CM 29

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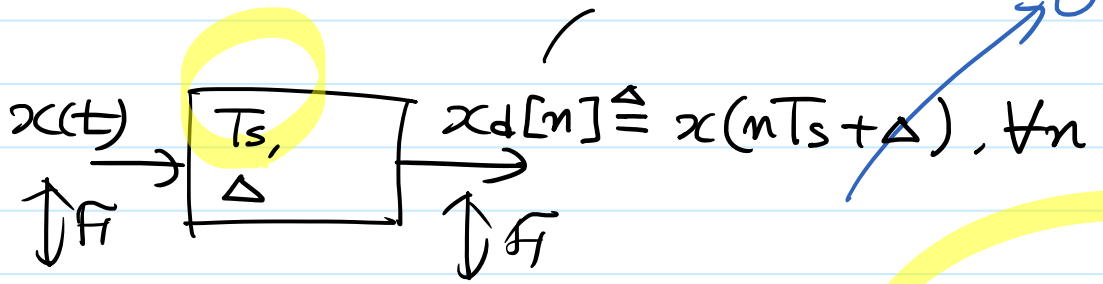
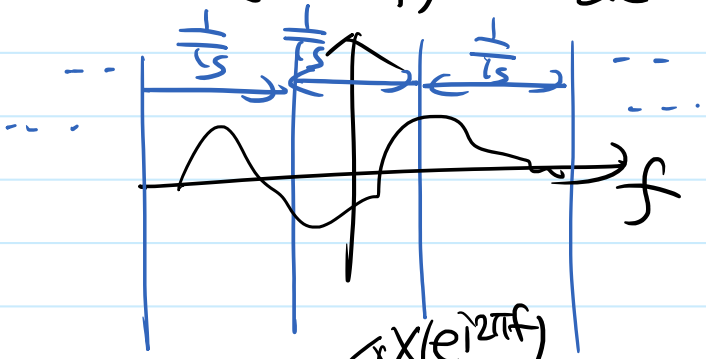
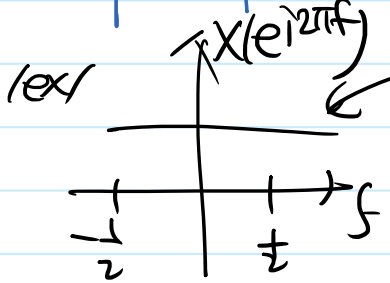
- Ann.
- Review
  - Sampling (uniform)

ADC



Q $X(f)$ & $X_d(e^{j2\pi f})$?





$$X_d(e^{j2\pi f}) = \frac{1}{T_s}\sum_{\ell=-\infty}^{\infty} X\left(\frac{f-\ell}{T_s}\right)$$

$$X_d(e^{j2\pi f T_s})$$

Spectral folding $= \frac{1}{T_s}\sum_{\ell=-\infty}^{\infty} X\left(f-\frac{\ell}{T_s}\right)$

⇕

"folded Spectrum"

"aliasing"

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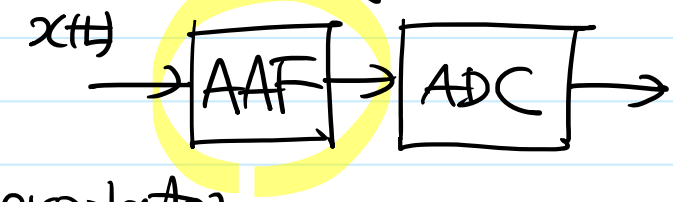
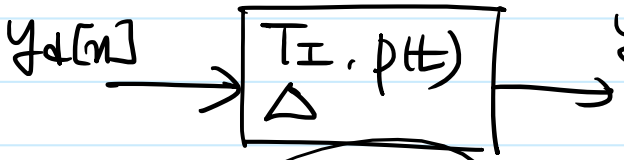
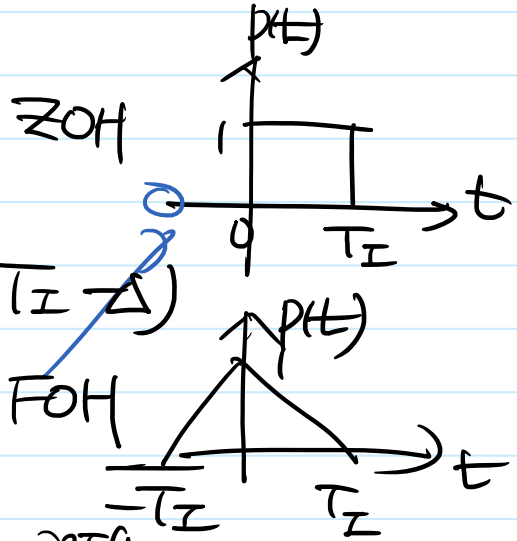
- AAF (Anti-Aliasing Filter)



□ DAC. Interpolator



$$y(t) \triangleq \sum_{n=-\infty}^{\infty} y_d[n]\, p(t - nT_I - \Delta)$$



$$Y(f) = Y_d(e^{j2\pi fT_I})P(f)$$

$$= \int_{-\infty}^{\infty} y(t) e^{-j2\pi ft} dt = \int_{-\infty}^{\infty} \sum_n y_d[n]\, p(t - nT_I)\, e^{-j2\pi ft} dt$$

$$= \sum_n y_d[n]\, P(f)\, e^{-j2\pi fnT_I}$$

$$= Y_d(e^{j2\pi fT_I})\, P(f)$$

$$\sum y_d[n]\, e^{-j2\pi fn} = Y_d(e^{j2\pi f})$$

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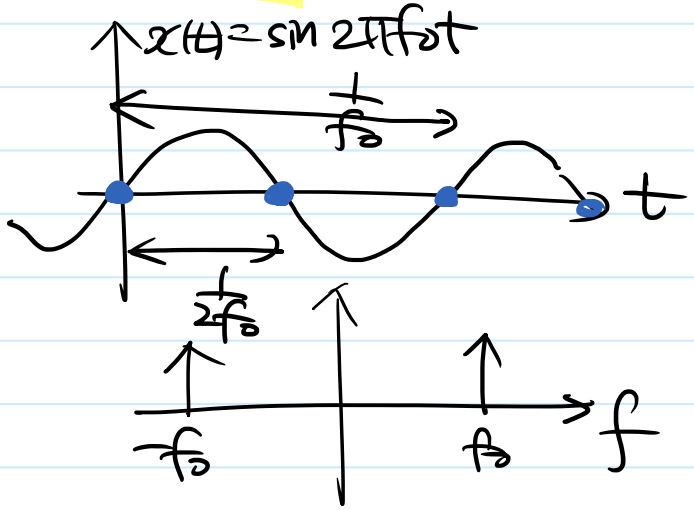
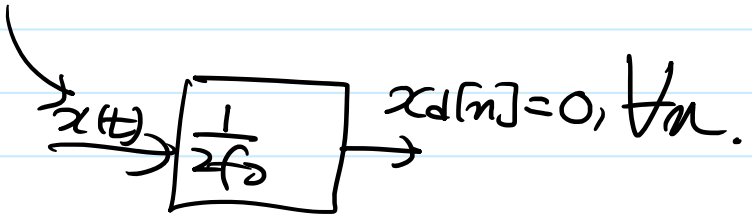
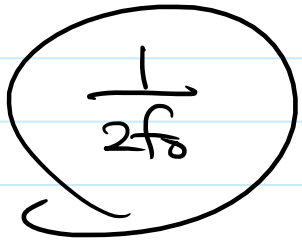
Nyquist Sampling Theorem.

① finite-energy signal $x(t)$, i.e., $\int_{-\infty}^{\infty} |x(t)|^2 dt < \infty$.



cf) $x(t) = \cancel{\cos} \sin 2\pi f_0 t$





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(ii) band-limited signal.

band-limited to $f \in [-B, B]$.

$$E_{xx} \triangleq \int_{-\infty}^{\infty} |x(t)|^2 dt = \int_{-\infty}^{\infty} |X(f)|^2 df = \int_{-B}^{B} |X(f)|^2 df$$

instantaneous power

energy spectrum

(a) $\frac{1}{T_s} \geq 2B$ ($\Leftrightarrow$ folded spectrum 겹치지 않음 No aliasing)

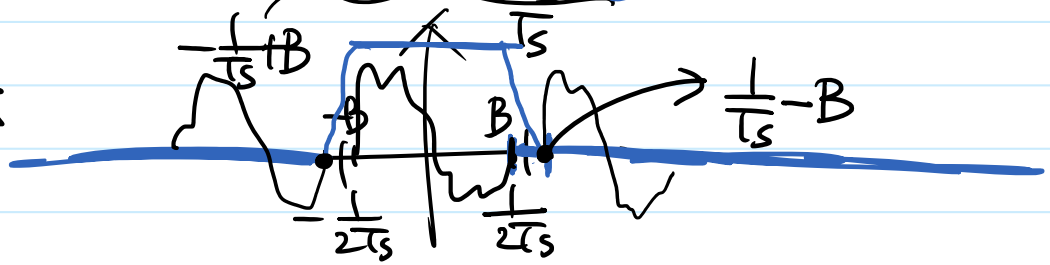
(b) $x(t)$ → Uniform sampler (T_s) → $x_d[n]$ → Interpolator $T_I = T_s$, $P(f)$ → $y(t)$

$$\frac{1}{T_s} \sum_{l} X\left(\frac{f-l}{T_s}\right)$$

$$= \frac{1}{T_s} X\left(\frac{f}{T_s}\right), \quad |f| \leq \frac{1}{2}$$

....

$$Y(f) = \left(\frac{1}{T_s} \sum_{l} X\left(f - \frac{l}{T_s}\right)\right) P(f)$$



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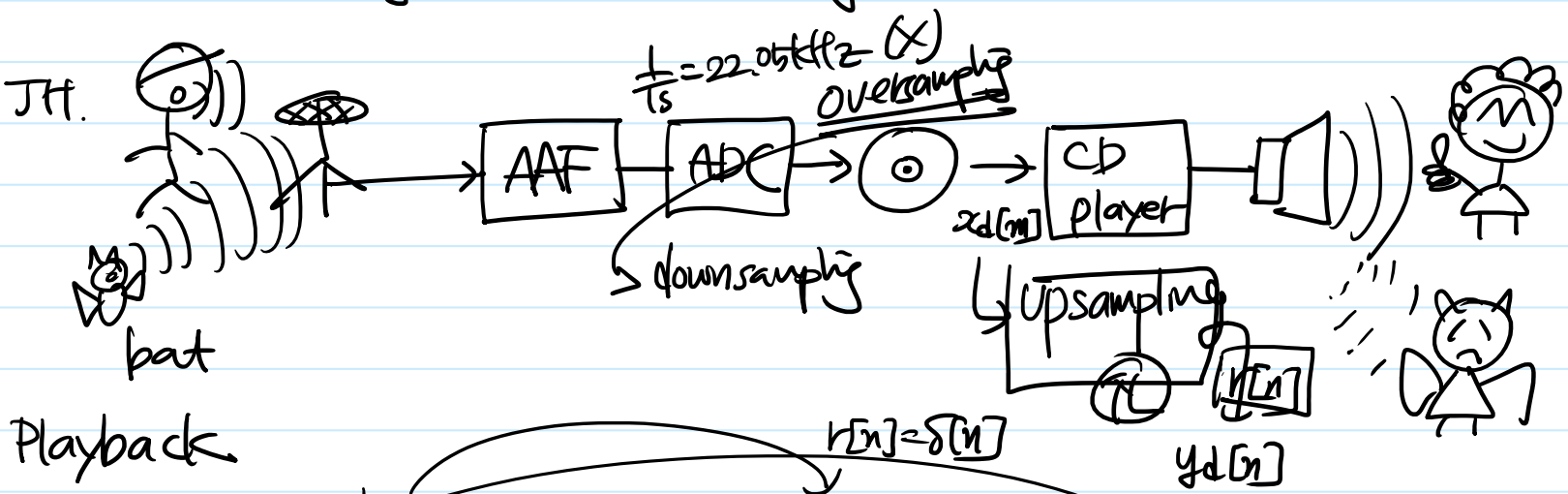
☐ Audio Recording @ CD Quality



☐ Playback

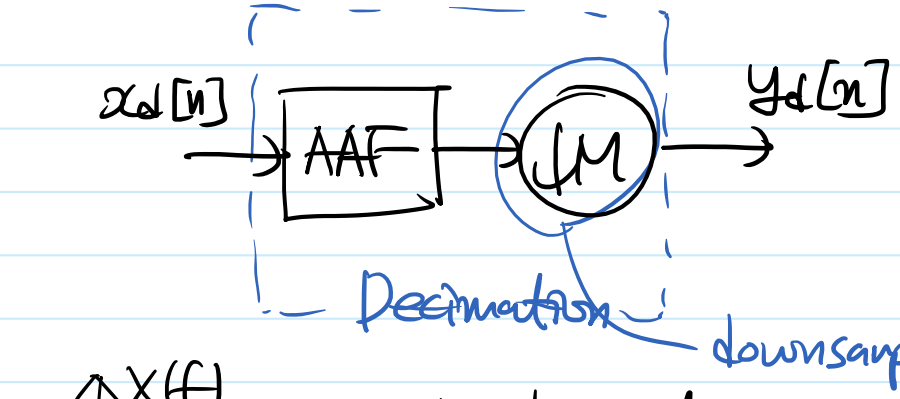
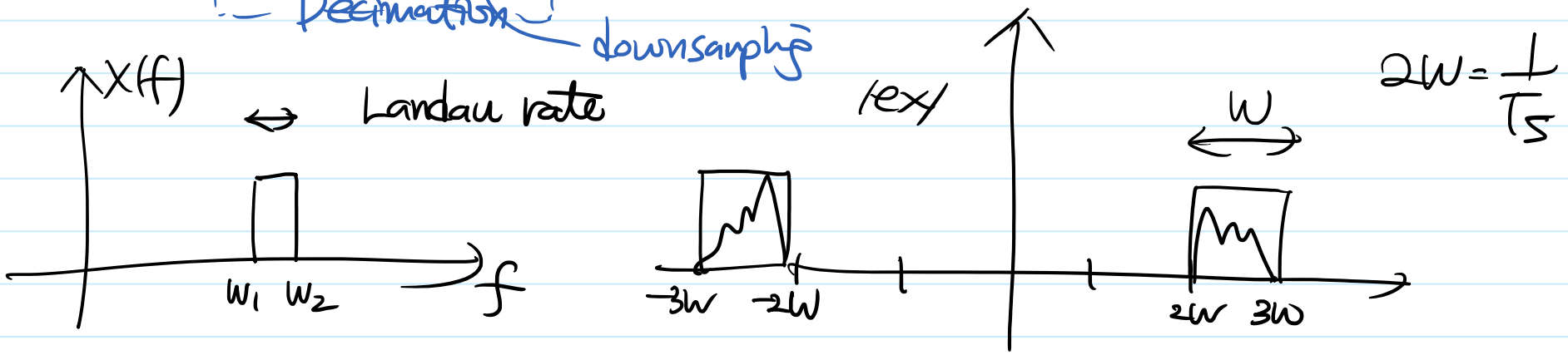
Upsampling $y_d[n]=\sum_m x_d[m]\,r[n-mL]$ ← $r[n]=\delta[n]$: Interpolation

$Y_d(e^{j2\pi f}) = X_d(e^{j2\pi fL})R(e^{j2\pi f})$

cf) $Y(f) = X_d(e^{j2\pi f T_I})P(f)$

Downsampling $x_d[m] \rightarrow \downarrow M \rightarrow y_d[n]$

$Y_d(e^{j2\pi f}) = \frac{1}{M}\sum_{l=<M>} X_d(e^{j2\pi(\frac{f-l}{M})})$

cf) $Y(e^{j2\pi f}) = \frac{1}{T_s}\sum_{l=-\infty}^{\infty} X(\frac{f-l}{T})$

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