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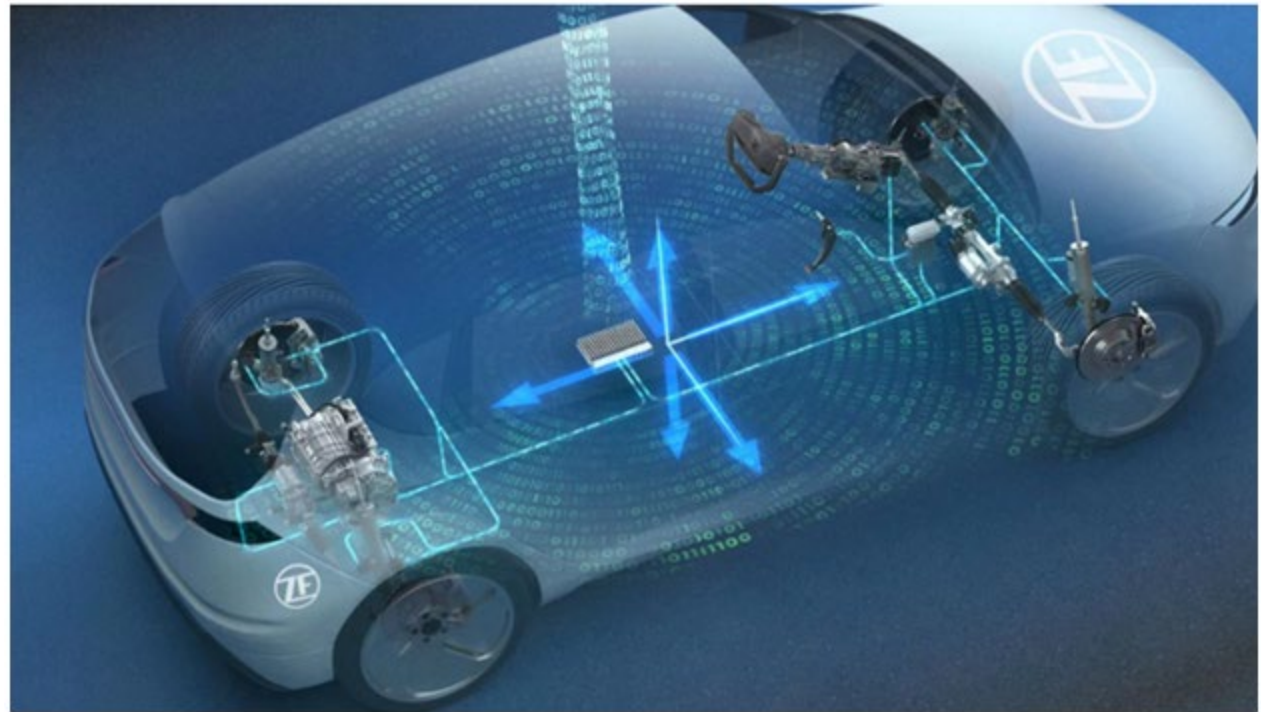
# Passenger Car Intelligent Chassis and Chassis Domain Controller Research Report, 2023

Nov. 2023

# Intelligent chassis

Passenger Car Intelligent Chassis and Chassis Domain Controller Research Report, 2023, released by ResearchInChina combs through three integration trends of brake-by-wire, steer-by-wire, and active suspension, and researches chassis control strategies, chassis domain controller products & planning of suppliers and OEMs.

As one of core technologies of vehicle intelligence, intelligent chassis can not only satisfy the requirements of high-level autonomous driving, but also bring safer and more comfortable driving experience to occupants and provide hardware support for vivid imagination of future intelligent cockpit. At this stage, intelligent chassis is composed of sub-components such as brake-by-wire, steer-by-wire and active suspension, and controls the chassis through digital signals to realize active adjustment at six degrees of freedom in lateral, longitudinal, and vertical directions, and provide bearings for vehicle autonomous driving system, cockpit system, and power system.



Source: ZF

# Intelligent chassis shows three major trends (1)

## Trend 1: Chassis single-system integration continues to increase

Chassis single-system integration is mainly X-by-wire system integration, of which brake-by-wire system integration is the most typical.

- For steering system, the mainstream core actuator is still EPS (electric power steering), while steer-by-wire systems are less used. In the future, the key development trend of steer-by-wire system is integration of steer-by-wire structure and mechanical redundant structure.
- Mainly based on air suspension, active suspension further adds sensors and electronic control systems for active adjustment of its height, stiffness and damping according to actual road conditions, so as to enable fine system control in driving/parking state and improve driving comfort.

\* Representative route of brake-by-wire integration is EHB integrated with ABS/ESP, often known as One Box solution that features high integration and low cost and can meet autonomous driving requirements in combination with RBU (redundant brake unit), having been the most marketable X-by-wire product at this stage.

In terms of brake-by-wire integration, leading companies such as Bethel Automotive, Tongyu Automotive and TruGo Tech have already released relevant products.

- Bethel Automotive's wire-controlled brake system (WCBS), a One Box solution, integrates vacuum booster, electronic vacuum pump, master cylinder, ESC and EPB, and features high integration, light weight, quick braking response and low overall costs. WCBS (OneBox) came into mass production in June 2021, and was mass-produced for more than 20 models in 2022.
- Tongyu Automotive's Electronic Hydraulic Braking System with Integrated Electrical Parking Brake (EHB-EPBi) integrates the EPB control module into the EHB controller to reduce components and lower costs. As of October 2023, Tongyu Automotive has shipped more than 100,000 units of EHB-EPBi products. In addition, its integrated brake-by-wire (iEHB) product integrates five functional modules, namely, EHB, ESC, redundant EPB, intelligent tire monitoring and chassis domain control, which enables such functions as basic braking, brake-by-wire, park-by-wire, and stability control. Tongyu Automotive iEHB has been designated exclusively by OEMs and will be production-ready in late 2023.

\* TruGo Tech's Electric Hydraulic Booster Integrated (EHBI), a One Box solution, integrates functions of ABS, ESC, E-booster, and EPB, and supports multi-sensor fusion, providing vehicles with good pedal feeling and emergency braking capability. EHBI (Onebox), officially launched in October 2022, combines over 30 intelligent functions such as booster control, cooperative brake energy recovery, wheel anti-lock braking control and body stability control.

# Intelligent chassis shows three major trends (2)

## Trend 2: Chassis intra-domain integration enables cooperative XYZ control

Under the cooperative control by the chassis domain controller, fusion control of brake, steer, suspension and other X-by-wire systems allows for quicker dynamic response, shorter pressure build-up time, fine-grained precision brake-by-wire, steer-by-wire, and precision adjustment of electronic suspension parameters (flexibly adjusting damping, stiffness, height, and vibration control), and it can constantly and actively learn road conditions and environmental patterns to continuously improve chassis comfort performance.

Realization of Cooperative XYZ Control by Intelligent Chassis Domain Controller of Typical Suppliers

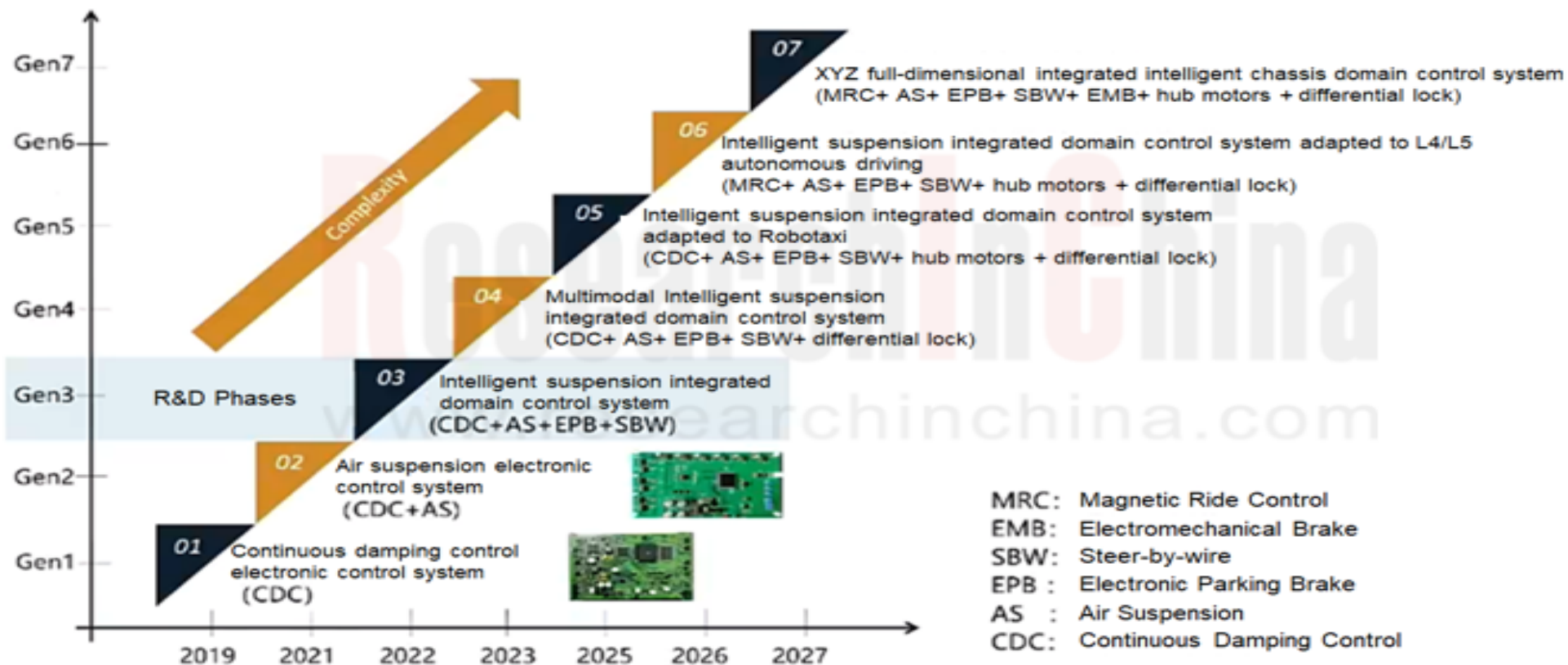
Typical Supplier	Chassis Domain Controller	Cooperative Control	Overview
China Vagon	Chassis Domain Control Unit (CDCU)	Brake + steer + suspension	Integrate functions of steering, braking, suspension and accelerator, as well as motor control, battery management, and vehicle control; put on sale in 2022H1.
Tongyu Automotive	Chassis Domain Control Unit (CDCU)	Brake + steer + suspension	CDCU 1.0 mainly integrates functions of suspension height control, damping control, dual-EPB control and rear-turn control, and is scheduled to be mass-produced in 2024. For CDCU 2.0, based on conventional stability functions, the additional functions of synergistic integration of wheel dynamic stability and vehicle stability control are developed, giving full play to synergy of chassis drive, braking, and steering systems. It is planned to complete demo development in 2024 and realize mass production and installation in late 2025.
LeeKr Technology	C-Trio™ Intelligent Chassis Domain Controller	Brake + steer + suspension	C-Trio™ represents longitudinal, lateral and vertical modules in chassis. By the end of 2023, core products of the Intelligent Chassis 1.0 will be fully implemented, realizing cooperative control of intelligent chassis brake-by-wire (longitudinal) + suspension-by-wire (vertical). In 2024, Intelligent Chassis 2.0 will start to realize by-wire control in longitudinal, lateral and vertical directions.
Global Technology	iCDS Chassis Domain Controller	Brake + steer + suspension	The "5-in-1" intelligent chassis domain controller iCDS serves as a central computing unit for electro-mechanical braking (EMB), and also integrates electronically controlled air suspension (ECAS), damper CDC, and EPS functions, as well as dual redundant EPB function.
Gates Electronics	Intelligent Chassis Domain Controller	Brake + steer + suspension	It provides a one-stop solution integrating vehicle steer, suspension, brake and other control functions in X, Y and Z directions. Considering functional safety and information security, it covers body height control, body stiffness control, continuous damping control, rear-wheel steering control, steering column position control and other functions.
NASN Automotive Electronics	Chassis Domain Controller NXU	Brake + steer + suspension	Integrating steer, brake and suspension control algorithms, NXU directly collects sensor signals such as APS, PTS, TAS, HSS, WSS and IMU to communicate with steer, brake, stability and suspension modules via CAN FD. It can be upgraded to Ethernet or FlexRay mode according to vehicle communication architecture, thereby realizing cooperative control in 6 degrees of freedom in lateral, longitudinal and vertical directions.

Source: ResearchInChina

# Gates Electronics' chassis integrated domain controller technology route

For example, according to Gates Electronics' chassis integrated domain controller technology route, the Gen3 realizes integration of suspension (CDC), air suspension (AS), steer-by-wire (SBW) and EPB (electronic parking brake); the Gen5 adds hub motors; the Gen7 adds EMB (brake-by-wire).

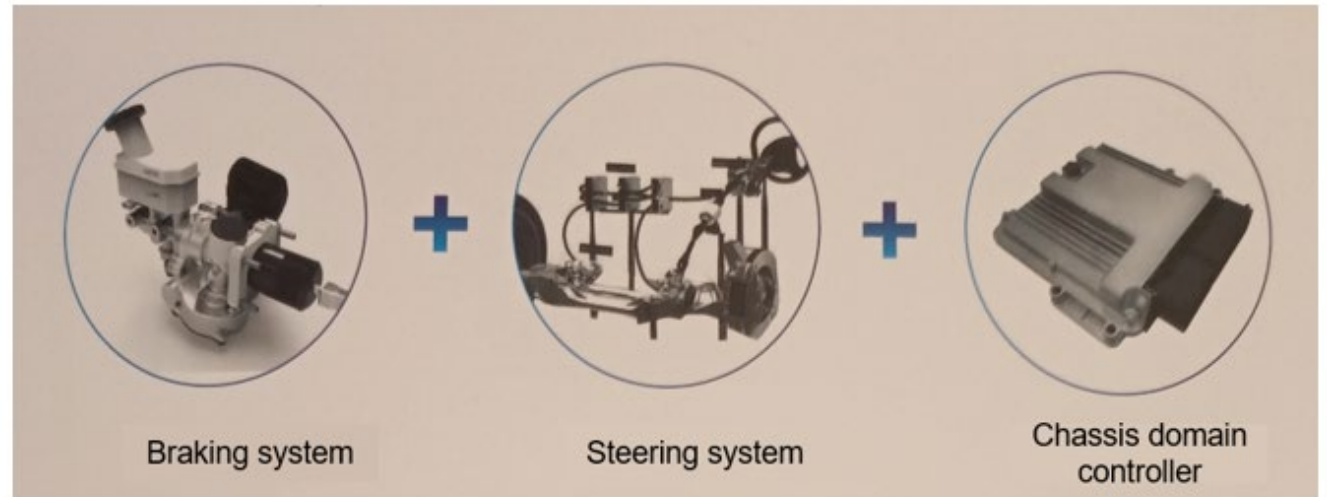
## Gates Electronics' Intelligent Chassis Suspension Integrated Domain Controller Technology Route



Source: Gates Electronics

As a representative supplier in the field of intra-domain integration, Tongyu Automotive makes product layout covering three major areas: intelligent braking system, steer-by-wire system and chassis domain controller. Tongyu Automotive is headquartered in Shanghai, and has two production bases in Jiading District of Shanghai and Yichun City of Jiangxi, with annual capacity of 1.5 million sets. As of October 2023, Tongyu Automotive has shipped nearly 400,000 sets of EHB systems, supporting over 100 vehicle models of over 80 well-known customers. After realizing mass adoption of X-by-wire systems in vehicles, Tongyu Automotive has started further developing EMB, steer-by-wire and chassis domain controller, heading in the direction of chassis intra-domain integration.

## Product Layout of Tongyu Automotive



Source: Tongyu Automotive

## Intelligent chassis shows three major trends (3)

### **Trend 3: Cross-domain integration of chassis domain with other domains brings bigger imaginable space to SDV**

Chassis intelligence includes not only intra-domain integration, but also cross-domain integration (with intelligent driving domain, body domain, power domain, etc.).

For example, China's first full-stack self-developed intelligent chassis controller (ICC) NIO introduced in June 2022 centralizes core components of conventional chassis, including more than 100 component controllers such as suspension, damper, and EBP, into one domain controller at perception and decision levels, which is intelligently called and controlled by software algorithms. ICC is adaptable to autonomous driving, and makes a quick response to the predictions and decisions made by intelligent driving systems, improving vehicle comfort. For instance, in a NAD scenario, the intelligent driving domain fusion control system can simultaneously control the vehicle's 4WD distribution, brake-by-wire, variable suspension and other functions, effectively improving the vehicle's dynamic performance. NIO ICC has already been mass-produced for NT2.0 models, such as ET7, ET5, and ES7.

### **Full-stack Self-developed Intelligent Chassis Controller (ICC) of NIO**



Source: NIO

Li L9 is equipped with Li Auto's self-developed central domain controller. All the hardware, systems and software of this controller are completely self-developed by Li Auto. The controller integrates functions of range-extended electric system, air-conditioning system, chassis system and seat control system. Li Auto's LEEA2.0 is three-domain architecture (central control domain + autonomous driving domain + intelligent cockpit domain), of which the central control domain contains power, body and partial chassis functions.

At the Auto Shanghai 2023, Continental first introduced its cross-domain vehicle control High Performance Computer (HPC), which is the first step in cross-domain integration of vehicle dynamic control functions. In addition to the original body control and gateway functions, this solution also integrates chassis control applications, and cross-domain vehicle control functions such as damping control, adaptive air suspension and chassis tuning. Continental's central dynamic control software acts as the command center that coordinates all vehicle motion actuators for longitudinal, lateral and vertical control. It is modular and scalable, serving as a unified interface that decouples driving functions from specific actuators and vehicle configurations.

## Continental's Cross-domain Vehicle Control High Performance Computer (HPC)



Source: Continental

In the future chassis cross-domain integration era, ECU and other control hardware as well as software algorithms all will be integrated into the chassis domain controller or the central computing unit, under which OEMs will tend to master their own control module technology. NIO, Li Auto and other OEMs with strong R&D strength have already held by way of self-development, and voices of conventional chassis suppliers are being weakened. In short, the chassis industry will see a big reshuffle in the intelligent transformation.



# Table of Content (1)

## 1 Overview of Automotive Intelligent Chassis Industry

- 1.1 Overview of Intelligent Chassis
- 1.2 Intelligent Chassis Features
- 1.3 Chassis System Evolution
- 1.4 Composition of Chassis-by-wire
- 1.5 Overall Architecture of Chassis-by-Wire
- 1.6 By-wire Redundancy
- 1.7 Investment and Financing in Intelligent Chassis Industry
- 1.8 Development Goals and Path of Passenger Car Intelligent Chassis
- 1.9 Development Goals and Path of Brake-by-wire
- 1.10 Development Goals and Path of Steer-by-wire
- 1.11 Development Goals and Path of Intelligent Chassis Development & Testing Platform
- 1.12 Goals and Path of Intelligent Chassis Standards and Specifications

## 2 Chassis-by-wire Market

- 2.1 Brake-by-wire Market
  - 2.1.1 Development History of Brake-by-Wire
  - 2.1.2 Brake-by-Wire Advantages
  - 2.1.3 Brake-by-Wire Technology Routes: EVP & EMB/EHB
  - 2.1.3 Brake-by-Wire Technology Routes: EHB & EMB
  - 2.1.3 Brake-by-Wire Technology Routes: Comparison of Two Box and One Box
  - 2.1.4 Major New Energy Models Equipped with Brake-by-wire
  - 2.1.5 Brake-by-wire Market Size: EHB to Reach RMB10.95 Billion in 2023
  - 2.1.5 Brake-by-wire Market Size: EHB to be Mass-produced and Launched in 2024
  - 2.1.6 Brake Product Layout of Suppliers
  - 2.1.7 Summary of Brake-by-wire Products by Suppliers

## 2.2 Steer-by-wire Market

- 2.2.1 Steering System Development Path
- 2.2.2 Steer-by-wire Systems
- 2.2.3 Structure of Steer-by-Wire System
- 2.2.4 Challenges in Implementing Steer-by-Wire System
- 2.2.5 Steer-by-Wire System Layout of Automakers

## 2.3 Suspension-by-wire Market

- 2.3.1 Overview of Suspension-by-wire
- 2.3.2 Classification of Automotive Suspension Systems
- 2.3.3 Value Comparison between Three Automotive Suspensions
- 2.3.4 Global Market Size of Suspension-by-wire
- 2.3.5 China Market Size of Suspension-by-wire
- 2.3.6 Variable Suspension Market Status: Installations and Installation Rate
- 2.3.6 Variable Suspension Market Status: Structure by Brand
- 2.3.6 Variable Suspension Market Status: Structure by Price
- 2.3.7 Suspension-by-wire Competitive Pattern
- 2.3.8 Mainstream Technology Routes of Suspension-by-wire
- 2.3.9 Air Suspension Systems
- 2.3.10 Air Suspension Working Principle
- 2.3.11 Air Suspension System Cost Breakdown
- 2.3.12 Air Suspension System Installation in Some Vehicles (Imported and Joint Venture)
- 2.3.13 Air Suspension System Installation in Some Vehicles (Local Brands)
- 2.3.14 Air Suspension Competitive Patterns
- 2.3.15 Electric Air Suspension System Integration (Open Loop & Closed Loop)
- 2.3.15 Electric Air Suspension System Integration - Open Loop System Example - Baolong Automotive
- 2.3.15 Electric Air Suspension System Integration - Closed Loop System Example - Tuopu Group

# Table of Content (2)

- 2.3.16 Air Suspension Market Status: Installations and Installation Rate
- 2.3.16 Air Suspension Market Status: Top 10 Brands
- 2.3.16 Air Suspension Market Status: By Price Range
- 2.3.17 E-Hydraulic Suspension Market Status: Installations and Installation Rate
- 2.3.17 E-Hydraulic Suspension Market Status: Top 10 Brands
- 2.3.17 E-Hydraulic Suspension Market Status: By Price Range
- 2.3.18 Electromagnetic Suspension Market Status: Installations and Installation Rate
- 2.3.18 Electromagnetic Suspension Market Status: Top 7 Brands
- 2.3.18 Electromagnetic Suspension Market Status: By Price Range

## 3 Chassis Domain Controller Market

- 3.1 Automotive Domain Controller
  - 3.1.1 Development Phases of Automotive Domain Controller
  - 3.1.2 Key Technologies of Automotive Domain Controller
  - 3.1.3 Background of Automotive Chassis Domain Controller
- 3.2 Automotive Chassis Domain Controller
  - 3.2.1 Classification of Automotive Chassis Domain Controller
  - 3.2.2 Automotive Chassis Domain Controller Associated Architecture
  - 3.2.3 Automotive Chassis Domain Controller Communication Networks
  - 3.2.4 Development Route of Passenger Car Intelligent Chassis Domain Controller
- 3.3 Automotive Domain Controller Industry Layout
- 3.4 “Cerebellum” Role of Automotive Chassis Domain Control
- 3.5 Importance of Constructing Automotive Chassis Domain Control System
- 3.6 Chassis-by-wire Integrated Solution for L3-L5
- 3.7 Chassis Domain Control Solutions of ZF and NIO
- 3.8 Electronic Chassis Will Become Mainstream in Future Development
- 3.9 Chassis-by-wire Domain Controller Architecture
- 3.10 Hardware Configuration Forecast of Automotive Chassis Domain
- 3.11 Price of Different Domain Controllers

- 3.12 Automotive Domain Controller Industry Size, 2020-2030E
- 3.13 Chassis Domain Controller Development Modes
- 3.14 Chassis Domain Controller Applications of OEMs
- 3.15 Summary of Chinese Chassis Domain Controller Suppliers (1)
- 3.15 Summary of Chinese Chassis Domain Controller Suppliers (2)
- 3.15 Summary of Chinese Chassis Domain Controller Suppliers (3)
- 3.16 Summary of Foreign Chassis Domain Controller Suppliers (1)
- 3.16 Summary of Foreign Chassis Domain Controller Suppliers (2)

## 4 Chinese Chassis Domain Controller Tier 1 Suppliers

- 4.1 Tuopu Group
  - 4.1.1 Profile
  - 4.1.2 Development History
  - 4.1.3 Major Product Lines
  - 4.1.4 Global Layout
  - 4.1.5 IBS (Onebox) Product Portfolio
    - 4.1.5.1 IBS-PRO Intelligent Brake System
    - 4.1.5.2 IBS-PRO Product Features
    - 4.1.5.3 IBS-EVO & IBS-RED Product Features
  - 4.1.6 Electric Control Air Suspension System (ECAS)
    - 4.1.6.1 Air Supply Unit (ASU)
  - 4.1.7 Steering System Product Line
  - 4.1.8 Revenue in 2022-2023H1
  - 4.1.9 Partners: NIO & Li Auto
- 4.2 Baolong Automotive
  - 4.2.1 Profile
  - 4.2.2 Development History

# Table of Content (3)

- 4.2.3 Global Layout
- 4.2.4 Air Suspension Full Stack Development
  - 4.2.4.1 Suspension Air Spring Production Line, Capacity and Matching
  - 4.2.4.2 Air Suspension Tanks
    - 4.2.4.3 Air Suspension Controller Production Line & Capacity
    - 4.2.4.4 Air Suspension Sensor Production Line & Capacity
    - 4.2.4.5 Air Suspension Air Supply Unit Production Line & Capacity
    - 4.2.4.6 Magic Carpet System
- 4.2.5 Revenue in 2022-2023H1
- 4.2.6 R&D Expenses in 2022-2023H1
- 4.2.7 Factory Opening in 2022-2023H1
- 4.2.8 Supporting Customers
- 4.2.9 Partners

## 4.3 Bethel Automotive

- 4.3.1 Profile
- 4.3.2 Development History
- 4.3.3 WCBS (onebox)
  - 4.3.3.1 WCBS2.0 & WCBS2.0 EHC
- 4.3.4 WCBS+EHC Braking System Solution
- 4.3.5 NLFC & DP-EPS
- 4.3.6 EPB & Project Designation
- 4.3.7 Lightweight Products & Project Designation
- 4.3.8 Capacity Building in 2023H1
- 4.3.9 Hal-year Report 2023
- 4.3.10 R&D Expenses in 2023H1
- 4.3.11 Supporting Customers

## 4.4 LeeKr Technology

- 4.4.1 Profile
- 4.4.2 Three-Step Strategy
- 4.4.3 Intelligent Chassis Product Matrix
- 4.4.4 Brake-by-wire Solutions
  - 4.4.4.1 DHB-LK? (Two-box)
    - 4.4.4.1 DHB-LK? (Two-box) Function List
  - 4.4.4.2 DHB+ESC
  - 4.4.4.3 IHB-LK? (one-box)
    - 4.4.4.3 IHB-LK? (one-box) Function List
  - 4.4.4.4 IHB Light + EMB
  - 4.4.4.5 EMB-LK?
- 4.4.5 ECAS-LK?
- 4.4.6 C-Trio? Intelligent Chassis Domain Controller
- 4.4.7 Capacity Layout/Planning

## 4.5 Global Technology

- 4.5.1 Profile
- 4.5.2 Development History
- 4.5.3 Intelligent Chassis Technology Route
- 4.5.4 Brake-by-wire Product Route
  - 4.5.4.1 EMB
  - 4.5.4.2 GIBC (Onebox)
  - 4.5.4.3 GDBC Decoupled Brake Control System
  - 4.5.4.4 GRBC Redundant Brake Control System
  - 4.5.4.5 ESC
  - 4.5.4.6 GESC pro
  - 4.5.4.7 Ebooster: GIBS
  - 4.5.4.8 ABS & ABSi
  - 4.5.4.9 EPB Electronic Parking Brake

# Table of Content (4)

- 4.5.5 iCDS Chassis Domain Controller
- 4.5.6 Production Lines and Production Capacities
- 4.5.6 GIBC Production Capacity
- 4.5.6 GIBC (onebox) Solenoid Valve Automated Production Line
  
- 4.6 Trinova
  - 4.6.1 Profile
  - 4.6.2 2022 Milestones
  - 4.6.3 Development Planning
  - 4.6.4 Intelligent Brake-by-Wire System Solutions (T-IBWS)
  - 4.6.5 T-IBC (Onebox)
    - 4.6.5.1 T-IBC Key Technologies
    - 4.6.5.2 T-IBC Function List
  - 4.6.6 Electronic Stability Control (ESC/EPBi)
  - 4.6.7 ESC Pro
  - 4.6.8 TBS Electric Power Brake System
  - 4.6.9 T-EPB Cable Electronic Parking
  - 4.6.10 EMB
  - 4.6.11 T-RES Redundant Electric Steering System
  - 4.6.12 Redundant RP-EPS (Rack and Pinion Electric Power Steering)
  - 4.6.13 DP-EPS (Dual Pinion Electric Power Steering)
    - 4.6.14 Trinova Steer-by-Wire Solution (T-SBW)
      - 4.6.14.1 Electrical Architecture of Steer-by-wire
      - 4.6.14.2 Algorithmic Architecture for Steer-by-wire
  - 4.6.15 DMC Chassis Domain Controller
  - 4.6.16 Customers
  
- 4.7 Tongyu Automotive
  - 4.7.1 Profile
  - 4.7.2 Development History
  - 4.7.3 Intelligent Brake Products
    - 4.7.3.1 EHB
    - 4.7.3.2 EHB-EPBi
    - 4.7.3.3 iEHB (Onebox)
    - 4.7.3.4 MOC-EPB
    - 4.7.3.5 BC-EPB
    - 4.7.3.6 CP-EPB
    - 4.7.3.7 ABS
    - 4.7.3.8 ESC
  - 4.7.4 Customers
  
- 4.8 TruGo Tech
  - 4.8.1 Profile
  - 4.8.2 Development History
  - 4.8.3 Core Business
  - 4.8.4 Product Planning
  - 4.8.5 EHBI (onebox) Electro-Hydraulic Braking Systems
  - 4.8.6 EMB
  - 4.8.7 VMC Vehicle Motion Control Software
  - 4.8.8 Production Line Construction
  - 4.8.8 Changshu Chassis-by-wire Smart Factory
  - 4.8.9 Partners
  
- 4.9 Gates Electronics
  - 4.9.1 Profile
  - 4.9.2 Product Matrix
  - 4.9.3 Intelligent Chassis Domain Controller
  - 4.9.4 Intelligent Chassis Domain Controller Integration Model

# Table of Content (5)

- 4.9.5 Intelligent Chassis Suspension Integrated Domain Controller System Technology Route
  - 4.9.5.1 Example of Intelligent Suspension Integrated Domain Controller System Gen3
  - 4.9.5.2 Intelligent Suspension Integrated Domain Controller Gen3: Hardware Architecture and Characteristics
  - 4.9.5.3 Intelligent Suspension Integrated Domain Controller Gen3: Software Architecture
  - 4.9.5.4 Intelligent Suspension Integrated Domain Controller Gen3: Software Functions

## 4.10 NASN Automotive Electronics

- 4.10.1 Profile
- 4.10.2 Product Layout
- 4.10.3 Onebox 2.0 Integrated Intelligent Braking System (NBC)
- 4.10.4 Chassis-by-wire Solutions for L3/L4
- 4.10.5 Chassis Domain Controller NXU
- 4.10.6 Partners

## 4.11 Zhongding Group

- 4.11.1 Profile
- 4.11.2 Global Distribution
- 4.11.3 Development History
- 4.11.4 Business Layout
- 4.11.5 Air Suspension Fixation
- 4.11.6 Magic Carpet Air Suspension

## 4.12 Bebest

- 4.12.1 Profile

## 4.12.2 Product Matrix

- 4.12.3 Intelligent Chassis Core Product Technology Route
- 4.12.4 Technical Route Implementation Solutions
- 4.12.5 Production and Manufacturing
- 4.12.6 Customers Supporting

## 4.13 BWI

- 4.13.1 Profile
- 4.13.2 Global Layout
- 4.13.3 Development History
- 4.13.4 Product Matrix
- 4.13.5 Customers

## 4.14 China Vagon

- 4.14.1 Profile
- 4.14.2 Development History
- 4.14.3 Business Layout
- 4.14.4 Chassis Domain Controller

## 4.15 Keboda

- 4.15.1 Profile
- 4.15.2 Production and R&D Layout
- 4.15.3 Development History
- 4.15.4 Layout of Chassis Domain Controller Products
- 4.15.5 Major Global Customers
- 4.15.6 Mass Production and Application of Chassis Domain Controller Products

## 4.16 Jingwei Hirain

- 4.16.1 Development History

# Table of Content (6)

- 4.16.2 Business Groups and Major Products
- 4.16.3 Production and R&D Layout
- 4.16.4 Chassis-by-wire Domain Controller CDC
- 4.16.5 CDC Application and Customers
- 4.16.6 Planning and Layout

## 4.17 Geshi Intelligent Technology

- 4.17.1 Profile
- 4.17.2 Development History
- 4.17.3 Chassis Domain Controller Gersh-VCU
- 4.17.4 Product Application and Customers

## 5 Foreign Chassis Domain Controller Tier 1 Suppliers

### 5.1 Bosch

- 5.1.1 Group Profile
- 5.1.2 Business Divisions
- 5.1.3 Automotive & Intelligent Transportation Business Layout
  - 5.1.3.1 Connectivity - Intelligent Integrated Braking System and 10th-Gen ESP
  - 5.1.3.2 Automation - Intelligent Decoupled Braking System and 2nd-Gen Intelligent Booster
  - 5.1.3.3 Automation - Steering System
  - 5.1.3.4 Automation - Driving Safety
- 5.1.4 Vehicle Dynamic Control System 2.0 (VDC2.0)
  - 5.1.4.1 Bosch VDC2.0 - Feed-forward Control Algorithm
  - 5.1.4.2 Bosch VDC2.0 - Comfort Braking CST2.0
  - 5.1.4.3 Bosch VDC2.0 - Intelligent Drift System iDCS
- 5.1.5 Overview of Bosch HUAYU Steering Systems (BHSS)

- 5.1.5.1 Development History
- 5.1.5.2 Steering Products
- 5.1.6 Cooperation between Bosch and Arnold NextG

### 5.2 Continental

- 5.2.1 Profile
- 5.2.2 Product Layout
- 5.2.3 Chassis Product Matrix
- 5.2.4 Braking System
- 5.2.5 New Generation ESC
- 5.2.6 FBS Route
- 5.2.7 Onebox Application: IM LS6
- 5.2.8 Braking system OEM Cooperation: Leap Motor
- 5.2.9 Electronic Suspension System (ESS) Business Global Distribution
- 5.2.10 Electronic Suspension System (ESS) Product Portfolio
- 5.2.11 Electronic Suspension System (ESS) Production Capacity
- 5.2.12 Air Suspension CAirS Open/Closed Loop System
- 5.2.13 Cross-Domain Vehicle Control HPC
- 5.2.14 Development Dynamics

### 5.3 ZF

- 5.3.1 Profile
- 5.3.2 Electric Drive Products
- 5.3.3 Braking Products
- 5.3.4 Air Suspension Products
- 5.3.5 Steering Products
- 5.3.6 X-by-wire Systems
- 5.3.7 Vehicle Motion Control Software cubiX
- 5.3.8 Vehicle High-performance Computer ProAI

# Table of Content (7)

5.3.9 Business Results

5.3.10 Development Dynamics

5.4 Schaeffler

5.4.1 Profile

5.4.2 Products and Solutions

5.4.3 Steer-by-wire Technology

5.4.4 Intelligent Chassis Application Solutions

5.4.5 Development Dynamics

5.4.6 Business Results

5.5 Nexteer

5.5.1 Profile

5.5.2 Global Layout

5.5.3 Development History

5.5.4 Solutions

5.5.5 Product Matrix

5.5.5.1 Electric Power Steering and Steer-by-Wire

5.5.5.2 Steering Columns

5.5.5.3 Hydraulic Power Steering

5.5.5.4 Software

5.5.6 Results in 2023H1

## 6 Intelligent Chassis Research Layout of OEMs

6.1 BYD

6.1.1 EEA Evolution Route

6.1.2 Next Generation EEA: "e4" Multi-Domain Computing + Zone Control Architecture

6.1.3 Chassis Integration Control

6.1.4 DiSus Intelligent Computing Control Center

6.1.5 DiSus Technology Matrix (C/A/P/X)

6.1.6 DiSus-C (First on Han EV)

6.1.7 Han Family: Upgraded DiSus-C Intelligent Damping Body Control System

6.1.8 DiSus-A (First on Denza N7)

6.1.9 Denza N7 DiSus-A Intelligent Chassis

6.1.10 DiSus-P (First on Yangwang U8)

6.1.11 DiSus-P Chassis Components

6.1.12 DiSus-P Chassis Performance

6.1.13 DiSus-X (First on Yangwang U9)

6.2 NIO

6.2.1 Intelligent Chassis Controller (ICC) (1)

6.2.1 Intelligent Chassis Controller (ICC) (2)

6.2.1 Intelligent Chassis Controller (ICC) (3)

6.2.1 Intelligent Chassis Controller (ICC) (4)

6.2.2 Collaborative Layout of Chassis Domain Controller System

6.3 Leap Motor

6.3.1 Iterations of Full Domain Self-development

6.3.2 "LPEE" Central Integrated EEA

6.3.2 Cooperation in Intelligent Chassis

6.3.3 C-Platform Chassis

6.3.4 Results in 2023Q3

6.3.5 Dynamics in 2023

6.3.6 Partners

# Table of Content (8)

## 6.4 Li Auto

6.4.1 LEEA1.0 /2.0/3.0

6.4.2 Central Domain Controller

6.4.3 Chassis Control System

6.4.4 Magic Carpet Air Suspension? 2.0

## 6.5 Xpeng Motors

6.5.1 Chassis Domain Controller to X-EEA 3.0

6.5.2 Suspension Control

## 6.6 Aion

6.6.1 AICS Intelligent Chassis System

## 6.7 Avatr

6.7.1 CHN Platform Chassis

## 6.8 Neta Auto

6.8.1 Hozon Skateboard Chassis Platform

## 6.9 Chery

6.9.1 EEA Evolutionary Route

6.9.2 EXEED Stellar Flying Fish Ultrasensitive Chassis

## 6.10 Tesla

6.10.1 Active Suspension System

6.10.2 Steer-by-wire System Implementation Plan

6.10.3 New Model 3 Chassis

6.10.4 Model Y Chassis

## 7 Passenger Car Intelligent Chassis Characteristics Summary and Development Trends

7.1 Trend 1

7.2 Trend 2

7.3 Trend 3

7.4 Trend 4

7.5 Trend 5

7.6 Trend 6

7.7 Trend 7

7.8 Trend 8





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