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Intel Programmable Solutions Group

# 첨단 전자전을 위한 FPGA의 역할

Intel Korea

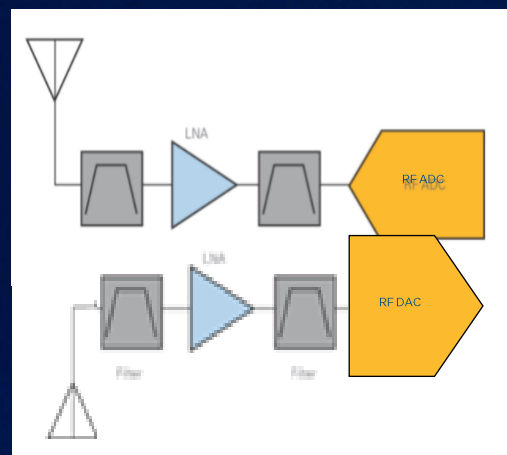
송영규 이사

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- AI를 이용한 FPGA 애플리케이션 강화
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- Intel® FPGA AI Suite 을 이용한 파형 분류 (Waveform Classification)
- 요약

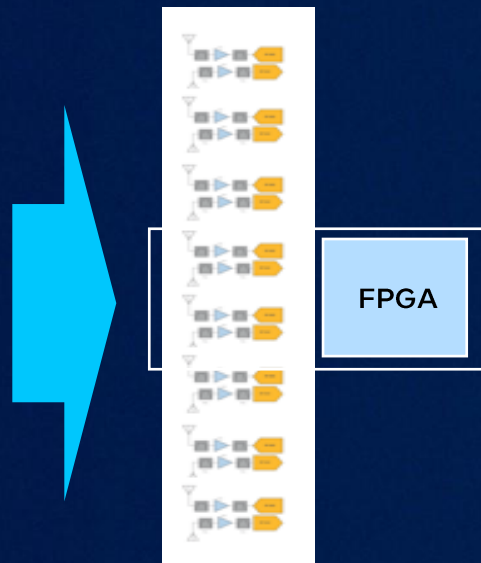
# Intel® FPGA 에 통합된 High Sample Rate ADC/DAC

- 최대 64 GSPS 의 Direct RF 아키텍처
- EMIB/AIB 패키징 기술
- SWaP-C



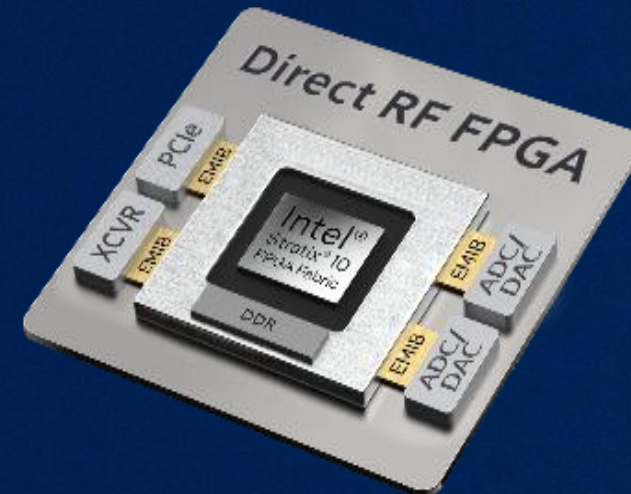
Direct RF architecture

8-Channel + FPGA



S10 AX

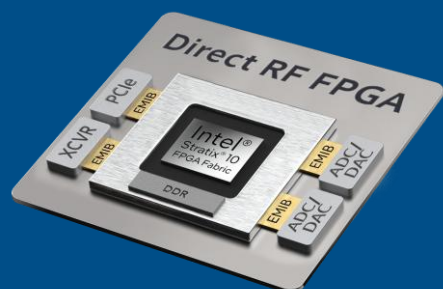
8-Channel S10 AX  
50x50mm, 64 GSPS





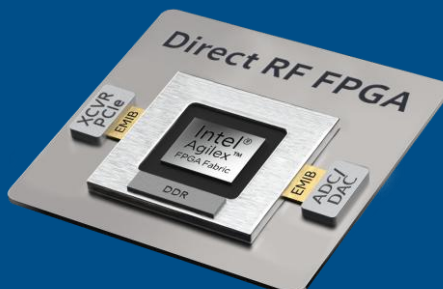
# Direct RF FPGA 제품군 – Intel Agilex® 9 시리즈

## 광대역 Direct RF FPGAs 64 GSPS ADCs, 64 GSPS DACs



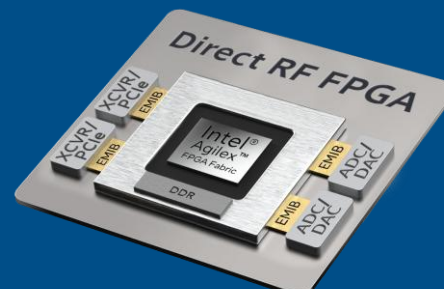
### 1SA28S

2.8 MLE FPGA  
8 ADCs, 8 DACs  
PRQ Now



### AGRW014

1.4 MLE FPGA  
4 ADCs, 4 DACs  
PRQ 3Q'23

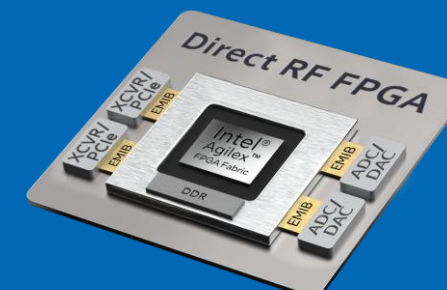


### AGRW027

2.7 MLE FPGA  
8 ADCs, 8 DACs  
PRQ 4Q'23

## 중간 대역 Direct RF FPGA

4 GSPS ADCs, 12 GSPS DACs



### AGRM027

2.7 MLE FPGA  
20 ADCs, 16 DACs  
PRQ 2Q'24

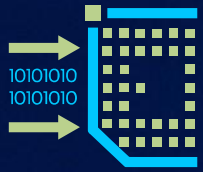
**Direct RF Series FPGAs Substantially Reduce Size, Weight and Power plus Cost (SWaP-C)**  
Direct RF 시리즈 FPGA는 크기, 무게, 전력 및 비용을 크게 줄일 수 있습니다.

# 인지 시스템 (Cognitive Systems)

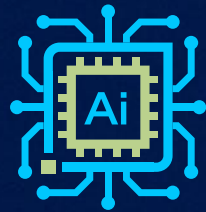
- 환경에 적응하는 지능형 감지 시스템
- 과거 환경을 활용하여 시스템 효율성 향상
- 사용 사례: 레이더, 전자전, 테스트 및 측정, 통신, 제어 등



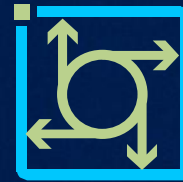
# • AI를 이용한 FPGA 애플리케이션 강화



재구성 가능한  
로직



AI 증강을 통한  
인라인 처리



I/O 유연성



지연 시간에 민감한  
애플리케이션을 위한  
실시간 실행



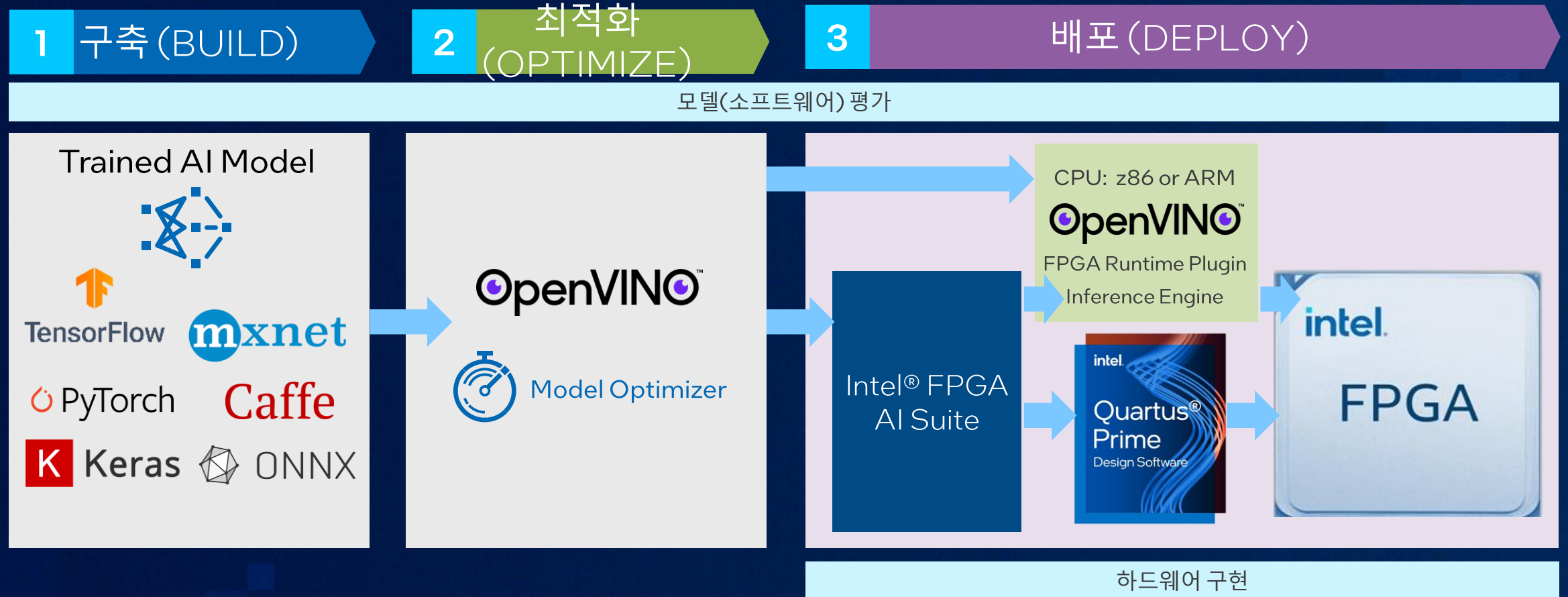
저전력

Intel® FPGA의 장점: 더 높은 효율의 AI를 위한 세분화된 FPGA 패브릭 유연성

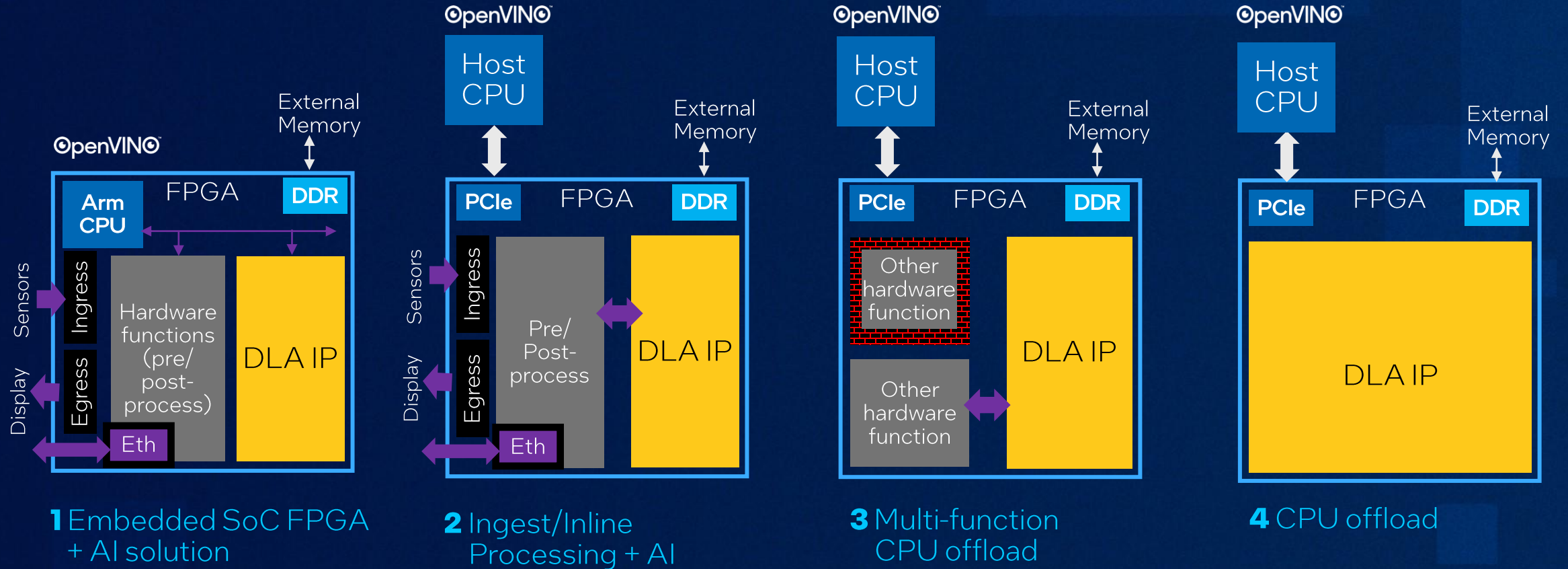


# Intel® FPGA AI Suite 을 이용한 맞춤형 솔루션

맞춤형 플랫폼을 위해 Intel® FPGA AI Suite 에 최적화된 AI IP 배포



# AI를 지원하는 FPGA 사용 사례

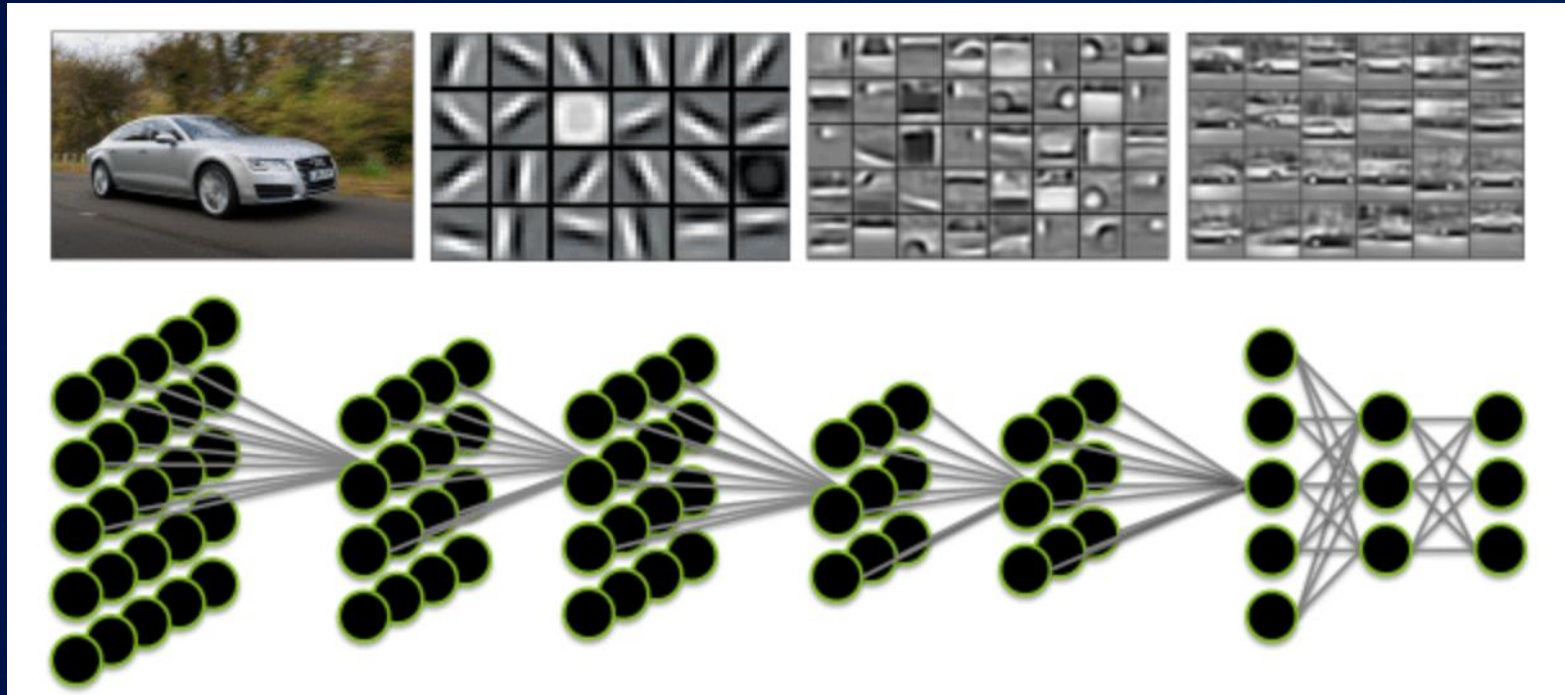


위의 예는 일반적인 예이며 Intel® FPGA AI Suite의 유연성을 설명하기 위한 것입니다. 애플리케이션은 소프트웨어 호스트 CPU(예: FPGA 패브릭의 RISC-V 기반 Nios® V 프로세서) 및/또는 HDMI와 같은 기타 인라인 스트리밍 소스를 활용할 수 있습니다.



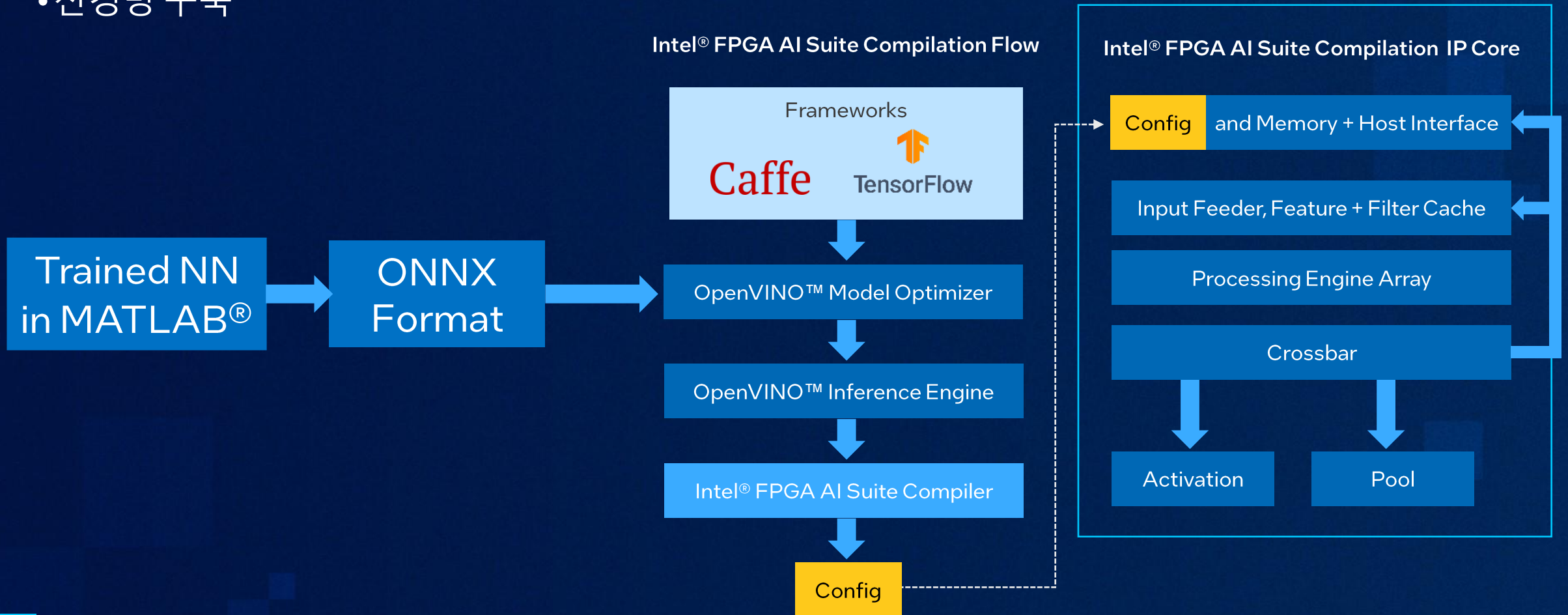
# 컨볼루션 신경망 (CNN; Convolutional Neural Network)

심층 신경망이 보는 방식



# EagleNet을 사용한 파형 분류 (Waveform Classification)

- 딥러닝을 이용한 파형 분류
- 신경망 구축



# EagleNet 트레이닝 (Training)

## 사용 Dataset

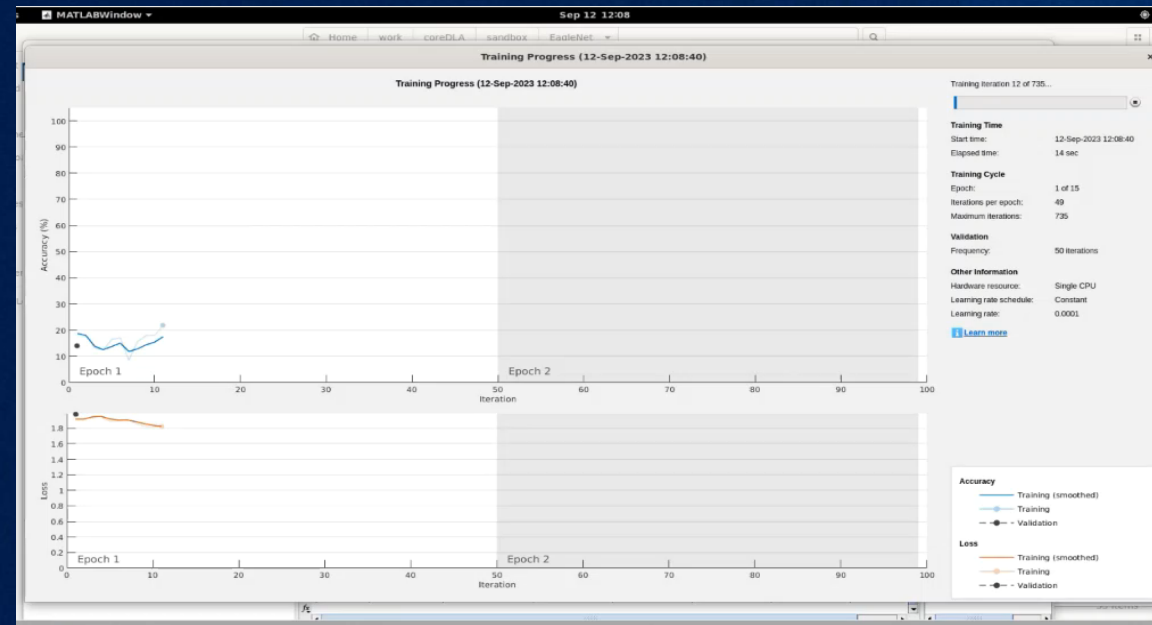
- Sample Rate 48 GSPS
- DDC x32 decimation mode
- NCOs: CNCO=3.75GHz, FNCO=0
- 캡처된 세그먼트의 크기: 4096 I/Q samples
- Waveform classes의 갯수: 7
  - AM, CW, FM, Noise, OFDM, QPSK, Ramp
- ADC 보정된 데이터

## 장비

- Signalhound VSG60A
- Intel® Stratix® 10 AX Development Kit

## 개발 도구

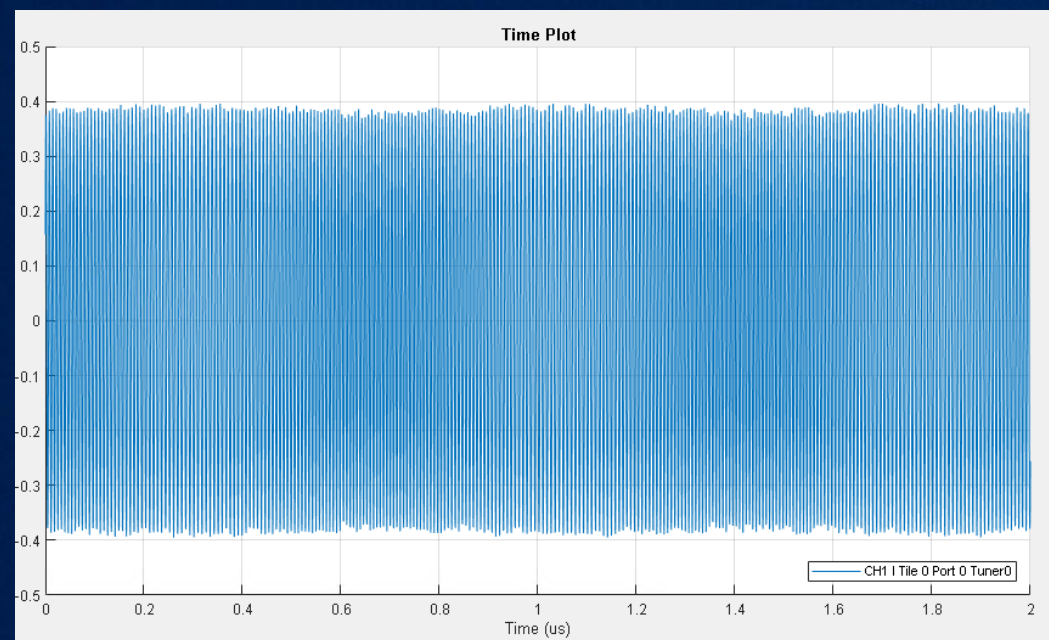
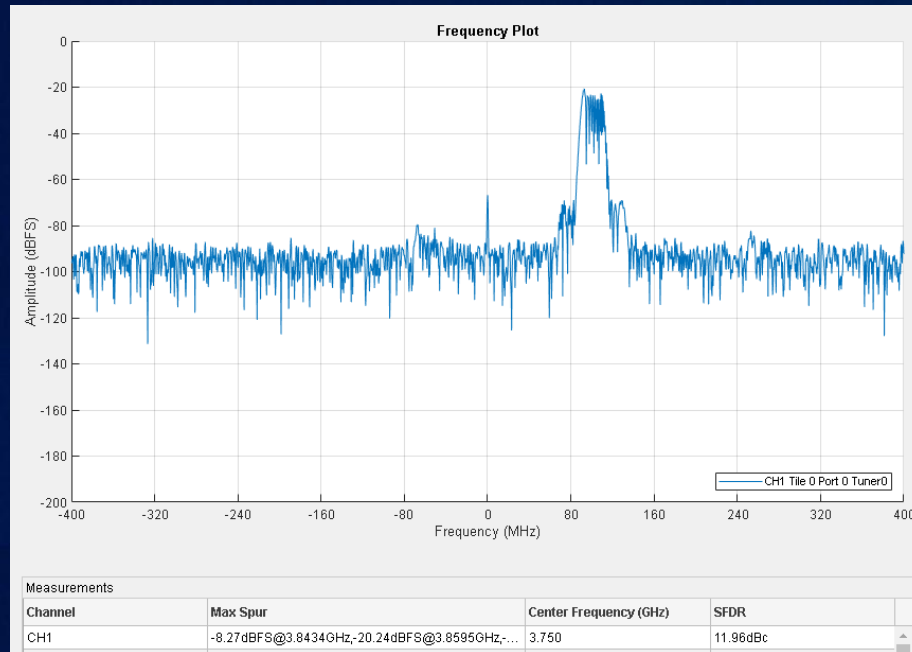
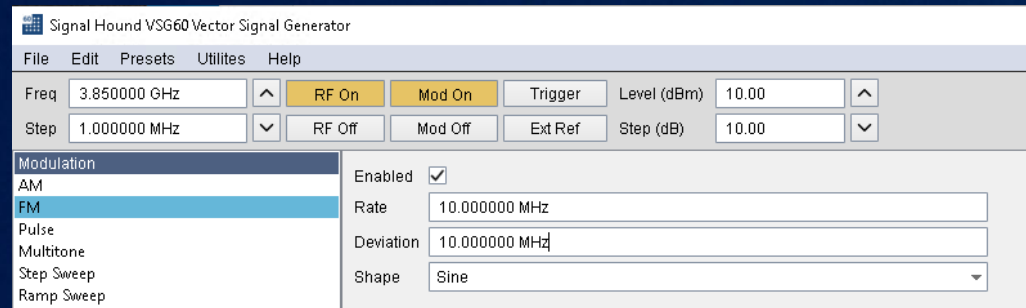
- MATLAB®
- Deep Learning Toolbox
- Parallel Computing Toolbox





# EagleNet을 사용한 파형 데이터 세트

## Example Class 2: FM Modulated signal



# EagleNet Network

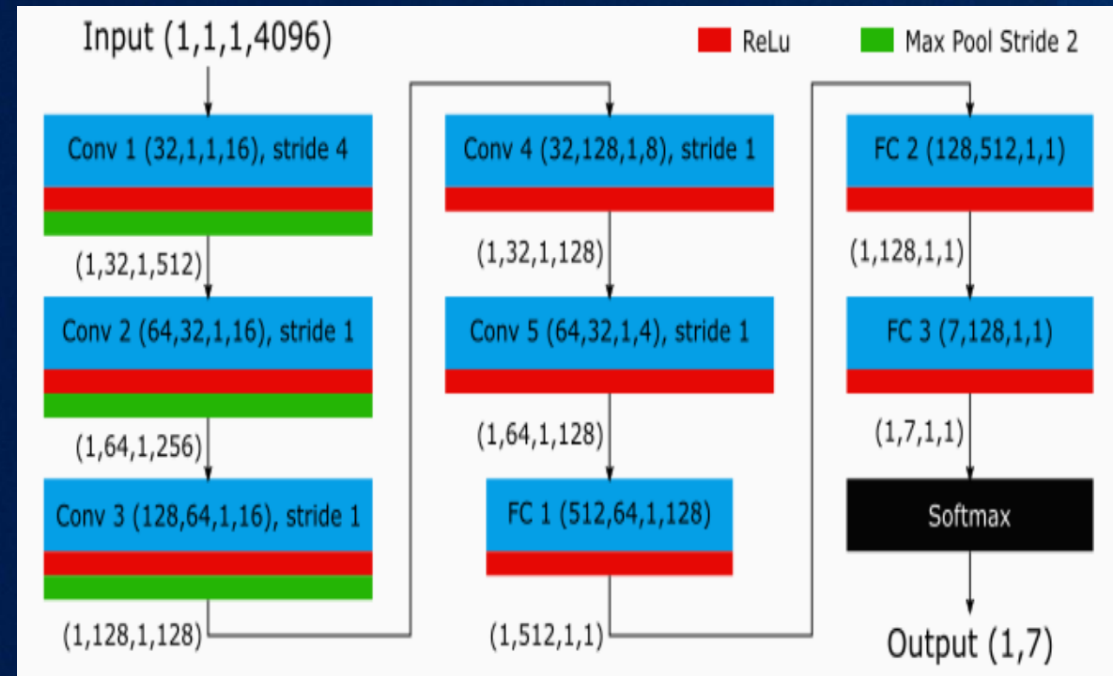
## 신경망 훈련 (Neural network training)

Deep Learning Network Analyzer

net

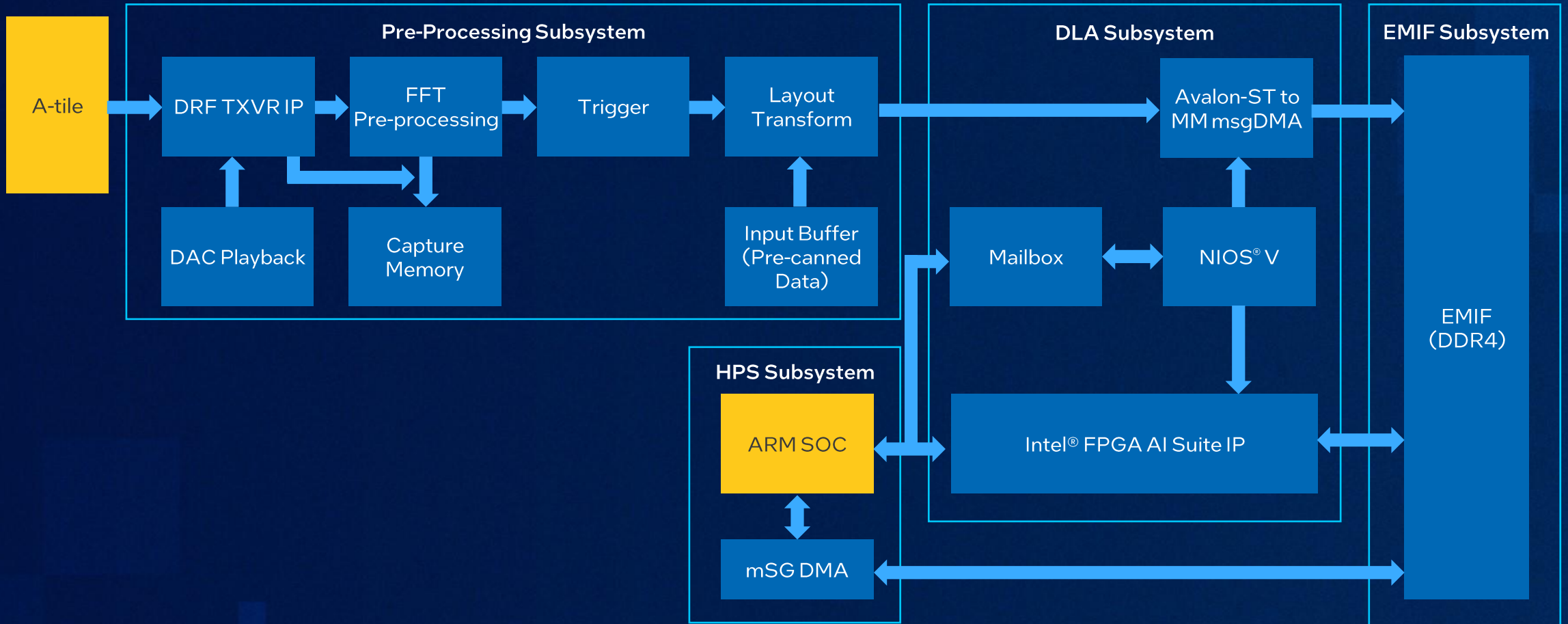
Analysis date: 03-Aug-2022 12:22:03

Name	Type	Activations	Learnables
1 data	Image Input	1+4096+1	-
2 conv1	Convolution	1+512+32	Weights 1+256+1+32 Bias 1+1+32
3 relu1	ReLU	1+512+32	-
4 maxpool1	Max Pooling	1+512+32	-
5 conv2	Convolution	1+512+64	Weights 1+128+32+64 Bias 1+1+64
6 relu2	ReLU	1+512+64	-
7 maxpool2	Max Pooling	1+512+64	-
8 conv3	Convolution	1+512+128	Weights 1+64+64+128 Bias 1+1+128
9 relu3	ReLU	1+512+128	-
10 conv4	Convolution	1+512+32	Weights 1+32+128+32 Bias 1+1+32
11 relu4	ReLU	1+512+32	-
12 conv5	Convolution	1+512+64	Weights 1+16+32+64 Bias 1+1+64
13 relu5	ReLU	1+512+64	-
14 maxpool4	Max Pooling	1+512+64	-
15 fc1	Fully Connected	1+1+512	Weights 512+32768 Bias 512+1
16 relu6	ReLU	1+1+512	-
17 fc2	Fully Connected	1+1+128	Weights 128+512 Bias 128+1
18 relu7	ReLU	1+1+128	-
19 fc3	Fully Connected	1+1+7	Weights 7+128 Bias 7+1
20 softmax	Softmax	1+1+7	-
21 classification	Classification Output	1+1+7	-



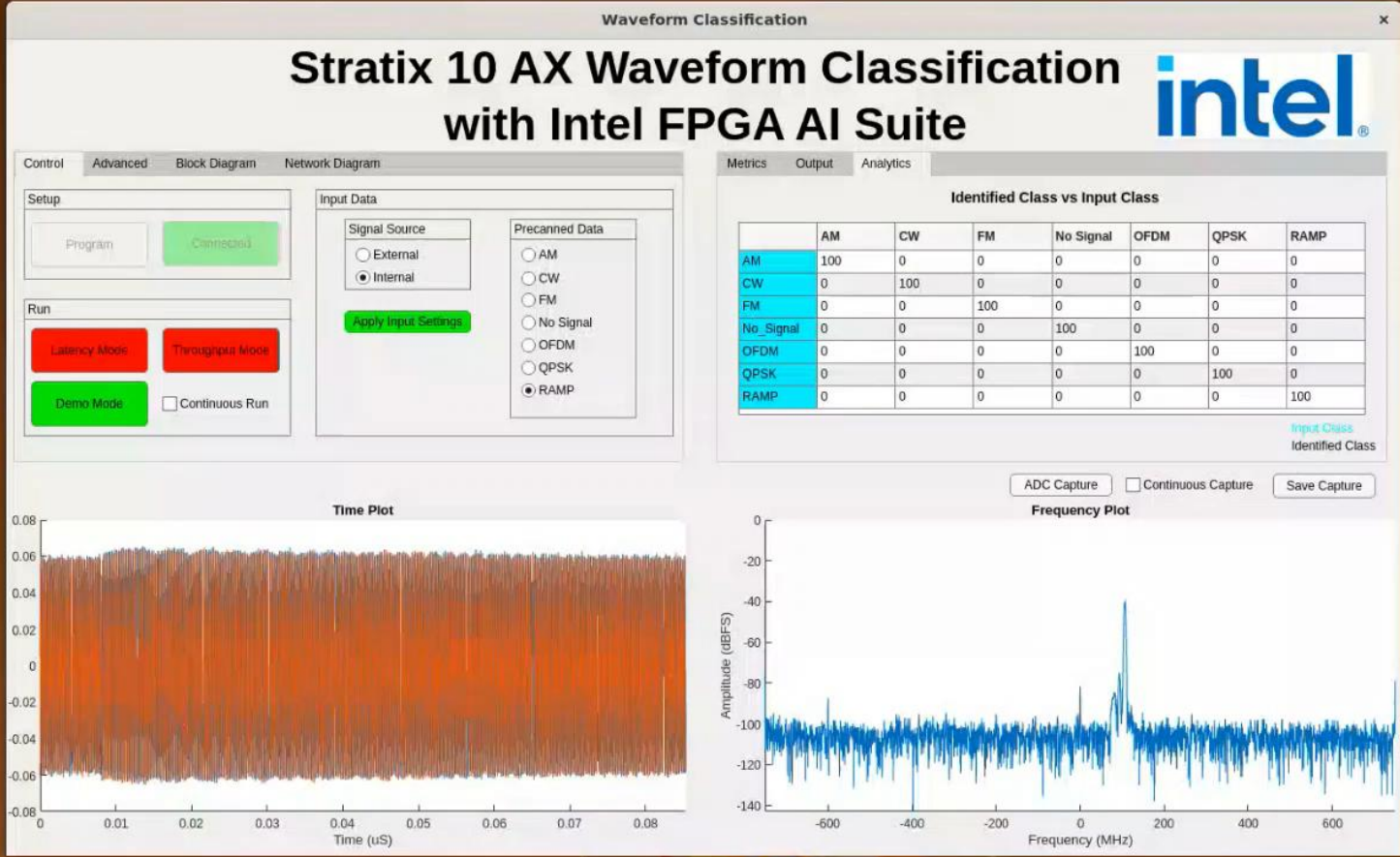
# 파형 분류 블록 다이어그램

단일 칩, 통합 및 확장 가능한 솔루션





# 파형 분류 시연



**Waveform Classification**

## Stratix 10 AX Waveform Classification with Intel FPGA AI Suite

Control | Advanced | Block Diagram | Network Diagram

Setup | Input Data | Metrics | Output | Analytics

Program | Connected

Latency Mode | Throughput Mode

Demo Mode | Continuous Run

Signal Source:  External,  Internal

Precanned Data:  AM,  CW,  FM,  No Signal,  OFDM,  QPSK,  RAMP

Apply Input Settings

	AM	CW	FM	No Signal	OFDM	QPSK	RAMP
AM	100	0	0	0	0	0	0
CW	0	100	0	0	0	0	0
FM	0	0	100	0	0	0	0
No_Signal	0	0	0	100	0	0	0
OFDM	0	0	0	0	100	0	0
QPSK	0	0	0	0	0	100	0
RAMP	0	0	0	0	0	0	100

ADC Capture | Continuous Capture | Save Capture

**Time Plot**

Time (uS)

**Frequency Plot**

Amplitude (dBFS)

Frequency (MHz)

실시간 스트리밍 데이터에 대한 인공지능 추론 (AI Inference)

# 파형 분류의 FPGA 리소스 사용량

	ALM	M20K	DSP Blocks
Pre-Processing Front-End	42,806	794	219
Intel® FPGA AI Suite	71,496	1,022	602
총 사용량	134,186 (14%)	1,879 (16%)	822 (14%)
Stratix® 10-AX 1SA28 의 사용 가능한 리소스	933,120	11,721	5,760

\* Notes/disclaimers:

- Quartus® Prime® Pro 22.4 Patch 0.01
- DSP Builder Advanced Blockset 22.4
- MATLAB® R2022a
- FPGA AI Design Suite 2023.2.1
- OpenVINO™ 2022.3.1 LTS Runtime

# 파형 분류 결과

Class	Frames Identified	Avg Confidence for Identified Frames
am	0	0
cw	0	0
fm	0	0
no_signal	0	0
ofdm	98	97.3563
qpsk	2	61.5234
ramp	0	0

Latency (mS/Frame)	Throughput (Frames/Second)
0.91976	613.497

Metrics	Output	Analytics
<pre>78 - ofdm 4, score = 99.707 79 - ofdm 4, score = 98.1445 80 - ofdm 4, score = 99.9023 81 - ofdm 4, score = 99.5117 82 - ofdm 4, score = 99.5605 83 - ofdm 4, score = 99.8535 84 - ofdm 4, score = 99.6582 85 - ofdm 4, score = 99.6582 86 - ofdm 4, score = 99.2188 87 - ofdm 4, score = 96.8262 88 - ofdm 4, score = 97.9492 89 - qpsk 5, score = 61.9629 90 - ofdm 4, score = 99.8047 91 - ofdm 4, score = 99.7559 92 - ofdm 4, score = 92.1875 93 - ofdm 4, score = 84.3262</pre>		



- AI를 통한 기존 신호 처리 파이프라인 강화
- SoC와 Direct RF 가 통합되어 지연 시간이 짧은 종단간 시스템 제공
- Intel® FPGA AI Suite 을 사용한 파형 분류 예제

방문해서 자세히 알아보세요:

## Intel® Direct RF-Series FPGAs

<https://www.intel.com/content/www/us/en/products/details/fpga/agilex/9/direct-rf-series.html>

고성능 광대역 주파수 민첩성

## Intel® FPGA AI Suite

<https://www.intel.com/content/www/us/en/software/programmable/fpga-ai-suite/overview.html>

**FPGA** 기반 **AI** 확장성 제공

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# EagleNet Dataset – 7 Classes

- Class 1: Amplitude Modulation (AM)
  - Carrier at 3.85GHz, AM modulated with 2MHz sine data
- Class 2: Continuous Waveform (CW)
  - No Modulation, sine tone at 3.85MHz
- Class 3: Frequency Modulation (FM)
  - Carrier at 3.85GHz, FM modulated with 10MHz maximum deviation sine
- Class 4: Background Noise
  - Signal Generator turned OFF
- Class 5: Orthogonal Frequency Digital Modulation (OFDM)
  - 32 carriers, modulated QAM16, Bandwidth of 20MHz
- Class 6: Quadrature Phase Shift Key (QPSK)
  - Digital modulation with symbol rate 12.5 MSPS
- Class 7: Chirp
  - 40MHz with period of 10us