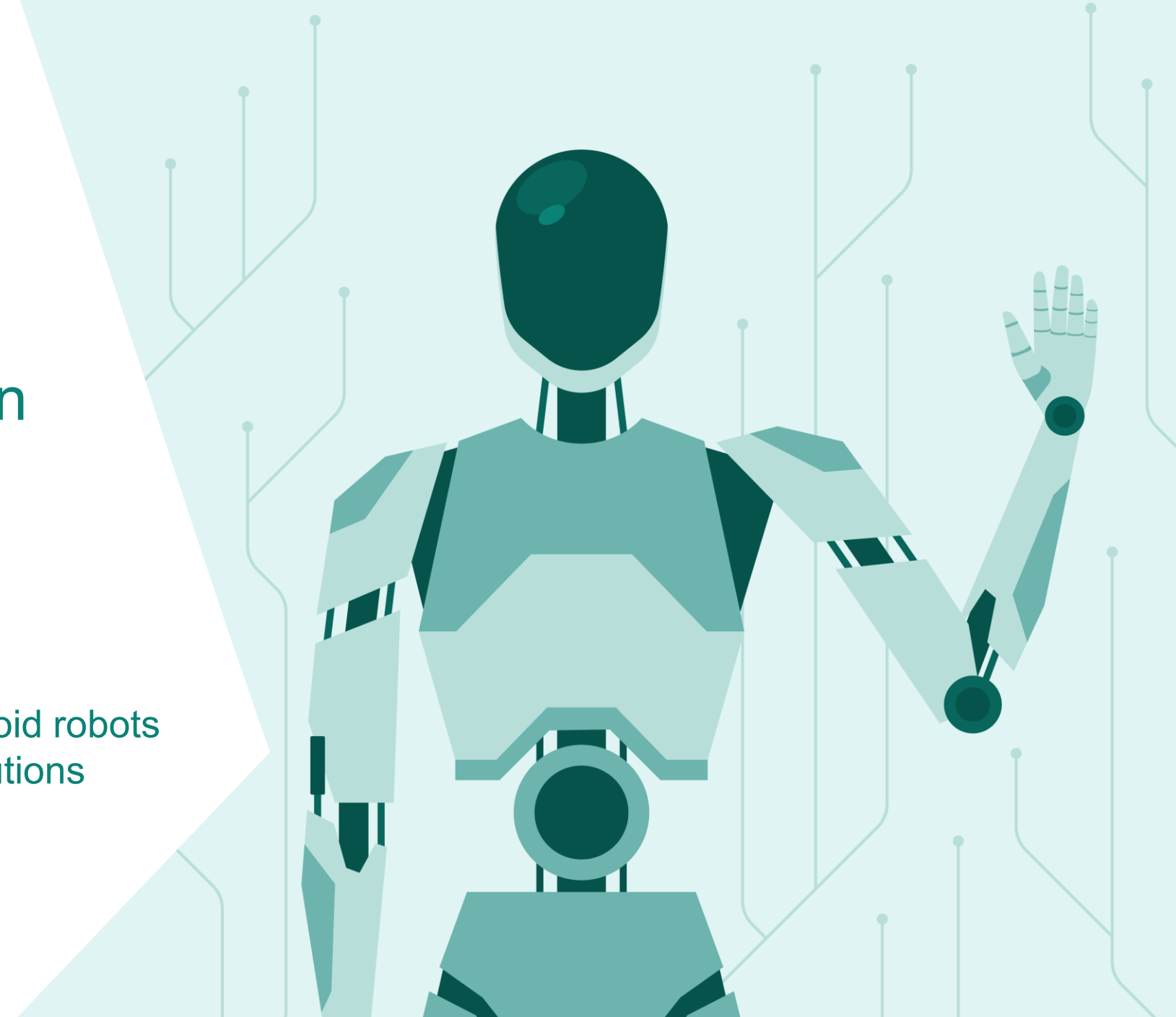
Application presentation
Humanoid robots

Unlocking the full potential of humanoid robots with cutting-edge semiconductor solutions



June 2026

Why will Robotics matter?

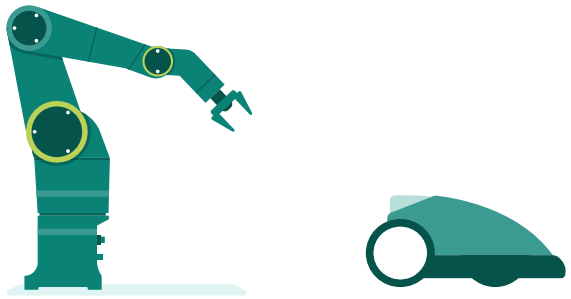
$1.7t

The humanoid robotics market is projected to reach 1.7 trillion US dollars within the next 25 years

300m

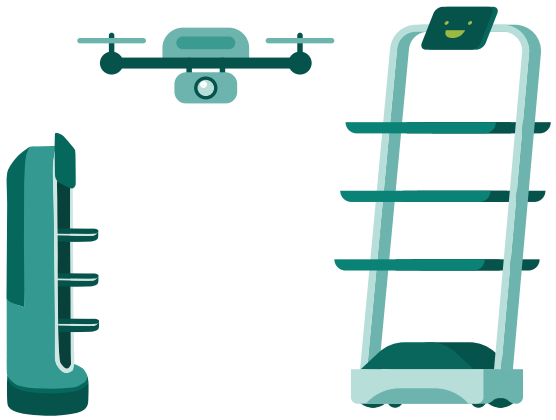
An estimated 300 million humanoid robots operating worldwide in factories, hospitals, and homes by 2050

Robotics: An evolving application across different industries



Established robotic assistance

- Cobots (Industrial)
- Logistic robots
- Lawn mowing robots
- Robot vacuums
- Drones (Consumer)
- Drone (Agriculture, Inspection)



Up and coming robotic assistance

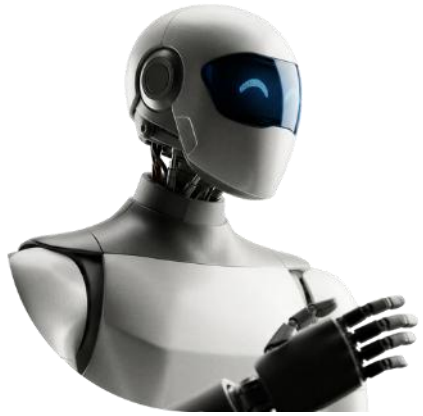
- Inspection robots
- Hospitality robots
- Drones (Transportation
- Cobots (Consumers)

Human level robotic assistance

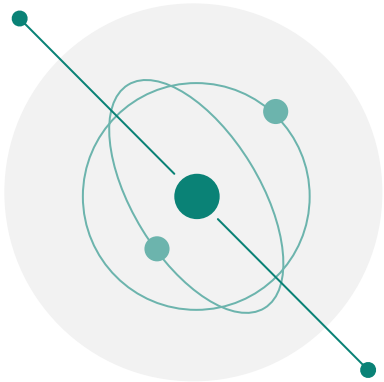
- Humanoid robots
- Exoskeletons
- Logistic robots (Outdoor)

Past | Present | Future

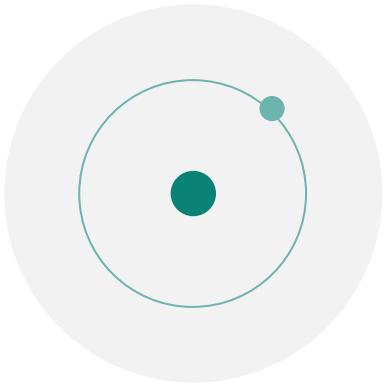
The next era of AI is emerging – Physical AI



Physical AI



Agentic AI



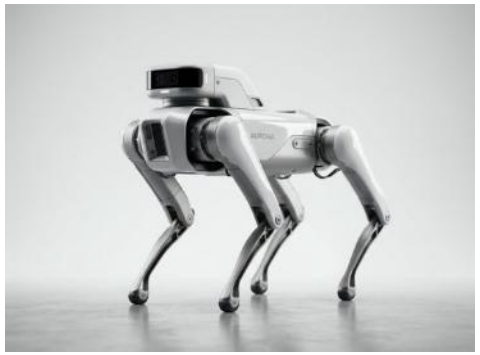
Generative AI

Robot form factors evolve, but the underlying electronics foundations remain the same

Humanoid

Mobile manipulator

Legged robots



Fixed industrial

Common electronics foundation

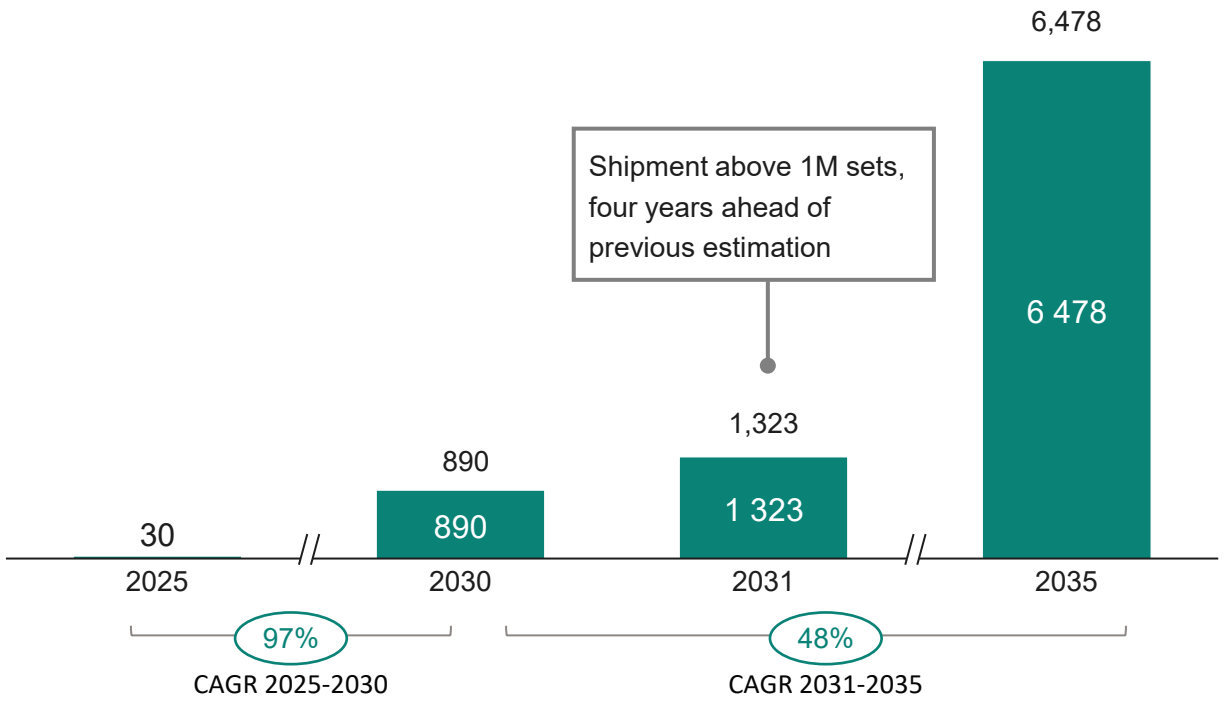
- **Sensing**
- **Compute and Control**
- **Battery management system (BMS)**
- **Connectivity**
- **Motor control**
- **Charging**

Source: ABI research (2025), Goldman Sachs (2025)

Humanoid robots: The rising robotics segment

Goldman has upwardly revised its global humanoid robotics forecast recently…

Global Humanoid Robot Market Size Estimation, 2025-2035
Unit: K sets



Data source: Goldman humanoid robotics report

…driven by the changes of technology, cost and policy

AI & Tech Innovations
- End-to-End AI Integration, streamlining AI development with a direct input-to-output model
- Unprecedented progress e.g., Established OEMs vs. Startup Culture

Cost Reductions on Hardware
- Notable reduction in BOM costs, likely by 40% according to Humanoid Robotics makers
- Optimization in design and manufacturing techniques

Industrial spillover
- Poised to leverage technological advancements and economies of scale developed in the EV sector, particularly in areas such as actuator control and ADAS and Functional Safety (FuSa)

Infineon solutions for every humanoid robot functional block

Battery charging

AC-DC conversion
Microcontroller:
XMC™ 1000, PSOC™ 4, PSOC™ Control C3P
Power MOSFETs/HEMTs:
OptiMOS™, CoolMOS™
CoolGaN™ & CoolSiC™
Gate drivers: EiceDRIVER™

Wireless charging
Wireless charging ICs
Authentication: OPTIGA™ Trust

USB-C Charging
USB-PD Charging ICs

Battery management System (BMS)

Battery management
Microcontroller: XMC™, PSOC™, AURIX™
Cell monitoring and balancing ICs: TLE90xx
Isolated transceiver ICs
Current sensing: XENSIV™ Current Sensors

Memory
Serial F-RAM (Ferroelectric RAM)

Protection
OptiMOS™ & OptiMOS™ Linear FET
XDP™ 7xx Protection & Hot Swap ICs ICs

Battery authentication
OPTIGA™ Authenticate S

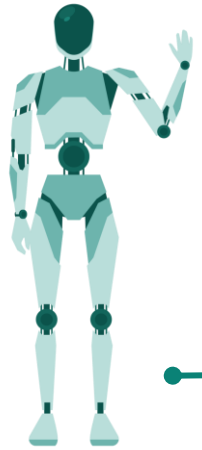
Power management

Voltage conversion
LDO & Step-down switching regulator
Single and dual MOSFETs: OptiMOS™

Power management Ics
XDP™ P11xx Digital Power Controllers

ESD Protection
Low capacitance and multi-purpose ESD diodes

Charger
Wireless charging
BMS
Smart power



BLDC motor control

Motor control

Microcontroller
XMC™ 1000, 4000, 7000
PSOC™ Control C3M
PSOC™ 4 & 6
AURIX™ TC3, TC4

Power MOSFETs
OptiMOS™, StrongIRFET™ MOSFETs
CoolGaN™ HEMTs

Gate Driver & Integrations
EiceDRIVER™
MOTIX™ Motor control ICs

Magnetic Sensors
XENSIV™: Position and Current Sensors

Memory
Standard SPI NOR Flash
Serial F-RAM (Ferroelectric RAM)

PMICs
OPTIREG™

Artificial intelligence
HMI

Compute and control

Microcontroller
XMC™ 4000, XMC™ 7000
PSOC™ 6, PSOC™ Edge
AURIX™ (Functional Safety)

HMI & IoT Controller
PSOC™ 4 & 6, PSOC™ EDGE

Memory
SEMPER™ NOR Flash
HYPERRAM™ (pSRAM)

PMICs
OPTIREG™

Sensing
Wireless communication
Security

Sensors

XENSIV™ 24/60 GHz radar
Obstacles and gesture detection, materials differentiation, speed over ground

REAL3™ 3D IR ToF sensors
Objects recognition, obstacles avoidance, navigation and tracking

XENSIV™ MEMS microphones
Sound detection / HMI, objects detection and tracking

Dexterous Hand Sensor
XENSIV™ 3D magnetic sensor
XENSIV™ Pressure sensor
PSOC™ 4 & PSOC™ 6 w/ CAPSENSE™

Ultra-wide-band UWB

Connectivity & Security

Ethernet Switches
BRIGHTLANE™

CAN transceiver
TLE9251VLE, TLE9351VSJ

USB – Serial bridge
EZ-USB™

Wi-Fi & Bluetooth® / BLE
Connected MCUs: PSOC™ 4 BLE, PSOC™ 6 BLE, BT®/BLE SoC and modules
Combos: AIROC™

Embedded-SIM Connectivity
OPTIGA™ Connect IoT

Security
OPTIGA™ Trust M, TPM

Memory
Standard SPI NOR Flash

Infineon offers complete solutions for compact, efficient and precise motor control systems

Microcontrollers

PSOC™ Control C3

XMC™

AURIX™

Discrete

MCU + GDU: MOTIX™

Gate Driver

EiceDRIVER™ & MOTIX™

DSO-8 MLPQ 4x4 TSSOP-28

VQFN-48 SOT-23 PG-TSNP

& many more packages

Discrete

GDU + Switch: MOTIX™

MCU + GDU + Switches: MOTIX™

Switches

OptiMOS™

CoolGaN™

& many more packages

Discrete

Sensing

XENSIV™ Position Sensor

TLE5501, TLE5014(D)
High resolution: TLE5009(D)
& TLx5012B(D)

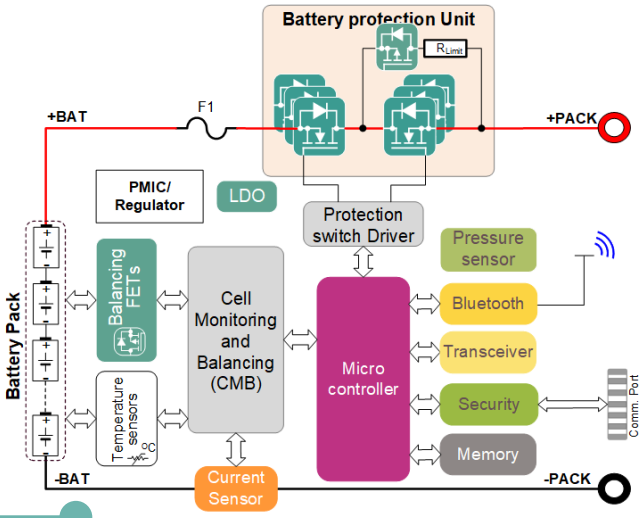
XENSIV™ Current Sensor

TLI4971, TLx5570/72

Discrete

Battery Management Systems (BMS)
Safe, secure, and reliable

BMS



Bluetooth

AIROC™ Bluetooth® LE
CYW20820
CYW4373E

Security

OPTIGA™ - SLE95401

Current sensor

XENSIV™ TLI4971, TLx5570//72

Protection

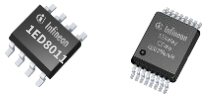
Balancing MOSFETs

Small Signal MOSFET

Protection FETs

OptiMOS™ 6, LinearFET™, CoolGaN™

High-side Drivers



EiceDRIVER™

& many more packages

Cell Balancing & Monitoring

TLE9012DQU
- 12-Cell Voltage monitoring

TQFP-48

TLE9018DQU
- 18-Cell Voltage monitoring

TQFP-80

MCU

PSOC™ 4 & 6

XMC™ 7000

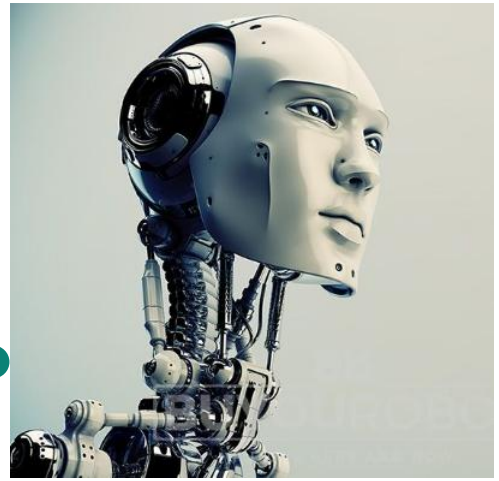
AURIX™

TLE925X

CAN Transceiver

& many more packages

Robotics brain
Compute, connectivity, memory & HMI



HMI

Cap-sense & Display

PSOC™ 4 & 6 family

PSOC™ Edge family

Memory

Memory

EXCELON™ Ferroelectric RAM

Non-volatile SRAM and SRAM

SEMPER™ Quad-SPI NOR flash

Wired & Wireless Connectivity

Ethernet*

Wi-Fi 5

Wi-Fi 6

Main Control and Safety Companion MCU

PSOC™ Control C3

XMC™ 7000

AURIX™

Low-latency real-time capable, secure and functionally safe MCUs

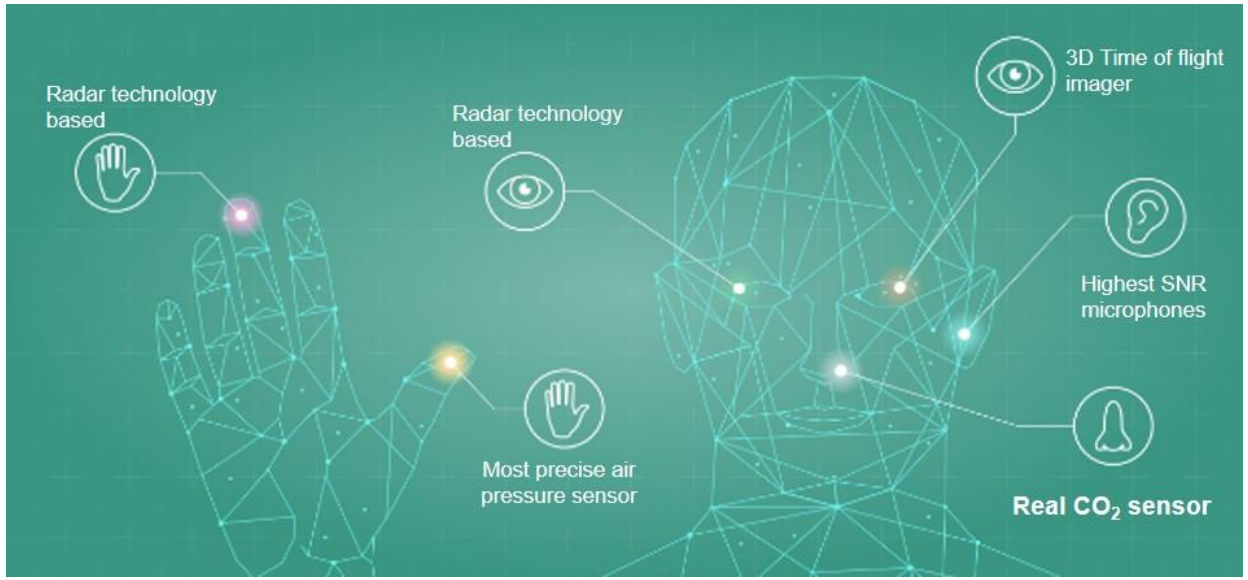
MPU Brain

NVIDIA Jetson™

Rockchip™

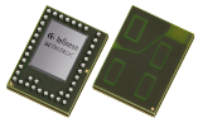
**All Ethernet PHY, switch and bridge products and related software may only be used in automotive, industrial and robotics applications."*

Advanced sensor solutions
Eyes and ears for robots



Radar


BGT24LTR22


BGT60TR13C


BGT60ATR24C

- XENSIV™ 24 & 60 Ghz radar

Time-of-Flight

REAL3™ hybrid ToF

- Object detection & obstacle avoidance
- SLAM capable for navigation

Silicon microphones

- Sound detection for HMI
- Objects detection for navigation

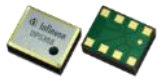
Other sensors

CO2 sensors

- Air quality monitoring for smart air purifier & controlled ventilation

Pressure sensors

- Touch sensing for Grippers
- Height / altitude sensing



Benefit from a wide range of MCUs and leverage our expertise in automotive and functional safety

Auto / Functional Safety

Consumer / Industrial

MOTIX™
Cortex-M0 and M3, ASIL-B
Up to 256KB Flash
Motor Control SoC

PSOC™ Multitouch
Touch controller SoC
Touchscreen, Slider, Touchpad
Wet-finger tracking

Auto PSOC™
ASIL-B
Up to 384KB Flash
CAPSENSE

TRAVEO™ T2G
Dual Cortex-M4/M7 and M0+
ASIL-B, Up to 16MB Flash
HSM, GPU (Cluster)

PSOC™ Fingerprint
Touch controller SoC
Capacitive fingerprint solution
Support multi-surface solution

Auto PSOC™ HV
ASIL-C
Up to 384KB Flash
Up to 42V tolerant MCU

XMC7000
Dual Cortex-M7 and M0+
Up to 350MHz and 8MB Flash
Motor and power control

XMC1000
Up to 48MHz and 200KB Flash
CORDIC Math co-processor
CCU8 timer

XMC4000
Up to 144MHz and 2MB Flash
Motor and power control
EtherCAT® support

PSOC™ 4
Up to 48MHz and 384KB Flash
Industry leading CAPSENSE™
Mixed-signal functionality

PSOC™ 6
Dual Cortex-M4 and M0+
Up to 150MHz and 2MB Flash
Ultra-low-power with security

FM0+
Up to 40MHz and 128KB Flash
Entry level USB

FM4
Up to 200MHz and 2MB Flash
High-performance motor control

PSOC™ C3 Performance
180MHz M33 + PPCA
25Msps ADCs
CORDIC Math co-processor

PSOC™ C3 Main
Up to 180MHz M33
12Msps ADCs
CORDIC Math co-processor

PSOC™ C3 Entry
Up to 100MHz M33
6Msps ADCs
CORDIC Math co-processor

AURIX™ TC4x
Up to 6x Tricore ASIL-D
Up to 24MB Flash
PPU, SRM, Lockstep, PCIe

AURIX™ TC3x
Up to 6x Tricore ASIL-D
Up to 16MB Flash
HSM, ETH, Lockstep, CAN FD

AURIX™ TC2x
Up to 3x Tricore ASIL-D
Up to 8MB Flash
HSM, ETH, Lockstep, CAN FD

PSOC™ Edge E86
400MHz M55/U55 and M33
Up to 9.5MB SRAM, 4MB NVM
Camera, GPU, Audio, Analog

PSOC™ Edge E84
400MHz M55/U55 and M33
Up to 6.5MB SRAM, 0.5MB NVM
GPU, Audio, Analog

PSOC™ Edge E83
400MHz M55/U55 and M33
Up to 5.5MB SRAM, 0.5MB NVM
Audio, Analog

PSOC™ Edge E81
400MHz M55 and M33
Up to 5.5MB SRAM, 0.5MB NVM
Audio, Analog

32-bit Arm® Cortex®-M0/M0+

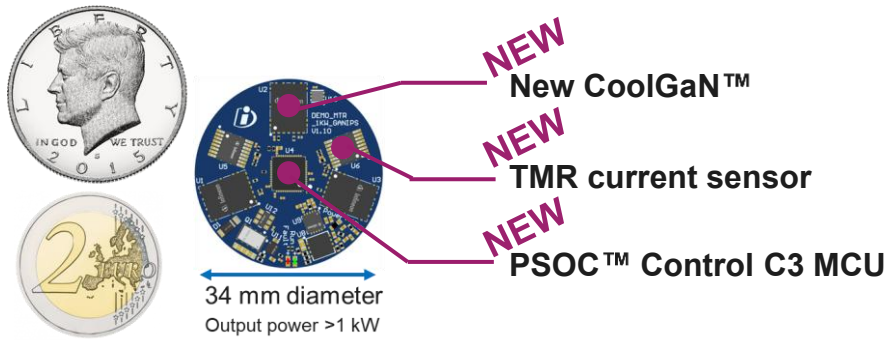
32-bit Arm® Cortex®-M4/M33/M7

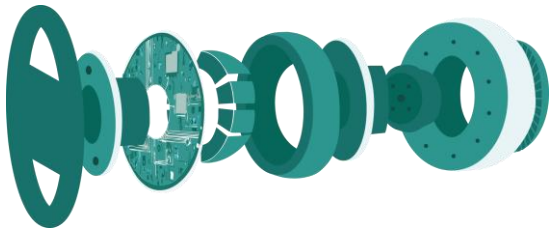
32-bit TriCore™

32-bit Arm® Cortex®-M55/M85, U55, M33 with ML accelerators

Infineon CoolGaN™ for robotics: Driving the new benchmark in power density and performance

Compact motor drives where space is tight, and heat dissipation limited





Benefits for humanoid robot developers

Small form factor

- ✓Enables embedding the inverter within the motor, addressing space constraints
- ✓Ideal for compact and tightly integrated humanoid robot designs

Improved system efficiency

- ✓Reduces motor core losses, especially at higher switching frequencies (fsw)
- ✓Leads to longer operational times and better performance of humanoid robots

Simplified and flexible system design

- ✓GaN integrated power stage combined with a new controller & current sensors
- ✓Flexible enough to fit any form factor, easing the integration process
- ✓Reduces the complexity of system design, allowing developers to focus on other aspects of the robot

CoolGaN™ enables higher end-to-end system efficiency and decreases motor core losses, i.e. less overheated motors!

Switching frequency: 20 kHz

- Overall system efficiency: **89%**
- Motor temperature: **68°C**
- Motor current ripple: **10 A_{pp}**

Motor runs 13°C cooler

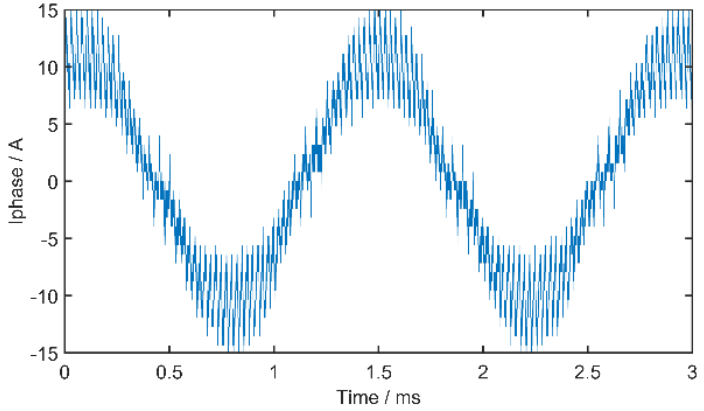
with 5x less torque ripple

Switching frequency: 100 kHz

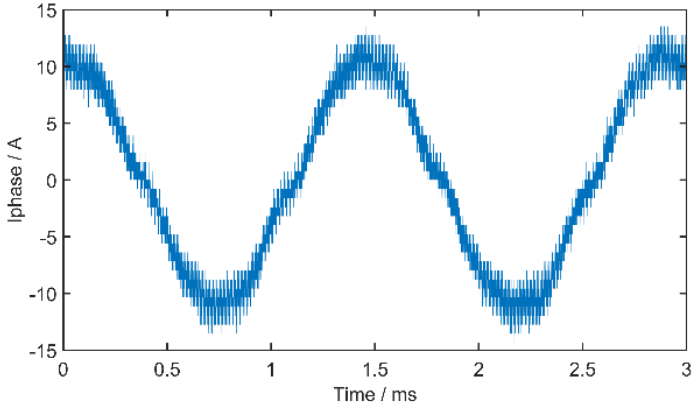
- Overall system efficiency: **96%**
- Motor temperature: **55°C**
- Motor current ripple: **2 A_{pp}**

Motor loss	↓↓↓
Inverter loss	↑
System loss	↓↓

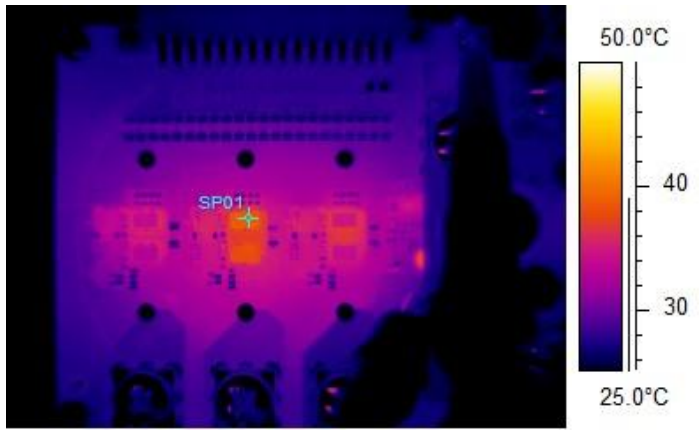
Phase current waveform:



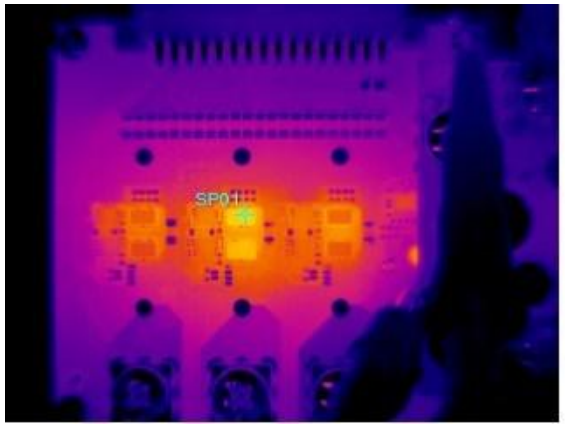
Phase current waveform:



CoolGaN™ board thermal image:



CoolGaN™ board thermal image:

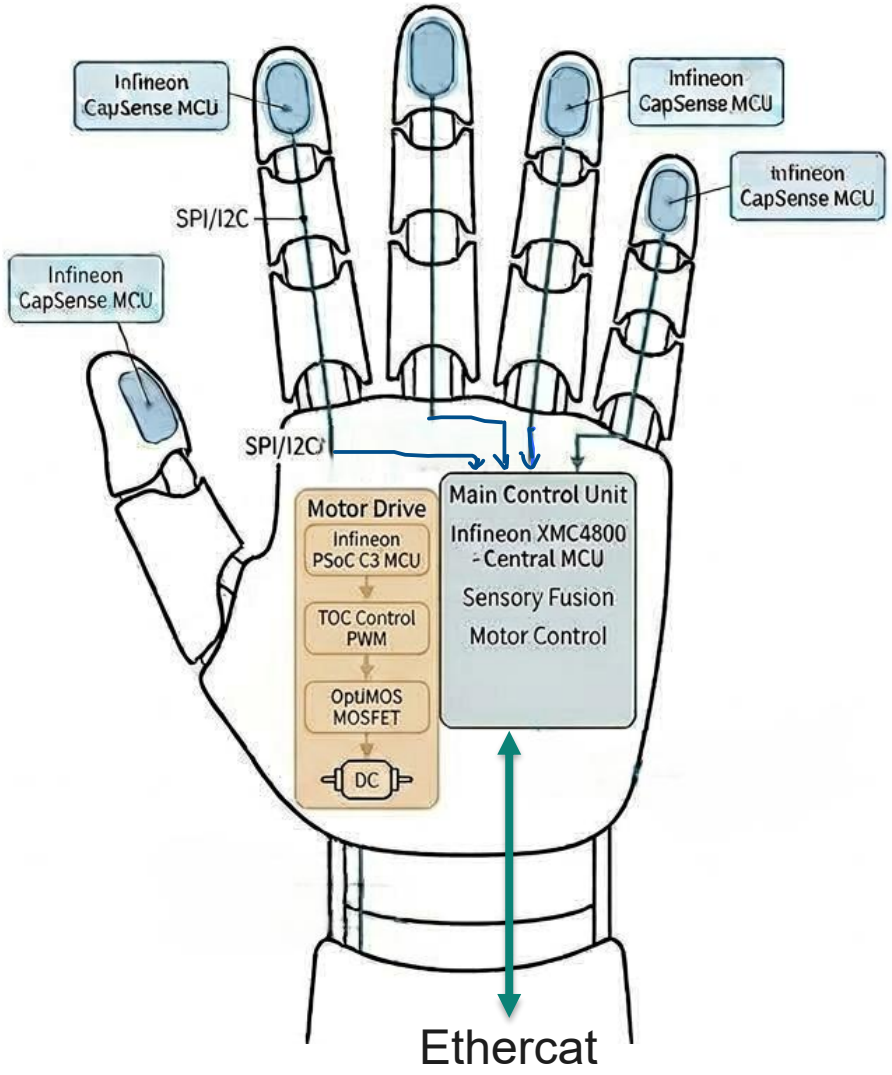


Test condition: 48 V, 308 W, 4000 RPM (min. UAV hovering speed)

Dexterous Hand

Tactile sensing

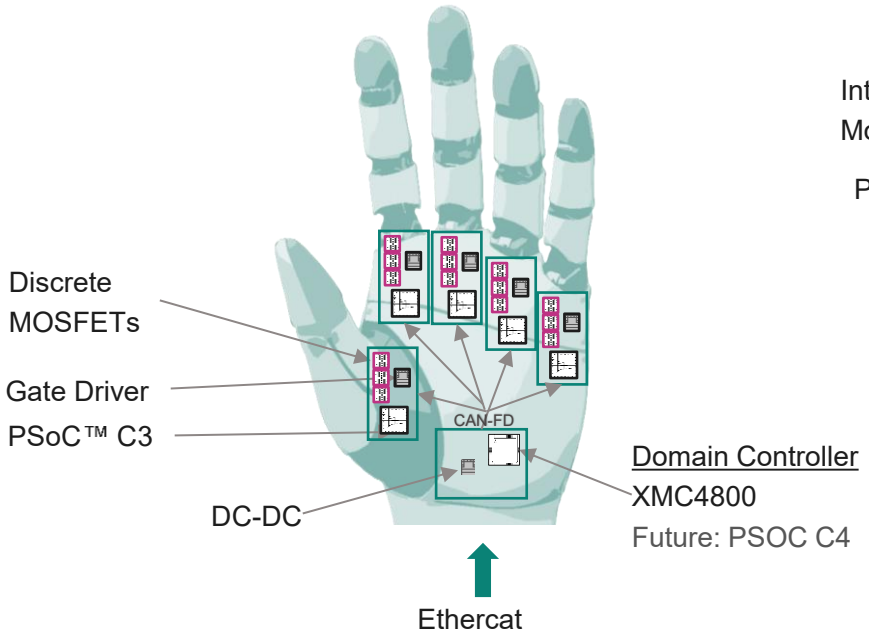
- Humanoid has to grasp, hold, and manipulate objects with delicacy, precision and speed. Tactile sensors enable:
  - Stable grasping
  - Dexterous manipulation
  - Texture and object recognition
  - Material perception
- Humanoid & AMR has to interact safely with humans:
  - Detecting and responding to human touch during shared tasks, such as handing over objects
  - Ensuring safety during physical contact
  - Interpret human touch gestures to understand intent or emotion and respond accordingly

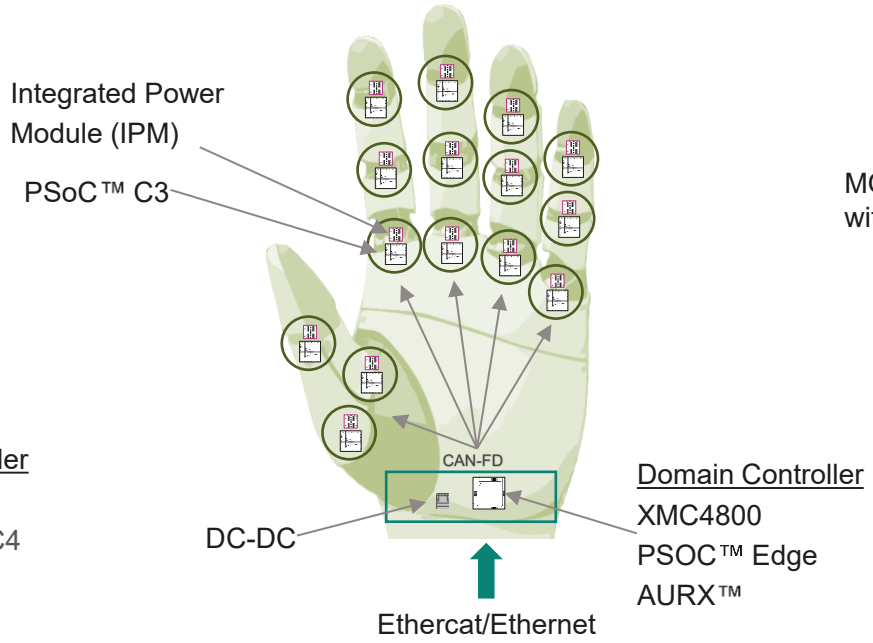


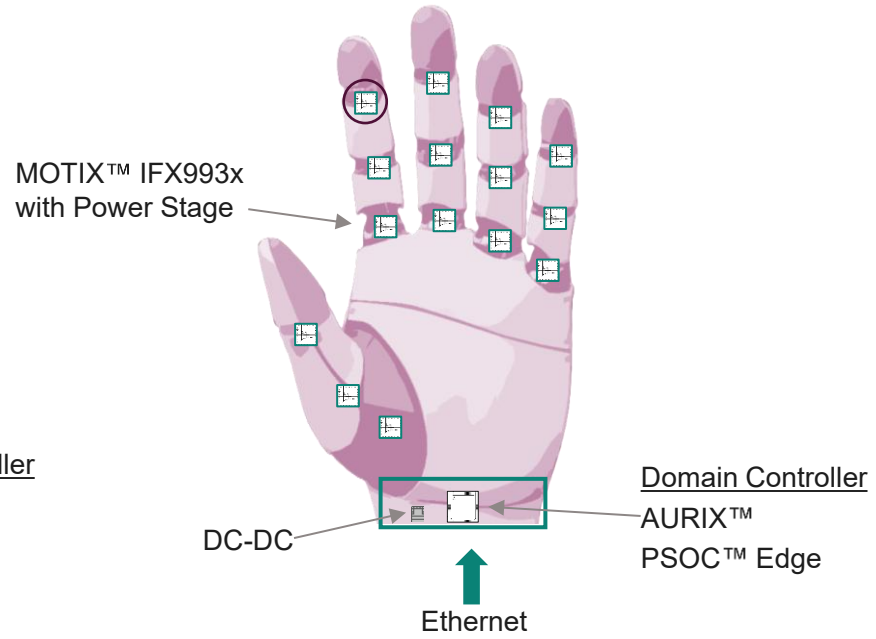
Motor drive

- Motor drives in the dexterous hands of humanoid robots are designed to simulate human hand anatomy, aiming to achieve high-precision manipulation, strong grasping capabilities, and adaptability in complex, unstructured environments.
- Object Rotation and Translation: Motors enable delicate reorientation of objects (e.g., rotating a cylinder or a screw) using finger coordination.
- Finger Gaiting: The drive system controls the frequent opening and closing of fingers to "walk" them along the object's surface for continuous reorientation.
- Fine Positioning: The motor drive allows precise translation and rotation of objects along multiple axes, mimicking human dexterity for tasks such as assembly

Humanoid Dexterous Hands: Semi and fully integrated solution paired with right fit MCUs enable advanced solutions







Discrete / centralized

- **Hand palm concepts** with low degrees of freedom (DOF) esp. for grippers
- One central MCU with **Ethercat or Ethernet interface**
- Individual motor drive PCB for each joint
- Discrete solution offers **flexibility and can scale**, but uses plenty of space

Semi-Integrated / hybrid

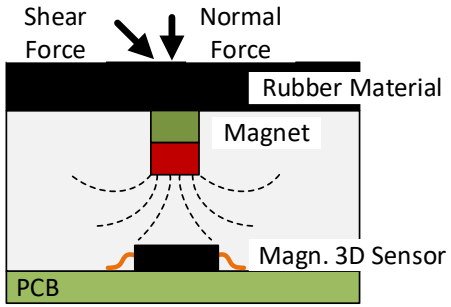
- Concept proposal **medium amount of DOF** based on Integrated Power Module (IPM), Half-Bridge or B6-Bridge
- **Located in the palm**: multiple medium µC typically drive 2-4 motors per µC
- Single large PCB or one for each finger
- Usage of gear, linkages or tendon systems

Monolithic / decentralized

- Optimized proposal for **high amount of DOF**
- **Smallest footprint** (PCB of 10-12mm in diameter)
- **Fully integrated in finger** joint on motor distributing power dissipation
- **Reduction of mechanics and complexity**
- Hybrid transmission possible: fully direct or with geared / linkage systems

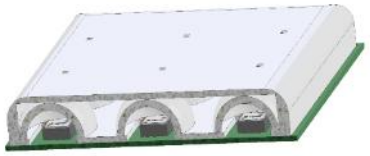
Force and touch sensors

Magnetics

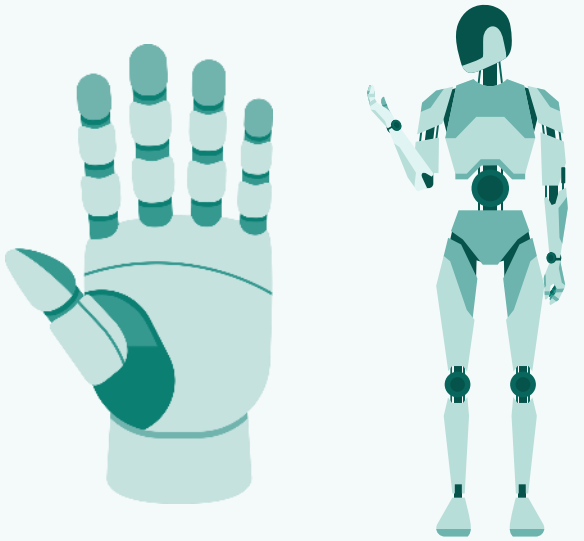


Magnet embedded in **flexible finger tip** above Hall sensor

Pressure



Array of pressure sensors used as tactile skin

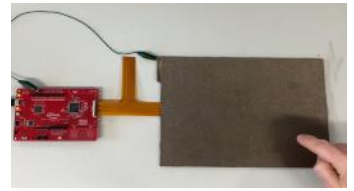


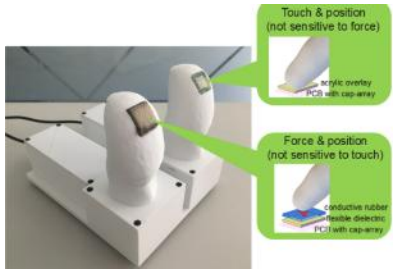
- **Different sensors** available for force and tactile sensing
- **Winning technology** not yet determined
- **Coexistence of multiple solutions** in parallel

Infineon provides multiple options

Please engage with customers and partners to identify ideal solution!

Capacitive





Capacitive electrodes embedded in flexible material

Sound/vibration

Rubber tip sliding across surface to detect material

Support Material

Quick links
Infineon product offering for humanoid robots

Microcontrollers
- XMC1000
- XMC4000
- XMC7000
- PSOC™ 4
- PSOC™ 6
- PSOC™ Control C3
- PSOC™ Edge
- AURIX™ TriCore™
- TRAVEO™

Sensors
- XENSIV™
- XENSIV™ magnetic sensors
- XENSIV™ current sensors
- XENSIV™ radar sensors
- XENSIV™ MEMS microphones
- XENSIV™ pressure sensors
- REAL3™ ToF 3D image sensors

ICs
- Wireless charging ICs
- OPTIREG™ PMICs
- Cell monitoring & balancing ICs
- Isolated UART transceiver ICs
- ISOFACE™ digital isolators
- LDO voltage regulators

Discrete switches
- OptiMOS™ MOSFETs
- StrongIRFET™ MOSFETs
- CoolGaN™ HEMTs
- CoolMOS™ MOSFETs
- CoolSiC™ MOSFETs
- TRENCHSTOP™ IGBTs

Memory
- SRAM
- nvSRAM
- EXCELON™ FRAM
- SEMPER™ Quad-SPI NOR flash

Gate driver ICs
- EiceDRIVER™
- MOTIX™ 3-phase BLDC

Security
- OPTIGA™ Trust
- OPTIGA™ Connect
- OPTIGA™ Authenticate

Connectivity
- AIROC™ combos
- AIROC Wi-Fi
- AIROC Bluetooth®
- PSOC™ 4 BLE
- PSOC™ 6 BLE

Controllers
- EZ-USB™ serial bridge
- CAPSENSE™
- XDP™ Protection ICs
- XDP™ Digital power controllers

Diodes
- ESD protection
- AF Schottky diodes

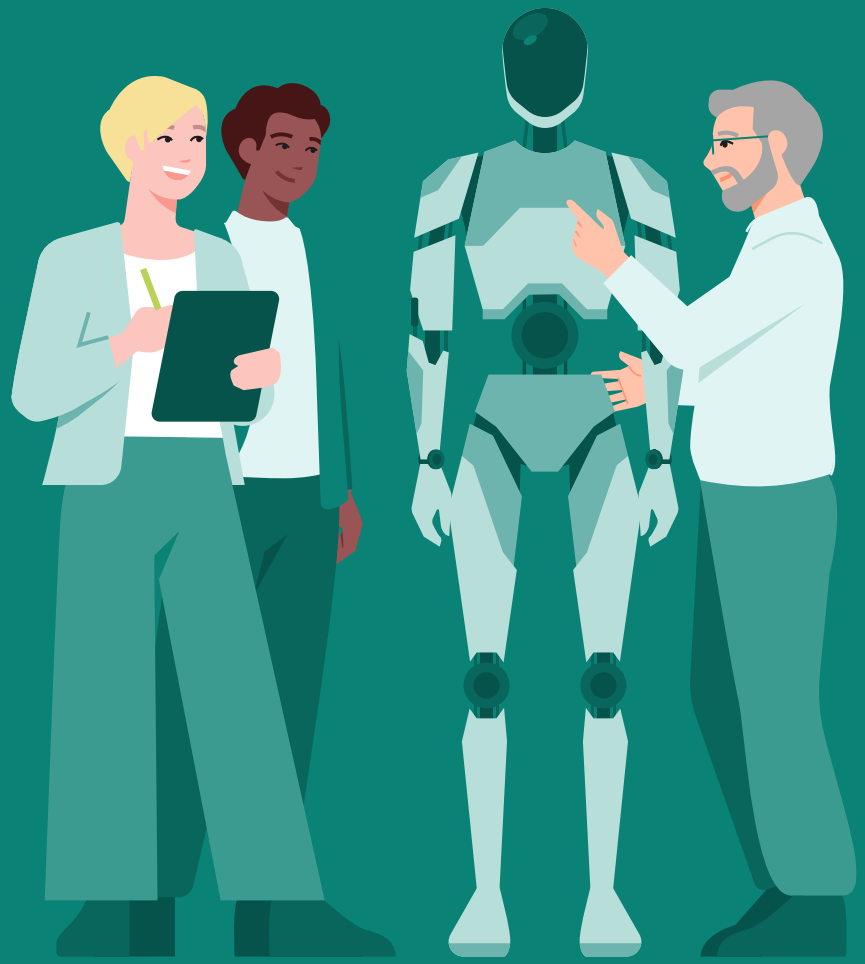
Integrated solutions
- MOTIX™ Motor control ICs
- CIPOS™ IPMs

Modules
- Si/SiC modules
- IGBT modules

Infineon robotics application
- Robotics landing page
- Robotics development platform

Let’s bring Physical AI to life

Together!



Scan for more information


Infineon