Problem 1 (25 Points):

a) Find the capacitor current $I_C$. Assume that the Zener has a breakdown voltage of $1.2V$. (17 Points)
b) If the capacitor voltage starts at zero volts, plot the capacitor voltage for 5 seconds. (8 Points)
Problem 2: (20 Points)

The OPAMP above is a MAX492 OPAMP.

a) Find the values of $a$ and $A_0$ for the MAX492. A datasheet is attached to the end of this exam. (5 points)
b) Find the upper -3dB frequency for this circuit. (15 points)
In the circuit above, if all of the resistors have the same value, the circuit is a difference amplifier where
\( V_0 = V_1 - V_2 \). Assume that the OPAMPS have bias currents of \( I_B = 1 \, \mu\text{A} \).

a) If the resistors are ideal and have no tolerance, what is the circuit’s output voltage due to bias currents? (5 Points)

b) If the resistors have a ±5% tolerance, and the resistors do not track one another (that is, one resistor could be \( R + 5\% \) while another resistor could be \( R - 5\% \)), find an equation for the largest possible output voltage of the circuit due to bias currents. (15 Points)

c) Assuming resistors with ±5% tolerance, what is the difference in the circuit’s output voltage due to bias currents if we use \( R = 10 \, \text{k}\Omega \) versus \( R = 1 \, \text{M}\Omega \)? (5 Points)

d) Given the result found in part (c), why don’t we use \( R = 1 \, \Omega \)? (5 Points)
Assume that the Zeners have a breakdown voltage of 4.3 V and a forward voltage of 0.7 V. You may assume that the diode is ideal.
a) Draw the transfer curve. (5 points)
c) Find numerical values for the UTP and LTP. (20 points)
**General Description**

The dual MAX492, quad MAX494, and single MAX495 operational amplifiers combine excellent DC accuracy with rail-to-rail operation at the input and output. Since the common-mode voltage extends from VCC to VEE, the devices can operate from either a single supply (+2.7V to +6V) or split supplies (±1.35V to ±3V). Each op amp requires less than 150µA supply current. Even with this low current, the op amps are capable of driving a 1kΩ load, and the input referred voltage noise is only 25nV/√Hz. In addition, these op amps can drive loads in excess of 1nF.

The precision performance of the MAX492/MAX494/MAX495, combined with their wide input and output dynamic range, low-voltage single-supply operation, and very low supply current, makes them an ideal choice for battery-operated equipment and other low-voltage applications. The MAX492/MAX494/MAX495 are available in DIP and SO packages in the industry-standard op-amp pin configurations. The MAX495 is also available in the smallest 8-pin SO: the µMAX package.

**Applications**

- Portable Equipment
- Battery-Powered Instruments
- Data Acquisition
- Signal Conditioning
- Low-Voltage Applications

**Features**

- Low-Voltage Single-Supply Operation (+2.7V to +6V)
- Rail-to-Rail Input Common-Mode Voltage Range
- Rail-to-Rail Output Swing
- 500kHz Gain-Bandwidth Product
- Unity-Gain Stable
- 150µA Max Quiescent Current per Op Amp
- No Phase Reversal for Overdriven Inputs
- 200µV Offset Voltage
- High Voltage Gain (108dB)
- High CMRR (90dB) and PSRR (110dB)
- Drives 1kΩ Load
- Drives Large Capacitive Loads
- MAX495 Available in µMAX Package—8-Pin SO

**Ordering Information**

*Dice are specified at TA = +25°C, DC parameters only.

<table>
<thead>
<tr>
<th>PART</th>
<th>TEMP. RANGE</th>
<th>PIN-PACKAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX492CPA</td>
<td>0°C to +70°C</td>
<td>8 Plastic DIP</td>
</tr>
<tr>
<td>MAX492CSA</td>
<td>0°C to +70°C</td>
<td>8 SO</td>
</tr>
<tr>
<td>MAX492C/D</td>
<td>0°C to +70°C</td>
<td>Dice*</td>
</tr>
<tr>
<td>MAX492EPA</td>
<td>-40°C to +85°C</td>
<td>8 Plastic DIP</td>
</tr>
<tr>
<td>MAX492ESA</td>
<td>-40°C to +85°C</td>
<td>8 SO</td>
</tr>
<tr>
<td>MAX492MJA</td>
<td>-55°C to +125°C</td>
<td>8 CERDIP</td>
</tr>
</tbody>
</table>

Ordering Information continued at end of data sheet.

**Typical Operating Circuit**

**Pin Configurations**

![Typical Operating Circuit](image)

![Pin Configurations](image)
## AC ELECTRICAL CHARACTERISTICS

(V\text{CC} = 2.7V to 6V, V\text{EE} = GND, TA = +25°C, unless otherwise noted.)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain-Bandwidth Product</td>
<td>RL = 100kΩ, CL = 100pF</td>
<td>500</td>
<td></td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>Phase Margin</td>
<td>RL = 100kΩ, CL = 100pF</td>
<td>60</td>
<td></td>
<td></td>
<td>degrees</td>
</tr>
<tr>
<td>Gain Margin</td>
<td>RL = 100kΩ, CL = 100pF</td>
<td>10</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Total Harmonic Distortion</td>
<td>RL = 10kΩ, CL = 15pF, V\text{OUT} = 2Vp-p, Av = +1, f = 1kHz</td>
<td>0.003</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Slew Rate</td>
<td>RL = 100kΩ, CL = 15pF</td>
<td>0.20</td>
<td></td>
<td></td>
<td>V/µs</td>
</tr>
<tr>
<td>Time</td>
<td>To 0.1%, 2V step</td>
<td>12</td>
<td></td>
<td></td>
<td>µs</td>
</tr>
<tr>
<td>Turn-On Time</td>
<td>V\text{CC} = 0V to 3V step, Vi = V\text{CC} / 2, Av = +1</td>
<td>5</td>
<td></td>
<td></td>
<td>µs</td>
</tr>
<tr>
<td>Input Noise-Voltage Density</td>
<td>f = 1kHz</td>
<td>25</td>
<td></td>
<td></td>
<td>nV/√Hz</td>
</tr>
<tr>
<td>Input Noise-Current Density</td>
<td>f = 1kHz</td>
<td>0.1</td>
<td></td>
<td></td>
<td>pA/√Hz</td>
</tr>
<tr>
<td>Amp-Amp Isolation</td>
<td>f = 1kHz</td>
<td>125</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
</tbody>
</table>

## DC ELECTRICAL CHARACTERISTICS

(V\text{CC} = 2.7V to 6V, V\text{EE} = GND, V\text{CM} = 0V, V\text{OUT} = V\text{CC} / 2, TA = 0°C to +70°C, unless otherwise noted.)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Offset Voltage</td>
<td>V\text{CM} = V\text{EE} to V\text{CC}</td>
<td>±650</td>
<td></td>
<td></td>
<td>µV</td>
</tr>
<tr>
<td>Input Offset Voltage Tempco</td>
<td>V\text{CM} = V\text{EE} to V\text{CC}</td>
<td>±2</td>
<td></td>
<td></td>
<td>µV/°C</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>V\text{CM} = V\text{EE} to V\text{CC}</td>
<td>±75</td>
<td></td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>V\text{CM} = V\text{EE} to V\text{CC}</td>
<td>±6</td>
<td></td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>Common-Mode Input Voltage Range</td>
<td>(V\text{EE} - 0.20) ≤ V\text{CM} ≤ (V\text{CC} + 0.20)</td>
<td>V\text{EE} - 0.20</td>
<td>V\text{CC} + 0.20</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Common-Mode Rejection Ratio</td>
<td>(V\text{EE} - 0.20) ≤ V\text{CM} ≤ (V\text{CC} + 0.20)</td>
<td>72</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Power-Supply Rejection Ratio</td>
<td>V\text{CC} = 2.7V to 6V</td>
<td>86</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Large-Signal Voltage Gain (Note 1)</td>
<td>V\text{CC} = 2.7V, RL = 100kΩ, V\text{OUT} = 0.25V to 2.45V</td>
<td>Sourcing</td>
<td>88</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>V\text{CC} = 2.7V, RL = 100kΩ, V\text{OUT} = 0.5V to 2.2V</td>
<td>Sinking</td>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage Swing (Note 1)</td>
<td>RL = 100kΩ, VoH</td>
<td>V\text{CC} - 0.075</td>
<td>V\text{EE} - 0.075</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VoL</td>
<td>V\text{CC} - 0.20</td>
<td>V\text{EE} + 0.20</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Operating Supply Voltage Range</td>
<td>RL = 1kΩ</td>
<td>VoH</td>
<td>V\text{CC} = 2.7V</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td>VoL</td>
<td>V\text{CC} = 5V</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Single/Dual/Quad, Micropower, Single-Supply Rail-to-Rail Op Amps

Typical Operating Characteristics

(T_A = +25°C, V_CC = 5V, V_EE = 0V, unless otherwise noted.)

GAIN AND PHASE vs. FREQUENCY

FREQUENCY (kHz)

GAIN (dB)

PHASE (DEG)

AV = +1000
NO LOAD

MAX492-01

FREQUENCY (kHz)

GAIN (dB)

PHASE (DEG)

CL = 470pF
AV = +1000
RL = ∞

MAX492-02

POWER-SUPPLY REJECTION RATIO vs. FREQUENCY

FREQUENCY (kHz)

PSRR (dB)

VIN = 2.5V
VCC
VEE

MAX492-03

CHANNEL SEPARATION vs. FREQUENCY

FREQUENCY (kHz)

CHANNEL SEPARATION (dB)

VIN = 2.5V

MAX492-04

INPUT BIAS CURRENT vs. COMMON-MODE VOLTAGE

VCM (V)

INPUT BIAS CURRENT (nA)

VCC = 2.7V
VCC = 6V

MAX492-07

OFFSET VOLTAGE vs. TEMPERATURE

TEMPERATURE (°C)

OFFSET VOLTAGE (µV)

VCM = 0V

MAX492-05

COMMON-MODE REJECTION RATIO vs. TEMPERATURE

TEMPERATURE (°C)

CMRR (dB)

VCM = 0V TO +5V
VCM = -0.1V TO +5.1V
VCM = -0.2V TO +5.2V
VCM = -0.3V TO +5.3V
VCM = -0.4V TO +5.4V

MAX492-06

INPUT BIAS CURRENT vs. TEMPERATURE

TEMPERATURE (°C)

INPUT BIAS CURRENT (nA)

VCC = 2.7V
VCC = 6V

MAX492-08

SUPPLY CURRENT PER AMPLIFIER vs. TEMPERATURE

TEMPERATURE (°C)

SUPPLY CURRENT PER OP AMP (µA)

VCC = 5V
VCC = 2.7V

MAX492-09