Common Sources of Nonlinearity

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

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

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

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

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

"Quantization" is used for analog to digital conversion.

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

For low input, 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 (Cont.)

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 clockwise.

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.

Magnetic 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.