JETSON AGX XAVIER AND THE NEW ERA OF AUTONOMOUS MACHINES
## Intro to Jetson AGX Xavier
- AI for Autonomous Machines
- Jetson AGX Xavier Compute Module
- Jetson AGX Xavier Developer Kit

## Xavier Architecture
- Volta GPU
- Deep Learning Accelerator (DLA)
- Carmel ARM CPU
- Vision Accelerator (VA)

## Jetson SDKs
- JetPack 4.1
- DeepStream SDK
- ISAAC SDK

## Resources & Support
- Developer Site & Documentation
- Community Forums & Wiki
- Tutorials
- Quick Start Platforms
BILLIONS OF AUTONOMOUS MACHINES

Industrial  Aerospace/Defense  Healthcare  Construction  Agriculture  Smart City

Retail  Logistics  Inventory Mgmt  Delivery  Inspection  Service
EXAMPLE - AI DELIVERY

Total: 20-30 TOPS
EXAMPLE - VIDEO ANALYTICS

Typical application: 30+ TOPS
## VISION NETWORKS

### Compute Demand

<table>
<thead>
<tr>
<th>Category</th>
<th>Input Size</th>
<th>GOPs/Frame</th>
<th>GOPs @ 30Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Image Recognition</strong></td>
<td></td>
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<tr>
<td>MobileNet</td>
<td>224x224</td>
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<td>AlexNet</td>
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<td>GoogleNet</td>
<td>224x224</td>
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<td>ResNet-50</td>
<td>224x224</td>
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<td>VGG19</td>
<td>224x224</td>
<td>20</td>
<td>600</td>
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<tr>
<td><strong>Object Detection</strong></td>
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<td>YOLO-v3</td>
<td>416x416</td>
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<td>SSD-VGG</td>
<td>512x512</td>
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<td>Faster-RCNN</td>
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<td><strong>Segmentation</strong></td>
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<td>FCN-8S</td>
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<td>SegNet</td>
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<td><strong>Pose Estimation</strong></td>
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<td>PRM</td>
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<tr>
<td>Multipose</td>
<td>368x368</td>
<td>136</td>
<td>4,080</td>
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<td><strong>Stereo Depth DNN</strong></td>
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<tr>
<td></td>
<td>1280x640</td>
<td>260</td>
<td>7,800</td>
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</tbody>
</table>
JETSON AGX XAVIER
World’s first AI computer for Autonomous Machines

AI Server Performance in 30W • 15W • 10W
512 Volta CUDA Cores • 2x NVDLA
8 core CPU
32 DL TOPS
COMPREHENSIVE HIGH PERFORMANCE I/O SUBSYSTEM

**PCIe**
- 5 16GT/s gen4 controllers
  - 1x8, 1x4, 1x2, 2x1
  - 3x Root port + Endpoint
  - 2x Root port

**USB**
- 3x USB3.1 (10 GT/s) ports
- 4x USB2.0 ports

**ETHERNET**
- 1x Gigabit Ethernet-AVB
  - RGMII PHY
  - PTP, WoL

**DISPLAY**
- 3x DP/HDMI/eDP
- 4K @ 60 Hz
- DP HBR3
- HDMI 2.0

**CAMERA**
- 16 CSI2 lanes, 8 SLVS-EC lanes
- 40 Gbps in DPHY 1.2 Mode
- 109 Gbps in CPHY 1.1 Mode
- Up to 36 Virtual Channels

**OTHER I/Os**
- I2C
- I2S
- UFS
- CAN
- SPI
- SD
- UART
- GPIO

Total I/O >650 Gbps
# JETSON AGX XAVIER

## Compute Module

<table>
<thead>
<tr>
<th>Feature</th>
<th>JETSON TX2</th>
<th>JETSON AGX XAVIER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GPU</strong></td>
<td>256 Core Pascal @ 1.3GHz</td>
<td>512 Core Volta @ 1.37GHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 Tensor Cores</td>
</tr>
<tr>
<td><strong>DL Accelerator</strong></td>
<td>-</td>
<td>(2x) NVDLA</td>
</tr>
<tr>
<td><strong>Vision Accelerator</strong></td>
<td>-</td>
<td>(2x) 7-way VLIW Processor</td>
</tr>
<tr>
<td><strong>CPU</strong></td>
<td>6 core Denver and A57 @ 2GHz</td>
<td>8 core Carmel ARM CPU @ 2.26GHz</td>
</tr>
<tr>
<td></td>
<td>(2x) 2MB L2</td>
<td>(4x) 2MB L2 + 4MB L3</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td>8GB 128 bit LPDDR4 58.4 GB/s</td>
<td>16GB 256-bit LPDDR4x @ 2133MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>137 GB/s</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>32GB eMMC</td>
<td>32GB eMMC</td>
</tr>
<tr>
<td><strong>Video Encode</strong></td>
<td>(2x) 4K @30 HEVC</td>
<td>(4x) 4Kp60 / (8x) 4Kp30 HEVC</td>
</tr>
<tr>
<td><strong>Video Decode</strong></td>
<td>(2x) 4K @30 12 bit support</td>
<td>(2x) 8Kp30 / (6x) 4Kp60 12 bit support</td>
</tr>
<tr>
<td><strong>Camera</strong></td>
<td>12 lanes MIPI CSI-2 D-PHY 1.2 30Gbps</td>
<td>16 lanes MIPI CSI-2 8 lanes SLVS-EC D-PHY 40Gbps / C-PHY 109Gbps</td>
</tr>
<tr>
<td><strong>PCI Express</strong></td>
<td>5 lanes PCIe Gen 2 1x4 + 1x1</td>
<td>2x1 + 1x4</td>
</tr>
<tr>
<td><strong>Mechanical</strong></td>
<td>50mm x 87mm 400 pin connector</td>
<td>100mm x 87mm 699 pin connector</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>7.5W / 15W</td>
<td>10W / 15W / 30W</td>
</tr>
</tbody>
</table>
JETSON AGX XAVIER
20x Performance in 18 Months

24x DL / AI

8x CUDA

2x CPU

2.4x DRAM BW

4x CODEC

Jetson TX2
Jetson TX2
Jetson AGX Xavier
Jetson AGX Xavier
Jetson AGX Xavier
Jetson AGX Xavier
Jetson TX2
Jetson TX2
Jetson AGX Xavier
Jetson AGX Xavier

TOPS

TFLOPS (FP16)

Cum. DMIPS

GB/s

4K Encode and Decode

1.3
11
112
137
2
8
1.3
11
112
137
2
8
JETSON AGX XAVIER

GPU Workstation Perf • 1/10\textsuperscript{th} Power

**AI Inference Performance**

- Core i7 + GTX 1070: 1000 Images/sec
- Jetson AGX Xavier: 1400 Images/sec

1.4X

**AI Inference Efficiency**

- Core i7 + GTX 1070: 50 Images/sec/W
- Jetson AGX Xavier: 70 Images/sec/W

14X
JETSON AGX XAVIER
Compute Module

- PMIC
- Xavier
- 32GB eMMC
- 16GB LPDDR4x
- Thermal Transfer Plate (TTP)

Price:
- $1599 (qty. 10+)
- $1299 (qty. 100+)

Coming Soon
# JETSON AGX XAVIER

## Developer Kit

### I/O

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PCIe x16</td>
<td>PCIe Gen4 x8 / SLVS-EC x8</td>
</tr>
<tr>
<td>RJ45</td>
<td>Gigabit Ethernet</td>
</tr>
<tr>
<td>USB-C</td>
<td>(2x) USB 3.1</td>
</tr>
<tr>
<td>eSATAp + USB 3.0</td>
<td>SATA (Power + Data for 2.5” SATA) + USB 3.0</td>
</tr>
<tr>
<td>Micro USB</td>
<td>(1x) USB 2.0</td>
</tr>
<tr>
<td>Camera Header</td>
<td>(16x) CSI-2 lanes</td>
</tr>
<tr>
<td>M.2 Key M</td>
<td>NVMe storage</td>
</tr>
<tr>
<td>M.2 Key E</td>
<td>PCIe x1 (for Wi-Fi / LTE / 5G)</td>
</tr>
<tr>
<td>40-pin Header</td>
<td>UART, SPI, CAN, I2C, I2C, DMIC, GPIOs</td>
</tr>
<tr>
<td>HD Audio Header</td>
<td>High-Definition Audio</td>
</tr>
<tr>
<td>HDMI Type A</td>
<td>HDMI 2.0, eDP 1.2a, DP 1.4</td>
</tr>
<tr>
<td>uSD / UFS Card</td>
<td>SD / UFS</td>
</tr>
<tr>
<td>DC Barrel Jack</td>
<td>9V - 20VDC</td>
</tr>
<tr>
<td>Size</td>
<td>105mm x 105mm</td>
</tr>
</tbody>
</table>

$2499 (Retail), $1799 (qty. 10+)  
$1299 (Developer Special, limit 1)  
Available Now, see NVIDIA.com
# JETSON AGX XAVIER

## Developer Kit

__Price:__
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<tr>
<td>Size</td>
<td>105mm x 105mm</td>
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</table>
JETSON AGX XAVIER
Developer Kit
Volta GPU
Deep Learning Accelerator (DLA)
Carmel ARM CPU
Vision Accelerator
VOLTA GPU
Optimized for Inference

8x Volta SM @ 1377MHz
512 CUDA cores, 64 Tensor Cores
22 TOPS INT8, 11 TFLOPS FP16
8x larger L1 cache size
4x faster L2 cache access
4 scheduler partitions per SM
CUDA compute capability 7.2
4x4 matrix processing array, \( D = A \times B + C \)

**HMMA/IMMA** FP16/INT8 Matrix Multiple Accumulate

Accumulation occurs in full precision with overflow protection

Each Tensor Core performs 64 floating-point or 128 integer ops per clock

Results can be composed to construct larger matrix multiplies & convolutions

Integrated with cuBLAS, cuDNN, TensorRT, and programmable through CUDA
DEEP LEARNING ACCELERATOR (DLA)

2x DLA engines per Xavier
5 TOPS INT8, 2.5 TFLOPS FP16 per DLA
Optimized for energy efficiency (500-1500mW)
Programmed with TensorRT 5.0
Supported layers include: Convolution, Deconvolution, Activations, Pooling, Normalization, Fully Connected

Open-source architecture: NVDLA.org
POWER MODES

Different power mode presets: 10W, 15W and 30W

Default mode is 15W

Users can create their own presets, specifying clocks and online cores in /etc/nvpmode.conf

```
< POWER_MODEL ID=2 NAME=MODE_15W >
  CPU_ONLINE CORE_0
  CPU_ONLINE CORE_4 0
  CPU_DENVER_0 MAX_FREQ 1200000
  GPU_MIN_FREQ 0
  GPU_MAX_FREQ 670000000
  EMC_MAX_FREQ 1331200000
```

NVIDIA Power Model Tool

```
sudo nvpmodel -q    (for current mode)
sudo nvpmodel -m 0  (for changing mode, persists after reboot)
sudo ~/tegrastats  (for monitoring clocks & core utilization)
```
# NVPMODEL CLOCK CONFIGURATION

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<th>Mode Name</th>
<th>EDP</th>
<th>10W</th>
<th>15W</th>
<th>30W</th>
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<td>DLA cores</td>
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<td>DLA Maximal Frequency (MHz)</td>
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<td>1</td>
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<tr>
<td>VA Maximal Frequency (MHz)</td>
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<td>550</td>
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<td>1600</td>
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</tbody>
</table>

The default mode is 15W (ID: 2)
CARMEL CPU COMPLEX

Full ARMv8.2 including RAS support

8 NVIDIA Carmel cores @ 2.26GHz

500-1500mW power per core

2 cores + 2MB L2 per cluster

Cache Coherent Across CPU Complex

NVIDIA Dynamic Code Optimization

I/O Coherent Memory

4MB Exclusive L3 cache
CPU BENCHMARKS

Speed-up of Xavier over TX2

- SpecINT-Rate 8X (est.): 2.6x
- SpecFP-Rate 8X (est.): 2.8x
VISION ACCELERATOR

2x Vision Accelerator engines

Optimized offloading of imaging & vision algorithms - feature detection & matching, stereo, optical flow

SW support enabled in future JetPack

Each Vision Accelerator includes:
- Cortex-R5 for config and control
- 2x 7-way VLIW Vector Processing Units
- 2x DMA for data movement to/from internal/external memories
JetPack - AI at the Edge
DeepStream - Intelligent Video Analytics (IVA)
ISAAC - Robotics & Autonomous Machines
JETSON SDKs

DEEPSTREAM SDK
FOR VIDEO ANALYTICS

ISAAC SDK
FOR AUTONOMOUS MACHINES

JETPACK SDK
FOR AI AT THE EDGE

JETSON AGX XAVIER
## JETPACK SDK

for AI at the Edge

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<tr>
<th>Sample Code</th>
<th>Nsight Developer Tools</th>
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</thead>
<tbody>
<tr>
<td>Deep Learning</td>
<td>Multimedia API</td>
</tr>
<tr>
<td>TensorRT, cuDNN, TF, PyTorch, ...</td>
<td>VisionWorks, OpenCV, NPP</td>
</tr>
<tr>
<td>CUDA, Linux For Tegra, ROS</td>
<td>Vulkan, OpenGL, EGL/GLES</td>
</tr>
<tr>
<td>Jetson AGX Xavier: Advanced GPU, 64-bit CPU, Video CODEC, DLAs</td>
<td>libargus, GStreamer, V4L2</td>
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</table>

### Deep Learning
- TensorRT
- cuDNN
- TensorFlow
- PyTorch
- ...

### Computer Vision
- VisionWorks
- OpenCV
- NPP

### Graphics
- Vulkan
- OpenGL
- EGL/GLES

### Media
- libargus
- GStreamer
- V4L2

### JETPACK SDK for AI at the Edge
- SDK for AI at the Edge
- JETPACK for AI
- JETPACK for AI at the Edge
- JETPACK for AI at the Edge
- JETPACK for AI at the Edge
- JETPACK for AI at the Edge
## Package Versions

<table>
<thead>
<tr>
<th>Package</th>
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<td>L4T BSP</td>
<td>31.0.2</td>
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<tr>
<td>Linux Kernel</td>
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<tr>
<td>CBoot</td>
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<tr>
<td>Vulkan</td>
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<td>OpenGL</td>
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<td>OpenGL-ES</td>
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<td>EGL</td>
<td>1.5</td>
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<td>GLX</td>
<td>1.4</td>
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<td>X11 ABI</td>
<td>24</td>
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<tr>
<td>Xrandr</td>
<td>1.4</td>
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<tr>
<td>Multimedia API</td>
<td>31.1</td>
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<tr>
<td>Argus Camera API</td>
<td>0.97</td>
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<tr>
<td>GStreamer</td>
<td>1.14</td>
</tr>
<tr>
<td>Nsight Systems</td>
<td>2018.1</td>
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<tr>
<td>Nsight Graphics</td>
<td>1.0</td>
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<tr>
<td>Jetson OS</td>
<td>Ubuntu 18.04</td>
</tr>
<tr>
<td>Host OS</td>
<td>Ubuntu 16.04 / 18.04</td>
</tr>
</tbody>
</table>

Install TensorFlow, PyTorch, Caffe, ROS, and other GPU libraries.

Available Now For Jetson AGX Xavier
[developer.nvidia.com/jetpack](http://developer.nvidia.com/jetpack)
Compile and Optimize Neural Networks
Support for Every Framework
Optimize for Each Target Platform

NVIDIA TensorRT
Production Inferencing
NVIDIA TensorRT 5
Deep Learning Inference Optimizer and Runtime

New support for Jetson AGX Xavier in TensorRT 5:

- Volta GPU INT8 & Tensor Cores (HMMA/IMMA)
- Early-Access DLA FP16 support
- Updated samples to enabled DLA
- Fine-grained control of DLA layers and GPU Fallback
- New APIs added to IBuilder interface:
  ```cpp
  setDeviceType()
  canRunOnDLA()
  getMaxDLABatchSize()
  allowGPUFallback()
  ```

developer.nvidia.com/tensorRT
AI - EDGE TO CLOUD

EDGE AND ON-PREMISES

Inference

EDGE AND ON-PREMISES

Training and Inference

CLOUD

Edge device

Server

TENSORRT • DEEPSTREAM • JETPACK

JETSON

TESLA

NVIDIA GPU CLOUD • DIGITS

DGX
NVIDIA DEEPSTREAM

Zero Memory Copies

Typical multi-stream application: 30+ TOPS
ISAAC
Isaac SDK: Simulation to Reality

Simulate

World model
- Warehouse
- Office
- Store
- Home

Robot model
- Carter
- URDF loader

Simulation Engine
- Photo-realistic Graphics
- Physics
- Soft bodies
- Procedural Generation
- Massive parallelism
- Unreal Engine 4 / Unity 3D

Simulate

Develop

ML
- TensorRT
- CUDA
- TensorFlow

Gems
- Optimizers
- Algebra
- EKFs
- Depth

Isaac Framework
- Codelets
- Behaviors
- 3D Poses
- Distributed
- Messaging
- Synchronization
- Record & Replay
- Configuration
- Visualization

Develop

World model
- Warehouse
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Simulation Engine
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- Unreal Engine 4 / Unity 3D

Virtual Sensors

Virtual Actuators

Sensor Processing

Actuator Control

Deploy

Drivers
- Lidar
- Camera
- IMU
- Robot Base

Jetson
- Fully integrated with TX2 and Xavier

Unified Message API
- Use the same messages for simulation, actual hardware and across all apps

Deploy

Use the same messages for simulation, actual hardware and across all apps

Simulate

Develop

World model
- Warehouse
- Office
- Store
- Home

Robot model
- Carter
- URDF loader

Simulation Engine
- Photo-realistic Graphics
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Simulate
RESOURCES & SUPPORT

Developer Site
Documentation
Forums & Wiki
Tutorials
Quick-Start Platforms
JETSON DEVELOPER SITE

End-to-end development from idea to final product

JetPack and Isaac SDKs
Developer tools
Design collateral
Developer forum
Training and tutorials
Ecosystem

developer.nvidia.com/jetson
GETTING HELP
Jetson Community

Developer Forums  devtalk.nvidia.com

Jetson AGX Xavier

TensorFlow uff for JetPack 4.3
JetPack 4.3 Developer Preview Early Access for Jetson AGX Xavier
Links to Jetson Xavier Resources & Wiki
NVIDIA Webinar — Jetson AGX Xavier and the New Era of Autonomous Machines
NVIDIA Announces Jetson AGX Xavier
Jetson AGX Xavier Developer Kit — Now Shipping!

Night not working with me
Setting up YNC server
Xavier Carrier Board Development started.
Default Boot Resolution?

Imx528 adapter not working
xavier lan question
Building Driver for A3505 USB-AE-53 Nano Wi-Fi Adapter
Ubuntu 18.04 has experienced an internal Error

eLinux Wiki  eLinux.org/Jetson

Jetson AGX Xavier

Jetson AGX Xavier is an embedded system-on-module (SOM) from the NVIDIA AGX System family, including an integrated Intel GPU with Tensor Cores, dual Deep Learning Accelerators (DLAs), two Arm AP180 CPU cores, 4 GB LPDDR4X memory, 16 GB eMMC storage, and 1 Gbps of Ethernet. The Jetson AGX Xavier is used for deploying computer vision and deep learning in the edge. Jetson AGX Xavier runs on Linux and provides 32 Terabytes of compute performance in case-configured. 1080P front camera. eLinux.org/Jetson is generally the same as the Jetson AGX Xavier Developer Kit, with the open source image being available in the future. See the wiki of previous Jetson’s here.

Contents
1. Jetson AGX Xavier Module
1.1 Processing Components
1.2 Video Processing Engines
1.2.1 VCP Engines
1.2.2 Video Processing System
1.2.3 Video Decoders
1.2.4 Video Encoders
1.3 Power System
1.4 Display Panel
1.5 System Tools
1.6 Deep Learning
1.7 Host/JavaScript & Linux
1.8 Setting Help

Jetson AGX Xavier Module

The Jetson AGX Xavier compute module contains all the active processing components. The I/O ports are broken out through a carrier board via a 660-pin connector. Below is a partial list of the modules. Features. Please see the Jetson AGX Xavier Module Specification for the complete specifications.

Processing Components
- Quad-core Intel Xeon "Zepto", 2.4 GHz, 2.3 GHz
- Quad-core Intel "1.5 GHz" with 512 Tensor Cores
- Dual Core "1.5 GHz" and "1.0 GHz"
- 1080P (HDMI); (DX10); (DX11)
- 2560x1600 (700 frames per second)
- "1.0 GHz" with 2560x1600 (600 frames per second)
- "1.0 GHz" with 3840x2160 (60 frames per second)
- "1.0 GHz" with 3840x2160 (60 frames per second)
TWO DAYS TO A DEMO
Getting Started with Deep Learning

AI WORKFLOW
Train using DIGITS and cloud/PC
Deploy to the field with Jetson

TRAINING GUIDES
All the steps required to follow to train your own models, including the datasets.

DEEP VISION PRIMITIVES
Image Recognition, Object Detection and Segmentation

github.com/dusty-nv/jetson-inference
TWO DAYS TO A DEMO
Reinforcement Learning Edition

OpenAI Gym
Test environments and games for research and verification

RL Algorithms
DQN, A3C, Actor Critic using PyTorch

Robotic Simulation
Observation from vision Pixels-to-actions

Transfer Learning
Adapt network to real robot Online learning in the field

github.com/dusty-nv/jetson-reinforcement
TENSORFLOW
Accelerated Performance with Jetson AGX Xavier

Download PIP Wheel installers from Jetson Download Center
Follow tutorials for popular vision tasks like object detection
Optimize for deployment with NVIDIA TensorRT (UFF/TFTRT)

developer.nvidia.com/embedded/downloads
github.com/NVIDIA-Jetson/tf_to_trt_image_classification
github.com/NVIDIA-Jetson/tf_trt_models
JETSON QUICK-START PLATFORMS

Toyota HSR
Clearpath Robotics - Jackal UGV
JetsonHacks RACECAR/J

Aion Robotics - R1 UGV
NVIDIA - Redtail UAV
Thank you!

Developer Site  developer.nvidia.com/jetson
Download JetPack  developer.nvidia.com/jetpack
2 Days To a Demo  github.com/dusty-nv
DevTalk Forums  devtalk.nvidia.com
Visit the Wiki  eLinux.org/Jetson

Q&A: What can I help you build?