

## ***TRF7970A External Power Amplifier***

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### **ABSTRACT**

This document is intended to give a practical example on how to design an external power amplifier based on the TRF7970A Transmitter device.

The specific reference design is EMVco compliant in the described configuration.

The design supports ISO14443A, ISO14443B, and ISO15693 as well as the related NFC/RFID protocols/standards.

The design as shown is not intended to be used for long range ISO15693 applications. In such applications the receiver channel has to use improved filters. An optional improved RX filter circuit example is available on the design.

This application note is based on [Felix Risch's](#) Bachelor work of 2013.

Preliminary

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## 1. Scope

This document is intended to give a practical example on how to design an external power amplifier (PA) based on the TRF7970A NFC/RFID transceiver. The design is primary intended to support the EMVco specifications as well as ISO14443A, ISO14443B, ISO15693, NFC and other standards referring to them. The current implementation is not optimized to give the full reading range performance for the ISO standards given above.

The key feature of this design is the support of the 100% modulation as well as the implementation of the 10% modulation depth from the Reader to Tag communication as used in ISO14443B and ISO15693 and the capability to pass the [EMVco](#) L1 Analog specification in the defined configuration.

The current document shows the design of a standalone power amplifier module. At the board an antenna connector for the use of external antennas and Test Points (TP) for fast access to all necessary signals are available.

An interface connector is also available with all necessary signals for the connection to the micro controller board. This external micro controller required to control the TRF7970A and the external amplifier circuit.

An optional RX circuit is included in the circuit concept with optimized filter characteristics for higher sensitivity. Any other concept to further improve the sensitivity can be used.

To simplify the tests procedure, the standard TI TRF7970A EVM with some modifications can be used to control the PA (<http://www.ti.com/tool/trf7970aevm>).

The FW in the TI TRF7970A EVM to control the PA, is the same used in the standard version on the EVM ([www.ti.com/litv/zip/sloc250](http://www.ti.com/litv/zip/sloc250))

## 2. Hardware Descriptions:

### TRF7970A

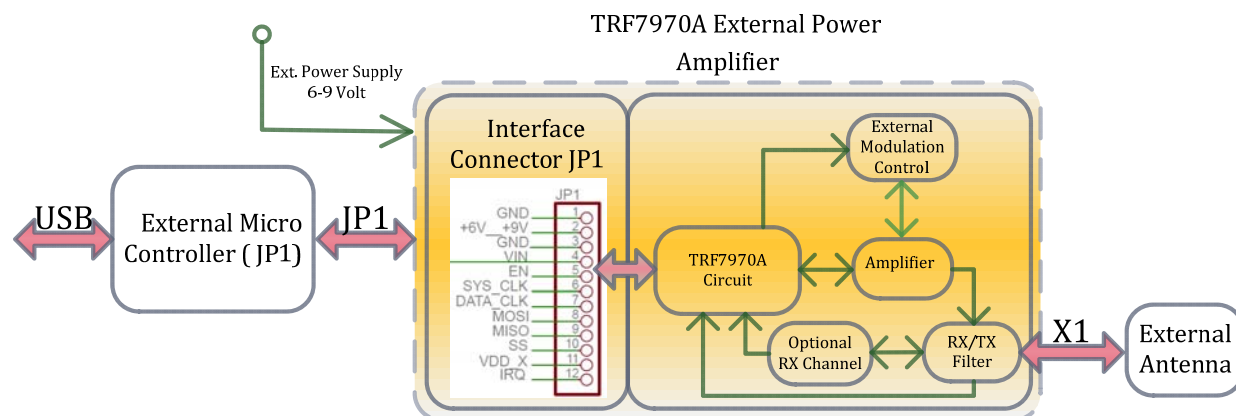
Detailed information can be found in <http://www.ti.com/product/trf7970a>

### TRF7970A EVM

Detailed information can be found in <http://www.ti.com/tool/trf7970aevm>

### 3. TRF7970A Power Amplifier Design

#### 3.1. Block Diagram



The TRF7970A external Power Amplifier (PA) board contains the TRF7970A IC circuit and the analog modules required for the PA functionality. The PA board is a standalone analog board including the TRF7970A and all the discrete circuitry required as well as an interface connector to the external control board. The concept having no micro controller (uC) on the PA board, keeps the PA design independent from the uC family intended to be used in the application. An external uC module with the control FW has to be connected to the PA board over the interface connector JP1. The communication mode between TRF7970A (on the PA board) and the external uC is SPI with slave select. For the high power generation of the PA, an external power supply is needed to supply the amplifier part with higher voltage.

#### Interface Connector (JP1):

The board provides an interface connector (JP1) to be connected to a micro controller (uC) module and the external power supply. The SPI interface is used for the communication between the TRF7970A and the uC.

#### External Antenna:

An external antenna has to be connected to the connector (X1). The antenna parameters are defined in chapter 4.

#### TRF7970A Circuit:

This part of the PA, implements the basic circuit of the TRF7970A as defined in the datasheet (*TRF7970A Data Sheet* (SLOS743)).

#### RX/TX Filter:

This filter circuit is used for impedance matching between the Class E amplifier output and the antenna impedance. Further the circuit filters the relevant signal components for the communication and eliminate unwanted spurious emission. The RX filter is kept very simple as the read range is sufficient for the EMVco compliance. For improved read range performance an improved circuit is needed in the RX channel.

#### Optional RX Channel:

To achieve higher read range, the RX filter characteristics have to be improved. The filter characteristics depend on the requirements, antenna parameters and output power. An example of an improved filter is given in this part of the circuit.

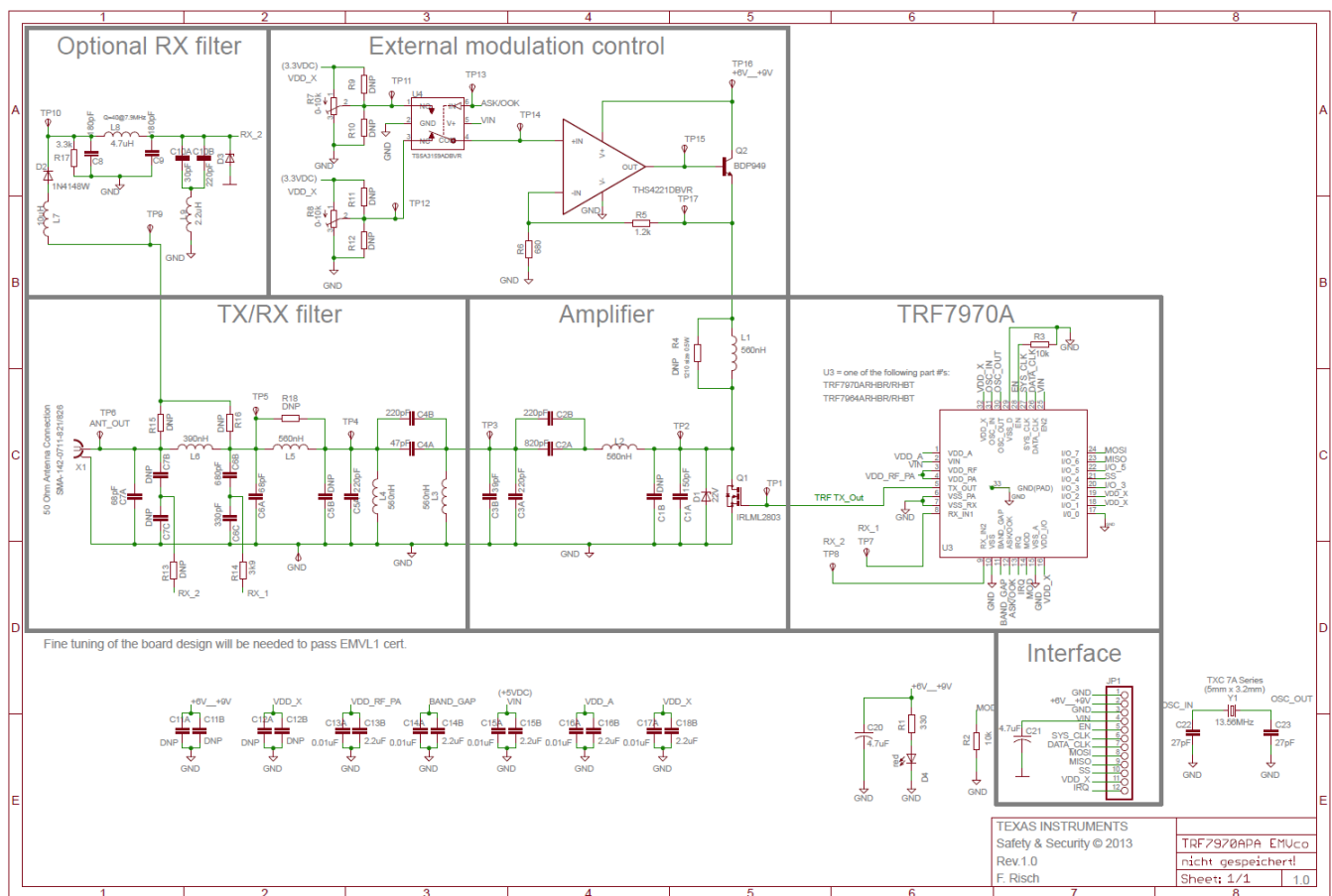
#### Amplifier

This part of the circuit shows the amplifier circuit. It is based on a Class E amplifier with additional components for impedance matching between TRF7970A output and RF/TF filter input.

### External Modulation Control:

This part of the circuit shows a possible solution to generate a 10% modulation signal using an external circuit. Based on Class E amplifier concept, this circuit is needed to vary the supply voltage at the transistor to generate the different output levels and consequently a modulation. The modulation depth can be adjusted using R7. For the 100% modulation the circuit is not used, but the modulation is done directly over the TX out of the TRF7970A.

## 3.2. Schematics



**Figure 1: TRF7970A Reference Power Amplifier Circuit**

Figure 1 shows the schematic of the external reference PA circuit. The reference design is optimized to cover the EMVco requirements in combination with the reference antenna. In case of using different antenna parameters and form factors, some parts of the design have to be adjusted to comply with the EMVco test specification.

### 3.3. Board / Layout

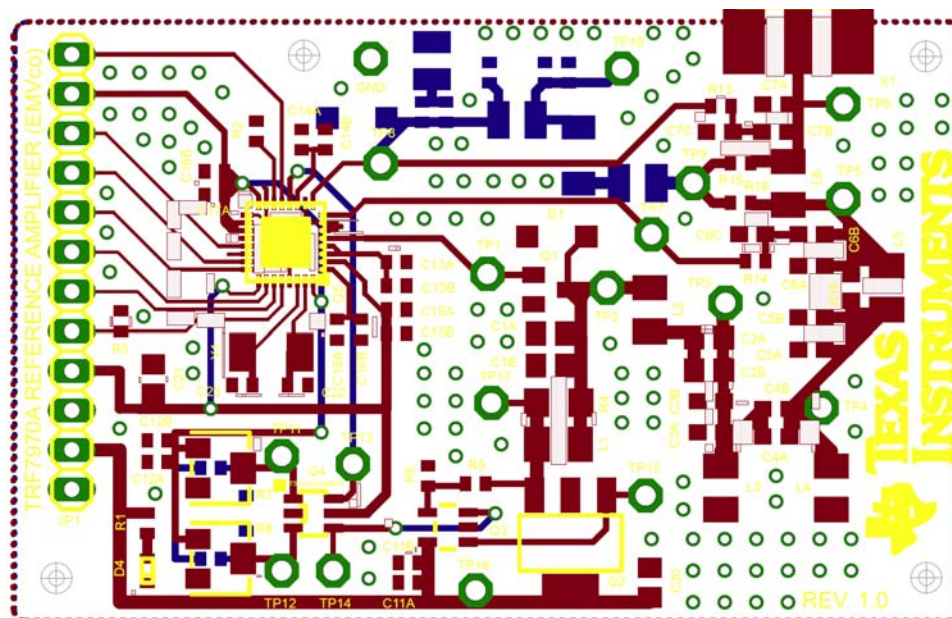


Figure 2: TRF7970A Reference Power Amplifier Layout

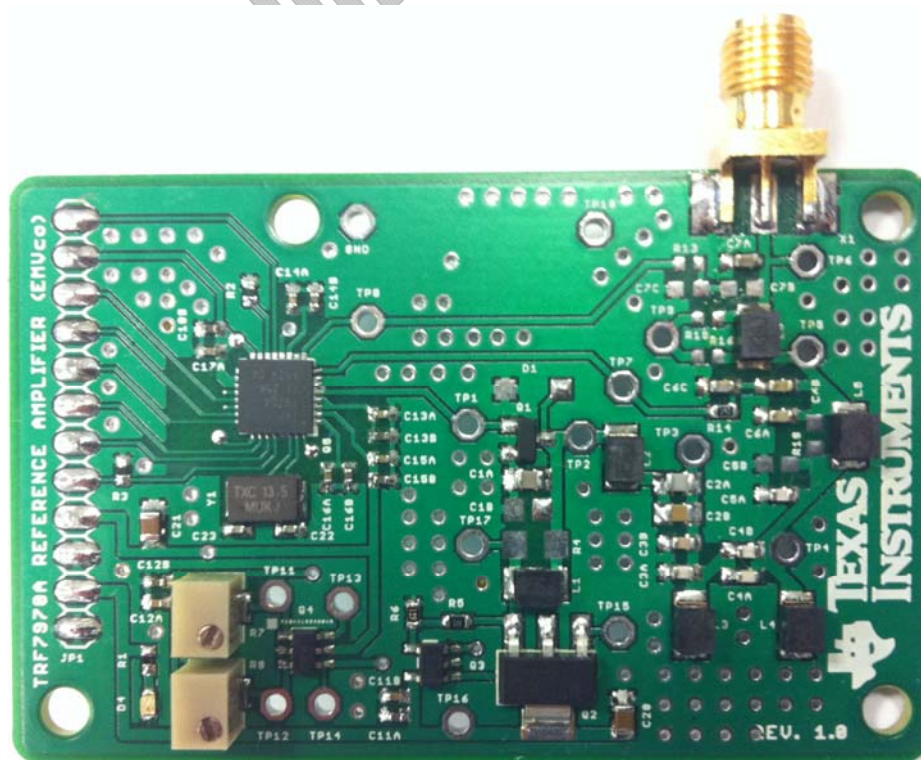


Figure 3: TRF7970A Reference Power Amplifier Board



# TX/RX Filter

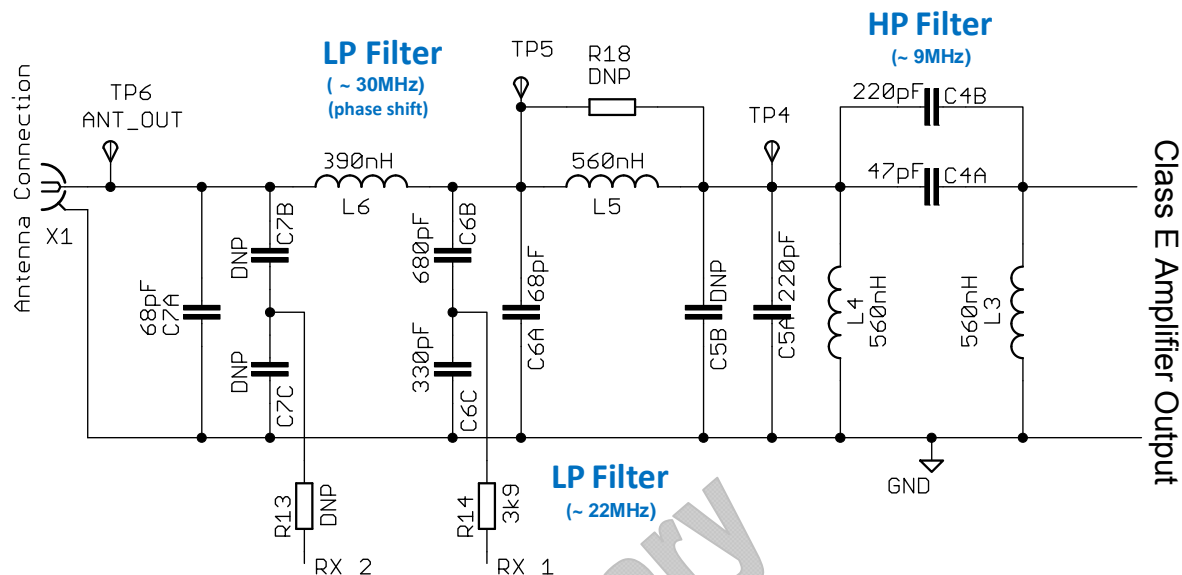


Figure 5: RX/TX Circuit

It is recommended to keep the defined component values of the filter as given and possible variation due to parasitic, tolerances etc., to be compensated by the antenna and Class E amplifier. The imaginary part of the impedance ( jxxx value) has to be compensated by antenna matching and Class E resonance circuit for proper Class E signal shape.

The complete filter is matched to  $Z_{in} = (45 + j7)$  input and  $Z_{out} = (57 - j3)$  output impedance at 13.56MHz.

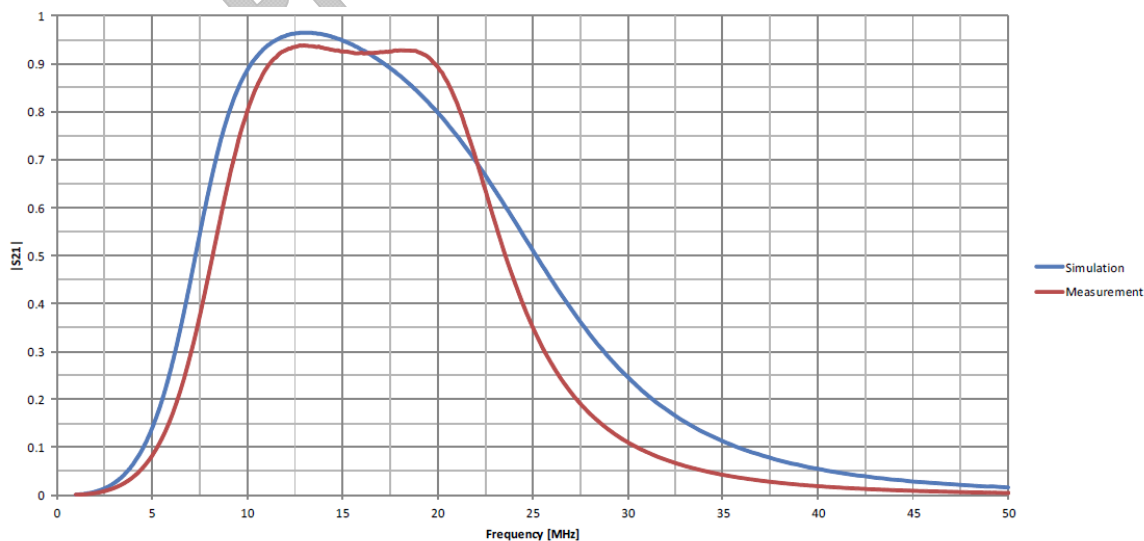


Figure 6: RX/TX Filter Characteristic (stand alone |s21|)

### 3.4.3. Class E Power Amplifier / Adjustment

This part of the circuit is supplied by an external power supply with up to 9V<sup>1</sup>. A class E amplifier generates a RF output power of about 1W (about 20Vpp at TP03). The circuit generates the impedance transformation from 4  $\Omega$  (TRF7970A TX out) to 50  $\Omega$  (TP03) and signal amplification. The components C1/C2/L2 are used for the matching and resonance frequency of the circuit. The curve shape of the Class E part is very important for the operation in view of efficiency and spurious emissions.

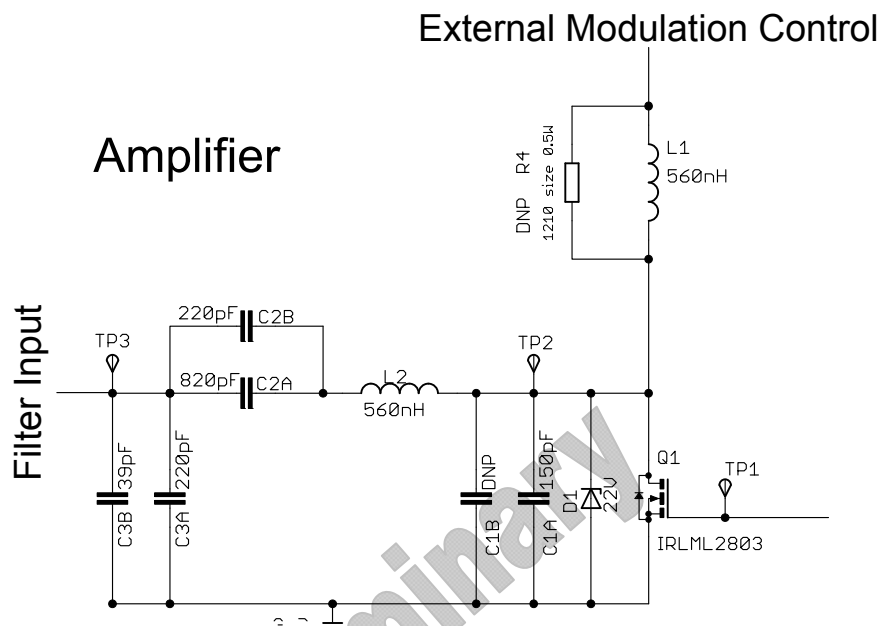


Figure 7: Class E Amplifier Circuit

To achieve the best efficiency and signal shape, the circuit can be adjusted according to the guidelines given in Figure 8.

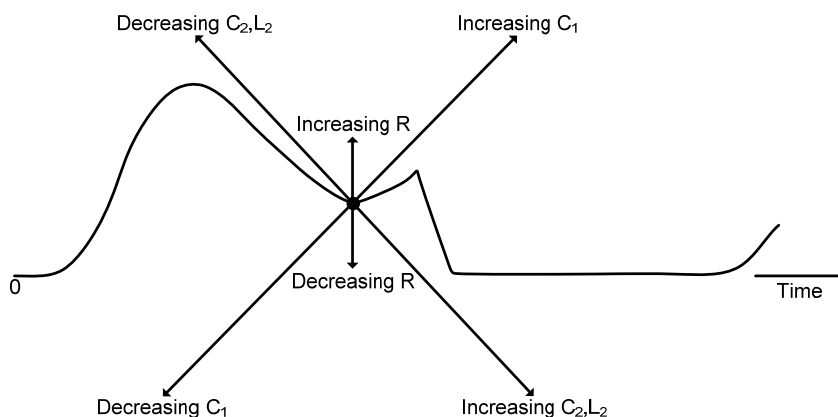


Figure 8: Class E Circuit Adjustment ([Sokal slope](#))

<sup>1</sup> External power supply voltage depending on the MOS transistor parameters

An example of the targeted Class E signal measured at TP2 is shown in Figure 8. For this measurement the RX/TX filter and the antenna are connected.

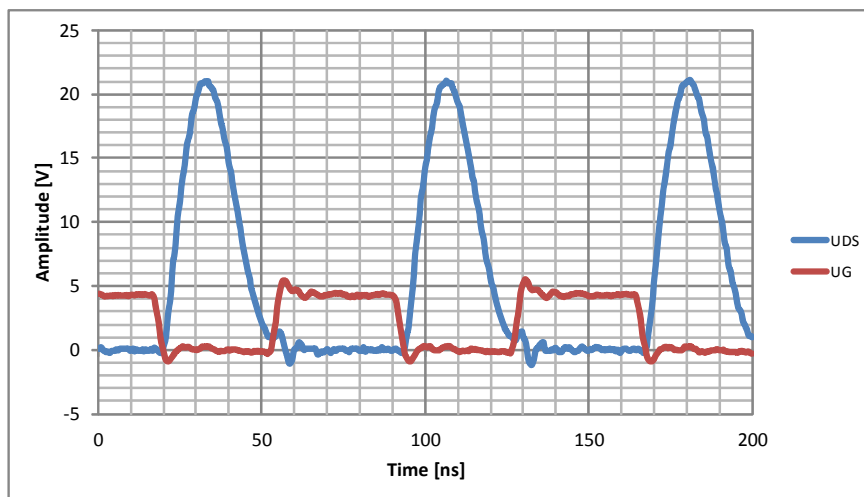


Figure 9: Class E Circuit, Ideal Signal Form at TP2

### 3.4.4. External Modulation Control

The unit acts as a variable voltage regulator and controls the voltage swing of the Class E Amplifier dependent on the ASK/OOK signal and the voltage at R7 used for the modulation depth adjustment. The circuit is used in case of a 10% modulation depth mode (e.g. for ISO14443B protocol).

## External Modulation Control

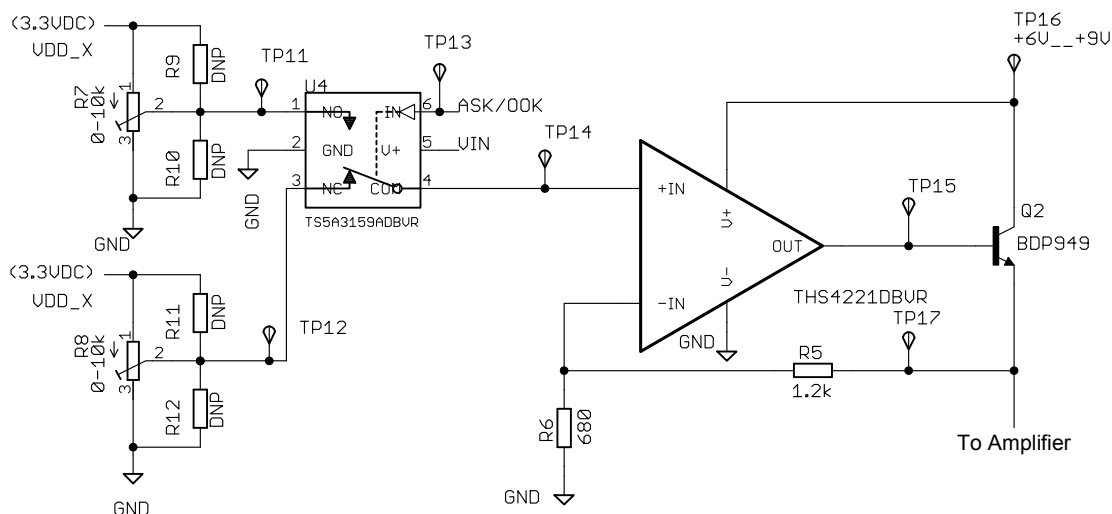


Figure 10: External Modulation Control Circuit

For activation of the external modulation at the TRF, bit 6 "en\_ext\_pa" of the "Regulator and I/O Control unit" (0x0B) must be set to one, which activates the ASK/OOK pin as a digital modulation output. This ASK/OOK signal is fed to the control pin 6 of the TS5A3159 (U4), which is an analog 2:1 multiplexer. At pin 1 and 3 of the TS5A3159, two adjustable voltages are connected.

At pin 3 of the TS5A3159 the voltage is provided for the output power adjustment (fine tuning) and at pin 1 the voltage is provided for the modulation depth adjustment in case of 10% modulation depth mode. In case of unwanted noise over the power supply, these voltages should be filtered (not implemented in the reference design).

The output of the TS5A3159 (pin 4) is connected to the positive input of the rail to rail operation amplifier THS4221 (OPA). Due to the low output current capabilities of the THS4221, a (BJT) bipolar transistor (Q2) in common collector configuration is connected at the output of the THS4221. The reason for using a rail to rail operational amplifier in combination with a BJT (BDP949) is due to the low voltage loss to the Class E amplifier part. The required feedback loop of the OPA is fed from the emitter of the BJT to the negative input to include the BJT in the regulation loop.

The supply voltage of the Class E amplifier is reduced to about  $U_{dd}-0.8V$  using the external modulation control. It is not recommended to adjust the output power using the resistor R8 connected to pin 1 of the TS5A3159, because of unnecessary energy losses. Adjusting the voltage at pin 1 slightly below the point where the output power decreases, an overdriven of the modulation control unit can be avoided (preventing of overshoots). This leads to the improved signal curve shape at the output. The result of this adjustment can be seen in Figure 11.

The result is an individually adjustable modulation depth to comply the ISO14443B specifications.

With this setting the voltage loss is about 1V for the external modulation control.

The final amplifier concept draws a current of 300mA @ 6V.



**Figure 11: Modulation Overshoot Control**

## 4. Antenna

The antenna dimensions are depended on the application. To avoid any modifications on the proposed amplifier and TX/RX filter circuit (3.4.1), the antenna should be designed in a way to provide matching flexibility to compensate the component and board tolerances. This can be achieved by using during the development phase variable capacitors in parallel to C1 and C2 given in Figure 12 to fine tune the output signal (power and shape).

At the current design, a 50 Ohm matching is done at 13.3MHz, as at that frequency, the best performance could be seen in combination with the EMVco test PICC.

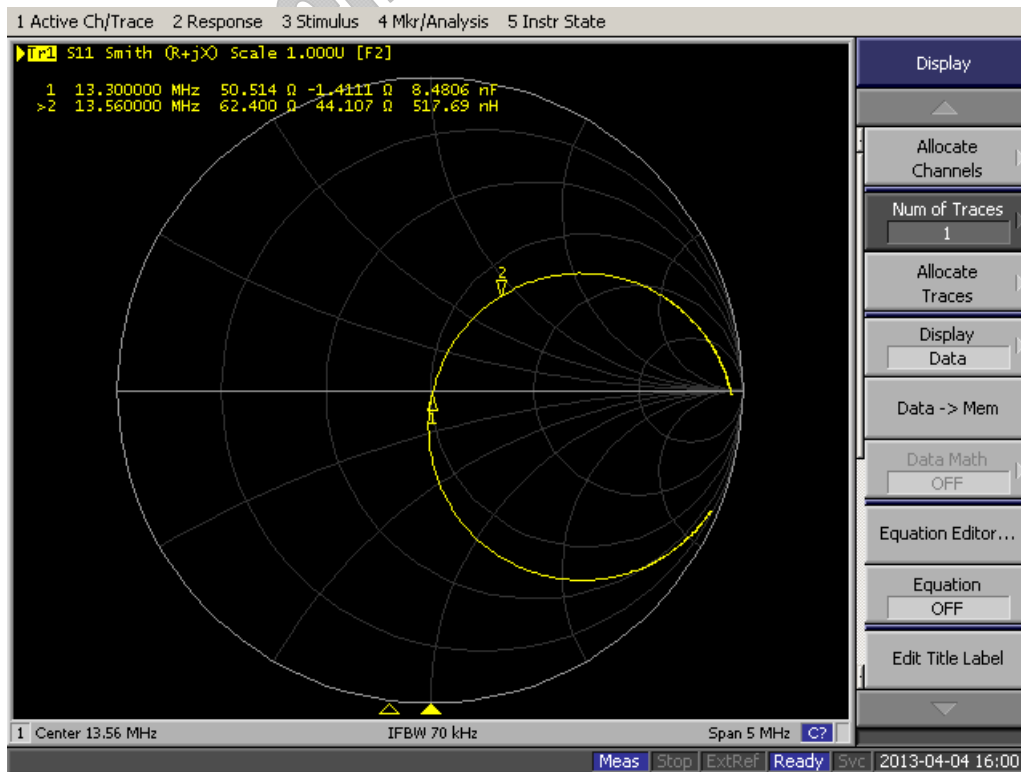
The inductance shall be in the range of about 1uH and <2uH.

The reference antenna parameters are:

- L=1.5uH
- Q~11
- Z=50 Ohm @ fres=13.3MHz
- Operating impedance of Z = (62.4 + j44.1) at 13.56MHz



**Figure 12: Reference Antenna (5x5cm)**



**Figure 13: Antenna Smith Chart Matched to 50 Ohm @13.3MHz**

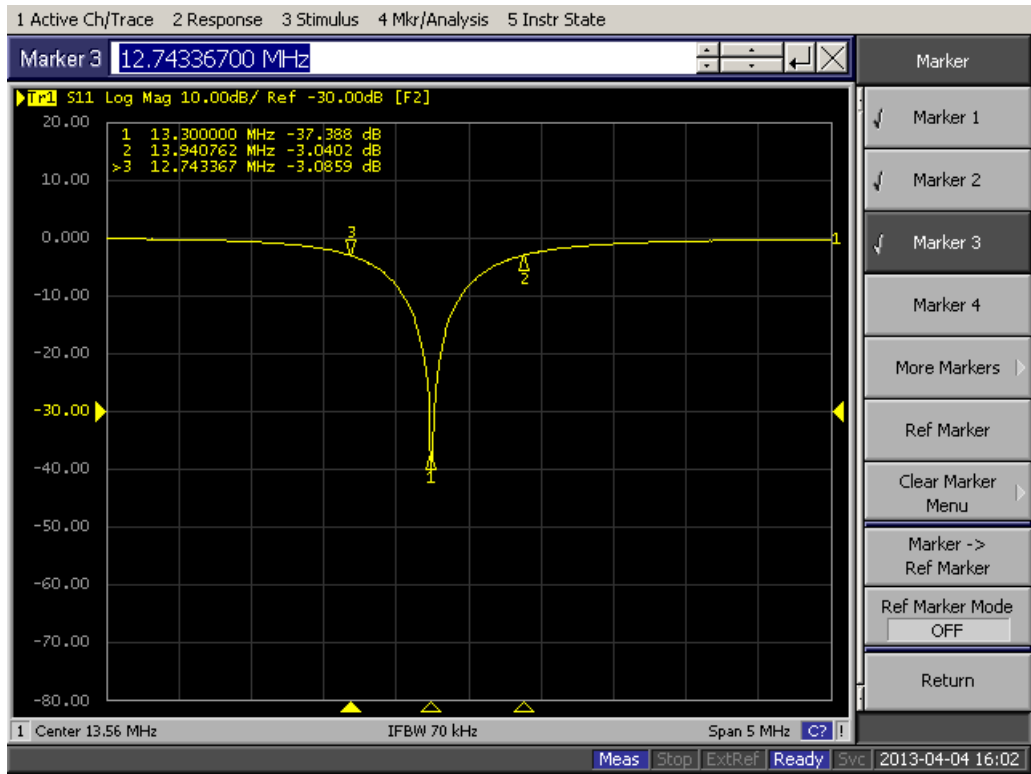


Figure 14: Magnitude Chart for the Antenna Matched to 50 Ohm @13.3MHz

## 5. TRF7970A EVM Modifications

A fast way to test the reference PA design, the TRF7970A EVM can be used as control module. In that case, some modifications have to be done on the board and the relevant signals from the TRF7970A EVM need to be connected to the Interface JP1 on the PA board.

The TRF7970A EVM is used as a uC board after these modifications.  
On the TRF7970A EVM the same FW can be used.

The modifications on the TRF7970A EVM are as follows:

1. Remove TRF7960A from Board (Optional: Remove C1-26, Y1, L1,L2, R2-6)
2. Remove all Jumpers from HDR\_4,5,6
3. At HDR\_7: Move Jumper from "I/O-Select" – "PARALLEL" to "I/O-Select" – "SPI"
4. EN must be tapped from R24
5. The supply voltage VDD\_X (3.3V) for the MSP430 from the Power Amplifier Board must be connected at C30/C31

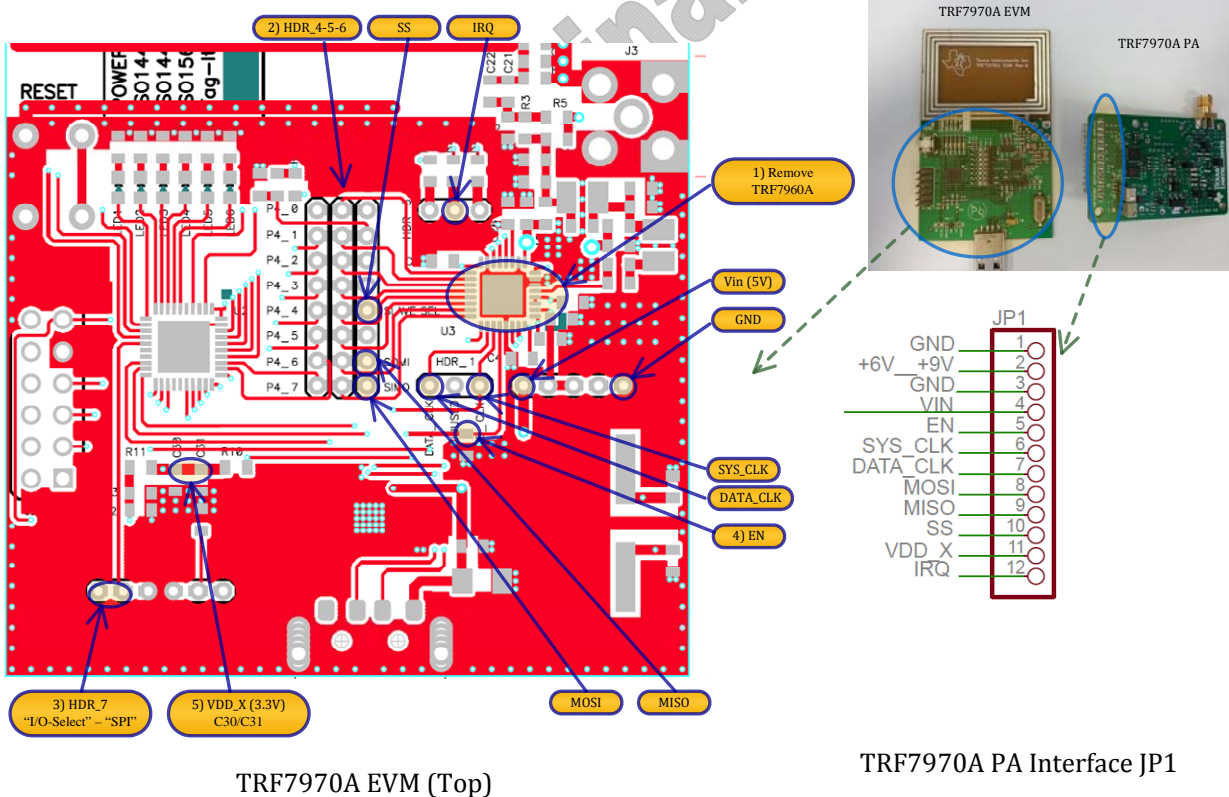


Figure 15: TRF7970A EVM Modifications (Top)

An alternative Control Module to be used with the PA can be found in ANNEX 9.1

## 6. Signal Analysis

Several test points (TP) have been included into the design. These TPs simplify the signal observation and adjustments during the development phase. A short explanation of the TPs and the expected signal form is shown below.

### 6.1. Test point definition

TP1	TX-Out signal from TRF7970A
TP2	Amplifier signal (UDS)
TP3	Class E Amplifier Out
TP4	Signal after HP filter
TP5	Signal after LP filter
TP6	Amplifier OUT, (signal at antenna connector)
TP7	RX_1 signal input @ TRF7970
TP8	RX_2 signal input @ TRF7970
TP9	Optional RX channel Input (same as TP5 or TP6 depending on the jumper setting)
TP10	Signal after RX channel rectifier
TP11	Amplifier power control voltage (fine-tuning for shape adjustment) PA supply voltage
TP12	Modulation depth voltage
TP13	ASK/OOK Signal from TRF7970A
TP14	Multiplexer output voltage
TP15	OPA output voltage
TP16	Amplifier supply voltage
TP17	Output External modulation control circuit.

## 6.2. Test Point signal overview

Test setup:

- Instead of the antenna a 50 Ohm load is used at antenna out.
- Supply voltage 6V (JP1 pin 2)
- Start GUI with continuous REQA
- Channel 1 is connected to TP13 and is used as trigger

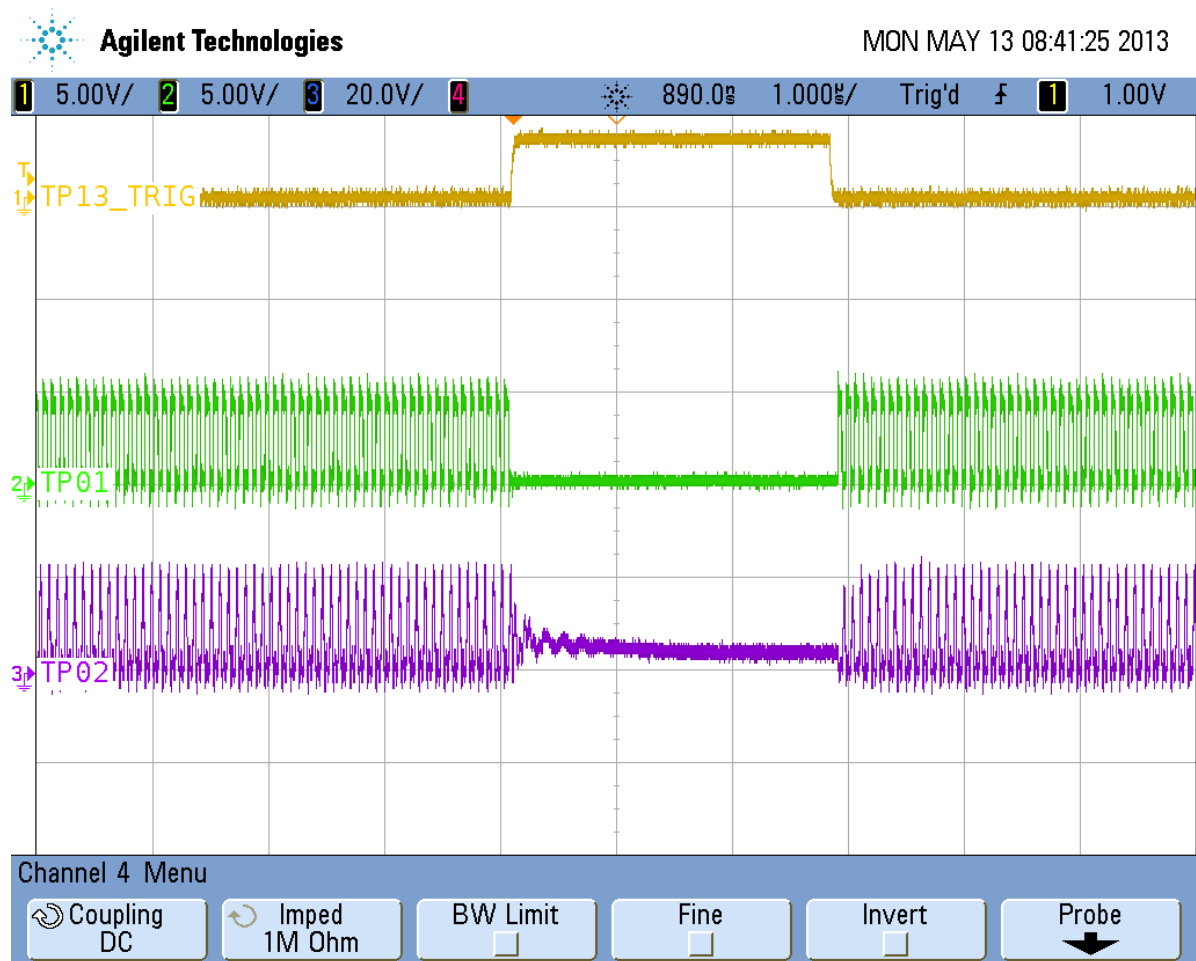
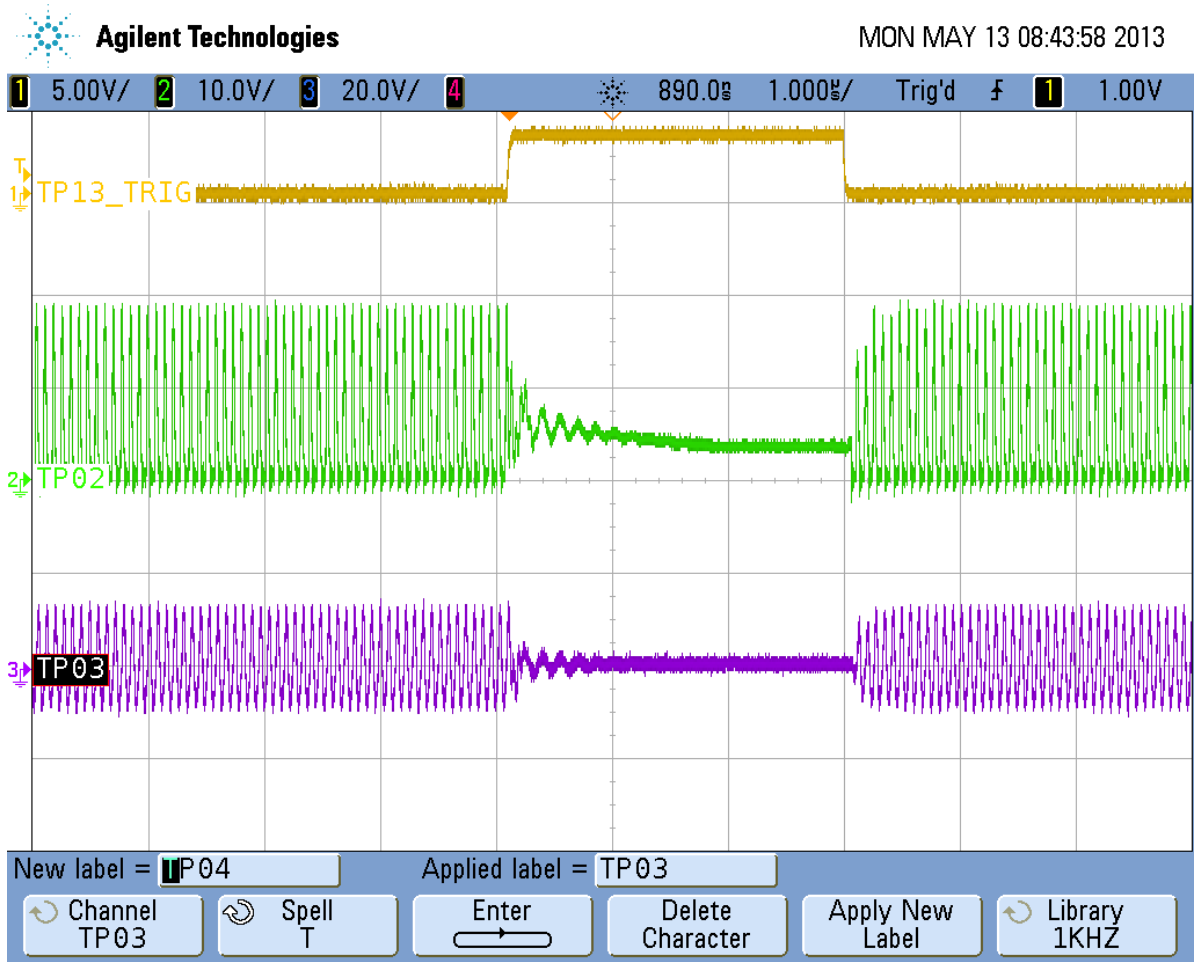


Figure 16: TP01 and TP02 Signal overview



**Figure 17: TP02 and TP03**

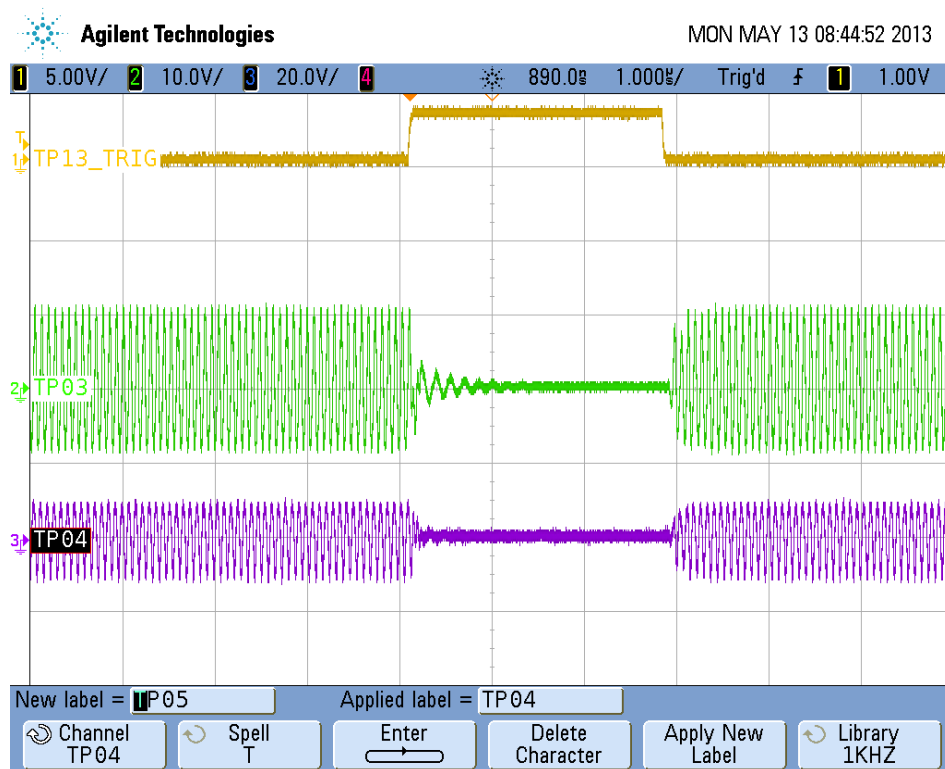


Figure 18: TP03 and TP04

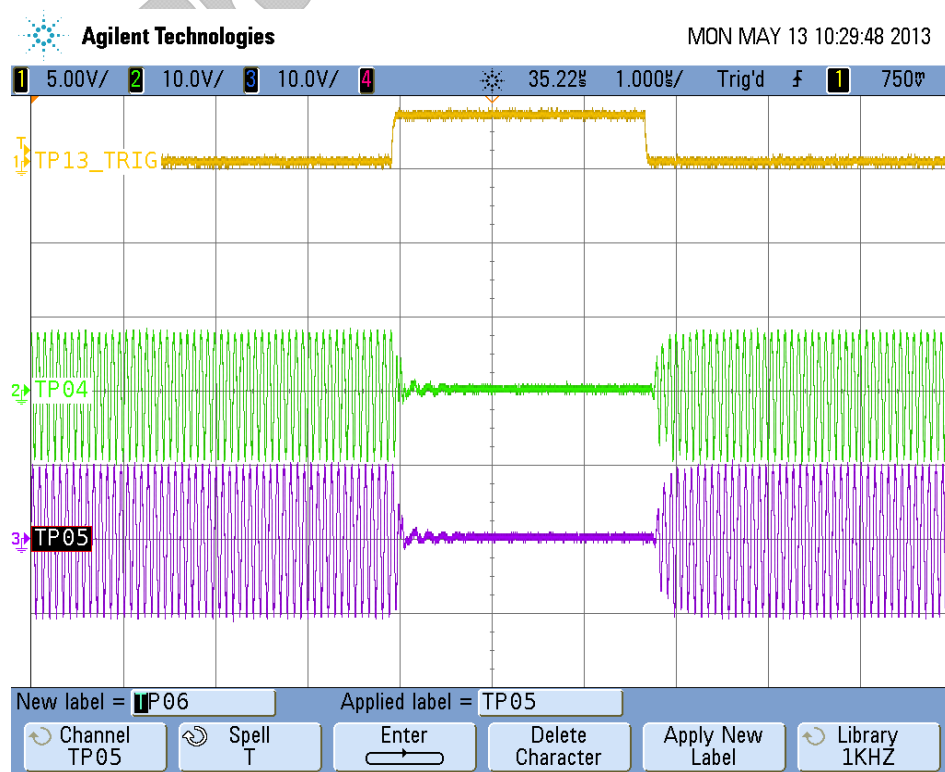


Figure 19: TP04 and TP05

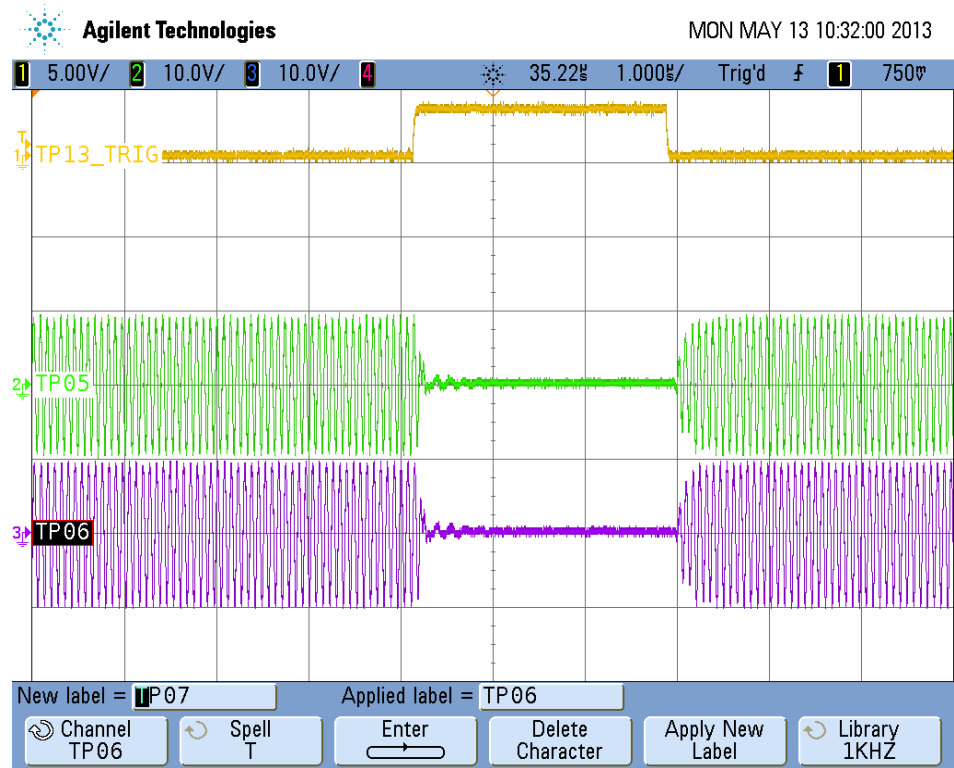


Figure 20: TP05 and TP06

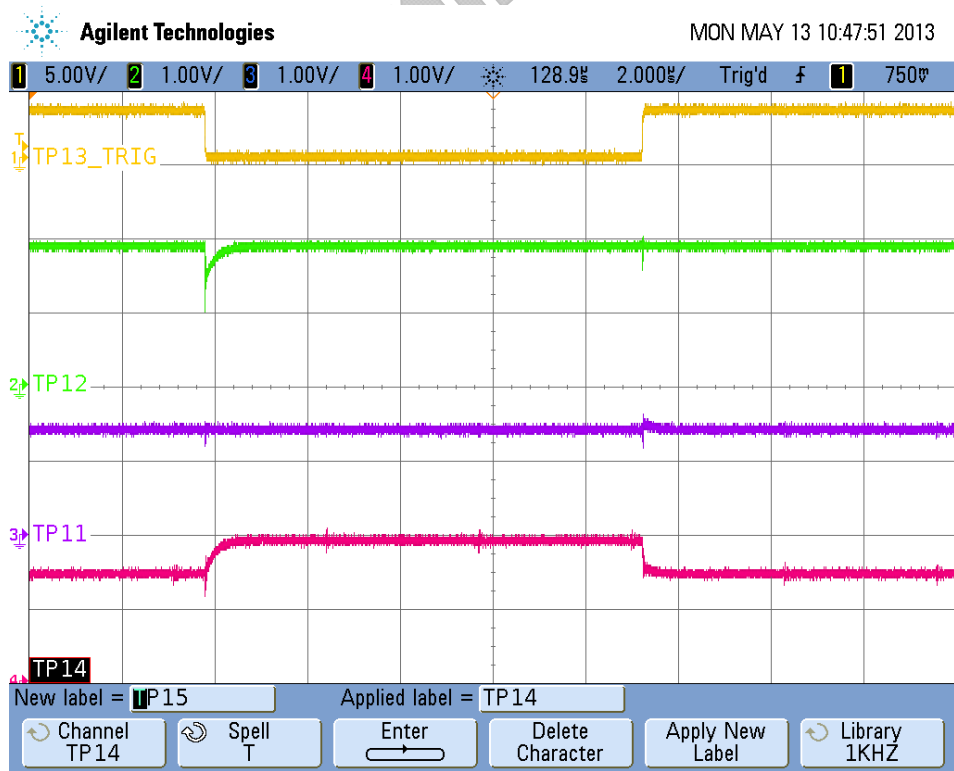


Figure 21: Multiplexer TP11 to TP14

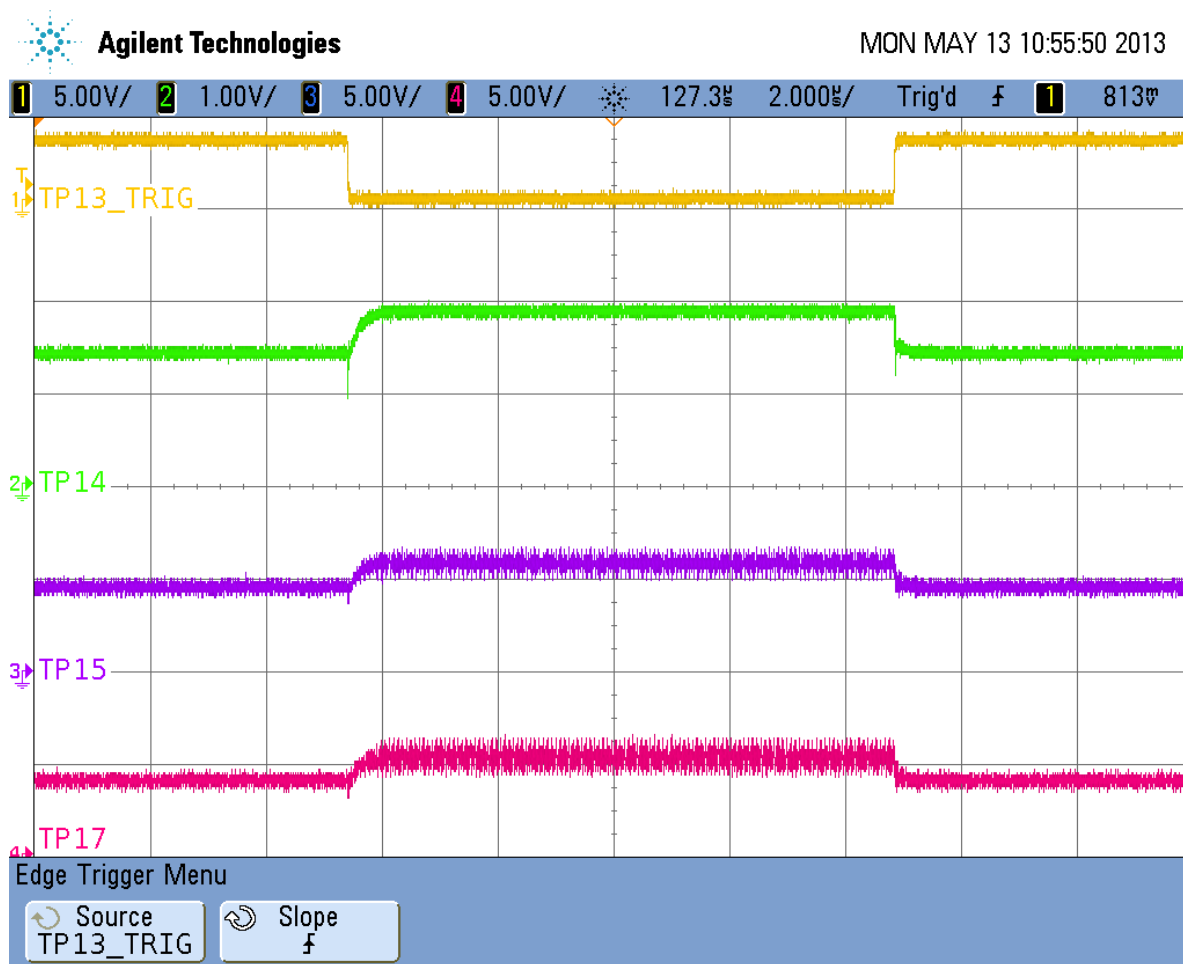


Figure 22: OPA TP14, TP15 and TP17

## 7. EMVco L1 Test

### 7.1. TRF7970A Power Amplifier Parameters/Settings

Micro Controller FW: The same FW can be used on the MSP430 uC.

USB: The TRF7970A EVM is connected over USB to the PC.

GUI: is not available at this moment.

The TRF7970A must be configured as follows:

- 5V operation Reg. 0x00, b0=1

- Full power Reg. 0x00, b4=0

- External PA, Reg. 0x0B, b6=1

External Operating Voltage: 6V

Current consumption: 260mA (for the current setup)

For 100% modulation tests the command REQA/WUPA must be used.

For 10% modulation tests the command REQB/WUPB must be used

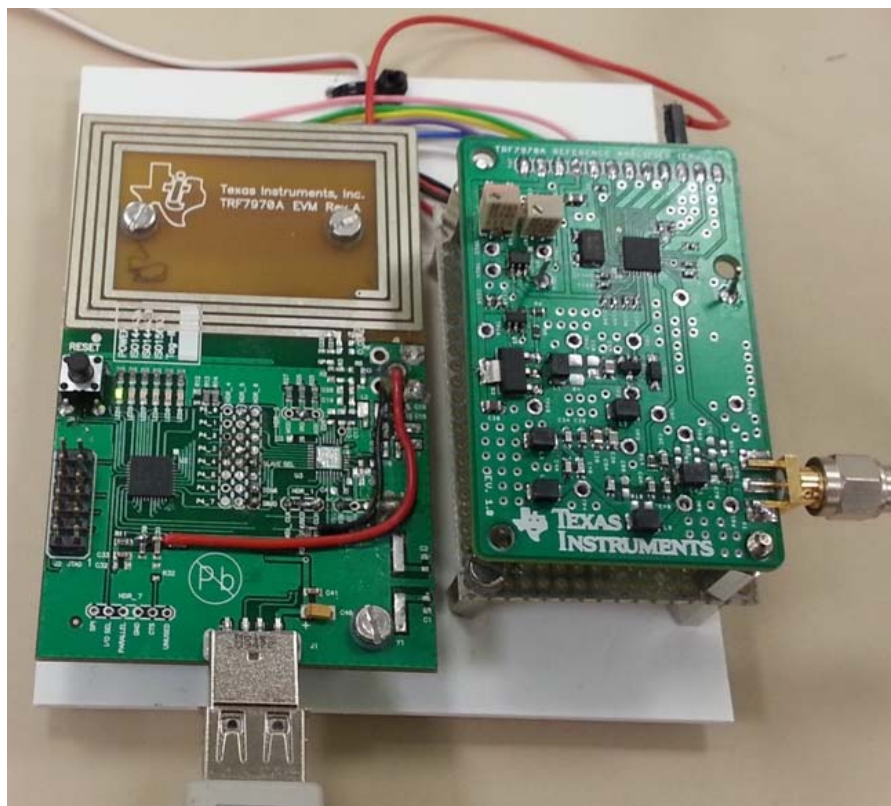


Figure 23: TRF7970A Reader with Power Amplifier and TRF7970A EVM

### 7.2. Antenna parameters

Antenna: 5x5 cm rectangular see paragraph 4.

### 7.3. EMVco L1 Analog Test Setup

A mechanical lab setup is used for the operating volume and signal shape test, as defined in the EMVco specification.

The test PICC is used as defined by EMVco specification



**Figure 24: EMVco Test Setup**

Detailed description of the EMVco test definition and procedures can be found on the EMVco web page <http://www.emvco.com/specifications.aspx?id=21> Book D.

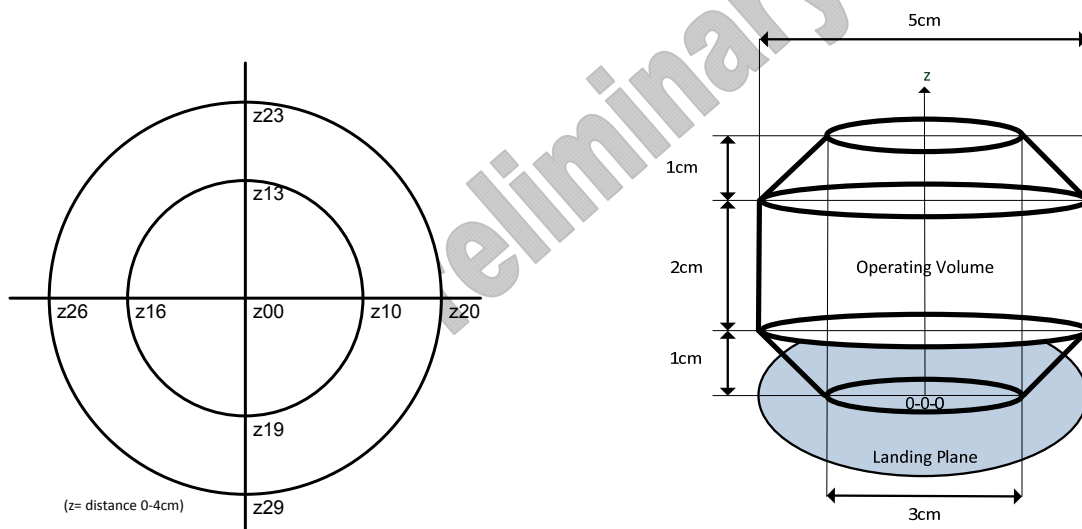
### 7.4. Operating Volume Results

Operating volume is one of the most critical test as it is directly related to the analog circuit properties. In these test, the induced voltage into the test PICC is measured at pre-defined positions (Figure 25). Under the given output power, it is not allowed to exceed a certain induced voltage level at close distance, but induce a min level at far distance positions. The most critical positions are considered to be at  $z=0\text{cm}$  and  $z=4\text{cm}$ .

Typical test results at some critical positions within the operating volume are given below.

Position []	Voltage @ PICC [V]
419	2.7
400	3.0
019	7.8
000	7.2

**Table 1: Voltage at PICC in critical Operating Volume position**



**Figure 25: EMVco Defined Operating Volume**

### 7.5. Modulation Depth

For the 100% modulation depth, no adjustments are required. Only in case of overshoot at rising edge, the trimmer R8 shall be used to flatten the signal shape at the rising edge (see 3.4.4).

For 10% modulation, the trimmer R7 shall be used to adjust the modulation depth. The modulation depth can be calculated using the EMVco test PICC at 0-4 cm distance at centered position.

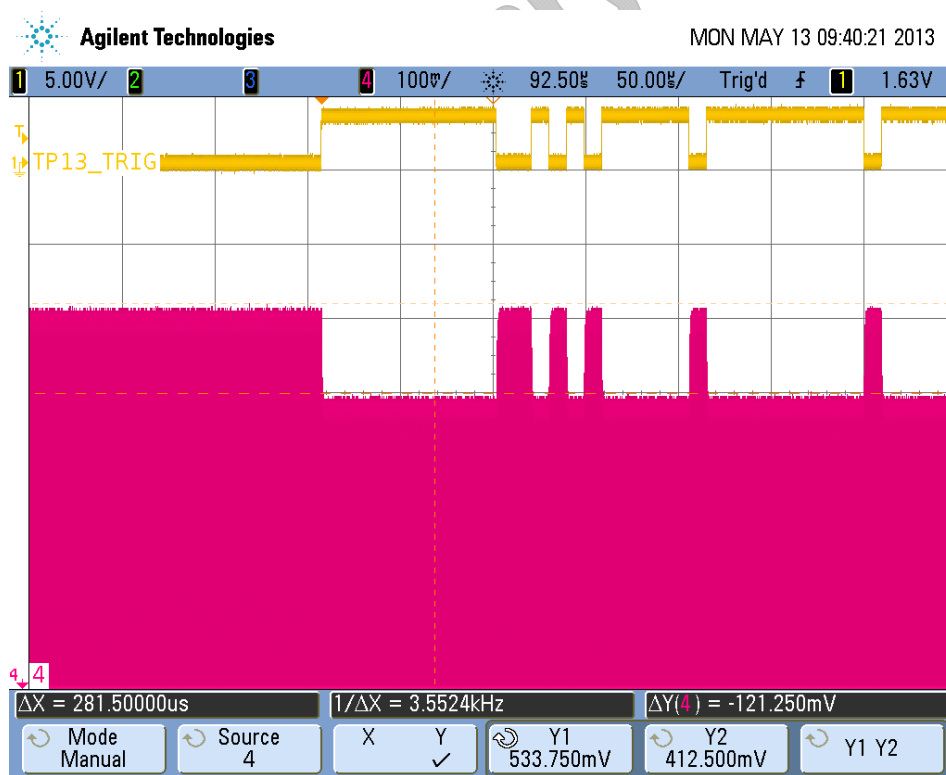
The resulting values are recommended to be within 10-14% modulation depth. Detailed modulation depth limits at the different positions can be found in the EMVco specification <http://www.emvco.com/specifications.aspx?id=21> Book D.

Typical modulation depth results of the current design:

Distance [cm]	Mod. Depth [%]
0	13.1
1	13.3
2	13.3
3	12.6
4	12.8

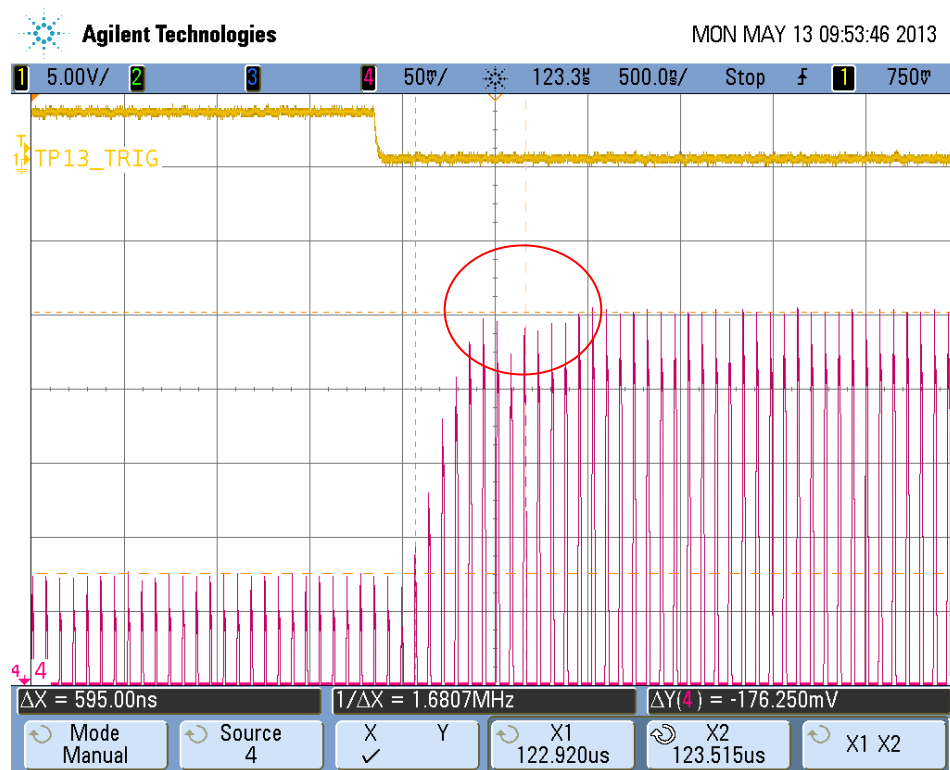
**Table 2: Modulation Depth Results at 10% Mode**

To avoid generation of inverse modulation during the 10% adjustment, Figure 26 shows the RF pattern of the WUPB command.



**Figure 26: 10% Modulation Depth Example**

## 7.6. EMVco L1 Analog Tests



**Figure 27: EMVco Test PICC, d= 0cm, timing tr/tf**

*In this position, due the strong coupling and depending on the antenna parameters, over and overshoots can be generated.*

*The shown undershoot is depending on the antenna characteristics, but is within the specified limits.*

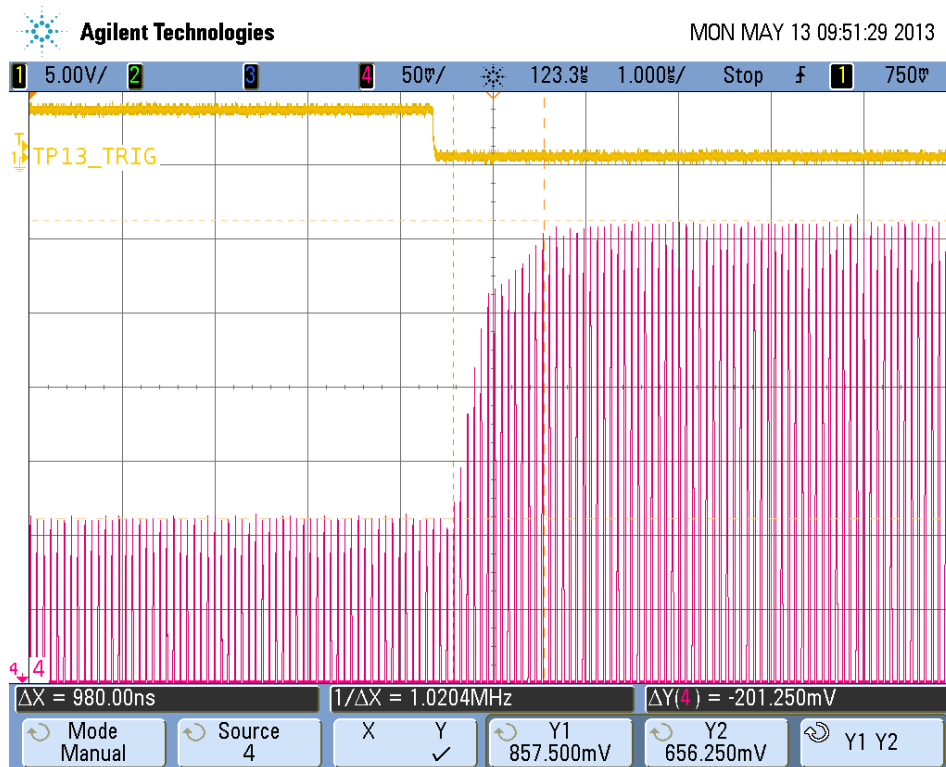


Figure 28: EMVco Test PICC, d= 1cm, timing tr/tf

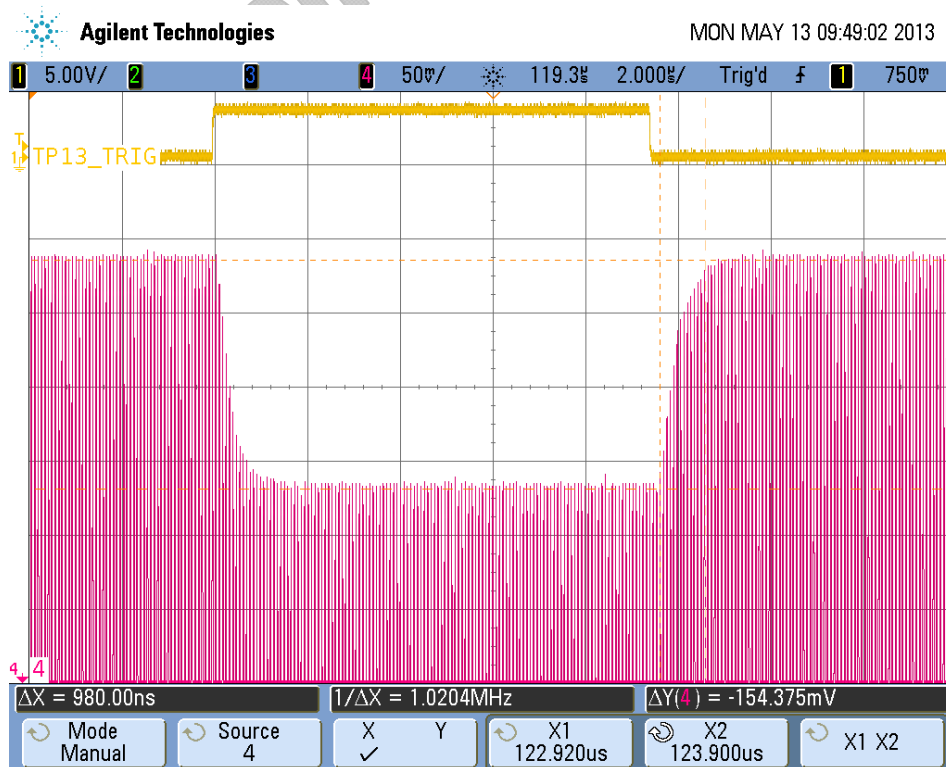


Figure 29: EMVco Test PICC, d= 3cm, timing tr/tf

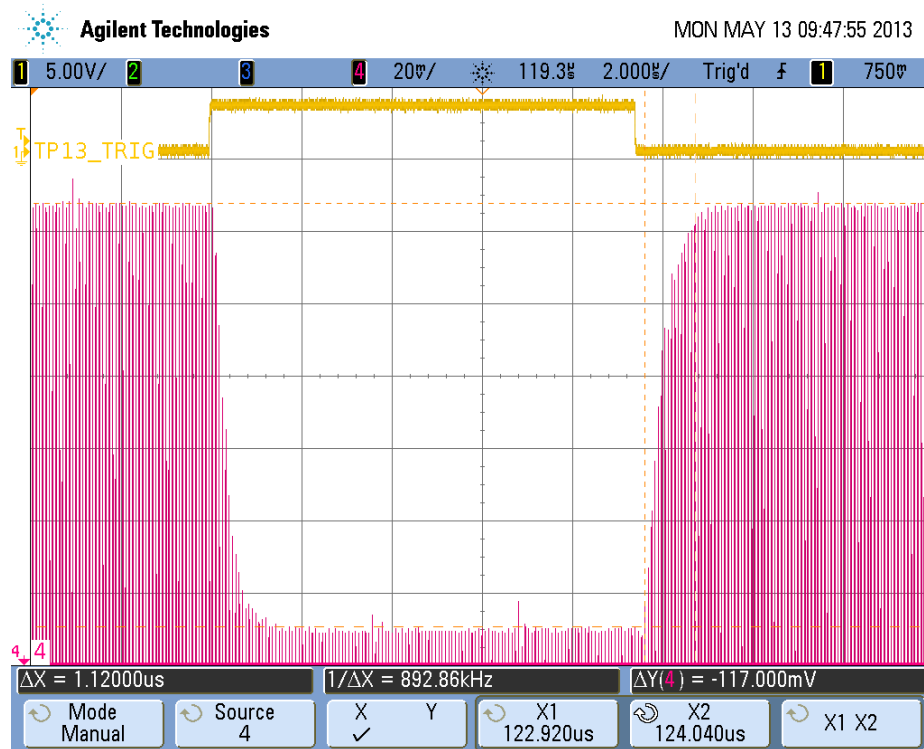


Figure 30: EMVco Test PICC, d= 4cm, timing tr/tf

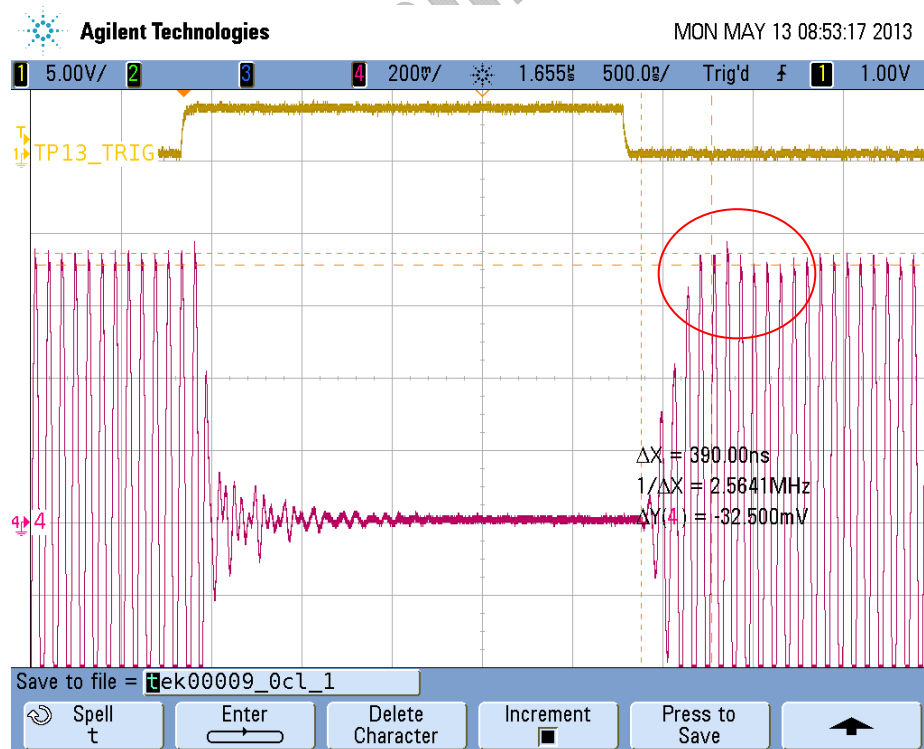
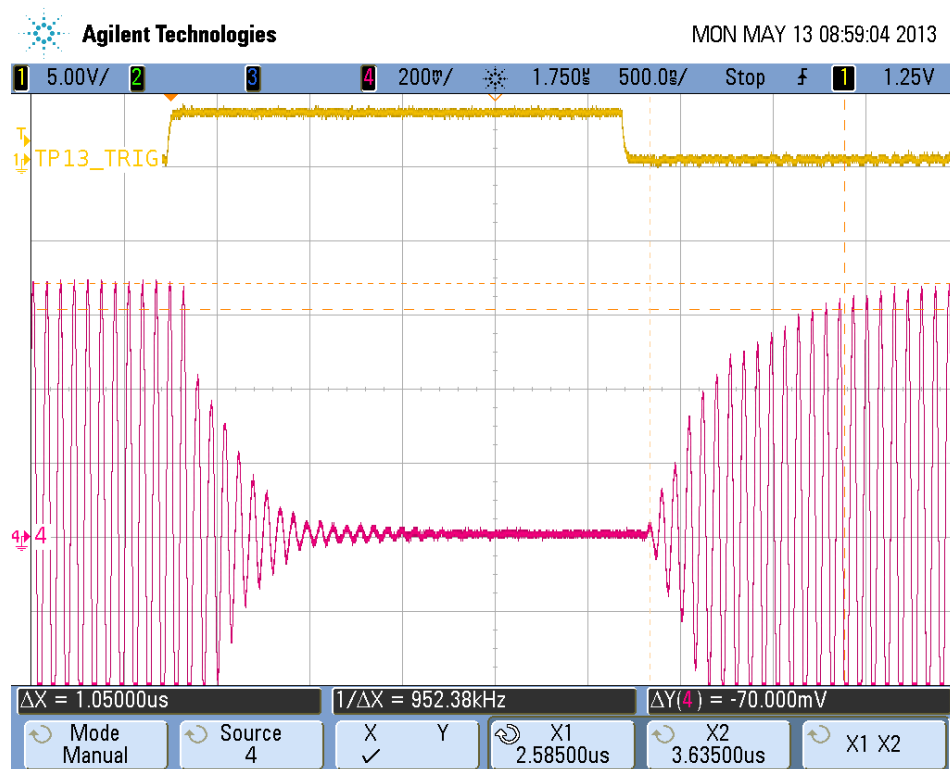


Figure 31: EMVco Test PICC Signal, d=0cm

*In this position, due the strong coupling and depending on the antenna parameters, over and overshoots can be generated. The shown overshoot is depending on the antenna characteristics, but is within the specified limits.*



Figure 32: EMVco Test PICC Signal, d=2cm



**Figure 33: EMVco Test PICC Signal, d=4cm**

*In this position, due the loose coupling and depending on the antenna parameters, the rising time could be critical. This can be adjusted by lower the antenna Q.*

## 8. References

1. [Texas Instruments](http://www.ti.com/) <http://www.ti.com/>
2. [TI Wireless Connectivity / RFID / NFC](#)
3. *TRF7970A Data Sheet* ([SLOS743](#))
4. *TRF7970A EVM* (<http://www.ti.com/tool/trf7970aevm> )
5. *ISO/IEC14443-2:2009(E)*
6. *ISO/IEC14443-3:2009(E)*
7. *ISO/IEC14443-4:2008(E)*
8. [EMVco](http://www.emvco.com/) (<http://www.emvco.com/> )
9. [Sokal slope](http://www.eel.ufsc.br/~lci/siteramo/documentos/mestres/artigos/classe.pdf) (<http://www.eel.ufsc.br/~lci/siteramo/documentos/mestres/artigos/classe.pdf> )

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## 9. ANNEX

### 9.1. Alternative Control Module “MSP-EXP430F5529”

An alternative control module which can be used with the TRF7970A Power Amplifier board is the [MSP-EXP430F5529](http://www.ti.com/tool/msp-exp430f5529) (<http://www.ti.com/tool/msp-exp430f5529>). This HW can be used in combination with the TI NFCLink FW for the board.

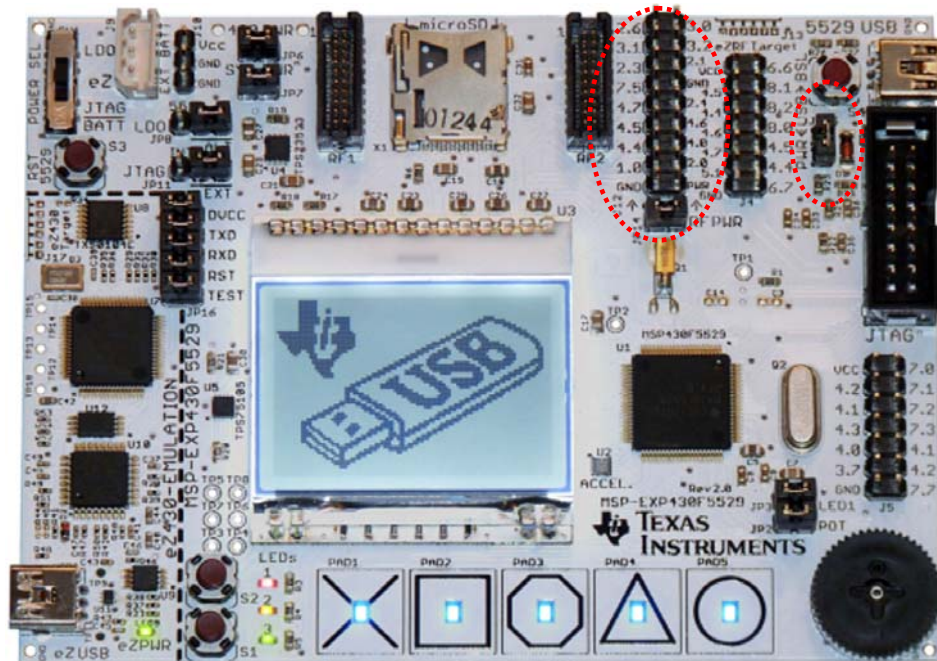


Figure 34: MSP-EXP430F5529 board

For operation the TRF7970A Power Amplifier board has to be connected to the MSP-EXP430F5529 board. J12 marked in Figure 34 is used to interface with the TRF7970A Power Amplifier board (JP1).

The detailed connection guidance can be found below.

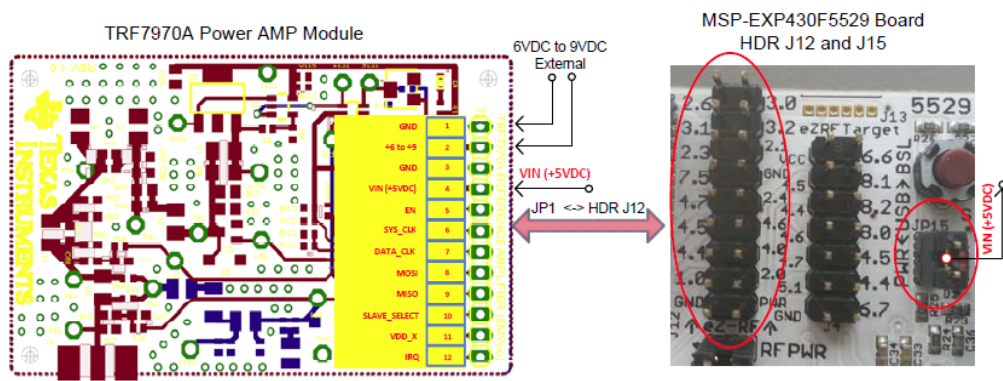


Figure 35: MSP-EXP430F5529 / TRF7970A PA interface

OTHER CONNECTION	MSP-EXP430F5529 HDR J15	MSP-EXP430F5529 HDR J12	SIGNAL NAME	TRF7970A AMP BOARD JP1
EXT. Power Supply		N/C	GND	PIN 1
EXT. Power Supply		N/C	+6VDC TO +9VDC	PIN 2
		GND	GND	PIN 3
	JP15 See Figure 35	N/C	VIN (+5VDC)	PIN 4
		P2.3	EN	PIN 5
		N/C	SYS_CLK	PIN 6
		P3.2	DATA_CLK	PIN 7
		P3.0	MOSI	PIN 8
		P3.1	MISO	PIN 9
		P2.6	SLAVE_SELECT	PIN 10
		N/C	VDD_X	PIN 11
		P2.0	IRQ	PIN 12

**Table 3: MSP-EXP430F5529 / TRF7970A PA Interface definition**

Table 3 shows the detail signal connection of the TRF7970A PA interface to the MSP-EXP430F5529 J12 and J15 pin headers. The +6VDC to +9VDC power supply for the power amplifier board is provided externally.

The FW required operating the TRF7970A PA with the MSPEXP430F5529, the GUI and additional information can be downloaded from <http://www.ti.com/tool/nfclink>

## 9.2. *Bill of Material*

The BOM will be available on the TI TRF7970A EVM Product Folder <http://www.ti.com/tool/trf7970aevm>



BOM

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	QTY	Nomenclature	Value	Description	Digi-Key PN	~Cost ea.	#VALUE!
	1	C1A	150pF	0805 NPO 50V	445-7495-1-ND	0.0186	\$ 0.0186
	1	C2A	820pF	0805 NPO 50V	445-7504-1-ND	0.0275	\$ 0.0275
	1	C2B	220pF	0805 NPO 50V	445-7497-1-ND	0.0186	\$ 0.0186
	3	C3A,C4B,C5A	220pF	0603 NPO 50V	445-1285-1-ND	0.0132	\$ 0.0396
	1	C3B	39pF	0603 NPO 50V	445-1276-1-ND	0.009	\$ 0.0090
	1	C4A	47pF	0603 NPO 50V	445-1277-1-ND	0.0075	\$ 0.0075
	1	C6A, C7A	68pF	0603 NPO 50V	445-1279-1-ND	0.009	\$ 0.0090
	1	C6C	330pF	0603 NPO 50V	445-1287-1-ND	0.015	\$ 0.0150
	1	C6B	680pF	0603 NPO 50V	445-5077-1-ND	0.0078	\$ 0.0078
	5	C13A,C14A,C15A,C16A,C17A	0.01uF	0402 X7R 16V	399-1038-1-ND	0.004	\$ 0.0200
	5	C13B,C14B,C15B,C16B,C17B	2.2uF	0402 X7R 16V	445-10935-1-ND	0.06435	\$ 0.3218
	2	C20,C21	4.7uF	0402 X7R 16V	445-1370-2-ND	0.02585	\$ 0.0517
	2	C22, C23	27pF	0402 NPO 50V	445-1240-1-ND	0.006	\$ 0.0120
							\$ -
<b>TOTAL # OF CAPS</b>	<b>25</b>					<b>TOTAL COST OF CAPS</b>	<b>\$ 0.5581</b>
	5	L1,L2,L3,L4,L5	560nH	Neosid / TDK	NLV32T-R56J-PF-ND	0.09702	\$ 0.4851
	1	L6	390nH	Neosid / TDK	NLV32T-R39J-PF-ND	0.09702	\$ 0.0970
							\$ -
<b>TOTAL # OF INDS</b>	<b>6</b>					<b>TOTAL COST OF INDS</b>	<b>\$ 0.5821</b>
	1	Q1	IRLML2803	SOT-23-3	IRLML2803GTRPBFCT-ND	0.1195	\$ 0.1195
	1	Q2	BDP949	TO-261-4	BDP949E6327INTR-ND	0.28512	\$ 0.2851
	1	Q3	THS4222DGNG4	THS4221 Data Sheet	TI	1.5	\$ 1.5000
	1	Q4	TS5A3159ADBVR	TS5A3159A Data Sheet	TI	0.33	\$ 0.3300
	1	Q5	TRF7970A	TRF7970A Data Sheet	TI	3.1	\$ 3.1000
	1	D1	Zener	22V SOD123	BZTS2C22-FDICT-ND	0.03945	\$ 0.0395
	1	D4	blue	LED 468NM RA BLUE CLEAR 0603 SMD	160-1650-2-ND	0.0945	\$ 0.0945
							\$ -
<b>TOTAL # OF Semi</b>	<b>7</b>					<b>TOTAL COST OF Semi</b>	<b>\$ 5.4686</b>
	1	R1	330	0402	P330JCT-ND	0.0048	\$ 0.0048
	2	R2,R3	10k	0402	P10KJCT-ND	0.0048	\$ 0.0096
	1	R5	1k2	0402	P1.2KJCT-ND	0.0048	\$ 0.0048
	1	R6	680	0402	P680JCT-ND	0.0048	\$ 0.0048
	2	R7, R8	10k	3214W	3214W-103ECT-ND	2.2257	\$ 4.4514
	1	R14	3k9	0402	P3.9KJCT-ND	0.0048	\$ 0.0048
	1	R17	3k3	0402	P3.3KJCT-ND	0.0048	\$ 0.0048
							\$ -
							\$ -
<b>TOTAL # OF RES</b>	<b>9</b>					<b>TOTAL COST OF RES</b>	<b>\$ 4.4850</b>
	1	Y1	13.56MHz	CRYSTAL-SMD-5X3.2	535-10904-1-ND	0.513	\$ 0.5130
	1	JP1	Pin Header 1x12				\$ -
	18	GND,TP1-TP17	Testpoint				\$ -
	1		PCB				\$ -
							\$ -
<b>TOTAL # OF MISC</b>	<b>21</b>					<b>TOTAL COST OF MISC</b>	<b>\$0.51</b>
		additional Class E matching					\$ -
	1	C1B	DNP	C-EUC0805		0	\$ -
	1	C5B	DNP	C-EUC0603		0	\$ -
		additional RX path					\$ -
	1	C7B	DNP	C-EUC0603		0	\$ -
	1	C7C	DNP	C-EUC0603		0	\$ -
	1	R13	DNP	R-EU_R0402		0	\$ -
		optiona block capacitors					\$ -
	1	C11A	DNP	C-EUC0402		0	\$ -
	1	C11B	DNP	C-EUC0402		0	\$ -
	1	C12A	DNP	C-EUC0402		0	\$ -
	1	C12B	DNP	C-EUC0402		0	\$ -
		curve shape					\$ -
	1	R4	DNP	R-EU_R1206		0	\$ -
	1	R18	DNP	R-EU_R0603		0	\$ -
		filtered RX path					\$ -
	1	R15,R16	OR	R-EU_R0402	P0.0JCT-ND	0.0048	\$ 0.0048
	1	R17	3.3k	R-EU_R0402	P3.30KJCT-ND	0.00672	\$ 0.0067
	1	L7	10uH	L-USL2825P	445-1737-1-ND	0.12397	\$ 0.1240
	1	L8	4.7uH	L-USL2825P	445-1733-1-ND	0.12397	\$ 0.1240
	1	L9	2.2uH	L-USL2825P	445-1754-1-ND	0.12397	\$ 0.1240
	1	D2	1N4148W	CGRM4007-G	1N4148W-V-GS18CT-ND	0.051	\$ 0.0510
	1	D3	ZENER-DIODE	SOD123	MMSZ5226B-FDICT-ND	0.03945	\$ 0.0395
	2	C8,C9	180pF	C-EUC0402	445-1250-1-ND	0.0081	\$ 0.0162
	1	C10A	90pF	C-EUC0402	445-4902-1-ND	0.0066	\$ 0.0066
	1	C10B	220pF	C-EUC0402	445-1251-1-ND	0.0081	\$ 0.0081
		replacement of trimmer					\$ -
	1	R9	DNP	R-EU_R0402		0	\$ -
	1	R10	DNP	R-EU_R0402		0	\$ -
	1	R11	DNP	R-EU_R0402		0	\$ -
	1	R12	DNP	R-EU_R0402		0	\$ -
		SMA connector					\$ -
	1	X1	SMA	J629	J629-ND	0	\$ -
							\$ -

### 9.3. Schematic

The Schematic and Board layout files in Eagle format and Gerber files, will be available on the TI TRF7970A EVM Product Folder <http://www.ti.com/tool/trf7970aevm>

## 10. Revision History

Revision	Date	Changes	Comment
	28-05-2013	Initial release	
V53	21-05-2013	Added 9.1	

Preliminary