AN933.3: Series 3 Minimal BOM

The purpose of this application note is to illustrate Bill-of-Material (BOM) and cost-optimized solutions for 2.4 GHz applications using the Series 3 Wireless SoCs.

Silicon Labs reference radio board designs typically use an extensive number of components and multiple layers for RF and VDD filtering to achieve the best possible RF performance even at the highest power levels. The number of PCB layers can be decreased and many of these elements can be eliminated from the design while still maintaining an acceptable RF performance, especially at lower power levels.

KEY POINTS

- BOM, cost, and PCB space-optimized reference design for 2.4 GHz applications
- Eliminates a number of components for RF and system performance
- Measurements for RX sensitivity, TX performance, and harmonics are provided

1. Device Compatibility

This application note applies to the following Series 3 devices:

- SiXG301

2. Outline

The following table summarizes the available minimal BOM solutions for the Series 3 Wireless SoC family.

Table 2.1. Minimal BOM Designs

Part(s)	BOM Reduction*	Max Power	Power Amplifier Used	PAVDD Voltage
SiXG301	19 pcs.	+10 dBm	+10 dBm PA	3.3 V

*Number of eliminated components compared to the full BOM solution.

Note: These designs are only guidelines to show how to reduce the BOM for Series 3 SoCs. Main RF parameters were tested on a limited number of devices; full validation and characterization on these minimal BOM solutions were not performed.

3. Minimal BOM Design for SiXG301

Silicon Labs developed a design for lowering the manufacturing cost of devices containing the SiXG301 ICs, and evaluated it using the High Power (+10 dBm) and the Low Power (+0 dBm) PA.

3.1 Design Considerations

This section summarizes the requirements and considerations for the BOM-optimized designs for SiXG301 devices.

- The high-frequency XTAL is required for operation of Series 3 parts. External load capacitors are not needed. Refer to section 3.9 Crystal Requirements.
- The measurements were performed using a radio board that included an external flash IC. However, the same minimal BOM design remains valid even if the external flash is omitted.
- The original design includes several supply filtering capacitors to optimize RF performance, but most can be removed with only minimal impact on sensitivity and harmonic performance.

3.2 Recommended BOM-Optimized 2.4 GHz Solution

The BRD4408A schematic was modified to represent the minimal-BOM configuration for power supply filtering and RF matching, seen in the following figures. Both C116 and C104 can be placed as 0201 components, saving PCB real estate.

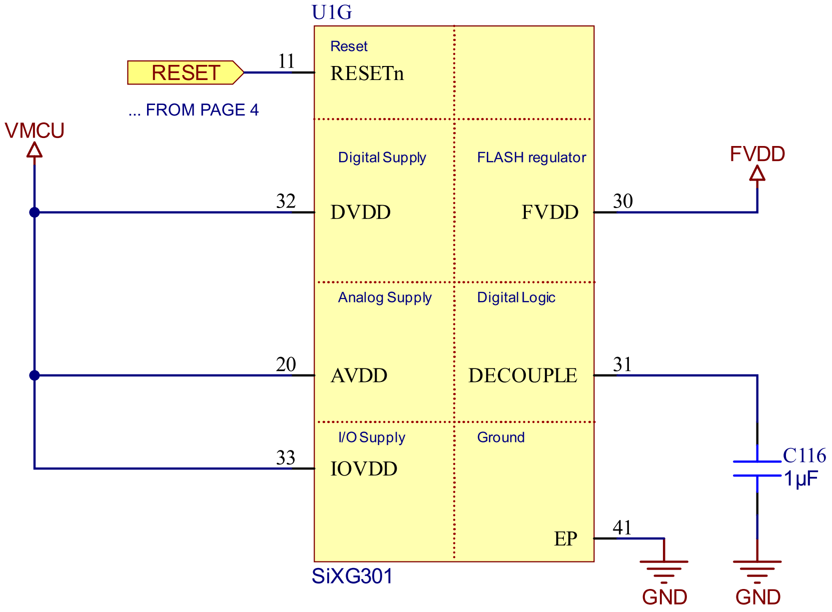


Figure 3.1. Schematic for Reduced Power Supply Filtering

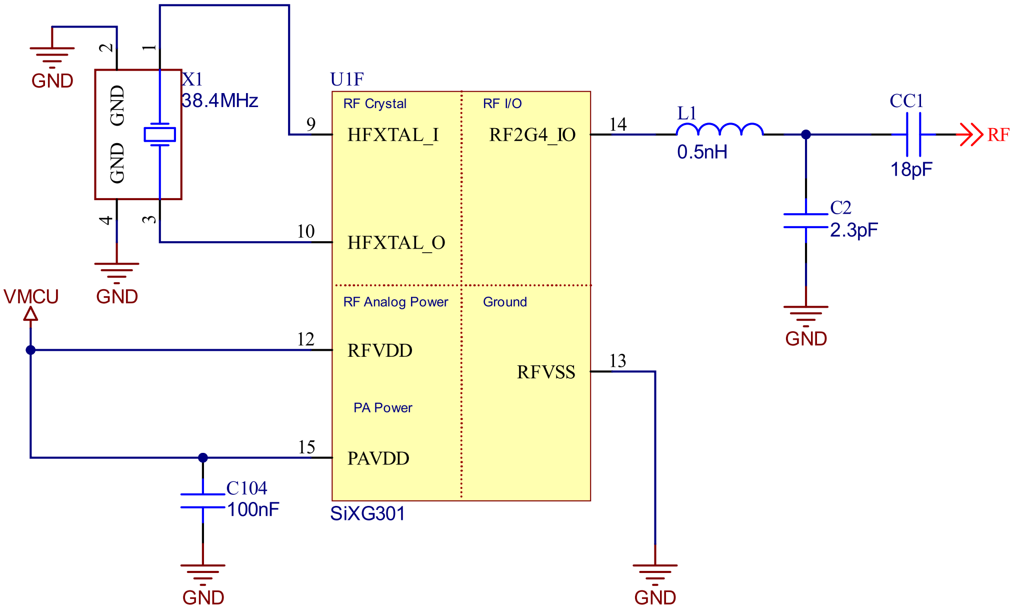


Figure 3.2. Schematic for Reduced RF Matching Network and Power Supply Filtering

You can see the new layout in Figure 3.3 Minimal BOM Layout on page 6. Placement of the C116 capacitor (on the DECOUPLE pin) is not critical; place it wherever possible in the general area. Do not modify the location and arrangement of the crystal oscillator or the RF section. The latter is described in more detail in the 3.4 Matching Network section.

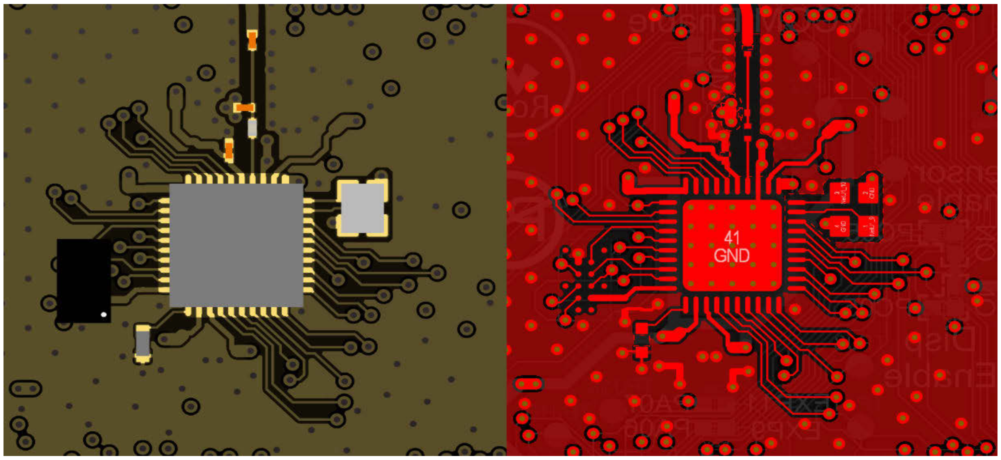


Figure 3.3. Minimal BOM Layout

3.3 Power Supply Filtering

Most of the decoupling capacitors can be omitted. Two are required: one for the digital circuitry on the DECOUPLE pin and one for bulk decoupling, near the PAVDD pin.

The bulk decoupling capacitor ensures that the MCU supply voltage (VMCU) near the chip does not drop below or above normal operating conditions specified by the data sheet, even when powered from an inductive source (tested with non-filtered power supplied through longer wires than in any practical application).

Note: The conditions described ensure that the SiXG301 operates correctly, does not degrade significantly in receiver performance, and its harmonics stay within regulatory limits. Other circuits sharing the same power supply may still be affected by the relatively simple filtering. If used along with other, possibly more sensitive parts, the new design should be thoroughly tested to ensure normal operating conditions for the surrounding circuits.

3.4 Matching Network

Silicon Labs designed a new matching network to achieve maximum BOM reduction. The matching network was reduced to an LC network, connected to the antenna transmission line with a coupling capacitor, CC1. CC1 is mandatory only if the +0 dBm PA is used.

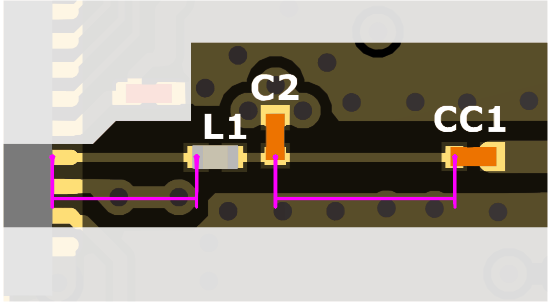


Figure 3.4. Reduced Matching Network Layout

You can see the reduced matching network layout in the figure above. The longer traces highlighted are part of the matching network, acting as high-impedance (~Z0 = 90 Ω) transmission lines. Their dimensions are shown in the following table, measured from pad center to pad center.

Table 3.1. Matching Transmission Line Dimensions

Dimension	Value
Length from RF2G4_IO to L1	78 mil (1.98 mm)
Length from C2 to CC1	97 mil (2.46 mm)
Width between RF2G4_IO and CC1	5 mil (0.127 mm)

The elements shown are referred to with their original designators. Their values and OPNs can be found in the table below. Components that do not have a value assigned to them were removed as part of minimizing the design.

Table 3.2. Matching Network Elements

Original Designator	Value	Part OPN
C1	—	—
L1	0.5 nH	LQP03HQ0N5W02D
C2	2.3 pF	GRM0335C1H2R3WA01D
L2	—	—
C3	—	—
CC1	18 pF	GRM0335C1H180GA01D

3.5 Conducted RX Sensitivity

Silicon Labs evaluated the receiver sensitivity for the minimal BOM solution and the original radio board for reference. We observed no significant reduction in sensitivity, as shown in the table and graph below.

Table 3.3. Conducted BLE 1M RX Sensitivity

Frequency [MHz]	Sensitivity [dBm]	
	Minimal BOM	Reference
2400	-97.7	-97.7
2410	-97.4	-97.6
2420	-97.7	-98
2430	-97.3	-98
2440	-97.6	-97.5
2450	-96.9	-97.2
2460	-97	-97
2470	-97.1	-97.6
2480	-97.1	-97.6

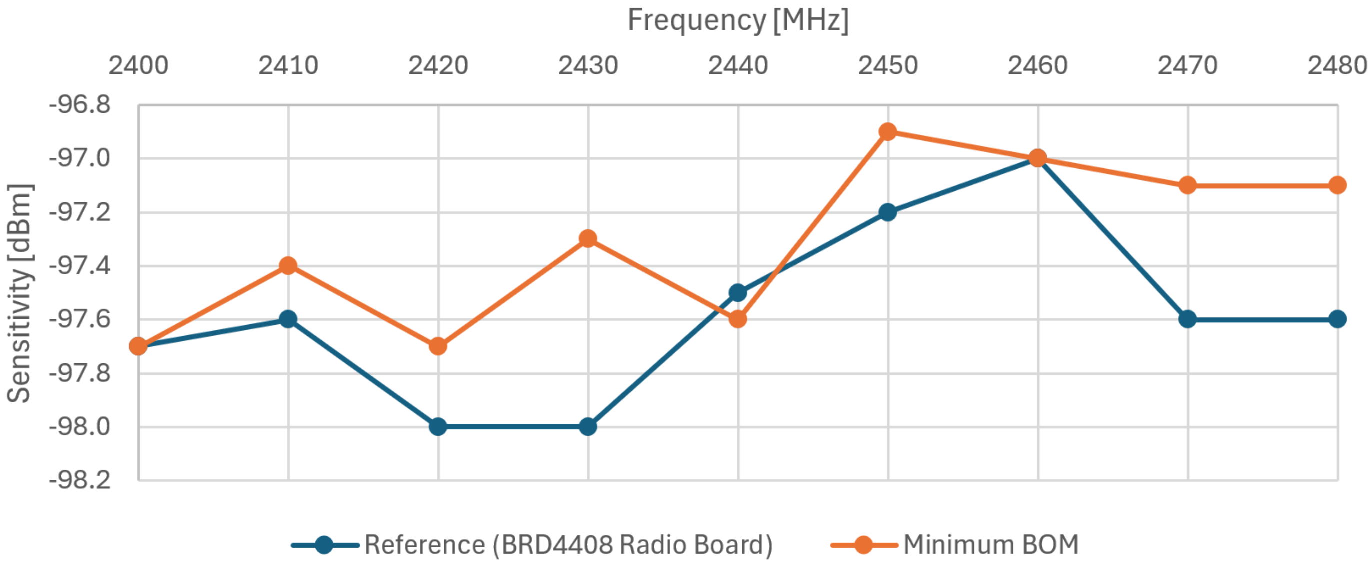


Figure 3.5. Receiver Sensitivity Comparison

3.6 Conducted TX Performance

The table below lists the measurements for conducted TX harmonic performance. You can use these measurements to adjust the power level for the desired output power.

Table 3.4. Conducted TX Harmonic Performance

Board	Power Level (raw)	Frequency [MHz]	Harmonic	Power [dBm]	
				+0 dBm PA	+10 dBm PA
Minimal BOM +10 dBm	22 @ +0 dBm 35 @ +10 dBm	2450	Fund.	0.0	10.03
			2nd	-47.8	< -68.7
			3rd	-50.8	-47.9
			4th	-66.7	-63.8
			5th	-74.8	-42.2
			6th	-66.2	-51.5
			7th	-68.0	< -75
			8th	< -80	< -70
			9th	-72.6	-69.5
Original BRD4408A	21 @ +0 dBm 35 @ +10 dBm	2450	Fund.	0.0	10.0
			2nd	-60.9	-54.8
			3rd	-79.7	-79.9
			4th	-104.9	-91.4
			5th	-94.5	-87.9
			6th	< -105	< -105
			7th	-75.0	-58.0
			8th	-82.3	-55.9
			9th	-69.5	-53.58

Regulations also apply to spur signals, caused by the high-frequency crystal oscillator. The table below lists the measurement results for the conducted TX spur performance.

Table 3.5. Conducted TX Spur Performance

Frequency [MHz]	Relative Spur Frequency [MHz]	Spur Power [dBm]	
		+0 dBm PA	+10 dBm PA
2450	-38.4	-54.49	-62.16
	-7.6	-77.84	-59.24
	7.6	-77.98	-59.26
	38.4	-57.36	-62.94

3.7 Radiated TX Performance

The harmonic values are the measured maximums of the radiated power in EIRP (dBm) taken in an unmodulated carrier transmission mode, so depending on the modulation scheme, the actual radiated power with modulated transmission will be lower. The calculated modulated EIRP using the minimal BOM configuration is provided in the table below, which shows that the critical 3rd and 5th harmonics are indeed compliant with FCC/ETSI limits.

Table 3.6. Radiated TX Performance at 2402 MHz, +10 dBm

Harmonic (2402 MHz)	Measured Unmodulated EIRP [dBm]	BLE 1Mbps Coded Modulation			Limit in EIRP [dBm]
		Correction Factor [dB]	Calculated Modulated EIRP [dBm]	Modulated Margin [dB]	
Fund.	11.5	N/A	11.5	18.5	30.0
2nd	-53.6	-3.3	-56.9	15.7	-41.2
3rd	-40.8	-2.5	-43.3	37.3	-6.0
4th	-53.7	-6.7	-60.4	30.4	-30.0
5th	-44.2	-8	-52.2	11.0	-41.2

Table 3.7. Radiated TX Performance at 2450 MHz, +10 dBm

Harmonic (2450 MHz)	Measured Unmodulated EIRP [dBm]	BLE 1Mbps Coded Modulation			Limit in EIRP [dBm]
		Correction Factor [dB]	Calculated Modulated EIRP [dBm]	Modulated Margin [dB]	
Fund.	10.5	N/A	10.5	19.5	30.0
2nd	-53.9	-3.3	-57.2	16.0	-41.2
3rd	-42.3	-2.5	-44.8	3.6	-41.2
4th	-49.6	-6.7	-56.3	26.3	-30.0
5th	-42.2	-8	-50.2	9.0	-41.2

Table 3.8. Radiated TX Performance at 2480 MHz, +10 dBm

Harmonic (2480 MHz)	Measured Unmodulated EIRP [dBm]	BLE 1Mbps Coded Modulation			Limit in EIRP [dBm]
		Correction Factor [dB]	Calculated Modulated EIRP [dBm]	Modulated Margin [dB]	
Fund.	9.2	N/A	9.2	20.8	30.0
2nd	-53.5	-3.3	-56.8	15.6	-41.2
3rd	-42.0	-2.5	-44.5	3.2	-41.2
4th	-45.9	-6.7	-52.6	22.6	-30.0
5th	-43.0	-8	-51.0	9.8	-41.2

The radiated TX performance values listed in the tables above were evaluated with the high-power PA, running at a +10 dBm output (at the power level determined by the conducted TX measurements). For operation at +0 dBm, the low-power PA is recommended, since it has lower current consumption than if the HP PA was used at this power. The LP PA also achieves significantly better margins than the HP PA, which already passes the regulatory requirements as seen in the tables above.

3.8 Current Consumption

The minimal BOM solution was compared to the original radio board, finding no significant difference in TX current consumption.

Table 3.9. Current Consumption Comparison

Board	TX Current [mA]	
	@ LP PA, +0 dBm	@ HP PA, +10 dBm
Minimal BOM +10 dBm	23	41
Original BRD4408A	23	41

3.9 Crystal Requirements

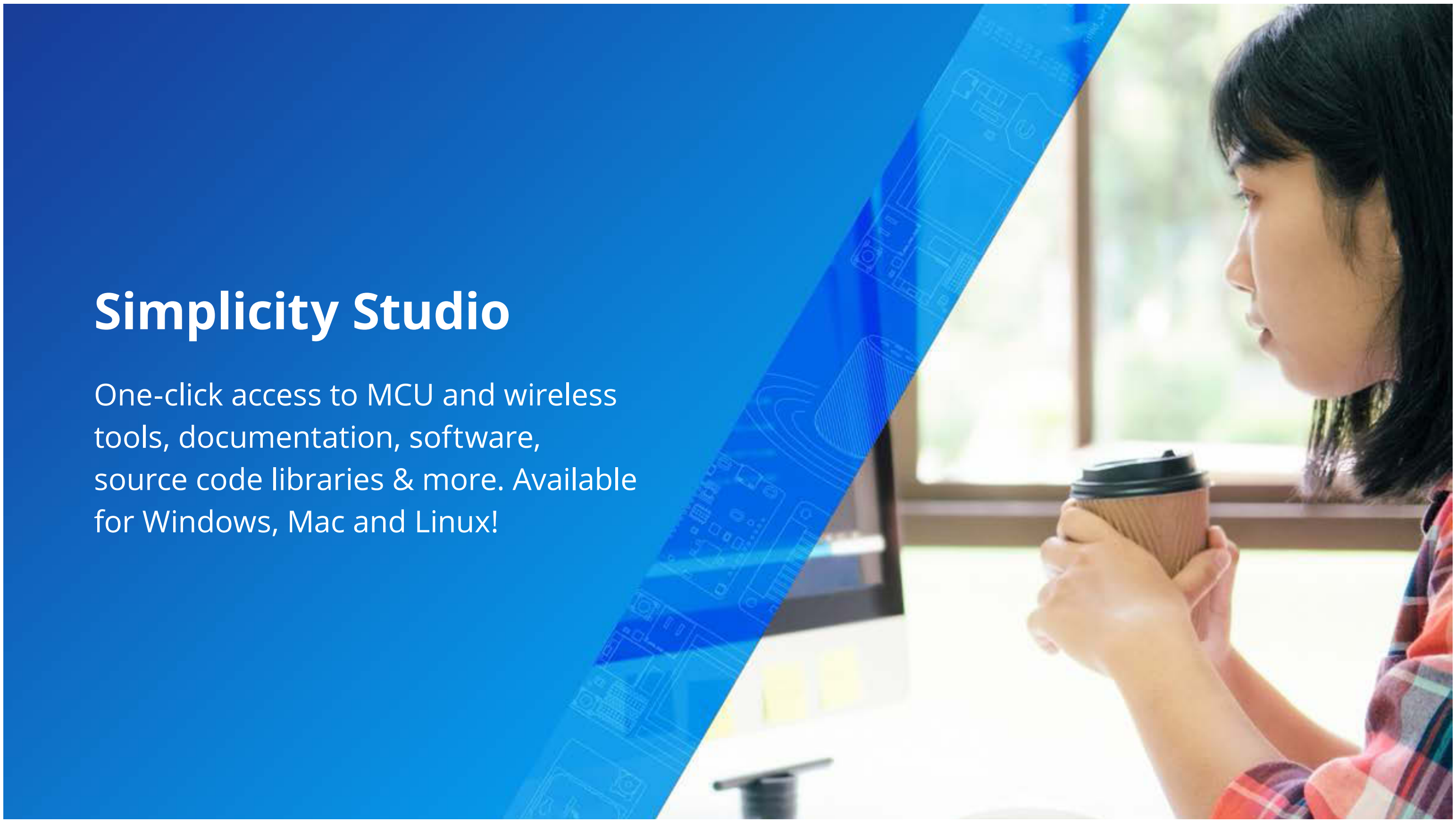
Refer to the component data sheet and AN0016.3 for recommended crystals.

4. Revision History

Revision 0.1

September 2025

- Initial release.



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