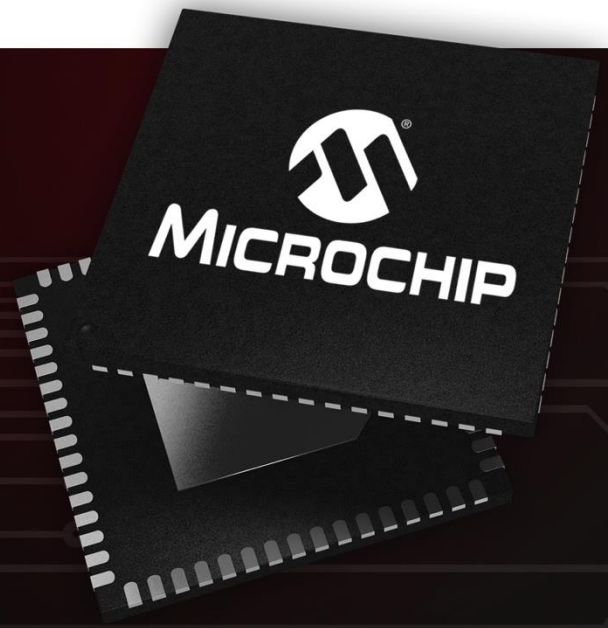
MICROCHIP



A Leading Provider of Microcontroller, Mixed-Signal, Analog & Flash-IP Solutions




Presented by:
Mason Han, Embedded Solutions Engineer
March 22, 2018

Motor Control Solutions

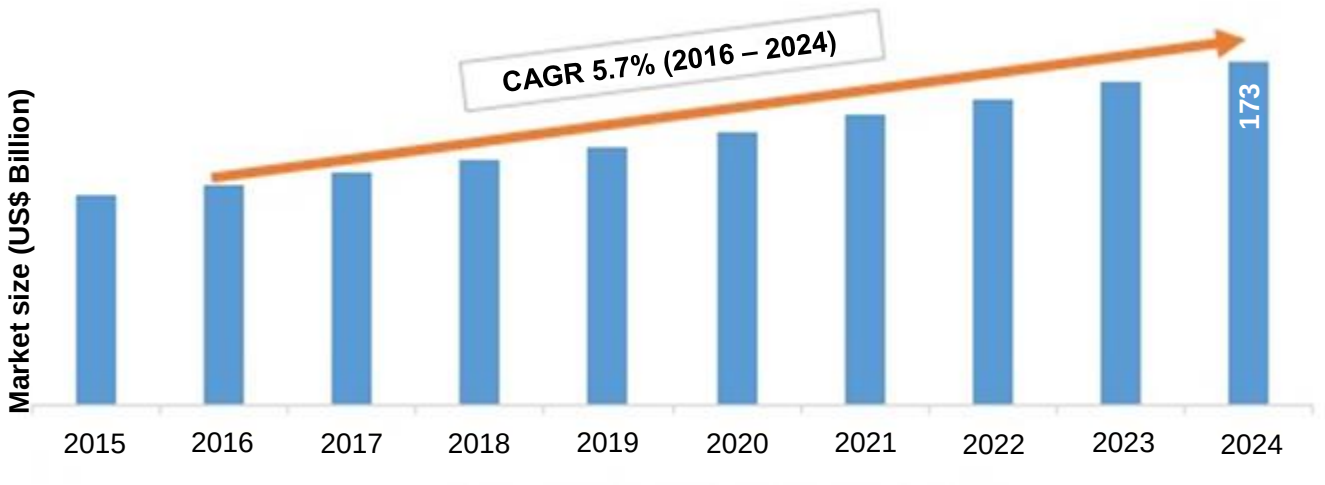
March 22, 2018

Content

- **Market Growth**
- **Motor Applications**
- **Motor Control System**
- **Microchip Solutions**
  - Microcontrollers, DSC and Motor Drivers
  - Application Notes including Open Source Code
  - Tuning Guides
  - Development Boards
- **Summary**

Motor Market Growth

Global Electric Motor Market Size and Forecast, 2015 – 2024 (US$ Billion)



Global electric Motor Market is estimated to reach $173 billion by 2024, growing at a CAGR of 5.7% from 2016 to 2024

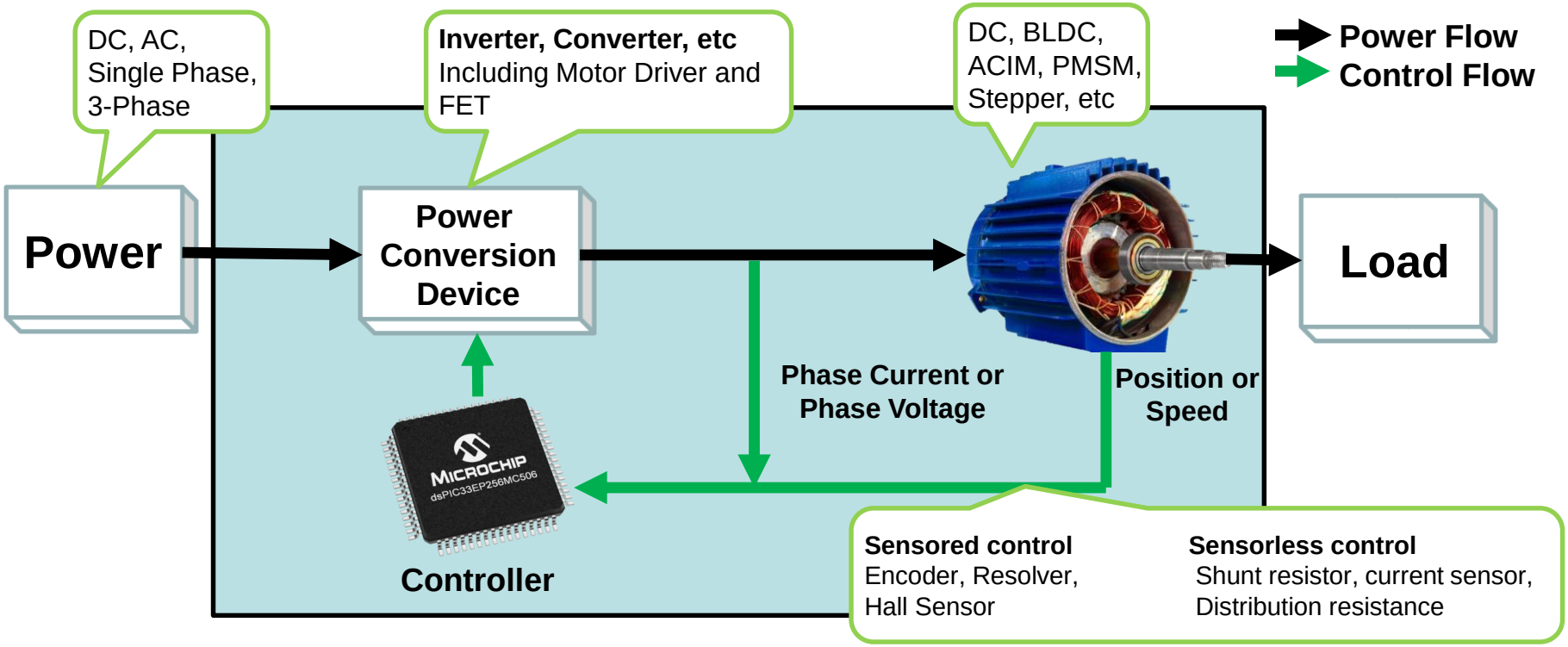
Key Factors:
- **Increasing automobile production**
- **Increasing adoption of electric vehicles**

Source: Global Electric Motor Market Size and Forecast, 2015-2024", Variant Market Research {July 2017}

Motor Applications

- **Appliance**
  - Air Conditioner
  - Washing Machines
  - Refrigerator Compressors
- **Industrial**
  - Commercial Sewing Machines
  - CNC Machines
  - HVAC Systems
  - Actuators
- **Automotive**
  - Cooling Fans
  - Fuel Pumps
  - Water Pumps
- **Consumer**
  - Drone
  - Power Tools

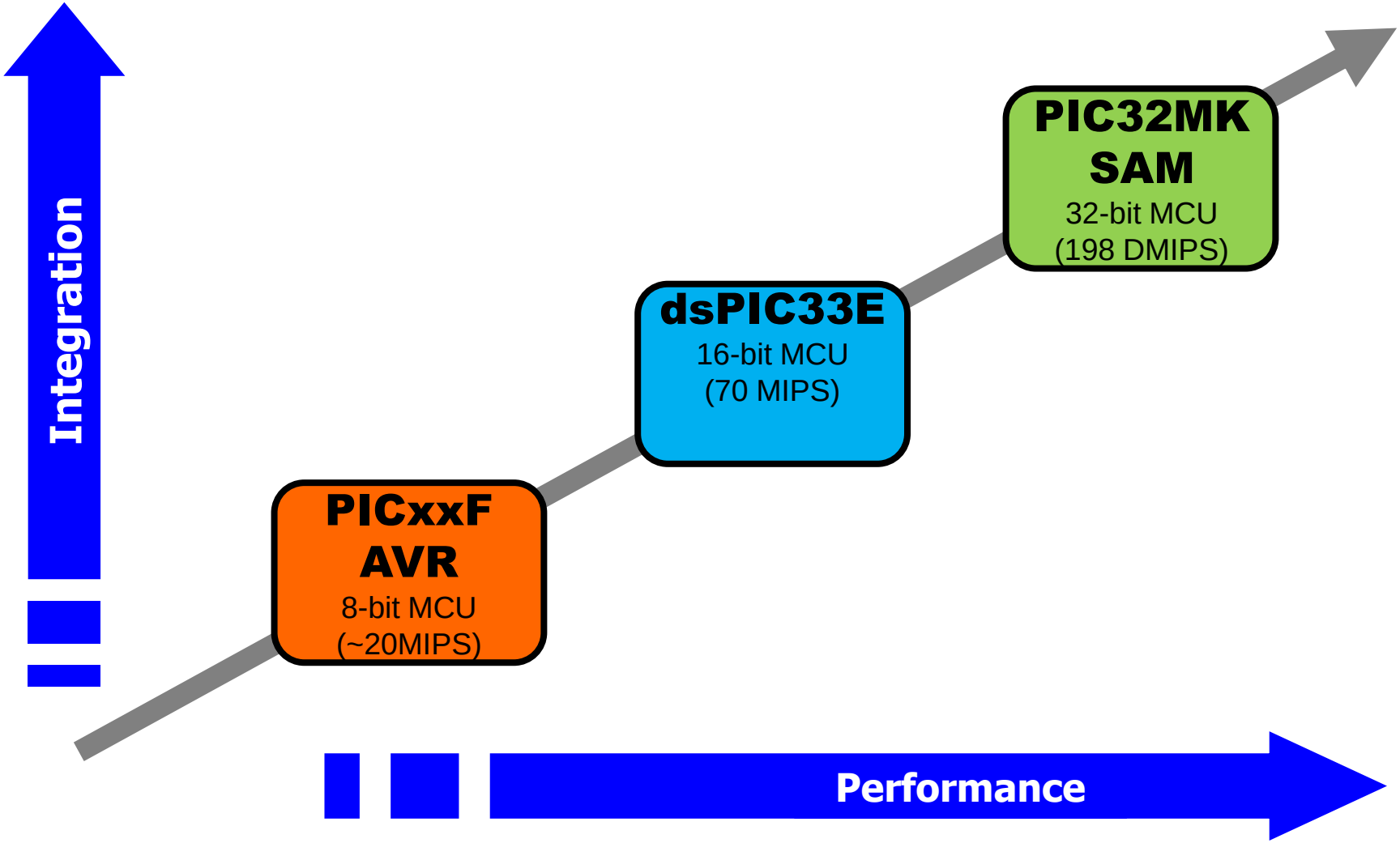
Motor Control System



1. **Power :** Supply the power to power conversion device
2. **Power Conversion Device:** Convert the base power input from the power source into power to control the speed and torque of the motor
3. **Motor :** Device that converts electrical energy into mechanical energy
4. **Controller:** Control the speed and torque of the motor using information of the motor or inverter

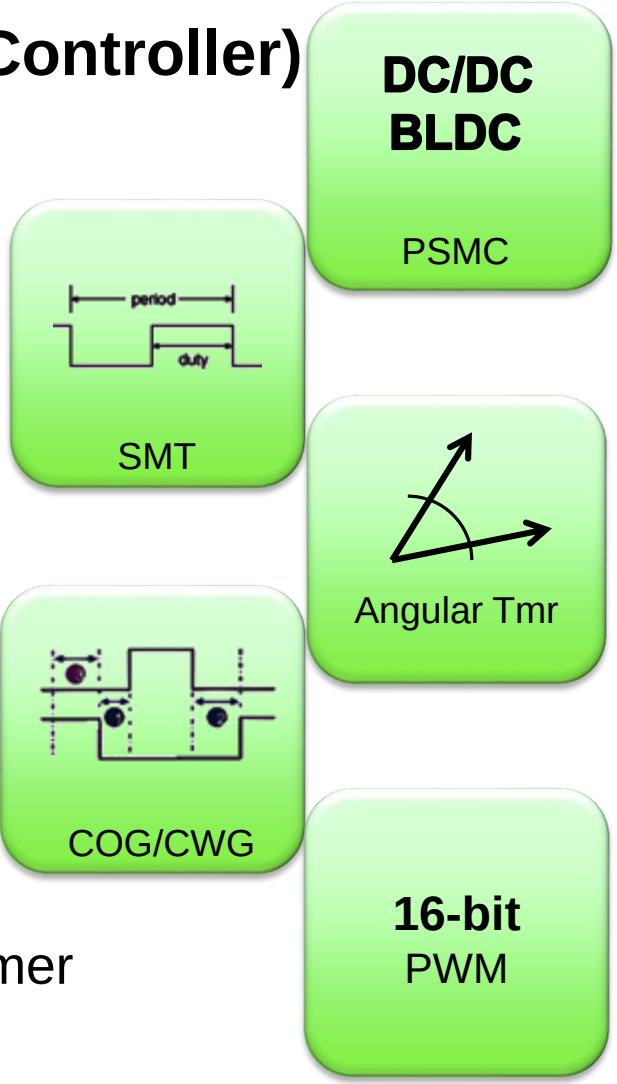
Microcontrollers

Microchip Motor Control Families



Motor Control
Core Independent Peripherals (CIPs)

- **PSMC (Programable Switch Mode Controller)**
  - Advanced PWM capabilities for motor
- **SMT (Signal Measurement Timer)**
  - High signal measurement for duty and period
- **Angular Timer**
  - Measures the angle of the motor
- **COG/CWG**
  - Bridge drive
  - Complementary Output Generator
  - Complementary Waveform Generator
- **16-bit PWM**
  - High-resolution PWM with independent timer



PIC10
Motor Control MCU

- **PIC10**
  - Application – Universal Motor Control via Triac, MOSFET or IGBT, Watchdog
  - Performance – Up to 4 MIPS, 8-bit
  - Packages – 2x3 DFN or 6-pin SOT-23
  - Peripherals - Comparator, 8-bit ADC, 10-bit PWM, CWG (Complementary Waveform Generator)

PIC12
Motor Control MCU

- **PIC12**
  - Application – BDC via H bridge, 1 ph BLDC
  - Performance – to 8 MIPS, 3.5 KB, 256B
  - Packages – 8-pin MSOP, SOIC, PDIP, DFN
  - Peripherals – CMPs(HS), ECCP,10-bit ADC, 5/8/9-bit DAC, 16-bit PWM, CWG, SMT, ZCD, 2x 50mA I/O
  - PWM steering enables Single Phase (Bifilar wound or Single winding) BLDC FAN motor control
  - Integrated LDO enables highly integrated solution (HV parts)
  - +150℃ rated parts available

PIC16
Motor Control MCU

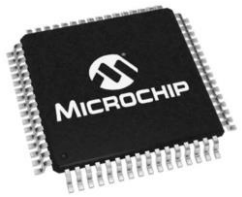
- **PIC16**
  - Best Fit Applications – BDC, 3 ph ACIM (V/f), BLDC (Sensor-less or Sensored), Basic Stepper, plus 1 ph Apps.
  - Performance – to 8 MIPS with F1 Core, 8-bit, 28 KB, 2 KB RAM, 256B EE, to 3x 16-bit Timers
  - Packages – QFN/UQFN (4x4), TQFP, SOIC, SSOP, SPDIP
  - Peripherals – CMPs(HS), OAs, 10-bit ADC (up to 90 ksps), 5/8-bit DAC, ECCPs, 16-bit PWM, CWG, PSMC, SMT, ZCD
  - Dead time for 3 phase control in complementary mode
  - ANG Timer for speed independent commutation
  - Comparator with mux enables back-EMF sampling
  - EUSART enables LIN communications
  - +150 ℃ parts available

PIC18
Motor Control MCU

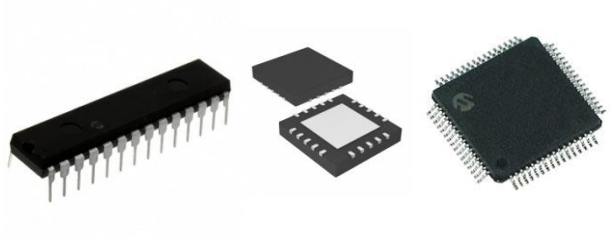
- **PIC18**
  - Best Fit Applications – BDC, 3 ph ACIM (V/f), BLDC (Sensor-less or Sensored), PMSM (Sensored), Basic Stepper, plus 1 ph Apps including SRM
  - Performance – Up to 16 MIPS, HW Multiply, 8-bit, 128 KB Flash, 4 KB RAM
  - Packages – QFN,TQFP,SSOP, SOIC,PDIP
  - Peripherals – PPS, ECCP, CCP, 5-bit DAC, 3x FVRs, HLT, ZCD
  - Parts offer migration from PIC16
  - More Timers, Deeper H/W stack
  - Peripheral Pin Select for flexibility on some
  - +150 ℃ parts available

dsPIC33/PIC24EP
Motor Control MCU

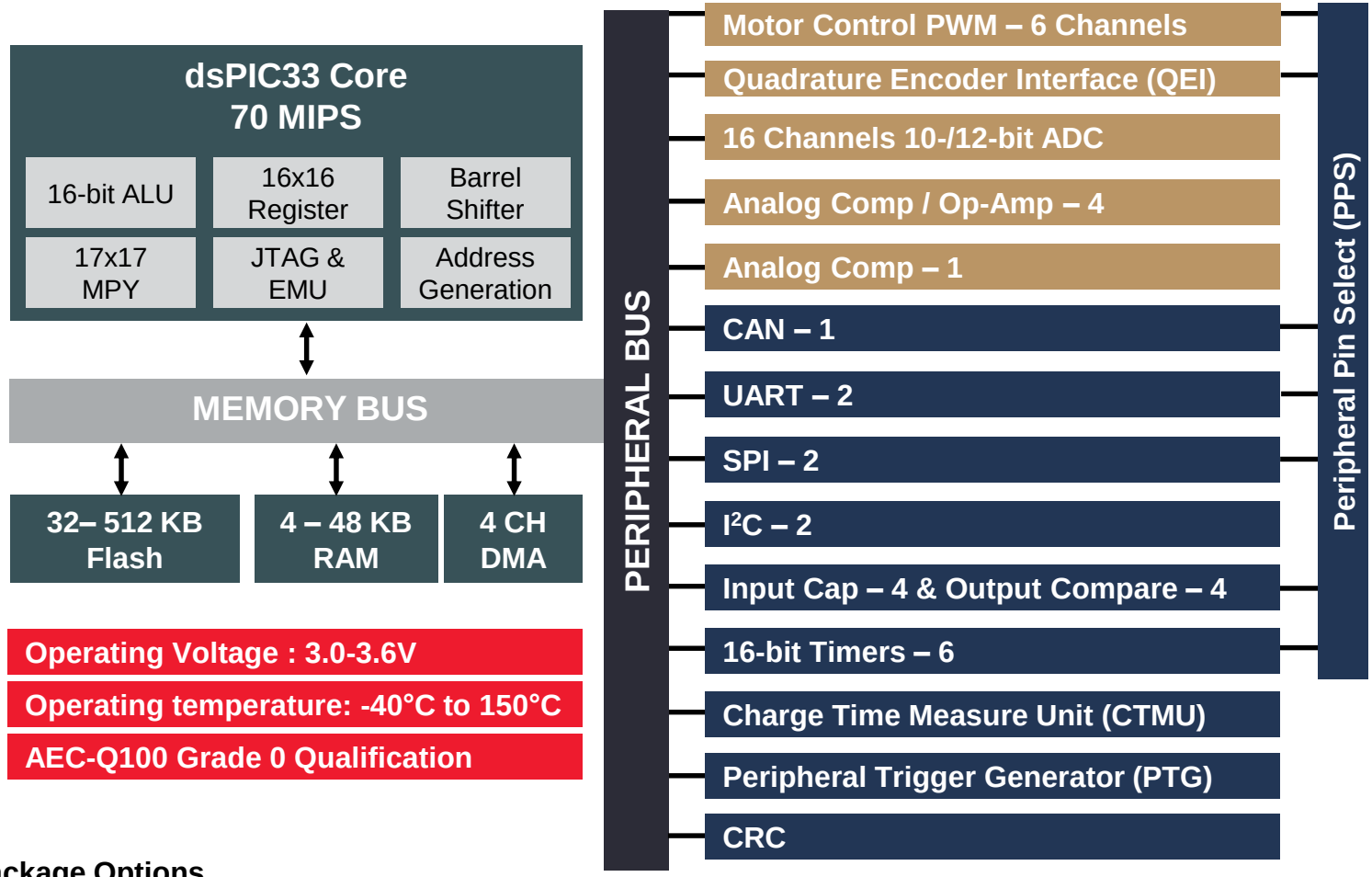
- **The 3rd generation 16-bit dsPIC® DSC/PIC24 MCU family:**
  - Upward compatible with the 2nd generation dsPIC33F/PIC24F
  - 0.18 µm process technology for die size and dynamic power reductions
- **70 MIPS performance, up to 512 KB of Flash & 48 KB of RAM**
- **On-chip Op-Amps reduce the need for external components**
  - Three phase motor current sensing can be done entirely with on-chip Op-Amps and ADC



- **Multiple package options**
  - 28-, 36-, 44-, 64-, 100- and 144-pin options in SPDIP, TQFP and QFN packages
  - Ultra thin 48-pin UQFN package option
  - 5×5 mm in 36-pin UQFN packages



dsPIC33EP Motor Control Family Block Diagram



Operating Voltage : 3.0-3.6V

Operating temperature: -40°C to 150°C

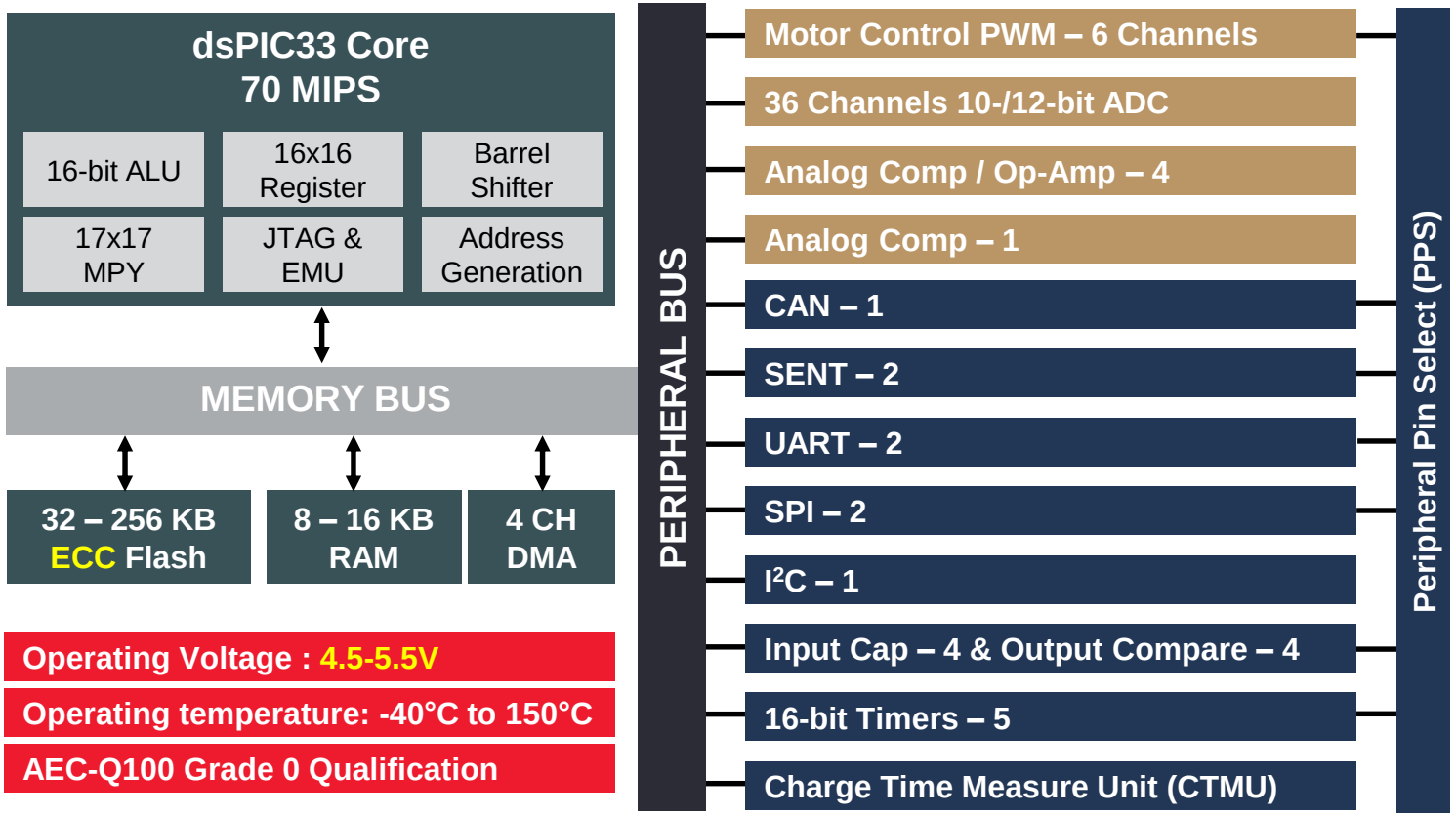
AEC-Q100 Grade 0 Qualification

- **Package Options**
  - 28-pin: SPDIP, SOIC, SSOP
  - 28-pin QFN-S
  - 36-pin uQFN
  - 44-pin: TQFP, QFN,
  - 48-pin: uQFN
  - 64-pin: TQFP, QFN

5V dsPIC33 “EV” Family
Motor Control MCU

- **Noise immunity and robustness**
  - 5V operation for harsh environments
  - Up to 150°C with AEC-Q100 Grade 0 automotive qualification
- **Peripheral integration**
  - Full support for 3-phase motor applications
    - 6 PWM pairs
    - ADCs with multiple sample & hold
    - 4 Op-Amps
  - CAN, LIN and SENT peripherals for automotive communications
  - Sensor interfaces such as touch, level and flow sensing
- **Increased reliability and safety**
  - Error Correcting Code (ECC) flash
  - Deadman Timer (DMT), Windowed Watchdog Timer (WWDT)
  - Certified Class B safety software
- **70 MIPS performance including DSP acceleration**
  - High-speed control algorithm execution
  - 2 additional 16 x 16 register sets for fast context switching

dsPIC33EV 5V Motor Control Family Block Diagram

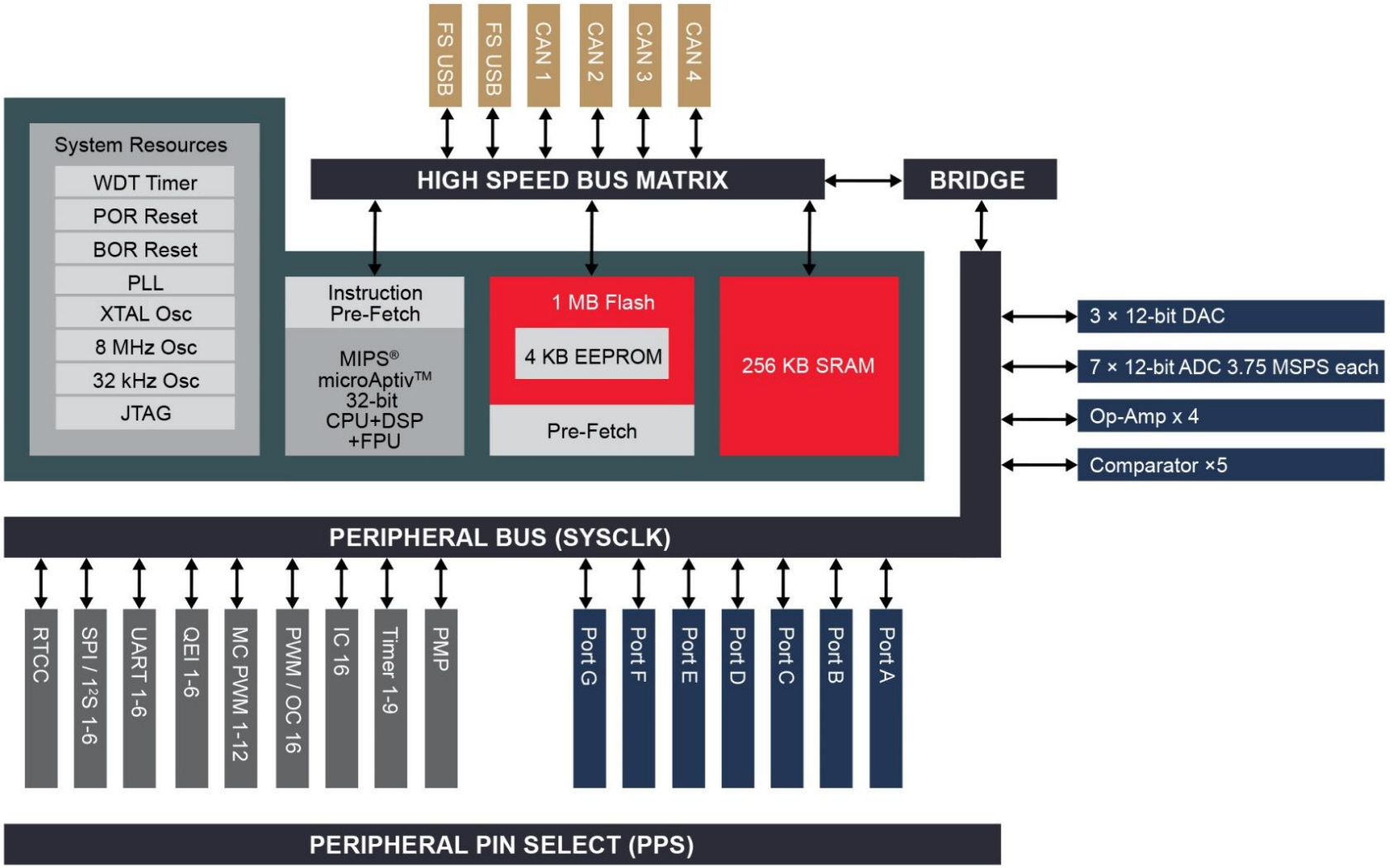


- **Package Options**
  - 28-pin: SPDIP, SOIC
  - 28-pin QFN-S
  - 44-pin: TQFP, QFN,
  - 64-pin: TQFP, QFN

PIC32MK MC Family
Motor Control MCU

- MIPS microAptiv™ Core
  - DSP instructions
  - (FPU – single/double precision)
- 120 MHz / 198 DMIPS
- Flash: 512 KB / 1 MB
- RAM: 128 KB / 256 KB
- 64-, 100-pin package choices
- 1× or 2× USB-OTG + PHY
- 2× or 4× CAN 2.0b modules
- 6× UART, 6× SPI/I²S, PMP: 8- or 16-bit
- **6×2 Advanced Motor PWM :Controls two 3-phase motors**
- **6× Quadrature Encoder Interfaces**
- Low active power (typical 250 µA/MHz)
- Power-down current (<20 µA max, <6 µA typical)
- 7x 12-bit ADC, 3.75 Msps each
- 8 S/H, up to 49 channels
- 4× Op-Amp
- 5x 50 nS Comparators
- Up to 3× 12-bit DAC
- CTMU, Temp Sensor
- 1% accurate on-chip oscillator
- IND and EXT temp range
- AEC Q-100 planned (125°C)

PIC32MK MC Family
Motor Control MCU



Motor Driver

Motor Driver ICs

Dual H-Bridge Motor Driver

- MTS62C19A
  10V – 40V, 750 mA
- MTS2916A
  10V – 40V, 750 mA

Integrated Half-Bridge Motor Drivers

- ATA6826C
  3 Half-bridges
  6.5V – 40V, 1A
- ATA6831/32C
  3 Half-bridges
  6.5V – 40V, 1A
  TJ=150/200°C
- ATA6836/38C
  6 Half-bridges
  6.5V – 40V,
  650/950 mA

3-phase Brushless Motor Driver

- MCP8063
  2V – 14V, 1.5A
- MTD6501C/G
  2V – 14V, 800 mA
- MTD6501D
  2V – 14V, 500 mA
- MTD6502B
  2V – 5.5V, 750 mA
- MTD6505
  2V – 5V, 750 mA
  Adj. km
- MTD6508
  2V – 5V, 750 mA
  Adj. Start-Up

H-Bridge Motor MOSFET Gate Driver

- ATA6823C
  7V – 21V,
  40V Load Dump
  TJ=150°C
  LDO, WWD, LIN
- ATA6824C
  7V – 21V,
  40V Load Dump
  TJ=200°C
  LDO, WWD, SIO

3-phase Brushless Motor MOSFET Gate Driver

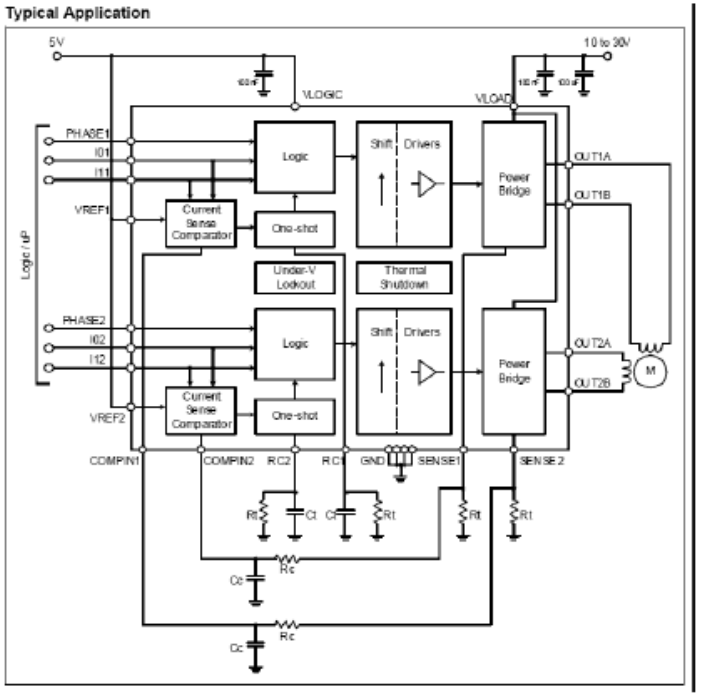
- MCP8024
  6V – 28V, 48V Load Dump
  Op-Amp & Vreg
- MCP8025
  6V –19V, 48V Load Dump
  Op-Amp x 1 & Vreg
- MCP8026
  6V – 28V, 48V Load Dump
  Op-Amp x 3 & Vreg

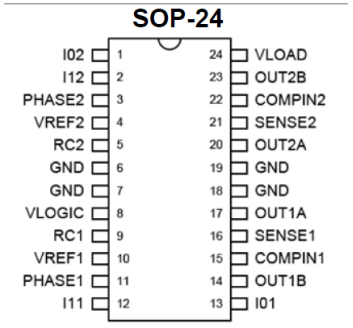
For Automotive

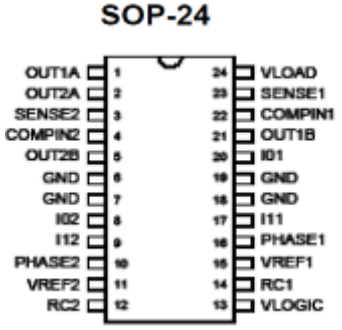
MTS62C19A/MTS2916A
Motor Driver

Features:

- Able to drive both windings of a bipolar stepper motor
- Load voltage supply range: 10V to 40V
- Output current up to 750 mA (each bridge)
- Internal fixed Toff time PWM current control
- Built-in protection diodes
- Internal thermal shutdown
- Under-voltage lockout
- LS-TTL compatible logic inputs with pull up resistors
- Low ron output resistance
- Low quiescent current



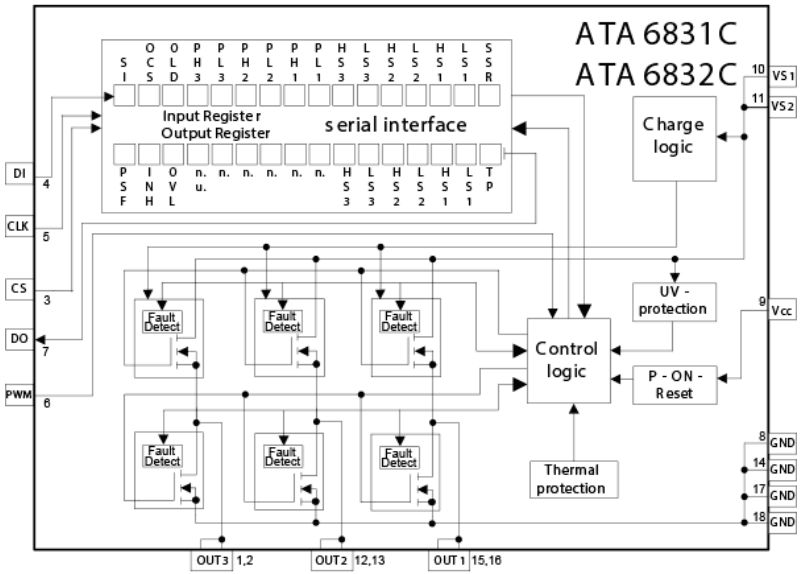


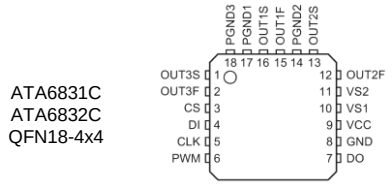


ATA6831C/32C
Motor Driver

Features:

- Three half-bridge outputs
- Typical loads DC motors, relays, etc
- PWM capability up to 25 kHz
- Supply voltage up to 40V
- R_{DSon} typically 0.8Ω, maximum 1.5Ω at 150°C
- ATA6832C: High temperature, max at 200°C, R_{DSon} maximum 1.8Ω at 200°C
- Up to 1.0A output current
- No shoot-through current
- Quiescent current I_{VS} < 2 µA
- Outputs short-circuit protected
- Over-temperature protection and pre-warning for each switch
- Under-voltage protection
- Diagnostic: short circuit, open load, over-temperature and power-supply fail detection
- SPI, daisy chain capable, up to 2 MHz clock frequency
- QFN18 package





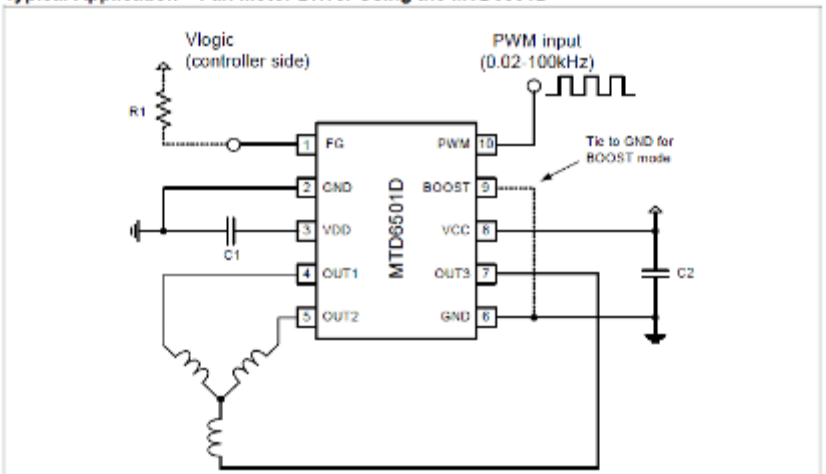
ATA6831C
ATA6832C
QFN18-4x4

MTD6501C/D/G
Motor Driver

Features:

- Position sensorless BLDC drivers (no Hall sensor required)
- 180° sinusoidal drive, for high efficiency and low acoustic noise
- Support 2V to 14V power supplies
- Speed control through PAM and/or PWM
- Built-in frequency generator
- Built-in lockup protection and automatic recovery circuit (external capacitor not necessary)
- Built-in over current limitation and short circuit protection
- Built-in thermal shutdown protection
- No external tuning required
- Boost Mode (Optional BEMF Pre-Amplification in MTD6501D)
- 20 kHz (MTD6501C/D), 23 kHz (MTD6501G)

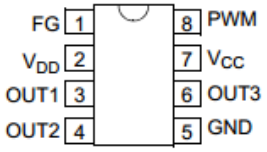
Typical Application – Fan Motor Driver Using the MTD6501D



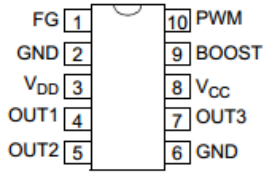
Recommended External Components for Typical Application

Element	Type/Value	Comment
C1	≥1 µF	Connect as close as possible to IC input pins
C2	≥1 µF	Connect as close as possible to IC input pins
R1	≥10 kΩ	Connect to Vlogic on controller side

MTD6501C, MTD6501G
SOP-8



MTD6501D
MSOP

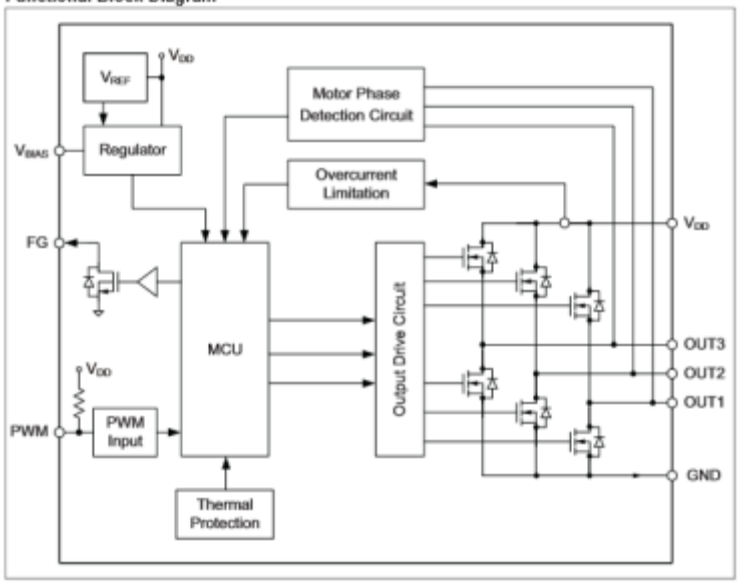


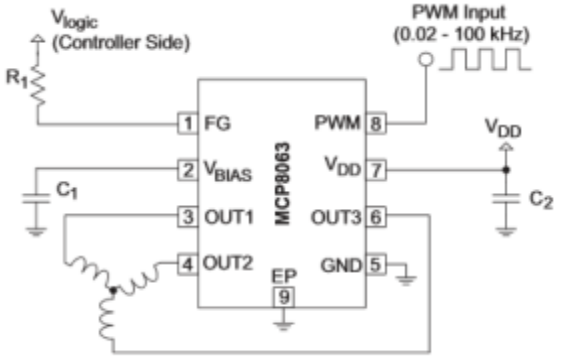
MCP8063
Motor Driver

Features:

- Automotive AEC-Q100 qualified
- Position sensorless BLDC drivers **(no Hall sensor required)**
- 23 kHz PWM output frequency
- 180° **s**inusoidal **d**rive, for high efficiency and low acoustic noise
- Support 2V to 14V power supplies
- Speed control through power supply and/or PWM
- Built-in 1.5A over current limitation
- Built-in frequency generator (FG Output Signal)
- Built-in lock-up protection and automatic recovery circuit
- Built-in thermal shutdown protection
- No external tuning required
- 8-pin 4x4 DFN
- Extended temperature range: -40 to +125°C

Functional Block Diagram

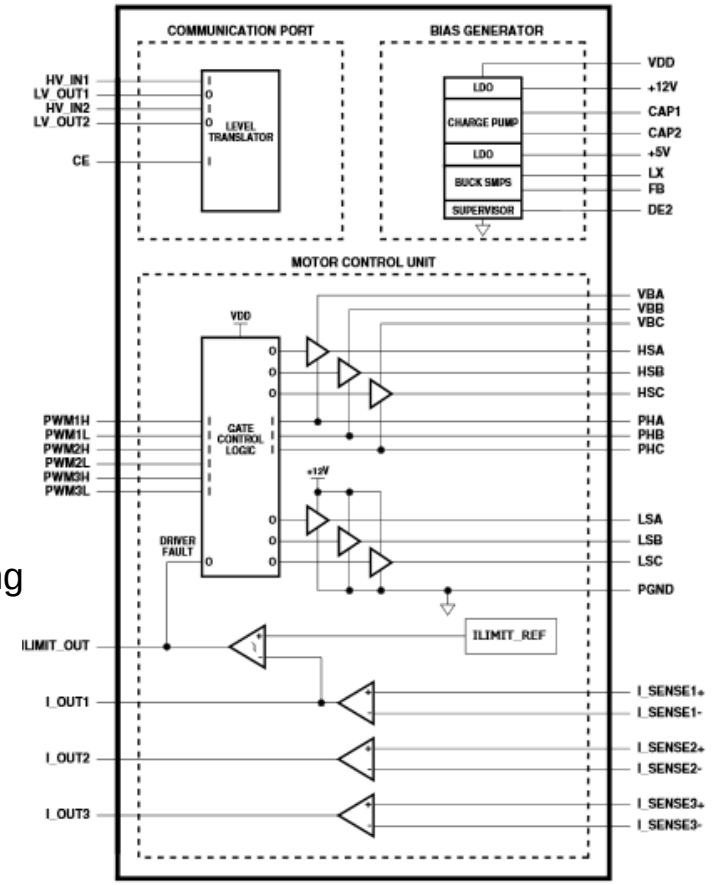




MCP8026
Motor Driver

Features:

- Three Half-bridge Drivers Configured to Drive External High-Side NMOS and Low-Side NMOS MOSFETs:
- Independent input control for high-side NMOS and low-side NMOS MOSFETs
- Peak output current: 0.5A @ 12V
- Shoot-through protection
- Overcurrent and short circuit protection
- Adjustable Output Buck Regulator (750 mW)
- Two LDOs: 5V @ 30 mA / 12V @ 30 mA
- Internal Bandgap Reference
- Buck Regulator Under voltage Lockout: 4.0V
- Three Operational Amplifiers for Motor Phase Current Monitoring and Position Detection
- Overcurrent Comparator and Thermal Shutdown
- Two Level Translators
- Operational Voltage Range: 6 - 28V
- Under voltage Lockout (UVLO): 5.5V
- Over voltage Lockout (OVLO): 32V
- Transient (100 ms) Voltage Tolerance: 48V
- Temperature Range: -40 to +150°C



Application notes and Tuning Guide

Application Notes

Motor Type	Application Note	Descriptions
Stepper Motor	AN907	Stepper Motor Fundamentals
	AN1307	Stepper Motor Control with the dsPIC®
Brushed DC Motor	AN905	Brushed DC Motor Fundamentals
BLDC and PMSM	AN957	Sensored Control of BLDC Motor using dsPIC30F2010
	AN1017	Sinusoidal Control of PMSM Motors with dsPIC30F
	AN1160	Sensorless BLDC Control with Back-EMF Filtering Using a Majority Function
	AN1292	Dual Shunt Sensorless FOC PSMS PLL Field Weakening
AC Induction Motor	AN887	AC Induction Motor Fundamentals
	AN908	Using the dsPIC30F for Vector Control of an ACIM
	AN1206	Field Weakening Sensorless FOC for ACIM
Other	AN1106	Power Factor Correction on dsPIC® DSC
	AN1229	Meeting IEC 60730 Class B Compliance with dsPIC DSC

- **Full source code included**
- **Royalty/license free**
- **Optimized performance**
- **Dynamometer tested**
- **Step-by-step tuning guides**
- **More application notes**

Tuning Guides

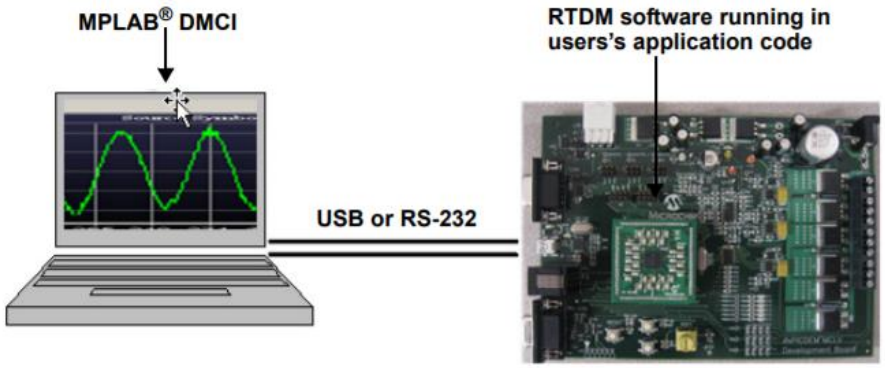
- **Various tuning guides according to application note**
  - Tuning guide is provided with source code as excel
  - Tuning guide is easy to tune the term of source code
  - Just change the parameter according to your condition

Stepper Motor Control	
AN1307	Stepper Motor Control
BLDC	
AN1160	Sensorless BLDC Control with BEMF Filtering Using a Majority Function
BLDC and PMSM	
AN1078	Sensorless Dual-Shunt FOC with SMO Estimator
AN1292	Sensorless Dual-Shunt FOC with PLL Estimator
AN1299	Sensorless Single-Shunt FOC with SMO Estimator

Development Tools

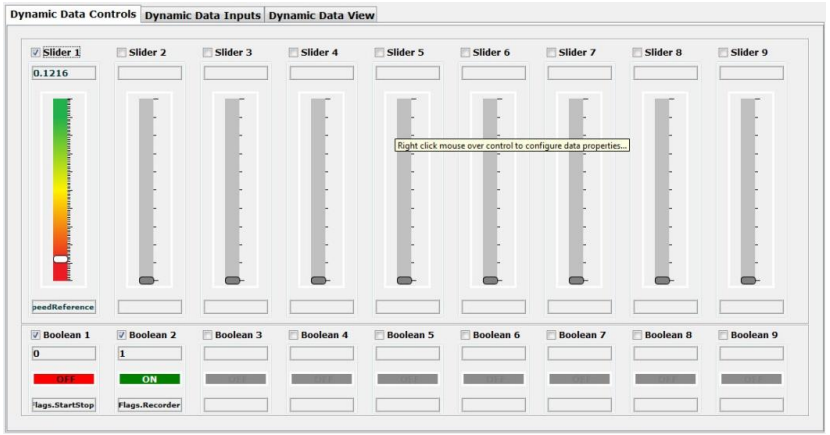
Real-Time Data Monitoring (RTDM)

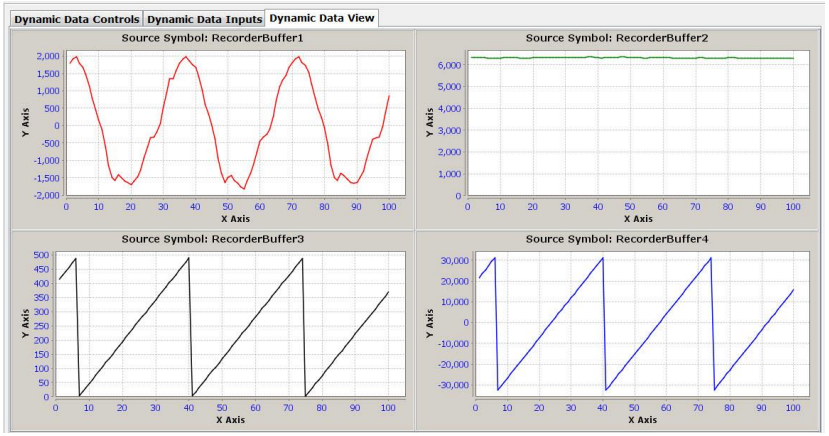
- **Real-Time Data Monitoring (RTDM)**
  - Software to monitor the status of motor using Data Monitor and Control Interface (DMCI)
  - Provides dynamic access to control monitor software variables without halting program execution
  - Uses the RS-232 standard protocol

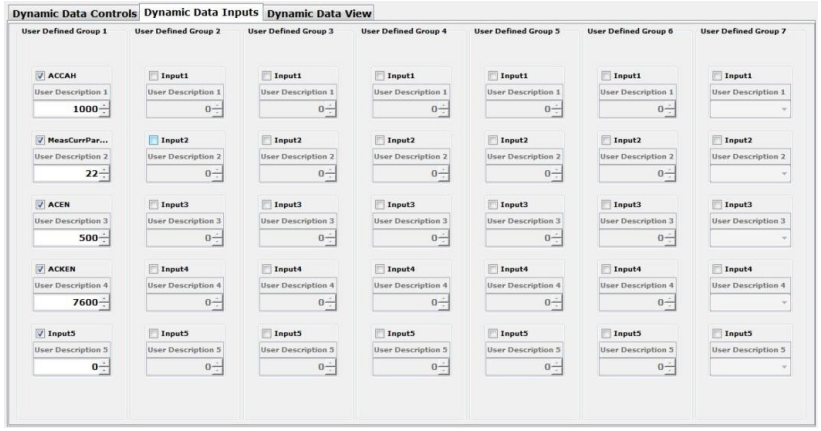


Data Monitor and Control Interface (DMCI)

- **Dynamic Data Control**
  - 9 slider controls
  - 9 boolean (on/off) controls
- **Dynamic Data Input**
  - 35 input controls (7 groups of 5)
- **Dynamic Data View**
  - 4 graphics





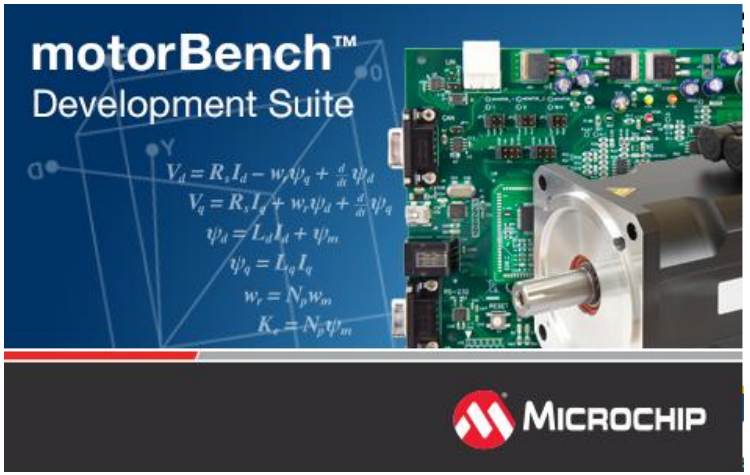


motorBench™ Development Suite

- **Description:**
  - Help motor control embedded engineers to design easily
  - Easy to utilize with advanced GUI-base
  - Automatically generate sensorless FOC code
  - Self-commissioning to measure the motor parameter and tune the gain of motor control algorithm

- **Key Features:**
  - Measures motor parameters
  - Automatic tuning of motor control algorithm
  - Generates code for MPLAB® X project
    - With Motor Control Application Framework (MCAF)
  - Works as an MPLAB X plug-in
    - Installation from within MPLAB X

- **Works with Software Development Tools:**
  - MPLAB X IDE



- **Supports:**
  - dsPIC33E Product Family
  - MCLV-2 Development Board
  - AC300022 - 24V 3-Phase BLDC Motor w/Encoder

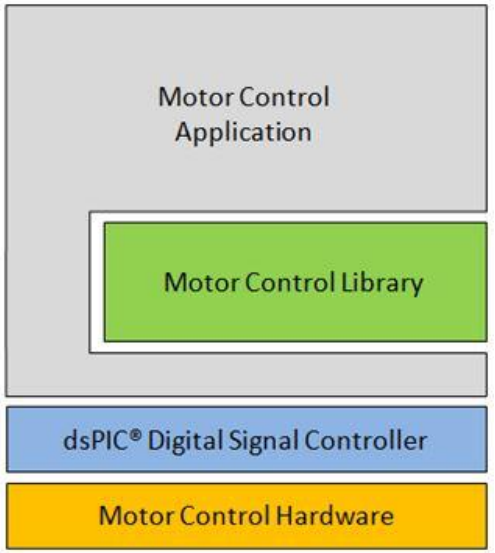
- **Pricing:**
  Free with registration

- **Product Info:**
  www.microchip.com/motorbench

Motor Control Library

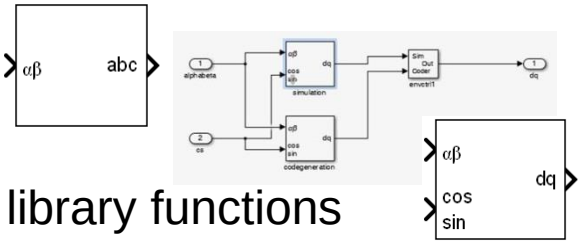
Motor Control Library

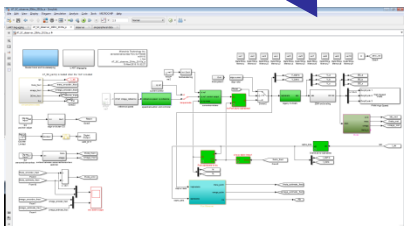
- Collection of optimized functions for 3-phase motor control applications
- Function blocks that are optimized for dsPIC33F and dsPIC33E
- Two implementation variants:
  - ***C-functions*** are declared with static and inline keywords
  - ***Assembly*** - functions are defined in a C-callable archive file

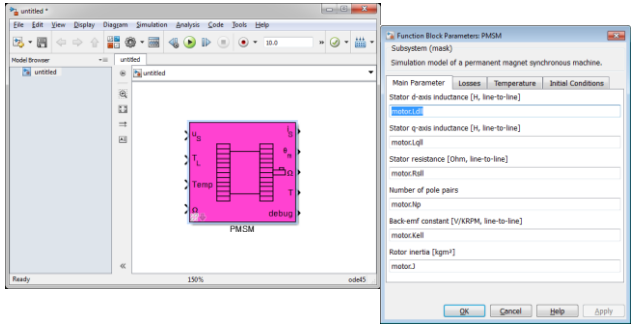


Motor Control Simulation & Code Generation

- **Simulink® Blocksets**
  - Motor Control Library Blocks
    - Very accurate simulation of motor control library functions
  - Simulink implementation of PMSM Sensorless FOC, AN1078
  - dsPIC® Optimized Code Generation
    - Code generated based on motor control library functions
    - Peripheral blocks for code generation only
- **Motor Models – MATLAB®/Simulink**
  - PMSM currently available







Motor Control Development Boards

- **Motor Control Starter Kit**
  - Sensorless BLDC
  - Includes BLDC motor
  - Integrated programmer/debugger
- **Low Voltage Development Board**
  - Low voltage output, 48V/15A
  - Single motor control with sensor input
  - CAN, LIN and UART ports
  - Compatible with all motor control PIMs
- **High Voltage Development Board**
  - 85 - 265 VAC input, 1000 Watt 400 V output
  - Power Factor Correction circuitry
  - Single motor control with sensor input
  - Isolated USB, UART, and programmer/debugger
  - Backwards compatible with previous MCHV-2 and all motor control PIMs

Motor Control Starter Kit with mTouch Sensing (Part Number: DM330015)

dsPICDEM™ MCLV-2 Development Board (Part Number: DM330021-2)

dsPICDEM MCHV-3 Development Board (Part Number: DM330023-3)

Dual Motor Control Development Board

- **Modular design**
  - Separate control and power boards
  - Allows for customer developed power boards
- **Power board supports dual motor drive**
- **Ships with dsPIC33EP512GM710 PIM**
- **dsPIC33EV256GM106 PIM available for *5V* product family**
- **PIC32MK PIM**

(Part number: DV330100)

Low Power High Voltage Reference Design

- **For BLDC motor, PMSM or ACIM**
- **110/230V AC input**
- **150W inverter stage**
  - Better efficiency than MCHV-2 for low wattage applications
- **Support for sensorless FOC**
  - Wind milling
  - Initial position detect
- **Available through tools loan program**
  - Contact local sales or marketing team

(Part number: LPHV-MC-BOARD)

- **Lean more: LPHV Reference Design**

Summary

Summary

Microchip offers many motor control solutions

- **Products**
  - MCU, DSC, Motor Drivers
- **Development Tools**
  - Application notes {including source code}, tuning guides
  - RTDM, DMCI, motorBench™ Development Suite, Motor Control Library and Simulink®
  - Development Boards: dsPICDEM™ MCLV-2, MCHV-3, Motor Control Starter Kit, Dual Motor Control EVB, Low Power High Voltage EVB

Thank you!