Integrated Circuits (ICs)

- Integrated Circuit (IC) = “chip”
  - Microprocessor
  - Application-Specific Instruction Set Processor (ASIP)
  - Application-Specific IC (ASIC)
- IC package contains:
  - silicon chip = “die”
  - pins

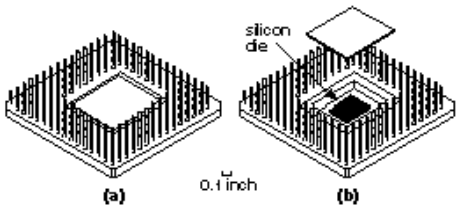

Figure from *Application-Specific Integrated Circuits*, Smith, Addison-Wesley, 1997

  - Package may have heat sink attached

Some Applications of ICs

- Home
  - Appliances, intercom, telephones, security system, garage door opener, answering machines, fax machines, home computers, TVs, cable TV tuner, VCR, camcorder, video games, cellular phones, sewing machines, cameras, exercise equipment, microwave oven
- Office
  - Telephones, computers, security system, fax machines, copier, printers, pagers
- Automobile
  - Trip computer, air bags, ABS, instrumentation, security system, transmission control, entertainment system, climate control, keyless entry, cellular phone, GPS

List from *Hardware/Software Codesign*, Giovanni De Micheli, 1996.

Integrated Circuits (ICs) (cont.)

- A modern digital system is built out of a collection of integrated circuits (ICs), each of which is made up of gates
- ICs are typically classified based on the number of gates they contain
  - SSI (small scale integration) < 10
    - 4 nand gates
    - 4 or gates
    - 4 and gates
  - MSI (medium…) 10-100
    - simple adders, counters
    - multiplexers
    - flip-flops
  - LSI (large…) 100-10,000
    - Interface devices
    - Calculators
    - Digital clocks
    - Simple microprocessors

Integrated Circuits (ICs) (cont.)

- Classification, cont.
  - VLSI (very large…) >10,000
    - Modern microprocessors
      - 8086 = 29,000
      - i386DX = 275,000
      - i486DX = 1,200,000
      - Pentium = 3,100,000
      - Pentium MMX = 4,500,000
      - Pentium Pro = 5,500,000
      - Pentium II = 7,500,000
      - PA8000 = 3,900,000
      - (Data from "CPU & System Performance Info" at CPU Info Center — http://infopad.eecs.berkeley.edu/cic)
    - Application-specific integrated circuits (ASICs):
      - Dedicated controllers (portable telephone, CD player, auto dashboard)
      - Digital signal processors (image processing, multimedia)
    - Field-programmable logic devices (FPLDs)

Types of ASICs

- IC contains a *chip* (“die”) cut from a *wafer*
  - Transistors, wires, etc. are built up on the chip in a series of layers (10-15 layers)
  - A *mask* is used to define the components of a layer as they are applied to the chip
- Types of ASICs (and pizza equivalent)
  - Full-custom ASIC
    - Pizza built from scratch, takes a long time to prepare and cook
  - Standard-cell-based ASIC
    - Custom-built from predefined selection, takes a long time to cook
  - Gate-array-based ASIC
    - Pre-cooked crusts, predefined selections, cooks quickly, somewhat cheaper
  - Field-programmable logic device
    - Frozen pizza — limited selection, cook it yourself at home, very cheap

Full-Custom ASICs

- Engineer designs some or all of the logic cells, circuit, and layout
- Mostly used:
  - If no pre-designed cells are available (e.g., new or highly specialized circuit)
  - If high-performance, less area, lower power, etc. is needed
- Fabricated in batches of 5 to 30 *wafer lots*, each wafer containing 10–100 chips
- Various technologies used (details later):
  - Bipolar — legacy from analog circuits, more consistent characteristics of components across chip / wafer
  - CMOS — more widely available, lots of cells and tools, wave of the future (at least for now)

Standard-Cell-Based ASICs

- Chip is built from pre-defined logic cells (gates, adders, etc.) called *standard cells*
  - Standard cells are built by someone else using full-custom design techniques
  - Save time, money, and risk by using a predesigned, pretested *cell library*
    - But — have to pay for the cell library
  - Also use larger cells (microprocessors, etc.) called *mega cells* (sometimes *cores*)

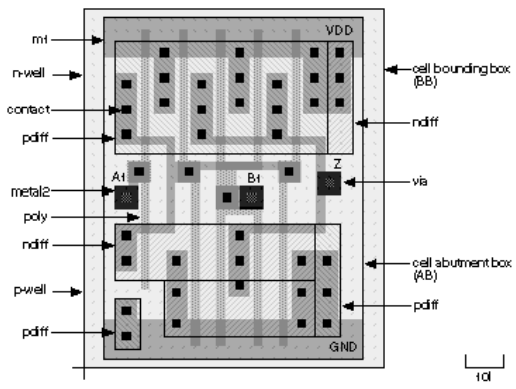

Figure from *Application-Specific Integrated Circuits*, Smith, Addison-Wesley, 1997

Standard-Cell-Based ASICs (cont.)

- Cells fit together like bricks in a wall — rows of (variable-width) cells
  - Most interconnect goes in *channels* between rows
  - Some cells may be designated as *feedthroughs* between rows
  - Other *metal layers* also provide interconnect
    - Connection between layers is called a *via*

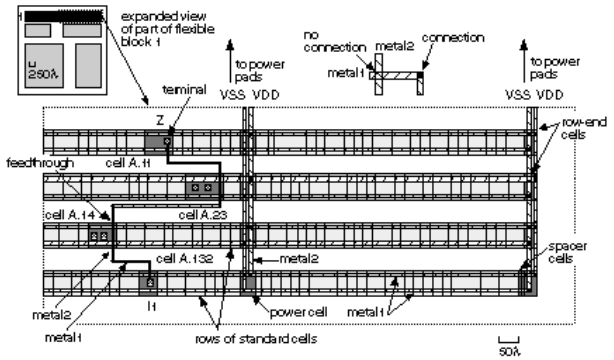

Figure from *Application-Specific Integrated Circuits*, Smith, Addison-Wesley, 1997