Senior Design Project
T307
8 April 2021
Operation Manual

Table of Contents

SECTION I: Product Description

Table I: List of Parts

Part	Specification	Quantity
Prototype	Box / Base	1
Prototype	Lid	1
Prototype	Lid EL Wire	1
SDR	Adalm Pluto	2
Arduino	Due	1
Screw(s)	#4 7/8"	4
Screw(s)	#4 1/2"	13
Screwdriver	Phillips	1
Cable	Micro USB to USB	2
Cable	SMA to SMA	2
Variable Attenuator	JFW 50DR-055 0-30dB	1
PC	Windows OS	1

Table 1: List of Parts contained in this table

Table II: List of Additional Parts

Part	Specification	Quantity
RF Pulse Generator	Bruker	1
Adapter	BNC to SMA	2
Splitter	1 SMA : 2 SMA	1
Cable	BNC Jumper	1
Cable	SMA	2
Cable	Micro USB to USB	3
Circuit	Arduino IC for EL Wire	1
Power Source	IC for EL Wire (3.3-12V)	1
Power Source	Outlet / Surge Protector	1
PC	Monior / Linux OS	1

Table 2: List of Additional Parts contained in this table

1.1: Instructions

The following Instructions are for the purpose of providing information to keep in mind when reading the document:

a) This document was created with the intention to aid the user with handling this Prototype but by no means does it cover in extensive detail every possible scenario or situation that could happen.
b) In case of failure, troubleshooting will be required by the user and not the team.
c) Each instance and OS where the Prototype may be used might have a different Set-up which will essentially require to use the document as a general mapping of how to get it working.
d) The document is written with the sense that the user should be knowledgeable enough in the field to follow the details in this document to make the product work.

1.2: Set-up (Software)

Initial set-up for software includes these few simple tasks to get started:

a) Upgrade the SDR Firmware using this link (https://github.com/analogdevicesinc/plutosdr-fw/releases/download/v0.32/plutosdr-fw-v0.32.zip).
b) Download the SDR latest drivers from this link (https://github.com/analogdevicesinc/plutosdr-m2k-drivers-win/releases/download/v0.7/PlutoSDR-M2k-USB-Drivers.exe).
c) Upgrade Adalm Pluto SDR Firmware using this link (https://github.com/analogdevicesinc/libiio/releases/download/v0.21/libiio-0.21.g565bf68-Windows-setup.exe).
    I. If Due is desired to be used also, download the Arduino software from here (https://www.arduino.cc/en/software) or use an editor of choice for programming in C (i.e., Visual Studio Code).
    II. Another great software that goes well with Arduino is called Processing and it can be found here (https://processing.org/download/).

At this point all the initial software drivers and firmware is installed.

a) Next, download the newest IIO-Oscilloscope software using this link (https://github.com/analogdevicesinc/iio-oscilloscope/releases) make sure to download the executable, not the source code zip folders.

Software is now set up, and the user is ready to proceed to the hardware set-up section.

1.3: Set-up (Hardware)

To construct the Prototype in the final configuration chosen by the team, the following steps must be followed:

a) Lay down the Prototype Box / Base in a non-slippery surface, gather the Philips screwdriver, screws, SDRs, Arduino Due, and Prototype Lid.
b) Unscrew the SDRs from the back and keep their lids in a safe place (it is helpful to number them to keep track of which part pertains to which SDR), also remove the Due from the clear plastic base that comes with it.
    I. The Due's base was modified slightly to fit into the box, if it is a brand new Due the tab sticking out used to connect it to breadboards or other Dues must be trimmed using sandpaper or a sharp knife.
c) Screw in two of the #4 7/8" screws per SDR and five #4 1/2" screws for the due (four to secure it to the Prototype Box / Base and one to secure the Due to its own base).

I. Any further configurations such as banana cables to / from the SDRs or Due (i.e., supplying power to the EL Wire with the Due) should now be connected.

d) Gather the Prototype Lid and secure it with the remaining eight #4 1/2" screws in a cross-hatch pattern (as if mounting a motherboard to a PC).
   I. Reference Appendix "Figure A" if needed to visualize assembly.

1.4: Wiring

The Prototype has the following ports available for wiring:

a) SDR External Ports
   I. T_x SMA
   II. R_x SMA
   III. Micro USB (I/O)
   IV. Micro USB (Power)
b) SDR Internal Ports
   I. GPIO
   II. DAC1 – DAC2
   III. GPO0 – DAC3
   IV. ADC
   V. VDD
   VI. GND
   VII. Please reference other ports here (https://wiki.analog.com/university/tools/pluto/hackers) or the main documentation here (https://wiki.analog.com/university/tools/pluto).
c) Due External Ports
   I. Micro USB (Programmer Port)
   II. Micro USB (Native Port)
   III. Power (7V – 12V 2.1mm DC Plug)
d) Due Internal Ports
   I. Please reference the Arduino Due pin-out diagram found here (https://forum.arduino.cc/index.php?topic=132130.0).
   II. More information and technical specs can also be found here (https://www.arduino.cc/en/pmwiki.php?n=Main/arduinoBoardDue).

To aid the user with this wiring, "Figure 1" depicts the proper connections.

a) Connect two SMA jumpers, carrying two RF analog signals, to the rightmost SMA ports of each SDR (the Rx port).
b) Connect two USB 2.0 cables to the middle port (USB data port) of each SDR.

Figure I: Prototype I/O

Figure 1: Prototype I/O (two input SMA cables on the top, and two output USB 2.0 cables on the bottom).

The final wiring configuration for the Prototype can also be referenced in the Appendix in "Figure B".

1.5: Integration

The final step of the prototype set-up process is to integrate the downloaded software (IIO-Oscilloscope) and earlier assembled hardware (prototype).

a) Make sure all USB ports of your device are empty.
b) Open two instances of IIO-Oscilloscope on the same screen.
    I. double click the shortcut  twice to open two instances of the software.
c) Connect the two USB cables coming from the prototype to the computer.
d) Search for *Command Window* in the Windows search bar and open it.
e) **Very important step!** Type this command: *iio_info -s* in the command window.
    I. this will output USB port IDs of the two SDRs that were just connected.

Figure II: Command Window Example

```
C:\Users\emilg>iio_info -s
Library version: 0.21 (git tag: 565bf68)
Compiled with backends: xml ip usb serial
Unable to create Local IIO context : Function not implemented
Available contexts:
        0: 0456:b673 (Analog Devices Inc. PlutoSDR (ADALM-PLUTO)), serial=1044730a1997000f10000500126f7c559d [usb:1.5.5]
        1: 0456:b673 (Analog Devices Inc. PlutoSDR (ADALM-PLUTO)), serial=1044730a19970001f4ff2e00811e7b82cd [usb:1.4.5]
```

Figure 2: Screenshot of the Command Window output, showing two usb ids on the most right in [usb:x.x.x] format.

f) Next, in the *osc.exe* windows that were opened in "Step b)", choose *USB Device,* and select the *Device* option to be *Manual*. In the newly appeared empty line type usb port ID exactly in the [usb:x.x.x] format shown in "Figure II" and press ***Enter*** on the keyboard.
g) Repeat "Step f)" for the second SDR.
h) Now, the two SDRs should be shown on the *osc.exe* bottom right, so the next step would be to simply click *Connect*.
i) Repeat "Step h)" for the second SDR.
j) At this point, two Plotting Windows will appear. It is the user's job to move manually each plot to two different sides of a screen to get access to both *ADI IIO Oscilloscope settings* windows that have now appeared behind the *Plotting* windows.
k) Drag each of the *settings* windows to split the screen. Navigate to the *AD936X* tab in settings.
l) Under *Controls* in *AD9361/AD9364 Receive Chain* the user should change four parameters related to specific RF signal test: *RF Bandwidth, Sampling Rate, RX LO Frequency (this is tune in frequency), and Hardware Gain(dB).*
    I. Note: User is advised to switch *Hardware Gain* to *Manual*.

Project demonstration example involved 500 [MHz] pulse trains, with 2 [ms] width and 200 [ms] delay between each pulse. For proper operation on this signal, we recommend RF Bandwidth of 10 [MHz], Sampling Rate of 11 [MSPS], RX LO Frequency of 500 [MHz], and Hardware Gain switched to *Manual* at 5 [dB]. Figure "Figure 3" demonstrates the above-mentioned settings.

Figure III: Core Software Settings

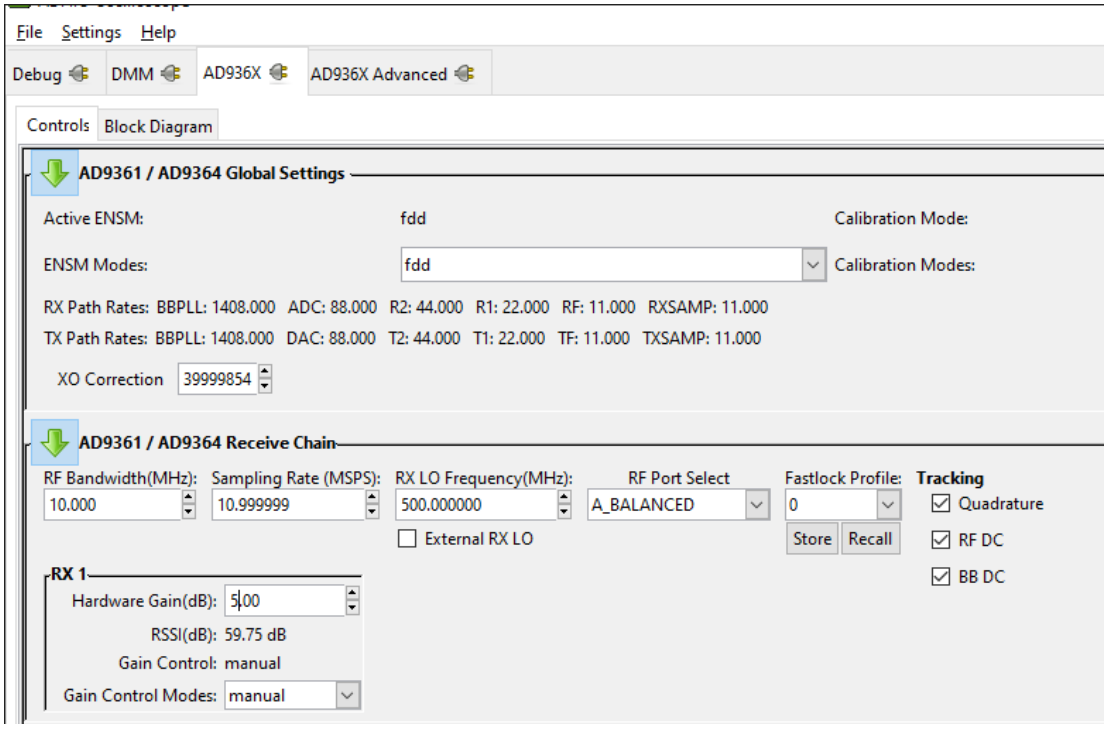

Figure 3: Core software set-up configuration window for analysis and plotting of RF signals.

m) Repeat "Step l)" for second the SDR.

n) Do not close the settings windows. Simply move the two Plotting panels in front and split the screen.

o) On the Plotting panel, the user can find the *Time Scale* setting. Specify any comfortable value in [µs]. We recommend 10000 [µs] for the test signal described above. Repeat this step for the second SDR.

p) Next, on the top left corner of the *Plotting* window press *Enable All.* This enables both *voltage0* and *voltage1* signals (which correspond to I and Q components of a received RF signal respectively). Repeat this step for the second SDR.

q) Right click on the main channel *cf-ad9361-lpc* and select *Trigger Settings*. Choose the voltage signal based on which software defined trigger will be enabled (we recommend using *Channel for trigger: voltage0* and *Trigger Level* of 100 for 500 MHz signal. Set the trigger to act on falling edge. Repeat this step for the second SDR.

r) Lastly, make sure both signals are enabled and press the triangular *Start* button on the top left of the Plotting Window. Repeat this for the second SDR.

The Entire set-up of hardware-software integration is now complete, and the two signals should appear on the two Plotting Windows of IIO-Oscilloscope software as depicted on "Figure 4".

I. Note: The red and green boxes, arrows, and values are placed posteriori for demonstration purposes.

Figure IV: Properly Set-Up Plotting Windows

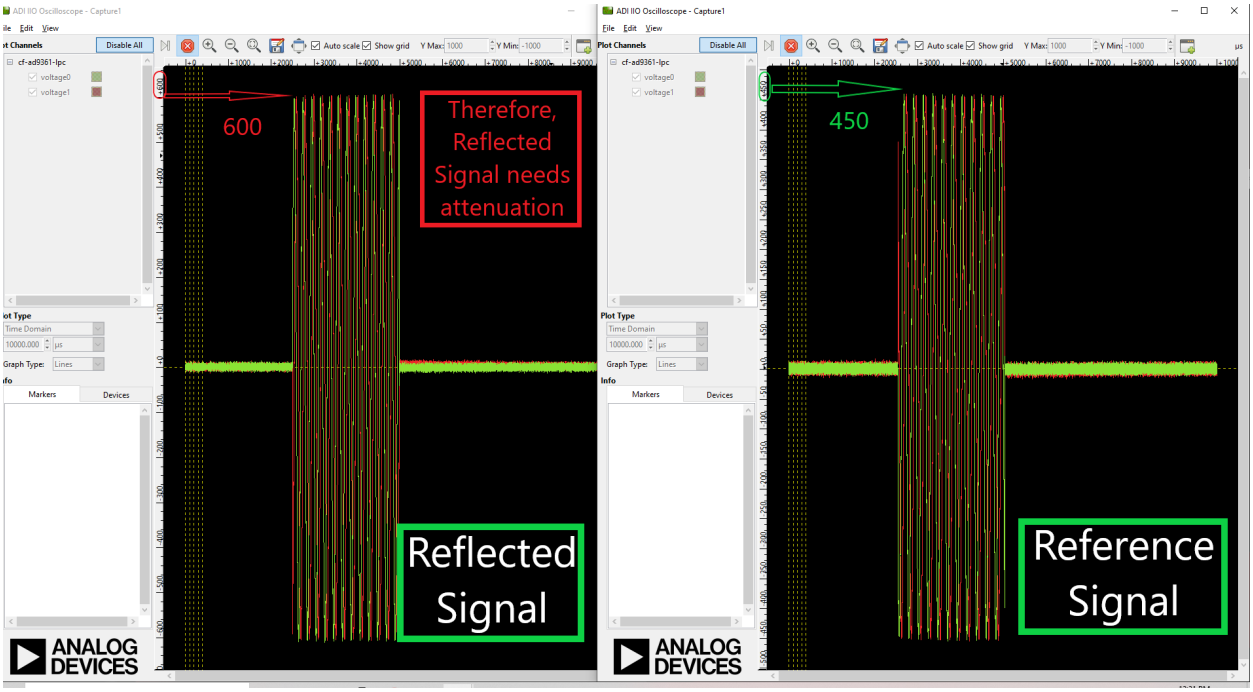

Figure 4: Properly set-up IIO-Oscilloscope Plotting Windows for RF signal tunning.

1.6: Important Documents

These documents can be found in either the compressed "T307_Oscilloscope.zip" file or in the team website here (https://web1.eng.famu.fsu.edu/ece/senior_design/2021/team307/).

Table III: Files

File	Description
Abstract	Project abstract and introduction
Bill of Materials	Materials bought for the project
Testing and Validation	Testing and analysis done for the project
Final Presentation	Final project presentation
Final Report	All relevant submitted documents

Table 3: Files contained in this table

A video demonstration of the Prototype can be found here (https://www.youtube.com/watch?v=xZnUgrdPSTs&t=79s).

SECTION II: Repair Info

2.1: Troubleshooting Tips (Software)

IIO Oscilloscope documentation can be found here (https://wiki.analog.com/resources/tools-software/linux-software/iio_oscilloscope).

a) Make sure to review "Section 1.2" if the software is causing issues.

2.2: Troubleshooting Tips (Hardware)

Adalm Pluto SDR documentation can be found here (https://wiki.analog.com/university/tools/pluto).

a) Make sure to review "Section 1.3" and "Section 1.4" if the hardware is causing issues.

Arduino Due documentation can be found here (https://www.arduino.cc/en/Guide/ArduinoDue).

a) Make sure to review "Section 1.2" and "Section 1.4" if the hardware is causing issues.

SECTION III: Safety Information

In general, it is relatively difficult for the product to cause injury. However, please follow the following rules for product use:

a) Avoid shorting pins or connections.
b) When connecting to I/O pins in the Adalm Pluto or Arduino Due, avoid applying external voltages or signals not specified in this Document.
c) When connecting to I/O pins in the Adalm Pluto or Arduino Due, make sure to ground the circuit schematic first if using an external breadboard or in the case of disconnecting the schematic for servicing before connecting the voltage again.
d) When disconnecting I/O pins from the Adalm Pluto or Arduino Due avoid disconnecting ground first (i.e., disconnect voltage first).
e) Use the "One Hand Rule" when dealing with circuitry, which implies using only one hand to modify the circuits while leaving the other hand in a pocket near your waist to avoid risk.
f) If in the National High Magnetic Field Laboratory (NHMFL), keep product away from magnet and follow their safety requirements.
g) Use common sense to maintain safety requirements, we are not liable in the case of an accident.

SECTION IV: Appendix

Figure A: Assembled Prototype

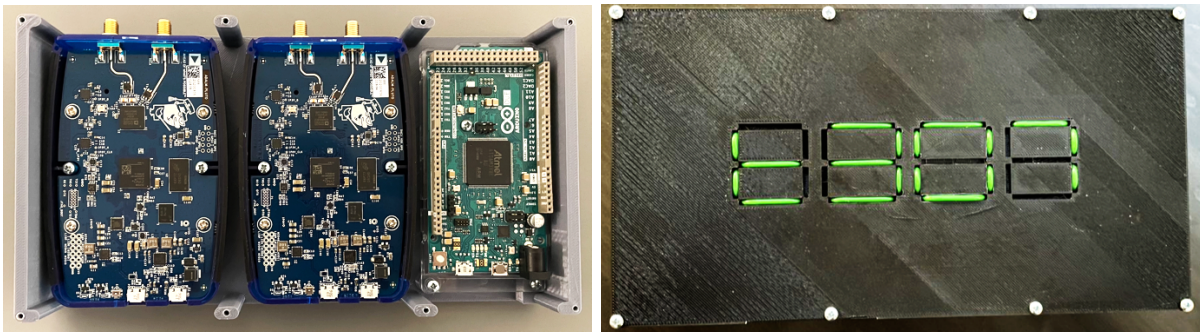

Figure A: Assembled Prototype contained in this figure

Figure B: Detailed Schematic

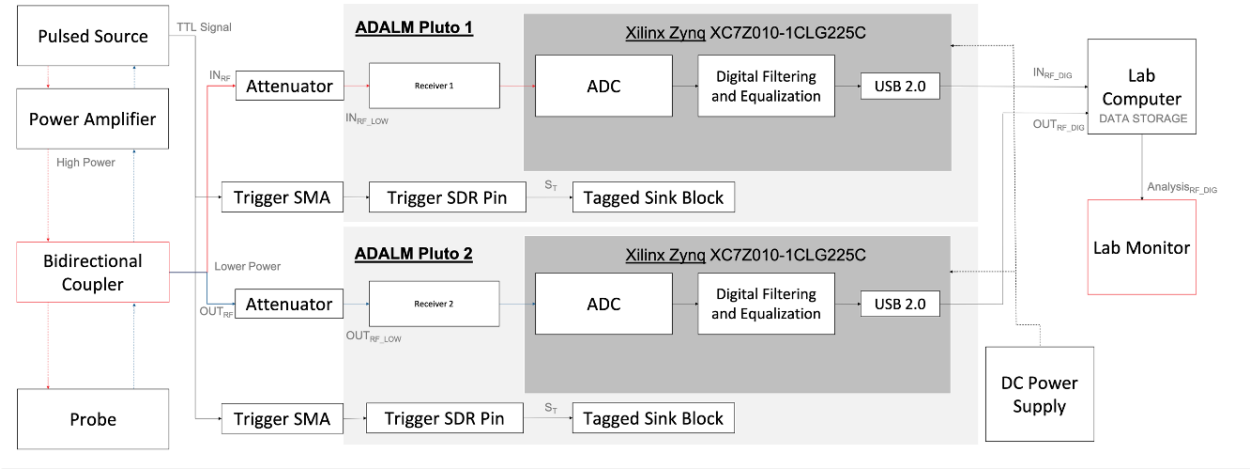

Figure B: Detailed Schematic contained in this figure

4.1: Resources

a) "A Narrow Band "Oscilloscope" for High Power Tuning of NMR Probes", Project Proposal, W. Brey, 2020.
b) "NMR Operation at NYSBC", NYSBC Solid State NMR Short Course, http://comdnmr.nysbc.org/comd-nmr-educ/comd-nmr-lecture-notes/lecture-notes/solidstateNMRcourse.pdf
c) "Design, Care and Feeding of NMR Probes" tutorial presented by Kurt Zilm at the 2011 ENC, http://www.enc-conference.org/Portals/0/Probes_2011_Part_I.pps

d) G. Amouzandeh, V. Ramaswamy, N. Freytag, A. S. Edison, L. A. Hornak and W. W. Brey, "Time and Frequency Domain Response of HTS Resonators for Use as NMR Transmit Coils," in IEEE Transactions on Applied Superconductivity, vol. 29, no. 5, pp. 1-5, Aug. 2019, Art no. 1102705, doi: 10.1109/TASC.2019.2902522.
e) “Zilm - The Inner Workings of NMR Probes For BioSolids NMR”, Stowe 2013, Yale University
f) Shaik, Asif. “Frequency Modulation.” Physics and RadioElectronics, 10 Oct. 2018, www.physics-and-radio-electronics.com/blog/frequency-modulation/
g) Sunnylearning, director. PCM - Analog to Digital Conversion. YouTube, YouTube, 16 Nov. 2018, www.youtube.com/watch?v=HlGJ6xxbz8s&t=356s.
h) StevesLectures, director. Pulse Code Modulation (ITS323, L11, Y15). YouTube, YouTube, 20 Sept. 2015, www.youtube.com/watch?v=9hkHO-klwME.

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