



Announcements

- Project Turn-In Process
 - * Put name, lab, UW NetID, student ID, and URL for project on a Word doc
 - * Upload to Catalyst Collect It



Announcements

- Project 1A:
 - * Turn in the Word doc or .txt file before 12 Noon on Monday
 - * Do *not* change your files after the deadline or we will mark you late.
- Project 1B:
 - * Make a copy of your Project1A folder and name it Project1b. Work in that!



Announcements

- Chapter 8 for today
- Project 1A was just turned in at noon
 - * If you haven't turned it in yet,
 - 1-1-1 Rule
 - * This week's lab time: all project time
 - Bring your questions!



Announcements

- Academic misconduct
 - * We've handled the situation
 - * We will be tightening up the quizzes to prevent any more possibilities



More Digitization

Light, Sound, Magic: Representing Multimedia Digitally

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Digitizing Color

- RGB Colors: Binary Representation
 - * Giving the intensities for the three constituent colors—red, green, blue—specifies color on monitor
 - Color intensity is represented as a quantity (0 through 255)



Digitizing Color

- Binary Numbers Compared with Decimal Numbers
 - * Number of digits is the base of numbering system
 - * Binary is two digits: 0 and 1
 - * Decimal is 10 digits: 0 through 9
 - * Hexadecimal is 16 digits: 0 through 9, A through F



Place Value in a Binary Number

- Works the same way except that the place values are successive powers of 2

Power	Decimal	Binary
0	$1 = 10^0$	$1 = 2^0$
1	$10 = 10^1$	$2 = 2^1$
2	$100 = 10^2$	$4 = 2^2$
3	$1,000 = 10^3$	$8 = 2^3$
4	$10,000 = 10^4$	$16 = 2^4$
...



Place Value in a Binary Number

- Given binary representation, we can find decimal equivalent value by multiplying the digit times the place value and adding the results

Table 11.2 The binary number 1010, representing the decimal number ten = 8 + 2

2^3	2^2	2^1	2^0	Binary Place Values
1	0	1	0	Bits of Binary Number
1×2^3	0×2^2	1×2^1	0×2^0	Multiply place bit by place value
8	0	2	0	and add to get a decimal 10



Converting a Binary Number to Decimal

- Add the decimal values for the places in the binary number with 1's

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	Binary Place Values
1	1	1	1	1	1	1	1	Bits of Binary Number
1×2^7	1×2^6	1×2^5	1×2^4	1×2^3	1×2^2	1×2^1	1×2^0	Multiply place bit by place value
128	64	32	16	8	4	2	1	and add to get decimal 255



Black and White Colors

- A byte is allocated to each **RGB** intensity
 - * The smallest intensity is 0000 0000
 - * The largest is 1111 1111 in binary
 - = 255 in decimal
 - = FF in hexadecimal
- Black (#000000) is no color
- White (#FFFFFF) has full intensity for each RGB color



Practice

- RGB

* #FFFFFF = _____

* #000000 = _____

* #333333 = _____

* #888888 = _____

* #00FF00 = _____

* #FF0000 = _____

* #0000FF = _____



More practice

- Team up with the person sitting next to you
- Figure out what color is represented for each of these hex or decimal numbers
- Ten minutes



Lighten Up: Changing Color by Addition

- What color does this represent:
1100 1000 1100 1000 1100 1000
- Each byte contains the decimal value 200. The color is RGB(200,200,200).
 - * In HTML, write in hexadecimal #C8C8C8
 - * Equal amounts of red, green, and blue, closer to white than black (medium gray)
 - * All colors with equal RGB values are black, white, or gray



To Increase Intensity: Add in Binary

- To make a lighter color of gray, change the common values to be closer to white (larger numbers)
 - * For example, add 0001 0000 (decimal 16) to each color:

1101 1000 1101 1000 1101 1000
RGB(216,216,216)

1100 1000	binary representing decimal number	200
+ 1 0000	binary representing decimal number	16
<hr/>		<hr/>
1101 1000	binary representing decimal number	216

Figure 11.1. Adding 16 to an RGB value.



Overflow

- Because computers use fixed-size bit sequences, what happens when there are not enough bits to represent the correct result of a binary addition?
- Called *overflow exceptions*
 - * Computers report them when the computation they're told to perform overflows; programmer has to find way to recover



Digitizing Sound

- An object creates sound by vibrating in a medium such as air
 - * Vibrations push the air
 - * Pressure waves emanate from the object and vibrate our eardrums
 - * The *force*, or intensity of the push determines the volume
 - * The *frequency* (number of waves per second) is the pitch

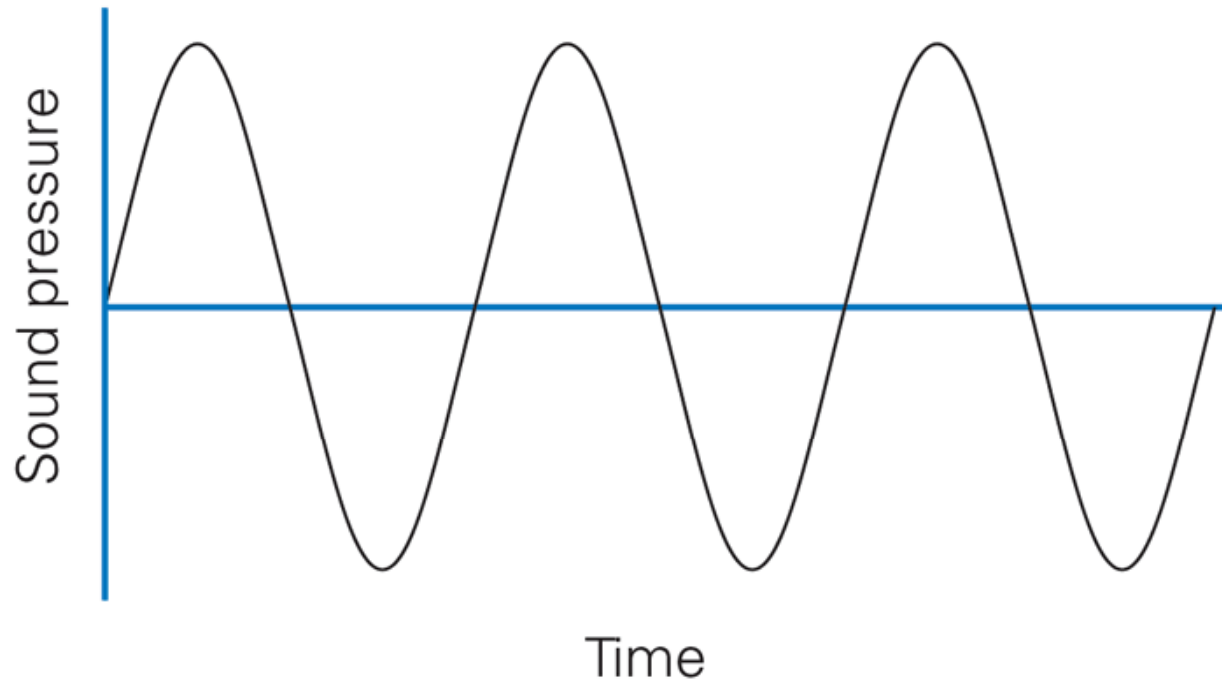


Figure 11.3. Sound wave. The horizontal axis is time; the vertical axis is sound pressure.



Analog to Digital

- To convert continuous information into discrete information, convert it to bits
- From zero line on graph, record with binary number the amount by which the wave is above or below it (positive or negative sound pressure)
- At what points do we measure? We can't record every position of the wave



Sampling

- Take measurements at regular intervals
- Number of samples in a second is the *sampling rate*
 - * The faster the rate, the more accurate the recording

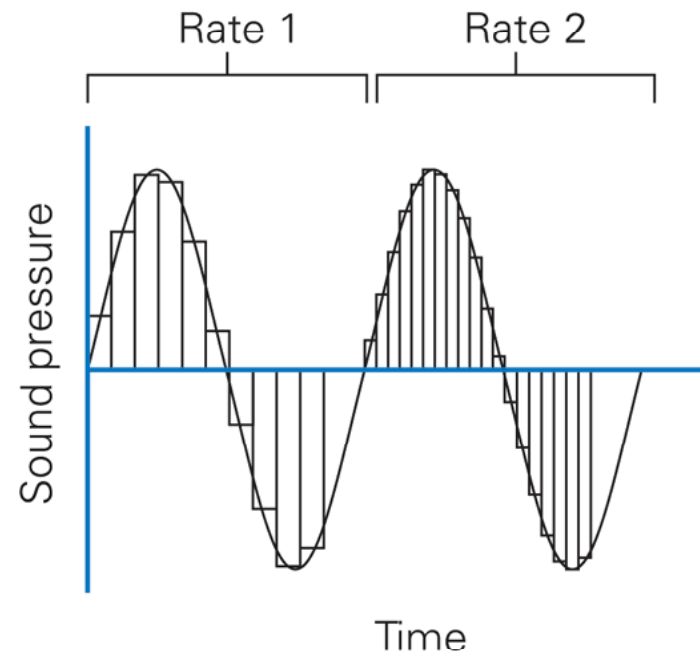


Figure 11.4. Two sampling rates; the rate on the right is twice as fast as that on the left.



How Fast a Sampling Rate?

- Sampling rate should be related to the wave's frequency
 - * Too slow a rate could allow waves to fit between the samples; we'd miss segments of sound
 - * Guideline is *Nyquist Rule*: Sampling rate must be at least twice as fast as the fastest frequency
 - Human perception can hear sound up to 20,000 Hz, so 40,000 Hz sampling rate is enough.
 - Standard for digital audio is 44,100 Hz (44.1 KHz) 11-22



ADC, DAC

- Digitizing Process:

- * Sound is picked up by a microphone (called a *transducer*)
- * The signal is fed into an *analog-to-digital converter (ADC)*, which samples it at regular intervals and outputs binary numbers to memory
- * To play the sound, the process is reversed
 - Numbers are read from memory into *digital-to-analog converter (DAC)*, which creates an electrical wave by filling in between the digital values
 - Electrical signal is output to speaker, which converts

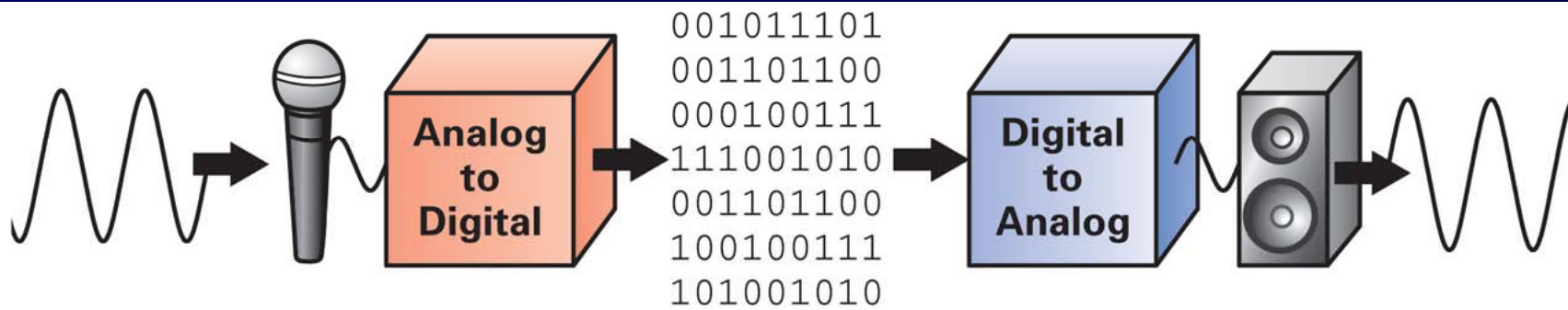
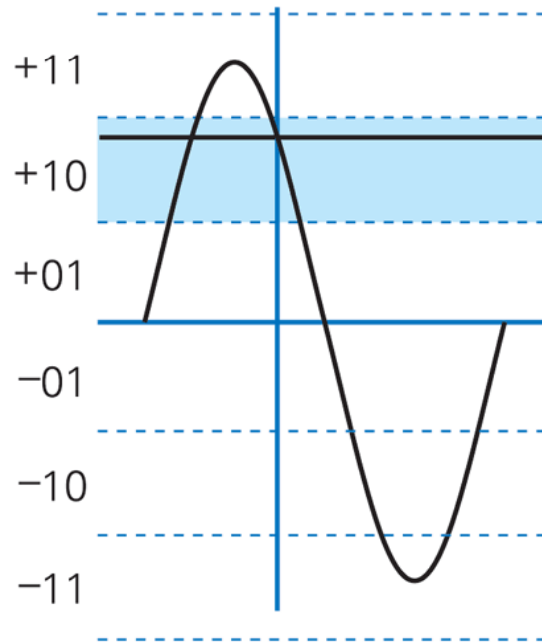


Figure 11.5. Schematic for analog-to-digital and digital-to-analog conversion.

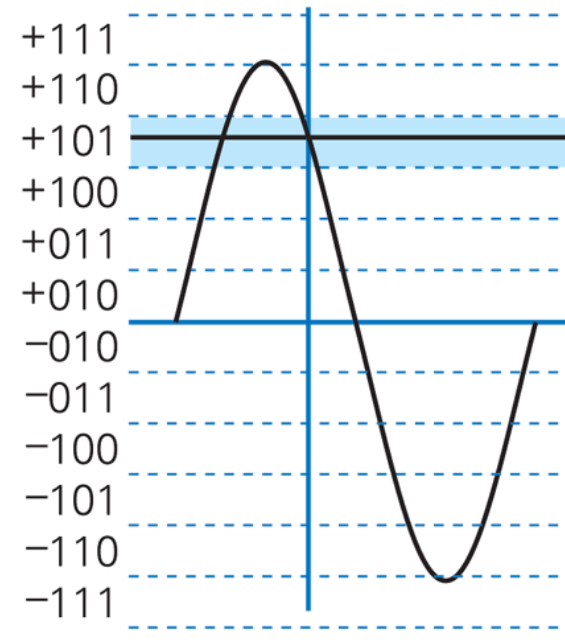


How Many Bits per Sample?

- How accurate must the samples be?
 - * Bits must represent both positive and negative values
 - * The more bits, the more accurate the measurement
 - * The digital representation of audio CDs uses 16 bits (records 65,536 levels, half above and half below the zero line)



(a)



(b)

Figure 11.6. (a) Three-bit precision for samples requires that the indicated reading is approximated as +10. (b) Adding another bit makes the sample twice as accurate.



Advantages of Digital Sound

- We can compute the representation
- MP3 Compression
 - * One computation is to compress the digital audio (reduce number of bits needed)
 - * Remove waves that are outside range of human hearing
 - * MP3 usually gets a compression rate of 10:1
 - Lower bandwidth requirements, popular for Internet transmission
- Reproducing the Sound Recording
 - * Bit file can be copied without losing any information
 - * Original and copy are exactly the same



Digitizing Images and Video

- It would take 51 minutes to display an 8 x 10 color image scanned at 300 pixels per inch (21.6 MB) with a 56kb/s modem
- How can we see screen-size pictures in second while surfing the web?
- Typical computer screen has under 100 pixels per inch
 - * Storing picture digitized at 100 ppi saves a factor of 9 in memory (reducing resolution)
 - This would still take 5 1/2 minutes to send at 56kb/s
 - * Solution: JPEG Compression scheme



Compression

- Changing the representation to use fewer bits to store or transmit information
 - * Example: fax is a long sequence of 0's and 1's encoding where page is white or black. Run length encoding is used to specify length of first sequence of 0's, following sequence of 1's, etc.
 - Lossless compression—original representation can be perfectly reproduced



JPEG

- Used for still images
- Our eyes are not very sensitive to small changes in hue (gradation of color), but are sensitive to small changes in brightness
 - * Store a less accurate description of hue (fewer pixels)
 - * Gets a 20:1 compression ratio without eyes being able to perceive the difference



(a)



(b)

Figure 11.7. Detail from an image compressed using JPEG.

(a) 14:1 compression (b) 140:1. Check images at www.aw.com/snyder



MPEG Compression Scheme

- Same idea as JPEG, applied to motion pictures
- JPEG-like compression is applied to each frame
- Then "interframe coherency" is used
 - * MPEG only has to record and transmit the differences between one frame and the next
 - * Results in huge amounts of compression



Optical Character Recognition (OCR)

- Reading license plate to deduct toll from car's account
- What are the difficulties?
 - * Computer must capture image of license plate but camera will see other highway images
 - * *Frame grabber* recognizes when to snap image and send to computer for processing
 - * Computer must figure out where in the image the plate is
 - Scans groups of pixels looking for edges where color changes
 - Looks for *features*
 - *Classifier* matches features to letters of alphabet



OCR Technology

- Enables computer to "read" printed characters
 - * Business applications
 - Sorting mail and banking



Virtual Reality: Fooling the Senses

- Creating an entire digital world
- Applies to all senses and tries to eliminate the cues that keep us grounded in reality
- *Haptic devices*
 - * Input/output technology for sense of touch and feel
 - * Haptic glove enables computer to detect where our fingers are. When we bring our fingers close enough together, gloves stop their movement so we feel like we're holding something



The Challenge of Latency

- The challenge is for the system to operate fast and precisely enough to appear natural
- *Latency* is the time it takes for information to be delivered
- Too long latency period ruins the illusion
 - * Absolute limit to how fast information can be transmitted—speed of light



Bandwidth Challenge

- How much information is transmitted per unit time
- Higher bandwidth usually means lower latency



Bits Are It

- *Bias-Free Universal Medium Principle:*
 - * Bits can represent all discrete information, but have no inherent meaning
- **Bits: The Universal Medium**
 - * Everything that can be represented in a sensible way, can be manipulated
- **Bits: Bias-Free**
 - * The meaning of bits comes entirely from the interpretation placed on them through programs
- **Bits are Not Necessarily Binary Numbers**
 - * Bits can be interpreted as binary numbers, or not, depending on use



Summary

0000 0000|1111 0001|0000 1000|0010 0000 = 15,796,256 interpreted as a binary number
= ■ interpreted as an RGB(241,8,32) color (last 3 bytes)
= ADD 1,7,17 interpreted as a MIPS machine instruction
= ^NU ^BS ñ ð interpreted as 8-bit ASCII—null, backspace,
n-tilde, blank
= L: +241, R: +280 interpreted as sound samples
= 0.241.8.32 interpreted as an
IP address
= 00 F1 08 20 interpreted as a
hexadecimal number

Figure 11.8. Illustration of the principle that “bits are bits.” The same 4 bytes shown can be interpreted differently.