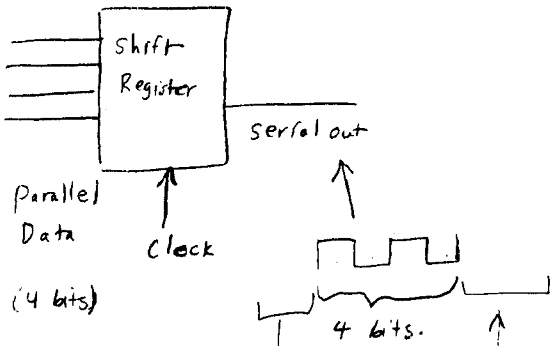
Sending PCM

Data bits are set in serial.

Parity bits might be added

Sync bits must be added



Add a "sync" bit ("Framing" bit in text)

This is something easily recognizable —
Always 1 ?

For better reliability — use a known sequence not just a single bit.

Add a "stop bit" — really just what happens when data runs out — but you need to account for it.

Needs to be easily recognizable — always 0?

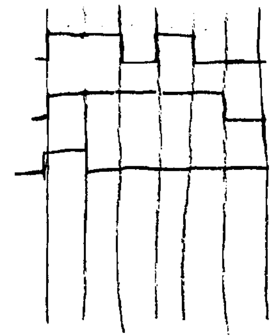
Hw: 6.2 – 1, 2, 3, 4, 6, 7

So --- to send / waveform is:

1010

1111

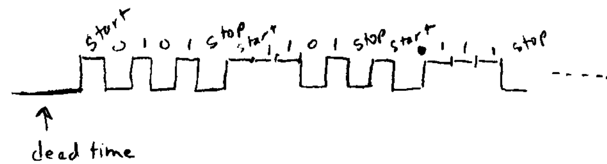
0000



This system has 2 bits overhead for every sample — "binary code word"

So .. to send : 5, 13, 7, 4, 0 :

0101, 1101, 0111, 0100, 0000

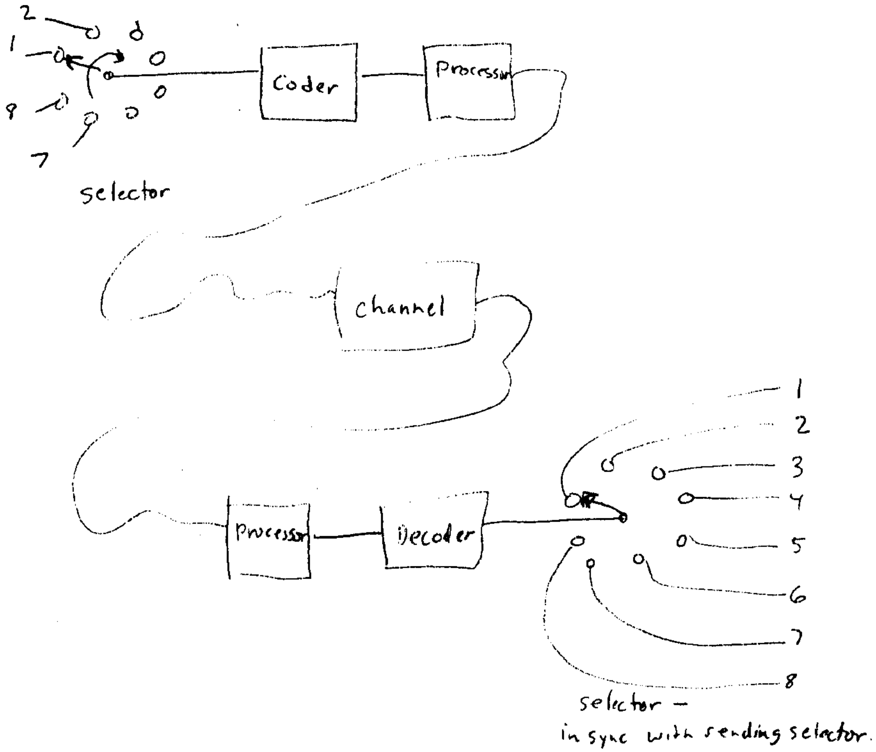


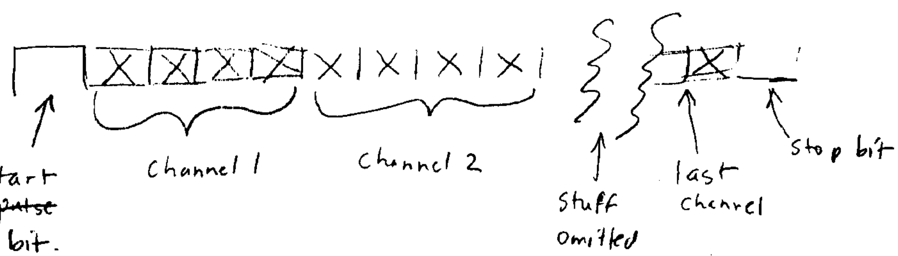
For efficiency — use long word lengths so start & stop take less time, by percentage.

or --- send multiple code-words with single sync.

Time division multiplexing –

intermix the codes of multiple signals.





This is one "Frame"

Bandwidth ...

if our channel has bandwidth B – A cycle can transmit 2 bits

so. can transmit $2B$ samples per second.

To send a signal with $\underline{n}$ bits of bandwidth B –

need $\underline{nB}$ bits per second.

This "n bits" includes framing bits.

Example: – We want to send $\underline{16}$ 3.5 kHz voice channels (telephone quality) with 30 dB S/N ratio, using PCM, TDM.

assuming square wave modulation, sample 20% above Nyquist rate.

Find # of samples, bandwidth, etc.

For 30 dB S/N --

$$\frac{S}{N} = 3L^2 \frac{\widetilde{m^2(t)}}{m_p^2}$$

For square wave --

$$\frac{\widetilde{m^2(t)}}{m_p^2} = 1$$

$$\frac{S}{N}_{DB} = 30\text{ dB} \Rightarrow \frac{S}{N}_{Power} = 1000$$

$$1000 = 3L^2$$

$$L^2 = \frac{1000}{3}$$

$$L = 18.2574$$

Need 19 levels.

For power of 2, use 32 levels, 5 bits will result in $\frac{S}{N} = 3072$ or 34.87 dB

Check: $10 \log_{10}(3) + 6n = 34.97$ dB.
Could have solved this way.

For $B_{baseband} = 3.5$ KHz

Nyquist rate is 7 KHz.

20% above is: 8.4 KHz.

For 16 channels, 5 bits each –

need $16 \times 5 = 80$ bits.

+ 2 bits for framing

= 82 bits per frame.

8.4 KHz sample rate $\Rightarrow$ 1.19×10^{-4} $\frac{\text{sec}}{\text{sample}}$

We need to send 82 bits in 1.19×10^{-4} sec.

1.452×10^{-6} sec/bit

Data clock = 688.8 KHz.

We can send 2 bits per cycle –

so Channel bandwidth = 344.4 KHz.

One channel would be ...

Need 7 bits in 1.19×10^{-4} sec

$= 1.7 \times 10^{-5}$ sec/bit

Data clock – 5.882×10^{4} = 58.8 KHz

channel BW = 29.41 KHz

Text: sec. 6.2.4 describes a T1 (telephone) system.

$\frac{S}{N}$ ratio with nonuniform quantization

Without deriving ...

$$\frac{S_o}{N_o} = C\,2^{2n} = C L^2$$

n = # of bits

$2^n = L$ = # of levels

$2^{2n} = L^2$

$$C = \frac{3}{[\ln(1+\mu)]^2}$$

← μ law encoding when $\frac{m_p^2}{\overline{m^2(t)}} \ll \mu^2$

---

5 bits, $\mu = 10$ would give us:

$$\frac{3}{[\ln(11)]^2} = .52$$

$\frac{S}{N} = .52(32)^2$

$= 532.4$

27.26 dB