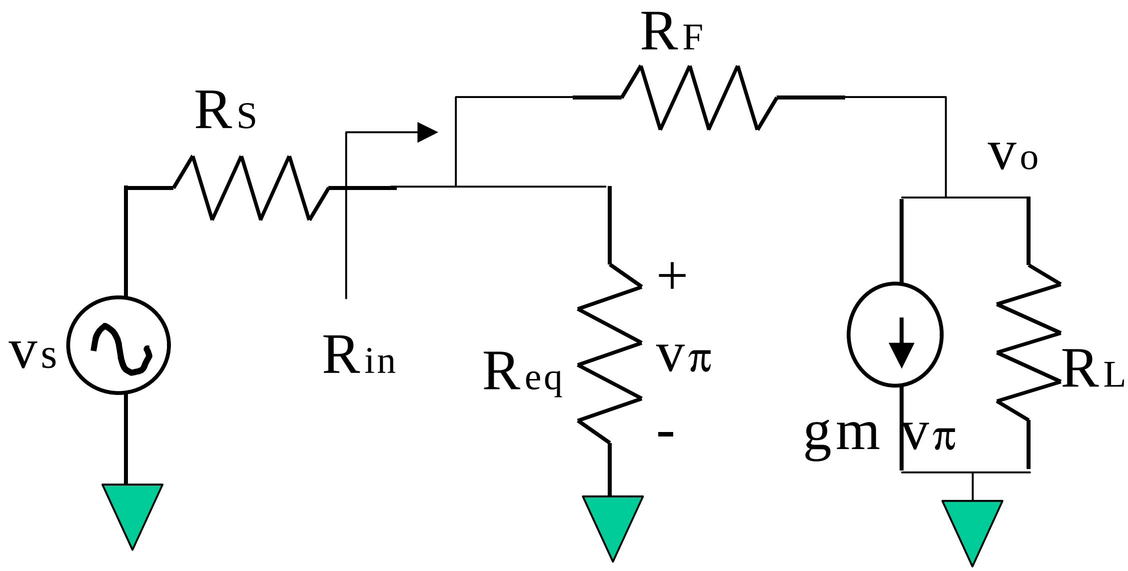
Rigorous Analysis of Shunt-Shunt Feedback Circuit

- Nodal Analysis
- One Assumption…$|g_m| >> |g_f|$…(see below)
- Results on the final pages:
  - Relationship to match Rs
  - Gain expression (both as voltage gain and trans-resistance with units "V/I")
  - Manipulations that put results into "classical" form (ala step-by-step done in **G**ray & **M**eyer)



Nodal – Equations:

$$(V_s - V_p)g_s - V_p g_{eq.} - (V_p - V_o)g_f = 0$$

$$(V_p - V_o)g_f - g_m V_p - V_o g_L = 0$$

rearranged:

$$V_p(g_s + g_{eq.} + g_f) - V_o g_f = V_s g_s$$

$$V_p(g_m - g_f) + V_o(g_f + g_L) = 0$$

$$\frac{V_o}{V_p}\ is:$$

$$\frac{V_o}{V_p} = \left(\frac{-g_m + g_f}{g_f + g_L}\right) \approx \left(\frac{-g_m}{g_f + g_L}\right)$$

$$assu\min g|g_m| \rangle\rangle |g_f|$$

$$Solving\_for\_V_p = f(V_s):$$

$$\left\{ use\_\left(\frac{V_o}{V_p}\right)\_in\_first\_equation: \right\}$$

$$V_p\left(g_s + g_{eq.} + g_f\right) + g_f\left(\frac{g_m}{g_f + g_L}\right)V_p = g_s V_s$$

$$V_p = \frac{g_s}{g_s + g_{eq.} + g_f + g_m\left(\frac{g_f}{g_f + g_L}\right)} V_s$$

$$and\ldots$$

$$V_s - V_p = \left(\frac{g_{eq.} + g_f + g_m\left(\frac{g_f}{g_f + g_L}\right)}{g_s + g_{eq.} + g_f + g_m\left(\frac{g_f}{g_f + g_L}\right)}\right)V_s$$

$$solving\_for\_the\_input\_conduc\tan ce:$$

$$i_{in} = g_s\left(V_s - V_p\right)\_and...$$

$$g_{in} = \frac{i_{in}}{V_s}$$

$$which\_in\_turn\_for\_a\_matched\_condition:$$

Assumption (I.e. that we want "match" with Rs)

$$g_{in} = \frac{g_s}{2} =$$

$$= g_s \cdot \left(\frac{g_{eq.} + g_f + g_m\left(\frac{g_f}{g_f + g_L}\right)}{g_s + g_{eq.} + g_f + g_m\left(\frac{g_f}{g_f + g_L}\right)} \right)$$

$$therefore:$$

$$g_s + g_{eq.} + g_f + g_m\left(\frac{g_f}{g_f + g_L}\right) = 2 \cdot \left(g_{eq.} + g_f + g_m\left(\frac{g_f}{g_f + g_L}\right)\right)$$

$$which\_gives:$$

$$g_s = g_{eq.} + g_f + g_m\left(\frac{g_f}{g_f + g_L}\right)$$

Note: this equation is a specific result of having the Rin of *amplifier with feedback* exactly equal Rs (I.e. a matched load condition)

$$solving\_for\_\frac{V_o}{V_s}:$$

$$\frac{V_o}{V_s} = \left(\frac{-g_m}{g_f + g_L}\right)\left(\frac{g_s}{g_s + g_{eq.} + g_f + g_m\left(\frac{g_f}{g_f + g_L}\right)}\right)$$

Design Example Coming Soon!

$$which\_can\_be\_rewritten\_as:$$

$$= \frac{-g_m \cdot g_s}{(g_f + g_L)(g_s + g_{eq.} + g_f) + g_m g_f}$$

$$this\_is\_exactly\_equivalent\_to\_G\,\&\,M(Eqn.8.56)$$

$$\frac{V_o}{V_s} = \frac{-g_m \cdot g_s}{\left(g_f + g_L\right)\left(g_s + g_{eq.} + g_f\right) + g_m g_f}$$

Looking at equation once more, putting it into the units which are consistent with feedback theory (I.e. shunt-shunt…see EE113 notes!)

$$which\_can\_be\_rewritten\_in\_\text{"standard"}\_feedback\_form:$$

$$\frac{V_o}{V_s/R_s} = \frac{V_o}{I_s} = \frac{\dfrac{-g_m}{\left(g_f + g_L\right)\left(g_s + g_{eq.} + g_f\right)}}{1 + \dfrac{g_m g_f}{\left(g_f + g_L\right)\left(g_s + g_{eq.} + g_f\right)}}$$

Actually, this is the exact equivalent of the G&M Eqn.8.56

$$= \frac{a}{1 + |af|}$$

Which can be written in the classical feedback equation form…

$$where:$$

$$a = \frac{-g_m}{\left(g_f + g_L\right)\left(g_s + g_{eq.} + g_f\right)}$$

$$and$$

$$f = -g_f$$

These are the "a" and "f" terms with natural units of: V/I and I/V respectively

$$solving\_the\_quadratic\_for\_g_f:$$

$$g_f = \frac{-(g_m + g_L + g_{eq} - g_s) \pm \sqrt{(g_m + g_L + g_{eq} - g_s)^2 + 4(g_s - g_{eq})g_L}}{2}$$

$$and\_the\_correct\_(physical)\_solution\_is:$$

$$g_f \approx \frac{(g_s - g_{eq})g_L}{(g_m + g_L + g_{eq} - g_s)}$$

Typical numbers based on Ic=5mA:

g_m=0.193 (mho)

g_{eq}=gp=0.0024 (mho)

and assuming…

g_L=0.0005 (mho) ->R_L=2KΩ

g_s=0.05 (mho) ->R_s=50Ω

The above equations give:

g_f=5.028 x 10^(-5) (mho) -> R_f=19.99KΩ

and using this value in the gain expression:

Vo/Vs= -175

Sounds good but… there are still potential issues related to stability!