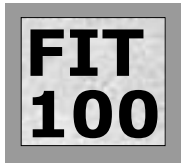
Digital Representation of Information



Digital encoding of information means the data is stored in discrete units -- effectively numbers -- and it is contrasted with analog encoding which uses a physical quantity, e.g. charge, varying over a continuous range. Digital is better.

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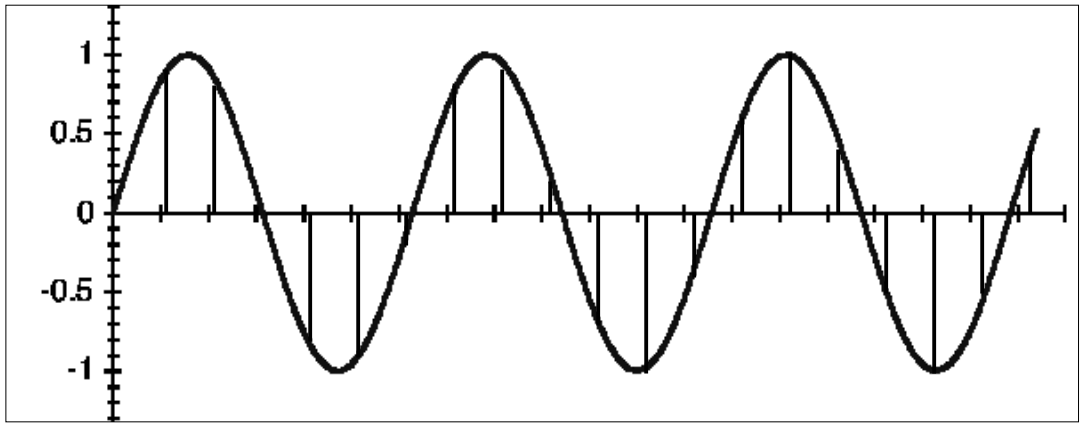
How Digital Works

- The physical world is analog -- sound comes from pushing air with a certain energy at a certain rate, etc
- By measuring a phenomenon one derives a value (number) of the phenomenon at that moment
- Sampling -- taking many measurements at uniform intervals -- gives a series of numbers, the digital form



Digital audio:
44,100 sample/s
2 bytes/sample
2 channels, L&R
176,400 B/s
635 MB/hour

.0 .8 .7 .0 -.8 -.9 -.2 .8 .9 .2 -.7 -1 -.4 .6 1 .4 -.5 -1 -.5 .4 …

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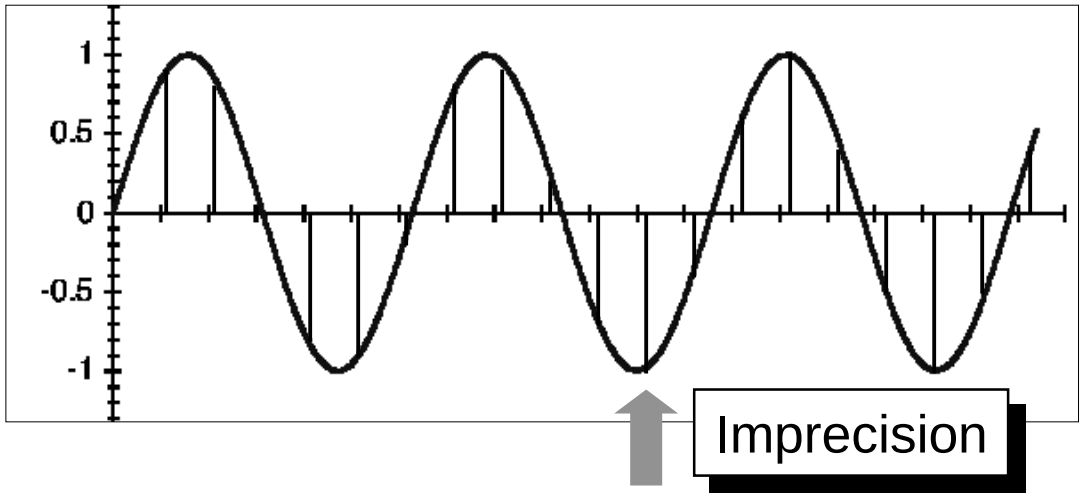
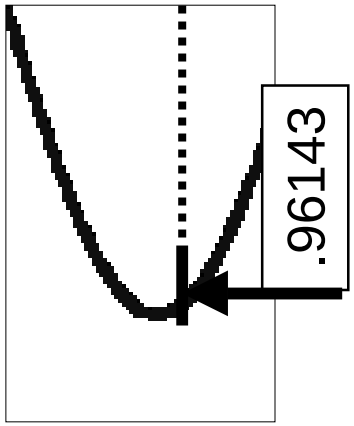
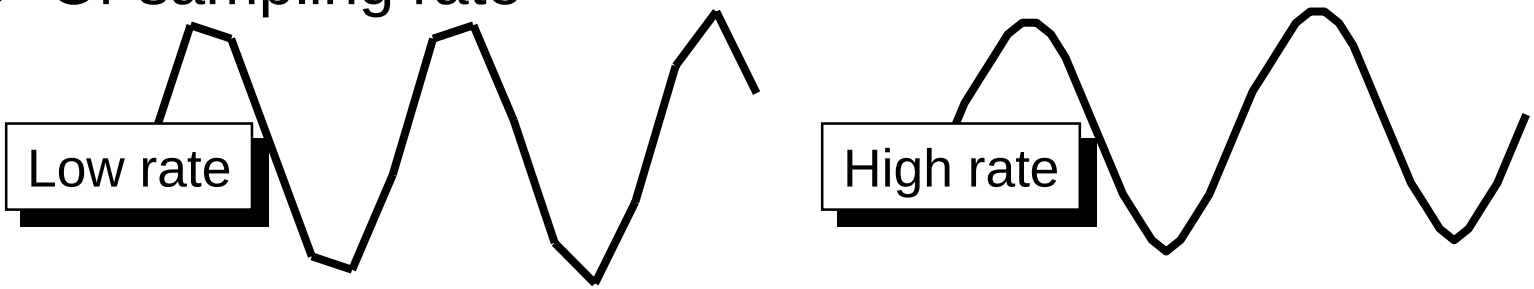
Digital Data

- Digital samples capture the basic structure of analog data, but it can be inaccurate due to limited precision





- Or sampling rate



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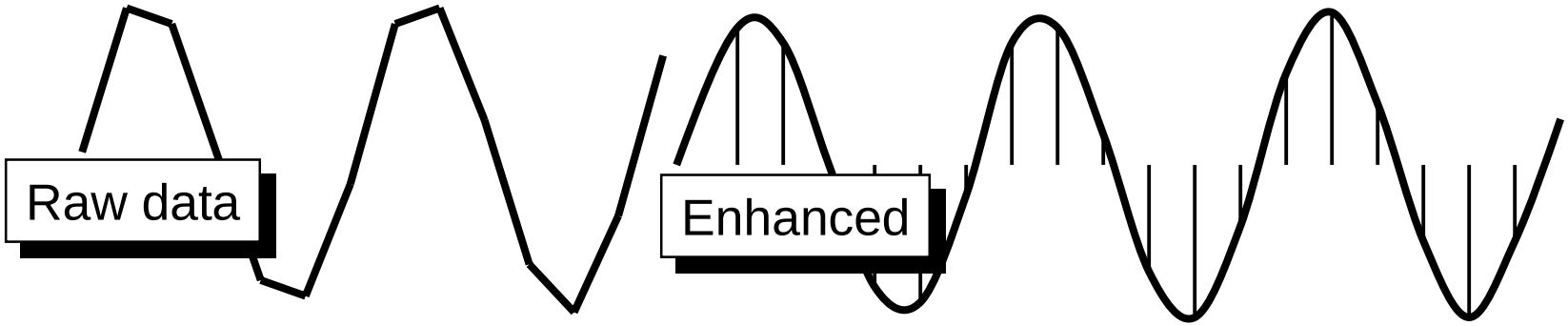
Two Advantages of Digital Data

- A computer can “compute on” digital data, enhancing it to remove noise, artifacts of imprecision, etc.



- Digital data can be transmitted and replicated exactly
  - The numbers are the complete representation of data
  - Assuring each number is duplicated or transmitted accurately, means the data is exact

.0 .8 .7 .0 -.8 -.9 -.2 .8 .9 .2 -.7 -1 -.4 .6 1 .4 -.5 -1 -.5 .4 …
.0 .8 .7 .0 -.8 -.9 -.2 .8 .9 .2 -.7 -1 -.4 .6 1 .4 -.5 -1 -.5 .4 …
.0 .8 .7 .0 -.8 -.9 -.2 .8 .9 .2 -.7 -1 -.4 .6 1 .4 -.5 -1 -.5 .4 …
.0 .8 .7 .0 -.8 -.9 -.2 .8 .9 .2 -.7 -1 -.4 .6 1 .4 -.5 -1 -.5 .4 …

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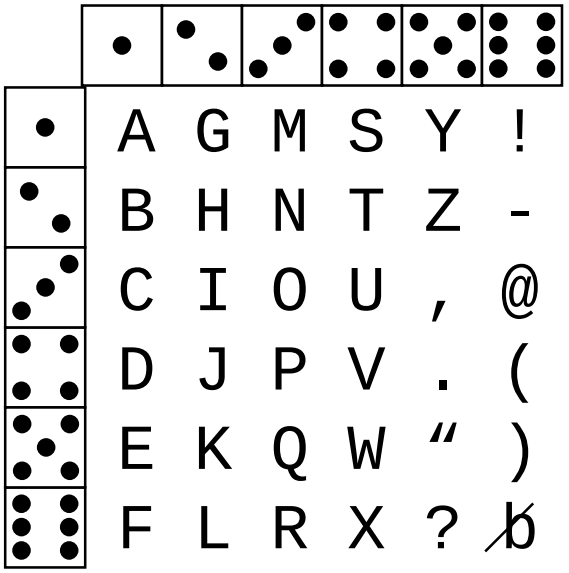
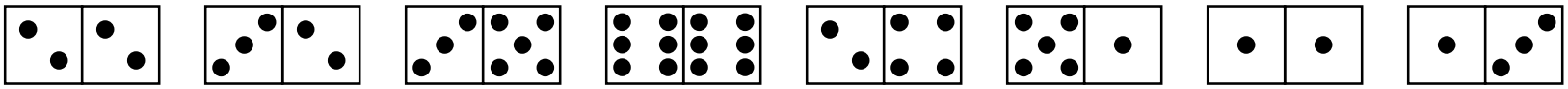
Some Information Is Discrete

- Keyboard characters can be represented exactly
- Imagine you and your friend are prohibited from talking -- its too noisy? -- and so you use dice to encode the letters and punctuation to communicate



With two dice there are 6x6 = 36 encodings, not enough for 26 letters, 10 numerals and punctuation. Three dice would give 6x6x6=216 representations, too many. So, you dump the numerals. Order matters: row then col!



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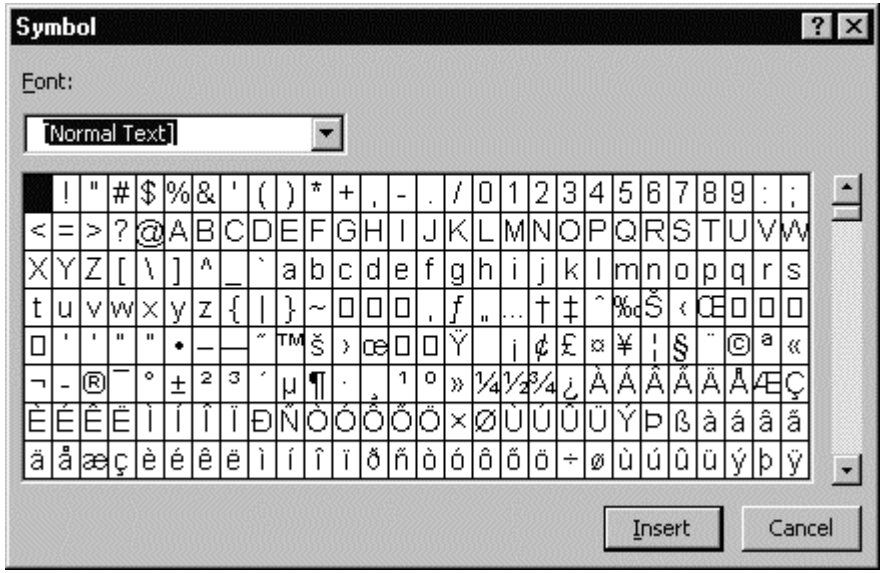
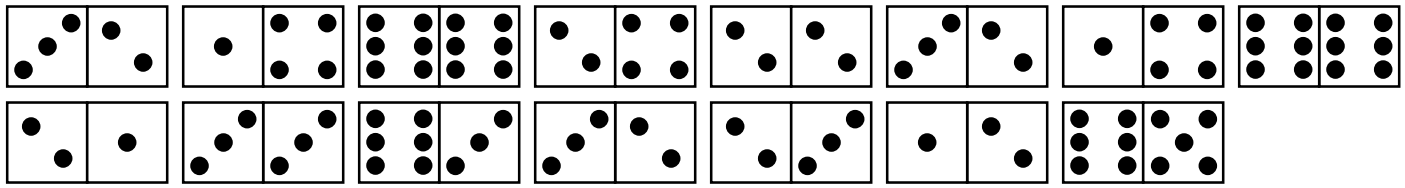
- Keyboard characters are encoded into a byte or two
- ASCII is one of many encodings of the characters
- A byte (8 bits) permits 256 things to be represented



ASCII, pronounced AS·key, stands for American Standard Code for Information Interchange



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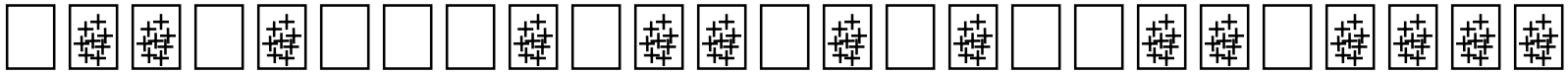
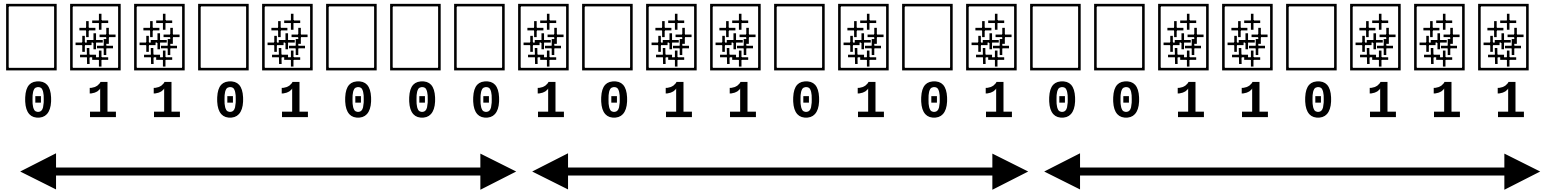
Encoding The Number

- Information is often stored by charge or magnetic field



Schematic diagram of magnetic spots, say on a disk

- Its presence or absence can be detected, leading to a natural association with 1 and 0 to the states, motivating the use of binary numbers



Binary is counting on your fists instead of your fingers

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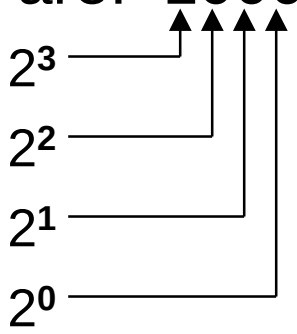
Decimal and Binary

❖	Decimal	Binary
Symbols:	0, 1, …, 9	0, 1
Base	10	2
Number xyz	$x \cdot 10^2 + y \cdot 10^1 + z \cdot 10^0$	$x \cdot 2^2 + y \cdot 2^1 + z \cdot 2^0$
Ex: 101	$1 \cdot 10^2 + 0 \cdot 10^1 + 1 \cdot 10^0$	$1 \cdot 2^2 + 0 \cdot 2^1 + 1 \cdot 2^0$
Place Value	101	5
Powers	1, 10, 100, 1000, …	1, 2, 4, 8, 16, 32, 64, ...

Binary works just like decimal, except that the base is 2

- What binary numbers are: 1000_2, 1010_2 and 1111_2

Use a subscript to indicate the number base, e.g $5_{10} = 101_2$



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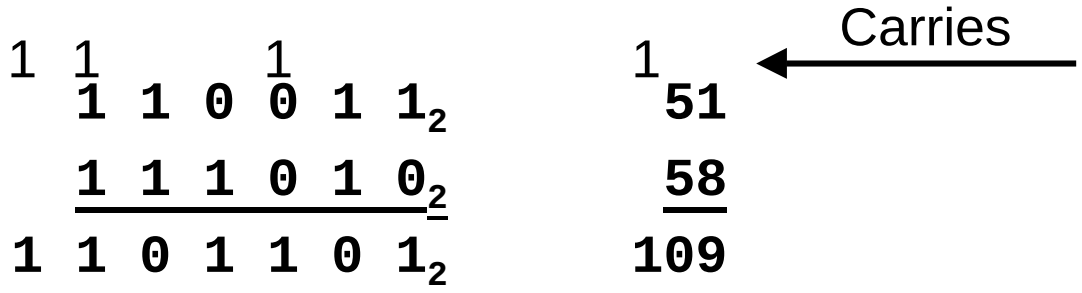
Adding Is Familiar

- To add in binary use the same technique (algorithm), but restrict yourself to 0 and 1 … everything else works the same way



- Binary is pretty tedious for humans because there are so many digits … circuitry benefits however because it uses the two states (on/off) efficiently

A sequence of b bits can represent 2^b things, e.g. 0 to 2^b-1

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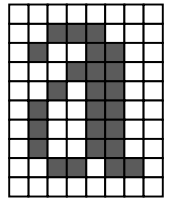
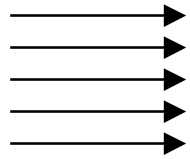
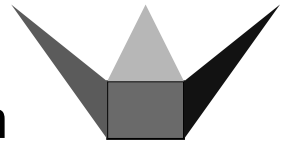
Picture Elements (Pixels)





- The phosphor on the screen naturally displays the on/off property of binary
  - Suitable for one color (B&W) video
  - The bits in memory are streamed out on the screen in “raster” order, like a standard TV
- For a color display, three (basic) colors of light must be displayed: red, green and blue (RGB)



  - Requires three different numbers, e.g. one byte each
  - Range of colors is determined by the intensity of each component
  - When all three values are at their maximum, the color is white, and when they are at their minimum the color is black

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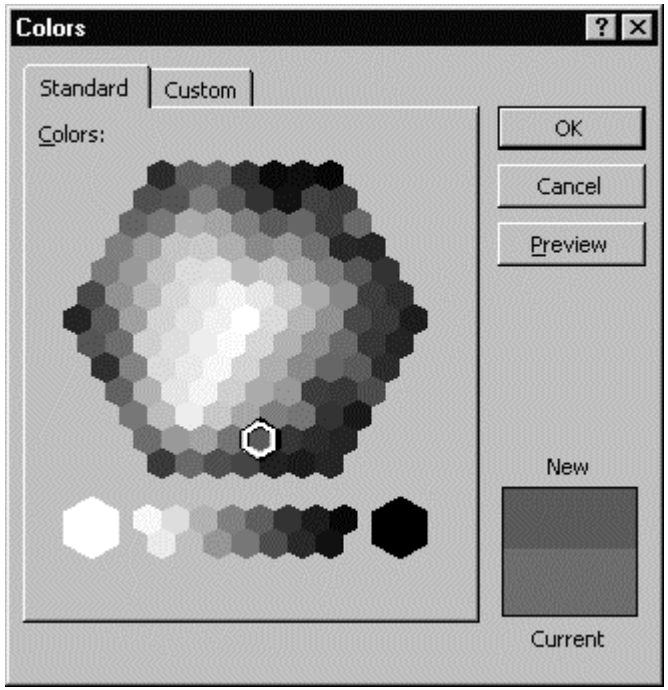
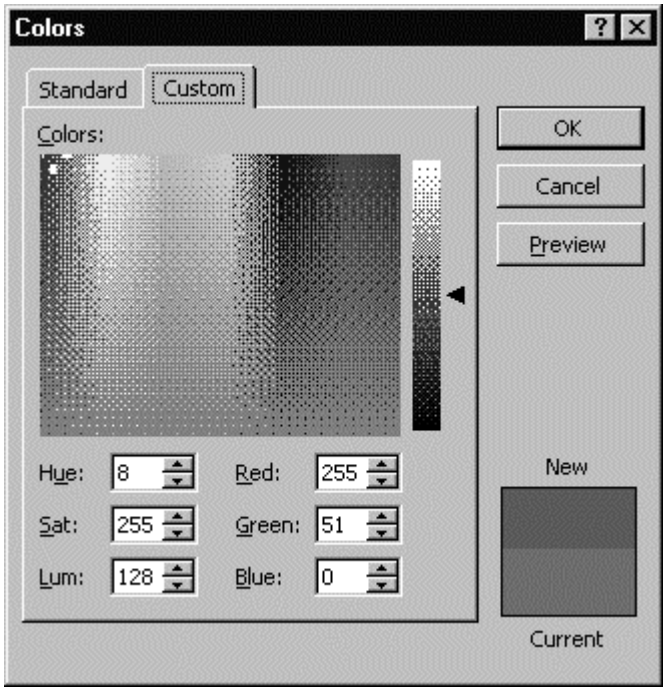
Color Control

- Select the color palette from an application and play
- Notice when values are equal -- gray results





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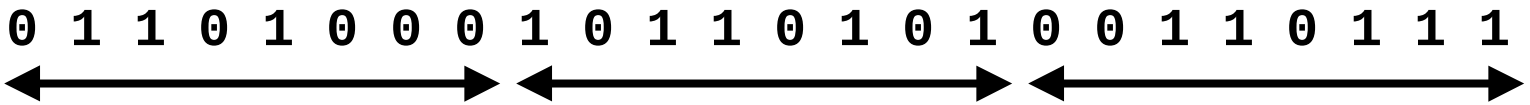
Bits As A Medium

- The way that bits represent information is determined by how we interpret the bits …



- As separate bytes these are: 104, 181, 56
- As ASCII these bytes are: h, □, 7
- As a 24 bit integer these bytes are: 6,862,136
- As a color value the bytes are
- The bytes can be interpreted in an unlimited number of ways

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Summary

- Digital representation can be faithfully replicated and transmitted
- It's common to "compute" on a digital representation
- The binary digits (bits) 0 and 1 are a natural way to interpret the presence or absence of a phenomenon
- Binary numbers and arithmetic are like decimal except the are limited to the two numerals 0 and 1
- Bits are bits -- what they mean depends on how we interpret their meaning … sometimes they are numbers, sometimes letters, sometimes sound, sometimes color, ...