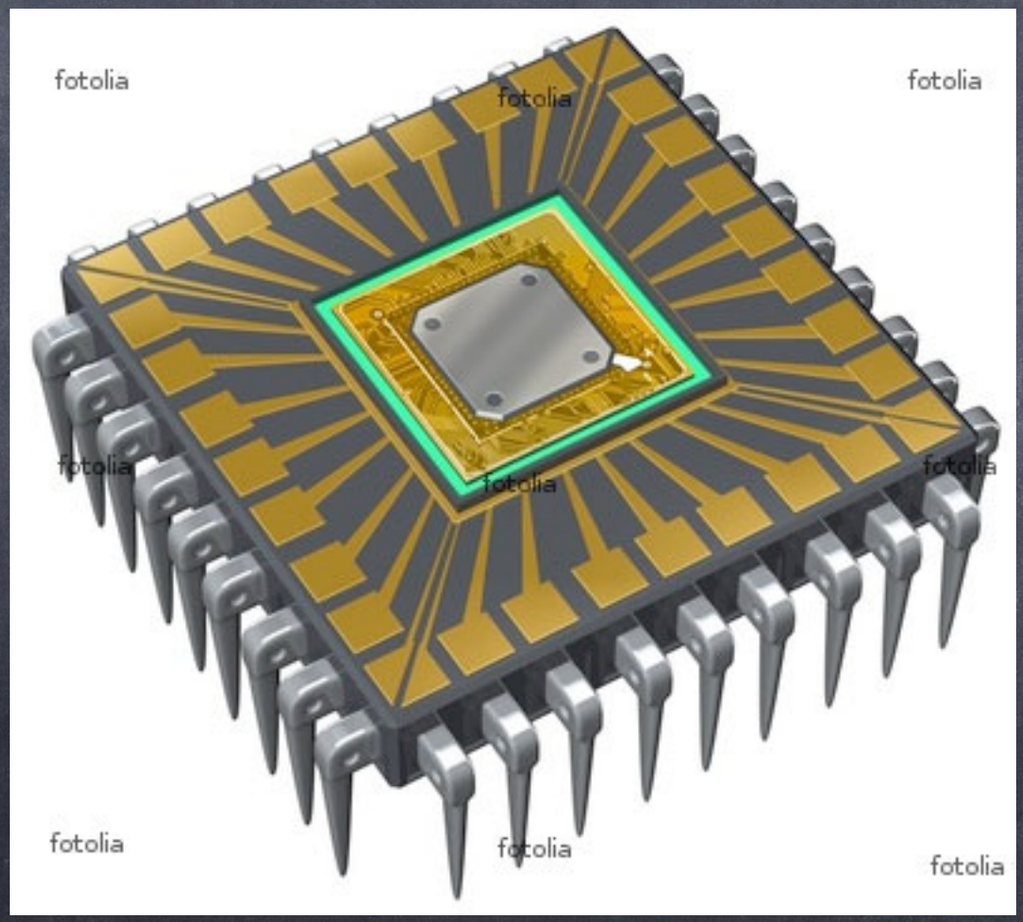
Bits and Bytes

COMP 102, lecture 3

Processors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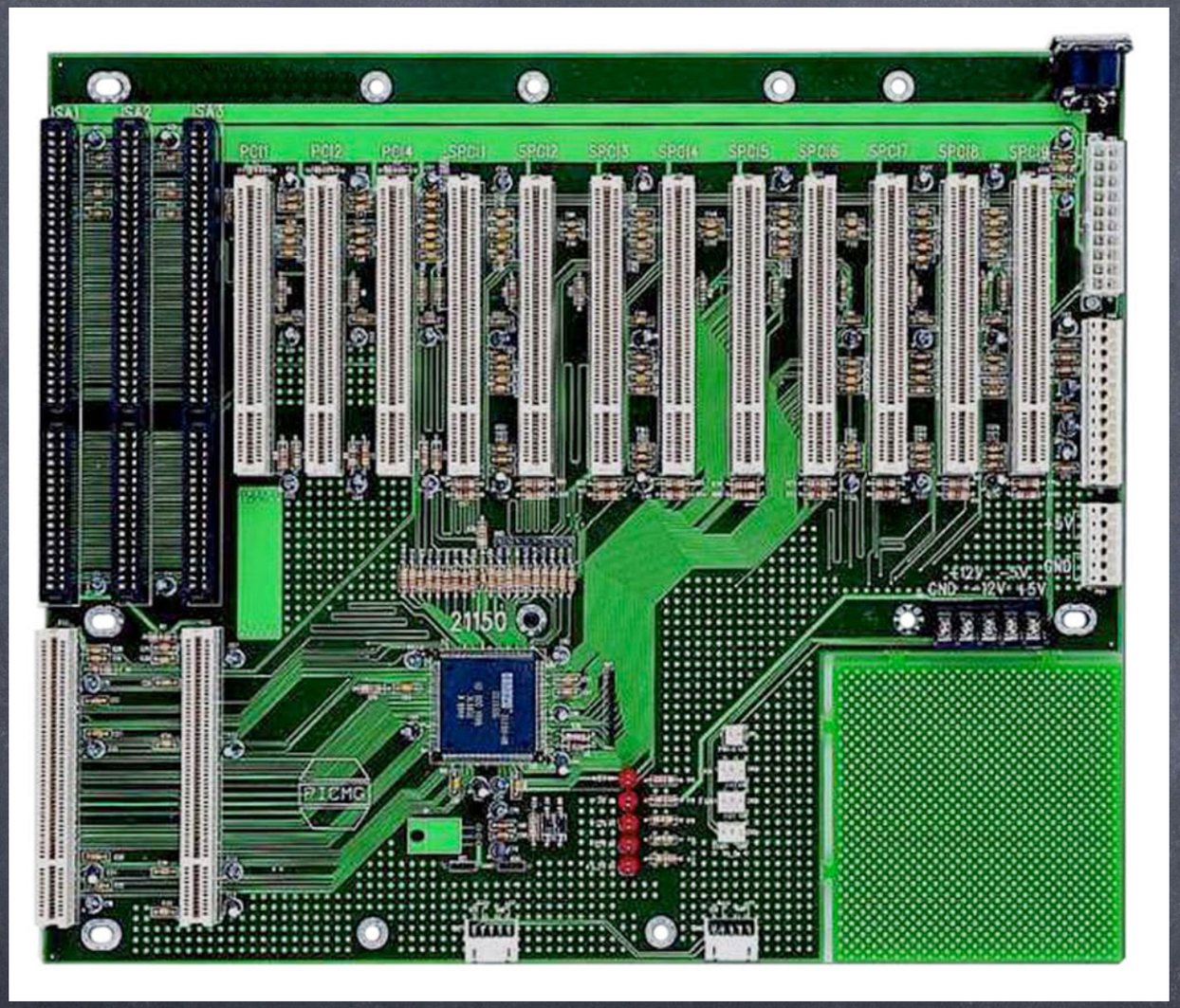
Current Processors

- Processor speed:
  single processor 4.0 GHz
  dual processors 2.4 GHz

Current Processors



- Bus speed: 800 MHz

Current Processors

- Memory addressing:

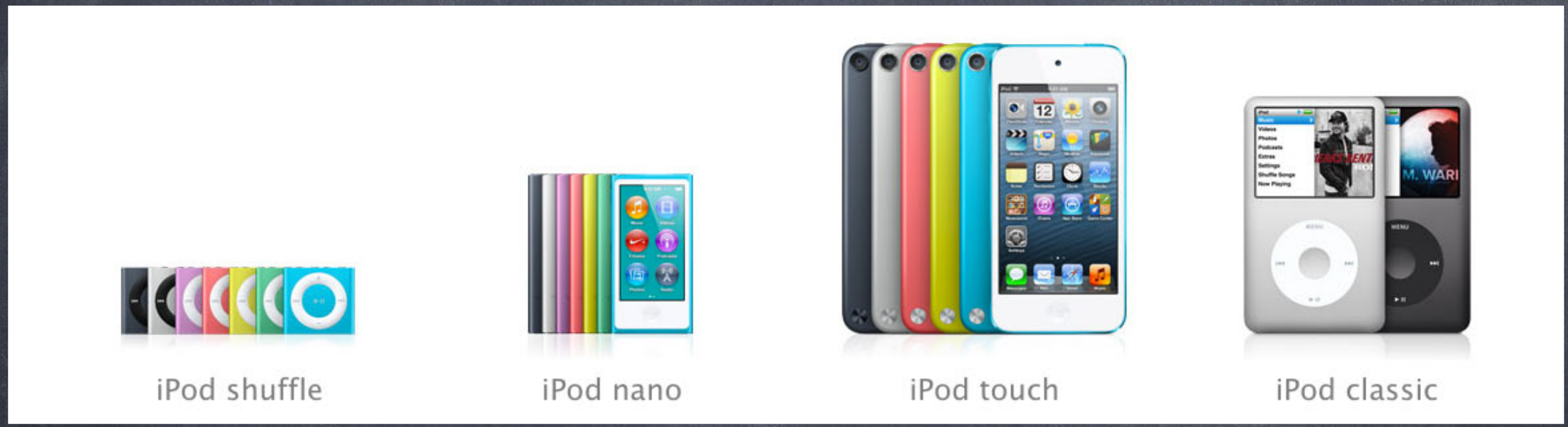
  32 bits (most)
  2^{32} addresses = 4 GB

  64 bits (recent)
  2^{64} addresses = 16 EB

- operands size: 32 bits (most), 64 bits (new)

Consumer Electronics...

Consumer Electronics…



- MP3 players
  shuffle: 2 GB, nano: 16 GB, touch 64 GB, classic: 160 GB

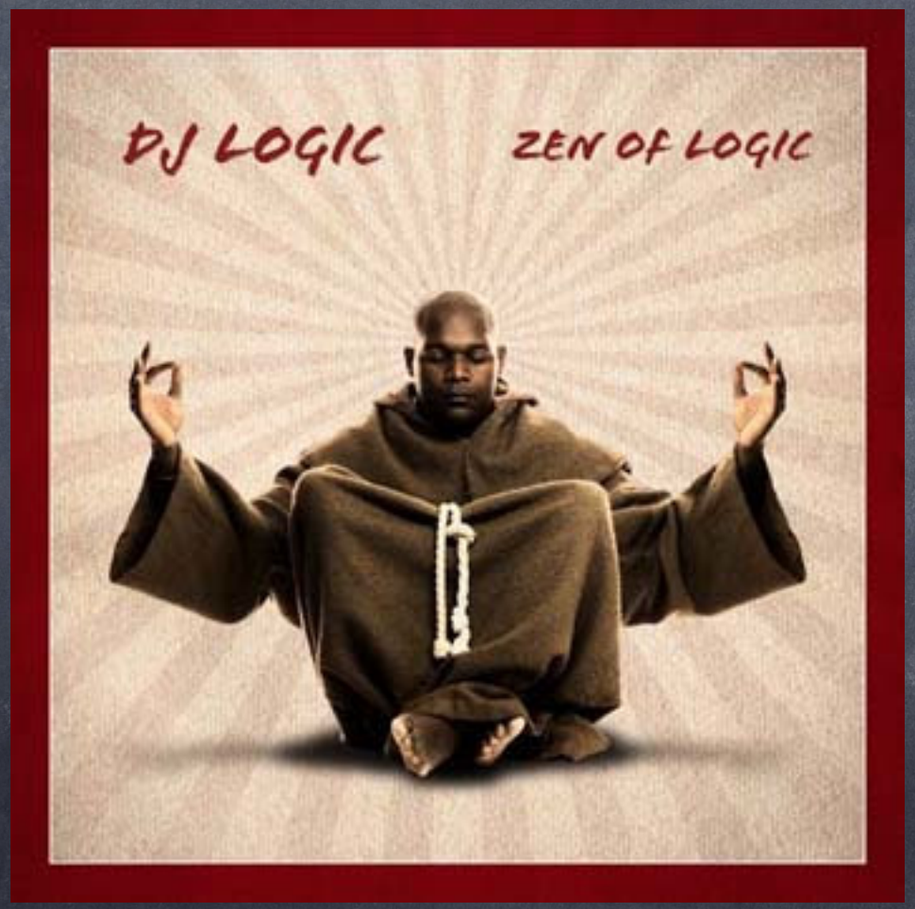
Consumer Electronics…

- Digital cameras:

  12 Mpixels/image ≈ 36 MB/image cheap

  36 Mpixels/image ≈ 108 MB/image expensive

Logic and calculation



Boolean (logic) operations

- NOT X = true if and only if X=false
- X AND Y = true iff both X=true and Y=true
- X OR Y = true iff any of X or Y = true
- X XOR Y = true iff either X=true and Y=false
  or X=false and Y=true

Bit operations

- NOT X = 1 iff X=0
- X AND Y = 1 iff both X=1 and Y=1
- X OR Y = 1 iff any of X or Y = 1
- X XOR Y = 0 iff both X=0 and Y=0
  or both X=1 and Y=1

binary addition

- Example:

```
  0 0 1 1 1 1 1 0
+ 0 1 0 0 1 0 0 1
-----------------
```

binary addition

- Example:

```
  0 0 1 1 1 1 1 0
+ 0 1 0 0 1 0 0 1
-----------------
              1
```

binary addition

- Example:

```
  0 0 1 1 1 1 1 0
+ 0 1 0 0 1 0 0 1
-----------------
            1 1
```

binary addition

- Example:

```
  0 0 1 1 1 1 1 0
+ 0 1 0 0 1 0 0 1
-----------------
        1 1 1
```

binary addition

- Example:

```
  0 0 1 1 1 1 1 0
+ 0 1 0 0 1 0 0 1
-----------------
        0 1 1 1
```

binary addition

- Example:

$$\begin{array}{r} {}^{}0\ {}^{}0\ {}^{1}1\ {}^{1}1\ {}^{}1\ {}^{}1\ {}^{}1\ {}^{}0 \\ +\ 0\ 1\ 0\ 0\ 1\ 0\ 0\ 1 \\ \hline 0\ 0\ 1\ 1\ 1 \end{array}$$

binary addition

- Example:

```
  0 0¹1¹1¹1 1 1 0
+ 0 1 0 0 1 0 0 1
-----------------
      0 0 0 1 1 1
```

binary addition

- Example:

$$\begin{array}{r} {}^{0}0^{1}1^{1}1^{1}1\ 1\ 1\ 0 \\ +\ 0\ 1\ 0\ 0\ 1\ 0\ 0\ 1 \\ \hline 0\ 0\ 0\ 0\ 1\ 1\ 1 \end{array}$$

binary addition

- Example:

$$\begin{array}{r} {}^{0}0^{1}1^{1}1^{1}1\ 1\ 1\ 0 \\ +\ 0\ 1\ 0\ 0\ 1\ 0\ 0\ 1 \\ \hline 1\ 0\ 0\ 0\ 0\ 1\ 1\ 1 \end{array}$$

binary addition

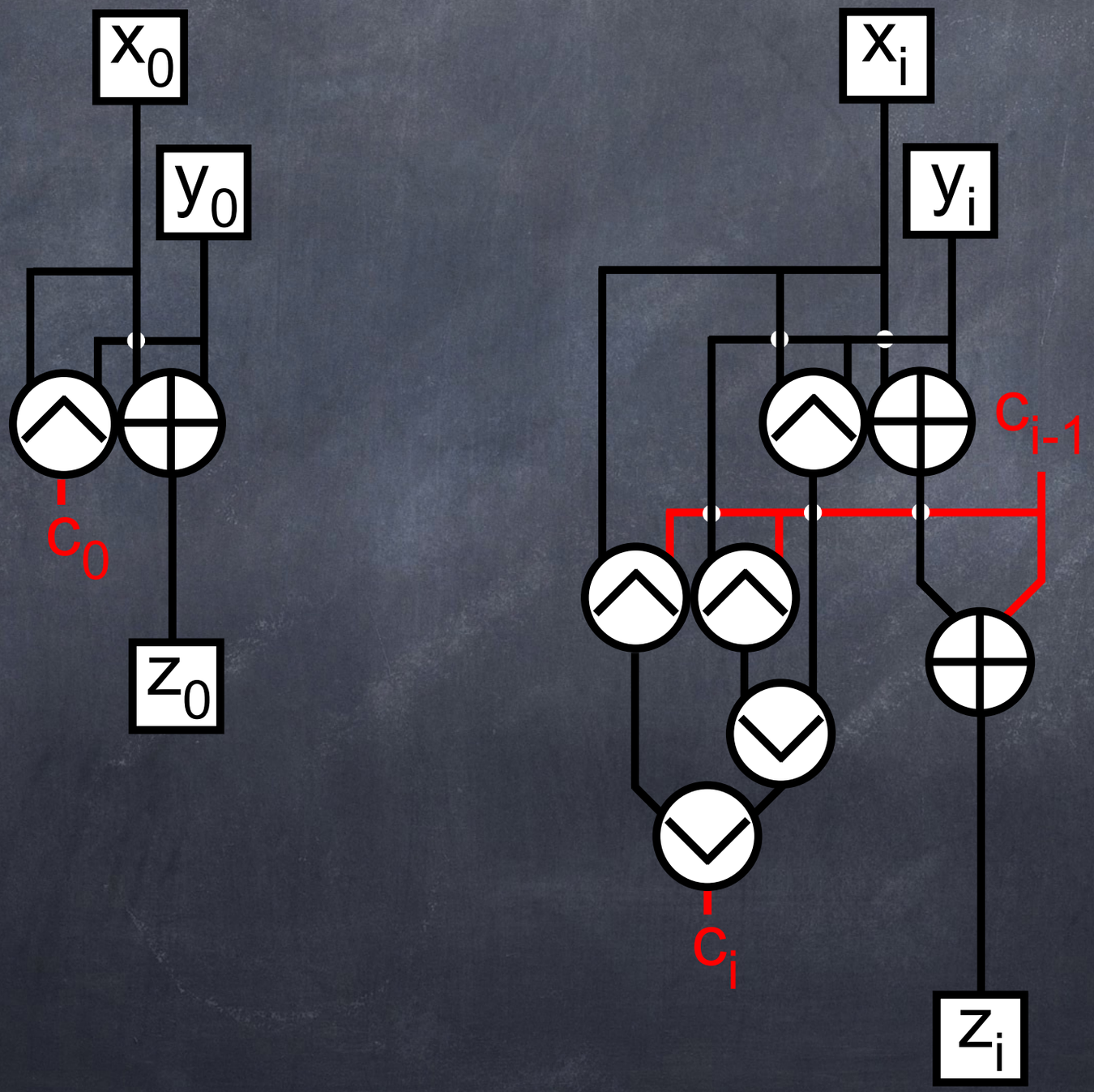
- $z = x+y$ where $x = x_n x_{n-1} \ldots x_0$,
  $y = y_n y_{n-1} \ldots y_0$,
  $z = z_{n+1} z_n z_{n-1} \ldots z_0$

- $z_0 = x_0 \oplus y_0$
  $c_0 = x_0 \wedge y_0$
  $z_{n+1} = c_n$

  and for $0<i\leq n$

  $z_i = x_i \oplus y_i \oplus c_{i-1}$
  $c_i = (x_i \wedge y_i) \vee (x_i \wedge c_{i-1}) \vee (y_i \wedge c_{i-1})$

Ingredients for an addition circuit



An addition circuit