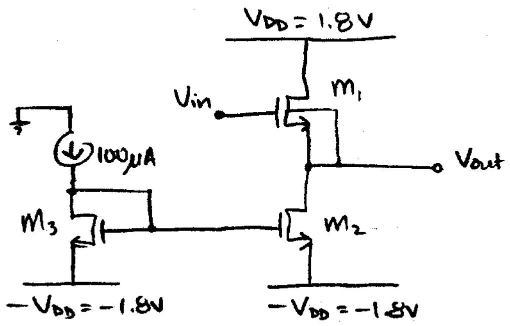
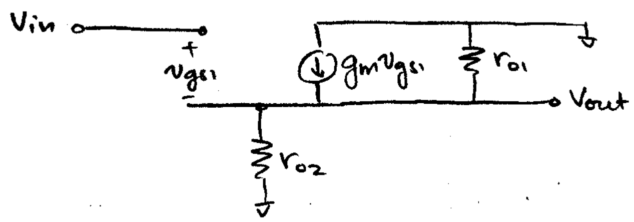
1)

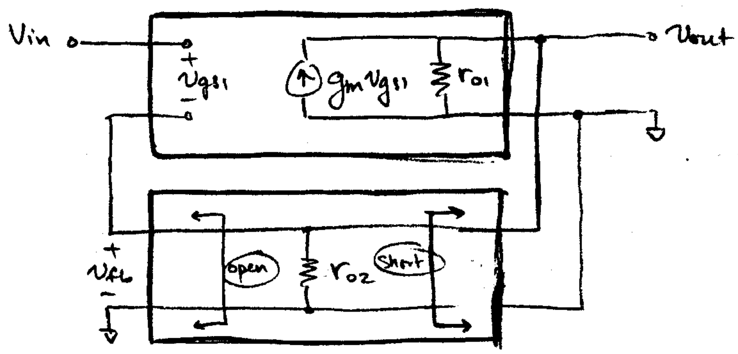


All $\left(\frac{W}{L}\right) = \frac{6}{0.18}$

a) The small-signal model for this circuit is:



Redrawing this gives:



Thus, the feedback is $\boxed{\text{series-shunt}}$.

b) The feedback factor is: $\boxed{f = \frac{v_{fb}}{v_o} = 1}$

c) $a_v' = g_m (r_{o1} \| r_{o2})$

$T' = a_v' \cdot f = \boxed{g_m (r_{o1} \| r_{o2})}$

$g_m = \sqrt{2(140\mu)\left(\frac{6}{0.18}\right)(100\mu)} = 966 \mu S$

$r_{o1} = r_{o2} = \frac{1}{(0.1)(100\mu)} = 100 \text{ k}\Omega$

$\Rightarrow \boxed{T' = 48.3}$

$r_{out}' = r_{o1} \| r_{o2}$

1) d) $\frac{v_{out}}{v_{in}} = \frac{1}{f}\cdot\frac{T}{1+T} = \boxed{\frac{g_m(r_{o1}\|r_{o2})}{1+g_m(r_{o1}\|r_{o2})} = 0.98}$

$R_{out} = \frac{r_{out}'}{1+T} = \boxed{\frac{r_{o1}\|r_{o2}}{1+g_m(r_{o1}\|r_{o2})} = 1.014\ k\Omega}$

The exact expression for R_{out} is:

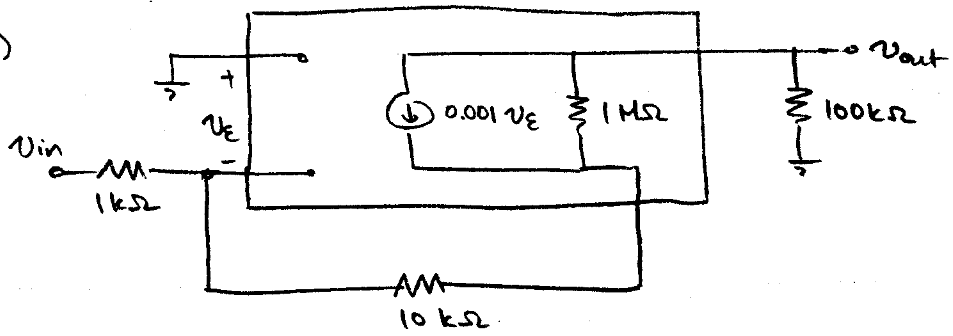
$$R_{out} = r_{o1}\|r_{o2}\|\frac{1}{g_m} = \frac{(r_{o1}\|r_{o2})\frac{1}{g_m}}{\frac{1}{g_m}+(r_{o1}\|r_{o2})} = \boxed{\frac{r_{o1}\|r_{o2}}{1+g_m(r_{o1}\|r_{o2})}}$$

The exact expression for $\frac{v_{out}}{v_{in}}$ is:

$$\frac{v_{out}}{v_{in}} = G_m R_{out} = g_m R_{out} = \boxed{\frac{g_m(r_{o1}\|r_{o2})}{1+g_m(r_{o1}\|r_{o2})}}$$

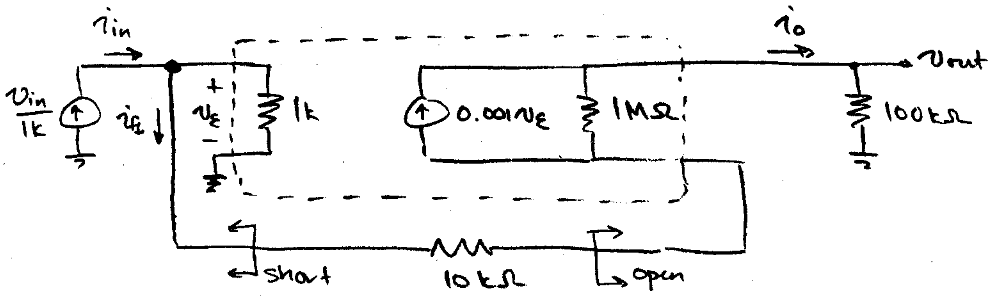
$\boxed{\text{Therefore, the feedback equations w/ loading are identical to the exact expressions calculated before.}}$

2)



a) The feedback is $\boxed{\text{shunt-series}}$.

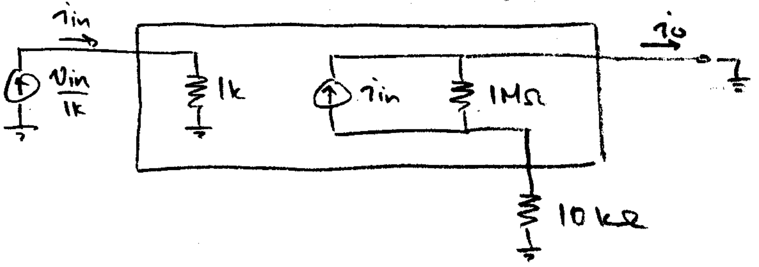
b) we should use a Norton equivalent source:



The feedback factor is: $\boxed{f = \frac{i_{fb}}{i_o} = 1}$

c) When considering loading effects, it is important to realize that the 100 kΩ load should <u>not</u> be included when analyzing the feedback circuit, only at the very end. This is because it is not a part of either the main amplifier or the feedback amp.

The main amplifier with loading is:



Thus, with loading, the main amplifier becomes:

$r_{in}' = r_{in} = 1\,k\Omega$

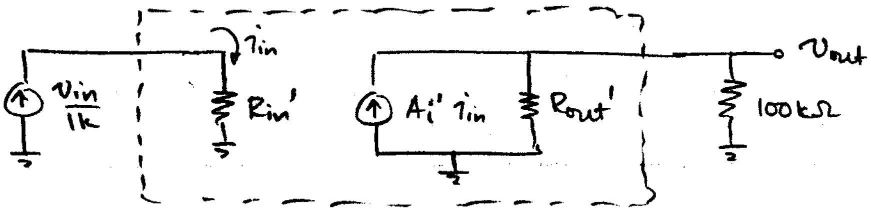
$r_{out}' = 1\,M\Omega + 10\,k\Omega = 1.01\,M\Omega$

$a_i' = \frac{i_o}{i_{in}} = \frac{1\,M}{1M + 10k} = \frac{1}{1.01}$

2) c) (cont.)

Therefore $T' = a_i' f = \frac{1}{1.01}$

So, the closed-loop circuit can be modeled as:



where $R_{in}' = \frac{r_{in}'}{1+T} = \frac{1\,k\Omega}{1+\frac{1}{1.01}} = 502\,\Omega$

$R_{out}' = r_{out}'(1+T) = (1.01\,M)\left(1+\frac{1}{1.01}\right) = 2.01\,M\Omega$

$A_i' = \frac{a_i'}{1+T'} = \frac{\frac{1}{1.01}}{1+\frac{1}{1.01}} = \frac{1}{2.01}$

$\therefore R_{out} = 100\,k\Omega \,\|\, R_{out}' = \boxed{95.3\,k\Omega}$

d) $\frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{i_{in}}\right)\left(\frac{i_{in}}{v_{in}}\right) = A_i'\left(\frac{R_{out}'}{R_{out}'+100k}\right)(100\,k)\left(\frac{1}{1k}\right)$

$= \frac{1}{2.01}\left(\frac{2.01}{2.01+0.1}\right)(100)$

$= \frac{100}{2.11}$

$= \boxed{47.4}$

e) From SPICE: $\boxed{R_{out} = 95.3\,k\Omega \quad \frac{v_{out}}{v_{in}} = 47.4}$

```
* hw9, 2: shunt-series feedback amplifier

vin     in 0 0
xamp    0 in- out+ out- opamp
r1      in in- 1k
r2      in- out- 10k
rl      out+ 0 100k

.subckt opamp in+ in- out+ out-
g1      out+ out- in+ in- 0.001
ro      out+ out- 1x
.ends

.options post=2 nomod

.tf v(out+) vin

.end


****     small-signal transfer characteristics

     v(out+)/vin                                  =    47.4183
     input resistance at         vin              =     2.1089k
     output resistance at v(out+)                 =    95.2629k
```