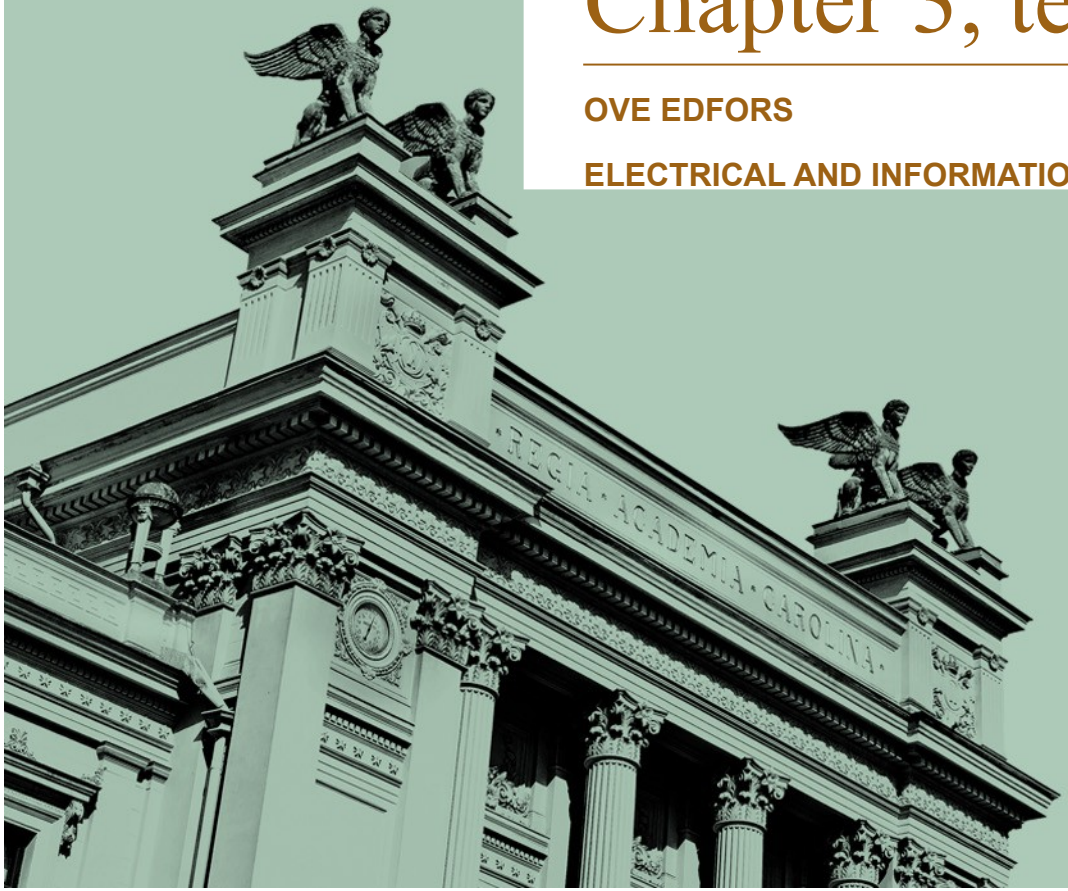
Information Transmission
Chapter 3, text and speech

OVE EDFORS

ELECTRICAL AND INFORMATION TECHNOLOGY



Learning outcomes

Understand

- some of the most important concepts regarding information and its representation (bits, bandwidth, SNR),
- how to perform decibel calculations,
- what text is and how it can be coded,
- signal frequency content/components and spectrum,
- voice generation and properties,
- audio quality measures, and
- basics of (digital) audio/music recording.

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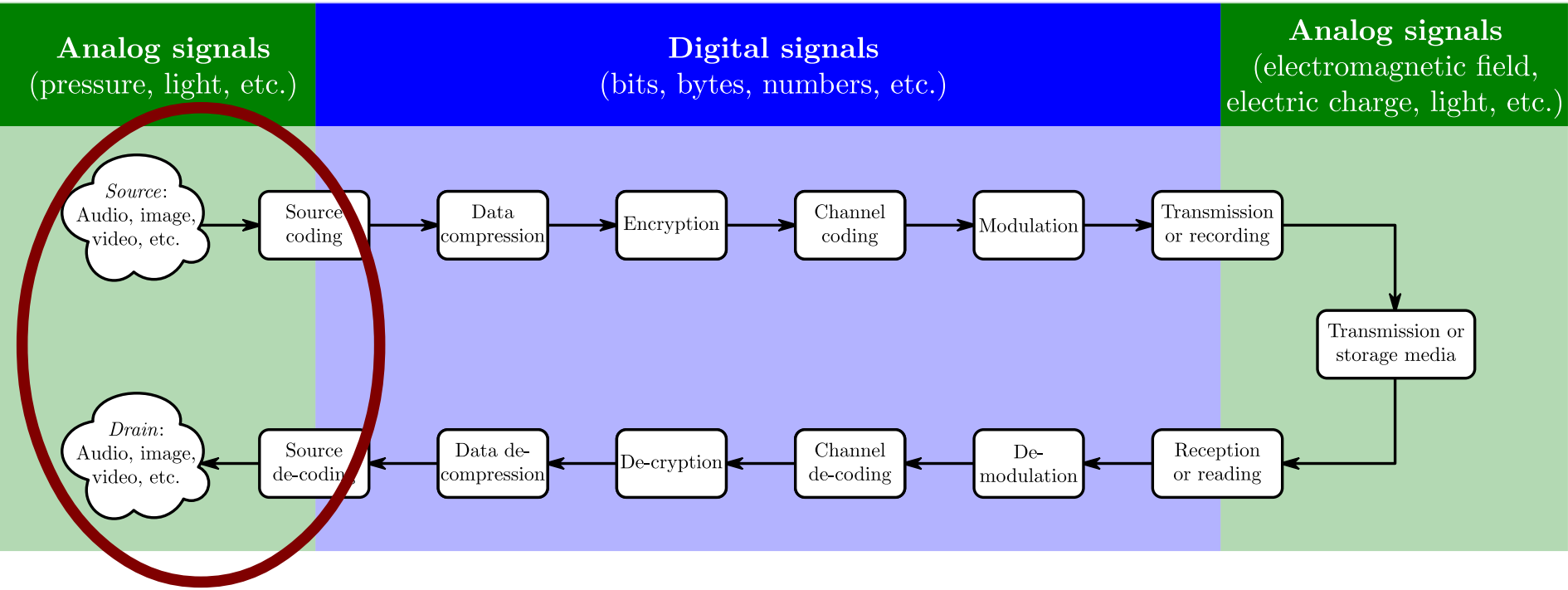
Where are we in the BIG PICTURE?



Some concepts

- Bits
  - Small pieces of information
  - The information in a 2-valued variable
- Bandwidth
  - Fourier transform of a signal
  - (The number of bits/s from a source)
- Signal to noise ratio – SNR
  - Average signal power / average noise power

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Decibel - dB

- Convenient when comparing values with a really small difference or a really large one

- If *A* and *B* are **power** values

$$10 \log_{10}(A/B) \text{ dB}$$

- Or if *A* and *B* are **amplitude** values

$$10 \log_{10}(A/B)^2 = 20 \log_{10}(A/B) \text{ dB}$$

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What is text?

Definition: A collection of letters (numbers, symbols, …) to form words (math figures, software, crypto-text, …)

Symbols come from a set called the *alphabet*

Do we have any standard alphabets?

ASCII american standard for information interchange

Binary to Hexadecimal

0000	0
1000	1
0100	2
1100	3
0010	4
1010	5
0110	6
1110	7
0001	8
1001	9
0101	A
1101	B
0011	C
1011	D
0111	E
1111	F

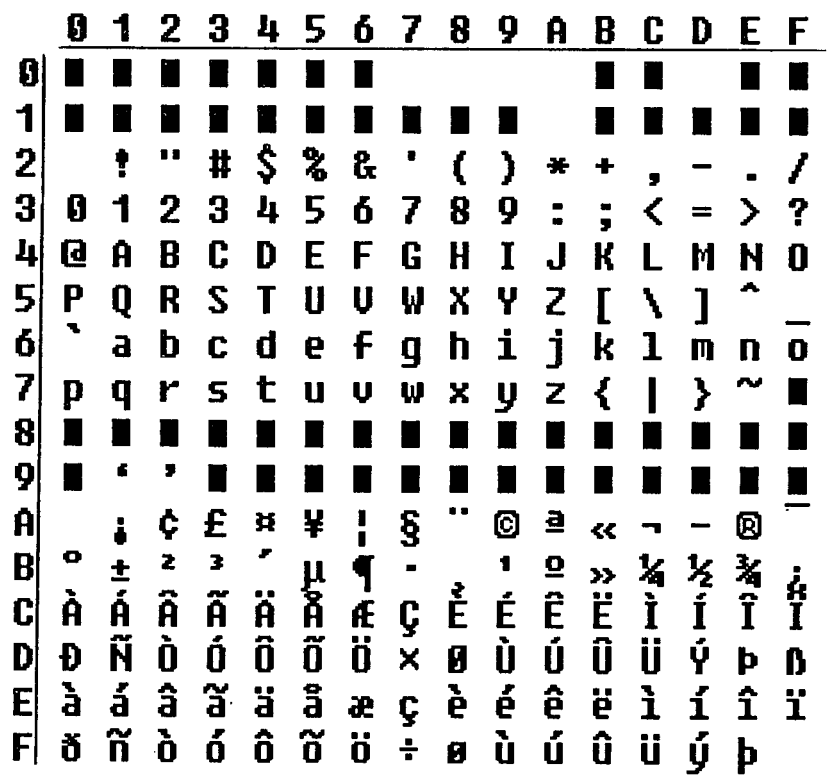

FIGURE FROM TEXTBOOK

A different type of ASCII table

Dec	Bin	Hex	Char	Dec	Bin	Hex	Char	Dec	Bin	Hex	Char	Dec	Bin	Hex	Char
0	0000 0000	00	[NUL]	32	0010 0000	20	space	64	0100 0000	40	@	96	0110 0000	60	`
1	0000 0001	01	[SOH]	33	0010 0001	21	!	65	0100 0001	41	A	97	0110 0001	61	a
2	0000 0010	02	[STX]	34	0010 0010	22	"	66	0100 0010	42	B	98	0110 0010	62	b
3	0000 0011	03	[ETX]	35	0010 0011	23	#	67	0100 0011	43	C	99	0110 0011	63	c
4	0000 0100	04	[EOT]	36	0010 0100	24	$	68	0100 0100	44	D	100	0110 0100	64	d
5	0000 0101	05	[ENQ]	37	0010 0101	25	%	69	0100 0101	45	E	101	0110 0101	65	e
6	0000 0110	06	[ACK]	38	0010 0110	26	&	70	0100 0110	46	F	102	0110 0110	66	f
7	0000 0111	07	[BEL]	39	0010 0111	27	'	71	0100 0111	47	G	103	0110 0111	67	g
8	0000 1000	08	[BS]	40	0010 1000	28	(	72	0100 1000	48	H	104	0110 1000	68	h
9	0000 1001	09	[TAB]	41	0010 1001	29	)	73	0100 1001	49	I	105	0110 1001	69	i
10	0000 1010	0A	[LF]	42	0010 1010	2A	*	74	0100 1010	4A	J	106	0110 1010	6A	j
11	0000 1011	0B	[VT]	43	0010 1011	2B	+	75	0100 1011	4B	K	107	0110 1011	6B	k
12	0000 1100	0C	[FF]	44	0010 1100	2C	,	76	0100 1100	4C	L	108	0110 1100	6C	l
13	0000 1101	0D	[CR]	45	0010 1101	2D	-	77	0100 1101	4D	M	109	0110 1101	6D	m
14	0000 1110	0E	[SO]	46	0010 1110	2E	.	78	0100 1110	4E	N	110	0110 1110	6E	n
15	0000 1111	0F	[SI]	47	0010 1111	2F	/	79	0100 1111	4F	O	111	0110 1111	6F	o
16	0001 0000	10	[DLE]	48	0011 0000	30	0	80	0101 0000	50	P	112	0111 0000	70	p
17	0001 0001	11	[DC1]	49	0011 0001	31	1	81	0101 0001	51	Q	113	0111 0001	71	q
18	0001 0010	12	[DC2]	50	0011 0010	32	2	82	0101 0010	52	R	114	0111 0010	72	r
19	0001 0011	13	[DC3]	51	0011 0011	33	3	83	0101 0011	53	S	115	0111 0011	73	s
20	0001 0100	14	[DC4]	52	0011 0100	34	4	84	0101 0100	54	T	116	0111 0100	74	t
21	0001 0101	15	[NAK]	53	0011 0101	35	5	85	0101 0101	55	U	117	0111 0101	75	u
22	0001 0110	16	[SYN]	54	0011 0110	36	6	86	0101 0110	56	V	118	0111 0110	76	v
23	0001 0111	17	[ETB]	55	0011 0111	37	7	87	0101 0111	57	W	119	0111 0111	77	w
24	0001 1000	18	[CAN]	56	0011 1000	38	8	88	0101 1000	58	X	120	0111 1000	78	x
25	0001 1001	19	[EM]	57	0011 1001	39	9	89	0101 1001	59	Y	121	0111 1001	79	y
26	0001 1010	1A	[SUB]	58	0011 1010	3A	:	90	0101 1010	5A	Z	122	0111 1010	7A	z
27	0001 1011	1B	[ESC]	59	0011 1011	3B	;	91	0101 1011	5B	[	123	0111 1011	7B	{
28	0001 1100	1C	[FS]	60	0011 1100	3C	<	92	0101 1100	5C	\	124	0111 1100	7C	|
29	0001 1101	1D	[GS]	61	0011 1101	3D	=	93	0101 1101	5D	]	125	0111 1101	7D	}
30	0001 1110	1E	[RS]	62	0011 1110	3E	>	94	0101 1110	5E	^	126	0111 1110	7E	~
31	0001 1111	1F	[US]	63	0011 1111	3F	?	95	0101 1111	5F	_	127	0111 1111	7F	[DEL]

Frequency and bandwidth

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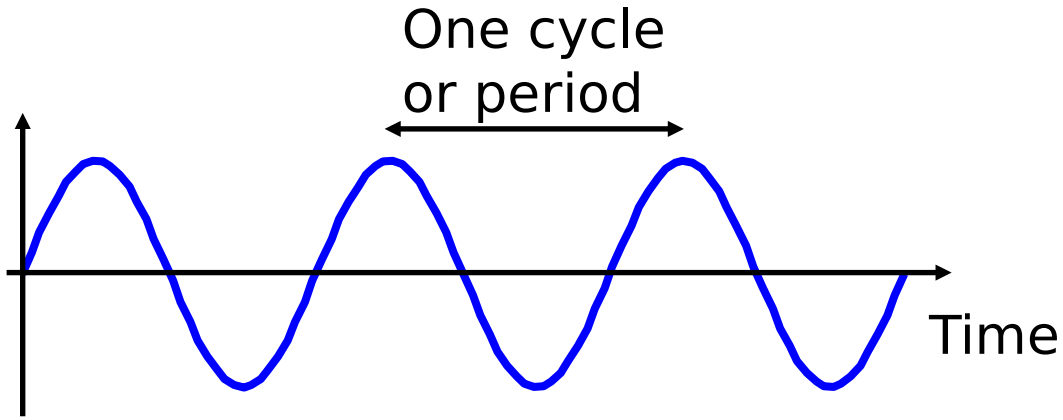
Frequency

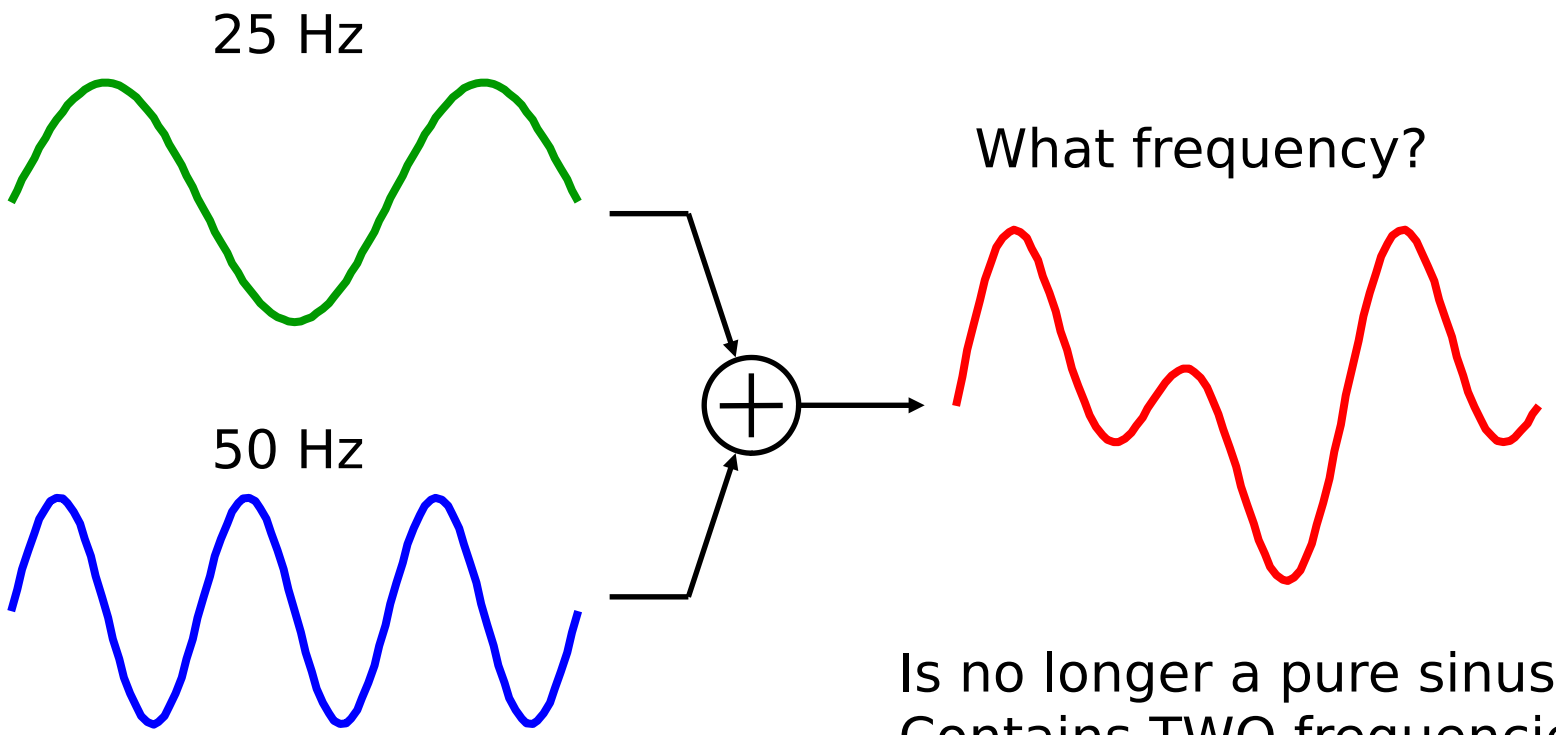
Sinusoidal signals:



Frequency = Number of cycles per second [Herz]

Example: The AC power in your home has a frequency of 50 Hertz.
This also means that the cycle time is 20 ms.

Adding sinusoids [1]



Is no longer a pure sinusoid.
Contains TWO frequencies.

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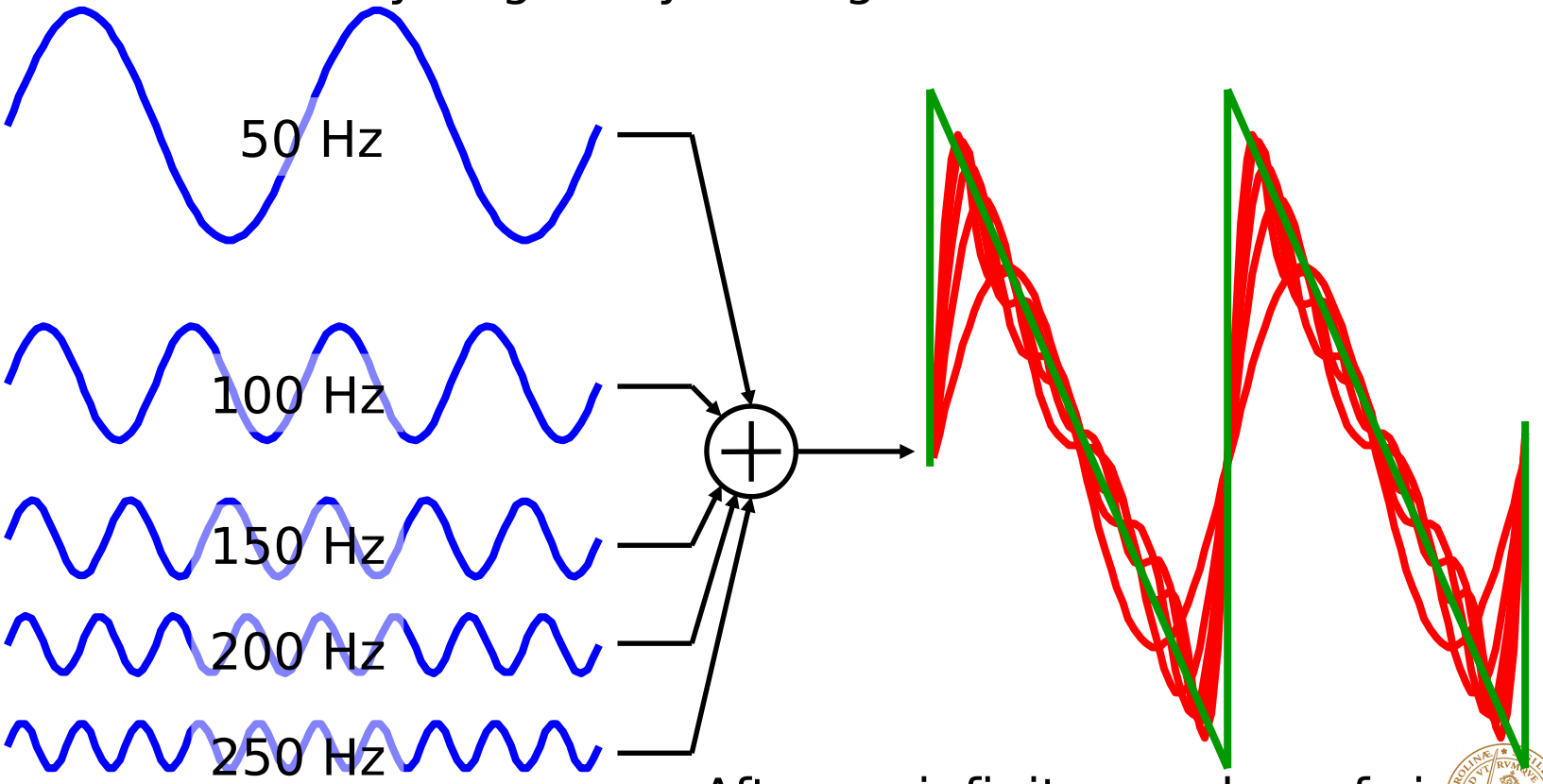
Adding sinusoids [2]

Can we build ”any” signal by adding sinusoids? Yes!



After an infinite number of sinusoids we get a sawtooth signal!

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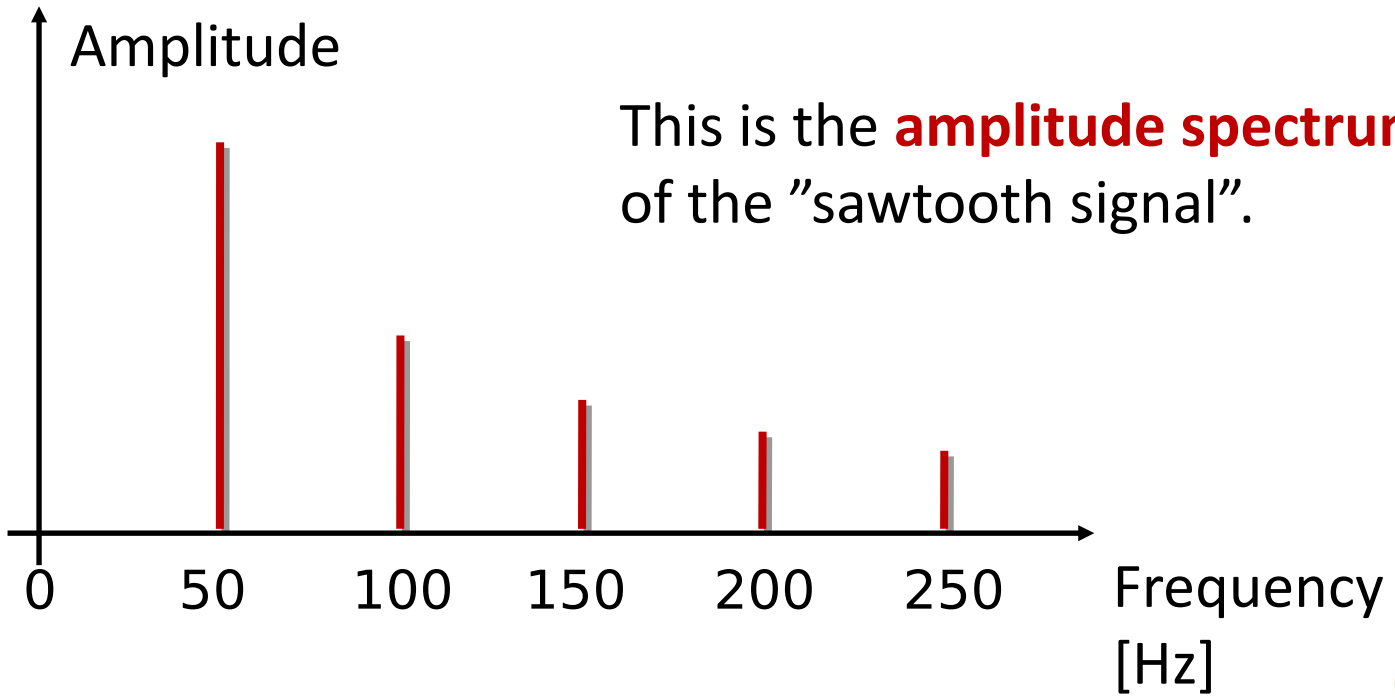
Spectrum

Spectrum [1]

If we can build any signal by adding sinusoids ... can we view the frequency content of a signal in some way?



This is the **amplitude spectrum** of the ”sawtooth signal”.

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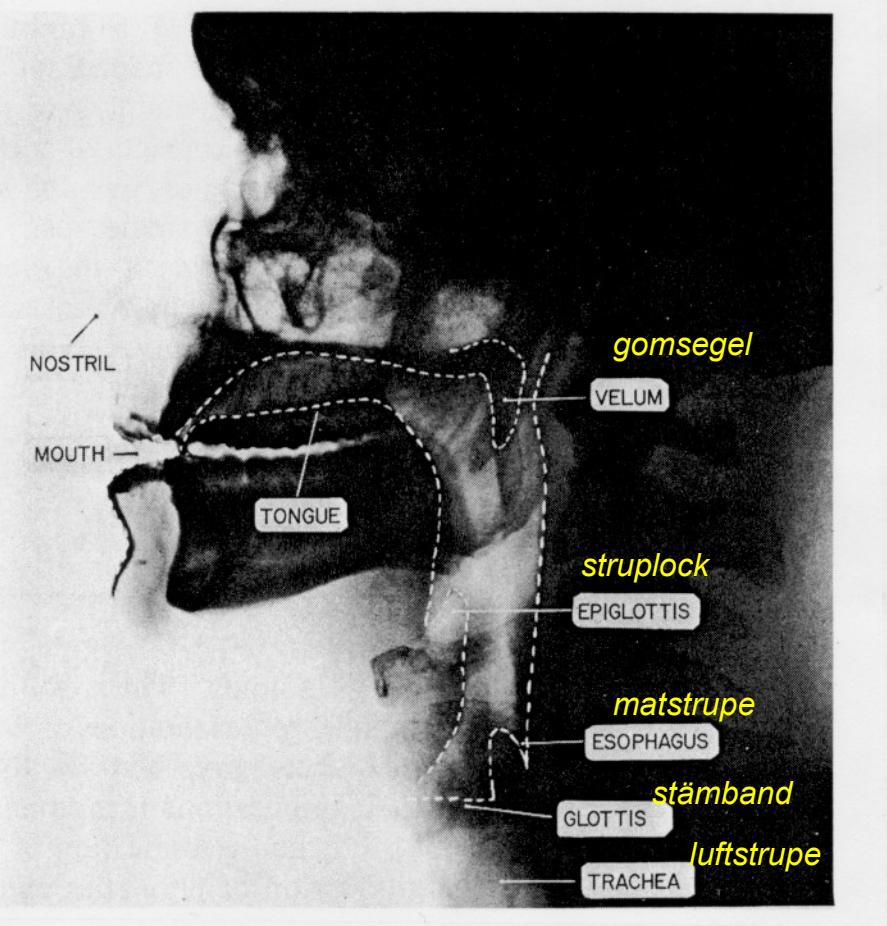
The vocal tract



- Vocal cord produces the tone, the rest is forming the sound
- Voiced sounds/unvoiced sounds
- 5-10 sounds/s in speech

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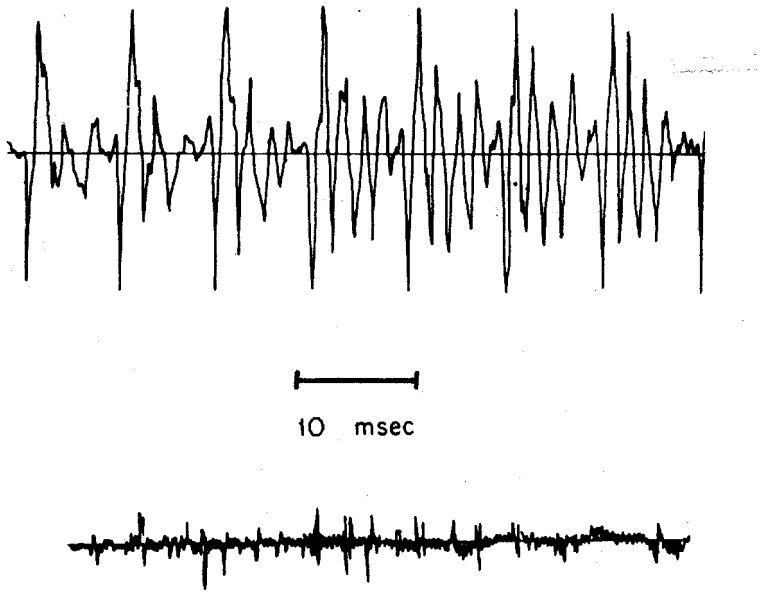
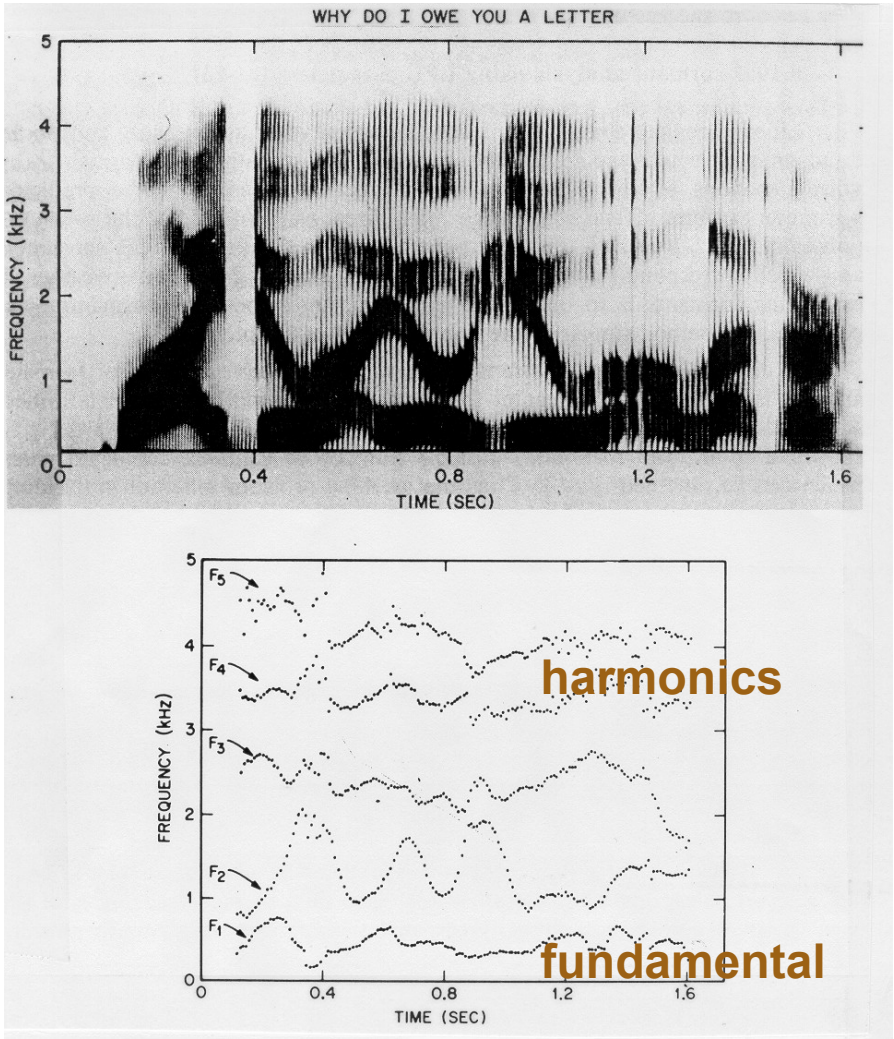
Voiced/unvoiced sounds



Frequency content of speech



Main energy in 100-800 Hz (speaker recognition)

800 Hz-4 kHz (intelligibility range)

Less than 1% above 4 kHz

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Demo:
Audio analyzer

Standard phone line

- 40 dB signal to noise ratio (SNR) desired
- 4 kHz bandwidth
- Uses uncompressed PCM, as opposed to cell phones where there is speech coding

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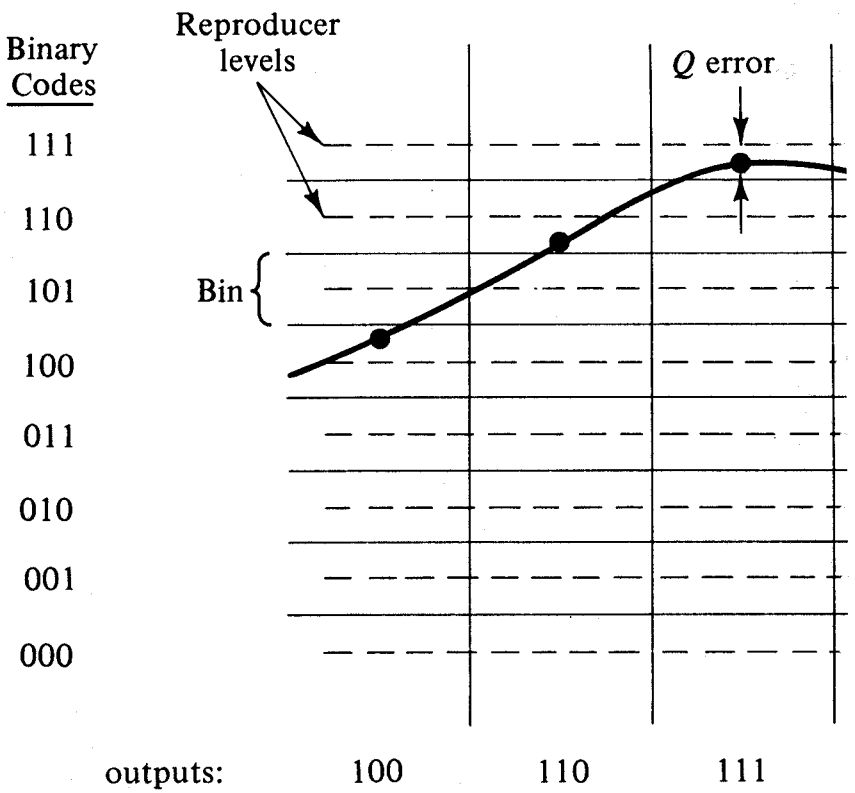
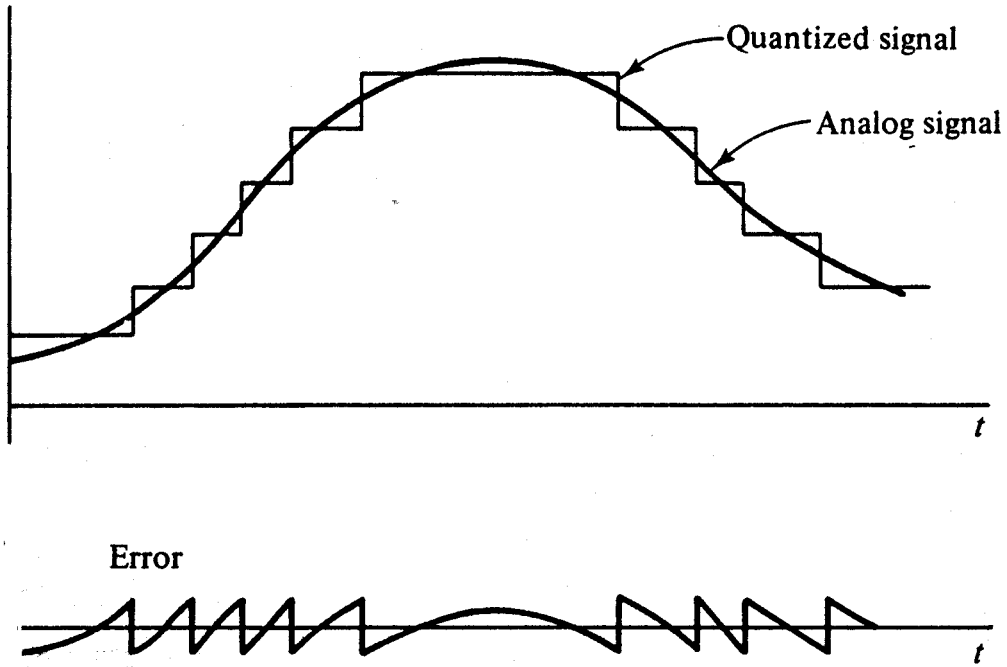
3 bit PCM



- 2^3 regions (bins)
- A deviation means an error – noise
- SNR= $6b$-C_0 dB
- If C_0 =7.3 ... how many bits do you need?

Reconstruction error



How often do you have to sample?

You need this simple version of the Sampling Theorem to solve Chapter 3 problems. We will go through it in more detail later.

A continuous-time signal $x(t)$ whose frequency components are all below some largest frequency f Hz is completely characterized by samples of the signal taken T_s seconds apart, $x(kT_s)$, as long as the sampling frequency $f_s = 1/T_s > 2f$.

In “plain” English: If you sample a signal at TWICE the largest frequency present in the signal, you can completely reconstruct the entire signal from those samples.

Example: A speech signal with frequency components up to f = 4 kHz needs to be sampled at f_s = 8 kHz, i.e. every T_s = 1/8000 second.

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Music

- Highly dynamic 30-50 dB power variations
- Funtamental tone+overtones, 20-20 000 Hz
  - Sensitive in the range 100-4000 Hz
  - No direction below 100 Hz

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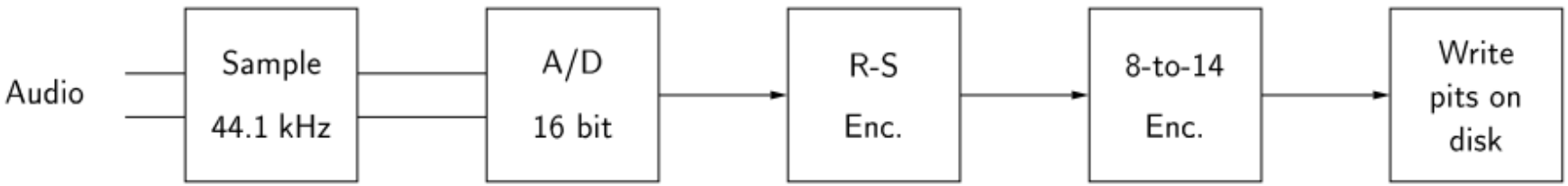
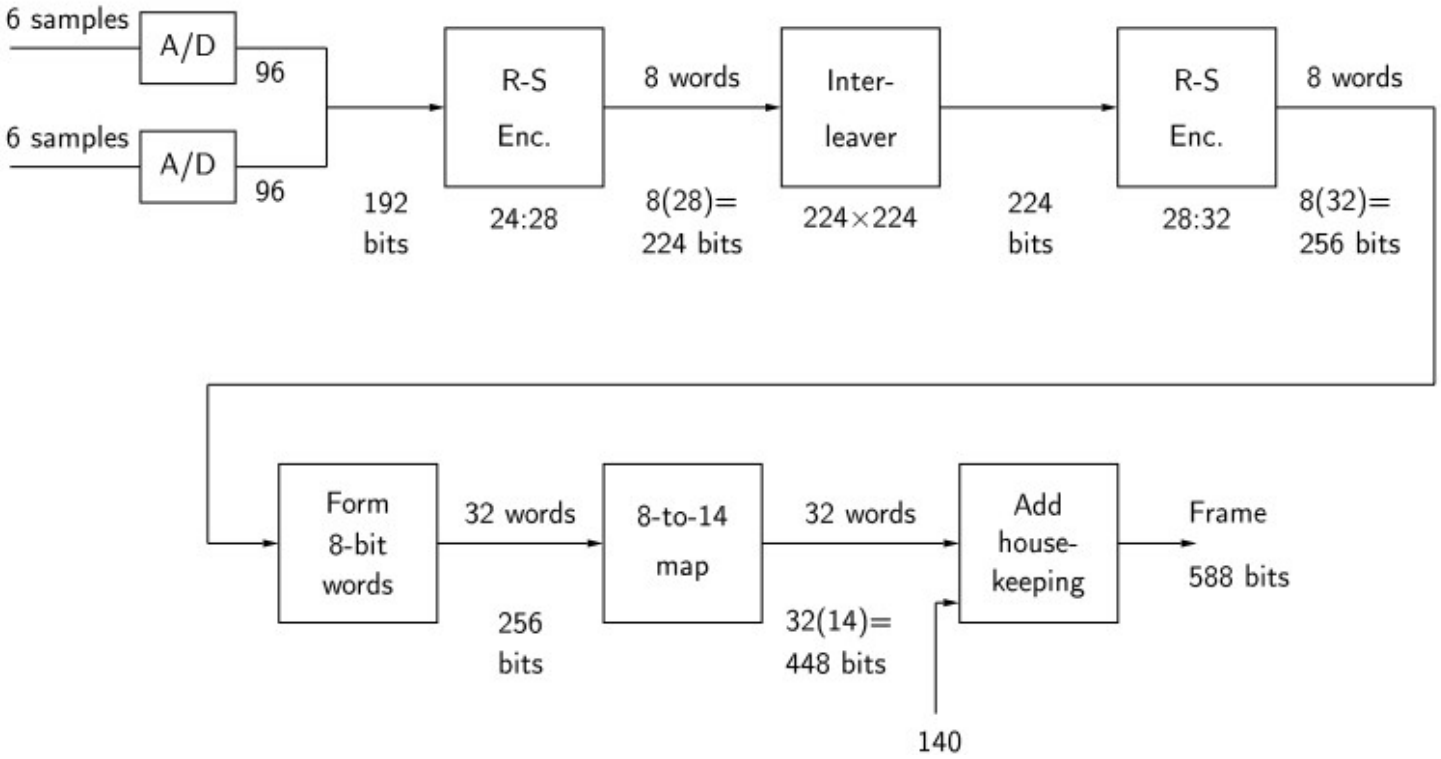
Music recording on a CD



2 channels*44.1 k samples/s*16 bits/sample result in a bit stream of 1.4 Mbit/s

How many bits are there?



SUMMARY

- Signal quality – dB measure
  - Power ratio in dB: $10\log_{10}(A/B)$ dB
  - Amplitude ratio in dB: $20\log_{10}(A/B)$ dB
- Text:
  - Sequence letters (symbols from an alphabet) forming words
  - Several coding standards, e.g. ASCII
- Sinusoidal signals
  - Have frequency (period time) and amplitude
  - Can be added to form signals of other shapes
  - Amount of each sinusoidal used (amplitude) called the spektrum
- Voice
  - Voice signals/speech created by vocal cords producing the tone
  - … and rest of the voice aparatus forming the spectrum
  - Voiced and univoiced sounds
  - Most information contained below 4 kHz
  - 40 dB SNR PCM coding: 8 kHz sampling x 8 bit/sample = 64 kbit/sek
- Music
  - Different instruments playing the same tone differ in their over-tones
  - Frequency span: from 20 Hz to 20 kHz
  - CD quality PCM (stereo): 44.1 kHz sampling x 2 channels x 16 bit/sample = 1.4 Mbit/sek
  - Error correcting codes used to protect against errors when reading from CD

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