

**October 1, 2010**

## **QFN Electrical Parasitics**

### **Introduction**

PROMEX offers overmolded QFN packaging service to the semiconductor industry for semiconductor die packaging.

A question asked more often is “What are the high frequency performance characteristics ?”

To answer that question, PROMEX undertook a study of the electrical parasitics of its standard overmolded QFNs working with Eric Bogatin, a Signal Integrity Evangelist. (See the insert to the right.)

The results of that effort are reported here.

In summary, the PROMEX overmolded QFNs in sizes from 7mm x 7mm to 3mm x 3mm will function well at frequencies as high as 20GHz.

**Eric Bogatin**

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<b>Table 1. Min &amp; Max Parasitics Measured in Overmolded QFN in sizes between 3 x 3 &amp; 7 x 7.</b>				
	C11 pF	L11 nH	C12pF	L21 nH
Min	0.212	0.825	0.004	0.228
Max	0.248	1.442	0.086	0.598

Table 1 above is a simple summary; Table 3 below contains more details.

### **Configuration and Fabrication Of The QFNs To Be Measured**

PROMEX utilized its capability to package semiconductor die to build the QFNs.

PROMEX procured 2 types of die; one type had only isolated wire bond pads; the second bussed all of the bond pads together. These 2 types of die were built into identical QFNs and the resulting characteristics measured and compared to extract the parasitics.

3 sizes of each type die were procured. The 3 sizes were 1 mm x 1 mm with 16 leads, 2.5 mm x 2.5 mm with 32 leads and 4 mm x 4 mm with 48 leads for a total of 6 kinds of die.

6 leadframes for different size QFNs were available.

**Table 2. Configuration of QFNs Fabricated & Measured**  
**For more specific values see Table 3.**

Size, mm x mm	Lead Count	Lead Pitch, mm
3 x 3	16	0.5
5 x 5	32	0.5
7 x 7	48	0.5
5 x 5	20	0.65
5 x 5	40	0.4
7 x 7	56	0.4

The die were attached to the appropriate leadframe, ball bonded with 0.001" gold wire with a bond from either the open metal pad on the die or the shorted metal pad on the die to each QFN finger, overmolded, marked, X-rayed to ensure wire bonds were not damaged during molding and finally saw singulated.

The result of the QFN fabrication effort was 6 sizes of QFN in the table above.

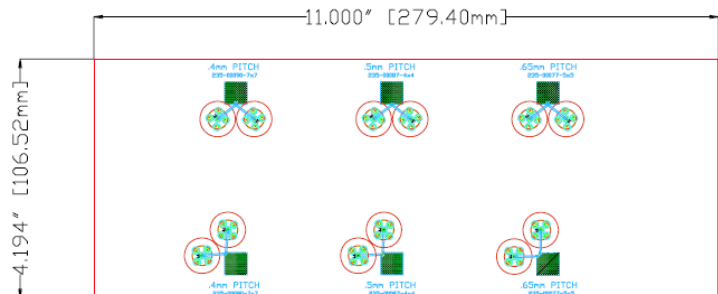
2 types of connection were available in the 6 sizes; in one type all of the leads were "open" because they went to the

die with pads. In the second type all of the leads were shorted because they were bonded to the fully metallized die. The result is a total of 12 different QFNs.

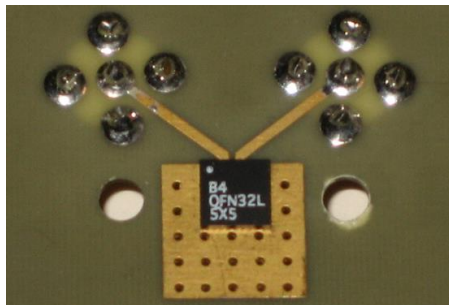
The measurement method to be described compares the properties of each pair of the two types (all opens and all shorts) of QFN to extract the parasitics for each.

### Measurement Of The Part Parasitics

Bogatin did not utilize the conventional microprobe method of measuring high frequency (>1GHz) parameters. A circuit board shown on the right was fabricated that had 6 probe sites. Coax cables, SMA connectors and 50 ohm microstrip traces on the circuit board were used to interface between the network analyzer and the circuit card.



The photo to the left shows one of the 6 sites on the circuit card. This site is used to connect to 0.5 mm pitch side by side contacts on a QFN of any size. 2 similar sites are available to contact to 0.4 mm and 0.65 mm pitch QFNs. In addition, another 3 sites are available to contact corner pads that are at 90° to each other. The solder pads for the 2 SMA connectors that connect to the network analyzer are visible in the top half of the photo.



The measurement effort centered around the 5 mm x 5 mm 32 lead package with a 0.5 lead pitch. The 3 x 3 and 7 x 7 0.5 pitch package were measured to show the variation with size. In addition, 5 x 5 packages with 0.4 mm and 0.65 mm pitch were also measured in

order to understand the impact of pitch on the parasitics.

The parasitics were measured at two points on the QFNs:

a., center pairs of IOs.

b., corner pairs of IO.

In general, 5 measurements were made for each data point. The resulting standard deviation was 5% or less of the average value of all of the parameters.

The actual measurements, data analysis and extraction of the parasitics (C11, C12, L11 L12, Zo, etc.) were made by Bogatin.

The steps in making one measurements are:

1. Measure S11 for the test card without a QFN and the **contact points open**.
2. Measure S11 for the test card without a QFN and the **contact points shorted together**.
3. Measure S11 with the QFN with the **open lead die** contacting the test card contact points.
4. Measure S11 with the QFN with the **shorted lead die** contacting the test card contact points.

S11 was measured and plotted from ~ 10 MHz to 8GHz for all 4 cases. The first 2 measurements on the test card alone showed a bandwidth limit of ~ 5GHz. Nevertheless, by measure S11 over a broad frequency range, accurate measure of S11 for the 4 cases results.

By taking the difference between S11 as measured with the “opens die” QFN and the open contact point test card (measurements 1 and 3 above), S11 for the open lead QFN results over the frequency range measured. Likewise, by taking the difference between S11 for the shorted die QFN and shorted contact test card (measurements 2 and 4 above) S11 for the shorted lead QFN results.

Since S11 is related to Zo, the value of C11 can be computed using the “opens” value of S11 vs frequency with the equations

$$Z_o = 50 \times \frac{(1+S_{11})}{(1-S_{11})}$$

and

$$C_{11} = 1/j\omega Z_o.$$

Likewise, L11 can be computed using the “shorts” value of S11 vs frequency with the equation

$$L_{11} = j\omega Z_o.$$

The values of C21 and L21 can be computed in a similar manner.

This is a little more complex than it looks because the S parameters and  $Z_0$  are complex numbers. See the detailed charts of S11, etc., in the Bogatin Powerpoint Presentation at the link below for the details.

The detailed results are shown in table 3 below.

The **bandwidth shown in table 3 is not the bandwidth of the QFN** but the bandwidth of the measurement method !!

The values of C11, L11, C21 and L2 computed above can be used in a simple lumped parameter model to characterize the QFN packages as long as the dimensions, meaning mostly wire bond length, are less than 1/10 of the wavelength of the frequency of interest. Since these lengths are  $< 1$  mm, the lumped parameter model should be good for signals with a wavelength of 10 mm or more. A 10 mm wavelength in this molding compound, that has a dielectric constant of 4, corresponds to a frequency of 15GHz.

Realistically, the QFN, especially the small sizes, will have minimal impact on signals to a higher frequency. How high is unclear from this work.

### **Links to Details of The Measurement Method and The Parts Measured**

The icon below is to a 25 slide presentation prepared by Eric Bogatin to present the results. The presentation repeats much of the information above but provides more detail and more complete explanations. IT includes; photos of some of the parts and the test apparatus; the data measured; a description of the method by which the parasitics (C11, L11, Ci2 etc.) and electrical parameters were extracted from the S parameter data.



QFN Package Characterization process 2010-07-28\_ppt - Microsoft PowerPoint Web App.mht

This link, [Images of the die used in QFNs](#), shows details of the die used.

The [Drawings of QFNs characterized](#) shows the package configurations of the QFNs measured.

Table 3, Results of the Measurement of QFN Parasitics.

<b>0.4 mm Pitch, Center Leads</b>									
<i>Package/Parameter</i>	<i>C11 (pF)</i>	<i>C21 (pF)</i>	<i>L11 (nH)</i>	<i>L21 (nH)</i>	<i>Z0 (ohms)</i>	<i>BW (GHz)</i>			
3x3	-	-	-	-	-	-	-	-	
5x5	0.231	0.086	0.906	0.568	62.553	6.913			
7x7	0.238	0.075	1.164	0.546	69.862	6.007			
<b>0.4 mm Pitch, Corner Leads</b>									
3x3	0.227	0.016	0.859	0.488	61.591	7.167			
5x5	0.246	0.018	0.919	0.479	61.113	6.661			
7x7	-	-	-	-	-	-			
<b>0.5 mm Center Leads</b>									
3x3	0.212	0.055	0.877	0.379	64.267	7.326			
5x5	0.228	0.059	1.001	0.406	66.203	6.616			
7x7	0.243	0.051	1.016	0.450	64.647	6.363			
<b>0.5 mm Corner Leads</b>									
3x3	0.226	0.013	0.825	0.468	60.416	7.325			
5x5	0.240	0.016	0.997	0.513	64.463	6.465			
7x7	0.262	0.012	1.308	0.598	70.721	5.410			
<b>0.65 mm Pitch, Center Leads</b>									
3x3	-	-	-	-	-	-			
5x5	-	-	-	-	-	-			
7x7	-	-	-	-	-	-			
<b>0.65 mm Pitch, Corner Leads</b>									
3x3	-	-	-	-	-	-			
5x5	0.248	0.004	1.442	0.228	76.193	5.284			
7x7	-	-	-	-	-	-			
<b>Notes</b>									
	1	-							Not measured.
	2	Most values in the above tables are the average of measurements made on 5 separate sites.							
	3	The standard deviation of most parameters was 5% or less.							