ANALOG SYSTEMS : PROBLEM SET 1

Problem 1

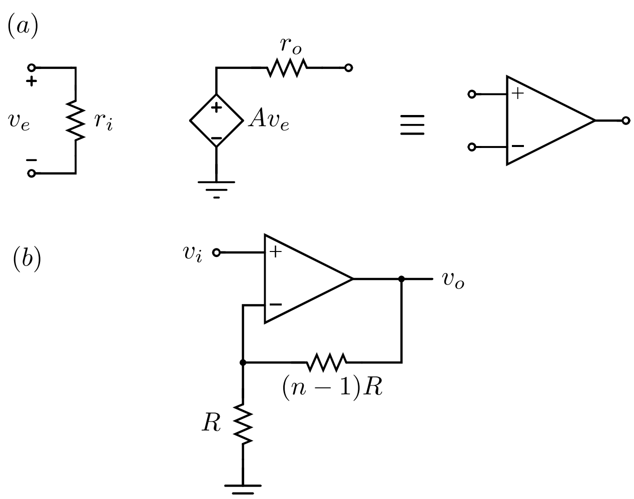


Figure 1: (a) Simplified equivalent circuit of a VCVS, with a large A. (b) The VCVS embedded in a negative feedback loop.

In class, we saw how a VCVS with a large but imprecise gain can be embedded inside a negative feedback loop to realize a VCVS with a stable gain. It turns out that in practice, the imprecise VCVS, shown in Fig. 1(a), is not all that ideal – its input resistance is finite, and its output resistance is nonzero. The symbol for the imprecise VCVS is also shown in Fig. 1(a). It is realized to make the VCVS shown in Fig. 1(b). If $A = \infty$, $v_o/v_i = n$.

Determine the input resistance, gain and output resistance of the VCVS of Fig. 1(b) in terms of A, r_i, r_o, R and n.

Evaluate the quantities above under the following limiting conditions.

a. Input resistance and gain when $r_o = 0$.

b. Output resistance and gain when $r_i = \infty$.

c. $A \to \infty$.

Problem 2

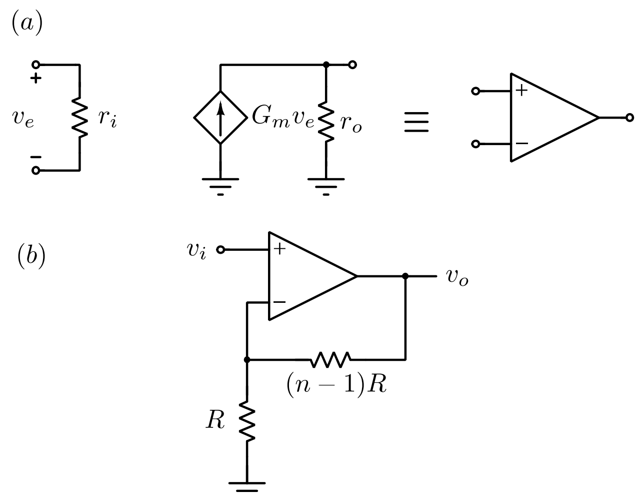


Figure 2: (a) Simplified equivalent circuit of a VCCS, with a large G_m. (b) The VCCS embedded in a negative feedback loop.

Rather than use a VCVS with a large (but uncertain) gain, this problem attempts to use a VCCS with a large (but uncertain) transconductance G_m. Further, the imprecise VCCS, shown in Fig. 2(a), is not all that ideal – its input and output resistances are finite. For simplicity, we use the same symbol for the imprecise VCCS as in Fig. 1(a). It is realized to make the VCVS shown in Fig. 2(b). What is v_o/v_i when $G_m = \infty$?

Determine the input resistance, gain and output resistance of the VCVS of Fig. 2(b) in terms of G_m, r_i, r_o, R and n.

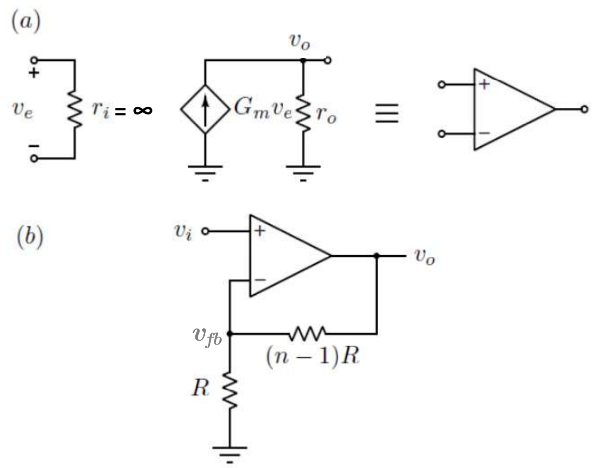
Evaluate the quantities above under the following limiting conditions.

a. Input resistance and gain when $r_o = \infty$.

b. Output resistance and gain when $r_i = \infty$.

c. $A \to \infty$.

Problem 3



Design the circuit shown in figure (a) and (b) in LTSpice and perform following simulations:

a. Configure the VCVS shown in figure (a) for gain, A_o=5 (G_m=1mS, r_o=5k) and A_o=10 (G_m=5mS r_o=2kΩ). Give a sinusoidal input of 1V amplitude at input v_e, observe the output voltage across *ro*) and verify that gain (v_o/v_e) is same as $G_m r_o$.
b. Connect a load resistance R_L=1kΩ at v_o (in parallel with r_o) and repeat exercise in a. Comment on the effect of R_L on the gain.
c. Configure the VCVS of figure (a) in negative feedback as shown in figure (b) with following parameters and analyze the gain (v_o/v_i) by giving sinusoidal input of 1V amplitude at input v_i and observe the feedback voltage v_{fb} and output v_o. Compare the results with analysis performed in a. and b. Determine the effect of VCVS gain ($A_o=G_m r_o$) and *n* on the closed loop gain (v_o/v_i).
   i. G_m=2mS, *ro*=10k, *R*=1MΩ, *n*=2
   ii. G_m=2mS, *ro*=50k, *R*=1MΩ, *n*=5
   iii. G_m=1mS, *ro*=200k, *R*=1MΩ, *n*=2
   iv. G_m=1mS, *ro*=100k, *R*=1MΩ, *n*=10
   v. G_m=10mS, *ro*=100k, *R*=1MΩ, *n*=10