The Silicon Saga

Recapitulating the Past & Speculating the Future

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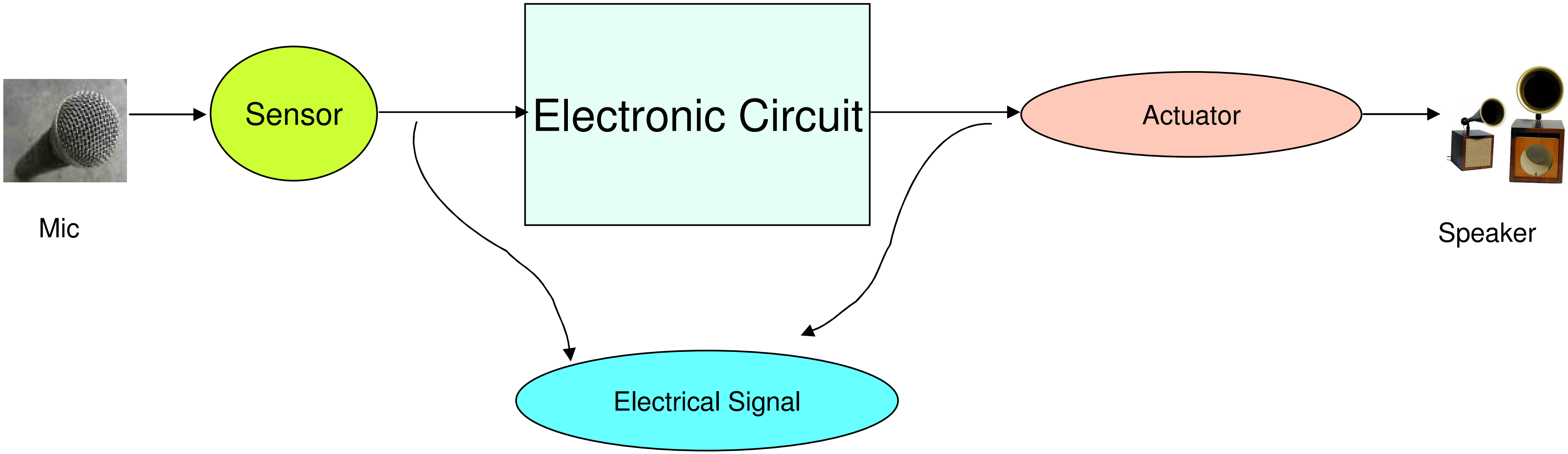
Epoch I: Transduction & Electronic Invasion

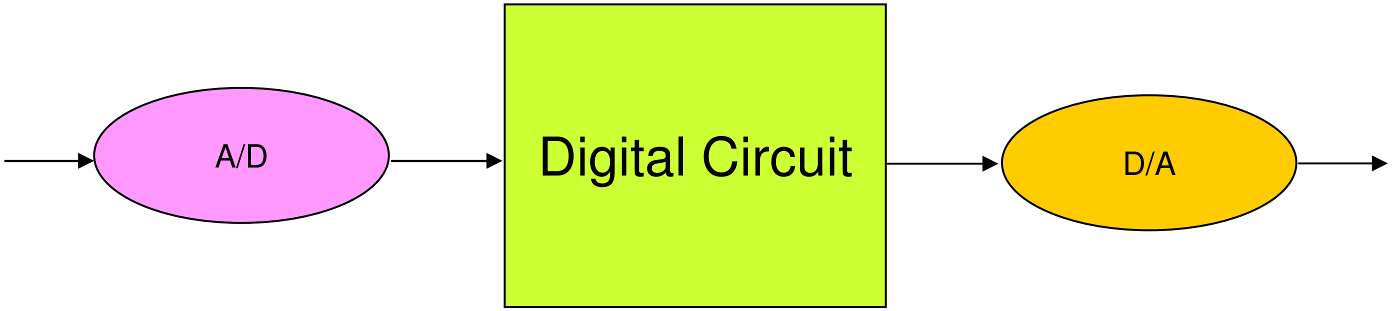


Temperature Sensor → Fuel Control Signal

Pressure Sensor → Pressure Valve Control Signal

Epoch II: Digitisation

- Nyquist/Shannon's revolution
- *Exact* storage, reproduction and transmission of signals
- "Everything" is a computation
- Legal (patent law) implications!
- The simplification of manufacturing: just a lot of transistors
- The convergence of hardware & software design



Epoch III: The Manufacturing Revolution

- Moore’s Law: the “automatic” commoditisation of products
- The consolidation of manufacturing
- The decoupling of manufacturing and design: “design rules”
- The consolidation of design?

Challenges & the Future

Clocking

- Problems
  - Clock distribution
  - Power
  - Radiation
  - Problems with composition
- Asynchronous design
  - Advantages: less power, less radiation, composable
  - Challenges: immature methodology & tools; verification

Size

- The problem of wires: lots of them!
- Asynchronous design: composable; hence local optimisation gives global optimisation
- Larger (FPGA-like) blocks: fewer wires
- “Structured” ASICs
- Reuse:
  - Largely for digital
  - Not quite plug-and-play
  - Third-party verification?
  - Hierarchical methodologies

Nanometer Electronics

- 90 nm going down to 60
- 6 nm transistors in the lab.
- Implications for design:
  - No fundamental change in device behaviour
  - Exacerbation of all DSM problems
- Implications for manufacturing:
  - Galloping costs
  - The (low cost) Chinese disruption
  - Deposit & grow v/s etch?

Adaptive Systems: What/Why

- Modification of behaviour in response to changing context
- Unanticipated changes in context:
  - Robotic systems
- Anticipated changes in context:
  - Telecom systems (Software Defined Radio)
    - Changes in available bandwidth
    - Changes in the transmission scheme
    - Changes in channel conditions
    - Need for new applications
    - Changes in device conditions (e.g. battery level)
- SDR for spectrum trading
- Need for adaptation driven by efficiency considerations

Adaptive Systems: How

- Requirements:
  - Context sensing
  - Self-awareness: context database
  - Downloads: adaptation to device capability; security & IP issues
- Enablers:
  - Spectral scanners; wideband RF
  - Lightweight tools: compilers, database systems
  - Meta-protocols
  - Reconfigurable architectures

Application Specific & Reconfigurable Architectures

- Need:
  - Time-to-market
  - Flexibility: market evolution; standards evolution
  - Adaptivity requirements
- Enablers:
  - All in software: power & performance problems
  - Application specific instructions: e.g. network processors
  - Application specific hardware blocks
  - NTT's PCA

MEMS

- Key application: sensor miniaturisation & integration
- Accelerometers, gyros, pressure sensors, …
- Challenges:
  - Cheaper materials
  - Process integration: single-chip solutions
  - Process standardisation: decoupling manufacturing from design
  - Characterisation of environmental effects: adaptive signal conditioning

Optoelectronics

- Optical manipulation of light:
  - Micromirrors: projectors, optical telecom switching
  - Optical amplifiers, beam splitters, …: all-optical telecom network
- Optical computation: with photons instead of electrons
  - Lenses (Fourier transform); gratings/prisms (filter banks)
  - Characterisation of “optical computability”
  - Challenges:
    - Process integration: single chip optoelectronic solutions
    - Electronic $\leftrightarrow$ optical transduction

Emerging "Next Generation" Ideas

- Molecular electronics:
  - Potentially 10^{19} operations/J
  - 1cc of DNA has more information than a trillion CDs
- Quantum computing:
  - May take on some NP-complete problems
  - Based on (one of several) brilliant insights of Feynman
- Quantum cryptography
  - Based on single-photon polarisation
  - You are sure if your key is secure

A Tool for Planning