WEIGH2x
WHITEPAPER

WEIGH2x

High-Precision Strain Sensing

On-Board Weighing Systems

Developed by Walkhorizon
WEIGH2x Technology Initiative

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High-Precision, Axle-based On-Board Weighing System

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CONTENT

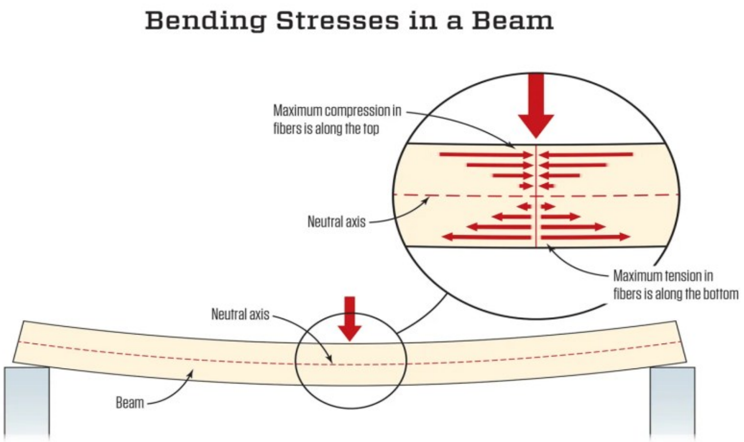
• 1. Executive Summary

This white paper introduces the WEIGH2x TRUCK NEW-T3000 system, a cutting-edge axle-based on-board weighing (OBW) system that sets a new standard for precision, affordability, and reliability in the commercial vehicle industry. The TRUCK NEW-T3000 leverages axle-strain measurement technology and sophisticated algorithms to deliver unparalleled weighing accuracy (±2% FS).

Our system provides a rapid return on investment (ROI) by optimizing load efficiency, preventing overweight fines, and enabling data-driven fleet management. This document details the technical architecture, innovative core technology, and quantifiable benefits of adopting the WEIGH2x solution for modern fleets.

1.1 What is Strain Measurement Technology

Strain measurement is a sensing method that captures microscopic deformation in a structure when it is subjected to external force.



When a load is applied, structural components undergo extremely small elastic deformation. In a typical load-bearing beam, one side is in compression while the opposite side is in tension.

The deformation is on the order of several micrometers (µm, 10^{-6} m), approximately one-tenth the diameter of a human hair —far beyond human perception.

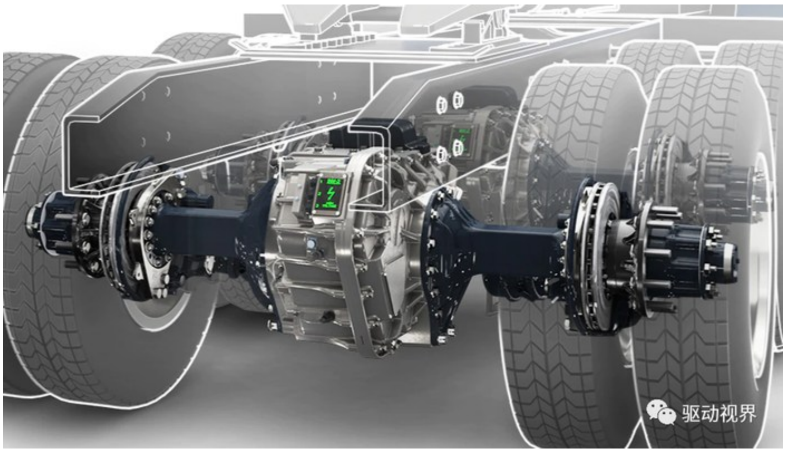
High-precision strain sensors (strain gauges) are bonded directly onto key structural components. They convert these invisible mechanical deformations into electrical signals, which can then be processed to quantify force, load, or stress in real time.

This enables real-time weighing of vehicle payload based on axle deformation.

1.2 What is WEIGH2x OBW

WEIGH2x OBW (On-Board Weighing) is a vehicle-based strain sensing system for real-time payload measurement.

Strain sensors are mounted on the axle to measure microscopic deformation when the vehicle is loaded. The measured strain is converted into real-time vehicle weight.



This enables onboard weighing during normal driving, without stopping or using external scales.

1.3 Where WEIGH2x OBW can be applied

The WEIGH2x strain-type axle weighing system is a high-precision, high-reliability vehicle-mounted measurement system based on the metal strain effect. The core consists of GH-200 strain sensors and GC-50 / GC-50C signal processors.

It features high sensitivity, precision, environmental tolerance, and anti-interference ability. Designed for harsh environments, it enables real-time dynamic weighing **without any structural modification to the vehicle**.

In addition to truck and trailer load monitoring, the system applies to health monitoring and efficiency management for construction machinery, agricultural equipment, sanitation vehicles, and heavy-duty machinery.

As a universal strain-sensing platform, it extends seamlessly to:

- Bridge health monitoring
- Railway track load analysis
- Building structural safety assessment
- Pressure vessel fatigue testing
- Chemical equipment stress monitoring

• 2. Weighing Challenge and WEIGH2x OBW System

2.1 The High Cost of Weight Management Inefficiency

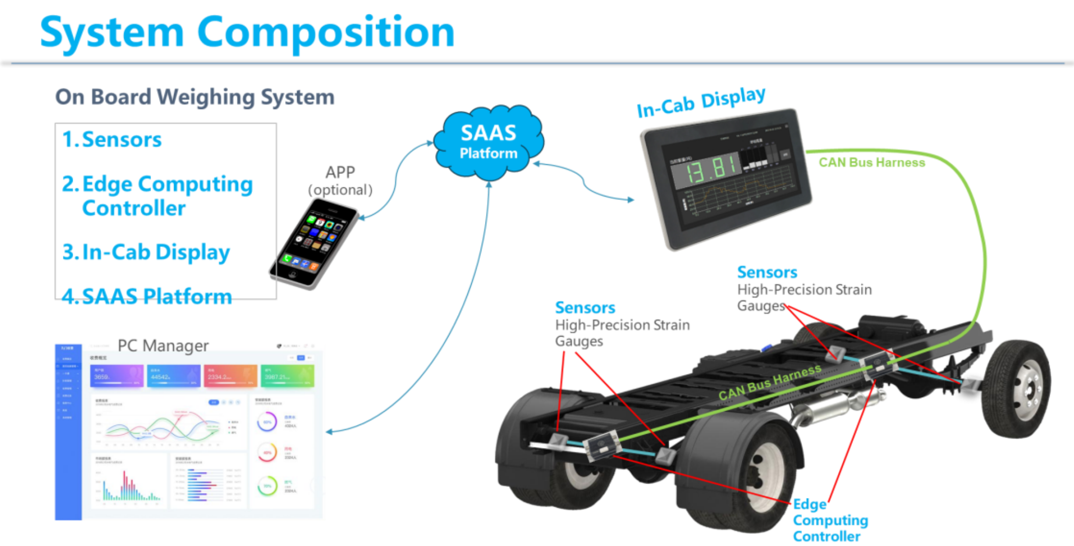
Fleet operators face mounting pressure from stringent regulations, rising operational costs, efficiency demands, and intense competition. Traditional reliance on static scales creates significant bottlenecks:

- Overweight Fines: Costly violations and vehicle downtime.
- Operational Inefficiency: Long queues at weigh scales reduce daily trips and revenue.
- Lack of Real-Time Data: Inability to monitor loading leads to guesswork and uneven load distribution.
- Accelerated Wear and Safety Risks: Chronic overloading damages tires, brakes, and suspensions, increasing maintenance costs and hazards.

2.2 System Architecture

The system uses an architecture of **distributed measurement, centralized processing, cab display, and cloud collaboration**. Its core idea is to deploy measurement units on each axle, collect data through a highly reliable industrial bus, and finally provide data display and decision support for drivers and managers in the cab and cloud.

The TRUCK NEW-T3000 is a full end-to-end solution including hardware, embedded software, and cloud API integration.



System Composition

1. High-Precision Strain Gauges (GH-200)
2. Edge Computing Controller (GC-50 / GC-50C)
3. In-Cab Display (NEW-T3000)
4. IoT SaaS Platform & API

High-Precision Strain Gauges(H200): The core sensing element, bonded to the truck axle.

Edge Computing Controller (GC50): A robust, IP68-rated module that performs real-time signal processing and data computation.

In-Cab Display (T3000): Provides instant weight feedback to the driver. 4G/5G transmission to cloud IoT platform.

API to IoT Platform: Provides standard APIs to a SaaS platform for fleet-wide data analytics, historical reports, overload alerts, etc. Remote monitoring, data analysis, overload alerts, and fleet management.

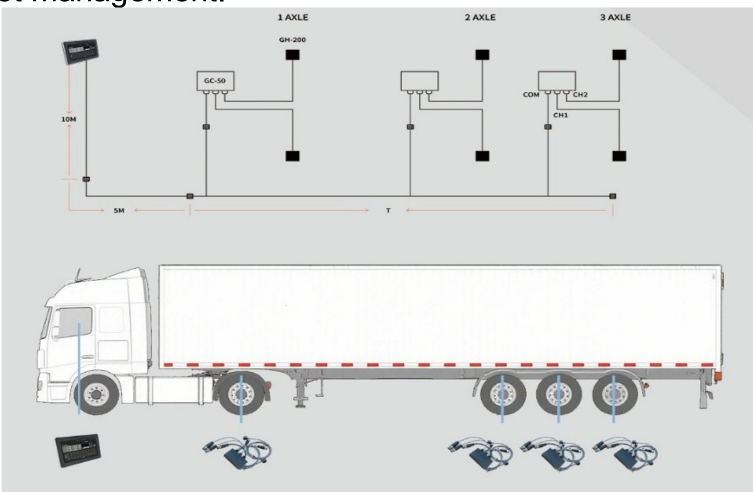


Fig1: System Architecture Diagram

2.3 Technical Advantages

High-Precision Measurement

- System accuracy: ±2% FS
- Resolution: 0.02%
- Static strain accuracy: <0.5% after calibration
- Temperature drift: <0.05% FS/°C

Flexible Configuration

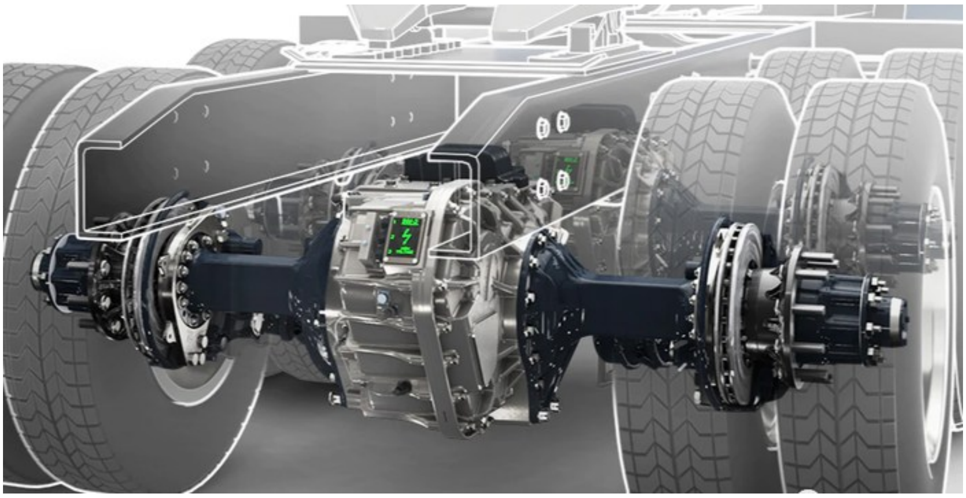
- 1:255 continuously variable gain
- Supports multi-node networking (up to 32 devices on CAN bus)
- Programmable device addresses

Engineering Stability & Reliability

- Operating temperature: -40°C to +85°C
- Protection: IP68 waterproof and dustproof
- Service life matches the axle lifetime
- Temperature compensation and vibration suppression algorithms

2.4 Why Axle-Strain Measurement is the Superior Technical Path

Axle deformation under load is extremely small—typically only about 1% of leaf spring deflection. At such subtle levels, the useful strain signal is often comparable to or even masked by noise,



creating inherent challenges for reliable measurement.

From first principles, axle weight represents the only direct, physically consistent, and truly accurate measure of a vehicle's actual payload.

Technology	Principle	Limitations	Accuracy Impact
Axle Strain (WEIGH2x)	Direct strain measurement on load-bearing axle	Requires high-sensitivity sensing & precise installation	Minimal; compensated by algorithms. ±2% FS
Leaf Spring Strain	Measures spring bending	Creep, hysteresis, aging, fatigue drift	Significant; typical 3–5% FS
Air Suspension Pressure	Indirect via air pressure	Affected by temperature, friction, inclination	Severe; errors >10% FS on slopes

Parameter	WEIGH2x NEW-T3000	Leaf Spring Strain	Air Suspension Based
Accuracy	±2% FS	±3–5% FS	±5–10% FS
Response Time	<1 ms	Slow, hysteretic	Slow, stabilization delay
Installation	Low (adhesive mount)	Medium (clamping)	High (plumbing + calibration)
Lifetime	Axle lifetime	Limited by spring fatigue	Limited by component wear
Typical Cost	~$3,000	$5,000+	$5,000+

Conclusion:

The axle-strain method provides **direct, fundamental, stable measurement** free from systemic errors that limit alternative technologies.

• 3. Technical Specifications

3.1 Processor Specifications【GC-50】

General Description

The GC-50 is a high-performance strain signal processor for precision structural and material strain measurement. It delivers high sensitivity, stability, and low noise for industrial and vehicular applications.

Features

- High accuracy & high sensitivity
- Excellent long-term stability
- 255-step adjustable gain
- Fast response
- Compact, rugged, easy installation
- Unique ID & programmable address
- Up to 15 devices on one RS485 bus

Parameters

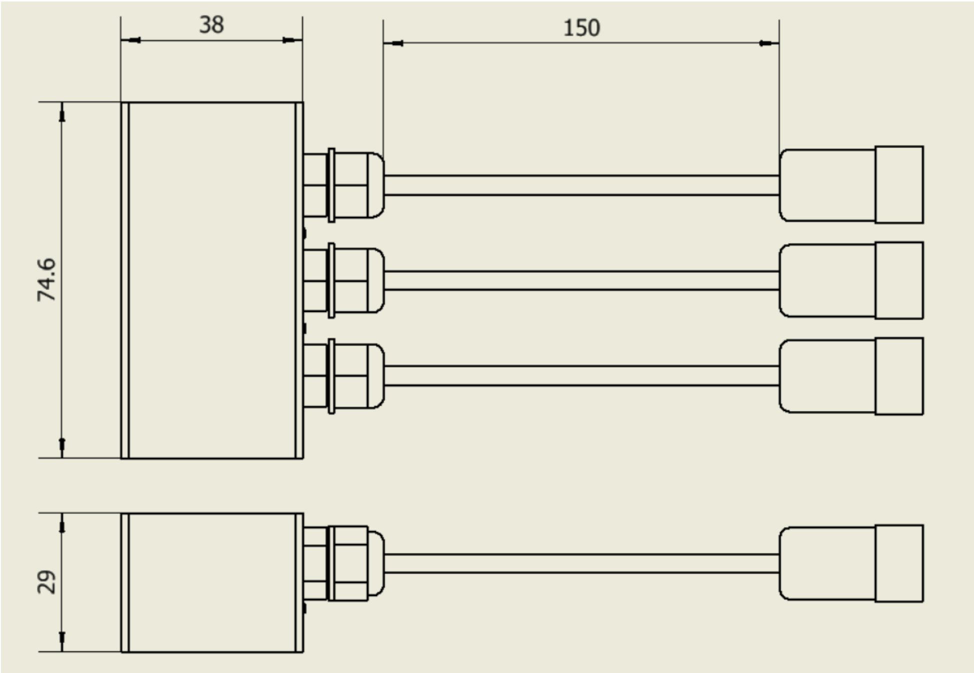
- Power supply: 9–14.5 VDC, 60 mA
- Communication: RS485, 9600 bps
- Sensor channels: 2
- Response time: <10 ms
- Sampling resolution: 12 bits
- Analog resolution: 0.02%
- Analog accuracy: <0.1%
- System accuracy: <2% after calibration
- Dimensions: 75 mm × 29 mm × 38 mm
- Weight: 105 g
- Protection: IP68

Connector & Pinout

COM port (power + RS485):

- Pin 1: RS485 A(+)
- Pin 2: VCC +12V
- Pin 3: GND
- Pin 4: RS485 B(-)

Appearance & Dimension

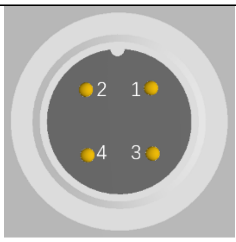


Connector and pinout

Port function:

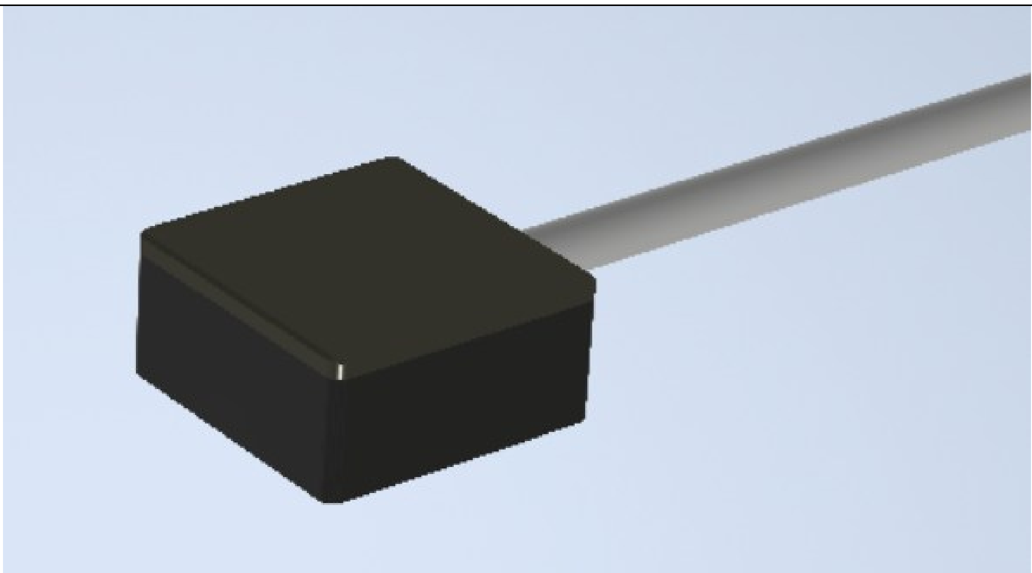
COM	Power and communication
CH1	Sensor Port 1
CH2	Sensor Port 2

COM port is used for RS485 communication and power supply. Multiple devices can ben connected to one bus in parallel. Pin map defined as followed:



Pin No	Function	Notes
1	RS485+（A）	
2	VCC	DC 9-12V
3	GND	
4	RS485-（B）	

3.2 Sensor Specifications【GH-200】



General Description

The GH-200 is a high-sensitivity, IP68 fully sealed strain sensor designed for truck onboard weighing and structural health monitoring.

It adheres securely to steel, aluminum, concrete, and composite surfaces using specialized structural adhesive (KN907Ti or equivalent).

Features

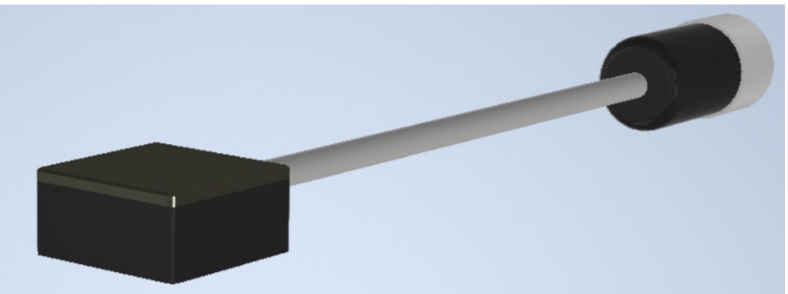
- High accuracy & high sensitivity
- Excellent long-term stability
- Compact, rugged, easy installation
- Unique ID & programmable address

Parameters

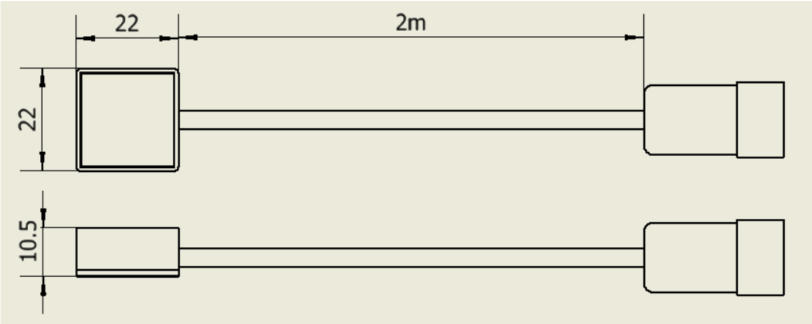
Parameter	Unit	Value
Sensitivity	ε	2xε
Max Strain	με	2000
Max Out Voltage	mV	±4
Overall Error	%FS	±3
Repeat Accuracy	%FS	±1
Nonlinearity	%FS	±1
Temp Drift	%FS/℃	0.02
Working Temp	℃	-40-85
Storage Temp	℃	-40-125
Case Material		PA66
Cable Length	m	2
Connector		5Pin Din Male
Weight	g	80 (w cable)
Dimension	mm	22x22x10.5
Water Proof		IP68

Appearance & Dimension

3D View



Dimension



3.3 Measurement Principle

The system operates based on strain measurement principles:
axle deformation → strain detected by the GH-200 sensor → millivolt-level signal → amplification, filtering, and 12-bit A/D conversion by the GC-50/GC-50C → digital weight output.

The GH-200 system measures structural strain and converts it into a digital output. The sensor is mounted directly on the component (e.g., axle) and detects deformation under load. The resulting signal is amplified, conditioned, and processed by the GC-50/GC-50C unit.
The system architecture includes three key modules:

- **Sensor** – Converts strain into electrical signals with high sensitivity and stability
- **Analog Frontend** – Amplifies and conditions low-level signals with adjustable gain
- **Processor** – Digitizes and processes data in real time, ensuring reliable output and communication

3.4 System Performance

After the system is correctly installed and calibrated, the overall performance indicators are as follows:

Performance Indicator	Target Value	Test Condition
System Comprehensive Accuracy	**±2% FS**	Compared with calibrated weighbridge
Linearity Error	**< ±1% FS**	Within full scale range
Repeatability Error	**< ±1% FS**	Multiple measurements under the same load
Temperature Stability	**< ±0.05% FS / ℃**	-40℃ ~ +85℃ environment
Response Time	**< 1 second**	From load change to stable display
Long-term Stability	**< ±1% FS / year**	Under normal use conditions

3.5 Environmental Requirements

Operating Conditions

- Temperature: -40°C to +85°C (sensor and processor units). The display terminal shall comply with automotive-grade requirements.
- Humidity: 5% to 95% RH, non-condensing.
- Protection Rating: IP68 for sensors and processing units, dust-tight and splash-proof.

Storage and Transportation Conditions

- Storage Temperature: -40°C to +125°C.

Electromagnetic Compatibility (EMC)

- The system is designed in compliance with automotive EMC requirements and is capable of withstanding electromagnetic interference generated by vehicle ignition systems, motors, and other onboard electrical equipment.
- The sensor installation should avoid proximity to high-intensity electromagnetic sources such as welding equipment.

- ## 4. Case Study

Case Study 1: Load Visibility Improves Fleet Payload Efficiency

Background

A bulk material transport fleet operating at a major port relied on static weighbridges for load verification, causing workflow interruptions and suboptimal payload utilization.

Challenge

- Conservative loading due to lack of real-time visibility
- Frequent off-route weighing delays
- Low payload utilization per trip

Solution

Deployment of the onboard weighing system provided real-time axle load measurement during loading operations, enabling continuous payload adjustment.

Result (KPI Impact)

- Trips per vehicle increased from 10 to 12 per day
- Improved payload utilization close to legal limits
- ~20% increase in transported tonnage
- Higher payload efficiency per trip

Case Study 2: Load-Normalized Fuel Efficiency Benchmarking

Background

A diesel truck fleet with identical vehicles showed inconsistent fuel consumption patterns due to unknown payload conditions and route variability.

Challenge

- No load-normalized fuel KPI
- Unfair comparison of fuel consumption across vehicles
- Difficulty identifying inefficiencies

Solution

The onboard weighing system enabled real-time load tracking and fuel consumption normalization based on transported mass.

Result (KPI Impact)

- Established fuel-per-ton benchmark across fleet
- Identified high-deviation fuel consumption outliers
- Enabled driver behavior optimization
- Improved fleet-level fuel efficiency transparency

Case Study 3: Real-Time Wheel Load Sensing for Autonomous Vehicle Control Enhancement

Background

An L4 autonomous truck system operating in port environments relies on vehicle mass estimation for control decisions. However, traditional estimation methods do not provide real-time wheel-level load distribution information.

Challenge

In dynamic loading conditions, the system faces limitations in:

- Detecting uneven load distribution between axles and wheels
- Adjusting braking and steering control based on real-time payload changes
- Maintaining consistent control performance under shifting center-of-gravity conditions
- These factors can increase reliance on conservative control strategies.

Solution

The GH-200 strain sensor system enables direct measurement of axle load, providing real-time load information that reflects both total weight and load distribution characteristics.

When integrated into the vehicle control architecture, this data can support:

- Real-time awareness of wheel/axle load distribution
- Improved understanding of center-of-gravity shifts under load variation
- Enhanced data input for adaptive control strategy design

Engineering Considerations (Expected Benefits)

Based on system-level analysis and customer engineering feedback, real-time load and wheel distribution data are expected to support:

More accurate braking and stability control under varying load conditions

- Improved handling of asymmetric loading scenarios
- Reduced dependency on conservative safety margins in control tuning
- Enhanced robustness of autonomous control systems in dynamic environments
- These benefits represent expected system-level advantages enabled by direct load sensing rather than measured performance results.

- ## 5. Vehicle Mass and Axle Load Measurement under Static and Dynamic Conditions

Static Load Validation – GH-200 System Accuracy

Test setup:

A six-axle tractor-trailer equipped with GH-200 sensors was tested under stationary conditions.

Measurement condition:

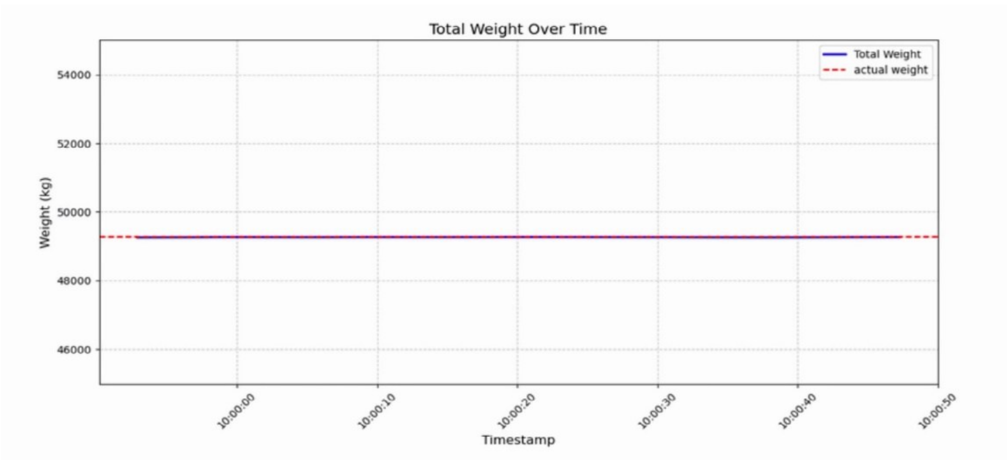
Static measurement over a 50-minute period.

Observation:

The GH-200 output remains stable and closely aligned with reference weighbridge measurements.

Interpretation:

The results confirm high repeatability and stability of the system for static mass estimation.



The displayed timestamps are formatted for visualization purposes and do not represent absolute clock time.

This figure presents the static validation results of the GH-200 strain-based weighing system under stationary vehicle conditions.

The x-axis represents relative time indexing during a 50-minute stationary test. The GH-200 output demonstrates high stability with no observable signal drift over the measurement period. The measured vehicle mass shows strong agreement with reference weighbridge data, confirming the system’ s capability for accurate static mass estimation.

This result validates the system’ s repeatability and baseline measurement accuracy under controlled conditions.

Real-Time Dynamic Axle Load Distribution (0.5 Hz Sampling)

Test setup:

Six-axle tractor-trailer operating under real road conditions.

Measurement condition:

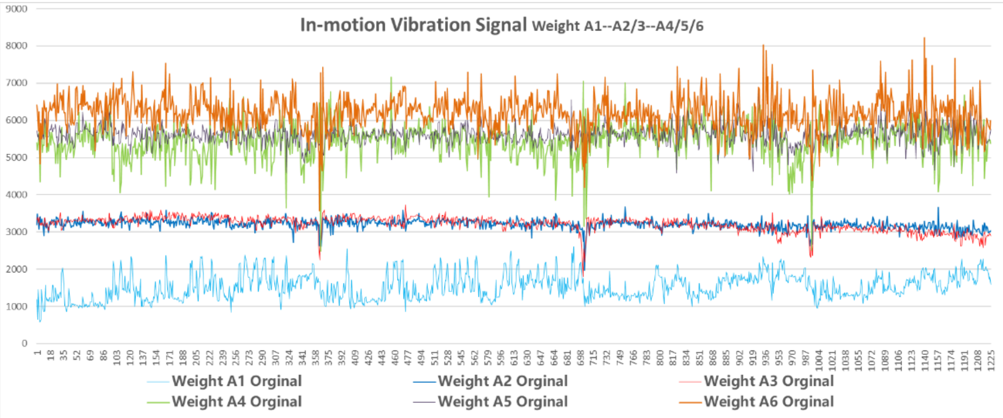
Sampling frequency: 0.5 Hz (2 s interval).

Observation:

Axle loads (A1–A6) show time-varying redistribution during vehicle motion.

Interpretation:

The system captures quasi-static load transfer behavior across axles under operational conditions.



This figure illustrates real-time axle load variation across a six-axle tractor-trailer during vehicle motion.

At a sampling frequency of 0.5 Hz, the system captures quasi-static load transfer behavior across axles A1–A6 under real operating conditions.

The data shows clear temporal redistribution of load across axles, reflecting changes in vehicle mass distribution during motion.

Filtered Axle Load Correlation – Front / Middle / Rear Groups

Test setup:

Same vehicle platform with post-processing applied to axle load signals.

Measurement condition:

0.5 Hz data with digital filtering applied.

Observation:

Distinct correlation patterns are observed between front, middle, and rear axle groups.

Interpretation:

The filtered representation highlights structured load transfer behavior across axle groups.

This figure shows the filtered axle load signals grouped into front, middle, and rear axle clusters.

Signal processing highlights the correlation between axle groups and reveals consistent structural load transfer patterns under dynamic conditions.

The processed representation provides a simplified view of vehicle load distribution behavior across the axle system.

- ## About Us — High-Precision Strain Sensing Engineering Team

an engineering-driven team

Our core strength lies in developing high-precision strain sensing technologies, converting microscopic structural deformation into reliable, measurable signals, and building precision instruments and AI-powered data-driven solutions.

In the initial stage, our work was primarily focused on heavy-duty industries such as heavy trucks, construction machinery, and mining operations. As the work has evolved, the team’ s research scope has gradually expanded into transportation and safety domains. In the same context, the GH-200 system can also be extended to typical structural health monitoring (SHM) applications, such as dynamic monitoring of crane structures and real-time assessment of bridge structural behavior.

Key members include Mr. Ding Liu, M.S., a senior scientist and product development expert specializing in high-precision sensing instruments and data processing; and Ms. Jing Tong, M.S., former Industry Solution Executive at Siebel and Oracle. Their expertise, combined with our core team' s background in precision instrumentation, strain mechanics, sensing signal processing, and data fusion analytics, jointly supports the development of structural health monitoring (SHM) and intelligent transportation applications.

Academic Engagement

Our strain sensing technology has attracted interest from researchers in the United States, particularly in intelligent transportation systems and real-world sensing applications. This approach bridges theoretical research, product development, and real-world application. Building on patented innovations that embed edge computing and IoT capabilities into precision instruments, the team is developing integrated solutions spanning research, consulting, engineering, and implementation.

Contact: United State
www.WEIGH2xTECH.com
Tel: +1 513 602 4346
Email: Heng.wei@uc.edu

Contact: China
www.walkhorizon.com
Tel: +86 13910108225
amytong@walkhorizon.com