8 Detailed Description

8.1 Overview

These devices consist of four independent high-gain frequency-compensated operational amplifiers that are designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies also is possible if the difference between the two supplies is 3 V to 32 V (3 V to 26 V for the LM2902 device), and $V_{CC}$ is at least 1.5 V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, DC amplification blocks, and all the conventional operational-amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM124 device can be operated directly from the standard 5-V supply that is used in digital systems and provides the required interface electronics, without requiring additional ±15-V supplies.

8.2 Functional Block Diagram

![Diagram of the functional block diagram]

<table>
<thead>
<tr>
<th>COMPONENT COUNT (total device)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Epi-FET</td>
<td>1</td>
</tr>
<tr>
<td>Transistors</td>
<td>95</td>
</tr>
<tr>
<td>Diodes</td>
<td>4</td>
</tr>
<tr>
<td>Resistors</td>
<td>11</td>
</tr>
<tr>
<td>Capacitors</td>
<td>4</td>
</tr>
</tbody>
</table>

† ESD protection cells - available on LM324K and LM324KA only
3) \( I_{\text{out}} = 50 \mu A \Rightarrow Q_2 = 50 \times Q_1 \)

\( I_{\text{tail}} = 6 \mu A \), so \( Q_4 = 6 Q_3 \)

\( I_{\text{C}} = 6 \mu A \) so \( Q_5 = 6 Q_3 \)

\( I_{\text{CE}} = 100 \mu A \) so \( Q_6 = 100 Q_3 \)

With finite \( \beta \) and device mismatch, you'd actually need to be much more careful, but this is OK.

4) For all transistors, \( g_m = \frac{2I_0}{V_{ov}} = \frac{200 \mu A}{200 mV} = 1 mS \)

\( r_o = \frac{1}{g_m} = \frac{5 V}{100 \mu A} = 50 k\Omega \)

For all circuits, \( g_m \) is just \( g_m \) of the input device, or \( 1 mS \)

So for all circuits, \( L_m = \frac{g_m}{L} = \frac{50 k\Omega}{5} = 10 k\Omega \)

\( V_{\text{out max}} \) with \( 1 V \) dropped on the resistor, this is \( 1.3 V \)
6) $$G_m = \frac{\mathcal{I}_0}{v_0} \bigg|_{v_0 = 0}$$

\[ v_s = i_0 R_s \]

d) KCL @ $V_s$:  
$$\mathcal{I}_0 - g_m v_{gs} - \frac{i_0}{r_0} (v_0 - v_s) = 0$$

$$\mathcal{I}_0 - g_m (v_c - i_0 R_s) - \frac{i_0}{r_0} (0 - i_0 R_s) = 0$$

$$\mathcal{I}_0 \left[ 1 + g_m R_s + \frac{R_s}{r_0} \right] = g_m v_c$$

$$G_m = \frac{\mathcal{I}_0}{v_c} = \frac{g_m}{1 + g_m R_s + \frac{R_s}{r_0}}$$

$$G_m = \begin{cases} 
\frac{g_m}{R_s} & R_s \ll \frac{1}{g_m} \\
\frac{g_m}{2} & R_s = \frac{1}{g_m} \\
\frac{1}{R_s} & R_s \gg \frac{1}{g_m} 
\end{cases}$$