Lec 17 – circuit switched – isochronous data
– packet " – bursty "

– HDLC frames start & end w/
HDLC flags: 0111 1110
bit stuffing: add a '0' after 5 '1''s

– OSI 7-layer model:

$$\left.\begin{array}{l}\text{LLC} \\ \text{MAC}\end{array}\right\} \text{DLL}$$

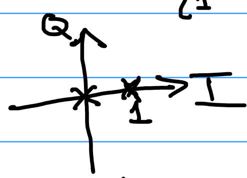
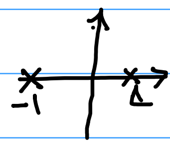
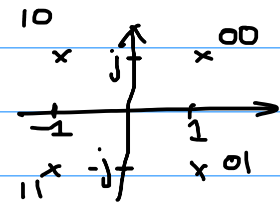
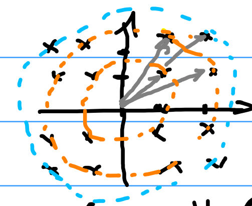
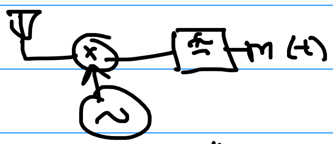
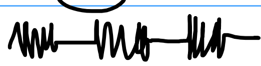
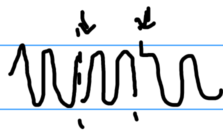
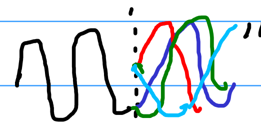
PHYsical

waveform	PHY
error detection & correction	LLC
media access control	MAC
addressing	LLC

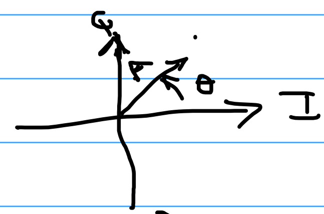
SDU – payload
PDU – frame w/ headers & trailers

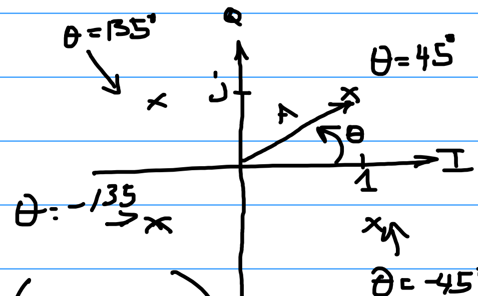
Lec. 9 FD – tx & rx at same time
HD – one direction at a time

TDD – $\boxed{Tx}\ \boxed{Rx}\ \boxed{Tx}\ \boxed{Rx}$
FDD – $f_1 \rightarrow$
$f_2 \leftarrow$

	ASK	BPSK	QPSK	M-QAM ($M=4,16,64,256...$)
bits/symbol	1	1	2	$\log_2 M = 2, 4, 6, 8$ bits/sym $=\log_2 M$
equation	$m(t)\cos(\omega_c t)$ $m(t)=\begin{cases}0\\1\end{cases}$	=		
constellation				 (e.g. 16-QAM)
mod	 $m(t)=\begin{cases}1\\0\end{cases}$	$m(t)=\begin{cases}+1\\-1\end{cases}$	$m(t)=\pm 1 \pm j$ $m(t)=\sqrt{2}e^{j\theta}$ $\theta=\pm 45^\circ, \pm 135^\circ$	$m(t)=\pm 1, \pm 3$ $\pm j, \pm 3j$
demod			$s(t)$ = see (3)	→
waveform			see next question 	→

$$Ae^{j\theta} = A(\cos\theta + j\sin\theta)$$





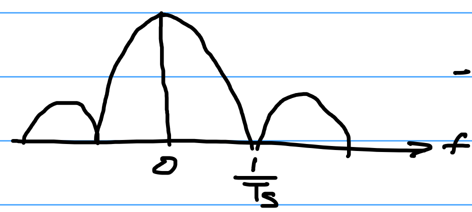
$$\frac{\pi}{4} + \left\{\frac{\pi}{2}, \frac{2\pi}{2}, \frac{3\pi}{2}, \frac{4\pi}{2}\right\} \qquad \sqrt{2}\left(e^{j(\quad)}\right)$$

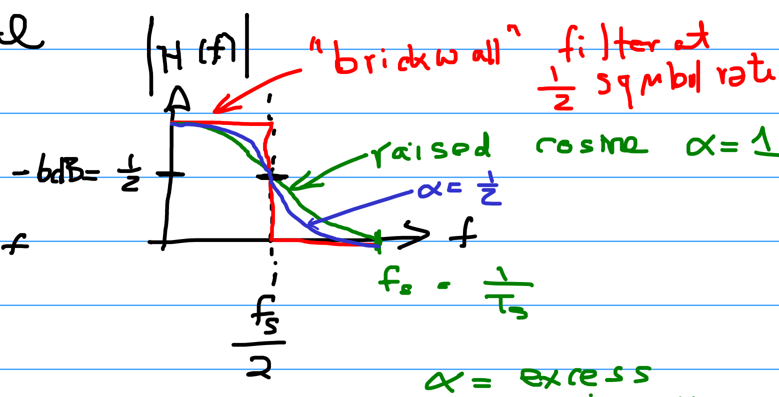
(3) $s(t)=\sqrt{2}\cos(\omega_c t+\theta)$ $\qquad \theta = \pm 45^\circ, \pm 135^\circ$

gray codes:

— 0 0
— 0 1
— ~~1 0~~ 1 1
— 1 0

bandwidth of QAM signal





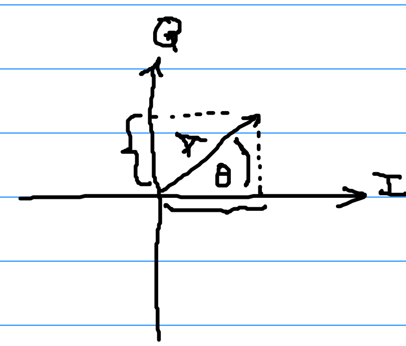
α = excess bandwidth.
= P.U. by which exceed minimum

1 Mb/s

$\frac{1}{2}$ voltage $\frac{1}{4}$ power
$= -6$ dB

$\frac{1}{\sqrt{2}}$ voltage $= \frac{1}{2}$ power
$= -3$ dB

for quadrature downconverter
if input is $A\cos(\omega_c t + \theta)$
$I = A\cos(\theta)$
$Q = (-)A\sin(\theta)$



	deviation/bitrate	filtering
GMSK	½	gaussian (t or f)
MSK	½	any
FSK	any	any

Lec. 11

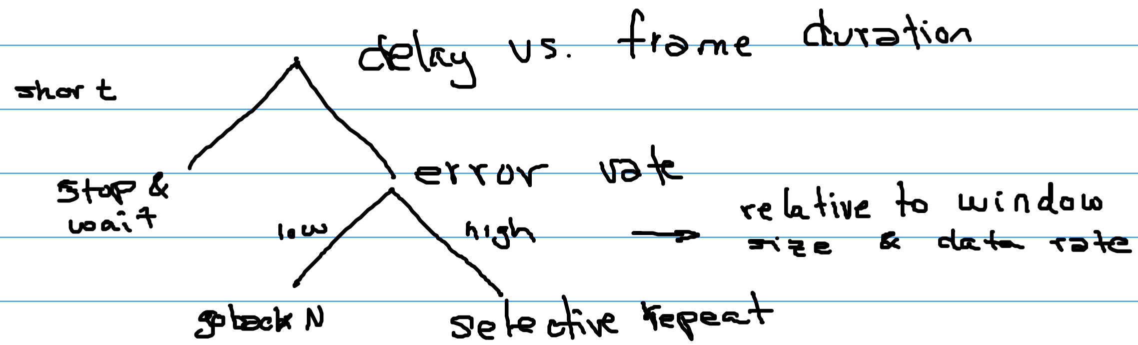
bandwith   SNR in linear units

$$C = B\log_2\left(1+\frac{S}{N}\right)$$ Shanon Capacity

if operating at $> C$ $\Rightarrow$ error rate cannot be reduced to a low value

$< C$ $\Rightarrow$ BER (if error rate) can be reduced to arbitralily low value

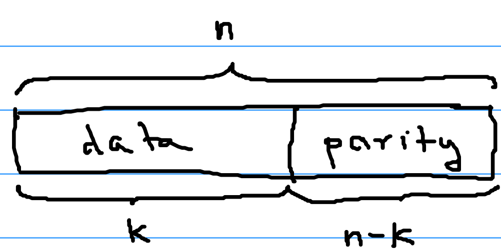
ARQ Selection



even parity: even number of 1's

0110 1011 $\Rightarrow$ 5 '1' bits (odd number)

for even parity, parity = 1
odd " , " = 0



(n,k) code

e.g. (7,4)

n = 7 total bits
k = 4 data bits

Hamming Distance = # of bits different between two codewords

e.g.

1011	1100
1101	1101
✓✓	✓

← 3 bits different

(3,1)

possible transmitted codewords	if 111 received Hamming dist.
010	2
101	1

$$\begin{array}{r} 111 \\ 010 \\ \hline ✓\ \ ✓ \end{array} \qquad \begin{array}{r} 111 \\ 101 \\ \hline ✓ \end{array}$$

$k = \log_2 (\#\text{ of codewords}) = \log_2 (2) = 1$

$n = \#$ of bits in codewords

Lec. 12

<u>in GF(2)</u> 0, 1

(+) add ≡ XOR

(×) multiply ≡ AND

$1 + 1 = 0$

$010 \Rightarrow 0x^2 + 1x^1 + 0x^0$

6 data bits = k
3 parity bits = n-k
9 total bits = n

$M(x) = 010101$

$G(x) = 1101$ $\quad 1x^3 + 1x^2 + 0x + 1$

$n-k = 3$

```
           0 1 1 0 1 1
      ___________________
1101 ) 0 1 0 1 0 1 0 0 0
       0 0 0 0
       -------
         1 0 1 0
         1 1 0 1
         -------
           1 1 1 1
           1 1 0 1
           -------
             0 1 0 0
             0 0 0 0
             -------
               1 0 0 0
               1 1 0 1
               -------
                 1 0 1 0
                 1 1 0 1
                 -------
                   1 1 1
```

transmit: 010101111

```
           0 1 1 0 1 1
      ___________________
1101 ) 0 1 0 1 0 1 1 1 1
       0 0 0 0
       -------
         1 0 1 0
         1 1 0 1
         -------
           1 1 1 1
           1 1 0 1
           -------
             0 1 0 1
             0 0 0 0
             -------
               1 0 1 1
               1 1 0 1
               -------
                 1 1 0 1
                 1 1 0 1
                 -------
                   0 0 0.
```

probability of undetected error: (CRC fails to detect an error)

for completely random bits : $\dfrac{1}{2^{n-k}}$

$n-k$ = # bits in CRC (16 or more commonly, 32)

e.g for 32-bit CRC $= \dfrac{1}{2^{32}} \approx 3 \times 10^{-10}$

for 1 burst error of length $< n-k$
prob. of undetected error = 0.

Lec. 13

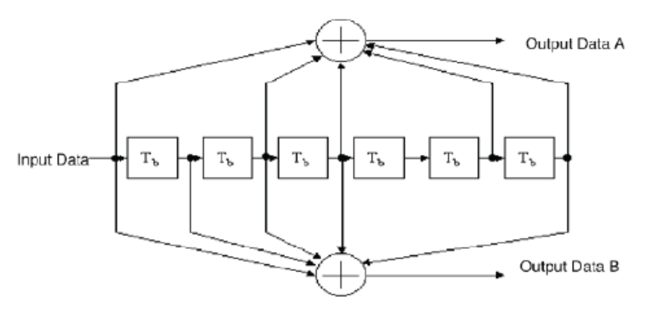
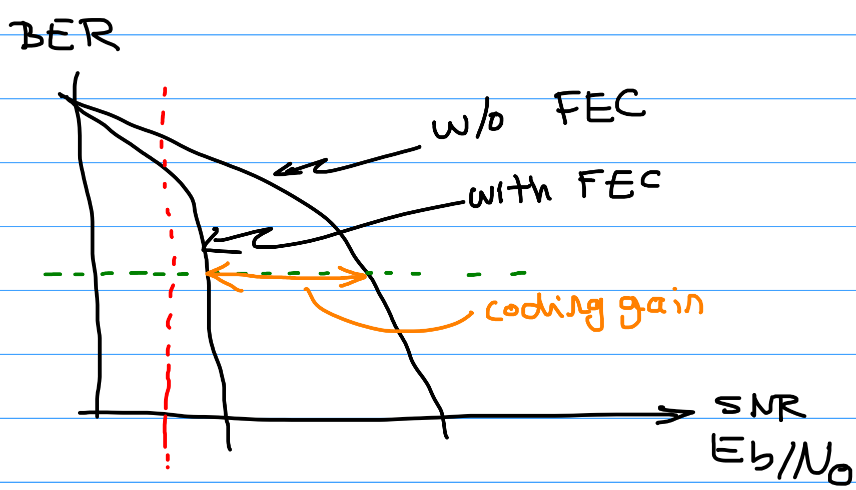


Figure 18-8—Convolutional encoder (k = 7)

K = # bits in SR + 1 (input)
$= 6 + 1 = 7$

$R = \text{rate} = \dfrac{\#\text{ input bits}}{\#\text{ output bits}} = \dfrac{1}{2}$ $\begin{pmatrix} k = 1 \\ n = 2 \end{pmatrix}$



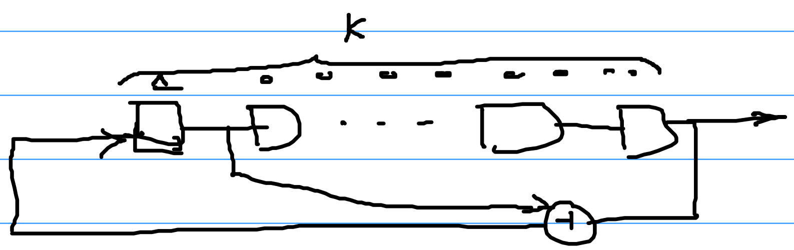
Turbo, LDPC } FEC Codes ⇒ allow systems to almost reach Shanon capacity

RS (Reed Solomon) ⇒ corrects words instead of bits
∴ good for bursty errors

Lec. 14

signal	voltage or current varies w/ time	
noise	random "	
pseudo-random	predictable w/ known statistic	
PN	noise-like "	
PRBS	2-valued "	
ML PRBS	period 2^k-1 "	(k is bits of state in generator)

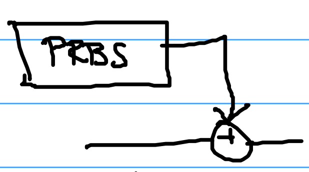
101 101 101 101 $k=2$



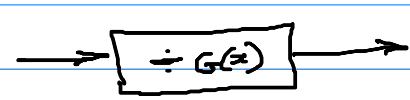
period $= (2^k-1)T_b$

maximum length of a run of 0s is $k-1$

scrambler.



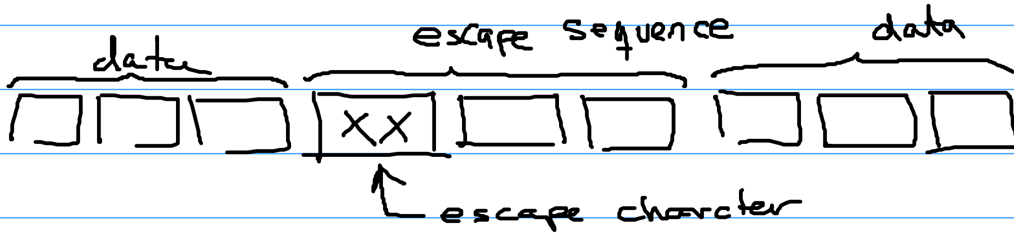
additive
for frame-based systems

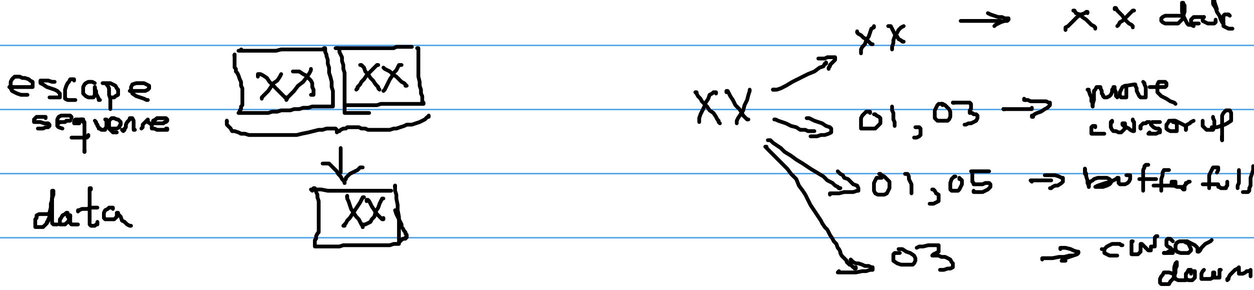


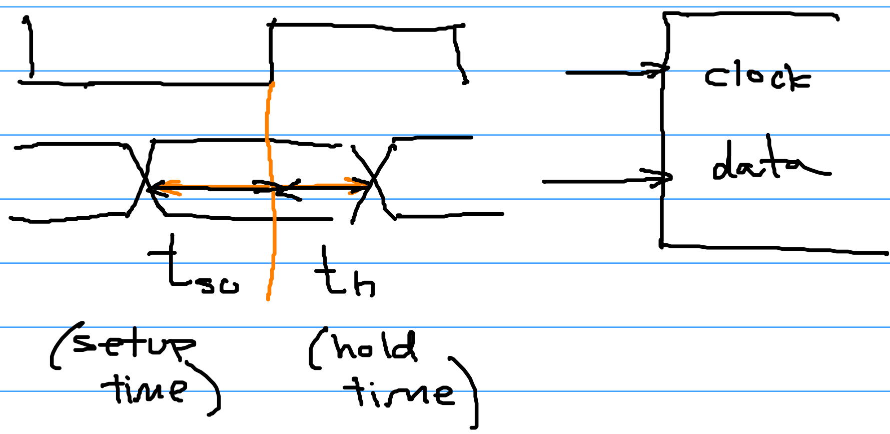
multiplicative
(self-synchronizing)
for undelimited bit streams

Lec. 15

escape sequences



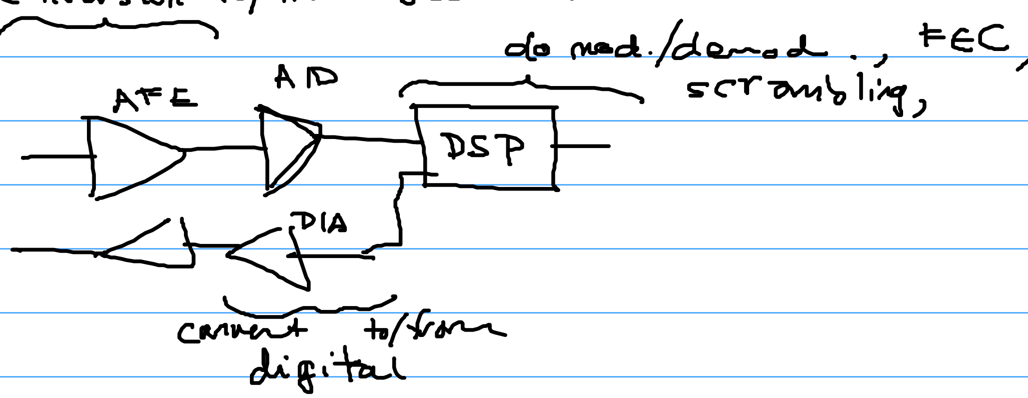




Lec. 17

- reason for integration : cost
- " " digital : cost (Moore's Law)

filtering
gain
conversion to/from baseband



	hardware	software
sampling rate	high	low
algorithmic complexity (how complicated are the algorithms) (lines of code)	low	high
computational complexity # instructions / sample	high	low

full-custom ICs
semi-custom " (gate arrays)
FPGA (CPLD's)
discrete logic ICs

volume
very high (millions)
⇕ in between
small (1 → thousands)
very simple

Lec. 18

- self configuring
- supplies power
- faster
- hot plug
- standard drivers (device classes)