AN11509

NXQ1TXA1 evaluation board

Rev. 2 — 2 February 2015 | Application note

Document information

Info	Content
Keywords	NXQ1TXA1, NWP2081, wireless charging, Qi, mobile devices, magnetic coupled power transfer
Abstract	This document illustrates how to create a Qi A10 wireless power base station using the NXQ1TXA1 charging controller and its evaluation board. It can deliver up to 5 W effective output at the wireless mobile device side.

Revision history

Rev	Date	Description
v.2	20150202	Second issue.
Modifications:	• Section Section 11 “Conclusion” added.	
v.1	20141210	Initial version

Contact information

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For sales office addresses, please send an email to: **salesaddresses@nxp.com**

1. Introduction

The ubiquity of mobile phones, increases the requirement of a convenient way to charge these devices while on the move. Especially the fast rising number of smart phones widely used and relied upon in daily life. Wireless charging is introduced into smart phones and tablets.

Wireless charging represents the future of public and private charging.

Qi (pronounced as "Chee") is a wireless charging standard developed by Wireless Power Consortium (www.wirelesspowerconsortium.com) for inductive power.

The Qi system (see Figure 1) comprises a base station or a transmitter (TX) pad and a mobile device or a compatible receiver (RX), such as a mobile phone. To use the system, the mobile device is placed on top of the base station pad which charges the device via electromagnetic induction.

The market demand for the convenience and safety of standard-compliant wireless power system continues to grow rapidly.

NXP offers Qi-compliant base station reference design to set you immediately on your way to a successful project. There are several types of Qi chargers available. NXP currently supports the so called A10 type. Check with your local NXP representative for the latest updates.

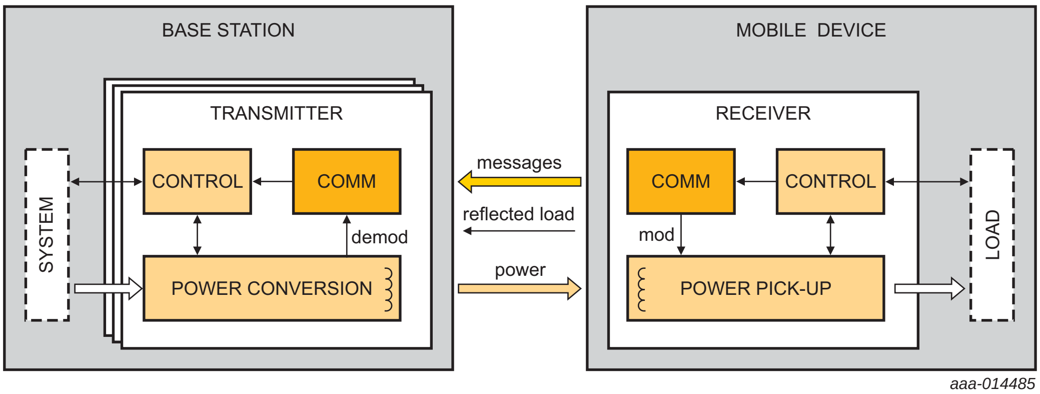

Fig 1. Wireless charging system as defined by Wireless Power Consortium

2. Scope

This document discusses the design of a WPC Qi A10 type base station based on the NXP NXQ1TXA1 Evaluation Board. The NXQ1TXA1 Evaluation Board is Qi certified and it complies with EMI regulation - EN5022 and FCC part 18.

The document is intended to provide engineers with real life practical design applications and get them started on the right note immediately.

For all topics covered, hints are provided to ensure system-level best performance, excellent EMC and lowest application cost.

Near Field Communication (NFC) option for tap to power on to enable zero power standby and Bluetooth pairing is included. There are many other use cases and possibilities with NFC technology but they are not within the scope of this application note.

3. Getting started

3.1 Package contents

The evaluation kit contains the following items:

- NXP NXQ1TXA1 wireless charger evaluation board (see Figure 2) containing:
  - NXQ1TXA1 charger controller IC
  - NWP2081 half-bridge level shift controller IC
  - NX2020 MOSFETs
  - NT3H1201 NTAG-I^{2}C NFC forum tag
- AC 110 V/220 V - DC 19 V power supply containing:
  - TEA1720xT HV start-up flyback controller for ultra-low no-load charger applications up to 12 W

Fig 2. Overview of the charging pad

A mobile device to receive the power is not included in the evaluation package. Refer to WPC website for a list of certified Qi receivers to be used with the evaluation board. To demonstrate NFC tap to power on, ensure that the receivers support both Qi wireless charging and NFC technology.

3.2 Main features

The NXQ1TXA1 evaluation board demonstrates:

- A reference design with key components from NXP for wireless charging applications based on inductive power transfer standard Qi
- Additional benefits resulting from integration of NFC with wireless charging. For example, enabling zero power standby with the “tap to power on” feature.

3.3 System efficiency

In Figure 3, the system efficiency of the evaluation board is shown using two different receivers.

System efficiency is measured as the ratio of output power of the receiver to the input power of the transmitter. Input power is averaged to take into account variation due to communication between receiver and transmitter.

The quality of the components used in both the transmitter and the receiver, determine the efficiency of the system.

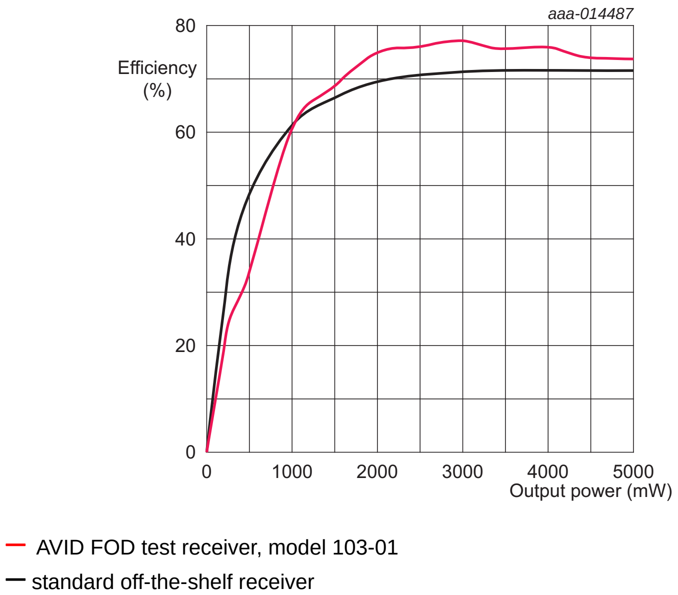

Fig 3. NXQ1TXA1 evaluation board system efficiency

3.4 Board overview

The evaluation board is shown in Figure 4. The left-hand side contains the charging area where the power receiver should be placed. The top right side has the electronics to drive the charging coil and communicate with the power receiver.

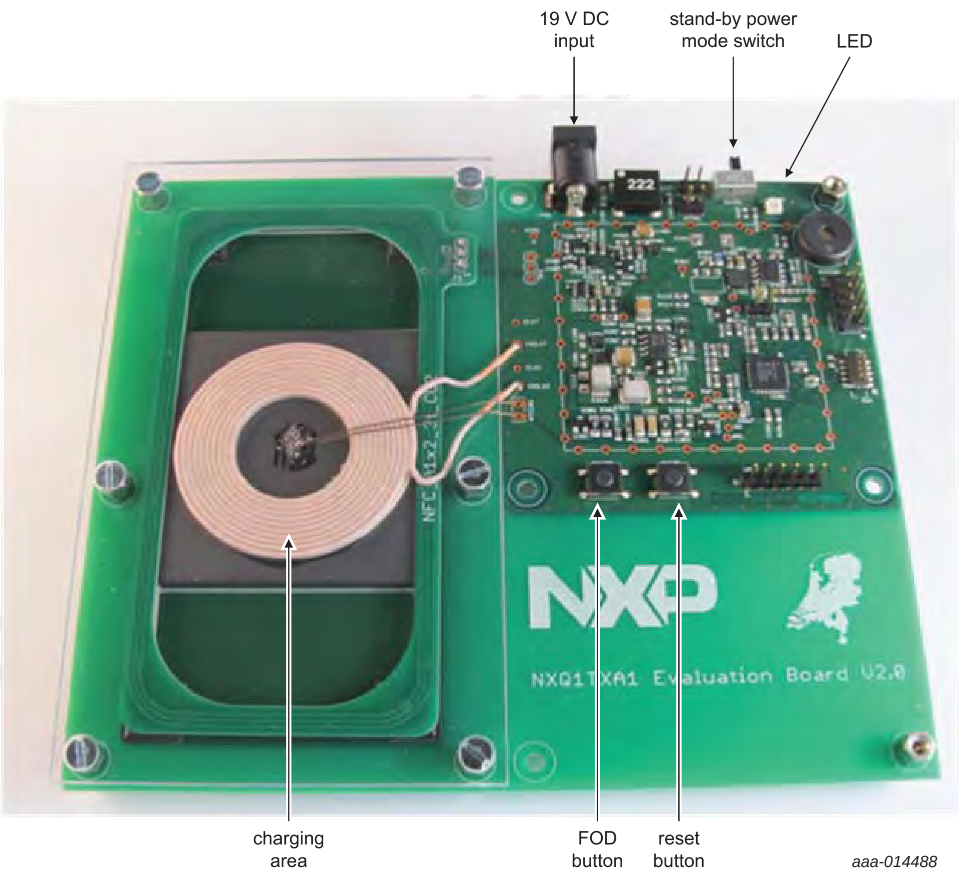

Fig 4. Switch, buttons and status LED location overview

The function of the switch and push buttons as well as the meaning of the status LED is explained in the next subsections.

3.5 Standby power-mode switch

The switch on the top of the board is not a power on/off switch. The switch is for alternating between the “Normal” and the NFC “tap to power on” position as illustrated in Figure 5.

NFC tap to power on position

normal mode position

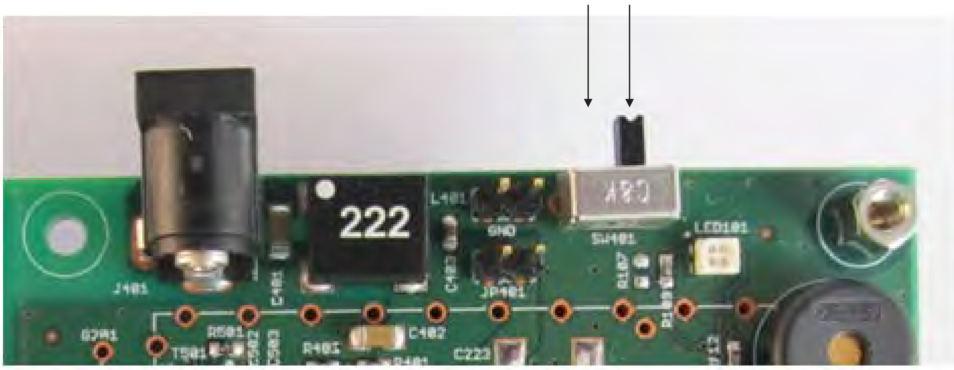

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Fig 5. Standby power-mode switch

In the *Normal* mode, the charging pad periodically monitors the coil for the presence of a Qi receiver. It starts power transfer, once a Qi power receiver is detected.

In the *NFC tap to power on* mode, the charging pad electronics are disconnected from the 19 V supply. The presence of an NFC enabled phone, switches on the 19 V system supply, enabling zero power in standby mode.

Important:

The present generation of NFC phones only performs periodic NFC operations when the display of the phone is on and unlocked. It is only under this condition that the charging pad is woken-up to start power transfer.

3.6 Reset button

Pressing the reset button marked SW101 on the board performs a reset of the charging pad.

3.7 Foreign object detection button

By pressing the left-most button marked SW102 on the board, the charging pad enables or disables Foreign Object Detection (FOD). This feature should be removed for final products.

While charging, the green status LED indicates whether FOD is activated. When FOD is active, the green LED blinks with a rate of 1 Hz. When FOD is disabled, the green LED blinks with a rate of 3 Hz.

3.8 Status LED

An overview of the status signaled by the LEDs is given in the following table:

Table 1. LED status indicator

LED status	Description
Off	If a 19 V DC supply is present, the pad is in the operation mode as defined by the mode switch
Green blinking 1 Hz	Ongoing power transfer - charging mobile device, FOD enabled
Green blinking 3 Hz	Ongoing power transfer - charging mobile device, FOD disabled
Green permanently On	Mobile device charged
Red blinking	No power transfer Error detected: Foreign object, temperature or Receiver indicated error

3.9 NFC functionality

The evaluation board provides a passive tag functionality with NT3H1201 NTAG-I^{2}C. The NTAG-I^{2}C is preprogrammed with a URL link to the NXP website. When most NFC phones are put on the charger pad while the screen is active, an automatic link to the NXP website is made.

Other content can be programmed into NTAG IC by using, for example, NXPs TagWriter.

4. NXP products

The NXQ1TXA1 evaluation board was designed based on the NXP products listed in Table 2. The part numbers are hyperlinked to the NXP website to provide quick access to product information and data sheets.

Table 2. NXP semiconductor components for wireless charger application

Type number	Function	Package		Order information
		Name	Description	12NC
NXQ1TXA1/001	wireless charger controller	HVQFN33	HVQFN: plastic thermal enhanced very thin quad flat package; no leads; 33 terminals; body 7 × 7 × 0.85 mm	9353 039 25551
NWP2081T	half-bridge level-shift IC	SOT96-1	plastic small outline package; 8 leads	9353 021 87518
NX2020N2	30 V, single N-channel Trench MOSFET	SOT1220	plastic thermal enhanced ultra thin small outline package; no leads; 6 terminals	9340 682 45115
BC847C	45 V, 100 mA NPN general-purpose transistors	SOT23	plastic surface-mounted package; 3 leads	9335 896 00215
BAS101S	high-voltage switching diodes	SOT23	plastic surface-mounted package; 3 leads	9340 608 49215
BAT54S	Schottky barrier diodes	SOT23	plastic surface-mounted package; 3 leads	9339 763 80215
TL431BFDT	adjustable precision shunt regulator	SOT23	plastic surface-mounted package; 3 leads	9352 932 76215
Optional				
NT3H1201	NTAG-I2C NFC forum tag 2 type-compliant IC with I^2C interface	XQFN8	plastic, extremely thin quad flat package; no leads; 8 terminals; body 1.6 x 1.6 x 0.5 mm	9353 028 43125
NX2020P1	30 V, single P-channel Trench MOSFET	SOT1220	plastic thermal enhanced ultra thin small outline package; no leads; 6 terminals	9340 682 44115
NX3008NBKW	30 V, N/P-channel Trench MOSFET	SOT323	plastic surface-mounted package; 3 leads	9340 656 35115
NX3008CBKS	30 V, single N-channel Trench MOSFET	SOT363	plastic surface-mounted package; 3 leads	9340 656 39115
BAT54C	Schottky barrier diodes	SOT23	plastic surface-mounted package; 3 leads	9339 763 70215
TDA3663	LDO (or use DC-to-DC RT8295A)	SOT223	plastic surface-mounted package with increased heat-sink; 4 leads	9352 629 68135
TEA1720BT/1	SMPS controller	SOT96-1	plastic small outline package; 8 leads	9353 021 95118

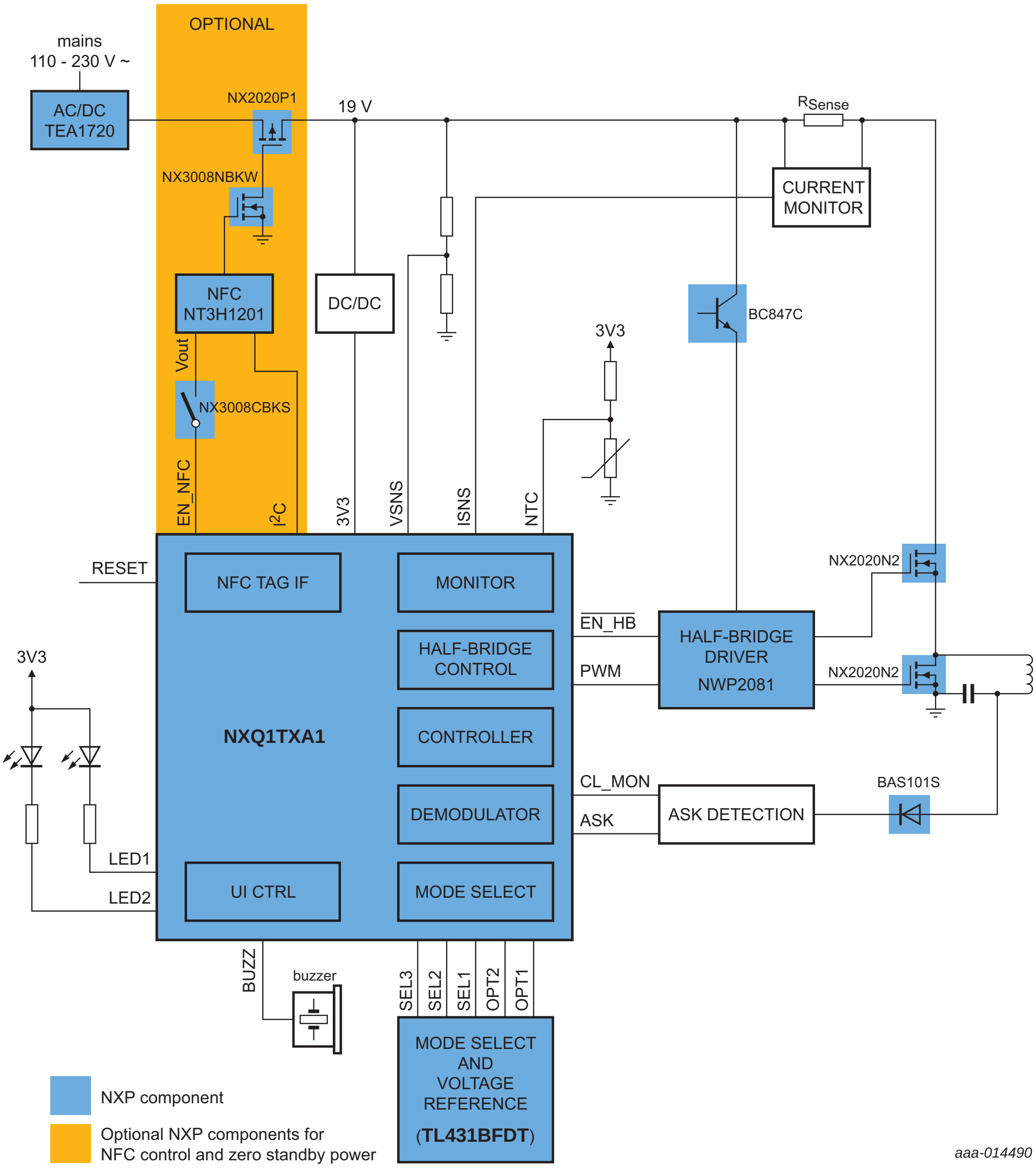
5. System overview

The NXQ1TXA1 Evaluation Board is a WPC Qi A10 type base station, powered by a +19 V AC-to-DC adapter.

It works on the basic principle of inductively coupled power transfer. An alternating current generated from the half-bridge driver is passed through the base station coil. It creates a magnetic field which induces a voltage in the mobile device coil. The mobile device communicates information related to power management and control to the base station.

When the NFC tap to power on feature is enabled, the evaluation board consumes zero power in standby mode.

A block diagram of the NXQ1TXA1 evaluation board is depicted in Figure 6. Each subblock is described in Section 5.1 to Section 5.7.



The block diagram does not depict all semiconductor components used to compile the system. For more details, refer to Section 6 “Schematics and bill of materials”.

The NXQ1TXA1/001 supports A1 or A10 single coil chargers only.

Fig 6. NXQ1TXA1 evaluation board block diagram

5.1 NXQ1TXA1 charging controller

The NXQ1TXA1 is a wireless charger controller for A1 and A10 type base stations. It offers WPC 1.1 Qi-compliant communication and safety functions including Foreign Object Detection (FOD), over-temperature protection and more. The controller supports ping mode during standby to detect potential mobile devices. It also works with the NXP NT3H1201 to enable tap to power on with an NFC enabled phone.

Settings are available via resistor networks for Foreign Object Detection (FOD) level, LED blinking and other options. Refer to NXQ1TXA1 data sheet for further information.

5.2 Half-bridge driver

The nEN_HB control signal from NXQ1TXA1 charging controller enables the half-bridge driver stage. It is designed to output approximately 7 W power to ensure a minimum of 5 W power is received at the mobile device.

The NXP NWP2081 controller IC and the NX2020N2 N-Channel Trench MOSFETs are the key semiconductor components. They drive the LC tank circuit at operating frequencies between 110 kHz and 205 kHz. The frequency and duty cycle are varied via a Pulse-Width Modulated (PWM) signal from the NXQ1TXA1 charging controller. The selection of base station coil L (24 μH ±10 %) and capacitor C (100 nF ±5 %) are defined in the Wireless Power Consortium (WPC) specifications.

5.3 Amplitude-Shift Key (ASK) envelope demodulator

One-directional communication from the mobile device to the base station is achieved via back-scattered ASK modulation as illustrated in Figure 1. The mobile device modulates the magnetic field of the base station using either a capacitive or resistive load, at a rate of 2 kbit/sec. An envelope detector is used to demodulate the communication data. High voltages up to 200 V_{p-p} can be observed at the input of detector. The envelope demodulated output is further processed in the NXQ1TXA1 charging controller.

5.4 +19 V Universal mains adapter

The power supply design is based on NXP TEA1720 low cost Switched Mode Power Supply (SMPS) controller IC. It is optimized for flyback converter topology to provide high-efficiency over the entire load range with ultra-low power consumption in the no-load condition.

5.5 Current measurement

The current flowing into the power stage is determined by measuring the voltage across a 22 mΩ current sense resistor. The current measurement is needed for Foreign Object Detection (FOD). If FOD is not required, it can be disabled by configuring the resistor networks (refer to NXQ1TXA1 data sheet) and the current measurement circuits can be removed. Connect the unused ISNS pin to ground, i.e. not left open. Note that FOD is required to pass Qi certification.

5.6 Bandgap reference voltage

NXQ1TXA1 wireless charging controller needs a band gap reference voltage (+/-0.5 % tolerance) for critical processing. The TL431 shunt regulator is used in the NXQ1TXA1 Evaluation Board to provide this reference voltage.

5.7 DC-to-DC Converter

A DC-to-DC buck converter steps the +19 V input down to +3.3 V, to supply the NXQ1TXA1 charging controller and other +3.3 V circuits.

A Richtek RT8295A DC-to-DC converter is used in the NXQ1TXA1 evaluation board. An option for a linear regulator TDA3663 is available on board. Take note however, that at operating currents of the NXQ1TXA1 evaluation board, the efficiency of the applied DC-to-DC converter is better than a linear regulator.

5.8 Near Field Communication (NFC) zero power in Standby mode

When using the optional feature "NFC tap to power on", the base station is designed for zero power consumption in standby mode. It uses an NT3H1201 NTAG-I2C NFC forum passive tag.

When this feature is enabled, there is no pinging to detect the presence of a mobile device on the charger pad. Instead, an NFC enabled mobile device, for example a phone, wakes up the base station via the NT3H1201. Power transfer takes place with a certified Qi mobile device.

To enable more functions such as Bluetooth pairing, smart advertisements, and connection handovers, the passive tag can be programmed with the NXP TagWriter application (see Section 3.9 “NFC functionality”).

6. Schematics and bill of materials

Customers should start directly from NXQ1TXA1 Evaluation Board as this board is optimized in terms of functional performance and EMI.

Deviations are possible, but they should be kept minimal, carefully weighed and associated potential risks considered. Where possible, customers are encouraged to send their schematics to NXP for review. Contact the nearest NXP application support team in your area for support in designing your wireless charging base station.

During schematic capture, indicate critical components clearly in the schematics so that they are not forgotten during procurement and production. For example, 47 nF C0G/NP0 capacitor, 100 kΩ 1 % tolerance resistor and 250 V rated components.

Certain critical components and PCB layout details are crucial to the success of the project and deserve special attention. In the later part of the document, these details are elaborated. Refer to Section "Critical Components" and "PCB Layout Guidelines" in the subsequent pages.

For development of prototype boards, it is best practice to include test points on key signal nodes. For production runs, these test points can be removed from the final PCB.

At the very minimum, create test point for the following signal nodes:

- Power supplies - +3.3 V and +19 V supply nodes
- Output of ASK demodulator - AM signal node
- Output of current sense amplifier - ISOUT signal node
- Pulse Width Modulation - PWM signal node
- The half-bridge driver stage enable - nENHB signal node
- System and power grounds - GNDx

6.1 Schematics

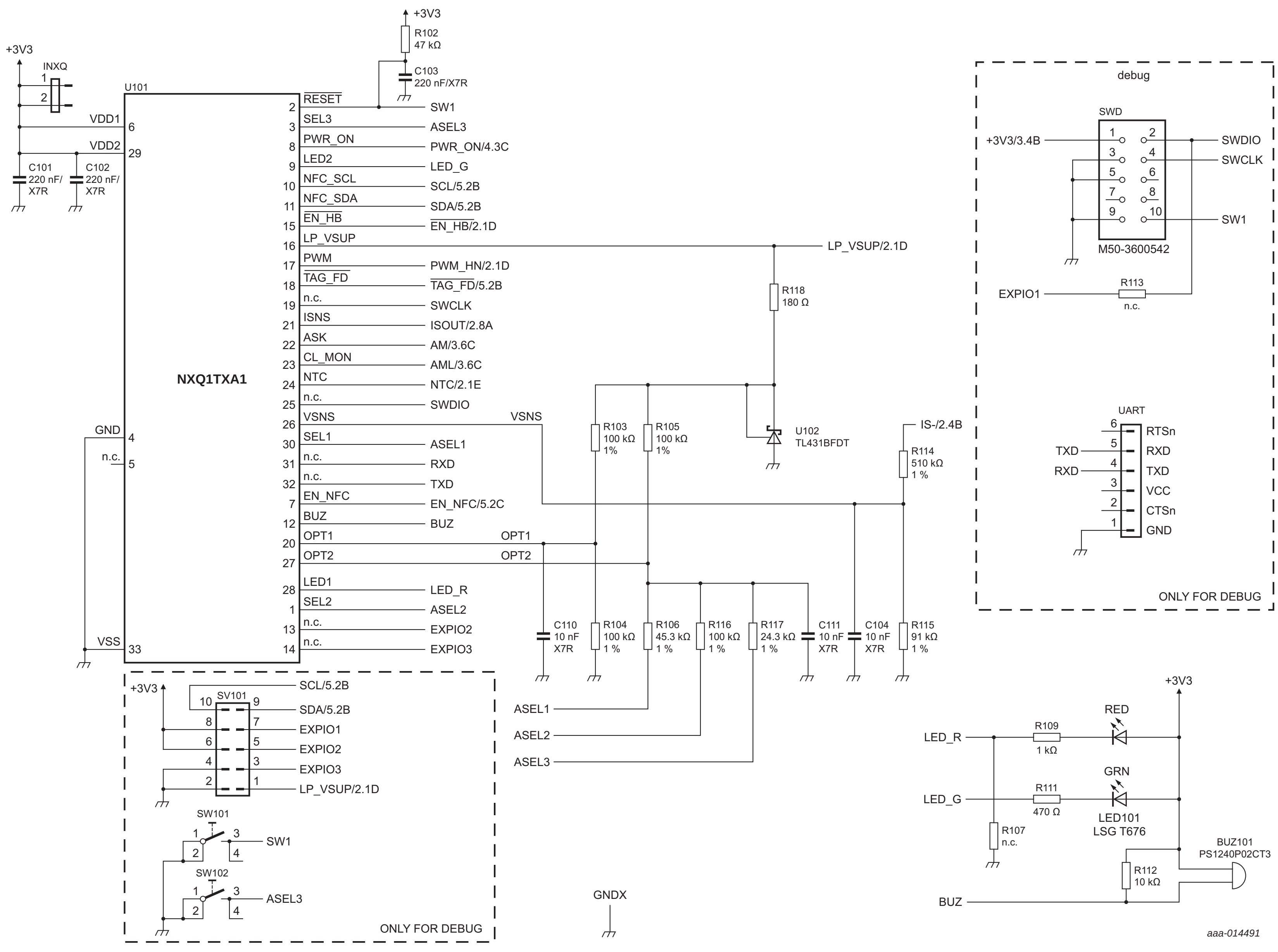


Fig 7. NXQ1TXA1 charging controller schematic

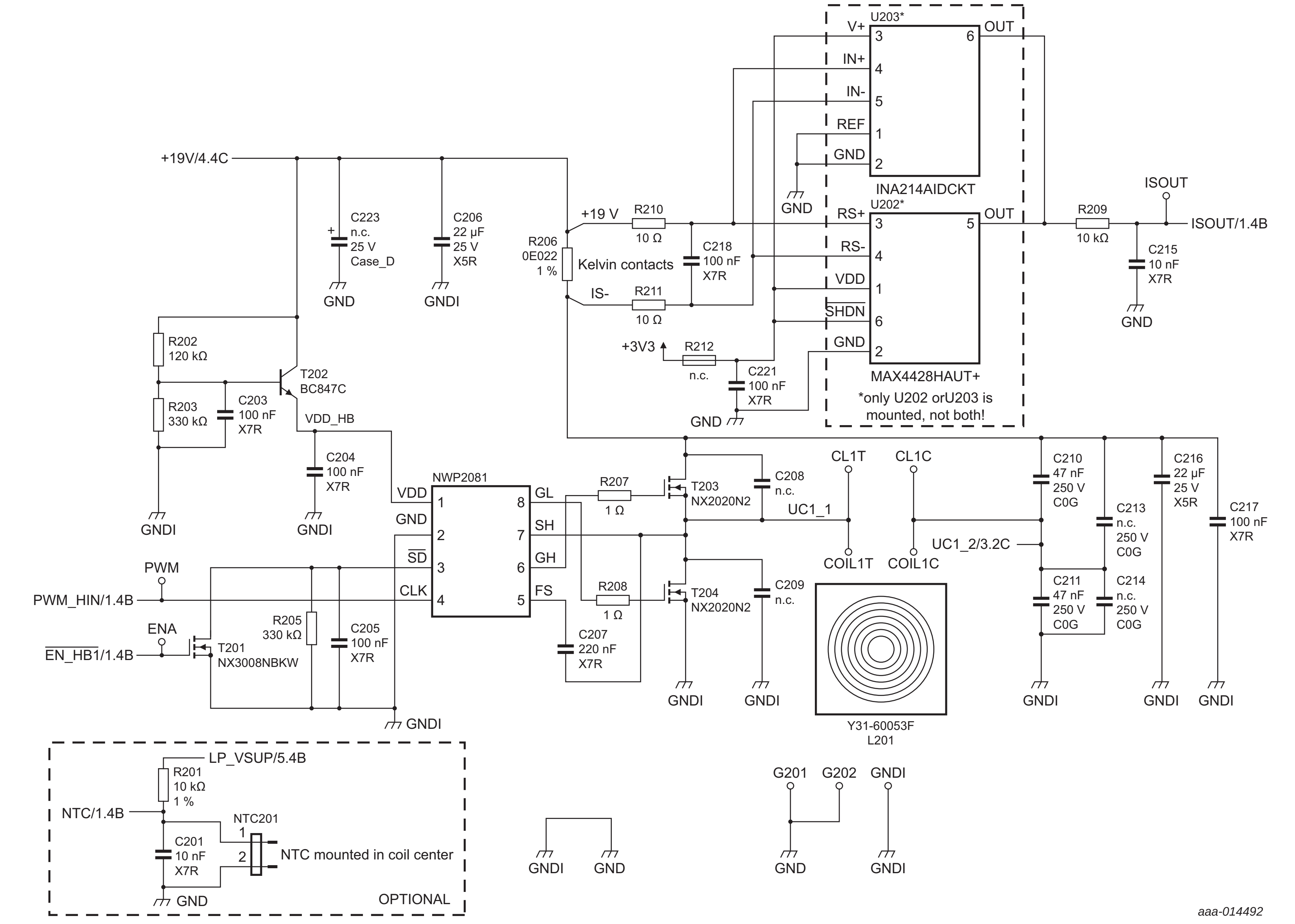


Fig 8. Half-bridge driver stage schematic

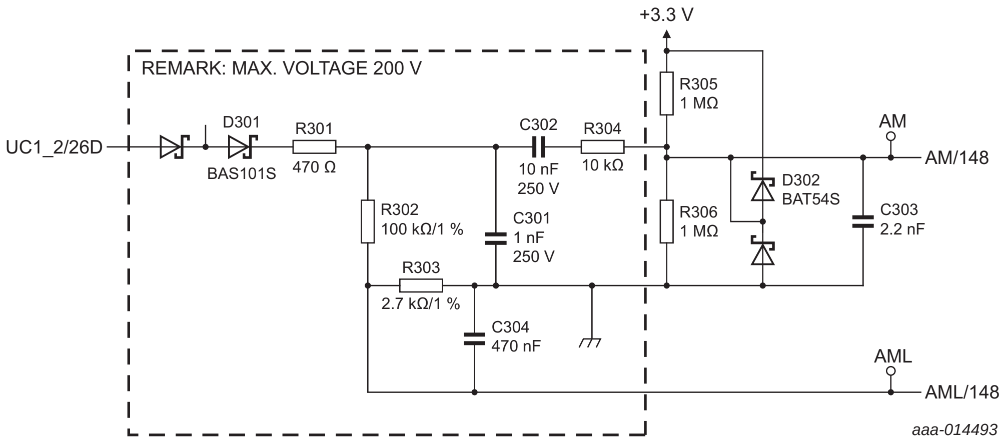


Fig 9. Amplitude Shift Keying (ASK) envelope detector schematic

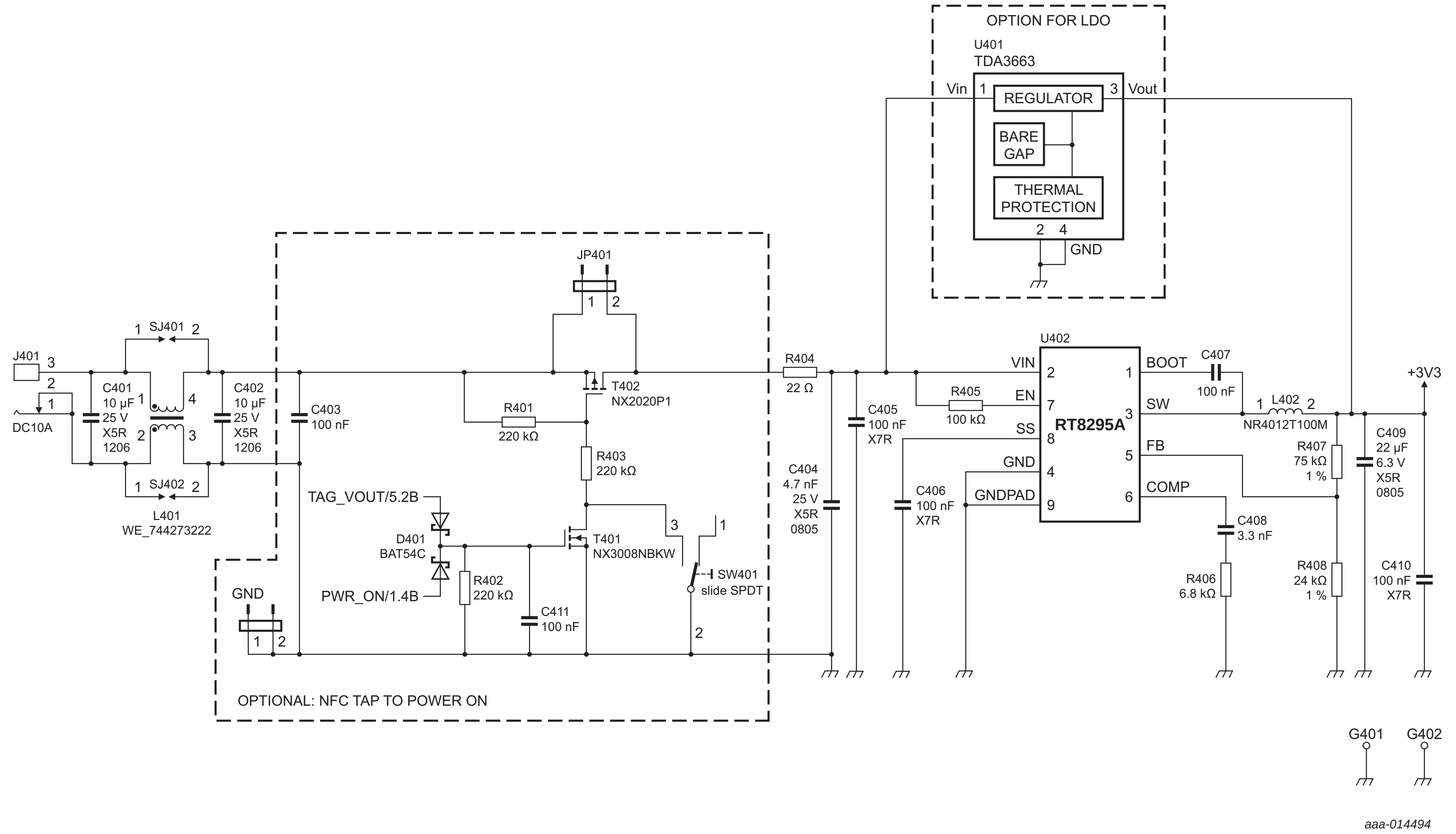


Fig 10. DC supply schematic

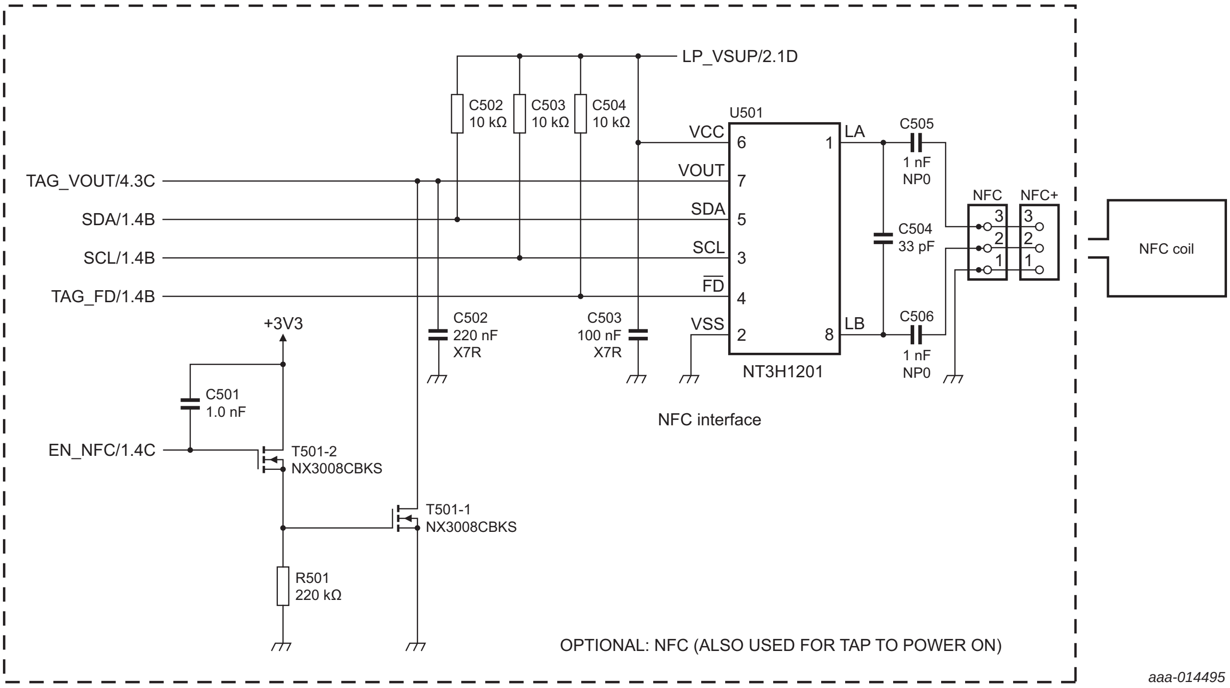


Fig 11. NFC schematic

6.2 Bill of materials

The NXQ1TXA1 Evaluation Board is assembled with maximum options for evaluation purposes. For final design, certain components can be removed depending on the required features. The available options and corresponding components are presented below.

Options:

- Buzzer - only when buzzer is needed
- DCDC - when a DC-to-DC converter for 3.3 V is preferred
- LDO - when LDO regulator for 3.3 V is preferred
- NFC - when NFC is needed
- ZERO - when zero power standby is needed (also requires NFC)
- FOD - when FOD is required
- Debug - only for debugging, not for production
- NTC - only when NTC is needed
- NC - not connected, do not place

Table 3. Bill of materials

Part	Value	Part number	Manufacturer	Package	Optional	Description
BUZ101	PS1240P02CT3	PS1240P02CT3	TDK	PS12	Buzzer	Audio Indicator, round 12.2 mm x 3.5 mm; 4 kHz; V_{in} = 3 V
C101	220 nF/X7R	Standard		C0603		Capacitor, Ceramic, 25 V; X7R; 20 %
C102	220 nF/X7R	Standard		C0603		Capacitor, Ceramic, 25 V; X7R; 20 %
C103	220 nF/X7R	Standard		C0603		Capacitor, Ceramic, 25 V; X7R; 20 %
C104	10nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C110	10 nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C111	10 nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C201	10 nF/X7R	Standard		C0603	NTC	Capacitor, Ceramic, 50 V; X7R; 10 %
C203	100 nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C204	100 nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C205	100 nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C206	22 µF/25V/X5R	GRM32ER61E226KE15L	Murata	C1210		Capacitor, Ceramic, 25 V; X5R; 10 %
C207	220 nF/X7R	Standard		C0603		Capacitor, Ceramic, 25 V; X7R; 20 %
C208	NC	Standard		C0603	NC	Capacitor, Ceramic, 25 V; NP0; 10 %
C209	NC	Standard		C0603	NC	Capacitor, Ceramic, 25 V; NP0; 10 %
C210	47 nF/250 V/C0G	CGA8R3C0G2E473J320KA	TDK	C1812		Capacitor, Ceramic, 250 V; NP0; 5 %
C211	47 nF/250 V/C0G	CGA8R3C0G2E473J320KA	TDK	C1812		Capacitor, Ceramic, 250 V; NP0; 5 %
C213	NC/250 V/C0G	Standard		C1206	NC	Capacitor, Ceramic, 250 V; NP0; 5 %
C214	NC/250 V/C0G	Standard		C1206	NC	Capacitor, Ceramic, 250 V; NP0; 5 %
C215	10 nF/X7R	Standard		C0603	FOD	Capacitor, Ceramic, 50 V; X7R; 10 %
C216	22 µF/25 V/X5R	GRM32ER61E226KE15L	Murata	C1210		Capacitor, Ceramic, 25 V; X5R; 10 %
C217	100 nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C218	100 nF/X7R	Standard		C0603	FOD	Capacitor, Ceramic, 50 V; X7R; 10 %
C221	100 nF/X7R	Standard		C0603	FOD	Capacitor, Ceramic, 50 V; X7R; 10 %
C223	NC/25 V/Case_D	Standard		SMC_D	NC	Polarized Capacitor, Case_D; 25 V
C301	1 nF/250 V	Standard		C1206		Capacitor, Ceramic, 250 V; X7R; 10 %
C302	10 nF/X7R/250 V	Standard		C1206		Capacitor, Ceramic, 250 V; X7R; 10 %
C303	2.2 nF	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C304	470 nF	Standard		C0603		Capacitor, Ceramic, 10 V; X5R; 10 %
C401	10 µF/25 V/X5R/1206	GRM31CR61E106KA12L	Murata	C1206		Capacitor, Ceramic, 25 V; X5R; 10 %

Table 3. Bill of materials *…continued*

Part	Value	Part number	Manufacturer	Package	Optional	Description
C402	10 µF/25 V/X5R/1206	GRM31CR61E106KA12L	Murata	C1206		Capacitor, Ceramic, 25 V; X5R; 10 %
C403	100 nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C404	4.7 µF/25 V/X5R/0805	GRM21BR61E475MA12L		C0805		Capacitor, Ceramic, 25 V; X5R; 20 %
C405	100 nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C406	100 nF/X7R	Standard		C0603	DCDC	Capacitor, Ceramic, 50 V; X7R; 10 %
C407	100 nF/X7R	Standard		C0603	DCDC	Capacitor, Ceramic, 50 V; X7R; 10 %
C408	3.3 nF	Standard		C0603	DCDC	Capacitor, Ceramic, 50 V; X7R; 10 %
C409	22 µF/6V3/X5R/0805	GRM21BR60J226ME39L	Murata	C0805		Capacitor, Ceramic, 6.3 V; X5R; 20 %
C410	100 nF/X7R	Standard		C0603		Capacitor, Ceramic, 50 V; X7R; 10 %
C411	100 nF/X7R	Standard		C0603	ZERO	Capacitor, Ceramic, 50 V; X7R; 10 %
C501	1.0 nF	Standard		C0603	NFC	Capacitor, Ceramic, 50 V; X7R; 10 %
C502	220 nF/X7R	Standard		C0603	NFC	Capacitor, Ceramic, 25 V; X7R; 20 %
C503	100 nF/X7R	Standard		C0603	NFC	Capacitor, Ceramic, 50 V; X7R; 10 %
C504	33 pF/NP0	Standard		C0603	NFC	Capacitor, Ceramic, 50 V; NP0; 5 %
C505	1.0 nF/NP0	Standard		C0603	NFC	Capacitor, Ceramic, 50 V; NP0; 5 %
C506	1.0 nF/NP0	Standard		C0603	NFC	Capacitor, Ceramic, 50 V; NP0; 5 %
D301	BAS101S	BAS101S	NXP Semiconductors	SOT23		High-voltage switching dual diode
D302	BAT54S	BAT54S	NXP Semiconductors	SOT23		Schottky barrier double diodes
D401	BAT54C	BAT54C	NXP Semiconductors	SOT23	ZERO	Schottky barrier double diodes
GND	JP1E	Standard		JP1	Debug	Header Pin, 2.54 MM, 2WAY, 1ROW
INXQ	JP1E	Standard		JP1	Debug	Header Pin, 2.54 MM, 2WAY, 1ROW
J401	DC10A	DC10A	CLIFF Electronic Components	DC10		DC10A - SOCKET, PCB, DC POWER, 2.1 MM
JP401	JP1E	Standard		JP1	Debug	Header Pin, 2.54 MM, 2WAY, 1ROW
L201	24 µH	Y31-60053F	Elec & Eltek	Qi-A10		Qi Charging Coil A10 (E&E)
L401	30 µH, 2.2 KΩ	744273222	Würth Elektronik	WE-SL5_HC		Line Filter, CMODE, 30 µH; 2.2 KΩ; 25 %
L402	NR4012T100M	NR4012T100M	TAIYO YUDEN	NR4012	DCDC	Inductor, Shielded; 10 µH, 740 MA, SMD
LED101	LSG T676	LSG T676-P7Q7-1+N7P7-24	OSRAM Opto Semiconductors	PLCC-4		Standard LEDs, SMD Red/Green
NFC	NFC-Antenna	NFC-Antenna			NFC	NFC-Antenna
NTC201	B57551G1103F005	B57551G1103F005	EPCOS		NTC	Thermistor, NTC, Radial Leaded

Table 3. Bill of materials *…continued*

Part	Value	Part number	Manufacturer	Package	Optional	Description
R102	47 kΩ	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R103	100 kΩ	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R104	100 kΩ	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R105	100 kΩ	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R106	45.3 kΩ/1 %	Standard		R0603		Resistor, 0.1 W; 1 %; 0603; SMD
R107	NC	Standard		R0603	NC	Resistor, 0.1 W; 5 %; 0603; SMD
R109	1.0 kΩ	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R111	470 Ω	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R112	10 kΩ	Standard		R0603	Buzzer	Resistor, 0.1 W; 5 %; 0603; SMD
R113	NC	Standard		R0603	NC	Resistor, 0.1 W; 5 %; 0603; SMD
R114	510 kΩ/1 %	Standard		R0603		Resistor, 0.1 W; 1 %; 0603; SMD
R115	91 kΩ/1 %	Standard		R0603		Resistor, 0.1 W; 1 %; 0603; SMD
R116	100 kΩ/1 %	Standard		R0603		Resistor, 0.1 W; 1 %; 0603; SMD
R117	24.3 kΩ/1 %	Standard		R0603		Resistor, 0.1 W; 1 %; 0603; SMD
R118	180 Ω	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R201	10 kΩ/1 %	Standard		R0603	NTC	Resistor, 0.1 W; 1 %; 0603; SMD
R202	120 kΩ	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R203	330 kΩ	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R205	330 kΩ	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R206	0E022/1 %	RL0805FR-7W0R022L	Yageo	R0805	FOD	Resistor, 0.25 W; 1 %; 0805; SMD
R207	1.0 Ω	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R208	1.0 Ω	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R209	10 kΩ	Standard		R0603	FOD	Resistor, 0.1 W; 5 %; 0603; SMD
R210	10 Ω	Standard		R0603	FOD	Resistor, 0.1 W; 5 %; 0603; SMD
R211	10 Ω	Standard		R0603	FOD	Resistor, 0.1 W; 5 %; 0603; SMD
R212	NC	Standard		R0603	FOD	Resistor, 0.1 W; 5 %; 0603; SMD
R301	470 Ω/250 V	Standard		R1206		Resistor, 0.25 W; 250 V; 5 %; 1206, SMD
R302	100 kΩ/1 %/250 V	Standard		R1206		Resistor, 0.25 W; 250 V; 1 %; 1206, SMD
R303	2.7 kΩ/1 %	Standard		R0603		Resistor, 0.1 W; 1 %; 0603; SMD
R304	10 kΩ/250 V	Standard		R1206		Resistor, 0.25 W, 250 V, 5 %, 1206, SMD
R305	1.0 MΩ	Standard		R0603		Resistor, 0.1 W, 5 %, 0603, SMD

Table 3. Bill of materials *…continued*

Part	Value	Part number	Manufacturer	Package	Optional	Description
R306	1.0 MΩ	Standard		R0603		Resistor, 0.1 W; 5 %; 0603; SMD
R401	220 kΩ	Standard		R0603	ZERO	Resistor, 0.1 W; 5 %; 0603; SMD
R402	220 kΩ	Standard		R0603	ZERO	Resistor, 0.1 W; 5 %; 0603; SMD
R403	220 kΩ	Standard		R0603	ZERO	Resistor, 0.1 W; 5 %; 0603; SMD
R404	22 Ω	Standard		R0805		Resistor, 0.25 W; 5 %; 0805; SMD
R405	100 kΩ	Standard		R0603	DCDC	Resistor, 0.1 W; 5 %; 0603; SMD
R406	6.8 kΩ	Standard		R0603	DCDC	Resistor, 0.1 W; 5 %; 0603; SMD
R407	75 kΩ/1 %	Standard		R0603	DCDC	Resistor, 0.1 W; 1 %; 0603; SMD
R408	24 kΩ/1 %	Standard		R0603	DCDC	Resistor, 0.1 W; 1 %; 0603; SMD
R501	220 kΩ	Standard		R0603	NFC	Resistor, 0.1 W; 5 %; 0603; SMD
R502	10 kΩ	Standard		R0603	NFC	Resistor, 0.1 W; 5 %; 0603; SMD
R503	10 kΩ	Standard		R0603	NFC	Resistor, 0.1 W; 5 %; 0603; SMD
R504	10 kΩ	Standard		R0603	NFC	Resistor, 0.1 W; 5 %; 0603; SMD
SH401	WE-36503505WE	36503505 + 36003500	Würth Elektronik	WE-36503505	NC	EMI Frame + Top
SV101	MA05-2	Standard		MA05-2	Debug	Header Pin, 2.54 MM, 10-WAY, 2-ROW
SW101	B3FS-1000	B3FS-1000	Omron Electronic Components	SWITCH-TACT _DTSM-6	Debug	B3FS-1000 - Switch, Flat; SPNO
SW102	B3FS-1000	B3FS-1000	Omron Electronic Components	SWITCH-TACT _DTSM-6	Debug	B3FS-1000 - Switch, Flat; SPNO
SW401	SLIDE-SPDT	SLIDE-SPDT	C & K Components	SLIDE-SPDT	ZERO	OS102011MA1QN1 - Switch, SPDT; 0.1 A; 12 V; PCB; R/A
SWD	M50-3600542	M50-3600542	Samtec	127_2R10 _SMT	Debug	Connector, Header, SMT; R/A; 1.27 MM; 10P
T201	NX3008NBKW	NX3008NBKW	NXP Semiconductors	SOT323		30 V, 350 mA N-channel Trench MOSFET
T202	BC847C	BC847C,215	NXP Semiconductors	SOT23-BEC		TRANSISTOR, NPN; 45 V; SOT-23
T203	NX2020N2	NX2020N2	NXP Semiconductors	SOT1220		30 V, N-channel Trench MOSFET
T204	NX2020N2	NX2020N2	NXP Semiconductors	SOT1220		30 V, N-channel Trench MOSFET
T401	NX3008NBKW	NX3008NBKW	NXP Semiconductors	SOT323	ZERO	30 V, 350 mA N-channel Trench MOSFET
T402	NX2020P1	NX2020P1	NXP Semiconductors	SOT1220	ZERO	30 V, single P-channel Trench MOSFET
T501	NX3008CBKS	NX3008CBKS	NXP Semiconductors	SOT363	NFC	30 / 30 V, 350 / 200 mA N/P-channel Trench MOSFET
U101	NXQ1TXA1	NXQ1TXA1	NXP Semiconductors	SOT-HVQFN33		Qi standard conforming charger controller

Table 3. Bill of materials *…continued*

Part	Value	Part number	Manufacturer	Package	Optional	Description
U102	TL431BFDT	TL431BFDT	NXP Semiconductors	SOT23		V_{REG}, 0.5 %; 2.495 V; 36 V
U201	NWP2081T	NWP2081T	NXP Semiconductors	SO-08		Half-bridge driver IC
U202	MAX44284HAUT+	MAX44284HAUT+	Maxim Integrated	SOT457	FOD	High-Precision, Low-Power Current-Sense Amplifier
U203	NC	INA214AIDCK	Texas Instruments	SC70	NC	Voltage Output, Current-Shunt Monitor
U401	TDA3663	TDA3663	NXP Semiconductors	SOT223	LDO	voltage regulator 3.3 V
U402	RT8295A	RT8295AHGSP	Richtek	SOP-8	DCDC	Synchronous Step-Down Converter, 2 A; 23 V; 340 kHz
U501	NT3H1201	NT3H1201W0FHK	NXP Semiconductors	XQFN8	NFC	NFC forum tag 2 type-compliant IC with I^2C interface
UART	MA06-1	Standard		MA06-1	Debug	Header, Pin, 2.54 MM, 6-WAY, 1 ROW

7. Critical components

As mentioned in Section 5 “System overview”, certain components are critical in the design. This section covers these components, associated design considerations and potential pitfalls.

7.1 Power stage

7.1.1 Capacitor in tank circuit

The capacitor value in the tank circuit must be correct or the system does not function properly. The Wireless Power Consortium (WPC) specify the capacitor values. To verify that the correct value is used in the base station design, refer to WPC specifications.

For an A10 type base station, WPC specifies a value of 100 nF to be used with the A10 charging coil. In addition to the capacitor value, the dielectric must be C0G/NP0 type. Otherwise, efficiency is lower and Qi compliance can be problematic.

The voltages in the tank circuits can swing as much as 200 V_{p-p} in the NXQ1TXA1 Evaluation Board. It is therefore important to choose the correct voltage rated capacitors. The capacitors C210 and C211 in Figure 12 “LC tank circuit”, are 250 V rated.

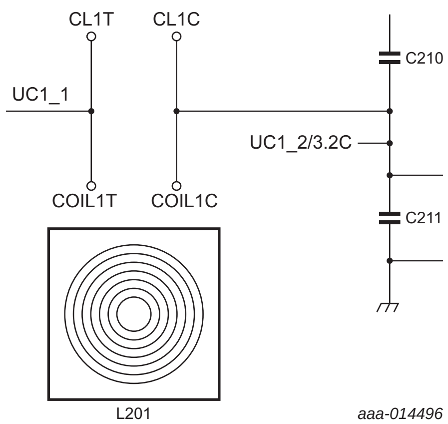


Fig 12. LC tank circuit

7.1.2 Half-bridge driver and MOSFETs

For +19 V system like the A10 type base station, the recommended maximum operating MOSFET conditions are 30 V and minimum 4 A. In NXQ1TXA1 Evaluation Board, an N-Channel Trench MOSFET NX2020N2 (T203 and T204) is used in combination with NWP2081 (U201) half-bridge controller IC.

If a different MOSFET other than NX2020N2 is used in the design, the gate resistor must be adjusted depending on the gate capacitance of the MOSFET. The applied gate resistance and gate capacitance forms an RC time constant which influences the on/off switching times. In particular, the upper FET drive resistor R207 serves to slow down the Trench MOSFET fast switching action, thus reducing noise.

The gate drive resistors themselves also serve as test points to observe the actual drive waveforms. Do not add any extra test points to the line from half-bridge driver NWP2081 to NX2020N2 MOSFET gates. They may introduce unwanted parasitic inductance or stray capacitance.

7.1.3 Capacitor snubber circuits

The option for capacitor snubber circuits (C208 and C209) is included, but not populated, in the NXQ1TXA1 Evaluation Board. They are located across the switching MOSFETs to allow tuning to reduce Electro-Magnetic (EM) emission. Capacitor snubber circuits must be placed close to the switching MOSFETs. If the snubber circuits are not required, they can be removed from the Bill of Materials.

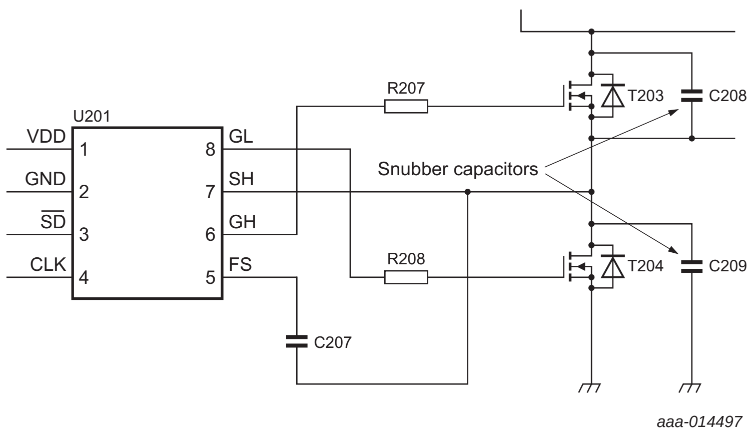


Fig 13. Half-bridge driver, MOSFETs and capacitor snubber circuits

7.1.4 MOSFET gate drive voltage

The NXQ1TXA1 Evaluation Board uses bipolar transistor T202 as regulator to create the half-bridge driver supply voltage from +19 V DC input power. It meets the bare essential requirements of a regulator. Half bridge driver U201 supply voltage should be maintained between 11 V < VDD < 15 V. Tuning can be done via resistors R202 and R203 in Figure 14.

Alternatively, if there are other auxiliary circuits to be powered that share the same voltage level, a dedicated voltage regulator can be considered.

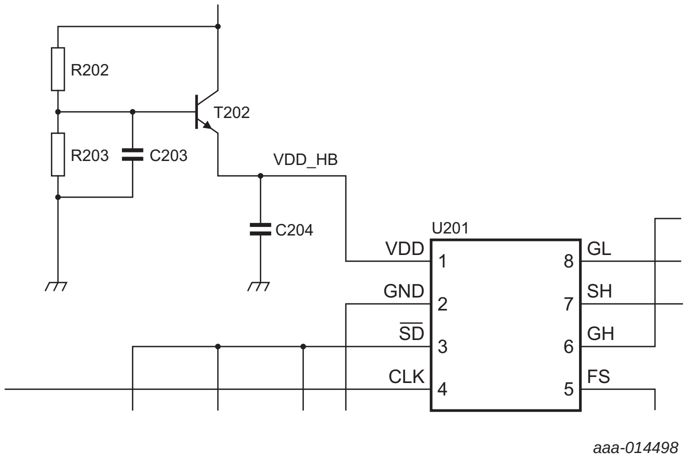


Fig 14. Half bridge driver supply voltage

7.2 Current sense circuitry

A current measurement circuit is used to measure the DC current into the power stage. This circuit is shown in Figure 15. A current sense amplifier is used in combination with a current sense resistor, in the DC supply to the half-bridge stage. The current sense resistor R206 in Figure 15 is 22 mΩ and the tolerance must be 1 % or better. It is used in combination with the current sense amplifier MAX44284HAUT on the NXQ1TXA1 evaluation board.

The above combination must be used for all NXQ1TXA1 based systems. Deviations could lead to lower efficiency, higher noise and wrong detection of foreign object (FOD). Refer to the Bill Of Materials in Section 6 for more information.

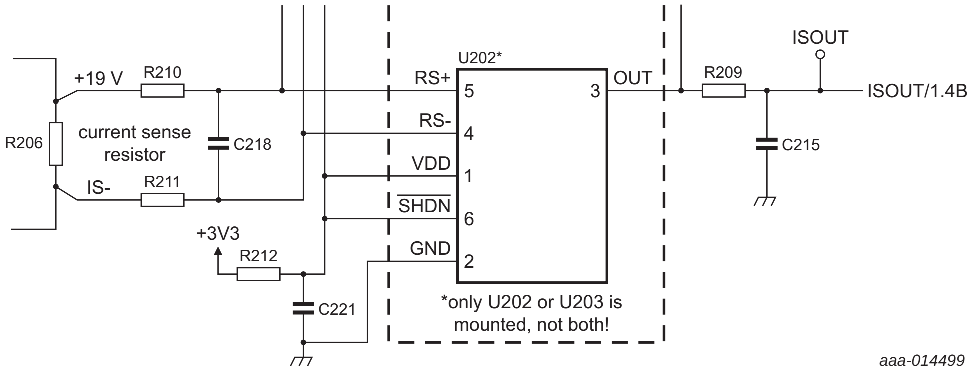


Fig 15. Current sense circuit

7.3 Amplitude-Shift Key (ASK) envelope detector

As previously mentioned, voltages as high as 200 V_{p-p} can be present at the input of the envelope detector (see Figure 16). Use only high-voltage capable devices in the detector circuits. A double BAS101S diode (D301), capable of withstanding 250 V reverse voltage, is used in the NXQ1TXA1 Evaluation Board. A larger 1206 SMD footprint is selected for the passive components - resistors R301, R302, R304 and capacitors C301 and C302 to withstand the higher voltage.

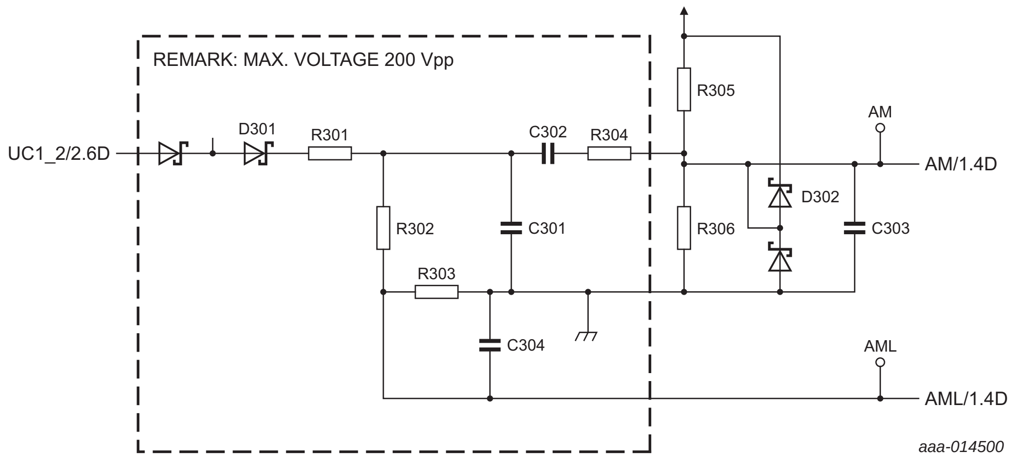


Fig 16. ASK envelope detector

7.4 Configuration and voltage measurement circuits

The inputs OPT1 and OPT2 are used for configuring the NXQ1TXA1 controller. Input OPT1 is used to select the user interface (LED and Buzzer) configurations. Multiple configurations for the LED blinking patterns are described in the NXQ1TXA1 data sheet.

When ASEL1 is enabled, the voltage divider on the OPT2 input sets the FOD threshold. The ASEL2 and ASEL3 signals are used for influencing the FOD detection method. Contact NXP for design specific configuration details. When the ASEL1, ASEL2 and ASEL3 lines are not driven, the OPT2 input expects a stable 2.495 V reference voltage at its input. The shunt regulator U102 TL431BFDT, which is accurate to 0.5 %, is used for this reference.

The power stage DC voltage is measured on input VSNS using R114 and R115.

Use only 1 % tolerance resistors in configuration (OPT1 and OPT2) and voltage sensing (VSNS) circuits.

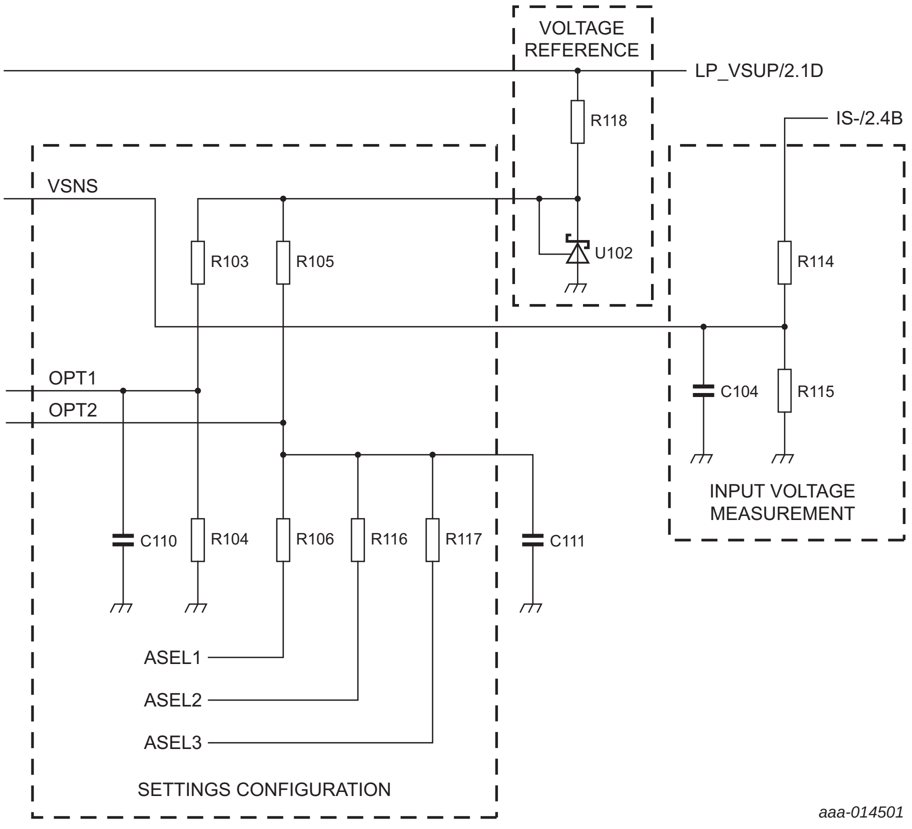


Fig 17. Configuration and voltage measurements

7.5 Thermal protection

Temperature sensing is provided by NTC201 to allow the controller to (optionally) sense temperature for safety reasons. When using a thermistor of type B57551G1103F005, the transmitter stops power transfer at a temperature of 70 °C and higher. The transmitter restart power transfer when the temperature measured by the NTC is below 60 °C. If not used, the input NTC should be connected to V_{DD}.

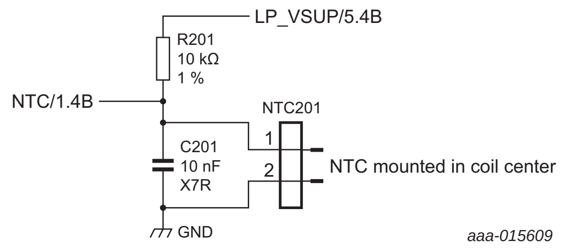


Fig 18. Temperature sensing circuit

7.6 NFC antenna tuning capacitor

Due to the variation in shapes and dimensions of different NFC antennas, it is inevitable that tuning is required for new designs. Tune the resonance frequency of the intended antenna close to13.56 MHz, using the parallel capacitor C504. The capacitor dielectric type must be C0G/NP0. If the resonance frequency is too low, even after removing the parallel capacitor C504, lower the 1 nF value of the series capacitors C505 and C506.

The internal capacitance of the NFC IC NT3H1201 (U501) is typically 50 pF typical (see NT3H1201 data sheet).

The tuning capacitor used for the NFC antenna, is shown in Figure 18.

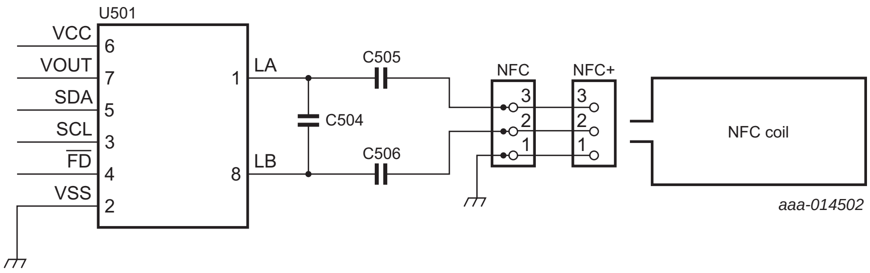


Fig 19. Tuning capacitor NFC antenna

The NFC functionality is optional and not needed for creating a wireless charging base station with the NXQ1TXA1 controller.

8. PCB Layout Guidelines

Having a proper Printed-Circuit-Board (PCB) layout is critical to the success of the application. A poor constructed PCB layout can cause the whole application not to function properly. Beyond basic circuit operation, it can also directly influence the ElectroMagnetic Compatibility (EMC) profile. Therefore, it is imperative that care should be exercised during the PCB layout stage. This section provides useful PCB layout guidelines.

8.1 Ground Planes

Design with a 4-layer PCB. The layer stack-up applied in NXQ1TXA1 Evaluation Board is as follows:

- Layer 1: Component placement and signal trace
- Layer 2: Clean uninterrupted ground
- Layer 3: Signal trace
- Layer 4: Ground and minimal routing trace (when required)

Notice that with this stacking technique, the signal traces are sandwiched between grounds. It provides a solid ground reference plane and helps to minimize ElectroMagnetic Interference (EMI) noise emissions.

As a rule, use ground planes: use copper-pour in unused areas of the PCB and stitch these areas with vias to inner ground planes.

8.2 NXQ1TXA1 charging controller

The center Pad (pin 33) under NXQ1TXA1 charging controller is a ground pin. It is important to stitch with vias to inner ground planes to provide solid ground reference. Make sure the decoupling capacitors C101 and C102 on V_{dd} supply pins (pin 6 and pin 26) are close by and connected with a wide trace. It ensures an effective decoupling action to ground.

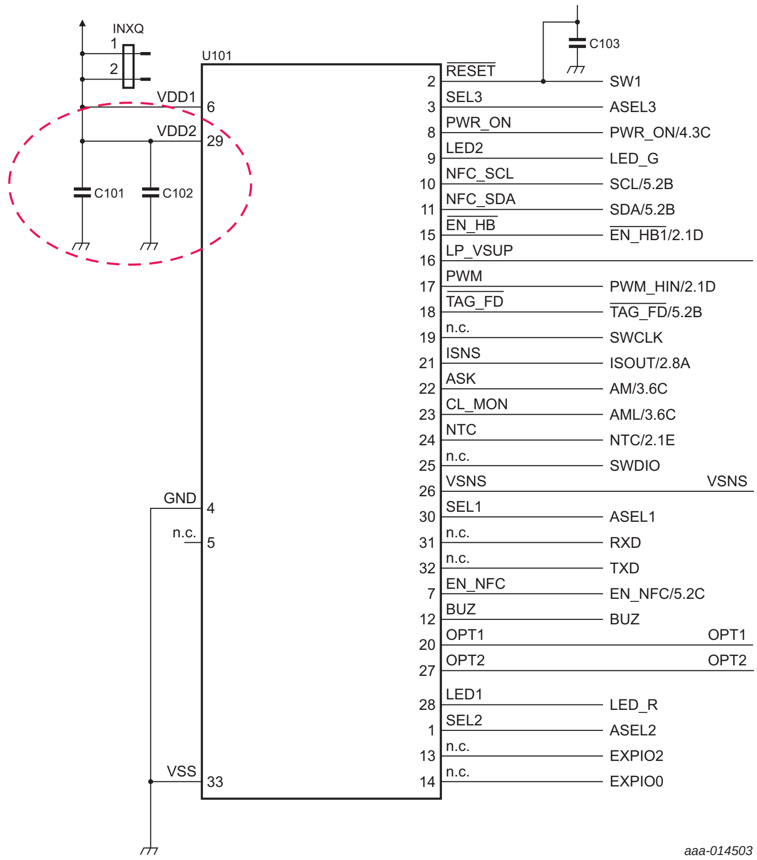


Fig 20. NXQ1TXA1 charging controller supply decoupling capacitors

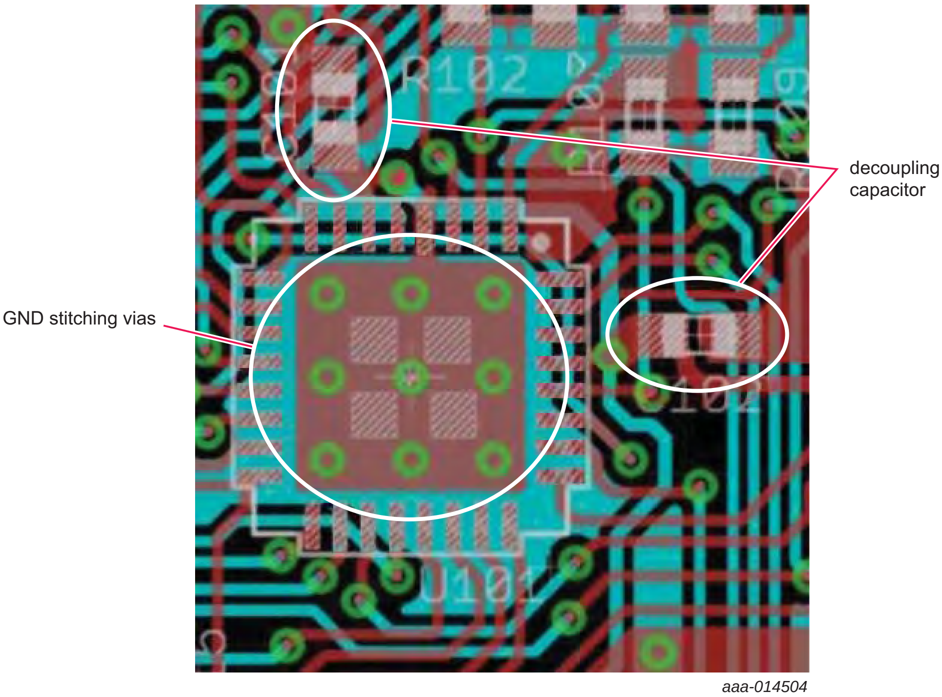


Fig 21. GND stitching vias underneath NXQ1TXA1, and wide traces to the supply

8.3 Power stage

Separate ground planes are used for the system ground and the power stage ground. It avoids crosstalk on sensitive signals which could otherwise result in erratic system behavior. It is important to tie the two ground planes together at only ONE point. Having several tie points makes the purpose of separating the grounds useless. Do not have any other non-related signals in the area of the power ground plane.

Keep the current loops, shown in green in Figure 22, compact to minimize radiation. Place the decoupling capacitor (C204), at the VDD supply pin of the NWP2081 (U201), close to the IC.

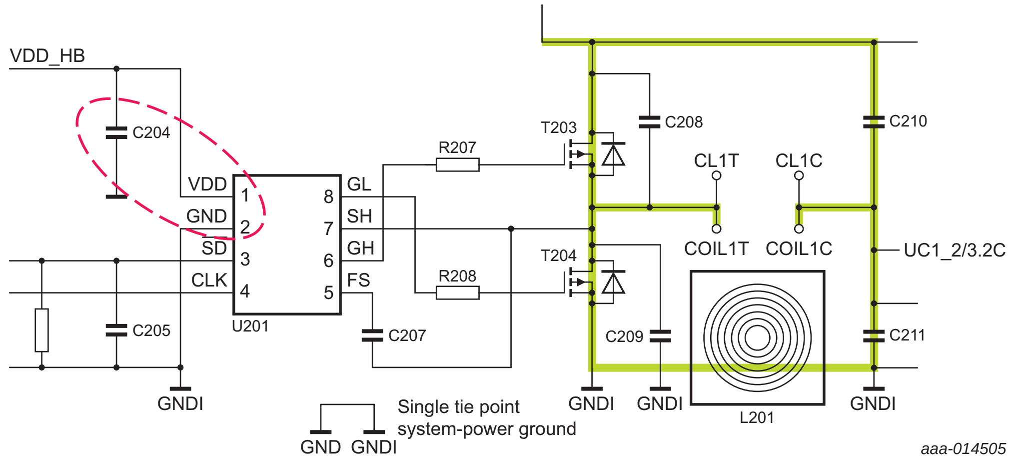


Fig 22. Half-bridge drive stage

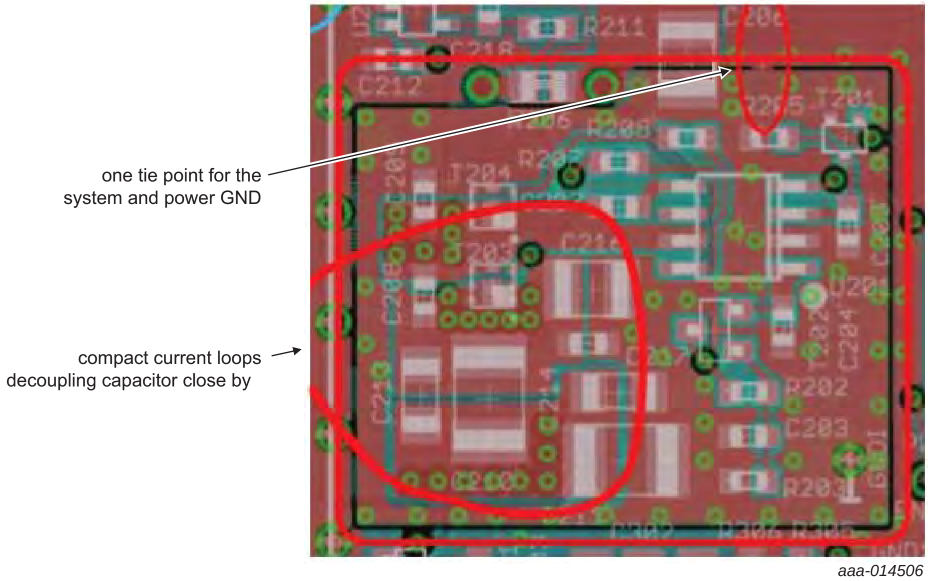


Fig 23. PCB layout of half-bridge drive in NXQ1TXA1 evaluation board

8.4 DC-to-DC converter

The same layout techniques implemented in the power stage can be applied to the DC-to-DC converter as shown in Figure 24 and Figure 25. Keep the current loop through L402 and C409 compact and make sure the decoupling capacitors, inductor and feedback components are close. Use good quality X7R capacitors for C405 and C409.

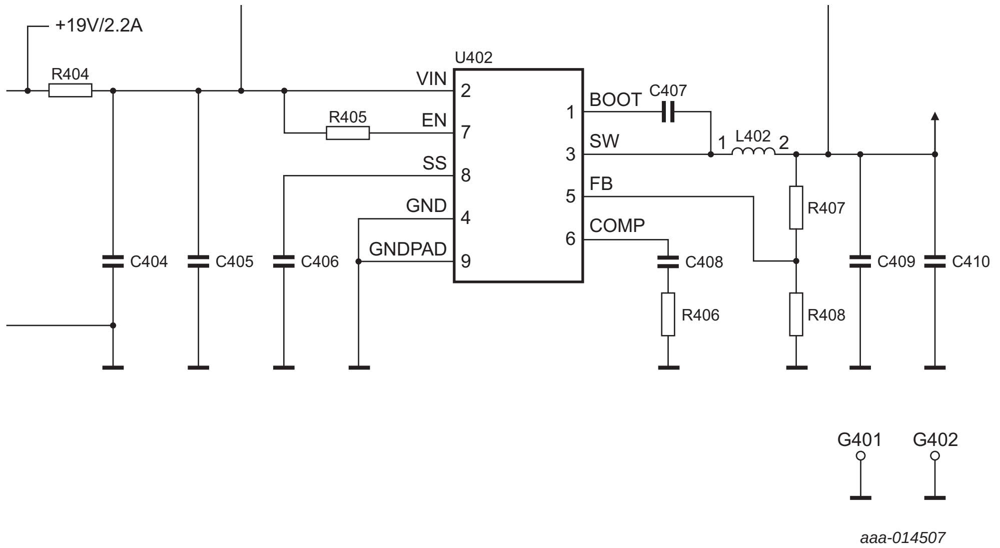


Fig 24. DC-to-DC converter

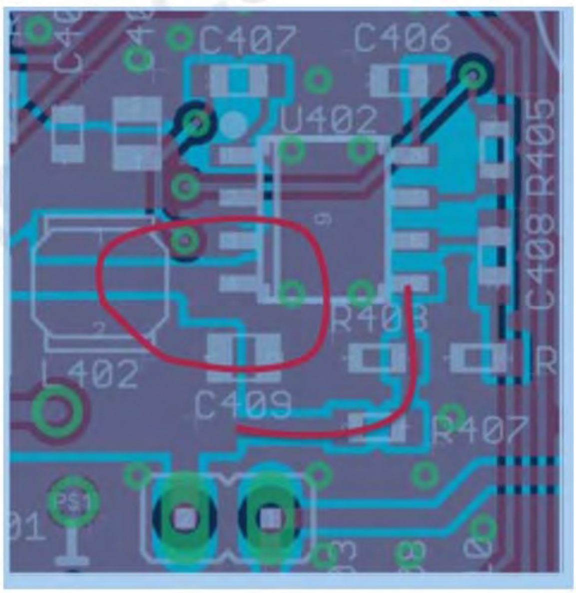


Fig 25. PCB layout of DC-to-DC converter in NXQ1TXA1 evaluation board

8.5 Current sense circuit

Figure 26 is the schematic of the current sensing circuit of the NXP NXQ1TXA1 Evaluation Board. It shows the current sense resistor R206 and the input current flows from right to left. Notice in Figure 27 how the resistors R210 and R211 are connected to the pad of R206. As a result, there is no measurement error introduced by copper conduction losses or copper resistance temperature dependency. It is referred to as a "Four-wire" or "Kelvin-connection" technique.

When dealing with very low voltages generated across a current sense resistor, be sure to use the "Four-wire" or "Kelvin-connection" technique. This technique is important to avoid introducing false voltage drops from adjacent pads and other copper routes.

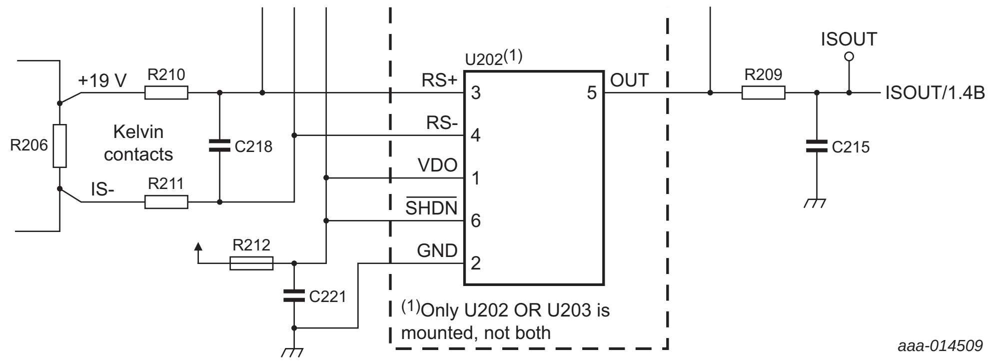


Fig 26. Current sensing circuit

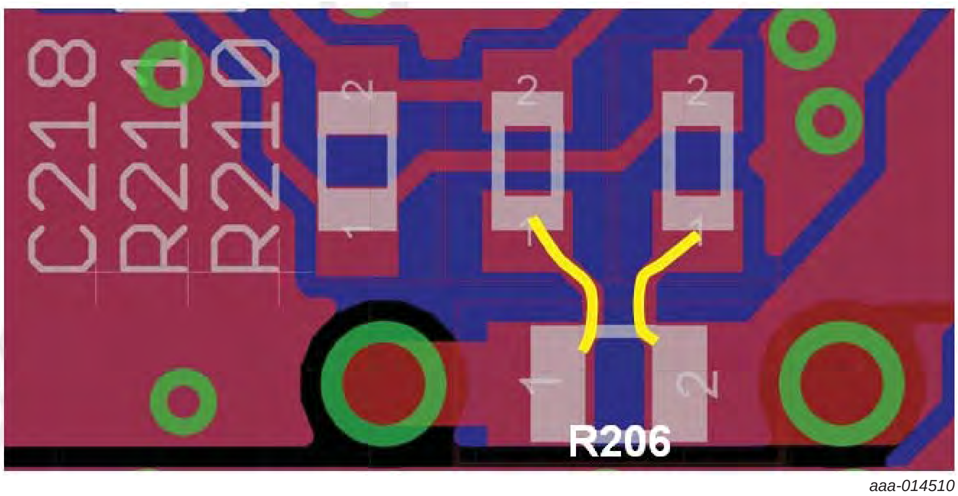


Fig 27. PCB layout of current sense resistor in NXQ1TXA1 evaluation board

Proper and accurate current sensing technique is critical to the correct performance of the Foreign Object Detection (FOD). The sense resistor R206 must be accurate to 1 % or better and have a temperature stability of maximum 200 PPM.

8.6 EMC Common Mode Filter

The common mode filter L401 in Figure 28 functions to prevent high frequency disturbance signals from traveling back to the DC input power connector J401. There must be no ground planes or other traces underneath the input power. They would defeat the purpose of having a common mode filter.

To prevent coupling of high frequency noise, sufficient gap must be created between the input power and the closest copper area as shown in Figure 29. It also shows that no copper fill or traces in the inner layers underneath component L401 should be used

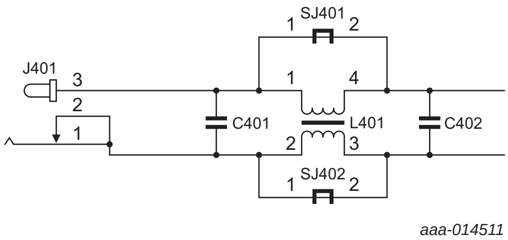


Fig 28. EMC common mode choke

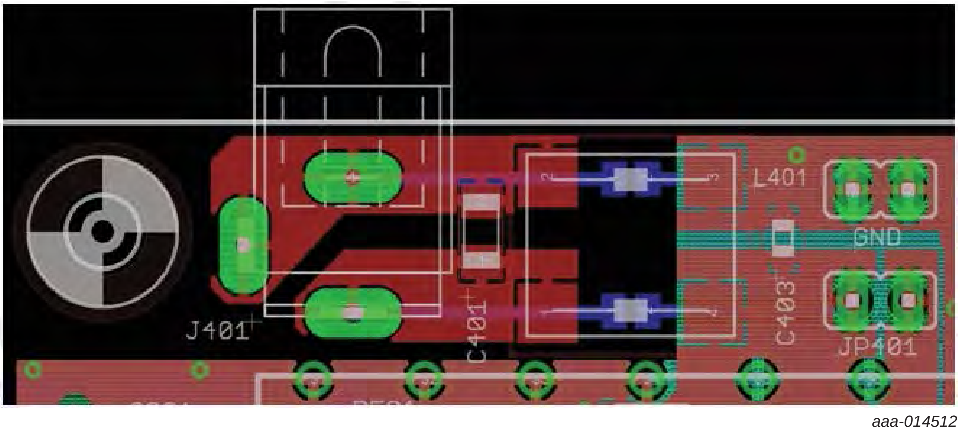


Fig 29. PCB layout of common mode choke in NXQ1TXA1 evaluation board

8.7 Summary

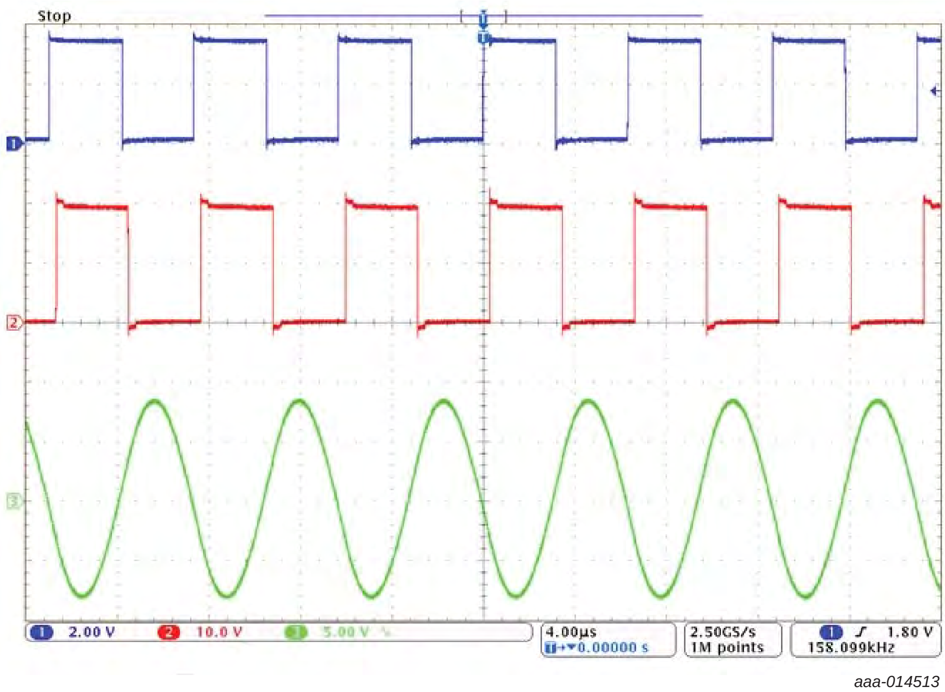
To recap the key notes for a successful design:

1. Use a 4-layer PCB with the following stacking:
   - Layer 1 - component placement and signal trace
   - Layer 2 - clean interrupted ground
   - Layer 3 - signal trace
   - Layer 4 - ground and minimal routing trace (when required)
2. Separate system ground plane from power ground plane and connect them together using one tie point.
3. Use only components with correct characteristics and ratings.
4. Design tight current loops in the half-bridge drive stage and DC-to-DC converter.
5. Place decoupling capacitors close by.
6. If NXQ1TXA1 Evaluation Board is followed closely, minimal effort is required.
7. Create test points for key signal nodes

9. Waveforms

This chapter shows several examples of typical waveform as can be observed on the test points in the design. For trace in the figures, the names of the corresponding schematic signal names are mentioned.

9.1 Power stage



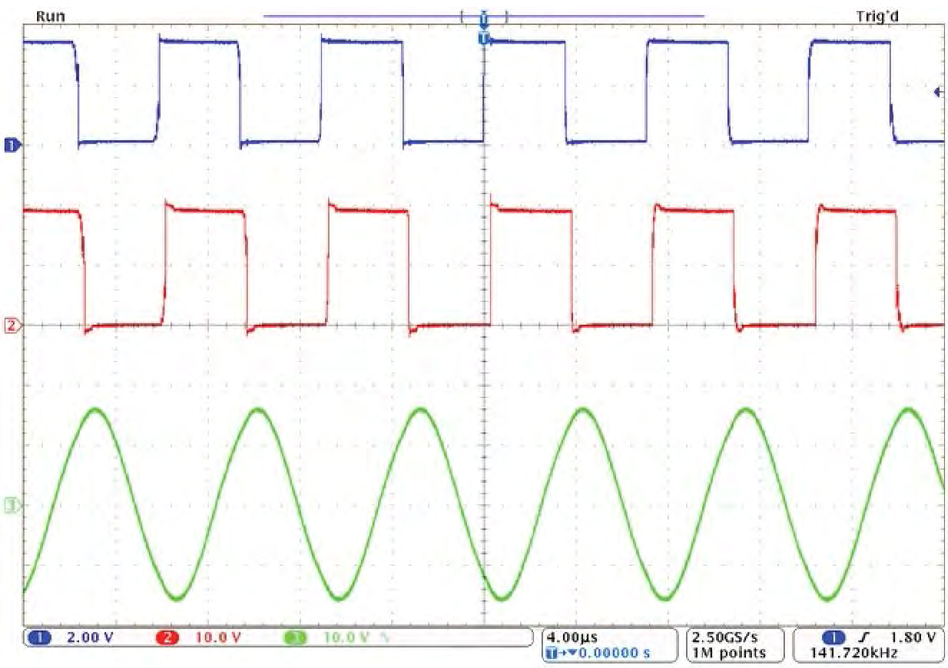
(1) Ch1: PWM_HIN - PWM input to half-bridge

(2) Ch2: UC1_1 - driver stage, connection of MOSFETs to LC tank

(3) Ch3: UC1_2 - connection of charging coil to resonant capacitor

Fig 30. Power stage 1.25 W load

Figure 30 shows the power stage behavior under a load condition of 1.25 W. Depending on receiver characteristics, the waveform on the connection between charging coil and capacitor can have a different shape.



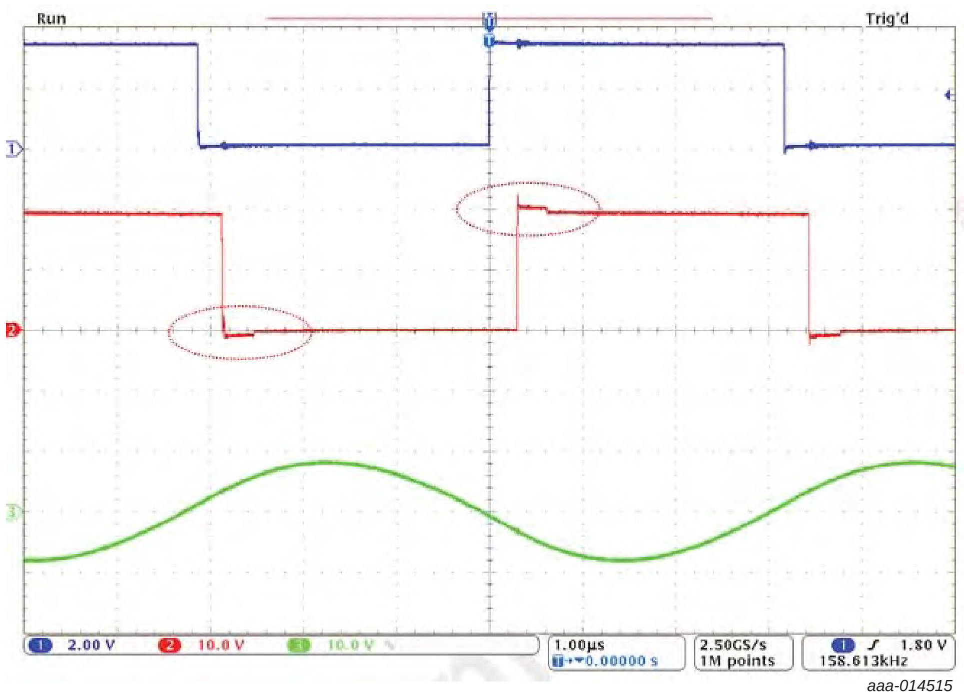
(1) Ch1: PWM_HIN - PWM input to half-bridge

(2) Ch2: UC1_1 - driver stage, connection of MOSFETs to LC tank

(3) Ch3: UC1_2 - connection of charging coil to resonant capacitor

Fig 31. Power stage 5 W load

Figure 31 shows the power stage behavior under a load condition of 5 Watt. Notice that the frequency is lower for the 5 W power transfer graphs in Figure 31 than the signals for 1.25 W power transfer in Figure 30. Depending on receiver characteristics, the waveform on the connection between charging coil and capacitor might have different shapes.



(1) Ch1: PWM_HIN - PWM input to half-bridge

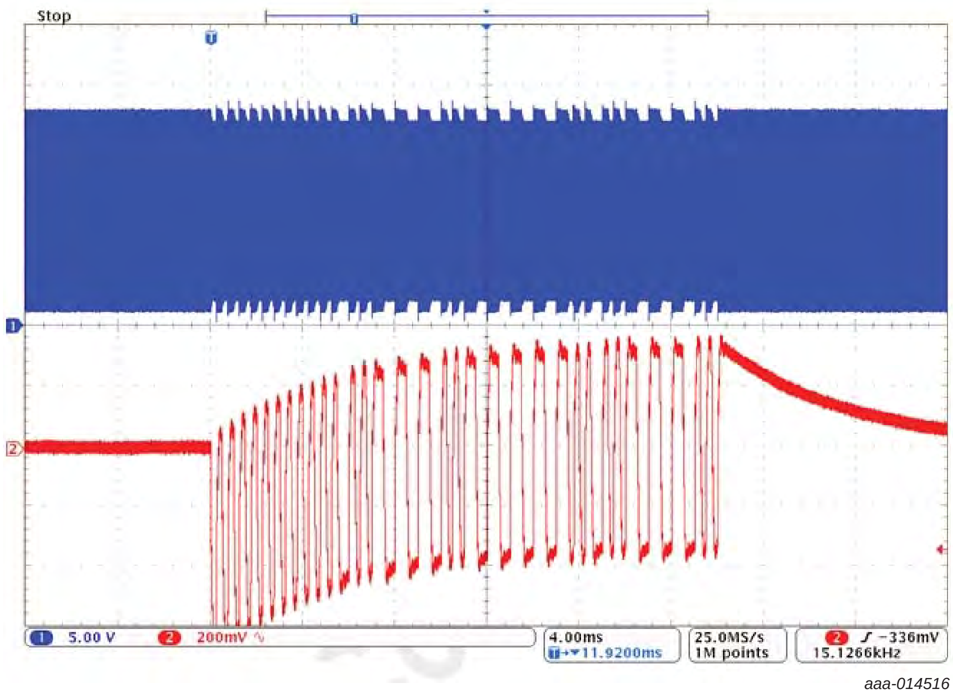
(2) Ch2: UC1_1 - driver stage, connection of MOSFETs to LC tank

(3) Ch3: UC1_2 - connection of charging coil to resonant capacitor

Fig 32. Power stage, fixed dead-time of 330 ns (load = 1.25 W)

In Figure 32, the dead time behavior of the half-bridge driver is visible in the waveform measured at the output of the driver stage.

9.2 ASK waveforms



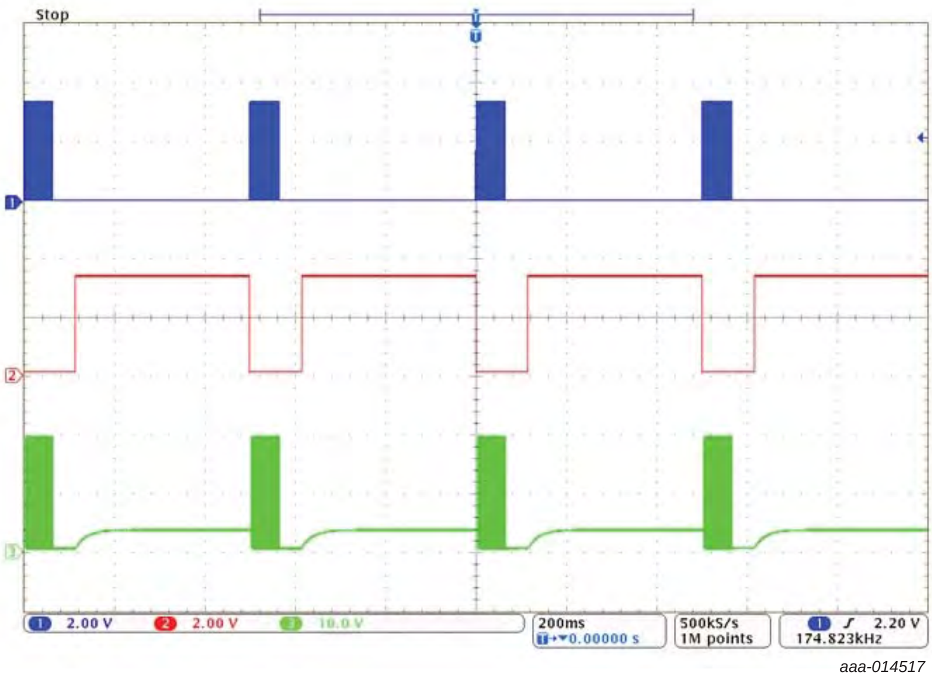
(1) Ch1: UC1_1 - driver stage, connection of MOSFETs to LC tank

(2) Ch2: AM - output of envelope detector

Fig 33. Typical ASK waveform

Figure 33 shows the ASK waveform visible on the charging coil voltage at spot UC1_1 and the resulting output AM of the envelope detector.

9.3 Digital ping



(1) Ch1: PWM_HIN - PWM input to half-bridge

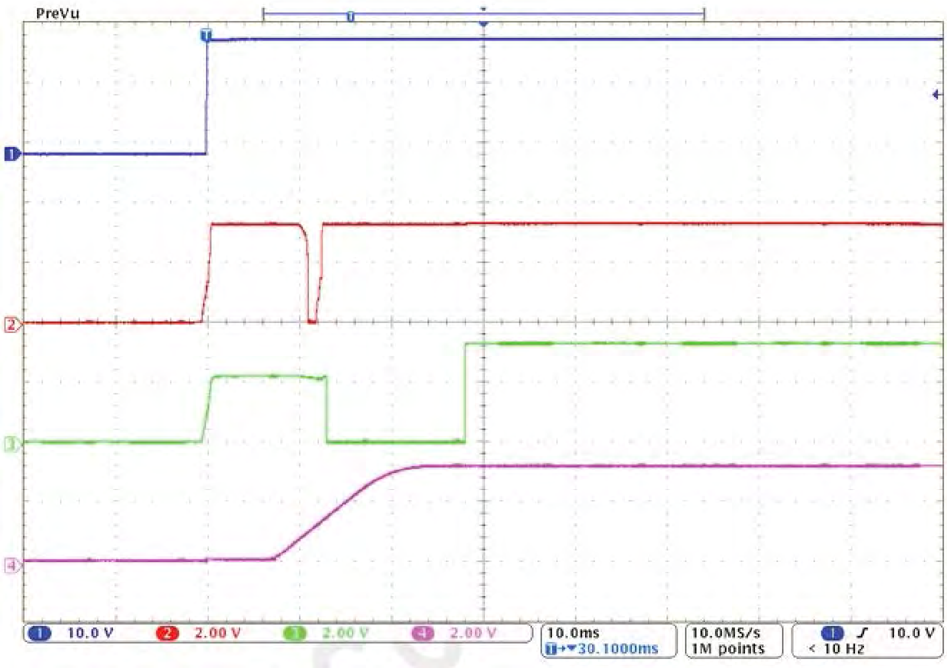
(2) Ch2: EN_HB1 - driver stage enable

(3) Ch3: UC1_1- driver stage, connection of MOSFETs to LC tank

Fig 34. Repeated digital ping

Figure 34 shows that a digital ping is performed every 500 ms to detect the presence of a Qi receiver device. The waveforms show the digital ping when no receiver is present.

9.4 NFC tap to power on



(1) Ch1: +19 V - switched 19 V supply

(2) Ch2: TAG_VOUT - power harvesting output from NFC NTAG IC

(3) Ch3: PWR_ON - PWR_ON take over signal to maintain power

(4) Ch4: +3V3 - charging controller power supply

Fig 35. NFC "tap to power on"

In NFC tap to power on mode, the charger is completely powered-down when not charging and it results in zero standby current. It can be seen with the Ch1 being 0 Volt in Figure 35. When an NFC field is applied to the charging pad by an NFC enabled telephone, the NFC NTAG chip TAG_VOUT, seen in Ch2, switches on the +19 V supply. After the DC-to-DC converter has created a 3.3 V supply, and the NXQ1TXA1 charging controller has started, the charging controller keeps the power switch active by enabling the PWR_ON signal (Ch4).

10. PCB layout

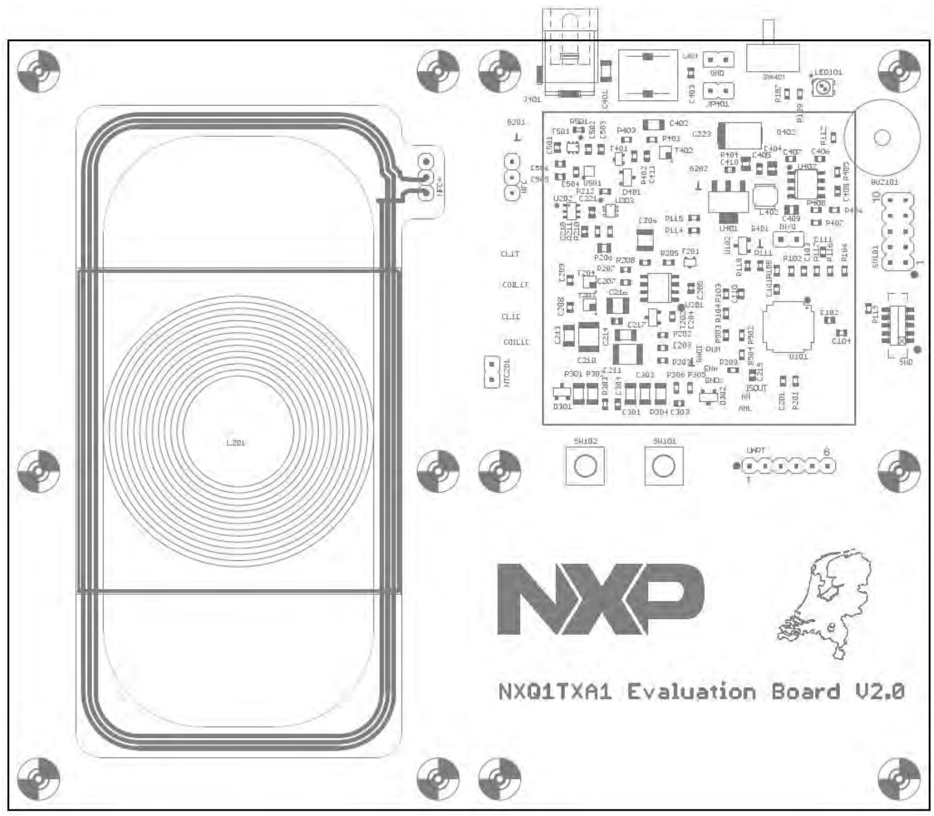


Fig 36. PCB component placement

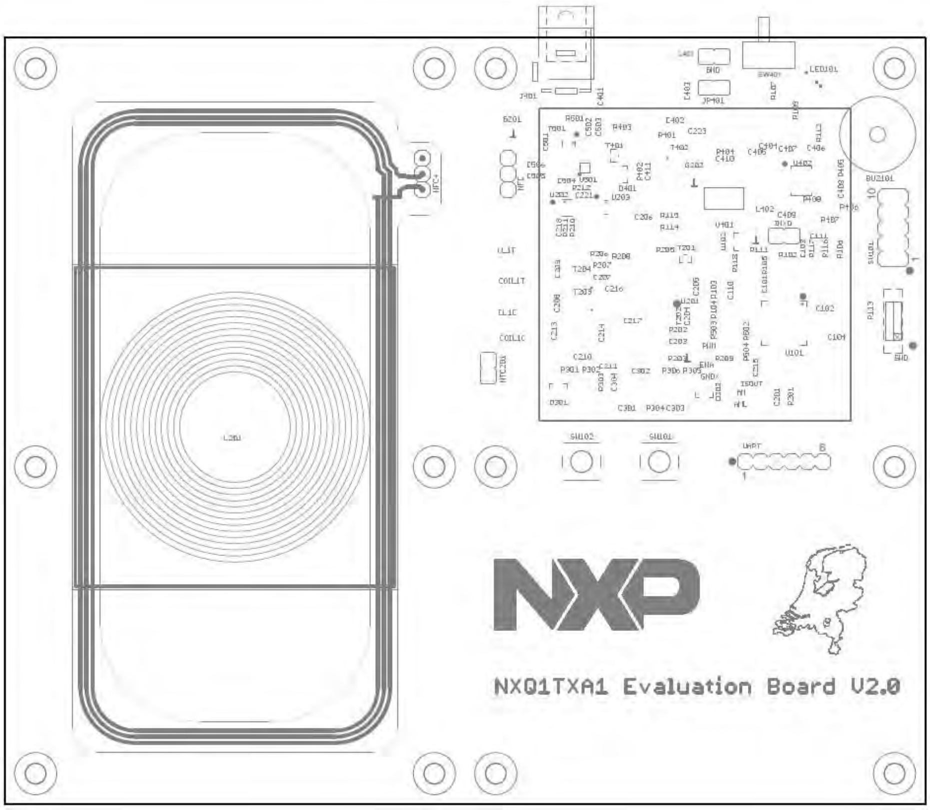
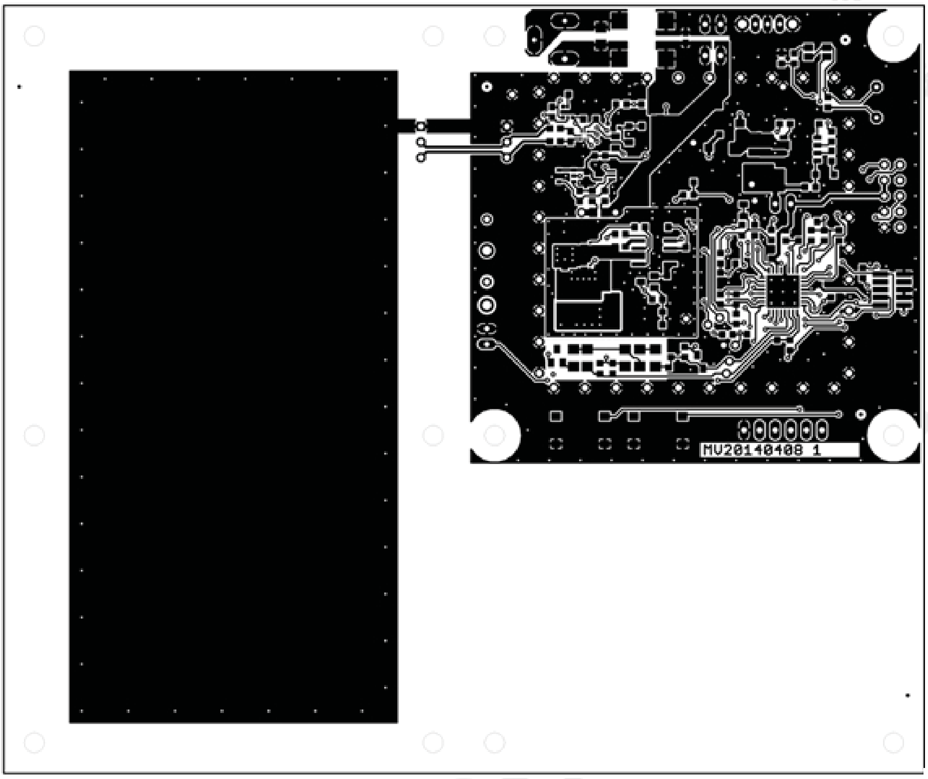


Fig 37. PCB top silkscreen



aaa-014521

Fig 38. PCB top layer

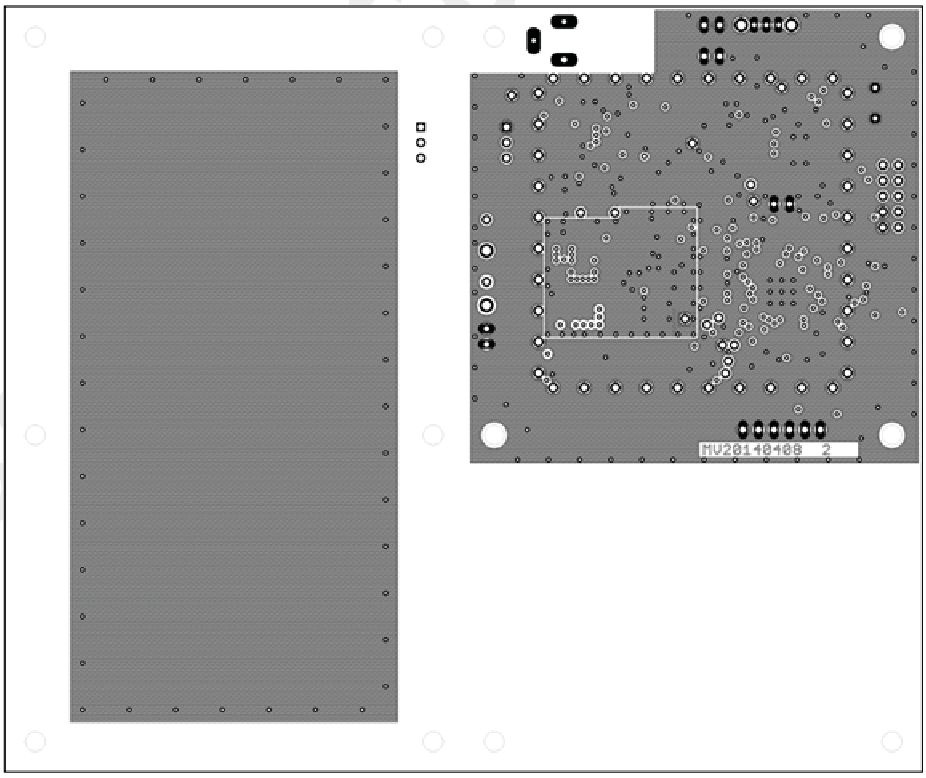
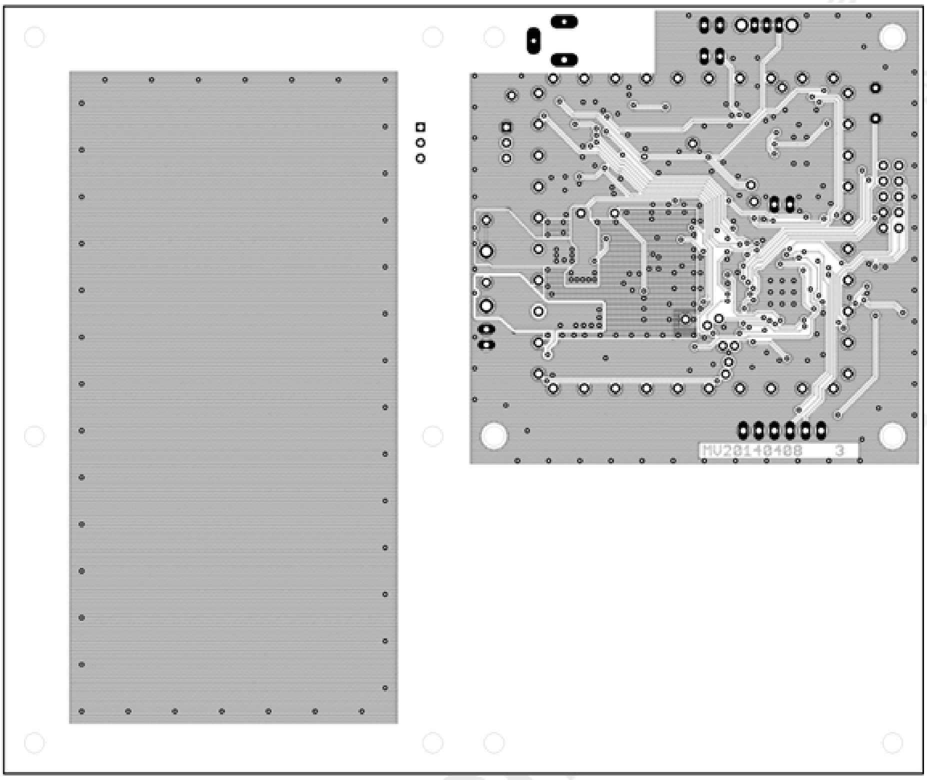
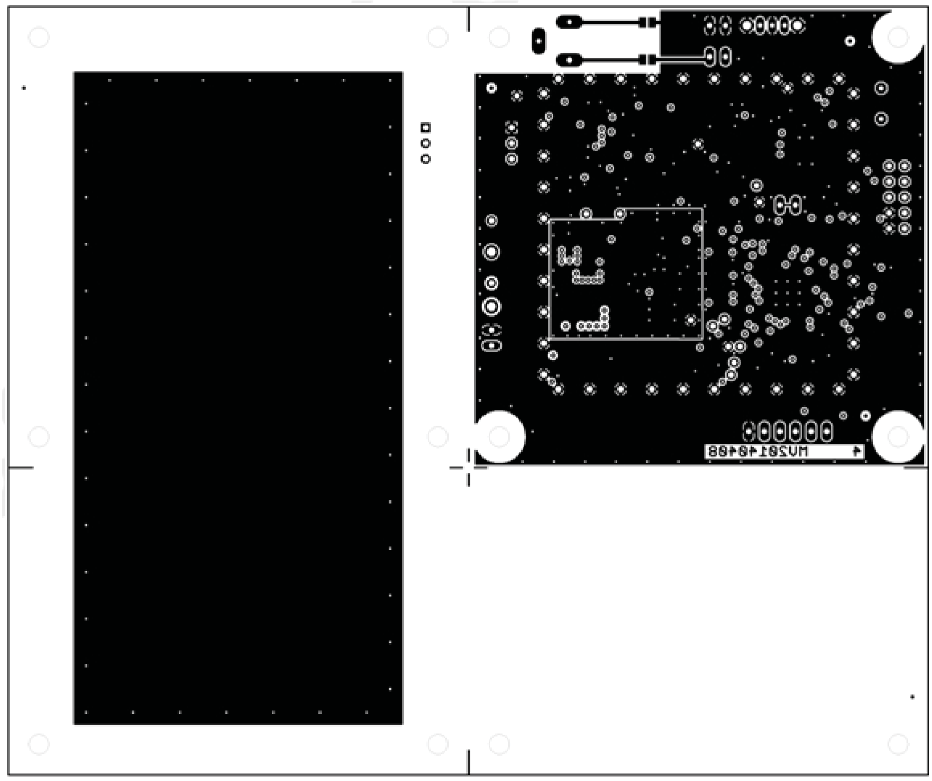


Fig 39. PCB Layer 2



aaa-014523

Fig 40. PCB Layer 3



aaa-014524

Fig 41. PCB Bottom Layer

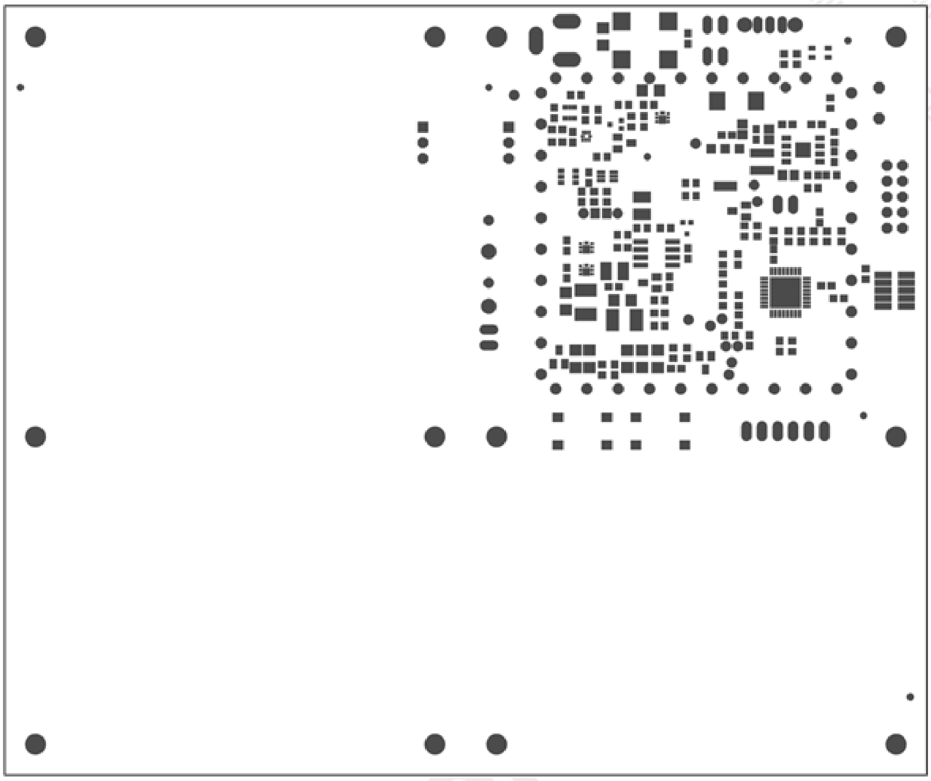


Fig 42. PCB Solder Mask

11. Conclusion

This document demonstrates how to create a Qi A10 wireless power base station that is optimized in terms of cost, functional performance and EMI. It utilizes NXPs NXQ1TXA1 charging controller, NWP2081 half-bridge driver, and NX2020N2 MOSFETs.

Using the NT3H1201, a base station with NFC technology can be created that has zero standby power in standby mode.

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