC	Single Axis Board	12V – 24V 12V – 60V	30A 20A	45mm x 90mm 1.8" x 3.5"	CAN, HALL, ENCODER

Why Boardlevel?

- ▶ Short Time to Market
- ▶ Hardware Design Resources / Expertise
 - ▶ Same for Firmware
- ▶ Small / Medium Demand



Board Level



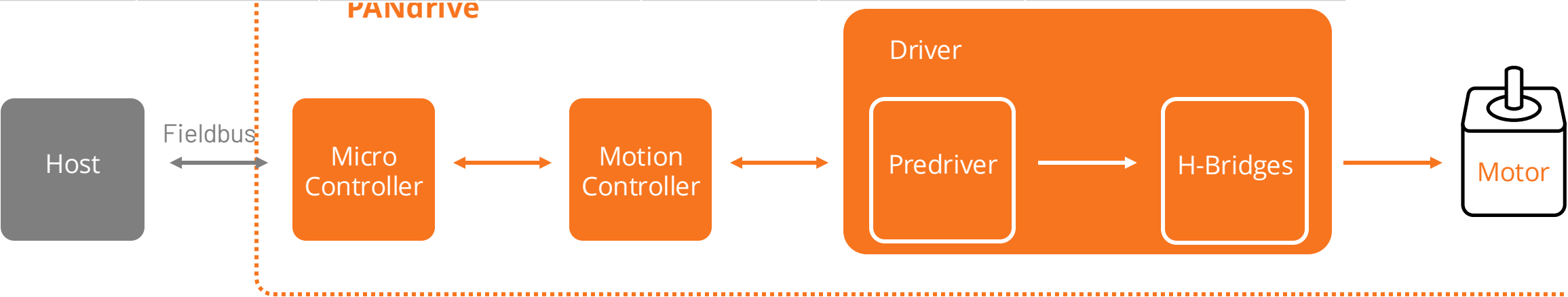
Smart Motor Turnkey Solutions



Product	Motor Type	Product Type	Motor Supply	Phase Current (RMS)	Size	Interface
TMCM-1260	2-Phase Stepper Motor	Single Axis Open Loop	12 – 48V	6A	60mm x 60mm 2.36" x 2.36"	CAN, RS485, USB, GPIO, Encoder
TMCM-3351	2-Phase Stepper Motor	3 Axis S-Ramps Closed loop	12V – 24V max 28V	3A	160mm x 100mm 6.2" x 3.9"	CAN, RS485, RS232, USB, GPIO, Encoder
TMCM-1640	3-Phase BLDC / EC	Single Axis Board	12V – 24V	5A	42mm x 42mm 1.7" x 1.7"	RS485, USB, HALL, Encoder
TMCM-1636	3-Phase BLDC / EC	Single Axis Board	12V – 24V 12V – 60V	30A 20A	45mm x 90mm 1.8" x 3.5"	CAN, HALL, ENCODER

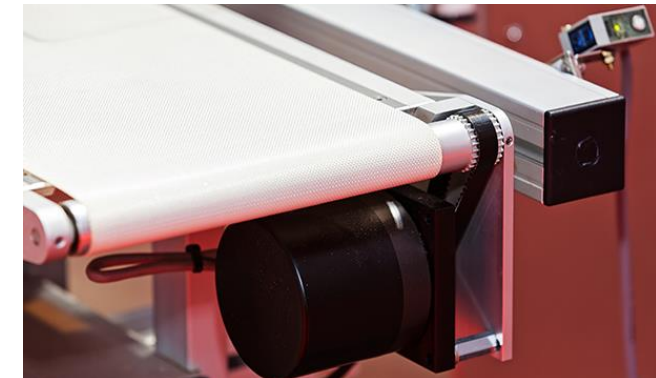
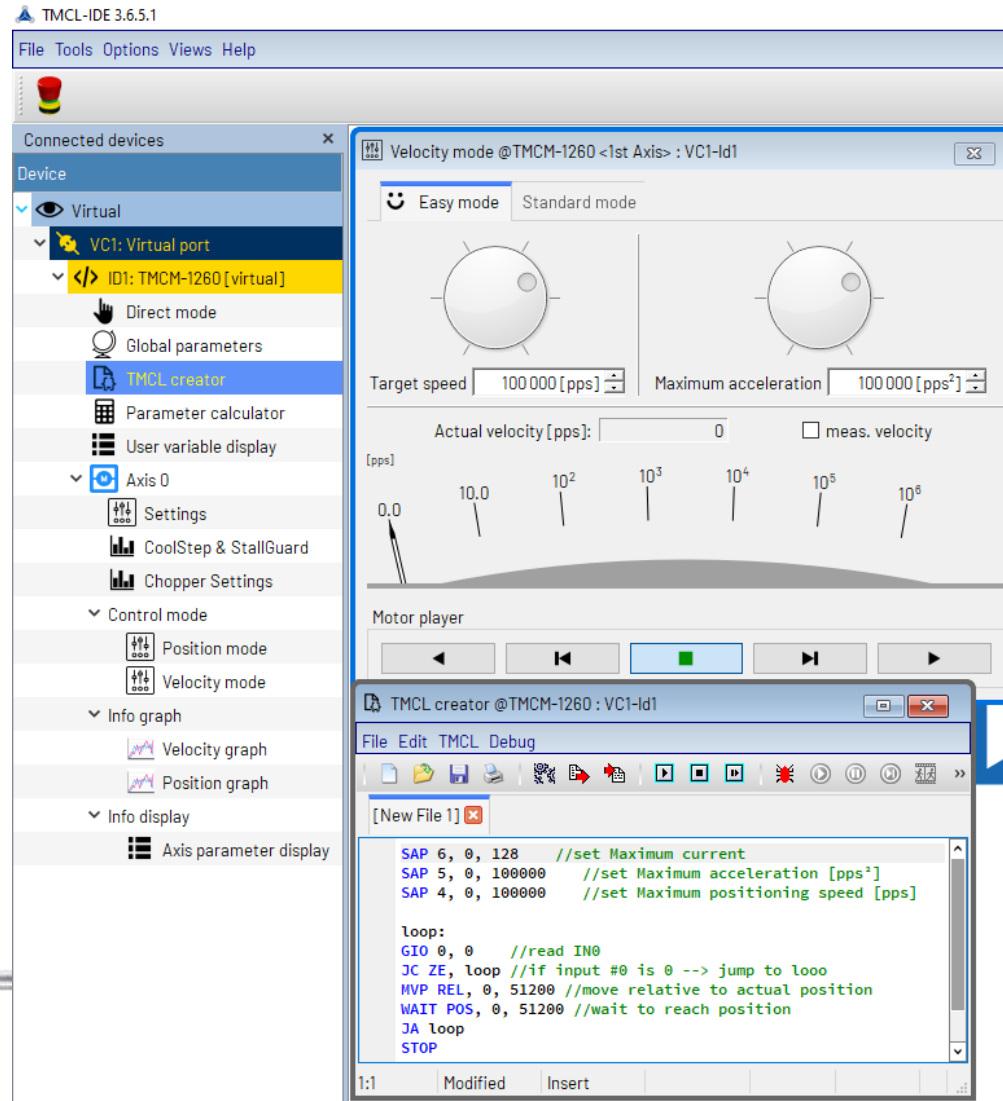
Why PANdrives? (and what is the PAN?)

- ▶ One-Stop Solution
- ▶ Matching Motor + Electronics
- ▶ Short Time to Market
- ▶ Wide Range of Solutions



Smart Motor Turnkey Solutions

- ▶ Fully Integrated Mechatronic
- ▶ SensOstep Encoder
- ▶ Serial interface
- ▶ I/Os
- ▶ Easy to built in
- ▶ NEMA 8 – NEMA 34
- ▶ Stand Alone Mode
- ▶ TMCL Firmware



TMC5271: 20V / 1.6A RMS Stepper Motor Driver and Motion Controller



Features and Specs

Supply voltage: 2.1 to 20V

Motor current: 1.6A RMS

Fully Integrated Lossless Current Sensing

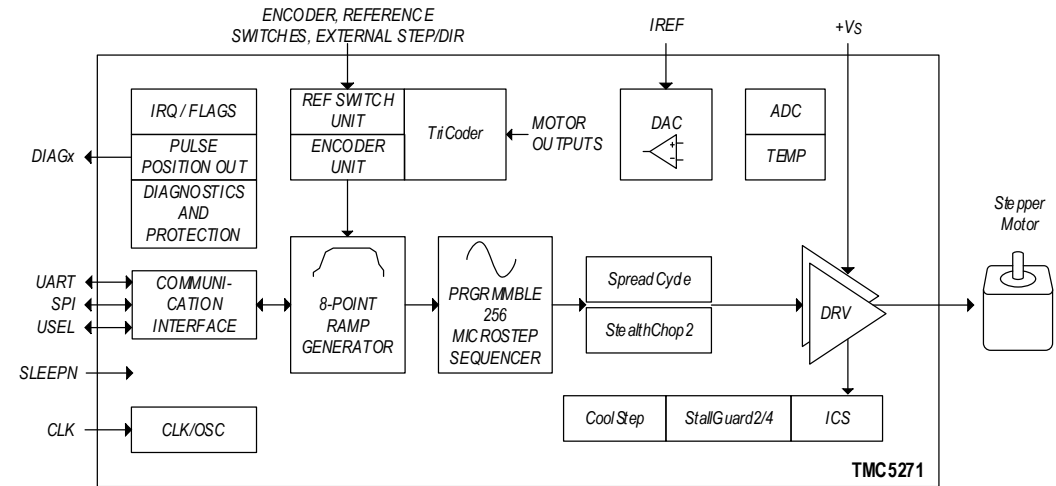
TriCoder Sensorless Standstill Steploss Detection and Full Step Encoder

EightPoint Motion Controller

256 microsteps per fullstep

Smooth and silent stepper motor motion with StealthChop™ and SpreadCycle™

Sensor less load & stall detection with StallGuard2/4™



Competitive Positioning

More efficiency than the competition

- 155 mΩ vs 400 mΩ RDS(on)

Advanced control optimizes power delivery to the motor

Up to 50% PCB space over integrated competition

- 9mm² vs (9mm² + external sense resistors)

Integrated best in class diagnostic functions

TMC5271: 20V / 1.6A RMS

Stepper Motor Driver and Motion Controller



Product Features	Customer Benefit	TMC5271	Comp1	Comp2
Integrated Motion Controller in HW	Offload calculation power from Micro Controller, reduce time to market, easier qualification of end product	Yes	No	No
Integrated Current Sensing	Saves power dissipation and board space	Yes	No	No
RDSON	Saves power dissipation and enables higher continuous motor current.	155mΩ	310mΩ	1000mΩ
TriCorder Standstill Movement Detect	Detect Movement in Standstill without Encoder or Sensory	Yes	No	No
Motor Temperature Estimation	Get an estimation of the motor temperature in standstill	Yes	No	No
StallGuard2&4™	Omits reference switches and allows for continuous monitoring of the load situation.	Yes	No	No
CoolStep™	Helps to save up to 75% power losses in the motor.	Yes	No	No
SpreadCycle™	Enables fastest silent movement	Yes	No	No
StealthChop™	Enables non audible movement at slow speed.	Yes, StealthChop4	Yes, but fixed duty cycle only	No
Package	Saves Board Space	3.2 x 3mm ² WLCSP36	3x3mm ² VFQFPN*	3x3mm ² WQFN*

Wrap Up / Problems we are solving

Pulsation in movement / vibrations High-resolution microstepping	SpreadCycle™
Dynamic load changes / overload and pot. position loss Sensorless load monitoring	StallGuard2/4™
Energy consumption / heat and power dissipation Current control based on sensorless StallGuard™ values	CoolStep™
Audible noise / mechanical resonances Advanced current control	StealthChop™
Jerky motion / position overshoot Advanced multi-segment / jerk-limiting acceleration ramps	EightPoint™



Solenoid and contactors control solutions (HW)

Markets and Applications

Industrial Automation

Hydraulics, Power and Control systems

Valve Manifolds

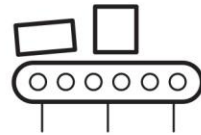
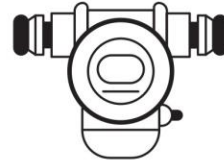
Proportional Valves

Relays / Contactors

DC Motor Drive

Electromechanical Brakes

Heat Pumps



Broad Market

Consumer Products

Vending Machines

Coffee Machines

Electronic Faucet
Smart Door Locks



Healthcare

Medical Equipment

Dialysis Machines

Oxygen Concentrators

Ventilators



Automotive (MAX22216V)

Subsystems

Suspension Systems Valves

Heating Systems

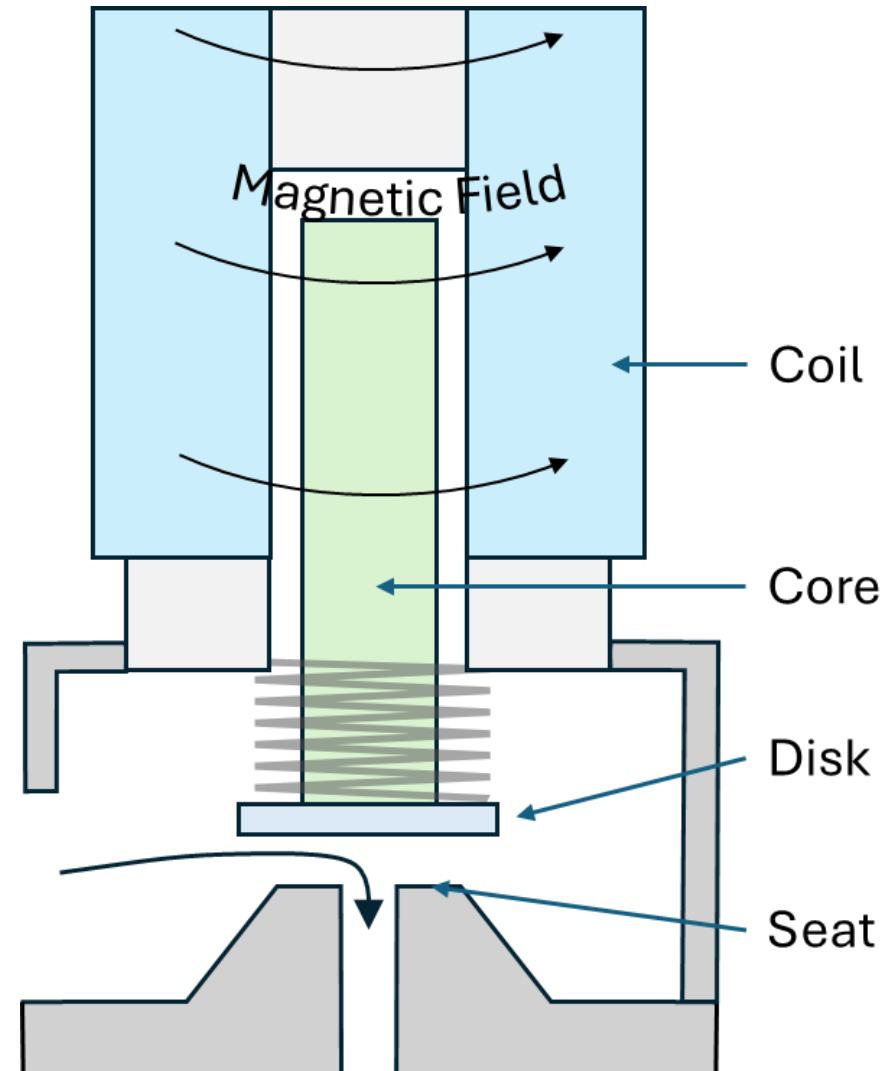
Battery charging

Fuel Pumps



Basic Introduction to Solenoid Actuators

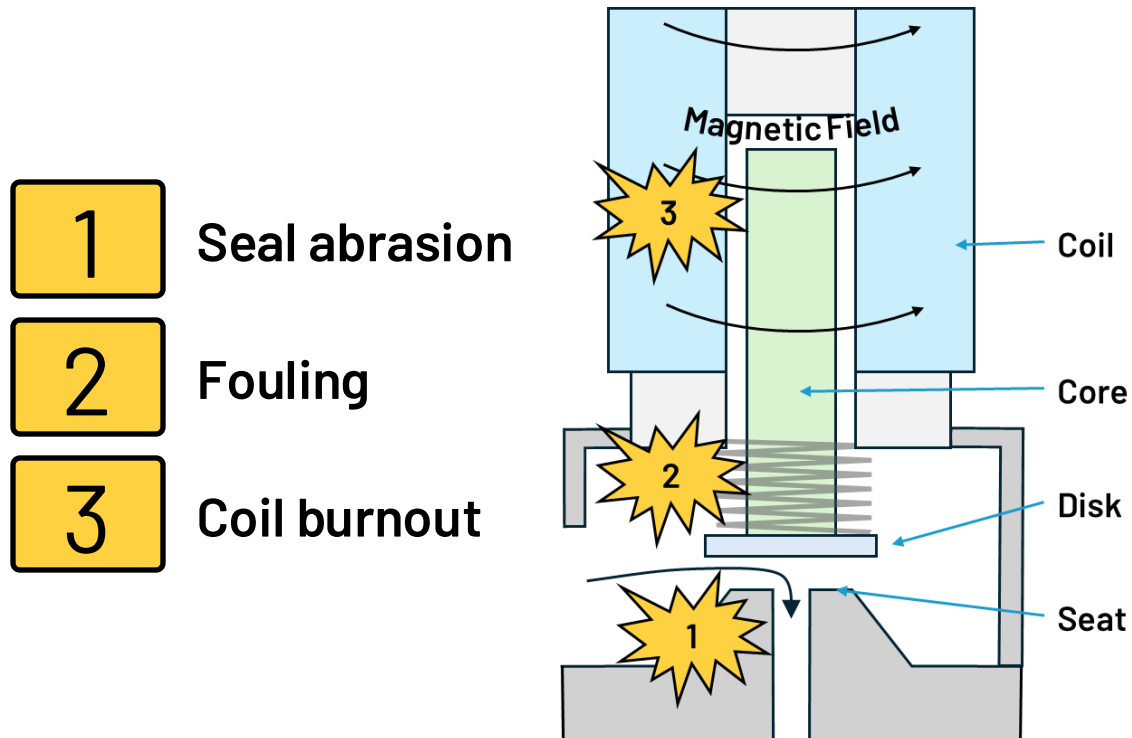
- Solenoids consist of an insulated copper wire wound around a ferromagnetic core
- By applying a voltage, a current flows through the coil, generating a magnetic field:
 - A solenoid actuator's plunger then moves to the other state (OFF/ON)
 - A spring pushes the plunger back to its original position when the voltage is removed
- A lower current is typically sufficient to hold the plunger in the ON position
- The state of the solenoid is unknown without feedback



How Valves Fail

GRADUALLY, AND THEN SUDDENLY

Faults build slowly at first, without detectable signatures. Then the valve crosses the tipping point!

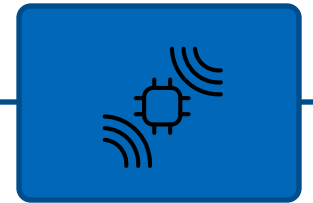


How to Detect Valve Failure

EXTERNAL MONITORING HAS A COST



Periodic manual inspections can be effective but maintaining the paper trail while ensuring quality adds complexity. As the number of valve points increases, so does the challenge.



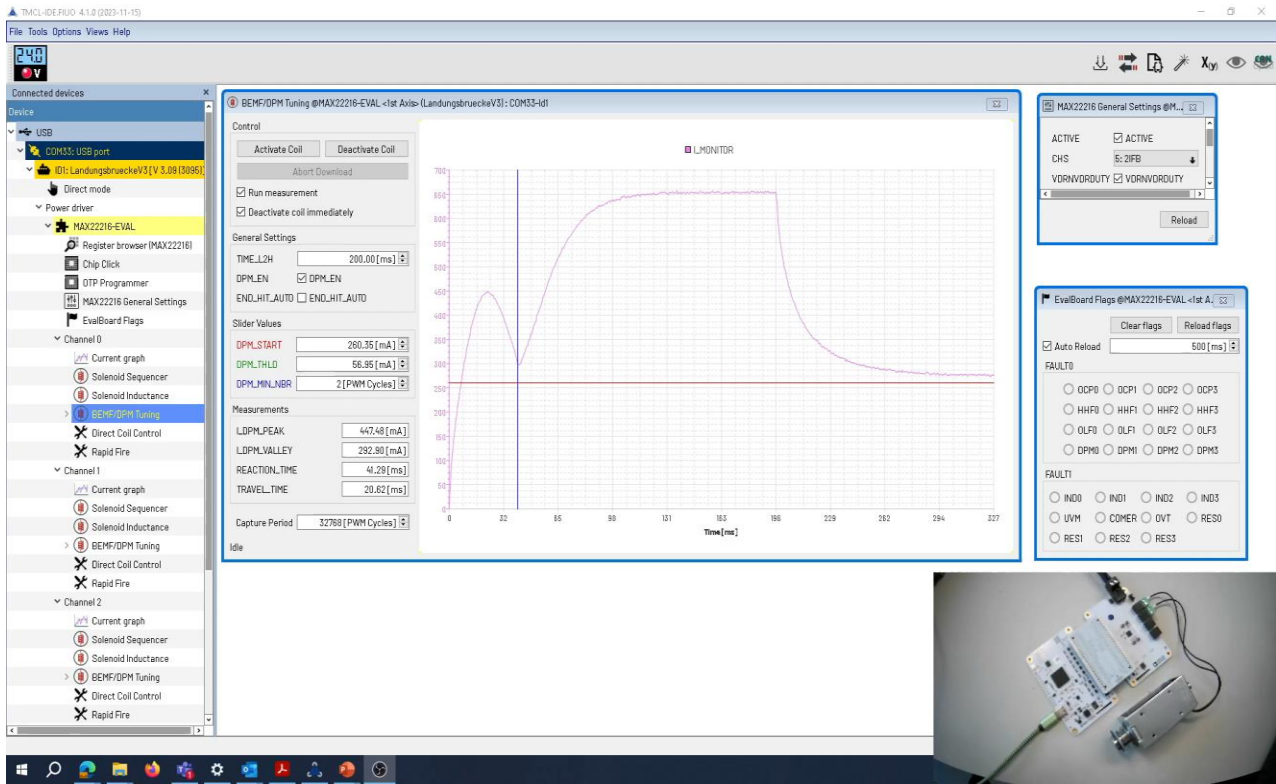
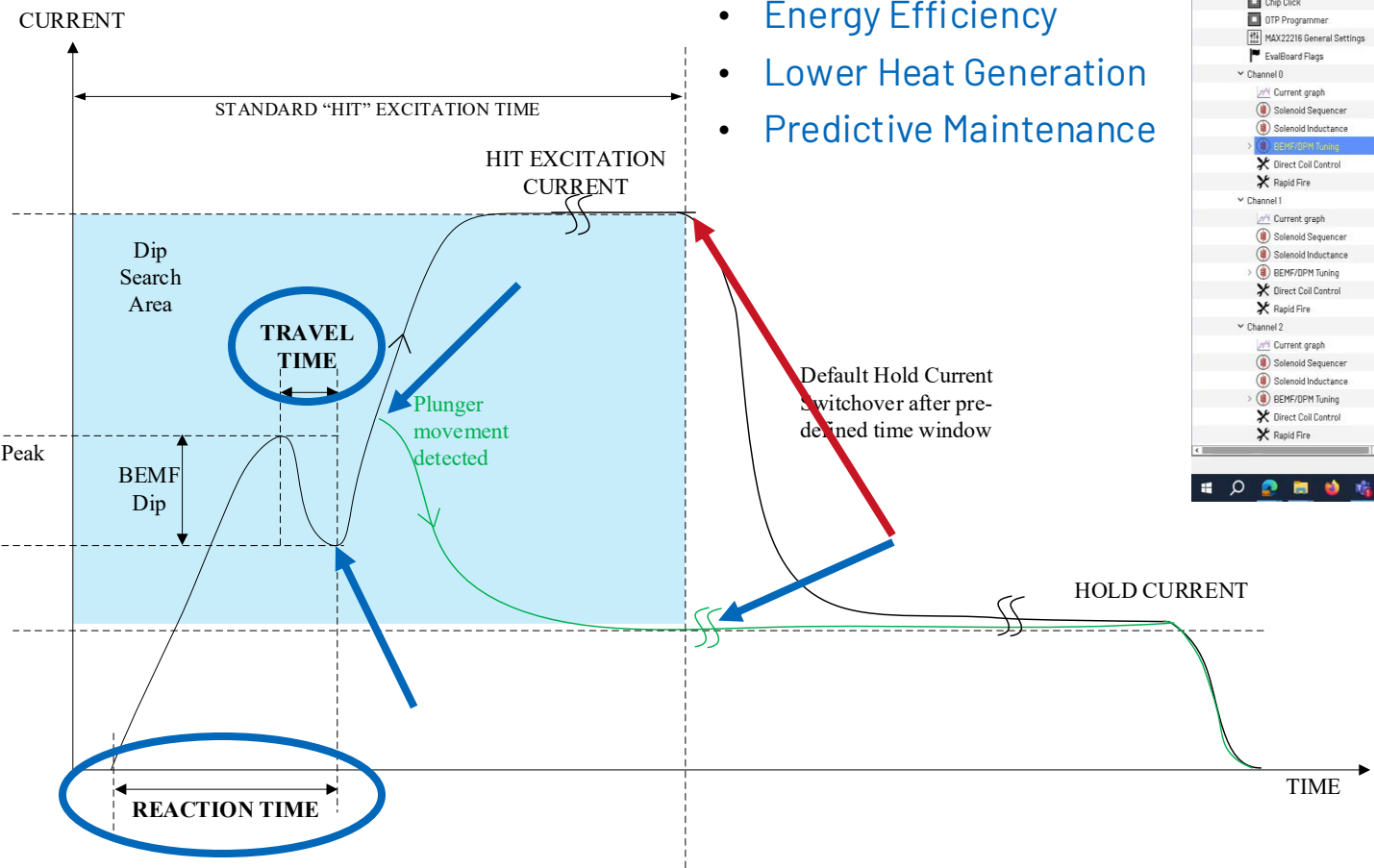
Designers can add various sensors (pressure/temperature/flow meters) but they must balance the benefit of extra data with the cost of installation.

Analog Device's Solution Overview



Enables...

- Detection of Plunger Movements
- Energy Efficiency
- Lower Heat Generation
- Predictive Maintenance

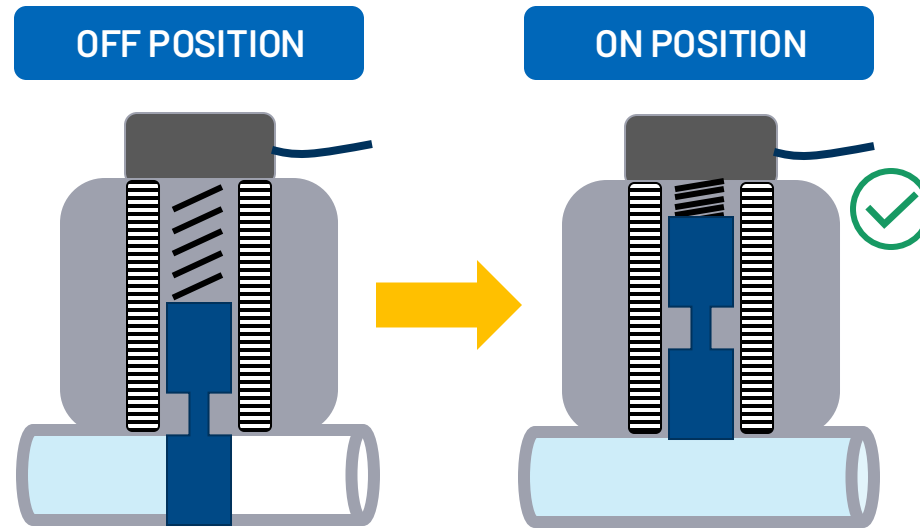


ADI SOLUTION

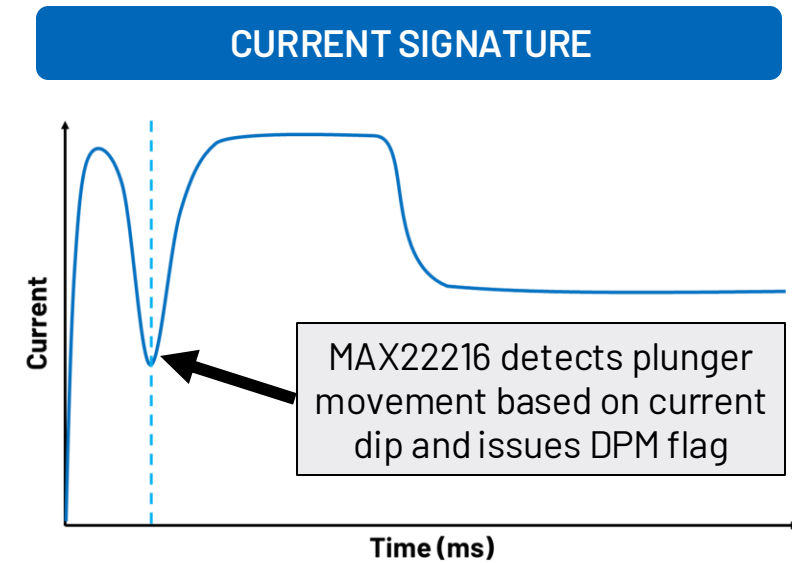
- No external encoders
- Reduce current to **minimum needed**
- Alert on slowing or stuck core
- Reduce coil temperature by **50°C**

Detection of Plunger Movement in Solenoid Valves

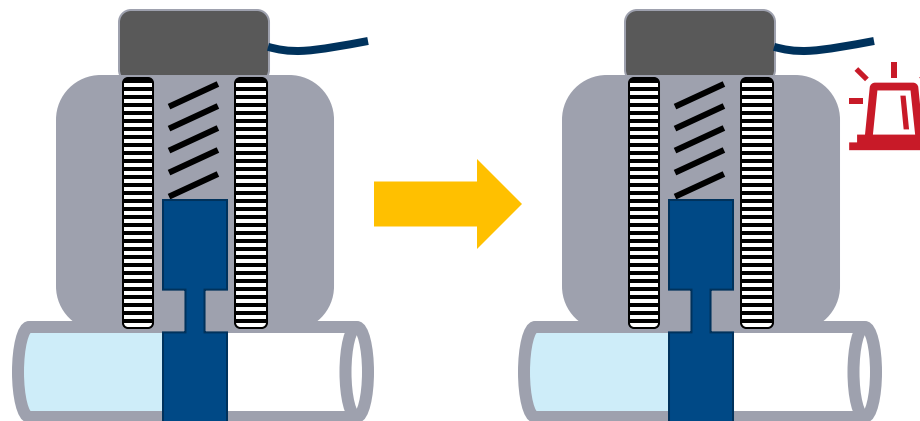
Properly Working Solenoid Valve



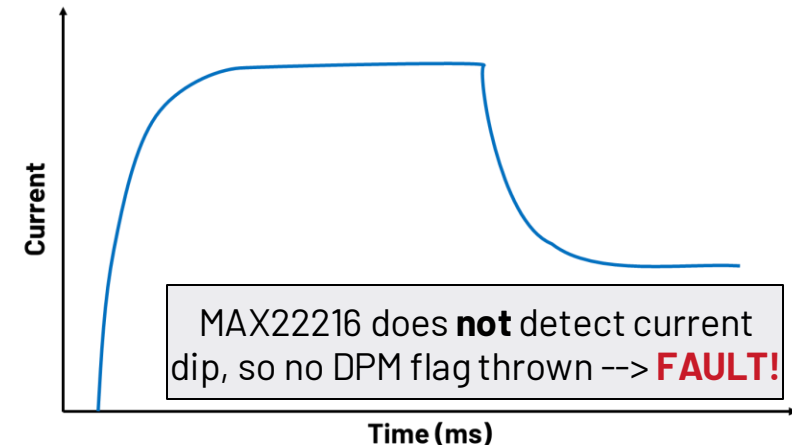
Solenoid actuates correctly and liquid can pass through.



Faulty Solenoid Valve

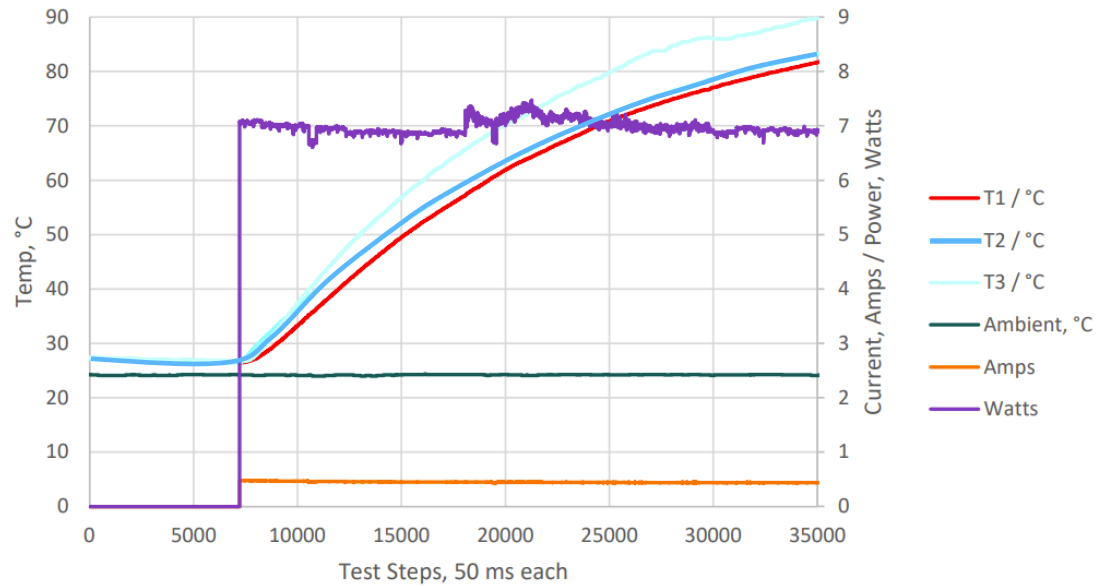


Solenoid does not actuate and liquid is blocked. System issues alarm.



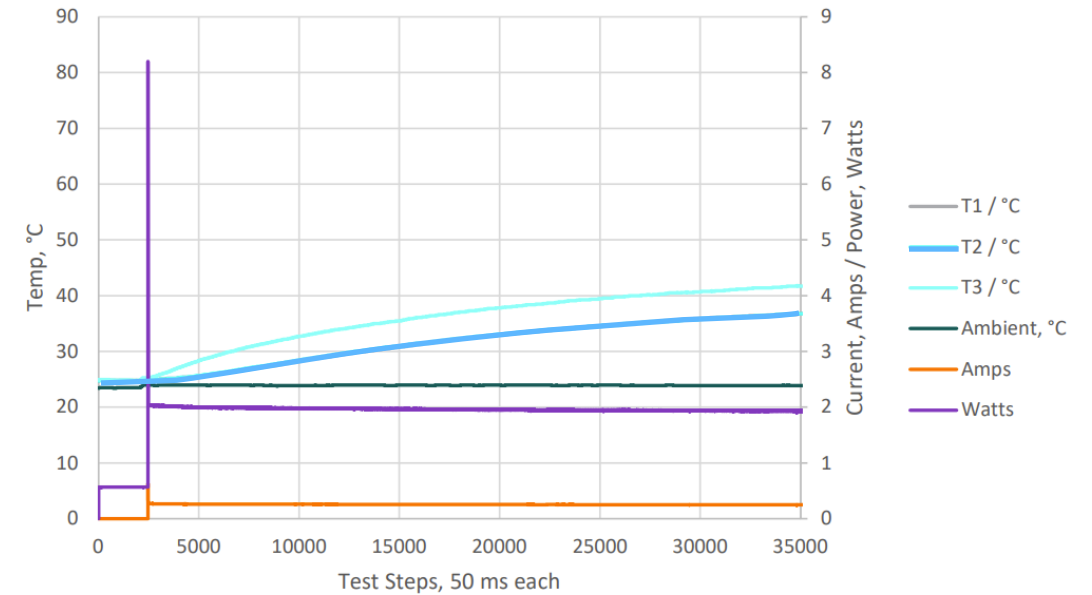
Detection of Plunger Movement in Solenoid Valves

24 VAC—SIMPLE RELAY CONTROL



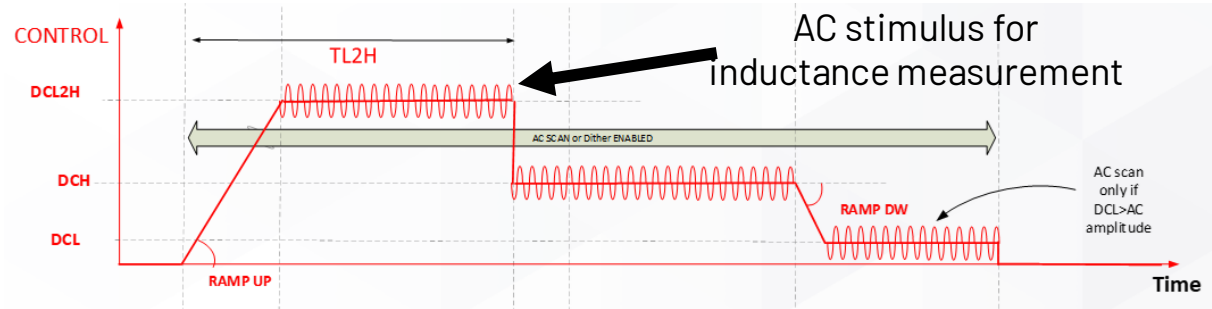
Basic relay control

TUNED SOLENOID DRIVE WITH MAX22216



“Just enough” current with MAX22216

MAX22216 Inductance + Resistance Measurement

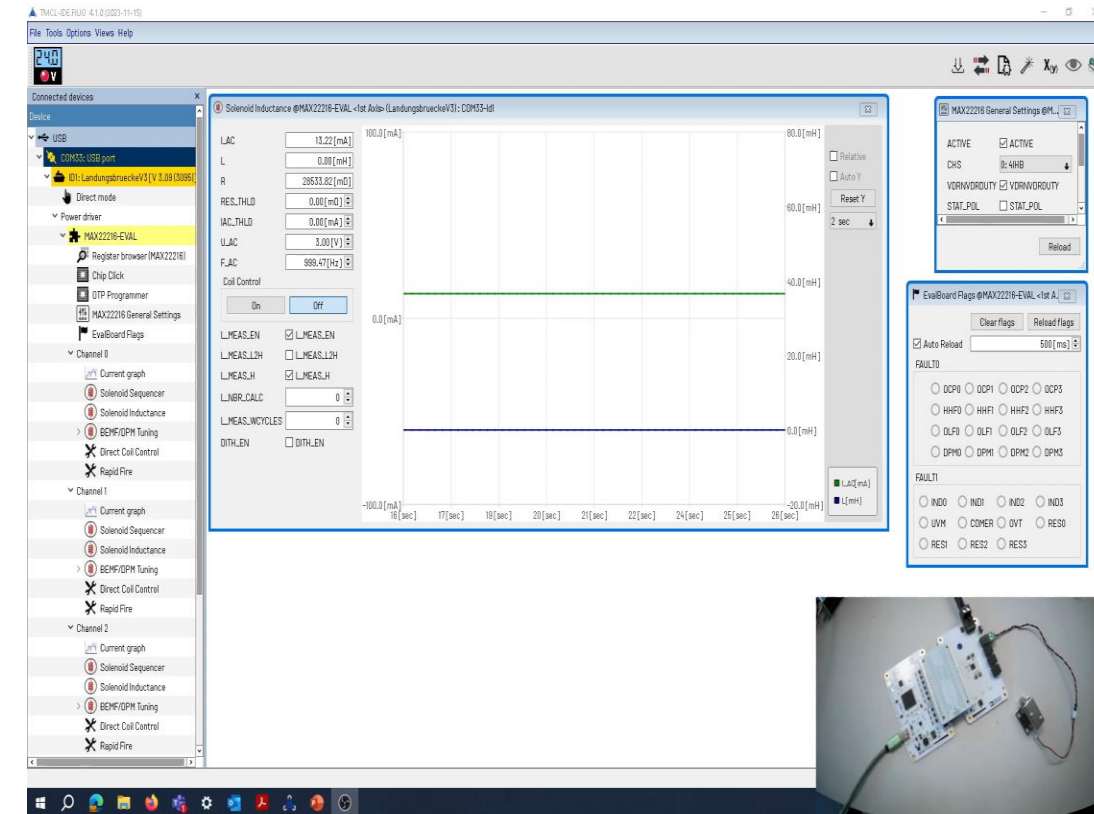


MAX22216 includes onboard circuitry for measuring solenoid **inductance** and **resistance**

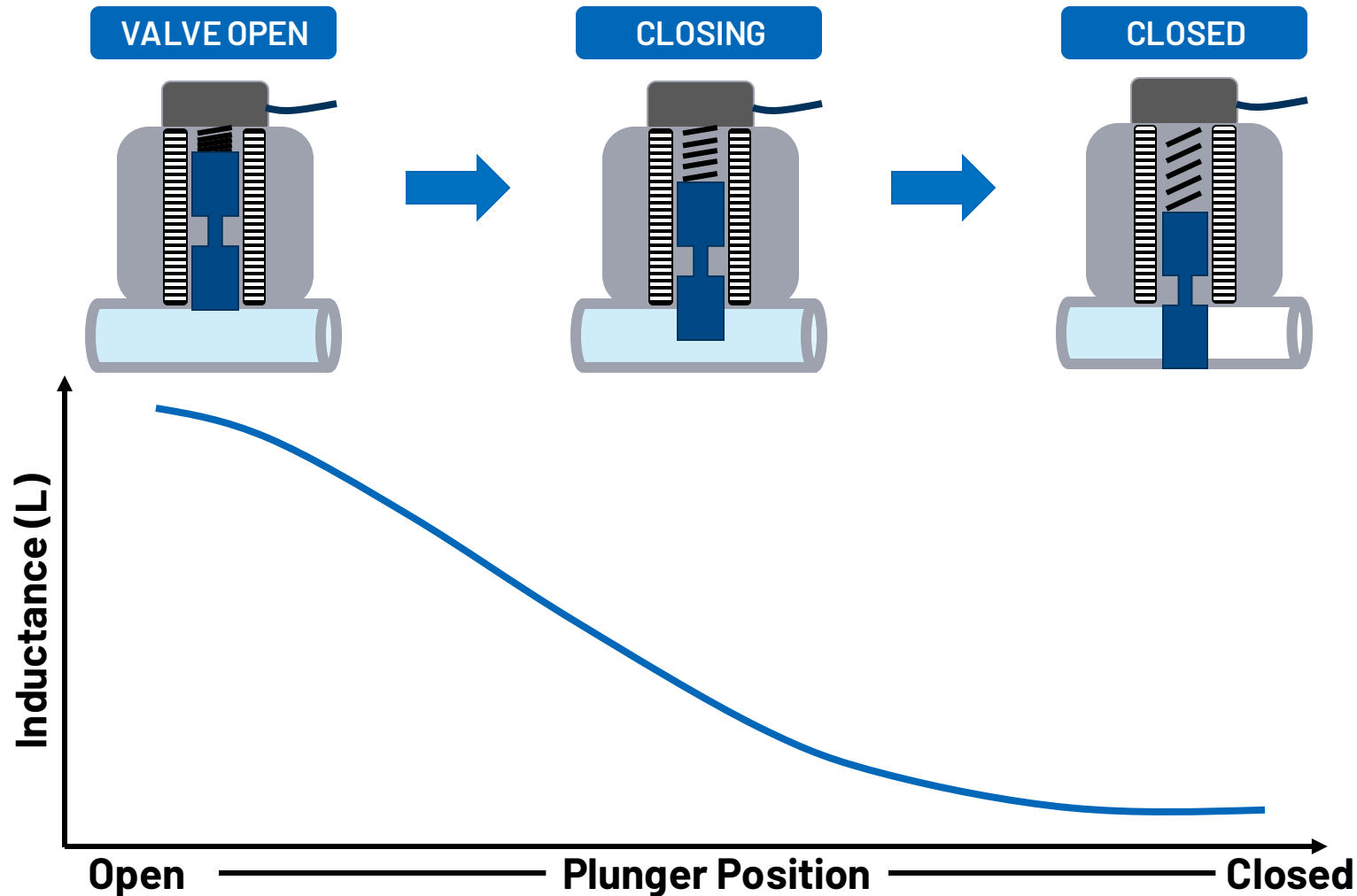
What's the benefit?

Insights Into Solenoid State & Health!

- **Inductance** can be used to estimate **plunger position** and **coil health**
- **Resistance** can be used to estimate **coil temperature** and **coil health**



Estimating Plunger Position via Inductance Measurements



Sensorless position feedback

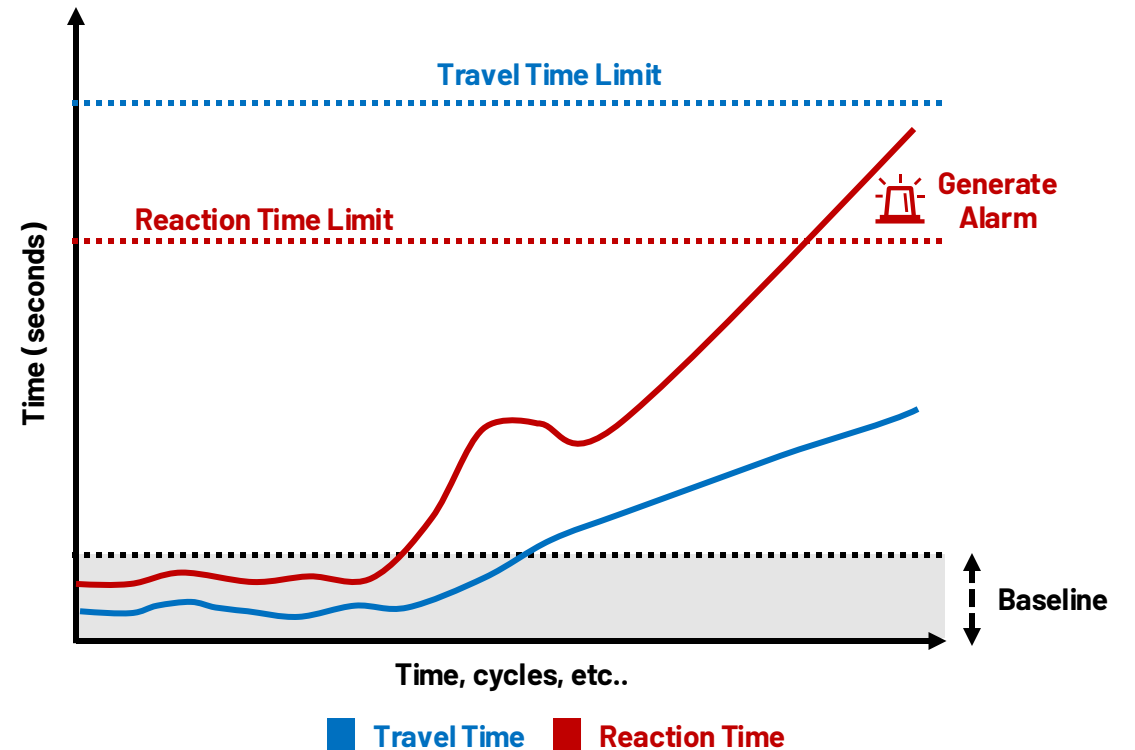
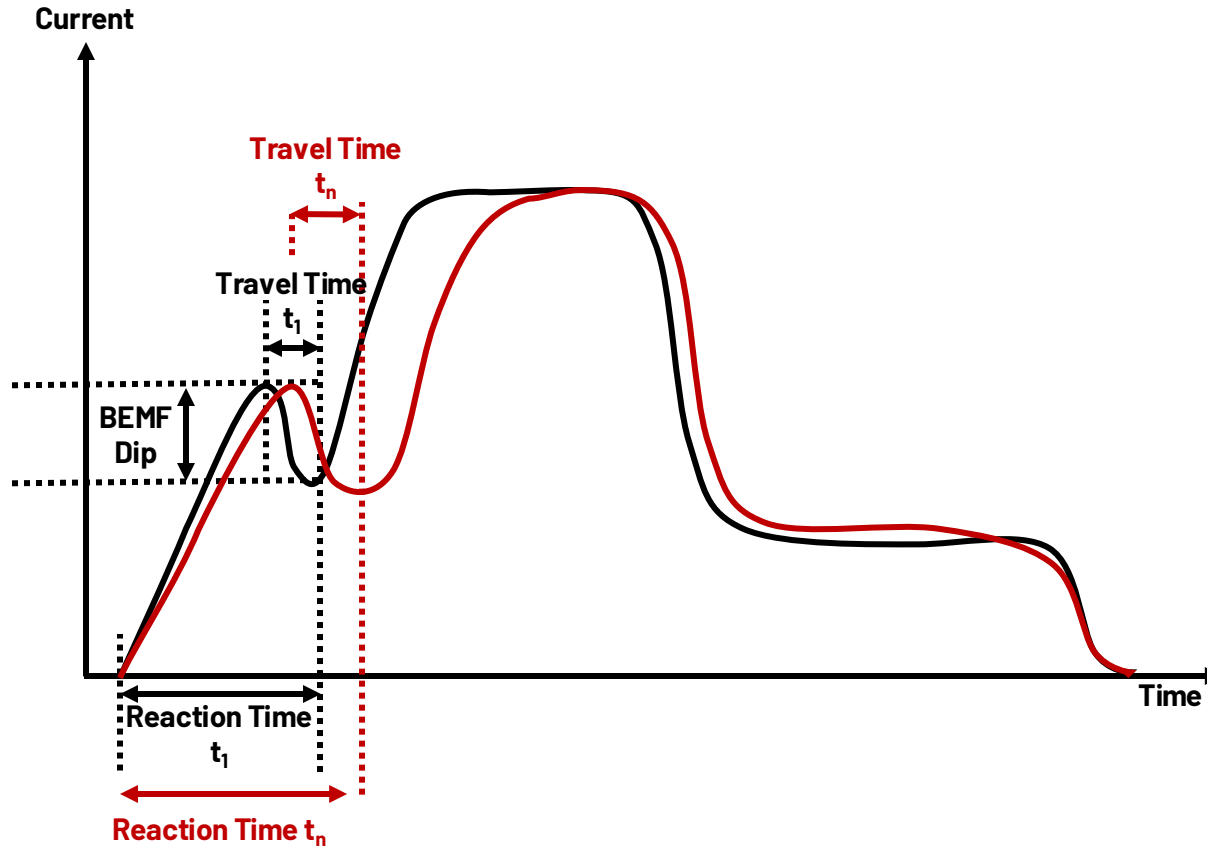
Inductance measurements verify plunger movement in real time, supporting accurate dosing and dependable assay performance

Benefits:

This real-time validation helps prevent dosing errors, reduces calibration drift, and increases confidence across high-throughput and point-of-care diagnostic platforms.

Predictive Maintenance

- Monitoring Reaction and Travel Time over the Lifetime of a Solenoid



Internal wear, friction, and contamination can cause slower valve response

Early detection would allow proactive maintenance before valve failure occurs

Drifting **reaction time** and **travel time** indicate gradual degradation

Exceeding defined drift thresholds trigger maintenance events before functional failure occurs.

MAX22216-17 – Single Ended Operation

► Energy Efficient 2-Level Sequencer

- Configurable Excitation, Hold and Low Levels
- Configurable Excitation Time

► Level Transition RAMP Control

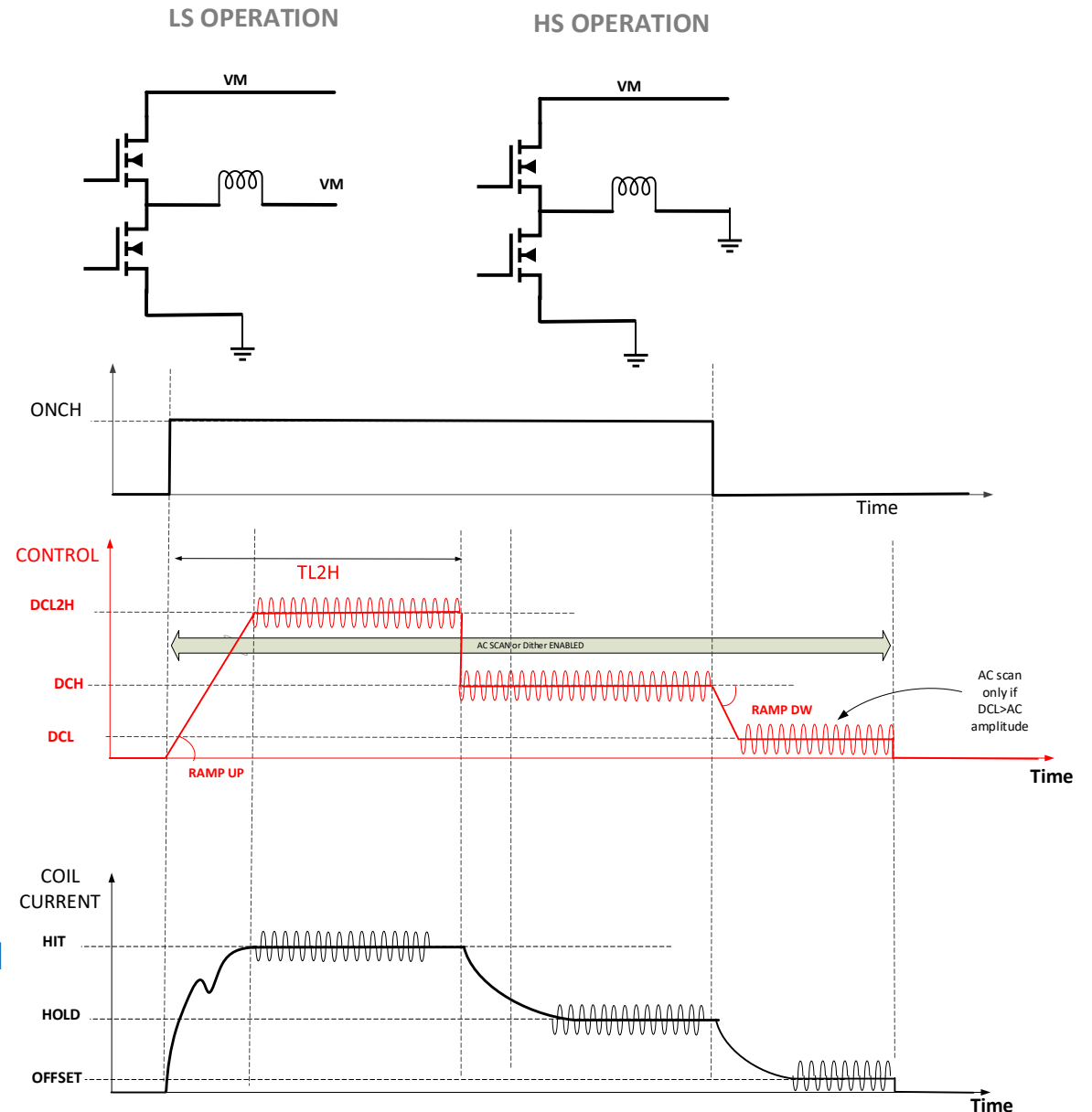
- Reduces mechanical acoustic noise

► PWM Control

- Globally Configurable 2.5 to 100 KHz
- Channel Independent Divider up to 1/8
- PWM Slew Rate Control to reduce EMI

► Sine Wave Generator

- Dithering (get rid of static friction issues / Drive of Proportional Valves)
- Inductance measurement (ON/OFF Status Detection and Coil Health, only in VDR)



MAX22216-17 – Full Bridge Operation

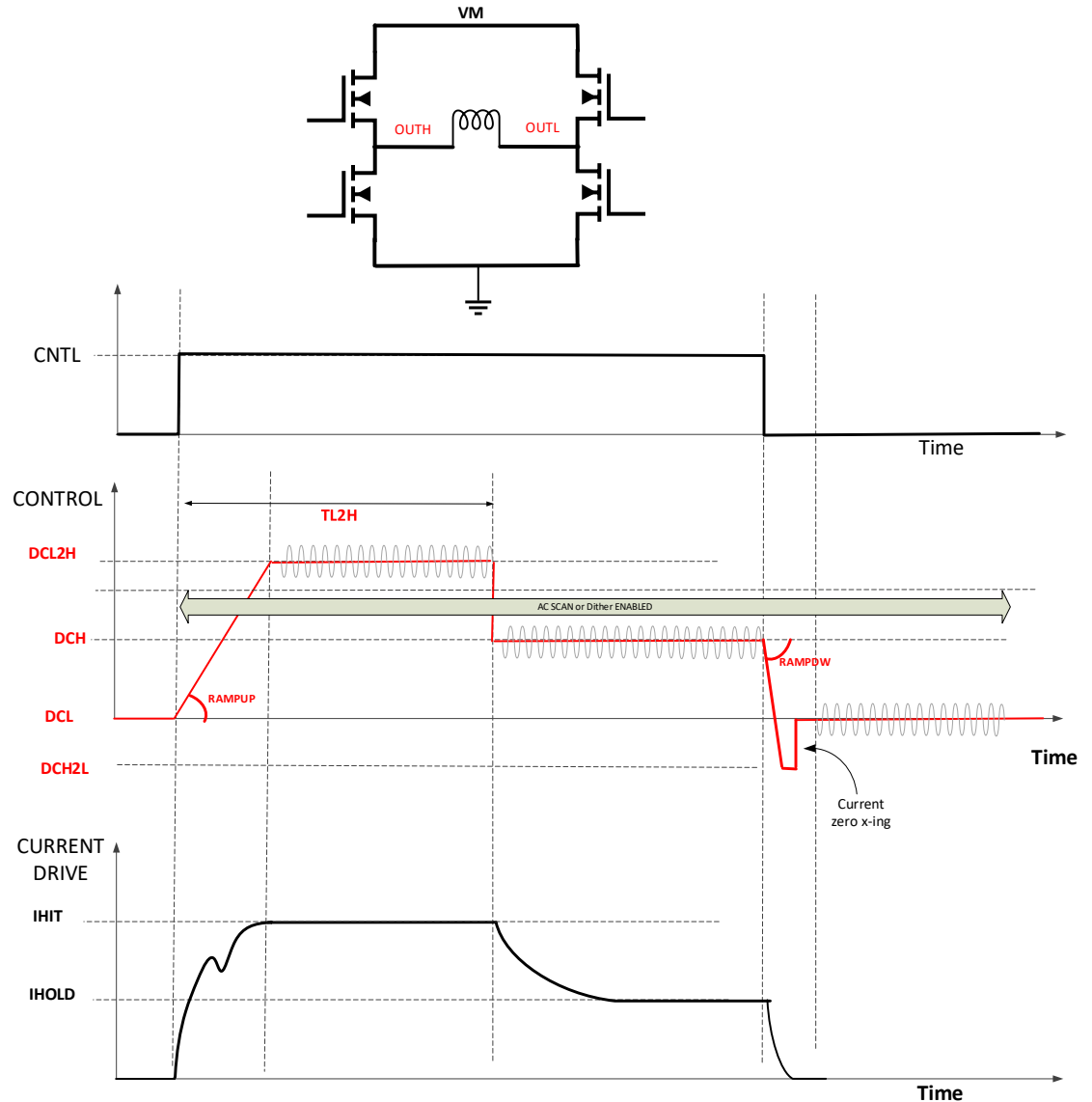
- Everything Single-Ended operation can do...
And more!

- Center-Aligned PWM

- The effective PWM Frequency is doubled
- Better HEAT distribution through the IC

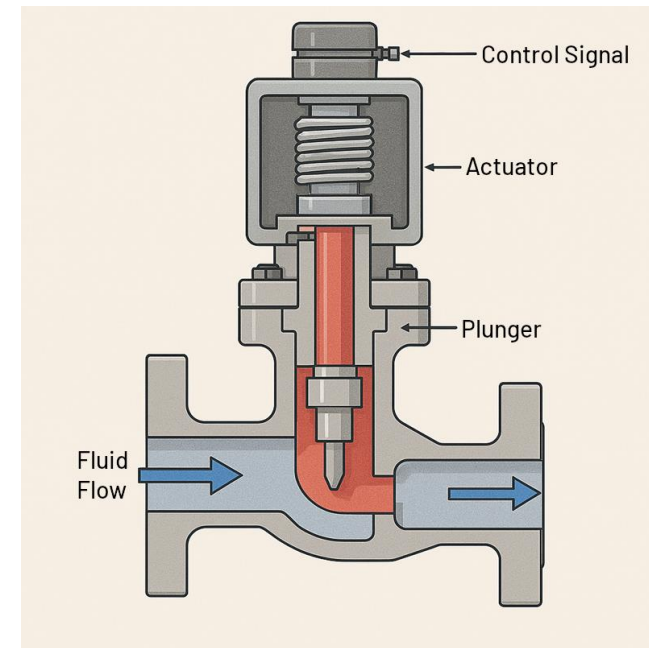
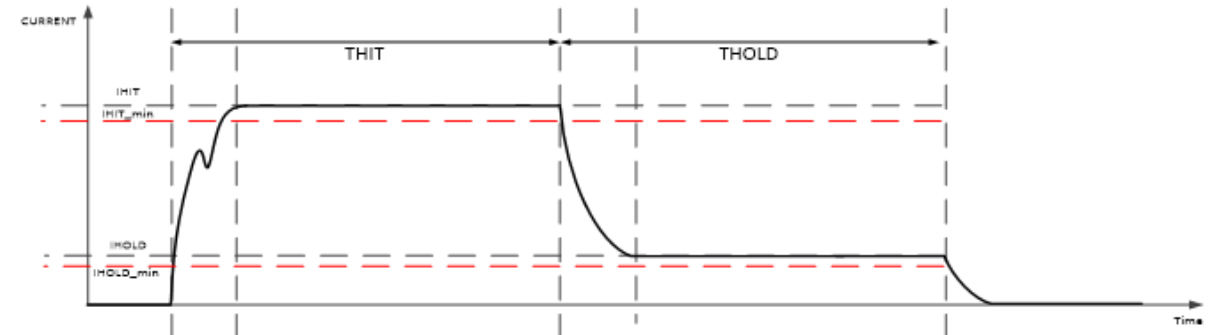
- Fast Demagnetization (zero x-ing)

- To shorten solenoid on-off cycles

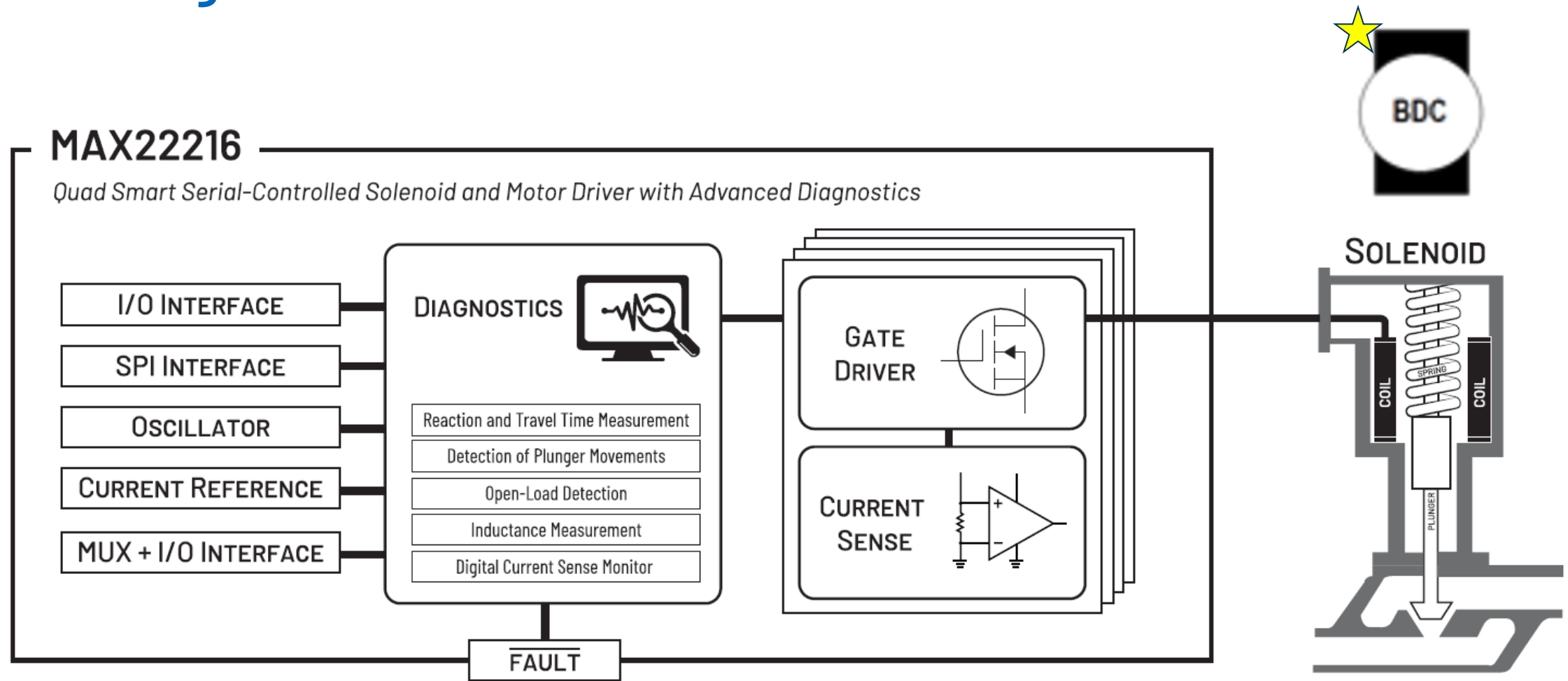


Driving Proportional Solenoid Valves

- Current Drive Regulation Mode (CDR):
 - The driver regulates the output current using internal sensing and feedback
 - You can configure **P**roportional and **I**ntegral gains to fine-tune the response for the whole position range
- Dithering Feature:
 - With configurable frequency the plunger “vibrates” to avoid getting stuck
- Real Time Current Feedback:
 - You can read the coil current via SPI which translates to the position



Block Diagram



Target Applications

- Valve Manifolds/Hydraulic Systems

CHALLENGE

MAX22216 SOLUTION

Miniaturization	Control up to 4 Channels + Integrated Current Sense and Shunts
Heat (Coil deterioration)	Resistance Measurement
Stuck plunger	Detection of Plunger Movements (DPM)
Plunger deformation	Current/Voltage Ramp Control
Acoustic noise	
Long on-off cycles	Fast Demagnetization to Shorten On-Off Cycles
Predictive maintenance	Impedance measurement + Detection of Plunger Movements
Energy efficiency	Two Level Current/Voltage Control
	Automatic HIT to HOLD Transition
EMI	Configurable Slope Control

Additional Benefits



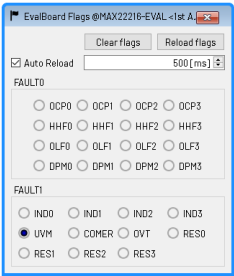
- Fault/Protections—Robustness

General Protections/Alarms

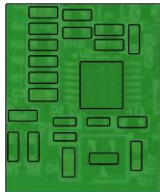
- Undervoltage lockout (UVM)
- Overtemperature protection (OVT)
- Communication error (COMER)

Channel Faults/Alarms

- Open-load detection (OL)
- Overcurrent protection (OCP)
- Hit current not reached alarm (HHF) - CDR
- Detection of plunger movement error (DPM)
- Resistance/inductance alarms (RES/IND)

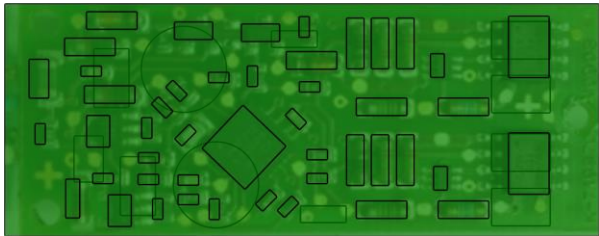


Miniaturization with Analog Device’s Solutions



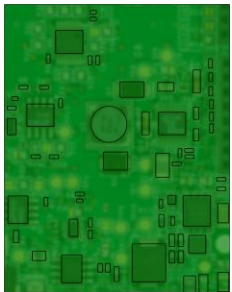
13×16mm²

Single Actuator
DPM Example



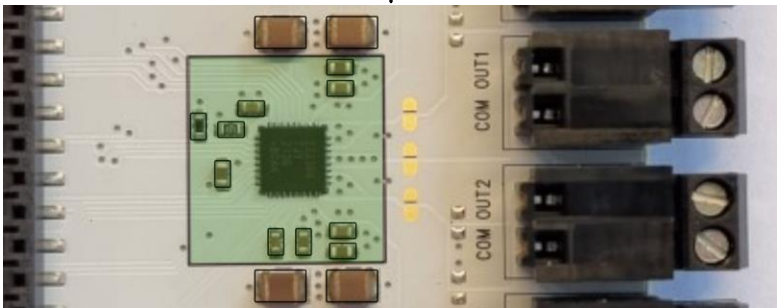
46×18mm²

Single Actuator
Fast Demagnetization Example



34×43mm²

Current Control
(Including Current
Sensing) Example



15×16mm², up to 4 Actuators
ADI Trinamic Solution—MAX22216

OTP and Standalone Mode

Customer OTP via SPI Interface

All writable registers!

STANDALONE CONFIGURATION

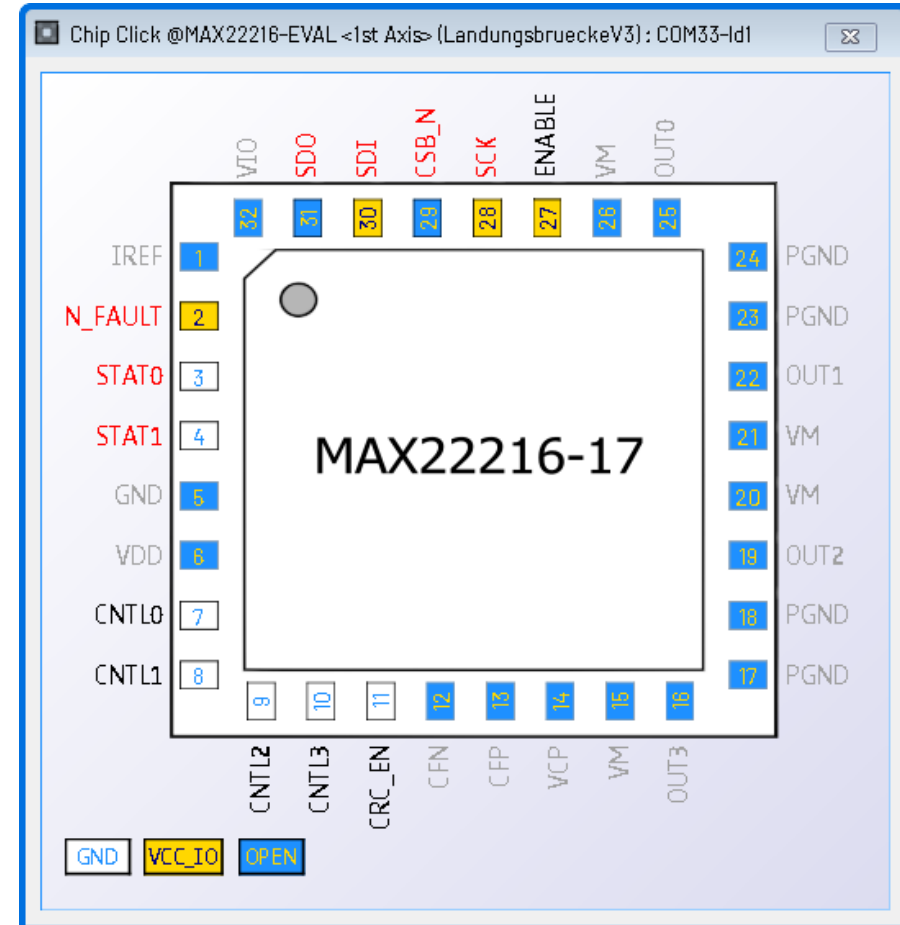
2 Stat Output Pins w Multiple Alarms

CNTL Pin (OR config with registers)

UVM Control with Hysteresis

Internal Voltage Regulator (3.3 or 5V)

nFault Pin + fault Stretching + Fault masking

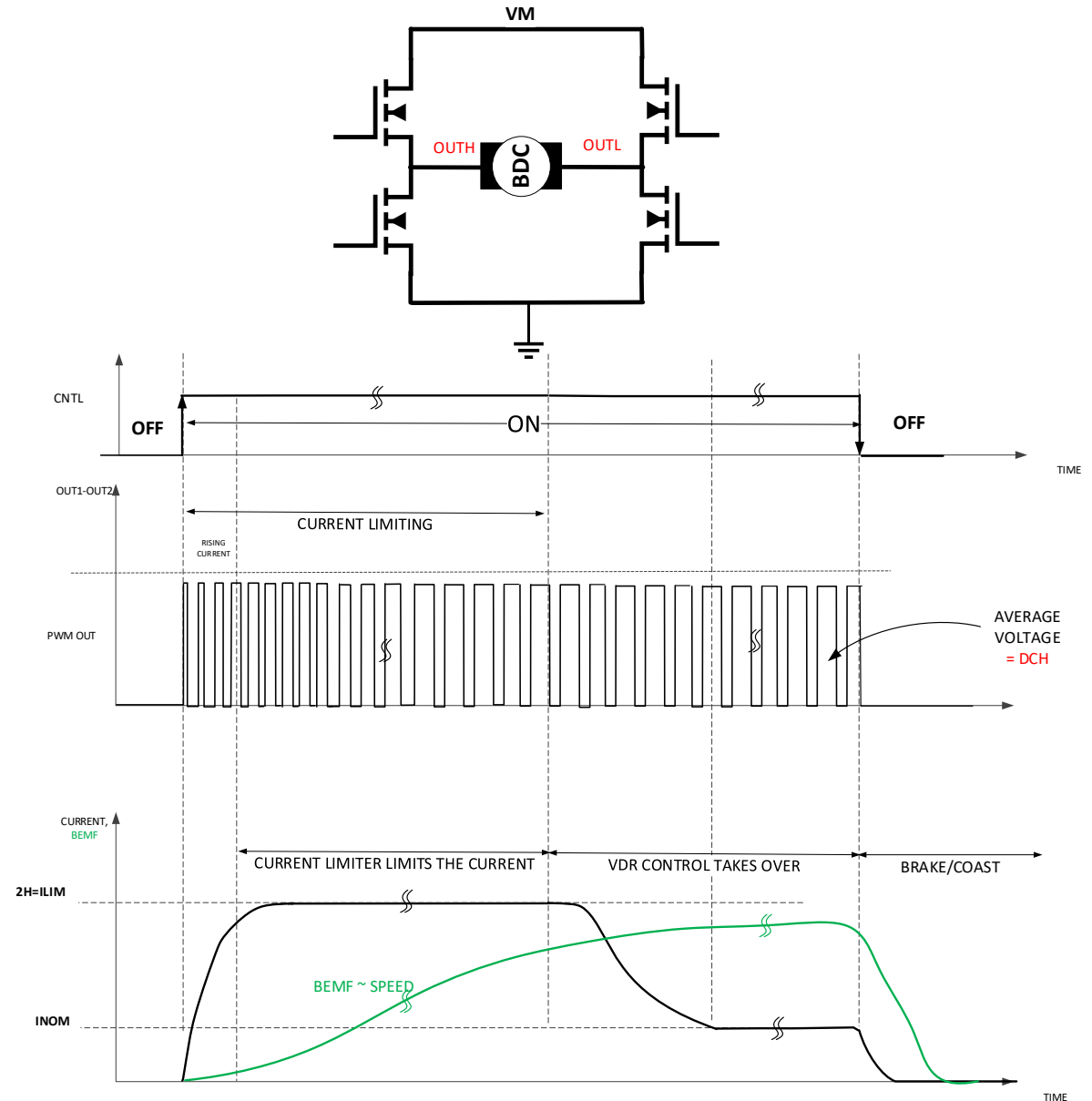


MAX22216-17 – DC Motor Drive Operation

- ▶ Programmable VDR (Speed) and CDR (Torque) Control
- ▶ SAME coil diagnostics as solenoids
- ▶ Special Motor Drive Mode
 - Current Control then Voltage Controlled
 - Limits the Start Inrush Current

KEY MOTOR CONTROL FEATURES IN MAX22216:

Feature	Details
VDR Mode	Voltage Drive Control for Speed Regulation
CDR Mode	Current Drive Control for Torque Regulation (12-bit PI Controller)
Motor Drive Mode	Current Control → Voltage Controlled, Limits Start Inrush
Brake Function	Integrated brake capability
Diagnostics	Plunger Movement Detection, Open Load Detection, Temperature Approximation
Current Sensing	Integrated Current Sense with Scaling
Package	5x5mm ² TQFN



Design Resources and Evaluation System

Product Home Page:

- [MAX22216](#)

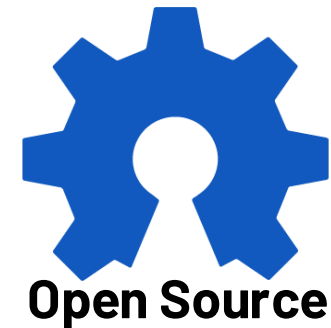
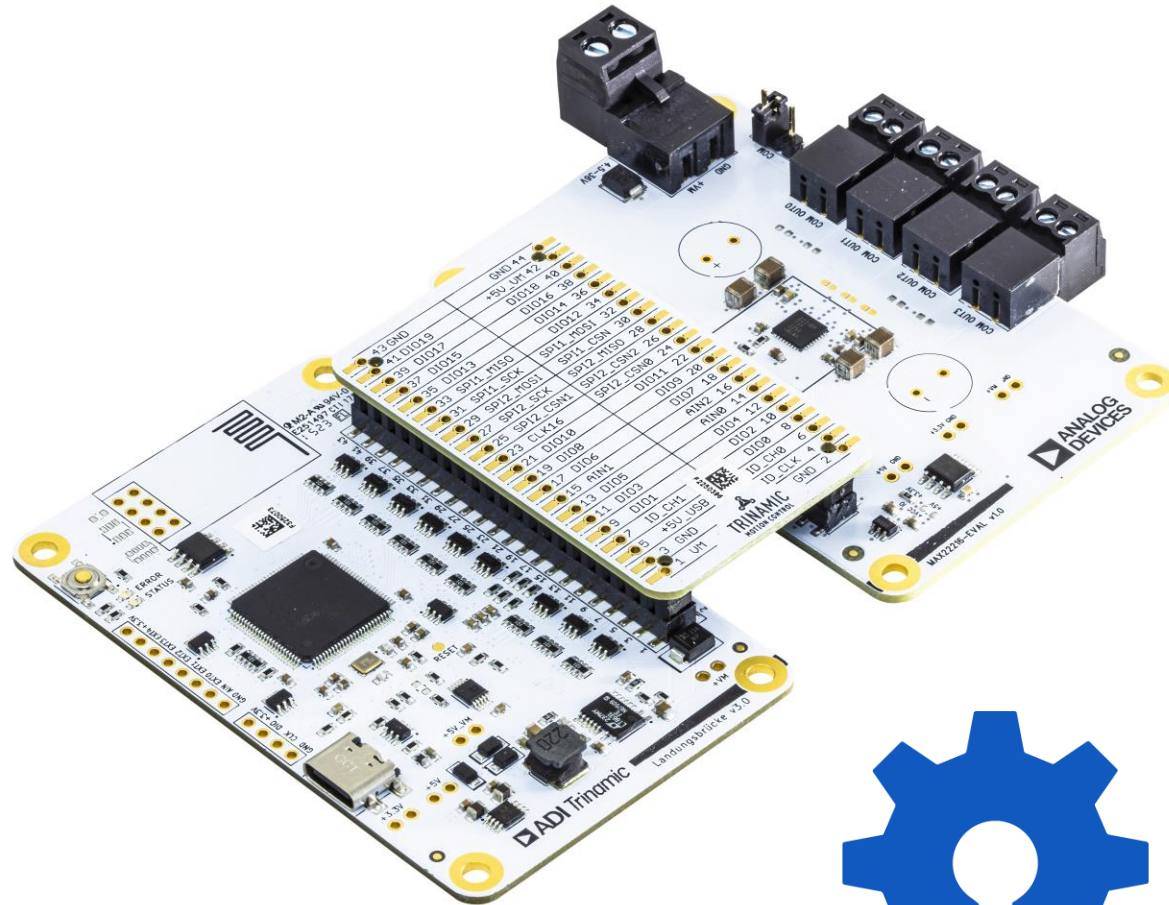
Evaluation Board:
[MAX22216-EVAL-KIT](#)

Software:

- [TMCL-IDE](#)

Landungsbrücke FW:

- [TMC-EvalSystem](#)



MAX22216/17: Internal Positioning and Comparison

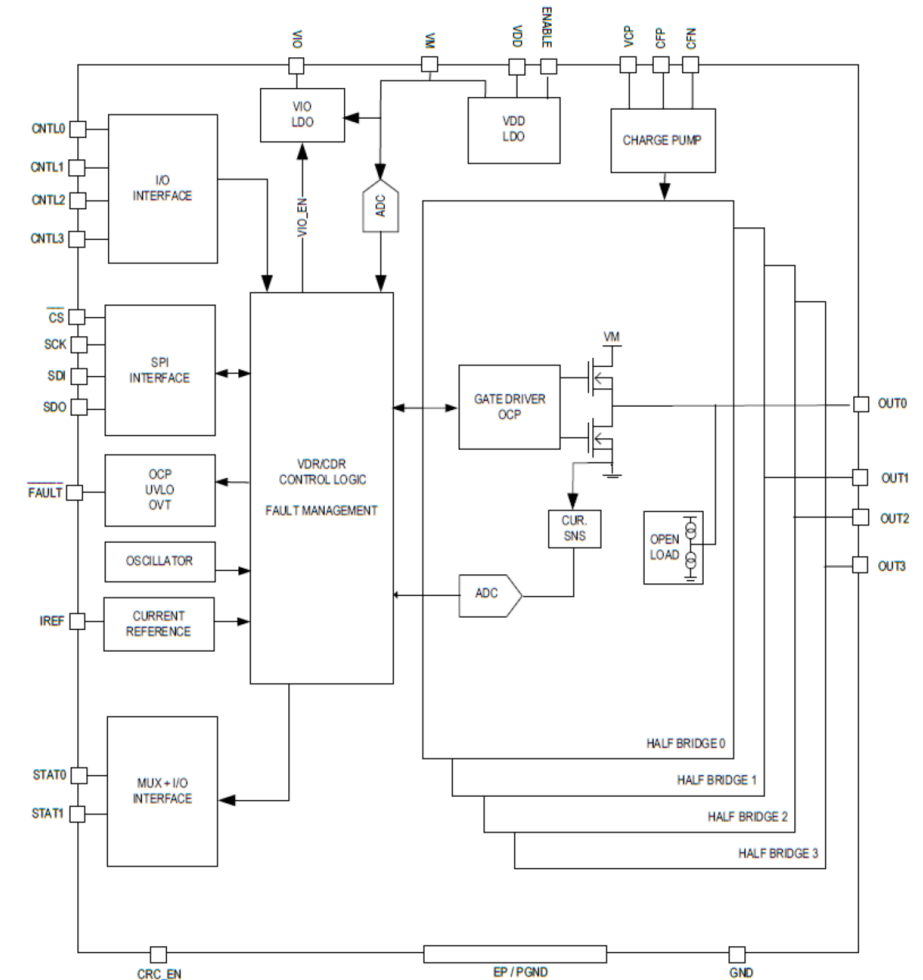
Product	MAX22200	MAX22216	MAX22217
Independent Half Bridges	8	4	
Current Capability (Channel)	1 A	1.7 A	0.55 A
Channel Configurations	Pairs of channels	All possible combinations	
Voltage Mode	YES: only DUTY	YES: DUTY + VM Comp	
Current Mode	YES: Peak Detection	YES: PI Control	
DPM	YES: Current	YES: Currents + Timing	
Ramp generator	NO	YES	
Inductance Measurement	NO	YES	
Current Monitor	NO	YES	
DC-Motor Drive	NO	YES	
BTL Mode - Fast Demag	YES: w/o zero x-ing	YES: with zero x-ing	
Dither	NO	YES	
Temp Grade	Industrial (-40°C, 85°C)	Auto (-40°C, 125°C)	

MAX22216/MAX22216V: Competition

Product	MAX22216V/MAX22216	Comp1	Comp2
Operating Voltage (V)	36	40	40
Maximum Current (A RMS) (per channel)	1.7	2	1.6
Nr Channels	4	4	3
Internal Current Sensing	YES	YES	YES
Current Drive Regulation	YES, PI Control	NO	YES, Current Limiter
Interface	SPI, I/O	SPI	SPI, I/O
DPM	YES	NO	NO
Open-Load Detection	YES	YES	YES
Dithering	YES	NO	YES
Motor Temp Estimate	YES	NO	NO
Position Estimation (Inductance Measurement)	YES	NO	NO
RDSon (Ω)	0.17	0.5	0.25
Package Size	5x5mm ²	5x4.4mm ²	15.9 x 14.2 mm ²

MAX22216/MAX22217 and MAX22216V

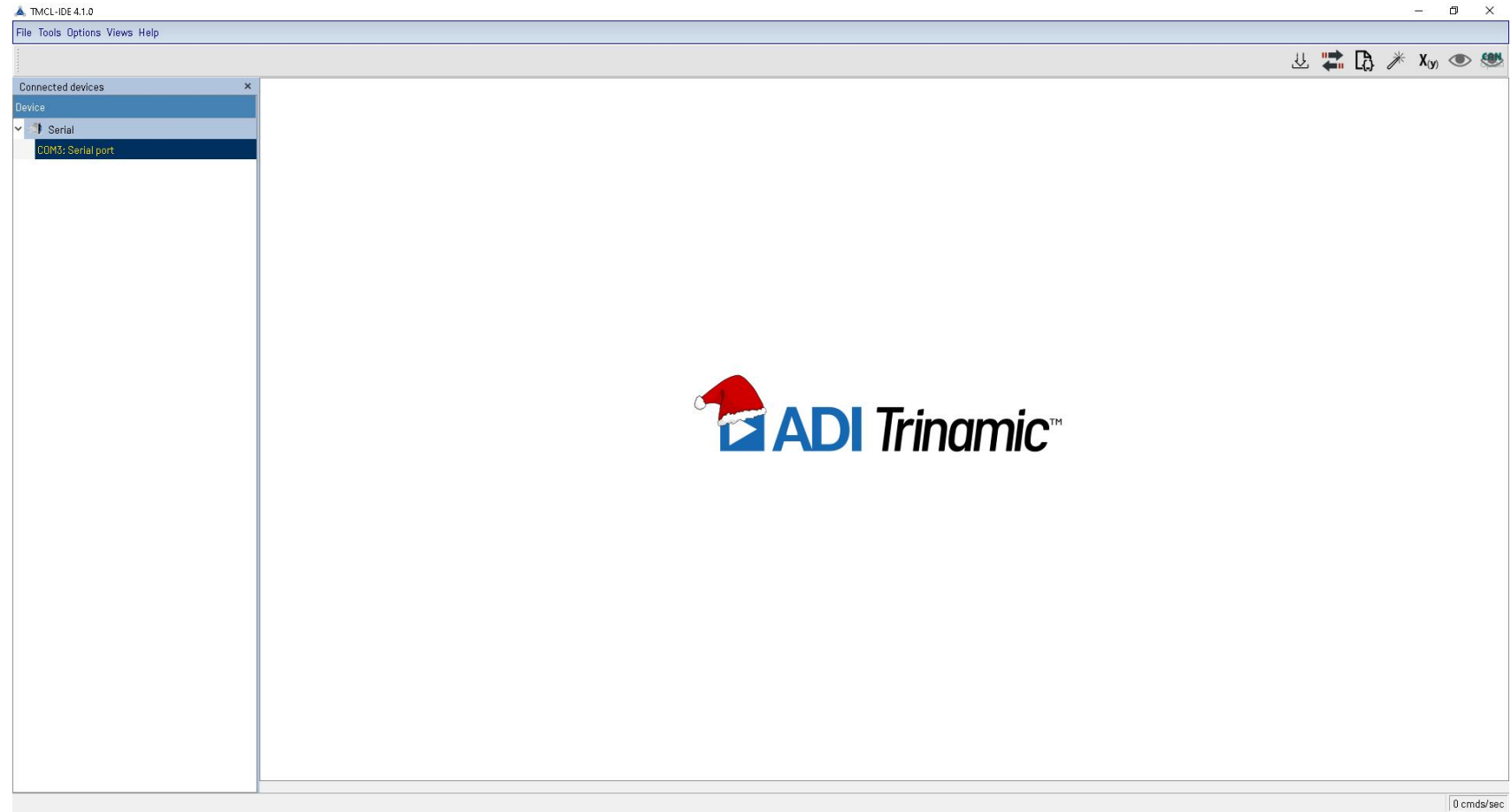
- Value Proposition
 - Low on-resistance (170 mΩ) provides high efficiency solution
 - Independent channel configuration settings programmable via SPI or OTP
 - Intelligent diagnostics include detection of plunger movement (PDM), plunger displacement sensing (PDS), and reaction time measurement (RTM)
 - MAX22216V version automotive qualified (AECQ100)
 - Easier system-level SIL/ASIL certification with MAX22216V
- Key Benefits
 - Reduced heat in module allows for more compact form factors
 - Advanced diagnostics and controls provide improved system reliability and enable predictive maintenance
 - Highly configurable solutions dynamically fits wide variety of applications



Software Platform (MAX22216)

Software:

- [TMCL-IDE](#)
- Install & RUN



Landungsbrücke FW Update

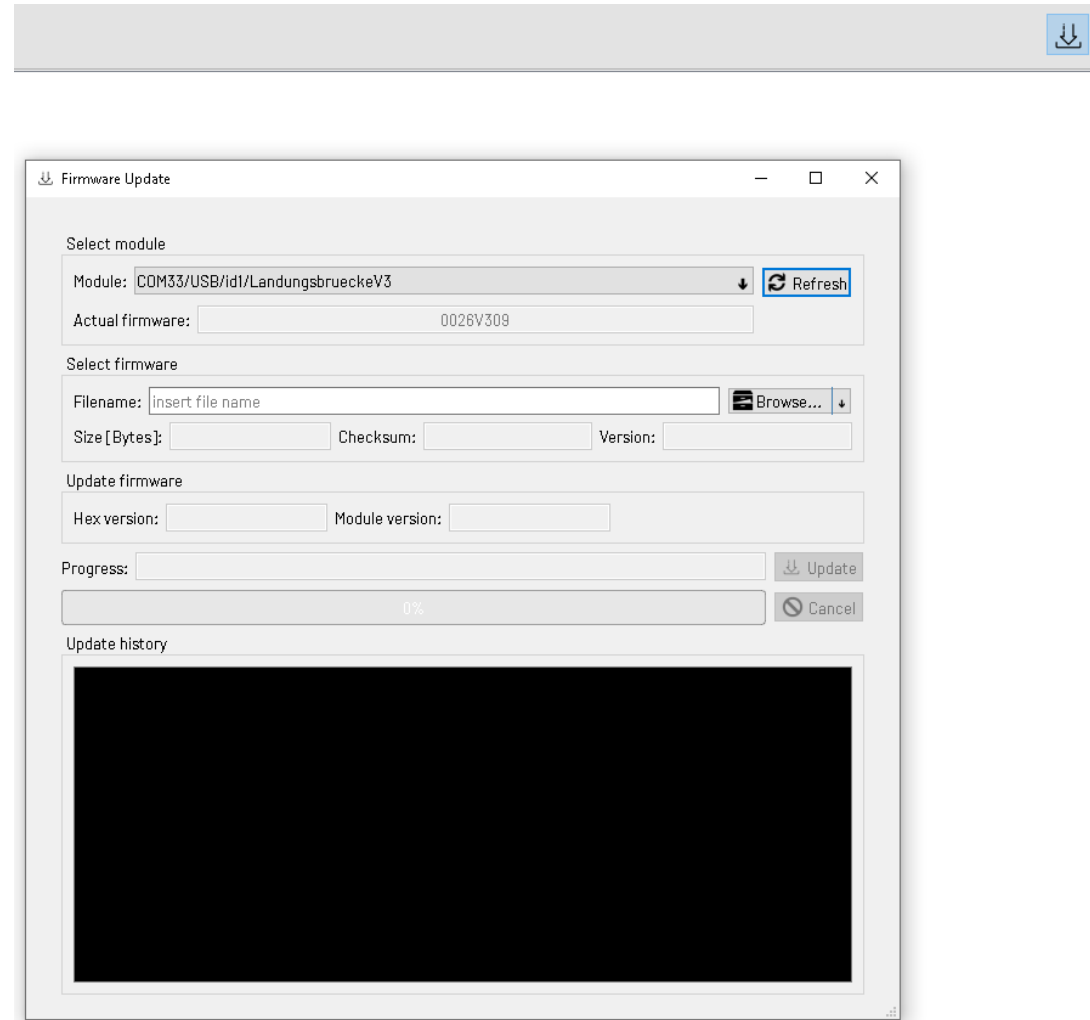
Landungsbrücke FW:

- [TMC-EvalSystem](#)

Inside the IDE, click on the ICON

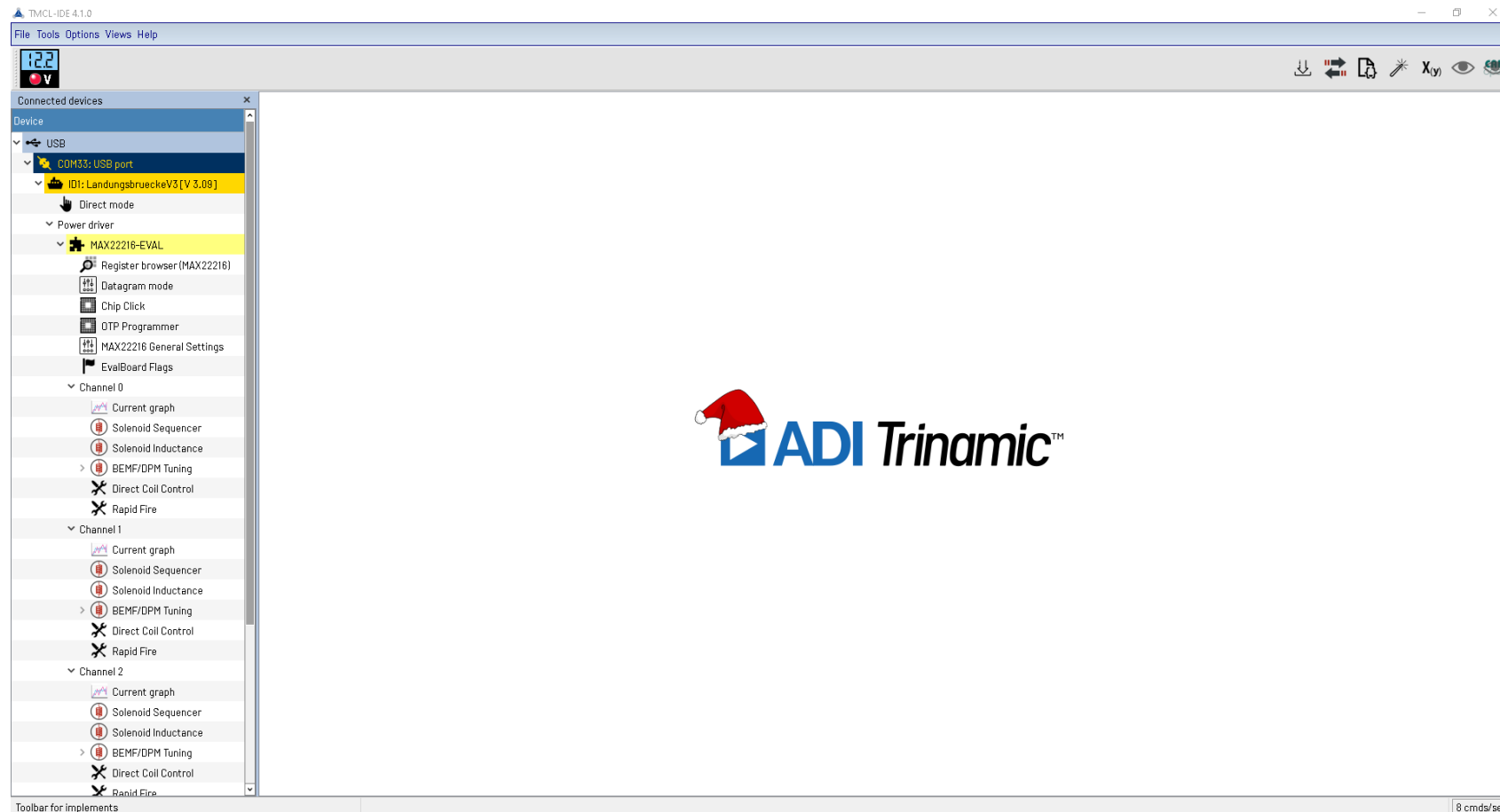
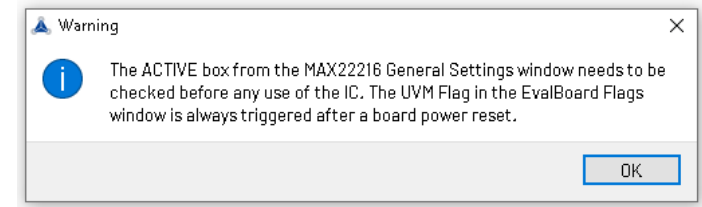
Inside the tool, select the firware file

Press Updatec



MAX22216-EVAL in the TMCL IDE

- Connect power to the MAX22216-EVAL-KIT
- Connect the MAX22216-EVAL-KIT to your PC



MAX22216 General Settings

➤ Turn on the IC

- ENABLE PIN HIGH and ACTIVE Register HIGH

➤ Select the channel configuration

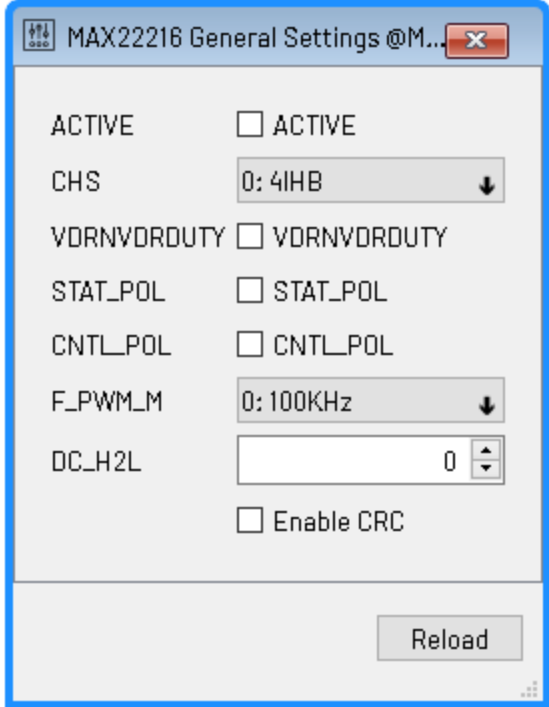
- CHS (I:Independent, P:Parallel, HB:Half-Bridge, FB:Full-Bridge)
- Please set it to CHS 6:1FB_2IHB

➤ DUTY or Internally Compensated VDR

- VDRnVDRDUTY – affects only channels using VDR

➤ Set Global PWM Frequency

- F_PWM_M (2.5 to 100 KHz) – can be divided further for each channel



A screenshot of a software window titled "MAX22216 General Settings @M...". The window contains several configuration options:

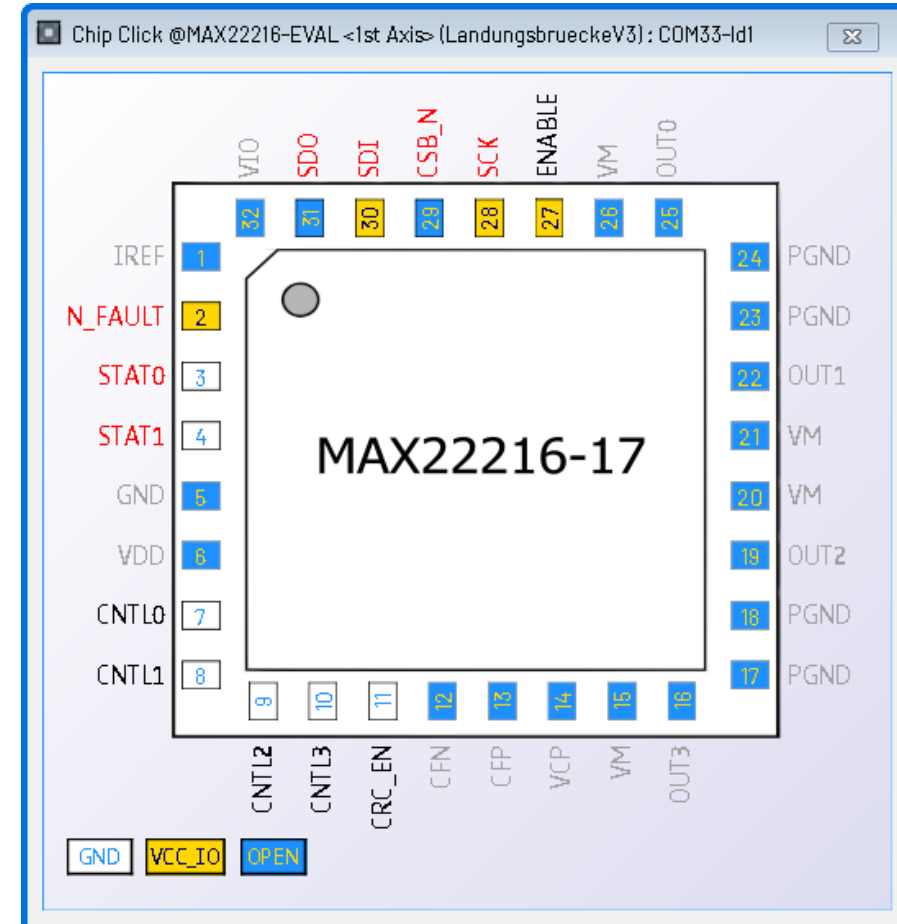
- ACTIVE**: ☐ ACTIVE
- CHS**: A dropdown menu showing "0: 4IHB" with a downward arrow.
- VDRnVDRDUTY**: ☐ VDRnVDRDUTY
- STAT_POL**: ☐ STAT_POL
- CNTL_POL**: ☐ CNTL_POL
- F_PWM_M**: A dropdown menu showing "0: 100KHz" with a downward arrow.
- DC_H2L**: A numeric input field showing "0" with up and down arrows.
- Enable CRC**: ☐ Enable CRC

At the bottom right of the window is a "Reload" button.

**ANALOG
DEVICES**

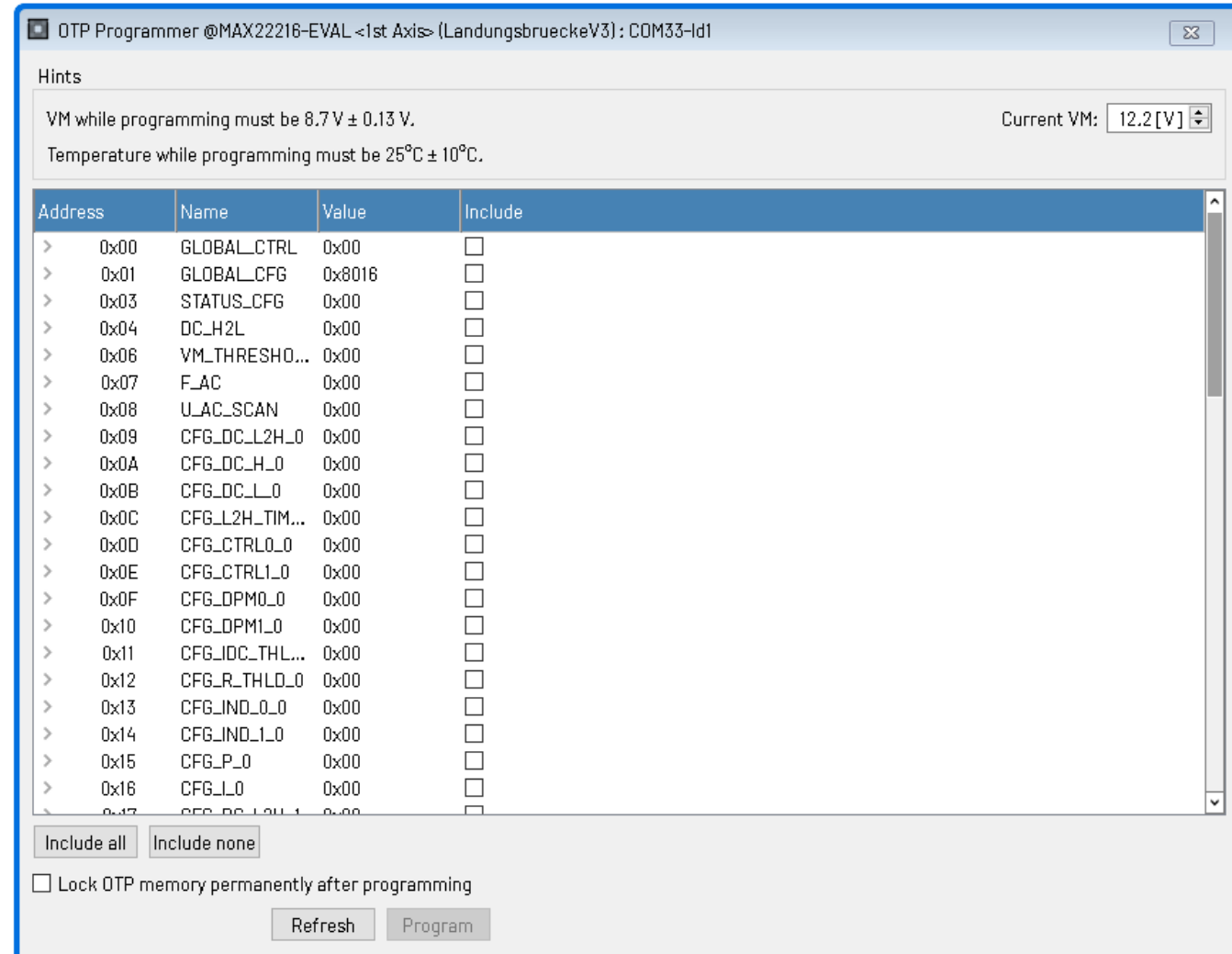
- **Can control/read pin status**

- `ENABLE` Pin must be HIGH (HIGH by default in the MAX22216-EVAL-KIT)
- `CNTL` Pins are on OR configuration with the `CNTL` Registers
- `CRC_EN` starts the CRC on the SPI



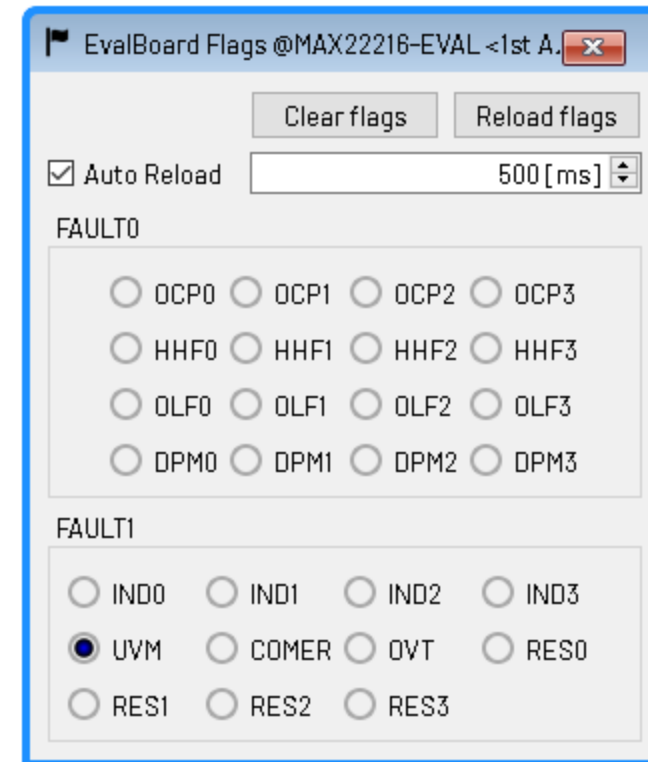
OTP Programmer

- All writable registers can be OTPd by the customer
- You can also start the internal 5V or 3.3V regulator
- You can also control the UVM and Mask Flags



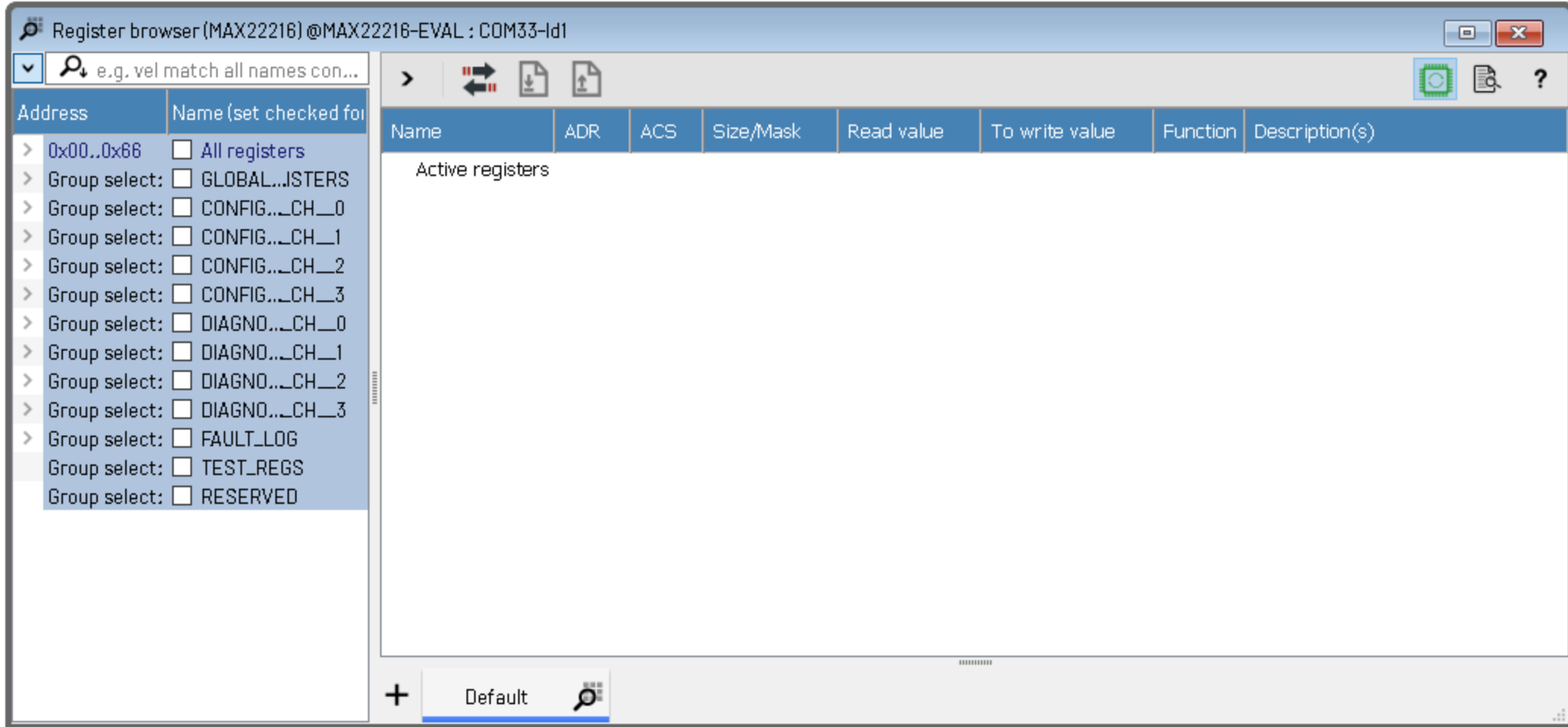
EvalBoard Flags

- Easy Overview of the FAULT Registers
- Can be set to automatically reload for near real-time Flag updates
- Always clear the UVM Flag at the start of the IC



Register Browser

- Easy overview and control of all the registers
- Can export settings as C Code



The screenshot shows the 'Register browser (MAX2216) @MAX2216-EVAL : COM33-Id1' window. It features a search bar at the top with the placeholder text 'e.g. vel match all names con...'. Below the search bar is a list of register groups with expandable arrows and checkboxes. The main area displays a table of registers with columns: Name, ADR, ACS, Size/Mask, Read value, To write value, Function, and Description(s). The table is currently empty, showing only the text 'Active registers'. At the bottom, there is a '+ Default' button and a search icon.

Address	Name (set checked for)
> 0x00..0x66	☐ All registers
> Group select:	☐ GLOBAL...ISTERS
> Group select:	☐ CONFIG..._CH__0
> Group select:	☐ CONFIG..._CH__1
> Group select:	☐ CONFIG..._CH__2
> Group select:	☐ CONFIG..._CH__3
> Group select:	☐ DIAGNO..._CH__0
> Group select:	☐ DIAGNO..._CH__1
> Group select:	☐ DIAGNO..._CH__2
> Group select:	☐ DIAGNO..._CH__3
> Group select:	☐ FAULT_LOG
> Group select:	☐ TEST_REGS
> Group select:	☐ RESERVED

Name	ADR	ACS	Size/Mask	Read value	To write value	Function	Description(s)
Active registers							

Channel Configuration – Settings + DPM

Register browser (MAX22216) @MAX22216-EVAL : COM33-Id1

Search: e.g. vel match all names contains vel

Address

Name (set checked for auto update)

0x00..0x68 ☒ All registers

Group select: ☐ GLOBAL_REGISTERS

Group select: ☒ CONFIGURATION_REGISTERS_CH__0

0x09 (9) ☒ CFG_DC_L2H_0

0x0A (10) ☒ CFG_DC_H_0

0x0B (11) ☒ CFG_DC_L_0

0x0C (12) ☒ CFG_L2H_TIME_0

0x0D (13) ☒ CFG_CTRL0_0

0x0E (14) ☒ CFG_CTRL1_0

0x0F (15) ☒ CFG_DPM0_0

0x10 (16) ☒ CFG_DPM1_0

0x11 (17) ☒ CFG_IDC_THLD_0

0x12 (18) ☒ CFG_R_THLD_0

0x13 (19) ☒ CFG_IND_0_0

0x14 (20) ☒ CFG_IND_1_0

0x15 (21) ☒ CFG_P_0

0x16 (22) ☒ CFG_L_0

Group select: ☐ CONFIGURATION_REGISTERS_CH__1

Group select: ☐ CONFIGURATION_REGISTERS_CH__2

Group select: ☐ CONFIGURATION_REGISTERS_CH__3

Group select: ☐ DIAGNOSTICS_CH__0

Group select: ☐ DIAGNOSTICS_CH__1

Group select: ☐ DIAGNOSTICS_CH__2

Group select: ☐ DIAGNOSTICS_CH__3

Group select: ☐ FAULT_LOG

Group select: ☐ TEST_REGS

Group select: ☐ RESERVED

Name	ADR	ACS	Size/Mask	Read value	To write value	Function	Description(s)
Active registers							
✕ CFG_DC_L2H_0	0x09	RWP	16	0x0000	0x0000		• CFG_DC_L2H
DC_L2H		RWP	FFFF	0	Signed ↓		Sets the DC_L2H level
✕ CFG_DC_H_0	0x0A	RWP	16	0x0000	0x0000		• CFG_DC_H
DC_H		RWP	FFFF	0	Signed ↓		Sets the DC_H level
✕ CFG_DC_L_0	0x0B	RWP	16	0x0000	0x0000		• CFG_DC_L
DC_L		RWP	FFFF	0	Signed ↓		Sets the DC_L level
✕ CFG_L2H_TIME_0	0x0C	RWP	16	0x0000	0x0000		• CFG_L2H_TIME
TIME_L2H		RWP	FFFF	0	Unsigned ↓		Sets the HIT Time
✕ CFG_CTRL0_0	0x0D	RWP	16	0x0000	0x0000		• CFG_CTRL0
RAMP		RWP	00FF	0	Unsigned ↓		Sets the Ramp up Slew Rate
RUPE		RWP	0100	☐ 0	☒ Set bit 8	disabled	Ramp UP enable
RMDE		RWP	0200	☐ 0	☒ Set bit 9	disabled	Ramp Mid Enable bit
RDWE		RWP	0400	☐ 0	☒ Set bit 10	disabled	Ramp Down Enable bit
H2L_EN		RWP	0800	☐ 0	☒ Set bit 11	disabled	H2L Fast Demagnetization Enable bit. "1" enforces DC_H2L...
OL_EN		RWP	1000	☐ 0	☒ Set bit 12	disabled	Open Load Circuit Enable (enable pull up/dw)
HHF_EN		RWP	2000	☐ 0	☒ Set bit 13	disabled	Current not reached Fault detection
CTRL_MODE		RWP	C000	id: 0	Choice ↓	0: VDR/...	Control mode setting
✕ CFG_CTRL1_0	0x0E	RWP	16	0x0000	0x0000		• CFG_CTRL1
SNSF		RWP	0003	id: 0	Choice ↓	0: IFS	Sets the Sense Scaling Factor
GAIN		RWP	000C	id: 0	Choice ↓	0: 1	Sets a a digital GAIN for the Current Driver Regulation (CDR)
SLEW_RATE		RWP	0030	id: 0	Choice ↓	0: Fast	Slew rate control bits
T_BLANKING		RWP	00C0	id: 0	Choice ↓	0: 0us	Defines an additional blanking time for current measurem...
F_PWM		RWP	0300	id: 0	Choice ↓	0: F_P...	Defines the PWM frequency that is used for the channel. S...
HSNLS		RWP	0400	☐ 0	☒ Set bit 10	LS	HS/LS: Bit Single Ended Mode Only
✕ CFG_DPM0_0	0x0F	RWP	16	0x0000	0x0000		• CFG_DPM0
DPM_THLD		RWP	0FFF	0	Unsigned ↓		DPM Fault Threshold
✕ CFG_DPM1_0	0x10	RWP	16	0x0000	0x0000		• CFG_DPM1
DPM_START		RWP	00FF	0	Unsigned ↓		The detections starts once the actual current has succeed...
DPM_MIN_NBR		RWP	0F00	0	Unsigned ↓		The condition in order to detect a valid BEMF dip has to be...
END_HIT_AUTO		RWP	1000	☐ 0	☒ Set bit 12	disabled	Enable Automatic DC_L2H to DH_H switchover
END_HIT_TO_HIZ_AUTO		RWP	2000	☐ 0	☒ Set bit 13	disabled	Enable Automatic DC_L2H to HIZ switchover
DPM_EN		RWP	4000	☐ 0	☒ Set bit 14	disabled	DPM Enable bit.
✕ CFG_IDC_THLD_0	0x11	RWP	16	0x0000	0x0000		• CFG_IDC_THLD
IDC_THLD		RWP	FFFF	0	Signed ↓		IDC_THLD thresholds IDC for mapping to status output ST...

Channel Configuration – Inductance + PI Settings

▼ ☒ CFG_IND_THLD_0	0x11	RWP	16	0x0000	0x0000	• CFG_IND_THLD
INDC_THLD		RWP	FFFF	0	Signed ↓	INDC_THLD thresholds INDC for mapping to status output ST...
▼ ☒ CFG_R_THLD_0	0x12	RWP	16	0x0000	0x0000	• CFG_R_THLD
RES_THLD		RWP	FFFF	0	Unsigned ↓	Threshold of measured resistance that triggers the corres...
▼ ☒ CFG_IND_0_0	0x13	RWP	16	0x0000	0x0000	• CFG_IND_0
L_NBR_CALC		RWP	000F	0	Unsigned ↓	Number of AC scan periods used to calculate the inductan...
L_MEAS_WCYCLES		RWP	00F0	0	Unsigned ↓	Number of AC scan periods (Tscan/1/F_AC) starting from ..
L_MEAS_H		RWP	0100	☐ 0	☒ Set bit 8	disabled Used to enable inductance measurement during hold time.
L_MEAS_L2H		RWP	0200	☐ 0	☒ Set bit 9	disabled Used to enable inductance measurement during L2H excita...
L_MEAS_EN		RWP	0400	☐ 0	☒ Set bit 10	disabled U_AC_SCAN is superimposed onto DC_L2H, DC_H, DC L if ...
DITH_EN		RWP	0800	☐ 0	☒ Set bit 11	disabled Used to enable dithering function.
▼ ☒ CFG_IND_1_0	0x14	RWP	16	0x0000	0x0000	• CFG_IND_1
IAC_THLD		RWP	0FFF	0	Unsigned ↓	IAC_THLD thresholds I_AC for mapping to status output S...
▼ ☒ CFG_P_0	0x15	RWP	16	0x0000	0x0000	• CFG_P
CFG_P		RWP	FFFF	0	Unsigned ↓	Set P parameter of PI controller
▼ ☒ CFG_I_0	0x16	RWP	16	0x0000	0x0000	• CFG_I
CFG_I		RWP	FFFF	0	Unsigned ↓	Set I parameter of PI controller

+ Default 

Channel Diagnostics

Register browser (MAX22216) @MAX22216-EVAL : COM33-Id1

Search: e.g. vel match all names contains vel

Address	Name (set checked for auto update)
> 0x00..0x86	☒ All registers
> Group select:	☐ GLOBAL_REGISTERS
> Group select:	☐ CONFIGURATION_REGISTERS_CH__0
> Group select:	☐ CONFIGURATION_REGISTERS_CH__1
> Group select:	☐ CONFIGURATION_REGISTERS_CH__2
> Group select:	☐ CONFIGURATION_REGISTERS_CH__3
> Group select:	☒ DIAGNOSTICS_CH__0
0x41 (65)	☒ LDPM_PEAK_0
0x42 (66)	☒ LDPM_VALLEY_0
0x43 (67)	☒ TRAVEL_TIME_0
0x44 (68)	☒ REACTION_TIME_0
0x45 (69)	☒ I_MONITOR_0
0x47 (71)	☒ I_AC_0
0x48 (72)	☒ RES_0
0x49 (73)	☒ PWM_DUTY_0
> Group select:	☐ DIAGNOSTICS_CH__1
> Group select:	☐ DIAGNOSTICS_CH__2
> Group select:	☐ DIAGNOSTICS_CH__3
> Group select:	☐ FAULT_LOG
> Group select:	☐ TEST_REGS
> Group select:	☐ RESERVED

Name	ADR	ACS	Size/Mask	Read value	To write value	Function	Description(s)
▼ Active registers							
▼ ☒ I_DPM_PEAK_0	0x41	R	16	0x0000			• I_DPM_PEAK
I_DPM_PEAK		R	FFFF	0			BEMF Current Local Peak during ramp up. I_DPM_PEAK= K _{cor}
▼ ☒ I_DPM_VALLEY_0	0x42	R	16	0x0000			• I_DPM_VALLEY
I_DPM_VALLEY		R	FFFF	0			BEMF Current Local Valley during ramp up. VDR or Duty Mode onl...
▼ ☒ TRAVEL_TIME_0	0x43	R	16	0x0000			• TRAVEL_TIME
TRAVEL_TIME		R	FFFF	0			Travel time from local maximum to local minimum detection: Exp...
▼ ☒ REACTION_TIME_0	0x44	R	16	0x0000			• REACTION_TIME
REACTION_TIME		R	FFFF	0			Reaction time from CNTL L2H to local minimum detection: Expres...
▼ ☒ I_MONITOR_0	0x45	R	16	0x0000			• I_MONITOR
I_MONITOR		R	FFFF	0			I_MONITOR Instantaneous current sampled Current sampled. Retur.
▼ ☒ I_AC_0	0x47	R	16	0x0000			• I_AC
I_AC		R	FFFF	0			AC current measured
▼ ☒ RES_0	0x48	R	16	0x0000			• RES
RES		R	FFFF	0			Measured resistance
▼ ☒ PWM_DUTY_0	0x49	R	16	0x0000			• PWM_DUTY
PWM_DUTYCYCLE		R	FFFF	0			Duty cycle

FAULT Logs

Register browser (MAX22216) @MAX22216-EVAL : COM33-Id1

☒ e.g. vel match all names contains vel

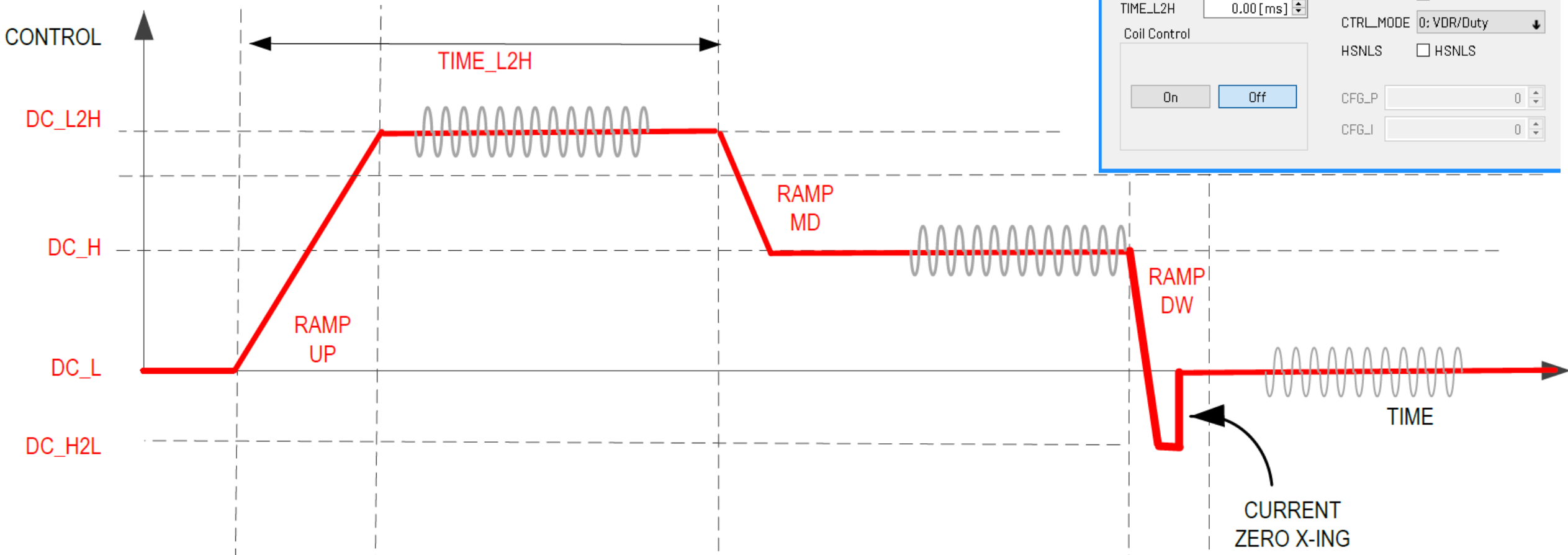
Address Name (set checked for auto update)

- > 0x00..0x66 ☒ All registers
- > Group select: ☐ GLOBAL_REGISTERS
- > Group select: ☐ CONFIGURATION_REGISTERS_CH__0
- > Group select: ☐ CONFIGURATION_REGISTERS_CH__1
- > Group select: ☐ CONFIGURATION_REGISTERS_CH__2
- > Group select: ☐ CONFIGURATION_REGISTERS_CH__3
- ▼ Group select: ☐ DIAGNOSTICS_CH__0
 - 0x41 (65) ☐ LDPM_PEAK_0
 - 0x42 (66) ☐ LDPM_VALLEY_0
 - 0x43 (67) ☐ TRAVEL_TIME_0
 - 0x44 (68) ☐ REACTION_TIME_0
 - 0x45 (69) ☐ LMONITOR_0
 - 0x47 (71) ☐ LAC_0
 - 0x48 (72) ☐ RES_0
 - 0x49 (73) ☐ PWM_DUTY_0
- > Group select: ☐ DIAGNOSTICS_CH__1
- > Group select: ☐ DIAGNOSTICS_CH__2
- > Group select: ☐ DIAGNOSTICS_CH__3
- ▼ Group select: ☒ FAULT_LOG
 - 0x65 (101) ☒ FAULT0
 - 0x66 (102) ☒ FAULT1
- Group select: ☐ TEST_REGS
- Group select: ☐ RESERVED

Name	ADR	ACS	Size/Mask	Read value	To write value	Function	Description(s)
▼ Active registers							
▼ ☒ FAULT0 0x65		RWCP	16	0x0000	0x0000		► FAULT0
OCP0		RWCP	0001	☐ 0	Clear bit 0	ok	Over Current Protection Detection Bit
OCP1		RWCP	0002	☐ 0	Clear bit 1	ok	Over Current Protection Detection Bit
OCP2		RWCP	0004	☐ 0	Clear bit 2	ok	Over Current Protection Detection Bit
OCP3		RWCP	0008	☐ 0	Clear bit 3	ok	Over Current Protection Detection Bit
HHF0		RWCP	0010	☐ 0	Clear bit 4	ok	Hit Current not Reached Detection Bit
HHF1		RWCP	0020	☐ 0	Clear bit 5	ok	Hit Current not Reached Detection Bit
HHF2		RWCP	0040	☐ 0	Clear bit 6	ok	Hit Current not Reached Detection Bit
HHF3		RWCP	0080	☐ 0	Clear bit 7	ok	Hit Current not Reached Detection Bit
OLF0		RWCP	0100	☐ 0	Clear bit 8	ok	Open Loop Detection Bit
OLF1		RWCP	0200	☐ 0	Clear bit 9	ok	Open Loop Detection Bit
OLF2		RWCP	0400	☐ 0	Clear bit 10	ok	Open Loop Detection Bit
OLF3		RWCP	0800	☐ 0	Clear bit 11	ok	Open Loop Detection Bit
DPM0		RWCP	1000	☐ 0	Clear bit 12	ok	DPM Status Bit
DPM1		RWCP	2000	☐ 0	Clear bit 13	ok	DPM Status Bit
DPM2		RWCP	4000	☐ 0	Clear bit 14	ok	DPM Status Bit
DPM3		RWCP	8000	☐ 0	Clear bit 15	ok	DPM Status Bit
▼ ☒ FAULT1 0x66		RWCP	16	0x0010	0x0010		► FAULT1
IND0		RWCP	0001	☐ 0	Clear bit 0	ok	Bit is set if measured inductance was not compliant according to Excitation H...
IND1		RWCP	0002	☐ 0	Clear bit 1	ok	Bit is set if measured inductance was not compliant according to Excitation H...
IND2		RWCP	0004	☐ 0	Clear bit 2	ok	Bit is set if measured inductance was not compliant according to Excitation H...
IND3		RWCP	0008	☐ 0	Clear bit 3	ok	Bit is set if measured inductance was not compliant according to Excitation H...
UVM		RWCP	0010	☒ 1	Clear bit 4	fault	Bit is set if under voltage was detected. Is active after IC startup
COMER		RWCP	0020	☐ 0	Clear bit 5	ok	Bit is set if communication error is detected
OVT		RWCP	0040	☐ 0	Clear bit 6	ok	Bit is set if over temperature was detected
RES0		RWCP	0080	☐ 0	Clear bit 7	ok	Bit is set if measured resistance exceeds R_THLD value of according channel.
RES1		RWCP	0100	☐ 0	Clear bit 8	ok	Bit is set if measured resistance exceeds R_THLD value of according channel.
RES2		RWCP	0200	☐ 0	Clear bit 9	ok	Bit is set if measured resistance exceeds R_THLD value of according channel.
RES3		RWCP	0400	☐ 0	Clear bit 10	ok	Bit is set if measured resistance exceeds R_THLD value of according channel.

Solenoid Sequencer

- All levels can be controlled in voltage or current
- RAMP control for all ramp sections
- HSnLS only in Single-Ended Configuration
- Fast Demagnetisation (DC_H2L and H2L_EN) only in Full-Bridge



Current and PWM Channel Configuration

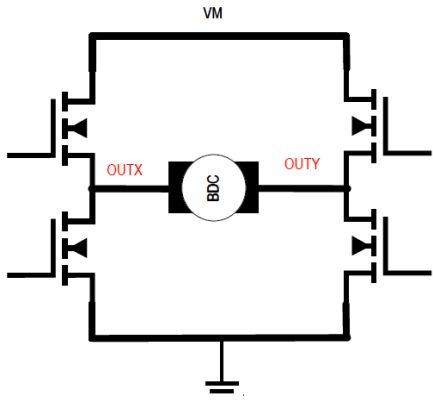
- I_MONITOR – Channel Current
- SNSF and GAIN – Current Scaling
- F_PWM – Channel PWM Divider (up to 1/8)
- PWM_DUTYCYCLE – Output Duty cycle

Full Scale and Sense Scale

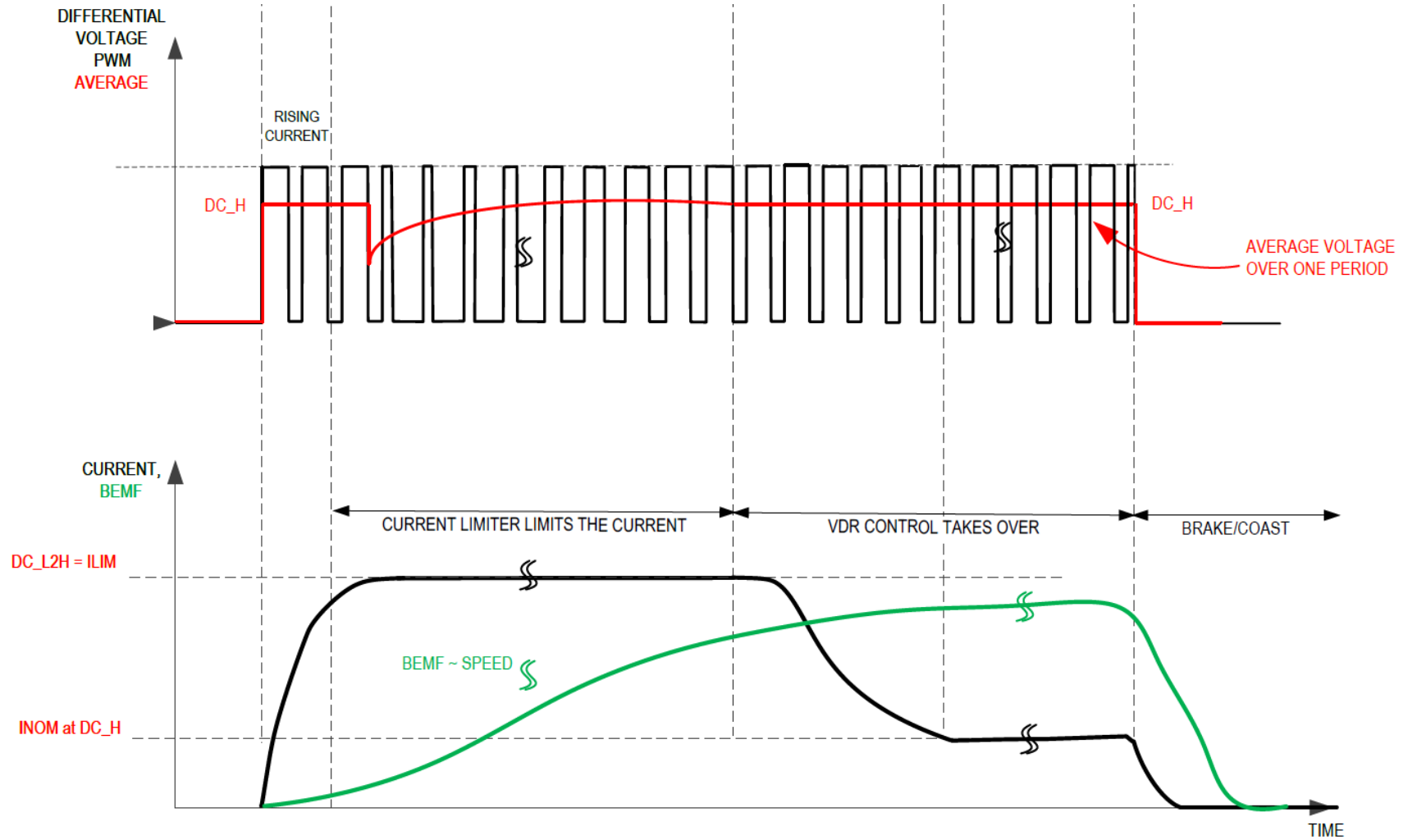
GAIN [1:0]	GAIN	SNSF [1:0]	SNSF	TYP. LS R _{ON} (Ω)	TOTAL FACTOR	MULTIPLIER	MAX CURRENT (A)
00	1	00	1	0.17	1	1.00	4.165
01	1/2				1/2	0.5	2.082
10	1/3				1/3	0.333	1.388
11	1/4				1/4	0.25	1.041
00	1	01	2/3	0.23	2/3	0.667	2.776
01	1/2				2/6	0.333	1.388
10	1/3				2/9	0.222	0.925
11	1/4				2/12	0.167	0.694
00	1	10	1/3	0.43	1/3	0.333	1.388
01	1/2				1/6	0.167	0.694
10	1/3				1/9	0.111	0.463
11	1/4				1/12	0.083	0.347

CFG_CTRL1_0 0x0E	RWP	16	0x0000	0x0000	CFG_CTRL1
SNSF	RWP	0003	id: 0	Choice ↓	0: IFS Sets the Sense Scaling Factor
GAIN	RWP	000C	id: 0	Choice ↓	0: 1 Sets a a digital GAIN for the Current Driver Regulation (CDR)
SLEW_RATE	RWP	0030	id: 0	Choice ↓	0: Fast Slew rate control bits
T_BLANKING	RWP	00C0	id: 0	Choice ↓	0: 0us Defines an additional blanking time for current measurement.
F_PWM	RWP	0300	id: 0	Choice ↓	0: F_P... Defines the PWM frequency that is used for the channel. See Table 5
HSNLS	RWP	0400	☐ 0 ☒ Set bit 10	LS	HS/LS: Bit Single Ended Mode Only
I_MONITOR_0 0x45	R	16	0xFFFF		I_MONITOR
I_MONITOR	R	FFFF	-1		I_MONITOR Instantaneous current sampled Current sampled. Returns ...

DC Motor Drive



- ▶ CDR to limit inrush current
- ▶ VDR for easy control
- ▶ TIME_L2H is a BRAKE



BEMF/DPM Tuning – Detection of Plunger Movement

BEMF/DPM Tuning @MAX22216-EVAL <1st Axis>

Control

Activate Coil Deactivate Coil

Abort Download

☒ Run measurement

☒ Deactivate coil immediately

General Settings

TIME_L2H 0.00 [ms]

DPM_EN ☐ DPM_EN

END_HIT_AUTO ☐ END_HIT_AUTO

Slider Values

DPM_START 0.00 [mA]

DPM_THLD 0.00 [mA]

DPM_MIN_NBR 0 [PWM Cycles]

Measurements

L_DPM_PEAK 0.00 [mA]

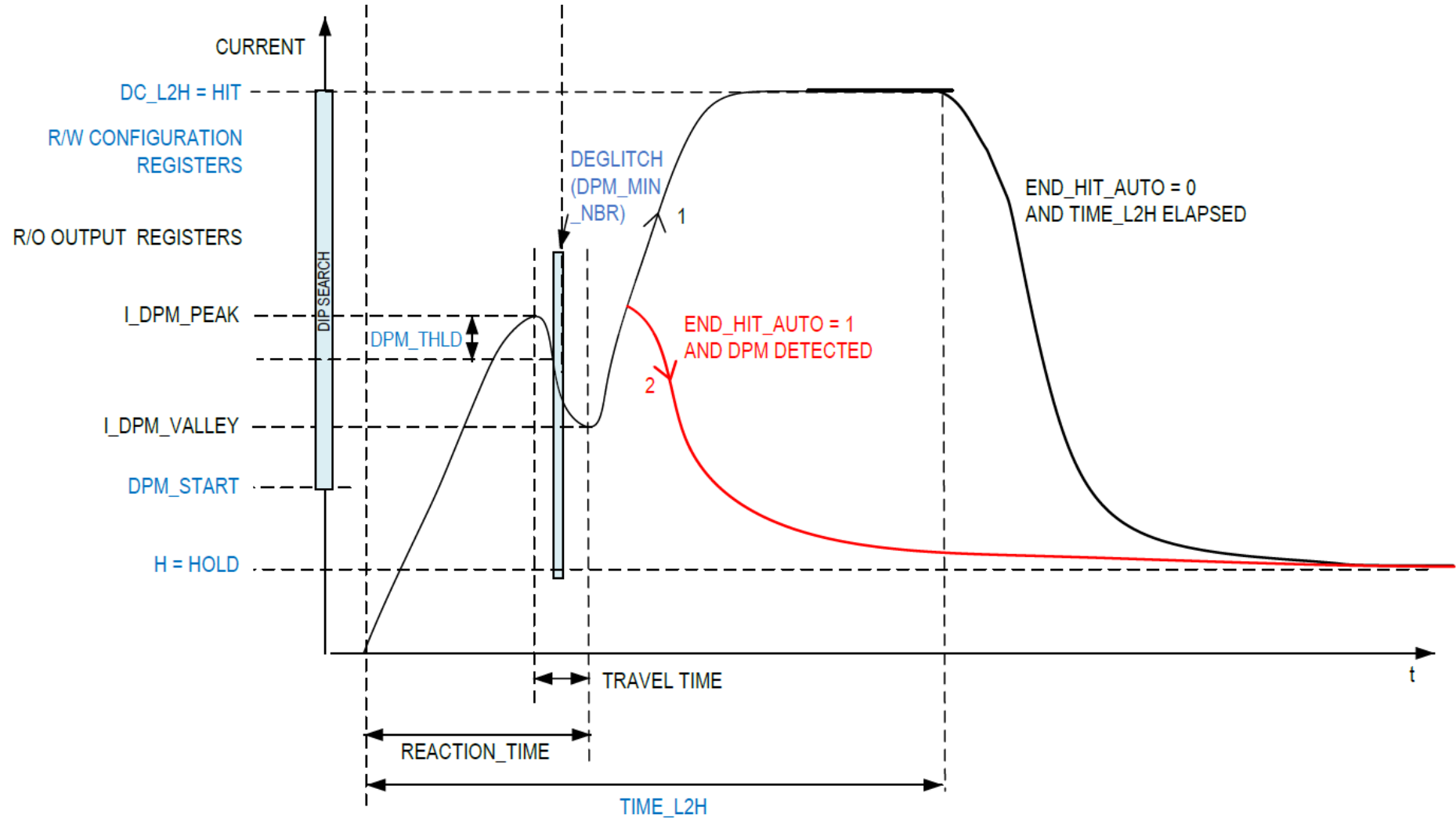
L_DPM_VALLEY 0.00 [mA]

REACTION_TIME 0.00 [ms]

TRAVEL_TIME 0.00 [ms]

Capture Period 32768 [PWM Cycles]

Idle



Solenoid Inductance

Solenoid Inductance @MAX22216-EVAL <1:

L_{AC}

L

R

RES_THLD

IAC_THLD

U_{AC}

F_{AC}

Coil Control

L_MEAS_EN ☐ L_MEAS_EN

L_MEAS_L2H ☐ L_MEAS_L2H

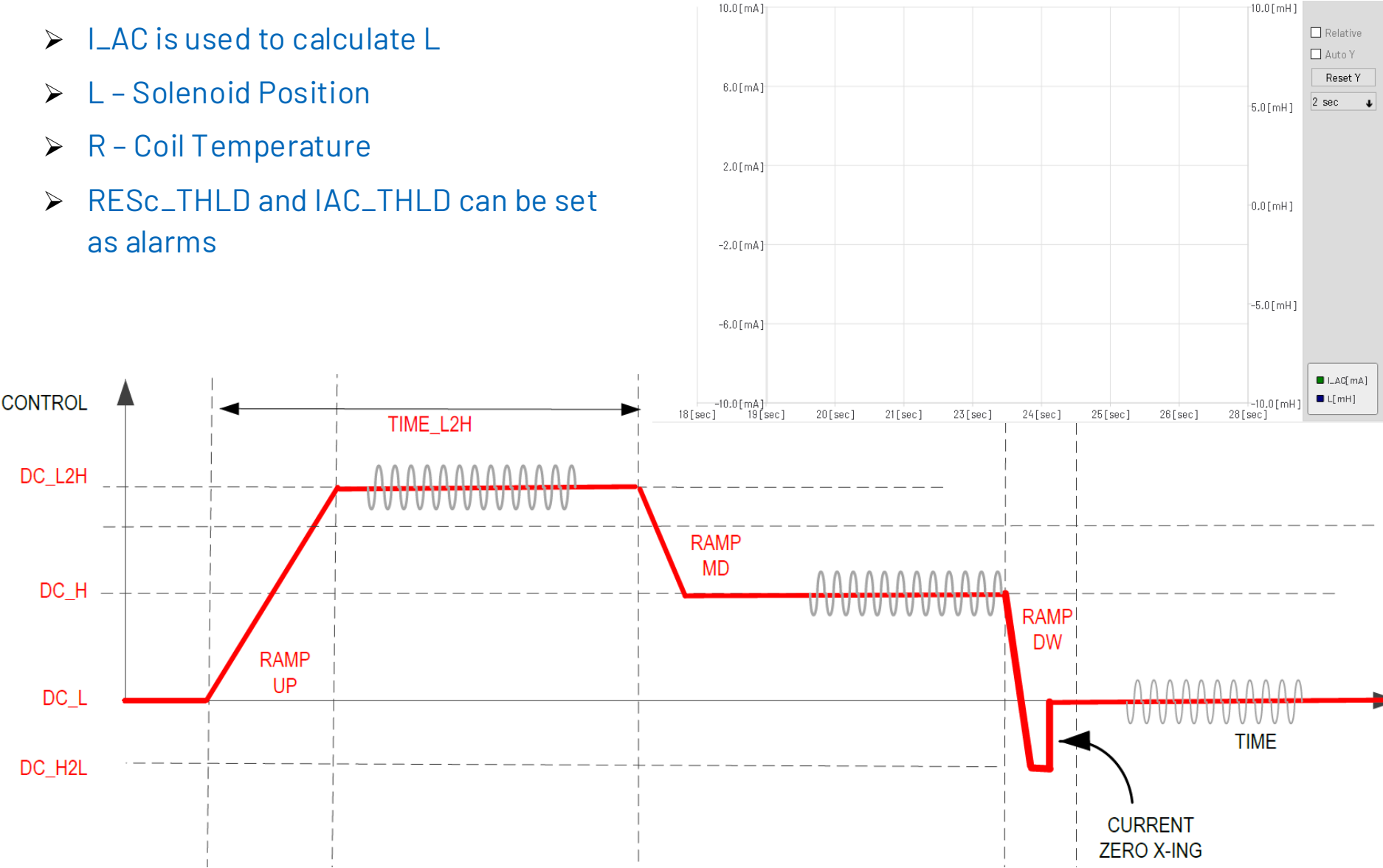
L_MEAS_H ☐ L_MEAS_H

L_NBR_CALC

L_MEAS_WCYCLES

DITH_EN ☐ DITH_EN

- I_{LAC} is used to calculate L
- L – Solenoid Position
- R – Coil Temperature
- RES_{Sc}_THLD and IAC_THLD can be set as alarms



Settable Faults



- ▶ Open-Load Detection (OL)
- ▶ Hit current not reached Alarm (HHF) - CDRc

▼ Active registers						
▼ ☒ CFG_CTRL0_0 0x0D	RWP	16	0x0000	0x0000	• CFG_CTRL0	
RAMP	RWP	00FF	0	Unsigned ↓	Sets the Ramp up Slew Rate	
RUPE	RWP	0100	☐ 0	☒ Set bit 8	disabled	Ramp UP enable
RMDE	RWP	0200	☐ 0	☒ Set bit 9	disabled	Ramp Mid Enable bit
RDWE	RWP	0400	☐ 0	☒ Set bit 10	disabled	Ramp Down Enable bit
H2L_EN	RWP	0800	☐ 0	☒ Set bit 11	disabled	H2L Fast Demagnetization Enable bit. "1" enforces DC_H2L after CNTL H2L ...
OL_EN	RWP	1000	☐ 0	☒ Set bit 12	disabled	Open Load Circuit Enable (enable pull up/dw)
HHF_EN	RWP	2000	☐ 0	☒ Set bit 13	disabled	Current not reached Fault detection
CTRL_MODE	RWP	C000	id: 0	Choice ↓	0: VDR/... Control mode setting	
▼ ☒ I_MONITOR_0 0x45	R	16	0x0001	• I_MONITOR		
I_MONITOR	R	FFFF	1	I_MONITOR Istantaneous current sampled Current sampled. Returns Late...		

Software Platform (BLDC)

3-phase BLDC Motor

➤ Basics:

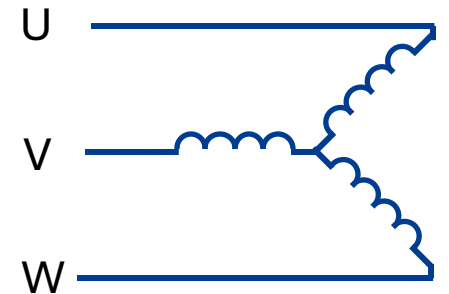
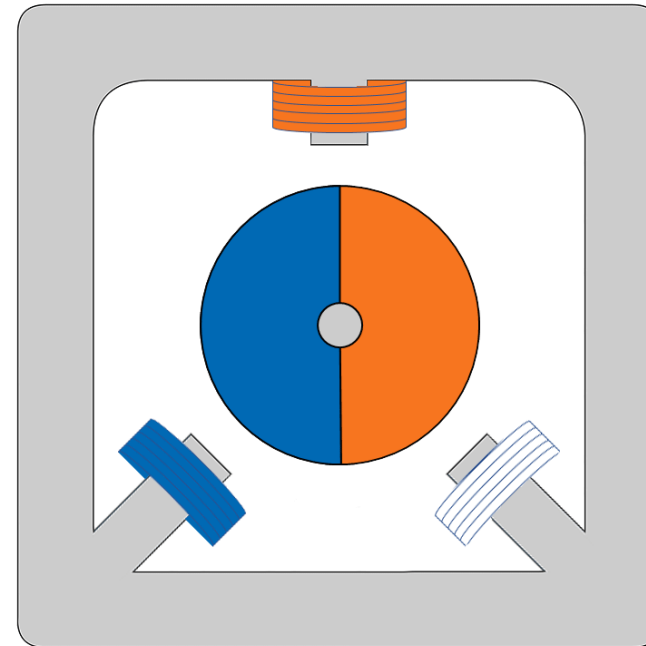
- Three motor phases : U, V, W

➤ Sequential energizing:

- Coils need to be energized in a specific sequence

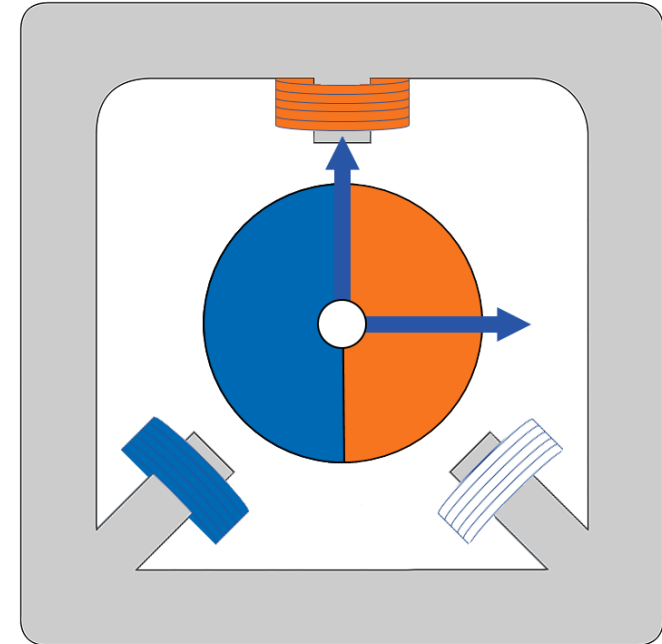
➤ Benefits:

- High velocity
- Precise RPM control



Field Oriented Control (FOC)

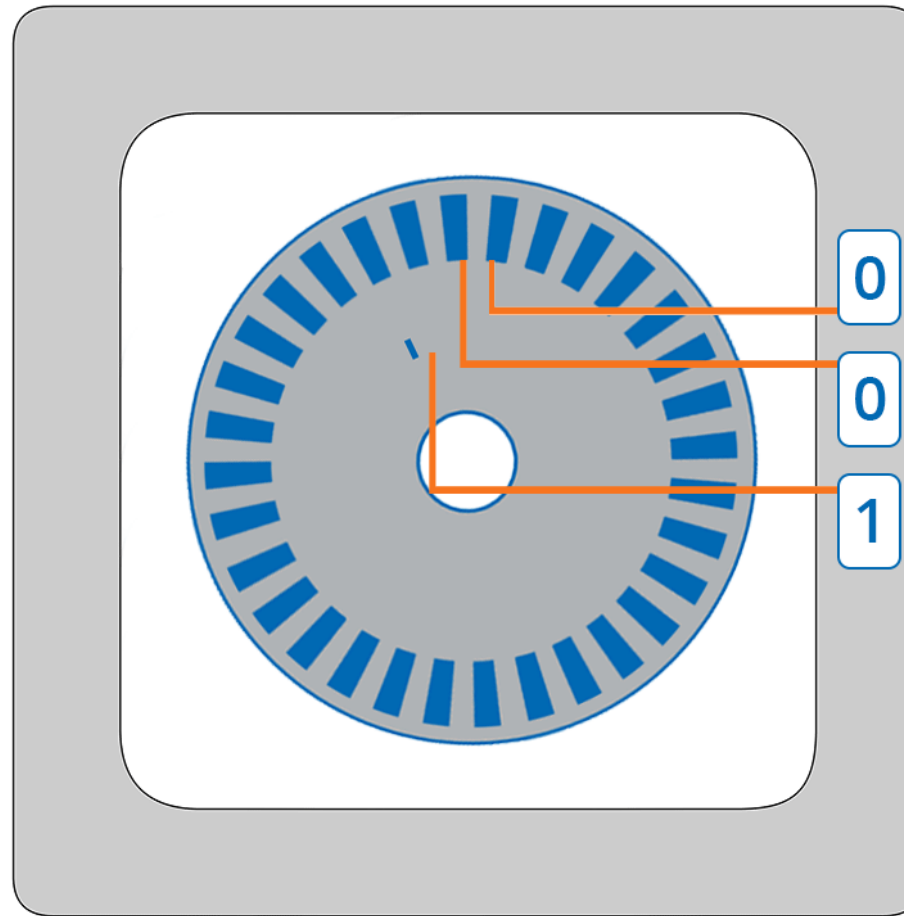
- **What is FOC:**
 - A method to apply the optimal current to the coils.
- **What is needed for FOC:**
 - We need to know the rotor position. Feedback required.
- **What is a Torque (Current):**
 - A coil current that pulls the motor into the turning direction.
- **What is a Flux (Current):**
 - A coil current that pulls the motor into the current angle position.



ABN - ENCODER

When to use:

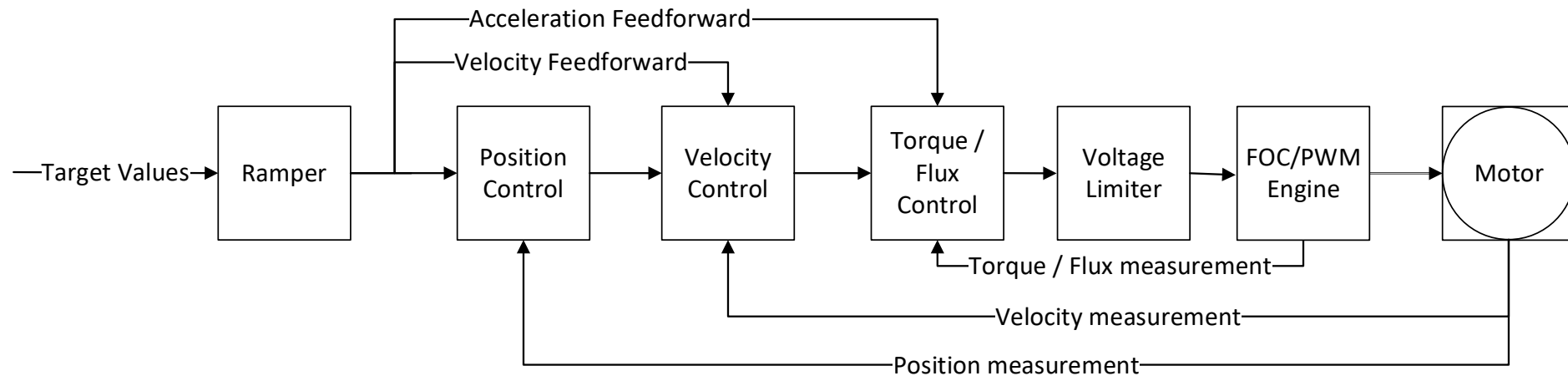
- High resolution
- Every motor type
- Initialization required



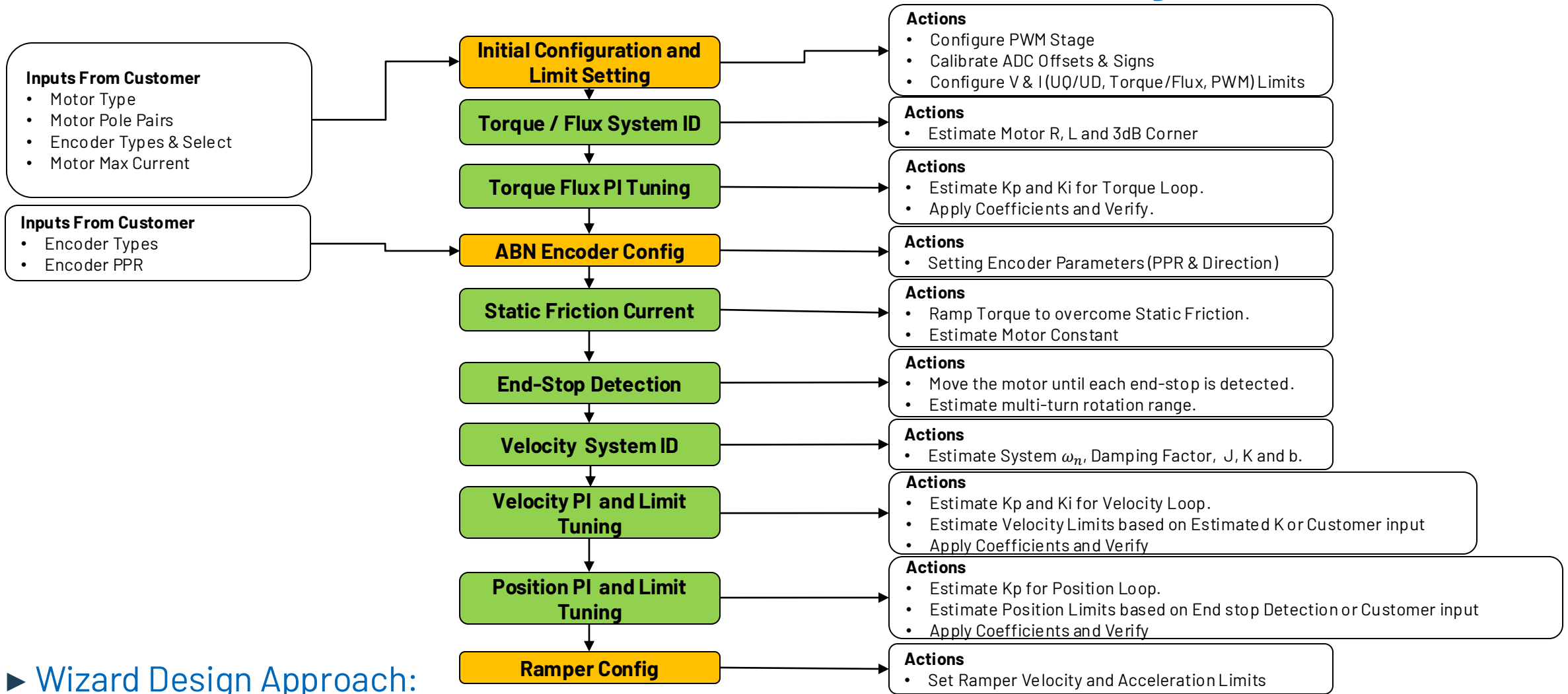
TMC9660: Motor Control Structure

Control Structure Includes:

- Cascaded control system
 - Torque / Flux Controller
 - Velocity Controller
 - Position Controller
- Further Info:
 - [TMC9660 Parameter Mode Reference Manual](#)



TMCL-IDE Brushless Motor Control Auto Tuning Flow



► Wizard Design Approach:

- Assume Minimal Customer Input – System does most of the work.
- At each step in the process, the system learns more about the Motor and Mechanical System.
- Customers can repeat and iterate on individual steps as required.

Setup TMC9660 for BLDC Motors



Wizard Pool

COM10/USB/id1/LandungsbrueckeV3/TMC9660-STEPPER-PARAM-EVAL [M1]

[Beta]TMC9660 configurator wizard (TR5W)(1/7)

Application Setup

1. Specify your motor

Motor type: 3: BLDC motor

Pole pairs: 4

PWM frequency: 25KHz

is Hall Connected: ☐ Yes ☒ No

is ABN Connected: ☒ Yes ☐ No

Limits

Output voltage limit: 18.900

Maximum Torque: 1000 [mA]

Maximum Flux: 1000 [mA]

Maximum Velocity: 134.217727 [internal]

Brake chopper

Enable Chopper: ☐ BRAKE_CHOPPER_ENABLE

Voltage Threshold: 700 [0..1V]

Voltage Hysteresis: 10 [0..1V]

Info

Welcome to the TMC9660 parameter mode wizard.

This wizard will help you configure the basics of motor control. This includes the configuration of the following items:

- General configuration
- Current shunt amplifier (CSA) and ADC
- Automatic or manual setup of current PI controller (Torque and Flux loop)
- Hall feedback (if applicable)
- ABN feedback (if applicable)
- Automatic or manual setup of velocity PI controller

Apply the defaults for your EVAL board and motor.

Below you find the default values for the evaluation boards offered. Select a set of default values for your EVAL and motor.

TMC9660-STEPPER-EVAL

BLDC Stepper

TMC9660-3PH-EVAL

Please specify the following values in any case:

- Current Limits
- Feedback: Is an ABN encoder connected?
- Feedback: Is a Hall encoder connected (BLDC only)?
- Is a brake chopper connected? If yes, specify the voltage threshold and hysteresis.

If the used MOSFETs and gate configuration diverge from the offered evaluation preset, you might need to configure the gate driver in the settings tool.

Application: Application: ADC config: Current P&I: ABN enc: Velocity P&I:

Next

1. Select BLDC Motor

2. Set ABN IS Connected.
2a Set Hall IS Disconnected

3. Set BLDC Maximum Torque and Flux Currents = 2000 mA

4. Move to next Wizard Page

Shunt and Current Sense Amplifier (CSA) Configuration.



Wizard Pool

COM10/USB/id1/LandungsbrueckeV3/TMC9660-STEPPER-PARAM-EVAL [M1]

[Beta] TMC9660 configurator wizard (TR5W) (2/7)

CSA and ADC configuration I

Info

This page helps to set the current scaling factor and the current shunt amplifier (CSA) gain. The TMC9660 parameter mode supports scaling all current related values to real world units. The parameter current scaling factor must be calculated based on the current shunt resistor and selected CSA gain. Use the calculation box on this page to calculate the current scaling factor.

For Stepper and BLDC motors the both peak to peak (PP) or root mean square (RMS) values can be used. Both have different formulas that can be found below.

$$Factor_{mA\ PP} = \frac{1024 \times 2.5 \times 1000}{(2^{16} - 1) \times G_{CSA} \times R_{shunt}} = \frac{39.06}{G_{CSA} \times R_{shunt}} \quad Factor_{mA\ RMS} = \frac{1024 \times 2.5 \times 1000}{\sqrt{2} \times (2^{16} - 1) \times G_{CSA} \times R_{shunt}} = \frac{27.62}{G_{CSA} \times R_{shunt}}$$

Calculation

This calculator helps to set up the current scaling factor and correct the current limits after that.

Instructions:

1. Select if the currents should be in RMS or peak to peak. Specify the resistance of the shunt resistors in mΩ depending on the PCB. Then specify the gain of the internal CSA depending on the currents expected and the shunt resistors. The maximum ADC input voltage is ±1.25V.
2. The tool calculated a maximum allowed current and a current scaling factor. Click "Apply" to write the current scaling factor to the system.
3. When changing the current scaling factor the maximum torque and flux values must be rewritten again to still be correct. The "Reapply Maximum Current" box shows you the current parameter values. Press "Apply" to correct the maximum values back to the previous maximum torque and flux. The active maximum torque and flux represent the values currently active in the system.

Shunt values for the standard evaluation boards:

- TMC9660-3PH-EVAL: R Shunt = 3 mΩ; Recommended CSA: 10x
- TMC9660-STEPPER-EVAL = 10 mΩ; Recommended CSA: 10x

1. Configuration

Measurement Type: Peak to Peak
R Shunt: 10.000 [mΩ]
Select CSA gain: 1: 10x
CSA Gain I0 to I2: 1: 10x
CSA Gain I3: 1: 10x

2. Current Scaling factor

Max Allowed Current: ±12 [A]
Calculated Factor: 390 [mA]
Active Factor: 391

3. Reapply Maximum Current

Original Max Torque: 1000 [mN]
Original Max Flux: 1000 [mWb]
Active Max. Torque: 1000 [mN]
Active Max. Flux: 1000 [mWb]

1. Make sure that Shunt Resistance to 10 mOhms

2. Apply Current Scaling Factor and Maximum Current Normalization Settings.

3. Move to next Wizard Page

Application: ADC config: Current P&I: ABN enc: Velocity P&I:

Navigation buttons

ADC Inversion Configuration & Test – BLDC Motor

1. Set Duty Cycle = 500, Target Velocity = 10,000, Press Play to actuate Motor Voltages.

2. Select ADC Inputs and Inverted signals to ensure that ADC and FOC_VOLTAGE Values are in Phase.

3. Move to next Wizard Page

The screenshot displays the TMC9660 configurator wizard interface. The top section, '1. Control', contains input fields for 'Duty cycle' (set to 500) and 'Target Velocity' (set to 5000), with a play button to the right. The middle section, '2. ADC setup', includes an 'Inversion' table with checkboxes for 'ADC_I0_INVERTED', 'ADC_I1_INVERTED', and 'ADC_I2_INVERTED', all of which are checked. To the right is a 'Phase mapping' table with entries for UX1, VX2, and WY1, each mapped to a specific ADC channel. The bottom section, '3. ADC mapping response', features three graphs: 'FOCVoltageUX & ADC[UX]', 'FOCVoltageV & ADC[VX2]', and 'FOCVoltageWY & ADC[WY1]'. Each graph plots two signals: a green line representing the FOC voltage and a red line representing the ADC input. The graphs show the signals over time, with the green line oscillating and the red line following its phase. At the bottom of the wizard, a navigation bar includes a home icon and a series of buttons for different configuration steps: Application, ADC config, Current P&I, ABN enc, and Velocity P&I. The 'ADC config' button is highlighted with a green circle and an arrow pointing to it from the text '3. Move to next Wizard Page'.

Current Loop System Identification and Tuning

- Perform Motor R, L System Identification

Wizard Pool

COM10/USB/id1/LandungsbrueckeV3/TMC9660-STEPPER-PARAM-EVAL [M1] [Beta] TMC9660 configurator wizard (TR5W) (4/7)

Current P&I Configuration

This page automatically tunes the current control loop. Please follow the steps one by one on this page.

Note:

- The system will automatically power the motor, but no movement is expected.
- The general setup from previous pages must be completed.
- It is always possible to test the system response to a flux step using the box below.

1. Select Find Parameters to Measure Motor R/L Values, Waveform updates when done.

Current P&I Tuning

☐ Manual ☒ Auto

Step 1 - Define maximum current and find Tuning parameters R, L and -3dB

Max Flux: 1000[mA] Duty cycle ramp Flux target 75% = 750[mA] **Find Parameters**

Step 2 - Found Parameters and Current PI Values - Fine tune Current PI values using the bandwidth slider

Average Flux of 67[mA] at 2992 Duty cycles

Resistance 5.818574[Ω] Inductance 0.011082[H] Motor Corner Frequency 83.560747[Hz]

Desired Torque/Flux loop bandwidth 30% = 1587.65[Hz]

10x 83.560747[Hz] 30x 83.560747[Hz]

Step 3 - Apply Torque and Flux PI values

Found Torque/Flux P&I

P: 2933 P Norm: ☐ I: 15785 I Norm: ☒

Active Torque/Flux P&I

P: 50 P Norm: 0: 8 bit shift I: 100 I Norm: 1: 16 bit shift

Test Flux response

Max Flux: 1000[mA] Open Loop Flux Target: 75% = 750[mA] Start Test

Maximum measured current 0[mA]

OpenLoop Flux Step response

Max measured current OPENLOOP_VOLTAGE TARGET_FLUX ACTUAL_FLUX

Value

Measurement tick

Time

1a. R, & Motor Corner Frequency Values Update.

Application: ☐ ADC config: ☐ Current P&I: ☒ ABN enc: ☐ Velocity P&I: ☐

Apply PI (Proportional-Integral) Tuning Values and Test Flux Current Loop

Wizard Pool

COM10/USB/id1/LandungsbrueckeV3/TMC9660-STEPPER-PARAM-EVAL [M1]

[Beta] TMC9660 configurator wizard (TR5W)(4/7)

Current P&I Configuration

This page automatically tunes the current control loop.
Please follow the steps one by one on this page.

Note:

- The system will automatically power the motor, but no movement is expected.
- The general setup from previous pages must be completed.
- It is always possible to test the system response to a flux step using the box below.

Current P&I Tuning

Manual

Auto

Step 1 - Define maximum current and find Tuning parameters R, L and -3dB

Max Flux: 1000 [mA]

Duty cycle ramp Flux target 75% = 750 [mA]

Find Parameters

Step 2 - Found Parameters and Current PI Values - Fine tune Current PI values using the bandwidth slider

Average Flux of 677 [mA] at 2992 Duty cycles

Resistance : 5.818574 [Ω]

Desired Torque/Flux loop bandwidth 30.1% = 1590.16 [Hz]

Inductance : 0.011082 [H]

Motor Corner Frequency : 83.560747 [Hz]

10x 83.560747 [Hz] 30x 83.560747 [Hz]

Step 3 - Apply Torque and Flux PI values

Found Torque/Flux P&I

Active Torque/Flux P&I

Test Flux response

Max Flux: 1000 [mA]

Open Loop Flux Target: 75% = 750 [mA]

Start Test

OpenLoop Flux Step response

Max measured current

OPENLOOP_VOLTAGE

TARGET_FLUX

ACTUAL_FLUX

Application: ☐ ADC config: ☐ Current P&I: ☒ ABN enc: ☐ Velocity P&I: ☐

Navigation icons

86

©2026 Analog Devices, Inc. All rights reserved.

Optional: Adjust Current Loop Bandwidth

Wizard Pool

COM10/USB/id1/LandungsbrueckeV3/TMC9660-STEPPER-PARAM-EVAL [M1]

[Beta] TMC9660 configurator wizard (TR5W)(4/7)

Current P&I Configuration

This page automatically tunes the current control loop.
Please follow the steps one by one on this page.

Note:

- The system will automatically power the motor, but no movement is expected.
- The general setup from previous pages must be completed.
- It is always possible to test the system response to a flux step using the box below.

Current P&I Tuning

Manual

Auto

Step 1 - Define maximum current and find Tuning parameters R, L and -3dB

Max Flux: 1000 [mA]

Duty cycle ramp Flux target 75% = 750 [mA]

10% 90%

Find Parameters

100%

Step 2 - Found Parameters and Current PI Values - Fine tune Current PI values using the bandwidth slider

Average Flux of 677 [mA] at 2992 Duty cycles

Resistance : 5.818574 [Ω]

Inductance : 0.011082 [H]

Motor Corner Frequency : 83.560747 [Hz]

Desired torque/Flux loop bandwidth 30.1% = 1590.16 [Hz]

10x 83.560747 [Hz] 30x 83.560747 [Hz]

Step 3 - Apply Torque and Flux PI values

Found Torque/Flux P&I

P: 2942 P Norm: ☐

I: 15835 I Norm: ☒

Apply

Active Torque/Flux P&I

P: 2933 P Norm: 0: 8 bit shi

I: 15785 I Norm: 1: 16 bit shi

Reset Defaults

Test Flux response

Max Flux: 1000 [mA]

Open Loop Flux Target: 75% = 750 [mA]

10% 90%

Start Test

100%

Maximum measured current 804 [mA]

OpenLoop Flux Step response

Max measured current OPENLOOP_VOLTAGE TARGET_FLUX ACTUAL_FLUX

Application: ☐ ADC config: ☐ Current P&I: ☒ ABN enc: ☐ Velocity P&I: ☐

◀ ▶

87 ©2026 Analog Devices, Inc. All rights reserved.

Configure and Test ABN Encoder Setup

Wizard Pool

COM10/USB/id1/LandungsbrueckeV3/TMC9660-STEPPER-PARAM-EVAL [M1] [Beta] TMC9660 configurator wizard (TR5W) (5/7)

Encoder configuration

This page configures and checks the ABN encoder.
An ABN encoder can be used to determine the motor shaft angle. This page helps to configure the basics to get the system running. The motor will be slowly turned in open loop current mode. The ABN measurement must move in the same direction with the same speed.

Please follow the steps:

1. Use the control panel to rotate the motor in open loop. Try a slow velocity of 5000.
2. Check the open loop angle in the diagram. The dot should move around the circle.
3. Configure the direction and the ABN encoder steps. The two dots must move in the same direction with the same speed.
4. If the ABN sensor is not moving, check the wiring and the initial IO configuration.
5. If the ABN sensor is set up correctly, you can stop the motor and proceed to the next page.

Control

Openloop current: 1000 [mA]

Target Velocity: 10000 [▶] [■]

ABN Direction

☐ ABN_1.DIRECTION

Motor Pole Pairs: 50

Encoder steps: 40000

Estimated encoder steps: 37657

1. Set Current to 50% of Max Current, Target Velocity = 5,000, Press Play.

2. Configure ABN Encoder.

1. Encoder Steps = 4 X Encoder Pulses Per Revolution
2. Adjust ABN1 Direction – red dot should move at the same speed and direction as the blue dot.

3. Encoder Angle should follow OL Angle with the same frequency. Adjust Encoder Parameters if Needed.

4. Move to next Wizard Page

▶Application: ○ ▶ADC config: ○ ▶Current P&I: ○ ▶ABN enc: ● ▶Velocity P&I: ○

◀ ▶

Test Closed Loop Torque Loop

NOTE: Do not do this with an End-Stopped System.

Wizard Pool

COM10/USB/id1/LandungsbrueckeV3/TMC9660-STEPPER-PARAM-EVAL [M1]

[Beta] TMC9660 configurator wizard (TR5W) (6/7)

Drive the motor with an encoder

On this page you can test the commutation with ABN feedback by rotating the attached motor in torque motor.

Please follow the steps:

1. To use this page the motor must be able to spin freely.
2. Configure a small target torque and increase until the motor starts spinning. (Recommended to start with 100mA)
3. If the motor is not spinning as expected return to the previous page. Verify that the ABN sensor setup is correct.

Torque

Velocity

Control

ABN Initialization

System Mode: 5: FOC (ABN)

Initialization Mode: 0: Forced phiLe zero with active swing

Velocity Sensor: 0: Same as commutation

Position Sensor: 0: Same as commutation

Initialize Encoder

Off

Torque

Control

100 [mA]

1. Initialize Encoder

2. Adjust Current and press Play.

3. Turn System Off when done.

4. Move to next Wizard Page

Active P&I

Torque P: 3763 P Norm: ☐

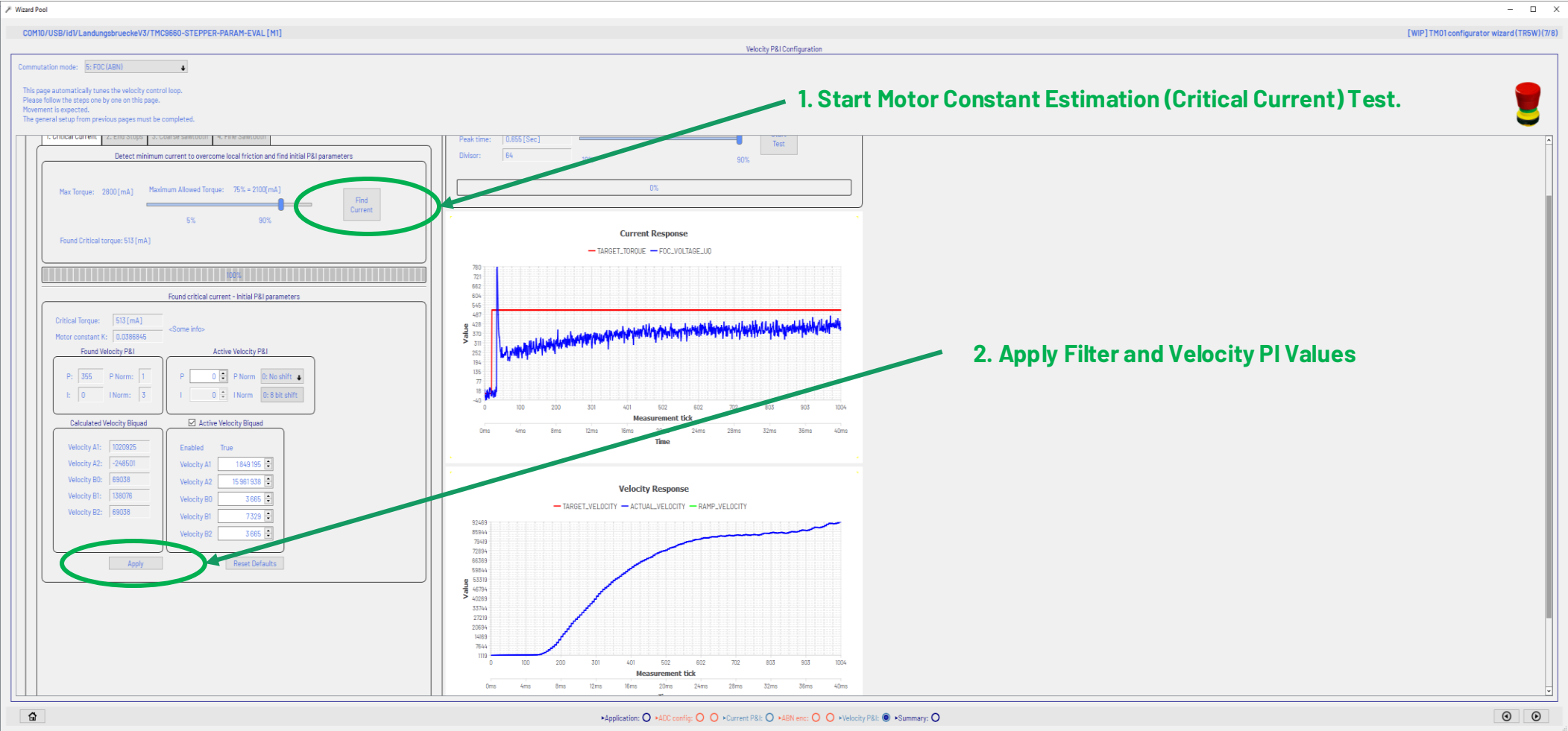
Torque I: 20250 I Norm: ☒

Application: ☐ ADC config: ☐ Current P&I: ☐ ABN enc: ☐ ☒ Velocity P&I: ☐

Navigation buttons: Home, Back, Forward, Stop

Velocity & Position Loop System Identification & PI Tuning

Step #1: Detect Static Friction Current and Initial Motor Constant Estimation.



Velocity & Position Loop System Identification & PI Tuning

Step #2: Acceleration Limit Estimation – Matches Target Velocity Acceleration Profile to Load Response.

1. Move to next Tab (Acceleration Limit) when done.

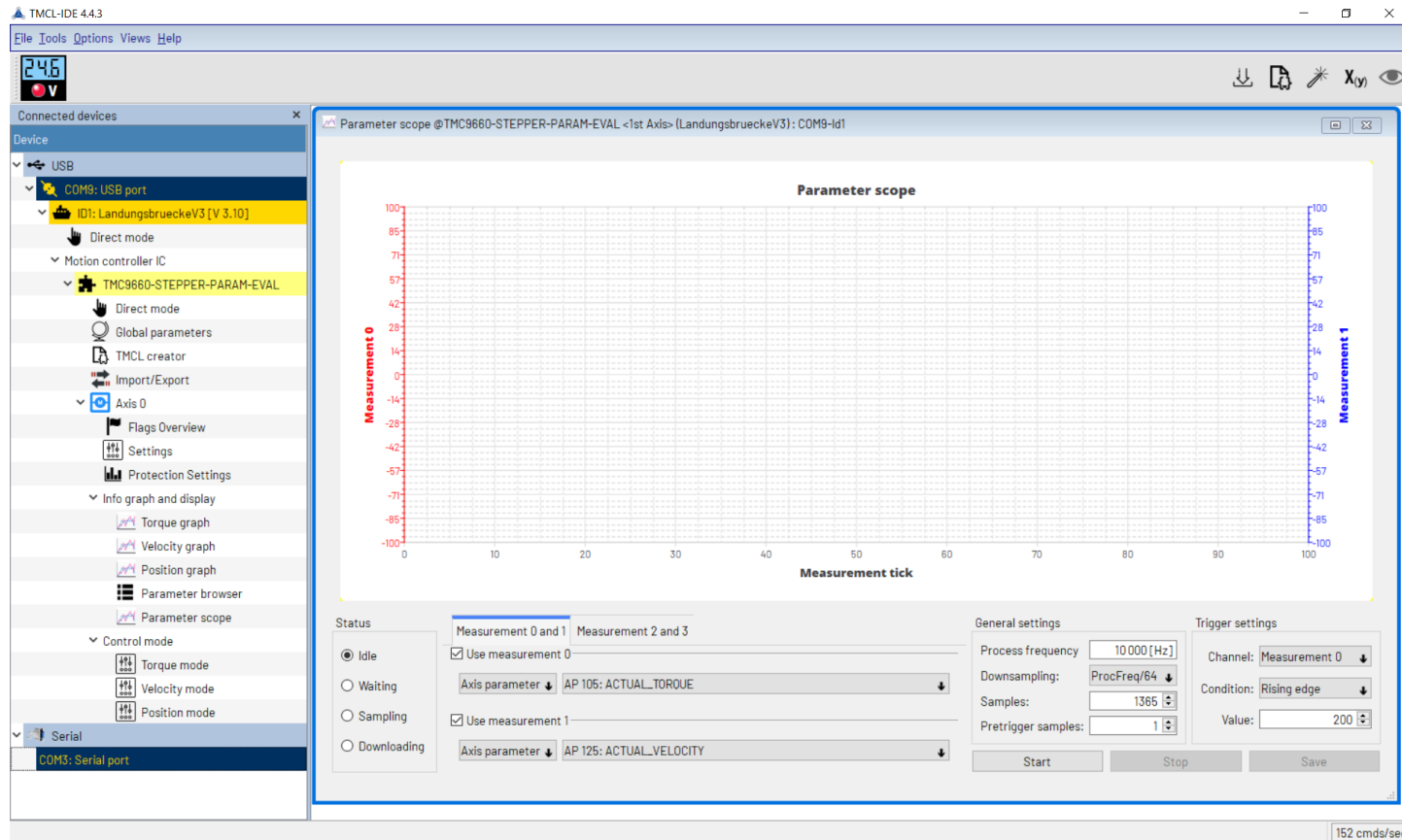
2. Run Acceleration Limit Test

3. Apply Filter and Velocity PI Values

1. At any point, a test with the latest settings can be run.

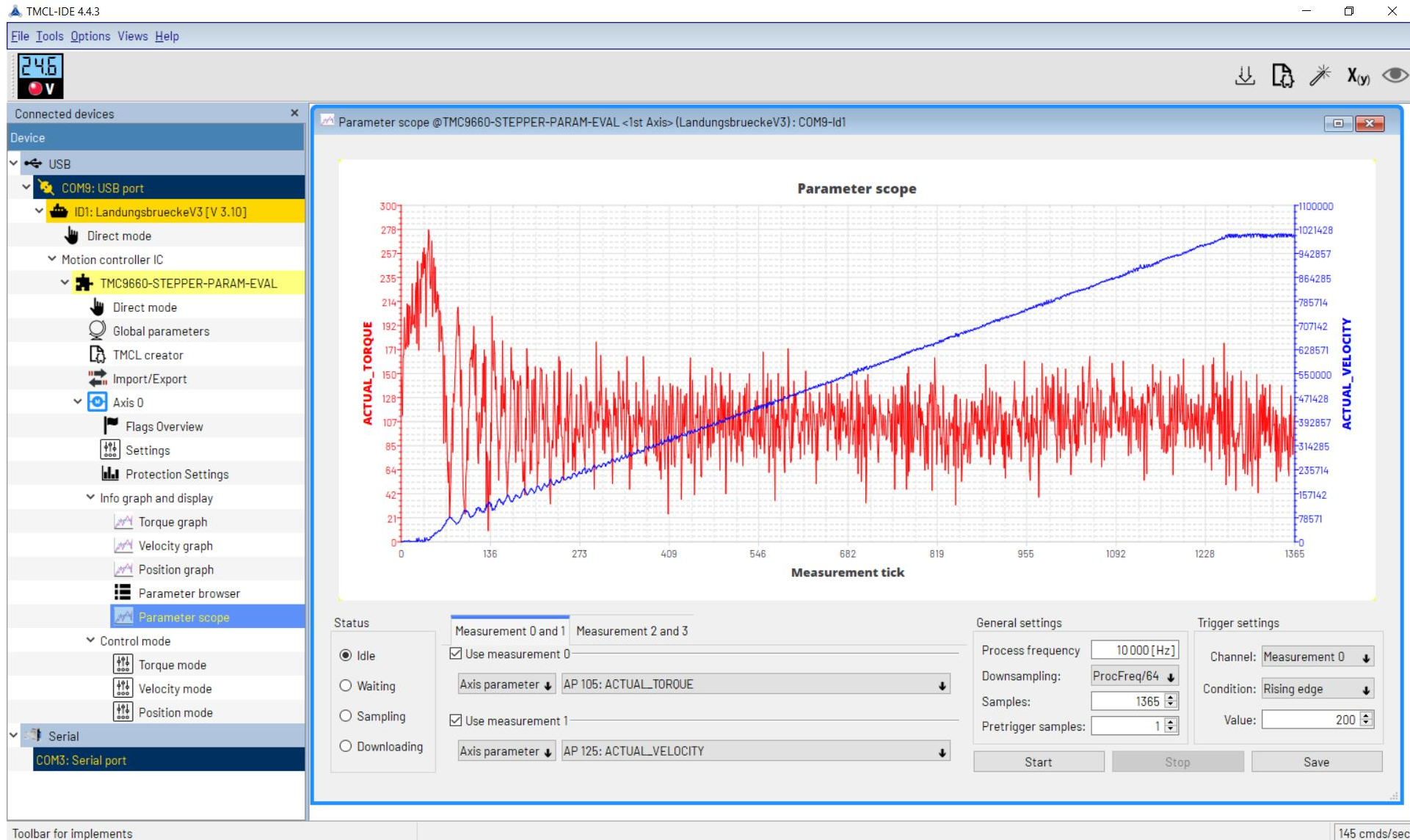
2. Make sure that the Apply button has been applied to get the latest settings.

RAMDebug: TMCL-IDE tool



- Measurement mechanism available in various ADI Trinamic products
- On-chip data acquisition
- 4 measurement channels
- Up to 25 kHz sampling frequency
- Edge-based trigger mechanism
- TMC9660: Up to 8192 total samples

RAMDebug: Measurement result



AHEAD OF WHAT'S POSSIBLE

analog.com



Presentation Feedback

