Formula sheet

<table>
<thead>
<tr>
<th>Configuration/Parameter</th>
<th>(A_v)</th>
<th>(Z_{\text{in}})</th>
<th>(Z_{\text{o}})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CE with feedback</strong></td>
<td>(\frac{\beta R_L'}{r_{\pi} + (\beta + 1)R_E})</td>
<td>(R_B \parallel (r_{\pi} + (\beta + 1)R_E))</td>
<td>(R_C)</td>
</tr>
<tr>
<td><strong>CE w/o feedback</strong></td>
<td>(-g_m R_L)</td>
<td>(R_B \parallel r_{\pi})</td>
<td>(R_C)</td>
</tr>
<tr>
<td><strong>CC</strong></td>
<td>(\frac{(1 + \beta)R_L'}{r_{\pi} + (1 + \beta)R_L'})</td>
<td>(R_B \parallel (r_{\pi} + (\beta + 1)R_L'))</td>
<td>(R_E + R_S\parallel r_{\pi})</td>
</tr>
<tr>
<td><strong>CB</strong></td>
<td>(g_m R_L)</td>
<td>(R_E \parallel [r_{\pi}/(\beta + 1)])</td>
<td>(R_C)</td>
</tr>
<tr>
<td><strong>CS with feedback</strong></td>
<td>(-g_m R_L)</td>
<td>(R_G)</td>
<td>(R_D)</td>
</tr>
<tr>
<td><strong>CS w/o feedback</strong></td>
<td>(-g_m R_L)</td>
<td>(R_G)</td>
<td>(R_D)</td>
</tr>
<tr>
<td><strong>CD</strong></td>
<td>(g_m R_L)</td>
<td>(R_G)</td>
<td>(\frac{1}{g_m} \parallel R_{\sigma})</td>
</tr>
<tr>
<td><strong>CG</strong></td>
<td>(g_m R_L)</td>
<td>(\frac{1}{g_m} \parallel R_{\sigma})</td>
<td>(R_D)</td>
</tr>
</tbody>
</table>

\[g_m = \frac{I_{\text{CQ}}}{V_T}\]
\[g_m = \frac{\partial i_D}{\partial v_{GS}}\bigg|_{Q_{\text{pt}}}\]
\[r_o = \frac{V_A}{I_{\text{CQ}}}\]

\[I_D = k(V_{GS} - V_T)^2 = I_{\text{DSS}}\left(1 - \frac{V_{GS}}{V_P}\right)^2\]

Effect of emitter bypass capacitor:

\[f_1 = \frac{1}{2\pi R_E C_E'}\] and \[f_2 = \frac{1}{2\pi R_E' C_E}\]

where \(R_E' = R_E \parallel \left(\frac{r_{\pi} + R_B}{\beta + 1}\right)\)

(continued next page)

Formula sheet (continued)
Current source design equations

Simple current source \( I_{ref} = \frac{V_{CC} + V_{EE} - V_f}{R_1} \)

Widlar current source \( I_o = \frac{V_T}{R_2} \ln \left( \frac{V_{CC} + V_{EE} - V_f}{R_1 I_o} \right) \)

Wilson current source \( I_o = \frac{V_{CC} + V_{EE} - 2V_f}{R_1} \)

Current source output impedances:

Simple current source \( R_o = r_o \)

Widlar current source \( R_o = r_o (1 + g_m R_2) \)

Wilson current source \( R_o = \left( 1 + \frac{\beta}{2} \right) r_o \)
\[ V_1 = h_{11}I_1 + h_{12}V_2 \]
\[ I_2 = h_{21}I_1 + h_{22}V_2 \]

\[ V_1 = z_{11}I_1 + z_{12}I_2 \]
\[ V_2 = z_{21}I_1 + z_{22}I_2 \]

\[ I_1 = y_{11}V_1 + y_{12}V_2 \]
\[ I_2 = y_{21}V_1 + y_{22}V_2 \]

\[ I_1 = g_{11}V_1 + g_{12}I_2 \]
\[ V_2 = g_{21}V_1 + g_{22}I_2 \]