XMC™ in Power Conversion Applications

XMC™ Microcontrollers

July 2016

Agenda

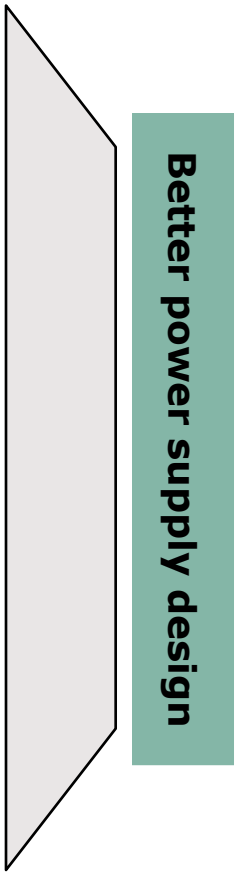
1. Why XMC™ for digital power control?
2. Key microcontroller features
3. Kits and reference design
4. Development tool and software

Agenda

1. Why XMC™ for digital power control?
2. Key microcontroller features
3. Kits and reference design
4. Development tool and software

Why XMC™ for digital power control?

Key factors in power supply design	Counter measure	XMC™
Efficiency at all conditions	Sophisticated/ flexible control schemes	Cortex® M0/M4 + dedicated peripherals (analog performance+ digital programmability)
Power density	Increase switching frequency	High resolution PWM (150 ps) and analog peripherals
Time to market	Ecosystem and examples	DAVE™ APPs and ARM® ecosystem (Keil/IAR/open source)
Reliability and security	Great technology + security solution	125°C technology Security technology



Product portfolio XMC™
XMC1000 family overview

ARM® Cortex® - M0

- Core up to 48 MHz / Peripherals up to 96 MHz
- Capture Compare Units (CCU4)
- 2x Serial Channels
- 12 Bit ADC
- TA = -40°C to 105°C

XMC1400
Up to 200 kB Flash
40 – 64 pins

XMC1300
Up to 200 kB Flash
16 – 40 pins

+ **2x CAN**
+ **2x CCU8**
+ **Up to 4 Serial Channels**

XMC1200
Up to 200 kB Flash
16 – 40 pins

+ **Math Co-Processor**
+ **CCU8 PWM Timer**
+ **Hall & Encoder I/F**

XMC1100
Up to 64 kB Flash
16 – 40 pins

+ **9ch LED Control (BCCU)**
+ **3x Analog Comparators**

High Volume Production

16/28/38 TSSOP – VQFN24/40/64 – TQFP64

Wide Supply Voltage Range 1.8 V – 5.5 V

Secure Boot Loader – ensure IP protection

Application Specific Peripherals

- **MATH co-processor**
- **Event Request Unit (ERU)**
- **High-performance analog comparators**
- **PWM Timer for Motor Control (CCU8)**
- **LED Brightness Color Control Unit**

Product portfolio XMC™
XMC4000 family overview

ARM® Cortex® - M4 (with FPU)

- CPU Frequency up to 144 MHz
- **High Performance Flash technology**
- Timers CCU4, CCU8, POSIF
- USB / Up to 3x CAN / Up to 6x Serial Channels
- Up to 4x 12 Bit ADC / 2x DAC

XMC4100/4200
Up to 256 kB Flash / 40 kB RAM
48-64 pins

XMC4400
Up to 512 kB Flash / 80 kB RAM
64-100 pins
+ **120 MHz Core**
+ **Ethernet**
+ **ΔΣ Demodulator**

XMC4500
Up to 1 MB Flash / 160 kB RAM
100 – 144 pins
+ **EBU**
+ **SD Card**

XMC4700
Up to 2 MB Flash / 352 kB RAM
100 – 196 pins
+ **144 MHz Core**
+ **6ch CAN**

XMC4800
Up to 2 MB Flash / 352 kB RAM
100 – 196 pins
+ EtherCAT®

High Volume Production

48 QFN – 64-144 LQFP – 196 BGA

Long Product Life Cycle (min. 2027)

Extended Temperature Range – up to T_A 125°C + continues up time of 20a@T_J 110°C

Application Specific Peripherals

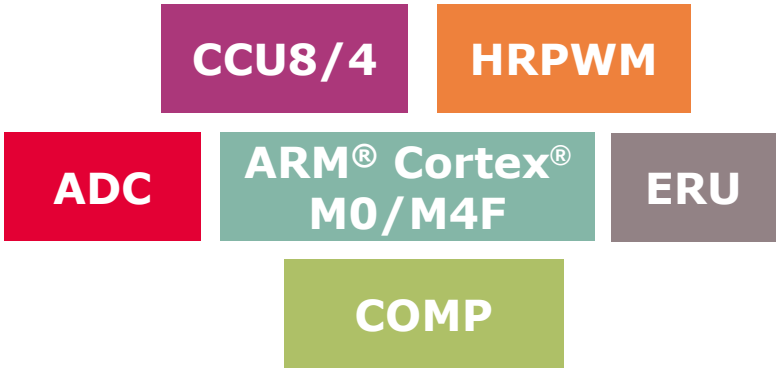
- **High Resolution PWM**
- **Event Request Unit (ERU)**
- **High-speed analog comparators + Slope generation**
- **Timer for Inverter Control (CCU8)**
- **Delta Sigma demodulator**

Agenda

1. Why XMC™ for digital power control?
2. Key microcontroller features
3. Kits and reference design
4. Development tool and software

Key features

Peripherals for Power Conversion Applications



Highlights

Analog front end together with full configurability allows most advanced power supply control
With the support of ARM® Cortex® cores and high resolution PWM (150 ps), accurate and fast control loops execution are possible for improved figure of merits in power supply design

Key Feature

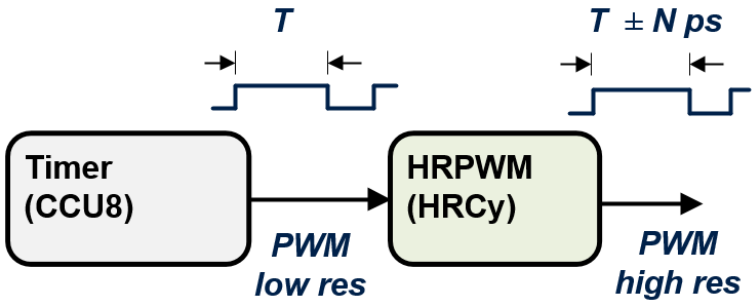
- High Resolution PWM (150 ps)
- Smart analog comparators
- Fast and flexible ADC and Timers

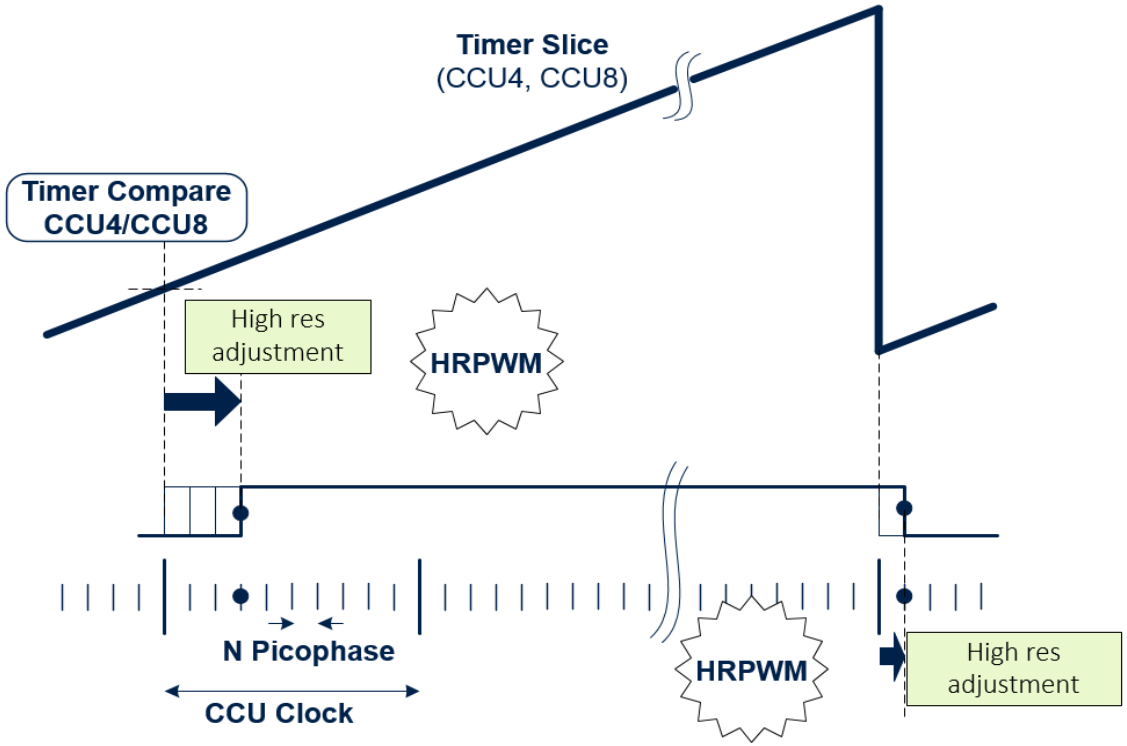
Customer Benefits

- Regulate voltages/current with higher accuracy
- Analog comparators with smart features such as slope compensation
- Permit complex PWM patterns and sophisticated measure sequences

High resolution PWM (150 ps) (1/3)

- High Resolution PWM receives a signal from other peripherals like CCU8 module
- HRPWM (HRC) takes this signal and shifts it in steps of 150 ps)





High resolution PWM (150 ps) (2/3)

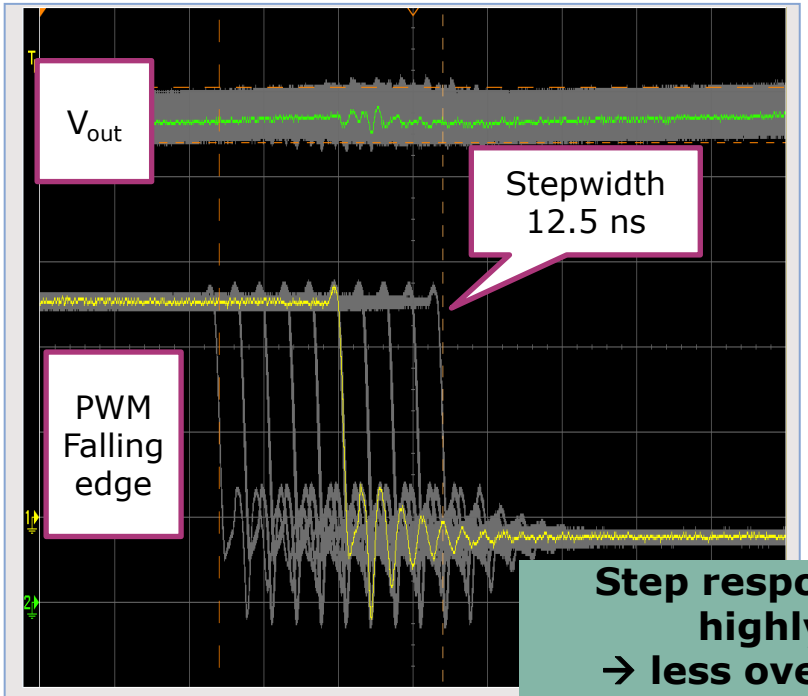
› Resolutions in bits achieved with and without HRPWM by different conditions : switching frequency of PWM and Duty cycle of PWM

Switching frequency	Duty cycle	Resolution w/o HRPWM @ 80 MHz	Resolution w/o HRPWM @ 120 MHz	Resolution w/ HRPWM
200 KHz	50%	7,6 bit	8,2 bit	14 bit
	20%	6,3 bit	6,9 bit	12,7 bit
	10%	5,3 bit	5,9 bit	11,7 bit
500 KHz	50%	6,3 bit	6,9 bit	12,7 bit
	20%	5 bit	5,5 bit	11,3 bit
	10%	4 bit	4,5 bit	10,3 bit
1,5 MHz	50%	4,7 bit	5,3 bit	11,1 bit
	20%	3,4 bit	4 bit	9,8 bit
	10%	2,4 bit	3 bit	8,8 bit

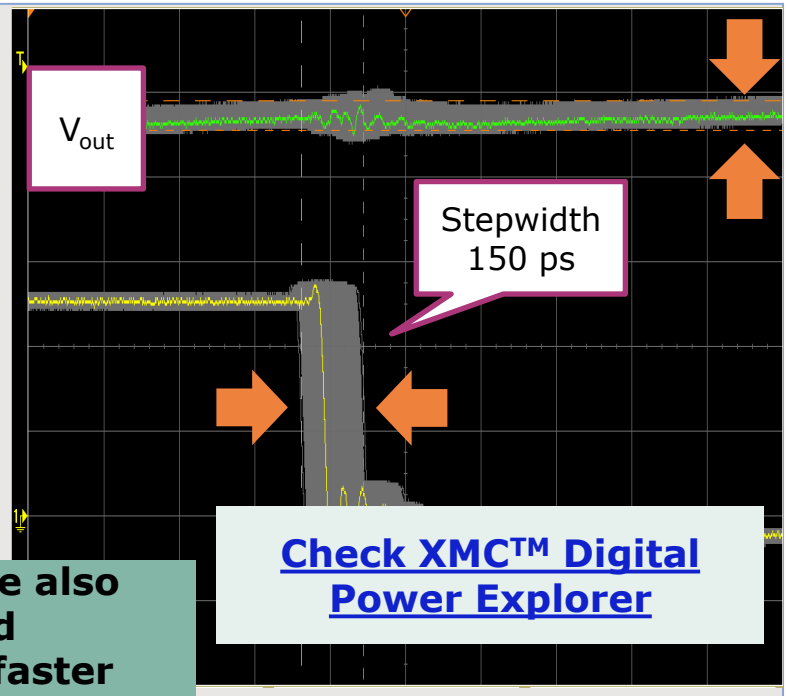
High resolution PWM (150 ps) (3/3)

- Example: thanks to a finer adjustment of the duty cycle, the output voltage (in this example in a buck converter), is regulated much more accurately. This reduces the output voltage ripple significantly

NO HRPWM



WITH HRPWM

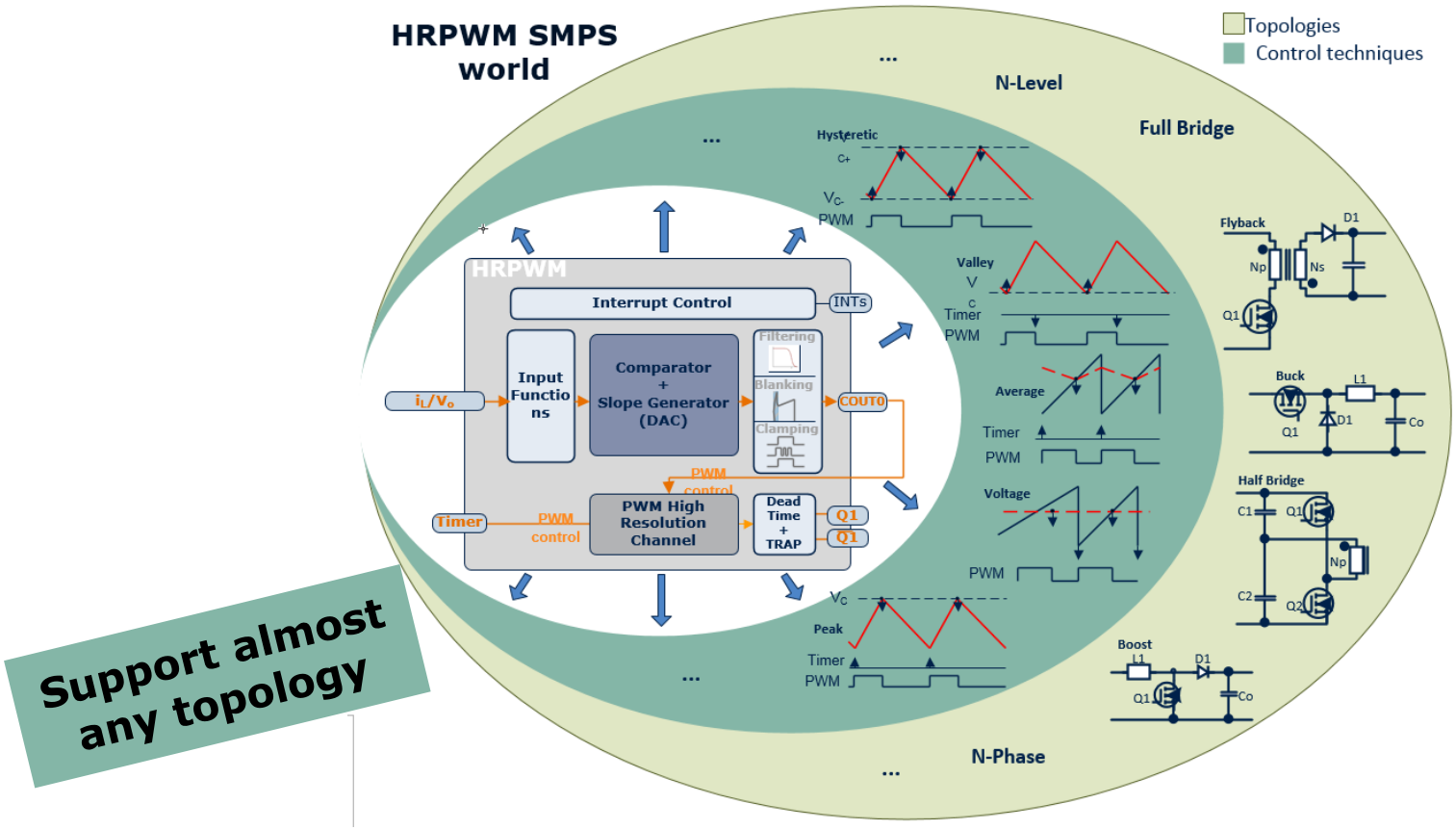


Step response will be also highly improved
→ less overshoot + faster settling time

Check XMC™ Digital Power Explorer

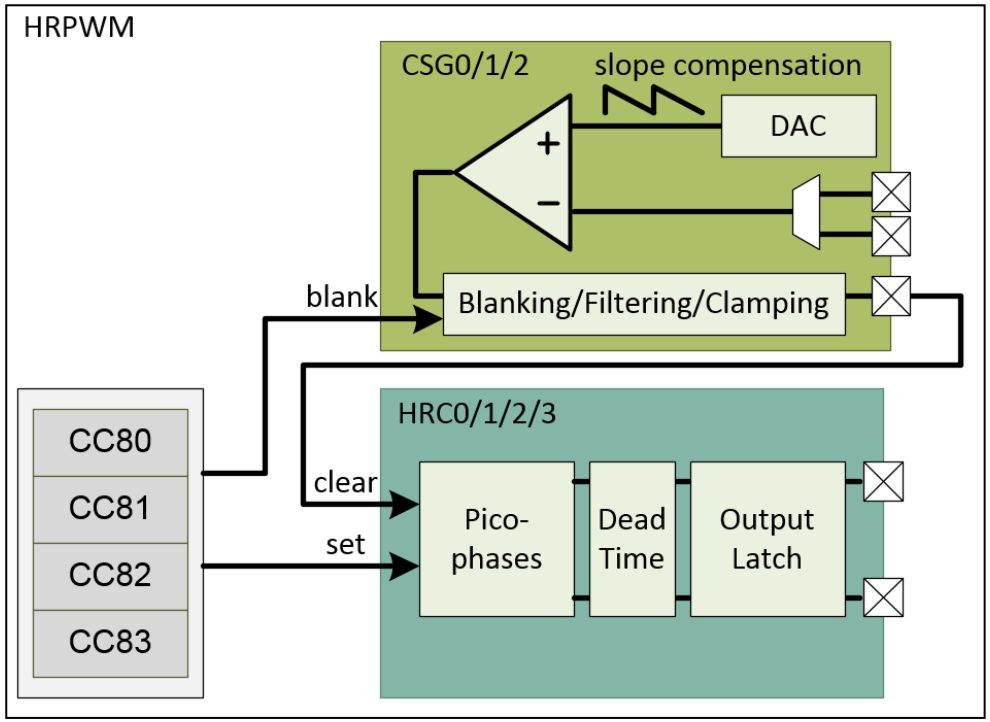
Smart analog comparators (1/3)

- XMC4000 comparators include **filtering, blanking and clamping** capabilities as well as a **DAC** for automatic reference or slope generation
- XMC1000 comparators can configure **hysteresis** and output **filtering**



Smart analog comparators (2/3)

- Analog frontend digitally controlled. Best of both worlds:
  - **Analog performance**
  - **Programmability/flexibility**
- **Supports almost any topology and combinations**:
  - LLC/LCC
  - PSFB
  - PFC stages
  - Flybacks/forwards
  - Buck-boost, sepic
  - Inverters
  - Etc…
- Can easily and efficiently perform:
  - **Voltage control**
  - **Current control**
  - **Customized controls**



Smart analog comparators (3/3)

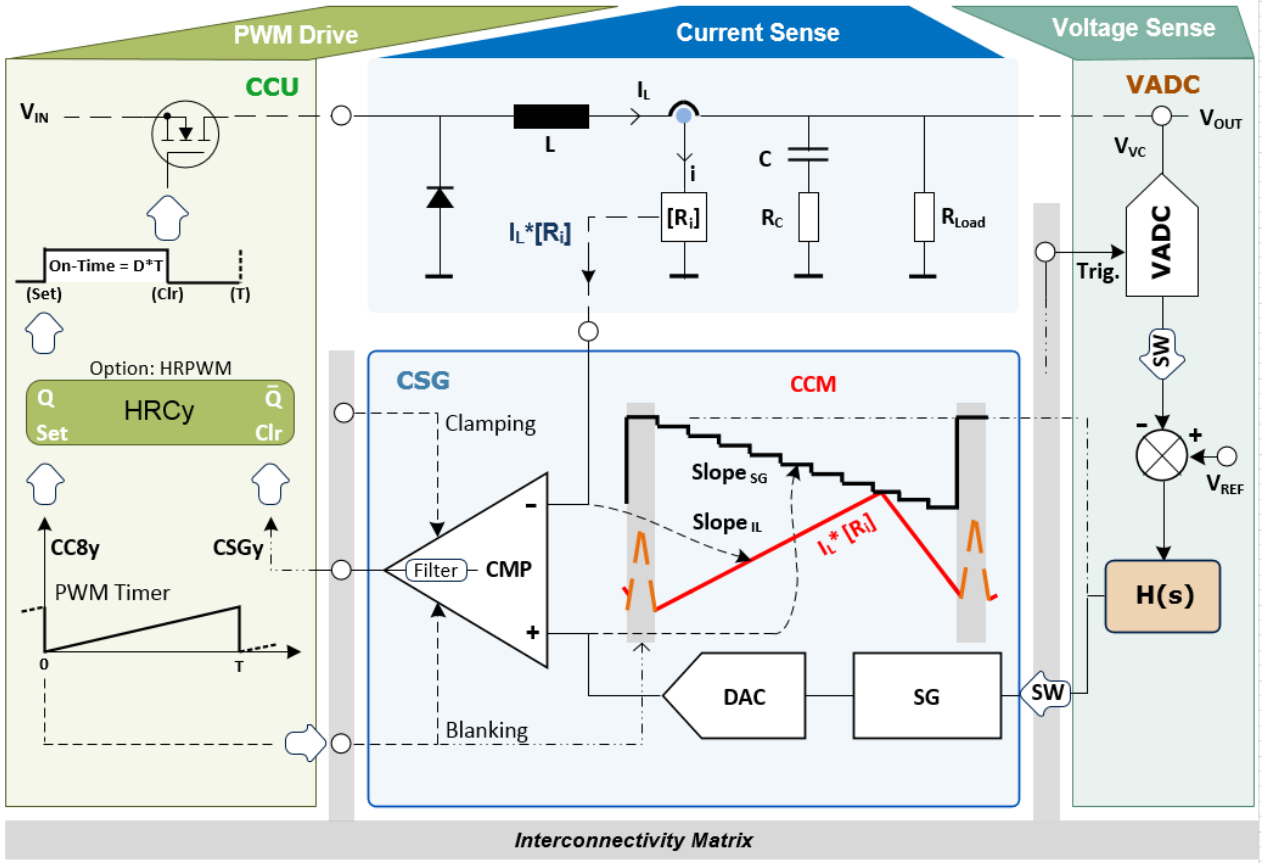
› Advanced peak current mode control is possible by making use of HRPWM peripheral, resulting in low CPU load

Internal DAC
10 bits resolution
30 Msamples/sec
Auto-waveform

Analog Comp
20 ns bandwidth
Filtering/blanking/clamping

[Check XMC™ Digital Power Explorer]

Peak Current Control Loop
Scheme Using CSG - embedded Compensation Slope Generator & Analog Comparator

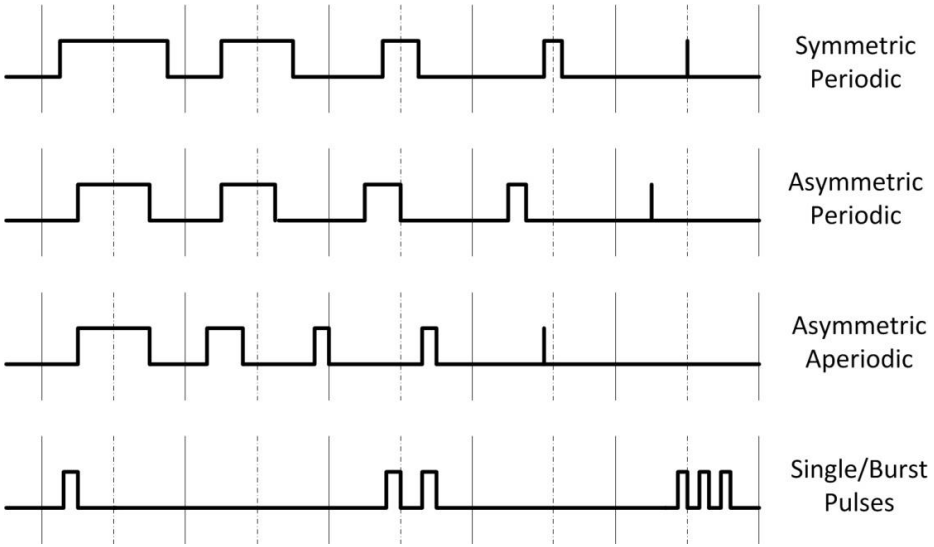


Fast and flexible ADC and timers (1/4)

- In order to cover the exigent requirements of power supplies, it is needed to provide:
  - Flexible and safe PWM patterns
  - Fast ADC sampling
  - Flexible ADC sequencing and synchronization to PWM
  - Post processing of conversions including
    - Filtering (FIR/IIR), FIFO, subtraction (for offset compensation), etc
  - Resolution in sampling signal and in PWM for accurate control:
    - 12 bits ADC
    - 150 ps resolution PWM in XMC4 and 15,6 ns in XMC1000

Fast and flexible ADC and timers (2/4)

- For power conversion continues and discontinues PWM signals have to be generated – switching between the two modes is needed to get efficiency over a wide load range
- CCU4/CCU8 supports any kind of pulse generation like
  - Asymmetric PWM
  - Aperiodic PWM
  - Single events and pulses
- CCU4/CCU8 can be controlled from external or internal events
  - External start / stop
  - Emergency trap
  - Override/modulation
  - Count gating
  - Capturing

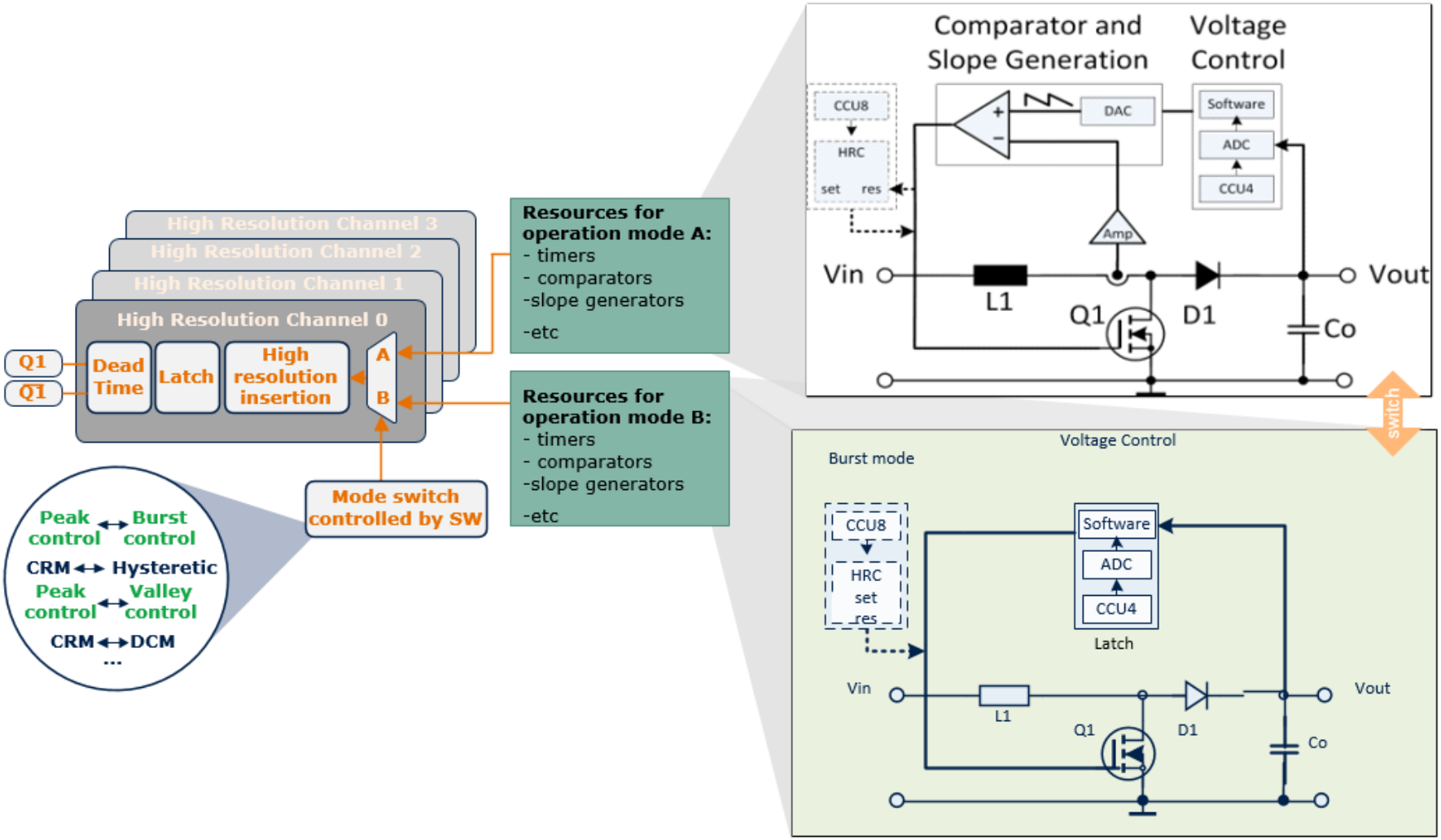


Fast and flexible ADC and timers (3/4)

- Multimode power supplies are very common in order to help with stringent requirements on THD, PF and efficiency at many different conditions of the load, input voltage and temperature

  → the way the power supply is controlled varies depending on the load or the input voltage
- For example:
  - PFCs than change between CCM and CrCM when reducing the load and even to DCM when load is lower.
  - Normal mode to burst mode in both ACDC and DCDC power supplies.
- Main issue in this idea, is how to switch the control scheme.
  - Usually controllers are specific for one or the other, making impossible this.
  - Others can switch the mode but during switching, the PWM is unpredictable and can create overcurrent and overvoltage situations damaging permanently the system
- In order to support a seamless switch between modes, HRPWM peripheral introduces a new switch event based.
  - This switch is connected to 2 different sets of timers and/or comparators that defines the 2 control schemes and links those to the output stage that is connected finally to the necessary pins
  - Should the event occur, then HRPWM peripheral will swap the set of timers and/or comparators connected to the output.
  - In this way, the HRPWM will immediately and safely → synchronized to the PWM pattern, move to the alternate control scheme.

Fast and flexible ADC and timers (4/4)



Additional features

- ERU module allows very flexible connections in the XMC. This is helpful in cases such as:
  - Detect a peak current with a comparator and send the signal to a timer → usually signal is directly connected
  - But if the comparator signal needs to be OR-ed with another one, this can be done with the available logic functions in ERU module
- Serial communications, like I2C for PMBus™, and CAN supported

Agenda

1. Why XMC™ for digital power control?
2. Key microcontroller features
3. Kits and reference design
4. Development tool and software

Kits and reference design

Development boards		Order number/ISAR order (SP)	Kit/ demo
XMC4200 Digital Power Control Card		**KIT_XMC4200_DP_CC_01** *SP001343128*	KIT
XMC1300 Digital Power Control Card		**KIT_XMC1300_DP_CC_01** *SP001343134*	KIT
XMC™ Digital Power Explorer		**KIT_XMC_DP_EXP_01** *SP001343072*	KIT
800 W PFC Boost CCM XMC1300		**EVAL_800W_130PFC_C7** *SP001360062*	DEMO
600 W LLC Eval Kit		**EVAL-600W-12V-LLC-D** *SP001293818*	DEMO
3 kW LLC dual phase XMC4400 Eval Kit		**EVAL_3KW_2LLC_C7_47 (_20)** *SP001360064(/SP001360066)*	DEMO

XMC4200 Digital Power Control Card

Link to WEB

Infineon components	
MCU	XMC4200 (LQFP64)
Supply	IFX54441LDV IFX90121ELV50
ESD protections	ESD8V0L2B-03L
Debugger MCU	XMC4200 (QFN48)

Key features:

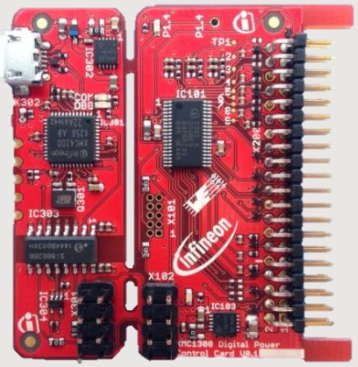
- Detachable isolated Jlink debugger integrated and isolated UART to USB channel
- 8 PWMs outputs, 8 ADCs and 3 CMP inputs. 2 communication channels and up to 4 general purpose pins
- Only 28 mm height vertically fits 1U rack standards (without debugger part)

Customer benefits:

- Fast evaluation of XMC™ power conversion applications
  - No need to design debuggers, isolations, XMC™ supply concepts
- Same interface as other XMC™ control cards permit 1 to1 comparison of different XMC™ devices in customer´s application

XMC1300 Digital Power Control Card

Link to WEB



Infineon components	
MCU	XMC1302 (TSSOP38)
Supply	IFX54441LDV
ESD protections	ESD8V0L2B-03L
Debugger MCU	XMC4200 (QFN48)

Key features:

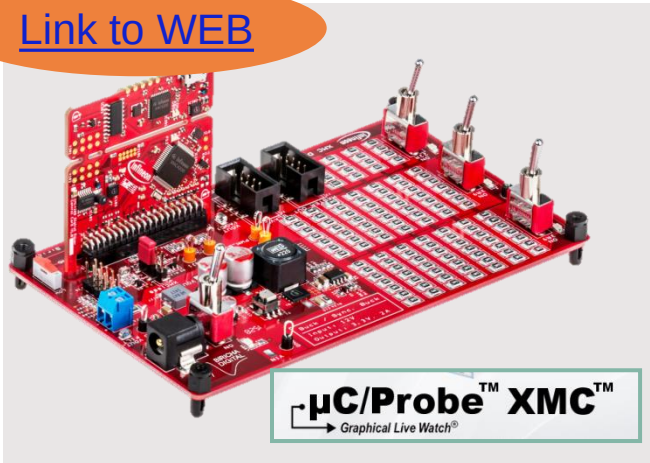
- Detachable isolated Jlink debugger integrated and isolated UART to USB channel
- 8 PWMs outputs, 8 ADCs and 3 CMP inputs. 2 communication channels and up to 4 general purpose pins
- Only 25 mm height vertically fits 1U rack standards (without debugger part)

Customer benefits:

- Fast evaluation of XMC™ power conversion applications
  - No need to design debuggers, isolations, XMC™ supply concepts
- Same interface as other XMC™ control cards permit 1 to1 comparison of different XMC™ devices in customer´s application

XMC™ Digital Power Explorer Kit (1/2)

Link to WEB



Specification	
V_{in}	$12V_{DC}$
V_{out_nom}	$3,3V_{DC}$
I_{out}	2A
P_{out}	6W

Infineon components	
MCU	XMC4200 or XMC1300
MOSFETs	OptiMOS BSC0924NDI
MOSFET HB Driver	IRS2011S (IRF)

Key features:

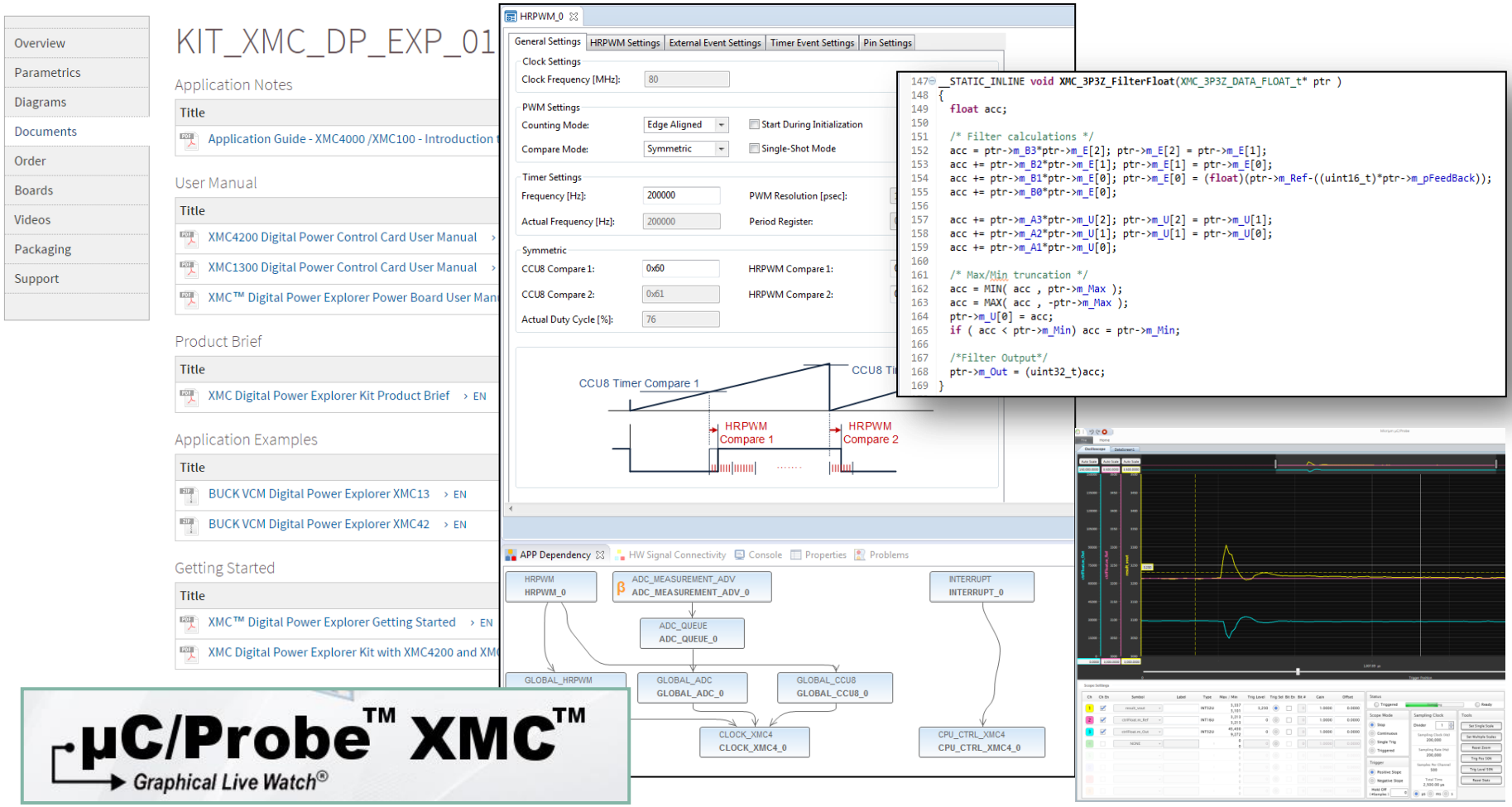
- Synchronous buck converter with XMC4200 and XMC1300 in collaboration with Biricha and Würth Elektronik
  - To be used in Biricha trainings
- Different control schemes possible
  - Voltage mode control
  - Peak current mode control

Customer benefits:

- Learn digital control with XMC™ by the hand of Biricha
- Understand the advantages of voltage/peak current control and how to extract the maximum of XMC™ devices
- Compatible with XMC4200 and XMC1300 Dig. Power Control Cards

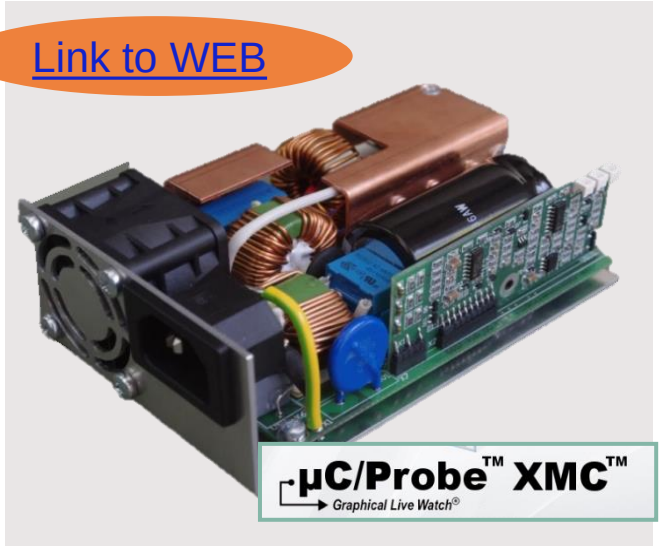
XMC™ Digital Power Explorer Kit (2/2)

- Website populated with plenty of support material



Digital Power
800 W PFC Boost CCM with XMC1302

Link to WEB



Specification	
V_{in}	90-265 V_{AC}
V_{out_nom}	380 V_{DC}
I_{out}	2.1 A
PWM freq	130 kHz
THD	<10%
Power Factor	>0.9 from 20% load
Efficiency	>96% from 20% load

Infineon components	
MCU	XMC1302 (TSSOP38)
MOSFET	CoolMOS™ C7 600 V
MOSFET Driver	2EDN7524F non isolated
Diode	SiC Gen 5 650 V
Auxiliary PSU	ICE2QR4780Z

Key features:

- Classic PFC Boost stage digitally controlled with XMC1302 including voltage and current loops
- Protections, including cycle by cycle current protection
- Run time debug with isolated UART to PC interface and PC Software

Customer benefits:

- High efficient PFC stage with a complete system solution from Infineon
  - HW and SW available
- Use MATH co-processor to accelerate calculations like divisions
- Higher switching frequency permits higher power density

600 W LLC Digital Control with XMC4200

Link to WEB

Specification	
V_{in}	350-410 VDC
V_{out_nom}	12 VDC
I_{out}	50 A
P_{out}	600 W
Peak eff.	97.8% @50% load
Eff.	>95% @ 10% load

Infineon components	
MCU	XMC4200 (VQFN48)
MOSFET SR	BSC010N04LS
HB Driver	2EDL05N06PF
LLC HB MOSFET	CoolMOS™ IPP60R190P6
Auxiliary PSU	ICE2QR2280Z

Key features:

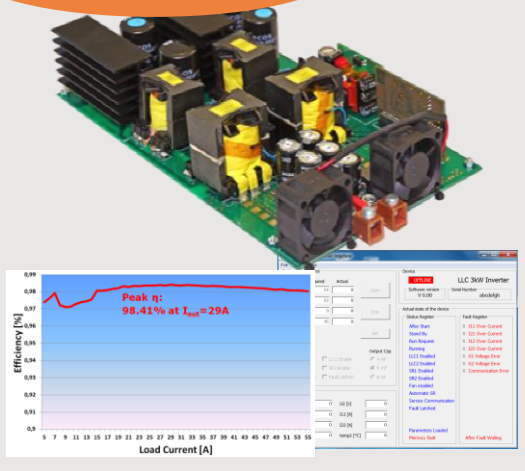
- 600 W LLC half bridge stage with Sync rectification (SR)
- All controlled with XMC4200 including:
  - Adaptive dead time and capacitive mode detection
  - No hard commutation at any condition

Customer benefits:

- Learn LLC topology with a complete system solution from Infineon
- Close to customer solution
  - high efficiency → 97,8%
  - Reliability and power density

3 kW Dual Phase LLC converter using XMC4400

Link to WEB



Specification	
V_{in}	350-410 V_{DC}
V_{out_nom}	54,3 V_{DC}
I_{out_max}	55 A
P_o	3 kW
Peak efficiency	>98,5%
Efficiency	>97.2% in all load range

Infineon components	
MCU	XMC4400 (LQFP64)
MOSFETs SR	OptiMOS 5 BSC093N15NS5
Gate Drivers	2EDN7524R 1EDI60N12AF
LLC MOSFET	CoolMOS™ P6/C7-IPP(W)60R040C7
Auxiliary PSU	ICE2QR2280Z

Key features:

- 3 kW Dual Phase LLC with Sync rectification
  - **Full digital control by XMC4400 on secondary side**
  - Digital current sharing with phase shedding
  - Accurate algorithm able to prevent hard commutation and capacitive load mode in LLC operation

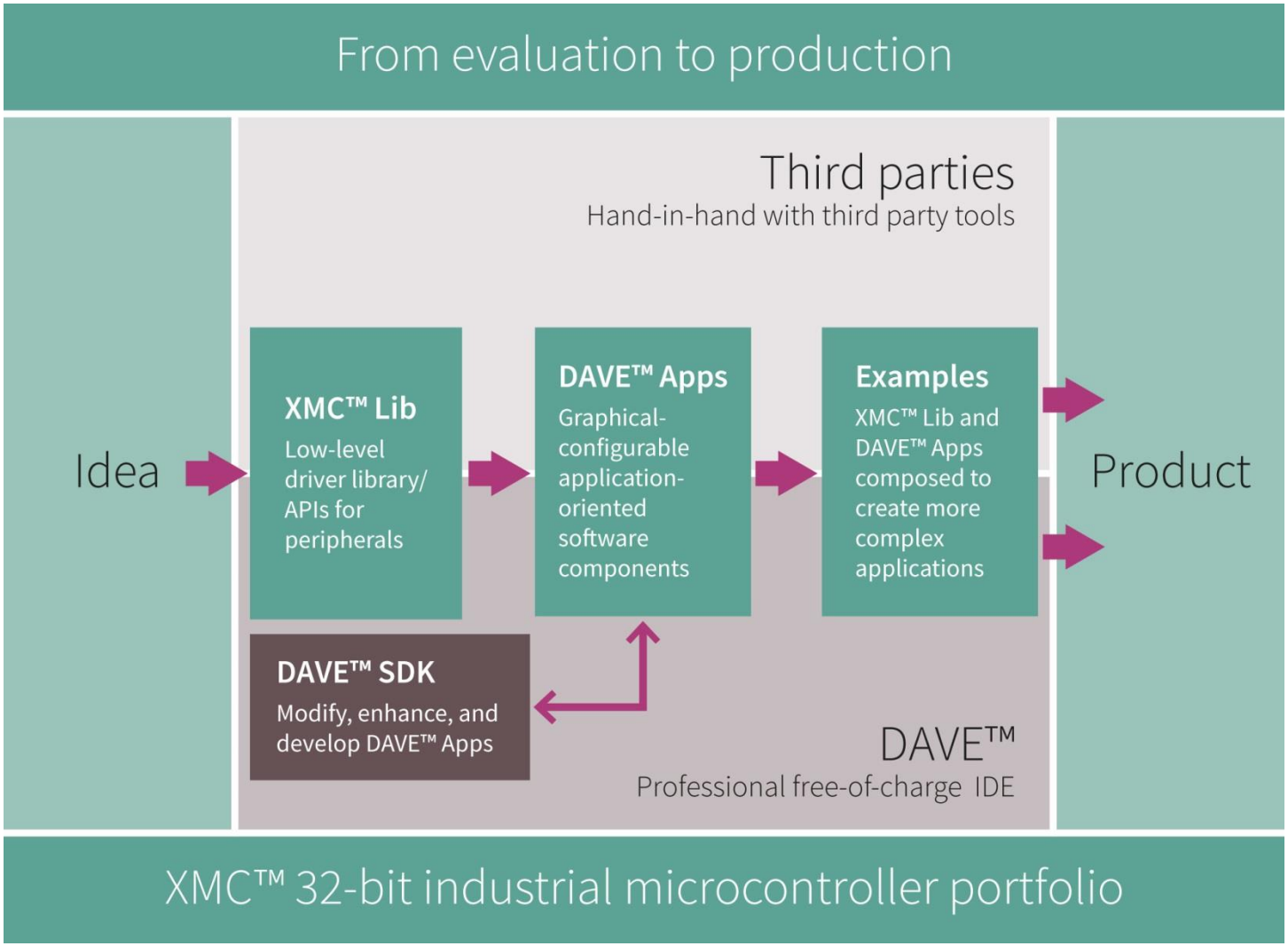
Customer benefits:

- Highly sophisticated HW and SW design available → very flat efficiency curve
  - Efficiency peak 98.5% and >97.2% in the entire load range thanks to current balancing algorithm (Cortex® M4 core at 120 MHz)
  - Improved performance thanks to adaptive dead time implemented with HRWPM

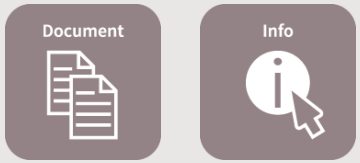
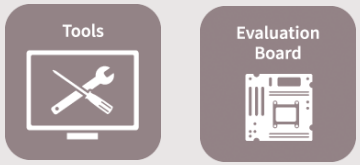
Agenda

1. Why XMC™ for digital power control?
2. Key microcontroller features
3. Kits and reference design
4. Development tool and software

Development Tools and Software
DAVE™– Software development made easy



Support material:

Collaterals and Brochures 	› Product Briefs › Selection Guides › Application Brochures › Presentations › Press Releases, Ads	› www.infineon.com/XMC
Technical Material 	› Application Notes › Technical Articles › Simulation Models › Datasheets, MCDS Files › PCB Design Data	› www.infineon.com/XMC › Kits and Boards › DAVE™ › Software and Tool Ecosystem
Videos 	› Technical Videos › Product Information Videos	› Infineon Media Center › XMC Mediathek
Contact 	› Forums › Product Support	› Infineon Forums › Technical Assistance Center (TAC)

Glossary abbreviations

VADC	Versatile Analog Digital Converter
CCM	Continuous Conduction Mode
CMP	Comparator
DAC	Digital to Analog Converter
DAVE™	Free development IDE for XMC
HRPWM	High Resolution PWM
LLC	Power stage topology built with 2 inductors (L) and 1 capacitor (C)
PFC	Power Factor Correction
PWM	Pulse Width Modulation

Disclaimer

The information given in this training materials is given as a hint for the implementation of the Infineon Technologies component only and shall not be regarded as any description or warranty of a certain functionality, condition or quality of the Infineon Technologies component.

Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind (including without limitation warranties of non-infringement of intellectual property rights of any third party) with respect to any and all information given in this training material.

Part of your life. Part of tomorrow.

Infineon