

Definition and Classification

An embedded system is a system that has software embedded into computer- hardware, which makes a system dedicated for an application (s)or specific part of an application or product or part of a larger system.

An embedded system is one that has dedicated purposes of embedded in computer hardware.

It is a dedicated computer based system for an application(s) or product. It may be an in dependent system or apart of large system. Its software usually embeds into a ROM (Read Only Memory) or flash.

-It is any device that includes a programmable computer but is not itself intended to be a general purpose computer. ||—**Wayne Wolf, Ref: 61**

D.Morton,Ref:38

Main Embedded System Components

1. Embeds hardware to give computer like functionalities
2. Embeds main application software generally into flash or ROM and the application software performs concurrently the number of tasks.
3. Embeds a real time operating system (RTOS), which supervises the application software tasks running on the hardware and organizes the accesses to system
4. resources according to priorities and timing constraints of tasks in the system.

PROCESSOR IN EMBEDDED SYSTEM

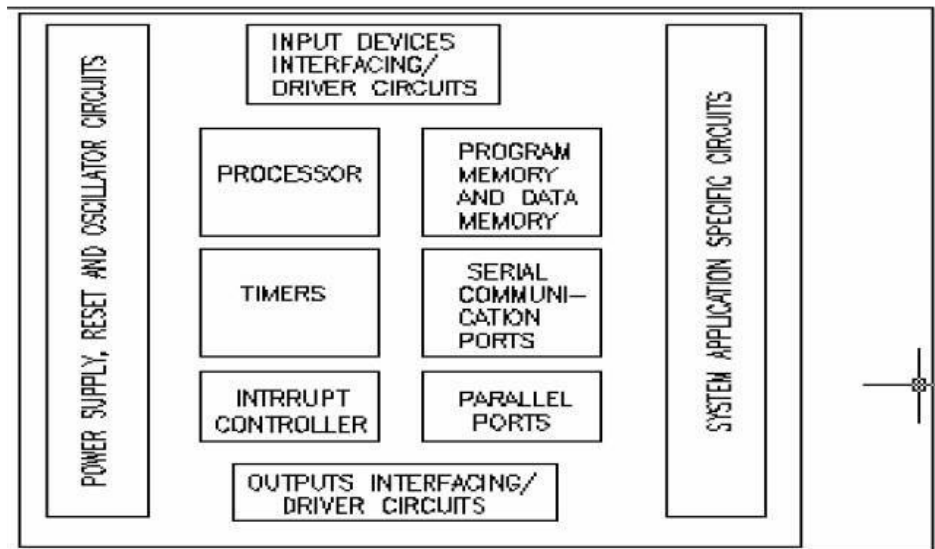


Fig: Typical Embedded System Hardware Unit.

Program Flow and data path Control Unit (CU)—includes a fetch unit for fetching instructions from the memory

Execution Unit (EU)—includes circuits for arithmetic and logical unit (ALU), and for instruction for a program control task, say, data transfer instructions, halt, interrupt, or jump to another set of instructions or call to another routine or sleep or reset

1.11a. General purpose microprocessor

For example, Intel80x86, Space, or Motorola68HCxxx

1b. Embedded general purpose processor

Fast context switching features, use of on-chip Compilers, for example, Intel® X Scale™ Applications Personal Internet Client Architecture-based PDAs, cell phones and other wireless devices,

2. Application Specific Instruction-Set Processor (ASIP)

(a) Microcontroller — Intel, Motorola, Hitachi, TI, Philips and ARM, for example, an Intel®MCS51, Philips®51XA, 51MX, or Motorola— 68HC11, 68HC12, 68HC16DSP or Typically a Texas Instruments- C28xSeries, C54xx or C64xx or Analog Device s SHARC or Tiger SHARC , Motorola 5600xx

(b) Media processor TIDSP TMS320DM310 or Trimedia Phillips Media Processor 1x00 series for Processing Streaming and Data Networks and Image, Video and Speech: PNX 1300, PNX1500(2002)

(c) IO processor or

(d) Network processor or

(e) A domain specific processor

3. GPP or ASIP core(s)

GPP or ASIP integrated into either an Application Specific Integrated Circuit (ASIC) , or a *Very Large Scale Integrated Circuit* (VLSI) circuit or a FPGA core integrated with processor unit(s) in a VLSI (ASIC) chip

4. Application Specific System Processor (ASSP)

Typically a set top box processor or mpeg video-process or network application processor or mobile application processor

Floating point Co processor

- CCD Pixel co processor and image codec in digital camera
- Graphic processor
- Speech processor
- Adaptive filtering processor Encryption engine
- Decryption engine
- Communication protocol stack processor
- Java accelerator

Examples Java Accelerator Noncommunication's Javacodes run 15 to 60 Times fast, Video Accelerator for fast Video Processing

5. Multi core processors or multiprocessor system using GPPs

Examples

- Multi processor system for Real time performance in a video-conference system,
- Embedded firewall cum router , High - end cell phone.

Hardware Elements in the Embedded Systems

(i) Power Source

1. System own supply with separate supply rails for IOs, clock, basic processor and memory and analog units
2. Supply from a system to which the embedded system interfaces, for example in a network card,
3. Charge pump concept used in a system of little power needs, for examples, in the mouse or contact-less smart card.

Power Dissipation Management

1. Clever real-time programming by Wait and Stop instructions
2. Clever reduction of the clock rate during specific set of instructions
3. Optimizing the codes and
4. Clever enabling and disabling of use of caches or cache blocks

(ii) Clock Oscillator Circuit and Clocking Units

1. Appropriate clock oscillator circuit
2. Real Time Clock (System Clock) and Timers driving hardware and

(iii) Reset Circuit

Reset on Power-up

1. External and Internal Reset circuit
2. Reset on Timeout of Watch dog timer

*(iv) Memory***a. Functions Assigned to the ROM or EPROM or Flash**

1. Storing 'Application' program from where the processor fetches the instruction codes
2. Storing codes for system booting, initializing, Initial input data and Strings.
3. Storing Codes for RTOS.
4. Storing Pointers (addresses) of various service routines.

b. Functions Assigned to the Internal, External and Buffer RAM

1. Storing the variables during program run,
2. Storing the stacks,
3. Storing input or output buffers for example, for speech or image.

**c. Functions Assigned to the EEPROM
or
Flash**

Storing non-volatile results of processing

d. Functions Assigned to the Caches

1. Storing copies of the instructions, data and branch-transfer instructions in advance from external memories
2. Storing temporarily the results in write back caches during fast processing

(v) Interrupts Handler

Interrupt Handling element for the external port interrupts, IO interrupts, timer and RTC interrupts, software interrupts and Exceptions

(vi) Linking Embedded System Hardware

Linking and interfacing circuit for the Buses by using the appropriate multiplexers, and decoders, demultiplexers Interface the various system units

3. IO Communication Unit

a. Communication Driver(s): Network Ethernet or serial driver to communicate with Host embedded system Expansion Facility...

Serial Bus (es): For example, UART (512kbps), 1-wireCAN(33 kbps),

Industrial

I2C(100kbps), SMI2C Bus(100kbps), SPI(100kbps), FaulttolerantCAN(110kbps),

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Serial Port (230 kbps) , Micro Wire (300 kbps), SC SI parallel (40Mbps), Fast SC SI(8Mto80Mbps), UltraSCSI-3(8Mto160Mbps),Fire

Wire/IEEE1394(400Mbps,72meter),HighSpeedUSB2.0 (480Mbps, 25 meter)

Parallel Bus(es) :PCI, PCI-X

- b. Media IO Control Element
- c. Keypad or Keyboard IO Interface
- d. LCD Display System Interface
- e. ADC—Single or Multichannel
- f. DAC
- g. GPIB Interface Element
- h. Pulse Dialing Element
- i. Modem
- j. Bluetooth,802.11, IrDA,

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1.2 Software for Embedding in a System

ROM image, Programming Languages and Program models

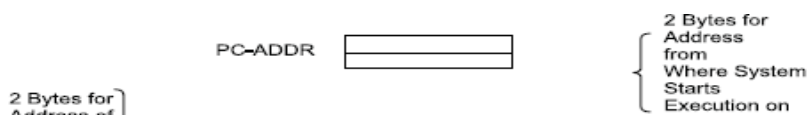
1. ROM Image

- Final stage software also called ROM

image (Just as an image is a --

Unique sequence and arrangement of pixels, embedded softwares also a unique placement and arrangement at each ROM address of bytes for instructions and data.)

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Final machine software

- Bytes at each address defined for creating the ROM image.
- By changing this image, the same hardware platform work differently and can be used for entirely different applications or for new upgrades of the same system.
- Distinct ROM image in a distinct Embedded System

Hardware elements between the distinct systems can be identical but it is the software that makes a system unique and distinct from the other.

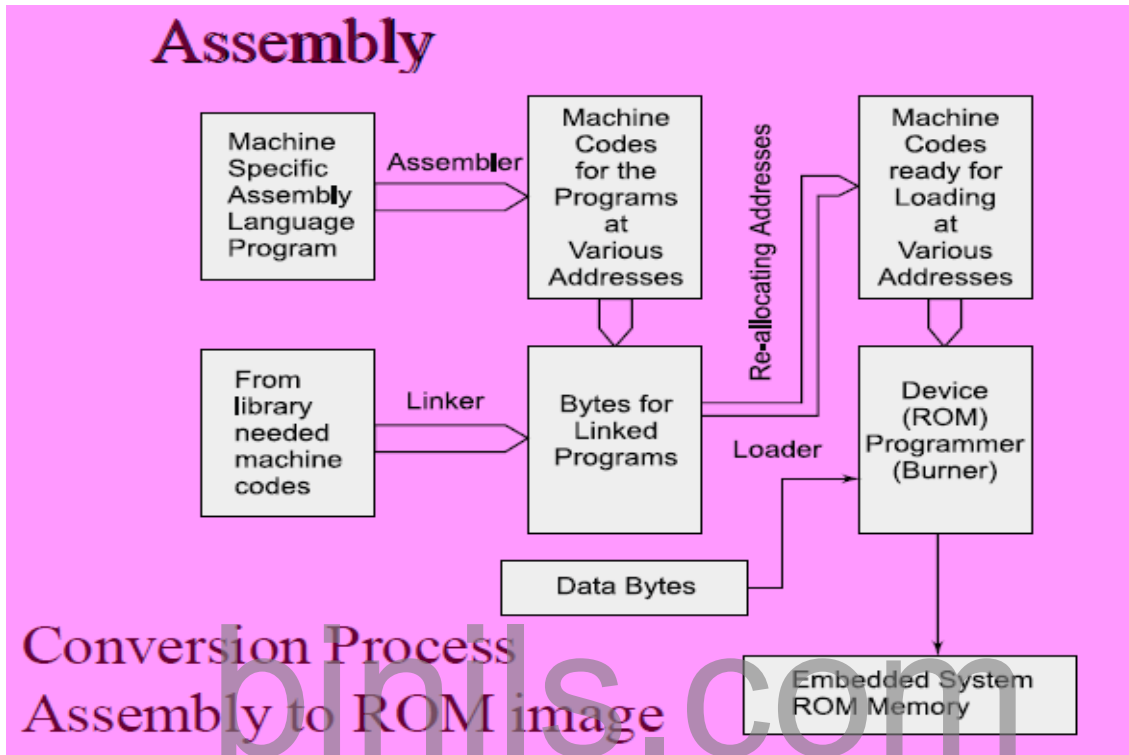
- Compressed Codes and Data ROM image may alternatively be compressed software (for example, the zip format) and data (for example, the pictures in jpg or gif format) along with the software required for decompression algorithm

Programming Languages

1. Machine Language Coding Programmer defines the addresses and the corresponding bytes or bits at each address.
2. Used in configuring some specific physical device or subsystem like transceiver, the machine code-based coding is used
3. Assembly Language Coding Needed for Invoking Processor
Specific Instructions Requires understanding of the processor and instruction set.

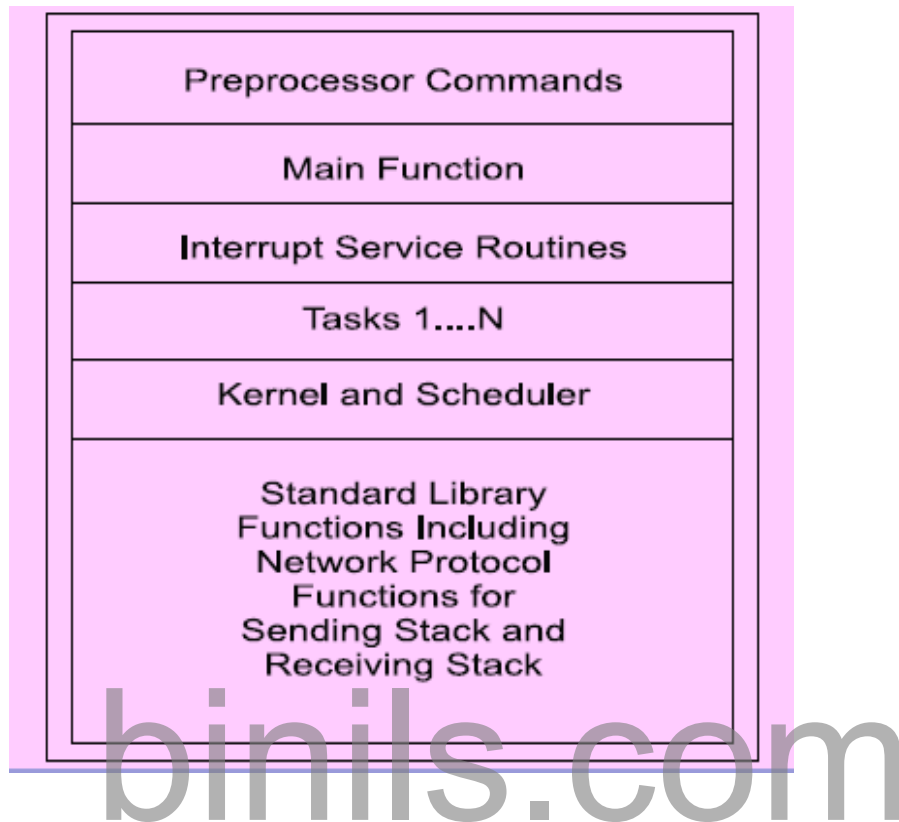
A program or a small specific part coded in the assembly language using an Assembler (

Three steps when using
assembly language'
Assembler',
'Linker' and



3. Programming language C or C++ or Visual

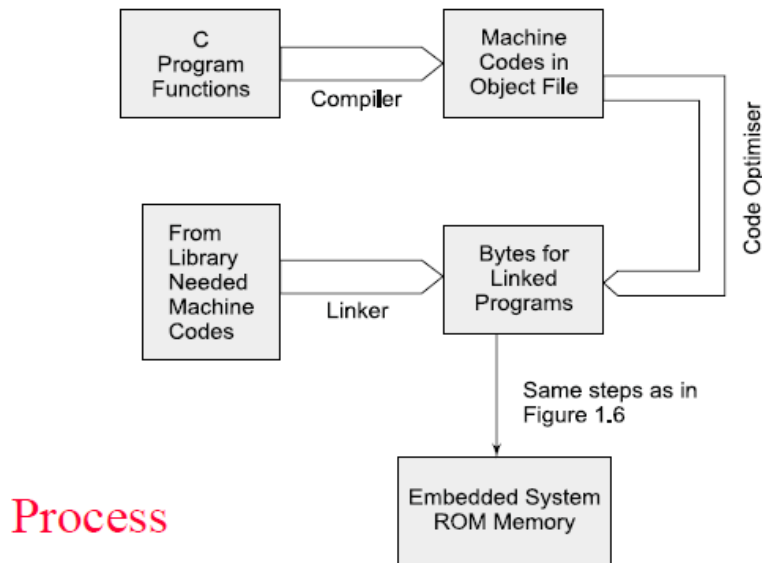
C++ or Java



Application Software - Different Program Layers Program various layers–

- process or commands,
- main function,
- Task functions and
- Library functions,
- Interrupt service routines
- And kernel (scheduler), Compiler
- Generates an object file. Using linker and locator , the file for ROM image is created for the targeted hardware. C++ and Java are other languages used for software coding

Converting a C program into ROM image



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Program Models

- Sequential Programming Model
- Object Oriented Programming Model
- Control and Data flow graphs or

Synchronous Data Flow(SDF) Graph or Multi Thread Graph (MTG)Model

- Finite State Machine for data path
- Multi threaded Model
- Concurrent Processing of processes or thread or tasks

Software embedding in System-Part2

Device drivers, Device manager, OS,
RTOS and Software tools `````` Devices

- In an embedded system , there are number of *physical devices*.
- Physical devices– keypad, LCD display or touch screen, memory stick (flash memory), wireless net working device, parallel port and network card In an embedded system, there are number of *virtual devices*.

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- Virtual devices—pipe, file, RAM disk, socket,

A *device driver* is software for controlling (configuring), receiving and sending a byte or a stream of bytes from or to a device.

A set of generic functions, such as `create()`, `open()`, `connect()`, `listen()`, `accept()`, `read()`, `write()`, `close()`, `delete()` for use by high level programmers. Each generic function calls a specific software (interrupt service routine), which controls a device function or device input or output.

Device controls and functions by:

1. Calling an ISR (also called Interrupt Handler Routine) on hardware or software interrupt.
2. Placing appropriate bits at the control register or word.
3. Setting status flag(s) in the status register for interrupting, therefore running (driving) the ISR, Resetting the status flag after interrupt service.

Device Manager for the devices and drivers

Device Management software (usually a part of the OS) provide codes for detecting the presence of devices, for initializing (configuring) these and for testing the devices that are present.

Also includes software for allocating and registering port(s) or device codes and data at memory addresses for the various devices at distinctly different addresses, including codes for detecting any collision between the allocated addresses, if any.

1.3 Multitasking using an operating

- System(OS) and Real-time operating system(RTOS), Concurrent Processes tasks or threads
- A System is composed of two or more concurrent processes that execute O peratin g System
- Multitasking (multiprocessing or multithreaded) software Scheduling multiple tasks,
- Processes, memory, device, ports, network, filesystem, timers, event functions, i nterprocessor communication, shared memory, security, GUIs, ... management

Real Time Operating System (RTOS)

Embedded software is most often designed for deterministic performance and task and ISR latencies in addition to the OS functions

Performing multiple actions and controlling multiple devices and their ISRs with defined real time constraints and with deadlines for these Task and ISRs priority allocations, their preemptive scheduling, OS for providing deterministic performance during concurrent processing and execution with hard (stringent) or soft timing requirements with priority allocation and pre-emption. RTOS is needed when the tasks for the system have real time constraints and deadlines for finishing the tasks

Important RTOS es

- OS μ COS-II
- V x Works
- Windows CE
- OSEK
- Linux 2.6.24 or RTLinux
- QNX

So Development Tools fit ware tools

1. Editor,
2. Interpreter,
3. Compiler,
4. Assembler and Cross Assembler, IDE,
5. Proto type

Application Software Development Tools

- Source Code Engineering Tools
- Stethoscope(trackstheswitchingfromonetasktoanotherasafunctionoftime,sto resbeats)
- Trace Scope(traces changes in a parameter (s)as a function of time)

Simulator

A Simulator used to simulate the target processor and hardware elements on a host PC and to run and test the executable module.

Project Manager

To manage the files that associates with a design stage project and keep several versions of the source file(s) in an orderly fashion.

EXAMPLES OF EMBEDDED SYSTEMS

Examples

- Telecom
- Smartcards,
- Missiles and Satellites,
- Computer Networking,
- Digital Consumer Electronics, and
- Automotive

Applications

- Mobile phone
- Digital camera
- Rob Point
- Automatic Chocolate Vending Machine

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- Stepper motor controllers for a robotics system
- Washing or cooking system
- Multitasking Toys
- Microcontroller-based single or multi-
display digital panel meter for voltage, current, resistance and
frequency
- Keyboard controller
- Serial port cards
- CD drive or Hard Disk drive controller
- Peripheral controllers, a CRT display controller, a
keyboard controller, a DRAM controller, a DMA controller, a
printer controller,
- A laser printer-controller, a LAN controller, a disk drive controller
- Fax or photocopy or printer or scanner Machine Remote(controller)
of TV
- Telephone with memory, display and other sophisticated features
- Motor controls Systems-for examples, an accurate control of
speed and position of
dc. motor, robot, and CNC machine; the automotive applications
like such as a
close loop engine control, a dynamic ride control, and an anti-lock
braking system monitor
- Electronic data acquisition and supervisory control system
Spectrum analyzer
- Biomedical systems-for example, an ECG LCD display-cum-
recorder, a blood-cell recorder cum analyzer and a patient monitor
system service.

1.4 Electronic instruments, such as industrial process controller

Electronic smart weight display system, and an industrial moisture recorder cum controller. Digital storage system for a signal wave form or Electric or Water Meter Reading

Computer networking systems, -for examples ,router ,front-end processor in a

serve

r, switch, bridge ,hub, and gateway

For Internet appliances, there are numerous application systems

- (i) Intelligent operation, administration and maintenance router (IOAMR) in a distributed network, and
- (ii) Mail Client card to store e-mail and personal addresses and to smartly connect to a modem or server

Banking systems -for examples ,Bank ATM and Credit card transactions

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Signal Tracking Systems - for examples, an automatic signal tracker and a target tracker.

Communication systems, for examples, such as for a mobile-communication a SIM card a numeric pager, a cellular phone, a cable TV terminal, and a FAX transceiver with or without a graphic accelerator. Image Filtering, Games

A system Image Processing, Pattern Recognizer, Speech Processing and Video Processing.

Entertainment systems-such as videogame, music system and Video that connects a pocket PC to the automobile driver mobile phone and a wireless receiver. The system then connects to a remote server for Internet e-mail or remote computer at an ASP (application Service Provider). A personal information manager using frame buffers in hand-held devices.

Thin Client to provide the disk-less nodes with the remote boot capability. [Application of thin-clients is accesses to a data center from a number of nodes; or in an Internet Laboratory accesses to the Internet leased line through a remote Server]. Embedded Firewall/R

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processor with two Ethernet interfaces and interface support for PPP, TCP/IP and UDP protocols.

Sophisticated Applications

- Mobile Smart Phones and Computing systems
- Mobile computer
- Embedded systems for wireless LAN and convergent technology devices
- Embedded systems for Video , Interactive video, broad band IPv6 (Internet Protocol version 6) Internet and other products, real time video and speech or multi time dia processing systems
- Embedded Interface and Networking systems using high speed (400 MHz plus), and ultra high speed (10 Gbps) and large bandwidth: Routers, LANs, switches and gateways , SANS (Storage Area Networks), WANs (Wide Area Networks), Security products and High-speed Network security, Giga bit rate encryption rate products

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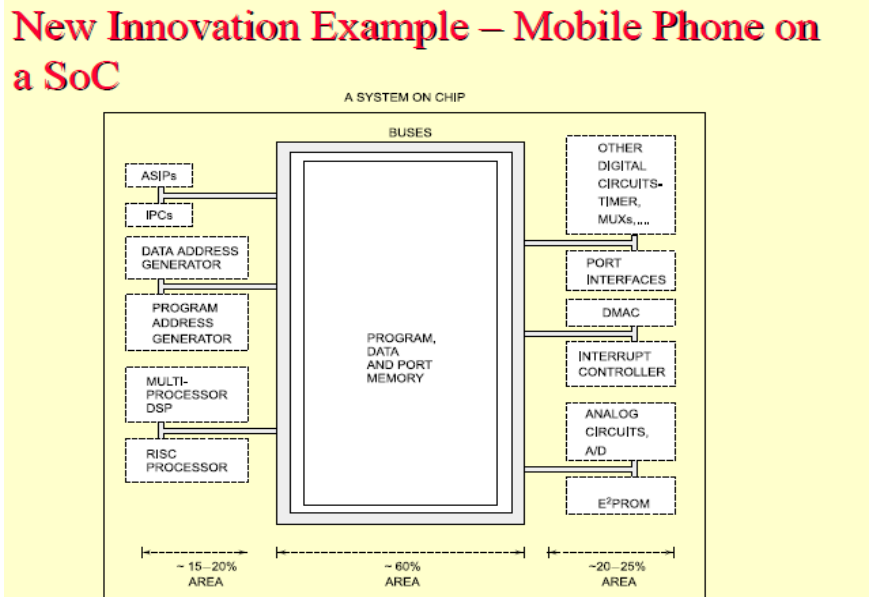
1.5 SYSTEM-ON-CHIP(SoC) AND USE OF VLSI CIRCUIT DESIGN TECHNOLOGY

VLSI chip

- Integration of high-level components
- Possess gate-level sophistication in circuits above that of the counter, register, multiplier, floating point operation unit and ALU.

System on chip (SoC) a new design innovation

SoC is a system on a VLSI chip that has all needed analog as well as digital circuits, processor and software, for example, single-chip mobile phone.



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SYSTEM-ON-CHIP

Embeds:

- Multipleprocessors,
- memories,
- multiplestandardsourcesolutions(IPCores),
- Logic

andanalogunits

Embeddinga

Microprocessor

GeneralPurposeProcessor(GPP)microprocessorcanbeembeddedonaVSL
I chip.

Embeddingan ASIP

Processor with instruction set designedfor specific application on a VLSI
chipfor

example,microcontroller,DSP,IO,media,networkorotherdomainspecificprocesso

- 68HC11xx,
- HC12xx,
- HC16xx8051,
- 80251PIC 16F84or
- 16C76,16F876 andPIC18Microcontroller
- Enhancements of ARM9/ARM7 ARM
- CortexM3 from Philips,Samsungand STMMicroelectronics

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Embedding a DSP Core

- TMS320Cxx, OMAP1 TigerSHARC5600xx PNX1300, 15002 DSP for mobile phones, for example, OMAP of Texas Instruments use the effective power dissipation methods of dynamic switching both of power supply voltage and operating frequency of the CPU core.
- Filtering, noise cancellation, echo elimination, compression and encryption

Embedding a Multi-processor or Dual Core using General Purpose Processors (GPP)

- Speech signal-compression and coding
- Signal decoding and decompression

Embedding an Accelerator

Accelerate the execution of codes, for example, a floating point coprocessor accelerates the mathematical operations and Java accelerator accelerates the Java code execution.

Embedding Single purpose processors

- For Dialling, Modulating, Transmitting, Demodulating and Receiving.
- Keypad interface and display interface handling.
- Touchscreen
- Message display and creation, SMS (Short Message Service) and MMS
- Protocol-stack generation.
- Pixel coprocessor and CODEC in a digital camera

So
C

- Embedded processor GPP or ASIP core,
- Single purpose processing cores or multiple processor cores,
- A network bus protocol core,
- An encryption and decryption function cores,
- Cores for FFT and Discrete cosine transforms for signal processing applications,
- Memories

Multiple standard source solutions, called IP (Intellectual Property) cores,

- Programmable logic device and FPGA (Field Programmable Gate Array) cores
- Other logic and analog units.

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IPs in SoC

- IP – a standard source solution for synthesizing a higher-level component by configuring a core of VLSI circuit or FPGA core available as an Intellectual Property, called (IP).
- High Level Components with gate level sophistication circuit much above level of counter and registers. IPs
- Designer or designing company holds the copyright for the synthesized design of a higher-level component for gate-level implementation of an IP.
- One might have to pay royalty for every chip shipped. An embedded system may incorporate several IPs.

An IP may provide a design for adaptive filtering of a signal.

- full design for implementing Hypertext Transfer Protocol (HTTP) or File Transfer Protocol (FTP) to transmit a web page or file on Internet.
- USB port controller, Bluetooth, GPS interface, Wireless 802.11 or 802.16 interfaces
- An FPGA consists of a large number of programmable gates on a VLSI chip. There is a set of gates in each FPGA cell, called 'macrocell'.
- Embedded system designed with a view of offering enhancing functionalities in future, then FPGA core can be used in the circuits. Each cell has several inputs and outputs. All cells interconnect like an array (matrix). Each interconnection is programmable through the associated memory RAM in a FPGA programming tool.
- A concept is using FPGA (Field Programmable Gate Arrays) core along with single or multiple processors.

Use of Xilinx Spartan-3 90 nm based FPGAs with

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PowerPCs(2003)Useof FPGAs cum ProcessorCores

- FPGA125136LogicCellsalongwiththeFourIBMPowerPCprocessors[ExemplaryAp plication:System withaData Encryption Engine at 1.5 Gbps]

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FPGA

- An SIMD instruction, Fourier transform and its inverse, DFT or Laplace transform and its inverse, compression or decompression, encrypting or deciphering, as specific pattern-recognition (for recognizing a signature or finger print or DNA sequence).
- Configure an algorithm into the logic gates of the FPGA.

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