File: f:/courses/fall2020/610/610F20finalversionexam.doc RWN for Tu 12/22/20

EE 610 Final Exam Fall 2020 Take Home due in Elms system on-line prior to end of scheduled exam period Tu 12/22/20 10:30-12:30.

Open Book Open Notes and calculators; 100 points, 2 hours. Your submission insures that the work is totally your own.

e-journals are also due at the end of the exam. Good luck and have a good semester break.

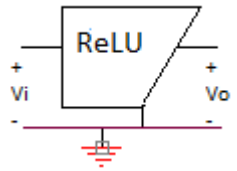
1. (15 points, 10 minutes)
   Synthesize by the first Cauer $z(s)=[s(s^2+4)]/[(s^2+2)(s^2+5)]$

2. (15 points, 10 minutes)
   Check the Hurwitz nature of the numerator and denominator of
   $f(s)= [s^3+2s^2+2s+4]/ [s^3+4s^2+8s+2]$

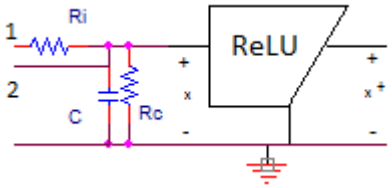
3. (40 points, 60 minutes) ReLU cells
   ReLU (=Rectifying Linear Unit) is an important component in Deep Neural Network (=DNN) theory.

   The ReLU component is described as a voltage controlled voltage source [with zero input current] for which the ouput voltage is the maximum of 0 or the input voltage, that is Vo=max{0,Vi}. If Vi=x and Vo=x+ this is often written $x^+(x)=\max\{0,x\}$. Although it is nonlinear it is a peicewise linear 2-port with possible circuit symbol shown below.

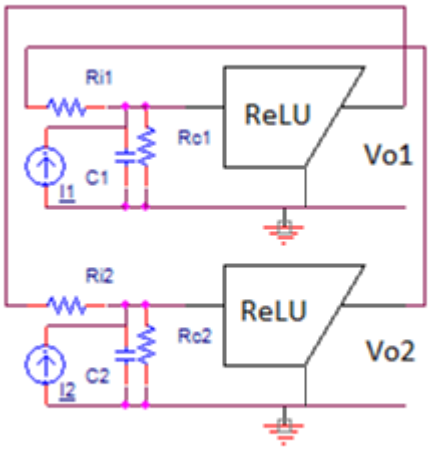
a) Sketch the $x^+=Vo$ versus x=Vi for -2<x<+2



The ReLU (neuron) cell is the following two-input single-output circuit where input 1 is a voltage and input two is a current.



A 2-input ReLU neuron is



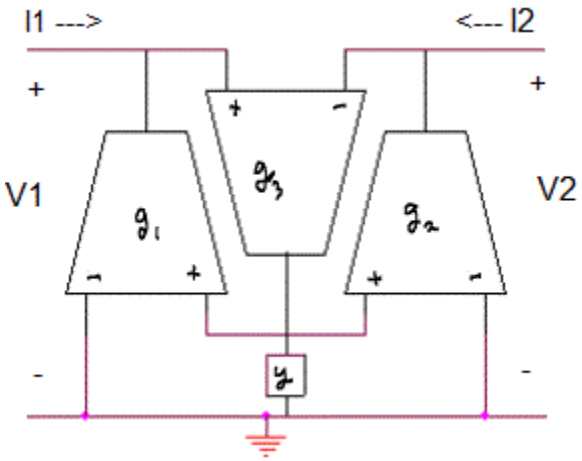
A state variable type representation of this neuron is the following where x is a 2-vector of capacitor voltages, Θ is a 2x2 diagonal matrix of time constants, W is a 2x2 matrix of "weights" and B & C are also 2x2 matrices

$$\Theta dx/dt = -x + Wx^{+} + Bi$$
$$vo = Cx^{+}$$

b) Using capacitor voltages (with respect to ground) write these two equations in matrix form exhibiting the four coefficient matrices.

c) These state equations are nonlinear but being peicewise linear, they cover 4 linear state variable cases. In all four cases the only coefficient matrix which changes is W. Keeping Θ, B, C as above, give the coefficient A on x in the following two different cases, 1) when both rectifiers give all x+ as max>0 and 2) when all x+ are 0.

4. (15 points, 10 min) For the following 2-port circuit of 3 OTAs having trnasconductances g_i, i=1,2,3, and an admittance y(s).
   a) Give the 2-port admittance matrix and on setting $g_1=g_2$ give conditions for this to give a negative inductor.
   b) Find the input admittance when loaded in a short circuit (that is a resistor of resistance R=0 => V_2=0).



5. (15 points, 20 min) The following circuit can be constant R.
   a) Determine the conditions on the 2-port components for this to be the case.
   b) Give its transfer function.V_2/V_1 where V_1 =V is the applied voltage at the left of the 2-port and V_2 is the output voltage on its right,