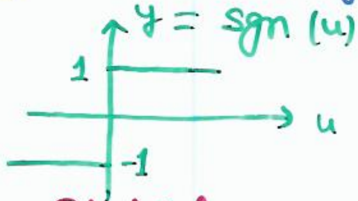
# Common Sources of Nonlinearity

- Some examples we show: Nonlinear resistance, nonlinear friction, Signoidal nonlinearity.

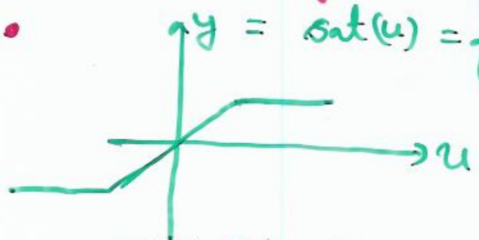
- $y = \text{sgn}(u) = \begin{cases} 1 & u > 0 \\ 0 & u = 0 \\ -1 & u < 0 \end{cases}$




Ideal Relay

"Ideal Relay" can be used to model: Electromechanical relays, thyristor ckts, (on-off operation)

- $y = \text{sat}(u) = \begin{cases} u & |u| \leq 1 \\ \text{sgn}(u) & |u| > 1 \end{cases}$




Ideal Saturation

"Ideal Saturation" can be used to model: amplifiers (electronic, magnetic, pneumatic, or hydraulic), motors, also limiters (intentional saturation)

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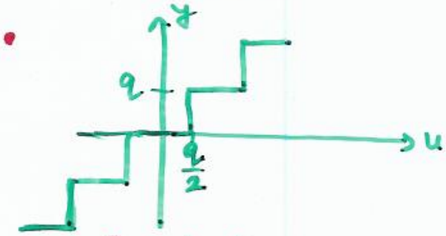
Dead-zone

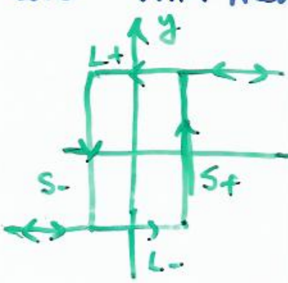
"Dead zone" can be used to model: Valves and some amplifiers (at low inputs)

- 

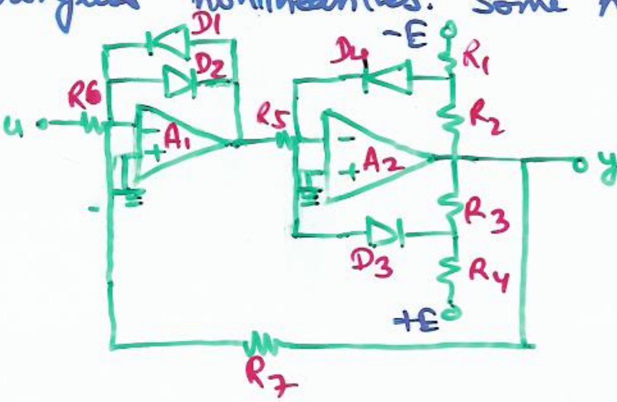

Quantization

"Quantization" is used for analog to digital conversion.

- Above are examples of "memoryless" nonlinearities. Some nonlinearities are "with memory".



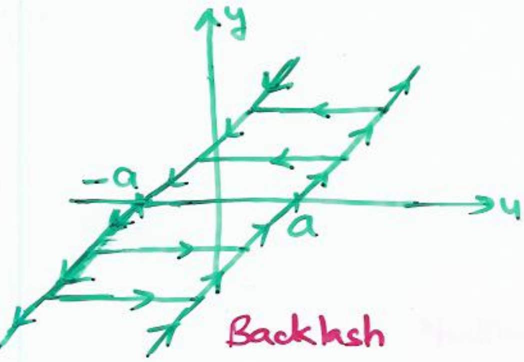

Ideal hysteresis




ckt with hysteresis.

For low inputs, output is at $L_-$. Input increased to $S_+$, then output switches to $L_+$ and stays there until input is decreased to $S_-$. (Example thermostat)

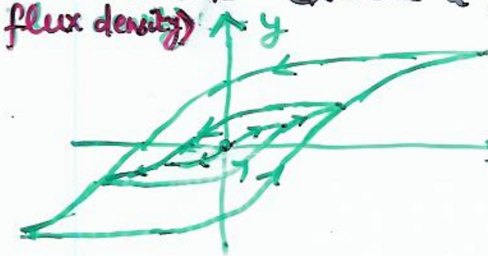
# Common Sources of Nonlinearity (ctnd.)


Backlash is seen between a pair of mating gears.

For driven gear to move clockwise driving gear must move at least "a" units of angle cockwise. Then the driven gear follows the driving gear. In the reverse direction, the driving gear has to move at least "-a" units of angle before the driven gear starts to follow the driving gear.

Magentic material also exhibit a similar hysteresis.




Magnetic flux density increases as magnetic field is increased in a ferromagnetic material due to alignment of dipoles, called magnetization. Magnetic flux density cannot increase beyond a point (once all dipoles are aligned), called magnetic saturation. Once a (partial) magnetization occurs, reducing magnetic field to zero does not necessarily demagnetizes the material; a -ve magnetic field is needed for doing that. Further reduction in magnetic field changes the dipole orientations leading to a -ve magnetic flux density, etc.