Problem 1

Find the small signal bandwidth limitation for the circuits below. (Do find $F$ where $F = \frac{B_{\text{ub}}}{\text{gain}}$)

Circuit 1

\[
\begin{align*}
V_1 &\quad \text{Input} \\
10K &\quad \text{Resistor} \\
V_2 &\quad \text{Input} \\
10K &\quad \text{Resistor} \\
\text{LMV324} &\quad \text{Op-amp} \\
10K &\quad \text{Resistor} \\
&\quad \text{Ground}
\end{align*}
\]

Circuit 2

\[
\begin{align*}
\text{Vin} &\quad \text{Input} \\
10K &\quad \text{Resistor} \\
100K &\quad \text{Resistor} \\
\text{LF347} &\quad \text{Op-amp} \\
V_0 &\quad \text{Output}
\end{align*}
\]

Circuit 3

\[
\begin{align*}
\text{Vin} &\quad \text{Input} \\
\text{LMV324} &\quad \text{Op-amp} \\
R_x &\quad \text{Resistor} \\
V_0 &\quad \text{Output}
\end{align*}
\]
Problem 2

In the circuits below, find the gain \( \frac{V_O}{V_S} \) and specify the value of \( R_x \) to eliminate bias currents.

Circuit 1

Circuit 2
Circuit 3

Find $V_0/I_s$ for this ckt.

Circuit 4

Find $V_0/I_s$ for this ckt.

Notes: To set a current source to zero, replace the current source by an open circuit.
Problem 3

Find $V_1$, $V_2$, $V_3$, $V_4$, $V_5$, $V_0$

- All Op-Amps Have ±15V Supplies

$V_s = ±5V$

$V_0 = ±5V$
Problem 4

Let \( V_{in} = A \sin \omega t \)

A) For Circuit A

i) For \( \omega = 100,000 \ \text{rad/s} \), what is the largest value of \( A \) we can have without seeing Slew Rate distortion at \( V_o \)?

ii) For \( A = 10 \), what is the largest value of \( \omega \) we can have without seeing Slew Rate distortion at \( V_o \)?

B) Repeat i and ii for Circuit B.
LMV321 Single/ LMV358 Dual/ LMV324 Quad
Operational Amplifiers

General Description
The LMV358/324 are low voltage (2.7–5.5V) versions of the
dual and quad commodity op amps, LM358/324, which cur-
cently operate at 5–30V. The LMV321 is the single version.
The LMV321/358/324 are the most cost effective solutions
for the applications where low voltage operation, space sav-
ing and low price are needed. They offer specifications that
meet or exceed the familiar LM358/324. The
LMV321/358/324 have rail-to-rail output swing capability and
the input common-mode voltage range includes ground.
They all exhibit excellent speed-power ratio, achieving
1 MHz of bandwidth and 1 V/μs of slew rate with low supply
current.
The LMV321 is available in space saving SC70-5, which is
approximately half the size of SOT23-5. The small package
saves space on pc boards, and enables the design of small
portable electronic devices. It also allows the designer to
place the device closer to the signal source to reduce noise
pick-up and increase signal integrity.
The chips are built with National's advanced submicron
silicon-gate BICMOS process. The LMV321/358/324 have
bipolar input and output stages for improved noise perfor-
mance and higher output current drive.

Features
(For V” = 5V and V’ = 0V, Typical Unless Otherwise Noted)
- Guaranteed 2.7V and 5V Performance
- No Crossover Distortion
- Space Saving Package SC70-5 2.0x2.1x1.0mm
- Industrial Temp.Range -40°C to +85°C
- Gain-Bandwidth Product 1MHz
- Low Supply Current
  - LMV321 130μA
  - LMV358 210μA
  - LMV324 410μA
- Rail-to-Rail Output Swing
  @ 10kΩ Load
  V” – 10mV
  V’ – 65mV
- V_CM –0.2V to V” –0.8V

Applications
- Active Filters
- General Purpose Low Voltage Applications
- General Purpose Portable Devices

Connection Diagrams

![Connection Diagrams](image-url)
5V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $T_J = 25^\circ C$, $V^+ = 5V$, $V^- = 0V$, $V_{CM} = 2.0V$, $V_O = V^+/2$ and $R_L > 1 \, M\Omega$.
Boldface limits apply at the temperature extremes.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Typ (Note 6)</th>
<th>Limit (Note 7)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>Slew Rate</td>
<td></td>
<td>1</td>
<td></td>
<td>$V/\mu s$</td>
</tr>
<tr>
<td>GBWP</td>
<td>Gain-Bandwidth Product</td>
<td>$C_L = 200 , pF$</td>
<td>1</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>$\Phi_m$</td>
<td>Phase Margin</td>
<td></td>
<td>60</td>
<td></td>
<td>Deg</td>
</tr>
<tr>
<td>$G_m$</td>
<td>Gain Margin</td>
<td></td>
<td>10</td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>$\theta_v$</td>
<td>Input-Referred Voltage Noise</td>
<td>$f = 1 , kHz$</td>
<td>39</td>
<td></td>
<td>nV/Hz</td>
</tr>
<tr>
<td>$i_n$</td>
<td>Input-Referred Current Noise</td>
<td>$f = 1 , kHz$</td>
<td>0.21</td>
<td></td>
<td>$\mu A$/V/Hz</td>
</tr>
</tbody>
</table>

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics.
Note 2: Human body model, 1.5 kΩ in series with 100 pF; Machine model, 0Ω in series with 200 pF.
Note 3: Shorting output to $V^+$ will adversely affect reliability.
Note 4: Shorting output to $V^-$ will adversely affect reliability.
Note 5: The maximum power dissipation is a function of $T_J$, $\theta_J$, and $T_a$. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_J(\text{MAX}) - T_a)/\theta_J$. All numbers apply for packages soldered directly into a PC board.
Note 6: Typical values represent the most likely parametric norm.
Note 7: All limits are guaranteed by testing or statistical analysis.
Note 8: $R_L$ is connected to $V^-$. The output voltage is $0.0V \leq V_O \leq 4.5V$.
Note 9: Connected as voltage follower with 3V peak input. Number specified is the slower of the positive and negative slew rates.
Note 10: All numbers are typical, and apply for packages soldered directly onto a PC board in still air.

Typical Performance Characteristics

Unless otherwise specified, $V_S = +5V$, single supply, $T_A = 25^\circ C$. 

![Supply Current vs Supply Voltage](DS100000-70)

![Input Current vs Temperature](DS100000-49)

![Sourcing Current vs Output Voltage](DS100000-50)

![Sourcing Current vs Output Voltage](DS100000-51)

![Sinking Current vs Output Voltage](DS100000-52)

![Sinking Current vs Output Voltage](DS100000-53)

www.national.com
LF147/LF347 Wide Bandwidth Quad JFET Input Operational Amplifiers

General Description
The LF147 is a low cost, high speed quad JFET input operational amplifier with an internally trimmed input offset voltage (BiFET™ technology). The device requires a low supply current and yet maintains a large gain bandwidth product and a fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The LF147 is pin compatible with the standard LM148. This feature allows designers to immediately upgrade the overall performance of existing LF148 and LM124 designs.

The LF147 may be used in applications such as high speed integrators, fast A/D converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The device has low noise and offset voltage drift.

Features
- Internally trimmed offset voltage: 5 mV max
- Low input bias current: 50 pA
- Low input noise current: 0.01 pA/Hz
- Wide gain bandwidth: 4 MHz
- High slew rate: 13 V/µs
- Low supply current: 7.2 mA
- High input impedance: 10^12Ω
- Low total harmonic distortion A_v = 10, <0.02%
- R_L = 10k, V_O = 20 Vp-p, BW = 20 Hz–20 kHz
- Low 1/f noise corner: 50 Hz
- Fast settling time to 0.01%: 2 µs

Simplified Schematic

Connection Diagram

Dual-In-Line Package

Top View
Order Number LF147J, LF347M, LF347BN, LF347N, LF147D/883 or LF147J/883*
See NS Package Number D14E, J14A, M14A or N14A

*Available per SMD #8102306, JM38510/11906.
BiFET™ is a trademark of National Semiconductor Corporation.

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### AC Electrical Characteristics (Note 5)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>LF147</th>
<th>LF347B</th>
<th>LF347</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amplifier to Amplifier Coupling</td>
<td>$T_A = 25^\circ$C, $f = 1 \text{ Hz} - 20 \text{ kHz}$ (Input Ref.); $V_S = \pm 15 \text{ V}$, $T_A = 25^\circ$C; $f = 1000 \text{ Hz}$</td>
<td>8</td>
<td>13</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Slew Rate</td>
<td>$V_S = \pm 15 \text{ V}$, $T_A = 25^\circ$C</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>GBW Gain-Bandwidth Product</td>
<td>$V_S = \pm 15 \text{ V}$, $T_A = 25^\circ$C</td>
<td>2.2</td>
<td>4</td>
<td>2.2</td>
<td>4</td>
</tr>
<tr>
<td>$e_n$</td>
<td>Equivalent Input Noise Voltage</td>
<td>$T_A = 25^\circ$C, $R_0 = 100\Omega$, $f = 1000 \text{ Hz}$</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>$I_n$</td>
<td>Equivalent Input Noise Current</td>
<td>$T_A = 25^\circ$C, $f = 1000 \text{ Hz}$</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

**Note 2:** Any of the amplifier outputs can be shorted to ground indefinitely, however, more than one should not be simultaneously shorted as the maximum junction temperature will be exceeded.

**Note 3:** For operating at elevated temperatures, these devices must be derated based on a thermal resistance of $\theta_{JA}$.

**Note 4:** The LF147 is available in the military temperature range $-55^\circ$C $\leq T_A \leq 125^\circ$C, while the LF347B and the LF347 are available in the commercial temperature range $0^\circ$C $\leq T_A \leq 70^\circ$C. Junction temperature can rise to $T_J \leq 5^\circ$C.

**Note 5:** Unless otherwise specified the specifications apply over the full temperature range and for $V_V = \pm 20 \text{ V}$ for the LF147 and for $V_V = \pm 15 \text{ V}$ for the LF347B/LF347. $V_G$, $I_G$, and $I_{GB}$ are measured at $V_{CM} = 0$.

**Note 6:** The input bias currents are junction leakage currents which approximately double for every $10^\circ$C increase in the junction temperature. $T_J$. Due to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, $P_J = T_J - T_A + \theta_{JA} P_J$, where $\theta_{JA}$ is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

**Note 7:** Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice from $V_V = \pm 5 \text{ V}$ to $\pm 15 \text{ V}$ for the LF347 and LF347B and from $V_V = \pm 20 \text{ V}$ to $\pm 5 \text{ V}$ for the LF147.

**Note 8:** Refer to RETS147X for LF147D and LF147J military specifications.

**Note 9:** Max. Power Dissipation is defined by the package characteristics. Operating the part near the Max. Power Dissipation may cause the part to operate outside guaranteed limits.

**Note 10:** Human body model, 1.5 kΩ in series with 100 pF.