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Freescale Solutions for Motor Control Technologies

Comprehensive 8-, 16- and 32-bit systems with advanced sensor and analog/mixed signal devices

Freescale offers complete solutions for every motor control application. Our superior portfolio and breadth of devices includes:
- 8-bit microcontrollers (MCUs)
- 16-bit digital signal controllers (DSCs)
- 32-bit embedded controllers
- Acceleration and pressure sensors
- Analog and mixed signal devices

Freescale delivers solutions that have wide ranging banks of flash and RAM memories, configurable timer options, pulse width modulators (PWMs), and some even offer an enhanced Time Processing Unit (eTPU).

Freescale supports these devices with motor control-related application notes, hardware/software tools, drivers, algorithms and helpful Web links including our motor control Web site at www.freescale.com/motorcontrol.

Freescale provides microcontrollers and development tool solutions for all of your motor control needs.

A Roadmap for Your Future Design Needs

Intelligent solutions driving new generations of motor control applications

Freescale MCUs, MPUs and DSCs, when coupled with analog/mixed-signal and power integrated circuits, are designed to provide system solutions for motor control, motion control and static load control for an incredible variety of applications.

The product roadmaps demonstrate that new feature integration and software compatibility will continue to drive future generations of embedded motor control solutions.
### Motor Control Applications

#### Motor type/control solution matrix

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**Technology/Application Match:**
- **Good**
- **Moderate**
- **Poor**

*Note: There are numerous possibilities of matches between a technology and an application other than what is shown in this table. This is intended to be a high-level guide, but it is not all-inclusive.*

### The Broadest Selection of Motor Control Solutions

When designing motor control systems, instruction set efficiency and sophisticated peripherals that are specifically tuned for electric motor control environments provide the greatest performance advantages. Freescale provides comprehensive motor control solutions for virtually all electric motor topologies. In the following pages we feature recommended devices—from 8-, 16- and 32-bit embedded processors to analog/mixed signal power ICs—as well as demonstration boards and reference designs for each electric motor system listed at right. Freescale has an extremely broad selection of embedded controller solutions for motor control applications. We give you the option to choose the system components that meet your specific electronic motor design needs.

#### Stepper Motor
Stepper motors are used to produce incremental, noncontinuous motion, and are used primarily for precise position control. Stepper motor application examples and information can be found on pages 6, 7 and 8 of this brochure.

#### Brushed DC Motor
Permanent magnet DC motor with rotor windings connected via “brushes” to a mechanical commutator. Brushed DC motor application examples and information can be found on page 9.

#### Brushless DC Motor (BLDC)
BLDC motors have a classic three-phase stator and a rotor with surface-mounted permanent magnets, and are driven by electronically switching the stator winding connections with a rectangular waveform in accordance with rotor position. BLDC application examples and information can be found on pages 10, 11 and 12.

#### AC Induction Motor (ACIM)
AC induction motors have a classic three-phase stator, and commonly have a “squirrel cage” rotor in which the conductors are shorted together at both ends. ACIM application examples and information can be found on pages 13, 14 and 15.

#### Permanent Magnet Synchronous Motor (PMSM)
Similar to BLDC motors, permanent magnet synchronous motors have a classic three-phase stator and a rotor with surface-mounted permanent magnets. The construction differs from BLDC motors in they are driven by electronically switching the stator winding connections with a sinusoidal waveform in accordance with rotor position. PMSM application examples and information can be found on pages 16, 17, and 18.

#### Switched Reluctance Motor
SR motors contain no magnets (mainly stamped metal elements), and are constructed such that both the stator and rotor have salient poles. The motor is driven by a sequence of current pulses applied at each phase, which requires control electronics for operation. SR motor application examples and information can be found on page 19.
Stepper Motors
General purpose stepper motor control

Advantages
• Precise position control

Applications
• Industrial machines
• Health care scanners
• Computers
• Office equipment
• Toys

Recommendations Devices
8-bit MCU: 9S08JK, 9S08MR, 9S08QT/QU, 9S08EB, 9S08RC, 9S08PR, 9S08AW, 9S08R6, 9S08RD, 9S08QP
16-bit DSC: MC68F80x, MC68F80xx, MC68F83xx
32-bit MCU: MC68F80x, MC68F80xx, MC68F83xx
Analog/Mixed-Signal Power ICs
Power Supply: MC34702, MC34717, MC33710
Motor Driver: MC33932, MC33925, MC34921, MC34920, MC34923, MC34987, MC33999, MC33926, MC33931, MPC17529, MPC17531, MM908E626

Application Notes
32-bit AN2353 The Essentials of the Enhanced Time Processing Unit
AN2848 Programming the eTPU
AN2869 Using the Stepper Motor (SM) eTPU Function

Reference Designs
RD68HC908LHID LIN-bus HID Lamp Leveling Stepper Motor Control Using the Freescale 908E625

Recommended Devices
8-bit MCU: 9S08EBxx
Analog/Mixed Signal Power ICs
Motor Driver: MM908E621, MM908E625, MM908E626
Stepper Motors

Micro-stepped gauge drivers

Advantages
• Precise position control

Applications
• Industrial machines
• Health care scanners
• Computers
• Office equipment
• Toys

Recommended Devices
Analog/Mixed-Signal Power ICs: MC33970, MC33976, MC33977, MC33991

Application Notes
32-bit AN2355 The Essentials of the Enhanced Time Processing Unit
AN2848 Programming the eTPU
AN2869 Using the Stepper Motor (SM) eTPU Function

Brushed DC Motor

Dual feedback loop control

Advantages
• Cost-effective control topology
• High-precision speed, torque control and position loop can be added

Applications
• Robots
• Traction control
• Servo systems
• Automotive
• Office equipment
• Toys
• Industrial machines

Recommended Devices
8-bit MCU: 9S18MR, 9S18GB, 9S18AC
16-bit DSC: MC56F80x, MC56F80xx, MC56F83xx
16-bit MCU: S12XE
32-bit MCU: MC6S12x, MC6S32x, MPC56x, MPC56x
Analog/Mixed-Signal Power ICs
Power Supply: MC34702, MC34717, MC3370, MC34923

Application Notes
32-bit AN2955 DC Motor with Speed and Current Closed Loops, Driven by at1P on MC6S12x, MC6S32x AN2955SW
AN2958 Using the DC Motor Control at1P Function Set (Set 3)
AN3008 DC Motor with Speed and Current Closed Loops, Driven by at1P on MCF5700 SW
AN3008SW AN3008SW
**Brushless DC Motor (BLDC)**

Sensorless back EMF/Hall sensor

**Advantages**
- Enables bi-directional operation with fast torque response
- Low noise, high efficiency
- Removes the position sensor
- Cost-effective control topology
- Speed and torque control

**Applications**
- Industrial control
- Large appliances
- HVAC
- Compressors
- Blowers
- Toys
- Pumps
- Health care equipment

**Recommended Devices**
- 8-bit MCU: 908MR, 908MAC, 9089GB, 9089QD, 9089KA
- 16-bit DSC: MC56F80x, MC56F80xx, MC56F83x
- 16-bit MCU: S12XE
- 32-bit MCU: MC951AC, MC9521x, MC9523x, MC956x, MC956xx
- Analog/Mixed-Signal Power ICs

**Application Notes**

8-bit
- AN2356: Sensorless BLDC Motor Control on MC68HC908MR32 Software Porting to Customer Motor
- AN2355: Sensorless BLDC Motor Control on MC68HC908MR32 Software
- AN1858: Sensorless Brushless DC Motor Control Using the MC68HC908MR32 Embedded Motion Control
- AN1853: Embedding Microcontrollers in Domestic Refrigeration Appliances
- AN2396: Servo Motor Control Application on a Local Area Interconnect Network (LIN)
- DRM068: Sensorless BLDC Motor Control using MC9508AW60

Development System
- 16-bit
- AN1913: 3-Phase BLDC Motor Control with Sensorless Back-EMF ADC Zero Crossing Detection Using DSP56F80x
- AN1914: 3-Phase BLDC Motor Control with Sensorless Back-EMF Zero Crossing Detection Using DSP56F80x
- AN1961: 3-Phase BLDC Motor Control with Quadrature Encoder Using 56F800/E
- DRM070: 3-Phase BLDC Motor Controller Using MC68F813/33

32-bit
- AN2382: 3-Phase BLDC Motor with Speed Closed Loop, Driven by eTPU on MCF53x, AN2932SW
- AN2948: Three 3-Phase BLDC Motors with Speed Closed Loop, Driven by eTPU on MCF53x AN2945SW
- AN2954: BLDC Motor with Speed Closed Loop and DC-Bus Break Controller, Driven by eTPU on MCF53x AN2965SW
- AN2977: BLDC Motor with Quadrature Encoder and Speed Closed Loop, Driven by eTPU on MCF53x AN2957SW
- AN3005: BLDC Motor with Quadrature Encoder and Speed Closed Loop, Driven by eTPU on MPC5554 AN3005SW
- AN3006: BLDC Motor with Hall Sensors and Speed Closed Loop, Driven by eTPU on MPC5554 AN3006SW
- AN3007: BLDC Motor with Speed Closed Loop and DC-Bus Break Controller, Driven by eTPU on MPC5554 AN3007SW

**Reference Designs**

- Sensorless Back EMF
  - RD68HC908BLDCZC: Sensorless BLDC Motor Control Using the MC68HC908MR32
  - RDDSCSENSORLESSBLDC: 3-Phase Brushless DC Motor Sensorless Control Using 56F801X
  - RDDSCNLSLESSBLDCAW60: 3-Phase BLDC Motor Sensorless Control Using MC9508AW60
  - RDDSF56F80BLDCZAC2: 3-Phase BLDC Motor Control with Sensorless Back-EMF ADC Zero Crossing Detection Using 56F80X or 56F800 Digital Signal Controllers

- Hall Effect Feedback
  - RD56F801XBLDCCHS: 3-Phase BLDC Motor Control with Hall Sensor Using 56F801X Digital Signal Controllers
  - RD68HC908BLDCCHS: 3-Phase BLDC Drive Control with Hall Sensors
  - RDDSF56F80BLDCCFPC: MC68HC908GT2 BLDC Fan for PCs Reference Design
  - RD68HC908NGC: High-Voltage BLDC Drive for Domestic Appliances Using the MC68HC908MR8
  - RDDSC3PHBLDCINV: 3-Phase BLDC Drive using DC/DC Inverter on MC56F8013
  - RDHC908BLDCF: Low-Power BLDC Drive for Fans Using the MC68HC908Q14 MCU
**Brushless DC Motor (BLDC) Encoder**

**Advantages**
- Enables bi-directional operation with fast torque response, low noise and high efficiency
- High precision speed
- Torque control
- Position loop can be added

**Applications**
- Robots
- Traction control
- Servo systems
- Office equipment
- Sewing machines
- Fitness machines/treadmills
- Toys
- Industrial machines

**MC33937, MC33927**
MPC17533, MC34923, MC33730

**Power Supply:**
MC34702, MC34717,
Analog/Mixed-Signal Power ICs

**MPC56x, MPC55xx**
MCF51AC, MCF521x, MCF523x, 32-bit MCU:
MC56F83xx

**16-bit DSC:**
9S08QD

**8-bit MCU:**
908MR, 9S08AW, 9S08GB,
32-bit MCUs:
MCF51AC, MCF521x, MCF523x, MPC56x, MPC568x,

**Recommended Devices**

**AC Induction Motors (ACIM)**

**3-phase ACIM with V/Hz open-loop control with PFC**

**Advantages**
- Enables bi-directional operation with fast torque response
- Simple cost-effective control topology
- Controls both motor and PFC by single MCU
- Targeted for modest applications accepting low-precision speed control
- High efficiency
- Precise speed control
- Enables indirect torque control
- Tolerant of motor parameters fluctuation

**Applications**
- Large appliances
- HVAC
- Blowers, fans
- Pumps
- Lifts, cranes, elevators
- Conveyors
- Frequency inverters
- Industrial controls
- Treadmills
- Industrial compressors
- Universal inverters

**MC68HC908MR32**
3-Phase, AC Motor Control System with Power Factor Correction Based on

**AN1857**
Cost-Effective, 3-Phase AC Motor Control System with Power Factor Correction Based on MC68HC908MR32

**AN1853**
3-Phase AC Motor Control System with Power Factor Correction Based on MC68HC908MR32

**AN1930**
3-Phase AC Induction Motor Vector Control

**AN1958**
3-Phase AC Motor Control with V/Hz Speed Closed Loop Application

**AN1930**
3-Phase AC Induction Motor Vector Control

**AN1958**
3-Phase AC Motor Control with V/Hz Speed Closed Loop using the 56F800/E

**AN1942**
32-bit MCU: MCF51AC, MCF521x, MCF523x, MPC56x, MPC568x

**32-bit MCUs:**
MCF51AC, MCF521x, MCF523x, MPC56x, MPC568x

**Recommended Devices**
AC Induction Motors (ACIM)

3-phase ACIM with field oriented control (sensored feedback)

Advantages
• Very high-precision speed/torque control
• Suitable for drives with high dynamic requirements
• Highly efficient

Applications
• Large appliances
• HVAC
• Blowers
• Fan pumps
• Industrial controls
• Lifts, cranes, elevators
• Universal inverters
• Conveyors

Recommended Devices
16-bit DSC: MC56F80x, MC56F80xx, MC56F83xx
32-bit MCU: MCF521x, MCF523x, MPC56x, MPC55xx

Application Notes
8-bit
AN2154 Cost-Effective, 3-Phase, AC Motor Control System with Power Factor Correction Based on MC68HC908MR32
AN1657 3-Phase, AC Motor Control System with Power Factor Correction Based on MC68HC908MR32
AN1664 Cost-Effective 3-Phase AC Motor Control System Based on MC68HC908MR32
AN1590 High-Voltage Medium Power Board for 3-Phase Motors
AN2149 Compressor Induction Motor Stall and Rotation Detection Using Microcontrollers
AN1853 Embedding Microcontrollers in Domestic Refrigeration Appliances

16-bit
AN1918 Indirect Power Factor Correction for 3-Phase AC Motor Control with V/Hz Speed Open Loop Application
AN1930 3-Phase AC Induction Motor Vector Control
AN1958 3-Phase AC Motor Control with V/Hz Speed Closed Loop Using the 56F800/E
AN1942 DSP56F80x Resolver Driver and Hardware Interface
DRM092 3-Phase AC Induction Motor Control Drive with Single-Shunt Current Sensing
AN3234 Washing Machine Three-Phase AC Induction Motor Drive

Reference Designs
RD56CACIMVC 3-Phase AC Induction Motor Control Drive with Single-Shunt Current Sensing
RD56P56F8ACVCD 3-Phase AC Induction Motor Vector Control Using 56F80x or 56F8300 Digital Signal Controllers

AC Induction Motors (ACIM)

3-phase ACIM with sensorless field oriented control

Advantages
• High-precision speed/torque control
• Suitable for drives with high dynamic requirements
• Removal of speed sensor

Applications
• Large appliances
• Industrial compressors
• Water pumps
• Construction machinery
• Universal inverters
• HVAC

Recommended Devices
16-bit DSC: MC56F80x, MC56F80xx, MC56F83xx
32-bit MCU: MCF521x, MCF523x, MPC56x, MPC55xx
Permanent Magnet Synchronous Motors (PMSM)

Sensored field oriented control

Advantages
- Exceptionally low noise operation
- Outstanding drive efficiency
- Precise speed/torque control

Applications
- Robotics
- Elevators
- Servo drivers
- Traction systems
- Industrial motion control
- Automotive

Recommended Devices
16-bit DSC: MC56F80x, MC56F80xx, MC56F83xx
32-bit MCU: MCF521x, MCF523x, MPC56x, MPC55xx

Application Notes
- AN2357 Sine Voltage Powered 3-Phase Permanent Magnet Motor with Hall Sensor
- AN2149 Compressor Induction Motor Stall and Rotation Detection Using Microcontrollers
- AN1853 Servo Motor Control Application on a Local Area Interconnect Network (LIN)
- DRM036 Sine Voltage Powered 3-Phase Permanent Magnet Motor with Hall Sensors

Recommended Devices
16-bit DSC: MC56F80x, MC56F80xx, MC56F83xx
32-bit MCU: MCF521x, MCF523x, MPC56x, MPC55xx

Application Notes
- AN1931 3-Phase PM Synchronous Motor Vector Control
- AN1942 DSP56F80x Resolver Driver and Hardware Interface
- DRM036 PMSM Vector Control with Single-Shunt Current-Sensing Using MC56F8013/23
- DRM099 Sensorless PMSM Vector Control with a Sliding Mode Observer for Compressors Using MC56F8013

Reference Designs
- RDSF8300EMB: Electro-Mechanical Braking Using 56F8300 Digital Signal Controllers
- RDSF8300EPAS: Electronic Power Assisted Steering (EPAS) with 56F800 Digital Signal Controllers
- RDSF8300FRBBW: FlexRay Brake-By-Wire Using 56F8300 Digital Signal Controllers
- RDDS56F808MSDE: 3-Phase PM Synchronous Motor Control with Quadrature Encoder Using 56F800 Digital Signal Controllers
- RDDS56F808MTVC: 3-Phase PM Synchronous Motor Torque Vector Control Using 56F800 or 56F8300 Digital Signal Controllers

Permanent Magnet Synchronous Motors (PMSM)

Low speed sensorless sinusoidal field oriented control

Advantages
- Low-noise operation
- High drive efficiency
- High-precision speed/torque control
- Suitable for drives with high dynamic requirements
- Removal of speed sensor

Applications
- Appliances
- HVAC
- Compressors
- Blowers
- Industrial motion controls

Recommended Devices
16-bit DSC: MC56F80x, MC56F80xx, MC56F83xx
32-bit MCU: MCF521x, MCF523x, MPC56x, MPC55xx

Application Notes
- AN2357 Sine Voltage Powered 3-Phase Permanent Magnet Motor with Hall Sensor
- AN2149 Compressor Induction Motor Stall and Rotation Detection Using Microcontrollers
- AN1853 Servo Motor Control Application on a Local Area Interconnect Network (LIN)
- DRM036 Sine Voltage Powered 3-Phase Permanent Magnet Synchronous Motor with Hall Sensors
Permanent Magnet Synchronous Motors (PMSM)
Sensorless sinusoidal field oriented control with zero speed torque capability

Advantages
• Low-noise operation
• High drive efficiency
• High-precision speed/torque control
• Suitable for drives with high dynamic requirements
• Removal of speed sensor

Applications
• Appliances
• HVAC
• Compressors
• Blowers
• Industrial motion controls

Recommended Devices
16-bit DSC: MC56F80x, MC56F86x, MC56F83x
32-bit MCU: MC9S12x, MC9S08x
Analog/Mixed Signal Power ICs
Motor Driver: MC33927, MC33937

Application Notes
8-bit AN2357 Sine Voltage Powered 3-Phase Permanent Magnet Motor with Hall Sensor
AN2149 Compressor Induction Motor Stall and Rotation Detection Using Microcontrollers
AN1853 Embedding Microcontrollers in Domestic Refrigeration Appliances
AN2036 Servo Motor Control Application on a Local Area Interconnect Network (LIN)
DRM036 Sine Voltage Powered 3-Phase Permanent Magnet Synchronous Motor with Hall Sensors

Switch Reluctance Motor Drive
Sensorless

Advantages
• Reliable electronics
• High starting torque
• Removal of position sensor

Applications
• Industrial machines
• Medical scanners
• Computers, office equipment
• Toys
• Food processors
• Vacuum cleaners
• Machine tools
• Large appliances

Recommended Devices
16-bit DSC: MC56F80x, MC56F80xx, MC56F83xx
16-bit MCU: S12XE
Analog/Mixed Signal Power ICs
Motor Driver: MC33927, MC33937

Reference Designs
RDDS56F68RDE 3-Phase Switched Reluctance Motor Control with Encoder Using 56F80X Digital Signal Controllers
RDDS56F68RDR 3-Phase Switched Reluctance Motor Control with Hall Sensor Reference Design for 56F80X or 56F8300 Digital Signal Controllers
RDDS56F68RDS 3-Phase Switched Reluctance Motor Sensorless Control Reference Design Using 56F80X or 56F8300 Digital Signal Controllers

Application Notes
16-bit AN1912 3-Phase Switched Reluctance (SR) Motor Control with Hall Sensors
AN1932 3-Phase Switched Reluctance (SR) Sensorless Motor Control
DRM100 Sensorless High-Speed SR Motor Drive for Vacuum Cleaners Using an MC56F8013

Recommended Devices
16-bit DSC: MC56F80x, MC56F80xx, MC56F83xx
16-bit MCU: S12XE
Power ICs for Motor Control Products
Analog/mixed-signal integrated circuits with SMARTMOS™ technology

Freescale's analog/mixed-signal and power integrated circuits provide comprehensive electric motor system solutions when coupled with MCUs or DSPs. Freescale's power integrated circuits (ICs) are manufactured using our advanced SMARTMOS™ technology, which enables key protection and performance functions to be monolithically integrated within the power IC silicon. When product designers rely on a printed circuit board loaded with discrete components (and the attendant poor MTBF number), Freescale delivers robust, highly integrated system solutions that provide a long life of reliable and highly functional service.

Motor Types vs. Market Power ICs and Applications

<table>
<thead>
<tr>
<th>Motor Types</th>
<th>Market Power ICs</th>
<th>Applications</th>
</tr>
</thead>
</table>
| Brush       | MPCI7510, 11     | DVR, DC Motors, Tape |<| Motor Control Products
Analog/mixed-signal integrated circuits as part of robust, highly integrated system solutions

Freescale offers the following analog evaluation boards and modules:

Device P/N | Evaluation Boards and Modules
---|---
MC33999 | KIT33999DEVB
MC33661 | KIT33661DEVB
MC33689 | KIT33689DWBEVB
MC33742 | KIT33742DHEVB
MC33800 | KIT33800KEKVE
MC33810 | KIT33810KEKVE
MC33880 | KIT33880DWBEVB
MC33887 | KIT33887DWBEBVB KIT33887DBPWBEVB
MC33999 | KIT33999DEVB
MC33926 | KIT33926DWBEBVB
MC33927 | KIT33927KEKKE
MC33972 | KIT33972AEKVEVB

Please visit [www.freescale.com/analog](http://www.freescale.com/analog) for more details.
8-bit Microcontroller Motor Control Products

Feature-rich portfolio that meets all of your 8-bit needs

Freescale’s 8-bit portfolio includes several low-end devices that provide cost-effective solutions for motor control applications. From flash to ROM, from 1 KB to 60 KB of memory and from tiny 8-pin QFN to 64-pin quad flat packages, the HC08 and RS08 families are designed to meet all of your 8-bit needs. They feature peripherals, such as 10-bit A/D converters and multi-channel timers, which make them ideal candidates for low-end motor control applications.

### 8-bit Product Summary

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<thead>
<tr>
<th>Device</th>
<th>Flash RAM</th>
<th>ADC</th>
<th>Channels</th>
<th>Bits</th>
<th>GPT</th>
<th>ESCI</th>
<th>SPI</th>
<th>I2C</th>
<th>ACMP</th>
<th>SW IO</th>
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** HDI = Hardware Deadtime Insertion

### 8-bit Development Tool Summary—HC08/R08

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<th>Evaluation Board Kit</th>
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</table>

### 16-bit Product Summary

16-bit digital signal controller (DSC) products—The S58000 core-based family of DSCs combines the processing power of a DSC and the functionality of a microcontroller, with a flexible set of peripherals on a single chip. This creates an extremely cost-effective motor control solution.

### 16-bit Development Tool Summary

<table>
<thead>
<tr>
<th>Device</th>
<th>Flash RAM</th>
<th>ADC</th>
<th>Channels</th>
<th>Bits</th>
<th>GPT</th>
<th>PIT</th>
<th>PWM</th>
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<th>TPU</th>
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<th>Packages</th>
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** HDI = Hardware Deadtime Insertion
24-bit Microcontroller Motor Control Products

High performance for complex, real-time motor control applications

These 23-bit embedded microcontrollers combine higher performance with increased on-chip functionality to address complex real-time control applications that require more system throughput. Both the ColdFire® family and MPC500 and MPC5500 families built on Power Architecture® technology are capable of fulfilling the most demanding motor control requirements in a wide range of operating environments.

32-bit Product Summary

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<th>PIT</th>
<th>PWM</th>
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<td>1, 2, 3, 4</td>
<td></td>
</tr>
<tr>
<td>MCF51AC225</td>
<td>32 KB</td>
<td>32 KB</td>
<td>12</td>
<td>6</td>
<td>2</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>PC, SPI, CAN</td>
<td>1, 2, 3, 4</td>
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</tr>
<tr>
<td>MCF51AC256</td>
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<td>6</td>
<td>2</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>PC, SPI, CAN</td>
<td>1, 2, 3, 4</td>
<td></td>
</tr>
</tbody>
</table>

** Specifications listed are for the superset device in each family. Memory sizes, peripherals and communication options vary by device. Please see appropriate data sheet for further information.**


tTPU System Infrastructure

The eTPU is a programmable I/O and control module with its own core and memory system dedicated to performing complex timing, control and I/O management functions independently of the main processor.

The eTPU is essentially a microcontroller itself, used in a variety of applications, including general timing functions, serial communications, motor control, custom logic replacement and engine control.

With some applications requiring more than 70 percent of the CPU bandwidth, the eTPU on the MCF523x and MPC55xx is an ideal solution.

32-bit Microcontroller Motor Control Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Library</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Motors</td>
<td>Motor Speed</td>
<td>DC Bus Break Control, Quadrature Decoder, Half Sensor Interface, Analog Sensing, Motor Control PWM, Current Control, Hall Sensor Decoder</td>
</tr>
<tr>
<td>AC Motors</td>
<td>Motor Speed</td>
<td>DC Bus Break Control, Quadrature Decoder, Half Sensor Interface, Analog Sensing, Motor Control PWM, ACM Vector, ACM VME Control, PMEM Vector Control</td>
</tr>
<tr>
<td>Electronic Motors and Controls Supported</td>
<td>ACIM VME Open Loop with Sine, ACIM VME Open Loop with SM, ACIM VME Speed Loop with Slow Wave Drive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ADM Torque Control</td>
<td></td>
</tr>
</tbody>
</table>

Freescale provides a free library of eTPU function including C source code, Host C API and detailed application notes. See it all at www.freescale.com/eTPU.

Users may customize library functions and/or develop custom functions using the Byte Craft C Compiler and ASH WARE Simulator.

ColdFire Development Tool Summary

<table>
<thead>
<tr>
<th>Family</th>
<th>Part Numbers</th>
<th>Starter Kit</th>
<th>Advanced Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCF51AC4</td>
<td>MCF51AC422</td>
<td>MCF51AC422</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
<tr>
<td>MCF51AC4</td>
<td>MCF51AC421</td>
<td>MCF51AC421</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
<tr>
<td>MCF521x4</td>
<td>MCF521x422</td>
<td>MCF521x422</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
<tr>
<td>MCF521x4</td>
<td>MCF521x421</td>
<td>MCF521x421</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
<tr>
<td>MCF522x4</td>
<td>MCF522x422</td>
<td>MCF522x422</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
<tr>
<td>MCF522x4</td>
<td>MCF522x421</td>
<td>MCF522x421</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
<tr>
<td>MCF525x4</td>
<td>MCF525x422</td>
<td>MCF525x422</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
<tr>
<td>MCF525x4</td>
<td>MCF525x421</td>
<td>MCF525x421</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
<tr>
<td>MCF525x4</td>
<td>MCF525x420</td>
<td>MCF525x420</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
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</table>

MPC Development Tool Summary

<table>
<thead>
<tr>
<th>Family</th>
<th>Part Numbers</th>
<th>Starter Kit</th>
<th>Advanced Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC553</td>
<td>—</td>
<td>—</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
<tr>
<td>MPC554</td>
<td>—</td>
<td>—</td>
<td>Demo Board 11 Software, Evaluation Board Kit 11 Software</td>
</tr>
</tbody>
</table>

CodeWarrior Development Studio Special Edition for all MPC devices is complimentary, and is supplied with all MPC55xx evaluation boards. This version of CodeWarrior supports object code sizes up to 128 KB. Upgrade available to support expanded memory sizes.

For information on these upgrade options, visit www.freescale.com/CodeWarrior.

www.freescale.com/motorcontrol
Motor Control Products

Algorithms and drivers provided by Processor Expert™

<p>| Microcontroller Drivers and Algorithms—Available in Processor Expert |</p>
<table>
<thead>
<tr>
<th>Motor Type</th>
<th>Available Drivers and Algorithms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Drivers</td>
<td>Timer</td>
</tr>
<tr>
<td></td>
<td>Flash</td>
</tr>
<tr>
<td></td>
<td>ADC</td>
</tr>
<tr>
<td>AC Induction</td>
<td>Power factor</td>
</tr>
<tr>
<td></td>
<td>3-phase waveform generation</td>
</tr>
<tr>
<td></td>
<td>Space vector modulation</td>
</tr>
<tr>
<td></td>
<td>Ramp</td>
</tr>
<tr>
<td></td>
<td>Switch/push-button</td>
</tr>
<tr>
<td>Brushless DC</td>
<td>BLDC commutation handler with sensor</td>
</tr>
<tr>
<td></td>
<td>BLDC commutation handler, sensorless</td>
</tr>
<tr>
<td></td>
<td>PIV/PID controllers</td>
</tr>
<tr>
<td></td>
<td>Position calculation and estimation</td>
</tr>
<tr>
<td></td>
<td>BLDC with zero crossing</td>
</tr>
<tr>
<td>Switched Reluctance</td>
<td>SR commutation handler</td>
</tr>
<tr>
<td></td>
<td>SR commutation angle calculation</td>
</tr>
<tr>
<td></td>
<td>SR with sensors</td>
</tr>
<tr>
<td></td>
<td>SCI communication routine</td>
</tr>
<tr>
<td></td>
<td>Ramp</td>
</tr>
</tbody>
</table>

16-bit Digital Signal Controller Drivers and Algorithms—Available in Processor Expert

<table>
<thead>
<tr>
<th>Standard Drivers</th>
<th>Available Drivers and Algorithms</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC</td>
<td>DAC</td>
</tr>
<tr>
<td>MBCAN</td>
<td>Analog Comparator</td>
</tr>
<tr>
<td>Flash</td>
<td>SPI</td>
</tr>
<tr>
<td>PLL</td>
<td>PWM</td>
</tr>
<tr>
<td>Serial/SCI (also with LIN)</td>
<td>SPI</td>
</tr>
<tr>
<td>SIM</td>
<td>SSI</td>
</tr>
<tr>
<td>FlexCAN</td>
<td></td>
</tr>
</tbody>
</table>

Drivers for off-Chip Peripherals

<table>
<thead>
<tr>
<th>Drivers for off-Chip Peripherals</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>Terminal</td>
</tr>
<tr>
<td>BLDC</td>
<td>LED</td>
</tr>
<tr>
<td>Codec</td>
<td>EEPRom/Flash (SPI-Bus Serial)</td>
</tr>
</tbody>
</table>

Tools

<table>
<thead>
<tr>
<th>Tools</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC Master</td>
<td>File I/O</td>
</tr>
<tr>
<td>ProofMaster</td>
<td>RTOS Support</td>
</tr>
<tr>
<td>JTAG/Flash Loader</td>
<td>MicroC/OS-II</td>
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</table>

Miscellaneous

<table>
<thead>
<tr>
<th>Miscellaneous</th>
<th>Function</th>
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</thead>
<tbody>
<tr>
<td>Serial Boot Loader</td>
<td>Data Structures (FIFO)</td>
</tr>
<tr>
<td>Stack Diver</td>
<td>Cycle Count</td>
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</tbody>
</table>

Motor Control Algorithms

<table>
<thead>
<tr>
<th>3-Phase Sine Wave Generation</th>
<th>Clarke/Park Transformation</th>
<th>Space Vector Modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp</td>
<td>D-Q System (2-Phase)</td>
<td>FOC Ocupling</td>
</tr>
<tr>
<td>BLDC Commutation Handler w/Sensors</td>
<td>BLDC Commutation Handler Sensorless-Zero Cross</td>
<td>SR Commutation Handler</td>
</tr>
<tr>
<td>PIV/PID Controllers</td>
<td>Velocity Calculation and Estimation</td>
<td>Leakage-Pipe Table</td>
</tr>
<tr>
<td>Brake Control</td>
<td>Switch Control</td>
<td>Flux Model</td>
</tr>
<tr>
<td>Brushless DC w/Encoder</td>
<td>AC Induction Motors V/Hz Closed Loop</td>
<td>Digital Power Factor Correction</td>
</tr>
<tr>
<td>Wave Generator</td>
<td>Phase Flux Estimation</td>
<td></td>
</tr>
<tr>
<td>Brushless DC Motors w/Hall Sensor</td>
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<td></td>
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</table>

Additional Motor Control Application Notes and Reference Designs

<table>
<thead>
<tr>
<th>Application Notes</th>
<th>Reference Designs</th>
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<tbody>
<tr>
<td>AN1976 Migrating from SDK to Processor Expert</td>
<td>RHC08AGIM</td>
</tr>
<tr>
<td>AN1920 DSP56800 Hardware Interface Techniques</td>
<td>RDD56F8BxxPPC</td>
</tr>
<tr>
<td>AN1926 Production Flash Programming 56F80x, 56F826 and 56F827</td>
<td>RD68HC908ACIMDTC</td>
</tr>
<tr>
<td>AN1933 Synchronization of On-Chip Analog to Digital Converter</td>
<td>RD68HC908ACIMVHD</td>
</tr>
<tr>
<td>AN1936 Programming On-Chip Flash Memories of DSP56F80x DSPs Using the JTAG/OnCE Interface</td>
<td>RDD56F8BACIMVHD</td>
</tr>
<tr>
<td>AN1947 DSP56800 ADC</td>
<td>RDMC3PHAC</td>
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<tr>
<td>AN1948 Real-Time Development of MC Applications PC Master Software Visualization Tool</td>
<td>RD68HC908SVFMD</td>
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<tr>
<td>AN1952 Using Program Memory as Data Memory</td>
<td></td>
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<tr>
<td>AN1965 Design of Indirect Power Factor Correction</td>
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<tr>
<td>AN1973 Production Flash Programming</td>
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<tr>
<td>AN1974 56F8300 and 56F8100 ADC</td>
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<tr>
<td>AN1975 Multiple Target Features Using Processor Expert and CodeWarrior</td>
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<tr>
<td>AN3116 Production Flash Programming for the 56F8000 Family</td>
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<tr>
<td>AN3103 56F8000 Clock Generation Guidelines to Ensure Correct Functionality</td>
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<td>AN3102 Unique Features of the 56F8010 Family of Devices</td>
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<td>AN2395 PC Master Software Usage</td>
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<tr>
<td>AN2263 PC Master Software: Creation of Advanced Control Pages</td>
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<tr>
<td>AN2095 Porting and Optimizing DSP56800 Applications to DSP56800E</td>
<td></td>
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<tr>
<td>AN1990 56F8300 Hybrid Controller Used in Control of Electro-Mechanical Brake</td>
<td></td>
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<tr>
<td>AN1994 Start-Up Considerations for 56F8300 and 56F8100 Family Devices</td>
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<tr>
<td>AN1991 Controlling Power Consumption in 56F8300 and 56F8100 Family Devices</td>
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<tr>
<td>AN1983 Software Compatibility Considerations for HCS12, HC16 and 56800/E Devices</td>
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<tr>
<td>AN1980 Using the 56F83xx Temperature Sensor</td>
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<tr>
<td>AN1734 Pulse Width Modulation Using the 16-bit Timer</td>
<td></td>
</tr>
</tbody>
</table>
Motor Control Product Development Tools

Hardware and software tools and reference designs that work for you

Freescale offers a comprehensive ecosystem of product development tools that can help you successfully complete your product design. Our extensive library of software tools and reference designs are designed to enable fast and inexpensive product development. This leads to fast time to market and cost-effective solutions.

- CodeWarrior—The backbone of Freescale’s software development tools is the CodeWarrior Integrated Development Environment (IDE). With compiler, debugger, linker, editor, assembler and other features, the CodeWarrior IDE makes C/C++ source-level debugging and embedded application development as worry-free as possible. The CodeWarrior tool suite is consistent across all supported platforms, without host-to-host incompatibilities.
- Processor Expert—CodeWarrior Development Studios can also come with UNIS Processor Expert, a Rapid Application Design (RAD) component-based application builder and system integration tool. This tool enables component-oriented programming, provides tested, ready-to-use code and delivers instant functionality of generated code. (See table on the next page for a list of algorithms and software examples provided by Processor Expert)
- Freescale software tools include GNU support plus additional development tools from a large network of third-party vendor partners.
- Comprehensive evaluation kits include demo boards, serial cables, quick start guides and CodeWarrior software development tools with Processor Expert. The kits give developers a comprehensive package to develop and evaluate applications using Freescale solutions.
- FreeMASTER is a free and intuitive application development tool for all motor control devices from 8- to 32-bit. This powerful diagnostic and demonstration tool allows real-time debugging and remote control of an application from a user friendly graphical environment running on a PC. FreeMASTER supports: HC68HC08, S12X, DSP66F800, MC56F8300, MC56F8100, MC56F8000, MPC5XXX and ColdFire families of devices.

In addition to all of the above, you can test drive our development tools and products through virtual labs and benefit from our motor control tutorials found at Freescale’s Embedded Learning Center.

Start with your idea
Then use Freescale’s Interactive Development Tool Ecosystem to design a development process that fulfills your specific needs.

Begin by selecting software and hardware tools you need to complete your design.

Get your product to market, on time and on budget.

Development Hardware

Demonstration boards (DEMOs) give designers a cost-effective platform to program and debug project application code, with basic I/O functions and I/O headers for easy expandability. It may be all you need for product evaluation before moving to prototyping.

Evaluation boards (EVBs) provide more functionality than demo boards with expanded capabilities. Programmers have the option to either step up to an EVB after initial evaluation on a demo board, or they can start with an EVB and move directly to prototyping.

BDM debug cables like the USB multilink and the open source BDM (OSBDM) are the link between the IDE running on your PC and the target hardware. These interfaces allow full, non-intrusive in-circuit emulation, and are provided by Freescale and our partners and are integrated in every Freescale Evaluation board. Acquiring one of these standalone cables is essential when designing a custom board.

Development Software

Software development tools, including CodeWarrior Development Studio and other third-party tools, provide a comprehensive set of integrated development environment (IDE) options, as well as other development tools such as debuggers, emulators, RTOSes, stacks and drivers.

Drivers and Stacks provide everything needed to begin using a complex module without spending any time writing module-specific code. Freescale and our Tools Alliance Program partners offer many drivers and stacks for all of our devices.
Specialized Motor Control Development Tools
Accelerate application development and speed time to market

Freescale provides complimentary start-up and diagnostic development tools that are unique to the industry. These are the DSP56800E Quick Start Initialization and Development Tool and the FreeMASTER Real-Time Control and Debugging Tool.

The DSP56800E Quick Start Initialization and Development Tool is a software environment for embedded applications development. It is based on the graphical configuration tool (GCT) and a unified application programming interface (API)-style of accessing the peripheral modules. The Quick Start toolset helps users to accelerate the application development, to become quickly familiar with the target device and to create real-time applications rapidly and efficiently while retaining complete control over each portion of the underlying hardware.

The DSP56800E Quick Start toolset was specially designed for the real-time applications written in C or mixed Assembler/C languages where a deterministic behavior and transparent software structure are required. It provides a software infrastructure that allows development of efficient applications that are portable and reusable between devices within the architecture family or even between different architectures. The Quick Start tool complements the other development and initialization tools for Freescale processors like Processor Expert or RApid.

FreeMASTER software (formerly known as PC Master) represents a sophisticated tool with intuitive navigation that can be used in any application development. This tool allows control of an application remotely from a user-friendly graphical environment running on a PC. It also provides the ability to view real-time application variables in both textual and graphical form. FreeMASTER gives you what you need to monitor the system in real-time, control the embedded application form a PC and demonstrate advanced capabilities of Freescale driven solutions. Designers may take advantage of the versatility and use FreeMASTER for multipurpose algorithms and applications. It may be used for real-time debugging, diagnostics as well as for demonstration, sales and educational purposes.

Below are some examples of interfaces created in FreeMaster for different motor control applications.

For additional information on these tools, as well as others like Processor Expert and RApid, please go to www.freescale.com.
Software Library Set for MC56F80XX and MCF51AC Families

Software libraries GFLIB, MCLIB, GDFLIB used to build digital control systems

The software libraries for MC56F80XX and MCF51AC families are designed to construct digital control systems for different motor types. The libraries contain software modules implemented in optimized assembly form and having C-callable function interface.

- General Function Library (GFLIB) contains math, trigonometric, look-up table and control functions. These software modules are basic building blocks.
- Motor Control Library (MCLIB) contains vector modulation, transformation and specific motor related functions to build digitally controlled motor drives.
- General Digital Filter Library (GDFLIB) contains filter functions for signal conditioning.

Upcoming Advanced Control Library (ACLIB) will contain functions to enable building the variable speed AC motor drive systems with field oriented control techniques without a position or speed transducer.

Individual libraries are delivered in library modules and are intended for use in small data memory model projects. The interfaces to the algorithms included in these libraries have been combined into a single public interface file. This is done to simplify the number of files required for inclusion by application programs. Refer to the specific algorithm sections of user document for details on the software Application Programming Interface (API).

Motor Control Libraries

- General Function Library (GFLIB)
  - Sin, cosine, tangent
  - Inverse sine, cosine, tangent
  - Two-argument inverse tangent
  - Sign
  - 1D look-up table
  - Hyperbolic
  - Square root
  - Ramp, dynamic ramp
  - Limitation on input signal
  - Proportional-integral (PI) controller of parallel form
  - Proportional-integral (PI) controller of recurrent form

- Motor Control Library (MCLIB)
  - Clark, inverse Clark
  - Park, inverse Park
  - Vector limitation
  - DC bus voltage ripple elimination
  - Space vector modulation techniques
  - PM motor decoupling
  - ACIM flux model
  - Angle tracking observer
  - Back EMF observer for PM motor
  - Saliency tracking observer

- Digital Filter Library (GDFLIB)
  - 1st order IIR filter
  - 2nd order IIR filter
  - Moving average filter
  - Simplified MA filter

* Indicates library is available only for MC56F80xx devices.

For more information on these libraries, please contact your Freescale sales representative.

Design Resources—Quick Start

Freescale offers easily accessible products, tools and services to help you speed your product to market

Freescale Fast Track

The companies that win the race to market with new product designs often become market leaders in their industries. Freescale Fast Track helps you win that race, accelerating the development cycle by providing immediate services at every step of the design process.

Fast Track opens the door to assistance programs that not only will help you be the first to market but also be the best in market. Below are just a few of our Fast Track services.

- Embedded Learning Center provides a wealth of online technical training courses and Webcasts—24 hours a day, 7 days a week—that can bring you up to speed on our latest products, tools and technologies.
- DevToolDirect is an easy way to order Freescale development tools, software and third-party design tools directly online for shipment anywhere in the world.
- Online Samples Program is simple and straightforward, starting with an "Order Sample" button next to a selected product that begins an easy three-step request process.
- Technical Support is available online by our worldwide team of specialists.

To access Freescale’s Fast Track services, visit freescale.com/fasttrack.