assignment5

(F84134102)

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Section: 1142_E227020_2

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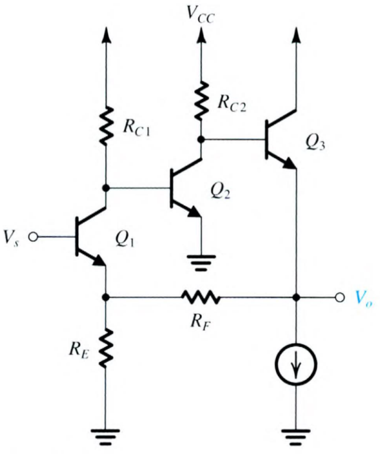
Problem 1. **(1 point)**
Design a feedback amplifier to have an ideal closed-loop gain of 13 and to have an amount of feedback of at least 40 dB.

What is the required value of β? ________ (V/V)

What is the minimum required value of the open-loop gain A? ________ (V/V)

What is the corresponding realized value of closed-loop gain A_f? ________ (V/V)

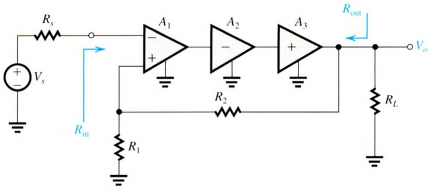
Problem 2. **(1 point)**



The figure shows a series-shunt feedback amplifier without details of the bias circuit.
(a) If R$_E$ is selected to be 43Ω, find the value for R$_F$ that results in a closed-loop gain with an ideal value of 22V/V.
(b) If Q$_1$ is biased at 0.5mA, Q$_2$ is at 1.4mA, Q$_3$ is at 3mA, and assuming that the transistors have β = 100 and larger r_o, and that R$_{C1}$ = 1.6kΩ and R$_{C1}$ = 1.2kΩ, find the value of the loop gain $A\beta$ and hence of the closed-loop gain A$_f$.

R_F = ________ Ω
$A\beta$ = ________ V/V
A$_f$ = ________ V/V

Problem 3. (1 point)
Below shows a three-stage feedback amplifier:
A_1 has an 76kΩ differential input resistance, a 20V/V open-circuit differential voltage gain, and a 3.7kΩ output resistance.
A_2 has a 6kΩ input resistance, a 19mA/V short-circuit transconductance, and a 15kΩ output resistance.
A_3 has a 23kΩ input resistance, unity open-circuit voltage gain, and a 1.1kΩ output resistance.
The feedback amplifier feeds a 0.8kΩ load resistance and is fed by a signal source with a 9kΩ resistance.



(a)If $R1 = 21\text{k}\Omega$, Find the value of R_2 that results in an ideal closed-loop gain of 5 V/V.
$R_2 =$ ________ kΩ

(b) Find the value of the open-loop gain $A \equiv V_o/V_s$.
$A =$ ________ V/V

(c) Find the feedback factor β and the amount of feedback.
$\beta =$ ________ V/V
Amount of feedback $(1 + \beta A) =$ ________

(d) Find the closed-loop gain A_f.
$A_f =$ ________ V/V

(e) Find the feedback amplifier's input resistance R_{in}.
$R_{\text{in}} =$ ________ MΩ

(f) Find the feedback amplifier's output resistance R_{out}
.
$R_{\text{out}} =$ ________ Ω

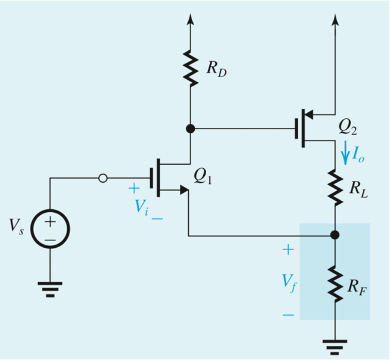
(g) If the high-frequency response of the open-loop gain A is dominated by a pole at 100Hz, what is the upper 3-dB frequency of the closed-loop gain.
$f =$ ________ kHz

(h) If for some reason A_1 is drops to half its nominal value, what is the absolute percentage change in A_f?
Absolute Percentage change $=$ ________ %

Problem 4. (1 point)
For the feedback transconductance amplifier shown in Fig. 4, evaluate the closed-loop transconductance gain A_f and the output resistance with feedback R_{of}.

$$g_{m1} = g_{m2} = 4 \text{ mA/V}, \quad R_D = 20 \text{ k}\Omega, \quad r_{o2} = 20 \text{ k}\Omega,$$
$$R_F = 100\ \Omega, \quad R_L = 1 \text{ k}\Omega.$$

For simplicity, neglect r_{o1}, and take r_{o2} into account only when calculating the output resistance.



Find A_f in mA/V:

$$A_f =$$

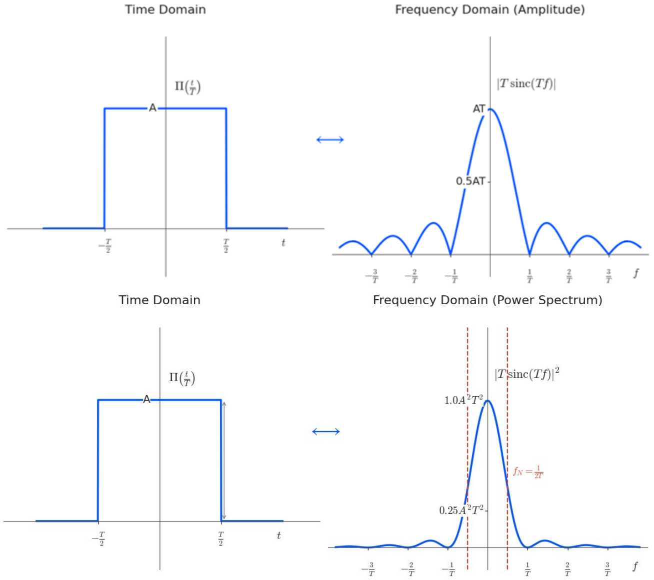
________ mA/V

Find R_{of} in kΩ:

$$R_{of} =$$

________ kΩ

Problem 5. (1 point)
In recent years, AI servers have needed to transmit large amounts of digital data between chips, modules, and systems. As a result, high-speed wireline transmission has become increasingly important. Although digital signals look like square waves composed of 0 and 1 in the time domain, they actually contain many high-frequency components in the frequency domain, as shown by the sinc-shaped spectrum in the figure.



As the transmission speed increases, the symbol period (T) becomes shorter, requiring higher circuit bandwidth. If the bandwidth is insufficient, high-frequency components are attenuated, causing waveform distortion and making data detection harder. Therefore, feedback is important in high-speed receiver circuits because it can extend bandwidth and stabilize the frequency response.

Therefore, in a high-speed wireline transmitter or receiver, the Nyquist frequency is an important bandwidth reference. If the symbol period is T, the Nyquist frequency is

$f_N = \frac{1}{2T}$

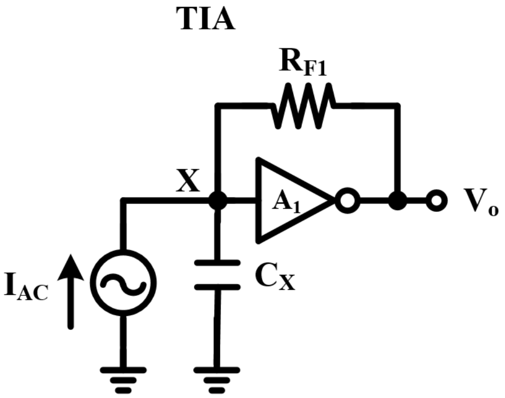
If we want to transmit data at a rate of 50 Gb/s. This means that a binary signal, either 0 or 1, is transmitted 50×10^9 times per second. What is the Nyquist frequency?

$Nyquist\ frequency =$ ________ GHz

Assume all transistor operate in saturation in all of the problems.

In a high-speed wireline receiver, the input signal is often a small AC current. A transimpedance amplifier, or TIA, is used to convert this input current into an output voltage.

The circuit contains an amplifier A_1, a feedback resistor R_F, and an input capacitance C_X at node X. The feedback resistor samples the output voltage and feeds a current back to the input node. Therefore, this is a shunt-shunt feedback circuit.



Assume:

$R_F = 2\text{k}\Omega$

$C_X = 175.9\text{fF}$
The amplifier A_1 is modeled as a ideal amplifier:
Gain is 20 V/V

$Transfer\ Function$ is $\frac{V_o}{I_{AC}} = \frac{A_0}{1+\frac{s}{\omega_p}}$

$\omega_p =$ ________ rad/s
$|A_0| =$ ________ V/A

Problem: Source Degeneration as Local Feedback

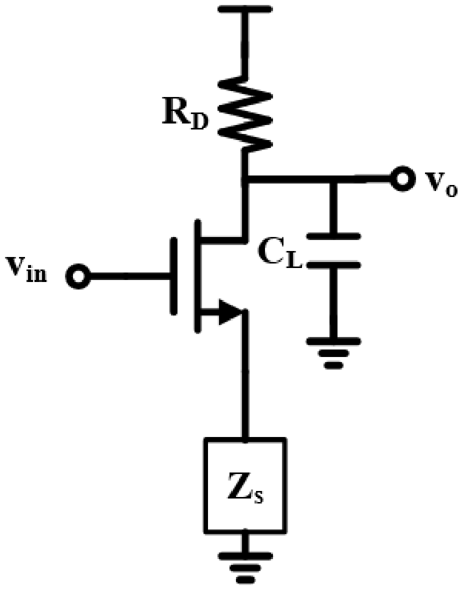
A common-source amplifier uses a source degeneration impedance Z_S, as shown in the figure. Source degeneration is a form of local negative feedback.

When the gate voltage increase then the drain current i_d increases, the source voltage v_s also increases. Since

$$v_{gs} = v_{in} - v_s$$

an increase in v_s reduces v_{gs}. As a result, the drain current is reduced. Therefore, the circuit feeds back a signal that opposes the original current change. This is why source degeneration is called local negative feedback.

CS Amplifier With Source Degeneration



$g_m = 36.1$mS
$Z_s = 0.99$kΩ

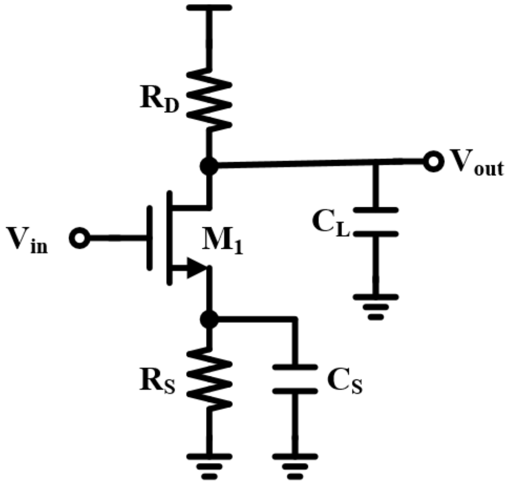
By what factor does source degeneration increase the bandwidth of a CS amplifier compared with the case without source degeneration?
$factor =$ ________

A CTLE, or continuous-time linear equalizer, is commonly used in high-speed wireline receivers. In wireline channels, high-frequency signal components are usually attenuated more than low-frequency components. This causes slower signal transitions, waveform distortion.

The CTLE helps solve this problem by boosting the high-frequency components of the received signal. In this circuit, R_S provides source degeneration at low frequency, which reduces the gain. At high frequency, C_S becomes a short circuit and bypasses (R$_S$)$, sothegainincreases.Therefore, theCTLEhashighergainathig$

As a result, the CTLE can compensate for high frequency component loss, and improve the signal quality at the receiver.

CTLE



$g_m = 36.1$mS
$R_s = 0.99$kΩ
$C_s = 116.4$fF
$R_D = 0.73$kΩ
$C_L = 200$fF

$Transfer\ Function$ is $\frac{V_{out}}{V_{in}} = \frac{A_1(1+\frac{\omega}{\omega_z})}{(1+\frac{s}{\omega_{p1}})(1+\frac{s}{\omega_{p2}})}$

$\omega_{p1} < \omega_{p2}$

$\omega_{p1} =$ ________rad/s
$\omega_{p2} =$ ________rad/s

$\omega_z =$ ________ rad/s
$A_1 =$ ________ V/V

As you can see, by suppressing the low-frequency components, we can relatively enhance part of the high-frequency components, which helps increase the overall system bandwidth.