Digital power conversion basics: from analog to digital control

XMC™ microcontrollers
May 2016
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Digital control is a natural evolution

Evolution

Would you get stock in the past?

*(Source: Freepik)*
### Benefits of digital control

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<th>Adaptability</th>
<th>Advance control</th>
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<tr>
<td>› Allow full performance by tuning SW to specific design</td>
<td>› Adaptive control</td>
</tr>
<tr>
<td>› Programmable operation limits</td>
<td>› Multimode operation: CCM, DCM</td>
</tr>
<tr>
<td>› Scalable to different designs</td>
<td>› Auto calibration</td>
</tr>
<tr>
<td>› Programmable fault handling</td>
<td>› Non lineal control</td>
</tr>
<tr>
<td></td>
<td>› System linearization</td>
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<th>Security</th>
<th>Communications</th>
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<tr>
<td>› Implement and protect your own IP from read access</td>
<td>› Housekeeping: diagnostics, metering &amp; reporting</td>
</tr>
<tr>
<td>› Embedded HW protections in case of SW fault</td>
<td>› Remote SW update</td>
</tr>
<tr>
<td></td>
<td>› Remote controllable, i.e. diming</td>
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What to expect when moving from analog to digital control?

Don’t panic! XMC™ ecosystem will provide you with what you need!

I heard I can do anything!? 

The major problem that digital control has is: freedom!

Together with freedom comes: responsibility!

*(Source: Pixabay)*
What to expect when moving from analog to digital control?

XMC™

XMC™ + SW example + demo board

Extra steps
› Adapt SW parameters for new design

Empty µC (without SW)

Extra steps
› Design control algorithms
› Resources assignment: pins, PWM, ADC...
› Code algorithms
› Debug
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Simple PI regulator: Analog vs. digital

Analog

Feedback pin
Reference pin

PWM pin

Digital

ADC

Calculate error

Reference

PI regulator

PWM unit

feedback pin

HW
SW
HW

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Digital PI regulator in C code

Digitalized feedback → Calculate error → PI regulator → Digital PI_output

error = reference - feedback;
PI_storage = (error * PI_ki) + PI_storage_1;
PI_storage_1 = PI_storage;
PI_output = (error * PI_kp) + PI_storage;

Where are the PI parameters?
The impact of the execution time

- Execution time add a delay to the control loop
- Due to execution time we may not be able to “regulate” the system every switching cycle
- The faster the CPU the faster we can close the loop
- Executing the control loop faster than switching frequency may not help
## Fix point vs. floating point

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<th><strong>Fix point</strong></th>
<th><strong>Floating point</strong></th>
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<tr>
<td>Cheaper HW</td>
<td>Do not need variables scaling</td>
</tr>
<tr>
<td>Faster execution (in general)</td>
<td>Low overflow risk</td>
</tr>
<tr>
<td>Danger of operations overflow</td>
<td>Easy coding and easy to understand</td>
</tr>
<tr>
<td>May required scaling factors</td>
<td>Higher code reusability</td>
</tr>
<tr>
<td></td>
<td>More expensive HW (or slow execution)</td>
</tr>
<tr>
<td></td>
<td>Type conversion to access HW registers</td>
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</table>
XMC™ examples SW architecture

Control loop

APIs

Hardware access layer (HAL)

XMC™ peripherals

HW

Target: Ensure code reusability and reliability by isolating control loops from HW

Options
- Low level drivers
- DAVE™ APPs (based on LLDs)
- Custom
- Combination of previous
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How key peripherals help? CPU usage

- Peripherals are state machines which can run independently and interact with the CPU or with other peripherals.

While(1)
{
  signal_high= 100;
  while (signal_high--);
  set_pin_low();
  signal_low= 200;
  while (signal_low--);
  set_pin_high();
}

- Precise
  - CPU is free

- Block CPU
  - It is unprecise

Key peripherals are a must to enable high performance control.
Key peripherals

Peripherals for power conversion applications

- CCU8/4
- HRPWM
- VADC
- ACMP
- ERU
- CSG

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

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Key peripheral example 1: High Resolution PWM

Higher accuracy
Better control
stability

1.8 V +/- 65 mV

With HRPWM
1.8 V +/- 35 mV

No HRPWM

V_{out}

Stepwidth 12.5 ns

PWM

Stepwidth 150ps
Key peripheral example 2: Smart analog comparators

- 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**.
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Development flow vs. Infineon support

- System specification
- Converter topology
- Control concept
- HW / SW function split
- HW
  - Parts selection
  - Schematic design
  - Board design
- SW
  - SW architecture
  - resource assignment
  - Coding

- Test / debugging

- Demo boards
- Code example
- Application notes
- DAVE™
- XMC™ pinout
- APPs / LLDs
- uC-Probe

Implementation

specs

concept
Shorten your development time

Which entry point do your target?

Want to reuse SW from a running system?

Want to code your own control loop?

Want to configure MCU peripherals?

System concept

Control loop

APIs

Hardware access layer (HAL)

XMC™ peripherals

HW
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Development tools and software
DAVE™ – software development made easy

From evaluation to production

Third parties
Hand-in-hand with third party tools

**Idea**
- XMC™ Lib
  - Low-level driver library/ APIs for peripherals
- DAVE™ SDK
  - Modify, enhance, and develop DAVE™ Apps

**Product**
- DAVE™ Apps
  - Graphical-configurable application-oriented software components
- Examples
  - XMC™ Lib and DAVE™ Apps composed to create more complex applications
- Professional free-of-charge IDE

XMC™ 32-bit industrial microcontroller portfolio
Development tool and software

› DAVE™ – Free development platform for code generation
  - Eclipse IDE
  - Compiler
  - Debugger
  - Application library and examples
  - Software can be used with 3rd party tools

› For download and support:

DAVE™ website
μC/Probe™: Read/write your data on the fly without code modification!

Debug

Built your own GUI

Parametrize your system

Digital scope*

PFC example GUI:

* Digital scope functionality requires adding of debug code
XMC™ Flasher

› Easy code download to your XMC™
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- [Kits and Boards](http://www.infineon.com/XMC)
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- [Infineon Media Center](http://www.infineon.com/XMC)
- [XMC Mediathek](http://www.infineon.com/XMC)
- [Infineon Forums](http://www.infineon.com/XMC)
- [Technical Assistance Center (TAC)](http://www.infineon.com/XMC)
Glossary abbreviations

› VADC Versatile Analog Digital Converter
› CCU Capture Compare Unit
› ACMP Analog Comparator
› PWM Pulse Width Modulation
› HRPWM High Resolution Pulse Width Modulation
› DAVE™ Free development IDE for XMC
› CSG Comparator & Slow Generator
› ERU Event Request Unit
› PFC Power Factor Correction
Part of your life. Part of tomorrow.
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