QUICK OVERVIEW OF COMMON NONLINEARITIES & NONIDEALITIES

For us : NL → Bad! We cannot properly analize / account for it

IN THIS COURSE : "DIVIDE & CONQUER" (and SIMULATE)

↳ NONLINEARITIES WILL BE THOUGHT AS <u>LOCALIZED</u>, with their own "blocks" in MATLAB

OR :

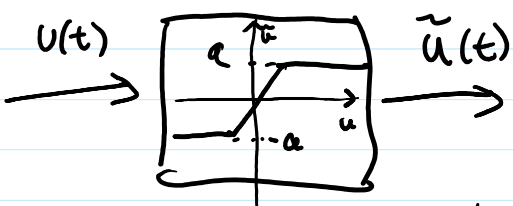
$\boxed{\text{APPROXIMATED}}$ w LINEAR COMPONENTS

↳ FOR SOME CRUCIAL ONES (i.e. SATURATION) WE WILL SEE WAYS TO LIMIT THEIR INFLUENCE (Diff. ARCHITECTURES ANTIWINDUP)

MAIN ONES [AS I/O "BLOCKS"]

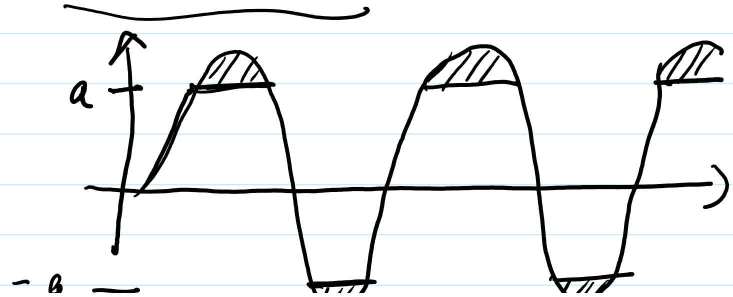
1 <u>SATURATION</u>

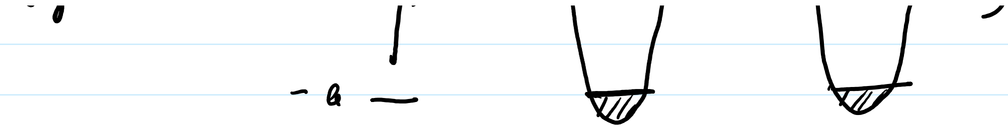
(we saw it in the sensor/actuator presentation)



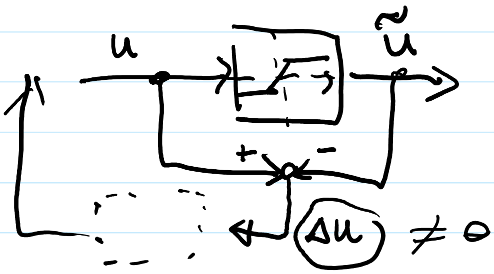
$$\tilde{u}(t) = \begin{cases} a & u(t) > a \\ u(t) & -a \leq u(t) \leq a \\ -a & u(t) < -a \end{cases}$$

<u>effect</u>: (on sinusoidal signal)

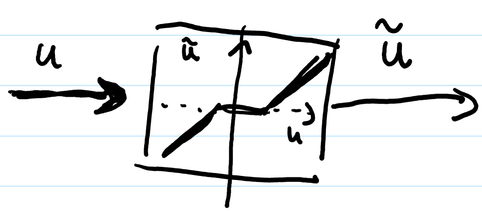




- CRITICALLY LIMITS THE EFFECTIVENESS OF CONTROLS (ACTUATORS IN REAL WORLD)
  real behavior $\neq$ designed one
- How do I know if I am saturating?



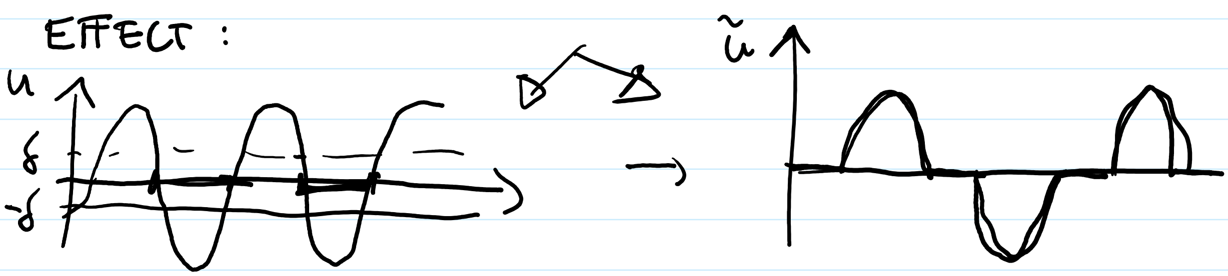
② DEAD ZONE



$$\tilde{u}(t) = \begin{cases} u(t) - \delta & u(t) > \delta \\ \boxed{0 \qquad -\delta \leq u(t) \leq \delta} & \\ u(t) + \delta & u(t) < -\delta \end{cases}$$

- GOOD DESCRIPTION OF STATIC FRICTION

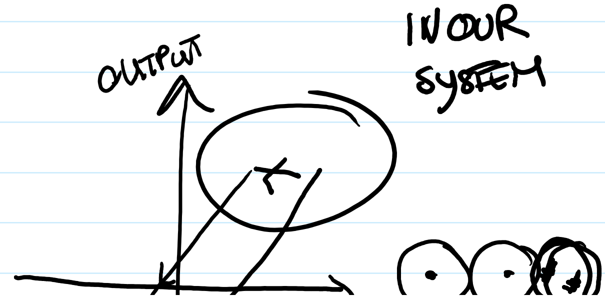
EFFECT :



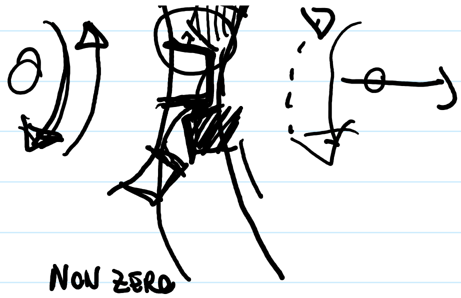
③ HYSTERESIS - seen in slides for sensors

↳ TYPICAL FOR GEARBOXES

Pb if I REVERSE

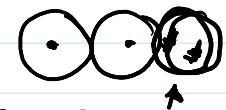


IN OUR SYSTEM



NON ZERO SPACE, ALLOWS FOR TEETH TO ENGAGE

1D ... REVERSE MOTION "Dead zone" effect



ANTI Backlash

EX try drawing effect on sinusoid

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(4) QUANTIZATION - Well known, modeled as NOISE

(5) D/A & A/D CONVERSIONS

Effects, exact & approximate conversions

when we will see the DIGITAL CONTROL LAB

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(6) DELAYS : everywhere! [Digital processing, Transmission, etc]

$$u(t) \to \boxed{\delta_T} \to u(t-T)$$

T−T

In $\mathcal{L}$-TRANSFORM

with $u(t)=0$ for $t<0$

$$\mathcal{L}[u(t-T)] = \int_0^{+\infty} u(\tau-T)e^{-\tau s}\,d\tau$$

$$= e^{-Ts}\int_0^{+\infty} u(\tau-T)\,e^{-(\tau+T)s}\,d\tau$$

$\tilde{\tau} = -\tau+T$

$$= e^{-Ts}\Big[\underbrace{\int_{-T}^{0} u(\tilde{\tau})\,e^{-\tilde{\tau}s}\,d\tilde{\tau}}_{\to 0} + \int_0^{+\infty} u(\tilde{\tau})\,e^{-\tilde{\tau}s}\,d\tilde{\tau}\Big]$$

$$\int u(\tilde{\tau})\, e \; d\tilde{\tau} \qquad \to U(s) = \mathcal{L}[U(t)]$$

$$= e^{-Ts}\, U(s)$$

$\Rightarrow$ LINEAR, But not rational $\qquad e^{-Ts} \neq \dfrac{B(s)}{A(s)}$

$\Rightarrow$ Padé approximations ~ RATIONAL FUNCT. $\dfrac{N(s)}{D(s)}$
indexed by (Deg N, Deg D) $\quad$ ~ Taylor-like expansions

$$(0,1):\quad e^{-Ts} \simeq \frac{1}{1+Ts} \quad \leftarrow \quad \mathrm{I}^{\circ}\ \text{ORDER}$$

$$(1,1):\quad e^{-Ts} \simeq \frac{1-\frac{Ts}{2}}{1+\frac{Ts}{2}}$$

$$(2,2):\quad e^{-Ts} \simeq \frac{1-\frac{Ts}{2}+\frac{T^2s^2}{12}}{1+\frac{Ts}{2}+\frac{T^2s^2}{12}}$$