

MOTOR CONTROL MADE EASY

PHILIP DRAKE

SYSTEMS ENGINEER

NXP MICROCONTROLLERS

AMF-DES-T2638 | JUNE 2017



SECURE CONNECTIONS
FOR A SMARTER WORLD

NXP and the NXP logo are trademarks of NXP B.V. All other product or service names are the property of their respective owners. © 2017 NXP B.V.
PUBLIC



AGENDA

- Kinetis V Series MCUs Introduction
- Kinetis Motor Suite (KMS) Overview
- KMS Demonstration
- KMS: The Technology
- KMS Products and Roadmap





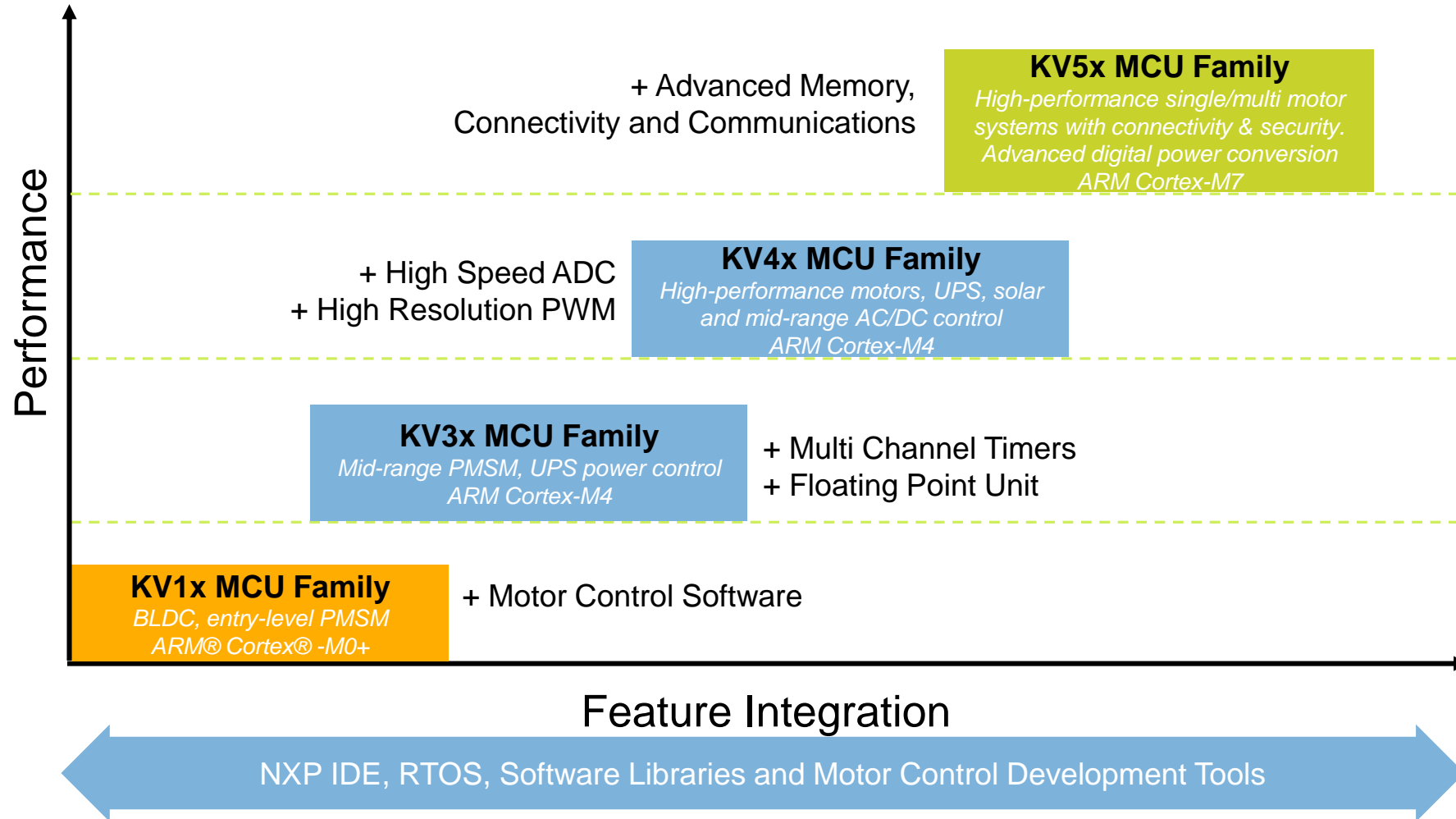
Kinetis V Series MCUs Introduction

Kinetis V Series MCUs for Motor Control

- NXP's **extensive motor control expertise** and the latest ARM Cortex-M0+, M4 and M7 cores bring secure, connected, high efficiency motor control to the mass market
- **Efficient, next generation** BLDC, PMSM and ACIM designs are enabled by optimized MCU performance and high speed/resolution analog and timing peripherals.
- **Performance and feature scalable** MCU families from entry-level 75MHz MCUs, to advanced 240MHz MCUs, maximize hardware & software reuse and end product flexibility
- Enablement including NXP High Voltage and Freedom development boards, Embedded Software Libraries and **Kinetis Motor Suite** reduce motor control learning curve and speed time to market



Kinetis V Series Portfolio



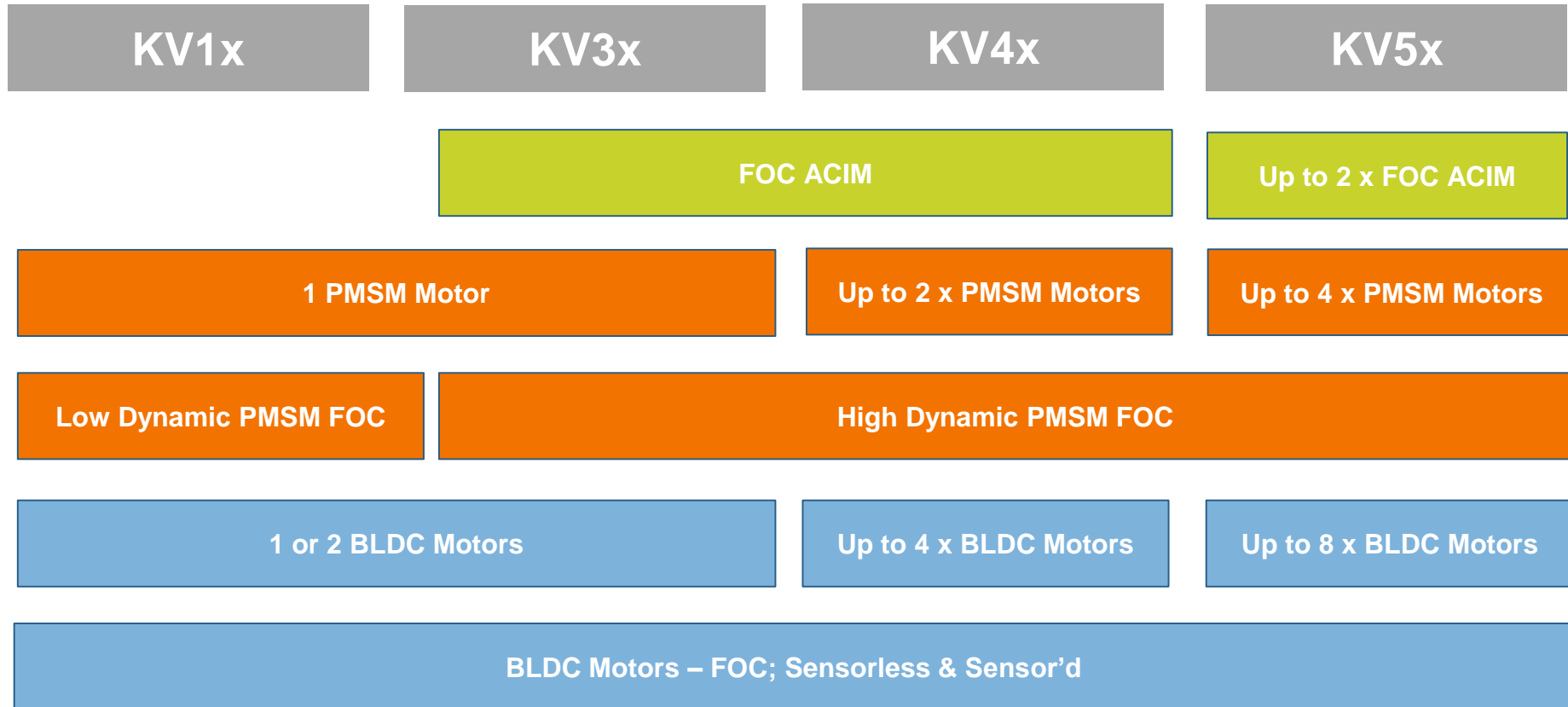
Kinetis V Series: Performance and Feature Scalability

Key Peripherals for Motor Control applications

MCU Family	Core	Memory	Motor Control Timers		ADC	DAC	ACMP	Comms.	Packages	10K unit pricing	Key
			FlexTimer	eFlexPWM							
KV5x	240MHz CM7 DSP + FPU	512kB-1MB Flash	2 x 8ch 1x 2ch FlexTimer	2 x 12ch eFlexPWM + Nano-Edge	4 x 12bit 5Msps, 1 x 16bit	1x 12-bit	4x ACMP with 6-bit DAC	Ethernet, 3 x CAN	144 pin 100 pin	\$4.49 to \$6.70	Common Peripherals
KV4x	168MHz CM4 DSP + FPU	64-256kB Flash	2 x 8ch 1x 2ch FlexTimer	12ch eFlexPWM + Nano-Edge	2x 12bit 4.1Msps	2x 12-bit	4x ACMP with 6-bit DAC	2 x CAN	100 pin 64 pin 48 pin	\$2.19 to \$3.41	Unique Peripherals
KV3x	100/120MHz CM4 DSP + FPU	64-512kB Flash	2x 8ch 2x 2ch FlexTimer	-	2x 16-bit 1.2Msps	2x 12-bit	2x ACMP with 6-bit DAC	-	100 pin 64 pin 48 pin 32 pin	\$1.19 to \$2.76	Unique Peripherals
KV1x	75MHz CM0+ H/W DIV & SQRT	16-128kB Flash	2x 6ch 2x 2ch FlexTimer	-	2x 16-bit 1.2Msps	1x 12-bit	2x ACMP with 6-bit DAC	1 x CAN	64 pin 48 pin 32 pin	\$0.90 to \$1.56	Unique Peripherals

Scalable performance, timing and analog functionality based on application need

Kinetis V – Motor Control Alignment



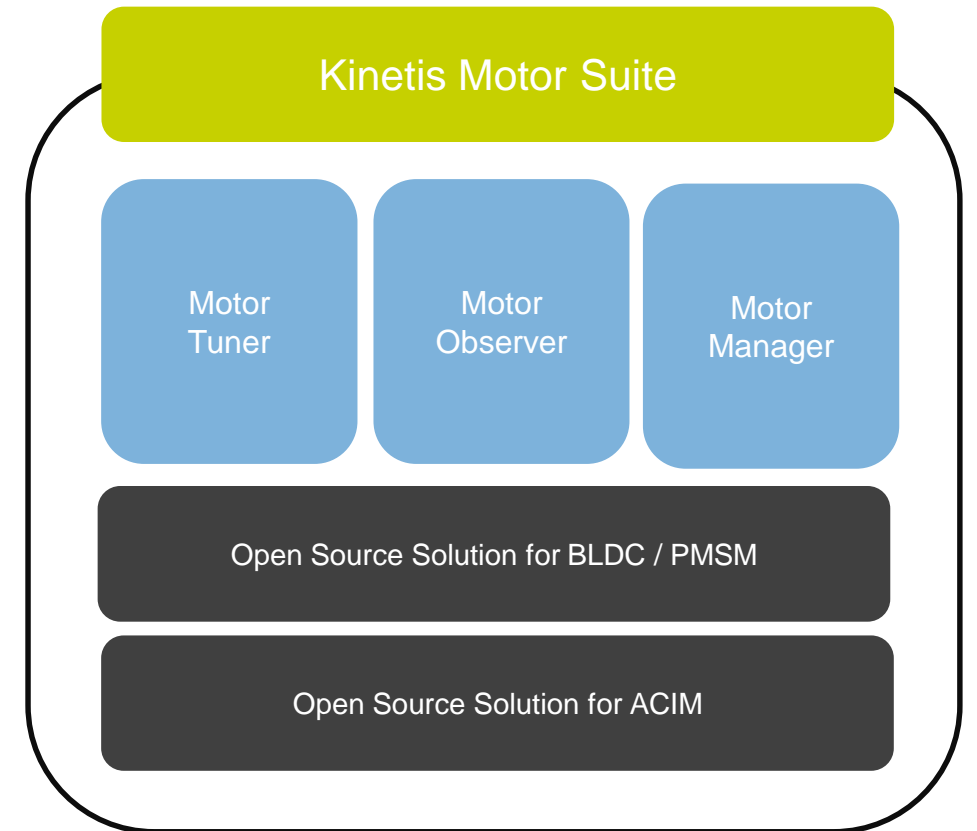


Kinetis Motor Suite Overview

www.nxp.com/KMS

Kinetis Motor Suite

- Kinetis Motor Suite, or KMS, is a software solution that builds on the Kinetis V series MCU portfolio, providing all the low level and middleware software required to tune and control your BLDC and PMSM motors.
- KMS enables you to focus your resources on your end application, removing the complex and time consuming task associated with motor control solution development.



Guiding Principles

Radical Simplicity

Pre-programmed, on-chip expertise
connected to streamlined user
interface

Powerful Performance

Proprietary disturbance
compensating control from
LineStream Technologies

Designed for Everyone

Enables any developer, regardless of
experience, to efficiently run a motor
out of the box

Kinetis Motor Suite Graphical User Interface

Kinetis Motor Suite: C:\Users\rxaa60\Documents\KMS_1.0.1\SavedProjects\FRDMKV31F_SNLESSVEL_KDS_1_0_1_211(1)\FRDMKV31F_SNLESSVEL_K...

File Project View **Motor Tuner**

1) Enter the Basics 2) Measure Motor 3) Measure Inertia 4) Spin! 5) Simulate Application 6) Next Steps

1) Enter your motor's basic information

The default values in the fields below are for the reference motor for this development platform. Overwrite the default values using values found on your motor's nameplate or datasheet.

Motor Name	Linux 45ZWN24-
Rated Speed	4000 [RPM]
Rated Current	2.3 [A rms]
Rated Voltage (DC)	24 [V]
Pole Pairs	2

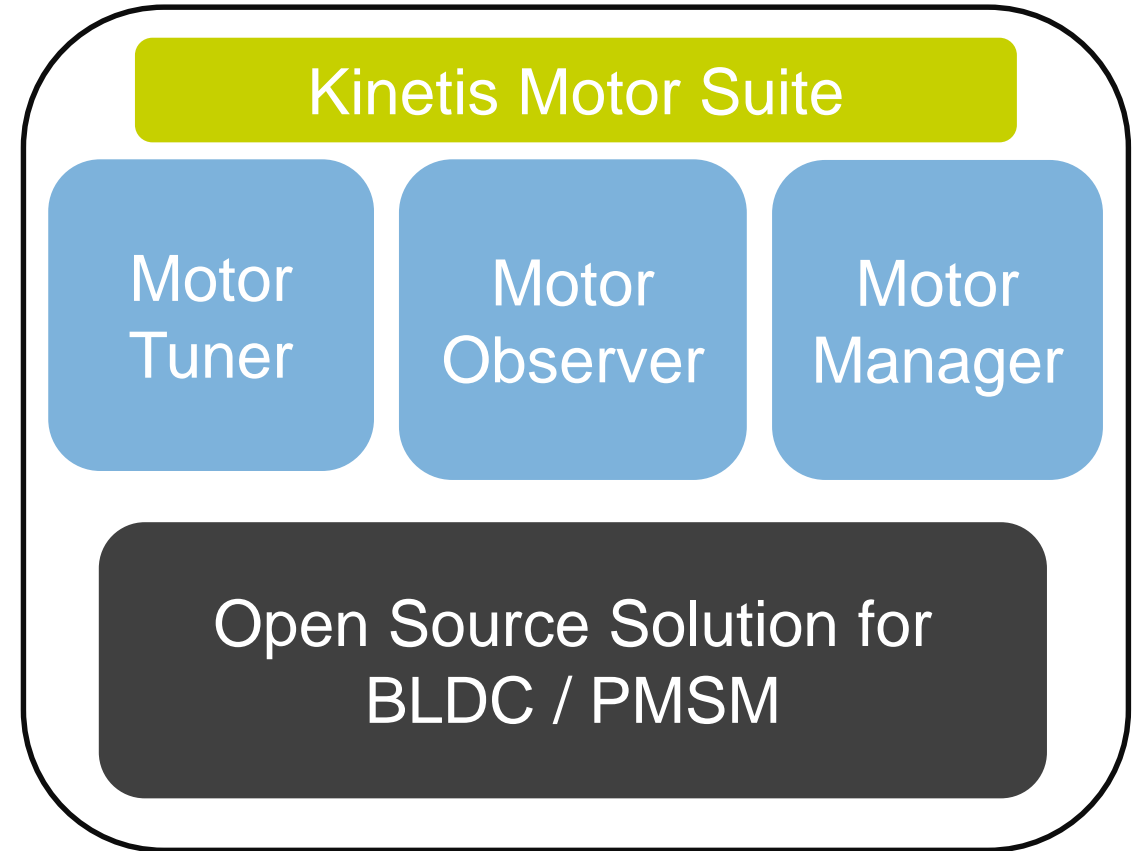
Click to Update Values

NXP

PUBLIC | 10

Kinetis Motor Suite Design

- A highly intuitive, high-performance motor control development solution that accelerates the design and deployment of motor control applications
- All motor configuration and control carried out through the graphical user interface
- Simplicity
 - On-chip expertise eliminates the need for in-depth knowledge of motor control, allowing those with limited experience to develop an application
- Performance
 - Proprietary disturbance compensating control from LineStream Technologies allows the motor to operate across speeds & loads, extends machine life, and improves energy efficiency



Application Perspective

Quicker Time to Market

Pre-programmed, on-chip expertise
connected to streamlined user
interface

More Efficiency

Proprietary disturbance
compensating control from
LineStream Technologies

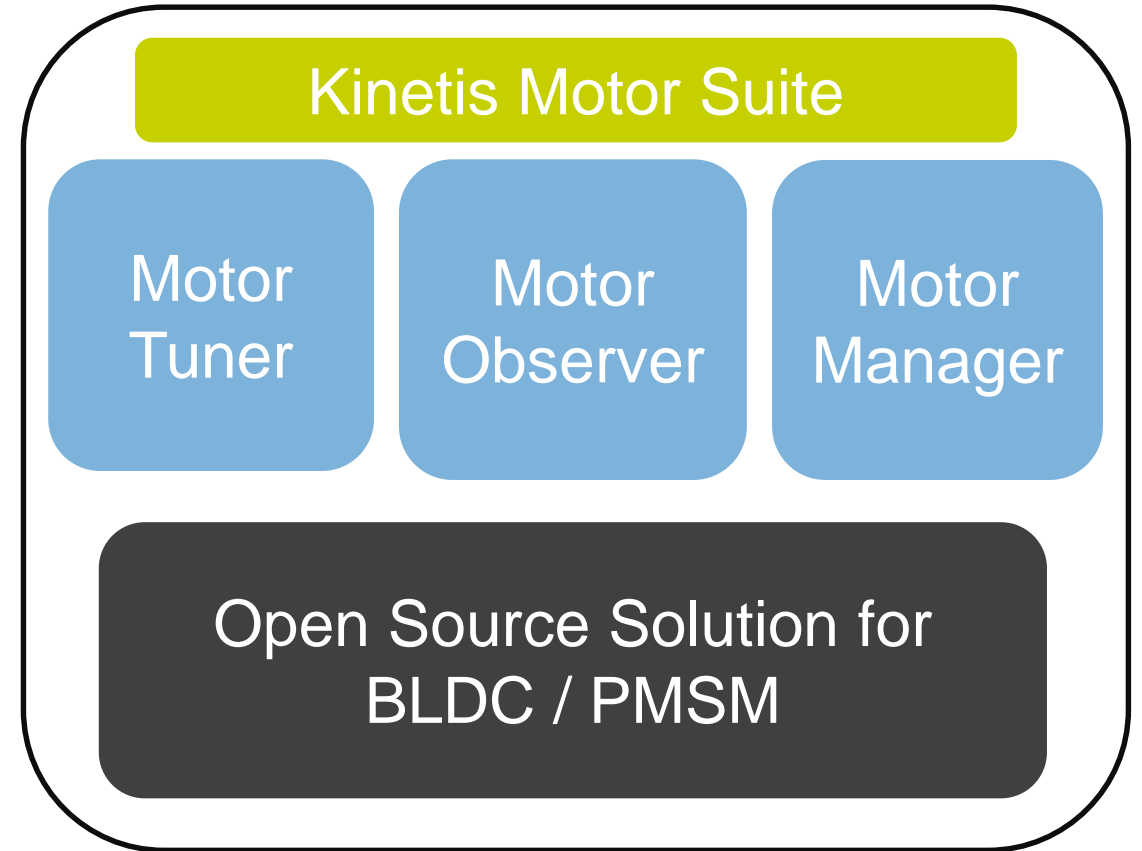
Extended Machine Life

Improves energy efficiency, auto-
compensating, simple production
process

Kinetis Motor Suite – Components

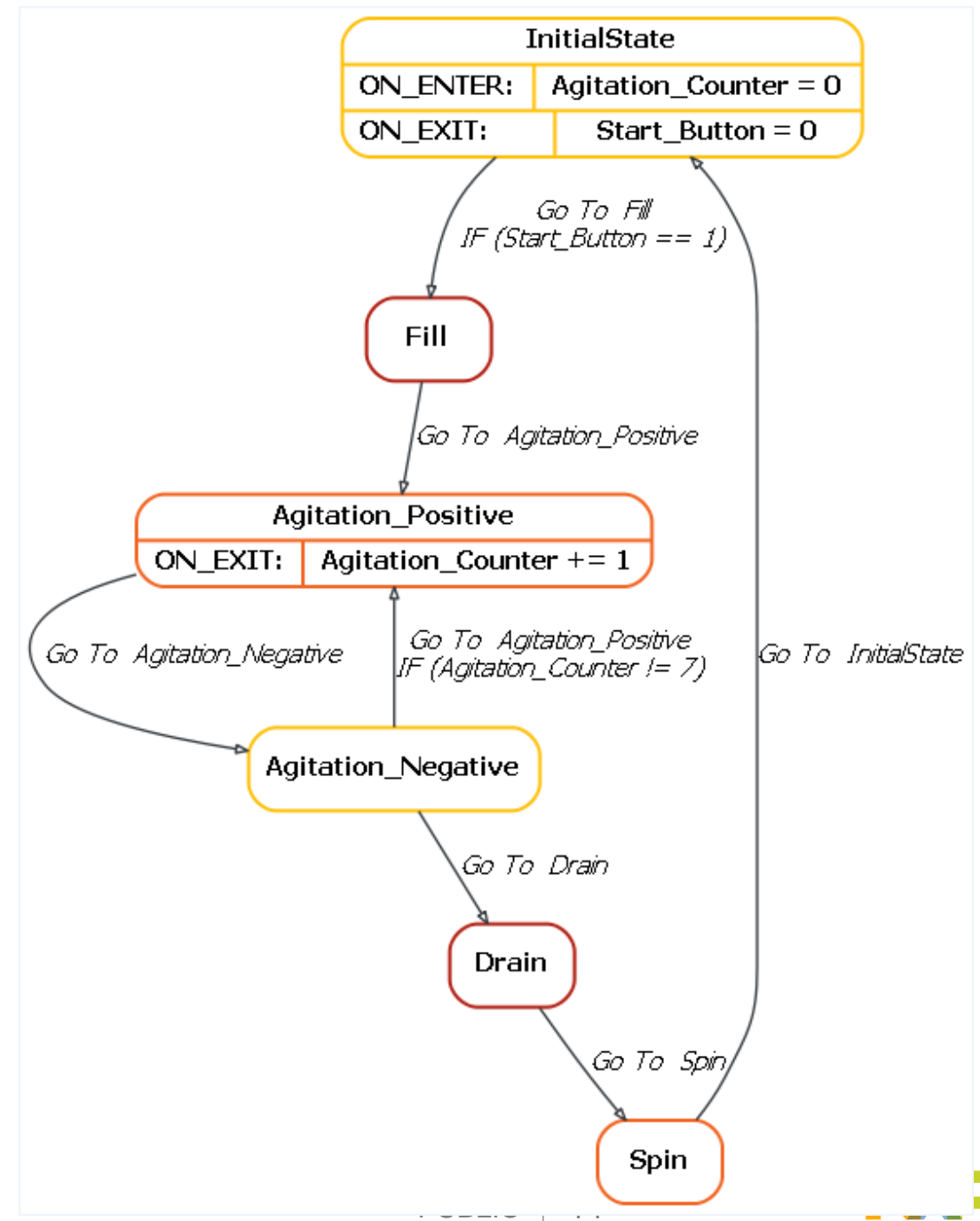
KMS consists of four main components:

1. **Motor Tuner:**
Wizard for initial motor configuration – gets your motor spinning in 5 steps
2. **Motor Observer:**
Factory programmed flash with embedded motor control firmware for dynamic motor tuning and control.
3. **Motor Manager:**
Application development environment where you can access and update real-time system components during application development.
4. **Open Source Solution:**
The open source project with the motor control firmware configured via the GUI, and also accessible via an API.



Reference Project Configurator

- KMS is designed to help quickly get a motor spinning
- Once motor is confirmed to work...
 - Reference project is automatically updated for the motor
 - Application motion sequence can be created graphically
 - KMS can compile and download updated reference project
- Now the starting “generic” reference project is tailored for the application



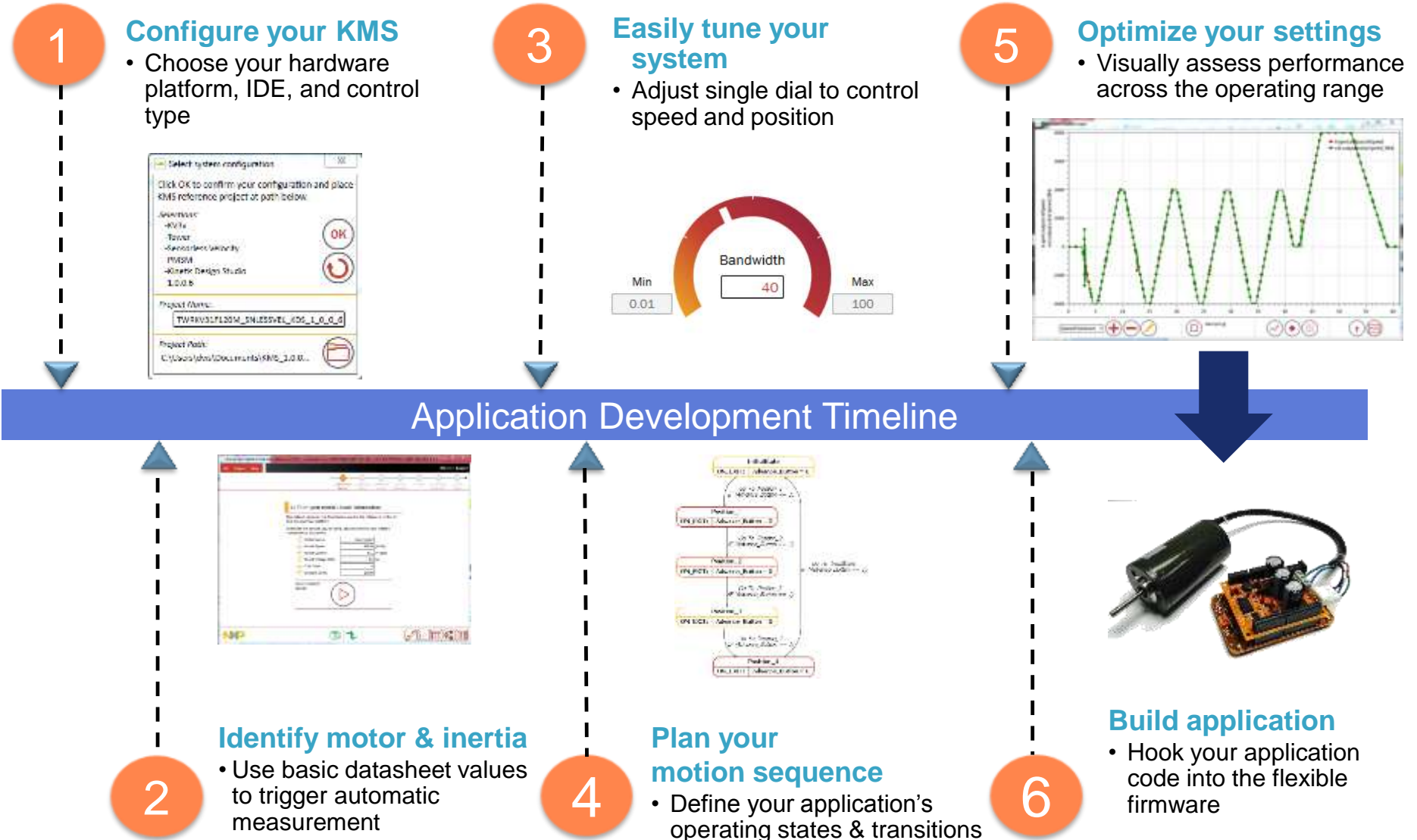
Scripting Engine

- KMS runs scripts on PC for complex tasks
 - Motor parameter identification
 - Inertia identification
 - Drive configuration
- Adapts drive settings based on identification results
 - Automatically adjusts PWM frequency
 - Automatically adjusts speed loop bandwidth
- Detects identification failures
 - Automatically adjusts settings and tries again
- Prompts user for possible “bad” settings
 - Warns user if CPU load might be too high



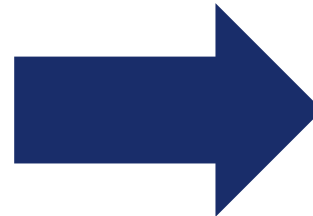
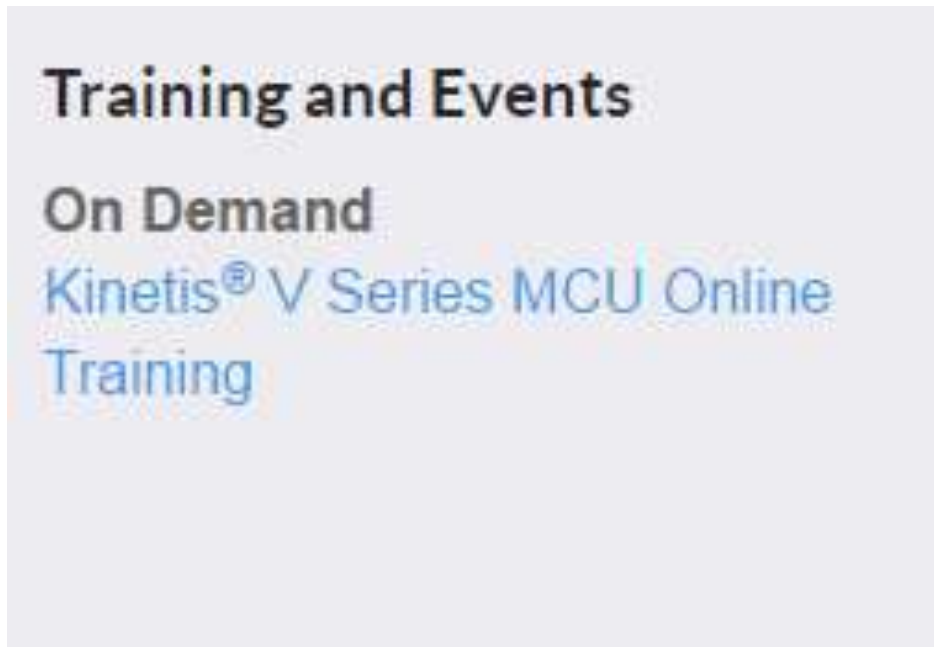
Kinetis Motor Suite Demonstration

Design A New Application in Just 6 Easy Steps



Kinetis Motor Suite Videos

- Go to <http://www.nxp.com/kms>
 - scroll down to Training and Events
 - click *Kinetis V Series MCU Online Training*



Outline
Introducing Concepts of FOC Motor Control (08:40)
Kinetis Motor Suite Introduction (07:58)
Kinetis Motor Suite Advantages (15:34)
Building a Kinetis Motor Suite Application - Identify Motor and Inertia (01:34)
Building a Kinetis Motor Suite Application - Tune speed bandwidth (02:07)
Building a Kinetis Motor Suite Application - Build a Motion Sequence (06:46)
Building a Kinetis Motor Suite Application - Optimizing Trajectories (03:54)
Building a Kinetis Motor Suite Application - Porting to KDS (07:19)

Getting Started

- Install the software tools
 - Kinetis Design Studio (KDS) Integrated Development Environment (IDE) 3.2 with all eclipse updates.
 - Kinetis Software Development Kit version 1.3 mainline
 - Kinetis Motor Suite rev 1.1.0
- KMS enabled MCU samples available from nxp.com.
 - Look for the Kinetis KV3x and KV1x MCU parts with a P suffix – like this:
MKV30F128VLF10P



Kinetis Motor Suite Technology

Motor Parameter Identification

- Automatically identifies motor electrical parameters
 - Resistance
 - Inductance
 - Flux
- Uses these to tune the motor control loops
- Designed to be done during development
- Should be done with motor disconnected from any load, if possible

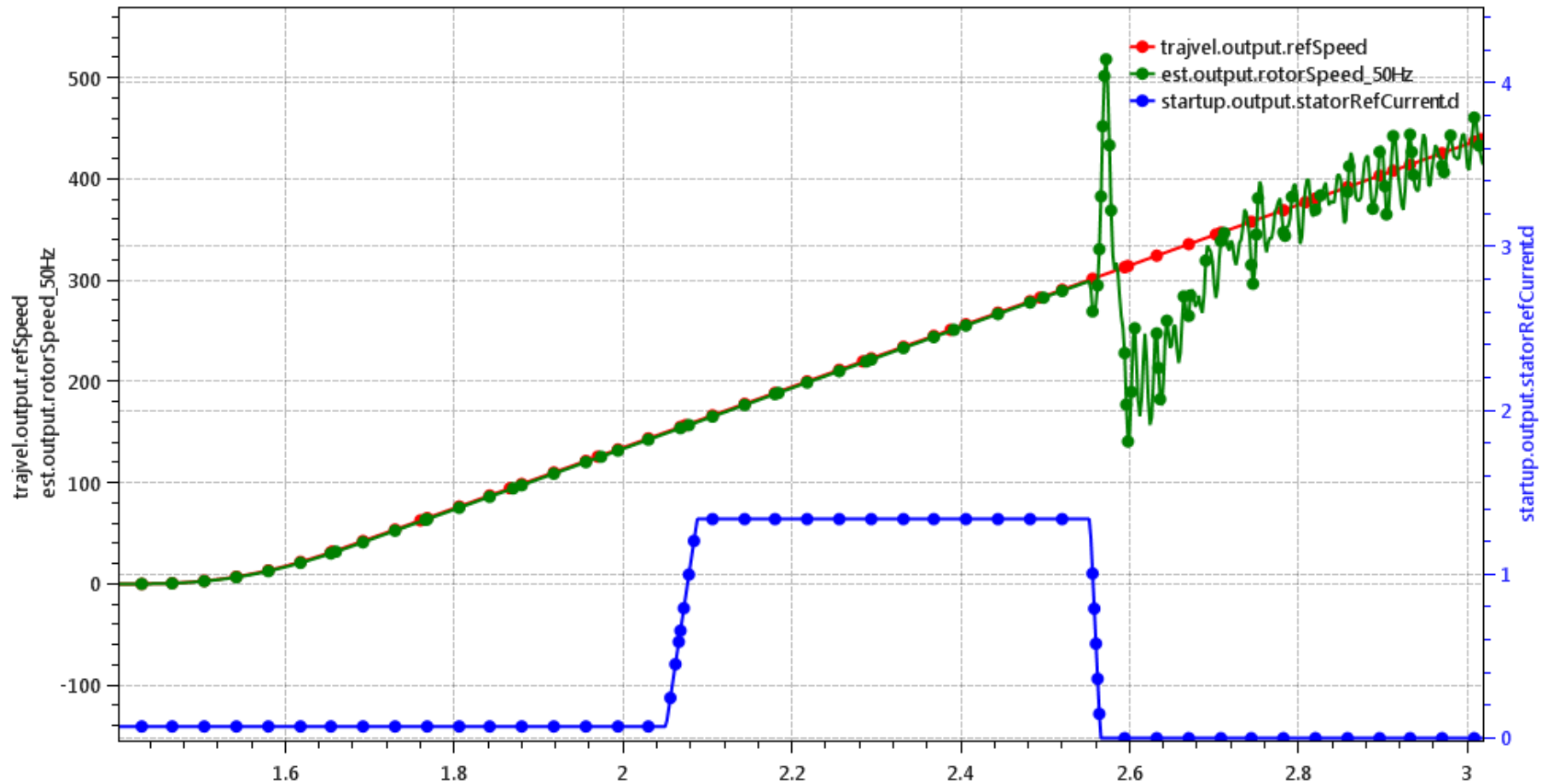
Start Motor
Measurement



Stator Resistance	0.30364 [Ohms]
Stator Inductance	0.000568 [H]
Rotor Flux	0.00782 [Wb]

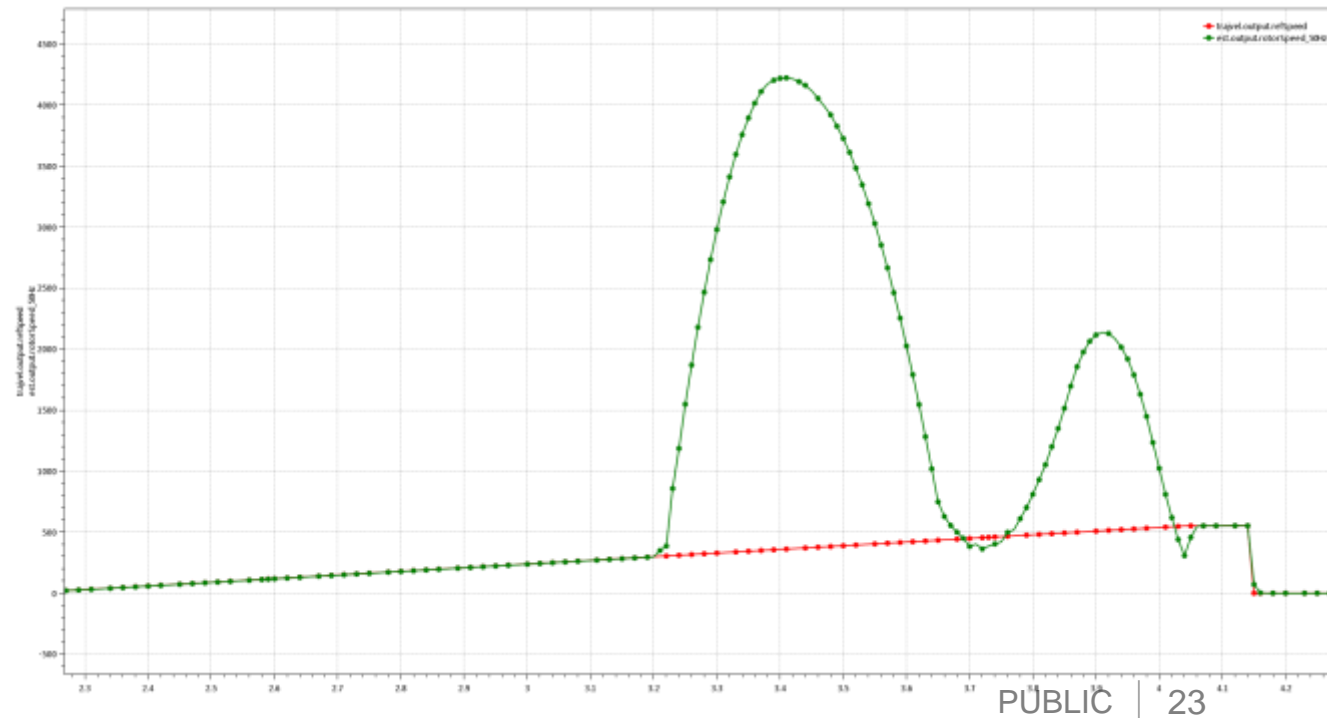
Soft Startup

- Automatically increases current to ensure successful startup
- Will retry startup if unsuccessful

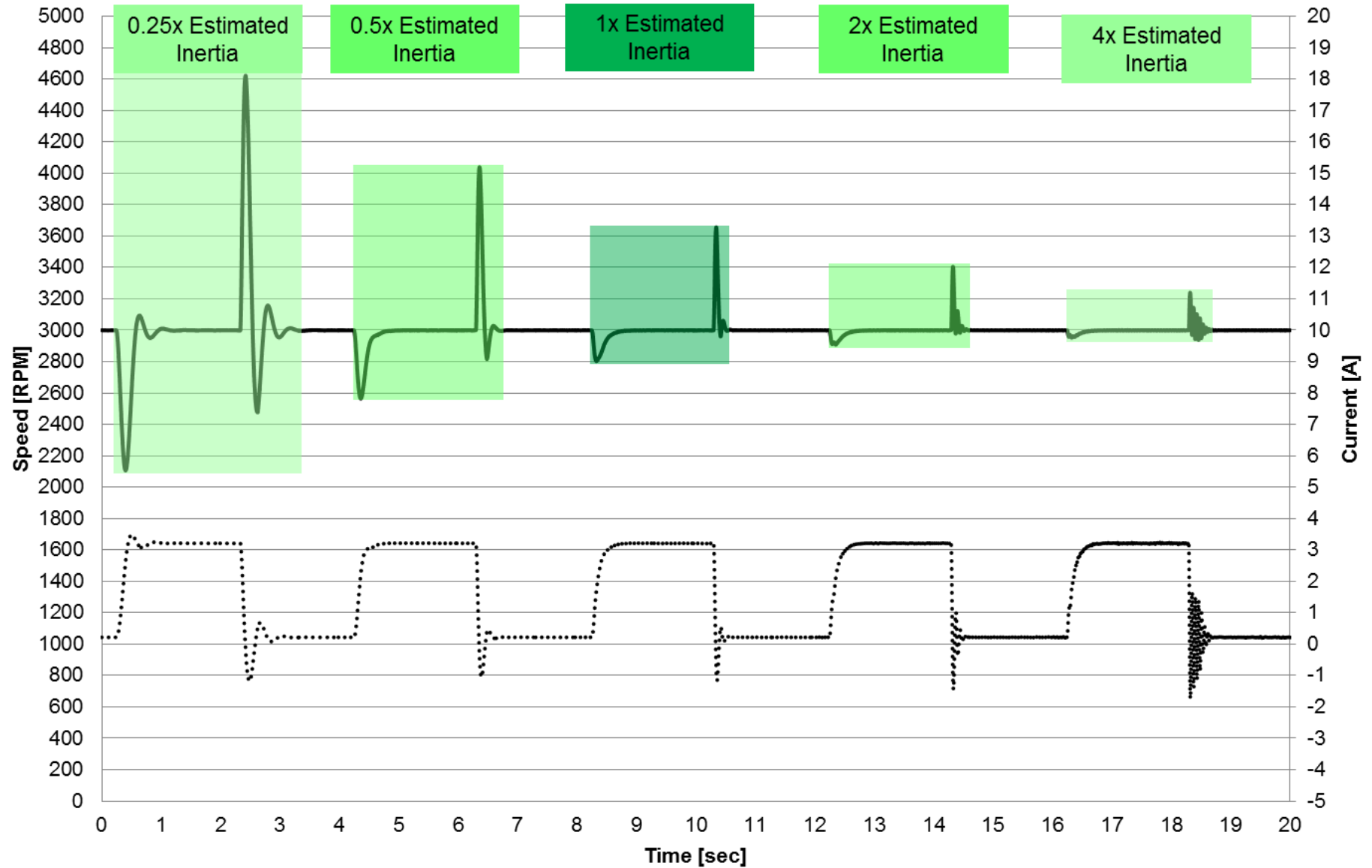


Inertia Estimation

- Value is critical for good motion control
- PI tuning indirectly takes this into account
 - Adjusting the K_p & K_i “tune” the controller for the motion system dynamics
- Estimating this value and directly using it in control yields better performance
- Designed to be done during development



Inertia Range Tolerance



Speed Controller

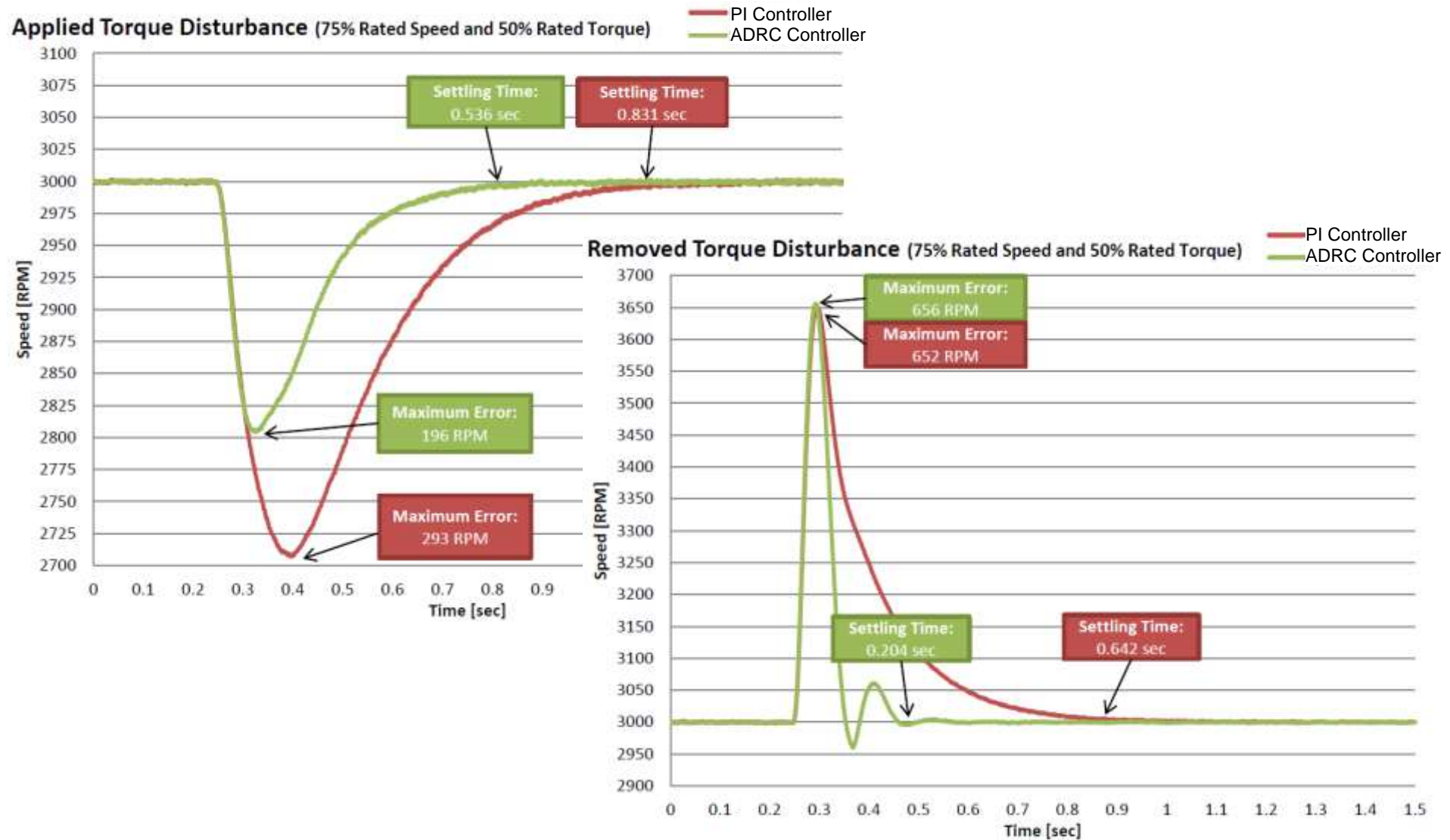
- Disturbance-rejecting controller
 - Not purely an error-based controller
 - Based on ADRC algorithm
- Single variable to tune response
 - Typically effective across full variable speed and load range



What is ADRC?

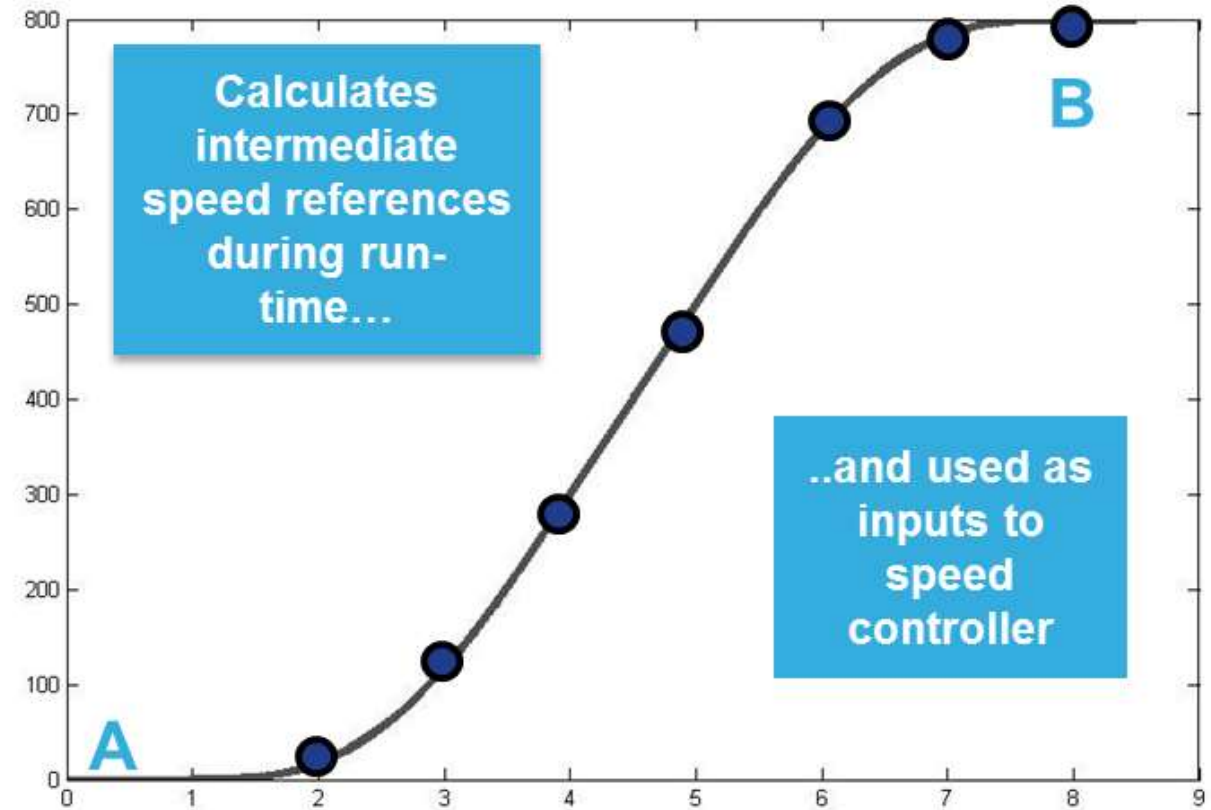
- **Active Disturbance Rejection Control**
- Fundamentally different control technique that outperforms PID
- Based on a minimum information model
 - System Inertia -> Measurable
 - System Order -> Known
- Disturbance based controller
 - Any non-ideal behavior (i.e. load, wear, inertia change) is observed and compensated for by the controller
- Single parameter control tuning

Performance Comparison



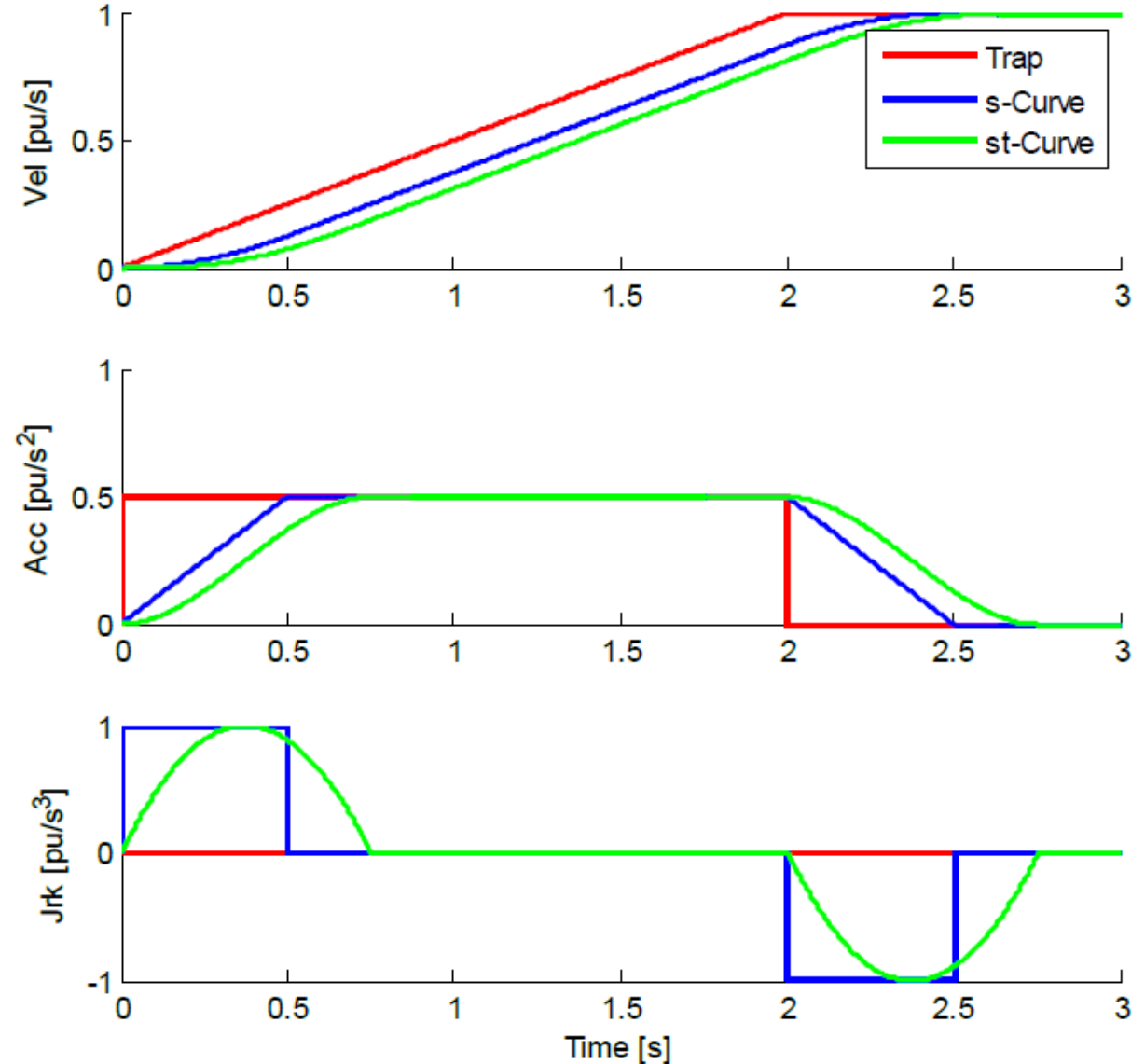
Advanced Profile Generation

- Constraint-based
 - User provides limits on motion
 - Profile will always respect those limits
- Time-optimal
 - Profile will be the fastest possible within limits
 - Profile will be sample time aligned
- Run-time Calculated
 - Profile is calculated on MCU
- Each profile can use a unique set of limits



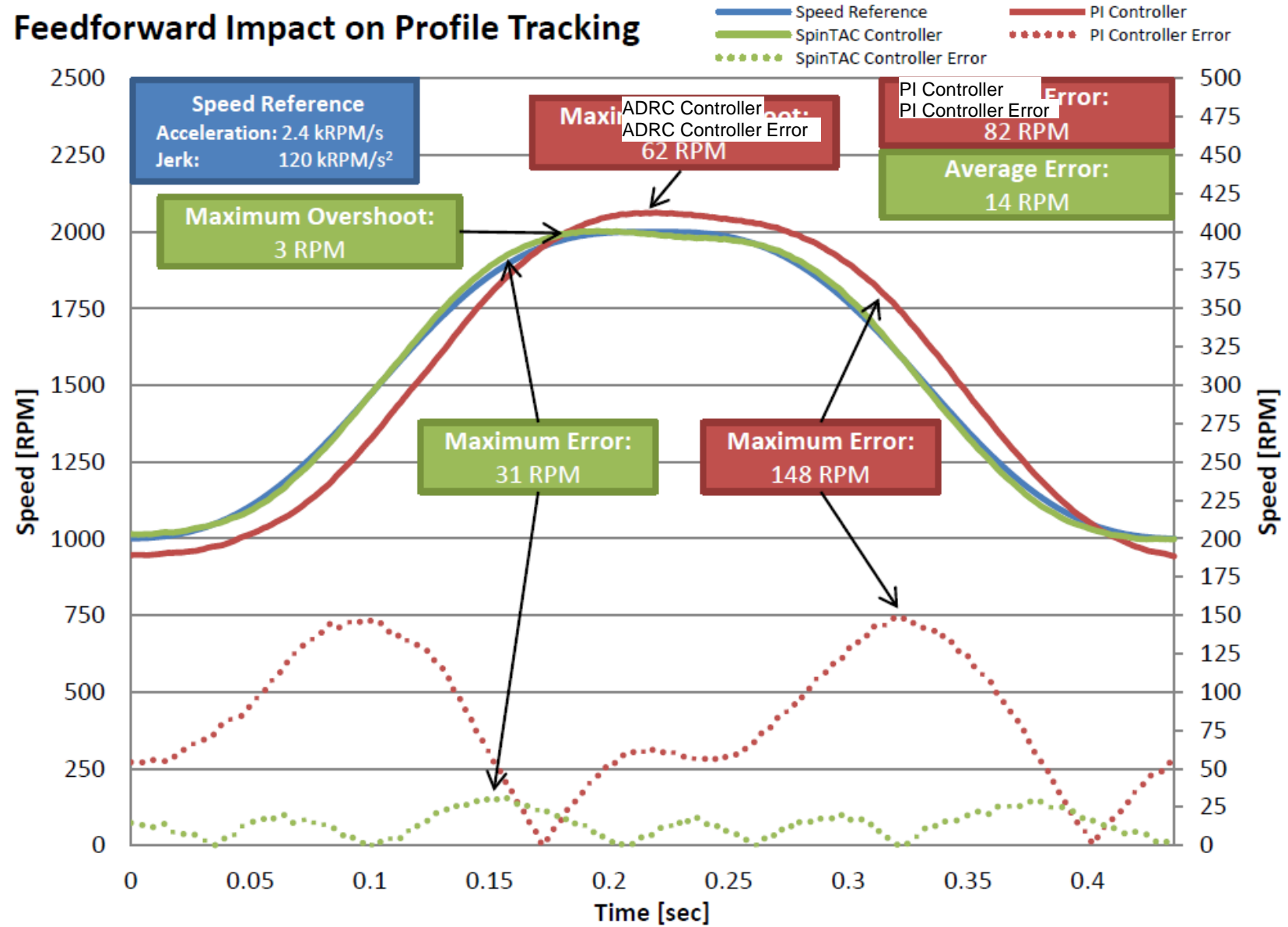
Profile Generation Curves

- **Trapezoid**
 - Bounded Acceleration
 - Impulse Jerk
- **s-Curve**
 - Continuous Acceleration
 - Bounded Jerk
- **st-Curve**
 - Smooth Acceleration
 - Continuous Jerk



Feedforward

Feedforward Impact on Profile Tracking



Low CPU Usage

- Sensorless FOC takes about 1/3 of 120MHz KV3 or about 45% of a 75 MHz KV1
- 4 ADC Channels
- 6 PWM Channels

Average CPU Usage

Use the below values to assess usage of your MCU's CPU by fast, slow, and communication ISRs. Preconfigured plots showing the change in usage over time have been provided. Use the button at bottom to clear data for maximum utilization.

→ CPU Usage

Fast ISR

Assess usage of your MCU's CPU by the fast (motor control) interrupt service routine.

→ CPU Clock Cycles	<input type="text" value="3731 [cycles]"/>
→ Maximum CPU Clock Cycles	<input type="text" value="3743 [cycles]"/>
→ Period	<input type="text" value="11996 [cycles]"/>

Fast ISR CPU
Utilization Plot



Advantages and Disadvantages of FOC

- Advantages
 - Performance
 - Efficiency
 - Low Speed Operation
 - Field Weakening
- Disadvantages
 - ~~CPU intensive~~
 - ~~Costly sensor~~
 - ~~Expertise required~~



Kinetis Motor Suite Products and Roadmap

KMS Product Enablement

- Unique part numbers help identify KMS enabled devices:
 - Part numbers are unique to the specific motor type enabled:
 - P = PMSM / BLDC – supports PMSM and BLDC motors with sinusoidal FOC control

Example: MKV30F128VLF10**P**

- License is specific to that MCU, enabling access to the KMS software components.
 - Only have to pay for the license's based on how many of your end products that you will build.
 - Enables access to NXP technical support for Kinetis Motor Suite and to the community.
 - Applications support available in each region.
- KMS is available on select Kinetis KV1x and KV3x MCU parts in production today and will be available for KV4x by end 2017
- Samples are available at www.NXP.com/kinetis/vseries

Kinetis V Series KV3x: Family Overview

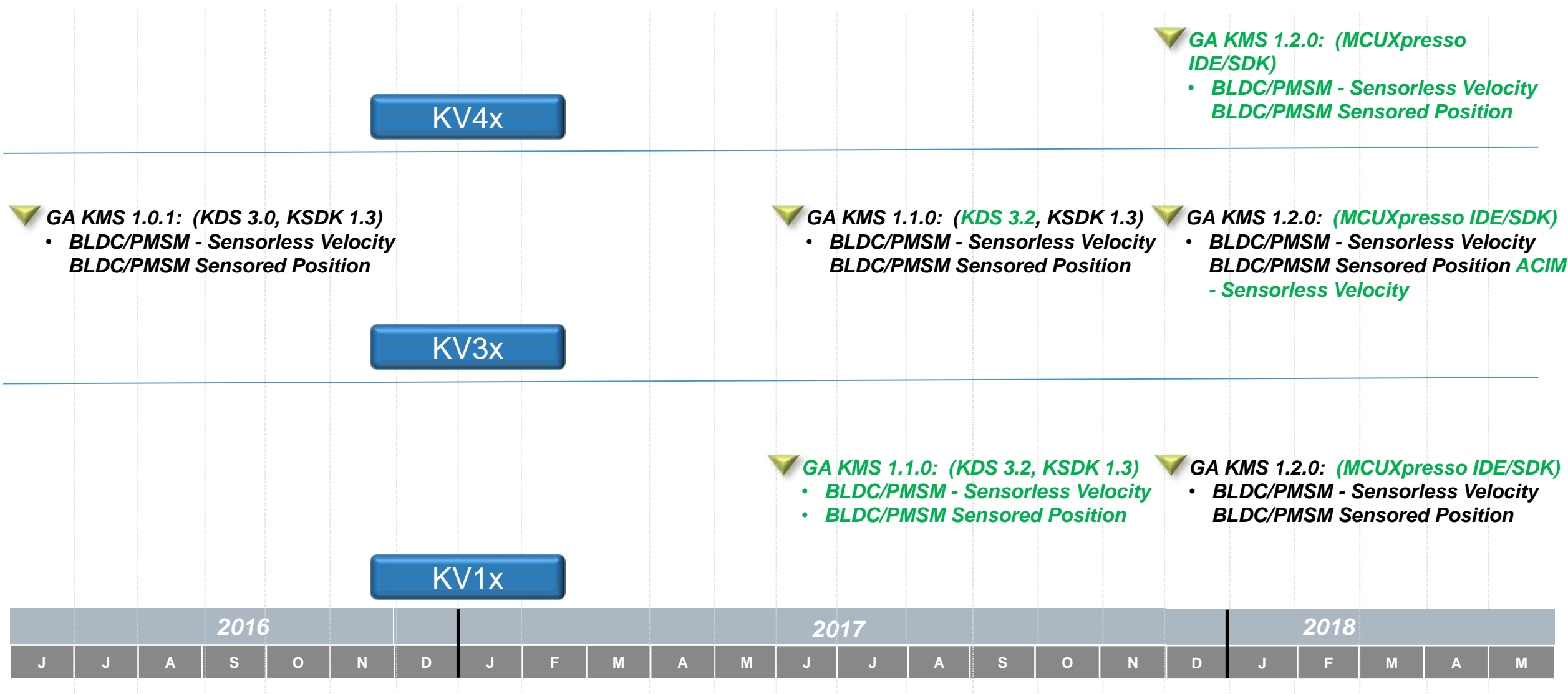
Sub-Family	Part Number	Max. Freq.	Package	Flash	SRAM	Flex. Bus	DMA	PLL / FLL	FTMs	DAC	GPIO	I/O with Digital Filters	KMS Enabled
KV31	MKV31F512VLL12 MKV31F512VLL12P	120MHz	100LQFP	512K	96KB	Yes	16-ch	PLL	2x8ch; 2x2ch	2	70	16	No Yes
	MKV31F512VLH12	120MHz	64LQFP	512K	96KB	Yes	16-ch	PLL	2x8ch; 2x2ch	2	46	16	No
	MKV31F256VLL12	120MHz	100LQFP	256K	48KB	No	16-ch	PLL	1x8ch; 2x2ch	1	70	8	No
	MKV31F256VLH12 MKV31F256VLH12P	120MHz	64LQFP	256K	48KB	No	16-ch	PLL	1x8ch; 2x2ch	1	46	8	No Yes
	MKV31F128VLL10	100MHz	100LQFP	128K	24KB	No	4-ch	FLL	1x8ch; 2x2ch	1	70	8	No
	MKV31F128VLH10 MKV31F128VLH10P	100MHz	64LQFP	128K	24KB	No	4-ch	FLL	1x8ch; 2x2ch	1	46	8	No Yes
KV30	MKV30F128VLH10	100MHz	64LQFP	128K	16KB	No	4-ch	FLL	1x8ch; 2x2ch	1	46	8	No
	MKV30F128VLF10 MKV30F128VLF10P	100MHz	48LQFP	128K	16KB	No	4-ch	FLL	1x8ch; 2x2ch	1	35	8	No Yes
	MKV30F128VFM10	100MHz	32QFN	128K	16KB	No	4-ch	FLL	1x8ch; 2x2ch	1	26	8	No
	MKV30F64VLH10 MKV30F64VLH10P	100MHz	64LQFP	64K	16KB	No	4-ch	FLL	1x8ch; 2x2ch	1	46	8	No Yes
	MKV30F64VLF10 MKV30F64VLF10P	100MHz	48LQFP	64K	16KB	No	4-ch	FLL	1x8ch; 2x2ch	1	35	8	No Yes
	MKV30F64VFM10	100MHz	32QFN	64K	16KB	No	4-ch	FLL	1x8ch; 2x2ch	1	26	8	No

Kinetis V Series KV1x: Family Overview

Part Number	Freq.	Package	Flash	SRAM	FlexTimers	DAC	CAN	KMS Enabled
MKV11Z128VLH7	75MHz	64LQFP	128KB	16KB	2x6ch; 4x2ch	1	1	No
MKV11Z128VLH7P								Yes
MKV11Z128VLF7	75MHz	48LQFP	128KB	16KB	2x6ch; 4x2ch	1	1	No
MKV11Z128VLF7P								Yes
MKV11Z128VFM7	75MHz	32QFN	128KB	16KB	2x6ch; 4x2ch	1	1	No
MKV11Z128VFM7P								Yes
MKV11Z128VLC7	75MHz	*32LQFP	128KB	16KB	2x6ch; 4x2ch	1	1	No
MKV11Z64VLH7	75MHz	64LQFP	64KB	16KB	2x6ch; 4x2ch	1	1	No
MKV11Z64VLF7	75MHz	48LQFP	64KB	16KB	2x6ch; 4x2ch	1	1	No
MKV11Z64VFM7	75MHz	32QFN	64KB	16KB	2x6ch; 4x2ch	1	1	No
MKV11Z64VLC7	75MHz	*32LQFP	64KB	16KB	2x6ch; 4x2ch	1	1	No
MKV10Z128VLH7	75MHz	64LQFP	128KB	16KB	2x6ch; 4x2ch	1	-	No
MKV10Z128VLF7	75MHz	48LQFP	128KB	16KB	2x6ch; 4x2ch	1	-	No
MKV10Z128VFM7	75MHz	32QFN	128KB	16KB	2x6ch; 4x2ch	1	-	No
MKV10Z128VLC7	75MHz	*32LQFP	128KB	16KB	2x6ch; 4x2ch	1	-	No
MKV10Z64VLH7	75MHz	64LQFP	64KB	16KB	2x6ch; 4x2ch	1	-	No
MKV10Z64VLH7P								Yes
MKV10Z64VLF7	75MHz	48LQFP	64KB	16KB	2x6ch; 4x2ch	1	-	No
MKV10Z64VLF7P								Yes
MKV10Z64VFM7	75MHz	32QFN	64KB	16KB	2x6ch; 4x2ch	1	-	No
MKV10Z64VFM7P								Yes
MKV10Z64VLC7	75MHz	*32LQFP	64KB	16KB	2x6ch; 4x2ch	1	-	No
MKV10Z32VLF7	75MHz	48LQFP	32KB	8KB	1x6ch; 2x2ch	1	-	No
MKV10Z32VFM7	75MHz	32QFN	32KB	8KB	1x6ch; 2x2ch	1	-	No
MKV10Z32VLC7	75MHz	32LQFP	32KB	8KB	1x6ch; 2x2ch	1	-	No
MKV10Z16VLF7	75MHz	48LQFP	16KB	8KB	1x6ch; 2x2ch	1	-	No
MKV10Z16VFM7	75MHz	32QFN	16KB	8KB	1x6ch; 2x2ch	1	-	No
MKV10Z16VLC7	75MHz	32LQFP	16KB	8KB	1x6ch; 2x2ch	1	-	No

* Package Your Way Option

Kinetis Motor Suite: General Availability Milestones



FRDM Low Cost Reference Platforms: Hardware + KMS Software

Complete
Reference
Design

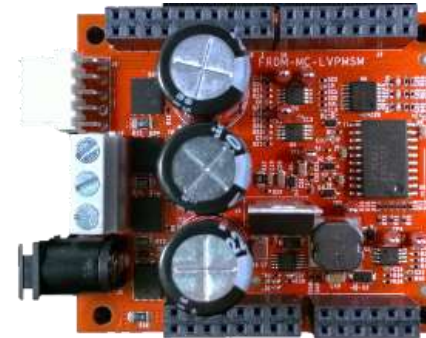
BLDC : \$85
PMSM : \$105



FRDM-KV11Z: \$25
FRDM-KV31F: \$25



FRDM-MC-LVPMSM: \$50
- Sinusoidal control
or
FRDM-MC-LVBLDC: \$30
- Trapezoidal control



FRDM-MC-LVMTR: \$35

Low cost motor for
Sinusoidal &
Trapezoidal control



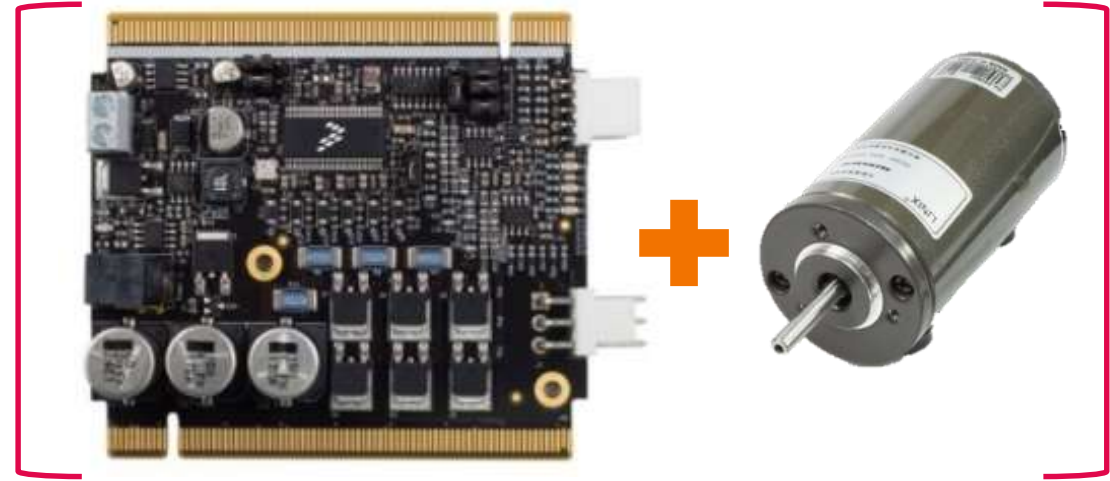
KMS SOFTWARE
BLDC Sensorless (Trapezoidal) &
PMSM Sensorless FOC (Sinusoidal) on
nxp.com/kms

TWR Reference Platforms: Hardware + KMS Software

Complete
Reference Design
\$449 / \$499



TWR-KV11Z75M: \$99
TWR-KV31F150M: \$149



TWR-MC-LV3PH: \$349
- Sinusoidal & Trapezoidal control



SOFTWARE

BLDC Sensorless (Trapezoidal) &
PMSM Sensorless FOC (Sinusoidal)
reference software on nxp.com/kms

High Voltage Reference Platforms: Hardware + KMS Software

HVP-MC3PH: \$600 includes **HVP-KV46F150M** controller card

Add KMS-Enabled Controller Cards:

- **HVP-KV31F120M** controller card \$79
- **HVP-KV11Z75M** controller card \$50

**KMS Enabled High Voltage
Reference Design**
\$650 / \$679



Your motor



SOFTWARE

BLDC Sensorless (Trapezoidal) &
PMSM Sensorless FOC (Sinusoidal) &
reference software on nxp.com/kms

High Voltage Development – Power Factor Correction



HARDWARE

- **High Voltage Platform HVP-MC3PH**
- 115/230 volt, support for Motor + **PFC**
- Main board with inverter & **2 phase Boost PFC circuitry supports plug-in controller cards for Kinetis KV1x/KV3x/KV4x MCUs**
- Voltage: 85 to 240V

SOFTWARE

- Interleaved Boost PFC
- Output power: 800W
- Input voltage: 90-265V AC
- Output voltage: 390V DC
- 2-phase interleaved boost topology
- Measured quantities: primary current, primary voltage, output voltage,
- Overcurrent fault protection
- Safe development via isolated debug interface, allows development without high voltage
- Supported with complete software reference solution based on KV4x.

How do I get started with Kinetis Motor Suite now?

1. Order your KMS enabled hardware, and walk through the OOBЕ video's;
 - Low voltage: nxp.com/frdm-kv31f or nxp.com/frdm-kv11z
 - High voltage: nxp.com/hvp
2. Install Kinetis Standard Tools:
 - [Kinetis Design Studio](#) (KDS version 3.2.0)
 - [Software Development Kit](#) (SDK version 1.3)
3. Download KMS Installer and Documentation:
 - Kinetis Motor Suite [Installer](#) (version 1.1.0)
 - Documentation: [Reference Manual](#) and [User Manual](#)
4. Walk through the [labs](#) to get familiar with KMS
5. Start your application development on the development boards
6. Order your free MCU samples from nxp.com to build your production board prototypes



Questions?



Resources

Resources and Support

- Kinetis V Training: www.nxp.com/kinetisvtraining
 - Kinetis Motor Suite 1Hr Webinar
 - Short Motor Control Introduction Videos
 - Short KMS Introduction Videos
- Kinetis V series MCUs: www.nxp.com/Kinetis
- Kinetis Motor Suite: www.nxp.com/KMS
- For questions, feel free to contact:
 - Michael Haight @ Michael.Haight@nxp.com Kinetis V Series Product Manager
 - Philip Drake @ philip.drake@nxp.com - KMS Technical Support
- For Support log on to the Kinetis Community
 - <http://community.nxp.com/community/kinetis/>



SECURE CONNECTIONS
FOR A SMARTER WORLD