From Hex to Binary and Back

- easy: replace each hexadecimal "digit" with the corresponding four binary digits using the conversion table
- examples:

<table>
<thead>
<tr>
<th>hex</th>
<th>binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>10101100</td>
</tr>
<tr>
<td>11</td>
<td>01101001</td>
</tr>
<tr>
<td>FF</td>
<td>11100001</td>
</tr>
</tbody>
</table>

Colour and Number Representation

- colours can be represented as RGB intensities– three numbers
- HTML specifications express the RGB numbers in hexadecimal notation
  - example: `<body bgcolor="#3A00FF">`

Colour and Number Representation

- adding 1 to a binary number: replace the rightmost 0 by a 1 and any 1’s to the right of that by a 0
  - example: `01011011 + 1 = 01011100`
- binary → decimal: for each place i in the binary number, multiply the digit (0 or 1) in that place by the place value $2^i$ (see next slides)
From Binary to Decimal

first recall meaning of decimal notation

| 2 4 8 |
|---|---|---|
| 1s place multiply by 1 \((10^0)\): | 8 |
| 10s place multiply by 10 \((10^1)\): | 40 |
| 100s place multiply by 100 \((10^2)\): | 200 |
| Total in decimal (add them up): | 248 |

From Binary to Decimal

adapt this meaning to binary notation

| 1 1 0 0 1 |
|---|---|---|---|---|
| 1s place multiply by 1 \((2^0)\): | 1 |
| 2s place multiply by 2 \((2^1)\): | 0 |
| 4s place multiply by 4 \((2^2)\): | 0 |
| 8s place multiply by 8 \((2^3)\): | 8 |
| 16s place multiply by 16 \((2^4)\): | 16 |
| Total in decimal (add them up): | 25 |

From Decimal to Hex

(here only for numbers up to 256):

if the given number \( n \) <= 15:
   translate \( n \) directly into a hex digit
   (and add 0 to the left);
else
   \( i \) := result of integer division of \( n \) by 16;
   \( j := n - 16*i; \) [this is the division remainder]
   look up the hex digits for \( i \) and \( j \);
   the result of the conversion is \( ij \);

Example: What is 33 (decimal) in hex?

\( n = 33 \)
33/16 = 2 remainder 1
\( \rightarrow i = 2, j = 1 \) (33 = 2*16+1)
2 in hex = 2
1 in hex = 1
\( \rightarrow \) result = 21 (hex)

(Check: 21 hex in decimal = 2*16+1*1 = 33)
### From Decimal to Binary

#### Approach 1: Decimal -> hex -> binary

#### Approach 2: Direct conversion
(here: 8-bit numbers only)

\[
\begin{align*}
\text{n < 128} & \rightarrow \text{1}\text{st bit := 0; otherwise 1, } n:=n-128; \\
\text{n < 64} & \rightarrow \text{2}\text{nd bit := 0; otherwise 1; } n:=n-64; \\
\text{n < 32} & \rightarrow \text{3}\text{rd bit := 0; otherwise 1; } n:=n-32; \\
\text{...} & \\
\text{n < 2} & \rightarrow \text{7}\text{th bit := 0; otherwise 1; } n:=n-2; \\
\text{8}\text{th bit} & = n; \text{ (at this point, n is either 0 or 1)};
\end{align*}
\]

### Challenges:

1. Rewrite Approach 2 as a function using for-loop. Hint: 128 = 2^7, 64 = 2^6, ...

1. Extend Approach 2 so that it works for 16-bit binary numbers (numbers between 65535 and 0).

### In your exam ...

1. You are expected to be able to do number conversions, without a calculator.

1. We will give you tables for hex digits and powers of 2.

1. We will keep the amount of calculation (divisions in particular) small.

1. If you find direct conversions decimal -> hex difficult, consider decimal -> binary -> hex.

### Clicker Exercise

The 8-bit binary representation of 57 is 00111001. What is the 8-bit binary representation of 58?

- A. 01011110
- B. 00111111
- C. 00111010
- D. 00111000
Clicker Exercise

The 8-bit binary representation of 57 is 00111001. What is the 8-bit binary representation of 56?

A. 01011110
B. 00111111
C. 00111010
D. 00111000

Selected RQs:

Binary notation has been used in computing for decades, due to the simplicity of implementing the physical circuitry (logic gates) required to process it. With advances in modern technology improving computer chip manufacturing abilities, is binary still the most efficient data structure on which to base a computing system?

Selected RQs:

In [photo processing] programs, there are often options to "boost" or "tint" the colours of the picture - how does the computer code this? Does it add a certain number to each of the RGB bytes? Or perhaps just one, depending on what colour it's tinting to?

(submitted by Daria, 2011W1 Student)

Learning Goals [revisited]

you should be able to

- define the RGB colour specification, explain its basis, and convert from hexadecimal to decimal
- define “bitmap image” and “pixel” and explain how to construct a bitmap image representation
- define “vector image” and explain how to construct a vector image representation
- compare and contrast the suitability of bitmap and vector representations for different uses of images
Representing Images

Exercise:

• How might you verbally describe the following images?
• Could someone accurately reproduce the images based on your description?

Bitmap Image Representation

Ask for a data representation to transmit this image.

• to fully specify an image using bitmap representation you need:
  – width and height of the image
  – number of rows and columns of the grid
  – the pixels, i.e. colour intensity values of each grid cell

zoom view of jpg file; grid of pixels apparent
Exercise (in groups)

How could you compress a bitmap image representation, *i.e.*, reduce the number of bits required to store it?

**Hint:** Think of the following images as examples:
- A completely black image.
- A night sky (mostly black).
- An empty chess board (regular pattern of two colours)

Compressing Bitmap Images

two techniques used by .jpg files

- areas with similar colour can be modified to have the same colour
- "runs" of identical intensities can be collapsed

Compressing Bitmap Images

collapsing runs: example

Ask for a data rep scheme to transmit this image

- Cells are ordered from top left to bottom right: [1,1],[1,2], ..., [1,6],[2,1],..., [2,6]
- Ordered list of four “maximum-length” runs:
  (9,33,25) 1 (221,192,127) 3
  (9,33,25) 4 (221,192,127) 4
- Can the matrix be reconstructed from the list of runs alone? (A – yes, B – no)

Selected RQs:

The second approach of compressing images is that “Areas with similar colour can be modified to have the same colour. This has the effect of increasing the lengths of runs with identical intensities, making the first approach more effective.”

But will this approach affect the quality of the compressed images since it considers areas with similar colour as ones with the same colour? (submitted by Qian Zeng)