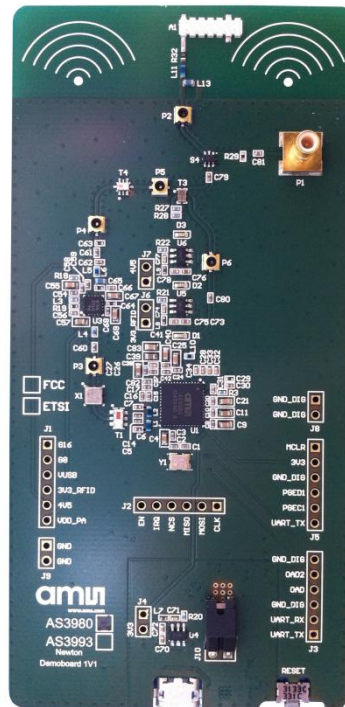




Application Note: Newton Demo Reader – HW Description



AS3980/AS3993

Newton Demo Reader – Hardware Description

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Revision History

Revision	Date	Owner	Description
1.0	May 2014	bhi	Initial Document

1 General Description

The Newton demo reader is an EPC Gen 2 UHF RFID reader system with the purpose of demonstrating the AS3980 or the AS3993 IC in a mid power reader application for medium read ranges.

The Newton is operated through a graphical user interface (GUI) running on a host computer which implements tag inventory and tag access routines. It also facilitates full access to the AS3980/AS3993 IC registers allowing the user to configure and optimize the reader for various use cases and is used for updating the firmware of the Newton reader. The USB interface is used for host computer communication and for DC power supply.

The AS3980/AS3993 IC is controlled via the SPI interface by a PIC24 MCU which can be disconnected¹ in order to allow other MCU types to control the AS3980/AS3993. The baseband data received from the MCU is PIE encoded and a shaped version of this information is used to modulate the high frequency carrier. The high frequency carrier is generated by a PLL/VCO circuitry integrated in the AS3980/AS3993 IC. As a frequency reference a 20 MHz crystal oscillator is used. The RF signal is output at the differential (100 ohms) low power outputs RFONX and RFOPX. After the Balun (2:1) the RF signal is fed through a SAW filter which is centered at 915 MHz with a 26 MHz bandwidth. After the filter stage the RF signal is amplified by a power amplifier and filtered again by a ceramic low pass filter in order to limit harmonics and spurious frequencies introduced by the gain stage. To isolate the TX signal from the single-ended mixer input of the AS3980/AS3993 IC a directional 10 dB coupler is used. At the direct output of the directional coupler a RF switch is placed which allows routing the RF signal either to the on-board antenna or to the SMB antenna jack for using an external antenna.

The incoming RX signal is coupled to the single-ended RX IQ mixer input of AS3980/AS3993 via a 2:1 balun. The tag response is directly down-converted to the baseband frequency. The AC coupled and filtered signal is digitized (1 bit) and decoded, framed to bytes and put to the internal FIFO for further processing by the MCU.

1.1 Kit Content

Every AS3980/AS3993 Newton Demo Kit contains:

- 1 x AS3980 or 1 x AS3993 Newton Reader
- 1 x Micro USB cable
- 1 x SMA/SMB coax antenna cable
- 1 x USB thumb drive with documentation
- 1 x Tag demo bag

¹ By desoldering zero ohm resistors

2 Getting Started

The following instructions describe step-by-step how to connect the hardware and how to operate the GUI to scan for tags:

- 1) Connect the Newton reader to the host computer using the Micro USB cable.
 - 2) At this point the MCU LED (D1) is flashing
 - 3) Start the AS3993 Reader Suite on the host computer.
 - 4) The Newton reader is listed in the main window and the state shows Online in green letters.
 - 5) To scan² for tag click on the Start Scan button in the lower left corner of the main window.
- Note: Per default the Newton reader will transmit in the 915MHz FCC ISM frequency range.

3 Hardware Description

This section describes the circuitry of the Newton reader in detail and outlines important measurement points as well as simple modification options.

3.1 RF Circuit

The high frequency carrier is generated by the integrated PLL/VCO circuit inside AS3980/AS3993. The reference frequency is provided by an external 20 MHz crystal oscillator with a specified load capacitance of 7.2 pF. The output of the internal PLL- charge pump is connected to LF_CEXT (pin 45) at which the external part of the loop filter is placed closely. An additional low pass filter stage is integrated in AS3980/AS3993 and is part of the loop filter circuit. The loop filter output is the control voltage of the internal VCO.

The RF signal is output at the differential low power outputs (pin 23, 24) which have a differential output impedance of 100 Ohms. The default output level of the Newton reader is approx. -1 dBm which is controlled by register 0x15 of AS3980/AS3993. The output stage is supplied via VDD_B (pin 12). 100 nH inductors block the RF signal from reaching VDD_B while two blocking capacitors (560pF) block the DC voltage towards the Balun. The Balun has a balanced impedance of 100 ohms and an unbalanced impedance of 50 ohms. The insertion loss of the Balun is ~1dB.

To limit spurious emissions a SAW filter is placed at the output of the Balun. The SAW filter has a band-pass filter characteristic with corner frequencies at approx. 899 MHz and 931 MHz. The insertion loss of the SAW filter is approx. 2dB.

The RF power is further amplified by an external PA (RFPA0133) to ~28 dBm depending on the output frequency. The external power amplifier is supplied by 4.5V from a dedicated LDO (U6 - AS1362) which has a low drop out voltage of 140 mV and can provide enough current (300mA) for the PA. The bias voltages of the PA is connected to VDD_PA (pin 13) of AS3980/AS3993 which is set to 3V (register 0x0B).

² Adhere to local RF regulations.

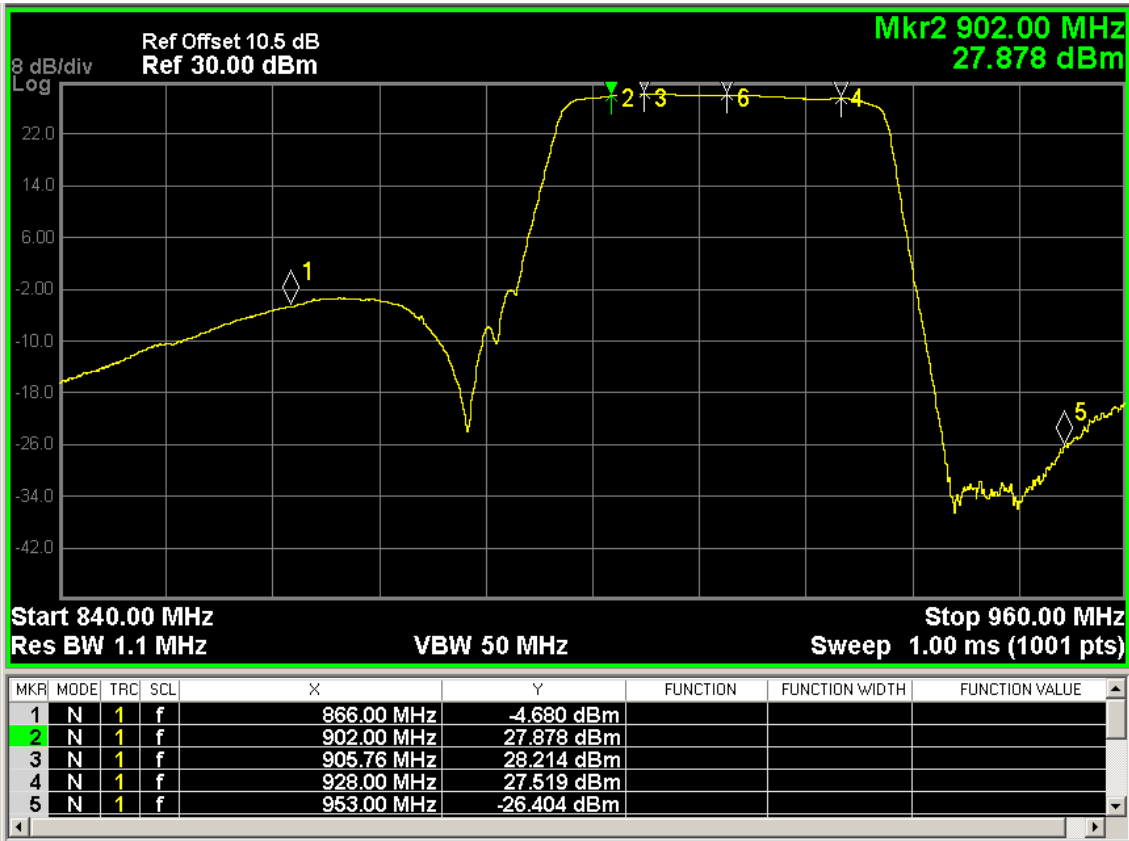


Figure 1 - TX power vs. frequency [dBm/MHz]

After the PA stage a low pass filter is placed which attenuates higher frequency harmonics and spurious frequencies generated by the amplifier stages. The low pass filter shows at 915 MHz an insertion loss ~0.3 dB and attenuation below 45dB attenuation a 1.83 GHz and 2.745 GHz. At 3.66 GHz the attenuation rises again to ~39.8 dB.

ETSI Operation:

As can be seen by the graph above an operation at 866 MHz with the default HW configuration of the Newton reader is not possible since the SAW filter pass frequency is much higher. In order to allow an operation at 866 MHz the SAW filter needs to be replaced by a SAW filter version which has a pass frequency range centered at 866 MHz. The recommended filter type would be B39871B3717U410.



Figure 2 – Ceramic low pass filter characteristic

The filtered RF signal is then connected to the directional coupler which isolates the TX signal from the single-ended mixer input of the AS3980/AS3993 IC. The directional coupler shows an isolation of ~20 dB depending on the frequency.

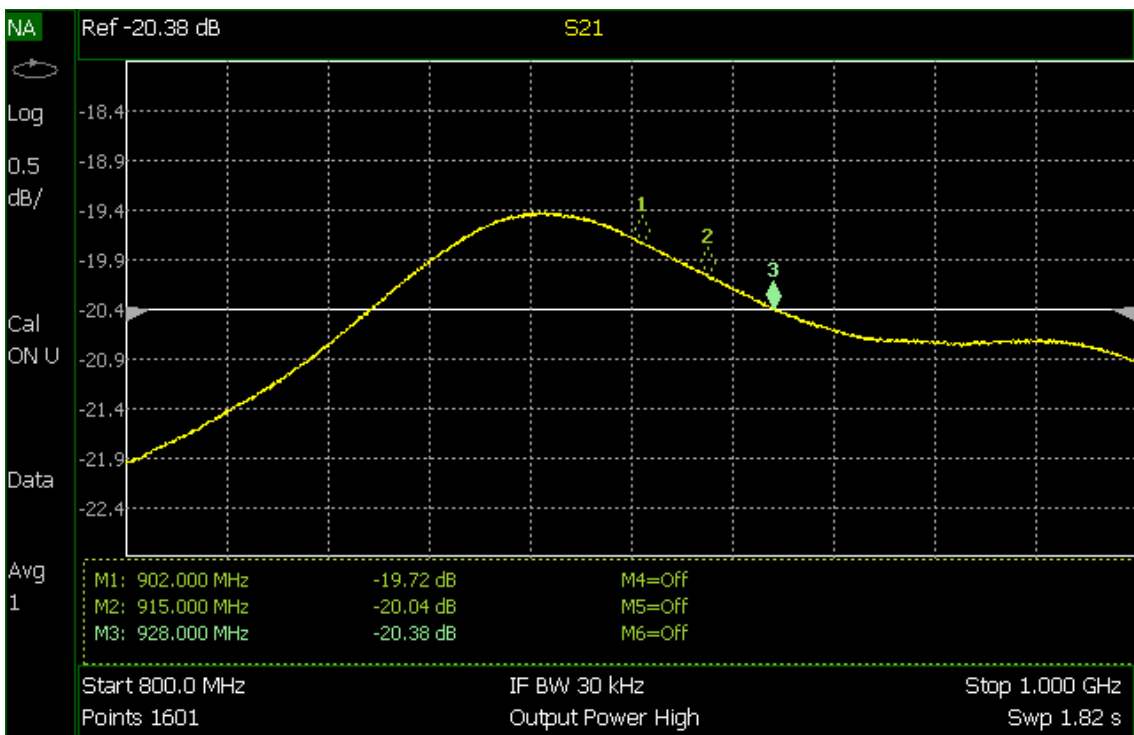


Figure 3 - Directional Coupler - Directivity Measurement

At the output of the directional coupler a RF switch is connected which routes the RF signal to either the on-board ceramic chip antenna or to the SMB jack. The combined insertion loss of the directional coupler and the RF switch has been measured to be ~1.2 dB.

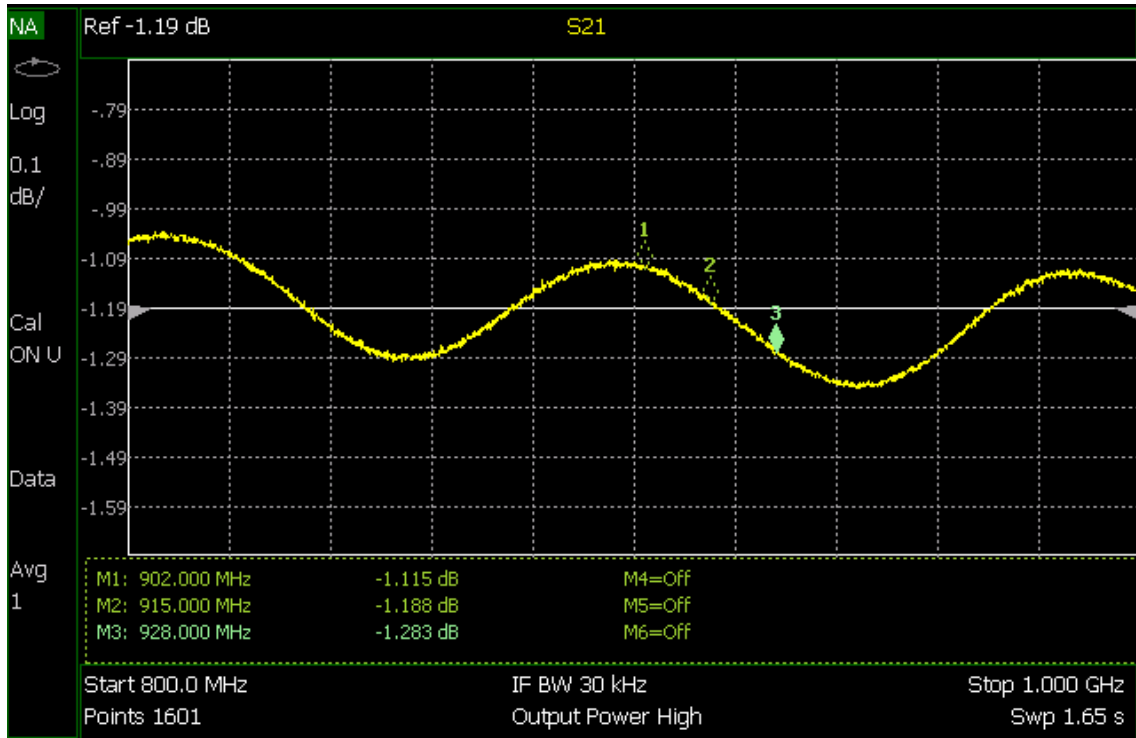


Figure 4 - Combined Insertion Loss of Dir. Coupler and RF Switch

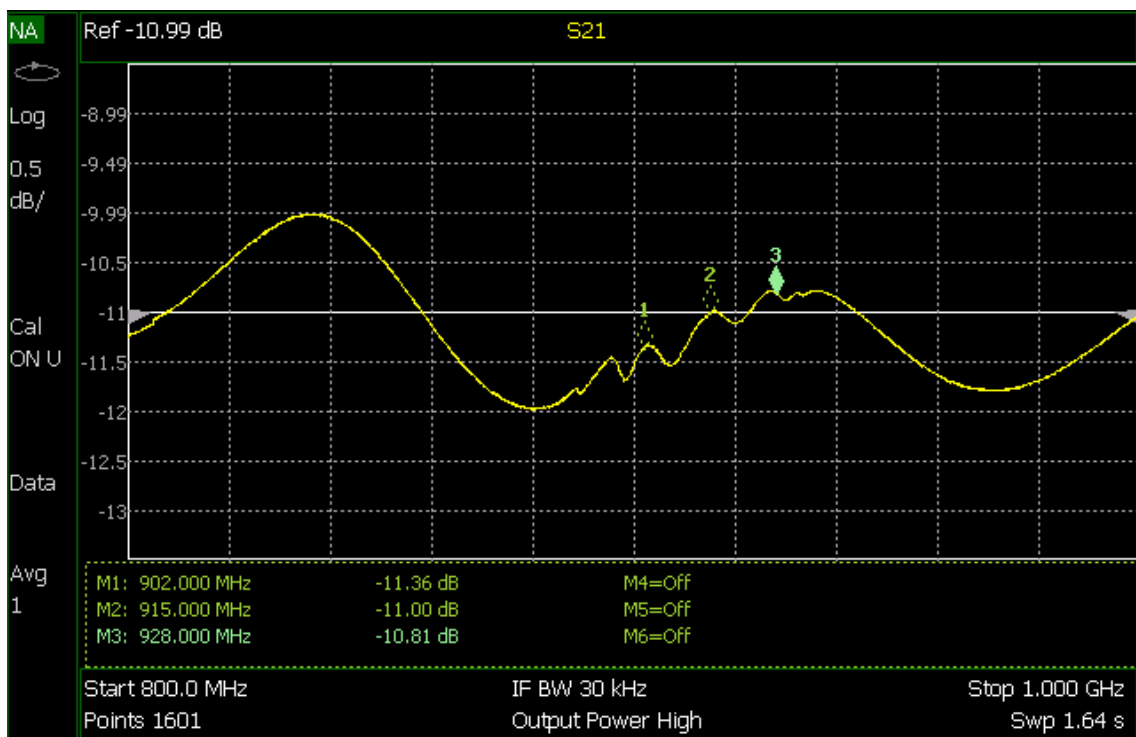


Figure 5 - RF Switch RX insertion loss combined with the coupling factor of the dir. coupler

In the graph above the measured coupling factor of the directional coupler and the RX insertion loss of the RF switch is shown and is ~11 dB.

The isolated output of the directional coupler is connected to the single-ended receiver input of AS3980/3993 (pin 5).

3.2 Power Supply

The Newton reader is DC powered by the USB interface. The MCU and the AS3980/3993 are supplied by a regulated 3.3 voltage (AS1364). The PA is also supplied by a 4.5 V trimmed version of the AS1364³ LDO

3.3 MCU

The MCU used for the Newton is a PIC24FJ64GB002 type in a 28 pin QFN package. The communication between the MCU and the host computer is done via the USB interface. A UART firmware version is also available. The UART interface is located at J3 on pin 1 (UART_TX) and pin 2 (UART_RX). Pin 3 is connected to digital GND. The square pin indicated pin 1. The MCU is clocked by a 12 MHz crystal. The MCU controls the AS3980/AS3993 IC via the SPI. The MCU is also controlling the MCU LED (D1).

The push button on the Newton reader resets the controller.

3.3.1 Bootloader

The bootloader is already programmed and does not need to be programmed by the user. In any case where this is still needed the bootloader can be programmed using an ICD3 Debugger from Microchip.

³ Early Newton builds are populated with AS1361.

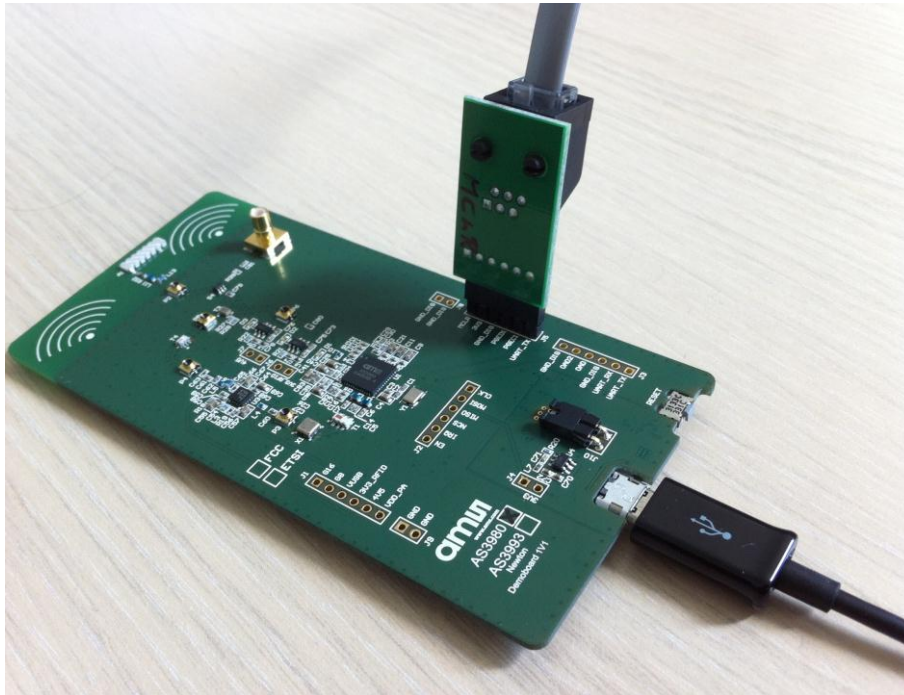


Figure 6 - Connecting the ICD3 box with Newton via the debug interface

The bootloader mode can also be forced which allows for instance to re-program the FW with the USB interface again if previously the UART version was loaded. To force the bootloader mode simply short the pins PGED1 or PGEC1 to GND_DIG.

The bootloader is programmed via the debug interface of the MCU (J5). The pin-out of the debug interface is shown below:

J5 PIN #	Pin Name	MCU Pin #	Description
1	/MCLR	26	Master Clear (device Reset) Input.
2	VCMU	-	Power supply
3	GND_DIG	-	Ground
4	PGED1	1	Data Line
5	PGEC1	2	Clock Line
6	UART_TX (RP8)	14	Used for UART logging in the bootloader

Figure 7 - Debug Interface Pinout

3.4 FW Programming

A new firmware version can be programmed using AS3993 Reader Suite via the Help menu. For more instruction please refer to the User Manual of the AS3993 Reader Suite. For programming only the USB interface needs to be connected.

3.5 UART

In order to operate the reader through the UART interface the TX and RX lines should be connected to J3. It is recommended to use a FTDI USB/TTL Serial Cable (TTL-232R-3V3)

J3 PIN #	Pin Name	MCU Pin #	Note
1 (square)	UART_TX	14	Connect with RXD (yellow) of TTL-232R-3V3
2	UART_RX	13	Connect with TXD (orange) of TTL-232R-3V3
3	GND_DIG	-	GND

Figure 8 - UART Interface Pinout

The UART connection settings are:

- Baud Rate: 115.2 kbps
- Data bits: 8
- Parity: None
- Stop Bits: 1
- Handshaking: none

3.6 Measurement & Test Points

The Newton has numerous measurement points built in which allows checking various important voltages, analog and digital signal lines.

3.6.1 DC Voltages:

Important voltages can be measured at the test points on J1.

Pin #	Pin Name	Description
J1-1	G16	(Gain selection input for external PA)
J1-2	G8	(Gain selection input for external PA)
J1-3	VUSB	5V from USB
J1-4	3V3_RFID	Supply voltage for AS3980/3993
J1-5	4V5	Supply voltage for external PA
J1-6	VDD_PA	Bias voltage for the external PA

Figure 9 – DC Testpoint Connector Pinout

3.6.1.1 OAD & OAD2

The OAD and OAD2 signals are very useful outputs of AS3980/AS3993 for debugging purposes or subsequent signal processing. Through register settings (0x10) it is possible to output

- Analog or digitized I, Q subcarrier signals
- TX modulation and selected subcarrier. Observe reader commands and tag responses.
- Analog Mixer DC output to determine the self-jamming level.

The OAD output is located on J3 (pin 4) and OAD2 is pin 5.

3.6.2 SPI Interface Signals

On J2 AS3980/AS3993 signal lines (EN, IRQ) and the SPI signals can be monitored.

Pin #	Pin Name	Description
J2-1 (square)	EN	EN (enable) line of AS3980/AS3993
J2-2	IRQ	IRQ line of AS3980/AS3993
J2-3	NCS	Chip select line of SPI (active low)
J2-4	MISO	M
J2-5	MOSI	GND_DIG
J2-6	CLK	AS3993_EN

Figure 10 - SPI Interface Connector Pinout

If it is required to control the Newton through an external MCU it is possible to unsolder the resistors R10 – R18 which disconnects the existing PIC24 MCU. This is sometimes beneficial and saves time as the firmware development can start early. R10 – R18 are located on the backside of the Newton PCB.

3.6.3 RF Test Points

The Newton reader allows measuring the RF power at various points. The RF tracks can be contacted through subminiature coax sockets with a built in switch. It is recommended to use matching connection adapters which are available from Hirose. For example a SMA conversion adapter MS-156-HRMJ-2



Figure 11 - RF Testpoint Adapter (not included in the demo kit)

If the adapter is connected to the coax socket the RF track on the PCB is disconnected. Please note that the coax sockets have limited plug/unplug cycles of 500 times.

Pin #	Description
P3	Single ended AS3993 output power after the SAW filter.
P4	PA output power
P5	Ceramic low pass filter output
P2	TX RF power in front of the on-board antenna
P6	RF power at the receiver for measuring the tag responses and self-jammer level.

Figure 12 - RF Test Point Description

3.6.4 On-Board Antenna

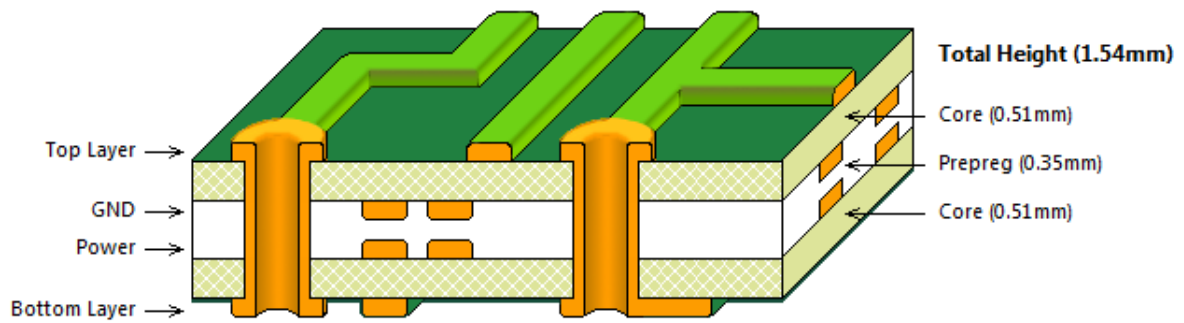
The AS3980/AS3993 Newton Reader features a ceramic chip antenna (Mitsubishi, AM11DG-ST01). The antenna matching and radiation pattern of the Newton reader is presented in a separated application note. More information about the antenna can be found at:

http://www.mmea.com/contents/antenna/mhz/am11dg_3.html

3.6.5 External Antenna Connection

Newton reader has one SMB port for connecting an external antenna.

3.7 PCB Stack-up



3.8 Impedance Controlled Traces

In the table below the design targets for trace width and GND separation are listed for single-ended and differential RF traces.

Structure Image	Structure Name	Impedance Signal Layer	Ref. Plane 1 in Layer	Ref. Plane 2 in Layer	Lower Trace Width	Upper Trace Width	Trace Separation	Lower Ground Strip Width	Upper Ground Strip Width	Trace Offset	Ground Strip Separation	Calculated Impedance	Target Impedance
	Coated Coplanar Waveguide With Lower Ground 1B	1	2	0	0,550	0,530	0,000	0,000	0,000	0,000	0,210	49,900	50,000
	Diff Coated Coplanar Waveguide With Lower Ground 1B	1	2	0	0,200	0,180	0,165	0,000	0,000	0,000	0,210	99,930	100,000

The FR4 core material used is: FR4-Core TypA-0,51mm 35/35 DE 104 ML with a thickness of 0.51mm. The epsilon_r of this material is 4.5.

3.8.1 Differential Traces

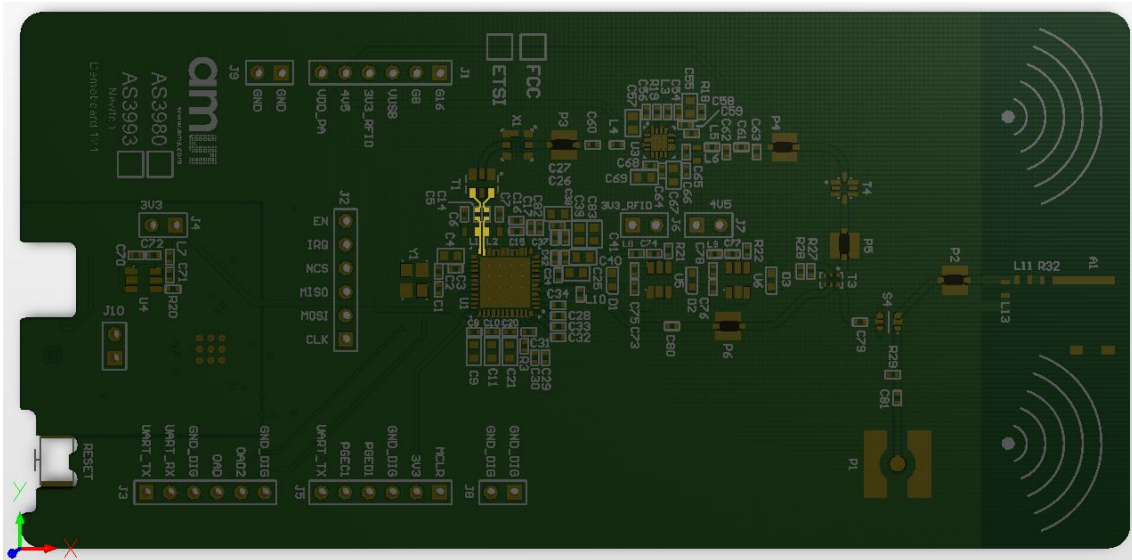


Figure 13 - Differential RF traces high-lighted

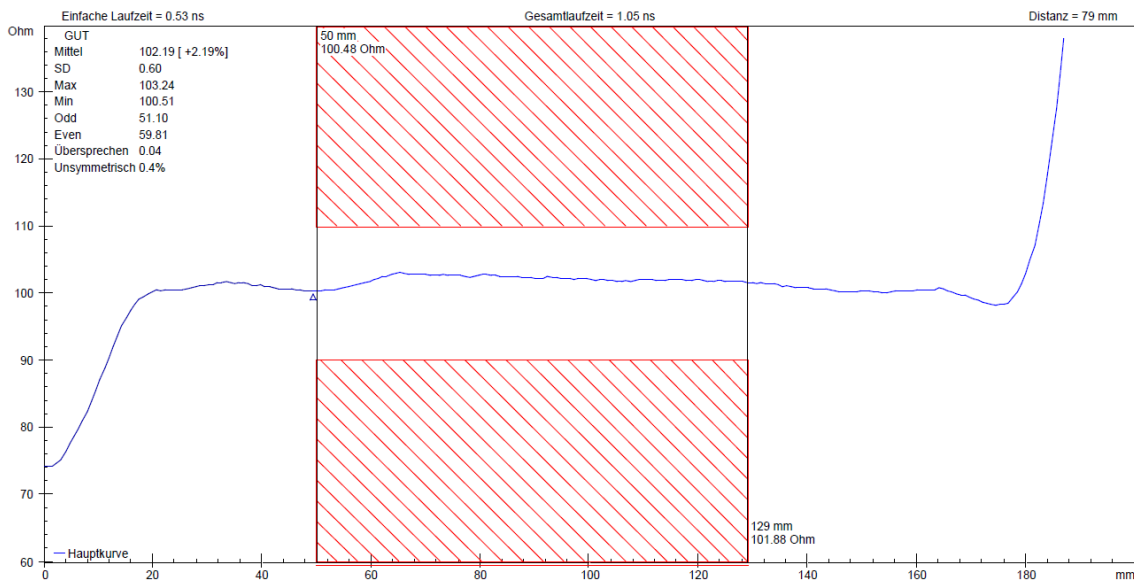


Figure 14 - Differential RF Trace - Impedance Measurement

3.8.2 Single-Ended Traces

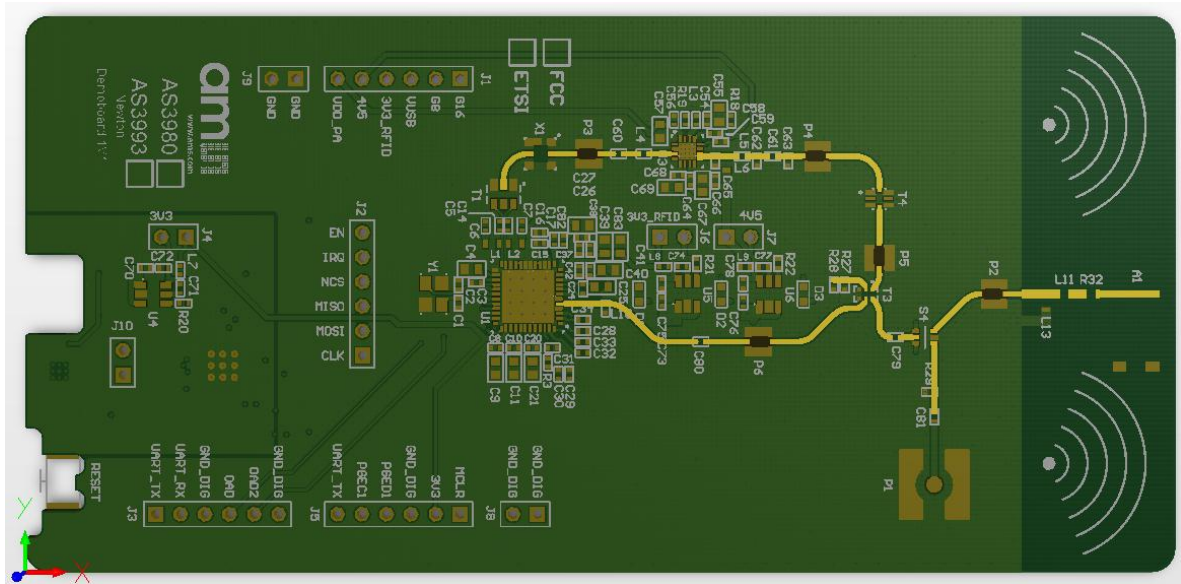


Figure 15 - Single-Ended RF traces high-lighted

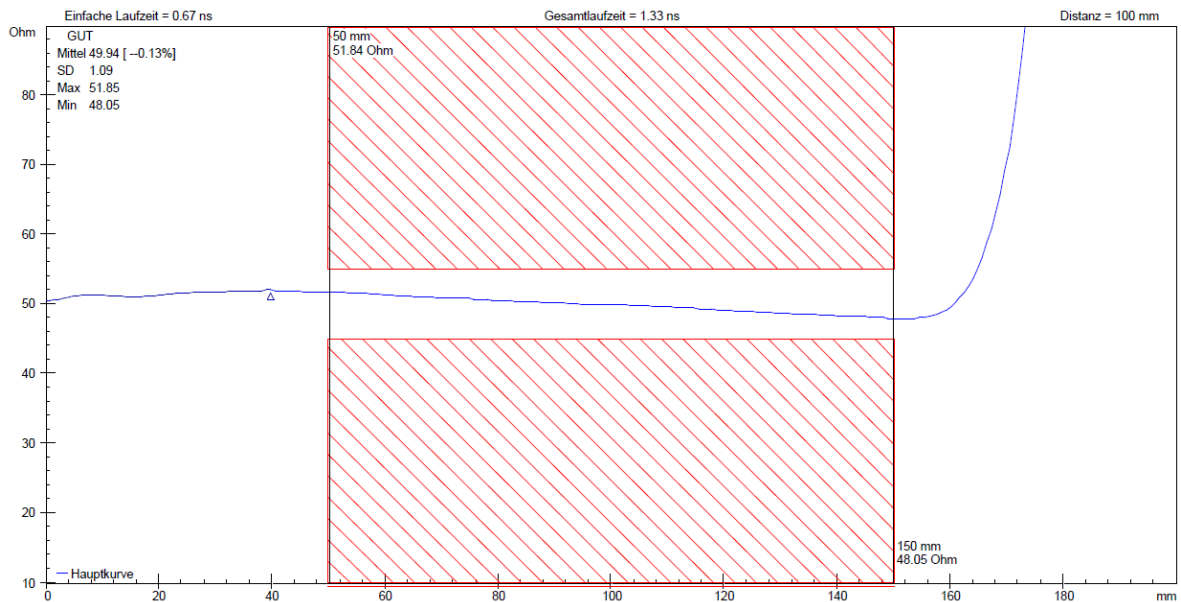


Figure 16 - Single-Ended RF Trace - Impedance Measurement

4 Software Description

Please refer to the User Manual for a more information on the AS3993 Reader Suite⁴.

Caution!

- **The Newton reader is intended for engineering usage to demonstrate the AS3993.**
- **Before turning the Newton reader ON please check your local RF regulations and configure the reader accordingly.**
- **Always connect a RF load to the external antenna port if in use.**

⁴ The AS3993 Reader Suite also operates the AS3980 based demo readers

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