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Integrated Solution of Motor Driver

PAC Integrated Motor Controller and Driver

active-semi®
Solutions for Sustainability
Is Now
qorvo®

May 2022

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We Are Qorvo®

Innovative RF solutions for everything that connects our world

- We provide innovative RF solutions at the center of connectivity
- 8,000+ global employees
- FY2022 revenue: $4.6 billion
- An S&P 500 company – Nasdaq: QRVO

- Active-Semi is now “Programmable Power Management” and Intelligent Motor Control at Qorvo

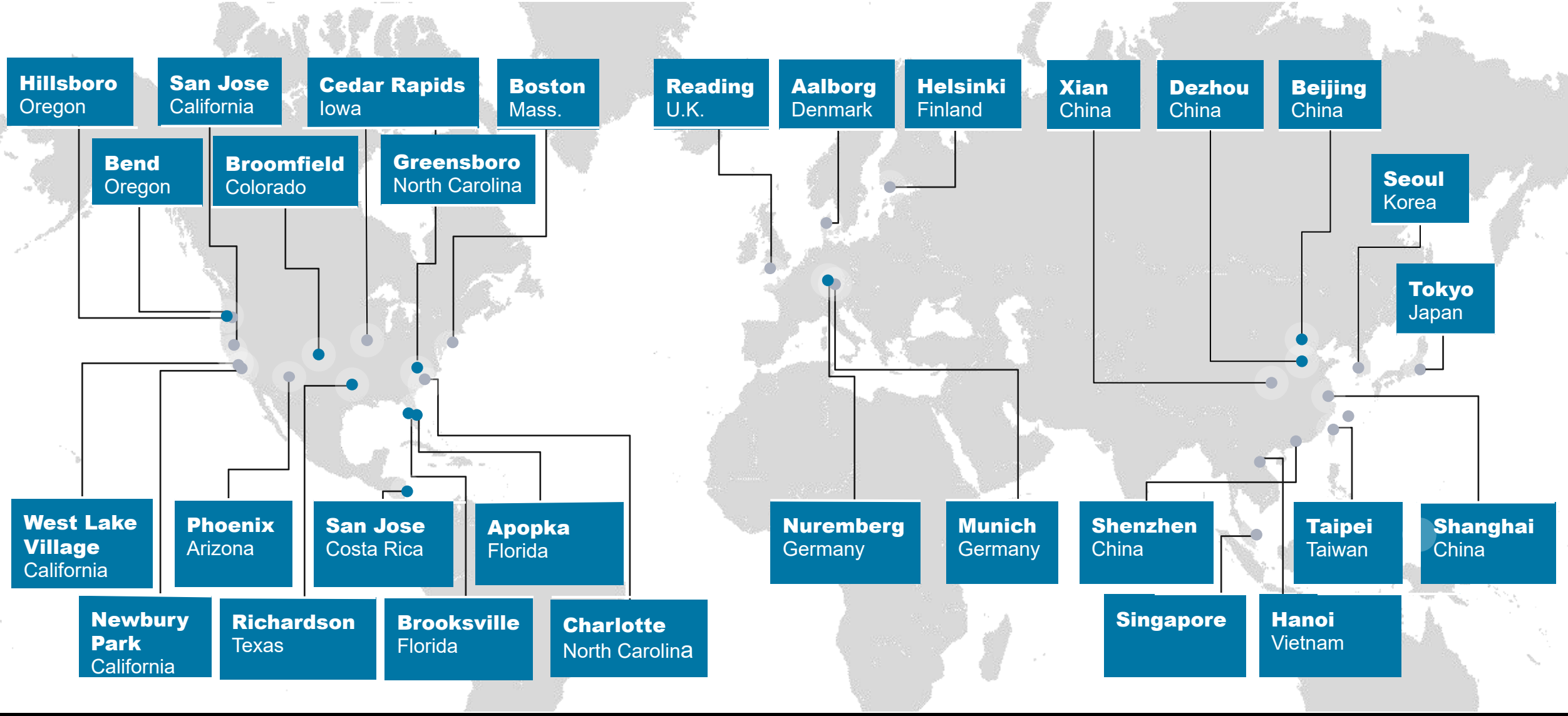


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Our Global Footprint

Blue dots indicate Manufacturing/ Test Operations

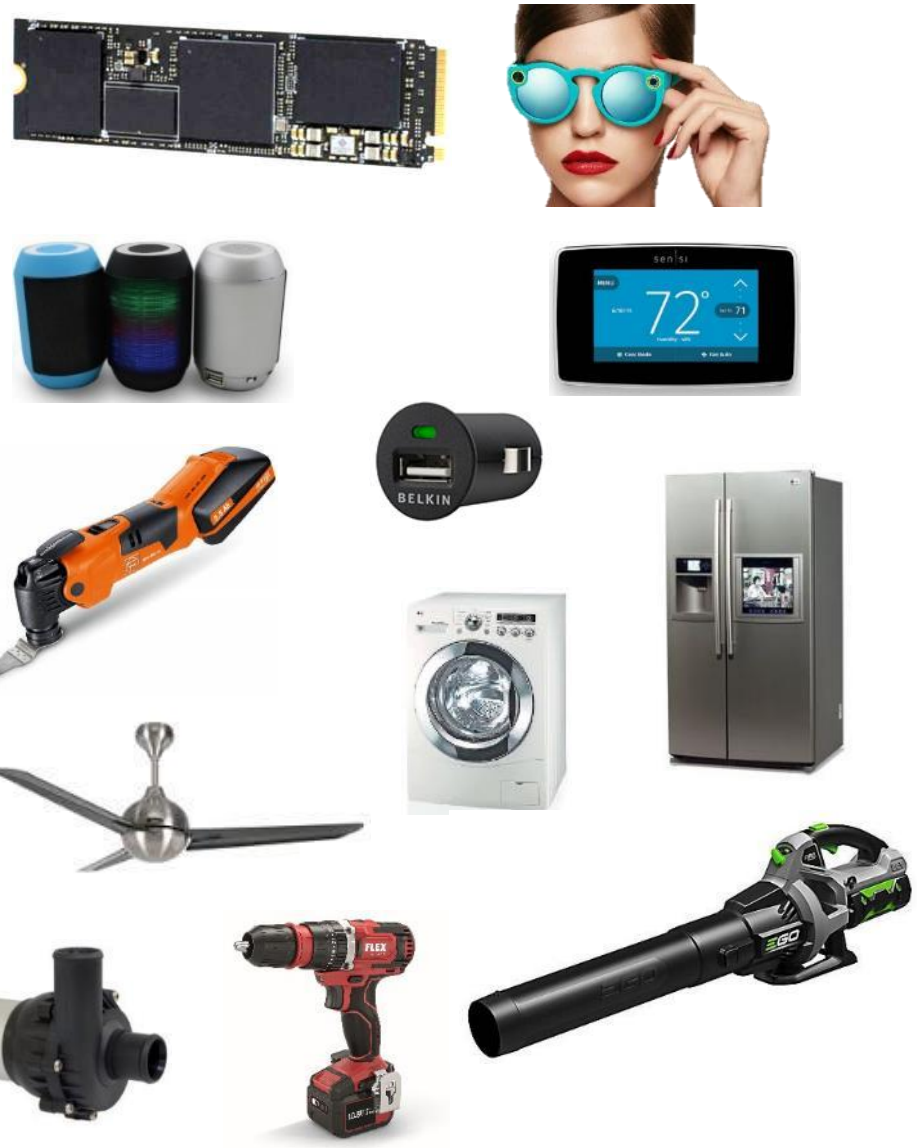
Gray dots indicate R&D and Sales Centers



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PPM Overview

- Active-Semi is now “Programmable Power Management” Group
- Mixed signal semiconductor provider focusing on Power Management and Intelligent Motor Control
- 175 Worldwide patents & pending in analog power & motor drive
- Multi-foundry strategy: SMIC, TowerJazz, Dongbu…
- Multiple Assembly/Test: Unisem & JCET…



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PPM Customers

PAC®





















PMIC























Battery Mgt.















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PPM Product lines



Intelligent Motor control



Power Management



Power Loss Protection



Battery Management



DC-DC Converter



DC-DC For RF

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Structures of Motor Control

Discrete

Advantage:
- Versatile
- Flexible

Weakness:
- Bag of chips
- Big board size





ASIC



Advantage:
- Single chip
- Simple circuit

Weakness:
- Fixed function
- Limited voltage/Speed range

Integration

Advantage:
- Less components
- Optimized circuit
- Relative flexible
- Creative systematic features

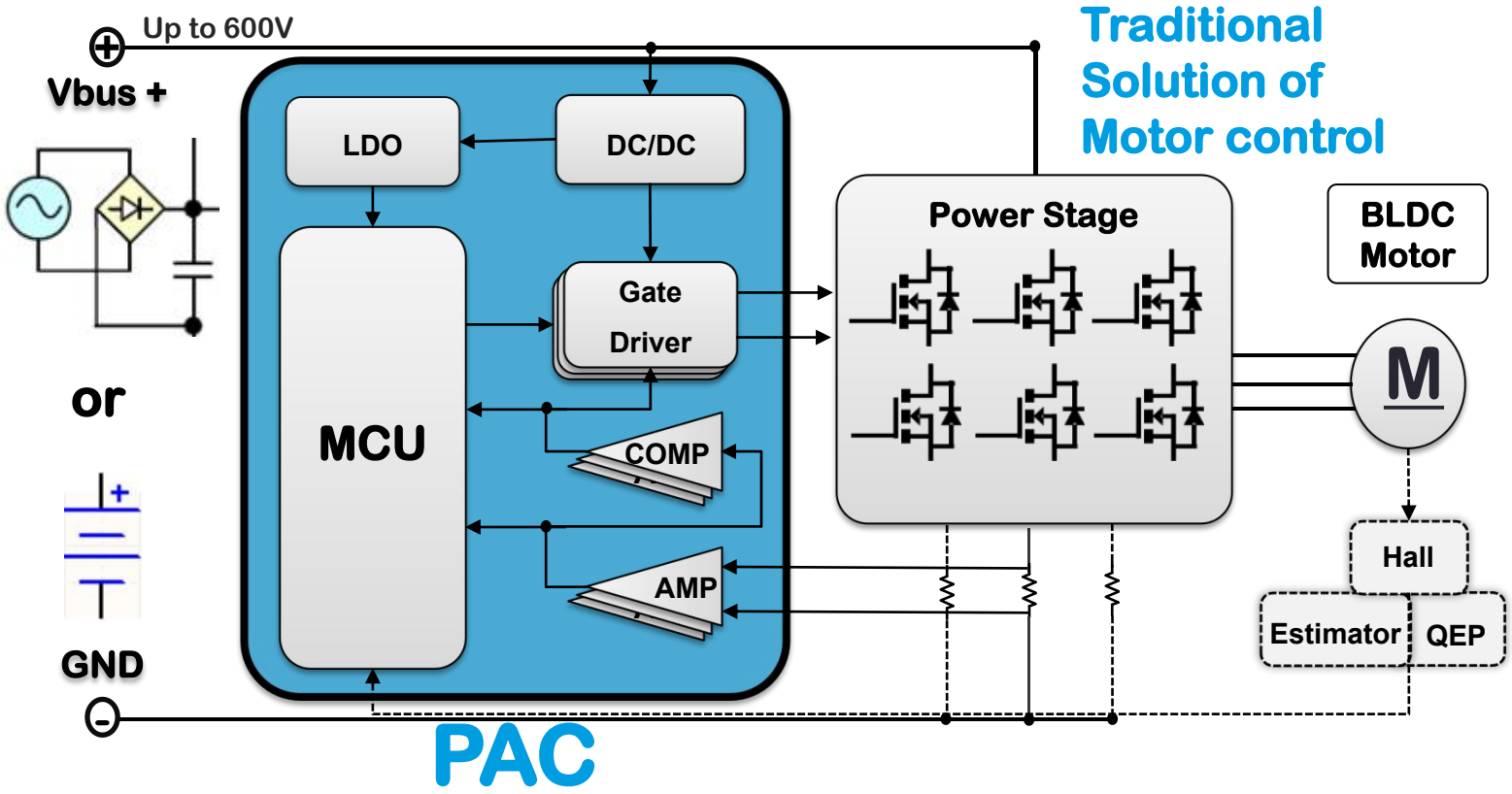


Weakness:
- Difficult to replace
- High cost to repair
- Fixed voltage range

PAC

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Power Application Controller

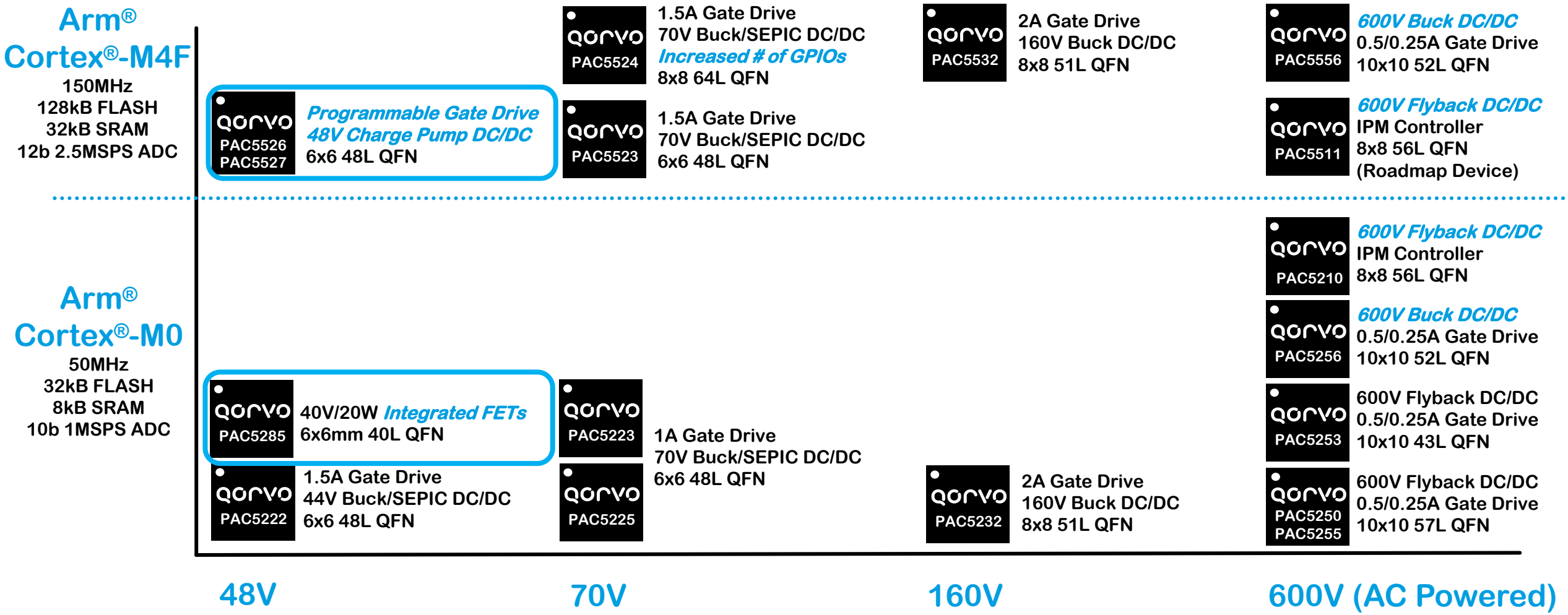


Solution	Description	IC number	Cost
Discrete	Extra DC/DC, LDO, MCU, Gate Driver x3, OpAmp	7	Medium
Integrated Power Module	Extra DC/DC, LDO, MCU, IPM, OpAmp	5	High
PAC enabled solution	One PAC device	1	Low

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PAC™ Family

Provides scalability across voltage and processing power



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PAC™ System Block Diagrams

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PAC™ 40V/20W BLDC Solutions

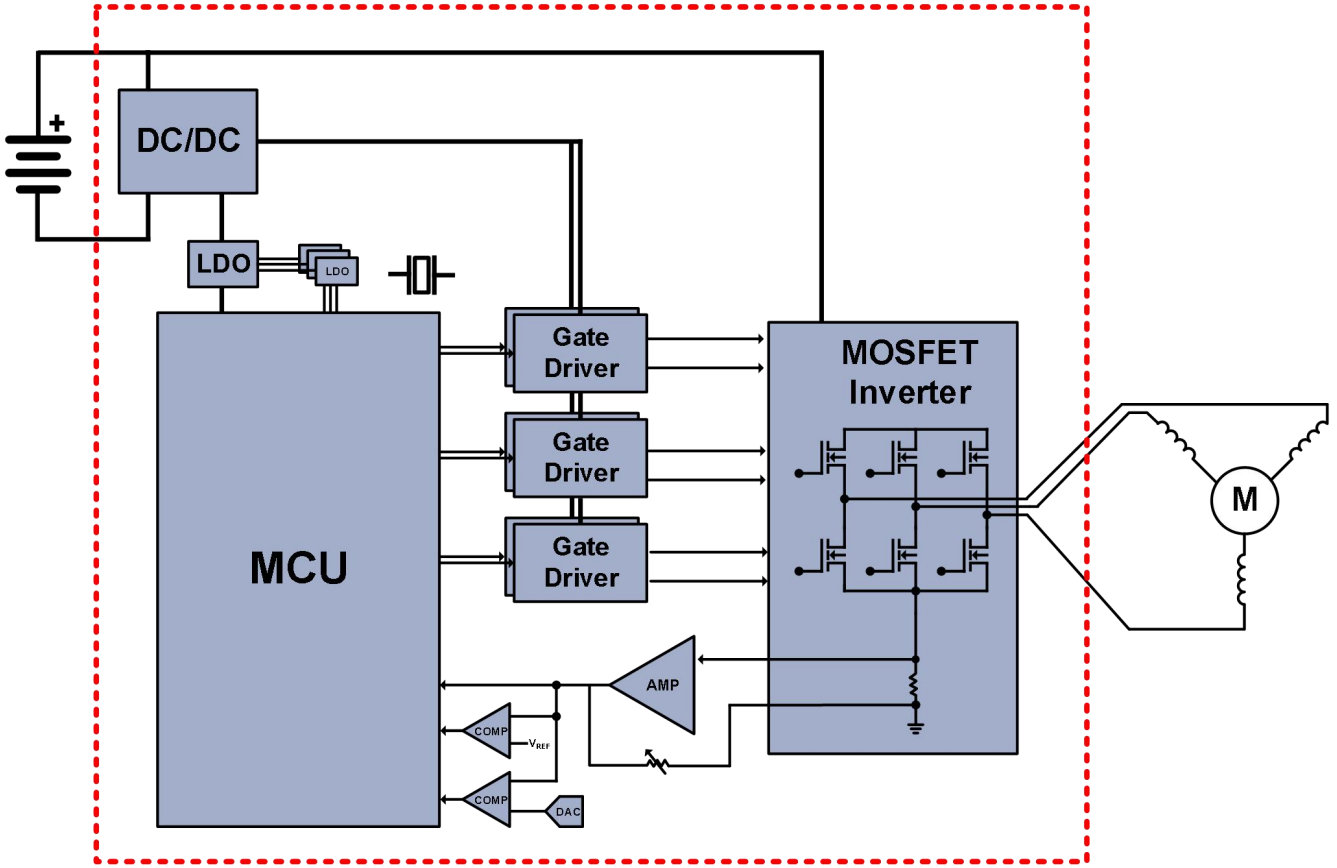
PAC5285 - World's Smaller High Voltage, 20W Motor Solution

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PAC5285 Integration for Motor Control Systems

Control, Power Management, Signal Chain, Gate Drive and MOSFET Inverter

- PAC5285 Integration:
  - FLASH-programmable MCU
  - Power Management:
    - Charge Pump DC/DC, LDOs
  - Signal Conditioning:
    - Differential PGA, DACs, Comparators
  - Gate Drivers/MOSFET Inverter
  - Voltage and Clock References
  - Small QFN Package (6x6mm, 40L)

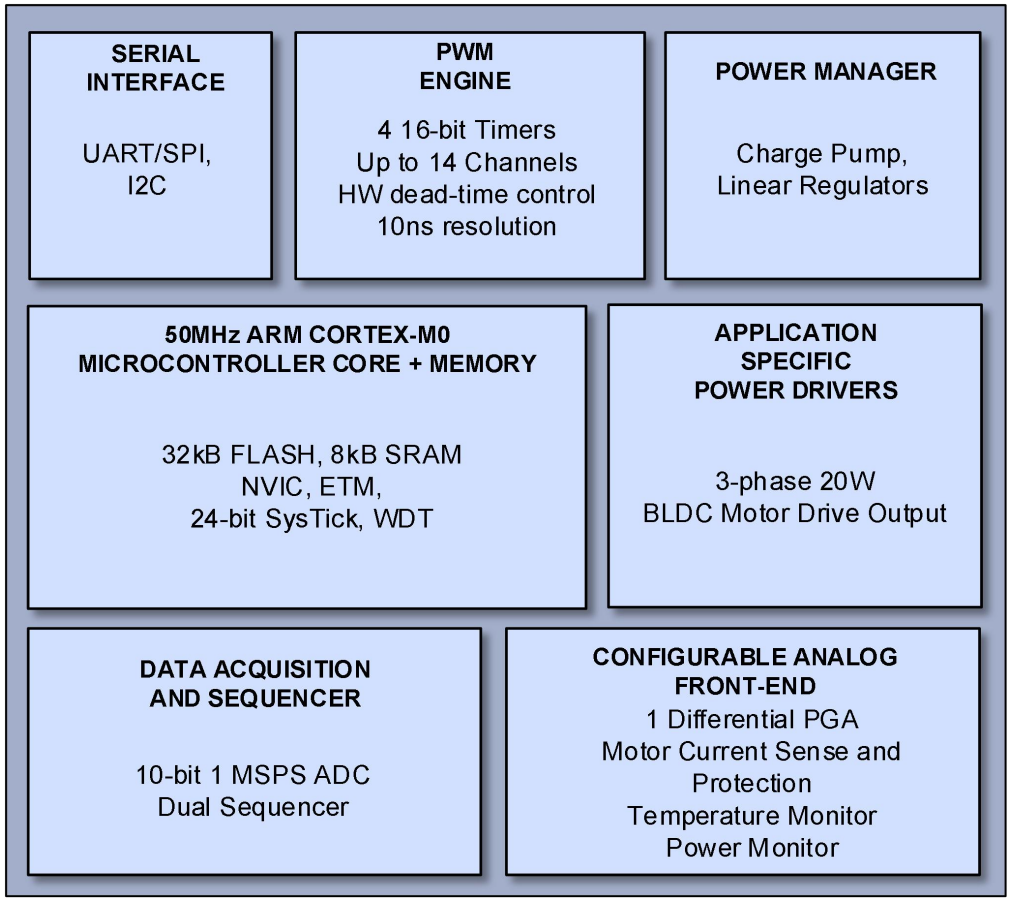


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PAC5285 Architecture

FLASH-based MCU with 40V Power Supply Input, Power MOSFETs

- **MCU:**
  - 50MHz Arm® Cortex®-M0 MCU
  - 32kB FLASH, 8kB SRAM
  - 10-bit 1MSPS SAR ADC
- **Integrated Power Management**
  - 40V Input Charge Pump DC/DC
  - LDOs for MCU core, IO and analog
- **Integrated 40V/300mΩ Power MOSFETs**
- **Integrated Differential PGA**

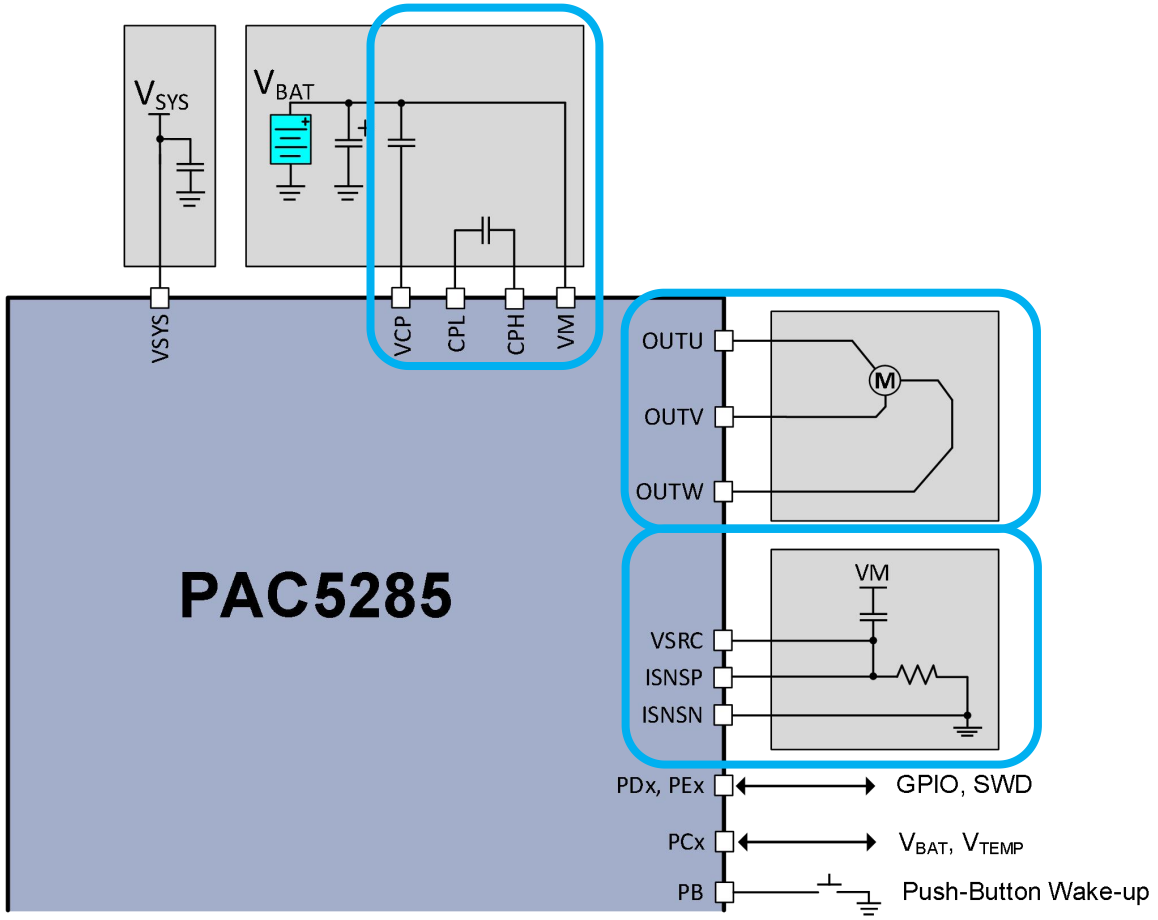


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PAC5285 System Block Diagram

40V BLDC Motor Controller/Driver with Power MOSFETs for Low-Power Applications

Sub-system	Details
• MCU	• 50MHz Arm® Cortex®-M0 • 32kB FLASH, 8kB SRAM • 10b 1MSPS SAR ADC with Trigger and Sequence engine
• IO	• 8 x 3.3V/5V IO • 4 x 3.3V IO
• Serial Communications	• UART/SPI, I2C • SWD FLASH programming
• Power Management	• 40V Input Supply Charge Pump DC/DC • 5V System Supply Regulator • Integrated LDOs for MCU Core and IO, Analog • Integrated high-accuracy ADC VREF
• Gate Drivers	• 3 high-side gate drivers with level-shifters • 3 low-side gate drivers • 3 phase BLDC Inverter with Power MOSFETs (300mΩ)
• Signal Conditioning	• Differential PGA (x1 to x8) for current sense • Integrated power supply monitoring using ADC • Over-current protection for inverter
• Physical	• T_A = -40°C to 105°C • 6x6mm, 40-pin QFN with wettable flank and power pad



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PAC5285

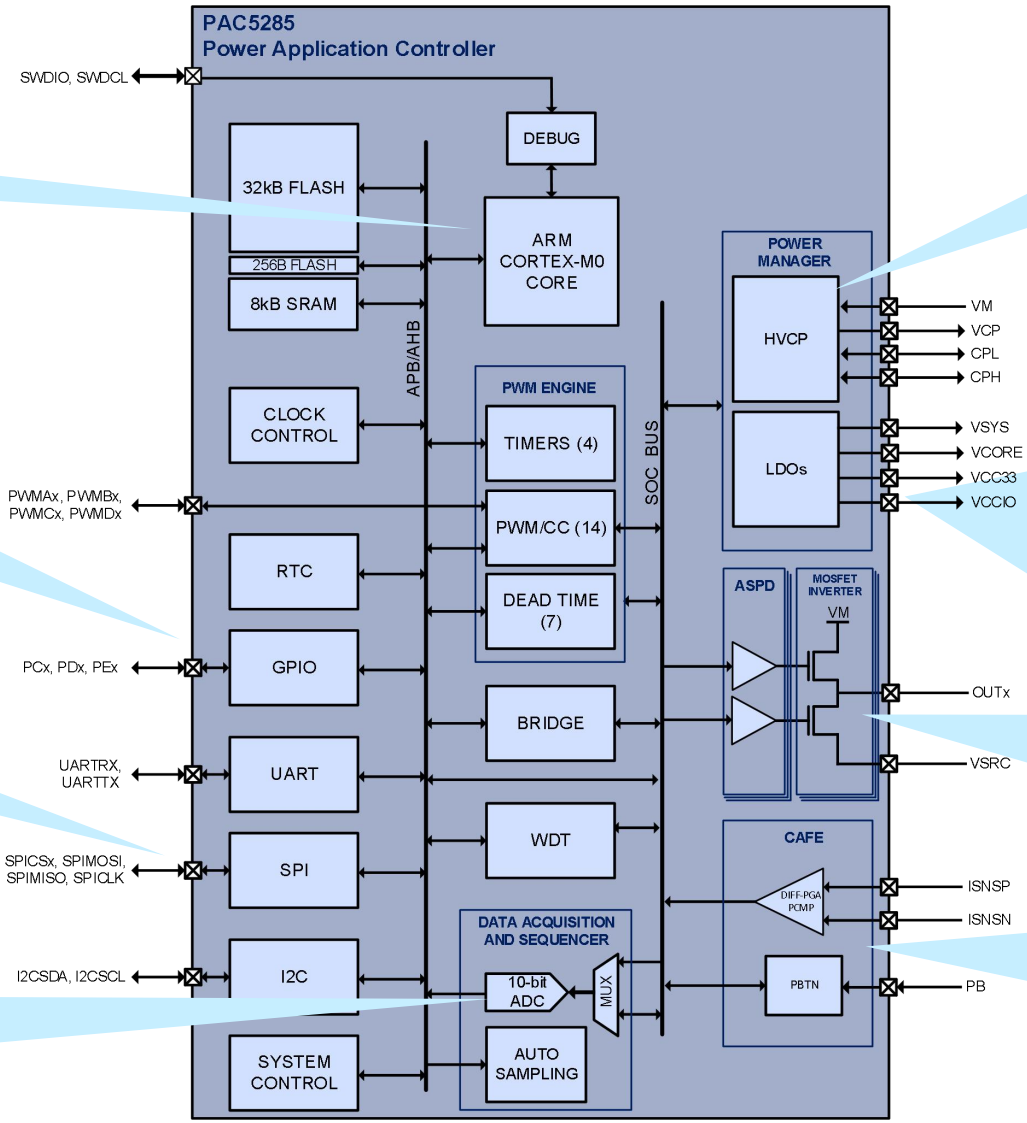
FLASH-based MCU with 40V Power Supply Input, integrated power MOSFETs

- 50MHz Arm® Cortex®-M0
- 32kB FLASH, 8kB SRAM

- 8 x 3.3V/5V IO
- 4 x 3.3V/IO or ADC input

- UART/SPIO, I2C
- SWD for debugging
- Field FLASH update using UART

- 10-bit 1MSPS SAR ADC with Dual sequencer engine
- Configurable Sequencer
- ADC Pre-MUX used with front-end for switching between ADC channels:



- 40V Charge Pump DC/DC for HS Gate Drive

- Integrated 3 LDOs for IC supplies
  - VSYS for 5V(100mA) system supply
  - VCC33 for 3.3V Analog Logic and IO
  - VCORE for digital logic
- Integrated High-accuracy VREF
  - 2.5V ADC reference
  - Comparator reference
- Integrated power supply sensing without external components
- Very low hibernate current: 8µA @ 12VDC

- 3 high-side gate drivers
- 3 low-side gate drivers
- Programmable HS and LS sink/source current
- Integrated 6 x 40V/300mΩ MOSFETs

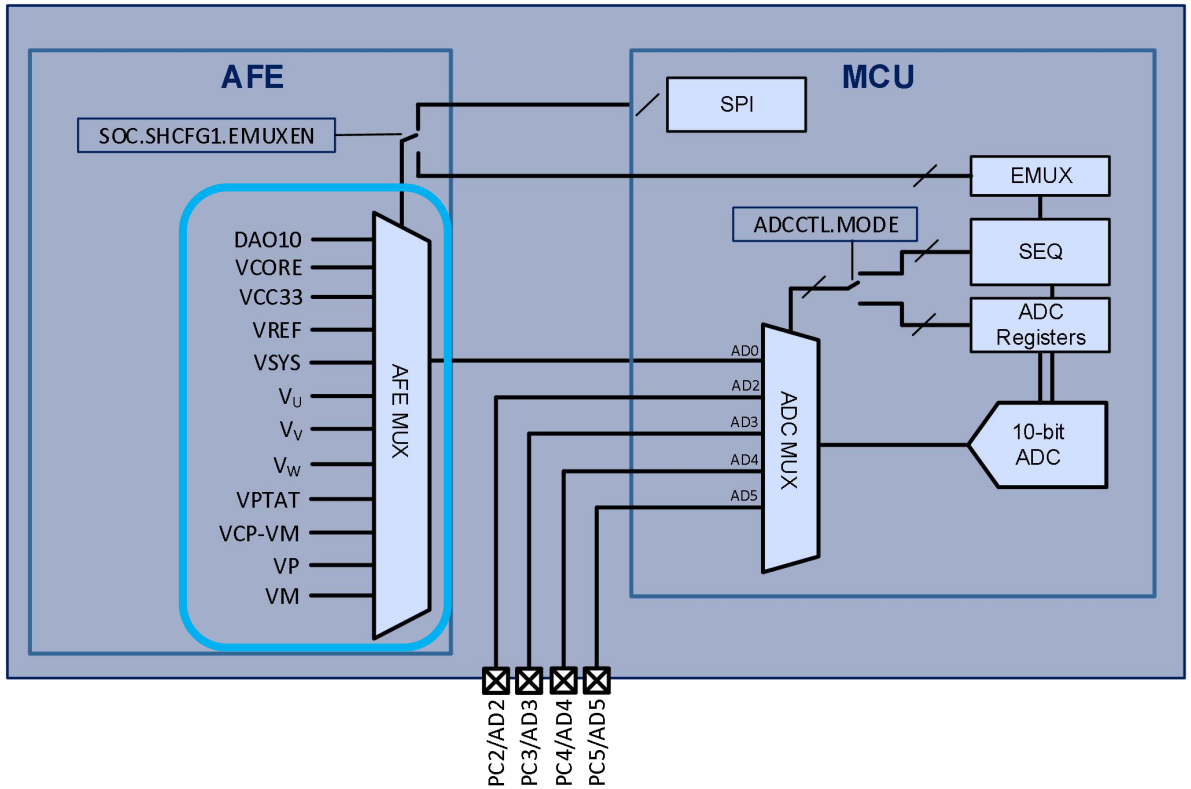
Configurable Analog Front End
- 1 x Differential Amplifier
- Integrated power supply monitoring using ADC
- Push Button for Hibernate mode wake-up

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PAC5285 ADC with Sequencer

Current, Voltage and Temperature Sampling

- 10-bit 1MSPS SAR ADC
- Configurable Dual Sequencer
- ADC Pre-MUX used with front-end for switching between ADC channels:
  - S&H configured by firmware and through sequencer
  - Dedicated serial channel (EMUX) for fast MUX switching and S&H enable/disable

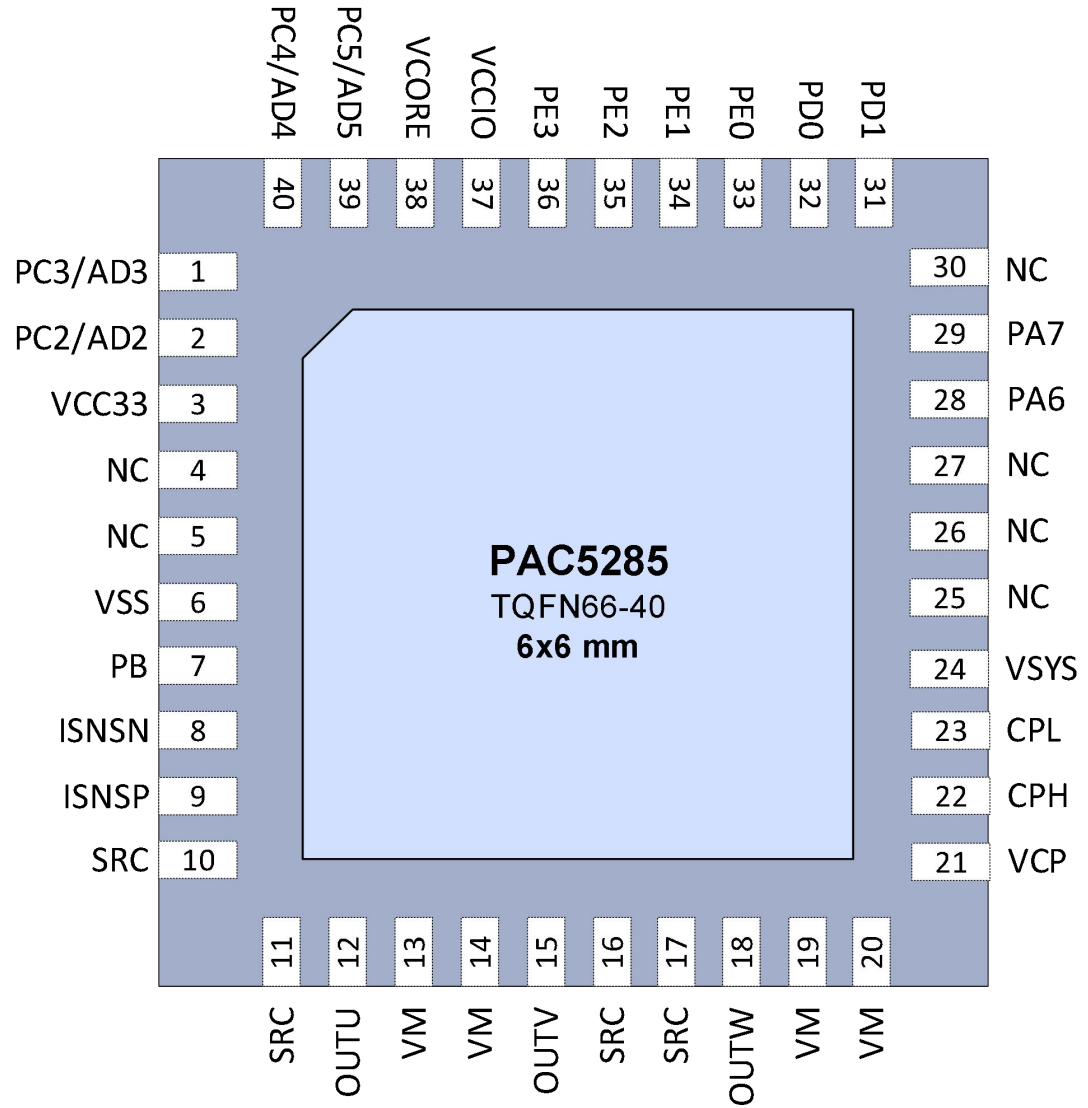


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PAC5285 Pin Configuration

6x6mm QFN with Thermal Pad

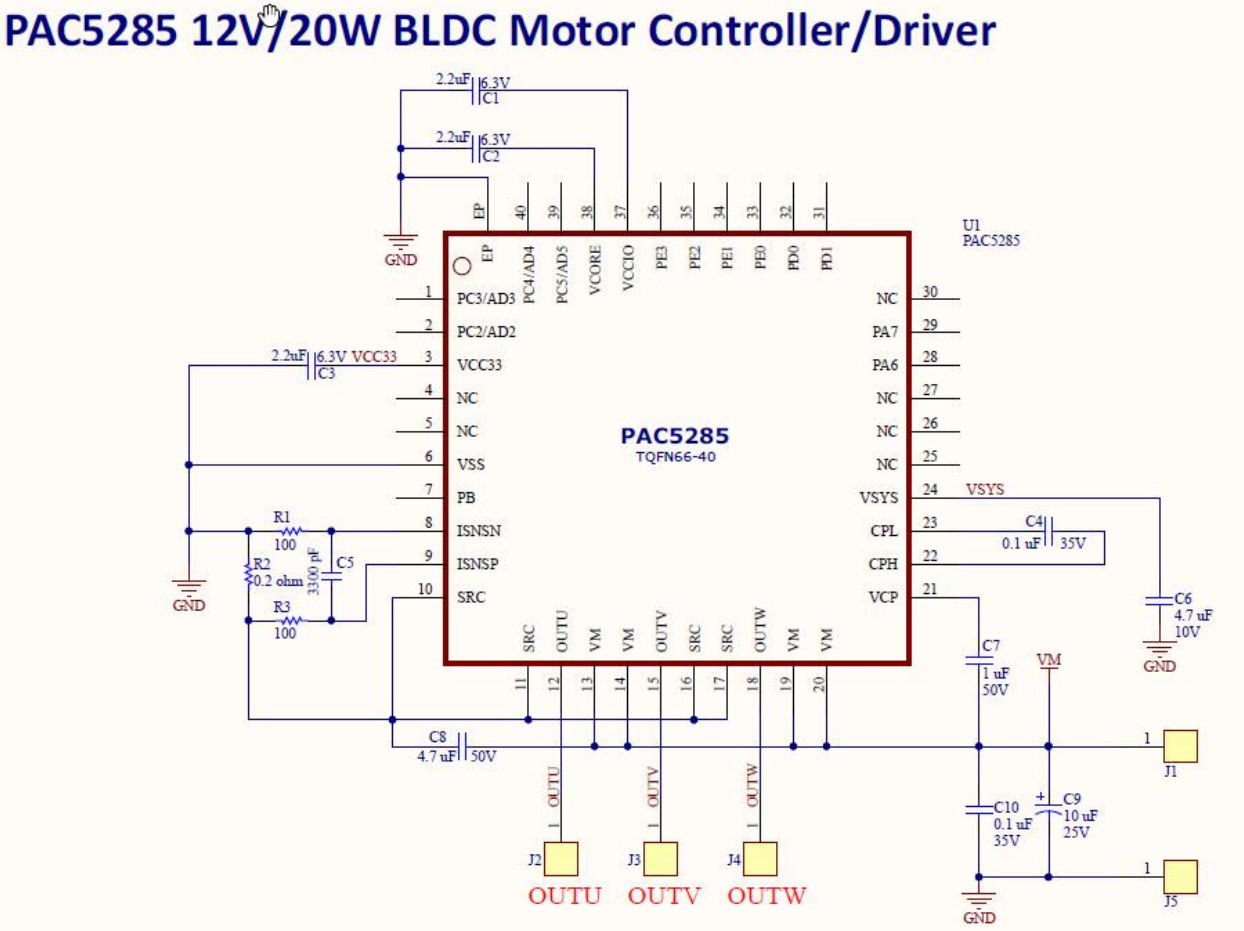
- 6x6mm QFN
- 40-lead
- 0.5mm pin pitch
- Power Pad for thermal management



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Reference Schematic

Very small BOM and footprint



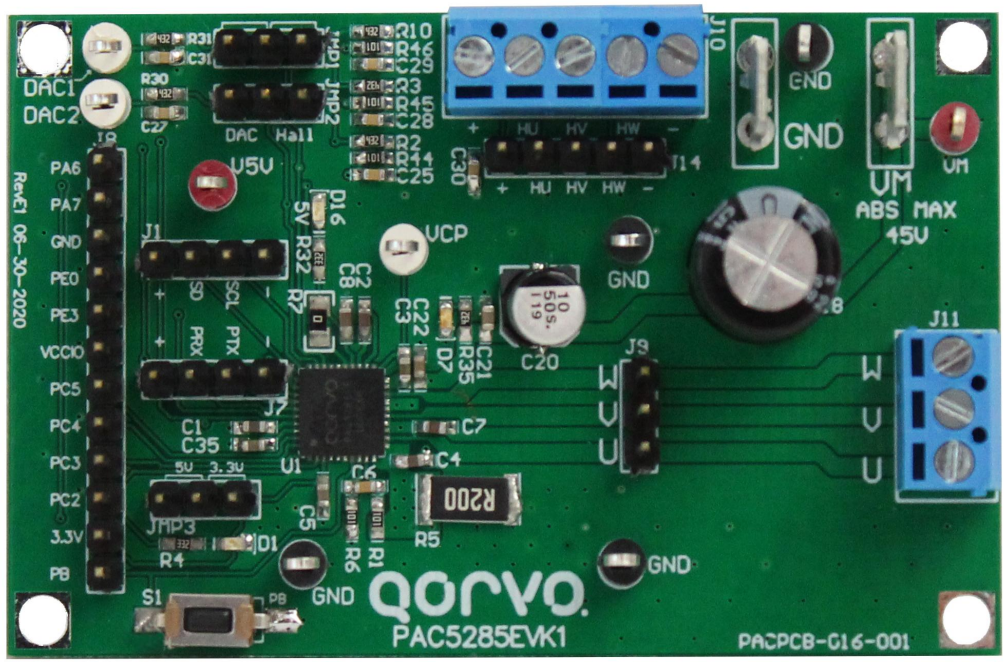
Quantity	Designator	Value	Description
2	C4, C10	0.1 uF	Capacitor
1	R2	0.2 ohm	Sense Resistor
1	C7	1 uF	Capacitor
3	C1, C2, C3	2.2uF	Capacitor
2	C6, C8	4.7 uF	Capacitor
1	C9	10 uF	Polarized Capacitor (Radial)
2	R1, R3	100 ohm	Resistor
1	C5	3300 pF	Capacitor
1	U1	PAC5285	TQFN66-28

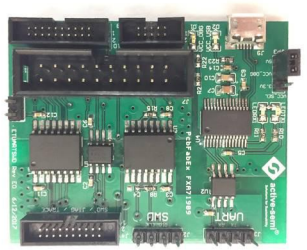
- 40V Supply Input
- 5V System Regulator
- Integrated LDO for Analog, MCU Digital and IO
- Integrated High-Speed Differential Amplifier for Current Sense
- 40V/300mΩ Motor Output
- OC, OV and UV Protection

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PAC5285EVK1

- For evaluation of low-power BLDC motors
  - Up to 40VDC absolute maximum
  - Optimized for 5.5V to 27V input
- SWD/UART headers for debug and GUI
- Support for Sensored or Sensorless BLDC or FOC
- Support for IAR, Keil or Eclipse IDEs
- Integrated Motor Control Peripherals:
  - Arm® Cortex®-M0 FLASH-programmable MCU
  - 40V Charge Pump DC/DC Controller, LDOs;
  - Programmable current HS/LS Gate Drivers; Amplifiers/Comparators
- Schematics, BOM, Layout Drawings available

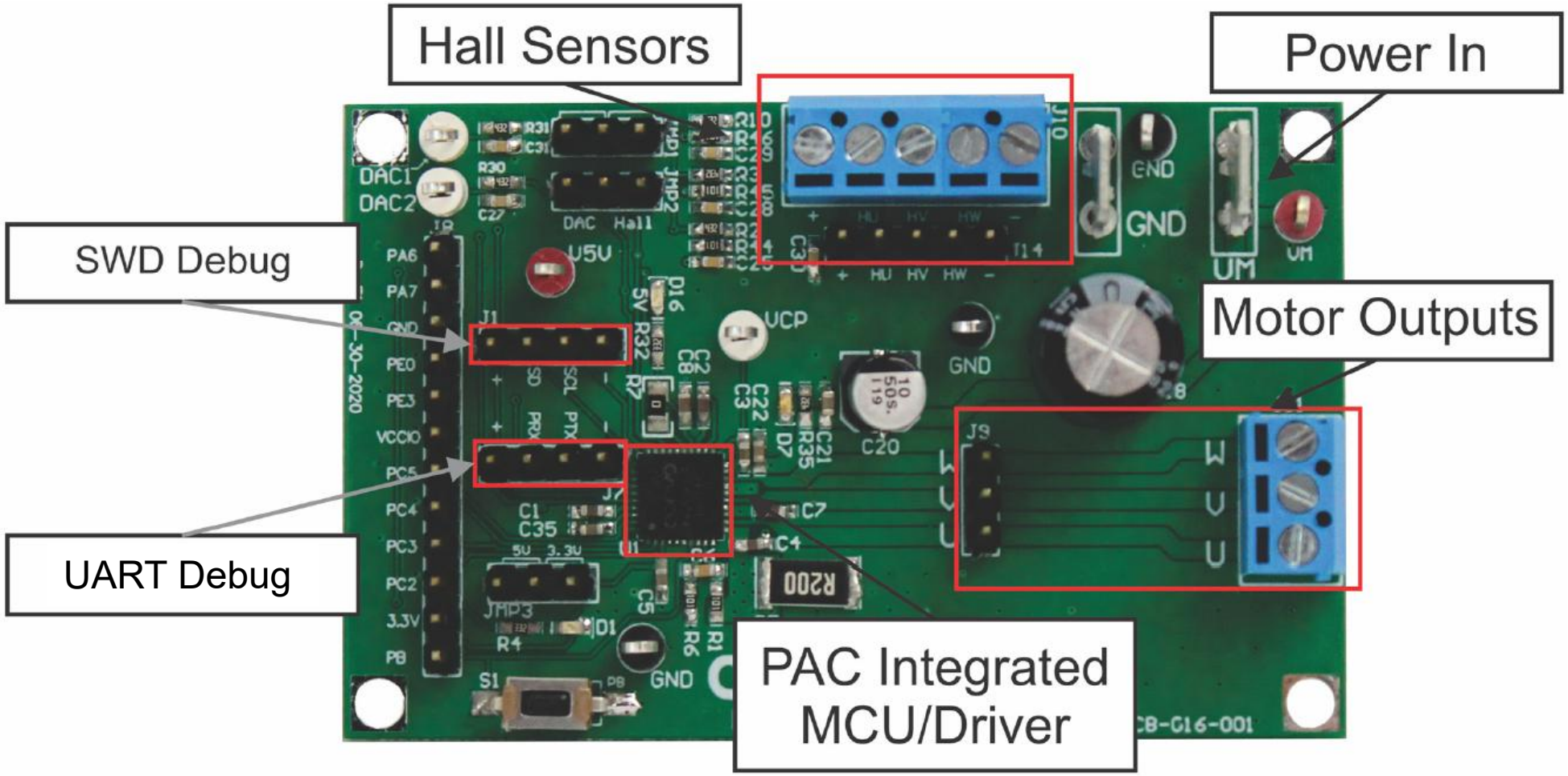




ET-UARTSWD
(USB-to-UART board with SWD debugger connector & Isolation)

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PAC5285EVK1



PAC5285EVK1

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PAC5285

40 Volt / 20 Watt Low-Power BLDC Controller and Driver with Integrated FETs

Production >

Product Data Sheet
Rev 0.14



Key Features

- Integrated FLASH programmable MCU
  - 50 MHz Arm® Cortex®-M0 with 32 kB FLASH
  - 10-bit 1 MSPS SAR ADC with dual sequencer
  - PWM Timers, Serial Communication
- Integrated Power Management
  - 40 V Input Charge Pump DC/DC, LDOs
  - 8 µA low-power hibernate mode
- Integrated Gate Drivers and MOSFETs
  - 40 V / 300 mΩ MOSFETs for BLDC 3-phase motors
- Integrated Signal Conditioning
  - Integrated Differential and Single-ended Amplifiers

Overview | Parameters | Documents

Data Sheets

Product Data Sheet
Rev 0.14

User Manuals

PAC5285 User Guide
Rev 1.0 – 12/19/2020

PAC5285EVK1 User Manual
Rev A

Other

PAC5285EVK1 Altium Files
Rev A

PAC5285EVK1 Output Files

Video: PAC5285: The Smallest Single Chip Motor Controller and Inverter Solution for Brushless DC Motors

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PAC™ 48V BLDC Controller

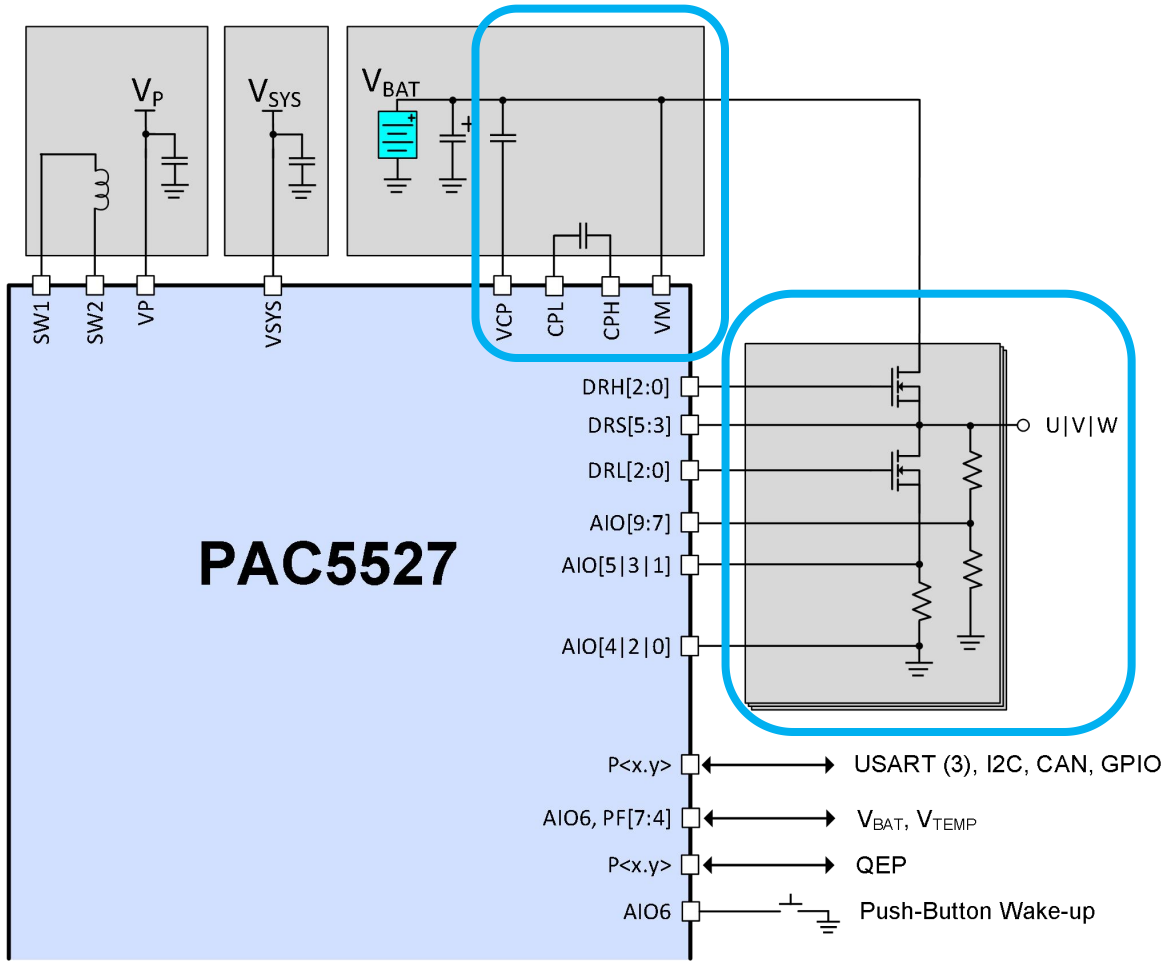
PAC5526/5527 - Advanced BLDC Controller

© Qorvo, Inc.

PAC5527

48V BLDC Motor Controller and Driver with Advanced Gate Driver

Sub-system	Details
• MCU	• **150MHz Arm® Cortex®-M4F** • 128kB FLASH, 32kB SRAM with ECC • 12b 2.5MSPS SAR ADC with Trigger and Sequence engine
• IO	• **16 x 3.3V IO**
• Serial Communications	• USART (3), I2C, CAN, QEP • SWD/JTAG for debugging • Field FLASH update using UART
• Power Management	• 6V-48V Supply Input • **Charge Pump DC/DC for HS Gate Drive** • Buck-Boost DC/DC for LS Gate Drive • 5V/100mA System Supply Regulator • Integrated LDOs for MCU Core and IO, Analog • Integrated high-accuracy ADC VREF
• Gate Drivers	• 3 high-side gate drivers • 3 low-side gate drivers • **Programmable HS and LS sink/source current**
• Signal Conditioning	• **3 x Differential,** 4 x Single-Ended PGA • Integrated power supply monitoring using ADC • Cycle-by-cycle control, OCP
• Physical	• T_A = -40°C to 125°C • 6x6mm, 48-pin QFN

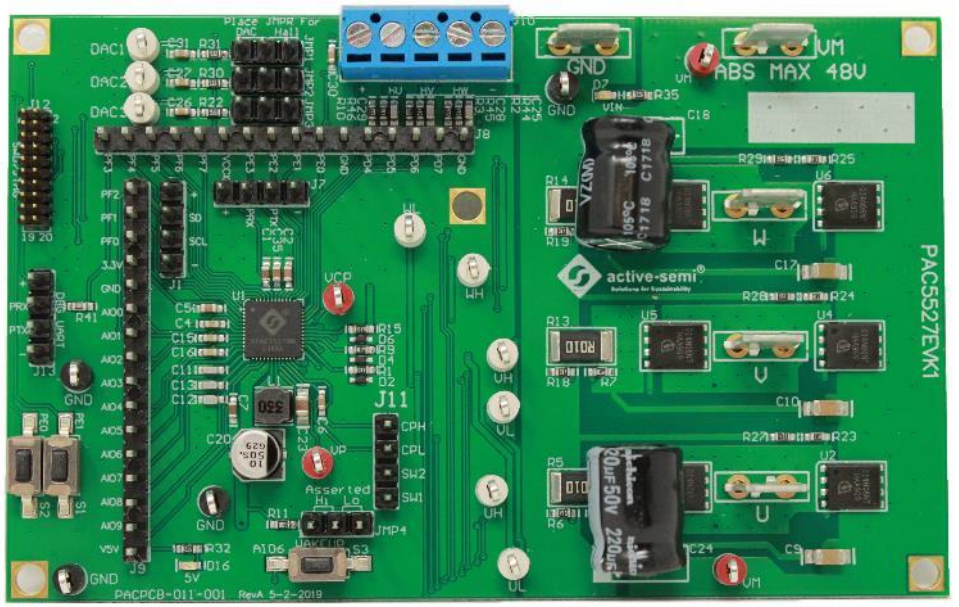


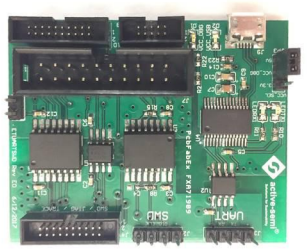
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PAC5527EVK

48V BLDC Evaluation Kit (EVK) with PAC5527

- For evaluation of low-voltage BLDC motors
  - Up to 48VDC absolute maximum
  - Optimized for 10VDC to 24VDC input
- SWD/UART headers for debug and GUI
- Support for Sensored or Sensorless BLDC or FOC
- Support for IAR, Keil or Eclipse IDEs
- Integrated Motor Control Peripherals:
  - Arm® Cortex®-M4F FLASH-programmable MCU
  - 48V Charge Pump DC/DC Controller, LDOs;
  - Programmable current HS/LS Gate Drivers; Amplifiers/Comparators
- Schematics, BOM, Layout Drawings available





ET-UARTSWD
(USB-to-UART board with SWD debugger connector & Isolation)

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PAC5227EVK1

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PAC5527

48 V BLDC Motor Controller and Driver

Production >

Product Data Sheet
Rev 1.2



Key Features

- Fully programmable 150 MHz Arm® Cortex-M4F®
- 128 kB flash, 32 kB SRAM
- Integrated 48 V charge pump DC/DC
- Integrated buck-boost DC/DC for regulated low-side gate drive
- Integrated programmable-current gate drivers (60 mA to 1 A)
- Integrated PGA (3 differential, 4 single-ended)
- Integrated DACs and comparators
- UART, CAN, I2C and SPI serial interfaces
- Extremely low total hibernate mode
- Minimal external components
- 6x6mm, 48-pin QFN

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DISTRIBUTOR INVENTORY

Overview | Parameters | Documents | Evaluation Tools

PAC5527EVK1 Evaluation Kit

Qorvo's PAC5527EVK1 evaluation kit is a complete hardware solution enabling users to evaluate the PAC5527 device, but also develop motor control applications revolving around the powerful and versatile 150MHz Arm® Cortex® -M4F based MCU. This evaluation kit is a motor controller and driver evaluation PCB, that uses the PAC5527 Power Application Controller®.

To aid in evaluation and application development the PAC5527EVK1 offers access to all of the PAC5527 device's signals by means of a series of female header connectors.

PAC5527EVK1 User's Guide

PAC5527EVK1 Schematics, Layout, BOM, Gerber Files

PAC5527EVK1 Altium Project Files

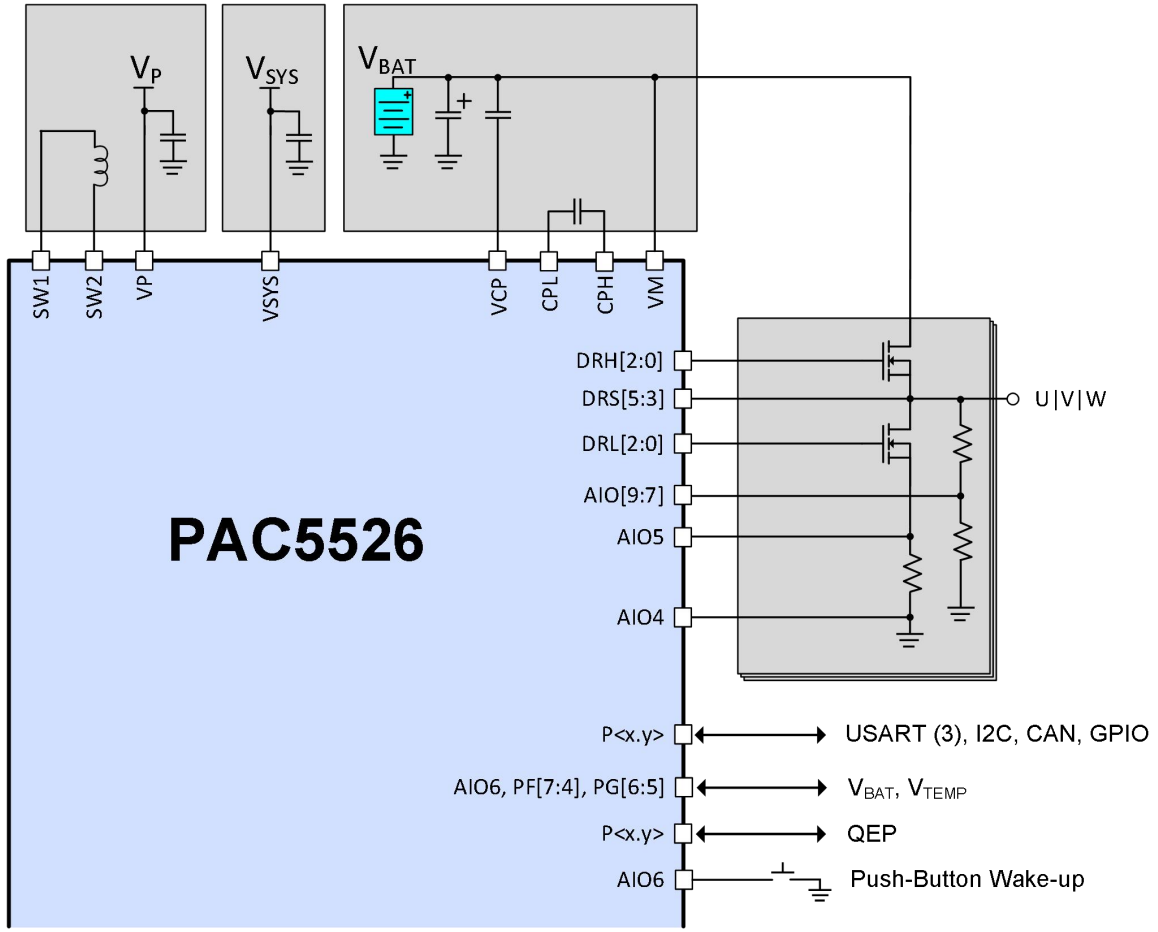


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PAC5526

48V BLDC Motor Controller and Driver with Advanced Gate Driver

Sub-system	Details
• MCU	• 150MHz Arm® Cortex®-M4F • 128kB FLASH, 32kB SRAM with ECC • 12b 2.5MSPS SAR ADC with Trigger and Sequence engine
• IO	• 20 x 3.3V IO
• Serial Communications	• USART (3), I2C, CAN, QEP • SWD/JTAG for debugging • Field FLASH update using UART
• Power Management	• 6V-48V Supply Input • Charge Pump DC/DC for HS Gate Drive • Buck-Boost DC/DC for LS Gate Drive • 5V/100mA System Supply Regulator • Integrated LDOs for MCU Core and IO, Analog • Integrated high-accuracy ADC VREF
• Gate Drivers	• 3 high-side gate drivers • 3 low-side gate drivers • Programmable HS and LS sink/source current
• Signal Conditioning	• 1 x Differential, 4 x Single-Ended PGA • Integrated power supply monitoring using ADC • Cycle-by-cycle control, OCP
• Physical	• T_A = -40°C to 125°C • 6x6mm, 48-pin QFN



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PAC5226EVK1

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PAC5526

48 Volt Charge Pump BLDC Motor Driver with Programmable Current

Production >

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Product Data Sheet
Rev 0.7



Key Features

- Fully programmable 150 MHz Arm® Cortex-M4F®
- 128 kB flash, 32 kB SRAM
- Integrated 48 V charge pump DC/DC
- Integrated buck-boost DC/DC for regulated low-side gate drive
- Integrated programmable-current gate drivers (60 mA to 1 A)
- Integrated PGA (1 differential, 4 single-ended)
- Integrated DACs and comparators
- UART, CAN, I2C and SPI serial interfaces
- Extremely low total hibernate mode
- Minimal external components
- 6x6 mm, 48-pin QFN

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DISTRIBUTOR INVENTORY

Overview | Parameters | Documents | Related Products

Qorvo's PAC5526 belongs to Qorvo's Power Application Controller (PAC) family. This family features highly-optimized SOC devices that can implement BLDC or PMSM programmable motor controller and driver functionality in a single integrated IC.

The product integrates a high-performance, high-memory FLASH-based 150MHz Arm® Cortex-M4F®, power management, high-side and low-side gate drivers and signal conditioning components in a single product.

PAC5526 is optimized for high-performance battery-powered BLDC motor control applications up to 24V.

Typical Applications

- Power Tools
- RC/Drones
- Battery powered BLDC motors up to 24V

Product Categories

- Products > Power Management > Intelligent Motor Controllers

Application Categories

- Applications > Consumer Goods & Electronics > Drones / RC Devices
- Applications > Consumer Goods & Electronics > Power Tools

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PAC Motor Control Firmware

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PAC Features for Motor Control

FOC Control

FOC control features and performance:

- Use LBG estimator observer
- Up support very high speed
- Support 1/2/3 shunt FOC
- Support Hall sensor
- Support QEP sensor(just PAC55xx)
- Support L&R measure and PI auto tuning
- Support Start In Motion
- Support Initial Position Detection
- Support Over Modulation
- Support Speed Control
- Support Torque Control
- Support Power Control
- Support Stall Detection
- Support Open Phase Detection
- Support Field Weakening
- More features is coming…

Trapezoidal Control

Trapezoid control features and performance:

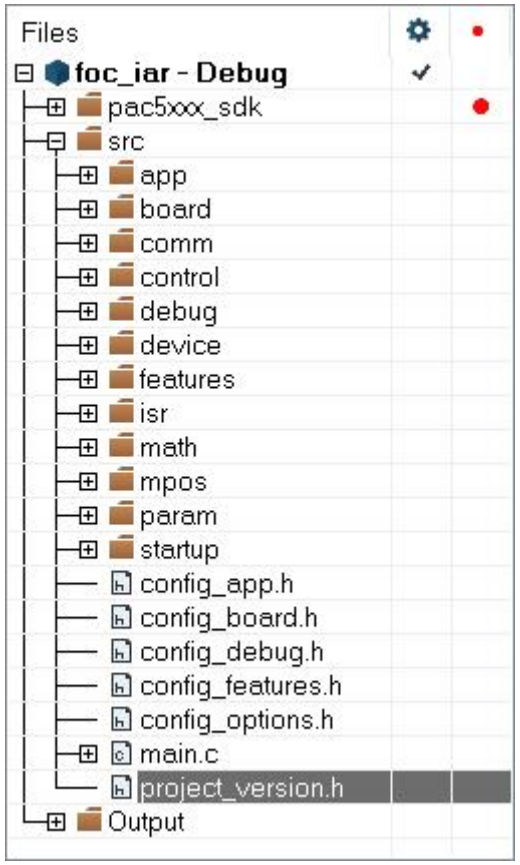
- Use Phase comparator commutate
- Can support ADC find zero point
- Up support very high speed
- Support Hall sensor
- Support Start In Motion
- Support Initial Position Detection
- Support Speed Control
- Support Current Control
- Support PWM Control
- Support Power Control
- Support Stall Detection
- Support Open Phase Detection
- Support advance commutate
- Support Sine start-up
- More features is coming…

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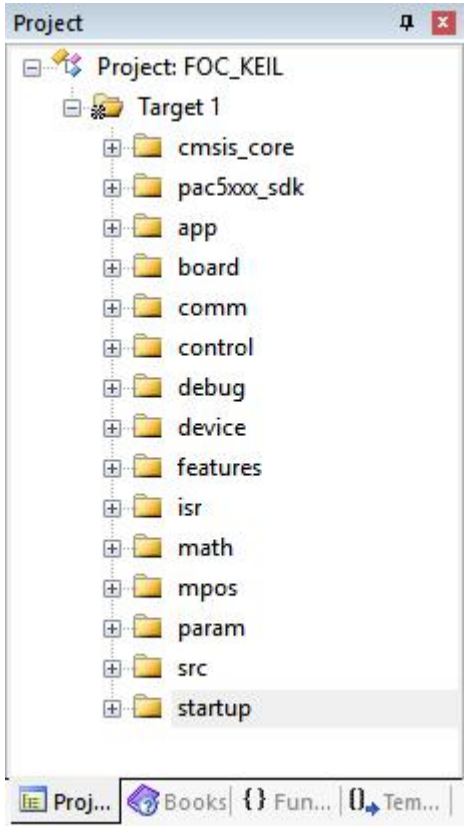
PAC Firmware for Motor Control

FOC Control

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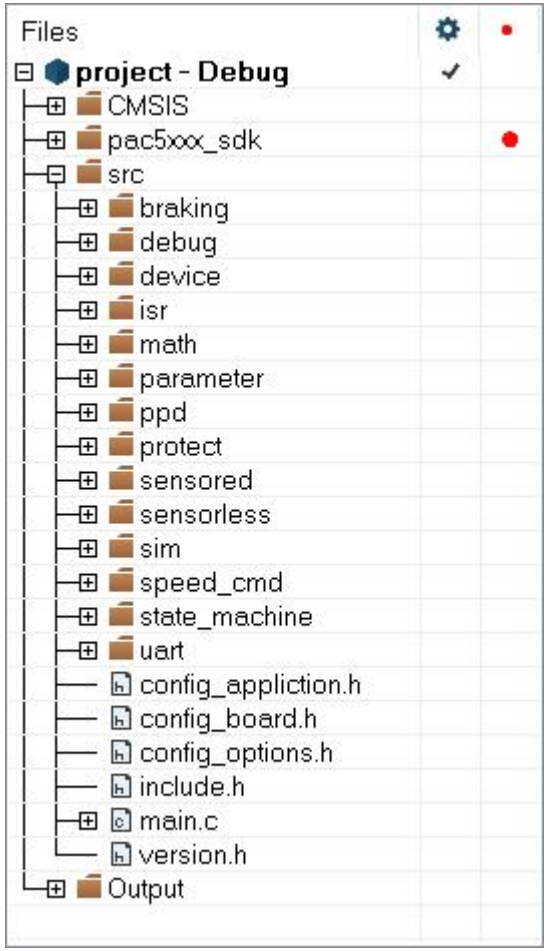


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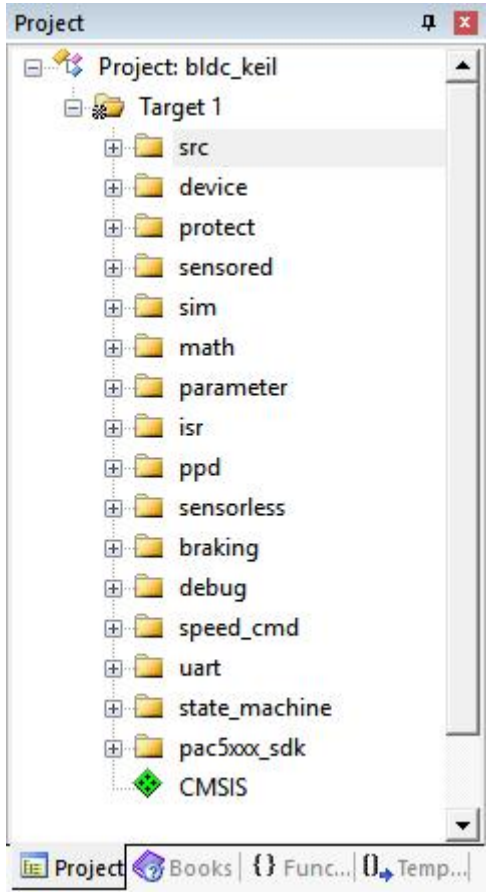


Trapezoidal Control

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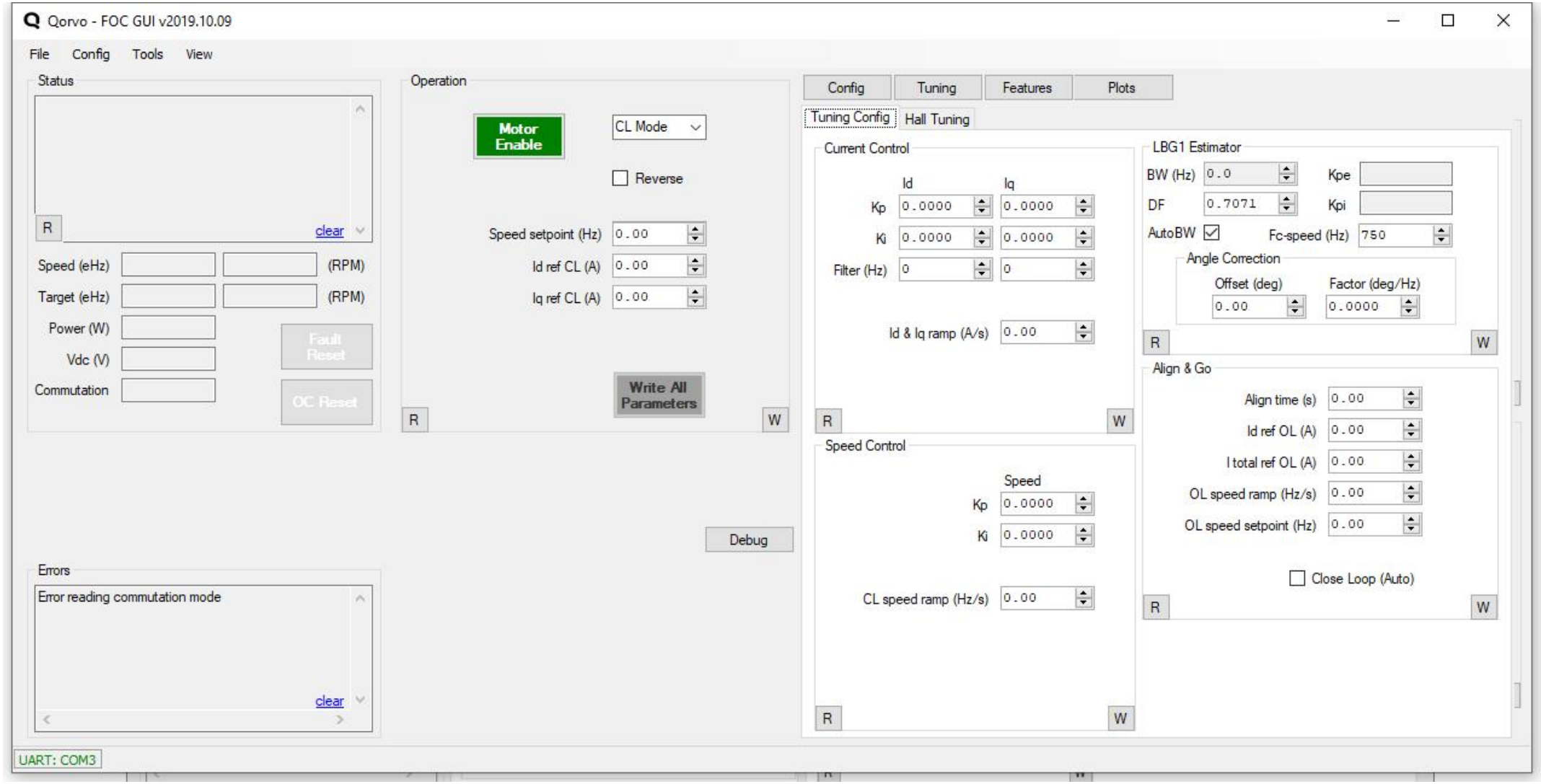
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PAC GUI for Motor Control

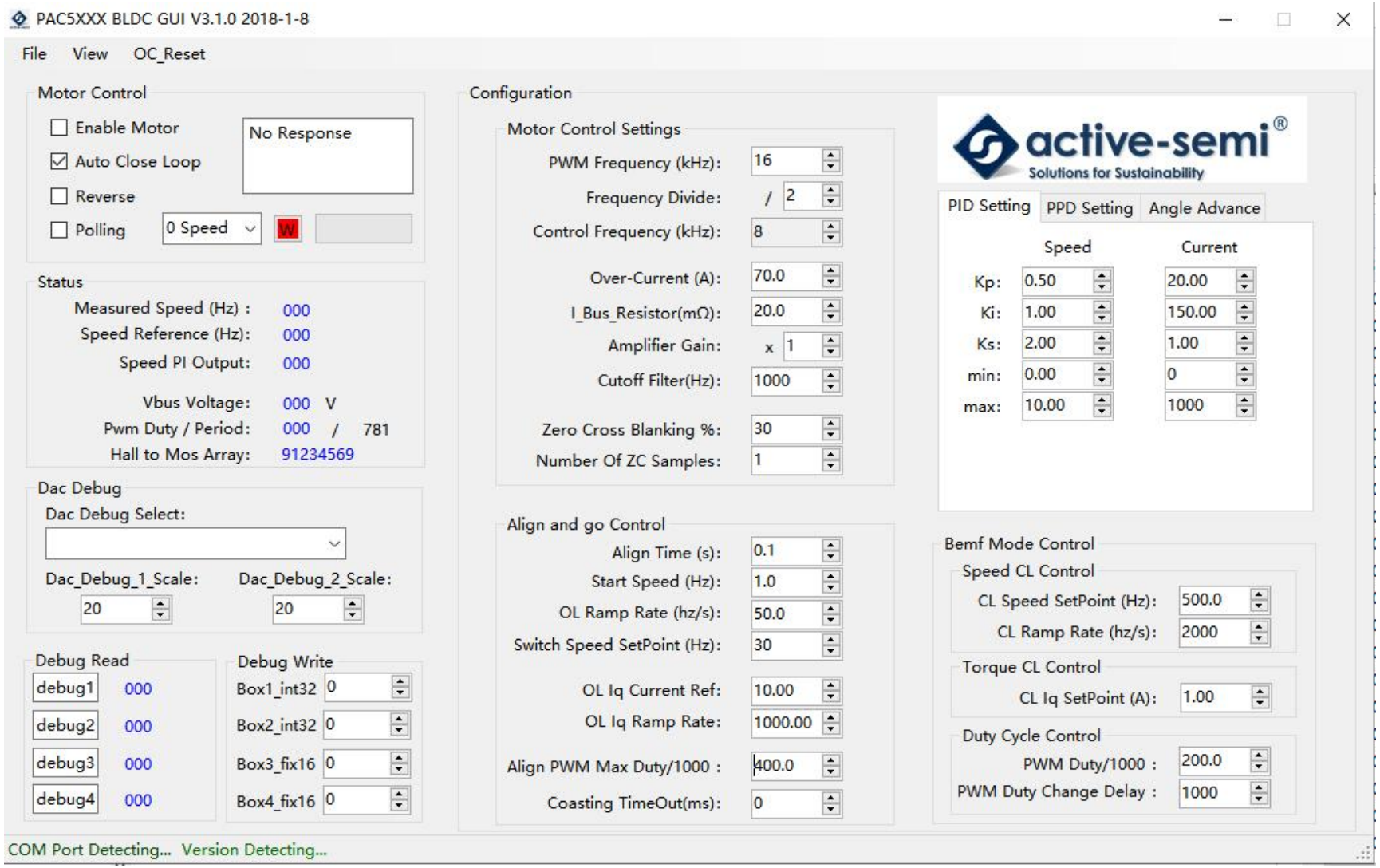
FOC Control GUI



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PAC GUI for Motor Control

Trapezoidal Control GUI



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PAC Document for Motor Control

FOC Control

Application Note :

- Ceiling Fan with Braking.pdf
- Guide_Auto_Tuning.pdf
- Guide_FOC_Firmware_Overview.pdf
- Guide_FOC_Getting_Started.pdf
- Guide_FOC_Tuning.pdf
- Guide_MPOS_Estimator.pdf
- Guide_MPOS_HallFOC.pdf
- Guide_MPOS_QEP.pdf
- Guide_SIM.pdf
- IPD Tuning.pdf
- PAC FOC v4.1.0 Release Notes.pdf
- Stall Tuning.pdf
- Guide_1Shunt.pdf
- Guide_PowerControl.pdf

Trapezoidal Control

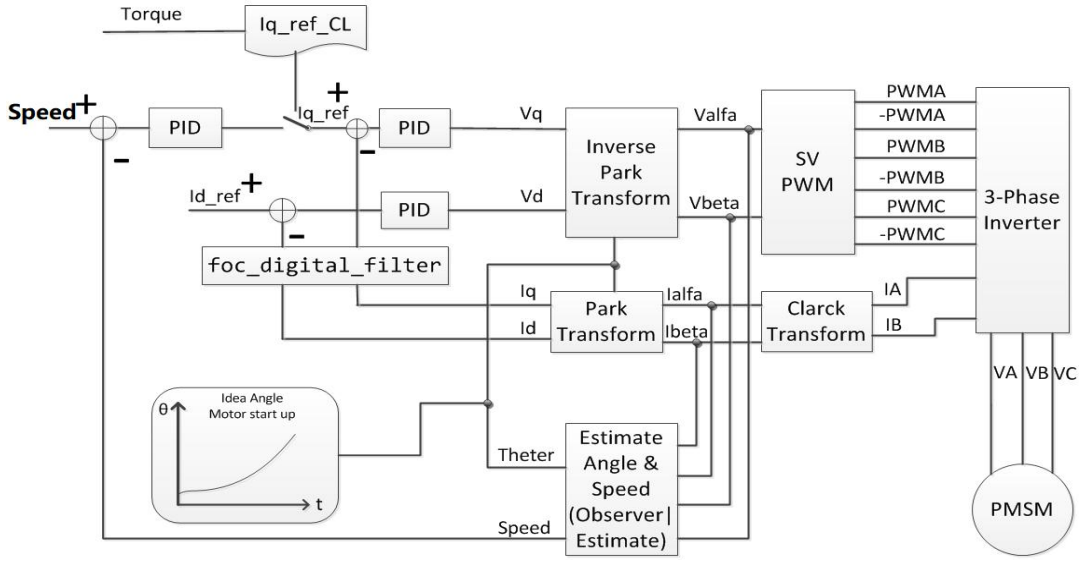
Application Note :

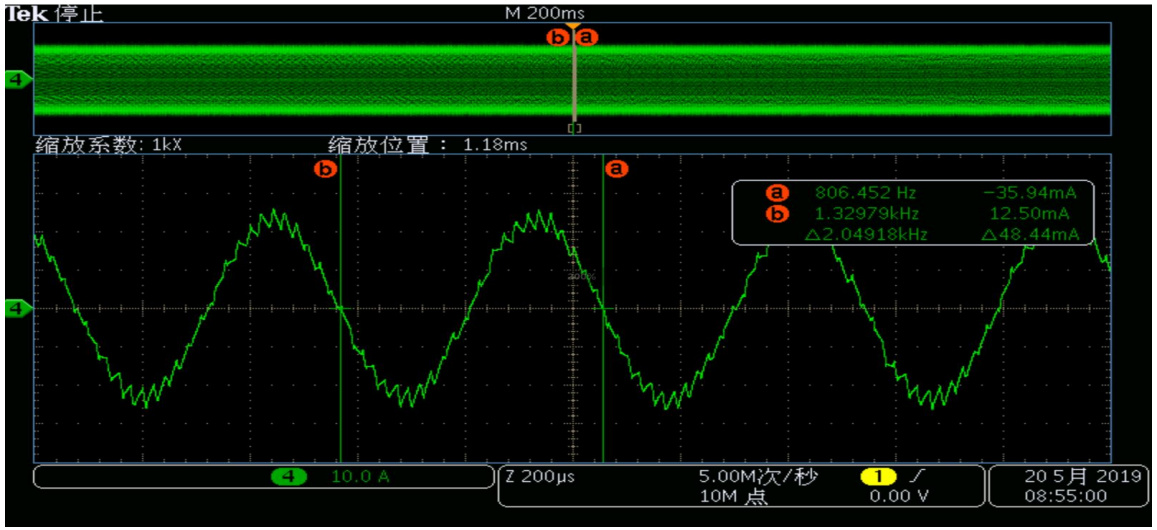
- AN1001 PAC52xx OverView & BLDC Tuning Guide.pdf
- AN1002 Brief introductions of square wave control theory.pdf
- AN1003 PAC peripheral configurations & Firmware Process.pdf
- AN1004 PAC52xx BLDC GUI Guide.pdf
- AN1005 Hall Mode Tuning Guide.pdf
- AN1006 Start In Motion Function Guide.pdf
- AN1007 Offline Tuning Guide in GUI.pdf

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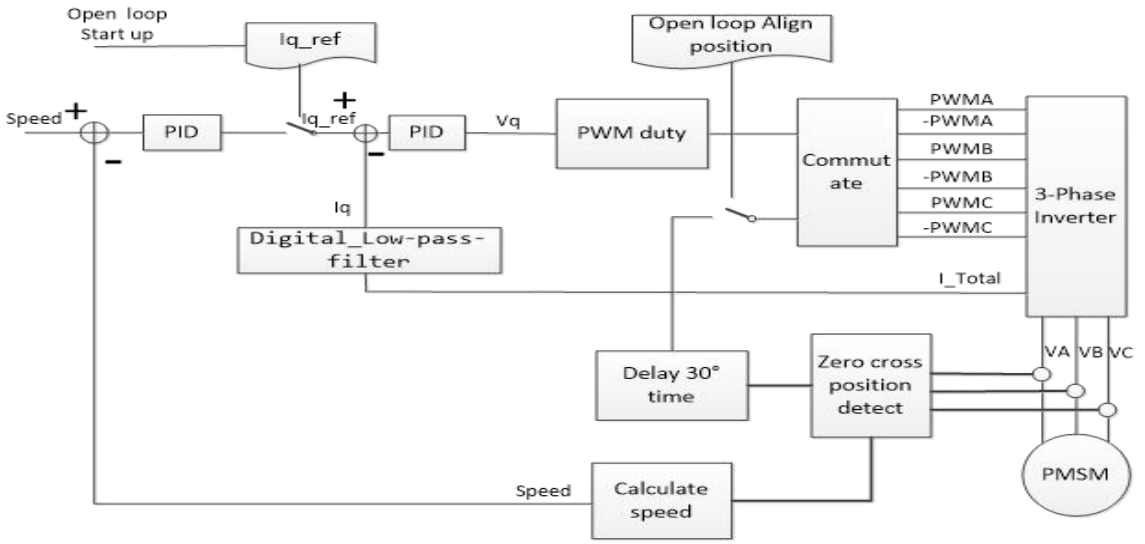
PAC Structure for Motor Control

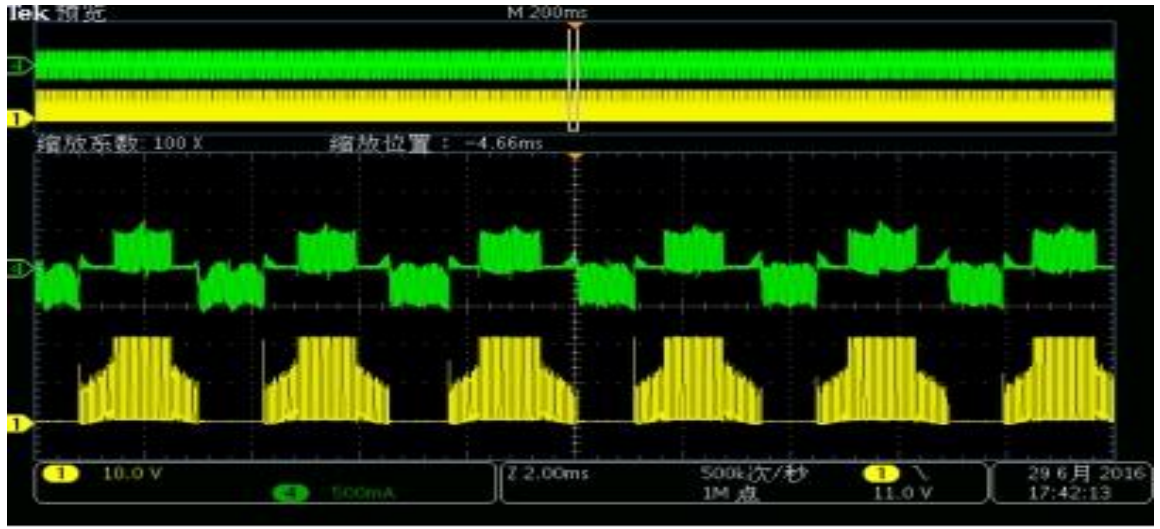
FOC Control





Trapezoidal Control





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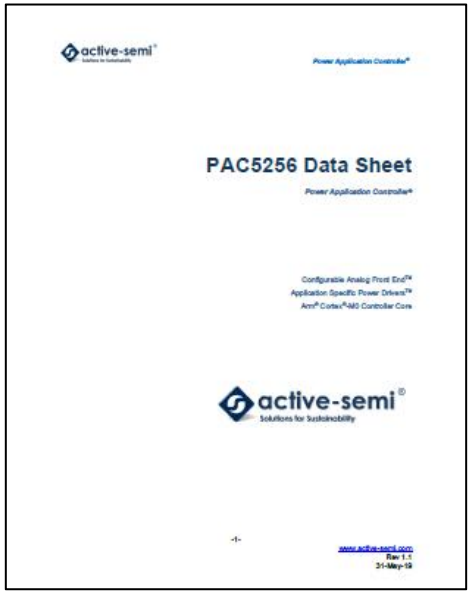
PAC™ Ecosystem

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Helpful Website Resources

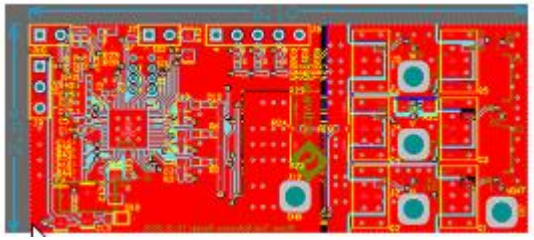
PPM Motor Control Collateral

- Get helpful PPM Motor Control resources:
  - Data Sheets, Programming Guides
  - Evaluation Kit (EVK) and Reference Designs
  - Application Notes
  - Software Development Kit (SDK)
  - Reference firmware and GUIs for BLDC and PMSM motors
  - Certifications



PAC5256EVK1





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PAC Hardware support for Motor Control

Documentation support PCB design and layout

PAC PCB package LIB:

- PAC_IntLib.LIBPKG
  类型: Altium Integrated Library Package
- PAC_IntLib_RevA.zip
  类型: 好压 ZIP 压缩文件
- PAC_PcbLib.PcbLib
  类型: Altium PCB Library
- PAC_Schlib.SchLib
  类型: Altium Schematic Library
- PAC52xx_Lib_Rev1p2.PcbLib
  类型: Altium PCB Library

Application note:

- AN1202 PCB布线规则 - PCB Layout Rules v1.4.pdf
- AN1205 PAC525x 高压控制板测试流程.pdf
- AN1206 针对PAC电机应用的PCB维修查错指南.pdf
- AN1207 PAC Hardware Tips -PAC Seminar.pdf
- AN1208 QFN PCB Layout Guidelines Rev5.pdf
- AN1209 PAC5232 电源设计注意事项.pdf

Hardware Tips:


PAC Hardware Tips -English.pptx

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PAC Support Active-Safe for Class B Safety (UL/IEC 60730)

Support PAC52xx and PAC55xx

PAC52xx

PAC55xx

PAC52xx:

installer-pac_foc_v4.0.1_active_safe_v1.1.0.exe
类型: 应用程序

installer-pac52xx_active_safe_v1.1.0.exe
类型: 应用程序

installer-pac52xx_foc_v3.1.5_active_safe_v1.1.0.exe
类型: 应用程序

PAC55xx:

installer-pac_foc_v4.0.1_active_safe_v1.0.0.exe
类型: 应用程序

installer-pac55xx_active_safe_v1.0.0.exe
类型: 应用程序

PAC55XX ActiveSafe.pdf



CERTIFICATE OF COMPLIANCE

Certificate Number 20180907-E502048
Report Reference E502048-20180907
Issue Date 2018-SEPTEMBER-07

Issued to: Active-Semi Inc
700 Central Expressway South
One Allen Center
Suite 330
Allen, TX, 75013

This is to certify that representative samples of COMPONENT - SAFETY-RELATED PROGRAMMABLE COMPONENTS AND SOFTWARE FOR AUTOMATIC ELECTRICAL CONTROLS
See Addendum Page

Have been investigated by UL in accordance with the Standard(s) indicated on this Certificate.

Standard(s) for Safety: See Addendum Page
Additional Information: See the UL Online Certifications Directory at www.ul.com/database for additional information

Only those products bearing the UL Certification Mark should be considered as being covered by UL's Certification and Follow-Up Service.

The UL Recognized Component Mark generally consists of the manufacturer's identification and catalog number, model number or other product designation as specified under "Marking" for the particular Recognition as published in the appropriate UL Directory. As a supplementary means of identifying products that have been produced under UL's Component Recognition Program, UL's Recognized Component Mark: , may be used in conjunction with the required Recognized Marks. The Recognized Component Mark is required when specified in the UL Directory preceding the recognitions or under "Markings" for the individual recognitions.

Recognized components are incomplete in certain constructional features or restricted in performance capabilities and are intended for use as components of complete equipment submitted for investigation rather than for direct separate installation in the field. The final acceptance of the component is dependent upon its installation and use in complete equipment submitted to UL LLC.

Look for the UL Certification Mark on the product.

Bruce Mahrenholz, Director North American Certification Program
UL LLC

Any information and documentation involving UL Mark services are provided on behalf of UL LLC (UL) or any authorized licensee of UL. For questions, please contact a local UL Customer Service Representative at http://ul.com/aboutul/locations/

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PAC Support Active-Flash-Light for UART Bootloader

Support PAC52xx and PAC55xx

bootloader_M0

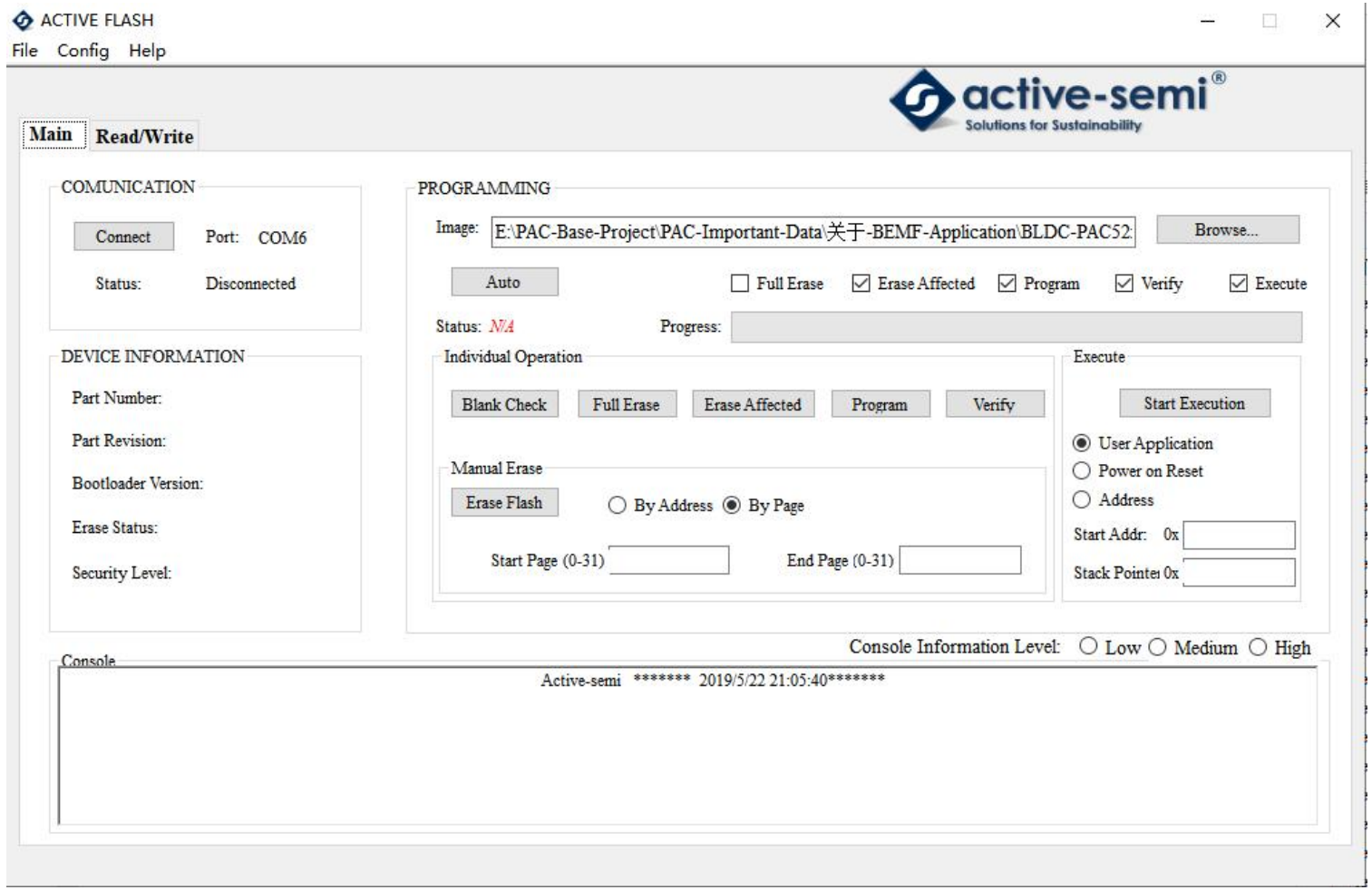
bootloader_M4

PAC52xx:

- improved_interrupt_handling
- ActiveFlashLight.exe
  类型: 应用程序
- config.xml
- PAC52xx ActiveFlashLightTM Bootloader.pdf
- PAC52xx ActiveFlashLightTM Integration Guide.pdf
- pc_cmd_line_app.exe
  类型: 应用程序

PAC55xx:

- ActiveFlashLight.exe
  类型: 应用程序
- config.xml
- PAC55xx ActiveFlashLightTM Bootloader.pdf
- PAC55xx ActiveFlashLightTM Integration Guide.pdf
- pc_cmd_line_app.exe
  类型: 应用程序



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IDE & Debugger for PAC

IDE: IAR Workbench v7.5 & v8.2
Programmer: Segger J-Flash v5.11a and above
HW Debugger: J-Link V8/V9/V10

IDE: Keil uVision v 5.15 & v5.26
Programmer: Segger J-Flash v5.11a and above
HW Debugger: J-Link V8/V9/V10



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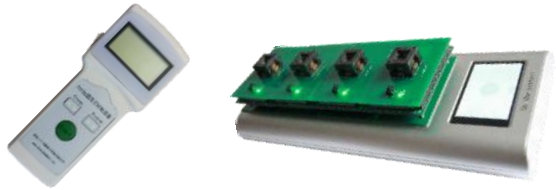
Mass-Production Programmer & Tools

Name	Location	Logo
XELTEK SuperPro7500	Nanjing	XELTEK
Leaptronix AH-480	Taiwan	力浦电子实业股份有限公司 LEAP ELECTRONIC CO.,LTD
MaxWiz WizPro200EPS	Shenzhen	MaxWiz Technology
37programmer P370x	Qingdao	青岛三十七度电子科技有限公司
Elprotronic Gangpro-X	Canada	Elprotronic www.elprotronic.com











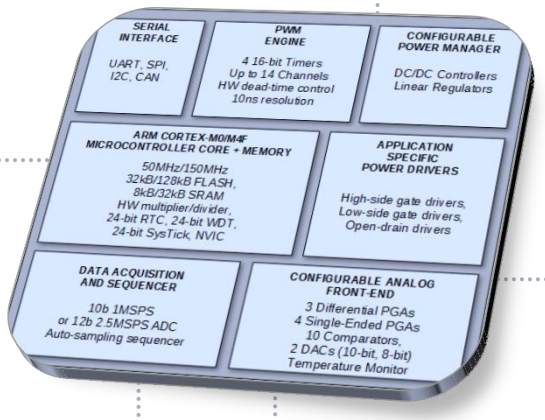
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PAC Ecosystem

Customer-Programmable Motor Control Solutions

Hardware support

- Motor Control EVK
- Application Expertise Design



Motor Control Firmware

- Sensored/Sensorless BLDC
- Sensored/Sensorless FOC
- PC GUI for Debugging

MCU SDK

- ARM CMSIS Library
- Peripheral Firmware Example Projects
- ActiveSafe IEC60730 Class B Safety Libraries
- ActiveFlash Field Update Boot-loader

IDE/Programmer

- IAR/Keil
- J-Link

3rd Party Support

- Production Programmer Support
- Advanced Algorithm and Support
- Total Solution

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Thank You