

Senior Design Project
T307
2 April 2021
Testing and Validation

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SECTION I: Unit Tests

Description: Unit tests are the initial building blocks of the overall judgement of the final prototype operation. Each unit test refers directly to a single component from a more complex system. There are two types of test for unit, integration, and acceptance testing. Namely, black box and white box tests. During a black box test only input and output of a block are considered, without knowledge or testing of the internal components. During a white box test, the internal components are very well known, and it is the tester's job to evaluate the correct operation of those components as well as the overall performance of a unit.

1.1: SDR ADC Module White Box Unit Test

Test Writer		EMIL LOBACHEV				
Test Case Name		SDR ADC Module			Test ID #:	1
Description		Testing the operation of ADALM-PLUTO SDR ADC with a lab oscilloscope			Type	White Box Unit Test
Tester Information						
Name of Tester		EMIL LOBACHEV			Date	3/4/2021
Hardware/Software Ver.		Hardware V1.0, Software V2.0			Time	15:00
Setup		ADALM-PLUTO SDR was connected to laptop running Windows OS for Power Supply purpose. The SDR setting was applied to manufacturer's settings (2.4 GHz tune-in, so called "Rx Lo Frequency"). The SDR module had been taking out of its casing to have access to PCB ports. A lab oscilloscope was used in collaboration with banana wires. The latter were connected directly to ADC output pin of PCB for testing the output of ADC.				
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Tune to 2.4 GHz	Able to visualize the output of ADC digitized signal on oscilloscope.	X			Lab oscilloscope have shown the digitized voltage at the output of ADC.
2	Tune to 101 MHz	Able to visualize the output of ADC digitized signal on oscilloscope.	X			Lab oscilloscope have shown the digitized voltage at the output of ADC.
3	Tune to 800 MHz	Able to visualize the output of ADC digitized signal on oscilloscope.	X			Lab oscilloscope have shown the digitized voltage at the output of ADC.
Overall Test Result			X			The operation of ADC module had been tested and verified as working correctly. The requirement of at least 8-bit ADC (ADALM-PLUTO ADC is 12-bit) had been satisfied.

1.2: MATLAB Simulink Software White Box Unit Test

Test Writer		EMIL LOBACHEV				
Test Case Name		MATLAB Simulink Software		Test ID #:	2	
Description		Testing the operation of MATLAB Simulink with ADALM-PLUTO SDR		Type	White Box Unit Test	
Tester Information						
Name of Tester		EMIL LOBACHEV		Date	3/4/2021	
Hardware/Software Ver.		Hardware V1.0, Software V1.0		Time	15:30	
Setup		Connected ADALM-PLUTO to a laptop running MAC OS. MATLAB Simulink software was updated with all necessary libraries (including PLUTO SDR add-on in MATLAB). MATLAB Simulink was started and parameters of tuning frequency, sampling rate and capture bandwidth were first tested with manufacturer's setting, and then changed to 101 MHz, 40 kHz, 1 MHz. Final setting test was 800 MHz, 11 MSPS, and 10 MHz.				
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Set: Tune: 2.4 GHz Sampling: 70 kHz BW: 1 MHz	ADALM-PLUTO SDR's settings will update and tune into all specified parameters.	X			All settings were successfully applied and SDR's blue LED blinked signaling successful implementation of new settings.
2	Set: Tune: 101 MHz Sampling: 40 kHz BW: 1 MHz	ADALM-PLUTO SDR's settings will update and tune into all specified parameters.	X			Same as previous description.
3	Set: Tune: 800 MHz Sampling: 11 MSPS BW: 10 MHz	ADALM-PLUTO SDR's settings will update and tune into all specified parameters.	X			Same as previous description.
Overall Test Result			X			Test results showed successful satisfaction of requirement that specified 800 MHz carrier signal frequency, 11 MSPS sampling rate and 10 MHz bandwidth.

1.3: IIO-Oscilloscope Software White Box Unit Test

Test Writer		EMIL LOBACHEV				
Test Case Name	IIO-Oscilloscope Software	Test ID #:	3			
Description	Testing the operation of MATLAB Simulink with IIO-Oscilloscope Software with ADALM-PLUTO SDR	Type	White Box Unit Test			
Tester Information						
Name of Tester	EMIL LOBACHEV	Date	3/4/2021			
Hardware/Software Ver.	Hardware V1.0, Software V2.0	Time	16:00			
Setup	Connected ADALM-PLUTO to a laptop running Windows OS. IIO-Oscilloscope Software was started and parameters of tuning frequency, sampling rate and capture bandwidth were first tested with manufacturer's setting, and then changed to 101 MHz, 40 kHz, 1 MHz. Final setting test was 800 MHz, 11 MSPS, and 10 MHz.					
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Set: Tune: 2.4 GHz Sampling: 70 kHz BW: 1 MHz	ADALM-PLUTO SDR's settings will update and tune into all specified parameters.	X			All settings were successfully applied and SDR's blue LED blinked signaling successful implementation of new settings.
2	Set: Tune: 101 MHz Sampling: 40 kHz BW: 1 MHz	ADALM-PLUTO SDR's settings will update and tune into all specified parameters.	X			Same as previous description.
3	Set: Tune: 800 MHz Sampling: 11 MSPS BW: 10 MHz	ADALM-PLUTO SDR's settings will update and tune into all specified parameters.	X			Same as previous description.
Overall Test Result			X			Test results showed successful satisfaction of requirement that specified 800 MHz carrier signal frequency, 11 MSPS sampling rate and 10 MHz bandwidth.

1.4: Prototype White Box Unit Test

Test Writer		EMIL LOBACHEV				
Test Case Name		Prototype Unit Box			Test ID #:	7
Description		Testing the dimensions of 3D printed prototype unit box			Type	White Box Unit Test
Tester Information						
Name of Tester		EMIL LOBACHEV			Date	3/19/2021
Hardware/Software Ver.		Hardware V1.0, Software V2.0			Time	16:00
Setup		Designed in SOLIDWORKS, the prototype unit box was 3D printed. The casing was placed on a workbench table and all related devices and cables were brought. The assembly required several standard 1.5 mm screws and a screwdriver for initial SDR module case opening.				
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Place two SDR modules in the provided locations	SDR modules are seated firmly in the prototype casing.	X			Two SDR modules were very well secured with screws, and enough room was provided for air flow underneath them.
2	Place Arduino Due in the provided location	Arduino Due is secured in the prototype casing.	X			Same as previous.
3	Pass all cables and internal connections	The holes made for cable entry are wide enough and all cables are connected on the inside	X			Cables were successfully passed to the internal components of the prototype casing and connections on the inside were established.
Overall Test Result			X			The prototype unit was able to fit all necessary equipment. This test satisfied the requirement of our prototype to be assembled in a single unit box.

SECTION II: Integration Tests

Description: Integration Tests verify proper operation combination of several units in a system, as well as their functionality. Even though a component/module can pass the unit test, it is not always guaranteed that during the integration phase of the project, it will perform all functionalities correctly. Therefore, integration tests are necessary to isolate functions that are faulty and fix errors before the final assembly and testing.

2.1: SDR Module I/O with MATLAB Black Box Integration Test

Test Writer		EMIL LOBACHEV				
Test Case Name	SDR Module I/O	Test ID #:		4		
Description	Testing the operation of ADALM-PLUTO SDR I/O	Type		Black Box Integration Test		
Tester Information						
Name of Tester	EMIL LOBACHEV	Date		3/4/2021		
Hardware/Software Ver.	Hardware V1.0, Software V1.0	Time		16:30		
Setup	ADALM-PLUTO was connected to a MAC OS laptop running MATLAB Simulink Software. The test was set up to initially tune to stock 2.4 GHz frequency on the receiver port of the SDR. The SDR was tested to successfully capture (Input test) and display (Output test) the signal on "Scope" block in MATLAB Simulink software. Manufacturer's antenna was connected to receiver port and the USB output digital data was connected from the SDR to the laptop USB port.					
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Tune to 2.4 GHz	Able to visualize the input signal on the display of Time Domain scope.		X		The resulted Scope signal output picture was very delayed. MATLAB software struggled to keep up with fast RF signal data input. At some point during the test, the screen froze.
2	Tune to 101 MHz	Able to visualize the input signal on the display of Time Domain scope.		X		The signal displayed was the ADC codes corresponding to the input signal. Making a harsh assumption that the digital data is full-scale i.e., 12-bit data, we could assume that input to the ADC was full-scale, with 0 dBFS corresponding to 0.625 V. However, this discrepancy was chosen to be not permitted, and therefore the test was failed.
3	Tune to 800 MHz	Able to visualize the input signal on the display of Time Domain scope.		X		The resulted Scope signal output picture was very delayed. MATLAB software struggled to keep up with fast RF signal data input. At some point during the test, the screen froze.

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Overall Test Result		X	Overall, the I/O operation was tested and found to be not appropriate. Another software must be used to satisfy given engineering requirements of the project.
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2.2: SDR Module I/O with IIO-Oscilloscope Black Box Integration Test

Test Writer		EMIL LOBACHEV				
Test Case Name	SDR Module I/O	Test ID #:	5			
Description	Testing the operation of ADALM-PLUTO SDR I/O	Type	Black Box Integration Test			
Tester Information						
Name of Tester	EMIL LOBACHEV	Date	3/11/2021			
Hardware/Software Ver.	Hardware V1.0, Software V2.0	Time	15:00			
Setup	ADALM-PLUTO was connected to a Windows OS laptop running ADI IIO-Oscilloscope Software. The test was set up to initially tune to stock 2.4 GHz frequency on the receiver port of the SDR. The SDR was tested to successfully capture (Input test) and display (Output test) the signal on Time Domain scope in IIO-Oscilloscope software. Manufacturer's antenna was connected to receiver port and the USB output digital data was connected from the SDR to the laptop USB port.					
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Tune to 2.4 GHz	Able to visualize the input signal on the display of Time Domain scope.	X			The signal was displayed. However, the signal was not voltage magnitude vs time. It was voltage I component vs time and voltage Q component vs time.
2	Tune to 101 MHz	Able to visualize the input signal on the display of Time Domain scope.	X			Same as previous description.
3	Tune to 800 MHz	Able to visualize the input signal on the display of Time Domain scope.	X			Same as previous description.
Overall Test Result			X			Overall, the I/O operation was tested and found to be appropriate. The requirement of our prototype being able to display the signal for further tuning was satisfied.

2.3: IIO Oscilloscope two ADALM-PLUTO SDR White Box Integration Test

Test Writer		EMIL LOBACHEV				
Test Case Name	IIO Oscilloscope two ADALM-PLUTO SDR	Test ID #:	6			
Description	Integration of two ADALM-PLUTO SDR modules in single IIO-Oscilloscope program.	Type	White Box Integration Test			
Tester Information						
Name of Tester	EMIL LOBACHEV	Date	3/11/2021			
Hardware/Software Ver.	Hardware V1.0, Software V2.0	Time	15:30			
Setup	Two ADALM-PLUTOs was connected to a Windows OS laptop running ADI IIO-Oscilloscope Software. The test was set up to initially tune to stock 2.4 GHz frequency on the receiver port of the SDR. Single instance of the software was opened and two SDR modules were connected to two separate USB ports of the laptop.					
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Connect 1 SDR and display received signal	Able to visualize the input signal on the display of Time Domain scope.	X			This was a quick check for the results of Test #5. The received signal was shown in Time Domain as expected.
2	Connect 2 SDRs and display two received signals on one instance of the software	Able to visualize the input signal on the display of Time Domain scope.		X		After connecting the second SDR, there was no option for its settings in software, and only first SDR was plotting the received signal.
3	Create two instances of IIO-Oscilloscope by running the application twice when SDRs are already connected to USB ports	Two instances of IIO-Oscilloscope will open on the main working space.		X		Running as Administrator IIO-Oscilloscope twice did not open the second instance of the software. Moreover, it was identified that if even one SDR is connected before the program is opened - the program will not open.

4	Download libiiio libraries for Windows and run <i>iio_info -s</i> command to find out USB port id for each ADALM-PLUTO	USB ids are displayed in command window.	X		Libiiio libraries were successfully installed and by running the specified command in command window, two SDR port USB ids were identified.
5	Create two instances of IIO-Oscilloscope by running the application twice when SDRs are not connected yet to USB ports	Two instances of IIO-Oscilloscope will open on the main working space.	X		It was found that previous step must be done before this step. Because the only way that two instances of the program open, is when no SDR is connected.
6	Connect two SDRs having two instances of IIO-Oscilloscope open at the same time	At the time of the connection of SDRs the two open instances of the program will still be available.	X		Test result was successful. The SDRs were connected, and USB ids were found, and ready to be specified in the program.
7	Switch the settings in software to <i>Manual</i> and specify USB port id local names there.	Each instance of IIO-Oscilloscope is connected to each SDR respectively.	X		The USB port ids were specified in each instance of the program when settings were switched to <i>Manual</i> . Each instance of the program successfully "tied" to each of SDRs.
8	Set the settings (tune frequency, sampling rate, bandwidth) for each SDR and visualize it on each application plot.	Following the previous outcome, the settings of each SDR are switched <u>one at a time</u> and the received signals are shown on two instances of the software, plotting the two input signals.	X		All settings were successfully applied to each SDR and the signals were displayed on two windows as expected.
Overall Test Result			X		Two SDRs were connected to the same computer, user was able to modify settings of each SDR separately, and the received signal were shown in two separate software instances. This therefor satisfies the requirement of prototype showing the envelope of two

				incoming signals on the same monitor.
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2.4: Initial Setup with RF Pulse Generator White Box Integration Test

Test Writer		EMIL LOBACHEV				
Test Case Name	Initial setup with RF Pulse generator			Test ID #:	8	
Description	Testing single SDR module operation with RF pulses coming from RF pulse generator.			Type	White Box Integration Test	
Tester Information						
Name of Tester	EMIL LOBACHEV			Date	4/1/2021	
Hardware/Software Ver.	Hardware V1.0, Software V2.0			Time	16:00	
Setup	The prototype unit was safely stationed on the workbench. To test the operation of prototype with RF pulses, only one SDR was connected in this test. The SDR was connected using a USB 2.0 cable to a laptop running Windows OS and IIO-Oscilloscope program. The pulse generator unit was controlled using separate lab computer running Linux OS. The pulses were set to be 2.5 ms long, at 600 MHz, and 200 ms delay between them.					
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Tune to 600 MHz frequency on the receiver module and tune its gain (in dB)	The SDR module is updated with specified by the user parameters and gain is set to level at which RF signal is clearly extracted in comparison to noise level	X			The SDR module was updated with new specifications. The gain was set to manual and brought down by 68 dB for isolation of noise amplification.
2	Tune software defined trigger function to operate without large displacement effect on the plotting of the RF signals	The in-built trigger function operates continuously, capturing and displaying up to 95% of the burst on the monitor.	X			The trigger function worked correctly on the falling edge of the I component of the received voltage signal. 2.4 out of 2.5 total duration of the pulse was plotted (96%).
3	Adjust Time Scale properly, so that the entire envelope of the signal is seen at once	The time scale is wide enough to visualize the entire envelope of the incoming signal	X			Time scale was adjusted to 4x the duration of the pulse, showing the entire envelope of the burst.
Overall Test Result			X			All required tuning parameters were satisfied. The tune in

			<p>frequency, sampling rate, bandwidth, gain, time scale, and trigger settings were successfully updated and applied to software. Success of step 2 provided satisfaction of project requirement of trigger function operation. Whereas success of Step 3 satisfied requirement of prototype displaying entire envelope of the incoming signal.</p>
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2.5: Final Setup with RF Pulse Generator White Box Integration Test

Test Writer		EMIL LOBACHEV				
Test Case Name	Final setup with RF Pulse generator	Test ID #:	9			
Description	Testing prototype operation with RF pulses coming from RF pulse generator.	Type	White Box Integration Test			
Tester Information						
Name of Tester	EMIL LOBACHEV	Date	4/1/2021			
Hardware/Software Ver.	Hardware V1.0, Software V2.0	Time	17:00			
Setup	The prototype unit was safely stationed on the workbench. To test the operation of prototype with RF pulses, both SDRs were connected to the PC. The SDRs were connected using a USB 2.0 cables to a laptop running Windows OS and IIO-Oscilloscope program. The pulse generator unit was controlled using separate lab computer running Linux OS. The pulses were set to be 2.5 ms long, at 600 MHz, and 200 ms delay between them. To demonstrate different pulse, the output of Pulse Generator SMA cable was split using a splitter. One cord was connected directly to the first SDR. The second SMA cord underwent physical attenuation using a 26 dB attenuator and then connected to the second SDR.					
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Tune to 600 MHz frequency on receiver modules and tune their gain (in dB)	Both SDR modules are updated with specified by the user parameters and gains are set to level at which RF signal is clearly extracted in comparison to noise level	X			SDR modules were updated with new specifications. The gain was set to manual and brought down by 68 dB for isolation of noise amplification.
2	Tune software defined trigger function to operate without large displacement effect on the plotting of the RF signals	The in-build trigger function operates continuously, capturing and displaying up to 95% of the burst on the monitor.	X			The trigger function worked correctly on the falling edge of the I component of the received voltage signal with both SDRs. 2.4 out of 2.5 total duration of the pulse was plotted (96%).
3	Adjust Time Scales properly, so that the entire envelopes of RF signals are seen	The time scale is wide enough to visualize the entire envelope of the incoming signal	X			Time scale was adjusted to 4x the duration of the pulse, showing the entire envelope of the burst for each SDR module.

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4	Repeat final six steps of Test №6 to display two plots of IIO-Oscilloscope program on the same screen for tuning purposes	Two instances of IIO-Oscilloscope are displayed on the same monitor and both SDRs' settings are properly controlled and adjusted	X			The two SDRs successfully were connected to the same PC. Two instances of the program were shown, plotting two received signals.
Overall Test Result			X			All required tuning parameters were satisfied. The tune in frequency, sampling rate, bandwidth, gain, time scale, and trigger settings were successfully updated and applied to software. Success of step 2 provided satisfaction of project requirement of trigger function operation. Whereas success of Step 3 satisfied requirement of prototype displaying entire envelope of the incoming signal. Finally, the ability to plot two signals on the same monitor satisfied the end goal of the project. This signified that an end user was able to visualize two incoming waveforms and tune the probe, accordingly, satisfying the overall goal of the project.

SECTION III: Acceptance Test

Description: Acceptance Test stipulates the conditions under which the customer will accept the system. The following test contains six steps (cases) that show that the requirements are met. In the case of our project the requirements were specifying that the final prototype is assembled in a single unit box and can be integrated with Windows machine. The prototype shall work as an oscilloscope, tuning to a specified frequency and clearly displaying envelopes of both reverse and reference RF signals in Time Domain. The following Acceptance demonstrates successful satisfaction of all these requirements.

3.1: Final Prototype Test Black Box Acceptance Test

Test Writer		EMIL LOBACHEV				
Test Case Name		Final Prototype Test			Test ID #:	10
Description		Testing prototype operation with RF pulses coming from RF pulse generator.			Type	Black Box Acceptance Test
Tester Information						
Name of Tester		EMIL LOBACHEV			Date	4/1/2021
Hardware/Software Ver.		Hardware V1.0, Software V2.0			Time	17:30
Setup		The prototype unit was safely stationed on the workbench. The setup was performed as if in real use. Therefore, only four connections were made: two USB 2.0 (SDRs' outputs) to a laptop running Windows OS and IIO-Oscilloscope program, one SMA cable directly connected to pulse generator, and another SMA cable connected to 26 dB attenuator and through a splitter to the same pulse generator output cable. The pulse generator unit was controlled using separate lab computer running Linux OS. The pulses were set to be 2.5 ms long, at 600 MHz, and 200 ms delay between them.				
Step	Actions	Expected Results	Pass	Fail	N/A	Comments
1	Repeat final six steps of Test №6 to display two plots of IIO-Oscilloscope program on the same screen for tuning purposes	Two instances of IIO-Oscilloscope are displayed on the same monitor and both SDRs' settings are properly controlled and adjusted	X			The two SDRs successfully were connected to the same PC. Two instances of the program were shown, plotting two received signals.
2	Connect IO. (i.e. connect two USB cables to main laptop. Connect two SMA cables carrying RF signals to the prototype).	Four connection are established, and the prototype is ready to operate.	X			All four cables were connected and secured.
3	Tune to 600 MHz frequency on receiver modules and tune their gain (in dB)	Both SDR modules are updated with specified by the user parameters and gains are set to level at which RF signal is clearly extracted in comparison to noise level	X			SDR modules were updated with new specifications. The gain was set to manual and brought down by 68 dB for isolation of noise amplification.
4	Tune software defined trigger on both SDRs.	The in-build trigger function operates continuously, capturing	X			The trigger function worked correctly on the falling edge of the I

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		and displaying up to 95% of the burst on the monitor.			component of the received voltage signal with both SDRs. 2.4 out of 2.5 total duration of the pulse was plotted (96%).
5	Adjust Time Scales properly, so that the entire envelopes of incoming signals are seen	The time scale is wide enough to visualize the entire envelope of the incoming signal	X		Time scale was adjusted to 4x the duration of the pulse, showing the entire envelope of the burst for each SDR module.
6	Use the split screen function of Windows OS to display two plots on the same monitor and control the LIVE view of both signals using two "Play" buttons in each IIO-Oscilloscope program window	Two plots are clearly seen on the same screen and from the plot end user can control LIVE display of two incoming signals.	X		Two plots were shown on the same screen. The use was able to start and stop the display of incoming RF signals.
Overall Test Result			X		All required tuning parameters were satisfied. The tune in frequency, sampling rate, bandwidth, gain, time scale, and trigger settings were successfully updated and applied to software. Finally, the ability to plot two signals on the same monitor satisfied the end goal of the project. This signified that an end user was able to visualize two incoming waveforms and tune the probe, accordingly, satisfying the overall goal of the project. These six steps all successfully passed the test and are therefore taken to be described in detail in Operation Manual Document for

				future users of the prototype.
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