MANISHA AGRAWAL and JITIN GEORGE

AUTONOMOUS ROBOTICS

BUILD SAFER, EFFICIENT AND INTELLIGENT AUTONOMOUS ROBOTS WITH TI SENSING AND PROCESSING TECHNOLOGIES

Agenda

- Introduction
  - Autonomous Robots
  - Functional Safety for Robotics
  - TI technologies serving Autonomous Robots
- Autonomous Mobile Robots (AMR)
  - AMR sensing challenges
  - TI mmWave sensors for AMR
  - Accelerate sensor fusion with TI Jacinto™ 7 processors
- Getting started

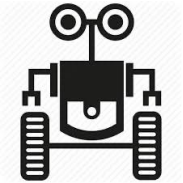
Autonomous Robots








Autonomous Mobile Robots



Sense

Sensors

Proximity Visuals Contact Internal GPS

Perceive & Plan

Where Am I?

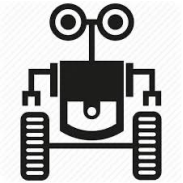
What are the objects around me?

How do I get there?

Act

Motor Control, break, throttle

Autonomous Mobile Robots



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Functional Safety

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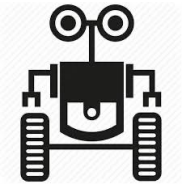
Motor Control, break, throttle

Autonomous Mobile Robots



Sense

IWR6843 | IWR1843

Functional Safety

Sensors

Proximity Visuals Contact Internal GPS

Perceive & Plan

TDA4VM

Functional Safety

Where Am I?

What are the objects around me?

How do I get there?

Act

DRA821 | AM6442 | Hercules™ MCU

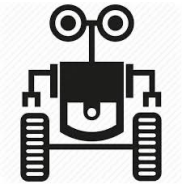
Functional Safety

Motor Control, break, throttle

TI Engineering expertise for functional safety

- Decades of safety engineering expertise
- Industry leadership as a participant in IEC 61508 and ISO 26262 standards organizations
- R&D processes enabling up to ASIL-D and SIL-3 systems
- Tools and expertise to simplify part selection
- Functional safety-compliant products leverage our TÜV SÜD-certified hardware and software development processes.

Autonomous Mobile Robots Sensing



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Where Am I? | What are the objects around me? | How do I get there?

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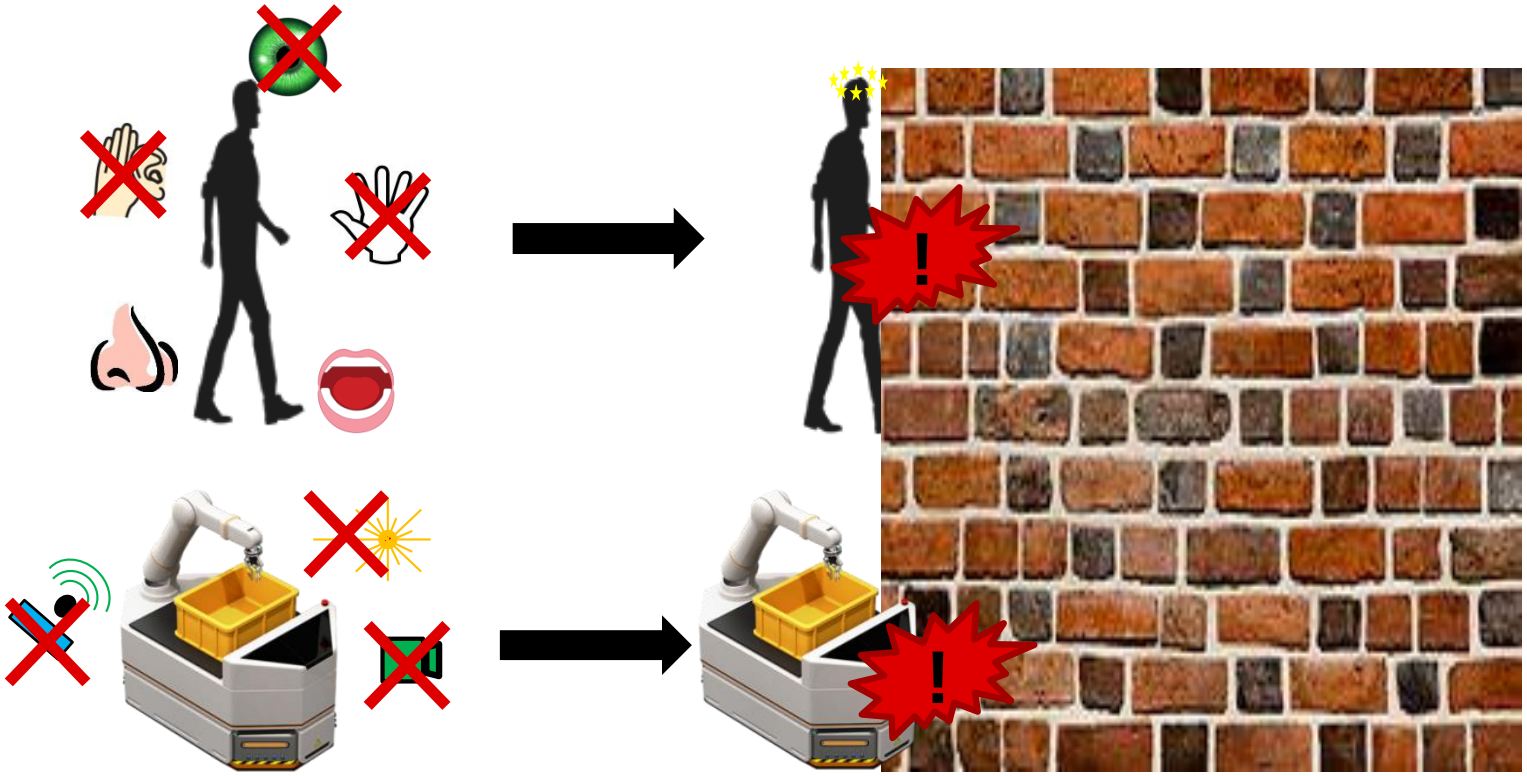
DRA821 | AM6442 | Hercules

Functional Safety

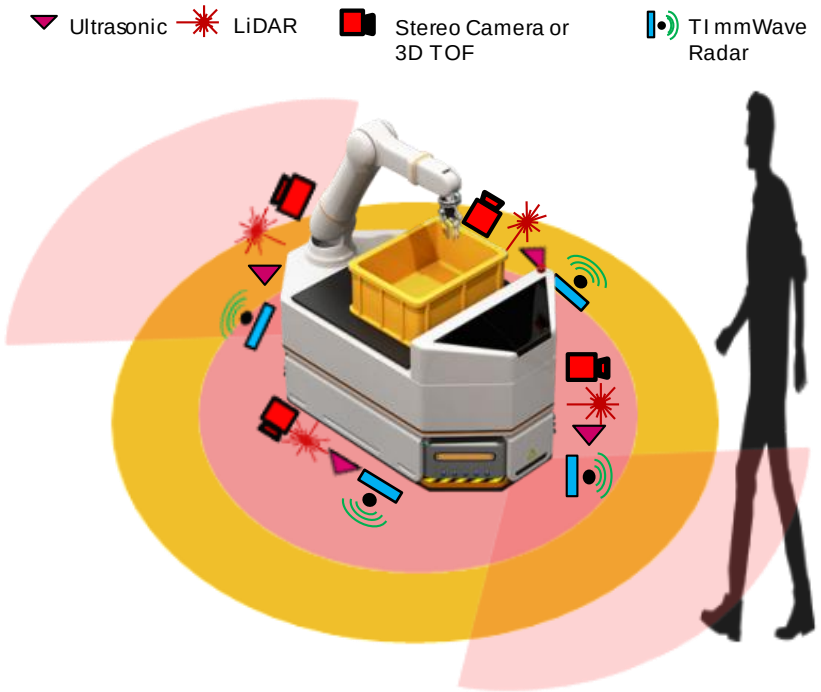
Motor Control, break, throttle

Why sensors are so important for robots
…and humans



Autonomous Mobile Robot challenges

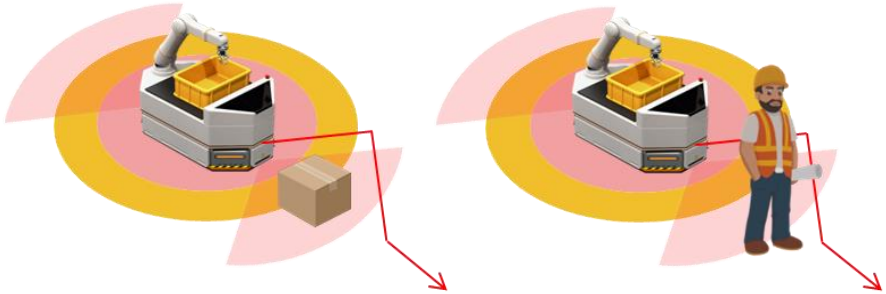
- **Safer human presence detection**
  (LIDAR, Radar)
- **Mapping and localization**
  (Stereo camera / LIDAR / Ultrasonic/Radar)
- **Collision avoidance**
  (Stereo Camera / LIDAR / Ultrasonic / Radar)



AMR Sensing with TI mmWave Radar Sensors

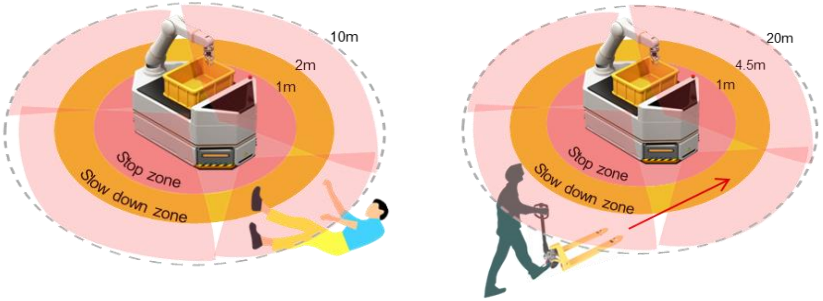
Complement or displace established sensor solutions with SIL 2 capable TI mmWave sensors that can solve the most challenging AGV and AMR sensing problems including safe human presence detection and autonomous navigation

Sense and Avoid - Collision Avoidance



Detect humans/obstacles and navigate around them to avoid collisions

360° Safety Bubble - Safe Human Presence Detection



Slow down and stop the robot when human is detected within safety bubble.
Robot resumes only when human is out of safety bubble

TI mmWave features	Robotics Benefits
3D presence detection	• True 3D information (range, velocity & angle) of objects vs. LIDAR/ToF used mainly for distance measurement • Quickly detect and prevent possible collisions minimizing machine downtimes
IEC 61508 SIL 2 targeted	• Enable safe human presence detection that has traditionally been solved by expensive safety certified LiDAR sensors
Accurate glass detection	• Ensure reliable detection of glass walls/doors over existing sensors that “see” through them
Wide azimuth area coverage	• Create 360 degree detection zones around the robot to prevent collisions with humans to minimize injury and reduce machine downtimes
Robust in challenging environments	• Increase reliability over existing vision/LiDAR based sensors in conditions such as rain, dust, smoke, complete darkness or in the glare of sunlight

TI mmWave Sense & Avoid Demo for AMRs

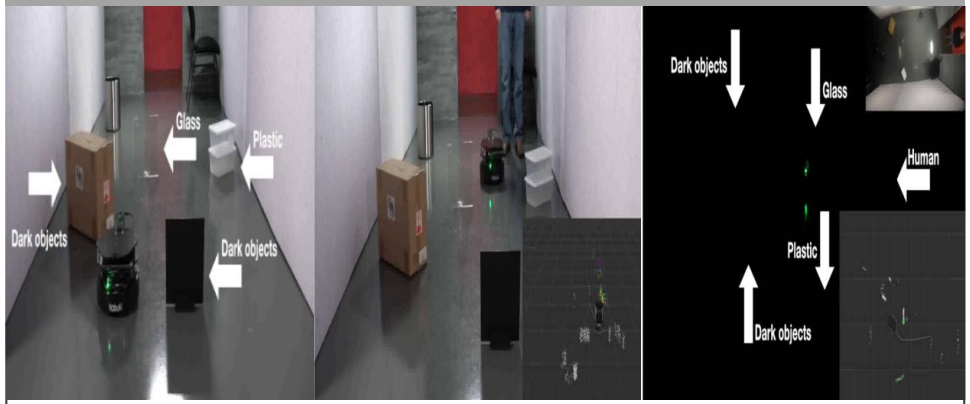
- **Enhanced workplace safety** with **collision avoidance** even in the **most challenging environmental conditions**
- Watch AMR Collision Avoidance use case video

	Sense and avoid [IWR6843]	Sense and avoid [IWR1843]
Tuning range	60-64 GHz.	77-81 GHz.
Offering	TIDEP – 01006 / TIREX Lab	TIREX Lab: Sense & Avoid
HW / EVM	IWR6843 ISK	IWR1843 BOOST
Field of View	120° Horizontal, 30° Vertical	120° Horizontal, 30° Vertical
Max Range (Resolution)	10m (0.047m)	10m (0.047m)

	Approved Deployability by Region					
Device		Americas	China	EMEA	Japan	RoA
IWR6843	60GHz transportation					
IWR1843	77GHz transportation					

Get started with mmWave for Robotics

TIDEP- 01006: Autonomous Robotics using mmWave and Sitara processor



1. Discover mmWave offering for robotics here
2. Evaluate the performance
   1. IWR6843 ISK
   2. IWR1843 BOOST
   3. Sense and Avoid Lab [IWR6843 and IWR1843]
   4. Detecting walls of different materials experiment
3. Design custom boards with IWR6843 silicon
   1. Online datasheet & other technical documents
   2. Hardware design checklist

TI mmWave 360° Safety Bubble Offering for AGVs/AMRs

- **Ensure worker safety** with **360° human presence detection** and collision avoidance even in the **most challenging environmental conditions**
- Watch 360° safety bubble performance video

Get started with mmWave for Robotics

TIREX - Lab: 360° Safety Bubble with ROS using mmWave

	360 Degree Safety Bubble [IWR6843]
Tuning range	60-64 GHz.
Offering	TIREX Lab
HW / EVM	4x IWR6843 ISK
Field of View	360° Horizontal, 30° Vertical
Max Range (Resolution)	10m (configurable) (0.047m)
Warning Zone (Slow Down)	2m (configurable)
Danger Zone (Stop)	1m (configurable)

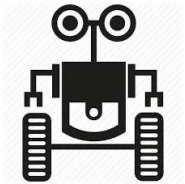
	Approved Deployability by Region				
Device		Americas	China	EMEA	Japan	RoA
IWR6843	60GHz transportation					
IWR1843	77GHz transportation					

1. Discover mmWave offering for robotics
2. Evaluate the performance
   a) IWR6843 ISK
   b) 360º Safety Bubble performance video
   c) 360º Safety Bubble with ROS Lab
   d) 360° Safety Bubble Lab FAQ
3. Design custom boards with IWR6843 silicon
   a) Online datasheet & other technical documents
   b) Hardware design checklist
4. Accelerate path to production with 3P solutions
   a) Industrial mmWave third-party search tool

Which sensors should I use for my robot?

Good Fair Poor	Human	LIDAR	Radar	2D Camera	3D Camera	Sensor Fusion
Object detection						
Object classification						
Range of visibility						
Distance estimation						
Object edge precision						
Detect transparent surfaces						
Functioning in poor lighting						

Autonomous Mobile Robots Processing



Sense

IWR6843 IWR1843

Functional Safety

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What are the objects around me?

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Act

DRA821 AM6442 Hercules

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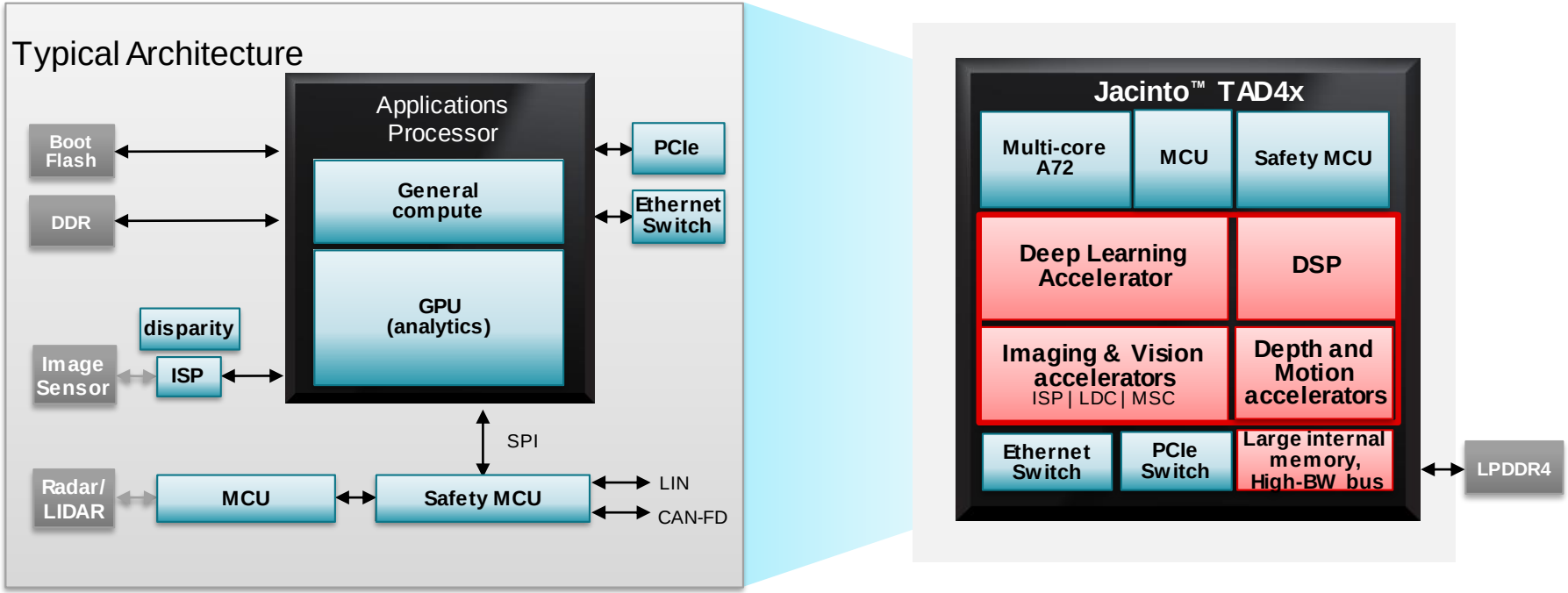
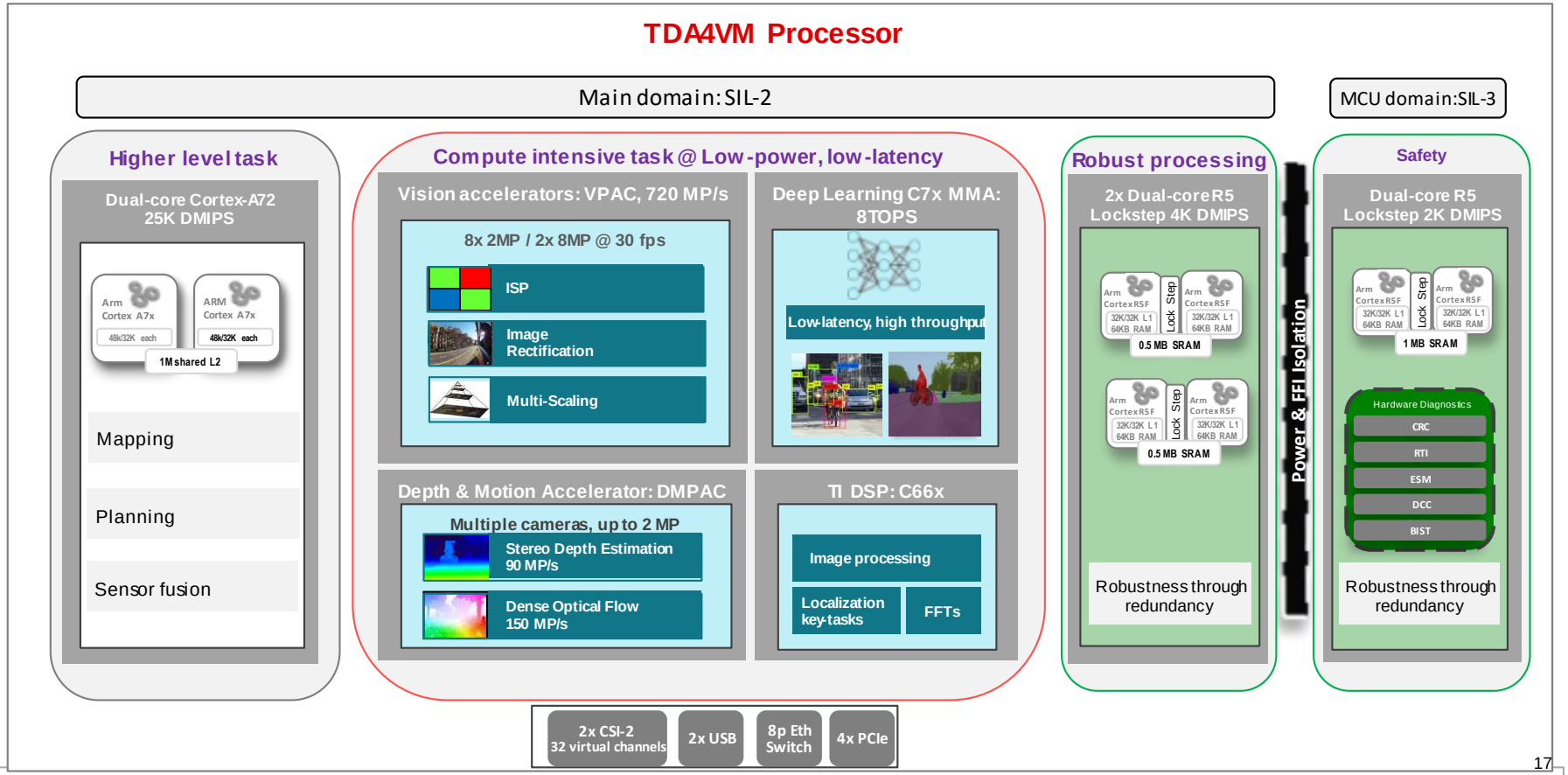
Jacinto™ 7 TDA4x Platform

Highly-integrated scalable family of processors: Purpose built for smart, safe, energy-efficient & cost-effective edge applications



Jacinto TDA4x for Autonomous Robots



TDA4x Processor enable smart, safe, energy efficient & cost-effective Robots

Efficient DL
More FPS/TOPS/W
&
Accelerated CV

Energy-efficient

Mono Camera

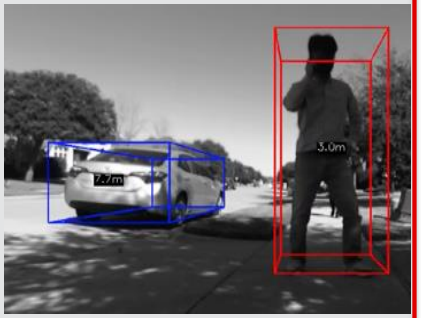
Stereo Camera

Low-power, low-latency & robust hybrid vision perception

Localization

Where Am I?

Obstacle detection



What, where and how far are the objects around me?

TDA4x Processor enable smart, safe, energy efficient & cost-effective Robots

Efficient DL
More FPS/TOPS/W
&
Accelerated CV

Energy-efficient

Safer
- SII-3/SIL-2 complaint* SoC
- Lock-Step R5s
- Redundancy w/ CV & DL

Cost-effective
Highly integrated SoC, single DDR instance

Mono Camera | Stereo Camera | Radar | Lidar | Other sensors

Low-power, low-latency & robust hybrid perception & navigation

Localization

Where Am I?

Obstacle detection

What, where and how far are the objects around me?

e-stop

Navigate safely

* Final certification pending

Deep Learning programming with open source RunTimes

TensorFlow PyTorch ONNX TensorFlow Lite

TensorFlow Lite — Now

tvm Neo-AI-DLR — Now

ONNX RUNTIME — Mar-end

Accelerated inference for large number of popular models

Model Training

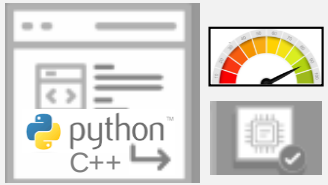
TI Model Zoo

Optional: Quantization Aware Training tool

Model Compilation

Post-training quantization

Calibration



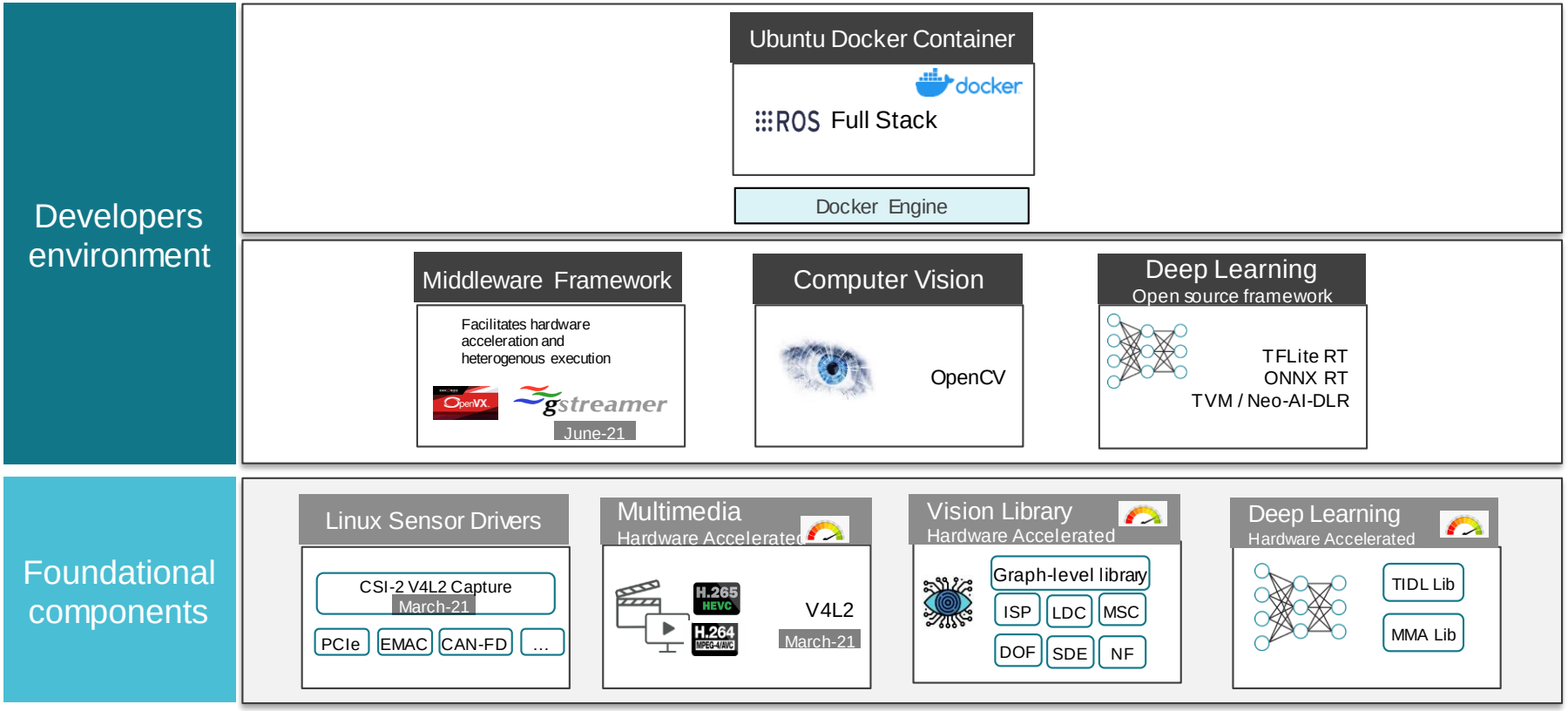
Accelerated Inference

Neural Network accelerator

Optimal DDR utilization

Programming experience of CPU, system benefit of specialized accelerators

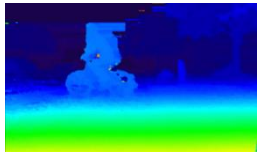
Processor SDK Robotics developers tools



Processor SDK Out-of-box Robotics applications

Hardware accelerated

Stereo Disparity



SemSeg + Stereo Obj Detect

Visual Localization

8x 2MP @ 30 fps image processing

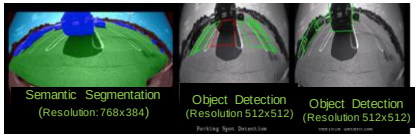
Hardware accelerated

Image Classification

Object Detection

Semantic Segmentation

Simultaneous execution of Multiple model



Accelerated DL and CV based Localization demo

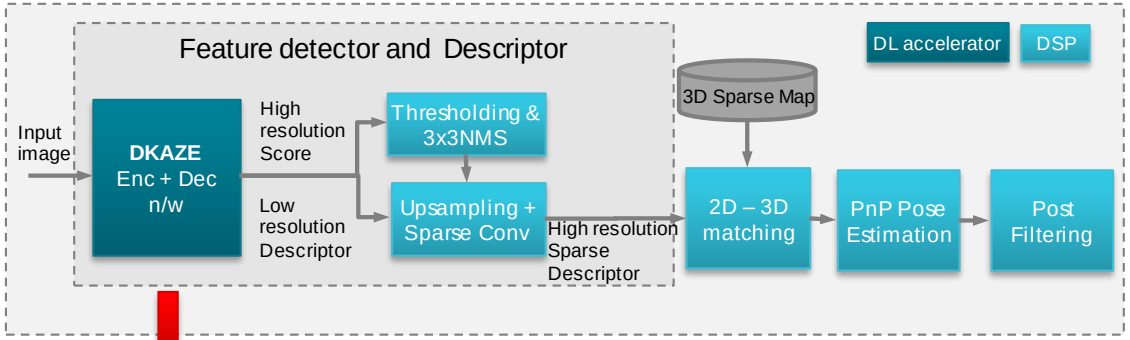
Mono camera 768x384 @ 30 fps,
localization average error 10.6 cm

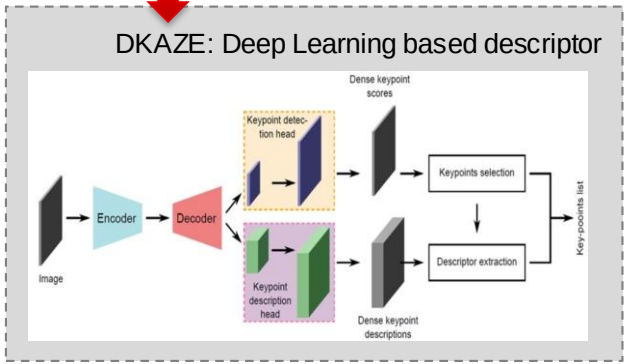
TDA4VM Resource loading

A72:	1%	**C7x+MMA:**	12%
1xR5:	6%	**C6x:**	45%
5xR5s:	free	**DDR BW:**	8%

Learn more about the demo in Processor SDK user guide

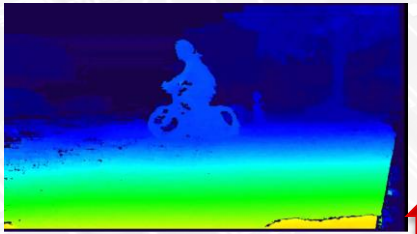
Mono camera Localization w/ accelerated DL & CV





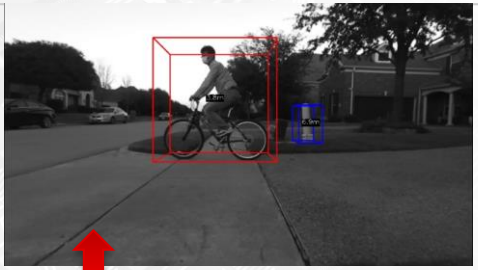
Accelerated DL and CV based 3D Obstacle detection demo

Stereo Depth Engine (SDE) produces 192 disparities @ 80 MP/sec



Ego-Centric Occupancy Grid Map

Fuse Deep Learning & Conventional Stereo Vision for Robust Detection



ZED Stereo Camera
YUV 422 1280 × 720 (L+R) @ 30 fps, USB 3.1

L

R

VectorNav VN-200
GPS + IMU, UART-to-USB

Hardware-Accelerated Stereo pipeline

- Stereo Rectification (LDC Mesh)
- Stereo HWA (DMPAC)
- Disparity Refinement (C71x)

Mapping & Obstacle Detection

- 3D Point Cloud Mapping (ARM A72)
- 2D Occupancy Grid Mapping (ARM A72)
- Class-Aware Connected Component Analysis (ARM A72)

Safety Bubble

- Stereo Safety Hazard Detection (ARM A72)

Deep Learning Pipeline

- Resize ↓ (MSC0)
- NV12→RGB (C66x)
- Semantic Segmentation (C7-MMA)

Pre-Processing

- OG Map Display (x86)
- 3D Object Localization (x86)
- Semantic Pixel Labeling (x86)

ROS Rviz Visualization (x86)

TDA4VM

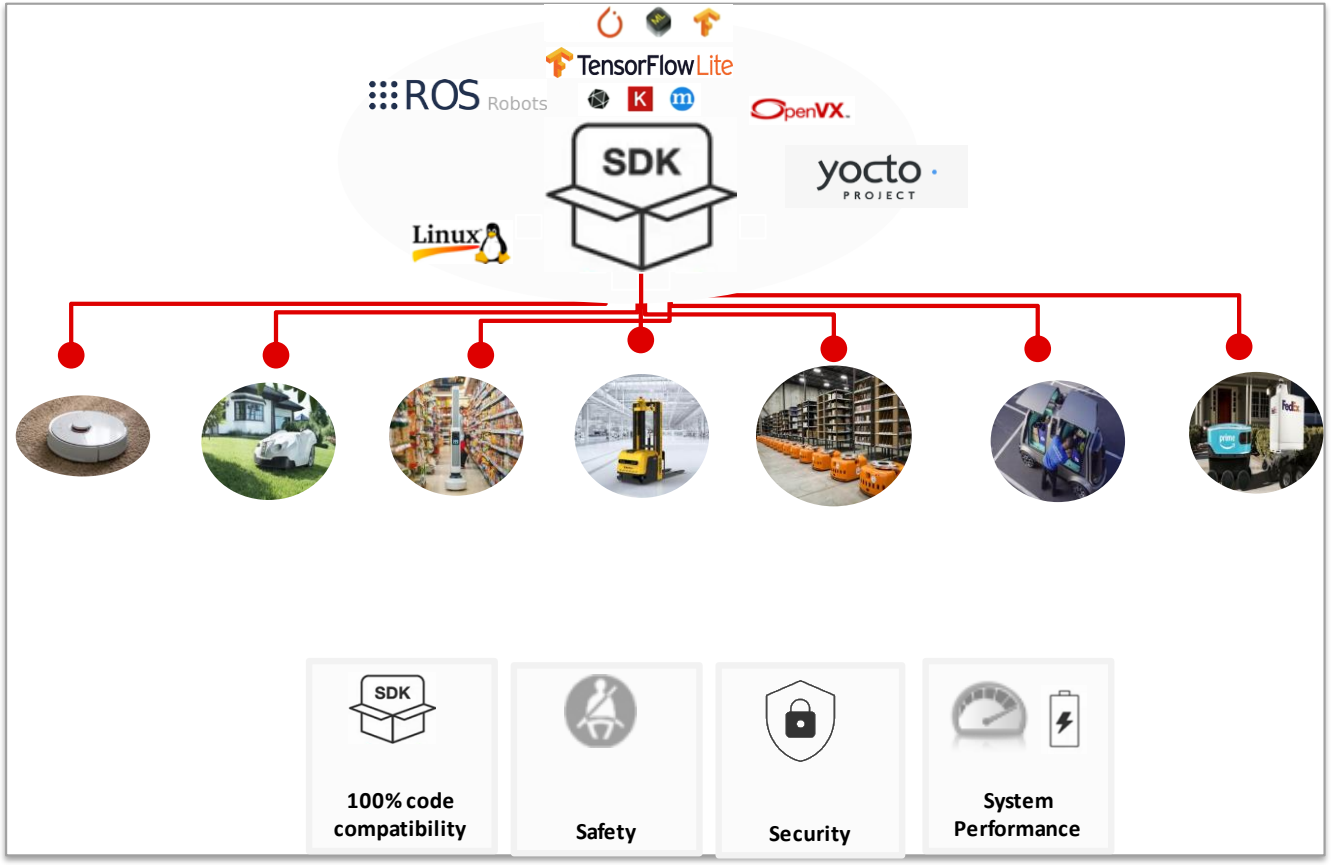
ROS PC

VPAC DMPAC A72 C7MMA C66 X86

C7 DSP (80 GFLOPs) with MMA (8 TOPs) accelerates deep learning and signal processing

Learn more about the demo building blocks here

TI Processors unified software platform



- Common to **all TI processors** and hardware
- Built on common foundation of drivers, frameworks, libraries/codecs, and development tools
- Industries best mainline LINUX support
- Quarterly updates to SDK
- Enables customers and 3P partners on all operating systems

NRE-free and royalty-free software!
Extensive support on e2e.ti.com

Explore Robotics Applications With TI Today

TDA4VM

Full development

http://www.ti.com/tool/TDA4VMXEVM

Turn-key designs

Automotive version of TDA4V Mid

http://www.ti.com/tool/D3-3P-TDAX-DK

Software development kits

TI Processor SDK – Seamlessly reuse and migrate Linux software across TI processors

http://www.ti.com/tool/PROCESSOR-SDK-DRA8X-TDA4X

mmWave Radar

Evaluation Modules

IWR6843 ISK (60 GHz)
IWR6843 AOP (60 GHz Antenna on Package)
IWR1843 BOOST (77 GHz)

Reference examples / Labs

Sense and Avoid Lab for Collision Avoidance
360º Safety Bubble with ROS Lab for Safe Human Presence Detection

Accelerate path to production with 3P

Designing TI mmWave made easier using 3rd party ecosystem
Industrial mmWave third-party search tool

Free Support on e2e.ti.com

Getting started with DRA821

Product	https://www.ti.com/product/DRA821U
Evaluation Module	SOM: https://www.ti.com/tool/J7200XSOMXEVM CP Board: https://www.ti.com/tool/J721EXCPXEVM
Software development kits	TI Processor SDK – Seamlessly reuse and migrate Linux software across TI processors https://www.ti.com/tool/PROCESSOR-SDK-J7200

Free Support on e2e.ti.com

Getting started with AM6442

GPNs	**AM6442** 2x A53, 4x R5F	**AM6441** 1x A53, 4x R5F	**AM6421** 1x A53, 2x R5F	**AM6412** 2x A53, 1x R5F	**AM6411** 1x A53, 1x R5F
Pricing	On ti.com:1/29/21 **Starting at $6.95**				
Evaluation boards	**EVM** **Part#:** TMDS64GPEVM **Price:** $299 **Description:** Designed for industrial networking & control and evaluating main device interfaces 				
Target Markets	• Servo drives • PLCs • Remote I/O modules	• Communication modules • I/O Link Master modules • Gateways	• Industrial robots • Automated machinery		
Key content	• Motor control demo (AM64x + F2800x) (video link) • AM64x overview technical article here. • AM64x benefits in Remote IO technical article • Refreshed motor drives and TSN white papers				

Hercules™ MCUs

Scalable Platform For Functional Safety Applications

RM41L2
80MHz
128kB Flash
32kB RAM
100p QFP

RM42L4
100 MHz
384kB Flash
32kB RAM
100p QFP

RM44L5
180 MHz
768K Flash
128kB RAM
100p QFP
144p QFP

RM44L9
180 MHz
1MB Flash
128kB RAM
100p QFP
144p QFP

RM46L8
220 MHz
1.2MB Flash
192kB RAM
144p QFP
337p BGA

RM48L7
200 MHz
2MB Flash
256kB RAM
144p QFP
337p BGA

RM48L9
220 MHz
3MB Flash
256kB RAM
144p QFP
337p BGA

RM57L
330 MHz
4MB Flash
512kB RAM
337p BGA

570LS02
80 MHz
128kB Flash
32kB RAM
100p QFP

570LS03
80 MHz
256kB Flash
32kB RAM
100p QFP

570LS04
80 MHz
384kB Flash
32kB RAM
100p QFP

570LS07
160 MHz
768kB Flash
128kB RAM
100p QFP
144p QFP

570LS09
160 MHz
1MB Flash
128kB RAM
100p QFP
144p QFP

570LS12
180 MHz
1.2MB Flash
192kB RAM
144p QFP
337p BGA

570LS31
180 MHz
3MB Flash
256kB RAM
144p QFP
337p BGA

570LC43
300 MHz
4MB Flash
512kB RAM
337p BGA

External certification: ISO 26262, IEC 61508

Documentation: Safety Manual, FMEDA reports

Software: Drivers, libraries, RTOS, Autosar, tools, debug

Development Kits: LaunchPad, HDK, SafeTI CSP, SafeTI CQK

Production

Texas Instruments

Hercules Training – Online Resources

- Hercules™ How to Tutorial: PWM Generation using the Hercules LaunchPad™
- Hercules How to Tutorial: 12bit ADC
- Hercules How to Tutorial: CAN Communication
- Hercules How to Tutorial: Ethernet
- Hercules How to Tutorial: Force a Clock Monitor Failure
- Hercules How to Tutorial: PCB Design Considerations
- Hercules How to Tutorial: Selecting a JTAG Emulator
- Hercules How to Tutorial: Turning on the LEDs
- Hercules How to Tutorial: Using Code Composer Studio UniFlash

➔To access them : https://training.ti.com/hercules

Functional safety 4-part training series:
https://training.ti.com/functional-safety

Hercules Support – Online Resources

Hercules Web Page: www.ti.com/hercules

- Data Sheets
- Technical Reference Manual
- Application Notes
- Software & Tools Downloads and Updates
- Order Evaluation and Development Kits

Engineer 2 Engineer Support Forum:
www.ti.com/hercules-support

- News and Announcements
- Ask Technical Questions
- Search for Technical Content

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