Anaren 0404 (BD2425N50ATI) balun optimized for Texas Instruments CC2500 Transceiver

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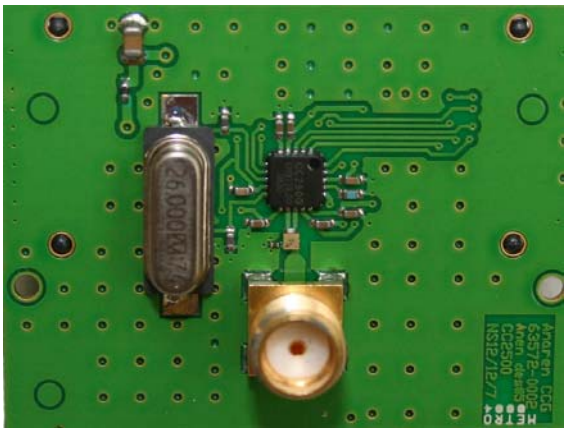


Introduction

Over the last few years, the drive for miniaturization and integration has intensified the challenges concerning the trade off between repeatability, cost and time to market. The design must be robust enough to achieve good yields, but also have the lowest possible bill of material cost. The total cost not only depends on the number and types of parts and their associated cost, but also on the size of the PCB and enclosure.

At Anaren the focus is on developing products that address these trade-offs. Integrating 100% RF tested components increase yield and decreases size and time to market. The following application note demonstrates these objectives clearly as we present a small and simple balun solution optimized for use with Texas Instruments' CC2500 transceiver. The CC2500 is a true single-chip 2.4 GHz ISM and SRD compliant RF transceiver, designed for low-power wireless applications. The same balun solution can also be used with CC2510, CC2511 and CC2550 since these parts uses the same RF front end as CC2500. The balun solution presented in this application note uses only three components: a 1mm square Anaren multilayer balun, a DC blocking capacitor and an inductor for impedance matching. This results in a solution that minimizes space and performs according to the specifications in the CC2500 data sheet.

The CC2500 is a low-cost, highly integrated solution for robust wireless communication in the 2400-2483.5 ISM/SRD band systems. CC2500 is designed to be compliant with SRD regulations covered by ETSI EN 300 328 and EN 300 440 class 2 (Europe), FCC CFR47 Part 15 (US) and ARIB STD-T66 (Japan). The CC2500 provides extensive hardware support for packet handling, data buffering, burst transmissions, data encryption, data authentication, clear channel assessment, link quality indication and packet timing information.

For more information about this or any other products currently available in the Anaren product portfolio, please visit our website at www.anaren.com for datasheets, S parameters and general corporate information.

For more information on Low Power Wireless products from Texas Instruments please visit www.ti.com\lpw for product information.

Comparisons of Different Balun Solutions

The RF front end for the CC2500 is architecturally simple in that both receiver LNA and transmitter PA are attached to the same set of balanced pins. Hence impedance matched, balanced to single ended transformation is all that is needed.

A multitude of possible balun implementations exist. Texas Instruments provides one such reference design which uses 9 discrete components. The solution from Anaren, described in this document, uses a discrete balun, one capacitor necessary for the DC blocking and one inductor for impedance matching. Below is a detailed comparison of the lumped element solution and the IC balun solution.

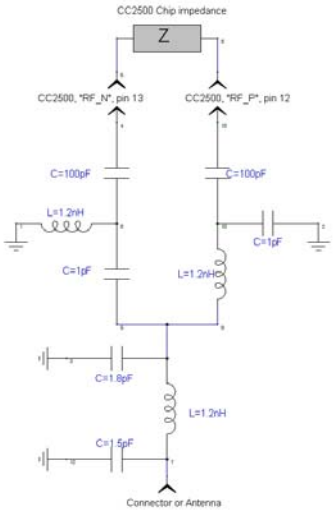


Figure 1 Schematic of Lumped element implementation

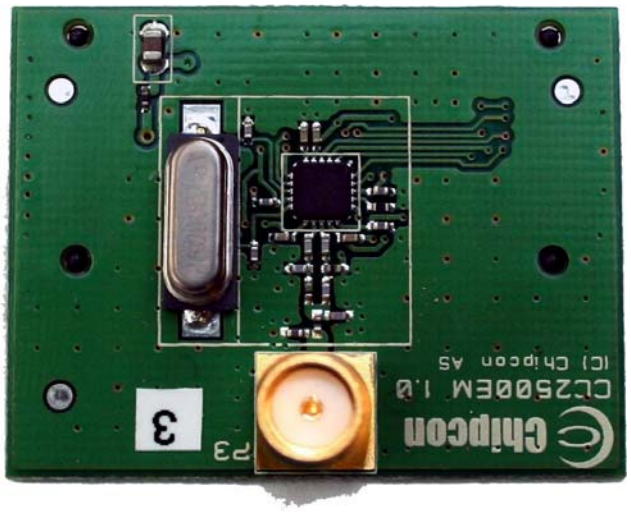


Figure 2 Layout of Lumped element implementation

The lumped element implementation shown in Figure 1 and Figure 2 uses 6 capacitors and 3 inductors. However the PCB real estate taken up is significant and the performance is sensitive to changes in component vendor, component placement, PCB thickness and variation in the PCB material.

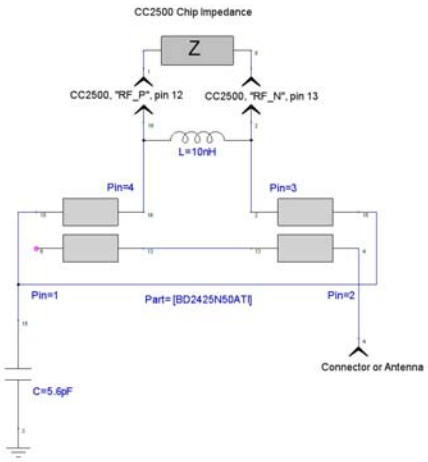


Figure 3 Schematic of the Anaren balun implementation with 0201 matching components

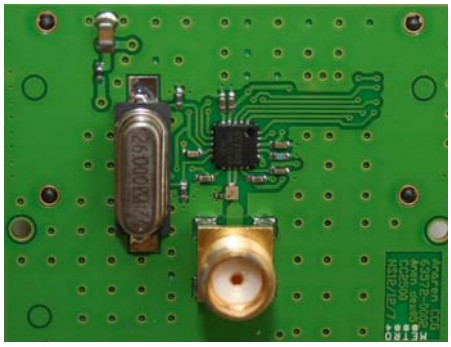


Figure 4 Layout of the Anaren balun implementation with 0201 matching components

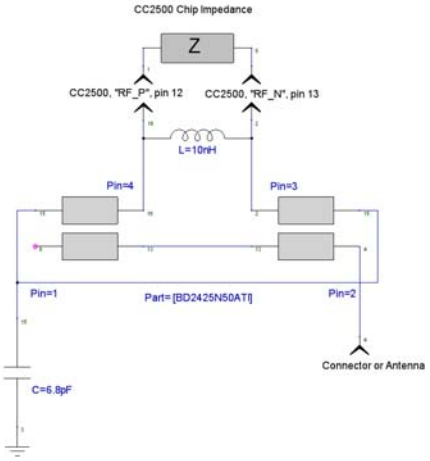


Figure 5 Schematic of the Anaren balun implementation with 0402 matching components

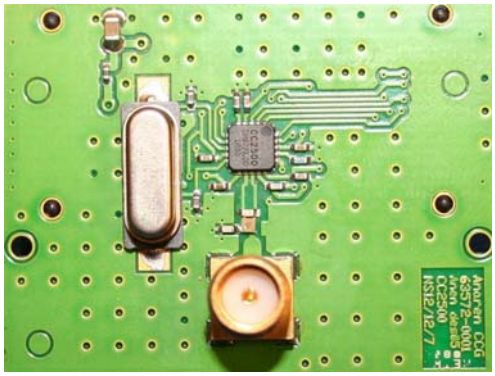


Figure 6 Layout of the Anaren balun implementation with 0402 matching components

The Anaren solutions shown in Figure 4 and Figure 6 take up significantly less PCB area and less number of external matching components which make them less susceptible to the discrete component tolerance/variation.

The recommended Anaren solutions are:

- BD2425N50ATI balun with 0201 matching components:10nH (TDK MLK0603L) and 5.6pF (AVX 02013A)
- BD2425N50ATI balun with 0402 matching components:10nH (TDK MLK1005S) and 6.8pF (ATC 600L)

Care should be taken using alternate vendors especially on the inductor as they do not have the same performance. Each vendor of inductors and capacitors have their own way of realizing the parts with associated differences in parasitic values. Even within a single vendor, different component series are made differently, with significantly different parasitics. Even

from one value to the next in the same series there can be parasitic differences, if for instance a spiral inductor requires another turn to fit in the same footprint from one value to the next then either the trace width drops, another trace layer is used or maybe a different material set – these, from a value point of view, can create subtle changes that cause significant parasitic change. If the change in impedance caused by parasitic changes fall within the circle outlined in Figure 10 the performance will be acceptable. One way to evaluate alternate vendors is to compare s-parameters of the components – however the s-parameters must be measured the same way from both vendors to be able to compare and this information is not often available. Another way is to use vendor or third party models but it is still important to know what each model represents; does it include the PCB pads, is the model valid for the PCB used, etc.

The Anaren recommended layouts with 0402 and 0201 matching components are fabricated on a 27.5mil (0.7mm) thick FR4 board. If a multilayer board is used it is recommended that internal power/GND planes be opened such that the effective height to GND is roughly 28mil (0.7mm), as illustrated in Figure 7. If it is not possible to open up internal layers then follow recommendations in Table 1 for changes to the transmission lines identified in Figure 8. The differential lines are identified with red arrows and the single ended connection identified with a blue arrow.

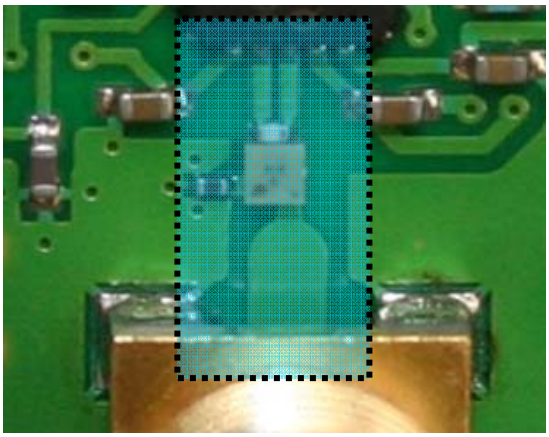


Figure 7 Opening in power/GND planes below RF circuitry

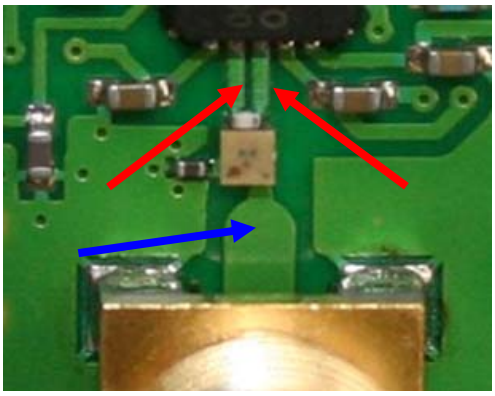


Figure 8 Differential (red) connecting lines and single ended (blue) connecting line

Distance between ground and circuit layer mil (mm)	Differential line width Width/Length mil(mm)/mil(mm)	Single ended line width Width/Length mil(mm)/mil(mm)
5 (0.127), PI	8(0.203)/48(1.219)	10(0.254)/320(8.128)
8 (0.203), Ro4350	10(0.254)/48(1.219)	17(0.432)/250(6.35)
10 (0.254), FR4	10(0.254)/48(1.219)	16(0.4064)/244(6.198)
20 (0.508), FR4	10(0.254)/48(1.219)	39(0.991)/244(6.198)
27.5 (0.699), FR4	10(0.254)/48(1.219)	55(1.397)/244(6.198)
30 (0.762), FR4	10(0.254)/48(1.219)	60(1.524)/244(6.198)
40 (1.016), FR4	10(0.254)/48(1.219)	82(2.083)/244(6.198)
60 (1.524), FR4	10(0.254)/48(1.219)	128(3.251)/280(7.112)

Table 1 : Differential line and single ended line width/length for various substrate heights based on Anaren 0404 balun with 0201 matching components

The above mentioned line lengths and widths are for BD2425N50ATI Anaren balun with 0201 matching components only. The line length will change for Anaren balun with 0402 matching components. The values in table1 are simulated results, except the row highlighted in green.

Changing the placement or value of the components and the dimensions of the PCB traces could affect the performance. It is therefore recommended to keep the DC block capacitor and the inductor for impedance matching close to the balun. The layout of the transmission lines connected to the balun should follow the recommendations in Table 1.

The value of the inductor and the capacitor also depends on the length of the transmission line used between the CC2500 chip and the balun. If the length of the transmission line between the chip and the balun is increased then the inductor and the capacitor values should be

decreased and vice versa if the length of the line is decreased.

The SMA on the reference design can be replaced with an antenna or a different SMA connector. It is important in such cases to implement a 50 ohm trace between the balun and the antenna to achieve proper performance.

Table 2 demonstrates the significant reduction in size and component count board layout achieved with the Anaren 0404 balun solution.

Solution	Lumped element design	Anaren balun 0402 matching components	Anaren balun 0201 matching components
Component Count and type	9 Total 6 Capacitors 3 Inductors	3 Total 1 Balun 1 Inductor 1 Capacitor	3 Total 1 Balun 1 Inductor 1 Capacitor
PCB Area	0.0233 sq. inch (0.592 sq.mm)	0.0113 sq inch (0.287 sq.mm)	0.0038 sq inch (0.097 sq.mm)
Space savings based on lumped element design	0%	52%	84%

Table 2 Comparison of the three different implementations

The Anaren balun performance is consistent and tolerant to PCB manufacturing tolerances. Production average and worst case data for the BD2425N50ATI are illustrated in Table 3.

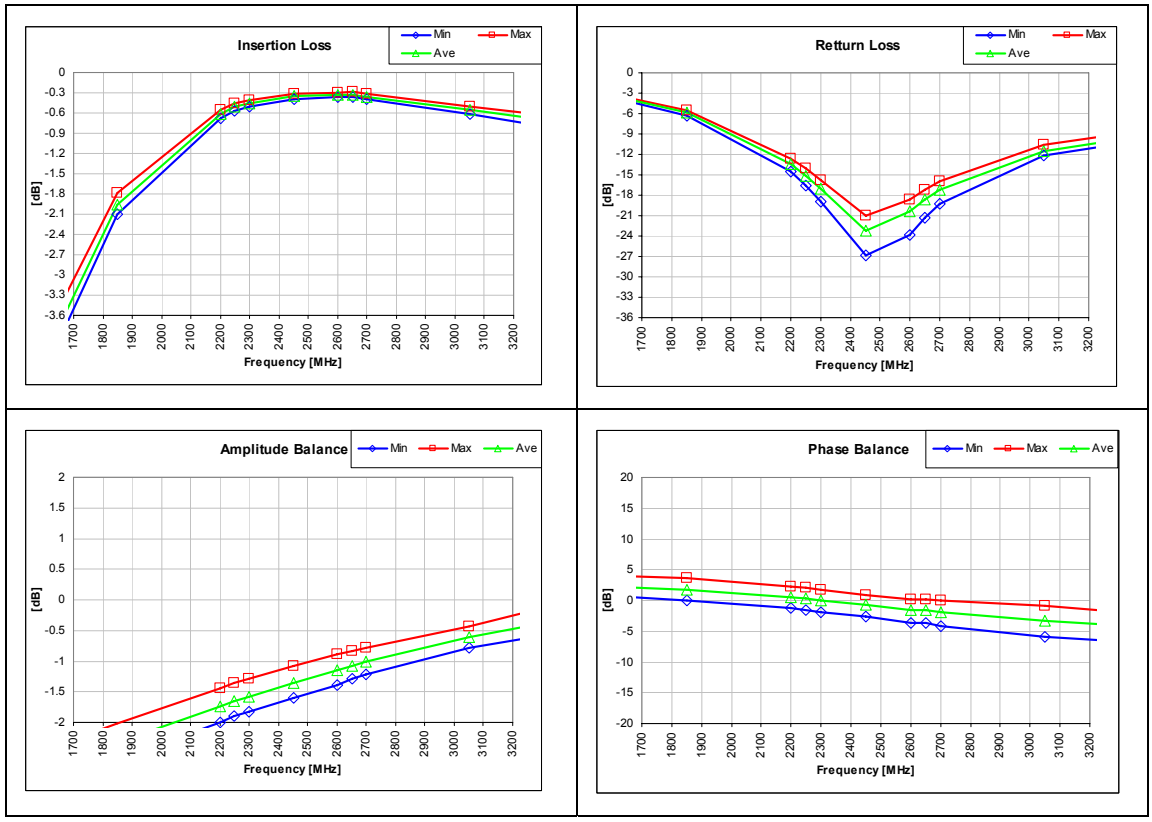


Table 3 Balun Performance

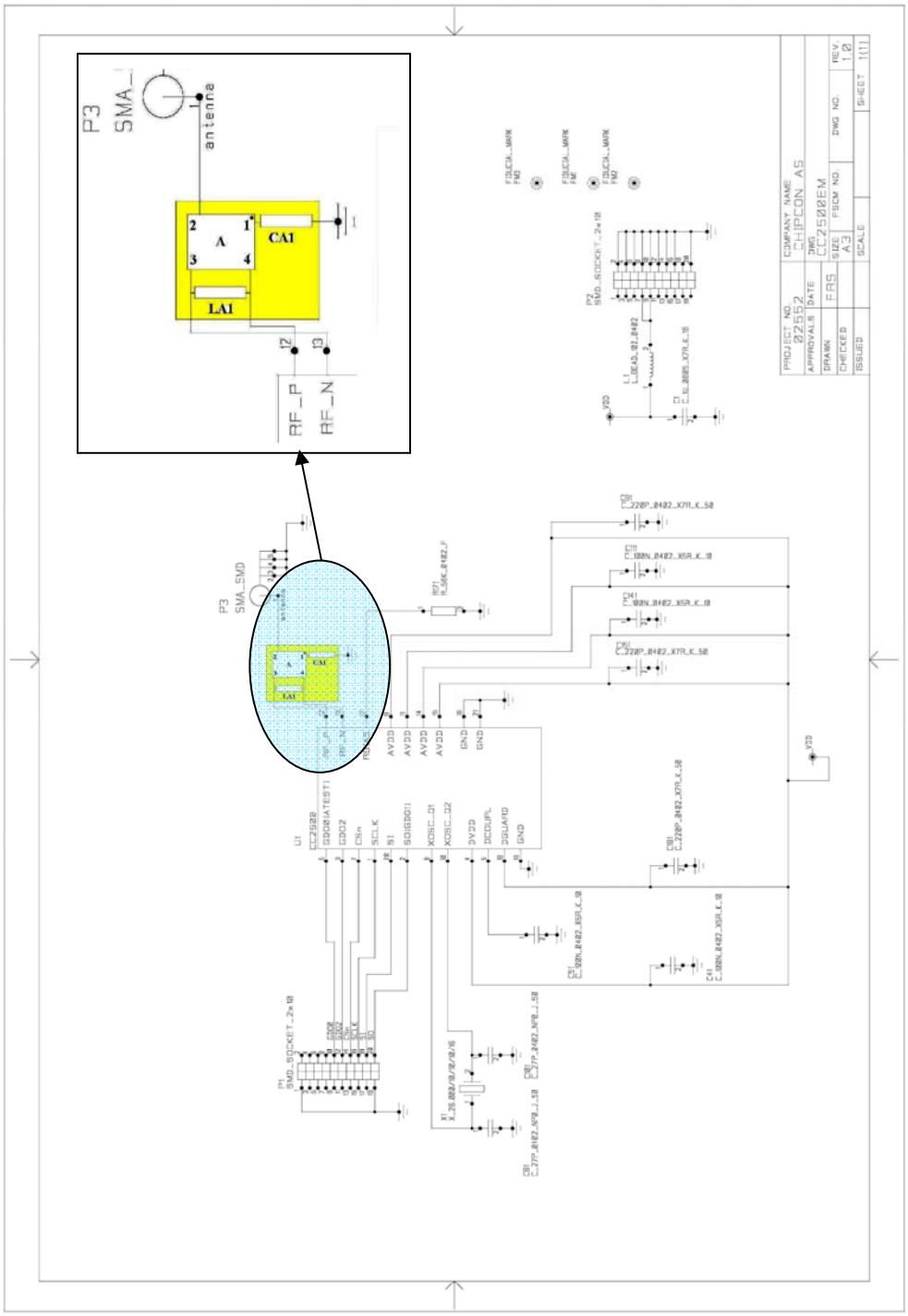


Figure 9 Evaluation daughter board schematic with the Anaren balun

Application Verification

Measurements verify that the reference design presented in this application note has the same performance as represented in the data sheet. These measurements include;

- Transmit Power
- Receive Sensitivity
- Current consumption

These measurements were performed independently by both Anaren and TI. Through further testing at Anaren the optimum impedance for the CC2500 Chip is found to be inside the range (circle) shown in Smith chart below.

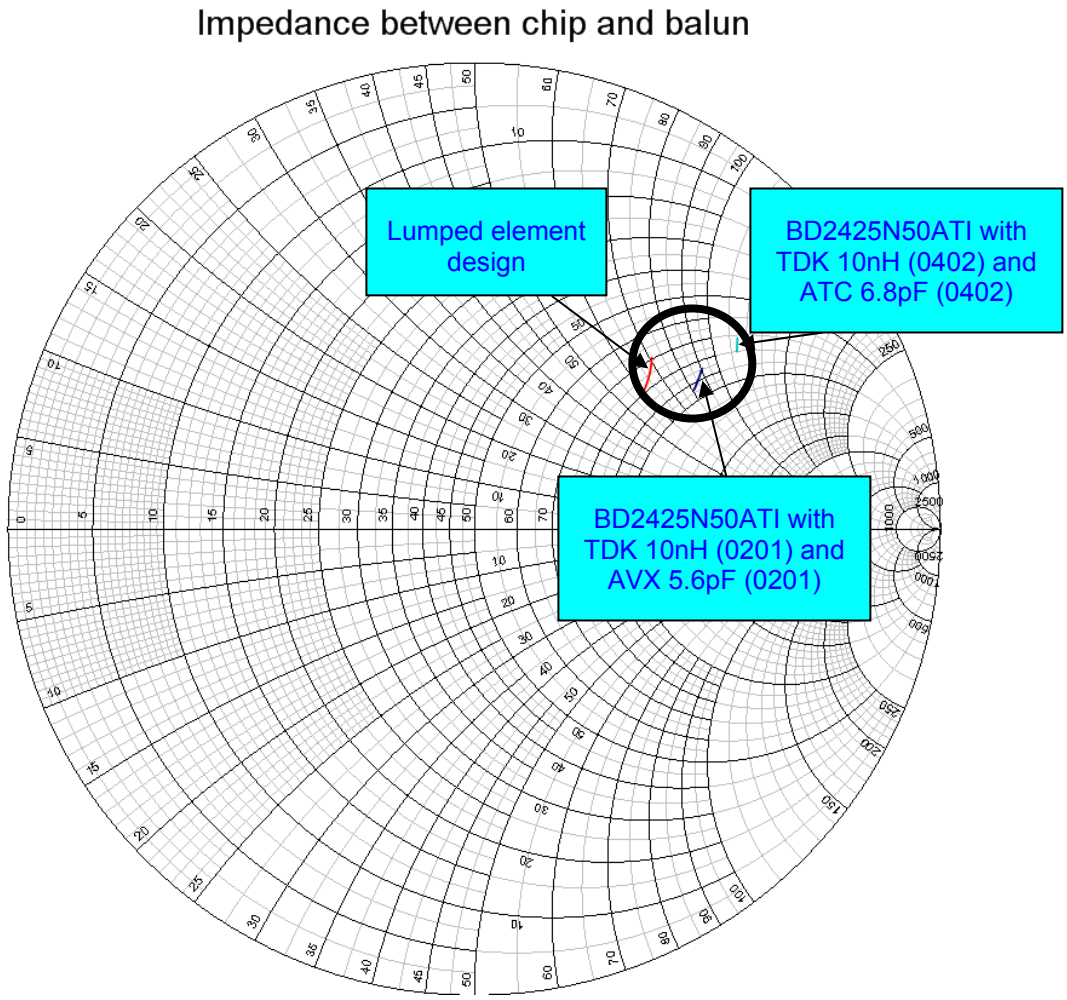


Figure 10 Anaren balun matching impedances

The Impedance Matching

The following is a description on the impedance matching steps and guidance for deviations if needed.

Optimum differential impedance as seen from the RF ports towards antenna is stated as 80+j74 Ω in the CC2500 data sheet. The BD2425N50ATI balun has 50 Ω single ended port impedance and 127+j34 Ω balanced port impedance. A 10nH inductor is connected across the balanced ports for matching purposes and a 5.6pF capacitor is used at pin 1 as a DC block (RF GND) to allow biasing through this pin to the differential ports, pin 3 and pin 4 of the balun. This is illustrated in Figure 11.

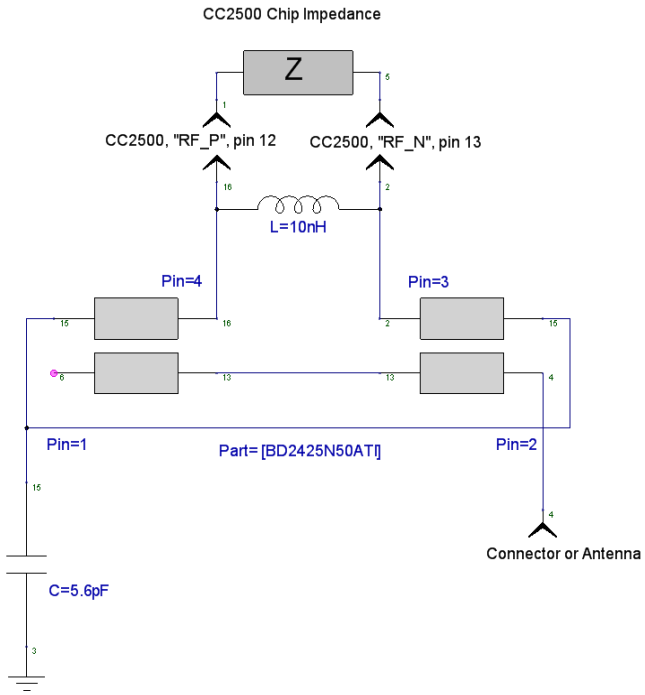


Figure 11 Anaren balun schematic

The impedance matching steps, with a SMA connector illustrated in the smith chart shown in Figure 12 performs the match as follows.

- The connector and the connecting line at the input transform 50 Ω to 47-j4 Ω. (Note1).
- The balun transforms 47-j4 Ω into 127+j34 Ω
- The inductor at the differential arm of the balun brings the impedance to 76+j66 Ω
- The transmission line to interface the chip to the balun brings the impedance to 83+j87 Ω.
- The DC-blocking capacitor transforms the impedance to 89+j86 Ω

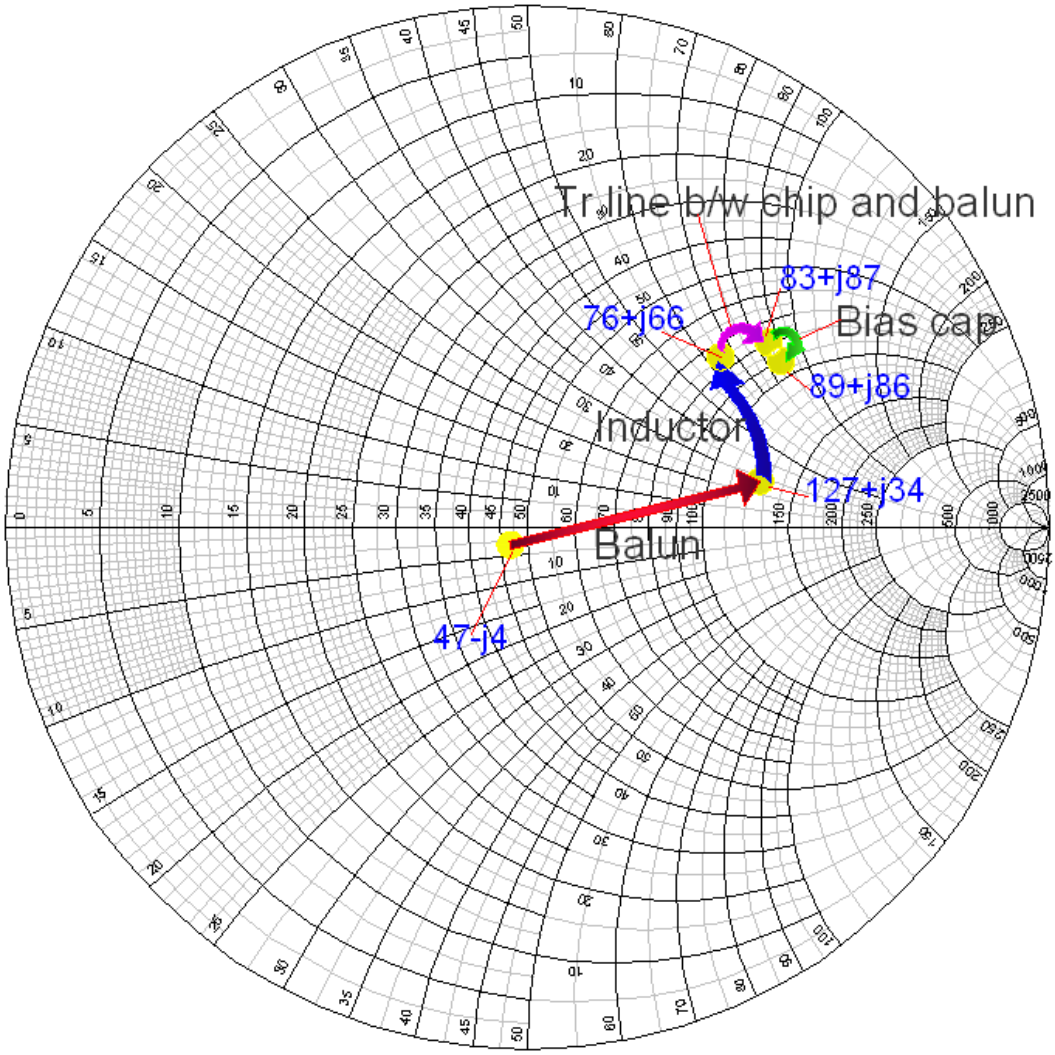


Figure 12 Smith chart showing the impedance matching steps

Note 1: If an SMA connector is not used then a 50 Ω transmission line should be used to connect to the balun, this change will cause a negligible shift in performance

References

1. http://focus.ti.com/docs/prod/folders/print/cc2500.html - CC2500EM Reference Design
2. http://focus.ti.com/docs/prod/folders/print/cc2500.html - CC2500 Development kit user manual

Please contact Anaren for gerber files of the recommended layout and other questions/enquiries.

Ultra Low Profile 0404 Balun for TI transceiver CC2500 50Ω to 127+j34Ω Balanced

(Anaren Application Note Ann-2003)

Description

The BD2425N50ATI is a low cost, low profile sub-miniature unbalanced to balanced transformer designed for differential inputs and output locations on modern chipsets in an easy to use surface mount package. The BD2425N50ATI is ideal for high volume manufacturing and delivers higher performance than traditional ceramic baluns. The BD2425N50ATI has an unbalanced port impedance of 50Ω and 127+ j34Ω balanced port impedance. This transformation enables single ended signals to be applied to differential ports on modern integrated chipsets. The output ports have equal amplitude (-3dB) with 180 degree phase differential. The BD2425N50ATI is available on tape and reel for pick and place high volume manufacturing.

Detailed Electrical Specifications: Specifications subject to change without notice.

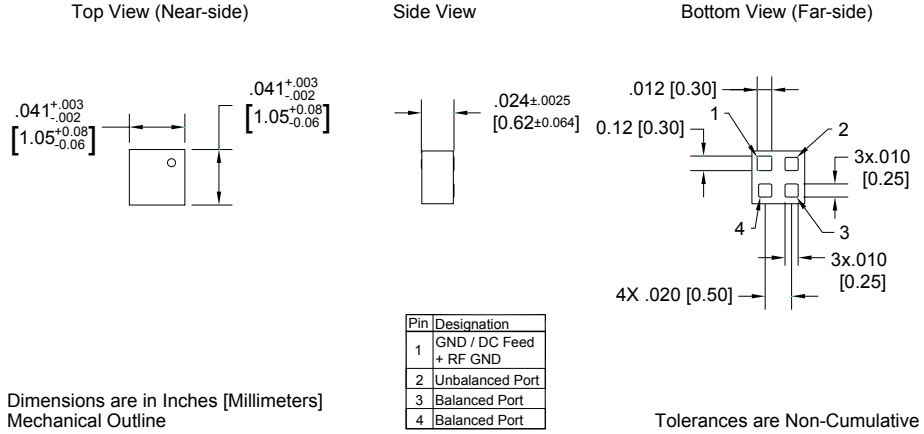
Features:

- **2400 – 2500 MHz**
- **0.65mm Height Profile**
- **50 Ohm to 2 x 63.5+j17 Ohm**
- **Low Insertion Loss**
- **Surface Mountable**
- **Tape & Reel**
- **Non-conductive Surface**
- **RoHS Compliant**
- **Zigbee**

Parameter	ROOM (25°C) Min.	Typ.	Max	Unit
Frequency	2300		2600	MHz
Unbalanced Port Impedance**		50		Ω
Balanced Port Impedance**		127+j34		Ω
Return Loss**	13	17		dB
Insertion Loss* **		0.4	0.6	dB
Power Handling		1	TBD	Watts
Operating Temperature	-55		+85	ºC

*Insertion Loss stated at room temperature (Insertion Loss is approximately 0.1 dB higher at +85 ºC)
** Stated performance assumes proper matching network found in application note: ANN-2003

Outline Drawing



Sales Desk USA: Voice: **(800) 544-2414** Fax: **(315) 432-9121**

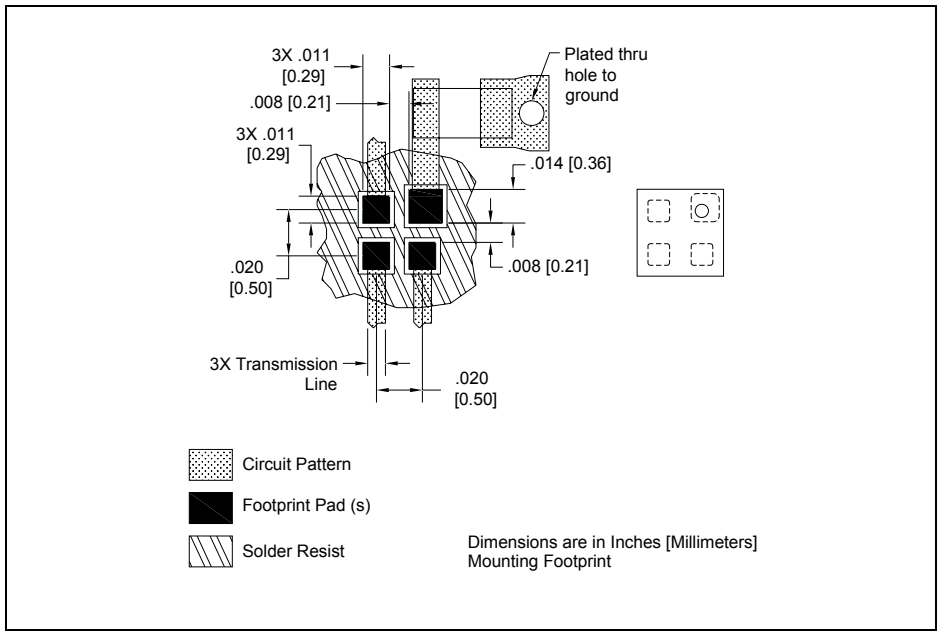
Sales Desk Europe: Voice: **(+44) 2392 232392** Fax: **(+44) 2392 251369**

Mounting Configuration:

In order for Xinger surface mount components to work optimally, the proper impedance transmission lines must be used to connect to the RF ports. If this condition is not satisfied, insertion loss, Isolation and VSWR may not meet published specifications.

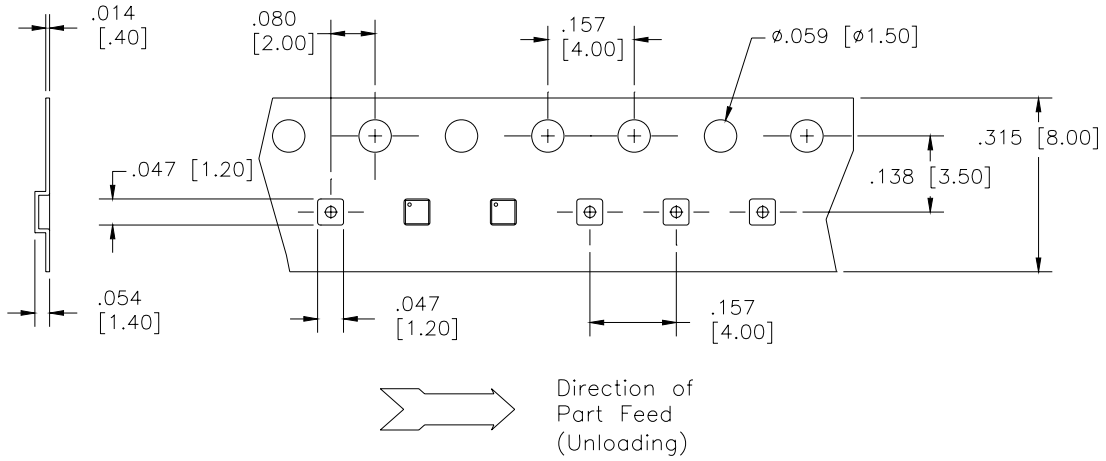
All of the Xinger components are constructed from ceramic filled PTFE composites which possess excellent electrical and mechanical stability having X and Y thermal coefficient of expansion (CTE) of 17 ppm/^{o}C.

An example of the PCB footprint used in the testing of these parts is shown below. An example of a DC-biased footprint is also shown below. In specific designs, the transmission line widths need to be adjusted to the unique dielectric coefficients and thicknesses as well as varying pick and place equipment tolerances



Packaging and Ordering Information

Parts are available in reel and are packaged per EIA 481-2. Parts are oriented in tape and reel as shown below. Minimum order quantities are 4000 per reel. See Model Numbers below for further ordering information.



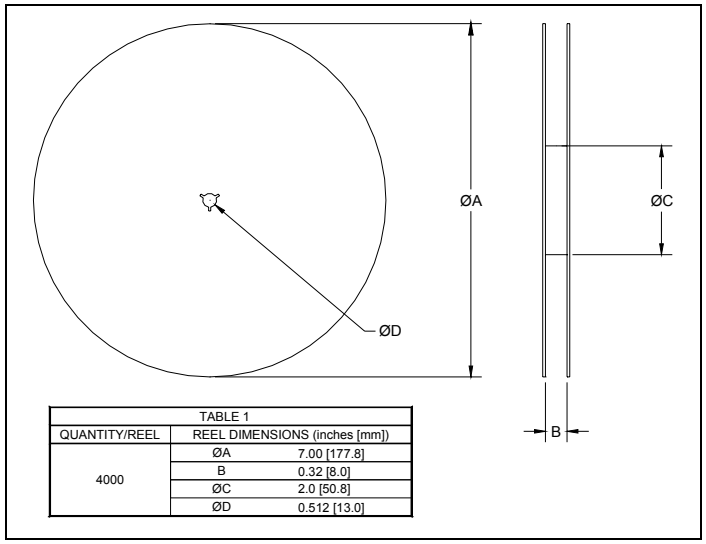


TABLE 1		
QUANTITY/REEL	REEL DIMENSIONS (inches [mm])	
4000	ØA	7.00 [177.8]
	B	0.32 [8.0]
	ØC	2.0 [50.8]
	ØD	0.512 [13.0]

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