Integrated Circuits (ICs)

- Integrated Circuit (IC) = "chip"
  - Microprocessor
  - Application-Specific Instruction Set Processor (ASIP)
  - Application-Specific IC (ASIC)

- IC package contains:
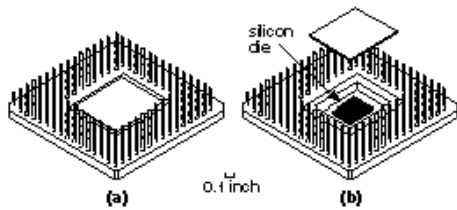 - silicon chip = "die"
  - pins

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

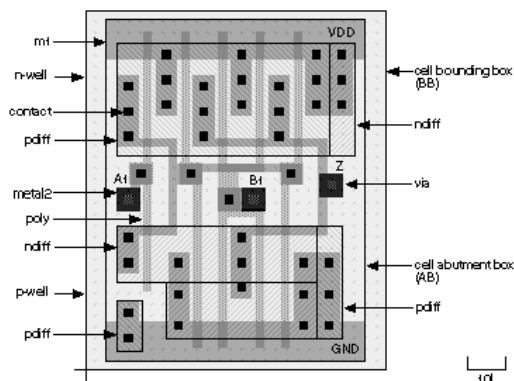 - Also use larger cells (microprocessors, etc.) called *mega cells* (sometimes *cores*)

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
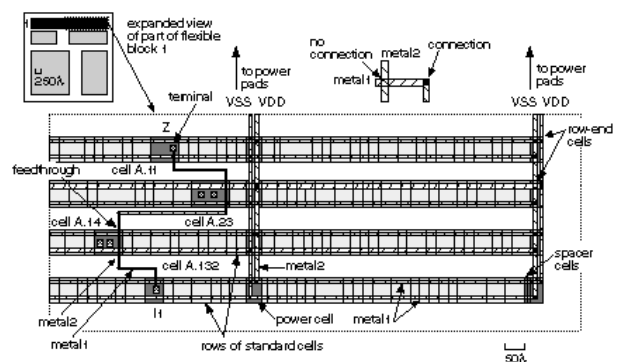   - Connection between layers is called a *via*

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