XMC1000 MCU BLDC PMSM

Infineon Technologies

2014

XMC1000: 8-bit price for 32-bit power

www.infineon.com/XMC1000

www.infineon.com/XMC4000

dabo Corporation

Infineon

Main Content

- Infineon Latest MCU portfolio
- System block, Key Features
- Supporting tool, Ecosystem
- BLDC Motor Driver Design Using XMC
- PMSM Motor Driver Design Using XMC

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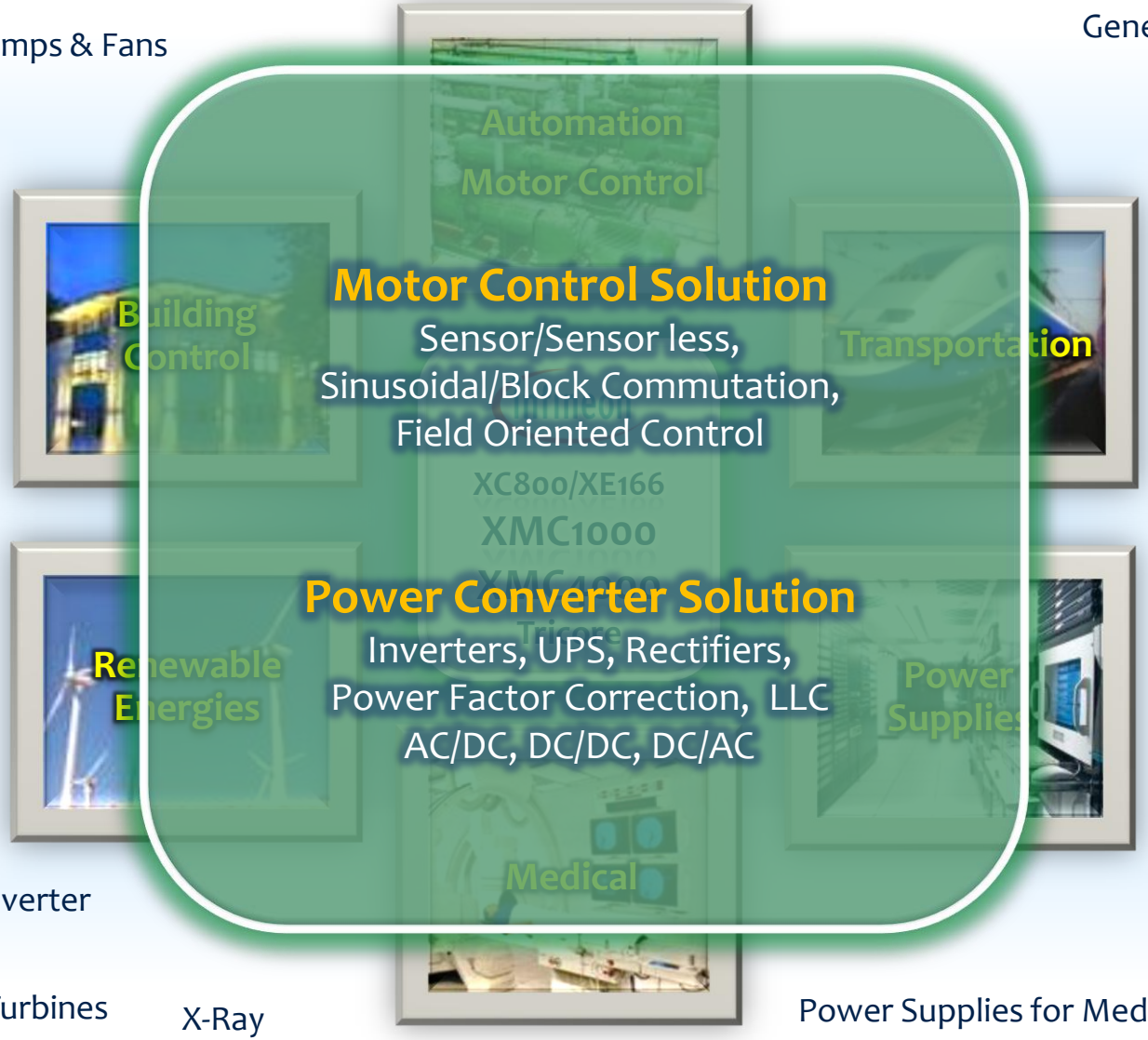
Core Applications



Compressors

Pumps & Fans

Aircon Sys

Escalators

Elevators

Battery Storage

Solar Inverter

Micro Inverter

Wind Energy Converter

Micro Turbines

Robotics

X-Ray

Servo Drive

General Purpose Drives

Process Control

E Vehicle

Traffic Lights

Fork Lifts

GP Inverter

UPS

Monitor/CTV

Telecom

Power Supplies for Medical Equipment

Infineon new generation XMC families targeted for Industrial Market

Cortex-M4

Addressing "32-bit/DSC" applications

MCU plus DSP

Accelerated SIMD, FP&DSP

XMC4000

Infineon first ARM Core released in Feb'2012

Target 32bit application from mid to high end

XMC4100, 4200, 4400, 4500

80~120MHz 64K~2.5M Flash, 48~256pin package

ARM

Cortex-M0

Addressing "8/16-bit" applications

Lowest cost

Optimised connectivity

XMC1000

Infineon second ARM Core released

Officially Press-release today on 17.Jan.13.

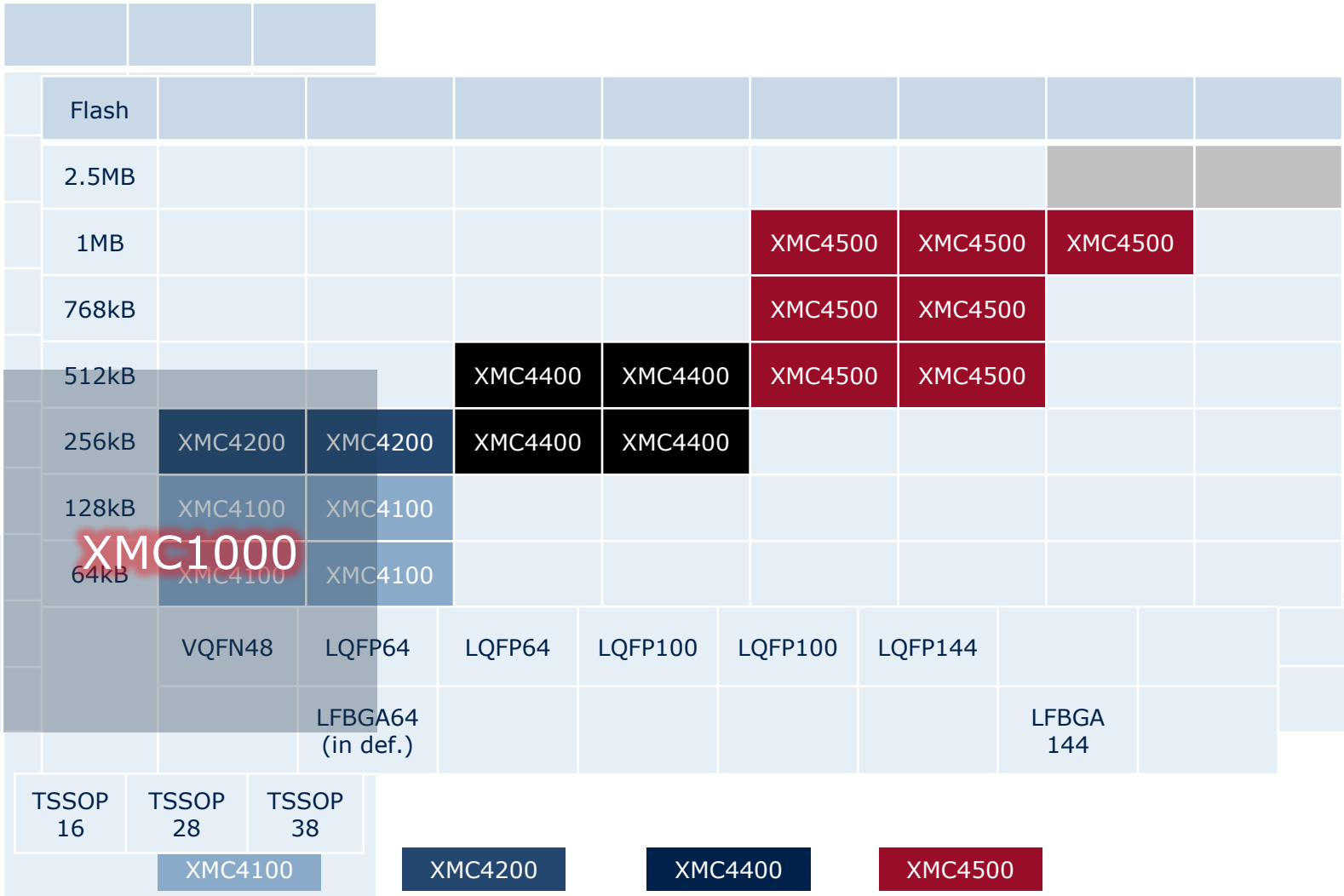
Sample available Mar 2013

Target low end market with 32bit MCU

XMC1100, 1200, 1300

32Mhz, 8~200K Flash, 16~38pin package

Infineon ARM based industrial Microcontrollers



One microcontroller platform. Countless solutions. XMC.

XMC1000:
8-bit price for 32-bit power

www.infineon.com/XMC1000

Where XMC1000 makes the difference

Standard Core in Leading edge technology

65nm

300mm

32-bit ARM® Cortex™-M0
Industry standard for 8-bit replaceme

AR

Scalable & user friendly

DAVE™

Apps

Flash F

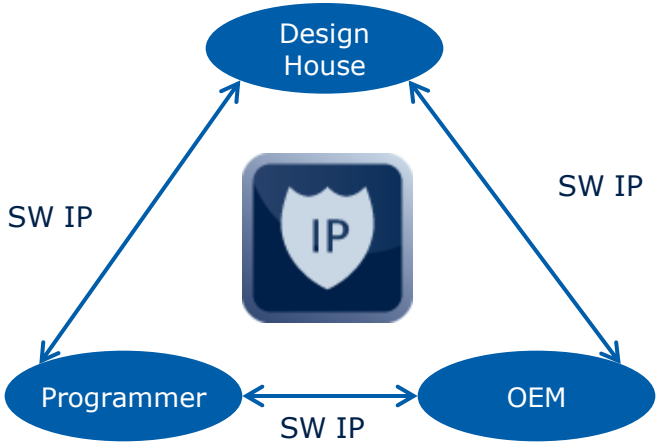
8KB

XMC Peripherals

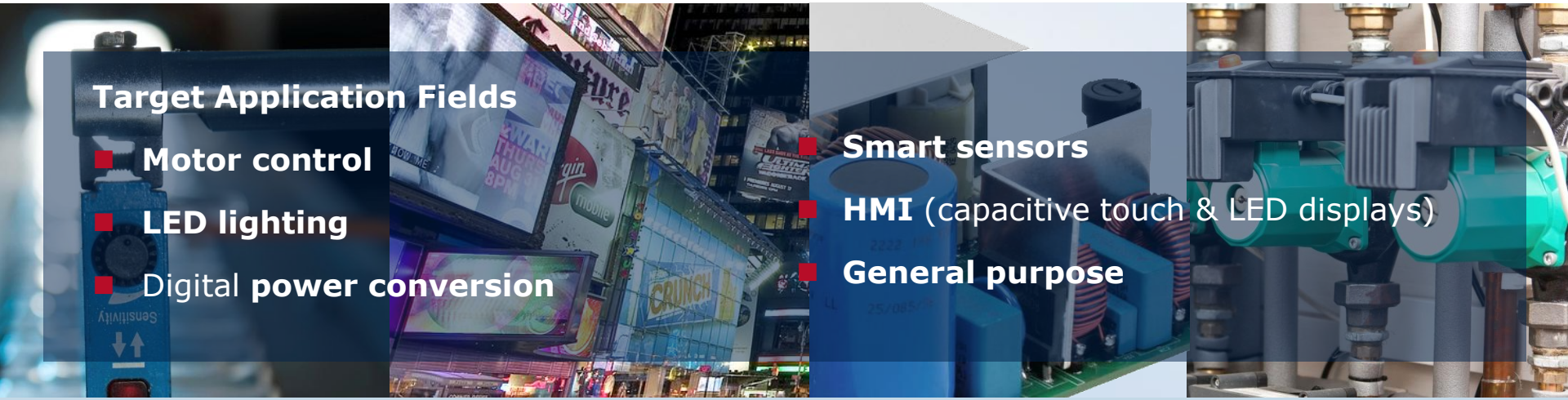
A/D *CCU8*
USIC *CCU4*

SW IP Protection

From # 1 in security microcontrollers



XMC1000 Key Features inspired by Target Application Fields

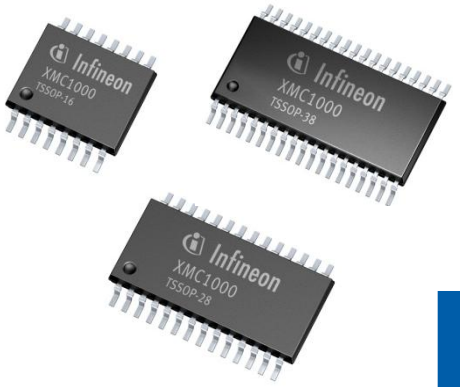


Key Features

- Most scalable **Flash** memory portfolio in Low-end: from **8KB** to **200KB**
- **AES 128-bit** secure loader for **SW IP protection**
- **LED lighting & color** control
- 32-bit **ARM® Cortex™-M0**, 32MHz
- Broadest supply range **1,8 - 5V**
- Leading edge **XMC** mixed signal and timer **peripherals**
- **64MHz MATH Co-processor** for advanced control loops (CORDIC / DIVIDE)
- **30ns analog comparators**
- **IEC 60730 Class B**
- Peripherals for **Touch** control and LED **display** control

XMC1000 (3 Product Series, 22 products, 5 packages)

+++ 22 products +++ 3 packages TSSOP-16, -28, -38 +++ 8KB to 200KB Flash +++
(VQFN-24, -40 available in Q1 2014)



XMC1100
Entry Series

- Basic feature set, state of the art

  (16-bit timers, 12-bit ADC, serial communication)
- Simplified documentation

XMC1200
Feature Series

- Additional features
  - **Patented LED-lighting** and –color control peripheral (BCCU)
  - Capacitive **touch** and LED-**Display** control (LEDTS)
- Extended temperature range to **105°C**

XMC1300
Control Series

- Special purpose **timers** for **motor control** & digital **power conversion** (CCU8)
- **MATH co-processor**
- **Motor position I/F** (POSIF)
- Extended temperature range to **105°C**

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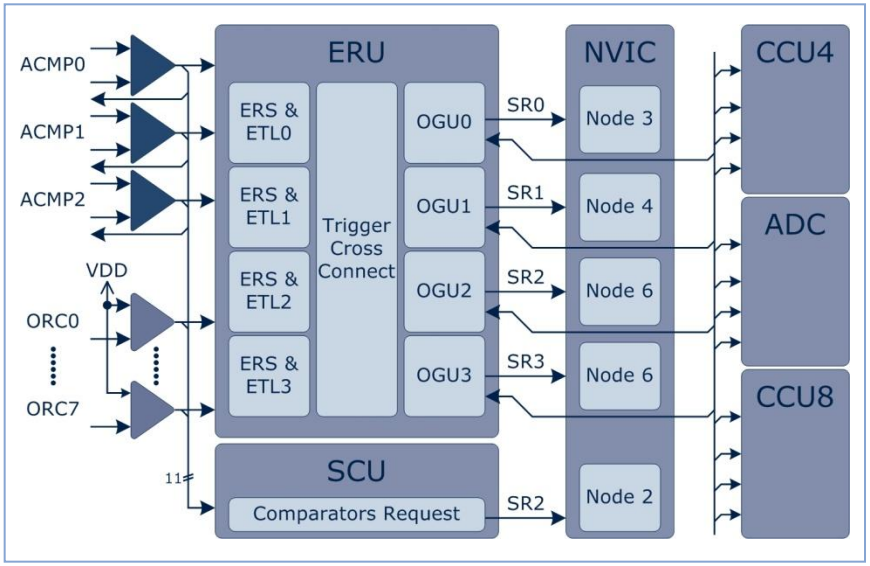
ACMP and ORC System Integration



- Target applications
  - Motor Control
  - Intelligent Lighting
  - Power Conversion
  - General Purpose

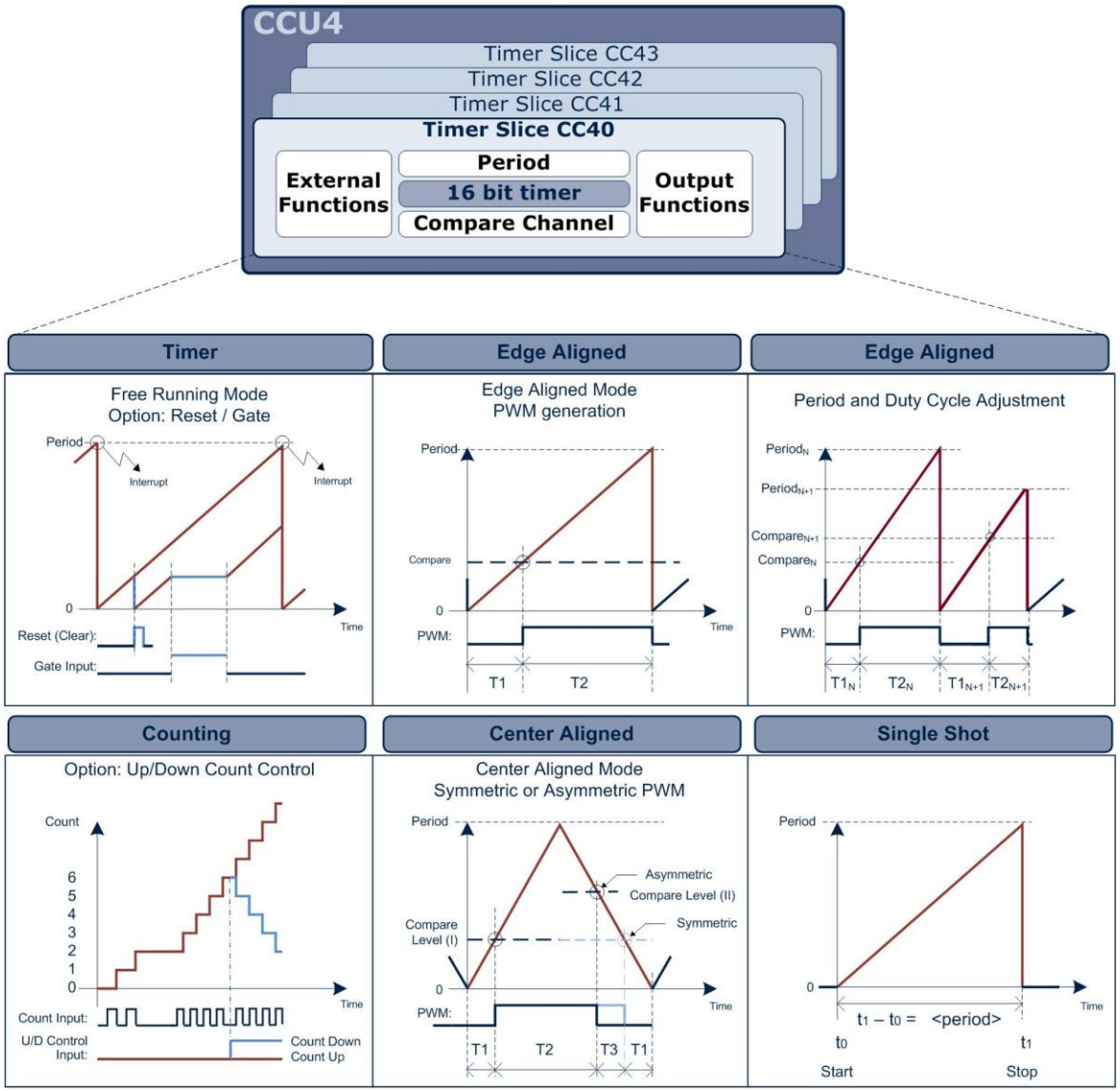
The output signals of ACMP as well as ORC are available at the input multiplexer of the event request unit ERU. As a result, they can be flexibly combined to logical signals that trigger interrupts, start timers or trigger ADC measurements.

It is the unique combination of fast analog signals and the powerful peripherals that provide a solution in various demanding control applications.

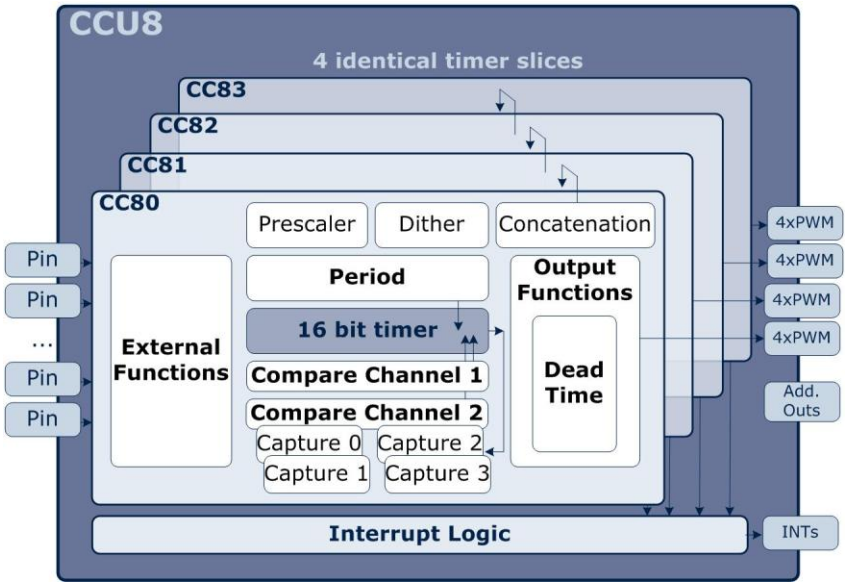
Both the fast ACMP as well as ORC comparators are functional in a wide supply voltage range (2.7V … 5.5V).

CCU4
Flexible PWM generation

- Each Timer Slice of the CCU4 can operate in center aligned or edge aligned mode
- Additional operation modes like single shot, counting or dithering modes are also available
- Update of the Duty Cycle and Period can be done on-the-fly to accommodate different operation requirements
- Additional external controllable functions give another degree of PWM manipulation (e.g. timer gate, timer load, timer clear, etc)



CCU8
Capture/Compare Unit 8 Key Features



Highlights

The CCU8 is a flexible timer module, comprised of 4 identical timer slices tailored for multi-phase PWM generation and signal conditioning.

Several input functions can be controlled externally (via pins or other modules) enabling a powerful resource arrangement for each application.

Key Feature

Modular timer approach with repeated external functions

Flexible PWM generation with on-the-fly duty cycle and period update plus dead time insertion

Flexible capture scheme

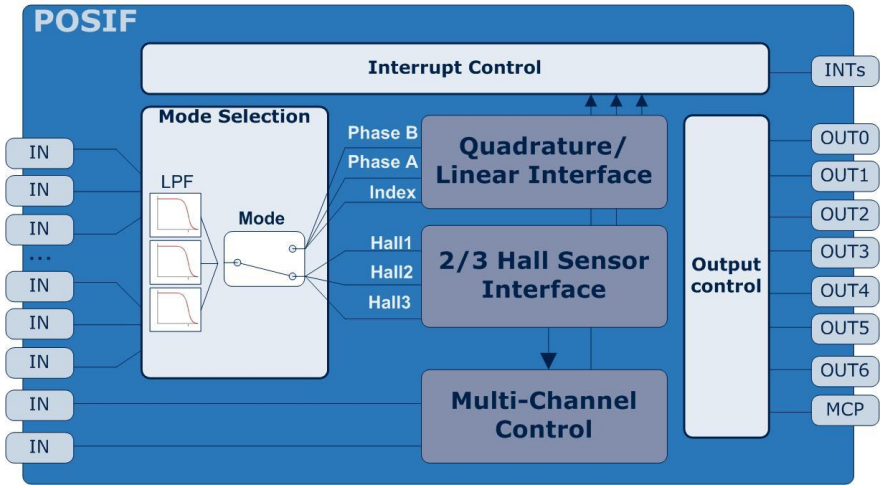
Customer Benefits

Each specific application function can be ported to any of the 4 Timers

Each Timer Slice can generate up to 4 PWM signals (2 pairs of complementary signals)

Parallel capture and compare modes

POSIF
Position Interface Key Features



Highlights

The POSIF module is the ideal solution for motor control applications using Hall Sensors and Quadrature Decoders. The user can configure freely the type and usage of the resources to perform an optimized mapping to the wanted application.

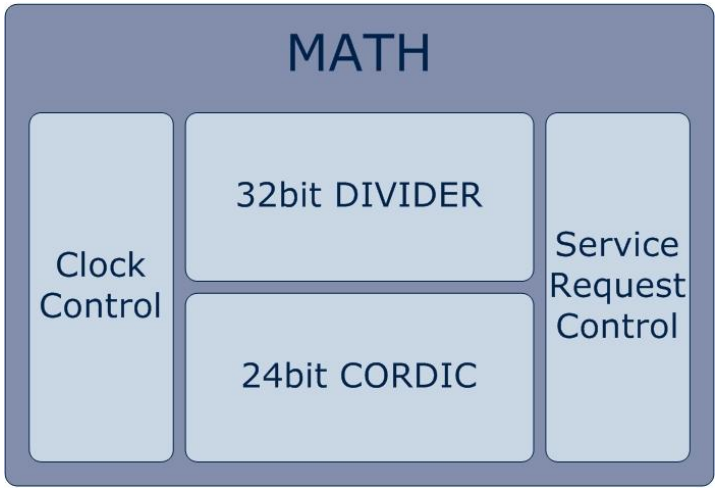
Key Feature

Interface for linear or quadrature rotary encoder
Interface for Hall Sensors
Stand-alone multi channel control

Customer Benefits

Application tailored motor position and velocity measurement.
Tailored solution for 2 or 3 Hall Sensor applications. Coupling with PWM generation.
Perform multi-level modulation for PWM. Tailored modulation development

MATH
MATH Co-Processor



Highlights

The math co-processor provides a 32bit signed or unsigned divider as well as a 24bit CORDIC for trigonometric calculations. Both DIVIDER and CORDIC can operate in parallel next to the CORTEX-M0 CPU core.

The MATH unit is connected to the PCLK which can be configured for 64MHz.

Key Feature

- 32bit divide for signed and unsigned long integer numbers
- sin(x), cos(x), arctan(y/x) is executed in parallel to CPU operation
- Vector rotation (PARK transform) is executed in 24bit resolution

Customer Benefits

- The calculation time of a divide operation is reduced to ..%
- Increase of computational power for real time critical tasks
- Field oriented motor control algorithms are implemented with high resolution

ADC
Analog to Digital Converter

Highlights

The ADC in all XMC1000 series is based on a high speed 12-bit analog to digital converter which is clocked with 32MHz. Resulting in high maximum sample rates for 12-bit conversions:

- 1.28MSPS calibrated
- 1.88MSPS un-calibrated

Target values, to be confirmed

Key Feature

12-bit, 10-bit and 8-bit conversion modes as well as fast compare mode

Individually adjustable gain for each analog input channel

Two independent sigma delta loops increase ENOBs

Customer Benefits

This fast ADC can be made faster when configuring in lower resolution conversion modes.
The 10-bit fast compare mode just takes 62.5ns.

An adjustable gain factor of x1, x3, x6 or x12 together with the fast conversion speed make an operational amplifier obsolete in many applications.

The two sigma delta loops individually hold the quantization error of the previous conversion in order to consider this tiny amount in the next conversion.

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Tools and SW Partners for XMC Micro Controllers

- Commercial tools and SW solutions
  - Infineon cooperates with all major tool and SW vendors for ARM based microcontrollers to support XMC1000 as well as XMC4000
- Free tools and SW solutions
  - The development platform DAVE is provided by Infineon
  - Open source
    - FreeRTOS
  - Free evaluation versions

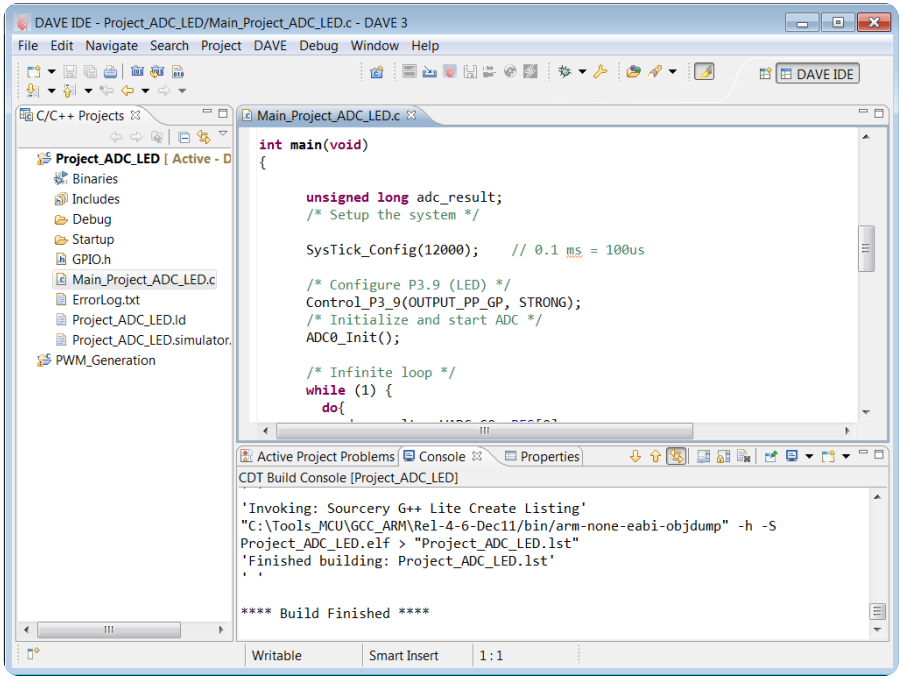
DAVE™ makes powerful hardware accessible
Free IDE and code generator

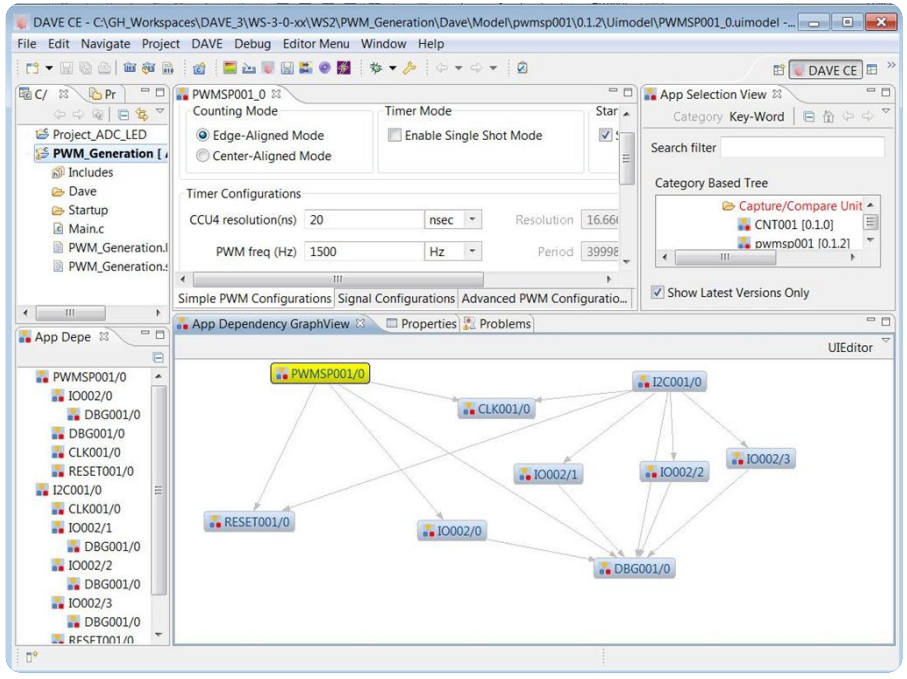
Integrated Development Environment (IDE)

- Eclipse based
- Free GNU Compiler, debugger, loader
- Free data visualization utilities
- Open for 3rd party tools (compiler, debugger) and software (operating systems, stacks) as plug-in

Auto-code generator (Code Engine)

- Easy selection of peripheral and application oriented DAVE™ Apps
- Configuration via graphical user interface
- Generated code can be used via well documented APIs (like a library)
- Extendable by user or 3rd party Apps





- Website: www.infineon.com/dave3

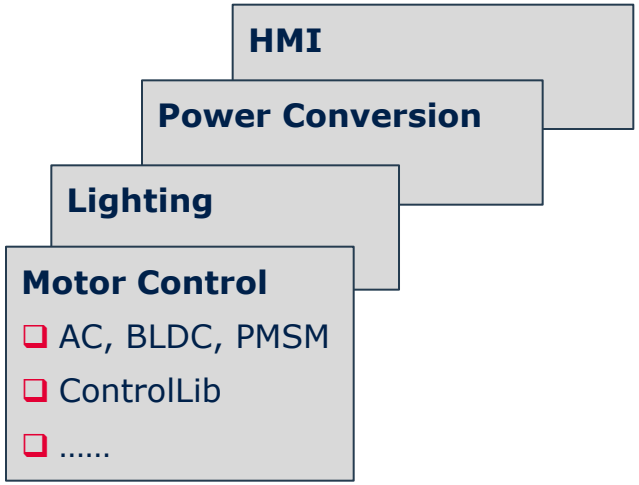
Overview of available and planned DAVE™ Apps for the XMC Families

Service Apps
- Clock
- Reset
- SystemControl
- Power Mgmt.
- Watchdog
- DMA
- NVIC /Exception
- Request Unit
- I/O
- EBU
- Flash
- CRC
- AES
- SW/SysTimer
- Debug Log
- CMSIS RTOS
- Libraries

Middleware
- USB stack, class drivers, host and device
- TCP/IP stack plus HTTP, FTP, SNMP
- SD/MMC, file system,…
- GUI lib plus driver for intel. LCD
- …..

Basic Applications
- PWM, Capture, Timer, Counter
- Communication
- Analog
- ……..

Application Specific Middleware

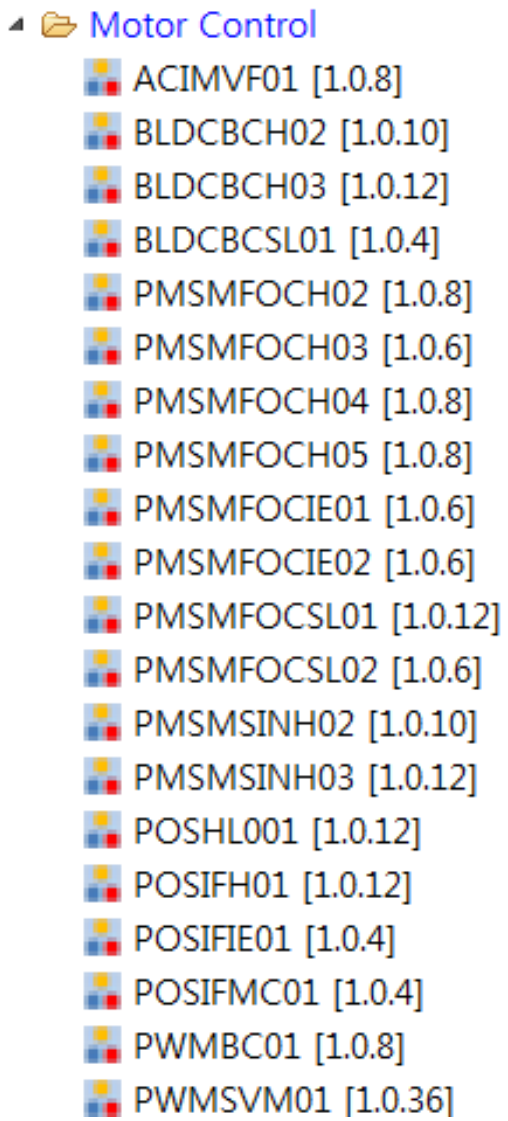


Ref. Projects
- elua
- HMI system
- ……

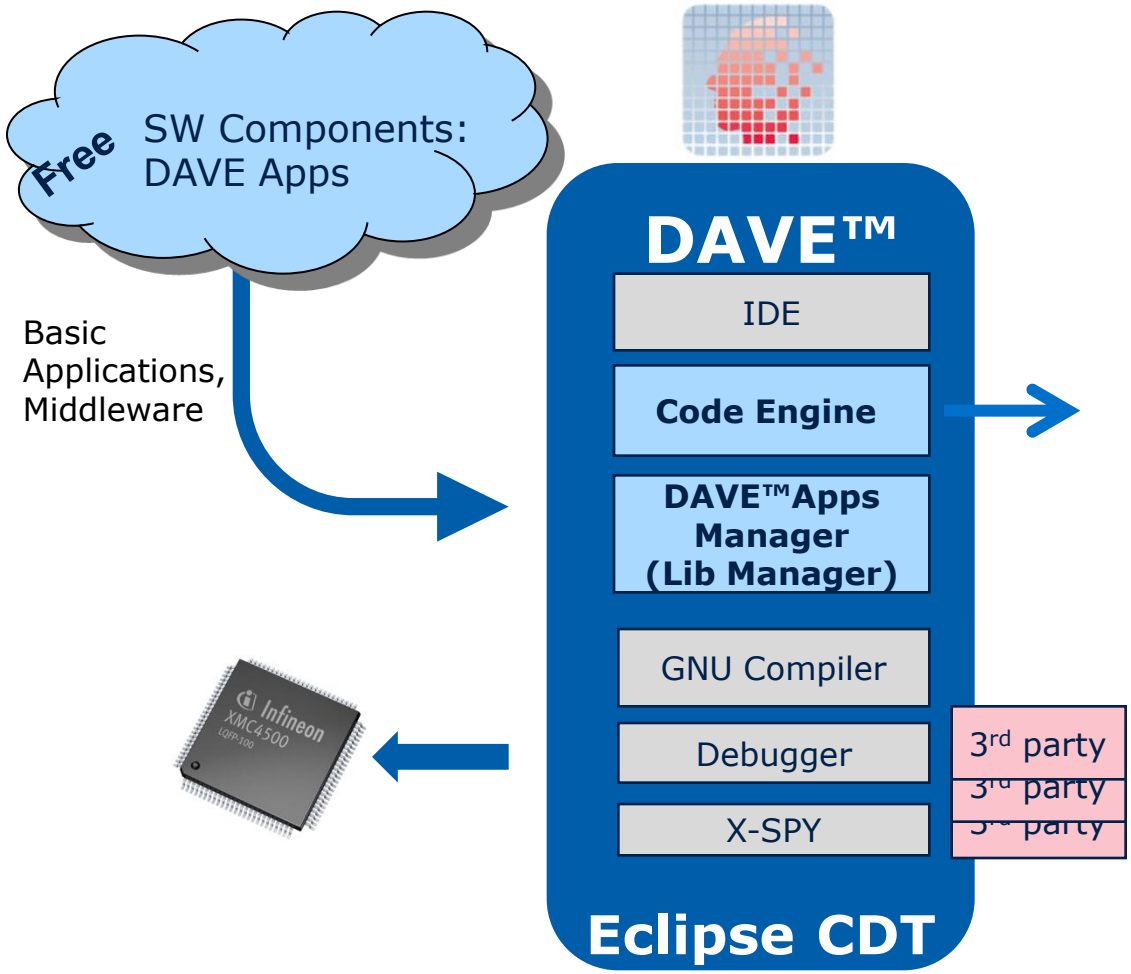
In total Infineon is providing 170+ DAVE Apps
Details about the latest released DAVE Apps can be found here:
http://www.infineon.com/cms/en/product/promopages/aim-mc/DAVE_3_Support_Portal/Release_Note_update.html

App Support for Motor Control

- V/F for simple open loop
- Block Commutation for Hall Sensor
- Sinewave commutation for Hall Sensor
- Sensorless FOC



The DAVE™ Development Platform

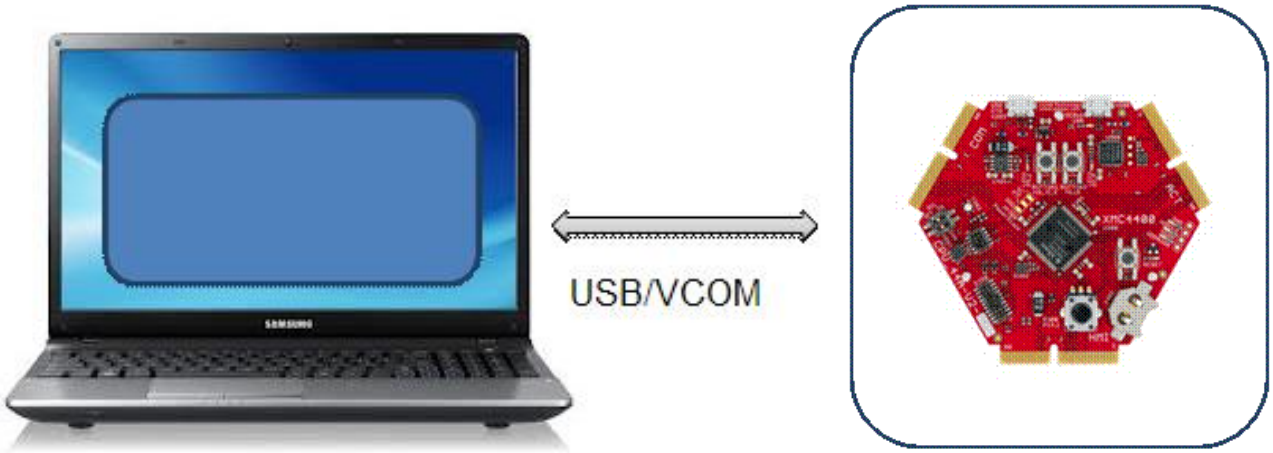


Library code generation based on predefined and tested SW components (DAVE™ Apps)

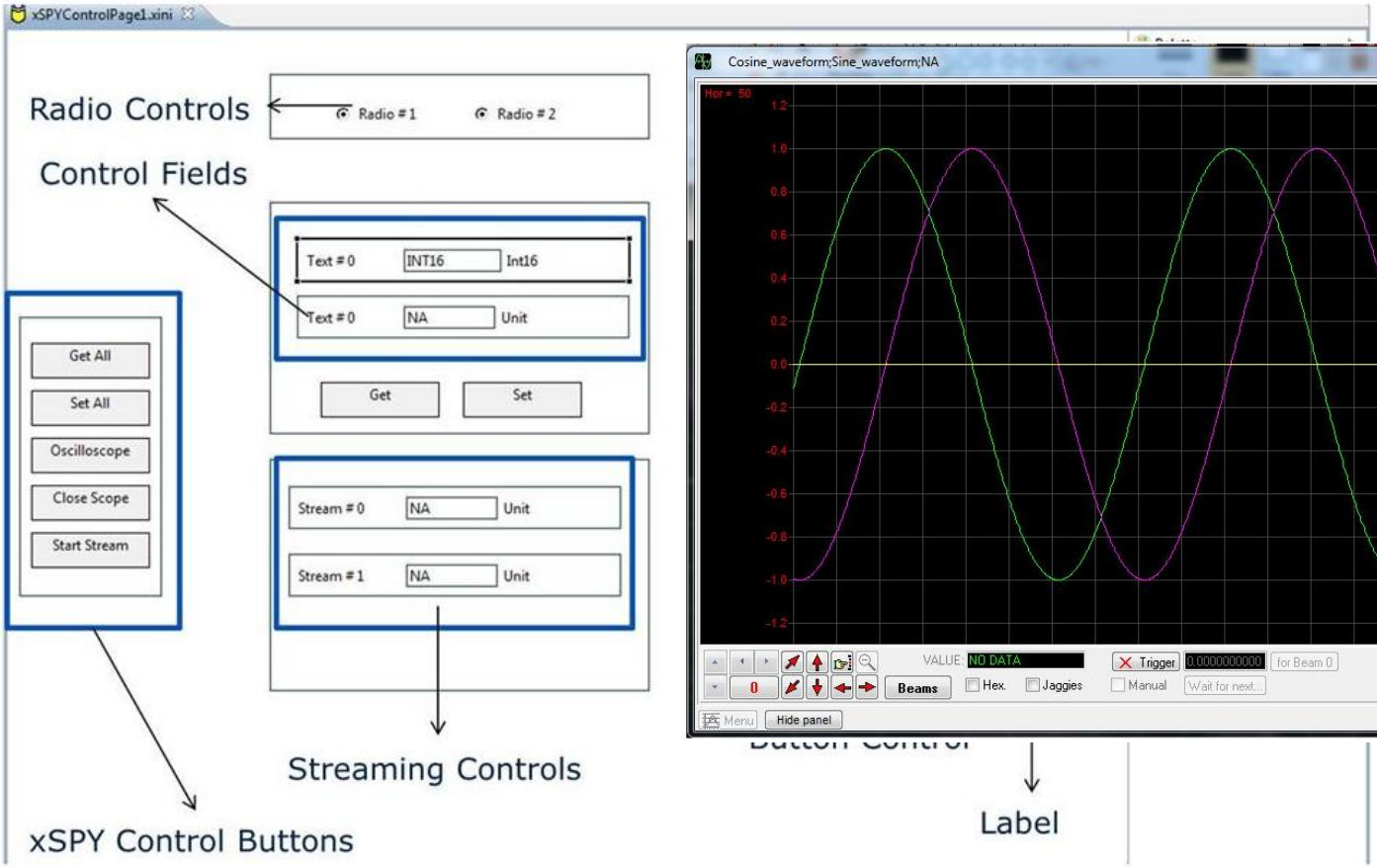
Option for third parties to plug in other commercial or free tools

XSPY for PC Monitoring Program

- Using xSPY the user can easily define an UI to control and monitor the microcontroller from the PC.
- xSPY is a DAVE plugin used to visualize and analyze the tracing data generated by DBG002 App by means of software oscilloscopes and logging views.



XSPY for PC Monitoring Program



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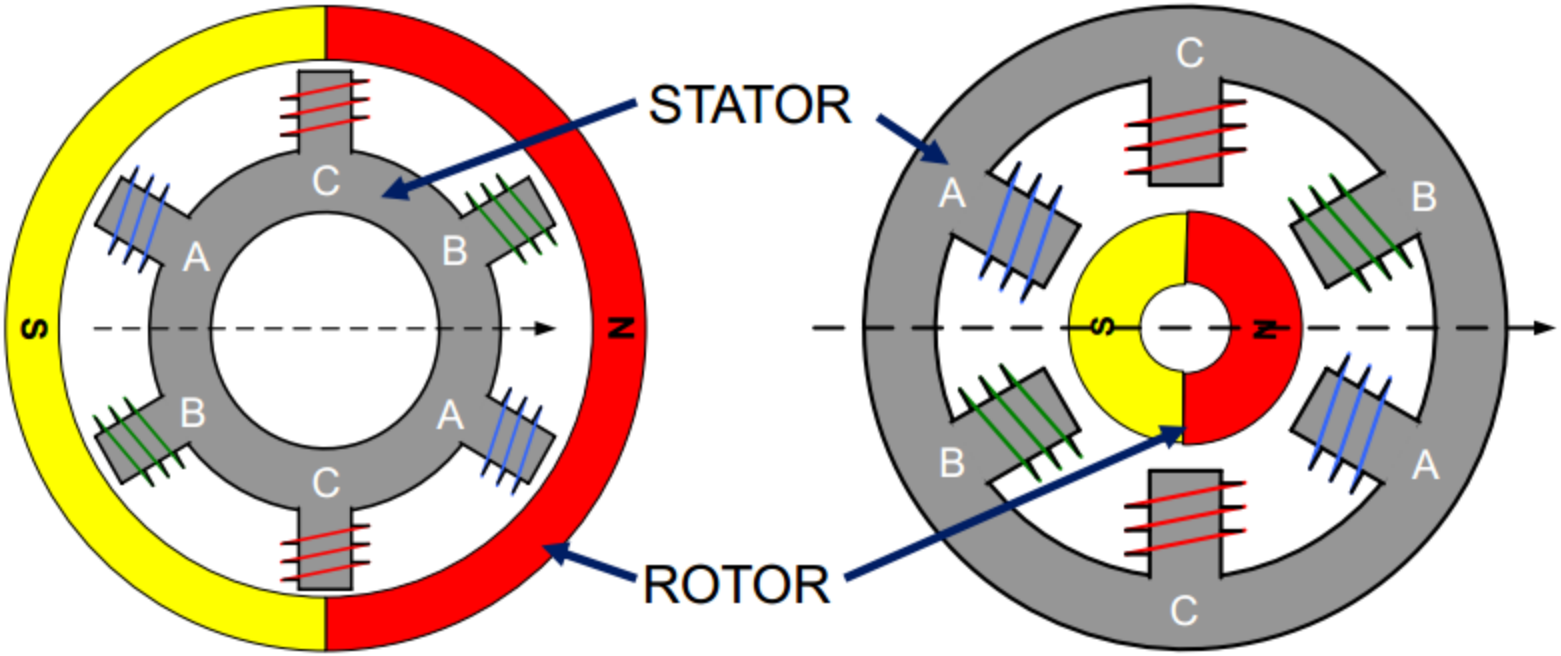
Introduction to Brushless DC (BLDC) Motor

- Constructed with a permanent magnet rotor and a stator comprising of wire wound poles and stacked steel laminations.
- Electrical energy is converted to electrical energy by the magnetic attractive force between permanent magnet and the rotating magnetic field induced in the wound stator poles



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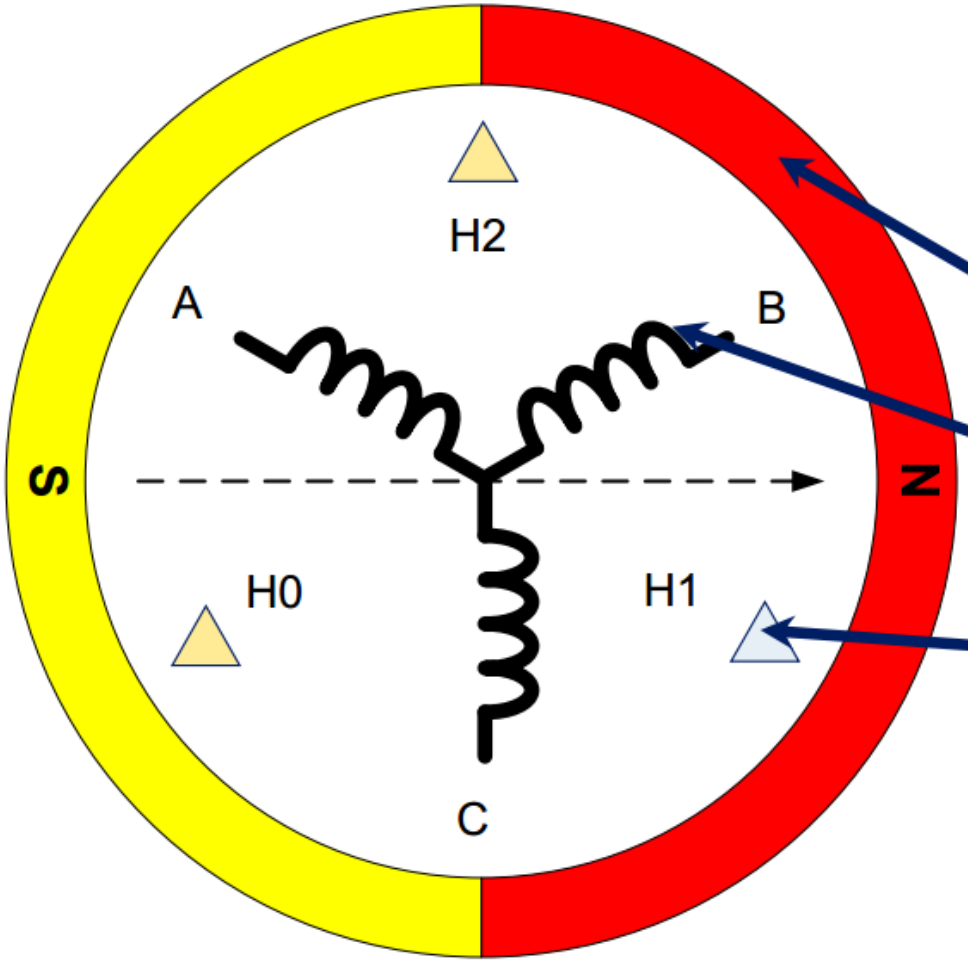
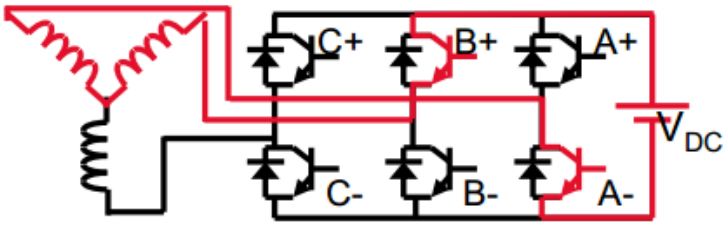
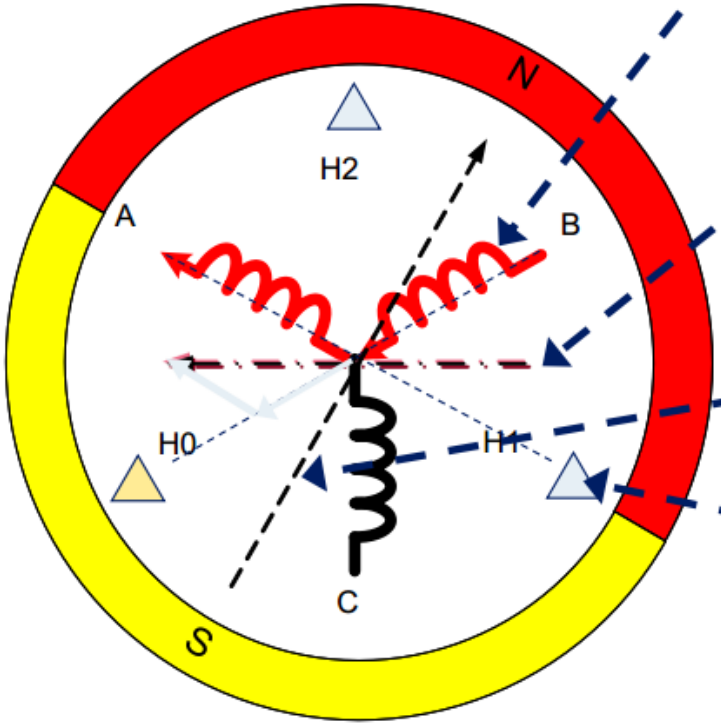


- This is a simplified and representational model of a single pole pair BLDC motor.
- Rotor – Made of permanent magnet.
- Stator - Three phase windings connected in star fashion.
- Hall Sensor – Devices that can detect magnetic field. In this case study, they are placed at 120 electrical degrees apart.

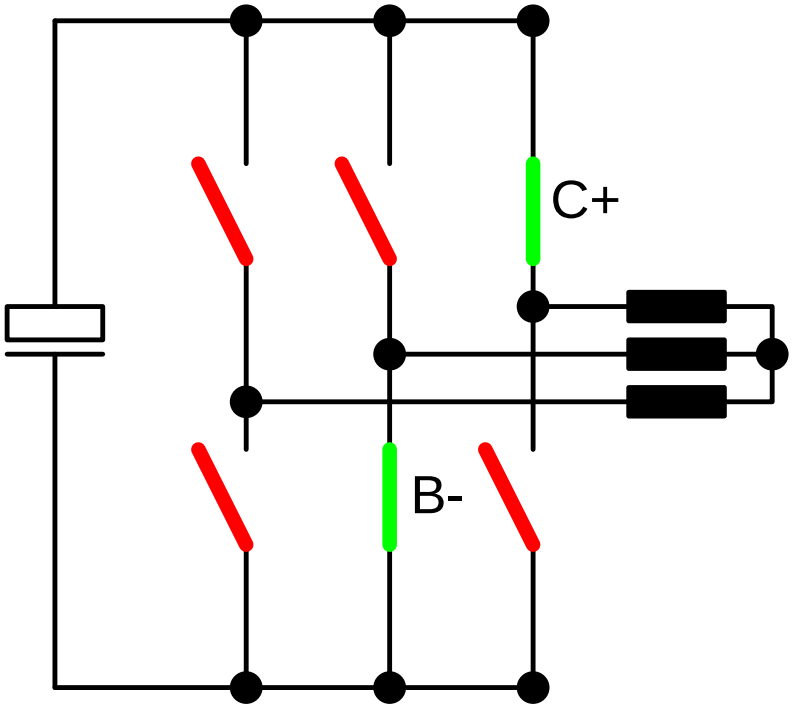
Introduction to Brushless DC (BLDC) Motor

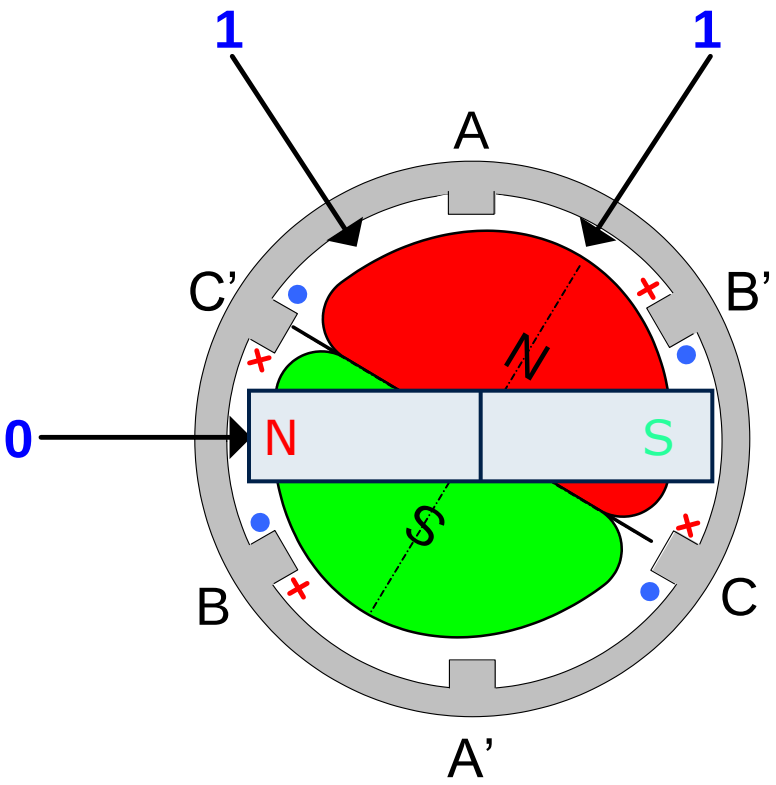




- For simplicity, the arrow that shows the direction of the energizing current also shows the direction of the magnetic field for each coil.
- Magnetic field of stator, it is a vector sum of the magnetic fields of the energized coils.
- Magnetic field of rotor (permanent magnet)
- Hall sensors output LOW when 'N' is sensed.

Introduction to Brushless DC (BLDC) Motor





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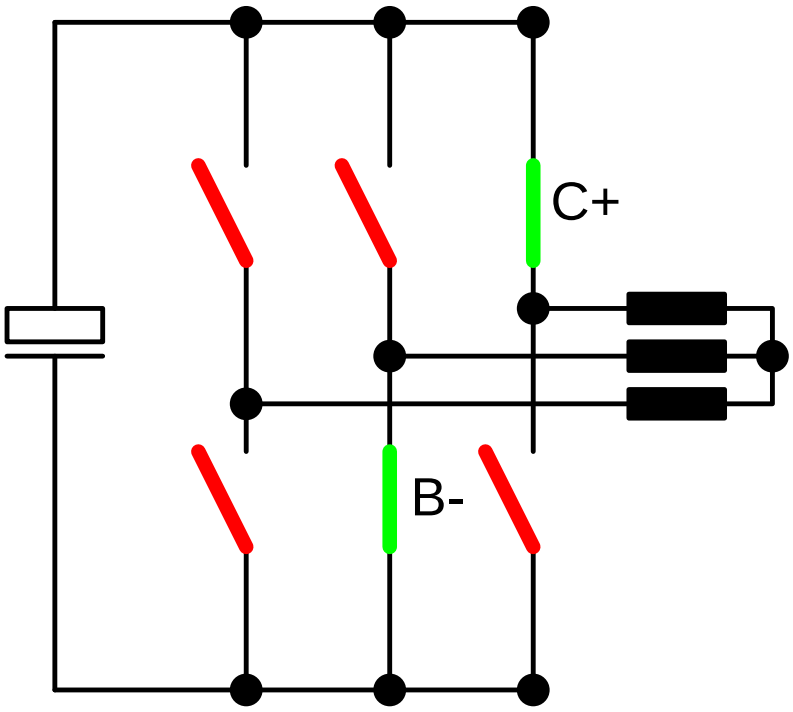

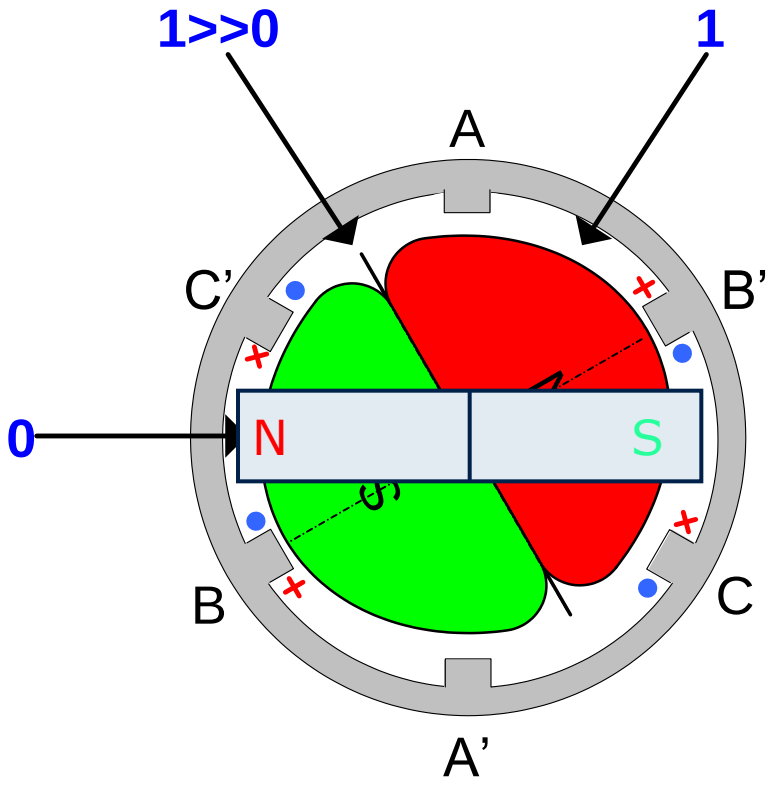

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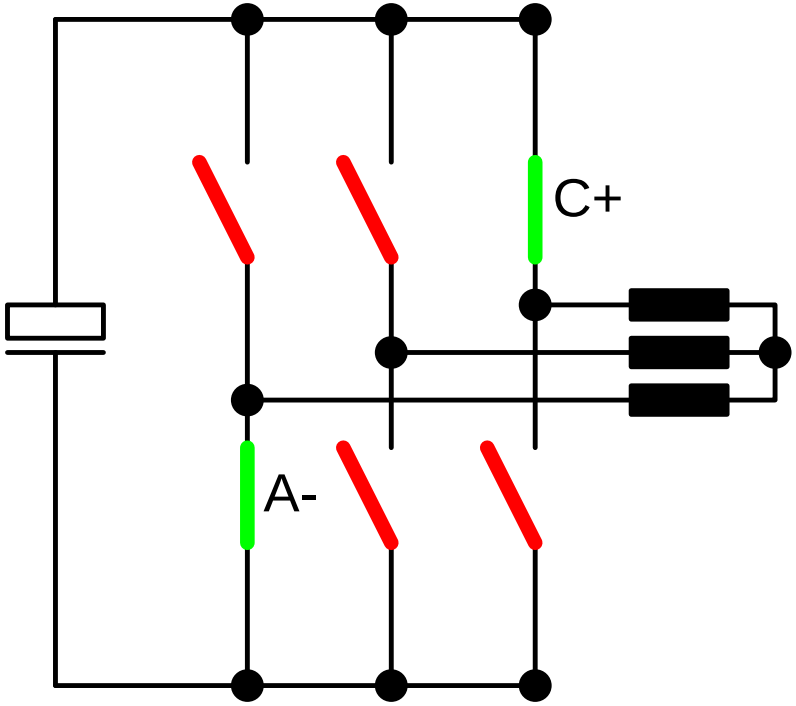

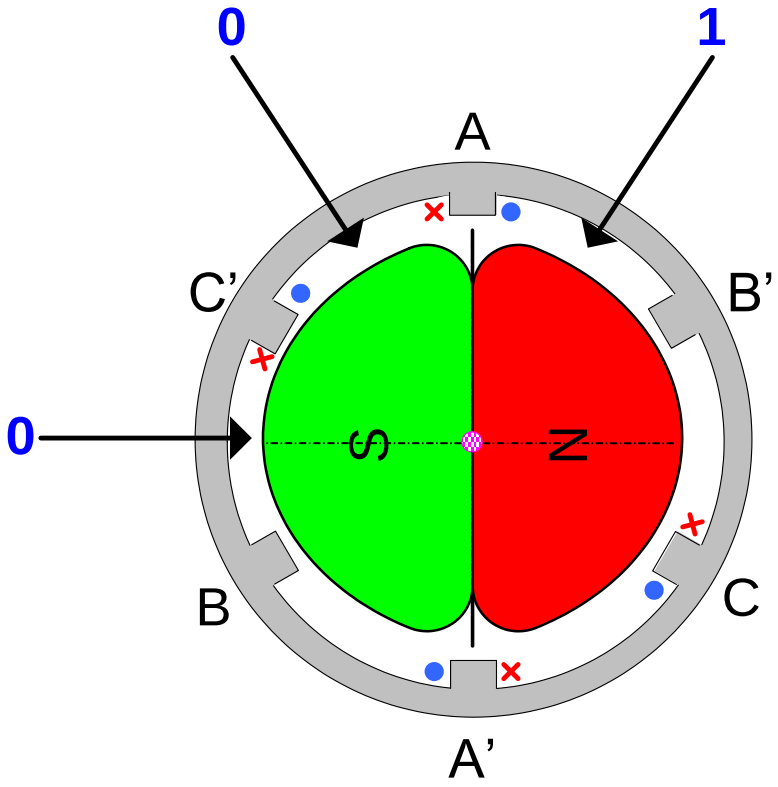

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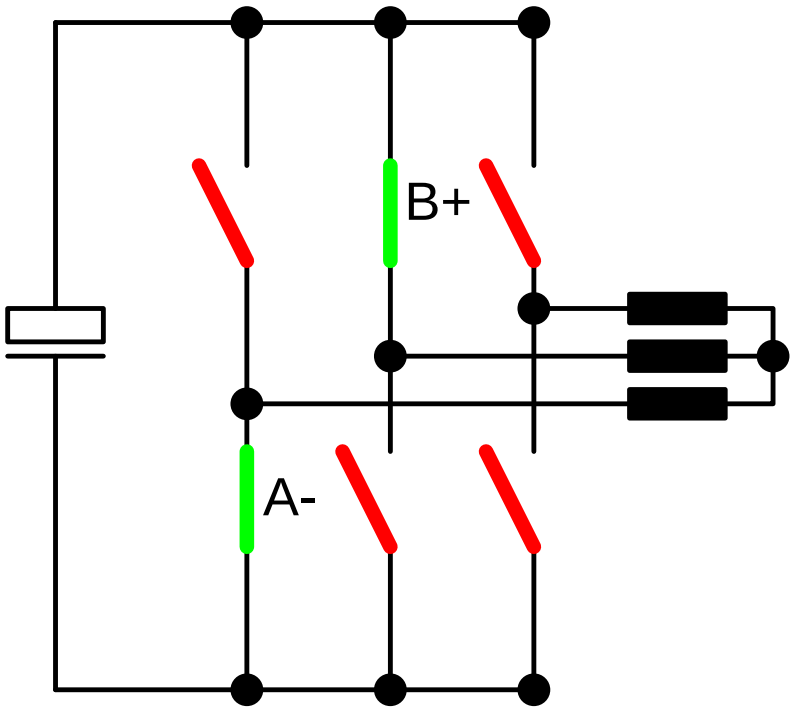

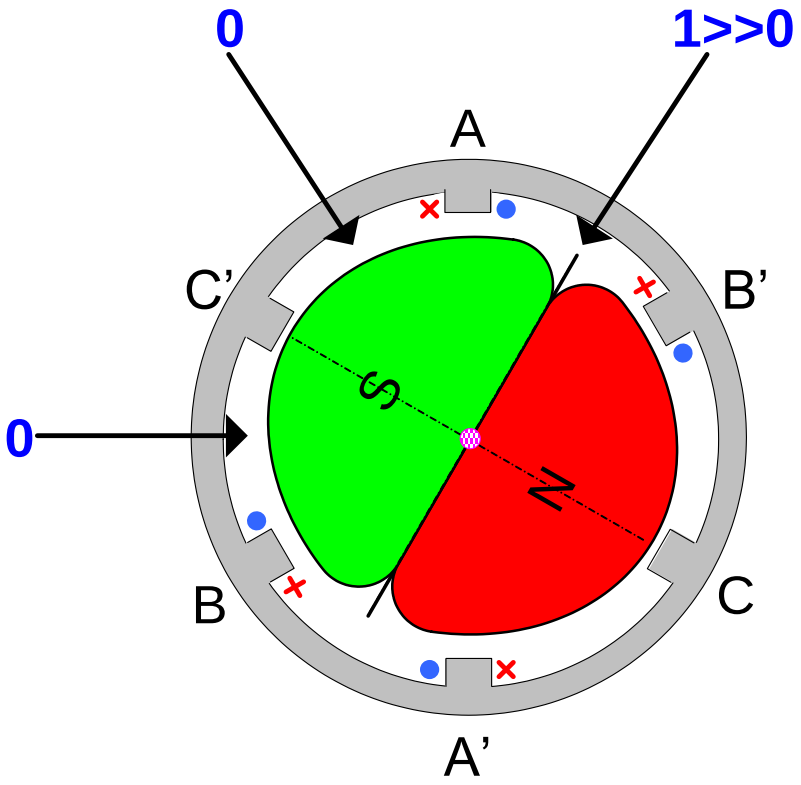

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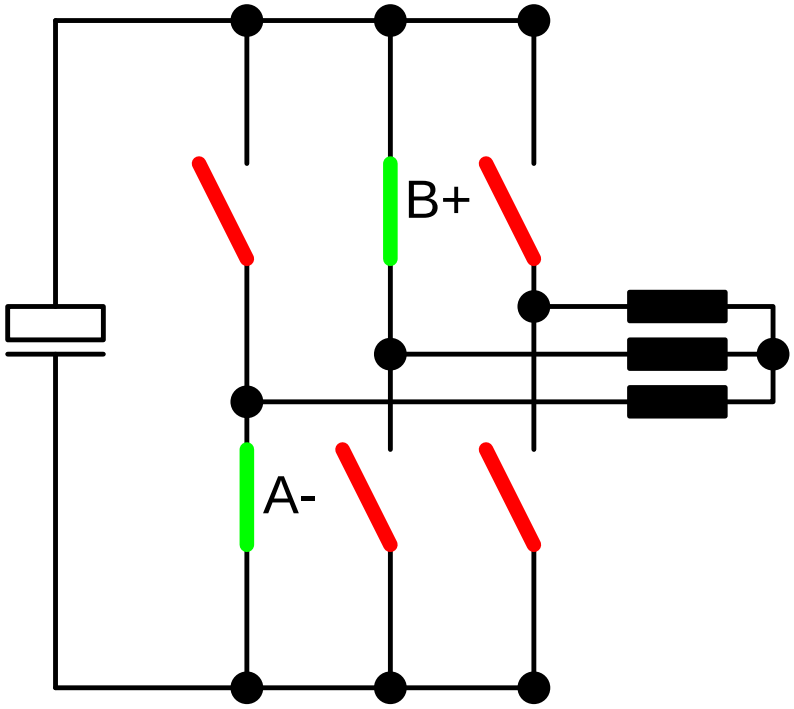
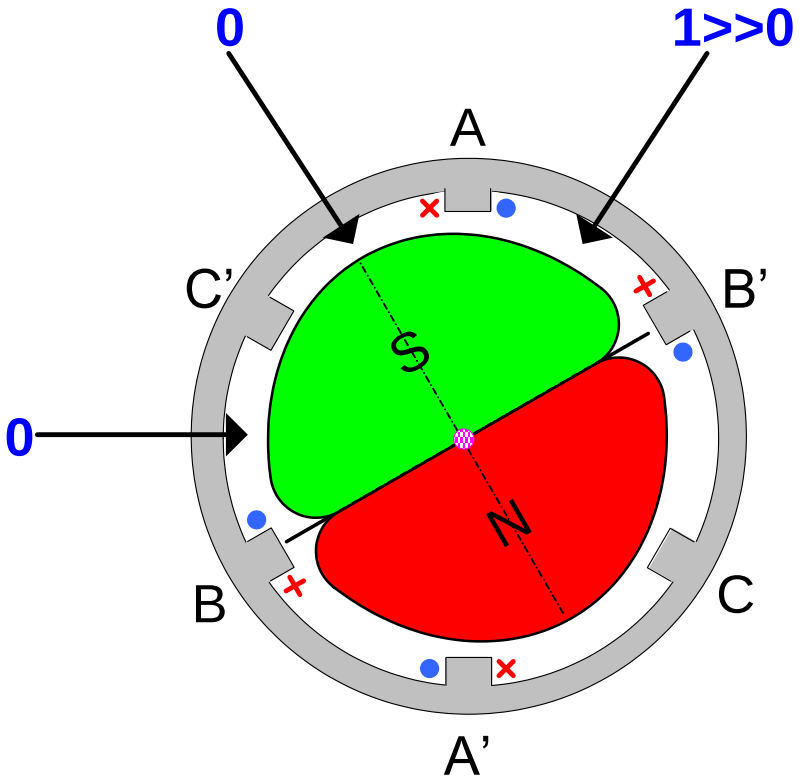
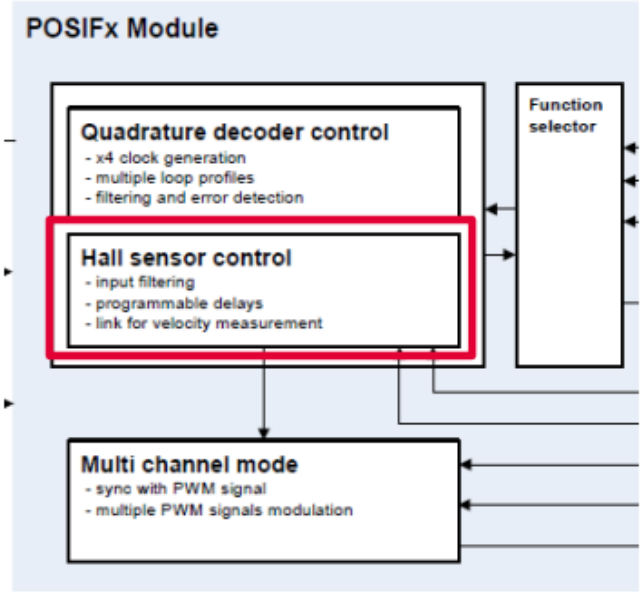




POSIF Feature

Hall Sensor Mode

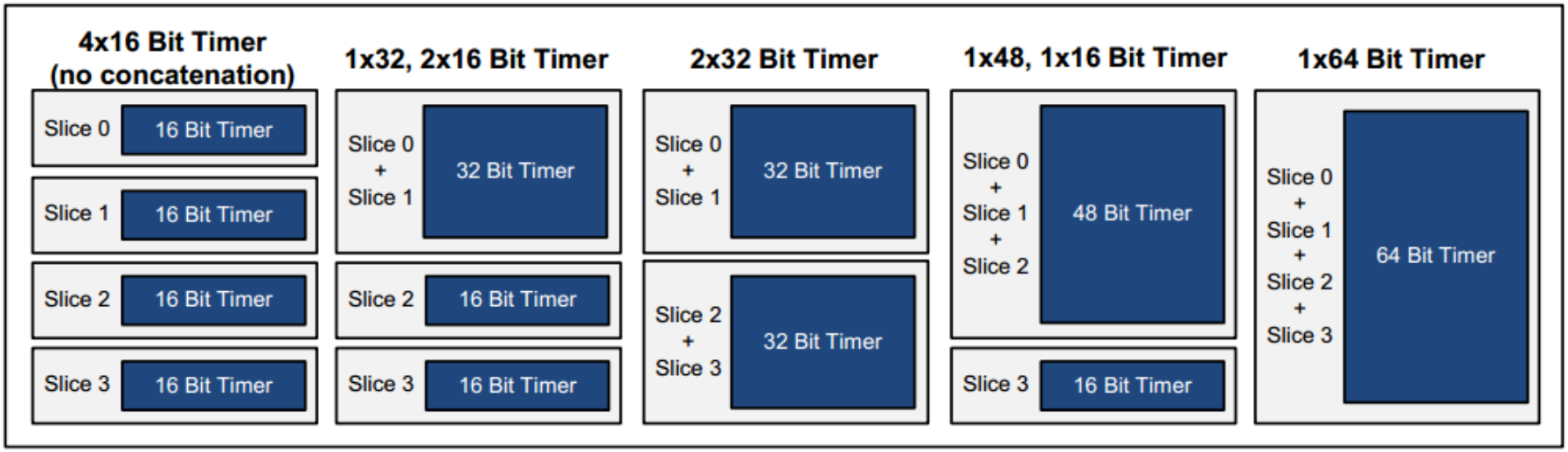
- Simple build-in mode for brushless DC motor control
- Shadow register for the multi-channel pattern
- Complete synchronization with the PWM signals and the multi-channel pattern update
- Interrupt sources for Correct Hall Event detection, Wrong Hall Event detection



CCU4 Feature

General Features

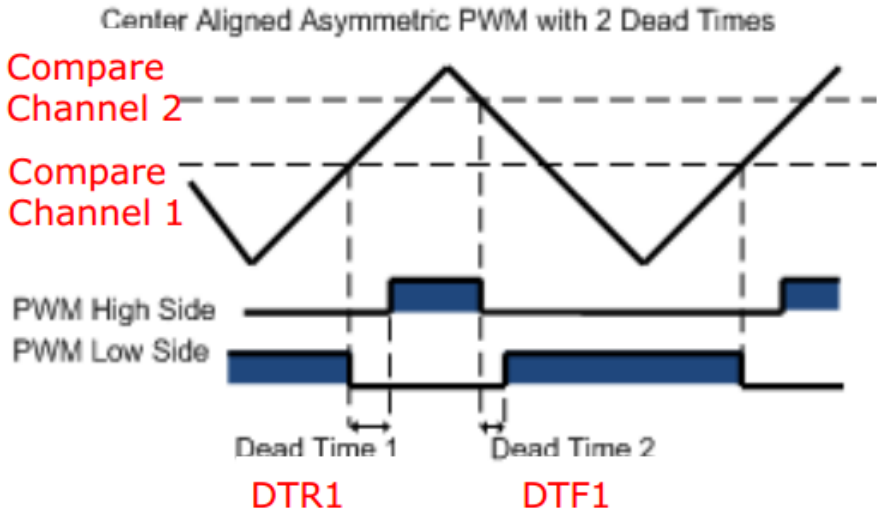
- Four identical 16-bit Capture/Compare Timer slices
- Concatenated timer cells
- Normal/Floating prescaler
- Linking with POSIF



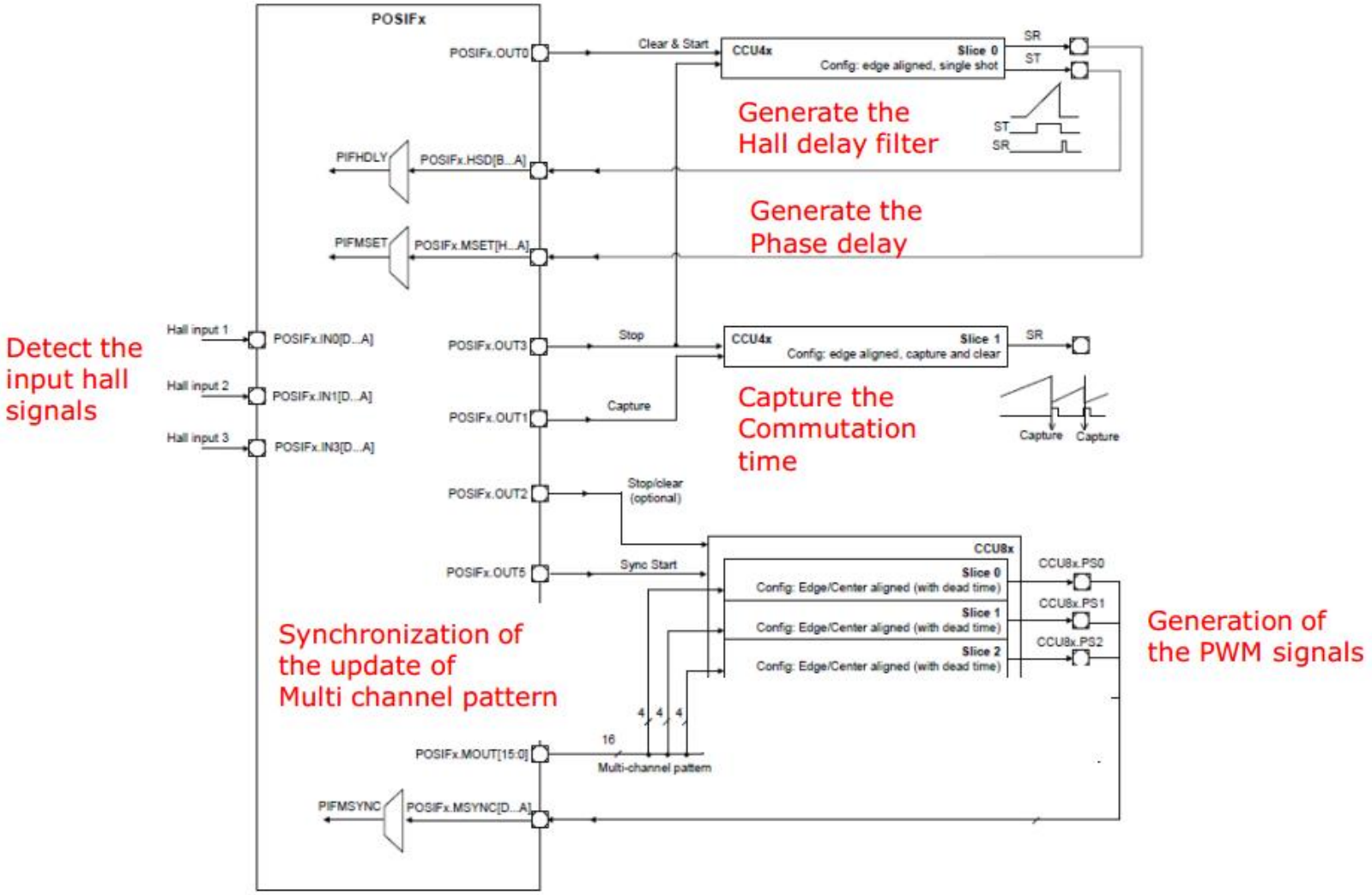
CCU8Feature

General Features

- Support Symmetric, Asymmetric, Periodic, Aperiodic PWM generation.
- Support different dead time values for rising and falling transition.

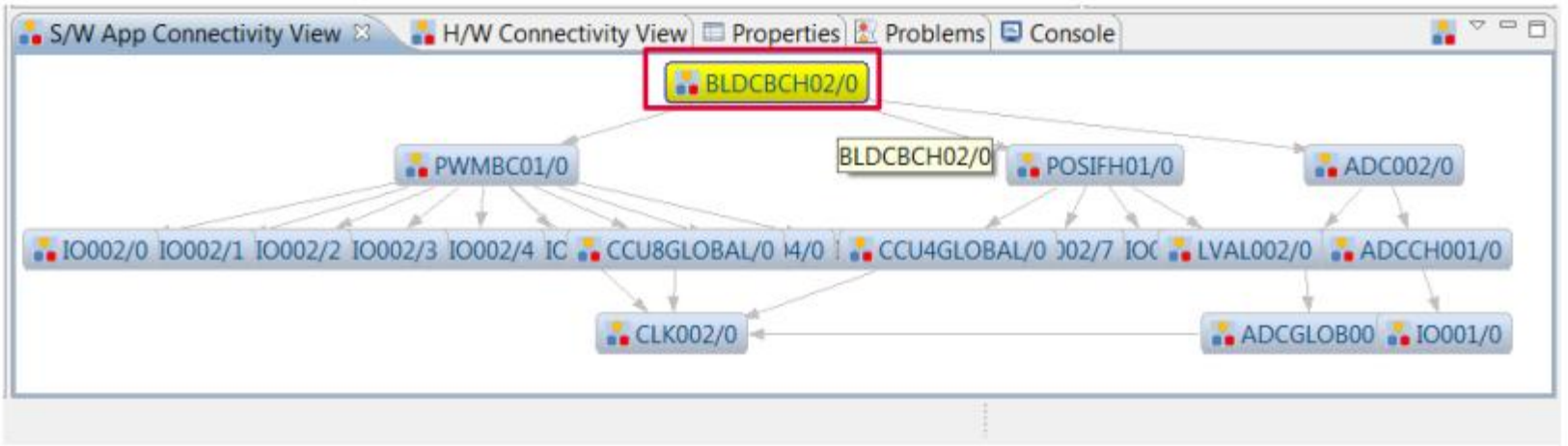


Overview of POSIF, CCU4 & CCU8 usage for Hall Sensor BLDC Motor control application

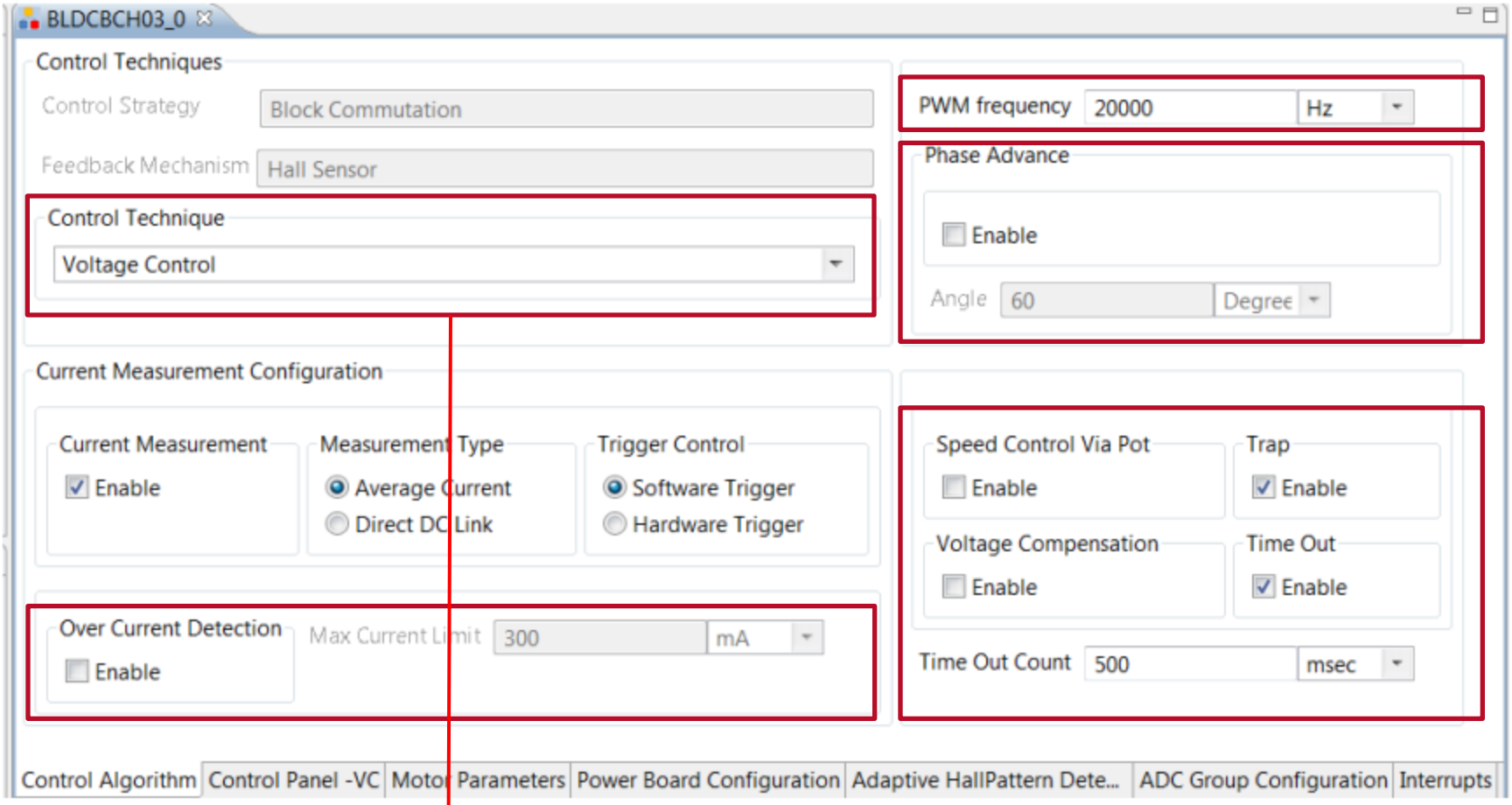


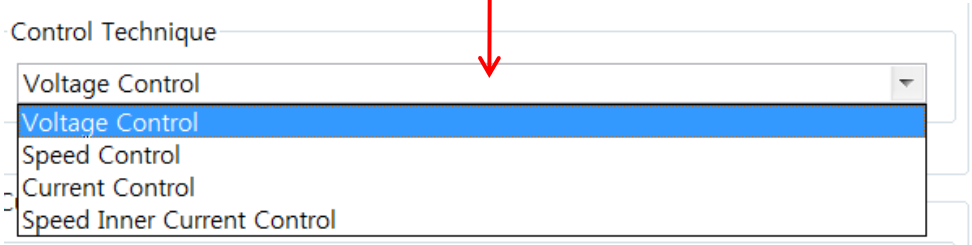
Hall Sensored Block Commutation

- Double click on "BLDCBCH02/0" in the S/W App Connectivity View.

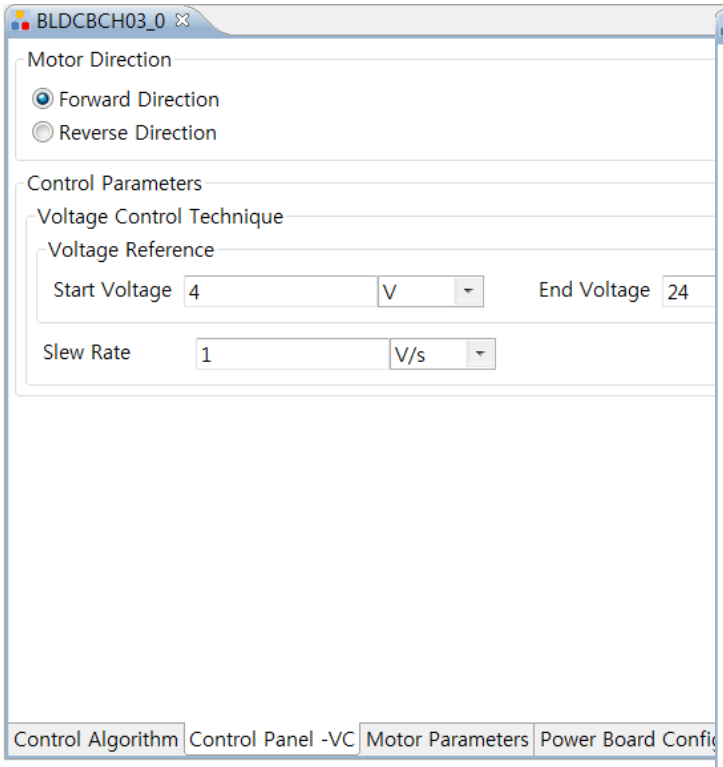


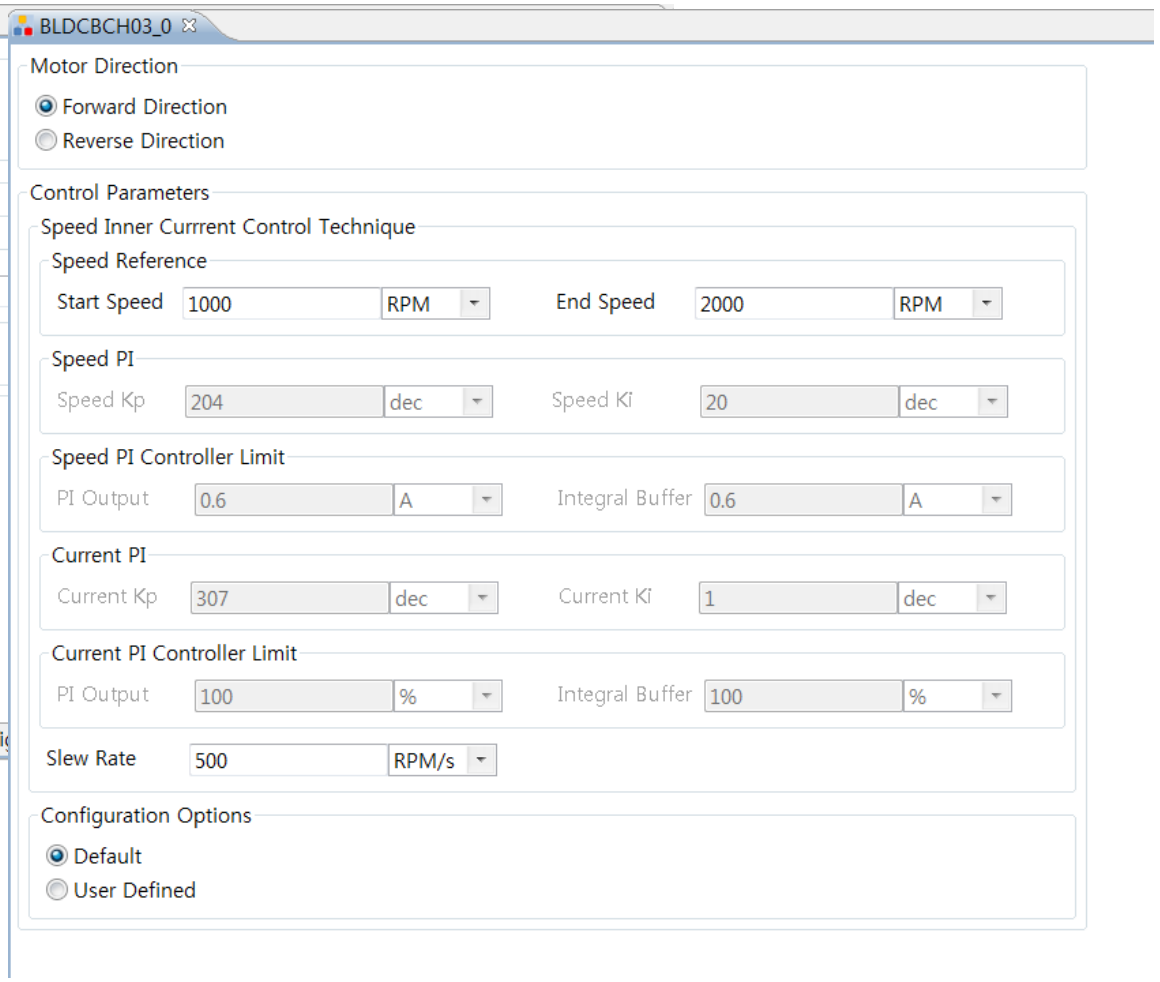
Hall Sensored Block Commutation –Control Algorithm



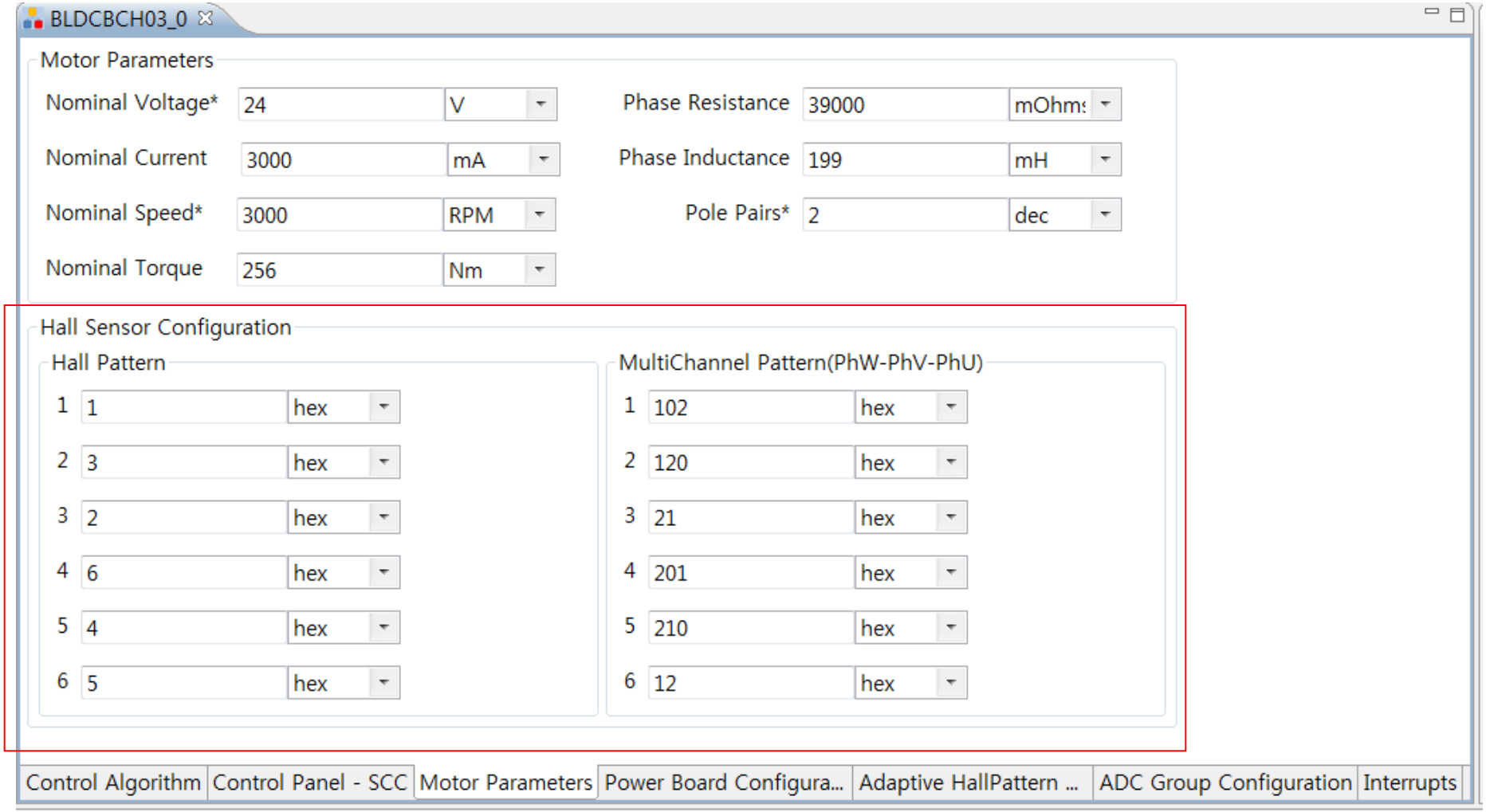


Hall Sensored Block Commutation – Control Panel

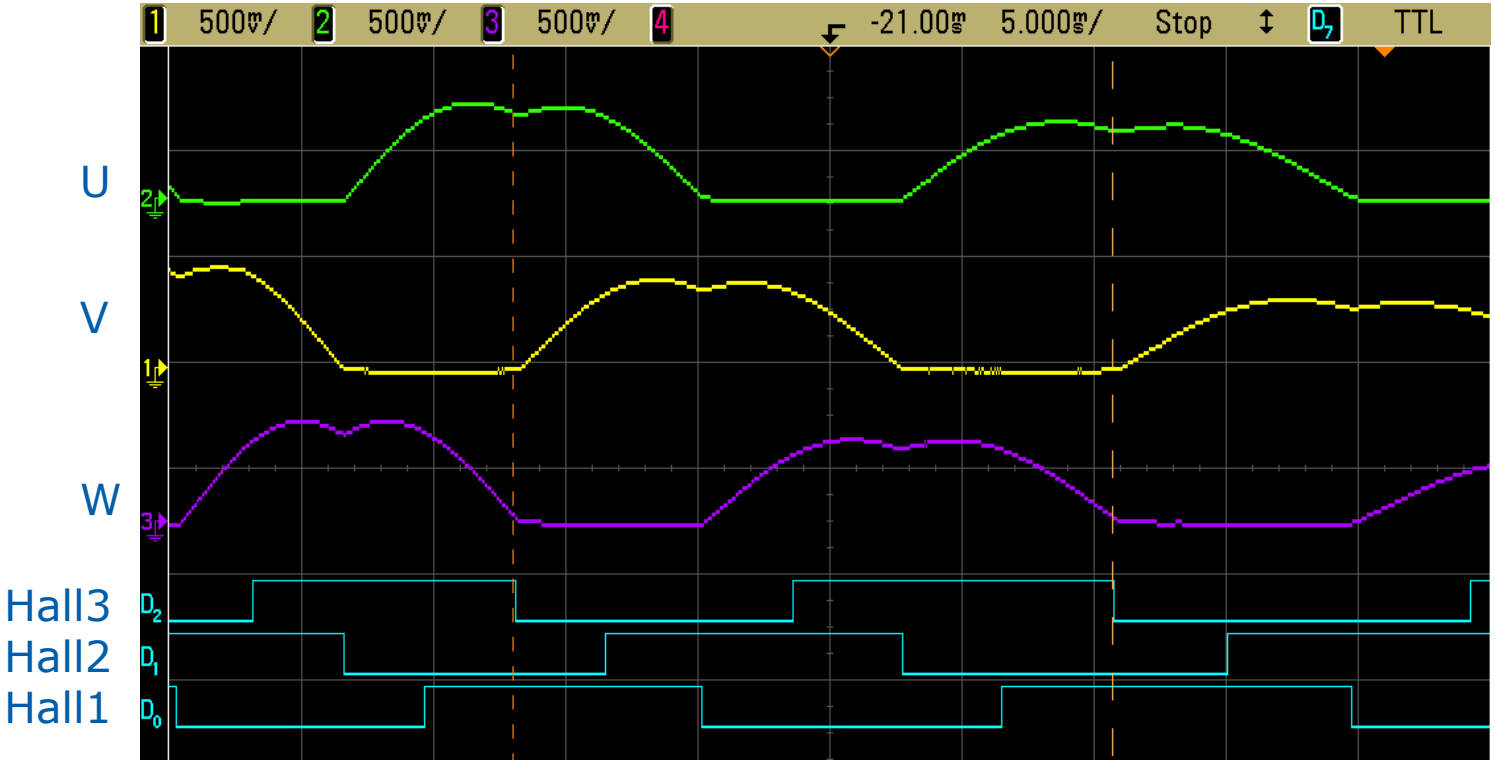




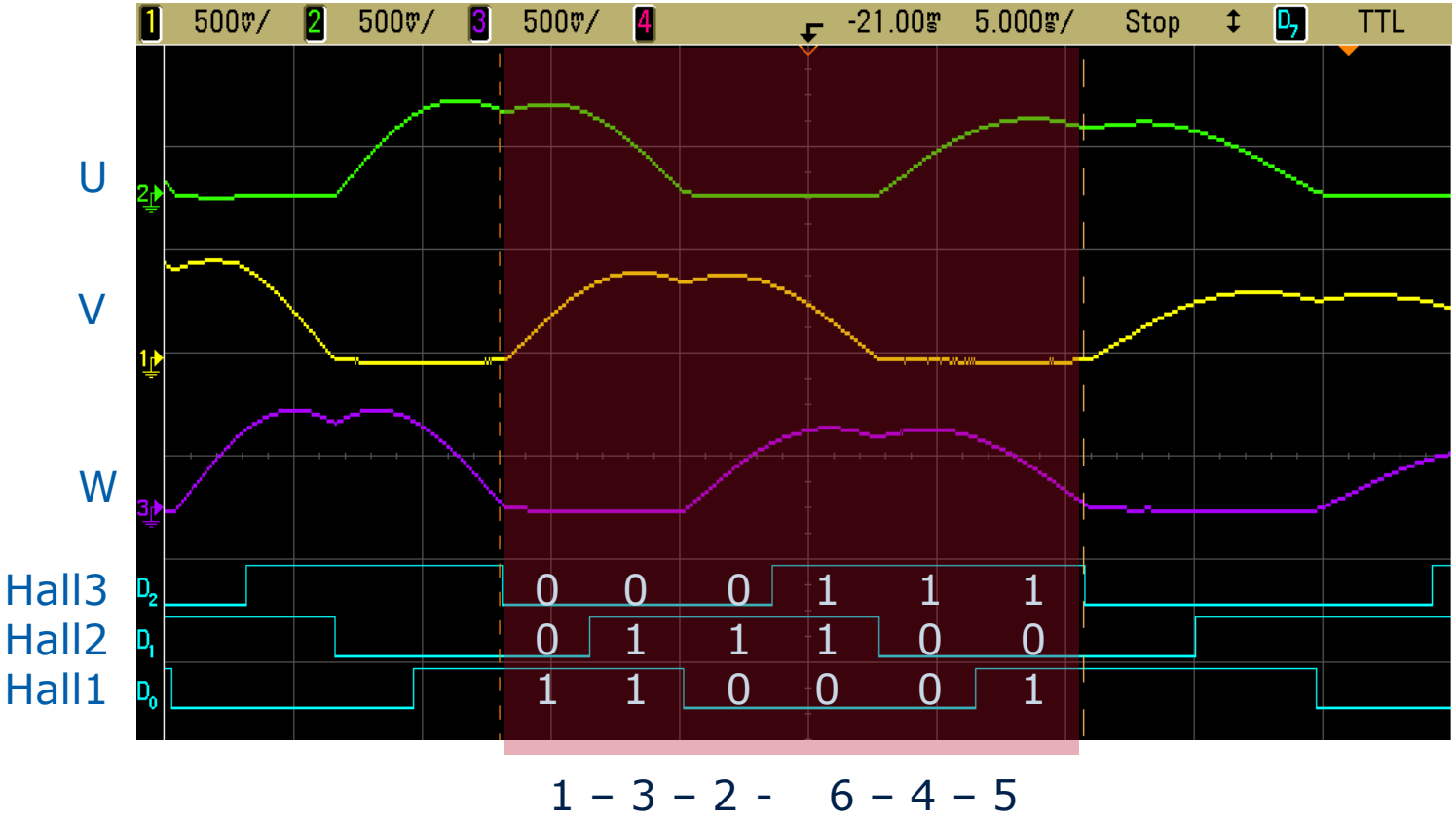
Hall Sensored Block Commutation – Motor Parameters



Hall Sensored Block Commutation – Motor Parameters

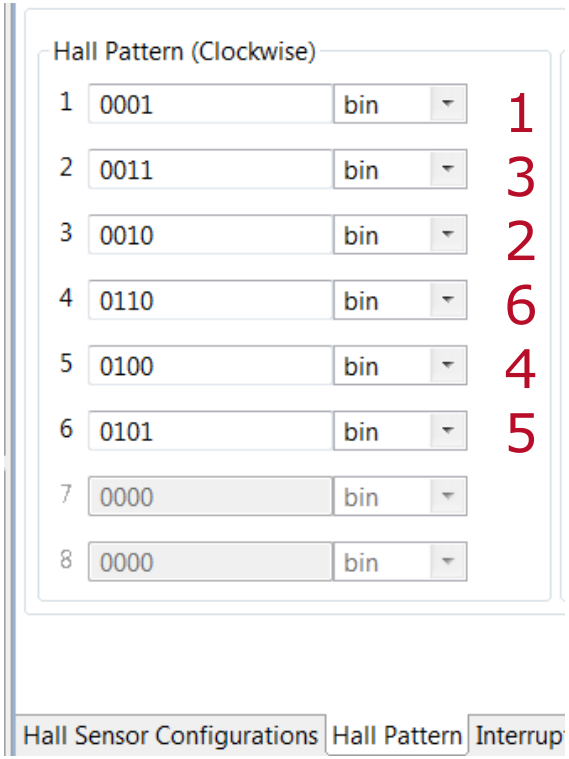


Hall Sensored Block Commutation – Motor Parameters



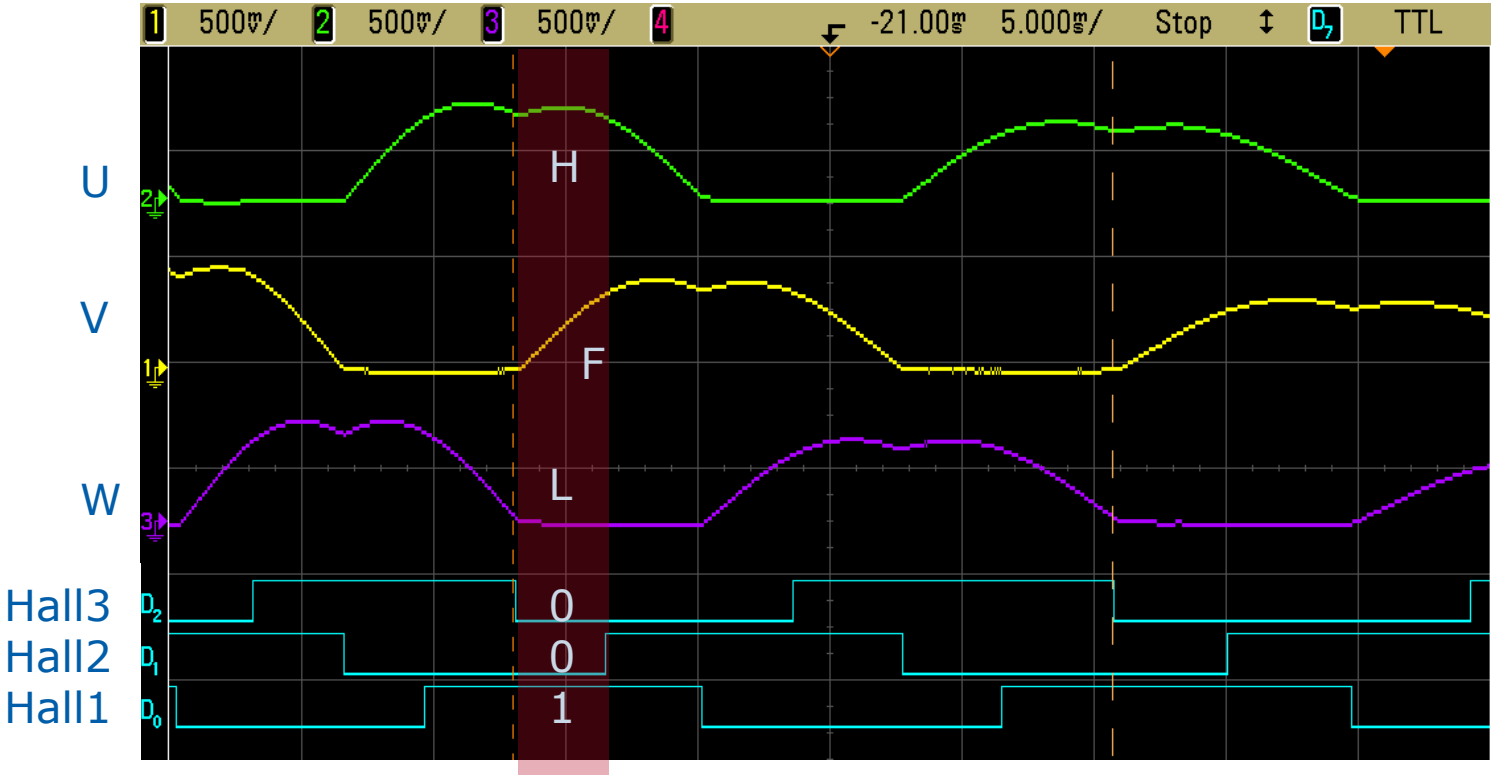
- The Hall Pattern for one electrical cycle is:
- 1 -> 3 -> 2 -> 6 -> 4 -> 5

Hall Sensored Block Commutation – Motor Parameters



- The Hall Pattern for one electrical cycle is:
- 1 -> 3 -> 2 -> 6 -> 4 -> 5

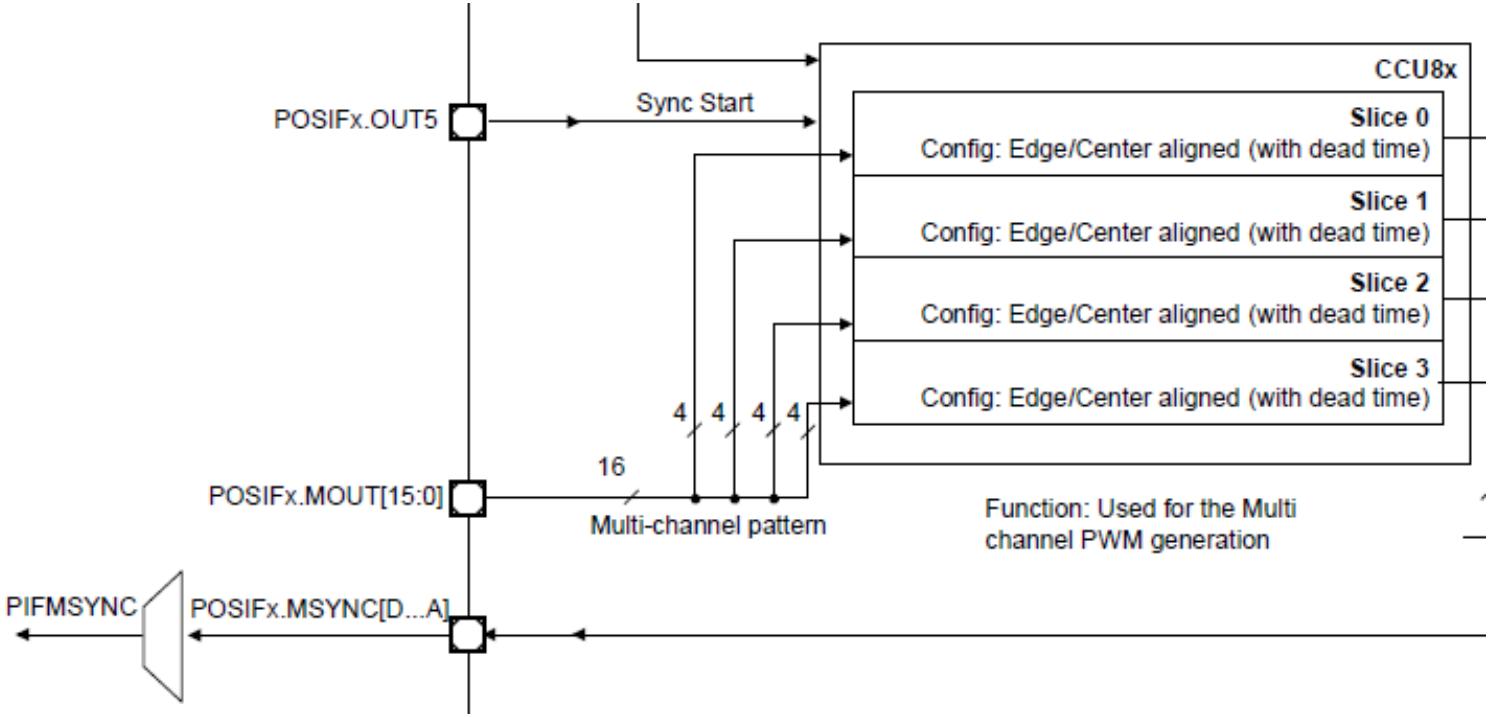
Hall Sensored Block Commutation – Motor Parameters



At Hall Position "1" :

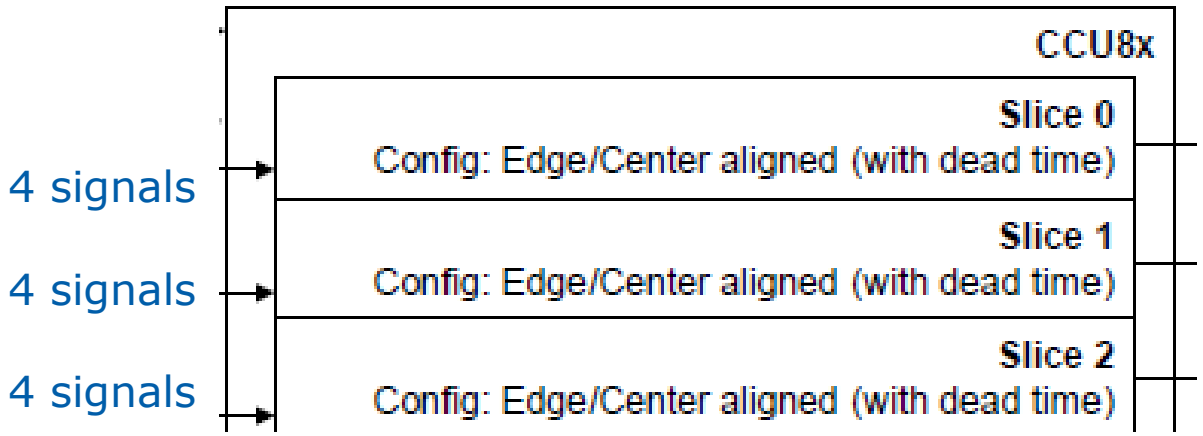
- U is "High"
- V is "Float"
- W is "Low"

Hall Sensored Block Commutation – Motor Parameters



- MOUT of the POSIF is used to control the PWM signal.

Hall Sensored Block Commutation – Motor Parameters



(LSB)

U	High side	1
	Low side	0
	NA	0
	NA	0
V	High side	0
	Low side	0
	NA	0
	NA	0
W	High side	0
	Low side	1
	NA	0
	NA	0

(MSB)

At Hall Position "1" :

- U is "High"
- V is "Float"
- W is "Low"

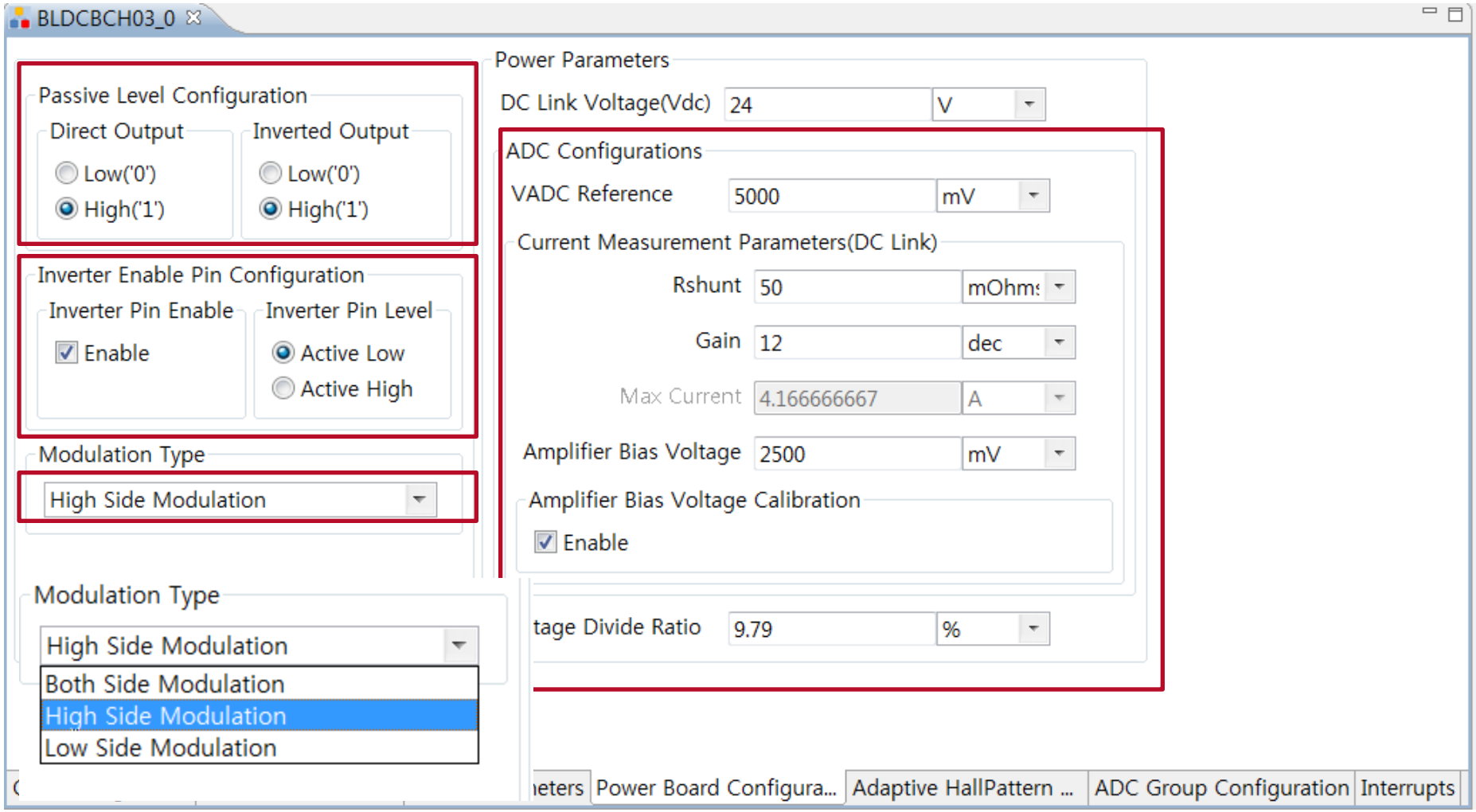
W V U

(MSB) (LSB)

The output pattern is "0010 0000 0001".

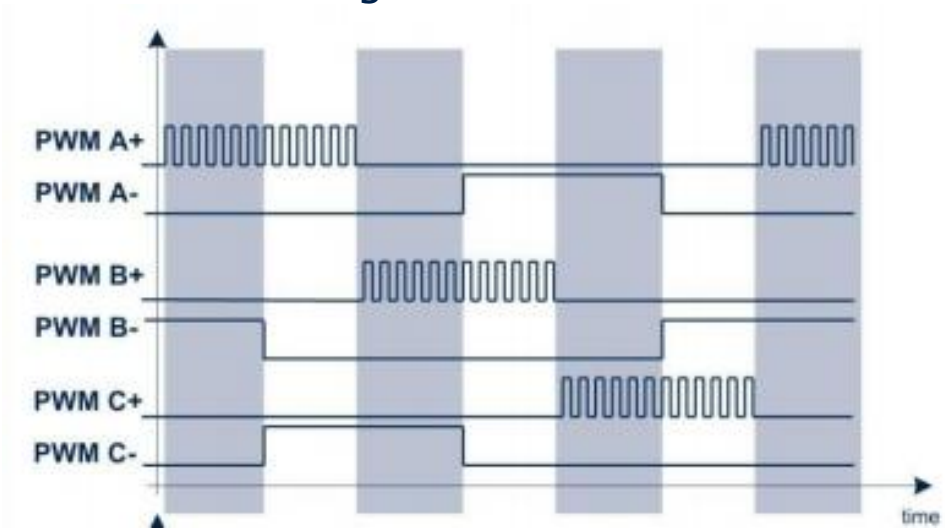
The output pattern is "201" (hex).

Hall Sensored Block Commutation – Power Board Configuration

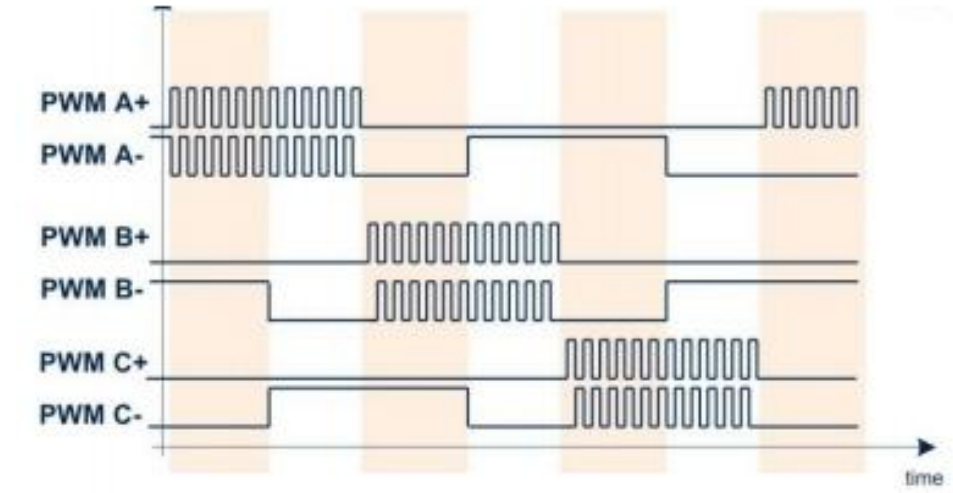


Hall Sensored Block Commutation – Motor Parameters

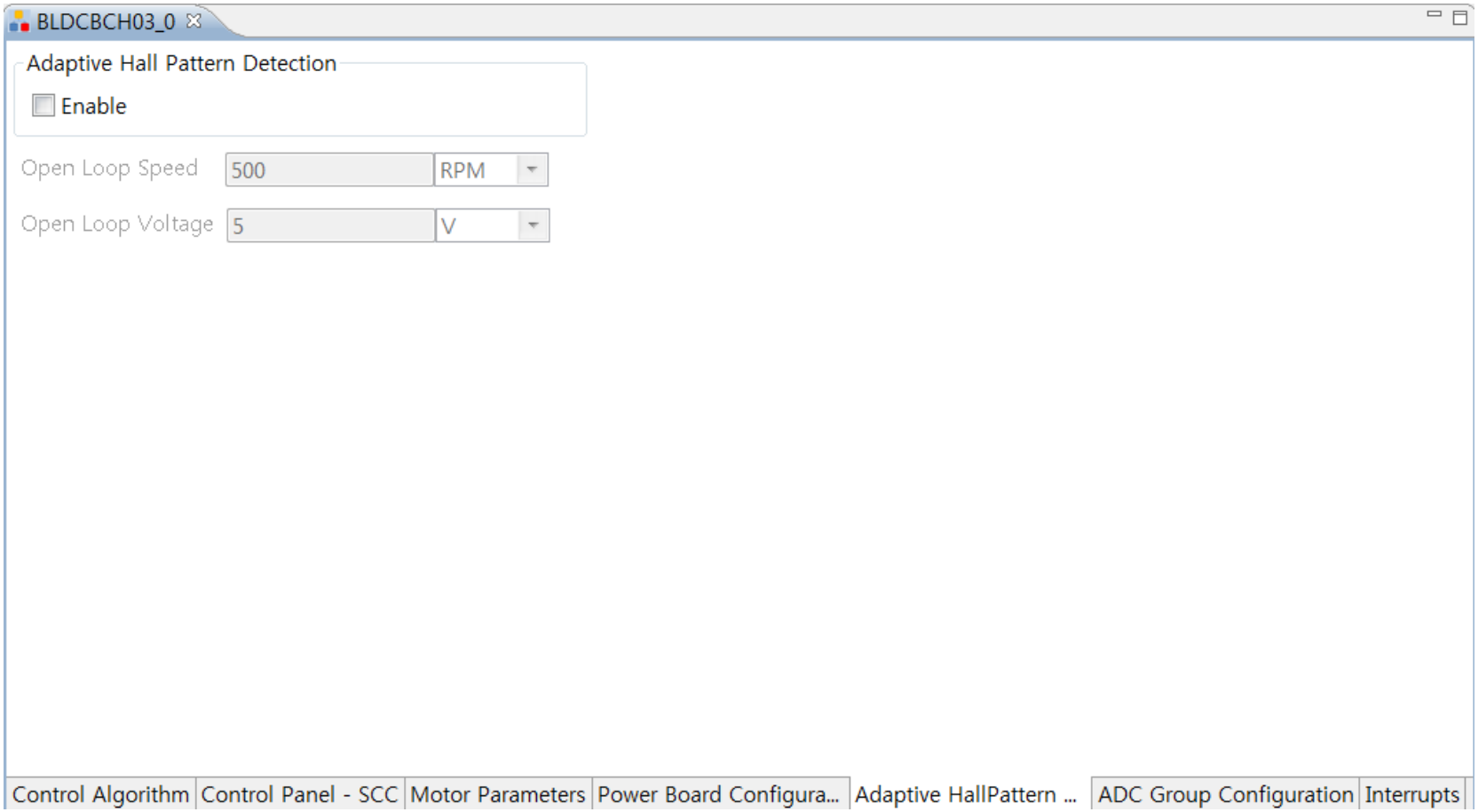
- High Side PWM



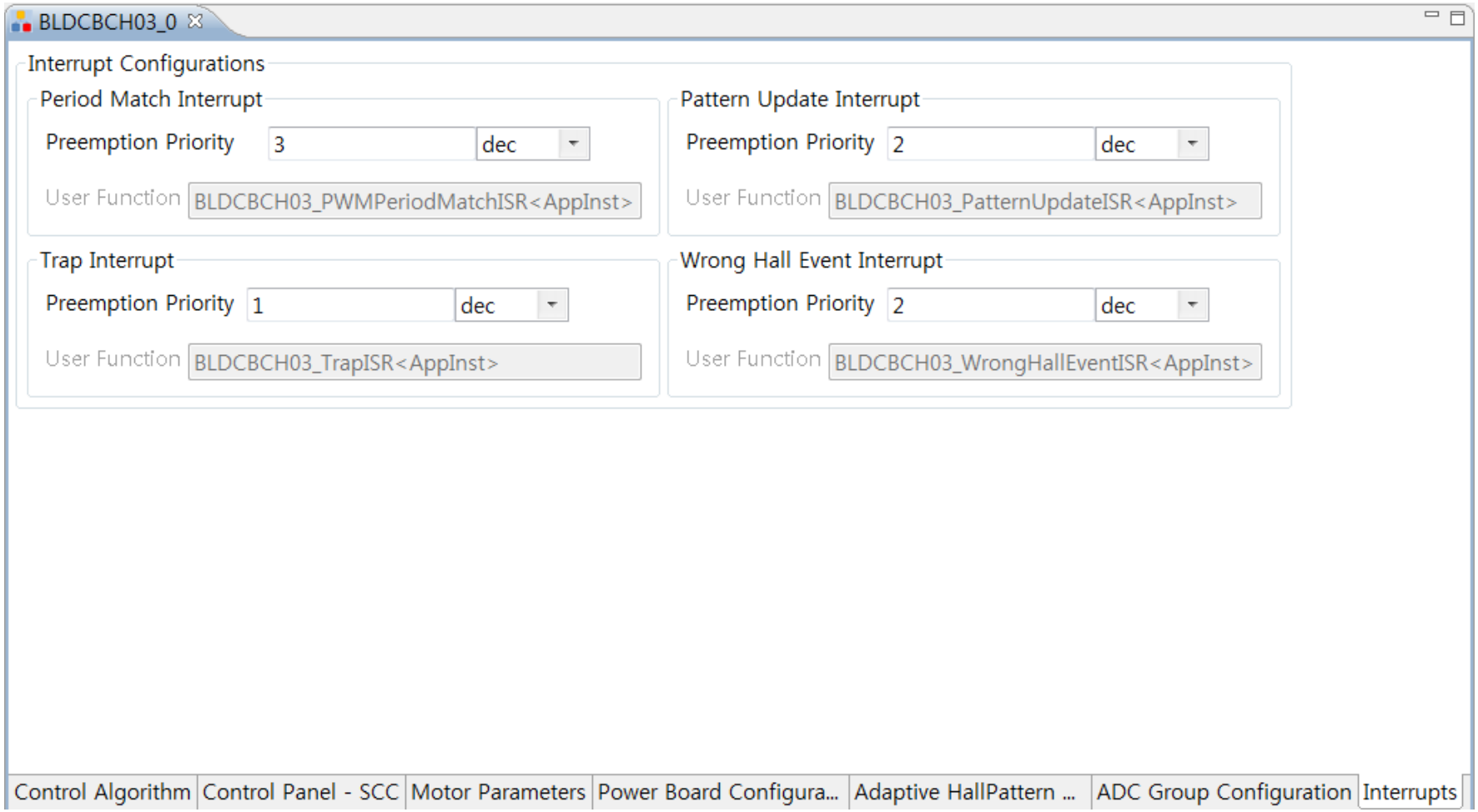
- Both Side PWM



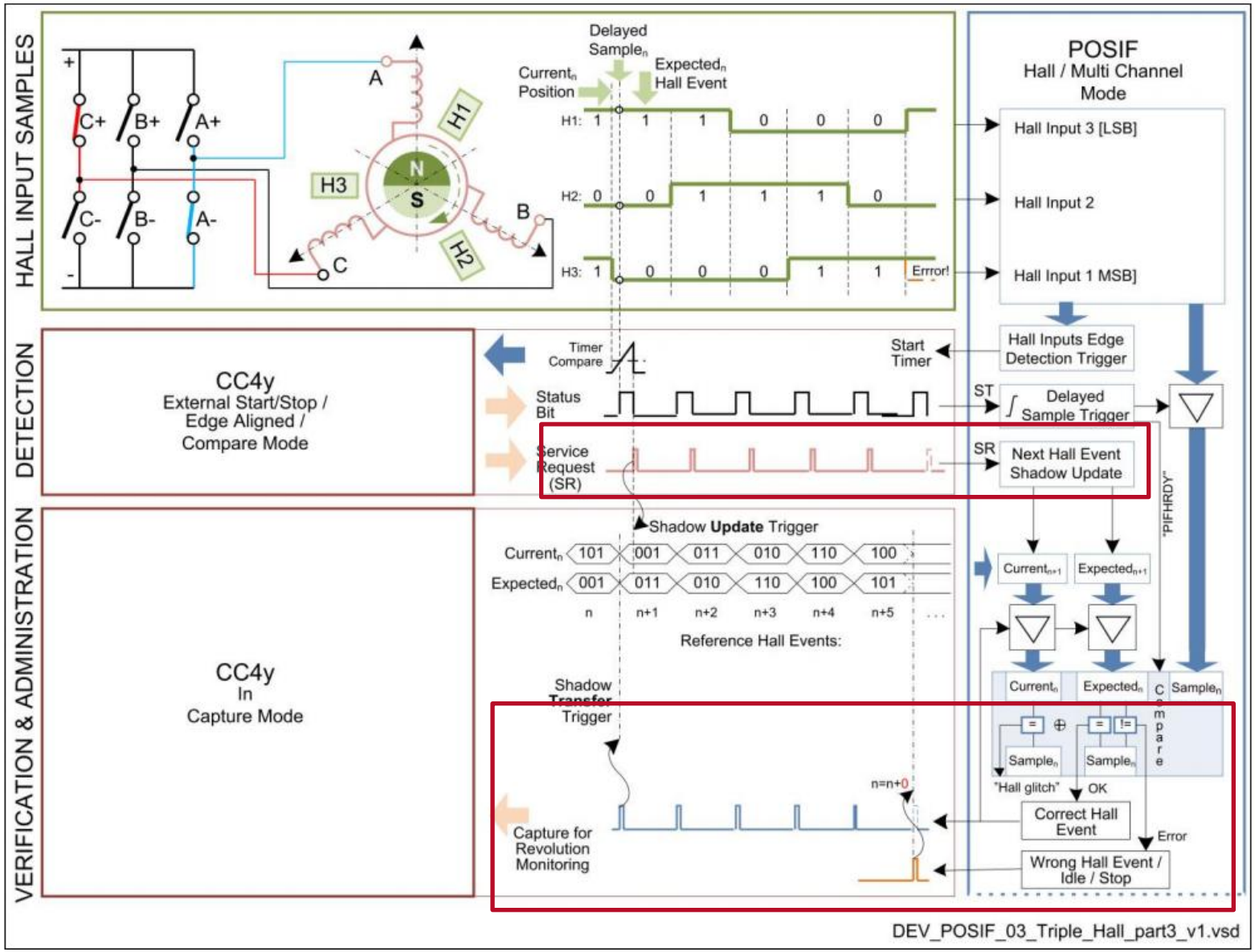
Hall Sensored Block Commutation – Adaptive Hall Pattern



Hall Sensored Block Commutation – Interrupts



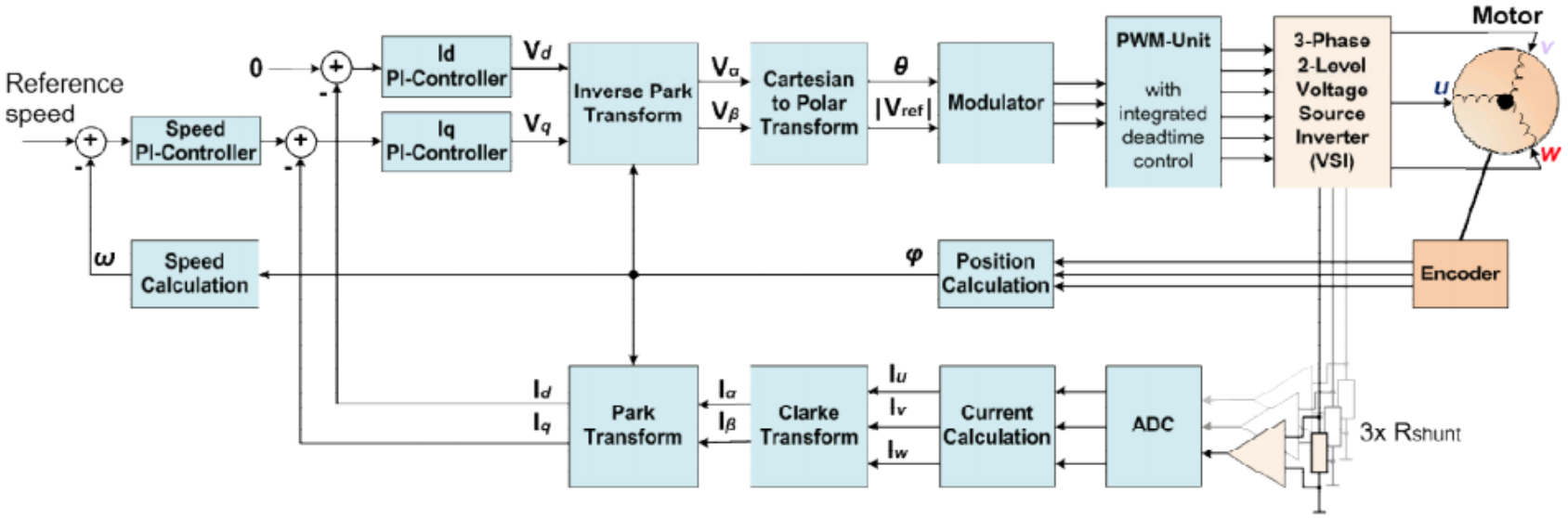
Hall Sensored Block Commutation – Interrupts



Main Content

- Infineon Latest MCU portfolio
- System block, Key Features
- Supporting tool, Ecosystem
- BLDC Motor Driver Design Using XMC
- PMSM Motor Driver Design Using XMC

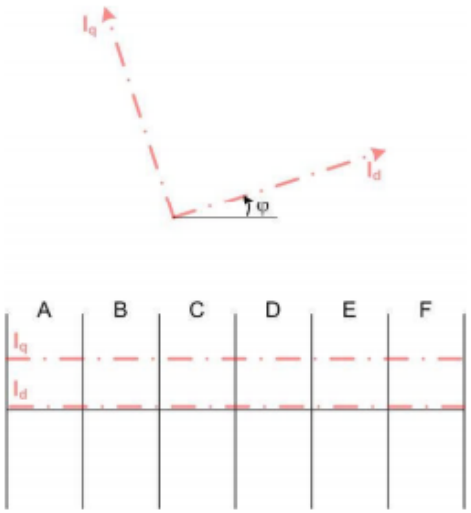
PMSM Field Oriented Control with Encoder



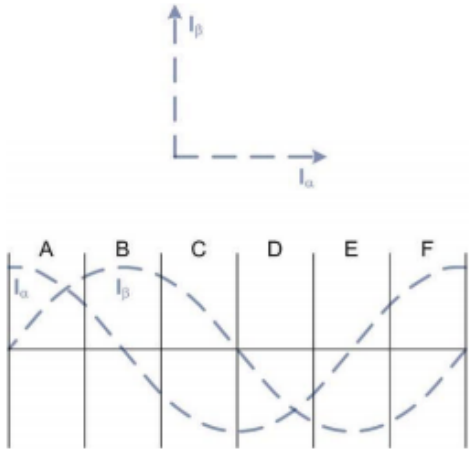
- FOC is a method to generate three phase sinusoidal signals which can easily be controlled in frequency and amplitude in order to minimize the current which means to maximize the efficiency
- The basic idea is the transform of three phase signals into two rotor-fix signals and vice versa

PMSM Field Oriented Control with Encoder

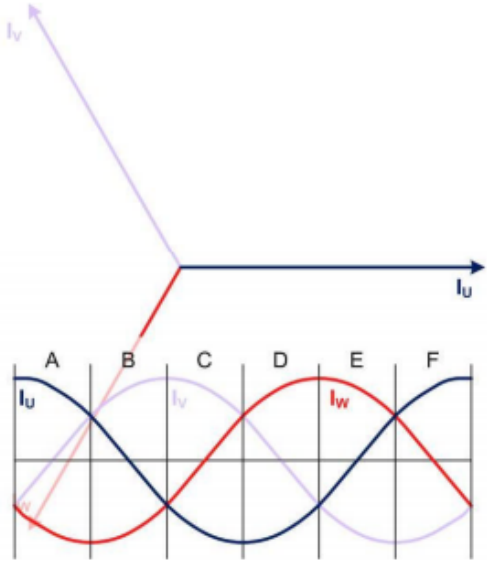
Rotating orthogonal reference frame



Two phase orthogonal reference frame



Three phase 120° reference frame



Park Transform

Clarke Transform

Mathematical Consideration

- Clarke Transform

$$i_\alpha = i_u$$

$$i_\beta = \frac{1}{\sqrt{3}} \cdot i_u + \frac{2}{\sqrt{3}} \cdot i_v = \frac{1}{\sqrt{3}} \cdot \left(i_u + 2 \cdot i_v\right)$$

$$i_u + i_v + i_w = 0$$

- Park Transform

$$i_d = i_\alpha \cdot \cos(\varphi) + i_\beta \cdot \sin(\varphi)$$

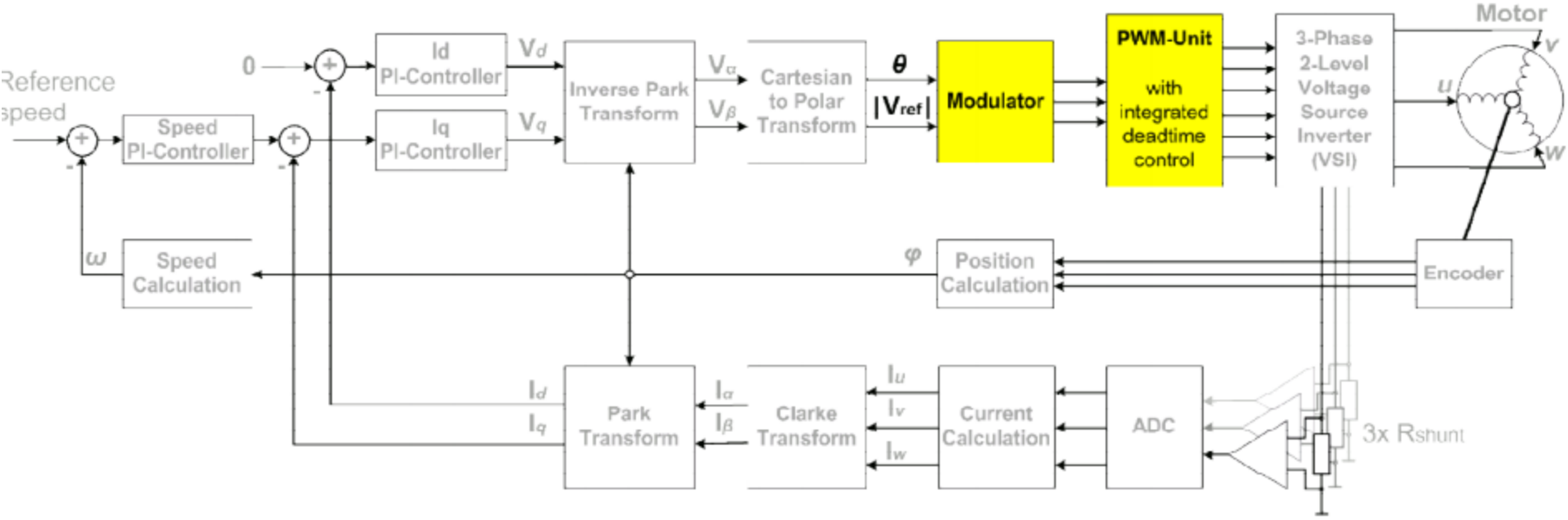
$$i_q = -i_\alpha \cdot \sin(\varphi) + i_\beta \cdot \cos(\varphi)$$

- Inverse Park Transform

$$V_\alpha = V_d \cdot \cos(\varphi) - V_q \cdot \sin(\varphi)$$

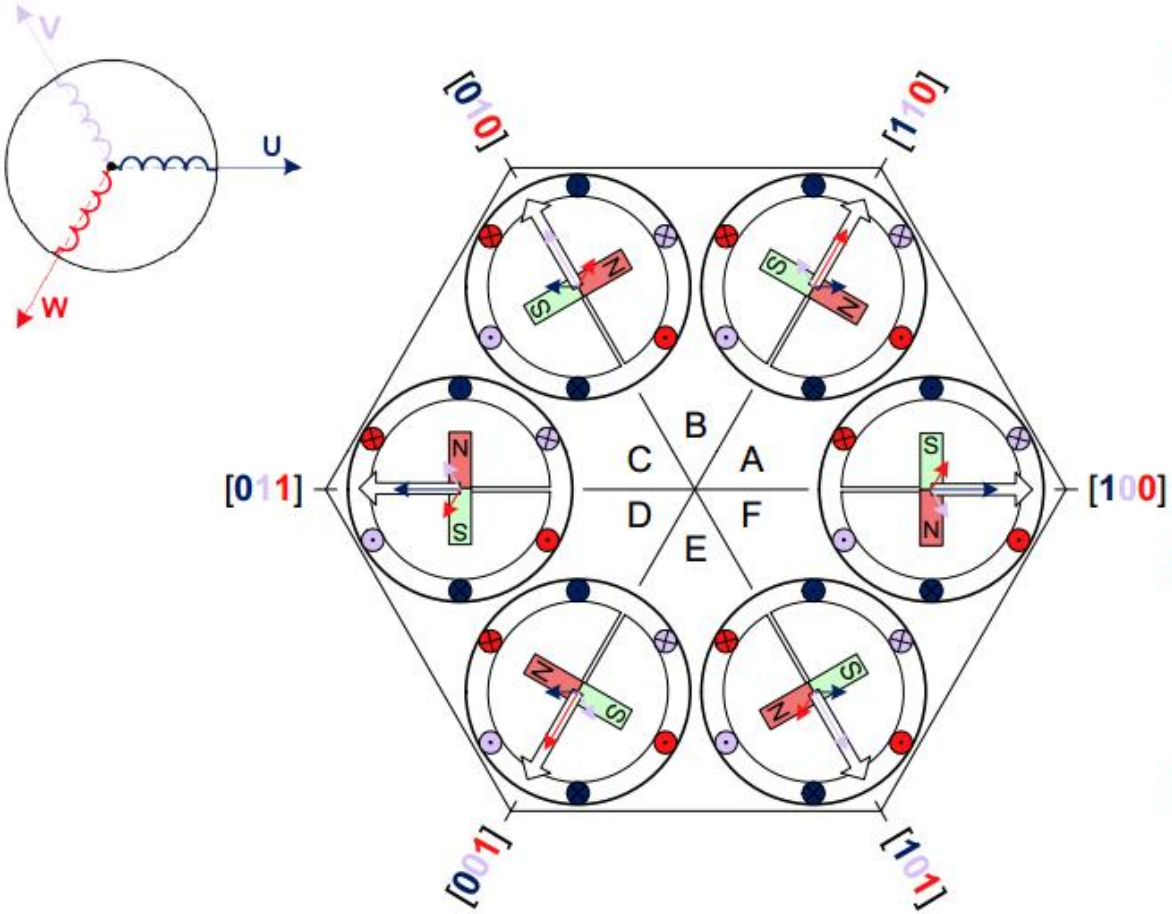
$$V_\beta = V_d \cdot \sin(\varphi) + V_q \cdot \cos(\varphi)$$

Space Vector Modulation



- Space Vector Modulation (SVM) is an algorithm for the control of Pulse Width Modulation (PWM)
- It is used for the creation of three phase sinusoidal waveforms

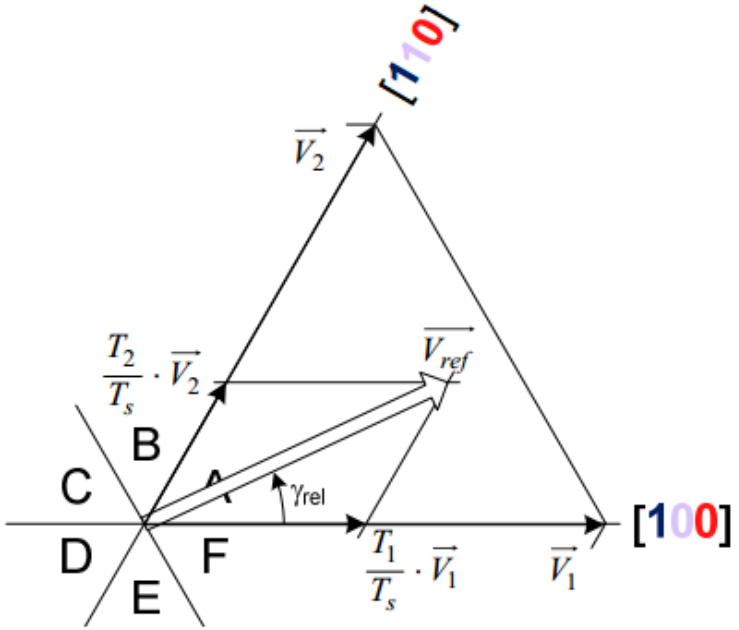
Space Vector Diagram



- **Active Vectors**
  - V1: 100
  - V2: 110
  - V3: 010
  - V4: 011
  - V5: 001
  - V6: 101
- **Passive Vectors**
  - V0: 000
  - V7: 111
- **Six Sectors**
  - A, B, C, D, E, F

Space Vector Diagram

- V_{ref} is approximated by two adjacent active vectors (e.g. V1, V2) and one or both of the passive vectors (e.g. V0 only)
- The plane is dissected in six sectors and the angle θ is transformed into the relative angle γ_{rel}
- T_1, T_2 and T_0 correspond with the active vectors and passive vector(s) (e.g.: V1, V2 and V0 in Sector A)

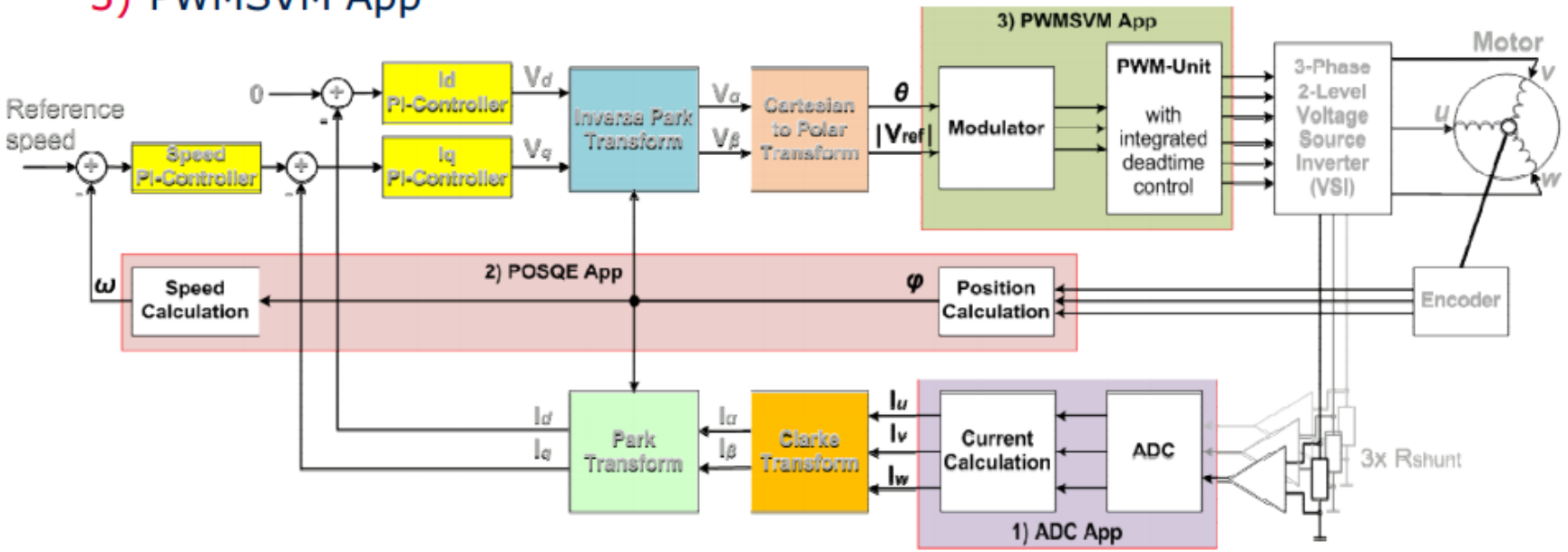


- $T_1 = \frac{\sqrt{3} \cdot T_s \cdot |V_{ref}|}{V_{DC}} \sin\left(\frac{\pi}{3} - \gamma_{rel}\right)$
- $T_2 = \frac{\sqrt{3} \cdot T_s \cdot |V_{ref}|}{V_{DC}} \sin(\gamma_{rel})$

$$T_0 = T_s - T_1 - T_2$$

FOC Example Project - Overview of Apps

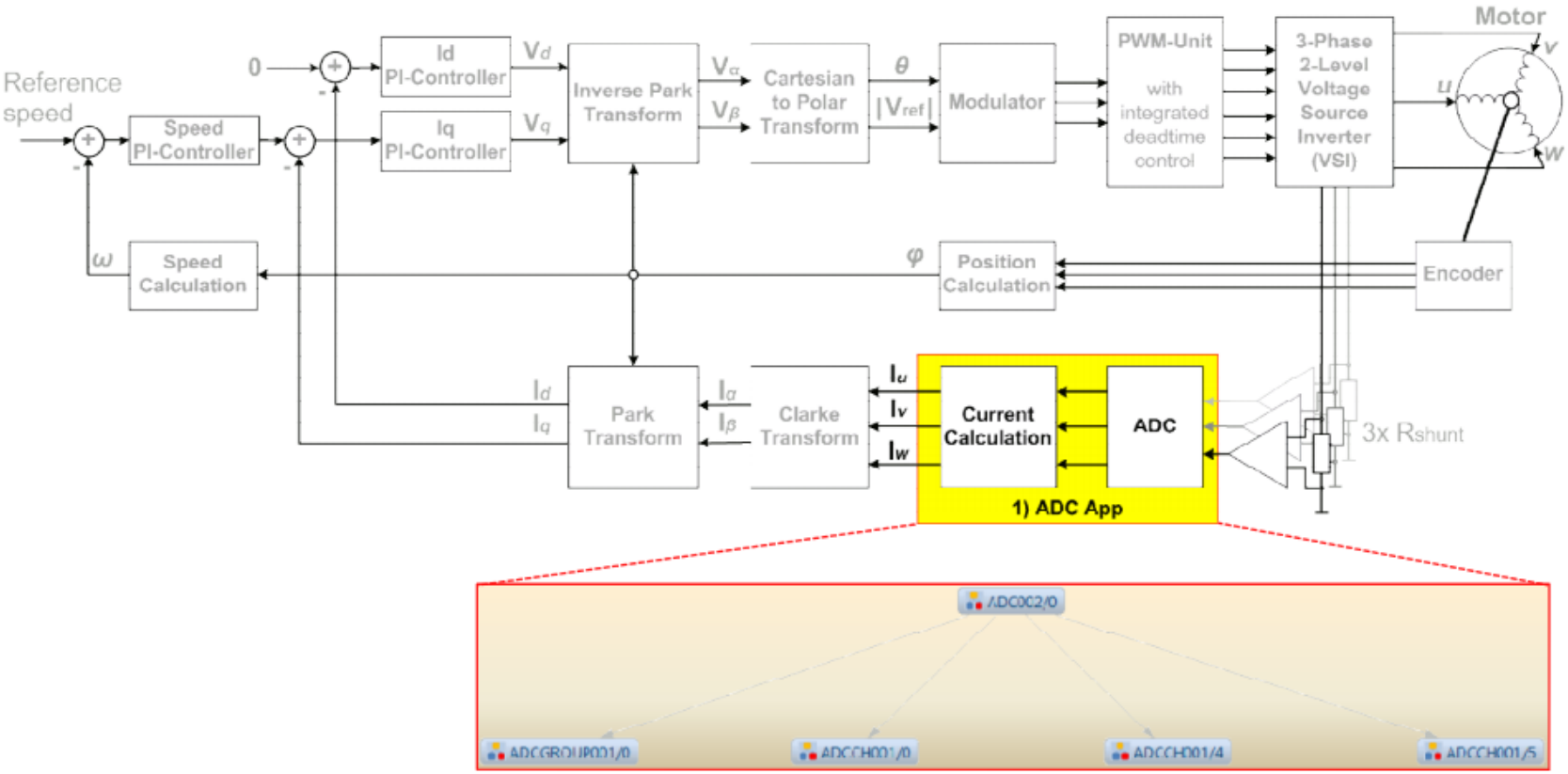
- Three key peripheral-specific DAVE™ Apps are used for FOC Example Project
  1) ADC App
  2) POSQE App
  3) PWMSVM App



- Other blocks of the algorithm use control library functions

ADC App

- ADC002 App configures queue request source of the ADC group.

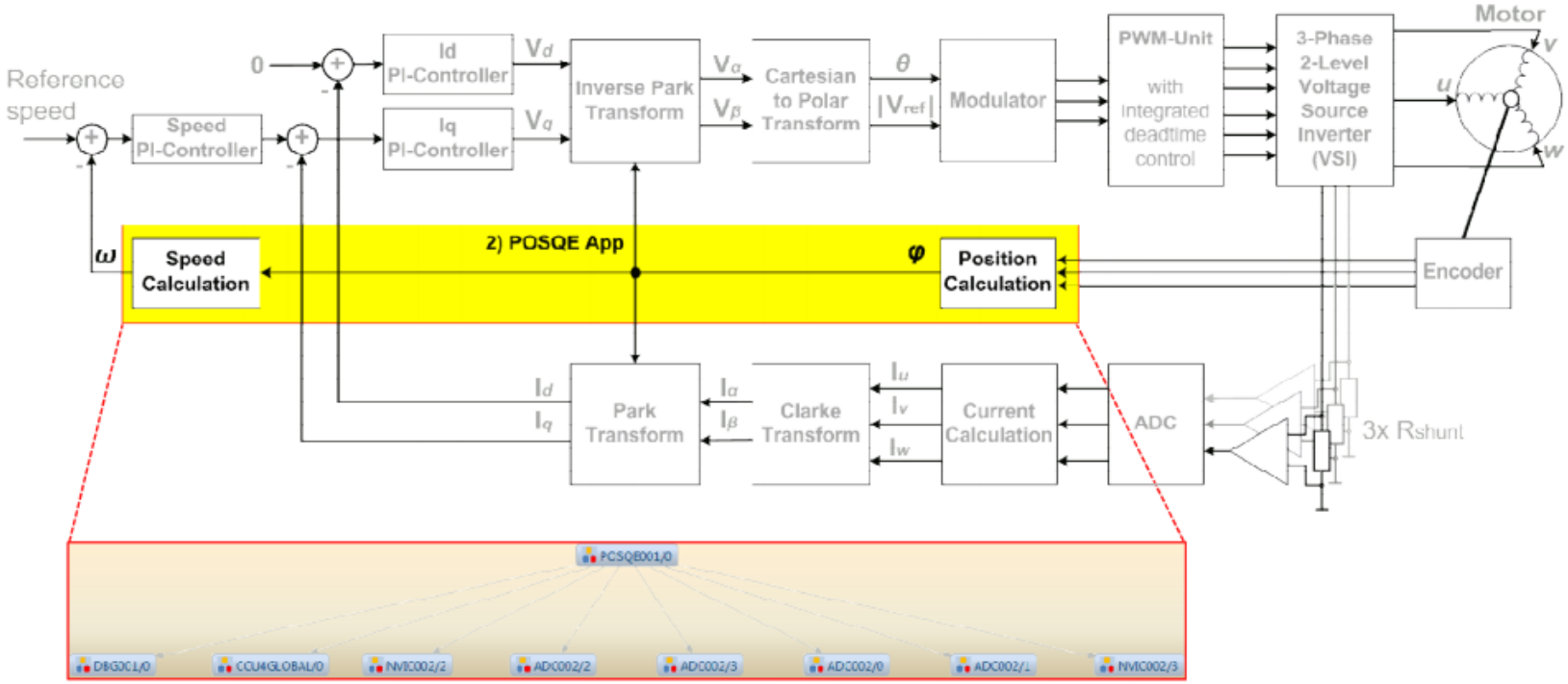


ADC App - Feature

- Consumes ADCGROUP001 App and a number of ADCCH001 Apps depending upon the number of channels configured
- Provides the following configurations
  - Number of channels (maximum 8 channels from the same ADC group)
  - Enable the queue request source
  - Request source priority configuration
  - External trigger mode
  - Gate mode configuration
  - Start mode configuration
  - Group input class 0 configuration
  - Queue entry configuration

POSQE App

- POSQE001 App is targeted to find the speed and position of a motor with quadrature encoder

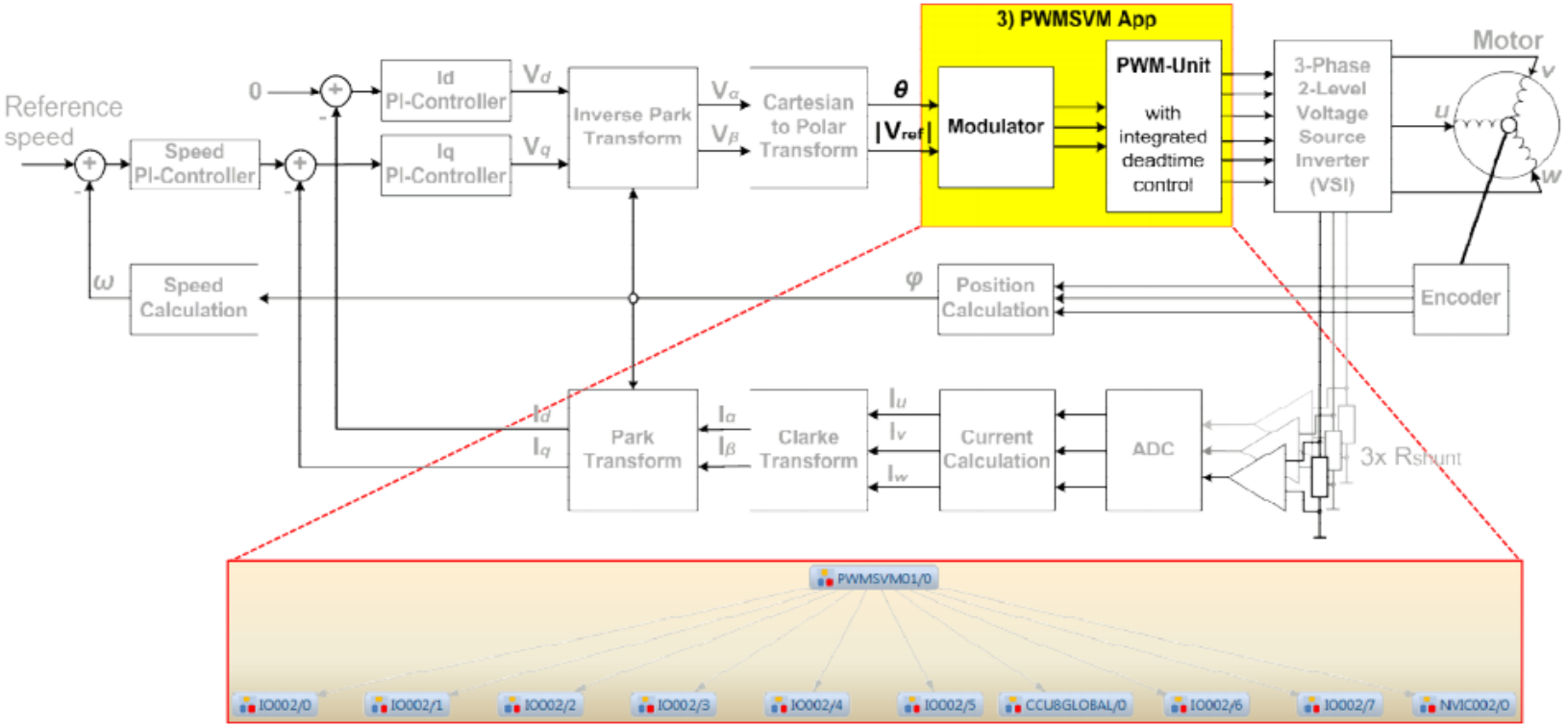


POSQE App - Feature

- Software controlled start and stop
- Get motor speed
- Get motor position:
  - Without interpolation
  - With interpolation (more precise position results)
- Get motor direction
- Get motor revolutions

PWMSVM App -

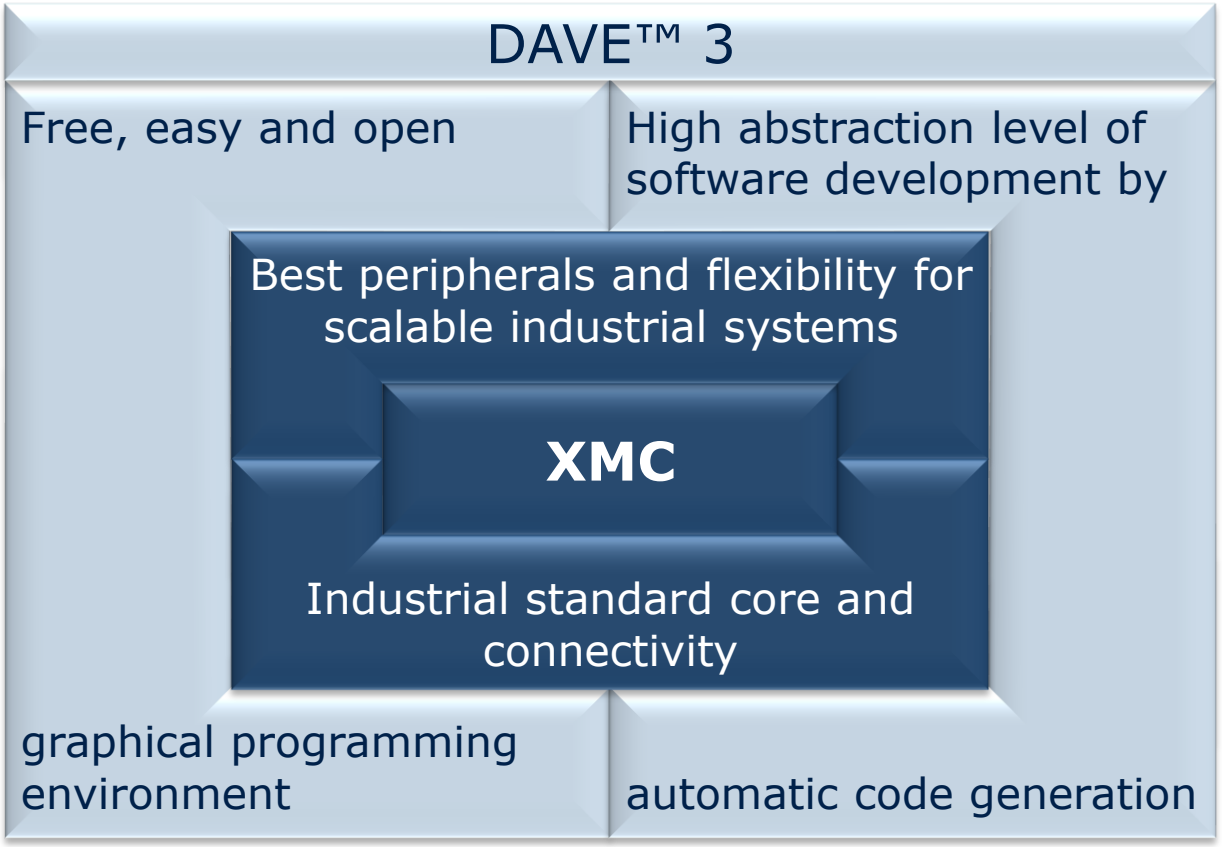
- PWMSVM01 App generates Space Vector Pulse Width Modulated output with deadtime to drive 3-phase 2-level voltage inverter



PWMSVM App - Feature

- Synchronous start of three phases of the 3-phase 2-level voltage inverter
- Symmetric and asymmetric SVM generation
- 7-segment and 5-segment SVM schemes
- Inverter enable pin configuration
- Trap feature
- Dead time generation

XMC family: 32-bit microcontroller family for industrial applications



Key differentiators of the Infineon XMC industrial microcontroller family

Combination of Infineon key IP and know-how with all the benefits of an industry standard core

Microcontroller Know-how

- >30 years automotive and industrial microcontroller experience
- Innovative application specific peripherals
- Highly configurable and flexible
- Fast flash

Quality and reliability

- High-performance Flash technology
- Extended temperature range on selected products (125 °C)
- Long product life time (min. 15 years)

SW Tool DAVE™ 3

- Next generation of DAVE™ with enhanced functionality
- Free tools
- Auto-code generation making powerful hardware easy to use
- Open to 3rd parties

Thank you!

ENERGY EFFICIENCY
MOBILITY
SECURITY

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기술문의 : 조용규 과장(yg.cho@dabo-corp.com)

Innovative semiconductor solutions for energy efficiency, mobility and security.