AT-32032
Low Current, High Performance
NPN Silicon Bipolar Transistor

Data Sheet

Description

Avago's AT-32032 is a high performance NPN bipolar transistor that has been optimized for maximum $f_t$ at low voltage operation, making it ideal for use in battery powered applications in cellular/PCS and other wireless markets. The AT-32032 uses the miniature 3 lead SOT-323 (SC-70) plastic package.

Optimized performance at 2.7 V makes this device ideal for use in 900 MHz, 1.8 GHz, and 2.4 GHz systems. Typical amplifier design at 900 MHz yields 1 dB noise figures with 15 dB associated gain at 2.7 V and 5 mA bias condition, with noise performance being relatively insensitive to input match. High gain capability at 1 V and 1 mA makes this device a good fit for 900 MHz pager applications. Moreover, voltage breakdown is high enough for use at 5 V.

The AT-32032 belongs to Avago's AT-3XXXX series bipolar transistors. It exhibits excellent device uniformity, performance and reliability as a result of ion-implantation, self-alignment techniques, and gold metalization in the fabrication process.

Features

- High Performance Bipolar Transistor Optimized for Low Current, Low Voltage Applications at 900 MHz, 1.8 GHz, and 2.4 GHz
- Performance at 2.7 V, 5 mA:
  - 900 MHz: 1 dB NF, 15 dB $G_A$
  - 1800 MHz: 1.3 dB NF, 11 dB $G_A$
  - 2400 MHz: 1.4 dB NF, 7.5 dB $G_A$
- Characterized for End-Of-Life Battery Use (2.7 V)
- Miniature 3-lead SOT-323 (SC-70) Plastic Package
- Lead-free

Applications

- LNA, Oscillator, Driver Amplifier, Buffer Amplifier, and Down Converter for Cellular and PCS Handsets and Cordless Telephones
- LNA, Oscillator, Mixer, and Gain Amplifier for Pagers
- Power Amplifier and Oscillator for RF-ID Tag
- LNA and Gain Amplifier for GPS
- LNA for CATV Set-Top Box

3-Lead SC-70 (SOT-323)
Surface Mount Plastic Package

Pin Configuration

```
+------------------+
|                  |
|  COLLECTOR       |
|                  |
+------------------+
                  +------------------+
                  |                  |
                  |  32               |
                  +------------------+
                  |                  |
                  |  BASE Emitter     |
```
### AT-32032 Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Units</th>
<th>Absolute Maximum[^1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_EBO</td>
<td>Emitter-Base Voltage</td>
<td>V</td>
<td>1.5</td>
</tr>
<tr>
<td>V_CBO</td>
<td>Collector-Base Voltage</td>
<td>V</td>
<td>11</td>
</tr>
<tr>
<td>V_CEO</td>
<td>Collector-Emitter Voltage</td>
<td>V</td>
<td>5.5</td>
</tr>
<tr>
<td>I_C</td>
<td>Collector Current</td>
<td>mA</td>
<td>40</td>
</tr>
<tr>
<td>P</td>
<td>Power Dissipation[^2, 3]</td>
<td>mW</td>
<td>200</td>
</tr>
<tr>
<td>T_J</td>
<td>Junction Temperature</td>
<td>°C</td>
<td>150</td>
</tr>
<tr>
<td>T_STG</td>
<td>Storage Temperature</td>
<td>°C</td>
<td>-65 to 150</td>
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</table>

[^1]: Operation of this device above any one of these parameters may cause permanent damage.
[^2]: T_MOUNTING_SURFACE = 25°C.
[^3]: Derate at 2.86 mW/°C for T_MOUNTING_SURFACE > 80°C.

### Electrical Specifications, $T_A = 25^\circ$C

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameters and Test Conditions</th>
<th>Units</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
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</thead>
<tbody>
<tr>
<td>NF</td>
<td>Noise Figure $V_{CE} = 2.7$ V, $I_C = 5$ mA</td>
<td>dB</td>
<td>1.0</td>
<td>1.25</td>
<td>1.3</td>
</tr>
<tr>
<td>G_A</td>
<td>Associated Gain $V_{CE} = 2.7$ V, $I_C = 5$ mA</td>
<td>dB</td>
<td>13.5</td>
<td>15.0</td>
<td>10.5</td>
</tr>
<tr>
<td>h_FE</td>
<td>Forward Current Transfer Ratio $V_{CE} = 2.7$ V, $I_C = 5$ mA</td>
<td>–</td>
<td>70</td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>I_CBO</td>
<td>Collector Cutoff Current $V_{CB} = 3$ V</td>
<td>µA</td>
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<td>0.2</td>
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<tr>
<td>I_EBO</td>
<td>Emitter Cutoff Current $V_{EB} = 1$ V</td>
<td>µA</td>
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<td>1.5</td>
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### AT-32032 Characterization Information, $T_A = 25^\circ$C

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameters and Test Conditions</th>
<th>Units</th>
<th>Typ.</th>
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</thead>
<tbody>
<tr>
<td>P_1dB</td>
<td>Power at 1 dB Gain Compression (opt tuning) $V_{CE} = 2.7$ V, $I_C = 20$ mA</td>
<td>dBm</td>
<td>13</td>
</tr>
<tr>
<td>G_1dB</td>
<td>Gain at 1 dB Gain Compression (opt tuning) $V_{CE} = 2.7$ V, $I_C = 20$ mA</td>
<td>dB</td>
<td>15.5</td>
</tr>
<tr>
<td>IP_3</td>
<td>Output Third Order Intercept Point (opt tuning) $V_{CE} = 2.7$ V, $I_C = 20$ mA</td>
<td>dBm</td>
<td>23</td>
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<tr>
<td></td>
<td>Gain in 50 Ω System $V_{CE} = 2.7$ V, $I_C = 2$ mA</td>
<td>dB</td>
<td>11.5</td>
</tr>
</tbody>
</table>
AT-32032 Typical Performance

Figure 1. AT-32032 Typical Noise Figure vs. Frequency at 1V, 1 mA.

Figure 2. AT-32032 Typical Noise Figure vs. Frequency and Current at 2.7V.

Figure 3. AT-32032 Typical Noise Figure vs. Frequency and Current at 5V.

Figure 4. AT-32032 Associated Gain vs. Frequency at 1V, 1 mA.

Figure 5. AT-32032 Associated Gain vs. Frequency and Current at 2.7V.

Figure 6. AT-32032 Associated Gain vs. Frequency and Current at 5V.

Figure 7. AT-32032 P1dB vs. Collector Current and Voltage (valid up to 2.4GHz).

Figure 8a. G1dB vs. Collector Current and Voltage (at 900MHz).

Figure 8b. G1dB vs. Collector Current and Voltage (at 1.8GHz).
### AT-32032 Typical Scattering Parameters

Common Emitter, \( Z_O = 50 \, \Omega \), \( V_{CE} = 1 \, V \), \( I_C = 1 \, mA \)

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>( S_{11} ) Mag</th>
<th>( S_{12} ) Mag</th>
<th>( S_{21} ) Mag</th>
<th>( S_{22} ) Mag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ang</td>
<td>Ang</td>
<td>Ang</td>
<td>Ang</td>
</tr>
<tr>
<td></td>
<td>dB</td>
<td>dB</td>
<td>dB</td>
<td>dB</td>
</tr>
<tr>
<td>0.5</td>
<td>0.852</td>
<td>-51</td>
<td>9.61</td>
<td>3.024</td>
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<tr>
<td>0.75</td>
<td>0.760</td>
<td>-74</td>
<td>8.68</td>
<td>2.717</td>
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<tr>
<td>1.0</td>
<td>0.655</td>
<td>-94</td>
<td>7.68</td>
<td>2.420</td>
</tr>
<tr>
<td>1.5</td>
<td>0.523</td>
<td>-130</td>
<td>5.75</td>
<td>1.939</td>
</tr>
<tr>
<td>2.0</td>
<td>0.451</td>
<td>-161</td>
<td>4.11</td>
<td>1.606</td>
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<td>3.0</td>
<td>0.403</td>
<td>147</td>
<td>1.76</td>
<td>1.224</td>
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<td>0.419</td>
<td>104</td>
<td>0.20</td>
<td>1.023</td>
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<tr>
<td>5.0</td>
<td>0.459</td>
<td>69</td>
<td>-0.92</td>
<td>0.899</td>
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<tr>
<td>6.0</td>
<td>0.497</td>
<td>45</td>
<td>-1.56</td>
<td>0.836</td>
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<td>7.0</td>
<td>0.529</td>
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<td>-1.84</td>
<td>0.809</td>
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<td>8.0</td>
<td>0.561</td>
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<td>-2.07</td>
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<td>9.0</td>
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<td>-2.34</td>
<td>0.764</td>
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<tr>
<td>10.0</td>
<td>0.626</td>
<td>-17</td>
<td>-2.74</td>
<td>0.729</td>
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### AT-32032 Typical Noise Parameters

Common Emitter, \( Z_O = 50 \, \Omega \), \( V_{CE} = 1 \, V \), \( I_C = 1 \, mA \)

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>( F_{min} ) dB</th>
<th>( \Gamma_{opt} ) Mag</th>
<th>( \Gamma_{opt} ) Ang</th>
<th>( R_n ) ohms</th>
<th>( G_{assoc} ) dB</th>
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<tbody>
<tr>
<td>0.9</td>
<td>1.1</td>
<td>0.48</td>
<td>63</td>
<td>14.5</td>
<td>11.5</td>
</tr>
<tr>
<td>1.8</td>
<td>1.3</td>
<td>0.51</td>
<td>129</td>
<td>6.8</td>
<td>8.3</td>
</tr>
<tr>
<td>2.0</td>
<td>1.4</td>
<td>0.52</td>
<td>143</td>
<td>5.2</td>
<td>7.4</td>
</tr>
<tr>
<td>2.5</td>
<td>1.6</td>
<td>0.54</td>
<td>177</td>
<td>2.9</td>
<td>6.4</td>
</tr>
<tr>
<td>3.0</td>
<td>1.8</td>
<td>0.57</td>
<td>-153</td>
<td>4.9</td>
<td>5.7</td>
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<tr>
<td>3.5</td>
<td>2.0</td>
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<td>-125</td>
<td>12.7</td>
<td>5.0</td>
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<td>4.0</td>
<td>2.2</td>
<td>0.65</td>
<td>-102</td>
<td>26.0</td>
<td>4.2</td>
</tr>
</tbody>
</table>

### Notes
- \( g_{\text{max}} = \text{maximum available gain (MAG) if } k > 1 \)
- \( g_{\text{max}} = \text{maximum stable gain (MSG) if } k < 1 \)
- \( k = \text{stability factor} \)

\[
\text{MAG} = \left| \frac{S_{21}}{S_{12}} \right| (k \pm \sqrt{k^2 - 1})
\]

\[
\text{MSG} = \left| \frac{S_{21}}{S_{12}} \right|
\]

\[
k = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |D|^2}{2 \cdot |S_{12}| \cdot |S_{21}|} ; D = S_{11}S_{22} - S_{12}S_{21}
\]

Figure 9. Gain vs. Frequency at 1 V, 1 mA.

Note: \( \text{dB}(|S_{21}|) = 20 \cdot \log(|S_{21}|) \)
AT-32032 Typical Scattering Parameters, Common Emitter, Z<sub>0</sub> = 50 Ω, V<sub>CE</sub> = 2.7 V, I<sub>C</sub> = 2 mA

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>S&lt;sub&gt;11&lt;/sub&gt; Mag</th>
<th>S&lt;sub&gt;11&lt;/sub&gt; Ang</th>
<th>S&lt;sub&gt;21&lt;/sub&gt; Mag</th>
<th>S&lt;sub&gt;21&lt;/sub&gt; Ang</th>
<th>S&lt;sub&gt;12&lt;/sub&gt; Mag</th>
<th>S&lt;sub&gt;12&lt;/sub&gt; Ang</th>
<th>S&lt;sub&gt;22&lt;/sub&gt; Mag</th>
<th>S&lt;sub&gt;22&lt;/sub&gt; Ang</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.744</td>
<td>-57</td>
<td>14.37</td>
<td>5.232</td>
<td>-23.72</td>
<td>0.065</td>
<td>60</td>
<td>0.839</td>
</tr>
<tr>
<td>0.75</td>
<td>0.609</td>
<td>-78</td>
<td>12.86</td>
<td>4.394</td>
<td>-21.73</td>
<td>0.082</td>
<td>52</td>
<td>0.755</td>
</tr>
<tr>
<td>1.0</td>
<td>0.489</td>
<td>-96</td>
<td>11.40</td>
<td>3.714</td>
<td>-20.58</td>
<td>0.094</td>
<td>49</td>
<td>0.694</td>
</tr>
<tr>
<td>1.5</td>
<td>0.351</td>
<td>-129</td>
<td>8.86</td>
<td>2.774</td>
<td>-19.05</td>
<td>0.112</td>
<td>48</td>
<td>0.625</td>
</tr>
<tr>
<td>2.0</td>
<td>0.280</td>
<td>-158</td>
<td>6.93</td>
<td>2.221</td>
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<td>0.592</td>
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<tr>
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<td>0.236</td>
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<td>0.561</td>
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<tr>
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<tr>
<td>5.0</td>
<td>0.317</td>
<td>72</td>
<td>1.36</td>
<td>1.170</td>
<td>-7.54</td>
<td>0.420</td>
<td>30</td>
<td>0.510</td>
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<tr>
<td>6.0</td>
<td>0.387</td>
<td>51</td>
<td>0.43</td>
<td>1.051</td>
<td>-5.11</td>
<td>0.555</td>
<td>13</td>
<td>0.447</td>
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<tr>
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<td>0.455</td>
<td>34</td>
<td>-0.24</td>
<td>0.973</td>
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<td>0.686</td>
<td>-8</td>
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<td>-2.00</td>
<td>0.795</td>
<td>-73</td>
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AT-32032 Typical Noise Parameters, Common Emitter, Z<sub>0</sub> = 50 Ω, V<sub>CE</sub> = 2.7 V, I<sub>C</sub> = 2 mA

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>F&lt;sub&gt;min&lt;/sub&gt; dB</th>
<th>Γ&lt;sub&gt;opt&lt;/sub&gt; Mag</th>
<th>Γ&lt;sub&gt;opt&lt;/sub&gt; Ang</th>
<th>R&lt;sub&gt;n&lt;/sub&gt; ohms</th>
<th>G&lt;sub&gt;assoc&lt;/sub&gt; dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>0.9</td>
<td>0.38</td>
<td>57</td>
<td>10.6</td>
<td>14.0</td>
</tr>
<tr>
<td>1.2</td>
<td>1.2</td>
<td>0.41</td>
<td>124</td>
<td>6.2</td>
<td>10.5</td>
</tr>
<tr>
<td>1.4</td>
<td>1.4</td>
<td>0.42</td>
<td>136</td>
<td>5.3</td>
<td>9.4</td>
</tr>
<tr>
<td>1.6</td>
<td>1.6</td>
<td>0.44</td>
<td>176</td>
<td>3.4</td>
<td>8.4</td>
</tr>
<tr>
<td>1.8</td>
<td>1.8</td>
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<td>0.57</td>
<td>-100</td>
<td>20.6</td>
<td>6.2</td>
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</tbody>
</table>

g<sub>max</sub> = maximum available gain (MAG) if k > 1  
g<sub>max</sub> = maximum stable gain (MSG) if k < 1  
k = stability factor  
MAG = \left|\frac{S_{21}}{S_{12}}\right| \left(k \pm \sqrt{k^2 - 1}\right)  
MSG = \left|\frac{S_{21}}{S_{12}}\right|  
k = \frac{1 - \left|S_{11}\right|^2 - \left|S_{22}\right|^2 + |D|^2}{2 |S_{12}| |S_{21}|}; D = S_{11}S_{22} - S_{12}S_{21}  

Figure 10. Gain vs. Frequency at 2.7 V, 2 mA.  
Note: dB(|S<sub>21</sub>|) = 20 * log(|S<sub>21</sub>|)
### AT-32032 Typical Scattering Parameters, Common Emitter, \( Z_O = 50 \Omega, V_{CE} = 2.7 \text{ V}, I_C = 5 \text{ mA} \)

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>( S_{11} )</th>
<th>( S_{21} )</th>
<th>( S_{12} )</th>
<th>( S_{22} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mag</td>
<td>Ang</td>
<td>dB</td>
<td>Mag</td>
</tr>
<tr>
<td>0.5</td>
<td>0.484</td>
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<td>0.257</td>
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<td>5.000</td>
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<td>0.70</td>
<td>1.084</td>
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<td>-0.12</td>
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<td>0.627</td>
<td>-9</td>
<td>-1.05</td>
<td>0.886</td>
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### AT-32032 Typical Noise Parameters, Common Emitter, \( Z_O = 50 \Omega, V_{CE} = 2.7 \text{ V}, I_C = 5 \text{ mA} \)

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>( F_{min} )</th>
<th>( \Gamma_{opt} )</th>
<th>( R_n )</th>
<th>( G_{assoc} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mag</td>
<td>Ang</td>
<td>ohms</td>
<td>dB</td>
</tr>
<tr>
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<td>0.9</td>
<td>0.23</td>
<td>71</td>
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</tr>
<tr>
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<td>0.295</td>
<td>138</td>
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<tr>
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<td>152</td>
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<td>-114</td>
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<tr>
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<td>1.9</td>
<td>0.54</td>
<td>-93</td>
<td>20.0</td>
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</table>

**gmax** = maximum available gain (MAG) if \( k > 1 \)

**gmax** = maximum stable gain (MSG) if \( k < 1 \)

\( k = \text{stability factor} \)

\[
\text{MAG} = \left| \frac{S_{21}}{S_{12}} \right| (k \pm \sqrt{k^2 - 1})
\]

\[
\text{MSG} = \frac{|S_{21}|}{|S_{12}|}
\]

\[
k = 1 - \frac{|S_{11}|^2 - |S_{22}|^2 + |D|^2}{2|S_{12}||S_{21}|}, \quad D = S_{11}S_{22} - S_{12}S_{21}
\]

Figure 11. Gain vs. Frequency at 2.7 V, 5 mA.

Note: \( \text{dB}(|S_{21}|) = 20 \times \log(|S_{21}|) \)
**AT-32032 Typical Scattering Parameters**, Common Emitter, $Z_O = 50$ $\Omega$, $V_{CE} = 2.7$ V, $I_C = 10$ mA

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>$S_{11}$ Mag</th>
<th>$S_{11}$ Ang</th>
<th>$S_{21}$ Mag</th>
<th>$S_{21}$ Ang</th>
<th>$S_{12}$ Mag</th>
<th>$S_{12}$ Ang</th>
<th>$S_{22}$ Mag</th>
<th>$S_{22}$ Ang</th>
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<td>5.600</td>
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<td>31.083</td>
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**AT-32032 Typical Noise Parameters**, Common Emitter, $Z_O = 50$ $\Omega$, $V_{CE} = 2.7$ V, $I_C = 10$ mA

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>$F_{min}$ dB</th>
<th>$\Gamma_{opt}$ Mag</th>
<th>$\Gamma_{opt}$ Ang</th>
<th>$R_n$ ohms</th>
<th>$G_{assoc}$ dB</th>
</tr>
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<td>0.23</td>
<td>159</td>
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<td>11.9</td>
</tr>
<tr>
<td>2.0</td>
<td>1.4</td>
<td>0.26</td>
<td>173</td>
<td>5.3</td>
<td>11.0</td>
</tr>
<tr>
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<td>1.5</td>
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</table>

$g_{max} =$ maximum available gain (MAG) if $k > 1$
$g_{max} =$ maximum stable gain (MSG) if $k < 1$

$k =$ stability factor

$$MAG = \left| \frac{S_{21}}{S_{12}} \right| (k \pm \sqrt{k^2 - 1})$$

$$MSG = \left| \frac{S_{21}}{S_{12}} \right|$$

$$k = 1 - \frac{|S_{11}|^2 - |S_{22}|^2 + |D|^2}{2|S_{12}|S_{21}}; \quad D = S_{11}S_{22} - S_{12}S_{21}$$

Figure 12. Gain vs. Frequency at 2.7 V, 10 mA.
Note: $dB(|S_{21}|) = 20 \times \log(|S_{21}|)$
AT-32032 Typical Scattering Parameters, Common Emitter, \(Z_O = 50\, \Omega\), \(V_{CE} = 5\, V\), \(I_C = 2\, mA\)

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>(S_{11}) Mag</th>
<th>(S_{11}) Ang</th>
<th>(S_{21}) Mag</th>
<th>(S_{21}) Ang</th>
<th>(S_{12}) Mag</th>
<th>(S_{12}) Ang</th>
<th>(S_{22}) Mag</th>
<th>(S_{22}) Ang</th>
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AT-32032 Typical Noise Parameters, Common Emitter, \(Z_O = 50\, \Omega\), \(V_{CE} = 5\, V\), \(I_C = 2\, mA\)

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>(F_{min}) dB</th>
<th>(\Gamma_{opt}) Mag</th>
<th>(\Gamma_{opt}) Ang</th>
<th>(R_n) ohms</th>
<th>(G_{assoc}) dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
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\(g_{max}\) = maximum available gain (MAG) if \(k > 1\)
\(g_{max}\) = maximum stable gain (MSG) if \(k < 1\)

\(k = \text{stability factor}\)

\[
\text{MAG} = \left| \frac{S_{21}}{S_{12}} \right| (k \pm \sqrt{k^2 - 1})
\]

\[
\text{MSG} = \left| \frac{S_{21}}{S_{12}} \right|
\]

\[
k = \frac{1 - |S_{11}|^2 - |S_{22}|^2 - |D|^2}{2^*|S_{12}||S_{21}|} \quad \text{D} = S_{11}S_{22} - S_{12}S_{21}
\]

Note: \(\text{dB}(S_{21}) = 20 \times \log|S_{21}|\)

Figure 13. Gain vs. Frequency at 5 V, 2 mA.
AT-32032 Typical Scattering Parameters, Common Emitter, ZO = 50 Ω, VCE = 5 V, IC = 5 mA

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<th>S(_{11}) Ang</th>
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<th>S(_{21}) Ang</th>
<th>S(_{12}) Mag</th>
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AT-32032 Typical Noise Parameters, Common Emitter, ZO = 50 Ω, VCE = 5 V, IC = 5 mA

<table>
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<tr>
<th>Freq. GHz</th>
<th>F(_{\text{min}}) dB</th>
<th>(\Gamma_{\text{opt}}) Mag</th>
<th>(\Gamma_{\text{opt}}) Ang</th>
<th>(R_n) ohms</th>
<th>(G_{\text{assoc}}) dB</th>
</tr>
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<tbody>
<tr>
<td>0.9</td>
<td>1.0</td>
<td>0.38</td>
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<td>11.7</td>
<td>16.1</td>
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<td>1.8</td>
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<td>124</td>
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<td>11.2</td>
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<td>3.0</td>
<td>1.6</td>
<td>0.40</td>
<td>-118</td>
<td>11.5</td>
<td>7.5</td>
</tr>
<tr>
<td>3.5</td>
<td>1.8</td>
<td>0.47</td>
<td>-92</td>
<td>22.0</td>
<td>6.8</td>
</tr>
<tr>
<td>4.0</td>
<td>2.0</td>
<td>0.54</td>
<td>-92</td>
<td>22.0</td>
<td>6.8</td>
</tr>
</tbody>
</table>

\(g_{\text{max}}\) = maximum available gain (MAG) if \(k > 1\)
\(g_{\text{max}}\) = maximum stable gain (MSG) if \(k < 1\)
\(k\) = stability factor

\[
\text{MAG} = \left| \frac{S_{21}}{S_{12}} \right| (k \pm \sqrt{k^2 - 1})
\]

\[
\text{MSG} = \left| S_{21} \right| / \left| S_{12} \right|
\]

\[
k = 1 - \frac{|S_{11}|^2 - |S_{22}|^2 + |D|^2}{2 |S_{12}| |S_{21}|} ; D = S_{11} S_{22} - S_{12} S_{21}
\]

Figure 14. Gain vs. Frequency at 5 V, 5 mA.

Note: \(\text{dB}(|S_{21}|) = 20 \times \log(|S_{21}|)\)
**AT-32032 Typical Scattering Parameters**, Common Emitter, $Z_0 = 50\ \Omega$, $V_{CE} = 5\ V$, $I_C = 10\ mA$

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>$S_{11}$</th>
<th>$S_{21}$</th>
<th>$S_{12}$</th>
<th>$S_{22}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mag Ang dB</td>
<td>Mag Ang dB</td>
<td>Mag Ang dB</td>
<td>Mag Ang dB</td>
</tr>
<tr>
<td>0.1</td>
<td>0.751 -26</td>
<td>24.169 152</td>
<td>-37.1 0.014</td>
<td>78 0.898 -13</td>
</tr>
<tr>
<td>0.5</td>
<td>0.322 -70</td>
<td>10.383 103</td>
<td>-26.4 0.048</td>
<td>68 0.584 -24</td>
</tr>
<tr>
<td>0.9</td>
<td>0.181 -84</td>
<td>6.208 85</td>
<td>-22.1 0.078</td>
<td>68 0.514 -25</td>
</tr>
<tr>
<td>1.0</td>
<td>0.160 -88</td>
<td>5.623 82</td>
<td>-21.3 0.086</td>
<td>67 0.508 -26</td>
</tr>
<tr>
<td>1.5</td>
<td>0.094 -102</td>
<td>3.885 68</td>
<td>-18.1 0.125</td>
<td>64 0.483 -30</td>
</tr>
<tr>
<td>1.8</td>
<td>0.068 -114</td>
<td>3.304 60</td>
<td>-16.5 0.149</td>
<td>61 0.473 -34</td>
</tr>
<tr>
<td>2.0</td>
<td>0.055 -123</td>
<td>3.012 56</td>
<td>-15.6 0.165</td>
<td>59 0.468 -37</td>
</tr>
<tr>
<td>3.0</td>
<td>0.032 146</td>
<td>2.161 34</td>
<td>-12.1 0.248</td>
<td>47 0.444 -52</td>
</tr>
<tr>
<td>4.0</td>
<td>0.075 86</td>
<td>1.759 14</td>
<td>-9.5 0.334</td>
<td>34 0.419 -70</td>
</tr>
<tr>
<td>5.0</td>
<td>0.148 67</td>
<td>1.538 5</td>
<td>-7.5 0.424</td>
<td>20 0.375 -92</td>
</tr>
<tr>
<td>6.0</td>
<td>0.243 58</td>
<td>1.397 4</td>
<td>-5.7 0.517</td>
<td>5 0.301 -120</td>
</tr>
<tr>
<td>7.0</td>
<td>0.354 47</td>
<td>1.292 4</td>
<td>-4.3 0.613</td>
<td>-12 0.214 -162</td>
</tr>
<tr>
<td>8.0</td>
<td>0.464 32</td>
<td>1.190 3</td>
<td>-3.2 0.695</td>
<td>-31 0.214 136</td>
</tr>
<tr>
<td>9.0</td>
<td>0.555 14</td>
<td>1.083 3</td>
<td>-2.5 0.751</td>
<td>-51 0.311 89</td>
</tr>
<tr>
<td>10.0</td>
<td>0.636 -5</td>
<td>0.967 3</td>
<td>-2.3 0.765</td>
<td>-71 0.426 57</td>
</tr>
</tbody>
</table>

**AT-32032 Typical Noise Parameters**, Common Emitter, $Z_0 = 50\ \Omega$, $V_{CE} = 5\ V$, $I_C = 10\ mA$

<table>
<thead>
<tr>
<th>Freq. GHz</th>
<th>$F_{min}\ dB$</th>
<th>$\Gamma_{opt}\ Mag\ Ang$</th>
<th>$R_n\ ohms$</th>
<th>$G_{assoc}\ dB$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>1.1</td>
<td>0.29 69 10.0 17.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>1.3</td>
<td>0.25 143 6.1 11.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>1.4</td>
<td>0.26 159 5.6 11.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>1.5</td>
<td>0.31 -165 5.5 9.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>1.7</td>
<td>0.37 -133 8.1 8.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>1.9</td>
<td>0.45 -106 14.6 7.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>2.1</td>
<td>0.52 -84 25.7 6.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$g_{max} = \text{maximum available gain (MAG) if } k > 1$

$g_{max} = \text{maximum stable gain (MSG) if } k < 1$

$k = \text{stability factor}$

\[
\text{MAG} = \frac{|S_{21}|}{|S_{12}|} (k \pm \sqrt{k^2 - 1})
\]

\[
\text{MSG} = \frac{|S_{21}|}{|S_{12}|}
\]

\[
k = 1 - \frac{|S_{11}|^2 - |S_{22}|^2 + |D|^2}{2 |S_{12}| |S_{21}|}; D = S_{11}S_{22} - S_{12}S_{21}
\]

Note: $\text{dB}(|S_{21}|) = 20 \log(|S_{21}|)$

Figure 15. Gain vs. Frequency at 5 V, 10 mA.
**AT-32032 Application Information**

The AT-32032 is described in a low noise amplifier for use in the 800 to 900 MHz frequency range. The amplifier is designed for use with .032 inch thickness FR-4 printed circuit board material.

**900 MHz LNA Design**

The amplifier is designed for a $V_{ce}$ of 2.7 volts and $I_c$ of 5 mA, and a nominal power supply voltage of 3 volts. The amplifier schematic is shown in Figure 16.

A component list is shown in Figure 17. The artwork including component placement is shown in Figure 18.

![Schematic Diagram](image)

**Figure 16. Schematic Diagram.**

<table>
<thead>
<tr>
<th>C1,C3</th>
<th>10 pF chip capacitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>Open circuited stub .275 inch long</td>
</tr>
<tr>
<td>C4,C5</td>
<td>1000 pF chip capacitor</td>
</tr>
<tr>
<td>L1</td>
<td>8 nH chip inductor (Coilcraft 1008CS-080)</td>
</tr>
<tr>
<td>L2</td>
<td>Optional (see R1)</td>
</tr>
<tr>
<td>L3</td>
<td>56 nH chip inductor (Coilcraft 1008CS-560)</td>
</tr>
<tr>
<td>L4</td>
<td>15 nH chip inductor (Coilcraft 1008CS-150)</td>
</tr>
<tr>
<td>Q1</td>
<td>Silicon Agilent AT-32032 Bipolar Transistor</td>
</tr>
<tr>
<td>R1</td>
<td>10 KΩ chip resistor (may want to substitute a 180 nH chip inductor and 50 W resistor for lower noise figure, better low freq stability, the readjust R2)</td>
</tr>
<tr>
<td>R2</td>
<td>26.1 KΩ chip resistor (adjust for rated $I_c$)</td>
</tr>
<tr>
<td>R3</td>
<td>3.32 KΩ chip resistor</td>
</tr>
<tr>
<td>R4</td>
<td>3.32 KΩ chip resistor</td>
</tr>
<tr>
<td>R5</td>
<td>51.1 Ω chip resistor</td>
</tr>
<tr>
<td>R6</td>
<td>13 Ω chip resistor (see text)</td>
</tr>
<tr>
<td>Zo</td>
<td>50 Ω microstripline</td>
</tr>
</tbody>
</table>

**Figure 17. Component Parts List.**

![Component Parts List](image)

The input matching network uses a shunt C series L input impedance matching circuit for low noise. The shunt C is accomplished with an open circuited stub while a chip inductor is used for the series element. The output impedance matching network consists of a series chip inductor. Bias insertion is accomplished by the use of small inductors suitably bypassed. A resistor is placed in series with the output bias decoupling inductor to de-Q the network and improve in-band and low frequency stability. Surface mount Coilcraft inductors were chosen for their small size. Resistor R6 enhances broad band stability especially in the 9 to 10 GHz frequency range.

**Biasing**

The bias network is designed for a nominal power supply voltage of 3 volts. Resistors R1 and R2 are used to adjust collector current. Resistor R4 can be attached to the junction of R5 and C5 to improve bias point stability.
Performance

The measured gain of the completed amplifier is shown in Figure 19. The gain varies from 15.5 to 16.5 dB over the 800 to 900 MHz frequency range. Noise figure versus frequency is shown in Figure 20. Best performance occurs at 950 MHz providing a 1.1 dB noise figure.

Measured input and output return loss is shown in Figure 21. The input return loss is 7 dB at 900 MHz and can be improved to 9 dB with a 0.1 dB increase in noise figure by increasing the amount of capacitance at C2. Additional capacitance at C2 increases the input return loss even further with increased noise figure. Output return loss is a nominal 12 to 15 dB.

Output intercept point, IP3, was measured at 900 MHz to be +14.3 dBm. This could be improved in two ways. The output resistors R5 and R6 could be varied in value. Increasing the value of R5 and decreasing the value of R6 will improve IP3 although circuit stability may be sacrificed. The second method would be to optimize the output match for power as opposed to matching for lowest VSWR.

Using the AT-32032 at Other Frequencies

The demo board and design techniques presented here can be used to build low noise amplifiers for other frequencies in the VHF through 1.9 GHz frequency range.

Figure 19. Gain vs Frequency.

Figure 20. Noise Figure vs Frequency.

Figure 21. Input/Output Return Loss.
### Ordering Information

<table>
<thead>
<tr>
<th>Part Numbers</th>
<th>No. of Devices</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT-32032-BLK</td>
<td>100</td>
<td>Bulk</td>
</tr>
<tr>
<td>AT-32032-BLKG</td>
<td>100</td>
<td>Bulk</td>
</tr>
<tr>
<td>AT-32032-TR1</td>
<td>3000</td>
<td>7” Reel</td>
</tr>
<tr>
<td>AT-32032-TR1G</td>
<td>3000</td>
<td>7” Reel</td>
</tr>
<tr>
<td>AT-32032-TR2</td>
<td>10000</td>
<td>13” Reel</td>
</tr>
<tr>
<td>AT-32032-TR2G</td>
<td>10000</td>
<td>13” Reel</td>
</tr>
</tbody>
</table>

Note: Order part number with a “G” suffix if lead-free option is desired.

### Package Dimensions

**SOT-323 Plastic Package**

![Diagram of SOT-323 Plastic Package]

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DIMENSIONS (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.80 – 1.00</td>
</tr>
<tr>
<td>A1</td>
<td>0.00 – 0.10</td>
</tr>
<tr>
<td>B</td>
<td>0.15 – 0.40</td>
</tr>
<tr>
<td>C</td>
<td>0.08 – 0.25</td>
</tr>
<tr>
<td>D</td>
<td>1.80 – 2.25</td>
</tr>
<tr>
<td>ET</td>
<td>1.10 – 1.40</td>
</tr>
<tr>
<td>e</td>
<td>0.60 typical</td>
</tr>
<tr>
<td>e1</td>
<td>1.30 typical</td>
</tr>
<tr>
<td>E</td>
<td>1.00 – 2.40</td>
</tr>
<tr>
<td>L</td>
<td>0.26 – 0.46</td>
</tr>
</tbody>
</table>

Notes:
- XXX: package marking
- Drawings are not to scale
### Tape Dimensions and Product Orientation
For Outline SOT-323 (SC-70 3 Lead)

**Diagram**

- **A**
- **B**
- **C**
- **D**
- **E**
- **F**
- **K**
- **P**
- **P₀**
- **P₂**
- **D₁**
- **T₁**

**Table**

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Size (mm)</th>
<th>Size (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAVITY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LENGTH</td>
<td>A₀</td>
<td>2.24 ± 0.10</td>
<td>0.088 ± 0.004</td>
</tr>
<tr>
<td>WIDTH</td>
<td>B₀</td>
<td>2.34 ± 0.10</td>
<td>0.092 ± 0.004</td>
</tr>
<tr>
<td>DEPTH</td>
<td>K₀</td>
<td>1.22 ± 0.10</td>
<td>0.048 ± 0.004</td>
</tr>
<tr>
<td>PITCH</td>
<td>P</td>
<td>4.00 ± 0.10</td>
<td>0.157 ± 0.004</td>
</tr>
<tr>
<td>BOTTOM HOLE DIAMETER</td>
<td>D₁</td>
<td>1.00 ± 0.25</td>
<td>0.039 ± 0.010</td>
</tr>
<tr>
<td>PERFORATION</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIAMETER</td>
<td>D</td>
<td>1.55 ± 0.05</td>
<td>0.061 ± 0.002</td>
</tr>
<tr>
<td>PITCH</td>
<td>P₀</td>
<td>4.00 ± 0.10</td>
<td>0.157 ± 0.004</td>
</tr>
<tr>
<td>POSITION</td>
<td>E</td>
<td>1.75 ± 0.10</td>
<td>0.069 ± 0.004</td>
</tr>
<tr>
<td>CARRIER TAPE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIDTH</td>
<td>W</td>
<td>8.00 ± 0.30</td>
<td>0.315 ± 0.012</td>
</tr>
<tr>
<td>THICKNESS</td>
<td>t₁</td>
<td>0.255 ± 0.013</td>
<td>0.010 ± 0.0005</td>
</tr>
<tr>
<td>COVER TAPE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIDTH</td>
<td>C</td>
<td>5.4 ± 0.10</td>
<td>0.205 ± 0.004</td>
</tr>
<tr>
<td>TAPE THICKNESS</td>
<td>T₁</td>
<td>0.062 ± 0.001</td>
<td>0.0025 ± 0.00004</td>
</tr>
<tr>
<td>DISTANCE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAVITY TO PERFORATION (WIDTH DIRECTION)</td>
<td>F</td>
<td>3.50 ± 0.05</td>
<td>0.138 ± 0.002</td>
</tr>
<tr>
<td>CAVITY TO PERFORATION (LENGTH DIRECTION)</td>
<td>P₂</td>
<td>2.00 ± 0.05</td>
<td>0.079 ± 0.002</td>
</tr>
</tbody>
</table>

**Notes**

- Tape Dimensions chart
- For Outline SOT-323 (SC-70 3 Lead)
- Data subject to change. Copyright © 2005-2009 Avago Technologies. All rights reserved. Obsoletes 5989-2644EN
- AV02-1963EN - June 9, 2009
- For product information and a complete list of distributors, please go to our web site: [www.avagotech.com](http://www.avagotech.com)