



NI USRP Hands-On

For Aero-Space and Defense

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July. 2024



Agenda

Introduction to NI (10m)

NI LabVIEW Basic (2h)

Introduction Software Defined Radio and USRP HW Architecture (30m)

Programming USRP with LabVIEW (2h 30m)

USRP Product Selection Guide (30m)

Q&A(30m)

Expanding Emerson's Boundless Automation Vision into Test & Measurement



Process & Hybrid Automation | Discrete Automation | Industrial Automation



Test & Measurement Automation



Oil & Gas



Chemical



Food & Beverage



Packaging



Pulp & Paper



Medical



Power Generation



Mining, Minerals & Metal



Electronics



Marine



Water & Wastewater



Life Sciences



Semiconductor



Aerospace/Defense



Transportation



Energy & Heavy Industry

NI is now part of Emerson

Future proofing Test & Measurement for our customers through NI's integrated software centric approach

\$1.7B

Revenue

35K

Customers Worldwide

7K

Employees Worldwide

45

Years in T&M

The NI Advantage



Proven



Connected



Modular



Future-proof

Growth Sectors



Semiconductor



Aerospace/Defense



Transportation



Energy & Heavy Industry

Product & Applications



Design & Prototyping



Automated Validation



Production Test

Anatomy of a PXI System

Software

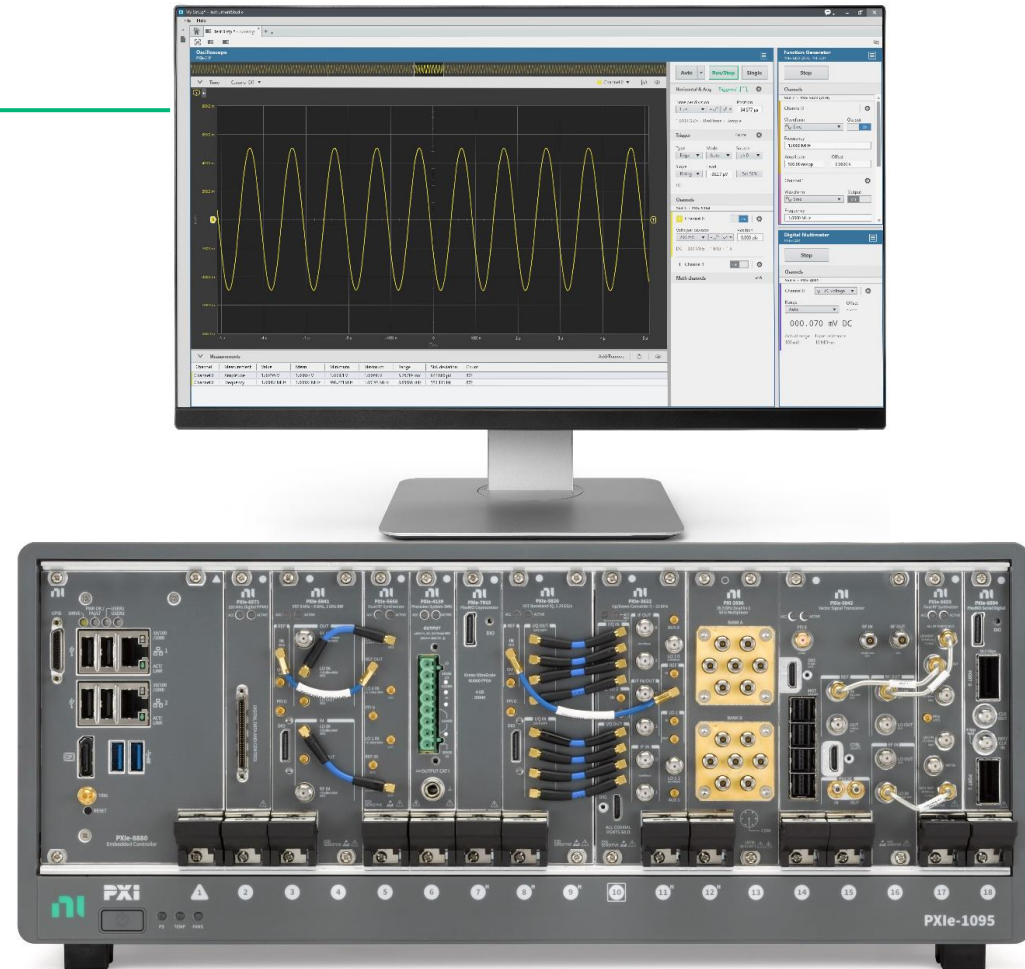
Test Management and Code Development

Computer

PXI Embedded Controller

Timing and Synchronization
PXI Chassis

Instrumentation
PXI Modules





Advantages of PXI Instrumentation

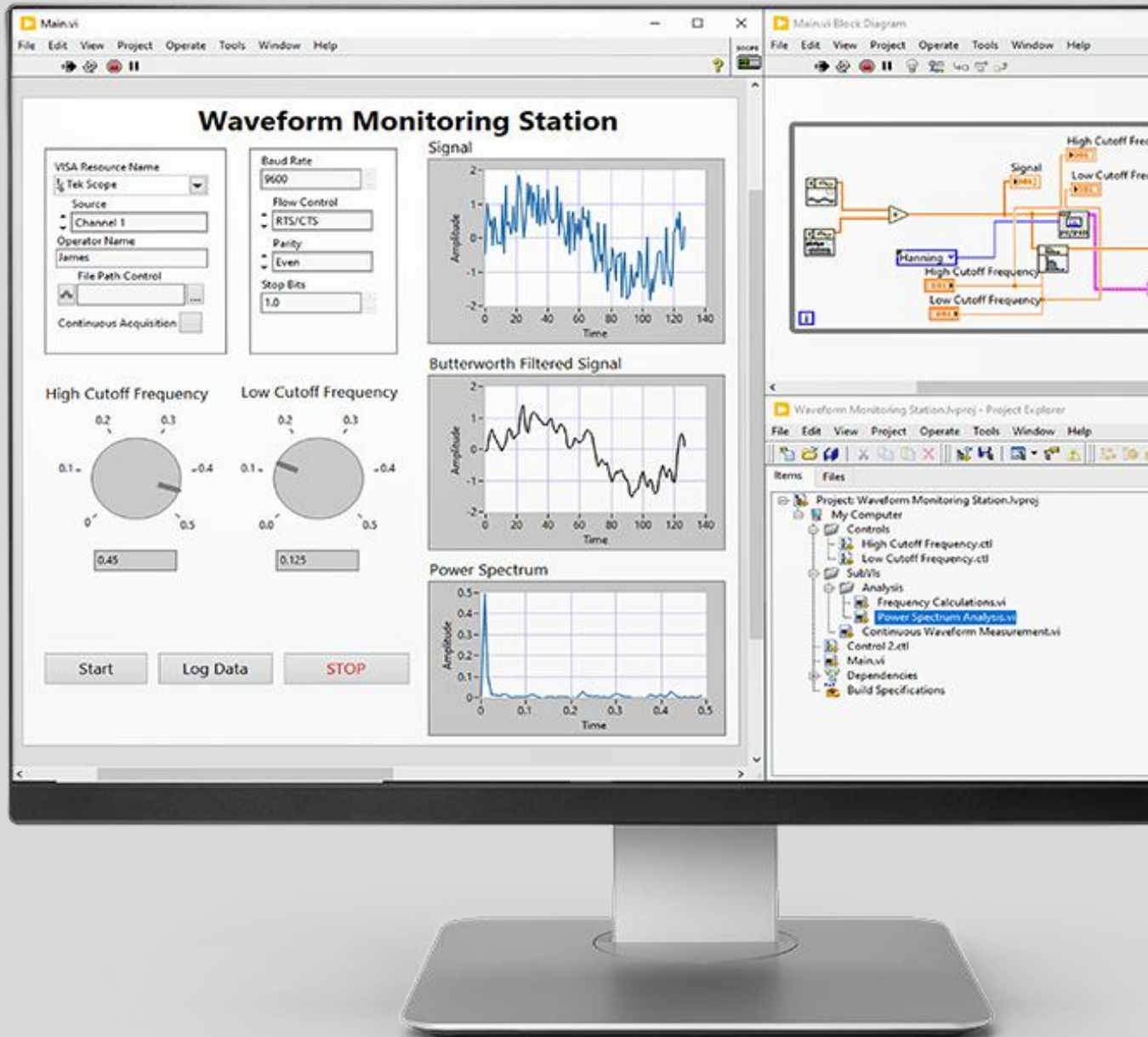
High Throughput and Low Latency

Software-Defined Functionality

Integrated Timing and Sync

High-Performance Processing

Reduced Size, Weight, and Power



**What is
LabVIEW?**



공학자들이 자동화된 연구, 검증 및 생산 테스트 시스템을 개발하는 데 최적화된 그래픽 프로그래밍 환경.



전문가 수준의 사용자 인터페이스

드래그 앤 드롭 UI 요소로 구축된 인터랙티브 UI를 통해 데이터를 보고, 테스트 시스템을 제어합니다.



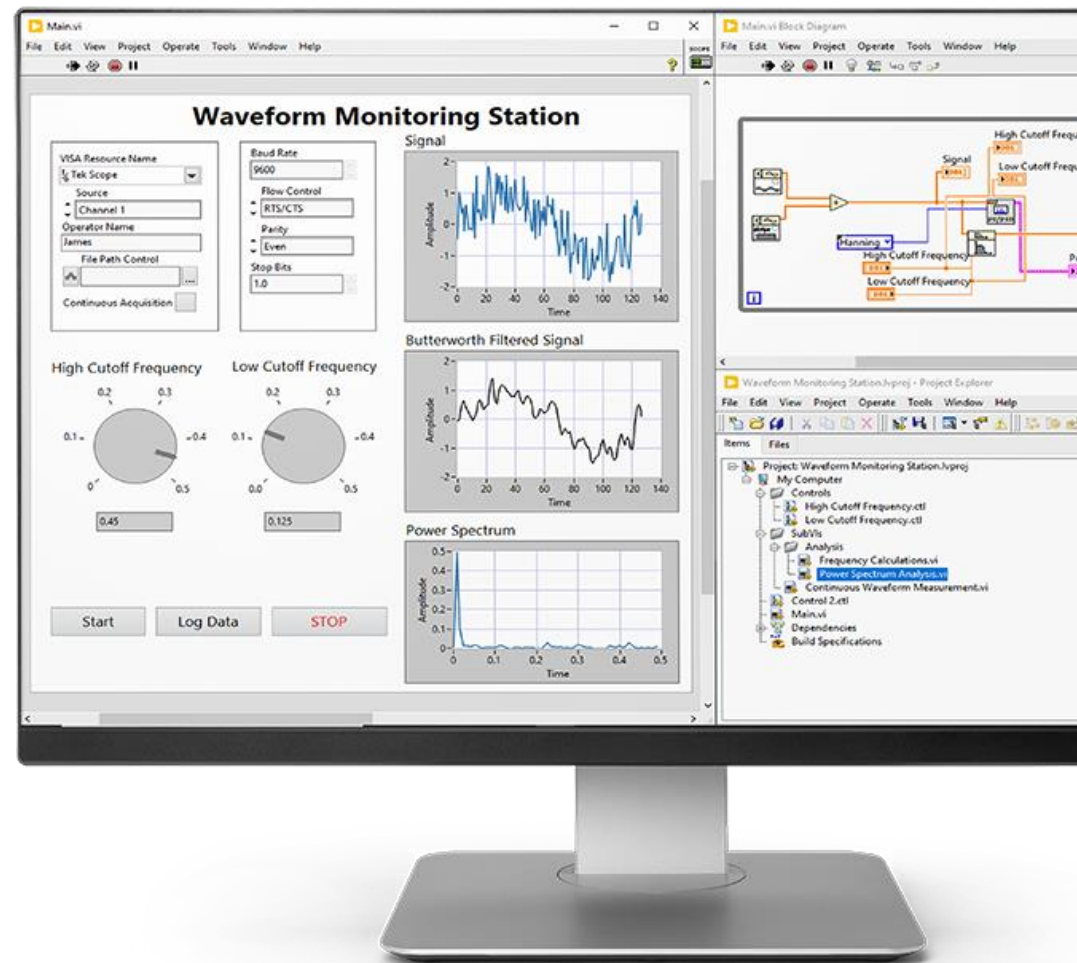
모든 기기 통합

수천 개의 장치 드라이버와 산업 표준 프로토콜을 통해 데이터를 수집하고 모든 기기를 제어합니다.



외부 코드 통합

Python, C/C++, MATLAB®, .NET으로 작성된 기존 코드를 활용할 수 있습니다



소프트웨어 및 드라이버 설치하기

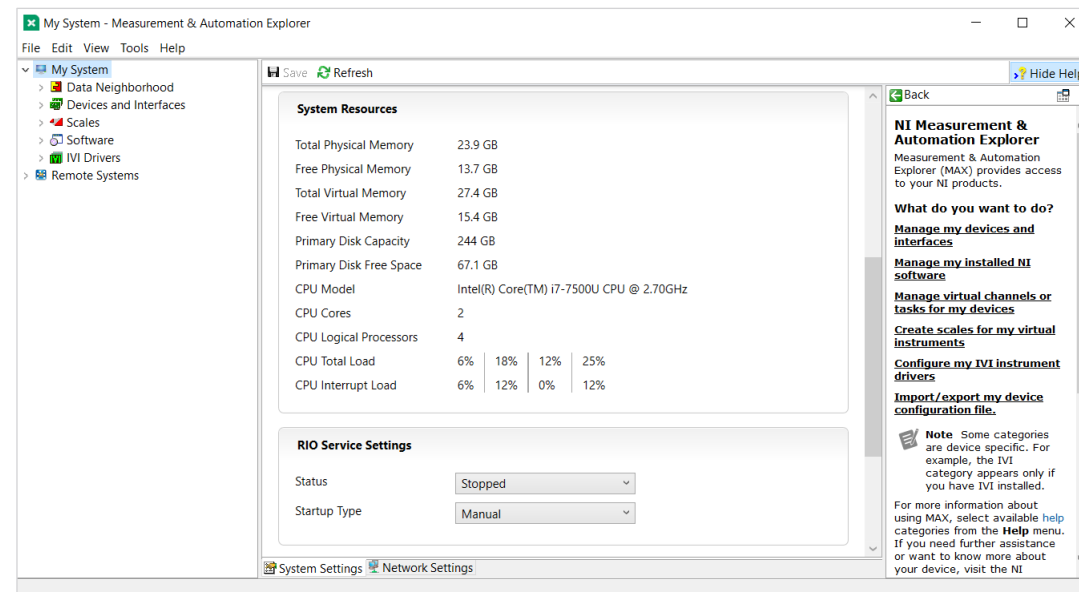
1. 제품 탐색(BROWSE PRODUCTS) 선택
2. 프로그래밍 환경(Programming Environments) 선택
3. LabVIEW 및 드라이버(LabVIEW and Drivers) 선택

The screenshot shows the NI Package Manager interface. The left sidebar has 'BROWSE PRODUCTS' selected at the top, and 'Programming Environments' is highlighted in the sub-menu. The main area displays 'LabVIEW and Drivers' as the first product, with a description: 'LabVIEW and Drivers provides LabVIEW software and compatible NI driver software and software add-ons.' Below it is 'Measurement Studio and Drivers' with a similar description. The top bar shows 'INSTALLED 148' and 'UPDATES 2'. A search bar is at the top right.

NI DAQ 디바이스 설정, 테스트 및 시뮬레이션하기

사용자는 NI MAX에서 다음 작업을 완료할 수 있습니다.

- NI 하드웨어 및 소프트웨어를 설정합니다.
- 설정 데이터를 백업하거나 복제합니다.
- 채널, 태스크, 인터페이스, 스케일을 생성 및 편집합니다.
- 시스템 진단을 실행합니다.
- 시스템에 연결된 디바이스와 계측기를 봅니다.



연습문제 2-1



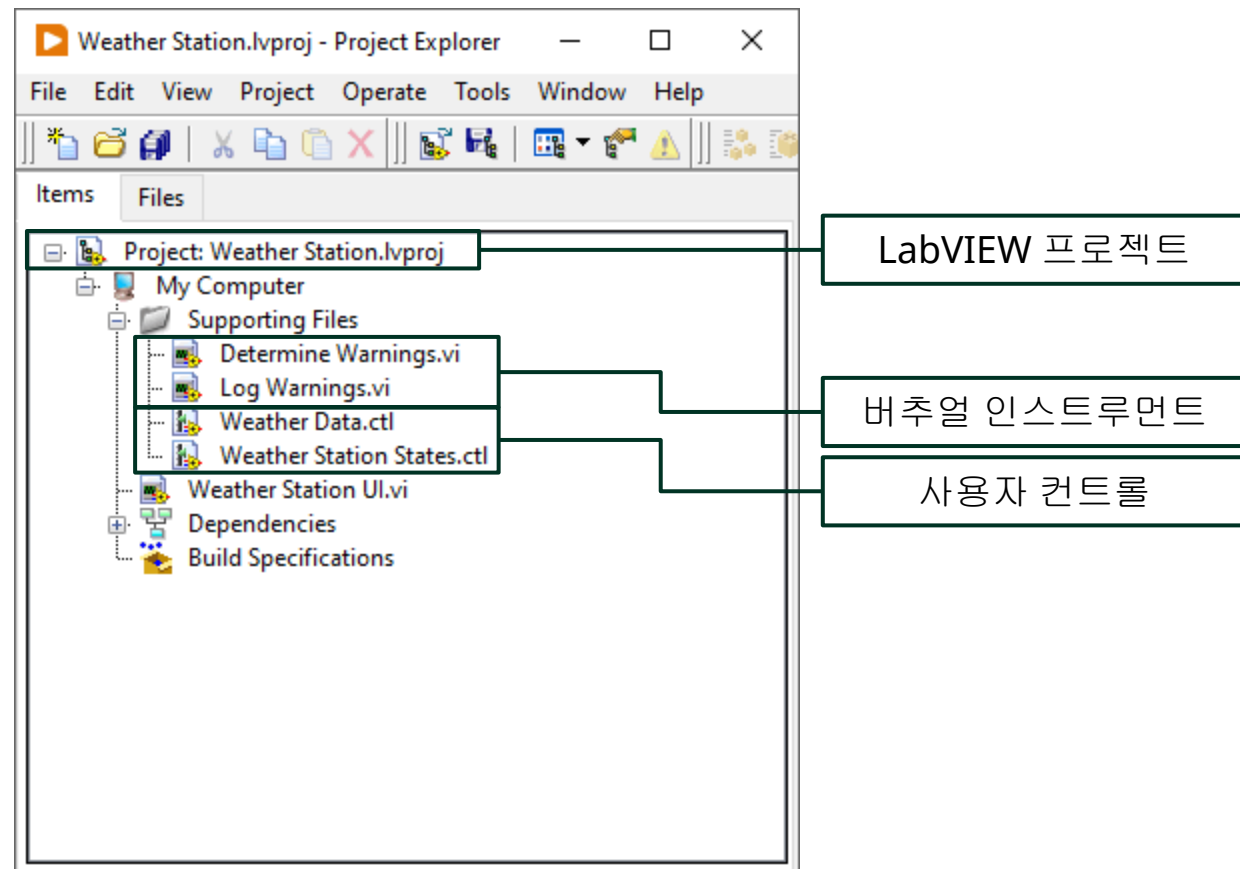
NI 하드웨어 시뮬레이션하기

물리적 하드웨어가 없는 경우에 NI DAQ 디바이스를 설정하거나 NI DAQ 디바이스를 시뮬레이션하는 방법을 살펴봅니다.

파일 및 폴더 다루기

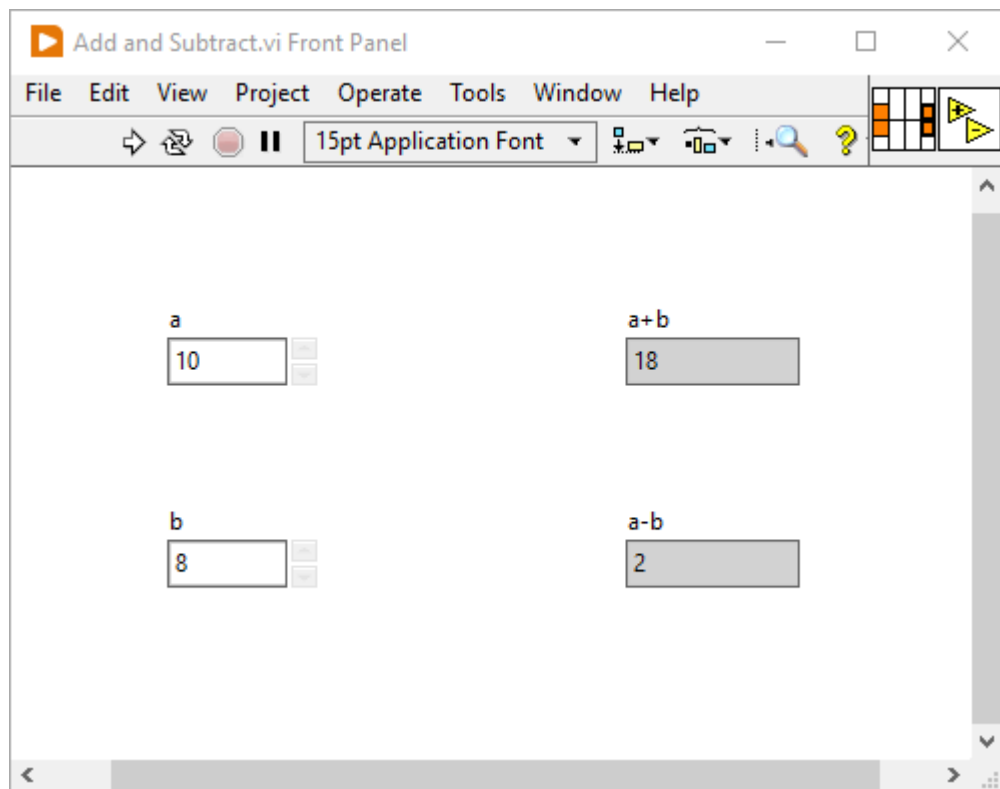
LabVIEW 파일에는 다음과 같은 다양한 유형이 있습니다.

- LabVIEW 프로젝트
- 버추얼 인스트루먼트 또는 VI
- 사용자 컨트롤

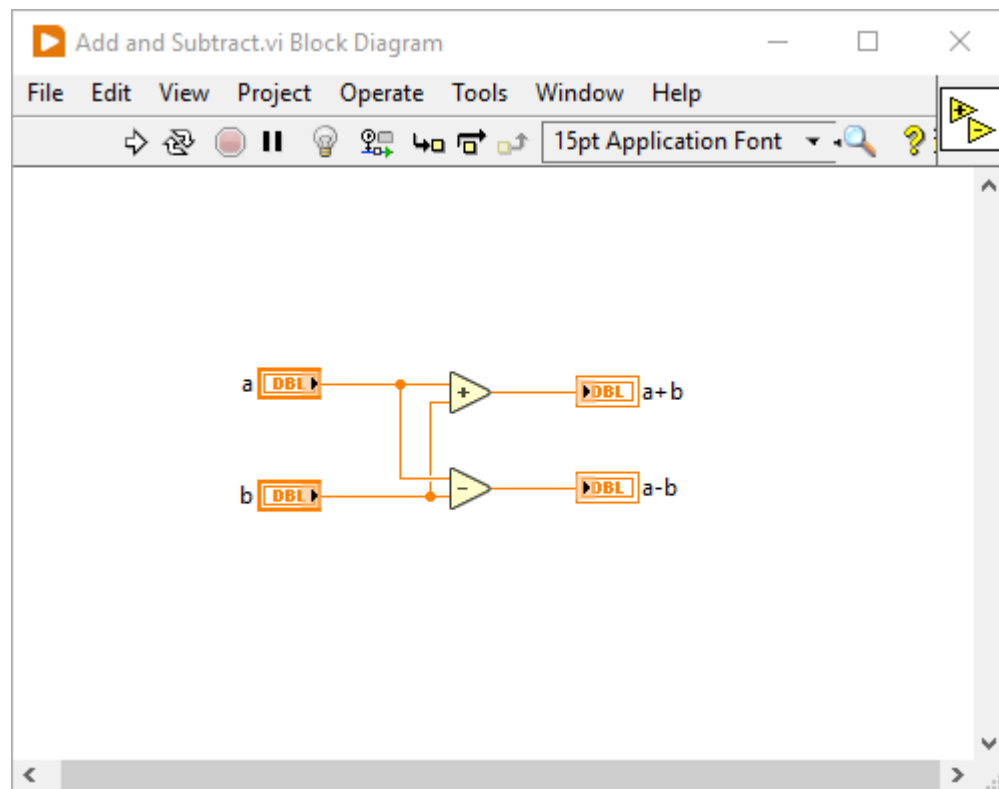


VI 구성요소

프런트패널



블록다이어그램





프런트패널 구성요소

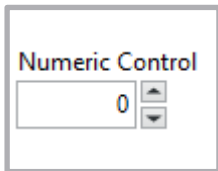
프런트패널 객체 데이터 타입

데이터 타입은 특정 값에 대해 수행할 수 있는 작업의 종류를 정의합니다.

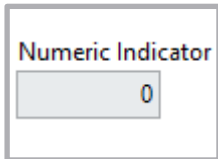
프런트패널 객체 데이터 타입	
숫자형	배열
불리언	웨이브폼
문자열	하드웨어 리소스

숫자형 데이터 타입

숫자형 데이터 타입은 정수 또는 부동소수점 실수와 같은 숫자를 나타냅니다.



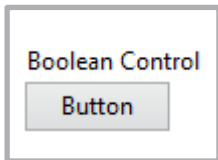
숫자형 컨트롤을 사용해 숫자값을 입력할 수 있으며 증가 및 감소 버튼이 있습니다.



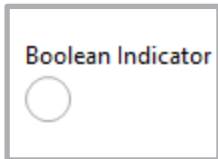
숫자형 인디케이터는 숫자값을 표시하고 출력합니다.

불리언 데이터 타입

불리언 데이터 타입은 두 가지 상태만 가능한 데이터를 나타냅니다.



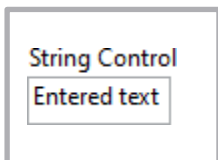
버튼과 토글은 불리언 컨트롤로 자주 사용됩니다.



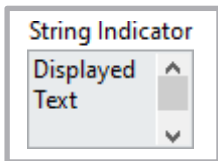
LED는 불리언 인디케이터로 자주 사용됩니다.

문자열 데이터 타입

문자열 데이터 타입은 일련의 문자입니다.



문자열 컨트롤을 사용하여 텍스트를 입력할 수 있습니다.



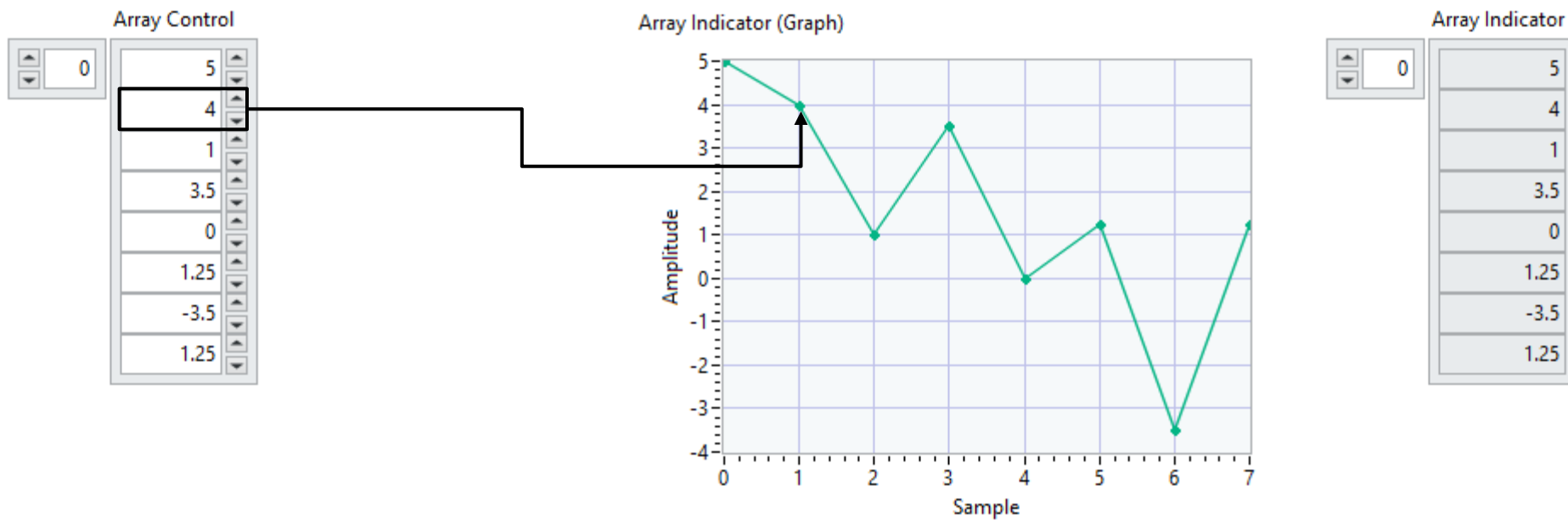
문자열 인디케이터는 텍스트를 표시하고 출력합니다.

배열 데이터 타입

배열은 동일한 데이터 타입의 여러 데이터를 하나의 데이터 구조로 결합합니다.

배열 컨트롤

배열
인디케이터



웨이브폼 데이터 타입

웨이브폼 데이터 타입은 타이밍 정보와 함께 데이터 값의 배열로 구성됩니다.

웨이브폼 컨트롤

웨이브폼 인디케이터

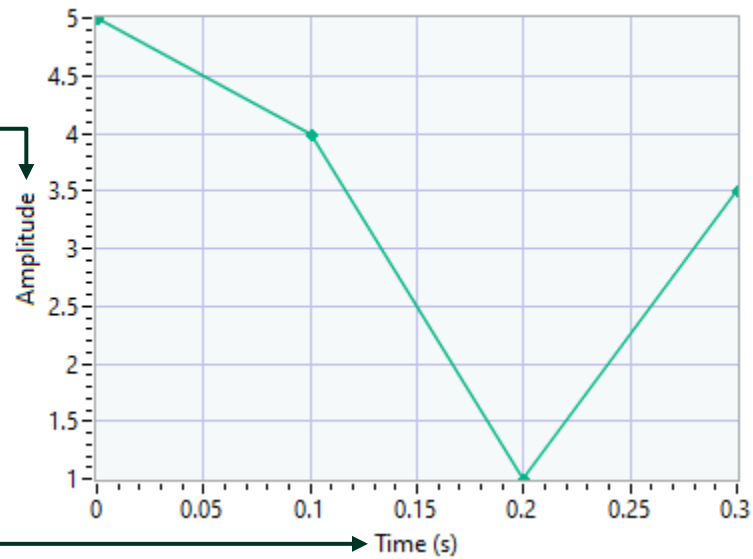
Waveform Control

t0 7/7/2021 12:25:31.451 PM dt 0.100000	Y 0 5 4 1 3.5
---	-------------------------------------

데이터 값

타이밍 데이터

Waveform Graph Indicator



하드웨어 리소스 데이터 타입

하드웨어 리소스 데이터 타입을 사용하면, 액세스하려는 특정 하드웨어 리소스를 선택할 수 있습니다.

NI-DAQmx 하드웨어

DAQmx Task Name

DAQmx Physical Channel

타사
하드웨어

VISA resource name

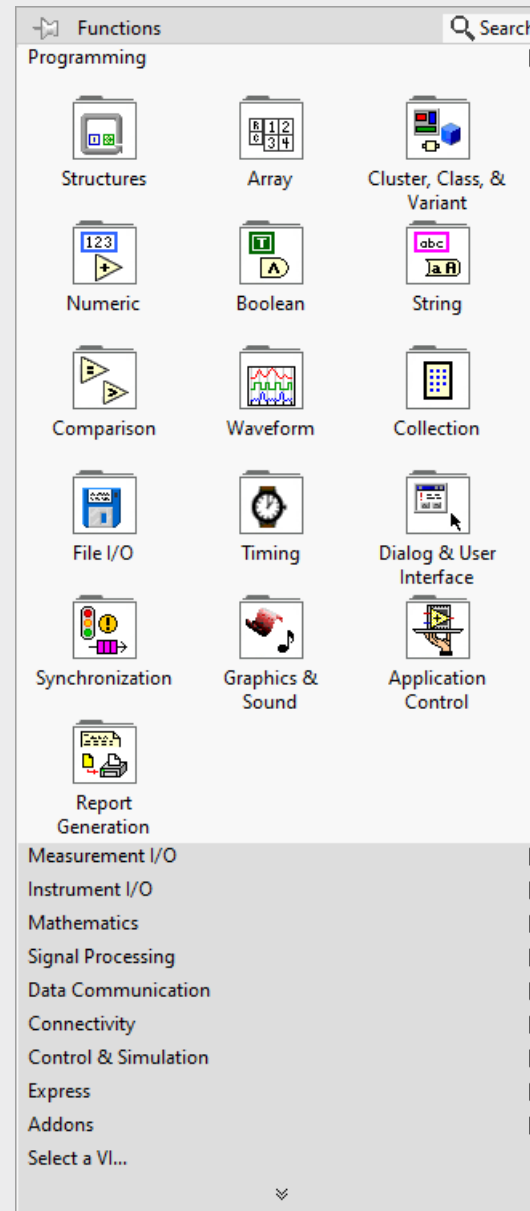


블록다이어그램 구성요소

함수 팔레트

함수 팔레트는 다음을 포함합니다.

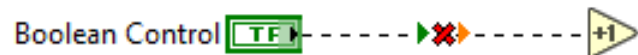
- VI
- 함수
- 상수



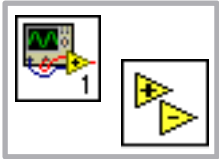
와이어

와이어는 다이어그램의 객체 간에 데이터를 전송합니다.

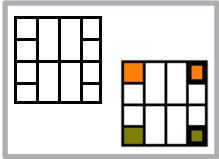
	부동소수	정수	문자열	불리언	웨이브폼
스칼라					
1D 배열					
2D 배열					



VI를 SubVI로 사용하기



VI 아이콘은 VI 다이어그램을 호출하는 VI의 그래픽 표현입니다.



커넥터 팬은 VI가 SubVI로 호출될 때의 입력과 출력을 정의합니다.

연습문제 4-1



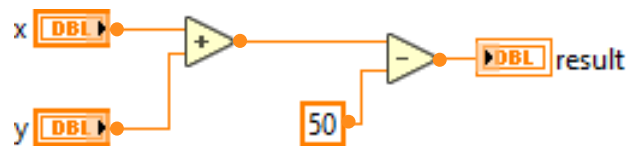
기존 프로젝트와 VI 살펴보기

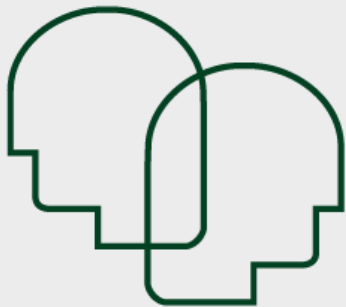
기존 LabVIEW 프로젝트, 해당 파일 및 구성요소를 살펴봅니다. 컨트롤, 인디케이터 및 해당 데이터 타입을 식별합니다.

데이터 흐름 이해하기

데이터 흐름 요약

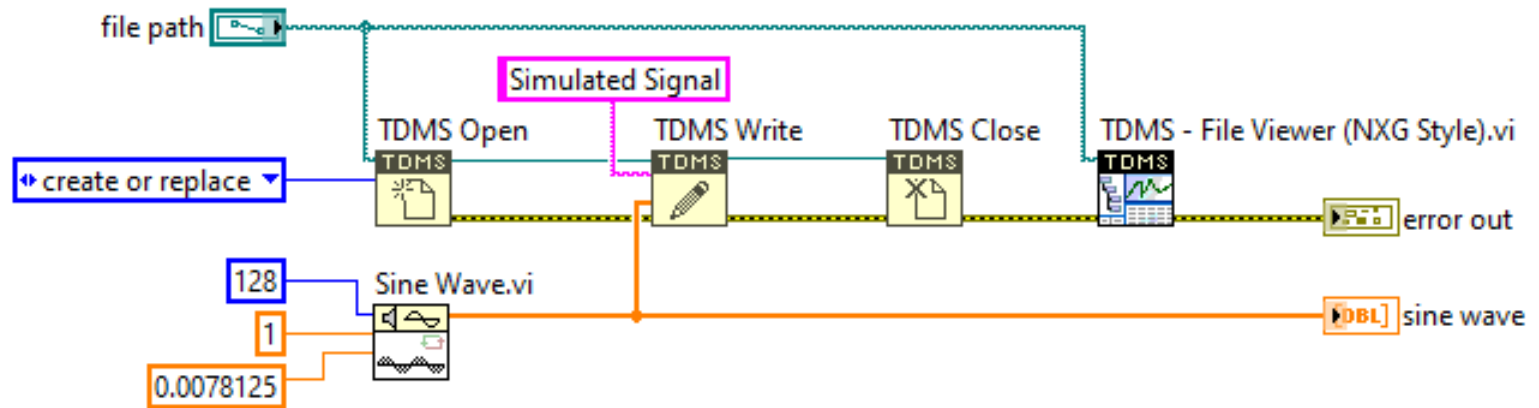
- 노드는 모든 입력 데이터를 사용할 수 있을 때만 실행됩니다.
- 노드는 실행을 마치면 출력 터미널에 데이터를 제공합니다.





데이터 흐름 이해하기

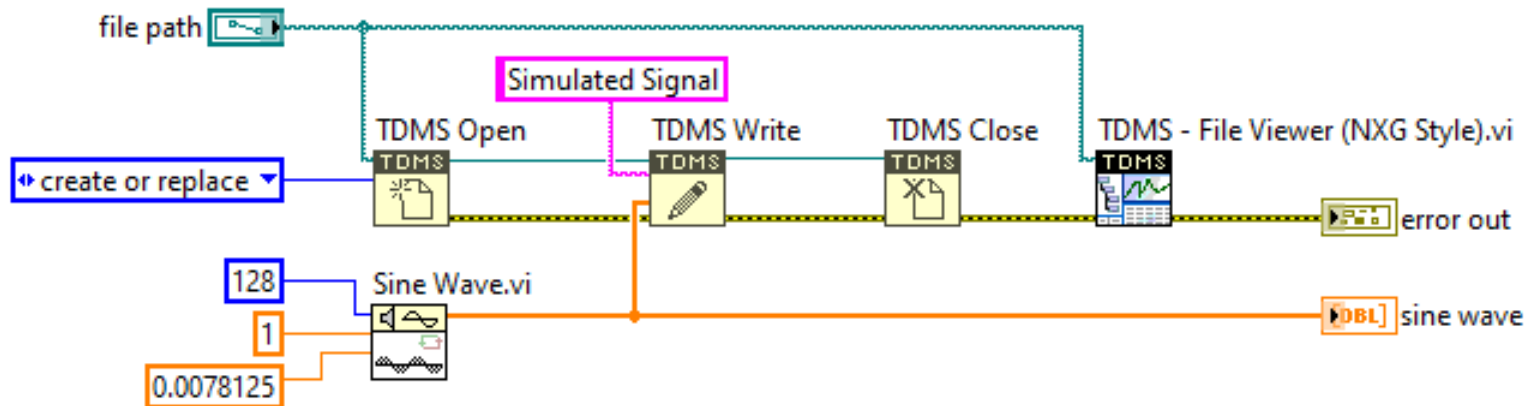
- 어느 노드가 가장 먼저 실행됩니까?
- [TDMS 열기](TDMS Open) 함수와 [사인파](Sine Wave.vi) 사이에 의존성이 있습니까?





데이터 흐름 이해하기

- 어떤 노드가 가장 나중에 실행됩니까?
- [TDMS 쓰기](TDMS Write) 함수가 실행되려면 먼저 몇 개의 노드가 실행되어야 합니까?
- 올바르게 설계된 다이어그램이라면 특정한 방향으로 흐름이 구현되어야 합니까?



LabVIEW 예제 검색하기



예제 찾기

연습문제 5-1



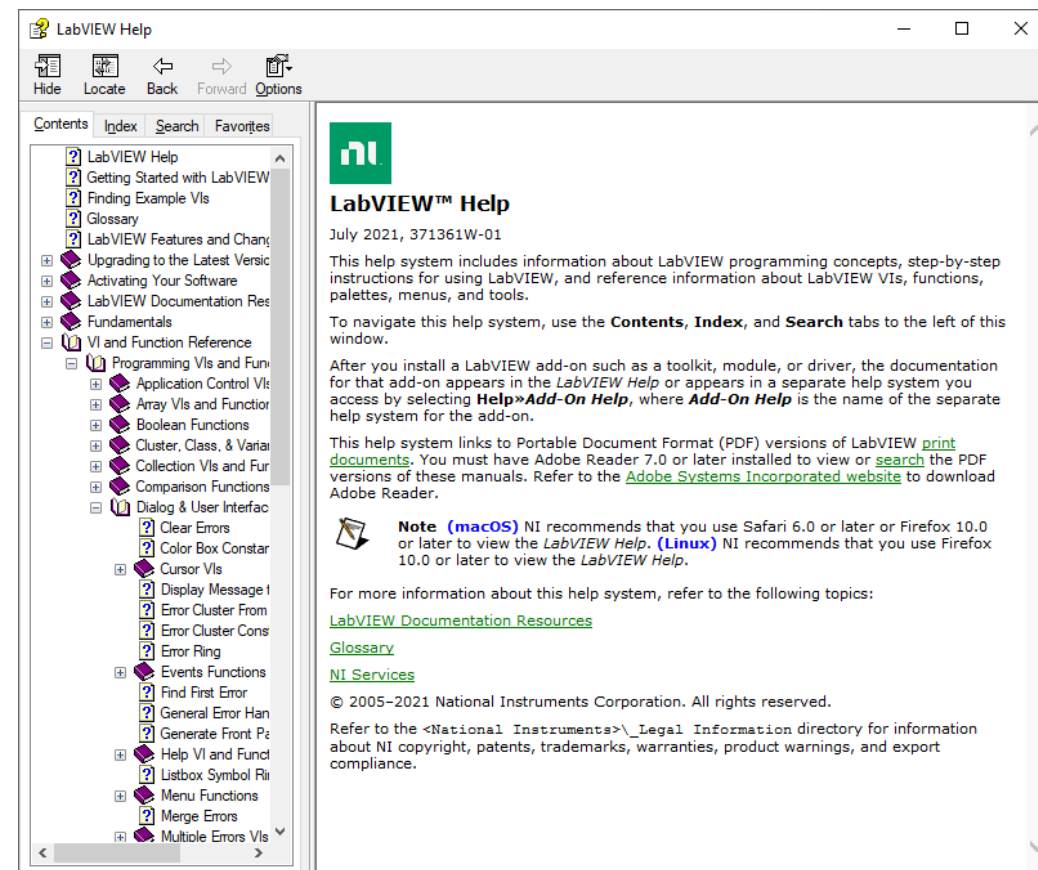
프로젝트와 VI 만들기

새 프로젝트와 직선 방정식, $y = mx+b$ 를 실행하는 새 VI를 생성합니다.

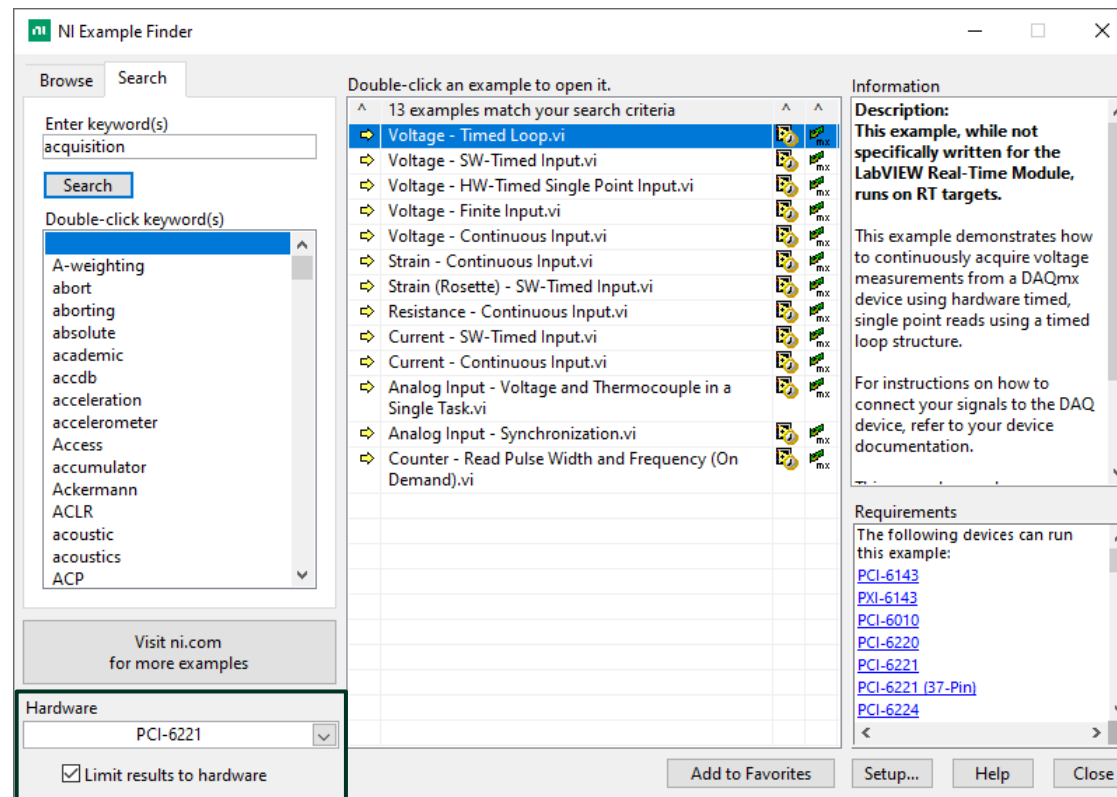
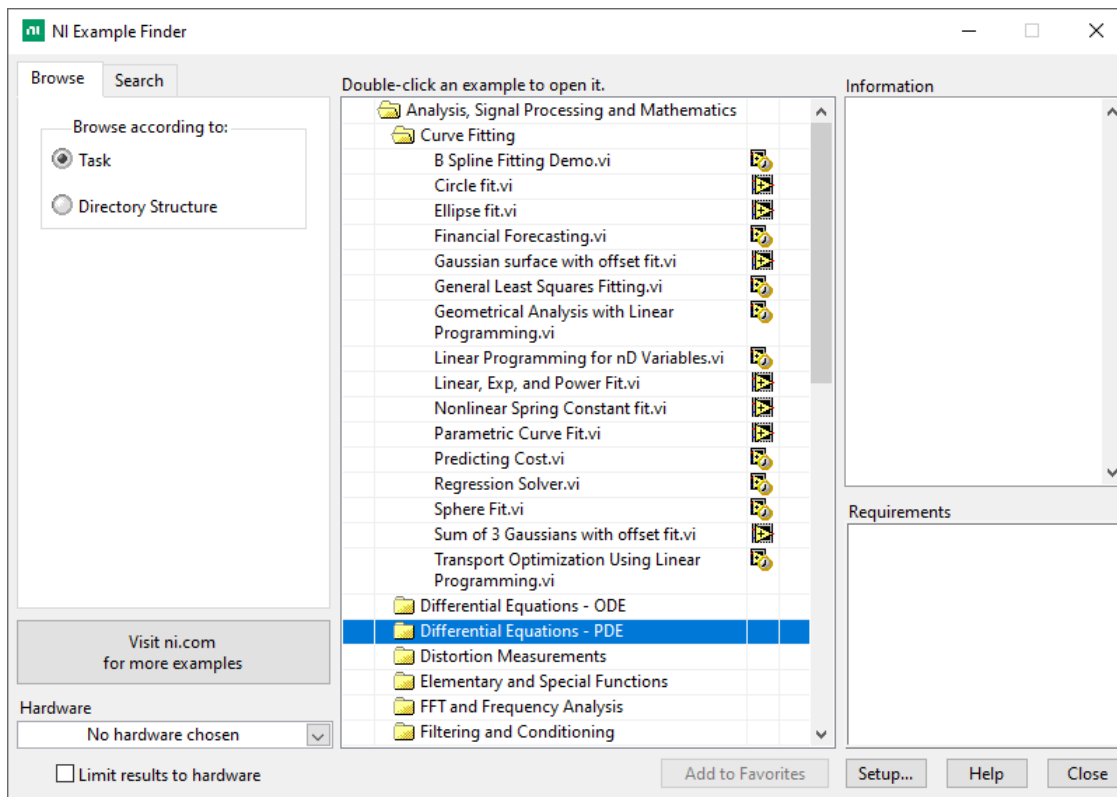
추가 LabVIEW 리소스 살펴보기

LabVIEW 도움말

LabVIEW 도움말은 LabVIEW에서 사용할 수 있는 토픽 중심의 절차 또는 참조 정보입니다.

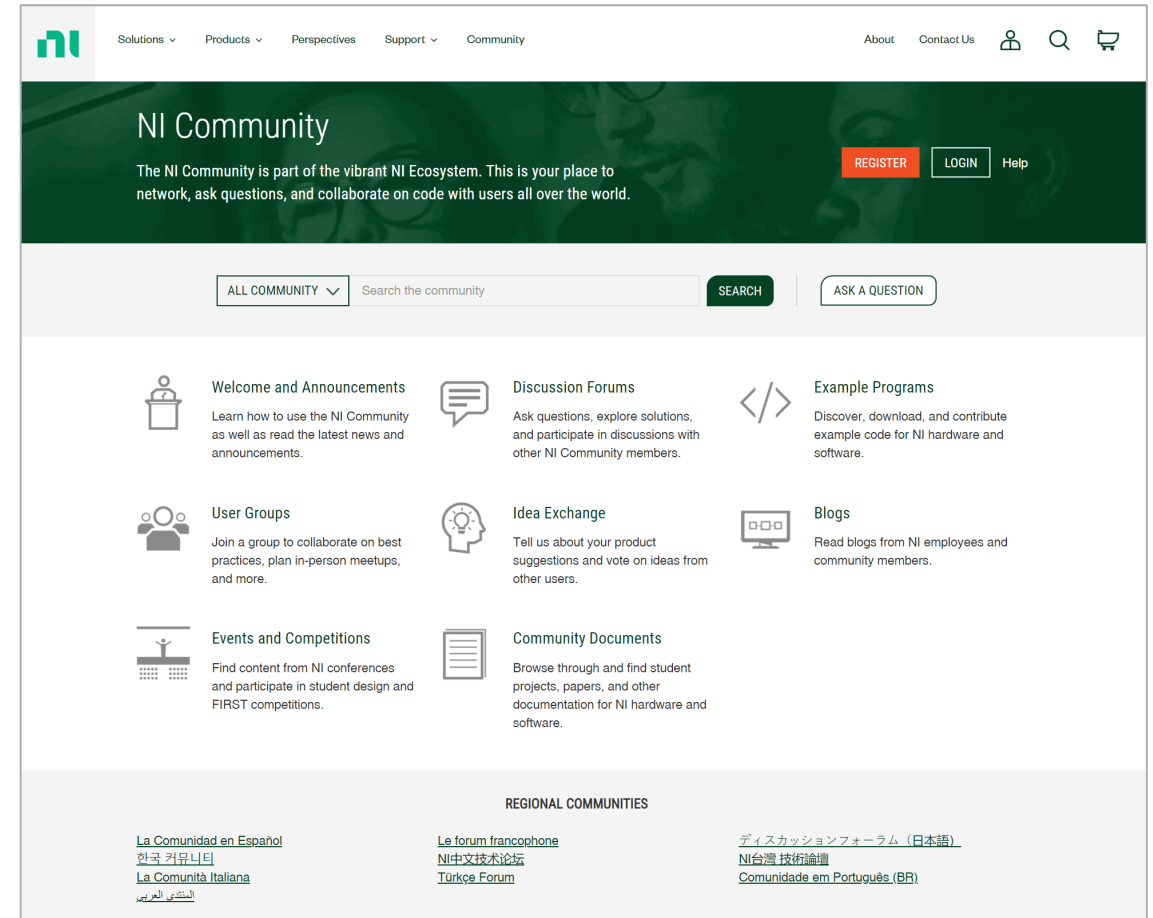


NI 예제 탐색기



포럼

NI 커뮤니티는 질문을 하고, 솔루션을 탐색하며, 우수 사례를 기반으로 다른 커뮤니티 회원들과 협업하는 장소입니다.



추가 교육 과정

고객 교육 교육과정을 통해 NI 소프트웨어 및 하드웨어로 지식과 기술을 개발할 수 있습니다.

Customer Education Courses

Customer Education Courses are available for new and experienced users in the form of on-location and virtual classrooms, labs, and collaborative sessions. Topics include working with LabVIEW, InsightCM™, TestStand, FPGA and data acquisition hardware, and more.

[LEARN ABOUT COURSE FORMATS](#)

[View Scheduled Virtual and Classroom Training](#)

Filter by: Training Learning Paths (1) Application Category Clear All

10 Results

Actor-Oriented Design in LabVIEW Course

Starting from \$ 3,000.00

The Actor-Oriented Design in LabVIEW Course teaches you how to build actors and design complex multi-actor systems using the LabVIEW Actor Framework.

Feature Highlights:

- Format: Classroom
- Prerequisites: LabVIEW Core 3 Object-Oriented Design and Programming in LabVIEW
- This course is also available in a [Private Virtual or Private Classroom format](#)

[Learn more about Actor-Oriented Design in LabVIEW](#)

Managing Software Engineering in LabVIEW Course

Starting from \$ 2,000.00

The Managing Software Engineering in LabVIEW Course teaches you how to manage the development of a medium to large project in LabVIEW.

Feature Highlights:

- Format: Virtual, Classroom
- Prerequisites: LabVIEW Core 3 or experience programming medium to large LabVIEW applications
- This course is also available in a [Private Virtual or Private Classroom format](#)

[Learn more about Managing Software Engineering in LabVIEW](#)

LabVIEW Core 3 Course

Starting from \$ 500.00

The LabVIEW Core 3 Course introduces you to structured practices to design, implement, document, and test LabVIEW applications.

Feature Highlights:

- Format: On-demand, Classroom, Virtual, and Kit
- Prerequisites: LabVIEW Core 1 and 2 or experience programming small to medium LabVIEW applications
- This course is also available in a [Private Virtual or Private Classroom format](#)

[Learn more about LabVIEW Core 3](#)

지원

- 제품 설명서, 예제 등을 포함한 지원 자료를 찾아봅니다.
- 지원을 요청하려면 유효한 서비스 계약이 필요합니다.

The screenshot displays the NI Support website. At the top, a navigation bar includes the NI logo, links for Solutions, Products, Perspectives, Support, and Community, and utility links for About, Contact Us, a user profile icon, a search icon, and a shopping cart icon. The main header area features a large 'Support' title over a background image of hands working on a circuit board, with a subtext describing support resources and a 'REQUEST SUPPORT' button. Below this is a search bar with a 'SEARCH' button. The content area is organized into sections: 'COMMON SETUP RESOURCES AND TOOLS' with a subtext 'These support resources help you install and set up NI products.' and three numbered cards (1. DOWNLOAD SOFTWARE, 2. REGISTER AND ACTIVATE, 3. SET UP COMMON HARDWARE). Below these are three columns of resources: 'PRODUCT DOCUMENTATION' (with links to User Manuals, Specifications and Dimensional Drawings, and Release Notes and Readmes), 'DISCUSSION FORUMS', and 'SUPPORT LIBRARY' (with links to KnowledgeBase, Tutorials, and Examples). At the bottom, there are two more sections: 'TRAINING' (with links to On-demand Training, Learning Paths, and Certifications) and 'ACADEMIC COURSEWARE'.



지원

Solutions ▾ Products ▾ Perspectives Support ▾ Community About Contact Us

Support

Find support resources including documentation, examples, and downloads. Learn about support services or open a service request with an NI engineer.

[REQUEST SUPPORT](#)

[SEARCH](#)

COMMON SETUP RESOURCES AND TOOLS

These support resources help you install and set up NI products.

1

DOWNLOAD SOFTWARE

NI provides downloads for NI products and both NI and third-party instrument drivers.

2

REGISTER AND ACTIVATE

The My Products page helps you register and activate your NI products.

3

SET UP COMMON HARDWARE

NI offers getting started content for DAQ, CompactRIO, and instrument control hardware.

PRODUCT DOCUMENTATION

Find complete product documentation to learn how to get started and use the product.

- [User Manuals](#)
- [Specifications and Dimensional Drawings](#)
- [Release Notes and Readmes](#)

DISCUSSION FORUMS

Ask questions, explore solutions, and participate in discussions with other NI Community members.

SUPPORT LIBRARY

Explore a wide range of support content, including examples and troubleshooting information.

- [KnowledgeBase](#)
- [Tutorials](#)
- [Examples](#)

TRAINING

Learn faster, on your own or with an NI expert, and build skills for this project and the next.

- [On-demand Training](#)
- [Learning Paths](#)
- [Certifications](#)

ACADEMIC COURSEWARE

Implement a hands-on approach to engineering education with resources developed by leaders in education.

Solutions ▾ Products ▾ Perspectives Support ▾ Community About Contact Us

[HOME](#) / [SHOP](#) / [NISERVICES](#) / [SOFTWARE SERVICES](#)

Software Services

Whether for an individual, a large development team, or an enterprise, NI provides services to ensure success with NI software. The Standard Service Program (SSP) is included with software purchases and also available through NI service programs.

[COMPARE PROGRAMS](#)

ENSURE PROJECT SUCCESS WITH SSP

Improved Tool Access

Stay up to date with the latest versions or access previous versions to support older projects. Gain insight into emerging technologies in the NI Software Technology Preview Program.

[Download NI software products](#)
[Learn about the Preview Program](#)

Connection to User Community

Join the extensive NI user community through online forums and find solutions that NI technical support engineers create. Participate in specialized community events including certification summits, NIWeek, user groups, and more.

[Visit the discussion forums](#)
[Explore the KnowledgeBase](#)

Guided Path to Success

Get live phone support from certified engineers in your local language, where available. Access online training courses or enroll in instructor-led courses (additional charges may apply).

[Manage your service requests](#)
[Access online training](#)

SSP PURCHASE OPTIONS

Single-Seat Program

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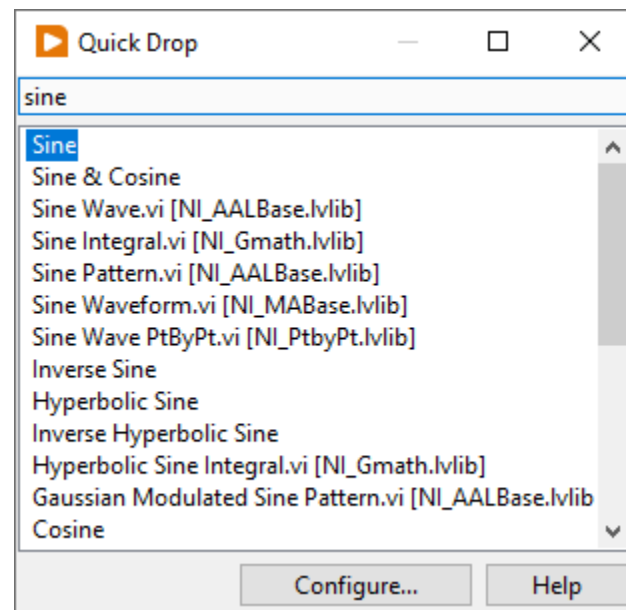
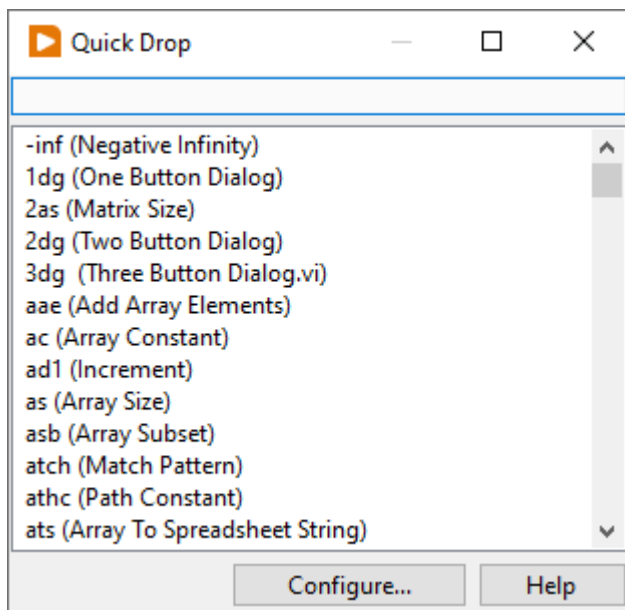
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LabVIEW 팁 및 요령

빠른 탐색

빠른 탐색(Quick Drop)을 사용하면 팔레트를 탐색하거나 검색을 시작하지 않아도 LabVIEW 프론트패널과 블록 다이어그램의 객체를 신속하게 찾아 배치할 수 있습니다.



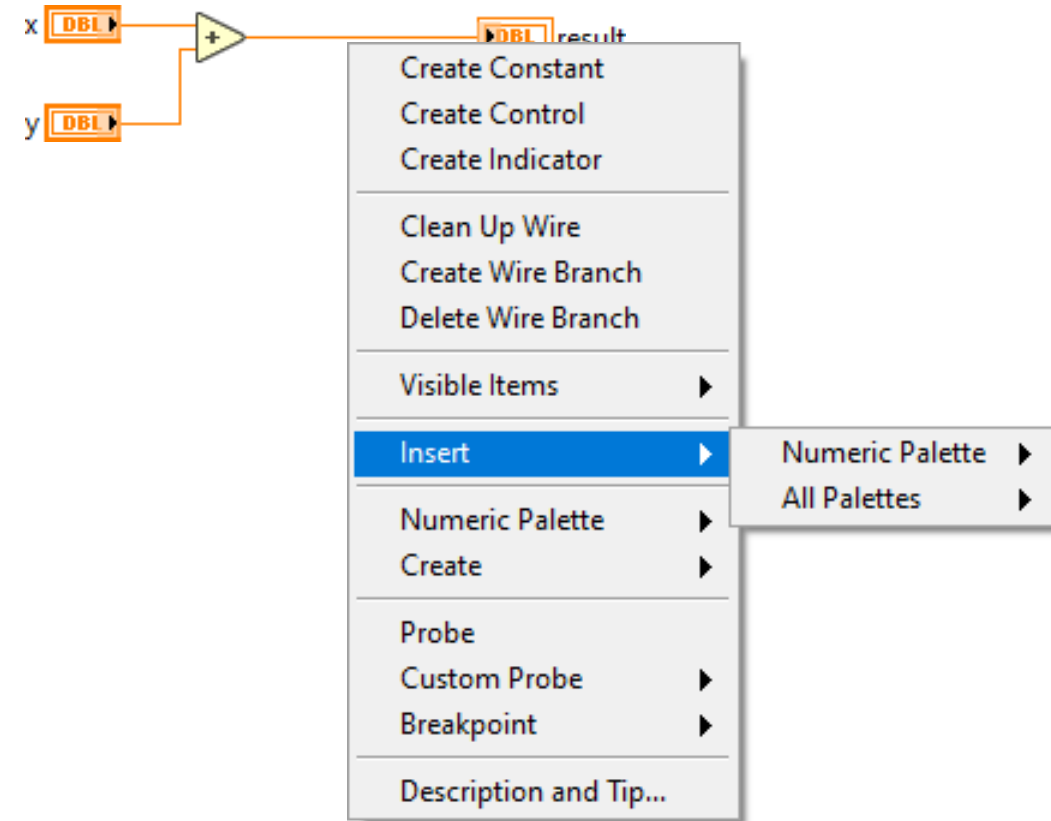
블록다이어그램에서 공간 만들기 및 공간 제거하기

- <Ctrl>을 누른 상태에서 마우스를 끌어 블록다이어그램에 공간을 추가합니다.
- 블록다이어그램에서 <Ctrl-Alt>를 누른 상태에서 마우스를 끌어 공간을 잘라냅니다.



함수 삽입하기 및 삭제하기

- 기존 와이어의 함수 팔레트에서 노드를 삽입하여 필요한 기능을 VI에 신속하게 추가할 수 있습니다.
- 마찬가지로 기존 와이어를 유지하면서 노드를 삭제할 수도 있습니다.

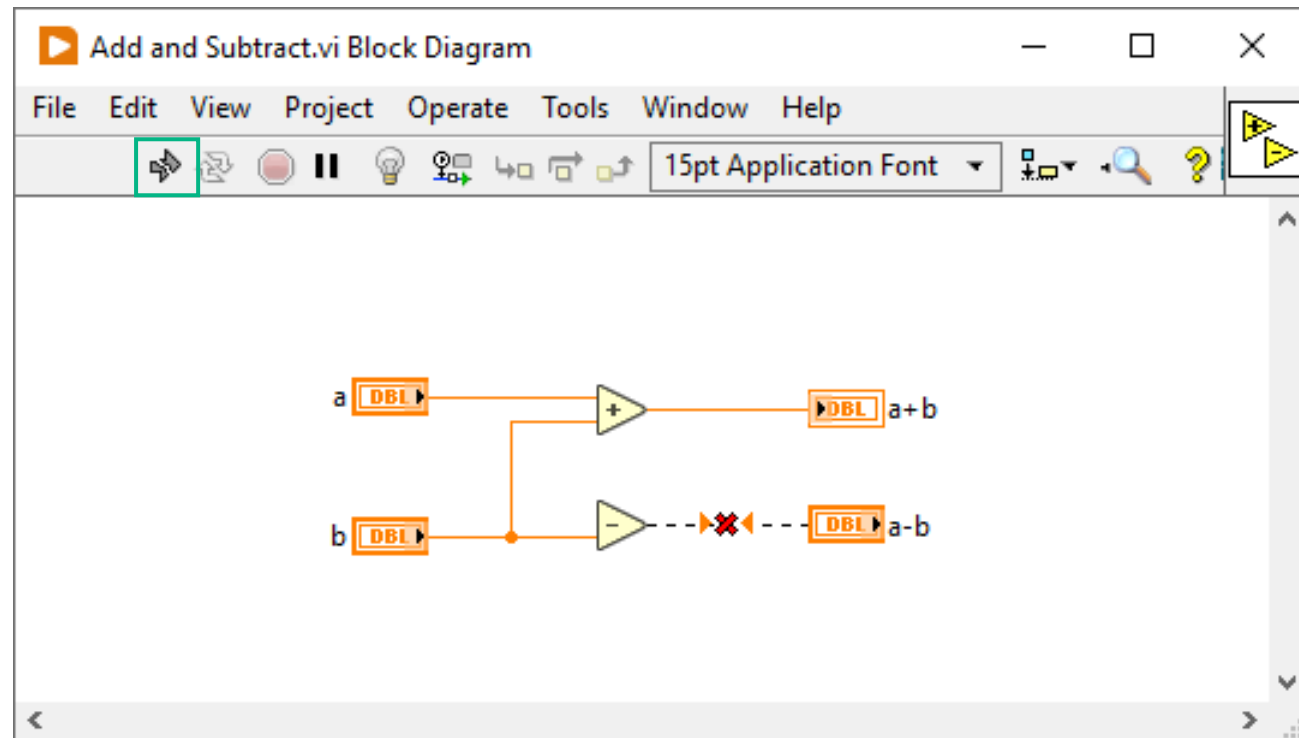


깨진 VI 문제 해결하기

- 깨진 VI와 그 원인
- 깨진 VI 확인 및 수정

깨진 VI

블록다이어그램 와이어 연결을 완료했을 때 실행(Run) 버튼이 깨져서 표시되는 경우는 VI 실행을 방해하는 에러가 있다는 것을 의미합니다.

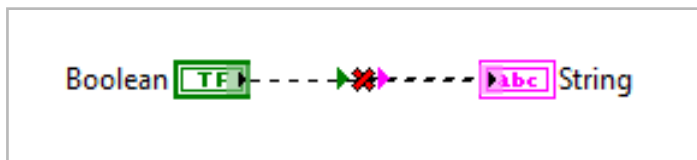


깨진 VI의 일반적인 원인

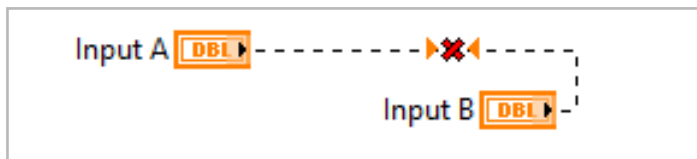
깨진 VI의 일반적인 이유는 세 가지가 있습니다.

예

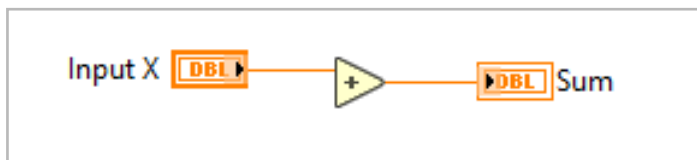
원인



데이터 타입의 불일치로 인해 와이어가 깨진 경우

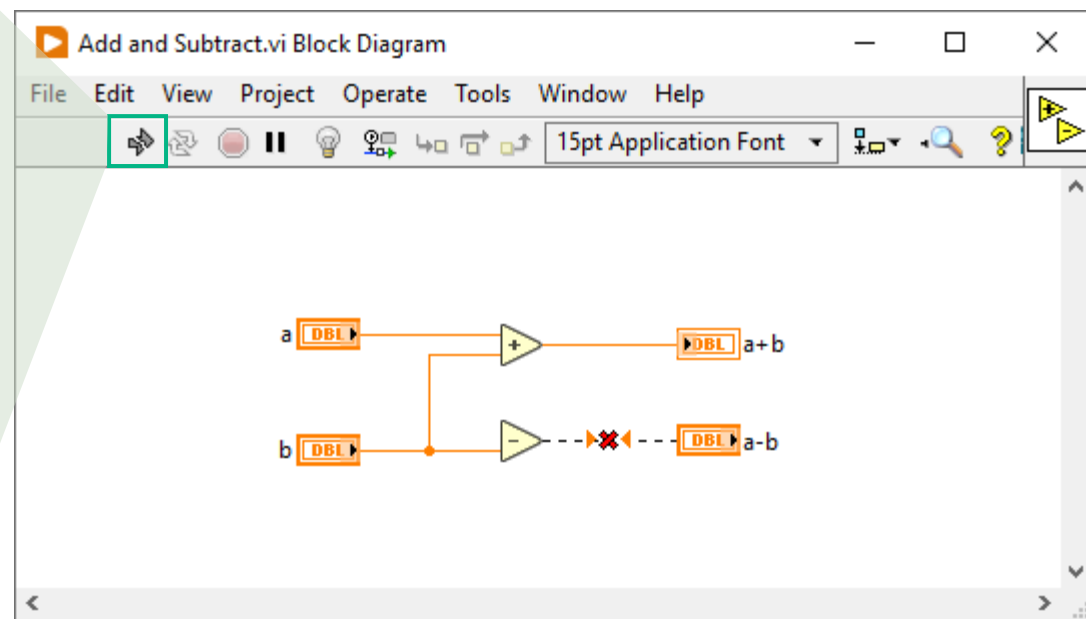
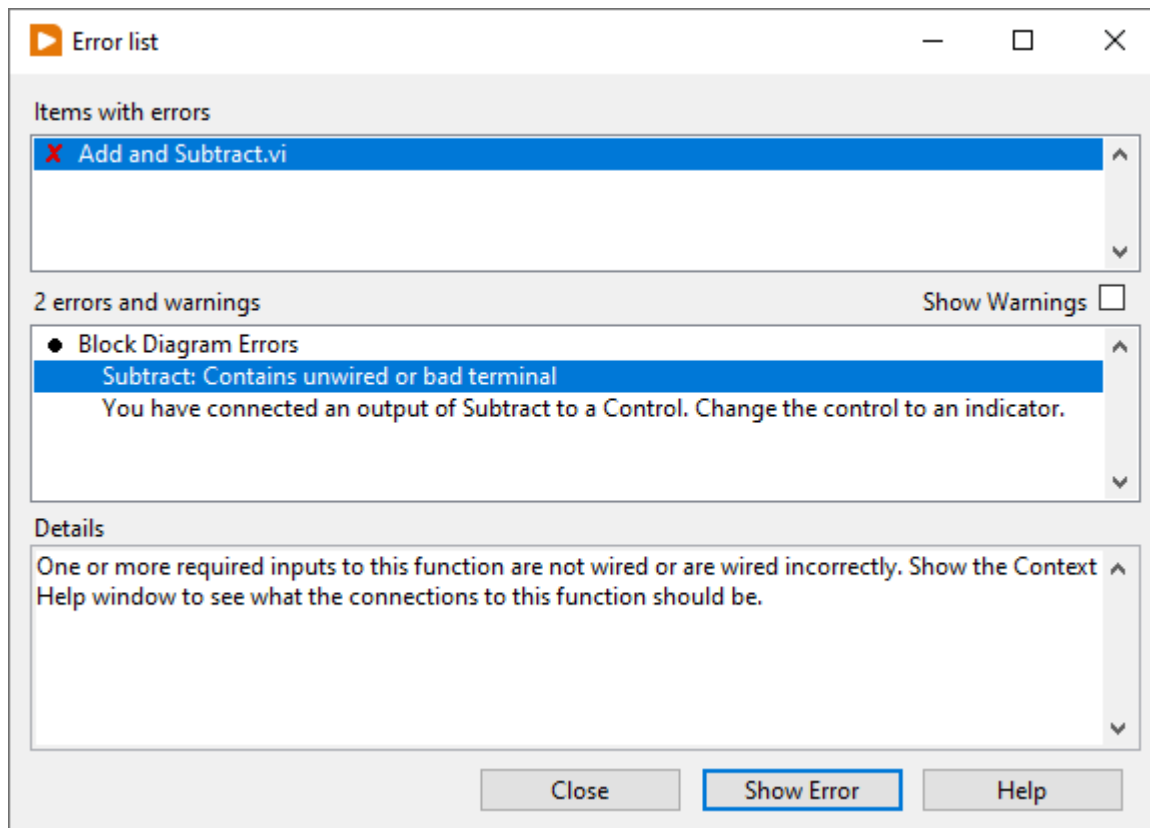


컨트롤이 다른 컨트롤에 연결된 경우



노드의 필수 입력이 연결되지 않은 경우

깨진 VI 확인 및 수정





깨진 VI 수정하기

디버깅 기법

- 디버깅 도구 종류
- 정의되지 않은 데이터 또는 예상치 못한 데이터

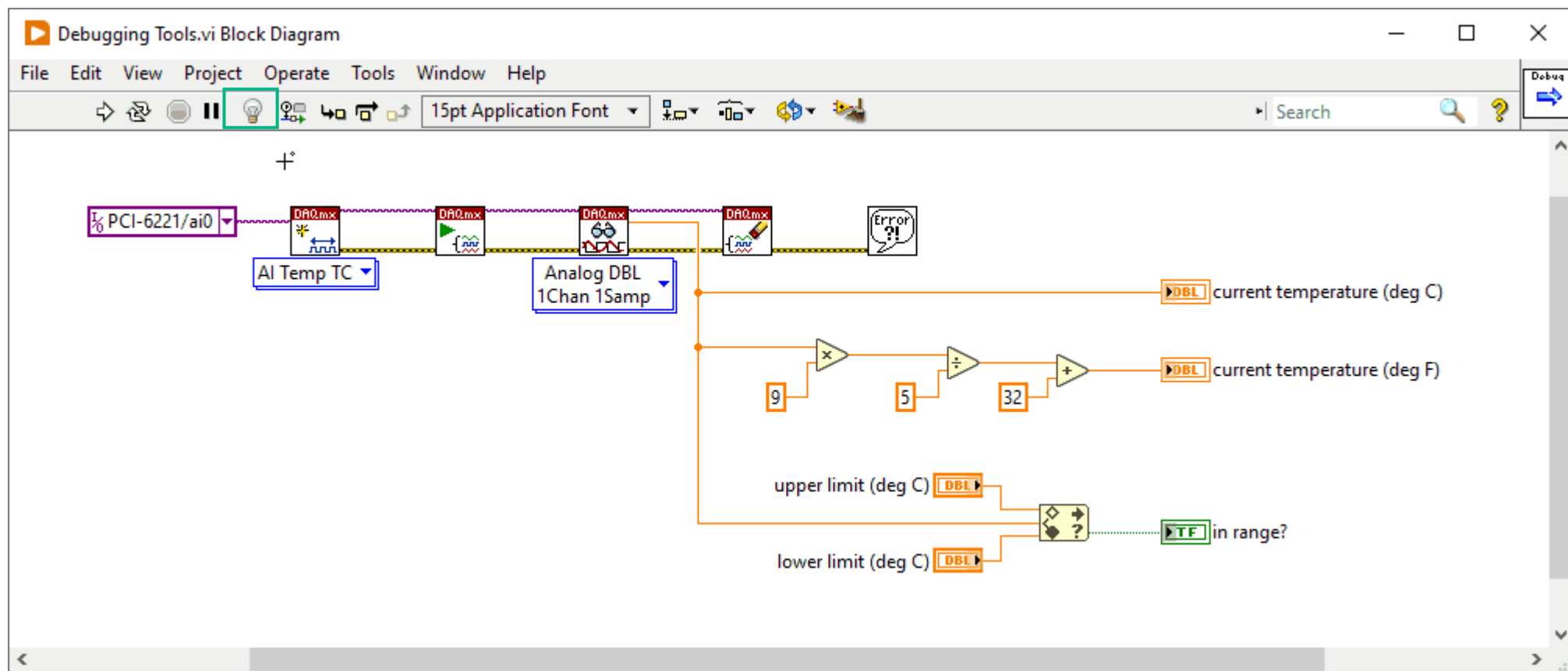
디버깅 도구 종류

VI가 실행되는 동안 코드 디버깅에 도움이 되는 디버깅 도구는 네 가지가 있습니다.

- 실행 하이라이트
- 단계별 실행
- 브레이크포인트
- 프로브

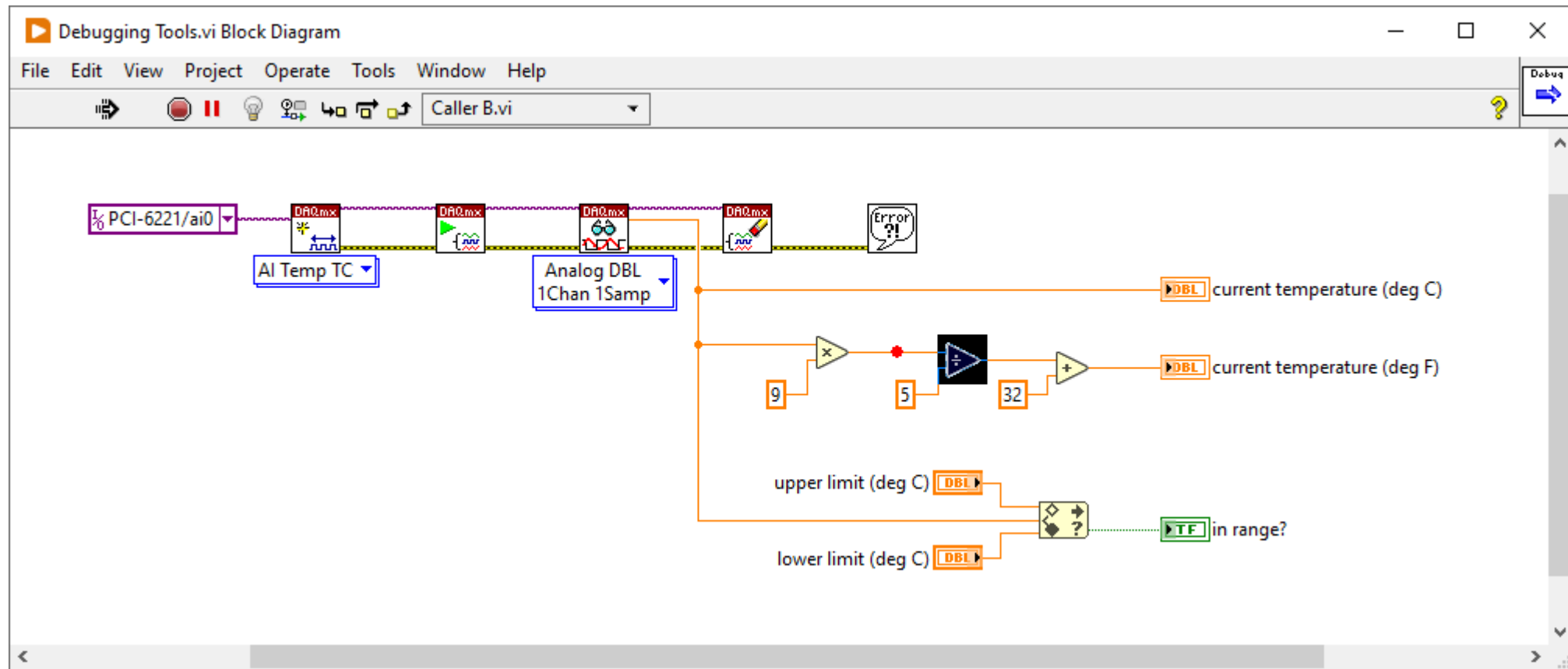
실행 하이라이트

실행 하이라이트는 데이터가 블록다이어그램 상의 한 노드에서 다른 노드로 이동되는 것을 보여줍니다.

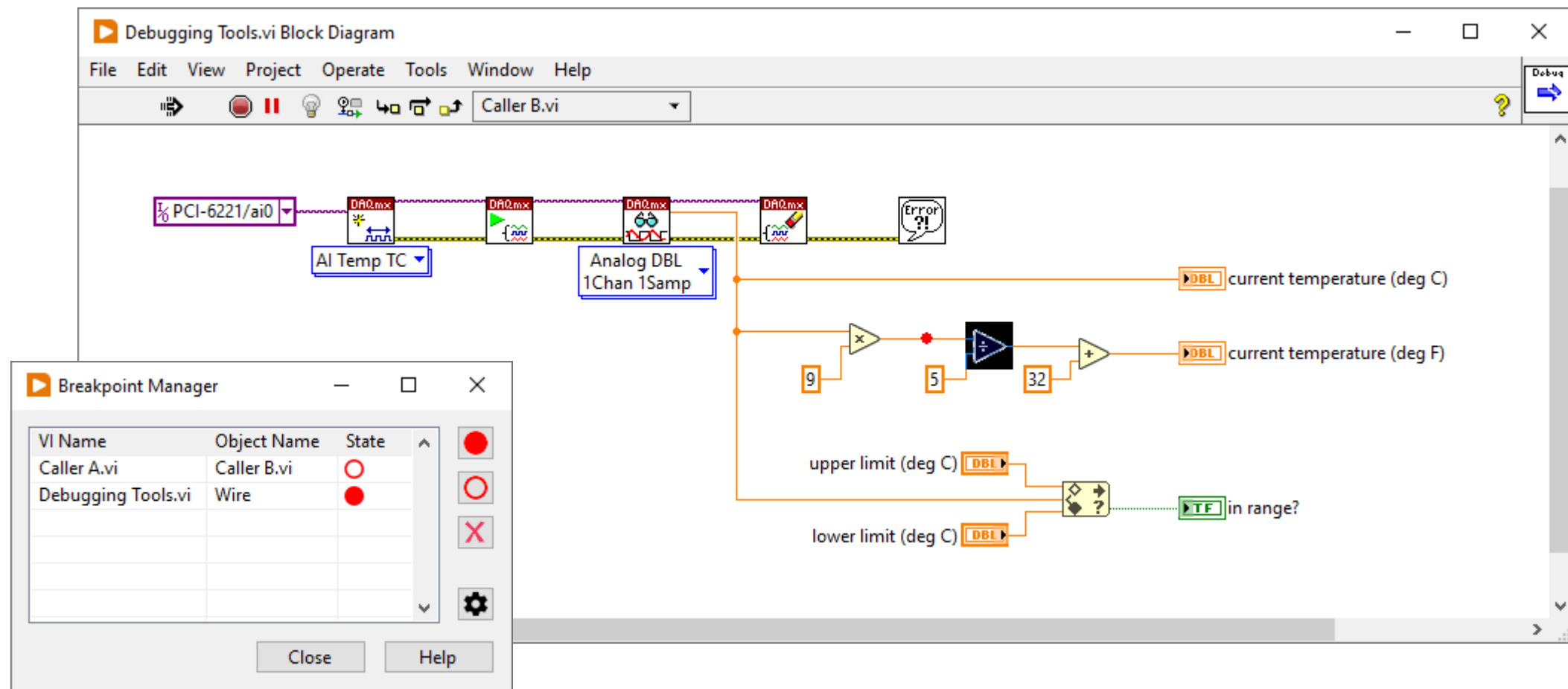


브레이크포인트

브레이크포인트는 프로그램의 지정된 포인트에서 VI 실행을 일시 중지합니다.

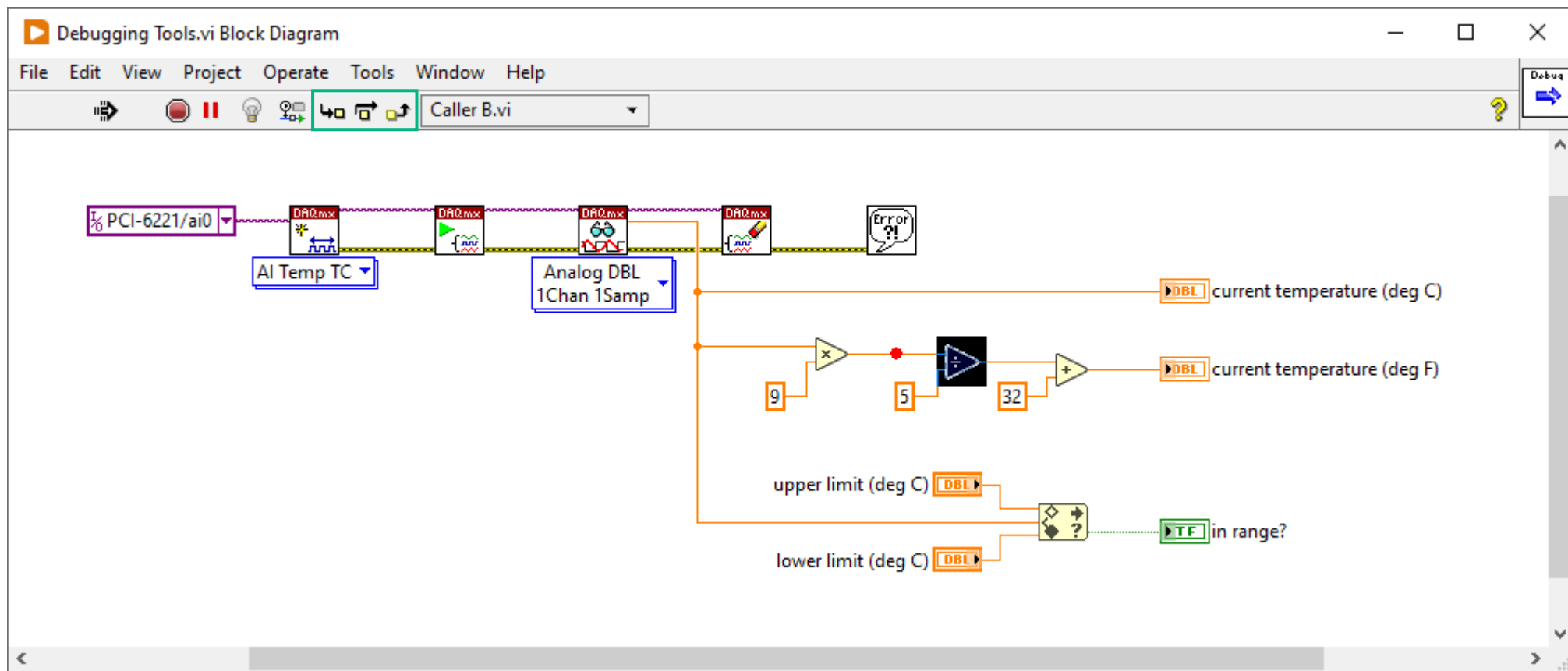


브레이크포인트는 프로그램의 지정된 포인트에서 **VI** 실행을 일시 중지합니다.



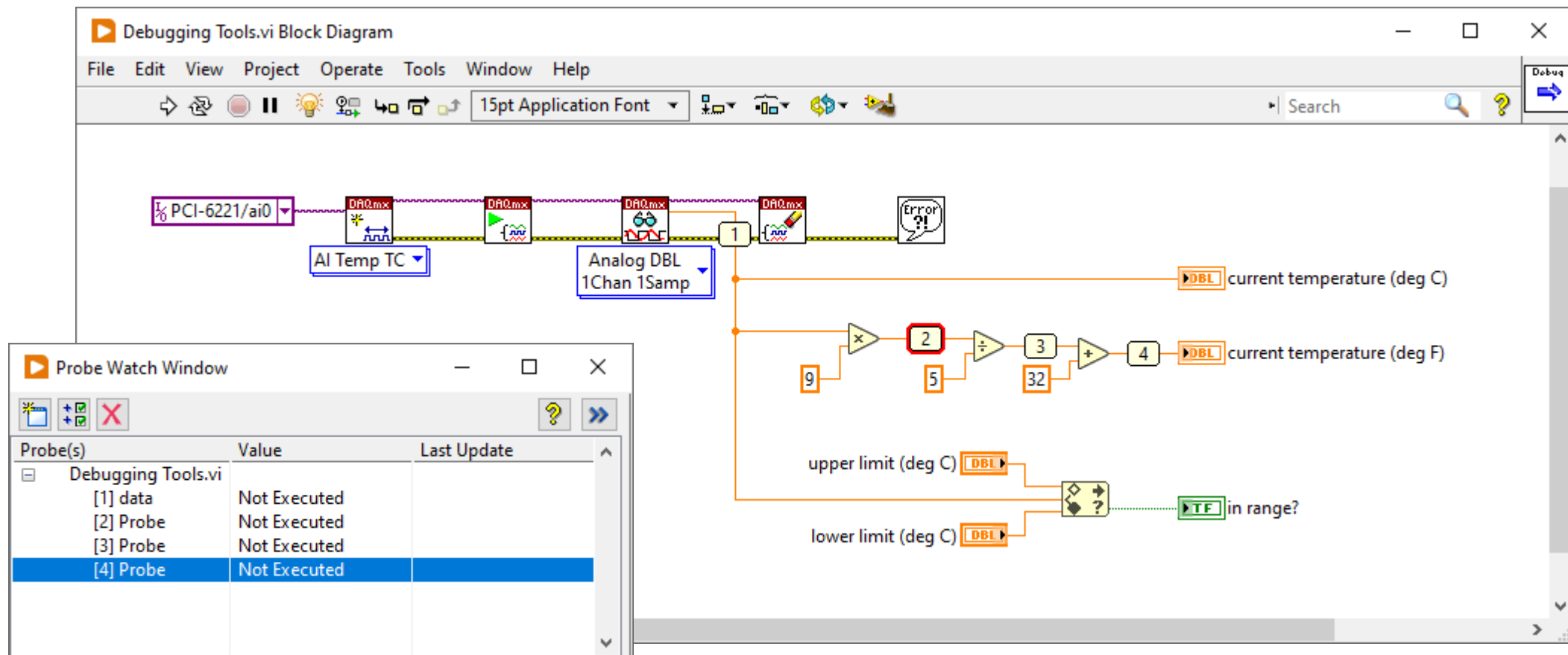
단계별 실행

단계별 실행을 사용하면 한 번에 한 노드씩 블록다이어그램의 실행을 모니터링할 수 있습니다.



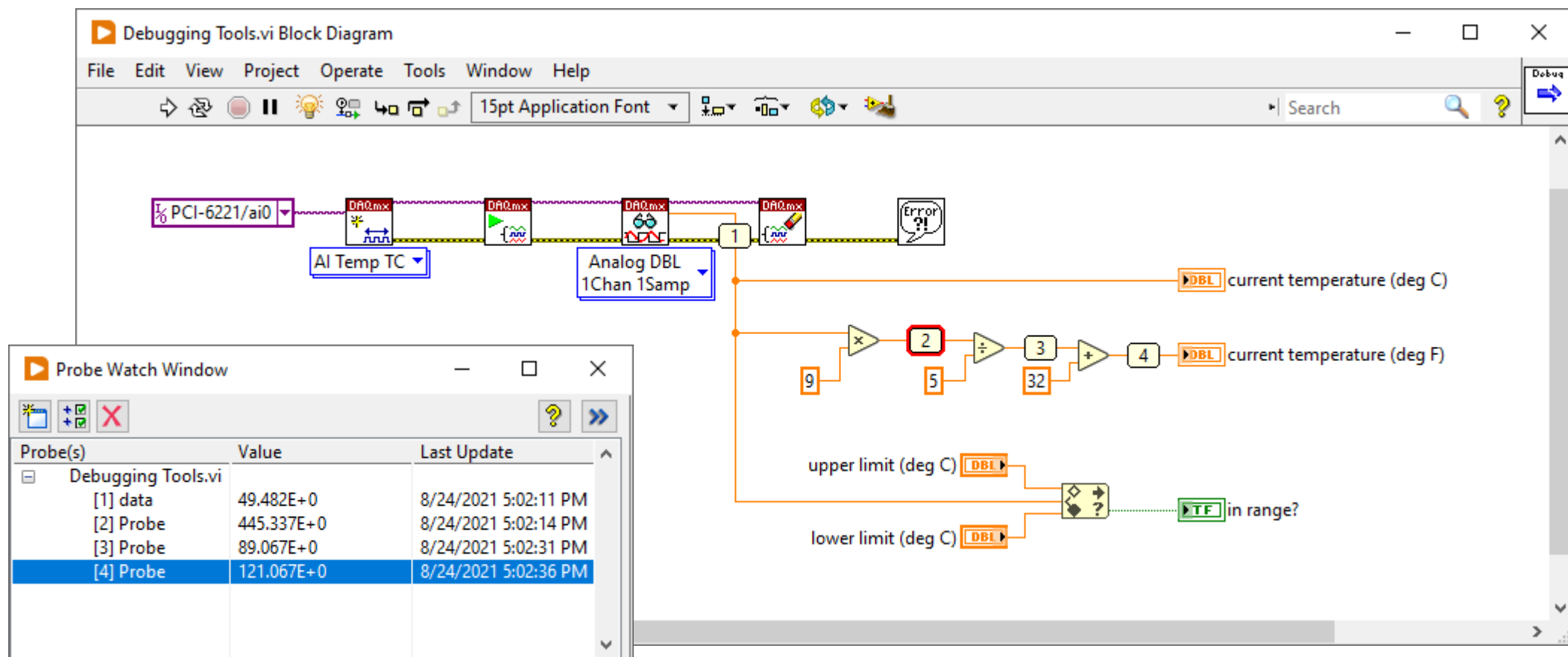
프로브

프로브는 VI가 실행될 때 와이어의 값을 디스플레이합니다.



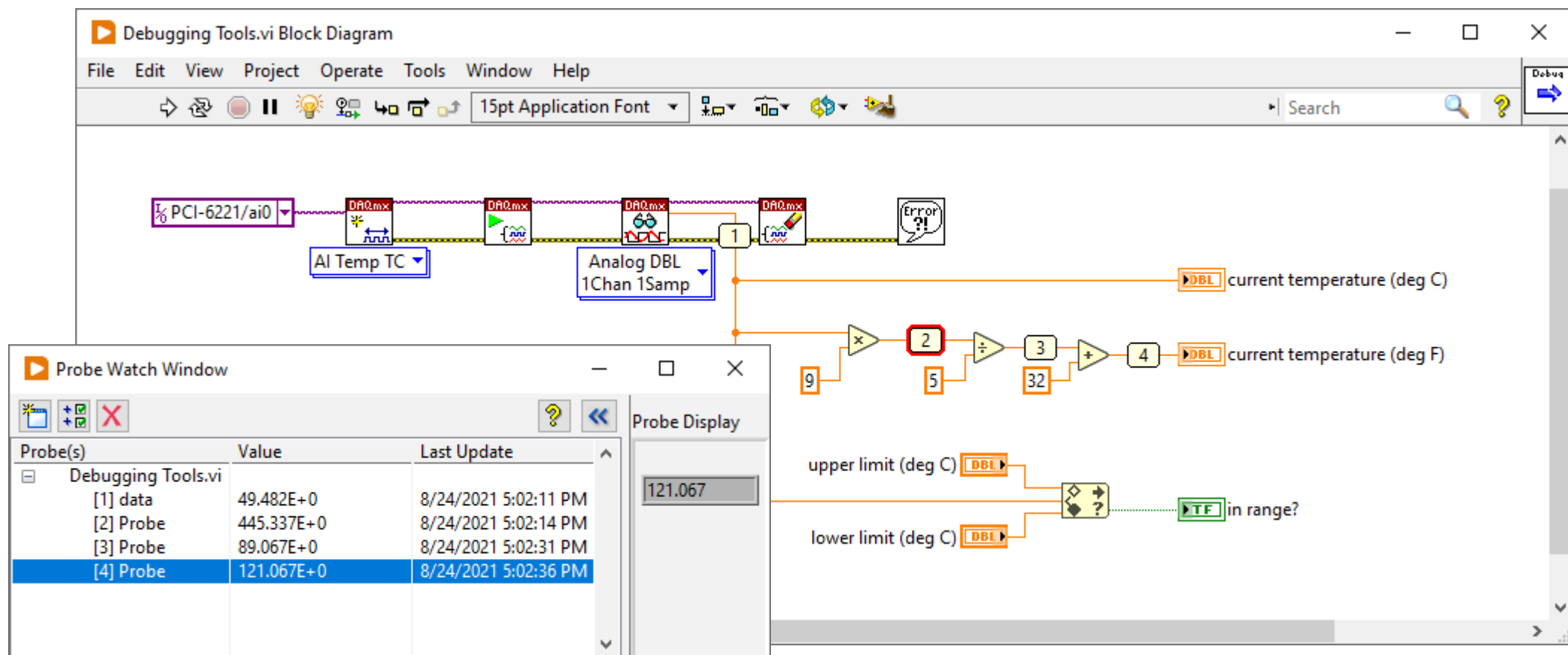
프로브

프로브는 VI가 실행될 때 와이어의 값을 디스플레이합니다.



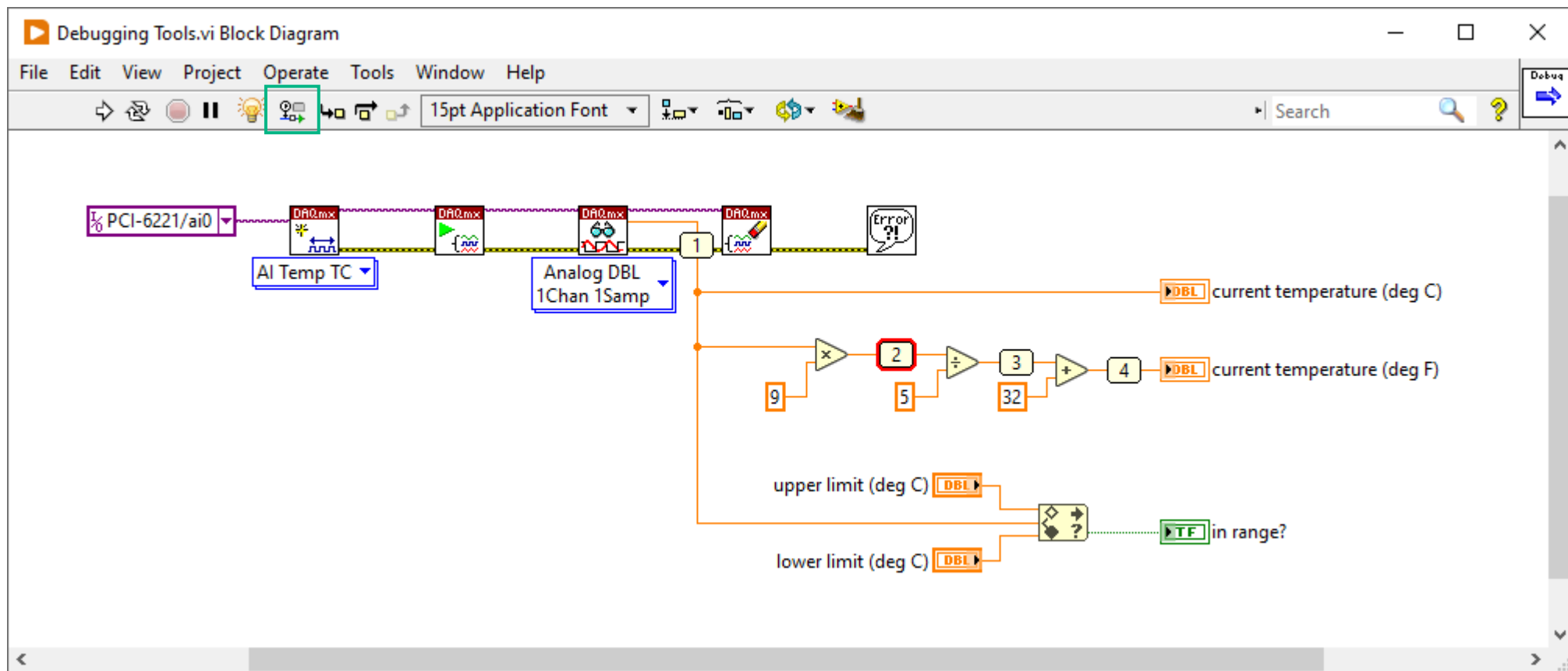
프로브

프로브는 VI가 실행될 때 와이어의 값을 디스플레이합니다.



프로브

프로브는 VI가 실행될 때 와이어의 값을 디스플레이합니다.



연습문제 7-1



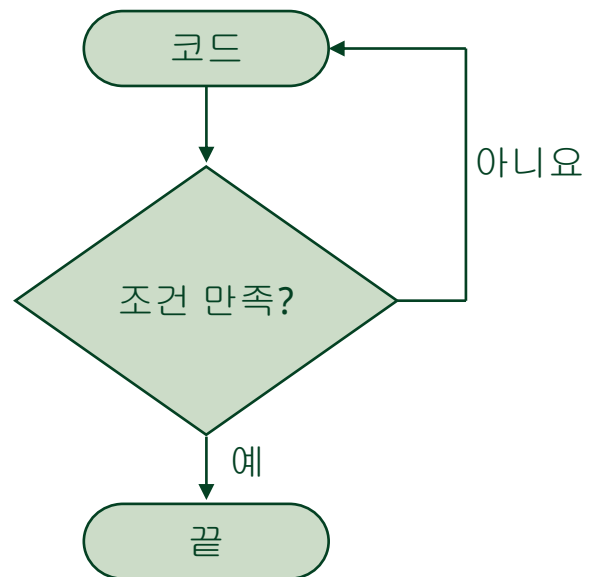
디버깅

디버깅 도구 및 문제 해결 기술을 사용하여 예기치 않은 데이터를 반환하는 깨진 **VI**를 수정합니다.

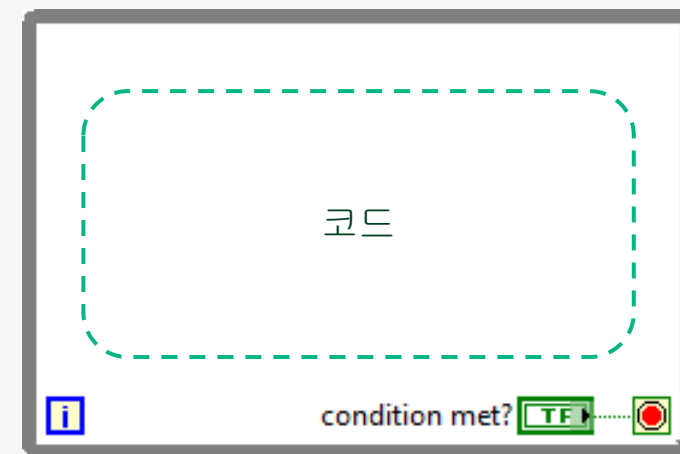
While 루프 살펴보기

While 루프 소개

While 루프는 조건이 충족될 때까지 코드를 실행합니다.



LabVIEW의 While 루프



유사 코드

```

Repeat (code);
Until condition is met;
End;
  
```

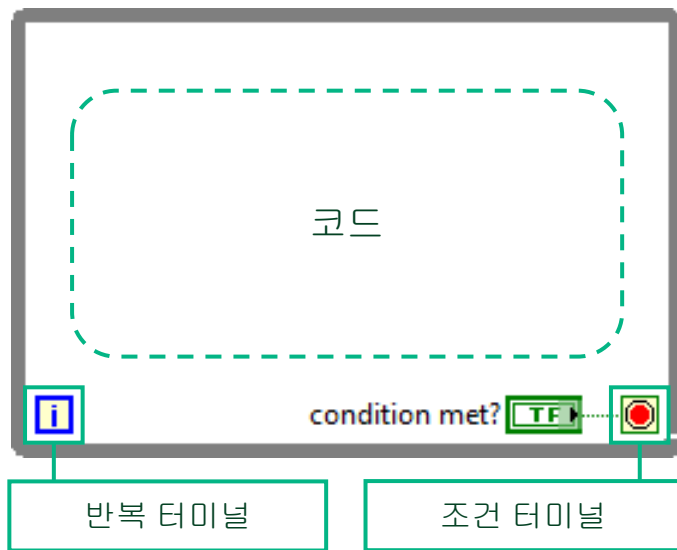
While 루프 터미널



반복 터미널은 현재 루프 반복 횟수를 제공합니다.

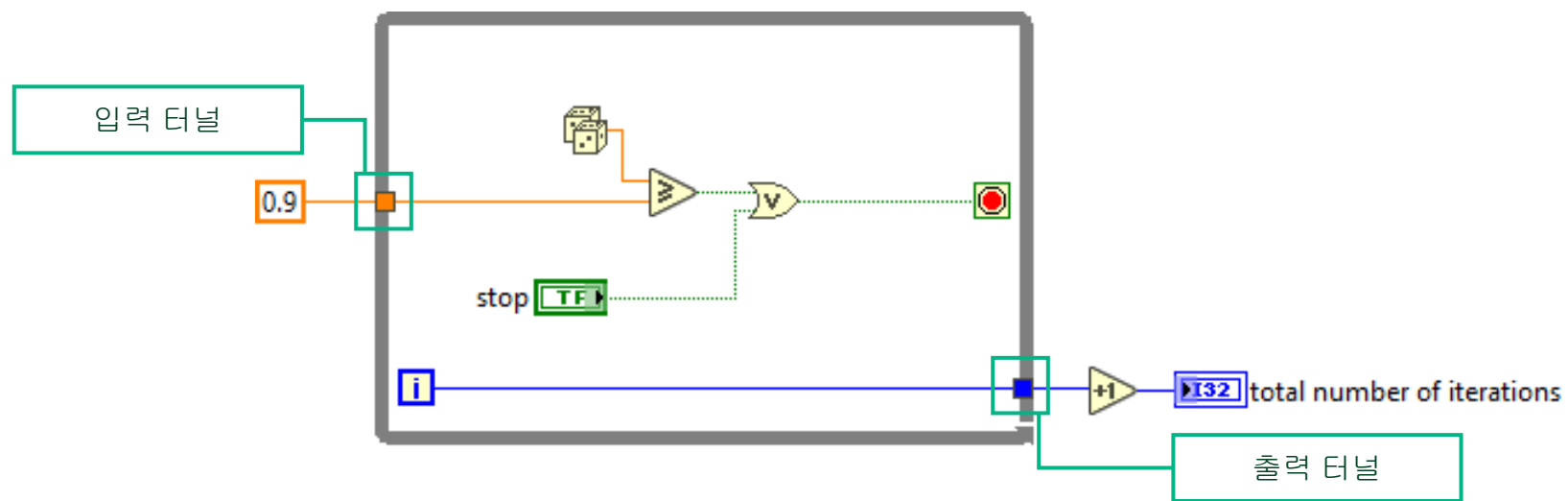


조건 터미널은 조건을 만족하면 루프가 어떻게 응답할지를 지정합니다.



터널

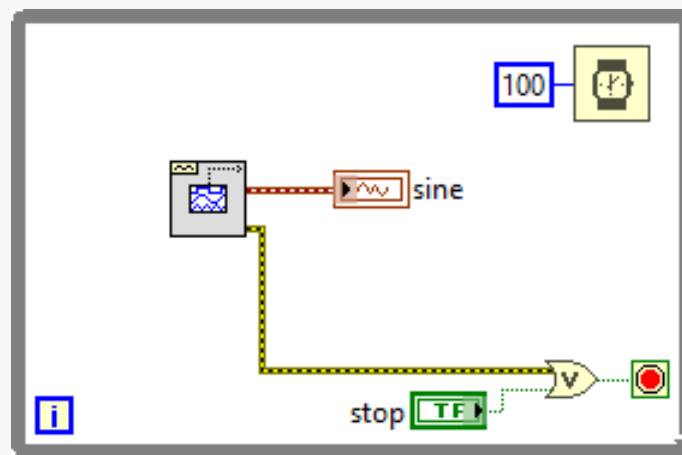
입력 터널은 데이터를 루프 안으로 전송하고 출력 터널은 데이터를 루프 밖으로 전송합니다.



참고 모든 입력을 사용할 수 있을 때 **While** 루프가 실행됩니다. 루프가 실행을 완료할 때까지 어떤 출력도 사용할 수 없습니다.

에러 확인 및 에러 처리

에러가 발생하는 경우 While 루프를 정지합니다.



연습문제 8-1



While 루프 소개

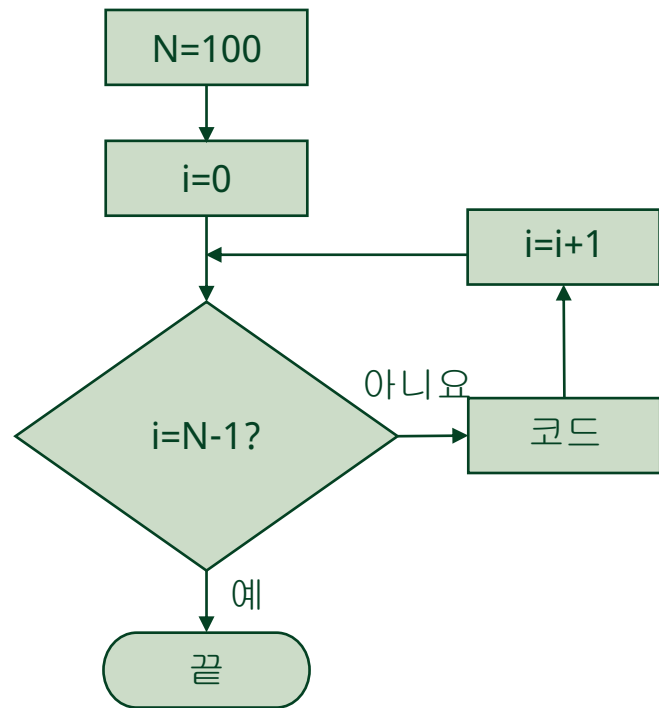
코드를 반복적으로 실행하고 구성 요소가 어떻게 작동하는지 설명하려면 **While** 루프를 사용합니다.

For 루프 살펴보기

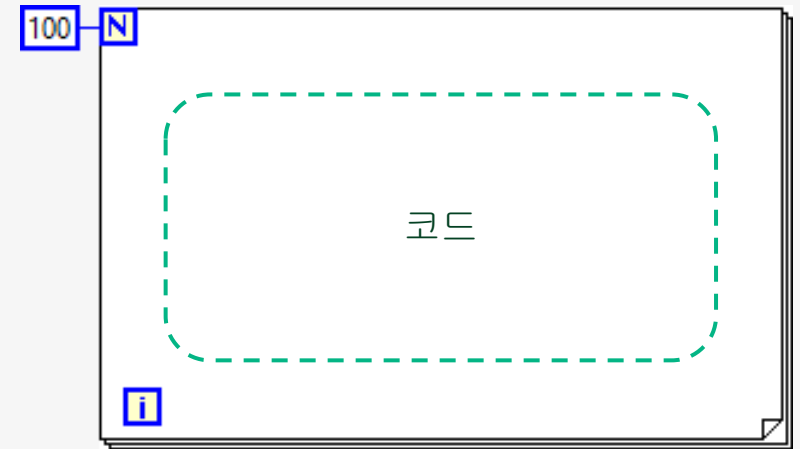
- For 루프 소개
- 반복 횟수 제어
- While 루프 대 For 루프

For 루프 소개

For 루프는 코드를 지정된 횟수만큼 실행합니다.



LabVIEW의 For 루프



유사 코드

```

N=100;
i=0;
Until i=N-1:
    Repeat (code;i=i+1);
End;
  
```

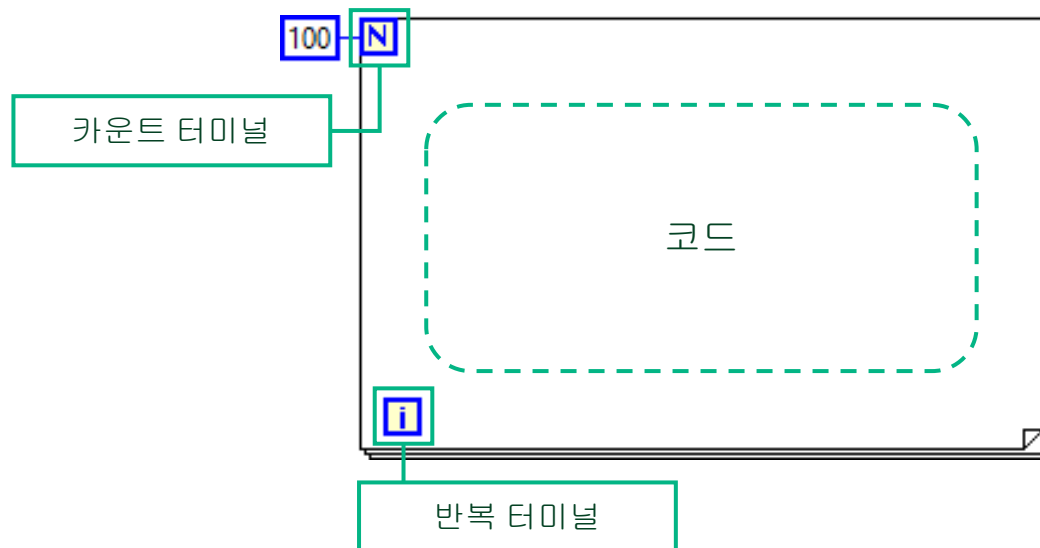
For 루프 터미널



카운트 터미널은 코드를 반복할 횟수를 지정합니다.



반복 터미널은 현재 루프 반복 횟수를 나타냅니다.



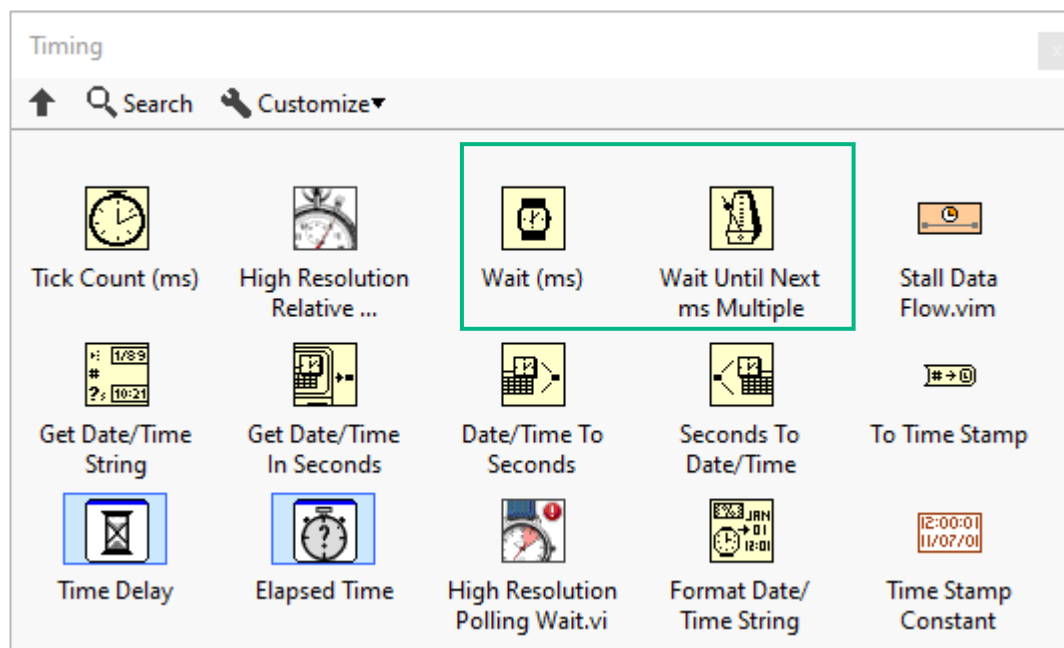
루프 타이밍 설정하기

- 타이밍을 사용하는 이유
- 타이밍 함수와 VI

타이밍을 사용하는 이유

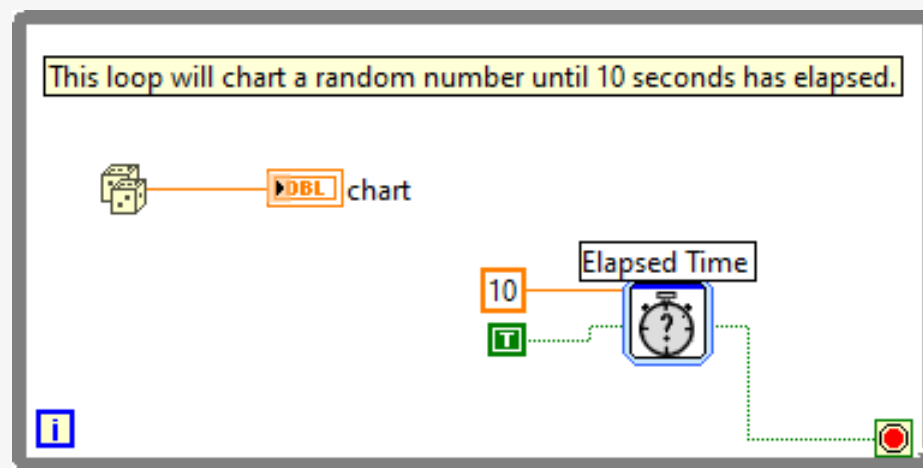


루프 타이밍을 설정하면 프로세서가 다른 태스크를 완료할 수 있으며 반복 빈도 또는 타이밍을 제어할 수 있습니다.



[경과 시간] 익스프레스 VI

경과 시간 익스프레스 VI는 첫 번째 호출 또는 마지막 재설정 이후 경과된 시간(초)을 반환합니다.



연습문제 8-2



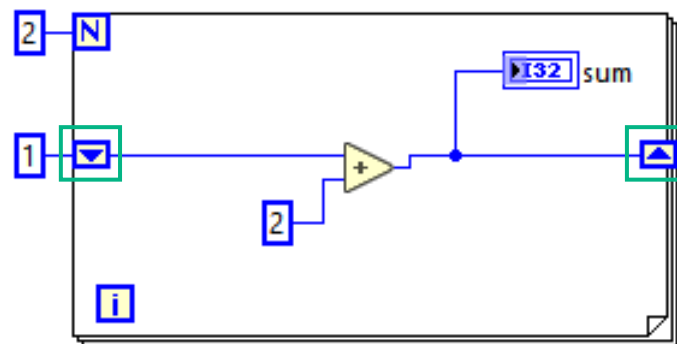
타이밍 함수와 **VI**를 루프에서 사용하기

루프 내에서 타이밍 함수와 **VI**를 사용하여 루프 주기를 설정하고, **CPU** 사용량을 줄이고, 현재 날짜/시간 및 경과 시간을 봅니다.

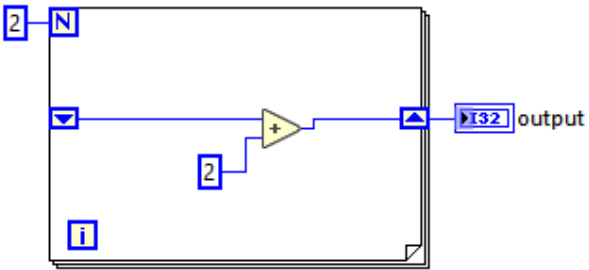
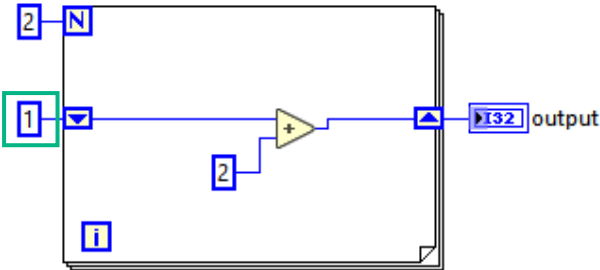
루프에서의 데이터 피드백

시프트 레지스터 다루기

시프트 레지스터는 한 루프 반복에서 다음 루프 반복으로 값을 보냅니다.

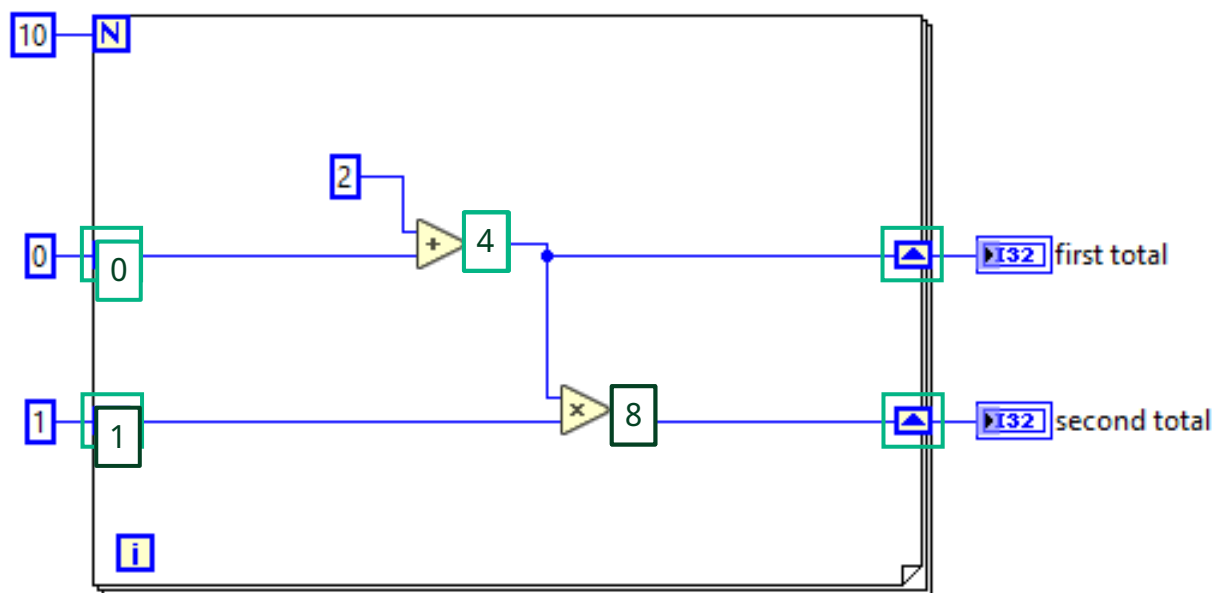


시프트 레지스터 초기화하기

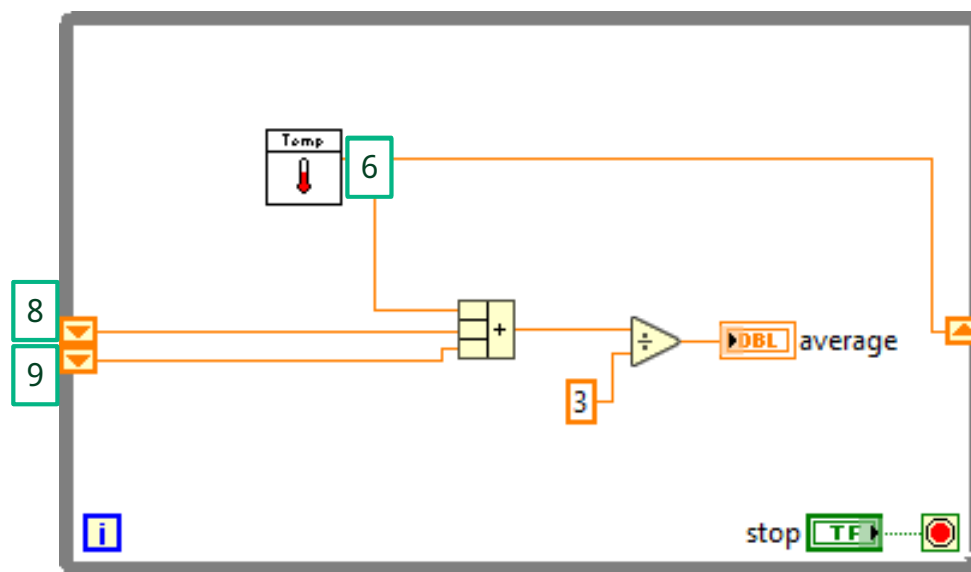
초기화되지 않은 시프트 레지스터	초기화된 시프트 레지스터
	
첫 번째 반복 전의 값은 0입니다	컨트롤 또는 상수를 사용하여 첫 번째 반복의 값을 재설정합니다
첫 번째 실행 출력 = 4 두 번째 실행 출력 = 8	첫 번째 실행 출력 = 5 두 번째 실행 출력 = 5

시프트 레지스터 만들고 사용하기

시프트 레지스터를 만들려면, 루프의 왼쪽이나 오른쪽 경계에서 마우스 오른쪽 버튼을 클릭한 후 바로 가기 메뉴에서 **시프트 레지스터 추가**를 선택합니다.



여러 이전 반복



연습문제 8-4



시프트 레지스터 사용하기

시프트 레지스터로 이전 반복 데이터를 사용하여
최대 수집 값을 추적합니다.

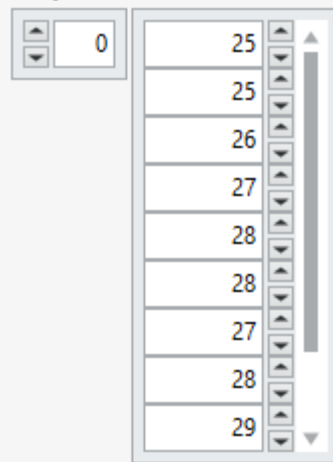
LabVIEW의 데이터 그룹 살펴보기

- 배열 데이터 타입
- 배열 데이터 처리하기
- 웨이브폼 데이터 타입

배열 데이터 타입

배열 데이터 타입은 데이터 타입이 동일한 데이터 원소의 그룹입니다.

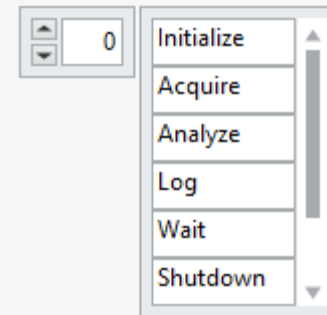
Array - Numeric



Array - Boolean



Array String



배열 데이터 타입

각 배열 원소에는 배열 내에서 배열 원소의 위치를 지정하는 인덱스 번호가 있습니다.

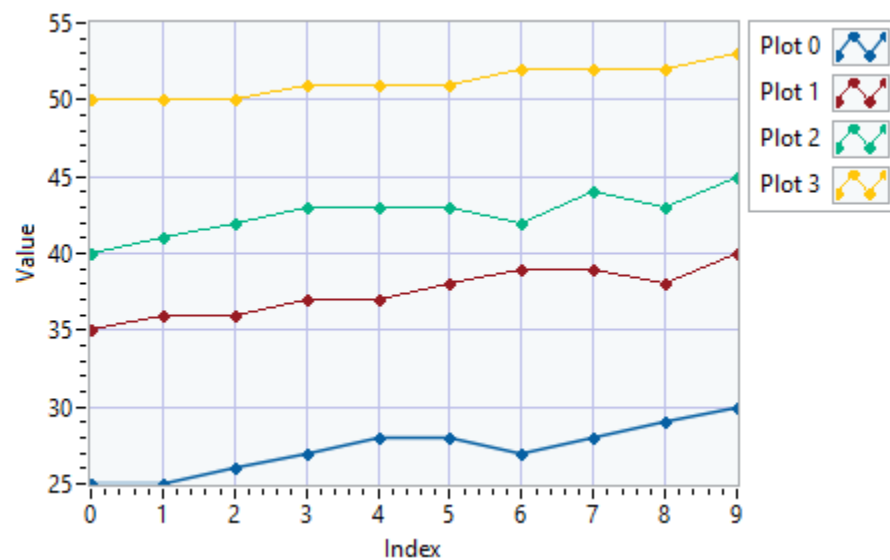


배열 데이터 보기: 2D

2D 배열 인디케이터

25	25	26	27	28	28	27	28	29	30	0
35	36	36	37	37	38	39	39	38	40	0
40	41	42	43	43	43	42	44	43	45	0
50	50	50	51	51	51	52	52	52	53	0
0	0	0	0	0	0	0	0	0	0	0

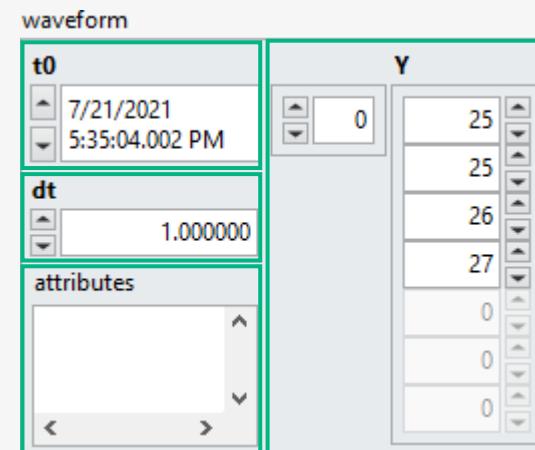
2D 배열 그래프



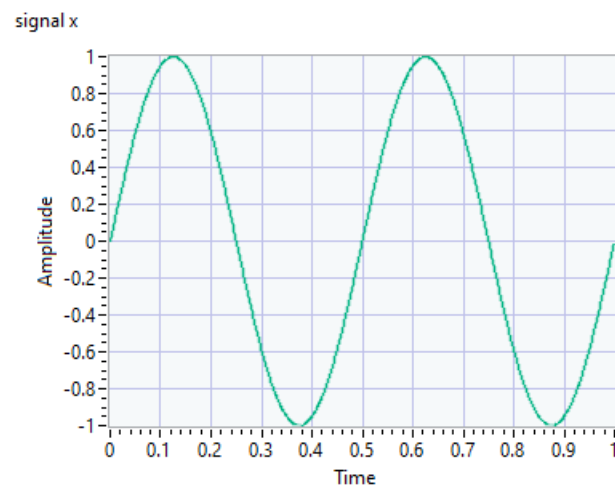
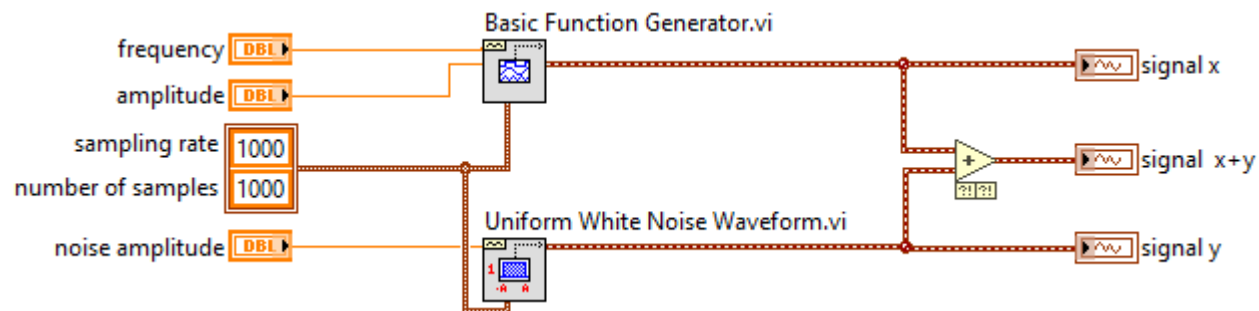
웨이브폼 데이터 타입

웨이브폼 데이터 타입은 다음 4개 아이템으로 구성됩니다.

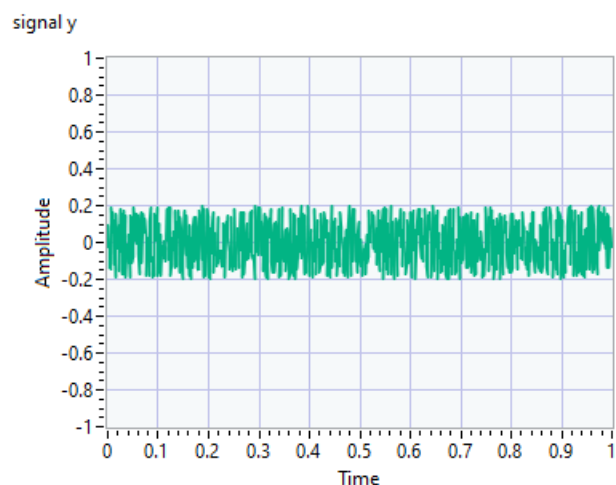
- 시작 시간(t0)
- 데이터 포인트 간의 시간 간격(dt)
- 데이터 값(Y 숫자 배열)
- 속성



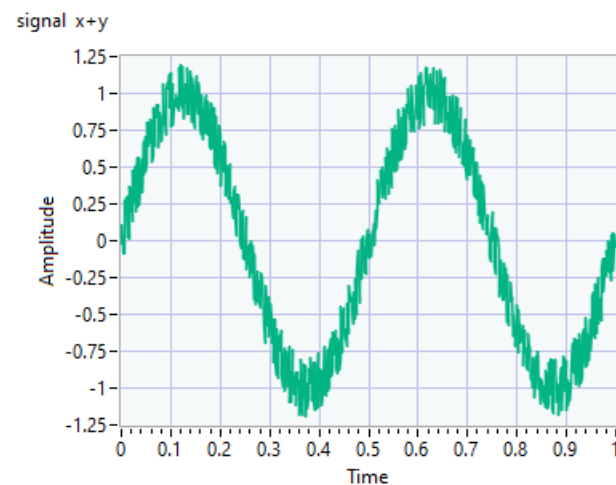
수학 함수: 웨이브폼 및 웨이브폼



+



=



연습문제 9-4

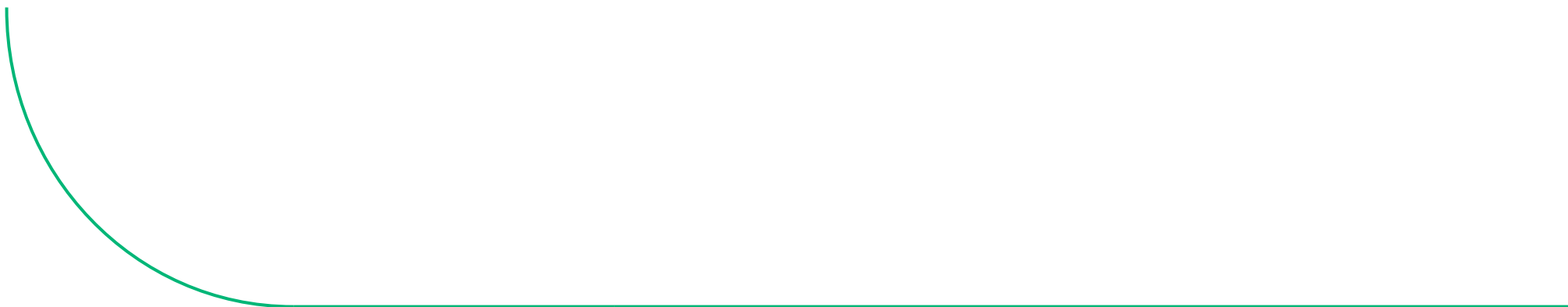


분석 함수 및 **VI**를 사용하여 데이터
분석하기

VI 블록다이어그램에서 분석 도구를 사용하여
데이터를 분석하십시오.



Software Defined Radio



Software Defined Radio

Physical 레이어 기능의 일부 또는 전체가 소프트웨어로 정의된 라디오.

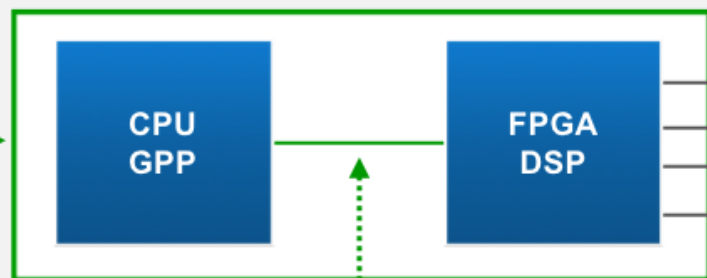
Multi-Processor Subsystem

Real-time signal processor

- Physical Layer (PHY)
- ex FPGA, DSP

Host processor

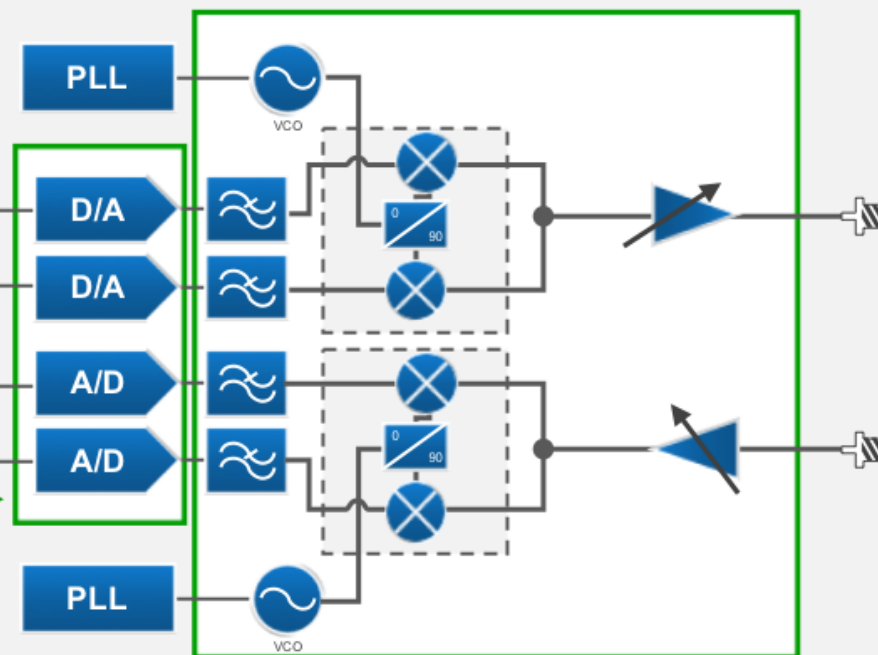
- Medium Access Control (MAC)
 - Rx/Tx control
- ex. Host GPP, multi-core CPU



Host Connection

Determines Streaming Bandwidth
Ex. Gigabit E-net, PCIe

Baseband Converters



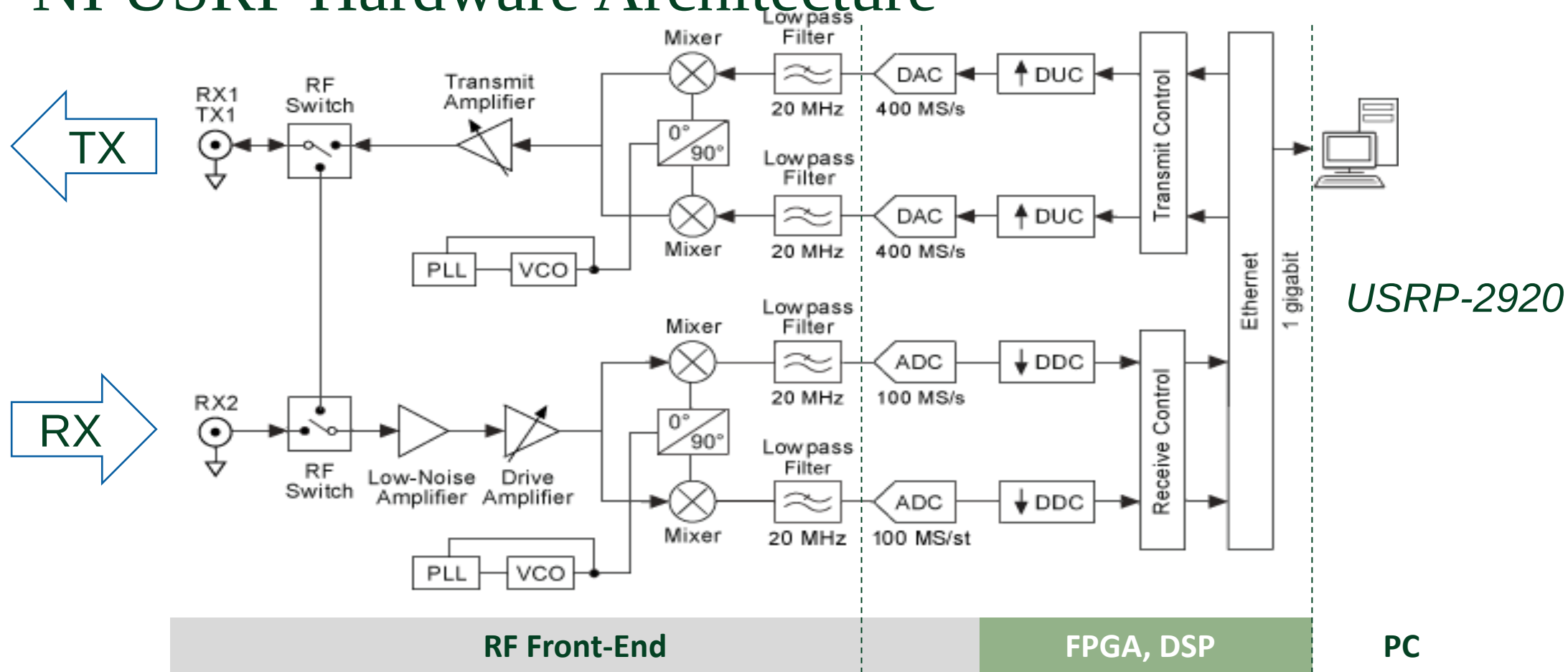
RF Front End

- General Purpose RF
- Dual LOs
- Contiguous Frequency Range

USRP

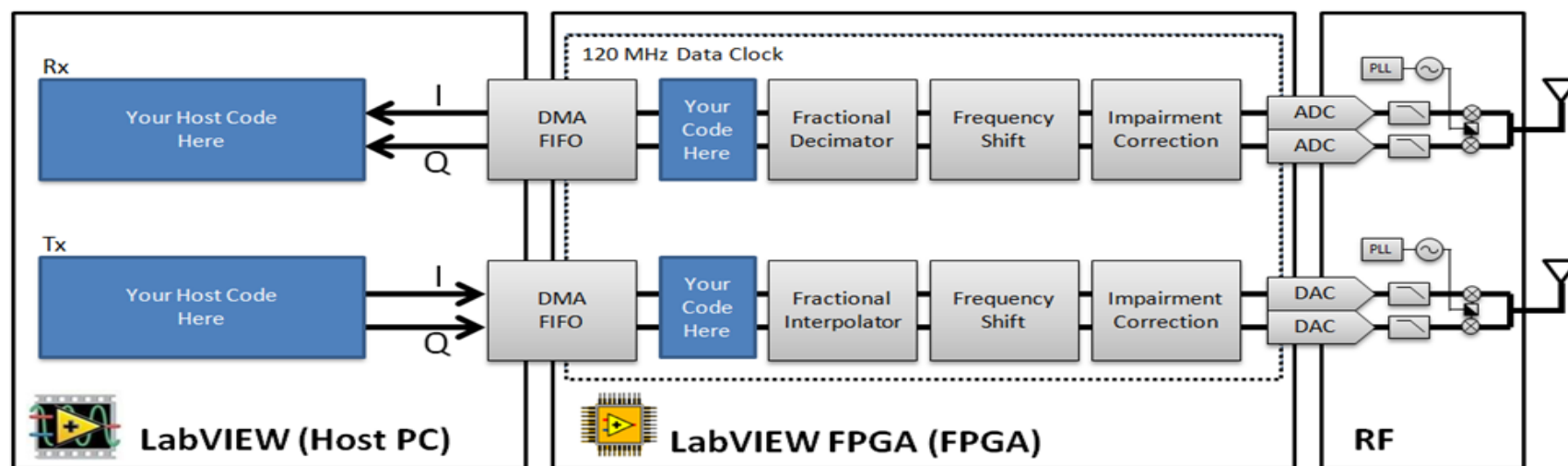
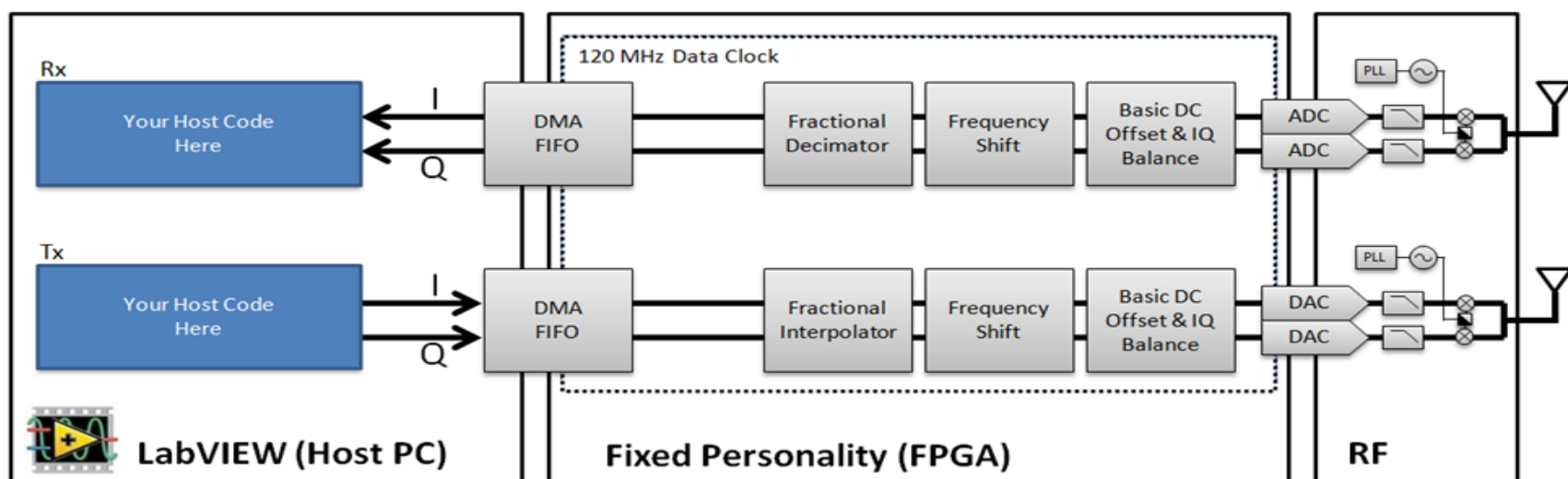
Hardware Architecture

NI USRP Hardware Architecture



USRP-2920

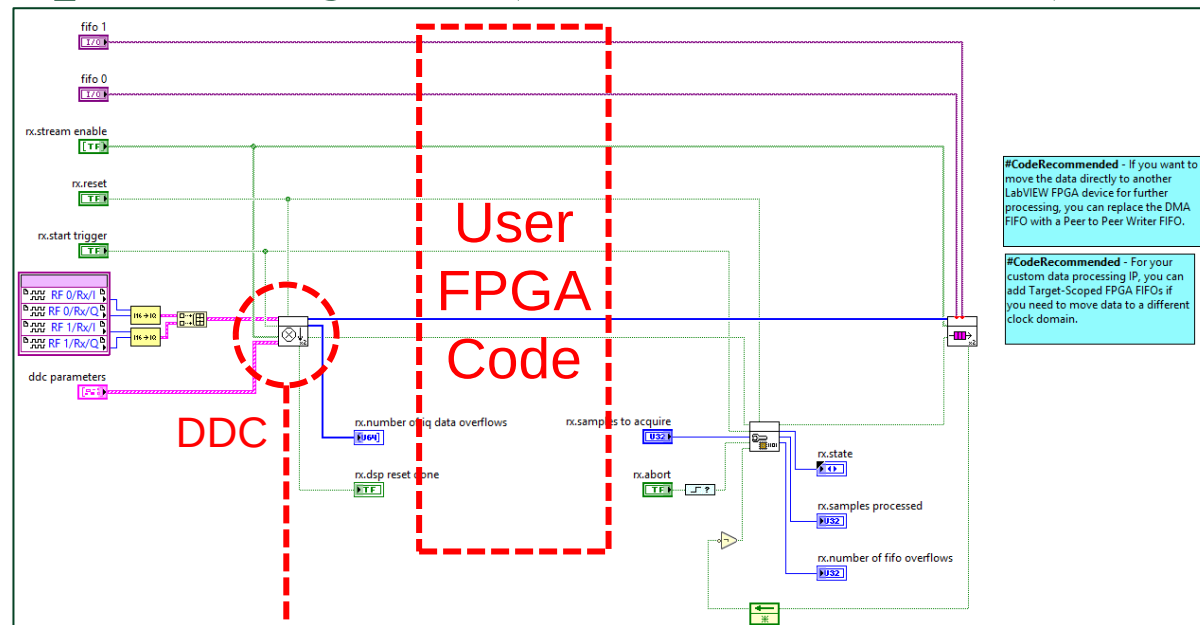
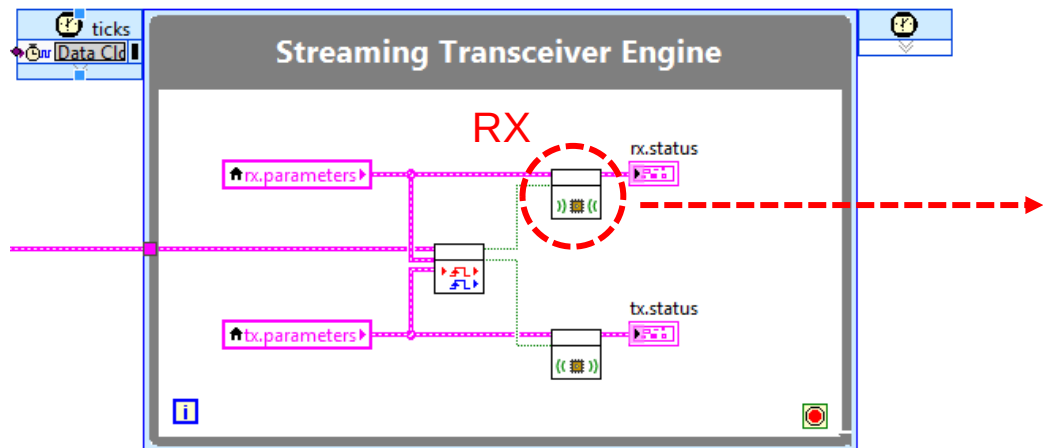
Difference between USRP and USRP-RIO



Ettus

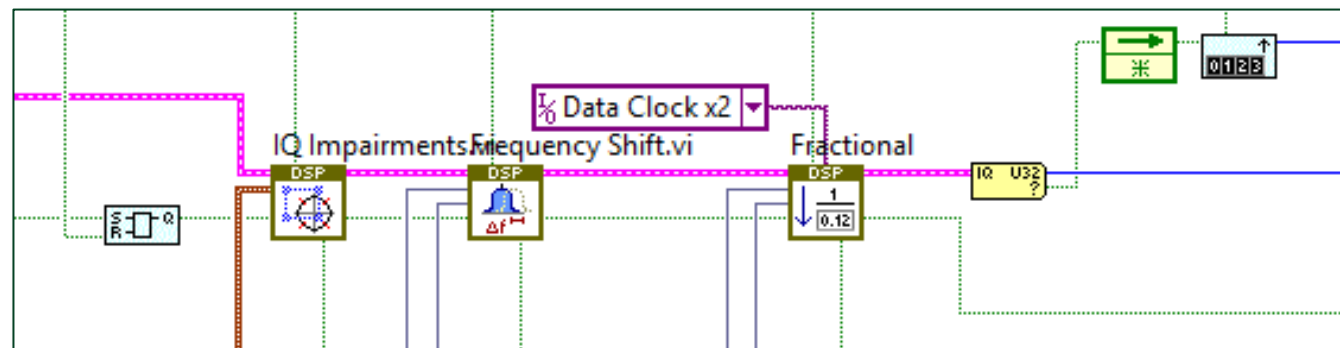
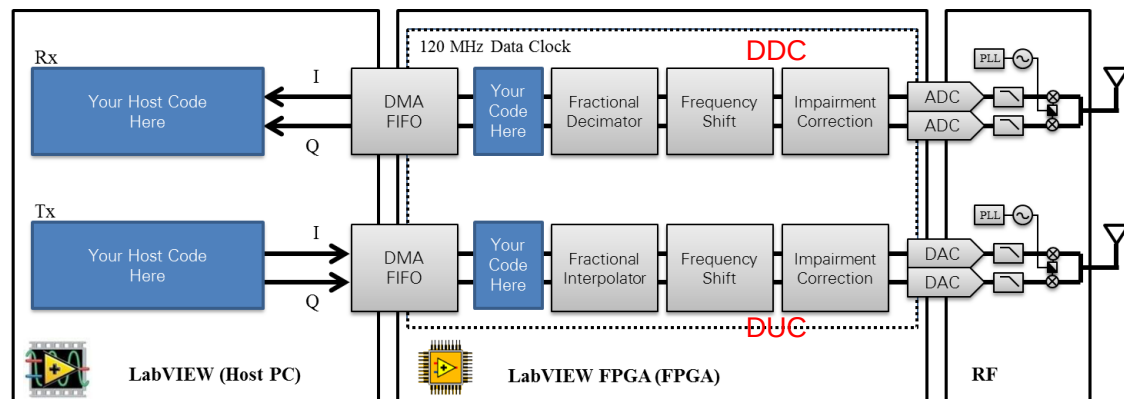
Research™
A National Instruments Brand

LabVIEW: NI-USRP Sample Project (Host + FPGA)

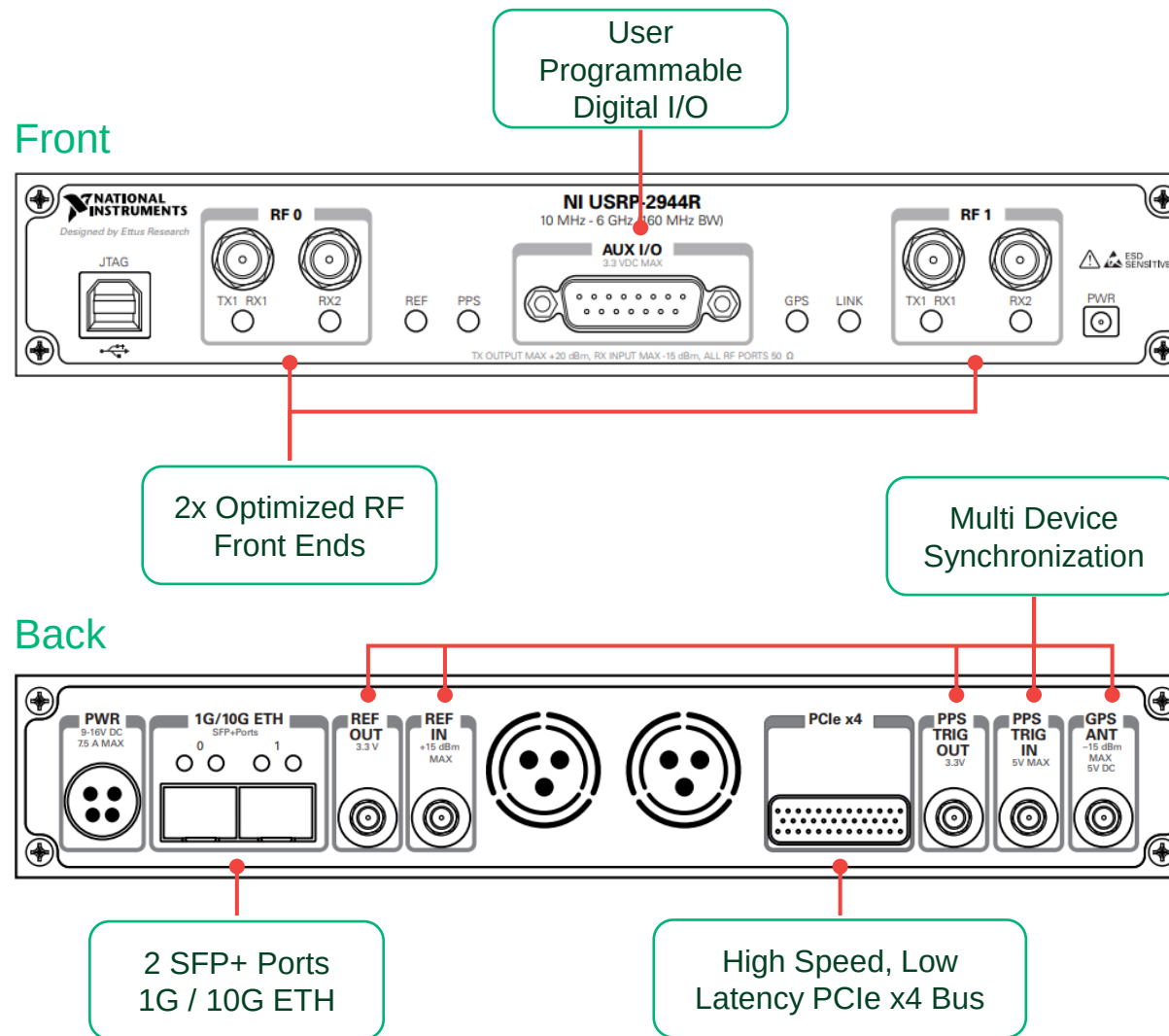


#CodeRecommended - If you want to move the data directly to another LabVIEW FPGA device for further processing, you can replace the DMA FIFO with a Peer to Peer Writer FIFO.

#CodeRecommended - For your custom data processing IP, you can add Target-Scoped FPGA FIFOs if you need to move data to a different clock domain.

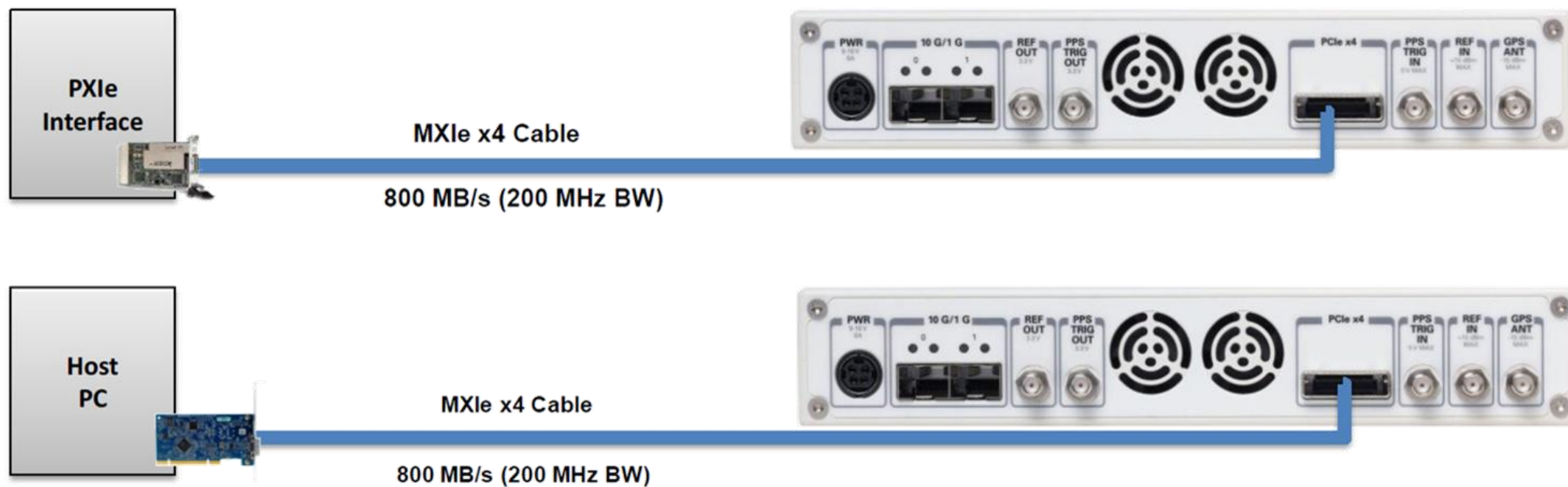


USRP-RIO Interfaces and Connectivity

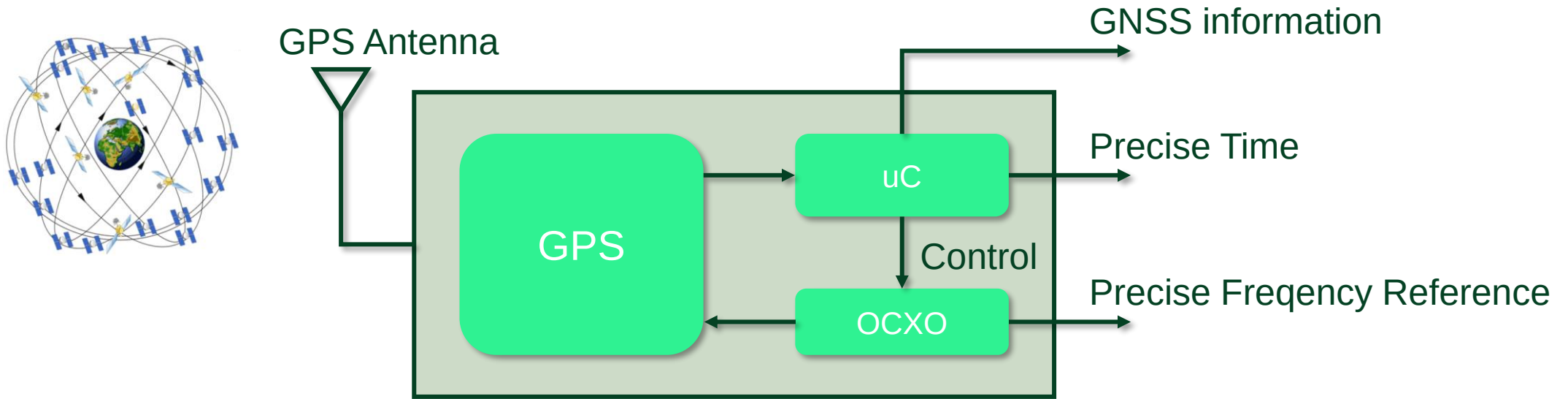


USRP-2944

USRP-RIO MXIe Interface Options



USRP-295x: GPS-Disciplined OCXO



NI USRP-295x Device

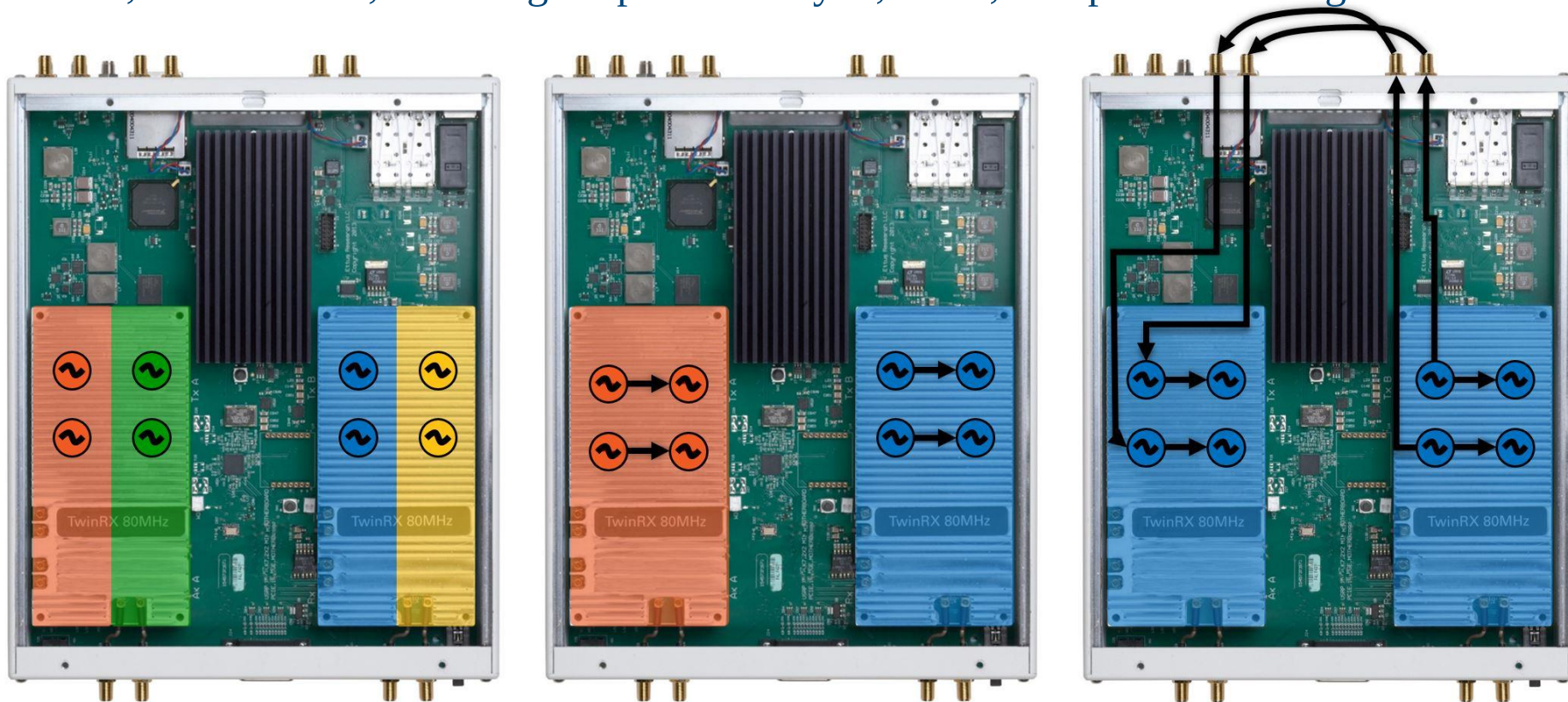


NI USRP RIO	GPS-Disciplined	Frequency Accuracy	
		Stand-alone	GPS Lock
NI USRP-294x	No	± 2.5 ppm	-
NI USRP-295x	Yes	± 25 ppb	± 0.5 ppb

USRP-2945/2955: LO Sharing

10MHz to 6GHz, 80 MHz BW, Two-stage super heterodyne, 2 RX, Independent tuning

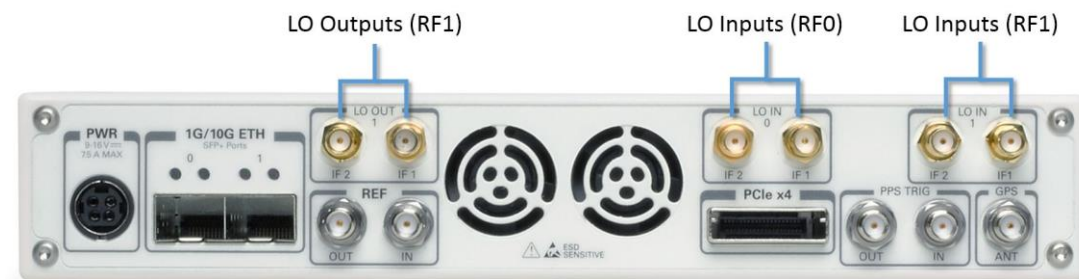
TwinRX



Independent LOs

Companion LOs

Exported & Shared LOs





Programming SDRs with LabVIEW

NI USRP-290X B-Series Overview

Specs

- Low Cost all-in-one solution
- Frequency Range: 70MHz - 6GHz
- 50-100mW output power
- USRP B200 / NI USRP 2900
 - XC6LX75 FPGA
 - 1 TX & 1 RX Half or Full Duplex
 - Up to 56 MHz RF Bandwidth
 - USB 3.0 Interface, bus powered
 - 12-bit ADC & DAC
- USRP B210 / NI USRP 2901
 - XC6LX150 FPGA
 - 2 TX & 2 RX Half or Full Duplex, Coherent
 - Up to 30.72 MHz RF Bandwidth in 2x2
 - USB 3.0 Interface, External
 - MICTOR, JTAG, and GPIO connectors



Applications

- FM, TV Broadcast
- Signals Intelligence
- Communications Research

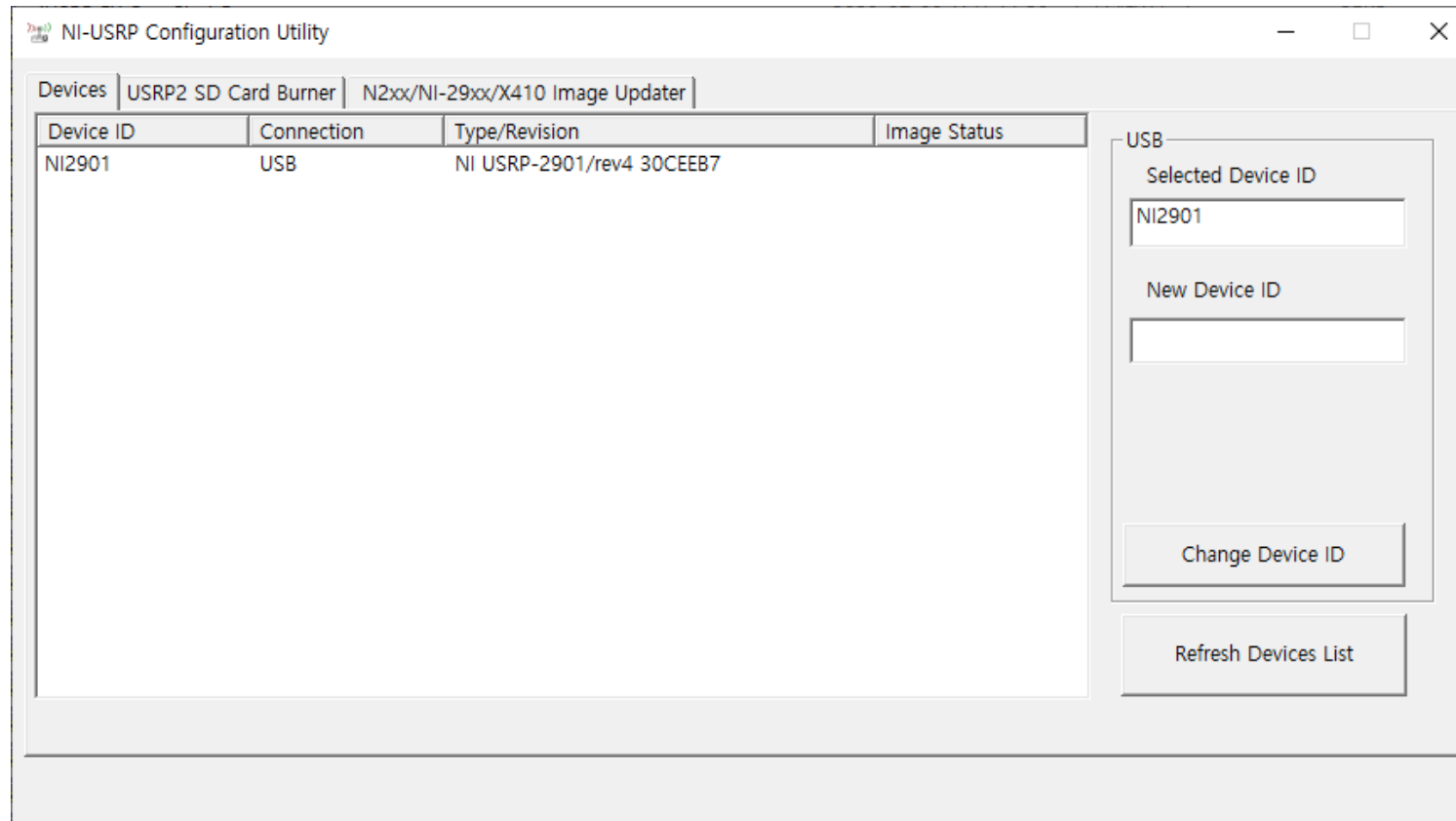
LabVIEW™	✓
LabVIEW Communications	✓
GNU Radio THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM	✓

Confirming Connection

- Select **Start » All Programs » National Instruments » NI-USRP » NI-USRP Configuration Utility** to open the NI-USRP Configuration Utility.
- Select the Devices tab of the utility.

Your device should appear in the list on the left side of the tab, similar to the following figure.

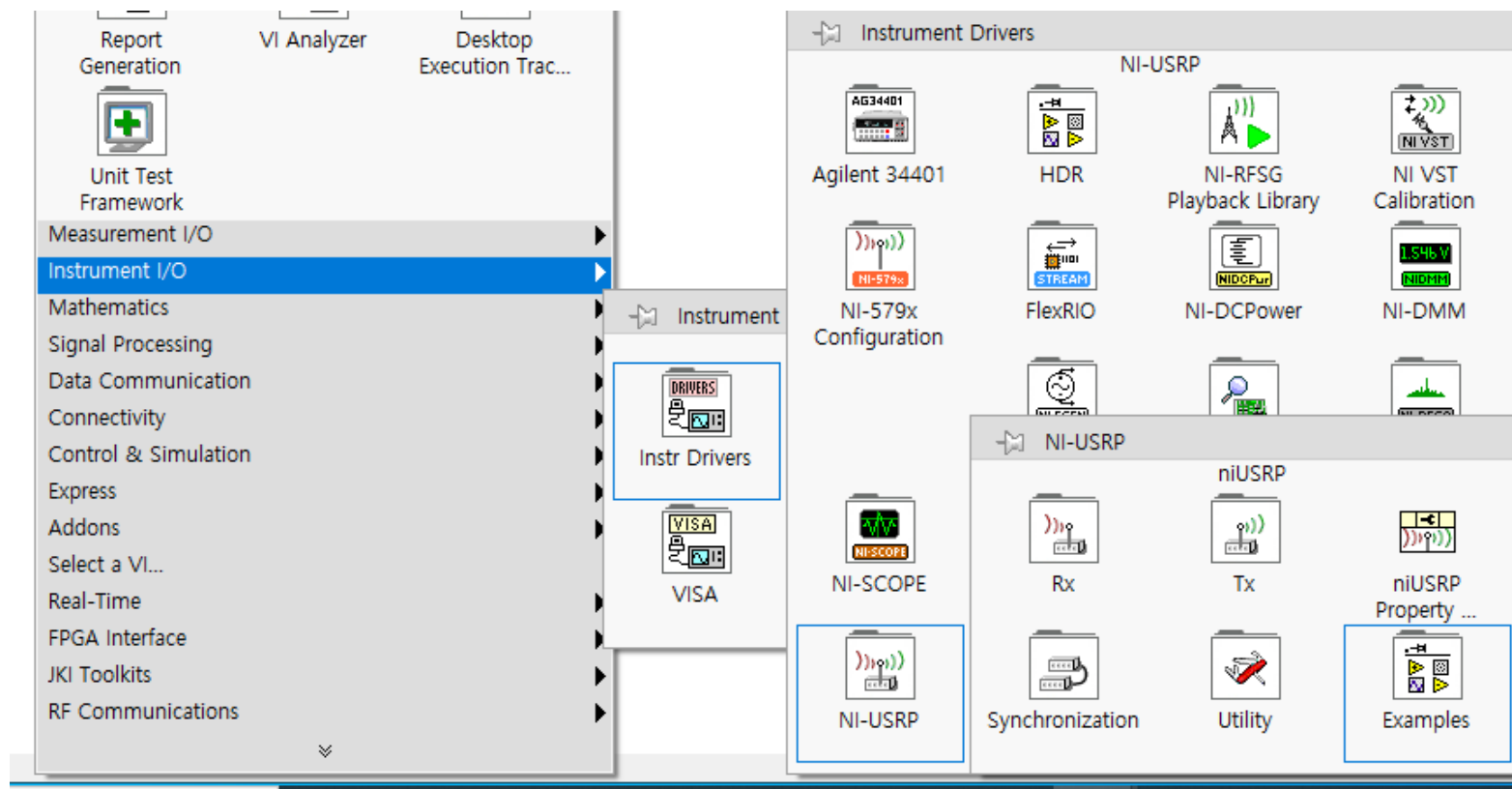
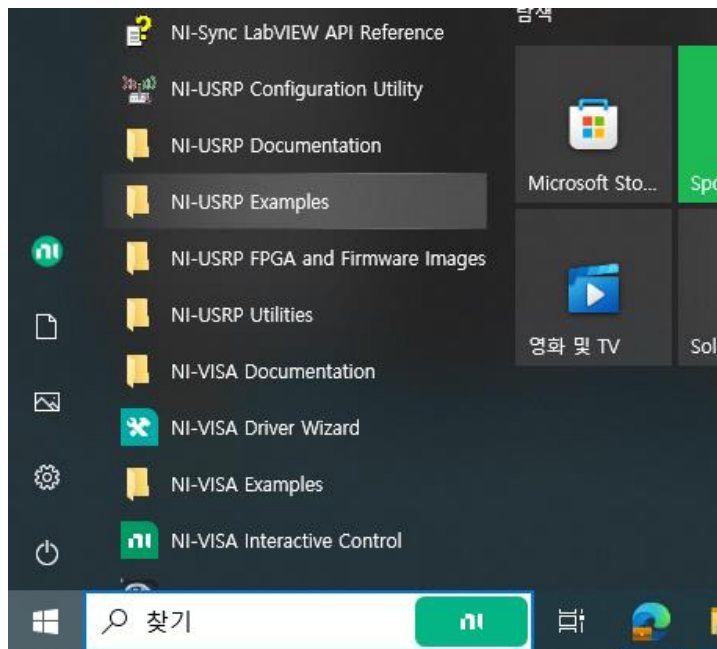
Figure 1. Confirming USB Connection



USRP Examples

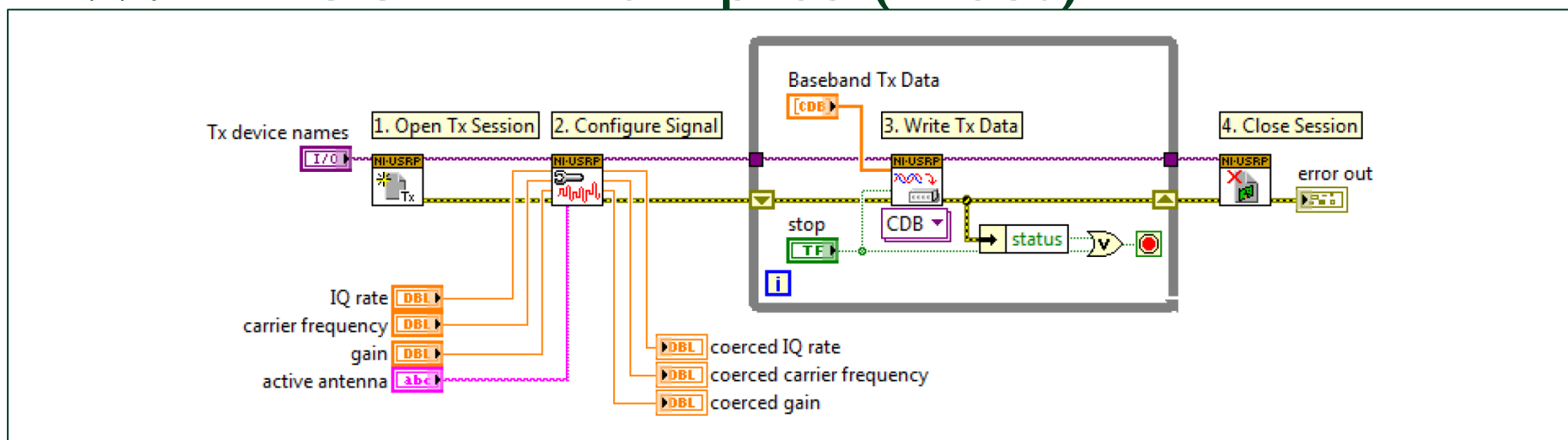
NI-USRP 예제는 다음 위치에서 접근할 수 있습니다:

- 시작 메뉴에서 Start » All Programs » National Instruments » NI-USRP » Examples.
- LabVIEW Functions 팔레트에서 Instrument I/O » Instrument Drivers » NI-USRP » Examples.

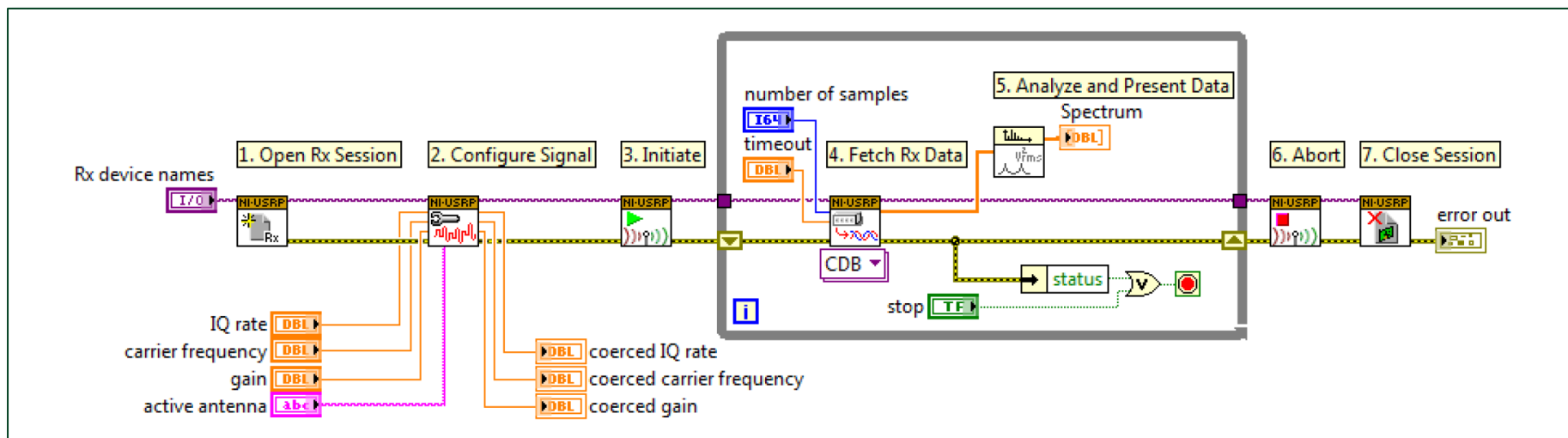


LabVIEW: NI-USRP Examples (Host)

TX



RX



USRP 실습1



연속 신호 생성 및 수집

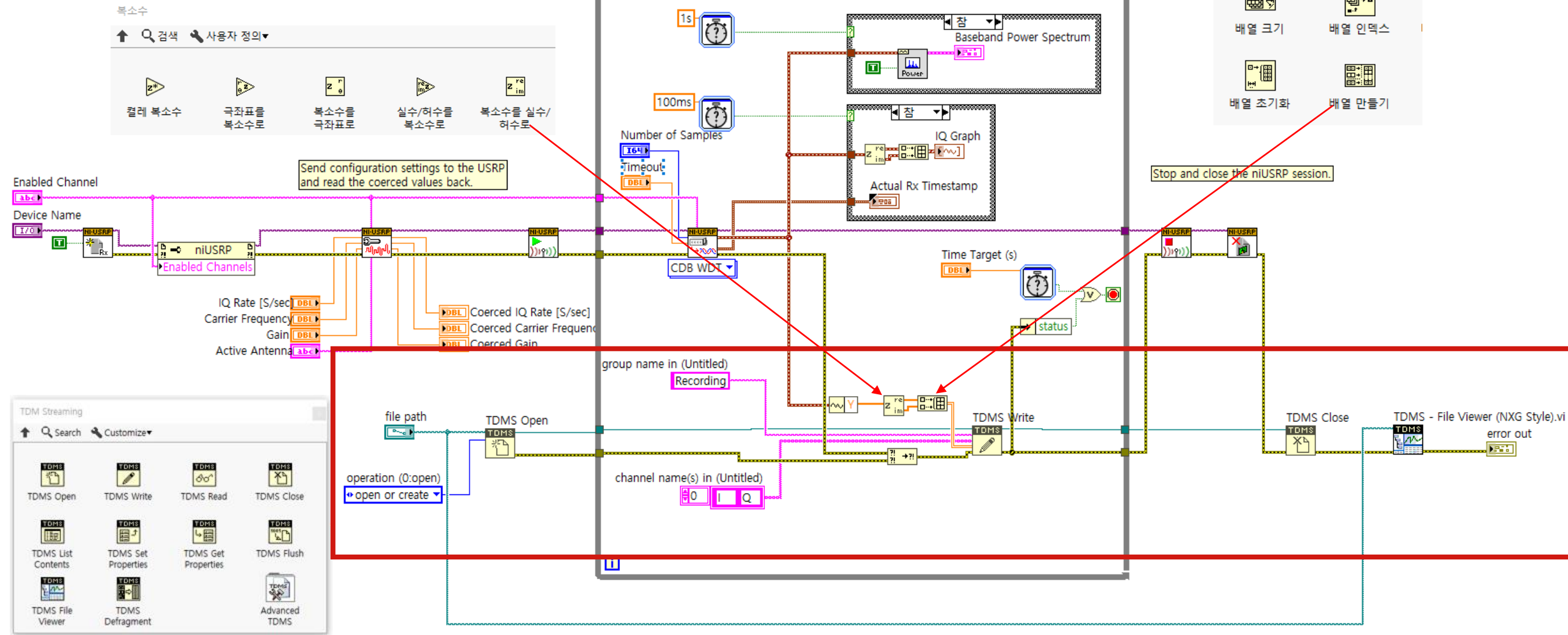
1. niUSRP EX Rx Continuous Async 예제를 열어 Device Name, IQ Rate, Carrier Frequency, Active Antenna, Enabled Channel을 설정하고 실행합니다.
2. niUSRP EX Tx Continuous Async 예제를 열어 Device Name, IQ Rate, Carrier Frequency, Active Antenna, Enabled Channel을 설정하고 실행합니다.

USRP 실습2

연속 신호 저장하기



Participants Guide\USRP
연습문제\Exercise\실습2 저장하기.vi

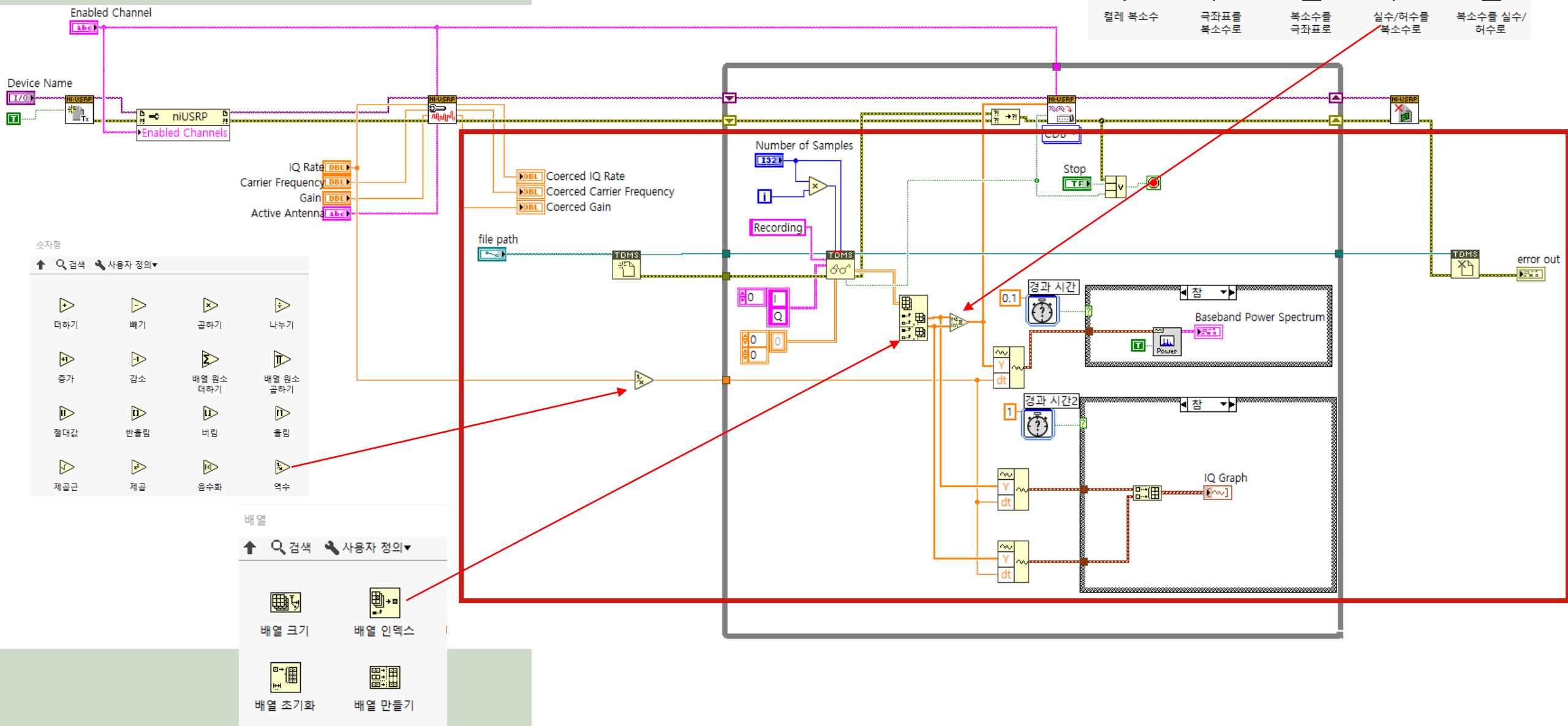




USRP 실습3

저장된 신호 재생하기

Participants Guide\USRP
연습문제\Exercise\실습3 재생하기.vi



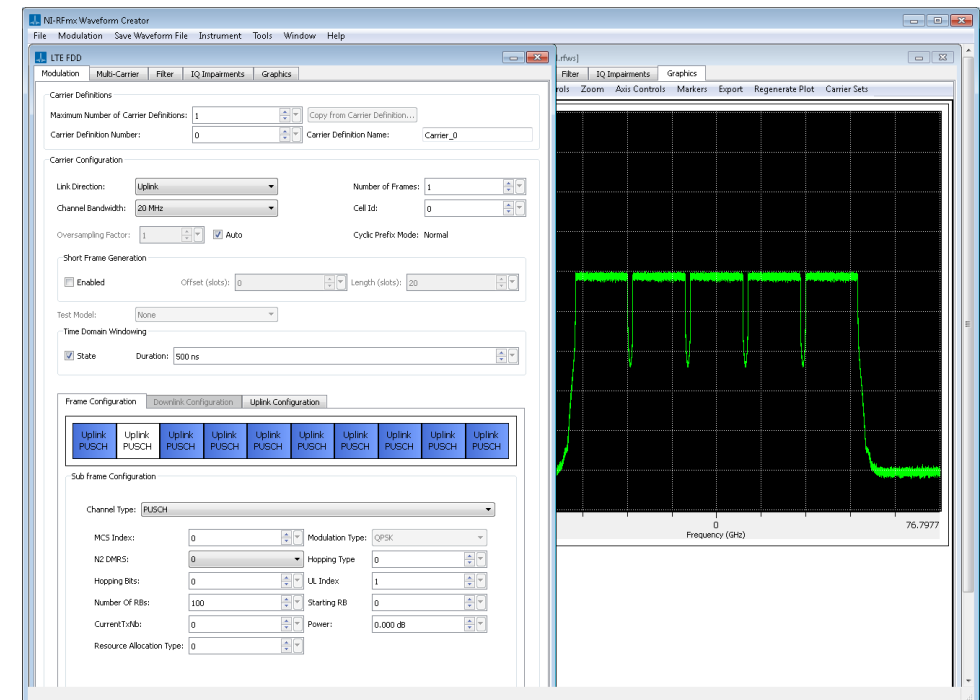
Introduction to NI-RFmx Waveform Creator

Create and generate waveforms for multiple wireless standards

Create IQ waveform files

Built-in waveform visualizer tools

Save the settings for future use



Introduction to NI-RFmx Waveform Creator

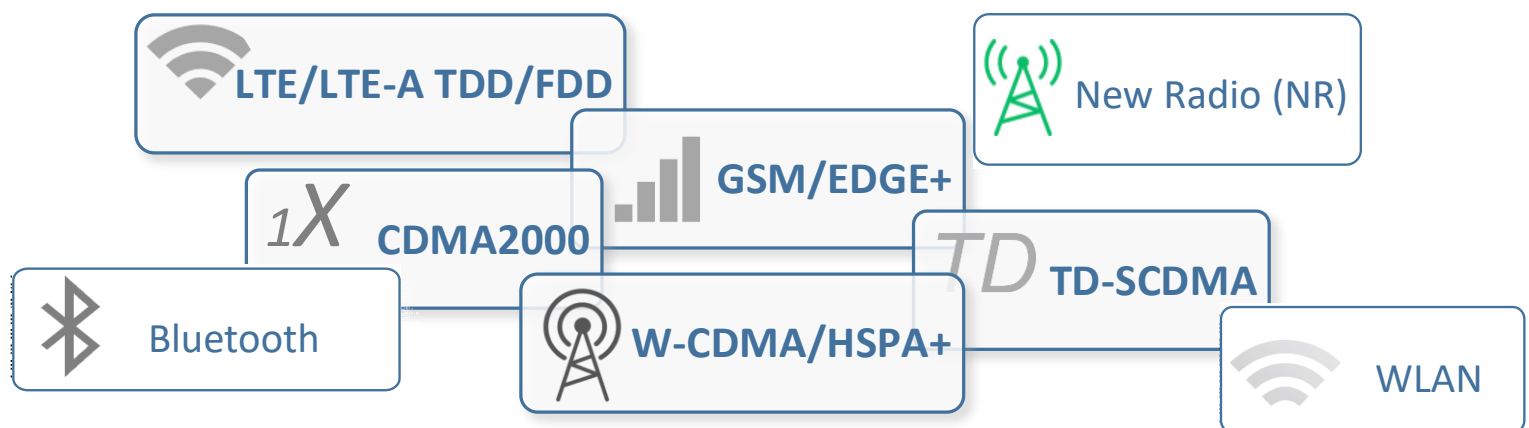
Supports generation for the following standards:

Cellular Standards:

- Bluetooth
- WLAN
- NR
- LTE/LTE-A TDD/FDD
- W-CDMA
- GSM
- TD-SCDM
- CDMA2k
- EV-DO

General Purpose:

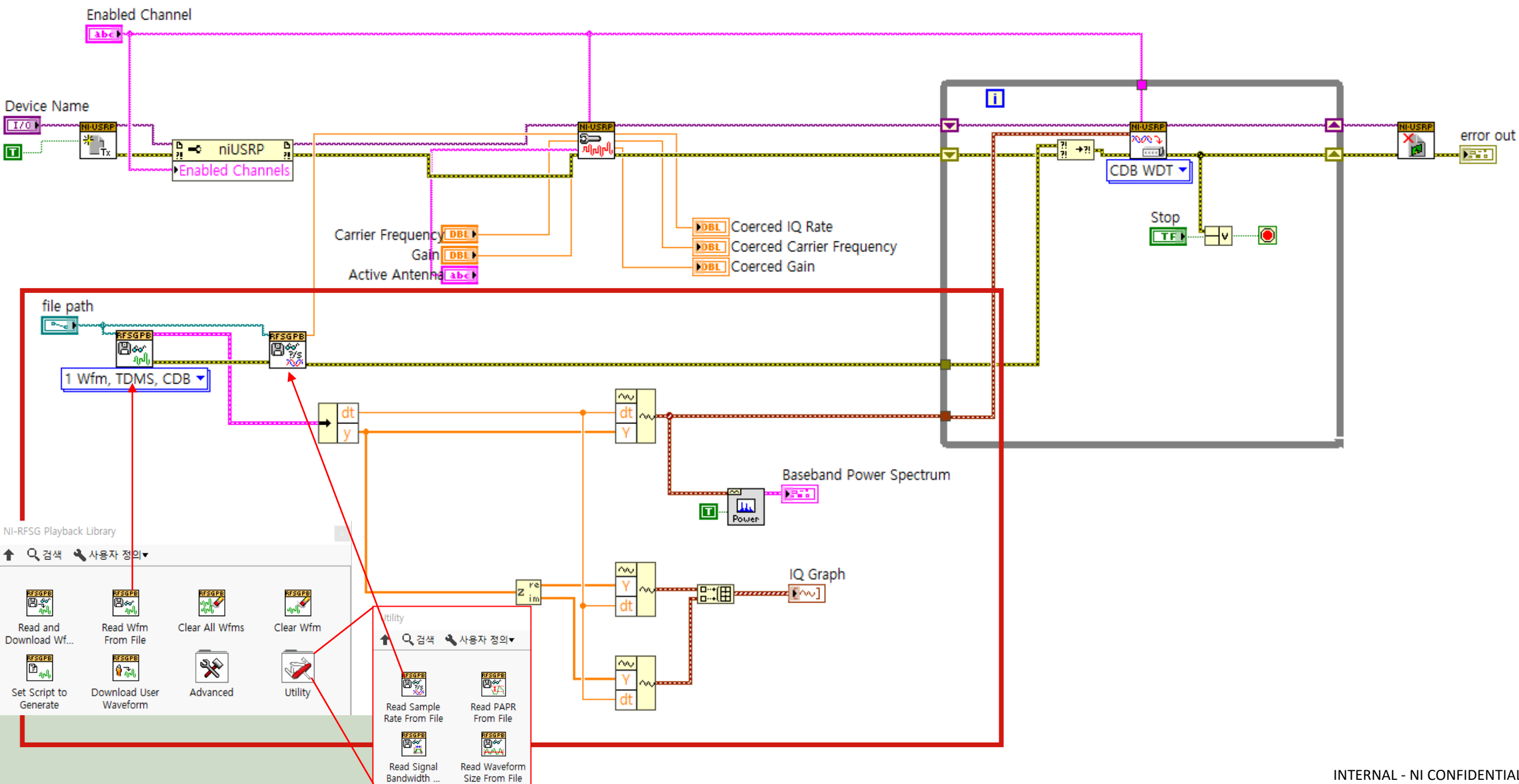
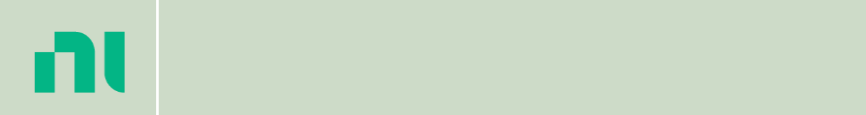
- FSK
- PSK
- QAM
- Tones





Demo

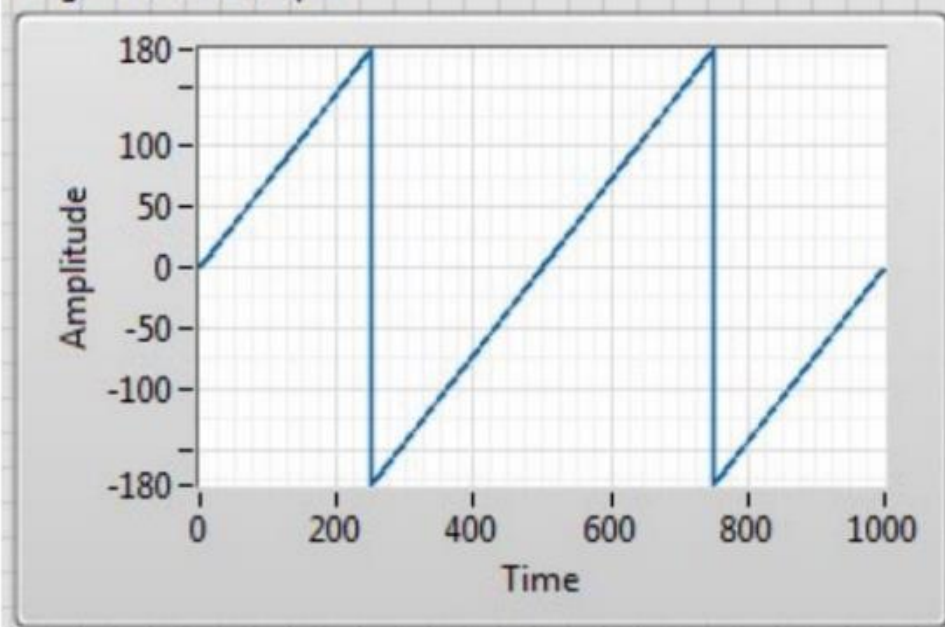
RFmx Waveform Creator로 생성된 신호
재생하기



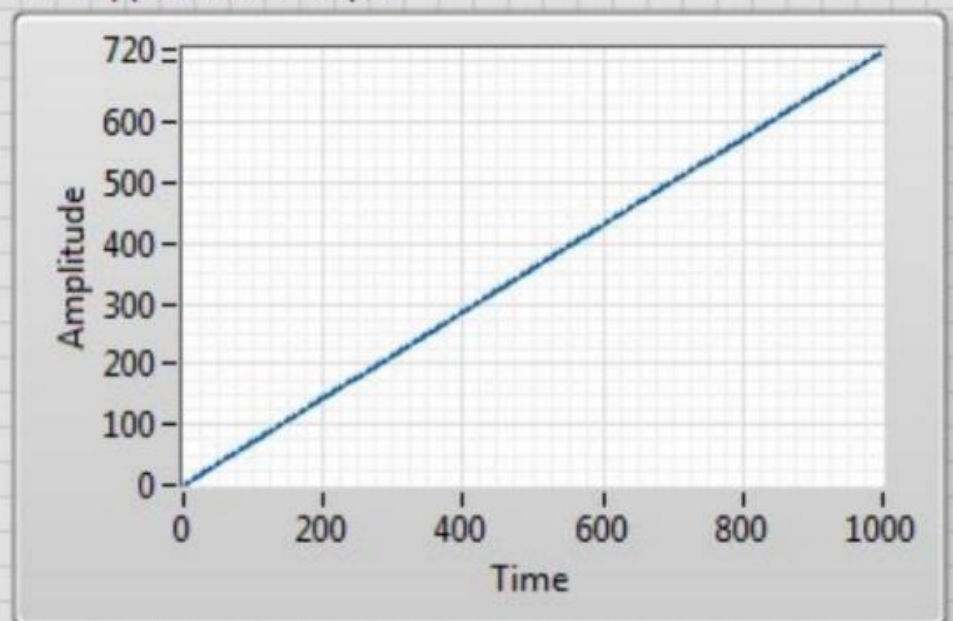
FM Demodulation

$$FM\ Signal = \sin\left(\underbrace{carrier\ frequency + \int_0^t message\ signal\ dt}_{Phase}\right)$$

Original Phase Graph



Unwrapped Phase Graph



← Unwrapping



USRP 실습4

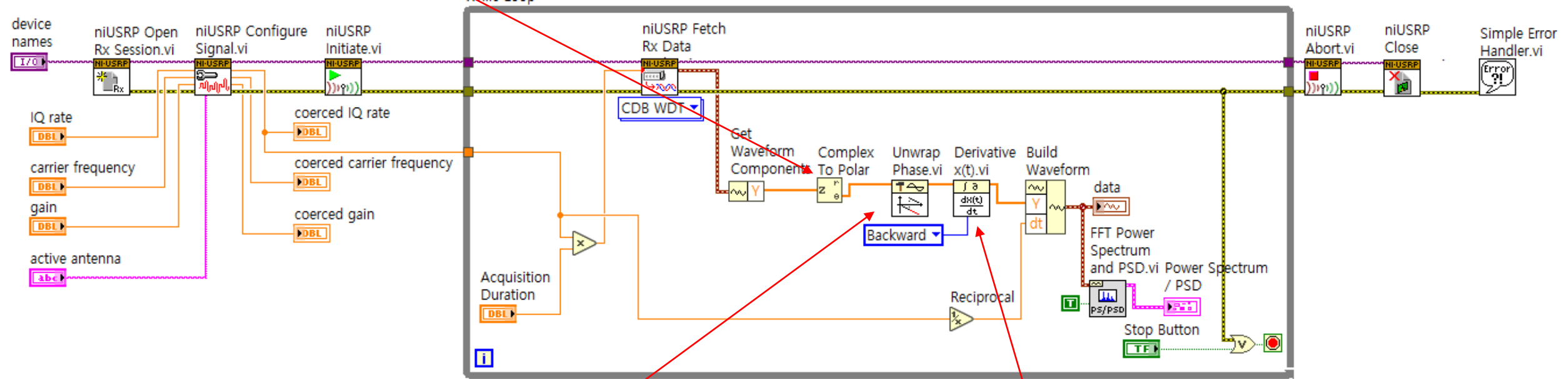
FM Demodulation

Participants Guide\USRP
연습문제\Exercise\실습4 FM 복조.vi

복소수

z^* $\angle \theta$ z^r $\angle \theta$ z^{re} $\angle \theta$ z^{re} $\angle \theta$

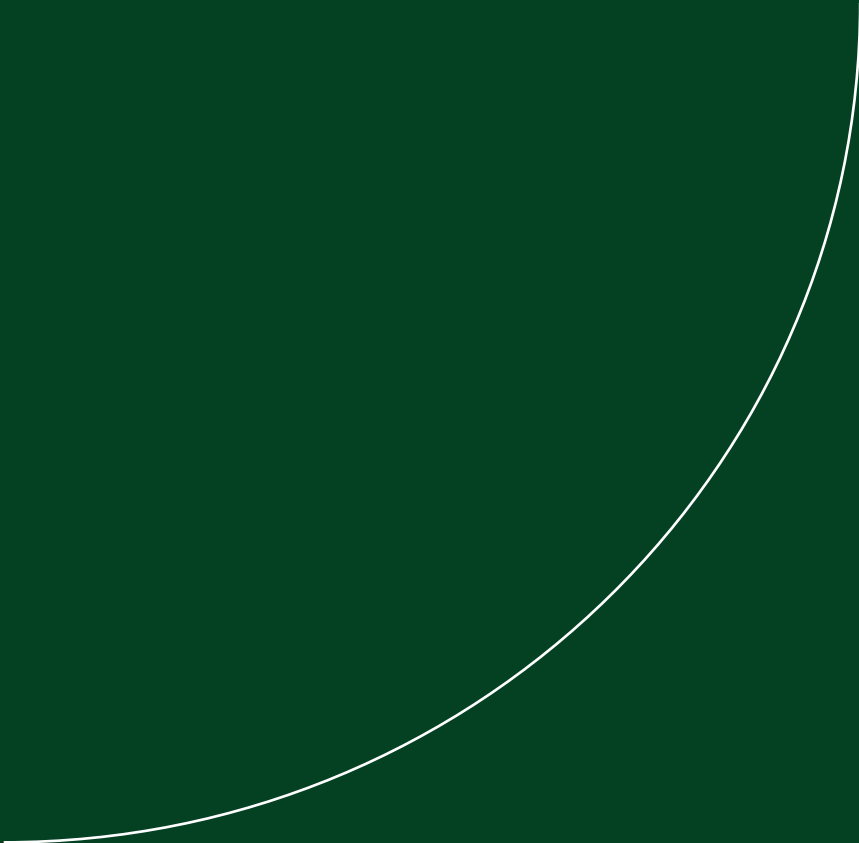
켈레 복소수 극좌표를 복소수로 복소수를 극좌표로 실수/허수를 복소수로 복소수를 실수/허수로 실수/허수를 극좌표로 극좌표를 실수/허수로



신호 처리 -> 신호 연산->위상 풀기

수학->적분&미분-> $x(t)$ 도함수

USRP Product Selection Guide

A decorative white curved line starts from the bottom right and curves upwards and to the left, ending near the center of the slide.

What's the Difference Between Ettus and NI?



Hardware



Sold as Modular Kits & Pre-Assembled
Some Units Not CE Certified
Stand Alone and Embedded Options Available



Sold Pre-Assembled
CE Certified
Based on Popular Configurations of NI Ettus Products.

Software



Open-Source Software: GNU Radio, UHD, C++/Python
FPGA Framework: RFNoC (Verilog/VHDL)
Popular Development Tools: Redhawk, MATLAB...



Unified Host / FPGA Design Flow with LabVIEW/LabVIEW FPGA
Uses NI-USRP Driver
Ability to Import/Export 3rd Party Tools (MATLAB, etc.)

Support

[Open Community and Email Support](#)
Extended Support Contracts Available
Extensive Online Knowledgebase www.ettus.com

[Supported by NI Technical Support Engineering](#)
Extended Support Contracts Available

Wireless Research Design Prototyping and Deployment Portfolio

Highly-Portable to High-performance



USRP 2901

56 MHz BW
6 GHz Fc

B200mini

56 MHz BW
6 GHz Fc

Host based (USB)
Low SWaP



USRP X310

160 MHz BW
6 GHz Fc

FlexRIO

200 MHz BW
4.4 GHz Fc

Large FPGA SDRs



2nd Gen VST

1 GHz BW
6 GHz Fc

mmWave VST

2 GHz BW
54 GHz Fc

3rd Gen VST

2 GHz BW
26.5 GHz Fc

High Frequency / Wide Bandwidth
Instrument Grade + Calibration



USRP E31X & E320

56 MHz BW
6 GHz Fc

Deployable



USRP RX310

Pixus Technologies



N321

200 MHz BW
6 GHz Fc



NI Ettus USRP X410

400 MHz BW
8 GHz Fc



NI Ettus USRP X440

1.6 GHz BW
4 GHz Fc

Stand Alone
FPGA + Embedded Processor



ATCA-3671

Massive BB
Processing

Multi-FPGA Platform High-
performance
connectivity and Inline processing

USRP Product Portfolio Overview



 Ettus Research	Ettus Research USRP B2XX	Ettus Research USRP E320	Ettus Research USRP N310 / N32X	Ettus Research USRP X310	Ettus USRP X410	Ettus USRP X440
Frequency	70 MHz – 6 GHz	70 MHz – 6 GHz	3 MHz-6 GHz (N32X) 10 MHz-6 GHz (N310)	*10MHz – 6 GHz	1MHz – 7.2 GHz	30MHz – 4 GHz IF
Bandwidth	56 MHz	56 MHz	200 MHz (N32X) 100 MHz (N310)	*160 MHz	400 MHz	Up to 1.6 GHz
Channels	2 Tx, 2 Rx	2 Tx, 2 Rx	2 Tx, 2 Rx (N32X) 4 Tx, 4 Rx (N310)	2 Tx, 2 Rx *4 Rx (TwinRx)	4 Tx, 4 Rx	8 Tx, 8 Rx
Architecture	Integrated	Integrated	Integrated	*Configurable w/ Daughterboards	Integrated	Integrated
Communication	USB	10 GbE	10 GbE or PCIe	10 GbE or PCIe	100/10 GbE or PCIe	100 GbE
Synchronization	2x2 MIMO	2x2 MIMO	Up to 128x128 (N32X) Full Phase Synchronization	*2x2 MIMO	4x4 MIMO	8x8 MIMO
SW Support	GNU Radio, C++, Python, MATLAB, LabVIEW	GNU Radio, C++, Python, MATLAB, RFNoC	GNU Radio, C++, Python, MATLAB, RFNoC	GNU Radio, C++, Python, MATLAB, RFNoC, LabVIEW, LabVIEW FPGA	GNU Radio, C++, Python, MATLAB, RFNoC, LabVIEW, LabVIEW FPGA	GNU Radio, C++, Python, RFNoC
Key Features	Low SWAP-C, Highly portable	Low SWAP, Embedded Deployable, Standalone	Stand Alone, Wide bandwidth, Multi- Channel Sync Ready (N32X)	*Configurable RF Front End, Programable FPGA	RFSoc based FPGA, 5G Ready, Wide bandwidth, Multi- Channel	RFSoc based direct sampling, phase coherency, wide bandwidth

Type	NI USRP Model	NI Ettus USRP Model	# Tx	# Rx	Frequency Range	BW	 LabVIEW™	 FPGA LabVIEW™	 OSS-UHD GNU Radio THE FREE & OPEN-SOURCE RADIO SOFTWARE	 OSS-FPGA RFNoC
Stand-Alone, FPGA Enabled High Performance	USRP X440		8	8	30 MHz – 4 GHz	1.6 GHz	X	X	✓	✓
	USRP X410		4	4	1 MHz – 7.2 GHz	400 MHz	✓	✓	✓	✓
	N/A	USRP N320, USRP N321	2	2	3 MHz – 6 GHz	200 MHz	X	X	✓	✓
	N/A	USRP N310	4	4	10 MHz – 6 GHz	100 MHz	X	X	✓	✓
	USRP-2974	N/A	2	2	10 MHz – 6 GHz	160 MHz	✓	✓	✓	✓
Host Connected, FPGA Enabled, High Performance	USRP-2944	USRP X310 + UBX	2	2	30 MHz – 6 GHz	160 MHz	✓	✓	✓	✓
	USRP-2945	USRP X310 + TwinRX	0	4	10 MHz – 6 GHz	80 MHz	✓	X	✓	✓
	USRP-2954	USRP X310 + UBX + GPSDO	2	2	30 MHz – 6 GHz	160 MHz	✓	✓	✓	✓
	USRP-2955	USRP X310 + TwinRX + GPSDO	0	4	10 MHz – 6 GHz	80 MHz	✓	X	✓	✓
Low SWAP Stand Alone Embedded	N/A	USRP E310 / E313	2	2	70 MHz – 6 GHz	56 MHz	X	X	✓	✓
	N/A	USRP E320	2	2	70 MHz – 6 GHz	56 MHz	X	X	✓	✓
Low SWAP Low Cost USB Connected	N/A	USRP B200mini / B205mini	1	1	70 MHz – 6 GHz	56 MHz	X	X	✓	X
	USRP-2900	USRP B200	1	1	70 MHz – 6 GHz	56 MHz	✓	X	✓	X
	USRP-2901	USRP B210	2	2	70 MHz – 6 GHz	56 MHz	✓	X	✓	X

A Platform Approach to Prototyping

Open Ecosystem of Software Tool flows



The Largest Breadth and Depth of HW in the Industry



Proven Customer Success

First 28GHz mm-wave 5G transceiver demoed in US
-Electronics Weekly

Bristol and Lund set a new world record in 5G wireless spectrum efficiency

-Bristol University

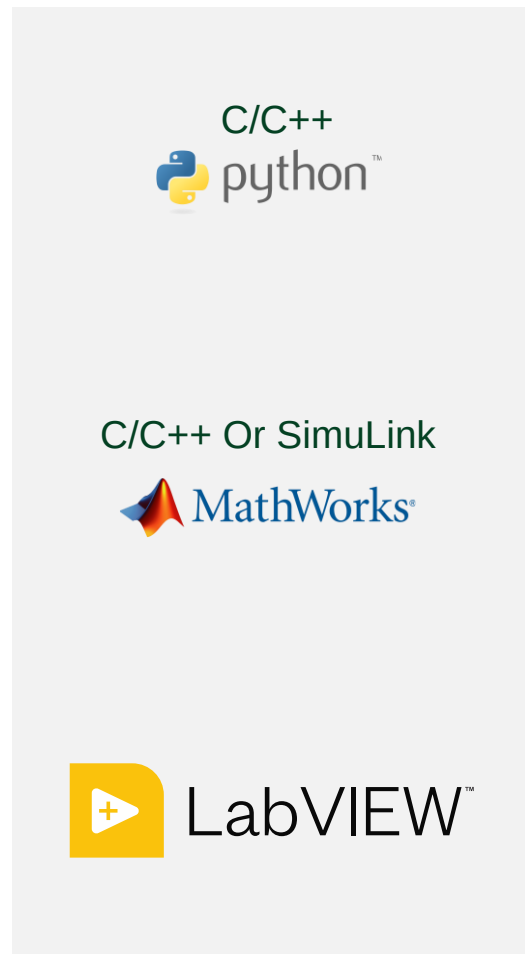
Massive MIMO gets a boost from National Instruments

World's Most Powerful Emulator of Radio-Signal Traffic Opens for Business

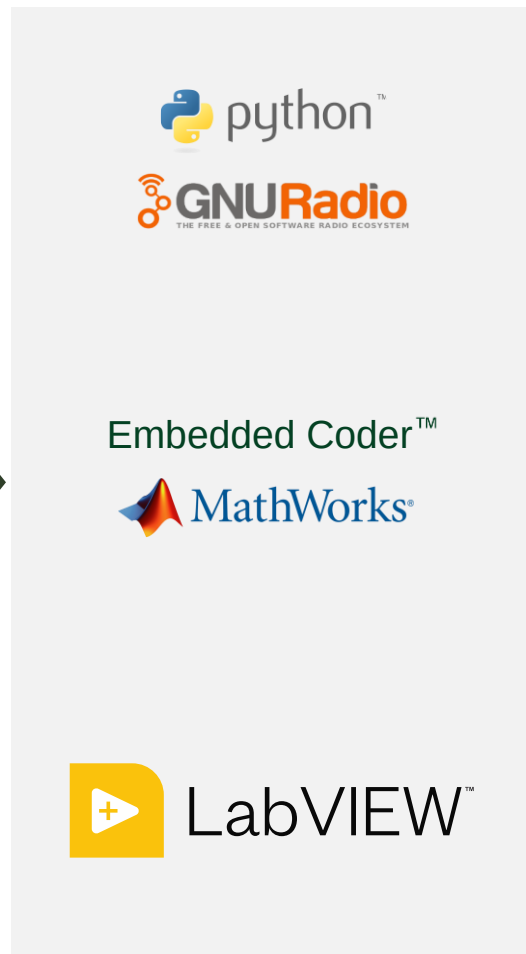
-DARPA

Support for Many Software Design Flows

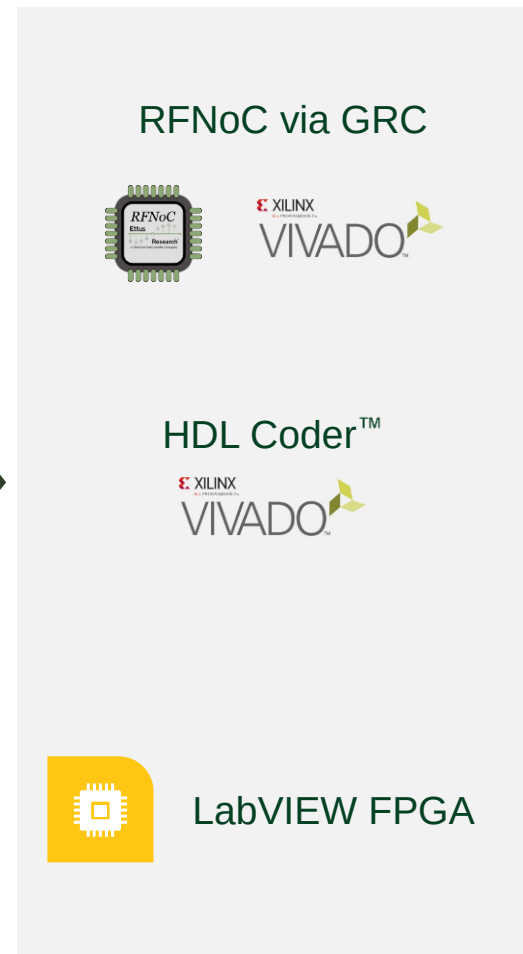
System Model



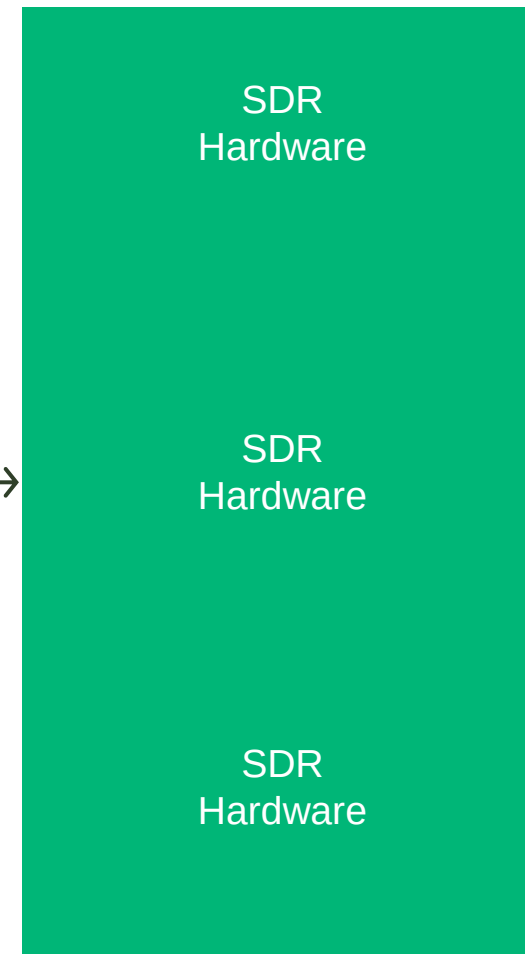
GPP Design



FPGA Design



Deploy



Which Software tool is right for you ?

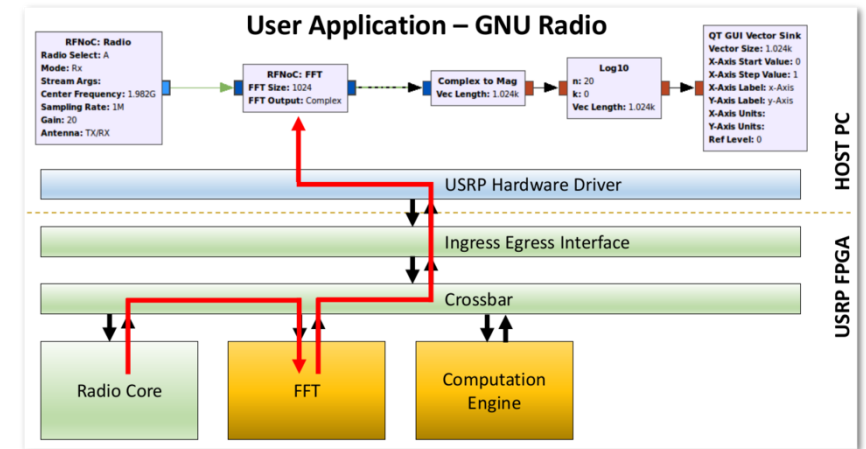
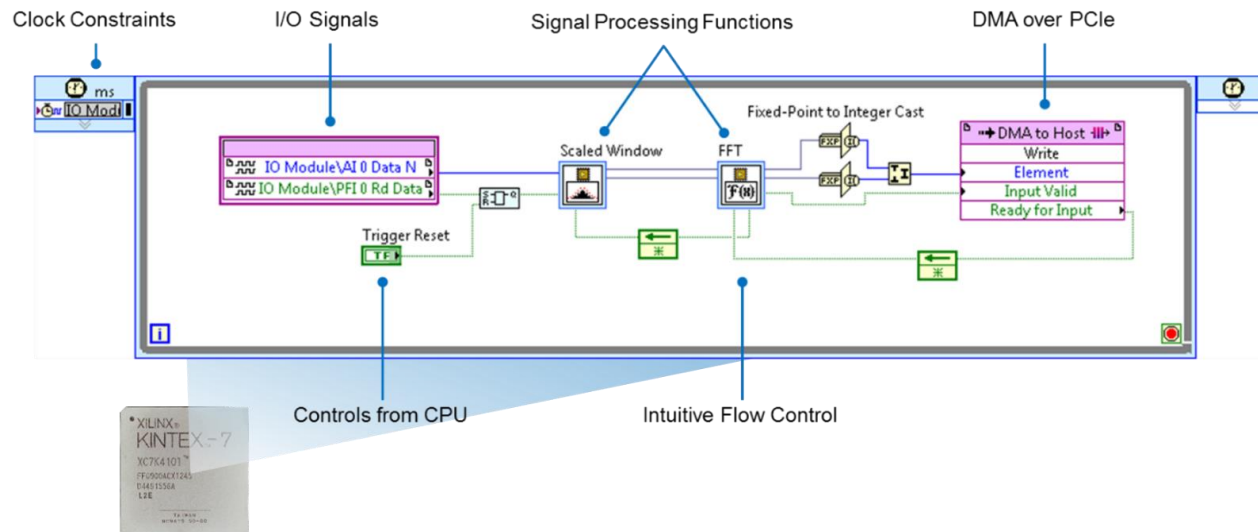
		
Operating System	Mature Windows Support Little Linux Support	Immature Windows Support Mature Linux Support
Licensing	Paid model, often have enterprise License from Test Engineering.	Free and Open Source
Programming Skills	Simpler Getting Started Graphical Programming New To Many SDR Developers	Familiarity Several Tool Chains (C/C++, VHDL, Python...)



SDR FPGA Programming Options

FPGA Software Abstraction Technology

Latest FPGAs Programmed with LabVIEW or Open Source Tools (RFNoC)



Kintex-7

Virtex-7

Kintex
Ultrascale



User Application – GNU Radio

RFNoC: Radio
Radio Select: A
Mode: Rx
Stream Args:
Center Frequency: 1.982G
Sampling Rate: 1M
Gains: 20
Antenna: TX/RX

RFNoC: FFT
FFT Size: 1024k
FFT Outputs: Complex

Complex to Mag
Vec Length: 1.024k

Log10
m: 20
k: 0
Vec Length: 1.024k

QT GUI Vector Sink
Vector Size: 1.024k
X-Axis Start Value: 0
X-Axis Step Value: 1
X-Axis Label: x-Axis
Y-Axis Label: y-Axis
X-Axis Units:
Y-Axis Units:
Ref Level: 0

USRP Hardware Driver

Ingress Egress Interface

Crossbar

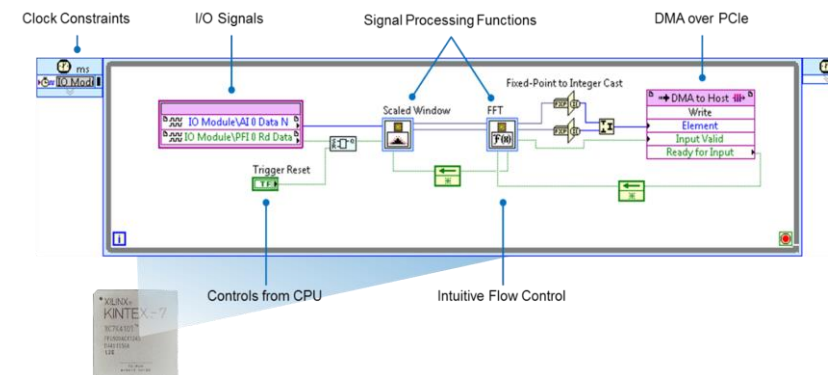
Radio Core

FFT

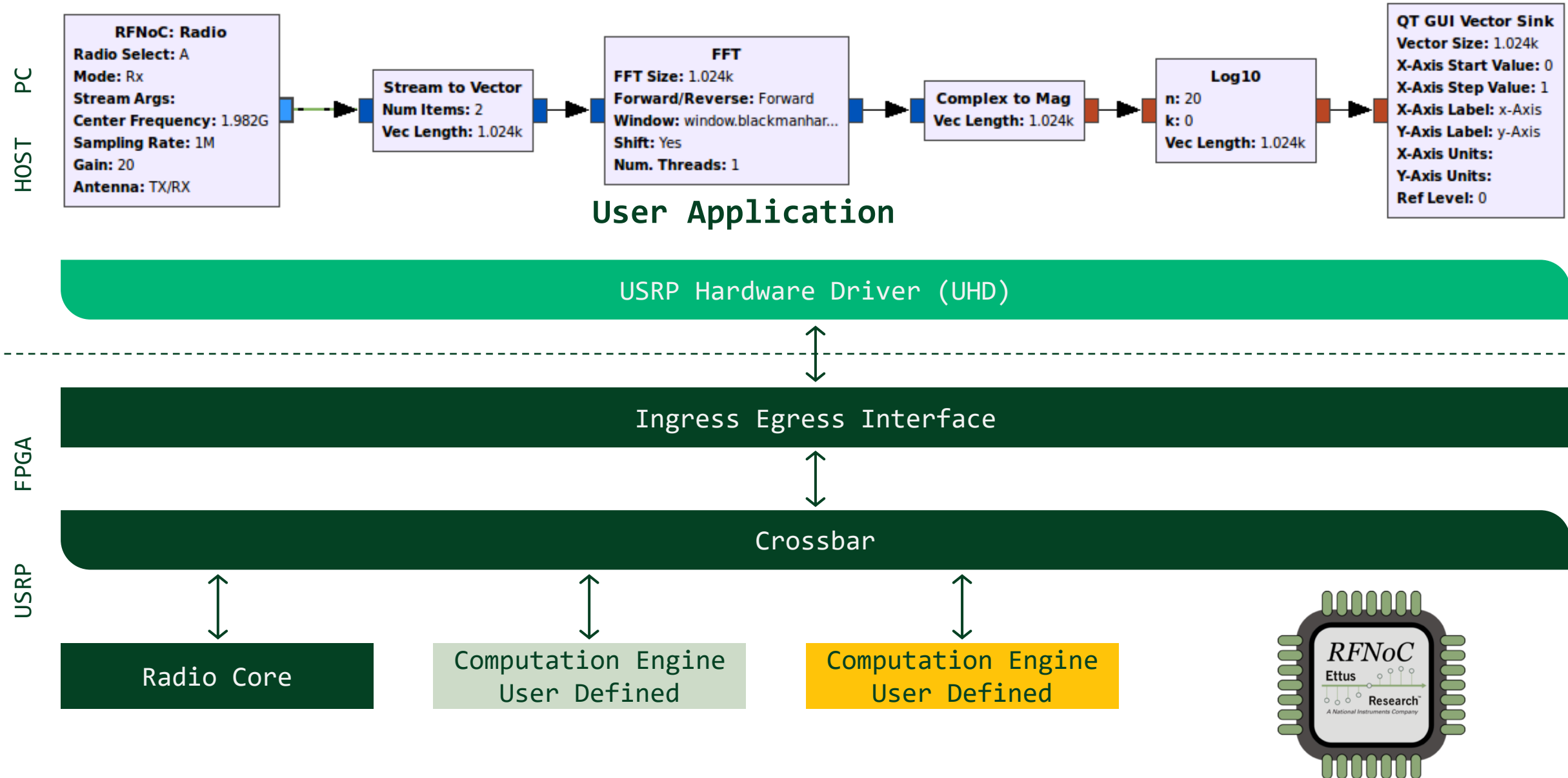
Computation Engine

HOST PC

USRP FPGA



USRP - RF Network On Chip (RFNoC)



Sample of Available Blocks

- FIFO
- FFT
- FIR
- fosphor (real-time spectrum analyzer)
- Decimator (Keep 1 in N)
- Log Power Calculator
- Radio Interface
- Vector IIR (moving average)
- Window multiplier (for FFT)
- OFDM: Burst detection + synchronization, equalizer, packet demodulator
- and [more...](#)

Best for Radar/EW Research, Design, and Prototyping

NI Ettus USRP X440

NI Ettus USRP X440 Overview

Key IF Capabilities

- Frequency Range: 30 MHz - 4 GHz*
- Signal Bandwidth: up to 1.6 GHz* / channel
3.2 GHz in aggregate
- Channels: 8 Rx - 8 Tx (or 8 TRx)
- Max Power: Tx Output: < 0 dBm full scale
Rx Input: 10 dBm full scale

Digital Capabilities

- FPGA Technology: Xilinx Zynq UltraScale+ RFSoc
- Interface Options: Dual 100/10/1 GbE via QFSP28
- Software Support: GNU Radio, UHD, C++, Python, RFNoC
- Synchronization: Onboard GPSDO, 10 MHz / PPS

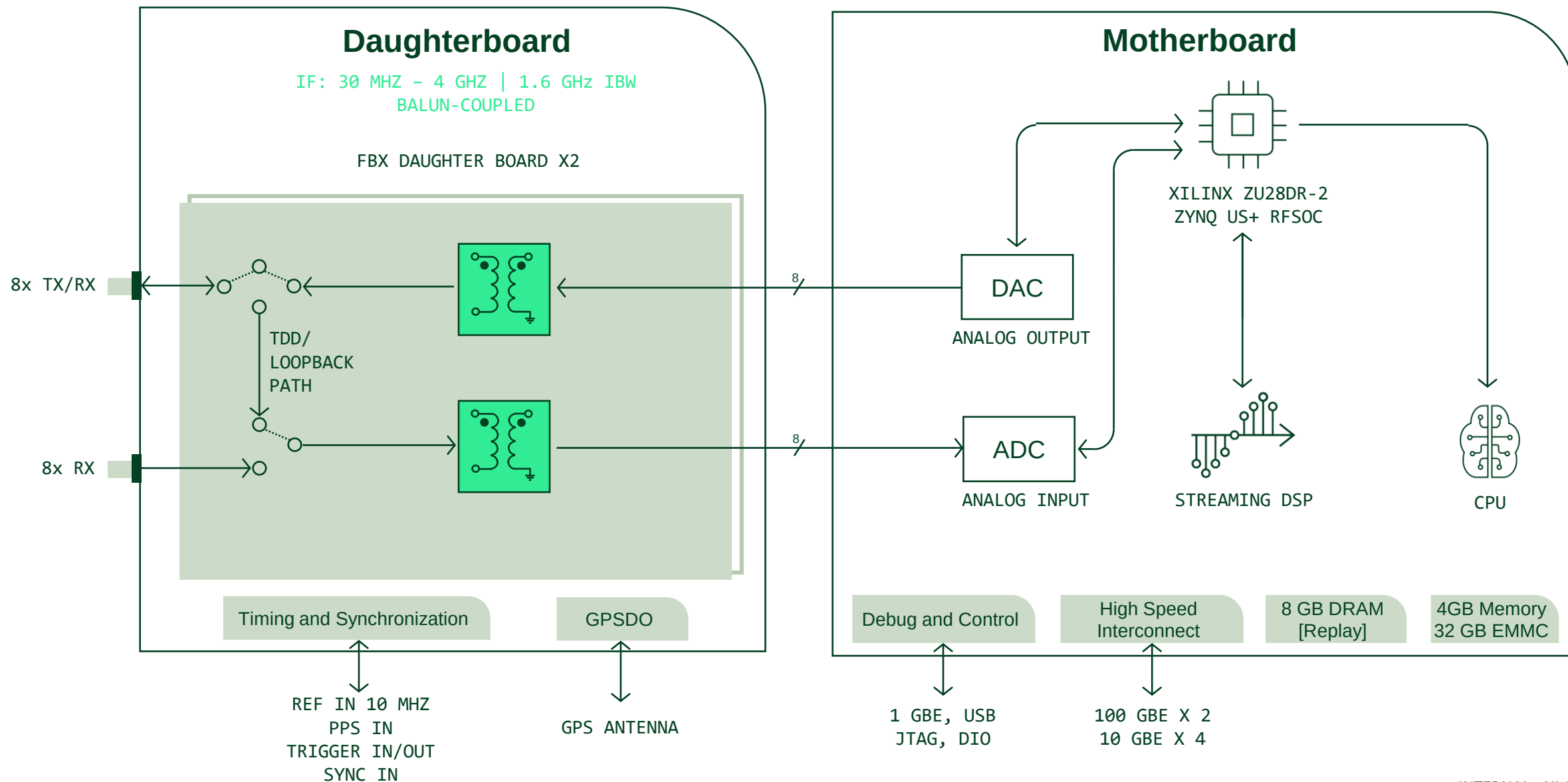
Key Applications

- Radar and EW Research and Prototyping
- SIGINT and Direction Finding
- SATCOM Ground Stations
- mmWave or sub-THz 6G Wireless Research

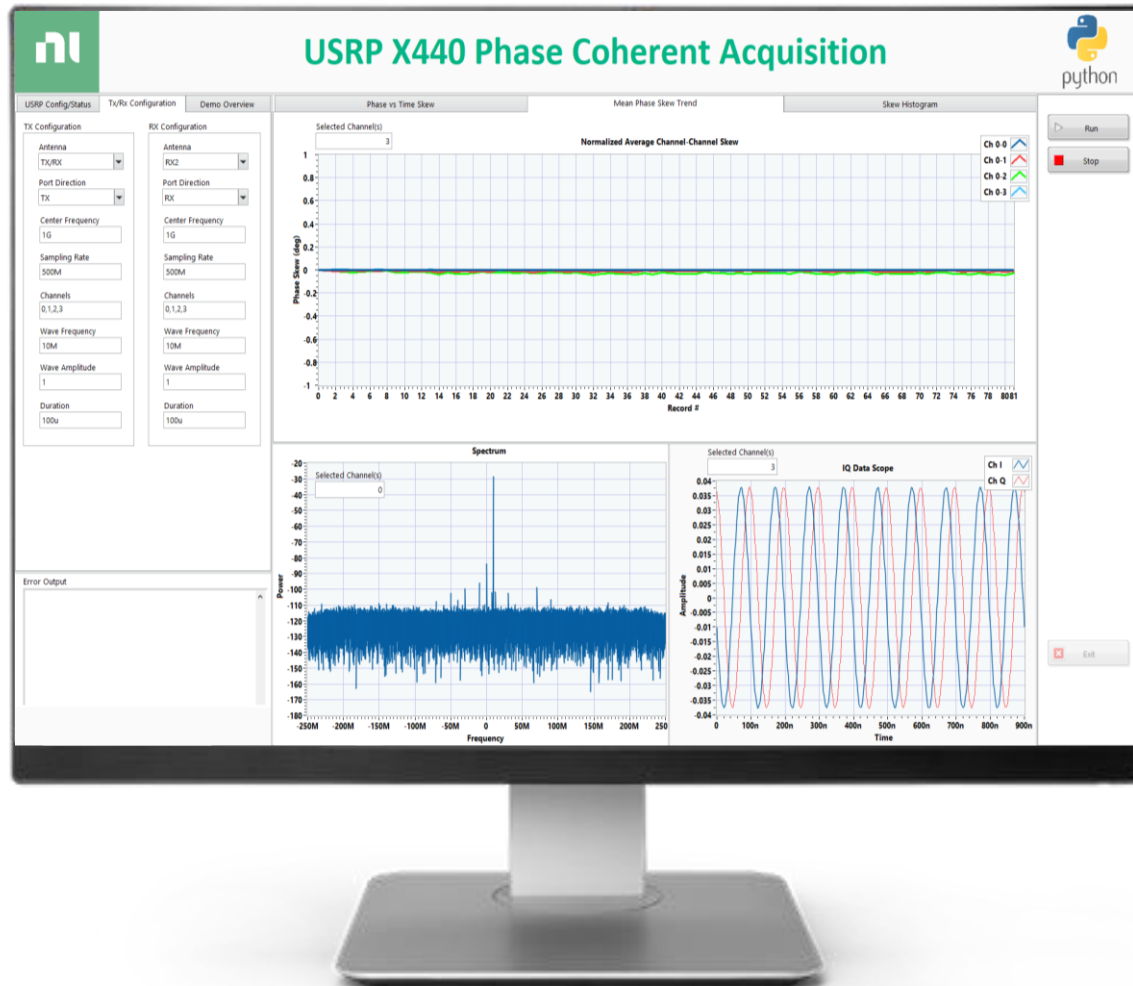
* IF-Bandwidth combination limitations apply due to Nyquist zones and gaps



NI Ettus USRP X440 High Level Block Diagram



NI Ettus USRP X440 | Phase Coherent on Eight Channels



Hardware Specifications of the USRP X440:

- Phase coherency is sample-based
 - Phase Stability (within device): $< 1^\circ$ RMS
 - Phase Repeatability (within device): $< 3^\circ$ Pk-Pk
 - Phase Stability (device-to-device): $< 2^\circ$ RMS
- TX Output Level: < 0 dBm full scale
- RX Output Level: 10 dBm full scale

Benefits of a phase coherent USRP:

- Easier to synchronize and phase-align multiple channels for MIMO systems and beamforming applications
- Enable accurate phase measurements, Doppler shift calculations, and precise direction determination in radar and direction-finding systems

Best for Wireless Communications Research, Design, and Prototyping

NI Ettus USRP X410

NI Ettus USRP X410 Overview

- Key RF Capabilities

- Frequency Range: 1 MHz - 7.2 GHz
- Signal Bandwidth: 400MHz
- Channels: 4 Rx - 4 Tx
- Max Power: Tx up to 22 dBm¹ - Rx 0 dBm

- Digital Capabilities

- FPGA Technology: Zynq Ultrascale+ RFSOC
- Interface Options: Dual QSFP28, PCIe Gen 3 x8
- Onboard IP: SD-FEC, DDC, DUC
- Software Support: GNURadio, LabVIEW
- Synchronization: Onboard GPS DO



Key Applications

- 5G / 6G Prototyping
- Signals Intelligence
- Wireless Communication
- Communications EW
- Software Defined Radio



Product Features

RF Capabilities

1 MHz – 8 GHz

FREQUENCY RANGE

400 MHz

SIGNAL BANDWIDTH

4X

TX/RX CHANNELS

23 dBm

MAX TX POWER

Digital Capabilities

ZYNQ ULTRASCALE+ RFSOC

FPGA TECHNOLOGY

SD-FEC,
DDC, DUC

ONBOARD IP

QSFP28 X2
PCIe Gen 3 X8

INTERFACE OPTIONS

NEXT GENERATION USRP SOFTWARE DEFINED RADIO PLATFORM

NI Ettus USRP X410



Smallest Size, Weight, Power, and Cost

B Series USRP

NI USRP-290X B-Series Overview

NI USRP-2900 / Ettus USRP B200 Specs

- Frequency Range: 70 MHz - 6 GHz
- Signal Bandwidth: Up to 56 MHz RF Bandwidth
- Channels: 1 Tx – 1 Rx Half or Full Duplex
- FPGA Technology: Xilinx Spartan 6 XC6LX75
- Connectivity: USB 3.0 Interface, Bus Powered

NI USRP-2901 / Ettus USRP B210 Specs

- Frequency Range: 70 MHz - 6 GHz
- Signal Bandwidth: Up to 30.72 MHz RF Bandwidth in 2x2
- Channels: 2 Tx – 2 Rx Half or Full Duplex
- FPGA Technology: Xilinx Spartan 6 XC6LX150
- Connectivity: USB 3.0 Interface, Externally Powered
- Maximum Power: Tx Output: 20 dBm
Rx Input: -15 dBm

Key Applications

- FM, TV Broadcast
- Signals Intelligence
- Wireless Communications RDP

Software Support

- LabVIEW and NI-USRP Driver
- GNU Radio and UHD



TwinRX Daughterboard for X300/310 USRP

- Daughterboard for X300/X310
- In a single X300 or X310 you can accommodate 2 TwinRX modules, giving 4 channels of phase coherent measurements for DF.
- The TwinRx is Ettus' first Superheterodyne design with residual spurious performance better than -80 dBm.

Target Applications:

- Direction Finding
 - TDOA/FDOA/FOA
- Spectrum Monitoring
- SIGINT/COMINT



NI-USRP & ER-USRP Product Mapping

NI-USRP	ER-USRP	NI-USRP	ER-USRP
USRP-2940	X310 + WBX (x2)	USRP-2950	X310 + WBX (x2) + GPSDO
USRP-2942	X310 + SBX (x2)	USRP-2952	X310 + SBX (x2) + GPSDO
USRP-2943	X310 + CBX (x2)	USRP-2953	X310 + CBX (x2) + GPSDO
USRP-2944	X310 + UBX (x2)	USRP-2954	X310 + UBX (x2) + GPSDO
USRP-2945	X310 + TwinRX (x2)	USRP-2955	X310 + TwinRX (x2) + GPSDO

Mapping Between ER-USRP and NI-USRP Product Numbers

https://kb.ettus.com/Mapping_Between_ER-USRP_and_NI-USRP_Product_Numbers

Selecting a RF Daughterboard

https://kb.ettus.com/Selecting_a_RF_Daughterboard

USRP N320 / N321

Common:

3 MHz – 6 GHz range

200-MHz BW per channel

2X2 MIMO

200/245.76/250-MHz sample rates

Preselection filters

Dual SFP+ ports (1 GbE, 10 GbE, Aurora)

QSFP+, RJ45

GPSDO

Ethernet-based sync (White Rabbit)

Stand-alone operation

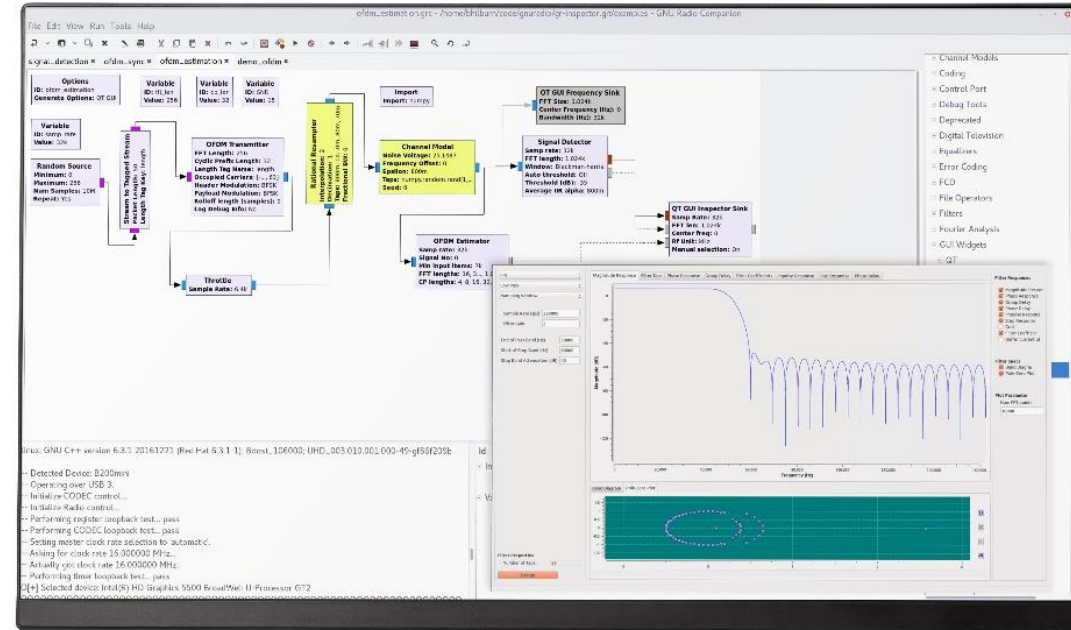
N320:

Zynq XC7Z100-2FFG900I

External LO input ports

N321:

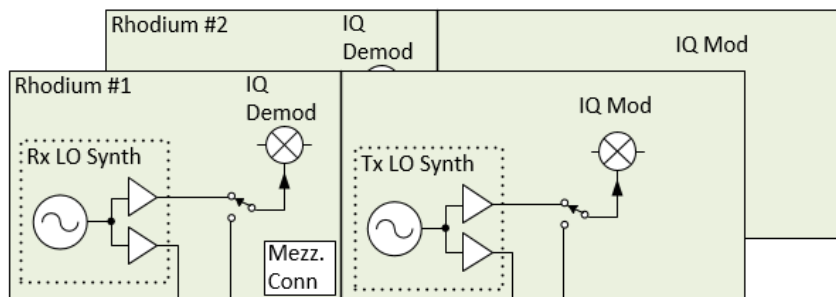
LO Distribution for up to 128x128 MIMO



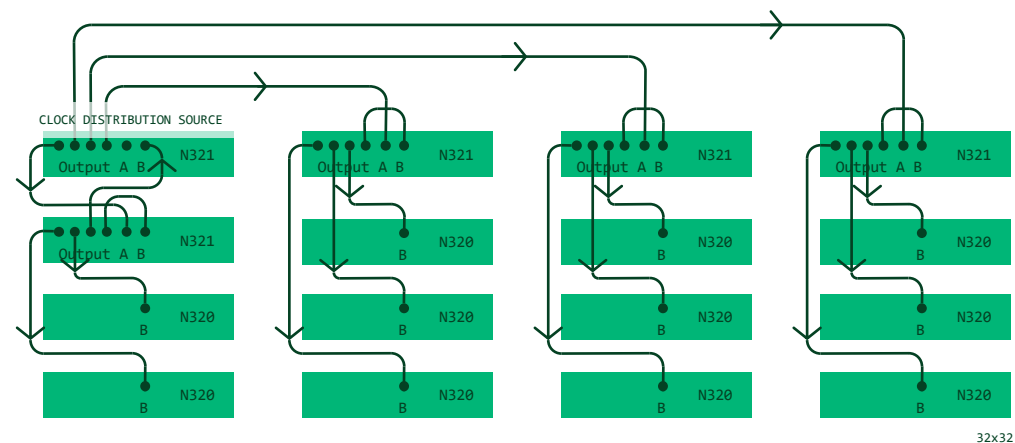
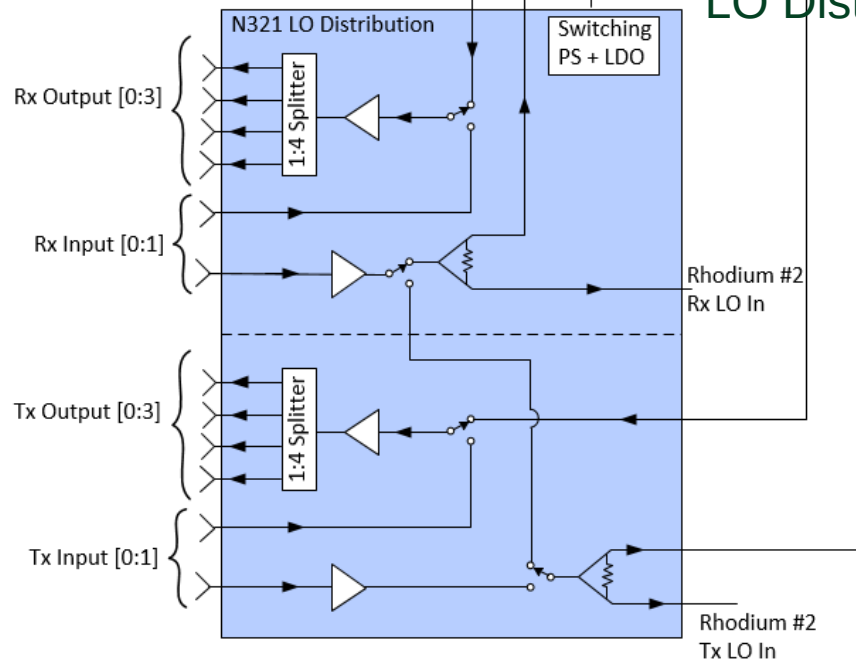
LO Distribution CCA Inside The N321

Star LO Distribution

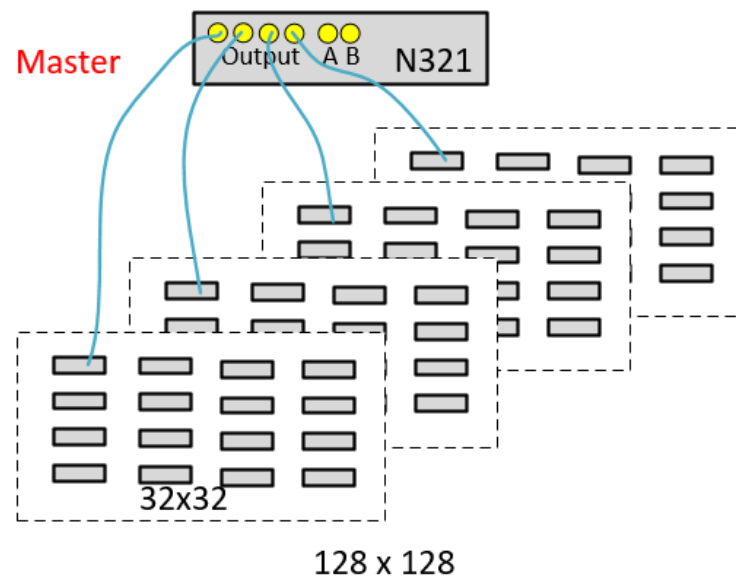
Support up to 128x128 MIMO



LO Distribution CCA Inside The N321

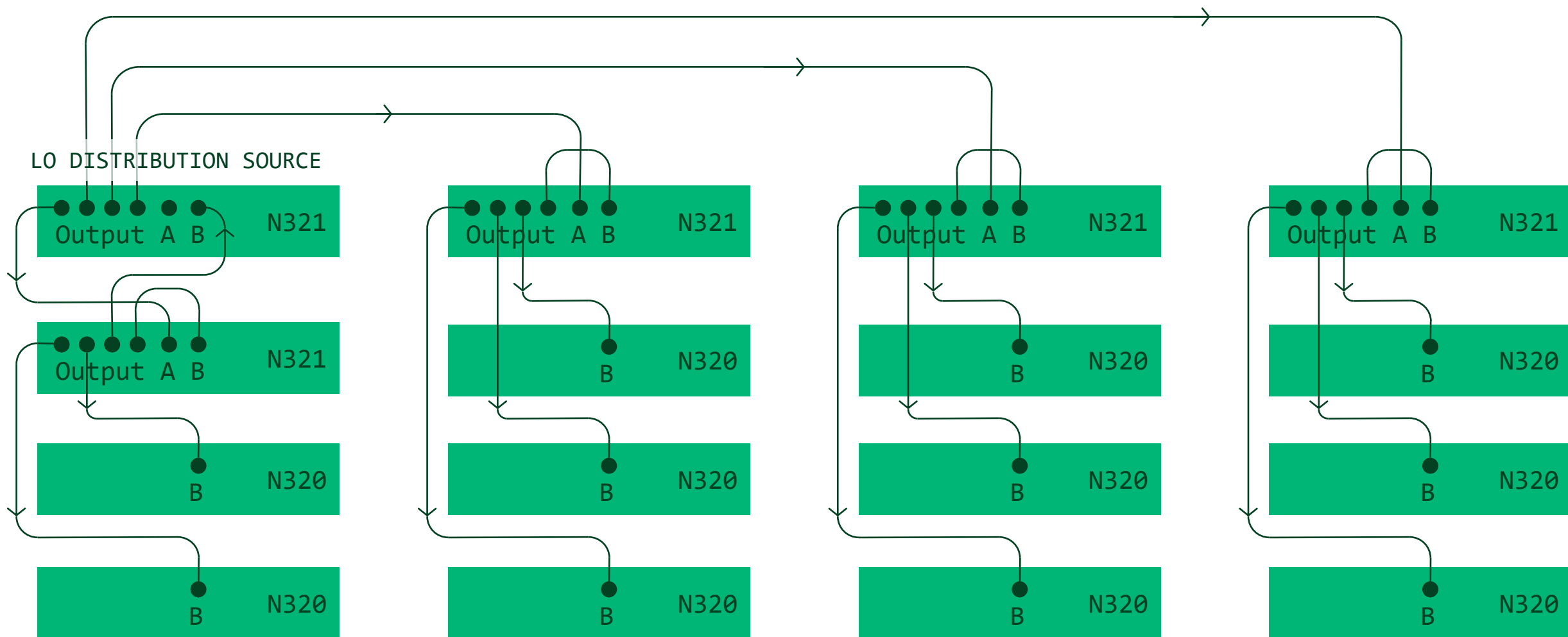


32x32



128 x 128

USRP N320/N321 LO Distribution



32x32

NI USRP N310/N300

Stand-Alone USRP Optimized for Remote Deployments



Fault
Recovery



Security



Distributed
Timing

Features

- High channel density: 4x4 MIMO in half wide RU form factor
- 10 MHz – 6 GHz frequency range
- 100 MHz of instantaneous BW per channel
- Zynq 7100/7035 user-programmable FPGA
- Dual-Core ARM Cortex-A9 processor
- 2 SFP+ ports (1 GbE, 10 GbE, Aurora)
- Ethernet sync with White Rabbit
- Self reset – watchdog timer



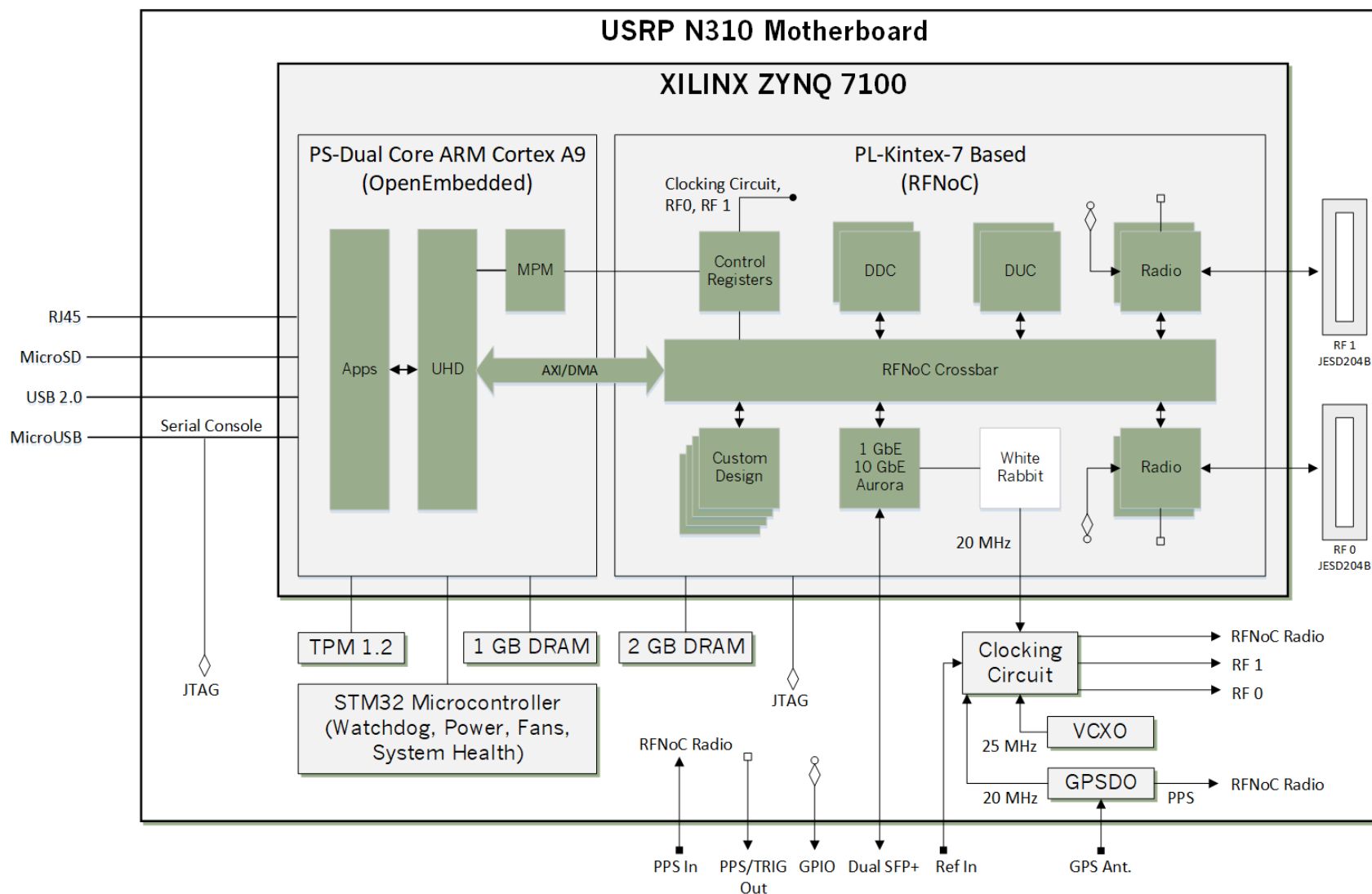
Benefits

- Stand-alone operation
- Ideal for distributed and large-scale deployments with features focused on reliability & remote management

Applications

- Wireless testbeds
- Remote radio heads
- Comms system prototyping
- Spectrum monitoring
- Record/Playback
- Spectrum sharing (e.g. CBRs)

USRP N310 Motherboard



Centralized Remote Management

Open source software development (no LV support)

Single host application remotely manages entire

Manage radios while streaming/processing data

Remote firmware & OS updates

Remote host PC and ARM application debugging

Remote reboot

Remote factory reset

Remote system health monitoring

Self corrections for IQ imbalance and DC offset



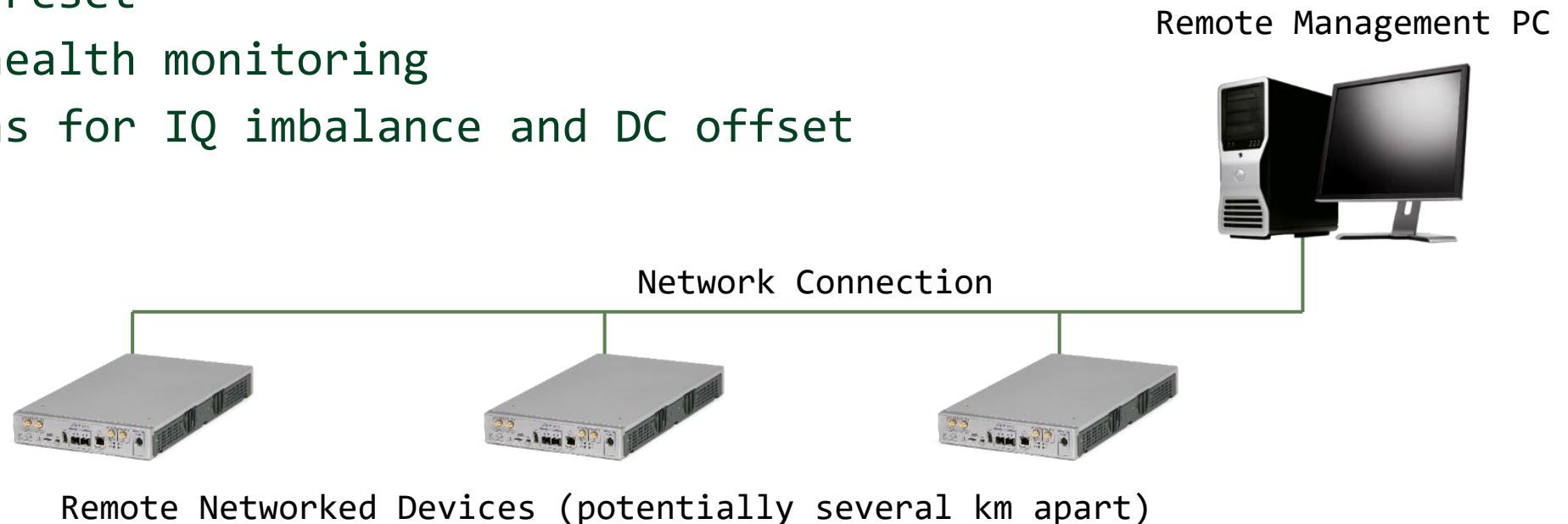
Central
Management



Remote
Administration



System
Diagnostics



USRP-2974 – Stand-Alone USRP-RIO

High performance SDR for compute intensive applications

Features at a Glance

10 MHz – 6 GHz frequency range

160 MHz instantaneous bandwidth per channel

Intel i7 processor with 8GB of RAM

Kintex-7 410T FPGA

GPS Disciplined Clock

2X2 MIMO

Hardware control over 1G/10G Ethernet

PCIe expansion port to connect to additional USRP RIO

2U Form Factor

LabVIEW Communications System Design Suite and 802.11 and LTE Application Frameworks support for programming Real-Time and FPGA

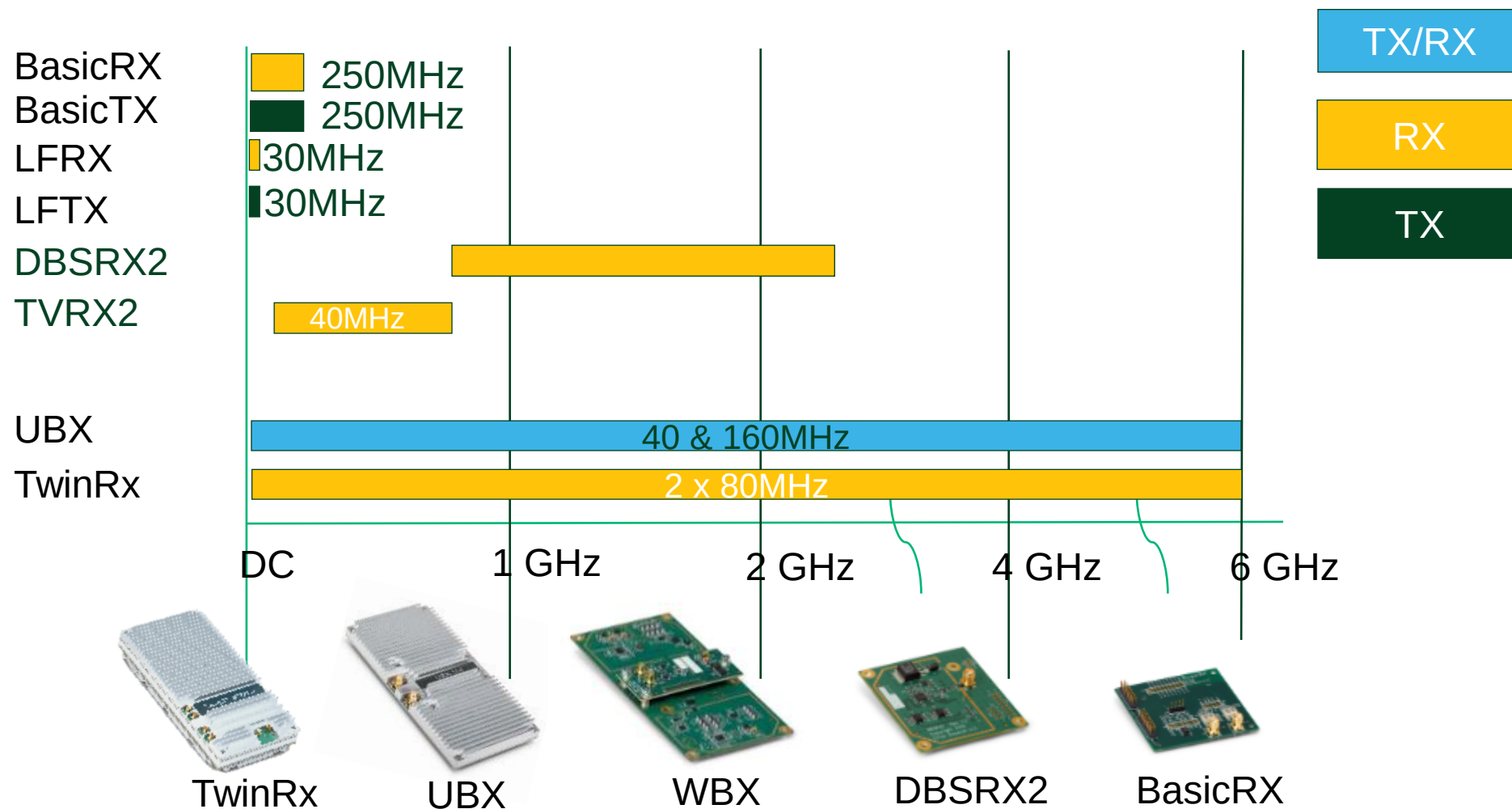
UHD Support (GNURadio, C++/Python, MathWorks)



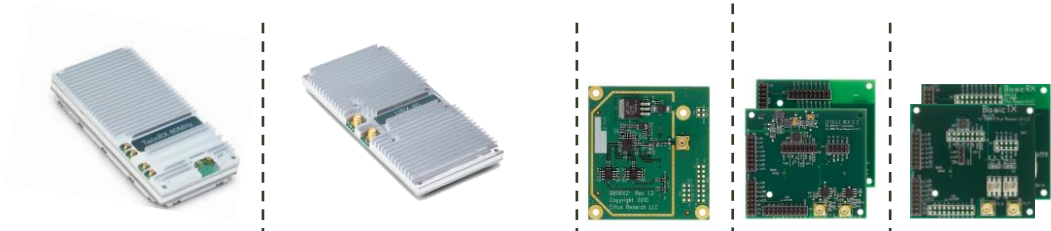
Applications

- Algorithm Engineering
- MAC/PHY Prototyping
- Stand-Alone SDR Applications
- LTE, WiFi, and MIMO Research
- UE Emulation

Daughterboard Frequency Range



USRP Daughterboard Compatibility Matrix



	# Daughter board	USRP Model	TwinRx*	UBX 160MHz	UBX 40MHz	DBSRX2	LFRX & LFTX	Basic TX / RX
		Freq Range	10MHz to 6GHz	10MHz to 6GHz	10MHz to 6GHz	800MHz to 2.3GHz	DC to 30MHz	1MHz to 250MHz
		TX / RX	2x Rx	1x Rx 1x Tx	1x Rx 1x Tx	1x Rx	1x RxIQ 1x TxIQ	1x RxIQ 1x TxIQ
	2	X300 X310	✓	✓	✓	✗	✓	✓
	1	N200 N210	✗	✗	✓	✓	✓	✓

B-Series, E-Series & N310, N320, N321 USRPs- do not have user configurable daughter boards.
Some x310 daughterboard configurations are disallowed based on software tool chain preference.

*TwinRx can only be combined with another TwinRx in the USRP-x310

** LabVIEW requires matching daughterboards per radio

Prototyping Platform Elements - USRP

Multiple Software Options



IP & Reference Designs

LTE	802.11	MIMO	mmWave
Key Features 20 MHz Real-Time Bandwidth - TDD/FDD Uplink & Downlink Modes - L1/L2 API Applications - LTE & Wi-Fi Coexistence - Cellular Network Layer Research - New Waveform Research	Key Features 20/40/80 MHz Real-Time Bandwidth - Fully Bidirectional Communication - Real-Time Channel Coding - MAC/PHY support Applications - LTE & Wi-Fi Coexistence 802.11ax Multi-User Prototyping	Key Features 20 MHz Real-Time Bandwidth - Supports up to 128 eNB Antennas and 12 Single Antenna UE's - TDD Uplink & Downlink Modes Based Upon LTE Applications - Massive MIMO - Multi-User MIMO Research	Key Features 2 GHz Real-Time Bandwidth - Supports 2x2 MIMO - Fully Bidirectional TDD Uplink & Downlink Modes Applications - Enhance Mobile Broadband Research - Ultra-Dense Cellular Research - Cellular Backhaul

Ready to Run FPGA IP Delivered in Source Code

* Lead User Availability *

Stand-Alone HW Form Factors



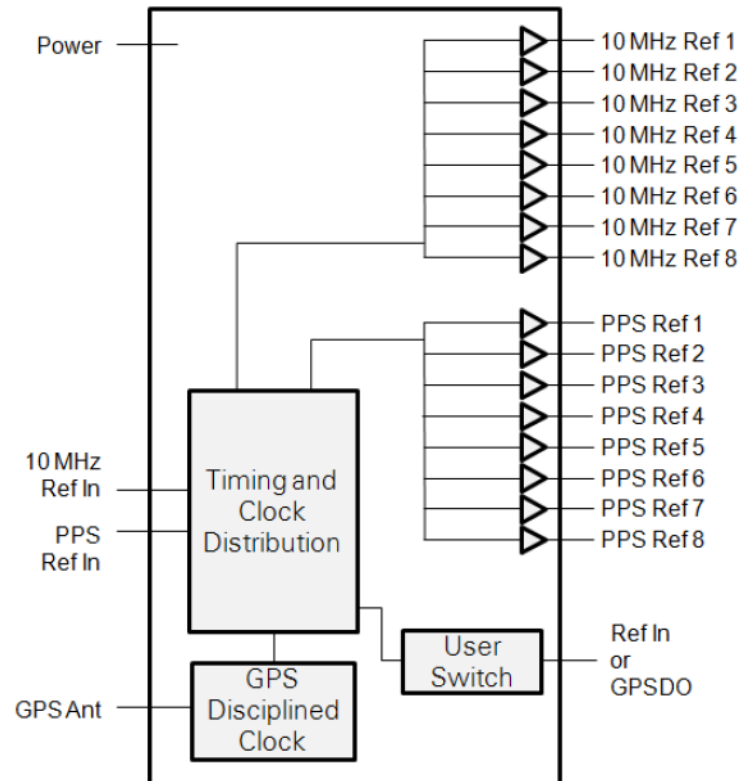
Timing/Synchronization & Control Accessories



Scalable to High-Channel Count Systems



OctoClock – 8 Channel Clock Synchronization



Applications

Time and frequency synchronization for large channel count systems

Features

8 Channel 10 MHz and PPS Distribution

Choose between Internal / External sources

Optional integrated GPS disciplined clock

Cabled PCI Express Switch Box - CPS-8910

- Easily connect USRP devices
- Either PCIe x8 or PCIe x4 uplink to host
- Supports up to 8 PCIe x4 downlinks for connecting external devices
- Software-transparent link, requires no programming
- Fits conveniently into a 1U rack





Thank you

SDR Case Studies

DRONE DEFENSE



“The NI - Ettus Research USRP X310 is the only commercially available SDR with the openness and raw RF and DSP capabilities to meet the needs of this rapidly evolving drone threat.”



—Scott Torborg, CTO,
SkySafe



DRONE DEFENSE



Defeating Commercial Drone Threats With Open-Source Software Defined Radio

CHALLENGE

Developing drone defense systems that rapidly evolve with ever-increasing threat frequency and sophistication.

SOLUTION

Rapidly prototyping and deploying with the NI USRP, to deliver industry-leading capability into the field faster and at a much lower cost to the government.





SPECTRUM COLLABORATION CHALLENGE

Channel
Emulation



COLOSSEUM



The World's Largest Channel Emulator Uses NI SDR

- 256 Channels
- 25.6 GHz Total Instantaneous Bandwidth
- 52.43 TB/s of digital RF Data
- Picture From the Finals of SC2 in LA
 - Winner = Team Gator Wings (University of Florida)

www.SpectrumCollaborationChallenge.com



- 128x NI USRP X310
- 16x NI ATCA-3671