Driving the GSPS ADCs in Single- or Dual-Channel Mode for High Bandwidth Applications

Texas Instruments Tech Days. San Jose, CA. 8 December 2011.

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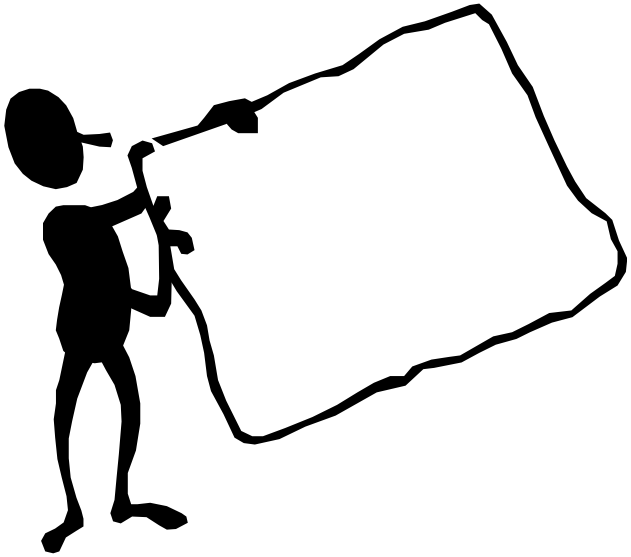
Outline



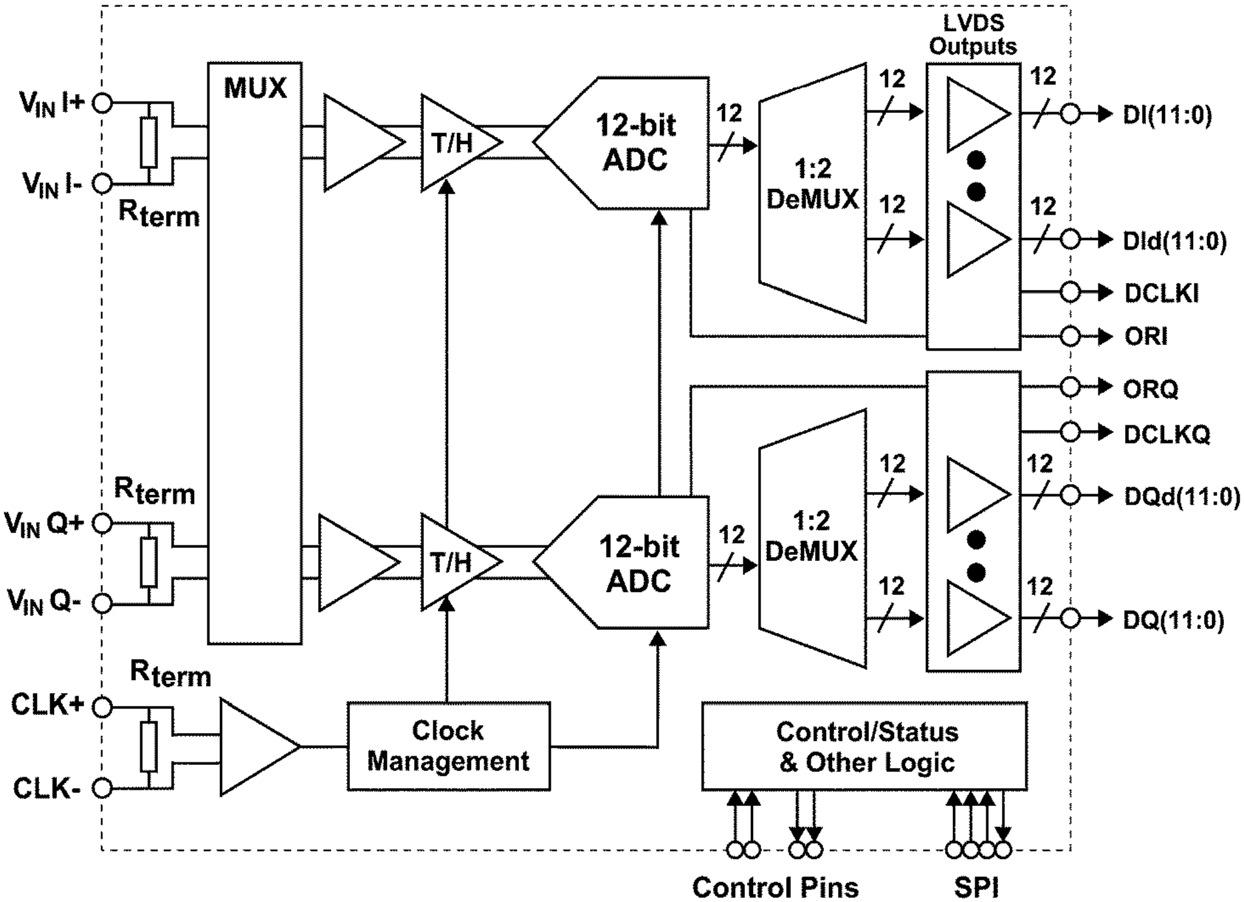
- Overview of the problem
- Solutions evaluation criteria
- Designs tested and key features
- Results summary
- Summary and recommendations

AN OVERVIEW OF THE PROBLEM

Products covered

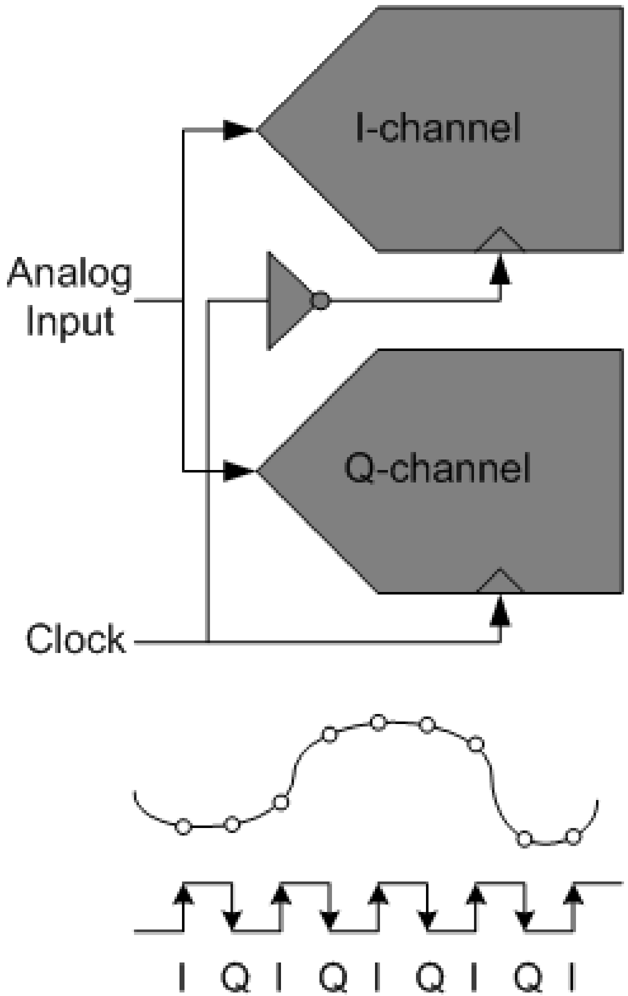
- Which products does the presentation pertain to?
  - ADC12D1800/1600/1000/800/500RF
  - ADC12D1800/1600/1000
  - ADC10D1500/1000
- Actual product evaluated is the ADC12D1600RF

Dual-channel ADCs may be interleaved to achieve 2x sampling rate



There are a number of options for driving the ADC in interleaved mode, which flexibility also presents a design challenge.

What is DES Mode?

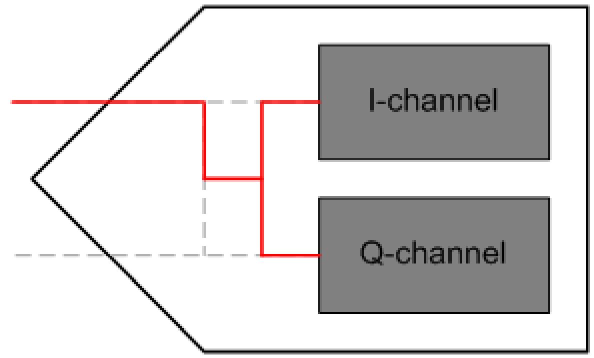


- DES is “Dual-Edge Sampling” Mode.
- This describes how the interleaved mode is clocked.
- One channel samples on the rising edge of the clock while the other channel samples on the falling edge of the clock.
- Both channels sample the same analog input.

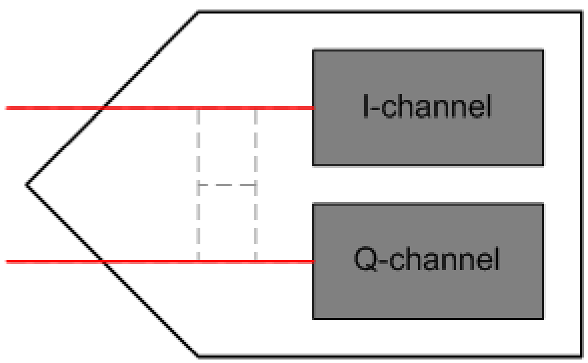
What are the various DES Modes?

	Input Driven	Interleaved
Non-DES	I, Q	No
DESI	I	Yes
DESQ	Q	Yes
DESIQ	I and Q	Yes
DESCLKIQ	I and Q	Yes

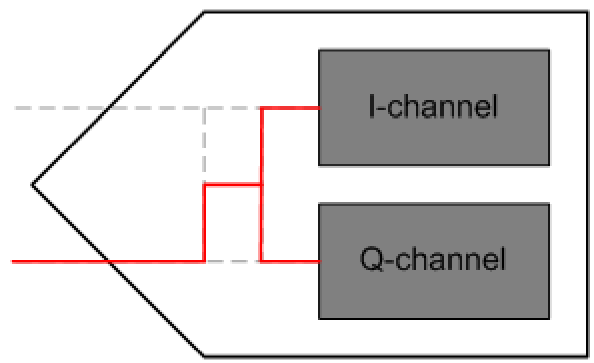
DESI Mode



Non-DES Mode



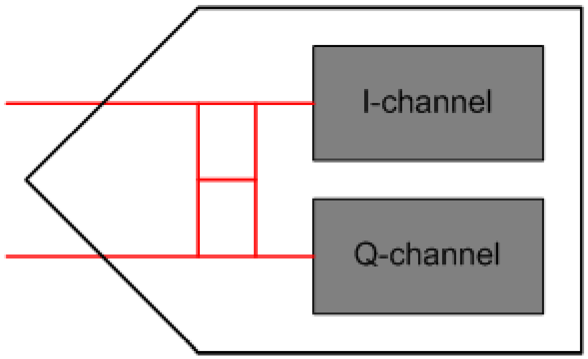
DESQ Mode



Note: Inputs are differential, e.g. V_{IN}Q+/-, but they are represented here as single-ended.

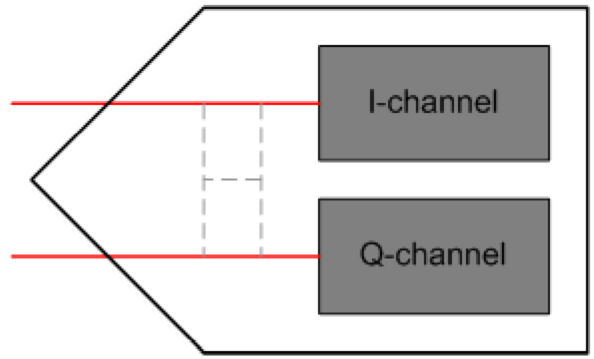
What is the difference between DESIQ and DESCLKIQ Mode?

DESIQ Mode



- Pros
  - Less insertion loss than DESI, DESQ
  - Shorted analog inputs to ensure same signal sampled
- Cons
  - More insertion loss than DESCLKIQ Mode

DESCLKIQ Mode

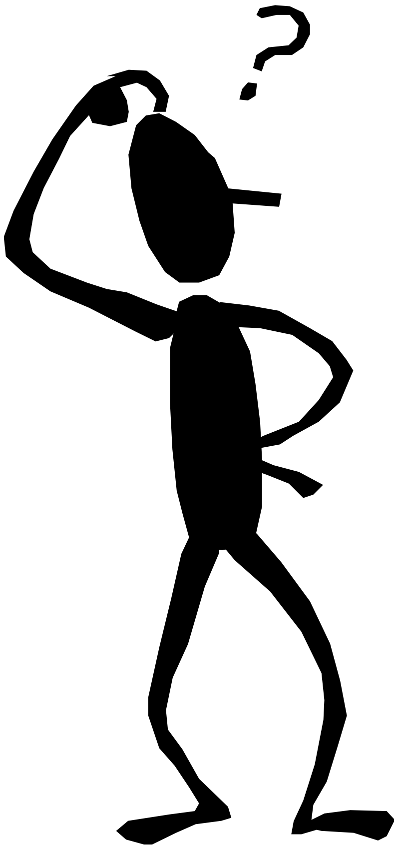


- Pros
  - Minimum insertion loss
- Cons
  - Driving the non-shorted inputs requires careful design to ensure the signal fidelity at each point

Which product has which mode available?

	Non-DES	DESI, DESQ	DESIQ	DESCLKIQ
ADC12D1800/1600/1000RF	✓	✓	✓	✓
ADC12D800/500RF	✓	✓	✓	✓
ADC12D1800/1600/1000	✓	✓	✓	
ADC10D1500/1000	✓	✓	✓	

Problem statement



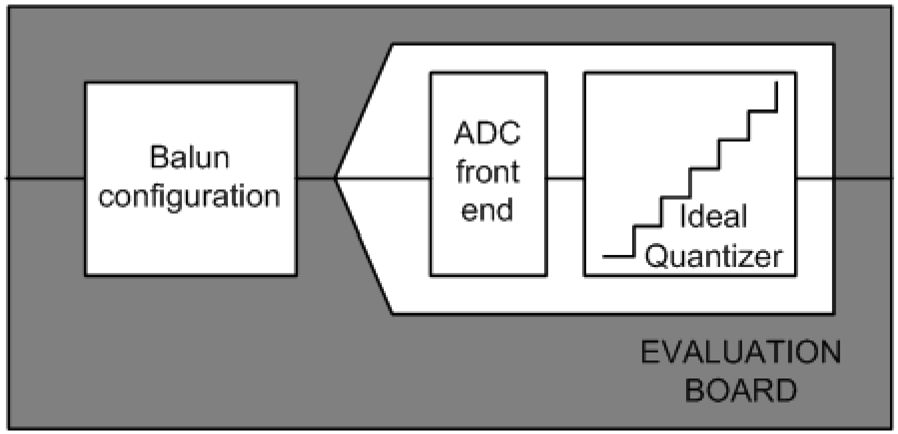
What is a recommended topology, layout, and type of balun to effectively drive each mode?

SOLUTIONS EVALUATION CRITERIA

Dynamic Performance

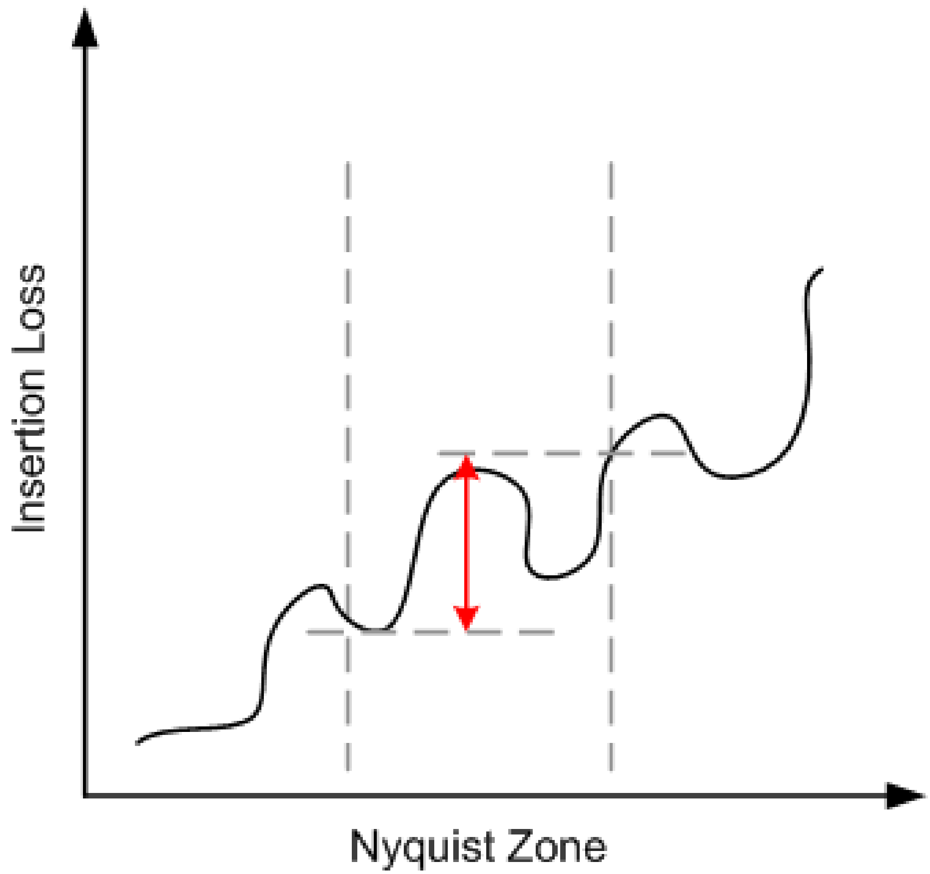
- Signal-to-Noise Ratio (SNR)
- Spurious Free Dynamic Range (SFDR)
- Total Harmonic Distortion (THD)
- Effective Number of Bits (ENOB)

Insertion Loss



- The system insertion loss, in dB, includes effects from:
  - Evaluation board
  - Balun configuration
  - ADC front-end

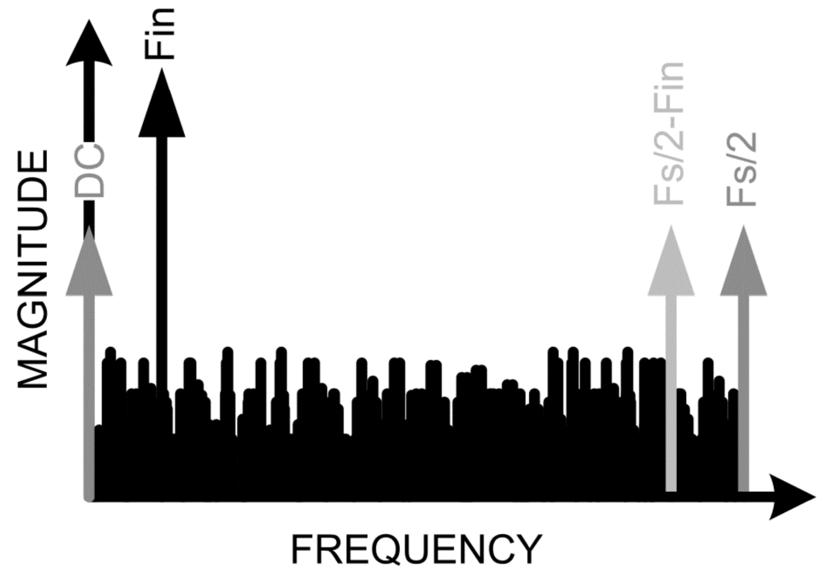
Gain Flatness



- The maximum ripple in insertion loss per Nyquist zone

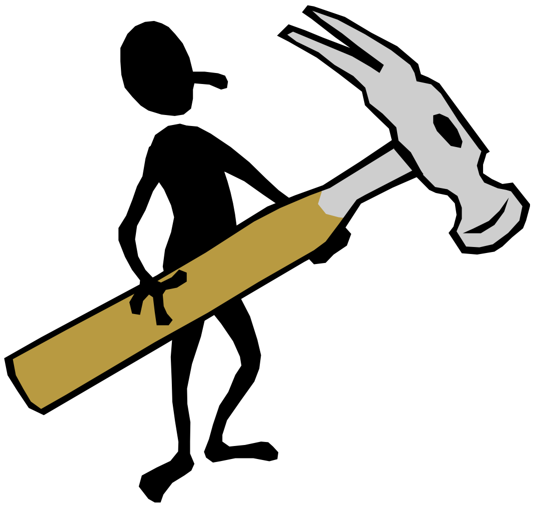
Ability to Minimize DES Timing Spur

- Gain mismatch and timing skew create an interleaving spur, located at Fs/2 – Fin.
- This spur can be minimized by the Channel Full-Scale Range and DES Timing Adjust features.
- The solution should allow for the magnitude of the interleaving spur to be adjusted below the level of other spurs, so that it is not the SFDR-limiting spur.



Spurious content generated from offset and gain mismatch and timing skew.

Multi-mode applications



- Some applications require the flexibility to configure the ADC into multiple interleaved modes.
- Can the topology accommodate that?

DESIGNS TESTED

Design Planning

Things to Consider

- Topology: I and Q inputs are differential and mirrored
- Input impedance: changes when inputs are driven in parallel
- Balun selection: test a wire-wound and a multi-layer balun

Designs Tested

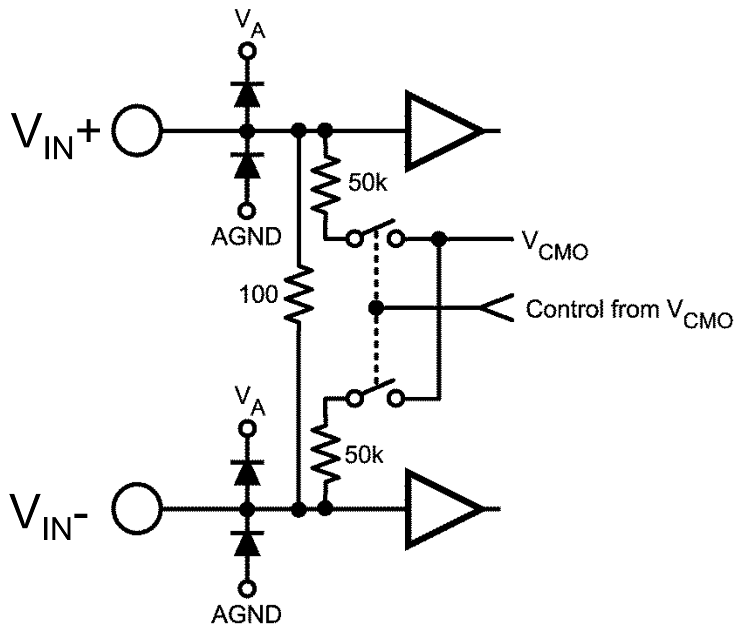
- Board A: Multi-layer balun with power splitter to I- and Q-channel input
- Board B: Multi-layer balun on I-channel input; wire-wound balun on Q-channel input
- Board C: Cascaded Multi-layer balun to I- and Q-channel input
- Board D: Cascaded Multi-layer balun to I- and Q-channel input with shorted inputs

Topological challenge

G	V_TC	GND_TC	V_TC	V_TC
H	VinI+	V_TC	GND_TC	V_A
J	VinI-	GND_TC	V_TC	VbiasI
K	GND	VbiasI	V_TC	GND_TC
L	GND	VbiasQ	V_TC	GND_TC
M	VinQ-	GND_TC	V_TC	VbiasQ
N	VinQ+	V_TC	GND_TC	V_A
P	V_TC	GND_TC	V_TC	V_TC

- Driving the I- and Q-channels externally at the same time is challenging because I+ and Q+ are not adjacent to one another. (Also, not I- and Q-).
- For a solution which is directly driven, this requires that at least one signal must cross over two of the others. It is challenging to design this layout to be symmetrical.

Impedance Considerations

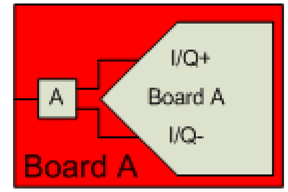


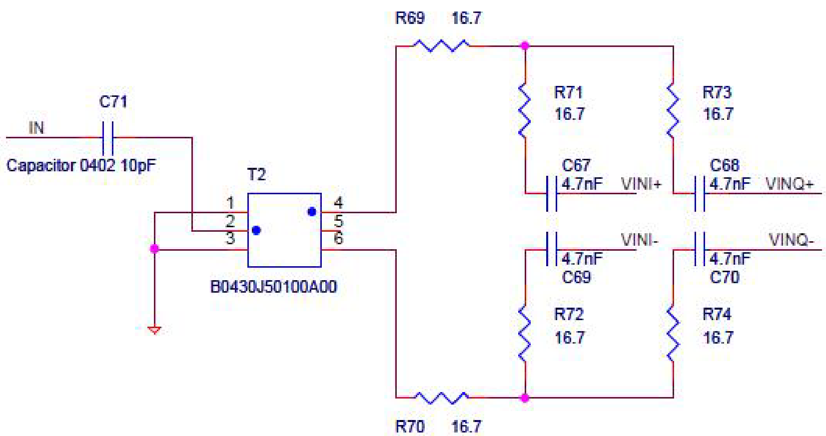
- When driving one I or Q input, the input impedance is 100Ω differential:
  - Non-DES
  - DESI
  - DESQ
- When driving both I and Q inputs, the combined input impedance is 50Ω differential:
  - DESIQ
  - DESCLKIQ

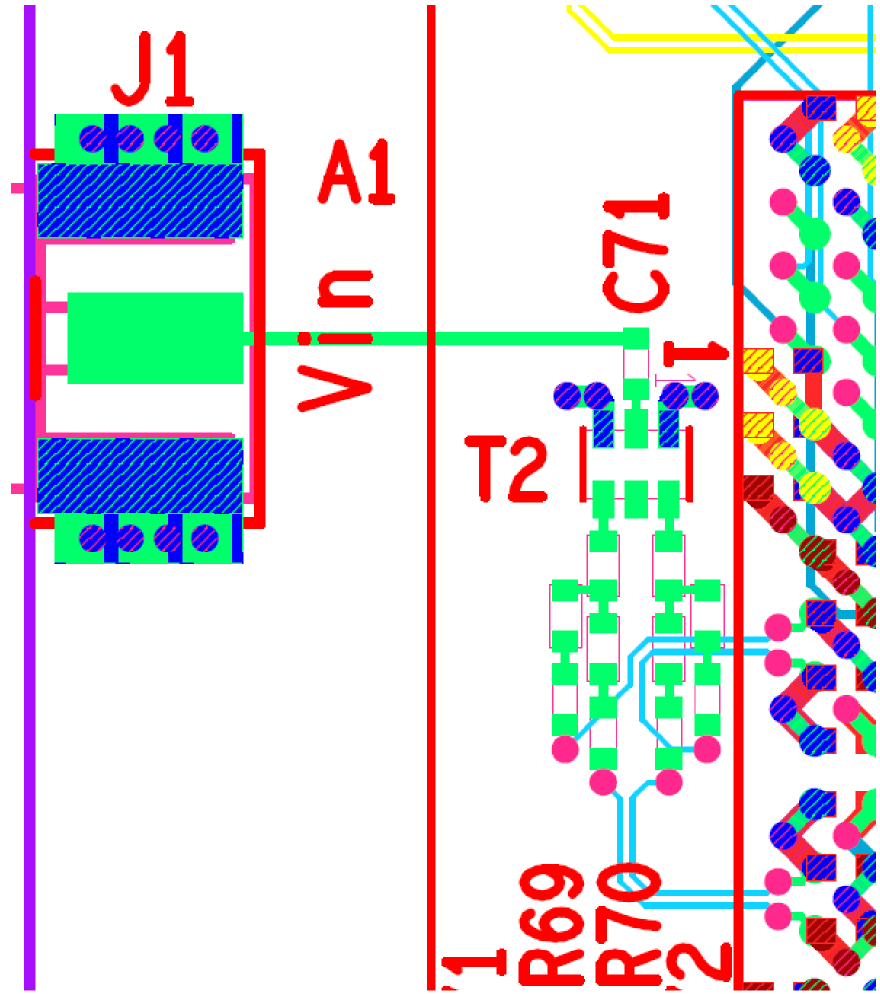
Baluns Evaluated

Manufacturer	Anaren	Mini-Circuits
Model	B0430J50100A00	TC1-1-13MA+
Frequency Range	{400 MHz, 3 GHz}	{4.5 MHz, 3 GHz}
Impedance Ratio	1:2	1:1
Description	Multi-layer: coupled strip-line with softboard dielectric	Wire-wound with ferrite core

Board A: Multi-layer balun with power splitter to I- and Q-channel input



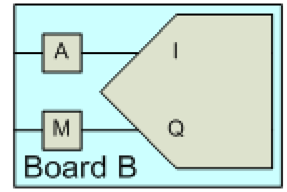


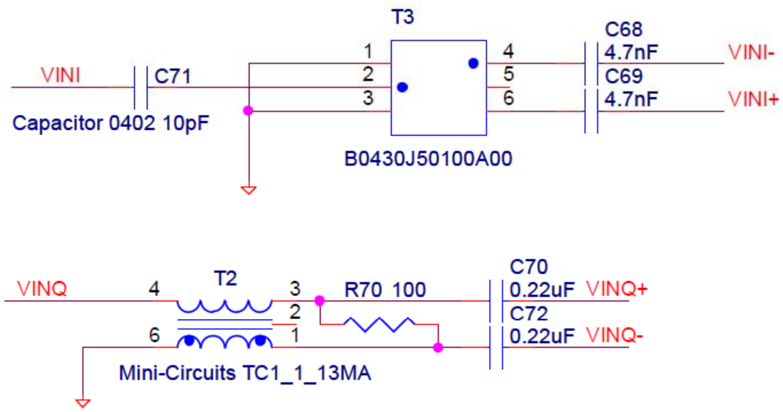


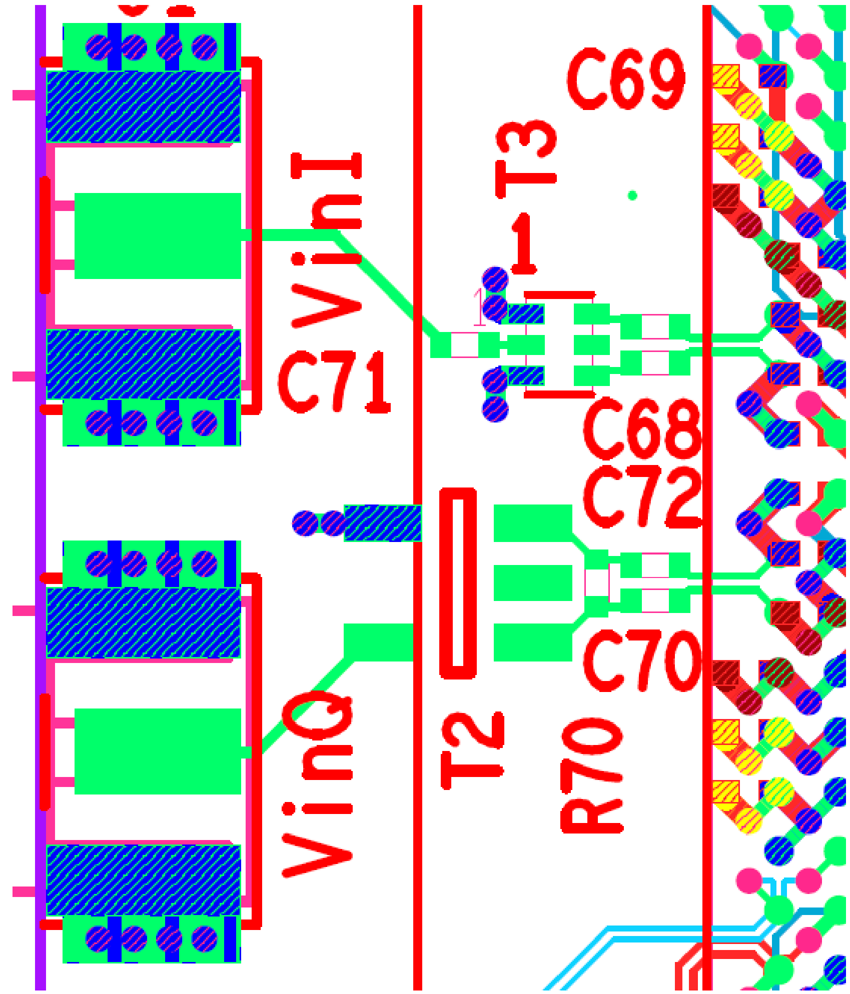
<u>Key Features:</u>

- Testing DESIQ and DESCLKIQ Modes
- Single Multi-layer balun
- Resistors are used to split the power and maintain impedance matching
- Routing in multiple layers

Board B: Multi-layer balun on I-input; wire-wound balun on Q-input



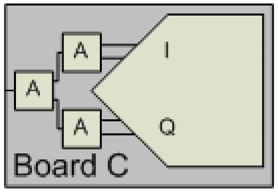


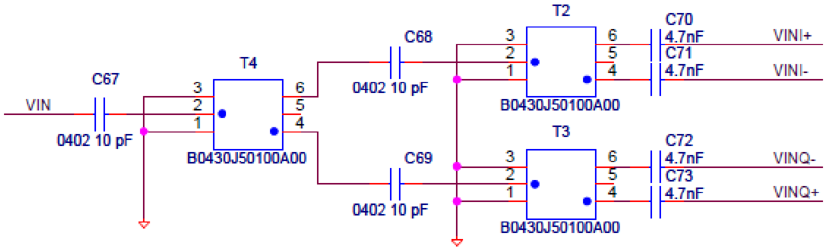


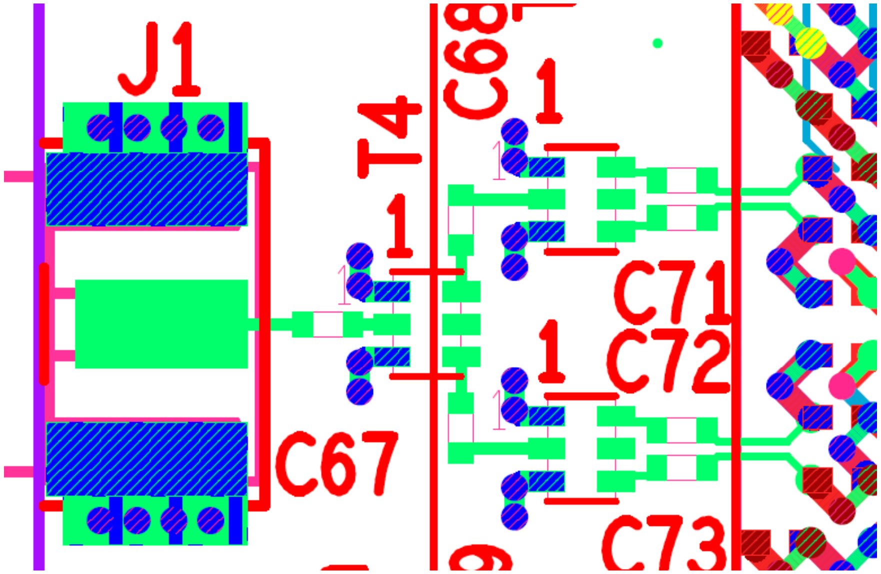
Key Features:

- Testing Non-DES, DESI, DESQ Modes
- One of each Multi-layer and wire-wound balun
- All routing accomplished in one layer
- Compact, balanced layout for best dynamic performance

Board C: Cascaded Multi-layer balun to I- and Q-channel input



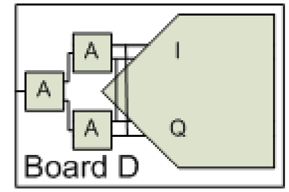


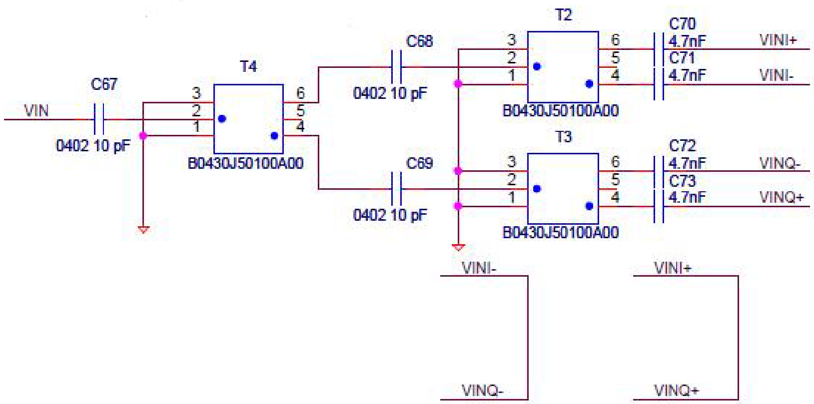


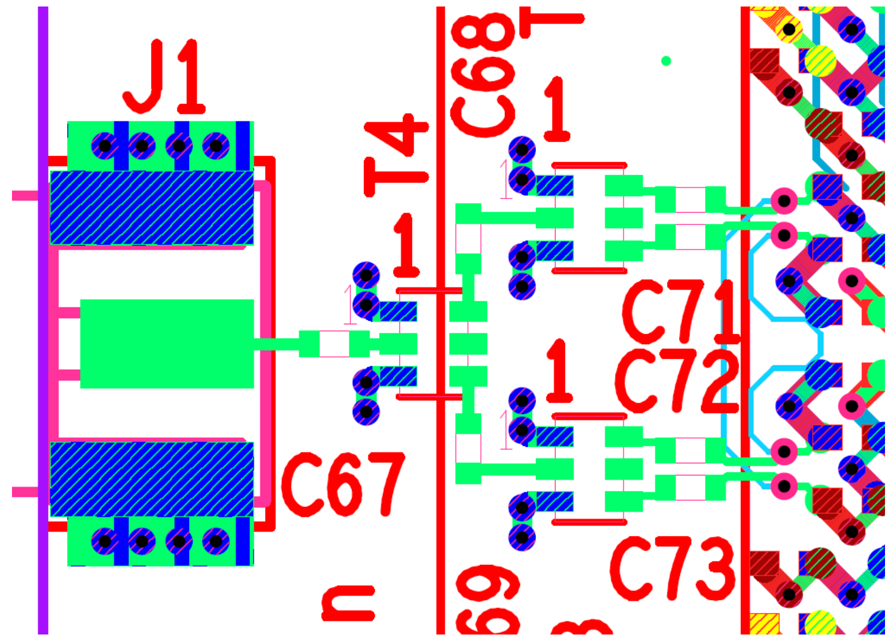
Key Features:

- Testing DESIQ, DESCLKIQ Modes
- Adding a selectable input to Pin 2 of T2 and Pin 2 of T3 can enable driving the part in DESI, DESQ, and Non-DES Modes, in addition to DESIQ Mode
- Cascaded Multi-layer balun design achieves impedance matching correct phase at each output, so that all routing may be accomplished in one layer

Board D: Cascaded Multi-layer balun to I- and Q- inputs with short







Key Features:

- Testing DESIQ, DESCLKIQ Modes
- Cascaded Multi-layer balun design achieves impedance matching correct phase at each output, so that all routing may be accomplished in one layer
- Shorted inputs (I+ to Q+, I- to Q-) to ensure same analog input signal is sampled

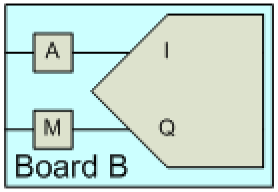
Non-DES Mode

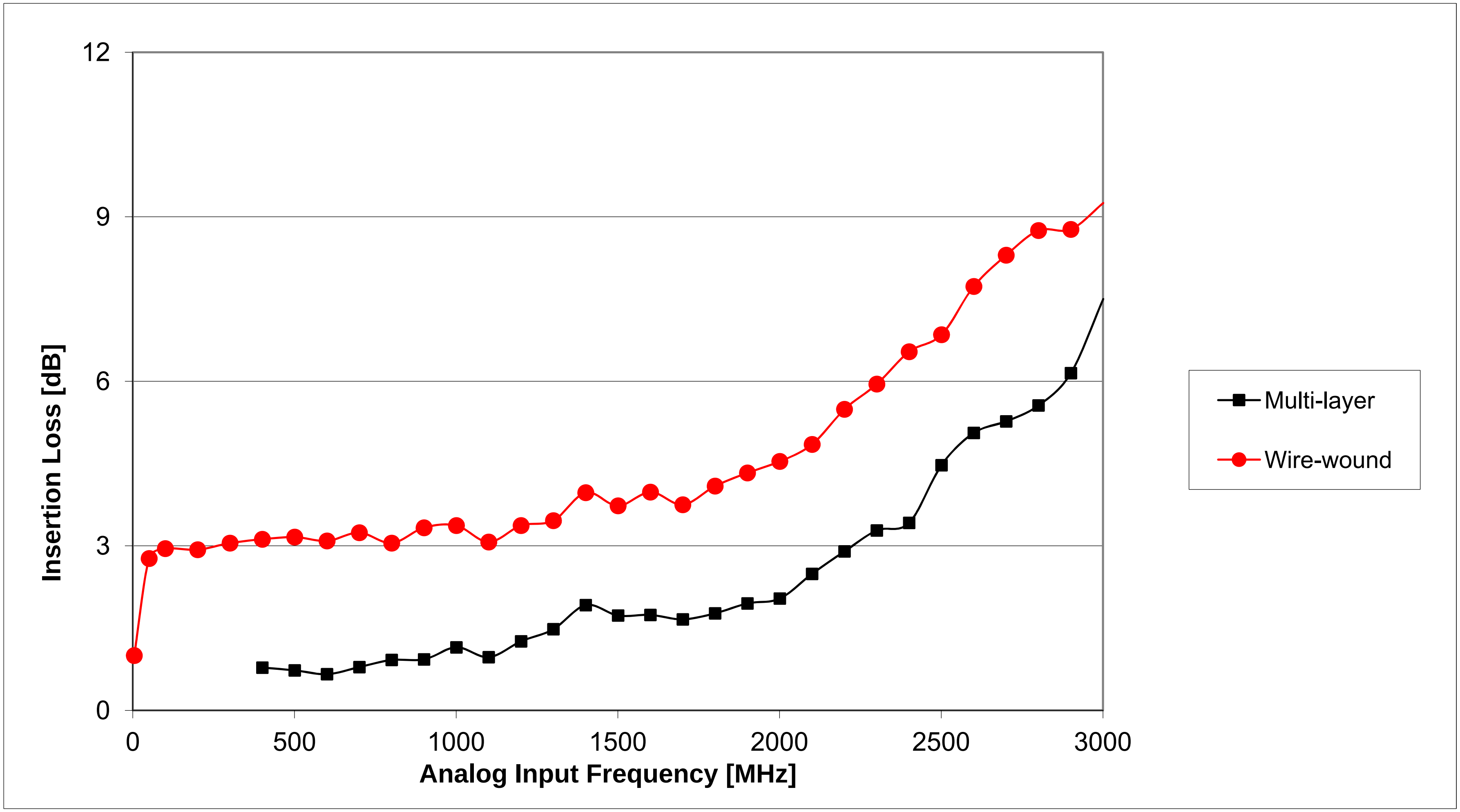
DESI and DESQ Mode

DESIQ and DESCLKIQ Mode

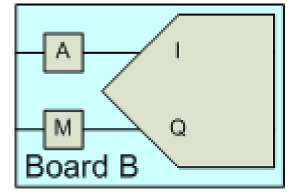
RESULTS SUMMARY

Non-DES Mode Insertion Loss





Non-DES Mode Gain Flatness

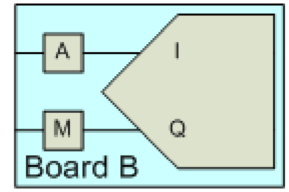


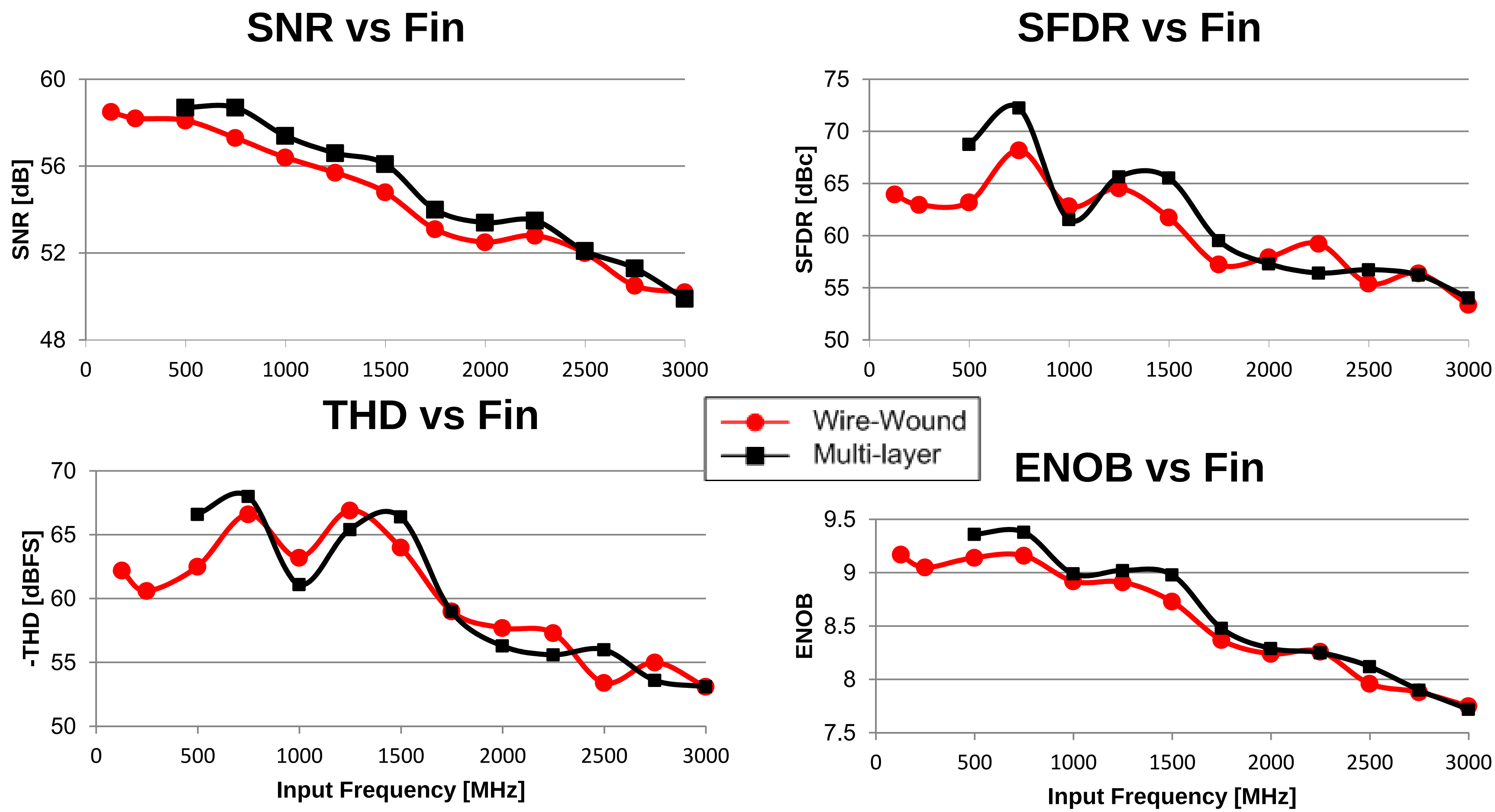
Nyquist Zone	Frequency Range	Multi-layer	Wire-wound
	[MHz]	[dB]	[dB]
1*	100 - 800	0.26	0.31
2	800 - 1600	1.00	0.93
3	1600 - 2400	1.76	2.79
4**	2400 - 3000	4.08	2.71

* The Multi-layer balun lower range is 400MHz. The wire-wound balun gain ripple is only measured from 100MHz.

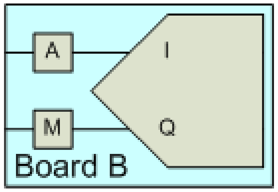
** Nyquist zone 4 covers up to 3200MHz, but the baluns' range covers only to 3000MHz.

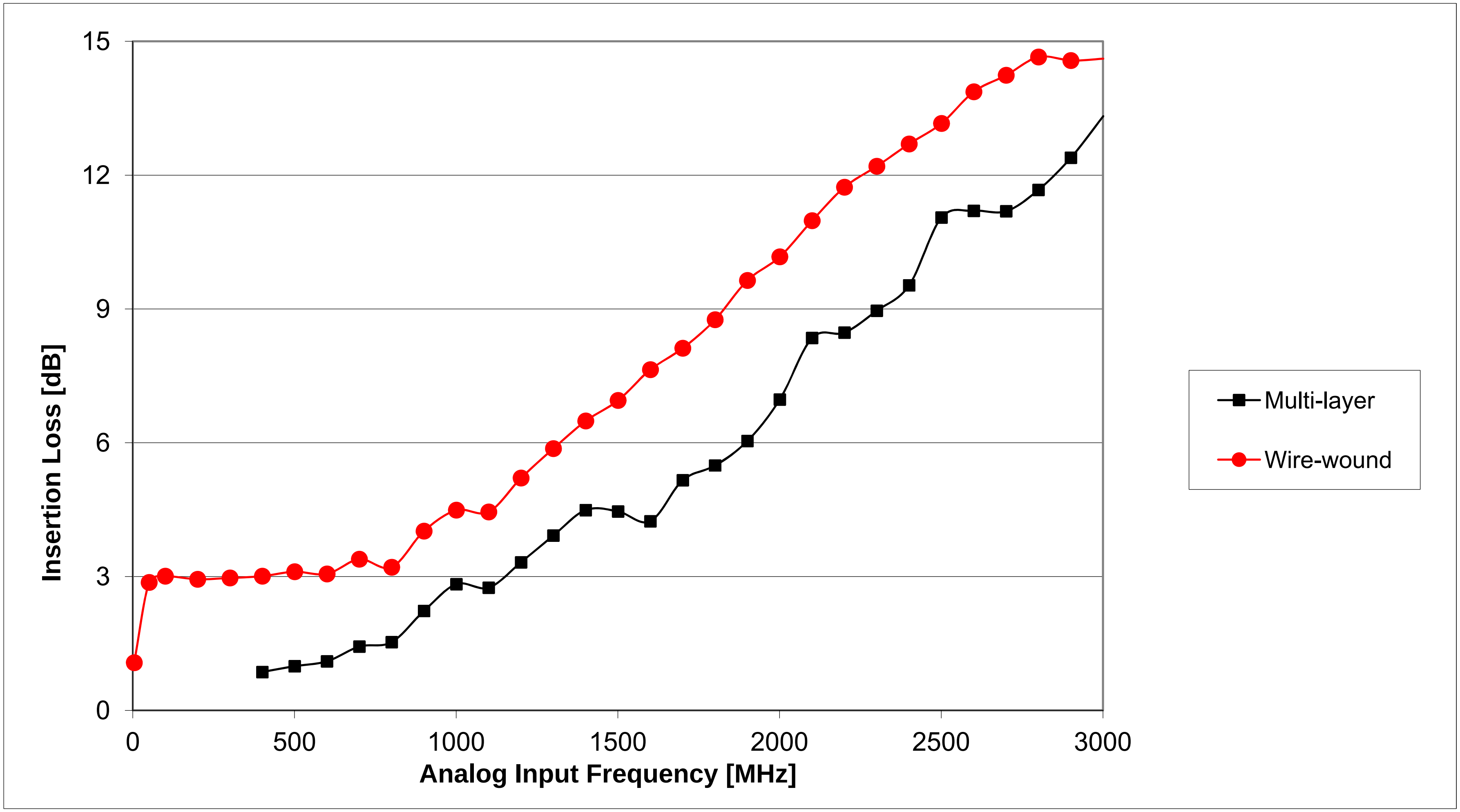
Non-DES Mode Dynamic Performance



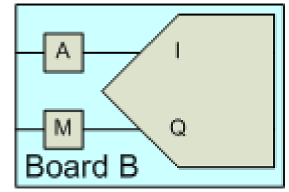


DESI & DESQ Mode Insertion Loss





DESI & DESQ Mode Gain Flatness

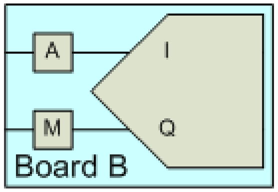


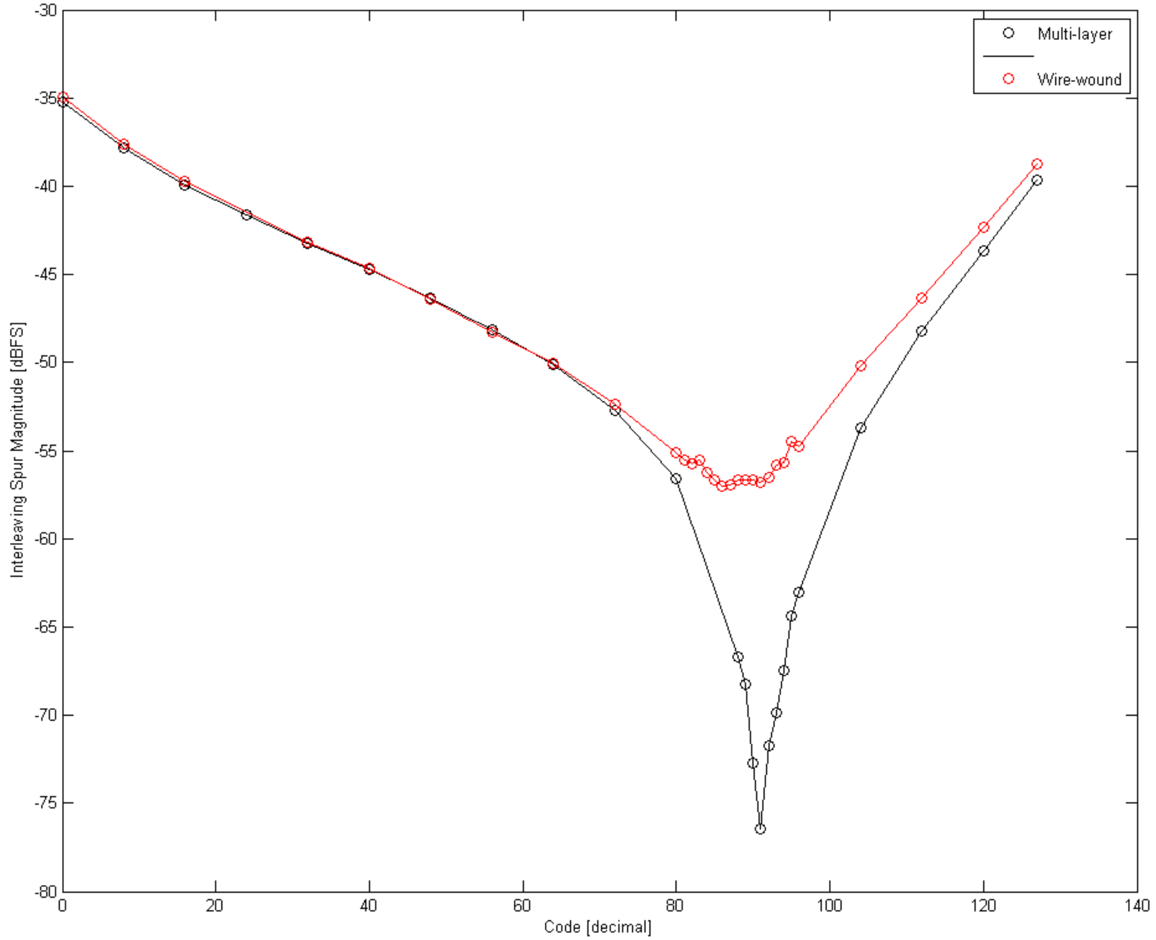
Nyquist Zone	Frequency Range	Multi-layer	Wire-wound
	[MHz]	[dB]	[dB]
1*	100 - 1600	3.56	4.7
2**	1600 - 3000	9.08	7.01

* The Multi-layer balun lower range is 400MHz. The wire-wound balun gain ripple is only measured from 100MHz.

** Nyquist zone 2 covers up to 3200MHz, but the baluns' range covers only to 3000MHz.

DESI & DESQ Mode DES Timing Adjust

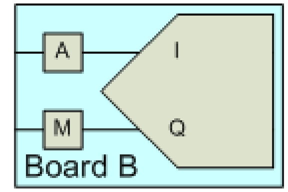


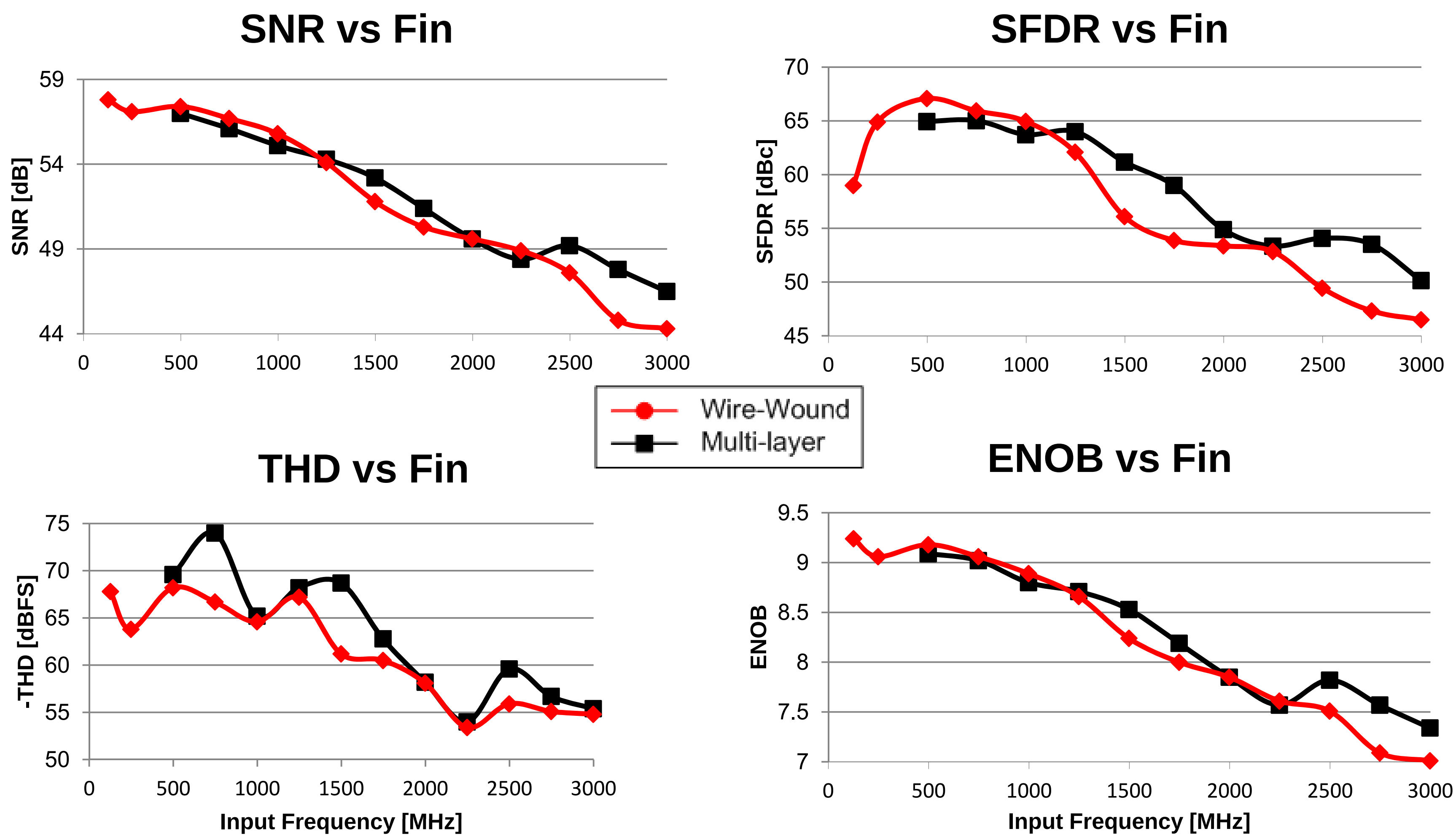


Balun	Unadjusted Gain Mismatch
Multi layer	0.14%
Wire wound	0.33%

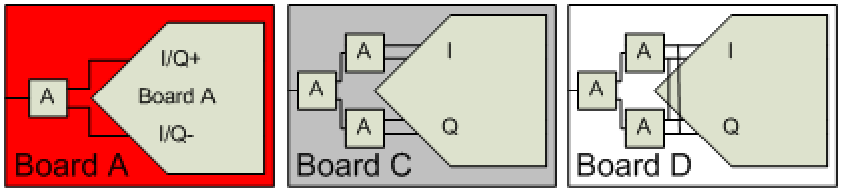
- Fin = 1300MHz @ -1dBFS
- Achieving a null in the interleaving spur is dependent upon I/Q-channel gain mismatch and timing skew.

DESI & DESQ Mode Dynamic Performance

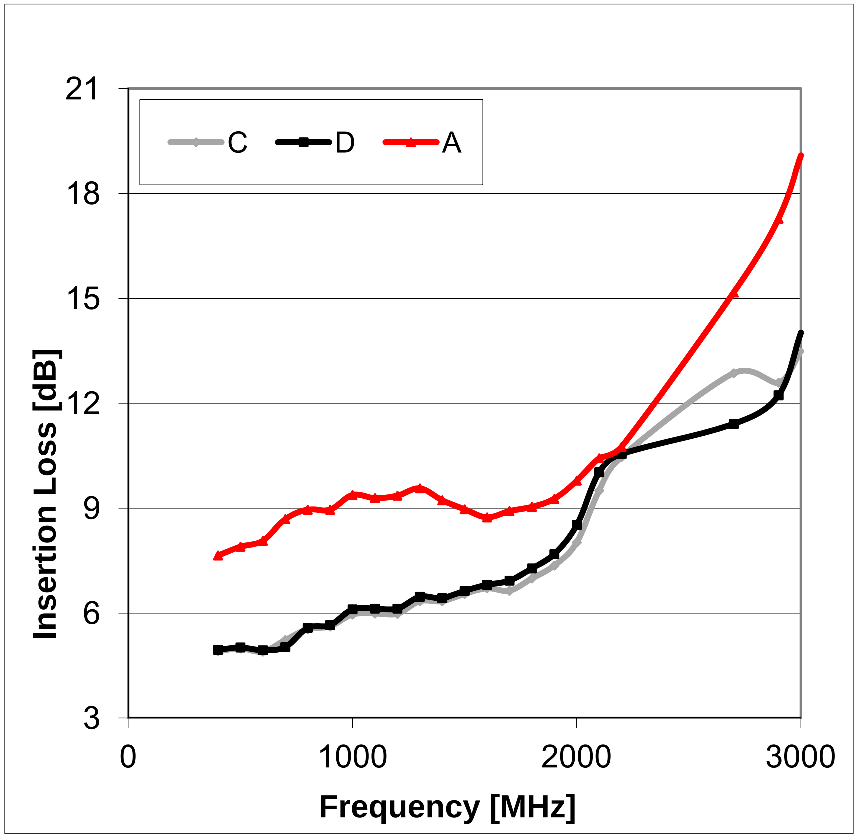




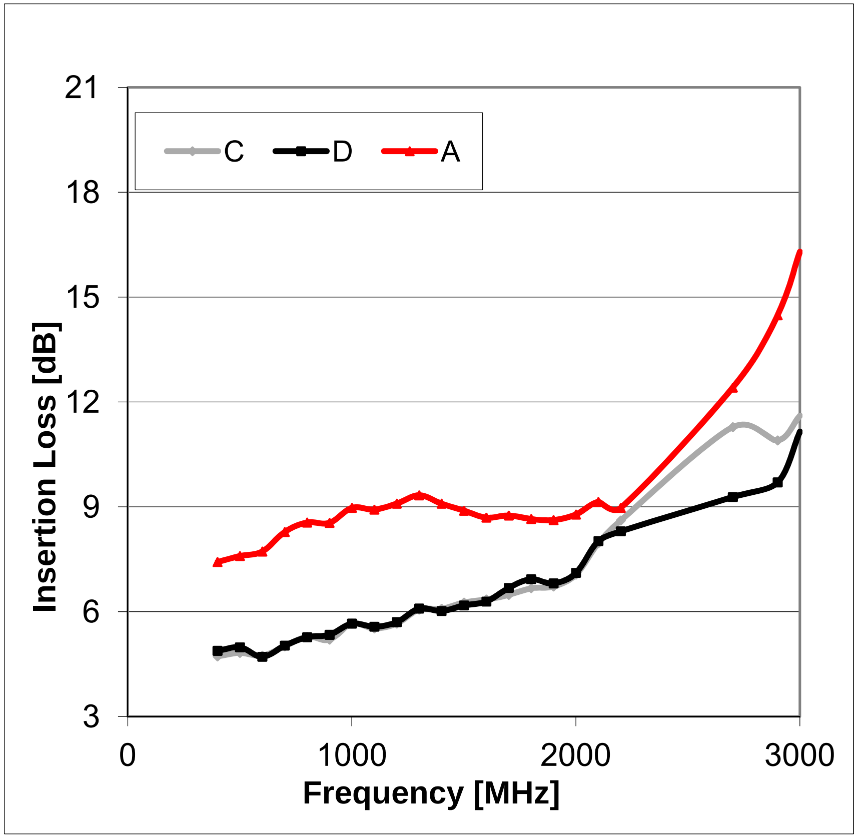
DESIQ and DESCLKIQ Mode Insertion Loss



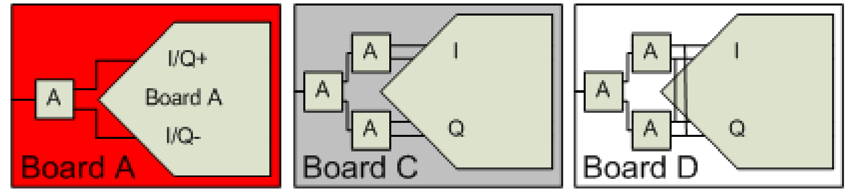
DESIQ Mode



DESCLKIQ Mode



DESIQ and DESCLKIQ Mode Gain Flatness



DESIQ Mode

Nyquist Zone	Frequency Range	Board A	Board C	Board D
	[MHz]	[dB]	[dB]	[dB]
1*	400 - 1600	1.92	1.81	1.87
2**	1600 - 3000	10.35	6.85	7.21

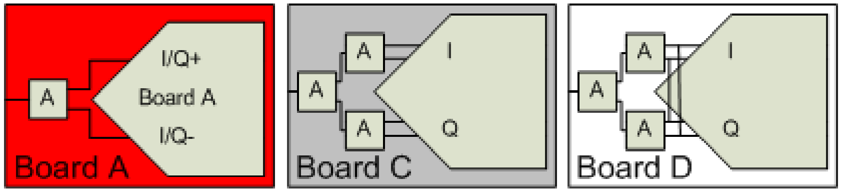
DESCLKIQ Mode

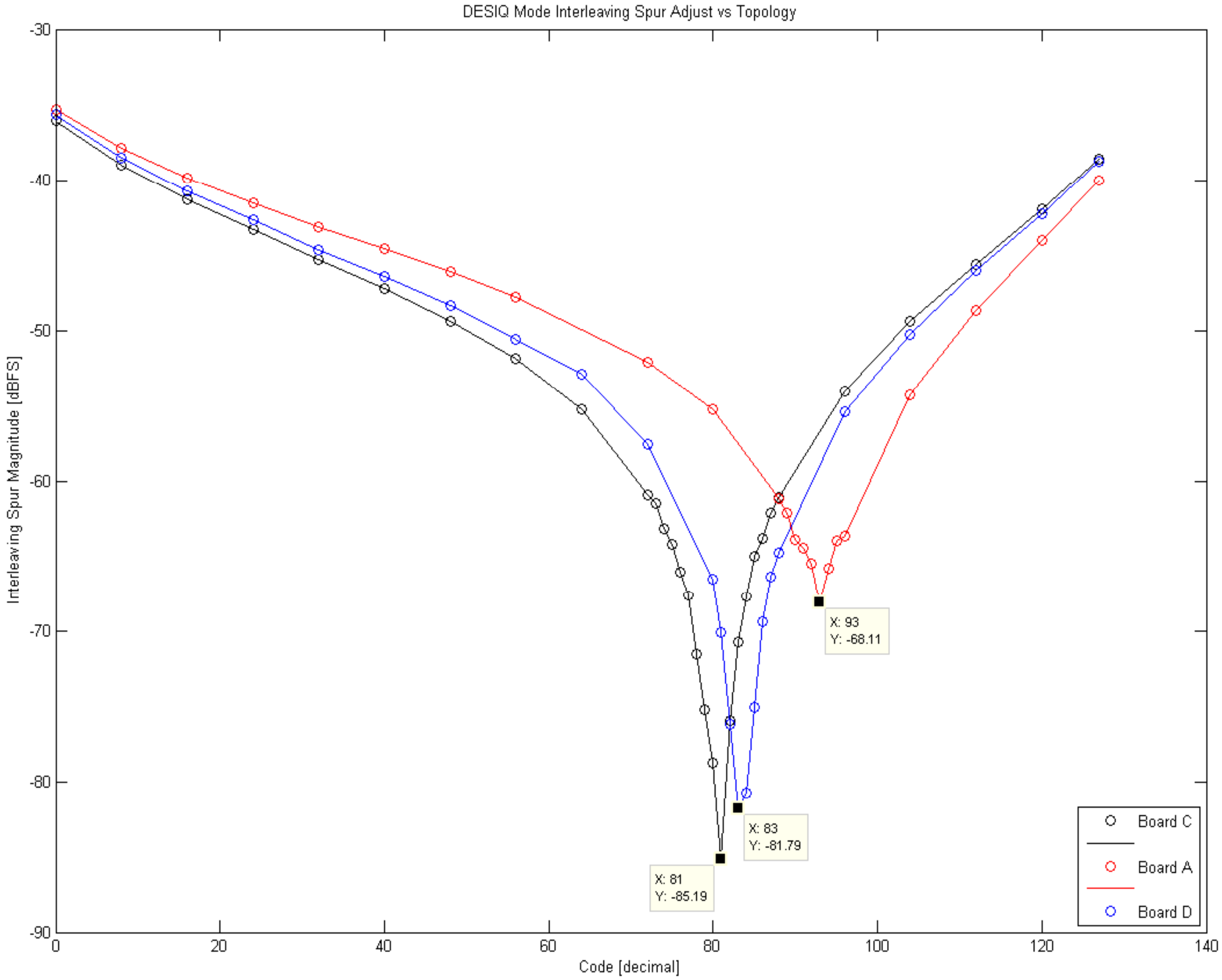
	[MHz]	[dB]	[dB]	[dB]
1*	400 - 1600	1.91	1.63	1.58
2**	1600 - 3000	7.68	5.26	4.86

* The Merrill balun lower range is 400MHz.

** Nyquist zone 2 covers up to 3200MHz, but the balun's range covers only to 3000MHz.

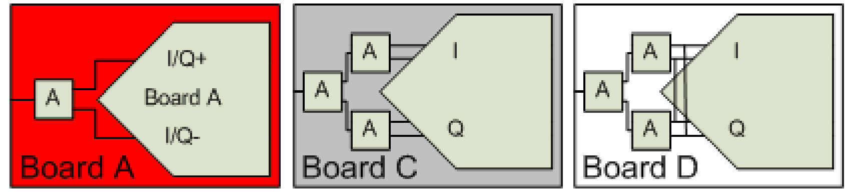
DESIQ Mode DES Timing Adjust

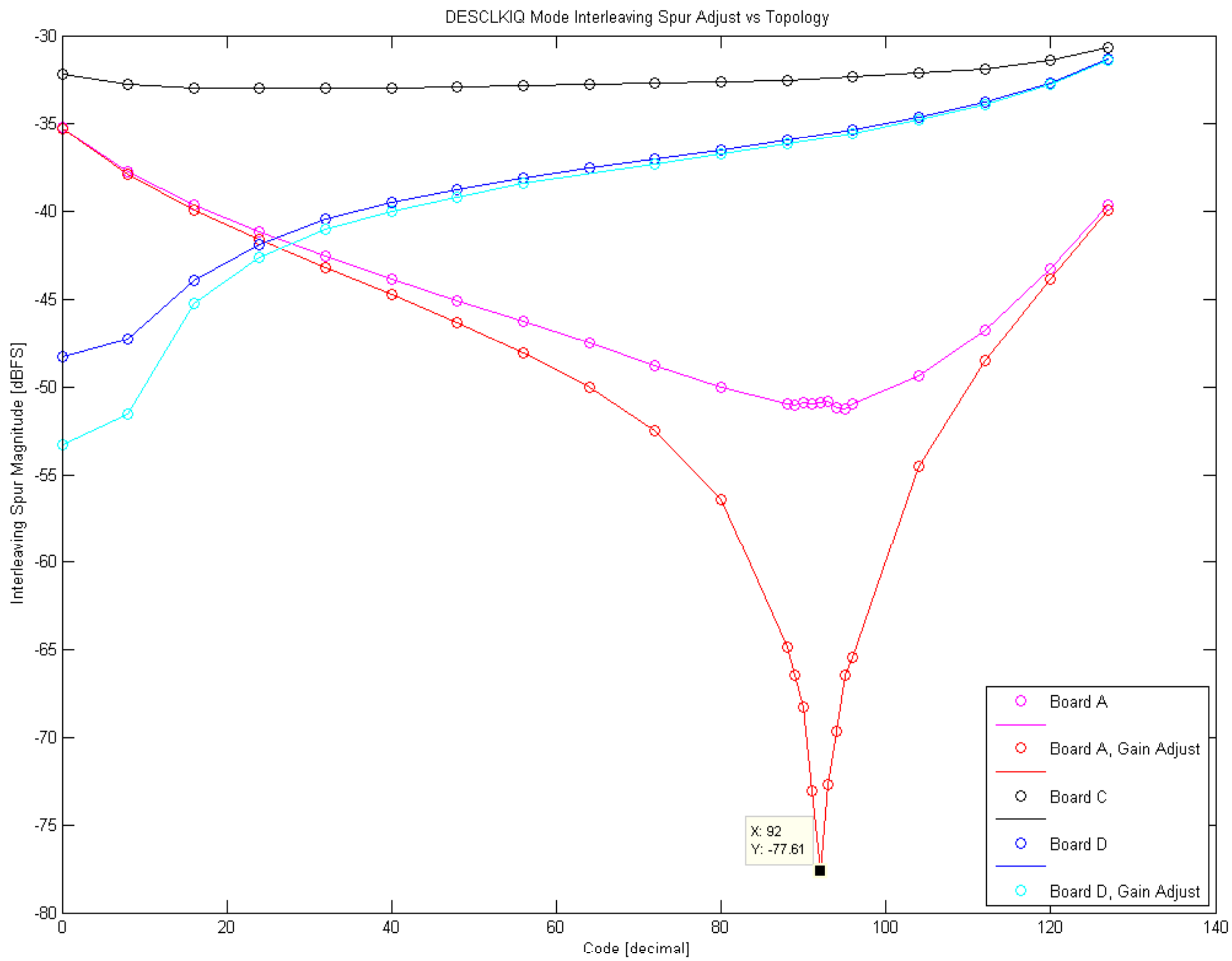




Board	Unadjusted Gain Mismatch
C	0.06%
A	0.04%
D	0.07%

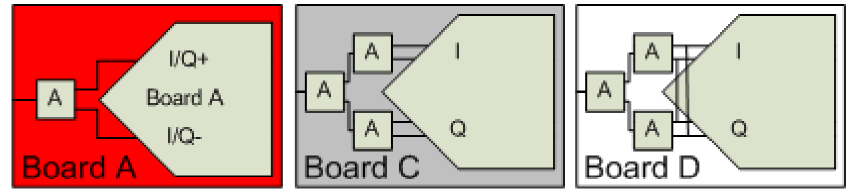
DESCLKIQ Mode DES Timing Adjust

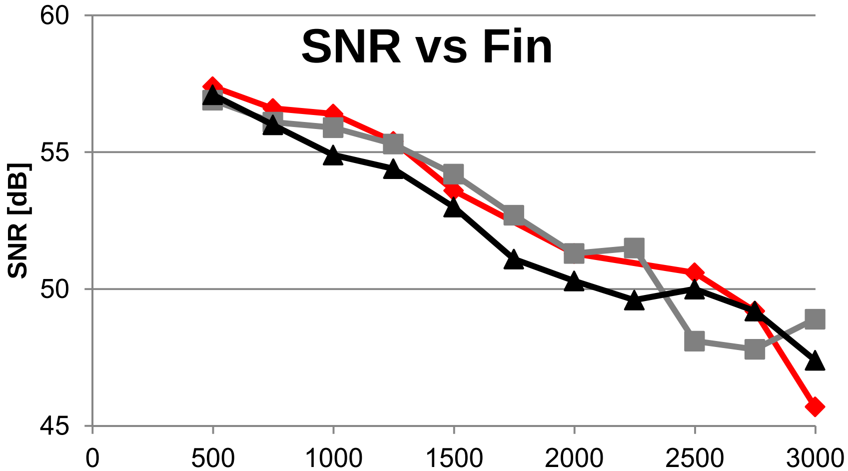


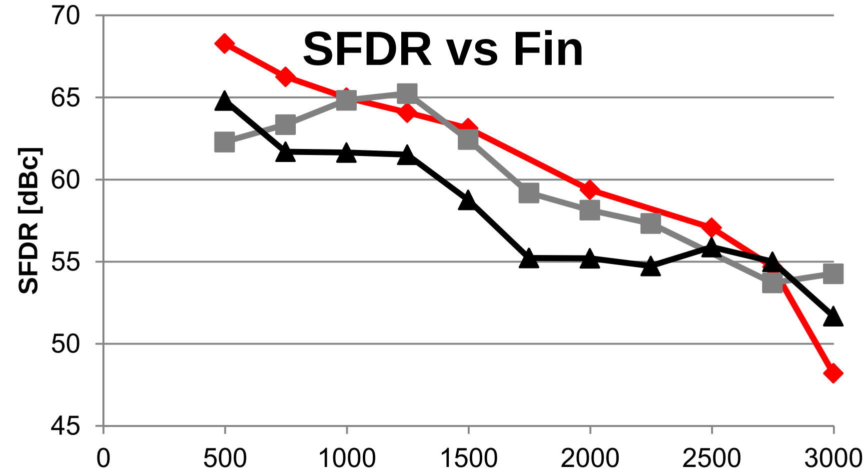


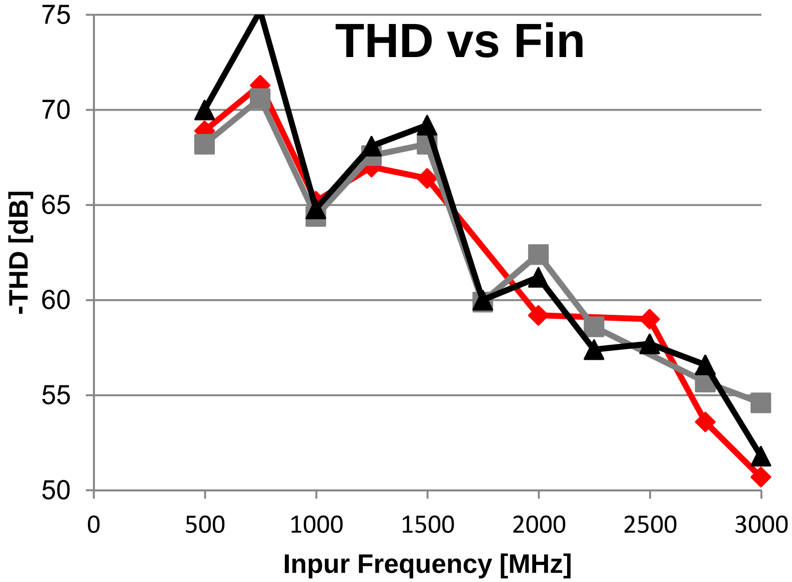
Board	Gain Adjust	Mis-match
A	No	5.4%
A	Yes	0.06%
C	No	4.45%
D	No	0.43%
D	yes	0.01%

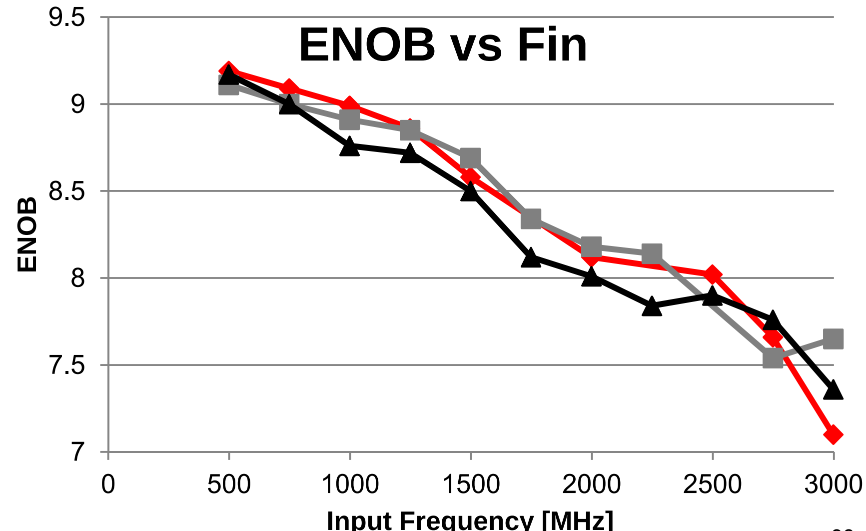
DESIQ Mode Dynamic Performance



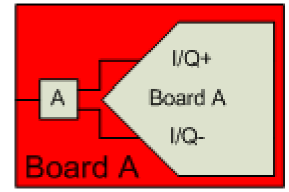


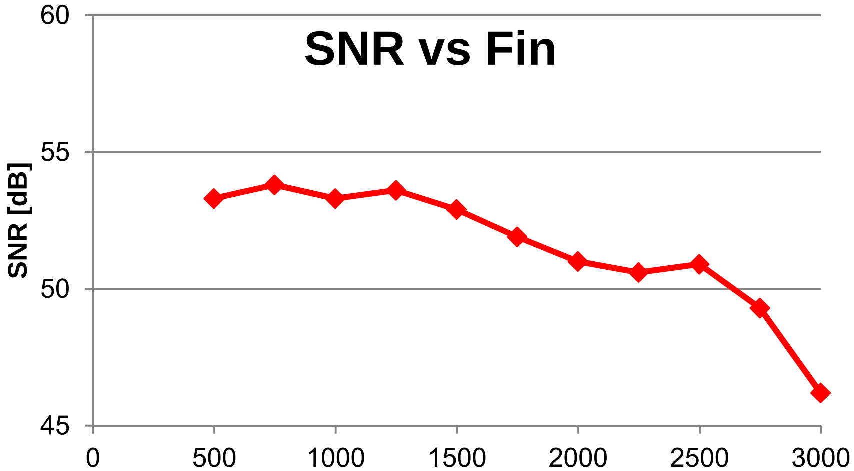


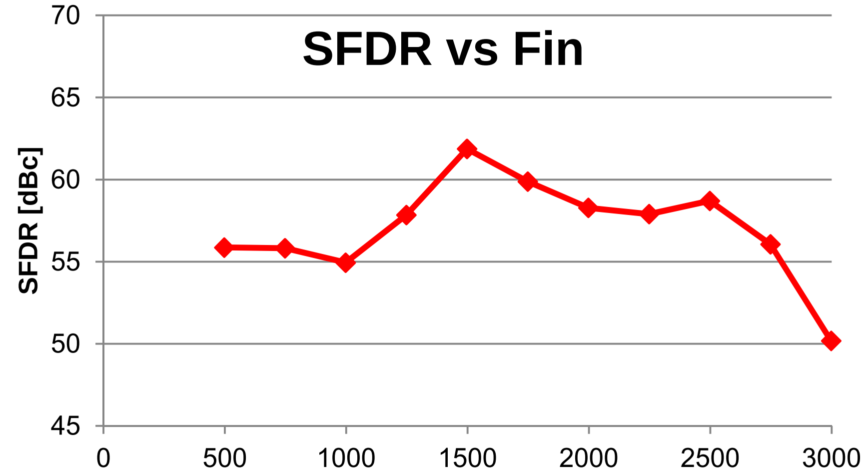


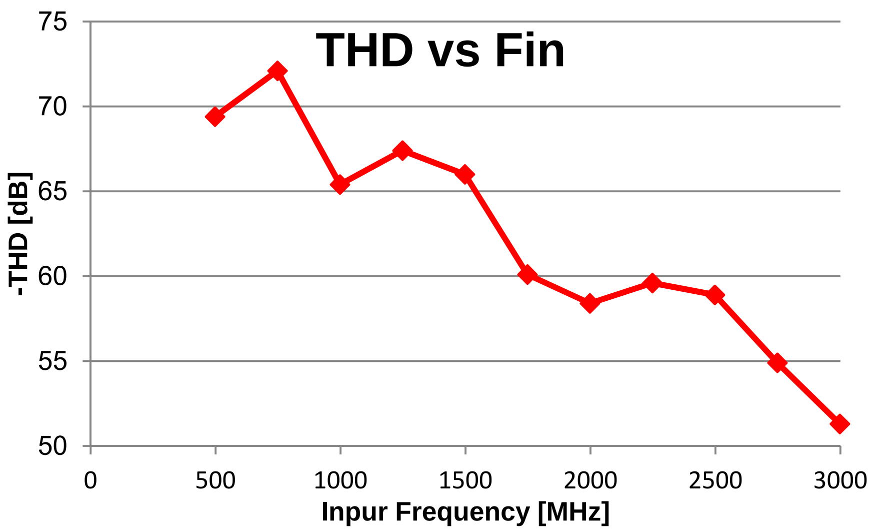


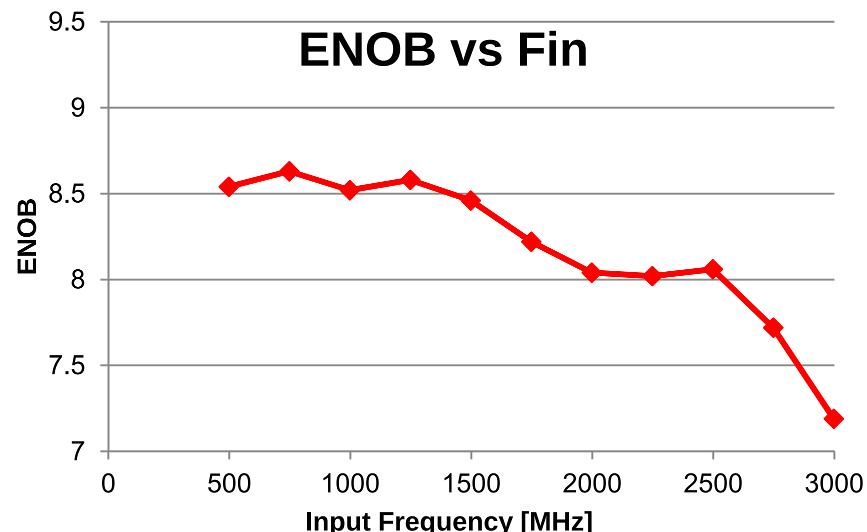
DESCLKIQ Mode Dynamic Performance











SUMMARY AND RECOMMENDATIONS

Non-DES Mode Summary

Criteria	Multi-layer	Wire-wound
Dynamic Performance	Excellent	Average
Insertion Loss	Excellent	Average
Gain Flatness	Good	Good
Frequency Range	Good	Excellent
Multi-mode Application	Average	Average

- The multi-layer balun excels in the areas of dynamic performance and insertion loss while the wire-wound balun is excellent for frequency range.
- Both baluns can easily drive both Non-DES Mode and DESI (or DESQ) Mode.

DESI and DESQ Mode Summary

Criteria	Multi-layer	Wire-wound
Dynamic Performance	Good	Average
Insertion Loss	Excellent	Average
Gain Flatness	Good	Good
Frequency Range	Good	Excellent
Multi-mode Application	Average	Average
Interleaving Spur Adjust	Excellent	Poor

- The multi-layer balun is a good all-round choice for multiple criteria.
- The wire-wound balun is excellent for frequency range, but poor for adjusting the interleaving spur.

DESIQ and DESCLKIQ Mode Summary

DESIQ Criteria	Board A	Board C	Board D
Dynamic Performance	Average	Good	Below Average
Insertion Loss	Below Average	Average	Average
Gain Flatness	Below Average	Good	Average
Interleaving Spur Adjust	Average	Good	Good
Multi-mode Application	Average	Excellent	Average

DESCLKIQ Criteria	Board A	Board C	Board D
Dynamic Performance	Below Average	Not Recommended	Not Recommended
Insertion Loss	Below Average	Good	Good
Gain Flatness	Average	Good	Good
Interleaving Spur Adjust	Good	Poor	Poor
Multi-mode Application	Average	Excellent	Average

Solutions Recommendation

- **Non-DES Mode: The multi-layer balun is the better solution for driving Non-DES Mode. This is true except for applications which require a large input frequency range, especially at low frequencies.**
- **DESI and DESQ Mode: Similarly, the multi-layer balun is better for driving DESI and DESQ Mode. It is also easier to adjust the DES timing spur using the multi-layer balun.**
- **DESIQ and DESCLKIQ Mode: The only design which can successfully adjust the DES timing spur for DESCLKIQ Mode was Board A. The best solution for driving DESIQ Mode is Board C; this design may also be used to drive all modes, except for DESCLKIQ Mode.**