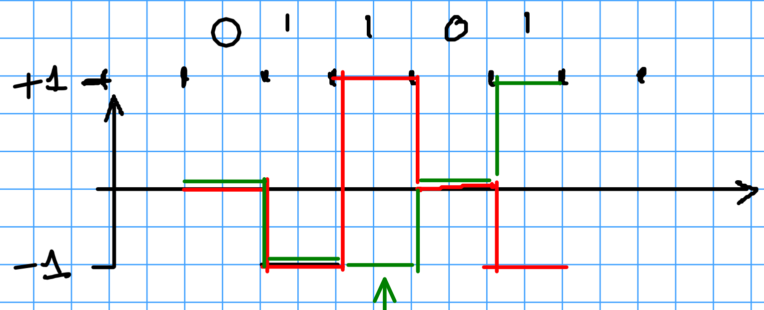
Exercise 1: Draw the waveform for an AMI-NRZ encoded sequence of bits '01101' assuming the previous mark was transmitted as a high. Draw the waveform assuming the second '1'



indicates start/end of a frame

Exercise 2: What is the average DC value for the two cases in the previous exercise?

$$\text{average} = \frac{\text{sum}}{\#\text{values}} = \frac{-1}{5} = -0.2$$

without violation: -0.2

with violations of line coding rules: average $= -0.2$

Exercise 3: What might be some advantages of using a preamble? What might be some disadvantages?

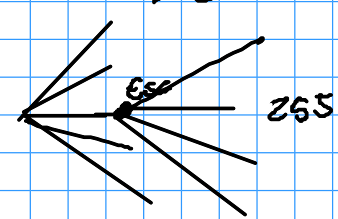
ADVANTAGES: – ALLOWS NEW PROTOCOLS (backwards compatibility)

DISADVANTAGES – ADDITIONAL COMPLEXITY

– OVERHEAD (REDUCES THROUGHPUT)

Exercise 4: By how much does the use of escape sequences slow down a link if random 8-bit characters are being transmitted? What is the overhead if a continuous stream of escape characters need to be sent over the link?

escape sequences



$\frac{1}{256}$ $\boxed{ESC}\boxed{ESC}$

255

$\frac{255}{256}$ $\boxed{'c'}$

0 ... 255 →

except 0x1B

0x1B → 2 characters

for $\frac{255}{256}$ characters there is no overhead

$\frac{1}{256}$ (character is ESC, then transmit 2 characters for each ESC i.e. ESC-ESC) total characters sent

$$= \Big(\underbrace{N \cdot \frac{255}{256}}_{\text{number of non-escape characters in } N \text{ bytes}} \times \underline{\underline{1}} \Big) + \Big(\underbrace{N \cdot \frac{1}{256}}_{\text{number of ESC characters in the data}} \times \underline{\underline{2}} \Big)$$

throughput = bit rate at sink =

$$\frac{\frac{\cancel{N}\,255}{256} + \frac{2 \cdot \cancel{N}}{256}}{\cancel{N}} = \frac{255 + 2}{256}$$

bytes sent on channel

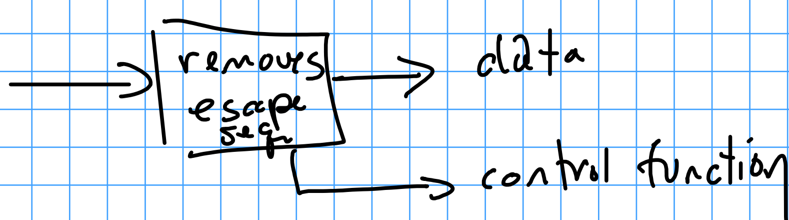
bytes received

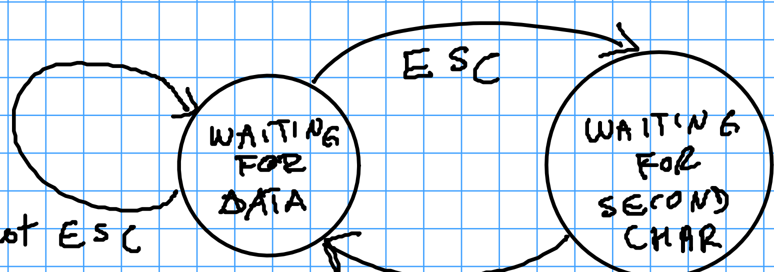
$$\text{relative throughput} = \frac{256}{257}$$

ESC, ESC, ESC

ESC-ESC ESC-ES ESC-ESC

$$\text{throughput} = \frac{\#\ \text{characters to sink}}{\text{total characters on channel}} = \frac{1}{2}$$





Exercise 5: Write out the complete sequence of 1's and 0's required to transmit the 12 bits 0110 1111 1100. Include the start and end flag sequences and any necessary bit stuffing.

count of 1's

0 1 2 0 1 2 3 4 5 1 0 0

$\underbrace{01111110}_{\text{start flag}}$ 0 1 1 0 1 1 1 1 1 0 1 0 0 $\underbrace{01111110}_{\text{end flag}}$

"stuffed" bit

Exercise 6: An HDLC receiver sees the sequence 1000 0111 1110 1111 1001 0111 1110 0110. What data bits were contained within the frame?

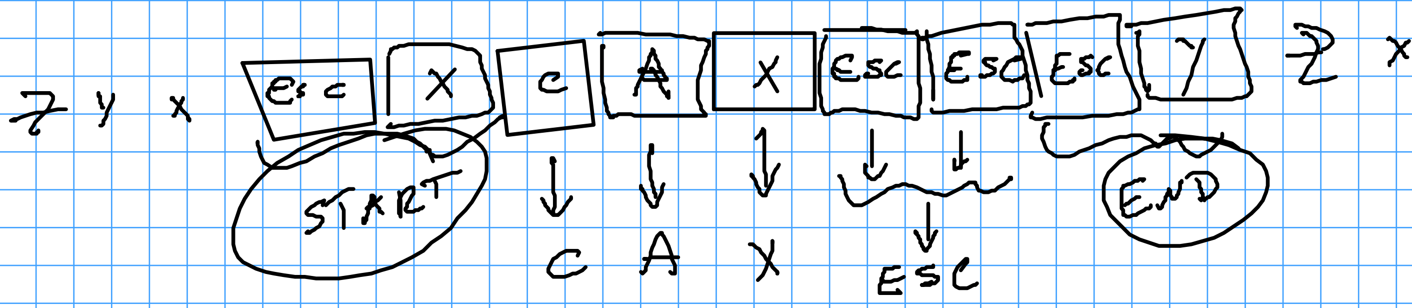
1 2 3 4 5 0 1 0 1 2 3 4 5 6

$\underbrace{1\,1\,1\,1\,1\,\cancel{0}\,0\,1}_{\text{data in the frame}}$ $\underbrace{0\,1\,1\,1\,1\,1\,1\,0}_{\text{end of frame flag}}$ 0 1 1 0

1 1 1 1 1 0 1

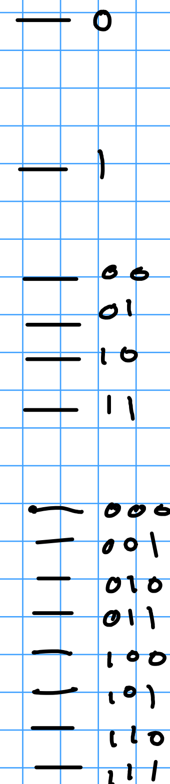
'c', 'a', 'x', Esc

Esc-X   Esc-Y



$$\text{throughput} = \frac{4}{9}$$

Exercise 7: A physical layer transmits 3-bits per symbol. A frame of 128 bytes is being transmitted. How many padding bits will have to be added to the frame?



$$128 \times 8 = 2^7 \times 2^3 = 2^{10} = 1024$$

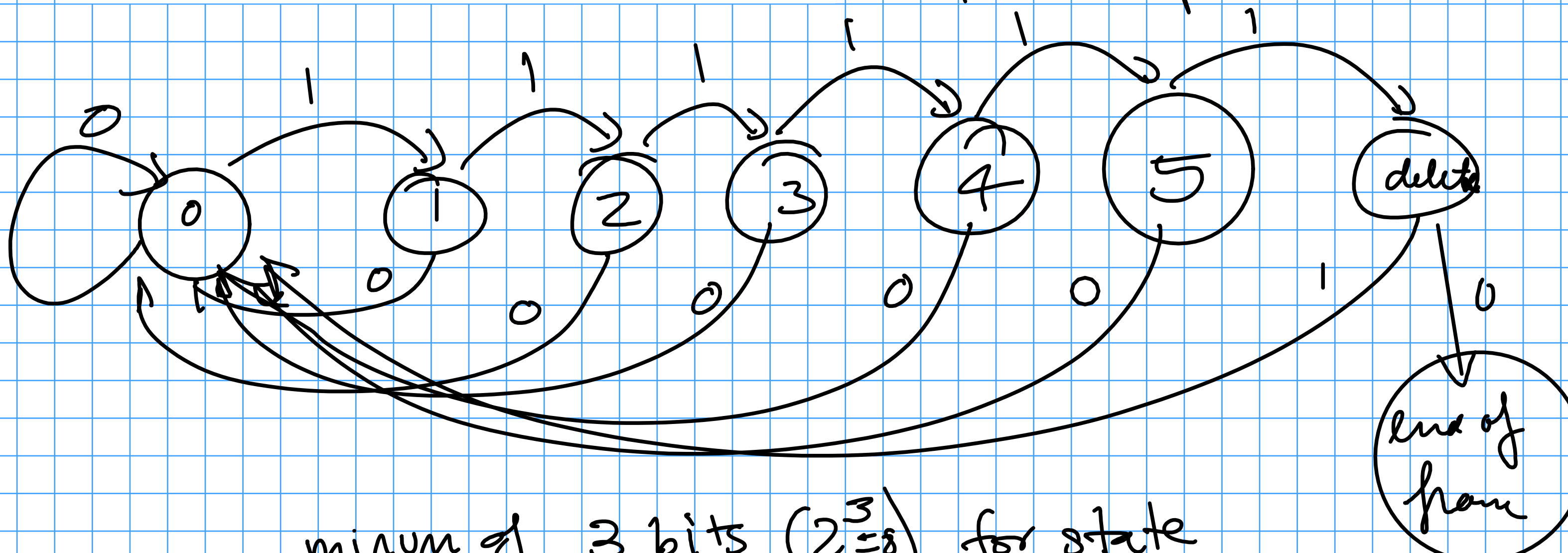
$$\left\lceil \frac{1024}{3} \right\rceil = \left\lceil 341\tfrac{1}{3} \right\rceil = 342$$

$$\mathrm{ceil}\left(\frac{1024}{3}\right)$$

$$\begin{array}{rl} 342 \times 3 = 1026 & \text{bits transmitted} \\ -1024 & \text{data bits} \\ \hline 2 & \text{padding bits} \end{array}$$

Exercise 8: How many states are required to implement a circuit that detects stuffed bits in an HDLC frame? How many bits of state are required?

state labels represent number of '1''s seen in the input.



minum of 3 bits ($2^3 = 8$) for state memory

could be more.