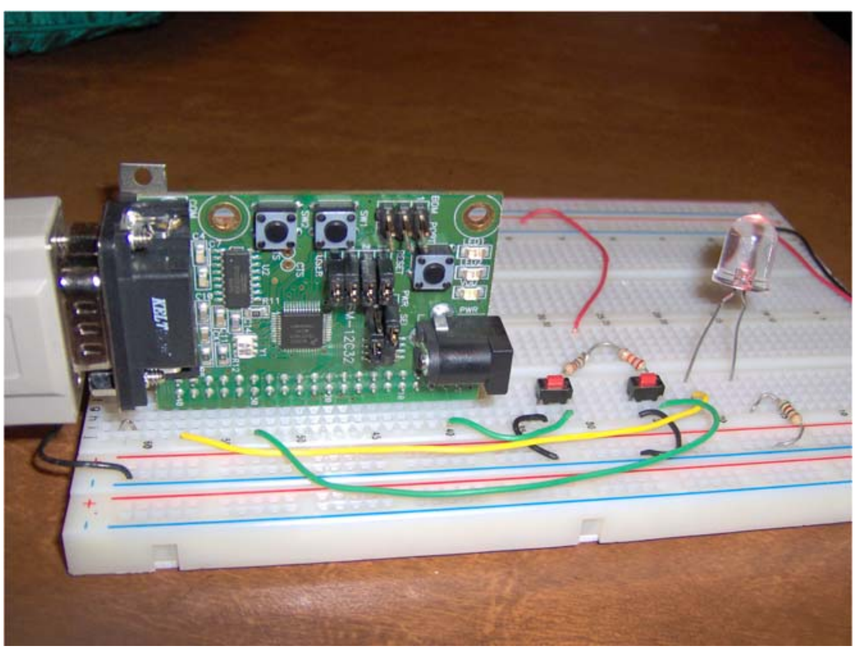
# ECE331 Embedded System Design

## Hardware Interfacing and Programming Featuring the FreeScale (formerly Motorola) MC9S12Cxx Microcontroller Family



## Lecture 1. Microcontrollers and the Freescale MC9S12



## What is a Microcontroller?

- Early microprocessors were merely CPU's (central processing units).
- Before the microprocessor could be useful, it had to be made into a "full microcomputer" by surrounding it on a PC board with several additional chips that provided:
  - **Program Memory (ROM -Read Only Memory)**
  - **Data Memory (RAM – Random Access Memory, also called Read/Write Memory)**
  - **Input and Output Ports (I/O peripherals)**
  - **Address Decoding Logic needed to locate the ROM, RAM, and I/O ports into specific address ranges in the microprocessors address space.**



- **The "microcontroller" was a natural outgrowth of this original board-level microcomputer technology, where the microprocessor, ROM, RAM, and I/O ports were integrated onto a single chip. Initially called the "Single-Chip Microcomputer", the name "microcontroller" soon became more popular. Those who designed products that used microcontrollers to control their designs became known as "embedded system designers".**

- **With the advent of microcontrollers, computerized control of simple "low-end" products such as VCRs, TVs, Ski Boots, light dimmers, smart soldering irons, Barbie Dolls,….etc, could now be achieved at the "chip-level" rather than at the board level! This resulted in much cheaper, much smaller, and much more reliable computer-controlled products!**

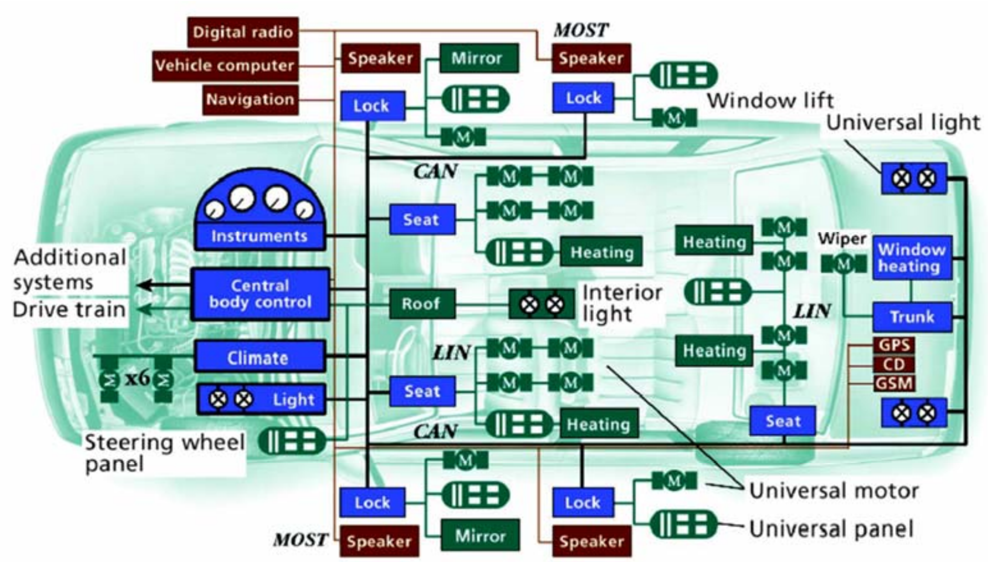
- **With "large quantity" part costs ranging from only $2 - $30, the microcontroller has justifiably been called "The bargain component of the century"!**

# Trends in Automotive Electronics

- Car component cost will increase from $940 per car in 1990 to $1,720 in 2005
- By 2005, 30% car component cost will be for electronic components
- Complex electronic systems on car
  - **Volvo S80 has 18 major electronic control units (> 30 microcontrollers)**
  - **It has two in-vehicle interconnection networks**
  - **A million lines of C code**



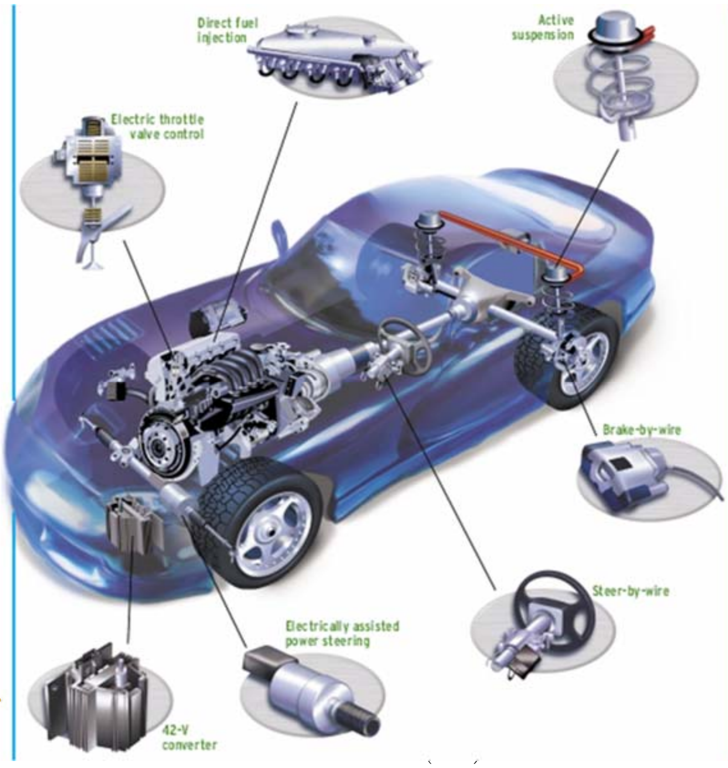
# One Subset of a Modern Vehicle's Network




CAN Controller area network
GPS Global Positioning System
GSM Global System for Mobile Communications
LIN Local interconnect network
MOST Media-oriented systems transport

•Expanding Automotive Electronic Systems, IEEE Computer, Jan. 2002

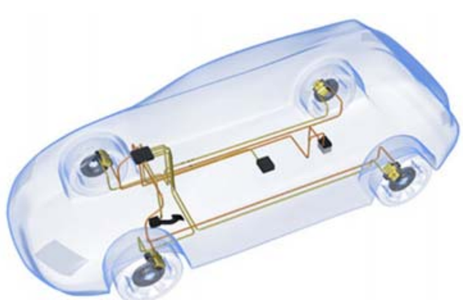
## By-wire systems replace mechanical systems

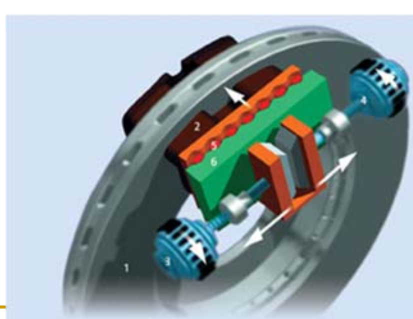


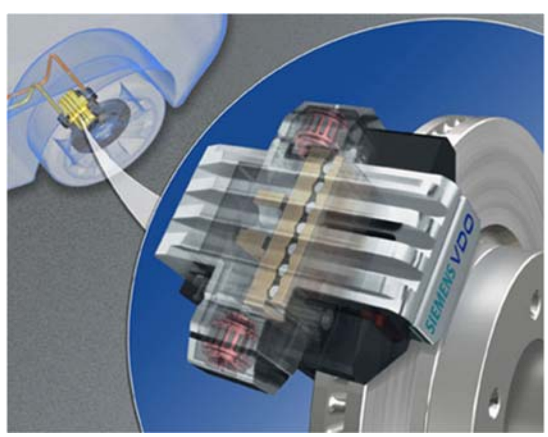

•By-wire cars turn the corner, IEEE Spectrum, April 2001



## Electronic Wedge Brake (EWB) at 12V from Siemens VDO



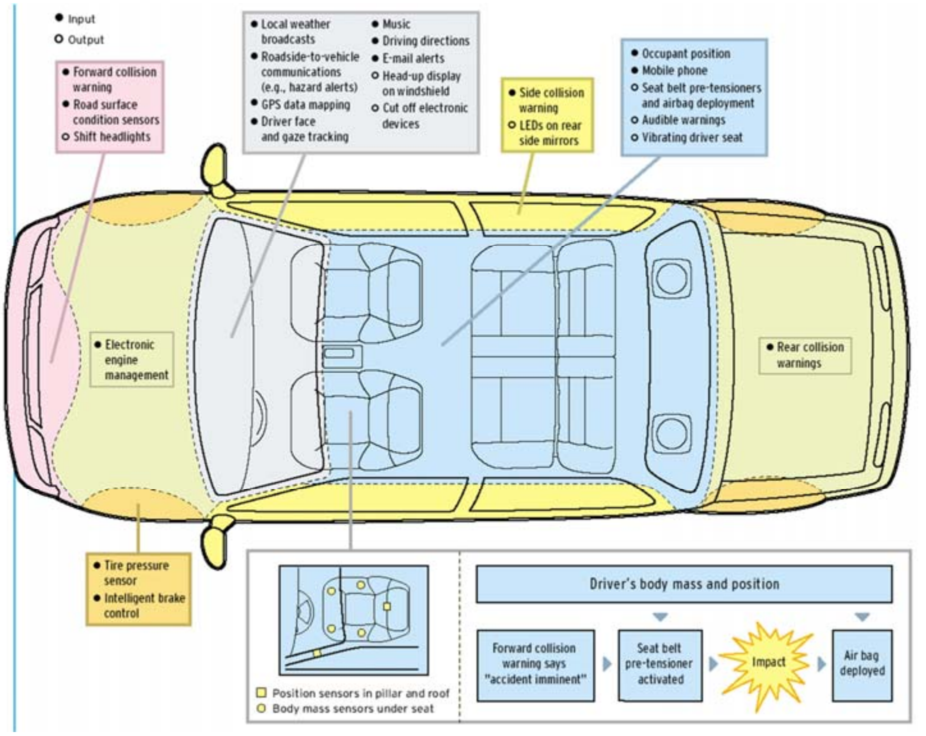





•Wedge brake design boosts by-wire stopping performance
By Bernd Gombert, Siemens VDO
Automotive DesignLine , Apr 06, 2006 (3:22 AM)
from Planet Analog

•Building Safer Cars, IEEE Spectrum, Jan. 2002

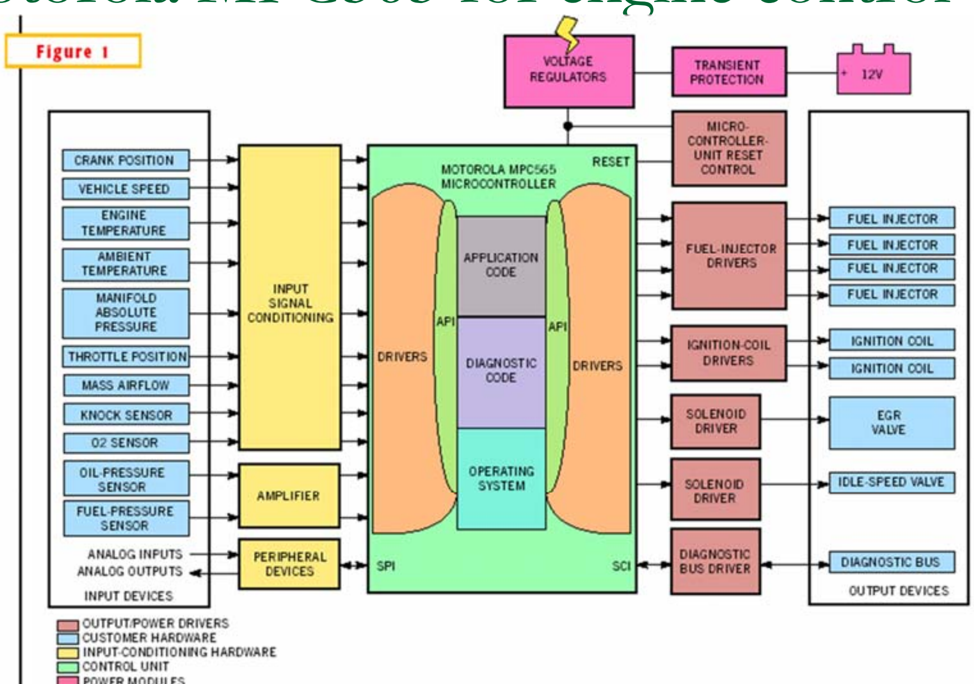
## Building safer cars




•Building Safer Cars, IEEE Spectrum, Jan. 2002



## Motorola MPC565 for engine control




The Motorola MPC565 microcontroller is designed for automotive-engine-control applications.

•Diagnose what ails your auto, EDN Magazine, December 2001

## A “fly in the ointment”

- The problem in designing a general-purpose microcontroller is anticipating just what I/O peripherals are needed by the largest number of customers, how much RAM, and how much ROM and other features should be integrated onto the very “limited real-estate” available on a microcontroller chip.

- A microcontroller with a certain set of I/O features desired by one company might not have the I/O features that are needed by another company!



## Emergence of Microcontroller “Families”

- Manufacturers such as Intel, Motorola (now called “FreeScale”) who had been accustomed to making just one generic microprocessor suddenly found themselves forced into making many different variants of the same microcontroller to match the various I/O needs of their various major customers! Microcontroller families with a bewildering number of “family members” seemed to spring up overnight!

- For example, the development of the first microcontrollers (such as the Motorola MC68HC11) was largely driven by the needs of the automotive industry.

## A "Rose-Hulman" Connection!

- **Back in the 1980's, one of my former RHIT students, Al Shipp, was working for Delco Electronics in Kokomo, IN. Delco made the electronics for General Motors (GM).**
- **Al negotiated with the architect of the 6801 microprocessor, Joel Boney, at Motorola in Austin, Texas to integrate onto a single chip a 6801 CPU core with specific I/O peripheral devices needed by GM for automotive engine control.**
- **Besides selling the resulting chip to GM for engine control, Motorola decided to sell the chip as a general-purpose microcontroller.**
- **Thus was the M68HC11 born!**



## 2005 RHIT Commencement

- The commencement address was delivered by Al Shipp, vice president of enterprise sales for Apple Computer Inc.
- Shipp is a 1978 Rose-Hulman electrical engineering graduate.
- He is responsible for business development to expand the worldwide market for Apple Computer Products.
- Shipp told the graduates that innovation is the key if American businesses, the government, and our country are to continue to prosper.
- The very next month, Apple announced the I-phone!

## Features Requested by the Automotive Industry

- On-chip, flexible "multi-channel hardware timer" suitable for simultaneously measuring pulse intervals from different optically-encoded tachometers to determine wheel and crankshaft rotational speeds; for generating precisely timed pulses (for spark and valve control); and also for generating pulse-width modulated (PWM) waveforms for dc motor speed control.
- Multiple-channel Analog-to-Digital (ATD) conversion for converting temperature, pressure, and other analog sensor input data



- Serial synchronous (clocked) communication capability --- Serial Peripheral Interface (SPI) to support long shift-register loops for input and output of dashboard data.
- "RS232" Serial asynchronous (unclocked) communication interface (SCI) capability suitable for interprocessor communication and easy connection to diagnostic service computers.
- Watchdog "Computer Operating Properly" (COP) timer for resetting the CPU in the event that a noise glitch "derails" the microcontroller's program.

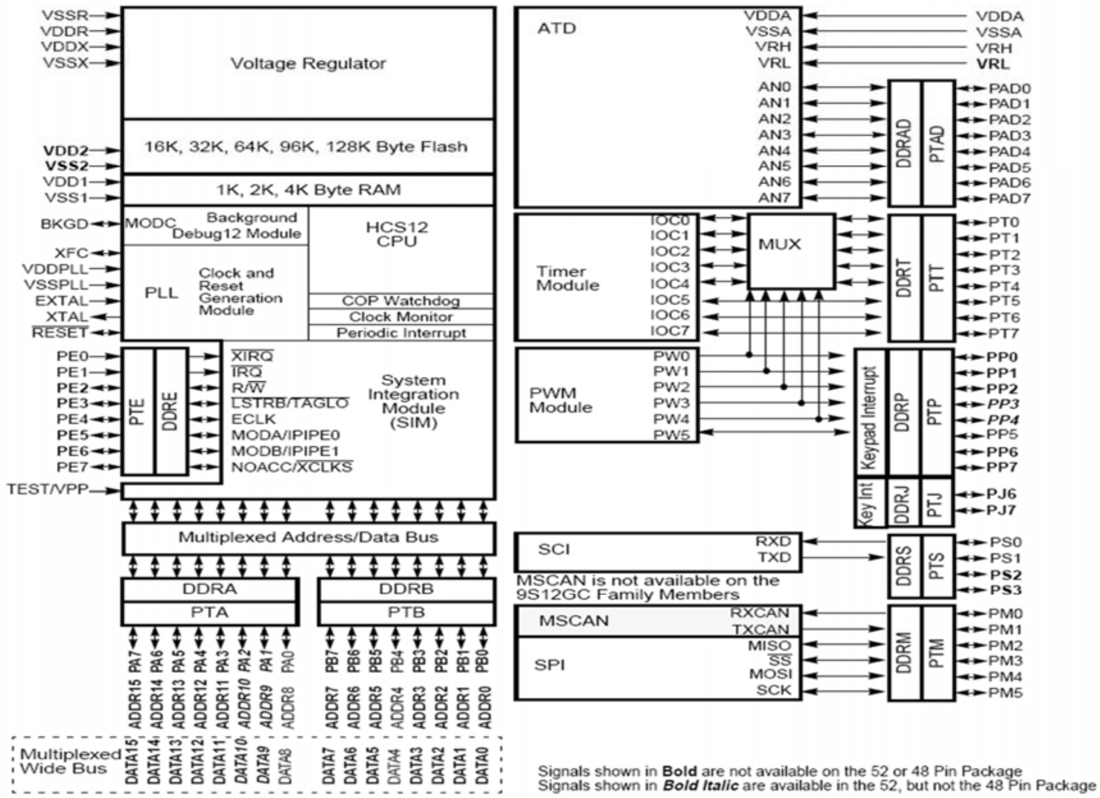
- Nonvolatile RAM (now "Flash programmable ROM" programmable memory) for storing calibration constant and configuration data.
- ROM memory (now "Flash programmable ROM") for storing the control program and also constant data such as lookup tables and ASCII text message strings.
- RAM (read/write) memory for storing temporary data (program variables)
- 6801 (now called CPU12) CPU core with flexible interrupt structure for efficient response to real-time I/O events.
- Low cost, easy to manufacture, yet high reliability!



## MC9S12Cxx family is a derivative of the MC68HC12 microcontroller, which is in turn, an improved version of the original MC68HC11.

- **9S12Cxx family has "inherited" all the features listed above, as shown on the next slide. Note the following features of the 9S12C128 that we will use in this class:**
  - **128 kBytes Flash memory for program AND calibration data. Note the number of kBytes of on-chip Flash memory corresponds the "xx" in the 9S12Cxx part number!**
  - **4kBytes RAM for program variable storage**
  - **HCS12 (CPU12) 8/16 bit CPU Core**
  - **COP watchdog**
  - **SPI (Serial Peripheral Interface) for synchronous serial I/O**
  - **SCI (Serial Communication Interface) for asynchronous serial I/O**
  - **8-Channel ATD Converter**
  - **Timer Module (Input Capture and Output Compare functions)**
  - **PWM (Pulse Width Modulation) Module**

Figure 1-1 MC9S12C-Family Block Diagram




- Additional Features of 9S12C Family
  - **General-purpose I/O on any I/O pins not being used for specialized I/O functions.**
  - **BDM (background debug mode)**
  - **Expanded Bus “microprocessor mode” (where time-multiplexed CPU data, address, and control bus brought out on Ports A, B, and E to permit adding additional I/O and memory functions.**
  - **Clock Multiplier Phase Locked Loop (PLL) allows microcontroller to be internally clocked at an integral multiple of the applied crystal oscillator frequency.**
  - **CAN serial bus controller implements a two-wire differential serial bus that is widely used in the automotive industry.**
  - **Keypad “interrupt on change” (Port J)**

# 9S12C128 Reference Material

- Our textbook ***The HCS12/9S12: An Introduction to Software & Hardware Interfacing***, Han-Way Huang, Thomson Delmar Learning.

- Assorted Freescale PDF Documents available for download from the ECE331 class AFS folder. Please download this entire PDF documents folder onto your laptop PC now.)



# Additional Reference PDF files

- **The ECE331 Class AFS folder "9S12DOCs" contains more than TWENTY! 9S12 reference documents in Adobe Acrobat PDF format.**
- **The S12CPUV2.pdf document describes the CPU12 core and explains *each machine instruction* in detail. You will be referring often to this document!**
- **The 9S12C128DGV1.pdf document provides an overview of the entire 9S12Cxx family (that is where I got the block diagram of the 9S12Cxx family that was presented earlier in this lecture), and it points the way to the other documents, as more information is needed about each functional block within the 9S12Cxx.**

# Reading Assignment

- Huang Text, Chapters 1 and 2