Industrial Motor Control Roadmap (Part 1)

AZ116

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Agenda

► Industrial motor control market
  • Target applications
  • Market trends
  • Freescale alignment with trends

► Industrial motor control solutions
  • Generic applications
  • Freescale motor control processors
  • Application examples
    ▪ Universal, stepper, BLDC, ACIM, PMSM, sensorless switch reluctance

► Motor control tools and enablement
Industrial Motor Control Target Applications

- Pumps and fans – pool pumps, factory systems
- HVAC – heating fans, air-conditioners
- Industrial drives – manufacturing assembly, robotics, wind turbines, printing presses
- Appliances – washers, dryers, power tools
- Medical – scanners, pumps, diagnostic and therapy equipment
# Industrial Motor Control – Market Trends

<table>
<thead>
<tr>
<th>Market Trend</th>
<th>Customer Requirements</th>
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<tbody>
<tr>
<td>Reduce power consumption</td>
<td>► Intelligent motor control improves efficiency by 30% or more</td>
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<td>► Implement variable speed motor control with inverter-based drive systems</td>
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<td>► Smarter systems to sense environment and react in real time</td>
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<td>Reduce system and development cost</td>
<td>► More on-chip peripherals to reduce component count</td>
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<td>► Libraries and reference designs for common functions</td>
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<td>► Expert customer support</td>
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<td>Reuse software, hardware and tools across platforms</td>
<td>► Support multiple motor types with one unified platform</td>
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<td></td>
<td>► Ease software migration across wide performance range</td>
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<td>► Tools to develop increasingly complex algorithms</td>
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<td>Cost-effective safety, reliability and security</td>
<td>► IEC regulatory approval requires single-bit failure detection</td>
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<td>► On-chip protection against IP cloning and network data hacking</td>
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<td>► Easier product certification to meet safety standards</td>
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## Industrial Motor Control – Freescale Alignment with Trends

<table>
<thead>
<tr>
<th>Market Trend</th>
<th>Freescale Alignment with Customer Requirements</th>
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<tbody>
<tr>
<td>Reduce power consumption</td>
<td>► Vector and sensorless control technology designed into every motor control processor</td>
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</table>
| Reduce system and development cost  | ► 8- and 16-bit MCUs start at <$0.70  
|                                     | ► 16-bit DSCs for ACIM and PMSM solutions  
|                                     | ► 32-bit Power Architecture MCUs for standard/premium drives                                                  |
| Reuse software, hardware, and tools | ► Rich tools, training, reference designs and libraries  
| across platforms                     | ► Devices are ruggedized with long life and reliability  
|                                     | ► Industrial products ship 10+ years, with high quality and expert customer support                       |
| Cost-effective safety, reliability  | ► Secure SRAM, on-chip data fusing to protect against IP cloning  
| and security                         | ► Hardware encryption to protect against network data hacking  
|                                     | ► Watchdog and ECC protection against soft errors  
|                                     | ► Certified IEC software modules                                                                           |
Industrial Motor Control Solutions

Generic Applications
Key Elements of Generic Drive Control

Motor control (DSC, DSP, FPGA)
Real-time motor control
- Start, stop, speed-up, slow-down
- Detect problems with motor
- PID loop

Application (MPU, MCU, FPGA)
Control algorithm
- Position elevators
- Coordinate motion in conveyors
- Decide what happens next

Input and output (I/O)
- Communications
  - Fieldbus, Ethernet, CAN
- Human interfaces
  - LED, LCD, keypad, HMI
- Sensor inputs
  - Temperature, current, position

Could be a one-chip or a two-chip solution

Monitor, configure, or run diagnostics
Fieldbus or Ethernet link to HMI, higher-level control or factory network
Basic compact AC drive (large fan, conveyor, simple pump):

- Combine motor control and I/O on one DSP/DSC or MCU with on-chip flash
- Simple or no application algorithm with minimal I/O and no operating system
- Hardware security to prevent application software cloning
- Optional sensors, network or fieldbus interfaces, keypad and display require galvanic isolation
Compact AC drive (material handling, factory machine control):

- Motor control on DSP/DSC and basic I/O on separate MCU with on-chip flash
- Simple or no application algorithm with minimal I/O and no operating system
- Hardware security to prevent application software cloning
- Optional sensors, network or fieldbus interfaces, keypad and display require galvanic isolation
Standard or premium AC drive (elevator, paper mill):

- Isolate motor control on DSP/DSC from application and I/O on separate MCU
- Application processor CPU performance 200 to 1500+ MIPS with optional external flash and/or RAM
- Might support multiple motor controllers
- Wide range of I/O -fieldbus or CAN migrating to Industrial Ethernet
Industrial Motor Control Solutions

Freescale Motor Control Processors
Typical Motor Control MCU Peripheral Functions

► Timer:
  • PWM signals < 20Khz
  • Dead time insertion
  • Commutation (mask-out)
  • ADC triggering
  • Fault control

► ADC
  • Measure current

► Delay block
  • Set ADC measurement at specific times

► Position decoder
  • Quadrature decoder inputs if not sensorless
Choosing your MCU therefore depends upon …

► The same application may perform differently if implemented on different MCUs

► Peripheral features can significantly impact target application performance, not just CPU

► Application features should be considered
  • Type of motor
  • Type of load
  • Operational mode
  • Minimal speed
  • Maximal speed
  • Current control
  • Speed control and/or position control
  • Number of PID controllers
  • Fault control
  • System Cost!
Key Differentiators for MC56F8006/2 DSC

► Cost-optimized solution for mathematically-intensive, power-sensitive real-time control applications

► Highest DSC performance per dollar
  • Dual Harvard Architecture + MAC and high operating frequency enable outstanding performance in single-cycle multiply-accumulate for filters and real-time feedback calculations

► Lowest DSC power stop modes in the market

► Twice the operating frequency of competitive DSCs
  • 96 MHz for key peripherals (timers, SCI, PWM)

► More resolution and channels
  • 2x high speed 12-bit x 24 channel ADC module with integrated temperature sensor

► Three analog comparators – more than any similar offering

► Programmable gain amplifier increases ADC input dynamic range
  • Shielded inputs in ADC reduce noise in conversion
**Features**
- Low power stop modes
- Up to 96 MHz for peripherals – timers, PWM & SCI
- 6 output PWM module with up to 4 programmable fault inputs
- Two wideband clocked programmable gain amplifiers
- 10/12-bit conversion done in 3.03 μs @32 MHz SysClk (8-bit conversion done in 2.65 μs @32 MHz SysClk)
- **Up to three analog comparators**
- Custom timer for precise control of ADC/PGA sample times relative to PWM reload cycles
- Two multiple-function programmable timers
- One periodic interval timer (PIT)
- Computer operating properly (COP) timer
- One serial communications interface (SCI)
- One serial peripheral interface (SPI)
- I^2^C communications interface
- Up to 40 GPIOs – versatile pin usage
- JTAG/EOnCE debug port

**Core**
32 MHz/32 MIPS 56F800E core
1.8V to 3.6V operating range

**Memory**
Up to 16 KB flash with flash security, 2 KB SRAM

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**MC 56F8006/2 Family**

- **Core**
  - 32 MHz/32 MIPS 56F800E core
  - 1.8V to 3.6V operating range

- **Memory**
  - Up to 16 KB flash with flash security, 2 KB SRAM

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**Memory Options**

- 2 KB SRAM
- 16 KB Flash
- 2 KB SRAM
- 12 KB Flash

- 3 Analog Comparators
- Power SuperVisor
- 2x 16-bit Timers

- Two 2X-16X Wideband PGAs
- COP
- 1x 16-bit Periodic Interval Timer

- Flash/RAM
- High Speed SCI
- 2x 12-bit ADCs

- Voltage Regulators
- SPI
- Programmable Delay Block (PDB)

- Interrupt Controller
- I^2^C
- 6 Output PWM

- System Integration Module (SIM)
- System Clock Control (PLL, SIM, Osc)

- 56800E Core/32MIPS
- JTAG/EOnCE™
Industrial Motor Control Solutions

Application Examples
Many Different Motor Types …

- DC motor
- Brushless DC motor
- Stepper motor (half step)
- Stepper motor (full step)
- AC induction motor
- Permanent magnet synchronous motor (PMSM)
- Switched reluctance motor
Universal Motor

Recommended devices

- 8-bit MCU:
  - MC9RS08KA
  - MC9S08SH
  - MC9S08AC
  - MC9S08QD
  - MC9S08QE

Applications

- Small kitchen appliances, e.g. food mixers, blenders
- Power tools
- Fans and simple pumps
**Recommended devices**

► Full and half-step function:
  - 8-bit: MC9RS08KA, MC9S08QD, MC9S08QE, MC9S08SH, MC9S08AC
  - MCF51QE ColdFire® MCU
  - MM908E625/626
  - Dual H-bridge motor driver IC: MPC17C724, MPC17530, MPC17550

► Micro-step function:
  - DSC: MC56F80xx
  - ColdFire MCU: MCF51AC256
  - MC9S12XH
  - Dual H-bridge motor driver IC: MPC17C724, MPC17530, MPC17550
  - Gauge drivers: MC33970/976/977
  - Field-effect transistor (FET) driver: MC33937

**Applications**

► Printers
► Instrumentation
► Medical pumps and scanners
► Simple robotics and positioning
Recommended devices

- Hall sensors (commutated) function:
  - 8-bit: MC9S08AW and MC9S08AC

- Sensorless function:
  - DSC: MC56F8006, MC56F8013, MC56F8037, MC56F8025 (MC56F83xx for servo)
  - ColdFire 32-bit: MCF5234 with 16-channel enhanced time processing unit (eTPU)
  - Dual H-bridge (12V): MC33932
  - FET driver: MC33937

Applications

- Fans and pumps
- HVAC, compressors, blowers
- Computer disk drives and peripherals
- Robotics, traction control, servo systems
- Office equipment, sewing machines, treadmills
AC Induction Motor (ACIM)

Recommended devices
► DSC: MC56F8006
  MC56F8013
  MC56F8037
  MC56F8025
  MC56F83xx
► ColdFire 32-bit MCU:
  MCF51AC256
  MCF5234 with eTPU
► Power Architecture®
  32-bit MCU:
  MPC5604P

Applications
► Large appliance, e.g. washer, dryer
► HVAC, blowers
► Fan, pumps
► Industrial lifts, cranes, elevators, conveyors
Permanent Magnet Synchronous Motor (PMSM)

Recommended devices
- DSC: MC56F8006
  - MC56F8013
  - MC56F8037
  - MC56F8025
  - MC56F83xx
- ColdFire 32-bit MCU:
  - MCF51AC256
  - MCF5234 with eTPU
- Power Architecture 32-bit MCU: MPC5604P

Applications
- Large appliances, e.g. washer, dryer
- HVAC, blowers, fan, pumps
- Industrial lifts, cranes, elevators, conveyors
- Robotics, industrial motion control
- Elevators, servo drivers, traction systems, automotive
Sensorless Switched Reluctance Motor Drive

Recommended devices
- DSC: MC56F8006
- MC56F8013
- MC56F8037
- MC56F8025
- MC56F83xx

Applications
- Vacuum cleaners, food processors, appliances
- High-speed power tools
- Industrial machines, medical scanners
- Computers, office equipment
Industrial Motor Control

Tools and Enablement
Development Tools to Speed Time-to-Market

► Demo Boards

**MC 56F8006DEMO**

$49 MSRP

**MC 56F8006DEMO-T**

(USB Tap included)

$99 MSRP

► CodeWarrior™ Development Studio for 56800/E Digital Signal Controllers

- Enables designers to build and deploy sophisticated DSC systems quickly and easily
- IDE with optimizing C compiler, extensive SW libraries built into IDE
- Processor Expert with free drivers and libraries
- Instruction-set simulation
- Free Special Edition with up to 32 KB code size [CWX-568-SE]

► FreeMASTER - remote real-time control and monitoring tool

► Accessories

- USB Tap - JTAG to USB adaptor (CWH-UTP-ONCE-HE)
- Motor control socket board (APMOTOR56F8000E)
- Includes ultra-small 3-phase BLDC motor
- MC56F80xx socket board (CPA56F8013)
Build things faster using Processor Expert

A rapid application design tool with …

► Graphical user interface that allows an application to be specified by the functionality needed
► Automatic code generator that creates tested, optimized C code tuned to the application needs and selected Freescale MCU
► Built-in knowledgebase that immediately flags resource conflicts and incorrect settings

Creating…

► Hardware abstraction layer (HAL) – hardware-dependent, low-level drivers with a known application programming interface (API)

Benefits

► Eases migration between Freescale devices
► Designers don’t have to be intimately familiar with every page of a specification
► Errors are caught early in design cycle; therefore designers get to market faster with higher quality product

Motor control library with Embedded Beans

► Embedded Beans easily incorporate software components of Freescale’s motor control library
► The Freescale motor control library includes
  • Transcendental functions
  • PID controllers
  • Clark and Park transform and inverse transforms
  • Algorithmic support for space vector modulation, and more..
► Embedded Bean Store is now available at http://www.freescale.com/BeanStore
FreeMASTER Interface

Application control and monitor

Live graphs, variable watches, and graphical control page

Real-time eTPU operation monitor
Low Cost BLDC Motor Control Demo Board

- Brushless motor, Maxon EC-200187, 6W 9V
- Motor interface connector
- Input power connector
- Daughter card connector for connecting the 56F8013 demonstration board
- LED power indicator
- Motor bus voltage sense logic
- Motor bus current sense logic
- Back EMF phase voltage sense logic
- Zero-crossing logic
- Hall-effect/zero-crossing selector
- 3-phase H-bridge power stage
- Power regulation logic
- (Optional) Five on-board real-time user debugging LEDs

Order Number: APMOTOR56F8000
BLDC Control Using MC56F8013

- 3-phase brushless DC motor sensorless drive
- Designed to fit into fan, pump and compressor applications
- Using MC56F8013 32 MIPS hybrid controller
- Available for two power stages and two motors
- Input power supply voltage +12 Vdc for power stages
- Control technique incorporates:
  - Sensorless, trapezoidal control of 3-phase brushless DC motor with back-EMF sensing
  - Using A/D converter zero-cross sensing for sensorless control
  - Speed and current closed loop with PI controller
- Speed range: 200 – 2000 and 500 – 5000 RPM (depending on the motor used)
- Manual interface (run/stop switch, up/down pushbuttons)
BLDC Control Using MC56F8013 (Continued)

- FreeMASTER interface for monitoring, control and tuning
- Fault protection (DC-bus over-current, DC-bus under-voltage, DC-bus over-voltage)
- Automatic calibration of phase back-EMF measurements
- Easy to tune for different power stages and motors

Applications

- Compressors
- Fans
- Pumps
- Washing machines
- Automotive drives
- Industrial drives
- Air conditioning units
- Appliances

3-phase power stage
DC motor
UNI-3 motor control interface
FreeMASTER connection
DSC 56F8013
56F8013 motor control board

DRM070
<table>
<thead>
<tr>
<th>Type</th>
<th>Title</th>
<th>Weblink</th>
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<tr>
<td>Demo</td>
<td>MC56F8006DEMO; MC56F8006DEMO-T (includes USB Tap)</td>
<td><a href="http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=DEMO56F8013&amp;parentCode=56F8013&amp;nodeId=01624686366292&amp;tid=t16hft">http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=DEMO56F8013&amp;parentCode=56F8013&amp;nodeId=01624686366292&amp;tid=t16hft</a></td>
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<td>DEMO56F8013-EE DSC development platform</td>
<td><a href="http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=APMOTOR56F8000&amp;parentCode=56F8000&amp;nodeId=01624686366292">http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=APMOTOR56F8000&amp;parentCode=56F8000&amp;nodeId=01624686366292</a></td>
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<td>APMOTOR56F8000 motor control demo</td>
<td><a href="http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=APMOTOR56F8000&amp;parentCode=56F8000&amp;nodeId=01624686366292">http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=APMOTOR56F8000&amp;parentCode=56F8000&amp;nodeId=01624686366292</a></td>
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<tr>
<td>Reference Design</td>
<td>Reference Designs page, lists &gt; 20 reference designs</td>
<td><a href="http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02nQXGzm8L&amp;tid=tMCdrRD">http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02nQXGzm8L&amp;tid=tMCdrRD</a></td>
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<td>3-Phase PM Synchronous Motor Torque Vector Control Using 56F80X or 56F8300 Digital Signal Controllers</td>
<td><a href="http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=RDSP56F8SMTVC&amp;nodeId=016246fNrg1P4YnQXGrrlPgzQMszYj6MJ">http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=RDSP56F8SMTVC&amp;nodeId=016246fNrg1P4YnQXGrrlPgzQMszYj6MJ</a></td>
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<td>QuickStart Initialization and Development Tool (MC56F80xx, MPC55xx)</td>
<td><a href="http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=DSP56800EQUICKSTART&amp;nodeId=016246fNrg1P4YnQXGrrlPgzQMszYj6MJ">http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=DSP56800EQUICKSTART&amp;nodeId=016246fNrg1P4YnQXGrrlPgzQMszYj6MJ</a></td>
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<td>eTPU Graphical Configuration Tool (MCF523x, MPC55xx)</td>
<td><a href="http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=ETPUGRAPHICAL&amp;fpsp=1">http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=ETPUGRAPHICAL&amp;fpsp=1</a></td>
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<td>3rd Party Solution</td>
<td>IXXAT (IEEE 1588, CANopen, POWERLINK)</td>
<td><a href="http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02nQXGzm8L&amp;tid=tMCdrRD">http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02nQXGzm8L&amp;tid=tMCdrRD</a></td>
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<td>Real-Time Automation (Modbus TCP, EtherNet/IP, DeviceNet)</td>
<td><a href="http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02nQXGzm8L&amp;tid=tMCdrRD">http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02nQXGzm8L&amp;tid=tMCdrRD</a></td>
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<td>National Semiconductor (Precision PHYTER - 10/100 Ethernet PHY for IEEE 1588)</td>
<td><a href="http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02nQXGzm8L&amp;tid=tMCdrRD">http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02nQXGzm8L&amp;tid=tMCdrRD</a></td>
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Enablement for Factory Automation – Industrial AC Drives

www.freescale.com/motorcontrol
Freescale:

► Motor Control Homepage – www.freescale.com/motorcontrol
► 8-bit Microcontrollers – www.freescale.com/8bit
► 16-bit DSC – www.freescale.com/dsc
► 16-bit Microcontrollers – www.freescale.com/16bit
► 32-bit ColdFire Microcontrollers – www.freescale.com/coldfire
► Analog Products – www.freescale.com/analog
► Connectivity – www.freescale.com/connectivity
► Industrial Segment – www.freescale.com/industrial
The embedded market needs long-term product support, which allows OEMs to provide assurance to their customers.

Freescale has a longstanding track record of providing long-term production support for our products.

Freescale is pleased to introduce a formal product longevity program for the market segments we serve.

- For the automotive and medical segments, Freescale will manufacture select devices for a minimum period of 15 years.
- For all other market segments in which Freescale participates, Freescale will manufacture select devices for a minimum period of 10 years.

A list of applicable Freescale products is available at www.freescale.com.
Summary

► Cutting Edge. Cost Effective. Complete. Freescale offers technology for every motor control application

► Energy efficient motor control
   Vector and sensorless control technology in motor control processors
   8- and 16-bit MCUs start at <$0.70
   16-bit DSCs for ACIM and PMSM solutions
   32-bit Power Architecture MCUs for standard and premium drives

► Strong technical support
   Rich tools, training, reference designs, libraries
   Devices are ruggedized with long life and reliability
   Industrial products ship 10+ years with high quality and expert support

► Cost-effective safety and security on-chip
   Protect against IP cloning, network data hacking and soft errors
Thank you for attending this presentation. We’ll now take a few moments for the audience’s questions and then we’ll begin the question and answer session.