Embedded Connectivity Summit 2004

Hands-Free and Feature Phone Applications for the Industrial and Commercial Markets Using the 56800/E Family

DSCO

Launched by Motorola

freescale™
semiconductor

Objective

Provide an overview of the hardware and software requirements for implementing full duplex speakerphone, hands-free cellular and feature phone applications. Demonstrate complete hardware implementations using the 56F8300 and 5685x families as well as software implementations using the CodeWarrior™ and Processor Expert™ software tools. Demonstrate the benefits of these complete solutions for the industrial, security, commercial and other markets.

Full Duplex Speakerphone Application

- **Your corded or cordless phones are full-duplex devices letting you and your caller speak simultaneously without any dropouts in either one of your voices.**

- **Conventional speakerphones must shut the speaker off when the mic is activated so as not to pick up your caller's voice and transmit it along with yours causing an echo effect. When you speak, you can't hear what your caller is saying. This is considered Half- Duplex operation. A full-duplex device digitizes the signal coming out of its speaker (your caller's voice). It then edits this info out of the signal it's transmitting (your voice) using a digital signal processor. This eliminates echo effect and more importantly, does away with the on-off mic/speaker dilemma. Full-duplex devices do all of this virtually instantaneously so your calls sound natural and free-flowing. It's this technology that differentiates high-end conferencing systems from ordinary, half-duplex speakerphones.**

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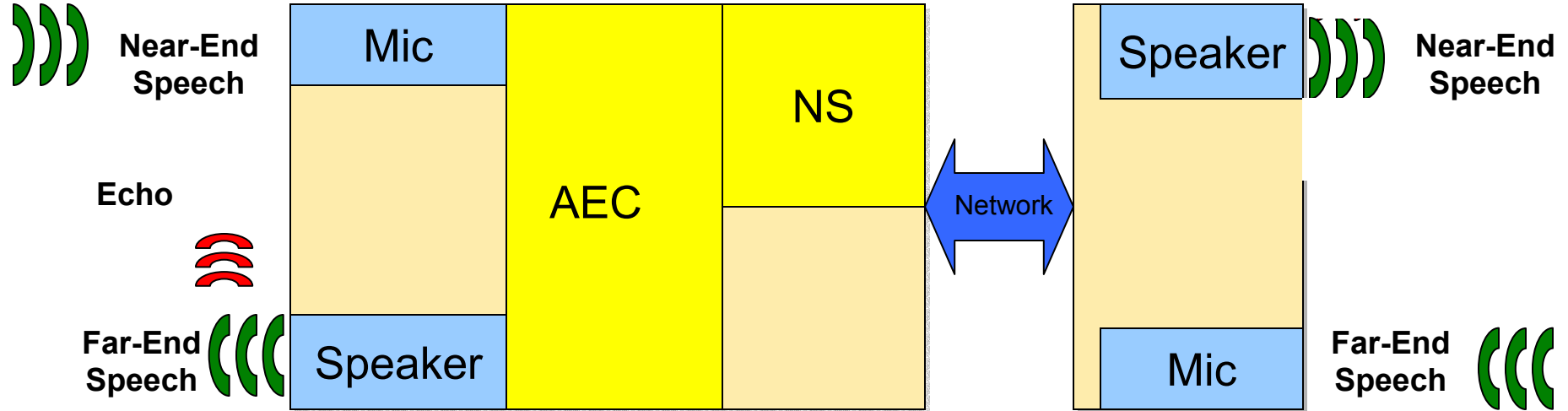semiconductor

Feature Phone Application

- **Feature phone includes all the functionality of basic telephone plus . . .**

  - A high-quality speakerphone (full duplex in Motorola's case)

  - On-hook caller ID and message waiting indicator services
    (*These are known as Type 1*)

  - Off-hook caller ID services –

    > Calling identity delivery on call waiting

    > Call Waiting Deluxe (CWD) (*Type 2 & Type 2.5*)

  - A large LCD display

- **Capabilities that distinguish feature phones in the market include:**

  - Corded or cordless

  - Call management software and user interfaces,
    such as ADSI or custom

  - Digital telephone answering machine capabilities

  - Call logs and directory database features

  - Single or multi-line

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Handsfree Cellular Application

Noise

Near-End Speech

Echo

Far-End Speech

Mic		
	AEC	**NS**
Speaker		

Network

Far-End

Speaker
Mic

Near-End Speech

Far-End Speech

Typical Handsfree Apps

Speakerphone
Mobile Phone

Typical Impairments

Acoustic Echo from Speaker
Background Noise

Handsfree Algorithm

Acoustic Echo Canceller (AEC) Algorithm
Removes near-end acoustic echo so the far-end won't hear it
Noise Suppression (NS) Algorithm
Removes near-end noise so the far-end won't hear it

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56800/E Hybrid Controller Roadmap

56850 Series
Telecom/voice, RAM-based, 120 MMACS, 81–144 pins

56F8400 Series
Automotive, industrial, Flash-based,120 MMACS, Flex-Ray, 2xCan, Improved PWM&ADC, low power, 48–160 pins

56F8500 Series
Automotive, industrial, Flash-based,150 MMACS, Flex-Ray, 2xCan, Improved PWM & ADC, low power,48- 160 pins
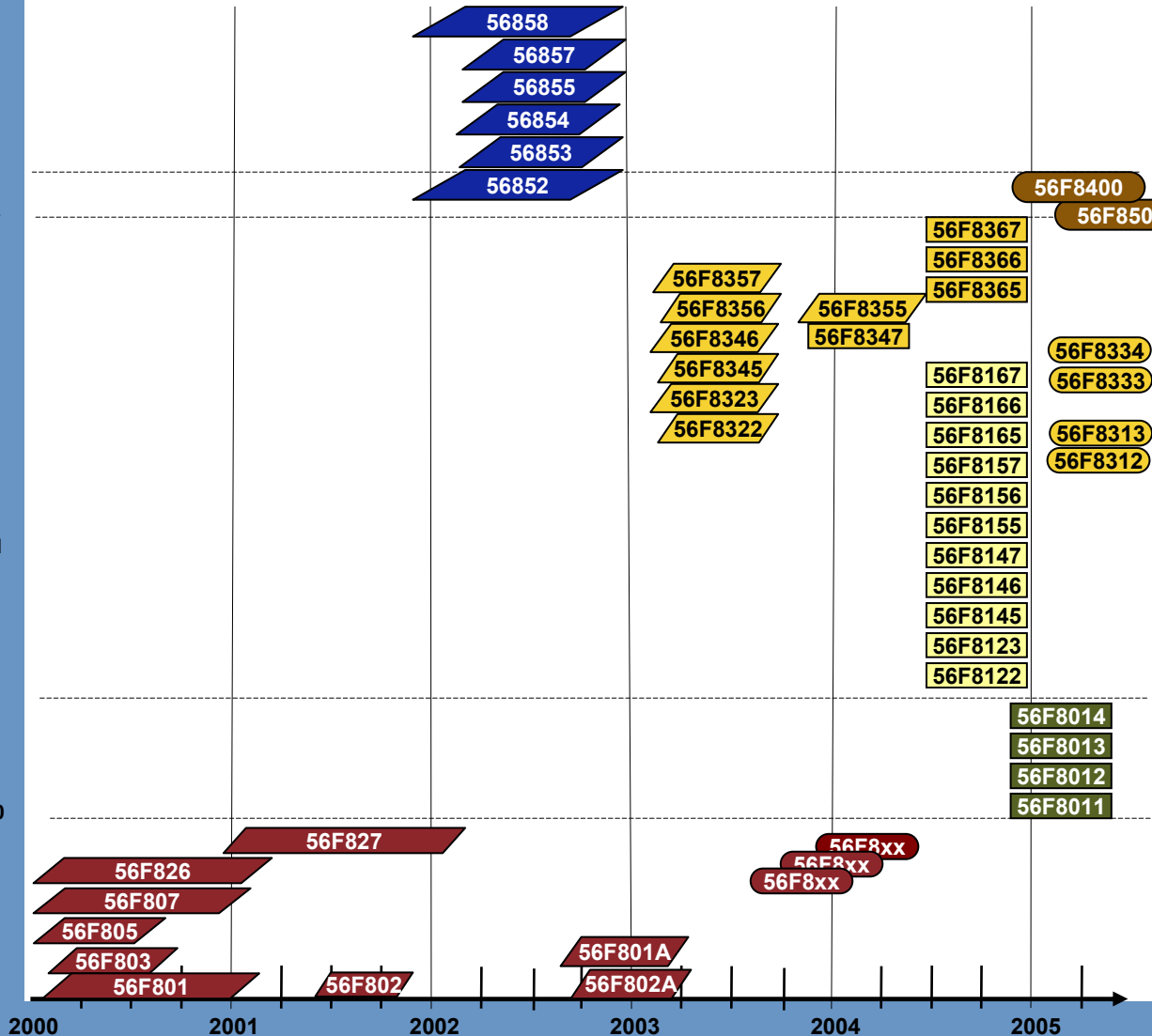
56F8300 Series
Automotive&Industrial, Flash-based, 60 MMACS, 16-512KB PFlash, 48–160 pins

56F8100 Family
Mid-Range Industrial and General Purpose, Flash Based, 40MMACs 48-144 pins

56F8000 Series
Low end industrial and automotive control, Flash-based, 32 MMACS, 28-32 pins

56F820 Series
General Purpose, Flash-based, 40 MMACS, 100–128 pins

56F80x Series
Industrial controllers, Flash-based, 40 MMACS, 32–160 pins

56858
56857
56855
56854
56853
56852

56F8400
56F8500

56F8367
56F8366
56F8365

56F8357
56F8356
56F8355
56F8347
56F8346
56F8345
56F8323
56F8322

56F8334
56F8333

56F8167
56F8166
56F8165
56F8157
56F8156
56F8155
56F8147
56F8146
56F8145
56F8123
56F8122

56F8313
56F8312

56F8014
56F8013
56F8012
56F8011

56F827
56F826
56F807
56F805
56F803
56F801

56F802

56F8xx
56F8xx
56F8xx

56F801A
56F802A

2000 2001 2002 2003 2004 2005

Proposal

Planning

Execution

Production

**0.1Xµ, 56F8400
120 MMACS**

**0.1Xµ, 56F8500
150 MMACS**

**0.18µ, 56800E
120 MMACS**

**0.25µ, 56800E
60 MMACS**

**0.25µ, 56800E
40 MMACS**

**0.25µ, 56800
30/40 MMACS**

**0.25µ, 56800E
32 MMACS**

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56850 Series

	56852	56853	56854	56855	56857	56858
Performance	120MHz/120MIPS	120MHz/120MIPS	120MHz/120MIPS	120MHz/120MIPS	120MHz/120MIPS	120MHz/120MIPS
Temp. Range	(-40, +85)°C	(-40, +85)°C	(-40, +85)°C	(-40, +85)°C	(-40, +85)°C	(-40, +85)°C
I/O Voltage	3.3V	3.3V	3.3V	3.3V	3.3V	3.3V
Core Voltage	1.8V	1.8V	1.8V	1.8V	1.8V	1.8V
On-Chip RAM	**22KB**	**34KB**	**66KB**	**58KB**	**130KB**	**130KB**
Program RAM	12KB	24KB	32KB	48KB	80KB	80KB
Data RAM	8KB	8KB	32KB	48KB	48KB	48KB
Boot RAM	2KB	2KB	2KB	2KB	2KB	2KB
Ext. Memory Expansion	4MB/12MB	4MB/16MB	4MB/16MB	4MB/16MB	-	4MB/16MB
Oscillator	Yes	Yes	Yes	Yes	Yes	Yes
PLL	Yes	Yes	Yes	Yes	Yes	Yes
Watchdog Timer	Yes	Yes	Yes	Yes	Yes	Yes
Interrupt Controller	Yes	Yes	Yes	Yes	Yes	Yes
16-bit Timers	4	4	4	4	4	4
SPI (Synchronous)	1	1	1	-	1	1
SCI	1	2	2	2	2	2
ISSI	1	-	-	-	-	-
ESSI	-	1	1	1	2	2
Parallel Host Interface	-	8-bit	8-bit	-	8-bit	8-bit
DMA	-	6-ch	6-ch	6-ch	6-ch	6-ch
GPIO (Max)	11	41	41	18	47	47
JTAG/EOnCE	Yes	Yes	Yes	Yes	Yes	Yes
Packages	81 MBGA	128 LQFP	128 LQFP	100 LQFP	100 LQFP	144 LQFP 144 MBGA
Availability	Now	Now	Now	Now	Now	Now

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56F8300 Series

	56F8322	56F8323	56F8333	56F8334
Performance	60MHz/MIPS	60MHz/MIPS	60MHz/MIPS	60MHz/MIPS
Temp. Range	(-40, +125)°C	(-40, +125)°C	(-40, +125)°C	(-40, +125)°C
Voltage (Core / I/O)	2.5/3.3V	2.5/3.3V	2.5/3.3V	2.5/3.3V
Program Flash	32KB	32KB	64KB	64KB
Program RAM	4KB	4KB	4KB	4KB
Data Flash	8KB	8KB	8KB	8KB
Data RAM	8KB	8KB	8KB	8KB
Boot Flash	8KB	8KB	8KB	8KB
Flash Security	Yes	Yes	Yes	Yes
Ext. Memory Interface	-	-	-	Yes
Regulator(On/Off-chip)	On-Chip	On/Off-Chip	On/Off-Chip	On/Off-Chip
On-Chip Relaxation Osc.	Yes	Yes	Yes	Yes
16-bit Timers	8	8	16	16
Quadrature Decoder	1 x 4ch	1 x 4ch	1 x 4ch	1 x 4ch
PWM	1 x 6ch	1 x 6ch	1 x 6ch	1 x 6ch
PWM Fault Input	1	3	3	3
PWM Current Sense Pins	0	3	3	3
12-bit ADC	2 x 3ch	2 x 4ch	2 x 4ch	2 x 4ch
Temperature Sensor	YES	Optional	Optional	Optional
CAN	FlexCAN	FlexCAN	FlexCAN	FlexCAN
SCI (UART)	2	2	2	2
SPI (Synchronous)	2	2	2	2
GPIO (Ded./Shrd/Tot)	0 / 21 / 21	0 / 27 / 27	0 / 27 / 27	0/61/61
JTAG/EOnCE	Yes	Yes	Yes	Yes
Package	48LQFP	64LQFP	64LQFP	100LQFP

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56F8300 Series

|	56F8345	56F8346	56F8347	56F8355	56F8356	56F8357	56F8365	56F8366	56F8367
Performance	60MHz/MIPS	60MHz/MIPS	60MHz/MIPS	60MHz/MIPS	60MHz/MIPS	60MHz/MIPS	60MHz/MIPS	60MHz/MIPS	60MHz/MIPS
Temp. Range	(-40, +125)°C	(-40, +125)°C	(-40, +125)°C	(-40, +125)°C	(-40, +125)°C	(-40, +125)°C	(-40, +125)°C	(-40, +125)°C	(-40, +125)°C
Voltage (Core / I/O)	2.5/3.3V	2.5/3.3V	2.5/3.3V	2.5/3.3V	2.5/3.3V	2.5/3.3V	2.5/3.3V	2.5/3.3V	2.5/3.3V
Program Flash	128KB	128KB	128KB	256KB	256KB	256KB	512KB	512KB	512KB
Program RAM	4KB	4KB	4KB	4KB	4KB	4KB	4KB	4KB	4KB
Data Flash	8KB	8KB	8KB	8KB	8KB	8KB	32KB	32KB	32KB
Data RAM	8KB	8KB	8KB	16KB	16KB	16KB	32KB	32KB	32KB
Boot Flash	8KB	8KB	8KB	16KB	16KB	16KB	16KB	16KB	16KB
Flash Security	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ext. Memory Interface	-	Yes	Yes	-	Yes	Yes	-	Yes	Yes
Regulator(On/Off-chip)	On/Off-Chip	On/Off-Chip	On/Off-Chip	On/Off-Chip	On/Off-Chip	On/Off-Chip	On/Off-Chip	On/Off-Chip	On/Off-Chip
On-Chip Relaxation Osc.	No	No	No	No	No	No	No	No	No
16-bit Timers	16	16	16	16	16	16	16	16	16
Quadrature Decoder	2 x 4ch	2 x 4ch	2 x 4ch	2 x 4ch	2 x 4ch	2 x 4ch	2 x 4ch	2 x 4ch	2 x 4ch
PWM	2 x 6ch	2 x 6ch	2 x 6ch	2 x 6ch	2 x 6ch	2 x 6ch	2 x 6ch	2 x 6ch	2 x 6ch
PWM Fault Input	4 + 4	3 + 4	3 + 4	4 + 4	3 + 4	3 + 4	4 + 4	3 + 4	4 + 4
PWM Current Sense Pins	3 + 3	3 + 3	3 + 3	3 + 3	3 + 3	3 + 3	3 + 3	3 + 3	3 + 3
12-bit ADC	4 x 4 ch	4 x 4 ch	4 x 4 ch	4 x 4ch	4 x 4ch	4 x 4ch	4 x 4 ch	4 x 4ch	4 x 4ch
Temperature Sensor	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional
CAN	FlexCAN	FlexCAN	FlexCAN	FlexCAN	FlexCAN	FlexCAN	FlexCAN (2)	FlexCAN (2)	FlexCAN (2)
SCI (UART)	2	2	2	2	2	2	2	2	2
SPI (Synchronous)	2	2	2	2	2	2	2	2	2
GPIO (Ded./Shrd/Tot)	21/ 28 / 49	0 / 62 / 62	0 / 76 / 76	21 / 28 / 49	0 / 62 / 62	0 / 76 / 76	21 / 28 / 49	0 / 62 / 62	0 / 76 / 76
JTAG/EOnCE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Package	128LQFP	144LQFP	160LQFP	128LQFP	144LQFP	160LQFP	128LQFP	144LQFP	160LQFP

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Feature Phone – *Our Solution*

- **Includes the DSP5685x silicon and implements the following features for a single or multi-line application in compliance with the caller ID telecommunications standard SR-3004:**

- Type 1 Caller ID and Visual Message Waiting Indicator
- Type 2 Call Waiting ID
- Type 2.5 Call Waiting Deluxe Options
- Full Duplex Speakerphone with System Optimization Diagnostic Tools
- Multi-line/VoIP Conference Bridge
- Adaptive Line and Acoustic Echo Cancellers

- Extension in Use Detection
- DTMF Detection/Generation
- EIA-470B DTMF Dialer
- Voice Activity Detection -- Call Progress Signal Detection
- Volume/Gain Control
- Tonal Ringing Generator
- AT Command/Keypad/LCD Control Interface

- **All Drivers for DSP5685x peripherals, Codec and DAA**

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DSP56858 Feature Phone Demo - *Components*
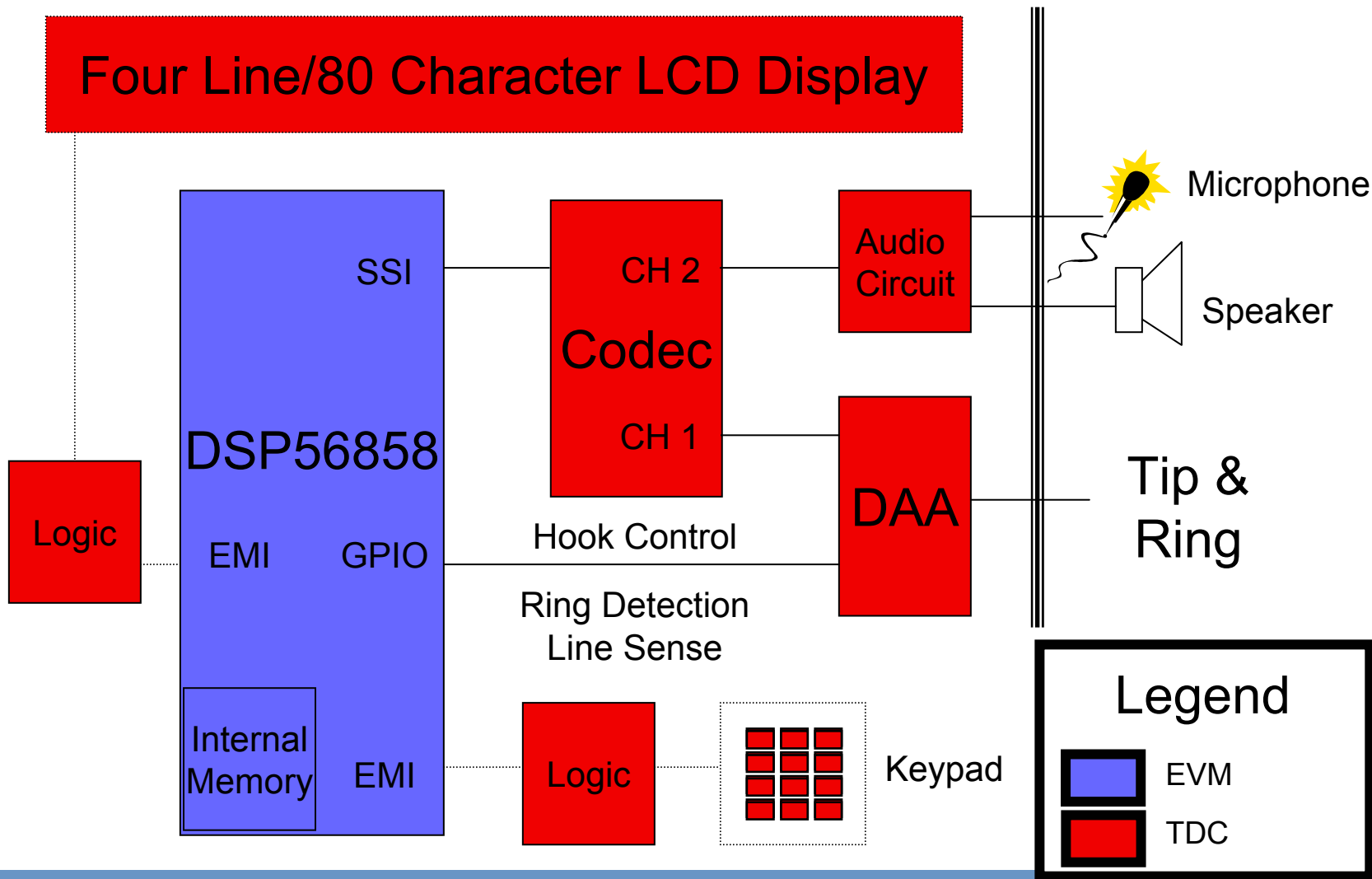
DSP56852 Feature Phone Demo - *Components*
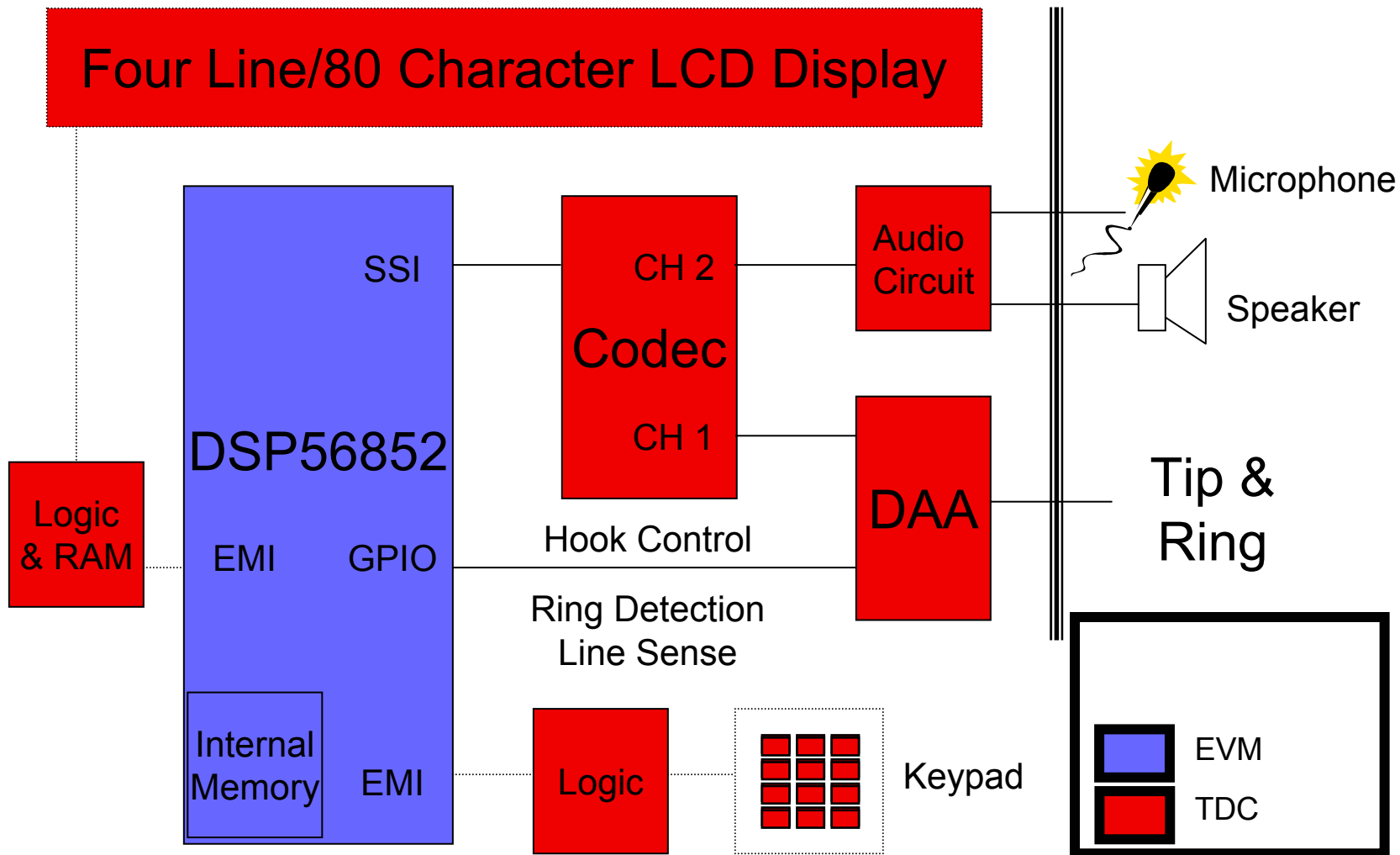
Feature Phone Software Structure
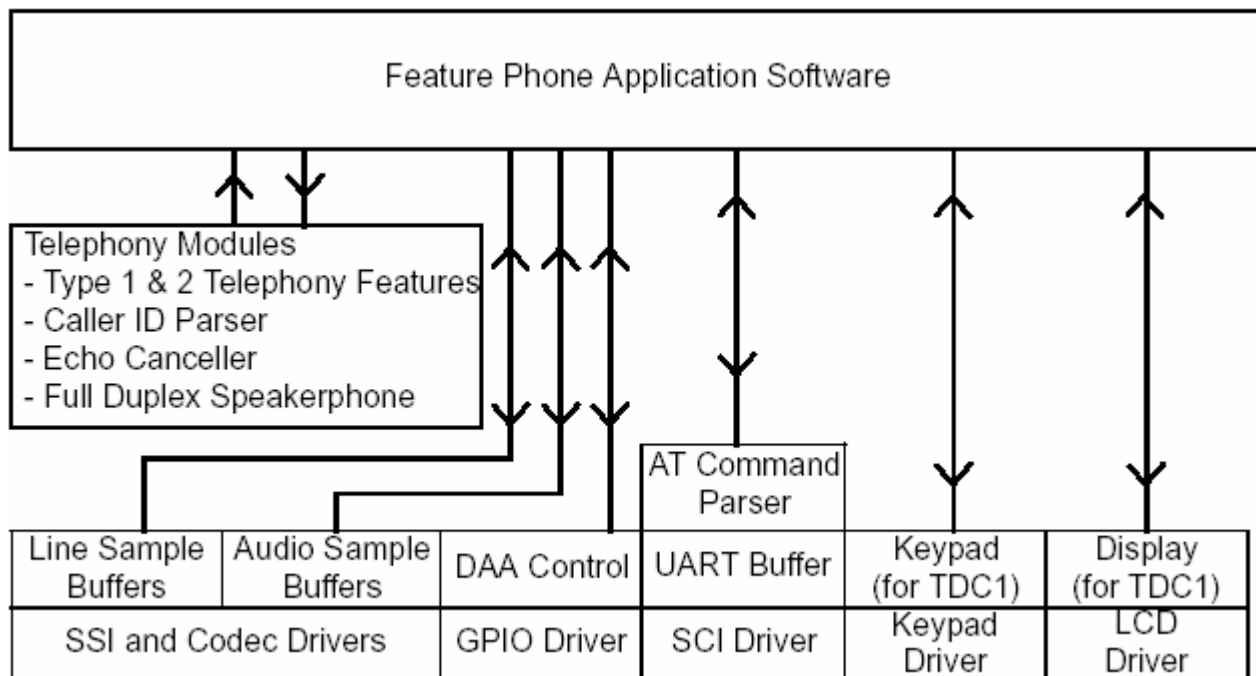
Feature Phone Data Flow
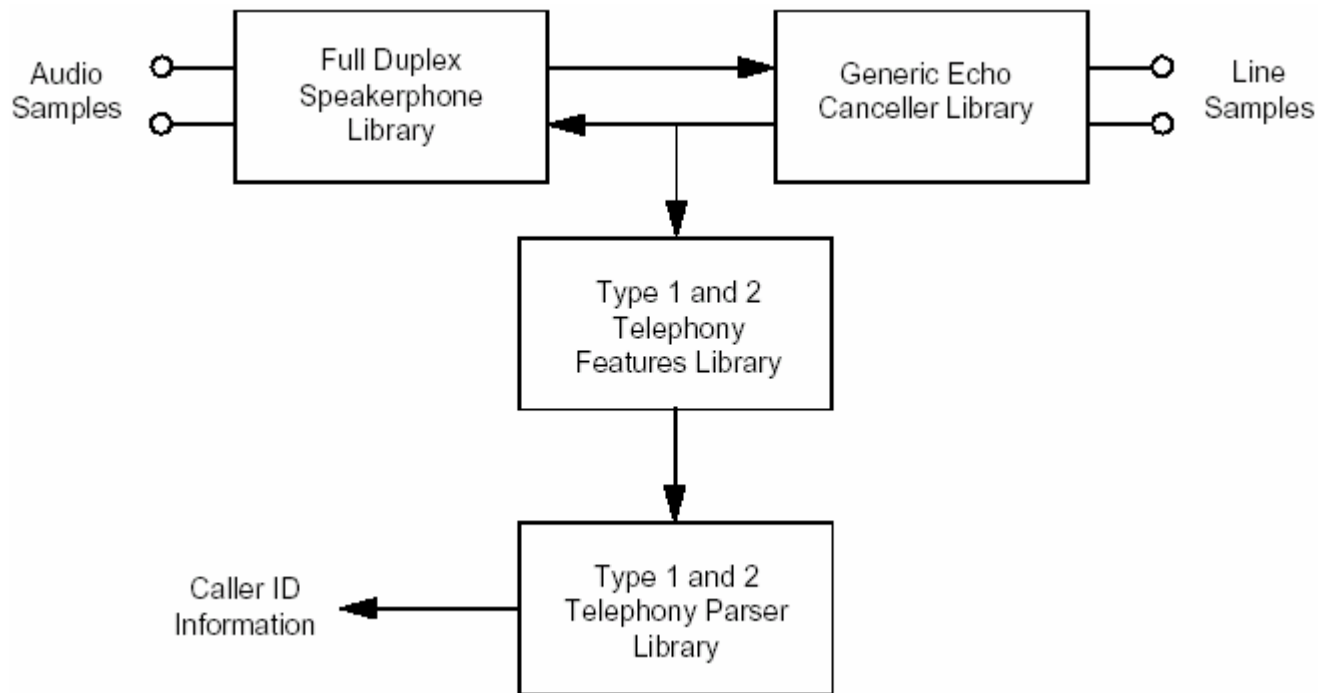
Why DSP56852 or DSP56858?

DSP56852

- Very low cost with 120 MIPS performance
- Full speaker/feature phone capabilities
- Ability to expand functionality with external memory
- Uses some external memory for feature phone

DSP56858

- Price per performance with 128KB of internal memory
- Full speaker/feature phone with just internal memory
- Expandable functionality with internal/external memory:
  - Answering machine
  - Voice recognition
  - Cordless technologies
  - Business phone (digital PBX)
  - Conference bridging
  - Key system unit (small PBX)

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Feature Phone Benefits

- Working reference code enables fast development

- Phone designer can add value quickly without toying with DSP algorithms

- Phone designers can focus on their own differentiation without spending resources on DSP programming

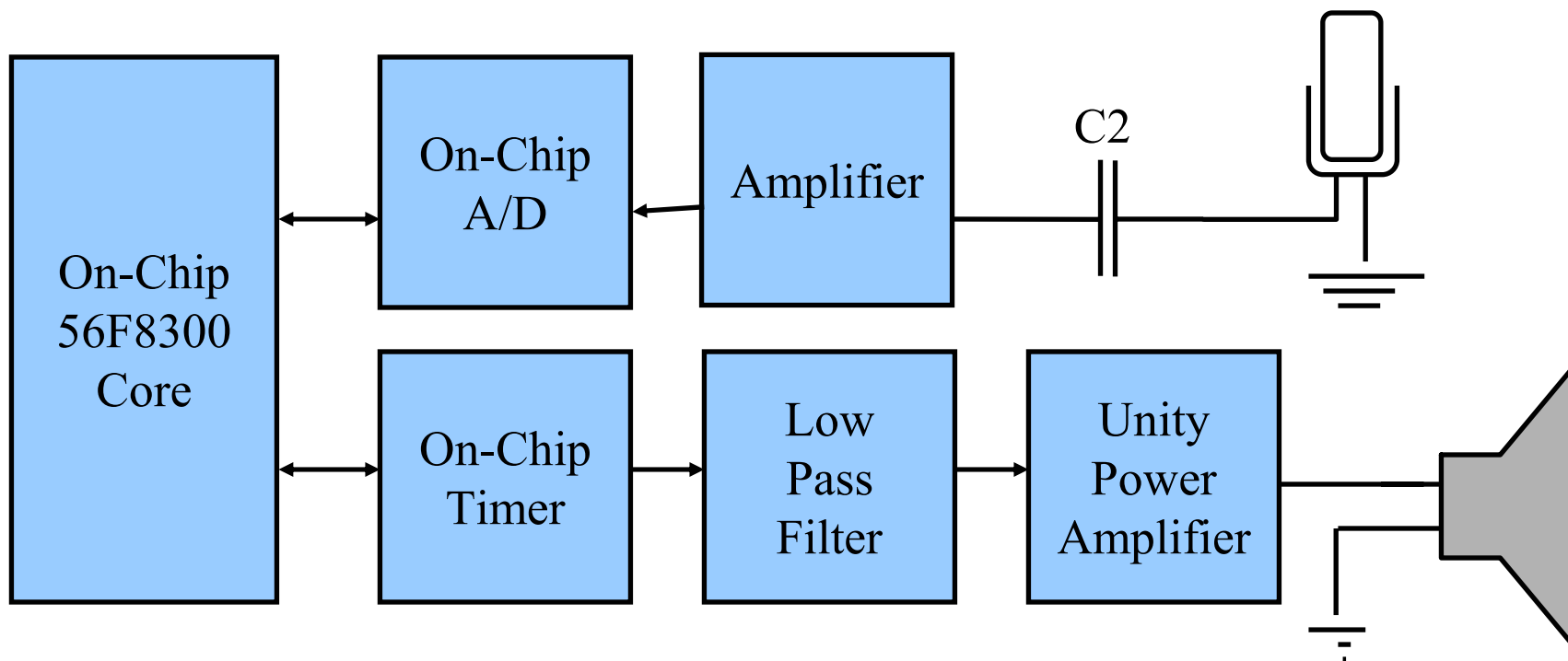- The MCU features and CodeWarrior tools make this simple and fast

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56F8300 based Speakerphone

- **Like the 5685x feature phone a full duplex speakerphone function is implemented using the same high performance digital echo canceling software enabling natural conversations with the far end**

- **56F83xx implementation enables more integration due to the internal flash and peripherals enabling lower cost combined hybrid industrial applications such as building control and security**

- **Creative use of internal peripherals enables to elimination of an external CODEC. This is referred to as the low cost CODEC.**

56F8300 Speaker Phone - *Components*

56F8300

PWM
ADC
PWM
ADC

GPIO

Flash Memory

Low Cost Codec

CH 2

CH 1

Hook Control

Ring Detection
Line Sense

Audio Circuit

DAA

Microphone

Speaker

Tip & Ring

Legend

EVM

Daughter Card

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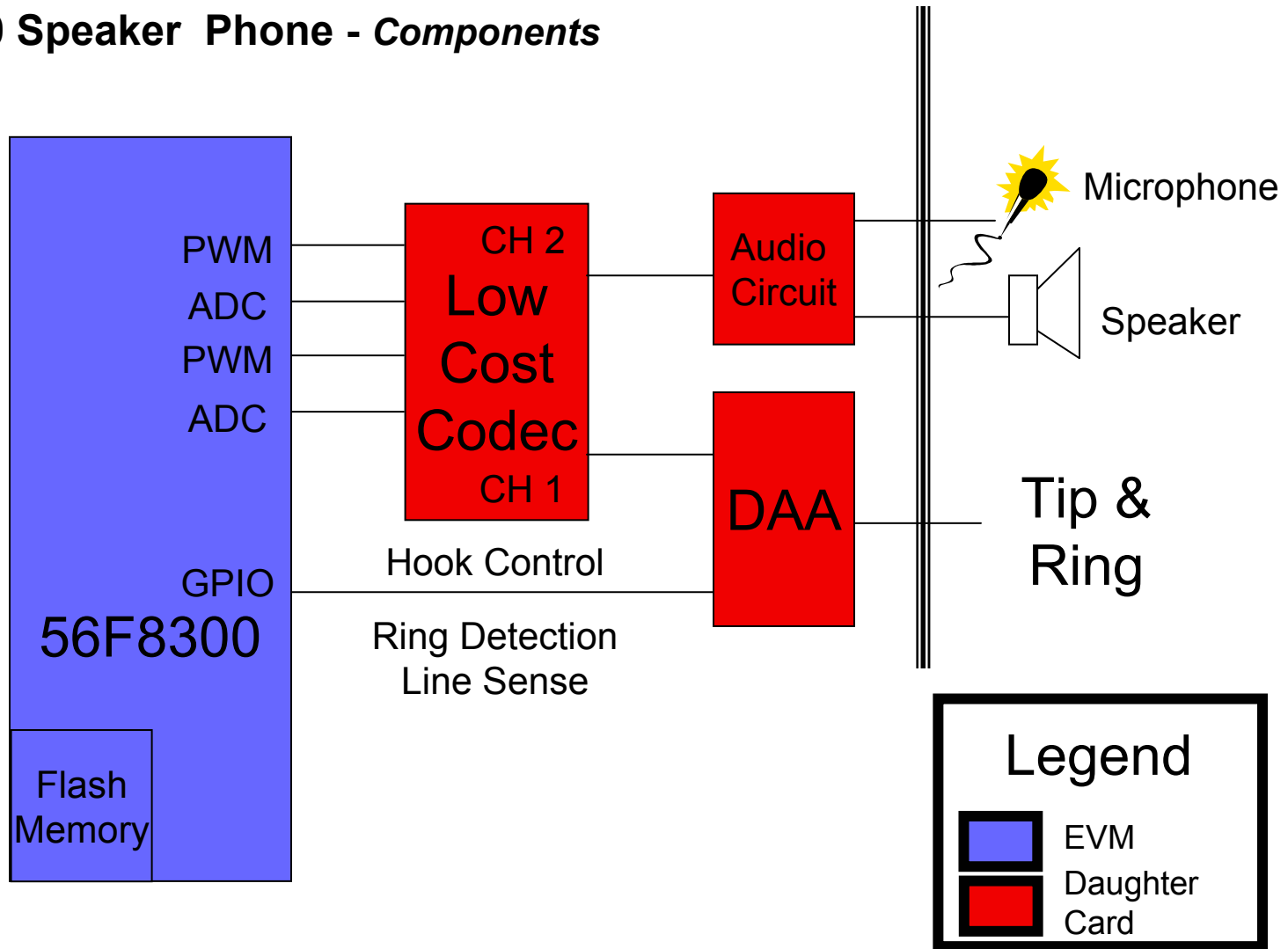
Low Cost Codec

Acoustic Echo Canceller Software

Many applications, such as full duplex speaker phones and mobile telephones, required AECs with high performance. In a speaker-mic telephone system, a part of the speaker output gets picked up by the microphone, either directly or indirectly, causing annoying echoes heard by the far-end telephone user. Acoustic echo cancellers circumvent these echoes.

The AECs perform echo cancellation by estimating the signal fed back to the microphone from the speaker, then subtracting it from the microphone input as shown in the figure. Room impulse response must also be estimated and is approximated by a linear transversal filter. The coefficients of this filter constitute the room impulse response. The existing echo cancellers use Normalized Least Mean Squares, (NLMS), algorithms for estimating the transversal filter coefficients. The identification, or adaptation, of the transversal filter coefficients is possible only in the absence of near-end speech. Also, when there is a near-end signal present, the estimation of the filter must be frozen; a double talk detection algorithm provides this functionality.
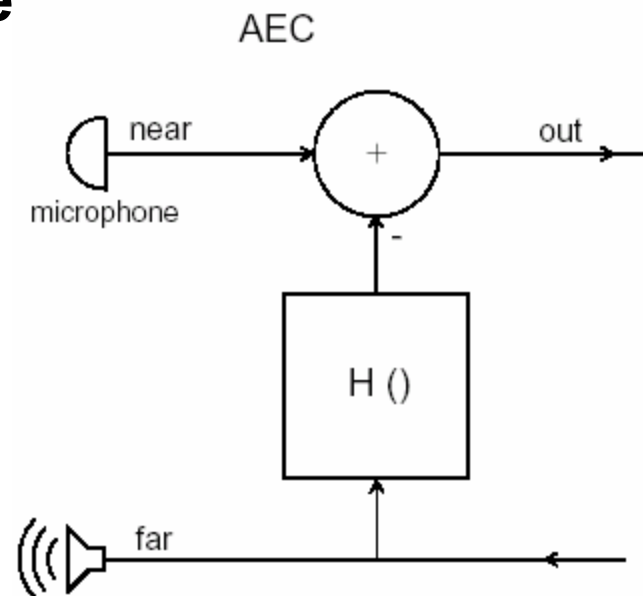
Example using full duplex speakerphone for a voice enabled building control system
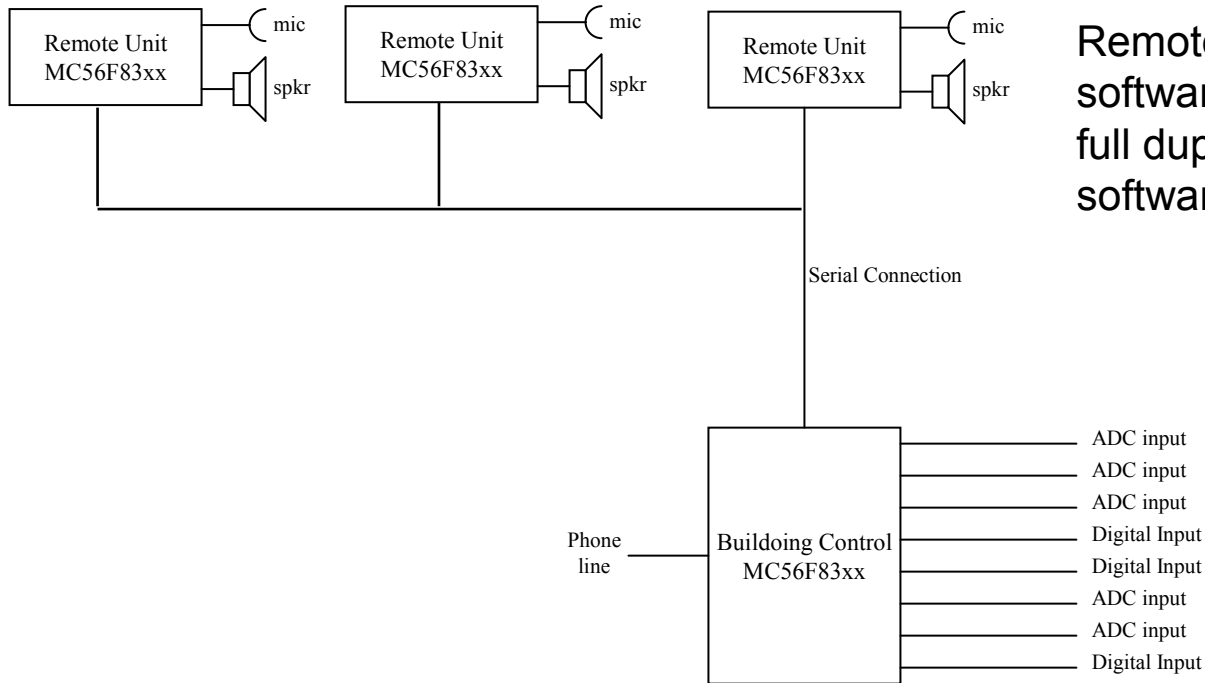
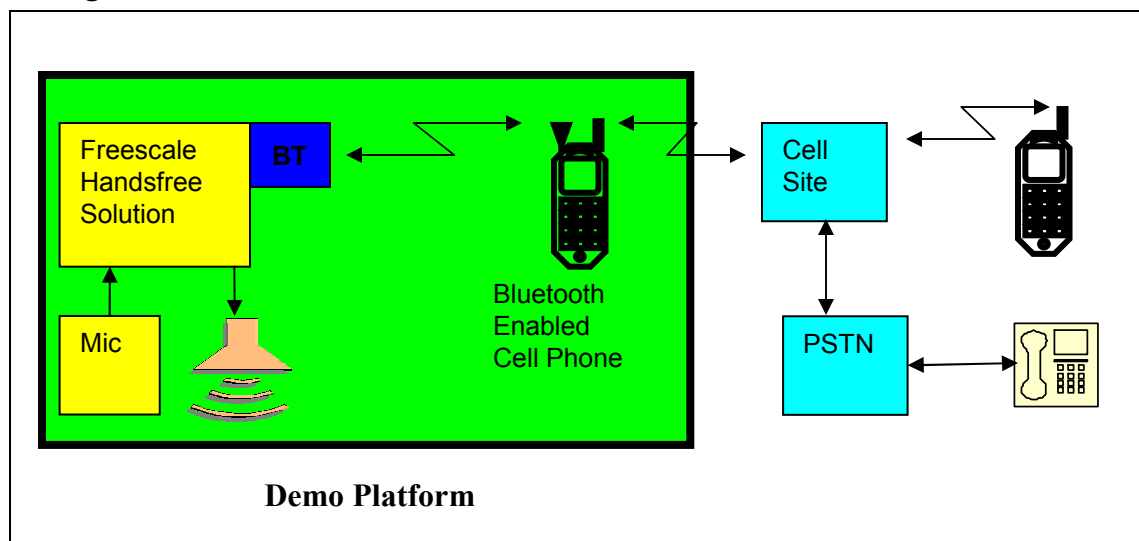Remote unit runs building control software, Vocoder Software, and full duplex speaker phone software.

Control unit runs building control system, Vocoder Software, and full duplex speakerphone software.
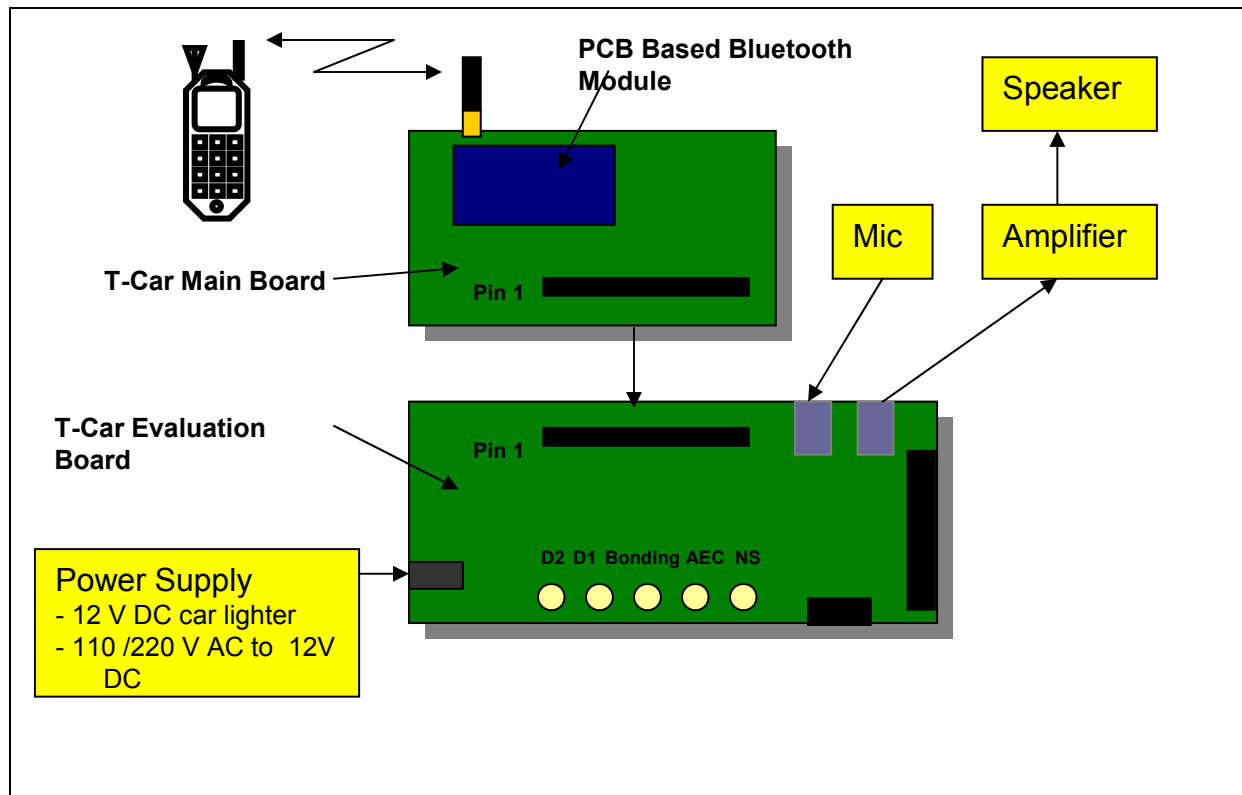
Handsfree Application Demonstration

Features

- Freescale's AEC/NS solution in a simulated automobile handsfree environment executing on a DSP56858 using a Bluetooth enabled cell phone

System Block Diagram

Demo Platform

Handsfree Demo

Hardware Block Diagram

PCB Based Bluetooth Module

Speaker

T-Car Main Board

Pin 1

Mic

Amplifier

T-Car Evaluation Board

Pin 1

Power Supply
- 12 V DC car lighter
- 110 /220 V AC to 12V DC

D2 D1 Bonding AEC NS

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Handsfree Library

Features

- Cancels Near-End Acoustic Echo
  - Maximum 64msec echo length
  - Reaches 25dB Echo Return Loss (ERL) in 370 msec
  - Typical ERL > 35dB in low noise environment
- Suppresses Near-End Noise
- Provides Automatic Gain Control (AGC)
- Detects Double-Talk Conditions
- Easily Configurable
- Performance when configured for 32 msec Echo Length
  - 24 MIPs, 3320 words program RAM, 582 words data ROM, 2279 words data RAM

Handsfree Software
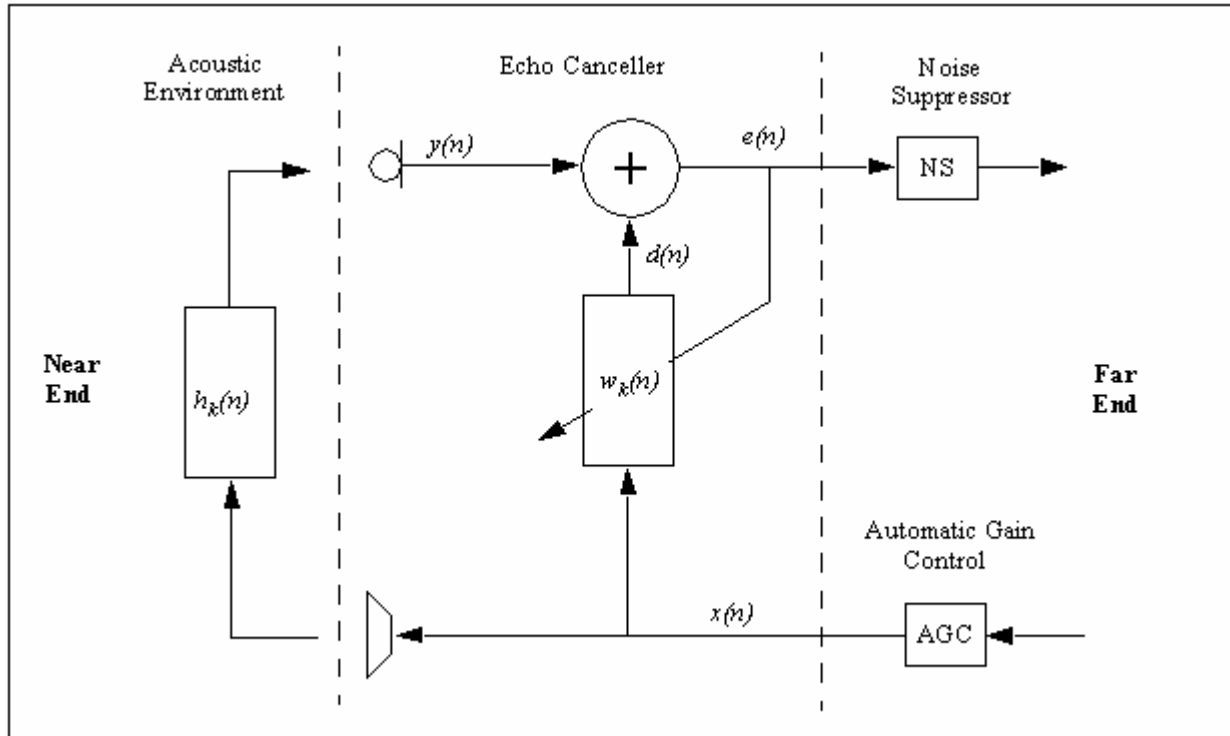
The Complete Development Environment
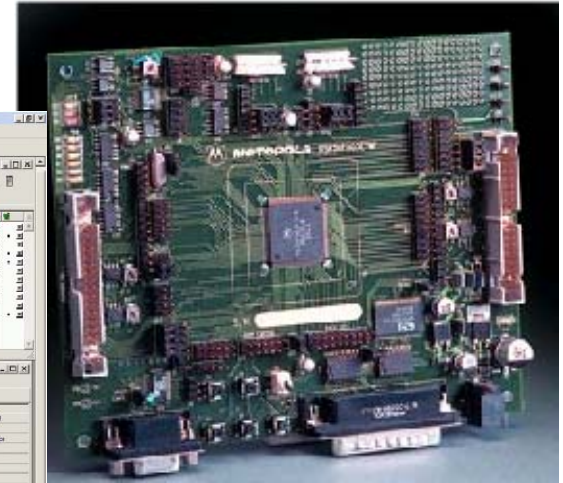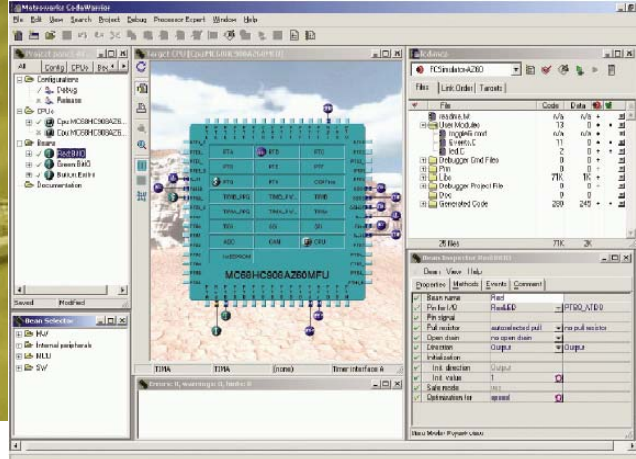
CodeWarrior for 56800/E

CodeWarrior for Motorola 56800/E is a windows based visual IDE that includes an optimizing C compiler, assembler and linker, project management system, editor and code navigation system, debugger, simulator, scripting, source control, and third party plug in interface.

Processor Expert

Processor Expert (PE) provides a Rapid Application Design (RAD) tool that combines easy-to-use component-based software application creation with an expert knowledge system. PE is fully integrated with the CodeWarrior for 56800/E.

Hardware Tools

The 56800/E solutions are supported with a complete set of evaluation modules which supply all required items for rapid evaluation and software and hardware development. In addition several command converter options exist for customer target system debugger connection.

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Processor Expert™ Overview
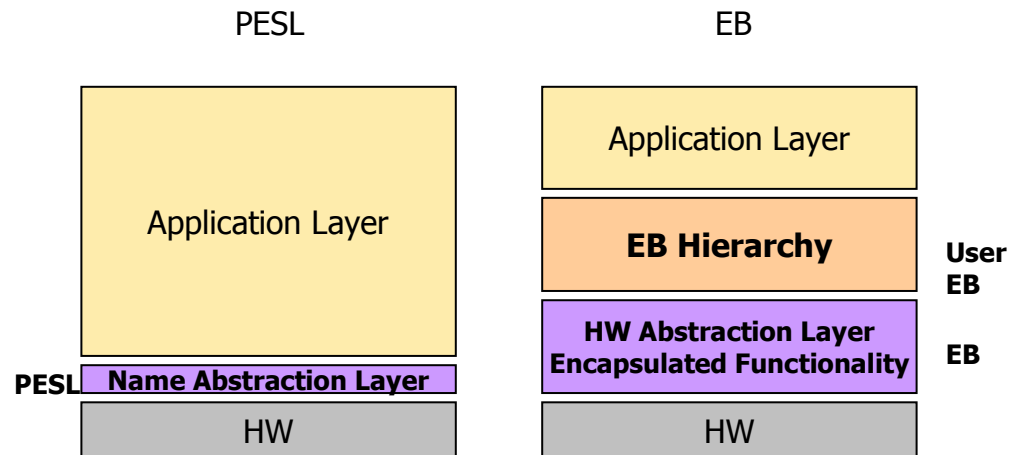
Processor Expert™

- Supports rapid application development
- Enables component oriented programming
- Provides expert advice if necessary
- Delivers instant functionality of generated code
- Provides tested ready-to-use code

Key Abstraction Technologies

- **PESL**
  - Processor Expert System Library
  - Peripheral oriented
- **EB – an abstraction provider**
  - Embedded Beans
  - Functionality oriented
  - Real *components* for building of an application

How Features of PE are Achieved

- Developed by experienced programmers of embedded systems
- Expert knowledge system is working on the background of PE and checks all the settings
- Provides context help and access to CPU/MCU vendor documentation
- All EB delivered by UNIS are tested according to ISO testing procedures (UNIS is ISO certified company)

PESL

Application Layer
PESL **Name Abstraction Layer**
HW

EB

Application Layer
EB Hierarchy
HW Abstraction Layer Encapsulated Functionality
HW

User EB

EB

Processor Expert Features

Available across 8/16 bit product lines

Rapid application development

Expert configuration system
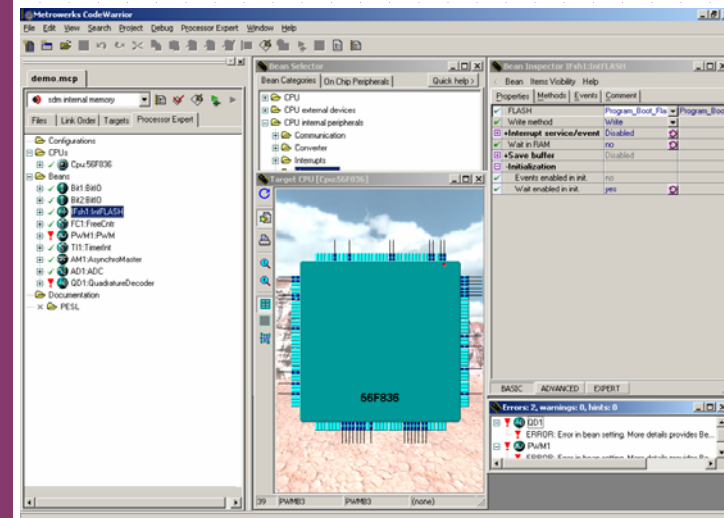
Instant functionality of generated code

Two Peripheral programming levels
- Embedded Beans
- PESL

Application Specific Algorithm Libraries
- All SDK algorithm libraries ported

Tested and ready-to-use code

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Application Specific Algorithm Libraries

Memory Manager
- Dynamic allocation

Feature Phone Library
- CallerID type 1&2, CallerID Parser, Generic Echo Cancellor

DSP Library
- FIR, IIR, FFT, Auto Correlation, Bit Reversal

Telephony Libraries
- AEC, AGC, Caller ID,
- CAS, CPT, CTG, DTMF
- G165, G168, G711
- G723, G726, G729

Modem Libraries
- V.8bis, V.21, V.22bis, V.42bis

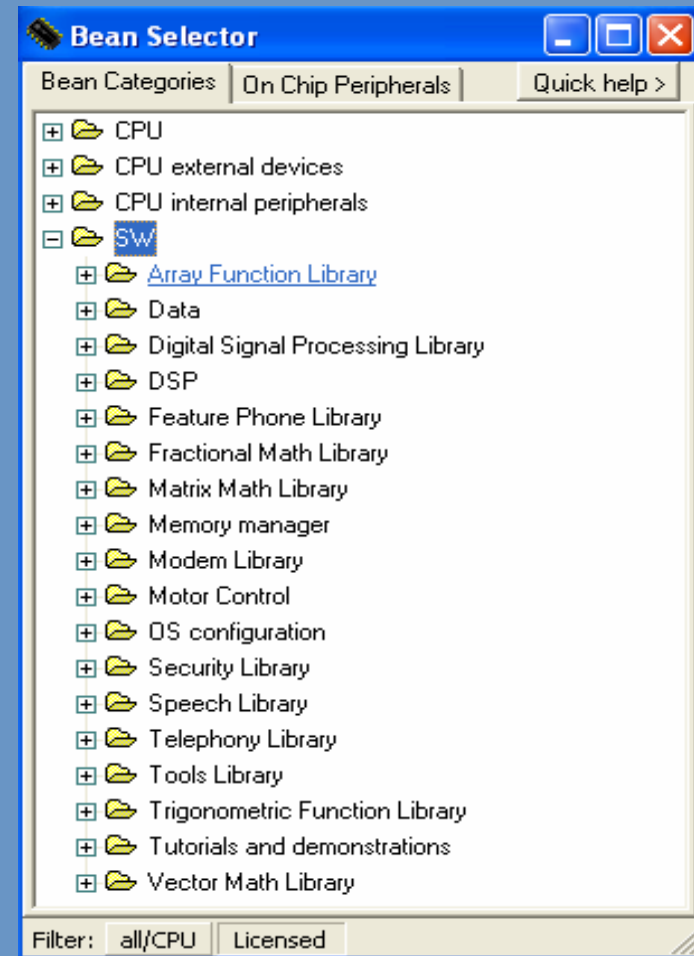**Security Libraries**
- RSA, DES, 3DES,

Motor Control
- BLDC, ACIM, SR motor specific algorithms
- General purpose algorithms

Math Libraries
- Matrix, Fractional, Vector
- Trigonometric

Tools Library
- Cycle Count, FIFO, FileIO, Test

Bean Selector

| Bean Categories | On Chip Peripherals | Quick help > |

- CPU
- CPU external devices
- CPU internal peripherals
- SW
  - Array Function Library
  - Data
  - Digital Signal Processing Library
  - DSP
  - Feature Phone Library
  - Fractional Math Library
  - Matrix Math Library
  - Memory manager
  - Modem Library
  - Motor Control
  - OS configuration
  - Security Library
  - Speech Library
  - Telephony Library
  - Tools Library
  - Trigonometric Function Library
  - Tutorials and demonstrations
  - Vector Math Library

Filter: all/CPU | Licensed

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Conclusion

- **56800/E Hybrid controllers are well suited to a broad range of voice telephony end applications in**
    - **Feature Phone**
    - **Hands free applications**
    - **Industrial Speakerphone and digital intercom enabled control applications**

- **Full hardware and software reference and demo systems available**

- **Very powerful CodeWarrior and Processor Expert development environment accelerates development cycle**