b) The resistor limits the current in that branch.

c) $I_{\text{tail}} = (3.5V - 0.7V - V_{\text{-}}) / 1 \text{ kohm} = 2.8 \text{ mA (assuming } V_{\text{-}} = 0\text{V)}$

The Zener voltage is relatively constant regardless of supply variation so $I_{\text{tail}}$ is mostly independent of the supply voltage.

d) See above.

#1) 9 pts total
   a) 5 pts, 1 for identifying each block
   b) 1 pt
   c) 2 pts, 1 for tail current, 1 for supply variation comment
   d) 1 pt
#2) 6 pts total
1 pt each for identifying each block
3)

**Figure 4. Voltage Follower Large Signal Response (50 pF)**

a) The rising slew rate is $1.75V/5\mu s = 350 \text{kV/s}$ and the falling is $2V/5\mu s = 400 \text{kV/s}$.

b) The smallest of all the source/sink values in the table is $1\text{mA}$, which leads to $dV/dt = I/C = 1\text{mA}/50\text{pF} = 20 \text{MV/s}$. This number is much larger than the slew rate in Fig 4 so the output stage is not the limiting factor.

c) The slew rate must then be due to the compensation capacitor, which on both rising and falling edges has a current limit of $6\text{uA}$ due to the $6\text{uA}$ diff pair current source. $C = I / (dV/dt)$. Taking the average of the rise/fall slew rates, $C = 6 \text{uA} / (375000 \text{ V/s}) = 16 \text{pF}$.

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#3) 6 pts total  
a) 2 pts, 1 each for rising and falling slew rates  
b) 2 pts, 1 for finding output current limit, 1 for saying it is not output slew limited  
c) 2 pts, 1 for tail current as limiting factor, 1 for calculating $C_c$
4)

a) \( A_{V0} = 100,000 \text{ V/V} \), \( f_{p1} = 5 \text{ Hz} \), \( f_u = 1 \text{ MHz} \)

b) The phase margin is 45 degrees for \( CL = 1000 \text{pF} \), so \( P2 \) must be at the unity gain frequency, \( f_{p2} = 1\text{MHz} \).

#4) 5 pts total
a) 3 pts, 1 each \( A_{V0}, f_{p1}, f_u \)
b) 2 pts, 1 for saying \( PM=45 \), 1 for saying \( wp2=wu \)
5)

a)

i. Gain at 0.1Hz is about 3e6. \( f = 0.001 \), so closed loop gain error is \(-1/\alpha f = -1/3000\).

ii. \( C_s = 10pF \) puts the pole at about 5 Hz, while \( C_F = 30pF \) puts the pole at about 0.2 Hz.

b)

For \( \text{PM}=60\text{deg} \),

- \( C_F = 3pF \), the minimum gain is 26dB @ 300kHz (feedback factor of 0.05).
- \( C_F = 30pF \), the minimum gain is 0dB @ 1MHz (feedback factor of 1, it is unity gain stable).

#5) 7 pts total
a) 3 pts, 1 for gain error, 1 each for the two poles in (ii)
b) 4 pts, 1 for min gain and 1 for bandwidth, for both values of \( CF \)
\[ \frac{V_{out}(s)}{V_{in}} = \frac{(C_c S - Gm_2) R_{o2}}{R_{o1} R_{o2} \xi \xi^2 + R_{o1} (1 + Gm_2 R_{o2}) (C_c + C_1) + R_{o2} (C_c + C_2) \xi^2 + 1} \]

where \( \xi = C_1 C_c + C_1 C_2 + C_c C_2 \)

c) i) \[ \omega_p = \frac{1}{\omega_{p_1}} \cdot \frac{1}{R_{o1} R_{o2} (C_1 C_c + C_1 C_2 + C_c C_2)} \]

ii) \[ \omega_{p_1} = \frac{1}{R_{o1} Gm_2 R_{o2} C_c} \]

\[ \omega_p = \frac{Gm_2 C_c}{C_1 C_c + C_1 C_2 + C_c C_2} \]

iii) For \( \phi_M \geq 45^\circ \), \( \omega_p \geq \omega_n = \frac{Gm_1}{C_c} \)

\[ \frac{Gm_2}{Gm_1} \cdot \frac{C_c^2}{C_1 C_c + C_1 C_2 + C_c C_2} \geq 1 \]