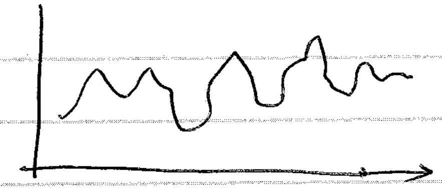
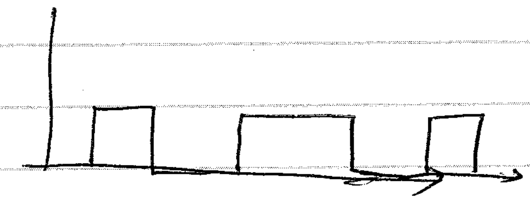
What is an analog signal
digital signal



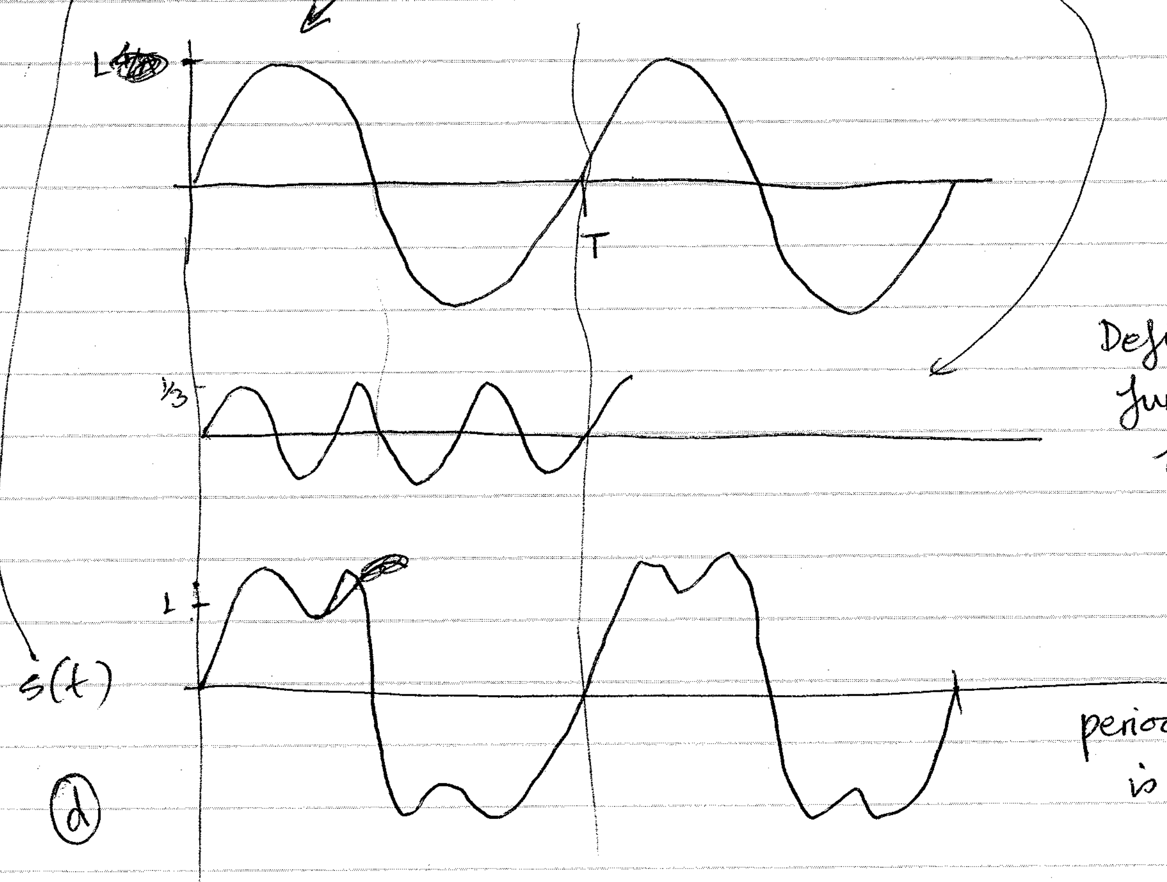


Periodic signal → repeats over time

$$s(t+T) = s(t) \quad -\infty < t < \infty$$

peak Amplitude, frequency, phase

$$s(t) = \left(\frac{4}{\pi}\right)\left[\sin 2\pi f t + \left(\frac{1}{3}\right)\sin\left(2\pi(3f)t\right)\right]$$



Define fundamental frequency

period of $s(t)$ is $\frac{1}{f}$ ← fundamental frequency

Spectrum of a signal → Range of frequencies contained.
i.e. in previous example f to $3f$

Absolute bandwidth $= 3f - f = 2f$.

Signals have most of their energy in a relatively narrow band.

Bandwidth vs Throughput ? or Data rate

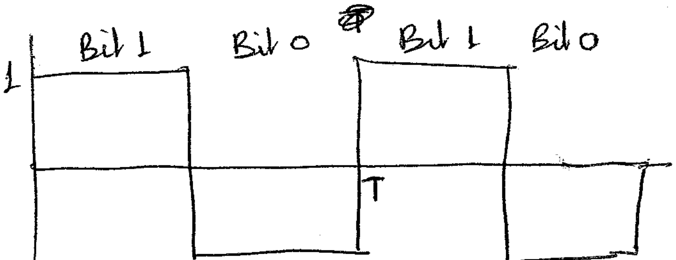
Square wave :

Data rate : 2 bits / T $\left(f = \frac{1}{T}\right)$

$= 2f$ bps.

Bandwidth = ?

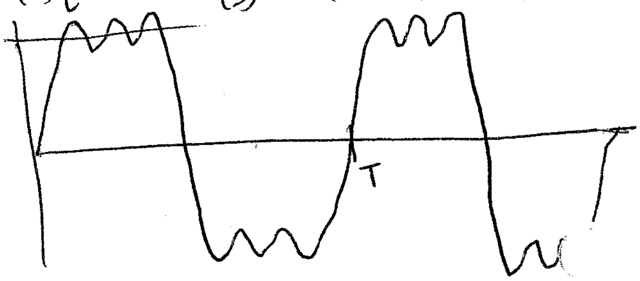
(a)



$\left(\frac{4}{\pi}\right)\left[\sin 2\pi f t + \left(\frac{1}{3}\right)\sin(2\pi(3f)t) + \frac{1}{5}\sin(2\pi(5f)t)\right]$

$$s(t) = A \times \frac{4}{\pi} \sum_{\substack{k\ odd \\ k=1}}^{\infty} \frac{\sin(2\pi k f t)}{k}$$

(b)



Infinite bandwidth

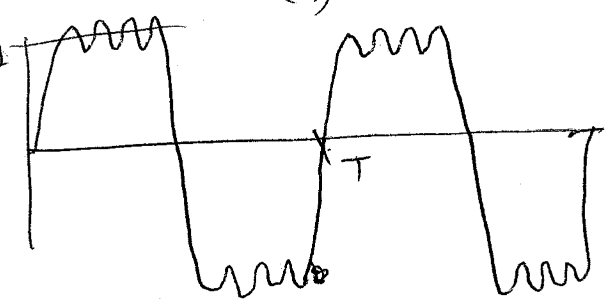
Peak amplitude of k^n freq. component kf is $\frac{1}{k}$

So most energy is in first few components

$\left(\frac{4}{\pi}\right)\left[\sin(2\pi f t) + \left(\frac{1}{3}\right)\sin 2\pi(3f)t) + \left(\frac{1}{5}\right)\sin(2\pi(5f)t) + \left(\frac{1}{7}\right)\sin(2\pi(7f)t)\right]$

Improved match to square wave

(c)



Case I $f = 1$ MHz
bw (b) = 4 MHz
$T = \frac{1}{f} = 10^{-6}$ s = 1 μs
For bit-string of 101010... = Data rate = 2 bits / μs = 2 Mbps

Case II $f = 2$ MHz
bw (b) = 8 MHz
Data rate = 2 bits / 0.5 μs = 4 Mbps

Case III $f = 2$ MHz
bw (a) = 4 MHz, Data rate = 4 Mbps

What is the difference? error probability

Nyquist bandwidth

- If rate of signal transmissions is 2B, then a signal which bandwidth $\leq B$ is sufficient
- Converse is also true.

Signal rate: If binary $C^{max} = 2B$

If M-ary $C^{max} = 2B \log_2 M$

Why not use $M = \infty$? Noise and error

$SNR_{dB} = 10 \log_{10} \frac{\text{signal power}}{\text{noise power}}$ high SNR ⇒ high quality

$C = B \log_2 (1 + SNR)$ ✓

→ just the ratio not the dB form

$dBW = 10 \log \frac{\text{Power(W)}}{1\,W}$ What is 0 dBW? 1 W

$dBm = 10 \log \frac{\text{Power (mW)}}{1\,mW}$ What is 0 dBm? 1 mW

30 dBm = 0 dBW

−30 dBW = 0 dBm

3 dB corresponds to a factor of 2 gain/loss in power.