Working Together for a Greener Society

Future of Power Electronics and the Earth

RISC-V Day Tokyo 2025 Spring

RISC-V + Heterogeneous Multi Core + 22nm ULL Process + ReRAM Technology

Advanced MCU for Power Electronics Control

MD6605

RISC-V® STRATEGIC MEMBER

Feb. 27, 2025
Takanaga Yamazaki
Sanken Electric Co., Ltd.

Sanken
Power Electronics for Your Innovation

Powering AI and HPCs + Driving xEVs and Home Appliances

Power Device + Power Module

PMIC for Middle~High Power

HPC Server

AI / GPU, SoC

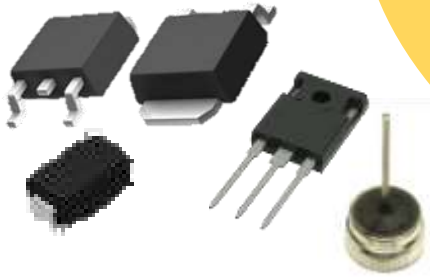
LED

LED Driver

LED Lighting

OLED TV

Discrete



Car Exterior and Interior

Automotive ECUs

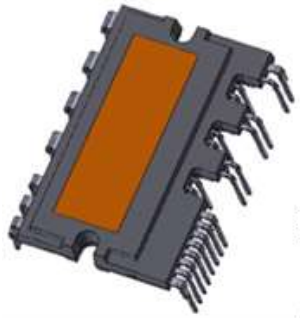
IC for Automotive

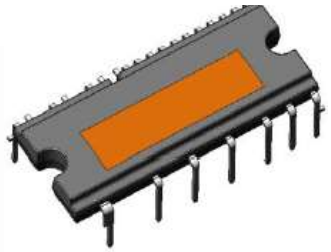
Automotive xEV

BLDC Motor

Home appliances

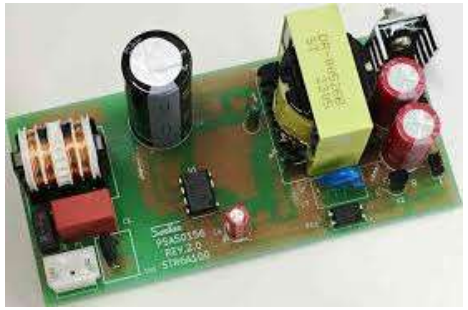
IPM, IGBT module, driver IC





PMIC for Power Supply

(High Watt Supply)



AC-DC

DC-DC

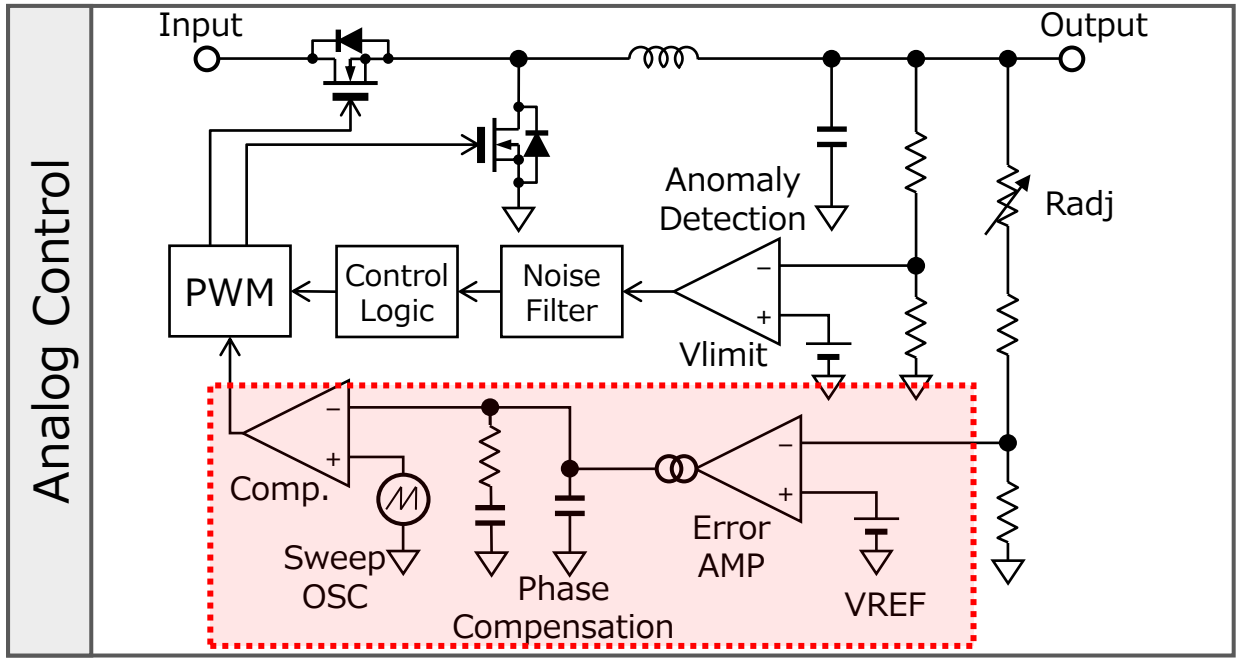
Analog Control

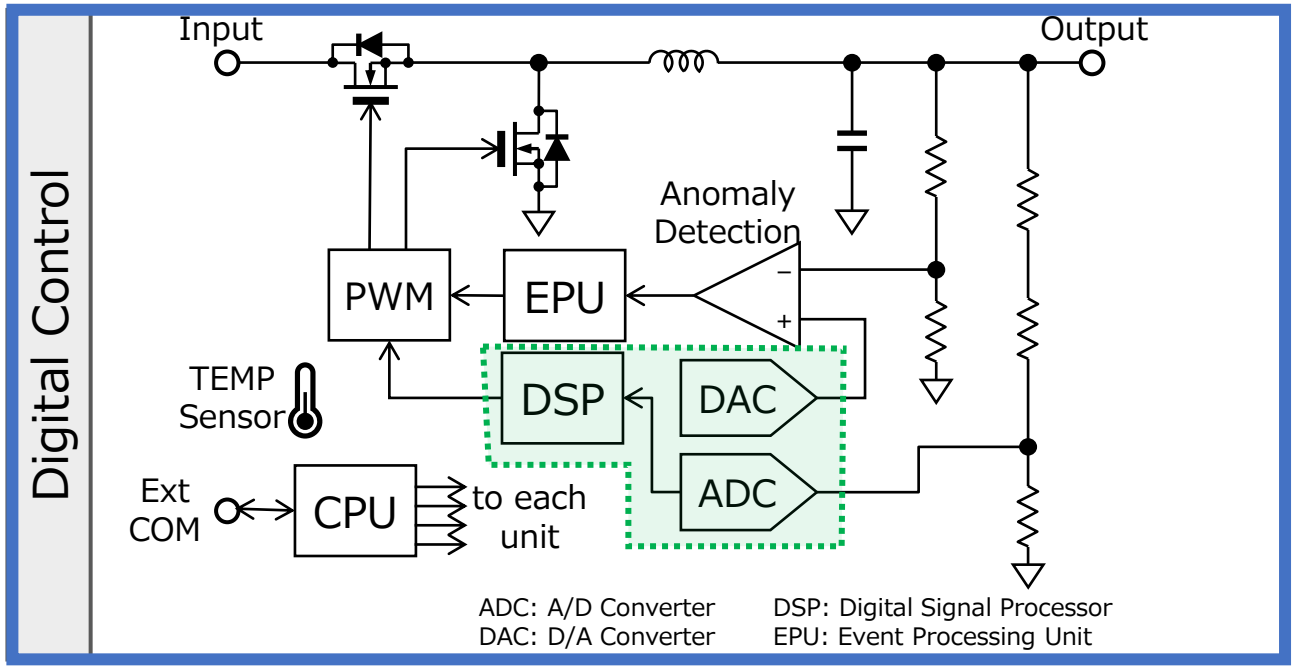
Digital Control

by dedicated original MCU

- ☑ High Efficiency
- ☑ High Precision
- ☑ Quick Response
- ☑ Low Noise
- ☑ Low Cost

Analog Control vs Digital Control in Power Supply System





Analog Control

Limited Linear Phase Compensation

- Fixed converter topology
- Characteristics can only be adjusted using R and C
- **Optimal control to improve efficiency is challenging**
- **Noise reduction by limited hardware methods**
- No external communication and no intelligence
- Many components and large heat sink on the board
- **High system cost** (High Watt Supply)

Digital Control (MCU)

Numerical Linear / Non-Linear Feedback Controls

- Flexible converter topology
- Desired characteristics obtained through flexible software
- **Optimal control to improve efficiency is easy**
- **Noise reduction by flexible software algorithm**
- External communication and full intelligence
- Reduced components and small/no heat sink on the board
- **Low system cost** (High Watt Supply)

Award History

High Efficiency Digital PMIC MD6750 Series

Energy Conservation Grand Prize 2022

Minister of Economy, Trade and Industry Award

省エネ大賞　経済産業大臣賞

HPC / Server

OLED TV

MD6750 Series

"The MD6750 series is a digital power management IC designed for high-power applications like HPC/Server Systems and OLED TVs. It helps address the issue of rising power consumption due to the global increase in digital devices and appliances."

ENERGY CONSERVATION GRAND PRIZE
2022年度
省エネ大賞
（製品・ビジネスモデル部門）
主催：一般財団法人省エネルギーセンター

Energy Saving

Conversion efficiency at full load

Improved over 2%

Resource Saving

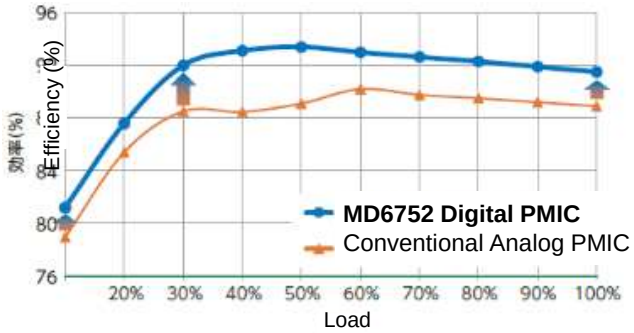
Components in the power supply circuit

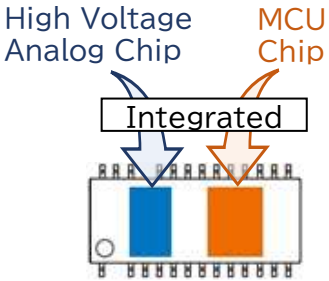
Reduced 30%

Size of the power supply

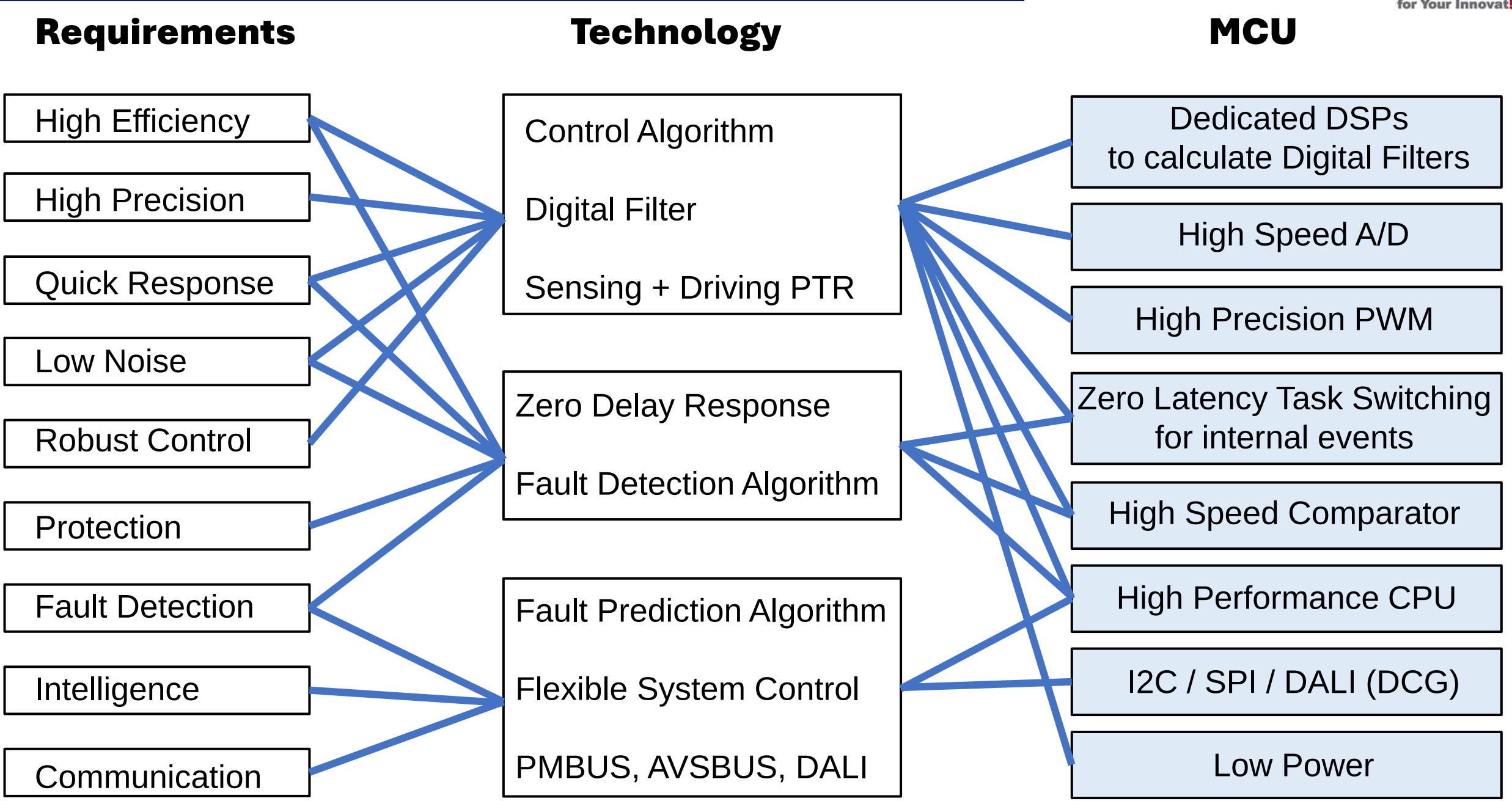
Reduced 20%

Comparison of efficiency between MD6752 and conventional analog power supply in OLED TV specifications

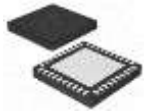
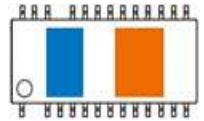




Know-hows in MCU as Power Supply Controller

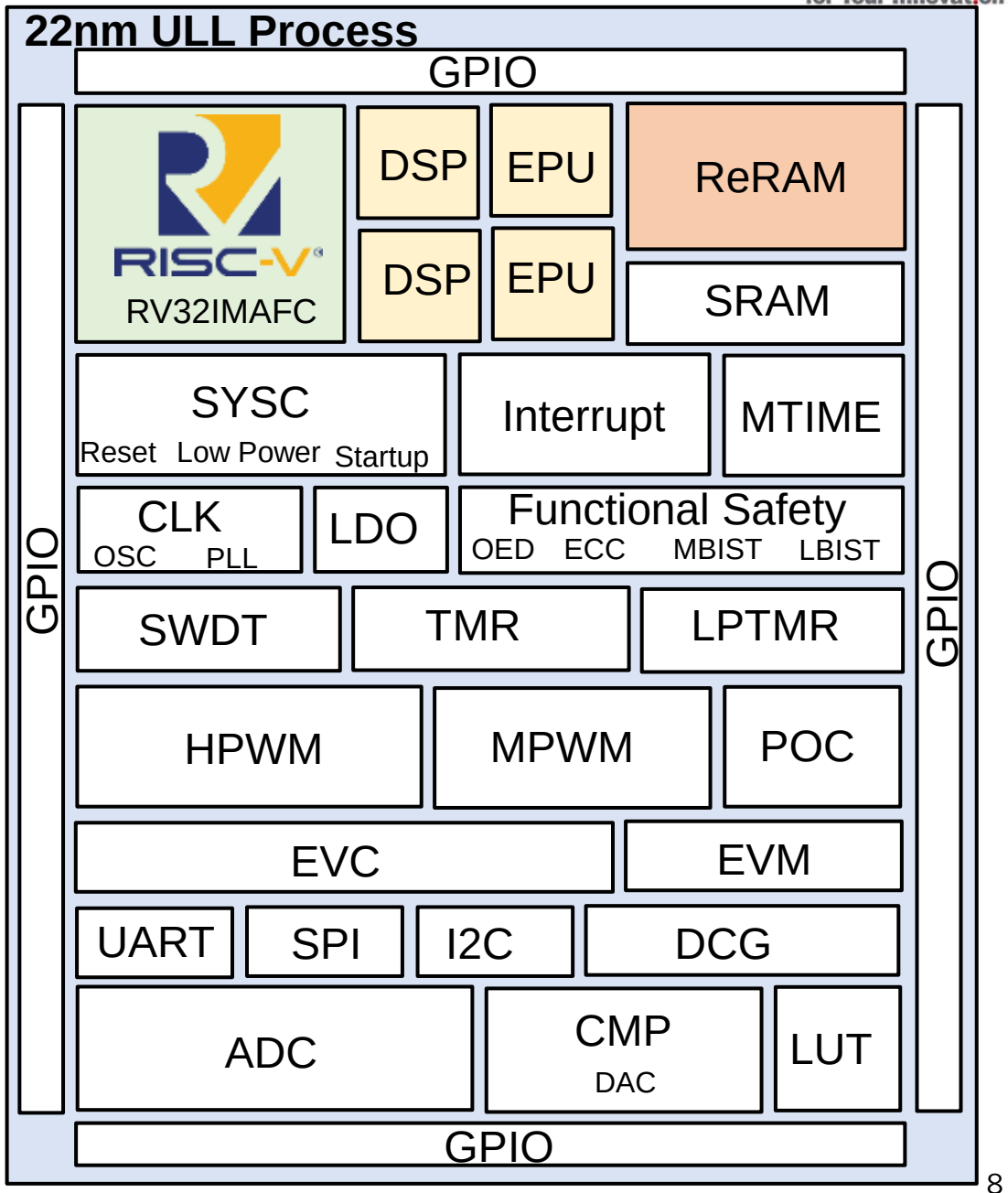


Sanken's MCU for Digital Power Controls

MCU Chip	Die	Process	NVM	CPU	DSP	EPU	Peripherals	Products	Application
MD6601 **MP**		180nm	FLASH 16KB	8051	fixed point 16bit x 2	N/A	HPWM/TMR UART/SPI/I2C 10bit ADC x2 12bit ADC x1 CMP/OPAMP	 QFN40	・DC-DC for POL module (FPGA/SoC)
MD6602 **MP**		180nm	FLASH 32KB	8051	fixed point 16bit x 2	N/A			
MD6603 **MP**		180nm	FLASH 32KB	8051	fixed point 16bit x 2	6-threads 16bit x 1	HPWM/TMR UART/SPI/I2C 12bit ADC x2 CMP	 SOP28/SSOP-32  HV-chip MCU chip	・AC-DC for OLED TV, LED Lighting and HPC Server
MD6603A **MP**		180nm	FLASH 32KB	8051	fixed point 16bit x 2	6-threads 16bit x 1			
MD6604 **DEV**		55nm	FLASH 256KB	Cortex-M4(FP)	floating point 32bit x 4	2-threads 32bit x 4	HPWM/TMR UART/SPI/I2C 12bit ADC x19 CMP, ASIL	 LFBGA225	・Multi-channel DC-DC for Large scale SoC
MD6605 **DEV**		22nm	ReRAM 128KB	**RISC-V** (FP)	floating point 32bit x 2	2-threas 32bit x 2	HPWM/TMR MPWM/DALI UART/SPI/I2C 12bit ADC x3 CMP	 QFN40  SSOP42  Module (SIM)	・DC-DC for SoC ・AC-DC for HPC, OLED TV, and LED Lighting ・Motor Control

MD6605 MCU Overview

Item	Specification
RISC-V CPU	RV32IMAFC + cJTAG On-Chip Debugger
DSP	x2 Floating Point DSPs
EPU	x2 Zero Latency Tack Switching Event Processing Units
ReRAM	128KB + ECC
SRAM	8KB + ECC
Interrupt	x64, 16-priorities, each
MTIME	RISC-V MTIME as Peripheral
System Control	Reset, Low Power, Startup
Clock	Internal Oscillator, PLL
Functional Safety	OED (Oscillation Error Detection), ECC, MBIST, LBIST
SWDT	Clock Separated Watch Dog Timer
TMR	x8 General Purpose Timers
LPTMR	x1 Low Power Timer to detect External Signal Duty
HPWM	x8ch High Resolution PWMs for Power Supply Control
MPWM	x6ch Dedicated PWMs for Motor Control
POC	Port Output Controller for Hardware Protection
EVC	Event Cross-Bar Switch
EVM	Event Signal Modulator
UART	x1 UART with Baud Rate Generator
SPI	x1 Master/Slave SPI
I2C	x1 Master¥Slave I2C
DCG	x1 DALI Control Gear for Lighting Applications
ADC	x3 12bit A/D Converters (3MSPS, 8inputs/unit)
CMP	x6 Fast Analog Comparators with 10bit DAC as Vref
LUT	Look-up-Table for logical operation of CMP outputs
GPIO	General Purpose Inputs / Outputs
Freq & VDD	66.6MHz, VDD=3.3V (Vcore=0.9V by internal LDO)
Process	TSMC 22nm ULL process and RRAM technology



Why RISC-V ?

Power Electronics for Your Innovation

■ RISC-V = Open Standard ISA

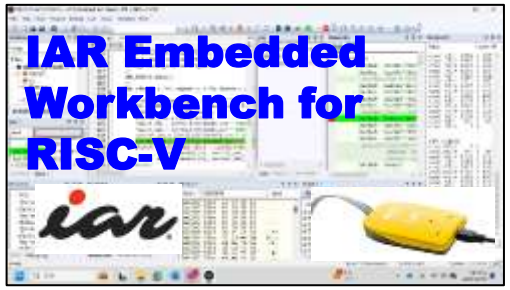
	Commercial IP	Open-Source IP	Self-made IP	
CPU Architecture	ARM, RISC-V, etc.	RISC-V	My original	RISC-V
Performance	☑ good	☑ good	☑ good	☑ good
Customization	✕ none or ☑ partially OK	✕ none	☑ any	☑ any
Eco System	☑ excellent	☑ excellent	✕ none	☑ excellent
Quality	☑ certificated	✕ not certificated	☑ controllable	☑ controllable
Fee (license / royalty)	✕ high ~ middle	☑ none	☑ none	☑ none
Man-Hour to design	☑ none	☑ none	✕ Good luck !	✕ Good luck !

■ **Self-made RISC-V** is one of the best way for MCU vendor

- **No license-fee, No royalty fee.**
- **Utilization of a fully established RISC-V ecosystem.**
- **Easy to design generic CPU for MCU (single issue, in-order)**
- **Easy to apply special customizations(*) for MCU.**
- **Well-understood Whitebox (easy to analyze return samples)**
- **Acquisition of know-hows in CPU design.**
- **Opportunity of engineer's training.**

(*) Special Customizations for MCU
- Extension of Interrupts (sources, priorities)
- Low-power support (STBY req/ack)
- Treatment of Asynchronous Clocks (JTAG)
- Timing improvements (STA)
- Treatments of DFT (SCAN clock/reset)
- Avoiding issues within EDA tools, etc...

RISC-V CPU Core

Item		Description	Note
ISA		**RV32IMAFC**	A: Shared memory among Multicore F: PMIC Control + Sensor less BLDC Motor FOC
Pipeline		Integer: 3~5 stages Floating : 5 ~ 6 stages	
32bit Multiplication		**1cyc**	
32bit Division		33cyc	
32bit Floating Point (IEEE754)		**ADD / SUB / MUL / MAC : 1cyc**	All rounding modes ae supported.
		DIV：11cyc, SQRT : 19cyc	
On-Chip-Debug		**2-wire cJTAG** or 4-wire JTAG Hardware Break Point x 4	**No limitation on the frequency relationship between JTAG clock and CPU system clock**
Interrupts		Standard x 3 + Extra x 64	Each extra input has configurable 16-level priorities
Dhrystone 2.1		1.6 DMIPS/MHz	GCC 10.20.0 –O3
Coremark 1.0		3.30 Coremark/MHz	IAR 3.30.1 High Speed, no size constraints
Eco System	IDE	MD Studio (Eclipse embedded CDT) +Compiler：GCC +Debugger：GDB+OpenOCD+cJTAG I/F	 
		IAR Embedded Workbench for RISC-V + I-jet Probe (cJTAG) **(In planning)**	
	RTOS	FreeRTOS	

Heterogeneous Multi Core

■ Requirements for Control Rate

(1) Motor control = Mechanical → **Control Rate 50us (20kHz)**

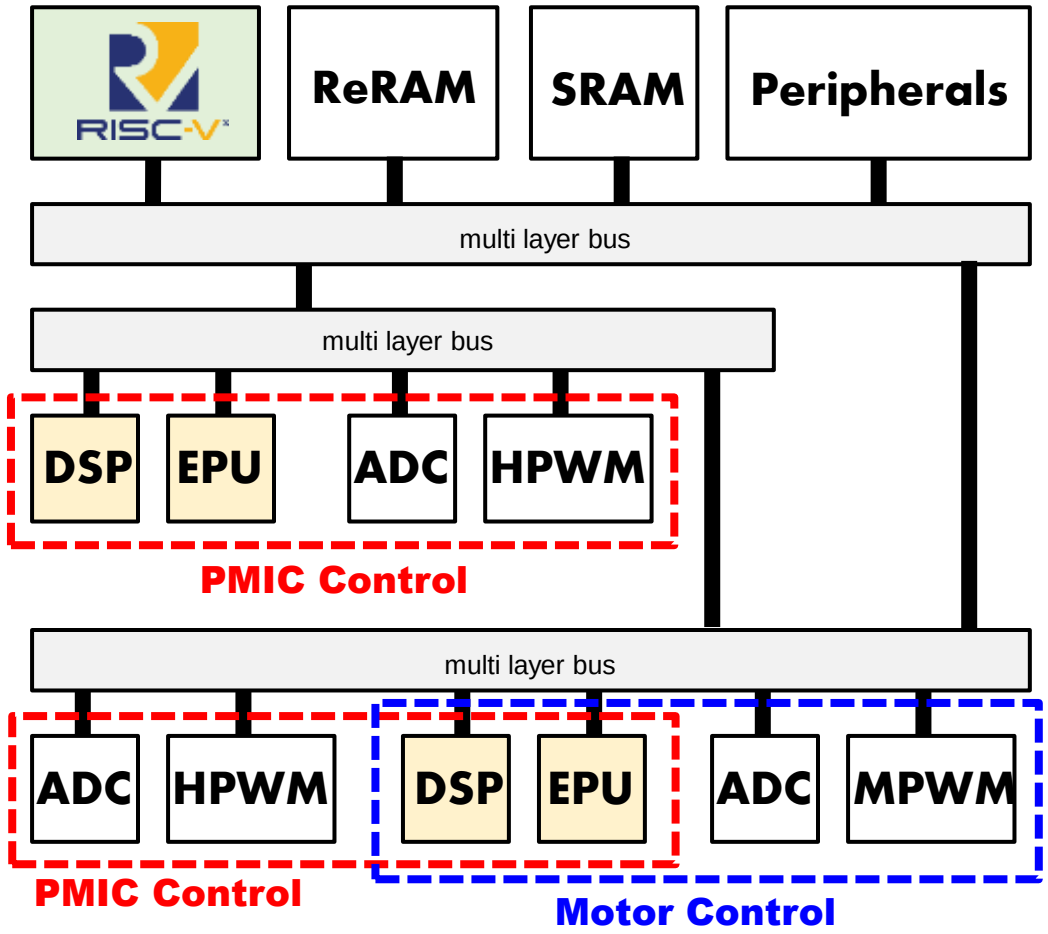
A single CPU with interrupt-based task switching can control motors.

(2) PMIC control = Electrical → **Control Rate 0.5us ~ 2us (2MHz ~ 500kHz)**

A single CPU can **NOT** control power supplies. → **Parallel Processing**

■ Heterogeneous Multi Core

Core	Role	Specification
CPU	System Control Communication Fault Prediction (Edge AI)	32bit Int 32bit Float
DSP x2	Main Feedback Control Digital Filter, Matrix operation	32bit Int 32bit Float
EPU x2	Zero Latency Task Switching Protection, Low-noise Switching	32bit Int 2 threads



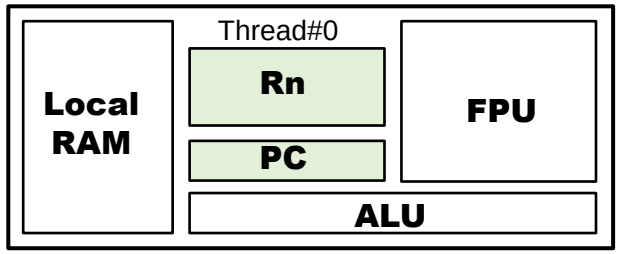
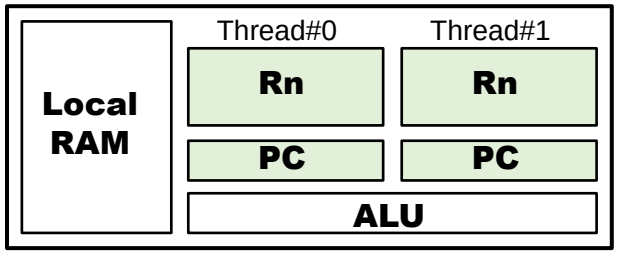
■ Total Performance @66.6MHz

32bit Floating Point
400MFLOPS (max)
x1 MAC → x1 MUL + x1 ADD

32bit Fixed Point (integer)
600MOPS (max)

■ Low Power → High Efficiency Power System

DSP and EPU

Item	**DSP** (Digital Signal Processor)	**EPU** (Event Processing Unit)
Architecture		
Purpose	Digital Filter, Matrix operation	Zero latency Task Switching in response to events
Number of Cores in MD6605	2 cores	2 cores
Number of Threads	1 Thread	2 Threads
Instruction Set	16bit Fixed Length	
Pipeline	3 ~ 5 stages	
General Purpose Registers	32bits x 16 (R0 ~ R15)	
Response to Events	Waiting for Events, Waiting for Timer, Generating Events	
Thread Control	n/a	Zero latency Thread Switching by Events
32bit Fixed Point	ADD/SUB/MUL/MAC: 1cyc DIV: 8cyc (Newton-Raphson)	
32bit Floating Point	FADD/FSUB/FMUL/FMAC: 1cyc FDIV: 8cyc (Newton-Raphson)	n/a
Debug Support	Step execution, PC-Break, Data-Break, Software-Break	

TSMC 22nm & RRAM (ReRAM)

■ Press Release on Feb.20, 2025

Sanken Electric has successfully developed a leading-edge microcontroller unit for power electronic controls, utilizing TSMC's 22ULL RRAM specialty process and featuring a RISC-V CPU core, Set for Volume Production in Q4 CY2025.

"Sanken is a valued, innovative partner to TSMC and a leading customer in adopting our 22RRAM technology in their next-generation MCU," said **Chien-Hsin Lee, Senior Director of Specialty Technology Business Development at TSMC**. "Our RRAM technology not only offers full logic baseline compatibility but also breaks through the scaling limitations of traditional embedded flash memory, empowering customers to innovate their products. As we expand RRAM to all applications, we look forward to continuing our successful partnership with Sanken for many years to come."

■ Why 22nm ?

- Low Cost (Small Chip Size)
- Low Power (ULL, HVT)
- Long-term stable Supply
  (The last generation planar process)

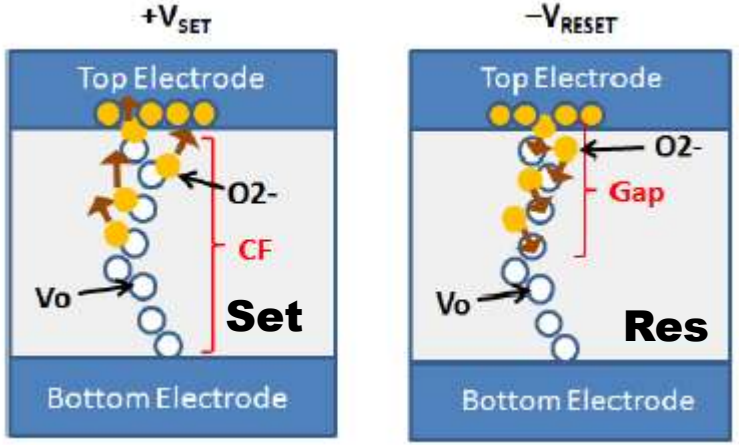
22ULL + RRAM

■ Why RRAM (Resistive RAM : ReRAM) ?

- Simple structure : Optimal for fine processes
- Overwritable : No block erasure required → Enhancing User Experience
- Reliability : Almost same as or better than eFlash memory

ReRAM Set / Reset

This is a generic principle of ReRAM, not specific to TSMC's RRAM.



Shimeng Yu, et al, "Understanding Metal Oxide RRAM Current Overshoot and Reliability Using Kinetic Monte Carlo Simulation", 2012 International Electron Devices Meeting, 2012

Product : AC-DC PMIC for PSU

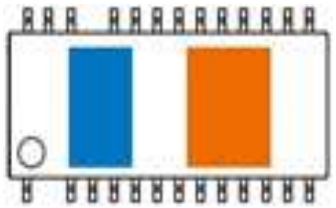
The numerical value is just one example.

Power Supply System for AI Computers and HPCs

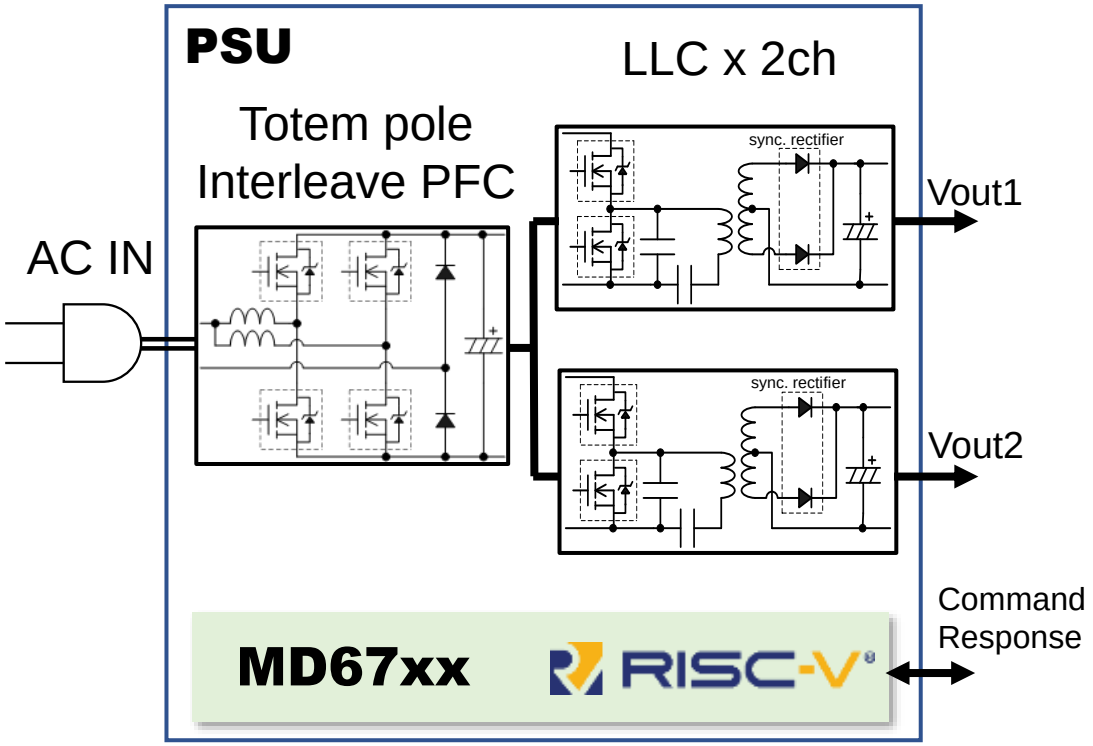
■ AC-DC PMIC for PSU

MD6774 SPL
MD677x (TBD)

SOP28 SSOP-32



HV-chip (650V) MD6605

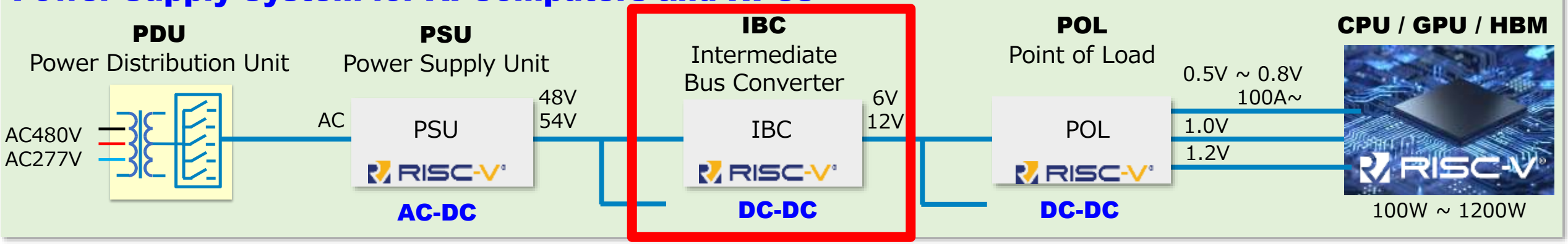


- **High Efficiency > 98%**
  - Totem pole PFC (no bridge diodes)
  - Zero-cross Switching
  - Optimal control according to the load
- **Low THD (Total Harmonic Distortion)**
  - Fast Optimal Algorithm for PFC
- **Quick Response**
  - Advanced Current-mode PFC
- **Small Footprint**
  - High SW-Frequency by GaN/SiC
  - Small heat-sink
- **Intelligence**
  - Communication

Product : DC-DC PMIC for IBC

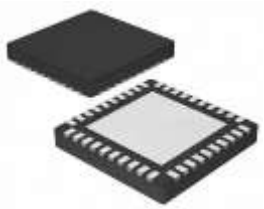
The numerical value is just one example.

Power Supply System for AI Computers and HPCs

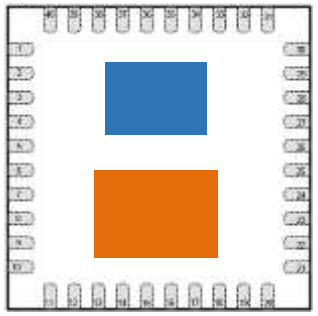


■ DC-DC PMIC for IBC

MD7701 Under Dev

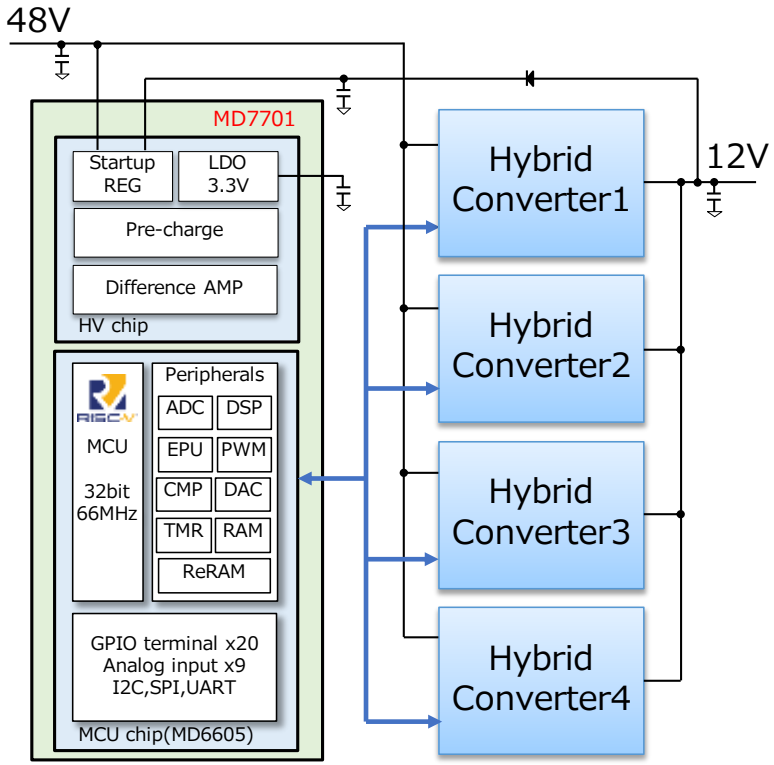


QFN40

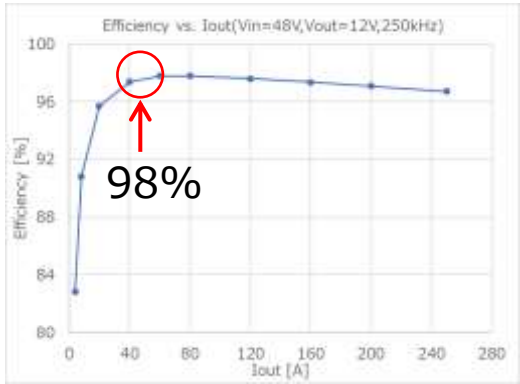


HV-chip (100V)

MD6605



- **High Efficiency > 98%**
  - Advanced Hybrid Converter
  - High Step-down Ratio



- **High Current > 200A**
  - Multi-phase Operation
  - Parallel Operation
  - Current Balance Control
- **Configurable Topology**
  - Dual IBC
  - Single IBC + POL x 6ch, etc...
- **Intelligence**
  - PMBUS / AVSBUS

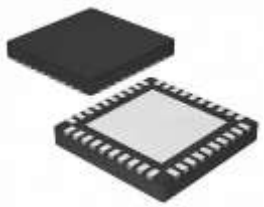
Product : DC-DC PMIC for POL

The numerical value is just one example.

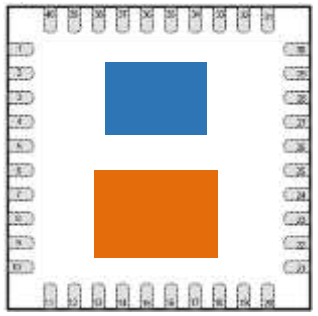
Power Supply System for AI Computers and HPCs

■ DC-DC PMIC for POL

MD7701 Under Dev

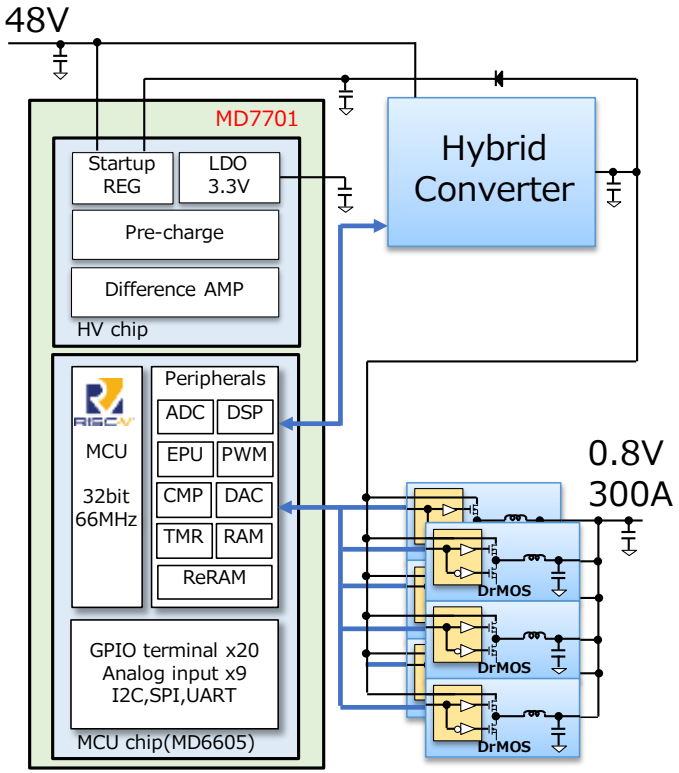


QFN40

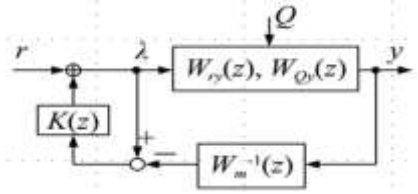


HV-chip (100V)

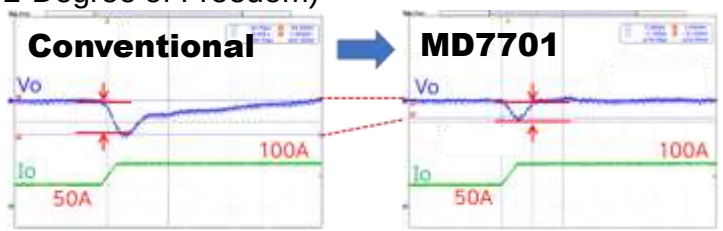
MD6605



- **Low Voltage + High Current**
  0.5V ~ 0.8V / 300A ~
- **High Precision Vdd @ Load Device pin < ±3%**
  in all Temperature Range (-40˚C ~ +125˚C)
  including Load fluctuation and IR-drop on PCB
- **Robust + Quick Response + Stable**
  Control : A2DoF (Approx. 2-Degree of Freedom)



r: Setpoint, Q: Disturbance, y: Output



Small Drop / Fast Settling

- **Intelligence**
  Any ON/OFF sequence among multiple outputs
  Fault Prediction by Edge AI, PMBUS / AVSBUS

Product : IPM for Motor Control

■ Applications

BLDC Motor Control for Industrial and Home appliances





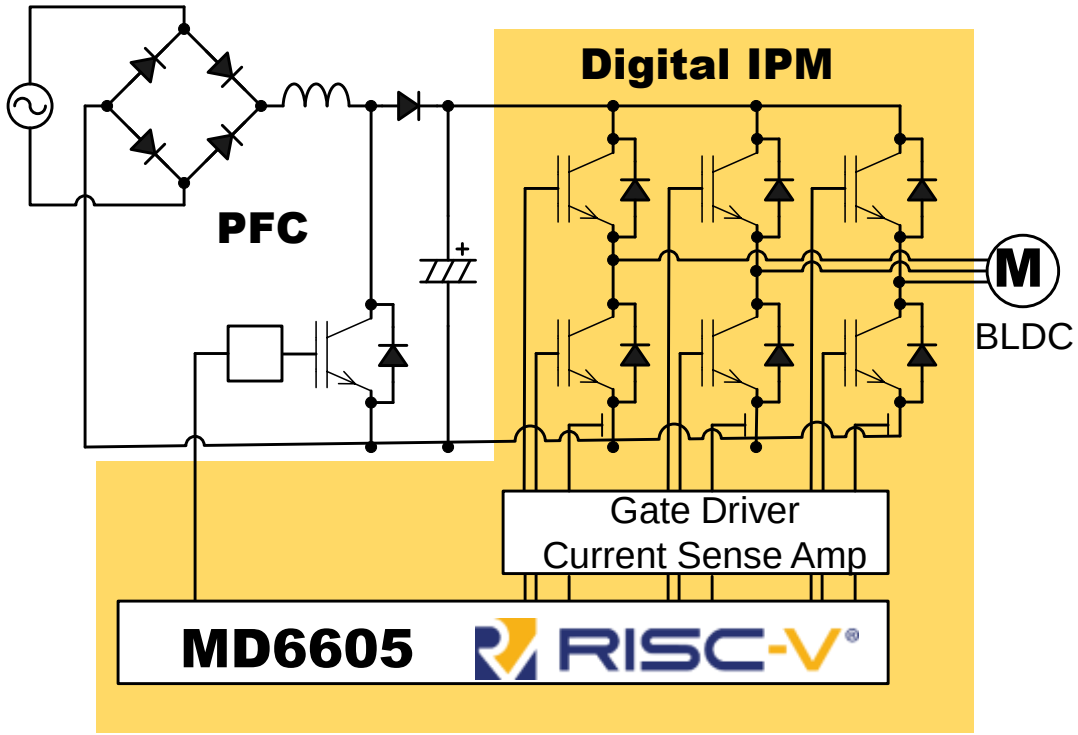
■ Digital IPM (Intelligent Power Module)

SIM1D05A1M SPL
SIM1D10F1M Under Dev

600V 5A~10A

SIM2D15F2M Under Dev

600V 15A



- **High Efficiency**
  BLDC Sensor-less FOC
  Optimal Control by Auto Self Alignment
- **Low Noise**
  Adjustable dv/dt
- **Reduce System Cost**
  Simultaneous PFC control
  All in one module
  IGBT + Driver + MCU + OPAMP + LDO
  Small PCB Size, Reduce BOM
- **Easy to develop**
  GUI application for tuning parameters
- **Intelligence**
  Communication
  Fault Detection and Prediction

Thank you !

Power Electronics for Your Innovation

powering RISC-V through RISC-V

SANKEN ELECTRIC CO., LTD.

YouTube
https://www.youtube.com/@sankenelectric

LinkedIn
https://www.linkedin.com/company/sanken-electric-co-ltd

facebook
https://www.facebook.com/SankenElectric/

X (Formerly Twitter)
https://twitter.com/SankenElectric

WeChat
https://www.semicon.sankenele.co.jp/common/images/wechat_qr.png