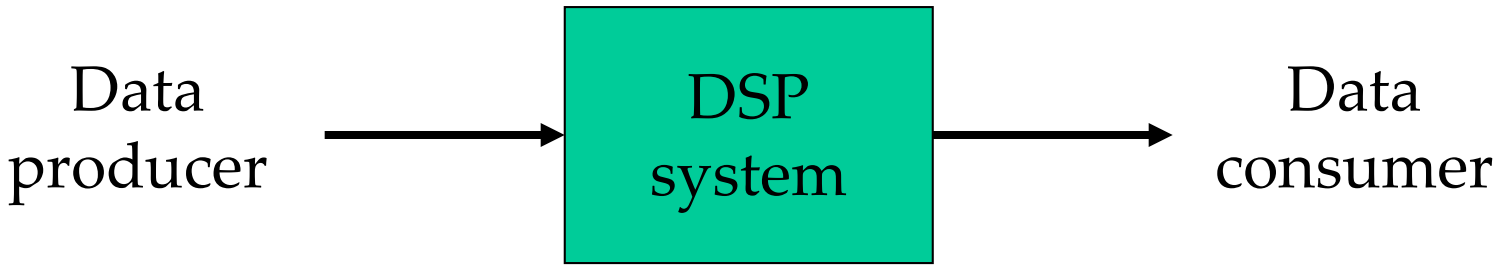
KEY ATTRIBUTES OF DIGITAL SIGNAL PROCESSORS

Digital Signal Processing

- Digital
  - Discrete time
  - Discrete valued
- Signal
  - 1, 2, 3,… dimensional
- Processing
  - Analysis
  - Synthesis
  - Enhancement

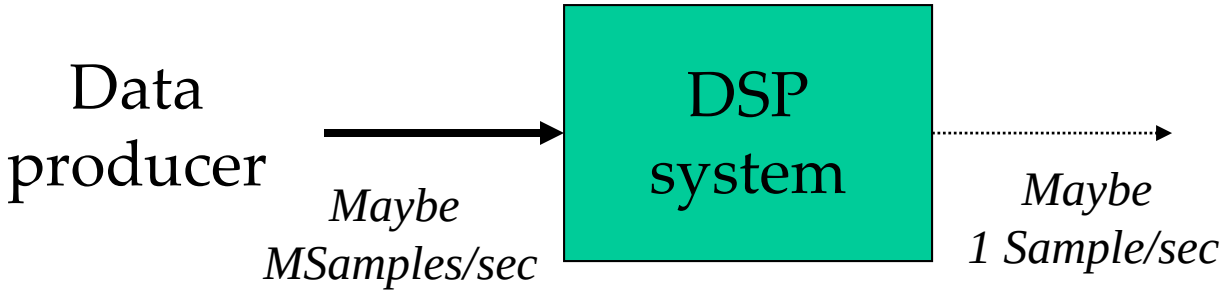
DSP Workloads

- Often "real-time"
  - Data producer and consumer can not be paused or held up
    - Examples: antenna, controller, camera, video monitor,…
  - Very strict minimum performance levels
  - Performance above that minimum is often of little value

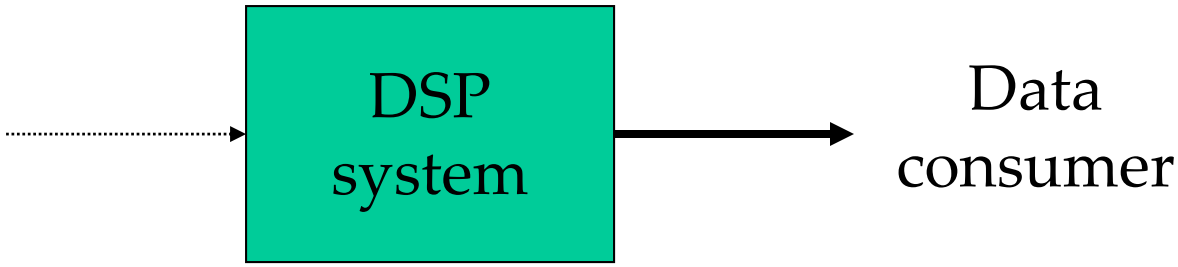


DSP Workloads

Analysis. Ex: anti-lock brakes

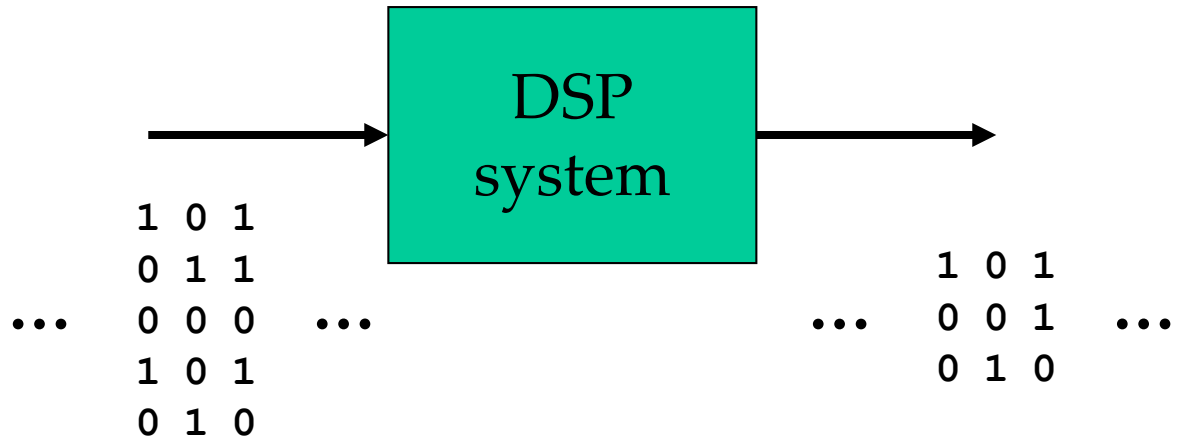


Synthesis. Ex: music keyboard



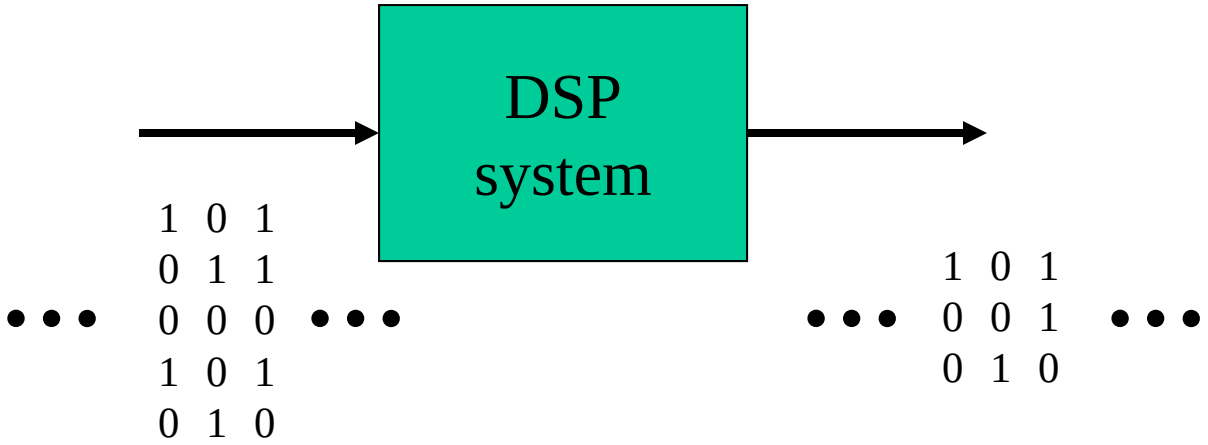
DSP Workloads

- Data stream can be considered infinite duration
  - Length of data stream >> any buffering
  - Ex: high-pass filter, automotive collision-detection radar distance measurement system



DSP Workloads

- Digital *signal processing*
- Typically very numerically intensive
  - Lots of +, –, x



DSP Compared with Analog Processing

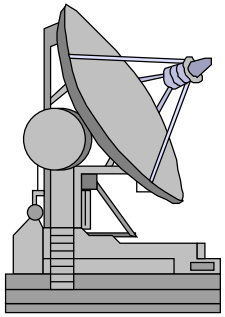
- Digital *signal processing*
  - Compare with *analog* signal processing
    - ☹ If possible in analog domain (at required precision), analog processing will likely require far fewer devices
    - 😐 If possible in analog domain, either domain may produce the most energy-efficient solution
    - ☺ Many algorithms are possible only with DSP (arbitrarily high precision, non-causal, …)
    - ☺ DSP arithmetic is completely stable over process, temperature, and voltage variations
      - Ex: 2.0000 + 3.0000 = 5.0000 will always be true as long as the circuit is functioning correctly

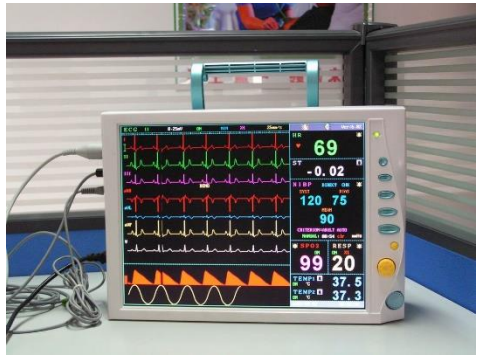
DSP Compared with Analog Processing

- Digital *signal processing*
  - Compare with *analog* signal processing
    - ☺ DSP energy-efficiencies are rapidly increasing
    - ☺ Once a DSP processor has been designed in a portable format (gate netlist, HDL, software), very little effort is required to "port" (re-target) the design to a different processing technology. Analog circuits typically require a nearly-complete re-design.
    - ☺ DSP capabilities are rapidly increasing
      - Analog A/D speed x resolution product doubles every 5 years
      - Digital processing performance doubles every 18-24 months
        (6x to 10x every 5 years)

Common DSP Applications

- Early applications
  - Instrumentation
  - Radar
  - Communication
  - Imaging
- Current applications
  - Consumer audio, video
  - Networking
  - Telecommunications
  - Machine learning
  - Imaging
  - Many many more…



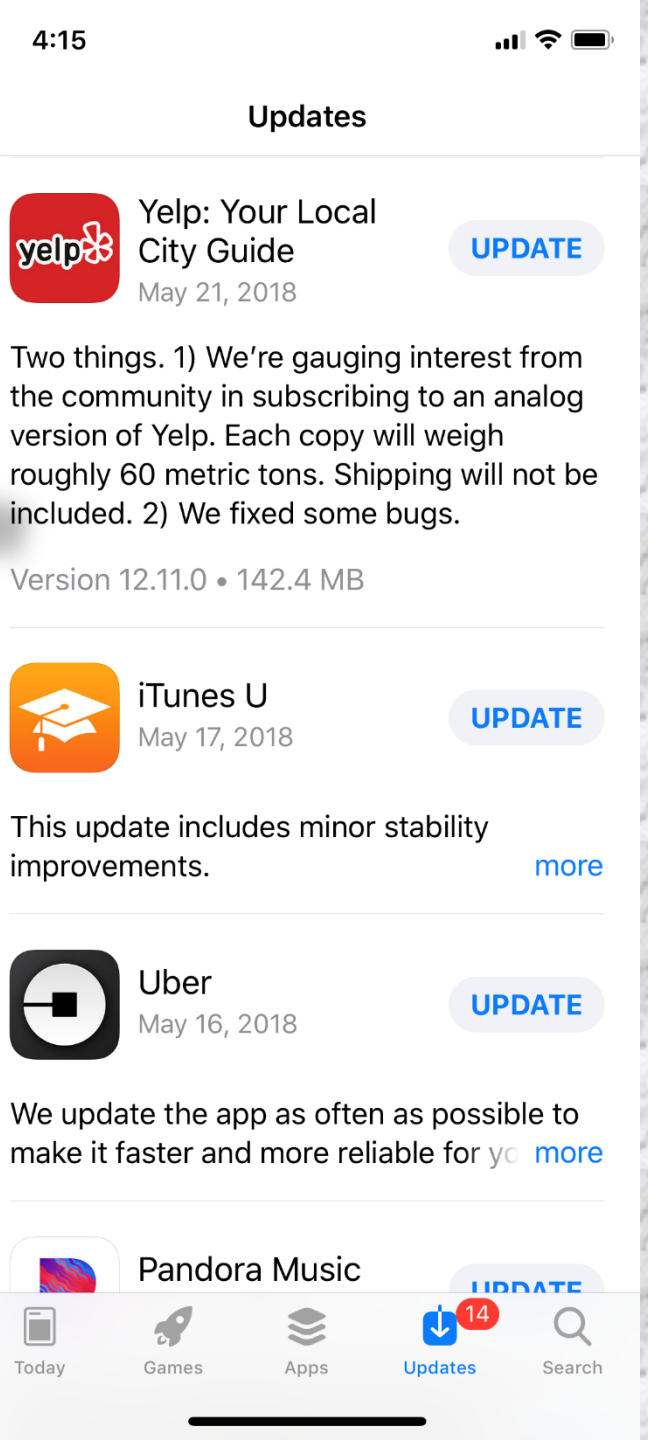


Consumer Products' Trends

- Analog based → Digital based
  - Music records, tapes → CDs, MP3s
  - Video VHS, 8mm → DVD, Blu-ray, H.264, H.265
  - Telephony analog mobile (1G) → digital (4G, LTE,…)
  - Television NTSC/PAL → digital (DVB, ATSC, ISDB, …)
  - Many products use digital data and "speak" digital: computers, networks, digital appliances

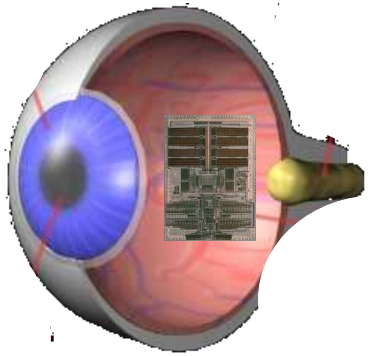
Consumer Products' Trends

- Analog based vs. Digital based
  - iphone apps???



Future Applications

- Very limited power budgets
- Require significant digital signal processing



Key Design Metrics (Means to Compare Multiple Designs)

1) Performance
   a) Throughput (high); e.g., 250 MSamples/sec
   b) Latency (low); e.g., 2.7 μsec from first sample in -> first out
   c) Numerical precision
2) Chip area (cost); e.g., mm^2 die area, area of standard cell netlist
3) Energy dissipation per workload, e.g., Joules per JPEG image
4) Design complexity
   - Design time = lower performance
   - Software more important as systems become more complex
5) Suitability for future fabrication technologies
   - Many transistors
   - Faulty devices
     i) During manufacturing process
     ii) device wear out due to effects such as NBTI