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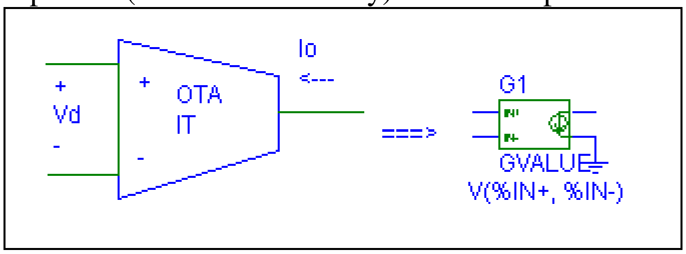
610 Fall 2008 – Homework 5

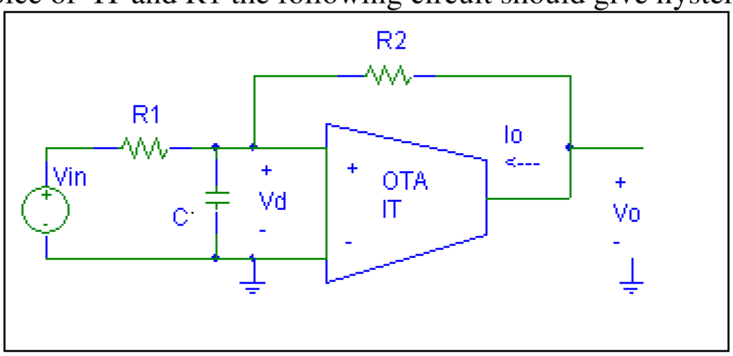
1. Synthesize using the Richards' function (and compare the results of a) with b)):
   a) $y(s) = (s^2+s+1)/(s^2+s+4)$
   b) $z(s)=(s^2+s+1)/(s^2+s+4)$ (which is in Secs. 8.5,6 of the book via Brune & Bott-Duffin)
2. This problem is associated with hysteresis. First is the diagram of an OTA (Operational Transconductance Amplifier) where in Spice the idealized OTA can be simulated using a GVALUE component (in the ABM library) with the expression for Io as the gain



An OTA is constructed as a differential pair with an "active" load to give the output to be the difference current of the pair collector (or drain) currents. In the NPN BJT pair case the current difference, Io, is derived to be

$$Io = -IT\cdot\tanh(Vd/(2VT))$$

where IT is the tail current. Also input current (into the difference voltage Vd leads) is assumed to be 0. With proper choice of IT and R1 the following circuit should give hysteresis.



a) Using semistate variables $x=[Vd\ Io]^T$ set up semistate equations assuming input u=Vin and output $y=[Io\ Vo]^T$.
b) For this circuit show that the DC load line equation is (where G1=1/R1)
   $Io = -G1(Vd-Vin)$
c) Sketch the OTA curve of Io versus Vd with the load line curves of Io versus Vd for several important values of Vin. From that show that this circuit has hysteresis at DC for some values of R1 given IT. Calculate the smallest R1, call it Rmin, such that hysteresis will result (for this you can set the tangents equal for the OTA curve and the load line). Find the voltages, ±Vj, at which the hysteresis jumps. Sketch Io versus Vin showing the hysteresis.
d) Choose R1 = 2Rmin, R2 = R1, IT=104uA (=4x26uA), VT=26mV, C=0, and run a transient response in Spice using an input voltage that is triangular via the piecewise linear voltage source, VPWL, starting at 0, going slowly negative to twice the hysteresis negative break voltage, and then to positive twice the hysteresis positive jump voltage, and then back to the most negative value. Plot Io versus Vin.
e) Calculate, at DC, Vo versus Vin and sketch the result; compare with Spice results.