AN383

ANTENNA SELECTION AND UNIVERSAL LAYOUT GUIDELINES

1. Introduction

This document provides an FM antenna selection and design guide, a typical application schematic, an expanded application schematic to address system generated noise and discuss typical system components, a core re-use schematic block and layout for the universal design, and design and layout checklists. A single layout for all Si47xx 3 x 3 mm 20-pin QFN devices is possible using two 0 Ω jumpers for the purpose of device configuration. The range of devices, functionality, and antenna interfaces is shown in Table 1.

Table 1. Supported Devices and Features

	Function			RDS		RPS	FM Antenna		AM Antenna
Device	**FM RX**	**FM TX**	**AM RX**	**FM RX**	**FM TX**		**Ext RX**	**Emb RX/TX**	**Ferrite**
Si4702	✓						✓		
Si4703	✓			✓			✓		
Si4704	✓						✓	✓	
Si4705	✓			✓			✓	✓	
Si4706				✓			✓	✓	
Si4710		✓						✓	
Si4711		✓			✓			✓	
Si4712		✓				✓		✓	
Si4713		✓			✓	✓		✓	
Si4720	✓	✓				✓	✓	✓	
Si4721	✓	✓		✓	✓	✓	✓	✓	
Si4730	✓		✓				✓		✓
Si4731	✓		✓	✓			✓		✓

Notes:
1. RX refers to receiver.
2. TX refers to transmitter.
3. RDS refers to Radio Data System.
4. RPS refers to Receive Power Scan.
5. Ext RX antenna refers to a half-wavelength antenna connected to pin 2 for receive or RPS operation.
6. Emb RX/TX antenna refers to an embedded antenna connected to pin 4 for receive, RPS, or transmit operation.
7. Si4706 is an enhanced, data only RDS receiver.

Specific information concerning each of the supported device layout recommendations and antenna interfaces is available in the following application notes:

"AN231: Si4700/01 Headphone Antenna Interface"

"AN306: Si4710/11 Short Monopole Antenna Interface"

"AN285: Si472x FM Transceiver Layout Guide"

"AN384: Si473x AM/FM Receiver Layout Guide"

"AN386: Si473x AM Ferrite Loopstick Antenna Interface"

2. FM Transmit and Receive Antenna Selection and Design

The Si47xx family supports a variety of FM antenna options to satisfy specific product requirements. The current market for portable devices requires maximum functionality with minimum board space and a compelling industrial design. This requirement can present challenges when designing devices with FM antennas. Some designs require that no external wires are attached to the device to act as the antenna (*e.g.*, a cellular handset FM transmitter with integrated antenna), while other devices inherently have an external cable that can be used for an antenna (*e.g.*, an MP3 player/FM transmitter with car charger cable). In addition to these form factor considerations, there may also be constraints placed on the internal design and construction of the device, the PCB area available, etc.

Antenna choices can be broken down into two broad categories: short antennas typically embedded inside the case of the end product and longer wire antennas typically attached as a cable external to the end product.

Short, embedded antennas allow for a cleaner, more compact end product design, but inherently have reduced efficiency relative to the larger, external antennas. The Si47xx family's enhanced features allow greatly improved performance from these shorter antennas by automatically tuning the antennas for optimal performance. Longer external wire antennas offer greater efficiency and typically do not require this automatic tuning process. Either antenna is supported by the Si47xx family.

The Si47xx family also supports devices which utilize both antenna types. This configuration is useful for devices that can be operated with an external accessory that includes a cable or is stand alone. In this case, the device uses the accessory cable antenna when plugged in, and uses the embedded antenna when the accessory is not plugged in. The accessory cable can be used as the antenna whenever the device is attached, and the embedded antenna when the device is operated stand alone. Using the application circuit and host software, the Si47xx family supports switching dynamically between both antenna types.

Figure 1 shows the on-chip circuitry and relevant pins for RX and TX antennas.

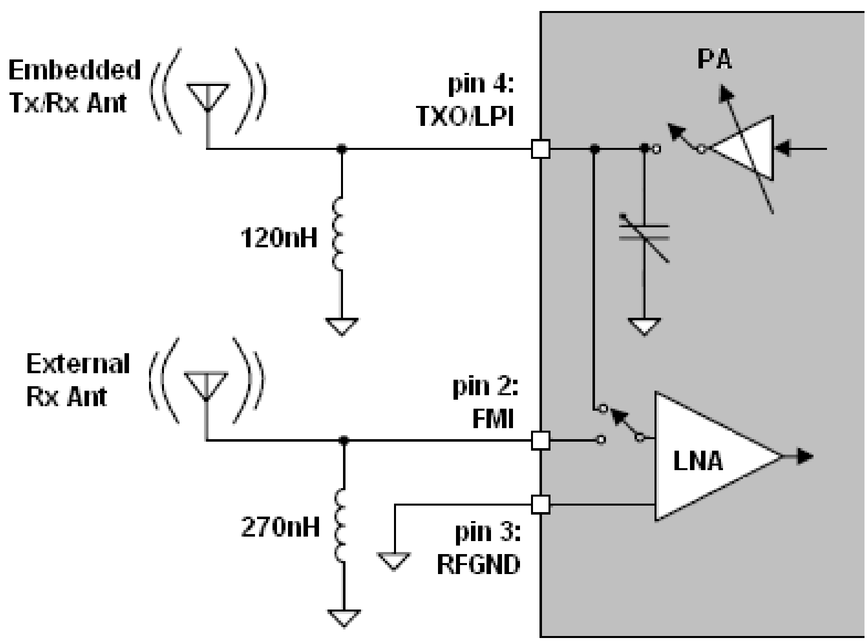

Figure 1. Si472x Antenna Configuration with Internal Switch

The Si47xx Pin 4 (LPI or TXO) has an internal varactor (variable capacitor) to resonate an antenna such as an embedded stub and loop. Pin 4 is connected to the LNA for FM RX operation with the Si4704/05/06/20/21 and for RPS operation with the Si4712/13/20/21. Pin 4 is connected to the PA for transmit operation with the Si4710/11/12/13/20/21. Longer external cables can be attached to pin 4, but given their impedance characteristics, they typically cannot be resonated to further improve their performance. Note that the Si4720/21 FM Transceivers have internal switches, which allow programmatic routing of pin 4 to either the LNA or PA.

Pin 2 (FMI) is connected to the LNA for receive operation and is programmatically selected with an internal switch. Users can choose to attach an antenna to both pin 4 and pin 2 on their device to support both internal and external antennas. Note that both antennas cannot operate at the same time.

This antenna selection guide will describe several antenna structures that can be used with the Si47xx, including stub in wire implementation, loop in wire implementation, stub in PCB trace implementation, loop in PCB slot implementation, and external cable. The flexibility of the Si47xx antenna interface allows designers to choose the optimal antenna for their particular application given the design constraints of the product. There is no one antenna which will be ideal for all products and this guide serves to illustrate some of the trade-offs between the options to help designers make an informed antenna choice. The following table provides general guidelines for each of the antennas described in this document.

Antenna	Description	Advantages	Disadvantages
Embedded Stub (Wire)	■ Wire attached to or molded inside product case ■ Connect to pin 4 for TX/RX	■ Placement flexibility ■ Minimum PCB space ■ Easy to adjust length during design testing	■ Mechanical attachment to case required ■ Performance can be impacted by case shielding
Embedded Loop (Wire)	■ Wire loop attached to or molded inside product case ■ Connect to pin 4 for TX/RX	■ Can achieve high efficiency per length ■ Placement flexibility ■ Minimum PCB space ■ Easy to adjust length during design testing	■ Mechanical attachment to case required ■ Performance can be impacted by case shielding
Embedded Stub (PCB Trace)	■ Wire trace fabricated on outer PCB copper layer ■ Connect to pin 4 for TX/RX	■ No mechanical attachment to case ■ Ease of product assembly	■ PCB keep out regions required around antenna ■ Additional PCB space ■ Performance can be impacted by case shielding
Embedded Loop (PCB Slot)	■ Area on PCB where all copper is removed creating a slot ■ Connect to pin 4 for TX/RX	■ No mechanical attachment to case ■ Ease of product assembly ■ Less area required for PCB keep out region	■ Additional PCB space ■ Need to void all PCB planes in the slot ■ Performance can be impacted by case shielding
External Half-Wave	■ External wire attached to product acts as antenna ■ Connect to pin 2 for RX or pin 4 for RX/TX	■ Longer antenna length can result in better efficiency ■ Can use existing external connectors as antenna (headphone, charger cable, etc.)	■ Cannot operate product if external cable is not present (headphone or charger cable removed) ■ Requires decoupling antenna wire from other traces in cable

Figure 2 is an example of a stub antenna in wire implementation buried inside a cellular handset. Explanations of the dimensions A, B, C, and D are included later in this document.

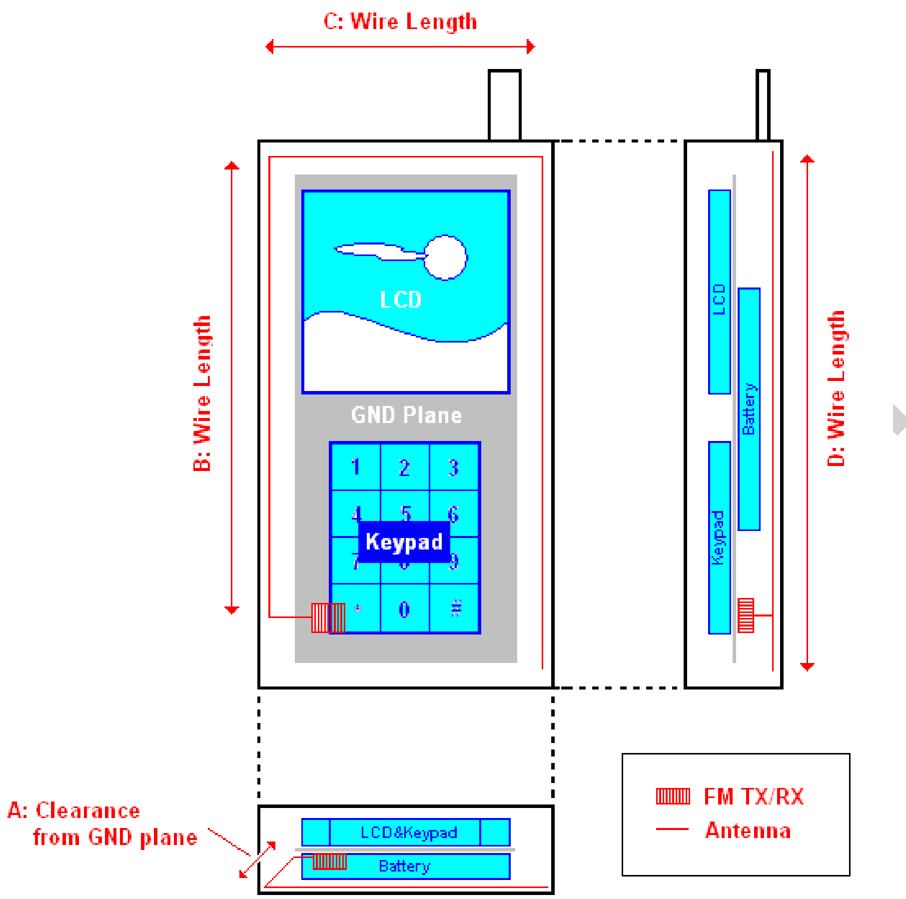

Figure 2. Stub Antenna in Wire Implementation

2.1. Embedded Stub Antenna—Wire Implementation (Pin 4)

A stub (wire) antenna is typically a floating wire that is approximately 10 cm in length and is embedded inside the device with FM functionality. The antenna can be longer if the device's industrial design will accommodate it. The material for a stub (wire) antenna can be an actual wire or a PCB trace. PCB traces can be either in flexible packaging (flexible PCB trace) or as a trace on the PCB. The 24AWG wire has been experimentally proven to have optimal performance.

The stub (wire) antenna should be placed such that it is not obstructed by a ground plane or shield. This requirement can be met by placing the antenna on an extremity of the device (*e.g.*, top or bottom) or on the perimeter. The antenna can also be embedded in the device plastic or outside the plastic with a protective covering. The flexible PCB antenna should be between a PCB and the device plastic such that the antenna trace is not obstructed by a ground plane or shield. The antenna is connected to pin 4 and resonated with the on-chip variable capacitor.

2.1.1. Antenna Matching

A 10 cm stub (wire) antenna has a capacitive impedance, typically more than 1~2 pF. The antenna is matched by resonating it with a shunt inductor and the on-chip shunt variable capacitor. See Appendix A and Appendix B for inductor value calculation.

2.1.2. Configuration

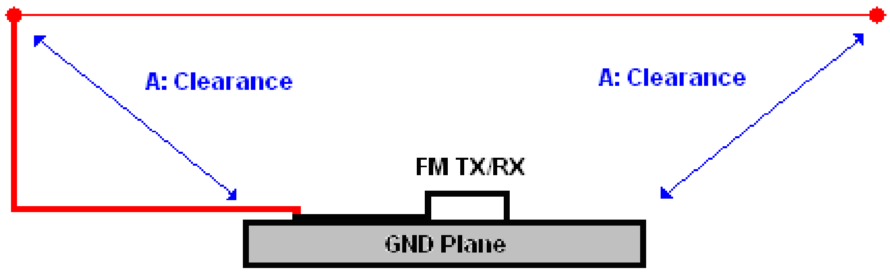

Figure 3. Stub (Wire) Antenna - Side View

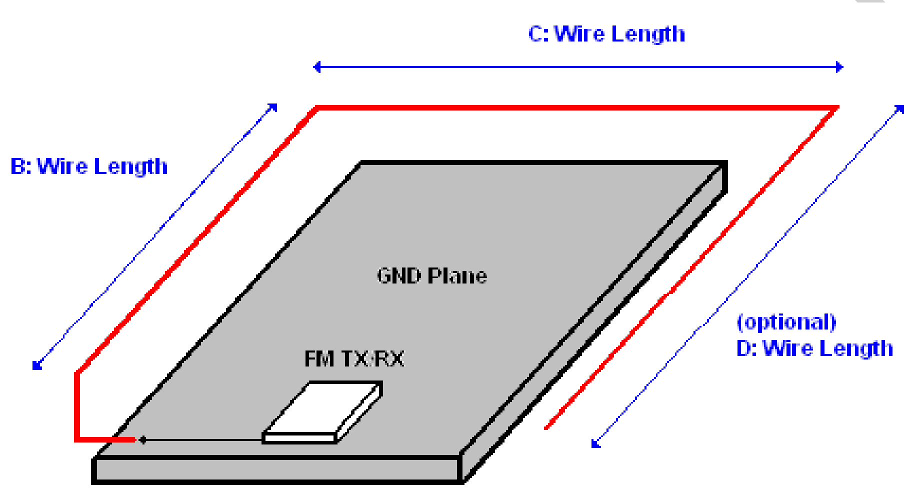

Figure 4. U-Shaped Stub (Wire) Antenna - Orthogonal View

2.1.3. Antenna Layout Guidelines

- Route the antenna as a "U" shape as shown in Figure 4.
  - A > 5 mm
  - B + C + D > 10 cm
  - C > 3 cm
- Route the antenna as an "L" by removing segment D if a "U" is not possible.
- Maximize antenna length (B+C+D >10 cm) to provide sufficient radiating power for transmit and maximize incident voltage for receive.
- It is not important to match D = B.
- Keep the antenna as far from the ground plane, shield, and other metal structures (*e.g.*, batteries) as possible (A > 5 mm), and make the enclosure from non-conductive material, such as plastic, to minimize parasitic capacitance and maximize radiation for transmit or maximize incident voltage for receive.
- Antenna capacitance for an ideal wire antenna is approximated by Cant = L/(198 x c), where L is length of wire in meters and c is speed of light (3.0 x 10^8 m/s). A general guideline to follow is to assume that each centimeter of wire antenna adds ~0.17 pF of capacitance (for L << λ/20).

Length (cm)	C Ant (pF)
10	1.68
11	1.85
12	2.02
13	2.19
14	2.36
15	2.53

- Use an ideal vertical wire antenna as a reference point to measure the performance of the wire antenna. Antenna capacitance will be larger and antenna performance will degrade in a practical application where the wire antenna is bent parallel to the GND plane.

2.2. Embedded Loop Antenna—Wire Implementation (Pin 4)

A loop (wire) antenna is typically a floating wire that is approximately 13 cm or greater in circumference and is embedded inside the device with FM functionality. It is constructed with a floating wire or flexible PCB trace. The shape of the antenna can be circular or rectangular with the goal of maximizing the enclosed area. The 24AWG has been experimentally proven to have optimal performance. A floating wire antenna is typically embedded in the plastics, or outside of the plastics (with protective covering), at the perimeter of the device such that the antenna trace is not obstructed by the ground plane, shield, or other metal structures (*e.g.*, batteries).

Placement of the flexible PCB is typically between the main PCB and plastics such that the antenna trace is not obstructed by a ground plane or shield. A loop antenna is similar to a short wire antenna with the exception that the other end of the antenna is grounded. Because the other end is grounded, a loop antenna by itself is an inductor.

2.2.1. Antenna Matching

A loop (wire) antenna is an inductor of high impedance. The antenna is matched by resonating it with a shunt inductor or capacitor and the on-chip shunt variable capacitor. See Appendix A and Appendix B for matching component calculation.

2.2.2. Configuration

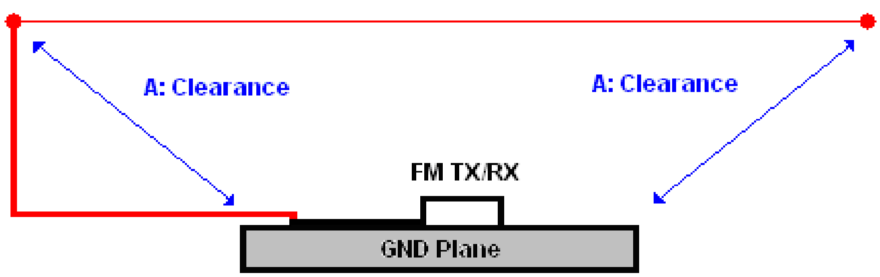

Figure 5. Loop (Wire) Antenna - Side View

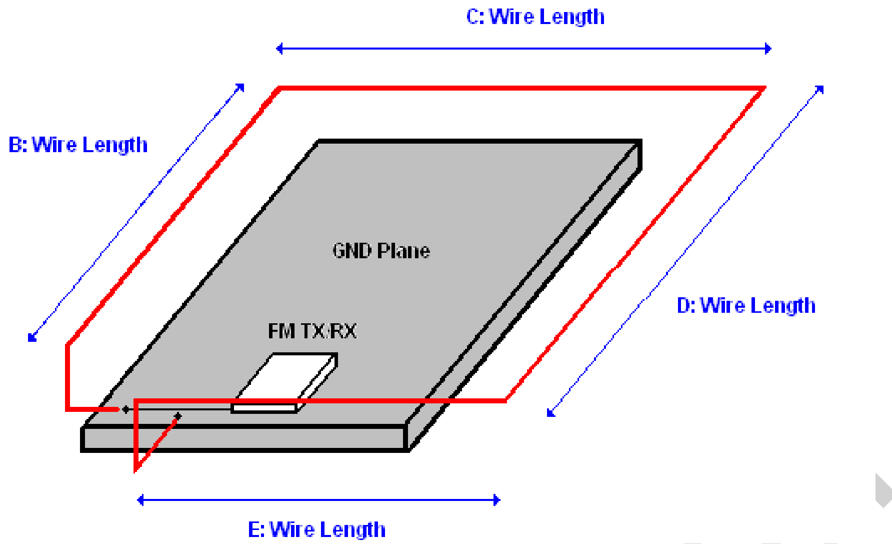

Figure 6. Rectangular Loop (Wire) Antenna - Orthogonal View

2.2.3. Design Guidelines

- Route the antenna as shown in Figure 6.
  - A > 5 mm
  - B + C + D + E > 13 cm
  - C > 3 cm
- Maximize antenna length (B+C+D+E >13 cm) to provide sufficient radiating power for transmit and maximize incident voltage for receive.
- Keep the antenna as far from the ground plane and shield as possible (A > 5 mm), and make the enclosure from non-conductive material (plastic), to minimize parasitic capacitance and maximize radiation for transmit or maximize incident voltage for receive.
- Antenna inductance for an ideal loop antenna is given by $L_{ant} = n^2\mu_0 r[\ln(8r/b)]$.

r: loop radius (m)

n: number of turns

μ_0: permeability ($4\pi \times 10^{-7}$ N/A^2)

b: wire radius (m)

A number of turns greater than one usually results in a high inductance loop with which the varactor cannot resonate. It is acceptable to place two loops in a parallel structure to reduce the effective inductance.

For a loop with a small radius used in cellular handset or mp3 applications, the loop antenna equation can be approximately applied to a rectangular loop of the same circumference.

Radius (cm)	Turns	Total Length (cm)	L_{ant} (nH)
2	1	12.6	111.5
3	1	18.8	182.6
4	1	25.1	257.9

- Use an ideal vertical loop (wire) antenna as a reference point to measure the performance of the loop antenna. Antenna performance will degrade in a practical application where the loop antenna is bent parallel to the GND plane.

2.3. Embedded Stub Antenna—PCB Trace Implementation (Pin 4)

A stub antenna (PCB trace) is constructed using a 10cm or longer PCB trace. The material can be any standard PCB. The PCB trace must be routed in an area without any copper fill such as ground or power planes, or other traces. The antenna is connected to pin 4 and resonated with the on-chip variable capacitor.

2.3.1. Antenna Matching

A 10 cm stub (wire) antenna has a capacitive impedance, typically more than 1~2 pF. The antenna is matched by resonating it with a shunt inductor and the on-chip shunt variable capacitor. See Appendix A and Appendix B for inductor value calculation.

2.3.2. Configuration

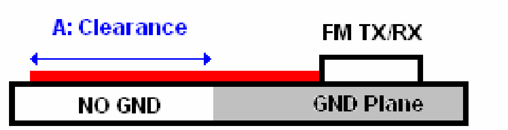

Figure 7. Stub (PCB Trace) Antenna - Side View

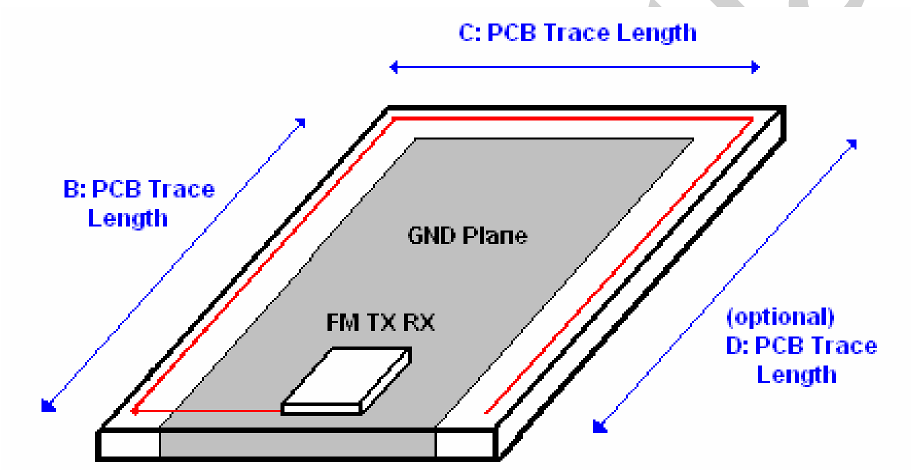

Figure 8. Stub (PCB Trace) Antenna - Orthogonal View

2.3.3. Design Guidelines

- Route the antenna as a "U" shape as shown in Figure 7.
  - A > 5 mm
  - B + C + D > 10 cm
  - C > 3 cm
- Route the antenna as an "L" by removing segment D if a "U" is not possible.
- Maximize antenna length (B+C+D >10 cm) to provide sufficient radiating power for transmit and maximize incident voltage for receive.
- It is not important to match D = B.
- Keep the antenna as far from the ground plane and shield as possible (A > 5 mm), and make the enclosure from non-conductive material (plastic), to minimize parasitic capacitance and maximize radiation for transmit or maximize incident voltage for receive.
- Antenna capacitance for an ideal PCB trace antenna is given by Cant = L/(198 x c), where L is length of wire in meters and c is speed of light (3.0 x 10^8 m/s). A general guideline to follow is to assume that each centimeter of wire antenna adds ~0.17 pF of capacitance (for L << λ/20).

Length (cm)	C_{ant} (pF)
10	1.68
11	1.85
12	2.02
13	2.19
14	2.36
15	2.53

2.4. Embedded Loop Antenna—PCB Slot Implementation (Pin 4)

A loop antenna (slot) consists of a 10 cm or longer cutout in the PCB planes. A cutout is a PCB space with no ground plane underneath. No traces may cross the cutout. A 2 mm slot width has been experimentally proven to work. A slot antenna must be routed in the PCB such that the cutout is not obstructed by a shield or conductive enclosure. The antenna slot is connected to pin 4 as shown in Figure 9 to provide a current path through the GND plane around the slot.

2.4.1. Antenna Matching

A 10 cm loop antenna (slot) is inductive. The antenna is matched by resonating it with a shunt capacitor and the on-chip shunt variable capacitor. See Appendix A and Appendix B for shunt capacitor value calculation.

2.4.2. Configuration

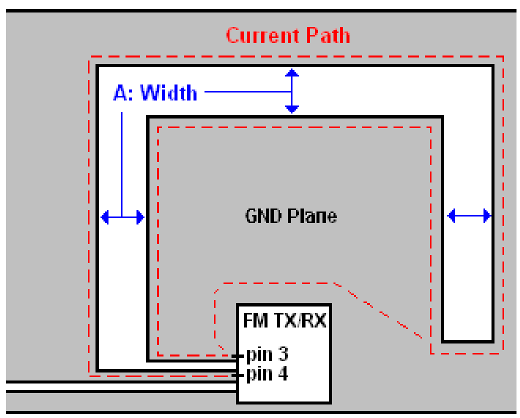

Figure 9. U-Shaped Slot Antenna - Top View

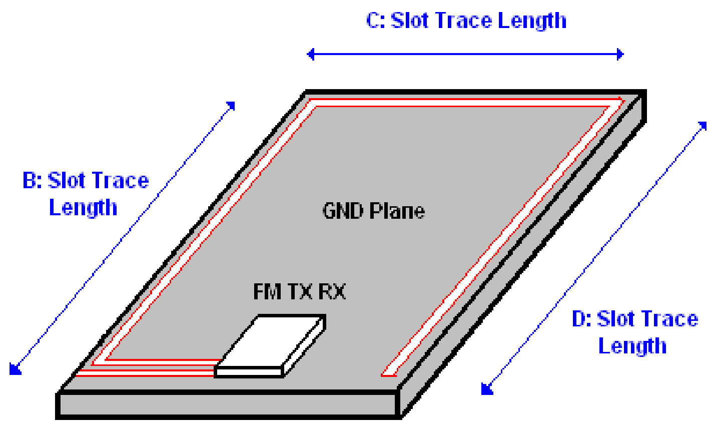

Figure 10. U-Shaped Slot Antenna - Orthogonal View

2.4.3. Guidelines

- Route the antenna as a "U" shape as shown in Figure 10.
  - A > 2 mm
  - B + C + D > 10 cm
  - C > 3 cm
- Route the antenna as an "L" by removing segment D if a "U" is not possible.
- Maximize antenna length (B+C+D >10 cm) to provide sufficient radiating power for transmit and maximize incident voltage for receive.
- Current path from TXO/LPI pin (pin 4) to RFGND (pin 3) must be through GND plane, and go around the slot traces.
- Keep the antenna as far from shielding as possible and make the enclosure from non-conductive material (plastic), to minimize parasitic capacitance and maximize radiation for transmit or maximize incident voltage for receive.
- A general guideline to follow is to assume that each centimeter of slot length with a width of 2 mm adds 7 nH to 9 nH of inductance.

2.5. External Half-Wavelength Antenna (Pin 2 or Pin 4)

A half-wavelength headphone or automotive charger cable will be ideally 1.45 m in length and consist of a conductor within a headphone cable or accessory cable. The common audio conductor is typically used for the audio return path and antenna. Additional conductors may be used for microphone audio, switching, power, or other functions, and in some applications the antenna will be a separate conductor within the cable. The antenna may be connected to pin 4 for receive and/or transmit operation. Alternatively, the antenna may be connected to pin 2 for receive operation. Please note that the antenna must be connected to pin 4 for transmit functionality.

2.5.1. Antenna Matching

An ideal half-wavelength antenna is a high impedance structure. See Appendix C and AN231 for shunt inductor value calculation.

2.5.2. Configuration

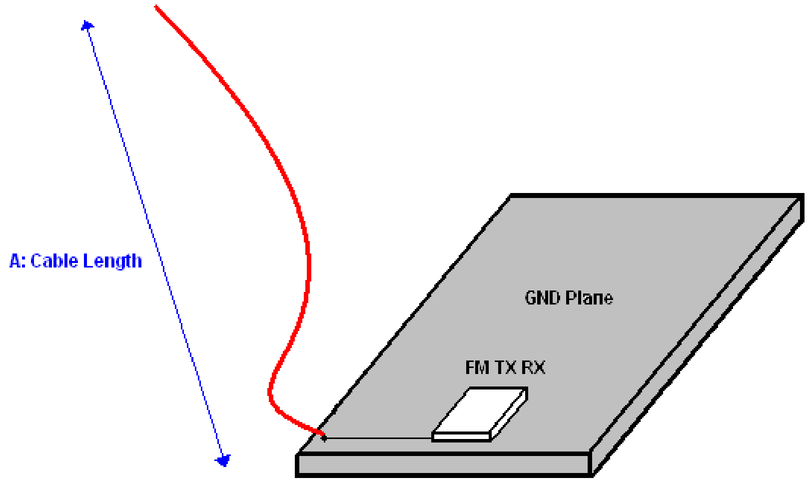

Figure 11. Cable Antenna - Orthogonal View

2.5.3. Guidelines

- Select an antenna length of 1.1 to 1.45 m. (1.1 m < A < 1.45 m)
- Minimize capacitive coupling between the antenna conductor and other conductors to reduce antenna loading and maintain a high impedance structure.
- Isolate other conductors with ferrite beads at the PCB.
- Remove dc offset from the cable through a dc blocking capacitor.
- Add a ferrite on the cable ground to provide ac return path.

3. Application Schematic

Figure 12 shows the typical application schematic for the Si47xx with a minimal recommended bill of materials.

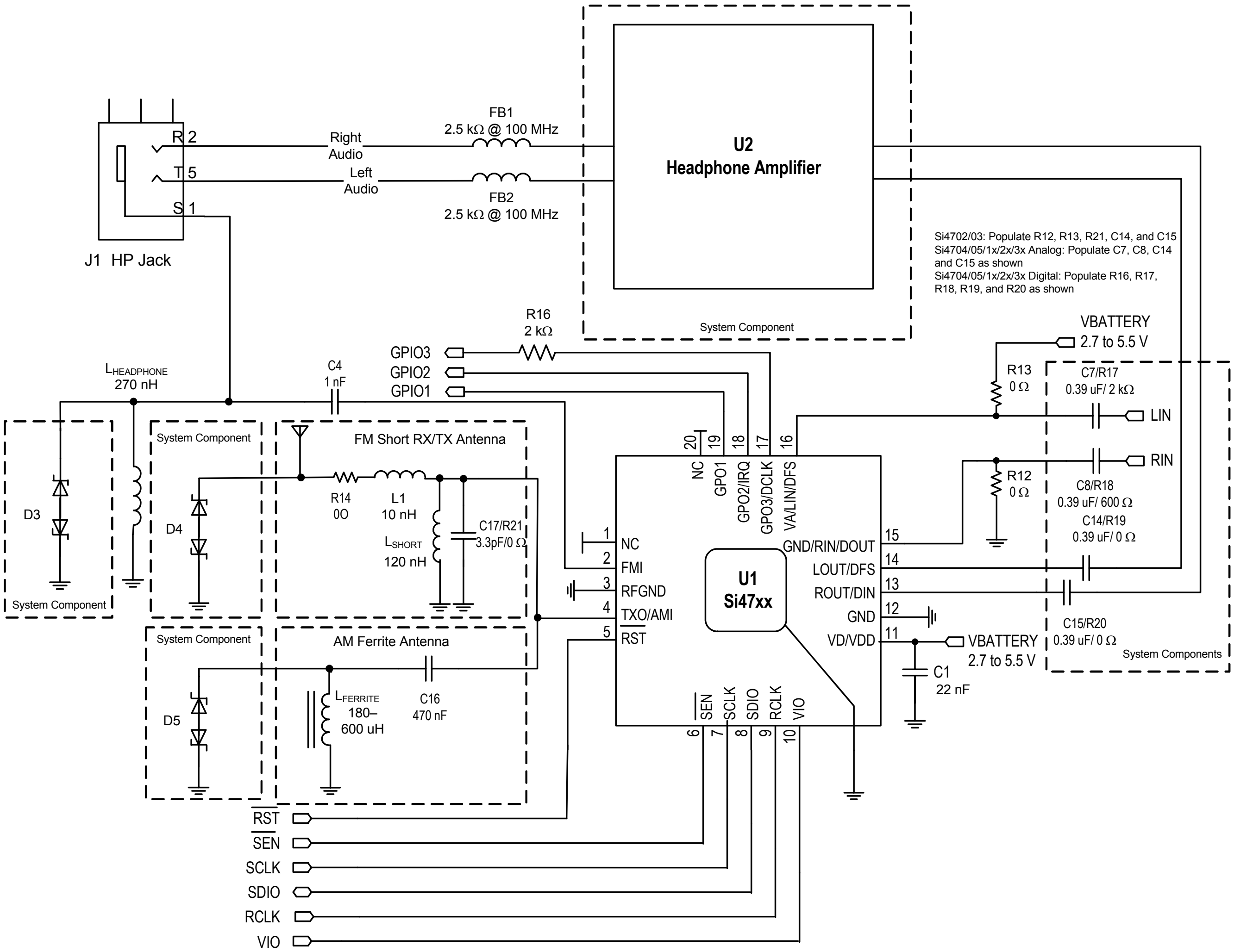

Figure 12. Typical Application Schematic

Following the schematic and layout recommendations detailed in this document will result in optimal performance with the minimal application schematic shown in Figure 12. “Typical Application Schematic”. For systems with constraints preventing implementation of these recommendations, optional components may be placed to address excess system noise. Generally it is not the case that all optional components are required to return to optimal performance. System components are those that are likely to be present for any tuner or transmitter design.

Figure 13, “Expanded Application Schematic,” includes the following components:

- Series resistors (noise suppression)
- VIO and VA (Si4702/03 only) supply bypass capacitor (noise suppression)
- Headphone amplifier bleed resistors (system components)
- Headphone amplifier shunt capacitors (system components)

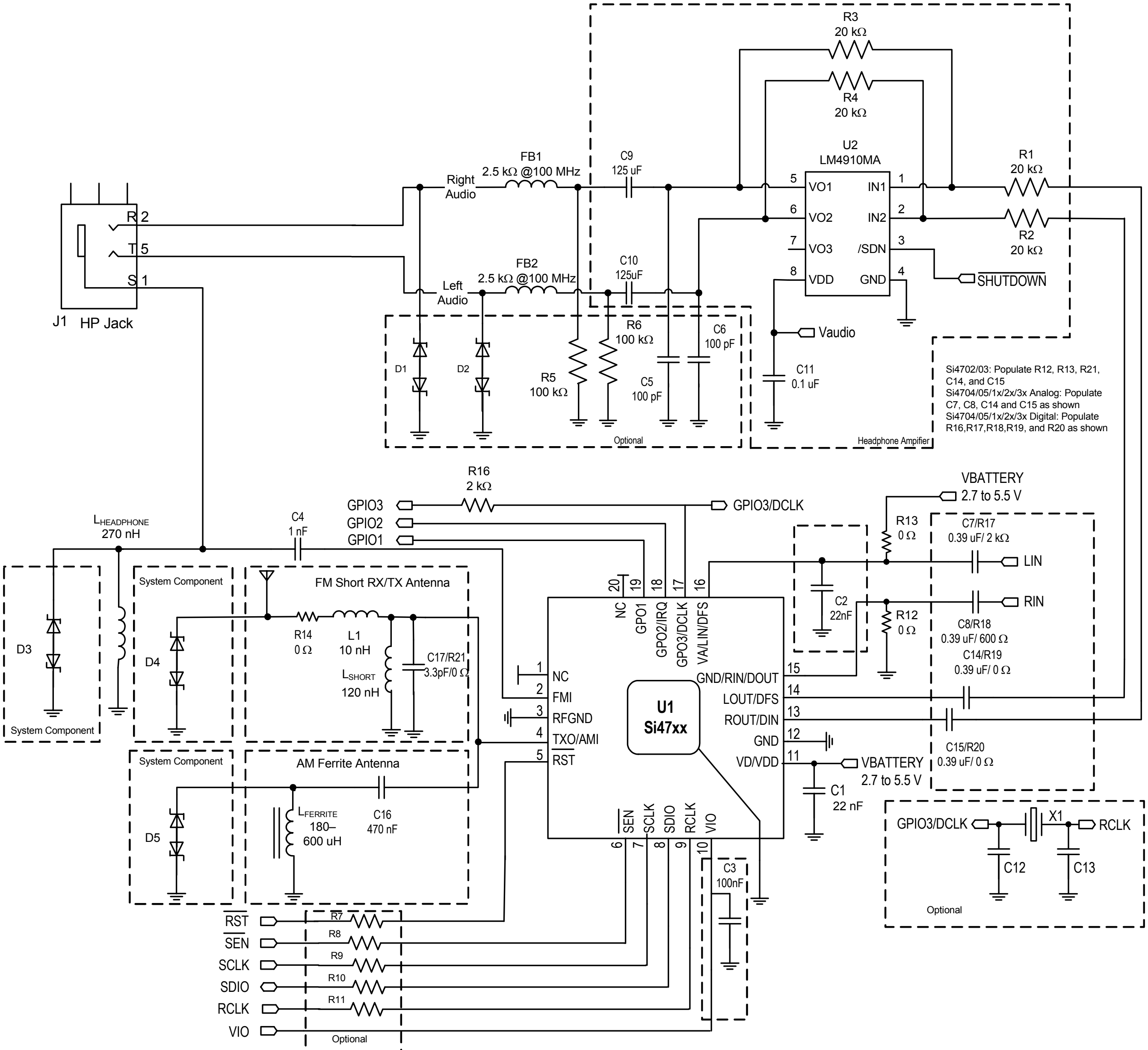

Figure 13. Expanded Application Schematic

The bill of materials for the expanded application schematic of Figure 13 is provided in Table 2. Refer to the individual device layout guides and antenna interface guides for a discussion of the purpose of each component.

Table 2. Bill of Materials

Designator	Description	Note
C1	Supply bypass capacitor, 22 nF, 10%, Z5U/X7R, 0402	
U1	Silicon Laboratories Si47xx, 3 mm x 3 mm, 20 pin, QFN	
R12, R13, R19, R20, R21	0 Ω jumper, 0402	R12, R13, and R21 for Si4702/03 Only
C16	AM antenna ac coupling capacitor, 470 nF, 20%, Z5U/X7R	AM Ferrite Antenna
LFERRITE	AM Ferrite loop stick, 180–600 µH	AM Ferrite Antenna
FB1,FB2	Ferrite bead, 2.5 kΩ @ 100 MHZ, 0603, Murata BLM18BD252SN1D	Headphone Antenna
LHEADPHONE	Headphone antenna matching inductor, 270 nH, 0603, Q>15, Murata LQW18ANR27J00D	Headphone Antenna
LSHORT	Short antenna matching inductor, 120 nH, 0603, Q>30, Murata LQW18ANR12J00D	Short Antenna
R14	Short antenna jumper, 2.2 Ω, 0402	Optional
C2	Supply bypass capacitor, 22 nF, 10%, Z5U/X7R, 0402	Optional
C3	Supply bypass capacitor, 100 nF, 10%, Z5U/X7R, 0402	Optional
C5, C6	Headphone amp output shunt capacitor, 100 pF, 10%, Z5U/X7R, 0402	Optional
R7-R11	Current limiting resistor, 20 Ω–2 kΩ, 0402	Optional
C12, C13	Crystal load capacitor, 22 pF, 5%, COG	Optional
X1	Crystal, Epson FC-135	Optional
C7, C8	Si47xx input ac coupling capacitor, 0.39 µF, X7R/X5R, 0402	System Component
D1-D5	ESD Diode, SOT23-3, California Micro Devices CM1214-01ST	System Component
C11	Supply bypass capacitor, 100 nF, 10%, Z5U/X7R, 0402	Headphone Amplifier
C4	Headphone antenna ac coupling capacitor, 1 nF, 10%, Z5U/X7R, 0402	Headphone Antenna
C9, C10	Headphone amp output ac coupling capacitor, 125 uF, X7R, 0805	Headphone Amplifier
C14, C15	Headphone amp input ac coupling capacitor, 0.39 µF, X7R/X5R, 0402	Headphone Amplifier
R1,R2,R3,R4	Headphone amp feedback/gain resistor, 20 kΩ, 0402	Headphone Amplifier
R5, R6	Headphone amp bleed resistor, 100 kΩ, 0402	Headphone Amplifier
U2	Headphone amplifier, National Semiconductor, LM4910MA	Headphone Amplifier
R16, R17	Current limiting resistor, 2 kΩ, 0402	System Component
R18	Current limiting resistor, 600 Ω, 0402	System Component
L1	VCO filter inductor, 10 nH, 0603, Q>30, Murata, LQW18ANR01J00D	Optional
C17	VCO filter capacitor, 3.3 pF, 0402, COG, Venkel, C0402COG2503R3JN	Optional

Figure 14 highlights the core components of the expanded application schematic shown in Figure 13. These core components can be the basis for a re-use block to support all Si47xx devices listed in Table 1 on page 1.

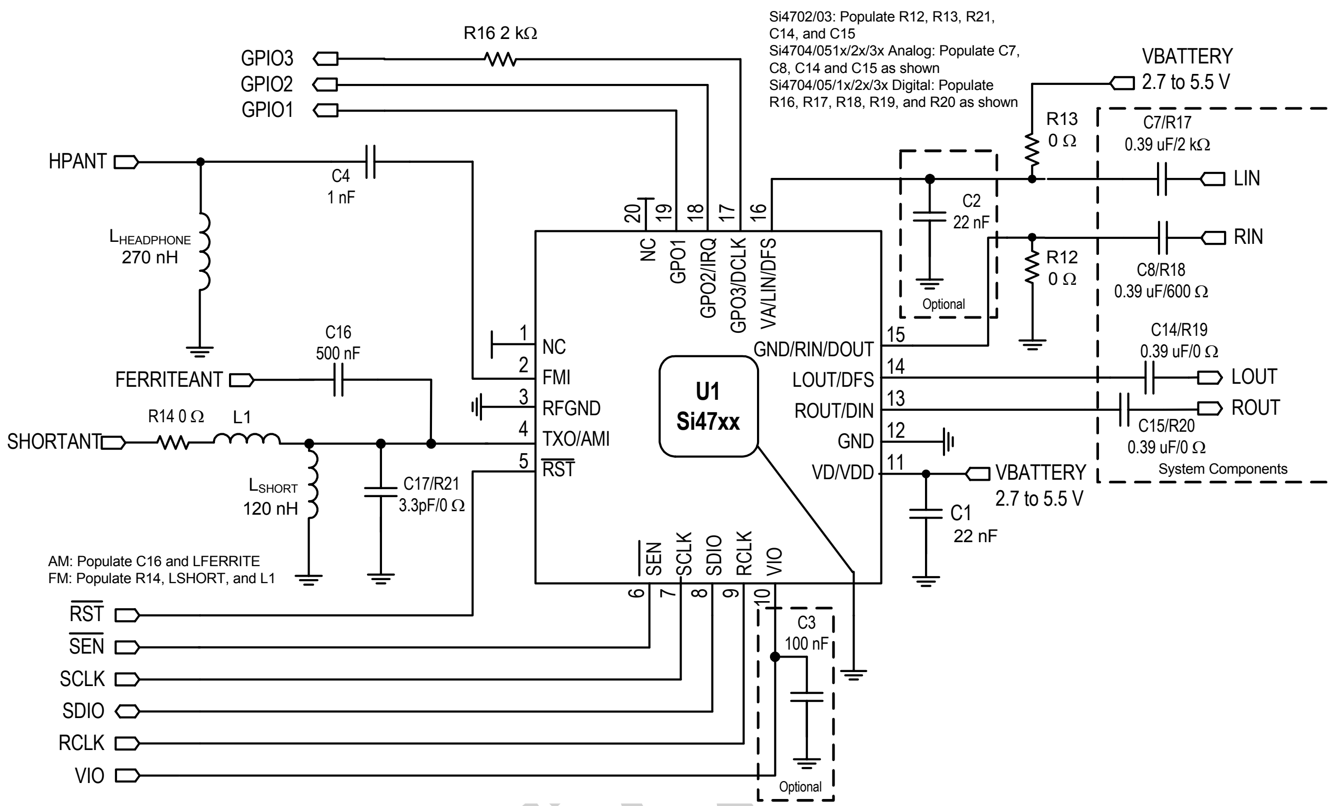

Figure 14. Re-Use Block for the Expanded Application Schematic

4. Layout and Placement Guidelines

Figure 15. “Re-use Block Layout for Expanded Application Layout” (0402 Component Size) shows the recommended layout for the schematic in Figure 14. “Re-use Block for the Expanded Application Schematic.” The following layout rules are used:

- Layer 1 top side routing (shown)
- Layer 2 GND (not shown)
- Power plane placed on a lower layer (not shown)
- 0402 component size or larger
- 6 mil traces
- 6 mil trace spacing
- 15 mil component spacing

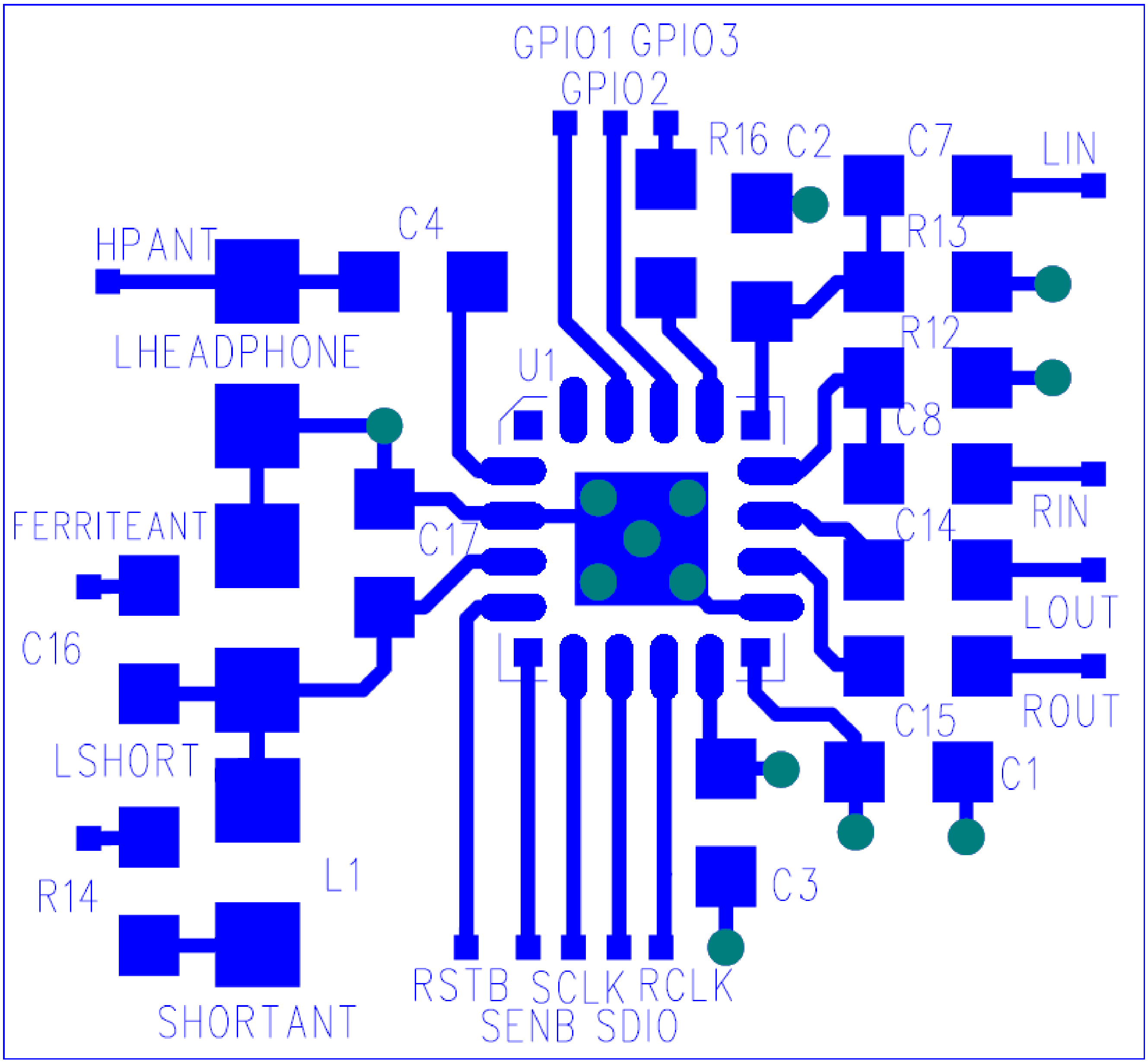

Figure 15. Re-Use Block Layout for Expanded Application Layout (0402 Component Size)

Figure 16 shows the recommended layout for the schematic in Figure 14. The following layout rules are used:

- Layer 1 top side routing (shown)
- Layer 2 GND (not shown)
- Power plane placed on a lower layer (not shown)
- 0201 component size or larger
- 6 mil traces
- 6 mil trace spacing
- 15 mil component spacing

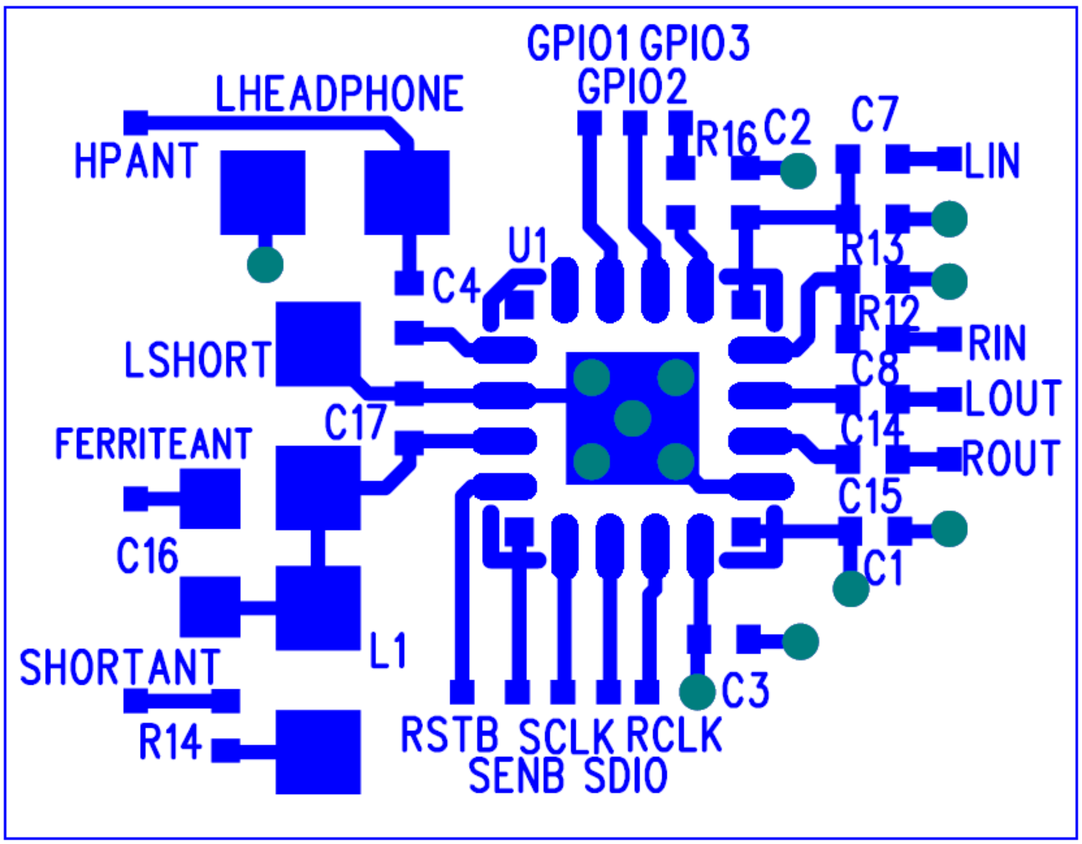

Figure 16. Re-Use Block Layout for Expanded Application Layout (0201 Component Size)

In addition to the layout guidelines found in individual device layout guidelines and antenna guides, the following guidelines are specific to the universal layout:

- **Place** RF matching circuits LHEADPHONE, LSHORT, L1, C4, and C16 are away from digital pins.
- **Place** R12 VDD VIA and R13 GND VIA close to each other to minimize current loops.
- **Place** C17 as close to pins 2 and 3 as possible.

5. Si47xx External RX Headphone Application Design Checklist

See “AN231: Si47xx Headphone Antenna Interface and Layout Guide” for additional information.

- **Select** an antenna length of 1.1 to 1.45 m.
- **Select** a stackup that has at least two layers. Four or more layers are preferred.
- **Select** matching inductor LHEADPHONE to maximize signal strength across the FM band.
- **Select** matching inductor LHEADPHONE with a Q of 15 or greater at 100 MHz and minimal dc resistance.
- **Select** ferrite beads FB1-FB2 with 2.5 kΩ or greater resistance at 100 MHz to maximize RSHUNT and, therefore, RP (refer to AN231).
- **Select** ESD diodes D1-D3 with minimum capacitance to reduce CSHUNT and, therefore, CP (refer to AN231).
- **Place** the Si47xx close to the headphone connector to minimize antenna trace length. Minimizing trace length reduces CP (refer to AN231) and the possibility for inductive and capacitive coupling into the antenna by noise sources. This recommendation must be followed for optimal device performance.
- **Place** inductor LHEADPHONE and headphone connector together and as far from potential noise sources as possible to reduce capacitive and inductive coupling.
- **Place** ferrite beads FB1-FB2 close to the headphone connector to minimize CSHUNT (refer to AN231) and, therefore, CP (refer to AN231).
- **Place** ESD diodes D1-D3 as close as possible to the headphone connector for maximum effectiveness.
- **Place** optional RF shunt capacitors near the headphone amplifier left and right audio output pins to reduce the level of digital noise passed to the antenna.
- **Place** optional system controller series termination resistors near the signal source, typically the system controller.
- **Place** VD bypass capacitor C1, and optional VA and VIO bypass capacitors C2 and C3, as close as possible to supply pins they bypass for maximum effectiveness.
- **Do Not Route** digital, analog, and RF traces parallel with one another to minimize inductive and capacitive coupling.
- **Do Not Route** traces under the Si47xx without a reference plane between the IC and the signal trace. In particular, care should be taken to avoid routing digital signals or reference clocks traces near or parallel to the RF pins inputs (pins 2,3,4), the VCO (pins 1, 20), or the antenna trace. This recommendation is made to minimize inductive and capacitive coupling.
- **Do Not Route** digital or RF traces over ground or power plane breaks. Signals and vias should be routed such that the ground plane is as solid as possible, with no large slots. Ground fills on other layers should have plentiful vias to the ground plane. This recommendation is made to minimize RF radiation.
- **Route** the antenna trace such that antenna capacitance, CPCBANT (refer to AN231), and therefore CP (refer to AN231), is minimized. To minimize capacitance, keep trace length short and narrow and as far above the reference plane as possible, restrict the antenna trace to a microstrip topology (trace routes on the top or bottom PCB layers only), minimize trace vias, and relieve ground fill on the trace layer.
- **Route** the antenna trace over an unobstructed ground plane to minimize antenna loop area and inductive coupling.
- **Route** all Si47xx ground pins to the ground paddle to minimize ground potential differences.
- **Design, Place,** and **Route** other circuits such that radiation in the FM band is minimized.

6. Si4704/05/06/1x/2x Embedded RX/TX Application Design Checklist

See "AN231: Si4700/01 Headphone Antenna Interface" for additional information.

See "AN306: Si4710/11 Short Monopole Antenna Interface" for additional information.

See "AN285: Si472x FM Transceiver Layout Guide" for additional information.

- **Select** a stackup that has at least two layers. Four or more layers are preferred.
- **Select** tuning inductor LSHORT with a Q>30 to maximize both radiated and received power.
- **Select** tuning inductor LSHORT as large as possible to maximize radiated power and incident voltage.
- **Select** ESD diode D4 with minimum capacitance.
- **Place** the antenna, and in particular the end of the antenna opposite the Si47xx as far from the ground plane as possible to maximize radiated and received power.
- **Place** inductor LSHORT, L1, and the Si47xx (U1) as far from potential noise sources as possible to reduce capacitive and inductive coupling.
- **Place** VDD bypass capacitor C1, and optional VIO bypass capacitor C3, as close as possible to supply pins they bypass for maximum effectiveness.
- **Place** C17 ground as close as possible to pin 3 RFGND and pin 2 TXO/LPI.
- **Place** optional components C17 and L1 to filter VCO spurs if needed.
- **Place** optional components D4, R14, and L1 to achieve 8 kV contact discharge ESD protection if the antenna is exposed.
- **Do Not Route** digital, analog, and RF traces parallel with one another to minimize inductive and capacitive coupling.
- **Do Not Route** traces under the Si47xx without a reference plane between the IC and the signal trace. In particular, care should be taken to avoid routing digital signals or reference clocks traces near or parallel to the VCO (pins 1, 20), audio inputs LIN/RIN (pins 15, 16), and audio outputs LOUT/ROUT (pins 14, 13). This recommendation is made to minimize inductive and capacitive coupling.
- **Do Not Route** digital or RF traces over ground or power plane breaks. Signals and VIAs should be routed such that the reference plane is as solid as possible, with no large slots. Ground fills on other layers should have plentiful VIAs to the ground plane. This recommendation is made to minimize RF radiation.
- **Route** the PCB antenna trace such that the antenna capacitance is minimized. To minimize capacitance, relieve the ground and power planes and ground fill.
- **Route** all Si47xx ground pins to the ground paddle to minimize ground potential differences.
- **Design, Place,** and **Route** other circuits such that radiation in the FM band is minimized.

7. Si473x AM Ferrite Application Design Checklist

See "AN231: Si4700/01 Headphone Antenna Interface" for additional information.

See "AN384: Si473x AM/FM Receiver Layout Guide" for additional information.

See "AN386: Si473x AM Ferrite Loopstick Antenna Interface" for additional information.

- **Select** a stackup that has at least two layers. Four or more layers are preferred.
- **Select** a shielded transformer if an air loop antenna is used.
- **Select** ESD diode Δ5 with minimum capacitance.
- **Place** the ferrite loop stick antenna or the transformer (when using an air loop antenna) away from any sources of interference and even away from the I/O signals of the Si473x. Please make sure that the AM antenna is as far away as possible from circuits that switch at a rate which falls in the AM band (520-1720 kHz).
- **Place** VDD bypass capacitor C1, and optional VIO bypass capacitor C3, as close as possible to supply pins they bypass for maximum effectiveness. Make sure the trace directly goes from the pin to the capacitor and then to the appropriate supply using a VIA.
- **Place** the AM ac coupling capacitor as close to the AMI pin of the Si47xx as possible.
- **Place** optional component D5 if the antenna is exposed.
- **Do Not Place** any ground plane under the ferrite loop stick antenna if the ferrite loop stick antenna is mounted on the PCB.
- **Route** traces from the transformer or the ferrite loop stick connectors to the AMI input via the ac coupling cap C16 such that the capacitance from the traces and the pads is minimized.
- **Route** all Si47xx ground pins to the ground paddle to minimize ground potential differences.
- **Do Not Route** digital, analog, and RF traces parallel with one another to minimize inductive and capacitive coupling.
- **Do Not Route** traces under the Si47xx without a reference plane between the IC and the signal trace. In particular, care should be taken to avoid routing digital signals or reference clocks traces near or parallel to the VCO (pins 1,20), or audio outputs LOUT/ROUT (pins 14,13). This recommendation is made to minimize inductive and capacitive coupling.
- **Do Not Route** digital or RF traces over ground or power plane breaks. Signals and VIAs should be routed such that the reference plane is as solid as possible, with no large slots. Ground fills on other layers should have plentiful VIAs to the ground plane. This recommendation is made to minimize RF radiation.
- **Design, Place,** and **Route** other circuits such that radiation in the AM band is minimized.

8. Si47xx Universal Layout Design Checklist

- **Place** RF matching circuits LHEADPHONE, LSHORT, L1, C4, and C16 away from digital pins.
- **Place** R12 VDD VIA and R13 GND VIA close to each other to minimize current loops.
- Place C17 as close to pins 2 and 3 as possible.

9. References

- AN231: Si4700/01 Headphone Antenna Interface
- AN306: Si4710/11 Short Monopole Antenna Interface
- AN285: Si472x FM Transceiver Layout Guide
- AN384: Si473x AM/FM Receiver Layout Guide
- AN386: Si473x AM Ferrite Loopstick Antenna Interface

Appendix A—FM Antenna Matching Component Selection with On-chip Tuning Capacitor (Pin 4)

This appendix describes how to select the matching components for antennas with known characteristics. The antenna characteristics used in the examples below are for ideal cases with no parasitic coupling effects. In practice, you must test the matching component in the actual application to verify expected performance using the selected matching components. Mistuned matching components can be identified by verifying the range of the internal varactor across the frequency band. If the varactor is set to either minimum or maximum value at the edges of the band, the matching circuit should be adjusted to compensate. The varactor values are represented in 1~192 with 0.25 pF steps and has a total range of 0~47.75 pF and 5 pF of fixed offset. The value of the varactor can be read through the FM_TUNE_STATUS command (0x22) for the FM receiver (Si4704/05/06/2x) and the TX_TUNE_STATUS command (0x33) for the FM transmitter (Si471x/2x).

Figure 17 is a simplified model of the antenna and its turning circuit when the short monopole antenna is connected to the on-chip tuning antenna pin. For the purpose of this calculation, resistors have been eliminated.

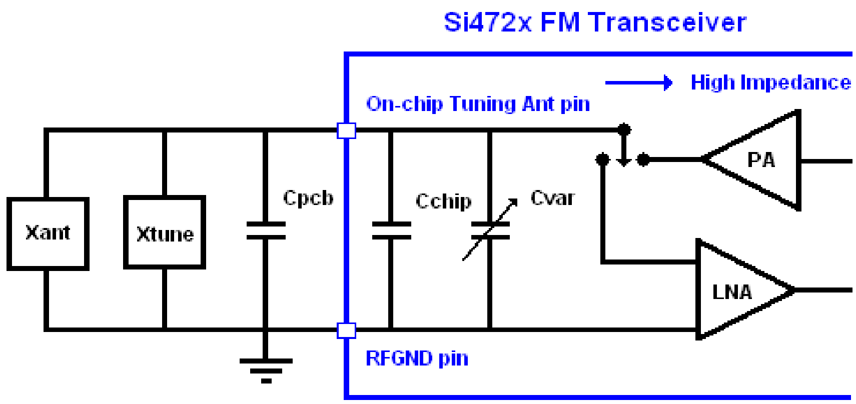

Figure 17. Simplified Resonating LC Circuit Model

X_{ant}: characteristic of the antenna

X_{tune}: impedance of the tuning shunt inductor or capacitor

C_{pcb}: PCB parasitic capacitance (typically 3 pF or more)

C_{chip}: on-chip parasitic capacitance (typically 5 pF)

C_{var}: on-chip varactor (variable capacitor) ranging from 0~47.75 pF

Once the characteristic of the antenna, X_{ant}, is known, select X_{tune} such that C_{var} will be 5 pF at 108 MHz.

Useful equation for resonating circuit: $\omega^2 = (2\pi f)^2 = 1/(LC)$

Case 1: Antenna is capacitive and C_{ant} < 5 pF (Example: C_{ant} = 2 pF)

This is typical for stub antennas in both wire and PCB trace implementation.

When the antenna is capacitive, you must select shunt inductor, Ltune, as your tuning component to create a resonating circuit.

1. Calculate total system capacitance and inductance.

   Assume: $C_{pcb} = 9$ (pF)

   Assume: $C_{var} = 5$ (pF) @ 108 MHz

   $C_{total} = C_{pcb} + C_{chip} + C_{var} + C_{ant}$

   $C_{total} = 9 + 5 + 5 + 2 = 21$ (pF)

   $L_{total} = L_{tune} = X_{tune}$

2. Calculate L_{tune} at 108 MHz.

   @108 MHz $L_{tune} = L_{total} = 1/(C_{total} {}^*\omega^2) = 103.4$ nH

3. Calculate the C_{var} (varactor capacitance) at FM band range to make sure it is within the range of 0~47.75 pF (varactor value of 1~192).

   C_{var} @ 76 MHz = 26.4 (pF) (varactor value: 106)

   C_{var} @ 87.5 MHz = 16.0 (pF) (varactor value: 64)

   C_{var} @ 108 MHz = 5.0 (pF) (varactor value: 20)

Case 2: Antenna is inductive and 60 nH < L_{ant} < 100 nH (Example: L_{ant} = 60 nH)

This is typical for a loop antenna in PCB slot implementation.

When the antenna structure presents a small inductance as an impedance, shunt capacitor, C_{tune}, can be used for the tuning component.

1. Calculate total system capacitance and inductance.

   Assume: $C_{pcb} = 9$ (pF)

   Assume: $C_{var} = 5$ (pF) @ 108 MHz

   $C_{total} = C_{pcb} + C_{chip} + C_{var} + C_{tune}$

   $C_{total} = 9 + 5 + 5 + C_{tune} = 19 + C_{tune}$ (pF)

   $L_{total} = L_{ant} = 60$ (nH)

2. Calculate C_{total} at 108 MHz.

   @108 MHz $C_{total} = 1/(L_{total} {}^*\omega^2) = 36.2$ (pF)

3. Calculate C_{tune}.

   $C_{tune} = C_{total} - C_{pcb} - C_{chip} - C_{var} = 17.2$ (pF)

4. Calculate the C_{var} (varactor capacitance) at FM band range to make sure it is within the range of 0~47.75 pF (varactor value of 1~192).

   C_{var} @ 76MHz = 41.9 (pF) (varactor value: 168)

   C_{var} @ 87.5MHz = 23.9 (pF) (varactor value: 96)

   C_{var} @ 108MHz = 5.0 (pF) (varactor value: 20)

Case 3: Antenna is inductive and L_{ant} > 140 nH (Example L_{ant} = 240 nH)

This is typical for a loop antenna in wire implementation.

When the antenna structure presents large inductance as an impedance, shunt inductor, L_{tune}, can be used for the tuning component to reduce the total inductance of the system.

1. Calculate total system capacitance and inductance.

   Assume: C_{pcb} = 9 (pF)

   Assume: C_{var} = 5 (pF) @ 108 MHz

   $C_{total} = C_{pcb} + C_{chip} + C_{var}$

   C_{total} = 9 + 5 + 5 = 19 (pF)

   $L_{total} = L_{tune} \parallel 240$ (nH)

2. Calculate L_{total} at 108 MHz.

   $L_{total} = 1/(C_{total}*\omega^2) = 114.3$ (nH)

3. Calculate L_{tune}.

   $L_{tune} = (L_{ant}*L_{total})/(L_{ant}-L_{total}) = 218.2$ (nH)

4. Calculate the C_{var} (varactor capacitance) at FM band range to make sure it is within the range of 0~47.75 pF (varactor value of 1~192).

   C_{var} @ 76MHz = 24.4 (pF) (varactor value: 98)

   C_{var} @ 87.5MHz = 14.9 (pF) (varactor value: 60)

   C_{var} @ 108MHz = 5.0 (pF) (varactor value: 20)

Case 4: Antenna is inductive and 75 nH < L_{ant} < 140 nH

This is typical for a loop antenna in wire implementation with area 10~15 cm².

Often loop antennas present an impedance that does not require any additional matching components. If the characteristic impedance of the loop antenna is approximately 75~140 nH, no external matching components should be required.

Example 1: X_{ant} = 75 nH

C_{var} @ 76MHz = 44.5 (pF) (varactor value: 178)

C_{var} @ 87.5MHz = 30.1 (pF) (varactor value: 120)

C_{var} @ 108MHz = 15.0 (pF) (varactor value: 60)

Example 2: X_{ant} = 140 nH

C_{var} @ 76MHz = 17.3 (pF) (varactor value: 69)

C_{var} @ 87.5MHz = 9.63 (pF) (varactor value: 39)

C_{var} @ 108MHz = 1.5 (pF) (varactor value: 6)

Case 5: Antenna is capacitive and X_{ant} is large (Example: X_{ant} = C_{ant} = 200 pF)

This is typical for an external antenna.

Please refer to Appendix C for matching component selections for external antennas.

Appendix B—FM Antenna Matching Component Selection Table

Case 1: Antenna is capacitive and C_{ant} < 5pf

Cant (pF)	Cpcb (pF)	Cchip (pF)	Optimal Ltune (nH)	Theoretical Cvar (pF)		
				@ 76 MHz	@ 87.5 MHz	@ 108 MHz
0.5	6	5	131.6	21.8	13.6	5.0
0.6	6	5	130.8	21.9	13.7	5.0
0.7	6	5	130.0	22.0	13.7	5.0
0.8	6	5	129.3	22.1	13.8	5.0
0.9	6	5	128.5	22.2	13.8	5.0
1.0	6	5	127.7	22.3	13.9	5.0
1.1	6	5	127.0	22.4	14.0	5.0
1.2	6	5	126.3	22.5	14.0	5.0
1.3	6	5	125.5	22.6	14.1	5.0
1.4	6	5	124.8	22.7	14.1	5.0
1.5	6	5	124.1	22.8	14.2	5.0
1.6	6	5	123.4	22.9	14.2	5.0
1.7	6	5	122.7	23.0	14.3	5.0
1.8	6	5	122.0	23.1	14.3	5.0
1.9	6	5	121.3	23.2	14.4	5.0
2.0	6	5	120.6	23.3	14.4	5.0
2.1	6	5	120.0	23.5	14.5	5.0
2.2	6	5	119.3	23.6	14.5	5.0
2.3	6	5	118.7	23.7	14.6	5.0
2.4	6	5	118.0	23.8	14.6	5.0
2.5	6	5	117.4	23.9	14.7	5.0
2.6	6	5	116.8	24.0	14.7	5.0
2.7	6	5	116.1	24.1	14.8	5.0
2.8	6	5	115.5	24.2	14.8	5.0
2.9	6	5	114.9	24.3	14.9	5.0
3.0	6	5	114.3	24.4	14.9	5.0
3.5	6	5	111.4	24.9	15.2	5.0
4.0	6	5	108.6	25.4	15.5	5.0
4.5	6	5	105.9	25.9	15.7	5.0
5.0	6	5	103.4	26.4	16.0	5.0

Cant (pF)	Cpcb (pF)	Cchip (pF)	Optimal Ltune (nH)	Theoretical Cvar (pF)		
				@76 MHz	@87.5 MHz	@108 MHz
0.5	9	5	111.4	24.9	15.2	5.0
0.6	9	5	110.8	25.0	15.3	5.0
0.7	9	5	110.2	25.1	15.3	5.0
0.8	9	5	109.7	25.2	15.4	5.0
0.9	9	5	109.1	25.3	15.4	5.0
1.0	9	5	108.6	25.4	15.5	5.0
1.1	9	5	108.0	25.5	15.5	5.0
1.2	9	5	107.5	25.6	15.6	5.0
1.3	9	5	107.0	25.7	15.6	5.0
1.4	9	5	106.5	25.8	15.7	5.0
1.5	9	5	105.9	25.9	15.7	5.0
1.6	9	5	105.4	26.0	15.8	5.0
1.7	9	5	104.9	26.1	15.8	5.0
1.8	9	5	104.4	26.2	15.9	5.0
1.9	9	5	103.9	26.3	15.9	5.0
2.0	9	5	103.4	26.4	16.0	5.0
2.1	9	5	102.9	26.5	16.0	5.0
2.2	9	5	102.4	26.6	16.1	5.0
2.3	9	5	102.0	26.7	16.1	5.0
2.4	9	5	101.5	26.8	16.2	5.0
2.5	9	5	101.0	26.9	16.3	5.0
2.6	9	5	100.5	27.0	16.3	5.0
2.7	9	5	100.1	27.1	16.4	5.0
2.8	9	5	99.6	27.2	16.4	5.0
2.9	9	5	99.2	27.3	16.5	5.0
3.0	9	5	98.7	27.4	16.5	5.0
3.5	9	5	96.5	27.9	16.8	5.0
4.0	9	5	94.4	28.4	17.0	5.0
4.5	9	5	92.4	29.0	17.3	5.0
5.0	9	5	90.5	29.5	17.6	5.0

Case2: Antenna is inductive and 60nH < L_{ant} < 100nH

Lant (nH)	Cpcb (pF)	Cchip (pF)	Optimal Ltune (nH)	Theoretical Cvar		
				@76 MHz	@87.5 MHz	@108 MHz
55	6	5	23.5	45.3	25.7	5.0
60	6	5	20.2	41.9	23.9	5.0
65	6	5	17.4	39.1	22.5	5.0
70	6	5	15.0	36.6	21.2	5.0
75	6	5	13.0	34.5	20.2	5.0
80	6	5	11.1	32.7	19.2	5.0
85	6	5	9.5	31.0	18.4	5.0
90	6	5	8.1	29.6	17.6	5.0
95	6	5	6.9	28.3	17.0	5.0
100	6	5	5.7	27.1	16.4	5.0
105	6	5	4.7	26.1	15.8	5.0

Lant (nH)	Cpcb (pF)	Cchip (pF)	Optimal Ltune (nH)	Theoretical Cvar		
				@76 MHz	@87.5 MHz	@108 MHz
55	9	5	20.5	45.3	25.7	5.0
60	9	5	17.2	41.9	23.9	5.0
65	9	5	14.4	39.1	22.5	5.0
70	9	5	12.0	36.6	21.2	5.0
75	9	5	10.0	34.5	20.2	5.0
80	9	5	8.1	32.7	19.2	5.0
85	9	5	6.5	31.0	18.4	5.0
90	9	5	5.1	29.6	17.6	5.0
95	9	5	3.9	28.3	17.0	5.0
100	9	5	2.7	27.1	16.4	5.0
105	9	5	1.7	26.1	15.8	5.0

Case3: Antenna is inductive and Lant > 140nH

Lant	Cpcb	Cchip	Optimal	Theoretical Cvar		
(nH)	(pF)	(pF)	Ltune (nH)	@76 MHz	@87.5 MHz	@108 MHz
140	6	5	4449.2	21.3	13.4	5.0
145	6	5	2122.8	21.3	13.4	5.0
150	6	5	1426.6	21.3	13.4	5.0
155	6	5	1091.7	21.3	13.4	5.0
160	6	5	894.8	21.3	13.4	5.0
165	6	5	765.1	21.3	13.4	5.0
170	6	5	673.3	21.3	13.4	5.0
175	6	5	604.8	21.3	13.4	5.0
180	6	5	551.9	21.3	13.4	5.0
185	6	5	509.6	21.3	13.4	5.0
190	6	5	475.2	21.3	13.4	5.0
195	6	5	446.5	21.3	13.4	5.0
200	6	5	422.4	21.3	13.4	5.0
210	6	5	383.8	21.3	13.4	5.0
220	6	5	354.3	21.3	13.4	5.0
230	6	5	331.1	21.3	13.4	5.0
240	6	5	312.4	21.3	13.4	5.0
250	6	5	296.9	21.3	13.4	5.0
260	6	5	284.0	21.3	13.4	5.0
270	6	5	272.9	21.3	13.4	5.0
280	6	5	263.4	21.3	13.4	5.0
290	6	5	255.1	21.3	13.4	5.0
300	6	5	247.9	21.3	13.4	5.0
310	6	5	241.4	21.3	13.4	5.0
320	6	5	235.7	21.3	13.4	5.0
330	6	5	230.6	21.3	13.4	5.0
340	6	5	225.9	21.3	13.4	5.0
350	6	5	221.7	21.3	13.4	5.0
360	6	5	217.9	21.3	13.4	5.0
370	6	5	214.4	21.3	13.4	5.0
380	6	5	211.1	21.3	13.4	5.0
390	6	5	208.2	21.3	13.4	5.0
400	6	5	205.4	21.3	13.4	5.0

Lant (nH)	Cpcb (pF)	Cchip (pF)	Optimal Ltune (nH)	Theoretical Cvar		
				@76 MHz	@87.5 MHz	@108 MHz
140	9	5	622.6	24.4	14.9	5.0
145	9	5	539.8	24.4	14.9	5.0
150	9	5	480.2	24.4	14.9	5.0
155	9	5	435.3	24.4	14.9	5.0
160	9	5	400.2	24.4	14.9	5.0
165	9	5	372.0	24.4	14.9	5.0
170	9	5	348.8	24.4	14.9	5.0
175	9	5	329.5	24.4	14.9	5.0
180	9	5	313.1	24.4	14.9	5.0
185	9	5	299.1	24.4	14.9	5.0
190	9	5	286.9	24.4	14.9	5.0
195	9	5	276.2	24.4	14.9	5.0
200	9	5	266.7	24.4	14.9	5.0
210	9	5	250.8	24.4	14.9	5.0
220	9	5	237.9	24.4	14.9	5.0
230	9	5	227.2	24.4	14.9	5.0
240	9	5	218.2	24.4	14.9	5.0
250	9	5	210.6	24.4	14.9	5.0
260	9	5	204.0	24.4	14.9	5.0
270	9	5	198.2	24.4	14.9	5.0
280	9	5	193.1	24.4	14.9	5.0
290	9	5	188.7	24.4	14.9	5.0
300	9	5	184.6	24.4	14.9	5.0
310	9	5	181.1	24.4	14.9	5.0
320	9	5	177.8	24.4	14.9	5.0
330	9	5	174.9	24.4	14.9	5.0
340	9	5	172.2	24.4	14.9	5.0
350	9	5	169.7	24.4	14.9	5.0
360	9	5	167.5	24.4	14.9	5.0
370	9	5	165.4	24.4	14.9	5.0
380	9	5	163.5	24.4	14.9	5.0
390	9	5	161.7	24.4	14.9	5.0
400	9	5	160.0	24.4	14.9	5.0

Case 4: Antenna is inductive and 75 nH < Lant < 140 nH

Lant (nH)	Cpcb (pF)	Cchip (pF)	Optimal Ltune (nH)	Theoretical Cvar		
				@76 MHz	@87.5 MHz	@108 MHz
70	6	5	none	51.6	36.3	20.0
75	6	5	none	47.5	33.1	18.0
80	6	5	none	43.8	30.4	16.1
85	6	5	none	40.6	27.9	14.5
90	6	5	none	37.7	25.8	13.1
95	6	5	none	35.2	23.8	11.9
100	6	5	none	32.9	22.1	10.7
105	6	5	none	30.8	20.5	9.7
110	6	5	none	28.9	19.1	8.7
115	6	5	none	27.1	17.8	7.9
120	6	5	none	25.5	16.6	7.1
125	6	5	none	24.1	15.5	6.4
130	6	5	none	22.7	14.4	5.7
135	6	5	none	21.5	13.5	5.1
140	6	5	none	20.3	12.6	4.5
145	6	5	none	19.2	11.8	4.0

Lant (nH)	Cpcb (pF)	Cchip (pF)	Optimal Ltune (nH)	Theoretical Cvar		
				@76 MHz	@87.5 MHz	@108 MHz
70	9	5	none	48.6	33.3	17.0
75	9	5	none	44.5	30.1	15.0
80	9	5	none	40.8	27.4	13.1
85	9	5	none	37.6	24.9	11.5
90	9	5	none	34.7	22.8	10.1
95	9	5	none	32.2	20.8	8.9
100	9	5	none	29.9	19.1	7.7
105	9	5	none	27.8	17.5	6.7
110	9	5	none	25.9	16.1	5.7
115	9	5	none	24.1	14.8	4.9
120	9	5	none	22.5	13.6	4.1
125	9	5	none	21.1	12.5	3.4
130	9	5	none	19.7	11.4	2.7
135	9	5	none	18.5	10.5	2.1
140	9	5	none	17.3	9.6	1.5
145	9	5	none	16.2	8.8	1.0

Appendix C—FM Antenna Matching Component Selection for Half-Wavelength Antenna

This appendix describes how to select a matching inductor for a half-wavelength headphone antenna connected to the FMI pin (pin 2) of the FM tuner or for a half-wavelength cigarette lighter cable connected to TXO/LPI pin (pin 4) of the FM transceiver. Please refer to "AN231: Si4700/01 Headphone and Antenna Interface."

The impedance of an ideal half-wavelength is a large resistive component with a small reactive component. When a headphone cable or cigarette lighter cable is used as a half-wavelength antenna, capacitive coupling between conductors can cause the reactive component to become very large. Capacitance of a headphone cable can be on the order of 10-20 pF and that of a cigarette lighter cable can be on the order of 100-200 pF.

The antenna matching strategy for a half-wavelength headphone antenna connected to the FMI pin (pin 2) of the FM tuner is to minimize antenna capacitance and select a tuning inductor to create a resonant structure with a Q of 3-5. The antenna matching strategy for a half-wavelength cigarette lighter cable antenna connected to the TXO/LPI pin (pin 4) of the FM transceiver is also to minimize antenna capacitance; however, it generally is not possible to resonate this type of antenna with a high Q.

Antenna capacitance can be reduced by placing ferrite beads on all conductor traces as shown in Figure 18. A dc blocking capacitor and ferrite to provide dc return current of cable ground is also recommended.

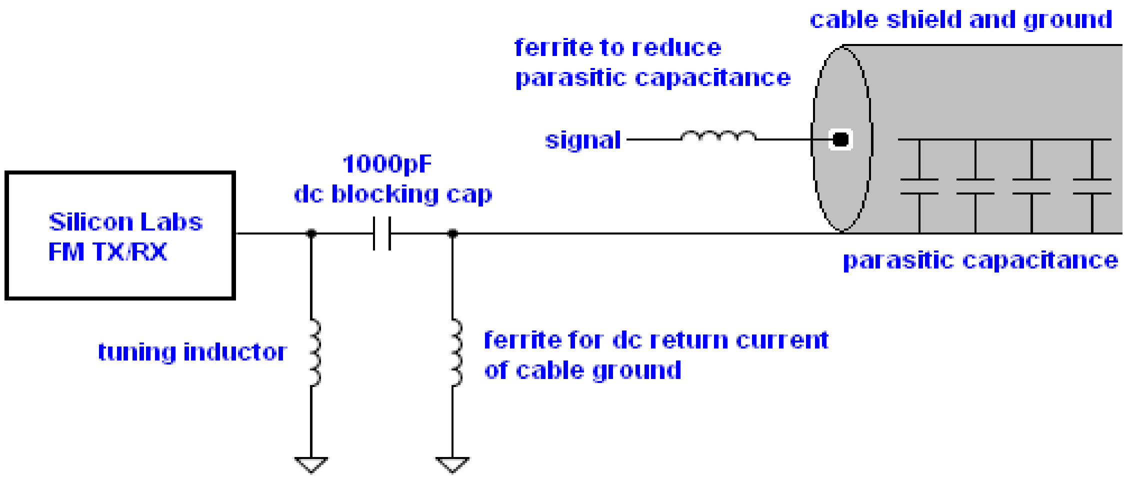

Figure 18. Schematic Recommendation for Half-Wavelength Antenna

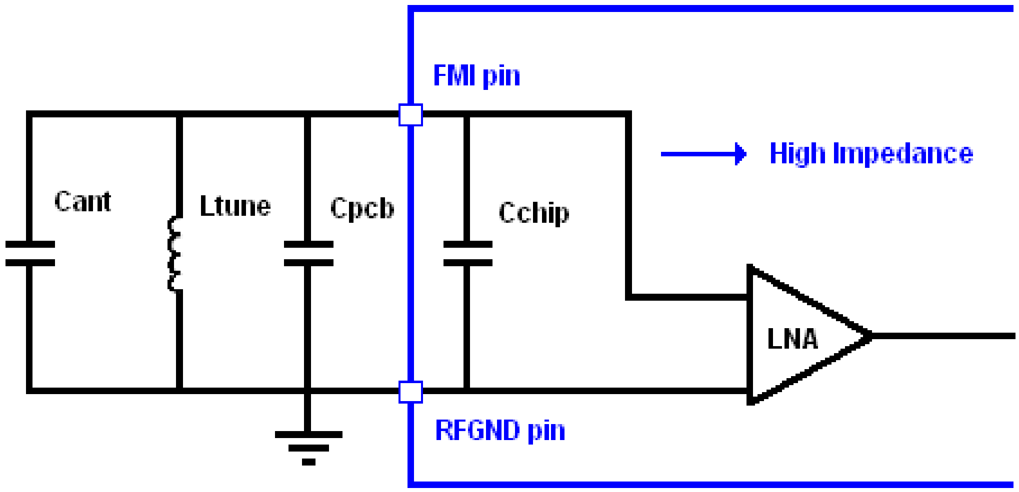

Figure 19. Simplified Resonating LC Circuit Model

To select the correct value of Ltune to properly match the headphone antenna connected to the FMI pin (pin 2) of the FM tuner as shown in Figure 19, inject a test signal through a large impedance into the network and:

1. Monitor the received signal strength (RSSI) measured by the FM tuner, or
2. Probe the FMI pin (pin 2) with a low capacitance FET probe and spectrum analyzer.

Adjust the tuning inductor, Ltune, to maximize the voltage at the LNA input. To maximize voltage gain across the FM band:

1. The Q of the circuit should be minimized to maintain a flat response.
2. The value of Ltune should be chosen such that the circuit resonates in the center of the FM band.

Typical tuning inductor values will range from 100 nH to 400 nH.

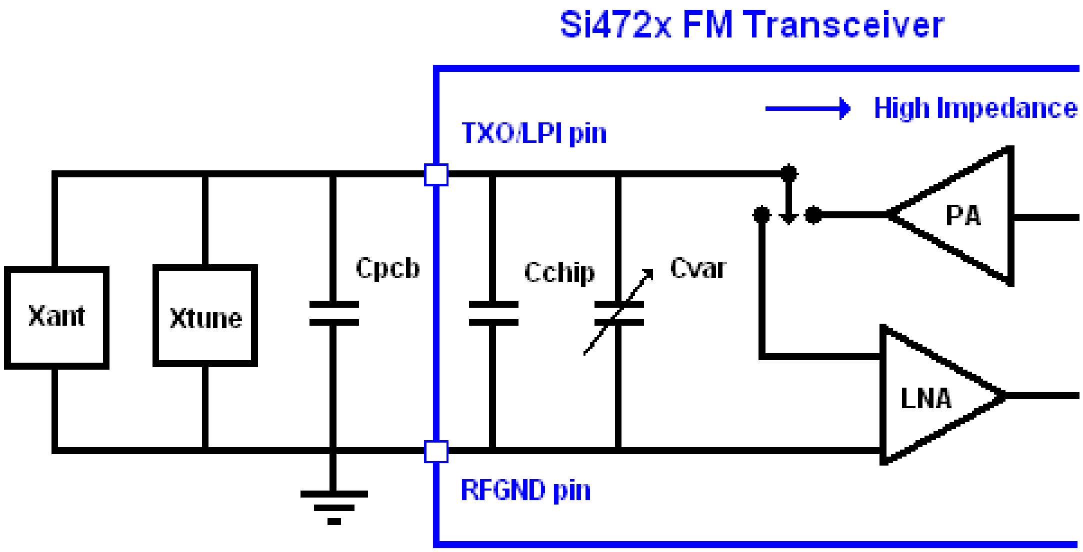

Figure 20. Simplified Resonating LC Circuit Model

To select the correct value of Xtune to properly match the cigarette lighter cable antenna connected to the TXO/LPI pin (pin 4) of the FM transceiver as shown in Figure 20, set the varactor to the minimum setting and follow the steps outlined on page 31 for matching the RX headphone antenna. To verify transmit performance, set the varactor to the minimum setting and:

1. Probe the TXO/LPI pin (pin 4) with a low capacitance FET probe and spectrum analyzer, or
2. Perform a radiated test in a calibrated RF chamber.

Typical tuning inductor values will range from 100 nH to 400 nH. Note that a dc path from the TXO/LPI pin (pin4) to GND is required.

NOTES:

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