TRF79x0ATB
NFC/HF RFID Reader Module

Users Guide/Application Note

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1. Purpose

This document is intended to provide direction for TRF7960A/-70A users who desire to implement a 13.56MHz NFC/RFID reader solution using the TRF79x0A IC connected to a Texas Instruments embedded microcontroller or microprocessor development platform. Examples of such development platforms are: the MSP-EXP430F5438 board, MSP-EXP430F5529 board, the ARM Cortex-M3/M4 based board, or any other TI embedded microcontroller platform with the EM socket headers populated.

2. Scope

This document will cover TRF79x0ATB module as it relates to using the module for evaluation and development purposes in conjunction with Texas Instruments Embedded Development platforms. This manual does not cover the in-depth details of the TRF79x0A NFC/RFID IC families, as those details are well documented in the data sheets for those parts, along with app notes that can be found on the product pages (see hyperlinks in References section below).

3. References

- TRF7960A Product Page: http://www.ti.com/product/trf7960A
- TRF7970A Product Page: http://www.ti.com/product/trf7970A
- TRF7960A Full Data Sheet: http://www.ti.com/lit/gpn/trf7960a
- TRF7970A Full Data Sheet: http://www.ti.com/lit/gpn/trf7970a
- TRF7960ATB Schematic, BOM and Design files: http://www.ti.com/litv/zip/sloc221
- MSP-EXP430F5438 Users Guide: http://www.ti.com/lit/pdf/slau263
- LM3S9B96 DK Users Guide: http://www.ti.com/litv/pdf/spmu036d
- TPS61222DCKT Product Page: http://www.ti.com/product/tps61222
- TI ISO15693/ISO18000-3 Inlays/Tags Parametric Search:
  - http://focus.ti.com/paramsearch/docs/parametricsearch.tsp?family=rfid&sectionId=475&tabId=2102&familyId=1352
- Samtec Header and Mate Information:
  - https://www.samtec.com/ProductInformation/TechnicalSpecifications/Overview.aspx?series=SFM
  - https://www.samtec.com/ProductInformation/TechnicalSpecifications/Overview.aspx?series=TFM
- Smith Chart Simulation Tool (licensed copy): http://www.fritz.dellsperger.net/

4. TRF79x0ATB Module(s) Description

The TRF79x0ATB Evaluation Modules are intended to allow the software application developer to get familiar with the functionalities of either of the TRF79x0A Multi-Standard Fully Integrated 13.56 MHz NFC/RFID reader ICs with the freedom to develop on their Texas Instruments Embedded microcontroller development platform of choice.

The TRF79x0ATB module is also intended to allow customer driven antenna tuning with onboard coil and customer driven antenna form factor design.

The module is hard wired for SPI communications, supports Slave Select and TRF79x0A Direct Mode 2 (default), Direct Mode 1 and Direct Mode 0 operations. The user also has access to and full control over the TRF79x0A EN2 and EN lines, allowing for design and development of ultra low power NFC/HF RFID systems.

The module has an onboard boost converter (TPS61222DCKT) which boosts +3.3VDC in to +5VDC out to TRF79x0A IC for +23dBm (full transmitter power out) operations.

An impedance matching circuit from 4Ω to 50Ω is populated on the module and this is connected to a tuned 50Ω antenna circuit which consists of onboard four turn coil with series and parallel passive elements (capacitors and a resistor).

Test points are available on the board for checking firmware operations with oscilloscope or logic analyzer, impedance matching and for attaching external antenna.

Connection to Texas Instruments Microcontroller platforms are made via Samtec EM headers located on the underside of the board (Connectors P1/RF1 and P2/RF2).

Figure 1: TRF7960ATB Evaluation Module

Figure 2: TRF7970ATB Evaluation Module

5. TRF79x0ATB Connections/Technical Details

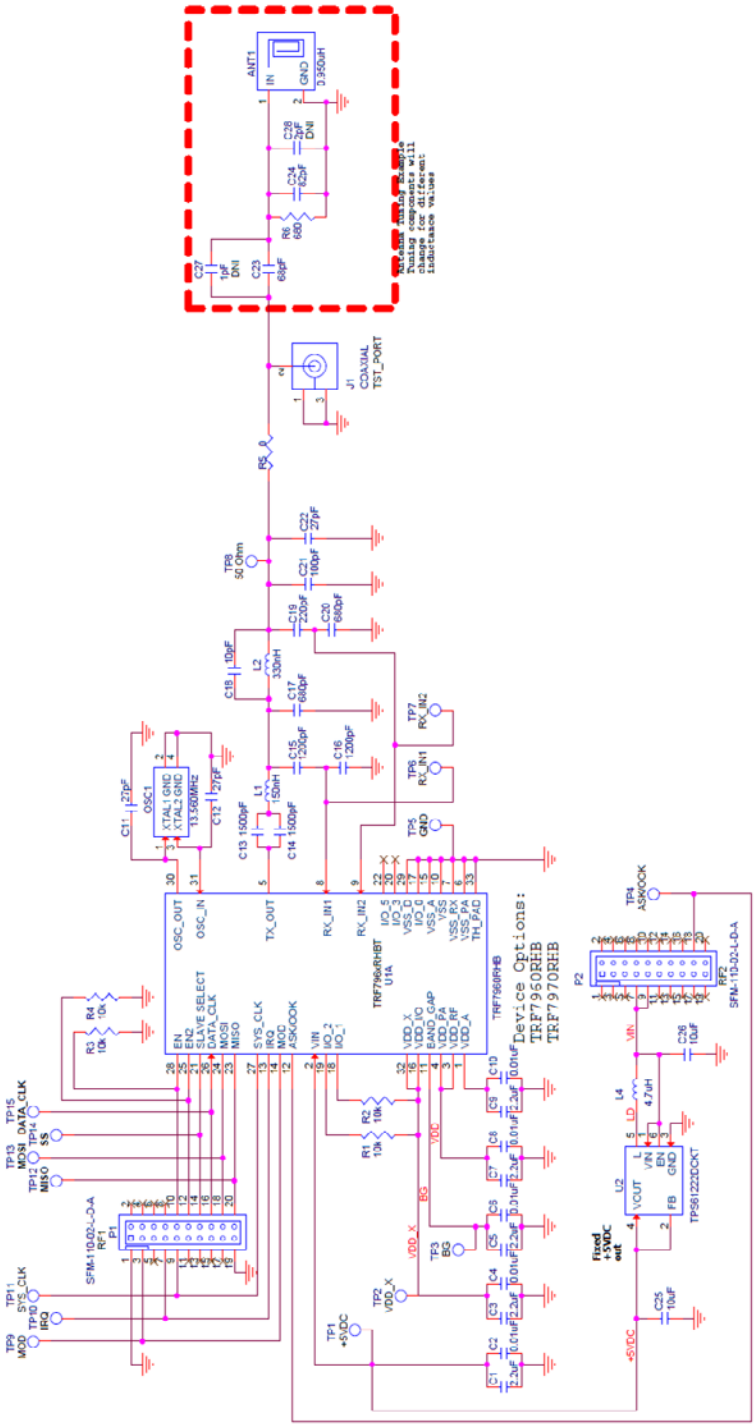
Connector P1/RF1

Pin #	Signal Name	Description
1	GND	Ground
2	n/c	
3	MOD	Direct mode, external modulation input
4	n/c	
5	n/c	
6	n/c	
7	IRQ	Interrupt request (from TRF79x0A to MCU)
8	n/c	
9	SYS_CLK	Clock for MCU (optional) If EN = 0 and EN2 = 1, then system clock is set to 60 kHz
10	EN	Chip enable input (If EN = 0, then chip is in power-down mode).
11	n/c	
12	EN2	Pulse enable and selection of power down mode. If EN2 is connected to VIN, then VDD_X is active during power down to support the MCU. Pin can also be used for pulse wake-up from power-down mode.
13	n/c	
14	SLAVE SELECT	Slave Select, I/O_4 (Active Low)
15	n/c	
16	DATA_CLK	Data Clock Input for MCU Communication (from MCU)
17	n/c	
18	MOSI	I/O_7, Master Out, Slave In (Data In from MCU)
19	GND	Ground
20	MISO	I/O_6, Master In, Slave Out (Data Out from TRF7960)

Connector P2/RF2

Pin #	Signal Name	Description
1	n/c	
2	n/c	
3	n/c	
4	n/c	
5	n/c	
6	n/c	
7	+3.3VDC IN	+VDC in (to TPS61222DCKT for generation of +5VDC)
8	n/c	
9	+3.3VDC IN	+VDC in (to TPS61222DCKT for generation of +5VDC)
10	n/c	
11	n/c	
12	n/c	
13	n/c	
14	n/c	
15	n/c	
16	n/c	
17	n/c	
18	ASK/OOK	Direct mode, selection between ASK and OOK modulation (0 = ASK, 1 = OOK) Also can be configured to provide the received analog signal output (ANA_OUT)
19	n/c	
20	n/c	

6. TRF79x0ATB Module Schematic



Note:
This schematic drives two separate layouts.
(TRF7960ATB.brd and TRF7970ATB.brd) the only difference is the bottom side silkscreen.

7. MSP-EXP430F5438 Experimenters Board

The MSP430F5438 Experimenter Board (MSP-EXP430F5438) is a development platform for the latest generation MSP430 MCUs. It features a 100-pin socket which supports the MSP430F5438 (datasheet) and other devices with similar pinouts. The socket allows for quick upgrades to newer devices or quick applications changes. It is also compatible with many TI low-power RF wireless evaluation modules such as the CC2520EMK and the TRF79x0ATB module discussed here in this document.

The Experimenter Board helps designers quickly learn and develop using the new F5xx MCUs, which provide the industry's lowest active power consumption, more memory and leading integration for applications such as energy harvesting, wireless sensing and automatic metering infrastructure (AMI).

A TI Flash Emulation Tool, like the MSP-FET430UIF, is required to program and debug the MSP430 devices on the experimenter board.

The TRF79x0ATB module plugs into the RF1 and RF2 headers on this MSP-EXP board (see Figure 3). For logic analyzer connection during firmware debug, user can use test points on TRF79x0ATB board or pins on header RF3.

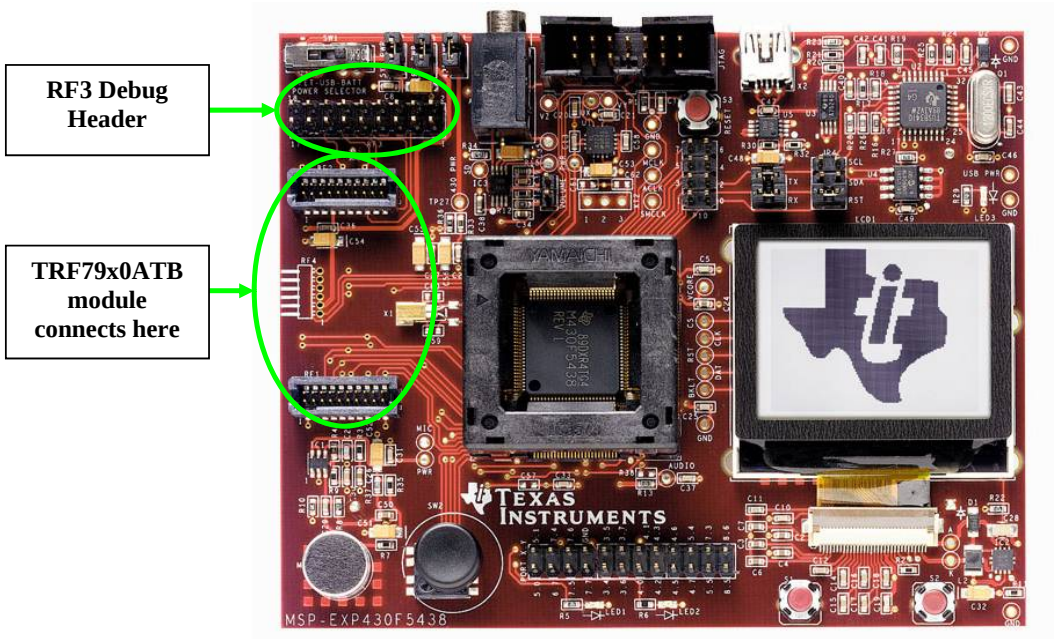


Figure 3: MSP-EXP430F5438 Development Board

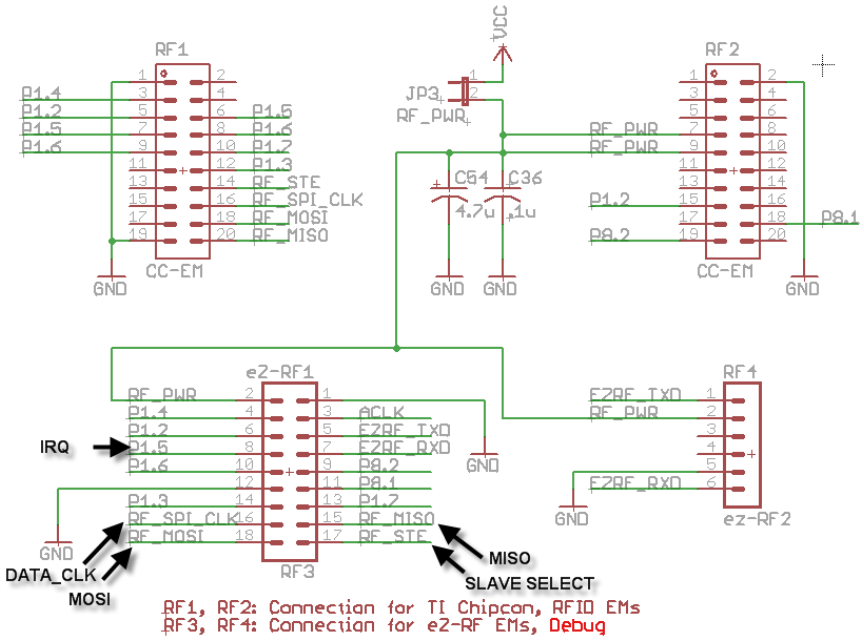


Figure 4: Debug Header (RF3) Logic Analyzer Connections for Monitoring SPI communications between MSP430F5438A and TRF79x0A on TRF79x0ATB module

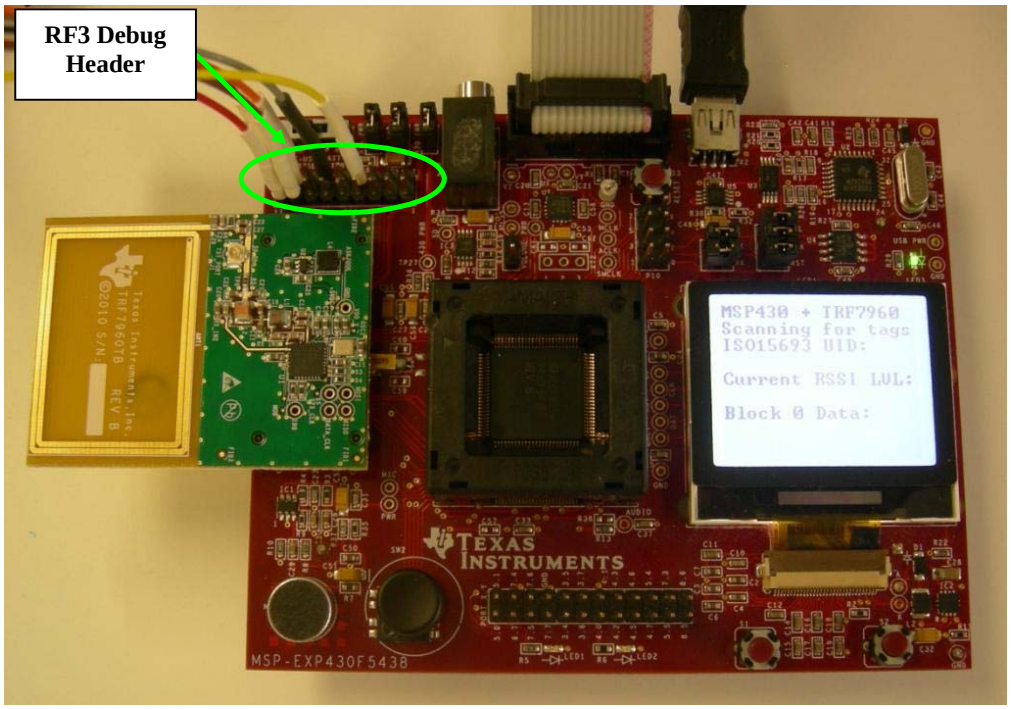


Figure 5: Firmware Development\Debug Setup for MSP-EXP430F5438 Experimenters Board

8. DK-LM3S9B96-EM2-TRF7960R ARM Cortex M-3 Development Board

The Stellaris DK-LM3S9B96-EM2-TRF7960R Development Kit provides a feature-rich development platform for Ethernet, USB OTG/Host/Device, and CAN enabled Stellaris ARM® Cortex™-M3-based microcontrollers. Each board has an In-Circuit Debug Interface (ICDI) that provides hardware debugging functionality not only for the on-board Stellaris devices, but also for any Stellaris microcontroller-based target board. The development kit contains all cables, software, and documentation needed to develop and run applications for Stellaris microcontrollers easily and quickly. The Stellaris DK-LM3S9B96-EM2-TRF7960R Development Kit features: StellarisWare® Peripheral Library, USB Library, and Graphics Library in conjunction with ARM development tools from ARM tools partners. An EPI header to EM header interface board (DK-LM3S9B96-EM2) is needed for use with the TRF7960TB module.

Figure 6: DK-LM3S9B96-EM2-TRF7960R Development Platform

9. Quick Start

1. Plug TRF79x0ATB Module into microcontroller development platform of choice.

Note: if DK-LM3S9B96 board, remove SDRAM module and replace with DK-LM3S9B96-EM2 interface board before attempting to mount TRF79x0ATB module.

2. Apply power
3. Load base application firmware specific to platform working with.
4. Test for basic communication and functionality
5. Modify and Debug code as desired for specific application or protocol
6. Test for advanced functionality as implemented by modified code.

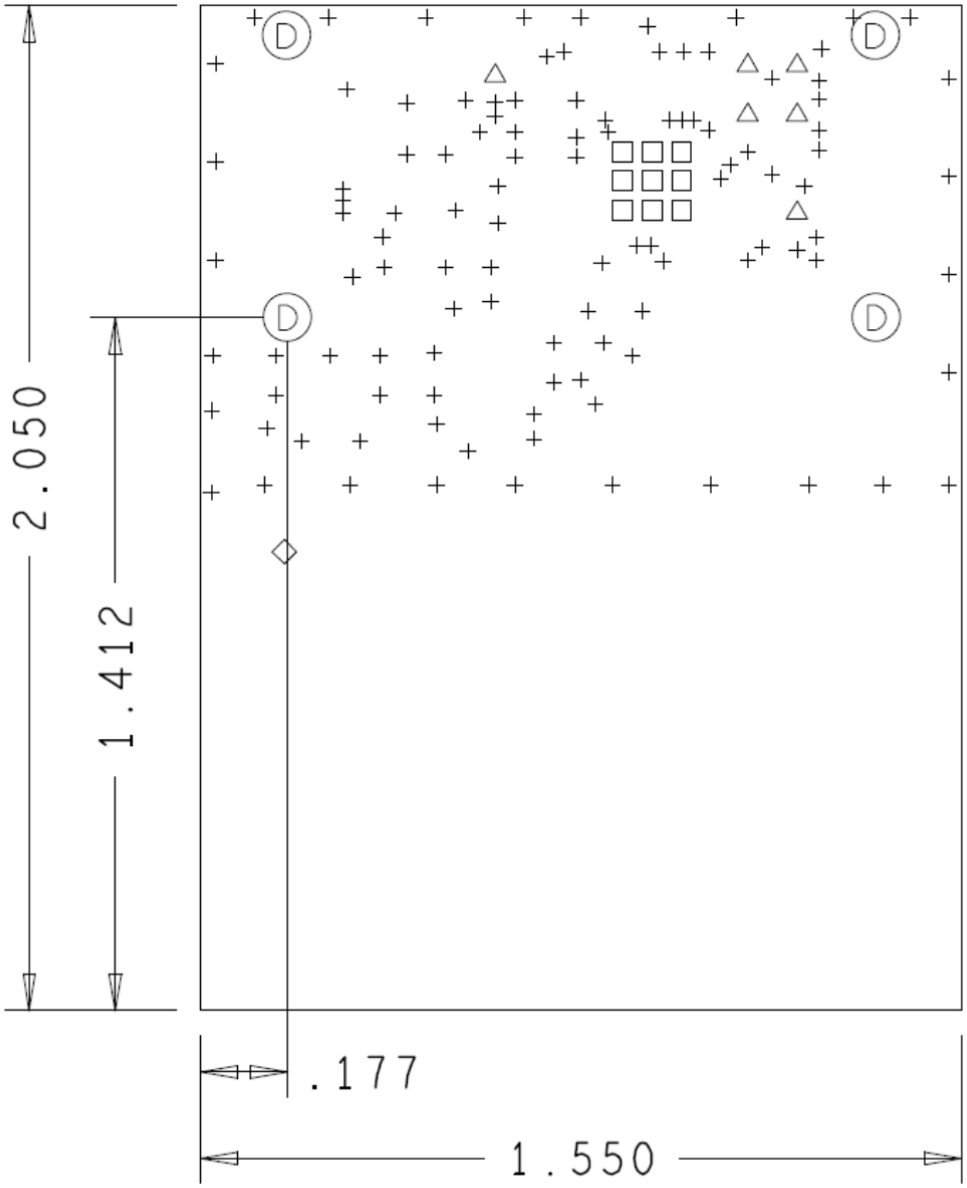
10. Base Application Firmware

TRF79x0ATB Module Base Application Firmware for various Texas Instruments Microcontrollers and Microprocessors is available here:
MSP430F23xx: http://www.ti.com/litv/zip/sloc203 (CCS or IAR)
MSP430F5438A: http://focus.ti.com/docs/toolsw/folders/print/msp-exp430f5438.html
LM3S9B96: http://focus.ti.com/docs/toolsw/folders/print/dk-lm3s9b96.html

11. Platform Specific Details

- DK-LM3S9B96 Platform
  - Mifare Specific Standalone Demo source code available
    - This code demonstrates (on up to two cards at a time) reading, authenticating and interacting with the Blocks and Sectors of Mifare Classic 1k and 4k transponders.
- MSP-EXP430F5438A Experimenters Board
  - Code Example interfaces with standard TRF7960EVM GUI
    - http://www.ti.com/litv/zip/sloc134 (GUI)
    - http://www.ti.com/lit/pdf/slou192 (GUI Users Guide)
  - ISO15693 UID & Block 0 Read/Automatic Product ID Demo
    - This code displays a single ISO15693 UID, RSSI Value & Block 0 Read/Automatic Product ID Demo on the LCD. If more tags are in the field, or a different protocol is desired, it requires use of the TRF7960 PC based GUI to display multiple tags or interact with other protocol based transponders.

12. Mechanical/Physical Information



13. Antenna Tuning Details

Module antenna as shipped is tuned for 50Ω impedance at 13.56MHz. It has a nominal bandwidth of 1.3MHz, which results in a quality factor of approximately 10. Module antenna circuit has a board mounted U.FL connector installed for users that want to experiment with different tuning solutions or disconnect onboard antenna and experiment with antennas of their own design or application. Below are some design/application notes for users to reference if they want to change the antenna Q factor or experiment further on their own in order to serve their particular application directly.

TRF79x0ATB coil antenna tuning details starts with calculations to produce the theoretical values shown below (and based on measurements of antenna coil on Rev B board.) Coil value nominally measures 0.95uH at 13.56MHz and
$X_L = 0.8 + j80.8 = 0.990 \text{ @ } 63.4°$.

To calculate the necessary values required for course resonance tuning and proper Q setting of the antenna, the following formula is used.

$$C_{RES(total)} = \frac{1}{\omega^2 L}$$

where $\omega = 2\pi f$

therefore;

$$C_{RES(total)} = \frac{1}{(2\pi \times 13.56MHz)^2 \times 0.95\mu H}$$

$$C_{RES(total)} = 145.157\,pF$$

The dampening resistor value can now be calculated for a desired Q value using the formula

$$Q = \frac{R_{PAR}}{2\pi fL}$$

therefore;

$$R_{PAR} = 2\pi fLQ$$

For Q = ~20 (ISO15693 operations):

$$R_{PAR} = 1.29k\Omega$$

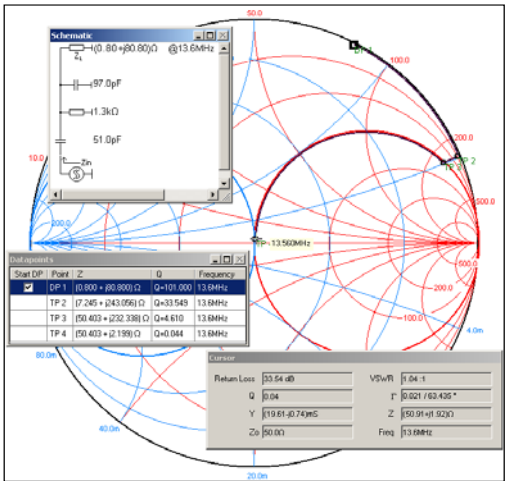
(move to standard value of 1.3kΩ)

For Q = ~10 (ISO14443 and ISO15693 operations):

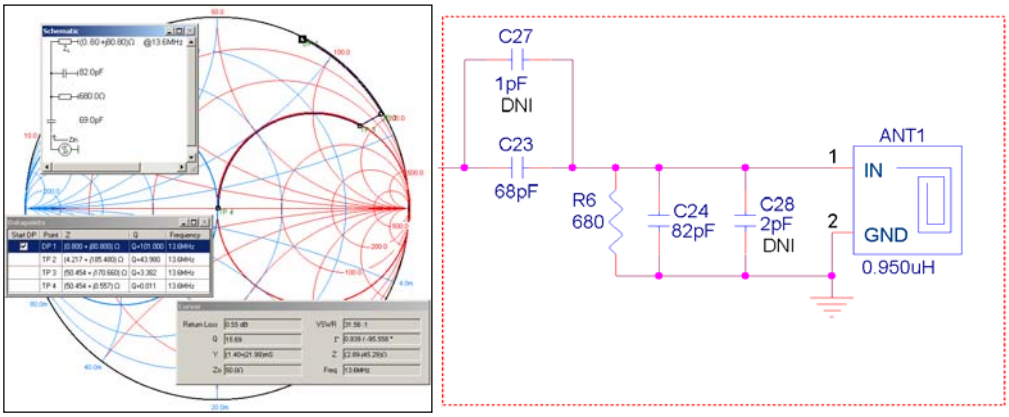
$$R_{PAR} = 647\Omega$$

(move to standard value of 680Ω)

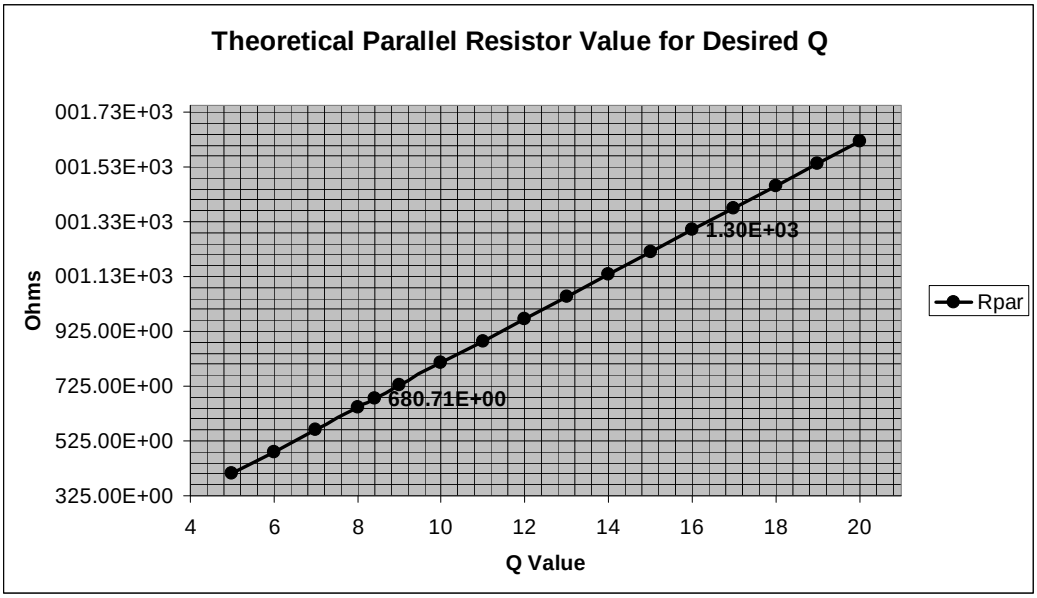
Smith Chart simulation for R_{PAR} value = 1.3kΩ reveals theoretical parallel and series capacitor values capacitor values to be 97pF and 51pF, respectively.
(This is < +2% change from the calculated total cap value.)

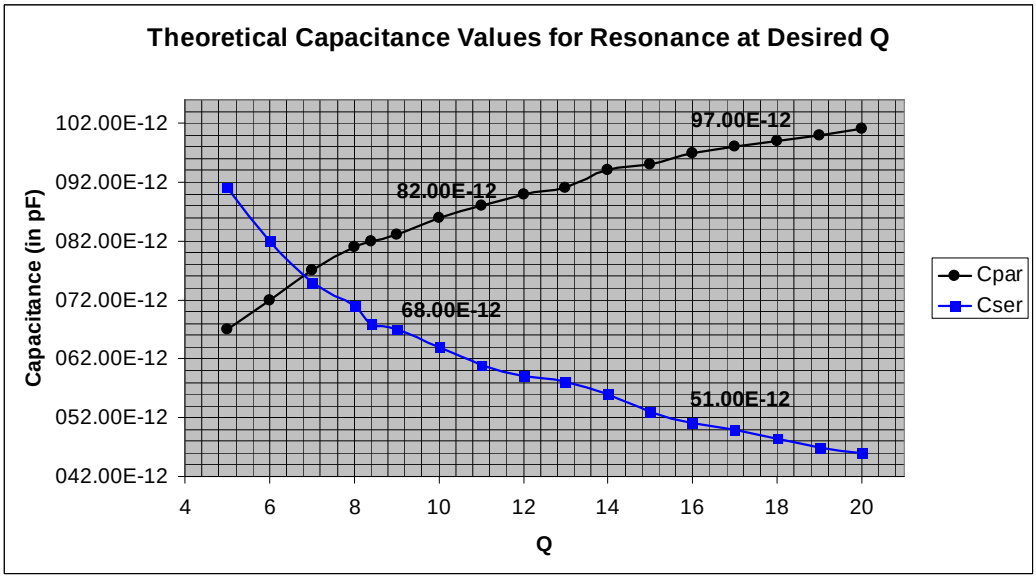


Smith Chart simulation for R_{PAR} value = 680Ω (standard value) reveals theoretical parallel and series capacitor values to be 82pF and 69pF, respectively.
(This is < +4% change from the calculated value.)

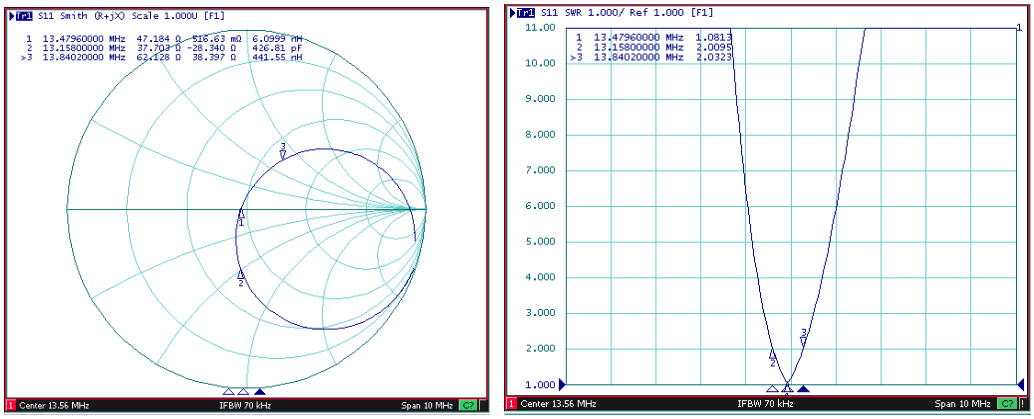


The calculations and simulations for a desired Q range of 5 to 20 results in the following diagrams which indicate the required resistor and capacitance values should be populated.

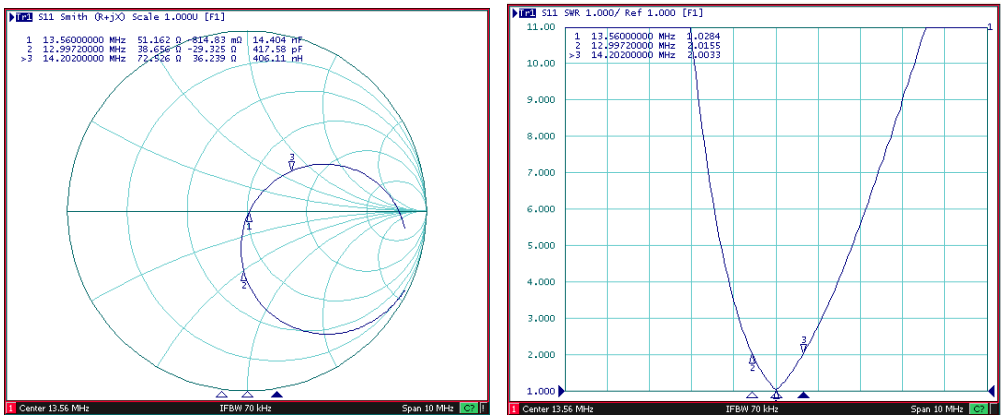




Actual measurements on TRF79x0ATB module for high and lower Q value tuning solutions.

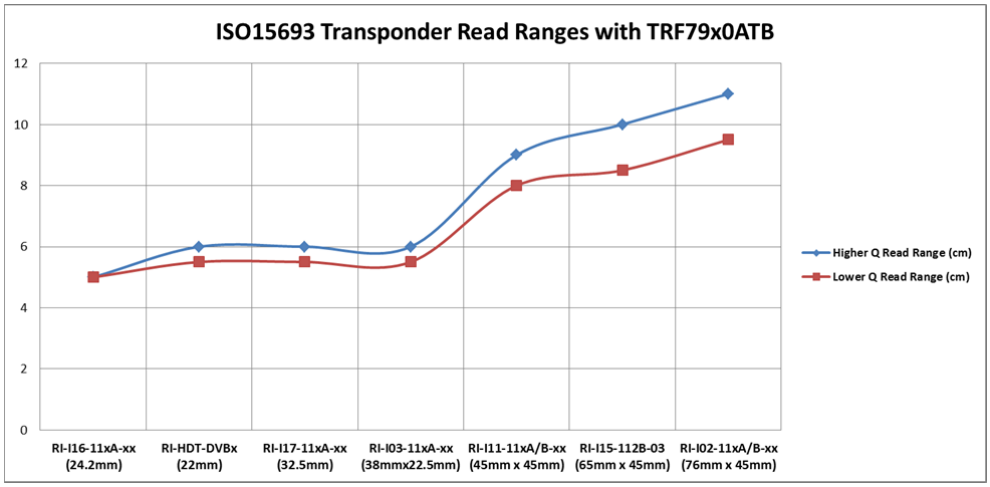


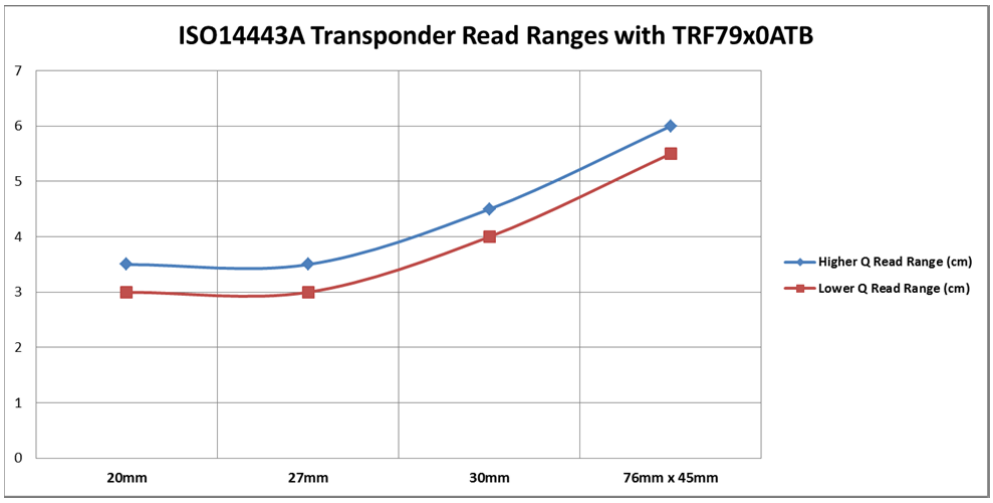
Higher Q Antenna Measurement Plots with Calculated Values (Q = ~20)

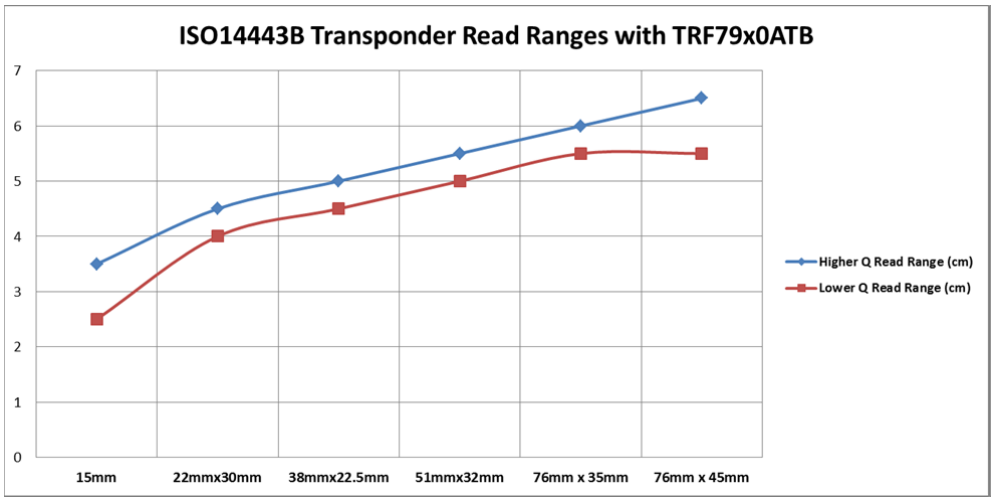


Lower Q Antenna Measurement Plots with Calculated Values (Q = ~10)

14. TRF79x0ATB Module Read Ranges







15. Revision History

Rev.	Version	SCN	Description of Change	Date submitted	By
0	0		New Issue	04/18/2013	Joshua Wyatt

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General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this is strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution
This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices
This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices
This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

Reorient or relocate the receiving antenna.

Increase the separation between the equipment and receiver.

Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

Consult the dealer or an experienced radio/TV technician for help.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.
Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Concerning EVMs including radio transmitters
This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas
Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.
~
Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.
Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

Concernant les EVMs avec appareils radio
Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concernant les EVMs avec antennes détachables
Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la

puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.
Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

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This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan!

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:
(1) Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
(2) Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
(3) Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product.

Also, please do not transfer this product, unless you give the same notice above to the transferee.

Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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東京都新宿区西新宿６丁目２４番１号
西新宿三井ビル
http://www.tij.co.jp

EVALUATION BOARD/KIT/MODULE (EVM)
WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM’s electronic components and packing materials

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60 C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.