Digital Power Supply Design Overview

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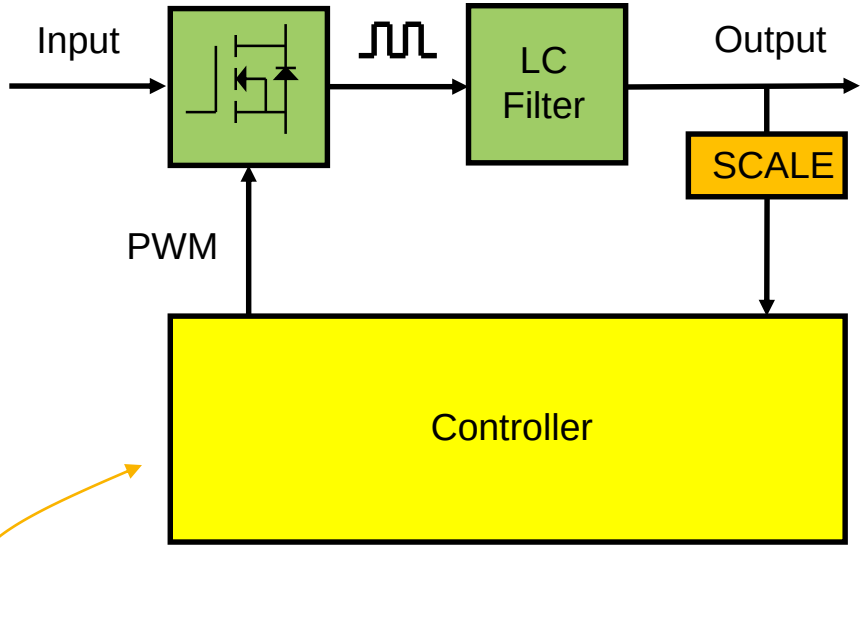
SECURE CONNECTIONS FOR A SMARTER WORLD

Agenda

- What is Digital Power Supply
- Why Digital Control Techniques
- CPU and Peripherals Used for Digital Power Supply
- Design a Digitally Controlled Server Power Supply
- Reference Design
- Digital Signal Controller & Kinetis V

What is Digital Power Supply

Generic SMPS Block Diagram



The controller block is the key difference between a digital switching-mode power supply and analog one

What is Digital Power Supply?

- "Digital Power Supply" is a power system that is controlled by digital circuits, in much the same way as would be with analog circuits, to monitor, supervise, communicate and control looping.
- A fully digital controlled power system includes both "Digital Control" and "Digital Power Management"

Digital Control

Power switch control feedback or feed forward loop, which is controlled by the digital circuit or programmable controller regulates the output of the power system
by driving the power switch duty cycle using pulse width modulation techniques

Advanced adaptive control system, the control circuits combine A/D conversion, pulse width modulation, communication interfaces, operating entirely or mostly in digital mode to gain excellent system performance

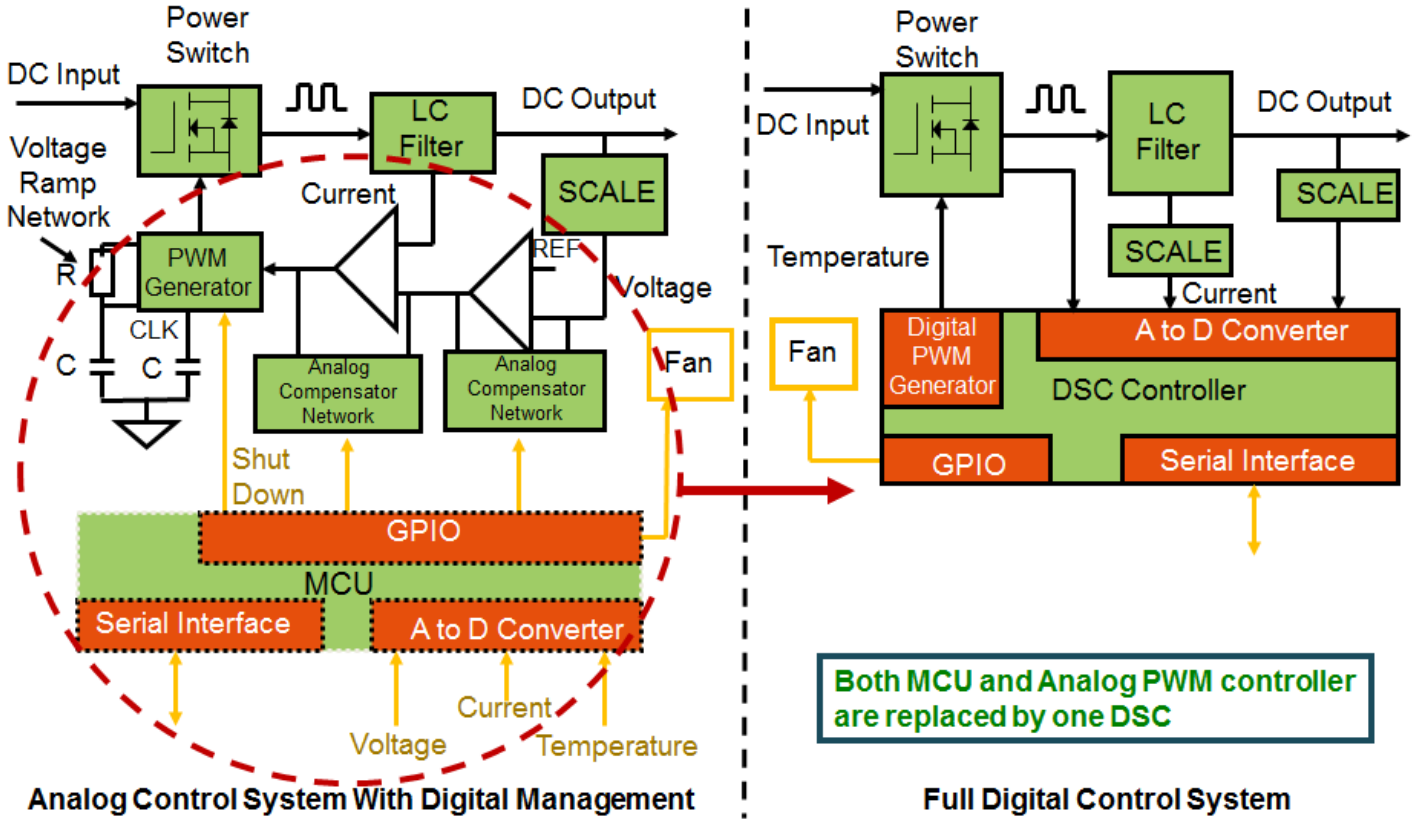
Digital Power Management

A digital circuit or programmable controller provides the functions of

- configuration,
- diagnosis,
- monitoring ,
- protection,
- supply sequencing, and
- communication

with the environment.

Analog vs. Digital Power Control System



Why Digital Control Techniques

The Trends of Power Supply Technology

- **High Efficiency**
  - Meet Energy Star, 80 plus specifications (www.plugloadsolutions.com/**80Plus**PowerSupplies.aspx)
  - High efficient from light load to full rated load range
- **High Power Density**
  - Compact size: high watt per cubic inch
- **High Intelligent Control**
  - Digital controlled multi-mode power conversion
  - Adaptive control algorithms – nonlinear loads and components drift
  - Fast transient response
  - Power management and communication
- **High Reliability**
  - Less components usage
  - System monitoring and protection
- **Quiet Operation**
  - Low harmonics, radiated and conducted EMI
- **Innovative Power Distribution**
- **Low Cost**

The Challenges of Power Supply Design

Increased performance and cost pressures
Pressure to increase performance while reducing cost to
meet customer demands

System complexity
On the rise with the need for more features and Functionality in smaller form factors

Time to market constraints
Increasingly complex development environments and design cycle time-frames that are constantly shrinking

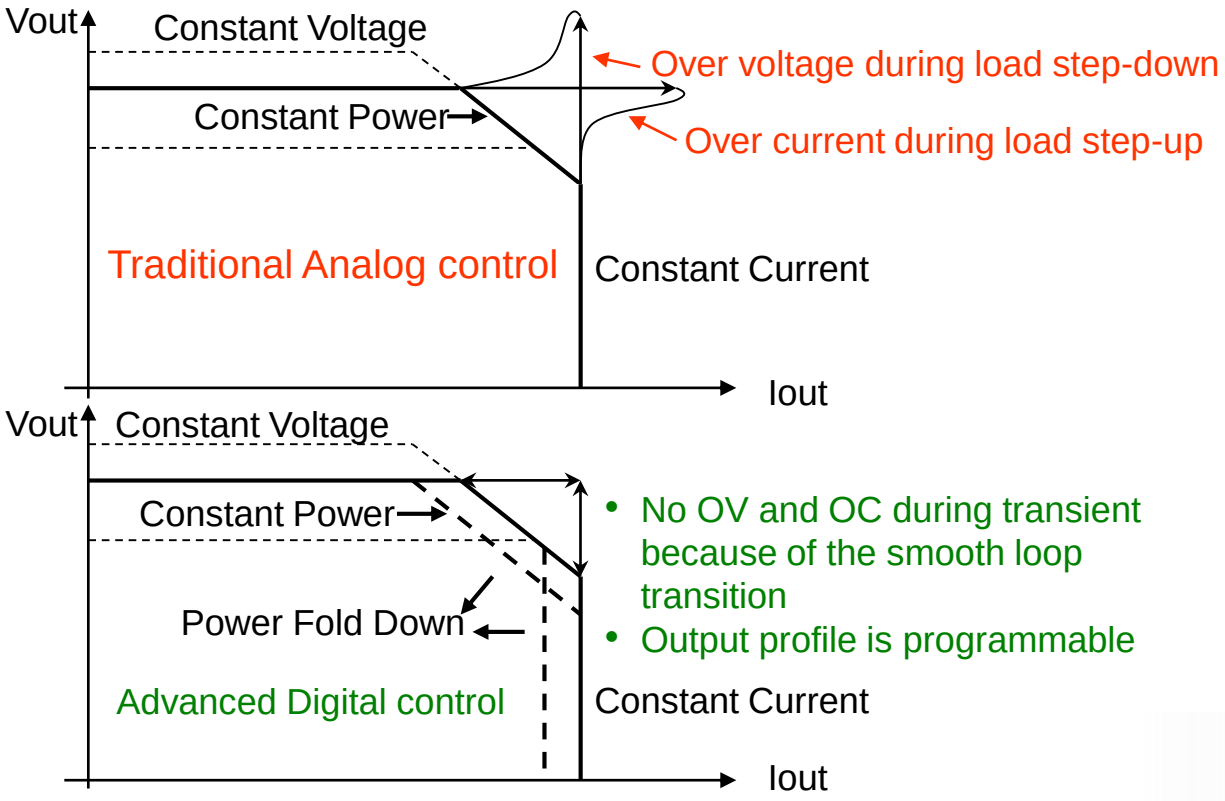
Scalable & Compatible
Easy migration from existing 8Bit product with common core, IP and tools

Benefits of Digital Controlled Power Supply

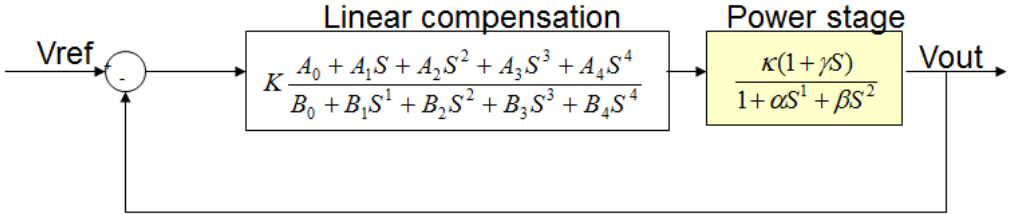
- Eliminate the effects of component tolerance, parametric drift, aging, etc
- Configurable feedback loop structure for specific application requirements
- Much greater product flexibility by adding new features without hardware changes
- Store operational data for diagnostic and record keeping
- Flexible communication capabilities
- Reduced component count and cost due to the over all integration
- Shorter R&D cycle, fewer turns of board prototyping
- Project portability
- Improved end system performance
- IP protection and technology differentiation

Analog Control vs. Digital Control

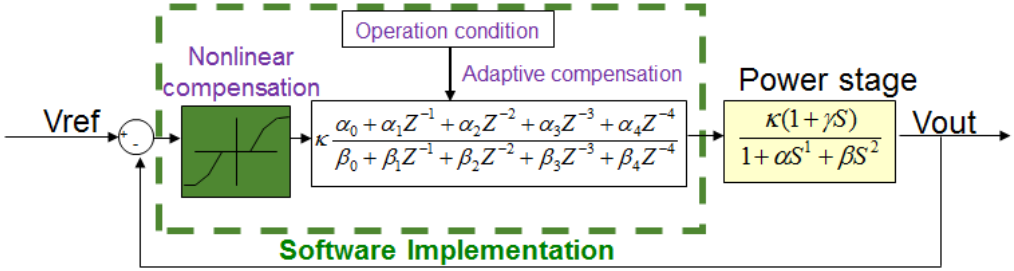
- Transient Response Comparison



Analog vs. Digital Control Algorithm



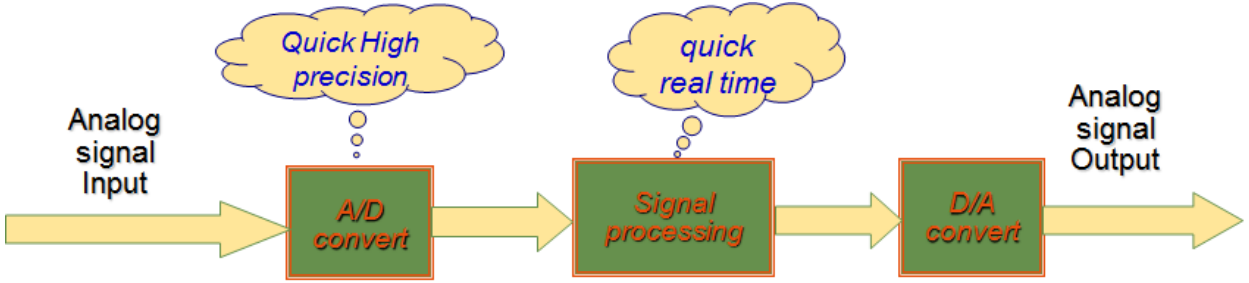
A typical control loop implemented by an analog circuit

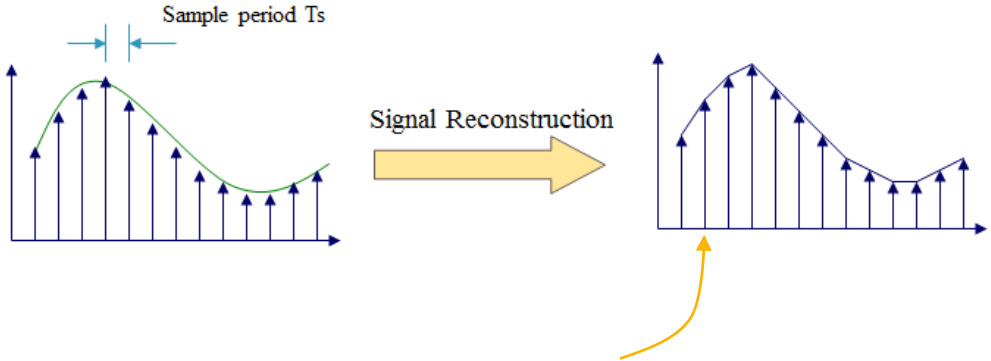


A digital control loop implemented by Digtal Signal Controller

Benefit of digital control:
1) Advanced control algorithm implemented to control complex topologies
2) Optimize feedback loop to meet application requirements
3) Runtime changes to compensation parameters according to operating conditions

Digital Control System





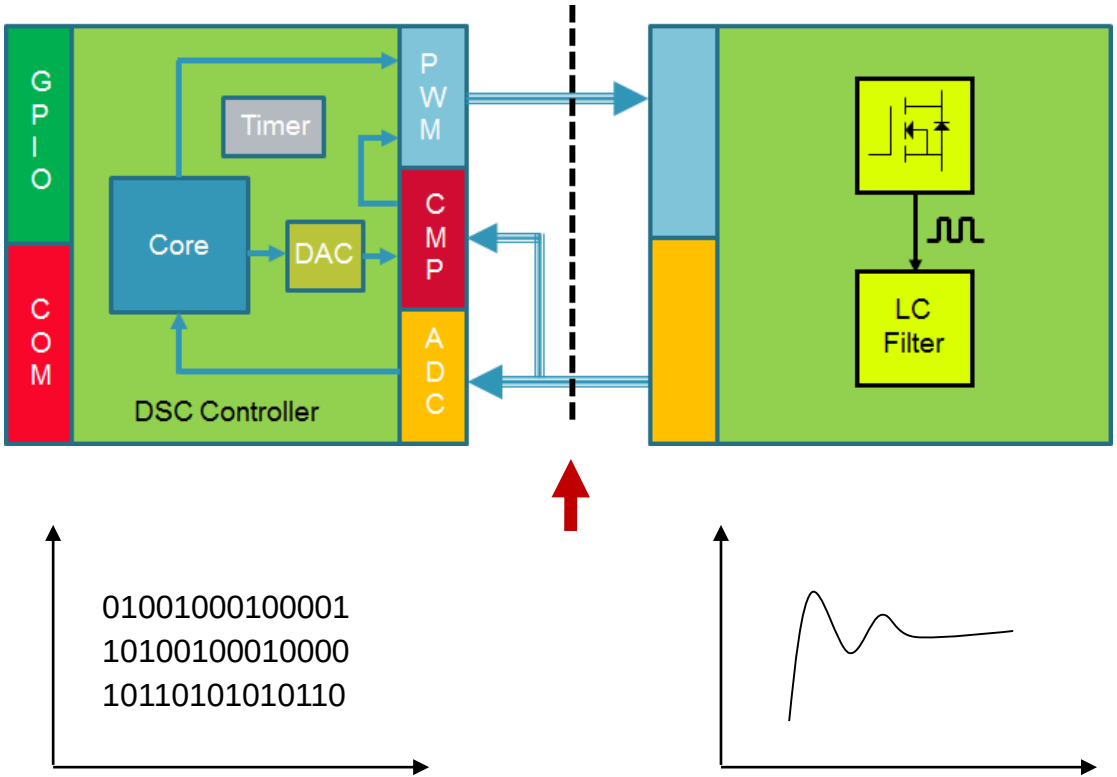
Processing delay and quantization effect reduce system precision and performance

Analog vs. Digital Power Control System Checklist

	Analog Control	Digital Control
Control Circuit	Complex, Bulky	Simple, Programmable, Integrated
IP Protection	Bad	Good
System Record	Bad	Good
Flexibility	Bad	Good
Reliability	Bad	Good
Design Continuity	Bad	Good
Update	No	Yes
Sample Mode	Continuous	Discrete
Processing	Continuous	Control Delay

CPU and Peripherals Used for Digital Power Supply Design

Digital Controlled Power Supply System Mapping



MC56F827xx (64kB Flash, 50/100MHz)

Key Features:

Core

• 56800EX @ 50/100MHz supporting fractional arithmetic with 4 accumulators, 8 cycle pipeline, separate program and data memory maps for parallel moves, single cycle math instructions, nested looping, and superfast interrupts that far outpace any competitive core on the market.

System

• Inter-module crossbar directly connecting any input and/or output with flexibility for additional logic functions (AND/OR/XOR/NOR)
• DMA controller for reduced core intervention when shifting data from peripherals
• Memory resource protection unit to ease safety certification

Timers

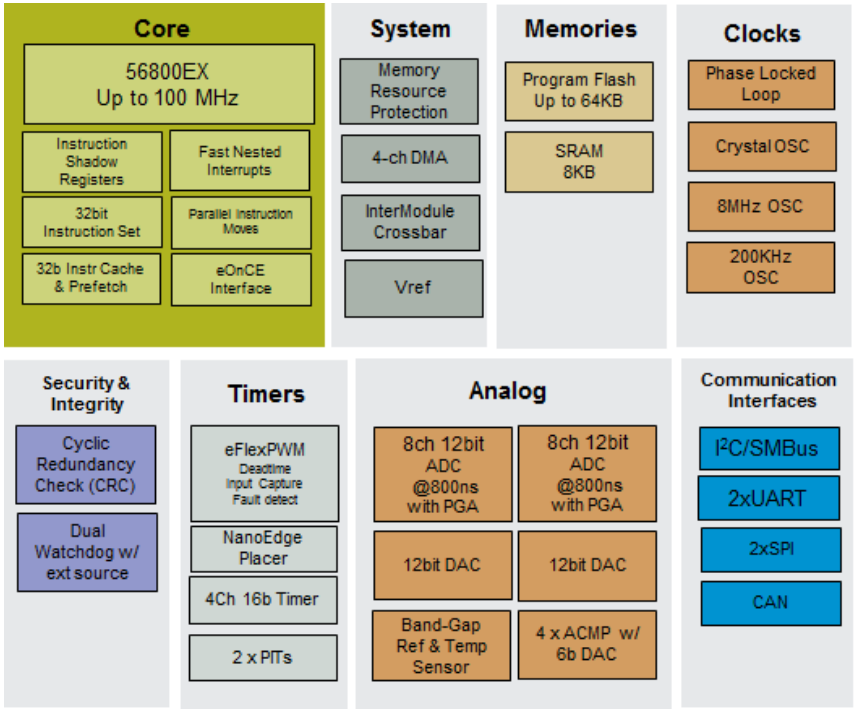
• eFlexPWM – Freescale's most advance timer for Digtial Power Conversion, up to 8ch and 312 pico-sec resolution, 4 independent time bases, with half cycle reloads for increased flexibility, automatic complimentary mode for ease of use and best in class performance

Analog

- 2x12-bit high-speed ADCs each with 800ns conversion rates
- 4 analog comparators with integrated 6-bit DACs that can enable emergency shutdown of the PWMs
- Integrated PGAs to increase the accuracy of ADC conversions on small voltages and currents

Power Consumption:

- Best in class Power Consumption – 50% better than nearest competitor

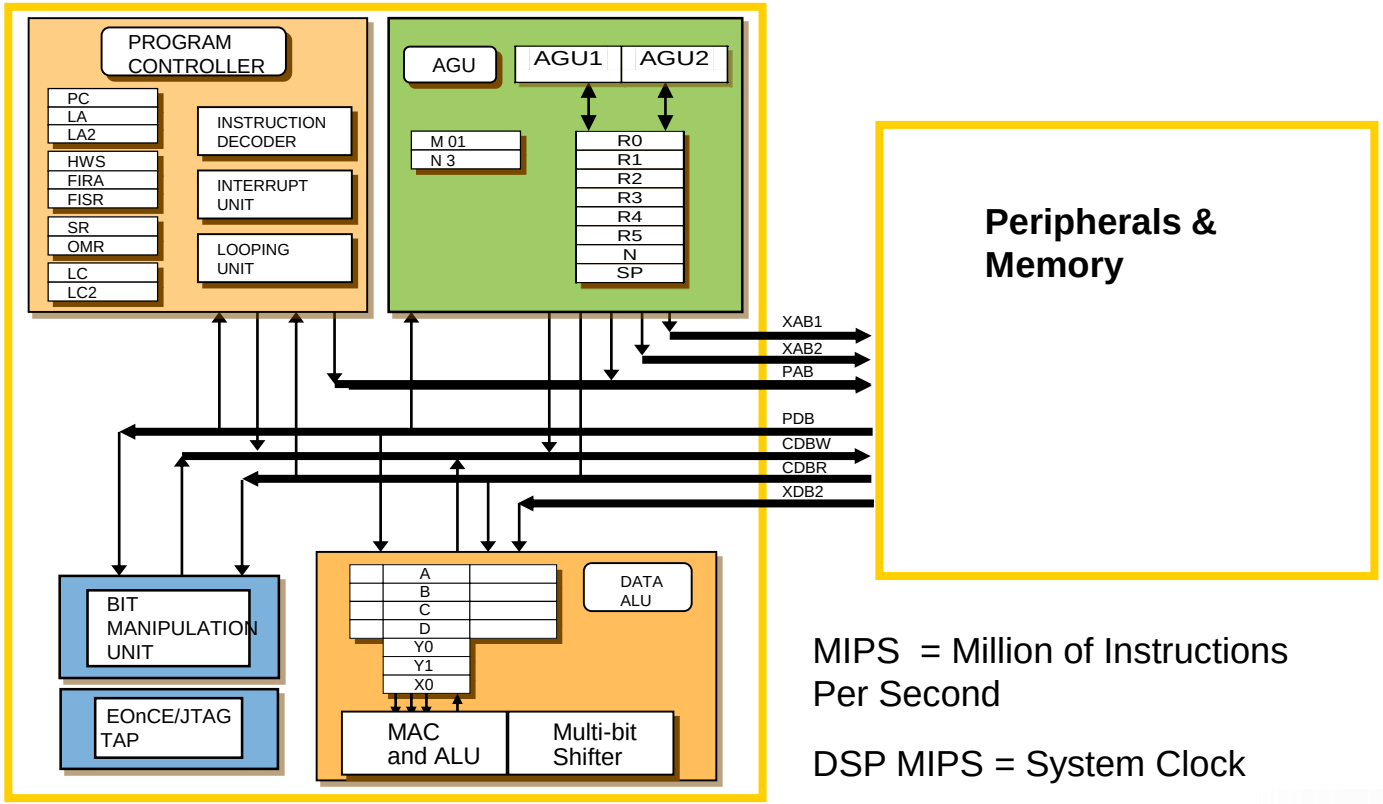


Others: 5-volt tolerant I/O for cost-effective board design

Packages: 32QFN (5x5), 32LQFP, 48LQFP, 64LQFP

Temperature: -40 to +105C across all packages, with -40 to +125C option on 64LQFP

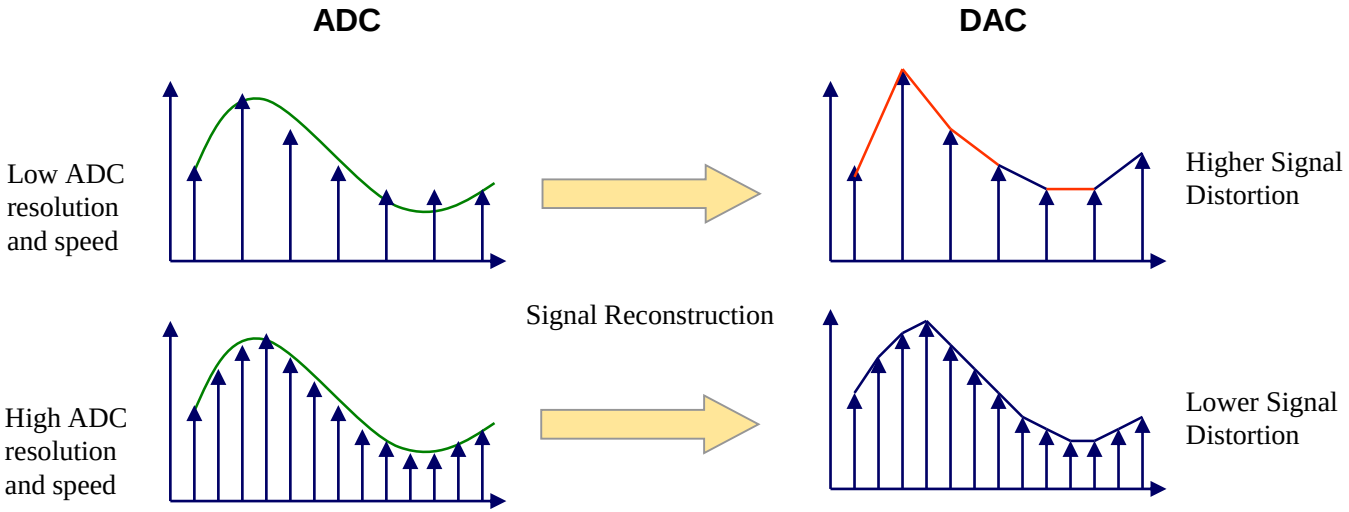
Efficient and Powerful 56800EX Core



MIPS = Million of Instructions Per Second

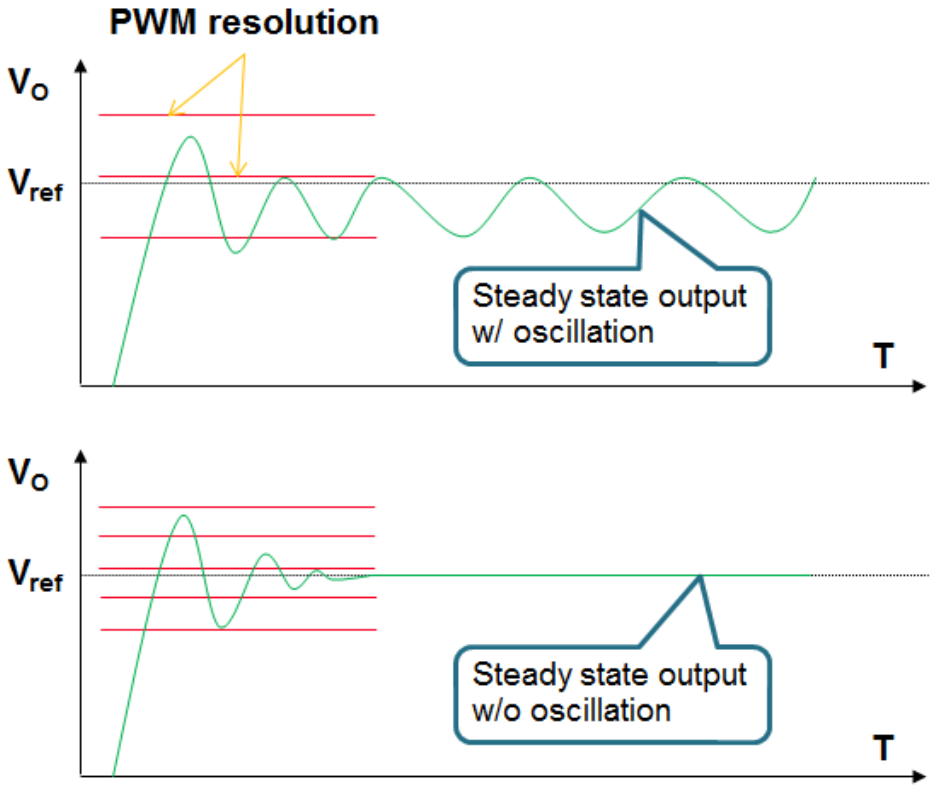
DSP MIPS = System Clock

ADC Requirements



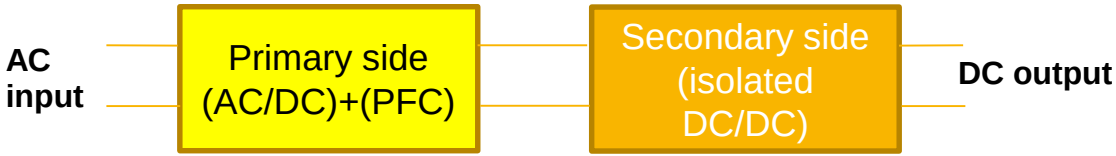
Real-time loop control requires high speed ADC to improve loop performance, high output precision requires high resolution ADC conversion. It's recommended that total ADC conversion time is less than 10% control loop execution time.

PWM Resolution Requirements



Reference Design

Popular Server Power Supply Topology



- Two controllers are required for primary side and secondary side control respectively
- Two-channel interleaved PFC for primary side
- Phase-shifted full-bridge or LLC resonant for secondary side

Totem pole bridgeless PFC Power topology

Target Devices/Platforms:

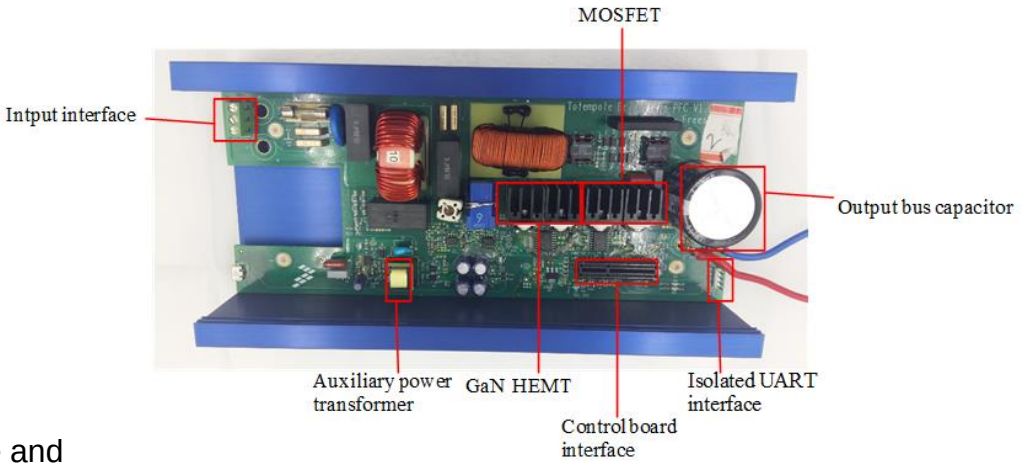
- MC56F82748

Applications Usage:

- Digital AC/DC power supply

Application Features:

- 600W output
- Output DC voltage: 380Vdc.
- Input AC voltage: 90~265Vac, 45~63Hz
- PF: full load > 0.99.
- Isolated SCI communication between primary side and secondary side; Efficiency 96%~98%.
- iTHD < 5%
- Isolated USB interface for FreeMASTER connection



Availability:

- Less internal boards
- Demo is ready
- DRM174 available on web

LLC Resonant Converter with Sync Rectifier Solution

Target Devices/Platforms:

- ❑ MC56F82748

Applications Usage:

- ❑ Digital AC/DC power supply

Application Features:

- ❑ 12V/240W output with universal mains input
- ❑ Half-bridge LLC with synchronous rectifier
- ❑ Modular software and hardware design for convenient internal reuse and customer evaluation
- ❑ Flash updating
- ❑ Isolated USB interface for FreeMASTER connection
- ❑ Isolated SCI communication between primary side and secondary side; IIC interface is reserved for PMBus communication.
- ❑ 120mVp-p output ripple; Overshoot < 5%@0 to 65% load step; Hold up time 20ms@50% load, 15ms@100% load.
- ❑ Over-current, over-/under-voltage, voltage brown-in, over-temperature, power limit protection functions

Availability:

- ❑ Less internal boards
- ❑ Demo is ready
- ❑ DRM172 available on web

HVP-MC3PH: High-Voltage Development Platform

- Main board (power stage) Input voltage 85-240V AC, 110-390VDC
- **Output power 1kW without PFC, 0.8kW with PFC**
- Output current 8A peak
- Analog sensing (input voltage, DCB voltage, DCB current, phase currents, back-EMF voltage, PFC currents, IGBT module temperature monitoring)
- Motor speed/position sensors interface (Encoder, Hall, Tacho generator)
- Over voltage comparator with DC-brake resistor interface
- Current inrush circuit
- Hardware over-current fault protection

Part number	Features
HVP-MC3PH	HVP-MC3PH High-Voltage Development Platform which includes the HVP-KV46F150M Controller Card
HVP-KV46F150M	KV46 150MHz ARM Cortex-M4 MCU
HVP-KV31F120M	KV31 120MHz ARM Cortex-M4 MCU
HVP-KV10Z32	KV10 75MHz ARM Cortex-M0+ MCU
HVP-56F82748	MC56F82748 Digital Signal Controller (DSC) Controller Card, optional

Digital Signal Controller & Kinetis V

MC56F827xx (64kB Flash, 50/100MHz)

Key Features:

Core

• 56800EX @ 50/100MHz supporting fractional arithmetic with 4 accumulators, 8 cycle pipeline, separate program and data memory maps for parallel moves, single cycle math instructions, nested looping, and superfast interrupts that far outpace any competitive core on the market.

System

• Inter-module crossbar directly connecting any input and/or output with flexibility for additional logic functions (AND/OR/XOR/NOR)
• DMA controller for reduced core intervention when shifting data from peripherals
• Memory resource protection unit to ease safety certification

Timers

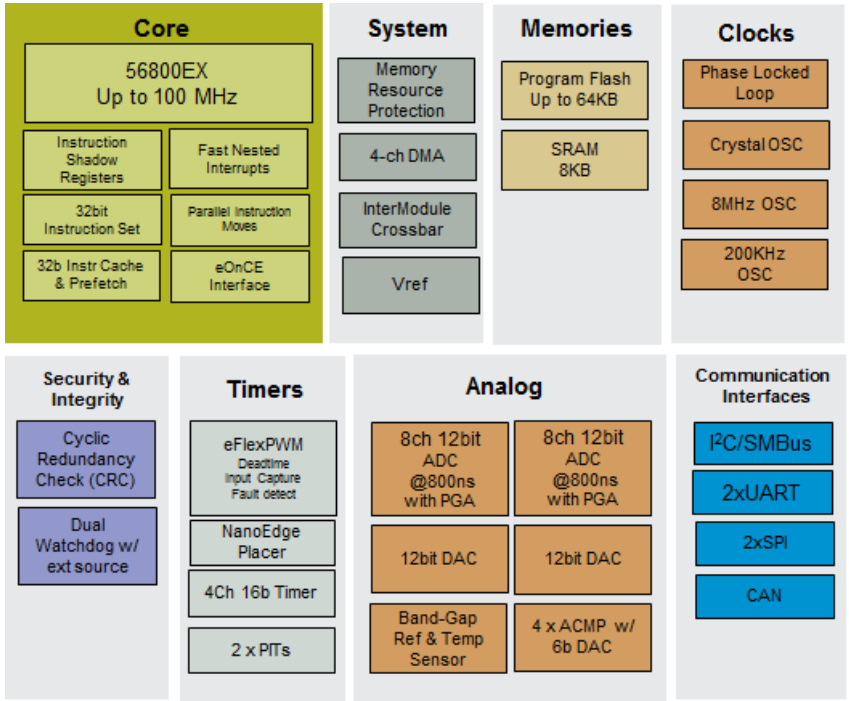
• eFlexPWM – Freescale's most advance timer for Digtial Power Conversion, up to 8ch and 312 pico-sec resolution, 4 independent time bases, with half cycle reloads for increased flexibility, automatic complimentary mode for ease of use and best in class performance

Analog

- 2x12-bit high-speed ADCs each with 800ns conversion rates
- 4 analog comparators with integrated 6-bit DACs that can enable emergency shutdown of the PWMs
- Integrated PGAs to increase the accuracy of ADC conversions on small voltages and currents

Power Consumption:

- Best in class Power Consumption – 50% better than nearest competitor



Others: 5-volt tolerant I/O for cost-effective board design

Packages: 32QFN (5x5), 32LQFP, 48LQFP, 64LQFP

Temperature: -40 to +105C across all packages, with -40 to +125C option on 64LQFP

MC56F823xx (32kB Flash, 50MHz)

Key Features:

Core

• 56800EX @ 50MHz supporting fractional arithmetic with 4 accumulators, 8 cycle pipeline, separate program and data memory maps for parallel moves, single cycle math instructions, nested looping, and superfast interrupts that far outpace any competitive core on the market.

System

• Inter-module crossbar directly connecting any input and/or output with flexibility for additional logic functions (AND/OR/XOR/NOR)
• DMA controller for reduced core intervention when shifting data from peripherals
• Memory resource protection unit to ease safety certification

Timers

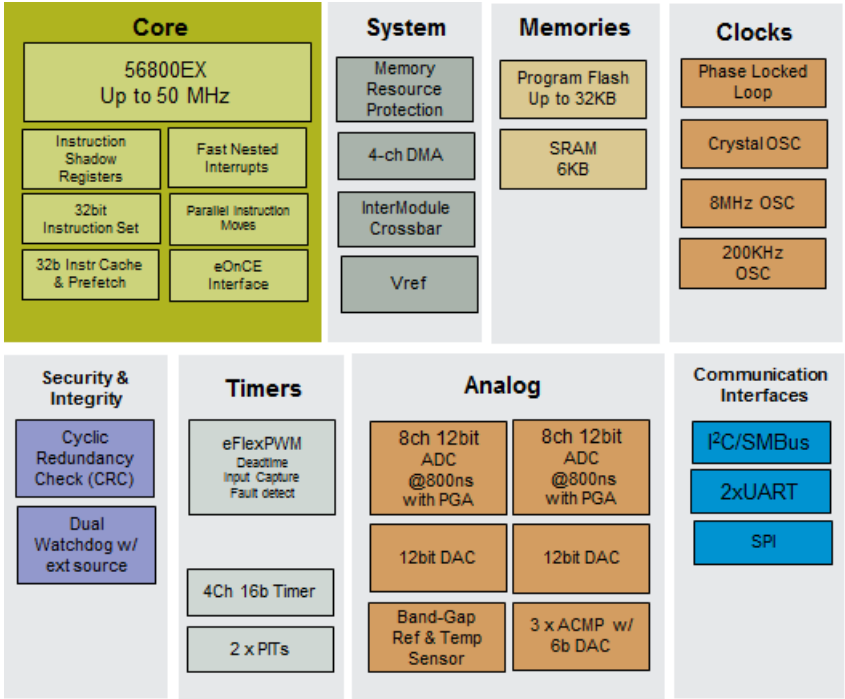
• eFlexPWM – Freescale's most advance timer for Digtial Power Conversion, up to 8ch, 4 independent time bases, with half cycle reloads for increased flexibility, automatic complimentary mode for ease of use and best in class performance

Analog

- 2x12-bit high-speed ADCs each with 800ns conversion rates
- 4 analog comparators with integrated 6-bit DACs that can enable emergency shutdown of the PWMs
- Integrated PGAs to increase the accuracy of ADC conversions on small voltages and currents

Power Consumption:

- Best in class Power Consumption – 50% better than nearest competitor



Others: 5-volt tolerant I/O for cost-effective board design

Packages: 32QFN (5x5), 32LQFP, 48LQFP

Temperature: -40 to +105C across all packages

MC56F84xxx (256kB Flash, 100MHz)

Key Features:

Core

• 56800EX @ 100MHz supporting fractional arithmetic with 4 accumulators, 8 cycle pipeline, separate program and data memory maps for parallel moves, single cycle math instructions, nested looping, and superfast interrupts that far outpace any competitive core on the market.

System

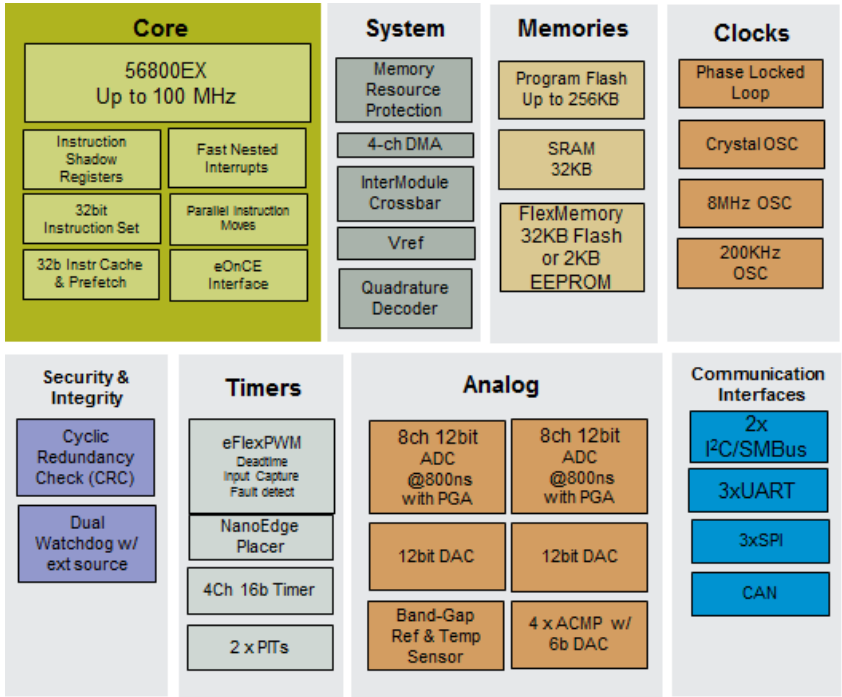
• Inter-module crossbar directly connecting any input and/or output with flexibility for additional logic functions (AND/OR/XOR/NOR)
• DMA controller for reduced core intervention when shifting data from peripherals
• Memory resource protection unit to ease safety certification

Timers

• eFlexPWM – Freescale's most advance timer for Digtial Power Conversion, up to 8ch and 312 pico-sec resolution, 4 independent time bases, with half cycle reloads for increased flexibility, automatic complimentary mode for ease of use and best in class performance

Analog

- 2x12-bit high-speed ADCs each with 300ns conversion rates
- 16 ch 16b SAR ADC that enables external sensors inputs and accurate system measurements
- 4 analog comparators with integrated 6-bit DACs that can enable emergency shutdown of the PWMs
- Integrated PGAs to increase the accuracy of ADC conversions on small voltages and currents



Others: 5-volt tolerant I/O for cost-effective board design
Freescale FlexMemory for simplified data storage

Packages: 48LQFP, 64LQFP, 80LQFP, 100LQFP

Temperature: -40 to +105C across all packages

Kinetis V Series KV4x

Core/System
- 150MHz Cortex-M4+ with 16ch DMA
- Floating Point Unit

Memory
- 64/128/256KB Flash @ 128bits wide w/ 128Byte cache
- 16/24/32KB SRAM
- Bootloader

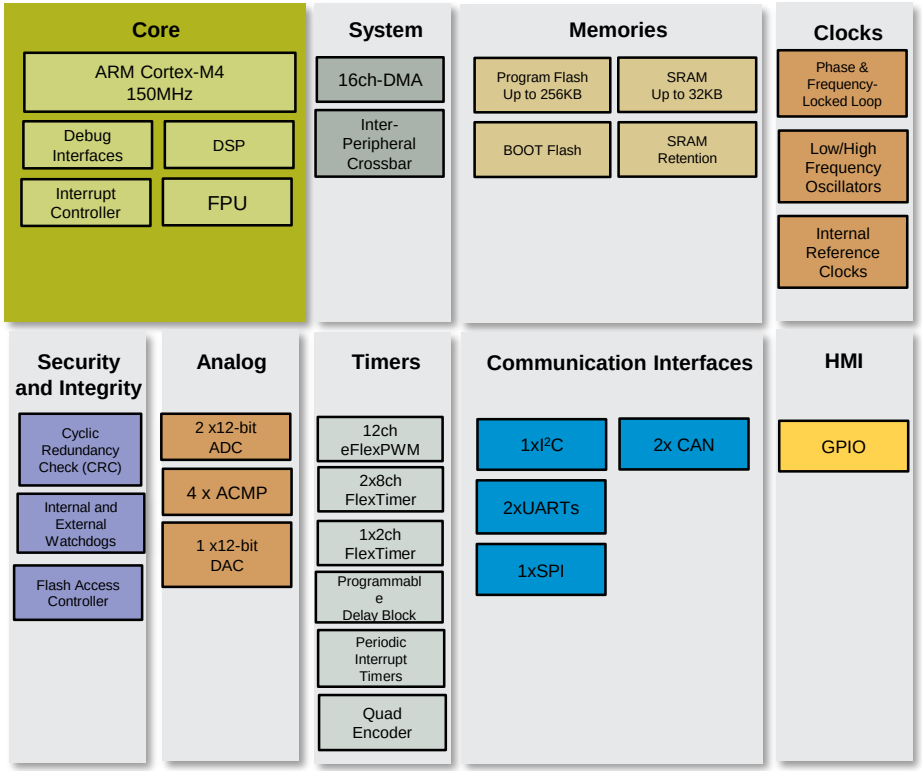
Communications
- Multiple serial ports
- Up to 2 x CAN

Analog
- 2 x 8ch 12-bit ADC
  - Sampling at up to 4.1MS/s (240ns)
  - PGA x1, x2, x4
- 12-bit DAC
- 4 x ACMP with 6-bit DAC

Timers
- Up to 12ch eFlexPWM
  - Up to 312ps PWM Resolution (*)
- 2x8ch + 1x2ch FlexTimer (PWM)
- Quadrature Encoder
- 2 x Programmable Delay Blocks

Other
- 32-bit CRC
- Inter-Peripheral Crossbar with AND/OR interface
- Up to 56 I/Os
- 1.71V-3.6V; -40 to 105oC

Packages
- 64 LQFP & 100LQFP



Kinetis V Series KV5x Family: 1M Flash – 200MHz

Key Features:

Core/System
- 200MHz Cortex-M4 with 32ch DMA
  - Floating Point Unit

Memory
- 1MB Flash, 128bits wide, 128Byte cache
- 256KB SRAM
- Boot Flash

Communications
- Multiple serial ports, USB
- 3 x CAN

Analog
- 2 x 8ch 12-bit ADC
  - Sampling at up to 4.1MS/s (240ns)
  - PGA x1, x2, x4
- 1 x12-bit DAC
- 4 x ACMP w/ 6b DAC

Timers
- 12ch eFlexPWM
  - 312ps PWM and PFM Resolution
- 2x8ch FlexTimer (PWM)
- 1x2ch FlexTimer (PWM)
- Quadrature Encoder
- 2 x Programmable Delay Blocks

Others
- 32-bit CRC
- Inter-module Crossbar Switch with AOI
- Memory Protection Unit
- 1.71V-3.6V; -40 to 105oC

Packages
100LQFP & 144MAPBGA
Pin to Pin compatible with Kinetis K & KV series