

Senior Design Project
T307
4 December 2020
Preliminary Detailed Design

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SECTION I: Introduction

1.1: Problem Statement

The team has been asked to create an oscilloscope-like prototype substitute for the magnetic labs' Nuclear Magnetic Resonance (NMR) experiments using a Software Defined Radio (SDR). The prototype must mimic the behavior of an oscilloscope so that the experiments may still be properly observed.

1.2: Motivation

The motivation behind creating this oscilloscope substitute is to potentially replace the currently used oscilloscopes with the SDRs and future oscilloscopes for these NMR experiments as these can be quite costly. The SDR has the ability to measure radio frequency (RF) signals and are significantly cheaper than a full-scale oscilloscope.

1.3: Requirements

The requirements for this project include that the prototype:

- Must not include any National Instruments components or software.
- Will have at least an 8-bit resolution for the output digital signal.
- Will have a range of 600MHz to 800MHz for the received and reflected signals.
- Has a sampling rate that will be higher than the minimum value of 11MSPS.
- Must have bandwidth several times larger than the carrier frequency of the pulse.
- Will capture the entire sample (pulse train).
- Will allow for quick physical and software repairs.
- Will have enough bandwidth to demonstrate the envelope.
- Will be connected to an external trigger.
- Will transmit data signals to a PC for review, analysis, and storage.
- Will receive experiment output for analysis.
- Has external storage to store received data.
- Stays under budget while performing all the software and hardware capabilities necessary.
- Will be assembled in a single unit.

SECTION II: Selected Concept

Two Adalm Pluto SDRs will be used for the prototype. The attenuation will be connected directly to the SDR, the trigger will be soldered onto the SDR and use tagged sink blocks to be implemented. The SDRs will be connected to the PC by USB 2.0 and a PC monitor will be used to display the information. Windows 10 and Simulink software will be used, and MATLAB and Python languages will be utilized for the prototype. The SDRs will use USB power, an external hard drive for storage, and a keyboard for the user interface. The prototype box will be cubical, made of ABS Plastic, with the dimensions of 10x8x4 inches (LxWxH). This can be more easily seen in the images below containing a tabulated form of the selected design. It is split for better readability.

Table I: Selected Design

Number	Concept	Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9
1	Prototype 1	Number of SDR	SDR	Attenuation	Trigger	Trigger implementation	Connection to PC	Display	Software	Language
		Two (one receiver port)	ADALM Pluto	On SDR	Soldered connection	Tagged Sink Block	USB 2.0	PC monitor	Windows 10 Simulink	MATLAB Python

Table 1: Selected Design Table

Table I: Selected Design (cont...)

Column10	Column11	Column12	Column13	Column14	Column15	Column16	Column17
Power	Storage	Interface	Prototype BoxMaterial	Prototype BoxShape	Prototype BoxDesign	Prototype Box Size (LxWxH)	Biomimicry
USB Power	Extemal (PC Hard Drive)	Keyboard	ABS Plastic (3D Printing)	Cubical	Closed and accessible	Medium (10x8x4 in)	Solid construction

Table 2: Selected Design Table continued

SECTION III: Preliminary Design

Based on the selected design concept, a block diagram of the prototype from the selected concept is shown below:

Figure I: Preliminary Detailed Design

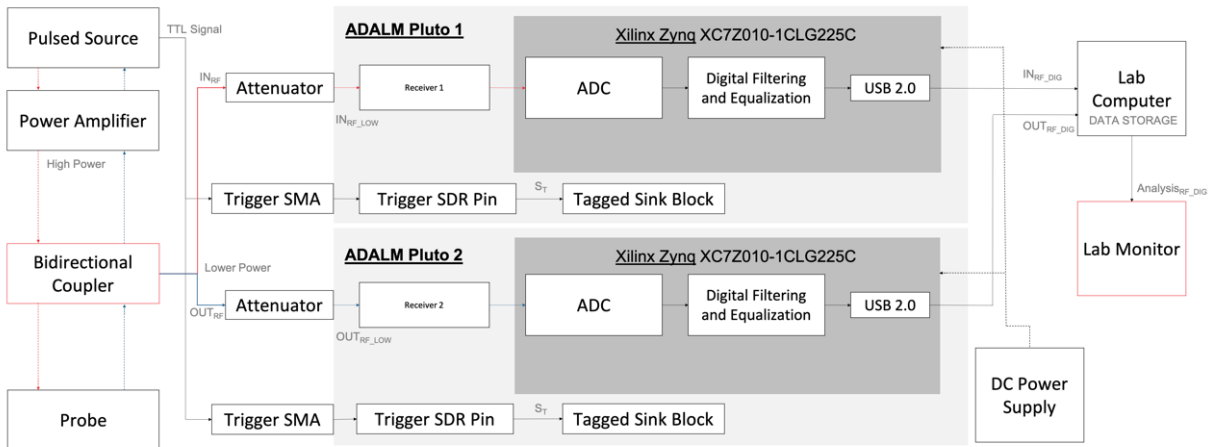


Figure 3: Preliminary Detailed Design elements contained in this figure

The working of the design begins on the left with the Pulsed Source, Power Amplifier, Bidirectional Coupler, and the Probe which are all a part of the NMR experiments. The prototype takes three inputs from the experiment environment: an input and reverse radio frequency (RF) signal, shown in red and blue respectively, from the bidirectional coupler; and the TTL trigger signal from the pulsed source. The Adalm Pluto only has one receiver port and thus two are used in the prototype. The TTL signal is split into two for both SDRs and is connected the same for both via an SMA connection to the prototype. Inside the prototype, this is soldered onto one of the SDR's GPIO pins; this is connected on the SDR internally to the Tagged Sink Block. These connections allow for the trigger implementation of the SDR "oscilloscope". The input RF signal from the bidirectional coupler is sent to the first Pluto through the attenuator (used to lower the power of the incoming signal) which is connected to its receiver port. From the receiver port, the signals make their way to the Xilinx Zynq Z7010 FPGA (included on the Adalm Pluto) where they are accepted by the ADCs, filtered and equalized, and moved to the USB 2.0 port to be outputted to the Lab Computer. This process is repeated on the second Pluto for the reverse RF signal. The Lab Computer receives the data from both SDRs and analyzes the data appropriately via MATLAB to see the ratio between the input and reverse RF signals. The final output is sent to the Lab Monitor to be viewed by the user. The DC Power supply is used to provide optional power for both SDRs to ensure the need of operating continuously for several days is met.

SECTION IV: Summary

The team's goal is to create a prototype that mimics the behavior of an oscilloscope using SDRs to allow the Magnetic Lab to replace the oscilloscopes currently used for their NMR experiments. The team's choice in SDR is the Adalm Pluto for its plethora of available documentation and MATLAB support. The main idea is the trigger implementation for the "oscilloscope" which will involve using a TTL trigger and Tagged Sink Blocks. Lastly, the DC power supply is optional as the SDRs can run using the PC's USB port, however, to ensure that the SDR is running for several days, a power supply will be used instead.

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