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Problem 1: For each of the following nonlinearities, sketch by hand the describing function magnitude curve ($|G_D|$ vs. $E$). Do not calculate the describing function $G_D(E)$.
Problem 2: Integrator-and-schmitt-trigger oscillator. Use both exact analysis and describing functions to determine the frequency and amplitude at which the system in the figure below will oscillate. Compare the results.

Problem 3: By using describing functions, determine the frequency and amplitude at which the system in the figure below will oscillate.
Extra Credit Problem: Consider the PLL shown below. Assume that the phase detector output levels are ground and $V_{DD}$. Assume that both the input to the loop and the VCO output are square waves that swing between ground and $V_{DD}$. Assume that the relationship between control voltage and output frequency of the VCO is 10 MHz per volt and that the op-amp is ideal.

(a) Suppose that the loop has been in lock forever and that the input frequency has been held constant. Sketch the input signals to the phase detector with respect to time.

(b) Find the loop transfer function $L(s)$.

(c) Assume $V_{DD} = 5$ V, $R_1 = 100$ Ω and $R_2 = 0$. What value of $C$ gives a loop crossover frequency of 100 kHz? What is the phase margin?

(d) With the value of $C$ from part (c), find the value of $R_2$ that will provide a phase margin of 45° while preserving the crossover frequency.