

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Department of Electrical Engineering

6.331 Advanced Circuit Techniques

Spring Term 2002  
Problem Set 5

Issued : April 12, 2002  
Due : Friday, April 19, 2002

**Problem 1** Consider the resonant oscillator in Figure 5.2. We wish to examine the conditions under which the circuit will oscillate. To make the analysis tractable, however, we must make the following simplifying assumption.

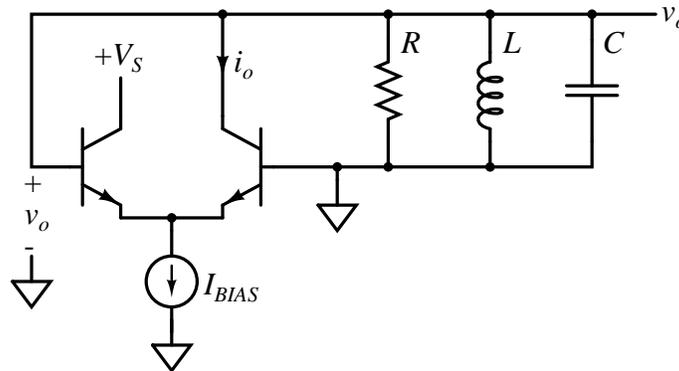


Figure 5.2: Resonant oscillator circuit

Recall that the output current ( $i_o$ ) of an emitter-coupled pair is a hyperbolic tangent function of the input voltage ( $v_o$ ). While very accurate, such a relationship between  $i_o$  and  $v_o$  is too complicated for describing function analysis to be applied. Instead, we will characterize the emitter-coupled pair by the piecewise linear I/V curve in Figure 5.3.

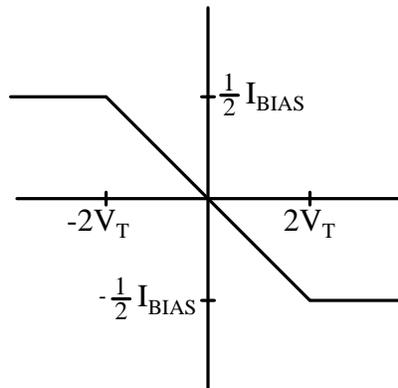


Figure 5.3: Piecewise linear I/V curve

Note that the incremental variables  $i_o$  and  $v_o$  have been plotted, which is why  $i_o$  can be negative. Note also that the slope near  $v_o = 0$  is consistent with the small-signal model of the transistors.

- A.** Using describing functions, find the condition on  $I_{BIAS}$  such that the circuit will oscillate. (Hint: relate  $v_o(s)$  to  $i_o(s)$  so that a block diagram of the form in Figure 5.4 can be drawn. You may need to read Section 6.3 in Operational Amplifiers if you are unfamiliar with describing functions.)

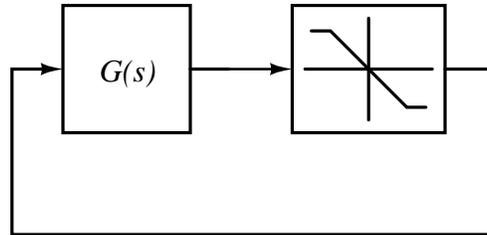


Figure 5.4: Block diagram with describing function

- B.** Let  $L = 0.1\mu\text{H}$ ,  $C = 1000\text{ pF}$ ,  $R = 1\text{ k}\Omega$ , and  $I_{BIAS} = 200\mu\text{A}$ . Using the describing function analysis from part A, compute the frequency and amplitude of the output of the oscillator ( $v_o$ ).
- C.** As an estimate of distortion, compute the ratio of the third harmonic to the first harmonic on the output voltage ( $v_o$ ). Is the number larger or smaller than you expected? Explain.

**Problem 2** While simple limiters can be used to establish the amplitude of an oscillator's output, they do so at the cost of some distortion. If much lower distortion is desired, one can use an amplitude control loop, as suggested in Figure 5.5. Such a control loop operates in the following manner. If the output amplitude is determined to be too small, the control loop adjusts a parameter (in this case the bias current) in such a way as to place the poles of the oscillator in the right-half plane, which causes the amplitude of the oscillation to grow. Similarly, if the output amplitude is too large, the control loop adjusts the parameter to place the poles of the oscillator in the left-half plane, which causes the amplitude of the oscillation to decay. In the steady state, the poles are placed precisely on the imaginary axis, and the output amplitude is constant.

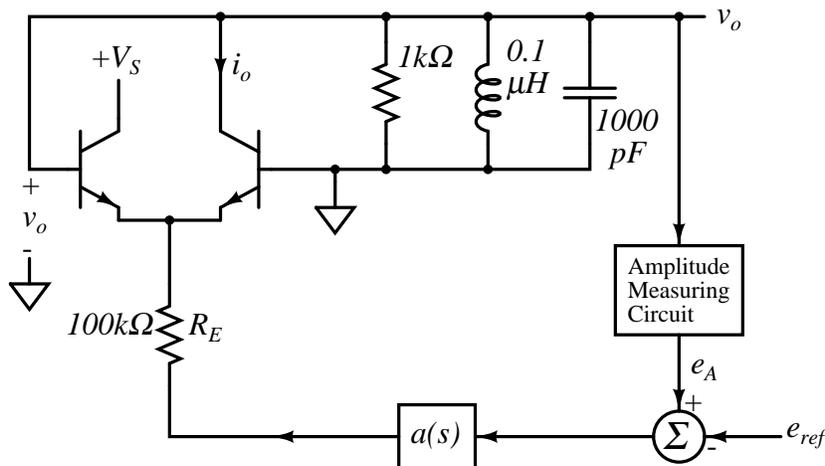


Figure 5.5: Amplitude-stabilized resonant oscillator circuit

The amplitude measuring circuit could be based on a full-wave rectifier, as in Problem Set 1, but the details are not important for this problem. All you need to know about it is that its gain is unity; that is, if the input to the amplitude measuring circuit is  $v_I = E \sin \omega t$ , its output has a DC average of  $E$ .

- A. What is the voltage across  $R_E$  in the steady state?
- B. To minimize distortion, we want the output amplitude to be  $0.1V_T$ . Choose  $a(s)$  and  $e_{ref}$  such that this amplitude is exactly maintained, the crossover frequency of the amplitude control loop equals 100 krad/s, and the phase margin is 75 degrees. Comment: the most difficult part of this problem is properly modelling the dynamics of amplitude growth and decay.