 midterm EXam on Feb 2
1 page of Formulas, tables & Calculators lined
coverage (up to Jan 31)

- Ohm’s Law
- Kirchhoff’s Laws (voltage, current)
- Capacitors (sheet, board, power, -
- Series-parallel circuit (Thevenin, Norton)
- Diodes, Diode circuits (including LEDs)
- Off-power circuit
5 problems for 45 min examination

Table 4-1: Characteristics and typical ranges of op-amp parameters. The rightmost column represents the values assumed by the ideal op-amp model.

<table>
<thead>
<tr>
<th>Op-Amp Characteristics</th>
<th>Parameter</th>
<th>Typical Range</th>
<th>Ideal Op-Amp</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Linear input-output impedance</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>- High input resistance</td>
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<tr>
<td>- Low output resistance</td>
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<tr>
<td>- No output noise</td>
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<td></td>
<td></td>
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<tr>
<td>- slew rate</td>
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<td></td>
<td></td>
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<tr>
<td>- Supply voltage</td>
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</tbody>
</table>

Figure 4.6: Equivalent circuit model for an op-amp operating
in the linear range ($v_{in} < |V_{cc}|$). Voltages $v_{in}$, $v_{out}$, and $i_{out}$ are referenced to ground.

Figure 4.7: Summing amplifier circuit of Example 4.1.
Basic Rules of Op-Amp Circuits

1. KCL and KVL always apply everywhere in the circuit, but KCL is inapplicable at the output node when applying the ideal op-amp model. All other circuit-analysis tools can be applied to op-amp circuits.

2. The op amp will operate in the linear range so long as $|v_{in}| < |V_{sat}|$.

3. The ideal op-amp model assumes that the source resistance $R_s$ (connected to terminals $v_{ip}$ or $v_{ip}$) is much smaller than the op-amp input resistance $R_i$ (which usually is no less than 10 MΩ), and the load resistance $R_L$ is much larger than the op-amp output resistance $R_o$ (which is in the order of tens of ohms).

4. The ideal op-amp constraints are $i_p = i_o = 0$ and $v_p = v_o$.

4.11 Determine the output voltage for the circuit in Fig. P4.11 and specify the linear range for $v_{in}$ given that $V_{sat} = 15$ V and $V_o = 0$. 

![Figure P4.11: Circuit for Problems 4.11 and 4.12.](image)

4.12 Repeat Problem 4.11 for $V_o = 0.1$ V.

![Figure P4.14: Circuit for Problem 4.14.](image)

4.17 Determine $v_{o}$ across the 10 kΩ resistor in the circuit of Fig. P4.17.

![Figure P4.17: Circuit for Problem 4.17.](image)

4.22 The circuit in Fig. P4.22 uses a potentiometer whose total resistance is $R = 10 k$Ω with the upper section being $\beta R$ and the bottom section $(1-\beta)R$. The stylus can change $\beta$ from 0 to 0.9. Obtain an expression for $G = i_o / i_o$ in terms of $\beta$ and evaluate the range of $G$ (as $\beta$ is varied over its own allowable range).

![Figure P4.22: Circuit for Problem 4.22.](image)
4.23 For the circuit in Fig. P4.23, obtain an expression for voltage gain $G = v_o/v_i$.

Figure P4.23: Circuit for Problem 4.23.

\[ \frac{v_o}{v_i} = -\frac{4K}{4K+6K} = -\frac{4}{10} = -0.4 \]

4.24 Find the value of $v_o$ in the circuit in Fig. P4.24.

Figure P4.24: Circuit for Problem 4.24.

\[ v_o = 4 \times (0) + (5) = 5 \]