8-bit Microcontrollers

Entry-Level Mechatronics

Converting from mechanical to embedded control

freescale™
semiconductor

The Freescale Difference

Freescale Semiconductor is a global leader in the design and manufacture of embedded semiconductors for the automotive, consumer, industrial, networking and wireless markets. During Freescale's 50+ years as part of Motorola, we developed our extensive technology portfolio, embedded expertise and innovative system-level solutions.

Trusted Leadership—Freescale is a trusted leader that provides the latest knowledge and products for mechatronics design.

Training and Documentation—We provide easy-to-use tools and comprehensive training to ease your design process.

Expert Knowledge—We provide access to experts through live webcasts and a full support ecosystem, which includes online and phone-assisted help.

Low-end Portfolio—We offer a broad low-end 8-bit portfolio and a range of powerful 32-bit devices, all of which are designed to bring intelligent design to a variety of everyday applications.

Easy-to-use Software Tools—Freescale's CodeWarrior® Development Studio with Processor Expert™ is a comprehensive toolset for application development. Processor Expert plug-ins allow users to automatically generate code in as few as seven clicks, enabling quick and easy product development and deployment.

Making Mechanical Systems Smarter

The disciplines of mechanical and electrical engineering are merging. It is a rare occurrence that mechanical systems don't interact with electronic controls, and as a result, traditional mechanical functions are evolving into smarter solutions that are more flexible, reliable and cost-effective.

Mechatronics is where mechanics, electronics, computing and control technology combine to improve performance of mechanical systems at all levels, from toasters to advanced robotics. For the mechanical engineer, making this transition can be a daunting task. Freescale can make it easier.

Our latest generation of low-cost, easy-to-use microcontrollers can help you incorporate embedded control into your next design quickly and efficiently. Freescale development tools and software have set the industry standard for fast and easy microcontroller (MCU) design implementation.

Even if you have no MCU software experience, our CodeWarrior® development studio can help you create working software code in just a few clicks of a mouse.

Supporting Mechatronics Design

Replacing discrete components with embedded control technology offers several advantages—not only to the product designers but also to the end users. Embedded control improves energy efficiency, system reliability and cost effectiveness, provides better precision control and enables reprogrammable design flexibility. What's more, mechatronics systems with embedded control are generally smaller, cost less and are easier to use. The best way for you to start learning about the advantages of embedded control in mechatronics applications is to visit our mechatronics web page: **www.freescale.com/mechatronics**

Here you can explore our products, tools and expertise—all dedicated to helping you incorporate all the advantages of embedded control to your next mechatronics project.

What is a Microcontroller?

A microcontroller is a complete computer system on a single integrated circuit chip. As in any computer, the MCU includes:

- A central processor unit (CPU)
- A clock to sequence the CPU
- Memory for instructions and data. A typical 8-bit MCU has from 2K to 128K of on-chip read-only-memory (ROM)
- Input ports for receiving instructions and data
- Output ports for exporting instructions and data (the combination of input and output ports is known as I/O)
- Program software that controls the MCU's functional capabilities

When some of these elements are missing, such as the I/O or memory, the integrated circuit would be called a microprocessor. MCUs can be embedded into systems to give computer capabilities to even very simple applications, such as low-end mechatronics.

MCU Integrated Peripherals

MCUs are very useful in designs that require a number of different decisions and calculations to operate properly. Many of these decisions may be specific to a particular application or family of applications. MCU designers can integrate certain peripherals onto the silicon to perform additional functions required by the application. A peripheral is simply any device that is not a part of the essential computer or MCU. They include:

- Serial communications interface (SCI) for high-speed, asynchronous communication with external peripheral devices and other MCUs
- Serial peripheral interface (SPI) for full-duplex, synchronous serial communication with external peripheral devices
- Inter-integrated circuit (I^{2}C) for multimodal serial bus communications

- Universal serial bus (USB) interface for serial communication with other USB enabled devices
- Analog-to-digital converter (ADC) for converting incoming analog signals to digital signals
- Pulse-width-modulator (PWM) for motor control applications
- Real-time clock (RTC) for applications that require keeping track of time/date information
- Liquid crystal display (LCD) driver for segment-based display applications

The combination of standard MCU elements and specific integrated peripherals provide an intelligent platform for application embedded control. It is a compact, fully functional computer system that enables new capabilities for mechatronics applications, such as touch-screen human-machine interface and wireless remote control.

TYPICAL MCU DIAGRAM
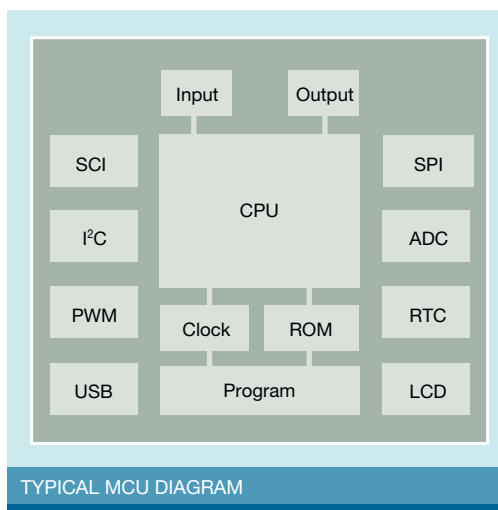
Freescale 8-bit Mechatronics Solutions

Typical Applications

Our HCS08 (S08) and RS08 families of 8-bit MCUs are ideal solutions for embedded control in mechatronics applications. The S08 core is an evolutionary step from the popular HC08 architecture with improved low-voltage/low-power performance. Created by an advance wafer fabrication process, the S08 MCU has a normal operating voltage of 1.8 volts to 2.7 volts and is capable of higher bus speeds at lower operating voltages than its predecessor. In short, this means it is better suited for battery operated applications or in systems where power conservation is a high priority.

The RS08 core is a reduced version of the S08 core that has been specifically designed for small pin-count devices with under 16K memory. 30 percent smaller than the S08 core, it's more efficient and cost effective for simple electro-mechanical devices that are migrating to fully solid-state electronic operation or portable devices that have evolved into smaller or even disposable versions.

Embedded Control for DC Fan

MCU based, intelligent, variable-speed control, brushless DC (BLDC) fans are increasingly needed to fulfill rapidly changing electronics products specification. Variable speed control, low acoustic noise, reliability, long lifetime, low power consumption, protection features, easy to maintain/upgrade and communication interface capability are the characteristics of flash MCU-based BLDC fan, such as one controlled by our MC9S08QD4 (QD4) device.

The conventional DC fan has a higher inertia due to the bulky rotor coils, while the BLDC fan has a lighter rotor due to its permanent magnets. The higher efficiency of the BLDC fan can be further enhanced by incorporating QD4 as an embedded controller. An intelligent variable speed control BLDC fan system can be easily reconfigured to meet the fast changing requirements of modern electronic products, and it adds such advanced features as lock detection, automatic restart, and automatic thermal shut down.
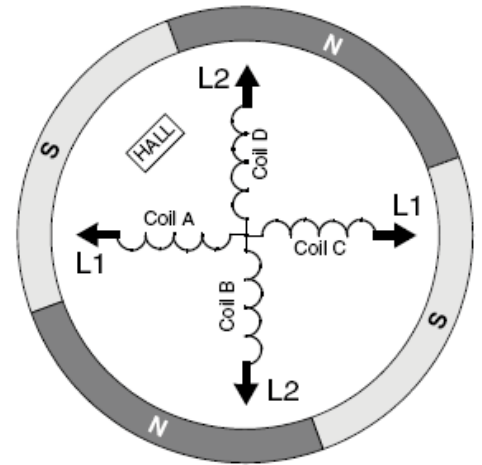

Construction of a BLDC fan

Need for an Intelligent BLDC Fan

The conventional DC fan has a higher inertia due to the bulky rotor coils, while the BLDC fan has a lighter rotor due to its permanent magnets. The BLDC fan has a higher efficiency as more energy can be transferred to the load because of the lighter rotor. The BLDC fan uses the electrical commutation and does not have some of the problems experienced by the conventional DC fan, such as mechanical wear of commutator brushes, sparking and electromagnetic interference (EMI) induced by its rotation.

An intelligent variable speed control BLDC fan system is becoming widely used because it is can be easily reconfigured to meet the fast changing requirements of modern electronic products, and includes enhanced features such as lock detection, automatic restart, and automatic thermal shut down.

Converting a Toaster Oven to Embedded Control

Toaster oven using discrete electronic components
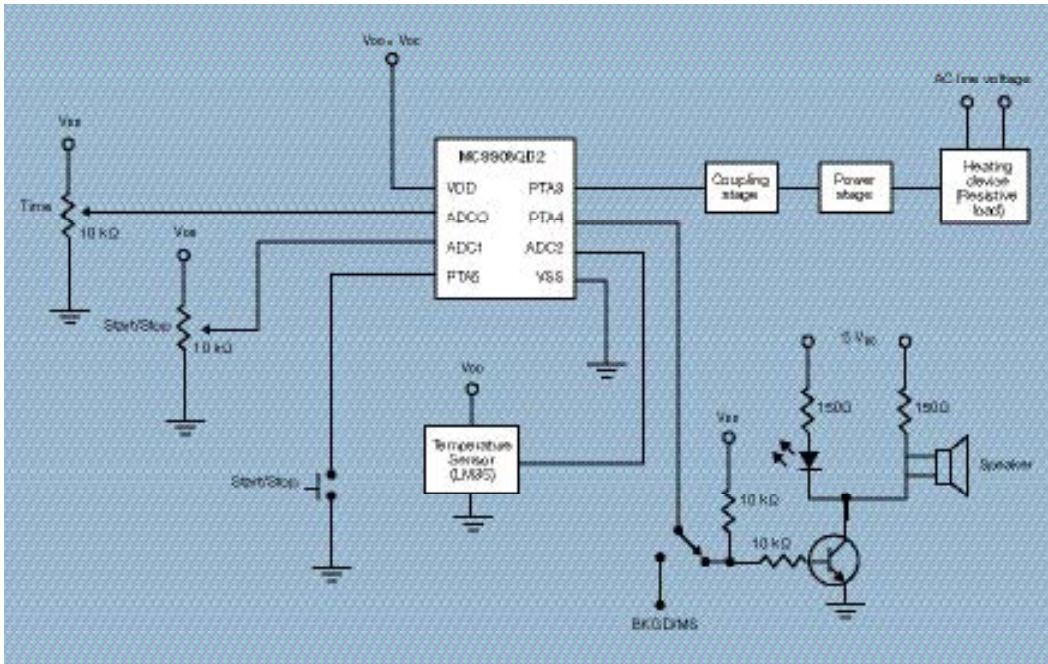
Embedded toaster oven solution employing a 9S08QD2 MCU

The traditional toaster oven uses discrete components to control temperature and cooking times, including solenoids, thermostats and thermal fuses. These components maybe more expensive than embedded control elements, and they are relatively imprecise. For instance, a mechanical timer will determine cooking time regardless of the initial heating element temperature. This process may esult in unnecessarily long cooking times, wasting electricity and over-cooking the food.

The Embedded Control Solution

A toaster oven using an embedded control system can adjust cooking time based on the existing temperature, providing more uniform cooking or toasting repeatedly and reliably. An embedded control system based on the MC9S08QD2 MCU (see Figure 2) uses two potentiometers to control the temperature and timing. The design also uses a low-cost temperature sensor for increased accuracy. This system provides flexibility to implement different control types, from a simple ON-OFF solution to a more accurate

Proportional Integral Derivative (PID) controller. In addition, embedded control systems save space and weight and provide longer system life.

Freescale's Mechatronics Program

To help you convert from discrete control designs to embedded control designs, we have a number of applications notes you can download from our web site that offer step-by-step assistance to meet the needs of a beginner embedded design engineer. We also offer CodeWarrior software that allow you to quickly copy and modify code for each customized application. This shortens product development cycles and helps you improve your time-to-market.

Entry Level Solutions: KA and QD Families

The MC9RS08KA and MC9S08QD families are Freescale's entry level MCU embedded control solutions for mechatronics applications. Below are the primary features and benefits for both.

KA2

Features	Benefits
Up to 10 MHz (bus frequencty) RS08 CPU at 1.8 V for 100 ns minimum instruction time	Offers high performance for applciations operated by battery - even at low voltage. Helps lower system power consumption from shorter writes
Extremely fast, byte-writable programming - up to 20 µs/byte	Helps reduce production programming costs through ultra fast programming. Helps lower system power consumption from shorter writes.
Offers 1 KB write/erase cycles minimum over temperature	Allows electronically erasable nonvolatile memory to help reduce firmware development cycle
Internal clock source module (ICS) contains a frequency-locked loop (FLL) controlled by internal reference	Helps eliminate the cost of all external clock components. Reduces board space. Increases sysem reliability.
Precision trimming of internal reference allows typical 0.1 percent resolution and +0.5 percent to -1 percent deviation over operating temperatures and voltage	Provides one of the most accurate internal clock sources on the market for the money
Option to compare to internal reference	Requires only a single pin for input signal
Option to route comparator output directly to pin	Allows other components in system to see result of comparator with minimal delay
Allows operation in MCU STOP mode	Offers function to wake up the MCU from WAIT/STOP
Low voltage detection with reset or interrupt	Allows system to write/save important variables before voltage drops too low Holds devices in reset until reliable voltage levels are reapplied to the part.
Security feature for Flash	Helps prevent unauthorized access to memory to protect valuable software intellectual property
On-chip BDM	Provides single-wire debugging and emulation interface Eliminates need for expensive emulation tools Provides circuit emulation without the need for additional, expensive development hardware

QD4

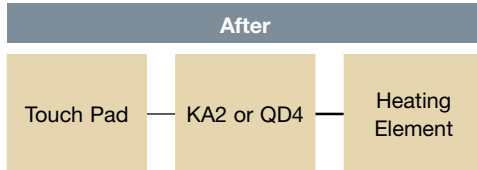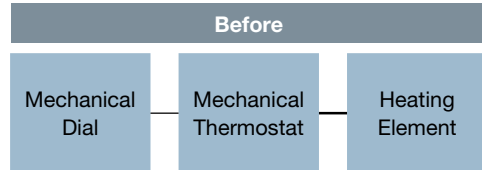| Features	Benefits
Up to 8 MHz S08 CPU for 125 ns minimum instruction time	Offers high performance for simplified applications
Supply voltage range of 2.7 - 5.5 V	Greater scalability of power and performance through range of voltage for application needs
Embedded flash that is in-application reprogrammable over the full operating voltage and and temperature range with single power supply	Provides users a single solution for multiple platforms or a single platform that is field reprogrammable in virtually any environment. Allows for software flexibility and optimization for real-time applications.
Outputs 10 mA each; 100 mA max for package	High-current I/O allows direct drive of LED and other circuits to virtually eliminate external drivers and to help reduce system costs
One input-only and one output-only line	Helps to reduce customer system cost by eliminating need for external resistors
4-channel, 10-bit analog-to-digital converter (ADC) with automatic compare function	Easy interface to analog inputs/sensors
Automatic compare function, software programmable for greater-than, equal-to, or less-than conditions	Can be used to set conversion complete and generate interrupt only when result matches condition
Temperature sensor	Calculates temperature without any external components and saves an ADC input channel for other use
Low-power and high-speed options	Takes periodic measurements without CPU involvement; can be used in STOP3 with compare function to take measurement and wake MCU from STOP3 only when compare level is reached.
Internal clock source module containing a frequency-locked loop controlled by internal reference	Can eliminate cost of external clock components, take little board spacke, and help to increase system reliability.
Watchdog computer operating properly reset with option to run from dedicated 1 kHz internal clock source or bus clock	Resets device in instance of runaway or corrupted code, and independent clock source provides additional protection in case of loss of clock.
Low-voltage detection with reset or interrupt	Allows system to write/save inportant variables before voltage drops too low
Security feature for flash and RAM	Helps prvent unauthorized access to memory to protect a customer's software

Mechatronics Applications with Embedded Control

Typical Consumer Applications

- Electric oven timer and heat control
- Fridge time and thermometer
- Sewing machine speed control
- Toaster oven
- Hair dryer
- Clothes iron
- Ceiling fan
- Illumination timer
- Door lock
- Stopping system for garage door
- Washing machine motor control and timer
- Dimming light ballast
- General purpose timer
- Interface buttons for home entertainment systems
- Shower temperature control

Typical Industrial and Automotive Applications

- Window lift
- Windshield wiper
- Automotive trunk opener
- Power measurement
- Voltage supervisor
- DC motor control for dentist applications
- Interface buttons for RF data modules
- Photoelectric relay for illumination
- Reed switch for alarm systems and passive infrared (PIR) intruder detection
- Hospital inhalator/portable inhalator
- Gauge meters
- Parabolic antenna positioning

Before		
Mechanical Dial	Mechanical Thermostat	Heating Element

After		
Touch Pad	KA2 or QD4	Heating Element

The Freescale Support Ecosystem

Transforming your mechatronics idea into a workable design takes ingenuity, dedication and the guidance to use the right tools at the right time. Our ultimate goal is to give you a positive "out-of-the-box experience" that will help accelerate your design cycle and speed you products to market.

We've developed an online support ecosystem with tools, training and documentation to accelerate your design process. To help you get started—whether you're an embedded control novice or an experienced engineer—our technical support web page (www.freescale.com/fasttrack) provides self-support and assisted support resources as well as additional online support for each stage of your design cycle.

To help you find exactly the information that will most help you put your design on the fast track to market launch, our improved search engine offers integrated parametric filtering that allows you to more easily refine your results, view only the parametric data that interests you and even quickly export your results to Excel or CSV format.

Development Tools for QD4 and KA2 MCUs

Freescale is creating the most efficient and usable software and hardware development tools in the industry. Tools for our low-end and ultra-low-end 8-bit MCUs are designed to provide maximum results with minimum effort and cost.

- **BDM Multilink**—This provides real-time, in-circuit flash programming, emulation and debugging for the RS08, HCS08 and HCS12 MCUs through the background debug (BDM) interface.

- **Cyclone Pro**—This is the universal debugging and real-time emulation tool for all RS08, HCS08 and HCS12 MCUs, providing all the capabilities of the BDM Multilink plus USB/Ethernet serial interfaces. It has the ability to function as a standalone programmer with push-buttons and LEDs to control operations.

- **Demonstration Boards**—These allow users to program and debug application code with basic I/O functions and peripherals. The cost-effective DEMO9S08QD4 and DEMO9S08KA2 boards each include a potentiometer, serial port, LEDs and built-in USB-BDM cable for programming and debugging.

- **CodeWarrior® Development Studio for HCS08/RS08 Special Edition**—A comprehensive toolset for fast and easy MCU software development, the Special Edition is available as a download, without cost*, from our Web site.

* Subject to registration and licensing agreement

Introduction to the Controller Continuum

Your Entry Point to the Controller Continuum

The QD and KA 8-bit MCU families are your entry point to the entire Freescale Controller Continuum—the industry's first portfolio of 8/32-bit compatible architectures. No other semiconductor company has the extensive collection of advanced MCUs and intellectual property to match our Controller Continuum. Once you have transitioned from discrete control to embedded control in your mechatronics applications, the seamless simplicity and continuous compatibility we offer through our Controller Continuum provides room to grow with unprecedented ease.

As your mechatronics designs mature, scaling your next generation products to new performance levels requires new levels of embedded control. Functionality and cost effectiveness will continue to drive your purchasing decisions, and Freescale's Controller Continuum allows you to find the best MCU solutions without counting bits. The Controller Continuum goes beyond bits to provide compatible on-chip peripherals and development tools for easy transition from low-end and ultra-low-end 8-bit solutions on up to the Freescale ColdFire® family of high-performance 32-bit solutions.

Freescale Controller Continuum

32-bit

Pin-Compatible 9S08/ColdFire® MCU
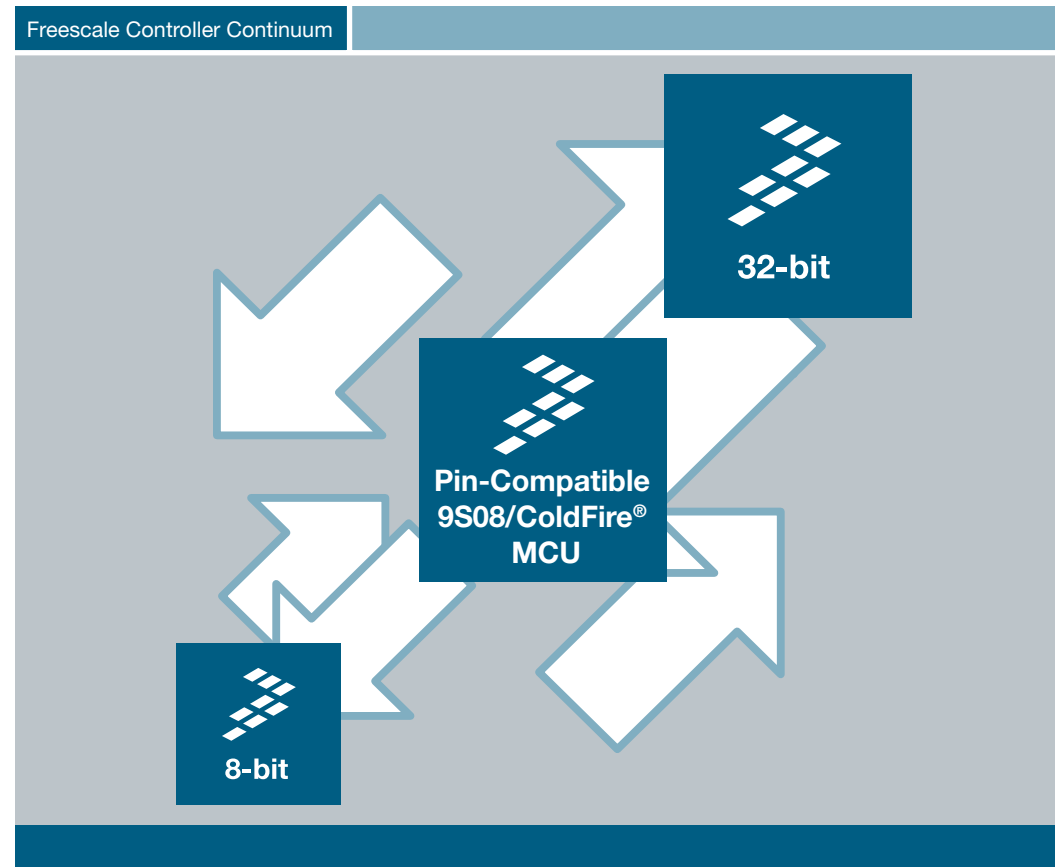
8-bit

The Freescale Controller Continuum is the industry's first and only roadmap for 8-bit and 32-bit compatible architectures. The Controller Continuum is genuine stepwise compatibility—from the bottom to the top. From whatever entry point you choose, whether it's the ultra-low-end RS08 family of MCUs, the more sophisticated S08 devices or the top-of-the-line ColdFire® embedded controllers, each step has family members that share packaging, peripherals or pin-outs with the next step up or down the Controller Continuum. Add common software and hardware tools, and you have true stepwise compatibility—even across the 8-bit to 32-bit boundary.