Module – 3: Architecture of Special Purpose Computing System

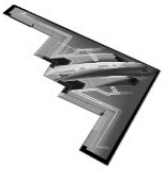
What is an embedded system?

1. Special Purpose Computer System
2. Embedded or 'hidden' in another system
3. Has several restrictions in design / development / operation
4. Embedded systems are Reactive
5. Often, it may have real-time restrictions (requirements for responding before a deadline expires)

- **First, it is a computer system**: anything that uses a microprocessor, but is not a general-purpose computer:

  - Consumer electronics:
    - cellular phones, set-top boxes, televisions, remote controls, game consoles, Internet appliances, PDAs, Alarm Systems, hi-fi systems, home cinemas,...
    - Home appliances ("White Appliances") like refrigerators, washing machines (...which now-days include microprocessors and may also have internet connection...)
  - Telecommunications systems equipment
  - Defense and weapon systems
  - Automotive systems

  - Systems for Process control



  - Robots, Cars, Planes, Nuclear plants,..., include several microprocessors / embedded systems

- **Second, it is embedded, or 'hidden' inside another system**:
  - the user interacts with a special-purpose system, and not with the computer inside the system
  - the end-user typically does not or cannot modify or upgrade the internal system himself

- **Third, it has many sets** of **constraints / limitations**, from the following:
  - Cost (€0.1 adds up over thousand/million units...)
  - Processor speed (for cost, size reasons)
  - Memory (probably no hard disk, sometimes only few Kbytes only)
  - Display and user interface (...also it may target users that are computer illiterate)
  - Network bandwidth (if network connection at all)
  - Low Power Consumption (limited battery, lack of cooling system)
  - Small Size, Low Weight (handheld devices, transportation cost issues)
  - Reliability
  - Safety-critical (must function correctly, must not function incorrectly)
  - Security
  - Operation in Harsh environmental conditions (Heat, vibration, shock, power fluctuations, RF interference, lightning,...)

- **Fourth:** Embedded Systems are **Reactive**:
  - computations occur in response to external events, that may be:
    - Periodic events (e.g., rotating machinery and control loops, timers,…)
    - Aperiodic events (e.g., button closures, user interactions)
- **Fifth:** it may have **real-time** requirements (responding before a deadline expires)
  - **Real-Time: timing correctness is part of system correctness**
    - Hard real-time
      - Absolute deadline, beyond which answer is useless
      - Deadline may include minimum time as well as maximum time
    - Soft real-time
      - Occasionally missing a deadline is not catastrophic
      - Utility of answer degrades with time difference from deadline
    - In general, Real Time **does not mean** Real Fast

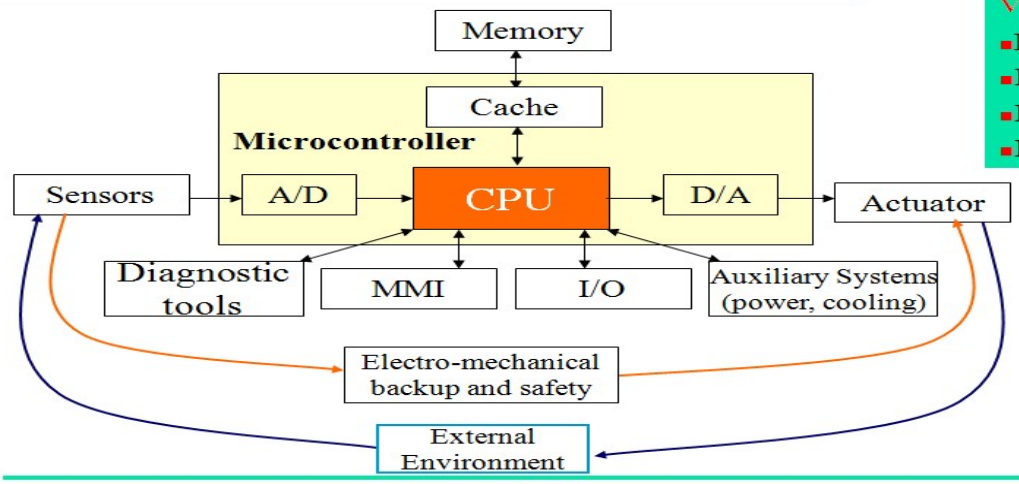
A Typical Embedded System

An Embedded Designer's View…

- CPU: Performance, Compilers, Operating Systems, Cost.
- Memory Size, I/O connections, peripherals, Cost.
- Functionality, Time-to-market, Cost & Cost.

And a customer's view…:

- Reduced Cost
- Increased Functionality
- Improved Performance
- Increased Dependability



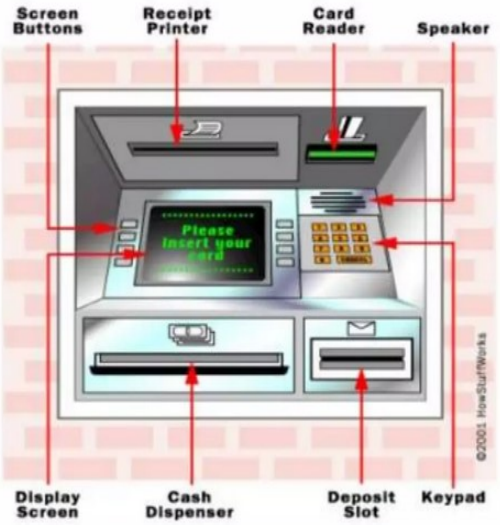
Special Purpose Embedded System Examples – Diverse Restrictions

- Pocket remote control RF transmitter
  - 100 KIPS, water/crush-proof, fits in pocket, 5-year battery life
  - Software hand-crafted for small size (less than 1 KB)
- Industrial equipment controller (e.g., elevator)
  - 1-10 MIPS for 1 to 10 CPUs, 1 - 8 MB memory
  - Safety-critical software; real-time control loops
- Digital TV Set Top Box
  - 50-350 MIPs, 2-16MB FLASH, 4-32 MB SDRAM
  - Software may be handcrafted at low layers, but at upper layers it supports hardware agnostic applications downloadable over the network!
- Military signal processing (e.g., Radar/Sonar)
  - 1 GFLOPS, 1 GB/sec I/O, 32 MB memory
  - Software hand-crafted for extremely high performance

1. Components of ATM

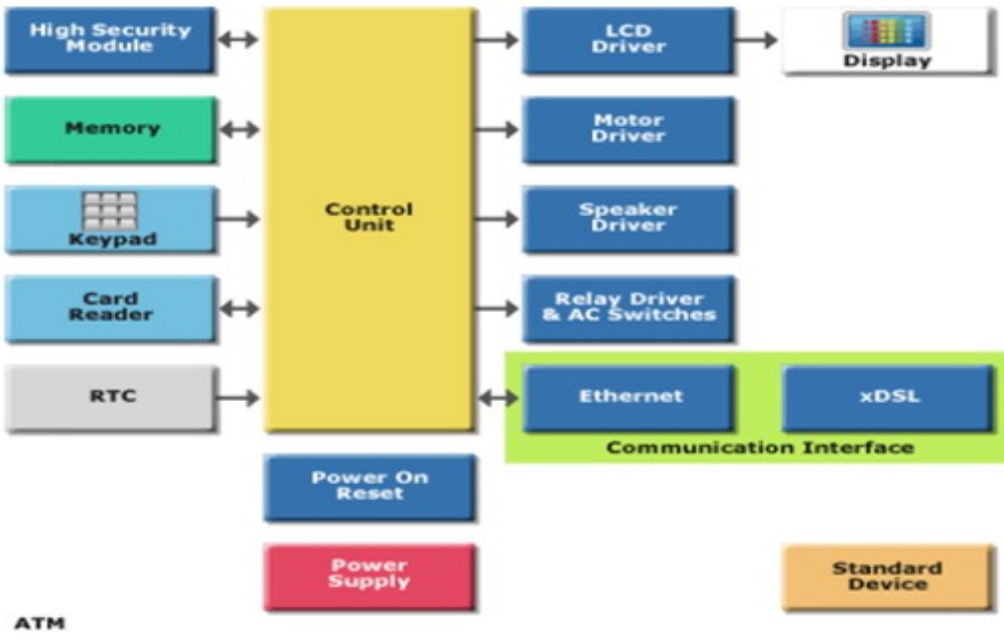
Parts of the Machine

You're probably one of the millions who has used an ATM. As you know, an ATM has two input devices:



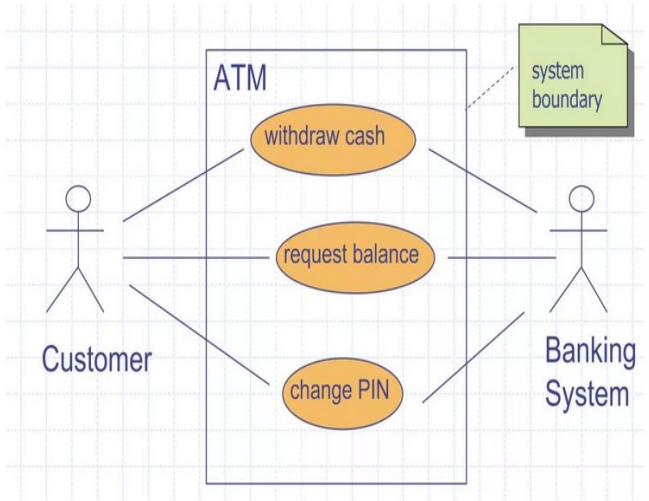
Functions of ATM

- 24-hour access to cash
- View Account Balances & Mini-statements
- Order a Cheque Book / Account Statement
- Transfer Funds between accounts
- Refill your Prepaid card
- Pay your utility bills
- Deposit cash or cheques
- Change your PIN
- Learn about other products



ATM

How does it come together?



Card reader

The card reader captures the account information stored on the magnetic stripe on the back of an ATM/debit or credit card. The host processor uses this information to route the transaction to the cardholder's bank.

Keypad

- The **keypad** lets the cardholder tell the bank what kind of transaction is required (cash withdrawal, balance inquiry, etc.) and for what amount.
- Also, the bank requires the cardholder's personal identification number (**PIN**) for verification. Federal law requires that the PIN block be sent to the host processor in encrypted form.

Display screen

- The display screen prompts the cardholder through each step of the transaction process.
- Leased-line machines commonly use a monochrome or colour CRT (cathode ray tube) display. Dial-up machines commonly use a monochrome or colour LCD.

Receipt printer

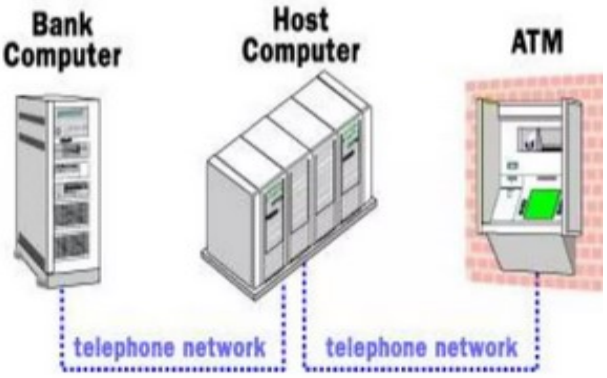
- The receipt printer provides the cardholder with a paper receipt of the transaction

Cash dispenser

- The heart of an ATM is the safe and cash-dispensing mechanism. The entire bottom portion of most small ATMs is a safe that contains the cash.

How Do ATMs Work?

- An ATM is simply a **data terminal** with two input and four output devices. Like any other data terminal, the ATM has to connect to, and communicate through, a **host processor**



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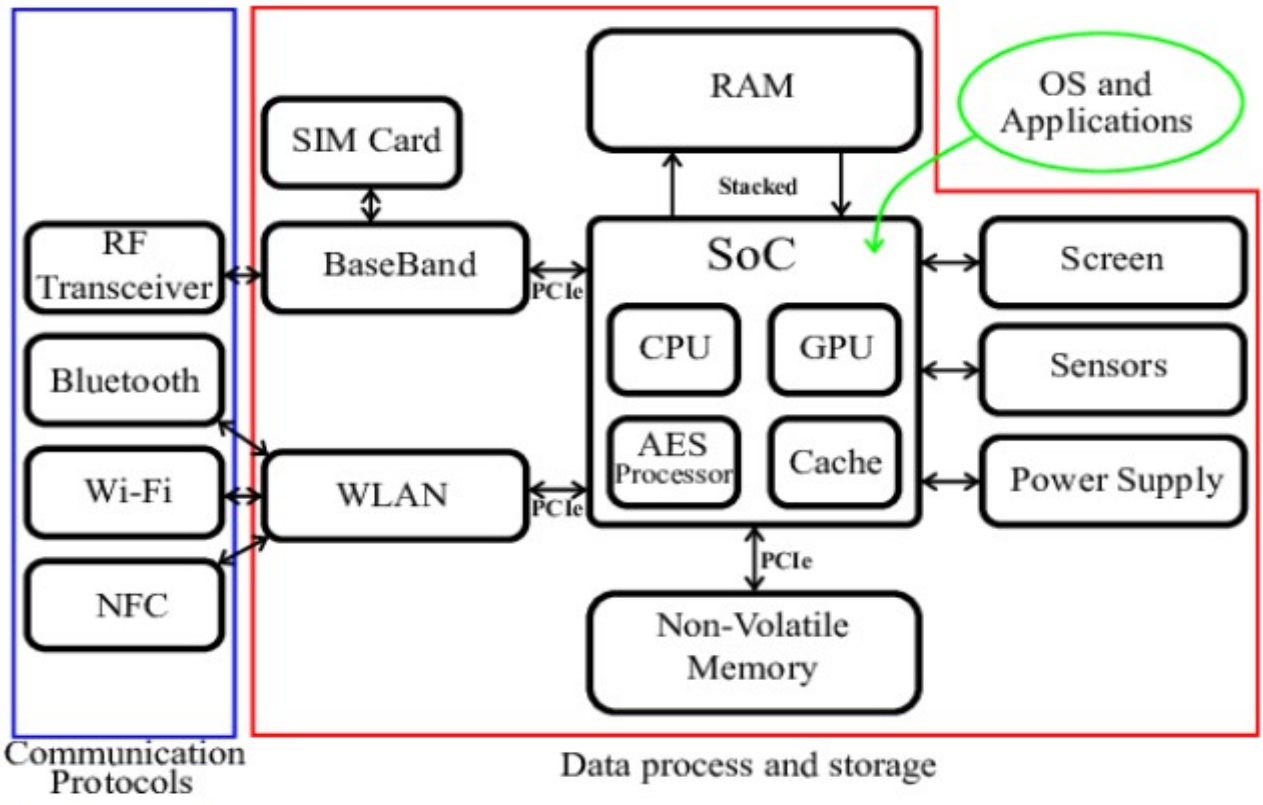
2. Handheld devices – Mobile Phone - Architecture



Simplified smartphone architecture.

Mobile Tools	Function
SMS	To send text messages
Camera	To take a photo
MMS	To send photo and video
Recorder	For recording sound/video
MP3/MP4	For listing what was already recorded
Memory	For data storage
Apps	For different purposes (e.g.communication)
Browsers	To navigate the Internet
GPS	To provides geolocation and time information
QR Code	To scan and generate for accessing information

Mobile Phone Design Requirements

1. **Provide simple navigation**
2. **Make a large touch area**
3. **Reduce clutter**
4. **Display large text**
5. **Use touch controls**
6. **Use simple forms**
7. **Consider thumb-friendly zones**
8. **Design consistent experience**

3. Image Capturing Devices–Digital Camera

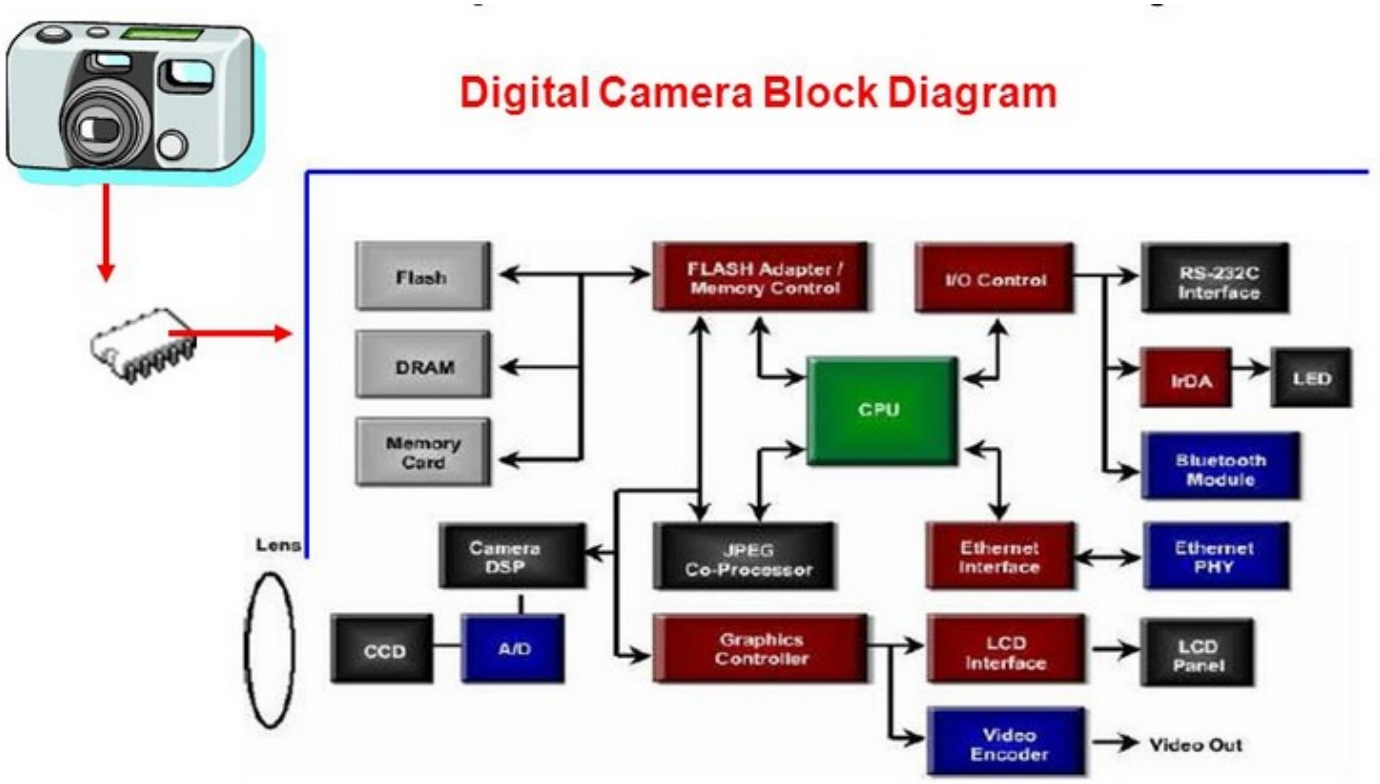


Image Capturing Devices– Digital Camera Requirements	
• Compact and simple. • Images can be stored in computer as **JPEG** files. • **Live preview** can be seen before taking photos. • Low power flashes are available for taking photos in the dark. • Contains **auto-focus** system with closer **focusing** ability. • **Zoom** capability.	• Fixed lens • Small image sensors • Live preview of the image to be taken • Auto-focus using contrast-detect method and also manual focus. • Image stabilization method to reduce sensitivity. • Image can be stored as a raw data as well as compressed JPEG format.
• Special type of sensors is setup in the mirror box for obtaining autofocus. • Has live preview mode. • Very high end sensors with crop factors from 2 to 1 with diagonal space from 18mm to 36mm. • High picture quality even at low light. • The depth of field is very less at a particular aperture. • The photographer can choose the lens needed for the situation and can also be easily interchangeable. • A focal plane shutter is used in front of the imager.	

4. Challenges, Constraints, Pros & Cons of special purpose computing system

Embedded vs general-purpose computer systems

- **Features of a computer system**
  - Receiving data from inputs, for example a touchscreen or sensor
  - Storing the data in memory so it can be accessed
  - Processing the data to make it more meaningful
  - Outputting data so that it can be experienced by a user or another device

Function of General-purpose systems

- A general-purpose system is a computer system that can be programmed to perform a large number of tasks.
- General-purpose computers are designed so that users or devices can interact with them in a variety of ways to meet a broad range of needs.
- The ability to run many different pieces of software allows a general-purpose system to be quite versatile in terms of the types of tasks it can perform.
- Software can be added, updated, and removed fairly easily, which alters the functionality of a system.

- Typically, a general-purpose system has a wide range of inputs and outputs that can be connected to it.
- For example, including USB ports on a laptop allows other devices to change the capabilities and features available to the laptop.
- As general-purpose systems are designed to carry out many different types of process, they are often not fully optimised to perform each individual task.
- **For some tasks, optimisation is key!**

Advantages of Special Purpose Computers

1. Efficiency and Performance

At the core of any machine's value is its ability to perform a task effectively. Special purpose computers epitomize this concept. While a general-purpose computer is built to handle a vast range of tasks—sometimes juggling multiple activities simultaneously—a special purpose computer is a master of one. Its entire architecture, from its processor to its storage mechanisms, is fine-tuned for that singular function, offering a level of performance a general-purpose machine can seldom match.

2. Optimized Hardware

One of the standout features of these computers is their hardware optimization. Consider an analogy: while a Swiss army knife can perform many functions, it can't match the efficiency

of a dedicated tool, like a chef's knife, for slicing vegetables. Similarly, the hardware components of special purpose computers are cherry-picked, designed, or even custom-made to cater to their unique tasks. Whether it's specialized graphic processing units for high-end graphic tasks or tailored memory configurations for data-intensive operations, every piece of hardware serves a pivotal role, ensuring a seamless, high-performance experience.

3. Energy Savings

In today's age of environmental consciousness, energy efficiency is more critical than ever. Special purpose computers excel in this department. By streamlining operations and focusing on one task, these machines can optimize their power consumption, ensuring minimal wastage. The elimination of redundant or unnecessary components further ensures that every joule of energy is utilized effectively, offering both economic and environmental benefits.

4. Reliability

A complex machine with multiple functions invariably has more points of potential failure. On the contrary, the simplicity inherent in special purpose computers, with fewer moving parts or software processes, translates to enhanced reliability. When a device is doing one thing repeatedly, it's easier to test and perfect that one process, ensuring that the machine rarely, if ever, falters.

5. Security Enhancements

In an era of heightened cyber threats, security is paramount. General-purpose computers, with their multifunctionality, present multiple points of vulnerability. Special purpose computers, however, with their narrow focus, can be fortified robustly against specific threats. The lack of unnecessary software or functionalities means there are fewer backdoors for malicious entities to exploit.

Disadvantages of Special Purpose Computers

1. Lack of Flexibility

The Achilles' heel of specialization is inflexibility. A computer designed for graphic rendering might be ill-suited for data analysis. While their efficiency in a particular task is unparalleled, they can't be repurposed easily, making them rigid in the face of evolving requirements.

2. Higher Initial Costs

Excellence comes at a price. The custom components, research, and development that go into crafting these precision machines often mean a steeper initial investment compared to off-the-shelf general-purpose systems. This cost can sometimes be a deterrent, especially for smaller organizations or individual users.

3. Difficulty in Upgrades

The intertwined, specialized nature of their components makes upgrades challenging. While you can easily swap out a component in a general-purpose PC, doing so in a special purpose machine might require recalibrations or even entire system overhauls to ensure compatibility and maintain performance.

4. Limited Market

Given their niche appeal, these computers cater to a smaller market segment. This limitation affects their production scale, accessibility, and sometimes even the availability of support or resources for end-users.

5. Rapid Obsolescence

The fast-paced world of technology is always evolving. A task or function that's critical today might be redundant tomorrow. Special purpose computers run the risk of becoming obsolete quicker than their general-purpose counterparts, especially if the tasks they are designed for diminish in relevance.