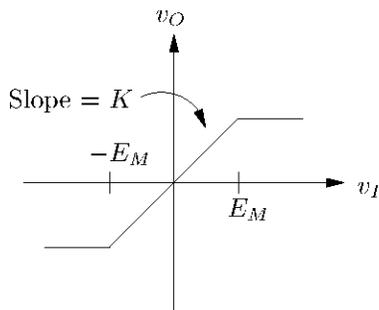


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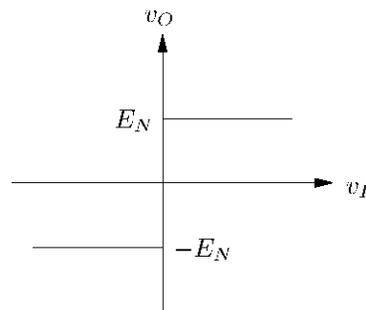
Spring Term 2007  
 Problem Set 10

Issued : May 1, 2007  
 Due : Tuesday, May 8, 2007

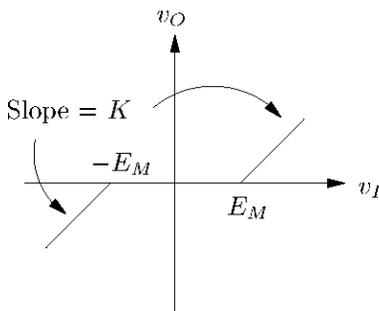
**Problem 1:** For each of the following nonlinearities, sketch *by hand* the describing function magnitude curve ( $|G_D|$  vs.  $E$ ). Do not calculate the describing function  $G_D(E)$ .



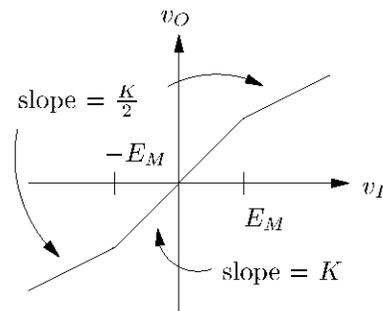
Describing Function A



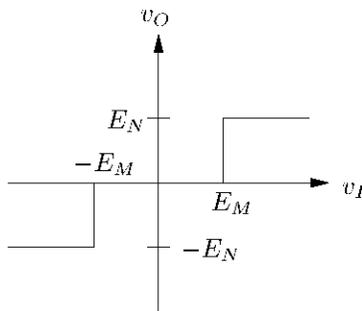
Describing Function B



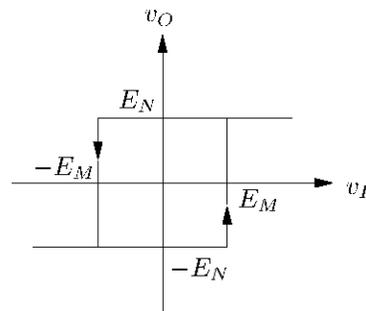
Describing Function C



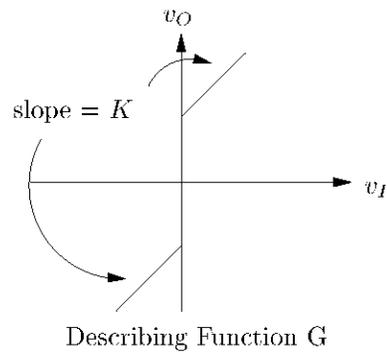
Describing Function D



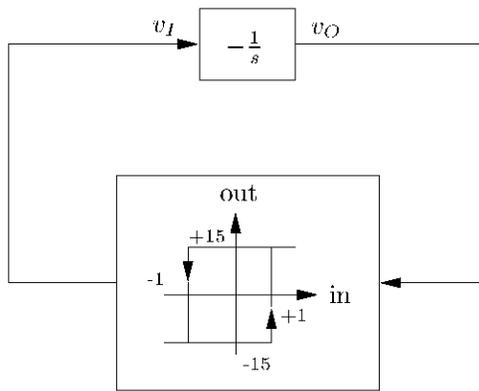
Describing Function E



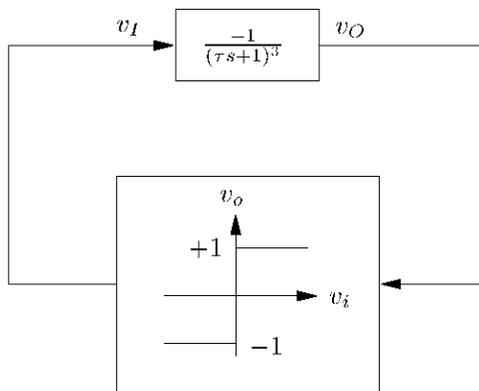
Describing Function F



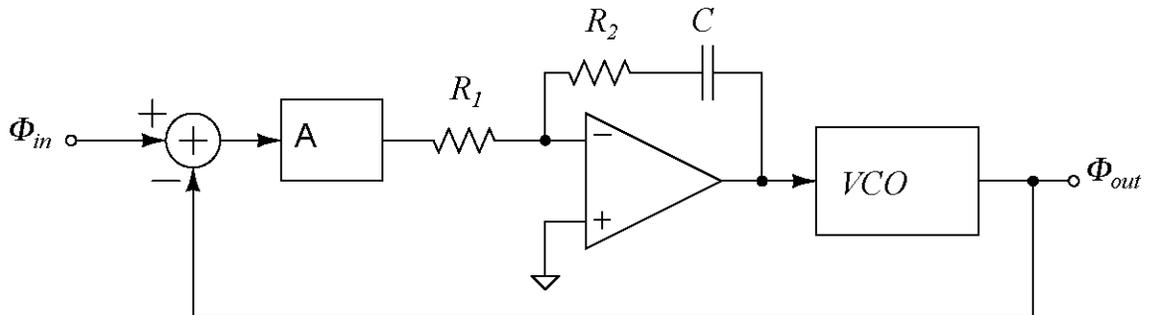
**Problem 2:** Integrator-and-schmitt-trigger oscillator. Use both exact analysis and describing functions to determine the frequency and amplitude at which the system in the figure below will oscillate. Compare the results.



**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  $V_{DD} = 5 \text{ V}$ ,  $R_1 = 100 \ \Omega$  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  $45^\circ$  while preserving the crossover frequency.