Politecnico di Milano

Embedded Systems: Communication

Embedded Systems: bus and interfacing

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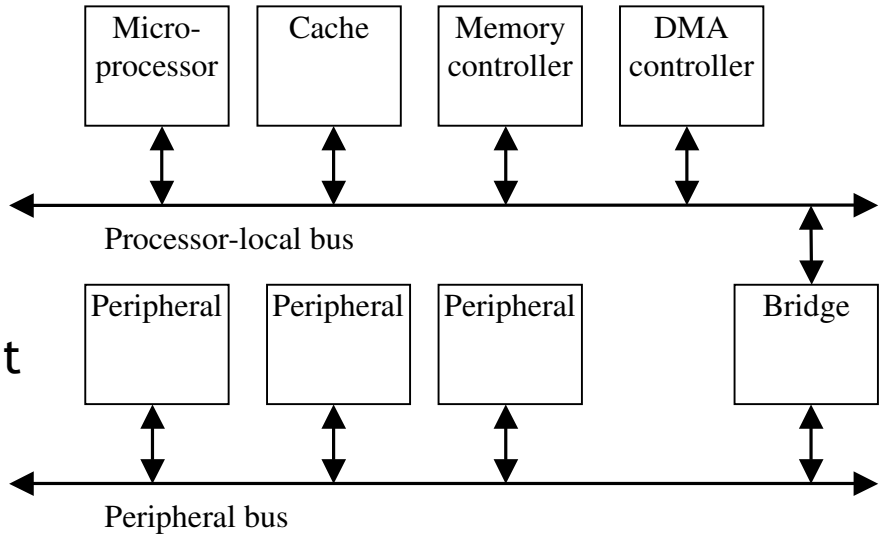
Outline

- Hierarchical buses
- Protocols
  - Serial
  - Parallel
  - Wireless

Multilevel bus architectures

- Don't want one bus for all communication
  - Peripherals would need high-speed, processor-specific bus interface
    - excess gates, power consumption, and cost; less portable
  - Too many peripherals slows down bus
- Processor-local bus
  - High speed, wide, most frequent communication
  - Connects microprocessor, cache, memory controllers, etc.
- Peripheral bus
  - Lower speed, narrower, less frequent communication
  - Typically industry standard bus (ISA, PCI) for portability
- Bridge
  - Single-purpose processor converts communication between busses



Advanced communication principles

- Layering
  - Break complexity of communication protocol into pieces easier to design and understand
  - Lower levels provide services to higher level
    - Lower level might work with bits while higher level might work with packets of data
  - Physical layer
    - Lowest level in hierarchy
    - Medium to carry data from one actor (device or node) to another
- Parallel communication
  - Physical layer capable of transporting multiple bits of data
- Serial communication
  - Physical layer transports one bit of data at a time
- Wireless communication
  - No physical connection needed for transport at physical layer

Parallel communication

- Multiple data, control, and possibly power wires
  - One bit per wire
- High data throughput with short distances
- Typically used when connecting devices on same IC or same circuit board
  - Bus must be kept short
    - long parallel wires result in high capacitance values which requires more time to charge/discharge
    - Data misalignment between wires increases as length increases
- Higher cost, bulky
  - ES. SCSI

Serial communication

- Single data wire, possibly also control and power wires
- Words transmitted one bit at a time
- Higher data throughput with long distances
  - Less average capacitance, so more bits per unit of time
- Cheaper, less bulky
- More complex interfacing logic and communication protocol
  - Sender needs to decompose word into bits
  - Receiver needs to recompose bits into word
  - Control signals often sent on same wire as data increasing protocol complexity

Wireless communication

- Infrared (IR)
  - Electronic wave frequencies just below visible light spectrum
  - Diode emits infrared light to generate signal
  - Infrared transistor detects signal, conducts when exposed to infrared light
  - Cheap to build
  - Need line of sight, limited range
- Radio frequency (RF)
  - Electromagnetic wave frequencies in radio spectrum
  - Analog circuitry and antenna needed on both sides of transmission
  - Line of sight not needed, transmitter power determines range

Error detection and correction

- Often part of bus protocol
- Error detection: ability of receiver to detect errors during transmission
- Error correction: ability of receiver and transmitter to cooperate to correct problem
  - Typically done by acknowledgement/retransmission protocol
- Bit error: single bit is inverted
- Burst of bit error: consecutive bits received incorrectly
- Parity: extra bit sent with word used for error detection
  - Odd parity: data word plus parity bit contains odd number of 1's
  - Even parity: data word plus parity bit contains even number of 1's
  - Always detects single bit errors, but not all burst bit errors
- Checksum: extra word sent with data packet of multiple words
  - e.g., extra word contains XOR sum of all data words in packet

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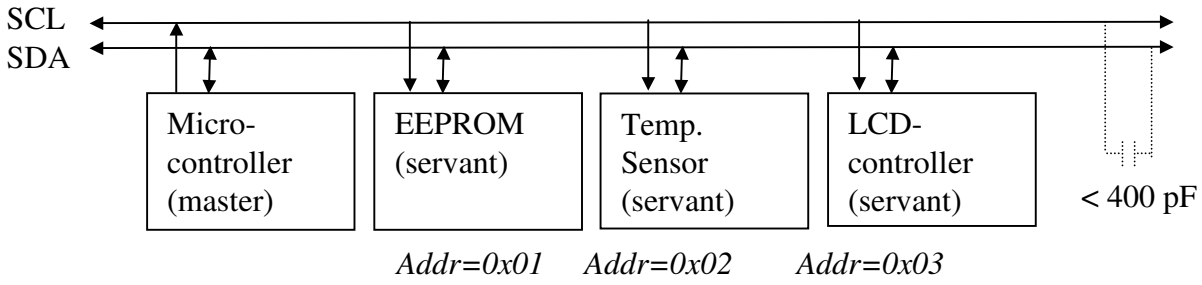
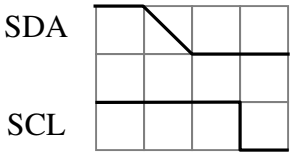
Serial protocols: I²C

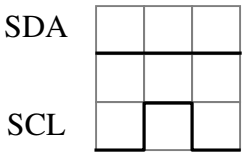
- I²C (Inter-IC)
  - Two-wire serial bus protocol developed by Philips Semiconductors nearly 20 years ago
  - Enables peripheral ICs to communicate using simple communication hardware
  - Data transfer rates up to 100 kbits/s and 7-bit addressing possible in normal mode
  - 3.4 Mbits/s and 10-bit addressing in fast-mode
  - Common devices capable of interfacing to I²C bus:
    - EPROMS, Flash, and some RAM memory, real-time clocks, watchdog timers, and microcontrollers

I2C bus structure

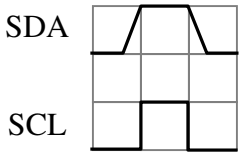




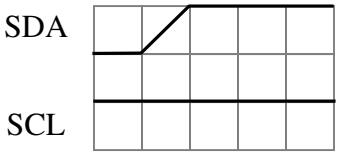
Start condition



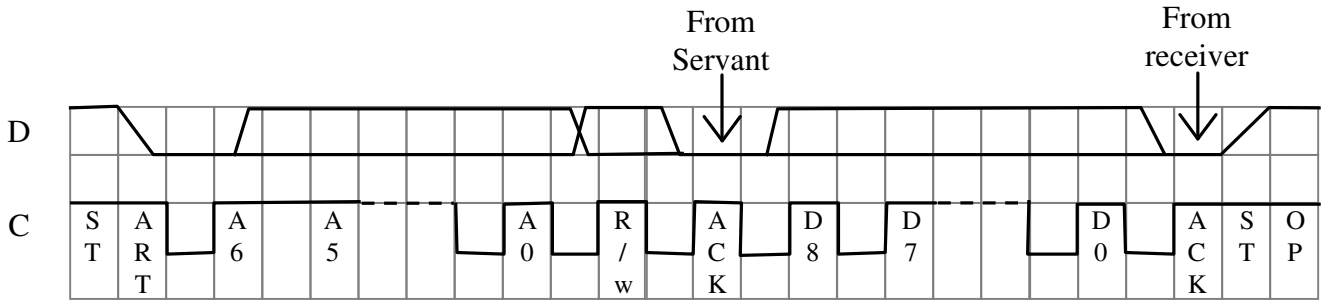
Sending 0



Sending 1



Stop condition



Typical read/write cycle

Serial protocols: CAN

- CAN (Controller area network)
  - Protocol for real-time applications
  - Developed by Robert Bosch GmbH
  - Originally for communication among components of cars
  - Applications now using CAN include:
    - elevator controllers, copiers, telescopes, production-line control systems, and medical instruments
  - Data transfer rates up to 1 Mbit/s and 11-bit addressing
  - Common devices interfacing with CAN:
    - 8051-compatible 8592 processor and standalone CAN controllers
  - Actual physical design of CAN bus not specified in protocol
    - Requires devices to transmit/detect dominant and recessive signals to/from bus
    - e.g., '1' = dominant, '0' = recessive if single data wire used
    - Bus guarantees dominant signal prevails over recessive signal if asserted simultaneously

Serial protocols: FireWire

- FireWire (a.k.a. I-Link, Lynx, IEEE 1394)
  - High-performance serial bus developed by Apple Computer Inc.
  - Designed for interfacing independent electronic components
    - e.g., Desktop, scanner
  - Data transfer rates from 12.5 to 400 Mbits/s, 64-bit addressing
  - Plug-and-play capabilities
  - Packet-based layered design structure
  - Applications using FireWire include:
    - disk drives, printers, scanners, cameras
  - Capable of supporting a LAN similar to Ethernet
    - 64-bit address:
      - 10 bits for network ids, 1023 subnetworks
      - 6 bits for node ids, each subnetwork can have 63 nodes
      - 48 bits for memory address, each node can have 281 terabytes of distinct locations

Serial protocols: USB

- USB (Universal Serial Bus)
  - Easier connection between PC and monitors, printers, digital speakers, modems, scanners, digital cameras, joysticks, multimedia game equipment
  - 2 data rates:
    - 12 Mbps for increased bandwidth devices
    - 1.5 Mbps for lower-speed devices (joysticks, game pads)
  - Tiered star topology can be used
    - One USB device (hub) connected to PC
      - hub can be embedded in devices like monitor, printer, or keyboard or can be standalone
    - Multiple USB devices can be connected to hub
    - Up to 127 devices can be connected like this
  - USB host controller
    - Manages and controls bandwidth and driver software required by each peripheral
    - Dynamically allocates power downstream according to devices connected/disconnected

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Parallel protocols: PCI Bus

- PCI Bus (Peripheral Component Interconnect)
  - High performance bus originated at Intel in the early 1990's
  - Standard adopted by industry and administered by PCISIG (PCI Special Interest Group)
  - Interconnects chips, expansion boards, processor memory subsystems
  - Data transfer rates of 127.2 to 508.6 Mbits/s and 32-bit addressing
    - Later extended to 64-bit while maintaining compatibility with 32-bit schemes
  - Synchronous bus architecture
  - Multiplexed data/address lines

Parallel protocols: ARM Bus

- ARM Bus
  - Designed and used internally by ARM Corporation
  - Interfaces with ARM line of processors
  - Many IC design companies have own bus protocol
  - Data transfer rate is a function of clock speed
    - If clock speed of bus is X, transfer rate = 16 x X bits/s
  - 32-bit addressing

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Wireless protocols: IrDA

- IrDA
  - Protocol suite that supports short-range point-to-point infrared data transmission
  - Created and promoted by the Infrared Data Association (IrDA)
  - Data transfer rate of 9.6 kbps and 4 Mbps
  - IrDA hardware deployed in notebook computers, printers, PDAs, digital cameras, public phones, cell phones
  - Lack of suitable drivers has slowed use by applications
  - Windows 2000/98 and Linux include support
  - Becoming available on popular embedded OS's

Wireless protocols: Bluetooth

- Bluetooth
  - New, global standard for wireless connectivity
  - Based on low-cost, short-range radio link
  - Connection established when within 10 meters of each other
  - No line-of-sight required
    - e.g., Connect to printer in another room

Wireless Protocols: IEEE 802.11

- IEEE 802.11
  - Proposed standard for wireless LANs
  - Specifies parameters for PHY and MAC layers of network
    - PHY layer
      - physical layer
      - handles transmission of data between nodes
      - provisions for data transfer rates of 1 or 2 Mbps
      - operates in 2.4 to 2.4835 GHz frequency band (RF)
      - or 300 to 428,000 GHz (IR)
    - MAC layer
      - medium access control layer
      - protocol responsible for maintaining order in shared medium
      - collision avoidance/detection