Lecture 1

Exercise 2: What units would be used to specify error rate, delay, and delay variability? For each of the following data sources/sinks identify the relative data rate variability and the tolerance it is likely to have to errors, to the absolute delay and to the delay variability: a phone call between two people, downloading a computer program, streaming a video over a computer network. Try to estimate typical values.

Units.

bit error rate : $\frac{\text{number of bits in error}}{\text{number of bits transmitted}}$

also : BER, P_e

dimensionless : 1%, 0.01, 10^{-2}

delay : dimension : time

units : seconds, ms

delay variability : {1s, 2s, 1s, 0.5s}

dimension : time (s.d.) {1.1s, 1.0s, 0.9s, 1.0s.

time^2 (variance)

	tolerance to errors	tolerance to delay	tolerance to jitter
phone or video call	H	L (interactive)	L (< delay)
download of program	L	H	H
streaming video	L (if compressed) H (sampled data)	H	H

Byte
bit

not a standard

What is a kilobyte? 10^3 or 2^{10}?

$k = 1000$, $1024 = 2^{10}$

$M = \frac{10^6}{k}$, $\frac{2^{20}}{Ki}$

M | Mi

base 10 | base 2

Information

units: bits

information $= -\log_2 P(\text{message})$

e.g. 2 messages, equally likely:

- black $P(\text{black}) = \frac{1}{2}$
- white $P(\text{white}) = \frac{1}{2}$

$\log_2 P(\cdot) = -1 \Rightarrow I = 1$ bit per message

example 2 : red, green, blue

$P(\ ): \frac{1}{2}, \frac{1}{4}, \frac{1}{4}$

Information in each message:

$= -\log_2\left(\frac{1}{4}\right)$

$= -\log_2\left(2^{-2}\right)$

$= 2$

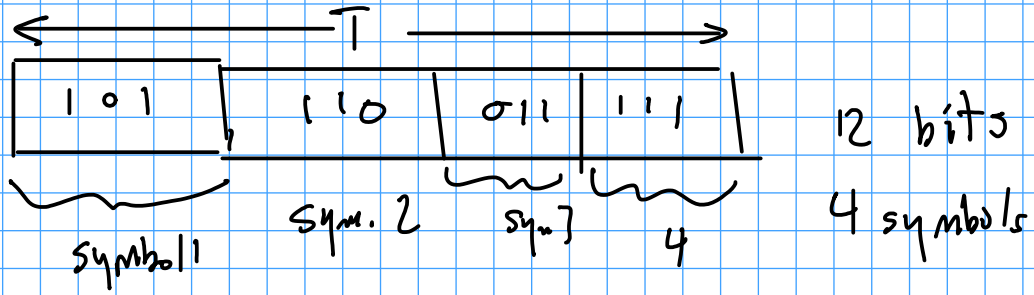
} for green, blue

sample encoding: 1 (Red), 00 (blue), 01 (green).

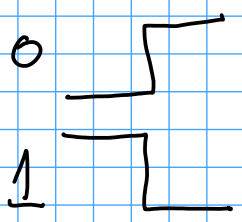
$$\frac{\text{bit rate}}{\text{bits/symbol}} = \text{symbol rate}$$

e.g. $\frac{8\ \text{kb/s}}{3\ \text{bits/symbol}} = 2\frac{2}{3}\ \text{ksymbols/second}$

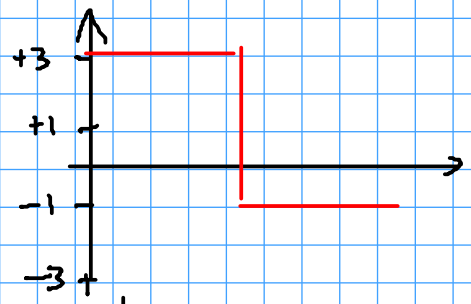
units: $\frac{b}{s} \cdot \frac{\text{symbols}}{b} = \frac{\text{symbols}}{s}$



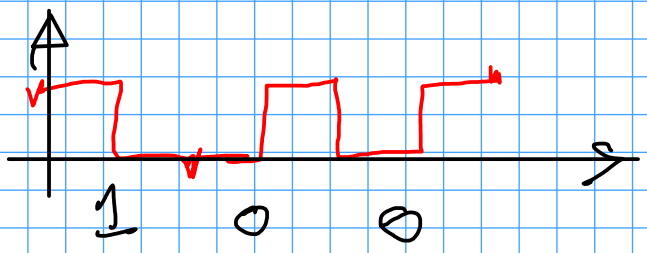
Examples of < 1 bits/baud & > 1 bits/baud



< 1 bits/band



> 1 bits/band



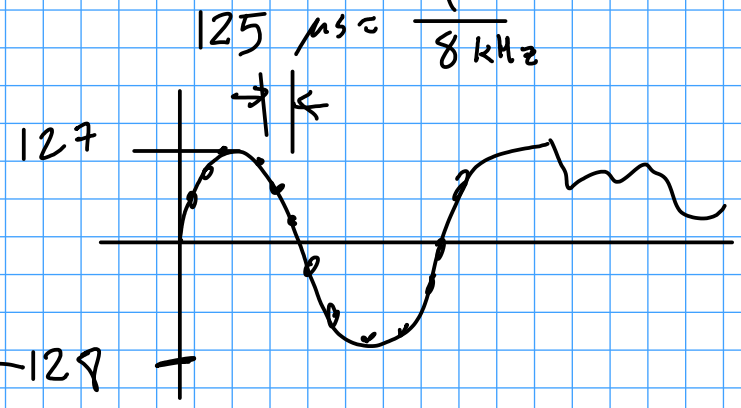
Lab 1

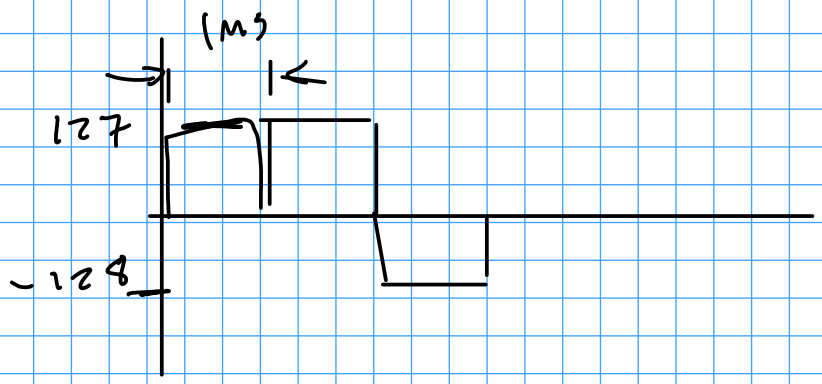
waveform samples values written to file as: $1\ byte = 8\ bits \Rightarrow 2^8$ values

interpreted as a number:

- if unsigned: 0 – 255
- if 2's complement: −128 … 127

1000 0000 (not 1111 1111) → 0000 0000 → 0111 1111



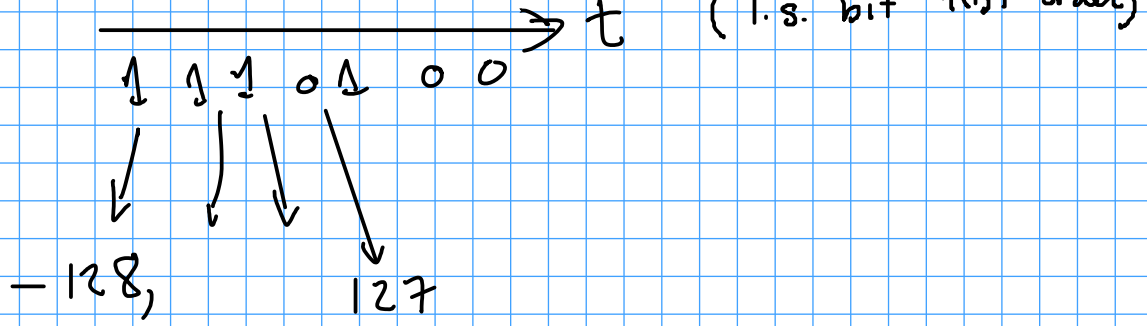


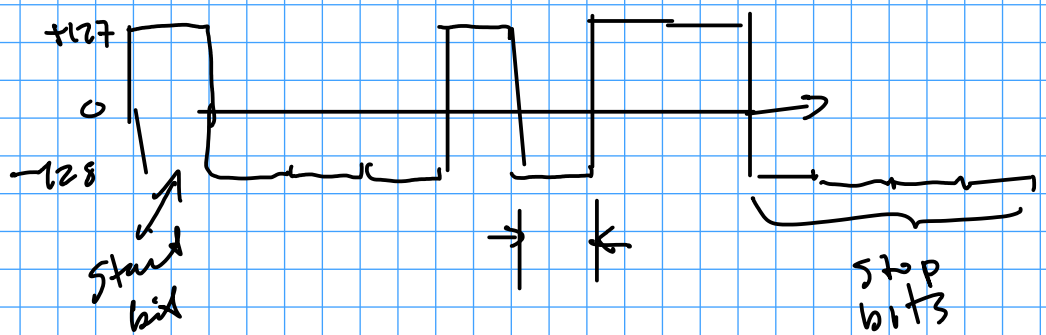
A 00 2 4 6 8 12 = 23

add up to

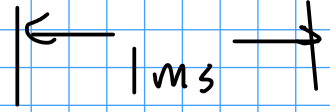
$23 = 16 + 4 + 2 + 1 = 0010\,111_2$

$= 2^4 + 2^2 + 2^1 + 2^0$





x x x x x x x y



$f_s = 8\,kHz$

$T_s = \frac{1}{8\,kHz} = 125\,\mu s$

Exercise 3: Convert the decimal number 3525 to a 16-bit (two-byte) binary number. Write the sequence of bits that would be transmitted if both the bytes and bits were transmitted in little-endian order. Write the sequence of bits that would be transmitted in "network order".

$2^0 = 1$

1 2 4 8 16 32 64 128 256 512 1024 2048

3525
2048 2^{11}
1477
1024 2^{10}
453
256 2^8
197
128 2^7
69
64 2^6
5
4 2^2
1 2^0

2^0

0000 1101 1000 1011 } binary in network order
0 D C 5 } hex

bytes in LSByte first order

1011 0000 → both bytes & bit in little-endian order
10100011
A 3
D 0

C5 0D

1100 0101 0000 1101

why bytes in little-endian order

Exercise 4: Write the 16-bit number above in hexadecimal notation.

Exercise 5: Find the ASCII codes for the characters '3525'. Write out the first 16 bits of the sequence that would be transmitted assuming each character is encoded using 8 bits per character and little-endian bit order. *Hint: the character code for a digit is 0x30 plus the value of the digit.*

'3525'

0x33, 0x35, 0x32, 0x35

0011 0011 0011 0101

1100 1100 1010 1100

code for a digit is 0x30 plus the value of the digit.

Exercise 6: Highlight or underline each term where it is defined in these lecture notes.

Component Manufacturers make components such as ICs, capacitors, cables, etc

Distributors buy components from manufacturers

Equipment Manufacturers buy components and build equipment

Retailers buy equipment and sell to customers

Service Providers buy equipment and provide services to customers

Standards Organizations write and publish standards so that equipment from different manufacturers will interoperate

Regulators publish and enforce regulations to ensure efficient use of public resources and protect the safety of the public

Exercise 7: Draw a diagram showing the flow of of goods and services between these various entities. Classify the following: Intel, Xilinx, Analog Devices, Belden, Avnet, DigiKey, Samsung, Apple, Cisco, Ericsson, Telus, Netflix, Walmart, Amazon, IEEE-SA, IETF, Industry Canada, CRTC, FCC. Look these up if you're not familiar with them.

The Electronics Ecosystem