0.50mm Pitch
BGA Socket Adapter System

SIGNAL INTEGRITY ANALYSIS AND MODELING

Rev. 3

www.advanced.com
At Advanced Interconnections Corporation, our Signal Integrity reporting method differs dramatically from the common industry practice of isolating the aggressor and victim terminals from each other by introducing dedicated ground terminals between them. We believe this method represents a theoretical, best-case, scenario that does not serve the needs of most systems engineers and circuit designers. An unrealistic number of connector terminals must be assigned to ground in order to achieve this scenario.

Our standard reporting practice is closely aligned with the decision-making processes of most systems engineers and circuit designers. The reported data addresses our customers I/O assignments (net-list) and helps them determine where to best run high-versus-low frequency signals through our connectors. As such, our reporting method represents a more practical net-list scenario. Utilizing our unbiased SPICE™ and IBIS™ files, system designers are able to create and/or debug their net-list quickly and accurately.
SI Test Setup

- The 0.50 mm Socket Adapter was measured from 50 MHz to 20.05 GHz.
- A pin-out of 3 rows and 4 columns was assigned from a 4x4 array:

<table>
<thead>
<tr>
<th>GND</th>
<th>GND</th>
<th>GND</th>
<th>GND</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1+</td>
<td>S1-</td>
<td>S2+</td>
<td>S2-</td>
</tr>
<tr>
<td>GND</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
</tr>
</tbody>
</table>
Performance Results

- The test and measurement tasks were completed and the recommended Operational Bandwidth for the Socket Adapter System is as follows:

  - **Differential:** DC to 1.0 GHz @ -15dB and ~0.7 to 1.1 Gbit/sec.
  - **Differential:** DC to 1.9 GHz @ -10dB and ~1.2 to 2.1 Gbit/sec.
  - **Single-ended:** DC to 1.6 GHz @ -15dB and ~1.0 to 1.7 Gbit/sec.
  - **Single-ended:** DC to 3.3 GHz @ -10dB and ~2.1 to 3.5 Gbit/sec.

- At the above Bandwidths, the Impedance of this connector system is low. This has been attributed to the geometry of the female shell and the proximity of adjacent terminals.
SI Test & Measurement Study

Performance Results – continued

- Differential Eye Diagrams were successfully formed at 5 Gbits/sec., with Jitter at 6psec and 12% eye closure.
  - The eye opening sustains a Data Mask with a voltage swing of ±175mV @ 100psec period.

- Single-ended Eye Diagrams were successfully formed at 5 Gbits/sec., with Jitter at 4psec and 8% eye closure.
  - The eye opening sustains a Data Mask with a voltage swing of ±125mV @ 140psec period.
### Performance Results – continued

<table>
<thead>
<tr>
<th></th>
<th>Return Loss (S_{Ω,θ})</th>
<th>Insertion Loss (S_{φ,β})</th>
<th>Zo @ 200 psec (10-90%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Differential</strong></td>
<td><img src="https://example.com/return_loss" alt="Return Loss" /></td>
<td><img src="https://example.com/insertion_loss" alt="Insertion Loss" /></td>
<td><img src="https://example.com/zo" alt="Zo" /></td>
</tr>
<tr>
<td>(Terminals S1+, S1-)</td>
<td>((S1,1))</td>
<td>((S2,1))</td>
<td>75.0Ω</td>
</tr>
<tr>
<td></td>
<td>-15.0dB @ 1.0 GHz</td>
<td>-0.40dB @ 1.0 GHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-10.0dB @ 1.9 GHz</td>
<td>-0.55dB @ 1.9 GHz</td>
<td></td>
</tr>
<tr>
<td><strong>Single-ended</strong></td>
<td><img src="https://example.com/return_loss" alt="Return Loss" /></td>
<td><img src="https://example.com/insertion_loss" alt="Insertion Loss" /></td>
<td><img src="https://example.com/zo" alt="Zo" /></td>
</tr>
<tr>
<td>(Terminals S1+)</td>
<td>((S1,1))</td>
<td>((S2,1))</td>
<td>42.8Ω</td>
</tr>
<tr>
<td></td>
<td>-15.0dB @ 1.9 GHz</td>
<td>-0.4dB @ 1.9 GHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-10.0dB @ 7.5 GHz</td>
<td>-2.5dB @ 7.5 GHz</td>
<td></td>
</tr>
<tr>
<td><strong>Single-ended</strong></td>
<td><img src="https://example.com/return_loss" alt="Return Loss" /></td>
<td><img src="https://example.com/insertion_loss" alt="Insertion Loss" /></td>
<td><img src="https://example.com/zo" alt="Zo" /></td>
</tr>
<tr>
<td>(Terminals S1-)</td>
<td>((S3,3))</td>
<td>((S4,3))</td>
<td>41.8Ω</td>
</tr>
<tr>
<td></td>
<td>-15.0dB @ 1.6 GHz</td>
<td>-0.55dB @ 1.6 GHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-10.0dB @ 3.3 GHz</td>
<td>-0.90dB @ 3.3 GHz</td>
<td></td>
</tr>
</tbody>
</table>

- A **Return Loss** at -15dB (~18% Reflection) is the normally accepted industry standard. Most applications will tolerate data at -10 dB (~32% Reflection), however in this instance, performance safety margins may be increased by *de-rating* the connectors Operational Bandwidth and Data Rate.

- A **Insertion Loss** at -3dB (~50% of applied Power & ~71% of applied Voltage arrives at the Output Port) is the normally accepted industry standard.

- An Effective Impedance of 100Ω ±10Ω for Differential and 50Ω ±5Ω for Single-ended is the normally accepted industry guideline. De-rating the signal input risetime will improve the above Zo values.
Performance Results– continued

<table>
<thead>
<tr>
<th></th>
<th>NeXT @ 200 psec (10-90%)</th>
<th>FeXT @ 200 psec (10-90%)</th>
<th>Eye-Diagram @ 5 Gbit/sec</th>
<th>Eye-Diagram @ 5 Gbit/sec with 6 Gbit/sec Aggressor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Differential</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| (Terminals S1+, S1-)| 1.75%                    | 1.1%                     | Peak-to-Peak Jitter = 1 psec  
Eye-Closure = 7%                              | Peak-to-Peak Jitter = 6 psec  
Eye-Closure = 12% |
| **Single-ended**    |                          |                          |                           |                                               |
| (Terminals S1-)     | 5.5%                     | 1.3%                     | Peak-to-Peak Jitter = 2 psec  
Eye-Closure = 4%                              | Peak-to-Peak Jitter = 4 psec  
Eye-Closure = 8% |

- A NeXT at 5% maximum is the normally accepted industry standard. Some customers may specify a value as low as 2% maximum for this attribute. NeXT results are good.
- A FeXT at 2% maximum is the normally accepted industry standard. Some customers may specify a value as low as 1% maximum for this attribute. FeXT results are excellent.
- A successful Eye-opening was created at 5 Gbit/sec and is excellent as this data rate is well within the Operational Bandwidths recommended for this connector system. See note below.

**NOTE:** It’s not practical to define pass-or-fail criteria for Jitter and Eye-Closure. However, guidelines for the connector’s transmit Data Mask can be defined to quantify the effective performance of the eye formation. For a Differential data mask, the total voltage equals 35% of the eye’s applied peak-to-peak voltage, (1V in this report), and its period equals 50% of the risetime, (200psec in this report). For a Single-ended data mask, the total voltage equals 50% of the eye’s applied peak-to-peak voltage, (500mV in this report), and its period equals 70% of the risetime, (200psec in this report).
Differential Return Loss

Plot Range: DC to 20 GHz

-10dB @ 1.9 GHz
-15dB @ 1.0 GHz
Differential Return Loss

Plot Range: DC to 5 GHz

$(S_{2,1})$
-10 dB @ 1.9 GHz
-15 dB @ 1.0 GHz
Differential Insertion Loss

Plot Range: DC to 20 GHz

\[ dB(\text{moving\_average}(S(2,1),21)) \]

-0.55 dB @ 1.9 GHz
-0.40 dB @ 1.0 GHz
Differential Insertion Loss

Plot Range: DC to 5 GHz

\( \text{dB}(S(2,1)) \)

-0.55 dB @ 1.9 GHz
-0.40 dB @ 1.0 GHz
Single-ended Return Loss for $S_{1+}$ & $S_{1-}$

Plot Range: DC to 20 GHz

- $S_{3,3}$
  - $-15.0$ dB @ 1.6 GHz
  - $-10.0$ dB @ 3.3 GHz

- $S_{1,1}$
  - $-15.0$ dB @ 1.9 GHz
  - $-10.0$ dB @ 7.5 GHz
Single-ended Return Loss for S1+ & S1-

Plot Range: DC to 5 GHz

-15.0dB @ 1.6 GHz
-15.0dB @ 1.6 GHz
-10.0dB @ 3.3 GHz
-10.0dB @ 7.5 GHz
Single-ended Insertion Loss for S1+ & S1-

Plot Range: DC to 20 GHz

- $\text{dB}(S(4,3))$
- $\text{dB}(S(2,1))$

- $-0.55\text{dB} @ 1.6\text{ GHz}$
- $-2.50\text{dB} @ 7.5\text{ GHz}$

- $-0.40\text{dB} @ 1.9\text{ GHz}$
- $-0.90\text{dB} @ 3.3\text{ GHz}$
Single-ended Insertion Loss for S1+ & S1-

Plot Range: DC to 5 GHz

- **dB(S(4,3))**
  - (-0.55dB @ 1.6 GHz)
  - (-0.90dB @ 3.3 GHz)

- **dB(S(2,1))**
  - (-0.40dB @ 1.9GHz)
  - (-2.50dB @ 7.5 GHz)
Differential Impedance Profile

200ps risetime (10-90%)
Single-ended Impedance Profile for S1+ & S1-

Simultaneous Plots at **200 psec** risetime (10-90%)
S1+ (Zsp Edge Terminals) vs. S1- (Zsn Interior Terminals)

- zsp[2][1::1200]
- zsn[2][1::1200]

41.8Ω

42.8Ω
Differential Near-end Crosstalk (NeXT)

Percent Differential NeXT @ 200ps risetime (10-90%)

100*(xne[p][0::1000]*xne[n][0::1000])

-1.8 -1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2

time, nsec

1.75%
Differential Far-end Crosstalk (FeXT)

Percent Differential FeXT @ 200ps risetime (10-90%)

1.1%
Single-ended Near-end Crosstalk (NeXT)

Percent Single-ended NeXT @ 200ps risetime (10-90%)

5.5%
Percent Single-ended FeXT @ 200ps risetime (10-90%)

Graph showing the percent single-ended far-end crosstalk (FeXT) over time.
Differential Eye-Diagram

Eye Opening @ 5 Gbit/sec.

Peak-to-peak jitter is 1 psec and Eye-Closure is 7%
Differential Eye-Diagram w/Aggressor

Eye Opening @ 5 Gbit/sec with a 6 Gbit/sec Aggressor

Peak-to-peak jitter is 6 psec and Eye-Closure is 12%

Data Mask

±175mV
@ 100psec

Advanced Interconnections Corp.
5 Energy Way, West Warwick, RI 02893 USA
401.823.5200 • 800.424.9850 • Fax: 401.823.8723
Product covered by patents issued and/or pending. Data subject to change without notice. Rev. 3
Eye Opening @ 5 Gbit/sec.

Peak-to-peak jitter is 2 psec and Eye-Closure is 4%
Single-ended Eye-Diagram w/Aggressor

Eye Opening @ 5 Gbit/sec with a 6 Gbit/sec Aggressor

Peak-to-peak jitter is 4 psec and Eye-Closure is 8%

±125mV
@ 140psec
Data Mask

eye(voutp, 2.5e9) ±125mV @ 140psec Data Mask

Advanced Interconnections Corp.
5 Energy Way, West Warwick, RI 02893 USA
401.823.5200 • 800.424.9850 • Fax: 401.823.8723
Product covered by patents issued and/or pending. Data subject to change without notice. Rev. 3
Propagation Delay

- Propagation delay analysis for m1 and m2.
- Time values: vout[0][0::1000] = 0.194
- Time values: vin[0][0::1000] = 0.191
- Time values: vout[0][0::1000] = 0.194
- Time values: vin[0][0::1000] = 0.191
- Time difference: 37 psec

Graph shows the propagation delay with time values for m1 and m2.